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Active Cable usage with ON Semiconductor Redrivers

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AND90081/D

APPLICATION NOTE

Introduction

With the increasing requirement for high speed transfer of larger bulk of data, better quality video and power delivery, change over from analog to digital videos, bi−directional transfers, it become essential to use a proper cable that delivers the data correctly between external hard drives and other systems or end products.

The use of Active cable becomes a necessity with increase in cable lengths of more than 5 meters, number of ports and data rates 10 Gbps and above. To match these using passive cables will become expensive with increased weight and thickness.

This application notes looks at need for active cables, cable losses and solutions available with ON redrivers for improving usage of long length cable with Type−C and Type−A connectors.

Necessity for Active Cables

Generally users would prefer to use a longer and thinner cable. With passive cables, this leads to signal loss and the end device may fail to work or not receive the expected input. The USB device will not function and with no output. To make a passive cable of higher quality with thicker or multiple copper wires, shielding and better quality connectors will lead to more expense increasing thickness and handling issues.

Factors like impedance, skew, cross−talk, attenuation, differential impedance, bit error rate (BER), jitter and insertion loss contribute to the cable length limit.

To overcome the above problems, use of active cables with built−in electronics will help.

Advantages of using Active Cables

Following are the positives in using active cables with redrivers:

- Can be of longer lengths than passive ones.
- The redriver compensates for signal loss due to skew, jitter, EMI, cross talk and attenuation that affects signal integrity.
- Redriver in active cables improves in boost of signal with increased eye opening, extending the link length and enabling pass of compliance test.
- Smaller wire gauge can be used providing more flexibility supporting better bending of cables with improved air flow.
- Less expensive due to use of low cost wire.
- Active cable supports connectivity of data, video, security and power application over a single connector as per USB Type−C standard that allow multiple functions over the same connector.

Requirement and Issues with Long Cables:

In order to connect to different outputs (like printer, scanner) that are at various distances from the main input without loss of data would call for use of a hub in the center that will act as a cable extension adding to hardware and electrical point.

Hence the need arises for use of longer cables. But long cables have losses that varies with frequency, length, thickness and with different vendors.

To overcome the issue of physical size and flexibility of usage and to maintain signal integrity calls for long cables with thinner wire gauge that leads to use of active cables with redrivers and control circuitry.

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Cable Losses:

In passive cables, the losses increases with increase in frequency, length and with change in wire gauge. Increasing the thickness of wire improves losses, but limited by the skin effect over frequency and handling becomes an issue due to increased cable thickness.

Figure 1 shows losses in cables for 1 meter and 5 meter cables with respect to wire thickness AWG and frequency. As can be seen, the variation is not linear when thickness and frequency is varied. The cable attenuation increases with increase in frequency. The same length of cable with different gauge wire will have different attenuation levels.

Figure 2 shows the loss allocation allowed by USB−IF with the center portion showing losses allowed in a cable. The system designers faces lot of issues in trying to stay within the allotted −6 dB spec for the cable.

From the Data shown in Figure 1 and Figure 2, materials, PCB, lengths are limiting factors to keep losses below the −6 dB spec. All of the above data indicates a need for a cable that compensates for these losses over longer lengths. This leads to need for active cables, adding redrivers allows them to use cheaper materials (PCB, copper wires), which saves money while in parallel extending the length of the cables.

For 28 AWG:

Frequency (MHz)	200	600	1250	2500	5000
Attenuation (dB/1m)	0.5	0.9	1.3	1.85	2.7
Attenuation (dB/5m)	2.5	4.5	6.5	9.25	13.5

For 30 AWG:

Frequency (MHz)	200	600	1250	2500	5000
Attenuation (dB/1m)	0.6	1	1.5	2.2	3.2
Attenuation (dB/5m)	3	5	7.5	11	16

For 32 AWG:

Frequency (MHz)	200	600	1250	2500	5000
Attenuation (dB/1m)	0.74	1.36	2	2.8	4
Attenuation (dB/5m)	3.7	6.8	10	14	20

Figure 1. Losses in Cables 1M and 5M Length with Respect to AWG and Frequency

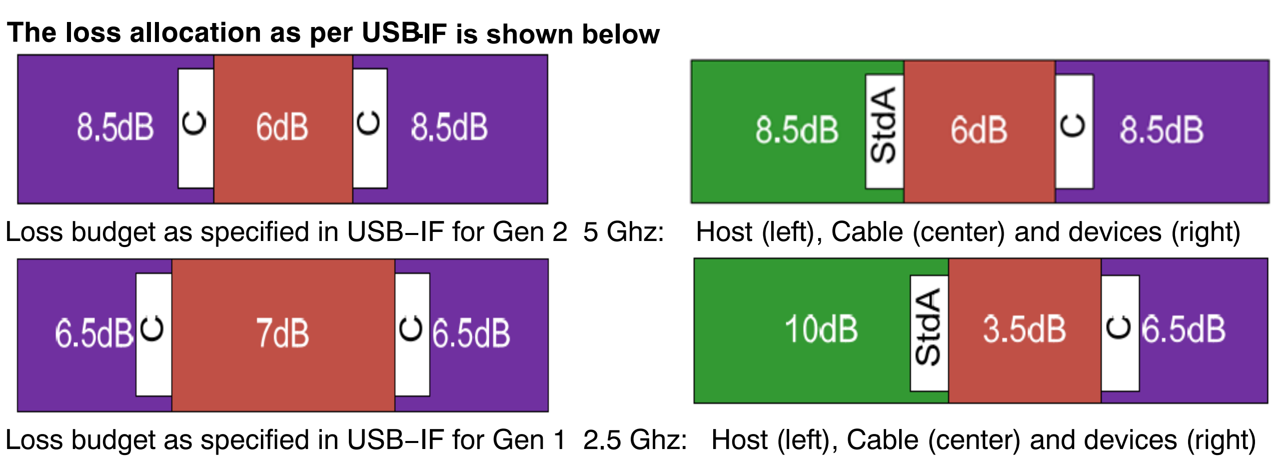

Figure 2. USB−IF Specified Loss Allocation for Cables

Active Cable basics:

Active Cable Basic Block Diagram:

The Active Cable consist of Plug/receptacle at one end that will get connected to Host, cable of specified length with inbuilt ICs (MCU, E−marker, Redriver, LDO) and Plug/receptacle at other end that will get connected to an Output. The embedded ICs may be at either or both ends of the cable. The MCU takes care of communicating with the basic signal processing and manage signal and power flow.

The responder ensures correct and efficient power delivery (PD) for charging and supply applications. It handles communication of product and/or cable capability information via PD protocol signal. It also provides Alternate mode support to transport non−USB data over Type−C.

An authentication IC is used to confirm the authenticity and capability of the cable, allowing devices to make informed policy decisions about which features can be safely enabled. For example, a system may want to authenticate a power supply and cable are trusted before enabling high power charging, to prevent damage that can be caused by non−authentic products.

Usage of redrivers in active cables:

The solution to signal integrity challenges in USB and HDMI cables lies in use of redrivers to boost signals.

A redriver is an analog amplifier that alters the high frequency differential signals to open eyes and improve signal integrity. Redrivers also takes care of line impedance matching, programmable gain, and add other analog parameters to compensate for line losses, impedance mismatch and channel effects.

Refer Figure 3 for improvement in eye diagram with redriver used in a 3 meter Cable.

The redrivers have internal blocks like Flat Gain, Equalization, Driver and detection that allows for accurate compensation of cable losses. It is essential to not just go by the cable length as it depends on the wire gauge used and for the same length may have different losses. Hence we must know the actual dB losses for correct settings in the redriver.

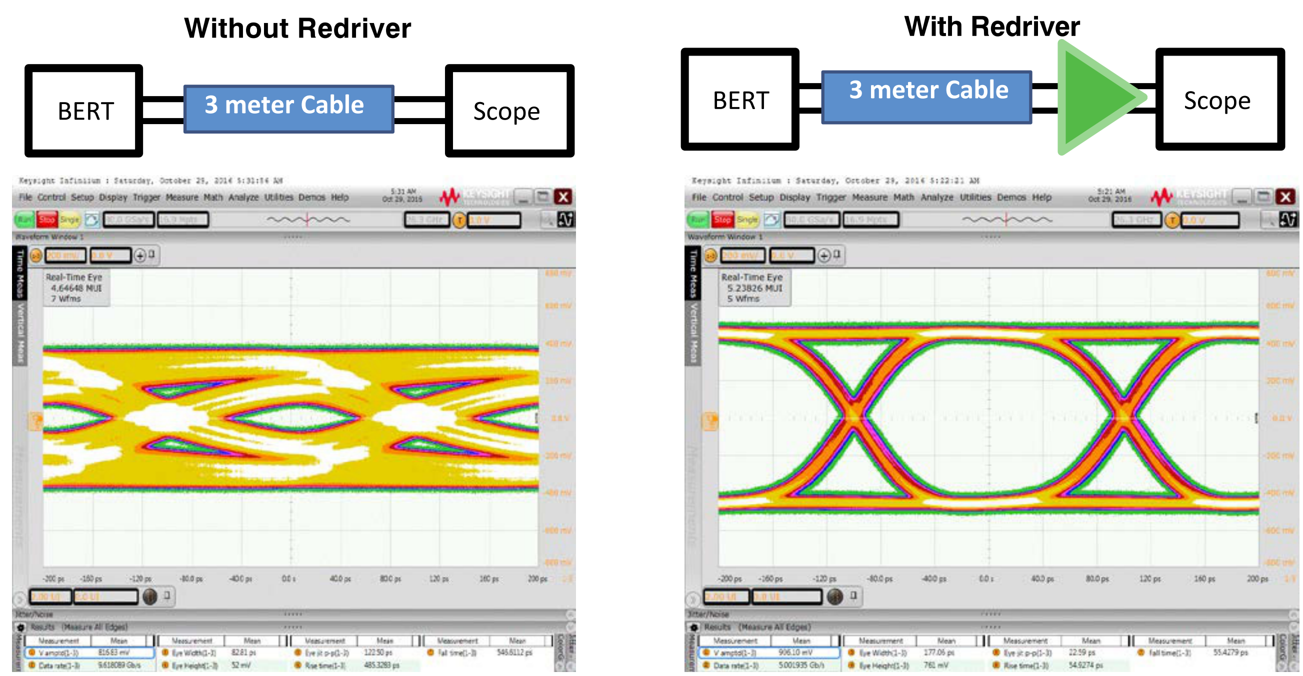

Figure 3. Example of Eye Diagram with and without Redriver when 3 Meter Cable is Used

Electronically Marked Cable Assembly EMCA – Basics:

Figure 4 shows the basic setup for EMCA in the Cable. The UFP (upstream facing port) has a pull down resistor Rd while the DFP (downstream facing port) has a pull up resistor Rp on the CC lines. This resistor divider decides the device attach or detach and the orientation since only one CC line connects across cable. Only one CC Pin connects through the Cable, the other CC Pin acts as Vconn by DFP when termination Resistor Ra is detected. Rp/Rd on one of the CC Pins allows detection of the connection and identify orientation of the Type−C plug. DFP/UFP checks both CC Pin for Voltage changes on Type−C receptacle for the connection event.

Generally DFP are ports on the Host and sources Vbus and Vconn and the UFP are ports on Device that connects to DFP. A regular Non−EMCA cables will have Vconn pin floating on the Type−C Plug. In EMCA cables, the Vconn Pin needs to be powered for Marker Electronics inside the cables. In the case of passive EMCA Cable, there will be no conditioning of the Data signals. The PD Controller is placed on one side or both sides. The max power that can be drawn from the Vconn is 1W and Vconn voltage should be between 2.7 V to 5.5 V. Refer Figure 5.

In the case of Active EMCA Cable, along with the Controller will have a redriver for signal conditioning to enable usage of longer cables. The Cable controller with marker IC can be either on one side or both sides powered from the Vconn (5 V/1 W) required for Electronics and for Cable status checking. Refer to figure 6.

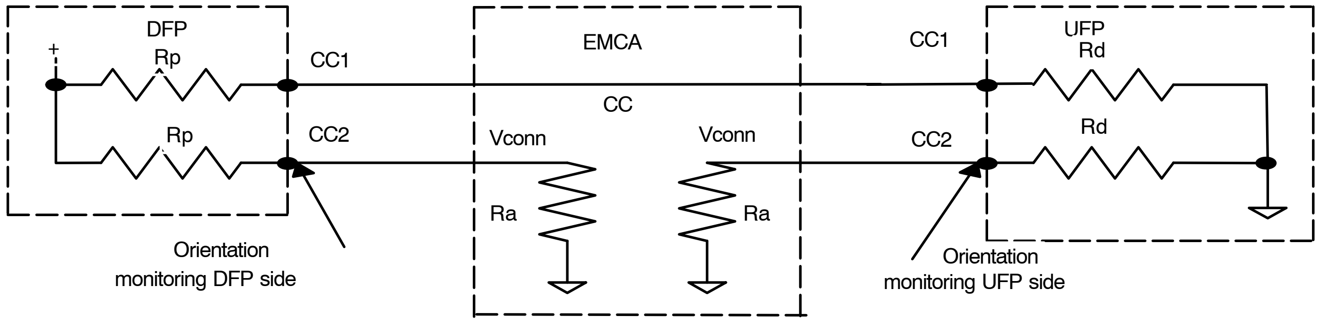

Figure 4. Basic Active Cable with EMCA

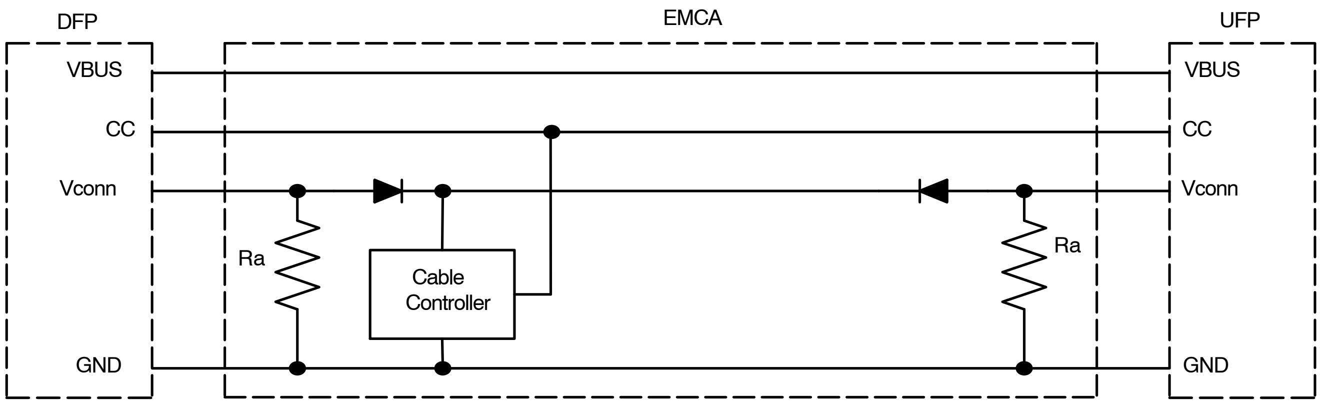

Figure 5. Passive EMCA Cable

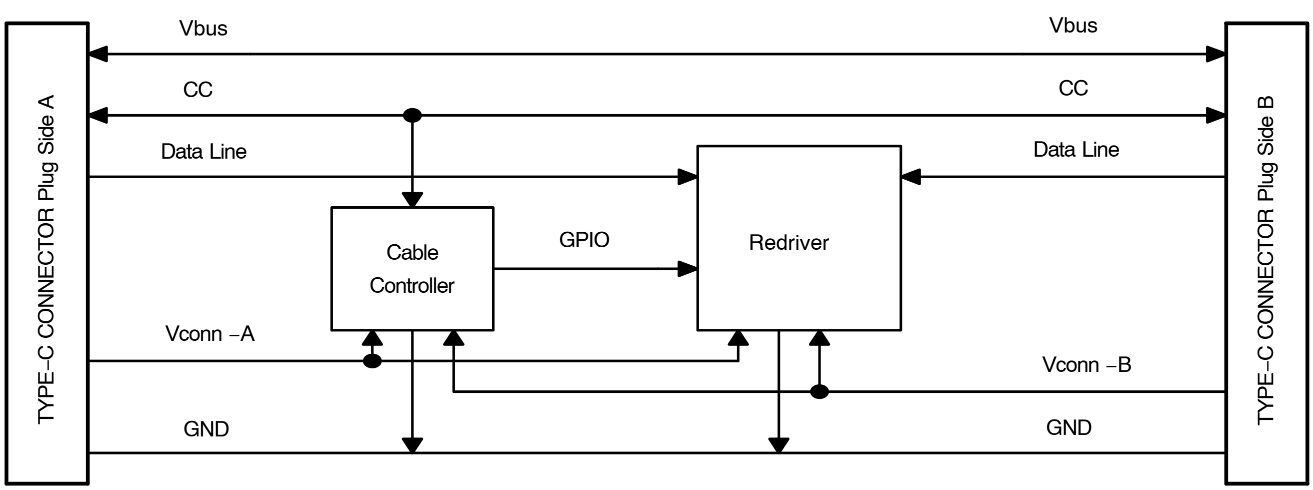

Figure 6. Active EMCA Cable with Redriver

ON Redrivers solutions for Active Cables:

ON Semiconductor provides 3 devices that can be used for Active cable application, namely NB7NPQ1102M, NB7NPQ7222M along with E−marker FUSB380 and NB7VPQ904M. Refer to appendix section for a brief note about these devices.

NB7NPQ1102M and NB7NPQ7222M:

Figure 7 given an example of the use of NB7NPQ7222M (or NB7NPQ1102M can also be used) in active cable with FUSB380 on both sides of the cable. The redriver and the E−Marker is powered from the VCONN that is routed through the cable. The isolation diodes (marked in red) are used to isolate the VCONN1 and VCONN2. Pin−strap mode helps to program the configuration without use of external devices. For only data transfer, these devices can be used with Type−A connector.

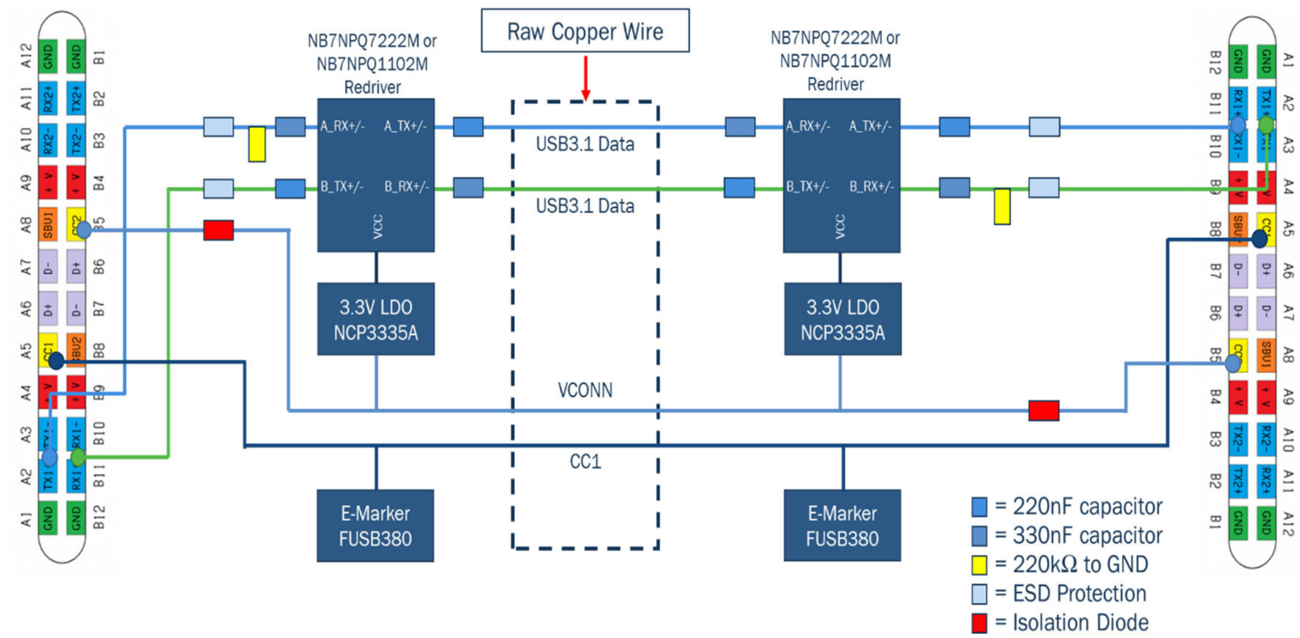

Figure 7. USB3.1 Gen 2 Type−C to Type−C Active Cable Connections using NB7NPQ7222M (or NB7NPQ1102M) on both sides of Cable with E−Marker FUSB380

NB7VPQ904M:

ON Semiconductor has developed solutions using Cypress CYPD2103−20 and Etron EJ903 E−Markers with NB7VPQ904M.

Figure 8 shows an example of usage of NB7VPQ904M in DP Alt. mode on a Type−C Cable. The powering is from VCONN using a Buck convertor and use of E−Marker with MCU control. While having same circuitry on both sides, TX & RX connections swap within the Type−C cable, so need to ensure that the proper connections are made between the two paddle cards as shown in Figure 9 below.

The differential impedance for the super speed data lines must be 90 Ω ± 10%. I2C programming provides more flexibility and tuning capability. Where Type−A to Type−C active cable use this device, it is required to reset the channel when the cable is unplugged.

Figure 10 and 11 shows the Schematic with Cypress and Etron E−Markers.

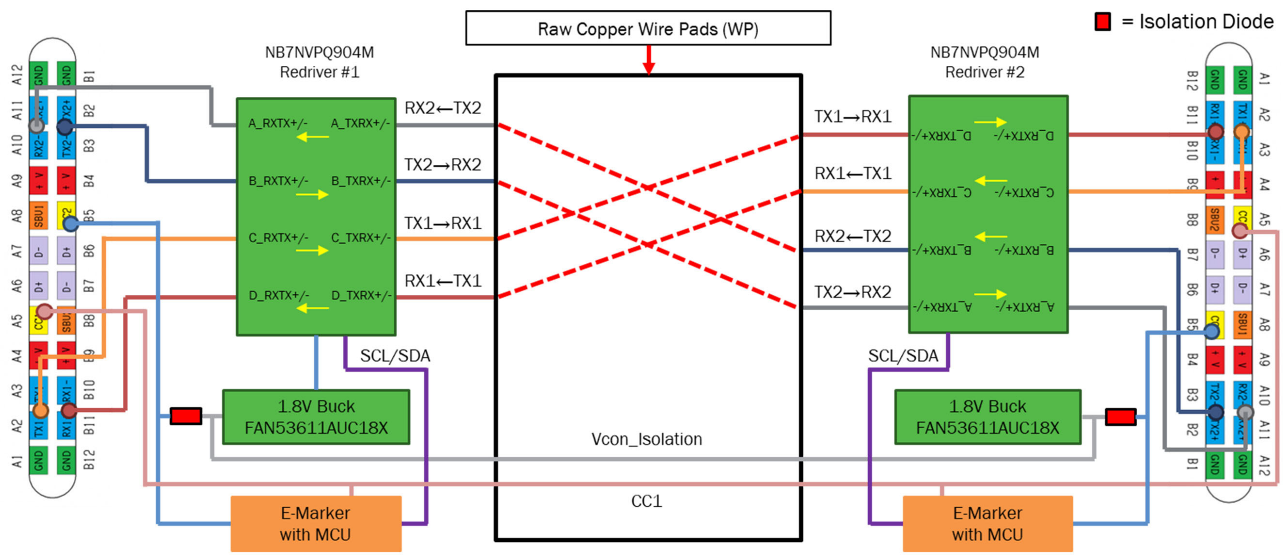

Figure 8. USB3.1 Type−C DP Alt. Mode Data Connections Using NB7VPQ904M on Both Sides of Cable

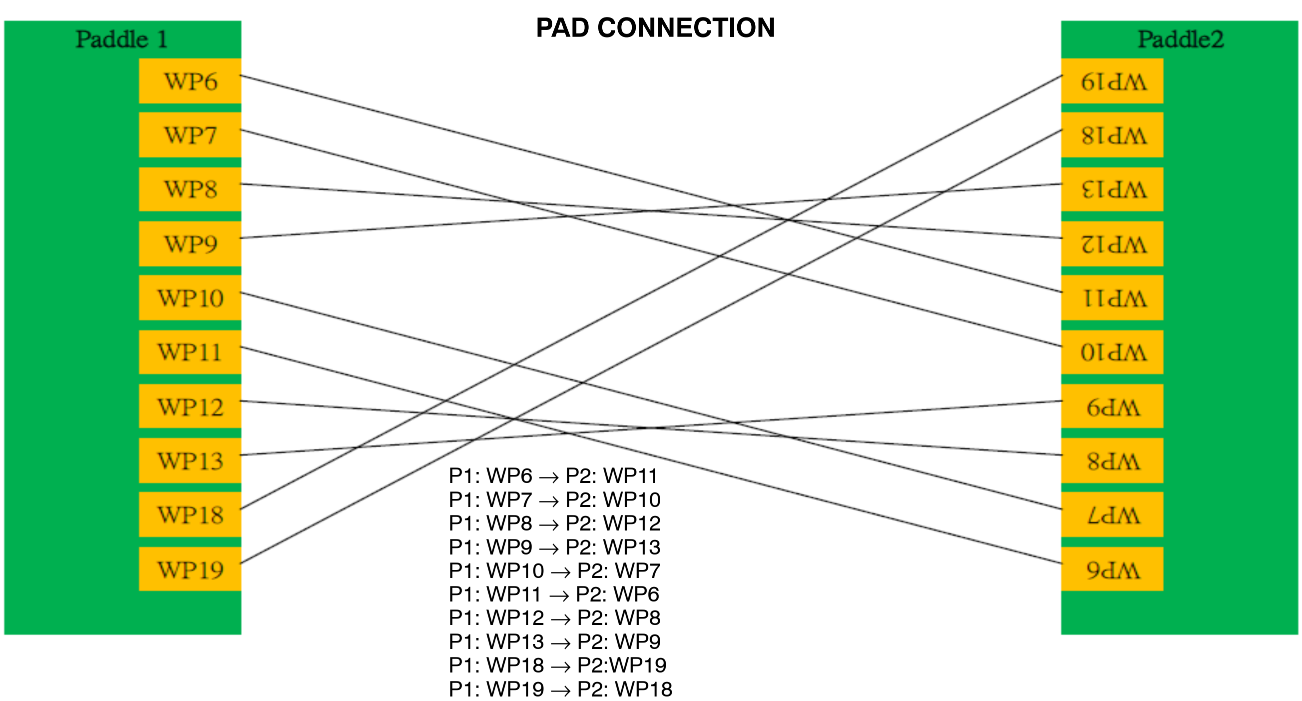

Figure 9. Paddle Card Pad Connection

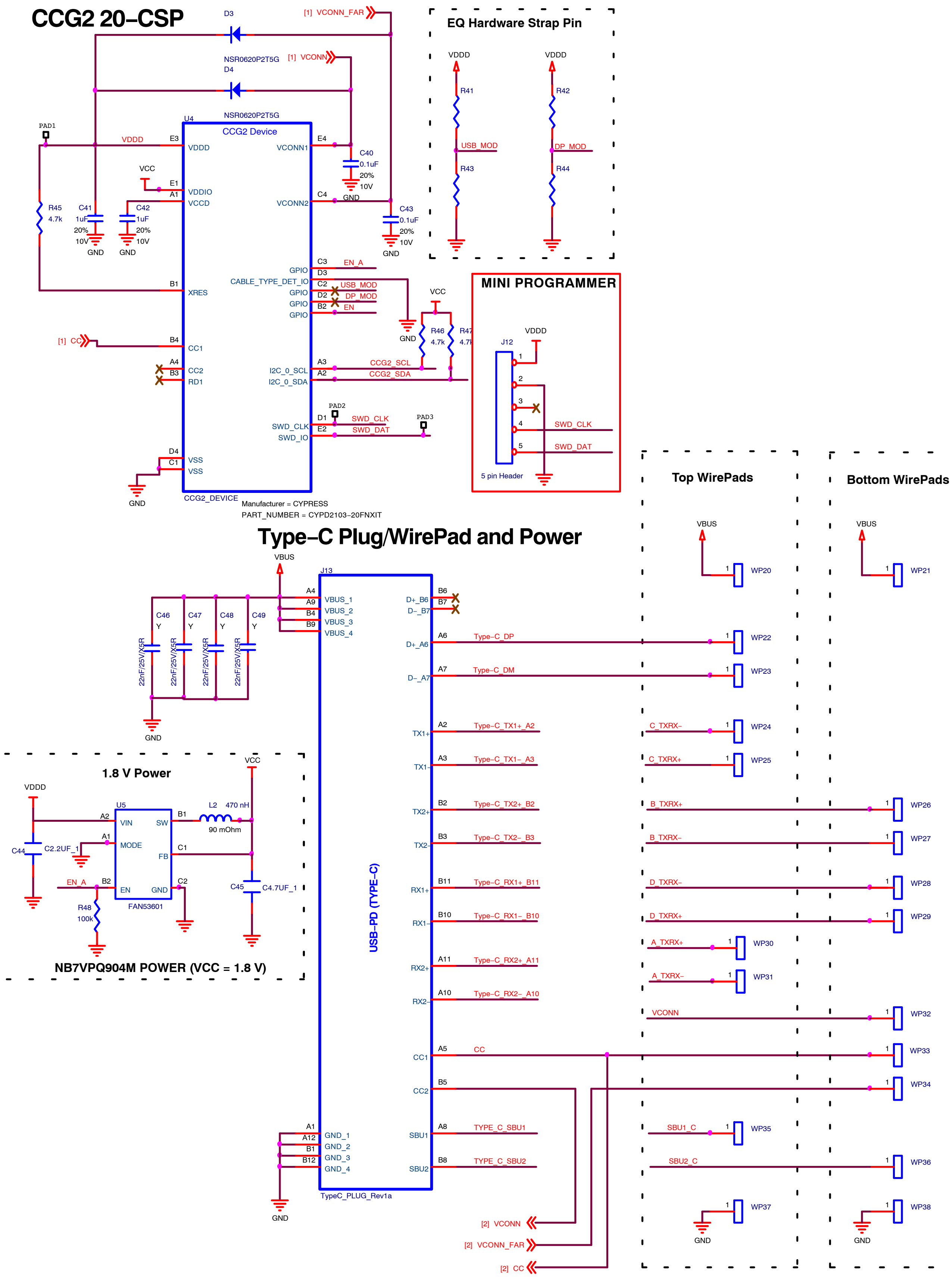

Figure 10. Schematic with Cypress E−Marker and NB7VPQ904M with Wire Pads and Power Connections

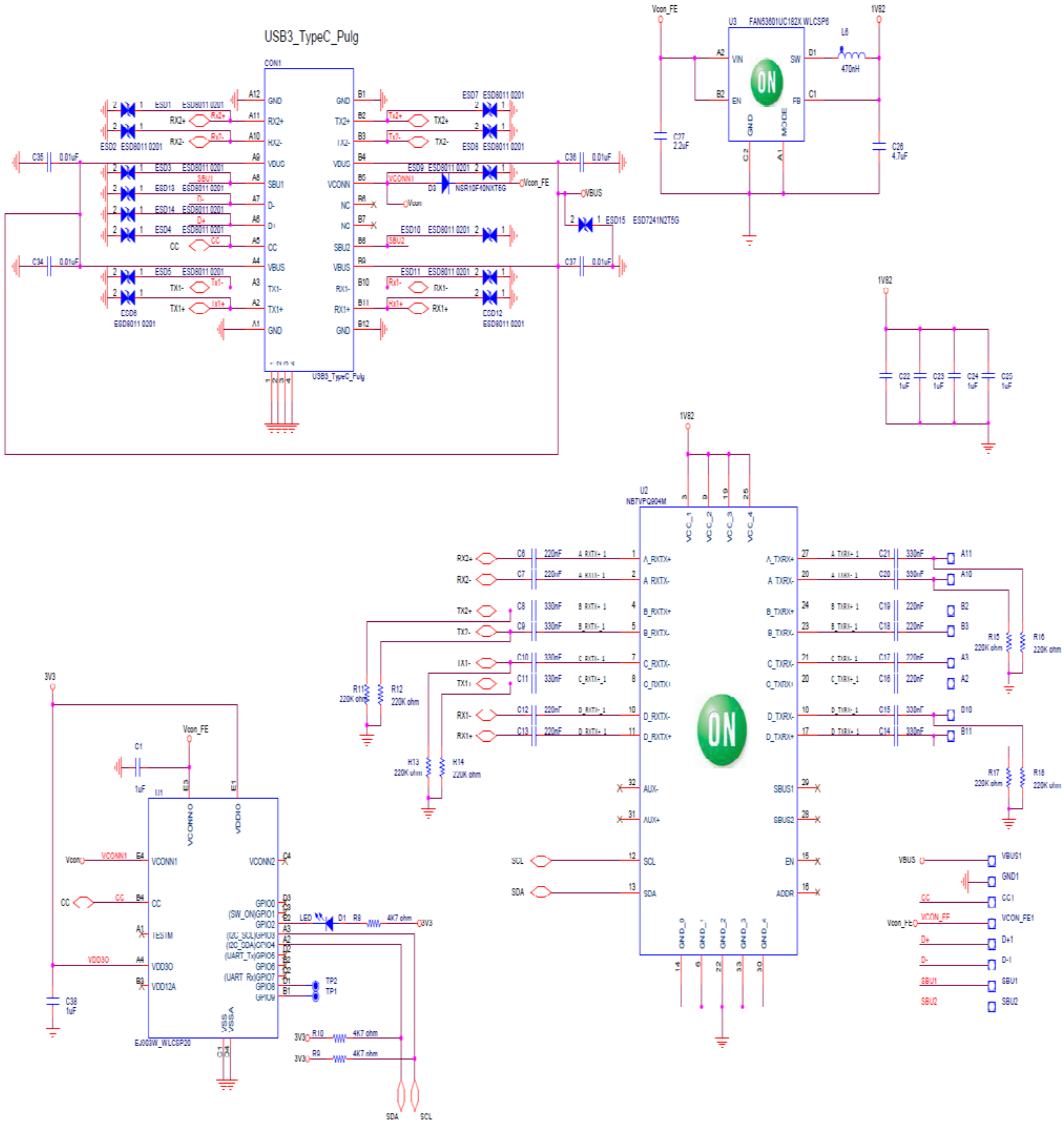

Figure 11. Schematic with Etron E−Marker and NB7VPQ904M with Power Connections

Conclusion

For the growing applications that calls for requirement of long cables with minimum attenuation losses and to be flexible in usage and being cost effective calls for use of Active cables with redrivers and EMCA that ensures maintaining signal integrity. ON Semiconductor Redrivers and E−Marker devices meeting these requirements has been discussed here. The appendix section below give a brief note for the Redrivers NB7NPQ1102M, NB7NPQ7222M and NB7VPQ904M devices along with ON Semiconductor E−Marker FUSB380.

APPENDIX

FUSB380 – Autonomous USB Type−C Cable Marker

Description:

The FUSB380 provides a small footprint solution for passive and active cable applications. 28 V Tolerant VCONN and CC provides VBUS shorting protection. One FUSB380 can be used in a VCONN through Type−C cable application or two FUSB380s can be used in each plug avoiding the high cost of routing VCONN through the Type−C cable. The FUSB380 offers industry leading VCONN operating range down to 2.4 V. Reduces cabling costs by being used at both ends of the able and eliminating the need to wire VCONN through entire cable. The device provides field programmable function, can be programmed by the customer via Vendor Defined Messages. Figure 12 shows the Block Diagram. Figure 13 shows typical application Diagram.

Features

- Integrated USB−PD 3.0 Protocol Layer and Device Policy Engines.
- 5x Programmable for Different Cable Configurations.
- USB PD 2.0 and 3.0 Certified.
- Robust Design Features:
  - 28 V Tolerant CC and VCONN.
  - Integrated Isolation Between VCONN1 and VCONN2.
  - 2.4 V – 5.5 V VCONN Operation,
- Field Programmable for Different Cable Configurations.
- SOP’ Signaling Support.
- Automatic Ra Weakening to Reduce Power Consumption.
- 12 Pin WLCSP (1.21 mm x 1.67 mm).

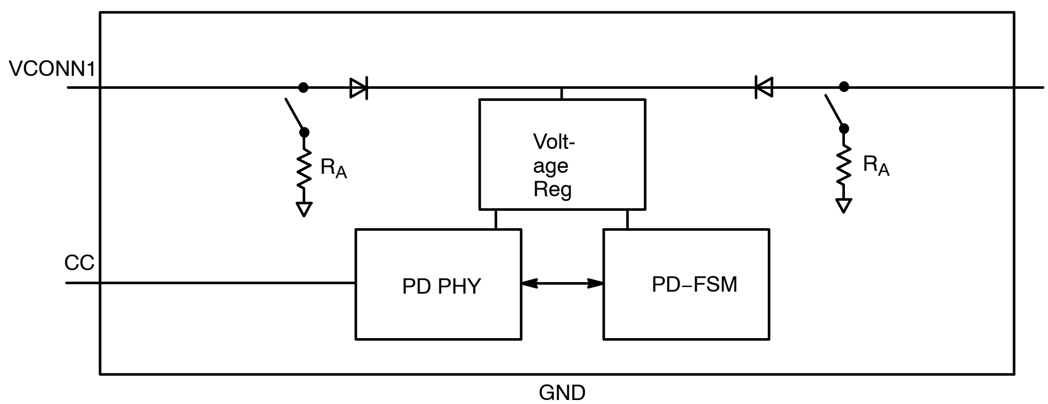

Figure 12. E−Marker Block Diagram

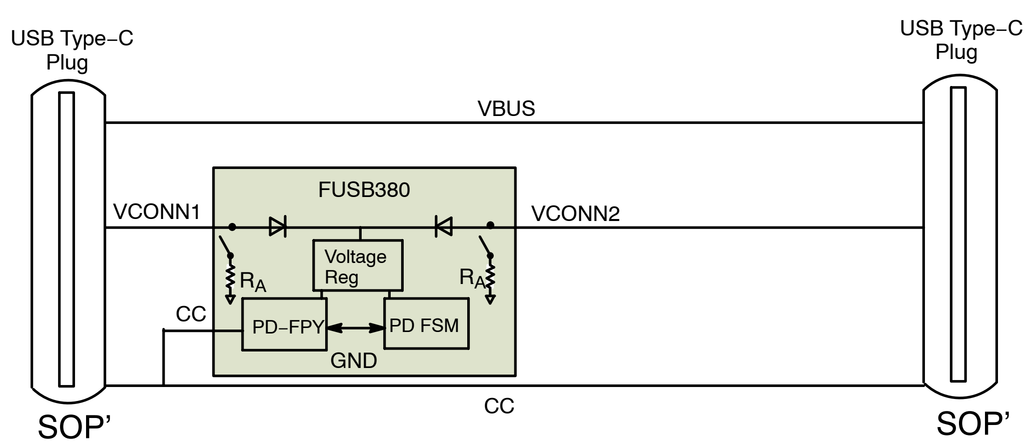

Figure 13. One E−Marker with VCONN through the Cable

NB7NPQ1102M: 3.3 V USB 3.1 Gen−2 10_Gbps Dual Channel /Single Port Linear Redriver

Description

The NB7NPQ1102M is a high performance single−Port linear redriver designed for USB 3.1 Gen 1 and USB 3.1 Gen 2 applications that supports both 5 Gbps and 10 Gbps data rates.

Signal integrity degrades from PCB traces, transmission cables, and inter−symbol interference (ISI). The NB7NPQ1102M compensates for these losses by engaging varying levels of equalization at the input receiver, and flat gain amplification on the output transmitter. The NB7NPQ1102M offers programmable equalization and flat gain to optimize performance over various physical mediums.

The NB7NPQ1102M contains an automatic receiver detect function which will determine whether the output is active. The receiver detection loop will be active if the corresponding channel's signal detector is idle for a period of time. The channel will then move to Unplug Mode if a load is not detected, or it will return to Low Power Mode (Slumber mode) due to inactivity. Both the channels are independent with individual controls. Figure 14 shows the Logic Diagram (NB7NPQ7222M will be similar).

The NB7NPQ1102M comes in a 2.5 x 4.5 mm WQFN30 package and is specified to operate across the entire industrial temperature range, –40°C to 85°C.

Features

- 3.3 V ± 0.3 V Power Supply
- 5 Gbps & 10 Gbps Serial Link with Linear Amplifier Device Supports USB 3.1 Gen 1 and USB 3.1 Gen 2 Data Rates USB 3.1
- Super Speed Gen1 & Gen2 Standard Compliant Automatic Receiver Detection
- Integrated Input and Output Termination
- Pin Adjustable Receiver Equalization and Flat Gain
- Pin Adjustable Output Linear Swing
- 100 Ω Differential CML I/O's
- Auto Slumber Mode for Adaptive Power Management
- Hot−Plug Capable
- ESD Protection ±4 kV HBM

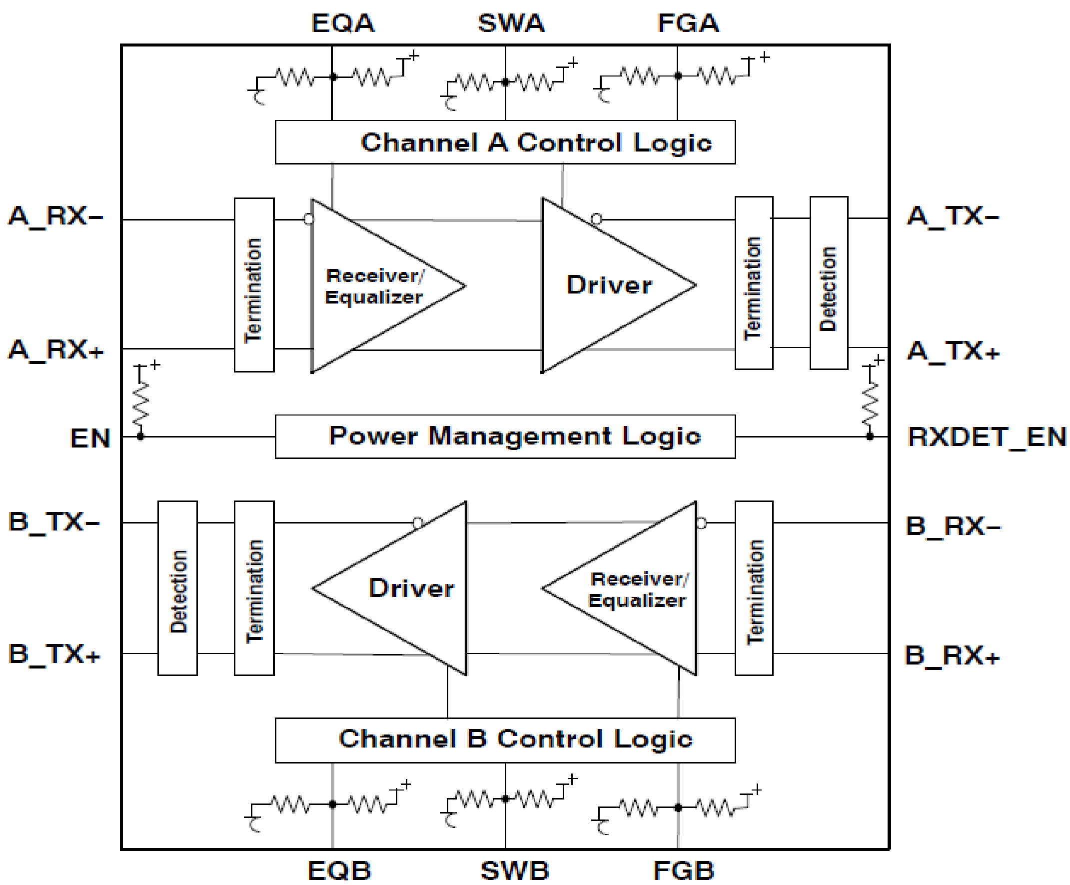

Figure 14. NB7NPQ1102M Logic Diagram

NB7NPQ7222M: USB 3.2 Dual Channel High Gain Linear Redriver, 3.3 V

Description

The NB7NPQ7222M is a 3.3 V dual channel, high gain, redriver for USB 3.2 Gen 1 and USB 3.2 Gen 2 applications that supports both 5 Gbps and 10 Gbps data rates. Signal integrity degrades from PCB traces, transmission cables, and inter−symbol interference (ISI).

The NB7NPQ7222M compensates for these losses by engaging varying levels of equalization at the input receiver, and flat gain amplification on the output transmitter. The Flat Gain and Equalization are controlled by four level control pins. Each channel has a set of independent control pins to make signal optimization possible.

After power up, periodic check of TX output is made for the receiver connection. When the receiver is detected, the RX termination becomes enabled and the device is set to perform the redriver function. Note that both channels are independent of each other.

The NB7NPQ7222M comes in a small 3 x 3 mm UQFN16 package and is specified to operate across the entire industrial temperature range of –40°C to 85°C. Figure 15 shows typical application (NB7NPQ1102M will be similar).

- 3.3 V ± 0.3 V Power Supply
- Low Power Consumption: 114 mA in Active Mode
- Supports USB 3.2 Gen 1 and USB 3.2 Gen 2 Data Rates
- Backwards Compatible with USB 3.1 Gen 1 / Gen 2 and USB 3.0
- Automatic Receiver Termination Detection
- Integrated Input and Output Termination
- Independent
- Selectable Equalization and Flat Gain
- Hot−Plug Capable
- Operating Temperature Range: −40°C to +85°C
- Small package allows flow through design for ease of PCB Layout

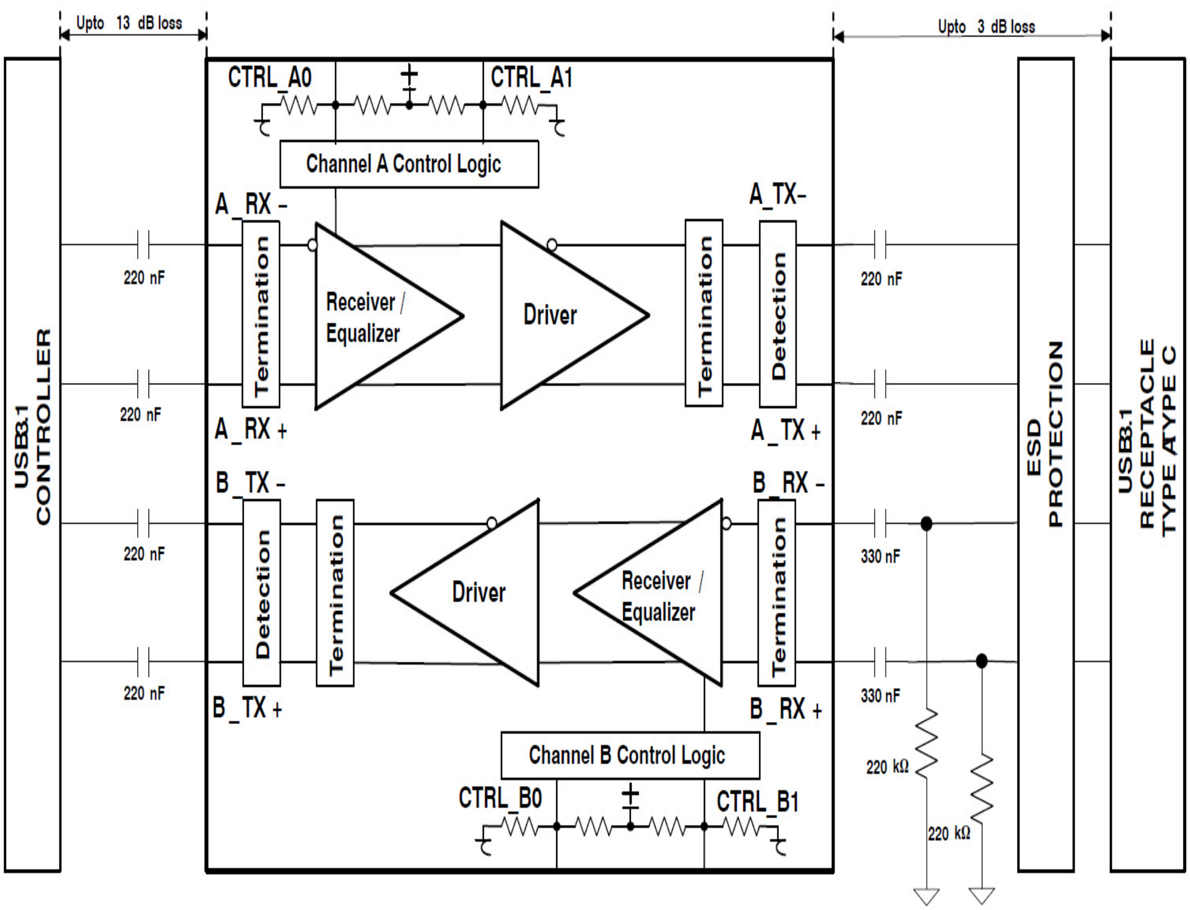

Figure 15. Typical USB 3.1 Host Side NB7NPQ7222M Application

NB7VPQ904M: 1.8 V USB Type−C^{TM} DisplayPort^{TM} ALT Mode 10_Gbps Linear Redriver

Description

The NB7VPQ904M is a 1.8 V USB Type−C DisplayPort Alternate Mode Linear redriver fully supporting DisplayPort 1.4 (8.1 Gbps) and USB 3.1 Gen 1/Gen 2 (5/1 Gbps) protocols. Signal integrity degrades from PCB traces, transmission cables, and inter−symbol interference (ISI). The NB7VPQ904M compensates for these losses by engaging varying levels of user selectable flat gain & equalization to create the best eye opening for the outgoing data signals.

The NB7VPQ904M's four channels are bi−directional and can be programmed to be receiving or transmitting channels. This allows the NB7VPQ904M to fully support up to four DisplayPort Lanes or two USB 3.1 Gen 2 Ports configurations. The NB7VPQ904M also features an integrated passive switch to control polarity of SBU1/SBU2 signals coming from the USB Type−C connector to match DisplayPort Auxiliary channel AUX+/AUX− signals.

The NB7VPQ904M is equipped with I2C programmability to easily control Auxiliary Channel Orientation, USB/DP operation modes, DP Channel Direction Control, Polarity Inversion, Channel Power Down, Equalization, Flat Gain and Output −1 dB Compression settings. After power up, the NB7VPQ904M periodically checks TX output pairs for a receiver. Once the receiver is detected the RX termination of that channel will be enabled and the NB7VPQ904M is set to perform the re−driver function.

Figure 16 shows the Block Diagram.

Features

- I2C Programming:
  - Equalization Settings: 0 to 10 dB @ 2.5 Ghz
  - Flat Gain Settings: 0 dB, +1.5 dB & +3.5 dB
  - Output −1 dB Compression Settings: 600 mV, 800 mV & 1000 mV,
  - Operation Modes: USB3.1 Gen1 & Gen2 and DisplayPort 1.4
  - Topologies with DP Channel Direction Control
  - Individual Channel Enable/Disable
  - Polarity Inversion Control for All Data I/O's
- Integrated Switch for DisplayPort Auxiliary Channel
- Chip Enable Pin for Deep Power−Saving Mode
- Automatic Receiver Termination Detection
- Integrated I/O Termination
- Hot−Plug Capable
- Operating Temperature Range: 0°C to 70°C
- 1.8 V ± 5% Power Supply
- Quad Channel Re−Driver Supporting Data Rates up to 10 Gbps

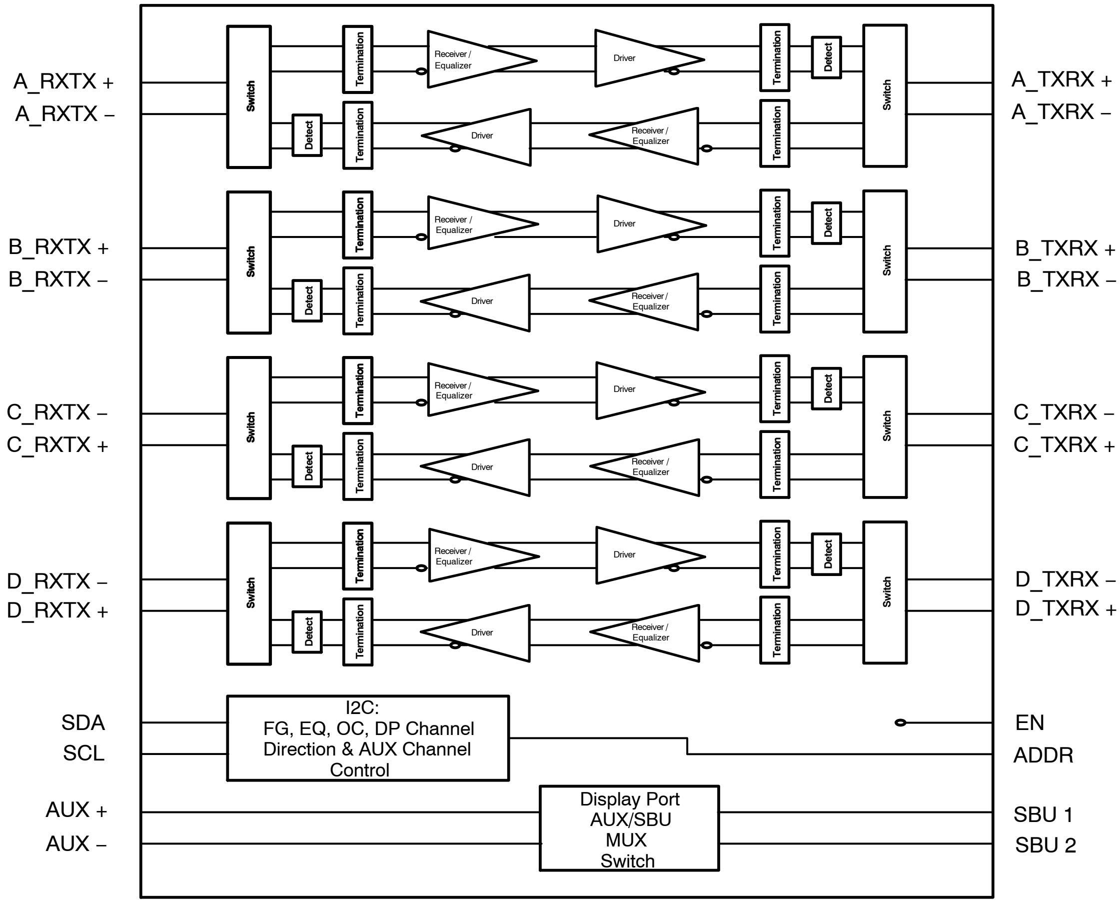

Figure 16. Simplified Block Diagram

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