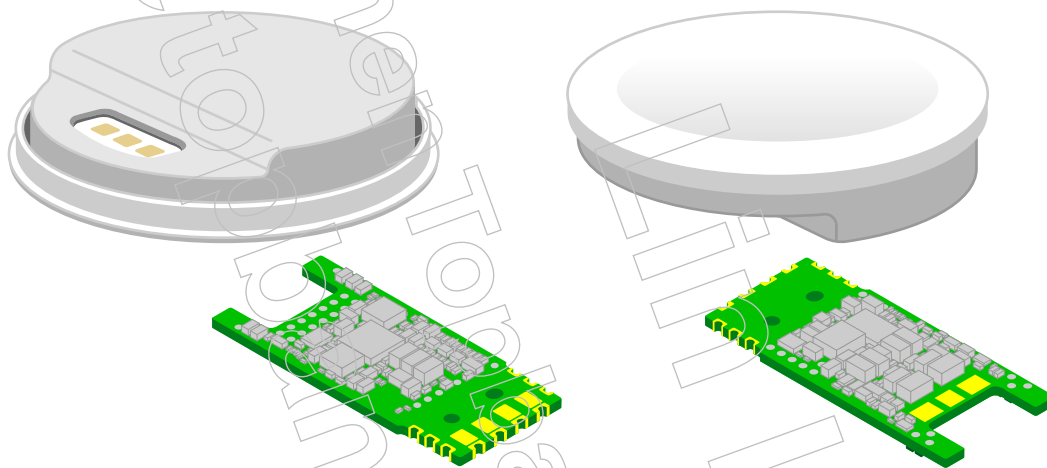


71. Apple Watch Fast Charger Module

The Watch Fast Charger Module (C962) enables accessories to charge the Apple Watch.

Figure 71-1 Watch Fast Charger Module



71.1 Accessory Integration

All C962 accessories shall:

- Provide power to Apple Watch. See [Electrical](#) (page 641).
- Hold the Apple Watch when it is magnetically connected to the C962.
- Permit the Apple Watch to move relative to the C962.
- Be intended for stationary use.

Accessories shall not integrate the C962 into wearable accessories such as wrist straps or watch bands.

71.2 Mechanical

The C962 consists of two parts:

- An inductive coil module, see [Watch Fast Charger Inductive Coil Module Dimensions](#) (page 650).

- A control module, see [Watch Fast Charger Control Module Dimensions](#) (page 651).

The accessory shall not interfere with, scratch, or damage the body of an Apple Watch or its attached band.

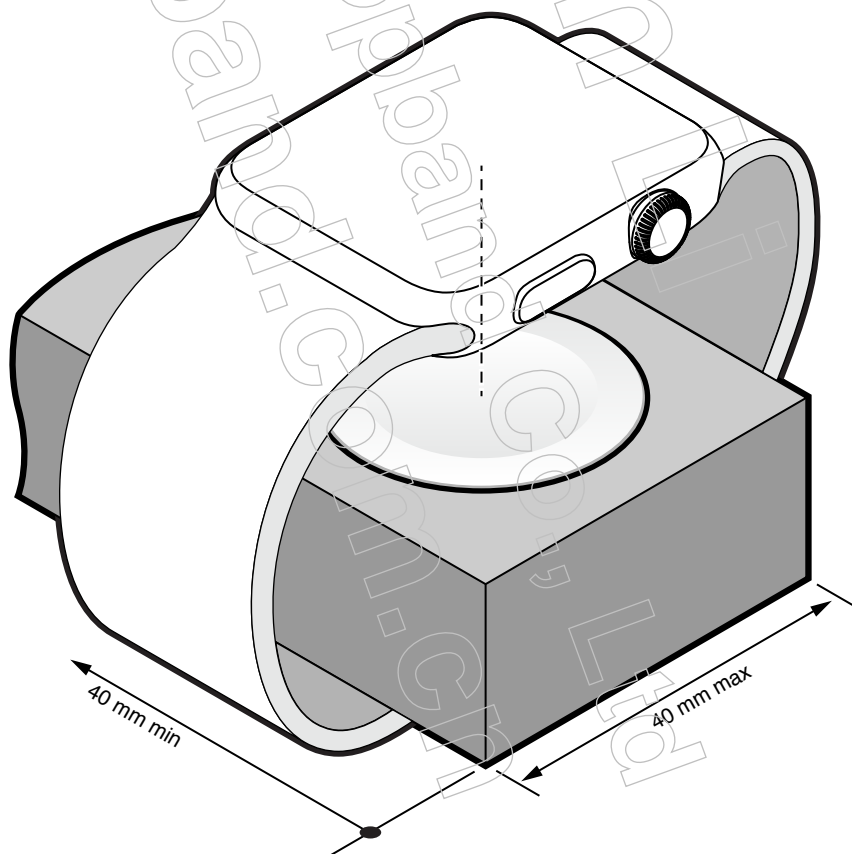
The accessory shall not require the watch band to be removed or detached.

The accessory should be compatible with all Apple bands including the Milanese Loop and the Link Bracelet.

To avoid interference with Apple Watch bands, accessories should:

- Not exceed 20 mm in radius around the center of the C962 inductive coil module surface if the Apple Watch can be attached in any orientation.
- Not exceed a length of 40 mm across the surface of the C962 inductive coil module (for a width of 40 mm) along the intended orientation of the Apple Watch if Apple Watch is intended to be attached in a specific orientation. See [Figure 71-2](#) (page 639).

Figure 71-2 C962 Charging Arm Clearance



The exposed surface of the C962 inductive coil module shall be 0.40 mm \pm 0.25 mm proud of the surface of the accessory.

The C962 inductive coil module shall be mounted such that any combination of Apple Watch and band shall not disengage and fall off due to gravity.

The C962 inductive coil module surface may be mounted either horizontally (recommended) or vertically:

- If mounted horizontally, the surface shall be mounted such that it cannot be positioned or oriented greater than 45° from horizontal.
- If mounted vertically, the surface shall have a non-adjustable mounting angle. Additionally, the accessory shall support any model of Apple Watch as well as band on its side (crown up) with a pocket or alignment feature that ensures the center of the Apple Watch aligns with the center of the C962 inductive coil module surface within \pm 1.0 mm. See [Table 71-1](#) (page 640) for Apple Watch vertical alignment heights.

Table 71-1 Apple Watch edge to center

Apple Watch Size	Apple Watch Edge to Center
38 mm (non-ceramic)	16.64 mm
38 mm (ceramic)	16.98 mm
40 mm (non-ceramic)	17.21 mm
40 mm (ceramic)	17.55 mm
41 mm (all)	17.39 mm
42 mm (non-ceramic)	18.22 mm
42 mm (ceramic)	18.27 mm
44 mm (non-ceramic)	18.92 mm
44 mm (ceramic)	19.26 mm
45 mm (all)	19.11 mm
45 mm (all) + 2 mm case	21.11 mm

Note:

Apple Watch placement tolerance is typically 820 μ m. This should be taken into account when designing the vertical mount alignment feature.

The C962 inductive coil module shall not be mounted near ferromagnetic metals or alloys.

All RF/metal keep out zones for the Apple Watch shall be respected, see [Device Dimensional Drawings](#) (page 893).

The C962 control module has the following mechanical characteristics:

- Not encapsulated in order to maximize compatibility with pick and place operations.

- FR4 PCB material.
- S70G-HF (CM) Type 4 solder is used. Solder reflow operations shall take this into consideration.
- 0-70 °C working temperature range.
- Packaged in a tray.

Note:

The C962 control module should be encapsulated to pass salt spray environmental testing.

The C962's maximum storage temperature is 60 °C.

71.2.1 Handling

Apple recommends the following handling guidelines:

- Use Pb-free solder.
- Use no-clean flux.
- Mitigate handling issues by assembling onto boards directly from tray.
- Use pick and place vision systems to automate assembly.

71.3 Electrical

Accessories integrating a C962 shall comply with the electrical requirements in this section.

71.3.1 Power

Accessories integrating a C962 shall provide power from either:

- An internal power supply.
- An external USB power source.

Components and terminations on the Watch Fast Charger Module control module shall be fully encapsulated with a rigid glue to protect C962 control module components. Apple recommends Loctite UV 9061F or equivalent.

The C962 control module should be contained within a sheet metal enclosure. Thermal paste with a thermal conductivity of at least 1.5 W/mK should be used to thermally bridge the C962 control module to the sheet metal enclosure. Apple recommends Coltech N-Sil 8615 thermal paste or equivalent.

If the accessory integrates an [Internal Power Supply](#) (page 642), it:

- May accept external power via any of the following integrated connectors so long as the accessory actively conditions and regulates the power:
 - USB-B receptacle (Standard, Mini, Micro).

- [USB-C Receptacle](#) (page 813).
- [USB-C Plug](#) (page 811).
- Non-USB connector.
- May consume some of the external power for its own purposes so long as all C962 power requirements are met.

If the accessory relies on an [External USB Power Source](#) (page 642) to provide power to the C962 and does not contain its own internal power supply, it:

- Shall connect to the external USB power source via a USB-A plug or [USB-C Plug](#) (page 811).
- Shall not consume any power from the external USB power source.
- Shall not monitor or modify the USB D+/D- or USB CC signals from the external USB power source.

The accessory shall integrate reverse voltage protection (RVP) between the C962 power and ground.

The C962 nominal current limit is 1.0 A at 5 V with transients up to 1.5 A. The current is further limited based on the power source identification (for example, USB D+/D- resistor network values for 1.0 A or USB enumeration for 500 mA).

The C962 includes:

- Overvoltage protection (OVP).
- Overcurrent protection (OCP).
- Overtemperature protection (OTP).
- Foreign object detection (FOD).

71.3.1.1 Internal Power Supply

The accessory's internal power supply for the C962 control module shall:

- Support a load of 0 W to 5 W (1 A at 5 V).
- Regulate input voltage at the PWR pin of the C962 to 4.75 V - 5.5 V under any supported load.
- Hold PWR ripple below 20 mVpp under any supported load.
- Use one of the following to declare its power providing capability:
 - Connect USB D+/D- to a resistor network, as shown in [Figure 54-1](#) (page 406), using resistor values for a 1000 mA power source as defined in [Table 54-1](#) (page 407).
 - Connect USB CC to a source termination resistor (R_p) for a 1.5 A power source according to the *USB Type-C Cable and Connector Specification Release 1.3*, section 4.6.2.

71.3.1.2 External USB Power Source

Accessories relying on an external USB power source to provide power to the C962 shall:

- Have maximum 95 m Ω round trip DCR (USB VBUS to Ground) between the C962 control module and the accessory's USB-A plug or [USB-C Plug](#) (page 811).
- Pass the USB-IF Full Speed signal quality test. See [Full Speed USB](#) (page 808) and [Full Speed USB](#) (page 819).

- Meet the USB-IF inrush current specification of 51.5 μ C.
- Meet the USB-IF suspend current specification of 2.5 mA in the following test scenarios:
 - *Suspend Current in USBIFCV on PC*
 - *Suspend Current in HSET on PC*
 - *Suspend Current With PC*

See the USB-IF *Full and Low Speed Electrical and Interoperability Compliance Test Procedure* and *Gold Suite Test Procedure* for USB-IF test procedures.

71.3.1.3 Apple Watch Charging Efficiency

Accessories integrating a C962 shall not impair Apple Watch's ability to efficiently charge from provided power.

71.3.2 Pads and Assignments

The C962 control module pad assignments are shown in [Watch Fast Charger Control Module Dimensions](#) (page 651).

Table 71-2 Watch Fast Charger Control Module Pads

Pad	Name	Assignment
1	PWR	USB VBUS
2	USB D-	USB D-
3	USB D+	USB D+
4	USB CC	USB CC
5	GND	USB Ground
6	COIL-	See Table 71-3 (page 643).
7	GND	See Table 71-3 (page 643).
8	COIL+	See Table 71-3 (page 643).

Signals from the USB D+ and D- pads shall be routed as a differential pair.

The C962 inductive coil module pad assignments are shown in [Watch Fast Charger Inductive Coil Module Dimensions](#) (page 650).

Table 71-3 Watch Fast Charger Inductive Coil Module Pads

Pad	Name	Assignment
1	COIL-	See Table 71-2 (page 643).
2	GND	See Table 71-2 (page 643).
3	COIL+	See Table 71-2 (page 643).

The C962 inductive coil module housing shall be grounded. Metallic accessory housings shall share the same ground as the C962 inductive coil module housing.

71.3.3 Operating Frequency

The C962 operates at 326.5 kHz and 1.778 MHz.

71.3.4 Cable

The C962 inductive coil module and C962 control module shall be connected by a cable consisting of COIL+ / COIL- signals and a cable shield for GND.

The cable connecting the C962 control module and C962 inductive coil module shall:

- Have an AC resistance of at least 80 mΩ at 1.778 MHz.
- Meet the AC resistance, AC inductance, and parallel capacitance limits defined in [Figure 71-3](#) (page 644) and [Figure 71-4](#) (page 645) when measured according to the procedures in [Measuring Cable Performance](#) (page 645).

Figure 71-3 Watch Fast Charger Module cable requirements at 326.5 kHz

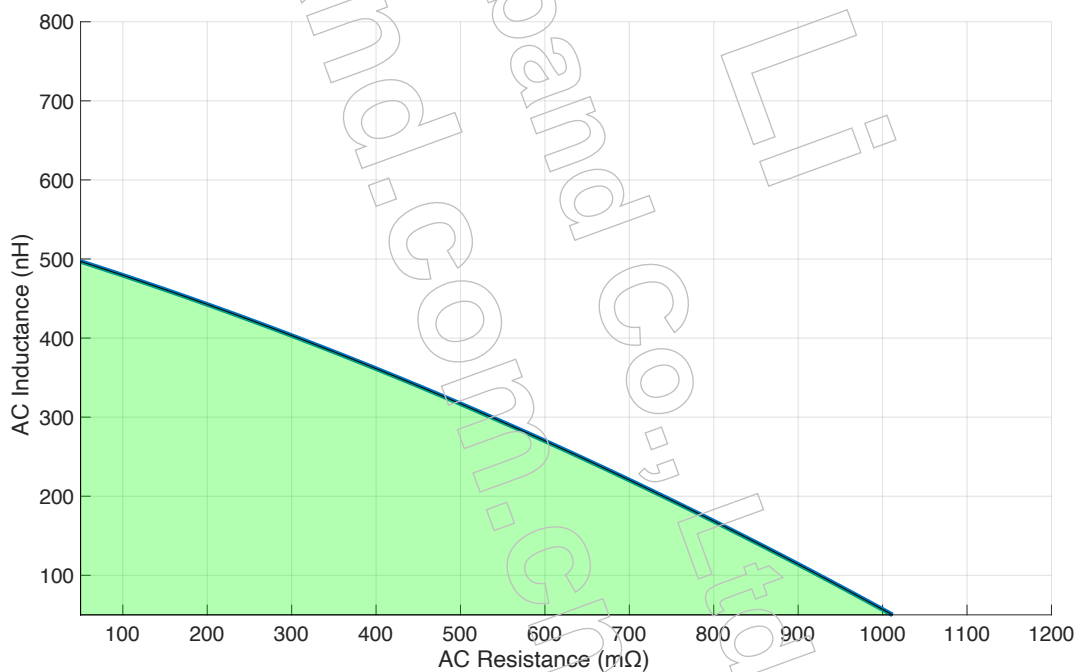
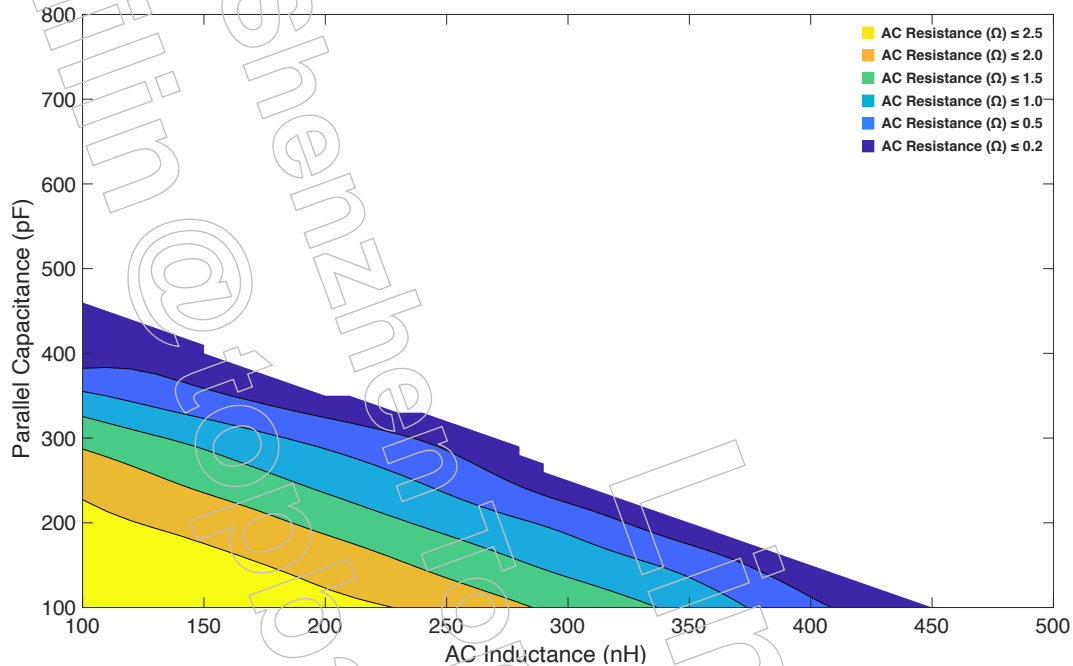


Figure 71-4 Watch Fast Charger Module cable requirements at 1.778 MHz



71.3.4.1 Measuring Cable Performance

AC resistance and AC inductance shall be measured between the COIL+ and COIL- signals at one end of the cable, shorting COIL+ / COIL- at the other end of the cable.

Parallel capacitance shall be measured between COIL+ and the COIL- signals at one end of the cable, leaving COIL+ / COIL- at the other end of the cable open.

Measurements should be taken when the cable is straight. Ground shielding should be left floating for all measurements.

Recommended equipment for measuring cable performance:

- VNA
- LCR meter
- Impedance analyzer

Recommended VNA settings:

- Set IF Bandwidth 10 kHz.
- Perform calibration from 100 kHz to 10 MHz.
- Max number of points.
- Markers set to the operating frequencies defined in [Operating Frequency](#) (page 644).

71.3.5 EMC

Accessories integrating the C962 should be designed for [Electromagnetic Compatibility \(EMC\)](#) (page 312).

A variety of Apple Watch models and wristband combinations should be tested with the C962 for EMC/EMI.

71.3.6 Inductive Coil

The C962 inductive coil has 9 turns with an outer diameter of ≈ 21.34 mm.

When an Apple Watch is attached, the C962 inductive coil module has an effective temperature limit of 45 °C.

71.4 Control Module

The C962 control module has a 60 °C temperature limit.

71.4.1 Firmware Update Over USB

C962 control module supports firmware updates over USB-C from Mac computers. To register an accessory for this support, email a request to mfi-uarp-adopters@group.apple.com with the following:

- Email subject containing the:
 - Module name (that is, "C962").
 - Accessory's USB VID/PID in hex (for example, "XXXX/XXXX").
- Email body containing:
 - Requesting company's name.
 - Apple MFi account number.
 - Apple MFi Product Plan ID (PPID) and/or Product Plan UID (PPUID).

71.5 Factory Configuration

The C962 exposes a USB HID interface to use for factory configuration. Connect the pads to a cable terminating in a USB-A plug or USB-C plug to access the interface.

The C962 factory configuration reference app available in the MFi Portal provides commands to set and read each configuration parameter.

71.5.1 Parameters

The following parameters shall be configured at the time of accessory manufacturing:

- [Vendor ID](#) (page 647)
- [Product ID](#) (page 647)
- [Product Plan UID](#) (page 647)
- [Vendor Name](#) (page 647)
- [Product Name](#) (page 647)
- [Model Number](#) (page 648)
- [Serial Number](#) (page 648)
- [Power Mode](#) (page 648)
- [AC Resistance](#) (page 648)
- [Vendor Lock](#) (page 648)

Every C962:

- Shall set the Vendor ID (VID) as assigned by the USB-IF and a unique Product ID (PID) assigned by the accessory developer. The VID shall correspond to the brand name that appears on the accessory or its packaging. See [USB Host Mode](#) (page 474).
- Shall set the Vendor Name, Product Name, and Model Number to human-readable strings that match names appearing on the accessory or its packaging.
- Shall not be configured with empty strings or generic string values.
- Shall be configured with a unique Serial Number (that is, serialized).

71.5.1.1 Vendor ID

The vendor ID (VID) from the manufacturer.

71.5.1.2 Product ID

The product ID (PID) from the manufacturer.

71.5.1.3 Product Plan UID

The Product Plan's UID (PPUID) from the MFi portal (up to 36 UTF8 characters). Note: the Product Plan UID is different from the Product Plan ID.

71.5.1.4 Vendor Name

The vendor name from the manufacturer (up to 64 UTF8 characters).

71.5.1.5 Product Name

The product name from the manufacturer (up to 64 UTF8 characters).

71.5.1.6 Model Number

The model number from the manufacturer (up to 32 UTF8 characters).

71.5.1.7 Serial Number

The serial number from the manufacturer (up to 32 UTF8 characters).

71.5.1.8 Power Mode

A number indicating the power mode:

- 1 = USB-A mode.
- 2 = USB-C / USB-PD mode.
- 3 = 5 V mode. Input voltage and operating current range is fixed.
- All other values are reserved.

71.5.1.9 AC Resistance

The AC resistance (in mΩ) measured at 326.5 kHz of the [Cable](#) (page 644) connecting the C962 control module and C962 inductive coil module (for example, 500 for 500 mΩ).

71.5.1.10 Vendor Lock

A number indicating the configuration lock mode:

- 0 = Unlocked.
- 1 = Temporarily use the configured parameters to enumerate over USB on the next boot, then return to factory configuration mode on the following boot. This setting may be used to verify that parameters have been set correctly. This setting does not enable inductive charging.
- 2 = Permanently lock configuration on the next boot. This setting shall be used for all production units.
- All other values are reserved.

71.5.2 Examples

71.5.2.1 Configure, Verify, and Lock

The following is an example factory configuration sequence which permanently locks the C962 immediately after configuration:

1. Apply power to the C962 and connect to the USB HID interface.
2. Issues all commands to configure the C962 control module.
3. Verify all parameters are set to the expected values.
4. Set the [Vendor Lock](#) (page 648) to 2 (permanently lock firmware configuration).

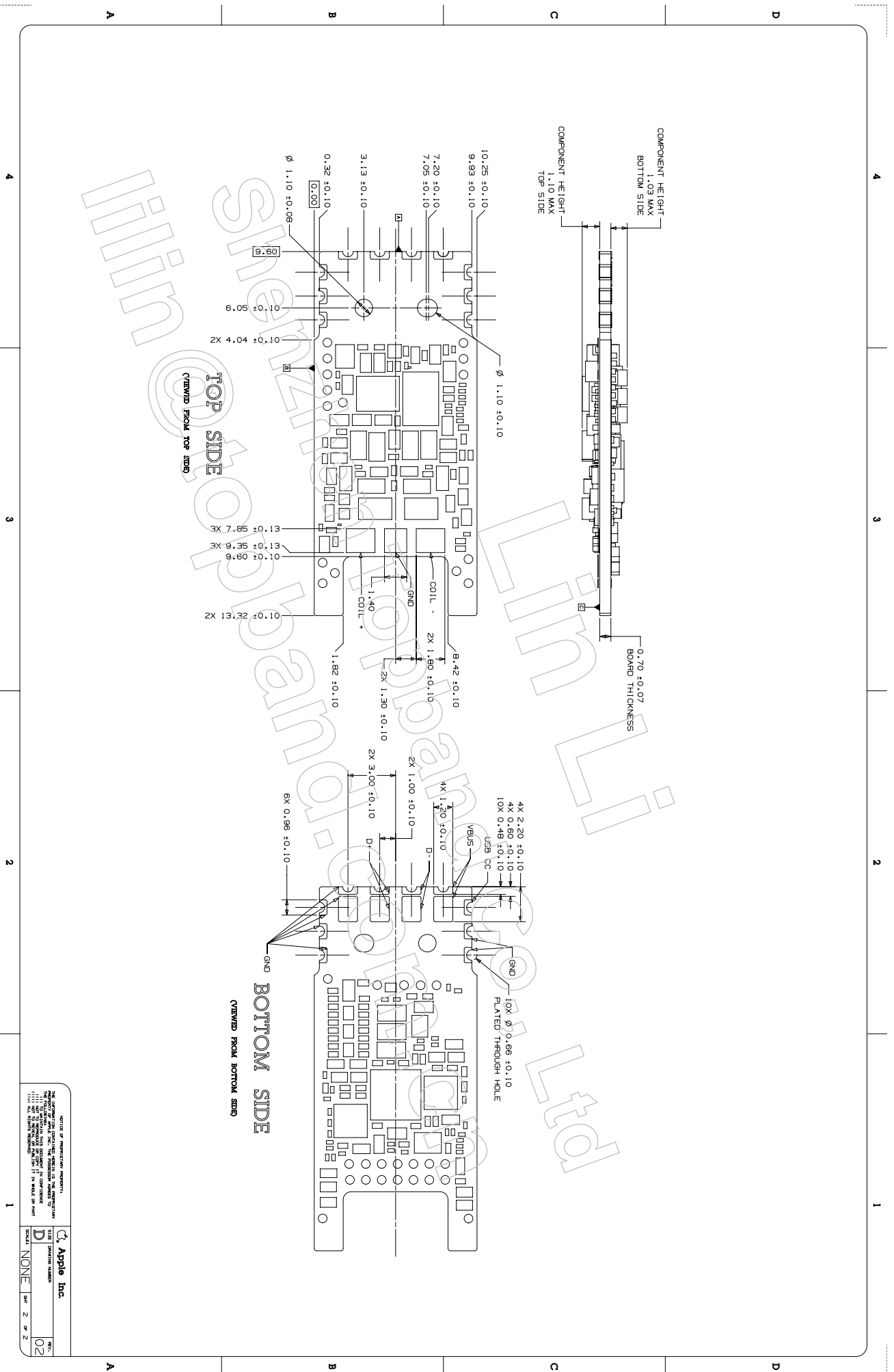
5. Cycle power, the C962 permanently boots in production mode.

71.5.2.2 Configure and Test

The following is an example manual configuration sequence to tests the configuration, but does not permanently lock the C962:

1. Apply power to the C962 and connect to the USB HID interface.
2. Issues all commands to configure the C962 control module.
3. Set the [Vendor Lock](#) (page 648) to 1 (next boot will use configured parameter values for testing).
4. Cycle power.
5. The C962 boots, enumerating using the configured parameters.
6. Verify that the C962 has been correctly configured using the following procedure on a Mac (or its equivalent for another computer/operating system combination):
 - a. Launch *System Information* on the Mac.
 - b. Select *USB* under the *Hardware* category on the left pane.
 - c. Verify that the "Example Product" is listed in the USB device tree.
 - d. Select the "Example Product" and verify all displayed values, for example, Product Name, Product ID, Vendor ID, Serial Number, Manufacturer (that is, Vendor Name).
7. Cycle power and connect to the USB HID interface to continue configuration.

71.7 Watch Fast Charger Control Module Dimensions



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71.8 Test Procedures

Test procedures for accessories integrating the C962 are contained in this section. Tests should be performed with an Apple Watch 44 mm Stainless Steel Case with Link Bracelet.

71.8.1 Mechanical

This section contains mechanical test procedures for accessories integrating the C962.

71.8.1.1 Product Design

1. Verify that the accessory:
 - a. Is intended for stationary use.
 - b. Does not require the watch band to be removed or detached.
 - c. Does not scratch or damage the body of the Apple Watch or watch band when magnetically connected.
2. Verify that the accessory does not have magnetic steel in proximity to the C962 using a ferromagnetic metal.
3. Verify that the C962 is $0.40 \text{ mm} \pm 0.25 \text{ mm}$ proud of the surface of the accessory using a caliper.

If mounted horizontally:

1. Verify that the C962 is not mounted at an angle greater than 45° from horizontal using a protractor.

If mounted vertically:

1. Verify that the accessory's mounting angle is not adjustable.
2. Verify that all Apple Watch models and band configurations are supported with the watch on its side (crown up).
3. Verify that the accessory has a pocket or alignment feature that ensures that the center of the Apple Watch aligns with the center of the C962 within $\pm 1.0 \text{ mm}$.

71.8.1.2 Drop Test

1. Drop the accessory onto plywood from a height of 32 inches.
2. Verify that the C962 has not been dislodged from the accessory.
3. Verify that the accessory still charges the Apple Watch.

71.8.2 Electrical

This section contains electrical test procedures for accessories integrating the C962.

71.8.2.1 Internal Power Supplies

This section contains electrical test procedures for accessories containing internal power supplies.

71.8.2.1.1 Equipment

The following equipment is needed for performing the electrical test procedures:

- Electronic load rated at 10 W or higher, capable of constant current (CC) mode.
- Oscilloscope with 100 MHz or higher bandwidth.

71.8.2.1.2 Test Setup

1. Disconnect the C962 from the accessory's internal power supply.
2. Connect the electronic load and the oscilloscope channel to VBUS and GND signals in the accessory.
3. Connect the accessory to the power source.

71.8.2.1.3 Supply Voltage (DC)

1. Configure the oscilloscope as follows:
 - Horizontal scale: 1 ms/div
 - Vertical scale: 1 V/div
 - Channel coupling: DC
2. With electronic load set to CC mode, record the average VBUS voltage on the scope for each load from 0 A to 1 A in 200 mA steps.
3. Verify that all recorded values are within 4.75 V and 5.50 V.

71.8.2.1.4 Supply Voltage Ripple

1. Configure the oscilloscope as follows:
 - Horizontal scale: 1 ms/div
 - Vertical scale: 10 mV/div
 - Channel coupling: AC
2. With electronic load set to CC mode, record the peak-peak VBUS voltage on the scope using cursors for each load from 0 A to 1 A in 200 mA steps. Capture at least 10 cycles and measure the worst-case peak-peak voltage, adjusting the horizontal scale if necessary based on the frequency of the ripple.
3. Verify that all recorded values are below 20 mV.

71.8.2.2 External USB Power Sources

This section contains electrical test procedures for accessories using external USB power sources.

71.8.2.2.1 Equipment

The following equipment is needed:

- DMM with 4-wire Kelvin sense capability
- [USB Breakout Board](#) (page 835) (if accessory uses a USB-A plug)

- USB-IF certified USB-C receptacle breakout board (if accessory uses a USB-C plug), see https://www.usb.org/compliancetools#anchor_electricaltools
- USB-C PD power source (if accessory uses a USB-C plug)

71.8.2.2.2 Test Setup

1. Disconnect the C962 from the accessory.

71.8.2.2.3 Round-Trip DC Resistance (DCR)

1. Connect the "Force" and "Sense" leads of the DMM to the VBUS and GND signals in the accessory.
2. Short the VBUS and GND signals at the USB plug using a USB breakout board.
3. Configure the DMM to perform a 4-wire Kelvin sense resistance measurement.