USB UART BOARD DESIGN RECOMMENDATIONS AND CONSIDERATIONS FOR USB COMPLIANCE

1.0 INTRODUCTION

The MaxLinear families of USB UARTs, USB Ethernet Bridges and USB Hubs are shown in Table 1. All have passed compliance for USB 2.0 Full-Speed peripherals (USB UARTs and Hubs) and USB 2.0 High-Speed (USB Hubs and Ethernet Bridges). This application note describes some scenarios to consider when designing a product using any of these USB families to ensure a robust product using basic good design practices, as well as to have a higher likelihood of passing USB compliance, if the product will be compliance tested.

TABLE 1: MAXLINEAR'S USB UART , USB ETHERNET BRIDGES AND USB HUB FAMILIES

Part	Power Input	Datasheet Title
XR21V1410	3.3V	1 Channel Full-Speed USB UART
XR21V1412		2 Channel Full-Speed USB UART
XR21V1414		4 Channel Full-Speed USB UART
XR21B1411	5V	Enhanced 1 Channel Full-Speed USB UART
XR21B1420	3.3V or 5V	Enhanced 1 Channel Full-Speed USB UART
XR21B1422		Enhanced 2 Channel Full-Speed USB UART
XR21B1424		Enhanced 4 Channel Full-Speed USB UART
XR21B1421	3.3V or 5V	Enhanced 1 Channel Full-Speed USB HID to UART Bridge
XR22800	3.3V or 5V	Hi-Speed USB to 10/100 Ethernet Bridge
XR22801		Hi-Speed USB to 10/100 Ethernet Bridge with 1 UART
XR22802		Hi-Speed USB to 10/100 Ethernet Bridge with 2 UARTs
XR22804		Hi-Speed USB to 10/100 Ethernet Bridge with 4 UARTs
XR22404	3.3V or 5V	USB 2.0 4-Port Hub
XR22414	3.3V or 5V	USB 2.0 4-Port MTT Hub
XR22417	5V	USB 2.0 7-Port Hub

2.0 DESIGN CONSIDERATIONS

The first design requirement is to ensure that connections of the USB data signals (USBD+ / USBD-) are routed with 90Ω differential impedance and are directly connected to the USB host with no external components that affect this impedance. All of MaxLinear's USB UARTs and USB Ethernet bridge devices are designed to be directly connected. Any external shunt or series capacitors, inductors or resistors will significantly degrade the USB data signals and potentially cause the device to fail communications with the host. However, some ESD protection diodes and some EMI filters have been tested at USB full and high speed and demonstrated not to affect the USB data signaling. Only components tested for USB 2.0 compliance should be used on the USBD+ and USBD- signals.

A second design option to consider is whether the USB product will be a self-powered or bus-powered design.

In a self-powered design, an alternative power source is supplied for example via a power jack or battery to the USB UART and other components on the board. Figure 1 shows a self-powered design using the XR21V141x

with 3.3V V_{CC}. Figure 2 shows a self-powered design using the XR21B142x with 5V V_{CC}. Design considerations for a self-powered design are discussed in Section 2.1.

In a bus-powered design, the 5V from the VBUS of the USB connector (from the USB host) provides the power source for the USB UART and possibly other components on the board. Figure 3 shows a bus powered design for XR21V141x and Figure 4 shows a bus powered design for XR2280x. Other families using 5V VCC would not require the 5V to 3.3V LDO. Design considerations for a bus-powered design are discussed in Section 2.2.

FIGURE 1. TYPICAL BLOCK DIAGRAM FOR SELF-POWERED APPLICATIONS WITH 3.3V V_{CC}

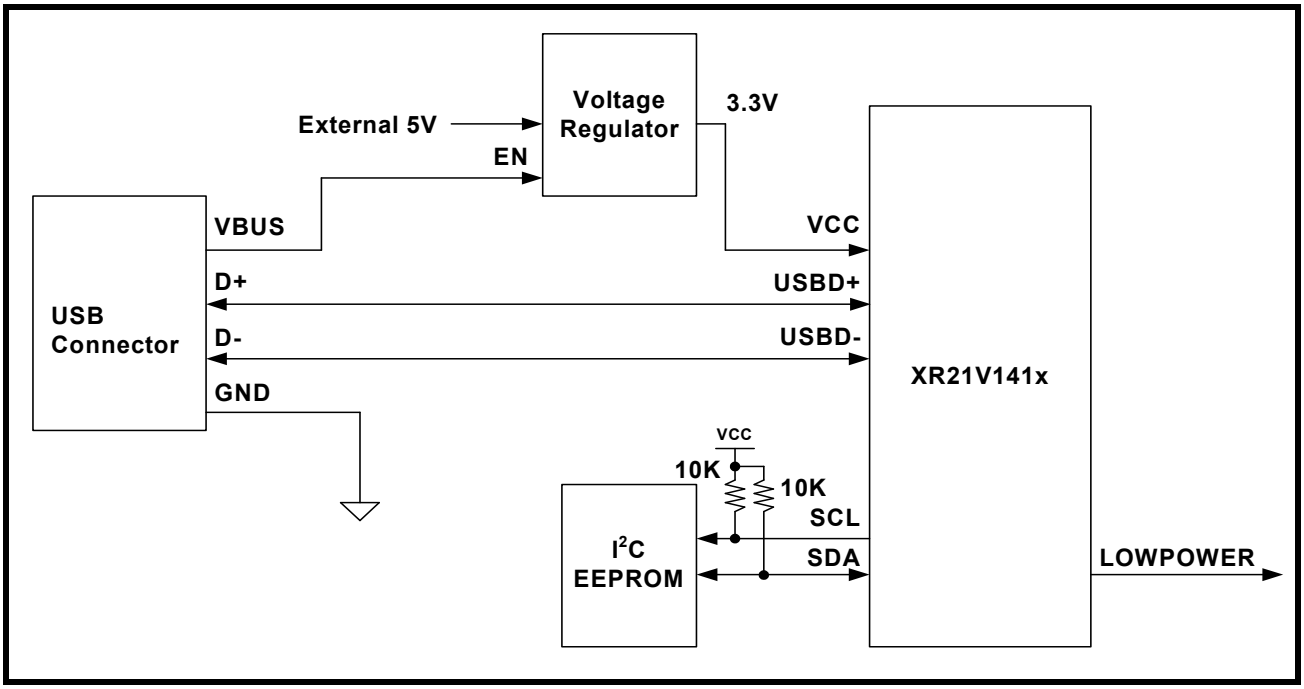
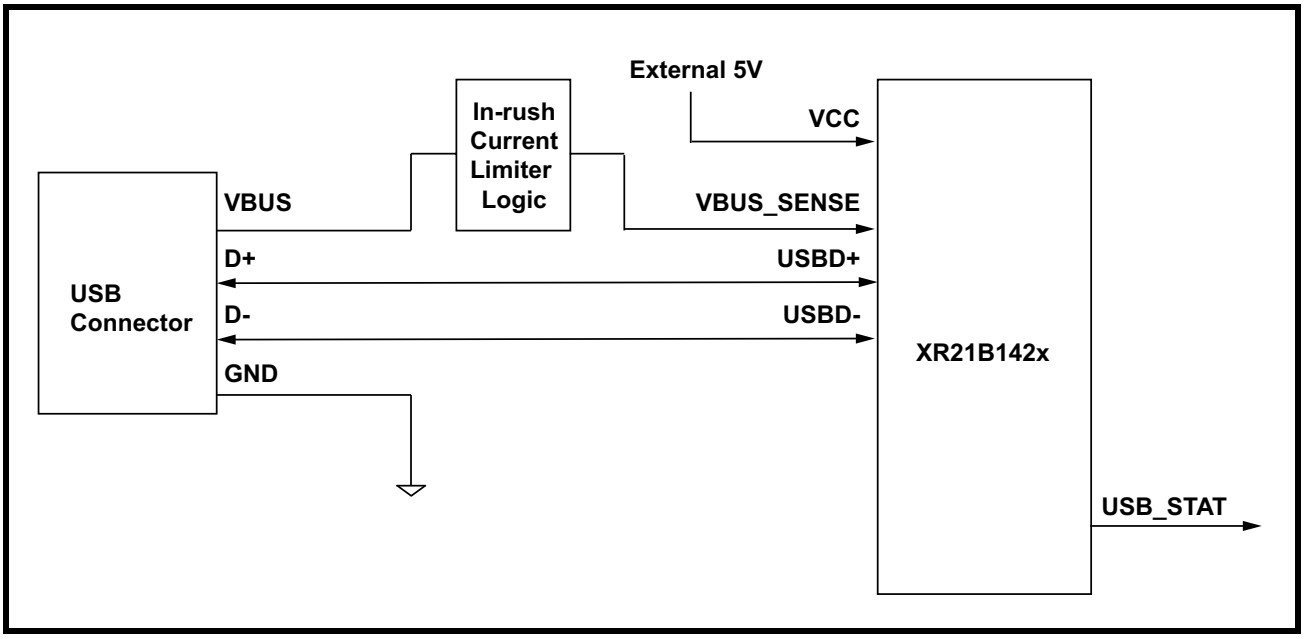


FIGURE 2. TYPICAL BLOCK DIAGRAM FOR SELF-POWERED APPLICATIONS WITH 5V V_{CC}



2.1 Design Considerations for Self-Powered Applications

This section discusses the various design considerations for a self-powered application.

2.1.1 VBUS

VBUS from a USB host is the 5V power which may vary from a minimum of 4.4V up to 5.25V. To conform to USB specification, the pull-up resistor on the USBD+ signal must not be pulled high unless VBUS from the USB host is connected to the device. To ensure this in self-powered mode, power to the USB UART must be disconnected or turned off. One way to do this in the XR21V141x family is to use the VBUS to disable power to the XR21V141x. For example, if using a voltage regulator, the VBUS can be connected to the ENABLE pin to enable/disable the voltage regulator. In XR21B1411, as well as the XR21B142x and XR2280x families of devices, when powered by 5V, VBUS can be connected to the VBUS_SENSE pin of these devices. Also note that by USB spec, a self powered USB peripheral is allowed to use up to 100mA of VBUS power for "basic" functionality.

2.2 Design Considerations for Bus-Powered Applications

This section discusses the various design considerations for a bus-powered application.

FIGURE 3. TYPICAL XR21V141X BLOCK DIAGRAM FOR BUS-POWERED APPLICATIONS

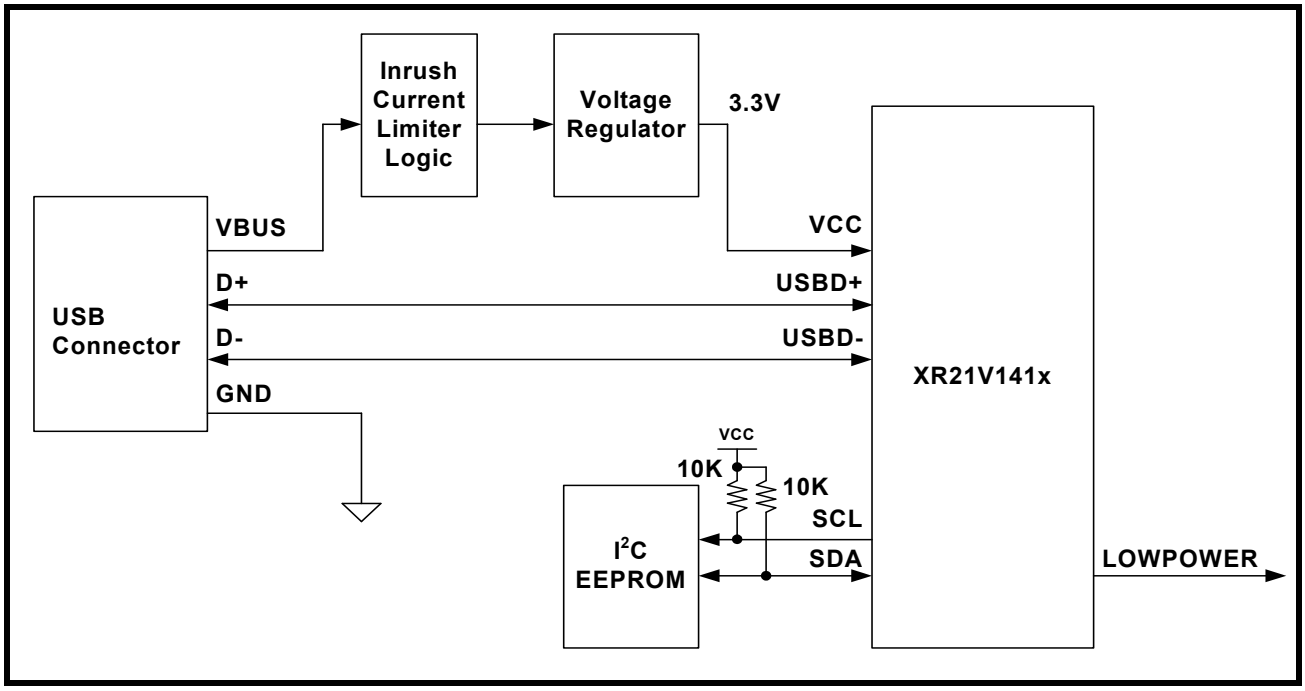
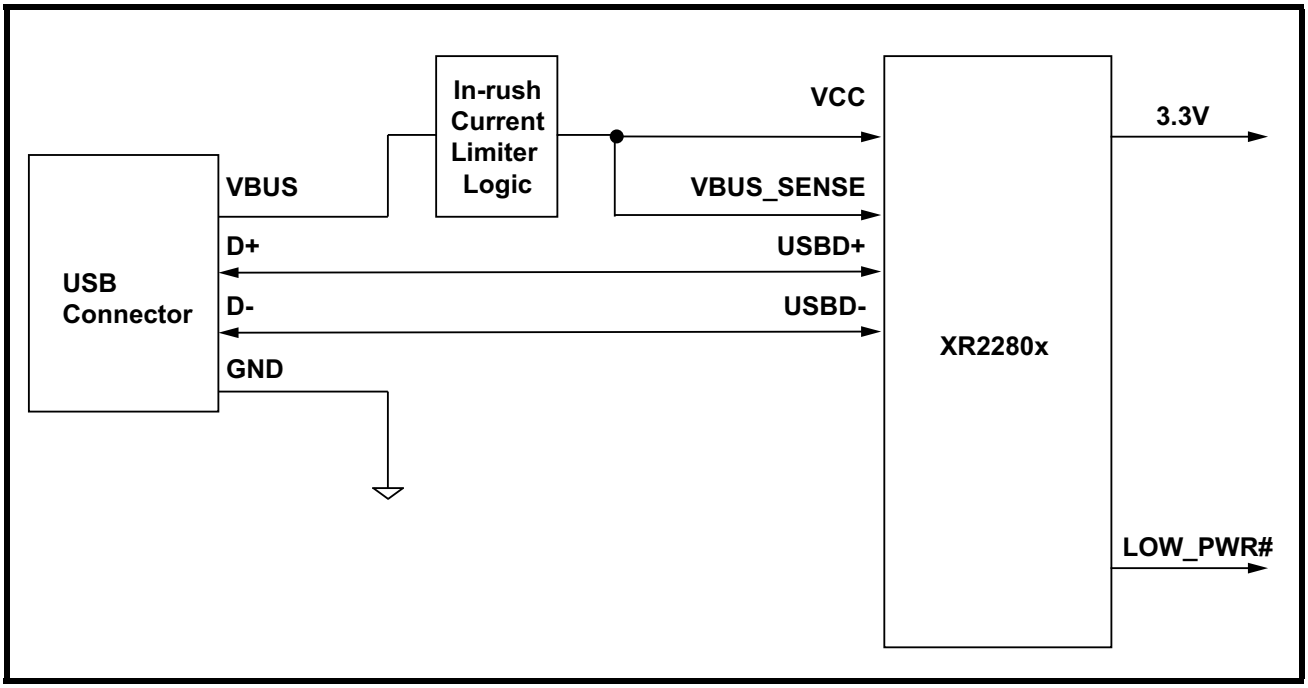


FIGURE 4. TYPICAL XR2280X BLOCK DIAGRAM FOR BUS-POWERED APPLICATIONS



2.2.1 VBUS

A voltage regulator is required to regulate the 5V VBUS signal down to 3.3V for XR21V141x family devices. An example of a cost-efficient MaxLinear LDO that can be used is the SP6260, which provides a guaranteed 200mA output current at 3.3V.

2.2.2 In-rush Current

The in-rush current is a measure of how much power the product draws when it is initially connected to a USB host/hub. According to the USB 2.0 specifications, the in-rush current needs to be limited to 100 mA/μs in order to prevent the surge of current into the board from pulling the VBUS from the host below its minimum operating level. To minimize the amount of in-rush current, an in-rush current limiting circuit (as depicted in Figures 2 and 3) is recommended and the bypass capacitance on the VBUS signal should be limited to 10μF. An example of an in-rush current limiter can be found in any of the MaxLinear USB UART evaluation board schematics.

If an in-rush current limiting circuit is not used (as for example in Figure 1), note that in some cases a voltage spike from the VBUS voltage applied to the USB UART PCB may occur. This voltage spike can cause damage to the USB UART and is caused by a known effect when a step voltage is applied through a large inductance to a shunt capacitance with low Equivalent Series Resistance (ESR). The step voltage is created when connecting a USB cable to the VBUS 5V source. The large inductance is induced by the USB cable and typical ceramic capacitors have a very low ESR. For embedded designs that connect an MCU on PCB traces, this is not an issue. The recommended solution, when the system will connect through a USB cable and no in-rush circuit is used, is to use a tantalum capacitor which can provide enough ESR to prevent a damaging voltage spike.

2.2.3 Suspend Mode Current

According to the USB specification, all USB peripheral devices must support the Suspend Mode when a USB host is put in a sleep / hibernation state or when selected USB ports are suspended. During normal operation, different USB packets including Start-Of-Frame (SOF) packets are sent by the USB host to a Full-Speed USB device. When the peripheral device does not see any USB traffic including Start-of-Frame (SOF) packets for more than 3ms, it begins to enter, and within 7ms completes the entry to a low power Suspend Mode.

2.2.3.1 Maximum Suspend Current

In April 2008, an ECN was issued by USB-IF increasing the maximum allowed suspend current of bus-powered products from 500μA to 2.5mA per device or device function. This 2.5mA limit includes all devices, i.e not just the USB peripheral device, that use power from the USB host VBUS power. Therefore, it is recommended that the other components on the board have low power or shutdown modes to minimize the power consumption during suspend mode. Note that the XR2280x family has multiple functions and thus has higher allowed suspend current. Consult each individual datasheet for lists of the XR2280x functions.

2.2.3.2 LOWPOWER / USB_STAT Output Pin

The LOWPOWER pin (or USB_STAT pin) on MaxLinear USB UARTs can be used as a control signal to enable/disable other devices in the design. When a MaxLinear USB UART enters the suspend mode, the LOWPOWER pin or USB_STAT pin will be asserted so that the other devices can be signaled to also enter into a low power mode.

2.2.4 VBUS_SENSE

The VBUS_SENSE pin for all devices except the XR21V141x family is used in self-powered mode to indicate the connection of the device to the USB host. In self-powered mode, external power to the device may be present when the host is not connected. In this condition, a “back-voltage” may be present on USB signals which will cause both a failure of USB certification testing and additionally may cause the host to fail to properly enumerate the device. The VBUS_SENSE pin in self-powered mode must be connected to the host VBUS power pin. Exact connections, additional component requirements, etc. are documented in the individual datasheets. In embedded applications where the host and device are powered by the same power source, VBUS_SENSE may be just pulled up to a logic ‘1’ state. In the XR21V141x family, the external power source can be disabled by VBUS as shown in Figure 1.

2.3 External EEPROM or On-chip OTP

An external I^2C EEPROM with the XR21V141x family, or on-chip OTP in the XR21B1411, XR21B142x and XR2280x families of devices, can be used to specify / modify various USB configuration values such as the Vendor ID, Product ID, Device Attributes, and Maximum Power consumption.

2.3.1 USB Descriptors

USB descriptors are the mechanism that peripheral devices use to pass information / values about the device functionality, manufacturer, USB class, etc. to the host. The primary USB descriptor a board designer might be concerned with is the Configuration descriptor. Within the Configuration descriptor are the bmAttributes and bMaxPopwer fields.

2.3.1.1 bmAttributes

The bmAttributes field lets the USB host/hub know whether the USB UART is bus-powered or self-powered and whether it has support for Remote Wakeup capability. All of MaxLinear’s USB UARTs advertise bus power by default and all support remote wakeup by default with the exception of the HID class XR21B1421 device. The external EEPROM or OTP can be used to modify these settings. Additionally, in the XR21V141x family, the SDA and SCL pins can be used to configure these settings if an EEPROM is not used.

To initiate remote wakeup signaling to a suspended USB host, typically a debounced switch connected to the RI# pin initiates the resume signaling to the USB host from either positive, negative or both edges depending upon the UART selected.

Note that all of MaxLinear’s USB UARTs are USB CDC class devices with the exception of the XR21B1421. As such, these devices can use a CDC-ACM driver native to all major OS or the custom supplied MaxLinear driver. However the CDC driver does not support remote wakeup, irrespective of the device descriptors.

2.3.1.2 bMaxPower

The bMaxPower field lets the USB host know the maximum VBUS power consumption requirement, if the device is bus powered. All of MaxLinear’s USB UARTs advertise a maximum of 100mA (or 1 unit load) by default. By USB 2.0 specification, a peripheral device requiring 100mA or less of VBUS power is classified as a

low power device. A device advertising a power requirement of greater than 1 and up to 5 unit loads is classified as a high power device. The XR2280x Ethernet bridge family all has high powered devices advertising a bus power requirement of 250 mA. In USB 3, these values increase to 150mA and 6 unit loads, respectively. To reiterate, the bMaxPower advertised to the USB host includes all power drawn from the host VBUS by any devices on the PCB.

2.4 External EEPROM or On-chip OTP

The VBUS_SENSE pin for all devices except the XR21V141x family is used in self-powered mode to indicate the connection of the device to the USB host. In self-powered mode, external power to the device may be present when the host is not connected. In this condition a “back-voltage” may be present on USB signals which will cause both a failure of USB certification testing and additionally may cause the host to fail to properly enumerate the device. The VBUS_SENSE pin in self-powered mode must be connected to the host VBUS power pin. Exact connections, additional component requirements, etc. are documented in the individual datasheets. In embedded applications where the host and device are powered by the same power source, VBUS_SENSE may be just pulled up to a logic ‘1’ state. In the XR21V141x family the external power source can be disabled by VBUS as shown in Figure 1.

Corporate Headquarters:
5966 La Place Court
Suite 100
Carlsbad, CA 92008
Tel.:+1 (760) 692-0711
Fax: +1 (760) 444-8598
www.maxlinear.com

High Performance Analog:
1060 Rincon Circle
San Jose, CA 95131
Tel.: +1 (669) 265-6100
Fax: +1 (669) 265-6101
www.exar.com