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USB UART Board Design Recommendations for USB Compliance

Application Note AN202

Revision History

Document No.	Release Date	Change Description
202ANR01	May 28, 2021	**Updated:** ■ "MaxLinear's USB UART, USB Ethernet Bridges, and USB Hub Families" table. ■ "Typical XR2280x Block Diagram for Bus-Powered Applications" figure. ■ Latest template and disclaimer applied.
202ANR00	August 8, 2018	Initial release.

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Introduction

Table 1 lists MaxLinear families of USB UARTs, USB Ethernet bridges, and USB hubs. All of them are USB 2.0 full-speed peripherals (USB UARTs and hubs) and USB 2.0 high-speed (USB hubs and Ethernet bridges) compliance.

This application note describes the scenarios to consider when you design a product using any of these USB families. It ensures a robust product by using basic design practices, as well as to have a higher likelihood of being USB compliant, if the product is compliance tested.

Table 1: MaxLinear's USB UART, USB Ethernet Bridges, and USB Hub Families

Part	Power Input	Data Sheet 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	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

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 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 significantly degrade the USB data signals and potentially cause the device to fail communications with the host. However, some of the ESD protection diodes and some of the EMI filters are 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 requirement to consider is whether the USB product is 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 on page 2 shows a self-powered design that uses the XR21V141x with 3.3V V_{CC}. Figure 2 on page 2 shows a self-powered design that uses the XR21B142x with 5V V_{CC}. For more information about design considerations for a self-powered design, see "Design Considerations for Self-Powered Applications" on page 3.
- 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 can also provide other components on the board. Figure 3 on page 3 shows a bus powered design for XR21V141x and Figure 4 on page 4 shows a bus powered design for XR2280x. Other families that use 5V V_{CC} should not require the 5V to the 3.3V LDO. For more information about design considerations for a bus-powered design, see "Design Considerations for Bus-Powered Applications.".

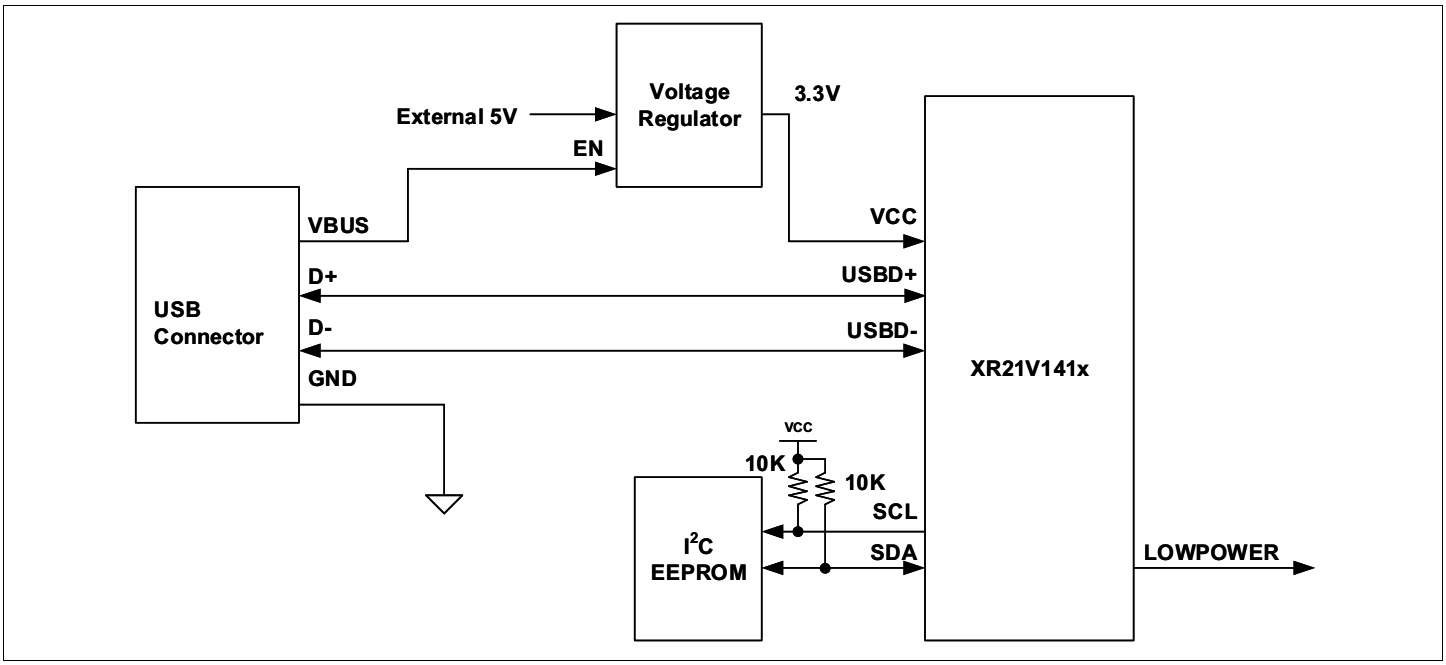

Figure 1: Typical Block Diagram for Self-Powered Applications with 3.3V V_{CC}

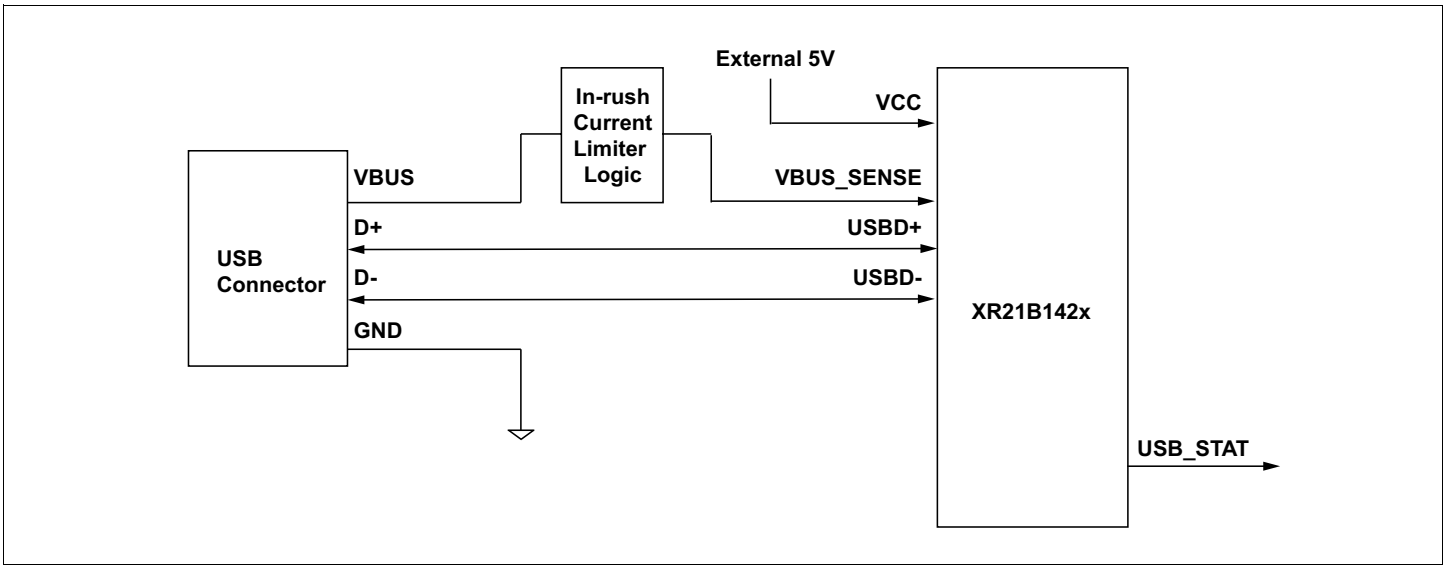

Figure 2: Typical Block Diagram for Self-Powered Applications with 5V V_{CC}

Design Considerations for Self-Powered Applications

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

VBUS

The VBUS from a USB host is the 5V power that can vary from a minimum from 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, the power to the USB UART must be disconnected or turned off. To do this in the XR21V141x family, you can use the VBUS to disable the power to the XR21V141x.

Example: If you use a voltage regulator, the VBUS can be connected to the `ENABLE` pin to enable/disable the voltage regulator. In the XR21B1411, XR21B142x, and XR2280x families, the VBUS can be connected to the `VBUS_SENSE` pin of these devices if powered by 5V. Also note that by the USB specification, a self-powered USB peripheral can use up to 100mA of the VBUS power for *basic* functionality.

Design Considerations for Bus-Powered Applications

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

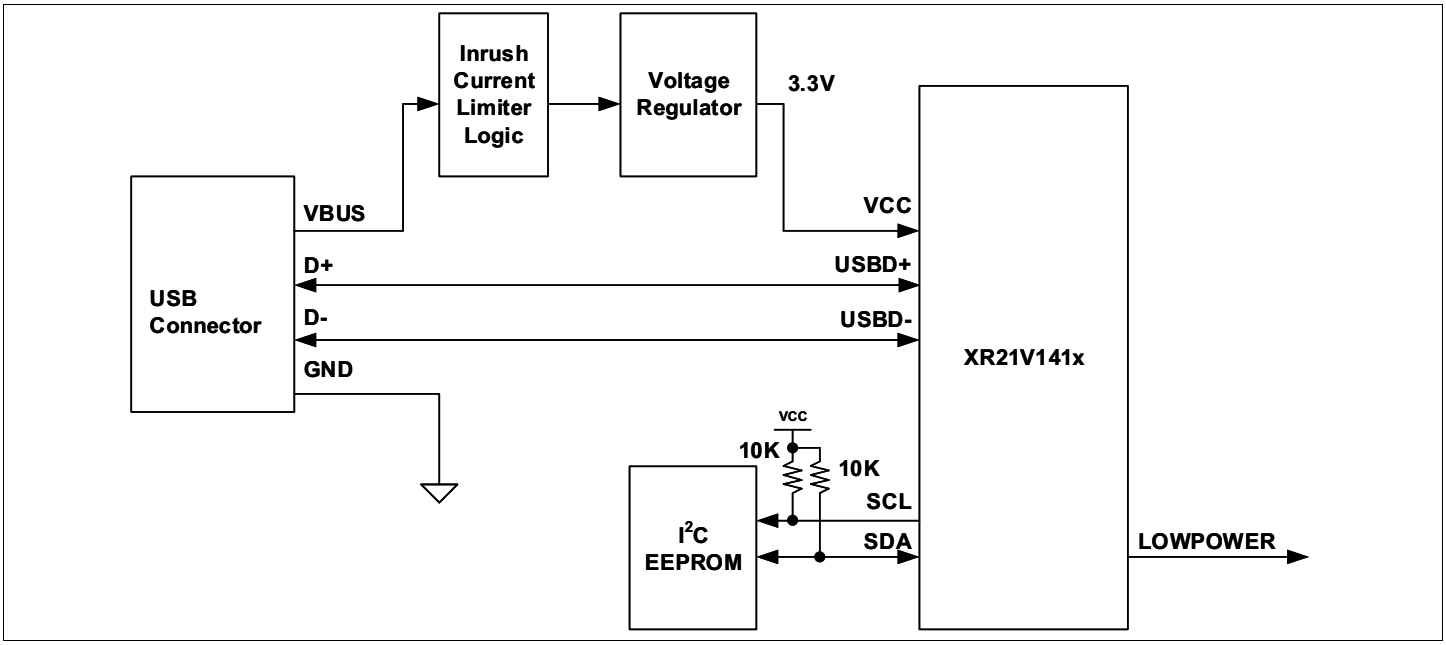

Figure 3: Typical XR21V141x Block Diagram for Bus-Powered Applications

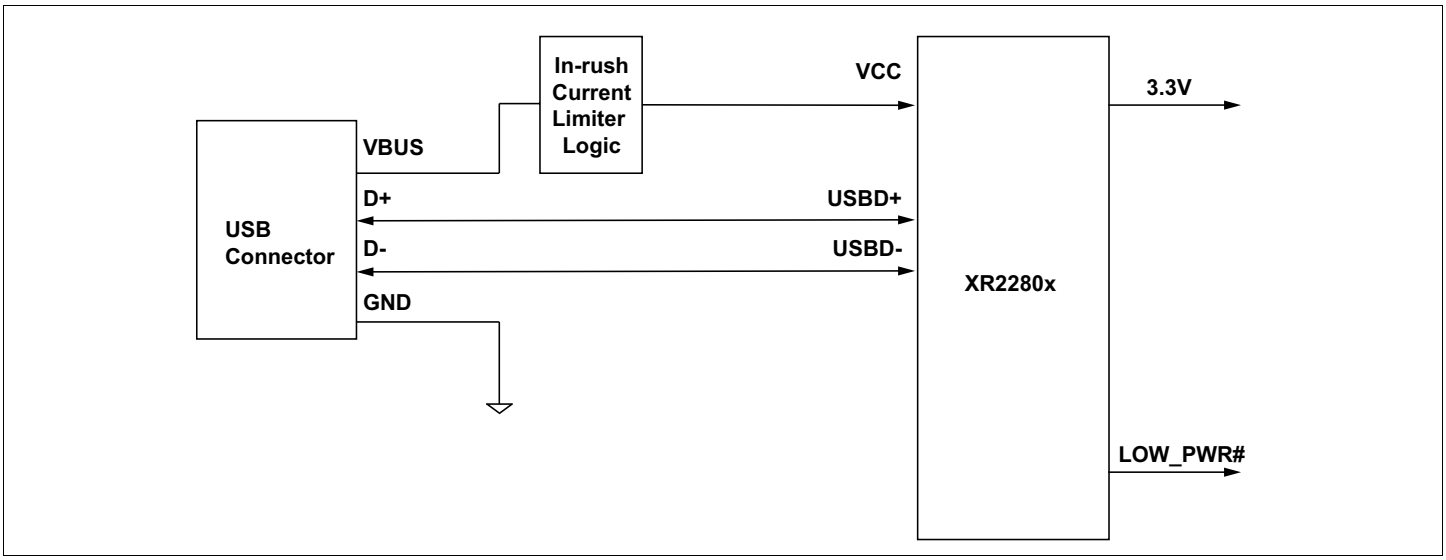

Figure 4: Typical XR2280x Block Diagram for Bus-Powered Applications

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.

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 must be limited to 100mA/µs 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 the in-rush current, MaxLinear recommends that you use an in-rush current limiting circuit (as shown in Figure 2 on page 2 and Figure 3 on page 3) and a bypass capacitance on the VBUS signal 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 shown in Figure 1 on page 2), note that in some cases a voltage spike from the VBUS voltage applied to the USB UART PCB can occur. This voltage spike can damage the USB UART due to 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 you connect 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. When the system connects through a USB cable and no in-rush circuit, MaxLinear recommends that you use a tantalum capacitor which can provide enough ESR to prevent a damaging voltage spike.

Suspend Mode Current

According to the USB specification, all of the USB peripheral devices must support the suspend mode when a USB host is put in a sleep/hibernation state or 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 identify any USB traffic including the start-of-frame (SOF) packets for more than 3ms, it begins to enter and completes the entry to a low power suspend mode within 7ms.

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 of the devices (not just the USB peripheral device) that use the power from the USB host VBUS power. Therefore, MaxLinear recommends that the other components on the board have low power or shutdown modes to minimize the power consumption during the suspend mode. Note that the XR2280x family has multiple functions and thus allows a higher suspend current. For more information about the lists of the XR2280x functions, refer the data sheets.

LOWPOWER/USB_STAT Output Pin

You can use the LOWPOWER pin or USB_STAT pin on MaxLinear USB UARTs 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 is asserted so that the other devices can be signaled to also enter into a low power mode.

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, the external power to the device can be present when the host is not connected. In this condition, a *back-voltage* can be present on the USB signals which cause both a failure of the USB certification testing and additionally can cause the host to fail when enumerates the device. The VBUS_SENSE pin in self-powered mode must be connected to the host VBUS power pin. For more information about theset connections or additional component requirements, refer to the data sheets.

In embedded applications where the host and device are powered by the same power source, the VBUS_SENSE pin can be pulled up to a logic *1* state. In the XR21V141x family, the external power source can be disabled by the VBUS as shown in Table 1 on page 2.

External EEPROM or On-chip OTP

You can specify or modify the USB configuration values such as the *Vendor ID*, *Product ID*, *Device Attributes*, and *Maximum Power Consumption* by using an external I^2C EEPROM with the XR21V141x family or on-chip OTP in the XR21B1411, XR21B142x, and XR2280x families of devices.

USB Descriptors

The USB descriptors are the mechanism that peripheral devices use to pass information/values about the device functionality, manufacturer, or USB class to the host. The primary USB descriptor that you can be concerned with is the configuration descriptor. Within the configuration descriptor are the `bmAttributes` and `bMaxPopwer` fields.

bmAttributes

The `bmAttributes` field lets the USB host/hub know if the USB UART is bus-powered or self-powered and if it supports remote wakeup capability.

> **Note:** By default, all of the MaxLinear's USB UARTs are bus-powered and all support remote wakeup except the HID class XR21B1421 device.
> To modify these settings, you can use the external EEPROM or OTP. 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.

bMaxPower

The `bMaxPower` field lets the USB host know the maximum VBUS power consumption requirement, if the device is bus-powered.

> **Note:** By default, all of the MaxLinear's USB UARTs support a maximum of 100mA (or 1 unit load).

By the USB 2.0 specification, a peripheral device that requires ≤100mA of the VBUS power is classified as a low power device. A device that requires a power greater than 1 and up to 5 unit loads is classified as a high power device. The R2280x Ethernet bridge family has high powered devices that requires a bus power of 250 mA.

In the USB 3 specification, these values increase to 150mA and 6 unit loads, respectively.

The `bMaxPower` required by the USB host includes all the power drawn from the host VBUS by any devices on the PCB.

External EEPROM or On-chip OTP

The VBUS_SENSE pin for all of the 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, an external power to the device can be present when the host is not connected. In this condition a *back-voltage* can be present on USB signals that cause a failure of USB certification testing and can also cause the host to fail when enumerates the device. The VBUS_SENSE pin in self-powered mode must be connected to the host VBUS power pin. For more information about these connections or additional component requirements, refer to the data sheets.

In embedded applications where the host and device are powered by the same power source, the VBUS_SENSE pin can be pulled up to a logic *1* state. In the XR21V141x family the external power source can be disabled by the VBUS as shown in Figure 1 on page 2.

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