ENVISIONING • EMPOWERING • EXCELLING

MAXLINEAR

Design with MaxLinear UARTs Auto RS-485 Direction Control Application Note

Revision History

Revision	Release Date	Change Description
290ANR01	May 12, 2023	**Updated:** ■ Title of the document. ■ “Introduction” section. ■ "UARTs with Programmable Turn-Around Delay" section.
290ANR00	November 24, 2022	Initial release.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

This application note describes how the automatic RS-485 half-duplex direction control feature in MaxLinear UARTs reduces driver development and frees up CPU/MCU loading. This feature eliminates the need to monitor the status of the UART's transmit shift register and automatically switches MaxLinear RS-485 transceivers from the transmit mode to the receive mode.

2.0 Reference Documentation

Figure 1 shows the typical connection of a UART to a half-duplex RS-485 transceiver. The same output from the UART controls both the driver enable (DE) and receiver enable (RE#) inputs to guarantee that the RS-485 transceiver is only either transmit mode or receive mode.

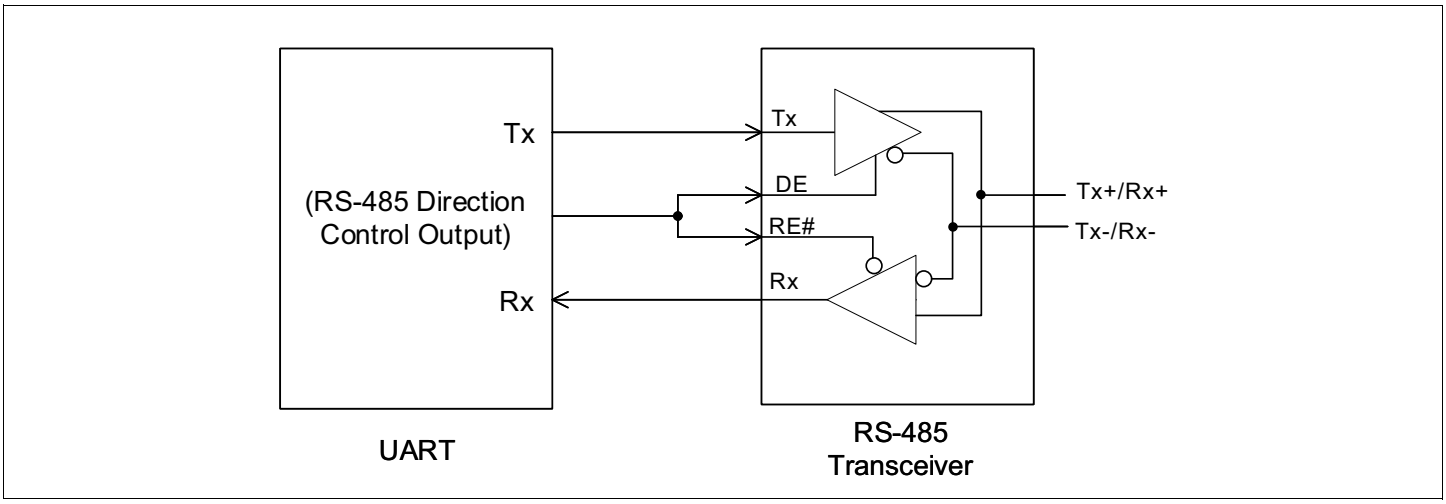

Figure 1: Typical Connection between UART and RS-485 Transceiver

3.0 Software Challenges

The main challenge for using a UART in a half-duplex RS-485 environment is making sure that the RS-485 transceiver is in the Tx mode before transmitting and the RS-485 transceiver does not return to the Rx mode until all of the data is transmitted. The *UART 16550* standard generates an interrupt when the Tx FIFO is empty, however there may be data in the Transmit Shift Register (TSR). Therefore, additional software is required to ensure that the TSR is also empty when using a UART that does not have MaxLinear's auto RS-485 half-duplex direction control feature.

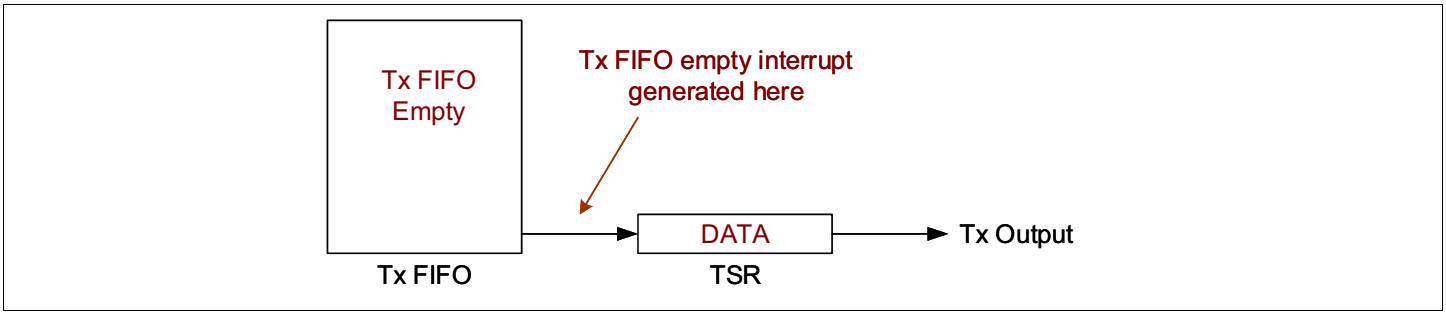

Figure 2: UART Transmit Interrupt Behavior

3.1 Possible Software Solutions

3.1.1 Polling Example

The first way to do this is to poll the LSR register. The RTS# signal should be used to control the direction of the RS-485 transceiver and the RTS# needs to be HIGH for transmitting and LOW for receiving.

```
//Initialization
IER = 0x00;                 //Interrupts are not enabled
MCR bit-1 = 1;              //Set RS-485 transceiver in RX mode
...
//Transmit Routine
MCR bit-1 = 0;              //Set RS-485 transceiver in TX mode
Write data to TX FIFO (THR);
While (LSR bit-6 = 0);      //wait until the TX FIFO + TSR is empty
MCR bit-0 = 1;              //TX completed, set RS-485 transceiver back to RX mode
```

However, this is not efficient as expected because the CPU/MCU has to wait for this routine to finish.

3.1.2 Interrupts + Polling Example

The other way is to use the Tx empty interrupt. However, the software still needs to poll the LSR register as described in “Software Challenges” on page 2

```
//Initialization
   IER = 0x02;                //TX empty interrupt enabled
   MCR bit-1 = 1;             //Set RS-485 transceiver in RX mode
   ...
   //Transmit Interrupt Service Routine
   if (more data to send)
         MCR bit-1 = 0;       //set or keep RTS# pin HIGH for TX mode
   else {
      while (LSR bit-6 = 0);   //poll until TX FIFO + TSR is empty
      MCR bit-1 = 1;          //TX completed, set RS-485 transceiver back to RX mode
   }
   while (more data to send AND data less than FIFO size)
      write data to THR;
```

This is more efficient than the polling example, but there is still a while loop that keeps the CPU/MCU busy when it can be doing other tasks.

3.1.3 Auto RS-485 Half-Duplex Direction Control Feature

The most efficient way to use a UART in a half-duplex RS-485 environment is to use a MaxLinear UART that has the automatic RS-485 half-duplex direction control feature. This feature changes the behavior of the UART in the following two ways:

- The behavior of one of the UART outputs becomes a control signal to control the direction of the RS-485 transceiver. While the UART is idle, the control output enables the receive mode of the RS-485 transceiver. When any data is loaded into the Tx FIFO, the control output automatically enables the transmit mode of the RS-485 transceiver. Once the UART sent all of the data in the Tx FIFO and TSR, the control output automatically changes the RS-485 transceiver back to the receive mode.
- The behavior of the transmit empty interrupt changes. Instead of generating an interrupt when the Tx FIFO is empty, the interrupt is generated when the Tx FIFO and TSR register are both empty and the transmitter is completely idle.

The only thing that needs to be done is:

```
//Initialization
Enable Auto RS-485 Half-Duplex Direction Control;
```

The direction of the transceiver isf automatically managed by the UART so that the CPU/MCU can perform other tasks.

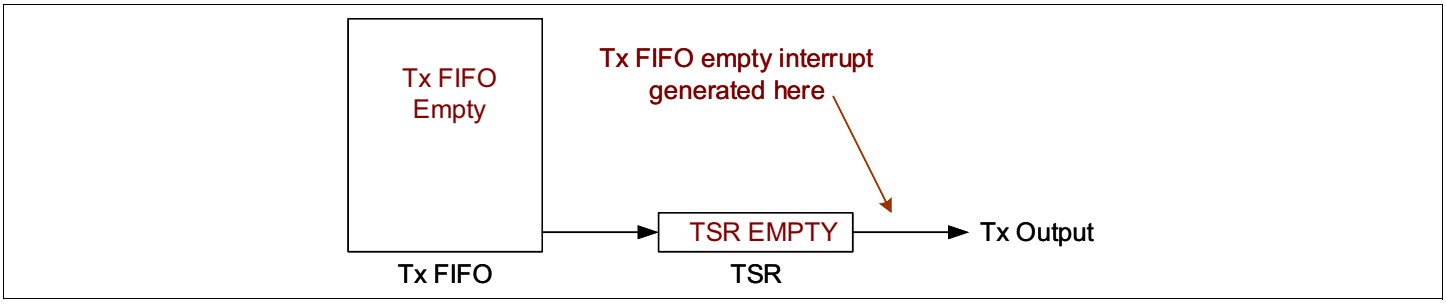

Figure 3: UART Transmit Interrupt Behavior with Auto RS-485 Feature

4.0 Enhanced Features

4.1 RS-485 Direction Control Outputs

Not all UARTs with the auto RS-485 half-duplex direction control feature use the same output to control the direction of the RS-485 transceiver. Most UARTs use the RTS# output, but some UARTs can use the DTR# output or OP1# output. For more information, see Table 1.

Table 1: UARTs with Auto RS-485 Direction Control

UART Product Number	RS-485 Control Output	Default Tx Polarity	Invert Polarity Feature	Enable RS-485 Pin	Programmable Turn-Around Delay
ST16C650A	RTS#	HIGH	Yes	No	No
XR16C2850	RTS#	LOW	No	No	No
XR16C2852	RTS#	LOW	No	No	No
XR16C850	OP1#	LOW	No	No	No
XR16C864	OP1#	LOW	No	No	No
XR16L2750	RTS#	LOW	Yes	No	No
XR16L2751	RTS#	LOW	Yes	No	No
XR16L2752	RTS#	LOW	Yes	No	No
XR16L784	RTS# or DTR#	HIGH	No	No	Yes
XR16L788	RTS# or DTR#	HIGH	No	No	Yes
XR16M752	RTS#	HIGH	No	No	No
XR16M780	RTS#	LOW	Yes	No	No
XR16M781	RTS#	LOW	Yes	No	No
XR16M890	RTS#	LOW	Yes	Yes (VLIO mode)	Yes
XR16V2750	RTS#	LOW	Yes	No	No
XR16V598	RTS# or DTR#	HIGH	No	No	Yes
XR16V698	RTS# or DTR#	HIGH	No	No	Yes
XR16V798	RTS# or DTR#	HIGH	No	No	Yes
XR68M752	RTS#	HIGH	No	No	No
XR17V352	RTS# or DTR#	HIGH	Yes	Yes	Yes
XR17V354	RTS# or DTR#	HIGH	Yes	Yes	Yes
XR17V358	RTS# or DTR#	HIGH	Yes	Yes	Yes
XR20M1170	RTS#	LOW	Yes	Yes	No
XR20M1172	RTS#	LOW	Yes	Yes	No
XR20M1280	RTS#	LOW	Yes	Yes	Yes
XR21B1411	RTS#	■ LOW (Default). ■ HIGH (When using Windows driver).	Yes	No	Yes
XR21B1420	RTS# or GPIO7/RS485#	■ LOW (Default). ■ HIGH (When using Windows driver or CDC-ACM driver).	Yes	No	Yes
XR21B1421	GPIO3/RS485# (Default) or RTS#	HIGH	Yes	No	Yes

Table 1: UARTs with Auto RS-485 Direction Control (Continued)

UART Product Number	RS-485 Control Output	Default Tx Polarity	Invert Polarity Feature	Enable RS-485 Pin	Programmable Turn-Around Delay
XR21B1422	RTS# or GPIO7/RS485#	■ LOW (Default). ■ HIGH (When using Windows driver or CDC-ACM driver).	Yes	No	Yes
XR21B1424	RTS# or GPIO7/RS485#	■ LOW (Default). ■ HIGH (When using Windows driver or CDC-ACM driver).	Yes	No	Yes
XR21V1410	RTS#	■ LOW (Default). ■ HIGH (When using Windows driver).	Yes	No	Yes
XR21V1412	RTS#	■ LOW (Default). ■ HIGH (When using Windows driver).	Yes	No	Yes
XR21V1414	RTS#	■ LOW (Default). ■ HIGH (When using Windows driver).	Yes	No	Yes
XR22801	RTS#	■ LOW (Default). ■ HIGH (When using Windows driver)	Yes	No	Yes
XR22802	RTS#	■ LOW (Default). ■ HIGH (When using Windows driver)	Yes	No	Yes
XR22804	RTS#	■ LOW (Default). ■ HIGH (When using Windows driver)	Yes	No	Yes
XR28V382	RTS#	HIGH	Yes	No	No
XR28V384	RTS#	HIGH	Yes	No	No

4.2 RS-485 Direction Control Polarity

The polarity of the control output varies depending on the UART. For some UARTs, the control output is HIGH for transmit mode and LOW for receive mode. However, there are UARTs where it is the opposite polarity. If the RS-485 control output is in the wrong state, then an external inverter may be required. To eliminate this external inverter, some MaxLinear UARTs have a register bit that can invert the default polarity of the auto RS-485 half-duplex direction control output.

For more information about the corresponding RS-485 control output information for specific part numbers, see Table 1.

4.3 UARTs with Enable RS-485 Pins

Upon power-up, the control output of the UART can be in the incorrect state until it is initialized. During this time, the UART can be unintentionally driving the RS-485 network preventing the other nodes from communicating. For the systems that require the RS-485 control output to be in the correct state upon power-up, some MaxLinear UARTs have the auto RS-485 enable pin. To check whether the feature is supported for the targeted part number, see Table 1.

4.4 UARTs with Programmable Turn-Around Delay

Most UARTs with the automatic RS-485 half-duplex direction control feature change from the Tx mode to the Rx mode almost immediately. After the Tx is done and changes to the Rx mode, it gives out control of the bus for other possible masters to acquire. Therefore, there are chances that the intended data *did not* reach the intended destination over long distance. This can be an issue for applications with long cables. Therefore, some MaxLinear UARTs also have a programmable turn-around delay with a range of 0-15 bits before the control output changes from the Tx mode to the Rx mode. It allows the signal to propagate to the furthest nodes. To check whether the feature is supported for the targeted part number, see Table 1.

5.0 MaxLinear's UART and Half-Duplex RS-485 Transceivers Solution

The UARTs in Table 1 can be used with MaxLinear's half-duplex RS-485 transceivers for a complete half-duplex RS-485 solution. Table 2 lists MaxLinear's half-duplex RS-485 transceivers.

Note: For more a most up-to-date list and key features, go to www.maxlinear.com.

Table 2: Half-Duplex RS-485 Transceivers

Half-Duplex RS-485 Transceiver Product Numbers		
SP1485E	SP483	XR33052
SP1486E	SP483E	XR33055
SP3072E	SP485	XR33058
SP3075E	SP485E	XR33152
SP3078E	SP485R	XR33155
SP3082E	XR3072X	XR33158
SP3085E	XR3078X	XR33202
SP3088E	XR3082X	MxL83101
SP3483	XR3085X	MxL83102
SP3485	XR3088X	MxL83111
SP3494	XR33032	MxL83112
SP4082E	XR33035	
SP481E	XR33038	

You can also use MaxLinear's dual protocol transceivers that support half duplex RS-485, as listed in Table 3.

Table 3: Multi-Protocol Transceivers with Half Duplex RS-485 Support

Multi-Protocol Transceivers with Half Duplex RS-485 Support Product Numbers		
SP330	SP335	SP339
SP331	SP336	SP339B
SP332	SP337	XR3160
SP334	SP338	XR34350

5.1 MaxLinear's UART and Full-Duplex RS-485 Transceivers

Any MaxLinear UART can be used with any full-duplex RS-485, RS-422, or RS-232 transceivers because the UART transmitter and receiver are independent of each other. UARTs can simultaneously transmit and receive at the same time.

6.0 Conclusion

MaxLinear's enhanced UARTS with the automatic RS-485 half-duplex direction control feature can simplify both the hardware design and software development of half-duplex RS-485 applications. MaxLinear offers enhanced UARTs with different CPU interfaces, FIFO sizes, channels, and operating voltages.
In addition, MaxLinear offers a complete portfolio of robust half-duplex RS-485 transceivers.

MaxLinear's enhanced UARTs combined with MaxLinear's RS-485 transceivers is a complete RS-485 application solution.

MaxLinear, Inc.
5966 La Place Court, Suite 100
Carlsbad, CA 92008
760.692.0711
760.444.8598

www.maxlinear.com