Chapter 6
Mechanical

This chapter provides the mechanical specification for the cables and connectors for USB hubs, functions, and hosts. The specification includes the dimensions, materials, electrical, and reliability requirements.

6.1 Architectural Overview

The physical topology of a USB channel consists of connecting a hub or function to another hub, function, or host. There are two possible speeds at which the channel can operate. The fully rated speed of 12 Mbs requires the use of a shielded cable with two internal power conductors and two internal signal conductors. For lower cost and lower speed, a sub-channel at 1.5 Mbs is allowed by the specification with the use of unshielded cabling.

The present plug and receptacle (series A) are to be used for those devices on which the external cable is permanently attached to devices such as keyboards, mice, and hubs. There may be internal connectors that will need to meet the electrical requirements of the USB specification, but the mechanical aspects of the internal connector are not part of the USB specification.

For those devices that require an external connector so that the USB cabling is detachable, such as printers, scanners, and modems, a series B connector and receptacle is now included in the specification. All cables that have a series A and series B connector should meet the construction requirements of the fully rated channel and have maximum gauge power conductors.

Series A and B connectors cannot be interchanged; therefore, there is no possibility that the integrity of the bus will be compromised.

6.2 Dimensioning Requirements

Default tolerances are listed in Table 6-1, unless otherwise specified. The dimensions are in millimeters.

Table 6-1. Default Tolerances

Over 1 to 5	Over 5 to 30	Over 30 to 100	Over 100 to 300	Over 300 to 1000	Over 1000 to 3000	Over 3000 to 5000
±0.3	±0.4	±0.6	±0.8	±1.6	±2.5	±10

6.3 Cable

All hubs and functions as defined in this specification will have one permanently attached cable or be terminated with a series B connector.

The standard USB cable will consist of one pair of 20-28 AWG wire for power distribution with another 28 AWG pair twisted, with a shield and overall jacket. This will be used for typical peripherals operating at the rated 12 Mbs signaling.

An alternative cable of identical gauge but without the twisted conductors and shield can be used for 1.5 Mbs signaling. This will be used in a sub-channel application where the wider bandwidth is not needed.

In all other respects, the mechanical specifications for the sub-channel will be identical to the fully rated specification.

6.3.1 Cable Specification

This specification defines the detailed requirements of a twisted pair, 28 AWG, PVC, round cable with two power leads (non twisted) for fully rated devices as well as a four-conductor cable with an overall jacket for the sub-channel devices.

6.3.1.1 Applicable Documents

Underwriters' Laboratory, Inc.

UL-STD-94	Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL-Subject-444	Communication Cables

American Standard Test Materials

ASTM-D-4565	Physical and Environmental Performance Properties of Insulation and Jacket for Telecommunication Wire and Cable, Test Standard Method
ASTM-D-4566	Electrical Performance Properties of Insulation and Jacket for Telecommunication Wire and Cable, Test Standard Method

6.3.1.2 Requirements

Mechanical

Material/Finish:

Outer Jacket: Polyvinyl Chloride (PVC)

Color: Recommended; Frost White

Conductor Insulation: Semi-Rigid PVC for power conductors and Polyethylene (optionally foamed) or equivalent meeting the requirements of Table 6-4 for the signal pair (fully rated 12 Mbs only).

Conductors: Refer to Table 6-2 for power distribution conductors. The signaling conductor pair is 28 AWG.

Table 6-2. Conductors - Pair for Power Distribution

Gauge and Conductor Outer Diameter
28 AWG - .84 ±.05 mm
26 AWG - 1.00 ±.05 mm
24 AWG - 1.10 ±.07 mm
22 AWG - 1.30 ±.07 mm
20 AWG - 1.50 ±.08 mm

Cable Construction:

Fully Rated: Cable shall consist of four conductors; one twisted pair with 28 AWG conductors (data pair), one non-twisted pair (power distribution pair) with an overall jacket. The twisted pair shall have one twist per 6-8 cm.

Sub-Channel: Cable shall consist of four conductors; one pair with 28 AWG conductors (data pair), one pair for power distribution with an overall jacket.

Outer Jacket:
A. Outside Diameter:
Fully Rated and Sub-Channel: 3.4 to 5.3 mm.

B. Color: Frost White recommended.

Conductor Insulation:
A. Outside Diameter: Refer to Table 6-2.
C. Color: Refer to Table 6-5.

Conductors:

Fully Rated:

A. 28 AWG stranded - Twisted Pair

B. Non Twist - One pair per Table 6-2 stranded selected as needed for proper DC power distribution.

C. Shield: Required for EMI compliance. Suggest aluminized mylar wrap with a 28 AWG drain wire and 65% min. coverage tinned copper mesh over the foil.

Sub-Channel:

A. 28 AWG stranded - Pair.

B. Non Twist - One pair per Table 6-2 stranded selected as needed for proper DC power distribution.

Break Strength: 45 Newtons minimum when tested in accordance with ASTM-D-4565.

Electrical:

Voltage Rating: 30 V (rms) maximum.

Conductor Resistance: As shown in Table 6-3, when tested in accordance with ASTM-D-4565. Refer to Section 6.4 for limitations on DC voltage drop.

Table 6-3. Conductor Resistance

Gauge	DC Resistance (max.)
28	0.232 Ω/m
26	0.145 Ω/m
24	0.0909 Ω/m
22	0.0574 Ω/m
20	0.0358 Ω/m

Resistance Unbalance: The resistance unbalance between the two conductors shall not exceed 5% when tested in accordance with ASTM-D-4566.

Length: Maximum cable length shall not exceed 3 meters for the sub-channel and 5 meters for the fully rated channel.

Fully rated only:

Attenuation: The attenuation of the signal pair measured in accordance with ASTM-D-4566 shall not exceed the values in Table 6-4.

Characteristic Impedance: The characteristic impedance of the signal pair shall be 90 Ω ±15%, when measured in accordance with ASTM-D-4566 over the frequency range of 1-16 MHz.

Propagation delay of the fully rated twisted signal pair must be equal to or less than 30 ns over the length of cable used in the frequency range of 1-16 MHz. Refer to Section 6.5 if the cabling cannot meet this requirement. Note that the signal pair might require a foamed polyethylene insulation on the signal pair to meet the propagation delay requirements for a full length cable.

Skew: The maximum skew between the two signal pair must be less than 65.6 ps/m at 10 KHz.

Table 6-4. Signal Attenuation

Frequency (MHz)	Attenuation (maximum) dB/305 m
0.064	4.80
0.256	6.70
0.512	8.20
0.772	9.40
1.000	12.0
4.000	24.0
8.000	35.0
10.000	38.0
16.000	48.0

Environmental:

Temperature Rating: -40 °C to 60 °C storage; 0 °C to 40 °C operating.

Laboratory Approvals: Item shall be UL listed per UL Subject 444. Class 2, Type CM for Communication Cable Requirements.

Flammability: Plastic material used in the construction of this item shall meet the Flammability Requirements of NEC Article 800.

Marking: Item shall be legibly and permanently marked with the vendor name or symbol, UL File Number, Type CM (UL).

Qualification: All suppliers, when requested, must be able to supply appropriate documentation to show conformance to the requirements of this chapter.

All electrical measurements should be made with a sample cable removed from the reel or container. The cable must rest on a non-conductive surface or be on aerial supports.

Table 6-5. Cable Color Code

Wire	Color
+ Data	Green
- Data	White
VCC	Red
Ground	Black

6.3.2 Connector (Series A)

6.3.2.1 Plug (Series A)

The USB (Series A) plug is a four-position plug with shielded housing compatible with the cabling as described in Section 6.3. The following guidelines ensure intermateability. The recommended color is frost white for the overmold. Internal plastic features can be frost white or equivalent.

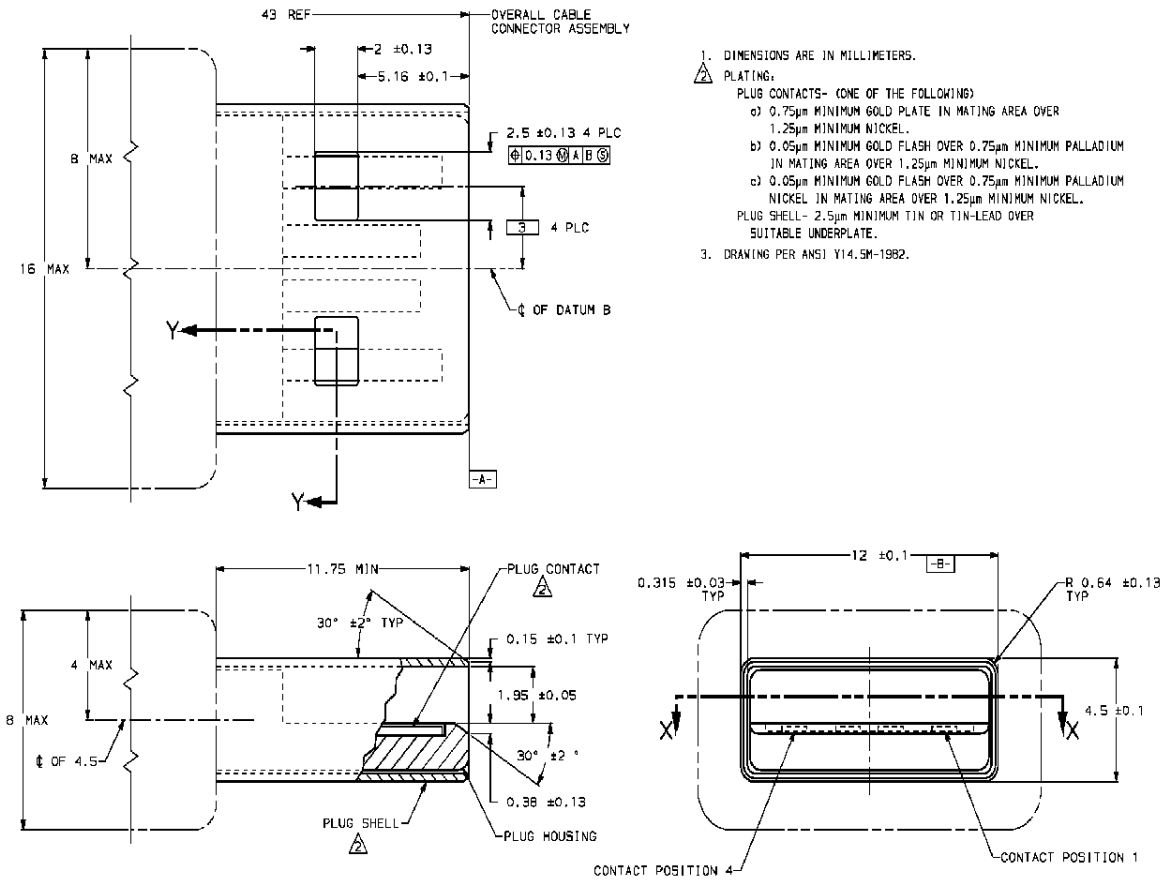


Figure 6-1. Plug Connector (Series A)

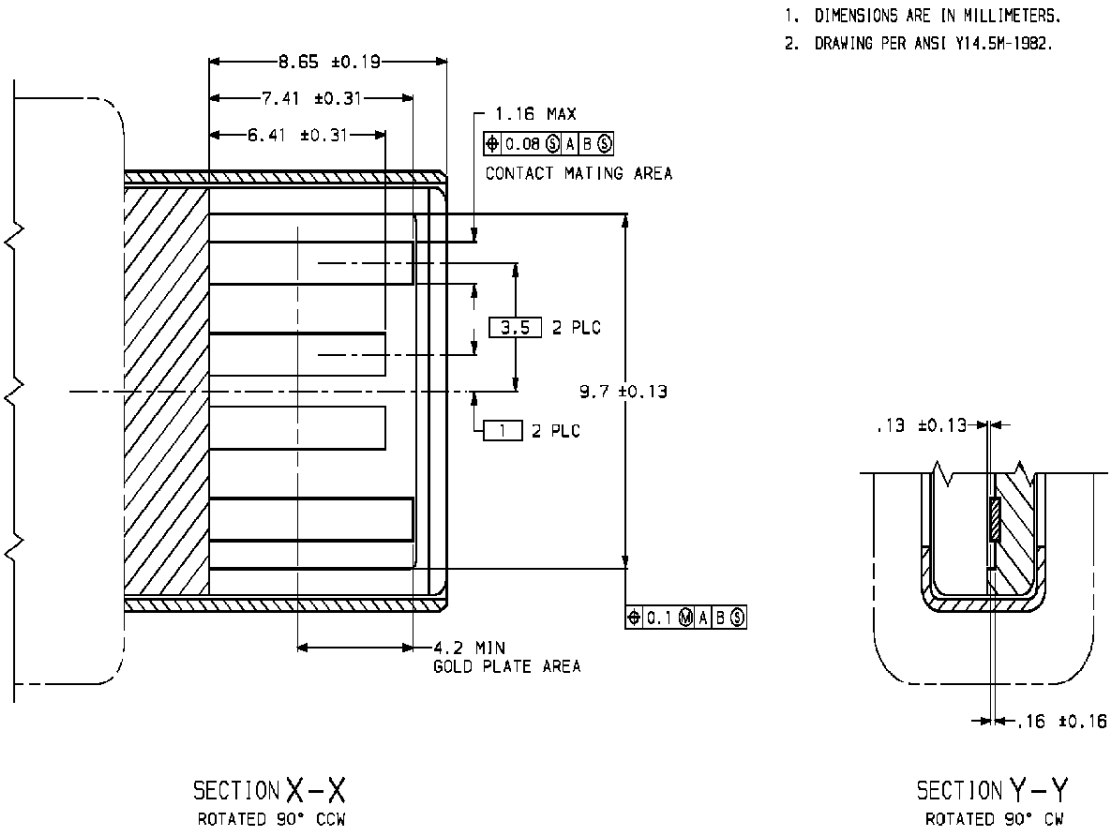


Figure 6-2. Plug Contact Detail (Series A)

The termination of the conductors to the plug contacts may be done as deemed appropriate by the connector's manufacturing process.

6.3.2.2 Receptacle (Series A)

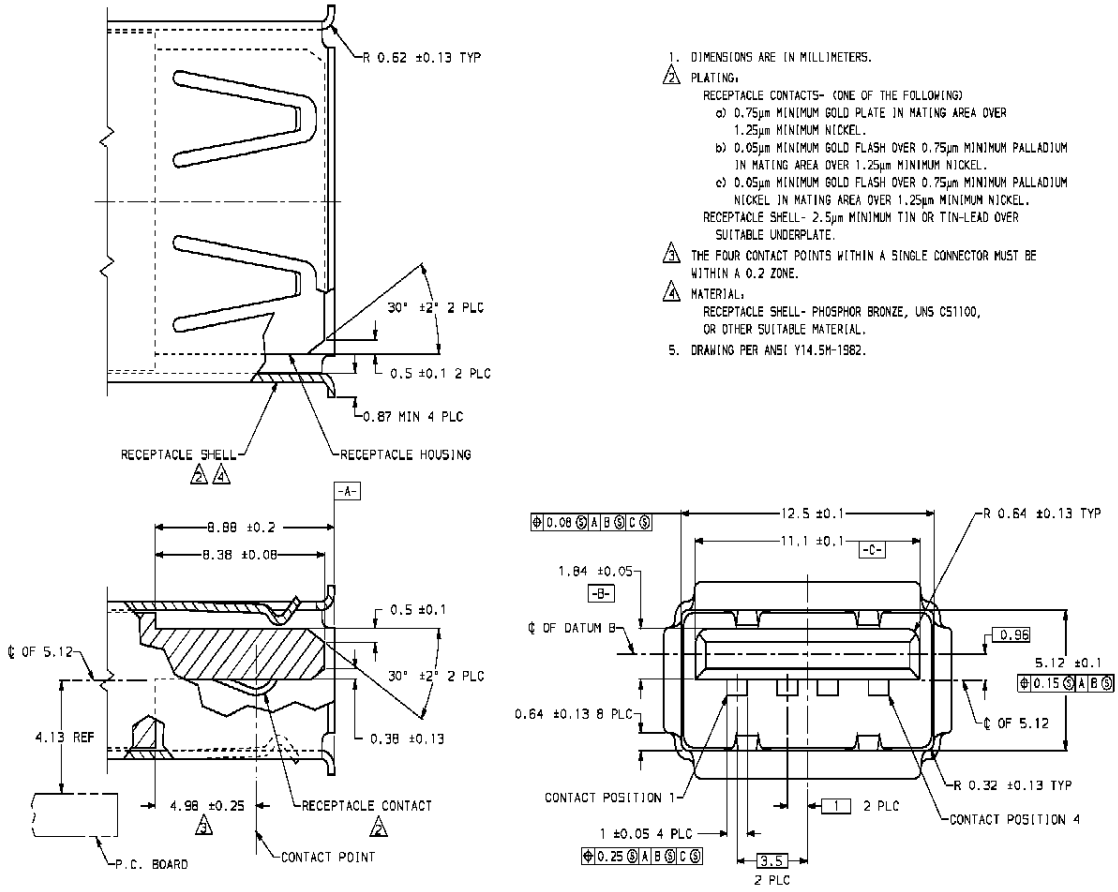
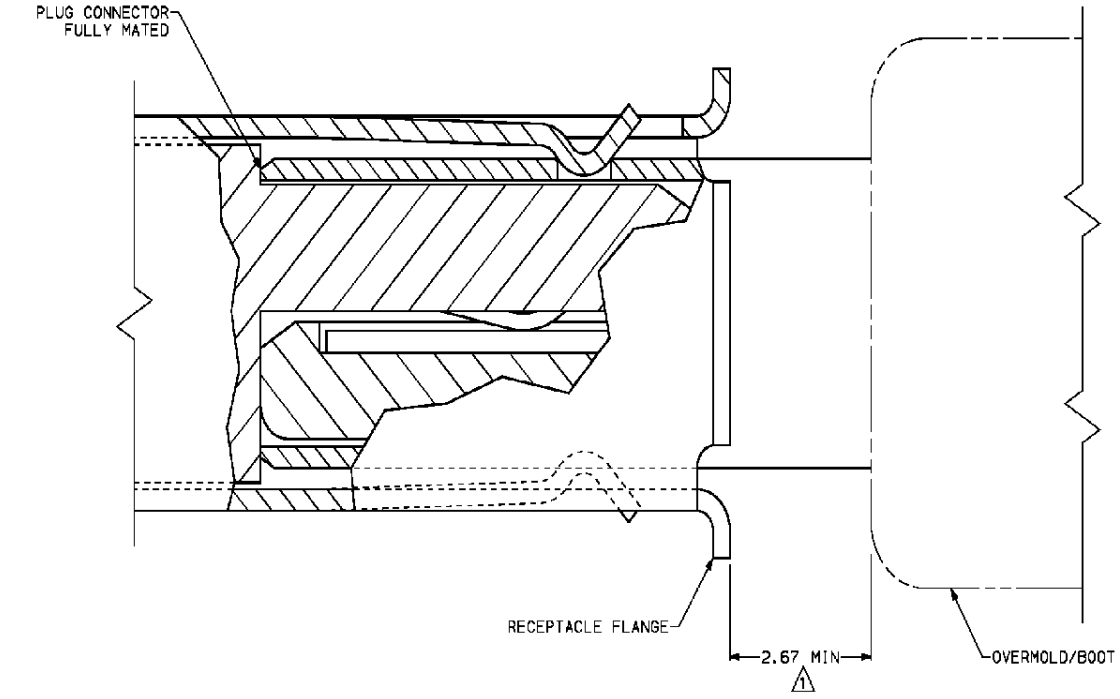


Figure 6-3. Receptacle (Series A)

There are four variants of the receptacle available for general use. They are vertical, right angled, panel mount, and stacked right angled with SMT as well as through hole variants. However, as long as the interface requirements of the specification are met, it is up to the implementer as to what form the receptacle will take. Internal plastic features should be frost white or equivalent.

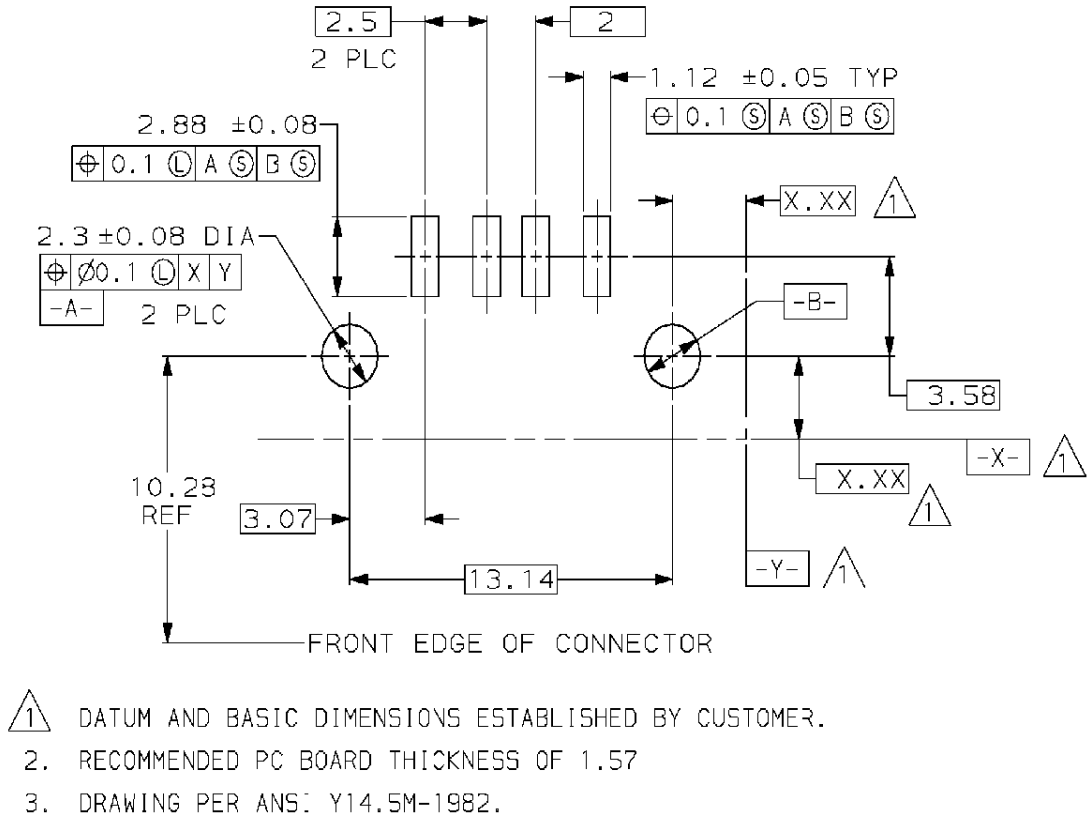
6.3.2.3 Connector Mating Features (Series A)



1 DIMENSIONS AS SPECIFIED IN FIGURES 6-1 AND 6-3 ALLOW A MINIMUM 2.67 BETWEEN RECEPTACLE FLANGE AND OVERMOLD/BOOT. THIS ALLOWS FOR A PANEL THICKNESS OF 2.67 MAXIMUM IF THE RECEPTACLE CONNECTOR IS MOUNTED BEHIND A PANEL.

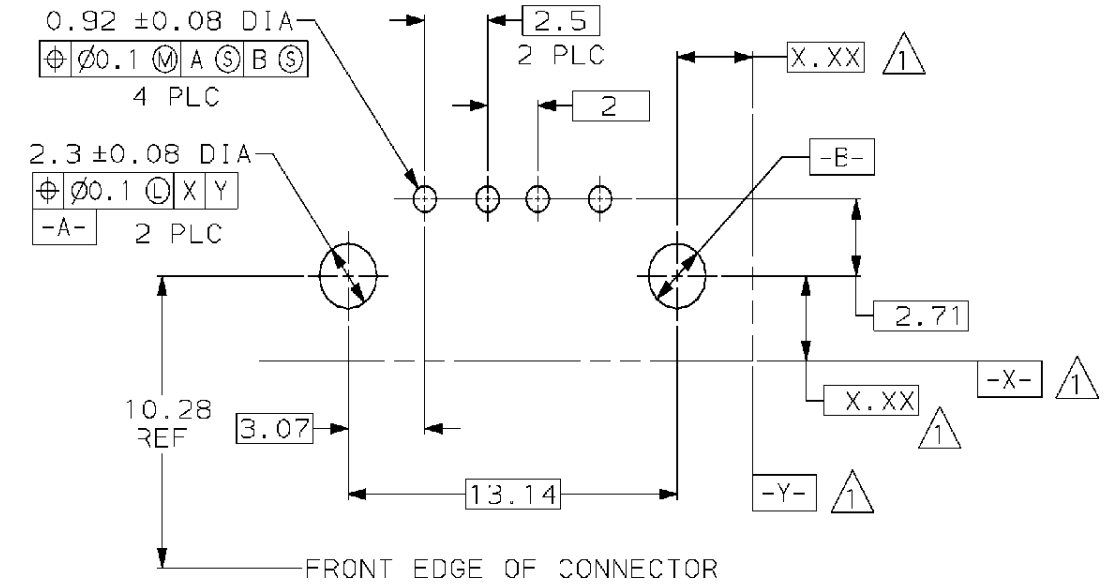
Figure 6-4. Connector Mating Features (Series A)

6.3.2.4 Receptacle PWB Foot Print (Series A)



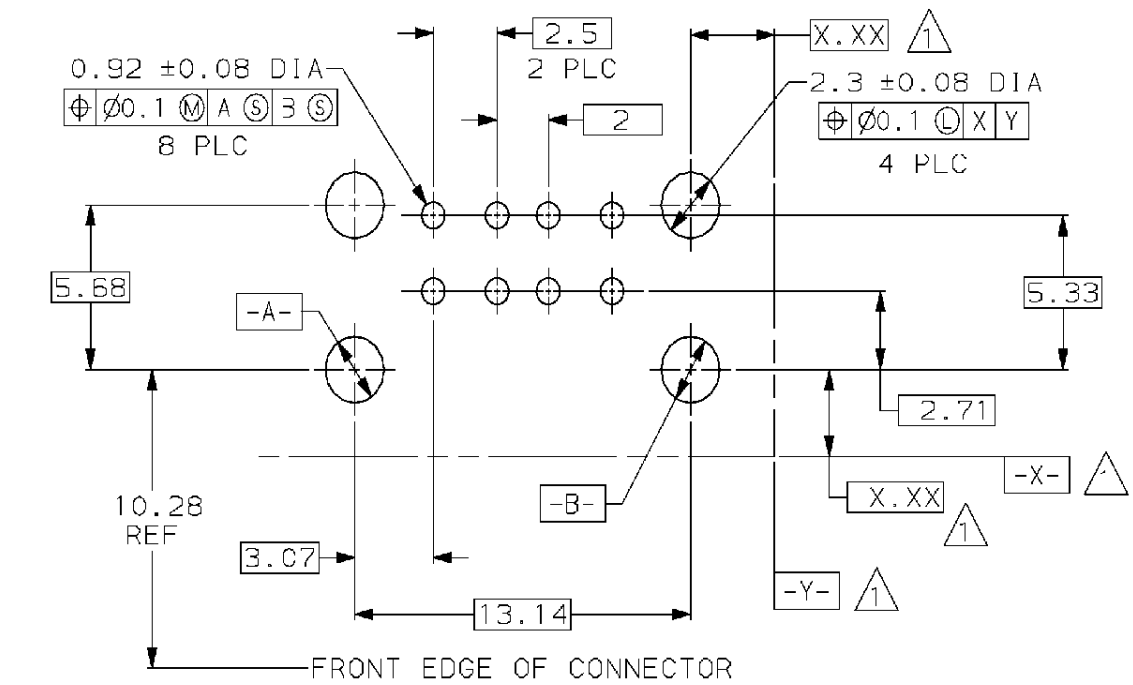
1. DATUM AND BASIC DIMENSIONS ESTABLISHED BY CUSTOMER.
2. RECOMMENDED PC BOARD THICKNESS OF 1.57
3. DRAWING PER ANSI Y14.5M-1982.

Figure 6-5. PWB Footprint for Receptacle, SMT (Series A)



1. DATUM AND BASIC DIMENSIONS ESTABLISHED BY CUSTOMER.
2. RECOMMENDED PC BOARD THICKNESS OF 1.57
3. DRAWING PER ANSI Y14.5M-1982.

Figure 6-6. PWB Footprint for Receptacle, Throughhole (Series A)



1. DATUM AND BASIC DIMENSIONS ESTABLISHED BY CUSTOMER.
2. RECOMMENDED PC BOARD THICKNESS OF 1.57
3. DRAWING PER ANSI Y14.5M-1982.

Figure 6-7. PWB Footprint for Receptacle, Stacked Right Angle (Series A)

6.3.3 Connector (Series B)

6.3.3.1 Plug (Series B)

The USB (Series B) plug is a four position plug with shielded housing compatible with the cabling as described in Section 6.3. The following guidelines ensure intermateability. The recommended color is frost white for the overmold. The internal features can be frost white or equivalent.

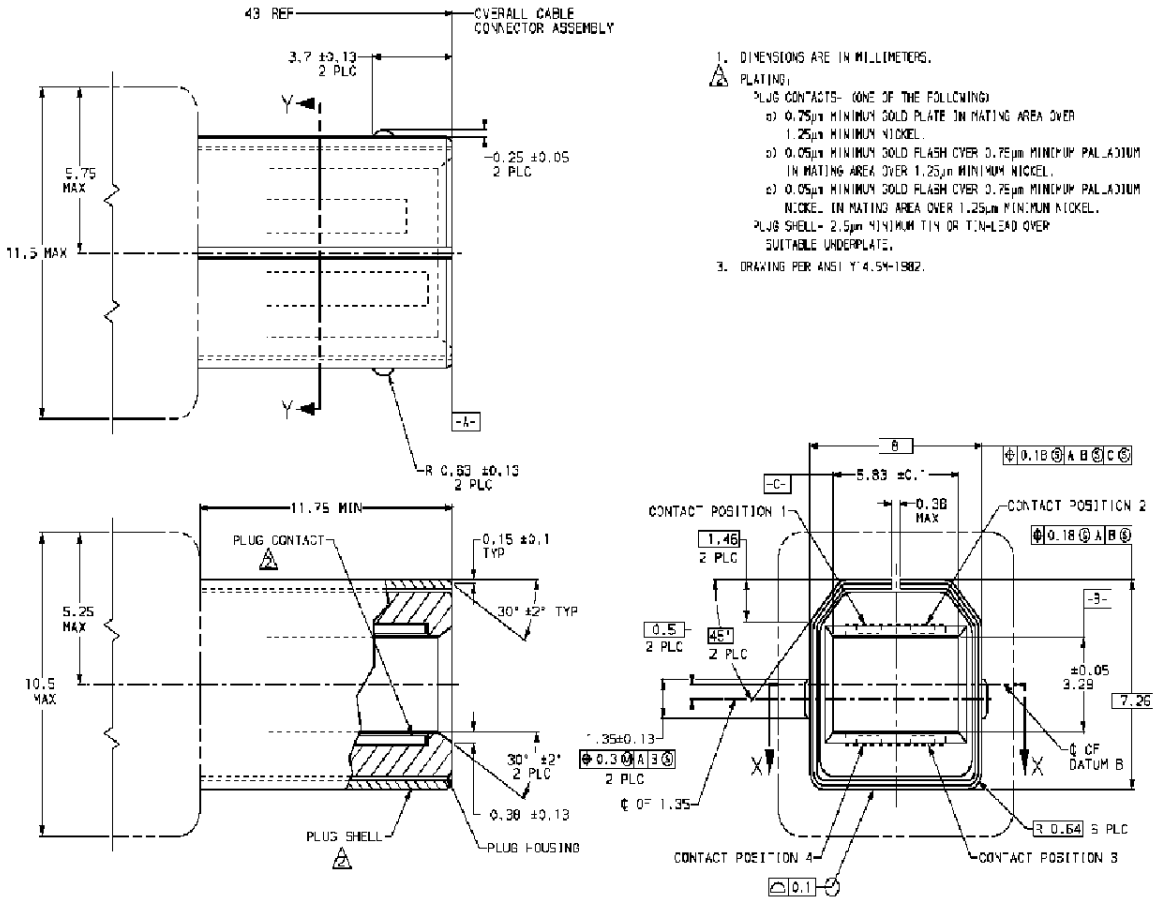


Figure 6-8. Plug Connector (Series B)

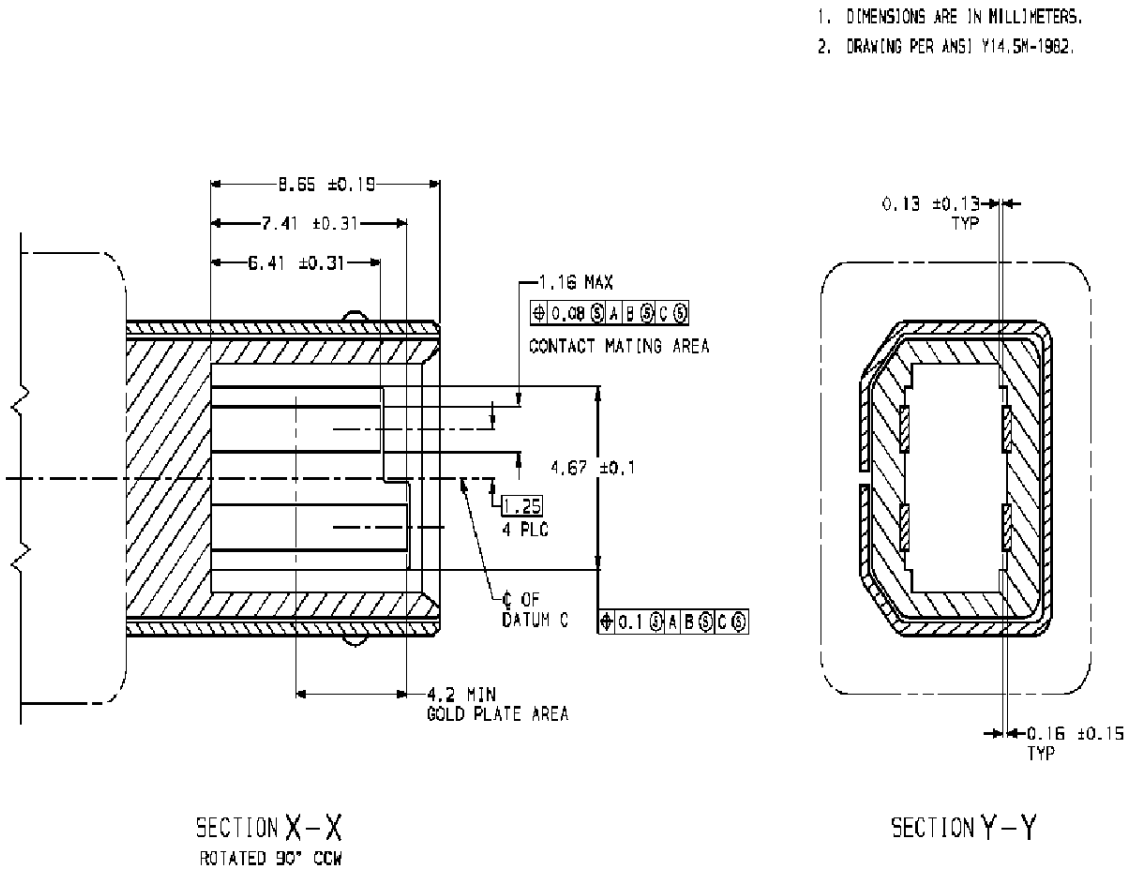


Figure 6-9. Plug Contact Detail (Series B)

6.3.3.2 Receptacle (Series B)

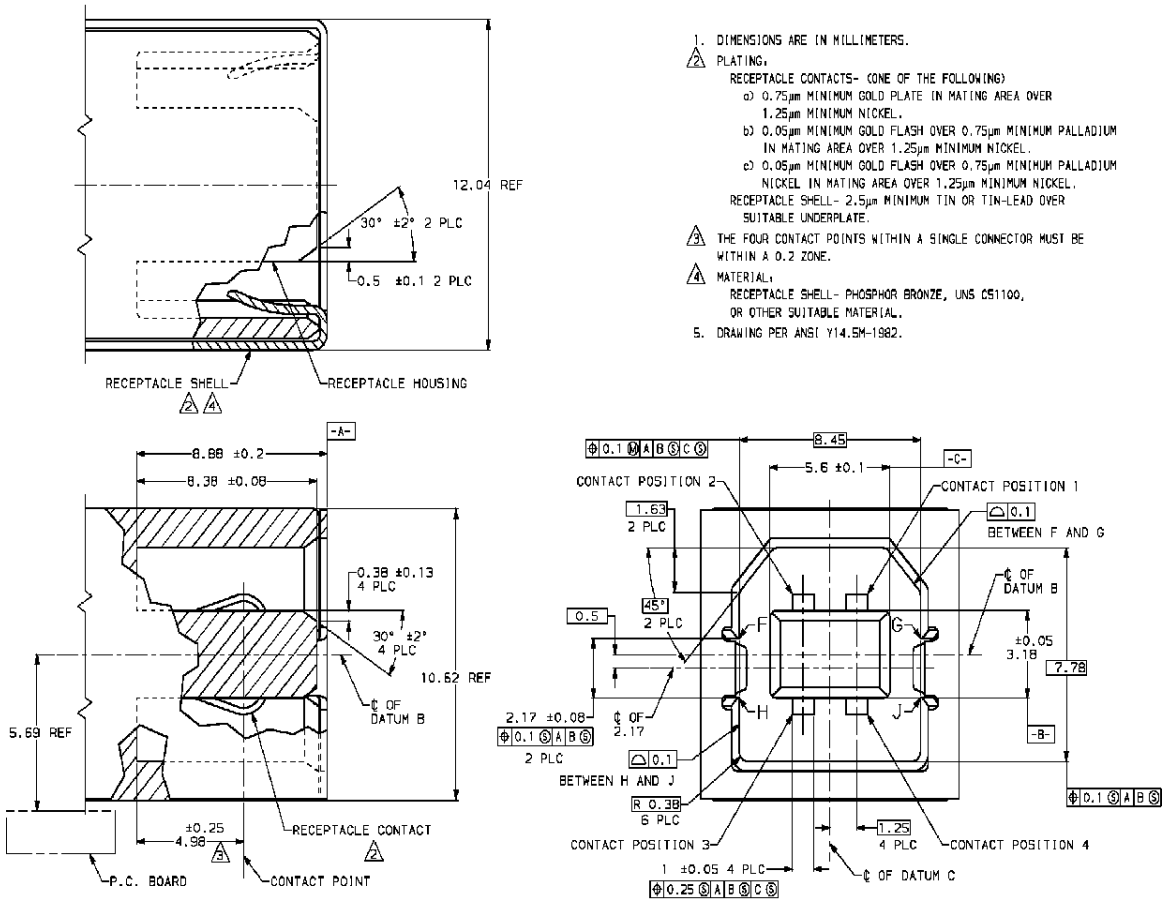


Figure 6-10. Receptacle (Series B)

6.3.3.3 Connector Mating Features (Series B)

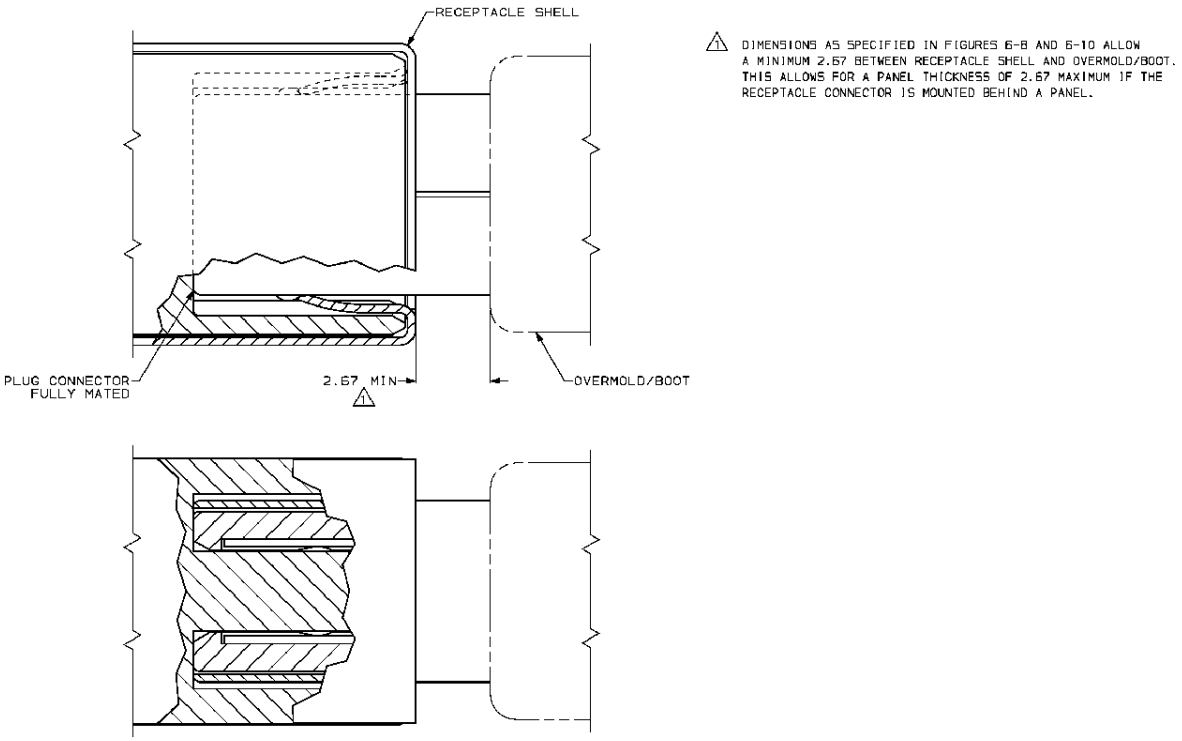
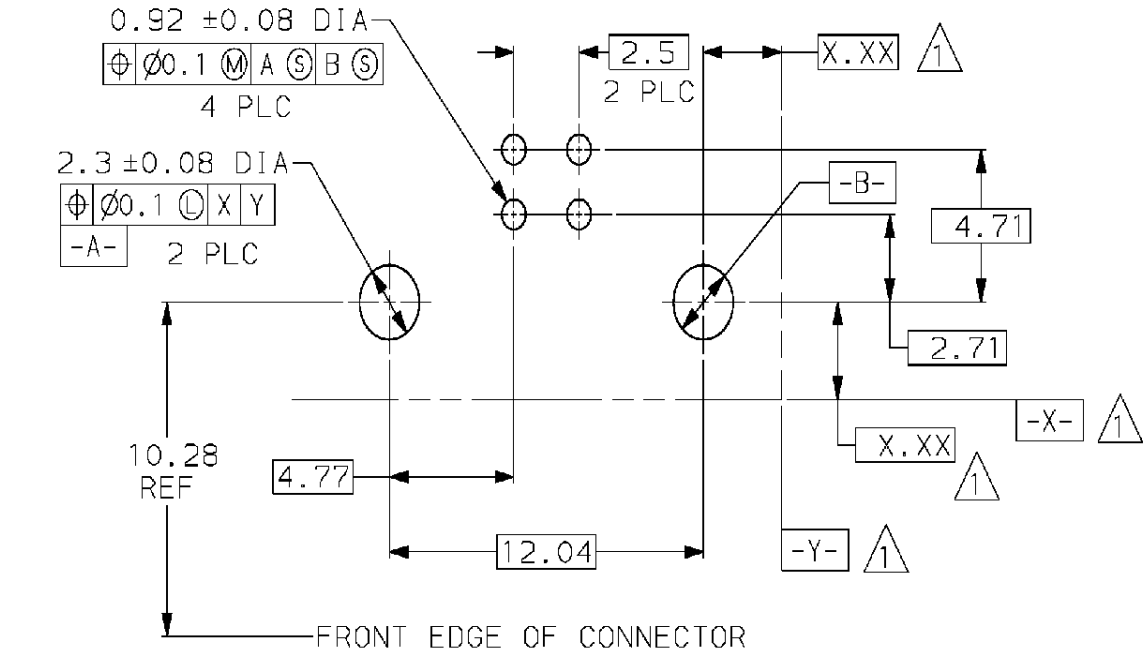


Figure 6-11. Connector Mating Features (Series B)

6.3.3.4 Receptacle PWB Foot Print (Series B)



1. DATUM AND BASIC DIMENSIONS ESTABLISHED BY CUSTOMER.
2. RECOMMENDED PC BOARD THICKNESS OF 1.57
3. DRAWING PER ANSI Y14.5M-1982.

Figure 6-12. PWB Footprint for Receptacle, Throughhole (Series B)

6.3.4 Serial Bus Icon

The USB icon, shown in Figure 6-13, should be molded into the connector and also placed on the product for ease of identifying the USB port. It is recommended that the icon on the product and the one on the plug be adjacent to each other when the plug and receptacle are mated. This icon can be used for both series A and B connector schemes. On the plug, there should be a .635 mm rectangular recessed area around the icon such that there is a perceptible feel of the icon.

Figure 6-13. USB Icon Artwork

6.3.5 Plug/Receptacle Mechanical and Electrical Requirements

6.3.5.1 Contact Numbering (Series A and B)

Table 6-6. Contact Numbering

Contact Number	Signal Name	Comment
1	VCC	Cable power
2	- Data	
3	+ Data	
4	Ground	Cable ground

6.3.5.2 Ratings

Voltage: 30 Vac (rms).

Current: 1 A maximum per contact not to exceed 30 °C T-Rise.

Temperature:-40 °C to 60 °C storage; 0 °C to 40 °C operating.

6.3.5.3 Performance and Test Description

Product is designed to meet electrical, mechanical, and environmental performance requirements specified in Table 6-7. Unless otherwise specified, all tests shall be performed at ambient environmental conditions. Cable construction and/or part number used for testing must be included with test report.

Table 6-7. Test Requirements and Procedures Summary

Test Description	Requirement	Procedure
Examination of product	Meets requirements of Section 6.3	Visual, dimensional, and functional compliance
ELECTRICAL		
Termination resistance	30 mΩ maximum	EIA 364-23 Subject mated contacts assembled in housing to 20 mV maximum open circuit at 100 mA maximum. See Figure 6-14.
Insulation resistance	1000 MΩ minimum	EIA 364-21 Test between adjacent contacts of mated and unmated connector assemblies
Dielectric withstanding voltage	750 Vac at sea level	EIA 364-20 Test between adjacent contacts of mated and unmated connector assemblies
Capacitance	2 pF maximum	EIA 364-30 Test between adjacent circuits of unmated connectors at 1 kHz
MECHANICAL		
Vibration, random	No discontinuities of 1 μs or longer duration. See Note (a)	EIA 364-28 Condition V Test letter A. Subject mated connectors to 5.35 G's rms. Fifteen minutes in each of three mutually perpendicular planes. See Figure 6-15.
Physical shock	No discontinuities of 1 μs or longer duration. See Note (a)	EIA 364-27 Condition H. Subject mated connectors to 30 G's half-sine shock pulses of 11 ms duration. Three shocks in each direction applied along three mutually perpendicular planes, 18 total shocks. See Figure 6-15 for the test setup.
Durability	See Note (a)	EIA 364-09 Mate and unmate connector assemblies for 1500 cycles at maximum rate of 200 cycles per hour

Table 6-7. Test Requirements and Procedures Summary (Continued)

Test Description	Requirement	Procedure
Mating force	35 Newtons maximum	EIA 364-13 Measure force necessary to mate connector assemblies at maximum rate of 12.5 mm per minute.
Unmating force	10 Newtons minimum	EIA 364-13 Measure force necessary to unmate connector assemblies at maximum rate of 12.5 mm per minute.
Cable Retention	Cable shall not dislodge from cable crimp	Apply axial load of 25 Newtons to the cable.
ENVIRONMENTAL		
Thermal shock	See Note	EIA 364-32 Test Condition I. Subject mated connectors to five cycles between -55 °C and 85 °C.
Humidity	See Note	EIA-364-31 Method II Test Condition A. Subject mated connectors to 96 hours at 40 °C with 90 to 95% RH.
Temperature life	See Note	EIA-364-17 Test Condition 3 Method A. Subject mated connectors to temperature life at 85 °C for 250 hours.

Note:

Shall meet visual requirements, show no physical damage, and shall meet requirements of additional tests as specified in Test Sequence in Table 6-8.

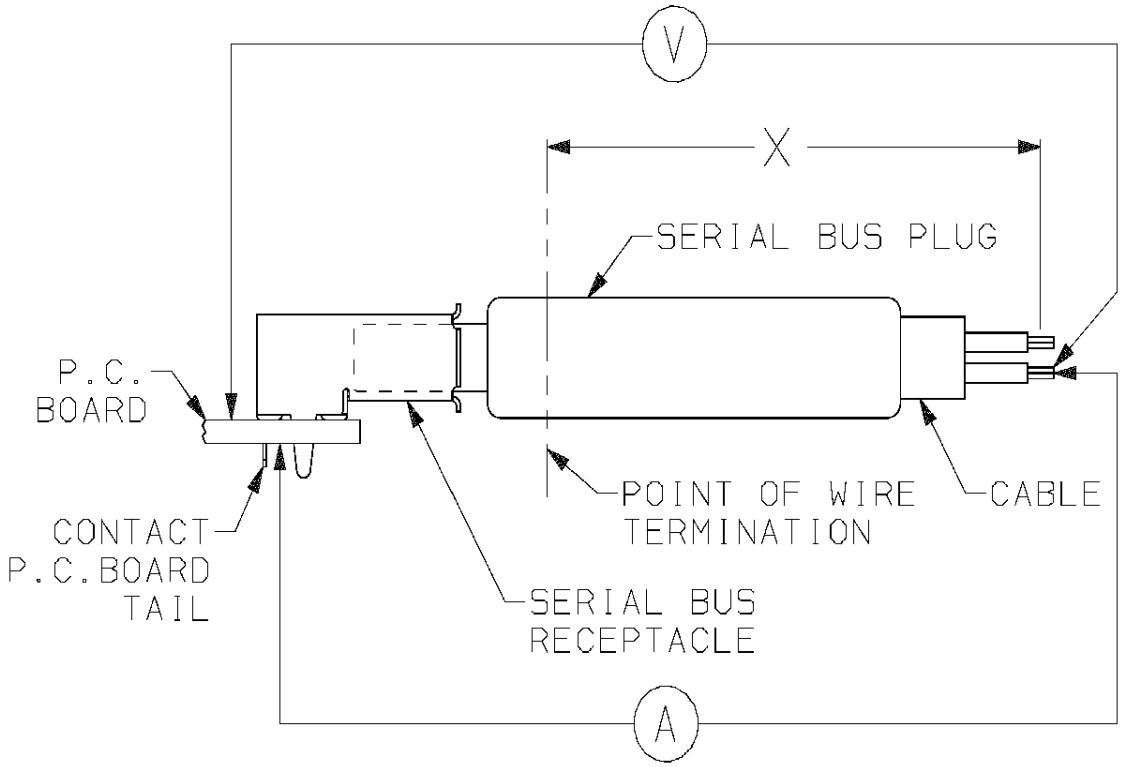
Table 6-8. Product Qualification Test Sequence

Test or Examination	Test Group (a)		
	1	2	3
	Test Sequence (b)		
Examination of product	1,10	1,5	1,9
Termination resistance	3,7	2,4	
Insulation resistance			3,7
Dielectric withstanding voltage			4,8
Capacitance			2
Vibration	5		
Physical shock	6		
Durability	4		
Mating force	2		
Unmating force	8		
Thermal shock			5
Humidity			6
Cable Retention	9		
Temperature life		3(c)	

Notes:
(a) Refer to Section 6.3.4.4.
(b) Numbers indicate sequence in which tests are performed.
(c) Precondition samples with 10 cycles durability.

6.3.5.4 Sample Selection

Samples shall be prepared in accordance with applicable manufacturers' instructions and shall be selected at random from current production. Test groups 1, 2, and 3 shall consist of a minimum of eight connectors. A minimum of 30 contacts shall be selected and identified. Unless otherwise specified, these contacts shall be used for all measurements.



1. RESISTANCE DUE TO X INCHES OF WIRE IS TO BE REMOVED FROM ALL READINGS.

Figure 6-14. Termination Resistance Measurement Points

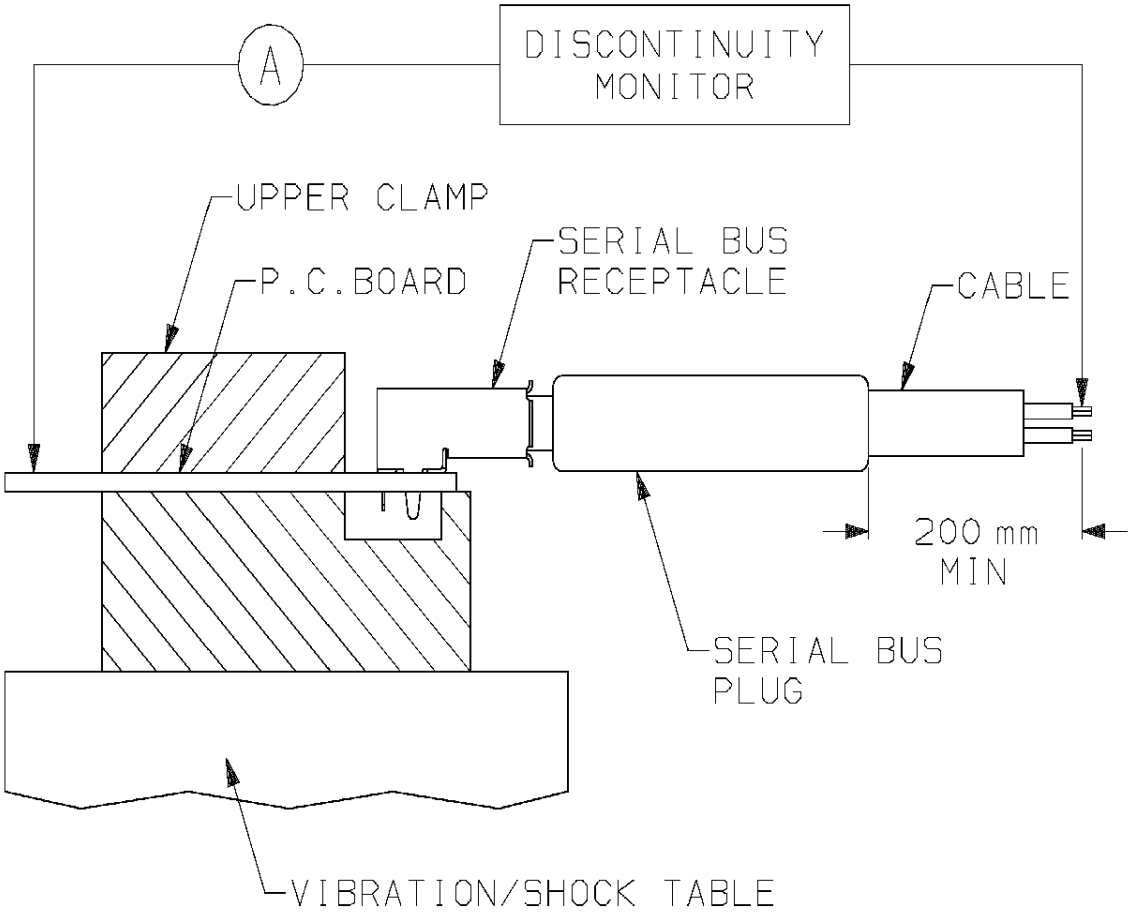


Figure 6-15. Vibration and Physical Shock Mounting Fixture

6.3.5.5 Additional Requirements

Flammability: Plastic material used in the construction of this item, shall be rated 94V-0, per UL-STD-94.

Marking: USB icon per Figure 6-13 on plug. Recommended that OEM's add an icon near the receptacle on end product where possible or practical.

Qualification: All suppliers when requested must be able to supply appropriate documentation to show conformance to the requirements of this chapter.

6.4 Cable Voltage Drop Requirements

The USB physical layer specification requires that the maximum power distribution voltage drop between two hubs or between hubs and functions should be 350 mV max. The table below lists the nominal lengths of power distribution cabling for each gauge of conductor. The following is a formula for the voltage drop to an unpowered hub of 350 mV.

$$V_{unpowered\_hub} = V_{switch} + 4 * V_{connector} + 2 * V_{cable}$$

Where: $V_{switch} = I_{max}$ * (board resistance and FET resistance) = 100 mV (max. by definition)

$V_{connector} = I_{max}$ * 30 mΩ (connector resistance) = 15 mV

$V_{cable} = I_{max}$ * cable resistance

I_{max} = 500 mA

With the above information, V_{cable} = 95 mV, assuming two connectors are used in the cable assembly,

For a 95 mV drop using copper wire at 20 °C, Table 6-9 lists cable lengths with a current of 500 mA. Refer to Figure 6-16.

Table 6-9. Cable Lengths vs. Gauge

Gauge	Resistance	Length (Max.)
28	0.232 Ω/m	.81 m
26	0.145 Ω/m	1.31 m
24	0.091 Ω/m	2.08 m
22	0.057 Ω/m	3.33 m
20	0.036 Ω/m	5.00 m

Note: This table does not include additional temperature effects (approximately 10%).

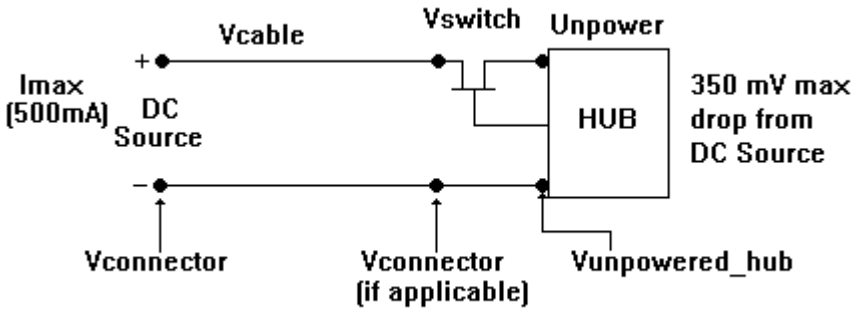


Figure 6-16. Cable and Connector Voltage Drop Distribution

It is recommended that each individual implementer verify proper DC voltage drop. If the implementer uses different materials than above, then it is responsible for proper DC voltage at the unpowered hub.

To meet the 5 meter maximum length requirement of this specification, a wire range of 20 AWG to 28 AWG is needed for the DC power distribution conductors.

Note: For typical functions that do not require 500 mA, smaller wire gauges can be used as appropriate per the voltage drop requirements.

6.5 Propagation Delay

If the cabling you have selected cannot meet the requirements of Section 6.3.1.2, then use Table 6-10 to limit the cable length for fully rated channels.

Table 6-10. Propagation Delay vs. Cable Length

Cable Propagation Delay Specification	Maximum Cable Length
9.0 ns/m	3.3 m
8.0 ns/m	3.7 m
7.0 ns/m	4.3 m
6.5 ns/m	4.6 m

Note: The implementation must use the shortest cable that meets the requirements of Section 6.3.1.2, Section 6.4, and Section 6.5.

6.6 Grounding

The shield must be terminated to the connector plug for completed assemblies. At the host end, the shield, DC power, and chassis ground should be bonded together. The complete bus should have only one DC ground point at the host end. All other devices should not connect the shield or DC return to chassis ground. This prevents circulating low frequency currents. However, AC coupling is permitted for EMI compliance. The coupling impedance must be less than 250 kΩ at 60 Hz and not greater than 15 Ω between 3 and 30 MHz. The dielectric voltage rating of the capacitor must be 250 Vac (rms).

6.7 Regulatory Information

Recommendation and guidelines for the installation of this cabling per applicable local regulations are the responsibility of the OEM. It is recommended that guidelines such as EIA CB8-1981[4] and ANSI/NFPA 70-1984 as well as local codes and regulations be followed.