Accessory Design Guidelines for Apple Devices

Release R32 Update 1

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Overview

1. Introduction

> **Note:**
> These Accessory Design Guidelines for Apple Devices ('Guidelines') are subject to the terms and conditions set forth on the final page of this document. By downloading, accessing, or otherwise utilizing these Guidelines, you agree to be bound by, and only utilize the Guidelines in accordance with, such terms and conditions.

These guidelines address:

- Physical compatibility with iPhone, iPad, Apple Watch, AirPods, Apple TV, Apple Vision Pro, and Mac computers.
- Using USB-C to connect to iPhone, iPad, and AirPods.
- Using Bluetooth to connect to iPhone, iPad, Apple Watch, Apple TV, Apple Vision Pro, and Mac computers.
- AC power adapters and battery packs compatible with iPhone, iPad, and AirPods.
- Qi wireless transmitters compatible with iPhone and AirPods.

Some aspects of accessory interaction are not addressed in this document and may require access to the Apple MFi Program (page 22) and the Accessory Interface Specification (page 22).

1.1 Dimensional Drawings

Dimensional drawings are available at https://developer.apple.com/accessories/dimensional-drawings/.

Drawings may contain additional requirements, including keep-out and keep-in regions for:

- Antennas.
- Connectors.
- Controls.
- Sensors.
- Cameras and flash.
- Touchscreens and displays.
- Speaker and microphone ports.
- Inductive charging.

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2. Requirements

The use of the words *shall*, *shall not*, *required*, *prohibited*, *should*, *should not*, *recommended*, *not recommended*, *may*, *optional*, and *deprecated* in a statement have the following meanings:

- *shall* or *required* means the statement is an absolute requirement.
- *shall not* or *prohibited* means the statement is an absolute prohibition.
- *should* or *recommended* means the full implications shall be understood before choosing a different course.
- *should not* or *not recommended* means the full implications shall be understood before choosing this course.
- *may* or *optional* means the statement is truly optional, and its presence or absence cannot be assumed.
- *deprecated* means the statement is provided for historical purposes only and is equivalent to 'shall not'.

2.1 Developer Preview

Content labeled as *developer preview* has been reviewed for accuracy, but it is not final. Apple is supplying this content to help accessory developers plan for the adoption of the accessory interface features described herein. This information is subject to change, and accessories implemented according to this content shall be tested with final operating system software and final documentation.

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3. Terminology

3.1 Device

Device refers to an iPhone or iPad.

iOS device refers to an iPhone running iOS.

iPadOS device refers to an iPad running iPadOS.

macOS device refers to a Mac running macOS.

tvOS device refers to an Apple TV running tvOS.

visionOS device refers to an Apple Vision Pro running visionOS.

watchOS device refers to an Apple Watch running watchOS.

Where appropriate, specific Apple product and operating system references will also be used.

3.2 Accessory

Accessory or *peer device* refers to any product connecting to a *device* using the interfaces described in this specification.

3.3 Component

A *component* is a functional unit or a constituent part of an accessory. Components interconnect and function as a part of a greater system. Examples include:

- Integrated circuits, microprocessors, flash memory, microphones, and speakers.
- Data transport interface, such as a Lightning connector, USB connector, or Bluetooth radio.
- Power sources, such as a battery or power supply.
- Human Interface Device (HID) Control Surface (page 21), such as a play/pause button.

A *component* may also refer to a group or collection, such as the keyboard portion of a keyboard/trackpad accessory.

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3.4 Control Surface

A *control surface* is a human interface device (HID) component enabling user interaction with an accessory. Examples include:

- Connectors
- Buttons
- Switches
- Rotary knobs
- Joysticks
- Touchscreens or touch-sensitive surfaces
- Microphones
- Motion/presence sensors

References to specific types of control surfaces such as buttons or switches are only applicable to those control surface types. If a requirement calls for a physical button to be implemented, a physical button shall be present.

3.5 Direct User Action

A *direct user action* is defined as user interaction with an accessory using a Control Surface (page 21). Examples include:

- Physical gestures, such as:
  - Attaching an accessory to a device.
  - Pressing a button.
  - Actuating a switch.
  - Turning a knob.
  - Interacting with a touchscreen.
  - Waving a hand.
  - Moving in/out of range (for wireless accessories).
- Voice input.

Accessories shall not autonomously perform user inputs unless explicitly authorized by the user.

3.6 Built-In Cable

A *built-in cable* is a cable with one end permanently attached to the accessory enclosure.

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3.7 Apple MFi Program

The Apple MFi Program provides access to specifications, components, connectors, and other resources to create accessories capable of communicating with devices.

See https://mfi.apple.com for more information.

3.8 Accessory Interface Specification

The *Accessory Interface Specification* is available through the Apple MFi Program (page 22).

Use of some features requires accessory developers to be a member of the program and to integrate specific MFi hardware into the accessory.

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Accessories

4. All Accessories

4.1 Scratches and Damage

Accessories shall not scratch or damage any device.

Accessories with abrasive surfaces and sharp edges (such as hard plastic, metal, or glass) shall not contact the active area of the device display.

4.2 Compliance Testing

Accessories shall not assume evidence of functionality when attached to a device means the accessory is specification compliant. Such an approach does not account for future devices or software releases, and runs a high risk of dependence on undocumented device behavior which is subject to change at any time.

If available, accessories should validate their design and implementation using the recommended test procedures for all supported features.

4.3 Testing with Apple Beta Software

The Apple Beta Software Program and the Apple Developer Program enable developers to try pre-release software and provide feedback to help Apple make the software even better. Apple recommends continuously testing accessories against Apple beta software.

4.3.1 Beta Software Access

Access to the public Apple Beta Software Program is available at https://beta.apple.com/.

Early access is available through the Apple Developer Program at https://developer.apple.com/programs/.

4.3.2 Profiles & Logging

Apple recommends installing relevant profiles from https://developer.apple.com/feedback-assistant/profiles-and-logs/ before testing accessories with beta software, such as:

- Bluetooth.
- Wi-Fi.

Profile installation may require restarting the device, if prompted.

4.3.3 Feedback Assistant

Apple recommends the Feedback Assistant which performs on-device diagnostics, collects crash logs, and initiates area-specific diagnostics for both the public Apple Beta Software Program and the Apple Developer Program. See https://developer.apple.com/feedback-assistant/.

Any issues found with accessory operation while testing against Apple beta software should be reported using the Feedback Assistant app included in the Apple beta.

4.4 USB-B Receptacles

Accessories integrating USB-B receptacles shall comply with *USB Battery Charging Specification – Release 1.2*.

4.5 User Supplied Cables and AC Power Adapters

Accessories intended for use with user-supplied cables and/or AC power adapters shall be designed to work with any cables, AC Power Adapters (page 80), or Battery Packs (page 83) compliant with this specification, including Apple branded cables and AC power adapters. Such accessories shall not declare compatibility with only Apple branded USB cables or AC power adapters.

This compatibility requirement applies to all aspects of user-supplied cables and power adapters. For example:

- Connector receptacles on accessories shall accommodate all specification-compliant connector overmolds, and any accessory opening surrounding the device receptacle shall provide sufficient clearance for specification-compliant connector overmolds.
- Accessories shall work with all specification-compliant cables with regards to electrical DCR and SI.

Such accessories shall be tested with a wide variety of specification-compliant cables (including various lengths of the same cable if applicable) and AC power adapters during accessory development, in addition to Apple branded cables and AC power adapters.

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4.6 TDMA Noise

GSM phones emit radiated and conducted RF noise, which can produce time division multiple access (TDMA) sounds from audio outputs. Accessories shall minimize coupling of audible interference from the device (commonly known as *TDMA noise* or *chopper noise*) into an accessory's electronics.

4.7 Attachments

Accessories shall remain compliant with the specification when connected to any attachments designed for the accessory.

Examples of accessory attachments include, but are not limited to:

- Car or desk mounts for a case.
- Wireless charging mats for a dongle or case.
- Detachable barcode scanners/credit card readers for a dock.

4.8 Magnetic Interference

Unless otherwise specified, Apple recommends avoiding the use of magnets and metal components in accessories.

Accessories claiming compatibility with a device with a digital compass (magnetometer) shall minimize interference with the digital compass and shall not repeatedly trigger compass recalibration.

Accessories claiming compatibility with a device with autofocus (AF) and/or optical image stabilization (OIS) shall not affect the operation of those features.

4.9 Radio Frequency (RF) Performance

4.9.1 Materials and Coatings

Accessories should avoid use of:

- Metals.
- Conductive materials or coatings.
- Materials with a high dielectric constant (relative permittivity greater than 5).

Such materials absorb radio frequency energy and may impair or degrade the performance of antennas for cellular communication, GPS, Wi-Fi, Bluetooth, and NFC.

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Examples include, but are not limited to:

- Steel, aluminum, magnesium, titanium, etc.
- Plastics with any carbon content, glass content, or metallic plating.
- Metallic paints.
- Black paints with high carbon loading.
- White paints with high titanium dioxide loading.
- Metallic Physical Vapor Deposition (PVD) coatings.

4.9.2 Antenna Keep-Out

Antenna keep-out regions can be found in Dimensional Drawings (page 18).

Accessory Materials and Coatings (page 26) which absorb radio frequency energy and are located in the antenna keep-out region have a higher risk of degrading a device's wireless performance.

4.9.3 Over The Air (OTA) Transmission/Reception

Accessories shall not excessively degrade a device's RF transmission efficiency. This can be quantified by measuring Total Radiated Power (TRP) across all of the device's operating bands.

Accessories shall not excessively degrade a device's RF reception sensitivity. This can be quantified by measuring Effective Isotropic Sensitivity (EIS) across all of the device's operating bands.

Accessories may have a higher risk of excessively degrading a device's RF performance if they:

- Contain magnets.
- Intrude on device Antenna Keep-Out (page 27) zones.
- Contain active electronic circuitry, such as:
  - Bluetooth radios.
  - Switched-mode power supplies.
  - High speed data interfaces.

Accessory configurations shall be taken into account when designing for maximum RF compatibility. Examples include, but are not limited to:

- Accessory on/off.
- Accessory open/closed.
- Attachments (page 26) present/not present.

Good design practices shall be followed to minimize emissions and maximize RF compatibility. These include, but are not limited to:

- Shielding digital circuitry and clock signals.
- Minimizing radiation from digital interfaces.
- Decoupling high frequency signals and power supplies.

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- Filtering off-board signals.
- Maintaining ground plane circuit board integrity.
- Minimizing current loop areas.
- Ensuring proper cable shielding terminations.

4.9.4 Specific Absorption Rate (SAR)

A list of labs performing SAR testing with devices is available through the Apple MFi Program (page 22).

4.9.5 Near Field Communication (NFC)

Accessories claiming compatibility with a device which has NFC shall not degrade its NFC transaction performance.

Accessories may have a higher risk of degrading a device's NFC transaction performance if they intrude on device Antenna Keep-Out (page 27) zones.

4.10 Thermal Management

The accessory's supported temperature range shall be greater than or equal to the published temperature ranges of every device the accessory claims compatibility with.

4.11 Tripod Connections

Tripod connections shall comply with *ISO 1222:2010, Photography—Tripod connections*, see https://www.iso.org/standard/55918.html.

4.12 Anthropometric Considerations

Children and people with smaller hands (5th percentile), as well as people with larger hands (95th percentile) should all be considered during the accessory design process.

Apple recommends using design resources such as:

- AnthroKids (https://math.nist.gov/~SRessler/anthrokids/).
- U.S. Army Anthropometry Survey (http://mreed.umtri.umich.edu/mreed/downloads.html#ansur2).
- Civilian American and European Surface Anthropometry Resource (CAESAR).

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5. Cases

Cases are accessories substantially enclosing devices.

The requirements shall be applied to each component separately for cases with multiple user-detachable components substantially enclosing the device.

5.1 Product Design

A well-designed case will securely house a device without interfering with the device's operation. Significant factors in mechanical design include access to the device's sensors, controls, and connectors. See Dimensional Drawings (page 18).

5.1.1 Device Protection

Cases shall protect the device from a 1 m drop onto a hard paved surface in any orientation.

Exposed glass on the device shall not come within 0.85 mm of a flat surface, such as a table or floor, in any orientation when the case is attached. Ideally the glass should not come within 1.00 mm. Device protection should be achieved by creating features around the exposed glass to keep it away from the flat surface.

Care should be given to the design of the bottom of the case to achieve both device protection and provide access to device speakers, microphones, and connectors.

5.1.2 Access to Inputs and Interconnects

Cases shall readily permit user access to inputs and interconnects.

5.1.2.1 Access to Controls

Cases shall readily permit user access to and operation of the device's mechanical controls, such as:

- Volume buttons.
- Camera Control.
- Side/Top button.
- Action button.
- Ring/Silent switch.

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- Home button.
- Touch ID sensor.

5.1.2.2 Access to the Camera Control

Cases for devices with Camera Control shall accommodate the following gestures across the entire surface of the Camera Control:

- Click.
- Light press.
- Slide.
- Swipe.

The case shall either:

- Have an opening meeting the keep-out defined in Dimensional Drawings (page 18).
- Integrate the Camera Control Case Interface (page 30).

The opening shall be large with smooth edges and a wide angle designed to accommodate:

- Various grip styles, including:
  - Portrait orientation, when held with either the right or left hand.
  - Landscape orientation, with the Camera Control at the top, when held with either one or two hands.
- Diverse hand and finger sizes, see Anthropometric Considerations (page 28).
- Diverse fingernail lengths, including nails extending beyond the tip of the finger.

The opening should not have sharp or hard edges causing the user to experience finger discomfort when engaging with the Camera Control.

5.1.2.2.1 Camera Control Case Interface

Cases may integrate their own Camera Control case interface.

A Camera Control case interface shall have a(n):

- Bottom layer consisting of 6 to 24 copper pads connecting to the Camera Control, see Figure 5-1 (page 31) for a 6-pad example.
- Top layer consisting of 6 to 24 copper pads, see Figure 5-1 (page 31) for a 6-pad example.
- PCB-like material to connect the bottom and top layers and to achieve proper thickness for the case design.
- Even number of copper pads.
- Spacing between the copper pads (pad gap) of at least 0.15 mm.

The outer dimensions of the user-facing side of the button may be sized differently depending on the case design.

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Figure 5-1 Example 6-pad Camera Control case interface top and bottom layers

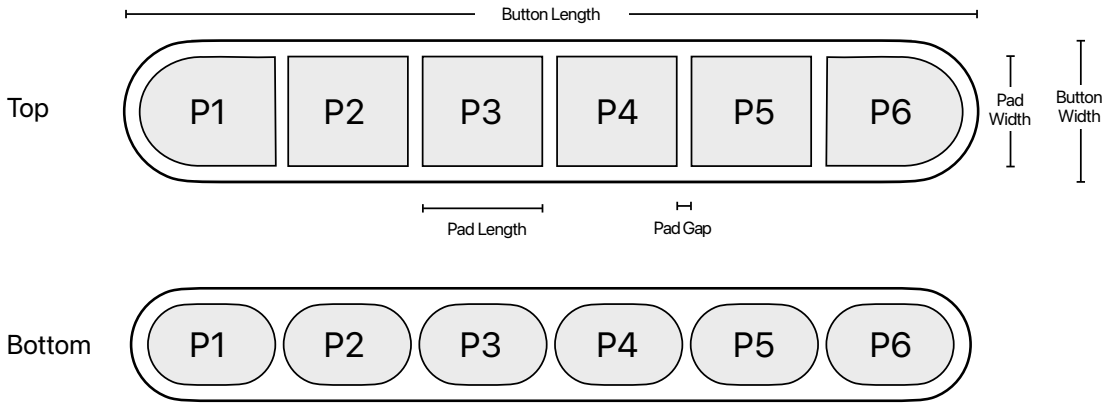


Table 5-1 Example Camera Control Top Button Dimensions

Device	Button Length	Button Width	Pads 1,6 Length	Pads 2–5 Length	Pad Width	Pad Gap
All devices except iPhone Duo and iPhone Air	16.83 mm	2.77 mm	2.68 mm	2.34 mm	2.15 mm	0.30 mm
iPhone Duo and iPhone Air	16.83 mm	2.27 mm	2.68 mm	2.34 mm	1.55 mm	0.30 mm

Table 5-2 Example Camera Control Bottom Button Dimensions

Device	Button Length	Button Width	Pad Length	Pad Width	Pad Gap
All devices except iPhone Duo and iPhone Air	16.53 mm	2.47 mm	2.35 mm	1.55 mm	0.30 mm
iPhone Duo and iPhone Air	16.53 mm	1.97 mm	2.35 mm	1.05 mm	0.30 mm

A Camera Control case interface shall:

- Have a top cap, such as a sapphire crystal. Plastic top caps will cause Camera Control to fail due to capacitive signal loss.
- Have a flatness of less than 25 µm where it makes contact with the Camera Control.
- Have a tilt of less than 160 µm in all directions.
- Have a static (no user contact) misalignment center to center along:
  - The width of the Camera Control of less than 160 µm.
  - The length of the Camera Control of less than 190 µm.

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- Have a dynamic (user contact) misalignment center to center in all directions of less than 130 µm.
- Have a maximum stiffness of 180 gf/mm.
  - Target stiffness should be 90 gf/mm throughout its range of travel.
- Be designed to maintain contact with the Camera Control across all copper pads and shall:
  - Have a case applied force (preload) of 45 gf or less at maximum button offset.
  - Not trigger a light press when the area around the Camera Control is squeezed up to 1050 gf.
  - Not have an air gap greater than 50 µm to the Camera Control. Apple recommends no air gap.
- Have a capacitance greater than 0.362 pF for pads P1 and P6.
- Have a capacitance greater than 0.432 pF for pads P2, P3, P4, and P5.
- Have a sheet resistance for inks and coatings greater than 50 GΩ/sq.

5.1.2.2.2 User Study

A study evaluating the usability and comfort of the Camera Control by end users shall be completed. Users should be able to perform all gestures without discomfort from pressing into the case material surrounding the Camera Control.

The study population shall include:

- Various hand sizes as defined in Anthropometric Considerations (page 28).
- Various finger shapes, taking into account:
  - Taper.
  - Flatness.
- Various fingernail lengths:
  - Shorter than the fingertip.
  - At the fingertip.
  - Slightly longer than the fingertip.
  - Much longer than the fingertip.

The user study shall be performed using the Gestures (page 61) portion of the Camera Control (page 61) test.

5.1.2.3 Access to the USB-C Connector

Cases shall readily permit user access to a device's USB-C connector, if present.

The USB-C receptacle keep-out:

- Shall be at least 12.35 mm by 6.50 mm.
- Should be at least 12.45 mm by 6.60 mm with full radii rounded edges for the greatest compatibility with the widest variety of cables and docks, see USB-C receptacle accessory keep-out (page 391).

USB-C connector openings shall be designed with enough margin to compensate for shifting or dimensional changes of the case material.

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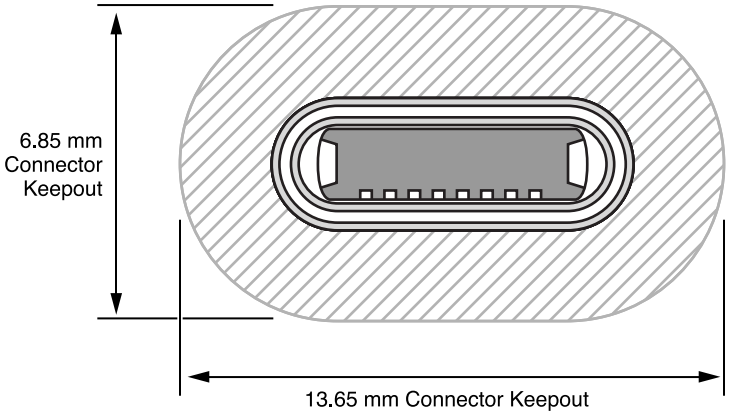
5.1.2.4 Access to the Lightning Connector

Cases shall readily permit user access to a device's Lightning connector, if present.

The Lightning receptacle keep-out:

- Shall be at least 12.05 mm by 6.30 mm with full radii rounded edges.
- Should be at least 13.65 mm by 6.85 mm for the greatest compatibility with the widest variety of cables and docks, see Figure 5-2 (page 33).

Figure 5-2 Lightning Receptacle (C37) keep-out



Lightning connector openings shall be designed with enough margin to compensate for shifting or dimensional changes of the case material.

5.1.2.5 Access to the Headset Jack

Cases shall readily permit user access to a device's headset jack, if present.

The headset jack keep-out:

- Shall be at least 6.0 mm in diameter and at most 14.0 mm deep.
- Should be at least 6.5 mm in diameter and at most 10.0 mm deep for the best compatibility with a range of headsets.

Headset jack openings shall be designed with enough margin to compensate for shifting or dimensional changes of the case material.

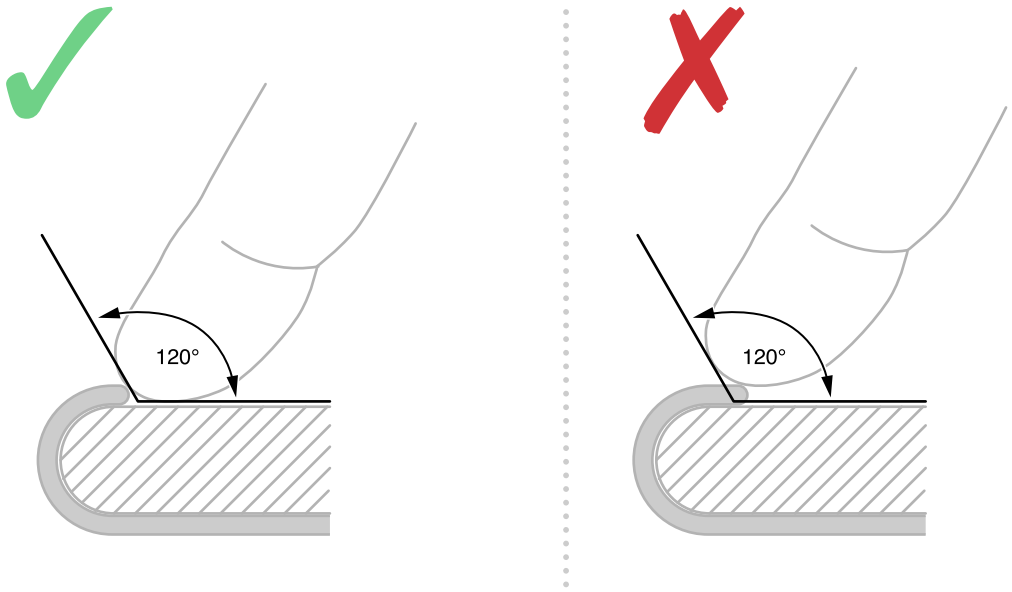
5.1.2.6 Touchscreen

Cases should not have edges trapping water on the touchscreen when the device is held at a 30° angle relative to the horizon.

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Cases shall allow a 120° opening, see Figure 5-3 (page 34), along the edges of a touchscreen's active area to ensure compatibility with touchscreen features. See Dimensional Drawings (page 18) for active areas.

Figure 5-3 Touchscreen keep-out angle



5.1.2.7 Edge Swipe Gestures

Cases shall not impede edge swipe gestures.

Examples of such gestures include, but are not limited to:

- Swipe in from the top edge for Control Center or Notification Center.
- Swipe in from the bottom edge for Home, App Switcher, or Reachability.
- Swipe in from the left edge in Messages or Mail to go back from a conversation.

5.1.2.8 Cover Glass Contact

Cases should not contact the cover glass of:

- iPhone SE (3rd generation)
- iPhone SE (2nd generation)
- iPhone 11 Pro Max
- iPhone 11 Pro
- iPhone 11

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5.1.3 Dock Compatibility

The distance from the bottom of the device to the outside of a case should not exceed 1.8 mm for compatibility with docks.

5.1.4 iPhone Duo

Cases for iPhone Duo shall:

- Provide access to the outer display active area, see Touchscreen (page 33).
- Not prevent the device from reaching either its closed or its fully open state.
- Not prevent the device from reaching or holding any partially folded pose.
- Not apply force to the hinge across any part of its range of motion.

Cases for iPhone Duo shall comply with Device Protection (page 29) when the device is in the closed state. Cases for iPhone Duo should also protect the hinge from damage in a drop.

5.1.4.1 StandBy

Cases for iPhone Duo may integrate a kickstand to support StandBy.

Cases supporting StandBy with a kickstand shall hold the device in landscape orientation at a backward tilt from 5° to 75° in each kickstand position intended for StandBy. The tilt is measured from vertical with the case standing on its kickstand on a flat level surface. The device can start StandBy only in this orientation and tilt range.

5.1.5 Wireless Power

Cases claiming compatibility with MagSafe or Qi wireless power 2.0 or later, see Device Power (Inductive) (page 251), shall:

- Integrate a MagSafe Case Magnet Array (page 264).
- Not have rear pockets or holders for credit cards, RFID cards, or other similar items. Cards may be damaged and/or impact wireless charging performance.

5.2 Acoustics

Cases shall not impair or degrade the acoustic performance of a device.

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5.2.1 Call Quality

Cases shall not impair or degrade the user experience making and receiving audio calls over a cellular network or audio/video calls using FaceTime in both handset and speakerphone modes. Cases should not change the frequency response of the speakers or microphones. In addition, the user should not hear distortion or echo resulting from using the case.

Cases shall not obstruct microphones during a phone call. Occluding microphones can result in call quality degradation.

5.2.2 Speaker to Microphone Coupling

Cases shall not facilitate the conduction of sound from speakers to microphones. Such sound conduction may cause echoing in phone calls.

5.2.3 Speaker/Microphone Openings

Device speaker/microphone port locations vary from model to model, see Dimensional Drawings (page 18).

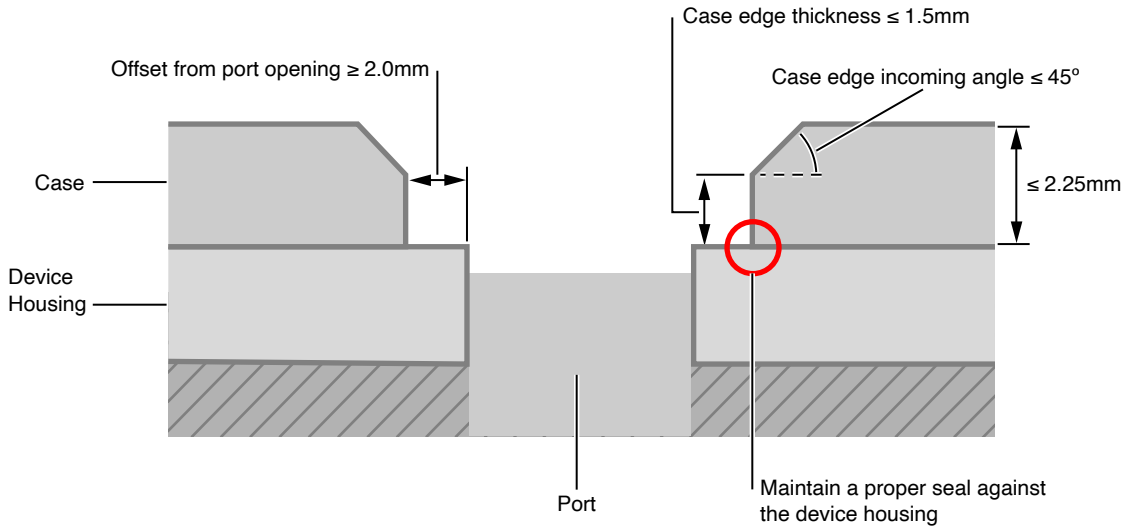
5.2.3.1 Thin Cases (≤2.25 mm)

Microphone/speaker openings in thin cases should:

- Be offset at least 2.0 mm from the edge of any device speaker/microphone port.
- Be at most 1.5 mm thick along their inner diameter.
- Have a maximum 45° incoming angle to their inner diameter.
- Maintain a proper seal against the device between speaker/microphone ports.

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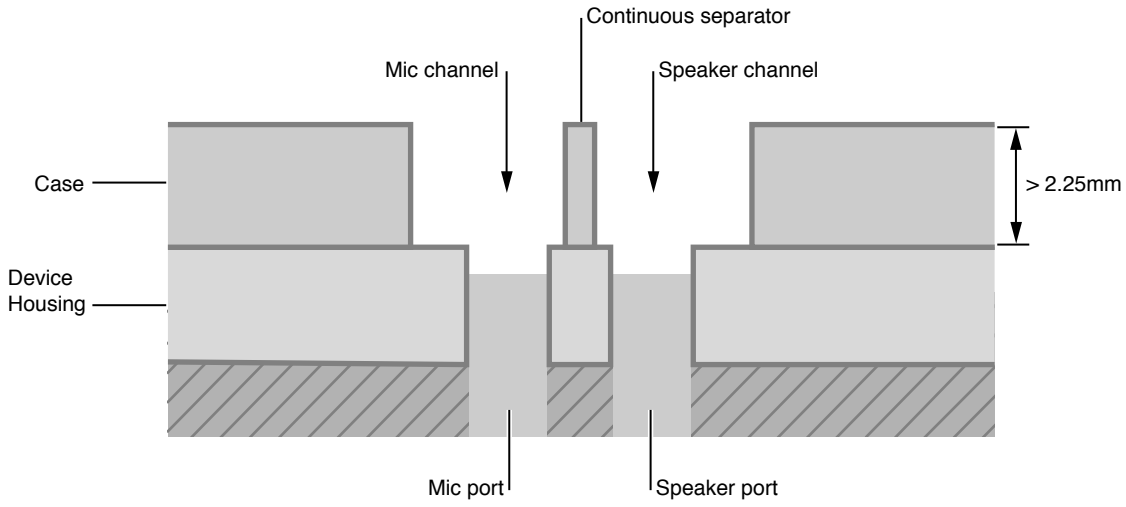
Figure 5-4 Microphone/speaker opening recommendations for thin cases



5.2.3.2 Thick Cases (>2.25 mm)

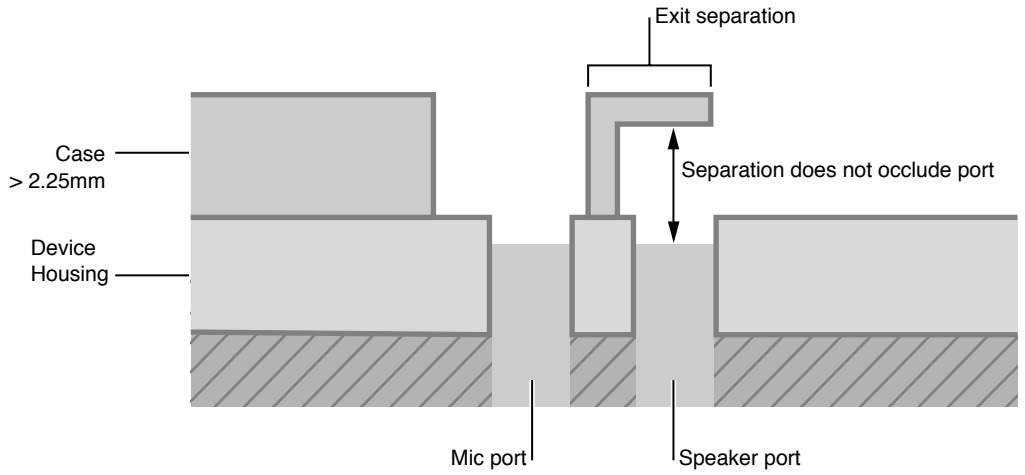
Speaker and microphone openings should be channeled independently and without interruption to/from the outside surface of a thick case.

Figure 5-5 Thick case acoustic channels



Thick cases should maximize exit separation between speaker and microphone channels.

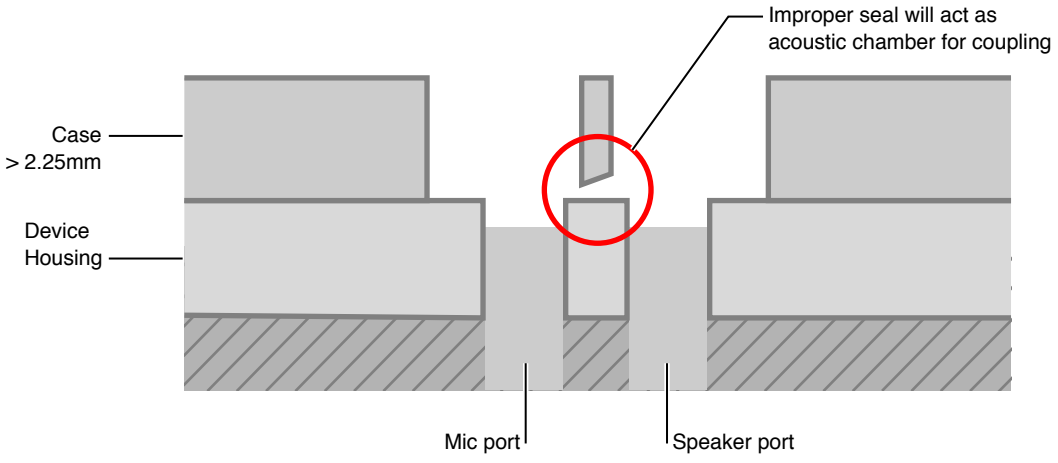
Figure 5-6 Thick case microphone and speaker exit separation



Thick case channels may act as a resonance chamber and detune microphone/speaker frequency response. The resulting frequency response may vary according to channel size/shape.

If a thick case does not maintain a proper seal against the device between microphone/speaker channels, the case itself may become an acoustic chamber.

Figure 5-7 Improper thick case seal



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5.3 Ambient Light Sensor and Proximity Sensor

Ambient light sensor and proximity sensor locations for various devices are illustrated in Dimensional Drawings (page 18). Some drawings indicate sensor keep-out areas.

5.4 Haptics

Cases should not cause a substantial change in the feel of the device's haptic feedback.

5.5 Magnetic Interference

Cases shall not interfere with the device's:

- Magnetic compass.
- Rear camera autofocus (AF).
- Rear camera optical image stabilization (OIS), if present.
- Front camera autofocus, if present.

See Magnetic Interference (page 26) for additional details.

5.6 Touch ID

Cases shall not inhibit use of the device's Touch ID sensor. Touch ID sensor keep-outs are indicated in Dimensional Drawings (page 18).

Cases overlaying the sensor may cause users to have difficulty using Touch ID.

5.7 Camera

The camera field of view (FOV) and the illumination provided by the flash are designed for each device's camera. It is exceptionally important manufacturers consult Dimensional Drawings (page 18) for each device. Manufacturers shall not assume any parameters are shared between devices.

Images from the camera may be affected by the geometry, color, and surface finish of the case, particularly when using a flash. Camera opening trim should be designed to avoid reflecting light into the camera.

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5.7.1 Geometry

The camera lens FOV shall not be blocked. Making the opening dimensions too small around the camera and flash may block the lens FOV and the illumination from the flash. Blocking the FOV may cause vignetting in the image, where one or more corners of the image are darker than the center. Blocking marginal rays just outside the lens FOV may also reduce the sharpness and contrast of the image. Blocking flash illumination may cause haze in the image, resulting in reduced contrast. See Dimensional Drawings (page 18) for camera keep-outs.

Case openings shall not be designed in a manner directing stray light into the camera lens. If the opening is too narrow or too steep, it may reflect light into the camera lens, washing out the image or adding unwanted color casting. Adding a chamfer to the opening trim near the camera may help direct stray light away from the camera lens. When the device includes a flash, a narrow or steep opening may reflect light from the camera and flash opening back into the camera lens. This may cause images to appear washed out or cause unwanted artifacts. Designers should also ensure mechanical keep-outs as outlined in Dimensional Drawings (page 18) are maintained with worst-case X-Y placement tolerances to minimize the risk of image haze.

5.7.2 Color

Light reflected from a case may carry the color of the case. Black material or black coatings may help avoid color bleeding into the camera lens from an external light source or the flash. The darker the color, the less likely light from a flash or external source may be reflected off the case and into the camera lens. Apple recommends a semi-gloss black material or coating around the camera and flash openings.

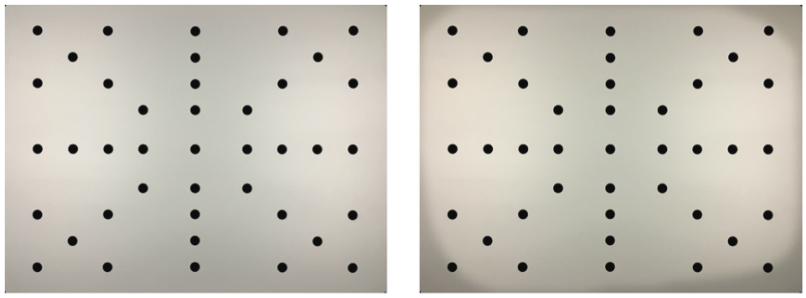
5.7.3 Surface Finish

Matte or diffuse materials scatter light in all directions increasing the likelihood light from the flash or other strong light sources may be reflected into camera lenses. Semi-gloss materials may direct light away from the camera lens.

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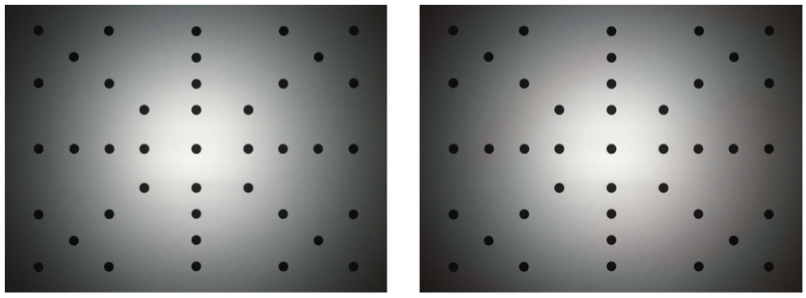
5.7.4 Image Degradation Examples

Figure 5-8 Sample image degradation by image blocking in an ambient condition



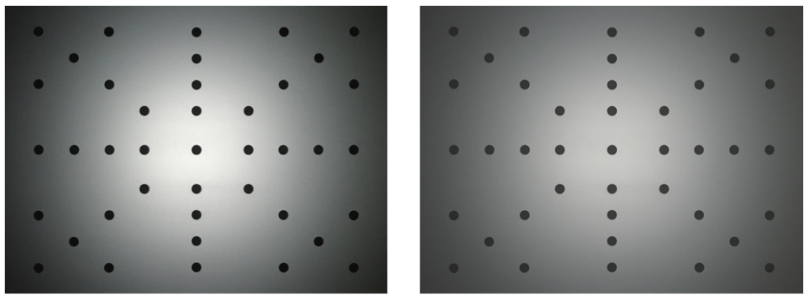
Reference Degraded

Figure 5-9 Sample image degradation by color shift through accessory with strong color



Reference Degraded

Figure 5-10 Sample image degradation by flash interference



Reference Degraded

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5.8 Reliability

Cases shall be tested to verify they will withstand long-term use under typical use conditions, and will not impair, functionally degrade a device, cause Scratches and Damage (page 24) to the device or its immediate surroundings, or adversely affect the user.

5.8.1 Device Insertion and Removal

Cases shall hold the device securely while readily permitting insertion and removal. A case shall not cause Scratches and Damage (page 24) to the device by the repeated insertion and removal of the device from the case under conditions representative of long-term use in a variety of environments.

5.8.2 Colorfastness

Dyes, inks, or coatings in or on the case shall not transfer or bleed color onto either the device or user, particularly while the case is in contact with common substances such as water, hand sanitizer, sunscreen, or lotions.

5.9 Environmental

Cases shall comply with applicable environmental regulations for the regions in which such accessories are to be sold, as well as applicable substance or material restrictions including:

- Organic tin compounds, PFOS, PFOA, phthalates, azo dyes, polybrominated biphenyls (PBBs), and PAHs, per requirements of the EU REACh regulation EC 1907/2006.
- Nickel leach rate on surfaces in prolonged skin contact, per requirements of the EU REACh regulation EC 1907/2006.
- Cadmium, lead, hexavalent chromium, and nickel, per requirements of EU Directive 2009/48/EC.
- Natural rubber latex, per requirements of EU Directive 93/42/EEC.
- Dimethylfumarate (DMFu), per requirements of EU Regulation 412/2012.
- pH and Formaldehyde, per requirements of China GB 18401 for textiles and China GB 20400 for leather.
- Endangered species of flora and fauna in products or packaging (US Lacey Act).
- Polybrominated diphenyl ethers (PBDE).
- Compliance with California proposition 65, as applicable.

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5.10 Verification

5.10.1 Device Models

Case testing procedures vary depending on the device they enclose.

5.10.1.1 iPhone Duo

Table 5-3 iPhone Duo case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone Duo	
Camera Control (page 61)	iPhone Duo	
Haptics (page 61)	iPhone Duo	
Image Quality (page 63)	iPhone Duo	Star White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone Duo	
Near-Field Communication (NFC) (page 67)	iPhone Duo	
Acoustics (page 69)	iPhone Duo	
MagSafe Case Magnet Array (page 278)	iPhone Duo	Cases supporting MagSafe only.

5.10.1.2 iPhone 18 Pro Max

Table 5-4 iPhone 18 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 18 Pro Max	
Camera Control (page 61)	iPhone 18 Pro Max	
Haptics (page 61)	iPhone 18 Pro Max	
Image Quality (page 63)	iPhone 18 Pro Max	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 18 Pro Max	
Near-Field Communication (NFC) (page 67)	iPhone 18 Pro Max	
Acoustics (page 69)	iPhone 18 Pro Max	
MagSafe Case Magnet Array (page 278)	iPhone 18 Pro Max	Cases supporting MagSafe only.

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5.10.1.3 iPhone 18 Pro

Table 5-5 iPhone 18 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 18 Pro	
Camera Control (page 61)	iPhone 18 Pro	
Haptics (page 61)	iPhone 18 Pro	
Image Quality (page 63)	iPhone 18 Pro	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 18 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 18 Pro	
Acoustics (page 69)	iPhone 18 Pro	
MagSafe Case Magnet Array (page 278)	iPhone 18 Pro	Cases supporting MagSafe only.

5.10.1.4 iPhone 17e and iPhone 16e

Table 5-6 iPhone 17e and iPhone 16e case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 17e	
Haptics (page 61)	iPhone 17e	
Image Quality (page 63)	iPhone 17e	White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 17e	
Near-Field Communication (NFC) (page 67)	iPhone 17e	
Acoustics (page 69)	iPhone 17e	
MagSafe Case Magnet Array (page 278)	iPhone 17e	Cases supporting MagSafe only.

It is not possible for a case to claim compatibility with only iPhone 17e, or only iPhone 16e.

5.10.1.5 iPhone 17 Pro Max

Table 5-7 iPhone 17 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 17 Pro Max	
Camera Control (page 61)	iPhone 17 Pro Max	
Haptics (page 61)	iPhone 17 Pro Max	
Image Quality (page 63)	iPhone 17 Pro Max	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 17 Pro Max	
Near-Field Communication (NFC) (page 67)	iPhone 17 Pro Max	

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Test	Using	Notes
Acoustics (page 69)	iPhone 17 Pro Max	
MagSafe Case Magnet Array (page 278)	iPhone 17 Pro Max	Cases supporting MagSafe only.

5.10.1.6 iPhone 17 Pro

Table 5-8 iPhone 17 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 17 Pro	
Camera Control (page 61)	iPhone 17 Pro	
Haptics (page 61)	iPhone 17 Pro	
Image Quality (page 63)	iPhone 17 Pro	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 17 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 17 Pro	
Acoustics (page 69)	iPhone 17 Pro	
MagSafe Case Magnet Array (page 278)	iPhone 17 Pro	Cases supporting MagSafe only.

5.10.1.7 iPhone 17

Table 5-9 iPhone 17 case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 17	
Camera Control (page 61)	iPhone 17	
Haptics (page 61)	iPhone 17	
Image Quality (page 63)	iPhone 17	White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 17	
Near-Field Communication (NFC) (page 67)	iPhone 17	
Acoustics (page 69)	iPhone 17	
MagSafe Case Magnet Array (page 278)	iPhone 17	Cases supporting MagSafe only.

5.10.1.8 iPhone Air

Table 5-10 iPhone Air case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone Air	

Test	Using	Notes
Camera Control (page 61)	iPhone Air	
Haptics (page 61)	iPhone Air	
Image Quality (page 63)	iPhone Air	Cloud White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone Air	
Near-Field Communication (NFC) (page 67)	iPhone Air	
Acoustics (page 69)	iPhone Air	
MagSafe Case Magnet Array (page 278)	iPhone Air	Cases supporting MagSafe only.

5.10.1.9 iPhone 16 Pro Max

Table 5-11 iPhone 16 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 16 Pro Max	
Camera Control (page 61)	iPhone 16 Pro Max	
Haptics (page 61)	iPhone 16 Pro Max	
Image Quality (page 63)	iPhone 16 Pro Max	White Titanium model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 16 Pro Max	
Near-Field Communication (NFC) (page 67)	iPhone 16 Pro Max	
Acoustics (page 69)	iPhone 16 Pro Max	
MagSafe Case Magnet Array (page 278)	iPhone 16 Pro Max	Cases supporting MagSafe only.

5.10.1.10 iPhone 16 Pro

Table 5-12 iPhone 16 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 16 Pro	
Camera Control (page 61)	iPhone 16 Pro	
Haptics (page 61)	iPhone 16 Pro	
Image Quality (page 63)	iPhone 16 Pro	White Titanium model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 16 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 16 Pro	
Acoustics (page 69)	iPhone 16 Pro	
MagSafe Case Magnet Array (page 278)	iPhone 16 Pro	Cases supporting MagSafe only.

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5.10.1.11 iPhone 16 Plus

Table 5-13 iPhone 16 Plus case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 16 Plus	
Camera Control (page 61)	iPhone 16 Plus	
Haptics (page 61)	iPhone 16 Plus	
Image Quality (page 63)	iPhone 16 Plus	White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 16 Plus	
Near-Field Communication (NFC) (page 67)	iPhone 16 Plus	
Acoustics (page 69)	iPhone 16 Plus	
MagSafe Case Magnet Array (page 278)	iPhone 16 Plus	Cases supporting MagSafe only.

5.10.1.12 iPhone 16

Table 5-14 iPhone 16 case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 16	
Camera Control (page 61)	iPhone 16	
Haptics (page 61)	iPhone 16	
Image Quality (page 63)	iPhone 16	White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 16	
Near-Field Communication (NFC) (page 67)	iPhone 16	
Acoustics (page 69)	iPhone 16	
MagSafe Case Magnet Array (page 278)	iPhone 16	Cases supporting MagSafe only.

5.10.1.13 iPhone 15 Pro Max

Table 5-15 iPhone 15 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 15 Pro Max	
Haptics (page 61)	iPhone 15 Pro Max	
Image Quality (page 63)	iPhone 15 Pro Max	White Titanium model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 15 Pro Max	

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Test	Using	Notes
Near-Field Communication (NFC) (page 67)	iPhone 15 Pro Max	
Acoustics (page 69)	iPhone 15 Pro Max	
MagSafe Case Magnet Array (page 278)	iPhone 15 Pro Max	Cases supporting MagSafe only.

5.10.1.14 iPhone 15 Pro

Table 5-16 iPhone 15 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 15 Pro	
Haptics (page 61)	iPhone 15 Pro	
Image Quality (page 63)	iPhone 15 Pro	White Titanium model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 15 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 15 Pro	
Acoustics (page 69)	iPhone 15 Pro	
MagSafe Case Magnet Array (page 278)	iPhone 15 Pro	Cases supporting MagSafe only.

5.10.1.15 iPhone 15 Plus

Table 5-17 iPhone 15 Plus case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 15 Plus	
Haptics (page 61)	iPhone 15 Plus	
Image Quality (page 63)	iPhone 15 Plus	Blue model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 15 Plus	
Near-Field Communication (NFC) (page 67)	iPhone 15 Plus	
Acoustics (page 69)	iPhone 15 Plus	
MagSafe Case Magnet Array (page 278)	iPhone 15 Plus	Cases supporting MagSafe only.

5.10.1.16 iPhone 15

Table 5-18 iPhone 15 case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 15	

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Test	Using	Notes
Haptics (page 61)	iPhone 15	
Image Quality (page 63)	iPhone 15	Blue model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 15	
Near-Field Communication (NFC) (page 67)	iPhone 15	
Acoustics (page 69)	iPhone 15	
MagSafe Case Magnet Array (page 278)	iPhone 15	Cases supporting MagSafe only.

5.10.1.17 iPhone 14 Pro Max

Table 5-19 iPhone 14 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 14 Pro Max	
Haptics (page 61)	iPhone 14 Pro Max	
Image Quality (page 63)	iPhone 14 Pro Max	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 14 Pro Max	
Near-Field Communication (NFC) (page 67)	iPhone 14 Pro Max	
Acoustics (page 69)	iPhone 14 Pro Max	
MagSafe Case Magnet Array (page 278)	iPhone 14 Pro Max	Cases supporting MagSafe only.

5.10.1.18 iPhone 14 Pro

Table 5-20 iPhone 14 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 14 Pro	
Haptics (page 61)	iPhone 14 Pro	
Image Quality (page 63)	iPhone 14 Pro	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 14 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 14 Pro	
Acoustics (page 69)	iPhone 14 Pro	
MagSafe Case Magnet Array (page 278)	iPhone 14 Pro	Cases supporting MagSafe only.

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5.10.1.19 iPhone 14 Plus

Table 5-21 iPhone 14 Plus case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 14 Plus	
Haptics (page 61)	iPhone 14 Plus	
Image Quality (page 63)	iPhone 14 Plus	Starlight model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 14 Plus	
Near-Field Communication (NFC) (page 67)	iPhone 14 Plus	
Acoustics (page 69)	iPhone 14 Plus	
MagSafe Case Magnet Array (page 278)	iPhone 14 Plus	Cases supporting MagSafe only.

5.10.1.20 iPhone 14

Table 5-22 iPhone 14 case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 14	
Haptics (page 61)	iPhone 14	
Image Quality (page 63)	iPhone 14	Starlight model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 14	
Near-Field Communication (NFC) (page 67)	iPhone 14	
Acoustics (page 69)	iPhone 14	
MagSafe Case Magnet Array (page 278)	iPhone 14	Cases supporting MagSafe only.

5.10.1.21 iPhone 13 Pro Max

Table 5-23 iPhone 13 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 13 Pro Max	
Haptics (page 61)	iPhone 13 Pro Max	
Image Quality (page 63)	iPhone 13 Pro Max	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 13 Pro Max	
Near-Field Communication (NFC) (page 67)	iPhone 13 Pro Max	
Acoustics (page 69)	iPhone 13 Pro Max	

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Test	Using	Notes
MagSafe Case Magnet Array (page 278)	iPhone 13 Pro Max	Cases supporting MagSafe only.

5.10.1.22 iPhone 13 Pro

Table 5-24 iPhone 13 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 13 Pro	
Haptics (page 61)	iPhone 13 Pro	
Image Quality (page 63)	iPhone 13 Pro	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 13 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 13 Pro	
Acoustics (page 69)	iPhone 13 Pro	
MagSafe Case Magnet Array (page 278)	iPhone 13 Pro	Cases supporting MagSafe only.

5.10.1.23 iPhone 13

Table 5-25 iPhone 13 case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 13	
Haptics (page 61)	iPhone 13	
Image Quality (page 63)	iPhone 13	Starlight model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 13	
Near-Field Communication (NFC) (page 67)	iPhone 13	
Acoustics (page 69)	iPhone 13	
MagSafe Case Magnet Array (page 278)	iPhone 13	Cases supporting MagSafe only.

5.10.1.24 iPhone 13 mini

Table 5-26 iPhone 13 mini case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 13 mini	
Haptics (page 61)	iPhone 13 mini	
Image Quality (page 63)	iPhone 13 mini	Starlight model only.

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Test	Using	Notes
Autofocus & Optical Image Stabilization (page 67)	iPhone 13 mini	
Near-Field Communication (NFC) (page 67)	iPhone 13 mini	
Acoustics (page 69)	iPhone 13 mini	
MagSafe Case Magnet Array (page 278)	iPhone 13 mini	Cases supporting MagSafe only.

5.10.1.25 iPhone 12 Pro Max

Table 5-27 iPhone 12 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 12 Pro Max	
Haptics (page 61)	iPhone 12 Pro Max	
Image Quality (page 63)	iPhone 12 Pro Max	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 12 Pro Max	
Near-Field Communication (NFC) (page 67)	iPhone 12 Pro Max	
Acoustics (page 69)	iPhone 12 Pro Max	
MagSafe Case Magnet Array (page 278)	iPhone 12 Pro Max	Cases supporting MagSafe only.

5.10.1.26 iPhone 12 Pro

Table 5-28 iPhone 12 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 12 Pro	
Haptics (page 61)	iPhone 12 Pro	
Image Quality (page 63)	iPhone 12 Pro	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 12 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 12 Pro	
Acoustics (page 69)	iPhone 12 Pro	
MagSafe Case Magnet Array (page 278)	iPhone 12 Pro	Cases supporting MagSafe only.

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5.10.1.27 iPhone 12

Table 5-29 iPhone 12 case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 12	
Haptics (page 61)	iPhone 12	
Image Quality (page 63)	iPhone 12	White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 12	
Near-Field Communication (NFC) (page 67)	iPhone 12	
Acoustics (page 69)	iPhone 12	
MagSafe Case Magnet Array (page 278)	iPhone 12	Cases supporting MagSafe only.

5.10.1.28 iPhone 12 mini

Table 5-30 iPhone 12 mini case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 12 mini	
Haptics (page 61)	iPhone 12 mini	
Image Quality (page 63)	iPhone 12 mini	White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 12 mini	
Near-Field Communication (NFC) (page 67)	iPhone 12 mini	
Acoustics (page 69)	iPhone 12 mini	
MagSafe Case Magnet Array (page 278)	iPhone 12 mini	Cases supporting MagSafe only.

5.10.1.29 iPhone 11 Pro Max

Table 5-31 iPhone 11 Pro Max case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 11 Pro Max	
Haptics (page 61)	iPhone 11 Pro Max	
Image Quality (page 63)	iPhone 11 Pro Max	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 11 Pro Max	
Near-Field Communication (NFC) (page 67)	iPhone 11 Pro Max	
Acoustics (page 69)	iPhone 11 Pro Max	

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5.10.1.30 iPhone 11 Pro

Table 5-32 iPhone 11 Pro case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 11 Pro	
Haptics (page 61)	iPhone 11 Pro	
Image Quality (page 63)	iPhone 11 Pro	Silver model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 11 Pro	
Near-Field Communication (NFC) (page 67)	iPhone 11 Pro	
Acoustics (page 69)	iPhone 11 Pro	

5.10.1.31 iPhone 11

Table 5-33 iPhone 11 case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone 11	
Haptics (page 61)	iPhone 11	
Image Quality (page 63)	iPhone 11	White model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone 11	
Near-Field Communication (NFC) (page 67)	iPhone 11	
Acoustics (page 69)	iPhone 11	

5.10.1.32 iPhone SE (3rd generation) and iPhone SE (2nd generation)

Table 5-34 iPhone SE (3rd generation) and iPhone SE (2nd generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPhone SE (3rd generation)	
Haptics (page 61)	iPhone SE (3rd generation)	
Touch ID Sensor Overlays (page 62)	iPhone SE (3rd generation)	
Image Quality (page 63)	iPhone SE (3rd generation)	Starlight model only.
Autofocus & Optical Image Stabilization (page 67)	iPhone SE (3rd generation)	
Near-Field Communication (NFC) (page 67)	iPhone SE (3rd generation)	
Acoustics (page 69)	iPhone SE (3rd generation)	

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It is not possible for a case to claim compatibility with only iPhone SE (3rd generation), or only iPhone SE (2nd generation).

5.10.1.33 iPad Air 13-inch (M4), iPad Air 13-inch (M3), and iPad Air 13-inch (M2)

Table 5-35 iPad Air 13-inch (M4), iPad Air 13-inch (M3), and iPad Air 13-inch (M2) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Air 13-inch (M4)	
Image Quality (page 63)	iPad Air 13-inch (M4)	Starlight model only.
Compass (page 68)	iPad Air 13-inch (M4)	

It is not possible for a case to claim compatibility with only iPad Air 13-inch (M4), or only iPad Air 13-inch (M3), or only iPad Air 13-inch (M2).

5.10.1.34 iPad Air 11-inch (M4), iPad Air 11-inch (M3), and iPad Air 11-inch (M2)

Table 5-36 iPad Air 11-inch (M4), iPad Air 11-inch (M3), and iPad Air 11-inch (M2) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Air 11-inch (M4)	
Image Quality (page 63)	iPad Air 11-inch (M4)	Starlight model only.
Compass (page 68)	iPad Air 11-inch (M4)	

It is not possible for a case to claim compatibility with only iPad Air 11-inch (M4), or only iPad Air 11-inch (M3), or only iPad Air 11-inch (M2).

5.10.1.35 iPad Pro 13-inch (M5) and iPad Pro 13-inch (M4)

Table 5-37 iPad Pro 13-inch (M5) and iPad Pro 13-inch (M4) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Pro 13-inch (M5)	
Image Quality (page 63)	iPad Pro 13-inch (M5)	Silver model only.
Compass (page 68)	iPad Pro 13-inch (M5)	

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It is not possible for a case to claim compatibility with only iPad Pro 13-inch (M5), or only iPad Pro 13-inch (M4).

5.10.1.36 iPad Pro 11-inch (M5) and iPad Pro 11-inch (M4)

Table 5-38 iPad Pro 11-inch (M5) and iPad Pro 11-inch (M4) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Pro 11-inch (M5)	
Image Quality (page 63)	iPad Pro 11-inch (M5)	Silver model only.
Compass (page 68)	iPad Pro 11-inch (M5)	

It is not possible for a case to claim compatibility with only iPad Pro 11-inch (M5), or only iPad Pro 11-inch (M4).

5.10.1.37 iPad (A16) and iPad (10th generation)

Table 5-39 iPad (A16) and iPad (10th generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad (A16)	
Image Quality (page 63)	iPad (A16)	Silver model only.
Compass (page 68)	iPad (A16)	

It is not possible for a case to claim compatibility with only iPad (A16), or only iPad (10th generation).

5.10.1.38 iPad Pro 12.9-inch (6th generation) and iPad Pro 12.9-inch (5th generation)

Table 5-40 iPad Pro 12.9-inch (6th generation) and iPad Pro 12.9-inch (5th generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Pro 12.9-inch (6th generation)	
Image Quality (page 63)	iPad Pro 12.9-inch (6th generation)	Silver model only.
Compass (page 68)	iPad Pro 12.9-inch (6th generation)	

It is not possible for a case to claim compatibility with only iPad Pro 12.9-inch (6th generation), or only iPad Pro 12.9-inch (5th generation).

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5.10.1.39 iPad Pro 11-inch (4th generation) and iPad Pro 11-inch (3rd generation)

Table 5-41 iPad Pro 11-inch (4th generation) and iPad Pro 11-inch (3rd generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Pro 11-inch (4th generation)	
Image Quality (page 63)	iPad Pro 11-inch (4th generation)	Silver model only.
Compass (page 68)	iPad Pro 11-inch (4th generation)	

It is not possible for a case to claim compatibility with only iPad Pro 11-inch (4th generation), or only iPad Pro 11-inch (3rd generation).

5.10.1.40 iPad mini (A17 Pro) and iPad mini (6th generation)

Table 5-42 iPad mini (A17 Pro) and iPad mini (6th generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad mini (A17 Pro)	
Image Quality (page 63)	iPad mini (A17 Pro)	Starlight model only.
Compass (page 68)	iPad mini (A17 Pro)	

It is not possible for a case to claim compatibility with only iPad mini (A17 Pro), or only iPad mini (6th generation).

5.10.1.41 iPad (9th generation)

Table 5-43 iPad (9th generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad (9th generation)	
Image Quality (page 63)	iPad (9th generation)	Silver model only.
Compass (page 68)	iPad (9th generation)	

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5.10.1.42 iPad Air (5th generation) and iPad Air (4th generation)

Table 5-44 iPad Air (5th generation) and iPad Air (4th generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Air (5th generation)	
Image Quality (page 63)	iPad Air (5th generation)	Starlight model only.
Compass (page 68)	iPad Air (5th generation)	

It is not possible for a case to claim compatibility with only iPad Air (5th generation), or only iPad Air (4th generation).

5.10.1.43 iPad Pro 12.9-inch (4th generation)

Table 5-45 iPad Pro 12.9-inch (4th generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Pro 12.9-inch (4th generation)	
Image Quality (page 63)	iPad Pro 12.9-inch (4th generation)	Silver model only.
Compass (page 68)	iPad Pro 12.9-inch (4th generation)	

5.10.1.44 iPad Pro 11-inch (2nd generation)

Table 5-46 iPad Pro 11-inch (2nd generation) case testing matrix

Test	Using	Notes
Product Design (page 58)	iPad Pro 11-inch (2nd generation)	
Image Quality (page 63)	iPad Pro 11-inch (2nd generation)	Silver model only.
Compass (page 68)	iPad Pro 11-inch (2nd generation)	

5.10.2 Product Design

5.10.2.1 Equipment

The following equipment is necessary:

- Device, see Device Models (page 43).
- Apple Lightning Digital AV Adapter for devices with a Lightning receptacle.

- Apple USB-C Digital AV Multiport Adapter for devices with a USB-C receptacle.
- EarPods with 3.5 mm Headphone Plug for devices with a 3.5 mm headset jack.
- Vernier calipers.
- 0.85 mm plastic feeler gauge.

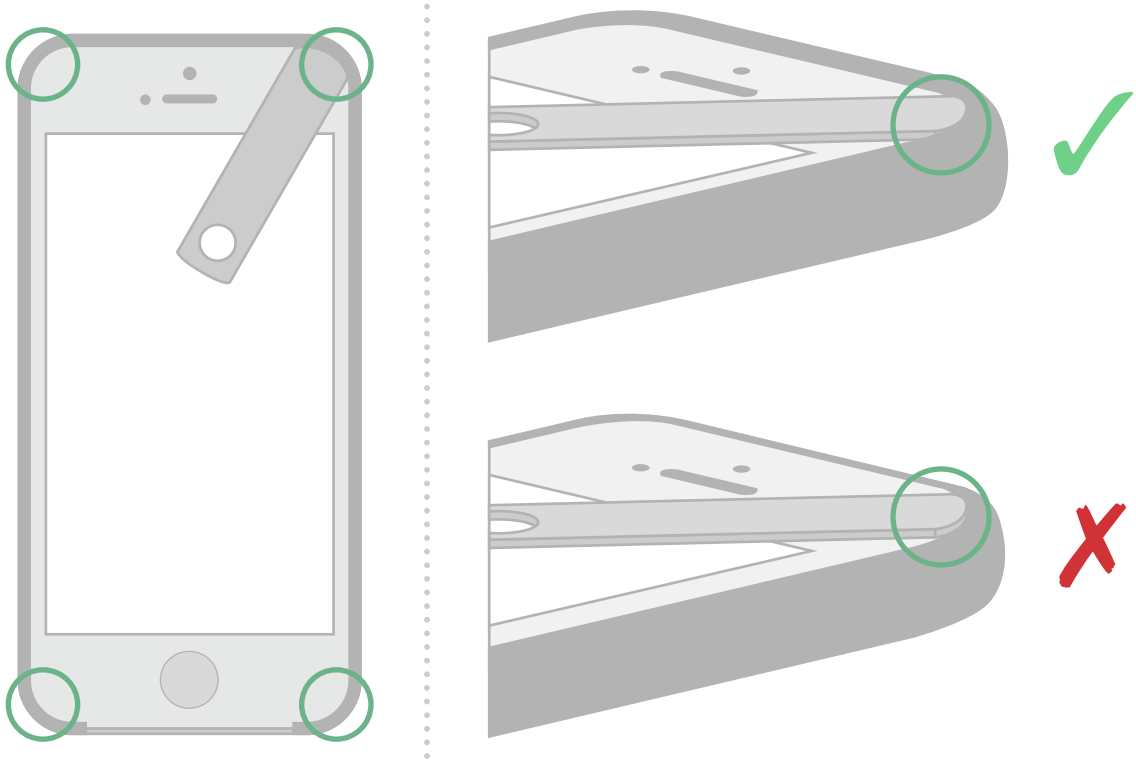
5.10.2.2 Procedure

1. Insert the device into the case.
2. Verify the device completely fits inside the case.
3. Verify the device is not loose.
4. Verify all buttons are accessible.
5. Inspect for button feel. Verify no button is too hard to press.
6. Verify speaker/microphone ports are not occluded.
7. If the device has an Apple Lightning receptacle:
   a. Insert the Apple Lightning Digital AV Adapter into the receptacle and verify it fits.
   b. Using vernier calipers, measure the Lightning connector opening on the case. Verify the opening meets the requirements in Access to the Lightning Connector (page 33).
8. If the device has a USB-C receptacle:
   a. Insert the Apple USB-C Digital AV Multiport Adapter into the receptacle and verify it fits.
   b. Using vernier calipers, measure the USB-C connector opening on the case. Verify the opening meets the requirements in Access to the USB-C Connector (page 32).
9. If the device has a 3.5 mm headset jack:
   a. Insert EarPods with 3.5 mm Headphone Plug into the headset jack and verify it fits.
   b. Using vernier calipers, measure the headset jack opening on the case. Verify the opening meets the requirements in Access to the Headset Jack (page 33).
10. If the device has a Touch ID sensor integrated with the Home button, use vernier calipers to verify the case is at least 2 mm away from the Touch ID sensor.
11. If the device has a Touch ID sensor integrated with the Side/Top button, use vernier calipers to verify the case meets the keep-out defined for each device the accessory claims compatibility with. See Dimensional Drawings (page 18).

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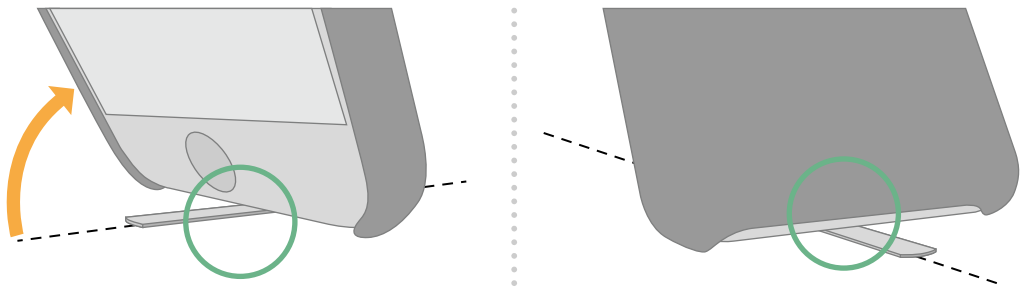
12. Verify the case is always proud of the feeler gauge when the gauge is placed at each corner of the device. See Figure 5-11 (page 60).

Figure 5-11 Device proudness test



13. Set the device flat on its face (screen facing down).
14. Roll the device towards any side not enclosed by the case until the gap between the device's exposed glass and flat surface is smallest.
15. Verify the feeler gauge fits into the gap between the device's exposed glass and flat surface.

Figure 5-12 Device gap test



16. If the case has an overlay, verify there are no air gaps introduced between it and the touchscreen.

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5.10.3 Camera Control

This test applies to devices with Camera Control.

5.10.3.1 Equipment

The following equipment is necessary:

- Device running iOS 27.2.
- Accessory Developer Assistant (ADA) (page 404) installed on the device.

5.10.3.2 Setup

1. Attach the case to the device.
2. Launch the Accessory Developer Assistant app and sign in.
3. Select Case, Camera Control.

5.10.3.3 Preload

1. Select Preload, and follow the on-screen instructions.
2. Verify the test passes.
3. Perform the Preload test again, firmly squeezing the device just above or below the Camera Control.
4. Verify the test passes.

5.10.3.4 Gestures

1. Perform the 'Light press', 'Click', and 'Slide' tests under Landscape, following the on-screen instructions for each.
2. Verify the tests pass.
3. Using only the left hand, perform the 'Light press', 'Click', and 'Slide' tests under Portrait, following the on-screen instructions for each.
4. Verify the tests pass.
5. Using only the right hand, perform the 'Light press', 'Click', and 'Slide' tests under Portrait, following the on-screen instructions for each.
6. Verify the tests pass.

5.10.4 Haptics

5.10.4.1 Equipment

The following equipment is necessary:

- Two devices of the same model.

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5.10.4.2 Setup

Repeat the following for each device:

1. Open Settings > Sounds & Haptics > Haptics, select Always Play.
2. If the device has an Action button, open Settings > Action Button, select Silent Mode.

5.10.4.3 Procedure

1. Attach the case to one device.
2. Verify the case does not cause substantial changes in the feel of the device's haptic feedback by comparing the haptic feedback between the devices for each of the following tasks:
   a. Turn Silent Mode on, then off:
      - If the device has a Ring/Silent switch, flip the switch.
      - If the device has an Action button, press and hold the Action button.
      - Otherwise, use the Silent Mode setting in Settings > Sounds & Haptics.
   b. Connect a charger, wait a few seconds, then disconnect the charger.
   c. Open Settings > Notifications > Phone > Sounds, select Reflection (Default).
   d. Open Settings > Notifications > Messages > Sounds, select Note (Default).
   e. Go to the Home Screen.
   f. Long press the Settings app to show the Quick Actions menu, then slide a finger across the menu and release to select Wi-Fi.
   g. Go to the Home Screen.
   h. Long press the Home app to show the Quick Actions menu. Release, then tap away from the menu to return to the Home Screen.
   i. Open the Clock app, select Timers, then scroll through the hours, minutes, and seconds.
   j. If the device has a Home button:
      a. Open Settings > General > Home Button, select option 2.
      b. Press the Home button.
      c. Place the device on a flat surface, like a table.
      d. Press the Home button.

5.10.5 Touch ID Sensor Overlays

This test procedure applies to accessories overlaying the Touch ID sensor.

5.10.5.1 Equipment

The following equipment is necessary:

- Nitrile gloves (for example, Ansell TNT Blue).
- Ethyl alcohol hand sanitizer (for example, Purell).
- Scissors.

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5.10.5.2 Procedure

1. Cut off a square of material from the nitrile glove's wrist portion.
2. Install the accessory onto the device.
3. Press the Side/Top button to place the device into a sleep state (display off).
4. Place the square of nitrile glove material over the Touch ID sensor with the glove's outer side facing away from the device.
5. Apply a small amount of hand sanitizer (approximately 2 cm in diameter) to the glove over the Touch ID sensor.
6. Repeat the following steps 10 times:
   a. Press the Touch ID sensor with a thumb.
   b. Verify the device wakes (display on).
   c. Place the device into a sleep state (display off).
7. Repeat the following steps 10 times:
   a. Press the Touch ID sensor with an index finger.
   b. Verify the device wakes (display on).
   c. Place the device into a sleep state (display off).

5.10.5.3 Pass/Fail Criteria

Verify the device wakes every time the Touch ID sensor is pressed.

5.10.6 Camera

5.10.6.1 Image Quality

This test applies to devices with a rear-facing camera.

5.10.6.1.1 Equipment

The following equipment is necessary:

- Dust-free rectangular room, see Figure 5-14 (page 65):
  - ≥400 cm width, ≥500 cm depth.
  - Symmetrical flat wall painted with a low reflectance (matte) black paint.
  - Average reflection factor <10%.
- 3D test charts, see https://developer.apple.com/download/files/camera-charts.zip:
  - Painted flat grey (10%) with micro beads (Mold-Tech MT11050 texture), see Figure 5-13 (page 64).
  - Small: 1270 mm (W) x 900 mm (H) x 47 mm (D) for wide and telephoto cameras.
  - Large: 1592 mm (W) x 1129 mm (H) x 13 mm (D) for ultra wide camera.
- Device running iOS 27.2 or iPadOS 27.2.

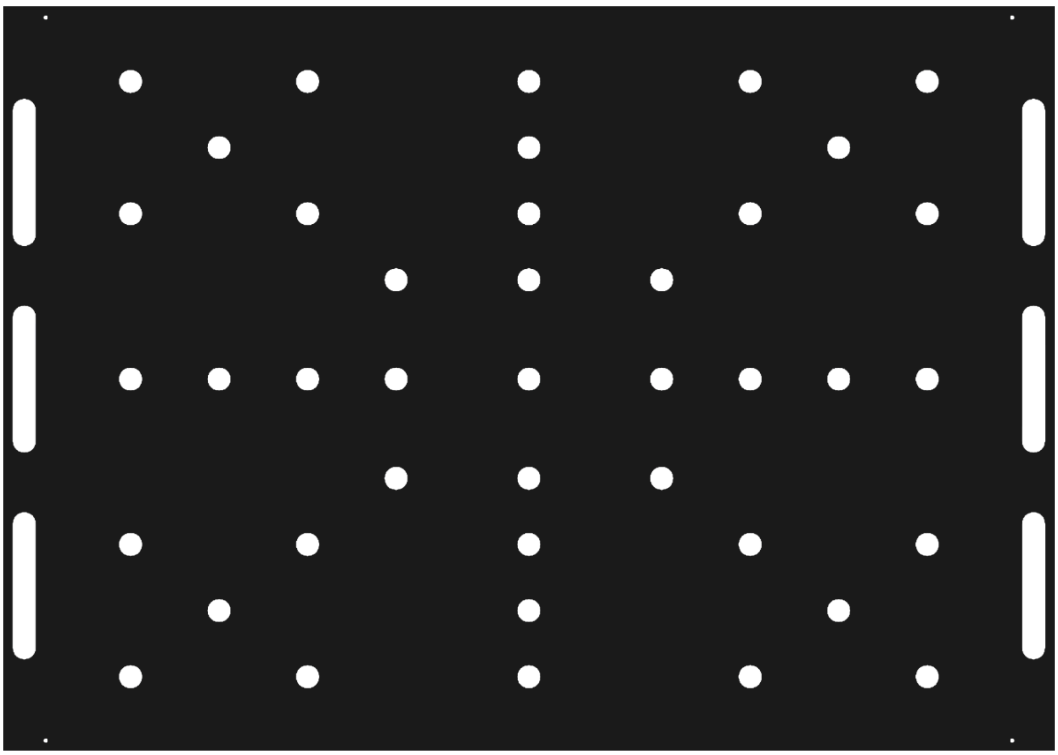
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- Tripod or fixture to hold the device.
- Accessory Developer Assistant (ADA) (page 404) installed on the device.

The following equipment is necessary for devices without a rear flash:

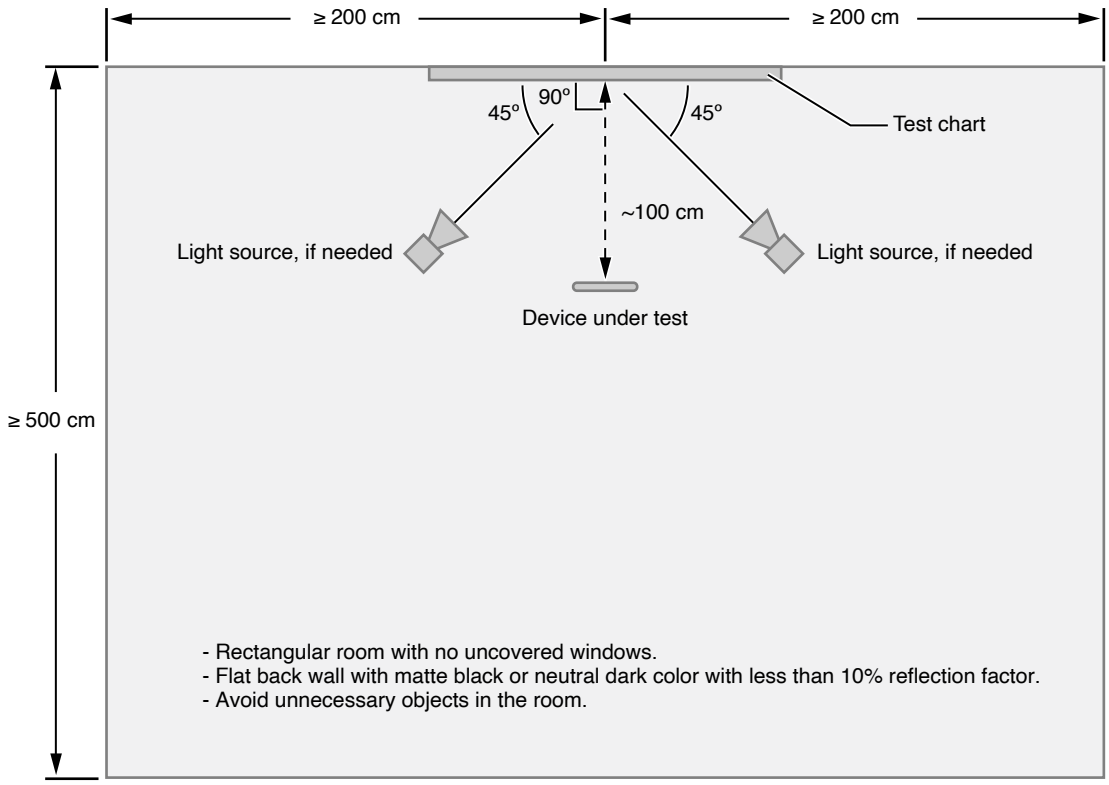
- Uniform light source:
  - Two dimmable fixtures capable of producing at least 400 lx of illuminance.
  - Correlated color temperature (CCT) of 5500 K ±200 K.
- Konica Minolta CL-200A chroma light meter or equivalent.

Figure 5-13 Camera image quality test chart



5.10.6.1.2 Setup

Figure 5-14 Image quality test setup



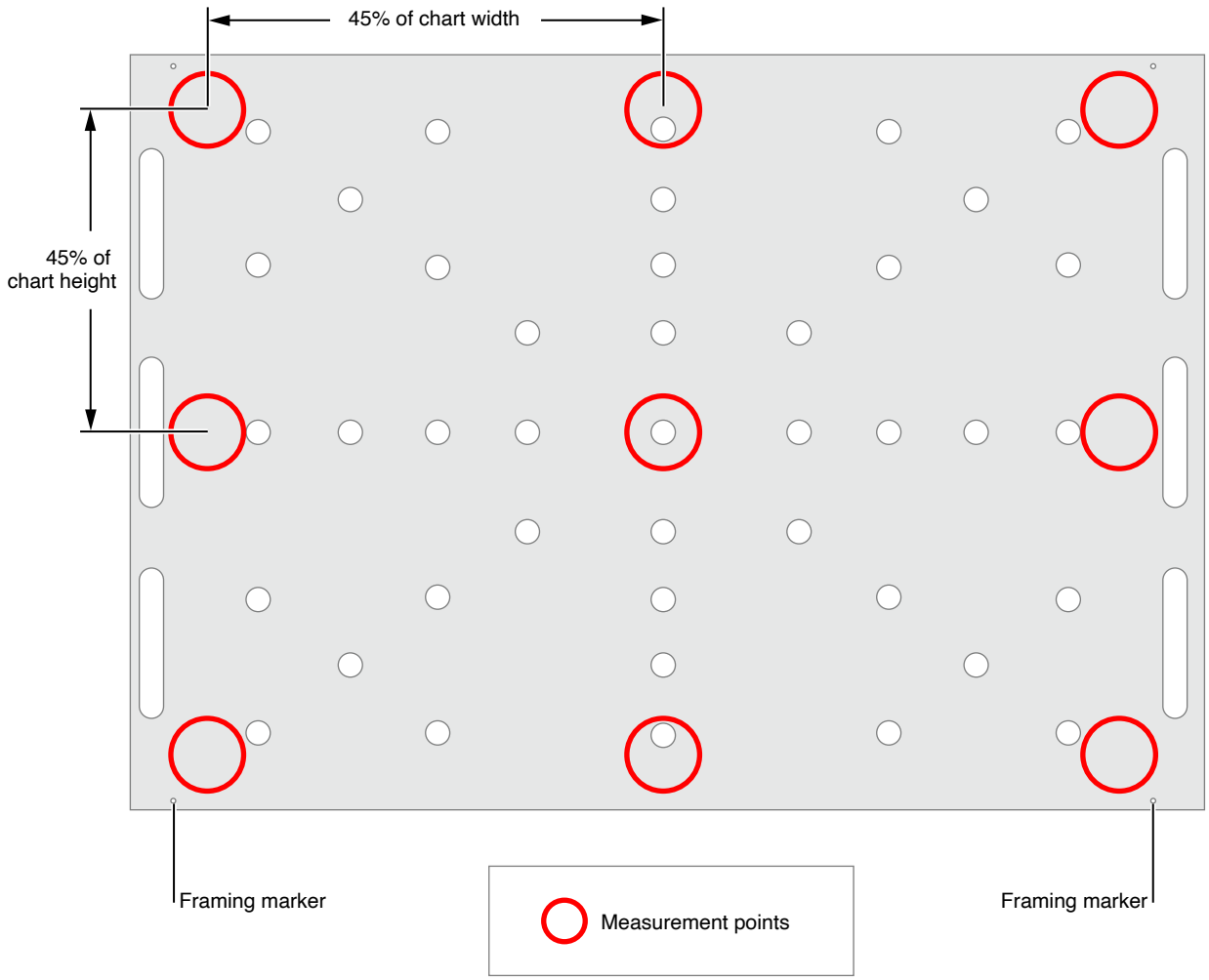
1. Center the test chart against the wall.
2. Take precautions to avoid stray light entering the camera lens or on the test chart.
3. Clean the camera lens and flash diffuser using a lens cleaning cloth or suitable alternative. Ensure no dust or fingerprints are visible on the camera lens.

If the device does not have a rear flash:

1. Place two light fixtures at an angle of 45° relative to the chart center. Verify shadows do not appear on the chart. A light diffuser may be used to reduce reflected glare.
2. Using the light meter, measure the light level at the 9 specified points in Figure 5-15 (page 66). Verify the illuminance at each point is 400 lx ±5% and all points are within 15 lx of each other.

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Figure 5-15 Illuminance measurement points



5.10.6.1.3 Procedure

1. Open Accessory Developer Assistant (ADA) (page 404) on the device.
2. Select Camera Image Quality Test.
3. Mount the appropriate test chart on the wall:
   - Small test chart for wide angle and telephoto.
   - Large test chart for ultra wide.
4. Mount the device on the tripod or fixture in landscape orientation so the rear camera(s) are at the top edge facing the test chart.
5. Align the camera lens with the center of the test chart at a distance of approximately 200 cm.
6. Verify the camera and the test chart are parallel.
7. Follow the instructions in the app, keeping the following in mind:

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- Move the device forwards or backwards until the test chart lines up with the test chart overlay on the app.
- Low lux: Power off all of the lights in the room. The image capture needs to be carried out in complete darkness.
- High lux: Set the illuminance at the test chart as specified in Setup (page 65).

5.10.6.2 Autofocus & Optical Image Stabilization

This test applies to devices with Autofocus (AF) and/or Optical Image Stabilization (OIS).

5.10.6.2.1 Equipment

The following equipment is necessary:

- Device running iOS 27.2 or iPadOS 27.2, see Device Models (page 43).
- Flat level non-ferrous test surface away from magnetic fields.
- Accessory Developer Assistant (ADA) (page 404) installed on the device.
- Autofocus & Optical Image Stabilization Test Profile (page 405) installed on the device.

5.10.6.2.2 Procedure

1. Launch the Accessory Developer Assistant (ADA) (page 404) app and sign in.
2. Select Case, Autofocus and Optical Image Stabilization.
3. Allow ADA to access the device camera, if prompted.
4. Set the device on the test surface.
5. Follow the on-screen instructions.
6. Select Measure Baseline and wait for the measurement to complete.
7. Attach the case being tested to the device.
8. Set the device back on the test surface.
9. Select Measure Attached and wait for the measurement to complete.
10. Verify all tests pass and note the results.

5.10.7 Near-Field Communication (NFC)

This test applies to devices with NFC.

5.10.7.1 Equipment

The following equipment is necessary:

- Device running iOS 27.2.
- Accessory Developer Assistant (ADA) (page 404) installed on the device.
- NFC tag.
- NFC transmitter.

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  - Another device with the ADA app may be used as an NFC transmitter.
- Flat level non-ferrous test surface away from magnetic fields.
- Straight edge non-metallic ruler.

5.10.7.2 Setup

1. Place the NFC tag or transmitter on the flat level non-ferrous test surface.
2. Position the ruler to measure the vertical distance from the NFC tag or transmitter to the device.

5.10.7.3 Procedure

This procedure establishes a detection baseline without a case attached and then tests are rerun with the case attached. The procedure is repeated for both NFC tag & transmitter modes.

1. Launch the Accessory Developer Assistant app and sign in.
2. Select Near Field Communication.
3. Select 'Test with NFC tag', and follow the on-screen instructions.
   a. Measure baseline average distance with no case attached.
   b. Attach case.
   c. Repeat measurements with case attached.
   d. Verify test passes.
4. Select 'Test with an NFC transmitter', and follow the on-screen instructions.
   a. If using a second device as an NFC transmitter:
      a. Open the ADA app on the second device.
      b. Select Apple Pay Detector.
      c. Select Start Detector.
   b. Measure baseline average distance with no case attached.
   c. Attach case.
   d. Repeat measurements with case attached.
   e. Verify test passes.
5. Perform multi-angle detection.
6. Verify multi-angle detection test passes.

5.10.8 Compass

5.10.8.1 Equipment

The following equipment is necessary:

- Device running iPadOS 27.2, see Device Models (page 43).
- Accessory Developer Assistant (ADA) (page 404) installed on the device.
- Flat level non-ferrous test surface away from magnetic fields.

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- Magnetometer, such as the Meda FVM400.

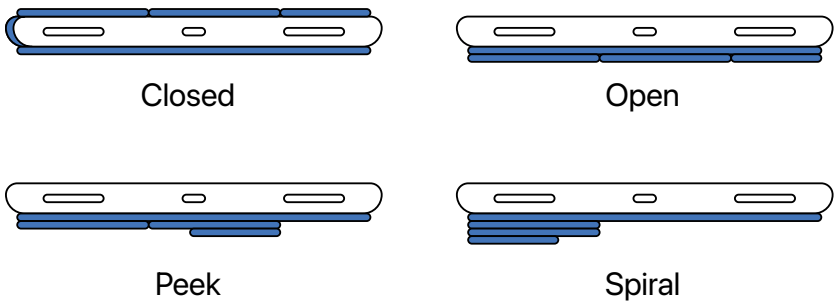
5.10.8.2 Setup

1. Place a mark on the test surface with a 90° angle to use for repeated device alignment. For example, use two pieces of tape perpendicular to each other.
2. Use the magnetometer to verify the test surface has a consistent magnetic field, not affected by nearby electronics or magnets.

5.10.8.3 Procedure

1. Launch the Accessory Developer Assistant app and sign in.
2. Select Compass and the case type, such as: Folio, Keyboard Folio, or Shell.
3. Scroll down and select all supported case configurations, see Figure 5-16 (page 69).

Figure 5-16 Case configurations



4. Scroll down and select all included case materials.
5. Select Start Test.
6. If a closed case configuration is selected, connect an external display and mouse when prompted.
7. Place the device with no case attached on the test surface, aligned to the mark.
8. Select Measure Baseline to collect an initial measurement.
9. Once the measurement is complete, follow the on-screen instructions to attach the case and collect a measurement for each supported case configuration.
10. Verify all tests pass and note the results.

5.10.9 Acoustics

Procedures apply to devices with a built-in speaker and/or microphone.

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5.10.9.1 Speakerphone Call

This procedure evaluates the impact of a case on the speakerphone performance of a device.

5.10.9.1.1 Setup

This procedure needs two operators in separate quiet rooms.

Room A:

- Operator A.
- The device used to evaluate the case with cellular service and at least two of four bars of cellular reception within the room.

Room B:

- Operator B.
- Landline speakerphone.
- Digital audio recorder (for example, a device with the Voice Memos app).

5.10.9.1.2 Pass/Fail Criteria

There are two categories of failure for this procedure:

- Echo: If Operator B hears their own voice from the landline.
- Double talk: If Operator B hears Operator A inconsistently.

Establish the pass/fail threshold for these two categories by performing the test procedure using the device (without the case) as a reference. If there is no perceivable difference between the reference and the same procedure conducted with the case on the device, the test passes.

5.10.9.1.3 Procedure

1. Operator A: Use the device (without a case) in Room A to call the landline phone in Room B.
2. Operator A: Place the device in speakerphone mode.
3. Operator B: Answer the call with the landline phone in Room B.
4. Operator B: Place the landline phone in speakerphone mode.
5. Operators A and B: Simultaneously recite the following phrases to evaluate the call quality:
   a. The birch canoe slid on the smooth planks.
   b. Glue the sheet to the dark blue background.
   c. It's easy to tell the depth of a well.
   d. These days a chicken leg is a rare dish.
   e. Rice is often served in round bowls.
   f. The juice of lemons makes fine punch.
   g. The box was thrown beside the parked truck.
   h. The hogs were fed chopped corn and garbage.

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i. Four hours of steady work faced us.
j. Large size in stockings is hard to sell.

6. Operator B: Evaluate the call. Ensure the call is audible and clear when there is no case on the device.
7. Operator A: Place the case on the device.
8. Operator B: Using a digital audio recorder, start audio recording.
9. Operator A: State the test date and identify the manufacturer name, case name, and a unique identifier (UID) for the case (production run name, design version, etc.).
10. Operators A and B: Simultaneously recite the same phrases as above.
11. Operator B: Stop audio recording.
12. Operator B: Evaluate the recording against the Pass/Fail Criteria (page 70).

The phrases used for this test procedure are from "IEEE Recommended Practice for Speech Quality Measurements," in *IEEE Transactions on Audio and Electroacoustics*, vol. 17, no. 3, pp. 225–246, September 1969.

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6. Covers

Covers are accessories providing protection by covering device displays.

6.1 Device Protection

Covers shall not damage coatings on the display in any operating condition (for example, when closed, carrying in a backpack, or storing).

6.2 Magnetic Interference

Accessory covers shall not interfere with the device's:

- Magnetic compass.
- Rear camera autofocus (AF).
- Rear camera optical image stabilization (OIS), if present.
- Front camera autofocus, if present.

See Magnetic Interference (page 26) for additional details.

6.3 Smart Covers

Magnet and Hall effect sensor locations may be found in Dimensional Drawings (page 18), see:

- iPad Air 13-inch (M4)
- iPad Air 11-inch (M4)
- iPad Pro 13-inch (M5)
- iPad Pro 11-inch (M5)
- iPad (A16)
- iPad mini (A17 Pro)
- iPad Pro 12.9-inch (6th generation)
- iPad Pro 11-inch (4th generation)
- iPad Air (5th generation)
- iPad mini (6th generation)
- iPad (9th generation)

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- iPad Pro 12.9-inch (5th generation)
- iPad Pro 11-inch (3rd generation)
- iPad Pro 12.9-inch (4th generation)
- iPad Pro 11-inch (2nd generation)

6.4 iPhone Duo

Covers for iPhone Duo shall:

- Be dimensioned for use either with or without an outer display overlay, allowing for the greatest overlay thickness recommended in Screen Overlays (page 74).
- Not prevent the device from reaching either its closed or its fully open state.
- Not prevent the device from reaching or holding any partially folded pose.
- Not apply force to the hinge across any part of its range of motion.

Covers for iPhone Duo which substantially enclose the device shall also comply with the requirements in Cases (page 29), other than providing access to the outer display active area.

Magnet and Hall effect sensor locations may be found in Dimensional Drawings (page 18).

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7. Screen Overlays

The displays on Apple products have been carefully engineered and tested to deliver exacting visual performance. Many products also feature Multi-Touch technology to support user interactions. Any material overlaying the screen or between the surface and users' fingers (or writing instruments on iPad) may impact the visual, touch, or sensor performance.

7.1 Product Design

A screen overlay shall not:

- Degrade the performance of Multi-Touch, Apple Pencil, or sensors.
- Introduce air gaps between the touchscreen and overlay.
- Be electrically conductive.
- Cause any color tinge to cool white light sources.

A screen overlay should have a relative permittivity (dielectric) of 3.1 to 3.2.

A screen overlay should not:

- Exceed 0.3 mm in thickness.
- Exceed 0.095 mm in thickness to support Apple Pencil.
- Have a water contact angle <110°.

> **Note:**
> Non-glossy surfaces may accelerate Apple Pencil tip wear.

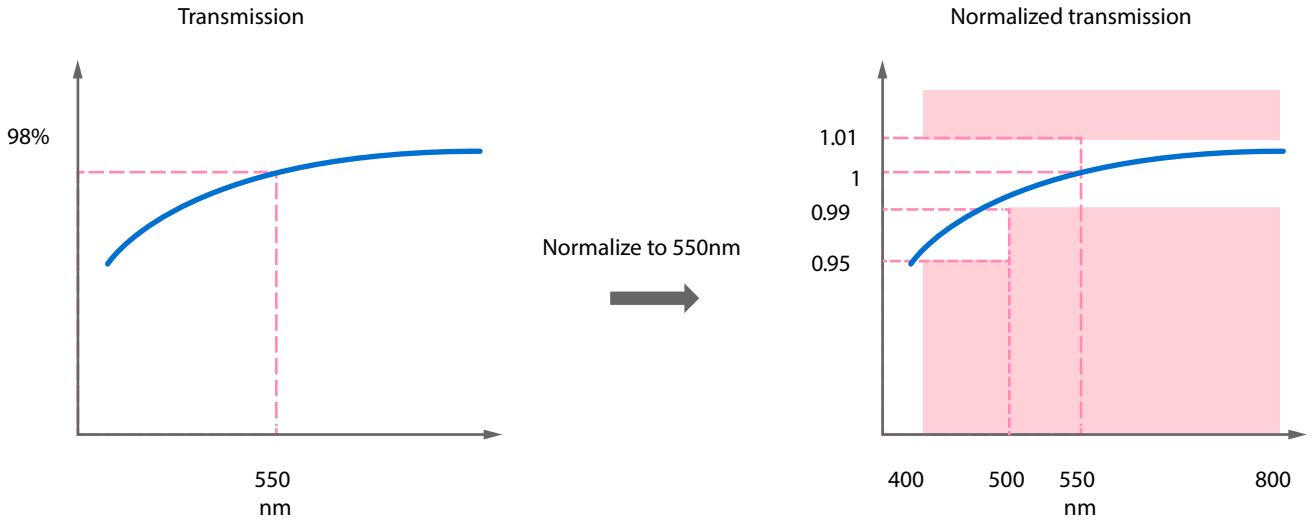
7.1.1 Optical Transmission

Optical transmission of screen overlays should:

- Be greater than 90% relative to clear glass for any viewing angle across the entire overlay.
- Remain flat as defined in Figure 7-1 (page 75). Upon normalizing the transmission spectrum to the value at 550 nm, the normalized spectrum should fall in the range of [0.99, 1.01] from 500 nm to 800 nm and [0.95, 1.01] from 400 nm to 500 nm.

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Figure 7-1 Transmission spectrum



7.1.2 Infrared Transmission

Infrared transmission variance shall not exceed 1.5% across the entire overlay. The infrared transmission in the 920–960 nm and 1200–1500 nm ranges relative to the light source should be greater than:

- 92% for an angle of incidence between 0° and 45°.
- 84% for an angle of incidence between 45° and 60°.

7.1.3 Transmission Haze

Transmission haze is the percentage of visible and infrared light scattered at more than 2.5° from the normal transmission. Screen overlay transmission haze, measured across the entire overlay, should:

- Not exceed 0.3% for:
  - iPhone Duo
  - iPhone 18 Pro Max
  - iPhone 18 Pro
  - iPhone 17 Pro Max
  - iPhone 17 Pro
  - iPhone 17
  - iPhone Air
  - iPhone 16 Pro Max
  - iPhone 16 Pro
  - iPhone 16 Plus
  - iPhone 16
  - iPhone 15 Pro Max
  - iPhone 15 Pro

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  - iPhone 15 Plus
  - iPhone 15
  - iPhone 14 Pro Max
  - iPhone 14 Pro
- Not exceed 13% for all other devices.
- Be measured with a haze meter, per *ASTM D1003*.

7.1.4 Coverage

A screen overlay shall not have a punch-out.

7.1.5 iPhone Duo

The requirements in this chapter apply to iPhone Duo outer display overlays. Apple does not recommend a screen overlay for the inner display.

An outer display overlay shall be dimensioned for use either with or without a case.

Outer display dimensions may be found in Dimensional Drawings (page 18).

7.2 Edge Swipe Gestures

See Edge Swipe Gestures (page 34).

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8. Camera Attachments

Camera attachments are accessories intentionally altering images captured by device cameras.

8.1 Magnetic Interference

Camera attachments shall not interfere with the device's:

- Magnetic compass.
- Rear camera autofocus (AF).
- Rear camera optical image stabilization (OIS), if present.
- Front camera autofocus, if present.

See Magnetic Interference (page 26) for additional details.

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9. Adapters

An adapter accessory is a dongle or a Built-In Cable (page 21) enabling connections between physically incompatible devices and accessories.

Unless otherwise specified, accessories may integrate one or more adapter components as well as other accessory features to create more advanced multi-port adapters. For example, a Lightning or USB-C adapter may support audio, power, external storage, media controls, app communication, and more.

See the Accessory Interface Specification (page 22) for more information.

9.1 Headset Adapters (Lightning to 3.5 mm)

Lightning to 3.5 mm headset adapters are accessories enabling 3.5 mm audio connections.

See the Accessory Interface Specification (page 22) for more information.

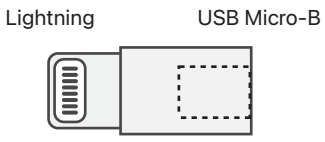
9.2 USB-A/USB-C to Lightning Headset Adapters

USB-A to Lightning or USB-C to Lightning headset adapters are accessories integrating a Lightning Receptacle (C37) to support Lightning headsets, speakers, and microphones.

See the Accessory Interface Specification (page 22) for more information.

9.3 Lightning to USB Micro-B Adapters

Figure9-1 Lightning to USB Micro-B adapter



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Lightning to USB Micro-B adapters are Lightning dongle accessories functioning exactly like the Apple Lightning to USB Micro-B Adapter and shall consist of:

- Lightning connector.
- USB Micro-B receptacle.

See the Accessory Interface Specification (page 22) for more information.

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10. AC Power Adapters

AC power adapters convert AC "mains" power to DC to provide power to a device and may provide power using:

- Device Power (Inductive) (page 251).
- Device Power (USB-C) (page 244).
- Device Power (Lightning) (page 246).

10.1 Converter Switching Frequencies

Device touchscreen or audio functionality may be degraded by converter switching frequencies. Converter switching frequencies shall:

- Be above 22 kHz under loads greater than 5 mA.
- Be above 60 kHz under loads greater than 20 mA.

Converter switching frequencies should be above 450 kHz under loads greater than 20 mA.

10.2 YCAP AC Capacitor

AC power adapters should include a YCAP AC capacitor (up to 1000 pF) between the primary and secondary sections of the adapter's transformer to reduce common-mode noise at switching frequencies. These frequencies or their harmonics can interfere with device touchscreen sensors.

10.3 Impedance Stability

AC power adapter series impedance should not change abruptly. Sudden changes in impedance may cause touchscreen sensor output oscillations.

Bridge diodes used in full-wave bridge rectifiers can be a major source of abrupt changes in the series impedance. If the bridge diodes have large inherent reverse capacitance (greater than 100 pF), then the net impedance change due to diode switching may be acceptably small. However, diode reverse capacitance may decrease in more compact IC designs due to decreased chip area.

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Impedance of bridge diodes with unacceptably low reverse capacitance can be stabilized using the example circuit shown in Figure 10-1 (page 81) and Table 10-1 (page 81). In this example, capacitors C1, C2, C3, and C4 have been placed in parallel with diodes D1, D2, D3, and D4 to stabilize the bridge impedance. Their values are larger than the inherent reverse capacitances of the diodes.

Resistors R1, R2, R3, and R4 are optional; if included, they can block noise at very high frequencies, which can help with EMI compatibility. The recommended values of R1, R2, R3, and R4 in Table 10-1 (page 81) were chosen to have trivial levels of impedance relative to the impedances of C1, C2, C3, and C4 at power line frequencies.

Figure 10-1 Typical AC power adapter diode bridge circuit

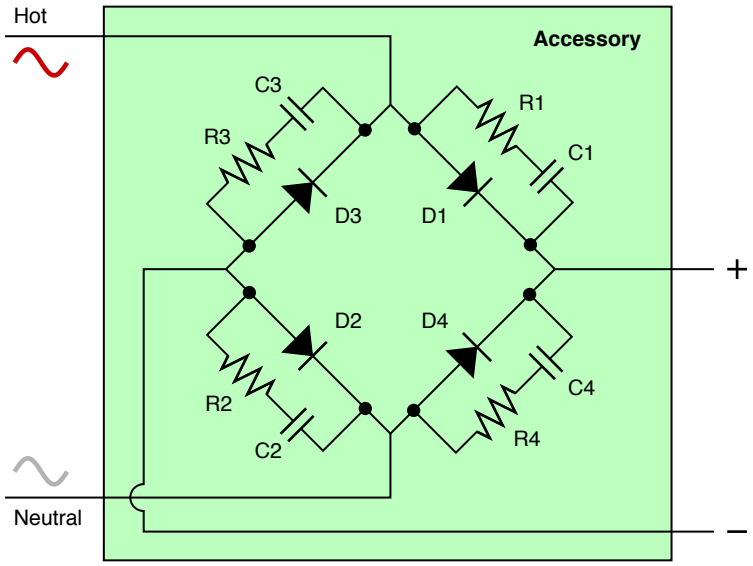


Table 10-1 Typical component values for an AC power adapter diode bridge circuit

Component	Value
C1, C2, C3, C4	47 pF
R1, R2, R3, R4	2 kΩ

10.4 Fuse Protection

A fuse should be present at the input of the AC power adapter to protect it under any fault condition.

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10.5 Short Circuit Response

The output of the AC power adapter should drop or fold back without any resulting damage if its output is shorted to the secondary common (less than 10 mΩ).

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11. Battery Packs

A battery pack is an accessory designed to provide power to the device.

The battery pack may provide power using:

- Device Power (Inductive) (page 251).
- Device Power (USB-C) (page 244).
- Device Power (Lightning) (page 246).

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12. Headsets

Headsets provide users with personal audio experiences. Devices treat headsets differently from accessories with speakers.

Headsets shall comply with:
- TDMA Noise (page 26) requirements.
- Applicable volume limit regulations in the regions in which they are sold.

Wired headsets should support Apple Music Lossless or Hi-Res Lossless, see https://support.apple.com/en-us/118295.

12.1 Product Design

Headsets shall have:
- Drivers positioned at user's ears.
- Microphone(s) positioned to record user's voice.

12.2 Audio Interface

Headsets shall establish audio connections to devices using one of the following interfaces:
- USB-C Plug (page 385), including the Apple USB-C Analog Headset Module (page 351).
- Bluetooth (page 331):
  - Hands-Free Profile (HFP) (page 335).
  - Advanced Audio Distribution Profile (A2DP) (page 340).
- Headset Plug (3.5 mm) (page 394).

If connected using the USB-C Plug (page 385), headsets shall integrate one of the following:
- Apple USB-C Analog Headset Module (page 351) (recommended for standard headsets).
- USB Audio Device Class 2.0 or 4.0 compliant codec.

12.3 Remote Controls

Headsets connecting to a device using the USB-C connector or Headset Plug (3.5 mm) (page 394) shall implement three physical controls (volume up, volume down, and center buttons) mimicking the labeling and behavior of an Apple wired headset.

Controls shall be implemented using one of the following:

- Direct electrical connections to a Headset Remote and Microphone Transmitter (page 364), when integrating:
  - Apple USB-C Analog Headset Module (page 351).
  - Headset Plug (3.5 mm) (page 394).
- HID Headset Remote (page 258) when using one of the following:
  - USB-C Plug (page 385) with a USB Audio Device Class 2.0 or 4.0 compliant codec.
  - Bluetooth (page 331).
- Bluetooth Audio/Video Remote Control Profile (AVRCP) (page 338).

Bluetooth headsets should implement controls identical to an Apple wired headset.

12.4 Analog Microphone

Headsets using a Headset Plug (3.5 mm) (page 394) and a Headset Remote and Microphone Transmitter (page 364) shall use one of the MEMS analog microphone components and its associated R8 resistor value specified in Table 12-1 (page 85).

Table 12-1 MEMS analog microphone and R8 value for transmitter circuit

MEMS Analog Microphone (U2)	Resistor (R8)
Knowles SPV3840LR5H	3.60 kΩ ±1%, 1/20 W
Goertek S15OB383-002	1.91 kΩ ±1%, 1/20 W

12.5 USB-C Headset Identification

USB-C headsets shall:

- Set the idVendor, idProduct, iManufacturer, iProduct, and iSerialNumber in the Standard Device Descriptor to reflect the accessory markings and packaging.
- Set the Output Terminal Type to `0x0302` (Headphones) if the headset does not integrate a microphone.
- Set the Output Terminal Type and Input Terminal Type to `0x0402` (Headset) if the headset integrates a microphone.

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- Set the Audio Function Category to `0x04` (Headset).

USB-C headsets should:

- Set the iInterface Playback and iInterface Record strings to reflect the accessory markings and packaging.
- Set a unique iSerialNumber in the Standard Device Descriptor.

> **Note:**
> C125 has its Output Terminal Type and Input Terminal Type set to `0x0402` (Headset) and Audio Function Category set to `0x04` (Headset). These configurations cannot be overwritten.

12.6 Verification

12.6.1 Product Design

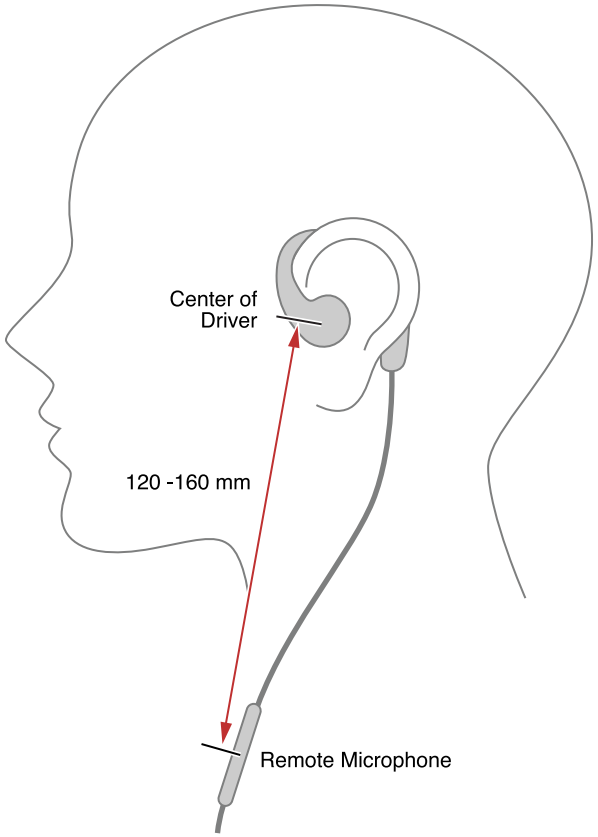
1. Verify the headset drivers are positioned at the user's ears.
2. Verify the headset microphone is positioned to record the user's voice.

If the headset incorporates a Headset Remote and Microphone Transmitter:

1. Verify the headset microphone is located 120–160 mm from the center of a headset driver. If the headset cable is intended to loop around the ear, measure the distance as if the accessory is being worn, see Figure 12-1 (page 87).

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Figure 12-1 Headsets looped around ear test setup



12.6.2 Headset Plug (3.5 mm)

If the headset connects using a 3.5 mm headset plug:

1. Perform the Headset Plug (3.5 mm) Verification (page 401).
2. Perform the Headset Remote and Microphone Transmitter Verification (page 370).

12.6.3 USB-C

If the headset connects to the device using a USB-C connector:

1. Using a USB protocol analyzer, verify the Standard Device Descriptor, terminal types, and Audio Function Category are set correctly. See USB-C Headset Identification (page 85).

12.6.4 Microphone

1. Start an audio recording using the Voice Memos app.
2. Blow or tap on the accessory microphone, and verify audio is clearly recorded.
3. Blow or tap on the device microphone, and verify minimal audio is recorded.

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4. Stop recording.

12.6.5 Controls

1. If the headset connects to the device using a USB-C connector or a 3.5 mm headset plug:
    a. Verify there is a volume up button, it is labeled with a '+', and it increases the volume on the device.
    b. Verify there is a volume down button, it is labeled with a '-', and it decreases the volume on the device.
    c. Verify there is a center button with the same behavior as a wired Apple headset:
        a. Verify the button is not labeled with a 'Play/Pause' icon.
        b. Verify play and pause work for songs and video tracks when pressing the center button.
        c. Verify next track works when pressing center button twice quickly.
        d. Verify fast forward works when pressing then press-and-holding the center button.
        e. Verify previous track works when pressing center button 3 times quickly.
        f. Verify pressing the center button once answers an incoming phone call.
        g. Verify pressing the center button once ends an active phone call.
        h. Verify a long press of the center button declines an incoming phone call.
    d. While the accessory is attached to the device:
        a. Verify the device enters a sleep state after a period of inactivity.
        b. Verify pressing the center button on the headset wakes the device from a sleep state.
        c. Verify pressing any other button on the headset does not wake the device from a sleep state.
        d. After the device enters a sleep state, activate Siri by pressing and holding either the device Side/Top/Home button, or headset center button. Verify the Siri tone is heard in full through the headset.
        e. After the device enters a sleep state, trigger a notification (such as an incoming text message). Verify the notification sound is heard in full through the headset.
2. If the headset has additional controls/buttons (beyond volume up, volume down, and center buttons):
    a. Verify each additional control has only one function associated with it.
    b. Verify each additional control has appropriate iconography/labeling for the associated function.
    c. Verify each associated function only triggers due to a direct user action.

12.6.6 Audio Quality

1. Verify the accessory output stream is devoid of pops/clicks or artifacts at all times, with and without music playing, especially during call connection or disconnection.

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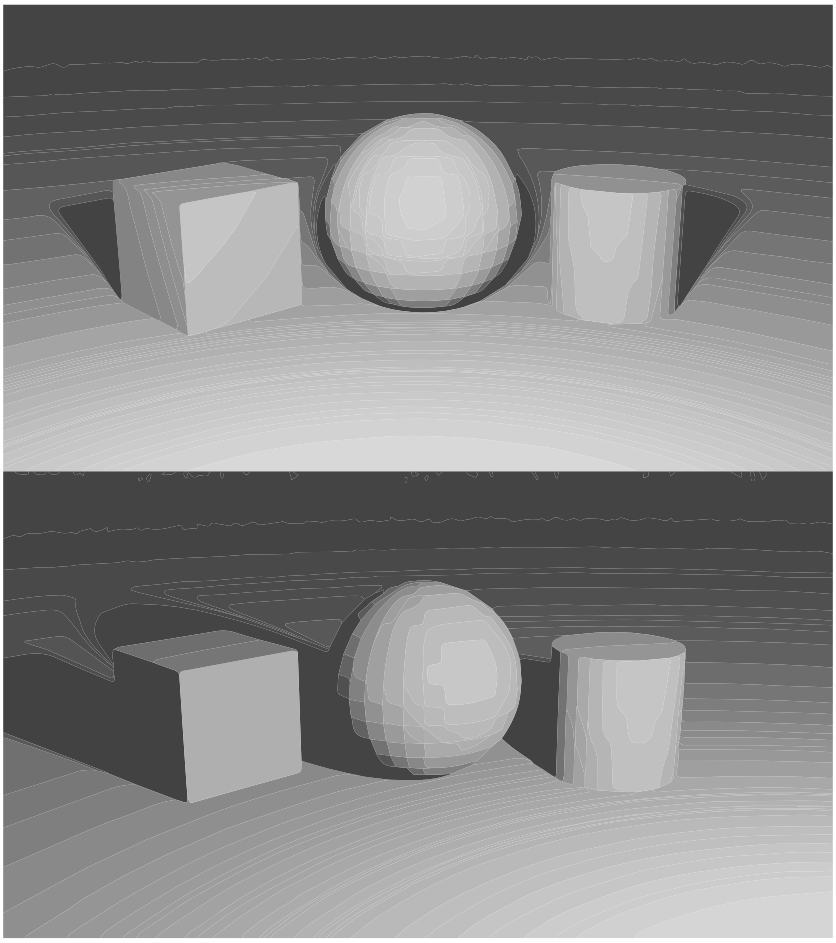
13. Strobes

Strobe accessories replace a device's integrated flash when capturing a still image from either the front or rear-facing cameras. Photographers can use such accessories to control scene lighting for creative purposes.

Strobes are:

- Compatible with all iOS camera applications.
- Synchronized with iPhone camera using the Lightning connector.

Figure 13-1 Example of integrated flash (top) vs. external strobe (bottom)



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Devices supporting strobe accessories:

- iPhone 14 Pro Max
- iPhone 14 Pro
- iPhone 14 Plus
- iPhone 14
- iPhone SE (3rd generation)
- iPhone 13 Pro Max
- iPhone 13 Pro
- iPhone 13
- iPhone 13 mini
- iPhone 12 Pro Max
- iPhone 12 Pro
- iPhone 12
- iPhone 12 mini
- iPhone SE (2nd generation)
- iPhone 11 Pro Max
- iPhone 11 Pro
- iPhone 11

This feature is supported starting in iOS 14.0.

See the Accessory Interface Specification (page 22) for more information.

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14. Keyboards

Devices may accept user input from accessory keyboards in place of the onscreen keyboard.

14.1 Requirements

Accessory keyboards shall:

- Support the Human Interface Device (HID) (page 320) protocol.
- Not identify themselves as Apple-branded accessories, for example, using the Apple Vendor ID and/or Product IDs.

Keyboards exhibiting any of the following behaviors are explicitly prohibited:

- Sending anything other than 'key pressed' or 'key released' for key(s) physically pressed/released.
- Emulating combinations or sequences of keys (for example, a Copy button sending ⌘-C or macros generating a timed sequence of events), or combinations of touch gestures.
- Emulating timed user actions, such as 'press-and-hold', 'click and hold', drag, and zoom gestures.
- Sending different HID usages depending on the state of another control surface.

HID reports sent from the keyboard shall only occur in response to a Direct User Action (page 21).

Keyboards may integrate LEDs to indicate the:

- Caps Lock status of the device.
- Connection status, such as Bluetooth state.
- Battery status of the accessory, if applicable.

Keyboards shall not incorporate any other status LEDs not supported by devices.

Apple recommends Keyboards Integrating a Trackpad (page 96), when possible, to provide an enhanced user experience.

Mechanical key layout shall be based on the *ISO/IEC 9995-2*, *ANSI-INCITS 154-1988*, or *JIS X 6002-1980* standards. Keyboard HID descriptors shall set the Keyboard Physical Layout usage to the appropriate layout code as defined in Table 14-5 (page 95).

Keyboard HID descriptors shall set the bCountryCode field to the appropriate country code as defined in *Device Class Definition for Human Interface Devices (HID) – Version 1.11, Section 6.2.1 HID Descriptor*.

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Keyboard HID descriptors shall declare support for the HID Keyboard/Keypad Page. HID report descriptors may declare an input usage minimum of 0 and maximum of 255 as shown in Example HID Report Descriptor (page 98) for efficiency. Otherwise, the descriptor shall individually enumerate each HID Keyboard/Keypad page usage the keyboard is capable of sending.

Keyboards shall implement individual keys emitting the following HID Keyboard/Keypad page usages:

Table 14-1 Required HID Keyboard/Keypad Page (`0x07`) controls for use by keyboards

Usage ID	Usage Name	Apple Function
`0x0004`	a and A	a and A
`0x0005`	b and B	b and B
`0x0006`	c and C	c and C
`0x0007`	d and D	d and D
`0x0008`	e and E	e and E
`0x0009`	f and F	f and F
`0x000A`	g and G	g and G
`0x000B`	h and H	h and H
`0x000C`	i and I	i and I
`0x000D`	j and J	j and J
`0x000E`	k and K	k and K
`0x000F`	l and L	l and L
`0x0010`	m and M	m and M
`0x0011`	n and N	n and N
`0x0012`	o and O	o and O
`0x0013`	p and P	p and P
`0x0014`	q and Q	q and Q
`0x0015`	r and R	r and R
`0x0016`	s and S	s and S
`0x0017`	t and T	t and T
`0x0018`	u and U	u and U
`0x0019`	v and V	v and V
`0x001A`	w and W	w and W
`0x001B`	x and X	x and X
`0x001C`	y and Y	y and Y
`0x001D`	z and Z	z and Z
`0x001E`	1 and !	1 and !
`0x001F`	2 and @	2 and @
`0x0020`	3 and #	3 and #

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Usage ID	Usage Name	Apple Function
0x0021	4 and $	4 and $
0x0022	5 and %	5 and %
0x0023	6 and ^	6 and ^
0x0024	7 and &	7 and &
0x0025	8 and *	8 and *
0x0026	9 and (	9 and (
0x0027	0 and)	0 and)
0x0028	Return/Enter	Return
0x002A	Delete/Backspace	Delete
0x002B	Tab	Tab
0x002C	Spacebar	Spacebar
0x002D	- and _	- and _
0x002E	= and +	= and +
0x002F	[and {	[and {
0x0030	] and }	] and }
0x0031	\ and |	\ and |
0x0033	; and :	; and :
0x0034	' and "	' and "
0x0035	Grave Accent and Tilde	` and ~
0x0036	, and <	, and <
0x0037	. and >	. and >
0x0038	/ and ?	/ and ?
0x0039	CapsLock	Caps Lock
0x004F	RightArrow	Right Arrow
0x0050	LeftArrow	Left Arrow
0x0051	DownArrow	Down Arrow
0x0052	UpArrow	Up Arrow
0x00E1	LeftShift	Left Shift
0x00E2	LeftAlt	Left Option / Alt
0x00E3	LeftGUI	Left Command / ⌘
0x00E5	RightShift	Right Shift
0x00E6	RightAlt	Right Option / Alt
0x00E7	RightGUI	Right Command / ⌘

Keyboards may implement individual keys emitting the following HID Keyboard/Keypad page usages:

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Table 14-2 Optional HID Keyboard/Keypad Page (0x07) controls for use by keyboards

Usage ID	Usage Name	Apple Function
0x0029	Escape	Escape
0x00E0	LeftControl	Left Control
0x00E4	RightControl	Right Control
0x004A	Home	Home
0x004D	End	End
0x0054	Keypad /	Keypad /
0x0055	Keypad *	Keypad *
0x0056	Keypad -	Keypad -
0x0057	Keypad +	Keypad +
0x0058	Keypad Enter	Keypad Enter
0x0059	Keypad 1 and End	Keypad 1
0x005A	Keypad 2 and Down Arrow	Keypad 2
0x005B	Keypad 3 and PageDn	Keypad 3
0x005C	Keypad 4 and Left Arrow	Keypad 4
0x005D	Keypad 5	Keypad 5
0x005E	Keypad 6 and Right Arrow	Keypad 6
0x005F	Keypad 7 and Home	Keypad 7
0x0060	Keypad 8 and Up Arrow	Keypad 8
0x0061	Keypad 9 and PageUp	Keypad 9
0x0062	Keypad 0 and Insert	Keypad 0
0x0063	Keypad . and Delete	Keypad .
0x0067	Keypad =	Keypad =

Keyboards may implement individual keys emitting the following HID Consumer page usages:

Table 14-3 HID Consumer Page (0x0C) controls for use by keyboards

Usage ID	Usage Name	Apple Function
0x0030	Power	Lock
0x0040	Menu	Home Button
0x0065	Snapshot	Screenshot
0x006F	Display Brightness Increment	Brighter
0x0070	Display Brightness Decrement	Dimmer
0x00B5	Scan Next Track	Transport Right
0x00B6	Scan Previous Track	Transport Left

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Usage ID	Usage Name	Apple Function
0x00CD	Play/Pause	Play/Pause
0x00CF	Voice Command	Siri
0x00E2	Mute	Mute
0x00E9	Volume Increment	Louder
0x00EA	Volume Decrement	Softer
0x01AE	AL Keyboard Layout	Toggle Onscreen Keyboard
0x029D	AC Keyboard Layout Select	Globe Key
0x0221	AC Search	Spotlight
0x025B	Promote	Play More Like This
0x025C	Demote	Play Less Like This
0x0262	Add to Cart	Add to Wish List
0x02C3	Keyboard Physical Layout	Keyboard Physical Layout, see Table 14-5 (page 95).

Keyboards may implement individual keys emitting the following HID Generic Desktop page usages:

Table 14-4 HID Generic Desktop Page (0x01) controls for use by keyboards

Usage ID	Usage Name	Apple Function
0x009B	System Do Not Disturb	Toggle Focus Mode

Table 14-5 Keyboard Physical Layout codes

Value	Description
1	101 (for example, US) - ANSI
3	102 (for example, German) - ISO
5	106 (DOS/V Japan) - JIS

JIS keyboards shall also implement additional keys found on the Japanese Apple Magic Keyboard. Non-JIS keyboards shall not implement the Japanese keys.

Table 14-6 Required HID Keyboard/Keypad Page (0x07) controls for use by JIS keyboards

Usage ID	Usage Name	Apple Function
0x0087	Keyboard International1	_
0x0089	Keyboard International3	¥
0x0090	LANG1	Switch to Previous Language
0x0091	LANG2	Switch to Next Language

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14.2 Keyboards Integrating a Trackpad

This feature is supported starting in iPadOS 14.5.

In addition to Requirements (page 91), keyboards integrating a trackpad shall support:

- 2–5 simultaneous contacts on the trackpad.
- Key and trackpad input together, for example, holding a modifier key while dragging, or switching rapidly between typing and moving the pointer.

14.2.1 HID Report Descriptor

The HID report descriptor for a keyboard integrating a trackpad shall:

- Define the trackpad's top-level application collection, with usage page `0x0D` (Digitizer Page) and usage ID `0x0005` (Touch Pad).
- Assign a Report ID to every report, including the keyboard's.

Devices provide no pointer movement, scrolling, or gestures for a trackpad with a HID report descriptor of its own, for example, on a separate USB HID interface or Bluetooth HID service.

The Touch Pad collection shall correspond to a physical trackpad on the accessory for tasks otherwise performed using the device's touchscreen.

The trackpad shall implement the following HID Digitizer page usages:

Table 14-7 Required HID Digitizer Page (`0x0D`) controls for use by keyboards integrating a trackpad

Usage ID	Usage Name	Apple Function
`0x0001`	Button 1	Primary button state
`0x0022`	Finger	Number of contact collection points
`0x0030`	X	X coordinate of contact position
`0x0031`	Y	Y coordinate of contact position
`0x0038` or `0x0051`	Transducer Index or Contact ID	Index (from 0 to 4) uniquely identifying the finger/contact
`0x0042`	Tip Switch	Contact is on the surface of the digitizer
`0x0047`	Confidence	Touch is an intended, valid contact
`0x0057`	Surface Switch	Digitizer surface on/off

The trackpad should implement the following HID Digitizer page usages:

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Table 14-8 Recommended HID Digitizer Page (`0x0D`) controls for use by keyboards integrating a trackpad

Usage ID	Usage Name	Apple Function
`0x0002`	Button 2	Secondary button state
`0x0056`	Scan Time	Relative scan time
`0x00A1`	Report Rate	Report rate (Hz)

14.2.2 Click to Wake

While the device has cleared the Surface Switch usage in the trackpad's feature report (Click to Wake mode), the trackpad shall report button clicks only and may scan the digitizer surface less often, or not at all, to save power. The trackpad shall return its current Surface Switch state and, if implemented, its Report Rate whenever the device reads the feature report after enumeration.

14.2.3 Input Confidence

The trackpad shall:

- Clear the Confidence usage when a contact transitions from valid to invalid.
- Detect and reject unintended or invalid inputs, such as palms, while continuing to report valid inputs to the device, such as multiple contacts.
- Distinguish between a valid large thumb and an invalid lightly resting palm.
- Reject inputs ≥1 mm from the tracking surface.

The trackpad should classify contacts quickly, accurately, and stably to achieve the best user experience. Incorrect or fluctuating classification of contacts may result in recognition of unintended gestures, interruption, or cancellation of intended gestures.

14.2.4 Performance

The trackpad shall:

- Behave uniformly across the digitizer surface.
- Uniquely detect contact points as close as 8 mm center to center.
- Detect contact sizes of at least 5 mm.
- Differentiate between multi-finger taps and single-finger drags.
- Maintain an effective input resolution less than 20 µm and immediately report positional updates greater than or equal to the effective input resolution.
- Maintain an effective resolution more than 600 DPI.
- Maintain the highest possible report rate to the device. Apple recommends 60 Hz or higher.
- Maintain a panning latency less than or equal to 23 ms.
- Maintain a touch down latency less than or equal to 35 ms.

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- Maintain a positional accuracy less than or equal to 500 µm.
- Maintain a stationary contact jitter less than or equal to 210 µm.
- Not deviate more than 250 µm from an ideal line.

14.2.5 Coexistence

The trackpad shall:

- Not degrade the performance of Multi-Touch or Apple Pencil.
- Not support a drive voltage greater than 6 V_{pp}.
- Not support drive frequencies less than 500 kHz.
- Support three or more drive frequencies, separated by at least 50 kHz each.
- Dynamically switch between drive frequencies whenever effective resolution drops below 120 DPI. For example, effective resolution may drop in the presence of 50 mV RMS noise from external power sources.

The trackpad should support a sine wave narrow band drive frequency.

14.3 Examples

14.3.1 Example HID Report Descriptor

```
USAGE PAGE (Generic Desktop)              05 01
USAGE (Keyboard)                          09 06
COLLECTION (Application)                  A1 01
  USAGE PAGE (LEDs)                       05 08
  LOGICAL MINIMUM (0)                     15 00
  LOGICAL MAXIMUM (1)                     25 01
  USAGE (Caps Lock)                       09 02
  REPORT SIZE (1)                         75 01
  REPORT COUNT (1)                        95 01
  OUTPUT (Data,Var,Abs)                   91 02
  REPORT SIZE (7)                         75 07
  REPORT COUNT (1)                        95 01
  OUTPUT (Cnst,Var,Abs)                   91 03
  USAGE PAGE (Keyboard)                   05 07
  USAGE MINIMUM (Keyboard Left Control)   19 E0
  USAGE MAXIMUM (Keyboard Right GUI)      29 E7
  REPORT SIZE (1)                         75 01
  REPORT COUNT (8)                        95 08
  INPUT (Data,Var,Abs)                    81 02
  LOGICAL MINIMUM (0)                     15 00
  LOGICAL MAXIMUM (255)                   26 FF 00
  USAGE MINIMUM (0)                       19 00
  USAGE MAXIMUM (255)                     2A FF 00
```

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```
  REPORT SIZE (8)                         75 08
  REPORT COUNT (5)                        95 05
  INPUT (Data,Ary,Abs)                    81 00
  USAGE PAGE (Consumer Devices)           05 0C
  LOGICAL MINIMUM (0)                     15 00
  LOGICAL MAXIMUM (1)                     25 01
  USAGE (Menu)                            09 40
  USAGE (AC Search)                       0A 21 02
  USAGE (AL Keyboard Layout)              0A AE 01
  USAGE (Scan Previous Track)             09 B6
  USAGE (Play/Pause)                      09 CD
  USAGE (Scan Next Track)                 09 B5
  USAGE (Mute)                            09 E2
  USAGE (Volume Down)                     09 EA
  USAGE (Volume Up)                       09 E9
  USAGE (Power)                           09 30
  REPORT SIZE (1)                         75 01
  REPORT COUNT (10)                       95 0A
  INPUT (Data,Var,Abs)                    81 02
  REPORT SIZE (6)                         75 06
  REPORT COUNT (1)                        95 01
  INPUT (Cnst,Var,Abs)                    81 03
END COLLECTION                            C0
```

14.3.2 Trackpad Example HID Report Descriptor

The following descriptor is for a 92.10 mm x 50.60 mm trackpad with two buttons supporting up to five simultaneous contacts.

To implement this HID report descriptor in the keyboard's firmware:

- Modify physical maximum values for X (`0x0030`) and Y (`0x0031`) positions of each finger to match the physical size of the trackpad. Units are in tenths of a mm (0.1 mm). In the example, X goes from `0x0000` to `0x0399` (92.10 mm) and Y goes from `0x0000` to `0x01FA` (50.60 mm).
- Modify logical maximum values for the X (`0x0030`) and Y (`0x0031`) positions of each finger to match the resolution of the trackpad. In the example, X (`0x0030`) goes from 0 to `0x0451` (for a resolution of 92.10/1105 = ~0.083 mm) and Y (`0x0031`) goes from 0 to `0x025F` (for the same resolution of 50.60/607 = ~0.083 mm).
- Combine this descriptor with the keyboard's, as HID Report Descriptor (page 96) requires, and give the keyboard's reports a Report ID other than `0x03`, which the example uses for its feature and input reports.

```
USAGE PAGE (Digitizer Device Page)                  05 0D
USAGE (Touch Pad)                                   09 05
COLLECTION (Application)                            A1 01
  REPORT_ID (3)                                     85 03
  LOGICAL MINIMUM (0)                               15 00
  LOGICAL MAXIMUM (65535)                           27 FF FF 00 00
  USAGE (Relative Scan Time (DV=Dynamic Value))     09 56
```

```
REPORT SIZE (16)                                75 10
REPORT COUNT (1)                                95 01
INPUT (Data,Var,Abs)                            81 02
LOGICAL MAXIMUM (1)                             25 01
REPORT SIZE (1)                                 75 01
USAGE (Surface Switch)                          09 57
FEATURE (Data,Var,Abs)                          B1 02
LOGICAL MAXIMUM (32767)                         26 FF 7F
REPORT SIZE (15)                                75 0F
USAGE (Report Rate)                             09 A1
FEATURE (Data,Var,Abs)                          B1 02
USAGE PAGE (Button Page)                        05 09
LOGICAL MAXIMUM (1)                             25 01
USAGE MINIMUM (Button 1)                        19 01
USAGE MAXIMUM (Button 2)                        29 02
REPORT COUNT (2)                                95 02
REPORT SIZE (1)                                 75 01
INPUT (Data,Var,Abs)                            81 02
REPORT COUNT (6)                                95 06
INPUT (Cnst,Ary,Abs)                            81 01
USAGE PAGE (Digitizer Device Page)              05 0D
USAGE (Finger)                                  09 22
COLLECTION (Physical)                           A1 00
USAGE (Tip Switch)                              09 42
USAGE (Confidence)                              09 47
REPORT COUNT (2)                                95 02
INPUT (Data,Var,Abs)                            81 02
LOGICAL MAXIMUM (5)                             25 05
USAGE (Transducer Index)                        09 38
REPORT SIZE (6)                                 75 06
REPORT COUNT (1)                                95 01
INPUT (Data,Var,Abs)                            81 02
USAGE PAGE (Generic Desktop Page)               05 01
PHYSICAL MAXIMUM (921)                          46 99 03
PHYSICAL MINIMUM (0)                            35 00
LOGICAL MAXIMUM (1105)                          26 51 04
REPORT SIZE (12)                                75 0C
UNIT EXPONENT (Unit Value x .01)                55 0E
GLOBAL UNIT (Distance in centimeters)           65 11
USAGE (X)                                       09 30
INPUT (Data,Var,Abs)                            81 02
PHYSICAL MAXIMUM (506)                          46 FA 01
LOGICAL MAXIMUM (607)                           26 5F 02
USAGE (Y)                                       09 31
INPUT (Data,Var,Abs)                            81 02
END COLLECTION (Physical)                       C0
USAGE PAGE (Digitizer Device Page)              05 0D
USAGE (Finger)                                  09 22
COLLECTION (PHYSICAL)                           A1 00
PHYSICAL MAXIMUM (0)                            45 00
UNIT EXPONENT (0)                               55 00
GLOBAL UNIT (None)                              65 00
LOGICAL MAXIMUM (1)                             25 01
```

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```
USAGE (Tip Switch)                          09 42
USAGE (Confidence)                          09 47
REPORT SIZE (1)                             75 01
REPORT COUNT (2)                            95 02
INPUT (Data,Var,Abs)                        81 02
USAGE (Transducer Index)                    09 38
LOGICAL MAXIMUM (5)                         25 05
REPORT SIZE (6)                             75 06
REPORT COUNT (1)                            95 01
INPUT (Data,Var,Abs)                        81 02
USAGE PAGE (Generic Desktop Page)           05 01
PHYSICAL MAXIMUM (921)                      46 99 03
LOGICAL MAXIMUM (1105)                      26 51 04
REPORT SIZE (12)                            75 0C
UNIT EXPONENT (Unit Value x .01)            55 0E
GLOBAL UNIT (Distance in centimeters)       65 11
USAGE (X)                                   09 30
INPUT (Data,Var,Abs)                        81 02
PHYSICAL MAXIMUM (506)                      46 FA 01
LOGICAL MAXIMUM (607)                       26 5F 02
USAGE (Y)                                   09 31
INPUT (Data,Var,Abs)                        81 02
END COLLECTION (Physical)                   C0
USAGE PAGE (Digitizer Device Page)          05 0D
USAGE (Finger)                              09 22
COLLECTION (Physical)                       A1 00
PHYSICAL MAXIMUM (0)                        45 00
UNIT EXPONENT (0)                           55 00
GLOBAL UNIT (None)                          65 00
LOGICAL MAXIMUM (1)                         25 01
USAGE (Tip Switch)                          09 42
USAGE (Confidence)                          09 47
REPORT SIZE (1)                             75 01
REPORT COUNT (2)                            95 02
INPUT (Data,Var,Abs)                        81 02
USAGE (Transducer Index)                    09 38
LOGICAL MAXIMUM (5)                         25 05
REPORT SIZE (6)                             75 06
REPORT COUNT (1)                            95 01
INPUT (Data,Var,Abs)                        81 02
USAGE PAGE (Generic Desktop Page)           05 01
PHYSICAL MAXIMUM (921)                      46 99 03
LOGICAL MAXIMUM (1105)                      26 51 04
REPORT SIZE (12)                            75 0C
UNIT EXPONENT (Unit Value x .01)            55 0E
GLOBAL UNIT (Distance in centimeters)       65 11
USAGE (X)                                   09 30
INPUT (Data,Var,Abs)                        81 02
PHYSICAL MAXIMUM (506)                      46 FA 01
LOGICAL MAXIMUM (607)                       26 5F 02
USAGE (Y)                                   09 31
INPUT (Data,Var,Abs)                        81 02
END COLLECTION (PHYSICAL)                   C0
```

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```
USAGE PAGE (Digitizer Device Page)              05 0D
USAGE (Finger)                                  09 22
COLLECTION (PHYSICAL)                           A1 00
PHYSICAL MAXIMUM (0)                            45 00
UNIT EXPONENT (0)                               55 00
GLOBAL UNIT (None)                              65 00
LOGICAL MAXIMUM (1)                             25 01
USAGE (Tip Switch)                              09 42
USAGE (Confidence)                              09 47
REPORT SIZE (1)                                 75 01
REPORT COUNT (2)                                95 02
INPUT (Data,Var,Abs)                            81 02
USAGE (Transducer Index)                        09 38
LOGICAL MAXIMUM (5)                             25 05
REPORT SIZE (6)                                 75 06
REPORT COUNT (1)                                95 01
INPUT (Data,Var,Abs)                            81 02
USAGE PAGE (Generic Desktop Page)               05 01
PHYSICAL MAXIMUM (921)                          46 99 03
LOGICAL MAXIMUM (1105)                          26 51 04
REPORT SIZE (12)                                75 0C
UNIT EXPONENT (Unit Value x .01)                55 0E
GLOBAL UNIT (Distance in centimeters)           65 11
USAGE (X)                                       09 30
INPUT (Data,Var,Abs)                            81 02
PHYSICAL MAXIMUM (506)                          46 FA 01
LOGICAL MAXIMUM (607)                           26 5F 02
USAGE (Y)                                       09 31
INPUT (Data,Var,Abs)                            81 02
END COLLECTION (Physical)                       C0
USAGE PAGE (Digitizer Device Page)              05 0D
USAGE (Finger)                                  09 22
COLLECTION (PHYSICAL)                           A1 00
PHYSICAL MAXIMUM (0)                            45 00
UNIT EXPONENT (0)                               55 00
GLOBAL UNIT (None)                              65 00
LOGICAL MAXIMUM (1)                             25 01
USAGE (Tip Switch)                              09 42
USAGE (Confidence)                              09 47
REPORT SIZE (1)                                 75 01
REPORT COUNT (2)                                95 02
INPUT (Data,Var,Abs)                            81 02
USAGE (Transducer Index)                        09 38
LOGICAL MAXIMUM (5)                             25 05
REPORT SIZE (6)                                 75 06
REPORT COUNT (1)                                95 01
INPUT (Data,Var,Abs)                            81 02
USAGE PAGE (Generic Desktop Page)               05 01
PHYSICAL MAXIMUM (921)                          46 99 03
LOGICAL MAXIMUM (1105)                          26 51 04
REPORT SIZE (12)                                75 0C
UNIT EXPONENT (Unit Value x .01)                55 0E
GLOBAL UNIT (Distance in centimeters)           65 11
```

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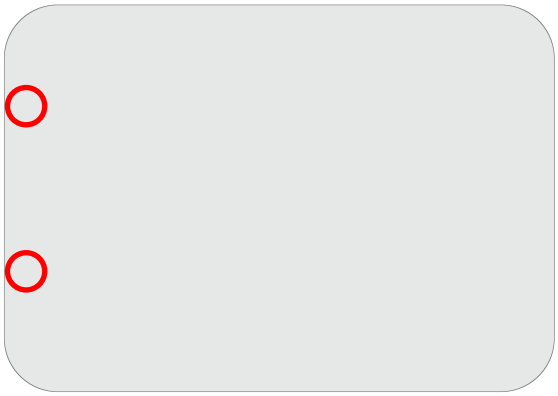
```
  USAGE (X)                                09 30
  INPUT (Data,Var,Abs)                     81 02
  PHYSICAL MAXIMUM (506)                   46 FA 01
  LOGICAL MAXIMUM (607)                    26 5F 02
  USAGE (Y)                                09 31
  INPUT (Data,Var,Abs)                     81 02
  END COLLECTION (Physical)                C0
END COLLECTION (Application)               C0
```

14.3.3 Trackpad Example HID Reports

The following HID reports, sent at 60 Hz, use the Trackpad Example HID Report Descriptor (page 99):

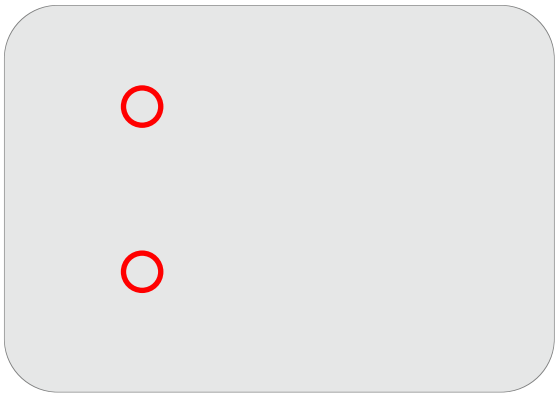
1. Two contacts are made on the surface of the trackpad.

   `03000000 0300100F 0700C016 00000000 00000000 00000000`



2. Two contacts move simultaneously along the X axis.

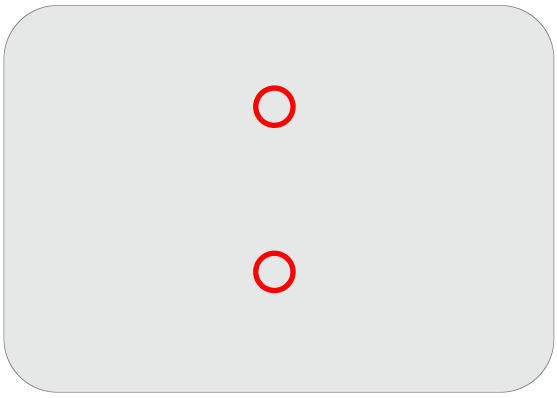
   `03A70000 0314110F 0714C116 00000000 00000000 00000000`



3. Two contacts continue moving until they reach the center of the digitizer surface.

   `034E0100 0328120F 0728C216 00000000 00000000 00000000`

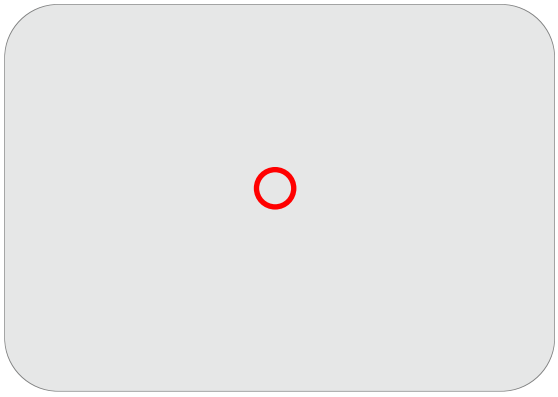
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4. One contact is removed. Confidence for removed contact is still 1 and its coordinates are unchanged.
   `03F50100 0328120F 0628C216 00000000 00000000 00000000`

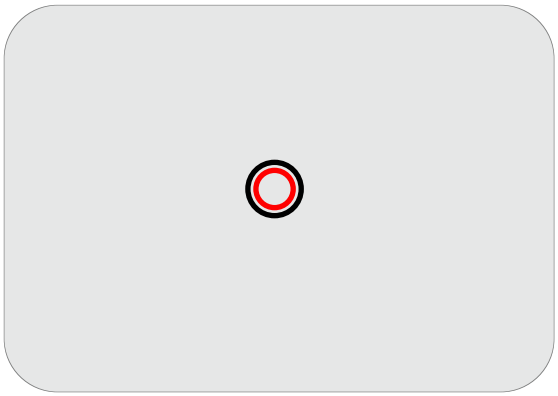


5. Remaining contact moves to the exact center of the digitizer surface. Confidence and coordinates of the removed contact are now 0.
   `039C0200 0328F212 00000000 00000000 00000000 00000000`

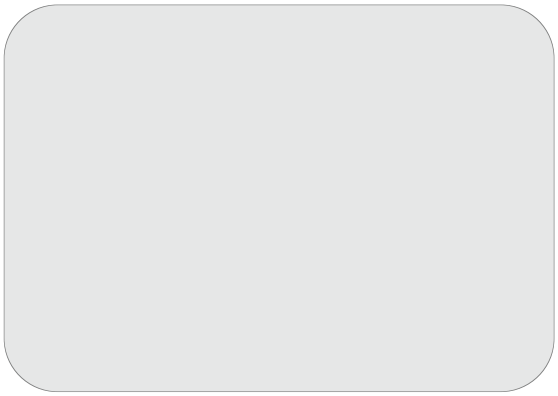


6. Button 1 is clicked.
   `03430301 0328F212 00000000 00000000 00000000 00000000`

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7. Button 1 is un-clicked and contact is removed. Confidence for removed contact is still 1 and its coordinates are unchanged.
   `03EA0300 0228F212 00000000 00000000 00000000 00000000`

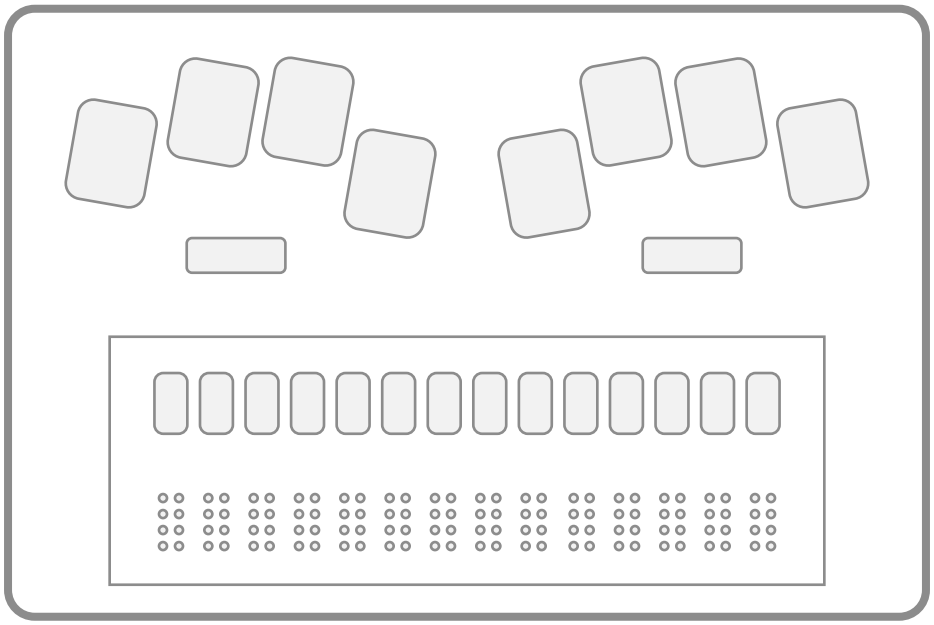


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15. Braille Displays and Keyboards

A braille display is an accessory enabling a user who is blind or has low vision to read text using raised pins. These accessories may include a braille keyboard to enter text, controls used to navigate a device, and controls to interface with a screen reader.

Figure 15-1 Braille display with keyboard



15.1 Requirements

Braille display accessories shall:

- Support the Human Interface Device (HID) (page 320) protocol.
- Not identify themselves as Apple-branded accessories, for example, using the Apple Vendor ID.

Braille display keys exhibiting any of the following behaviors are explicitly prohibited:

- Sending anything other than a 'key pressed' or 'key released' for a physically pressed key.
- Emulating combinations of other keys (for example, macros like Command-C for Copy).
- Emulating timed user actions, such as 'press-and-hold'.

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HID reports sent from braille displays shall only occur in response to Direct User Action (page 21).

HID report descriptors for braille displays shall declare support for the Braille Display Page (`0x41`). HID report descriptors shall individually enumerate each usage the accessory is capable of receiving or sending.

Braille display accessories shall declare a braille display collection containing one or more braille rows with 8 dot and/or 6 dot braille cells with the following usages:

Table 15-1 Required Braille Display Page (`0x41`) usages for use by display

Usage ID	Usage Name	Apple Function
`0x0001`	Braille Display	Braille Display
`0x0002`	Braille Row	Braille Row
`0x0003`	8 Dot Braille Cell	8 Dot Braille Cell
`0x0004`	6 Dot Braille Cell	6 Dot Braille Cell

Braille display accessories may support the following usages:

Table 15-2 Optional Braille Display Page (`0x41`) usages for use by display

Usage ID	Usage Name	Apple Function
`0x0005`	Number of Braille Cells	Number of Braille Cells
`0x00FA`	Router Set 1	Primary Button
`0x00FB`	Router Set 2	Secondary Button
`0x00FC`	Router Set 3	Tertiary Button
`0x0100`	Router Key	Router Key for a Braille Cell
`0x0101`	Row Router Key	Router Key for a Braille Row
`0x020C`	Braille Face Controls	Braille Face Controls
`0x020D`	Braille Left Controls	Braille Left Controls
`0x020E`	Braille Right Controls	Braille Right Controls
`0x020F`	Braille Top Controls	Braille Top Controls
`0x0210`	Braille Joystick Center	Braille Joystick Center
`0x0211`	Braille Joystick Up	Braille Joystick Up
`0x0212`	Braille Joystick Down	Braille Joystick Down
`0x0213`	Braille Joystick Left	Braille Joystick Left
`0x0214`	Braille Joystick Right	Braille Joystick Right
`0x0215`	Braille D-Pad Center	Braille D-Pad Center
`0x0216`	Braille D-Pad Up	Braille D-Pad Up

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Usage ID	Usage Name	Apple Function
0x0217	Braille D-Pad Down	Braille D-Pad Down
0x0218	Braille D-Pad Left	Braille D-Pad Left
0x0219	Braille D-Pad Right	Braille D-Pad Right
0x021A	Braille Pan Left	Braille Pan Left
0x021B	Braille Pan Right	Braille Pan Right
0x021C	Braille Rocker Up	Braille Rocker Up
0x021D	Braille Rocker Down	Braille Rocker Down
0x021E	Braille Rocker Press	Braille Rocker Press

15.1.1 Braille Keyboards

Braille displays may include a braille keyboard to enter text.

Braille display accessories with braille keyboards shall implement individual keys emitting the following usages:

Table 15-3 Required Braille Display Page (0x41) controls for use by display with keyboard

Usage ID	Usage Name	Apple Function
0x0200	Braille Buttons	Braille Buttons
0x0201	Braille Keyboard Dot 1	Braille Keyboard Dot 1
0x0202	Braille Keyboard Dot 2	Braille Keyboard Dot 2
0x0203	Braille Keyboard Dot 3	Braille Keyboard Dot 3
0x0204	Braille Keyboard Dot 4	Braille Keyboard Dot 4
0x0205	Braille Keyboard Dot 5	Braille Keyboard Dot 5
0x0206	Braille Keyboard Dot 6	Braille Keyboard Dot 6
0x0209	Braille Keyboard Space	Braille Keyboard Space

Braille display accessories with braille keyboards may implement individual keys emitting the following usages:

Table 15-4 Optional Braille Display Page (0x41) controls for use by display with keyboard

Usage ID	Usage Name	Apple Function
0x0207	Braille Keyboard Dot 7	Braille Keyboard Dot 7
0x0208	Braille Keyboard Dot 8	Braille Keyboard Dot 8
0x020A	Braille Keyboard Left Space	Braille Keyboard Left Space
0x020B	Braille Keyboard Right Space	Braille Keyboard Right Space

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Braille display accessories with braille keyboards shall support the ability to send all Braille Keyboard Dot and Space usages simultaneously.

15.1.2 Screen Reader Controls

Braille displays may include a controls to interface with a screen reader.

Braille display accessories supporting screen reader controls shall support the following usages:

Table 15-5 Required Braille Display Page (0x41) usages for use by display with screen reader controls

Usage ID	Usage Name	Apple Function
0x0006	Screen Reader Control	Screen Reader Controls (See Table 15-7 (page 109).)
0x0007	Screen Reader Identifier	Screen Reader Identifier (See Table 15-6 (page 109).)

The screen reader identifier is a 128 bit UUID from the device identifying the active screen reader. Table 15-6 (page 109) lists Apple screen reader identifiers.

VoiceOver (https://www.apple.com/accessibility/features/?vision) is the screen reader feature built into Apple's operating systems. Users who are blind or have low vision can interact with and control devices and Mac computers simply by moving their finger over the touchscreen or touch-sensitive trackpad. When VoiceOver is paired with a Braille display, users are able to use VoiceOver even if they are unable to touch the device display.

Table 15-6 Apple screen reader identifiers

Screen Reader	Screen Reader Identifier
iOS/iPadOS/tvOS VoiceOver	D211EC73–AE43–4B2B–A691–5F6620B4DBF6
macOS VoiceOver	BC4B74EA–B787–4A6D–B572–4E2D746A9AFD

The screen reader control array is populated with Button Page (0x09) usages. The behavior of each usage depends on the active screen reader. Table 15-7 (page 109) lists Apple screen reader functions for each usage.

Braille display accessories may support the following screen reader control usages:

Table 15-7 Optional Button Page (0x09) usages for use by display with screen reader controls

Usage ID	Usage Name	Apple Function
0x0001	Button 1	Next Braille Input Mode

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Usage ID	Usage Name	Apple Function
0x0002	Button 2	Next Braille Output Mode
0x0003	Button 3	Pan Braille Left
0x0004	Button 4	Pan Braille Right
0x0005	Button 5	Delete Braille
0x0006	Button 6	Forward Delete Braille
0x0007	Button 7	Activates Return Key
0x0008	Button 8	Escape Current Context
0x0009	Button 9	Toggle Contracted Braille
0x000A	Button 10	Toggle Eight-Dot Braille
0x0011	Button 17	Go to Status Bar
0x0012	Button 18	Go to First Item
0x0013	Button 19	Go to Last item
0x0014	Button 20	Move to Previous Item
0x0015	Button 21	Move to Next Item
0x0016	Button 22	Read Page
0x0017	Button 23	Read Page Starting at Focused Item
0x0018	Button 24	Scroll Left One Page
0x0019	Button 25	Scroll Right One Page
0x001A	Button 26	Scroll Up One Page
0x001B	Button 27	Scroll Down One Page
0x0021	Button 33	Next Virtual Menu Item
0x0022	Button 34	Previous Virtual Menu Item
0x0023	Button 35	Select Previous Virtual Menu Item Setting
0x0024	Button 36	Select Next Virtual Menu Item Setting
0x0025	Button 37	Perform Tap
0x0026	Button 38	Pause/Continue Speech
0x0027	Button 39	Perform Contextual Action
0x0031	Button 49	Move to Desktop
0x0032	Button 50	Move to Taskbar
0x0033	Button 51	Move to Menu Bar
0x0034	Button 52	Start Interaction with Item
0x0035	Button 53	Stop Interaction with Item
0x0041	Button 65	Navigate Up
0x0042	Button 66	Navigate Down
0x0043	Button 67	Navigate Left
0x0044	Button 68	Navigate Right
0x0045	Button 69	Navigate Up with Wrapping
0x0046	Button 70	Navigate Down with Wrapping

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Usage ID	Usage Name	Apple Function
0x0047	Button 71	Navigate Left with Wrapping
0x0048	Button 72	Navigate Right with Wrapping
0x0049	Button 73	Next Heading
0x004A	Button 74	Previous Heading
0x004B	Button 75	Next Graphic
0x004C	Button 76	Previous Graphic
0x004D	Button 77	Next Table
0x004E	Button 78	Previous Table
0x004F	Button 79	Next List
0x0050	Button 80	Previous List
0x0051	Button 81	Next Control
0x0052	Button 82	Previous Control
0x0053	Button 83	Next Blockquote
0x0054	Button 84	Previous Blockquote
0x0055	Button 85	Next Same Blockquote
0x0056	Button 86	Previous Same Blockquote
0x0057	Button 87	Next Link
0x0058	Button 88	Previous Link
0x0059	Button 89	Next Visited Link
0x005A	Button 90	Previous Visited Link
0x005B	Button 91	Next Same Heading
0x005C	Button 92	Previous Same Heading
0x005D	Button 93	Next Bold Text
0x005E	Button 94	Previous BoldT ext
0x005F	Button 95	Next Italic Text
0x0060	Button 96	Previous Italic Text
0x0061	Button 97	Next Underline Text
0x0062	Button 98	Previous Underline Text
0x0063	Button 99	Next Misspelled Word
0x0064	Button 100	Previous Misspelled Word
0x0065	Button 101	Next Plain Text
0x0066	Button 102	Previous Plain Text
0x0067	Button 103	Next Color Change
0x0068	Button 104	Previous Color Change
0x0069	Button 105	Next Font Change
0x006A	Button 106	Previous Font Change
0x006B	Button 107	Next Style Change
0x006C	Button 108	Previous Style Change

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Usage ID	Usage Name	Apple Function
0x006D	Button 109	Next Same Element
0x006E	Button 110	Previous Same Element
0x006F	Button 111	Next Different Element
0x0070	Button 112	Previous Different Element

15.2 Examples

15.2.1 Example HID Report Descriptor

The following descriptor is for a 20 cell braille display with integrated keyboard and screen reader controls.

```
0x05, 0x41,        // Usage Page (Braille)
0x09, 0x01,        // USAGE (Braille Display)
0xA1, 0x01,        // Collection (Application)
0x1A, 0x01, 0x02,  //   Usage Minimum (Braille Keyboard Dot 1)
0x2A, 0x08, 0x02,  //   Usage Maximum (Braille Keyboard Dot 8)
0x75, 0x01,        //   Report Size (1)
0x95, 0x08,        //   Report Count (8)
0x15, 0x00,        //   Logical Minimum (0)
0x25, 0x01,        //   Logical Maximum (1)
0x81, 0x02,        //   Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x05, 0x41,        //   Usage Page (Braille)
0x0A, 0x09, 0x02,  //   Usage (Braille Keyboard Space)
0x0A, 0x0A, 0x02,  //   Usage (Braille Keyboard Left Space)
0x0A, 0x0B, 0x02,  //   Usage (Braille Keyboard Right Space)
0x75, 0x01,        //   Report Size (1)
0x95, 0x03,        //   Report Count (3)
0x15, 0x00,        //   Logical Minimum (0)
0x25, 0x01,        //   Logical Maximum (1)
0x81, 0x02,        //   Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x75, 0x01,        //   Report Size (1)
0x95, 0x05,        //   Report Count (5)
0x15, 0x00,        //   Logical Minimum (0)
0x25, 0x01,        //   Logical Maximum (1)
0x81, 0x03,        //   Input (Const,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x05, 0x41,        //   Usage Page (Braille)
0xA1, 0x02,        //   Collection (Logical)
0x05, 0x0A,        //     Usage Page (Ordinal)
0x09, 0x01,        //     Usage (Instance 1)
0xA1, 0x02,        //     Collection (Logical)
0x05, 0x41,        //       Usage Page (Braille)
0x0A, 0x10, 0x02,  //       Usage (Braille Joystick Center)
0x0A, 0x11, 0x02,  //       Usage (Braille Joystick Up)
0x0A, 0x12, 0x02,  //       Usage (Braille Joystick Down)
0x0A, 0x13, 0x02,  //       Usage (Braille Joystick Left)
```

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```
0x0A, 0x14, 0x02,  //       Usage (Braille Joystick Right)
0x75, 0x01,        //       Report Size (1)
0x95, 0x05,        //       Report Count (5)
0x15, 0x00,        //       Logical Minimum (0)
0x25, 0x01,        //       Logical Maximum (1)
0x81, 0x02,        //       Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //     End Collection
0x05, 0x0A,        //     Usage Page (Ordinal)
0x09, 0x02,        //     Usage (Instance 2)
0xA1, 0x02,        //     Collection (Logical)
0x05, 0x41,        //       Usage Page (Braille)
0x0A, 0x10, 0x02,  //       Usage (Braille Joystick Center)
0x0A, 0x11, 0x02,  //       Usage (Braille Joystick Up)
0x0A, 0x12, 0x02,  //       Usage (Braille Joystick Down)
0x0A, 0x13, 0x02,  //       Usage (Braille Joystick Left)
0x0A, 0x14, 0x02,  //       Usage (Braille Joystick Right)
0x75, 0x01,        //       Report Size (1)
0x95, 0x05,        //       Report Count (5)
0x15, 0x00,        //       Logical Minimum (0)
0x25, 0x01,        //       Logical Maximum (1)
0x81, 0x02,        //       Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //     End Collection
0x75, 0x01,        //     Report Size (1)
0x95, 0x06,        //     Report Count (6)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x03,        //     Input (Const,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //   End Collection
0x0A, 0x0D, 0x02,  //   Usage (Braille Left Controls)
0xA1, 0x02,        //   Collection (Logical)
0x05, 0x09,        //     Usage Page (Button)
0x19, 0x01,        //     Usage Minimum (Button 1)
0x29, 0x03,        //     Usage Maximum (Button 3)
0x75, 0x01,        //     Report Size (1)
0x95, 0x03,        //     Report Count (3)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x05, 0x41,        //     Usage Page (Braille)
0x0A, 0x1A, 0x02,  //     Usage (Pan Left)
0x75, 0x01,        //     Report Size (1)
0x95, 0x01,        //     Report Count (1)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //   End Collection
0x05, 0x41,        //   Usage Page (Braille)
0x0A, 0x0E, 0x02,  //   Usage (Braille Right Controls)
0xA1, 0x02,        //   Collection (Logical)
0x05, 0x09,        //     Usage Page (Button)
0x19, 0x01,        //     Usage Minimum (Button 1)
0x29, 0x03,        //     Usage Maximum (Button 3)
0x75, 0x01,        //     Report Size (1)
```

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```
0x95, 0x03,        //     Report Count (3)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x05, 0x41,        //     Usage Page (Braille)
0x0A, 0x1B, 0x02,  //     Usage (Pan Right)
0x75, 0x01,        //     Report Size (1)
0x95, 0x01,        //     Report Count (1)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //   End Collection
0x05, 0x41,        //   Usage Page (Braille)
0x0A, 0x0F, 0x02,  //   Usage (Braille Top Controls)
0xA1, 0x02,        //   Collection (Logical)
0x05, 0x09,        //     Usage Page (Button)
0x19, 0x01,        //     Usage Minimum (Button 1)
0x29, 0x03,        //     Usage Maximum (Button 3)
0x75, 0x01,        //     Report Size (1)
0x95, 0x03,        //     Report Count (3)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x05, 0x41,        //     Usage Page (Braille)
0x0A, 0x15, 0x02,  //     Usage (Braille D-Pad Center)
0x0A, 0x16, 0x02,  //     Usage (Braille D-Pad Up)
0x0A, 0x17, 0x02,  //     Usage (Braille D-Pad Down)
0x0A, 0x18, 0x02,  //     Usage (Braille D-Pad Left)
0x0A, 0x19, 0x02,  //     Usage (Braille D-Pad Right)
0x75, 0x01,        //     Report Size (1)
0x95, 0x05,        //     Report Count (5)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //   End Collection
0x05, 0x41,        //   Usage Page (Braille)
0x0A, 0x0C, 0x02,  //   Usage (Braille Face Controls)
0xA1, 0x02,        //   Collection (Logical)
0x05, 0x09,        //     Usage Page (Button)
0x19, 0x01,        //     Usage Minimum (Button 1)
0x29, 0x04,        //     Usage Maximum (Button 4)
0x75, 0x01,        //     Report Size (1)
0x95, 0x04,        //     Report Count (4)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x05, 0x41,        //     Usage Page (Braille)
0x0A, 0x1C, 0x02,  //     Usage (Braille Rocker Up)
0x0A, 0x1D, 0x02,  //     Usage (Braille Rocker Down)
0x0A, 0x1E, 0x02,  //     Usage (Braille Rocker Press)
0x75, 0x01,        //     Report Size (1)
0x95, 0x03,        //     Report Count (3)
0x15, 0x00,        //     Logical Minimum (0)
```

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```
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0x75, 0x01,        //     Report Size (1)
0x95, 0x01,        //     Report Count (1)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x03,        //     Input (Const,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //   End Collection
0x05, 0x41,        //   Usage Page (Braille)
0x09, 0x06,        //   USAGE (Screen Reader Controls)
0xA1, 0x02,        //     Collection (Logical)
0x05, 0x09,        //     Usage Page (Button)
0x19, 0x01,        //     Usage Minimum (Button 1)
0x29, 0x08,        //     Usage Maximum (Button 8)
0x75, 0x01,        //     Report Size (1)
0x95, 0x08,        //     Report Count (8)
0x15, 0x00,        //     Logical Minimum (0)
0x25, 0x01,        //     Logical Maximum (1)
0x81, 0x02,        //     Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //   End Collection
0x05, 0x41,        //   Usage Page (Braille)
0x09, 0x02,        //   USAGE (Braille Row)
0xA1, 0x02,        //   Collection (Logical)
0x09, 0x03,        //     Usage (8 Dot Braille Cell)
0x15, 0x00,        //     Logical Minimum (0)
0x26, 0xFF, 0x00,  //     Logical Maximum (255)
0x75, 0x08,        //     Report Size (8)
0x95, 0x14,        //     Report Count (20)
0x91, 0x02,        //     Output (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null
Position,Non-volatile)
0x09, 0xFA,        //     USAGE (Router Set 1)
0xA1, 0x02,        //     Collection (Logical)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x0A, 0x00, 0x01,  //       Usage (Router Key)
0x15, 0x00,        //       Logical Minimum (0)
```

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```
0x25, 0x01,        //       Logical Maximum (1)
0x75, 0x01,        //       Report Size (1)
0x95, 0x14,        //       Report Count (20)
0x81, 0x02,        //       Input (Data,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
// 4-bit padding
0x75, 0x04,        //       Report Size (4)
0x95, 0x01,        //       Report Count (1)
0x81, 0x03,       //       Input (Const,Var,Abs,No Wrap,Linear,Preferred State,No Null Position)
0xC0,              //     End Collection
0xC0,              //   End Collection
0x05, 0x41,        //   Usage Page (Braille)
0x09, 0x07,        //   USAGE (Screen Reader Identifier)
0x95, 0x01,        //   Report Count (1)
0x75, 0x80,        //   Report Size (128)
0xB1, 0x02,        //   FEATURE (Data,Var,Abs)
0xC0,              // End Collection
```

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16. External Storage

Devices support external storage, such as USB drives and SD card readers, to:

- Store and access files.
- Import and export photos.
- Record video.

16.1 Overview

Accessories may support moving data to or from a device using:

- *USB Mass Storage Class Specification Overview – Version 1.4*, see https://www.usb.org/document-library/mass-storage-class-specification-overview-14.
- External Accessory Protocol (page 257).

16.2 Apple ProRes 4K

To support Apple ProRes capture at 4K, external storage shall:

- Be ExFAT formatted.
- Sustain a write speed of incompressible data, sampled every second, across the entire storage capacity, of at least:
  - 440 MB/s for 4K at 120 fps.
  - 220 MB/s for 4K at 60 fps.
  - 510 MB/s for ProRes RAW (4K at 120 fps).
- Not exceed 900 mA of current draw at any point in time. See Accessory Power (USB-C) (page 229).

For more information on Apple ProRes, including specific device support, see https://support.apple.com/en-us/109041.

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16.3 Verification

16.3.1 Apple ProRes 4K

16.3.1.1 Equipment

The following equipment is necessary:

- Device supporting external Apple ProRes 4K capture running iOS 27.2, see https://support.apple.com/en-us/109041.

16.3.1.2 Setup

1. Fully charge the device.
2. Attach the external storage.
3. Erase and format the external storage as ExFAT:
   a. Open Files and browse to the top level.
   b. Long press the external storage entry and select Erase.
   c. Verify the external storage is empty.
4. Open Settings > Camera > Formats and enable Apple ProRes under Video Capture.
5. Verify ProRes encoding is set to HDR.

16.3.1.3 Procedure

1. Attach the external storage to the device.
2. Open Camera, select Video and enable ProRes HDR from the Camera header.
3. Select the resolution indicator until it displays 4K.
4. Select the fps indicator until it displays:
   - 120 for devices and accessories supporting 4K at 120 fps.
   - 60 for devices and accessories supporting 4K at 60 fps.
5. Verify the Max Time indicator is displayed.
6. Verify the 'USB-C' indicator is displayed near the USB-C port.
7. Record video including motion (camera pan/tilt, people, vehicles) for at least 10 minutes.
8. Stop recording and wait for all data to be written to external storage.
9. Verify no error messages are displayed.
10. Attach the external storage to a Mac and play the video.
11. Verify the video playback is smooth, with no choppiness or missing frames.
12. Repeat the procedure, recording video until the drive is full, and verify all video is smooth, with no choppiness or missing frames.

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17. AirPods Accessories

Accessories shall not interfere with AirPods operation. Keep-out regions may be found in Dimensional Drawings (page 18), see:

- AirPods 5
- AirPods Pro 3
- AirPods 4
- AirPods Pro (2nd generation)
- AirPods (3rd generation)
- AirPods Max 2
- AirPods Max
- AirPods Pro (1st generation)
- AirPods (2nd generation)

17.1 Charging Case Covers

Charging case covers shall:

- Not interfere with AirPods charging case operation.
- Have a uniform thickness across the metal keep-out region.
- Not exceed 2.5 mm in thickness. Apple recommends 1.0 mm for maximum compatibility with inductive transmitters.

Keep-out regions may be found in Dimensional Drawings (page 18), see:

- MagSafe Charging Case for AirPods Pro 3
- Wireless Charging Case (USB-C) for AirPods 5 and AirPods 4
- MagSafe Charging Case (USB-C) for AirPods Pro (2nd generation)
- MagSafe Charging Case for AirPods Pro (2nd generation)
- MagSafe Charging Case for AirPods (3rd generation)
- Wireless Charging Case for AirPods Pro (1st generation)
- Wireless Charging Case for AirPods

Case covers claiming compatibility with Apple Watch chargers shall not obstruct the Apple Watch charger keep-out region, see:

- MagSafe Charging Case for AirPods Pro 3
- Wireless Charging Case (USB-C) for AirPods 5 and AirPods 4
- MagSafe Charging Case (USB-C) for AirPods Pro (2nd generation)

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- MagSafe Charging Case for AirPods Pro (2nd generation)

17.2 Chargers

Wired charging accessories shall:

- Provide 5 W (1.0 A at 5 V) at all times using:
  - *USB Battery Charging Specification – Release 1.2*.
  - USB enumeration.
  - USB Power Delivery (PD) (page 310).
  - USB Type-C Current (page 311).

Wireless charging accessories shall meet the requirements in Device Power (Inductive) (page 251).

17.3 AirPods Max Accessories

Accessories shall not stretch the headband or canopy. Accessories should use soft, compliant materials such as microfiber or silicone.

If the accessory is a case for AirPods Max 2 or AirPods Max (USB-C), the keep-out for the USB-C connector:

- Shall be at least 12.35 mm by 6.50 mm.
- Should be at least 12.45 mm by 6.60 mm with full radii rounded edges for the greatest compatibility with the widest variety of cables and docks, see USB-C receptacle accessory keep-out (page 391).

17.3.1 Sleep Mode

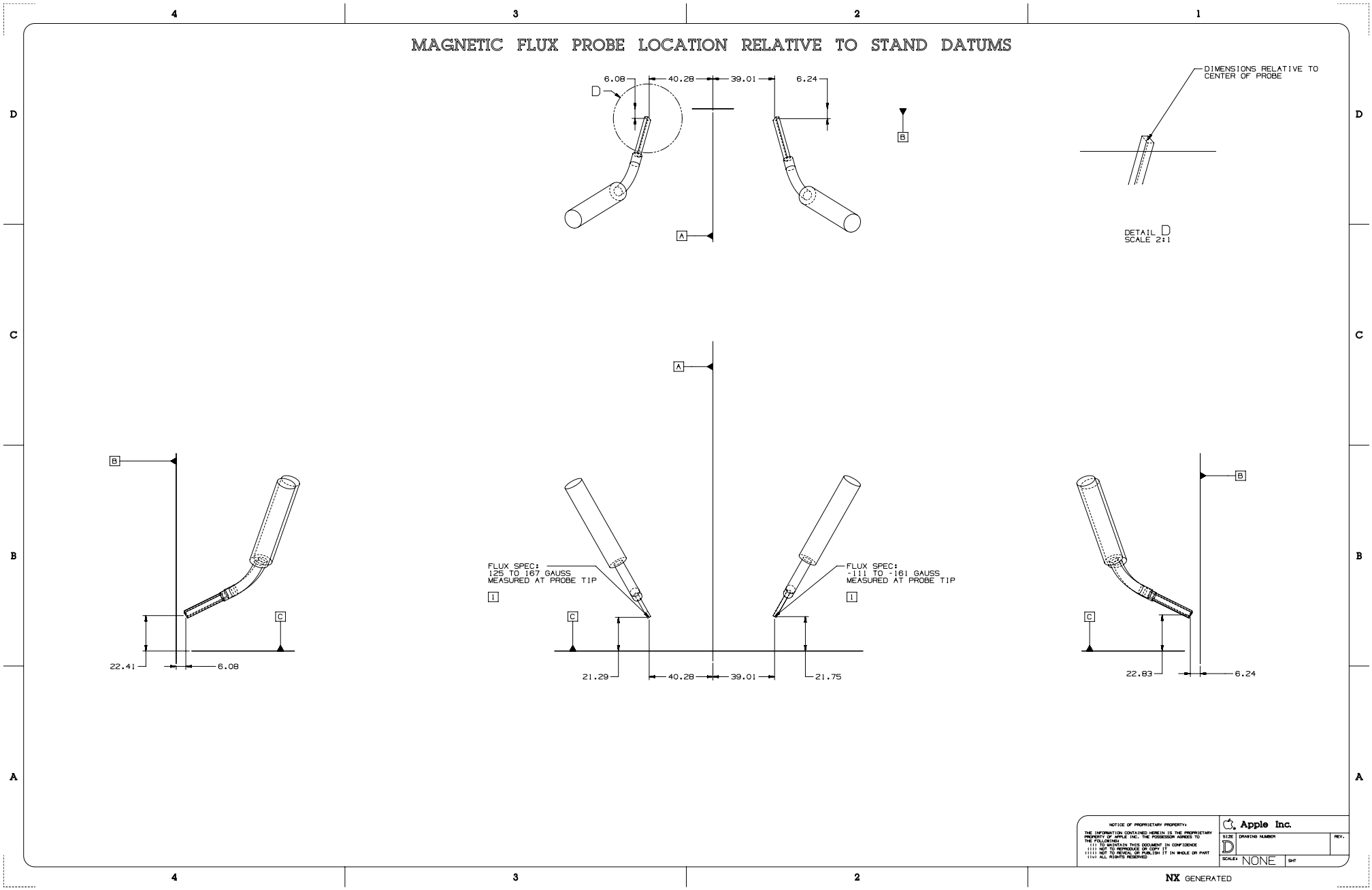
Accessories may enable sleep mode to help maintain the battery charge. Sleep mode is activated when AirPods Max:

- Is not charging.
- Magnetic flux at the:
  - Right earcup is 125 to 167 gauss.
  - Left earcup is -111 to -161 gauss.

See Magnetic Flux Probe (page 121) for the precise measuring point, and Dimensional Drawings (page 18) for AirPods Max datums.

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17.4 Magnetic Flux Probe



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17.5 Verification

Test procedures for AirPods accessories.

17.5.1 MagSafe Charging with Case Cover

Power test procedures for AirPods charging case covers.

17.5.1.1 Equipment

The following equipment is necessary:

- AirPods.
- AirPods charging case.
- Apple MagSafe Charger.
- Device running iOS 27.2.

17.5.1.2 Setup

1. Insert AirPods into charging case.
2. Unlock the device and open the charging case lid.
3. Pair AirPods with the device, if necessary.
4. Using the device, verify the state of charge for:
   a. Charging case is less than 80%.
   b. AirPods is less than 50%.
5. Close the charging case lid.
6. Verify the MagSafe charger is plugged into a functional power source.
7. Place the charging case onto the MagSafe charger on a flat surface.
8. Verify the charging case LED turns on momentarily.
9. Monitor the charging case LED for 30 seconds and verify the LED turns off.
10. Tap the charging case and verify the LED turns on momentarily.

17.5.1.3 Procedure

1. Attach the cover to the AirPods charging case.
2. Place the charging case and attached cover onto a MagSafe charger on a flat surface.
3. Verify the charging case LED turns on momentarily.
4. Monitor the charging case LED for 30 seconds and verify the LED turns off.
5. Tap the charging case and verify the LED turns on momentarily.

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18. Apple Vision Pro Cases and Bands

Apple Vision Pro cases and bands are passive accessories for Apple Vision Pro hardware, including storage cases, Apple Vision Pro Battery holders, and bands attaching to the Apple Vision Pro Audio Strap connector. Trackable spatial input accessories are covered separately in Spatial Accessories (page 126).

Apple Vision Pro cases and bands shall not interfere with Apple Vision Pro operation. Keep-out regions may be found in Dimensional Drawings (page 18), see:

- Apple Vision Pro
- Apple Vision Pro Battery
- Apple Vision Pro Audio Strap
- ZEISS Optical Inserts

18.1 Apple Vision Pro Storage Cases

Storage cases shall:

- Not interfere with the click or rotation function of the top button, digital crown, and fit dial.
- Not apply force on the top button, digital crown, and fit dial.
- Minimize contact with all glass surfaces, including the display and optics. When necessary, use a soft non-abrasive material.
- Maintain a power cable bend radius of at least 13 mm at the Apple Vision Pro Battery.

18.2 Apple Vision Pro Battery Holders

Battery holders should maintain at least 25% surface exposure for heat dissipation, see Dimensional Drawings (page 18) for Apple Vision Pro Battery.

18.3 Apple Vision Pro Bands

Bands attaching to the Apple Vision Pro Audio Strap connector shall:

- Be designed to prevent hair snag between the connector and mating parts, particularly in small spaces and between hard materials.

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- Not detach with a peel force less than 100 N at 12 mm from the connector.
- Have a maximum insertion force of 18.3 N.
- Not have metal contact with the elastomer portion of Apple Vision Pro Audio Strap.
- Not have a material hardness exceeding 320 HV for portions contacting the Apple Vision Pro Audio Strap connector.
- Have a maximum normal pull force of 300 N on the Apple Vision Pro Audio Strap connector.

18.4 Verification

Test procedures for Apple Vision Pro cases and bands.

18.4.1 Equipment

The following equipment is necessary:

- Apple Vision Pro Audio Strap.
- Digital force gauge, such as the Chatillon DFX II.
- Hook attachment for digital force gauge.
- Clamps, or a vice, to securely hold the Apple Vision Pro Audio Strap on a flat level surface.

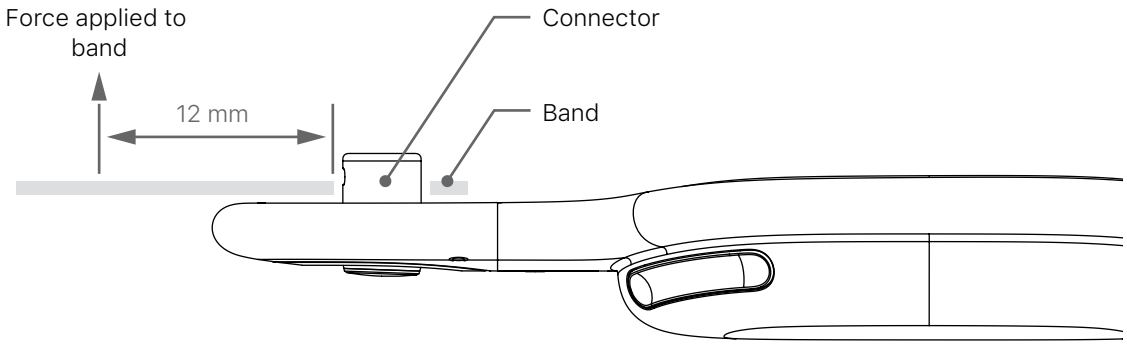
18.4.2 Peel Force

Peel force test procedure for Apple Vision Pro Bands.

1. Clamp the Apple Vision Pro Audio Strap as close to the connector as possible.
2. Apply ramping force to the band at 12 mm from the connector until 100 N of force is reached, see Figure 18-1 (page 125).
3. Verify the band is still attached to the Apple Vision Pro Audio Strap. Material failure on the band is allowed.

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Figure 18-1 Peel force test setup



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19. Spatial Accessories

This feature is supported starting in visionOS 27.0.

Spatial accessories are electronic objects tracked in space by a device. The accessory enables tracking with an integrated inertial measurement unit (IMU) and an LED constellation, used by the device to compute the accessory's position and orientation in real time. Spatial accessories may also host input and output modalities to enable spatial interactions.

19.1 Overview

Spatial accessories shall:

- Support Bluetooth Low Energy (BLE) (page 343) 5.4 or later.
- Support Human Interface Device (HID) (page 320), see HID Over GATT Profile (HOGP) (page 157).
- Integrate a 6-Axis Inertial Measurement Unit (IMU) (page 128).
- Integrate an LED Constellation (page 130).

19.2 Product Design

A well-designed spatial accessory will position its LEDs in a constellation pattern whose sub-combinations remain unique and visible to the device's cameras across the full range of intended motion, distance, grip, and field of view, while using materials avoiding reflections or other distortions of the pattern.

Spatial accessories shall have a minimum dimension of 10 mm along any single axis.

Accessory developers should:

- Verify LED pattern uniqueness through computational tools and manual inspection.
- Validate LED visibility empirically.
- Rigidly attach the IMU and all LEDs within the form factor.

19.2.1 Reference Tutorial

An example reference design is described in the following sections.

- Reference Tutorial: MLB Design (page 179).

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- Reference Tutorial: Design and Build a Spatial Accessory (page 185).
- Reference Tutorial: Annotated USDZ Generation (page 188).
- Reference Tutorial: Using Debug View to Fine-Tune (page 190).

19.3 HID

HID reports sent from the accessory shall only occur in response to a Direct User Action (page 21).

Spatial accessories shall not send different HID usages depending on the state of another Control Surface (page 21).

19.3.1 Top-Level Application Collection

The HID report descriptor for a spatial accessory shall define exactly one top-level application collection using one of the following usages:

Table 19-1 Permitted top-level application collection usages for spatial accessories

Usage Page	Usage	Description
`0x01`	`0x000F`	Spatial Controller
`0x01`	`0x0005`	Game Controller

Spatial accessories shall support the following inputs and control surfaces in their report descriptor:

- 6-Axis Inertial Measurement Unit (IMU) (page 128).
- LED Constellation (page 130).

Spatial accessories conforming to a particular class specification shall also support any additional inputs and controls required by the class.

19.3.2 Inputs and Controls

Within the top-level application collection, a spatial accessory may define additional inputs and sensors. The following sections define the required descriptor format for each.

Each of the 6-Axis Inertial Measurement Unit (IMU) (page 128), LED Constellation (page 130), Thumbsticks (page 133), Buttons (page 135), Proximity Sensor (page 137), and Force Sensors (page 138) collections shall:

- Nest all of its items directly within itself.
- Ignore any nested item whose usage is not listed for the collection.
- Assign the same report ID to all of its input items, and the same report ID to all of its output items.

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Note:
This section makes references to several standard HID usages. See *HID Usage Tables for Universal Serial Bus (USB) – Version 1.7* for additional information, including default units, at https://usb.org/document-library/hid-usage-tables-17.

19.3.3 Time Sync Clock Format

To provide the optimal tracking and input experience, the device and the accessory synchronize their clock domains. Timestamps exchanged between the device and the spatial accessory therefore use a common clock domain. This clock domain, called the Accessory Tracking Clock, represents an instant in time as an offset in microseconds from a particular Bluetooth Low Energy (BLE) connection event, see Time Sync (page 168).

An Accessory Tracking Clock timestamp shall be represented in the HID report descriptor by an item with the vendor-defined usage page `0xFF15` and usage ID `0x0006`. This item shall be 8 bytes in size, and a value of 0 for this field shall be considered invalid or out of range. The format of the item is as follows, with all fields assumed to be little-endian integers:

Table 19-2 Accessory Tracking Clock timestamp byte layout (8 bytes total, little-endian)

Part	Offset / Size (Bytes)	Description
bCECount	0 / 2	BLE Connection Event Count
bCEOffset	2 / 4	BLE Connection Event Offset (units: µs)
Reserved	6 / 2	

19.3.4 6-Axis Inertial Measurement Unit (IMU)

A spatial accessory report descriptor shall support exactly one 6-axis IMU. It shall be defined using a physical collection with usage page `0x20` (Sensors Page) and usage ID `0x0070` (Motion), nested directly within the top-level application collection.

In addition to the common collection requirements in Inputs and Controls (page 127), the physical collection shall:

- Contain at most one of each feature item.
- Contain exactly one of each required feature item.
- Contain an equal number of each input item.
- Contain at least three input items of each usage, see Multiple Samples (page 129).

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Table 19-3 Required and optional report elements for the 6-axis IMU collection (Sensors Page `0x20`, usage ID `0x0070`)

Item Type	Usage Page	Usage	Usage Type	Description	Note
Input	`0x20`	`0x0453`	SV	Data Field: Acceleration Axis X	Required
Input	`0x20`	`0x0454`	SV	Data Field: Acceleration Axis Y	Required
Input	`0x20`	`0x0455`	SV	Data Field: Acceleration Axis Z	Required
Input	`0x20`	`0x0457`	SV	Data Field: Angular Velocity about X-axis	Required
Input	`0x20`	`0x0458`	SV	Data Field: Angular Velocity about Y-axis	Required
Input	`0x20`	`0x0459`	SV	Data Field: Angular Velocity about Z-axis	Required
Input	`0xFF15`	`0x0006`	SV	Sample Timestamp (Time Sync Clock)	Required
Feature	`0x20`	`0x030E`	DV	Property: Report Interval	Required
Feature	`0x20`	`0x0317`	DV	Property: Sampling Rate	Optional

19.3.5 Multiple Samples

The input usages listed in Table 19-3 (page 129) comprise the required fields for an IMU sample. To support sensor sampling rates faster than the transport's maximum input report delivery rate, an input report may include multiple samples by defining multiple fields for each usage. The report fields are grouped into samples by their order of appearance in the report; for example, the first X-axis acceleration value in the report belongs to the first sample, the second to the second, and so on, and likewise for the other usages. The fields for a given sample may be grouped or interleaved with other samples, but the report shall not contain incomplete samples. Samples shall be ordered within each input report from oldest to newest.

To deliver the required IMU sample rate over the connection interval, the IMU input report shall contain enough input items to describe three samples, see IMU Sensor Operating Configuration (page 170).

The following are example report descriptors for the 6-axis IMU:

```
/// ------------------------------------------------------
/// 6-Axis IMU collection with three samples per input report
/// ------------------------------------------------------
HID_USAGE_PAGE_8(0x20),
HID_USAGE_8(0x70),
HID_REPORT_ID(0x01),
HID_COLLECTION(Physical), // (Sensor, Motion)
    HID_REPORT_SIZE(32),
    HID_REPORT_COUNT(1),
    HID_LOGICAL_MIN_8(0x00),
    HID_LOGICAL_MAX_32(0xFF, 0xFF, 0xFF, 0x7F),
    HID_UNIT_EXPONENT(0x0D),
    HID_USAGE_16(0x0E, 0x03),
    HID_FEATURE(Data_Var_Abs), // Report Interval (microseconds)
    HID_USAGE_16(0x17, 0x03),
```

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```
    HID_FEATURE(Data_Var_Abs), // Sample Interval (microseconds)
    HID_UNIT_EXPONENT(0),
    HID_REPORT_SIZE(16),
    HID_REPORT_COUNT(3),
    HID_LOGICAL_MIN_16(0x00, 0x80),
    HID_LOGICAL_MAX_16(0xFF, 0x7F),
    HID_PHYSICAL_MIN_8(0xF0),
    HID_PHYSICAL_MAX_8(0x10),
    HID_USAGE_MIN_16(0x53, 0x04),
    HID_USAGE_MAX_16(0x55, 0x04),
    HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (±16 g) (Sample 1)
    HID_USAGE_MIN_16(0x53, 0x04),
    HID_USAGE_MAX_16(0x55, 0x04),
    HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (±16 g) (Sample 2)
    HID_USAGE_MIN_16(0x53, 0x04),
    HID_USAGE_MAX_16(0x55, 0x04),
    HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (±16 g) (Sample 3)
    HID_PHYSICAL_MIN_16(0x60, 0xF0),
    HID_PHYSICAL_MAX_16(0xA0, 0x0F),
    HID_USAGE_MIN_16(0x57, 0x04),
    HID_USAGE_MAX_16(0x59, 0x04),
    HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (±4000 dps) (Sample 1)
    HID_USAGE_MIN_16(0x57, 0x04),
    HID_USAGE_MAX_16(0x59, 0x04),
    HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (±4000 dps) (Sample 2)
    HID_USAGE_MIN_16(0x57, 0x04),
    HID_USAGE_MAX_16(0x59, 0x04),
    HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (±4000 dps) (Sample 3)
    HID_REPORT_SIZE(64),
    HID_REPORT_COUNT(1),
    HID_LOGICAL_MIN_8(Undefined),
    HID_LOGICAL_MAX_8(Undefined),
    HID_PHYSICAL_MIN_8(Undefined),
    HID_PHYSICAL_MAX_8(Undefined),
    HID_USAGE_PAGE_16(0x15, 0xFF),
    HID_USAGE_8(0x06),
    HID_INPUT(Data_Var_Abs), // (Apple Vendor Sensor, Time-Sync Timestamp) (Sample 1)
    HID_USAGE_8(0x06),
    HID_INPUT(Data_Var_Abs), // (Apple Vendor Sensor, Time-Sync Timestamp) (Sample 2)
    HID_USAGE_8(0x06),
    HID_INPUT(Data_Var_Abs), // (Apple Vendor Sensor, Time-Sync Timestamp) (Sample 3)
HID_END_COLLECTION
```

19.3.6 LED Constellation

A spatial accessory report descriptor shall support exactly one array or "constellation" of LEDs. These LEDs will be flashed in alignment with the exposure of cameras on the device to support visual tracking of the accessory's pose in space.

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The LED constellation shall be defined using a logical collection with vendor-defined usage page `0xFF1F` and usage ID `0x00F0` nested directly within the top-level application collection. In addition to the common collection requirements in Inputs and Controls (page 127), this logical collection shall:

- Contain at most one of each output item.
- Contain exactly one of each required output item.

Table 19-4 Required and optional report elements for the LED constellation collection (vendor-defined usage page `0xFF1F`, usage ID `0x00F0`)

Item Type	Usage Page	Usage	Usage Type	Description	Note
UM Collection	`0x08`	`0x003C`	UM	Usage Multi-Mode Indicator	Required
Output (Array)	`0x08`	`0x003D`	Sel	Indicator Mode: On	Optional
Output (Array)	`0x08`	`0x0040`	Sel	Indicator Mode: Fast Blink	Required
Output (Array)	`0x08`	`0x0041`	Sel	Indicator Mode: Off	Required
Output	`0x08`	`0x0056`	DV	LED Intensity	Required
Output	`0x08`	`0x0045`	DV	Fast Blink On Time (Duration)	Required
Output	`0x08`	`0x0046`	DV	Fast Blink Off Time (Duration)	Required
Output	`0xFF15`	`0x0006`	DV	Fast Blink Pulse Midpoint (Time Sync Clock)	Required

The LED constellation shall support at least two modes: fast blink (where the LEDs blink in unison on a schedule according to the relevant output report fields) and off. The constellation may also optionally support an on mode; Apple strongly recommends supporting this, as it enables testing of the LED hardware independently of the fast blink scheduling parameters. This shall be represented in the descriptor as a Usage Modifier collection with usage page `0x08` (LED Page) and usage ID `0x003C` (Usage Multi-Mode Indicator). Nested within this usage modifier collection should be the indicator mode selector usages from the table and a single array output item.

The LED constellation shall also support controlling the intensity of the LEDs. The intensity control is represented as a percentage between 1 and 100 (inclusive). The accessory may implement this control by any means (for example, current control or pulse-width modulation), subject to the requirements in LED (page 172). The LED controller shall guarantee this intensity level across the entire Fast Blink On Duration.

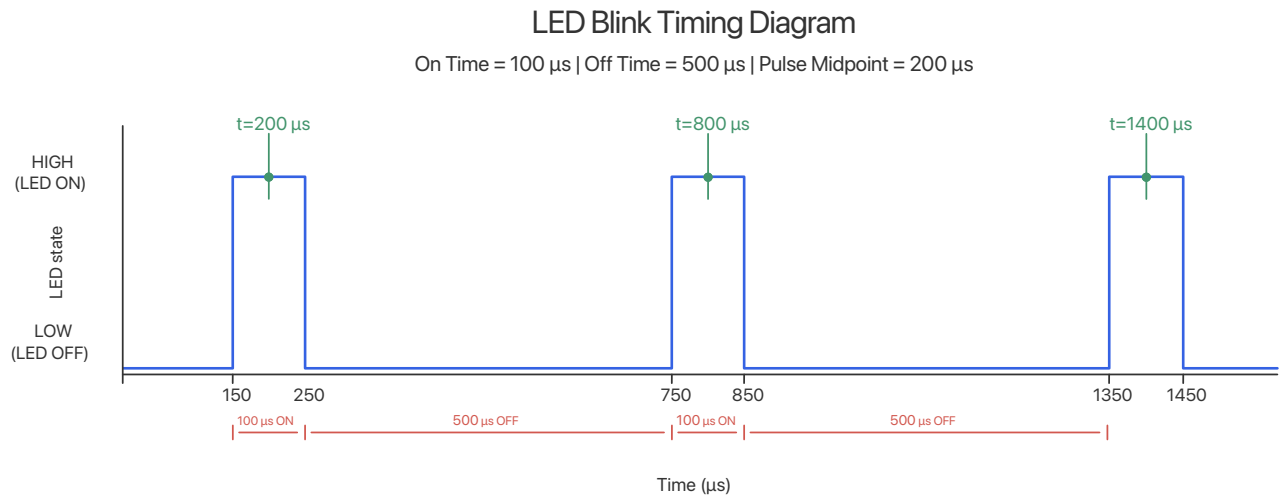
Fast Blink mode is the primary mode used for visual accessory tracking and has three parameters.

- Fast Blink On Time (Duration) is the amount of time the LEDs should be on each cycle. This item shall be defined as an unsigned 24 bit integer and units of microseconds.
- Fast Blink Off Time (Duration) is the amount of time the LEDs should be off each cycle. This item shall be defined as an unsigned 24 bit integer and units of microseconds. The sum of the Fast Blink On and Off time gives the blink cycle period.

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- Fast Blink Pulse Midpoint refers to the instant in time at which the midpoint of the first LED pulse after handling the output report should occur. It is represented as an Accessory Tracking Clock timestamp, see Time Sync Clock Format (page 128). To illustrate this, consider the following example, using a microsecond timestamp rather than Accessory Tracking Clock for the sake of simplicity (assume the LEDs are initially off and the output report is received at t=0 µs):
  - On Time = 100 µs, Off Time = 500 µs, Pulse Midpoint = 200 µs. The LEDs would first power on at t=150 µs, then power off at t=250 µs, giving a total on time of 100 µs with a midpoint of t=200 µs. The LEDs would next power on at t=750 µs (having been off for 500 µs) and off again at t=850 µs. The LEDs would continue blinking in this pattern until another output report is received which either changes their mode or the blink schedule parameters.

Figure 19-1 Fast Blink LED pulse-timing diagram showing On Time, Off Time, and Pulse Midpoint relative to the device-supplied Accessory Tracking Clock timestamp



See LED Constellation, Time Synchronized Pulse (page 174) for details.

The following is an example report descriptor for the LED constellation:

```
/// ------------------------------------------------------
/// Example collection for an LED Constellation
/// ------------------------------------------------------
HID_USAGE_PAGE_16(0x1F, 0xFF), // Vendor-Defined
HID_USAGE_8(0xF0), // LED Constellation
HID_COLLECTION(Logical),
    HID_REPORT_ID(1),
    HID_REPORT_SIZE(8),
    HID_REPORT_COUNT(8),
    HID_USAGE_PAGE_16(0x15, 0xFF),
    HID_USAGE_8(0x06), // Pulse Midpoint (Accessory Tracking Clock)
    HID_OUTPUT(Data_Var_Abs),
```

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```
    HID_REPORT_COUNT(1),
    HID_USAGE_PAGE_8(0x08), // LED Page
    HID_USAGE_8(0x3C), // Usage Multi Mode Indicator
    HID_COLLECTION(UsageModifier),
        HID_LOGICAL_MIN_8(1),
        HID_LOGICAL_MAX_8(3),
        HID_USAGE_8(0x3D), // Indicator On
        HID_USAGE_8(0x40), // Indicator Fast Blink
        HID_USAGE_8(0x41), // Indicator Off
        HID_OUTPUT(Data_Arr_Abs),
    HID_END_COLLECTION,
    HID_LOGICAL_MAX_8(100),
    HID_USAGE_8(0x56), // LED Intensity
    HID_OUTPUT(Data_Var_Abs),
    HID_REPORT_SIZE(24),
    HID_LOGICAL_MIN_8(0),
    HID_LOGICAL_MAX_32(0xFF, 0xFF, 0xFF, 0x00),
    HID_UNIT_16(0x01, 0x10), // seconds
    HID_UNIT_EXPONENT(0x0A), // −6 (microseconds)
    HID_USAGE_8(0x45), // Fast Blink On Time
    HID_OUTPUT(Data_Var_Abs),
    HID_USAGE_8(0x46), // Fast Blink Off Time
    HID_OUTPUT(Data_Var_Abs),
HID_END_COLLECTION
```

19.3.7 Thumbsticks

A report descriptor may support zero or more thumbstick inputs. Each thumbstick shall be defined using a physical collection with usage page `0x01` (Generic Desktop Page) and usage ID `0x0096` (Thumbstick), nested directly within the top-level application collection. Multiple thumbsticks may be defined by nesting a logical collection with a usage ID from page `0x0A` (Ordinal Page) directly within each thumbstick physical collection. In the remainder of this section, collection refers to this nested ordinal logical collection if it is present. Otherwise, it refers to the thumbstick physical collection.

In addition to the common collection requirements in Inputs and Controls (page 127), the collection shall contain exactly one of each required input item.

Table 19-5 Required report elements for a thumbstick collection (Generic Desktop Page `0x01`, usage ID `0x0096`)

Item Type	Usage Page	Usage	Usage Type	Description	Physical Range	Note
Input	`0x01`	`0x0030`	SV	X	(-1, 1)	Required
Input	`0x01`	`0x0031`	SV	Y	(-1, 1)	Required

In addition to the items listed above, the collection may also contain nested collections for inputs and sensors directly associated with the thumbstick, such as a button or proximity sensor.

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Thumbsticks and other analog controls shall not have any physical or algorithmic dead zones. If dead zones are expressly needed, they shall be configurable within the app.

The following is an example report descriptor for a thumbstick:

```
/// ------------------------------------------
/// Example collection for a single thumbstick
/// ------------------------------------------
HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
HID_USAGE_8(0x96), // Thumbstick
HID_COLLECTION(Physical),
    HID_REPORT_ID(0x01),
    HID_REPORT_SIZE(16),
    HID_REPORT_COUNT(2),
    HID_LOGICAL_MIN_16(0x00, 0x80),
    HID_LOGICAL_MAX_16(0xFF, 0x7F),
    HID_USAGE_MIN_8(0x30),
    HID_USAGE_MAX_8(0x31),
    HID_PHYSICAL_MIN_8(-1),
    HID_PHYSICAL_MAX_8(1),
    HID_INPUT(Data_Var_Abs), // X, Y
HID_END_COLLECTION
/// ------------------------------------------
/// Example collections for multiple thumbsticks
/// ------------------------------------------
HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
HID_USAGE_8(0x96), // Thumbstick
HID_COLLECTION(Physical),
    HID_USAGE_PAGE_8(0x0A),
    HID_USAGE_8(0x01),
    HID_COLLECTION(Logical),
        HID_REPORT_ID(0x01),
        HID_REPORT_SIZE(16),
        HID_REPORT_COUNT(2),
        HID_USAGE_PAGE_8(0x01),
        HID_LOGICAL_MIN_16(0x00, 0x80),
        HID_LOGICAL_MAX_16(0xFF, 0x7F),
        HID_USAGE_MIN_8(0x30),
        HID_USAGE_MAX_8(0x31),
        HID_PHYSICAL_MIN_8(-1),
        HID_PHYSICAL_MAX_8(1),
        HID_INPUT(Data_Var_Abs), // X, Y
    HID_END_COLLECTION,
HID_END_COLLECTION,
HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
HID_USAGE_8(0x96), // Thumbstick
HID_COLLECTION(Physical),
    HID_USAGE_PAGE_8(0x0A),
    HID_USAGE_8(0x02),
    HID_COLLECTION(Logical),
        HID_REPORT_ID(0x02),
        HID_REPORT_SIZE(16),
```

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```
        HID_REPORT_COUNT(2),
        HID_USAGE_PAGE_8(0x01),
        HID_LOGICAL_MIN_16(0x00, 0x80),
        HID_LOGICAL_MAX_16(0xFF, 0x7F),
        HID_USAGE_MIN_8(0x30),
        HID_USAGE_MAX_8(0x31),
        HID_PHYSICAL_MIN_8(-1),
        HID_PHYSICAL_MAX_8(1),
        HID_INPUT(Data_Var_Abs),  // X, Y
    HID_END_COLLECTION,
HID_END_COLLECTION
```

19.3.8 Buttons

A report descriptor may support zero or more user-defined button inputs. Each button shall be defined using a physical collection with a usage ID from usage page `0x09` (Button Page), nested directly within the top-level application collection or within a thumbstick collection.

A button's input may be described in one of two ways:

- The first is as a binary input signal, which shall be represented according to:
  - The button collection shall contain exactly one single-bit, MC input item.
  - The input item shall have the same usage as the encompassing collection.
  - The input item shall have a logical range of 0 to 1.
  - Input value 0 shall indicate the button is not pressed, and 1 shall indicate the button is pressed.
- The second is as a multi-bit input signal, which shall be represented according to:
  - The button collection shall contain exactly one multi-bit SV input item.
    - The required input item shall have the same usage as the encompassing collection.
    - The required input item shall have a physical range of 0 to 1.
    - Physically-scaled input value 0 shall indicate the button is not depressed, and 1 shall indicate the button is fully depressed. Intermediate input values shall represent varying levels of depression.
  - The button collection may optionally contain an additional, single-bit MC input item.
    - The optional input item, if present, shall have the same usage as the encompassing collection.
    - The optional input item, if present, shall have a logical range of 0 to 1.
    - Input value 0 from this field shall indicate the button is in a conceptual "not pressed" state. Input value 1 shall indicate the button is conceptually "pressed".

The physical collection may also contain nested collections for sensors directly associated with the physical button, such as a proximity sensor.

Buttons shall be debounced, filtering bounces of up to 20 ms in length. Shorter debounce durations are possible and preferred with higher quality buttons or hardware solutions to improve the user experience. A button represented as a binary input signal shall default to the OFF (not pressed) state.

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The following is an example report descriptor for a button:

```
/// ------------------------------------------------------------------------
/// Example HID report descriptor for a device with two binary buttons and three
/// multi-bit buttons.
/// ------------------------------------------------------------------------
HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
HID_USAGE_8(0x0F), // Spatial Controller
HID_COLLECTION(Application),
    HID_REPORT_ID(1),
    HID_REPORT_COUNT(1),
    HID_REPORT_SIZE(1),
    HID_LOGICAL_MIN_8(0),
    HID_LOGICAL_MAX_8(1),
    HID_USAGE_PAGE_8(0x09), // Button Page
    HID_USAGE_16(0x00, 0x01), // Button 256
    HID_COLLECTION(Physical),
        HID_USAGE_16(0x00, 0x01),
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_16(0x01, 0x01), // Button 257
    HID_COLLECTION(Physical),
        HID_USAGE_16(0x01, 0x01),
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_REPORT_SIZE(6),
    HID_INPUT(Const_Var_Abs), // padding
    HID_REPORT_SIZE(8),
    HID_LOGICAL_MAX_16(0xFF, 0x00),
    HID_PHYSICAL_MIN_8(0),
    HID_PHYSICAL_MAX_8(1),
    HID_USAGE_16(0x02, 0x01), // Button 258
    HID_COLLECTION(Physical),
        HID_USAGE_16(0x02, 0x01),
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_16(0x03, 0x01), // Button 259
    HID_COLLECTION(Physical),
        HID_USAGE_16(0x03, 0x01),
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_16(0x04, 0x01), // Button 260
    HID_COLLECTION(Physical),
        HID_USAGE_16(0x04, 0x01),
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
HID_END_COLLECTION
/// ------------------------------------------------------------------------
/// Example collection for a multi-bit which reports a press state.
/// ------------------------------------------------------------------------
HID_USAGE_PAGE_8(0x09), /* Button Page */
HID_USAGE_16(0x00, 0x01), /* Button 256 */
HID_COLLECTION(Physical),
```

```
    HID_USAGE_16(0x00, 0x01),
    HID_REPORT_SIZE(8),
    HID_REPORT_COUNT(1),
    HID_LOGICAL_MIN_8(0),
    HID_LOGICAL_MAX_16(0x64, 0x00),
    HID_PHYSICAL_MIN_8(0),
    HID_PHYSICAL_MAX_8(1),
    HID_INPUT(Data_Var_Abs),
    HID_USAGE_16(0x00, 0x01),
    HID_REPORT_SIZE(1),
    HID_LOGICAL_MAX_8(1),
    HID_INPUT(Data_Var_Abs),
    HID_REPORT_SIZE(7),
    HID_INPUT(Const_Var_Abs),
HID_END_COLLECTION
```

19.3.9 Proximity Sensor

A report descriptor may support zero or more proximity sensors. Each proximity sensor shall be defined using a physical collection with usage page `0x20` (Sensors Page) and usage ID `0x0012` (Biometric: Human Proximity), nested directly within a button or thumbstick collection. The sensor is associated with the input described by the encompassing collection. There shall be at most one proximity sensor nested directly within a given collection.

In addition to the common collection requirements in Inputs and Controls (page 127), the physical collection shall:

- Contain at most one of each input item.
- Contain exactly one of each required input item.

Table 19-6 Required and optional report elements for the proximity sensor collection (Sensors Page `0x20`, usage ID `0x0012`)

Item Type	Usage Page	Usage	Usage Type	Description	Note
Input	`0x20`	`0x04B4`	SF	Data Field: Human Touch State	Required
Input	`0x20`	`0x04B2`	SV	Data Field: Human Proximity Range	Optional

According to *HID Usage Tables for Universal Serial Bus (USB) – Version 1.7*, the default unit for the Human Proximity Range usage is meters. However, in this chapter, if units are unspecified the item is treated as a unit-less value where the logical maximum indicates the "maximum" detectable proximity and the logical minimum indicates physical contact with the sensor.

The following is an example report descriptor for a proximity sensor:

```
/// ------------------------------------------
/// Example collection for a binary touch sensor
/// ------------------------------------------
```

```
HID_USAGE_PAGE_8(0x20), // Sensors Page
HID_USAGE_8(0x12), // Biometric: Human Proximity
HID_COLLECTION(Physical),
    HID_REPORT_ID(1),
    HID_REPORT_SIZE(1),
    HID_REPORT_COUNT(1),
    HID_LOGICAL_MIN_8(0),
    HID_LOGICAL_MAX_8(1),
    HID_USAGE_16(0xB4, 0x04),
    HID_INPUT(Data_Var_Abs), // Human Touch State
    HID_REPORT_SIZE(7),
    HID_INPUT(Const_Var_Abs),
HID_END_COLLECTION
/// ------------------------------------------------------
/// Example collection for a combined touch/proximity sensor
/// ------------------------------------------------------
HID_USAGE_PAGE_8(0x20), // Sensors Page
HID_USAGE_8(0x12), // Biometric: Human Proximity
HID_COLLECTION(Physical),
    HID_REPORT_ID(1),
    HID_REPORT_SIZE(1),
    HID_REPORT_COUNT(1),
    HID_LOGICAL_MIN_8(0),
    HID_LOGICAL_MAX_8(1),
    HID_USAGE_16(0xB4, 0x04),
    HID_INPUT(Data_Var_Abs), // Human Touch State
    HID_REPORT_SIZE(7),
    HID_INPUT(Const_Var_Abs),
    HID_REPORT_SIZE(8),
    HID_LOGICAL_MAX_16(0xFF, 0x00),
    HID_USAGE_16(0xB2, 0x04), // Human Proximity Range
    HID_INPUT(Data_Var_Abs),
HID_END_COLLECTION
```

19.3.10 Force Sensors

A report descriptor may support zero or more force sensors. Each force sensor shall be defined using a physical collection with usage page `0x20` (Sensors Page) and usage ID `0x0064` (Mechanical: Force), nested directly within a button or thumbstick collection. The sensor is associated with the input described by the encompassing collection. There shall be at most one force sensor nested directly within a given collection.

In addition to the common collection requirements in Inputs and Controls (page 127), the physical collection shall:

- Contain exactly one of each required input item.
- Represent force values in units of newtons.

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Table 19-7 Required report elements for the force sensor collection (Sensors Page `0x20`, usage ID `0x0064`)

Item Type	Usage Page	Usage	Usage Type	Description	Note
Input	`0x20`	`0x0494`	SV	Data Field: Force	Required

The following is an example report descriptor for a force sensor:

```
/// ------------------------------------------------------------------------------
/// Example collection for a multi-bit button with an associated force sensor
/// ------------------------------------------------------------------------------
HID_REPORT_ID(1),
HID_REPORT_COUNT(1),
HID_REPORT_SIZE(8),
HID_LOGICAL_MIN_8(0),
HID_LOGICAL_MAX_16(0xFF, 0x00),
HID_PHYSICAL_MIN_8(0),
HID_PHYSICAL_MAX_8(1),
HID_USAGE_PAGE_8(0x09), // Button Page
HID_USAGE_8(0x01), // Button 1
HID_COLLECTION(Physical),
    HID_USAGE_8(0x01),
    HID_INPUT(Data_Var_Abs),
    HID_USAGE_PAGE_8(0x20), // Sensors
    HID_USAGE_8(0x64), // Mechanical: Force
    HID_COLLECTION(Physical),
        HID_PHYSICAL_MAX_8(10),   // 10 N
        HID_USAGE_16(0x94, 0x04), // Data Field: Force
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
HID_END_COLLECTION
```

19.3.11 User-Input Timestamp

Input reports containing user input (thumbsticks, buttons, proximity sensor, or force sensor) data shall also have an Accessory Tracking Clock timestamp field to represent the (approximate) instant in time when the input was sampled. The input item describing this field shall be nested directly within the top-level application collection.

This "input timestamp" applies to all user inputs in the report. Different user inputs within the same report cannot be individually timestamped, so Apple recommends sampling all user input at approximately the same time when possible to achieve the best user experience.

If an input report contains both IMU samples and user input, the input timestamp shall be present in addition to the timestamp for each IMU sample.

The following is an example report descriptor including a user-input timestamp:

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```
/// ------------------------------------------------------------
/// Example descriptor demonstrating the user-input timestamp
///
/// There are two input reports, each containing button data
/// and the user input timestamp.
/// ------------------------------------------------------------
HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
HID_USAGE_8(0x0F), // Spatial Controller
HID_COLLECTION(Application),
    HID_REPORT_COUNT(1),
    HID_REPORT_SIZE(8),
    HID_LOGICAL_MIN_8(0),
    HID_LOGICAL_MAX_16(0xFF, 0x00),
    HID_PHYSICAL_MIN_8(0),
    HID_PHYSICAL_MAX_8(1),
    HID_REPORT_ID(1),
    HID_USAGE_PAGE_8(0x09), // Button Page
    HID_USAGE_8(0x01), // Button 1
    HID_COLLECTION(Physical),
        HID_USAGE_8(0x01), // Button 1
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_REPORT_ID(2),
    HID_USAGE_PAGE_8(0x09), // Button Page
    HID_USAGE_8(0x02), // Button 2
    HID_COLLECTION(Physical),
        HID_USAGE_8(0x02), // Button 2
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_REPORT_COUNT(8),
    HID_REPORT_SIZE(8),
    HID_LOGICAL_MIN_8(Undefined),
    HID_LOGICAL_MAX_8(Undefined),
    HID_PHYSICAL_MIN_8(Undefined),
    HID_PHYSICAL_MAX_8(Undefined),
    HID_REPORT_ID(1),
    HID_USAGE_PAGE_16(0x15, 0xFF), // Accessory Tracking Clock Timestamp
    HID_USAGE_8(0x06),
    HID_INPUT(Data_Var_Abs),
    HID_REPORT_ID(2),
    HID_USAGE_PAGE_16(0x15, 0xFF), // Accessory Tracking Clock Timestamp
    HID_USAGE_8(0x06),
    HID_INPUT(Data_Var_Abs),
HID_END_COLLECTION,
```

19.3.12 Simple Haptic Controller

A report descriptor may support a haptic controller, as described by usage page `0x0E` (Haptics Page). The haptic controller shall be defined using a Logical Collection with usage page `0x0E` (Haptics Page) and usage ID `0x0001` (Simple Haptic Controller) nested directly within the top-level application

collection. Nested within the haptic controller collection, the report descriptor shall declare both a Waveform List and Duration List as described in Section 17.2 of *HID Usage Tables for Universal Serial Bus (USB) – Version 1.7*.

Haptic feedback shall be provided either by a rotating-weight electric motor or a Linear Resonant Actuator (LRA) supporting at minimum 60 Hz vibration.

The haptic controller shall support exactly five waveforms: Waveform None, Waveform Stop, Waveform Click, Waveform Buzz Continuous, and Waveform Rumble Continuous. Waveform None and Stop are implicitly supported and therefore shall not be declared in the Waveform list. The haptic controller shall support Manual Trigger only.

Waveform Click shall be implemented as a short vibration. Waveforms Buzz Continuous and Rumble Continuous should be implemented as an extended vibration, with Buzz having a higher frequency than Rumble.

Waveform Buzz Continuous and Waveform Rumble Continuous shall be continuous waveforms (duration 0). The haptic controller shall also declare a Waveform Cutoff Time (usage `0x0028`) item in the report descriptor, as it supports continuous waveforms.

Finally, the haptic controller shall declare an Intensity (usage `0x0023`) item to control the relative intensity of haptic waveforms.

The following is an example report descriptor for a haptic controller, as well as example C code to illustrate the expected behavior of the controller:

```
/// ------------------------------------------------
/// Example collection for a Simple Haptic Controller
/// ------------------------------------------------
    HID_USAGE_PAGE_8(0x0E), // Haptics Page
    HID_USAGE_8(0x01), // Simple Haptic Controller
    HID_COLLECTION(Logical),
        HID_REPORT_ID(1),
        HID_REPORT_SIZE(16),
        HID_REPORT_COUNT(3),
        HID_USAGE_8(0x10), // Waveform List
        HID_COLLECTION(Logical),
            HID_USAGE_PAGE_8(0x0A), // Ordinal Page
            HID_USAGE_MIN_8(0x03), // Ordinal 3
            HID_USAGE_MAX_8(0x05), // Ordinal 5
            HID_LOGICAL_MIN_16(0x03, 0x10),
            HID_LOGICAL_MAX_16(0x05, 0x10),
            HID_FEATURE(Data_Var_Abs),
        HID_END_COLLECTION,
        HID_USAGE_PAGE_8(0x0E), // Haptics Page
        HID_USAGE_8(0x11), // Duration List
        HID_COLLECTION(Logical),
            HID_USAGE_PAGE_8(0x0A), // Ordinal Page
```

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```
            HID_USAGE_MIN_8(0x03), // Ordinal 3
            HID_USAGE_MAX_8(0x05), // Ordinal 5
            HID_LOGICAL_MIN_8(0),
            HID_LOGICAL_MAX_32(0xFF, 0xFF, 0x00, 0x00),
            HID_FEATURE(Data_Var_Abs),
        HID_END_COLLECTION,
        HID_USAGE_PAGE_8(0x0E), // Haptics Page
        HID_USAGE_8(0x28), // Continuous Waveform Cutoff Time
        HID_REPORT_COUNT(1),
        HID_REPORT_SIZE(8),
        HID_FEATURE(Data_Var_Abs),
        HID_USAGE_8(0x21), // Manual Trigger
        HID_REPORT_SIZE(3),
        HID_LOGICAL_MIN_8(1),
        HID_LOGICAL_MAX_8(5),
        HID_OUTPUT(Data_Var_Abs),
        HID_REPORT_SIZE(5),
        HID_OUTPUT(Const_Var_Abs), // Padding
        HID_REPORT_SIZE(8),
        HID_LOGICAL_MIN_8(0),
        HID_LOGICAL_MAX_8(100),
        HID_USAGE_8(0x23), // Intensity
        HID_OUTPUT(Data_Var_Abs),
    HID_END_COLLECTION
/// ----------------------------------------
/// Example haptic controller implementation
/// ----------------------------------------
typedef struct __attribute__((packed)) {
    uint8_t  report_id;
    uint16_t waveform_usage[3];    // Ordinals 3, 4, 5
    uint16_t waveform_duration[3]; // Ordinals 3, 4, 5
    uint8_t  cutoff_time;
} HapticControllerFeature01;
typedef struct __attribute__((packed)) {
    uint8_t report_id;
    uint8_t trigger : 3; // Manual Trigger
    uint8_t reserved : 5;
    uint8_t intensity;
} HapticControllerOutput01;
/*
 * Waveform and Duration Lists (Units derived from the respective usage default units)
 */
static const HapticControllerFeature01 HAPTIC_CONTROLLER_FEATURE_01 = {
    .report_id = 0x01,
    .waveform_usage = {
        0x1003, // Ordinal 3: Waveform Click
        0x1004, // Ordinal 4: Waveform Buzz
        0x1005, // Ordinal 5: Waveform Rumble
    },
    .waveform_duration = {
        10, // Ordinal 3 (Waveform Click): 10 ms
        0,  // Ordinal 4 (Waveform Buzz): Continuous
        0,  // Ordinal 5 (Waveform Rumble): Continuous
```

```
    },
    .cutoff_time = 10, // Continuous Waveform Cutoff Time: 10 s
};
static void play_waveform(uint16_t ordinal, uint8_t intensity) {
    switch(ordinal) {
        case 1:
            // Waveform None (no-op)
            break;
        case 2:
            stopWaveform();
            break;
        case 3:
            startClickWaveform(intensity);
            break;
        case 4:
            startBuzzWaveform(intensity);
            break;
        case 5:
            startRumbleWaveform(intensity);
            break;
        default:
            // out-of-bounds value; ignore
            break;
    }
}
void handle_set_report(uint8_t * report, size_t length) {
    switch (report[0]) {
        case 1:
            uint16_t ordinal = ((HapticControllerOutput01 *)report)->trigger;
            uint8_t intensity = ((HapticControllerOutput01 *)report)->intensity;
            play_waveform(ordinal, intensity);
            break;
        default:
            break;
    }
}
void handle_get_report(uint8_t * report, size_t * length) {
    switch (report[0]) {
        case 1:
            *(HapticControllerFeature01 *)report = HAPTIC_CONTROLLER_FEATURE_01;
            *length = sizeof(HapticControllerFeature01);
            break;
        default:
            break;
    }
}
```

19.3.13 Additional Code Examples

The following section contains some common definitions used in the examples throughout this chapter, as well as some more complex example descriptors.

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```
/// ------------------------------
/// HID Report Descriptor Utilities
/// ------------------------------
#define Undefined                       0x00
#define HID_USAGE_PAGE_8(a)             0x05,a
#define HID_USAGE_PAGE_16(a,b)          0x06,a,b
#define HID_USAGE_8(a)                  0x09,a
#define HID_USAGE_16(a,b)               0x0A,a,b
#define HID_USAGE_MIN_8(a)              0x19,a
#define HID_USAGE_MIN_16(a,b)           0x1A,a,b
#define HID_USAGE_MAX_8(a)              0x29,a
#define HID_USAGE_MAX_16(a,b)           0x2A,a,b
#define HID_REPORT_ID(a)                0x85,a
#define HID_REPORT_SIZE(a)              0x75,a
#define HID_REPORT_COUNT(a)             0x95,a
#define HID_LOGICAL_MIN_8(a)            0x15,a
#define HID_LOGICAL_MIN_16(a,b)         0x16,a,b
#define HID_LOGICAL_MIN_32(a,b,c,d)     0x17,a,b,c,d
#define HID_LOGICAL_MAX_8(a)            0x25,a
#define HID_LOGICAL_MAX_16(a,b)         0x26,a,b
#define HID_LOGICAL_MAX_32(a,b,c,d)     0x27,a,b,c,d
#define HID_PHYSICAL_MIN_8(a)           0x35,a
#define HID_PHYSICAL_MIN_16(a,b)        0x36,a,b
#define HID_PHYSICAL_MIN_32(a,b,c,d)    0x37,a,b,c,d
#define HID_PHYSICAL_MAX_8(a)           0x45,a
#define HID_PHYSICAL_MAX_16(a,b)        0x46,a,b
#define HID_PHYSICAL_MAX_32(a,b,c,d)    0x47,a,b,c,d
#define HID_UNIT_EXPONENT(a)            0x55,a
#define HID_UNIT_8(a)                   0x65,a
#define HID_UNIT_16(a,b)                0x66,a,b
#define HID_UNIT_32(a,b,c,d)            0x67,a,b,c,d
#define Data_Arr_Abs                0x00
#define Const_Arr_Abs               0x01
#define Data_Var_Abs                0x02
#define Const_Var_Abs               0x03
#define Data_Var_Rel                0x06
#define HID_INPUT(a)                0x81,a
#define HID_OUTPUT(a)               0x91,a
#define HID_FEATURE(a)              0xB1,a
#define Physical                    0x00
#define Application                 0x01
#define Logical                     0x02
#define NamedArray                  0x04
#define UsageSwitch                 0x05
#define UsageModifier               0x06
#define HID_COLLECTION(a)           0xA1,a
#define HID_END_COLLECTION          0xC0
/// ------------------------------------------------------------
/// Example Descriptor: Generic Accessory (IMU, LEDs, One Button)
/// ------------------------------------------------------------
HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
HID_USAGE_8(0x0F), // Spatial Controller
HID_COLLECTION(Application),
```

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```
    HID_REPORT_ID(3),
    HID_REPORT_SIZE(8),
    HID_REPORT_COUNT(8),
    HID_USAGE_PAGE_16(0x15, 0xFF),
    HID_USAGE_8(0x06), // Accessory Tracking Clock Timestamp
    HID_INPUT(Data_Var_Abs), // Input Timestamp (Accessory Tracking Clock)
    HID_USAGE_PAGE_8(0x20), // Sensors Page
    HID_USAGE_8(0x70), // Motion
    HID_COLLECTION(Physical),
        HID_REPORT_ID(2),
        HID_REPORT_SIZE(32),
        HID_LOGICAL_MIN_8(0x00),
        HID_LOGICAL_MAX_32(0xFF, 0xFF, 0xFF, 0x7F),
        HID_UNIT_EXPONENT(-3),
        HID_USAGE_16(0x0E, 0x03), // Report Interval
        HID_FEATURE(Data_Var_Abs),
        HID_USAGE_16(0x17, 0x03), // Sampling Interval
        HID_FEATURE(Data_Var_Abs),
        HID_UNIT_EXPONENT(0),
        HID_REPORT_SIZE(16),
        HID_REPORT_COUNT(3),
        HID_LOGICAL_MIN_16(0x00, 0x80),
        HID_LOGICAL_MAX_16(0xFF, 0x7F),
        HID_PHYSICAL_MIN_8(0xF8), // -8 g
        HID_PHYSICAL_MAX_8(0x08), // +8 g
        HID_USAGE_MIN_16(0x53, 0x04),
        HID_USAGE_MAX_16(0x55, 0x04),
        HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (Sample 1)
        HID_USAGE_MIN_16(0x53, 0x04),
        HID_USAGE_MAX_16(0x55, 0x04),
        HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (Sample 2)
        HID_USAGE_MIN_16(0x53, 0x04),
        HID_USAGE_MAX_16(0x55, 0x04),
        HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (Sample 3)
        HID_PHYSICAL_MIN_16(0x18, 0xFC), // -1000 dps
        HID_PHYSICAL_MAX_16(0xE8, 0x03), // +1000 dps
        HID_USAGE_MIN_16(0x57, 0x04),
        HID_USAGE_MAX_16(0x59, 0x04),
        HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (Sample 1)
        HID_USAGE_MIN_16(0x57, 0x04),
        HID_USAGE_MAX_16(0x59, 0x04),
        HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (Sample 2)
        HID_USAGE_MIN_16(0x57, 0x04),
        HID_USAGE_MAX_16(0x59, 0x04),
        HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (Sample 3)
        HID_REPORT_SIZE(8),
        HID_REPORT_COUNT(8),
        HID_LOGICAL_MIN_8(0),
        HID_LOGICAL_MAX_8(0),
        HID_PHYSICAL_MIN_8(0),
        HID_PHYSICAL_MAX_8(0),
        HID_USAGE_PAGE_16(0x15, 0xFF),
        HID_USAGE_8(0x06), // Accessory Tracking Clock Timestamp (Sample 1)
```

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```
        HID_INPUT(Data_Var_Abs),
        HID_USAGE_8(0x06), // Accessory Tracking Clock Timestamp (Sample 2)
        HID_INPUT(Data_Var_Abs),
        HID_USAGE_8(0x06), // Accessory Tracking Clock Timestamp (Sample 3)
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_PAGE_8(0x09), // Button Page
    HID_USAGE_8(0x01), // Button 1 (Primary)
    HID_COLLECTION(Physical),
        HID_REPORT_ID(3),
        HID_REPORT_SIZE(1),
        HID_REPORT_COUNT(1),
        HID_USAGE_8(0x01), // Button 1 (Primary)
        HID_LOGICAL_MIN_8(0),
        HID_LOGICAL_MAX_8(1),
        HID_PHYSICAL_MIN_8(Undefined),
        HID_PHYSICAL_MAX_8(Undefined),
        HID_INPUT(Data_Var_Abs),
        HID_REPORT_SIZE(7),
        HID_INPUT(Const_Var_Abs), // Padding
    HID_END_COLLECTION,
    HID_USAGE_PAGE_16(0x1F, 0xFF),
    HID_USAGE_8(0xF0), // LED Constellation
    HID_COLLECTION(Logical),
        HID_REPORT_ID(4),
        HID_REPORT_SIZE(8),
        HID_REPORT_COUNT(8),
        HID_USAGE_PAGE_16(0x15, 0xFF),
        HID_USAGE_8(0x06), // Pulse Midpoint (Accessory Tracking Clock)
        HID_OUTPUT(Data_Var_Abs),
        HID_REPORT_COUNT(1),
        HID_USAGE_PAGE_8(0x08), // LED Page
        HID_USAGE_8(0x3C), // Usage Multi Mode Indicator
        HID_COLLECTION(UsageModifier),
            HID_LOGICAL_MIN_8(1),
            HID_LOGICAL_MAX_8(3),
            HID_USAGE_8(0x3D), // Indicator On
            HID_USAGE_8(0x40), // Indicator Fast Blink
            HID_USAGE_8(0x41), // Indicator Off
            HID_OUTPUT(Data_Arr_Abs),
        HID_END_COLLECTION,
        HID_LOGICAL_MAX_8(100),
        HID_USAGE_8(0x56), // LED Intensity
        HID_OUTPUT(Data_Var_Abs),
        HID_REPORT_SIZE(24),
        HID_LOGICAL_MIN_8(0),
        HID_LOGICAL_MAX_32(0xFF, 0xFF, 0xFF, 0x00),
        HID_UNIT_16(0x01, 0x10), // seconds
        HID_UNIT_EXPONENT(0x0A), // −6 (microseconds)
        HID_USAGE_8(0x45), // Fast Blink On Time
        HID_OUTPUT(Data_Var_Abs),
        HID_USAGE_8(0x46), // Fast Blink Off Time
        HID_OUTPUT(Data_Var_Abs),
```

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```
    HID_END_COLLECTION,
HID_END_COLLECTION,
```

19.3.14 Game Controller Class

Spatial game controllers are accessories providing high-performance low-latency input to devices for gaming. Game controller functionality is directly exposed to applications through the APIs in the Game Controller framework.

Spatial game controllers shall include the `com.apple.spatial-gamepad` identifier in the Uniform Type Identifier characteristic as the second-to-last identifier value. Any other accessory-specific types defined shall conform to the `com.apple.spatial-gamepad` type.

Spatial game controllers shall implement the following control surfaces:

- Face Button Group.
- Joystick.
- Grip Button.
- Trigger Button.
- Menu Button.
- Home Button.

Spatial game controllers shall define the following named transforms from the *OpenXR Specification – Version 1.1* (https://registry.khronos.org/OpenXR/specs/1.1/html/xrspec.html):

- Grip.
- Aim.
- Grip Surface (Palm).

19.3.14.1 HID

The top-level application collection of a spatial game controller shall have usage page `0x01` (Generic Desktop Page) and usage ID `0x0005` (Gamepad). The descriptor shall support the collections required of all spatial accessories, namely, a 6-axis IMU and LED constellation.

Additionally, the report descriptor shall support physical collections for all button and thumbstick inputs described in the following table nested directly under the top-level application collection:

Table 19-8 Required button and thumbstick inputs for spatial game controllers, mapped to Apple-defined functions

Usage Page	Usage ID	Ordinal	Usage Name	Apple Function
`0x09`	`0x0001`	—	Button 1	A
`0x09`	`0x0002`	—	Button 2	B
`0x09`	`0x0005`	—	Button 5	Grip

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Usage Page	Usage ID	Ordinal	Usage Name	Apple Function
0x09	0x0007	—	Button 7	Trigger
0x09	0x0200	—	Button 512	Home Button
0x09	0x0201	—	Button 513	Menu Button
0x01	0x0096	0x0001	Thumbstick 1	Thumbstick 1

A button collection may be nested under any thumbstick collection, indicating a clickable thumbstick. Use button usage ID 0x0001 for thumbstick buttons to denote the click action. Due to their nesting, such buttons do not satisfy the requirement from Table 19-8 (page 147) and will not be interpreted as the "A" button.

A proximity sensor collection may be nested under any button collection, indicating the button can detect contact with the user's finger.

19.3.14.2 Reserved Usages

The following usages and ordinals are reserved by Apple for future use. Spatial game controller class accessories shall not include inputs with these usages/ordinals in their report descriptors.

Table 19-9 Reserved button and thumbstick usages and ordinals for spatial game controller class accessories (shall not be used)

Usage Page	Usage ID	Ordinal	Usage Name
0x09	0x0003–0x0004		Button 3–4
0x09	0x0006		Button 6
0x09	0x0008–0x0064		Button 8–100
0x09	0x0100–0x0164		Button 256–356
0x09	0x0202–0x0210		Button 514–528
0x01	0x0096	0x0002–0x0004	Thumbstick 2–4

19.3.14.3 Accessory Bundle

The accessory bundle for a spatial gamepad shall define the following named transforms for the controller model:

Table 19-10 Named transforms required in the spatial gamepad accessory bundle

Transform Name	Apple Function
grip	A transform allowing applications to reliably anchor the virtual representation of the controller held in the user's hand.

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Transform Name	Apple Function
aim	A transform allowing applications to anchor a pointer emitting from the virtual representation of the controller.
grip_surface	A transform allowing applications to reliably anchor the virtual representation of the controller to the user's hand.

These transforms align with the standard poses defined in the *OpenXR Specification – Version 1.1*.

19.3.14.4 Face Button Group

The face button group shall contain two circular buttons. The buttons should be labeled 'A' and 'B' in capital letters.

Each button shall use a digital switch or analog position encoder. Each button may optionally contain a capacitive sensor capable of detecting, at a minimum, user contact with the button surface.

19.3.14.5 Grip Button

The button shall use a digital switch or analog position encoder. The button may optionally contain a capacitive sensor capable of detecting, at a minimum, user contact with the button surface.

19.3.14.6 Trigger Button

Triggers shall use either analog position encoders (recommended) or pressure sensitive switches. Analog triggers shall have a linear response curve. Triggers may optionally contain a capacitive sensor capable of detecting, at a minimum, user contact with the button surface. An analog trigger may include an additional end-stop tactile switch as a separate input.

19.3.14.7 Menu Button

The menu button shall use a digital switch.

19.3.14.8 Home Button

The home button shall use a digital switch.

19.3.14.9 Joystick

Joystick horizontal and vertical axis shall use analog position encoders.

Joysticks shall include digital switches for click function. The click switch shall be depressible from any joystick deflection angle.

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The joystick shall report a full range of movement between the unit circle and unit square using two signed *n*-bit integers where *n* is 8 or more, one for the X axis and one for the Y axis. Each axis shall report a full range of values between $-2^{n-1}+1$ and $+2^{n-1}-1$ inclusive on a linear scale. The values shall be linearly reported with respect to physical displacement or angular displacement of the joystick.

At rest, the joystick shall report (0,0) for the X and Y axes, respectively.

The following are example report descriptors for a spatial game controller:

```
/// ----------------------------------------
/// Basic spatial game controller with:
///  - IMU, transmitting three timestamped samples per input report
///  - LED constellation
///  - One clickable thumbstick without integrated touch or proximity sensors
///  - Four digital buttons without integrated touch or proximity sensors: A, B, HOME, MENU
///  - One digital button with integrated touch sensor: Grip
///  - One analog button without integrated touch or proximity sensors: Trigger
///
///  IMU and controller inputs are transmitted in separate HID reports. This allows the accessory
 to send less data when controller inputs are unchanged.
HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
HID_USAGE_8(0x05), // Gamepad
HID_COLLECTION(Application),
    // <Begin IMU>
    HID_USAGE_PAGE_8(0x20), // Sensors Page
    HID_USAGE_8(0x70), // Motion
    HID_REPORT_ID(0x02),
    HID_COLLECTION(Physical),
        HID_REPORT_SIZE(32),
        HID_REPORT_COUNT(1),
        HID_LOGICAL_MIN_8(0x00),
        HID_LOGICAL_MAX_32(0xFF, 0xFF, 0xFF, 0x7F),
        HID_UNIT_EXPONENT(-3),
        HID_USAGE_16(0x0E, 0x03),
        HID_FEATURE(Data_Var_Abs), // Report Interval (microseconds)
        HID_USAGE_16(0x17, 0x03),
        HID_FEATURE(Data_Var_Abs), // Sampling Interval (microseconds)
        HID_UNIT_EXPONENT(0),
        HID_REPORT_SIZE(16),
        HID_REPORT_COUNT(3),
        HID_LOGICAL_MIN_16(0x00, 0x80),
        HID_LOGICAL_MAX_16(0xFF, 0x7F),
        HID_PHYSICAL_MIN_8(0xF0), // -16 g
        HID_PHYSICAL_MAX_8(0x10), // +16 g
        HID_USAGE_MIN_16(0x53, 0x04),
        HID_USAGE_MAX_16(0x55, 0x04),
        HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (±16 g) (Sample 1)
        HID_USAGE_MIN_16(0x53, 0x04),
        HID_USAGE_MAX_16(0x55, 0x04),
        HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (±16 g) (Sample 2)
        HID_USAGE_MIN_16(0x53, 0x04),
```

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```
        HID_USAGE_MAX_16(0x55, 0x04),
        HID_INPUT(Data_Var_Abs), // Accel X, Y, Z (±16 g) (Sample 3)
        HID_PHYSICAL_MIN_16(0x60, 0xF0), // −4000 dps
        HID_PHYSICAL_MAX_16(0xA0, 0x0F), // +4000 dps
        HID_USAGE_MIN_16(0x57, 0x04),
        HID_USAGE_MAX_16(0x59, 0x04),
        HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (±4000 dps) (Sample 1)
        HID_USAGE_MIN_16(0x57, 0x04),
        HID_USAGE_MAX_16(0x59, 0x04),
        HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (±4000 dps) (Sample 2)
        HID_USAGE_MIN_16(0x57, 0x04),
        HID_USAGE_MAX_16(0x59, 0x04),
        HID_INPUT(Data_Var_Abs), // Gyro X, Y, Z (±4000 dps) (Sample 3)
        HID_REPORT_SIZE(64),
        HID_REPORT_COUNT(1),
        HID_LOGICAL_MIN_8(Undefined),
        HID_LOGICAL_MAX_8(Undefined),
        HID_PHYSICAL_MIN_8(Undefined),
        HID_PHYSICAL_MAX_8(Undefined),
        HID_USAGE_PAGE_16(0x15, 0xFF),
        HID_USAGE_8(0x06),
        HID_INPUT(Data_Var_Abs), // (Apple Vendor Sensor, Time-Sync Timestamp) (Sample 1)
        HID_USAGE_8(0x06),
        HID_INPUT(Data_Var_Abs), // (Apple Vendor Sensor, Time-Sync Timestamp) (Sample 2)
        HID_USAGE_8(0x06),
        HID_INPUT(Data_Var_Abs), // (Apple Vendor Sensor, Time-Sync Timestamp) (Sample 3)
    HID_END_COLLECTION,
    // <End IMU>
    // <Begin LED Constellation>
    HID_USAGE_PAGE_16(0x1F, 0xFF), // Vendor-Defined
    HID_USAGE_8(0xF0), // LED Constellation
    HID_COLLECTION(Logical),
        HID_REPORT_ID(0x03),
        HID_REPORT_SIZE(8),
        HID_REPORT_COUNT(8),
        HID_USAGE_PAGE_16(0x15, 0xFF),
        HID_USAGE_8(0x06), // Pulse Midpoint (Accessory Tracking Clock)
        HID_OUTPUT(Data_Var_Abs),
        HID_REPORT_COUNT(1),
        HID_USAGE_PAGE_8(0x08), // LED Page
        HID_USAGE_8(0x3C), // Usage Multi Mode Indicator
        HID_COLLECTION(UsageModifier),
            HID_LOGICAL_MIN_8(1),
            HID_LOGICAL_MAX_8(3),
            HID_USAGE_8(0x3D), // Indicator On
            HID_USAGE_8(0x40), // Indicator Fast Blink
            HID_USAGE_8(0x41), // Indicator Off
            HID_OUTPUT(Data_Arr_Abs),
        HID_END_COLLECTION,
        HID_LOGICAL_MAX_8(100),
        HID_USAGE_8(0x56), // LED Intensity
        HID_OUTPUT(Data_Var_Abs),
        HID_REPORT_SIZE(24),
```

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```
        HID_LOGICAL_MIN_8(0),
        HID_LOGICAL_MAX_32(0xFF, 0xFF, 0xFF, 0x00),
        HID_UNIT_16(0x01, 0x10), // seconds
        HID_UNIT_EXPONENT(0x0A), // −6 (microseconds)
        HID_USAGE_8(0x45), // Fast Blink On Time
        HID_OUTPUT(Data_Var_Abs),
        HID_USAGE_8(0x46), // Fast Blink Off Time
        HID_OUTPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    // <End LED Constellation>
    // <Begin Controller Inputs>
    HID_REPORT_ID(0x01),
    HID_REPORT_SIZE(8),
    HID_REPORT_COUNT(8),
    HID_USAGE_PAGE_16(0x15, 0xFF),
    HID_USAGE_8(0x06), // Accessory Tracking Clock Timestamp
    HID_INPUT(Data_Var_Abs), // Input Timestamp (Accessory Tracking Clock)
    HID_REPORT_SIZE(1),
    HID_REPORT_COUNT(1),
    HID_LOGICAL_MIN_8(0),
    HID_LOGICAL_MAX_8(1),
    HID_PHYSICAL_MIN_8(Undefined),
    HID_PHYSICAL_MAX_8(Undefined),
    HID_USAGE_PAGE_8(0x09), // Button Page
    HID_USAGE_8(0x01), // Button 1 (A)
    HID_COLLECTION(Physical),
        HID_USAGE_8(0x01), // Button 1 (A)
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_8(0x02), // Button 2 (B)
    HID_COLLECTION(Physical),
        HID_USAGE_8(0x02), // Button 2 (B)
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_8(0x05), // Button 5 (Grip)
    HID_COLLECTION(Physical),
        HID_USAGE_8(0x05), // Button 5 (Grip)
        HID_INPUT(Data_Var_Abs),
        HID_USAGE_PAGE_8(0x20), // Sensors Page
        HID_USAGE_8(0x12), // Proximity
        HID_COLLECTION(Physical),
            HID_USAGE_16(0xB4, 0x04), // Human Touch State
            HID_INPUT(Data_Var_Abs),
        HID_END_COLLECTION,
    HID_END_COLLECTION,
    HID_USAGE_16(0x00, 0x02), // Button 512 (HOME)
    HID_COLLECTION(Physical),
        HID_USAGE_16(0x00, 0x02), // Button 512 (HOME)
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_16(0x01, 0x02), // Button 513 (MENU)
    HID_COLLECTION(Physical),
        HID_USAGE_16(0x01, 0x02), // Button 513 (MENU)
```

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```
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
    HID_USAGE_8(0x96), // Thumbstick
    HID_COLLECTION(Physical),
        HID_USAGE_PAGE_8(0x0A),
        HID_USAGE_8(0x01),
        HID_COLLECTION(Logical),
            HID_USAGE_PAGE_8(0x09), // Button Page
            HID_USAGE_8(0x01), // Button 1 (Thumbstick)
            HID_COLLECTION(Physical),
                HID_USAGE_8(0x01), // Button 1 (Thumbstick)
                HID_INPUT(Data_Var_Abs),
            HID_END_COLLECTION,
            HID_REPORT_SIZE(1),
            HID_INPUT(Const_Var_Abs), // Padding
            HID_USAGE_PAGE_8(0x01), // Generic Desktop Page
            HID_REPORT_SIZE(16),
            HID_REPORT_COUNT(2),
            HID_LOGICAL_MIN_16(0x00, 0x80),
            HID_LOGICAL_MAX_16(0xFF, 0x7F),
            HID_USAGE_MIN_8(0x30), // X
            HID_USAGE_MAX_8(0x31), // Y
            HID_PHYSICAL_MIN_8(-1),
            HID_PHYSICAL_MAX_8(1),
            HID_INPUT(Data_Var_Abs),
        HID_END_COLLECTION
    HID_END_COLLECTION,
    HID_USAGE_PAGE_8(0x09), // Button Page
    HID_USAGE_8(0x07), // Button 7 (Trigger)
    HID_COLLECTION(Physical),
        HID_REPORT_SIZE(8),
        HID_REPORT_COUNT(1),
        HID_LOGICAL_MIN_8(0x00),
        HID_LOGICAL_MAX_16(0xFF, 0x00),
        HID_PHYSICAL_MIN_8(0),
        HID_PHYSICAL_MAX_8(1),
        HID_USAGE_8(0x07), // Button 7 (Trigger)
        HID_INPUT(Data_Var_Abs),
    HID_END_COLLECTION,
    // <End Controller Inputs>
HID_END_COLLECTION,
// IMU input report sent from spatial controller to the host.
typedef struct __attribute__((packed)) {
    uint8_t report_id; // 0x02
    int16_t accel_x;
    int16_t accel_y;
    int16_t accel_z;
    int16_t gyro_x;
    int16_t gyro_y;
    int16_t gyro_z;
    uint64_t sample_timestamp;
} SpatialControllerIMUInputReport02;
```

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```
// IMU feature report sent from spatial controller to the host in response to host GET FEATURE
0x02
typedef struct __attribute__((packed)) {
    uint8_t report_id; // 0x02
    uint32_t report_interval;
    uint32_t sampling_interval;
} SpatialControllerIMUFeatureReport02;
typedef struct __attribute__((packed)) {
  uint8_t report_id; // 0x03
  uint8_t timestamp[8];
  uint8_t mode;
  uint8_t intensity;
  uint8_t on_time[3];  // 24-bit
  uint8_t off_time[3]; // 24-bit
} SpatialControllerLEDOutputReport03;
// Input report sent from spatial controller to the host when states of control surfaces change.
typedef struct __attribute__((packed)) {
  uint8_t report_id; // 0x01
  uint8_t input_timestamp[8];
  uint8_t button_a_press : 1;
  uint8_t button_b_press : 1;
  uint8_t button_grip_press : 1;
  uint8_t button_grip_touch : 1;
  uint8_t button_home_press : 1;
  uint8_t button_menu_press : 1;
  uint8_t thumbstick_press : 1;
  uint8_t : 1;
  int16_t thumbstick_x;
  int16_t thumbstick_y;
  uint8_t trigger_press;
} SpatialControllerControllerInputReport01;
```

19.4 Wireless

This section describes the Bluetooth Low Energy (BLE) interface between a spatial accessory and the device.

The accessory transmits input and feature reports to the device, and the device transmits output and feature reports to the accessory. The Bluetooth and HID role assignments are defined in Generic Access Profile (GAP) (page 157) and HID Over GATT Profile (HOGP) (page 157).

The device, as Central, selects the connection interval, see Connection Procedures (page 159). The accessory shall send IMU data to the device at the selected interval, see IMU (page 169) for IMU sampling frequencies.

Devices support a maximum of two spatial accessories simultaneously.

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19.4.1 Payload Size

HID packets at the Bluetooth Link Layer shall have an L2CAP payload less than or equal to 100 bytes.

19.4.2 Report Types

The accessory implements three kinds of report characteristics:

- Input Report, used to transmit data from the spatial accessory to the device.
- Output Report, used to transmit data from the device to the spatial accessory.
- Feature Report, used to set or get properties (such as configurations and states) in both directions.

See HID (page 127).

19.4.3 Retransmission Policy

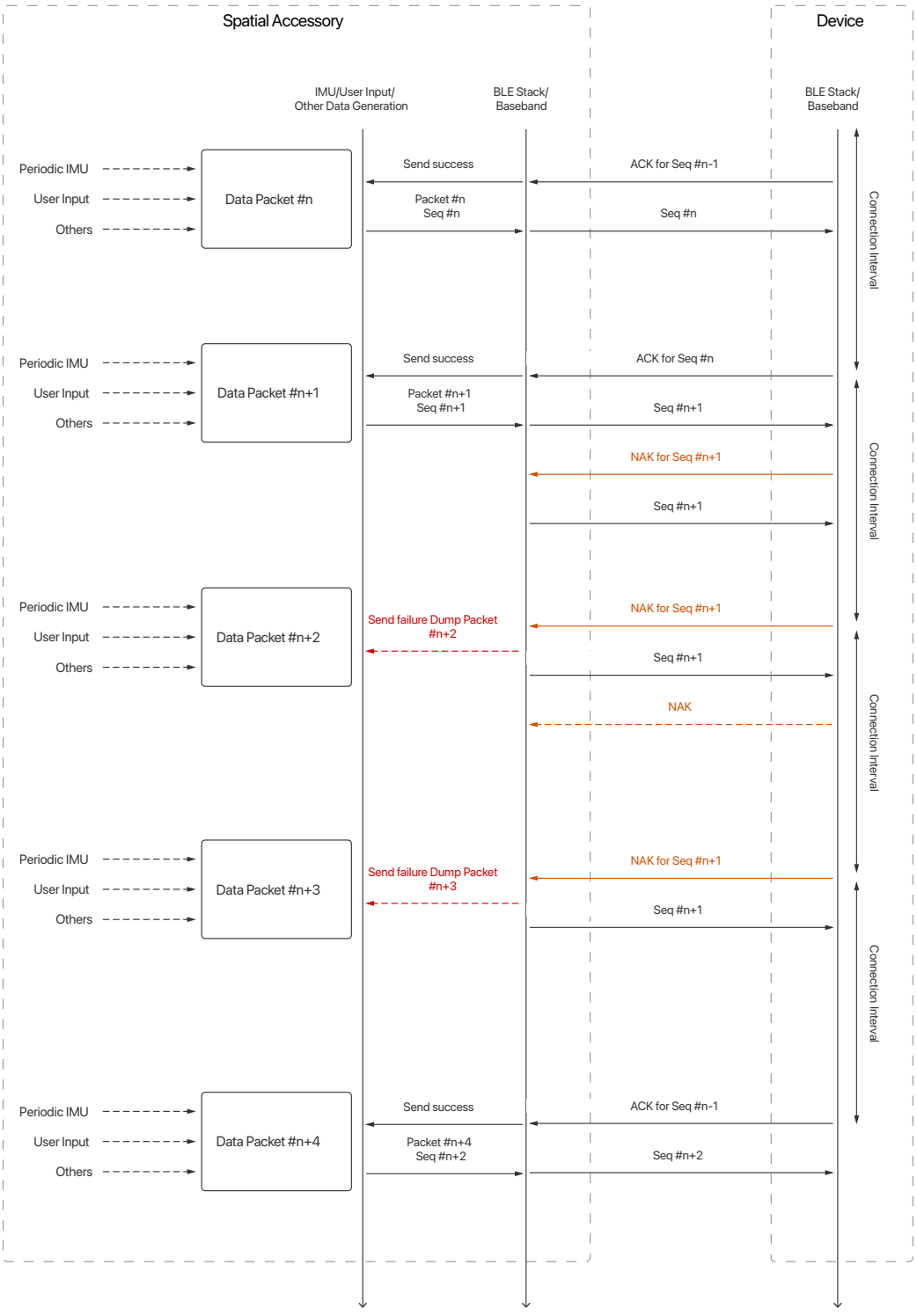
The link layer retransmits input reports when an RF packet transmission fails. Data packets include, but are not limited to, IMU data and user input. The accessory shall:

- Keep the sequence ID in the baseband buffer.
- Increment the sequence ID of an input report only after receiving an ACK for the previous report from the device.
- Sample IMU data periodically.
- Queue a new data packet only after receiving an ACK for the previous report.
- Send only non-flushable packets.
- Send the most recently generated data packet upon receiving the ACK.

A sample retransmission protocol is shown in Figure 19-2 (page 156). Retransmission may happen in the same connection event if it is within the connection event length. Dumped packets do not consume a sequence number. The sequence number (Seq #) only advances on successfully queued data, which is why packet #n+4 carries Seq #n+2.

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Figure 19-2 Sample retransmission protocol sequence showing how an unacknowledged input report is retransmitted within the same connection event



19.4.4 Report Timing

Spatial accessories shall:

- Maintain the highest possible report rate at the connection interval selected by the BLE Central, see Connection Procedures (page 159).
- Report any change on their inputs (button press, analog value change, etc.) to the device within the same BLE interval cycle of the event occurring unless a previous input report is still awaiting ACK or the event occurred less than 500 µs before the current interval ends.

19.4.5 Bluetooth Host Requirements

19.4.5.1 Roles

Multiple spatial accessories with unique Bluetooth addresses may be used simultaneously. When two accessories are used as a left/right pair, the accessory's Bluetooth device name shall include the word 'Left' or 'Right' according to the intended hand.

19.4.5.2 Generic Access Profile (GAP)

- The accessory shall be the GAP Peripheral.
- The device is the GAP Central.

19.4.5.3 HID Over GATT Profile (HOGP)

The device implements the HID Host role defined in the *HID Over GATT Profile – Version 1.0, Section 2.1*. The accessory shall support the HID Device role defined in the *HID Over GATT Profile – Version 1.0, Section 2.1*.

19.4.5.4 Dependencies

The accessory shall support Bluetooth Low Energy (BLE) 5.4 or later, including the following Core Specification features:

- LE Enhanced Connection Update. See *Bluetooth Core Specification – Version 5.4*.
- Data Packet Length Extension. See *Bluetooth Core Specification – Version 5.4, Volume 6, Part B, Section 4.6.6*.
- LE 2M PHY rate.
- Bluetooth pairing with the Central conforming to the Device Security Considerations specified in the *HID Over GATT Profile – Version 1.0, Section 6.1*.
- Extended advertising.

The device does not support the following optional HOGP features:

- Scan Parameters Service.

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- Boot Host Role.

19.4.5.5 Connection Parameter Considerations

The device may choose to use a Peripheral latency parameter ≥1 in order to allow for the accessory to conserve power when there is no data to be transmitted. The Host implementation on the accessory shall ensure it enqueues all available IMU data to the accessory at an appropriate report rate, to ensure the accessory responds at every connection instant (where data is available to send) irrespective of the Peripheral latency configuration.

19.4.5.6 Apple Spatial Accessory Profile (ASAP)

The accessory shall support the Apple Spatial Accessory Profile (ASAP), a combination of the Apple Spatial Accessory Service (ASAS) and the HID Device role, see HID Over GATT Profile (HOGP) (page 157).

The accessory shall host the ASAS in its GATT server, see GATT Server Requirements (page 163).

19.4.5.7 Other Profiles and Services

The accessory shall support the Bluetooth Low Energy Battery Service (page 242).

19.4.5.8 Disconnection upon Power Off

If the user powers off the accessory when connected to a device, the accessory shall first disconnect the Bluetooth connection with the error code `0x13` (Remote User Terminated Connection), as specified in the *Bluetooth Core Specification – Version 5.4*, before completing power off procedures.

19.4.6 Bluetooth SoC Selection

The Bluetooth SoC shall be capable of compliance with the Bluetooth Host Requirements (page 157). Specifically, it shall be certified by the Bluetooth SIG to support at least Core Specification 5.4 or later and be capable of supporting the required features.

The SoCs in the table below have been ratified by Apple to meet these requirements. This list is not exhaustive, and an alternative not listed may be used.

Table 19-11 Bluetooth SoCs ratified by Apple to meet the Bluetooth Host Requirements

Manufacturer Part Number	Manufacturer	BT Variant	Maximum BT Version
nRF5340	Nordic	BLE	5.4
nRF52840	Nordic	BLE	5.4

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Manufacturer Part Number	Manufacturer	BT Variant	Maximum BT Version
nRF52833	Nordic	BLE	5.4
nRF52832	Nordic	BLE	5.4
nRF52820	Nordic	BLE	5.4
nRF52811	Nordic	BLE	5.4
nRF52810	Nordic	BLE	5.4
nRF52805	Nordic	BLE	5.4

19.4.7 Connection Procedures

19.4.7.1 Advertisement Configuration

The accessory shall advertise to reconnect with connectable advertisement.

The accessory should follow the advertising procedure in Advertising Interval (page 344) for discovery and reconnection.

19.4.7.2 Advertisement Payload

The accessory shall advertise as specified in Apple Spatial Accessory Profile (ASAP) (page 158), including the following Advertising Data blocks in an extended advertisement payload:

Table 19-12 Required Advertising Data blocks in the accessory's extended advertisement payload

Advertising Data Type	Contents	Typical Value
Appearance (`0x19`)	Generic Human Interface Device (`0x03C0`)	`C0 03`
Flags (`0x01`)	General Discoverable Mode (`0x02`), BR/EDR Not supported (`0x04`)	`06`
Complete List of 16-bit Service UUIDs (`0x03`)	Human Interface Device Service, Battery Service	`12 18 0F 18`
Complete List of 128-bit Service UUIDs (`0x07`)	Apple Spatial Accessory Service	`37 A0 08 E7 66 87 65 BF 32 4A CB 64 85 E6 77 E2`
Service Data - 128 bit UUID	Apple Spatial Accessory Service: Accessory Status Flags	`37 A0 08 E7 66 87 65 BF 32 4A CB 64 85 E6 77 E2 07`
Complete Local Name (`0x09`)	Accessory Name	"My Device"
Manufacturer Data (`0xFF`)	Company Identifier (or `0xFFFF`, if the manufacturer does not have an official identifier)	`FF FF`

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"Complete List" AD Types may be replaced with their "Incomplete List" counterparts if the latter is more appropriate for the application.

Within the Service Data - 128 bit UUID data, the Accessory Status Flags byte shall have the following structure:

Table 19-13 Bit layout of the Accessory Status Flags byte in the Service Data - 128 bit UUID advertising data

Bit	Contents	Value	Description
3–7	Reserved	0	Reserved for future use
2	Sentinel	1	Indicates the accessory supports the two lower bits.
1	User active	0 or 1	Should be set to 1 whenever the user has recently interacted with the accessory.
0	Externally powered	0 or 1	Should be set to 1 whenever the accessory is running off external power (or the battery is charging).

The User active bit shall reflect the accessory's user activity flag, see User Activity (page 178).

19.4.7.3 Connection Configuration

The Central determines the appropriate connection parameters. The accessory (as Peripheral) shall accept the requested connection parameters sent by the Central.

The accessory shall support the following configurations:

- Peripheral latency ≤ 30.
- 2 seconds ≤ connSupervisionTimeout ≤ 6 seconds.
- Interval min ≥ 7.5 ms.
- Interval min + 7.5 ms ≤ Interval Max.
- Interval Max * (Peripheral Latency +1) ≤ 2 seconds.
- Interval Max * (Peripheral Latency +1)*3 < connSupervisionTimeout.

The Central may change the connection interval (directly or through LE Enhanced Connection update procedures) to any of the following:

- 15 ms.
- 30 ms.
- 45 ms.
- 60 ms.
- 120 ms.
- 240 ms.

The accessory may terminate and trigger a disconnection of the BLE connection at any time.

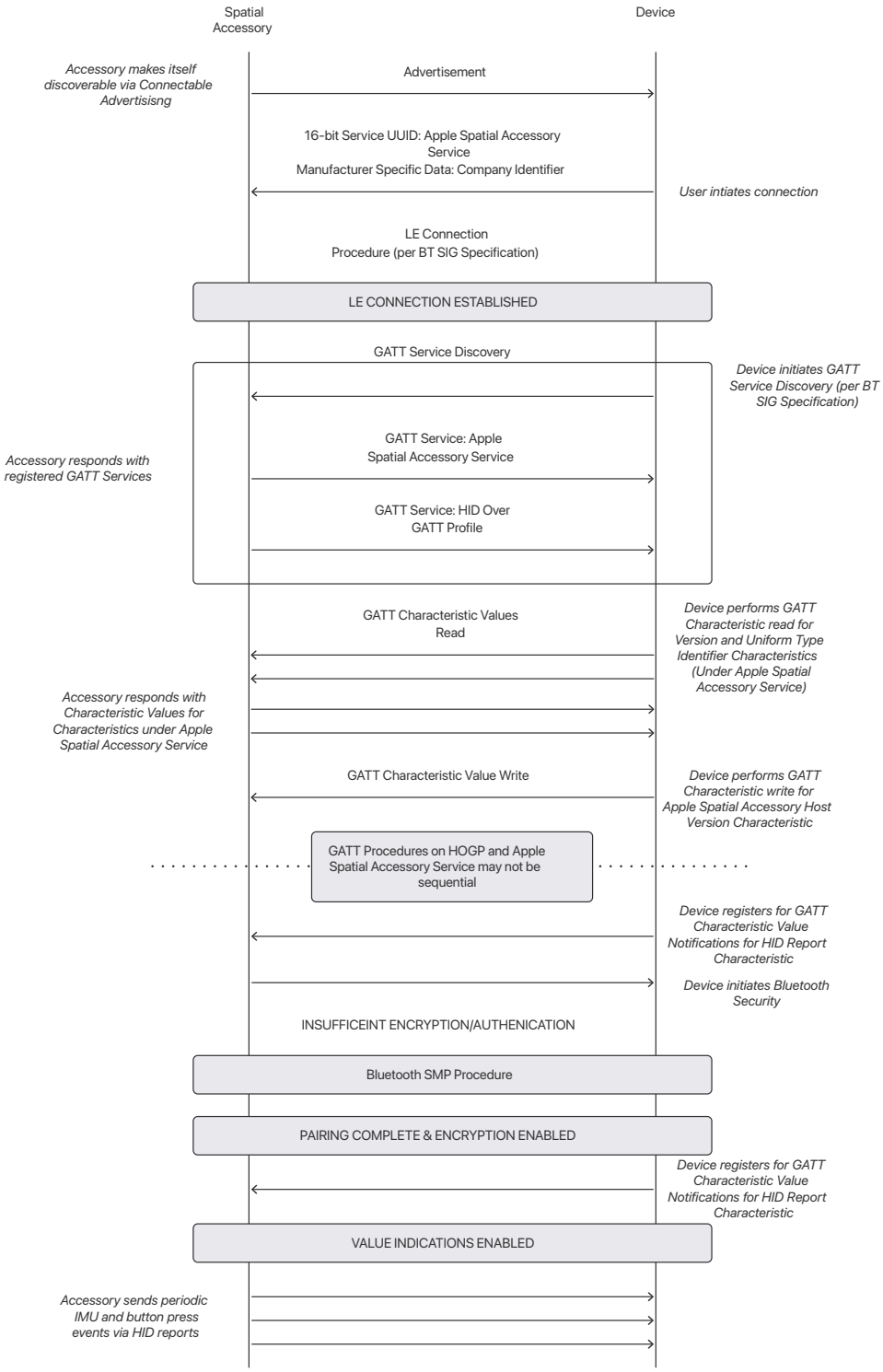
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19.4.7.4 Connection Procedure

The following diagram describes the expected Connection Procedure.

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Figure 19-3 Expected BLE connection procedure between the accessory and the device, showing GATT service discovery, ASA protocol version exchange, and HID notification subscription



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Once a connection is established, the device starts service discovery to discover the Generic Attribute Profile (GATT) Services hosted by the accessory, see GATT Server Requirements (page 163).

Upon service discovery, the device reads the Apple Spatial Accessory Version and Uniform Type Identifiers characteristics, see Table 19-14 (page 163). It then writes to the Apple Spatial Accessory Host Version characteristic to set the protocol version and common features for the subsequent ASA Service exchange. Once this configuration is complete, the device subscribes for Characteristic Value Notifications for the HID Report characteristic of the HOGP Service. This may initiate pairing between the accessory and the device if they are not already paired.

19.4.7.5 Pairing

The accessory shall support pairing with the Central.

Pairing is not expected to be initiated directly by the accessory. The recommended approach towards Pairing is to wait for an Attribute (ATT) protocol request to be rejected using the Insufficient Authentication error code. The specific procedure is described in Pairing (page 346).

19.4.8 GATT Server Requirements

The accessory shall implement the:

- Generic Attribute Profile (GATT).
- HID over GATT Profile (HOGP).
- Apple Spatial Accessory Service with UUID `E277E685-64CB-4A32-BF65-8766E708A037`.

Table 19-14 Apple Spatial Accessory Service Characteristics

Characteristic	Type	Access	Required	Values
Apple Spatial Accessory Version `E3AB6C3D-3E94-7A2C-DB59-B8B91723CAD4` The protocol version and features the accessory supports.	blob	Read	Yes	Supported ASA protocol version and the Features Supported bitfield. See Table 19-15 (page 164) and Table 19-16 (page 164).
Apple Spatial Accessory Host Version `3C7F9BDC-3BCB-A75F-C969-9BBD7F058F2B` Written by the device to set the protocol version and common features for the session.	blob	Read, Write	Yes	ASA protocol version and the common Features Supported bitfield. See Table 19-17 (page 165).
Uniform Type Identifiers `8640382C-DF0A-4E46-9CAB-36C05467949E` Identifies the accessory family, model, and appearance.	utf8	Read	Yes	Up to five reverse-DNS identifiers, ordered most to least specific. See Table 19-19 (page 167).

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Characteristic	Type	Access	Required	Values
Automatic Disconnection Timeout `FF88100C-9158-44EF-AD0B-60591555F6B5`	uint16	Read, Write	No	Inactivity timeout in seconds before the device may disconnect. See Table 19-20 (page 167).

The accessory shall require Authenticated or Unauthenticated encryption for all characteristic values, see Authentication Requirements for Characteristic Values (page 167). The following subsections define the structured value of each characteristic.

19.4.8.1 Apple Spatial Accessory Version

The value of the Apple Spatial Accessory Version characteristic is defined as follows:

Table 19-15 Apple Spatial Accessory Version characteristic value

Attribute Type	Length	Description
Supported_ASA_Protocol_Version_Len	1	Length in bytes for the Supported_ASA_Protocol_Version
Supported_ASA_Protocol_Version	2	ASA_Protocol_Version is a 2-byte field with the Major byte first followed by the Minor byte. Shall be set to `0x0101`.
Features Supported length (in Bytes)	1	Length in bytes for the Supported feature set
Features Supported	k	k is the number of bytes needed to convey the bitfield for the list of features supported

Features supported shall be defined as follows:

Table 19-16 Features Supported Definition Bitmap for the Apple Spatial Accessory Version characteristic

Attribute Type / Feature Supported	Attribute Value
Bit(0)	TimeSync Support
Bit(1)	Allow Modification of Automatic Disconnection Timeout
Bit(2–7)	Reserved for Future use (RFU)

19.4.8.2 Apple Spatial Accessory Host Version

The value of the Apple Spatial Accessory Host Version characteristic is defined as follows:

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Table 19-17 Apple Spatial Accessory Host Version characteristic value

Attribute Type	Length	Description
Supported_ASA_Protocol_Version	2	ASA_Protocol_Version is a 2-byte field with the Major byte first followed by the Minor byte. Shall be set to `0x0101`.
Features Supported length (in Bytes)	1	Length in bytes for the Supported feature set
Features Supported	k	k is the number of bytes needed to convey the bitfield for the list of features forming a common subset of those supported by the accessory and the device

The total size of the attribute value for the Apple Spatial Accessory Version characteristic and for the Apple Spatial Accessory Host Version characteristic shall be less than 512 bytes.

19.4.8.3 Uniform Type Identifiers

A Uniform Type Identifier is a string uniquely identifying a type of thing, such as a device category, a product family, or a specific accessory. Uniform Type Identifiers use a reverse-DNS naming convention (for example, `com.example.myaccessory`). A Uniform Type Identifier has at least three components: first a domain (typically `com`) followed by a company name. The third and any additional components are product characteristics such as family, name, model code, and SKU.

Uniform Type Identifiers form a hierarchy through conformance: a specific type declares it conforms to a more general type, much like a subclass inherits from a superclass. This allows software to handle types at whatever level of specificity it needs without needing to know every specific product on the market. In the context of spatial accessories, Uniform Type Identifiers serve as the link between physical hardware, applications, and Apple's accessory tracking system.

Uniform Type Identifiers may be defined at multiple levels of specificity for a product line:

- Accessory Family identifies a category of accessories sharing a common use case and set of control surfaces (buttons, triggers, joysticks, etc.). The family level is what app developers program against. A well-chosen family identifier allows a future model of an accessory to work with existing apps without the app developer needing to update their code, so long as the new model retains all of the control surfaces from the original. Example: `com.example.spatialaccessory`.
- Accessory Model identifies a specific hardware revision within a family. Apple recommends integrating the accessory model code into the identifier (for example, `com.example.spatialaccessory.sa001`).
- Identifiers may be optionally defined for additional levels of specificity, such as SKU or cosmetic variants of the same model.

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The type identifier hierarchy will be difficult to change once accessories are in the field, so plan for evolution. Use a stable family identifier. The family is the level app developers target, so it should remain constant when new hardware revisions are released. Choose a name reflecting the accessory's function and control surfaces, not a specific product generation. If a future model adds or removes control surfaces, breaking compatibility with existing apps, a new family is warranted (for example, `com.example.spatialaccessory2`).

Uniform Type Identifiers are opaque strings; the system does not parse the segments of an identifier. Instead, the system uses each identifier as a key to look up the corresponding exported UTType declaration, and follows the conformance chain defined to understand the relationships between a family, models, and appearances.

The Uniform Type Identifiers a spatial accessory chooses shall:

- Begin with a reverse-DNS domain (for example, `com.example`), and never with a prefix reserved by Apple.
- Use only alphanumeric characters, hyphens, and periods, with no spaces, underscores, or other special characters. Uniform Type Identifiers are case-insensitive ASCII.

The accessory shall publish its Uniform Type Identifiers through the Uniform Type Identifiers characteristic. The system reads this list to determine what the accessory is and how to handle it.

Every spatial accessory shall include `com.apple.spatial-device` as the final (least specific) identifier in the list. This allows the system to recognize the accessory as a spatial accessory even if an app for the accessory is not installed on the user's device.

Apple defines multiple spatial accessory classes for common use cases. Each class has an Apple-assigned Uniform Type Identifier, see Table 19-18 (page 166). If the accessory falls into one of Apple's defined classes, ensure the appropriate class identifier is included. The class identifier is more specific than `com.apple.spatial-device`, so it appears earlier in the list.

Table 19-18 Apple-defined spatial accessory classes

Type Identifier	Description
`com.apple.spatial-gamepad`	Spatial Game Controller class identifier. Include this identifier only if the accessory is used for gaming and meets the requirements in Game Controller Class (page 147).

The value of the Uniform Type Identifiers characteristic is defined as follows:

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Table 19-19 Uniform Type Identifiers characteristic value

Attribute Type	Length	Description
Uniform_Type_Identifiers_Len	1	Length in bytes for the Uniform_Type_Identifiers
Uniform_Type_Identifiers_List	Uniform_Type_Identifiers_Len	Up to five strings of UTF-8 encoded strings, each up to a maximum of 128 bytes long. Each String shall be terminated by the UTF LF character to separate it from subsequent strings. Allowed characters are in the range of (a-zA-Z0-9). Additionally, the '-' and '.' are allowed.

19.4.8.4 Automatic Disconnection Timeout

The Automatic Disconnection Timeout is the amount of time of inactivity before the device may disconnect the accessory.

The accessory may request a different value through the Automatic Disconnection Timeout characteristic. To do so, it shall set bit 1 of the Features Supported bitfield in the Apple Spatial Accessory Version characteristic.

The value of the Automatic Disconnection Timeout characteristic is defined as follows:

Table 19-20 Automatic Disconnection Timeout characteristic value

Attribute Type	Length	Description
Automatic_Host_Initiated_Disconnection_Timeout	2	Value in seconds of the amount of time of inactivity before the device may disconnect the accessory.

Automatic_Host_Initiated_Disconnection_Timeout value shall be encoded as big-endian. It may range from 5 minutes (`0x012C`) to 30 minutes (`0x0708`), and defaults to the 5-minute minimum if not set.

19.4.8.5 Authentication Requirements for Characteristic Values

If the accessory can support the I/O Capabilities necessary for Authenticated Link Keys (Bluetooth Core Specification v6.0, Vol 3, Part C, Sections 5.2.2.4–5.2.2.6), then it shall set the Attribute permissions for Characteristic values to "Authenticated Encryption Required". If these I/O capabilities cannot be supported, then the Attribute Permissions shall be set to "Encryption Required".

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19.4.9 Time Sync

The accessory shall support time synchronization and:

- Synchronize with the device within 2000 ms of a connection establishment.
- Maintain time synchronization indefinitely with a maximum allowed jitter of 500 µs.

The device communicates the exact time at which to flash the LED constellation on the accessory. The Accessory Tracking Clock is a tuple of the following three values:

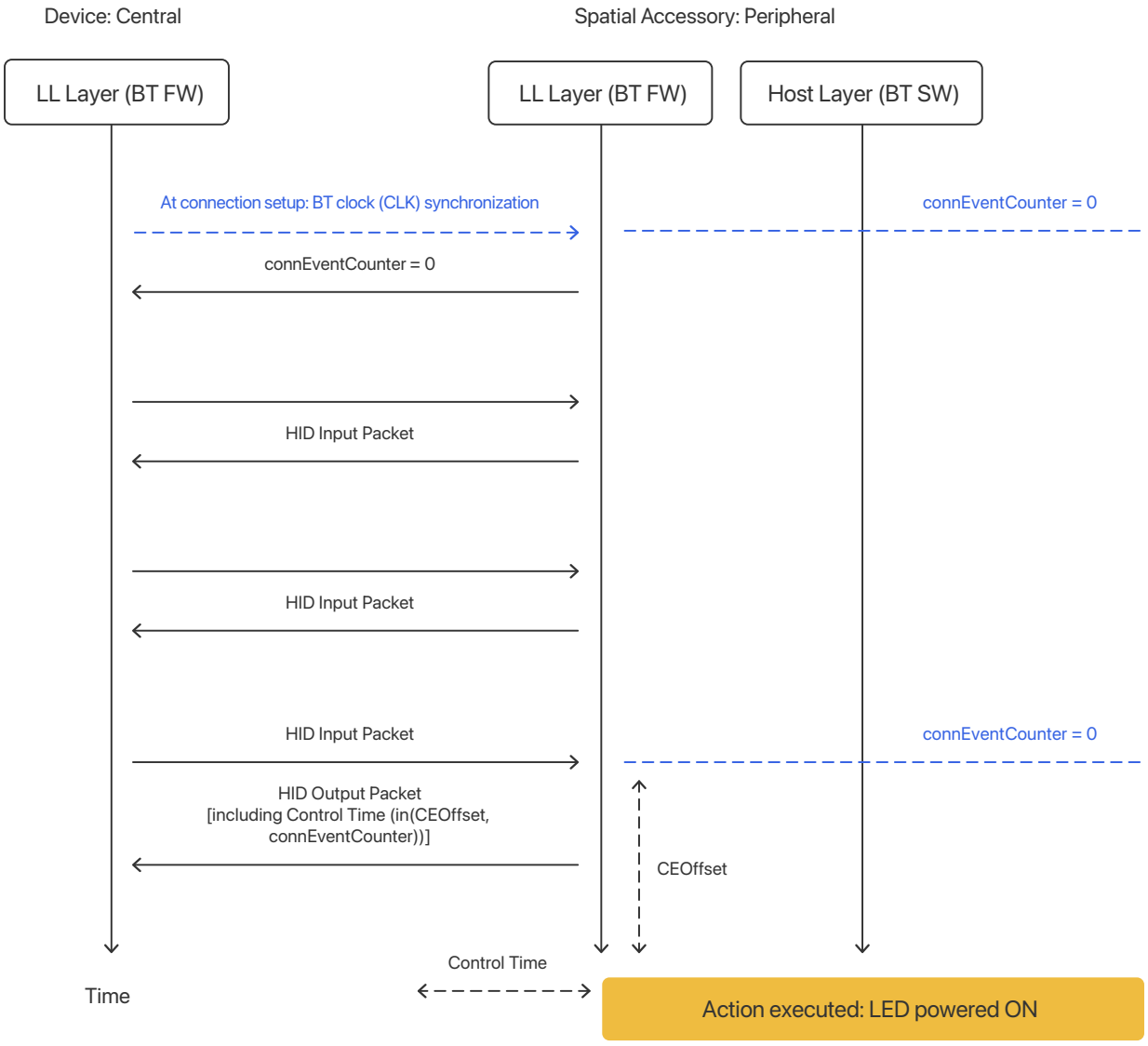
- Connection event counter (`connEventCounter`, 2 bytes).
  - Represents the counter for the connection event from the connection anchor point, as defined by the *Bluetooth Core Specification – Version 5.4*.
  - See 'connEventCounter' in *Bluetooth Core Specification – Version 6.0, Volume 6, Part B, Section 4.5.1*.
- CEOffset (4 bytes).
  - Time offset in microseconds from the anchor point of the provided connection event counter (connEventCounter).
  - Always provided along with a connection event counter.
  - See *Bluetooth Core Specification – Version 6.0, Volume 6, Part B, Section 4.5.4* for the definition of the anchor point.
- Reserved (2 bytes).
  - This value shall be set to `0x0000`.

In the Accessory Tracking Clock, the accuracy of the CEOffset shall be less than 50 µs.

A future agreed time is an Accessory Tracking Clock value defining a future instant. The "Control Time" in the HID packet is an example of a future agreed time, indicating when the LED is powered on. See HID (page 127) for more details.

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Figure 19-4 Accessory Tracking Clock time domain showing connEventCounter and CEOffset, and how a future agreed time is constructed for time-synchronized LED constellation pulses



19.5 IMU

19.5.1 IMU Candidates

The accessory should support a single IMU chosen from the following list of validated IMUs:

Table 19-21 Validated IMU candidates and recommended configuration for the BMI323 and ICM-42686

	Parameter	BMI323 Recommended Configuration	ICM-42686 Recommended Configuration
	Manufacturer	Bosch	TDK
Accelerometer	Number of bits	16	16
Accelerometer	Max g range (±)	16	16
Gyro	Number of bits	16	16
Gyro	Max dps range (±)	2000	2000

19.5.2 IMU Factory Calibration and Lifetime Drift

IMU data shall be factory calibrated, by the vendor, to the following minimum specification, and the calibrated IMU data shall be the data streamed to the device:

- Gyro to accelerometer orientation error < 0.2°.
- Gyro and accelerometer scale error per axis < 0.5%.
- Gyro and accelerometer skewness error (upper triangular formulation) per entry < 0.5%.

IMU Lifetime Drift:

- Gyro to accelerometer orientation error < 0.2°.
- Gyro and accelerometer scale error per axis < 1%.
- Gyro and accelerometer skewness error (upper triangular formulation) per entry < 1%.

IMU Extrinsics to LED:

- IMU Orientation error with respect to LED schematic layout design < 1° (total orientation angle error).
- IMU translation error with respect to LED schematic layout design < 1 mm (per dimension).

See the IMU debugging instructions in Reference Tutorial: Using Debug View to Fine-Tune (page 190).

19.5.3 IMU Sensor Operating Configuration

Regardless of the chosen IMU, the accessory shall:

- Deliver IMU samples to the device at 400 Hz, transmitted using the method in HID (page 127).
- Operate the gyro and accelerometer in high performance combo mode.

The IMU full scale should be Gyro FS = ±2000 dps, Accelerometer FS = ±16 g.

The following part-specific filtering and noise requirements apply to the validated IMUs in Table 19-21 (page 170).

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19.5.3.1 BMI323 IMU Sensor Operating Configuration

- IMU filtering configuration shall have a 2nd order filter with -3 dB of ODR/2 = 200 Hz.
- Noise densities over entire frequency range shall be ≤ 8 mdps/sqrt(Hz) / 60 µg/sqrt(Hz) (one-sided noise density).

19.5.3.2 ICM-42686 IMU Sensor Operating Configuration

- IMU UI filtering configuration shall be a 2nd order filter with 3 dB @ 180 Hz.
- Noise densities over entire frequency range shall be ≤ 5.5 mdps/sqrt(Hz) / 70 µg/sqrt(Hz) (one-sided noise density).

19.5.4 IMU Clocking and BLE Delivery

- IMU ODR maximum frequency error shall be less than ±2%.
- IMU sample timing jitter shall be less than 50 µs in terms of deviation from a fixed ODR clock rate.
- IMU gyro and accelerometer samples shall be delivered through BLE to the device at the sample rate in IMU Sensor Operating Configuration (page 170), batched as described in Multiple Samples (page 129), meeting a packet error rate of less than 1% under ideal operating conditions, and a packet error rate of less than 10% under nominal operating conditions.
- Upon IMU data packet loss, apply the retransmission policy in Retransmission Policy (page 155).

19.5.5 Haptic-IMU Coex

- To ensure high quality accessory tracking performance, minimize the haptic driver coupling to the IMU sensor.
- The haptic driver coupling to IMU could be minimized using proper isolation and haptic driver waveform frequency selection.
- Apple recommends the following test to ensure a good selection of haptic waveform:
  - Record the gyro and accel waveforms RMS level of the accessory when stationary on a table without haptic feedback for one second.
  - Record the gyro and accel waveforms RMS level of the accessory when stationary on a table with haptic feedback for one second.
  - Ensure the RMS level with haptic feedback is less than 10% higher compared to the RMS level without haptic feedback.

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19.6 LED

19.6.1 LED Constellation, Overview

1. Four or more LEDs shall be visible at each viewing angle of interest.
2. The constellation shall have a distinct layout across different viewing angles to avoid ambiguity of the orientation.
3. The ratio of the largest to smallest pairwise inter-LED distance across all LED pairs should be less than 15.
4. Apple recommends having no more than 30 LEDs in total.
5. The developer shall provide 3D LED coordinates, in the frame of Annotated USDZ Asset Format (page 175), with high precision. Sub-millimeter precision is expected to achieve high tracking quality.
6. LED blobs shall appear as uniformly as possible in terms of size and intensity when viewed in Reference Tutorial: Using Debug View to Fine-Tune (page 190) to achieve high tracking quality.
7. LED blobs shall not overlap with each other when viewed in Reference Tutorial: Using Debug View to Fine-Tune (page 190).
8. LED blobs shall be clearly visible in desired operation distance range in Reference Tutorial: Using Debug View to Fine-Tune (page 190).
9. Handheld spatial accessories shall have LED blobs 5–12 mm in diameter as observed in Reference Tutorial: Using Debug View to Fine-Tune (page 190) when the accessory is held at a 0.7 meter distance from the device's cameras.
10. To avoid overlapping, the physical distance between any two constellation LEDs shall be no less than 2 times the LED blob diameter observed in Reference Tutorial: Using Debug View to Fine-Tune (page 190).

The LED Constellation and USD Validation (page 172) tool helps verify the geometric requirements above (LED count, layout distinctness, inter-LED distance ratio, and coordinate precision) when the developer provides both the LED coordinate and the LED normal.

The Reference Tutorial: Using Debug View to Fine-Tune (page 190) tool verifies the visual blob requirements above (four or more visible LEDs per viewing angle, uniformity, non-overlap, visibility, and blob size).

19.6.2 LED Constellation and USD Validation

The Spatial Accessory Command Line Interface Tool shall be used to facilitate the bringup of the accessory. The Validation tool within the Interface can be used to validate the constellation design.

The input to the validation tool is:

- 3D USD asset of the accessory and LED constellation in the required format. Apple recommends including the LED normal information in the USD asset.

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The tool helps to:

- Validate the general format of the provided USD assets and emit warnings.
- Validate the LED constellation for LED placement, visibility, and orientation ambiguity, and emit warnings.
- Estimate the trackable distances from the provided constellation information.

The validation tool provides only an estimate, as LED visibility depends on the hardware design and the LED emission angles.

In addition, the developer shall verify the LED constellation using Reference Tutorial: Using Debug View to Fine-Tune (page 190).

19.6.3 LED Selection

LEDs should meet the following specifications for optimal LED synchronization performance:

- LED angular emission shall be larger than 130° FWHM (Full-Width at Half Maximum).
- Apple recommends an LED light spectrum between 800 nm and 870 nm (infrared).
- When driven, LEDs should meet the following radiance specifications:
  - Greater than or equal to 10 mW Radiant Flux.
  - Greater than or equal to 2 mW/sr.

Sample LEDs with specifications meeting the performance requirements of spatial accessories are shown in the table below.

These specific components are not required in the accessory; alternative solutions should provide greater than or equivalent performance.

Table 19-22 Sample LEDs meeting the radiance specifications for spatial accessory tracking

MFGR Part Number	MFGR	Total Radiant Flux	Radiant Intensity	FWHM	Wavelength
SFH4053	ams OSRAM	10 mW @ 20 mA IF	2.42 mW/sr @ 20 mA IF	140°	850 nm
SML-H15RTT86	ROHM	10.2 mW @ 20 mA IF	2.2 mW/sr @ 20 mA IF	150°	850 nm
HIR17-215C/L289/TR8(LT)	Everlight	10 mW @ 20 mA IF	2.42 mW/sr @ 20 mA IF	140°	850 nm

19.6.4 LED Driver

LED drivers should have the following features for optimal LED synchronization performance:

- Capable of >20 mA current per LED.

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- Direct PWM input pin.
- PWM response time < 50 µs.
- Max PWM switching frequency >20 kHz.
- Hardware and/or software programmable LED current.

LEDs do not need to be individually addressable, so either parallel low-voltage multi-channel LED solutions or series high-voltage single-channel LED solutions are acceptable.

Sample LED drivers providing a feature set to support integration of the Time Sync feature in the accessory are shown in the table below.

These specific parts are not required in the accessory; alternative solutions should provide equivalent features.

Table 19-23 Sample LED drivers supporting Time Sync integration in the accessory

MFGR Part Number	MFGR	Features
LP5569	Texas Instruments	I^2C Programmable LED brightness (PWM and linear) Direct PWM input up to 20 kHz 9x individually controllable LED channels Integrated charge pump can generate up to 4.5 V, or user can provide up to 5.5 V 25.5 mA maximum per channel
LP8557	Texas Instruments	I^2C or resistor programmable Direct PWM input up to 25 kHz Integrated boost converter capable of generating up to 28 V 6x individually controllable LED channels 25 mA maximum per channel
ISL97671A	Renesas	I^2C or resistor programmable Direct PWM input up to 30 kHz Integrated boost converter capable of generating up to 45 V 6x individually controllable LED channels 50 mA maximum per channel
CAT4104	OnSemi	Resistor programmable Direct PWM input up to 50 kHz 4x LED channels tolerant of up to 25 V each 175 mA maximum per channel
MIC2843A	Micrel	Resistor programmable Direct PWM input up to 500 kHz 6x LED channels tolerant of up to 5.5 V each >200 mA maximum per channel

19.6.5 LED Constellation, Time Synchronized Pulse

- LED pulse durations shall be no less than 50 µs and no greater than 2.5 ms.
- LED pulse durations shall be measured from rising edge to falling edge.

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19.7 USD

19.7.1 Annotated USDZ Model

The developer shall provide a Universal Scene Description (USD) 3D model (see https://openusd.org/release/index.html) for the accessory body and constellation. A USD 3D model defines the geometry and material for the accessory and can be exported to USDA or USDZ format. The training tool only takes in the USDZ format. A USDA format model can be converted to USDZ using 3D design tools. Example design tools supporting USDZ include Reality Composer Pro and Blender. When converting a CAD output to USDZ, further annotate the transformations and rotations of interest, particularly the IMU and LEDs.

The USDZ model shall:

- Contain the correct metersPerUnit scale metadata.
- Use upAxis = "Y".
- Use the same coordinate system as the position definition.
- Match the geometry of the accessory.
- Have material and texture defined as follows:
  - The surface shall match the real-world appearance.
  - Texture resolution shall be ≤ 4096 x 4096 pixels and color accurate.
  - Material of accessory body shall be non-reflective and non-transparent.
- LEDs shall be placed at the surface of the accessory, so they are visible in the rendered image. The LEDs may be represented as surface meshes, spheres, or any other geometries as long as the appearance and the location of the geometry is consistent with the form factor surface location from where the LED emits.
- Provide LED coordinates on the surface of the accessory in the corresponding prim following Annotated USDZ Asset Format (page 175).
- Match the appearance of LEDs as observed in Reference Tutorial: Using Debug View to Fine-Tune (page 190).
- Be provided in USDZ format.

This USDZ is used for model training, and the same USDZ file is contained in the resulting .referenceaccessory file. When creating USDZ files, balance visual fidelity with rendering performance. High-quality visual details accurately modeling the real world are important for tracking, but an overly detailed USDZ file can degrade the rendering performance of apps rendering the USDZ file included with the accessory. Reducing the mesh count in the USDZ can improve rendering performance.

19.7.2 Annotated USDZ Asset Format

To retrieve the meta data needed for training, the developer shall provide a USDZ model in an annotated pre-defined structure containing the following information:

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- MetersPerUnit scale.
- Use upAxis = "Y" in the metadata.
- Reference to the spatial accessory body mesh and material.
  - The body specifies the accessory asset without any LED.
- Location, mesh, and material for each LED in the constellation.
  - LED prim names.
    - LED prims shall be "ACCESSORY_LED_([0-9]+)".
    - The prefix is case sensitive; use all capital letters for the prefix.
  - LED location.
    - The transform of each LED with regard to the main USD frame shall be defined directly in the corresponding LED prim.
      - The LED location shall be provided at the perceived accessory surface.
      - The translation part of the transform is mandatory and used for training.
      - (Optional) If provided, the rotation part of the transform is only used for LED requirement verification to estimate LED visibility. The Z-axis of the LED prim will be treated as the LED emission direction in the verification. If all LEDs have the same LED orientation, this information will be ignored.
  - LED Shape.
    - Option 1 LED reference USDZ mesh: The developer can reference a mesh in the LED prim to define the shape of each LED, as follows:
      - 3D mesh in USDZ format with material.
      - The origin of each referenced LED USDZ asset itself shall be the center of the corresponding LED, so the referenced USDZ asset does not contain any transform with regard to the main USD frame.
    - Option 2 Primitive USD shapes to proxy the blobs.
  - Material.
    - The developer shall define realistic material (including emissive color) for the LED.
- IMU transform.
  - The transform from IMU to the USD frame shall be provided in "ACCESSORY_IMU".
  - The developer can refer to the USD documentation at https://openusd.org/release/api/class_usd_geom_xformable.html for all the options to define a transform (for example, an ordered sequence of "xformOp:translate" and "xformOp:rotateXYZ" operations, or the row-major 4x4 "xformOp:transform" directly).
  - The developer can also use a 3D modeling tool (for example, Reality Composer Pro) to create these transforms from the UI.
- Point of interest transforms (for example, those defined for Game Controller Class (page 147)) shall be provided in "ACCESSORY_TRANSFORM_([a-zA-Z0-9]+)".

Apple recommends verifying the correctness of the LED locations and the point of interest transforms in the USDZ by visualizing using both Reality Composer Pro and third-party 3D tools.

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Once the USDZ is ready, the developer can follow the tutorial at https://developer.apple.com/documentation/arkit/preparing-spatial-accessories-for-tracking-in-your-visionos-app to launch training.

Example USDA (extracted from USDZ) file for a spatial accessory: The transforms defined inside a USD prim in this text example are local-to-parent transforms. Apple recommends visualizing and verifying the correctness of transforms in Reality Composer Pro or third-party 3D tools.

```
#usda 1.0
(
    defaultPrim = "accessory"
    metersPerUnit = 0.001  # 1 mm per unit
    upAxis = "Y"  # The USD model shall use upAxis = "Y"
)
def Xform "accessory" {
    def Xform "accessory_body" (references = [@./body.usdz@]) {
    }
    def Xform "led" {
        # Example of one LED formed by a sphere
        # ACCESSORY_LED_([0-9]+) for indicator prim name
        def Sphere "ACCESSORY_LED_0" (
            active = true
            prepend apiSchemas = ["MaterialBindingAPI"]
        )
        {
            rel material:binding = </accessory/led/LED_Material>
            double radius = 4  # mm
            double3 xformOp:translate = (0, -20, 10)
            uniform token[] xformOpOrder = ["xformOp:translate"]
        }
        # Example of one LED formed by referencing a mesh
        # ACCESSORY_LED_([0-9]+) for LED prim name
        def Xform "ACCESSORY_LED_1" ( references = [@led.usda@] )
        {
            double3 xformOp:translate = (0, -20, -10)
            float3 xformOp:rotateXYZ = (0.0, 0.0, 0.0)
            uniform token[] xformOpOrder = ["xformOp:translate", "xformOp:rotateXYZ"]
        }
    }
    # IMU transform
    # ACCESSORY_IMU for prim name
    def Xform "ACCESSORY_IMU" {
        double3 xformOp:translate = (0, -10, 0)
        float3 xformOp:rotateXYZ = (45, 0.0, 0.0)
        uniform token[] xformOpOrder = ["xformOp:translate", "xformOp:rotateXYZ"]
    }
    # Additional transforms (for example, aim, grip)
    # ACCESSORY_TRANSFORM_([a-zA-Z0-9]+)
    def Xform "ACCESSORY_TRANSFORM_aim" {
        double3 xformOp:translate = (0, -50, 0)
        float3 xformOp:rotateXYZ = (0.0, 0.0, 0.0)
        uniform token[] xformOpOrder = ["xformOp:translate", "xformOp:rotateXYZ"]
    }
```

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```
}
```

19.8 Power

This section describes the power management and advertising behavior of the accessory in different usage scenarios.

19.8.1 User Activity

The user activity state shall be tracked whenever the accessory is powered on but not connected to the device. The accessory may continue to track user activity state while connected to the device.

- When the user interacts with the accessory in any of the following ways ("user activity triggers"), the user activity flag shall be set to "active".
  - Pressing or releasing a button.
  - Interacting with another control surface, such as a touch sensor or a proximity sensor.
  - Turning the accessory on (by pressing a power button, toggling a power switch, or by providing an external power source, such as plugging in a USB cable).
  - Connecting an accessory to a power source when the accessory is already powered on.
  - Optionally: When the accessory detects significant movement, for example, by analyzing inertial measurements.
- When the accessory is no longer used (for example, placed aside, no buttons are pressed, and no significant movement is detected), the accessory shall set the user activity flag to "inactive" within 30 seconds.
- When the accessory becomes disconnected from the device, the user activity flag shall be set to "inactive".

19.8.2 Expected Accessory Behavior

- Upon disconnection, accessories shall go into advertising mode rather than powering off or going into a non-advertising, low-power state.
- After the user-activity state becomes "inactive", the accessory shall update the User Activity bit (if advertising) and may reduce its advertising rate.
- If the user-activity state changes back to "active" and the accessory is not already connected to the device, advertisement shall be started (if not already advertising) and the User Activity bit shall be set in the advertising payload within 500 ms of the trigger event.
- After successful reconnection, the time and constellation LEDs shall be synchronized, see Time Sync (page 168).

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- If a battery-powered accessory remains unconnected and the user stops interacting with the accessory, the accessory may power off after an appropriate amount of time in which there is no user interaction, see Disconnection upon Power Off (page 158).
- Spatial accessories shall remain on as long as they are connected to a host.
- Spatial accessories connected to an external power source shall not power off, even if disconnected from the host.
- Battery-powered accessories shall remain on for at least 5 minutes when not connected to a host.
- Spatial accessories not connected to a host shall continue to advertise as long as they remain powered on.

19.8.3 Expected Host-side Behavior

- The device will keep an accessory connected as long as an application is tracking the accessory (as indicated by the app's use of the accessory tracking API).
- After an accessory is no longer in use, the device will keep the accessory connected for some amount of time, depending on the accessory's state and the device's state. If the accessory is externally powered, the device will keep the accessory connected as long as the user keeps wearing the device. If the accessory is battery-powered, the device will keep the accessory connected for the Automatic Disconnection Timeout interval, see Automatic Disconnection Timeout (page 167). Regardless of the power supply state and the requested timeout, the device will disconnect from an accessory about 30 seconds after the user stops wearing the device.

19.9 Examples

The following reference tutorials illustrate how the requirements in the preceding sections can be applied in practice. They are non-normative and document one example design rather than a prescribed set of steps.

19.9.1 Reference Tutorial: MLB Design

A reference MLB design is presented here to assist in rapidly designing and bringing up spatial accessories. This MLB was initially designed for an example reference design described in the following sections.

- Reference Tutorial: Design and Build a Spatial Accessory (page 185).
- Reference Tutorial: Annotated USDZ Generation (page 188).
- Reference Tutorial: Using Debug View to Fine-Tune (page 190).
- Verification (page 197).

Together, this section provides an example pipeline for creating a spatial accessory.

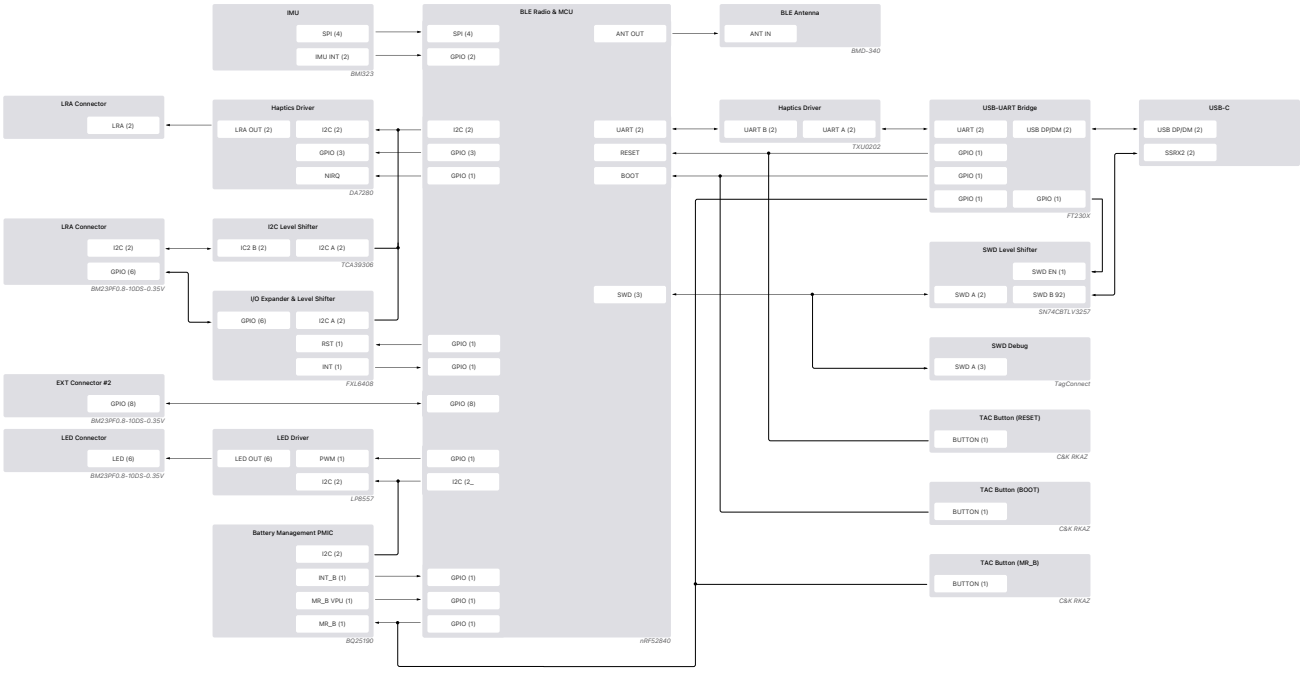
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19.9.1.1 Features

- 3 on-board momentary buttons.
- 1x header with LED power supply and 6x low-side LED driver outputs.
  - LED driver provides up to 28 V and 25 mA per channel.
- 6-axis IMU.
- Haptic LRA driver.
- BLE ≥5.4 radio.
- Generic 3.7 V Li-Ion protection and charger circuit.
- 1x level-shifted header with support for:
  - 6x generic user buttons.
  - 1x I^2C port.
- 1x header with support for:
  - 8x generic I/O.
- Programmable via SWD with onboard 6-pin TagConnect pads.
- UART-over-USB debug port to MCU (NRF52).

The block diagram for this design is below:

Figure 19-5 Reference MLB block diagram showing IMU, BLE radio, LED driver, haptic driver, MCU, PMIC, and supporting circuitry



19.9.1.2 MLB Schematic Design Consideration

This section steps through each page of the MLB schematic and explains the design decisions, considerations, and calculations performed.

19.9.1.3 Haptics

Haptics Driver. The DA7280 from Renesas was chosen as the system haptics driver. Its key features include:

- Storage of up to 6 haptics waveforms.
- 3x GPIO which can directly trigger waveforms.
- Waveform streaming via I^2C or direct PWM input.
- Closed-loop control to improve haptic response.
- Configurable for specific LRAs to prevent over-voltage or over-current.

19.9.1.4 IMU

The following are recommended off-the-shelf IMUs:

- BMI323.
- ICM-42686.

These IMUs have the same footprint and pinout, so only the BMI323 is placed in the schematic.

The IMUs are configured in SPI mode and have 2x INT output pins to relay when accelerometer and gyroscope data are ready.

19.9.1.5 LEDs

LED Driver. The main features driving the selection of the LP8557 LED driver IC from Texas Instruments are:

- Full individual control (PWM and linear) of 6x LED channels.
- Integrated boost converter capable of up to 28 V LED voltage generation.
- Direct PWM input with switching up to 25 kHz.

LED Array. The LED array consists of SFH4053 LEDs from Osram. The main features driving the selection include:

- 850 nm IR LED with a 140° beam angle.
- 70 mA current capability.
- 1.0 mm x 0.5 mm package.

These LEDs are not on the reference design; the LED driver can support driving others.

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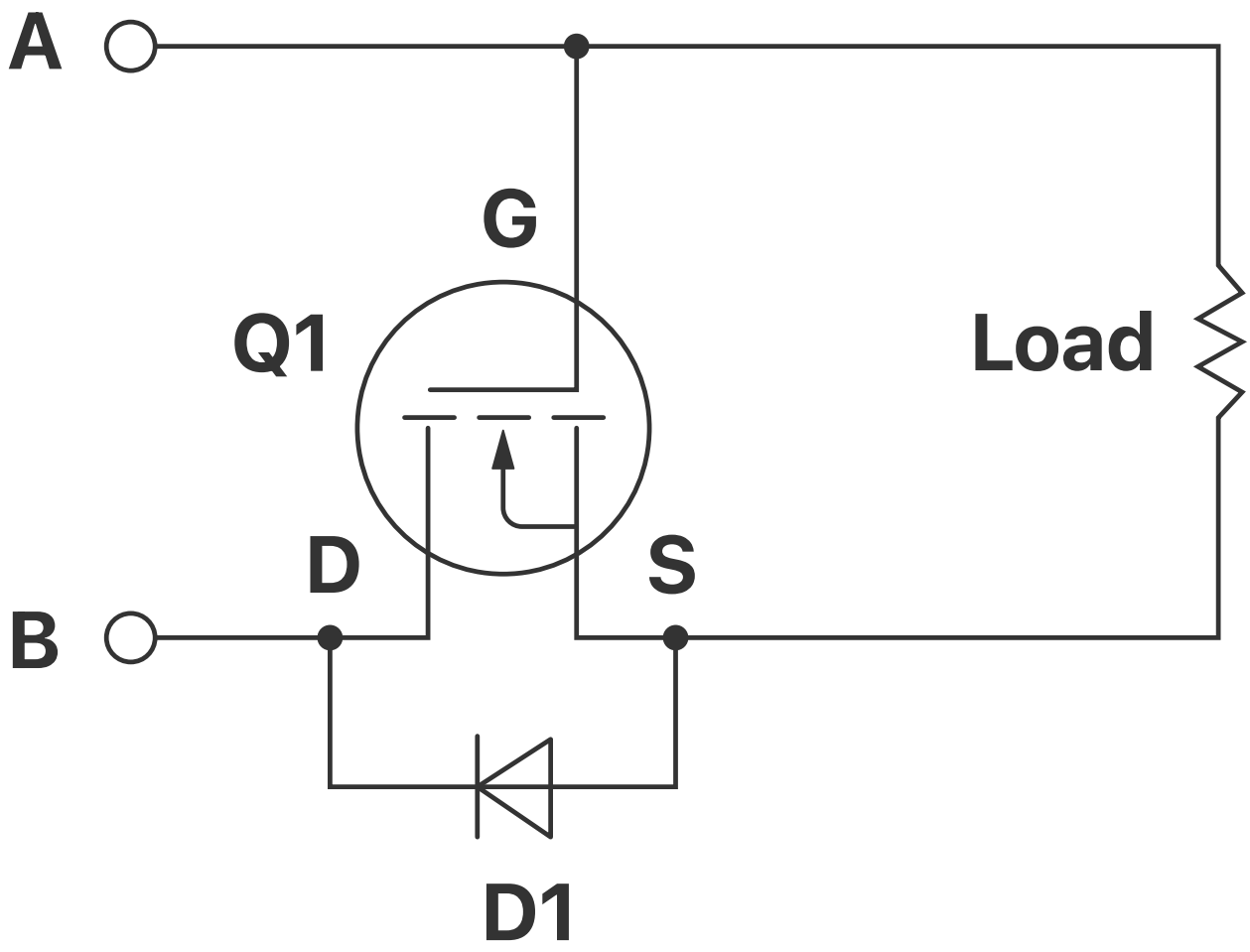
19.9.1.6 Battery and Power Management

The battery management system comprises the following:

- Reverse polarity protection.
- System PMIC.

Reverse Polarity Protection. The entirety of the reverse polarity protection circuit is a TSM250N02DCQ NMOS in the battery negative terminal path with its GATE tied to the battery positive terminal.

Figure 19-6 Reverse polarity protection circuit using a TSM250N02DCQ NMOS in the battery negative terminal path with GATE tied to the battery positive terminal



With a battery voltage from 3.0 V to 4.2 V, this NMOS will only introduce 30–40 mΩ of series resistance.

System PMIC. Both system power rails and battery charging are managed by the BQ25190 from Texas Instruments. The BQ25190 provides the following capabilities:

- Single-cell Li-Ion battery charging and monitoring.

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- I^2C communication.
- Manual reset with system on/off configurability.
- Status LED configurability.
- Integrated buck-boost.
- Integrated buck.
- 2x LDO.

The primary system voltage is 1.8 V and comes from the LDO1 output, which is enabled by default at power on.

19.9.1.7 Debug

This section describes all debug features of the reference PCB.

Indicator LEDs. This section contains a list of visible indicator LEDs and their functions.

Table 19-24 Indicator LEDs on the reference MLB and their functions

Color	Description
BLUE	BLE status indicator. Blinks at different intervals to signify advertising, connected, and powered on but not advertising.
YELLOW	USB/Charger connected indicator
RED	Battery low indicator

In Circuit Serial Programming (ICSP) Interface. The nRF52 provides SWD connections for programming/debugging.

UART-over-USB Bridge. The FT230XH provides a UART-over-USB bridge from the system to the nRF52840 MCU. The FT230X operates at 3.3 V, so level-shifters are included to down-shift 3.3 V to the 1.8 V system voltage. The level-shifters also perform the more important secondary task of blocking active UART connections from the SoCs when there is no VSYS present but USB is connected and the FT230X is powered.

In addition to UART-over-USB, 4x of the spare GPIO pins of the FT230X are connected to pull-down transistors which can be used to:

- Reset the nRF52840.
- GPIO input to the nRF52840.
- Enable SWD over USB level-shifter.
- Manual Reset to the system PMIC.

Resets. The MCU and BLE Radio can be reset by the following sources:

- TAC Button.

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- USB-UART Bridge GPIO.
- SWD Debug connector.

19.9.1.8 AP/SoC MCU

The nRF52840 from Nordic Semiconductor was selected as the Interface SoC for this system for its balance of low-power operation and performance and its abundance of peripherals. The key features driving this selection are listed below.

Wireless Connectivity.

- Bluetooth ≥5.4 support with -95 dBm sensitivity (1 Mbps BLE) and -103 dBm sensitivity (125 kbps long range mode), enabling robust wireless tracking performance.
- Hardware AES/CCM encryption co-processor for secure communication with minimal CPU overhead.

Processing Performance.

- Arm Cortex-M4 processor with FPU running at 64 MHz provides sufficient computational capability for sensor fusion, haptic control, and wireless communication.
- 1 MB flash and 256 kB RAM accommodate application firmware, BLE stack, and runtime data buffers.

Power Efficiency.

- Ultra-low power modes: 0.4 µA in System OFF and 1.5 µA in System ON (wake on RTC) are critical for battery-operated spatial accessories.
- Wide supply voltage range (1.7 V to 5.5 V) with integrated DC/DC and LDO regulators compatible with the 1.8 V system rail.
- Automated peripheral power management extends battery life.

Peripheral Integration.

- High-speed 10 MHz SPI host interfaces the BMI323/ICM-42686 IMU at maximum data rates.
- Multiple I^2C ports connect to the DA7280 haptics driver, LP8557 LED driver, and user I^2C header.
- 48 GPIO pins support the 3x onboard buttons, 6x user button header, and 8x general I/O header.
- Four 4-channel PWM units with EasyDMA can directly drive LED patterns.
- Serial Wire Debug (SWD) enables programming via TagConnect.

Security Features.

- Secure boot, flash ACL, and root-of-trust capabilities protect firmware and user data.
- Essential for products requiring secure pairing and authenticated tracking.

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19.9.2 Reference Tutorial: Design and Build a Spatial Accessory

This section provides an example of the process for how a spatial accessory might be built. Specifically, it shows how one example spatial accessory, a flashlight, was created, validated, and prepared for tracking. This example is intended to serve as an illustration of how the specifications might be applied; these are not prescribed steps which shall be taken in this order to develop a spatial accessory.

19.9.2.1 Design Intent

Since the requirements for spatial accessories are broad and encompassing, a target use case was first identified from which a form factor design was derived. Inspired by general household tools, the example accessory was envisioned as a trackable spatial flashlight able to interact with devices. As designed, it is intended to replicate and enhance the purpose of a flashlight in the virtual space, unlocking immersive experiences like cave explorations where targeted projection of light is desired.

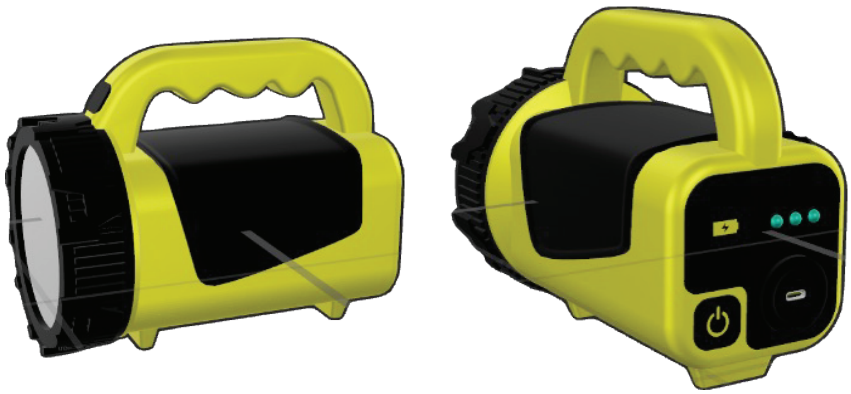
Given the intent to design a flashlight, this accessory includes familiar buttons for power and light control. Since this is a light for virtual space, the buttons are user inputs for the device. The flashlight also features a haptic engine as a user output to improve immersive experiences. The exterior layer is made of an IR-transmissive material to maintain a visually smooth surface finish to the human eye while hiding the constellation of IR LEDs visible to the camera under the shell. The main PCB design was driven by the components needed to support this use case, along with the supporting architecture needed for HID compliance, see HID (page 127). See Reference Tutorial: MLB Design (page 179) for details.

19.9.2.2 Initial Design

Knowing the use case and associated BOM required, the design of the form factor, see Product Design (page 126), started with an ergonomic shell to house the intended components consistent with other design considerations for the use case. Special attention was paid to rigidly mounting the MLB, which housed the IMU, to ensure consistent tracking. This resulted in the form factor shown below.

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Figure 19-7 Example flashlight initial form factor (front and back views)



19.9.2.3 LED Constellation Design

Once the overall geometry was set, the flashlight was configured as a spatial accessory by integrating an LED constellation, enabling a device to track the accessory's position and orientation. Wide field of view IR LEDs were chosen to create this constellation, and the LEDs were placed as close to the exterior IR-transmitting wall as possible to ensure the constellation remains visible across a large range of angles from which the device camera might observe the accessory.

Visual inspection in CAD was used to initially distribute LEDs around the remaining space of the form factor interior for the initial constellation design. The flashlight design was constantly rotated during this process to visually ensure patterns look unique from different viewing angles and distances, consistent with the guidelines provided in LED Constellation, Overview (page 172). Knowing the hand is intended to sit on the handle, LEDs were intentionally left off of the handle since those placements would be easily occluded. The distribution of LEDs, significantly more on the top surface towards the handle and less on the front, back, and bottom, reflected the expectation of how the flashlight would likely be used: most often handheld in front of the user at waist-height. With a first constellation set, the Annotated USDZ Asset Format (page 175) guidelines were followed to convert the initial design file into a USD file for use with the LED Constellation and USD Validation (page 172) tool.

The resulting LED constellation is shown below, where the white patches represent the locations of the LEDs.

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Figure 19-8 Example flashlight final LED constellation after iteration; bright patches indicate LED locations



19.9.2.4 LED Constellation Validation

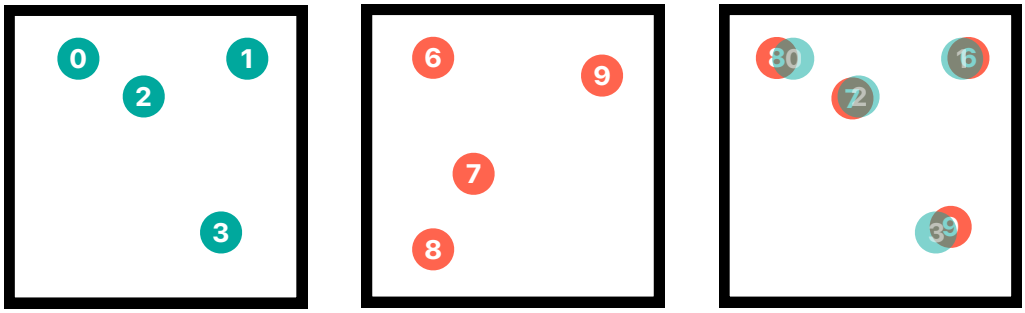
The final flashlight constellation features a total of 25 LEDs. The LED spacing and tilt angle were arranged to ensure they can be seen from all angles and always provide a unique, trackable constellation.

The Command Line Interface (CLI) tool can check whether the LED Constellation, Overview (page 172) requirements are met before training and provides more detailed constellation design recommendations in text format. For example, it may print out "Two or more LEDs are closer than 1 cm. This may reduce tracking robustness.", so the developer can double-check and modify the LED placement.

The tool reads the LED emission direction from each LED prim's orientation, using the prim's local Z-axis as the normal, with which the CLI tool may also compute and print out potential confusion cases to the developer to double-check. For example, for the first pass of the following accessory, the tool printed out the confusion cases between LED group (0, 1, 2, 3) and (6, 7, 8, 9). This means the two viewing angles of the accessory yield very similar constellation patterns, which can cause pose confusion. In these cases, the developer shall modify the design of the indicated LEDs so the LED Constellation, Overview (page 172) requirements are met.

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Figure 19-9 Example accessory with 10 LEDs showing two viewing angles with confusable LED groupings (LEDs 0–3 and 6–9), illustrating a constellation requiring modification to satisfy distinct-layout requirements



Viewing Angle 1 | Viewing Angle 2 | Confusion

19.9.2.5 Material Selection

To hide the IR LEDs and ensure a uniform exterior shell for the flashlight, iterative testing was used to finalize the material for an IR transmissive outer shell. Swatches of yellow materials at different thicknesses were manufactured for use with the device to observe how the chosen IR LEDs looked through each swatch. This tested whether the shell combination was transmissive enough for the LEDs to look visible on the device but did not diffuse the light to an extent causing individual LEDs to merge together. In testing different materials and processes, an IR-transmissive SLA resin was eventually chosen due to its smooth exterior appearance while allowing for IR light to be transmitted.

19.9.2.6 Initial Accessory Build and Training

With the production material identified to help the LEDs remain visible, the flashlight was physically built and components installed. In parallel, the final annotated USDZ was created using information extracted from CAD. Finally, CreateML training was launched to prepare the accessory for tracking.

19.9.3 Reference Tutorial: Annotated USDZ Generation

19.9.3.1 Annotated USDZ Creation

To allow the tracking training tool to correctly learn on the visual features of the accessory, information about the LED constellation shall be specifically conveyed via a single annotated USDZ file. See USD (page 175) for USDZ requirements. At minimum, the annotated USDZ file shall contain the following:

- Color-accurate base surface contour of the accessory with texture.
- Pose-accurate representation of the LED constellation embedded in the accessory.
- Pose-accurate representation of the IMU embedded in the accessory.

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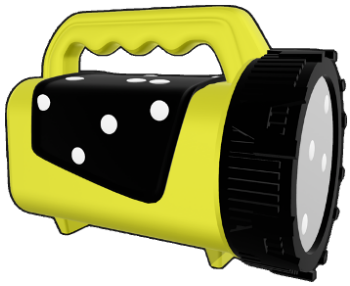
19.9.3.2 Base Contour Representation

The base surface contour shall be representative of the exterior appearance of the form factor, in color, texture, etc. It is derived from design files for the USDZ, and no specific formatting requirements need to be met for its representation.

19.9.3.3 LED Constellation Representation

The points on the accessory surface from which constellation LEDs emit light shall be marked and labeled as specified in Annotated USDZ Asset Format (page 175). These blobs should be created so they resemble the LED blobs of the real spatial accessory, as seen by Reference Tutorial: Using Debug View to Fine-Tune (page 190), as closely as possible with sizes accurate to how the LEDs appear in the developer view. These LEDs can be represented in the annotated USDZ as any primitive shapes, such as spheres or patches represented by meshes. In the example flashlight design, the blob meshes are represented as spheres about 10 mm in diameter.

Figure 19-10 Example flashlight USDZ asset showing LED blob primitives (about 10 mm spheres) at the surface where each LED emits light



The exact coordinates on the surface in the center of each blob, for each LED, shall be determined and defined in the appropriate prim in the USDZ. The training tool uses this information to assign the correct LED designation to each LED blob in the training dataset and later during tracking. Tracking cannot function without this information.

19.9.3.4 IMU Transforms

The IMU pose shall also be specifically notated in the annotated USDZ. This is the location and orientation of the IMU within the accessory, notated to convey the rotation and translation of the IMU frame relative to the USD frame. This pose needs to be represented as accurately as possible using the CAD design and the IMU data sheet. Axis direction and orientation shall be determined and stored according to Annotated USDZ Asset Format (page 175), which may be represented as a 4x4 transform matrix, a chain of translation and rotation, or another supported form.

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19.9.3.5 Optional Annotations

A number of Reference Coordinate Systems (RCS) may be defined to further aid tracking and visualization. When designing form factors like game controllers and styluses, considerate thought about the various RCS present is necessary, and these additional considerations can be similarly notated in Annotated USDZ Asset Format (page 175) to be used by the app later. In addition, the LED emission direction for each LED can also be useful to include. They can help the training tool to evaluate the constellation design.

19.9.3.6 Launching Training

Once the annotated USDZ is created, the accessory is ready to be tracked. More information about this annotated USDZ creation and training process is available at https://developer.apple.com/documentation/arkit/preparing-spatial-accessories-for-tracking-in-your-visionos-app.

19.9.4 Reference Tutorial: Using Debug View to Fine-Tune

ARKit Accessory Tracking Debug View is provided as a tool in visionOS to help developers meet the LED and IMU requirements outlined in the program. This tool enables developers to see a version of the signals the device receives from an accessory. The tool can be found in the Developer section of the visionOS Settings app after putting the visionOS device into developer mode.

19.9.4.1 LED Verification

The tool can be used to help verify the LEDs of the accessory appear as expected to the device's infrared-sensitive cameras. This tool is especially useful to verify accessories built with Infrared LEDs which would be otherwise invisible, but even those built with visible LEDs may look different on the tracking camera due to the camera's unique wavelength sensitivities and exposure time. For example, when LED modulation in a prototype meets the driver and time-synchronization requirements, each LED will appear as a distinct blob in the tool's camera stream viewer. In addition to helping the developer verify the appearance of individual LEDs, the tool is useful for verifying the LED Constellation, Overview (page 172) requirements visually. Also, see the LED Constellation and USD Validation (page 172) tool.

If LED modulation is configured correctly, the LEDs should appear bright and distinct from one another. They should also look distinct from the surrounding surfaces of the accessory and from the background. The illumination from the LEDs should not appear to bleed past the borders of the transmissive material surrounding the LEDs.

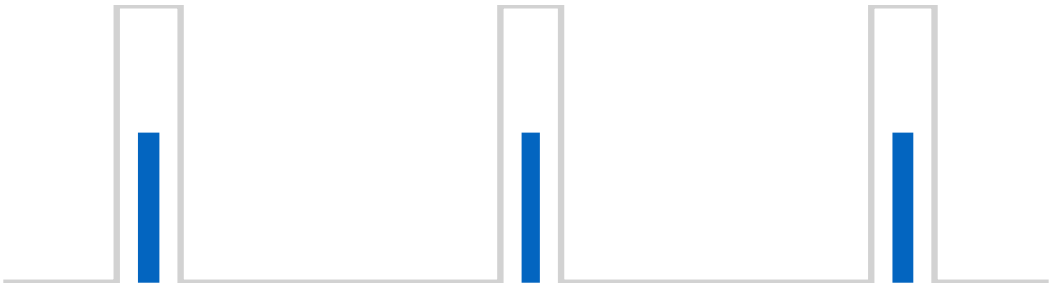
The LEDs should appear illuminated, and they should be clearly distinguishable from each other and from the background:

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Figure 19-11 Device infrared-camera view of an example accessory with well-illuminated, distinguishable LEDs ready for tracking



Figure 19-12 Camera-and-LED timing diagram showing well-synchronized LEDs and cameras: camera exposure periods fully overlap LED emission periods with normal LED brightness



Dark LEDs may indicate an issue with device-to-accessory communication, misconfiguration, or a problem with how the accessory handles LED illumination commands:

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Figure 19-13 Device infrared-camera view of an accessory with all LEDs off, illustrating a failure case where the system cannot track the accessory

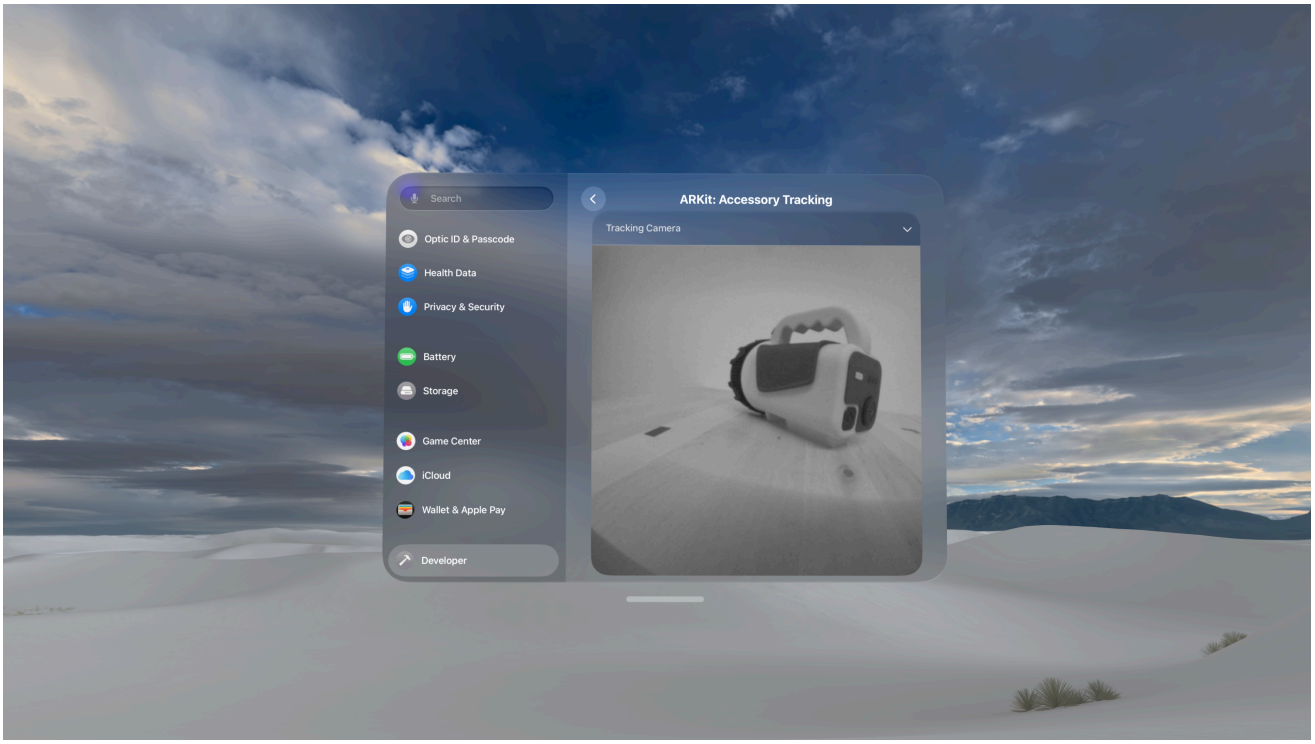
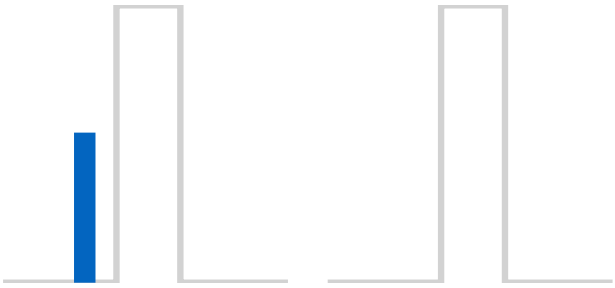


Figure 19-14 Camera-and-LED timing diagrams showing LED synchronization failures: (left) LEDs flash outside the camera exposure period; (right) LEDs do not flash at all



A dim appearance indicates the LEDs are not properly synchronized with the camera's exposure periods, or the LEDs' intensity and/or duration are incorrect:

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Figure 19-15 Device infrared-camera view of an accessory with LED brightness set to minimum, illustrating a failure case where LEDs are too dim to distinguish

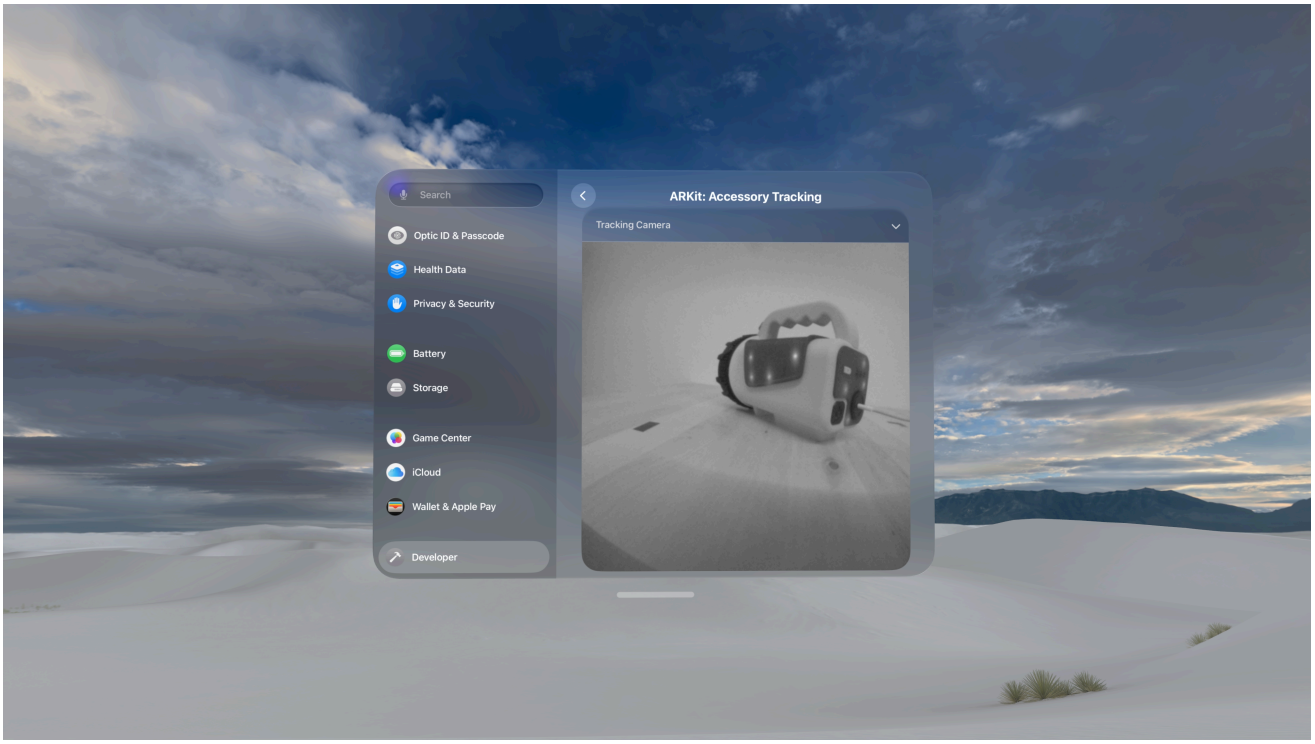


Figure 19-16 Camera-and-LED timing diagrams showing LED dimness failures: (left) LEDs are too dim; (right) LED illumination overlaps only partially with camera exposure



Light bleeding past the edges of the LEDs indicates the LEDs are too bright or are being illuminated for too long:

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Figure 19-17 Device infrared-camera view of an accessory with LED brightness at maximum and constant illumination, illustrating a failure case where LEDs bleed into each other

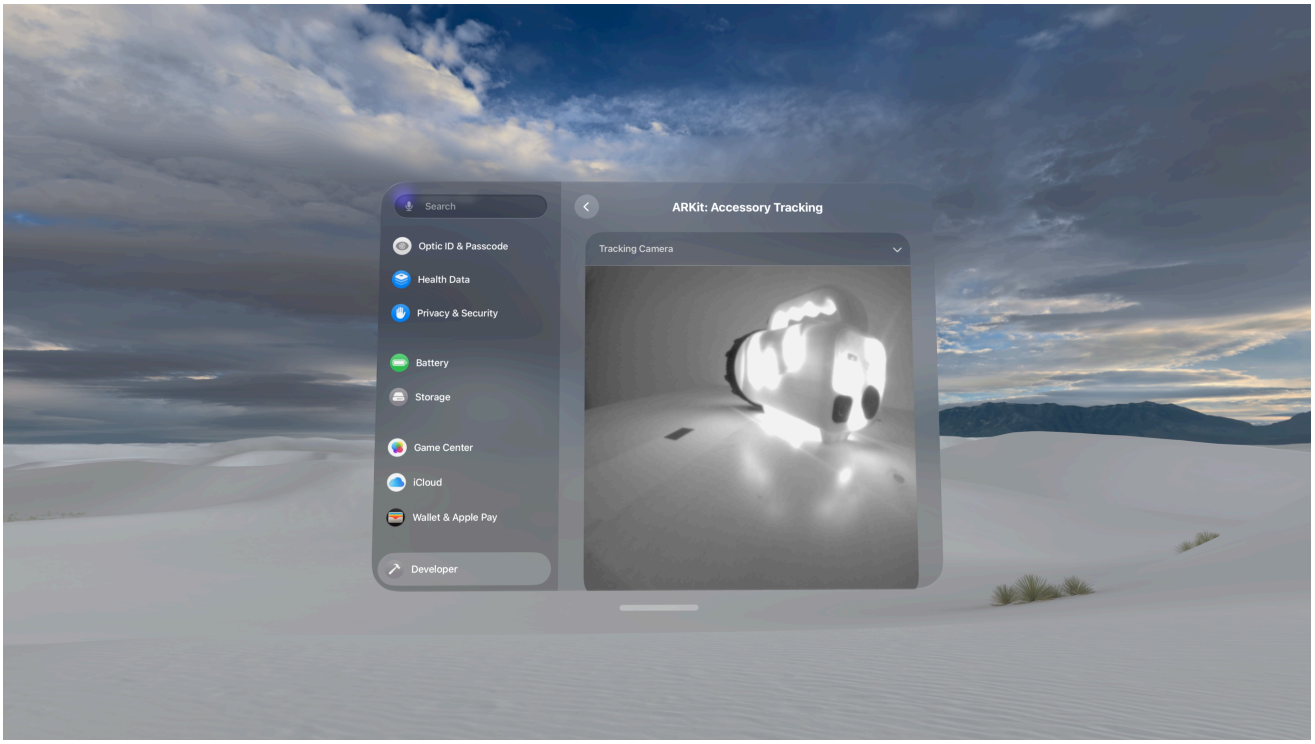
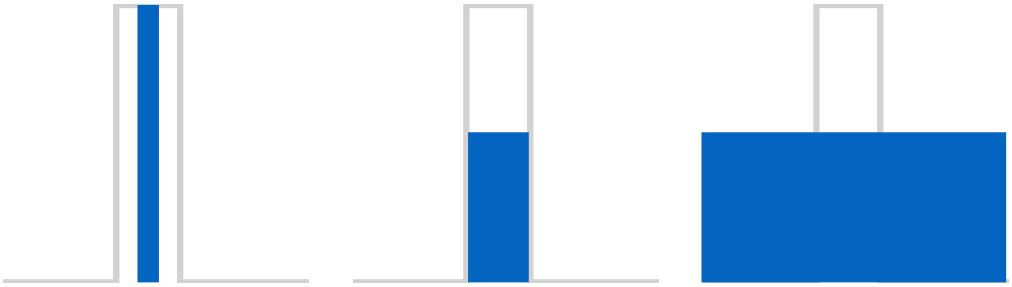


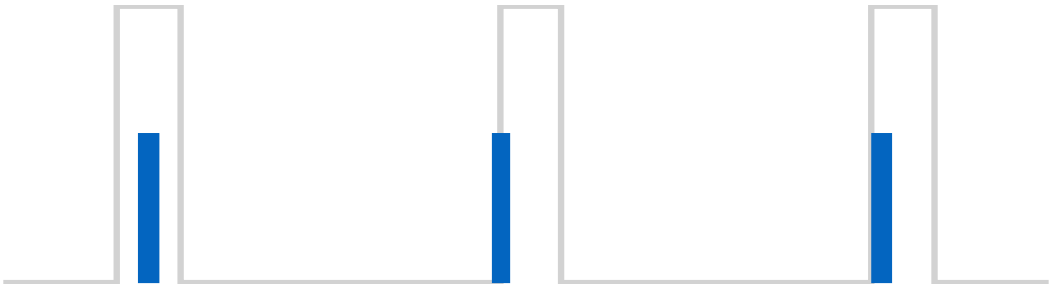
Figure 19-18 Camera-and-LED timing diagrams showing LED brightness/duration failures: LEDs are brighter than expected, with emission overlapping too large a fraction of the camera exposure, and always on rather than blinking



If the LEDs appear to flicker, there may be a problem with time-synchronization between the accessory and the device, or with the accessory's internal LED modulation:

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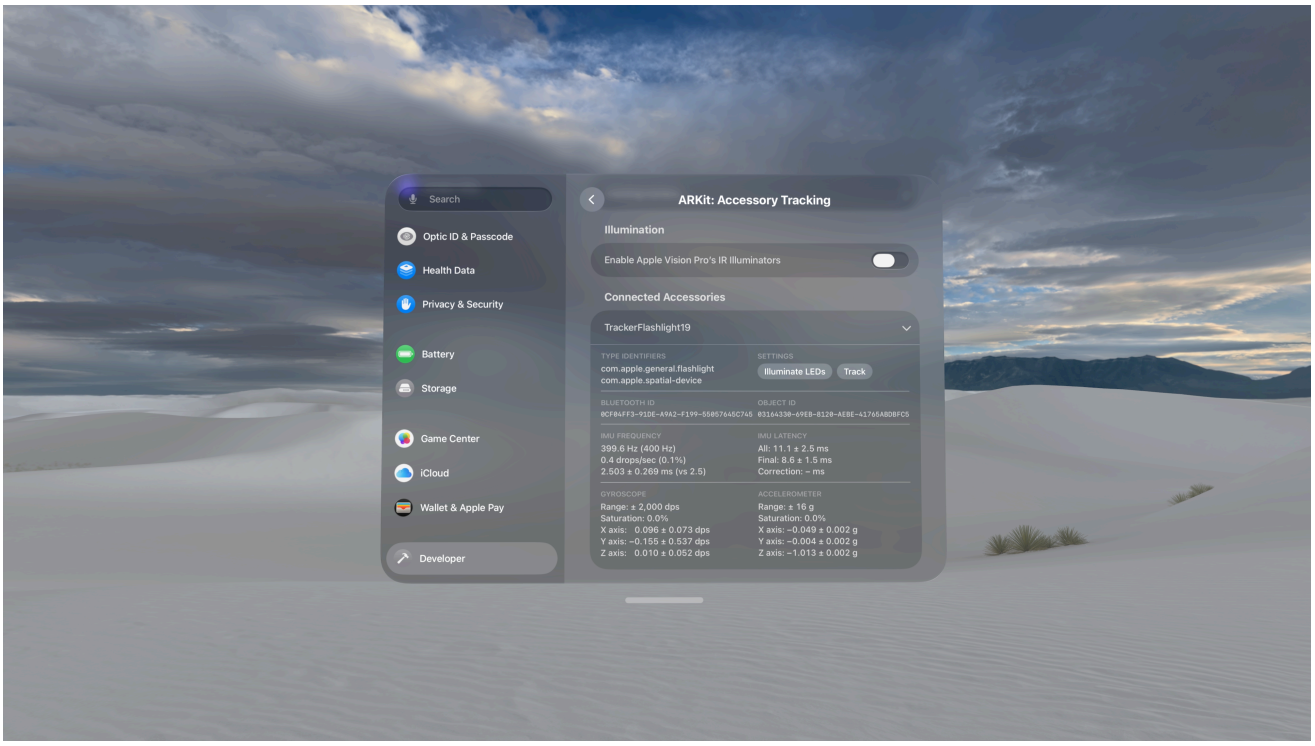
Figure 19-19 Camera-and-LED timing diagram showing LED-camera synchronization drift across three consecutive frames, illustrating a flicker failure mode



19.9.4.2 IMU Verification

The tool can also be used to verify an IMU data stream of a spatial accessory. If a spatial accessory is connected to the device while the tool is active, the tool will provide metrics about the IMU signal, describing signal qualities such as frequency, dropped-sample rate, and latency. The tool will also display average per-axis values, which the developer should inspect in order to verify sensor scale, axis alignment, and response to motion.

Figure 19-20 Screenshot of the ARKit Accessory Tracking Debug View showing the connected accessory's section expanded, with nominal values for frequency, latency, and static sensor readings

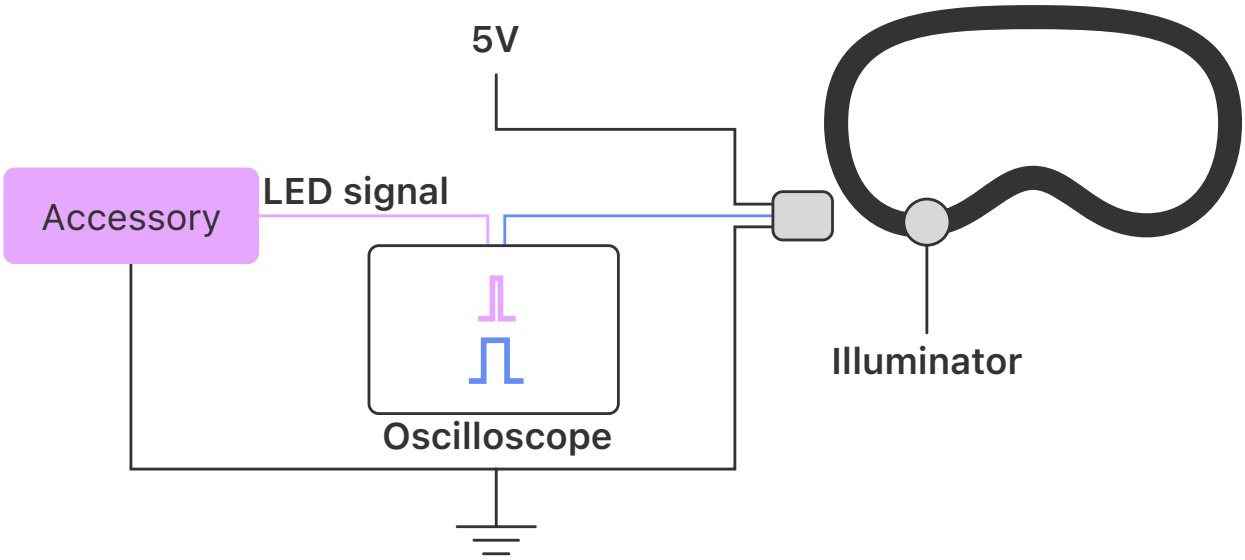


19.9.4.3 Debugging Host-Accessory Synchronization

Additionally, toggling "Enable device's IR Illuminators" will cause the IR illuminators built into the device to flash in sync with the device's cameras. The IR illuminators will flash each time the camera captures an image, and the center of this pulse will occur at the same time as the middle of the camera's exposure period.

This can be a useful signal for development. Below is an image showing a photodetector placed near the IR illuminators of a device to capture this debug signal:

Figure 19-21 OPL820 photodetector placed near the IR illuminators of a device to capture the IR illuminator debug signal

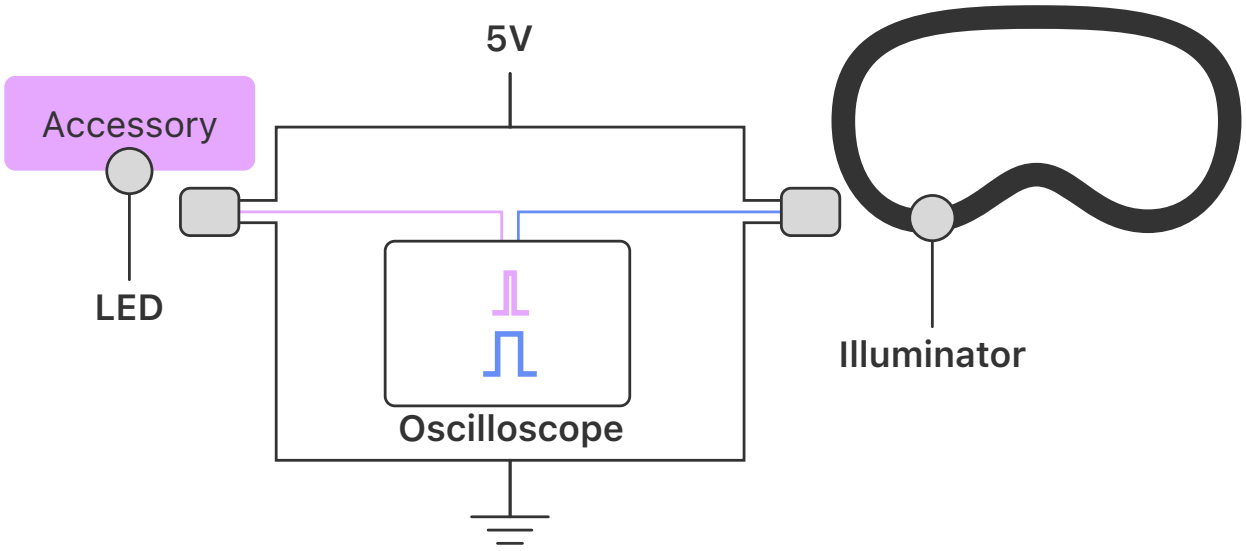


The developer may wish to capture this signal and compare its timing vs. the accessory's LED-control activity.

Similarly, using two photodiodes and an oscilloscope, the developer could measure the precise frequency and time transform between the LED modulation of the accessory and the middle of the tracking camera's exposure periods.

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Figure 19-22 Two-photodiode oscilloscope setup measuring the frequency and time transform between the accessory's LED modulation and the tracking camera's exposure periods



When the device's "Illuminate LEDs" toggle is enabled, each flash of the LEDs should coincide with a flash of the device's IR illuminator. The middle of the LED flash should occur at the same time as the middle of the IR illuminators' flash.

19.10 Verification

This section outlines the procedure to verify the functionality and performance of a spatial accessory used with a device. A spatial accessory can accommodate a variety of form factors and can support a variety of user inputs and usage scenarios.

The procedure assumes the spatial accessory complies with the necessary hardware specifications and adheres to the software-communication protocols as defined in this chapter.

19.10.1 Equipment

- Spatial accessory conforming to hardware specifications.
- Apple Vision Pro running visionOS 27.2.
- ARKit Accessory Tracking Debug View. See Reference Tutorial: Using Debug View to Fine-Tune (page 190).
- Sample Code, see https://developer.apple.com/documentation/visionOS/working-with-generic-spatial-accessories.

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- Test environment with dynamic lighting conditions.

19.10.2 Procedure

19.10.2.1 BLE Pairing and Connectivity

1. Open the Settings app on the device and select the Bluetooth tab.
2. Verify the accessory can be made discoverable and shows up in Available devices.
3. Select the accessory and verify it pairs and displays as Connected.
4. Verify the accessory shows up in the list of connected devices.
5. Power off the accessory, then power it on again. Verify the accessory reconnects automatically and shows as Connected.
6. Wait at least 60 s. Verify the accessory is still registered as connected to the device.

19.10.2.2 Visual Inspection of LEDs

1. Inspect the accessory's LEDs and verify they are clean and clear of scratches and cracks.
2. Move the accessory through its expected range of motion and verify the LEDs are securely fastened in place and do not move from their position.

19.10.2.3 LED Alignment and Position

1. Verify the LEDs satisfy the minimum-distance and constellation requirements. See LED Constellation, Overview (page 172).
2. Launch ARKit Accessory Tracking Debug View. See Reference Tutorial: Using Debug View to Fine-Tune (page 190).
3. Verify the LED blobs are clear, contrasted from the rest of the body, and do not overlap.
4. Move the accessory through expected grip positions and verify at least four LEDs are visible at any given angle.

19.10.2.4 Functional LED Testing

1. Launch ARKit Accessory Tracking Debug View. See Reference Tutorial: Using Debug View to Fine-Tune (page 190).
2. With time synchronization disabled (if possible), power on the accessory's LEDs. Verify the LED requirements are met. See LED Constellation, Overview (page 172).
3. With time synchronization enabled, power on the accessory's LEDs. Verify the LED requirements are met while the LEDs are synchronized with the device's cameras. See LED Constellation, Overview (page 172).

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4. Verify the LEDs are continuously on and do not flicker. If the LEDs fail to maintain a consistent level of luminance, see Reference Tutorial: Using Debug View to Fine-Tune (page 190) for debugging guidance.
5. Verify the LEDs have similar brightness levels.
6. Place the accessory under each of the lighting conditions in which it is expected to be used (bright, dim, multi-color environments). Verify the LEDs remain consistently visible in each.

19.10.2.5 Tracking Quality

1. Launch the Sample Code Project app on the device.
2. Verify the accessory tracks at all appropriate times while in the field of view (FoV) of the device.
3. Hold the accessory at various angles, in either hand (left, right, both), and place it static on a surface (such as a desk or couch). Verify the accessory does not lose tracking.
4. Move the accessory through different motion conditions (gentle, complex, slow, fast). Verify the accessory does not lose tracking and exhibits no perceptible lag.
5. Make contact with another accessory or object during motion. Verify the accessory does not lose tracking.
6. Place the accessory under different lighting conditions in the range 10 lx to 9000 lx (low, nominal, bright). Verify the accessory does not lose tracking.
7. Move the accessory to the edge of the FoV and partially truncate it. Verify the accessory does not lose tracking.
8. Move the accessory out of the FoV and back in. Verify the accessory regains tracking promptly.
9. Occlude the accessory with hands or other surrounding accessories so at least four LED blobs remain visible. Verify the accessory does not lose tracking.
10. Hold the accessory static and verify the visible anchor does not jitter. Toggle the visible anchor locations in the Sample Code Project.
11. Trigger haptics feedback. Verify the visible anchor remains stable.
12. Verify the accessory transforms properly correspond to the expected points on the accessory; toggle the visible anchor locations in the Sample Code Project to help verify device translation and orientation.
13. Handheld accessories: hold in each hand individually and verify the proper gripping hand is identified in the Sample Code Project.

19.10.2.6 User Interaction

1. Launch the Sample Code Project app.
2. Test all input buttons or controls by using them in the Sample Code Project (clicking, pressing, squeezing, tapping, navigating left, right, up, and down).
3. Verify the inputs are registered correctly and consistently without significant delay or mis-detection.
4. Perform complex input actions such as double-clicks or long-presses. Verify these actions work as expected in appropriate scenarios.

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5. Power off the accessory, then power it on again. Verify the inputs are still properly registered.
6. Accessories with touch-sensitive areas or gesture-based inputs: test swipe and tap gestures. Verify the gestures are detected and lead to the correct output (page scroll, zoom, back gesture).
7. Accessories with haptics feedback: trigger each haptics waveform. Verify the accessory provides the expected haptics feedback.

19.10.2.7 IMU Testing

1. Launch ARKit Accessory Tracking Debug View. See Reference Tutorial: Using Debug View to Fine-Tune (page 190).
2. Inspect the IMU information displayed in the debug viewer (delay, IMU noise, IMU rates).
3. Verify the IMU is correctly configured and its data processed as expected. See IMU (page 169) for the authoritative IMU requirements.

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20. Watch Bands

A well-designed watch band will securely attach to Apple Watch without interfering with Apple Watch operation. See Dimensional Drawings (page 18) for Apple Watch keep-out zones.

20.1 Requirements

Watch bands for Apple Watch shall integrate two lugs to mate with the watch band interface, see:

- Apple Watch Band Interface (49 mm) (page 205)
- Apple Watch Band Interface (42 mm & 46 mm) (page 206)
- Apple Watch Band Interface (41 mm & 45 mm) (page 207)
- Apple Watch Band Interface (40 mm & 44 mm) (page 208)

Apple Watch uses a high precision interface profile, see https://developer.apple.com/accessories/apple-watch-lug-profile.zip for a sample 2D lug profile. Lugs should lock into the watch band mating slot with a 'lug latch' feature to prevent accidental removal of the watch band.

Exposed edges of watch bands and lugs shall pass *UL 1439, Tests for Sharpness of Edges on Equipment* and *BS EN 71-1:2014, Safety of toys—Part 1: Mechanical and physical properties*.

The lug latch shall never become jammed in the extended position.

Watch bands shall not integrate magnetic chargers.

Watch bands and lugs should:

- Pass a 72-hour salt mist test as specified in *ASTM B117* with no visible corrosion.
- Resist a 5–20 kgf lateral slide-out force when installed in Apple Watch.
- Resist a 20 kgf or greater pull force as specified in *ISO 6425:2018, Divers' watches – Section 4.9*.
- Detach easily from Apple Watch when the watch band release buttons are pressed.
- Take into account the weight of Apple Watch.

Watch bands shall enable the user to maintain direct skin contact with Apple Watch heart sensors and the back of Apple Watch, and shall incorporate sufficient margin to compensate for shifting or dimensional changes of the watch band material. Failure to do so may interfere with Apple Watch wrist detect and Apple Pay features. Watch bands should:

- Have length sizing adjustment pitch of less than 7 mm (center to center).

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- Provide sufficient adjustability for the user to achieve a snug, yet comfortable fit preventing movement of Apple Watch relative to the wearer's skin.

Watch bands intended for use during exercise should maintain a snug fit through a full range of motion to maintain compatibility with Apple Watch heart sensors.

Apple recommends the following materials for lug bodies:

- 75 Shore A silicone.
- 50%–55% glass-filled nylon.
- 240–270 HV 316L / EN 1.4435 stainless steel.

Apple recommends the following materials for lug latches:

- 50%–55% glass-filled nylon.
- 240–270 HV 316L / EN 1.4435 stainless steel.

Watch bands for Apple Watch shall comply with applicable environmental regulations for the regions in which the watch bands are to be sold, and any applicable substance or material restrictions, including applicable restrictions on:

- Organic tin compounds, PFOS, PFOA, phthalates, azo dyes, polybrominated biphenyls (PBBs) and PAHs, per requirements of the EU REACh regulation EC 1907/2006.
- Nickel leach rate on surfaces in prolonged skin contact, per requirements of the EU REACh regulation EC 1907/2006.
- Cadmium, lead, hexavalent chromium, and nickel, per requirements of EU Directive 2009/48/EC.
- Natural rubber latex, per requirements of EU Directive EC 93/42/EEC.
- Dimethylfumarate (DMFu), per requirements of EU Regulation 412/2012.
- pH and Formaldehyde, per requirements of China GB 18401 for textiles and China GB 20400 for leather.
- Endangered species of flora and fauna in products or packaging (US Lacey Act).
- Polybrominated diphenyl ethers (PBDE).

20.2 Example Apple Watch Lug Assembly

Assembly instructions are based on an assembly fixture with a clamping mechanism and example watch bands:

- Example Apple Watch Lug (49 mm) (page 209)
- Example Apple Watch Lug (42 mm & 46 mm) (page 210)
- Example Apple Watch Lug (41 mm & 45 mm) (page 211)
- Example Apple Watch Lug (40 mm & 44 mm) (page 212)

Proper assembly of the lug is critical to ensure the watch band securely attaches to Apple Watch. Improper assembly may result in damage to Apple Watch and/or the watch band.

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Screw threads should be secured with Loctite 435. Previously installed/used screws should not be reused.

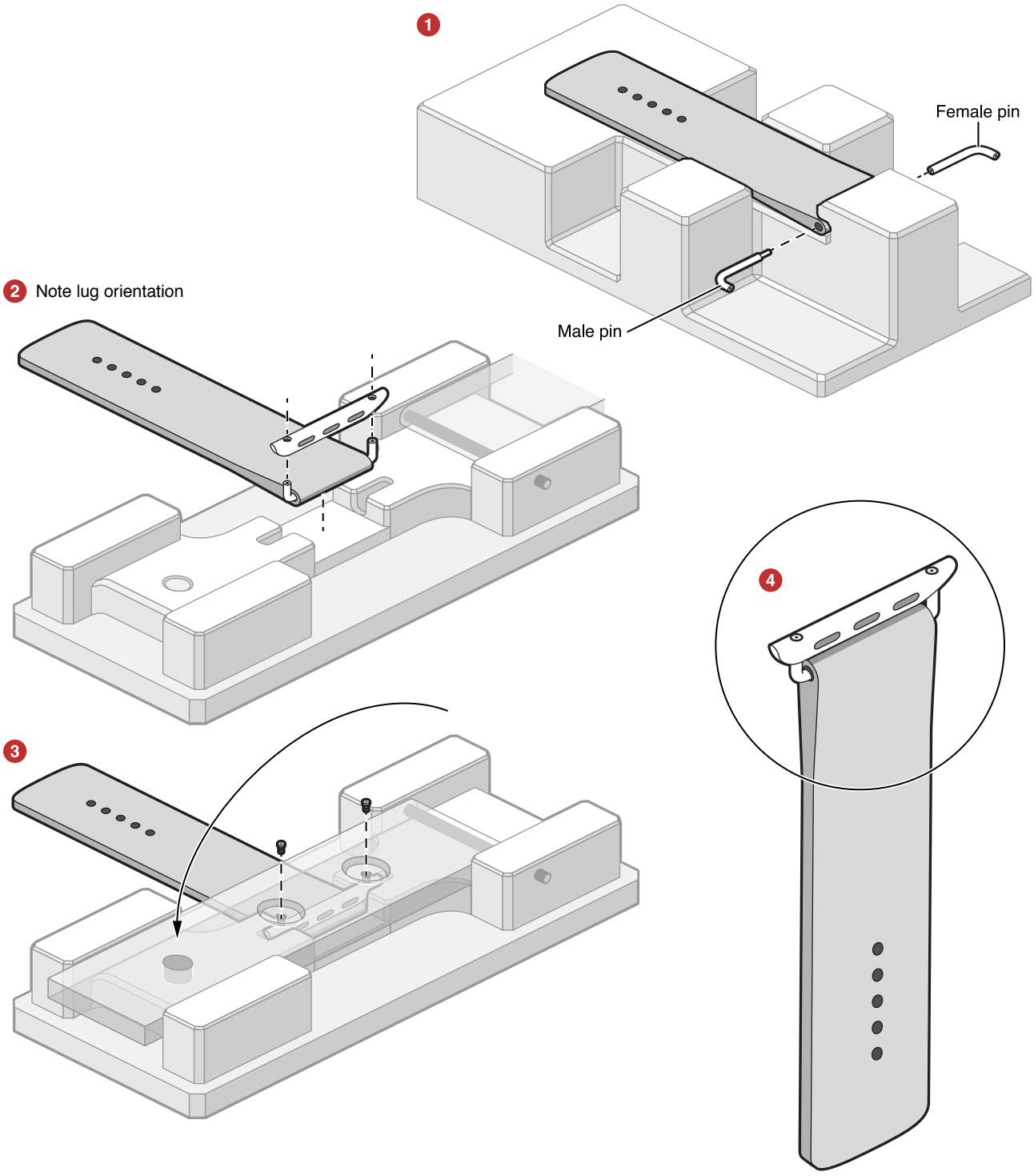
The assembly fixture should hold the lug assembly in place and a clamping mechanism should compress the lug during screw insertion.

Assemble the watch band and lug as follows, see Figure 20-1 (page 204).

1. Lightly insert the long end of the female pin in the watch band until hard stop. Ensure there is no warping or damage in the watch band.
2. Lightly insert the long end of the male pin in the other side of the band until it interlocks with the female pin and both pins are seated together. Ensure there is no warping or damage in the watch band.
3. Align the holes on the bottom of the lug with the exposed ends of the female and male pins. Note lug latch top/bottom orientation relative to the watch band. Latch shall be on the side of the watch band against the wrist.
4. Apply Loctite 435 to screw threads.
5. Install both screws using the following specification:
   - Torque: 1.1 kgf-cm ±10%
   - RPM: 120 ±10%
6. Visually inspect at 1200–1400 lx for screw proudness and cross-threading.
7. Ensure screws are just sub-flush to the lowest part of the counterbore and appear parallel to the long axis of the lug.
8. Ensure screws are undamaged, flat, and concentric with the counterbore.

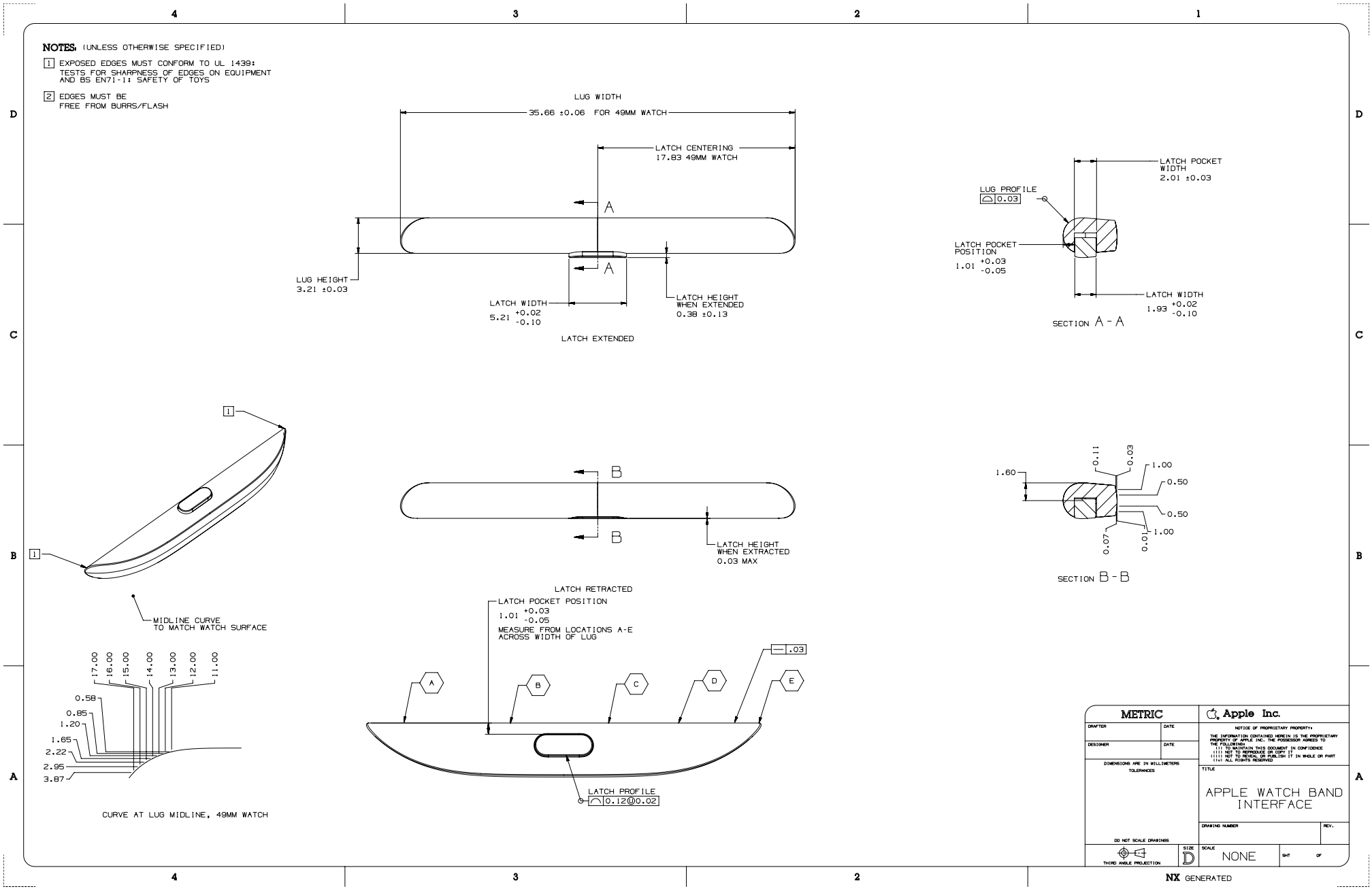
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Figure 20-1 Apple Watch lug assembly fixture



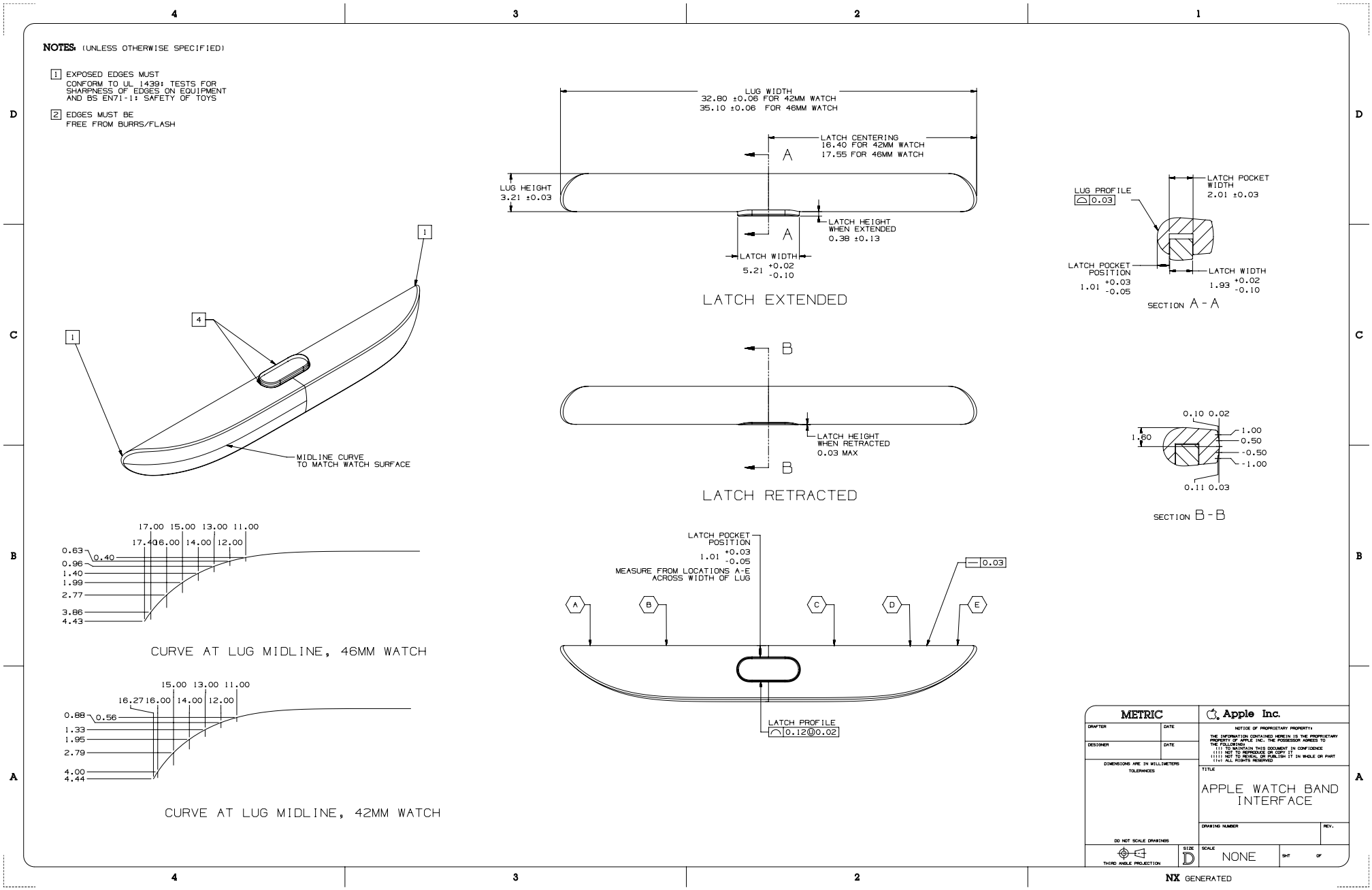
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20.3 Apple Watch Band Interface (49 mm)



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20.4 Apple Watch Band Interface (42 mm & 46 mm)

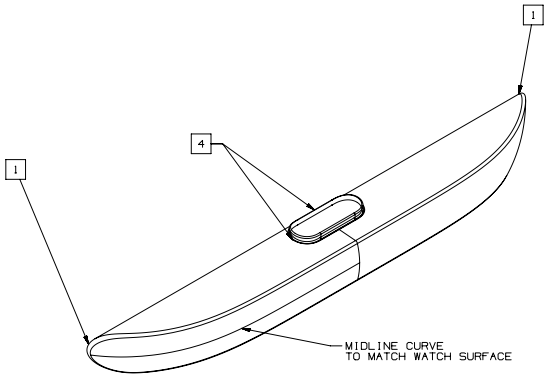


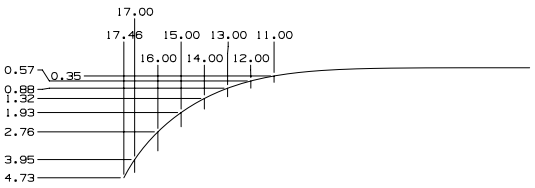
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20.5 Apple Watch Band Interface (41 mm & 45 mm)

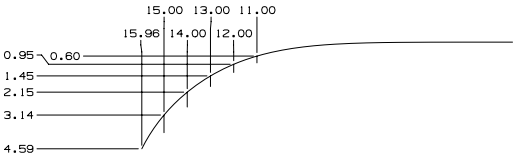
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1. EXPOSED EDGES MUST CONFORM TO UL 1439: TESTS FOR SHARPNESS OF EDGES ON EQUIPMENT AND BS EN71-1: SAFETY OF TOYS
2. EDGES MUST BE FREE FROM BURRS/FLASH

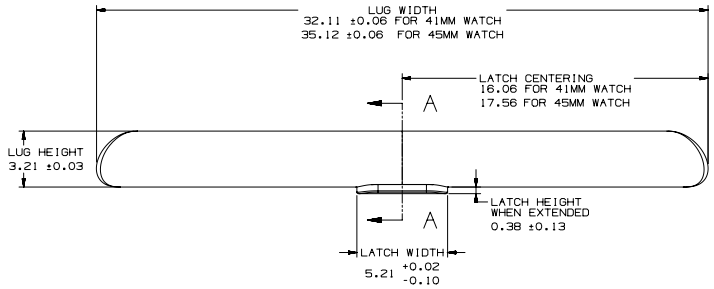




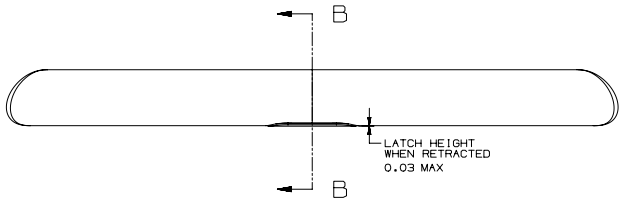
CURVE AT LUG MIDLINE, 45MM WATCH



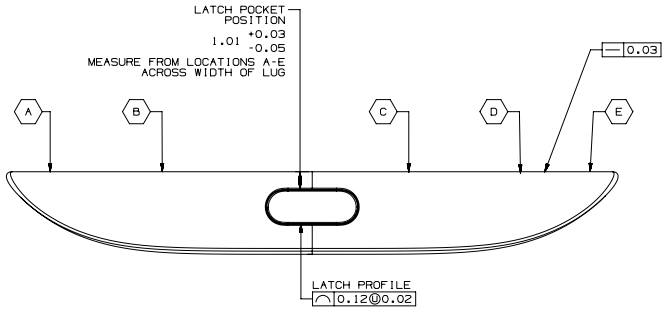
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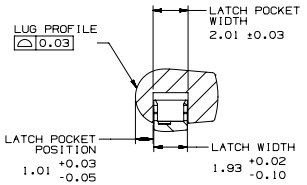


LATCH EXTENDED

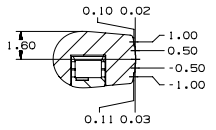


LATCH RETRACTED





SECTION A - A



SECTION B - B

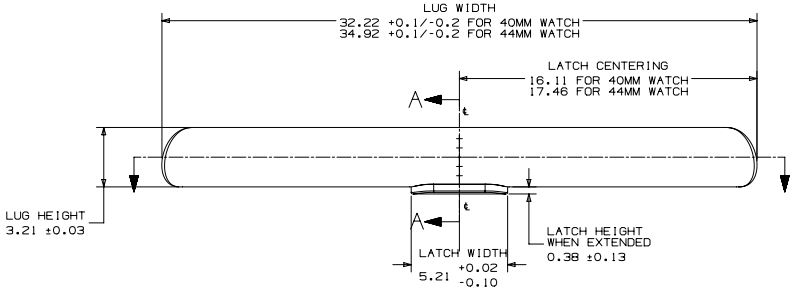
METRIC	Apple Inc.
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DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION	SIZE D / SCALE NONE / SHT / OF

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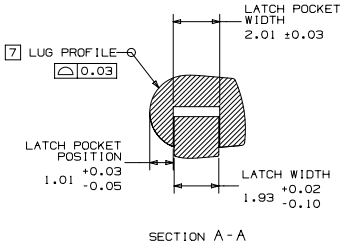
20.6 Apple Watch Band Interface (40 mm & 44 mm)

NOTES:

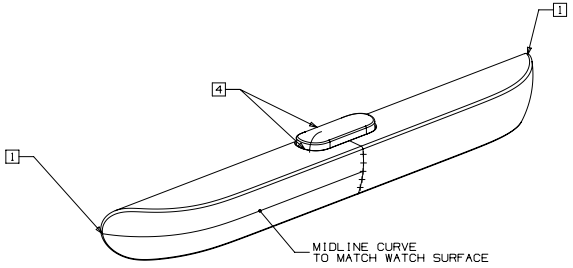
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2. EDGES MUST BE FREE FROM BURRS/FLASH

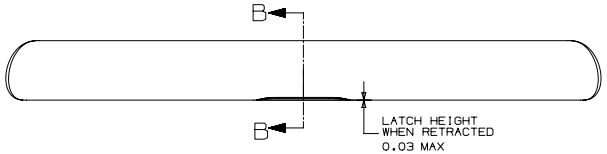


LATCH EXTENDED

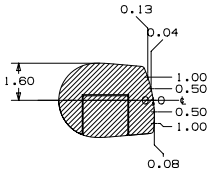


SECTION A-A

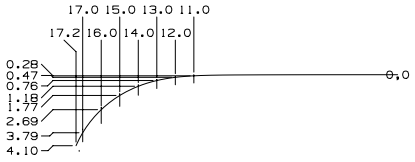




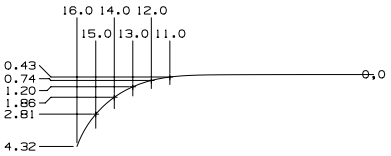
LATCH RETRACTED



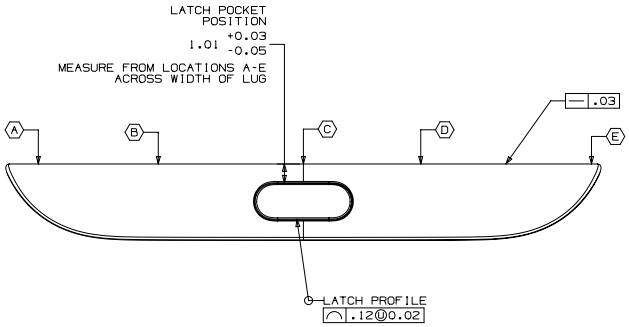
SECTION B-B



CURVE AT LUG MIDLINE, 44MM WATCH



CURVE AT LUG MIDLINE, 40MM WATCH



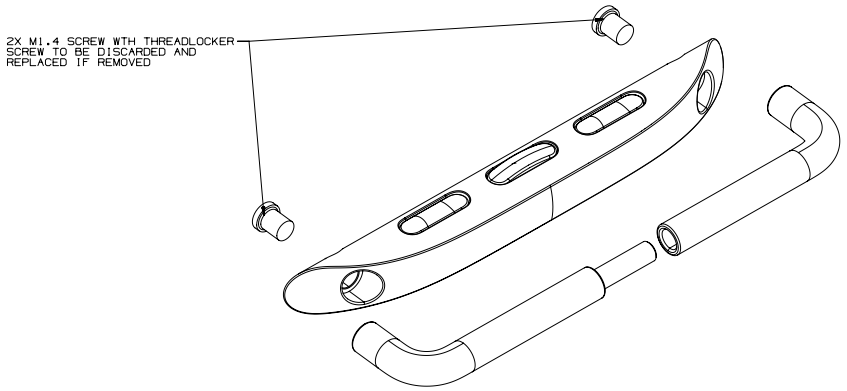
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DESIGNER / DATE	
DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE: APPLE WATCH BAND INTERFACE
DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION / SIZE D	SCALE: NONE / SHT / OF

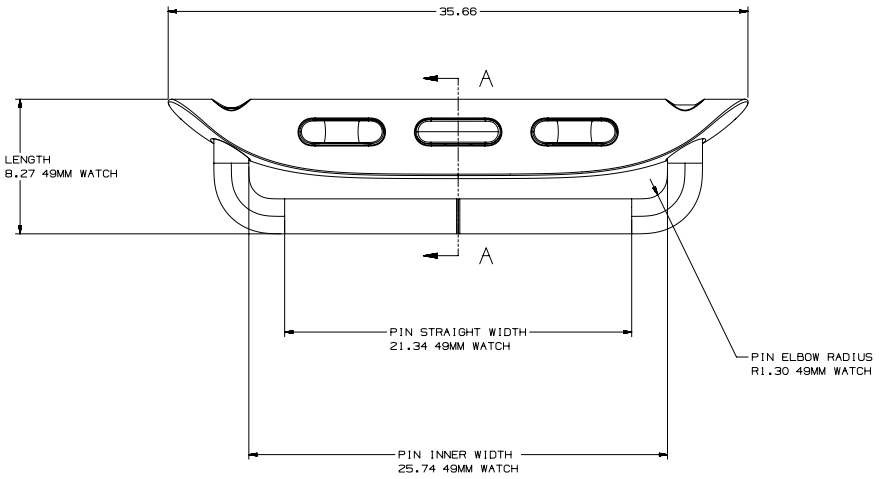
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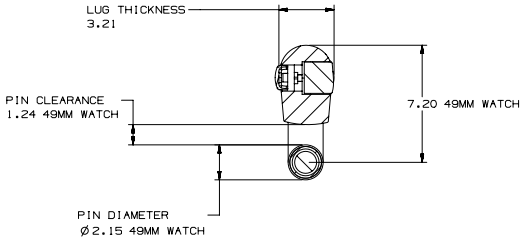
20.7 Example Apple Watch Lug (49 mm)

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. EXPOSED EDGES MUST CONFORM TO UL 1439: TESTS FOR SHARPNESS OF EDGES ON EQUIPMENT AND BS EN71-1: SAFETY OF TOYS







SECTION A - A

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DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE: APPLE WATCH LUG
DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION	SIZE D / SCALE NONE / SHT / OF

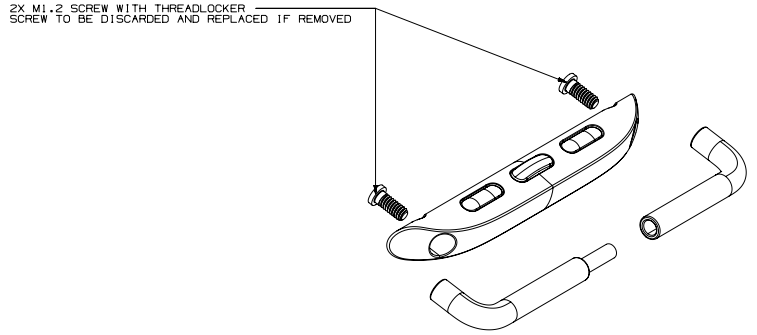
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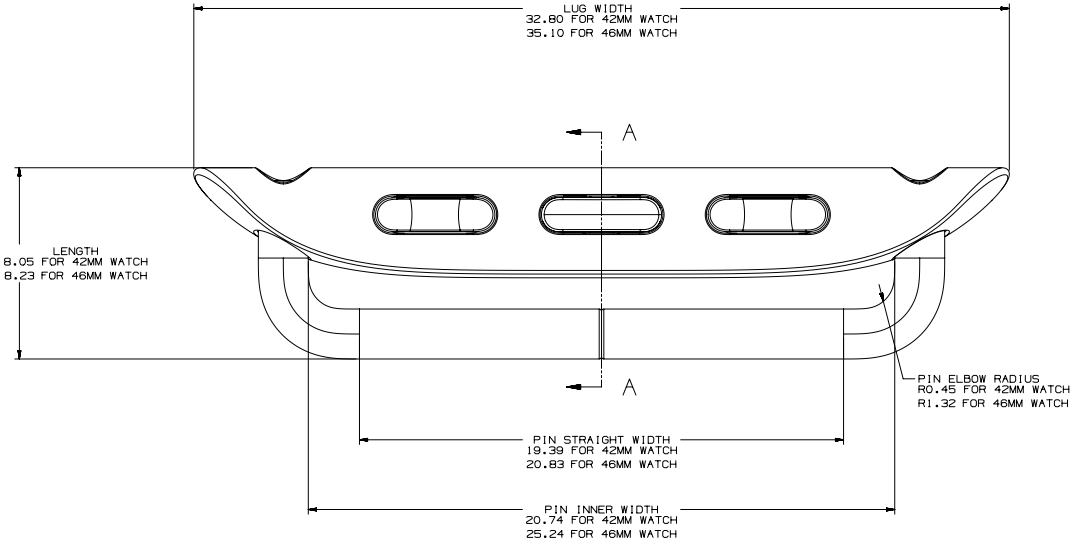
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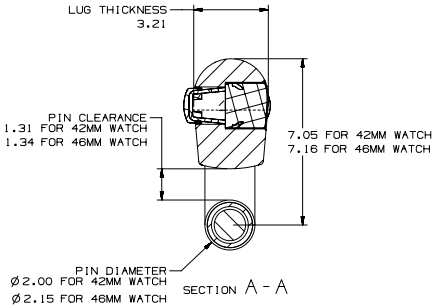
20.8 Example Apple Watch Lug (42 mm & 46 mm)

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. EXPOSED EDGES MUST CONFORM TO UL 1439: TESTS FOR SHARPNESS OF EDGES ON EQUIPMENT AND BS EN71-1: SAFETY OF TOYS







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DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE: APPLE WATCH LUG
DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION	SIZE D / SCALE NONE / SHT / OF

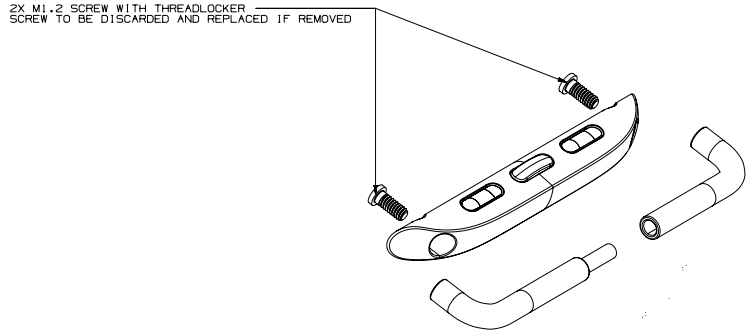
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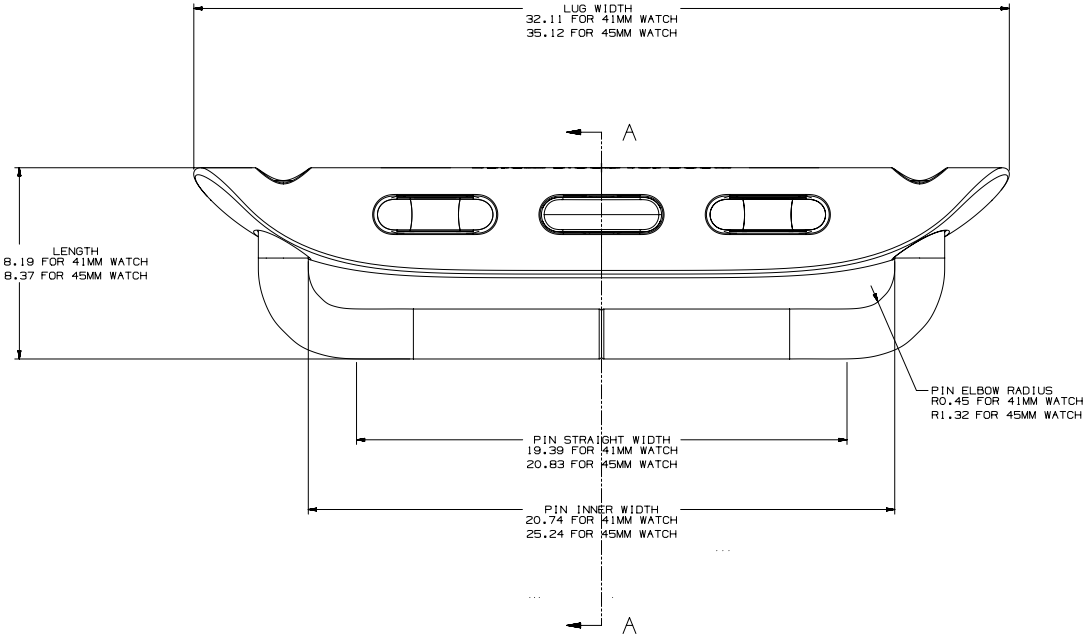
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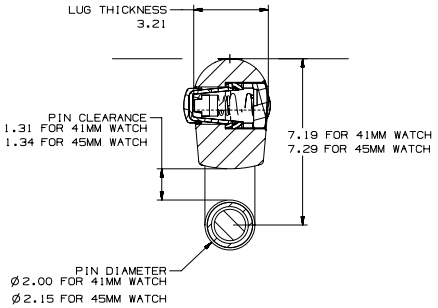
20.9 Example Apple Watch Lug (41 mm & 45 mm)

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. EXPOSED EDGES MUST CONFORM TO UL 1439: TESTS FOR SHARPNESS OF EDGES ON EQUIPMENT AND BS EN71-1: SAFETY OF TOYS







SECTION A - A

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DESIGNER / DATE	
DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE: APPLE WATCH LUG
DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION	SIZE D / SCALE NONE / SHT / OF

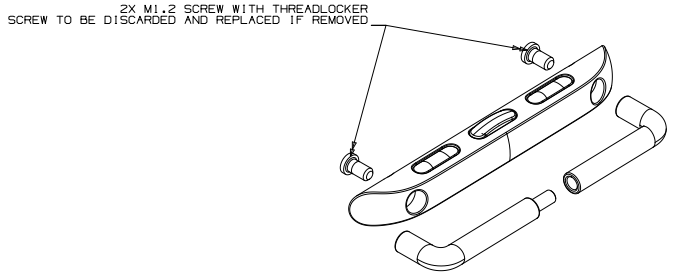
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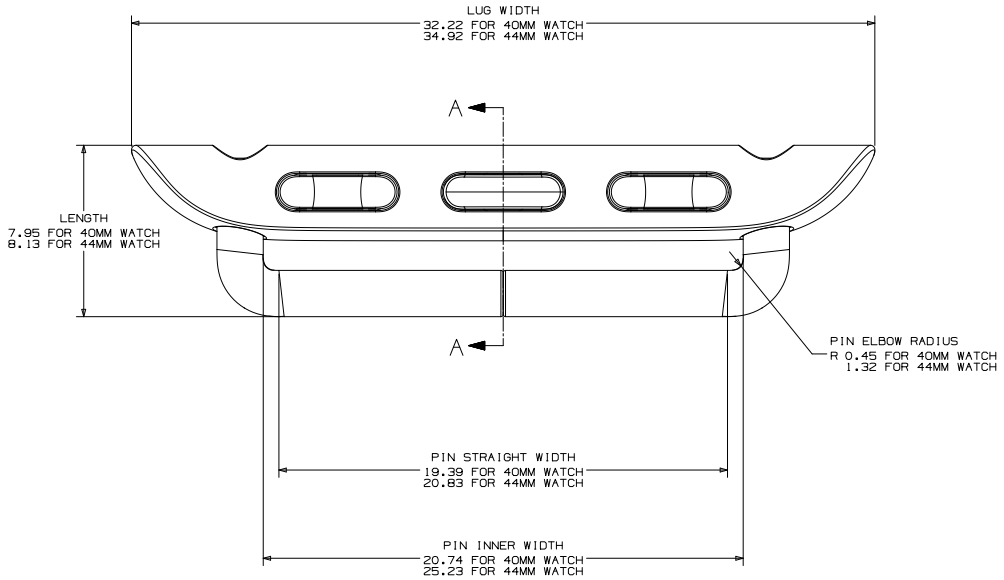
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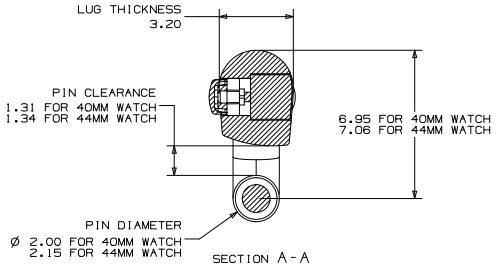
20.10 Example Apple Watch Lug (40 mm & 44 mm)

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. EXPOSED EDGES MUST CONFORM TO UL 1439: TESTS FOR SHARPNESS OF EDGES ON EQUIPMENT AND BS EN71-1: SAFETY OF TOYS.







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DESIGNER / DATE	
DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE: APPLE WATCH LUG
DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION	SIZE D / SCALE NONE / SHT / OF

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21. Apple MagSafe Charger Holders

Apple MagSafe Charger holders position the charger for easier access and may also support StandBy, see StandBy (page 224).

To directly integrate the MagSafe Accessory Magnet Array (page 268), see MagSafe Mounts (page 223).

To integrate wireless charging in an accessory, see Device Power (Inductive) (page 251).

21.1 Mechanical

Holders shall not interfere with Apple MagSafe Charger operation. Keep-in regions may be found in Dimensional Drawings (page 18).

Holders shall:

- Not interfere with or cause Scratches and Damage (page 24) to the device.
- Maintain sufficient Clearance (page 269).

Holders should keep the Apple MagSafe Charger secure when attaching, detaching, or rotating a device.

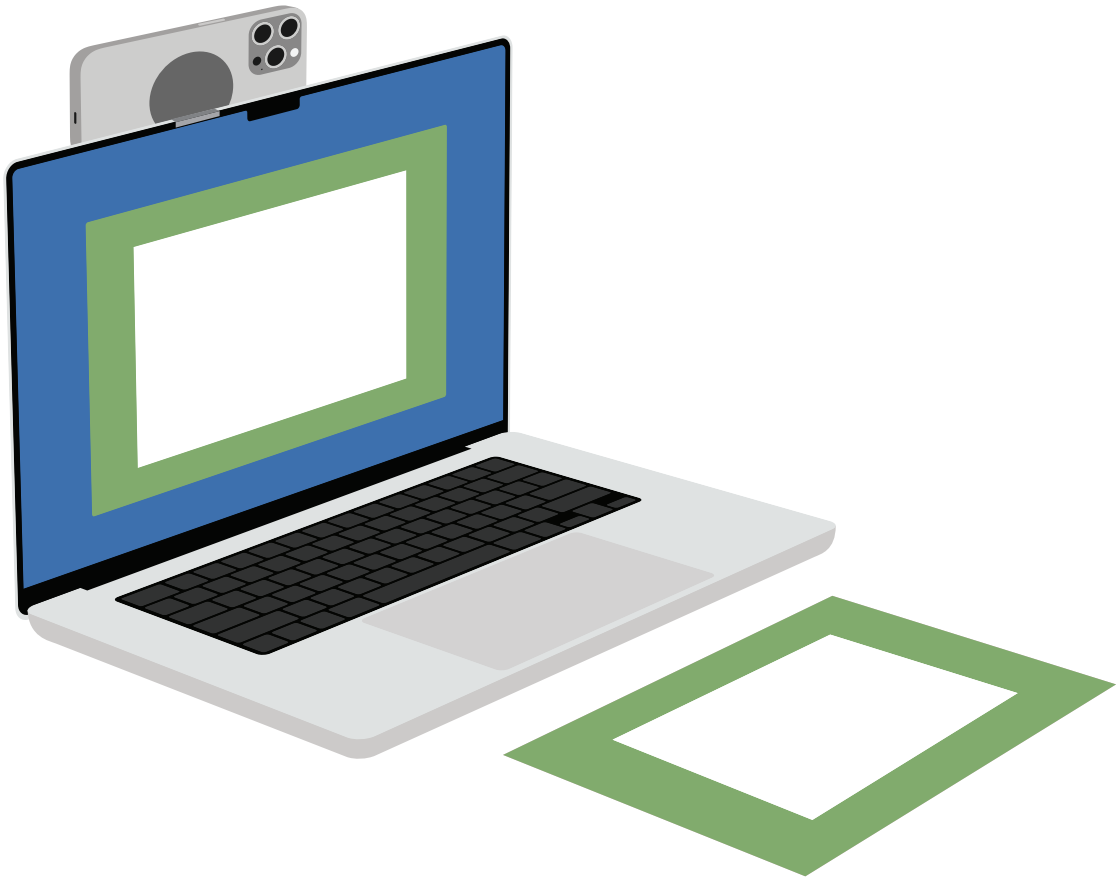
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22. Continuity Camera Mounts

Continuity Camera enables device cameras to be used with Apple TV or Mac and supports Portrait, Studio Light, Center Stage, Reactions, and Desk View video effects. System requirements for Continuity Camera are available at https://support.apple.com/en-us/108046#camera.

Mounts supporting Continuity Camera securely hold a device at the optimal height and angle to use with FaceTime and other apps.

Figure 22-1 MacBook Desk View example



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22.1 Product Design

Mounts supporting Continuity Camera shall:

- Support devices in portrait and landscape orientations.
- Enable use of a USB-C cable or USB to Lightning charge cable.
- Not touch the device cover glass, block any device camera field of view, or obstruct any ambient light sensors, see Dimensional Drawings (page 18).
- Not cause Scratches and Damage (page 24).

The mounts should:

- Prevent Free Rotation (page 224) of the device.
- Enable a device camera lens height of at least 228 mm to support Desk View.
- Not obstruct Access to Controls (page 29).
- Implement the MagSafe Accessory Magnet Array (page 268).
- Support Tripod Connections (page 28).

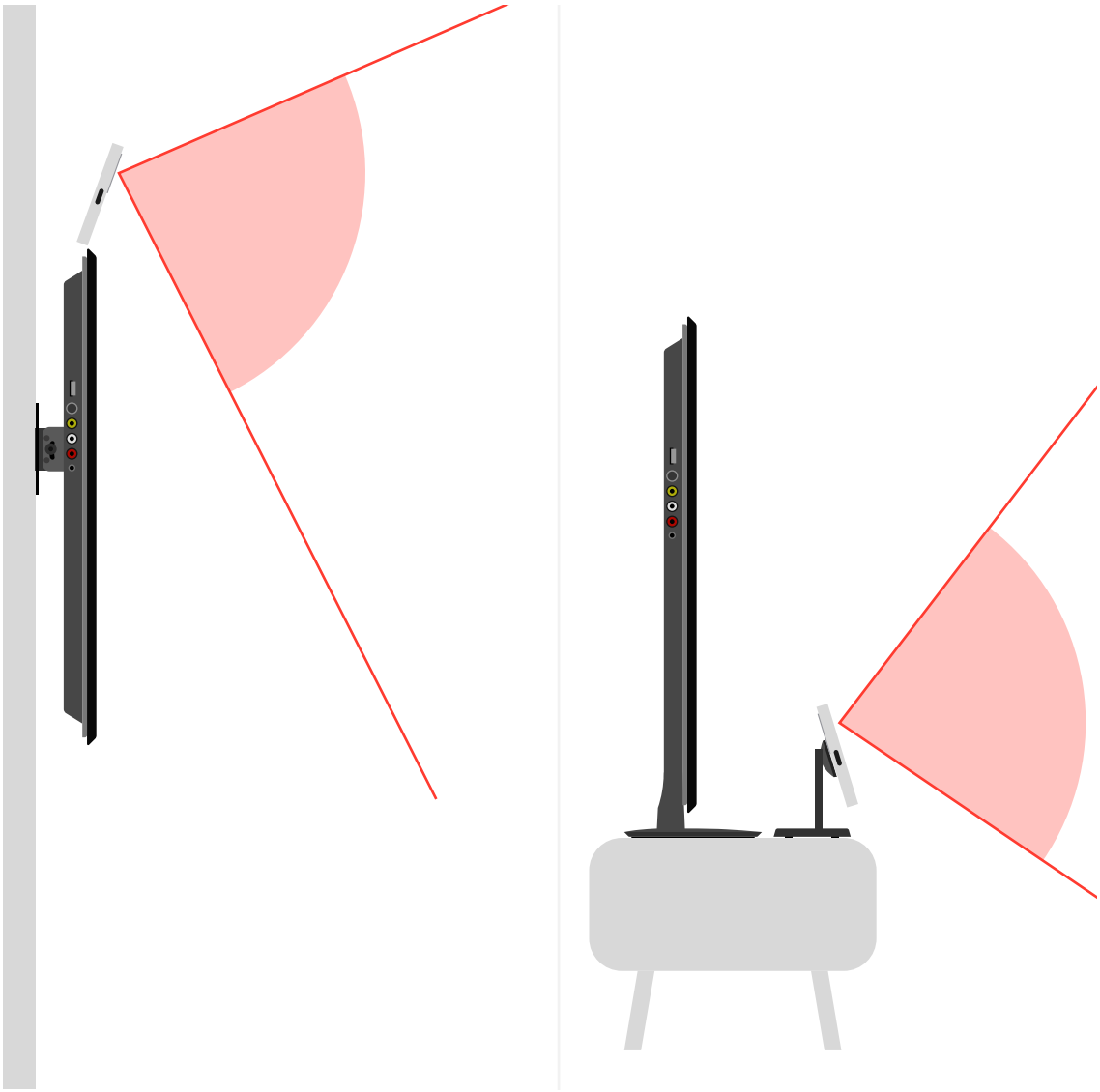
Additional requirements apply to mounts used in the following scenarios:

- Apple TV Mount (page 216)
- MacBook Mount (page 217)
- iMac or Display Mount (page 218)

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22.2 Apple TV Mount

Figure 22-2 Apple TV mount example



A mount designed for Apple TV shall:

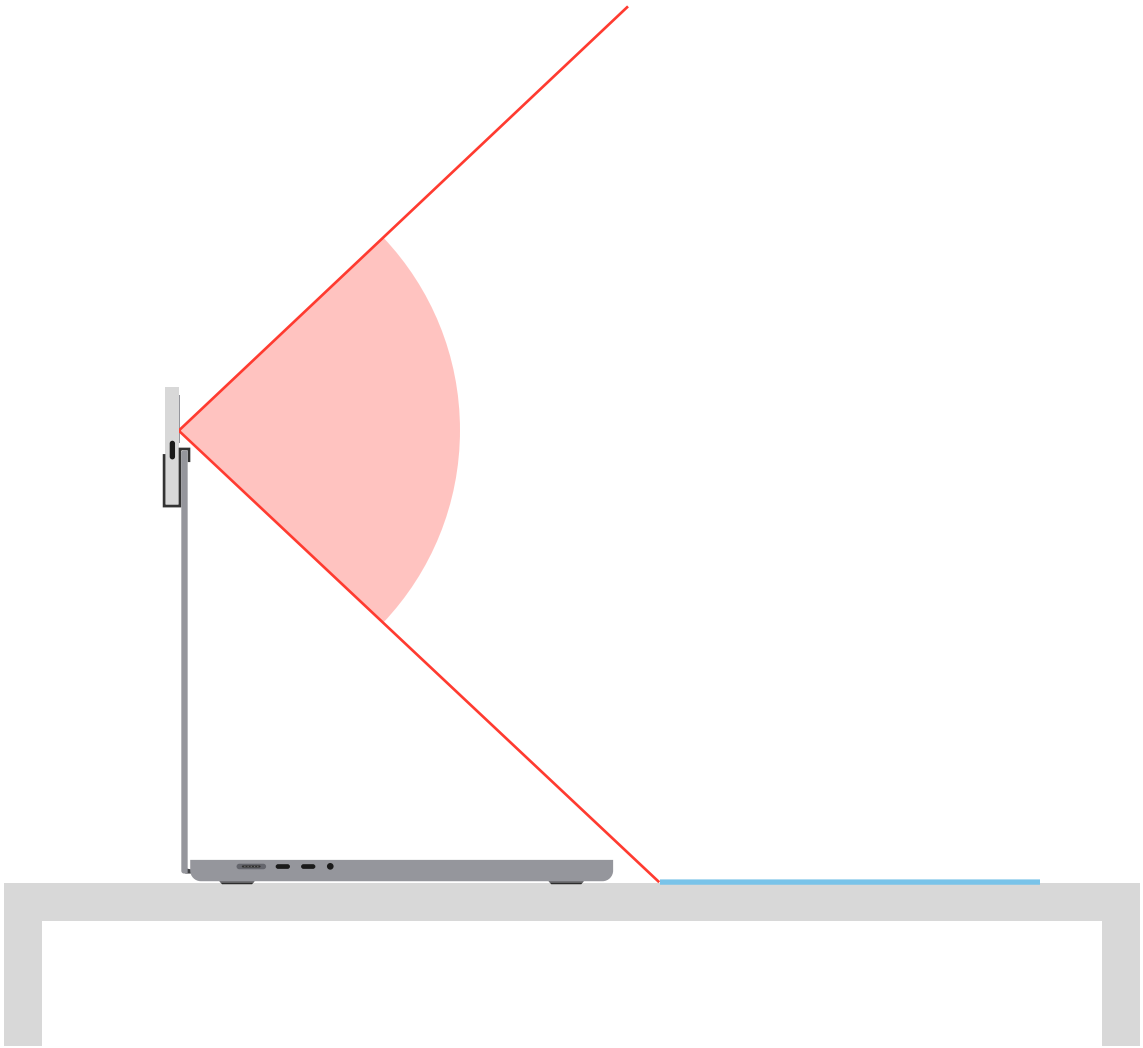
- Be stable when placed on top, or in front of a TV.
- Not touch the display glass (active and non-active areas).
- Not sandwich or squeeze the TV and device together.

The mount should enable upward and downward tilt.

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22.3 MacBook Mount

Figure 22-3 MacBook mount example



A mount designed for MacBook, MacBook Air, and MacBook Pro shall:

- Not scratch or damage the MacBook.
- Not touch the MacBook display glass (active and non-active areas).
- Not interfere with or prevent fully closing the MacBook.
- Not sandwich or squeeze the MacBook and device together.

The mount should:

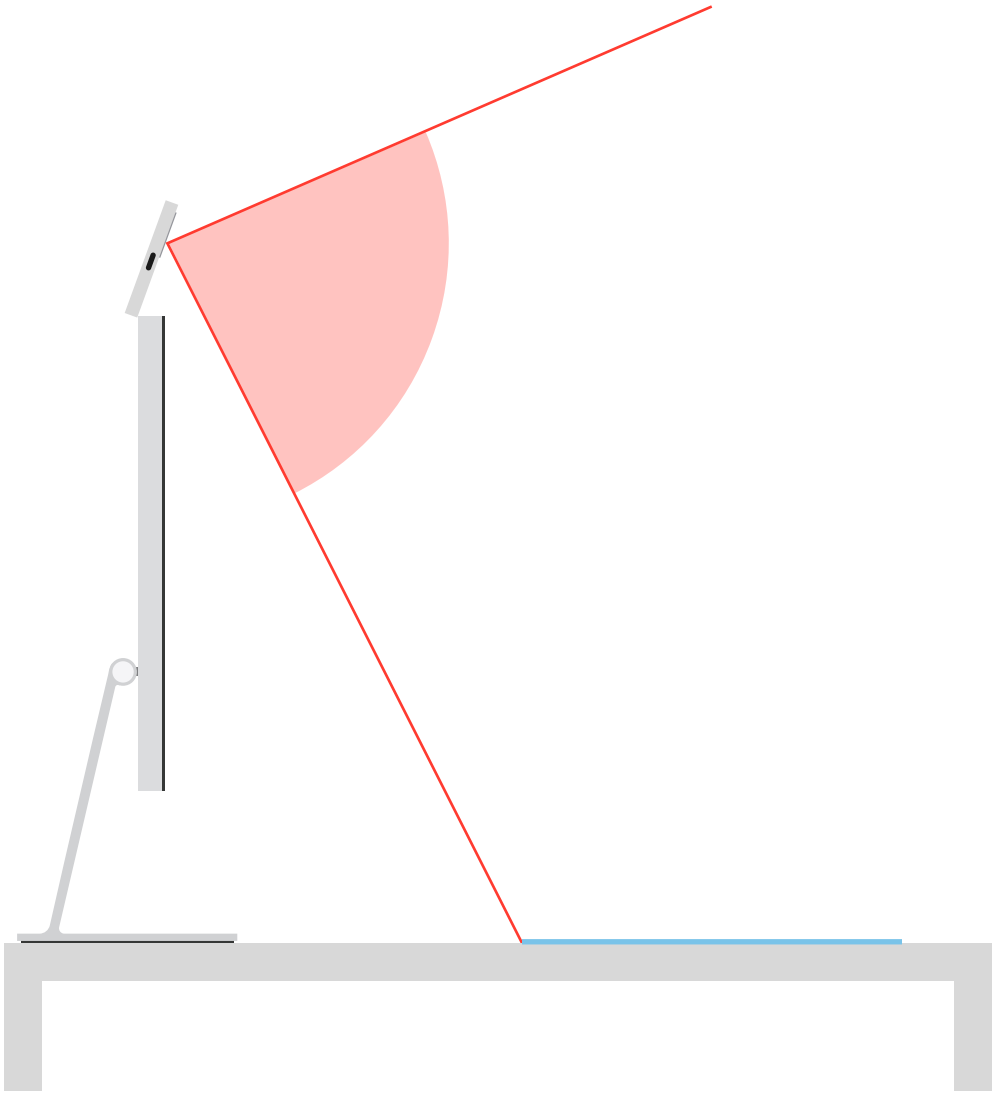
- Not cover or touch any portion of the MacBook display glass, camera, or other sensors.
- Enable a downward tilt in portrait orientation from 0° to 12° to support Desk View.

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- Minimize the mass to maintain stability of the display.

22.4 iMac or Display Mount

Figure 22-4 Display mount example



A mount designed for iMac or displays shall:

- Not scratch or damage the iMac or display.
- Not touch the display glass (active and non-active areas).
- Not sandwich or squeeze the iMac or display and device together.

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The mount should:

- Not cover or touch any portion of the display glass, camera, microphones, or other sensors.
- Enable a downward tilt from 0° to 30° to support Desk View.

22.5 Verification

22.5.1 Equipment

The following equipment is necessary:

- If the mount is designed for Apple TV:
  - Supported devices running iOS 27.2.
  - Apple TV running tvOS 27.2, connected to a TV.
- If the mount is designed for Mac:
  - Supported devices running iOS 27.2.
  - Mac running macOS 27.2.
  - MacBook, MacBook Air, and MacBook Pro if the mount is designed for MacBook.
  - iMac if the mount is designed for iMac.
  - Variety of displays if the mount is designed for external displays.
  - USB-C cable.
  - USB to Lightning charge cable.
- Apple Account with two-factor authentication enabled and used on devices, Apple TV, and all Mac computers.
- Tripod, if the mount is designed for tripod connections.
- Case for the device, if the mount claims support for a case.
- Timer.
- Protractor.
- Second phone, to call the device.

22.5.2 Setup

22.5.2.1 Enable Continuity Camera on Apple TV

Configure an Apple TV and a device to enable Continuity Camera:

1. Open FaceTime on the Apple TV.
2. Select the user matching the device Apple Account.
3. Using the device, select the Continuity Camera notification and select Accept.
4. Attach the device to mount and orient it as prompted.
5. Verify Continuity Camera view displays full screen in FaceTime.

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22.5.2.2 Enable Continuity Camera on Mac

Configure a Mac and a device to enable Continuity Camera:

1. Connect the device to the Mac using a cable.
2. If the Mac is not a trusted computer, select Trust on the Trust This Computer alert on the device.
3. To use Continuity Camera wirelessly, disconnect the cable.
4. Attach the device to mount.
5. Open FaceTime on the Mac.
6. If the 'Use your iPhone as a Camera for your Mac' alert appears, select Continue.
7. Select the Continuity Camera option from the Video menu.
8. Verify Continuity Camera view displays in FaceTime.

Reconnect after the Mac and/or device are in sleep mode:

1. Wake the device and the Mac.
2. Connect the device to the Mac using a cable for a wired connection or disconnect the cable for a wireless connection.
3. Attach the device to the mount.
4. Open FaceTime on the Mac and select Continuity Camera from the Video menu.
5. Verify Continuity Camera view displays in FaceTime.

22.5.3 Product Design

Verify the mount:

1. Supports portrait and landscape orientations.
2. Does not touch the device cover glass or block any device camera field of view.
3. Does not scratch or damage the device.
4. Passes the Free Rotation (page 226) test.
5. When designed for tripods, complies with ISO 1222:2010.

If the mount is designed for Apple TV, verify the mount:

1. Is stable when placed on top, or in front of a TV.
2. Does not touch the display glass.
3. Does not sandwich or squeeze the TV and device together.

If the mount is designed for MacBook, iMac, or displays, verify the mount:

1. Does not touch the display glass.
2. Does not block any MacBook, iMac, or display camera field of view.
3. Does not sandwich or squeeze the device, MacBook, iMac, or display together.
4. Does not scratch or damage the device, MacBook, iMac, or display.
5. Enables use of USB-C cables or USB to Lightning charge cables.

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22.5.4 Center Stage

Center Stage is a video effect available on Apple TV and in the Mac Control Center. Enabling Center Stage on Apple TV, or selecting it in the Control Center Video Effects causes the video to follow people's faces as they move within the Continuity Camera field of view. The video will zoom (in and out) and pan (left to right, right to left, up and down), to keep people's faces in the video frame.

22.5.4.1 Center Stage on Apple TV

Perform mount testing using the FaceTime app on Apple TV to ensure the mount is not visible in the field of view:

1. Observe the Continuity Camera video from different positions using Center Stage face tracking, from the most extreme visible positions (left, right, top, bottom, and all four corners).
2. Verify there are no visual anomalies caused by the mount in any position.

22.5.4.2 Center Stage on Mac

Perform mount testing using the Photo Booth app on the Mac, with and without Center Stage enabled, to ensure the mount is not visible in the field of view:

1. Open the Photo Booth app on the Mac:
   a. Use the Camera menu to select Continuity Camera.
   b. Use the still photo mode.
2. Use the Mac Control Center menu to select Video Effects, and enable Center Stage.
3. Capture photos from different positions using Center Stage face tracking, in portrait and landscape orientation from the most extreme visible positions (left, right, top, bottom, and all four corners), waiting 5 seconds between each photo.
4. Use the Mac Control Center menu to select Video Effects, and disable Center Stage.
5. Capture photos in portrait and landscape orientation, waiting 5 seconds between each photo.
6. Using the Photo Booth film strip feature, verify all photos taken during the test:
   a. Are saved to the computer.
   b. Are clearly displayed when viewed.
   c. Have no visual anomalies caused by the mount in either portrait and landscape orientation.

22.5.5 Desk View

Desk View is a video effect available in the Mac Control Center. Selecting Video Effects and enabling Desk View causes a confirmation dialog box to appear, then a separate Desk View window opens. The tilt angle of the mount and its position determines the Desk View field of view. Adjust the tilt angle as necessary to display the desktop subject matter. Remote viewers will see the subject matter from the presenters perspective. Closing the Desk View window disables Desk View.

1. Ensure the device is logged into the same Apple Account used on the Mac.

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2. Place the device in the mount and on the MacBook, iMac, display, tripod or free-standing support.
3. Perform mount testing using the FaceTime app with the Desk View video effect enabled.
   a. Open the FaceTime app on the Mac, and use the Video menu to select the Continuity Camera.
   b. Use the Mac Control Center menu to select Video Effects, and enable Desk View.
   c. Verify the Desk View window is displayed.
4. In both landscape and portrait orientation:
   a. Adjust the tilt angle of the mount to display the desktop subject matter in the Desk View window.
   b. Verify the desktop subject matter is visible in the Desk View window, and clearly displayed.
   c. Verify there are no visible anomalies caused by the mount in the Desk View window.
   d. Verify the user's face is still visible in FaceTime while Desk View is showing the desktop subject matter.

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23. MagSafe Mounts

MagSafe mounts hold and position a device using the MagSafe magnet ring, and may charge it, see Device Power (Inductive) (page 251).

To hold the Apple MagSafe Charger rather than a device, see Apple MagSafe Charger Holders (page 213).

Figure 23-1 MagSafe mount example



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23.1 Product Design

Mounts shall:

- Not obstruct or touch the device cover glass or any device sensors, see Dimensional Drawings (page 18).
- Not cause Scratches and Damage (page 24).
- Maintain sufficient Clearance (page 269).
- Comply with the requirements in Magnetic Interference (page 26).

Mounts should:

- Not obstruct Access to Controls (page 29).
- Implement Qi Wireless Power (page 251), version 2.0 or later, or the MagSafe Accessory Magnet Array (page 268).

23.1.1 Free Rotation

Mounts preventing free rotation of the device shall keep it within 2° of the position where the user placed it:

- While the mount is left undisturbed for at least 4 hours.
- After a haptic event, such as an incoming phone call.

23.1.2 StandBy

StandBy provides iPhone users a full-screen experience with glanceable information designed to be viewed from a distance when iPhone is in landscape orientation, locked, and charging. StandBy can be personalized to display a range of widgets and supports Live Activities, Siri, incoming calls, and notifications. StandBy remembers the user's preferred views when using a MagSafe Charger.

This feature is supported starting in iOS 17.0.

Mounts supporting StandBy shall:

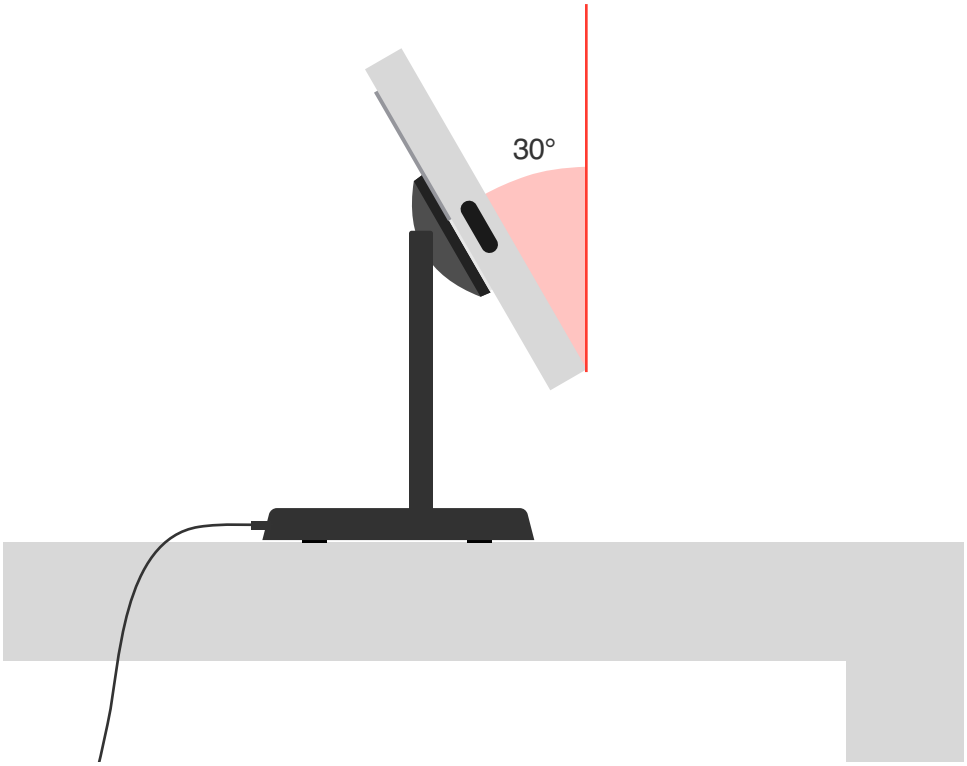
- Support landscape orientation.
- Keep the device charging while it is attached, either inductively or through a wired connection.

Mounts supporting StandBy should:

- Prevent Free Rotation (page 224) of the device across their intended orientations and poses.
- Enable an adjustable backward tilt of at least 30° for optimal visibility, see Figure 23-2 (page 225).
- Be stable to prevent unintentionally exiting StandBy.

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Figure 23-2 StandBy mount tilt example



23.1.3 iPhone Duo

Mounts for iPhone Duo shall:

- Comply with the requirements in Stability (page 225).
- Not obstruct the outer display active area, see iPhone Duo (page 35).
- Not prevent the device from reaching either its closed or its fully open state.
- Not impair the device's ability to reach or hold any partially folded pose.
- Not apply force to the hinge across any part of its range of motion.

Mounts should support the device with a case attached, see iPhone Duo (page 35).

23.1.3.1 Stability

The MagSafe magnet ring alone does not retain the device in the open state.

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Mounts holding the device in the open state shall:

- Not rely on the MagSafe magnet ring alone to retain the device.
- Prevent Free Rotation (page 224) of the device.

Mounts may combine the MagSafe magnet ring with additional retention means, such as increased friction between the mount and the device.

23.2 Verification

23.2.1 Equipment

The following equipment is necessary:

- Supported device running iOS 27.2.
- Case for the device, if the accessory claims support for a case.
- Charger, if not integrated in the accessory.
- Timer.
- Protractor.
- Second phone, to call the device.

23.2.2 Product Design

1. Attach the device to the accessory in each device state the accessory supports.
2. Verify the accessory does not obstruct or touch the device cover glass or any device sensors.
3. Verify the accessory does not scratch or damage the device.
4. Repeat with a case attached, if the accessory claims support for a case.

23.2.3 Charging

Perform for each accessory charging the device inductively.

1. Attach the device to the accessory in each device state the accessory supports.
2. Verify the device begins charging.
3. Verify no visible artifact appears on the device display while charging.
4. Detach and reattach the device, and verify the device is retained only in positions where it charges.

23.2.4 Free Rotation

Perform when another test refers to this test.

1. Open Settings > Sounds & Haptics > Haptics, select Always Play.

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2. Attach the device to the accessory in an orientation and pose the accessory supports, and mark the position of the device on the accessory.
3. Start the timer and leave the accessory undisturbed for 4 hours.
4. Measure the rotation of the device from the marked position, and verify the rotation is within the limit. See Free Rotation (page 224).
5. Call the device from the second phone, and let it ring without touching the device.
6. Measure the rotation of the device from the marked position again, and verify the rotation is within the limit. See Free Rotation (page 224).
7. Repeat in each orientation and pose the accessory supports.
8. Repeat with a case attached, if the accessory claims support for a case.

23.2.5 StandBy

Perform for each accessory claiming support for StandBy.

1. Attach the locked device to the accessory in landscape orientation.
2. Attach a charger if the accessory does not integrate inductive or wired charging.
3. Verify the device begins charging.
4. Verify the device enters StandBy within a few seconds.
5. Verify the accessory supports landscape orientation.
6. Adjust the backward tilt across its full range, and verify the device remains in StandBy.
7. Perform the Free Rotation (page 226) test.

23.2.6 iPhone Duo

Perform for each accessory claiming support for iPhone Duo.

1. Attach iPhone Duo to the accessory in each device state the accessory supports.
2. Verify the accessory does not obstruct the outer display active area.
3. Open and close the device while it is attached, and verify the device reaches both its closed and its fully open state.
4. Fold the device to each partially folded pose the accessory supports while it is attached, and verify the device reaches and holds each pose.

23.2.6.1 Stability

Perform for each accessory claiming to hold iPhone Duo in the open state.

1. Perform the Free Rotation (page 226) test with the device in the open state.
2. Verify the device has not detached from the accessory.

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Features

24. Accessory Power (USB-C)

Accessory power enables accessories to draw a limited amount of power from a device, thereby avoiding the need to integrate a battery or connect to an external power source. This eliminates the need for users to monitor and charge the accessory and enables the accessory to function as long as the device has power. Accessories designed to temporarily connect to the device are good candidates for using accessory power.

Accessories drawing power from the device shall comply with *USB Type-C Cable and Connector Specification – Release 2.3*. Accessories should also support USB Power Delivery (PD) (page 310).

Accessories benefitting from accessory power include:

- Headsets (page 84).
- Adapters (page 78).
- Keyboards (page 91).
- External Storage (page 117).

24.1 Available Current

The following table lists the current available to an accessory.

Table 24-1 Available current

Device	Default	USB Type-C Current (page 311)	USB Power Delivery (PD) (page 310)
iPhone Duo	900 mA	900 mA	900 mA (4.5 W)
iPhone 18 Pro Max	900 mA	900 mA	900 mA (4.5 W)
iPhone 18 Pro	900 mA	900 mA	900 mA (4.5 W)
iPhone 17e	500 mA	500 mA	900 mA (4.5 W)
iPhone 17 Pro Max	900 mA	900 mA	900 mA (4.5 W)
iPhone 17 Pro	900 mA	900 mA	900 mA (4.5 W)
iPhone 17	500 mA	500 mA	900 mA (4.5 W)
iPhone Air	500 mA	500 mA	900 mA (4.5 W)
iPhone 16e	500 mA	500 mA	900 mA (4.5 W)
iPhone 16 Pro Max	900 mA	900 mA	900 mA (4.5 W)

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Device	Default	USB Type-C Current (page 311)	USB Power Delivery (PD) (page 310)
iPhone 16 Pro	900 mA	900 mA	900 mA (4.5 W)
iPhone 16 Plus	500 mA	500 mA	900 mA (4.5 W)
iPhone 16	500 mA	500 mA	900 mA (4.5 W)
iPhone 15 Pro Max	900 mA	900 mA	900 mA (4.5 W)
iPhone 15 Pro	900 mA	900 mA	900 mA (4.5 W)
iPhone 15 Plus	500 mA	500 mA	900 mA (4.5 W)
iPhone 15	500 mA	500 mA	900 mA (4.5 W)
iPad Air 13-inch (M4)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Air 11-inch (M4)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Pro 13-inch (M5)	900 mA	3.0 A	3.0 A (15 W)
iPad Pro 11-inch (M5)	900 mA	3.0 A	3.0 A (15 W)
iPad Air 13-inch (M3)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Air 11-inch (M3)	900 mA	1.5 A	1.5 A (7.5 W)
iPad (A16)	900 mA	1.5 A	1.5 A (7.5 W)
iPad mini (A17 Pro)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Pro 13-inch (M4)	900 mA	3.0 A	3.0 A (15 W)
iPad Pro 11-inch (M4)	900 mA	3.0 A	3.0 A (15 W)
iPad Air 13-inch (M2)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Air 11-inch (M2)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Pro 12.9-inch (6th generation)	900 mA	3.0 A	3.0 A (15 W)
iPad Pro 12.9-inch (5th generation)	900 mA	3.0 A	3.0 A (15 W)
iPad Pro 12.9-inch (4th generation)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Pro 11-inch (4th generation)	900 mA	3.0 A	3.0 A (15 W)
iPad Pro 11-inch (3rd generation)	900 mA	3.0 A	3.0 A (15 W)
iPad Pro 11-inch (2nd generation)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Air (5th generation)	900 mA	1.5 A	1.5 A (7.5 W)
iPad Air (4th generation)	900 mA	1.5 A	1.5 A (7.5 W)
iPad mini (6th generation)	900 mA	1.5 A	1.5 A (7.5 W)
iPad (10th generation)	500 mA	1.5 A	1.5 A (7.5 W)

24.2 VCONN

USB 2.0 accessories capable of being powered from VCONN alone shall also be capable of being powered from VBUS.

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24.3 Fast Role Swap (FRS)

iPads with a USB-C connector support USB Power Delivery (PD) (page 310) Fast Role Swap (FRS).

24.4 Verification

24.4.1 Maximum Accessory Power

This test procedure applies to accessories drawing power from the device. The accessory needs to be exercised to its full capability.

The example accessory in this test procedure is an external USB 3 drive claiming to draw up to 900 mA from the USB 3 host. The accessory is exercised by reading and writing a large file. Adapt this procedure as needed for different accessory types.

24.4.1.1 Equipment

The following equipment is necessary:

- External USB drive in APFS format (the example accessory).
- Mac with USB-C.
- USB-IF certified USB-C to USB-C Full-Featured cable.
- USB-C breakout board or USB-IF approved test fixture, such as:
  - FS-HUCP available at https://fixturesolution.com/product/usb2-0-type-c-signal-quality-test-fixture/.
  - FS-HUCR available at https://fixturesolution.com/product/usb-type-c-high-speed-signal-quality-test-fixture/.
- Oscilloscope with a current probe.

24.4.1.2 Setup

1. Using the current probe, attach the oscilloscope to the current loop circuit of the accessory, or the USB-C breakout board.
2. Verify the oscilloscope configuration settings match the following:
   a. Acquisition: >5 M samples/s.
   b. Current Channel: 200 mA/div.
   c. Horizontal Channel: 100 µs/div.
   d. Voltage Channel: 1 V/div, bandwidth limited.
   e. Infinite persistence (reset before each test case).
   f. Adjust offset down to see seven divisions.
   g. Adjust offset towards the left, to maximize the window.

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h. Trigger: Current Channel, Positive Threshold, 900 mA, Normal Mode.

3. Connect the Mac to the external USB drive using the USB-C cable.
4. Launch Terminal on the Mac, and enter the following command:
   - `dd if=/dev/random of=~/Desktop/testfile.dat count=1024 bs=78643200`
5. The new file `~/Desktop/testfile.dat` is the file to use for testing.

24.4.1.3 Procedure

24.4.1.3.1 Enumeration

1. Verify the external USB drive fully enumerates in the Mac System Report:
   a. Select Apple Menu > 'About This Mac'.
   b. Select 'More Info...'.
   c. Select 'System Report...'.
   d. Select USB from the sidebar.
2. Verify the accessory is displayed in the USB Device Tree.
3. Verify the speed displayed is one of the following:
   a. Up to 5 Gb/s.
   b. Up to 10 Gb/s.

24.4.1.3.2 Idle

1. Record the maximum current while idle.
2. Verify the maximum current does not exceed 900 mA.

24.4.1.3.3 Write to USB Drive

1. Use Finder to copy the `testfile.dat` from the Mac to the USB drive.
2. Record the maximum current.
3. Verify the maximum current does not exceed 900 mA.

24.4.1.3.4 Read from USB Drive

1. Use Finder to copy the `testfile.dat` from the USB drive to the Mac.
2. Record the maximum current.
3. Verify the maximum current does not exceed 900 mA.

24.4.2 VCONN

This test procedure applies to USB 2.0 accessories drawing power from the device.

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24.4.2.1 Equipment

The following equipment is necessary:

- iPhone Air

24.4.2.2 Procedure

1. Connect the device to the accessory.
2. Verify the accessory works as expected.

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25. Accessory Power (Lightning)

Accessory power enables accessories to draw a limited amount of power from a device, thereby avoiding the need to integrate a battery or connect to an external power source. This eliminates the need for users to monitor and charge the accessory and enables the accessory to function as long as the device has power. Accessories designed to temporarily connect to the device are good candidates for using accessory power.

See the Accessory Interface Specification (page 22) for more information.

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26. App Discovery

The App Discovery feature enables accessories to retrieve a list of installed apps on the device capable of communicating with the accessory. See App Launch (iAP2) (page 236) to use the list.

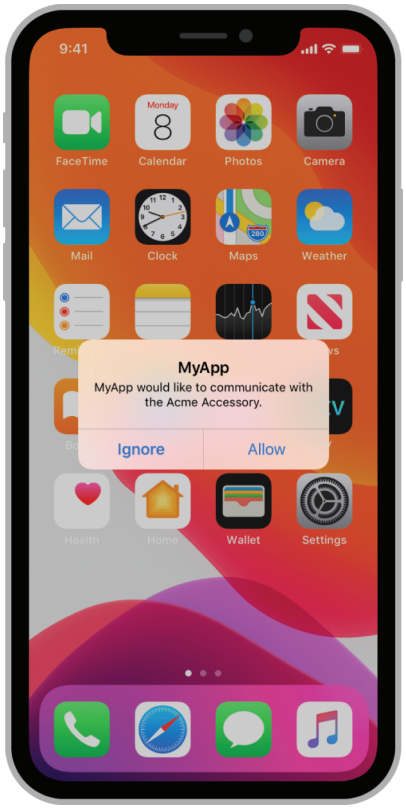
See the Accessory Interface Specification (page 22) for more information.

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27. App Launch (iAP2)

Accessories supporting the App Launch (iAP2) feature can request a device launch an app on its behalf.

Figure 27-1 App Launch alert



See the Accessory Interface Specification (page 22) for more information.

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28. App Launch (BLE)

Accessories supporting the App Launch (BLE) feature can request a device launch an app on its behalf.

See the Accessory Interface Specification (page 22) for more information.

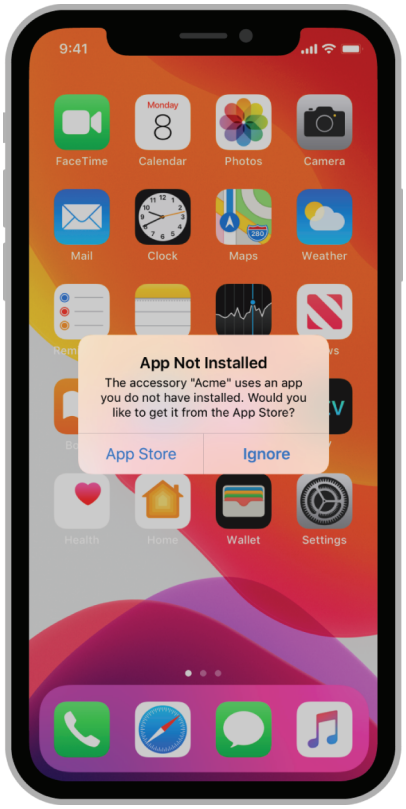
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29. App Match (iAP2)

The App Match feature enables accessories supporting an External Accessory Protocol to match with compatible apps on the App Store.

When connected for the first time, the device asks the user if they would like to visit the App Store and view compatible apps. Subsequently, this action may be repeated using Settings > General > About > '[Accessory name]' > 'Find App for Accessory'.

Figure 29-1 App Match alert



See the Accessory Interface Specification (page 22) for more information.

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30. App Match (BLE)

The App Match feature enables BLE accessories to match with compatible apps on the App Store.

When connected for the first time, the device asks the user if they would like to visit the App Store and view compatible apps. Subsequently, this action may be repeated using Settings > General > About > '[Accessory name]' > 'Find App for Accessory'.

See the Accessory Interface Specification (page 22) for more information.

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31. Bluetooth HFP Siri and Battery Reporting

Apple-specific Bluetooth commands extend accessory capabilities beyond those supported by standard Bluetooth profiles. To enable Apple-specific features, the accessory shall support HFP Command AT+XAPL (page 240), which provides accurate information about the accessory's supported features. The device will use the information sent by this command to enable and disable custom commands.

The accessory shall send the following AT+XAPL command after making a successful HFP Service Level Connection (SLC) to the device. The accessory should send an AT+XAPL command first, before sending any additional Apple-specific commands. See Siri (page 287) and Bluetooth Headset Battery Level Indication (page 241).

31.1 HFP Command AT+XAPL

Description: Enables custom AT commands from an accessory.

Initiator: Accessory

Format: AT+XAPL=*vendorID*-*productID*-*version*,*features*

Parameters:

- *vendorID*: A string representation of the hex value of the vendor ID from the manufacturer, without the `0x` prefix.
- *productID*: A string representation of the hex value of the product ID from the manufacturer, without the `0x` prefix.
- *version*: The software version.
- *features*: A base-10 representation of a bit field. Available features are:
  - Bit 0 = Reserved.
  - Bit 1 = The accessory supports battery reporting (reserved only for battery operated accessories).
  - Bit 2 = The accessory is docked or powered (reserved only for battery operated accessories).
  - Bit 3 = The accessory supports Siri status reporting.
  - Bit 4 = The accessory supports noise reduction (NR) status reporting.
  - All other bits are reserved.

Example: AT+XAPL=ABCD-1234-0100,10 (Supports battery reporting and Siri status)

Response: +XAPL=iPhone,*features*

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32. Bluetooth Headset Battery Level Indication

Bluetooth headsets may report their battery level, which the device displays to the user as an indicator icon in its status bar. This feature is supported on all devices supporting the Hands-Free Profile, including iPhone and iPad.

Headset battery indication is implemented by two Apple-specific Bluetooth HFP AT commands, HFP Command AT+XAPL (page 240) and HFP Command AT+IPHONEACCEV (page 241).

32.1 HFP Command AT+IPHONEACCEV

Description: Reports a headset state change.

Initiator: Accessory

Format: `AT+IPHONEACCEV=`*Number of key/value pairs*`,`*key1*`,`*val1*`,`*key2*`,`*val2*`,...`

Parameters:

- *Number of key/value pairs*: The number of parameters coming next.
- *key*: the type of change being reported:
  - 1 = Battery Level
  - 2 = Dock State
- *val*: the value of the change:
  - Battery Level: string value between '0' and '9'
  - Dock State: 0 = undocked, 1 = docked

Example: `AT+IPHONEACCEV=1,1,3`

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33. Bluetooth Low Energy Battery Service

This feature is supported starting in iOS 26.0, iPadOS 26.0, macOS 26.0, visionOS 26.0, and watchOS 26.0.

33.1 Overview

Accessories may communicate battery status using the Battery Level and Battery Level Status characteristics defined in the *Bluetooth Battery Service Specification – Version 1.1*.

If the Battery Level Status characteristic implements the optional Battery Level field, the accessory shall send the same battery value as the Battery Level characteristic.

Accessories shall only notify battery level change with Battery Level characteristic, and Power State change with Battery Level Status characteristic.

33.2 All Accessories

A Characteristic Presentation Format descriptor is only required if there are multiple instances of Battery Service, this descriptor may be excluded for an accessory with a single instance of Battery Service.

The following descriptors are supported:

- Main
- Left
- Right

> **Note:**
> The Main descriptor is interpreted as a "Case" when both Left and Right descriptors are present. This applies only to headset accessories.

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33.2.1 Hands Free Profile (HFP) Accessories

Accessories supporting the *Bluetooth Battery Service Specification – Version 1.1* should not use the *Battery Level Indicator* defined in the *Bluetooth Hands-Free Profile Specification – Version 1.8*. The device will ignore the *Battery Level Indicator* value in favor of the Bluetooth Low Energy Battery Service.

The device will read the Bluetooth Low Energy Battery Service value via GATT over Classic to avoid multiple ACL (Asynchronous Connection-oriented logical) transport links.

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34. Device Power (USB-C)

Accessories may provide power to devices using USB-C.

Apple recommends providing power to the device whenever possible for the best user experience.

Accessories providing power to a device shall:

- Connect to the device either through an integrated USB-C Plug (page 385) or a USB-C cable.
- Use USB Type-C Current (page 311) to identify their power capability and should use USB Power Delivery (PD) (page 310) to provide higher power, see https://support.apple.com/en-us/102574.
- Provide power at all times unless a direct user action is taken turning the accessory 'off'. Failure to provide power at all times may result in the accessory being unable to charge a device whose battery level is too low to boot.

Accessories may use the iAP2 (page 319) protocol in conjunction with USB Type-C Current (page 311) to allow for more granular control of the available current after the initial connection. Accessories shall not use iAP2 (page 319) to adjust available current in conjunction with USB Power Delivery (PD) (page 310).

Accessories providing power from a USB-C receptacle shall comply with the requirements in Providing Power (page 390).

34.1 External Power Source

Accessories drawing power from external power sources and providing all or a portion of their power to the device shall:

- Identify the power source's capability and report accordingly to the device.
- Not manipulate a device into drawing more power from the external power source than the device would normally draw when directly connected to the external power source.
- Derate the available power by the amount of power consumed by the accessory, if applicable.

Accessories drawing power from external power sources may inform the device when power is not available or only available at a reduced level (for example, from an internal battery) or when the user unplugs the accessory from the external power source (for example, an AC power adapter or AC "mains" power outlet). Power to the device shall be restored and the updated power providing capability change shall be communicated to the device when the user re-connects the external power source.

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See AC Power Adapters (page 80), Providing Power (page 390), and User Supplied Cables and AC Power Adapters (page 25) for additional requirements specific to external USB power supplies/cables.

34.2 Power State Changes

Accessories shall not change the amount of power provided to a device unless:

- Direct user action is taken to turn the accessory on or off.
- External power source (for example, mains electricity or battery) is connected to or disconnected from the accessory.
- Accessory's internal power source (for example, a battery) is depleted or loaded to the point where it is no longer capable of supplying its declared power providing capability or is now capable of supplying more power than previously declared.

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35. Device Power (Lightning)

Accessories may provide power to devices using Lightning.

Apple recommends providing power to the device whenever possible for the best user experience.

Accessories providing power to a device shall connect to the device either through an integrated Lightning connector or a USB to Lightning cable. To incorporate an integrated Lightning connector, the accessory developer shall be a member of the Apple MFi Program (page 22).

Accessories providing power to a device shall either:

- Provide direct power, see Direct Power Source (page 246).
- Manage power from external sources, see External Power Source (page 246).

Accessories without the potential for data communication with the device shall provide direct power to the device, see Direct Power Source (page 246).

35.1 Direct Power Source

Accessories providing power directly shall provide power at all times unless disabled by a direct user action. Failure to provide power at all times may result in the accessory being unable to charge a device whose battery level is too low to boot.

Accessory power source testing shall be performed with programmable loads, not devices. Device power draw varies with environmental factors.

35.2 External Power Source

Accessories drawing power from external power sources and providing all or a portion of their power to the device:

- Shall identify the power source's capability and report accordingly to the device.
- Shall not manipulate a device into drawing more power from the external power source than the device would normally draw when directly connected to the external power source.
- Shall not manipulate a device into drawing less than the minimum power required by the accessory compatibility claims if it is available from the external source, see Providing Power using USB Connectors (page 247).

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Accessories drawing power from external power sources may inform the device when power is not available or only available at a reduced level (for example, from an internal battery) or when the user unplugs the accessory from the external power source (for example, an AC power adapter or AC "mains" power outlet). Power to the device shall be restored and the updated power providing capability change shall be communicated to the device when the user re-connects the external power source.

See AC Power Adapters (page 80), Electrical (page 384), and User Supplied Cables and AC Power Adapters (page 25) for additional requirements specific to external USB power supplies/cables.

35.3 Declaring Capability

If the accessory provides power using a:

- USB-A receptacle, it shall use one of the following to declare its power providing capability:
  - USB Power Capability Vendor Request (page 306).
  - USB D+/D- Resistor Networks (page 307).
- USB-C receptacle, then:
  - It shall use one of the following to declare its power providing capability:
    - USB Type-C Current (page 311).
    - USB Power Delivery (PD) (page 310).
  - If the accessory does not have the potential for data communication with the device, it shall also support the *USB Battery Charging Specification – Release 1.2*.

35.4 Providing Power using USB Connectors

Accessories providing power from:

- USB-C Receptacle (page 389).
- USB-A Receptacle (page 384).

35.5 Labeling Multiple Connectors

If the accessory has multiple connectors with different device compatibilities, iPad-compatible connectors shall be labeled with the text 'iPad' unless it is physically impossible to connect an iPad to iPhone-compatible connectors.

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35.6 Fast Charge for iPhone (20 W)

Accessories advertising "fast charge" for iPhone (https://support.apple.com/en-us/102574) shall:

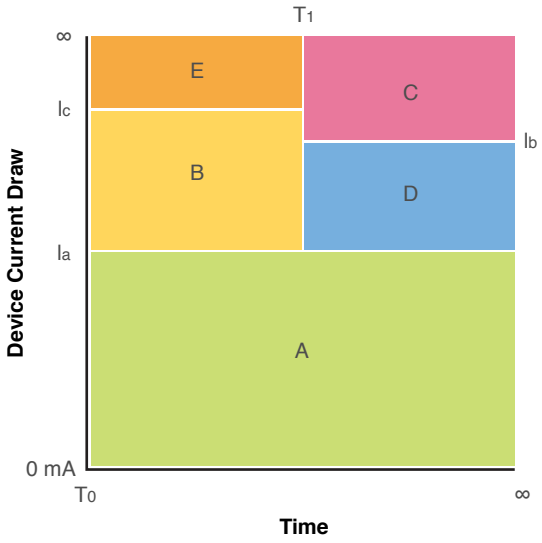
- Support USB Power Delivery (PD) (page 310).
- Supply at least 20 W (2.22 A at 9 V) using USB PD.
- Claim compatibility with at least one of the following iPhone models:
  - iPhone 14 Pro Max
  - iPhone 14 Pro
  - iPhone 14 Plus
  - iPhone 14
  - iPhone SE (3rd generation)
  - iPhone 13 Pro Max
  - iPhone 13 Pro
  - iPhone 13
  - iPhone 13 mini
  - iPhone 12 Pro Max
  - iPhone 12 Pro
  - iPhone 12
  - iPhone 12 mini
  - iPhone SE (2nd generation)
  - iPhone 11 Pro Max
  - iPhone 11 Pro
  - iPhone 11

Accessories such as charging cables should be capable of supporting up to 60 W (3 A at 20 V) to provide compatibility with a variety of sources and devices.

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35.7 Overcurrent and Short Circuit Protection

Figure 35-1 Overcurrent and short circuit protection



Power-providing accessories shall implement overcurrent and short circuit protection for each region in Figure 35-1 (page 249) according to Table 35-1 (page 249), Table 35-2 (page 249), and Table 35-3 (page 250).

Table 35-1 Overcurrent / short circuit protection current thresholds

Threshold	Definition
I_a	Nominal accessory output current (for example, 1000 mA, 2100 mA, 2400 mA, 3000 mA).
I_b	I_a + 60%.
I_c	Lowest device current draw causing accessory output voltage (measured at Lightning Device Power) to drop below 2 V.

Table 35-2 Overcurrent / short circuit protection time thresholds

Threshold	Definition
T_0	Start of any device current draw transient.
T_1	Accessory overcurrent/short circuit deglitch/debounce time, which shall be ≥ T_0 + 1 ms.

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Table 35-3 Overcurrent / short circuit protection behaviors

Region	Name	Accessory Behavior
A	Normal Operation	The accessory shall not limit or shut down output current.
B	Overcurrent Transient	The accessory shall not shut down output current. The accessory may limit output current to I_a or higher.
C	Overcurrent	The accessory shall shut down output current.
D	Potential Overcurrent	The accessory may shut down output current.
E	Potential Short Circuit	If Lightning Device Power voltage drops below 2 V, the accessory may trigger short circuit protection. Accessories shall not trigger short circuit protection on device current draw.

35.8 Overcurrent and Short Circuit Protection Resets

Accessory overcurrent and short circuit protection shall reset without mechanical intervention.

35.9 Power State Changes

Accessories shall not change the amount of power provided to a device unless:

- Direct user action is taken to turn the accessory on or off.
- External power source (for example, mains electricity or battery) is connected to or disconnected from the accessory.
- Accessory's internal power source (for example, a battery) is depleted or loaded to the point where it is no longer capable of supplying its declared power providing capability or is now capable of supplying more power than previously declared.

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36. Device Power (Inductive)

Accessories may provide power to devices using Qi Wireless Power (page 251).

36.1 Qi Wireless Power

Devices supporting Qi wireless power:

- iPhone Duo
- iPhone 18 Pro Max
- iPhone 18 Pro
- iPhone 17e
- iPhone 17 Pro Max
- iPhone 17 Pro
- iPhone 17
- iPhone Air
- iPhone 16e
- iPhone 16 Pro Max
- iPhone 16 Pro
- iPhone 16 Plus
- iPhone 16
- iPhone 15 Pro Max
- iPhone 15 Pro
- iPhone 15 Plus
- iPhone 15
- iPhone 14 Pro Max
- iPhone 14 Pro
- iPhone 14 Plus
- iPhone 14
- iPhone SE (3rd generation)
- iPhone 13 Pro Max
- iPhone 13 Pro
- iPhone 13
- iPhone 13 mini
- iPhone 12 Pro Max
- iPhone 12 Pro

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- iPhone 12
- iPhone 12 mini
- iPhone SE (2nd generation)
- iPhone 11 Pro Max
- iPhone 11 Pro
- iPhone 11
- MagSafe Charging Case for AirPods Pro 3
- Wireless Charging Case (USB-C) for AirPods 5 and AirPods 4
- MagSafe Charging Case (USB-C) for AirPods Pro (2nd generation)
- MagSafe Charging Case for AirPods Pro (2nd generation)
- MagSafe Charging Case for AirPods (3rd generation)
- Wireless Charging Case for AirPods

Accessories incorporating a Qi transmitter shall use an embedded Qi Certified subsystem or shall be Qi Certified according to *The Qi Wireless Power Transfer System, Power Class 0 Specification – Version 2.0 or later*, see https://www.wirelesspowerconsortium.com. Accessories should support version 2.2 or later.

Accessories shall maintain Clearance (page 269) outside the magnetic attach area.

36.2 MagSafe

Devices supporting MagSafe:

- iPhone Duo
- iPhone 18 Pro Max
- iPhone 18 Pro
- iPhone 17e
- iPhone 17 Pro Max
- iPhone 17 Pro
- iPhone 17
- iPhone Air
- iPhone 16 Pro Max
- iPhone 16 Pro
- iPhone 16 Plus
- iPhone 16
- iPhone 15 Pro Max
- iPhone 15 Pro
- iPhone 15 Plus
- iPhone 15
- iPhone 14 Pro Max

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- iPhone 14 Pro
- iPhone 14 Plus
- iPhone 14
- iPhone 13 Pro Max
- iPhone 13 Pro
- iPhone 13
- iPhone 13 mini
- iPhone 12 Pro Max
- iPhone 12 Pro
- iPhone 12
- iPhone 12 mini
- MagSafe Charging Case for AirPods Pro 3
- MagSafe Charging Case (USB-C) for AirPods Pro (2nd generation)
- MagSafe Charging Case for AirPods Pro (2nd generation)
- MagSafe Charging Case for AirPods (3rd generation)

36.3 Coil Alignment

Alignment between the accessory's transmitter coil and the device's receiver coil determines the coupling of the inductive link. A misaligned coil reduces the power transferred, increases the power dissipated as heat, and increases the interference the accessory couples into the device. Depending on the alignment, this interference may appear as a visible artifact on the display while charging.

Accessories providing inductive device power shall:

- Align the transmitter coil to the device's receiver coil, see Dimensional Drawings (page 18).
- Maintain the alignment throughout the accessory's intended use, including across any adjustment the accessory allows.

Accessories relying on the user to position the device should provide a positive alignment feature, such as Qi 2.0 or MagSafe magnetic alignment, a recess, or a registration surface. Accessories should indicate the alignment position on the charging surface where the user can see it.

Accessories should minimize false attach, in which the accessory retains the device without charging it. Accessories should retain the device only where they charge it.

36.4 Electromagnetic Compatibility (EMC)

Accessories providing inductive device power should be designed for electromagnetic compatibility.

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Apple recommends shielding the magnetic field from the charging coil and maintaining a low impedance shield termination for cables to comply with regulatory EMC requirements for the completed product. Implementation, final compliance testing, report preparation, and labeling are the responsibilities of the company marketing and producing the product.

Cable termination is critical for reduced emissions. Cable termination and connectors should be kept away from the charging coil and cables should be routed away from the charging surface.

If emissions are present, adding clamp-on ferrites/absorbers to the cable can help reduce emissions. Selected ferrite/absorber materials should be rated for the failing frequencies.

Depending on the accessory's supported use cases, testing should be performed with the following power supplies:

- Apple USB-C Power Adapters:
  - Apple 140W USB-C Power Adapter
  - Apple 96W USB-C Power Adapter
  - Apple 70W USB-C Power Adapter
  - Apple 67W USB-C Power Adapter
  - Apple 40W Dynamic Power Adapter with 60W Max
  - Apple 30W USB-C Power Adapter
  - Apple 20W USB-C Power Adapter
  - Apple 35W Dual USB-C Port Compact Power Adapter
  - Apple 35W Dual USB-C Port Power Adapter
- Apple USB-A Power Adapters:
  - Apple 12W USB Power Adapter
  - Apple 5W USB Power Adapter
    - Model A1385 (US)
    - Model A1400 (Int.)
    - Model A1552 (UK)
    - Model A1443 (China)
    - Model A1444 (Australia)
    - Model A1486 (Brazil)
    - Model A1487 (Korea)
    - Model A1501 (Argentina)
- Apple Mac computers:
  - Apple MacBook Pro
  - Apple MacBook Air

If power sources are used differing from those listed above, emission testing should be performed while the power sources are on.

In addition to the use cases above, charging devices should be tested in idle mode for emissions.

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Emissions tests should be conducted in accordance with standards referenced in the following:

- FCC CFR 47, Part 15
- ICES-003, Issue 5, CAN/CSA-CEI/IEC CISPR 22-10
- CISPR 22: 2008
- EN 55022: 2010
- AS/NZS CISPR 22:2009, TCVN 7189:2009
- VCCI V-3/2013.04
- GB 9254-2008, GB 17625.1-2012, GB 17625.2-2007, CNS 13438-2006
- CISPR 24: 2010
- EN 55024: 2010

Once the highest emitting combination is identified, complete testing should be performed on the configuration. Some regulatory domains may require EMC certification.

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37. Ethernet over USB

Accessories may support Ethernet over USB using the Network Control Model (NCM) protocol to enable a device to access a wired network.

Accessories shall comply with the *Network Control Model Devices Specification – Revision 1.0*, see https://www.usb.org/document-library/network-control-model-devices-specification-v10-and-errata-and-adopters-agreement.

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38. External Accessory Protocol

The External Accessory (EA) framework provides accessories the means to communicate with one or more apps using EA sessions, providing a read/write bytestream interface. Accessory developers specify a custom protocol between the application and the accessory. The design and maintenance of communication protocols between accessories and applications are entirely the responsibility of the accessory and app developers. External Accessory framework documentation can be found at https://developer.apple.com/documentation/externalaccessory.

See the Accessory Interface Specification (page 22) for more information.

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39. HID Headset Remote

Devices may accept user input from headsets to control audio volume and media playback.

39.1 Requirements

Accessories implementing HID headset remote controls shall:

- Connect to the device using one of the following:
  - USB-C Plug (page 385).
  - Bluetooth (page 331).

HID headset remotes shall support the Human Interface Device (HID) (page 320) protocol.

The HID report descriptor for a headset remote shall declare support for the HID Consumer and/or Telephony pages and only send usages from Table 39-1 (page 258) and Table 39-2 (page 258).

Table 39-1 HID Consumer Page (`0x0C`) controls for use by headset remotes

Usage ID	Usage Name	Apple Function
`0x00B5`	Scan Next Track	Transport Right
`0x00B6`	Scan Previous Track	Transport Left
`0x00B9`	Random Play	Shuffle
`0x00BC`	Repeat	Repeat
`0x00E2`	Mute	Mute
`0x00E9`	Volume Increment	Volume Up
`0x00EA`	Volume Decrement	Volume Down
`0x025B`	Promote	Play More Like This
`0x025C`	Demote	Play Less Like This

Table 39-2 HID Telephony Page (`0x0B`) controls for use by headset remotes

Usage ID	Usage Name	Apple Function
`0x0021`	Flash	Center

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If a user presses and holds the accessory control surface corresponding to the 'Transport Right' or 'Transport Left' function, devices may scrub forwards or backwards within the current playing media item. Accessories shall not present a separate 'Fast-Forward' or 'Reverse' control surface to the user for the same feature.

39.2 Examples

39.2.1 Headset Remote Example HID Report Descriptor (Telephony)

The following sample HID descriptor demonstrates how to implement telephony and volume controls.

```
USAGE_PAGE (Consumer Devices) 05 0C
USAGE (Consumer Control)      09 01
COLLECTION (Application)      A1 01
  LOGICAL_MINIMUM (0)         15 00
  LOGICAL_MAXIMUM (1)         25 01
  REPORT_SIZE (1)             75 01
  REPORT_COUNT (2)            95 02
  USAGE (Volume Increment)    09 E9    // Volume Up
  USAGE (Volume Decrement)    09 EA    // Volume Down
  INPUT (Data,Var,Abs)        81 02
  USAGE_PAGE (Telephony)      05 0B
  REPORT_COUNT (1)            95 01
  USAGE (Flash)               09 21    // Center
  INPUT (Data,Var,Abs)        81 02
  REPORT_SIZE (5)             75 05
  REPORT_COUNT (1)            95 01
  INPUT (Cnst, Var, Abs)      81 03
END_COLLECTION                C0
```

Each report is one byte, and each bit corresponds to one of the functions. For example, the following sample reports communicate the referenced button having been pressed:

- `0x01` for volume up.
- `0x02` for volume down.
- `0x04` for center.

39.2.2 Headset Remote Example HID Report Descriptor (Media Playback)

The following sample HID descriptor demonstrates how to implement media playback controls.

```
USAGE PAGE (Consumer Devices) 05 0C
USAGE (Consumer Control)      09 01
COLLECTION (Application)      A1 01
  LOGICAL MINIMUM (0)         15 00
```

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```
  LOGICAL MAXIMUM (1)         25 01
  REPORT SIZE (1)             75 01
  REPORT COUNT (7)            95 07
  USAGE (Scan Next Track)     09 B5    // Transport Right
  USAGE (Scan Previous Track) 09 B6    // Transport Left
  USAGE (Mute)                09 E2    // Mute
  USAGE (Shuffle)             09 B9    // Shuffle
  USAGE (Repeat)              09 BC    // Repeat
  USAGE (Promote)             0A 5B 02 // Play More Like This
  USAGE (Demote)              0A 5C 02 // Play Less Like This
  INPUT (Data,Var,Abs)        81 02
  REPORT COUNT (1)            95 01
  INPUT (Cnst,Var,Abs)        81 03
END COLLECTION                C0
```

Each report is one byte, and each bit corresponds to one of the functions. For example, the following sample reports communicate the referenced button having been pressed:

- `0x01` for transport right.
- `0x02` for transport left.
- `0x04` for mute.

39.2.3 Headset Remote Example HID Report Descriptor (Telephony and Media Playback)

The following sample HID descriptor demonstrates how to implement all possible media playback controls along with the same controls found on the Apple headset remote.

```
USAGE_PAGE (Consumer Devices) 05 0C
USAGE (Consumer Control)      09 01
COLLECTION (Application)      A1 01
  LOGICAL_MINIMUM (0)         15 00
  LOGICAL_MAXIMUM (1)         25 01
  REPORT_SIZE (1)             75 01
  REPORT_COUNT (9)            95 09
  USAGE (Scan Next Track)     09 B5    // Transport Right
  USAGE (Scan Previous Track) 09 B6    // Transport Left
  USAGE (Mute)                09 E2    // Mute
  USAGE (Shuffle)             09 B9    // Shuffle
  USAGE (Repeat)              09 BC    // Repeat
  USAGE (Promote)             0A 5B 02 // Play More Like This
  USAGE (Demote)              0A 5C 02 // Play Less Like This
  USAGE (Volume Increment)    09 E9    // Volume Up
  USAGE (Volume Decrement)    09 EA    // Volume Down
  INPUT (Data,Var,Abs)        81 02
  USAGE_PAGE (Telephony)      05 0B
  REPORT_COUNT (1)            95 01
  USAGE (Flash)               09 21    // Center
  INPUT (Data,Var,Abs)        81 02
  REPORT_SIZE (6)             75 06
```

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```
  REPORT_COUNT (1)            95 01
  INPUT (Cnst, Var, Abs)      81 03
END COLLECTION                C0
```

Each report is two bytes. The bits are assigned top-to-bottom (from 'Transport Right' to 'Center'). For example, the following sample reports communicate the referenced button having been pressed:

- `0x0100` for transport right.
- `0x0200` for transport left.
- `0x0400` for mute.
- `0x8000` for volume up.
- `0x0001` for volume down.
- `0x0002` for center.

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40. Location Information

Location features enable accessories to provide Global Navigation Satellite System (GNSS) and sensor data (for example, speed) to devices in the form of National Marine Electronics Association (NMEA) sentences. Devices can use the additional information to augment built-in location services. For example, some external accessories provide more accurate or more frequent position updates. Additionally, devices can conserve power by using location information from a self-powered external accessory.

See the Accessory Interface Specification (page 22) for more information.

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41. MagSafe Attach

Devices supporting MagSafe Attach:

- iPhone Duo
- iPhone 18 Pro Max
- iPhone 18 Pro
- iPhone 17e
- iPhone 17 Pro Max
- iPhone 17 Pro
- iPhone 17
- iPhone Air
- iPhone 16 Pro Max
- iPhone 16 Pro
- iPhone 16 Plus
- iPhone 16
- iPhone 15 Pro Max
- iPhone 15 Pro
- iPhone 15 Plus
- iPhone 15
- iPhone 14 Pro Max
- iPhone 14 Pro
- iPhone 14 Plus
- iPhone 14
- iPhone 13 Pro Max
- iPhone 13 Pro
- iPhone 13
- iPhone 13 mini
- iPhone 12 Pro Max
- iPhone 12 Pro
- iPhone 12
- iPhone 12 mini

MagSafe Cases (page 29) shall:

- Claim compatibility with a MagSafe-capable device.
- Integrate a MagSafe Case Magnet Array (page 264).

Other MagSafe accessories shall:

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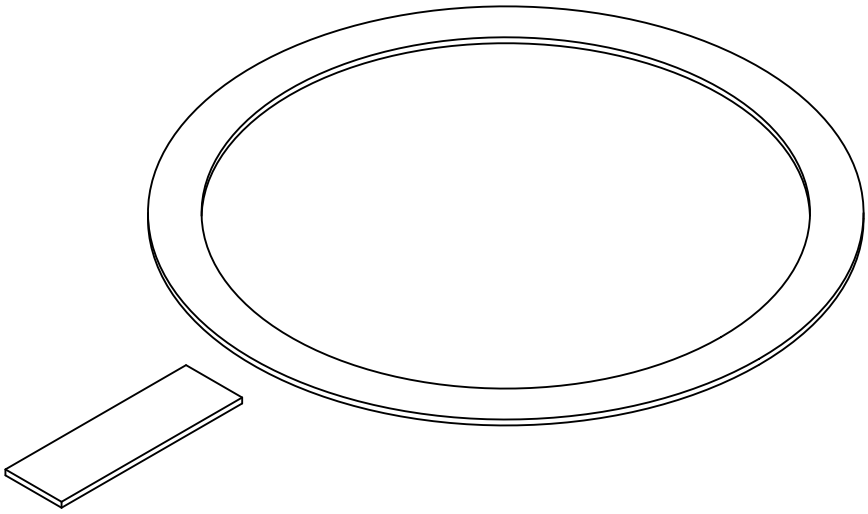
- Claim compatibility with a MagSafe-capable device.
- Integrate a MagSafe Accessory Magnet Array (page 268).

Apple recommends the following magnet array vendors:

- Baotou INST Magnetic New Materials Co., Ltd. (https://www.instmagnets.com)
- Ningbo Sanhuan Magsound Industry & Trade Co., Ltd. (https://www.magsound.com)
- Quadrant Solutions, Inc. (https://www.quadrant.us)

41.1 MagSafe Case Magnet Array

Figure 41-1 MagSafe case magnet array



41.1.1 Product Design

Cases integrating a MagSafe case magnet array shall:

- Enclose the device.
- Have a uniform thickness no greater than 2.1 mm; Apple recommends 2.0 mm.
- Firmly attach to the device without relying on the magnets.
- Not integrate magnets on the back of the case other than the MagSafe magnets.
- Comply with requirements for Cases (page 29).
- Work with:
  - Apple MagSafe Charger.

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- iPhone FineWoven Wallet with MagSafe.

41.1.2 Mechanical

Magnets in the MagSafe case magnet array shall be positioned in the same plane.

The case and MagSafe case magnet array shall enable MagSafe accessories to magnetically self align within a 1.55 mm radial maximum.

41.1.2.1 Magnets

MagSafe case magnets shall be N45SH NdFeB with an 8–16 µm epoxy coating (or similar non-metallic coating) and shall meet the requirements in Table 41-1 (page 265). A reference design is provided for how to achieve the desired retention force for MagSafe accessories, see Figure 41-3 (page 267).

Table 41-1 Magnet properties

Property	Minimum	Maximum
Br	13.2 kGs	13.6 kGs
Hcb	12.75 kOe	
Hcj	20.50 kOe	
BHmax	43 MGOe	46 MGOe

Cases shall not exceed a surface gauss of 0.215 T on either the interior (contacting the device) or exterior (contacting MagSafe accessories) surface of the case.

41.1.2.2 Magnet Array

The magnets shall be positioned in the case following the dimensions and polarity shown in Figure 41-2 (page 266), Figure 41-3 (page 267), and Figure 41-4 (page 267).

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Figure 41-2 MagSafe magnet array dimensions

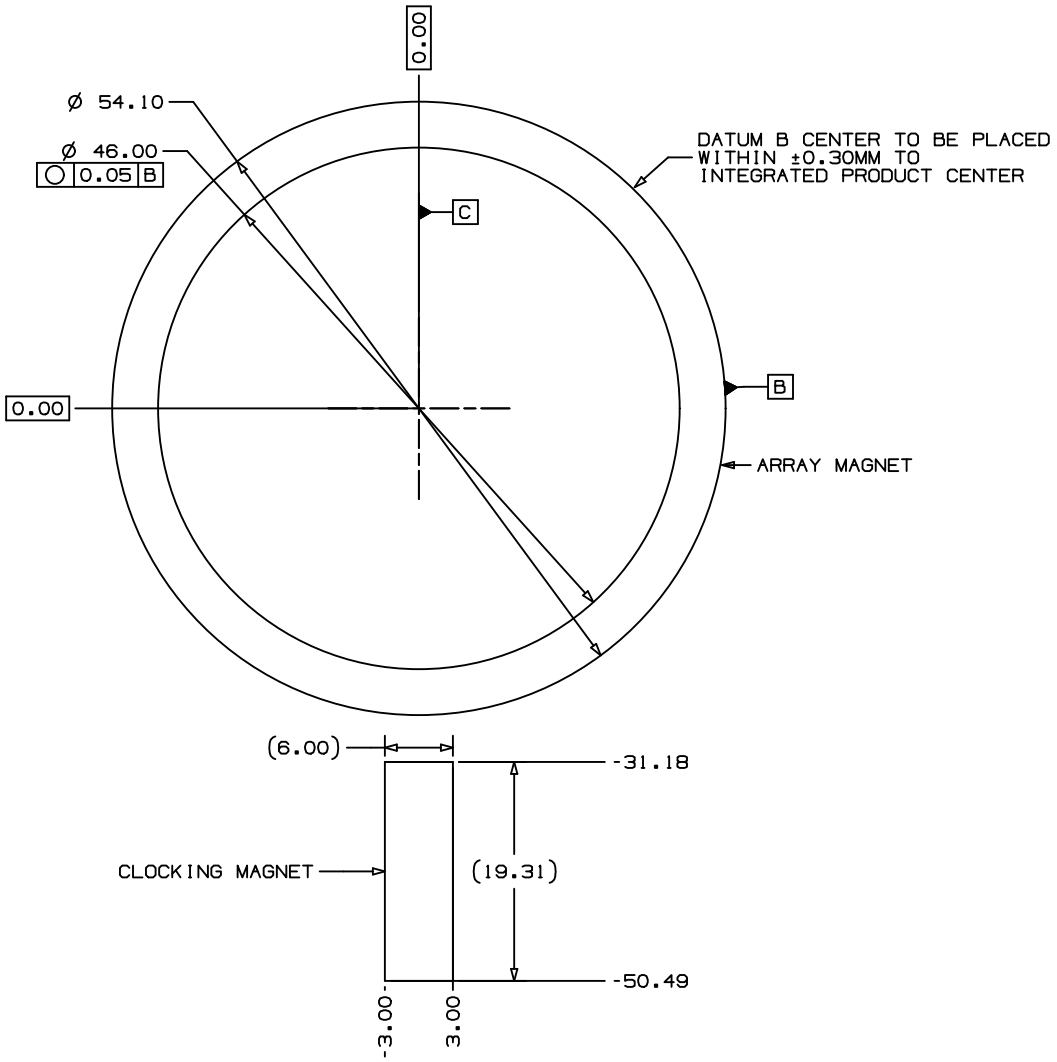


Figure 41-3 MagSafe magnet ring dimensions and polarity

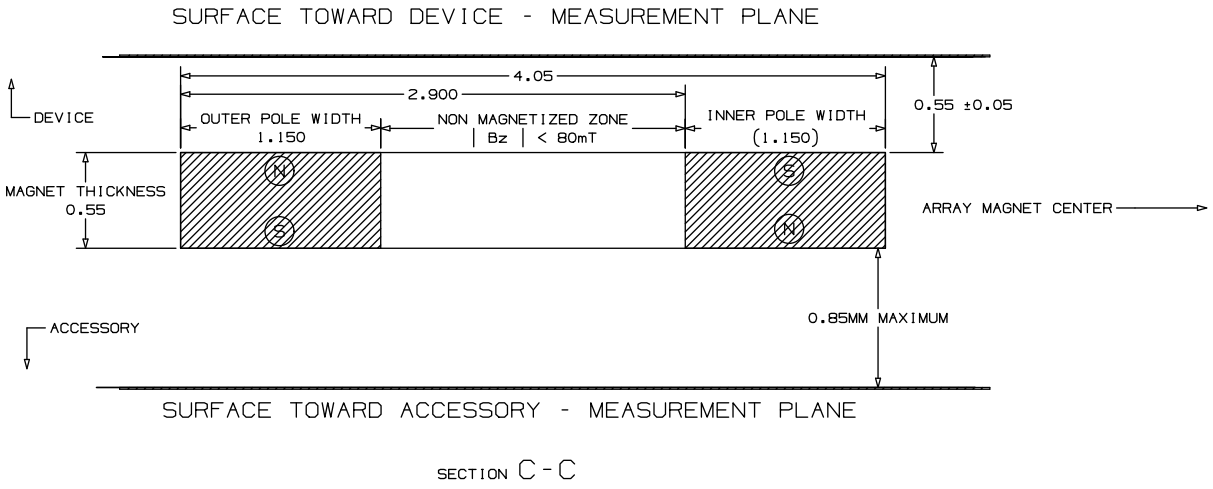
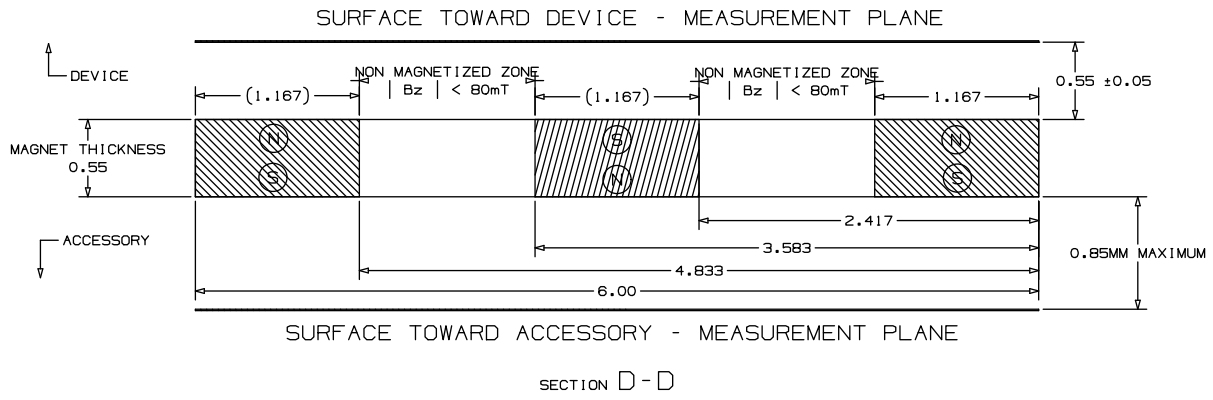


Figure 41-4 MagSafe orientation magnet dimensions and polarity



41.1.2.3 Magnetic Force

The force normal to the back of the case needed to dislodge a MagSafe accessory, such as the Apple MagSafe Charger, shall have a nominal target between 1000 gf and 1300 gf when the case is attached to the device.

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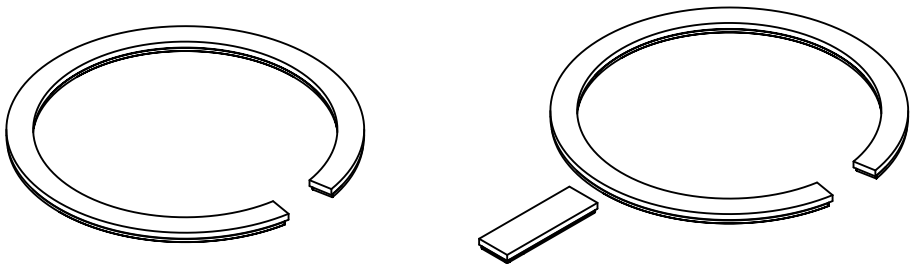
41.1.3 Magnetic Interference

Cases with an integrated MagSafe magnet array shall not interfere with:

- Inductive charging.
- Magnetic stripe cards in an attached iPhone FineWoven Wallet with MagSafe.

41.2 MagSafe Accessory Magnet Array

Figure 41-5 MagSafe accessory magnet array options



The MagSafe accessory magnet array shall implement one of the following magnet array configurations:

- Magnet Ring (page 270): This configuration allows the accessory to attach in any rotational orientation.
- Extended Magnet Ring (page 272): Apple recommends this configuration, which provides a higher attachment force.

An Orientation Magnet (page 274) may be included in either of the above array configurations to enforce a specific attachment orientation.

41.2.1 Product Design

Accessories integrating the MagSafe accessory magnet array shall not enclose the device.

41.2.2 Mechanical

Accessories shall:

- Not interfere with or cause Scratches and Damage (page 24) to the device.
- Maintain sufficient Clearance (page 269).

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Magnets in the MagSafe accessory magnet array shall be positioned in the same plane.

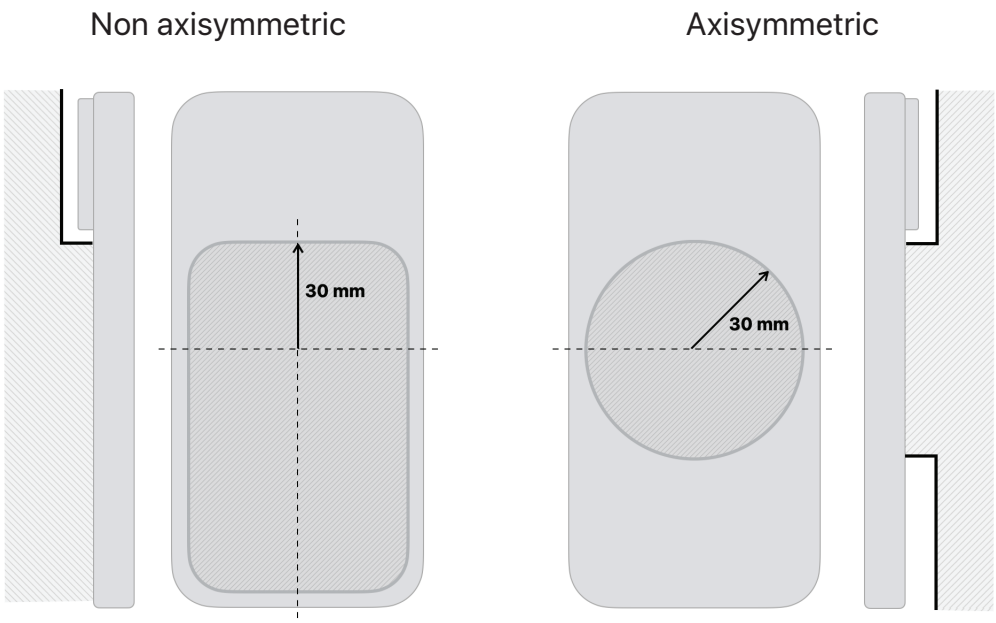
The MagSafe accessory's Magnet Ring (page 270) or Extended Magnet Ring (page 272) shall magnetically self align to the device's magnet ring within a 1.55 mm radial maximum.

41.2.2.1 Clearance

To avoid interference with devices, the accessory's magnetic attach surface shall:

- Not exceed 30 mm from the center of the magnet ring towards the top edge of the device for all supported device orientations. If the device can be attached in any orientation, the accessory shall not exceed 30 mm radius around the center of the magnet ring.
- Maintain a clearance of 6 mm for any part of the accessory past the 30 mm keep-in constraint.
- Stay within the MagSafe Accessory Enclosure Geometry (page 277).

Figure 41-6 MagSafe accessory clearance



41.2.2.2 Magnets

MagSafe accessory magnets shall be N48H NdFeB with a 7–13 µm NiCuNi plating finish (or similar) and shall meet the requirements in Table 41-2 (page 270).

Table 41-2 Magnet properties

Property	Minimum	Maximum
Br	13.7 kGs	14.1 kGs
Hcb	13.25 kOe	
Hcj	17 kOe	
BHmax	45 MGOe	48 MGOe

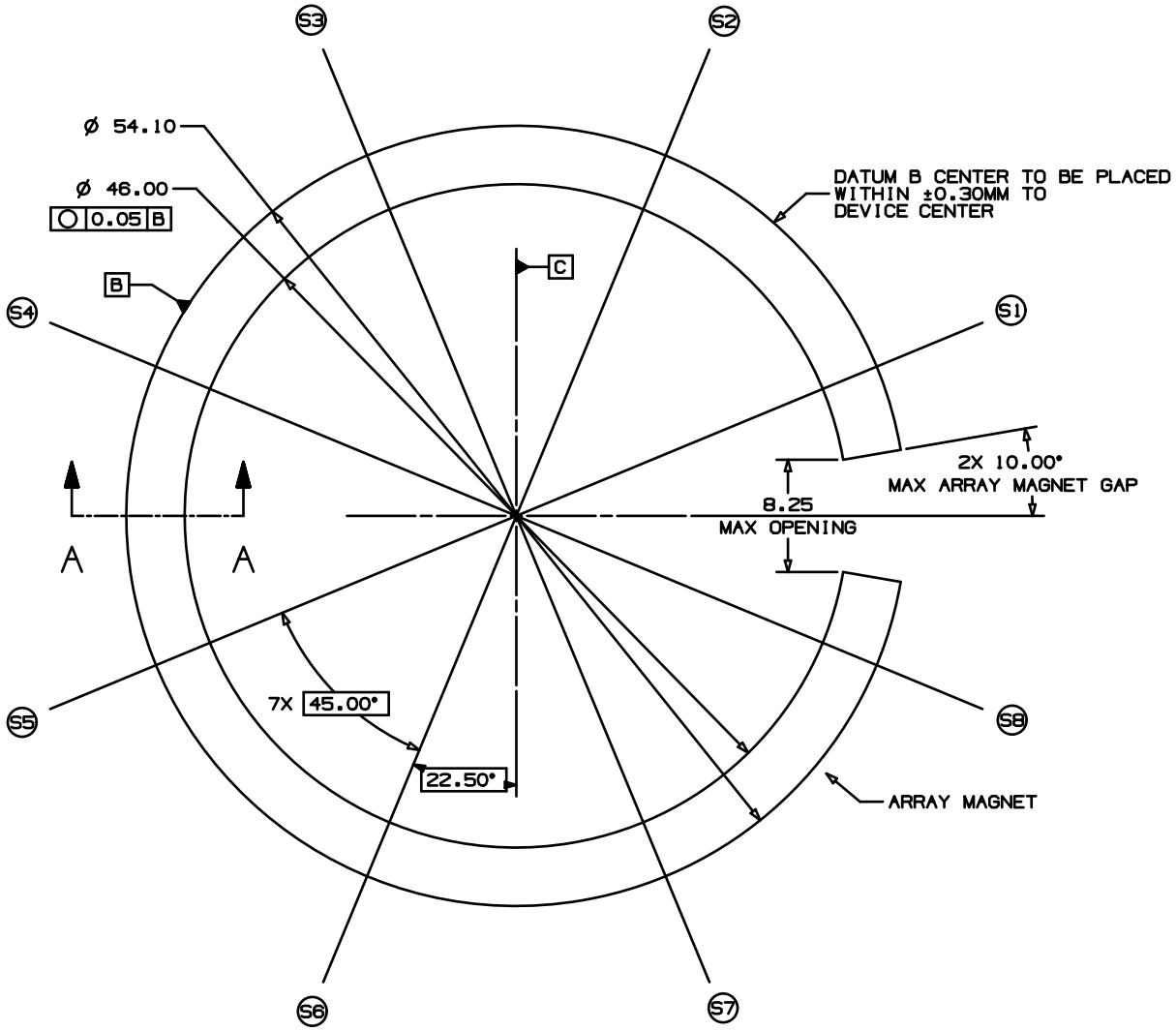
Flux density of the MagSafe accessory shall not exceed 0.215 T at the product surface.

41.2.2.3 Magnet Ring

The magnet ring shall be positioned in the accessory in compliance with the dimensions and polarity requirements in Figure 41-7 (page 271) and Figure 41-8 (page 272).

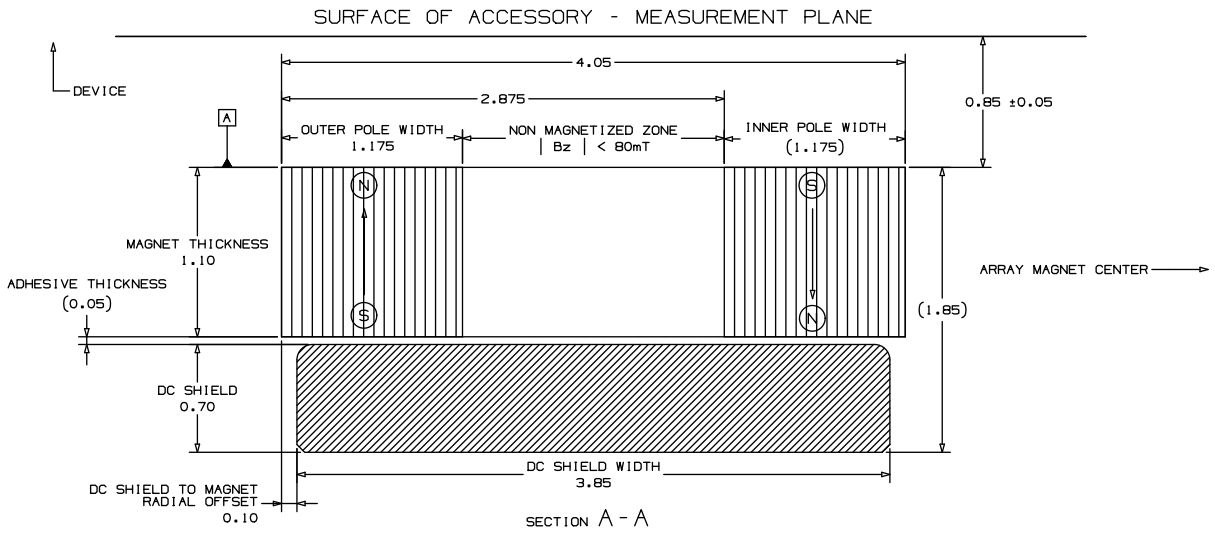
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Figure 41-7 MagSafe magnet ring dimensions



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Figure 41-8 MagSafe magnet ring dimensions and polarity



See DC Shield (page 276) for additional requirements of the DC shield specified in Figure 41-8 (page 272).

41.2.2.4 Extended Magnet Ring

The magnet ring shall be positioned in the accessory in compliance with the dimensions and polarity requirements in Figure 41-9 (page 273) and Figure 41-10 (page 273).

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Figure 41-9 MagSafe extended magnet ring dimensions

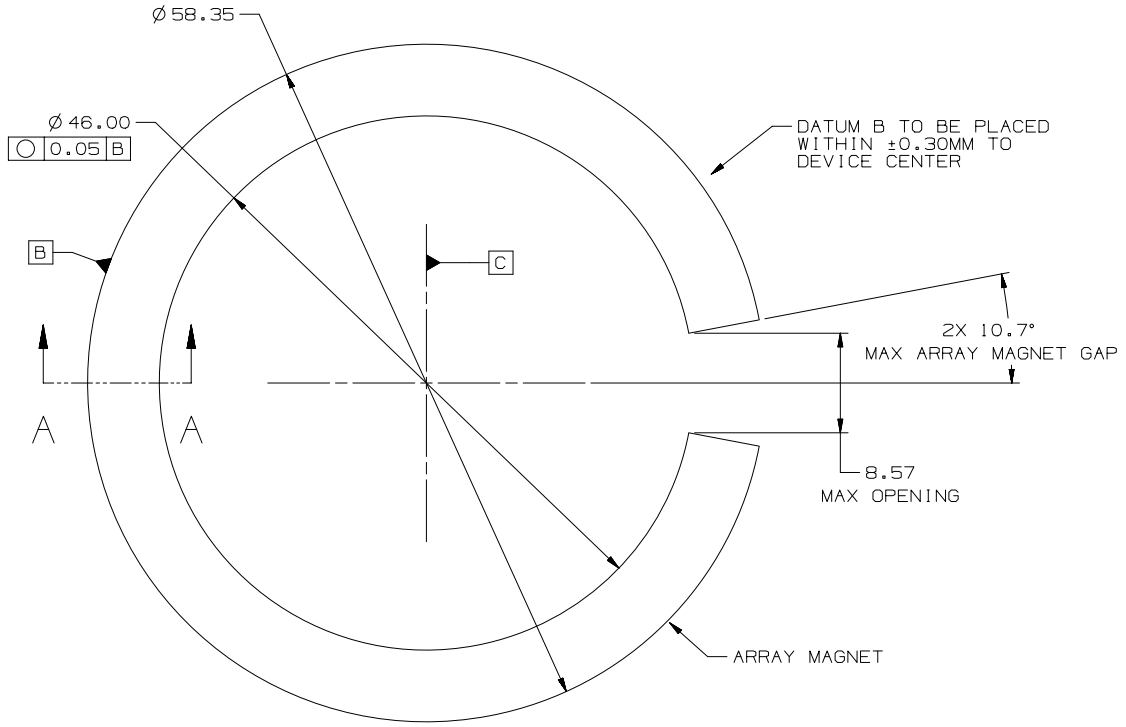
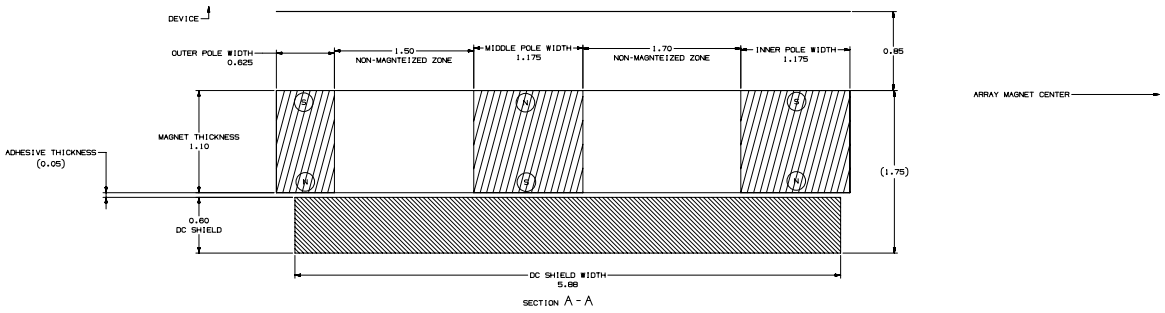


Figure 41-10 MagSafe extended magnet ring dimensions and polarity



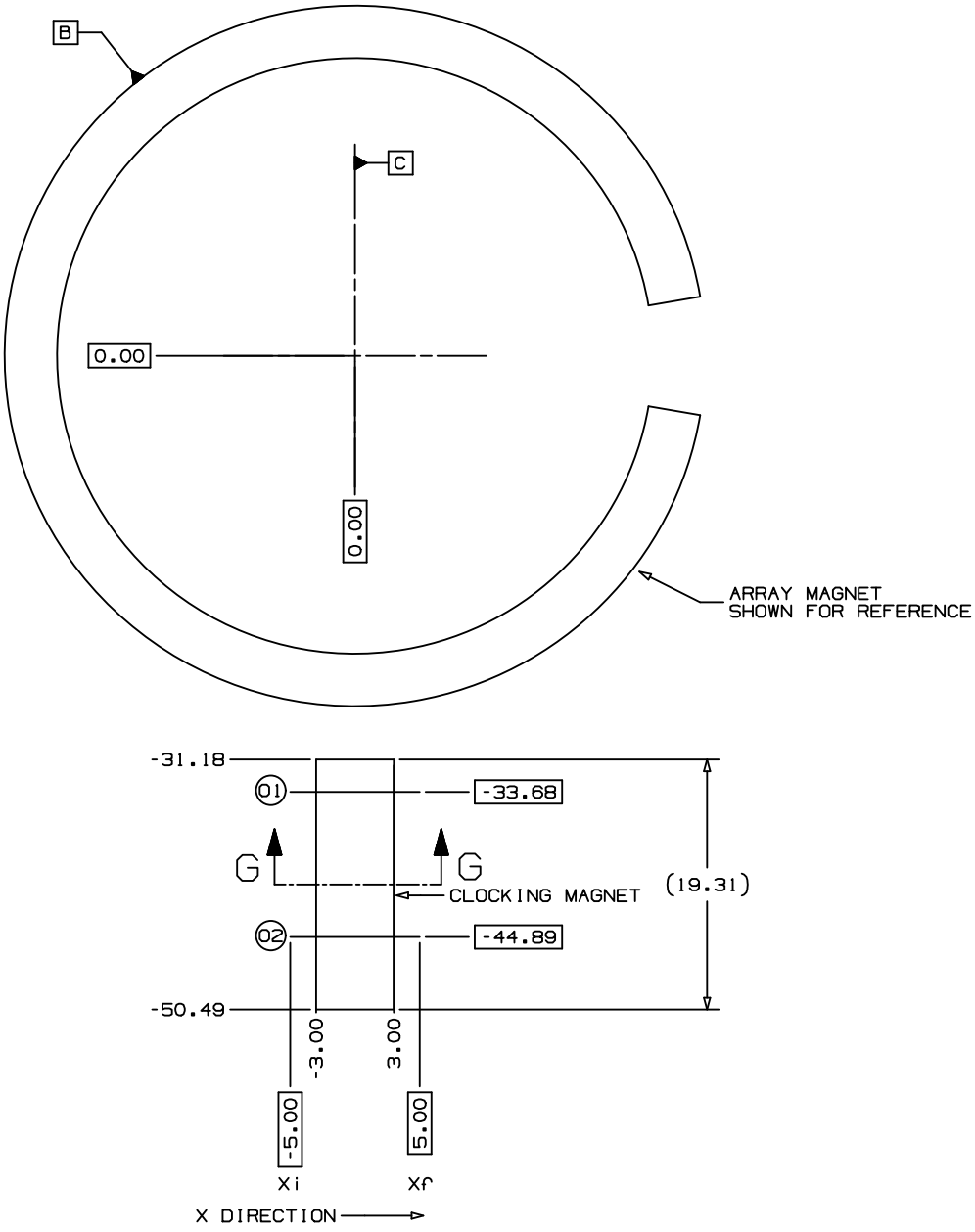
See DC Shield (page 276) for additional requirements of the DC shield specified in Figure 41-10 (page 273).

41.2.2.5 Orientation Magnet

If orientation magnets are included, the magnets shall be positioned according to Figure 41-11 (page 275) and Figure 41-12 (page 276).

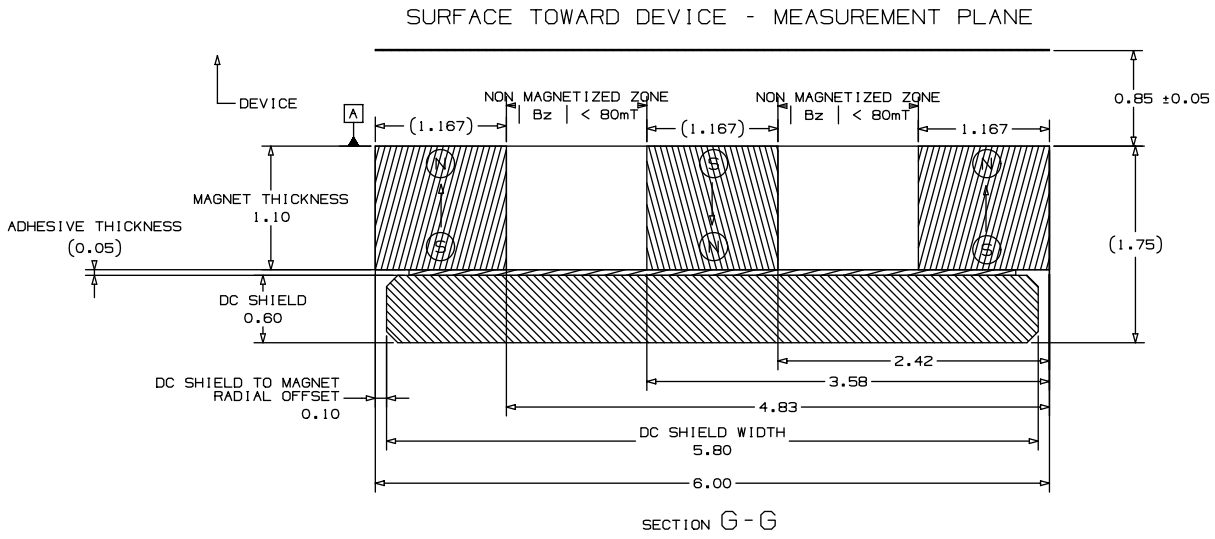
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Figure 41-11 MagSafe orientation magnet dimensions



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Figure 41-12 MagSafe orientation magnet dimensions and polarity



See DC Shield (page 276) for additional requirements of the DC shield specified in Figure 41-12 (page 276).

41.2.2.6 Magnetic Force

The force normal to the back of the device needed to dislodge the MagSafe accessory shall meet the requirements in Table 41-3 (page 276).

Table 41-3 Magnetic force

Scenario	Minimum	Maximum
Accessory attached to device	650 gf	1510 gf

41.2.2.7 DC Shield

The DC shield shall be low-carbon steel (1010, DT4, or similar), per *ASTM A848*, with a 5–10 µm Ni plating finish or similar.

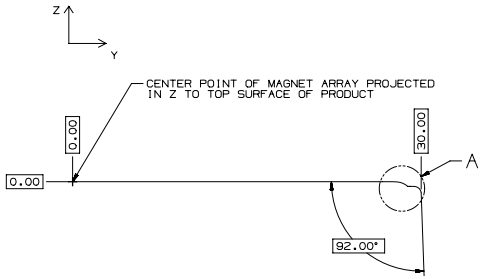
The DC shield shall have a saturation flux density (B_{sat}) of at least 2.0 T.

41.3 MagSafe Accessory Enclosure Geometry

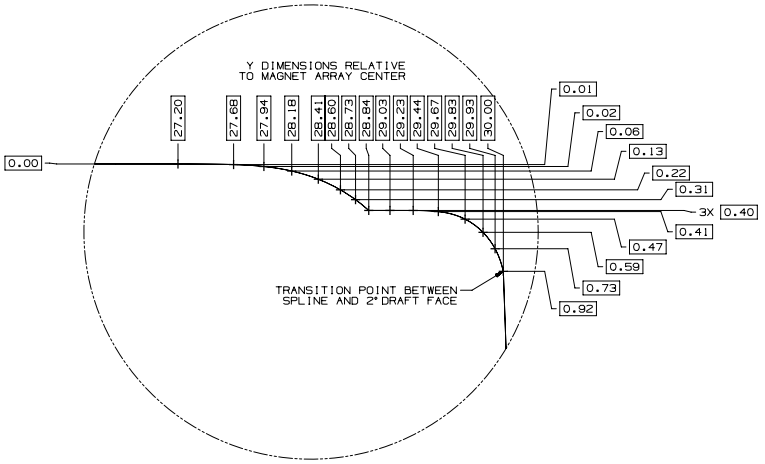
REV	ECO#	DESCRIPTION OF REVISION

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. SPLINE REPRESENTS MAX MATERIAL CONDITION FOR AN EXTERIOR PRODUCT SURFACE. MAGSAFE COMPATIBLE ACCESSORIES SHALL STAY WITHIN THE PROVIDED SPLINE.
2. FOR NON AXISYMMETRIC APPLICATIONS, SPLINE REPRESENTS MAX MATERIAL CONDITION WHEN VIEWED ALONG X AXIS
3. FOR AXISYMMETRIC APPLICATIONS, A REVOLUTION OF THE SPLINE AROUND THE Z AXIS THROUGH THE CENTER POINT OF THE MAGNET ARRAY REPRESENTS THE MAX MATERIAL CONDITION



SIDE VIEW PROJECTION OF POSTIVE Y PRODUCT EDGE (CUT IN X AT MAGNET ARRAY CENTER POINT)



DETAIL A
SCALE 50:1

METRIC	Apple Inc.
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DESIGNER: APPLE — DATE	
DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE: MAGSAFE COMPATIBLE ENCLOSURE GEOMETRY
	DRAWING NUMBER — REV. 01
DO NOT SCALE DRAWINGS	
THIRD ANGLE PROJECTION — SIZE D	SCALE NONE — SHT 1 OF 1

NX GENERATED

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41.4 Verification

41.4.1 MagSafe Case Magnet Array

41.4.1.1 Case Thickness

41.4.1.1.1 Equipment

The following equipment is necessary:

- Digital thickness gauge, such as the Mitutoyo 547-520S.

41.4.1.1.2 Procedure

1. Using the digital thickness gauge, verify the thickness is less than or equal to 2.1 mm at:
   - Four points along the magnet ring.
   - Two points along the orientation magnet.

41.4.1.2 Accessory Clearance

41.4.1.2.1 Equipment

The following equipment is necessary:

- MagSafe-capable device.
- Apple MagSafe Battery Pack.

41.4.1.2.2 Procedure

1. Attach the case to the device.
2. Attach the Apple MagSafe Battery Pack to the back of the case.
3. Verify the case does not interfere with the Apple MagSafe Battery Pack and only the mating surface is in contact.

41.4.1.3 Magnetic Force

41.4.1.3.1 Equipment

The following equipment is necessary:

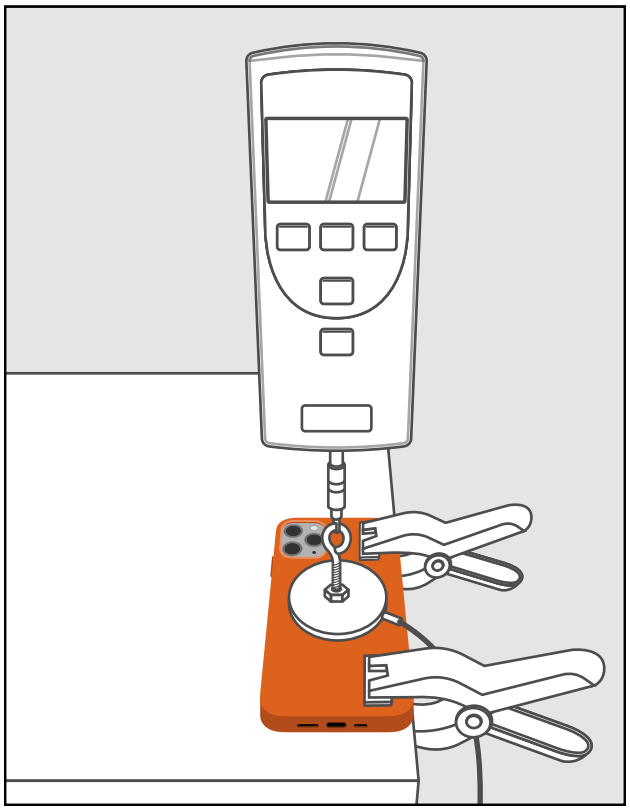
- MagSafe-capable device.
- Apple MagSafe Charger.
- Non-magnetic eyelet screw.

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- Digital force gauge capable of capturing peak values, such as the Chatillon DFX II.
- Hook attachment for digital force gauge.
- Clamps to securely hold the device on a flat level surface.

41.4.1.3.2 Setup

Figure 41-13 Magnetic force test setup



1. Attach the case to the device.
2. Place the device on a flat level surface with the display facing down and clamp it firmly in place.
3. Glue the non-magnetic eyelet to the center of the back of the Apple MagSafe Charger so pulling on the eyelet exerts a force on the center of the charger.

41.4.1.3.3 Procedure

1. Repeat the following steps 5 times:
   a. Attach the Apple MagSafe Charger and eyelet assembly to the back of the case, allowing them to magnetically align.
   b. Connect the force gauge hook to the eyelet.

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c. Reset the force gauge's peak force value.
d. Pull the force gauge vertically until the Apple MagSafe Charger and eyelet assembly dislodge from the case.
e. Note the peak value from the force gauge.

2. Calculate the average of the 5 peak force measurements.
3. Verify the average force, after removing the mass of the Apple MagSafe Charger and eyelet assembly, is within the range specified in Magnetic Force (page 267).

41.4.1.4 iPhone FineWoven Wallet with MagSafe Detection

41.4.1.4.1 Equipment

The following equipment is necessary:

- MagSafe-capable device.
- iPhone FineWoven Wallet with MagSafe.

41.4.1.4.2 Procedure

1. Attach the case to the device.
2. Attach the wallet to the back of the case.
3. Verify the device displays the wallet animation.

41.4.1.5 Magnetic Stripe Cards in iPhone FineWoven Wallet with MagSafe

41.4.1.5.1 Equipment

The following equipment is necessary:

- MagSafe-capable device.
- iPhone FineWoven Wallet with MagSafe.
- Low Coercivity Magnetic stripe (LoCo) cards, such as cards from the following vendors:
  - American Card Service.
  - Allsafe.
  - CI Solutions.
  - PSA.
- LoCo card reader/writer, such as:
  - Q-card Mag3x.
  - Magtek InSpec 9000.
  - Misiri X6BT.
  - Deftun MSR605X.

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41.4.1.5.2 Procedure

1. Attach the accessory to the device.
2. Repeat this procedure for three different brands of LoCo cards:
   a. Write to the LoCo card.
   b. Read from the LoCo card and verify it was written successfully.
   c. Insert the LoCo card into the wallet with the magnetic stripe facing the magnets.
   d. Place additional cards into the wallet to ensure a LoCo card is in contact with the magnetic side of the wallet.
   e. Attach the wallet to the accessory (attached to the device).
   f. Wait 10 seconds.
   g. Remove the wallet from the accessory.
   h. Remove the LoCo card from the wallet.
   i. Verify the LoCo card is readable and its contents have not changed.

41.4.2 MagSafe Accessory Magnet Array

41.4.2.1 Orientation Magnet

If the accessory includes an orientation magnet:

1. Use a straight edge to verify the device contact surfaces of the magnet ring and orientation magnet are coplanar (aligned in the same plane).
2. Attach a MagSafe-capable device to the accessory and align it with the orientation magnet. Verify there are no gaps between the:
   - MagSafe magnet ring and device.
   - MagSafe orientation magnet and device.

41.4.2.2 Magnetic Force

41.4.2.2.1 Equipment

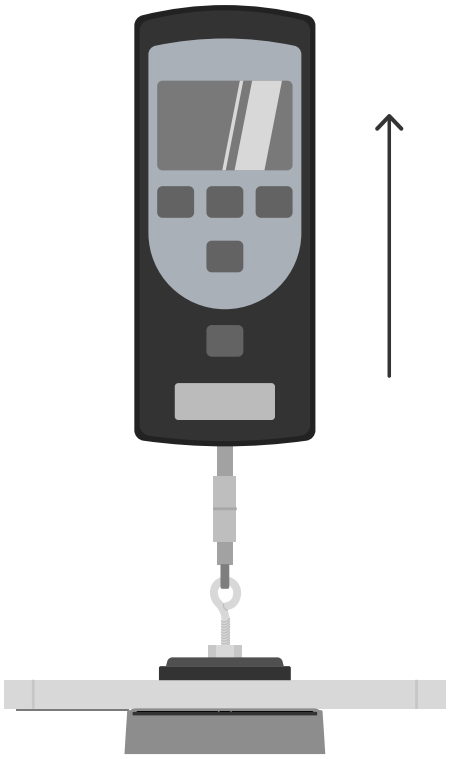
The following equipment is necessary:

- MagSafe-capable device.
- Non-magnetic eyelet to attach to the device.
- Digital force gauge capable of capturing peak values, such as the Chatillon DFX II.
- Hook attachment for digital force gauge.
- Clamps, or a vice, to securely hold the accessory on a flat level surface.

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41.4.2.2.2 Setup

Figure 41-14 Magnetic force test setup



1. Clamp the accessory in place so the MagSafe surface is level.
2. Attach the non-magnetic eyelet to the MagSafe-capable device so pulling on the eyelet exerts a force on the center of the back of the device. A bracket, strong suction cup, or glue may be used.

41.4.2.2.3 Procedure

1. Repeat the following steps 5 times:
   a. Attach the device and eyelet assembly to the accessory, allowing them to magnetically align.
   b. Connect the force gauge hook to the eyelet.
   c. Reset the force gauge's peak force value.
   d. Pull the force gauge vertically until the device and eyelet assembly dislodge from the accessory.
   e. Note the peak value from the force gauge.
2. Calculate the average of the 5 peak force measurements.
3. Verify the average force, after removing the mass of the device and eyelet assembly, is within the range specified in Table 41-3 (page 276).

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42. Media Library Access

The Media Library feature allows accessories to download the metadata contents of a device's media libraries (not the media items themselves) and request playback of media items. The feature is divided into the following sub-features:

- Media Library Information informs the accessory about media libraries available on the device.
- Media Library Updates provide an accessory with an updated view of the contents of a particular media library.
- Media Library Playback allows the accessory to request playback of one or more items from a media library.

See the Accessory Interface Specification (page 22) for more information.

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43. Musical Instrument Digital Interface (MIDI)

Compatible USB and Bluetooth Low Energy MIDI accessories can interface directly with apps using the Core MIDI framework, see https://developer.apple.com/documentation/coremidi.

43.1 Requirements

Accessories supporting MIDI as a USB device shall implement a MIDI Streaming IN endpoint and shall support either:

- *USB Device Class Definition for MIDI Devices – Version 2.0*, see https://www.usb.org/document-library/usb-class-definition-midi-devices-v20.
- *USB Device Class Definition for MIDI Devices – Release 1.0*, see https://www.usb.org/document-library/usb-midi-devices-10.

Accessories supporting MIDI over Bluetooth Low Energy shall support:

- *MIDI Association MIDI over Bluetooth Low Energy (BLE-MIDI) – Version 1.0a*, see https://midi.org/midi-over-bluetooth-low-energy-ble-midi.

43.2 Verification

Developers should test accessory designs against macOS 27.2 using the Audio MIDI Setup app and its MIDI Studio and Test MIDI Setup features. See the user guide at https://support.apple.com/guide/audio-midi-setup/welcome/mac.

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44. Now Playing Updates

The Now Playing feature enables an accessory to display information about the current "Now Playing" media source and media item on a device. Media sources include both the built-in Apple Music and Apple TV apps on devices and certain third-party iOS apps supporting the generation of Now Playing metadata, see *MPNowPlayingInfoCenter* in the iOS SDK documentation. Accessories shall be prepared for the Now Playing media source and media item to change at any time, whether the accessory requested the change or not.

See the Accessory Interface Specification (page 22) for more information.

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45. Out-of-Band Bluetooth Pairing

Accessories with the ability to connect to a device using Bluetooth and a wired transport should use the Out-of-Band Bluetooth Pairing feature to simplify Bluetooth connection setup.

For example, USB to Lightning charge cables or Lightning to USB accessory cables can be used to exchange Bluetooth pairing information upon initial connection. This may reduce or eliminate the need for instruction manuals to describe how to:

- Put the accessory into a discoverable and pairable mode.
- Initiate Bluetooth pairing on the device using the Settings app.
- Download the accessory's companion app and initiate pairing from the app.

See the Accessory Interface Specification (page 22) for more information.

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46. Siri

Siri enables a user to have rich interactions with a device by primarily using their voice.

Accessories supporting Siri over Bluetooth using HFP commands shall not use an icon resembling the Siri microphone icon.

To support Siri using other transports and protocols, the accessory developer shall be a member of the Apple MFi Program (page 22).

46.1 Enabling Custom Siri Commands

Accessories supporting Siri over Bluetooth using HFP commands shall support HFP Command AT+XAPL (page 240). The device will use the information sent by this command to enable and disable custom commands related to Siri.

To receive Siri status events, the accessory shall send the AT+XAPL command after making a successful HFP Service Level Connection (SLC) to the device. The accessory should send an AT+XAPL command first, before sending any of the additional Siri-specific commands described below.

46.2 Obtaining Siri Availability Information

After establishing an HFP profile connection, an accessory can determine if Siri is available and enabled on a device. It can also receive notifications of changes in Siri status. If Siri is disabled, Voice Control will be activated instead.

46.2.1 Obtaining Status Information at Connection

The accessory should send the following command after making a successful HFP profile (SLC) connection and sending an AT+XAPL command.

46.2.1.1 HFP Command AT+APLSIRI?

Description: An accessory sends this command to retrieve Siri status information.

Initiator: Accessory

Format: `AT+APLSIRI?`

Response: `+APLSIRI:` *value*

Defined Values:
- 0 = Siri is not available on this platform.
- 1 = Siri is available and enabled.
- 2 = Siri is available but not enabled.

Example: `+APLSIRI:1` (Siri is available and enabled)

46.2.2 Receiving Siri Availability Updates from the Device

After initialization has been completed, the device will send the accessory the following notification if there is a change in Siri status. This notification will be provided only if the accessory has requested Siri status (by sending `AT+APLSIRI?`) at least once after connection and if the device has reported Siri is available and enabled.

46.2.2.1 HFP Command +APLSIRI

Description: Unsolicited event indicating a change in Siri status.

Initiator: Device

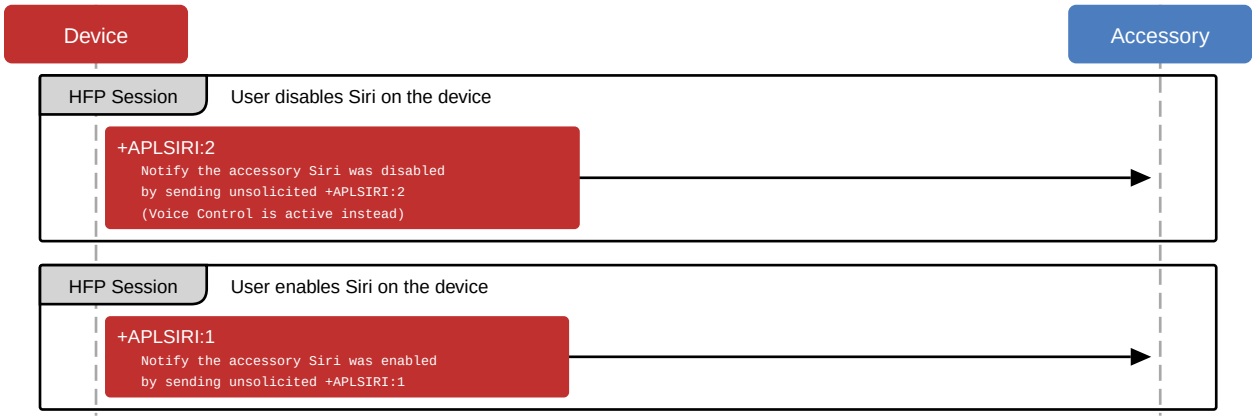
Format: `+APLSIRI:` *value*

Defined Values:
- 1 = Siri is available and enabled.
- 2 = Siri is available but not enabled.

Example: `+APLSIRI:2` (Siri is available but not enabled)

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Figure 46-1 Siri is Disabled/Enabled from the Device's Settings



46.3 Initiating a Siri Session

Once support for Siri is established on both the accessory and the device, a Siri session can be started from either one.

46.3.1 Initiating a Session from the Accessory

The accessory should only initiate a Siri session as a result of a direct user action.

The accessory shall use the voice recognition command AT+BVRA defined in the *Bluetooth Hands-Free Profile Specification – Version 1.6, Section 4.25* to initiate a Siri session.

The HFP profile shall be connected and SLC shall exist.

The accessory should use the following command sequence:

- The accessory sends an AT+BVRA=1 command to the device.
- The device sends an OK response.
- The device activates a Siri session and creates a Synchronous Connection (SCO) for the audio.
- If the Siri session is not finished, the accessory shall send AT+BVRA=1 to continue the conversation. This may need to happen multiple times.
- When the Siri session is finished, the device sends a +BVRA:0 result code to the accessory.
- The device disconnects the SCO connection.

While a Siri session is active, the accessory shall let the user continue the conversation and ask follow up questions within the current context. In order to do so, the accessory shall be able to send an AT+BVRA=1 command to the device even after Siri has been already activated and before +BVRA:0

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is received. Figure 46-2 (page 290) shows an overview of the interaction when Siri is triggered from the accessory, the running session was continued twice and once Siri was finished, the device dismissed the session.

Figure 46-2 Initiating a Siri Session from the Accessory



46.3.2 Initiating a Session from the Device

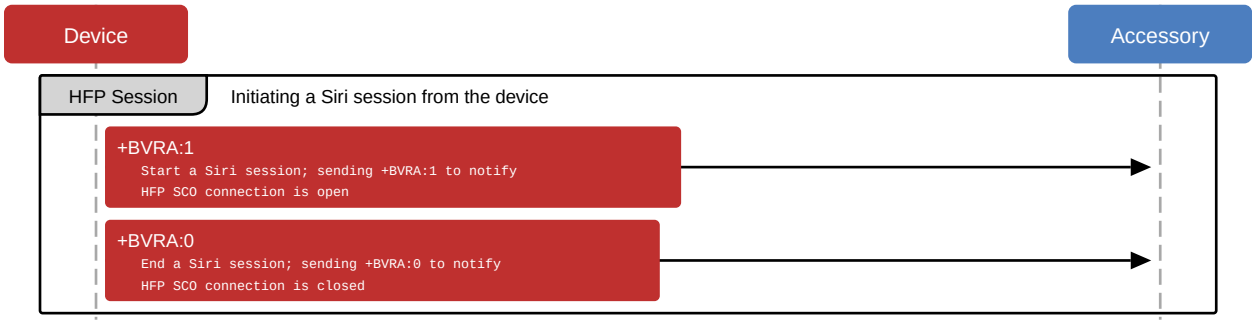
If the accessory supports voice recognition commands, the device sends a +BVRA event to indicate the start of a Siri session. The accessory shall enable support for voice recognition and indicate it in its feature response as described in the *Bluetooth Hands-Free Profile Specification – Version 1.6, Section 4.34.1*. Specifically, the HFP profile shall be connected, SLC shall exist, and voice recognition activation (bit 3) shall be enabled in the AT+BRSF command. The device will not use virtual call functionality for the Siri session if voice recognition activation is supported by the accessory.

The accessory should expect the following command sequence:

- The device sends a +BVRA`:1` event to the accessory.
- The device activates a Siri session and creates a SCO connection for the audio.
- When the Siri session is finished, the device sends a +BVRA`:0` result code to the accessory.
- The device disconnects the SCO connection.

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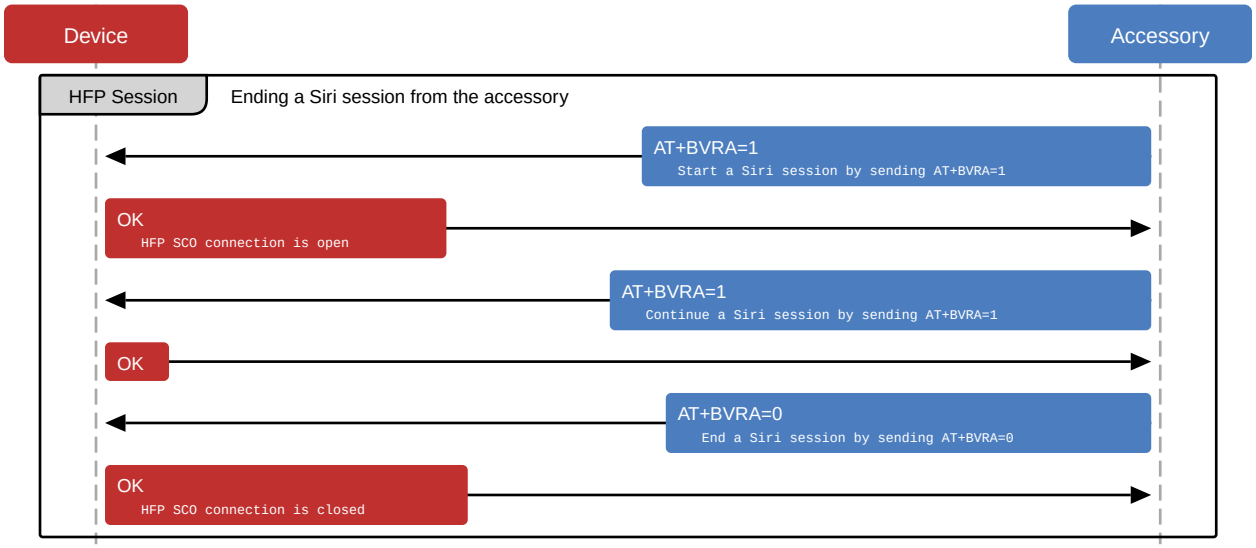
Figure 46-3 Initiating a Siri Session from the Device



46.3.3 Ending a Session from the Accessory

Once a Siri session is running the accessory shall be capable of ending the session by sending an AT+BVRA=0 command to the device. Figure 46-4 (page 291) shows an example of ending a running Siri session from the accessory. The accessory should only end an active session as a result of a direct user action.

Figure 46-4 Ending a Siri Session from the Accessory



46.4 Siri Eyes Free Mode

Siri Eyes Free mode is a feature to control Siri responses including display information and can be enabled or disabled as needed. In Siri Eyes Free mode, the user experience is tailored towards a driving scenario and interactions with Siri are done primarily using voice to minimize the need for the user to look at a screen. Siri Eyes Free mode is supported only for Bluetooth-enabled vehicle entertainment systems and should not be used by any other accessories. Siri Eyes Free should not be triggered using a voice command.

The device will listen for the HFP AT command `AT+APLEFM` to enable or disable Siri Eyes Free mode.

This command is used by the device to modify Siri responses containing visual information or requiring user interaction. Suitable audio feedback and voice commands will be available to the user based on the initiated Siri use case.

Siri Eyes Free mode is disabled by default. Once the accessory has enabled Siri Eyes Free mode, it remains enabled for all subsequent Siri sessions initiated from the accessory until the accessory disables it or the Bluetooth connection is disconnected.

46.4.1 HFP Command AT+APLEFM

Description: An accessory sends this command to notify a device of the preferred state of Siri Eyes Free mode.

Initiator: Accessory

Format: `AT+APLEFM=`*value*

Response: `OK`

Defined Values:

- `0x00` = Disable Siri Eyes Free mode.
- `0x01` = Enable Siri Eyes Free mode.
- `0x02`–`0xFF` = reserved

Example: `AT+APLEFM=1`

46.5 Improving Voice Recognition

The microphone audio an accessory sends to the device during a Siri session should be suitable for voice recognition. Audio requirements for optimal voice recognition may differ from requirements for optimal human perception (for example, during a cellular phone call).

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Filtering of the audio signal to remove echoes or feedback noise is acceptable.

To provide the best possible audio quality as Siri input, the accessory shall observe the following recommendations:

- **Echo cancellation and noise suppression (EC/NR)**: Directional microphones and linear beamforming with microphone arrays giving improved SNR are recommended. Linear echo cancellation for reducing unwanted audio sources (such as audio output from the system) without having any other effect on the speech signal is also recommended. Any approach taken should not have any other effect on the speech signal. Single channel noise reduction methods (such as spectrum subtraction) shall not be applied, as they will be detrimental to the speech recognition accuracy. Similarly, automatic gain control, residual echo suppression and attempts to blank out non-speech periods in the waveform shall not be applied.
- **Signal gain**: When adjusting signal levels, the accessory shall avoid artifacts, dropouts, and clipping in all circumstances. Automatic Gain Control is not recommended. If the accessory adjusts signal gain, the gain should be held constant across each spoken utterance. The nominal level measured at the uplink output of the accessory should be A-weighted -30 dB ±2 dB root-mean-square (RMS), expressed in units relative to full-scale (dBFS(A)). Alternatively, the nominal level may be 13 dB ±2 dB SLR if using the ITU measurement procedure.
- **Signal-to-noise ratio (SNR)**: The average SNR should be greater than 20 dB. Below 20 dB, recognition rates will be impacted.
- **Reverberation**: An RT60 time less than 200 ms should be maintained.

46.5.1 Wide Band Speech Support

An accessory using Siri should support 16 kHz wide band speech audio for better audio quality and voice recognition performance. See the *Bluetooth Hands-Free Profile Specification – Version 1.6* for details about wide band speech audio. A narrow band audio signal (8 kHz) is supported but not recommended.

46.6 Optimizing the Siri Experience

The start of a Siri session should not be accompanied by local beeps or verbal indications (such as an announcement of "...voice dialing...") from the accessory. When a Siri session becomes active, the device sends two beeps indicating Siri is ready to receive instructions. Adding extra audible notifications only inserts delays in the system.

The accessory should wait for the device to end each Siri session.

The accessory should not send an `AT+BVRA=0` command unless it is prompted to do so by user interaction.

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The accessory should be capable of rendering audio within 200 ms of SCO connection activation to ensure the user always hears the Siri introductory beeps.

46.7 Common Siri Applications

Siri can send messages, find points of interests, place phone calls, and much more. As Siri capabilities are constantly growing, additional use cases may become available after the initial integration. In Siri Eyes Free mode, some of these use cases may not be accessible as the user experience is tailored towards a driving scenario.

46.7.1 Initialization Procedure After Connection is Established

Figure 46-5 (page 294) outlines the sequence the accessory has to trigger to be able to use Siri on a device. After establishing an HFP profile connection, the accessory shall first enable the custom Siri commands by sending `AT+XAPL` and provide the features it supports. After a confirmation is received from the device, the accessory should determine Siri's availability with `AT+APLSIRI?`.

Vehicles with Bluetooth-enabled infotainment systems can also enable Siri Eyes Free Mode during initialization. This is detailed in Figure 46-6 (page 295).

Figure 46-5 Siri Initialization Procedure

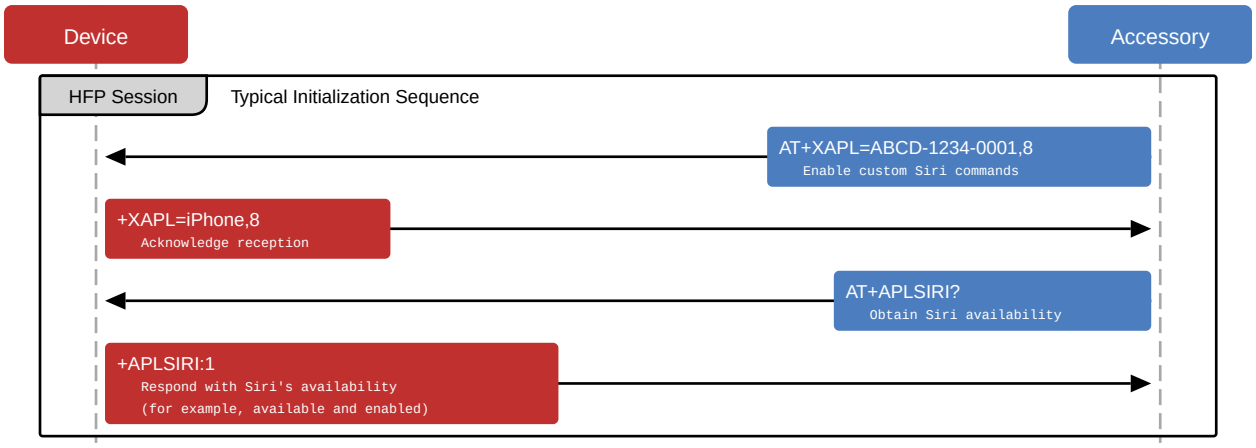
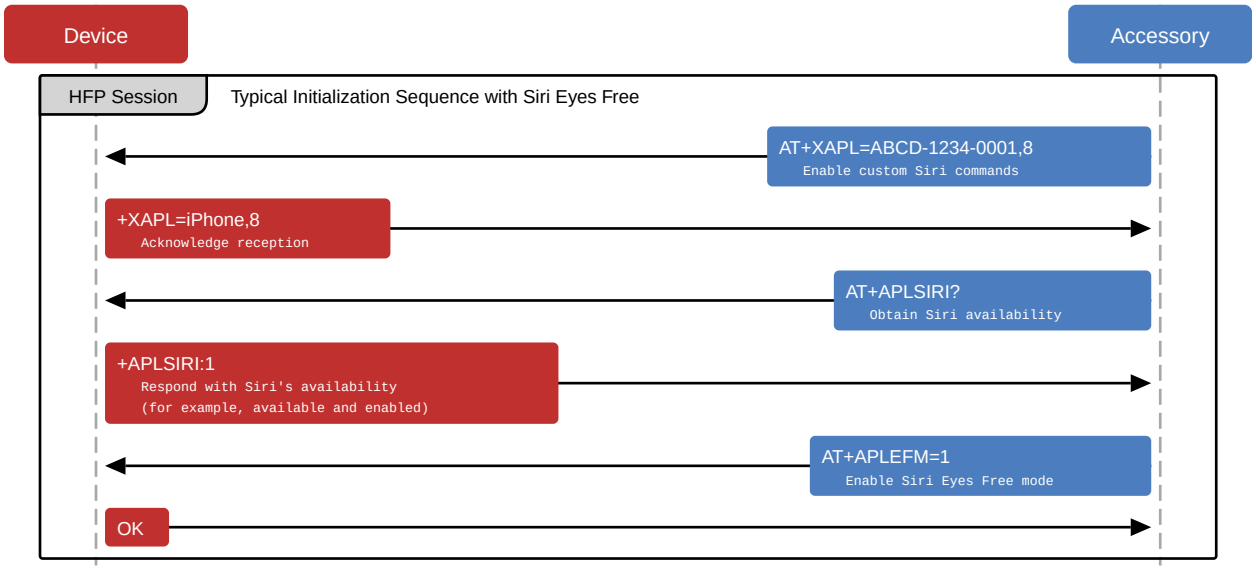


Figure 46-6 Siri Initialization Procedure with Siri Eyes Free



46.7.2 Phone Dialing Using Siri

Upon user request, Siri can initiate an outgoing phone call. The device will initiate HFP call signaling to establish a phone call as described in Bluetooth (page 331). The accessory shall be able to transition to Hands-Free dialing at any time during or after a Siri session when signaled by the device.

46.7.3 Audio Routing and Media Playback Using Siri

Siri can control the media playback on a device, and if Siri determines the user wants to play or pause music, Siri will either start, pause or resume media playback. The device will send a notification to the accessory indicating a change in playback state and any associated track information. The accessory shall respond to the notifications, start or stop the music playback as requested, as well as update the correct playback state (for example, shuffle, repeat).

The accessory shall not force a change in the playback state after a Siri session is ended. If music was playing before Siri was started, it shall continue playing, if it was paused, it shall remain paused.

After Siri starts music playback the accessory shall set its current audio route to match the audio source, depending on how audio is being received from the device (using Bluetooth or by a wired connection).

The available media playback notifications depend on the audio route being used:

- Bluetooth audio routes shall use the approach described in Notifications (page 338) and Audio Data Received using A2DP Profile (page 341).
- Wired audio routes shall use iAP2.

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46.7.4 Turn-By-Turn Directions Using Siri

Siri can initiate active route guidance to provide turn-by-turn directions. In case the device is the active source and is already playing music, turn-by-turn directions will be mixed in as part of the audio stream. In case the device is not playing music, the accessory should be able to mix in turn-by-turn directions with the active audio source.

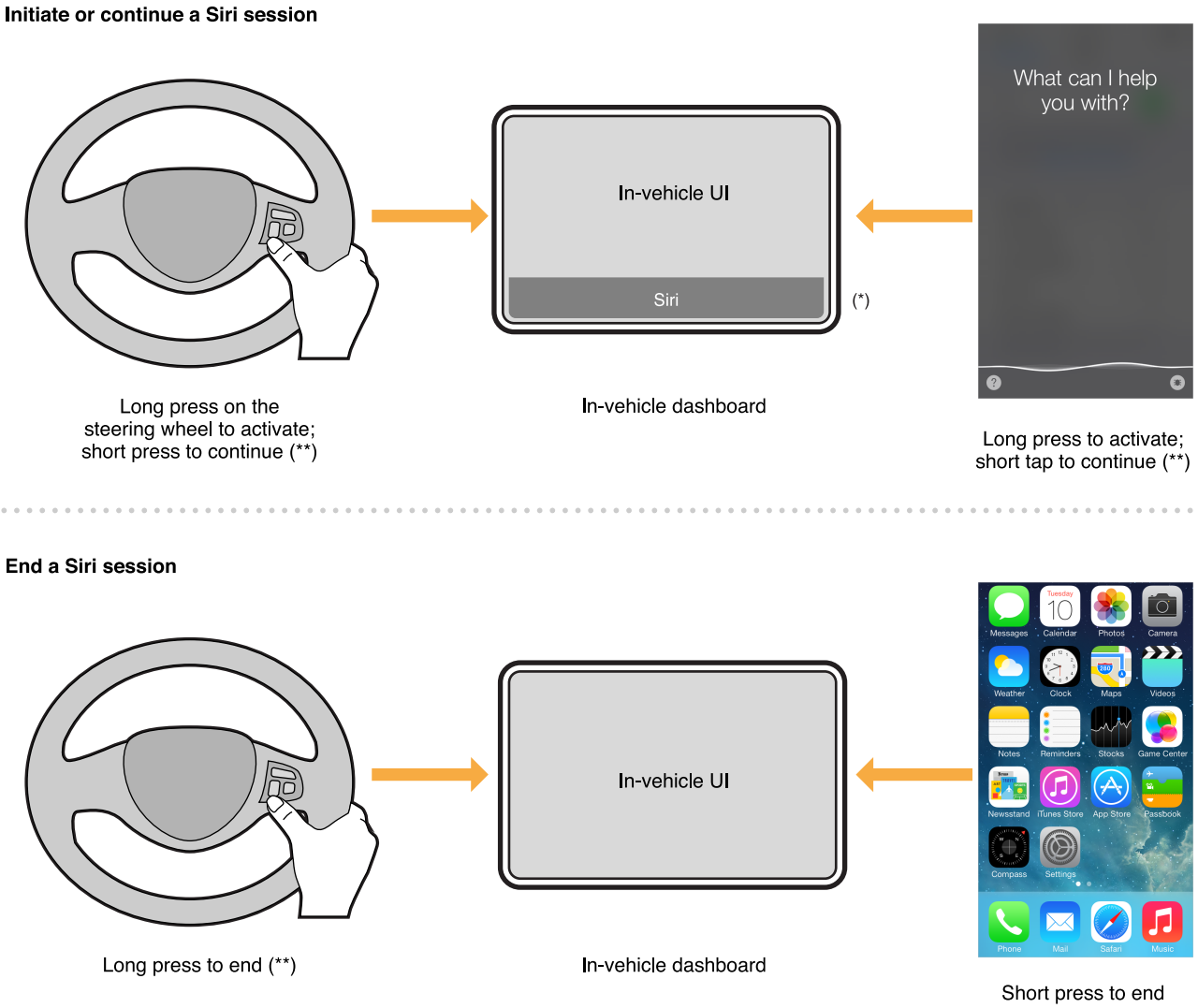
The device will notify the accessory to play turn-by-turn directions only over Bluetooth. Detailed information on how to distinguish between music playback and turn-by-turn notifications is available in Notifications (page 338).

46.8 User Interaction with Siri Eyes Free in a Vehicle

A vehicle using Siri Eyes Free mode shall integrate the Siri experience with the existing in-vehicle entertainment system and controls. The vehicle should provide a convenient interface to initiate, continue, and end a Siri session. Once a Siri session is running, the vehicle shall display a visual cue indicating voice recognition is in use. Figure 46-7 (page 297) outlines how a Siri interaction should be designed.

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Figure 46-7 Siri Eyes Free user interaction



As shown in Figure 46-7 (page 297):

- (*) If the accessory wishes to indicate Siri is active, it shall either:
  - Display the word 'Siri' (as capitalized) with no additional text or icon.
  - Use generic text or icon not resembling the Siri microphone icon.
- (**) If the vehicle is equipped with steering wheel controls, the steering wheel shall have a dedicated button or a long-press action on a button to start, continue and end a Siri session. The button long-press shall be 600 ms or less. If no steering wheel controls are available, a soft button shall be available within the in-vehicle user interface to start, continue or end a Siri session.

When a vehicle enables Siri Eyes Free mode, the device will not display any onscreen Siri content. If the device was locked at the time the Siri session was activated from the vehicle, it will remain locked and the screen will not wake. If the user unlocks or manually activates the device while in an Eyes Free Session there will be a notification the device is in an active Siri session but there will be no visual Siri content displayed.

46.9 Enabling/Disabling Siri from the Device

The user has the ability to disable or enable Siri from the Settings menu on the device. When Siri is disabled, Voice Control becomes the recognition engine on the device and will be triggered by default. The accessory may choose to either:

- Activate Voice Control (in the same way Siri is activated) as in Figure 46-8 (page 298).
- Display a warning message and not send an activation command to the device as in Figure 46-9 (page 299).

Figure 46-8 Siri is disabled: activating Voice Control

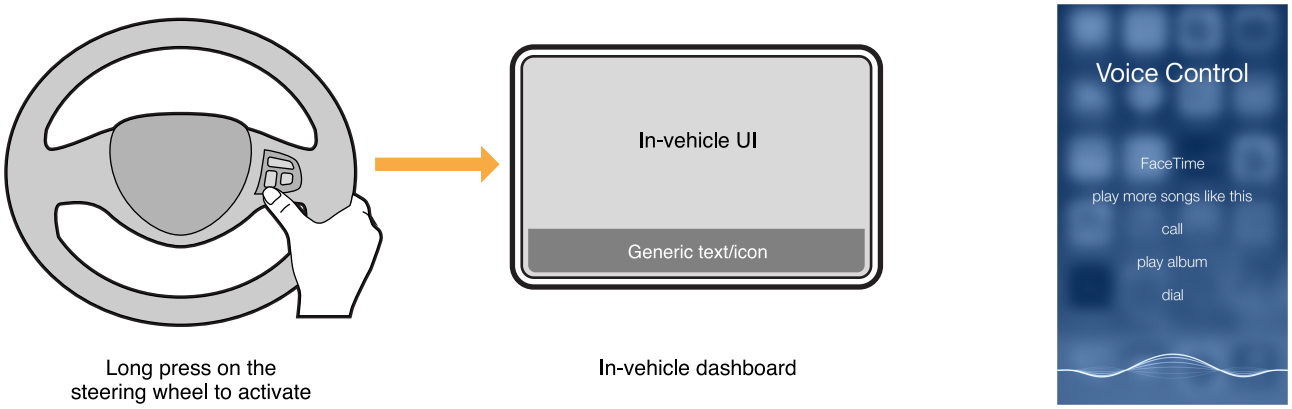
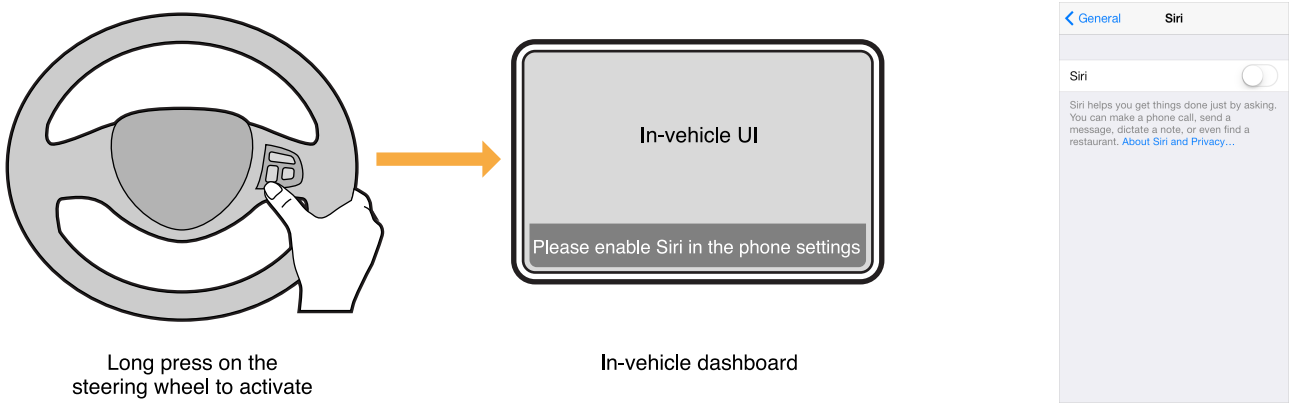


Figure 46-9 Siri is disabled: displaying a warning message



46.10 Verification

46.10.1 Siri Eyes Free

The following test procedures are applicable to accessories interacting with Siri Eyes Free.

The ideal test operator is a native speaker of North American English. If the operator's native language is not North American English, set Siri to the operator's native language and translate the provided phrases into their native language.

46.10.1.1 General

1. Pair and establish a Bluetooth Hands-Free Profile (HFP) connection between the device and the head unit. Activate Siri from the vehicle steering wheel button (for example, by pressing and holding):
   a. Observe the device screen remains inactive after a Siri session has started (a visual indicator will be visible on the device if the screen is activated manually).
   b. Ensure Siri's opening chime is heard completely through the vehicle speakers.
   c. Observe a visual notification in the in-car User Interface (UI) indicating a Siri session is active (for example, text notification, on-screen UI).
2. Activate Siri from the vehicle steering wheel button and say "Send a message to Peter. How are you?". While still saying the message, press the vehicle steering wheel button to cancel Siri:
   a. Ensure the device screen remains inactive (if manually activated, the visual indicator on the phone will disappear).
   b. Verify the in-car Siri UI interaction is dismissed and the head unit returns to its prior state before the Siri interaction.

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3. Activate Siri from the vehicle steering wheel button and say "How is the weather in San Francisco?". Wait for Siri to respond with the weather forecast. Once the weather forecast is complete, resume Siri from the vehicle steering wheel button and say "What about New York?":
   a. Confirm the visual indicator is still active on the phone.
   b. Listen for the Siri opening chime.
   c. Verify the vehicle UI indicates a Siri session is active.
   d. Verify Siri responds with the weather forecast for New York.
4. If the vehicle UI offers on-screen controls to activate/cancel/resume Siri, repeat the activate, cancel, and resume steps above for all on-screen controls.
5. Activate Siri from the steering wheel button and say "What's the time?". Listen to the current time and do not interact with Siri or the device. After 5 seconds have expired:
   a. Observe the visual Siri session indicator on the phone is no longer visible.
   b. Verify the in-car UI for Siri interaction was dismissed.
   c. Verify the head unit returned to its prior state before the Siri interaction.
6. Listen to FM radio from the car speakers (for example, no A2DP streaming active). Press and hold the device Side/Top/Home button to activate Siri:
   a. Observe a visual notification in the in-car UI indicating a Siri session is active (textual notification, on-screen UI, etc.).
   b. Observe Siri's interaction on the device screen and ask "What's the time?".
   c. After Siri has responded, lock the device again to dismiss the Siri session by pressing the device Side/Top/Home button.
7. Open Settings and turn Siri off. Activate Siri from the head unit. Observe one of the following depending on the actual implementation (a) Voice Control starts instead of Siri (b) The head unit displays a warning indicating Siri Eyes Free is not available.
8. Open Settings and turn Siri back on. Verify Siri can be activated/cancelled from the head unit and from the device Side/Top/Home button.
9. Open Settings and turn Bluetooth off. Verify Siri cannot be started.
10. Open Settings and turn Bluetooth back on. Verify Bluetooth HFP profile reconnects and Siri can be activated/cancelled from the head unit and from the device Side/Top/Home button.
11. Confirm there is no accessory battery status level indicator icon displayed on the device status bar.

46.10.1.2 Siri Dialog

1. Activate Siri from the vehicle's steering wheel button and say "Send a text message to *insert contact name*". When Siri prompts "What would you like it to say?", dictate a short message. After Siri has read back the dictated message, say "Review it". After Siri has read back the message again, say "Review it" again. Repeat this cycle ~5 times to ensure the head unit is able to handle a long interaction with Siri. At the end say "Send it" and verify the message is sent. Verify the opening

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chime is audible and the message is sent. After the Siri session is closed, verify the audio playback went back to the audio state it was in before Siri was activated (that is, if audio was paused it remains paused, if it was playing it resumes playing).

2. Start Siri from the vehicle's steering wheel button and ask for directions. Follow up through the dialog until the navigation is started. Verify the Siri session is closed and the audio playback returns to the audio state it was in before Siri was activated (that is, if audio was paused it remains paused, if it was playing it resumes playing).
3. Start Siri from the vehicle's steering wheel button and say "Search the web for polar bears". Verify Siri Eyes Free mode is on and this use case is blocked by Siri. In some implementations the vehicle has to be in motion before Siri Eyes Free is activated by the car kit.
4. Start Siri from the vehicle's steering wheel button and say "What is the current time in Munich?". After Siri answers but before ~5 seconds have elapsed, resume Siri (for example, using a short press on the steering wheel button) and verify Siri is activated again. Say "What about San Francisco?". Repeat (with a different city) and verify this can continue indefinitely as long as there is a short press on the steering wheel button within 5 seconds of the last response.

46.10.1.3 Bluetooth HFP A2DP Music

1. Establish a Bluetooth A2DP connection and switch to Bluetooth audio source on the head unit. Activate Siri and say "Next track". Verify the track advances and audio is played through the vehicle speakers. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
2. Activate Siri and say "Pause the music". Verify audio remains paused after Siri has been dismissed. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
3. Pause music playback on the head unit (using AVRCP command). Activate Siri and ask "What time is it?". Verify the music playback remains paused after the Siri session has been dismissed. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
4. Switch to FM radio on the head unit. Activate Siri and say "Play me a song". Verify the head unit is able to automatically switch to Bluetooth audio and music starts playing. Verify the beginning of the selected track is heard (for example, there is no skipping of audio packets). Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
5. Activate Siri and say "Shuffle all songs". Verify the head unit correctly updates the NowPlaying track information. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
6. Activate Siri and ask to play a specific artist or title. Verify the Siri session is dismissed after the music starts. Confirm the correct metadata is displayed on the screen. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.

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46.10.1.4 Call

1. Activate Siri and call a contact with more than one phone number (for example, home and mobile). Wait for Siri's response asking which phone number to call. Answer with "home". Verify call transition is handled correctly by the head unit and any Siri UI displayed on the vehicle screen is dismissed.
2. While device music is playing, activate Siri and say "Call *(insert contact to call)*". Verify call transition is handled correctly by the head unit. Verify device music playback resumes after the call has been answered and terminated on the far end. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
3. While device music is playing, start Siri and say "Call *(insert contact to call)*". Verify call transition is handled correctly by the head unit. Verify device music playback resumes after the call has been answered and terminated on the near end (that is, on the head unit). Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
4. While in a Siri session, receive an incoming call on the head unit. Verify the head unit handles call-signaling correctly and transitions to the phone UI once the call has been accepted. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.

46.10.1.5 Bluetooth + Wired iAP2

1. Connect the device to the head unit. Switch to device audio and verify audio is playing. Activate Siri and say "Next track". Verify the track advances and the head unit displays the track metadata correctly. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
2. From the head unit UI, select a playlist with a single song and start playing it. Start Siri from the vehicle steering wheel and say "Play ..... *make sure to select a song to play (a) not in the same album as the single-track playlist and (b) not song track index 0 of its album*". Verify the new song starts playing and the head unit correctly displays the track metadata for the new song. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
3. Turn Shuffle off on the head unit UI. Then start Siri and say "Shuffle all songs". Verify the shuffle indicator on the head unit UI is updated and the correct track metadata for the new now playing song is displayed correctly. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
4. Switch to FM radio on the head unit. Activate Siri and say "Play me a song". Verify the head unit is able to automatically switch to device audio source and music starts playing through the speakers. Verify there is no skipping of audio at the beginning of the selected track. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
5. Pause music playback on the head unit (using iAP2 commands). Activate Siri and ask "What time is it?". Verify music playback remains paused after the Siri session has been dismissed. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.

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6. While device music is playing, start Siri and say "Call *(insert contact to call)*". Verify call transition is handled correctly by the head unit. Verify device music playback resumes after the call has been answered and terminated on the far end. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
7. While device music is playing, start Siri and say "Call *(insert contact to call)*". Verify call transition is handled correctly by the head unit. Verify device music playback resumes after the call has been answered and terminated on the near end (for example, on the head unit). Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.
8. Pause music playback on the head unit (using iAP2 commands). Start Siri and say "Call *insert contact name to call*". Verify call transition is handled correctly by the head unit. Verify device music playback remains paused after the call has been answered and terminated on the far end. Verify the Siri in-car UI is dismissed and the head unit returns to its initial audio state.

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47. Wi-Fi Information Sharing

Devices can share Wi-Fi configuration information with an accessory. The accessory can initiate this process, but the device shares this information only after the user grants permission. The device can only share information about the currently connected Wi-Fi network, and this feature will not account for other router-configured access control mechanisms, such as RADIUS or MAC address filtering.

Figure 47-1 Wi-Fi information sharing alert



See the Accessory Interface Specification (page 22) for more information.

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Protocols

48. USB Power Capability Vendor Request

If the accessory is a USB host, and it does not implement iAP2 (page 319), then it may send an Apple-specific USB vendor request communicating how much power is available to the device. In this case, the accessory shall enumerate and identify the presence of a device, then send the vendor request. The vendor request shall be sent every time the device is enumerated by the accessory.

Table 48-1 USB Vendor Request for non-iAP2 accessory USB Embedded Host

Field	Value	Comments
`bmRequestType`	`0x40`	Host-to-device request, vendor-defined type, device is recipient.
`bRequest`	`0x40`	Vendor-defined USB power capability request.
`wValue`	See comments.	Charging current available, expressed as an offset from 500 mA. Shall be 500 (1000 mA charging current available), 1000 (1500 mA charging current available), 1600 (2100 mA charging current available), 1900 (2400 mA charging current available), or 2500 (3000 mA charging current available).
`wIndex`	See comments.	Shall be the same as wValue.
`wLength`	`0`	0 bytes expected.

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49. USB D+/D- Resistor Networks

Accessories not implementing any of the following may use USB resistor networks to identify their current capability:

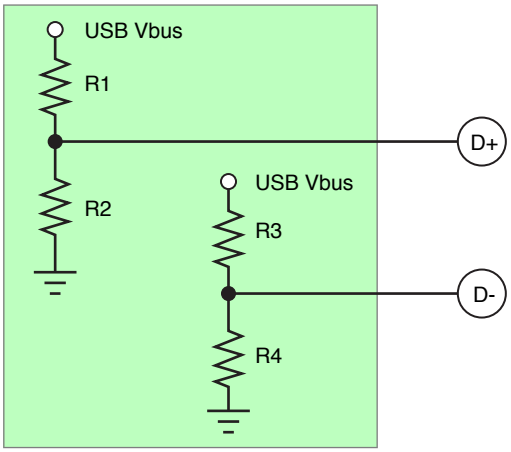
- iAP2 (page 319).
- USB Power Capability Vendor Request (page 306).
- USB Type-C Current (page 311).
- USB Power Delivery (PD) (page 310).

Device power draw varies with environmental factors. Accessory power source testing shall be performed with programmable loads, not devices.

49.1 Declaring Power Source Capability

Accessories shall connect the USB D+ and USB D- pins to resistor networks as shown in Figure 49-1 (page 307).

Figure 49-1 USB D+/D- resistor networks



Every device-compatible connector on an accessory using a USB resistor network shall have its own set of resistors. The accessory shall be capable of supplying the total current required when all connectors are in use, regardless of whether the connectors are compatible with devices or not.

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The resistor network shall be connected at all times unless the accessory uses one of the following methods to enable charging or detect the presence of a device. In these cases, it shall immediately present the resistor network. The accessory:

- Uses a direct user action to enable charging.
- Senses the attachment of the device using electromechanical means such as a contact switch.

The accessory shall not monitor the USB D+ and USB D- pins to detect the presence of a device.

Resistors used to implement the networks specified in Figure 49-1 (page 307) shall have a tolerance of 1% or better. The resistor network shall not be emulated by driving the voltage of the USB D+/D- pins using some other means.

Table 49-1 USB D+/D- resistor values

Max Current	R1	R2	R3	R4
3000 mA	43.2 kΩ	49.9 kΩ	24.9 kΩ	49.9 kΩ
2400 mA	43.2 kΩ	49.9 kΩ	43.2 kΩ	49.9 kΩ
2100 mA	43.2 kΩ	49.9 kΩ	75.0 kΩ	49.9 kΩ
1000 mA	75.0 kΩ	49.9 kΩ	43.2 kΩ	49.9 kΩ

49.2 Identifying Power Source Current Limit

Accessories shall take into account the variation of USB VBUS voltage and resistor tolerances.

The resistor network values and corresponding current source limits should be identified using the following procedures:

1. Read the VBUS voltage using an ADC. If the value is less than 4.5 V, return no resistors detected.
2. Pull down the D+ and D- lines and read the voltages using an ADC. If either voltage value is less than 1 V, return no resistors detected.
3. Disable the D+ and D- pull-downs and allow the voltage to return to normal.
4. Read the D+ and D- voltages using an ADC (to determine the value for R1 and R3 respectively):
   - If the voltage is greater than 2.995 V (based on 1 MΩ load impedance), assume a resistor value of 24.9 kΩ.
   - If the voltage is between 2.320 V and 2.995 V (based on 1 MΩ load impedance), assume a resistor value of 43.2 kΩ.
   - If the voltage is less than 2.320 V (based on 1 MΩ load impedance), assume a resistor value of 75.0 kΩ.
5. Determine the max current based on Table 49-2 (page 309).
6. If resistor values could not be identified, proceed to identify the power available based on the *USB Battery Charging Specification – Release 1.2*.

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Table 49-2 USB D+/D- resistor values

Max Current	R1	R2	R3	R4
1000 mA	24.9 kΩ	49.9 kΩ	24.9 kΩ	49.9 kΩ
1000 mA	24.9 kΩ	49.9 kΩ	43.2 kΩ	49.9 kΩ
1000 mA	24.9 kΩ	49.9 kΩ	75.0 kΩ	49.9 kΩ
3000 mA	43.2 kΩ	49.9 kΩ	24.9 kΩ	49.9 kΩ
2400 mA	43.2 kΩ	49.9 kΩ	43.2 kΩ	49.9 kΩ
2100 mA	43.2 kΩ	49.9 kΩ	75.0 kΩ	49.9 kΩ
1000 mA	75.0 kΩ	49.9 kΩ	24.9 kΩ	49.9 kΩ
1000 mA	75.0 kΩ	49.9 kΩ	43.2 kΩ	49.9 kΩ
500 mA	75.0 kΩ	49.9 kΩ	75.0 kΩ	49.9 kΩ

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50. USB Power Delivery (PD)

Accessories providing direct power using USB Power Delivery (PD) or drawing power from USB PD sources shall comply with the *USB Power Delivery Specification – Revision 3.2, Version 1.1*, see https://www.usb.org/document-library/usb-power-delivery.

Accessories implementing USB PD shall incorporate a USB-IF certified PD controller with a *Silicon* Test ID from the USB-IF, see https://www.usb.org/products.

Apple recommends the GRL-USB-PD-C2-EPR (see https://www.grlps.com/en-us/test-solutions/protocol-power-test-solutions/grl-usb-pd-c2-epr) for USB PD testing and compliance verification.

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51. USB Type-C Current

Accessories providing direct power using USB Type-C Current or drawing power from USB Type-C Current sources shall comply with the *USB Type-C Cable and Connector Specification – Release 2.3, Section 4.6.2*.

Apple recommends the GRL-USB-PD-C2-EPR (see https://www.grlps.com/en-us/test-solutions/protocol-power-test-solutions/grl-usb-pd-c2-epr) for USB Type-C Current testing and compliance verification.

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52. Advanced Audio Distribution Profile (A2DP)

Accessories may implement the Advanced Audio Distribution Profile (A2DP) over Bluetooth (page 331) to receive audio from iPhone, iPad, Apple Watch, Apple TV, Mac, and Apple Vision Pro.

The audio content from the device can be broadly classified into two categories:

- Audio content from music, video, or gaming applications.
- System-generated sounds for alerts and notifications.

A2DP is often implemented in speakers and headsets.

Accessories implementing A2DP shall satisfy all requirements stated in Bluetooth (page 331).

52.1 Bluetooth A2DP Specification

Accessories implementing the Advanced Audio Distribution Profile (A2DP) shall meet the requirements of the Bluetooth *Advanced Audio Distribution Profile Specification – Version 1.2*.

52.1.1 AVDTP Transactions

Accessories shall respond to Audio/Video Distribution Transport Protocol (AVDTP) signaling transactions before the device's 5-second RTX_SIG_TIMER expires, or the device will terminate the signaling channel. See Bluetooth *Audio/Video Distribution Transport Protocol – Version 1.3, Section 6.2 Transaction Model and Section 6.4 Signal Command Set*.

52.2 SubBand Codec (SBC)

The SBC Codec Specific Information Elements applicable to devices and Mac computers, defined in *Advanced Audio Distribution Profile Specification – Version 1.2, Section 4.3.2*, are listed in Table 52-1 (page 313).

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Table 52-1 SubBand Codec Information Elements for devices and Mac computers

Element	Value
Sampling Frequency	16 kHz, 32 kHz, 44.1 kHz, and 48 kHz.
Channel Mode	Stereo
Block Length	16
Subbands	8
Allocation Method	Loudness
Bitpool range	2 to 53. Accessories should support 53.

52.3 AAC-LC Codec

Accessories should support the MPEG-2/4 Advanced Audio Coding Low Complexity (AAC-LC) codec over A2DP, as defined in the *Advanced Audio Distribution Profile Specification – Version 1.2, Section 4.5*. AAC-LC provides higher audio quality than the SubBand Codec (SBC) (page 312) for a given bit rate.

> **Note:**
> The following specifications provide details of Apple's implementation of the MPEG-2/4 AAC-LC codec. In case of conflicts, the A2DP specification governs.

The AAC-LC Codec Specific Information Elements applicable to devices, defined in *Advanced Audio Distribution Profile Specification – Version 1.2, Section 4.5*, are listed in Table 52-2 (page 313).

Table 52-2 AAC-LC Codec Information Elements for devices

Element	Value
Object Type	MPEG-2 AAC LC
Sampling Frequency	8 kHz, 11.025 kHz, 12 kHz, 16 kHz, 32 kHz, 44.1 kHz, 48 kHz, 64 kHz, 88.2 kHz, and 96 kHz.
Channels	2
Bit rate	264,630 bps
VBR	1

AAC-LC audio stream packets in devices have the structure shown in Table 52-3 (page 314).

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Table 52-3 AAC-LC audio packet for devices

L2CAP	AVDTP	MPEG-4 LATM	MPEG-4 AAC-LC
Header	Header	AudioMuxElement	Audio Payload

The AAC-LC Media Payload Format, as defined in the *Advanced Audio Distribution Profile Specification – Version 1.2, Section 4.5.4*, is formatted using LATM as defined in *IETF RFC 3016 – Section 4*. The following notes apply to the packet fields shown in Table 52-3 (page 314):

- The recommended L2CAP MTU value for each device's AAC-LC streaming channel is 885 bytes.
- The AVDTP Header is shown as the RTP header in *RFC 3016 – Figure 4*, defined in Bluetooth *Audio/Video Distribution Transport Protocol – Version 1.2, Section 7.2.1*.
- The `AudioMuxElement` is the same as the *RFC 3016 – RTP payload*, defined in *ISO/IEC 14496-3:2009 – Subpart 1, Section 1.7.3, Table 1.41*. The `muxConfigPresent` argument to the `AudioMuxElement` is set to 1 (in-band mode), as recommended in *RFC 3016 – Section 4.1*. Only one `AudioMuxElement` is put into each AVDTP packet, as recommended in *RFC 3016 – Section 4.3*.
- The audio payload is encoded using MPEG-4, as recommended in *Advanced Audio Distribution Profile Specification – Version 1.2, Section 4.5.4*.
- The accessory should support AAC-LC VBR and handle bit rate changes without audio gaps. Devices will vary AAC-LC bit rate depending on the content. Accessories supporting VBR shall support a minimum bitrate of 96 kbps.

52.4 AAC-ELD Codec

This feature is supported starting in iOS 27.0.

Accessories should support the MPEG-4 Advanced Audio Coding Enhanced Low Delay (AAC-ELD) codec over A2DP. AAC-ELD provides lower latency than the AAC-LC Codec (page 313) at comparable audio quality.

52.4.1 Requirements

Apple's implementation of AAC-ELD uses the vendor-specific codec type (AVDTP Codec Type `0xFF`) defined in *Advanced Audio Distribution Profile Specification – Version 1.3, Section 4.7*.

Accessories shall:

- Expose a Codec Information Element (page 315) matching the layout in Table 52-4 (page 315).
- Advertise a maximum bitrate in bytes 11 through 13 at or above the minimum bitrate listed in Table 52-5 (page 316).

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- Decode up to the maximum number of AAC-ELD frames per RTP packet listed in Table 52-5 (page 316).
- Handle VBR-encoded frames of varying byte length.
- Include AVDTP Delay Reporting (page 334) in the endpoint capabilities.

Devices validate each of the above requirements before selecting AAC-ELD. If any check fails, the device falls back to the AAC-LC Codec (page 313) or the SubBand Codec (SBC) (page 312).

52.4.1.1 Codec Information Element

The AAC-ELD Codec Information Element is a 14-byte vendor-specific structure exchanged during AVDTP capability negotiation (`AVDTP_GET_CAPABILITIES` and `AVDTP_SET_CONFIGURATION`). The byte layout is listed in Table 52-4 (page 315).

Table 52-4 AAC–ELD Codec Information Element byte map

Byte	Field	Value	Description
0	Company Identifier, octet 0	`0x4C`	Least significant byte.
1	Company Identifier, octet 1	`0x00`	
2	Company Identifier, octet 2	`0x00`	
3	Company Identifier, octet 3	`0x00`	Most significant byte.
4	Codec Version	`0x01`	
5	Codec Identifier	`0x80`	Bit 7 set identifies AAC-ELD. All other bits reserved and set to 0.
6	Block Sizes 120–360	`0x00`	Reserved.
7	Block Sizes 480 and above	`0x80`	Bit 7 set indicates support for 480 samples per frame.
8	Sampling Frequency, most significant byte	`0x00`	Reserved.
9	Sampling Frequency and Channels	`0x84`	Bit 7 set indicates 48 kHz. Bit 2 set indicates 2-channel stereo.
10	Multichannel	`0x00`	Reserved.
11	VBR flag and maximum bitrate, bits 22–16	`0x84`	Bit 7 set enables VBR. Bits 6–0 carry maximum bitrate bits 22–16.
12	Maximum bitrate, bits 15–8	`0xE2`	
13	Maximum bitrate, bits 7–0	`0x00`	

Bytes 11 through 13 encode the maximum bitrate in bits per second as a 23-bit value, with the VBR flag in bit 7 of byte 11. The values shown in Table 52-4 (page 315) correspond to a maximum bitrate of 320 kbps with VBR enabled.

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52.4.2 Streaming Parameters

Accessories supporting AAC-ELD shall operate using the parameters listed in Table 52-5 (page 316).

Table 52-5 AAC–ELD streaming parameters

Parameter	Value
Sample Rate	48,000 Hz
Channels	2
Samples per Frame	480
Frames per RTP Packet	Up to 3
Default Bitrate	256 kbps
Minimum Bitrate	96 kbps
Maximum Advertised Bitrate	320 kbps
VBR	Enabled

The device determines the encoded frame length and the number of frames packed per RTP packet while streaming.

Accessories shall accept a reduced target bitrate when requested by the device.

52.4.3 RTP Payload Format

AAC-ELD frames are transported in standard RTP packets as defined in *IETF RFC 3550*. The RTP payload starts with a 2-byte per-packet command header used for in-band commands, followed by one or more AAC-ELD frames. Each frame begins with a 2-byte ELD size header identifying the frame and its payload length. The per-frame header expands to 10 bytes by appending optional fields selected by opcode.

The opcodes used in the ELD headers are listed in Table 52-6 (page 316).

Table 52-6 AAC–ELD ELD header opcodes

Opcode	Value	Description
Complete packet size header	`0x01`	Mandatory per-frame header indicating a complete frame.
Sequence Number	`0x0B`	Optional per-frame sequence counter.
Timestamp	`0x0E`	Optional presentation timestamp.
Extension bit	`0x08`	Set in a header byte to signal the presence of additional fields.

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52.4.4 Codec Selection Priority

Accessories supporting AAC-ELD shall expose the AAC-ELD Codec Information Element alongside any AAC-LC Codec (page 313) or SubBand Codec (SBC) (page 312) endpoints. Devices select a codec in the following order of priority:

1. AAC-ELD Codec (page 314).
2. AAC-LC Codec (page 313).
3. SubBand Codec (SBC) (page 312).

52.5 Verification

52.5.1 Audio Quality

Verify there are no audio quality issues in each of the following scenarios:

1. Stream music from the Apple Music app.
2. Stream music from a radio station within the Apple Music app.
3. Stream audio using the Apple Podcasts app.

52.5.2 Audio Switching

1. During A2DP streaming, switch audio back to the device and switch back to the accessory.
2. Verify audio was routed to the intended source, and audio quality was good switching back to Bluetooth.

52.5.3 HFP Interaction

1. Make an incoming/outgoing call during A2DP.
2. Verify audio was suspended during the call and resumed after the call.

52.5.4 Siri

1. Trigger Siri during A2DP.
2. Verify audio resumed after the Siri session.

52.5.5 Video Playback

1. Stream A2DP while watching a video.
2. Verify audio/video synchronization and quality are good.

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52.5.6 AAC-ELD Codec Selection

1. Pair the accessory with the device over Bluetooth BR/EDR.
2. Initiate A2DP streaming from the Apple Music app.
3. Using ATS or an equivalent Bluetooth protocol analyzer, capture the AVDTP signaling exchange.
4. Verify the accessory advertises an AAC-ELD stream endpoint whose Codec Information Element is correctly formatted. See Requirements (page 314).
5. Verify the device sends `AVDTP_SET_CONFIGURATION` selecting the accessory's AAC-ELD endpoint rather than an AAC-LC or SBC endpoint.

52.5.7 VBR Handling

1. Pair the accessory and establish an AAC-ELD A2DP stream.
2. Play content exercising varying bitrate, such as transitioning between a dense Apple Music track and a sparse podcast segment.
3. Verify the audio output contains no gaps, clicks, or artifacts as the frame size varies.

52.5.8 Frames Per RTP Packet

1. Establish an AAC-ELD A2DP stream.
2. Using a Bluetooth protocol analyzer, observe RTP packets carrying multiple AAC-ELD frames, and verify the audio output contains no gaps, clicks, or artifacts. See Table 52-5 (page 316).

52.5.9 Delay Reporting

1. Establish an AAC-ELD A2DP stream.
2. Using a Bluetooth protocol analyzer, verify the accessory sends an AVDTP delay report to the device during streaming.
3. Verify the delay reports follow the maximum-delay and update-rate recommendations. See Delay Reporting (page 334).

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53. iAP2

Accessories may use the iAP2 protocol to access advanced device features, such as:

- Communicating securely with third-party iOS/iPadOS apps using the External Accessory Protocol (page 257).
- Accessing the media library and retrieving album artwork using Media Library Access (page 283) and Now Playing Updates (page 285).
- Launching apps using App Launch (iAP2) (page 236).
- Discovering compatible apps using App Discovery (page 235).
- Helping users find compatible apps in the App Store using App Match (iAP2) (page 238).
- Providing GNSS location data using Location Information (page 262).
- Supporting connectivity with Out-of-Band Bluetooth Pairing (page 286) and Wi-Fi Information Sharing (page 304).

See the Accessory Interface Specification (page 22) for more information.

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54. Human Interface Device (HID)

Devices can accept input from and send output to Human Interface Device (HID) accessories, such as external keyboards, trackpads, mice, and game controllers. This capability is made available system-wide for all apps on the device as well as to support features built into iOS, iPadOS, and tvOS. If an accessory is designed to provide human input events to a specific third-party app, the accessory should use the External Accessory Protocol feature instead; see the Accessory Interface Specification (page 22) for more information.

The HID protocol can be implemented over:

- USB
- Bluetooth

54.1 Requirements

Accessories shall only send HID reports for changes in physical or virtual control surfaces declared in the corresponding HID descriptor.

Accessories shall not send a HID report if there has not been any change in the state of the corresponding physical or virtual control surface. For example, the accessory shall never generate a "Play/Pause" event without the user pressing a dedicated "Play/Pause" button.

Each HID report shall contain the correct number of bytes as described in its corresponding HID descriptor.

The accessory shall not anticipate or assume corresponding state changes in the device after sending HID reports.

Unless otherwise specified:

- The accessory shall be capable of generating and receiving all HID usages declared in its HID descriptor.
- The accessory's declared HID usages shall map directly to physical or virtual control surfaces on a 1:1 basis. For example, a button labeled "Play/Pause" shall send a Play/Pause HID usage and not "Play" or "Pause" usages. Compound controls such as knobs, joysticks, and directional pads may be considered multiple control surfaces. For example, clockwise and counterclockwise rotation may map to separate HID usages.

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- Physical or virtual control surfaces generating HID reports shall be labeled with appropriate iconography or text corresponding to the resulting device behavior. For example, a Play/Pause button shall be labeled with the text 'Play/Pause' or a Play/Pause icon.
- The accessory shall send one HID report in response to each direct user action on the corresponding physical or virtual control surface. For example:
  - When the user presses a button, one 'button pressed' HID report shall be sent to the device.
  - When the user releases the button, one 'button released' HID report shall be sent to the device.

54.1.1 Report Descriptor

When padding packets to align within a byte boundary, each Main item tag (Input, Output, or Feature) shall be marked constant. Padding bits should be set to 0.

When defining Variable type Input/Output fields, either:

- Report Count number shall correspond to the number of Usages specified.
- Report Size shall be 8 and the Report Count shall correspond to the size of a multi-byte blob.

54.1.2 USB

If implementing HID over USB, the accessory shall comply with the *Device Class Definition for Human Interface Devices (HID) – Version 1.11*, see https://www.usb.org/hid.

54.2 Verification

54.2.1 General

1. Verify the accessory generates and receives all HID usages declared in the component's HID descriptor.
2. Verify the accessory does not send a HID report if there has not been any change in the state of the control surfaces (that is, no polling of HID reports).
3. Verify if any accessory has physical or virtual control surfaces generating accessory HID usages, the controls are labeled with appropriate iconography or text corresponding to the resulting device behavior (for example, a Play/Pause button is labeled with the text "Play/Pause" or a Play/Pause icon).
4. Verify HID usages map to physical or virtual controls on a 1:1 basis (for example, a Play button only sends Play usages, not Play/Pause).

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5. Verify one accessory HID report is sent in response to each direct user action on the corresponding physical or virtual control surface. For example, when the user presses a button, one 'button pressed' usage report is sent, and a separate 'button released' usage report is sent when the user releases the button.

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Transports

55. Wi-Fi Aware

Peer devices and accessories integrating Wi-Fi Aware technology shall support the *Wi-Fi Aware Specification – Version 4.0*.

This feature is supported starting in iOS 26.0 and iPadOS 26.0.

55.1 Overview

Wi-Fi Aware, also known as Neighbor Awareness Networking (NAN), is a Wi-Fi Alliance specification enabling devices to discover, pair, and communicate directly and securely with nearby devices. This connection does not require a traditional access point or an internet connection.

A *peer device* is any third-party product (such as an accessory, embedded system, or non-Apple phone/tablet) communicating with a device using Wi-Fi Aware.

Applications can use the Wi-Fi Aware framework (see https://developer.apple.com/documentation/WiFi-Aware) to discover, pair, and securely connect with Wi-Fi Aware certified accessories and peer devices. Use cases include:

- Smart cameras transferring photos or videos to a device.
- Personal computers transferring files to or from a device.

55.2 Requirements

To ensure compatibility, peer devices shall be Wi-Fi Aware certified and support the following enabled features, as defined in the specification:

- Secure pairing with NIK caching, including pairwise data and management frame protection.
- Multicast Data protection.
- Multicast Management Frame protection.
- Beacon protection.

> **Note:**
> The Neighbor Discovery Protocol (NDP) for IPv6 address resolution is not supported.

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55.3 Peer as a Subscriber

When acting as a subscriber, a peer device can browse for services offered by a device, then pair and connect. To do this, configure the peer device as an active subscriber to discover a publisher of the intended service. The peer device's Subscribe Service Discovery Frames (SDF) shall include the following attributes:

- **Service Descriptor Extension Attribute:** The device, as a publisher, does not use the Service-Specific Information (SSI) field. Therefore, Apple recommends omitting this field. Within the control field, set the `GTK Required` subfield to `1`. This ensures the peer device can encrypt and decrypt multicast data packets. Failing to set this bit will cause the device to reject the data path connection request. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.4.2, Table 55*.
- **Country Code Attribute:** If the peer device has a user-configured locale or can automatically determine its geo-location (for example, via GPS, Wi-Fi location, or IP address), the country code in the `Condensed Country String` field shall be set to reflect this location. If the locale is unknown, set the field to XZ. When the country code is XZ, the 5 GHz band will not be used for the Wi-Fi Aware protocol. In this case, the peer device should use the country code from the device's beacon or published SDF. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.12*.
- **WLAN Infrastructure Attribute:** If the peer device is connected to a Wi-Fi access point, all Wi-Fi Aware management frames it transmits shall include the `Extended WLAN Infrastructure Attribute`. The `Non–NAN Operating Channel Information` field shall be set to the Wi-Fi infrastructure channel. The `BSSID` and `MAC Address` fields are not required and may be set to all `0`'s to improve privacy. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.23.3*.
- **NAN Identity Resolution Attribute (NIRA):** This attribute contains the peer device's identity key, enabling the device to recognize previously paired peer devices.
- **Cipher Suite Information Attribute:** The supported `Cipher Suite ID` values are NCS-GTK-CCMP-128 (5) and NCS-PK-PASN-128 (7). Set the `Capabilities` field bits 1 and 2 to `0b10` to specify GTKSA, IGTKSA, and BIGTKSA are supported. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.21.2*.

After discovery, the peer device initiates pairing with the device for authentication, as defined in *Wi-Fi Aware Specification – Version 4.0, Section 7.6.4*. The peer device initiates the pair setup by transmitting a bootstrap request containing the following attributes:

- **NAN Pairing Bootstrap Attribute:** Set the `Pairing Bootstrap Method` field to `pin–code only (keypad)`. The device, acting as a publisher, currently supports a 6-digit PIN as the pairing method. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.21.7*.
- **Device Capability Extension Attribute:** This attribute shall be included in `Bootstrap Request` frames. The `NPK/NIK Caching` bit in the `Capability Info` field shall be set to `1` to indicate support for pair verification.
- **Service Descriptor Extension Attribute:** Use the TXT Record (`key=value`) format for the SSI field, as specified in *RFC 6763 – Section 6.3*. Use the following keys with human-readable, UTF-8 string values, each with a maximum length of 63 bytes:

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- `vendorName`: The vendor name of the peer device.
- `modelName`: The model name of the peer device.
- `pairingName`: The hostname of the peer device used for pairing.

For example:

- `vendorName=Apple`
- `modelName=iPhone`
- `pairingName=Joe's iPhone`

Upon completion of pair setup or pair verification, the data path negotiation shall exchange the IGTK, BIGTK, and GTK along with the PTK. The `Data Path Request` frame shall include the following attributes in addition to the mandatory fields:

- **NAN Data Path Extension Attribute:** The `GTK Required` subfield in the `NDPE Control` field shall be set to 1, indicating the device supports encryption and decryption of multicast data frames.

55.4 Peer as a Publisher

When acting as a publisher, a peer device advertises services, allowing a device to discover, pair, and connect to it. To save power, Apple recommends configuring the peer device as a solicited publisher. It may temporarily switch to an unsolicited publisher to announce an update. The peer device's Publish SDFs shall include the following attributes:

- **Service Descriptor Extension Attribute:** When a publisher is in pairing mode, the SSI field shall contain device information in the TXT Record format specified in Peer as a Subscriber (page 325). Conversely, a publisher not in pairing mode shall not include this device information. Within the control field, set the `GTK Required` subfield to 1. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.4.2, Table 55*.
- **Country Code Attribute:** If the peer device has a user-configured locale or can automatically determine its geo-location (for example, via GPS, Wi-Fi location, or IP address), the country code in the `Condensed Country String` field shall be set to reflect this location. If the locale is unknown, set the field to XZ. When the country code is XZ, the 5 GHz band will not be used for the Wi-Fi Aware protocol. In this case, the peer device should use the country code from the device's beacon or subscribe SDF. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.12*.
- **WLAN Infrastructure Attribute:** If the peer device is connected to a Wi-Fi access point, all Wi-Fi Aware management frames it transmits shall include the `Extended WLAN Infrastructure Attribute`. The `Non–NAN Operating Channel Information` field shall be set to the Wi-Fi infrastructure channel. The `BSSID` and `MAC Address` fields are not required and may be set to all `0`'s to improve privacy. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.23.3*.
- **NAN Identity Resolution Attribute:** This attribute contains the peer device's identity key, enabling the device to recognize previously paired peer devices.

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- **NAN Pairing Bootstrap Attribute:** Set the `Pairing Bootstrap Method` field to `pin-code only (display)`. The device, acting as a subscriber, currently supports a 6-digit PIN as the pairing method. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.21.7*.
- **Cipher Suite Information Attribute:** The supported `Cipher Suite ID` values are NCS-GTK-CCMP-128 (5) and NCS-PK-PASN-128 (7). Set the `Capabilities` field bits 1 and 2 to `0b10` to specify GTKSA, IGTKSA, and BIGTKSA are supported. See *Wi-Fi Aware Specification – Version 4.0, Section 9.5.21.2*.
- **Device Capability Extension Attribute:** The publisher shall set the `Pairing Setup` subfield to 1 to indicate it is in pairing mode and will accept new pairing requests. When not discoverable for pairing, this subfield shall be set to 0. Publishers should only enter pairing mode temporarily, typically following a user action to pair new devices, and should exit this mode after the process is complete. The `NPK/NIK Caching` bit in the `Capability Info` field shall be set to 1 to enable pair verification.

Upon completion of pair setup or pair verification, the data path negotiation shall exchange the IGTK, BIGTK, and GTK along with the PTK. The `Data Path Request` frame shall include the following attributes in addition to the mandatory fields:

- **NAN Data Path Extension Attribute:** The `GTK Required` subfield in the `NDPE Control` field shall be set to 1, indicating the device supports encryption and decryption of multicast data frames.

55.5 Privacy

Wi-Fi Aware transmissions can be detected by any nearby device, including devices operated by malicious actors. To protect user privacy and prevent tracking, peer devices shall not transmit uniquely identifying information in unauthenticated or unencrypted frames. This information should only be exchanged through the secure, encrypted NAN Datapath established after pairing is complete.

55.5.1 Service & Device Discovery

Data sent in service discovery frames, such as Subscribe, Publish, and Insecure Follow-Up frames, is neither authenticated nor encrypted and may be viewed or manipulated by an attacker. To minimize exposure, devices should only include the recommended minimum information in these frames.

When Pairing Devices:

- Include the service name.
- Include the NAN Identity Resolution Attribute.
- Include pairing-related fields, such as `pairingName`, `vendorName`, and `modelName`.
- Avoid using additional service-specific information.
- Publishers shall set the `Pairing Setup` subfield in the Device Capability Extension attribute to 1 (enabled) to indicate they are in pairing mode and will accept new pairing attempts.

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When Connecting to already-paired devices:

- Include the service name.
- Include the NAN Identity Resolution Attribute to enable discovery and identification between paired devices.
- Do not include pairing-related fields, such as `pairingName`, `vendorName`, or `modelName`.
- Avoid using additional service-specific information.
- Publishers shall set the `Pairing Setup` subfield in the Device Capability Extension attribute to `0` (disabled) to indicate they are not in pairing mode. In this state, the publisher shall allow connections only from previously paired devices and shall not accept any new pairing attempts.

55.5.2 Frame Identifiers

Certain standard fields in Wi-Fi frames can be used to identify and track users if configured improperly. To mitigate this risk, peer devices shall randomize the following information using a secure random number generator each time Wi-Fi Aware is started:

- **MAC Addresses:** Set all Wi-Fi MAC Addresses (including the NMI Address and NDI Addresses) to new, randomly-generated, locally-administered, unicast MAC addresses.
- **NAN Cluster ID:** Set to a new value randomly chosen from the range `50:6F:9A:01:00:00` to `50:6F:9A:01:FF:FF`.
- **NAN TSF:** Set the lower 56 bits to a new random starting value and the upper 8 bits to `0`.
- **NAN Master Preference** and **NAN Random Factor:** Set to `0` until the warmup period expires or the device joins a NAN Cluster, as described in the Wi-Fi Aware specification.
- **Current & Last NAN Anchor Master Record:** Set all fields to `0`.
- **802.11 Sequence Numbers:** Set to a new random starting value.
- **802.11 Scrambler Seed:** Set to a new, random, non-zero starting value.
- **802.11 Dialogue Tokens:** Set to a new random starting value.
- **802.11 BSS Color:** If supported on the NAN interface, set to a new, random, non-zero value not in use by other nearby networks. Otherwise, this is not applicable.

To save power and further limit tracking risks, the Wi-Fi Aware radio should be turned off when idle for an extended period.

55.6 Improving Quality of Service (QoS)

To accelerate initial synchronization with a device, the peer device should park on the social channel for at least 256 TUs and transmit a beacon every 100 TUs for the first two seconds after powering on.

To maintain presence detection and synchronization status, the peer device should transmit a few beacons every 8 seconds, even when in a non-beaconing Wi-Fi Aware role.

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The standard IPv6 Neighbor Discovery Protocol (NDP) can introduce delays before application data can flow. To eliminate this latency, NDP is not supported on this datapath. Instead, the peer device shall immediately derive the device's IPv6 link-local address from its MAC address and update its network routing table directly. Refer to the *Wi-Fi Aware Specification – Version 4.0, Appendix J* for the conversion method.

The Wi-Fi Aware API provides a performance mode parameter to optimize datapath performance for different use cases. To achieve the best results, the committed availability setting should match between the device and the peer device. The device will choose the 5 GHz band for data transmission if the peer device supports both 2.4 GHz and 5 GHz bands.

There are two performance modes:

1. **Bulk Mode:** Designed for efficient, bursty data transfers while minimizing power consumption.
    a. The radio adapts its availability based on transmit/receive activity.
    b. Committed availability is primarily limited to the social channel.
2. **Realtime Mode:** Intended for latency-sensitive applications at the expense of higher power usage.
    a. The radio maintains high availability for fast packet exchange.
    b. Committed availability spans the social channel, the peer device's Wi-Fi infrastructure channel, and the device's Wi-Fi infrastructure channel.
    c. Potential availability should include the infrastructure channel with a usage preference set to 3 in the NAN Availability attribute, as defined in *Wi-Fi Aware Specification – Version 4.0, Section 9.5.17.1*.
    d. Requires synchronized availability between peers for consistent, low-latency performance. See Figure 55-1 (page 330) for different availability scenarios based on the Wi-Fi infrastructure channel.

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Figure 55-1 Availability Cases

		Device A					
		Infra Not Associated	Infra 2.4 GHz e.g. Channel 11	Infra 5GHz (non-DFS) e.g. Channel 36	Infra 5GHz (non-DFS) e.g. Channel 161	Infra 5GHz DFS e.g. Channel 60	Infra 6GHz e.g. Channel 69
Device B	Infra Not Associated	Case 0-0	1-0	0-1	0-1	0-1	0-1
	Infra 2.4 GHz e.g Channel 11	1-0	1-0	1-1	1-1	1-1	1-1
	Infra 5 GHz non-DFS e.g. Channel 36	0-1	1-1	0-1	0-2	0-X	0-2
	Infra 5GHz DFS e.g. Channel 60	0-1	1-1	0-X	0-X	0-1	0-X
	Infra 6GHz e.g. Channel 69	0-1	1-1	0-2	0-2	0-X	0-1

Case 0-0

	512 TUs								512 TUs							
	64 TUs								64 TUs							
	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Slot 11	Slot 12	Slot 13	Slot 14	Slot 15
map 0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
map 1	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149

Case 0-1

	512 TUs								512 TUs							
	64 TUs								64 TUs							
	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Slot 11	Slot 12	Slot 13	Slot 14	Slot 15
map 0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
map 1	I	I	149	I	I	I	I	I	I	I	149	I	I	I	I	I

Case 1-0

	512 TUs								512 TUs							
	64 TUs								64 TUs							
	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Slot 11	Slot 12	Slot 13	Slot 14	Slot 15
map 0	6	I	I	I	I	I	I	I	6	I	I	I	I	I	I	I
map 1	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149

Case 0-2

	512 TUs								512 TUs							
	64 TUs								64 TUs							
	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Slot 11	Slot 12	Slot 13	Slot 14	Slot 15
map 0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
map 1	149	149	149	149	I1	I1	I2	I2	149	149	149	149	I1	I1	I2	I2

Case 1-1

	512 TUs								512 TUs							
	64 TUs								64 TUs							
	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Slot 11	Slot 12	Slot 13	Slot 14	Slot 15
map 0	6	I1	I1	I1	I1	I1	I1	I1	6	I1	I1	I1	I1	I1	I1	I1
map 1	I2	I2	149	I2	I2	I2	I2	I2	I2	I2	149	I2	I2	I2	I2	I2

Case 0-X

	512 TUs								512 TUs							
	64 TUs								64 TUs							
	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Slot 11	Slot 12	Slot 13	Slot 14	Slot 15
map 0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
map 1	149	149	149	149	0	0	0	0	149	149	149	149	0	0	0	0

6	2.4GHz DW
149	5GHz DW
I1	Infra Channel device A
I2	Infra Channel device B

I1 < I2

56. Bluetooth

Accessories integrating Bluetooth technology shall support the *Bluetooth Core Specification – Version 2.1+EDR or later*.

56.1 Enhanced Data Rate

The Enhanced Data Rate (EDR) feature introduced in the *Bluetooth 2.0 Specification* enables accessories to communicate more efficiently. Accessories shall use EDR for the following reasons:

- EDR provides higher data rates compared to Basic Data Rate (BDR).
- EDR communicates more efficiently, transferring more data bits in less time.
- EDR reduces power consumption per bit transferred.
- EDR improves coexistence with Wi-Fi and other Bluetooth accessories by using less airtime.
- EDR improves performance in multipoint configurations.

56.2 Adaptive Frequency Hopping

Adaptive Frequency Hopping (AFH), introduced in the *Bluetooth 1.2 Specification*, improves coexistence with Wi-Fi and other connected Bluetooth accessories. Accessories shall use AFH.

56.3 Sniff Mode for Low Power Consumption

Minimizing power consumption is critical for all mobile devices. Accessories shall:

- Support Bluetooth sniff mode.
- Accept sniff mode requests and support valid parameters from the Bluetooth specification.
- Support a sniff interval of 15 ms.
- Support sniff subrating.
- Not renegotiate sniff mode after it is established.

Accessories should request Bluetooth sniff mode.

Accessories should use sniff mode values of:

- Max Interval: 15 ms

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- Min Interval: 15 ms
- Sniff Attempt: 1
- Sniff Timeout: 0

Accessories compatible with devices and Mac computers should use sniff mode as often as possible, especially when there is little or no data being transmitted over the Bluetooth link. Sniff mode enables better antenna sharing with Wi-Fi, in addition to the power consumption advantages.

Sniff mode parameters are specific to the usage model and Bluetooth profile. Accessories should request sniff mode with appropriate parameters for specific usage models. If the accessory does not send a sniff mode request, the device may send a sniff mode request. When the device sends a sniff mode request, the accessory shall accept the request and parameters without negotiation.

If the accessory requests sniff mode, the accessory shall set the sniff interval to less than a third of the Bluetooth baseband Link Supervision Timeout (page 334), to make the Bluetooth link less susceptible to interference. To improve link robustness, the accessory should use a shorter sniff interval instead of multiple sniff attempts.

Links with a sniff interval of 1 second or more require a large correlation window, which has to be taken into account when calculating the number of sniff attempts. With sniff intervals shorter than 1 second, multiple sniff attempts can improve link robustness, but will increase power consumption.

56.4 Role and Topology Management

Accessories shall:

- Accept device Role Switch requests.
- Continue with the connection when the device rejects a request for Role Switch.

In a Bluetooth connection, there are two entities:

- The Central entity establishes a common clock and frequency hopping synchronization reference.
- The Peripheral entity synchronizes with the Central entity.

The Central entity can be synchronized with multiple Peripheral entities, thus forming a piconet. The Central entity can also be a Peripheral entity to another Central entity, creating a scatternet.

Accessories simultaneously connecting to multiple devices or Mac computers shall support creating a scatternet.

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Scatternets create complications since the device has to alternate between piconets, wasting valuable bandwidth. Efficiently managing network topology is important to maximize performance. The device may request a Role Switch, depending on its current topology, and the accessory shall accept the request. The device may also reject a Role Switch request due to topology concerns, as suboptimal topologies may degrade audio quality and the user experience.

Accessories should avoid requesting to be the Central entity, as in more frequently occurring scenarios the device needs to be the Central entity. Accessories insisting on being the Central entity may negatively impact the overall user experience.

56.5 Extended Inquiry Response

Accessories shall provide the following information in their Extended Inquiry Response packet:

- Local Name of the accessory (Complete or Shortened).
- TX Power Level.

During Bluetooth discovery, devices display accessories' Friendly Names when available. Extended Inquiry Response enables accessories to proactively send their Local Name, and other information, as part of an Inquiry Response to increase the speed and efficiency of the discovery process.

Accessory Local Name should match the accessory's labeling and packaging without colons ':' or semi-colons ';'. Accessories may append up to six differentiating characters to their Local Name, such as the last few digits of a serial number or MAC address, if users are likely to encounter multiple accessories at the same time using the same name. If the accessory allows a user to customize the Local Name parameter, the accessory should provide a means to restore the factory default name.

56.6 Secure Simple Pairing

Accessories shall:

- Use Secure Simple Pairing.
- Use the Numerical Comparison method if they have a display and input device supporting it.

Secure Simple Pairing greatly increases security, and is a mandatory security feature in the *Bluetooth 2.1 Specification*. To protect against a 'man-in-the-middle' attack, the Numerical Comparison association model should be used whenever feasible. See *Bluetooth 2.1+EDR Specification – Volume 1, Section 5.4*.

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56.7 Pairing Button

If the accessory has a labeled dedicated pairing control, it should use official Bluetooth branding. See https://www.bluetooth.com/develop-with-bluetooth/marketing-branding/.

56.8 Class of Device (CoD)

Devices and Mac computers use the accessory's Class of Device for UI purposes or to configure specific features. Accessories shall accurately set their Class of Device using the Bluetooth SIG-defined Major Device Class and Minor Device Class. See *Bluetooth 5.0 Specification – Volume 3, Part C, Section 3.2.4*. For example, an audio/video accessory intended to operate in a vehicle should set Major Device Class to 'audio/video' and Minor Device Class to 'car-audio'.

56.9 Link Supervision Timeout

Link supervision timeout is used to detect link loss between an accessory and a device. An accessory shall set the link supervision timeout to 2 seconds or greater when it is the Central entity, to account for the unpredictable nature of RF signals, as well as the device's need to service other concurrent wireless systems.

56.10 Delay Reporting

Devices support Delay Reporting commands as specified in the Bluetooth *Audio/Video Distribution Transport Protocol – Version 1.3*. Accessories should provide this information to improve audio/video synchronization for video playback. Accessories should not report a delay of more than 1000 ms, and should not update the delay more than once per second.

56.11 Profiles

The Apple Bluetooth profiles knowledge base article https://support.apple.com/en-us/102842 provides a complete list of the profiles supported by devices. Bluetooth specifications are the starting point for designing accessories compatible with these devices. The following sections provide additional information and requirements for common profiles to help accessory developers achieve superior results.

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56.11.1 Device ID Profile (DID)

Accessories shall:

- Support Bluetooth Device ID Profile, Version 1.3 or later.
- Use their Company Identifier from the Assigned Numbers specification assigned by the Bluetooth SIG as the Vendor ID value (VID), see https://www.bluetooth.com/specifications/assigned-numbers/. Bluetooth HID Profile accessories may use a VID assigned by the USB Implementers Forum (USB-IF), see https://www.usb.org/getting-vendor-id, if the manufacturer does not have a Bluetooth SIG Company Identifier.
- Use its VID value for the end product manufacturer.
- Not use the Company ID assigned to Apple by the Bluetooth SIG, or the Vendor ID assigned to Apple by the USB Implementers Forum.
- Use the Vendor ID Source field to identify which organization assigned the value used in the Vendor ID field. See *Bluetooth Device ID Profile Specification – Section 5.6*.
- Use a ProductID value uniquely identifying the product.
- Use a Version value uniquely identifying the software version.

The Device ID record enables devices to identify the implementation of the accessory, which is used to bridge alternate interpretations of the Bluetooth specification when communicating with an accessory. It is important the information in the Device ID record uniquely identify the implementation in use.

In the case of Bluetooth car kit devices, the same car kit may be present in different car models. Ideally, the two car kits should have different ProductIDs. However, it is acceptable for them to have the same ProductID as long as they have identical hardware, software, and features. If the implementations differ at all, they should have different ProductIDs. The accessory can also use a secondary Device ID record to uniquely identify the product ID, or model number.

56.11.2 Service Discovery Protocol (SDP)

To facilitate caching Service Discovery Protocol service records, accessories shall:

- Support the ServiceDiscoveryServer Service Class.
- Support the ServiceDatabaseState attribute.
  - Attribute's value shall change whenever any SDP service record or attributes within a record are added, removed, or modified.
  - Attribute's value shall not change based on RFCOMM channel protocol parameters. Devices query these values separately at connection time.

56.11.3 Hands-Free Profile (HFP)

Accessories supporting the Hands-Free Profile should meet the requirements of the *Bluetooth Hands-Free Profile Specification – Version 1.5 or later*.

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Accessories can use the Bluetooth Hands-Free Profile for telephony. To achieve the best user experience, the accessory should support the following features, which are optional in the Bluetooth specification.

56.11.3.1 Remote Audio Volume Control

Accessories supporting HFP should:

- Support Remote Audio Volume Control, so speaker volume on the hands-free accessory can be controlled from the device as described in *Bluetooth Hands-Free Profile Specification – Version 1.5, Section 4.28*.
- Set the Remote Volume Control bit in the Supported Features bitmap sent with the `AT+BRSF=` command.

In some situations the user may prefer to control the output volume through the device instead of directly on the accessory. For example, a car passenger (or if the car is parked, the driver) could use the volume slider on the phone to control audio volume. Volume control synchronization is outlined in *Bluetooth Hands-Free Profile Specification – Version 1.5, Section 4.48.2*.

56.11.3.2 Indicator Event Reporting

Accessories supporting HFP should use Indicator Event Reporting, and not perform repetitive status polling.

Devices and Mac computers support all mandatory and optional indicators specified in HFP version 1.5 (`service`, `call`, `callsetup`, `callheld`, `signal`, `roam`, `battchg`). To minimize unnecessary status polling using the `AT+CIND?` command, the accessory should enable Indicator Event Reporting by sending an `AT+CMER` command. The device will then send a `+CIEV` event when there is a status change. The accessory should request initial status using the `AT+CIND=?` and `AT+CIND?` commands, according to the HFP specification.

56.11.3.3 Voice Recognition Activation

Accessories supporting HFP shall:

- Support Voice Recognition Activation, both Audio Gateway (AG) and Hands-Free (HF), initiated as described in *Bluetooth Hands-Free Profile Specification – Version 1.5, Section 4.25*.
- Set the Voice Recognition Activation bit in the Supported Features bitmap sent with the `AT+BRSF=` command.

Devices and Mac computers support voice recognition initiated by accessories (Hands-Free) and devices (Audio Gateway).

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56.11.3.4 Echo Cancellation and Noise Reduction

When echo cancellation and noise reduction are performed locally on a hands-free accessory, the accessory should disable echo cancellation and noise reduction on the device by sending an AT+NREC command, as described in the *Bluetooth Hands-Free Profile Specification – Version 1.5, Section 4.24*.

Devices and Mac computers support echo cancellation and noise reduction by default. If a hands-free accessory performs echo cancellation and noise reduction, the accessory needs to turn these features off on the device (the Audio Gateway), to avoid unnecessary audio quality degradation due to duplicate audio processing.

56.11.3.5 In-Band Ringing

Accessories supporting HFP should also support In-Band Ringing as specified in the *Bluetooth Hands-Free Profile Specification – Version 1.5, Section 4.13.1*. If the user sets a ring tone on the device, the same ring tone should sound on the hands-free accessory.

56.11.3.6 Synchronous Connection

Accessories supporting HFP shall:

- Support eSCO parameter sets S2 and S3 and accept requests for these settings. See *Bluetooth Hands-Free Profile Specification – Version 1.5, Section 5.6*.
- Request eSCO parameter set S2 or S3 when setting up a Synchronous Connection. eSCO parameter set S1 should not be requested.
- Render audio within 40 ms after the SCO/eSCO connection has been set up.

eSCO packet types offer packet retransmission, whereas traditional SCO packets are not retransmitted. This improves audio quality and the user experience. eSCO packet types 2-EV3 and 3-EV3 offer a greater time interval between packets, which can improve Wi-Fi performance and allow time for other concurrent Bluetooth connections to send data.

Accessories should use 2-EV3 and 3-EV3 packets for SCO connections. Using HV3 packets is not recommended. HV3 packets require more link time and do not allow audio packet retransmission, which impacts audio performance in the presence of RF interference.

56.11.3.7 Wide Band Speech

Accessories supporting HFP should support Wide Band Speech as described in the *Bluetooth Hands-Free Profile Specification – Version 1.6, Section 5.7.4*. If Wide Band Speech is supported, the accessory should support the T2 link parameter settings.

Devices use Wide Band Speech for eSCO connections, such as cellular calls, FaceTime, and Siri.

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56.11.4 Message Access Profile (MAP)

Accessories supporting Message Access Profile shall:

- Support Message Notification, as described in *Bluetooth Message Access Profile Specification – Version 1.1, Section 4.1*.
- Register for notifications immediately after the connection is established, as described in *Bluetooth Message Access Profile Specification – Version 1.1, Section 4.5*.

Devices support MAP 1.1.

56.11.5 Audio/Video Remote Control Profile (AVRCP)

Accessories supporting the Audio/Video Remote Control Profile should meet the requirements of the *Bluetooth Audio/Video Remote Control Profile Specification – Version 1.4*.

56.11.5.1 Supported Operations

Devices and Mac computers support the following operation_IDs in passthrough commands:

- Play
- Stop
- Pause
- Fast Forward
- Rewind
- Forward
- Backward

56.11.5.2 Repeat and Shuffle Modes

Every device in the role of an AVRCP target supports Repeat and Shuffle modes. An AVRCP controller may use `SetPlayerApplicationSettingValue` to set a value on the device and `GetPlayerApplicationSettingValue` to read a value, as described in *Bluetooth Audio/Video Remote Control Profile Specification – Version 1.4, Sections 6.5.4 and 6.4.3*.

56.11.5.3 Notifications

Accessories supporting AVRCP shall:

- Register for notifications.
- Not perform repetitive device status polling.

Every device in the role of an AVRCP Target supports registering for notifications, as described in *Bluetooth Audio/Video Remote Control Profile Specification – Version 1.4, Section 6.7*. The commands `RegisterNotification` and `GetPlayStatus` are supported for these notifications:

- EVENT_PLAYBACK_STATUS_CHANGED

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- EVENT_TRACK_CHANGED
- EVENT_NOW_PLAYING_CONTENT_CHANGED
- EVENT_AVAILABLE_PLAYERS_CHANGED
- EVENT_ADDRESSED_PLAYER_CHANGED
- EVENT_VOLUME_CHANGED

56.11.5.4 Play/Pause Button

Accessories supporting AVRCP implementing a Play/Pause control surface shall confirm the playback status of the device using AVRCP Notifications (page 338), before sending a Play or Pause command. See Supported Operations (page 338). Specifically:

- If a device notifies the accessory it is paused, pressing the accessory's Play/Pause control surface should send a Play command.
- If a device notifies the accessory it is playing, pressing the accessory's Play/Pause control surface should send a Pause command.
- The accessory should not infer device playback status based on the number of times the Play/Pause control surface has been pressed.

56.11.5.5 Volume Handling

Accessories supporting AVRCP should support Absolute Volume, as described in the *Bluetooth Audio/Video Remote Control Profile Specification – Version 1.4, Section 6.13*.

Every device in the role of AVRCP Controller supports volume handling.

56.11.5.6 Browsing

Accessories supporting Browsing (in controller role) as part of AVRCP shall:

- Not try to index or cache the entire library upon connection. The device may contain tens of thousands of media items, and each may be present multiple times in the hierarchy.
- Not fetch all items when browsing a folder; only fetch items displayed to the user. The accessory may prefetch a few items to improve the responsiveness of the user interface.
- Not reorder items (for example, alphabetically).
- Not assume UIDs to be statically defined, especially in the root folder. The ordering and UIDs of folders and items may change at any point in future releases.
- Send the `SetBrowsedPlayer` command after receiving an EVENT_UIDS_CHANGED notification.
- Not assume the UID passed to the `PlayItem` command will result in the media player playing the UID.

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Currently only the built-in Music app supports browsing. When switching between players, an EVENT_AVAILABLE_PLAYERS_CHANGED notification, and an EVENT_ADDRESSED_PLAYER_CHANGED notification will be generated. The UI needs to look at the feature bit mask of the listed player to determine whether browsing is currently available.

Devices support AVRCP Browsing.

56.11.5.7 iOS App-Provided Metadata

An audio app running on a device may use the iOS Media Player Framework to provide metadata about the current audio stream to the accessory using AVRCP. Requirements and usage for these messages may be found in the `MPNowPlayingInfoCenter` class in Apple Media Player Framework documentation.

56.11.6 Advanced Audio Distribution Profile (A2DP)

See Advanced Audio Distribution Profile (A2DP) (page 312).

56.12 Audio Routing

Accessories can differentiate between various audio content provided by a device, and determine playback behavior.

An accessory can receive audio data from the device using either of two Bluetooth profiles:

- HFP using eSCO channel.
- A2DP using ACL channel.

The device determines which channel to use, depending on how the audio content is used. An audio path created for two-way communication (for example, phone calls or FaceTime) always uses the HFP (eSCO) route for sending audio data. Music and similar content uses the A2DP channel route. In the absence of a defined route, audio playback defaults to the device.

56.12.1 Audio Data Received using HFP Profile

Most of the audio content sent using HFP (eSCO) route requires two-way communication. Scenarios where HFP (eSCO) is used include, but are not limited to: cellular calls, FaceTime, and voice mail.

The accessory speaker and microphone should be dedicated to the HFP (eSCO) route, and not mixed/muxed with any other audio sources.

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56.12.2 Audio Data Received using A2DP Profile

Audio content transferred using A2DP profiles can be broadly classified into two categories:

- Audio content from music, video, or game-like applications.
- System-generated sounds used for alerts and notifications.

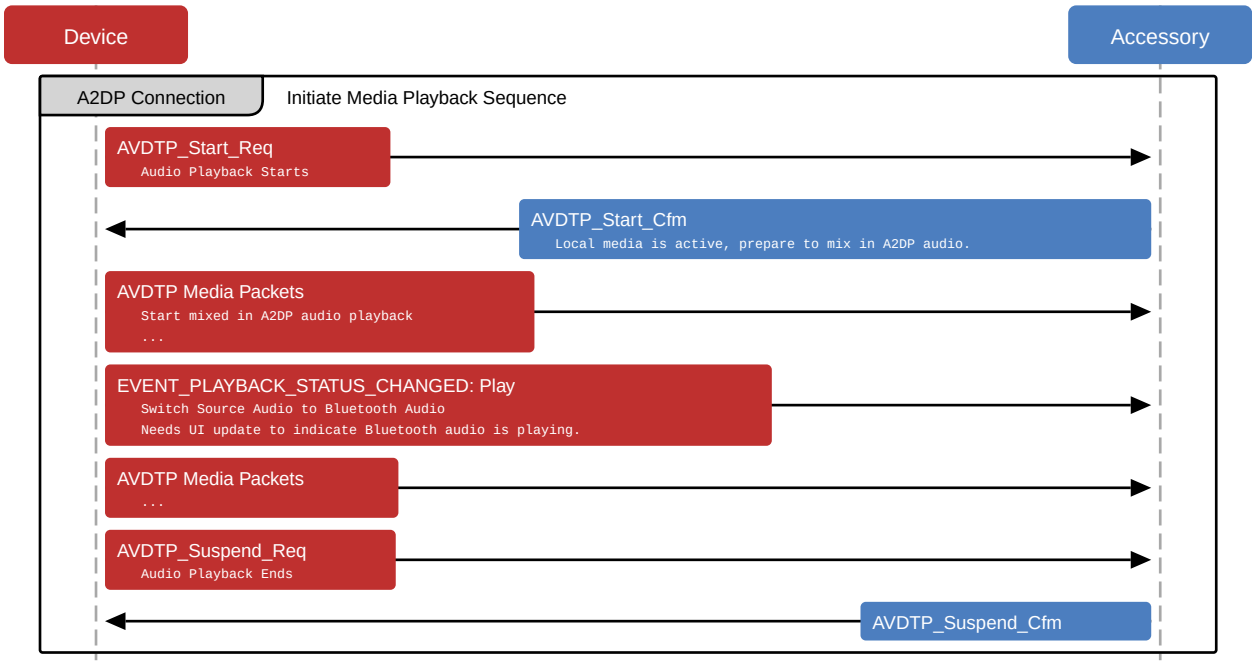
56.12.2.1 Differentiating Audio Content from System Sounds

Music-like content can be differentiated from system sounds by adding support for Audio/Video Remote Control Profile (AVRCP) (page 338) version 1.3 or later. The AVRCP profile allows an accessory to be aware of the audio playback device state, using notifications.

When a device initiates audio playback over an A2DP channel for playing music content, an AVRCP notification EVENT_PLAYBACK_STATUS_CHANGED is sent to indicate playback status has changed to the play state. See *Bluetooth Audio/Video Remote Control Profile Specification – Version 1.4, Section 6.7.2*. This indicates audio data using the A2DP profile contains music. When a device initiates audio playback over an A2DP channel for playing system sounds, no AVRCP notifications are sent.

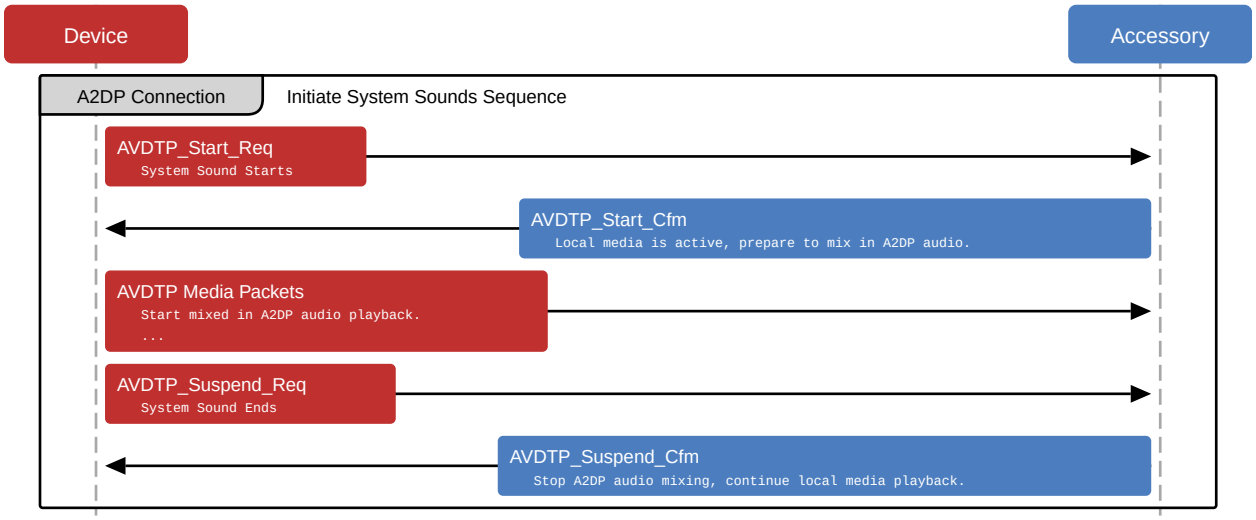
Figure 56-1 (page 341) and Figure 56-2 (page 342) show the difference between notifications for music playback, and system sounds.

Figure 56-1 Initiate Audio Playback (for example, music)



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Figure 56-2 Initiate System Sound (such as turn-by-turn directions)



56.12.2.2 Expected Audio Routing Behavior for A2DP

The accessory should tune its audio routing behavior based on audio content over the A2DP channel.

If audio data contains music, accessory speakers are expected to be dedicated to audio data using the Bluetooth link, and any other audio playback is paused. If audio data contains system sounds, it is expected the accessory can render audio as desired. If the accessory is playing audio from a different source, it is not necessary to pause existing audio playback on the device, and system sound data can be mixed with the existing track for playback.

56.13 HID

When implementing HID over Bluetooth, the accessory should:

- Support Bluetooth HID Profile 1.1.
- Support Sniff Mode for Low Power Consumption (page 331).

The accessory should:

- Use the following parameters in SDP for sniff subrating:
  - HIDSSRHostMaxLatency - 450 ms (720 slots)
  - HIDSSRHostMinTimeout - 45 ms (72 slots)
- Use a typical report packet of 22 bytes or less. This is small enough to fit into a DH1 packet with L2CAP and HID header.

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57. Bluetooth Low Energy (BLE)

Accessories integrating Bluetooth Low Energy (BLE) technology shall support the *Bluetooth 4.0 Specification* or later.

57.1 Role

The accessory should implement either the Peripheral role or the Broadcaster role as defined in the *Bluetooth 4.0 Specification – Volume 3, Part C, Section 2.2.2.3 and Section 2.2.2.1*.

57.2 Advertising Channels

The accessory should advertise on all three advertising channels (37, 38, and 39) at each advertising event. See the *Bluetooth 4.0 Specification – Volume 6, Part B, Section 4.4.2.1*.

57.3 Advertising PDU

The accessory should use one of the following advertising PDUs:

- ADV_IND
- ADV_NOCONN_IND
- ADV_SCAN_IND

ADV_DIRECT_IND should not be used. See the *Bluetooth 4.0 Specification – Volume 6, Part B, Section 2.3.1*.

57.4 Advertising Data

The advertising data sent by the accessory should contain at least the following information as described in the *Bluetooth Core Specification Supplement – Part A*:

- Flags.
- TX Power Level.
- Local Name.

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- Services.

The Local Name should match the accessory's markings and packaging and not contain a colon ':' or semi-colon ';'.

The accessory may put the Local Name and the TX Power Level data in the SCAN_RSP PDU if, for example, it needs to reduce power consumption or not all of the advertising data fit into the advertising PDU. Depending on its state, the device may not always perform active scanning.

The primary services should always be advertised in the advertising PDU. Secondary services should not be advertised. Services not significant to the primary use case of the accessory may be omitted if space is limited in the Advertising PDU.

The advertising data and the scan response data in the SCAN_RSP PDU should comply with the formatting guidelines in the *Bluetooth 4.0 Specification – Volume 3, Part C, Section 18*: each starts with a length field, followed by AD Type and AD Data.

57.5 Advertising Interval

The accessory should first use the recommended advertising interval of 20 ms for at least 30 seconds.

If it is not discovered within the initial 30 seconds, Apple recommends using one of the following longer intervals to increase chances of discovery by the device:

- 152.5 ms
- 211.25 ms
- 318.75 ms
- 417.5 ms
- 546.25 ms
- 760 ms
- 852.5 ms
- 1022.5 ms
- 1285 ms

> **Note:**
> Longer advertising intervals usually result in longer discovery and connect times, but may lower accessory power consumption.

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57.6 Connection Parameters

If both the Central and Peripheral support the Connection Parameters Request procedure, then either shall use the procedure. The device will not read or use the parameters in the Peripheral Preferred Connection Parameters characteristic. See *Bluetooth 5.3 Specification – Volume 6, Part B, Section 5.1.1 Connection Update*.

Connection parameter requests may be rejected if they do not meet these guidelines.

General connection parameter request guidelines:

- Peripheral Latency ≤ 30 connection intervals.
- Supervision Timeout from 6 seconds to 18 seconds.
- Interval Min ≥ 15 ms.
- Interval Min ≤ 2 seconds.
- Interval Min is a multiple of 15 ms.
- One of the following:
  - Interval Max at least 15 ms greater than Interval Min.
  - Interval Max and Interval Min are both 15 ms.
- Interval Max * (Peripheral Latency + 1) of 6 seconds or less.
- Supervision Timeout greater than Interval Max * (Peripheral Latency + 1) * 3.

If Bluetooth Low Energy HID is one of the connected services of an accessory, a connection interval down to 11.25 ms may be accepted by some devices.

> **Note:**
> When Interval Max and Interval Min are both 15 ms, some devices (such as Apple Watch) will offer a 30 ms interval to better balance power and performance constraints.

Apple Watch connection parameter request guidelines:

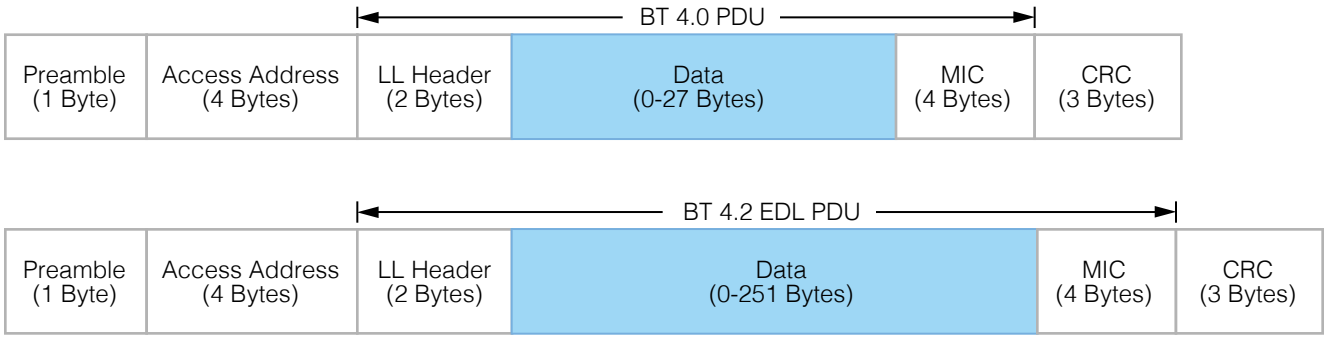
- Interval Min ≥ 30 ms.
- Interval Min is a multiple of 30 ms.
- One of the following:
  - Interval Max at least 30 ms greater than Interval Min.
  - Interval Max and Interval Min are both 30 ms.

57.7 Data Packet Length Extension

Data Packet Length Extension increases the maximum data length from 27 bytes to 251 bytes. Using larger per-packet data lengths improves radio efficiency, greatly increasing application data rates and boosting battery life. See *Bluetooth 5.0 Specification – Volume 6, Part B, Section 4.6.6*.

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Figure 57-1 Data Packet Length Extension



Accessories should support Data Packet Length Extension for best performance with devices.

Devices and Mac computers operating as the Central will negotiate optimal data packet lengths based on various factors, such as connection event length, system topology, and protocol.

57.8 Privacy

The accessory should be able to resolve a Resolvable Private Address in all situations. Due to privacy concerns, the device will use a Random Device Address as defined in the *Bluetooth 4.0 Specification – Volume 3, Part C, Section 10.8*.

57.9 Permissions

The accessory should not require special permissions, such as pairing, authentication, or encryption, to discover services and characteristics. It may require special permissions only for access to a characteristic value or a descriptor value. See the *Bluetooth 4.0 Specification – Volume 3, Part G, Section 8.1*, fifth paragraph.

57.10 Pairing

The accessory should not request pairing until an ATT request is rejected using the Insufficient Authentication error code. See the *Bluetooth 4.0 Specification – Volume 3, Part F, Section 4*.

If, for security reasons, the accessory requires a bonded relationship with the Central, the Peripheral should reject the ATT request using the Insufficient Authentication error code, as appropriate. As a result, the device may proceed with the necessary security procedures.

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Similarly, if the device acts as a Central and a GATT server, it may reject an ATT request using the Insufficient Authentication error code. The accessory should initiate the security procedure for pairing in response.

Pairing may require user authorization depending on the device. Once an accessory is paired with a device, the accessory shall retain the distributed keys of both central and peripheral for future use. If the pairing is no longer required, the accessory shall delete both sets of keys.

57.11 MTU Size

An accessory supporting packet length extension shall perform the packet length update procedure before performing the Exchange MTU Request handshake, see Data Packet Length Extension (page 345).

Devices will support and request an MTU size larger than the default during the Exchange MTU Request handshake. See the *Bluetooth 4.0 Specification – Volume 3, Part F, Section 3.2.8*.

When operating as ATT client, the device will request the optimal MTU size based on factors such as the Bluetooth topology, connection event length, maximum data length, and protocol (GATT or connection-oriented L2CAP).

An accessory operating as ATT server should select an MTU equal to or greater than the device's MTU request.

57.12 Services

57.12.1 Generic Access Profile Service

The accessory should implement the Device Name characteristic per the *Bluetooth 4.0 Specification – Volume 3, Part C, Section 12.1*. The Device Name characteristic should be writeable.

57.12.2 Generic Attribute Profile Service

The accessory shall implement the Service Changed characteristic only if the accessory has the ability to change its services during its lifetime.

The device may use the Service Changed characteristic to determine if it can rely on previously read (cached) information from the accessory. See the *Bluetooth 4.0 Specification – Volume 3, Part G, Section 7.1*.

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57.12.3 Device Information Service

The accessory shall implement the Device Information Service. The service UUID for this service should not be advertised in the Advertising Data. The following characteristics should be supported:

- Manufacturer Name String (26 characters maximum).
- Model Number String (26 characters maximum).
- Hardware Revision String.
- Firmware Revision String.
- Software Revision String.
- Serial Number String.

57.12.4 Available Services

Devices make Battery Service, Current Time Service, and Apple Notification Center Service (ANCS) available to an accessory. The Current Time Service supports the current time and local time information characteristics. The service does not provide an "Adjust Reason" when the current time changes. ANCS uses `7905F431-B5CE-4E99-A40F-4B1E122D00D0` as its UUID.

These services are not guaranteed to be available immediately after connection, and the accessory shall support Characteristic Value Indication of the Service Changed characteristic (see *Bluetooth 4.0 Specification – Volume 3, Part G, Section 7.1*) to be notified when the services become available. The device will maintain a connection to an accessory as long as it is paired and uses one of the available services.

57.13 HID

When implementing HID over Bluetooth Low Energy, the accessory shall advertise the HID Service in the Advertising Data (page 343).

57.14 GATT Server

Applications may contribute services and characteristics to the GATT server the device makes available to the accessory.

The following services are implemented internally by iOS and shall not be published by third-party iOS applications:

- Generic Attribute Profile Service
- Generic Access Profile Service
- HID Service
- Battery Service

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- Current Time Service
- Apple Notification Center Service

The device implements the GATT Service Changed characteristic, because the database contents can change at any time. The accessory should therefore support the Characteristic Value Indication of this characteristic and, upon receiving indications, invalidate its database cache accordingly. See the *Bluetooth 4.0 Specification – Volume 3, Part G, Section 7.1*.

The accessory should minimize the use of ATT/GATT requests and commands and only send what is necessary. For example, do not use GATT Discover All Services when the accessory is looking for specific services. Use Discover Primary Service By Service UUID instead. Less airtime equals less power consumption and better performance for both the accessory and the device.

When third-party iOS applications discover services on the accessory, the following services are used internally by iOS and are filtered out from the list of discovered services:

- Generic Attribute Profile Service
- Generic Access Profile Service
- HID Service
- Apple Notification Center Service

The accessory should be robust enough to handle any error gracefully. Pairing and Characteristic Value reads/writes may fail if the application owning the service is not in the foreground and is not entitled to run in the background.

If an ATT Prepare Write Request is used, all queued attributes are contained within the same GATT Service.

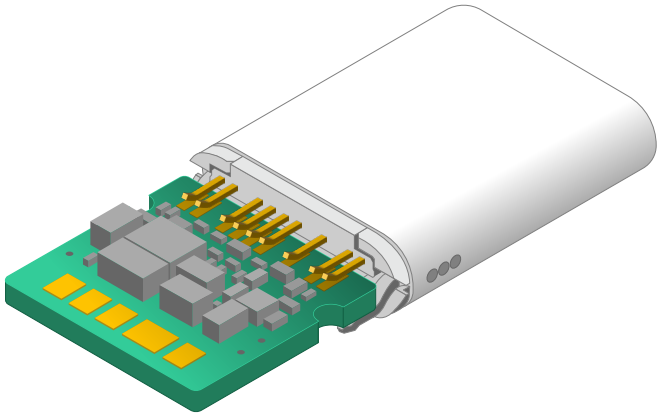
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Modules

58. Apple USB-C Analog Headset Module

The Apple USB-C Analog Headset Module (C125) may be used to create USB-IF compliant Headsets (page 84) supporting up to 24-bit/384 kHz stereo and up to 24-bit/48 kHz mono (microphone) audio. C125 supports Apple Music Lossless and Hi-Res Lossless.

Figure 58-1 USB-C Analog Headset Module (C125)



58.1 Overview

C125 is a USB-IF certified USB Audio Device Class 2.0 and 3.0 codec (Test ID: 14167, see https://www.usb.org/single-product/14167) with an integrated USB-C plug.

C125 supports:

- 16-bit and 24-bit samples.
- 44.1 kHz, 48 kHz, 88.2 kHz, 96 kHz stereo headphone-level output.
- Optional:
  - 176.4 kHz, 192 kHz, 384 kHz stereo headphone-level output.
  - 7-band output EQ.
- 44.1 kHz, 48 kHz mono microphone input.
- Optional:
  - 7-band microphone input EQ.
  - 3-band sidetone EQ.

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- Headset remote controls (volume up, volume down, and center buttons).

C125 does not support USB-C to 3.5 mm headset jack adapters.

58.1.1 Additional Specifications & Support

Additional software and support for C125 is available from Cirrus Logic, Inc.

Get started at https://www.cirrus.com/resources/c125.

58.1.2 Procurement

The C125 is available at https://c125.proscalnext.com/:

Variant	Part Number
C125	AB23169-1A033-AH

58.2 Configurations

C125 accessories shall implement one of the following configurations. The microphone and buttons may be located on either the left or right side of the headset.

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Figure 58-2 USB-C Analog Headset Module (C125), single detachable cable

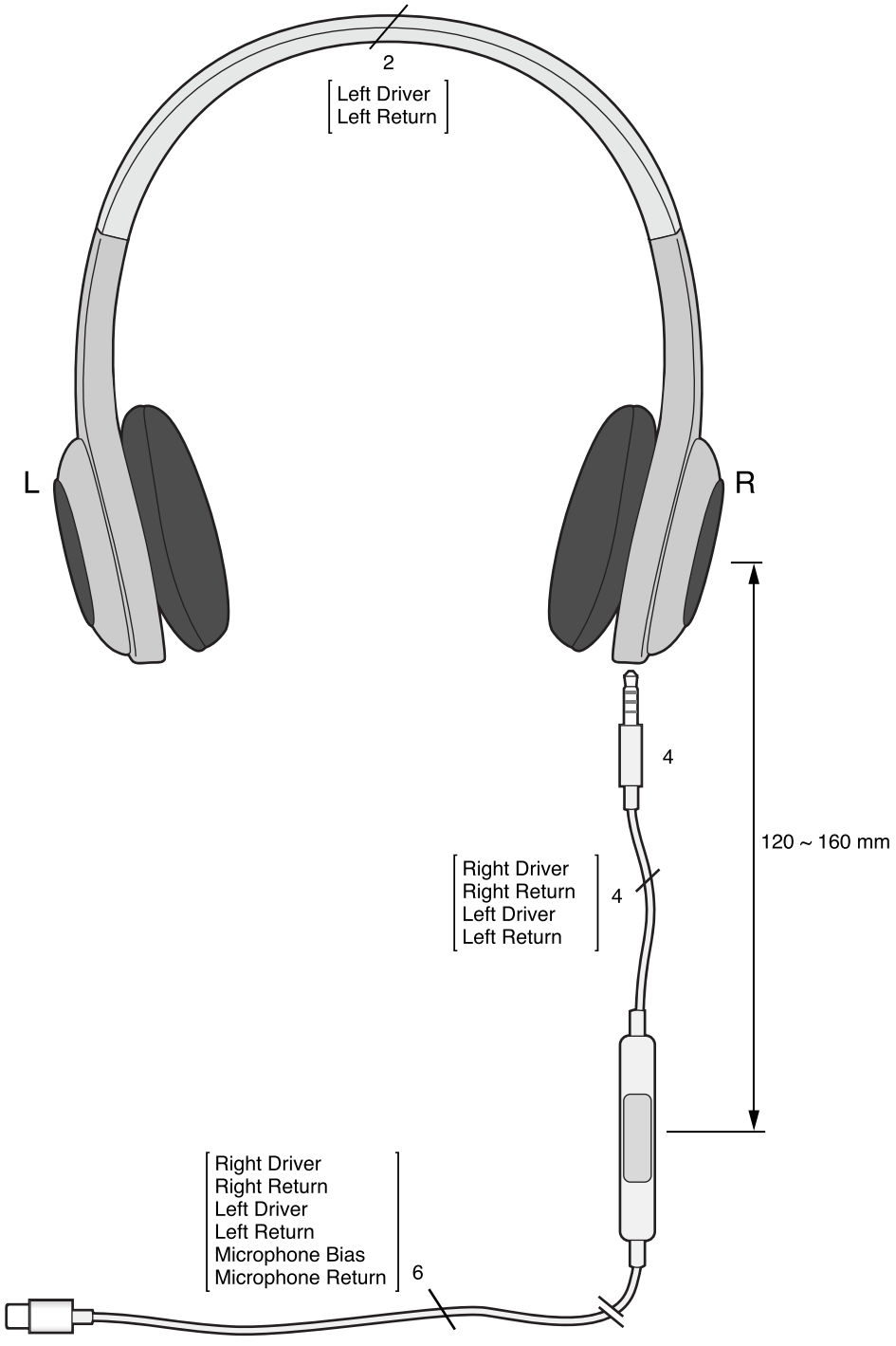
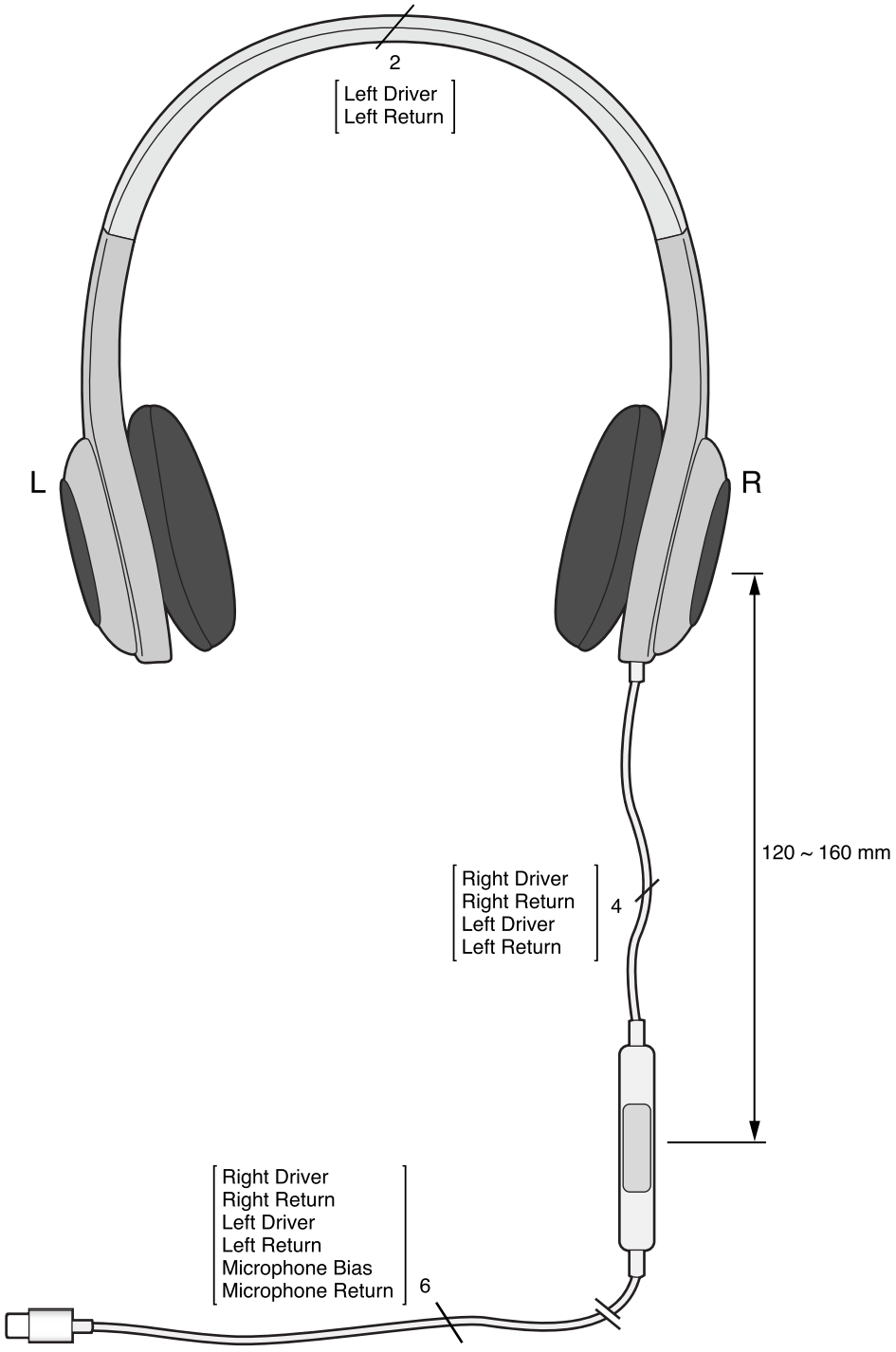


Figure 58-3 USB-C Analog Headset Module (C125), single built-in cable



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Figure 58-4 USB-C Analog Headset Module (C125), split detachable cable

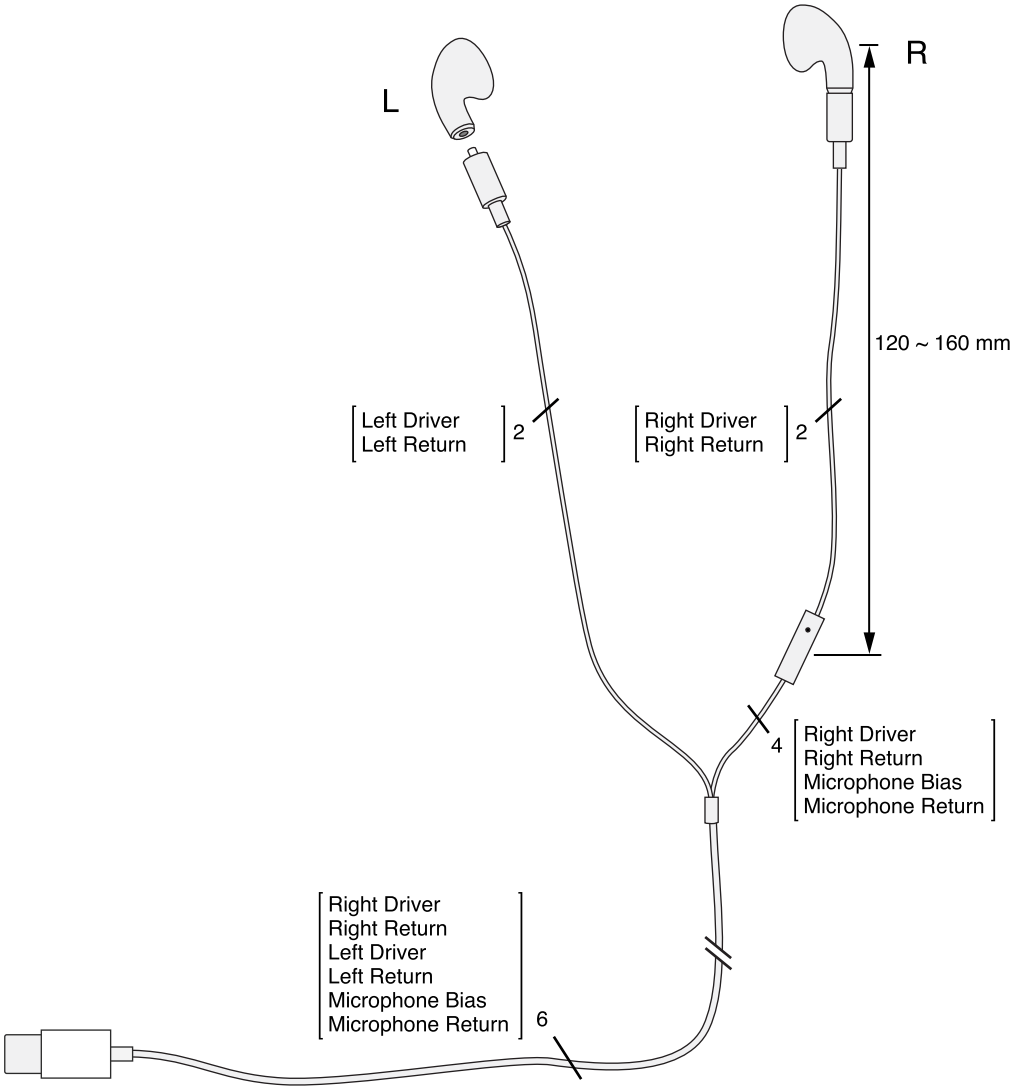
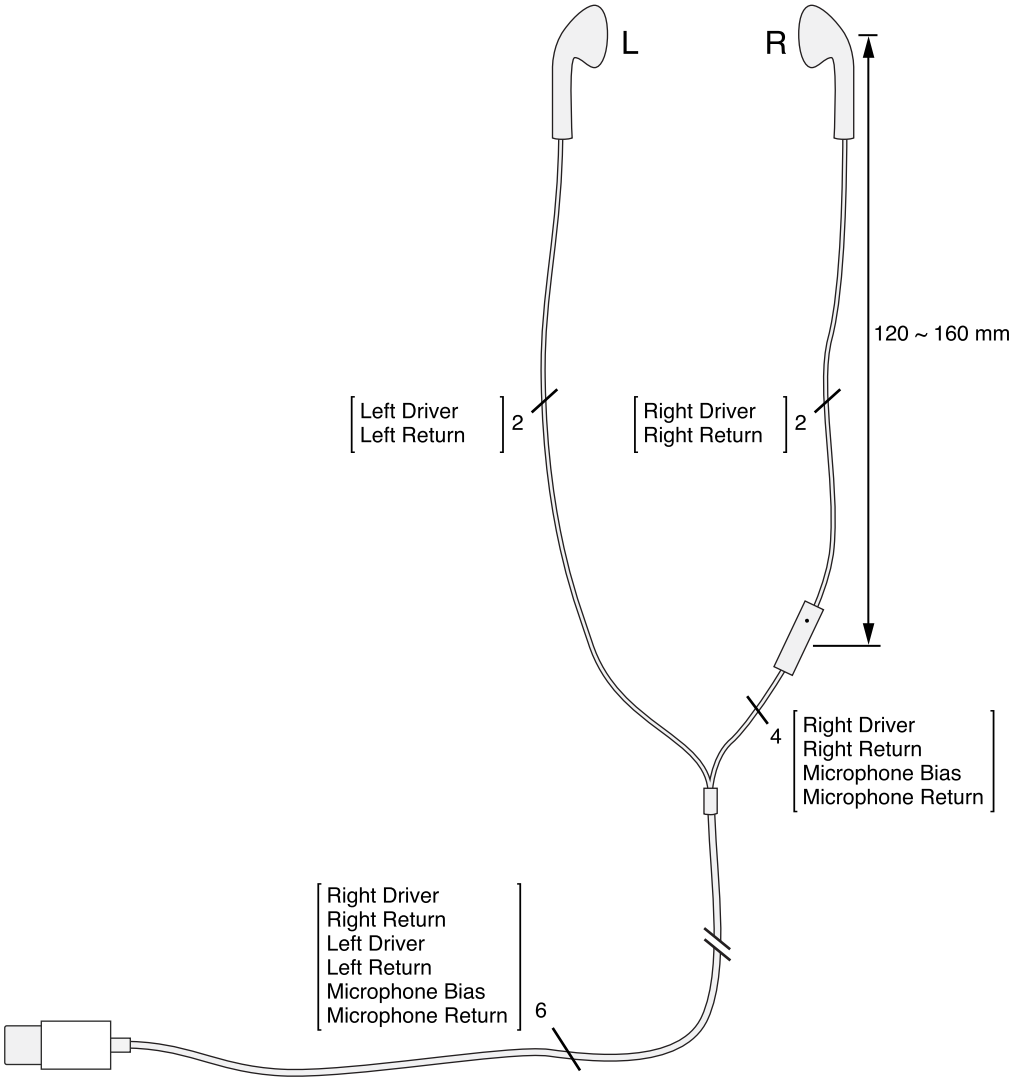


Figure 58-5 USB-C Analog Headset Module (C125), split built-in cable



58.3 Mechanical

C125 has the following mechanical characteristics:

- Integrated USB-C connector.
- Not encapsulated.
- -20° to 65° C working temperature range.

See C125 Dimensions (page 360) for dimensional drawing.

C125 headsets shall:

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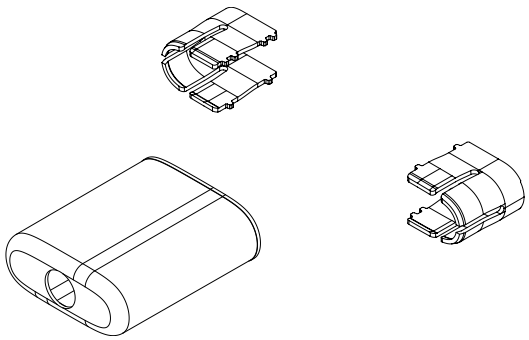
- Meet the requirements for USB-C connector integration, see Mechanical (page 385).
- Encapsulate both sides of C125.

58.3.1 Shielding

C125 headsets shall:

- Protect the C125 electronic components with a SUS shield.
- Laser weld the SUS shield to the C125 ground ring.

Figure 58-6 C125 recommended three-part shield design



Apple recommends the following three-part shield design as shown in Figure 58-6 (page 357) for C125:

- C125 Recommended Clamshell Shields (page 361)
- C125 Recommended Rear Shield (page 362)

58.4 Pad Assignments

Figure 58-7 (page 358) and Table 58-1 (page 358) detail the layout, names, description, and assignments of the C125 pads.

Figure 58-7 C125 pads

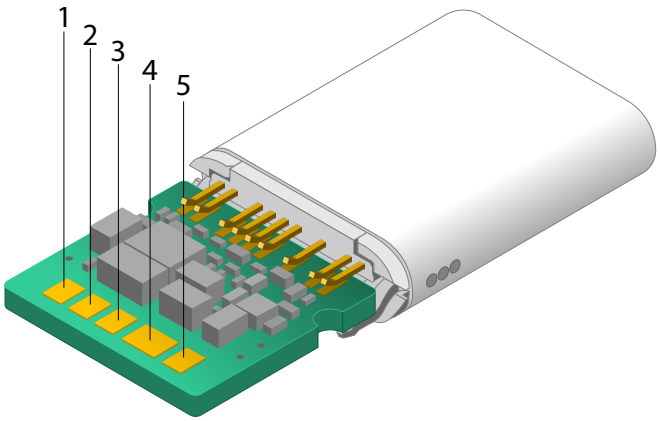


Table 58-1 C125 pad assignments

Pad	Name	Assignments
1	Left Driver	Left Driver
2	Microphone Bias	Microphone Bias
3	Reserved	NC
4	Ground	Right Return, Left Return, Microphone Return
5	Right Driver	Right Driver

58.5 Electrical

C125 headsets shall incorporate the Headset Remote and Microphone Transmitter (page 364) using Tone Mode (page 366).

The C125 shield may be treated as an electrical ground.

58.5.1 DAC Characteristics

The C125 DAC receives lossless 24-bit stereo audio from the device.

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Table 58-2 C125 DAC characteristics, 24-bit/96 kHz mode

Driver	Parameter	Typical
32 Ω, 1 nF	Dynamic range (A-weighted)	117 dB
	THD+N (FS = 48 kHz, BW = 20 kHz)	-91 dB
	Full-scale output voltage	2.4 V_{PP}
	Output power	22.6 mW
16 Ω, 1 nF	Dynamic range (A-weighted)	112 dB
	THD+N (FS = 48 kHz, BW = 20 kHz)	-83 dB
	Full-scale output voltage	1.3 V_{PP}
	Output power	14.2 mW

Table 58-3 C125 DAC characteristics, 24-bit/384 kHz mode

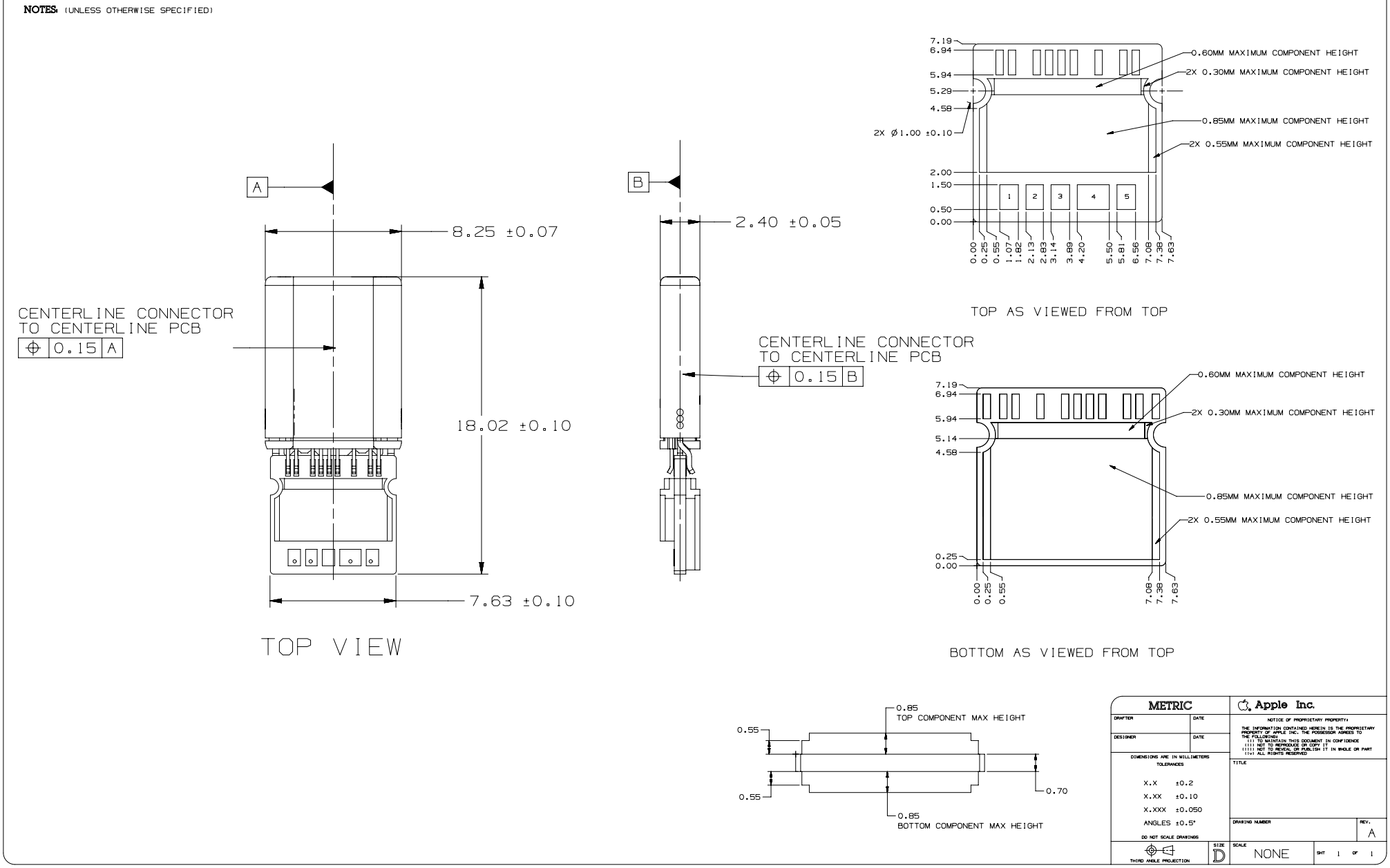
Driver	Parameter	Typical
32 Ω, 500 pF	Dynamic range (A-weighted)	117 dB
	THD+N (FS = 48 kHz, BW = 20 kHz)	-91 dB
	THD+N (FS = 192 kHz, BW = 80 kHz)	-90 dB
	Full-scale output voltage	2.4 V_{PP}
	Output power	22.6 mW
16 Ω, 500 pF	Dynamic range (A-weighted)	112 dB
	THD+N (FS = 48 kHz, BW = 20 kHz)	-84 dB
	THD+N (FS = 192 kHz, BW = 80 kHz)	-83 dB
	Full-scale output voltage	1.3 V_{PP}
	Output power	14.2 mW

The characteristics in Table 58-2 (page 359) and Table 58-3 (page 359) were measured under the following conditions:

- Left Driver, Right Driver, and Ground pads on C125 connected to a load and an audio analyzer, such as the Audio Precision APx series.
- Microphone Bias pad connected to the Ground pad.
- Full-scale 1 kHz sine wave input test signal.

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58.6 C125 Dimensions

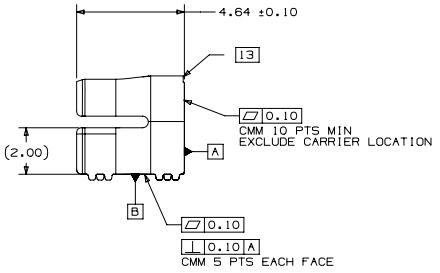


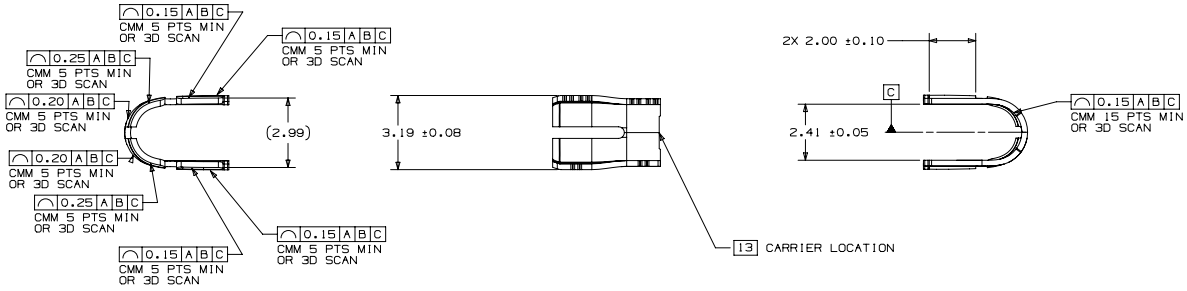
58.7 C125 Recommended Clamshell Shields

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. ALL DIMENSIONS AND TOLERANCES APPLY PER ASME Y14.5M, 1994. IT IS EXPECTED THAT THE SUPPLIER UNDERSTAND AND COMPLY WITH ALL TOLERANCES AS DESCRIBED IN THIS STANDARD AND APPLIED TO THIS DRAWING.
2. DIMENSIONS ARE MEASURED AFTER PLATING.
3. ALL DIMENSIONS THAT LOCATE GEOMETRICAL TOLERANCE FEATURES (PROFILE AND POSITION CHARACTERISTICS) ARE CONSIDERED BASIC AS DEFINED IN THE ASME Y14.5M, 1994 STANDARD.
4. WHEN DATUMS ARE SPECIFIED ON A DRAWING, DIMENSIONS ARE RELATED TO DATUM A (AS THE PRIMARY DATUM), DATUM B (SECONDARY), AND DATUM C (TERTIARY).
5. PERFECT ORIENTATION AND/OR PERFECT LOCATION AT MMC REQUIRED FOR THE INTERRELATIONSHIP OF ALL DATUM FEATURES OF SIZE, UNLESS OTHERWISE SPECIFIED ON DRAWING.
6. UNLESS OTHERWISE SPECIFIED, ALL SURFACES TO BE WITHIN A SURFACE PROFILE TOLERANCE OF ⌓ 0.1 A B C.
7. ALL BURRS TO BE LESS THAN 0.02 mm.
8. BREAK ALL EDGES 0.05 mm R UNLESS SPECIFIED.
9. PART NEEDS TO SURVIVE 8HR SALT SPRAY TEST.
10. MATERIAL: SUS304-1/2H, 0.25mm THK
11. FINISH: 2-5 μm NICKEL PLATING PER AMS QQ-N-290
12. ALL PLATING TO OCCUR AFTER PART STAMPING AND FORMING

[13] BURRS SHALL BE SUBFLUSH TO DATUM A



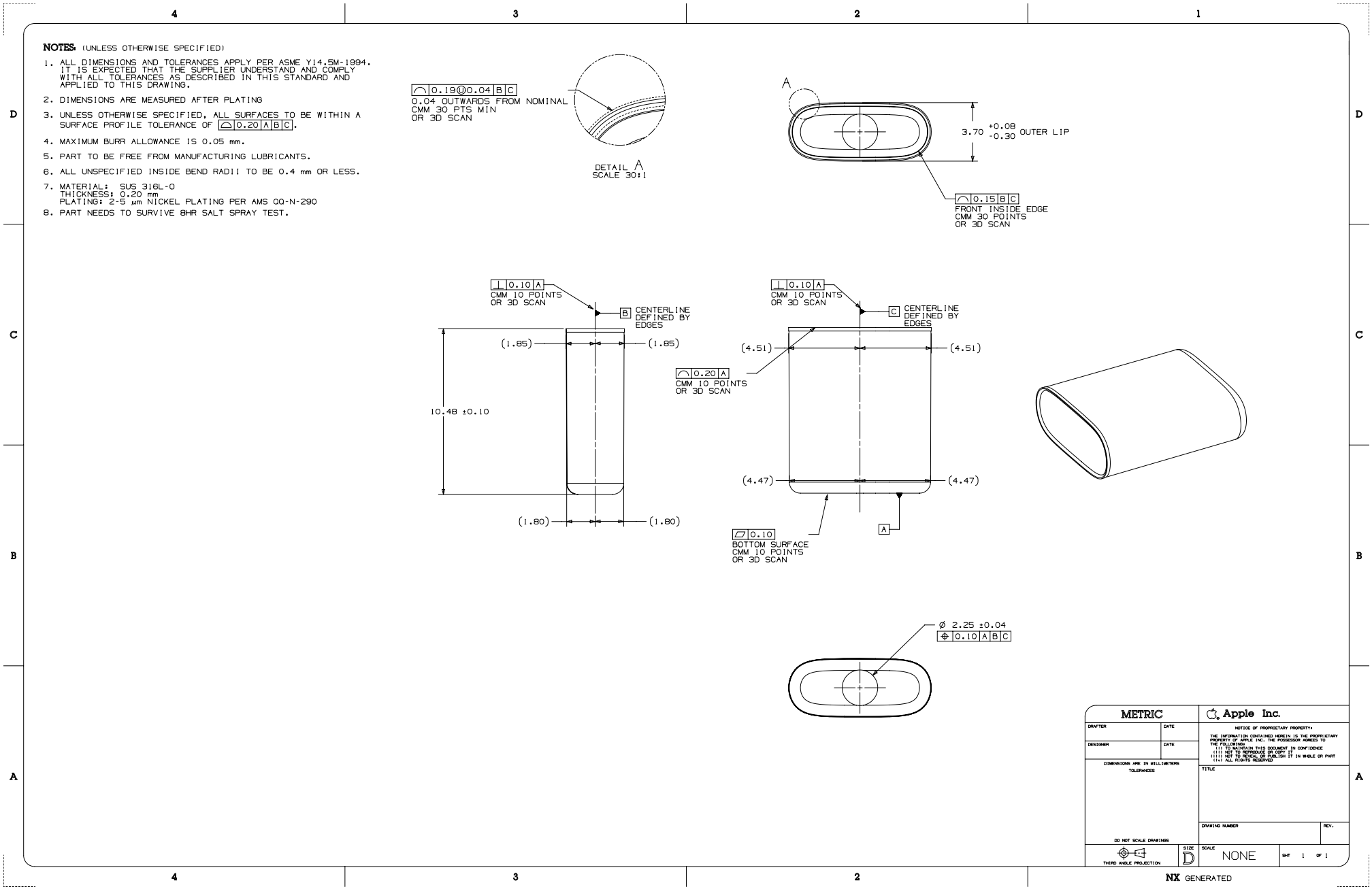


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DESIGNER / DATE	
DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE
DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION / SIZE D	SCALE NONE / SHT 1 OF 1

NX GENERATED

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58.8 C125 Recommended Rear Shield



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Components

59. Headset Remote and Microphone Transmitter

Devices and accessories can receive button presses from Headsets (page 84) incorporating a Headset Remote and Microphone Transmitter using:

- Apple USB-C Analog Headset Module (page 351).
- Headset Plug (3.5 mm) (page 394).

The transmitter conveys Remote Controls (page 85) (volume up, volume down, and center buttons) over the microphone bias signal.

59.1 Overview

The Headset Remote and Microphone Transmitter is available from Texas Instruments:

Variant	Part Number
Noise-occluding, for headsets blocking or canceling outside sound. See https://www.ti.com/product/CD3268A.	TI CD3268A0YZPR
Non-occluding, for standard headsets. See https://www.ti.com/product/CD3269A.	TI CD3269A0YZPR

Subjective listening tests with the latest devices are recommended to determine which part produces the best user experience.

59.2 Requirements

Headsets and headset cables implementing the transmitter shall:

- Integrate a MEMS analog microphone located 120–160 mm from the center of a headset driver when worn by the user.
- Have three physical buttons for remote controls (volume up, volume down, and center buttons).
- Use six wires from the plug corresponding to the following signals:
  - Right Driver
  - Right Return
  - Left Driver
  - Left Return
  - Microphone Bias

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    - Microphone Return
- Run signals separately to their respective components.

Headset drivers shall have:

- Minimum load impedance of 16 Ω.
- Maximum load capacitance of 150 pF.

59.3 Usage

The transmitter operates with a receiver in a device, an accessory, or a module (for example, C125) to enable remote button press detection using the microphone bias line. The receiver provides regulated downstream power (nominally 2.7 V or 2.0 V) to the transmitter and MEMS microphone through the microphone bias line, and the receiver decodes the button information from the transmitter.

The transmitter sends button press state over the microphone bias line in either:

- Button mode.
- Tone mode.

If the voltage on the microphone bias line is less than 2.35 V, the microphone is not in use. The transmitter enters button mode and sends button-press information as discrete voltage levels.

If the voltage on the microphone bias line greater than 2.35 V, the microphone is in use. The transmitter enters tone mode and sends button-press information as ultrasonic tone sequences in the range of 99 kHz to 300 kHz.

59.3.1 Button Mode

In button mode, the transmitter operates as a passthrough element switching a button switch-resistor network onto the bias line. Each switch represents a unique button. When a button is pressed, the DC level on the bias line is changed and detected by the receiver.

When the transmitter is in button mode (V_{MIC} has never reached 2.35 V), it shorts the MIC and REM pins together and disables all other inputs and outputs. When a button event occurs, the DC voltage on the microphone bias line changes. This DC level is then detected by the receiver. Switch S0 is a unique switch shorting the V_{MIC} line to ground.

When the V_{MIC} line is shorted to ground, power is removed from the transmitter. When power recovers, the transmitter enters button mode or tone mode, depending on the voltage detected at the MIC pin.

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59.3.2 Tone Mode

When the transmitter detects a voltage greater than 2.35 V at the MIC pin, it enters tone mode. With a microphone biased and in use, the switch-resistor network used for button mode would cause large DC level shifts in the bias voltage. Such shifts would result in unwanted audible clicks or pops or would cause de-biasing of the microphone. To prevent this problem, when the transmitter enters tone mode it disconnects the switch-resistor network from the microphone bias line, enables the microphone using the FET switch, and engages the tone generation circuit.

In tone mode the transmitter has two functions. First, it powers on the MEMS microphone by forcing a FET switch to ground. Second, it detects button events and places a discrete tone sequence onto the microphone bias line. The tone frequencies in each sequence are unique to each button press. The receiver detects the tones on the bias line and determines the corresponding button event.

The tone generation circuit of the transmitter internally detects each button press and sends a high frequency tone sequence between 99 kHz and 300 kHz. The high frequency tone sequence is unique to each button. The receiver detects the frequency of each tone and translates it into a predetermined button event. A button release has a different frequency than a button press.

The transmitter sends two tones for each button press to improve accuracy. The first tone, lasting 1 ms, is a calibration frequency and the second, lasting 2 ms, is the unique frequency for the selected button. The ratio of these two frequencies is calculated and translated into button press information. This provides a very accurate result independent of clock frequency variation.

The transmitter remains in tone mode until the MIC pin is pulled below 0.8 V. When power recovers, the transmitter enters button mode or tone mode depending on the voltage detected at the MIC pin.

59.4 Reference Circuit

The accessory shall support the transmitter using the circuits in Figure 59-1 (page 367) and Figure 59-2 (page 368). See Table 59-1 (page 368) for the nominal values of the components in these circuits.

These circuits are designed to produce a tone amplitude between the microphone bias line and the microphone return of at least 30 mV peak-to-peak into a 2 kΩ load at the end of a 1 m long cable. If necessary, the value of R3 shall be adjusted to achieve this result. Figure 59-2 (page 368) shows how a voltage on the microphone power line from the transmitter enables the MEMS microphone chip through Q1. It also shows components R7, C4, and R8, which control the microphone frequency response. See Reference Circuit Adjustments (page 369) for equations to determine the values of these components.

Figure 59-1 (page 367) and Figure 59-2 (page 368) are two parts of one circuit minimizing crosstalk between the separate driver channels and the microphone:

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- The two microphone return lines in these sub-circuits shall be connected at the components.
- The common return line and the return lines for each of the two drivers shall be routed separately through the cable and shall all be tied together only at the headset connector.

Figure 59-1 Transmitter circuit

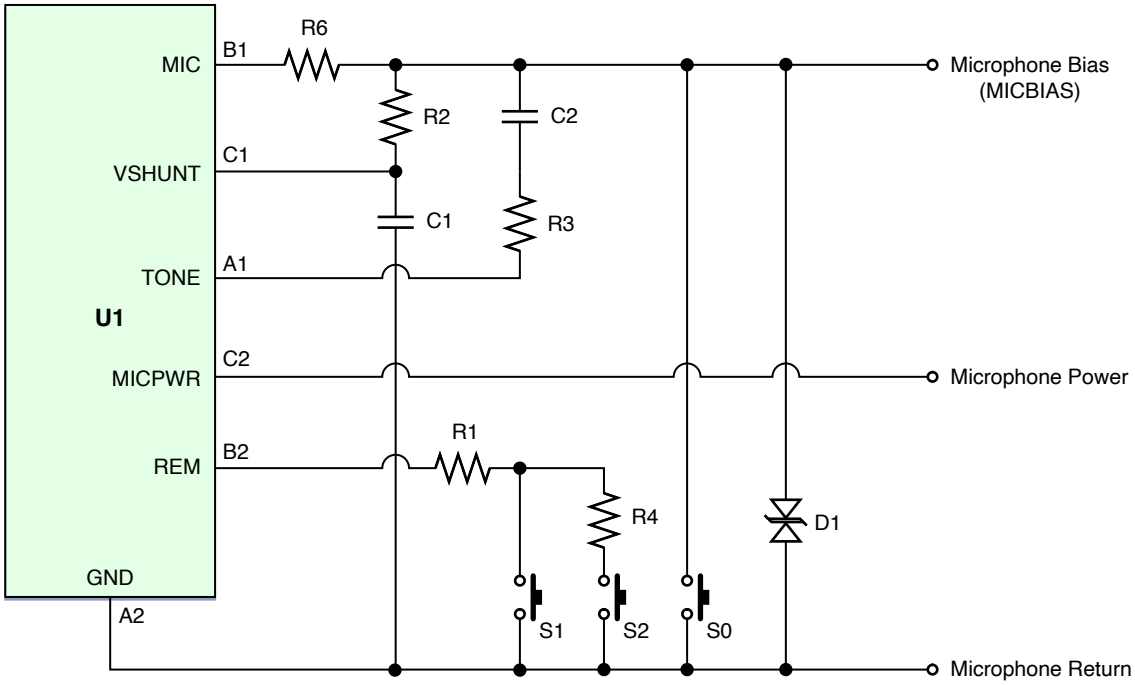


Figure 59-2 Microphone circuit

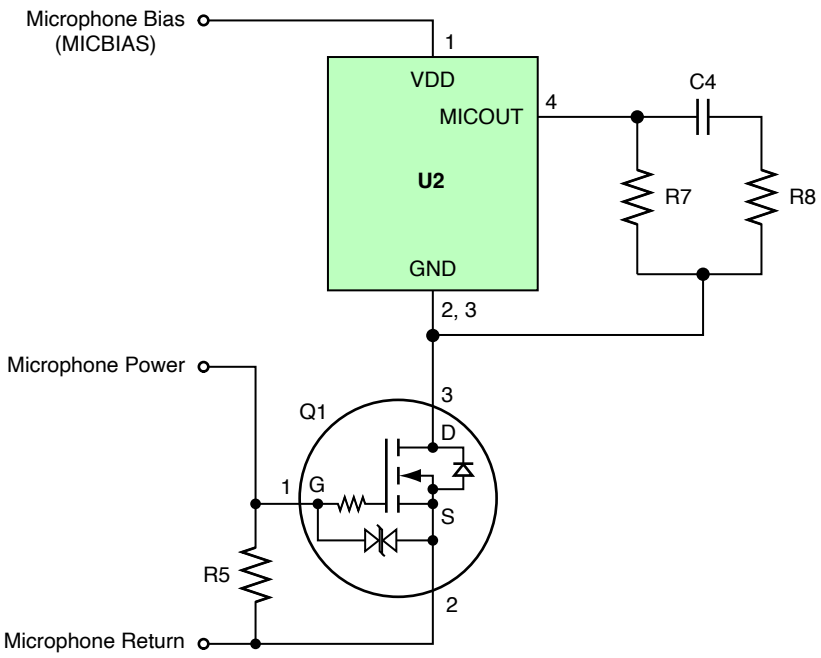


Table 59-1 Transmitter circuit components

Symbol	Description	Notes
C1	Capacitor, 0.1 µF ±10%, 6.3 V	
C2	Capacitor, 220 pF ±5%, 25 V	Ceramic
C4	Capacitor, 2.2 µF ±10%, 6.3 V	
D1	ESD protection diode, 5 pF, 6.1 V	ST Micro ESDALC6V1-1BU2; install as close to transmitter pin B1 as possible.
Q1	MOS field-effect transistor	CEDM 7001
R1	Resistor, 6.81 kΩ ±0.5%, 1/20 W	
R2	Resistor, 2 kΩ ±1%, 1/20 W	
R3	Resistor, 1.2 kΩ ±0.5%, 1/20 W	
R4	Resistor, 2.61 kΩ ±0.5%, 1/20 W	
R5	Resistor, 887 kΩ ±1%, 1/20 W	
R6	Resistor, 49.9 Ω +0.2%/-1%, 1/20 W	Shall not exceed 50 Ω.
R7	Resistor, 17.4 kΩ ±1%, 1/20 W	
R8	Resistor, value depends on U2.	See Table 12-1 (page 85) or Additional Specifications & Support (page 352).
S0	Dome switch	Center button; shall not exceed 20 Ω when closed.

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Symbol	Description	Notes
S1	Dome switch	Volume down; shall not exceed 20 Ω when closed.
S2	Dome switch	Volume up; shall not exceed 20 Ω when closed.
U1	Headset interface transmitter	Headset Remote and Microphone Transmitter
U2	MEMS analog microphone	See Table 12-1 (page 85) or Additional Specifications & Support (page 352).

59.4.1 Reference Circuit Adjustments

The values of some of the components listed in Table 59-1 (page 368) may be adjusted to optimize the performance of the headset accessory, using these formulas:

- **High-pass filter corner frequency in Hertz** $\approx 1/(2\pi \cdot R_8 \cdot C_4)$, where:
  - R_8 is the value of resistor R8 in ohms.
  - C_4 is the value of capacitor C4 in Farads.
  - The value of R7 is greater than the value of R8.
- **System sensitivity at 1 Pascal in Volts** = $(M_0/R_8) \cdot R_2$, where:
  - M_0 is the microphone sensitivity in Volts per Pascal.
  - R_8 is the value of resistor R8 in ohms.
  - R_2 is the value of resistor R2 in ohms in parallel with 1.05 kΩ.
- **Maximum excursion of the microphone in Volts** = $(1/R_7) \cdot R_2$, where:
  - R_7 is the value of resistor R7 in ohms.
  - R_2 is the value of resistor R2 in ohms in parallel with 1.05 kΩ.

Note:
If the microphone bias voltage drops below 1.6 V, the transmitter will begin to fail and the microphone chip may produce indeterminate outputs.

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59.5 Verification

59.5.1 Electrical

59.5.1.1 Headset Plug (3.5 mm)

59.5.1.1.1 Equipment

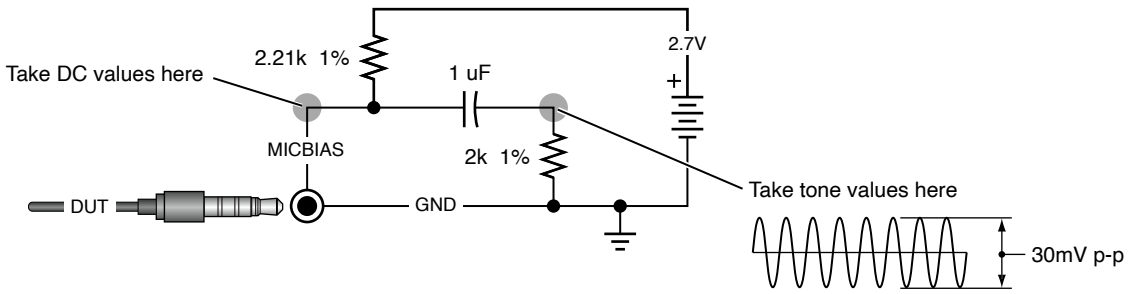
The following equipment is necessary:

- Precision low-voltage DC power supply.
- Oscilloscope with measuring capabilities.
- 4-pin 3.5 mm headset jack, such as SJ-43515RS-SMT.
- 2.21 kΩ 1% resistor.
- 2 kΩ 1% resistor.
- 1 µF capacitor.

59.5.1.1.2 Setup

1. Create test circuit and connect equipment as shown in Figure 59-3 (page 370).

Figure 59-3 Transmitter test setup



59.5.1.1.3 Procedure

1. Verify all tones have a peak-to-peak amplitude of at least 30 mV as measured across the 2 kΩ load.
2. Generate labeled oscilloscope pictures for all button press tones, button release tones, and acknowledgment tones, showing their amplitudes. Verify the button release frequency of 99 kHz has an amplitude of at least 30 mV peak-to-peak.

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3. Verify the MICBIAS point static DC voltage is between 1.85 V and 2.0 V. Generate a labeled oscilloscope picture showing the voltage at the MICBIAS point is stable and within specification within 50 ms after power-on.
4. Set the power supply in the test circuit to 2.0 V to place the transmitter in button mode. Generate an oscilloscope picture to demonstrate DC shifts occurring during button presses. Verify the static DC MICBIAS voltages match Table 59-2 (page 371).

Table 59-2 Transmitter expected MICBIAS voltages in button mode

Switch Closure	Voltage
S0	0.000 V ±1%
S1	1.510 V ±1%
S2	1.603 V ±1%

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60. MagSafe Case NFC Chip

The MagSafe Case NFC Chip is intended for iPhone Duo cases which partially occlude the outer display active area. It helps the device guide the user to adjust the display settings for the attached case.

The MagSafe Case NFC Chip is a single-function part which needs no configuration. The device powers it through an NFC field when the case is attached, and its only interface is the antenna connection, LA and LB.

> **Note:**
> iPhone Duo responds to the MagSafe Case NFC Chip only when the user has an Apple Account registered in the European Union (EU) and the device is located within the EU.

Cases integrating the MagSafe Case NFC Chip shall:

- Integrate a MagSafe Case Magnet Array (page 264).
- Implement the MagSafe Case NFC Chip Reference Antenna (page 382), using a copper antenna conductor.
- Connect the antenna to LA and LB, see Pad Assignments (page 380), through the land pattern of the delivery form used: Figure 60-3 (page 375) for the bare die, or Figure 60-7 (page 378) for the wafer-level chip scale package (WLCSP).
- Place the antenna at the MagSafe magnets, with its center aligned with the center of the magnet ring, see Dimensional Drawings (page 18).

The MagSafe Case NFC Chip Reference Antenna (page 382) is designed for a bare die implementation. The bare die pads and the WLCSP balls have different layouts, see Pad Assignments (page 380).

Cases integrating the MagSafe Case NFC Chip may occlude the outer display active area up to the maximum case occlusion in the iPhone Duo Dimensional Drawings (page 18), as an exception to the outer display access requirement in iPhone Duo (page 35).

Cases should keep conductive material other than the MagSafe magnets away from the antenna, as it can degrade NFC performance. A case integrating the MagSafe Case NFC Chip is responsible for verifying NFC performance with the complete case.

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60.1 Overview

The MagSafe Case NFC Chip will soon be available through an authorized distributor:

Variant	Part Number
MagSafe Case NFC Chip for iPhone Duo cases (bare die)	Coming soon
MagSafe Case NFC Chip for iPhone Duo cases (WLCSP)	Coming soon

The MagSafe Case NFC Chip Export Control Classification Number (ECCN) is 3A991A2.

60.2 Mechanical

Neither the bare die nor the WLCSP has mechanical protection, so the MagSafe Case NFC Chip is sensitive to mechanical damage. Its electrostatic discharge (ESD) robustness is at least 1000 V human body model, per ANSI/ESDA/JEDEC JS-001-2017, and 250 V charged device model, per ANSI/ESDA/JEDEC JS-002-2018. The MagSafe Case NFC Chip complies with the *Apple Regulated Substances Specification, 069-0135*, see https://www.apple.com/environment/pdf/Apple_Regulated_Substances_Specification.pdf.

60.2.1 Bare Die

Figure 60-1 (page 373) shows the bare die, Figure 60-8 (page 380) gives its size, and Figure 60-2 (page 374) gives the thicknesses of the die and of its dielectric and redistribution layer (RDL).

Figure 60-1 MagSafe Case NFC Chip, pad side up (bare die)

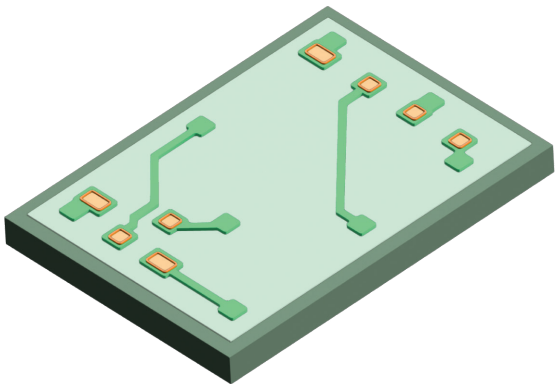
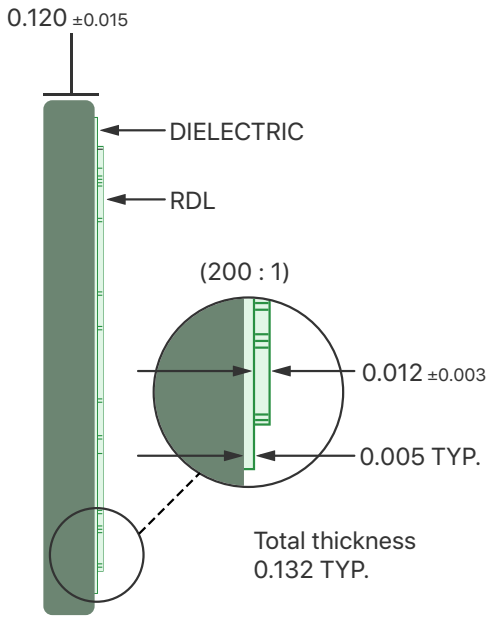


Figure 60-2 MagSafe Case NFC Chip pad stack (bare die)

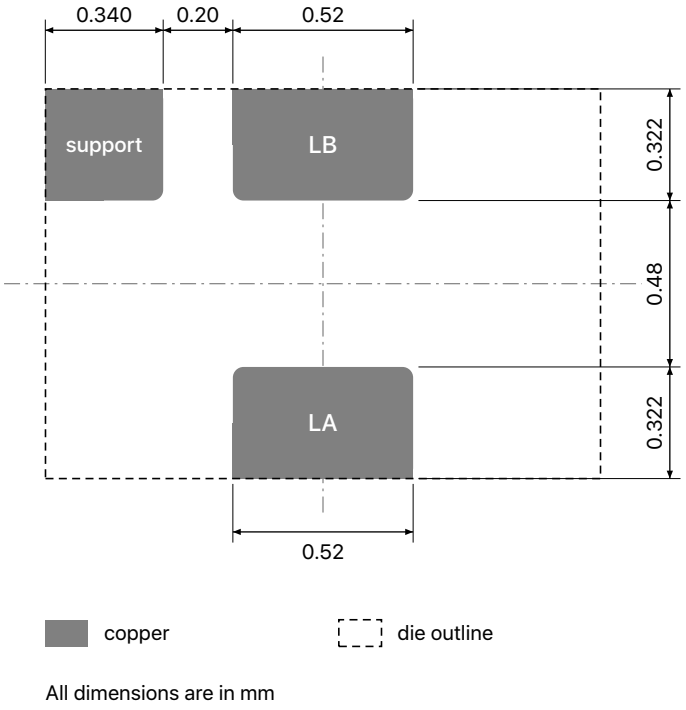


Heights are measured from the imide surface of the die. Measurements are given in mm.

The bare die attaches to the antenna with anisotropic conductive adhesive (ACA) rather than solder. Figure 60-3 (page 375) shows the antenna land pattern. The die mounts pad side down, so the land pattern is the mirror image, left to right, of Figure 60-8 (page 380). The land pattern tolerances depend on the antenna design and antenna supplier, and are the responsibility of the assembly house.

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Figure 60-3 MagSafe Case NFC Chip antenna land pattern, conductor side up (bare die)



The bare die ships as a thinned, sawn 300 mm wafer on a plastic frame. Each wafer box is sealed in a nitrogen-filled moisture barrier bag, and each wafer comes with an electronic wafer map. Any die the wafer map does not mark as passing is a failed die.

Accessories should:

- Expose unpacked wafers to an atmosphere other than nitrogen for no more than 1 month in total within the storage time.
- Handle unpacked wafers only in a cleanroom of Class 10,000 or better.

60.2.2 WLCSP

The WLCSP has a moisture sensitivity level (MSL) of 1, classified per J-STD-020, and ships in tape and reel. Figure 60-4 (page 376), Figure 60-5 (page 376), and Figure 60-6 (page 377) show the package outline and dimensional tolerances.

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Figure 60-4 MagSafe Case NFC Chip package, top (WLCSP)

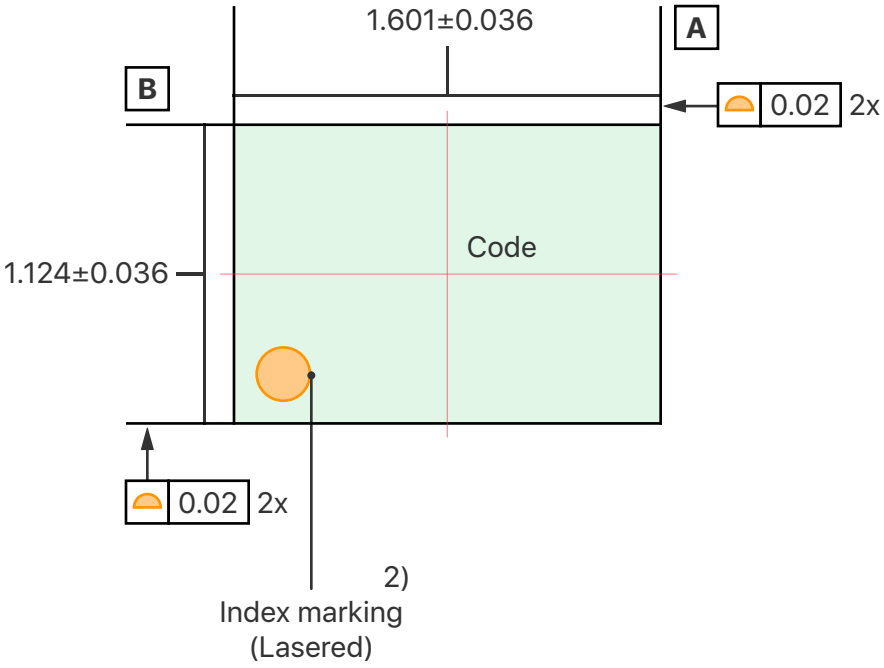
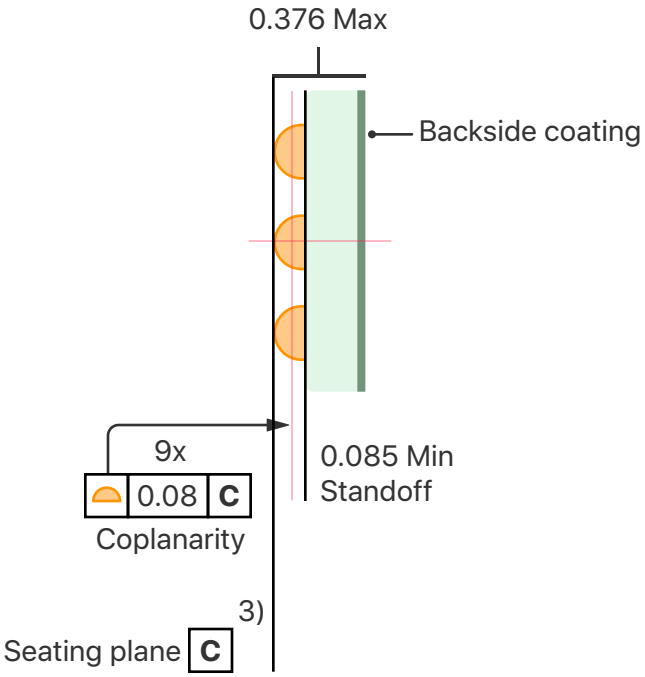
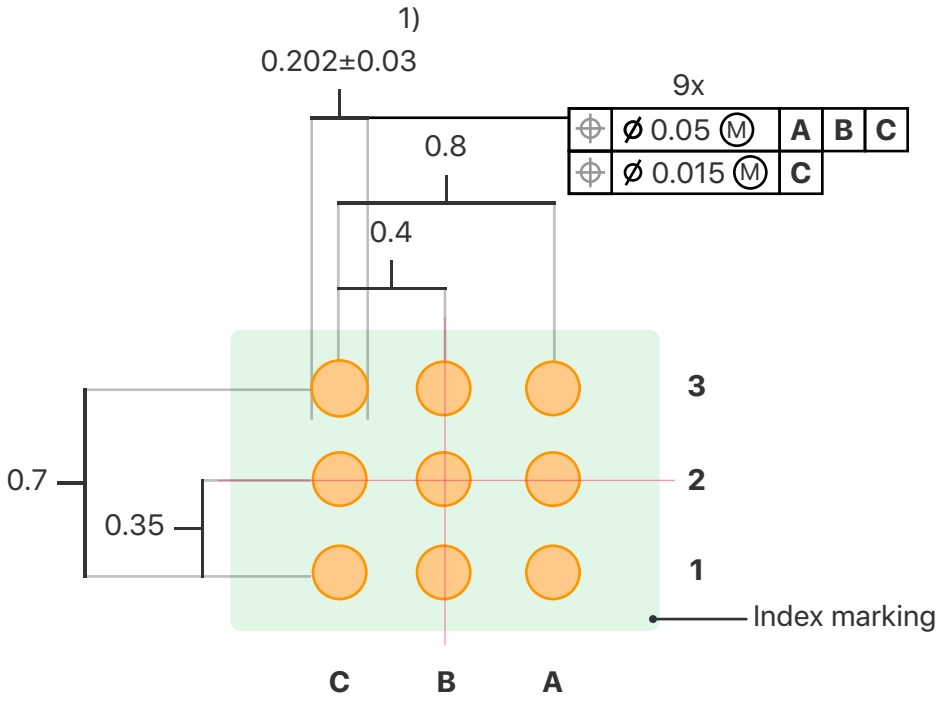


Figure 60-5 MagSafe Case NFC Chip package, side (WLCSP)



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Figure 60-6 MagSafe Case NFC Chip package, ball side up (WLCSP)



1. Dimension is measured at the maximum ball diameter, parallel to primary datum C.
2. Ball A1 corner identified by marking.
3. Primary datum C and seating plane are defined by the domed crowns of the balls.

Measurements are given in mm.

Both before and after the WLCSP is soldered to the antenna substrate, accessories should:

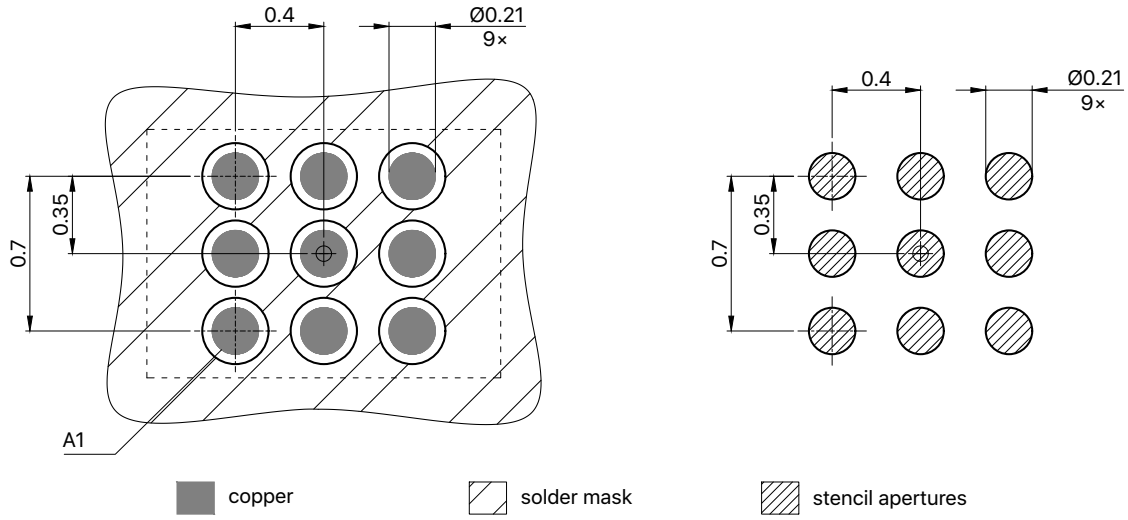
- Assemble the WLCSP directly from its original packing rather than handling it manually.
- Use plastic or bamboo tweezers, or a vacuum wand, whenever manual handling is unavoidable.
- Protect an assembled WLCSP from mechanical impact during subsequent handling, such as solder-paste printing of the other side of the substrate, insertion into magazines, clamping in test adapters, and case assembly.
- Support the substrate directly opposite the WLCSP whenever force is applied to the substrate underneath it, so the package is not placed in tension.

Metal tweezers, ceramic tooling, and probe pins bearing on the package top are the most common sources of handling damage.

The WLCSP uses non-solder-mask defined (NSMD) land pads, where the wettable area is defined by the copper outline and the solder mask is cleared around it. Figure 60-7 (page 378) gives the land pattern and stencil aperture dimensions.

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Figure 60-7 MagSafe Case NFC Chip land pattern and stencil apertures (WLCSP)



Solder mask openings are Ø0.30 (9×)
Solder mask clearance to copper is 0.045
Narrowest solder mask dam is 0.05
All dimensions are in mm

The narrowest solder mask dam in Figure 60-7 (page 378) is at the limit of typical substrate manufacturing. Accessories whose substrate supplier can not hold it should use a gang relief, clearing the solder mask across the whole ball array as a single opening with a 50 µm clearance to the package outline. Accessories should not mix NSMD and solder-mask defined pads within the land pattern, as the alignment tolerance between the copper and solder mask layers shifts the wettable area of each pad type in a different direction.

At the stencil aperture diameter in Figure 60-7 (page 378), a Type 4 solder paste is too coarse. Table 60-1 (page 378) lists the recommended stencil and solder paste.

Table 60-1 MagSafe Case NFC Chip recommended stencil and solder paste (WLCSP)

Parameter	Value
Stencil thickness	80 µm or 100 µm
Stencil type	Laser-cut stainless steel or electroformed nickel

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Parameter	Value
Solder paste alloy	SAC305 or an equivalent Pb-free SnAgCu alloy
Solder paste powder type	Type 5 per J-STD-005
Flux	No-clean

The WLCSP is Pb-free and is designed to withstand a standard J-STD-020 solder profile. The WLCSP is reflowed in a forced convection oven, and Table 60-2 (page 379) lists the boundaries within which the reflow profile falls. The WLCSP is a wafer-level ball grid array and can not be wave soldered, as wave soldering brings the whole package body into contact with molten solder.

Table 60-2 MagSafe Case NFC Chip reflow profile boundaries (WLCSP)

Parameter	Value
Soak temperature	150° to 180° C
Soak duration	60 to 90 seconds
Liquidus temperature (SAC305)	220° C
Time above liquidus	Approximately 60 seconds
Peak temperature at the solder joint	Above 235° C
Peak temperature at the package body	Below 260° C
Maximum reflow cycles	3

Apple strongly recommends against underfilling the WLCSP. Its board-level qualification, including drop, temperature cycling, and bend testing, used no underfill, and underfill can either help or hurt joint reliability depending on the underfill and substrate materials. An accessory choosing to underfill is responsible for qualifying the result, and a non-reworkable underfill prevents both repair and failure analysis.

The solder joints of the WLCSP sit underneath the package, so an automated optical inspection system can not see them. Accessories should use automated X-ray inspection instead, and may use an endoscope to inspect the outermost joints. The general acceptance criteria for a soldered assembly are in *IPC-A-610, Acceptability of Electronic Assemblies*, whose 25% maximum voiding criterion for a ball grid array applies to the WLCSP.

60.2.3 Transport and Storage

Table 60-3 (page 380) lists the transport and storage conditions in the original packing. The storage conditions are based on IEC 62258-3, and bare die storage time starts at shipment from the supplier.

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Table 60-3 MagSafe Case NFC Chip transport and storage conditions

Delivery form	Transport	Storage
Bare die	-20° to +60° C, up to 10 days	+17° to +28° C, up to 6 months
WLCSP	-20° to +60° C, up to 10 days	+5° to +40° C and 10%–75% humidity, up to 24 months

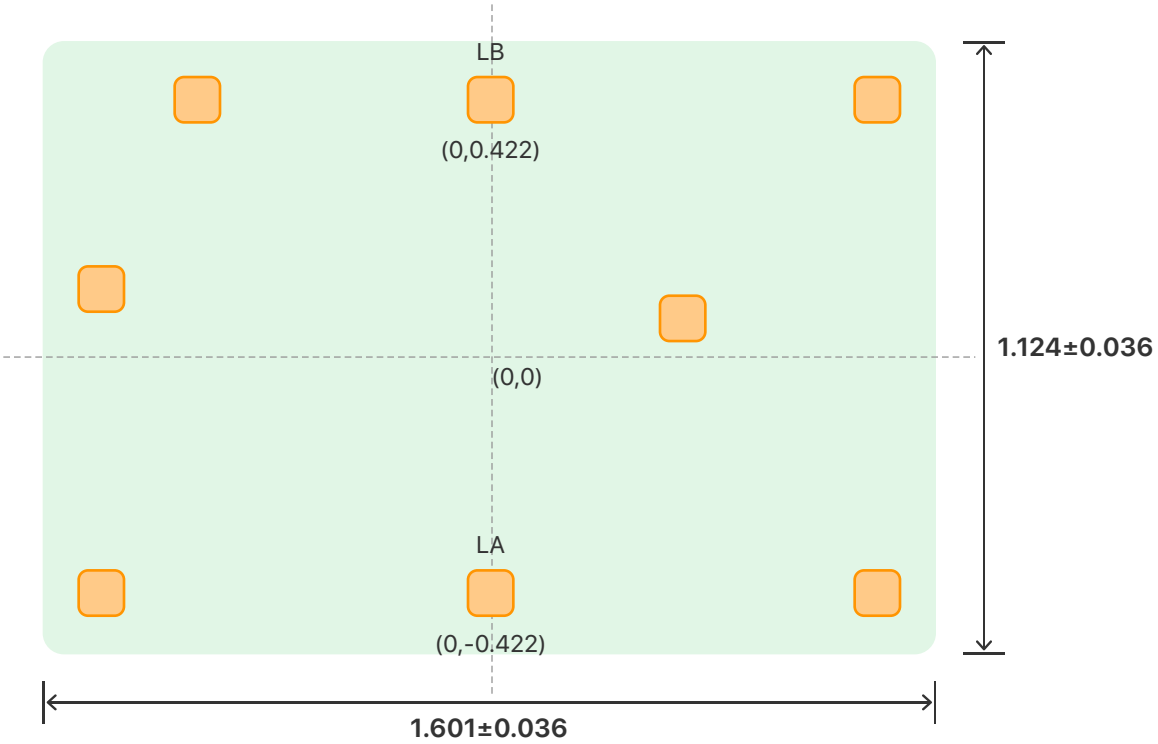
60.3 Pad Assignments

Figure 60-8 (page 380) and Figure 60-9 (page 381) show the locations of LA and LB. The land pattern in Figure 60-7 (page 378) is the mirror image of Figure 60-9 (page 381).

The other bare die pads and WLCSP balls are not connected (NC). Accessories shall:

- Not connect an NC pad or ball to the antenna, to another pad or ball, or to any other circuit.
- Place no antenna conductor under the bare die other than the lands in Figure 60-3 (page 375), as the ACA connects each pad to any conductor beneath it.
- Solder each NC WLCSP ball to its own isolated land for mechanical robustness.

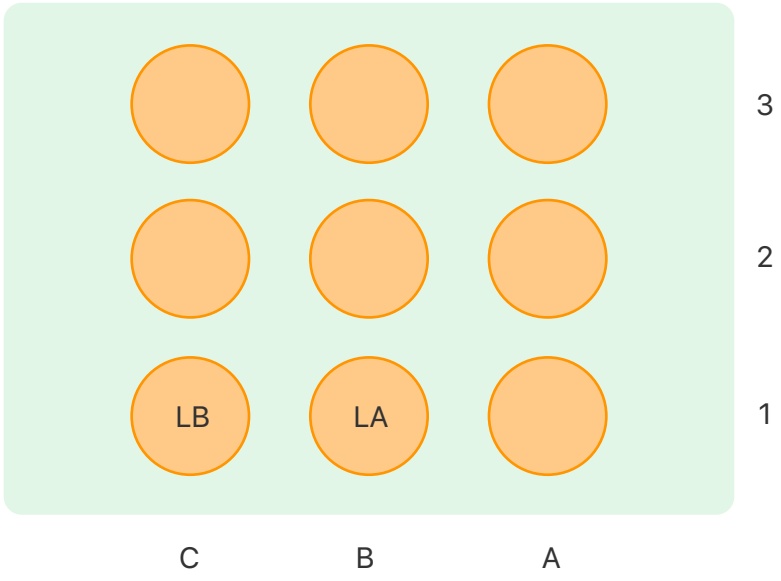
Figure 60-8 MagSafe Case NFC Chip LA and LB pads, pad side up (bare die)



Pad size: 0.080±0.005 square. Not to scale.

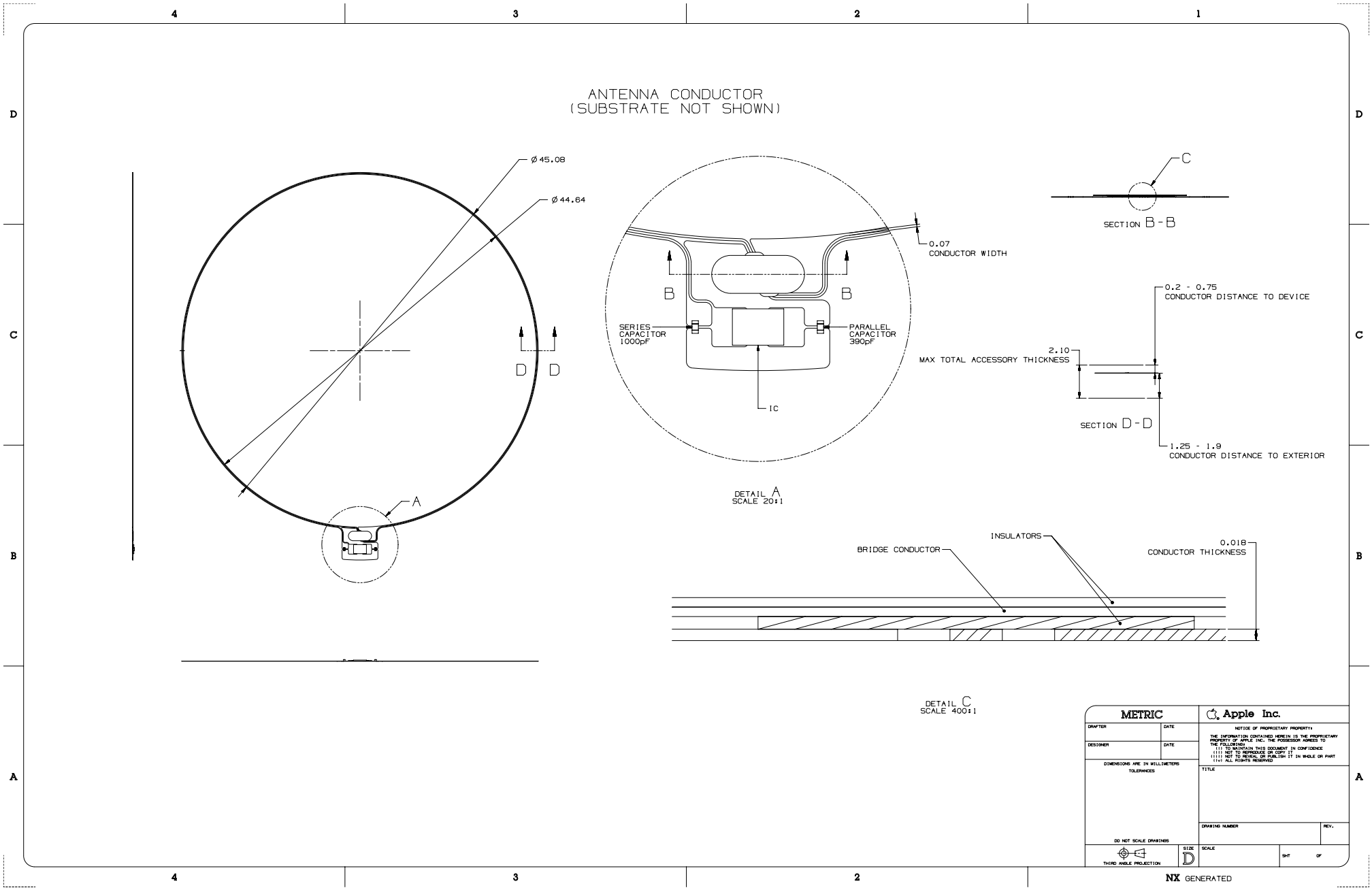
Measurements are given in mm.

Figure 60-9 MagSafe Case NFC Chip LA and LB balls, ball side up (WLCSP)



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60.4 MagSafe Case NFC Chip Reference Antenna



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Connectors

61. USB-A Receptacle

Accessories may incorporate a USB-A receptacle to:

- Provide power to a device.

61.1 Mechanical

The USB-A receptacle shall meet or exceed all applicable USB-IF mechanical specifications.

61.2 Electrical

The USB-A receptacle shall meet or exceed all applicable USB-IF electrical specifications.

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62. USB-C Plug

Accessories incorporating a USB-C plug shall comply with the *USB Type-C Cable and Connector Specification – Release 2.3*.

Accessories may incorporate a USB-C plug to:

- Provide power to a device.
- Draw power from USB Type-C Current sources.
- Draw power from USB Power Delivery sources.
- Draw power from USB Dedicated Charging Ports and USB hosts.

Accessories benefiting from integrating a USB-C plug include cables, headsets, battery packs, and adapters.

62.1 Overview

The USB-C plug shall comply with the *USB Type-C Cable and Connector Specification – Release 2.3*.

62.2 Mechanical

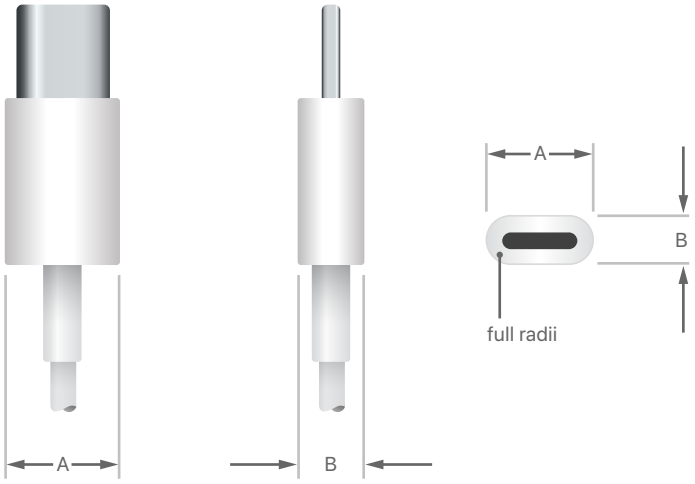
Accessories incorporating a USB-C plug shall comply with USB-C plug interface dimensions as specified in *USB Type-C Cable and Connector Specification – Release 2.3*.

USB-C plug enclosures shall not exceed the following dimensions as shown in Figure 62-1 (page 386):

- 'A' ≤ 12.35 mm.
- 'B' ≤ 6.50 mm.

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Figure 62-1 USB-C plug example



USB-C plug enclosures should have full radii rounded edges for the greatest compatibility with the widest variety of cases, see USB-C receptacle accessory keep-out (page 391).

62.3 Electrical

62.3.1 Drawing Power

Accessories drawing power from the USB-C plug shall:

- Correctly identify all USB Type-C Current (page 311) sources.
- Correctly identify all USB Dedicated Charging Ports (DCP) as defined in the *USB Battery Charging Specification – Release 1.2*.
- Enumerate as a USB device when connected to a USB host and:
  - Not draw more than 100 mA of current until they have been successfully enumerated.
  - Request no more than 500 mA of charging current in their USB device descriptor.
- Not draw more power than the USB power source claims it is capable of providing using one of the above methods.

Accessories may also correctly identify all USB Power Delivery (PD) (page 310) sources.

Accessories drawing power from a device may do so using one of the following protocols:

- USB Type-C Current (page 311)
- USB Power Delivery (PD) (page 310)

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62.3.2 Providing Power

Accessories providing power to a device using a USB-C plug shall:

- Provide at least 15 W (3 A at 5.0 V) of power.
- Meet the requirements in Device Power (USB-C) (page 244).
- Support USB Type-C Current (page 311).

These accessories should:

- Support USB Power Delivery (PD) (page 310).
- Carry a label indicating how much power they supply, in watts.

62.4 Verification

62.4.1 Mechanical

1. Verify the USB-C plug interface dimensions comply with Mechanical (page 385).
2. Using calipers, verify the USB-C plug enclosure does not exceed the dimensions in Mechanical (page 385).

62.4.2 Drawing Power

This procedure applies to accessories drawing power using the USB-C plug.

62.4.2.1 Equipment

The following equipment is necessary:

- Apple 140W USB-C Power Adapter.
- Apple 96W USB-C Power Adapter.
- Apple 70W USB-C Power Adapter.
- Apple 67W USB-C Power Adapter.
- Apple 40W Dynamic Power Adapter with 60W Max.
- Apple 30W USB-C Power Adapter.
- Apple 20W USB-C Power Adapter.
- Apple 35W Dual USB-C Port Compact Power Adapter.
- Apple 35W Dual USB-C Port Power Adapter.
- Bundled USB-C power adapter (if applicable).
- Mac with USB-C running macOS 27.2.
- iPad with USB-C running iPadOS 27.2.

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62.4.2.2 Procedure

1. Verify the accessory correctly identifies all Apple branded or bundled power sources:
   a. Verify each USB-C power adapter is correctly identified and provides power.
2. Verify the accessory correctly identifies a Mac and an iPad:
   a. Verify the Mac is correctly identified and provides power.
   b. Verify the iPad is correctly identified and provides power.

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63. USB-C Receptacle

Accessories incorporating a USB-C receptacle shall comply with the *USB Type-C Cable and Connector Specification – Release 2.3*.

Accessories may incorporate a USB-C receptacle to:

- Provide power to device.
- Draw power from Apple branded power sources.
- Draw power from USB Type-C Current sources.
- Draw power from USB Power Delivery sources.
- Draw power from USB Dedicated Charging Ports and USB hosts.

Accessories benefiting from incorporating a USB-C receptacle include AC Power Adapters (page 80), Battery Packs (page 83), and speakers.

63.1 Overview

The USB-C receptacle shall comply with the *USB Type-C Cable and Connector Specification – Release 2.3*.

63.2 Mechanical

Accessories incorporating a USB-C receptacle shall comply with USB-C receptacle interface dimensions as specified in *USB Type-C Cable and Connector Specification – Release 2.3*.

See the recommended minimum USB-C receptacle accessory keep-out (page 391).

63.3 Electrical

63.3.1 Drawing Power

Accessories drawing power from the USB-C receptacle shall:

- Correctly identify all Apple branded power sources.

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- Correctly identify all USB Type-C Current (page 311) sources.
- Enumerate as a USB device when connected to a USB host and:
  - Not draw more than 100 mA of current until they have been successfully enumerated.
  - Request no more than 500 mA of charging current in their USB device descriptor.
- Correctly identify all USB Dedicated Charging Ports (DCP) as defined in the *USB Battery Charging Specification – Release 1.2*.
- Not draw more power than the USB power source claims it is capable of providing using one of the above methods.

Accessories may also correctly identify all USB Power Delivery (PD) (page 310) sources.

63.3.2 Providing Power

Accessories providing power to a device using a USB-C receptacle shall:

- Provide at least 15 W (3 A at 5.0 V) of power.
- Meet the requirements in Device Power (USB-C) (page 244).
- Meet the requirements in Device Power (Lightning) (page 246) when providing power through a USB-C to Lightning cable.
- Support USB Type-C Current (page 311).

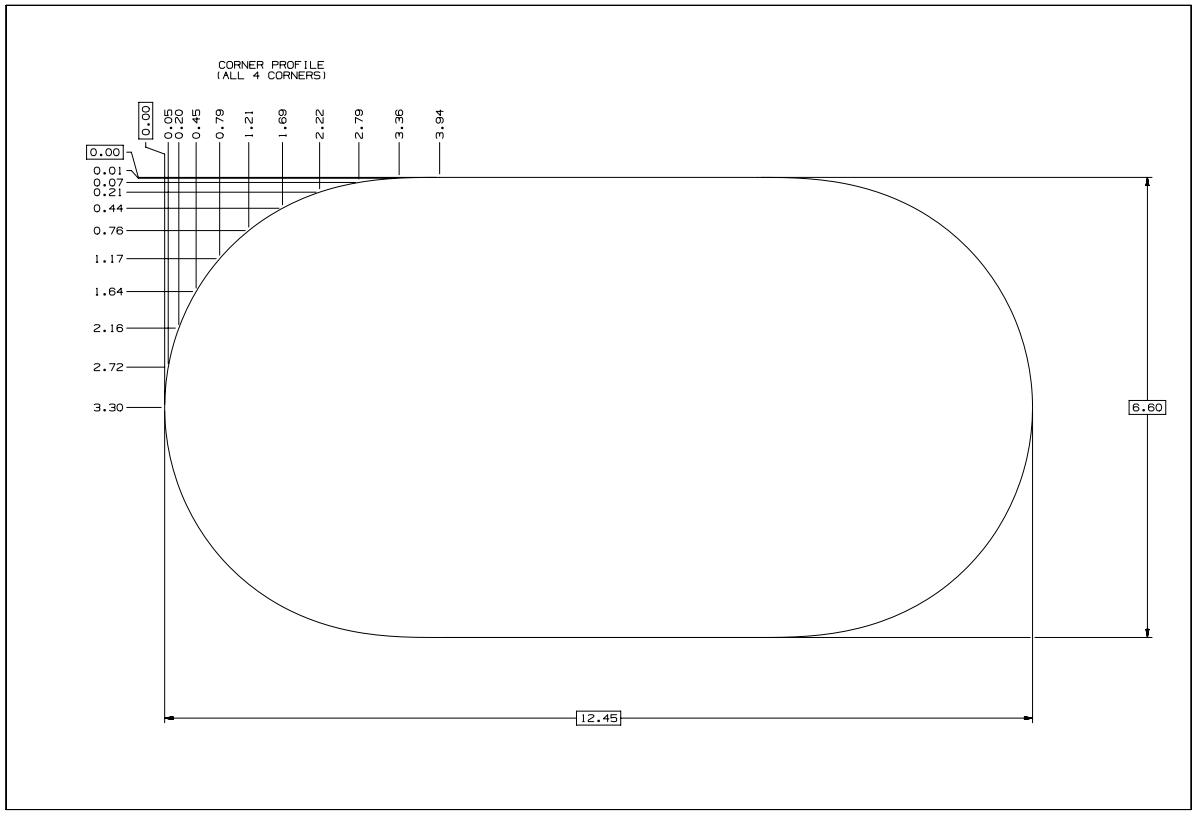
The accessories should:

- Support USB Power Delivery (PD) (page 310).
- Label the receptacle indicating how much power is supplied in watts.

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63.4 USB-C receptacle accessory keep-out

NOTES: (UNLESS OTHERWISE SPECIFIED)



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DESIGNER / DATE	
DIMENSIONS ARE IN MILLIMETERS TOLERANCES	TITLE: PROFILE,USB-C
DO NOT SCALE DRAWINGS	DRAWING NUMBER / REV.
THIRD ANGLE PROJECTION	SIZE D / SCALE 30:1 / SHT 1 OF 1

NX GENERATED

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63.5 Verification

63.5.1 Drawing Power

This procedure applies to accessories drawing power using the USB-C receptacle.

63.5.1.1 Equipment

The following equipment is necessary:

- Apple USB-C Charge Cable (1 m)
- Apple USB-C Charge Cable (2 m)
- Bundled USB-C to USB-C cable (if applicable)
- Bundled USB-A to USB-C cable (if applicable)
- Third-party USB-A to USB-C cable
- Apple 140W USB-C Power Adapter
- Apple 96W USB-C Power Adapter
- Apple 70W USB-C Power Adapter
- Apple 67W USB-C Power Adapter
- Apple 40W Dynamic Power Adapter with 60W Max
- Apple 30W USB-C Power Adapter
- Apple 20W USB-C Power Adapter
- Apple 35W Dual USB-C Port Compact Power Adapter
- Apple 35W Dual USB-C Port Power Adapter
- Apple 12W USB Power Adapter
- Apple 5W USB Power Adapter
- Bundled USB-C power adapter (if applicable)
- Bundled USB-A power adapter (if applicable)

63.5.1.2 Procedure

1. Verify the accessory correctly identifies all Apple branded or bundled power adapters:
   a. Using each USB-A to USB-C cable, verify each USB-A power adapter is correctly identified and provides power.
   b. Using each USB-C to USB-C cable, verify each USB-C power adapter is correctly identified and provides power.
2. Verify the accessory correctly identifies a Mac and an iPad:
   a. Using each USB-A to USB-C cable and USB-C to USB-C cable, verify the Mac is correctly identified and provides power.
   b. Using each USB-A to USB-C cable and USB-C to USB-C cable, verify the iPad is correctly identified and provides power.

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63.5.2 Providing Power

This procedure applies to accessories providing power using the USB-C receptacle.

63.5.2.1 Equipment

The following equipment is necessary:

- Apple USB-C to Lightning Cable (1 m)
- Apple USB-C to Lightning Cable (2 m)
- Apple USB-C Charge Cable (1 m)
- Apple USB-C Charge Cable (2 m)
- Bundled USB-C to USB-C cable (if applicable)

63.5.2.2 Procedure

1. Verify the accessory correctly provides power to devices:
   a. Using each USB-C to Lightning cable, verify the accessory uses USB Type-C Current or USB PD to identify at least 15 W of power providing capability.
   b. Using each USB-C to Lightning cable, verify the accessory provides power to the device.
2. Verify the accessory correctly provides power to a Mac and an iPad:
   a. Using each USB-C to USB-C cable, verify the accessory is correctly identified and provides power to the Mac.
   b. Using each USB-C to USB-C cable, verify the accessory is correctly identified and provides power to the iPad.

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64. Headset Plug (3.5 mm)

Accessories may incorporate a 3.5 mm headset plug to pass audio and control signals between the accessory and a device or another accessory.

Figure 64-1 Headset plug



An accessory headset plug may support the following features (that is, the full functionality of the EarPods with 3.5 mm Headphone Plug):

- Stereo audio input.
- Microphone output.
- Remote Controls (page 85) (volume up, volume down, and center buttons).

If an accessory supports headset remote controls, it shall incorporate a Headset Remote and Microphone Transmitter (page 364).

64.1 Headset Remote and Microphone Transmitter Configurations

Headsets and headset cables incorporating a Headset Remote and Microphone Transmitter (page 364) should implement one of the following configurations. The microphone and buttons may be located on either the left or right side of the headset.

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Figure 64-2 Headset plug (3.5 mm), single detachable cable

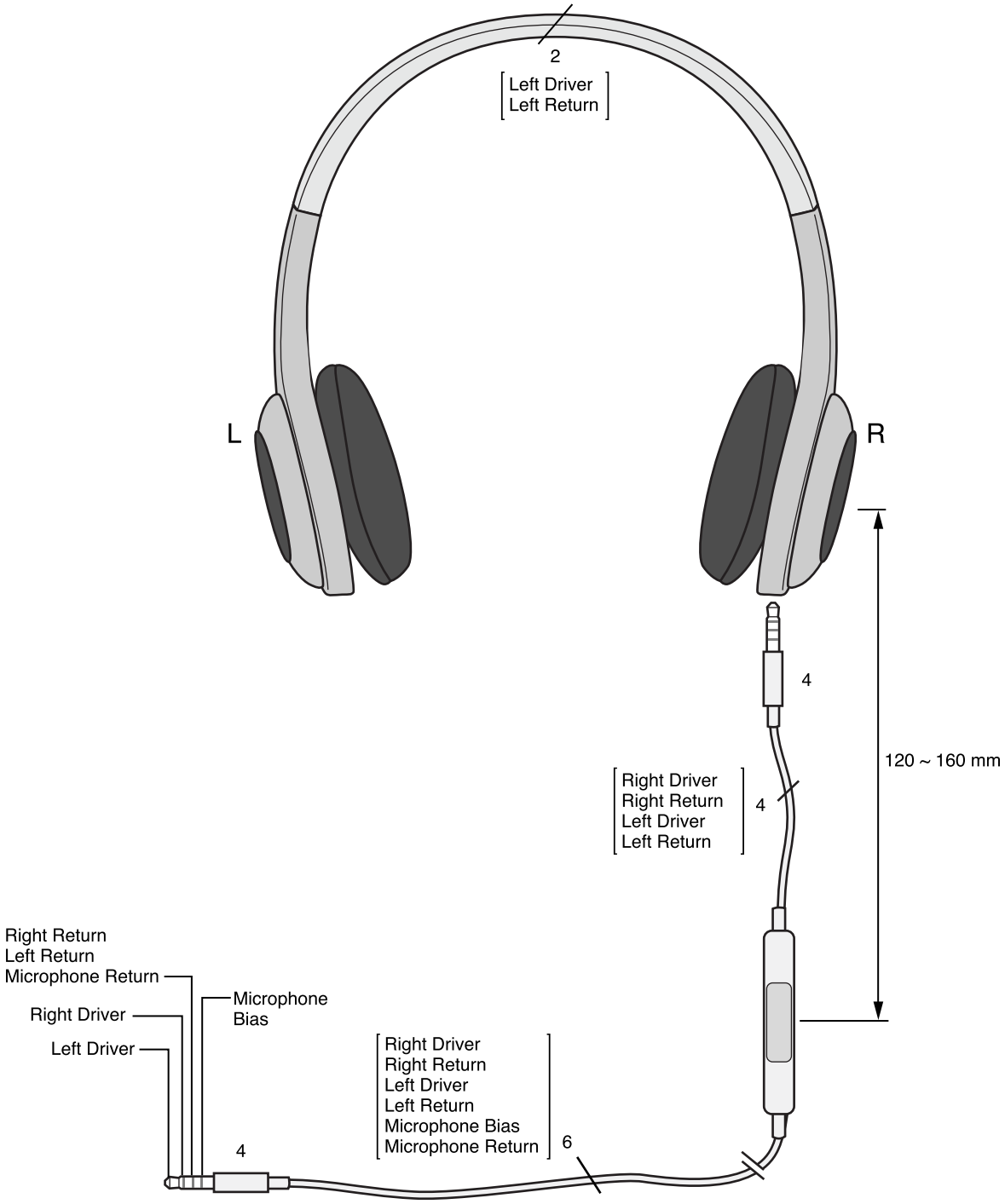


Figure 64-3 Headset plug (3.5 mm), single built-in cable

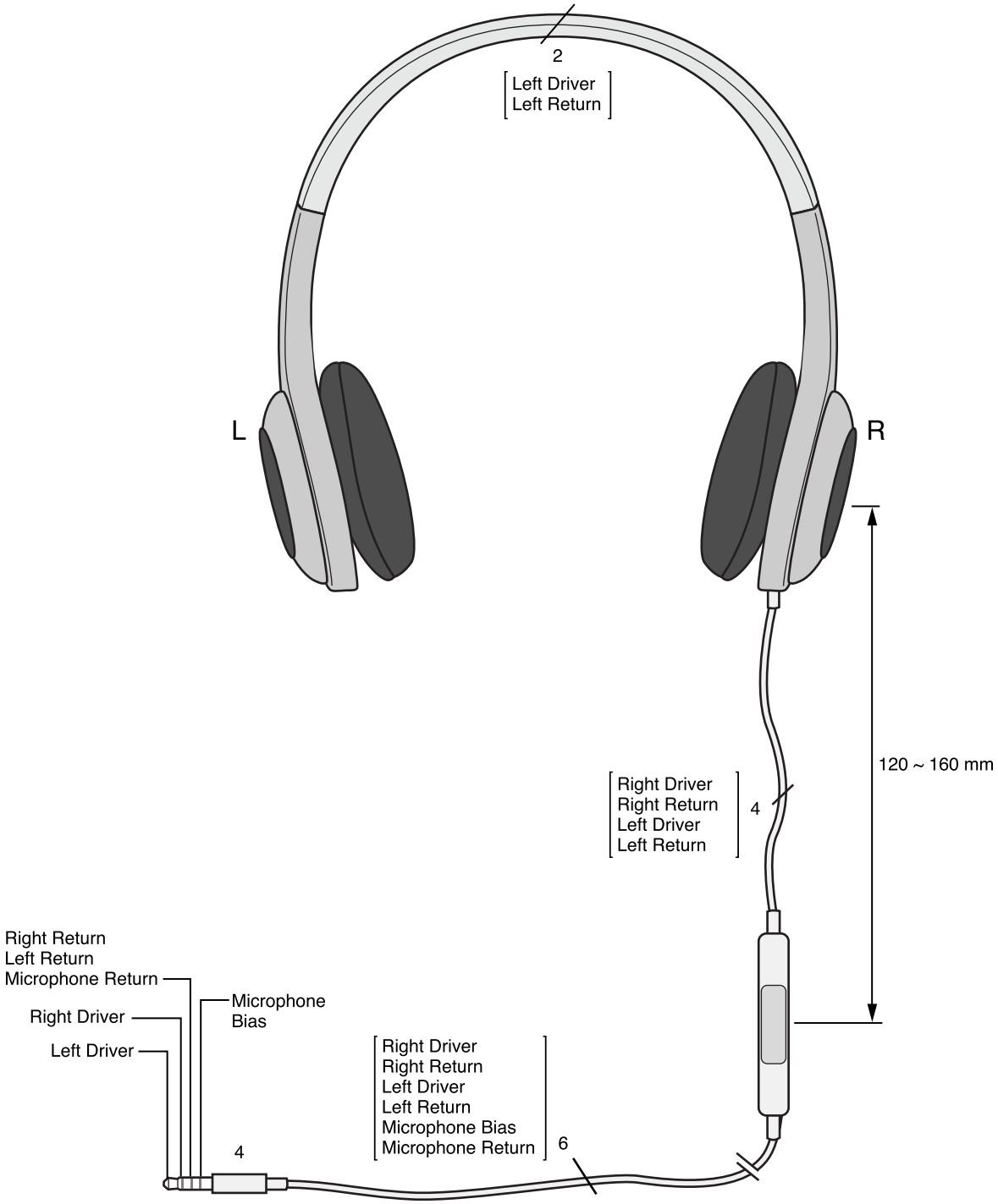


Figure 64-4 Headset plug (3.5 mm), split detachable cable

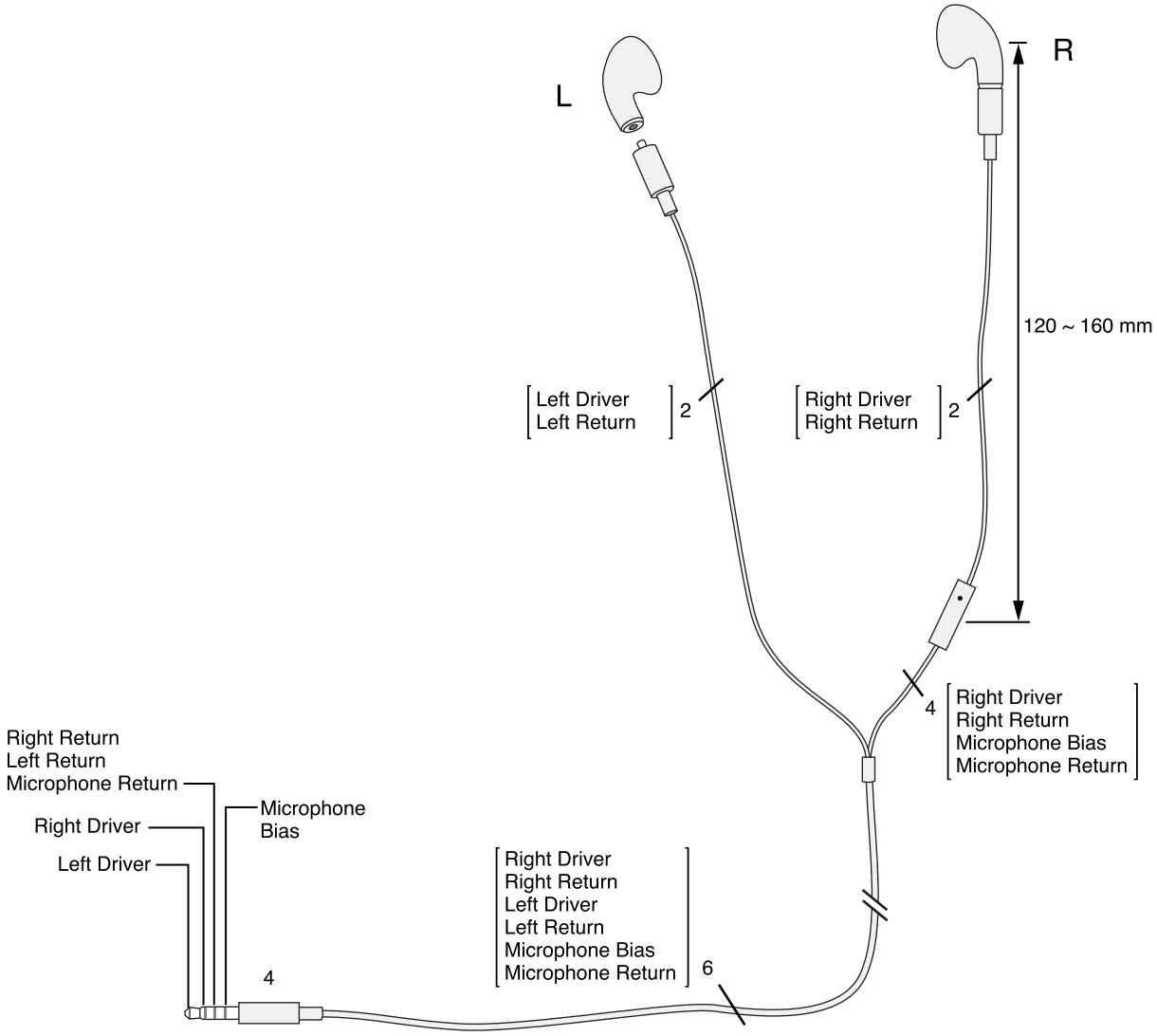
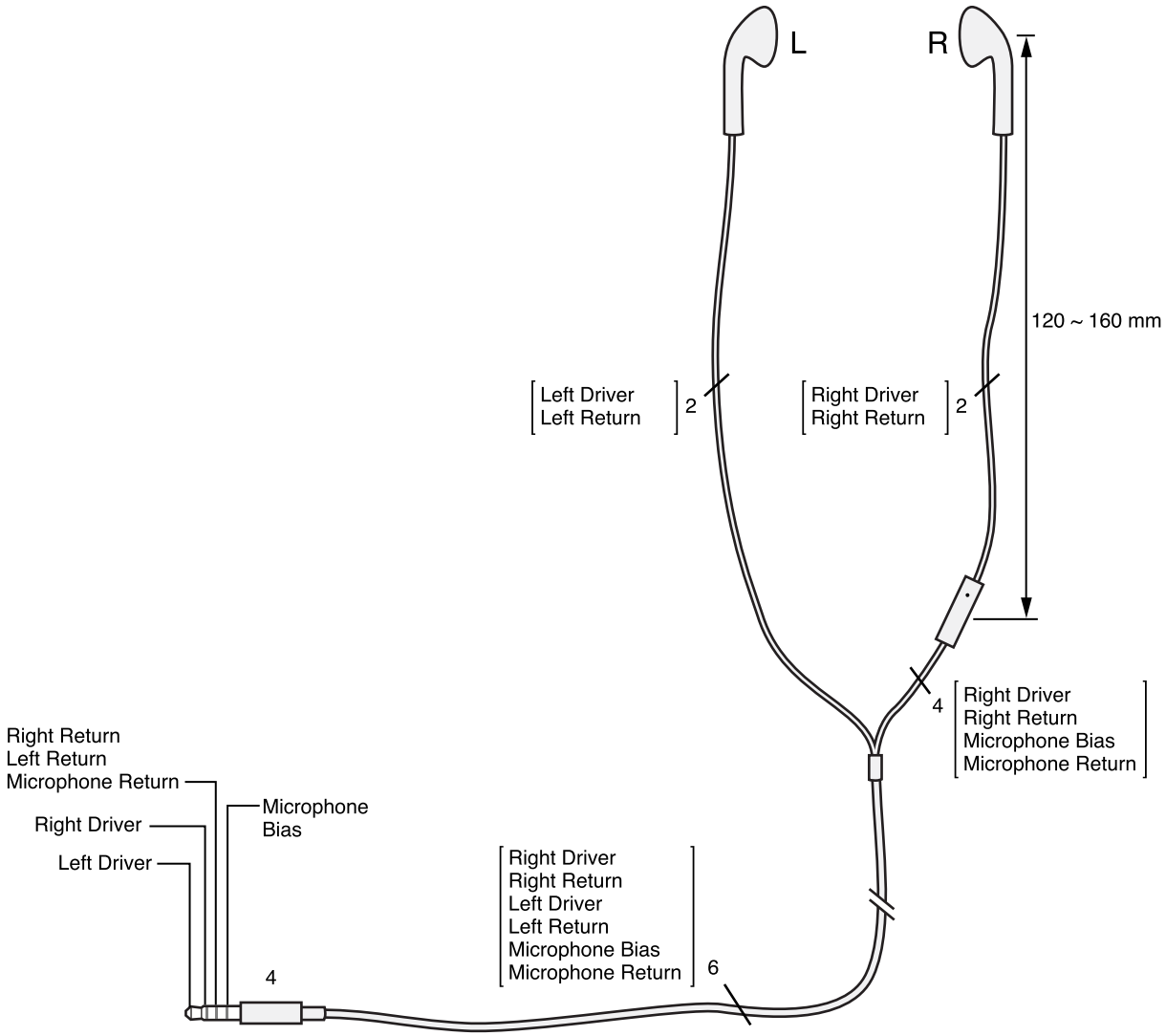


Figure 64-5 Headset plug (3.5 mm), split built-in cable



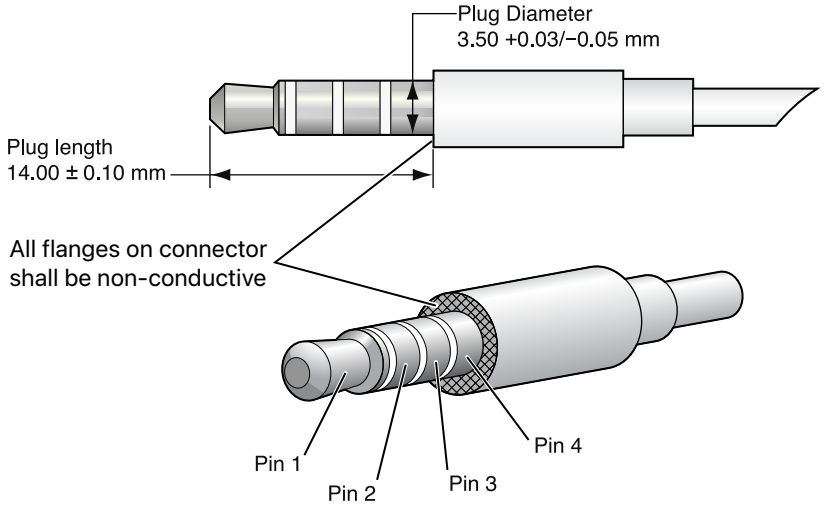
64.2 Mechanical

The headset plug shall:

- Conform to the JEITA standard *RC 5325A, 4-Pole Miniature Concentric Plugs and Jacks*.
- Have a length and diameter matching those specified in Figure 64-6 (page 399).

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Figure 64-6 Headset plug dimensions and details



64.3 Pins

Table 64-1 (page 399) lists pin assignments for the headset plug corresponding to Figure 64-6 (page 399).

Table 64-1 Headset plug pin assignments

Pin	Description
1	Audio Output (Left)
2	Audio Output (Right)
3	Signal Return
4	Microphone Input

Some devices will apply and then measure a voltage across Pin 3 and Pin 4 in order to determine whether the headset is wired as specified in Table 64-1 (page 399) or not. The measured voltage shall be greater than 1.5 V.

Some devices will also apply a reverse bias voltage across Pin 3 and Pin 4 and then measure the response for the same purpose. The measured voltage shall not be less than -0.75 V.

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64.4 Example Circuitry

Figure 64-7 (page 400) is an example of circuitry in an accessory with a single control button.

Figure 64-7 Typical headset plug circuitry

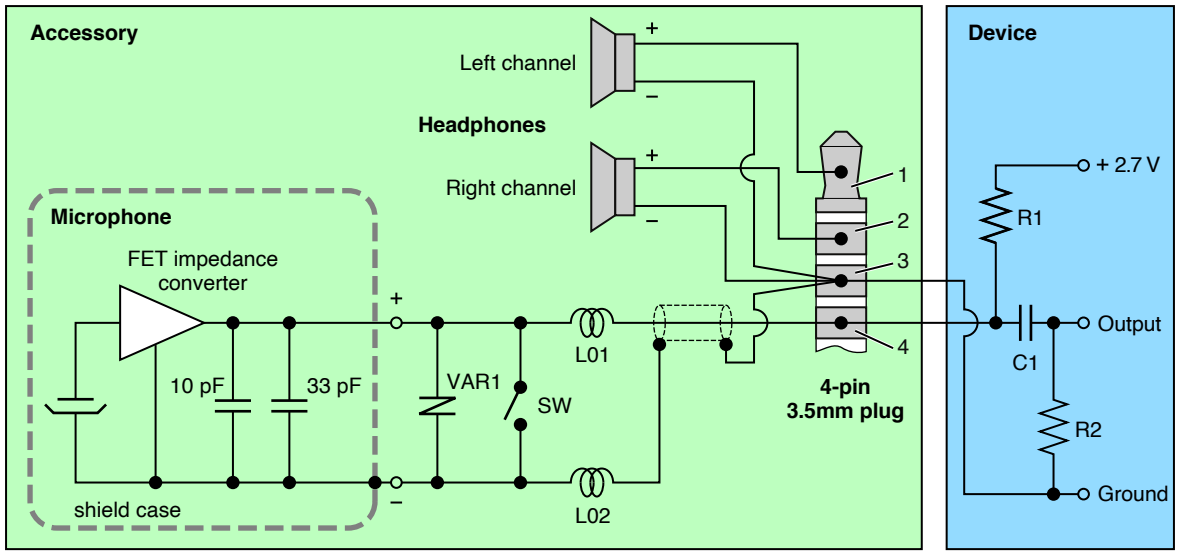


Table 64-2 Recommended component values for typical headset plug circuitry

Component	Value
C1	1 µF
R1	2.21 kΩ ±1%
R2	Codec input impedance ≥2 kΩ
L01/L02	600 Ω at 100 MHz
SW	Control button
VAR1	12 V varistor

Note:
The value given for L01 and L02 is typical. These ferrite chokes reduce time division multiple access (TDMA) noise; their exact values depend on the specific accessory design.

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Switch SW shorts the microphone signal to ground. The device treats its closure as a headset button press and initiates a context-specific action (for example, answering a phone call). The microphone bias current shall be between 210 µA and 500 µA, measured into a circuit pulled up to 2.7 V through 2.21 kΩ, to ensure button press detection.

The recommended microphone sensitivity is -44 dBV with a maximum impedance of 2.2 kΩ at the output of the equivalent circuit shown above, measured under test conditions of V_S = 2.0 V, R_L = 2.2 kΩ, T_A = 20° C, and relative humidity = 65%.

64.5 Verification

1. If the accessory connects to the device using a detachable cable:
   a. Verify the end of the cable closest to the microphone is inserted into the headset and not the device.
   b. Perform subsequent tests on the device end of the cable.
2. Verify the connector has a non-conductive flange.
3. Verify the 3.5 mm shell diameter does not exceed 5.9 mm for a minimum length of 11 mm from where the flange starts.
4. Verify the 3.5 mm plug length is 14.00 mm ±0.10 mm.
5. Verify the 3.5 mm plug diameter is 3.50 mm +0.03/-0.05 mm.
6. Verify the 3.5 mm plug can be fully inserted into the device's headset jack. Verify there are no physical defects in the 3.5 mm plug preventing insertion.
7. Verify there are no grounding issues, heavy static, or audio interference when headset is attached to device.
   a. Repeatedly plug the headset in and out of the headset jack.
   b. Wiggle the connector.

64.5.1 Connectivity

1. Connect the accessory to the device.
2. Verify the following will not wake the device from a sleep state:
   a. Connect the accessory to the device.
   b. Press any button other than the center button on the headset remote.
   c. Disconnect the accessory from the device.
3. Connect the accessory to the device and verify the Controls (page 402).

64.5.2 Microphone

1. Connect the accessory to the device.

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2. Start an audio recording using the Voice Memos app.
3. Blow or tap on the headset microphone and verify audio is clearly recorded.
4. Blow or tap on the device microphone and verify minimal audio is recorded.
5. Stop audio recording.

64.5.3 Controls

1. Connect the accessory to the device.
2. Verify the device will enter a sleep state after a period of inactivity while the accessory is still connected.
3. Verify pressing the center button on the accessory will wake the device from a sleep state.
4. Verify pressing any other button on the accessory will not wake the device from a sleep state.
5. After the device enters a sleep state, activate Siri by pressing and holding the accessory center button. Verify the Siri tone is heard in full.
6. After the device enters a sleep state, trigger a notification (for example, send an iMessage to the device). Verify the notification sound is heard in full.
7. Verify pressing volume up increases the volume on the device.
8. Verify pressing volume down decreases the volume on the device.
9. Verify pressing the center button matches the behavior of a directly connected Apple headset:
    a. Verify Play and Pause work for songs and video tracks when pressing the center button.
    b. Verify Next Track works when pressing the center button twice quickly.
    c. Verify Fast Forward works when pressing then press-and-holding the center button.
    d. Verify Previous Track works when pressing the center button three times quickly.
    e. Verify pressing the center button once will answer an incoming phone call or start playing music.
    f. Verify pressing the center button once will end a phone call or stop playing music.
    g. Verify pressing and holding the center button will activate Siri.

64.5.4 Audio Quality

1. Connect the accessory to the device.
2. Verify there are no audible pops/clicks/artifacts and no audible grounding issue, heavy static, or audio interference at all times in the following scenarios:
    a. When the device is not playing music through the accessory:
        a. Repeatedly plug and unplug the accessory at slow, normal, and rapid speeds.
        b. Wiggle the connector.
        c. Repeat plug/unplug/wiggle steps while holding the accessory center button pressed.
        d. Repeat all (plug/unplug/wiggle, with/without center button pressed) with the device screen on (face-up) and off (face-down).
    b. When the device is playing music through the accessory.
    c. When the device is shutting down (open Settings > General > Shut Down) or powering on.

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Tools

65. Accessory Developer Assistant (ADA)



Some test procedures in this specification require use of the Accessory Developer Assistant app, available from the App Store at https://apps.apple.com/us/app/accessory-developer-assistant/id1635862694.

The Accessory Developer Assistant app is a set of utilities designed to help accessory makers test new accessories. Use the Accessory Developer Assistant app to ensure iPhone and iPad performance for features such as:

- Camera Control (page 61)
- Autofocus & Optical Image Stabilization (page 67)
- Image Quality
- Near-Field Communication (NFC) (page 67)
- Compass (page 68)

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65.1 Autofocus & Optical Image Stabilization Test Profile

The Autofocus & Optical Image Stabilization (page 67) test procedure requires an additional profile to be installed:

1. Use the device to access the ADA Camera Test profile at https://download.developer.apple.com/Developer_Tools/Accessory_Developer_Assistant_Camera_Test_Profile/ADACamera.mobileconfig.
2. Install the profile to the device.
3. Open Settings > Profile Downloaded and complete the installation.
4. Reboot the device.

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Revision History

Added Content

Update 1:

- Cases (page 29)
  - StandBy (page 35)
- MagSafe Case NFC Chip (page 372)

Release R32:

- Cases (page 29)
  - iPhone Duo (page 35)
- Covers (page 72)
  - iPhone Duo (page 73)
- Screen Overlays (page 74)
  - iPhone Duo (page 76)
- Headsets (page 84)
  - USB-C (page 87)
- MagSafe Mounts (page 223)
- Device Power (Inductive) (page 251)
  - Coil Alignment (page 253)

Updated Content

Release R32:

- Cases (page 29)
  - Camera Control Case Interface (page 30)
  - Device Models (page 43)
  - Haptics (page 61)
- Screen Overlays (page 74)
  - Transmission Haze (page 75)
- Keyboards (page 91)
- Braille Displays and Keyboards (page 106)
- Watch Bands (page 201)
- Continuity Camera Mounts (page 214)
- Accessory Power (USB-C) (page 229)

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- Available Current (page 229)
- HID Headset Remote (page 258)
- MagSafe Attach (page 263)
- Advanced Audio Distribution Profile (A2DP) (page 312)
  - Verification (page 317)
- Bluetooth Low Energy (BLE) (page 343)
  - Device Information Service (page 348)
- USB-C Plug (page 385)
  - Providing Power (page 387)
  - Verification (page 387)
- USB-C Receptacle (page 389)
  - Providing Power (page 390)
  - Verification (page 392)

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