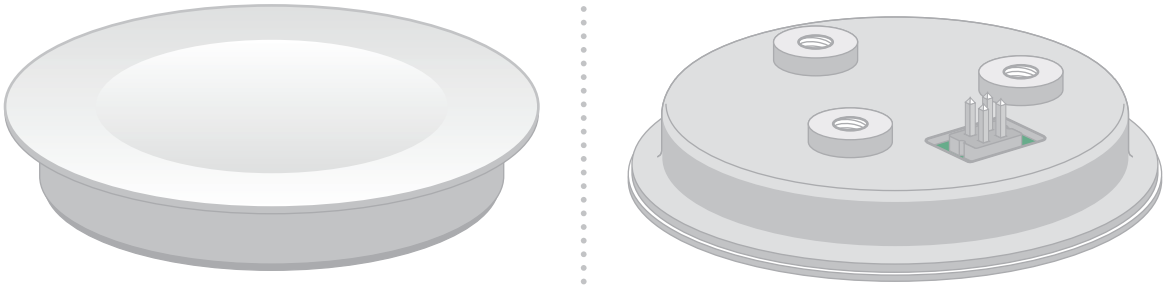
72. Apple Watch Charger Module

The Watch Charger Module (C162) enables accessories to charge the Apple Watch.

Figure 72-1 Watch Charger Module



72.1 Accessory Integration

All C162 accessories shall:

- Provide power to Apple Watch. SeeElectrical (page 658).
- Hold the Apple Watch when it is magnetically connected to the C162.
- Permit the Apple Watch to move relative to the C162.
- Be intended for stationary use.

Accessories shall not integrate the C162 into wearable accessories such as wrist straps or watch bands.

72.2 Mechanical

See Watch Charger Module Dimensions(page 666) for dimensional drawing.

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

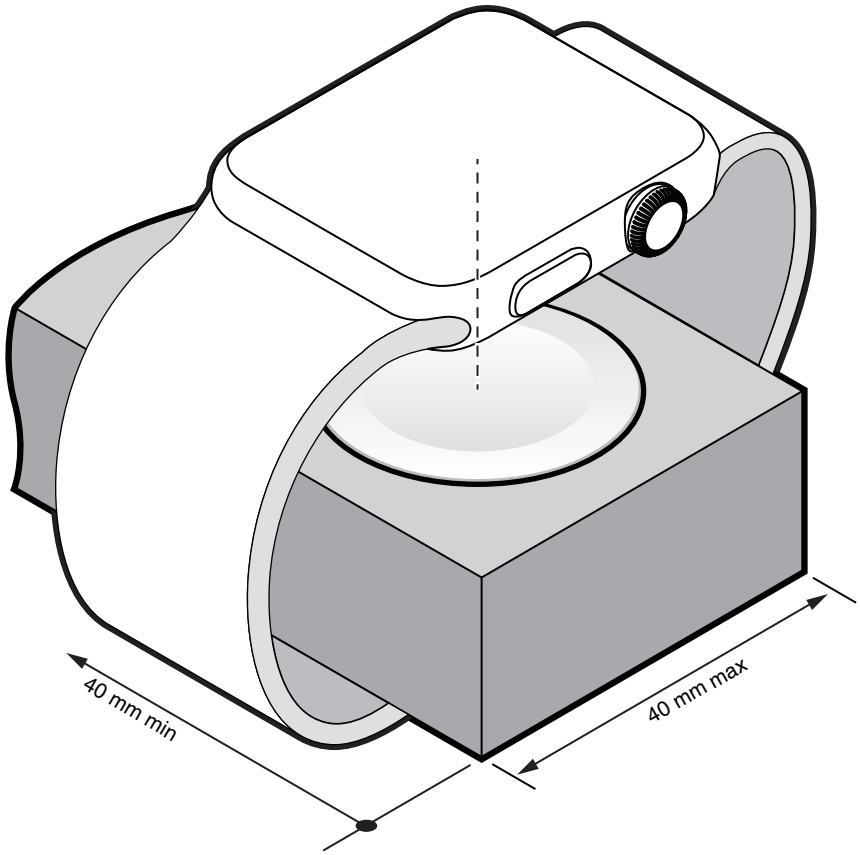
The accessory shall not require the watch band to be removed or detached.

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 C162 surface if the Apple Watch can be attached in any orientation.
- Not exceed a length of 40 mm across the surface of the C162 (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. SeeFigure 72-2 (page 656).

Figure 72-2 C162 Charging Arm Clearance



The exposed surface of the C162 shall be 0.40 mm ±0.25 mm proud of the surface of the accessory.

The C162 shall be mounted such that any combination of Apple Watch and band shall not disengage and fall off due to gravity.

The C162 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 C162 surface within ±1.0 mm. See Table 72-1 (page 657) for Apple Watch vertical alignment heights.

Table 72-1 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 μm. This should be taken into account when designing the vertical mount alignment feature.

The C162 shall be mounted using at least one of the following:

- 3 M2 x 0.4 threaded screws in the 3 mounting holes with a minimum of 2 thread engagement.
- An adhesive to bond the lip of the cap to the surface of the accessory. Apple recommends pressure sensitive adhesive (PSA) in a ring with an inner diameter of 29.12 mm, a width of 1.05 mm to 1.25 mm, and a thickness of 0.15 mm.

The C162 shall not be mounted in proximity to magnetic steel.

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

The C162's maximum storage temperature is 60° C.

72.3 Electrical

Accessories integrating a C162 shall comply with the electrical requirements in this section.

72.3.1 Power

Accessories integrating a C162 shall provide power from either:

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

If the accessory integrates an Internal Power Supply(page 658), 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 C162 power requirements are met.

If the accessory relies on an External USB Power Source (page 659) to provide power to the C162 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).
- If using a USB-C plug, a 5.1 k Ωpull-down with a tolerance of 5% or better shall be connected to the USB CC wire.
- Shall not consume any power from the external USB power source.
- Shall not monitor or modify the USB D+/D- signals from the external USB power source.

The C162 absolute current limit is 1.2 A at 5 V. 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).

72.3.1.1 Internal Power Supply

The accessory's internal power supply for the C162 shall:

- Regulate input voltage at the PWR pin of the C162 to 4.75 V - 5.4 V under any load from 0 A to 1 A.
- Hold PWR ripple below 20 mVpp under any supported load.
- Implement overcurrent protection with a 1.5 A threshold.
- 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).

72.3.1.2 External USB Power Source

Accessories relying on an external USB power source to provide power to the C162 shall:

- Have maximum 500 mΩround trip DCR (USB VBUS to Ground) between the C162 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 μC.
- 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.

Overcurrent protection (OCP) is optional. If the accessory implements OCP, the maximum round trip DCR shall include the on-resistance of the OCP switch.

72.3.1.3 Apple Watch Charging Efficiency

Accessories integrating a C162 shall not impair Apple Watch's ability to efficiently charge from provided power.

72.3.2 Pins and Assignments

The module pin assignments are shown inWatch Charger Module Dimensions(page 666).

Table 72-2 C162 Pins

Pin	Name	Assignment
1	PWR	USB VBUS
2	GND	Ground
3	USB D+	USB D+
4	USB D-	USB D-

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

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

One of the following approaches shall be used to connect to the module pins:

- Use a 4-pin 0.050" micro pitch connector mounted to a PCB. The PCB shall be attached to the module using the 3 mounting holes.

- Use a 4-pin 0.050" micro pitch connector attached to a cable.
- Solder pins directly to a PCB using through-hole mounting. The pins shall not be reflow soldered, but shall be manually soldered with heat contained to the pin region.
- Solder wires directly to the pins.

Micro pitch connectors are available from Samtec (https://www.samtec.com) and others.

72.3.3 EMC

Accessories integrating the C162 should be designed forElectromagnetic Compatibility (EMC)(page 312).

If an adapter board is used between the C162 and a cable, the cable should have 360° termination to the board. The design of the adapter board should limit exposed traces on external layers.

A variety of Apple Watch models and wristband combinations should be tested with the C162 for EMC/EMI.

72.3.4 Inductive Coil

The C162 inductive coil has 12 turns with an outer diameter of ≈22 mm.

The C162 inductive coil has a 55 °C temperature limit.

72.4 Factory Configuration

The C162 exposes a USB Virtual COM Port (page 664) (VCP) on the 4-pin header to use for factory configuration. Connect the 4 pins to a cable terminating in a USB-A plug or USB-C plug to access the interface. If using a USB-C plug, a 5.1 kΩ pull-down with a tolerance of 5% or better shall be connected to the USB CC wire.

The C162 factory configuration interface provides commands to set and read each configuration parameter. Commands take two forms:

- "[*CommandName* *Value*]" to set the value of a parameter.
- "[*CommandName*]" to read the current value of a parameter.

Command responses for both setting and reading parameters take the form: "<*CommandName* *CurrentValue*>". This response may be used to confirm the value has been set correctly.

72.4.1 Parameters

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

- Set Vendor Name (page 661)
- Set Product Name (page 661)
- Set Model Number(page 662)
- Set Serial Number (page 662)
- Set USB Vendor ID (page 662)
- Set USB Product ID (page 662)
- Lock Configuration(page 663)

Every C162:

- 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 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 not be configured with empty strings or generic string values.
- Shall be configured with a unique Serial Number (that is, serialized).

72.4.1.1 Set Vendor Name

Description : Sets the Vendor Name string.

Format : [SetVN- *vendorName*]

Parameters :

- *vendorName* A string representation of the vendor name from the manufacturer (up to 64 UTF8 characters).

Example : [SetVN-Example Product Developer]

Response : <SetVN-Example Product Developer >

72.4.1.2 Set Product Name

Description : Sets the Product Name string.

Format : [SetPN- *productName*]

Parameters :

- *productName* A string representation of the product name from the manufacturer (up to 64 UTF8 characters).

Example : [SetPN-Example Product]

Response : <SetPN-Example Product >

72.4.1.3 Set Model Number

Description : Sets the Model Number string.

Format : [SetMN- *modelNumber*]

Parameters :

- *modelNumber* A string representation of the model number from the manufacturer (up to 32 UTF8 characters).

Example : [SetMN-ABC 123]

Response : <SetMN-ABC 123 >

72.4.1.4 Set Serial Number

Description : Sets the Serial Number string.

Format : [SetSN- *serialNumber*]

Parameters :

- *serialNumber* A string representation of the serial number from the manufacturer (up to 32 UTF8 characters).

Example : [SetSN-ABCDEF123456]

Response : <SetSN-ABCDEF123456 >

72.4.1.5 Set USB Vendor ID

Description : Sets the USB Vendor ID hex value.

Format : [SetUV- *vendorID*]

Parameters :

- *vendorID* A string representation of the hex value of the vendor ID from the manufacturer, without the 0x prefix.

Example : [SetUV-0000]

Response : <SetUV-0000 >

72.4.1.6 Set USB Product ID

Description : Sets the USB Product ID hex value.

Format : [SetUP- *productID*]

Parameters :

- *productID*: A string representation of the hex value of the product ID from the manufacturer, without the 0x prefix.

Example : [SetUP-0000]

Response : <SetUP-0000 >

72.4.1.7 Lock Configuration

Description : Locks the configuration for production use.

Format : [LkCfg- *mode*]

Parameters :

- *mode*:
  - 1 = Test configuration on the next boot. The module will enumerate over USB using the configured parameters on the next boot, then it will return to VCP 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.

Example : [LkCfg-2]

Response : <LkCfg-2 >

72.4.2 Examples

72.4.2.1 Configure, Verify, and Lock

The following is an example factory configuration sequence which permanently locks the C162 immediately after configuration:

1. Apply power to the C162 and connect to USB VCP interface.
2. Issues all [Set *XX*] commands to configure the module.
3. Verify all parameters are set to the expected values.
4. Issue [LkCfg-2] (permanently lock firmware configuration).
5. Cycle power, the C162 permanently boots in production mode.

72.4.2.2 Configure and Test

The following is an example factory configuration sequence which tests the settings in production mode, but does not permanently lock the C162:

1. Apply power to the C162 and connect to USB VCP interface.
2. Issue all [Set *XX*] commands to configure the module.
3. Issue [LkCfg-1] (next boot will come up in production mode).
4. Cycle power.
5. The C162 boots, enumerating using the configured parameters.
6. Verify that the C162 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 VCP interface to continue configuration.

72.4.3 USB Virtual COM Port

The USB Virtual COM Port (VCP) enables configuration of the C162.

72.4.3.1 Mac

When using a Mac, the C162 is recognized as a USB serial device. The accessory will appear as /dev/tty.usbmodem- <identifier >. The interface may be accessed using various serial interface programs (for example, executing screen /dev/tty.usbmodem- <identifier > given the appropriate identifier in a terminal).

72.4.3.2 Windows XP/7/8

When using a computer running Windows XP/7/8, first install the STM32 Virtual COM Port Driver (part number STSW-STM32102) from https://www.st.com/en/development-tools/stsw-stm32102.html. Once installed, edit the stmcdc.inf file to add Apple VID 0x05AC and the C162 PID 0x1709 to the DeviceList sections as follows:

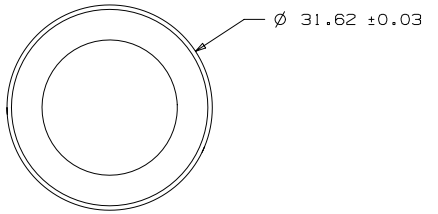
```
[DeviceList.NT]
%DESCRIPTION%=DriverInstall,USB\VID_0483&PID_5740
%DESCRIPTION%=DriverInstall,USB\VID_05AC&PID_1709
[DeviceList.NTamd64]
%DESCRIPTION%=DriverInstall,USB\VID_0483&PID_5740
%DESCRIPTION%=DriverInstall,USB\VID_05AC&PID_1709
```

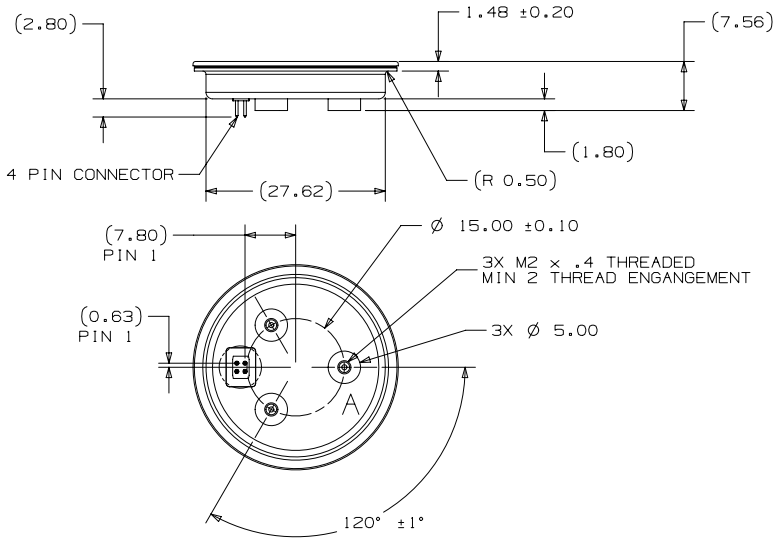
If the VCP is not identified properly upon connection, update the driver using the Windows Device Manager. If the accessory is listed as a Composite device, select it and update the driver (choose "Have Disk", and browse to the folder containing the updated stmcdc.inf file).

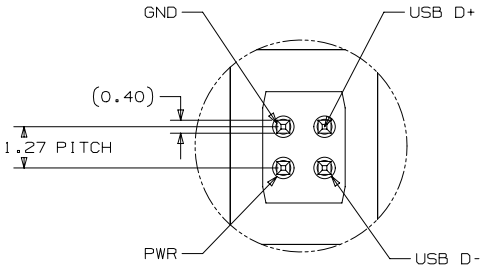
72.5 Watch Charger Module Dimensions

NOTES: (UNLESS OTHERWISE SPECIFIED)

REV	ECO#	DESCRIPTION OF REVISION
01		INITIAL RELEASE
02		CORRECTED PINOUT DESIGNATION.







DETAIL A
4 PIN CONNECTOR PINOUT

METRIC	Apple Inc.
DRAFTER: APPLE — DATE	NOTICE OF PROPRIETARY PROPERTY: THE INFORMATION CONTAINED HEREIN IS THE PROPRIETARY PROPERTY OF APPLE INC. THE POSSESSOR AGREES TO THE FOLLOWING: (I) TO MAINTAIN THIS DOCUMENT IN CONFIDENCE (II) NOT TO REPRODUCE OR COPY IT (III) NOT TO REVEAL OR PUBLISH IT IN WHOLE OR PART (IV) ALL RIGHTS RESERVED
DESIGNER: APPLE — DATE	TITLE: MAGNETIC CHARGING MODULE
DIMENSIONS ARE IN MILLIMETERS TOLERANCES X.X ±0.2 X.XX ±0.10 X.XXX ±0.050 ANGLES ±0.5° DO NOT SCALE DRAWINGS	DRAWING NUMBER — REV. 02
THIRD ANGLE PROJECTION — SIZE C	SCALE: NONE — SHT 1 OF 1
NX GENERATED	

72.6 Test Procedures

Test procedures for accessories integrating the C162 are contained in this section. Tests should be performed with an Apple Watch 44 mm Stainless Steel Case with Link Bracelet.

72.6.1 Mechanical

This section contains mechanical test procedures for accessories integrating the C162.

72.6.1.1 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 C162 using a ferromagnetic metal.
3. Verify that the C162 is 0.40 mm ±0.25 mm proud of the surface of the accessory using a caliper.

If mounted horizontally:

1. Verify that the C162 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 C162 within ±1.0 mm.

72.6.1.2 Drop Test

1. Drop the accessory onto plywood from a height of 32 inches.
2. Verify that the C162 has not been dislodged from the accessory.
3. Verify that the accessory still charges the Apple Watch.

72.6.2 Electrical

This section contains electrical test procedures for accessories integrating the C162.

72.6.2.1 Internal Power Supplies

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

72.6.2.1.1 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.

72.6.2.1.2 Test Setup

1. Disconnect the C162 from the accessory's 4-pin connector.
2. Connect the electronic load and the oscilloscope channel to VBUS and GND pins on the connector.
3. Connect the accessory to the power source.

72.6.2.1.3 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 5.40 V.

72.6.2.1.4 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.

72.6.2.1.5 Overcurrent Protection (OCP)

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, observe the average VBUS voltage on the scope as the load is varied from 1.4 A to 1.6 A in 10 mA increments.

3. Verify that the VBUS voltage reading on the scope falls within 4.75 V and 5.4 V with the electronic load setting of 1.4 A and the output current draw falls to less than 20 mA with the electronic load setting of 1.5 A ±2% (between 1.47 A and 1.53 A).

72.6.2.2 External USB Power Sources

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

72.6.2.2.1 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)

72.6.2.2.2 Test Setup

1. Disconnect the C162 from the accessory's 4-pin connector.

72.6.2.2.3 Round-Trip DC Resistance (DCR)

1. Connect the "Force" and "Sense" leads of the DMM to the VBUS and GND pins on the accessory's 4-pin connector.
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.

72.6.2.2.4 Round-Trip DC Resistance (DCR) with Overcurrent Protection (OCP)

When OCP circuitry is included, the total resistance (on-resistance of the OCP switch and the DCR of the cable) should be measured.

1. Connect the power supply's positive and negative terminals to the USB plug's VBUS and GND pins respectively using a breakout board.
2. Connect the electronic load to the VBUS and GND pins on the accessory's 4-pin connector.
3. Connect the positive lead of the DMM to the USB plug's VBUS pin on the breakout board.
4. Connect the negative lead of the DMM to the 4-pin connector's VBUS pin.
5. Set the power supply to supply 5 V and turn it on.
6. Set the electronic load to draw 100 mA.
7. Record the voltage, V_{VBUS} in mV, from the DMM.
8. Connect the positive lead of the DMM to the 4-pin connector's GND pin.

9. Connect the negative lead of the DMM to the USB plug's GND pin on the breakout board.
10. Record the voltage, V_{GND} in mV, from the DMM.
11. Calculate the total resistance: DCR = (V_{VBUS} + V_{GND}) / 100

72.6.2.2.5 USB-C CC Pull-Down

Use the USB-C receptacle breakout board.

1. Configure the DMM to perform a resistance measurement.
2. Connect the positive lead of the DMM to the USB plug's CC pin on the breakout board.
3. Connect the negative lead of the DMM to the USB plug's GND pin on the breakout board.
4. Verify that the resistance is within 5% of 5.1 kΩ