PI5USB31213 Application Information
Plug-in Detector for Type-C Connector with USB3 10Gbps Switch
Version 2.1

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1 Introduction

Pericom's PI5USB31213 is a dual differential channel bi-directional Mux/Demux switch with plug-in detector for USB3.1 Gen2 (10.0 Gbps) Type-C connector.

The device includes:

1) The Plug-in Detector for Type-C connector (CC Sensing)
   a) Supports DFP/UFP/DRP/Try.SRC DRP/Try.SNK. DRP
      *Does not support Bus-Powered UFP configuration
2) Integrated 2:1 USB3 10Gbps Mux/DeMux
   a) Auto-configure ports orientation through CC sensing
3) Integrated VCONN switch to power active cables

The device implements CC pins for port attachment, detachment, cable orientation, role detection and Type-C Current Mode control. The device supports host mode, device mode and dual role mode ports with automatic configuration based on the voltage levels detected on CC pins. The device supports both pin and I^2C control mode. I^2C control mode allows higher flexibility for port control and communications.

Packaging: 24-contact TQFN (2mmx4mm)

2 Why need PI5USB31213 in USB3.1 Gen2 Type-C application

USB Type-C connectors support flipping and swapping. Type-C Connector specification defined the new pin "CC" to resolve port roles and cable orientation to establish power routing and data bus routing. Please see Figure 1 below for the USB Type-C implementation with USB3 switch.

PI5USB31213 Type-C port controller detects and control CC1/2 pin and configure its integrated 2:1 USB3 10Gbps Mux/DeMux automatically to establish USB3 data bus.

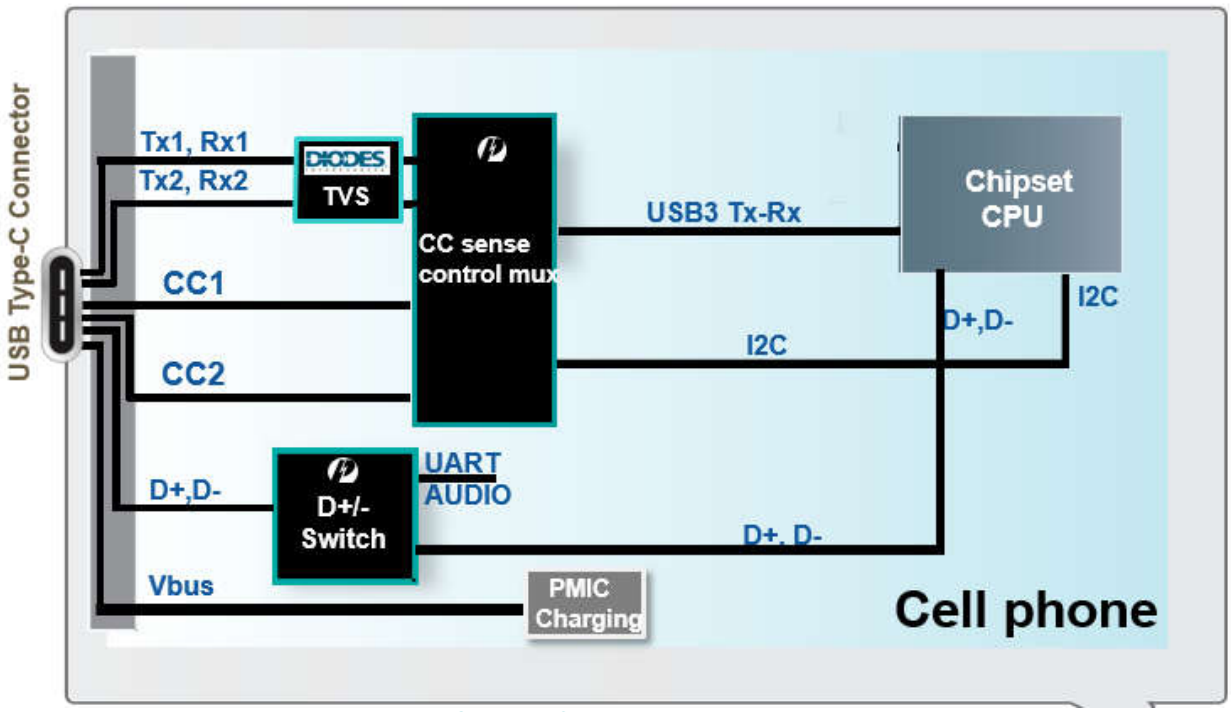


Figure 1: USB Type-C implementation with switch.

2.1 Type-C Port Channel Budget

For Type-C application, Host & device channel loss budget defined is 8.5dB @ 10Gbps by USB3.1 spec. (See below table from USB-IF development day slide)

PCB routing estimates

	Type-A Port		Type-C Port	
	Baseline	Best case	Baseline	Best case
SS Gen 1 5Gbps Insertion Loss Budget	10 dB	10 dB	6.5 dB	6.5 dB
Gen 1	10"	10"	5.5"	7"
Gen 1 + DP 1.2 discrete MUX			4.0"	5.5"
Gen 1 + DP 1.2 integrated MUX**			5.5"	7"
SS Gen 2 10Gbps Insertion Loss Budget	8.5 dB	8.5dB	8.5dB	8.5dB
Gen 2	5.5"	7"	5.5"	7"
Gen 2 + DP 1.3 discrete MUX			4"	5.5"
Gen 2 + DP 1.3 integrated MUX**			5.5"	7"

Table 1: USB3.1 Type-A Port vs Type-C Port channel loss budget

If total channel loss from SOC to end connector is less than 8.5dB→ use PI5USB31213

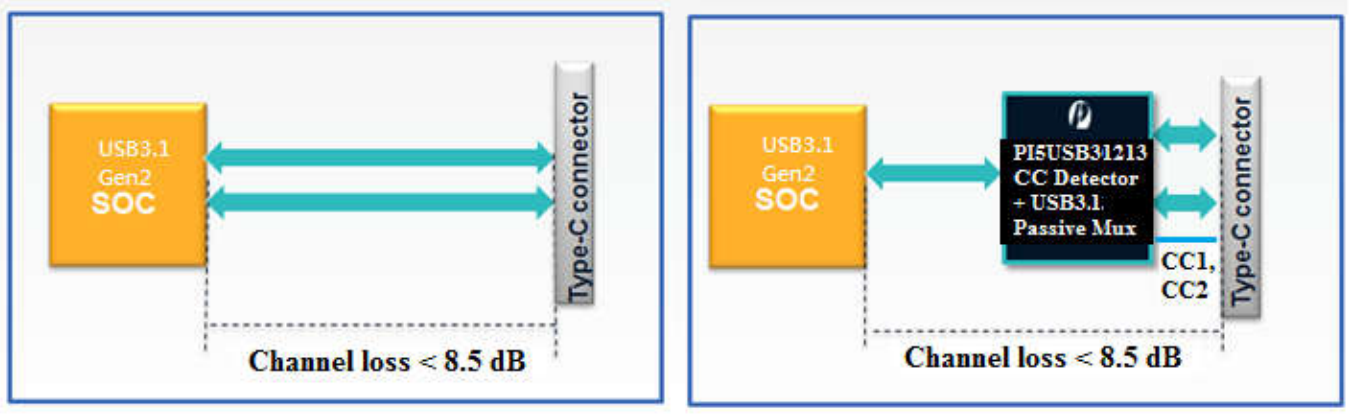


Figure 2: USB3.1 Type-C application needs passive Mux if total channel loss from SOC to end connector is less than 8.5dB.

2.2 VCONN

In non USB Power Delivery (USB-PD) application,

a) VCONN support is a must in USB3 Source/DRP to power active cable per USB Type-C spec
b) VCONN support is not needed in USB3 UFP
c) VCONN support is optional in USB2 Type-C application

The VCONN source requirement is below:

Table 4-3 VCONN Source Characteristics

	Minimum	Maximum	Notes
Voltage	4.75 V	5.5 V	Ports that support VCONN-powered accessories are allowed to supply at a lower minimum of 2.7 V when operating in the PoweredAccessory state.
Power	1.0 W		Source may latch-off VCONN if excessive power is drawn beyond the specified inrush and mode wattage.
Bulk Capacitance	10 µF	220 µF	The VCONN source shall disconnect the bulk capacitance from the receptacle when VCONN is powered off.

Figure 3: VCONN Source requirement. Reprinted from USB Type-C Connector Spec 1.1.

2.3 USB3 SoC VBUS detection in DRP/UFP Mode

Per Type-C spec recommendation, USB3.1 SuperSpeed shall hold off VBUS detection to the device controller until PI5USB31213 has reported host/DFP attachment (PI5USB31213 in “attached.SNK” state) via I2C. Otherwise, it may connect as USB2.0 when attached to a legacy host or hub’s DFP.

3 Processor Communication via I²C

ADDR is used to set I²C address as below. Please noted that PI5USB31213 does not have offset byte*. All registers must be read or written sequentially from 0x01. For example, in order to read address 0x04, PI5USB31213 I²C registers must be read sequentially from 0x01, 0x02, 0x03 to 0x04. In order to write address 0x02, it must be written sequentially from 0x01 to 0x02.

*Please use "I²C Transport" API to communicate with PI5USB31213 if needed.

ADDR pin	I²C address format	I²C address
ADDR=GND	7-bit addressing	0x0D
	8-bit address	Write:0x1A; Read:0x1B
ADDR=VDD	7-bit addressing	0x2D
	8-bit address	Write:0x5A; Read:0x5B

Table 2: I2C Slave Address Setting

Processor shall use following procedure to process PI5USB31213 interrupt request:

1. INTB asserted LOW, indicating Type-C port status change.
2. Processor first masks PI5USB31213 interrupt by writing a '1' to Bit 0 of Control Register(0x02). INTB returned Hi.
3. Processor then read Register(0x01), Control Register (0x02), Interrupt Register(0x03) and CC Status Register(0x04). Interrupt Register(0x03) indicates if an attach or detach event was detected. All interrupt flags in Interrupt Register will be cleared after the I2C read action. CC Status Register(0x04) is used to determine plugin details and charging profile. Processor can configure the power and USB channels according to information in CC Status Register.

Processor unmask PI5USB31213 interrupt by writing a '0' to Bit 0 of Address 0x02 before ending the interrupt service routine.

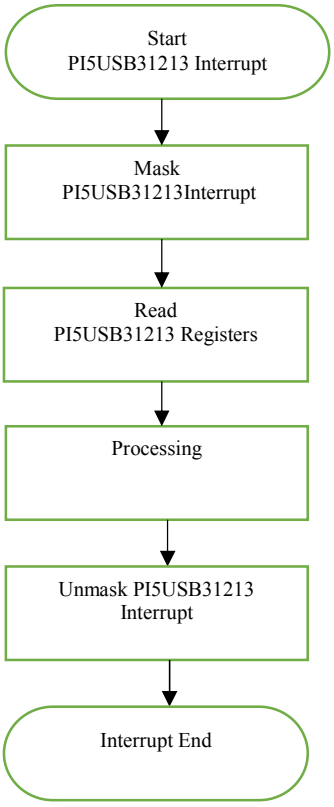


Figure 4: Suggested Flow of Processor Communication with PI5USB31213 via I²C

3.1 I²C Configuration Sequence

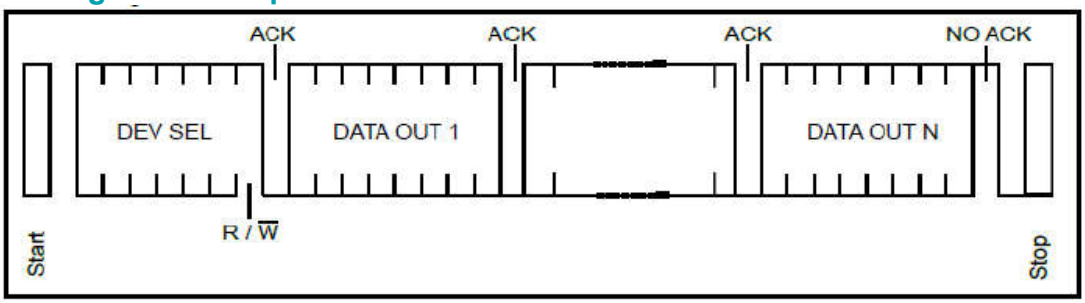


Figure 5: READ Sequence Diagram

Figure 6 below is one example for read sequence at ADDR=GND and Data Reg [1:4]=00,04,01,06.

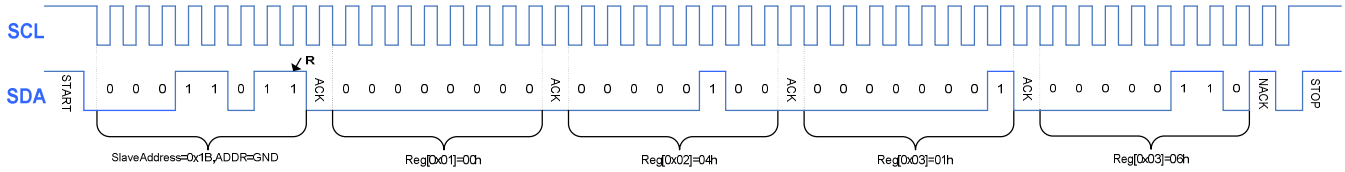


Figure 6: I²C Read Sequence Sample

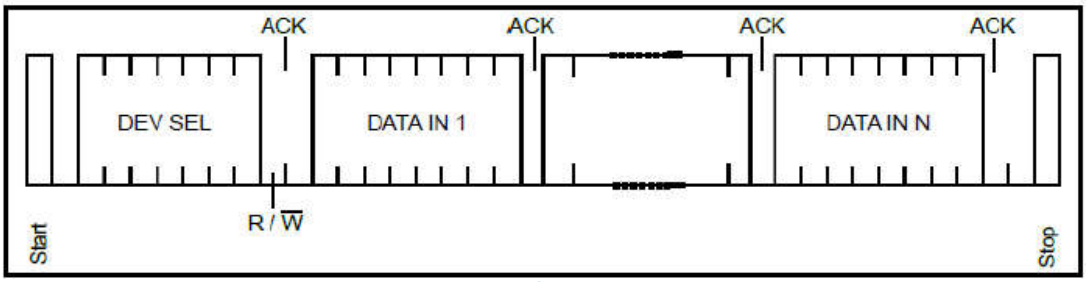


Figure 7: WRITE Sequence Diagram

Figure 8 below is one example for write sequence at ADDR=GND and Data Reg [1:2]=00,05.

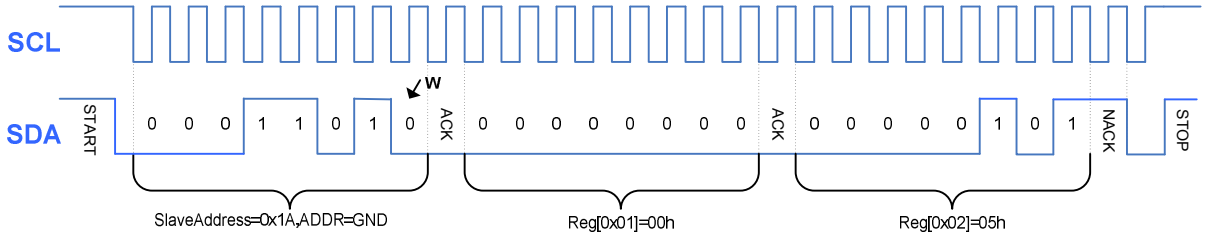


Figure 8: I²C WRITE Sequence Sample

3.2 ENB pin and Power-On Sequence

ENB pin shall be pin controlled in DRP/UFP application. When power-on, ENB pin of PI5USB31213 shall be float or connected to VDD to ensure CC1 and CC2 are pulled low by PI5USB31213 built-in Rd and the port acts as a Sink during Power-On Reset (POR). As a reset, the port would not accidentally detach any connected Type-C host when power-on and disturb VBUS supply from the Type-C host. PI5USB31213 is reset only by POR.

Please also note that, PI5USB31213 in DRP mode comes up as a Unattached.SRC when ENB pin is pulled down after power-on. This may detach an already connected Type-C host. To avoid this, user may connect PORT pin to GND and PI5USB31213 shall always initialized as a Sink after power-on and user can change the mode through I^2C afterwards.

3.3 Power-Saving mode through I^2C

User can put PI5USB31213 into low power state by writing a '1' to Bit 7 of Reg [0x02] with ENB pin is pulled low. User can re-enable the part through the I^2C by writing a '0' to Bit 7 of Reg[0x02].

3.4 I^2C Register Quick Reference Table

Reg[0x02]	PI5USB31213 Operating Mode	CC1/2 voltage when unattached	ID pin
00h	Sink/UFP; No accessory support	GND	"H"
01h	Sink/UFP; No accessory support; Mask Interrupt		
02h	Source/DFP; Default USB Power	VDD	"L" when UFP is attached
03h	Source/DFP; Default USB Power; Mask Interrupt		
04h	DRP; Default USB Power	Toggle between VDD and GND	
05h	DRP; Default USB Power; Mask Interrupt		
06h	Try.SRC DRP; Default USB Power	Toggle between VDD and GND	
07h	Try.SRC DRP; Default USB Power; Mask Interrupt		
0Ah	Source/DFP; 1.5A Type-C Current Mode	VDD	
0Bh	Source/DFP; 1.5A Type-C Current Mode; Mask Interrupt		
0Ch	DRP; 1.5A Type-C Current Mode	Toggle between VDD and GND	
0Dh	DRP; 1.5A Type-C Current Mode; Mask Interrupt		
0Eh	Try.SRC DRP; 1.5A Type-C Current Mode	Toggle between VDD and GND	
0Fh	Try.SRC DRP; 1.5A Type-C Current Mode; Mask Interrupt		
12h	Source/DFP; 3A Type-C Current Mode	VDD	
13h	Source/DFP; 3A Type-C Current Mode; Mask Interrupt		
14h	DRP; 3A Type-C Current Mode	Toggle between VDD and GND	
15h	DRP; 3A Type-C Current Mode; Mask Interrupt		
16h	Try.SRC DRP; 3A Type-C Current Mode	Toggle between VDD and GND	
17h	Try.SRC DRP; 3A Type-C Current Mode; Mask Interrupt		
46h	Try.SNK DRP; Default USB Power	Toggle between VDD and GND	
47h	Try.SNK DRP; Default USB Power; Mask Interrupt		
4Eh	Try.SNK DRP; 1.5A Type-C Current Mode	Toggle between VDD and GND	
4Fh	Try.SNK DRP; 1.5A Type-C Current Mode; Mask Interrupt		
56h	Try.SNK DRP; 3A Type-C Current Mode	Toggle between VDD and GND	
57h	Try.SNK DRP; 3A Type-C Current Mode; Mask Interrupt		
20h	Sink/UFP; Support accessory	Toggle between VDD and GND	"H"
21h	Sink/UFP; Support accessory; Mask Interrupt		

Table 3: Control Register (Reg[0x02]) Quick Reference Table

Reg[0x03]	PI5USB31213 Attach/Detach Event and VCONN switch status
00h	No attach or detect event occurred since last I²C read.
01h	Attach event occurred since last I²C read.
02h	Detach event occurred since last I²C read.
04h	Fault is occurring for VCONN switch detector. If not use VCONN, please ignore it.
08h	OTP event, VCONN Over-temperature protection detected. If not use VCONN, please ignore it.
20h	OVP event, VCONN Over-voltage protection detected. If not use VCONN, please ignore it.
40h	OCP event, VCONN Over-current protection detected. If not use VCONN, please ignore it.
80h	Fault condition recovery.

Table 4: Interrupt Register (Reg[0x03]) Quick Reference Table

Reg[0x04]	Type-C Port Status	Plug Position	CC1 Voltage	CC2 Voltage	ID
00h	Unattached; The port shall not drive VBUS.	-	-	-	H
04h	Attached.SRC state but the connected CC pin is shorted to GND.	-	-	-	L
05h	Attached to a Sink/UFP; The port shall drive VBUS.	CC1	Default Host: 0.41V 1.5A Host: 0.92V 3A Host: 1.7V	VCONN voltage	L
06h	Attached to a Sink/UFP; The port shall drive VBUS.	CC2	VCONN voltage	Default Host: 0.41V 1.5A Host: 0.92V 3A Host: 1.7V	L
0Fh	Attached to an audio accessory. *4	Accessory	0.08V	0.08V	H
13h	Attached to an debug accessory. *4	Accessory	0.4V	0.4V	H
8Fh	Attached to a charge-through audio accessory	Accessory	0.08V	0.08V	H
93h	Attached to an debug accessory with VBUS detected. *4	Accessory	0.4V	0.4V	H
A8h	Attached to a Host; CC pin is detached. Check cable connection. *1	-	-	-	H
A9h	Attached to a Host; *1	CC1	0.4V	-	H
AAh	Attached to a Host; *1	CC2	-	0.4V	H
C8h	Attached to a Host; CC pin is detached. Check cable connection. *2	-	-	-	H
C9h	Attached to a Host; *2	CC1	0.92V	-	H
CAh	Attached to a Host; *2	CC2	-	0.92V	H
E8h	Attached to a Host; CC pin is detached. Check cable connection. *3	-	-	-	H
E9h	Attached to a Host; *3	CC1	1.7V	-	H
EAh	Attached to a Host; *3	CC2	-	1.7V	H

Table 5: CC Status (Reg[0x04]) Quick Reference Table

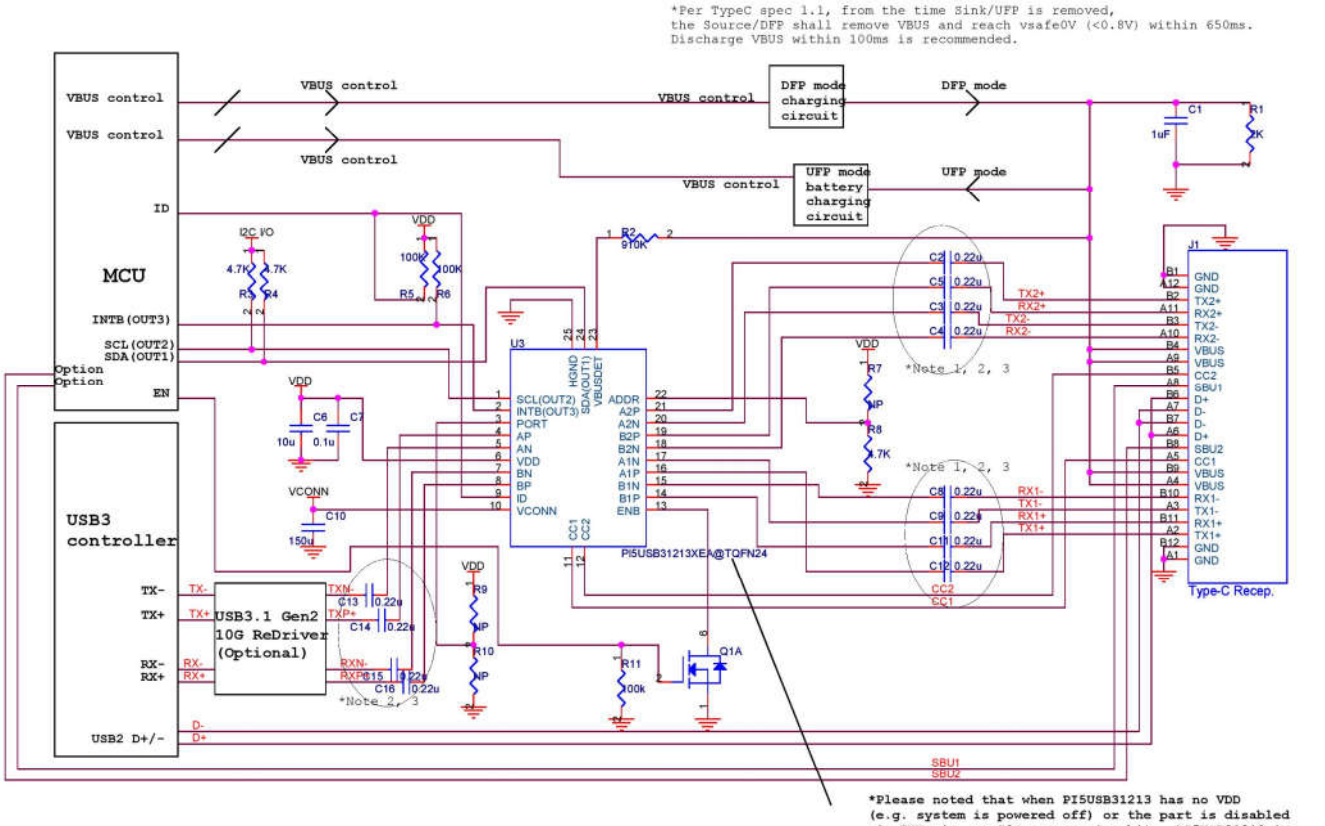
Note
*1: The port shall draw no more than the default USB power from VBUS.
*2: The port shall draw no more than 1.5A from VBUS.
*3: The port shall draw no more than 3A from VBUS.
*4: According to Type-C spec 1.1, the port shall not drive VBUS.
*5: The port shall not sink more than 500mA from VBUS.

4 Typical Application Circuit

4.1 DRP in I²C Mode

Figure 9 shows a typical DRP mode Type-C configuration. Please noted that when PI5USB31213 has no power (e.g. the system is powered off) or the part is disabled via ENB pin or I2C powersaving bit, PI5USB31213 is configured automatically in Sink/UFP mode with pull-low on CC pins.

Per USB Type-C specification, VCONN source requires 10uF-220uF bulk capacitance.
Per USB Type-C specification, system should discharge VBUS to <0.8V within 650ms after sink is detached.



Control mode	R8	R7
I2C mode address: 7-bit addressing: 0x0D or 8-bit write address:0x1A 8-bit read address: 0x1B	4.7K	NC
I2C mode address: 7-bit addressing: 0x2D or 8-bit write address:0x5A 8-bit read address: 0x5B	NC	4.7K
Pin Control Mode	NC	NC

Type-C port mode	R9	R10
UFP/Sink/Device	NC	4.7K
DFP/Source/Host	4.7K	NC
DRP	NC	NC

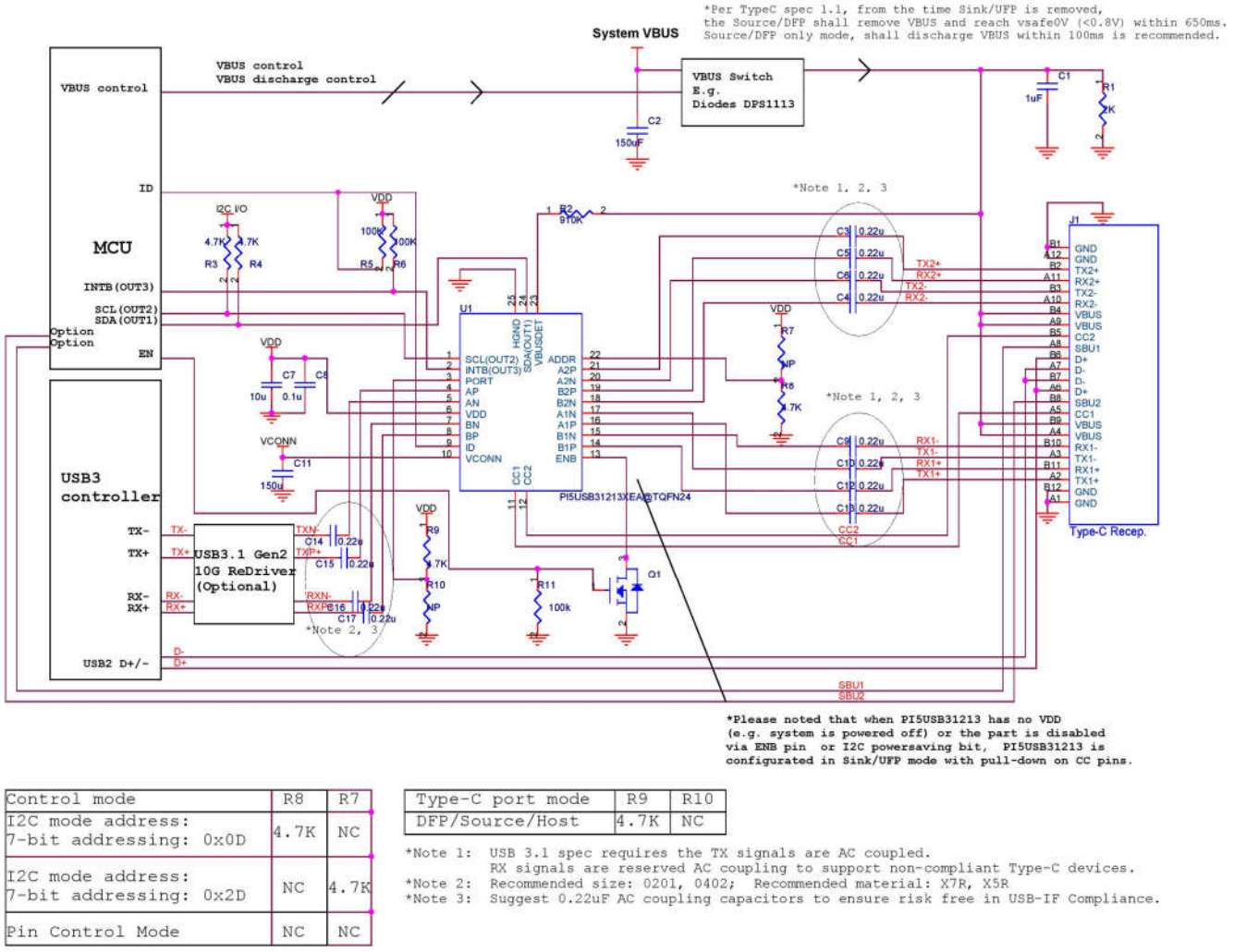
*Note 1: USB 3.1 spec requires the TX signals are AC coupled. RX signals are reserved AC coupling to support non-compliant Type-C devices.
*Note 2: Recommended size: 0201, 0402; Recommended material: X7R, X5R
*Note 3: Suggest 0.22uF AC coupling capacitors to ensure risk free in USB-IF Compliance.

Figure 9: Typical Application Circuit of PI5USB31213 DRP I²C Mode

4.2 DFP Mode

4.2.1 DFP in I²C Mode

Figure 10 shows a typical Source/DFP mode Type-C configuration.
Per USB Type-C specification, system should discharge VBUS to <0.8V within 650ms after sink is detached. In Source/DFP only mode, shall discharge VBUS within 100ms.



Control mode	R8	R7
I2C mode address: 7-bit addressing: 0x0D	4.7K	NC
I2C mode address: 7-bit addressing: 0x2D	NC	4.7K
Pin Control Mode	NC	NC

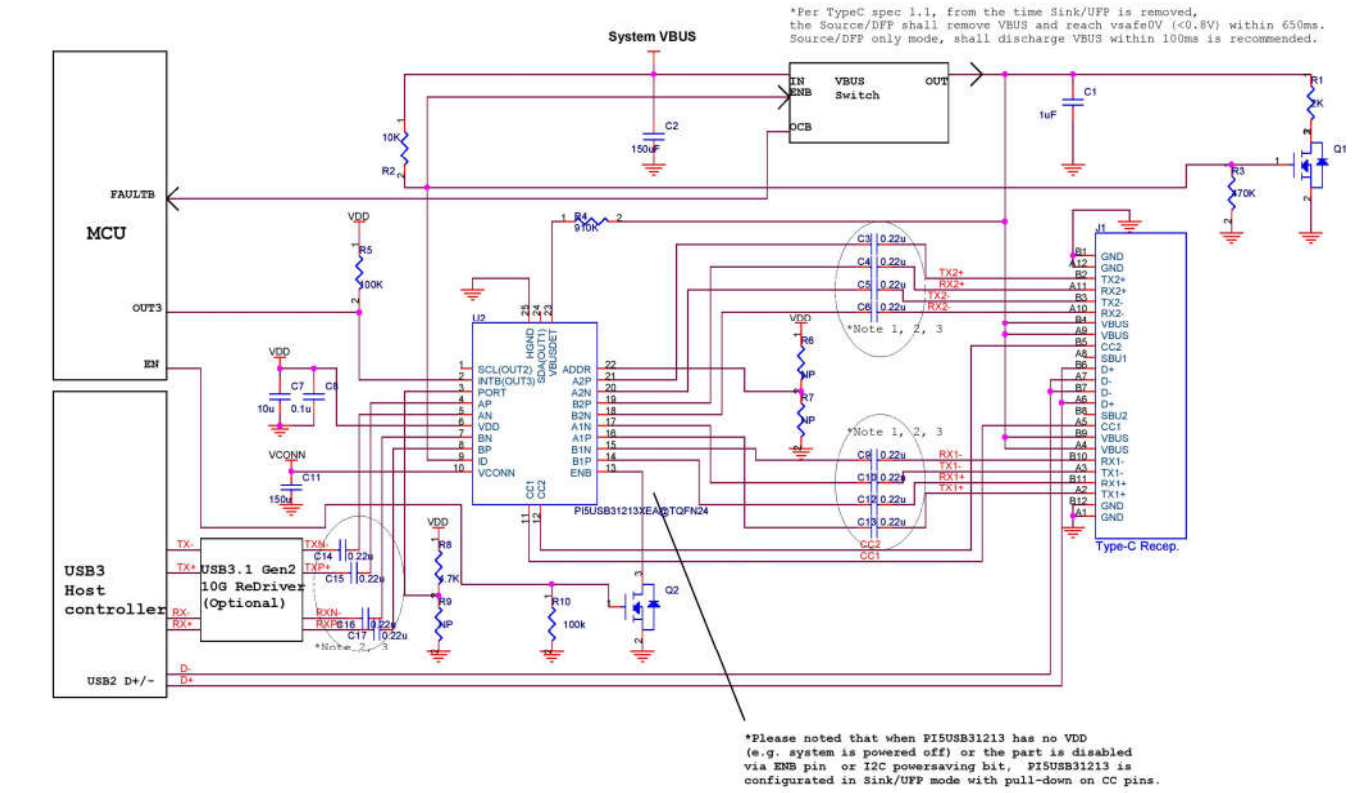
Type-C port mode	R9	R10
DFP/Source/Host	4.7K	NC

*Note 1: USB 3.1 spec requires the TX signals are AC coupled. RX signals are reserved AC coupling to support non-compliant Type-C devices.
*Note 2: Recommended size: 0201, 0402; Recommended material: X7R, X5R
*Note 3: Suggest 0.22uF AC coupling capacitors to ensure risk free in USB-IF Compliance.

Figure 10: Typical Application Circuit of PI5USB31213 DFP I²C Mode

4.2.2 DFP (Default Current) in Pin Control Mode

Figure 11 shows a Source/DFP default current mode Type-C configuration. In Source/DFP only mode, shall discharge VBUS within 100ms.



Control mode	R7	R6
I2C mode address: 7-bit addressing: 0x0D	4.7K	NC
I2C mode address: 7-bit addressing: 0x2D	NC	4.7K
Pin Control Mode	NC	NC

Type-C port mode	R8	R9
DFP/Source/Host	4.7K	NC

*Note 1: USB 3.1 spec requires the TX signals are AC coupled. RX signals are reserved AC coupling to support non-compliant Type-C devices.
*Note 2: Recommended size: 0201, 0402; Recommended material: X7R, X5R
*Note 3: Suggest 0.22uF AC coupling capacitors to ensure risk free in USB-IF Compliance.

Figure 11: Typical Application Circuit of PI5USB31213 DFP Pin Control Mode

4.2.3 DFP Mode Design Note and Waveform

Please noted that when PI5USB31213 has no power (e.g. the system is powered off) or the part is disabled via ENB pin or I2C powersaving bit, PI5USB31213 is configured automatically in Sink/UFP mode with pull-low on CC pins.

A 150uF is used to meet USB2 DFP bulk capacitance requirement (minimum 120uF).

Per USB Type-C specification, VCONN source requires 10uF-220uF bulk capacitance. The USB Type-C specification also has VBUS turn-on and turn-off timing requirement. Please refer to the USB Type-C specification for details.

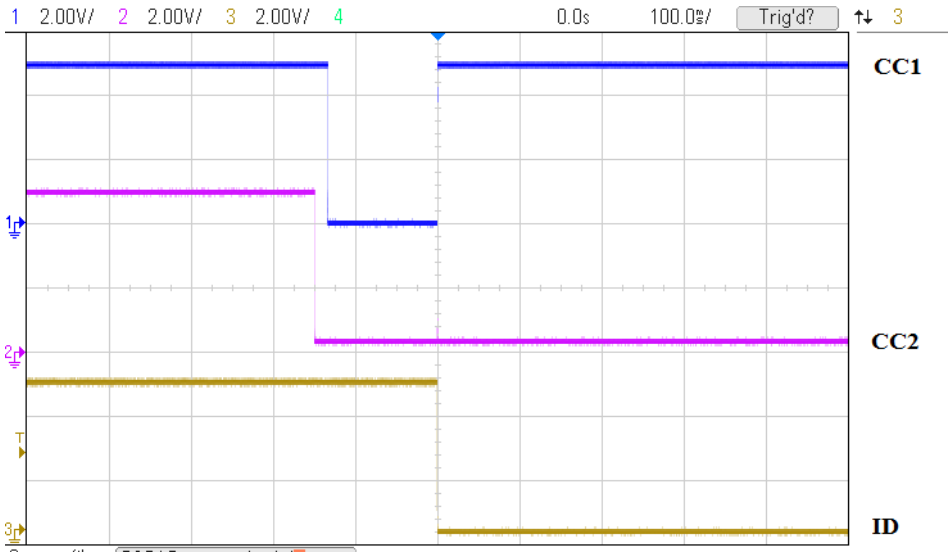


Figure 12: Application Waveform for DFP Mode. ID pin is pulled low after a sink/UFP is attached to the port.

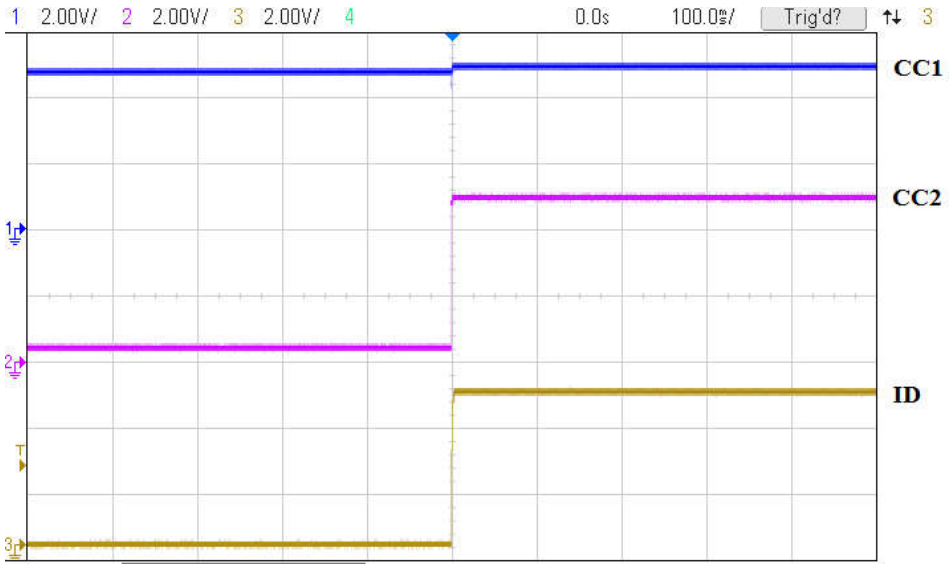


Figure 13: Application Waveform for DFP mode. Once device is detached, ID pin is released to high.

4.3 Battery-Powered UFP Mode

Figure 14 shows a typical Battery-Powered UFP mode Type-C configuration.

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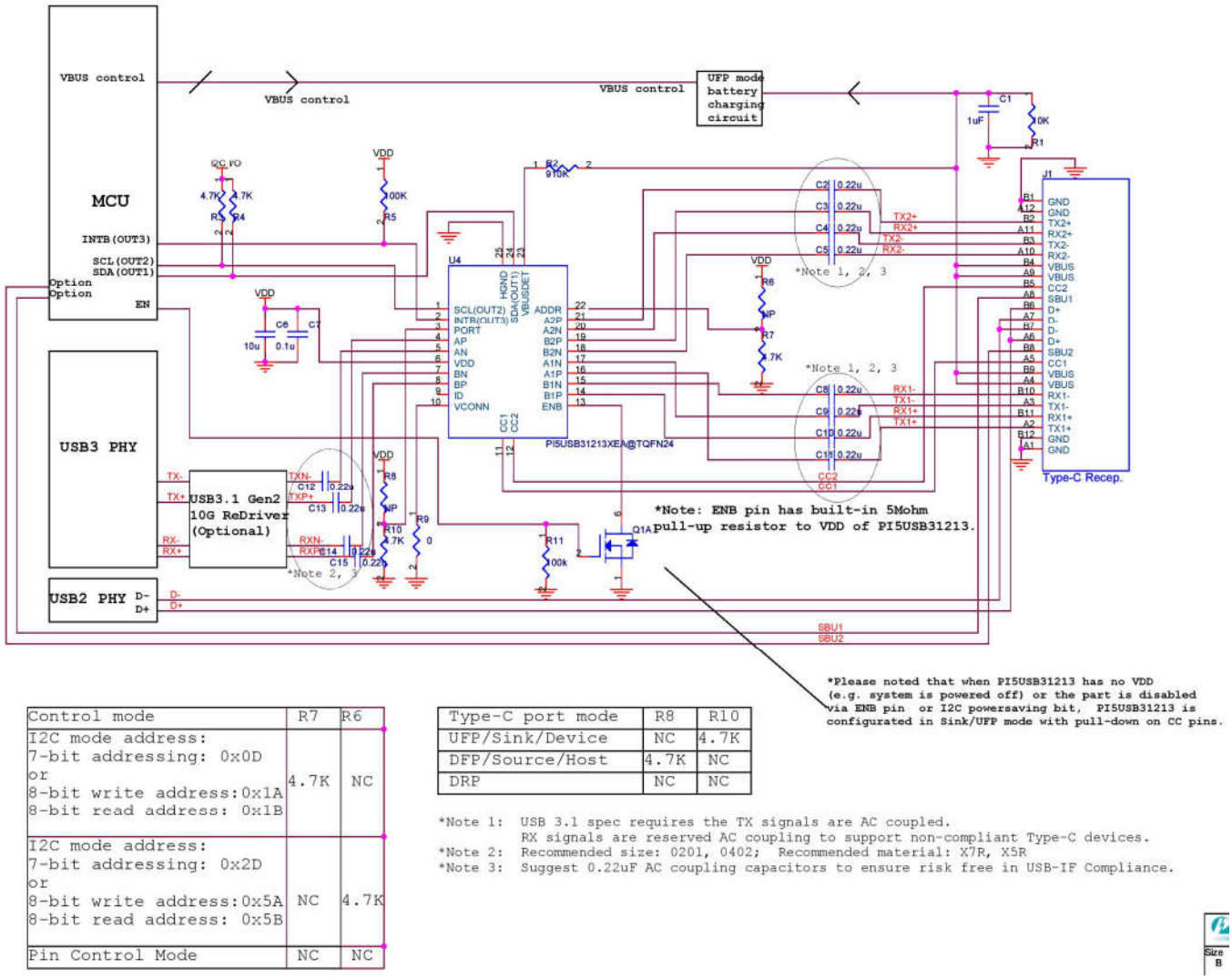

Control mode	R7	R6
I2C mode address: 7-bit addressing: 0x0D or 8-bit write address:0x1A 8-bit read address: 0x1B	4.7K	NC
I2C mode address: 7-bit addressing: 0x2D or 8-bit write address:0x5A 8-bit read address: 0x5B	NC	4.7K
Pin Control Mode	NC	NC

Type-C port mode	R8	R10
UFP/Sink/Device	NC	4.7K
DFP/Source/Host	4.7K	NC
DRP	NC	NC

*Note 1: USB 3.1 spec requires the TX signals are AC coupled.
RX signals are reserved AC coupling to support non-compliant Type-C devices.
*Note 2: Recommended size: 0201, 0402; Recommended material: X7R, X5R
*Note 3: Suggest 0.22uF AC coupling capacitors to ensure risk free in USB-IF Compliance.

Figure 14: Typical Application Circuit of PI5USB31213 Battery-Powered UFP I²C Mode

4.4 Bus-Powered UFP Mode

Not supported

5 Layout Recommendation

5.1 Power Decoupling Capacitor Recommendation

At least 1pc 4.7uF and 1pc 0.1uF decoupling capacitors are recommended for VDD of PI5USB31213. Each decoupling capacitor should be connected to PCB power plane via shortest path. VDD and GND pins should be shorted to PCB power planes via shortest paths.

At least 1uF decoupling capacitor is recommended at VBUS.

5.2 Layout Example

Typical application Layout suggestion

- Use 6/7/6 mils for trace-space-trace for the micro-strip lines (the traces on top and bottom layers) for 90ohm differential impedance.
- Use 6/5/6 mils for trace-space-trace for the strip-lines (the traces inside layers) for 90ohm differential impedance.
- Use FR4.
- Using standard 4 to 8 layers stack-up with 0.062 inch thick PCB.
- For micro-strip lines, using ½ OZ Cu plated is ok.
- For strip-lines in 6 plus players, using 1 OZ Cu is better.
- The trace length miss-matching shall be less than 5 mils for the "+" and "–" traces in the same pairs
- More pair-to-pair spacing for minimal crosstalk

Target differential Zo of 90ohm ±15%

The PCB layout recommended:

- Use 0.1uf in size of 0402 for all the Vdd (any power pins) pins of the IC device, as close to the Vdd pins as possible, within 2-3mm if feasible.
- Use dedicated Vdd and GND planes for to minimize the jitters coupled between channel trough power sources

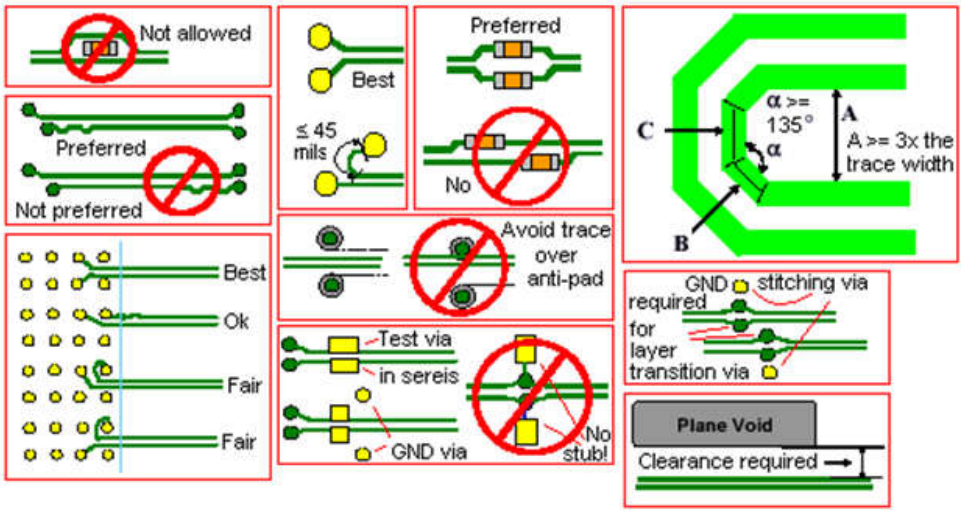

Figure 16: The Layout Guidance for the trace routings

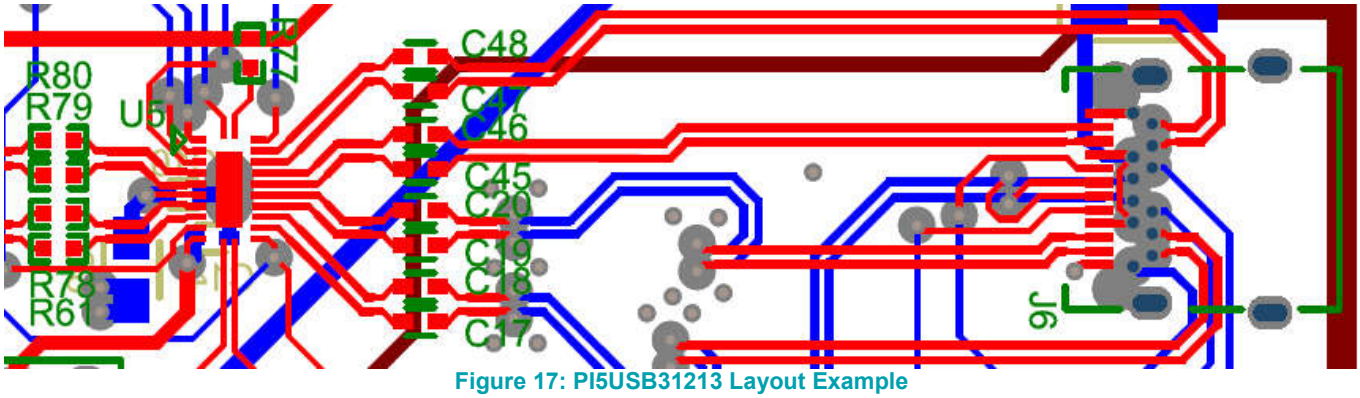

Figure 17: PI5USB31213 Layout Example

6 Firmware Example

```
bool vconn_flag = FALSE; //Global Variable for VCONN function flag.
char i2c_read_buf[4]={0x00,0x00,0x00,0x00};
char i2c_write_buf[2]={0x00,0x00};

void PI5USB31213_INTN_handler (void)
{
        char vconn_status = 0x00;  //Variable for VCONN switch status;
        char int_status = 0x00;                 //Interrupt status;
        char cc_status =0x00;
        char port_status=0x00;
        char control_status;

        pi5usb31213_i2c_read(pi5usb31213_slaveAddr, i2c_read_buf, 4);
 //Read PI5USB31213 registers when Interrupt occurred

        control_status=i2c_read_buf[1];

        if(vconn_flag)
//if vconn_flag is TRUE, means VCONN connected to 5V power supply, and PI5USB31213 will control the vconn switch and monitor switch status.
        {
                vconn_status = i2c_read_buf[2];
                if(vconn_status&0x80)    printf("PI5USB31213 recover from fault condition.\n");
                if(vconn_status&0x40)    printf("PI5USB31213 OCP event, VCONN Over-current protection detected. If not use VCONN, please ignore it.\n");
                if(vconn_status&0x20)    printf("PI5USB31213 OVP event, VCONN Over-voltage protection detected. If not use VCONN, please ignore it.\n");
                if(vconn_status&0x08)    printf("PI5USB31213 OTP event, VCONN Over-temperature protection detected. If not use VCONN, please ignore it.\n");
                if(vconn_status&0x04)    printf("PI5USB31213 Fault is occurring for VCONN switch detector. If not use VCONN, please ignore it.\n");

        }

        int_status = i2c_read_buf[2];
        if(int_status&0x02)
        {
                printf("Unpluged.\n");
                switch_off_VBUS_PWR();          //CPU switch off the VBUS power supply when port unpluged
        }
        if(int_status&0x01)         printf("Plug in.\n");

        cc_status = i2c_read_buf[3];
        if(cc_status&0x01)          printf("CC1 connected.\n");

        if(cc_status&0x02)          printf("CC2 connected.\n");

        port_status = (i2c_read_buf[3]>>2)&0x07;
        if((cc_status&0x01)|(cc_status&0x02))
        {
                switch(port_status)
```

```
                {
                case 1:
                        printf("Device plug in.\n");
                        switch_on_VBUS_PWR(); //CPU switch on the VBUS power supply when UFP/Device plug in
                        break;
                case 2:
                        printf("Host plug in.\n");
                        break;
                case 3:
                        printf("Audio Adapter Accessory plug in.\n");
                        break;
                case 4:
                        printf("Debug Accessory plug in.\n");
                        break;
                default:
                        break;
                }
        }
        if(i2c_read_buf[3]==0x04)                       //special process for PI5USB31213
                {
                        i2c_write_buf[1]=0x01;
                        pi5usb31213_i2c_write(pi5usb31213_slaveAddr,i2c_write_buf,2);
                        delay(30);
                        i2c_write_buf[1]=control_status;
                        pi5usb31213_i2c_write(pi5usb31213_slaveAddr,i2c_write_buf,2);
                        delay(10);
                }
}

void Initial_prog(void)
{
        vconn_flag = TRUE; //If vconn connected to 5V power supply, vconn_flag set to TRUE.
        set_ENB_low();   //Enable the PI5USB31213 when ENB pin by GPIO control
        i2c_write_buf[1]=0x01;   //Support DRP/DFP/Try.SNK DRP/Try.SRC DRP mode
        //i2c_write_buf[1]=0x05;  //Support UFP mode
        pi5usb31213_i2c_write(pi5usb31213_slaveAddr,i2c_write_buf,2);
        delay(30);
        i2c_write_buf[1]=0x04;    //Support DRP mode with default current mode
        //i2c_write_buf[1]=0x46;  //Support Try.SNK DRP mode
        pi5usb31213_i2c_write(pi5usb31213_slaveAddr,i2c_write_buf,2);

}
```