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GENERAL DESCRIPTION

The XR16M680[1] (M680) is an enhanced Universal Asynchronous Receiver and Transmitter (UART) with 32 bytes of transmit and receive FIFOs, selectable transmit and receive FIFO trigger levels, automatic hardware and software flow control, and data rates of up to 16 Mbps at 3.3V, 12.5 Mbps at 2.5V and 7.5 Mbps at 1.8V with 4X data sampling rate.

The Auto RS-485 Half-Duplex Direction control feature simplifies both the hardware and software for half-duplex RS-485 applications. In addition, the Multidrop mode with Auto Address detection increases the performance by simplifying the software routines.

The Independent TX/RX Baud Rate Generator feature allows the transmitter and receiver to operate at different baud rates. Power consumption of the M680 can be minimized by enabling the sleep mode and PowerSave mode.

The M680 has a 16550 compatible register set that provide users with operating status and control, receiver error indications, and modem serial interface controls. An internal loopback capability allows onboard diagnostics. The M680 is available in 32-pin QFN, 48-pin TQFP and 25-pin BGA packages. All three packages offer both the 16 mode (Intel bus) interface and the 68 mode (Motorola bus) interface which allows easy integration with Motorola processors.

NOTE: *1 Covered by U.S. Patent #5,649,122.*

FEATURES

- Pin-to-pin compatible with XR16L580 in 32-QFN and 48-TQFP packages
- Intel or Motorola Bus Interface select
- 16Mbps maximum data rate
- Selectable TX/RX trigger levels
- TX/RX FIFO Level Counters
- Independent TX/RX Baud Rate Generator
- Fractional Baud Rate Generator
- Auto RTS/CTS Hardware Flow Control
- Auto XON/XOFF Software Flow Control
- Auto RS-485 Half-Duplex Direction Control
- Multidrop mode w/ Auto Address Detect
- Sleep Mode with Automatic Wake-up
- PowerSave mode
- Infrared (IrDA 1.0 and 1.1) mode
- 1.62V to 3.63V supply operation
- Crystal oscillator or external clock input

APPLICATIONS

- Personal Digital Assistants (PDA)
- Cellular Phones/Data Devices
- Battery-Operated Devices
- Global Positioning System (GPS)
- Bluetooth

FIGURE 1. XR16M680 BLOCK DIAGRAM

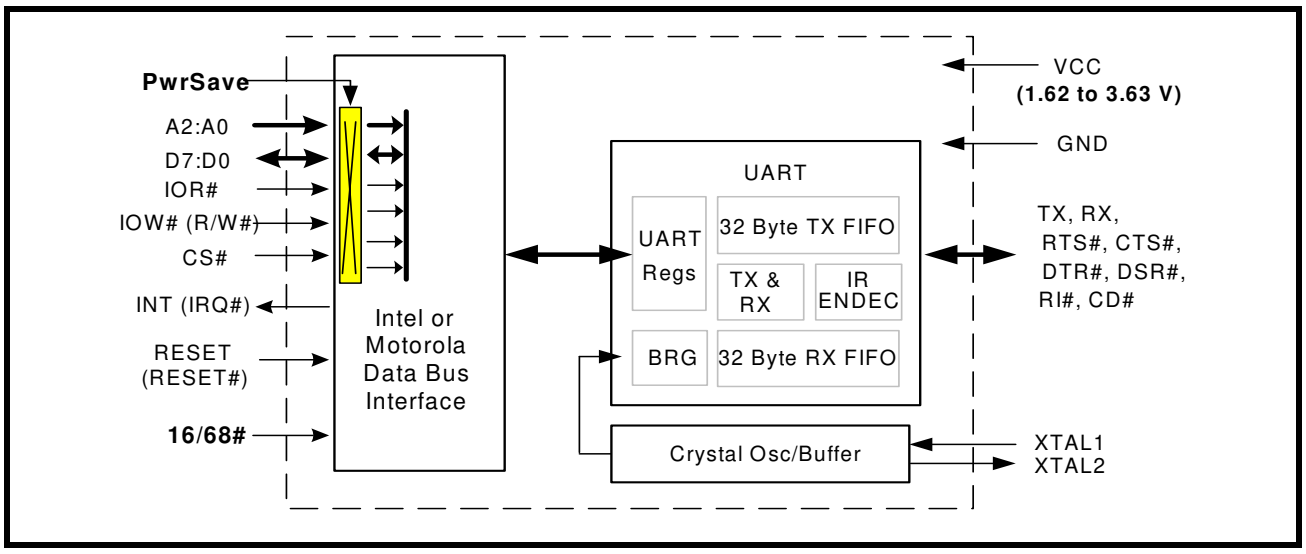


FIGURE 2. PIN OUT ASSIGNMENT FOR 32-PIN QFN AND 48-PIN TQFP PACKAGES IN 16 AND 68 MODE

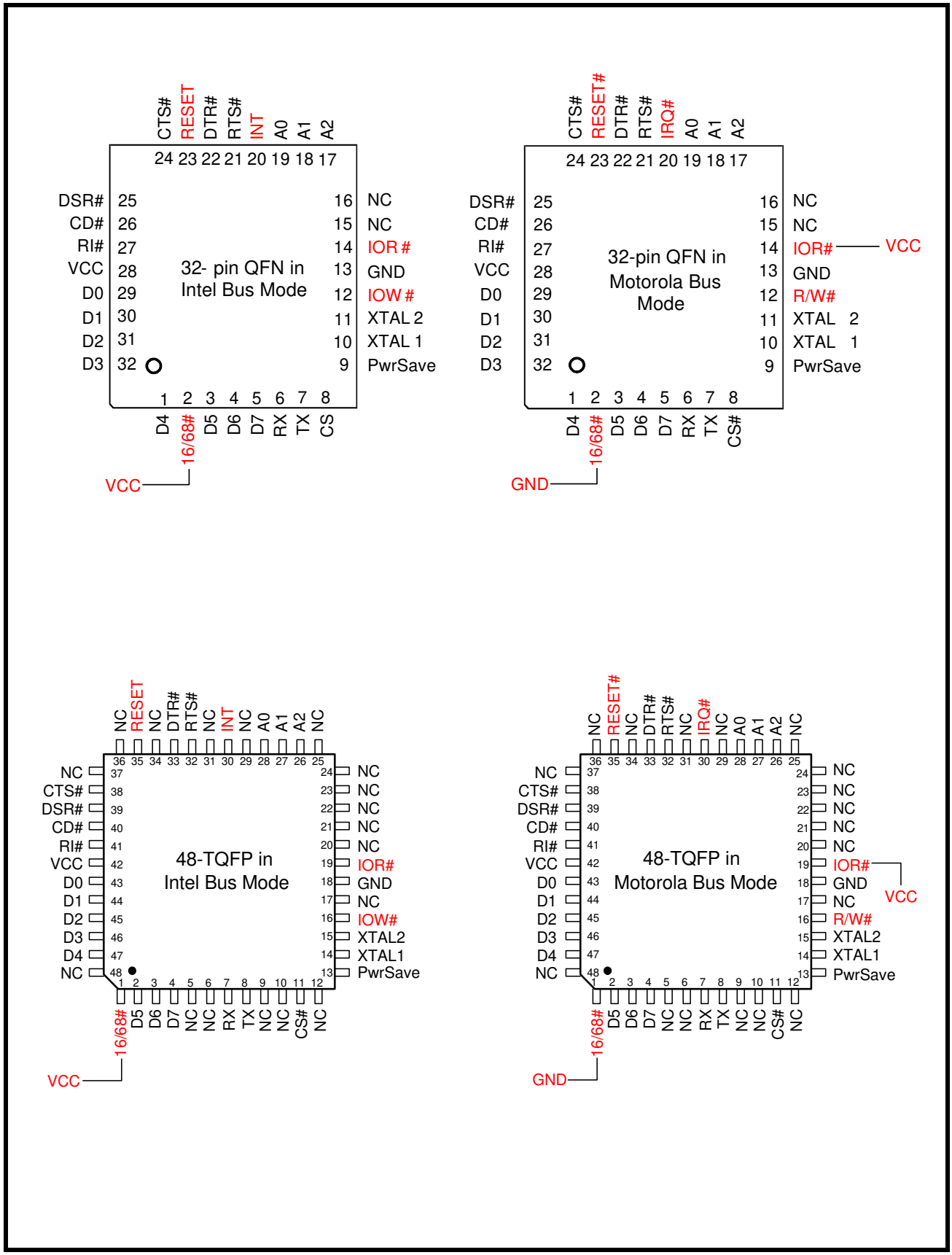
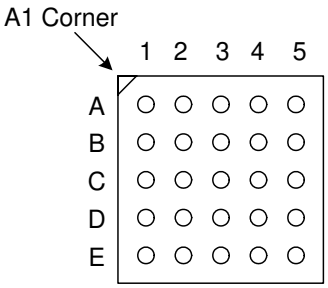


FIGURE 3. PIN OUT ASSIGNMENT FOR 25-PIN BGA PACKAGE



Transparent Top View

CTS#	RESET	INT	A1	A2
VCC	16/68#	RTS#	A0	IOR#
D0	D6	D7	PwrSave	IOW#
D3	D1	TX	CS#	XTAL1
D4	D2	D5	RX	GND

ORDERING INFORMATION

PART NUMBER	PACKAGE	OPERATING TEMPERATURE RANGE	DEVICE STATUS
XR16M680IL32	32-pin QFN	-40°C to +85°C	Active
XR16M680IM48	48-Lead TQFP	-40°C to +85°C	Active
XR16M680IB25	25-Pin BGA	-40°C to +85°C	Active

PIN DESCRIPTIONS

Pin Description

NAME	32-QFN PIN#	48-TQFP PIN#	25-BGA PIN#	TYPE	DESCRIPTION
DATA BUS INTERFACE					
A2 A1 A0	17 18 19	26 27 28	A5 A4 B4	I	Address lines [2:0]. These 3 address lines select the internal registers in UART channel during a data bus transaction.
D7 D6 D5 D4 D3 D2 D1 D0	5 4 3 1 32 31 30 29	4 3 2 47 46 45 44 43	C3 C2 E3 E1 D1 E2 D2 C1	I/O	Data bus lines [7:0] (bidirectional).
IOR#	14	19	B5	I	When 16/68# pin is at logic 1, the Intel bus interface is selected and this input becomes read strobe (active low). The falling edge instigates an internal read cycle and retrieves the data byte from an internal register pointed by the address lines [A2:A0], puts the data byte on the data bus to allow the host processor to read it on the rising edge. When 16/68# pin is at logic 0, the Motorola bus interface is selected and this input should be connected to VCC.
IOW# (R/W#)	12	16	C5	I	When 16/68# pin is at logic 1, it selects Intel bus interface and this input becomes write strobe (active low). The falling edge instigates the internal write cycle and the rising edge transfers the data byte on the data bus to an internal register pointed by the address lines. When 16/68# pin is at logic 0, the Motorola bus interface is selected and this input becomes read (logic 1) and write (logic 0) signal.
CS#	8	11	D4	I	This input is chip select (active low) to enable the device.
INT (IRQ#)	20	30	A3	O (OD)	When 16/68# pin is at logic 1 for Intel bus interface, this output become the active high device interrupt output. The output state is defined by the user through the software setting of MCR[3]. INT is set to the active mode when MCR[3] is set to a logic 1. INT is set to the three state mode when MCR[3] is set to a logic 0. See MCR[3]. When 16/68# pin is at logic 0 for Motorola bus interface, this output becomes the active low device interrupt output (open drain). An external pull-up resistor is required for proper operation.
MODEM OR SERIAL I/O INTERFACE					
TX	7	8	D3	O	UART Transmit Data or infrared encoder data. Standard transmit and receive interface is enabled when MCR[6] = 0. In this mode, the TX signal will be a logic 1 during reset or idle (no data). Infrared IrDA transmit and receive interface is enabled when MCR[6] = 1. In the Infrared mode, the inactive state (no data) for the Infrared encoder/decoder interface is a logic 0. If it is not used, leave it unconnected.

Pin Description

NAME	32-QFN PIN#	48-TQFP PIN#	25-BGA PIN#	TYPE	DESCRIPTION
RX	6	7	E4	I	UART Receive Data or infrared receive data. Normal receive data input must idle at logic 1 condition. The infrared receiver idles at logic 0. This input should be connected to VCC when not used.
RTS#	21	32	B3	O	UART Request-to-Send (active low) or general purpose output. This output must be asserted prior to using auto RTS flow control, see EFR[6], MCR[1] and IER[6].
CTS#	24	38	A1	I	UART Clear-to-Send (active low) or general purpose input. It can be used for auto CTS flow control, see EFR[7], MSR[4] and IER[7]. This input should be connected to VCC when not used.
DTR#	22	33	-	O	UART Data-Terminal-Ready (active low) or general purpose output.
DSR#	25	39	-	I	UART Data-Set-Ready (active low) or general purpose input. This input should be connected to VCC when not used.
CD#	26	40	-	I	UART Carrier-Detect (active low) or general purpose input. This input should be connected to VCC when not used.
RI#	27	41	-	I	UART Ring-Indicator (active low) or general purpose input. This input should be connected to VCC when not used.
ANCILLARY SIGNALS					
XTAL1	10	14	D5	I	Crystal or external clock input.
XTAL2	11	15	-	O	Crystal or buffered clock output.
PwrSave	9	13	C4	I	Power-Save (active high). This feature isolates the M680's data bus interface from the host preventing other bus activities that cause higher power drain during sleep mode. See Sleep Mode with Auto Wake-up and Power-Save Feature section for details. This pin does not have an internal pull-down resistor. This input should be connected to GND when not used.
16/68#	2	1	B2	I	Intel or Motorola Bus Select. When 16/68# pin is at logic 1, 16 or Intel Mode, the device will operate in the Intel bus type of interface. When 16/68# pin is at logic 0, 68 or Motorola mode, the device will operate in the Motorola bus type of interface. This pin does not have an internal pull-up or pull-down resistor.
RESET (RESET#)	23	35	A2	I	When 16/68# pin is at logic 1 for Intel bus interface, this input becomes RESET (active high). When 16/68# pin is at logic 0 for Motorola bus interface, this input becomes RESET# (active low). A 40 ns minimum active pulse on this pin will reset the internal registers and all outputs of the UART. The UART transmitter output will be held at logic 1, the receiver input will be ignored and outputs are reset during reset period (see UART Reset Conditions).
VCC	28	42	B1	Pwr	1.62V to 3.63V power supply.
GND	13	18	E5	Pwr	Power supply common, ground.
GND	Center Pad	-	-	Pwr	The center pad on the backside of the QFN package is metallic and should be connected to GND on the PCB. The thermal pad size on the PCB should be the approximate size of this center pad and should be solder mask defined. The solder mask opening should be at least 0.0025" inwards from the edge of the PCB thermal pad.

Pin Description

NAME	32-QFN PIN#	48-TQFP PIN#	25-BGA PIN#	TYPE	DESCRIPTION
NC	15, 16	5, 6, 9, 10, 12, 17, 20-25, 29, 31, 34, 36, 37, 48	-	-	No Connects.

Pin type: I=Input, O=Output, I/O= Input/output, OD=Output Open Drain.

1.0 PRODUCT DESCRIPTION

The XR16M680 (M680) is a high performance single channel UART. It has its set of device configuration registers. The configuration registers set is 16550 UART compatible for control, status and data transfer. Additionally, the M680 channel has 32 bytes of transmit and receive FIFOs, Automatic RTS/CTS Hardware Flow Control, Automatic Xon/Xoff and Special Character Software Flow Control, infrared encoder and decoder (IrDA ver 1.0 and 1.1), programmable fractional baud rate generator with a prescaler of divide by 1 or 4, and data rate up to 16 Mbps. The XR16M680 can operate from 1.62 to 3.63 volts. The M680 is fabricated with an advanced CMOS process.

Larger FIFO

The M680 provides a solution that supports 32 bytes of transmit and receive FIFO memory, instead of 16 bytes in the XR16L580. The M680 is designed to work with high performance data communication systems, that requires fast data processing time. Increased performance is realized in the M680 by the larger transmit and receive FIFOs, FIFO trigger level control and automatic flow control mechanism. This allows the external processor to handle more networking tasks within a given time. For example, the XR16L580 with a 16 byte FIFO, unloads 16 bytes of receive data in 1.53 ms (This example uses a character length of 11 bits, including start/stop bits at 115.2Kbps). This means the external CPU will have to service the receive FIFO at 1.53 ms intervals. However with the 32 byte FIFO in the M680, the data buffer will not require unloading/loading for 6.1 ms. This increases the service interval giving the external CPU additional time for other applications and reducing the overall UART interrupt servicing time. In addition, the selectable FIFO level trigger interrupt and automatic hardware/software flow control is uniquely provided for maximum data throughput performance especially when operating in a multi-channel system. The combination of the above greatly reduces the CPU's bandwidth requirement, increases performance, and reduces power consumption.

Data Rate

The M680 is capable of operation up to 16 Mbps at 3.3V with 4X internal sampling clock rate. The device can operate at 3.3V with a 24 MHz crystal on pins XTAL1 and XTAL2, or external clock source of 32 MHz on XTAL1 pin. With a typical crystal of 14.7456 MHz and through a software option, the user can set the prescaler bit and sampling rate for data rates of up to 3.68 Mbps.

Enhanced Features

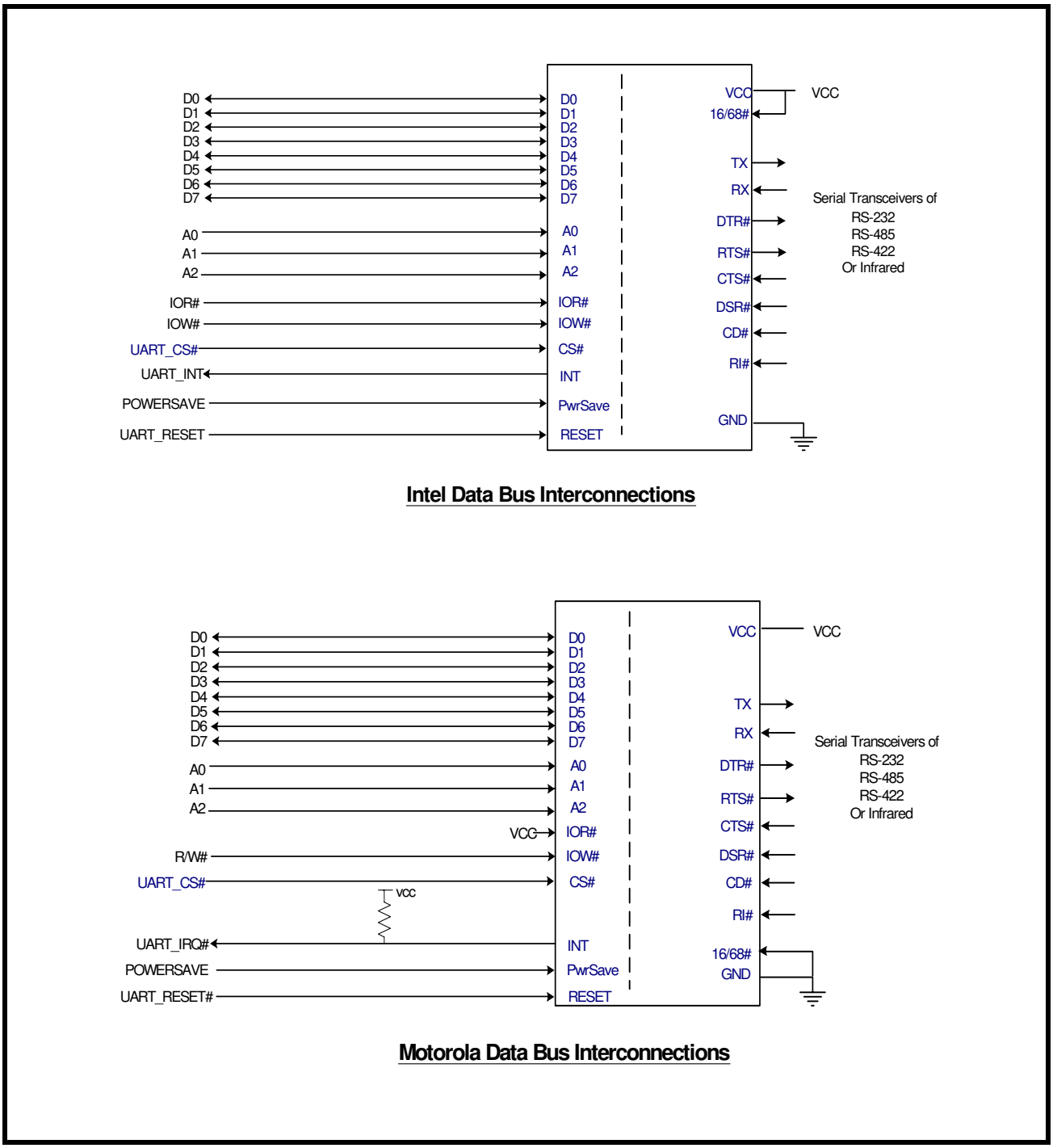
The rich feature set of the M680 is available through the internal registers. Automatic hardware/software flow control, selectable transmit and receive FIFO trigger levels, selectable baud rates, infrared encoder/decoder, modem interface controls, and a sleep mode are all standard features. MCR bit-5 provides a facility for turning off (Xon) software flow control with any incoming (RX) character. The M680 includes new features such as 9-bit (Multidrop) mode, auto RS-485 half-duplex direction control, different baud rate for TX and RX, fast IR mode and fractional baud rate generator.

2.0 FUNCTIONAL DESCRIPTIONS

2.1 CPU Interface

The CPU interface is 8 data bits wide with 3 address lines and control signals to execute data bus read and write transactions. The M680 data interface supports the Intel and Motorola compatible types of CPUs. No clock (oscillator nor external clock) is required for a data bus transaction. Each bus cycle is asynchronous using CS#, IOR# and IOW# or R/W# inputs. A typical data bus interconnection for Intel and Motorola mode is shown in Figure 4.

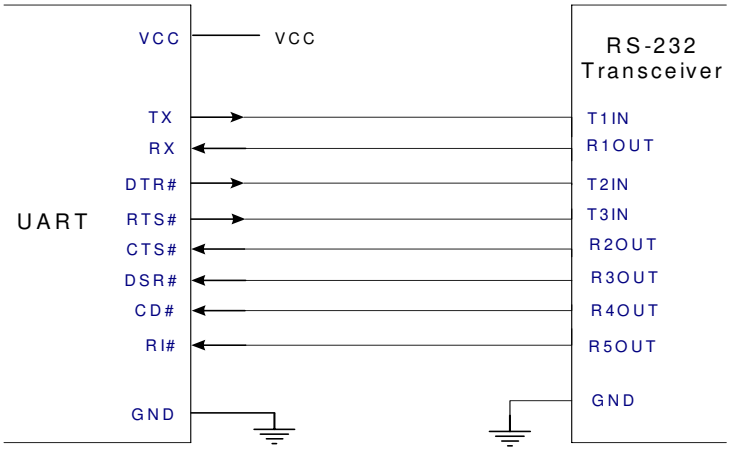
FIGURE 4. XR16M680 TYPICAL INTEL/MOTOROLA DATA BUS INTERCONNECTIONS



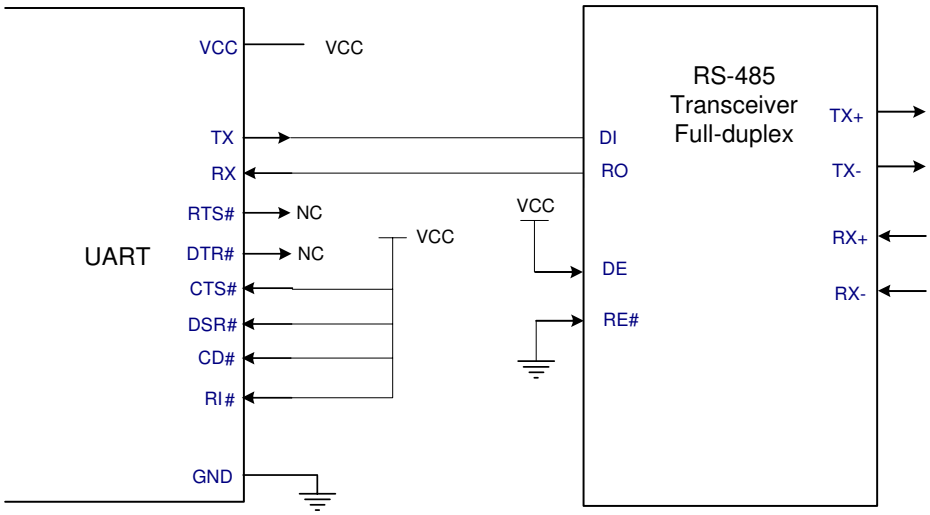
2.2 Serial Interface

The M680 is typically used with RS-232, RS-485 and IR transceivers. The following figure shows typical connections from the UART to the different transceivers. For more information on RS-232 and RS-485/422 transceivers, go to www.exar.com or send an e-mail to uarttechsupport@exar.com.

FIGURE 5. XR16M680 TYPICAL SERIAL INTERFACE CONNECTIONS

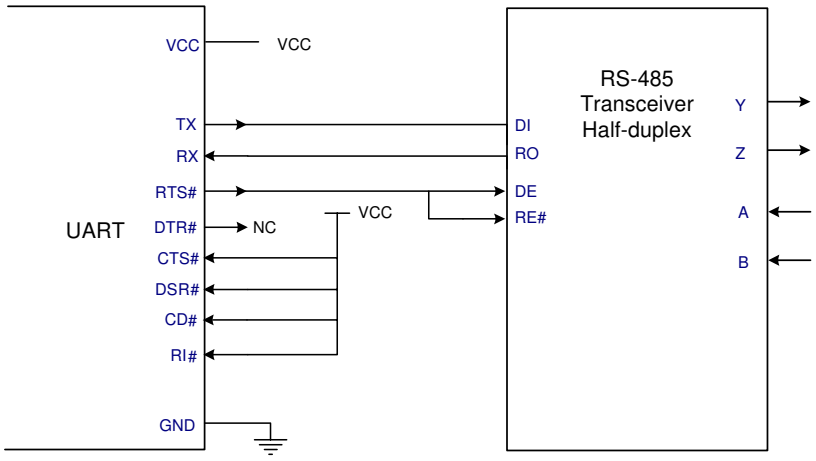


RS-232 Full-Modem Serial Interface

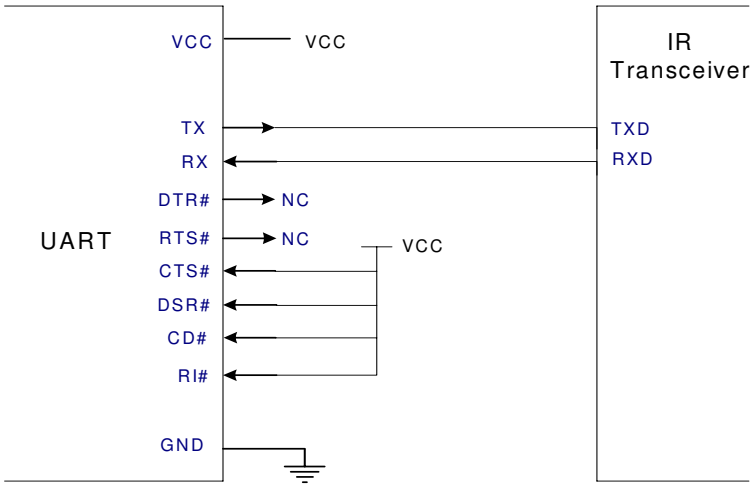


RS-485 Full-Duplex Serial Interface

FIGURE 6. XR16M680 TYPICAL SERIAL INTERFACE CONNECTIONS



RS-485 Half-Duplex Serial Interface



Infrared Connection

2.3 Device Reset

The RESET input resets the internal registers and the serial interface outputs to their default state (see Table 16). An active high pulse of longer than 40 ns duration will be required to activate the reset function in the device. Following a power-on reset or an external reset, the M680 is software compatible with previous generation of UARTs, XR16L580 and ST16C550.

2.4 Internal Registers

The M680 has a set of 16550 compatible registers for controlling, monitoring and data loading and unloading. These registers function as data holding registers (THR/RHR), interrupt status and control registers (ISR/IER), a FIFO control register (FCR), receive line status and control registers (LSR/LCR), modem status and control registers (MSR/MCR), programmable data rate (clock) divisor registers (DLL/DLM/DLD), and a user accessible scratchpad register (SPR).

Beyond the general 16C550 features and capabilities, the M680 offers enhanced feature registers (EFR, Xon1/Xoff 1, Xon2/Xoff 2, DLD, FCTR, EMSR and FC) that provide automatic RTS and CTS hardware flow control, automatic Xon/Xoff software flow control, 9-bit (Multidrop) mode, auto RS-485 half duplex control, different baud rate for TX and RX and fractional baud rate generator. All the register functions are discussed in full detail later in "Section 3.0, UART INTERNAL REGISTERS" on page 25.

2.5 INT Ouput

The interrupt outputs change according to the operating mode and enhanced features setup. Table 1 and 2 summarize the operating behavior for the transmitter and receiver. Also see Figure 22 through 25.

NOTE: *The IRQ# pin requires a pull-up resistor for proper operation.*

TABLE 1: INT PIN OPERATION FOR TRANSMITTER

	FCR BIT-0 = 0 (FIFO DISABLED)	FCR BIT-0 = 1 (FIFO ENABLED)
INT Pin (16/68# = 1)	LOW = One byte in THR HIGH = THR empty	LOW = FIFO above trigger level HIGH = FIFO below trigger level or FIFO empty
IRQ# Pin (16/68# = 0)	HIGH = One byte in THR LOW = THR empty	HIGH = FIFO above trigger level LOW = FIFO below trigger level or FIFO empty

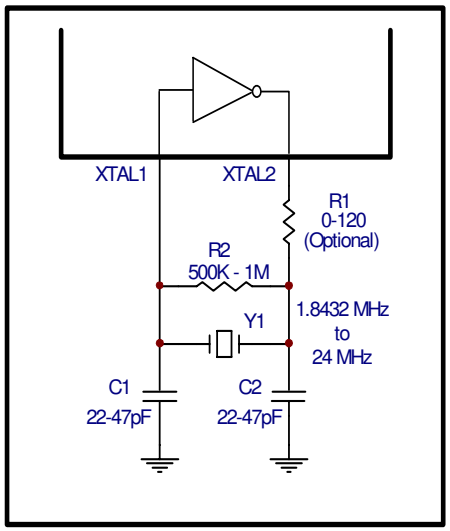
TABLE 2: INT PIN OPERATION FOR RECEIVER

	FCR BIT-0 = 0 (FIFO DISABLED)	FCR BIT-0 = 1 (FIFO ENABLED)
INT Pin (16/68# = 1)	HIGH = One byte in RHR LOW = RHR empty	LOW = FIFO below trigger level HIGH = FIFO above trigger level or RX Data Timeout
IRQ# Pin (16/68# = 0)	LOW = One byte in RHR HIGH = RHR empty	HIGH = FIFO below trigger level LOW = FIFO above trigger level or RX Data Timeout

2.6 Crystal Oscillator or External Clock Input

The M680 includes an on-chip oscillator to produce a clock for the baud rate generators in the device when a crystal is connected between XTAL1 and XTAL2 as show below. The CPU data bus does not require this clock for bus operation. The crystal oscillator provides a system clock to the Baud Rate Generators (BRGs) in the UART. XTAL1 is the input to the oscillator or external clock buffer input with XTAL2 pin being the output. For programming details, see **"Section 2.7, Programmable Baud Rate Generator with Fractional Divisor" on page 13**.

FIGURE 7. TYPICAL CRYSTAL CONNECTIONS



The on-chip oscillator is designed to use an industry standard microprocessor crystal (parallel resonant, fundamental frequency with 10-22 pF capacitance load, ESR of 20-120 ohms and 100ppm frequency tolerance) connected externally between the XTAL1 and XTAL2 pins. Typical oscillator connections are shown in **Figure 7**. Alternatively, an external clock can be connected to the XTAL1 pin to clock the internal baud rate generator for standard or custom rates. The BGA package has XTAL1 only, the external clock is required. For further reading on oscillator circuit, see application note DAN108 on EXAR's web site.

2.7 Programmable Baud Rate Generator with Fractional Divisor

The M680 has independent Baud Rate Generators (BRGs) with prescalers for the transmitter and receiver. The prescaler is controlled by a software bit in the MCR register. The MCR register bit-7 sets the prescaler to divide the input crystal or external clock by 1 or 4. The output of the prescaler clocks to the BRG. The BRG further divides this clock by a programmable divisor between 1 and (2^{16} - 0.0625) in increments of 0.0625 (1/16) to obtain a 16X or 8X or 4X sampling clock of the serial data rate. The sampling clock is used by the transmitter for data bit shifting and receiver for data sampling. For transmitter and receiver, the M680 provides respective BRG divisors. The BRG divisor (DLL, DLM, and DLD registers) defaults to the value of '1' (DLL = 0x01, DLM = 0x00 and DLD = 0x00) upon reset. Therefore, the BRG must be programmed during initialization to the operating data rate. The DLL and DLM registers provide the integer part of the divisor and the DLD registers provides the fractional part of the divisor. The four lower bits of the DLD are used to select a value from 0 (for setting 0000) to 0.9375 or 15/16 (for setting 1111). Programming the Baud Rate Generator Registers DLL, DLM and DLD provides the capability for selecting the operating data rate. **Table 3** shows the standard data rates available with a 24MHz crystal or external clock at 16X clock rate. If the pre-scaler is used (MCR bit-7 = 1), the output data rate will be 4 times less than that shown in **Table 3**. At 8X sampling rate, these data rates would double. And at 4X sampling rate, they would quadruple. Also, when using 8X sampling mode, please note that the bit-time will have a jitter (+/- 1/16) whenever the DLD is non-zero and is an odd number. When using a non-standard data rate crystal or external clock, the divisor value can be calculated with the following equation(s):

Required Divisor (decimal)=(XTAL1 clock frequency / prescaler) /(serial data rate x 16), with 16X mode, **DLD[5:4]='00'**
Required Divisor (decimal)= (XTAL1 clock frequency / prescaler / (serial data rate x 8), with 8X mode, **DLD[5:4] = '01'**
Required Divisor (decimal)= (XTAL1 clock frequency / prescaler / (serial data rate x 4), with 4X mode, **DLD[5:4] = '10'**

The closest divisor that is obtainable in the M680 can be calculated using the following formula:

ROUND((Required Divisor - TRUNC(Required Divisor))*16)/16 + TRUNC(Required Divisor), where

DLM = TRUNC(Required Divisor) >> 8
DLL = TRUNC(Required Divisor) & 0xFF
DLD = ROUND((Required Divisor-TRUNC(Required Divisor))*16)

In the formulas above, please note that:

TRUNC (N) = Integer Part of N. For example, TRUNC (5.6) = 5.

ROUND (N) = N rounded towards the closest integer. For example, ROUND (7.3) = 7 and ROUND (9.9) = 10.

A >> B indicates right shifting the value 'A' by 'B' number of bits. For example, 0x78A3 >> 8 = 0x0078.

2.7.1 Independent TX/RX BRG

The XR16M680 has two independent sets of TX and RX baud rate generator. Please see the **Figure 8**. TX and RX can work in different baud rate by setting DLD, DLL and DLM register. For example, TX can transmit data to the remote UART at 9600 bps while RX receives data from remote UART at 921.6 Kbps. For the baud rate setting, please **See "Section 4.13, Baud Rate Generator Registers (DLL, DLM and DLD) - Read/Write" on page 39.**.

FIGURE 8. BAUD RATE GENERATOR

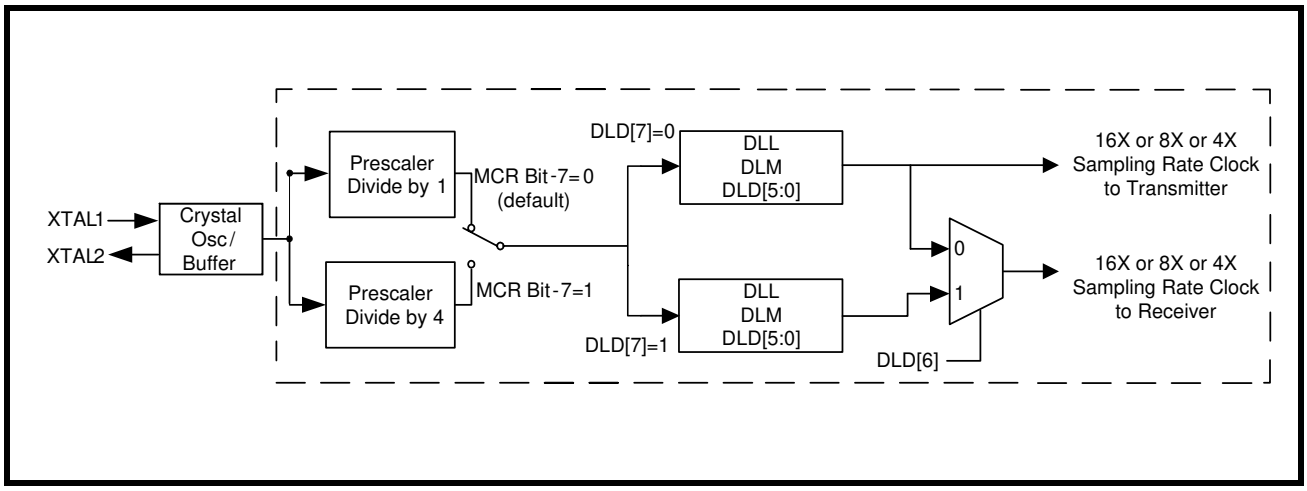


TABLE 3: TYPICAL DATA RATES WITH A 24 MHZ CRYSTAL OR EXTERNAL CLOCK AT 16X SAMPLING

Required Output Data Rate	DIVISOR FOR 16x Clock (Decimal)	DIVISOR OBTAINABLE IN M680	DLM PROGRAM VALUE (HEX)	DLL PROGRAM VALUE (HEX)	DLD PROGRAM VALUE (HEX)	DATA ERROR RATE (%)
400	3750	3750	E	A6	0	0
2400	625	625	2	71	0	0
4800	312.5	312 8/16	1	38	8	0
9600	156.25	156 4/16	0	9C	4	0
10000	150	150	0	96	0	0
19200	78.125	78 2/16	0	4E	2	0
25000	60	60	0	3C	0	0
28800	52.0833	52 1/16	0	34	1	0.04
38400	39.0625	39 1/16	0	27	1	0
50000	30	30	0	1E	0	0
57600	26.0417	26 1/16	0	1A	1	0.08
75000	20	20	0	14	0	0
100000	15	15	0	F	0	0
115200	13.0208	13	0	D	0	0.16
153600	9.7656	9 12/16	0	9	C	0.16
200000	7.5	7 8/16	0	7	8	0
225000	6.6667	6 11/16	0	6	B	0.31
230400	6.5104	6 8/16	0	6	8	0.16
250000	6	6	0	6	0	0
300000	5	5	0	5	0	0
400000	3.75	3 12/16	0	3	C	0
460800	3.2552	3 4/16	0	3	4	0.16
500000	3	3	0	3	0	0
750000	2	2	0	2	0	0
921600	1.6276	1 10/16	0	1	A	0.16
1000000	1.5	1 8/16	0	1	8	0

2.8 Transmitter

The transmitter section comprises of an 8-bit Transmit Shift Register (TSR) and 32 bytes of FIFO which includes a byte-wide Transmit Holding Register (THR). TSR shifts out every data bit with the 16X/8X/4X internal clock. A bit time is 16/8/4 clock periods. The transmitter sends the start-bit followed by the number of data bits, inserts the proper parity-bit if enabled, and adds the stop-bit(s). The status of the FIFO and TSR are reported in the Line Status Register (LSR bit-5 and bit-6).

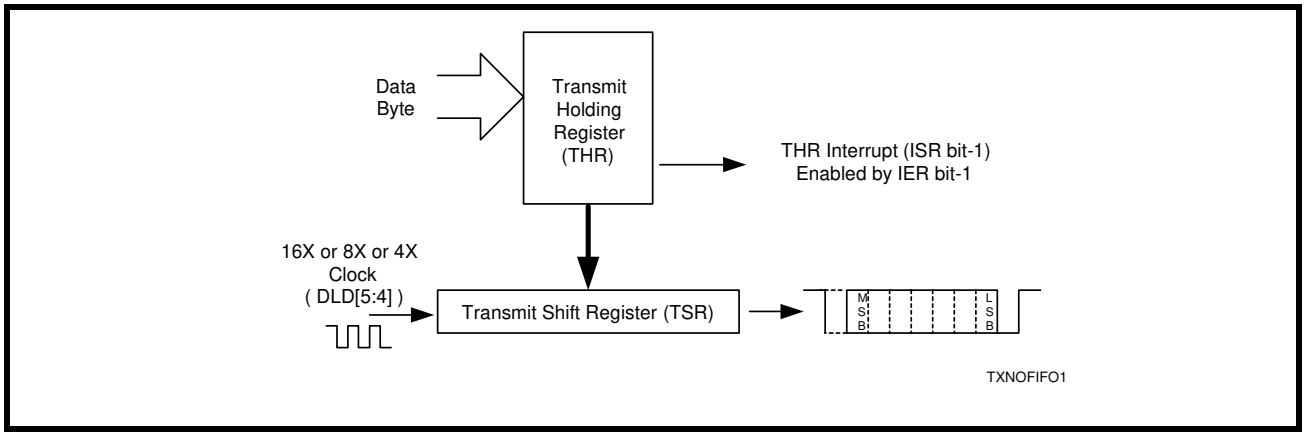
2.8.1 Transmit Holding Register (THR) - Write Only

The transmit holding register is an 8-bit register providing a data interface to the host processor. The host writes transmit data byte to the THR to be converted into a serial data stream including start-bit, data bits, parity-bit and stop-bit(s). The least-significant-bit (Bit-0) becomes first data bit to go out. The THR is the input register to the transmit FIFO of 32 bytes when FIFO operation is enabled by FCR bit-0. Every time a write operation is made to the THR, the FIFO data pointer is automatically bumped to the next sequential data location.

2.8.2 Transmitter Operation in non-FIFO Mode

The host loads transmit data to THR one character at a time. The THR empty flag (LSR bit-5) is set when the data byte is transferred to TSR. THR flag can generate a transmit empty interrupt (ISR bit-1) when it is enabled by IER bit-1. The TSR flag (LSR bit-6) is set when TSR becomes completely empty.

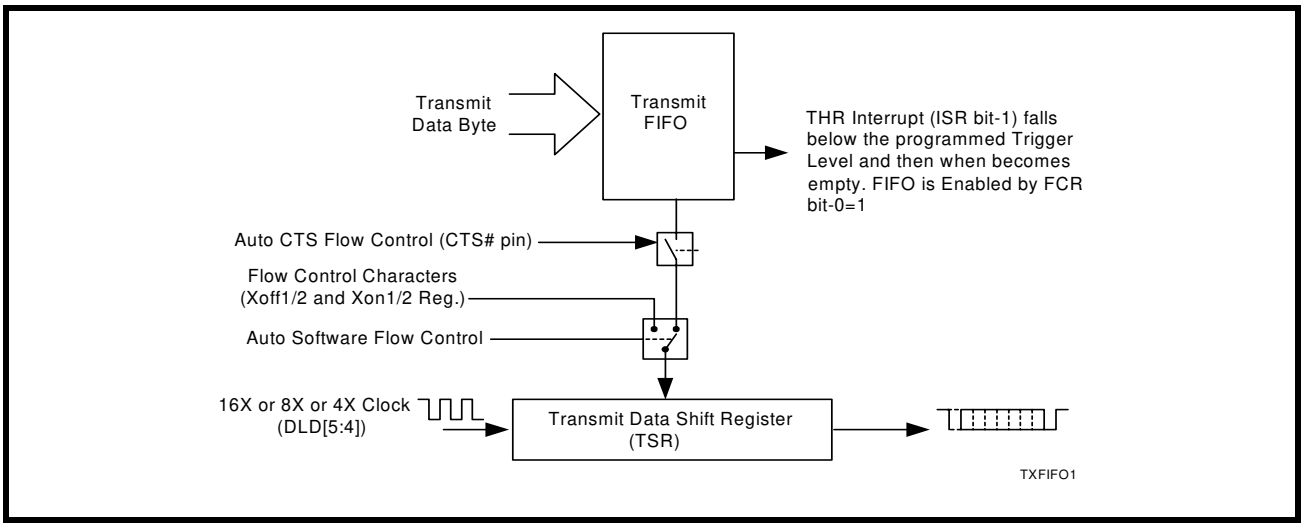
FIGURE 9. TRANSMITTER OPERATION IN NON-FIFO MODE



2.8.3 Transmitter Operation in FIFO Mode

The host may fill the transmit FIFO with up to 32 bytes of transmit data. The THR empty flag (LSR bit-5) is set whenever the FIFO is empty. The THR empty flag can generate a transmit empty interrupt (ISR bit-1) when the FIFO becomes empty. The transmit empty interrupt is enabled by IER bit-1. The TSR flag (LSR bit-6) is set when TSR/FIFO becomes empty.

FIGURE 10. TRANSMITTER OPERATION IN FIFO AND FLOW CONTROL MODE



2.9 Receiver

The receiver section contains an 8-bit Receive Shift Register (RSR) and 32 bytes of FIFO which includes a byte-wide Receive Holding Register (RHR). The RSR uses the 16X/8X/4X clock (DLD[5:4]) for timing. It verifies and validates every bit on the incoming character in the middle of each data bit. On the falling edge of a start or false start bit, an internal receiver counter starts counting at the 16X/8X/4X clock rate. After 8 clocks (or 4 if 8X or 2 if 4X) the start bit period should be at the center of the start bit. At this time the start bit is sampled and if it is still a logic 0 it is validated. Evaluating the start bit in this manner prevents the receiver from assembling a false character. The rest of the data bits and stop bits are sampled and validated in this same manner to prevent false framing. If there were any error(s), they are reported in the LSR register bits 2-4. Upon unloading the receive data byte from RHR, the receive FIFO pointer is bumped and the error tags are immediately updated to reflect the status of the data byte in RHR register. RHR can generate a receive data ready interrupt upon receiving a character or delay until it reaches the FIFO trigger level. Furthermore, data delivery to the host is guaranteed by a receive data ready time-out interrupt when data is not received for 4 word lengths as defined by LCR[1:0] plus 12 bits time. This is equivalent to 3.7-4.6 character times. The RHR interrupt is enabled by IER bit-0. See **Figure 11** and **Figure 12** below.

2.9.1 Receive Holding Register (RHR) - Read-Only

The Receive Holding Register is an 8-bit register that holds a receive data byte from the Receive Shift Register. It provides the receive data interface to the host processor. The RHR register is part of the receive FIFO of 32 bytes by 11-bits wide, the 3 extra bits are for the 3 error tags to be reported in LSR register. When the FIFO is enabled by FCR bit-0, the RHR contains the first data character received by the FIFO. After the RHR is read, the next character byte is loaded into the RHR and the errors associated with the current data byte are immediately updated in the LSR bits 2-4.

FIGURE 11. RECEIVER OPERATION IN NON-FIFO MODE

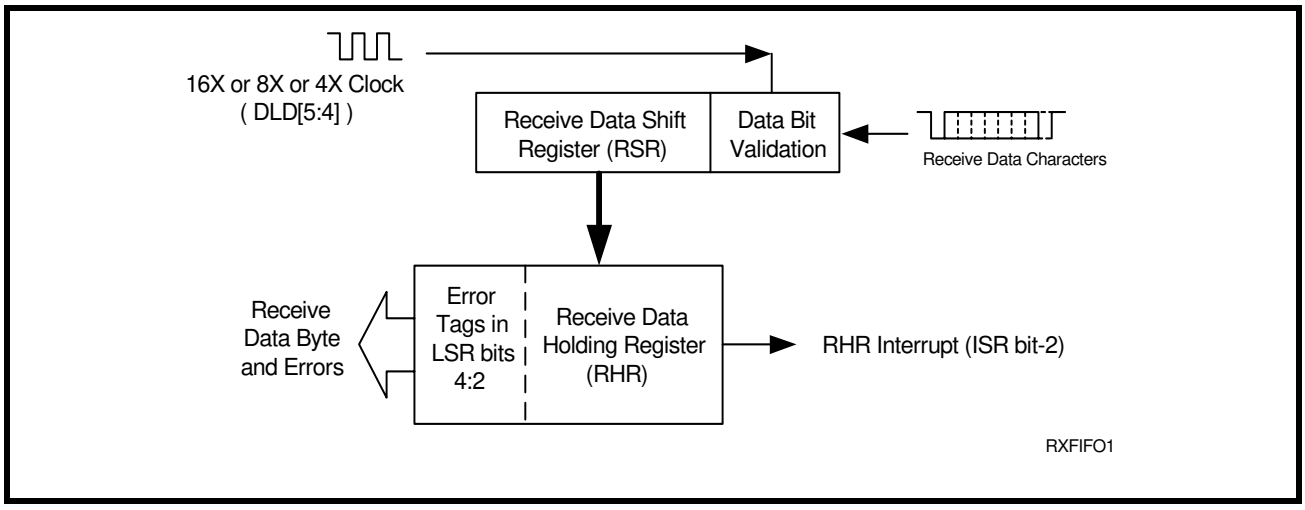
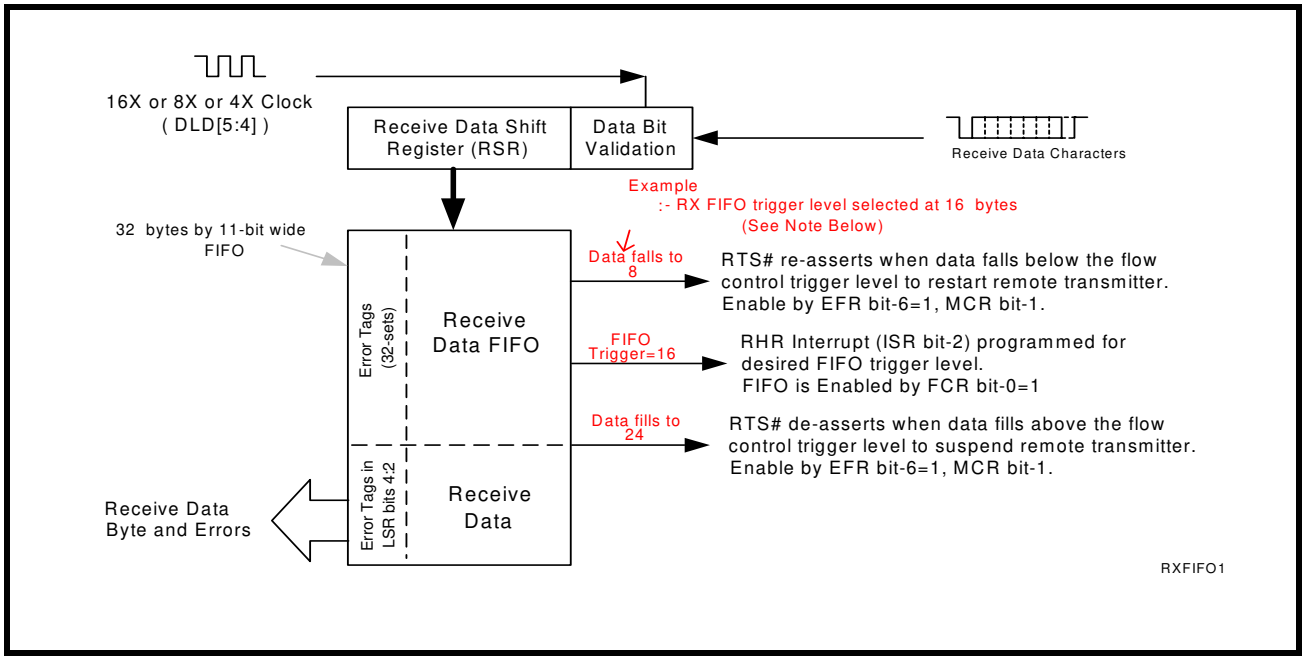


FIGURE 12. RECEIVER OPERATION IN FIFO AND AUTO RTS FLOW CONTROL MODE



2.10 Auto RTS (Hardware) Flow Control

Automatic RTS hardware flow control is used to prevent data overrun to the local receiver FIFO. The RTS# output is used to request remote unit to suspend/resume data transmission. The auto RTS flow control features is enabled to fit specific application requirement (see Figure 13):

- Enable auto RTS flow control using EFR bit-6.
- The auto RTS function must be started by asserting RTS# output pin (MCR bit-1 to logic 1 after it is enabled).

If using the Auto RTS interrupt:

- Enable RTS interrupt through IER bit-6 (after setting EFR bit-4). The UART issues an interrupt when the RTS# pin makes a transition from low to high: ISR bit-5 will be set to logic 1.

2.11 Auto RTS Hysteresis

With the Auto RTS function enabled, an interrupt is generated when the receive FIFO reaches the selected RX trigger level. The RTS# pin will not be forced HIGH (RTS off) until the receive FIFO reaches one trigger level above the selected trigger level in the trigger table (Table 9). The RTS# pin will return LOW after the RX FIFO is unloaded to one level below the selected trigger level. Under the above described conditions, the M680 will continue to accept data until the receive FIFO gets full. The Auto RTS function is initiated when the RTS# output pin is asserted LOW (RTS On).

TABLE 4: AUTO RTS (HARDWARE) FLOW CONTROL

RX TRIGGER LEVEL	INT PIN ACTIVATION	RTS# DE-ASSERTED (HIGH) (CHARACTERS IN RX FIFO)	RTS# ASSERTED (LOW) (CHARACTERS IN RX FIFO)
8	8	16	0
16	16	24	8
24	24	28	16
28	28	28	24

2.12 Auto CTS Flow Control

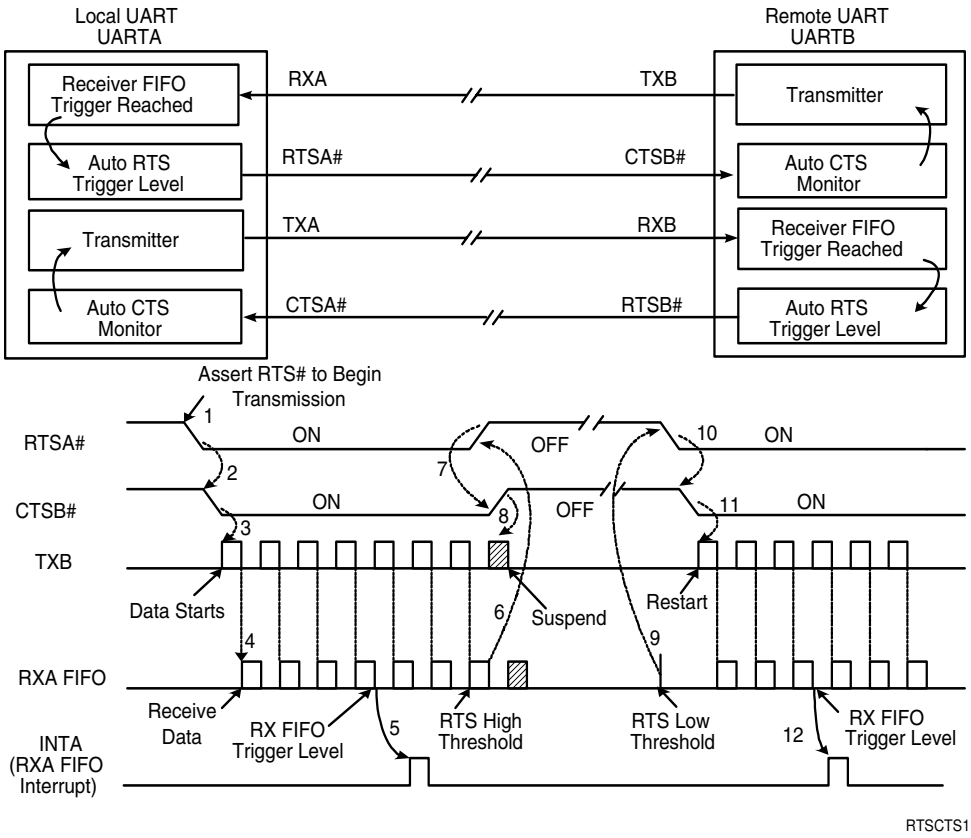
Automatic CTS flow control is used to prevent data overrun to the remote receiver FIFO. The CTS# input is monitored to suspend/restart the local transmitter. The auto CTS flow control feature is selected to fit specific application requirement (see Figure 13):

- Enable auto CTS flow control using EFR bit-7.

If needed, the CTS interrupt can be enabled through IER bit-7 (after setting EFR bit-4). The UART issues an interrupt when the CTS# pin is de-asserted (HIGH): ISR bit-5 will be set to 1, and UART will suspend

transmission as soon as the stop bit of the character in process is shifted out. Transmission is resumed after the CTS# input is re-asserted (LOW), indicating more data may be sent.

FIGURE 13. AUTO RTS AND CTS FLOW CONTROL OPERATION



The local UART (UARTA) starts data transfer by asserting RTSA# (1). RTSA# is normally connected to CTSB# (2) of remote UART (UARTB). CTSB# allows its transmitter to send data (3). TXB data arrives and fills UARTA receive FIFO (4). When RXA data fills up to its receive FIFO trigger level, UARTA activates its RXA data ready interrupt (5) and continues to receive and put data into its FIFO. If interrupt service latency is long and data is not being unloaded, UARTA monitors its receive data fill level to match the upper threshold of RTS delay and de-assert RTSA# (6). CTSB# follows (7) and request UARTB transmitter to suspend data transfer. UARTB stops or finishes sending the data bits in its transmit shift register (8). When receive FIFO data in UARTA is unloaded to match the lower threshold of RTS delay (9), UARTA re-asserts RTSA# (10), CTSB# recognizes the change (11) and restarts its transmitter and data flow again until next receive FIFO trigger (12). This same event applies to the reverse direction when UARTA sends data to UARTB with RTSB# and CTSA# controlling the data flow.

2.13 Auto Xon/Xoff (Software) Flow Control

When software flow control is enabled (See Table 15), the M680 compares one or two sequential receive data characters with the programmed Xon or Xoff-1,2 character value(s). If receive character(s) (RX) match the programmed values, the M680 will halt transmission (TX) as soon as the current character has completed transmission. When a match occurs, the Xoff (if enabled via IER bit-5) flag will be set and the interrupt output pin will be activated. Following a suspension due to a match of the Xoff character, the M680 will monitor the receive data stream for a match to the Xon-1,2 character. If a match is found, the M680 will resume operation and clear the flags (ISR bit-4).

Reset initially sets the contents of the Xon/Xoff 8-bit flow control registers to a logic 0. Following reset the user can write any Xon/Xoff value desired for software flow control. Different conditions can be set to detect Xon/Xoff characters (See Table 15) and suspend/resume transmissions. When double 8-bit Xon/Xoff characters are selected, the M680 compares two consecutive receive characters with two software flow control 8-bit values (Xon1, Xon2, Xoff1, Xoff2) and controls TX transmissions accordingly. Under the above described flow control mechanisms, flow control characters are not placed (stacked) in the user accessible RX data buffer or FIFO.

In the event that the receive buffer is overfilling and flow control needs to be executed, the M680 automatically sends an Xoff message (when enabled) via the serial TX output to the remote modem. The M680 sends the Xoff-1,2 characters two-character-times (= time taken to send two characters at the programmed baud rate) after the receive FIFO crosses the selected trigger level. To clear this condition, the M680 will transmit the programmed Xon-1,2 characters as soon as receive FIFO is less than one trigger level below the selected trigger level. Table 5 below explains this.

TABLE 5: AUTO XON/XOFF (SOFTWARE) FLOW CONTROL

RX TRIGGER LEVEL	INT PIN ACTIVATION	XOFF CHARACTER(S) SENT (CHARACTERS IN RX FIFO)	XON CHARACTER(S) SENT (CHARACTERS IN RX FIFO)
8	8	8*	0
16	16	16*	8
24	24	24*	16
28	28	28*	24

* *After the trigger level is reached, an xoff character is sent after a short span of time (= time required to send 2* characters); for example, after 2.083ms has elapsed for 9600 baud and 10-bit word length setting.

2.14 Special Character Detect

A special character detect feature is provided to detect an 8-bit character when bit-5 is set in the Enhanced Feature Register (EFR). When this character (Xoff2) is detected, it will be placed in the FIFO along with normal incoming RX data.

The M680 compares each incoming receive character with Xoff-2 data. If a match exists, the received data will be transferred to the RX FIFO and ISR bit-4 will be set to indicate detection of special character. Although the Internal Register Table shows Xon, Xoff Registers with eight bits of character information, the actual number of bits is dependent on the programmed word length. Line Control Register (LCR) bits 0-1 defines the number of character bits, i.e., either 5 bits, 6 bits, 7 bits, or 8 bits. The word length selected by LCR bits 0-1 also determines the number of bits that will be used for the special character comparison. Bit-0 in the Xon, Xoff Registers corresponds with the LSB bit for the receive character.

2.15 Normal Multidrop Mode

Normal multidrop mode is enabled when MSR[6] = 1 (requires EFR[4] = 1) and EFR[5] = 0 (Special Character Detect disabled). The receiver is set to Force Parity 0 (LCR[5:3] = '111') in order to detect address bytes.

With the receiver initially disabled, it ignores all the data bytes (parity bit = 0) until an address byte is received (parity bit = 1). This address byte will cause the UART to set the parity error. The UART will generate an LSR

interrupt and place the address byte in the RX FIFO. The software then examines the byte and enables the receiver if the address matches its slave address, otherwise, it does not enable the receiver.

If the receiver has been enabled, the receiver will receive the subsequent data. If an address byte is received, it will generate an LSR interrupt. The software again examines the byte and if the address matches its slave address, it does not have to do anything. If the address does not match its slave address, then the receiver should be disabled.

2.15.1 Auto Address Detection

Auto address detection mode is enabled when MSR[6] = 1 (requires EFR[4] = 1) and EFR bit-5 = 1. The desired slave address will need to be written into the XOFF2 register. The receiver will try to detect an address byte that matches the porgrammed character in the XOFF2 register. If the received byte is a data byte or an address byte that does not match the programmed character in the XOFF2 register, the receiver will discard these data. Upon receiving an address byte that matches the XOFF2 character, the receiver will be automatically enabled if not already enabled, and the address character is pushed into the RX FIFO along with the parity bit (in place of the parity error bit). The receiver also generates an LSR interrupt. The receiver will then receive the subsequent data. If another address byte is received and this address does not match the programmed XOFF2 character, then the receiver will automatically be disabled and the address byte is ignored. If the address byte matches XOFF2, the receiver will put this byte in the RX FIFO along with the parity bit in the parity error bit.

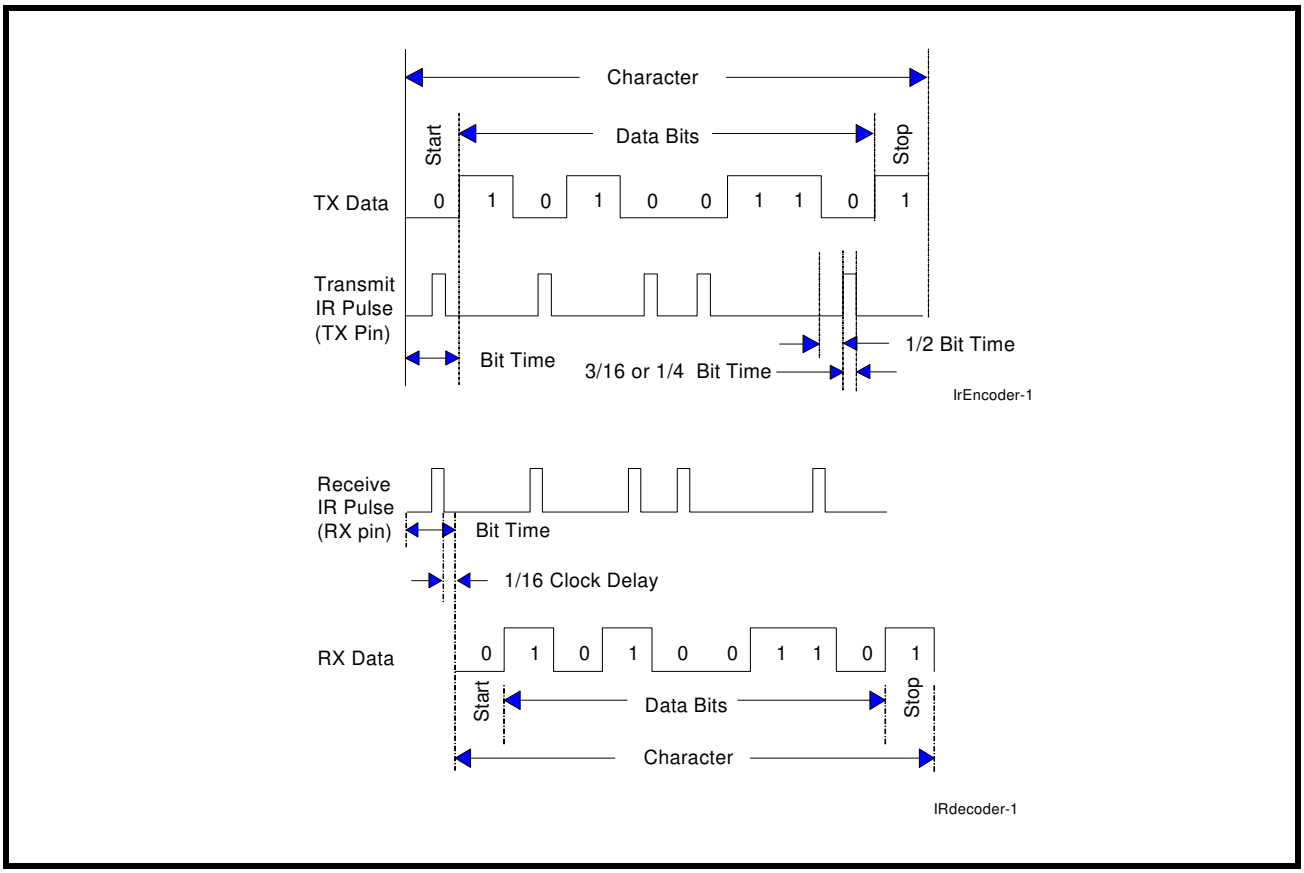
2.16 Infrared Mode

The M680 UART includes the infrared encoder and decoder compatible to the IrDA (Infrared Data Association) version 1.0 and 1.1. The IrDA 1.0 standard that stipulates the infrared encoder sends out a 3/16 of a bit wide HIGH-pulse for each “0” bit in the transmit data stream with a data rate up to 115.2 Kbps. For the IrDA 1.1 standard, the infrared encoder sends out a 1/4 of a bit time wide HIGH-pulse for each "0" bit in the transmit data stream with a data rate up to 1.152 Mbps. This signal encoding reduces the on-time of the infrared LED, hence reduces the power consumption. See **Figure 14** below.

The infrared encoder and decoder are enabled by setting MCR register bit-6 to a ‘1’. With this bit enabled, the infrared encoder and decoder is compatible to the IrDA 1.0 standard. For the infrared encoder and decoder to be compatible to the IrDA 1.1 standard, MSR bit-7 will also need to be set to a ’1’ when EFR bit-4 is set to ’1’. Likewise, the RX input assumes an idle level of logic zero from a reset and power up, see **Figure 14**.

Typically, the wireless infrared decoder receives the input pulse from the infrared sensing diode on the RX pin. Each time it senses a light pulse, it returns a logic 1 to the data bit stream.

FIGURE 14. INFRARED TRANSMIT DATA ENCODING AND RECEIVE DATA DECODING



2.17 Sleep Mode with Auto Wake-Up and Power-Save feature

The M680 supports low voltage system designs, hence, a sleep mode with auto wake-up and power-save feature is included to reduce its power consumption when the chip is not actively used.

2.17.1 Sleep mode

All of these conditions must be satisfied for the M680 to enter sleep mode:

- no interrupts pending (ISR bit-0 = 1)
- sleep mode is enabled (IER bit-4 = 1)
- modem inputs are not toggling (MSR bits 0-3 = 0)
- RX input pin is idling HIGH in normal mode or LOW in infrared mode
- divisor is non-zero
- TX and RX FIFOs are empty

The M680 stops its crystal oscillator to conserve power in the sleep mode. User can check the XTAL2 pin for no clock output as an indication that the device has entered the sleep mode.

The M680 resumes normal operation by any of the following:

- a receive data start bit transition (HIGH to LOW)
- a data byte is loaded to the transmitter, THR or FIFO
- a change of logic state on any of the modem or general purpose serial inputs: CTS#, DSR#, CD#, RI#

If the M680 is awakened by any one of the above conditions, it will return to the sleep mode automatically after all interrupting conditions have been serviced and cleared. If the M680 is awakened by the modem inputs, a read to the MSR is required to reset the modem inputs. In any case, the sleep mode will not be entered while

an interrupt is pending from any channel. The M680 will stay in the sleep mode of operation until it is disabled by setting IER bit-4 to a logic 0.

A word of caution: owing to the starting up delay of the crystal oscillator after waking up from sleep mode, the first few receive characters may be lost. Also, make sure the RX pin is idling HIGH or “marking” condition during sleep mode. This may not occur when the external interface transceivers (RS-232, RS-485 or another type) are also put to sleep mode and cannot maintain the “marking” condition. To avoid this, the system design engineer can use a 47k ohm pull-up resistor on each of the RX input.

2.17.2 Power-Save Feature

If the address lines, data bus lines, IOW#, IOR#, CS# and modem input lines remain steady when the M680 is in sleep mode, the maximum current will be in the microamp range as specified in the DC Electrical Characteristics on **page 44**. If the input lines are floating or are toggling while the M680 is in sleep mode, the current can be up to 100 times more. If not using the Power-Save feature, an external buffer would be required to keep the address and data bus lines from toggling or floating to achieve the low current. But if the Power-Save feature is enabled (PwrSave pin connected to VCC), this will eliminate the need for an external buffer by internally isolating the address, data and control signals (see **Figure 1** on **page 1**) from other bus activities that could cause wasteful power drain. The M680 enters Power-Save mode when this pin is connected to VCC and the M680 is in sleep mode (see Sleep Mode section above).

Since Power-Save mode isolates the address, data and control signals, the device will wake-up only by:

- a receive data start bit transition (HIGH to LOW) at the RX input or
- a change of logic state on the modem or general purpose serial input CTS#, DSR#, CD#, RI#

The M680 will return to the Power-Save mode automatically after a read to the MSR (to reset the modem input CTS#) and all interrupting conditions have been serviced and cleared. The M680 will stay in the Power-Save mode of operation until it is disabled by setting IER bit-4 to a logic 0 and/or the Power-Save pin is connected to GND.

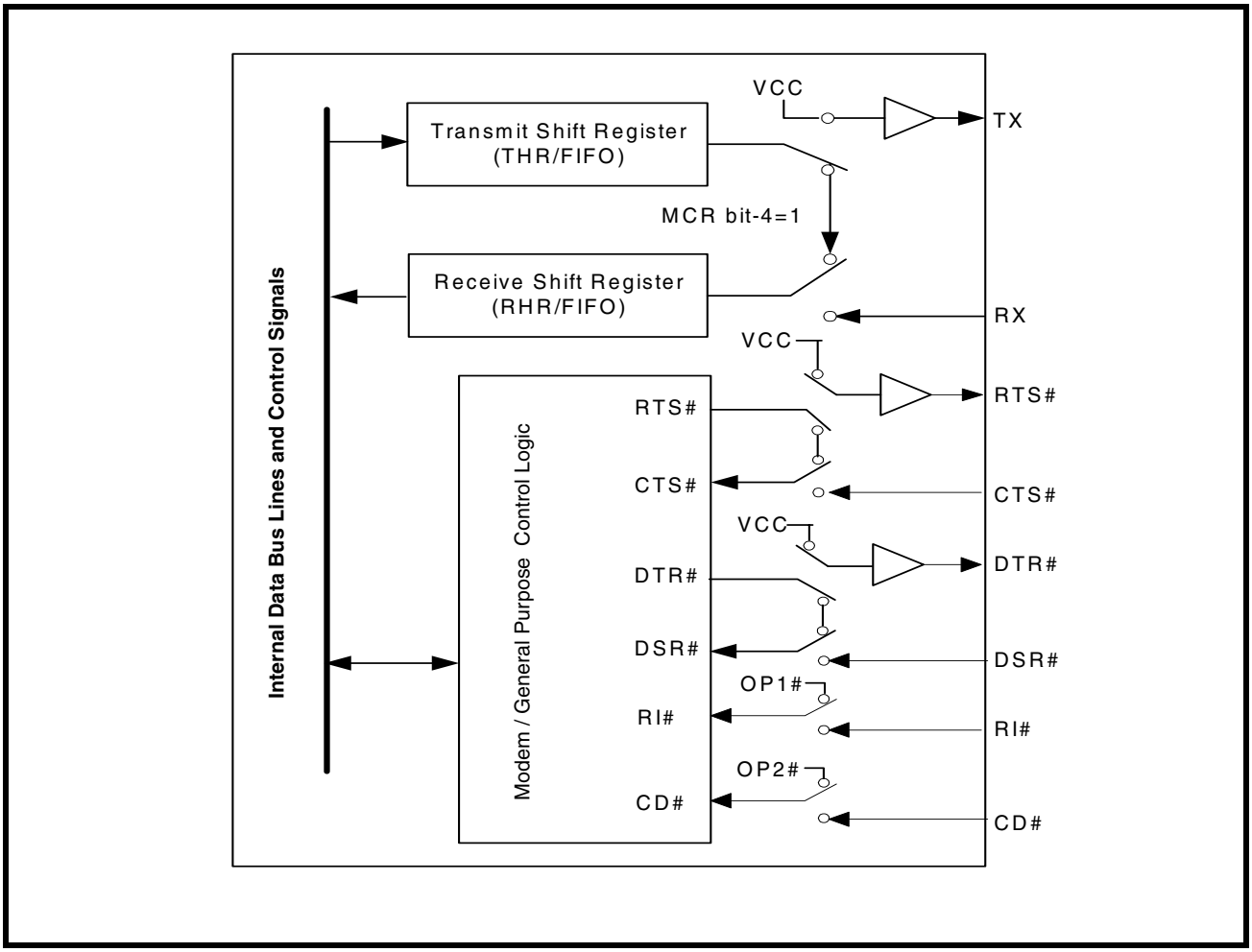
2.17.3 Wake-up Interrupt

The M680 has the wake up interrupt. By setting the FCR bit-3, wake up interrupt is enabled or disabled. The default status of wake up interrupt is disabled. Please **See ”Section 4.5, FIFO Control Register (FCR) - Write-Only” on page 31.**

2.18 Internal Loopback

The M680 UART provides an internal loopback capability for system diagnostic purposes. The internal loopback mode is enabled by setting MCR register bit-4 to logic 1. All regular UART functions operate normally. Figure 15 shows how the modem port signals are re-configured. Transmit data from the transmit shift register output is internally routed to the receive shift register input allowing the system to receive the same data that it was sending. The TX pin is held HIGH or mark condition while RTS# and DTR# are de-asserted, and CTS#, DSR# CD# and RI# inputs are ignored. Caution: the RX input must be held HIGH during loopback test else upon exiting the loopback test the UART may detect and report a false “break” signal.

FIGURE 15. INTERNAL LOOPBACK



3.0 UART INTERNAL REGISTERS

The complete register set for the M680 is shown in Table 6 and Table 7.

TABLE 6: UART INTERNAL REGISTERS

A2 A1 A0 ADDRESSES	REGISTER	READ/WRITE	COMMENTS
16C550 COMPATIBLE REGISTERS			
0 0 0	DREV - Device Revision	Read-only	LCR[7] = 1, LCR ≠ 0xBF, DLL = 0x00, DLM = 0x00
0 0 1	DVID - Device Identification Register	Read-only	
0 0 0	DLL - Divisor LSB Register	Read/Write	LCR[7] = 1, LCR ≠ 0xBF See DLD[7:6]
0 0 1	DLM - Divisor MSB Register	Read/Write	
0 1 0	DLD - Divisor Fractional Register	Read/Write	LCR[7] = 1, LCR ≠ 0xBF, EFR[4] = 1
0 0 0	RHR - Receive Holding Register THR - Transmit Holding Register	Read-only Write-only	LCR[7] = 0
0 0 1	IER - Interrupt Enable Register	Read/Write	
0 1 0	ISR - Interrupt Status Register FCR - FIFO Control Register	Read-only Write-only	LCR[7] = 0 if EFR[4] = 1 or LCR ≠ 0xBF if EFR[4] = 0
0 1 1	LCR - Line Control Register	Read/Write	
1 0 0	MCR - Modem Control Register	Read/Write	LCR ≠ 0xBF
1 0 1	LSR - Line Status Register	Read-only	
1 1 0	MSR - Modem Status Register	Read-only	
1 1 0	MSR - Modem Status Register	Write-only	LCR ≠ 0xBF EFR[4] = 1
1 1 1	SPR - Scratch Pad Register	Read/Write	LCR ≠ 0xBF, FCTR[6] = 0
1 1 1	EMSR - Enhanced Mode Select Register	Write-only	LCR ≠ 0xBF, FCTR[6] = 1
1 1 1	FC - RX/TX FIFO Level Counter Register	Read-only	
ENHANCED REGISTERS			
0 0 0	FC - RX/TX FIFO Level Counter Register	Read-only	LCR = 0xBF
0 0 1	FCTR - Feature Control Register	Read/Write	
0 1 0	EFR - Enhanced Function Reg	Read/Write	
1 0 0	Xon-1 - Xon Character 1	Read/Write	
1 0 1	Xon-2 - Xon Character 2	Read/Write	
1 1 0	Xoff-1 - Xoff Character 1	Read/Write	
1 1 1	Xoff-2 - Xoff Character 2	Read/Write	