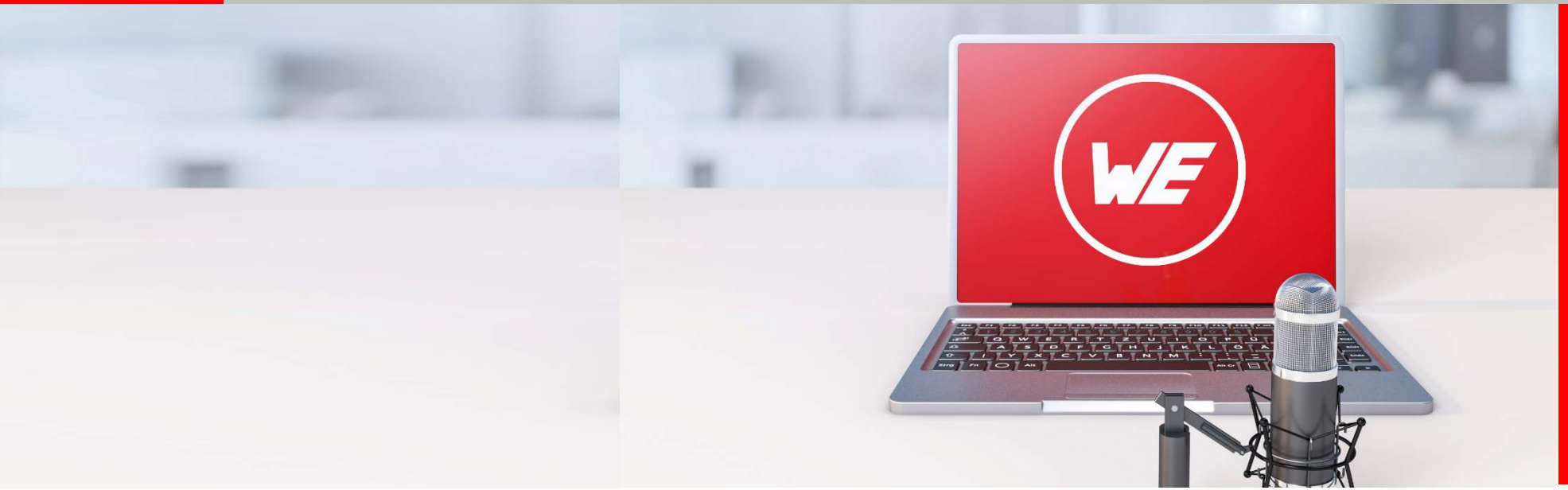
USB 3.1 – a connector for multiple applications

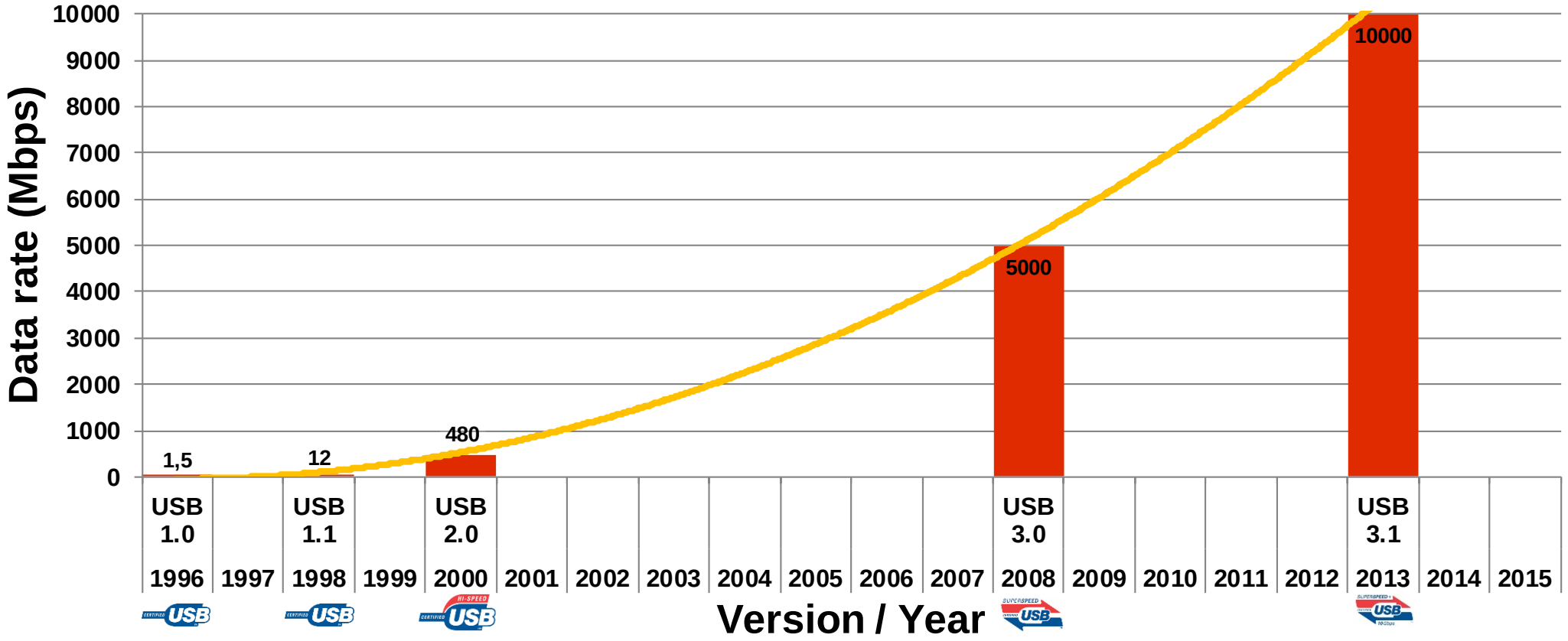


Würth Elektronik
Technical Academy
Fabian Altenbrunn

Table of Content

A little bit of history – USB Versions

- USB = Universal Serial Bus



A little bit of history – From 2.0…

- **Year/Version** — **USB 2.0 – 2000**
- **A**

- **B**

- **Mini**

- **Micro**

- **Data rate** — **480 Mbps**
- **Power** — **500mA / 5V**

A little bit of history – …to USB 3.0 …

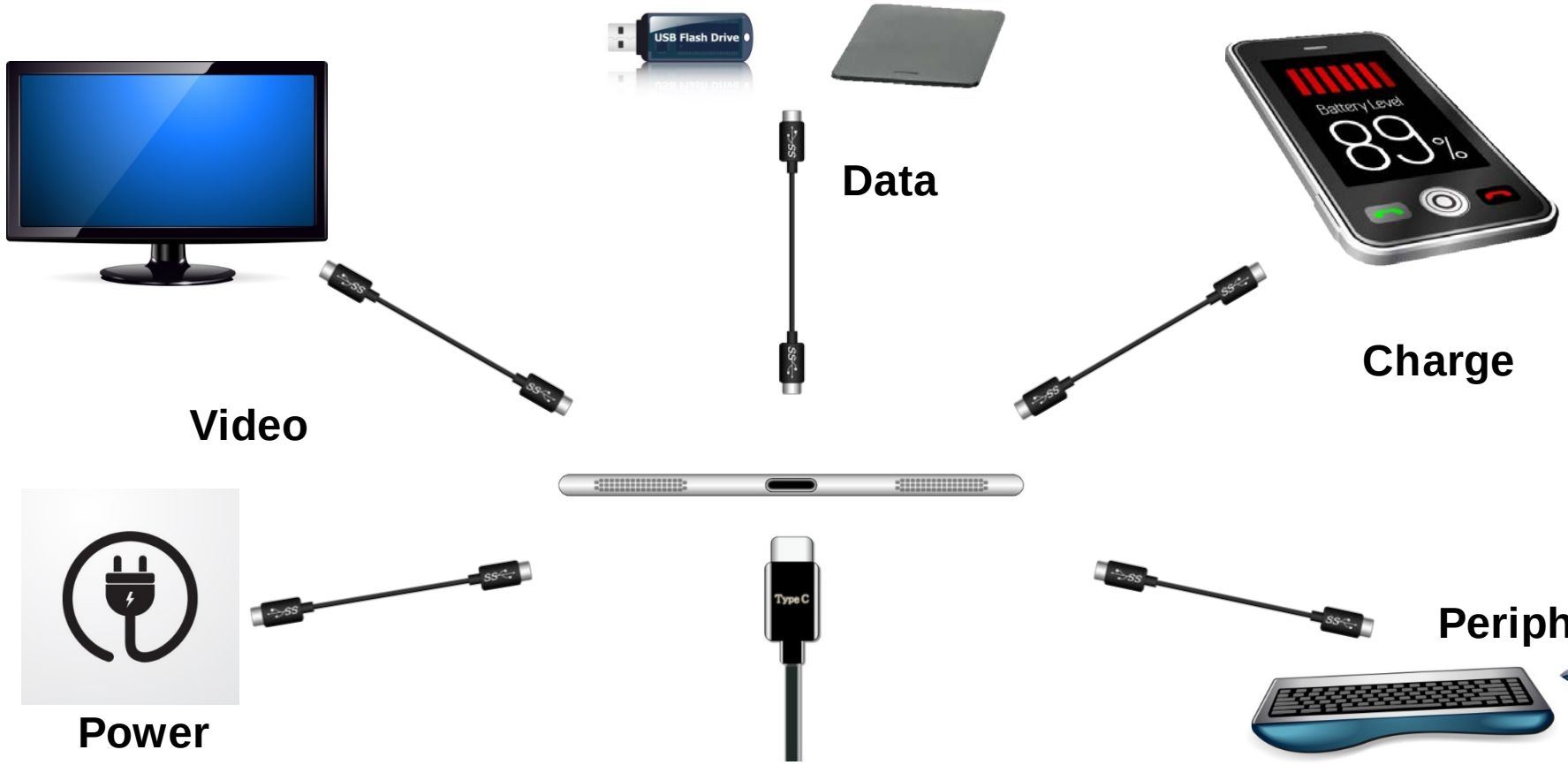
	USB 2.0 – 2000	USB 3.0 – 2008
Year/Version		
A		
B		
Mini		
Micro		
Data rate	480 Mbps	5000 Mbps
Power	500mA / 5V	900mA / 5V

A little bit of history – …to USB 3.1

	USB 2.0 – 2000	USB 3.0 – 2008	USB 3.1 – 2013
Year/Version			
A			
B			
Mini		✗	✗
Micro			
C			
Data rate	480 Mbps	5000 Mbps	10000 Mbps
Power	500mA / 5V	900mA / 5V	5A / 20V

USB Type-C for All Connectivity

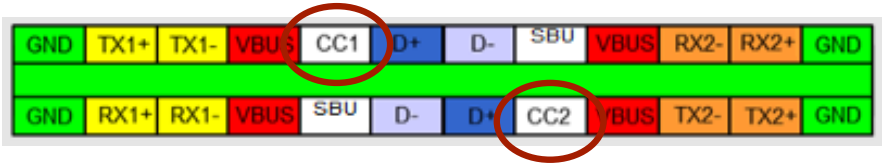
First connector supporting power in both ways



Configuration Channel

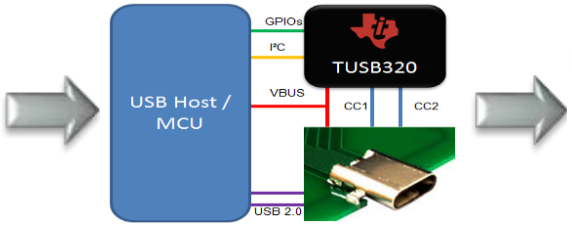
Providing the flexibility of Type-C

- **Functionally the Configuration Channel (CC) is used to serve the following purposes:**
- **Detect connect of USB ports,**
- **Resolve cable orientation and twist connections to establish USB data bus routing**
- **Establish DFP (sink) and UFP (source) roles between two connected ports**
- **Discover and configure power: USB Type-C current modes or USB Power Delivery**
- **Discovery and configuration of optional Alternate and Accessory modes**

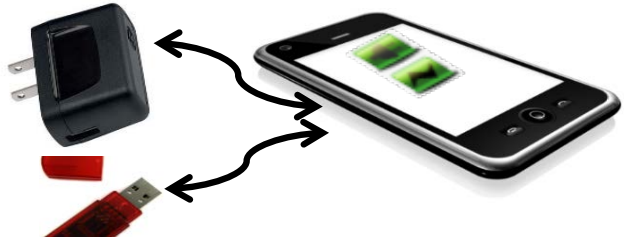


Typical CC flow for DFP to UFP configuration:

Detect valid connection



Establish USB power method



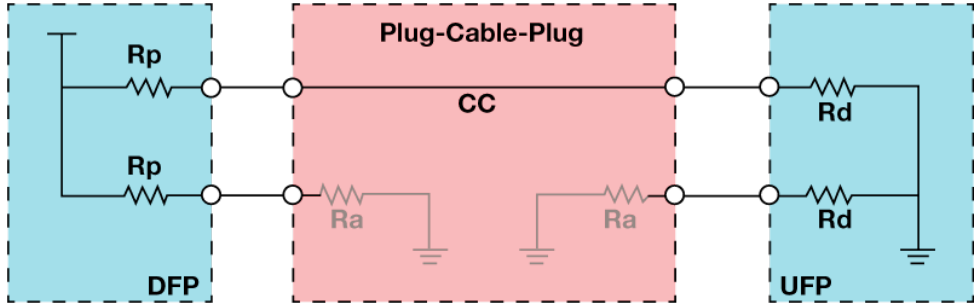
Configure as a DFP or UFP

USB Power Delivery (PD)

Extends USB Type-C capability – more power, Alt Mode, flexibility

What is USB PD?

- USB PD is a single wire communication protocol over CC lines
- A negotiation method to extend USB Type-C interface capability for more power, alt mode and flexibility
- Both ends must support certain extended feature(s) for an successful PD contract



Why USB PD?

- **Extended Power**
  - USB Type-C provides up to 15W (5V/3A) power through VBUS with simple resistor divider network
  - USB PD must be used to extend the power delivery beyond 5V/3A
  - PD can negotiate power up to 100W (20V/5A) – faster charging
  - PD can also negotiate >1W of VCONN power up to 6W
- **Alternate Mode**
  - USB PD must be used for any Alt mode
  - Through PD Alt Mode negotiation USB Type-C interface can be used for non-USB use cases
  - SS differential pairs and SBU lines are available for Alt Mode use
  - USB2 must be preserved when in Alt Mode
- **Role Flexibility**
  - By default Host/DFP is power source and Device/UFP is power sink
  - USB PD must be used to decouple the data/power roles

USB Type-C Power Modes

Flexible and Modular Power Delivery Methods

USB Type-C can be used to deliver power via a number of different protocols:

Precedence	Mode of Operation	Nominal Voltage	Maximum Current
Highest	USB PD	Up to 20 V	Up to 5 A
	USB Type-C current @ 3A	5 V	3 A
	USB Type-C current @ 1.5A	5 V	1.5 A
	USB BC1.2	5 V	Up to 1.5 A
	USB 3.1		900 mA
Lowest	USB 2.0		500 mA

Port Power Roles

Following the introduction of USB PD, port power roles are now defined separately from the port data roles.

- **Provider:** device can only provide power
- **Consumer:** device can only receive power
- **Consumer provider:** the device can act as either a consumer or provider. This is only possible for devices that support USB PD

Capable of delivering up to 100W over one USB Type-C port!

USB PD Alternate Mode Negotiation

Scope Trace between a Dock and Notebook establishing a USB PD Contract

Electronically Marked Cable

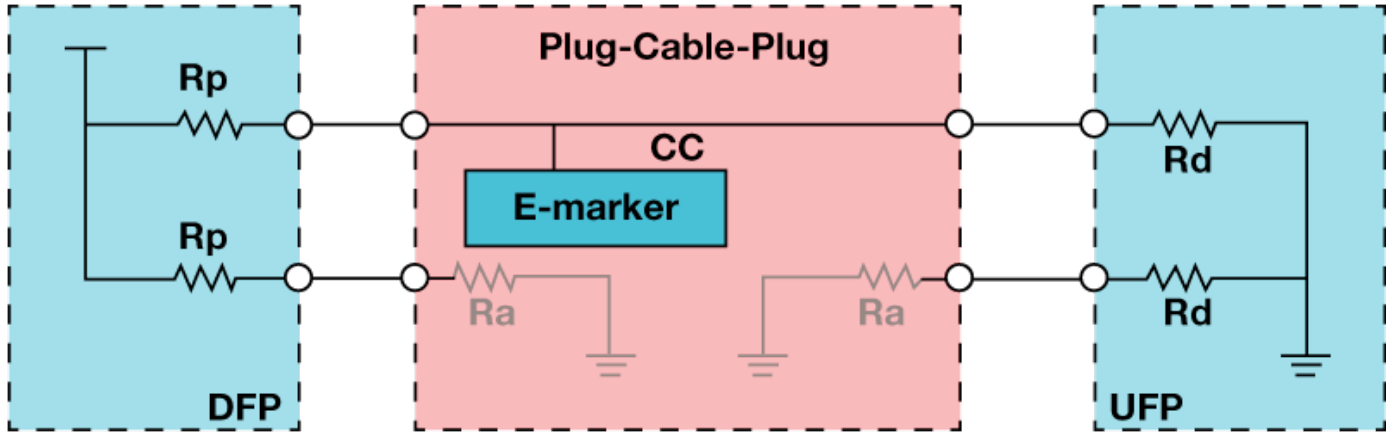
Making USB Type-C interface ubiquitous

What is E-marker ?

- Simple USB PD controller inside a cable
- Responds to USB PD commands from DFP/source
- Provide cable characteristics such as current carrying capability, performance, vendor identification etc.
- Typically powered by VCONN

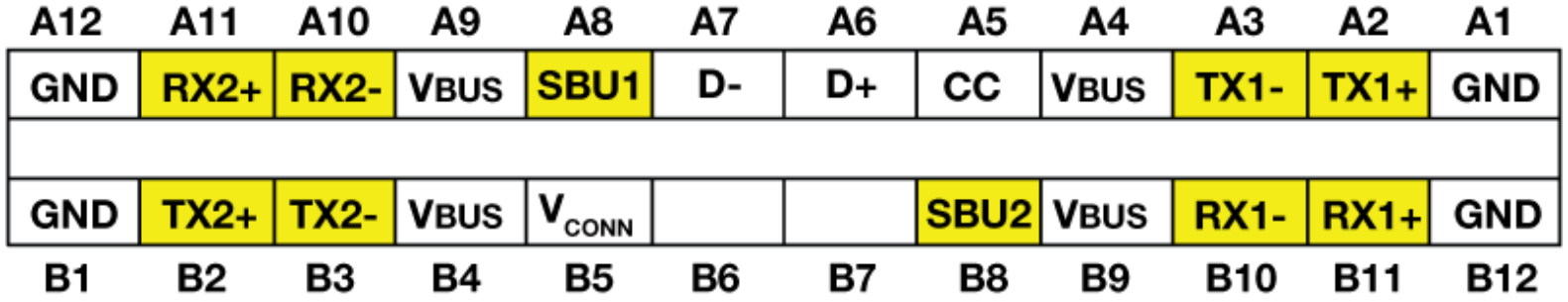
When E-marker is needed?

- USB Type-C cable supporting more than 3A current
- USB Type-C full featured cable with USB 3.1 or alternate mode signaling



USB Type-C Alternate Mode

Extends beyond USB data



What is Alt Mode?

- Alternate use of USB Type-C interface for non-USB functions
- USB2 must be preserved
- USB PD must be used to negotiate an alternate mode
- Definition: Operation defined by a vendor or standards organization that is associated with a SVID assigned by the USB-IF. Entry and exit into and from an Alternate Mode is controlled by the USB PD Structured VDM Enter Mode and Exit Mode commands

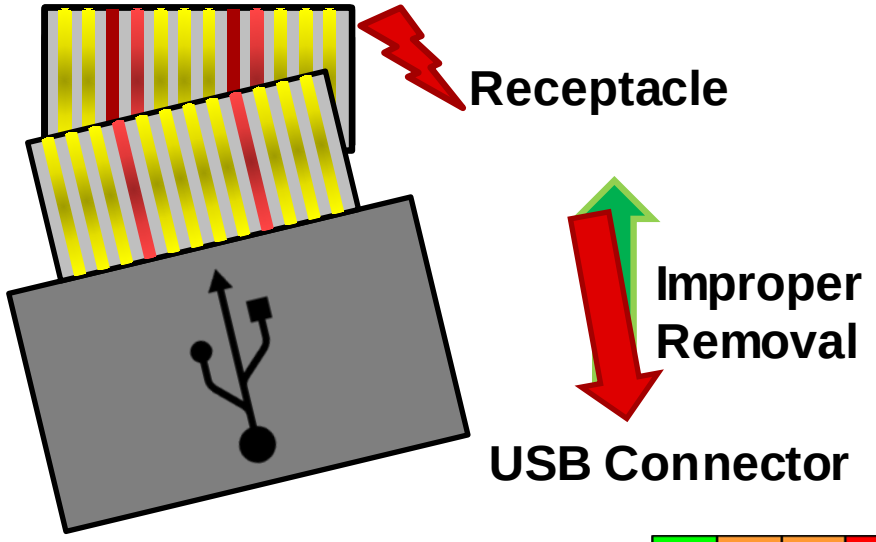
Example of Alt Modes

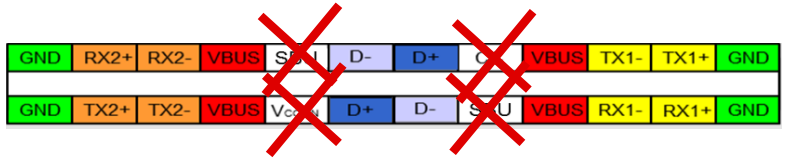
- DisplayPort (DP)
- Thunderbolt
- PCI Express
- MHL
- HDMI (for dongle/adapters)

Can you create your own alternate mode?

- Option 1: create an official alternate mode approved by USB-IF (will be given a SID, standard ID)
- Option 2: Get a VID from USB-IF and create a non-official alternate mode (you must own both sides of the system for this to work)

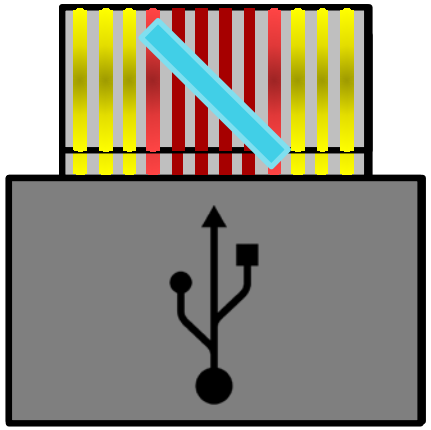
Potential Failure: Mechanical Twist



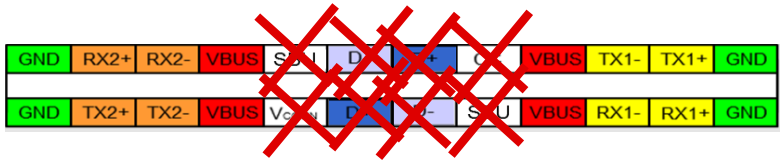


If the USB plug is removed at an angle, it might cause the VBUS pin to short with SBU or CC/Vconn pins

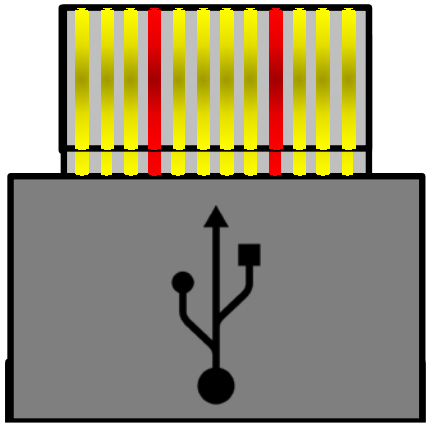
Potential Failure: Debris or Water



Any debris or water that is conductive could short the SBU and CC pins to the 20V Vbus lines

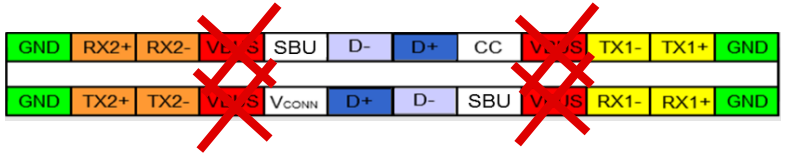


Potential Failure: Noncompliant Cables



- Even if your system is not using USB PD (you are charging at 5V, 500mA), there are non-compliant cables that output 20V without PD negotiation
- If your system is not designed to handle 20V, then there would be a failure
- In a survey of USB Type-C cables available on Amazon, 28% of cables were not compliant to USB-IF specification. (Google Engineer Benson Leung: 20/71 cables out of specification)

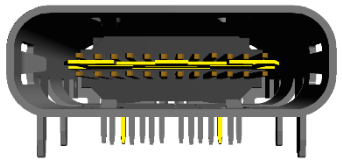
- Despite Amazon's ban there is still a risk of end user's purchasing non-compliant USB Type-C cables from cable manufacturers



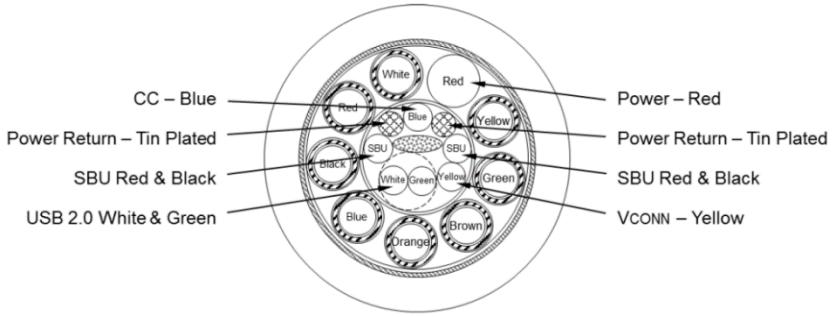
USB 3.1 Product Overview

Type C

USB Type-C Receptacle



USB Type-C Cable



OD = 4.8mm

Coax are SS pairs – specific pairs not defined in cable

USB Type-C Plug

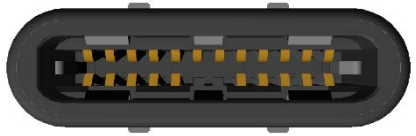


Figure 2-1 USB Type-C Receptacle Interface (Front View)

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1−	VBUS	CC1	D+	D−	SBU1	VBUS	RX2−	RX2+	GND
GND	RX1+	RX1−	VBUS	SBU2	D−	D+	CC2	VBUS	TX2−	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

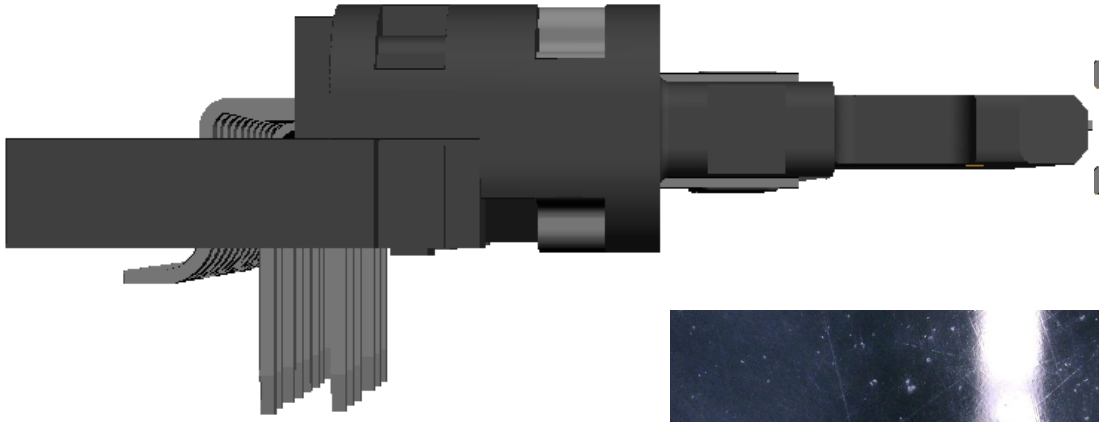
Figure 2-2 USB Full-Featured Type-C Plug Interface (Front View)

A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2−	VBUS	SBU1	D−	D+	CC	VBUS	TX1−	TX1+	GND
GND	TX2+	TX2−	VBUS	VCONN			SBU2	VBUS	RX1−	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

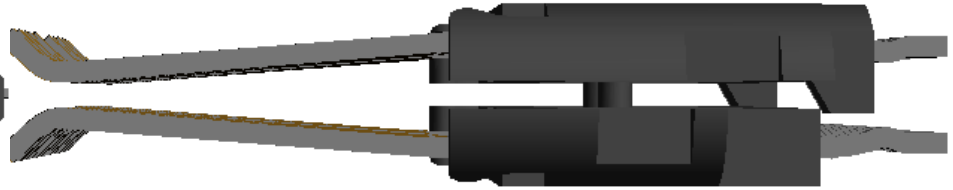
USB 3.1 Product Overview

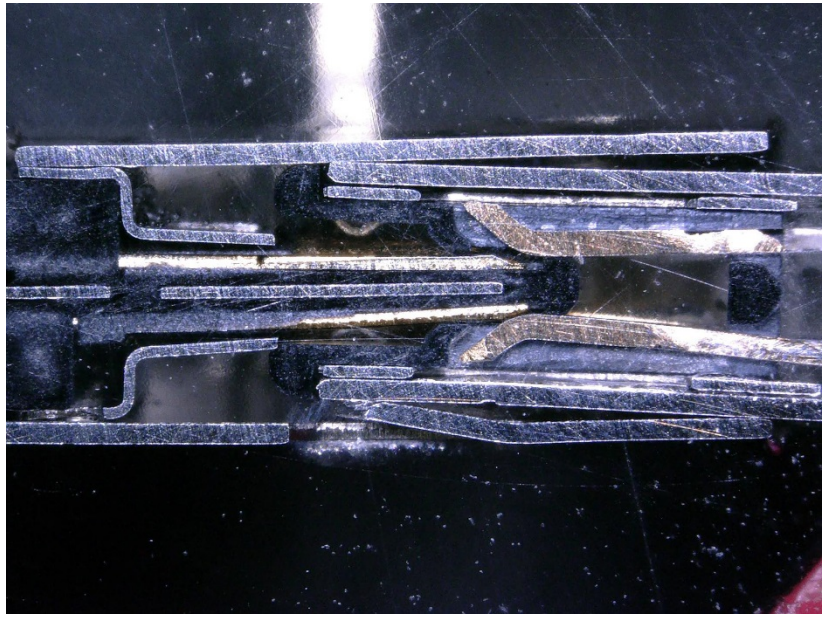
Type C Plug Design – 632 712 000 011

Receptacle – Side crossed view



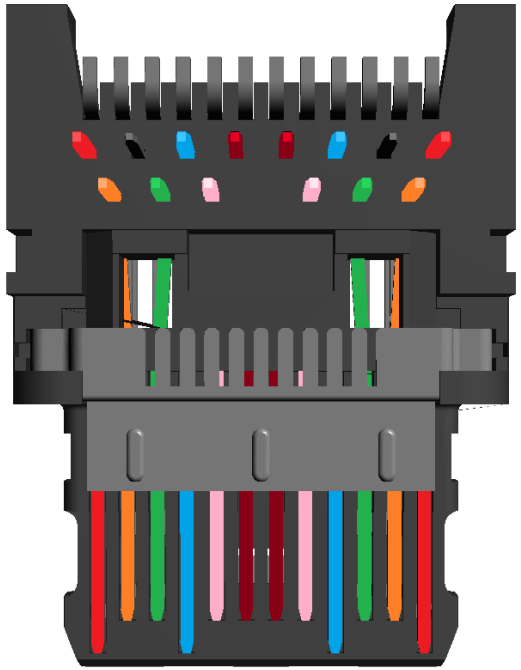
Plug – Side crossed view

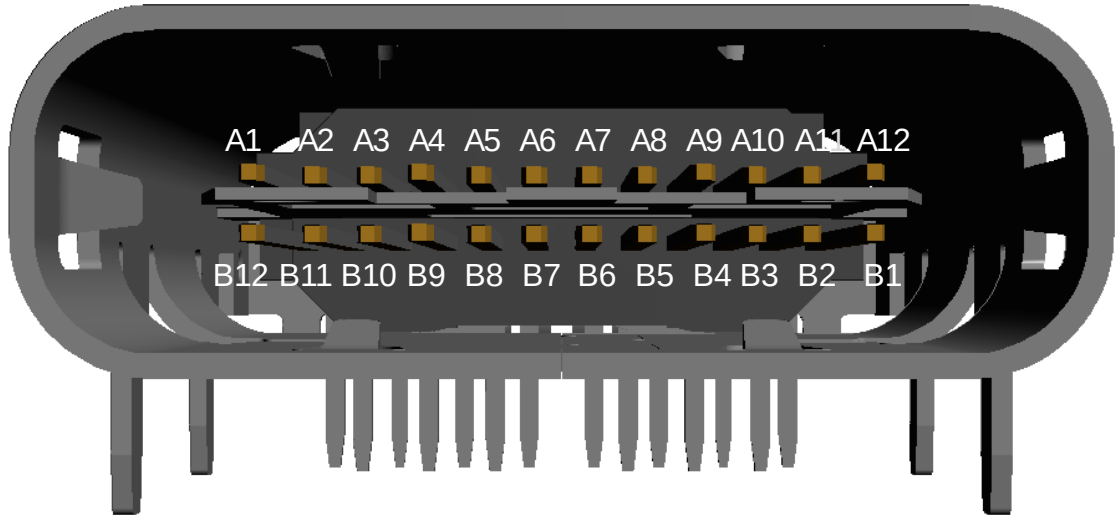




USB 3.1 Product Overview

Type C Receptacles Design – 632 723 x00 011





Bottom contacts (B): THT Pins
Top contacts (A) : SMT Pins

USB 2.0
USB 3.0
USB 3.1

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1-	V_{BUS}	CC1	D+	D-	SBU1	V_{BUS}	RX2-	RX2+	GND
GND	RX1+	RX1-	V_{BUS}	SBU2	D-	D+	CC2	V_{BUS}	TX2-	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

Type C Receptacles

- **Order code:**
  - 632 723 X00 011

X	PCB Thickness	Pin length
1	1.00 mm	1.50 mm
3	1.60 mm	1.90 mm

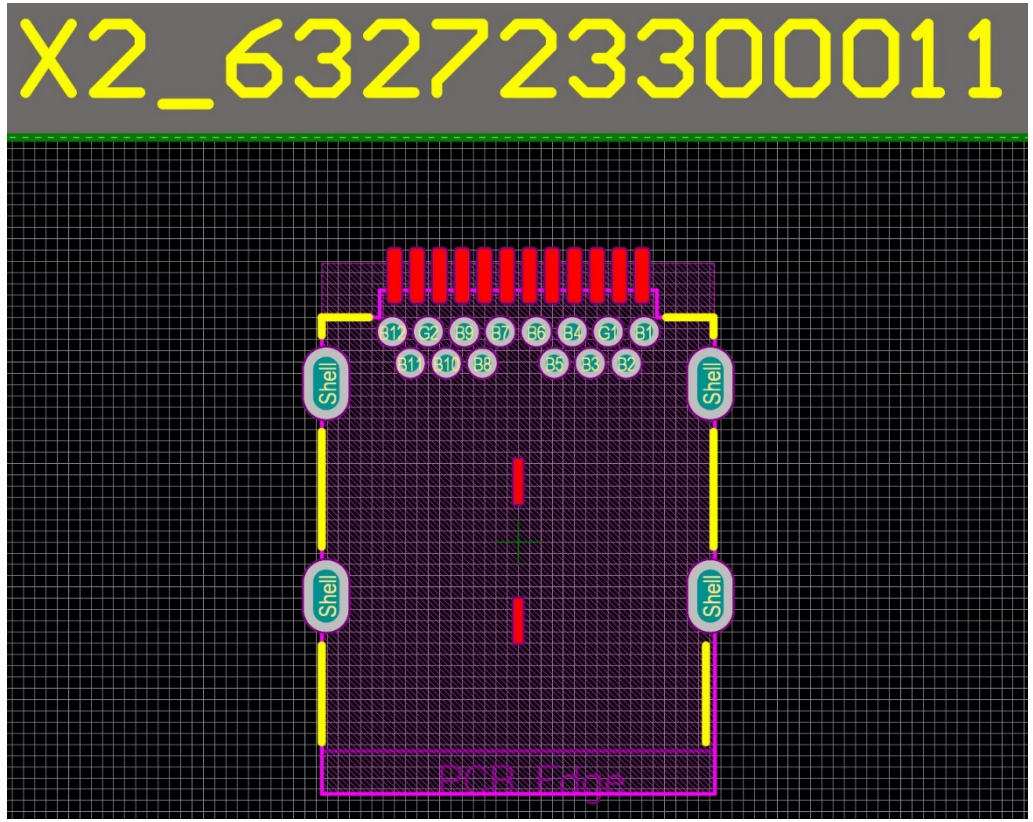
- **Product features:**
  - Material: LCP; black
  - Rated Current: 5 A
  - Rated Voltage: 5 VDC (12VDC/20VDC)
  - Durability: 10 000 cycles
  - Soldering: JEDEC lead free wave and reflow soldering

- **Order code:**
  - 632 723 X30 112

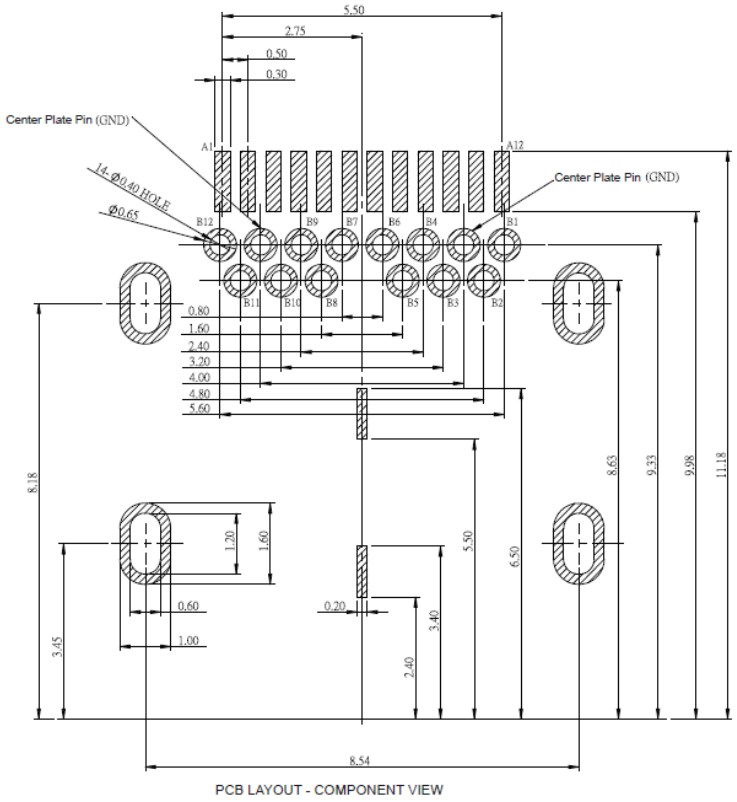
X	PCB Thickness	Pin length
1	1.60 mm	1.60 mm

Layout PCB – horizontal USB-C 3.1

Footprint



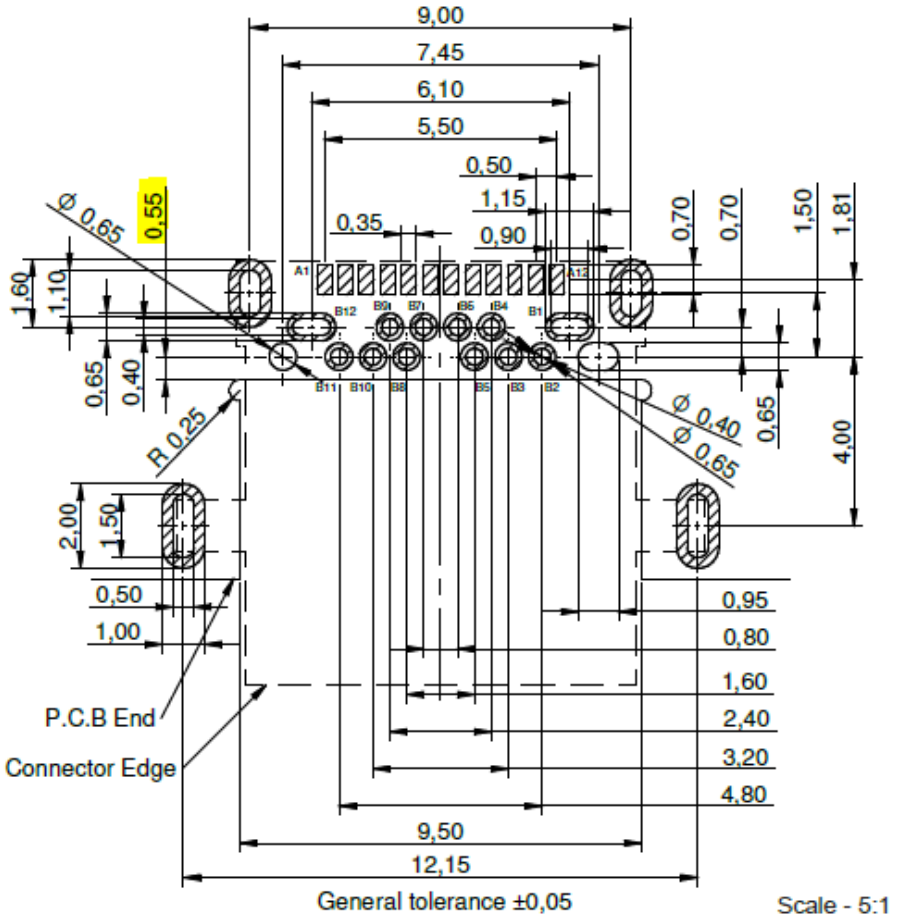
PCB Layout



Layout PCB – mid mount

Attention: Distance from center PIN to the upper edge of the milling track.

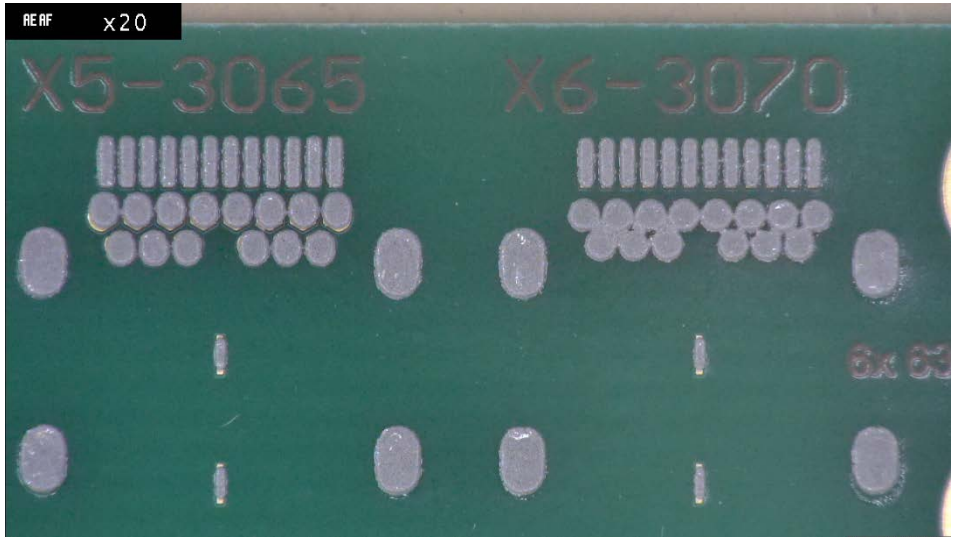
Distance center-pin to center-milling track is 0.55mm + the radius of the milling cutter (0.25mm) equal to **0.80mm.**



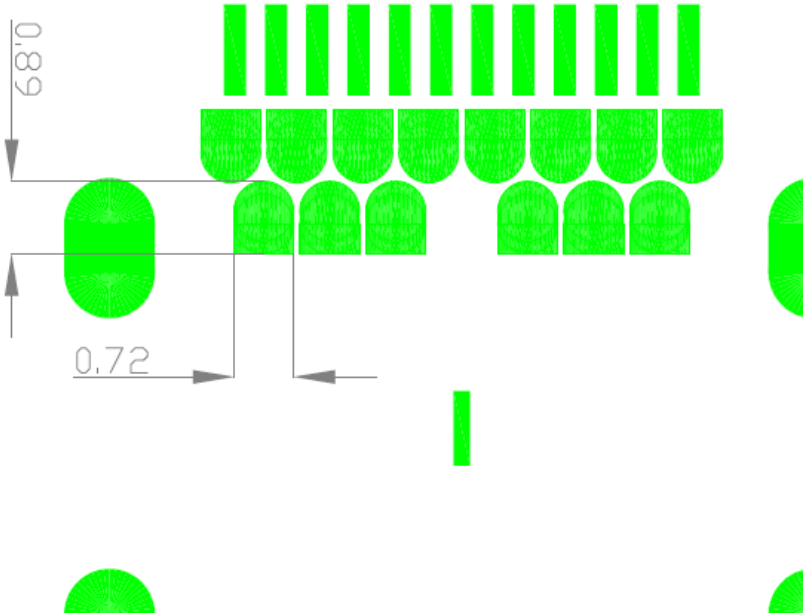
Pasteprinting & Stencil

left Solderpad diameter: 0,65mm

right Solderpad diameter: 0,70mm

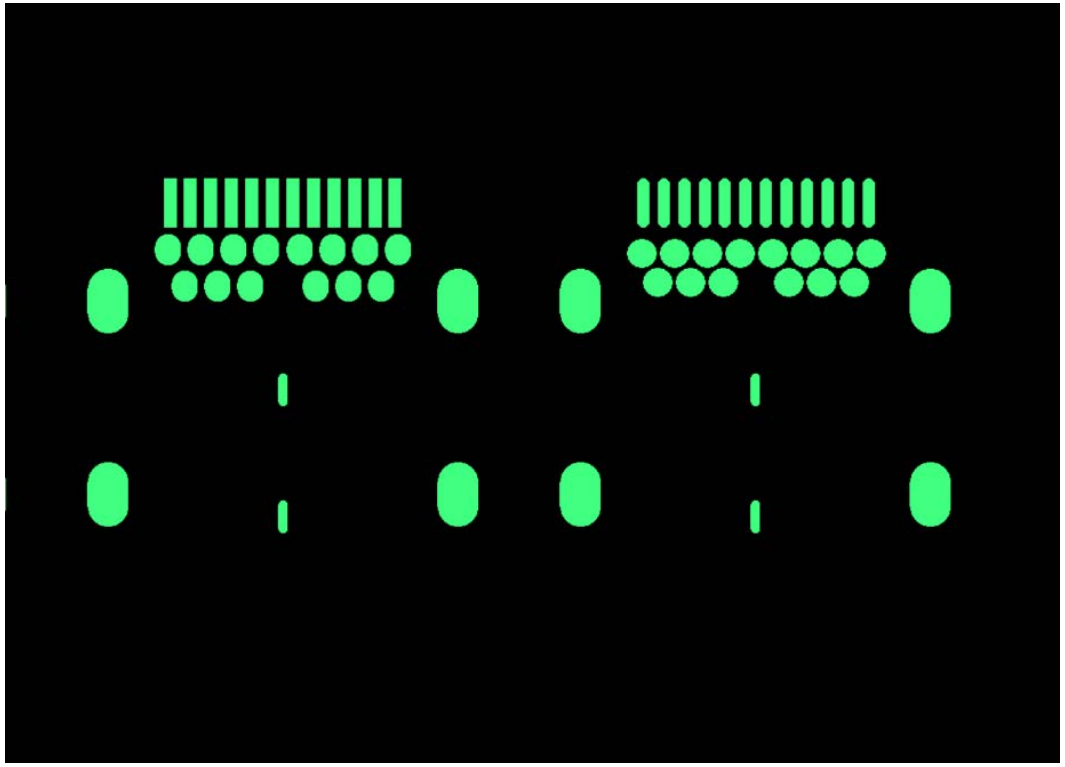


Stencil example

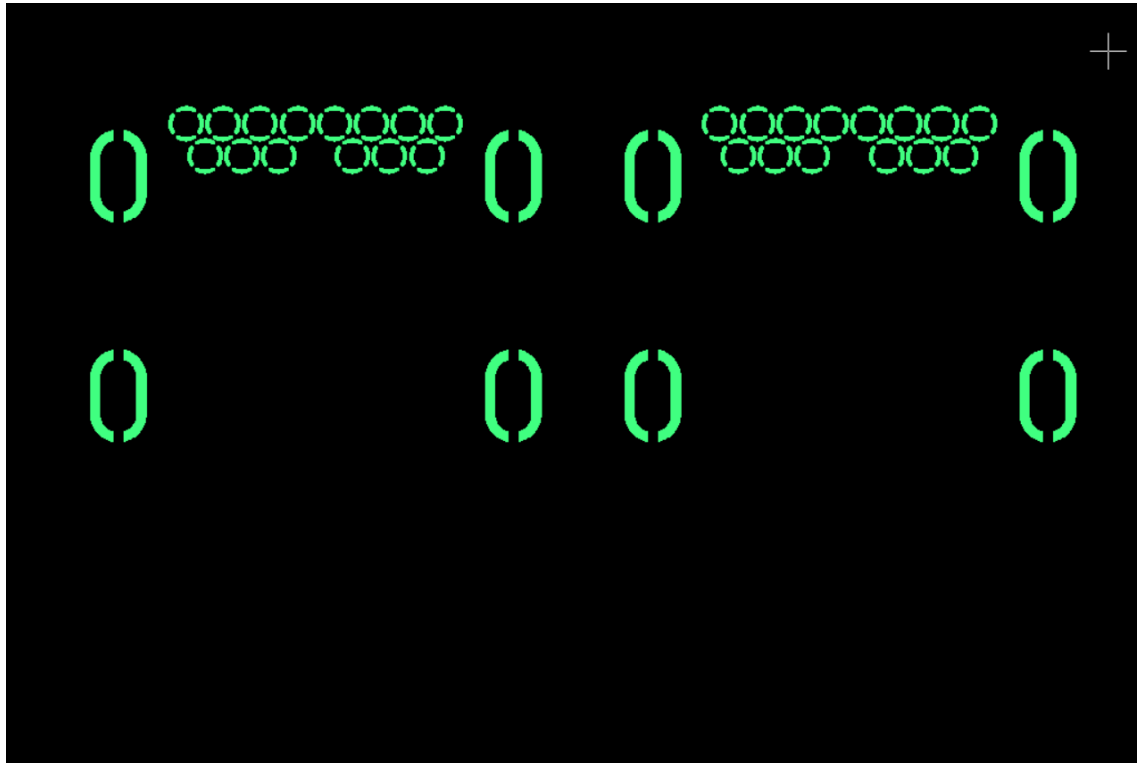


Pasteprinting & Stencil

Top View

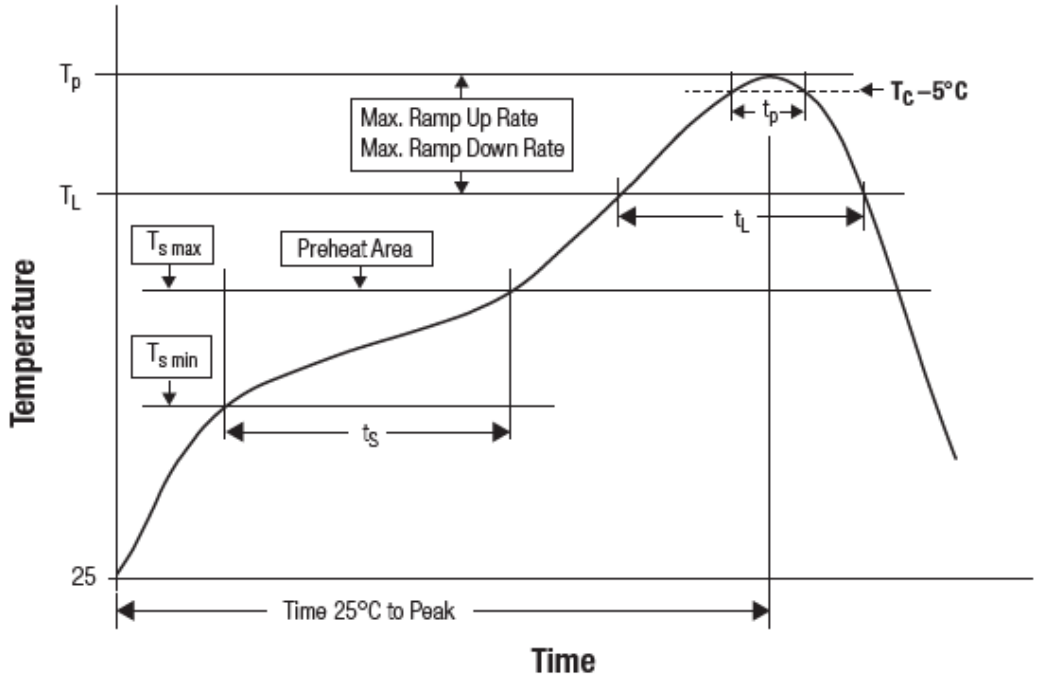


Bottom View



Solderingprofile

Classification Reflow Profile for SMT components:



Classification Reflow Soldering Profile:

Profile Feature		Value
Preheat Temperature Min [1]	$T_{s\,min}$	150 °C
Preheat Temperature Max	$T_{s\,max}$	200 °C
Preheat Time t_s from $T_{s\,min}$ to $T_{s\,max}$	t_s	60 - 120 seconds
Ramp-up Rate (T_L to T_P)		3 °C/ second max.
Liquidous Temperature	T_L	217 °C
Time t_L maintained above T_L	t_L	60 - 150 seconds
Peak package body temperature	T_p	see table
Time within 5°C of actual peak temperaure	t_p	20 - 30 seconds
Ramp-down Rate (T_L to T_P)		6 °C/ second max.
Time 25°C to peak temperature		8 minutes max.

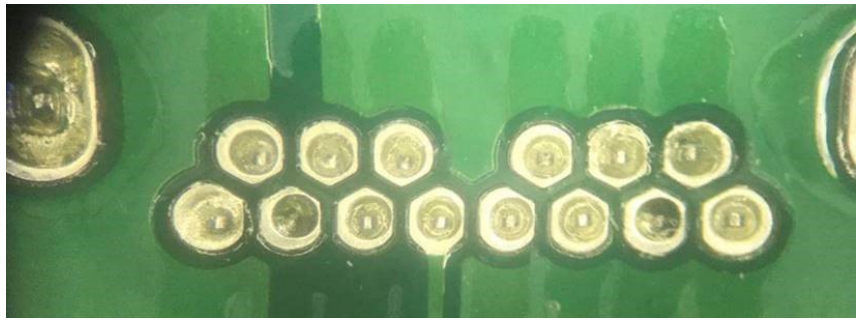
[1] refer to IPC/JEDEC J-STD-020D
refer to IPC/ JEDEC J-STD-020E

Package Classification Reflow Temperature:

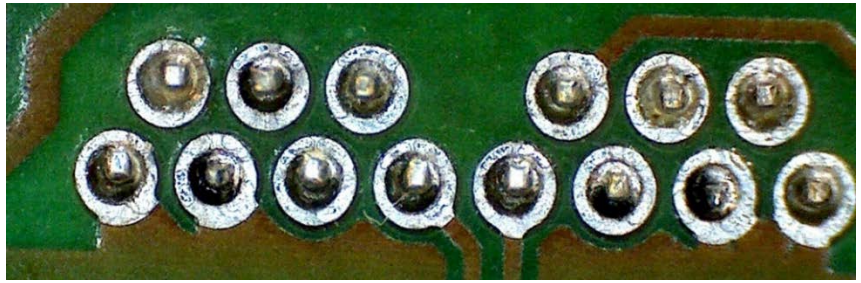
Properties	Volume mm³ <350	Volume mm³ 350-2000	Volume mm³ >2000
PB-Free Assembly I Package Thickness < 1.6 mm [1]	260 °C	260 °C	260 °C
PB-Free Assembly I Package Thickness 1.6 mm - 2.5 mm	260 °C	250 °C	245 °C
PB-Free Assembly I Package Thickness ≥ 2.5 mm	250 °C	245 °C	245 °C

[1] refer to IPC/JEDEC J-STD-020D
refer to IPC/ JEDEC J-STD-020E

Soldering Examples



Soldering without defects

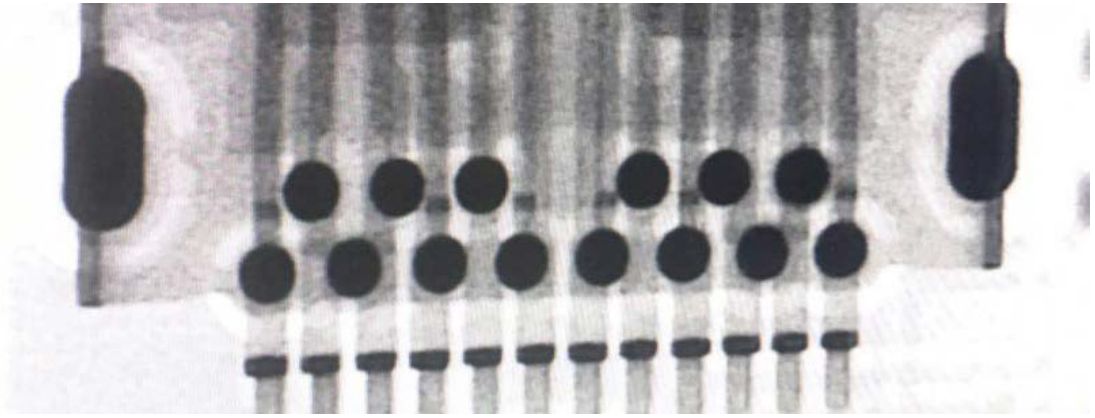


Soldering with defects

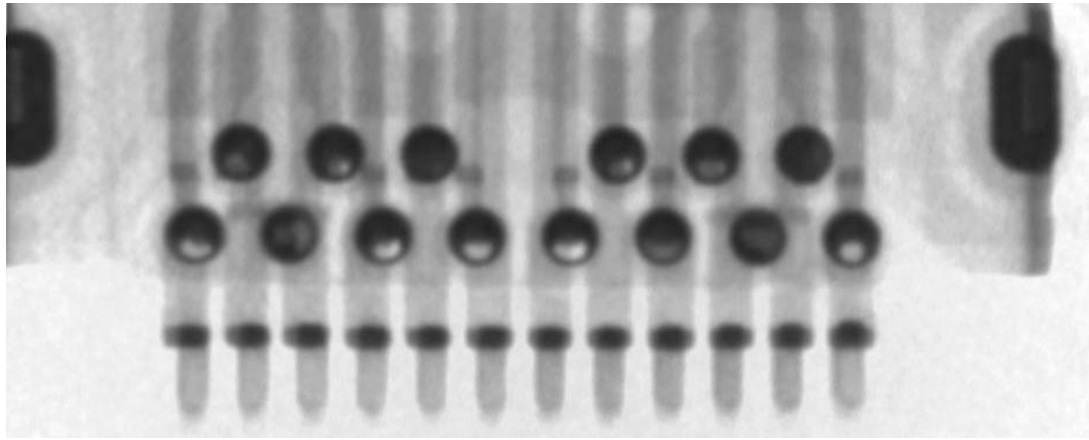
Handsoldering

Soldering inspection via X-Ray

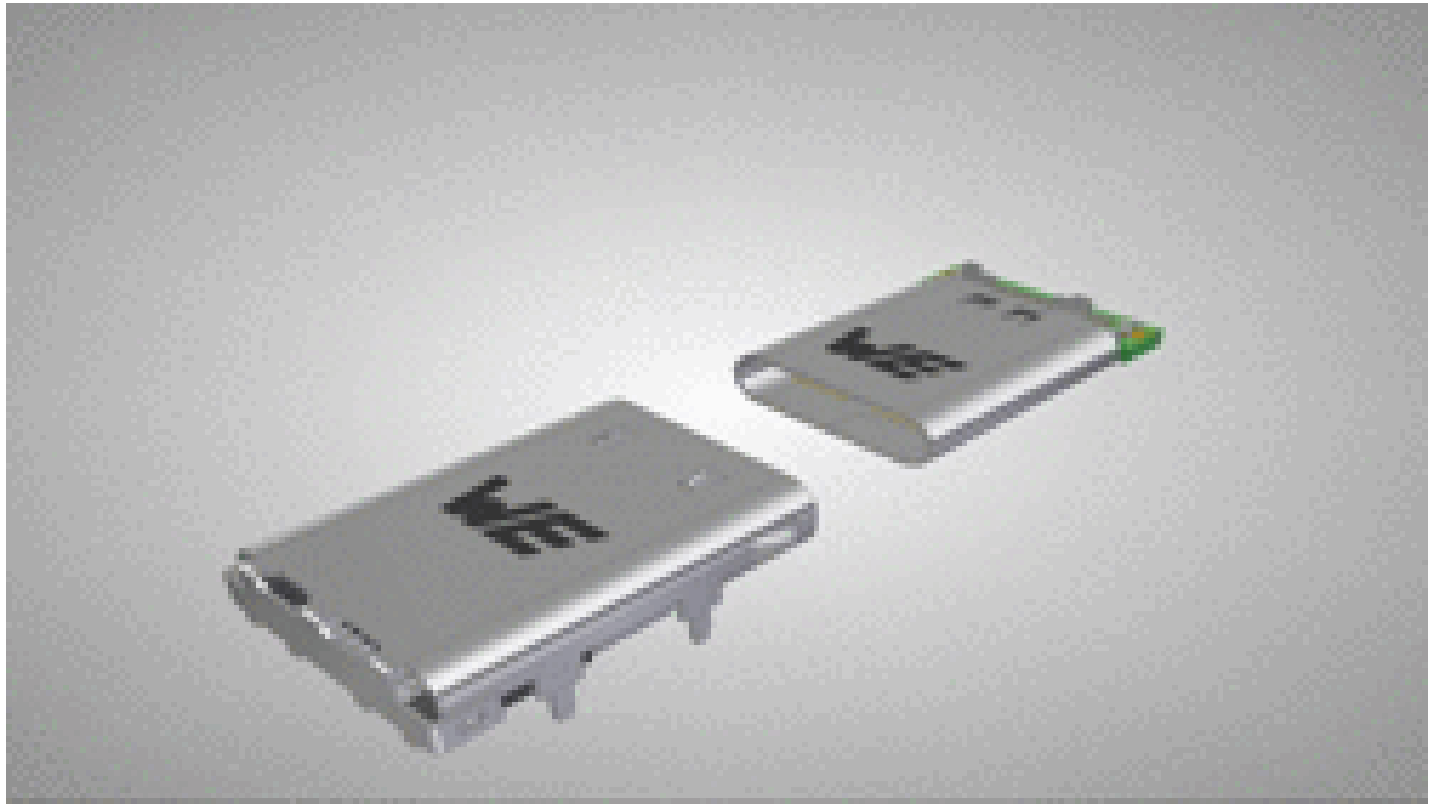
Solderingresult without defects



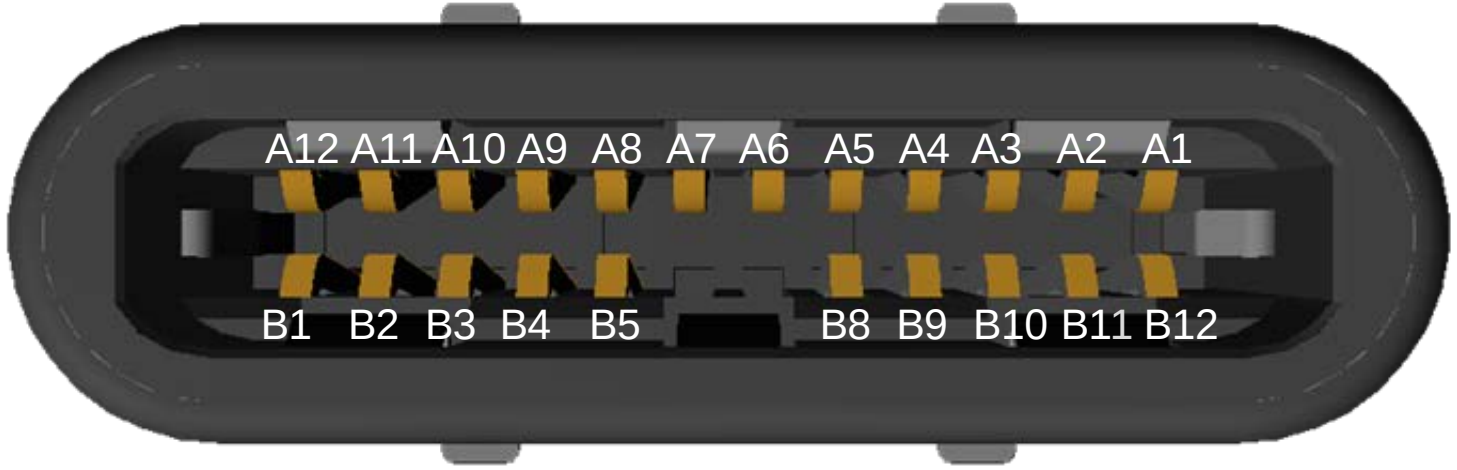
Solderingresult with defects



Type C Plug – 632 723 x00 011



Type C Plug – 632 712 000 011

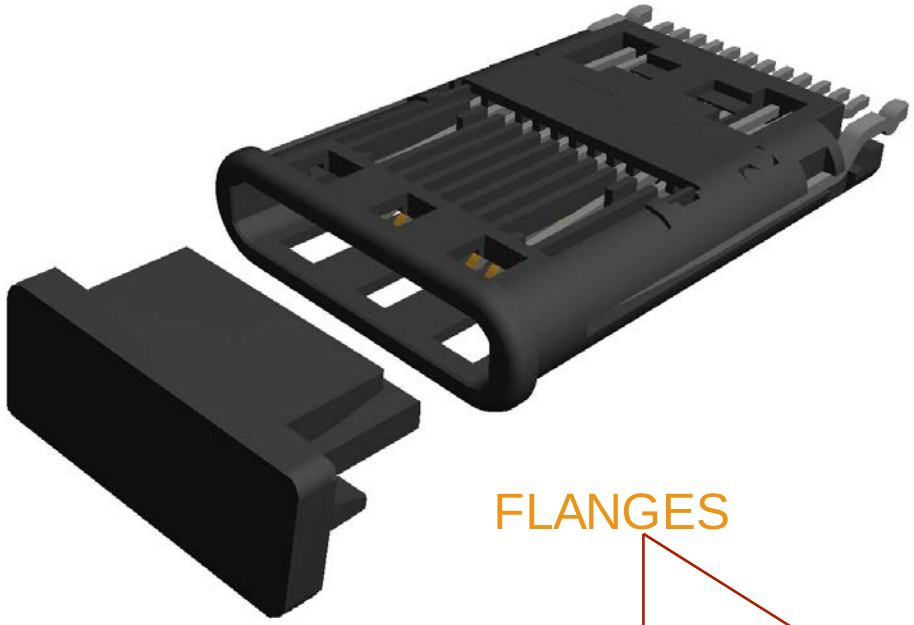


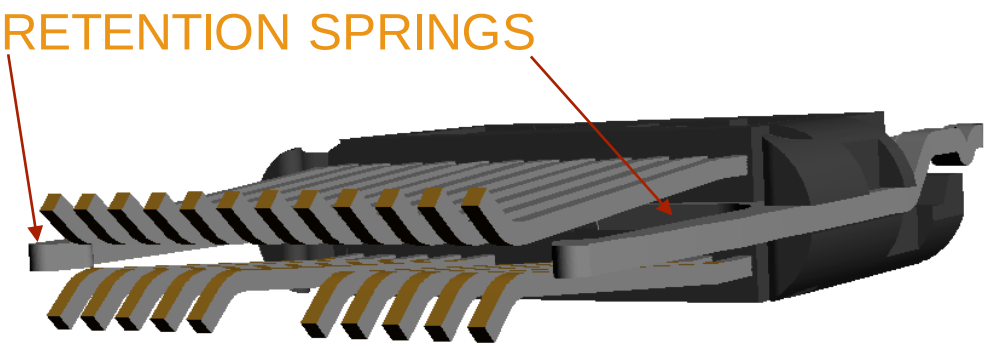
USB 2.0
USB 3.0
USB 3.1

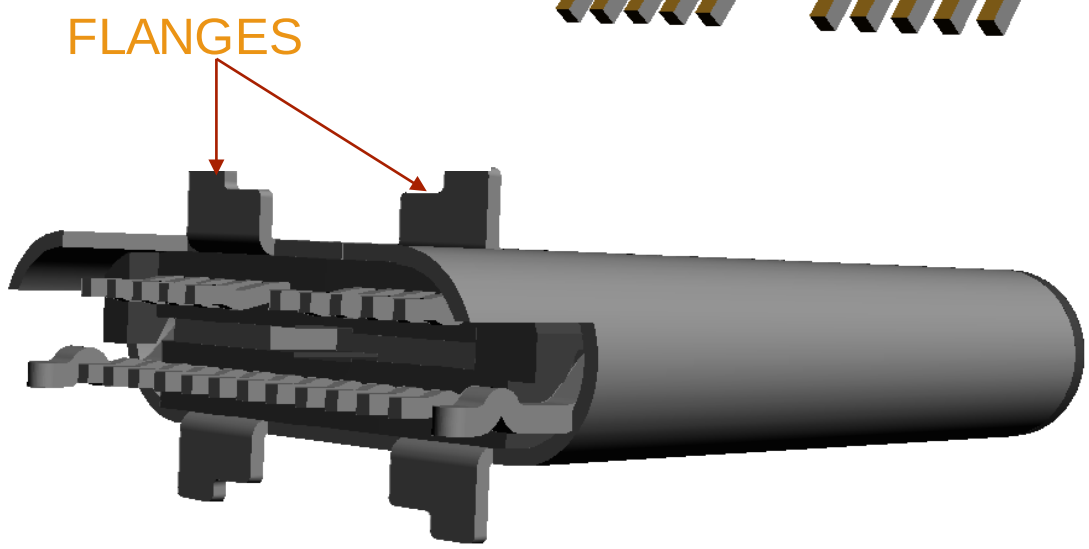
A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2-	V_{BUS}	SBU1	D+	D-	CC1	V_{BUS}	TX1-	TX1+	GND
GND	TX2+	TX2-	V_{BUS}	CC2			SBU2	V_{BUS}	RX1-	RX1+	GND
B1	**B2**	**B3**	**B4**	**B5**			**B8**	**B9**	**B10**	**B11**	**B12**

USB 3.1 Product Overview

Type C Plug Design – 632 712 000 011

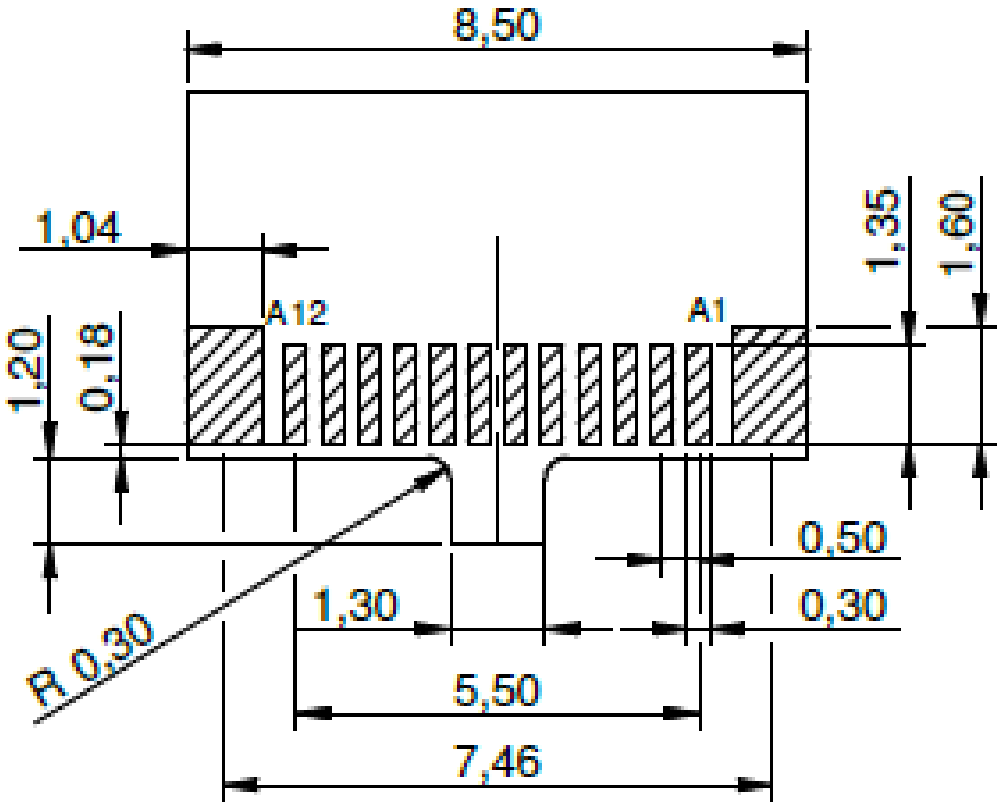




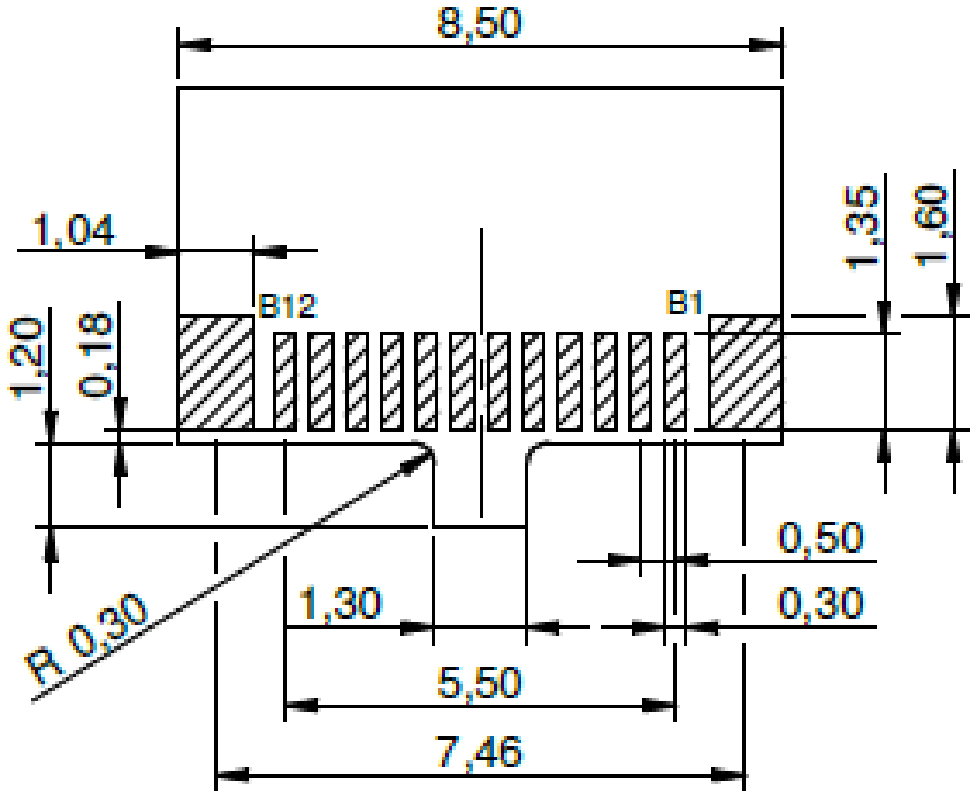


Layout PCB

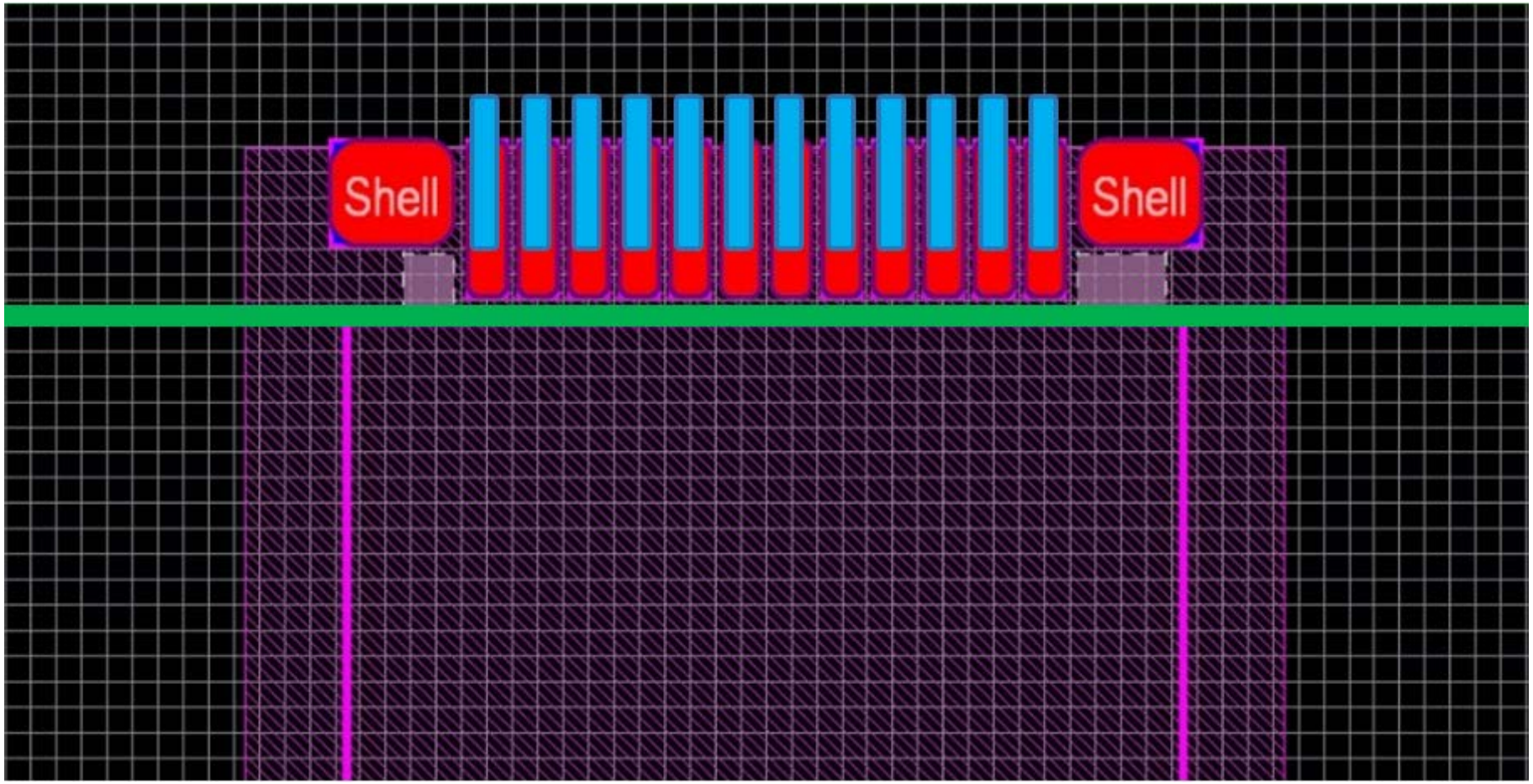
Top View



Bottom View

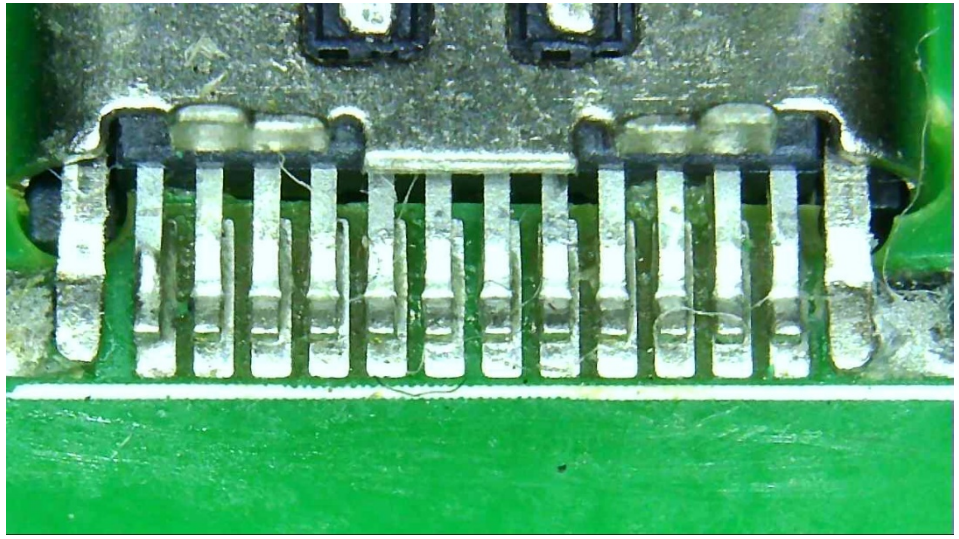


Pasteprinting & Stencil

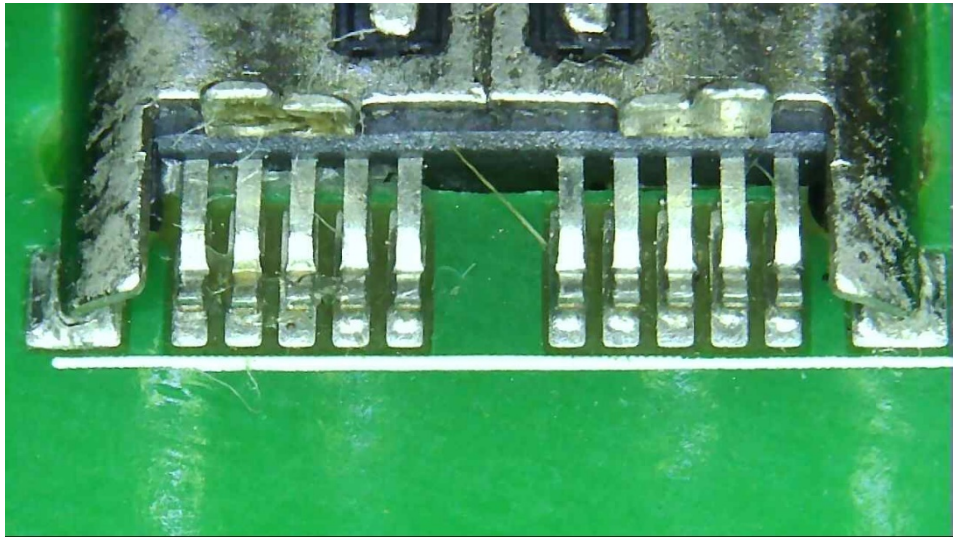


Soldering Example

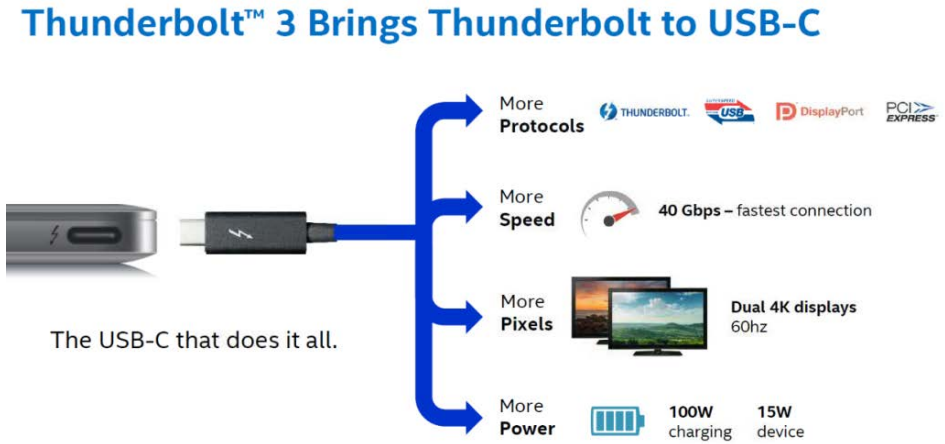
Top side view



Bottom side view



Conclusion



Mechanical Performance:

- 10.000 mating cycles
- High extraction (retention) force
- Long time reliability
- Time saving (only one type of connector is needed)
- Space saving

RF Behaviour:

- high data rate (over 10GHz)
- EMC / EMI protection
- mix mode is possible (e.g. USB 2.0 & I²C; USB 2.0 and DC/DC controller)

Electrical Performance:

- 5V / 12V / 20V
- up to 5A
- PD (up to 100W)

Thank you !

We are here for you now ! Ask us directly in the chat!

You can also contact us after the session:

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