

**GENERAL DESCRIPTION**

The XR16L788<sup>1</sup> (788), formerly XR16L758, is a 5V and 3.3V with 5V tolerant inputs octal Universal Asynchronous Receiver and Transmitter (UART). The highly integrated device is designed for high bandwidth requirement in communication systems. A new feature increases device driver efficiency includes a global interrupt pin with global interrupt source registers that provide complete and detailed interrupt status information for all 8 channels that will speed up interrupt parsing. Other new facilities include simultaneous UART registers initialization, individual UART channel soft-reset, DTR/DSR hardware flow control, software flow control (Xoff/Xon) detection indicators, RS-485 half-duplex direction control with programmable turn-around delay, Intel or Motorola bus interface and sleep mode now has a wake-up indicator.

**NOTE:** Covered by US patents #5,649,122 and #5,949,787

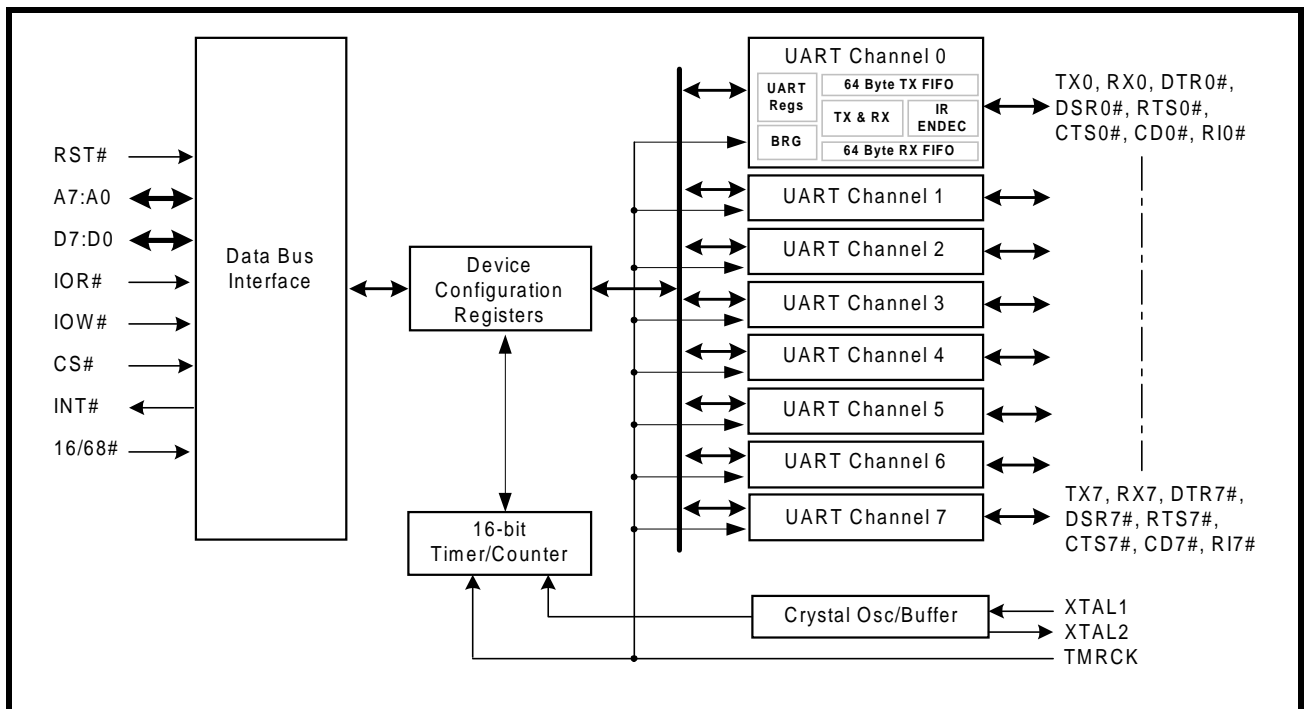
**APPLICATIONS**

- Remote Access Servers
- Ethernet Network to Serial Ports
- Network Management
- Factory Automation and Process Control
- Point-of-Sale Systems
- Multi-port RS-232/RS-422/RS-485 Cards

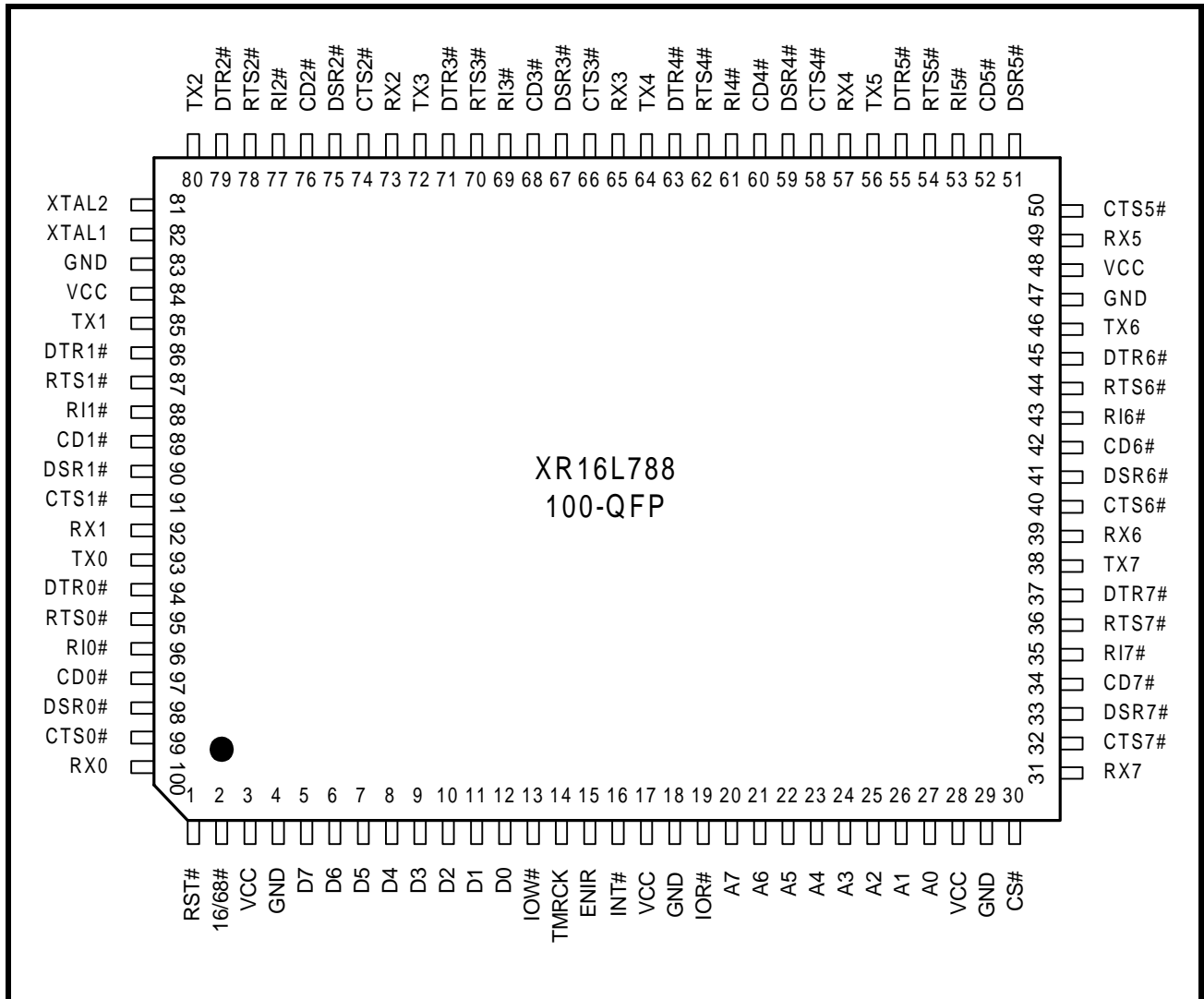
**NEW FEATURES:**

- **5V and 3.3V with 5V Tolerant Inputs Operation**
- **Single Interrupt Output for all 8 UARTs**
- **Global Interrupt Source for all 8 UARTs**
- **5G “Flat” UART Registers for Configurations**
- **Simultaneous UART Channels Initialization**
- **Auto RS485 Half-duplex Control with Programmable Turn-around Delay**
- **A General Purpose 16-bit Timer/Counter**
- **Sleep Mode with Wake-up Indication**
- **Highly Integrated Device for Space Saving**
- First eight registers are 16C550 compatible
- 64-byte Transmit and Receive FIFOs
- Transmit and Receive FIFO Level Counters
- Programmable TX and RX FIFO Trigger Levels
- Automatic RTS/CTS or DTR/DSR Flow Control
- Selectable Hardware Flow Control Hysteresis
- Automatic Xon/Xoff Software Flow Control with Status Indicator
- Infrared (IrDA 1.0) Data Encoder/Decoder
- Programmable Data Rate with Prescaler
- Up to 6.25 Mbps Serial Data Rate at 5V
- 100-pin QFP Package (14x20x3 mm)

**FIGURE 1. BLOCK DIAGRAM**



**FIGURE 2. PIN OUT OF THE DEVICE**



**ORDERING INFORMATION**

PART NUMBER	PACKAGE	OPERATING TEMPERATURE RANGE
XR16L788CQ	14x20x3mm 100-QFP	0°C to +70°C
XR16L788IQ	14x20x3mm 100-QFP	-40°C to +85°C

REV. 1.1.3

## PIN DESCRIPTIONS

NAME	PIN #	TYPE	DESCRIPTION
<b>DATA BUS INTERFACE</b>			
A7:A0	20-27	I	Address data lines [7:0]. A0:A3 selects individual UART's 16 configuration registers, A4:A6 selects UART channel 0 to7, and A7 selects the global device configuration registers.
D7:D0	5-12	IO	Data bus lines (7:0) (bidirectional).
IOR#	19	I	When 16/68# pin is at logic 1, it selects Intel bus interface and this input is 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 [A7:A0], places it on the data bus to allow the host processor to read it on the leading edge. When 16/68# pin is at logic 0, it selects Motorola bus interface and this input should be connected to VCC.
IOW#	13	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 leading 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, it selects Motorola bus interface and this input becomes read (logic 1) and write (logic 0) signal (R/W#).
CS#	30	I	When 16/68# pin is at logic 1, this input is chip select (active low) to enable the XR16L788 device. When 16/68# pin is at logic 0, this input becomes the read and write strobe (active low) for the Motorola bus interface.
INT#	16	OD	Global interrupt output from XR16L788 (open drain, active low). This output requires an external pull-up resistor (47K-100K ohms) to operate properly. It may be shared with other devices in the system to form a single interrupt line to the host processor and have the software driver polls each device for the interrupt status.
<b>MODEM OR SERIAL I/O INTERFACE</b>			
TX0	93	O	UART channel 0 Transmit Data or infrared transmit data.
RX0	100	I	UART channel 0 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].
RTS0#	95	O	UART channel 0 Request to Send or general purpose output (active low). This port may be used for one of two functions: 1) auto hardware flow control, see EFR bit-6, MCR bits-1 & 2, FCTR bits 0-3 and IER bit-6 2) RS485 half-duplex direction control, see FCTR bit-5, MCR bit-2 and MSR bits 4-7.
CTS0#	99	I	UART channel 0 Clear to Send or general purpose input (active low). It can be used for auto hardware flow control, see EFR bit-7, MCR bit-2 and IER bit-7.
DTR0#	94	O	UART channel 0 Data Terminal Ready or general purpose output (active low). This port may be used one of two functions. 1) auto hardware flow control, see EFR bit-6, FCTR bits-0 to 3, MCR bits-0 & 2, and IER bit-6 2) RS485 half-duplex direction control, see FCTR bit-5, MCR bit-2 and MSR bit 4-7.
DSR0#	98	I	UART channel 0 Data Set Ready or general purpose input (active low). It can be used for auto hardware flow control, see EFR bit-7, MCR bit-2 and IER bit-7.
CD0#	97	I	UART channel 0 Carrier Detect or general purpose input (active low).

NAME	PIN #	TYPE	DESCRIPTION
RI0#	96	I	UART channel 0 Ring Indicator or general purpose input (active low).
TX1	85	O	UART channel 1 Transmit Data or infrared transmit data.
RX1	92	I	UART channel 1 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].
RTS1#	87	O	UART channel 1 Request to Send or general purpose output (active low). See description of RTS0# pin.
CTS1#	91	I	UART channel 1 Clear to Send or general purpose input (active low). See description of CTS0# pin.
DTR1#	86	O	UART channel 1 Data Terminal Ready or general purpose output (active low). See description of DTR0# pin.
DSR1#	90	I	UART channel 1 Data Set Ready or general purpose input (active low). See description of DSR0# pin.
CD1#	89	I	UART channel 1 Carrier Detect or general purpose input (active low).
RI1#	88	I	UART channel 1 Ring Indicator or general purpose input (active low).
TX2	80	O	UART channel 2 Transmit Data or infrared transmit data.
RX2	73	I	UART channel 2 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].
RTS2#	78	O	UART channel 2 Request to Send or general purpose output (active low). See description of RTS0# pin.
CTS2#	74	I	UART channel 2 Clear to Send or general purpose input (active low). See description of CTS0# pin.
DTR2#	79	O	UART channel 2 Data Terminal Ready or general purpose output (active low). See description of DTR0# pin.
DSR2#	75	I	UART channel 2 Data Set Ready or general purpose input (active low). See description of DSR0# pin.
CD2#	76	I	UART channel 2 Carrier Detect or general purpose input (active low).
RI2#	77	I	UART channel 2 Ring Indicator or general purpose input (active low).
TX3	72	O	UART channel 3 Transmit Data or infrared transmit data.
RX3	65	I	UART channel 3 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].
RTS3#	70	O	UART channel 3 Request to Send or general purpose output (active low). See description of RTS0# pin.
CTS3#	66	I	UART channel 3 Clear to Send or general purpose input (active low). See description of CTS0# pin.
DTR3#	71	O	UART channel 3 Data Terminal Ready or general purpose output (active low). See description of DTR0# pin.
DSR3#	67	I	UART channel 3 Data Set Ready or general purpose input (active low). See description of DSR0# pin.
CD3#	68	I	UART channel 3 Carrier Detect or general purpose input (active low).
RI3#	69	I	UART channel 3 Ring Indicator or general purpose input (active low).
TX4	64	O	UART channel 4 Transmit Data or infrared transmit data.
RX4	57	I	UART channel 4 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].

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NAME	PIN #	TYPE	DESCRIPTION
RTS4#	62	O	UART channel 4 Request to Send or general purpose output (active low). See description of RTS0# pin.
CTS4#	58	I	UART channel 4 Clear to Send or general purpose input (active low). See description of CTS0# pin.
DTR4#	63	O	UART channel 4 Data Terminal Ready or general purpose output (active low). See description of DTR0# pin.
DSR4#	59	I	UART channel 4 Data Set Ready or general purpose input (active low). See description of DSR0# pin.
CD4#	60	I	UART channel 4 Carrier Detect or general purpose input (active low).
RI4#	61	I	UART channel 4 Ring Indicator or general purpose input (active low).
TX5	56	O	UART channel 5 Transmit Data or infrared transmit data.
RX5	49	I	UART channel 5 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].
RTS5#	54	O	UART channel 5 Request to Send or general purpose output (active low). See description of RTS0# pin.
CTS5#	50	I	UART channel 5 Clear to Send or general purpose input (active low). See description of CTS0# pin.
DTR5#	55	O	UART channel 5 Data Terminal Ready or general purpose output (active low). See description of DTR0# pin.
DSR5#	51	I	UART channel 5 Data Set Ready or general purpose input (active low). See description of DSR0# pin.
CD5#	52	I	UART channel 5 Carrier Detect or general purpose input (active low).
RI5#	53	I	UART channel 5 Ring Indicator or general purpose input (active low).
TX6	46	O	UART channel 6 Transmit Data or infrared transmit data.
RX6	39	I	UART channel 6 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].
RTS6#	44	O	UART channel 6 Request to Send or general purpose output (active low). See description of RTS0# pin.
CTS6#	40	I	UART channel 6 Clear to Send or general purpose input (active low). See description of CTS0# pin.
DTR6#	45	O	UART channel 6 Data Terminal Ready or general purpose output (active low). See description of DTR0# pin.
DSR6#	41	I	UART channel 6 Data Set Ready or general purpose input (active low). See description of DSR0# pin.
CD6#	42	I	UART channel 6 Carrier Detect or general purpose input (active low).
RI6#	43	I	UART channel 6 Ring Indicator or general purpose input (active low).
TX7	38	O	UART channel 7 Transmit Data or infrared transmit data.
RX7	31	I	UART channel 7 Receive Data or infrared receive data. Normal RXD input idles at logic 1 condition. The infrared pulses can be inverted internally prior the decoder by FCTR[4].
RTS7#	36	O	UART channel 7 Request to Send or general purpose output (active low). See description of RTS0# pin.
CTS7#	32	I	UART channel 7 Clear to Send or general purpose input (active low). See description of CTS0# pin.
DTR7#	37	O	UART channel 7 Data Terminal Ready or general purpose output (active low). See description of DTR0# pin.

NAME	PIN #	TYPE	DESCRIPTION
DSR7#	33	I	UART channel 7 Data Set Ready or general purpose input (active low). See description of DSR0# pin.
CD7#	34	I	UART channel 7 Carrier Detect or general purpose input (active low).
RI7#	35	I	UART channel 7 Ring Indicator or general purpose input (active low).
<b>ANCILLARY SIGNALS</b>			
XTAL1	82	I	Crystal or external clock input.
XTAL2	81	O	Crystal or buffered clock output.
TMRCK	14	I	16-bit timer/counter external clock input.
ENIR	15	I	Infrared mode enable (active high). This pin is sampled during power up, following a hardware reset (RST#) or soft-reset (register RESET). It can be used to start up all 8 UARTs in the infrared mode. The sampled logic state is transferred to MCR bit-6 in the UART.
RST#	1	I	Reset (active low). The configuration and UART registers are reset to default values, see Table-18.
16/68#	2	I	Intel or Motorola data bus interface select. Logic one selects Intel bus interface and logic zero selects Motorola interface. This input affects the functionality of IOR#, IOW# and CS# pins.
VCC	3,17,28,48,84		+3.3V supply with 5V tolerant inputs.
GND	4,18,29,47,83,		Power supply common, ground.

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

**DESCRIPTION**

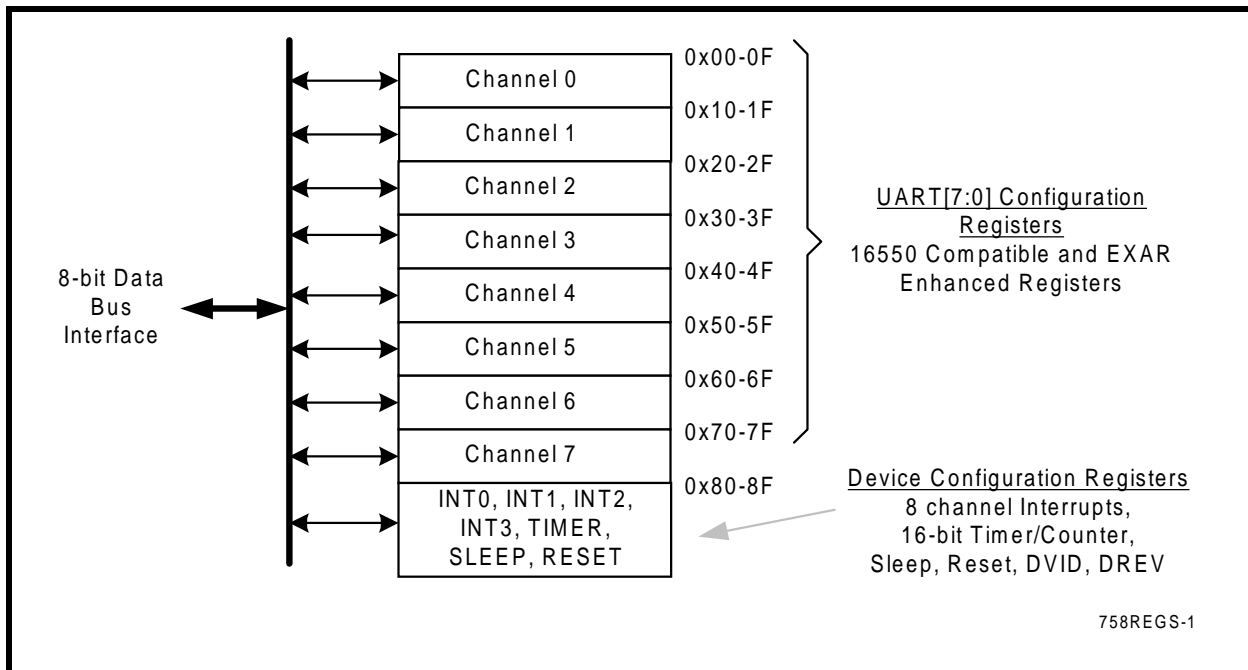
The XR16L788 (788) integrates the functions of 8 enhanced 16550 UARTs, a general purpose 16-bit timer/counter and an on-chip oscillator. The device configuration registers include a set of four consecutive interrupt source registers that provides interrupt-status for all 8 UARTs, timer/counter and a sleep wake up indicator. Each UART channel has its own 16550 UART compatible configuration register set for individual channel control, status, and data transfer. Additionally, each UART channel has 64-byte of transmit and receive FIFOs, automatic RTS/CTS or DTR/DSR hardware flow control with hysteresis control, automatic Xon/Xoff and special character software flow control, programmable transmit and receive FIFO trigger levels, FIFO level counters, infrared encoder and decoder (IrDA ver. 1.0), programmable baud rate generator with a prescaler of divide by 1 or 4, and data rate up to 6.25 Mbps with 8X sampling clock rate

or 3.125Mbps in the 16X rate. The XR16L788 is a 5V and 3.3V device with 5 volt tolerant inputs.

**1.0 XR16L788 REGISTERS**

The XR16L788 octal UART register set consists of the Device Configuration Registers that are accessible directly from the data bus for programming general operating conditions of the UARTs and monitoring the status of various functions. These functions include all 8 channel UART's interrupt control and status, 16-bit general purpose timer control and status, sleep mode, soft-reset, and device identification and revision. Also, each UART channel has its own set of internal UART Configuration Registers for its own operation control, status reporting and data transfer. These registers are mapped into a 256-byte of the data memory address space. The following paragraphs describe all the registers in detail.

**FIGURE 3. THE XR16L788 REGISTERS**



**1.1 DEVICE CONFIGURATION REGISTER SET**

The device configuration registers are directly accessible from the bus. This provides easy programming of general operating parameters to the 788 UART and for monitoring the status of various functions. The device configuration registers are mapped onto address 0x80-8F as shown on the register map in

Table 2 and Figure 3. These registers provide global controls and status of all 8 channel UARTs that include interrupt status, 16-bit general purpose timer control and status, 8X or 16X sampling clock, sleep mode control, soft-reset control, simultaneous UART initialization, and device identification and revision.

**TABLE 1: XR16L788 REGISTER SETS**

ADDRESS [A7:A0]	UART CHANNEL SPACE	REFERENCE	COMMENT
0x00 - 0x0F	UART channel 0 Registers	(Table 7 & 8)	First 8 registers are 16550 compatible
0x10 - 0x1F	UART channel 1 Registers	(Table 7 & 8)	
0x20 - 0x2F	UART channel 2 Registers	(Table 7 & 8)	
0x30 - 0x3F	UART channel 3 Registers	(Table 7 & 8)	
0x40 - 0x4F	UART channel 4 Registers	(Table 7 & 8)	
0x50 - 0x5F	UART channel 5 Registers	(Table 7 & 8)	
0x60 - 0x6F	UART channel 6 Registers	(Table 7 & 8)	
0x70 - 0x7F	UART channel 7 Registers	(Table 7 & 8)	
0x80 - 0x8F	Device Configuration Registers	(Table 2)	Interrupt registers and global controls

**TABLE 2: DEVICE CONFIGURATION REGISTERS**

ADDRESS [A7:A0]	READ/WRITE	REGISTER	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x80	R	INT Source	UART 7	UART 6	UART 5	UART 4	UART 3	UART 2	UART 1	UART 0
0x81	R	INT 1	UART 2 source bit 1	UART 2 source bit 0	UART 1 interrupt bit 2	UART 1 interrupt bit 1	UART 1 interrupt bit 0	UART 0 interrupt bit 2	UART 0 interrupt bit 1	UART 0 interrupt bit 0
0x82	R	INT 2	UART 5 bit 0	UART 4 interrupt bit 2	UART 4 interrupt bit 1	UART 4 interrupt bit 0	UART 3 interrupt bit 2	UART 3 interrupt bit 1	UART 3 interrupt bit 0	UART 2 interrupt bit 2
0x83	R	INT 3	UART 7 interrupt bit 2	UART 7 interrupt bit 1	UART 7 interrupt bit 0	UART 6 interrupt bit 2	UART 6 interrupt bit 1	UART 6 interrupt bit 0	UART 5 interrupt bit 2	UART 5 interrupt bit 1
0x84	R/W	TIMER CTRL	0	0	0	0	clock source	function select	start timer	enable timer INT
0x85	R	TIMER	0	0	0	0	0	0	0	0
0x86	R/W	TIMER LSB	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0x87	R/W	TIMER MSB	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0x88	R/W	8X MODE	UART 7	UART 6	UART 5	UART 4	UART 3	UART 2	UART 1	UART 0
0x89	R	REG 1	0	0	0	0	0	0	0	0
0x8A	W	RESET	Reset UART 7	Reset UART 6	Reset UART 5	Reset UART 4	Reset UART 3	Reset UART 2	Reset UART 1	Reset UART 0
0x8B	R/W	SLEEP	Enable sleep UART 7	Enable sleep UART 6	Enable sleep UART 5	Enable sleep UART 4	Enable sleep UART 3	Enable sleep UART 2	Enable sleep UART 1	Enable sleep UART 0
0x8C	R	DREV	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0x8D	R	DVID	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
0x8E	R/W	REG 2	0	0	0	0	0	0	0	write to all UARTs



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1.1.1 The Global Interrupt Source Registers

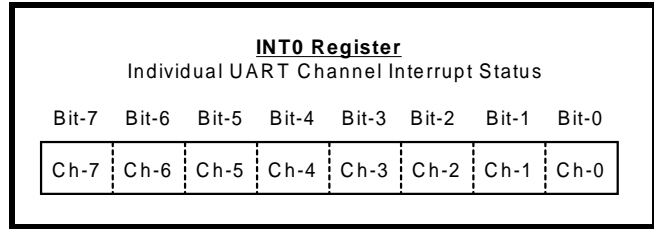
The XR16L788 has a global interrupt source register set that consists of 4 consecutive registers [INT0, INT1, INT2 and INT3]. The four registers are in the device configuration register address space.

INT3 [0x00]	INT2 [0x00]	INT1 [0x00]	INT0 [0x00]
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All four registers default to logic zero (as indicated in square braces) for no interrupt pending. All 8 channel interrupts are enabled or disabled in each channel's IER register. INT0 shows individual status for each channel while INT1, INT2 and INT3 show the details of the source of each channel's interrupt with its unique 3-bit encoding. Figure 4 shows the 4 interrupt registers in sequence for clarity. The 16-bit timer and sleep wake-up interrupts are masked in the device configuration registers, TIMERCNTL and SLEEP. An interrupt is generated (if enabled) by the 788 when awakened from sleep if all 8 channels were placed in the sleep mode previously.

Each bit gives an indication of the channel that has

INT0 CHANNEL INTERRUPT INDICATOR:

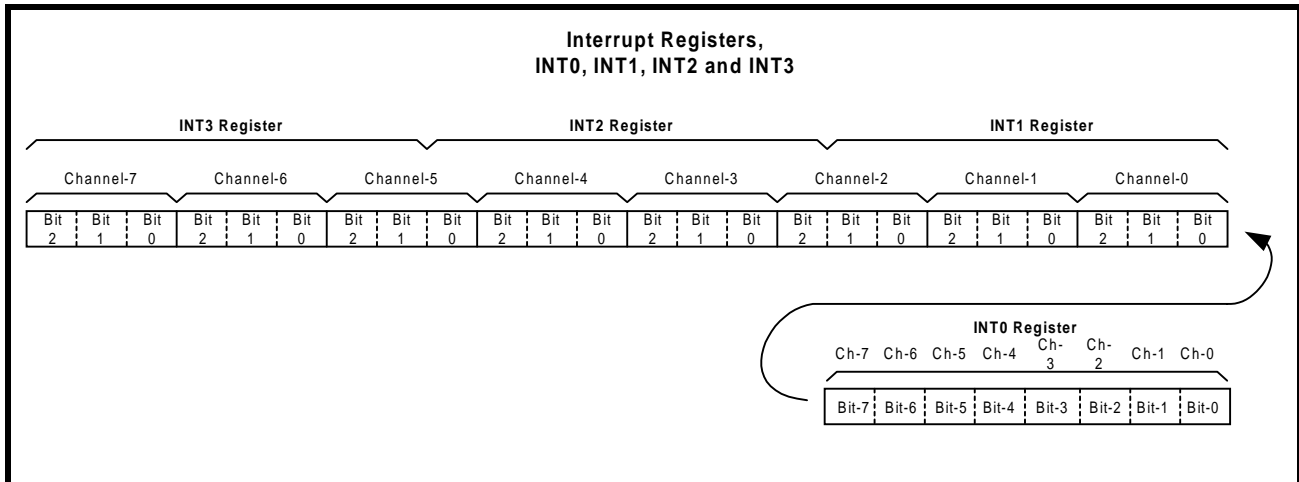


requested for service. For example, bit-0 represents channel 0 and bit-7 indicates channel 7. Logic one indicates the channel N [7:0] has called for service. The interrupt bit clears after reading the appropriate register of the interrupting UART channel register (ISR, LSR and MSR). See Table 9 for interrupt clearing details.

INT1, INT2 AND INT3 INTERRUPT SOURCE LOCATOR

INT3, INT2 and INT1 provide a 24-bit (3 bits per channel) encoded interrupt indicator. Table 3 shows the 3 bit encoding and their priority order. The 16-bit Timer time-out interrupt will show up only as a channel 0 interrupt. For other channels, interrupt 7 is reserved.

FIGURE 4. THE GLOBAL INTERRUPT REGISTERS, INT0, INT1, INT2 AND INT3



**TABLE 3: UART CHANNEL [7:0] INTERRUPT SOURCE ENCODING AND CLEARING**

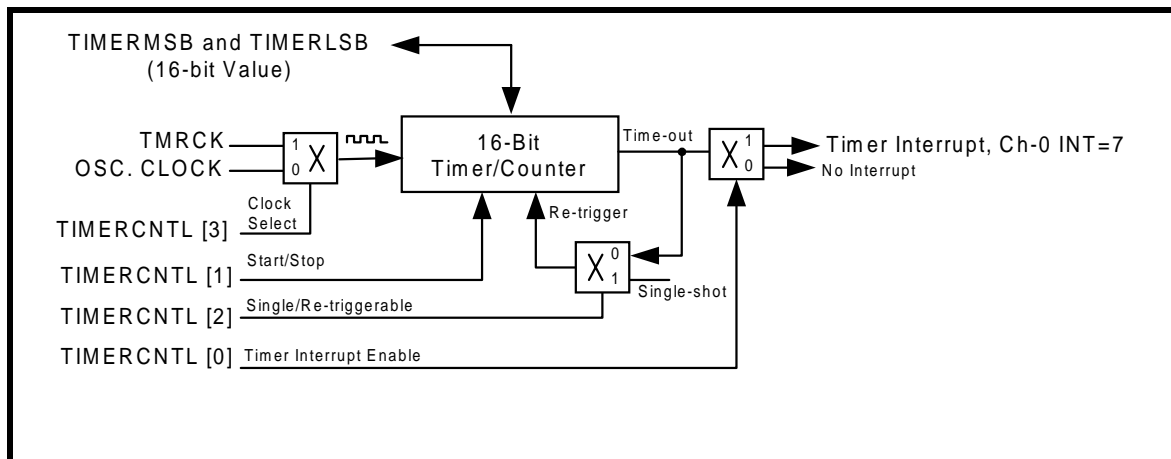
PRIORITY	Bit2	Bit1	Bit0	INTERRUPT SOURCE(S) AND CLEARING
x	0	0	0	None
1	0	0	1	RXRDY & RX Line Status (logic OR of LSR[4:1]). RXRDY INT clears by reading data in the RX FIFO until it falls below the trigger level; RX Line Status INT cleared after reading LSR register.
2	0	1	0	RXRDY Time-out: Cleared same way as RXRDY INT.
3	0	1	1	TXRDY, THR or TSR (auto RS485 mode) empty, clears after reading ISR register.
4	1	0	0	MSR, RTS/CTS or DTR/DSR delta or Xoff/Xon or special character detected. The first two clears after reading MSR register; Xoff/Xon or special char. detect INT clears after reading ISR register.
5	1	0	1	Reserved.
6	1	1	0	Reserved.
7	1	1	1	TIMER Time-out, shows up as a channel 0 INT. It clears after reading the TIMERCNTL register. Reserved in other channels.

**1.1.2 General Purpose 16-bit Timer/Counter.**  
**[TIMERMSB, TIMELSB, TIMER, TIMECNTL]**  
**(DEFAULT 0xXX-XX-00-00)**

A 16-bit down-count timer for general purpose timer or counter. Its clock source may be selected from internal crystal oscillator or externally on pin TMRCK. The timer can be set to be a single-shot for a one-time event or re-triggerable for a periodic event. An

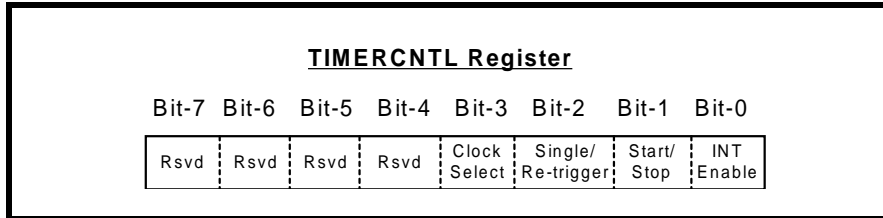
interrupt may be generated in the INT Register when the timer times out. It is controlled through 4 configuration registers [TIMERCNTL, TIMER, TIMELSB, TIMERMSB]. These registers provide start/stop and re-triggerable or one-shot operation. The time-out output of the Timer can be set to generate an interrupt for system or event alarm.

**FIGURE 5. TIMER/COUNTER CIRCUIT.**



**TABLE 4: TIMER CONTROL REGISTER**

TIMERCNTL [0]	Logic zero (default) disables Timer-Counter interrupt and logic one enables the interrupt, reading the TIMERCNTL clears the interrupt.
TIMERCNTL [1]	Logic zero (default) stops/pauses the timer and logic one starts/re-starts the timer/counter.
TIMERCNTL [2]	Logic zero (default) selects re-trigger timer function and logic one selects one-shot (timer function).
TIMERCNTL [3]	Logic zero (default) selects internal and logic one selects external clock to the timer/counter.
TIMERCNTL [7:4]	Reserved (defaults to zero).

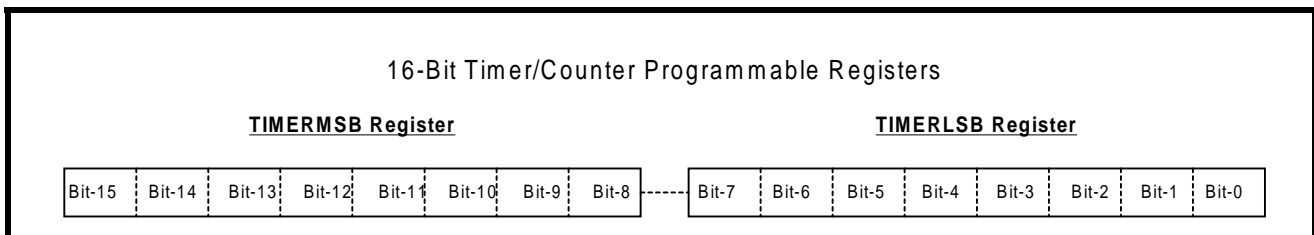


**TIMER [7:0] (default 0x00):** Reserved.

**TIMERMSB [7:0] and TIMERLSB [7:0]**

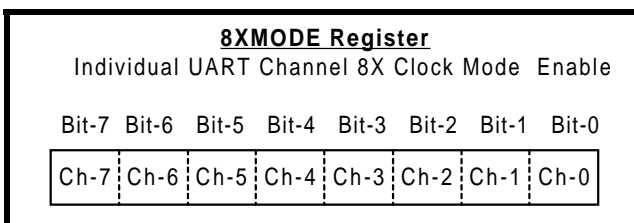
TIMERMSB and TIMERLSB form a 16-bit value. The least-significant bit of the timer is being bit [0] of the

TIMERLSB with most-significant-bit being bit [7] in TIMERMSB. Reading the TIMERCNTL register will clear its interrupt. Default value is zero upon power-up and reset.

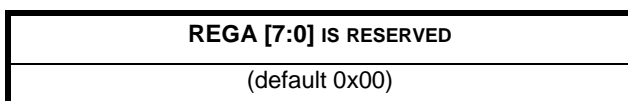


**1.1.3 8XMODE [7:0] (default 0x00)**

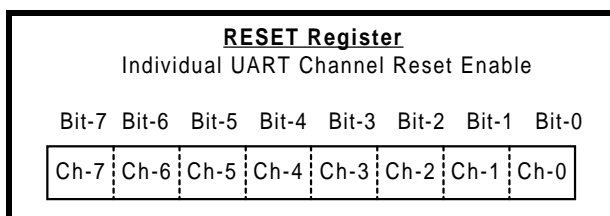
Each bit selects 8X or 16X sampling rate for that UART channel, bit-0 is channel 0. Logic 0 (default) selects normal 16X sampling with logic one selects 8X sampling rate. Transmit and receive data rates will double by selecting 8X.



**1.1.4 REGA [15:8] is reserved (default 0x00)**



**1.1.5 RESET [7:0] (default 0x00)**

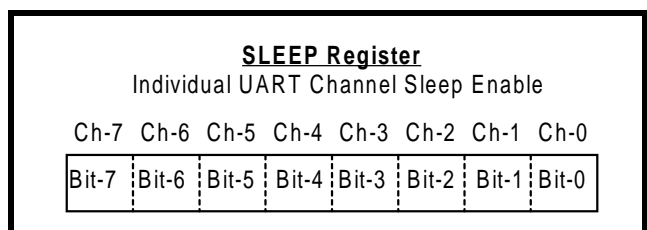


The 8-bit Reset register [RESET] provides the software with the ability to reset the UART(s) when there is a need. Each bit is self-resetting after it is written a

logic 1 to perform a reset to that channel. All registers in that channel will be reset to the default condition, see Table 15 for details. As an example, bit-0 =1 resets UART channel 0 with bit-7=1 resets channel 7.

**1.1.6 SLEEP [7:0] (default 0x00)**

The 8-bit Sleep register enables each UART separately to enter Sleep mode. Sleep mode reduces power consumption when the system needs to put the UART(s) to idle. The UART enters sleep mode when there is no interrupt pending. When all 8 UARTs are put to sleep, the on-chip oscillator shuts off to further conserve power. In this case, the octal UART is awoken by any of the UART channel on from a receive data byte or a change on the serial port. The UART is ready after 32 crystal clocks to ensure full functionality. Also, a special interrupt is generated with an indication of no pending interrupt. Logic 0 (default) and logic 1 disable and enable sleep mode respectively.



**1.1.7 Device Identification and Revision**

There are 2 internal registers that provide device identification and revision, DVID and DREV registers. The 8-bit content in the DVID register provides device

identification. A return value of 0x28 from this register indicates the device is a XR16L788. The DREV register returns a 8-bit value of 0x01 for revision A, 0x02 for revision B and so on. This information is very useful to the software driver for identifying which device it is communicating with and to keep up with revision changes.

**DVID [7:0] default 0x28)**

Device identification for the type of UART. The upper nibble indicates it is a XR16L78x series with lower nibble indicating the number of channels.

Examples:

XR16L788 = 0x28

XR16L784 = 0x24

**DREV [7:0] (default (0x01)**

Revision number of the XR16L788. A 0x01 represents "revision-A" with 0x02 for rev-B and so forth.

**1.1.8 REGB [7:0] (default 0x00)**

REGB register provides a control for simultaneous write to all 8 UARTs configuration registers or individually. This is very useful for device initialization in the power up and reset routines.

REGB[0]	Logic 0 (default) write to each UART configuration registers individually.
	Logic 1 enables simultaneous write to all 8 UARTs configuration register. Useful during device initialization.
REGB[7:1]	Reserved

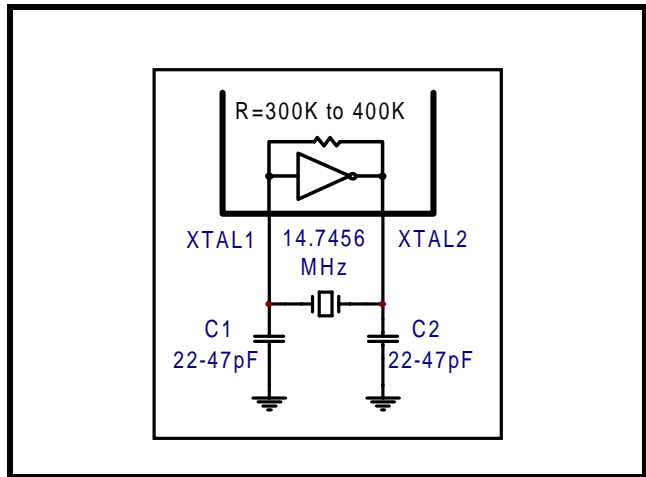
**2.0 CRYSTAL OSCILLATOR / BUFFER**

The 788 includes an on-chip oscillator (XTAL1 and XTAL2). The crystal oscillator provides the system clock to the Baud Rate Generators (BRG) in each of the 8 UARTs, the 16-bit general purpose timer/counter and internal logics. XTAL1 is the input to the oscillator or external clock buffer input with XTAL2 pin being the output. For programming details, see "Programmable Baud Rate Generator" on page 13.

The on-chip oscillator is designed to use an industry standard microprocessor crystal (parallel resonant with 10-22 pF capacitance load, 100ppm) connected

externally between the XTAL1 and XTAL2 pins (see Figure 6). Alternatively, an external clock can be connected to the XTAL1 pin to clock the internal 8 baud rate generators for standard or custom rates. Typically, the oscillator connections are shown in Figure 6. For further reading on oscillator circuit please see application note DAN108 on EXAR's web site.

**FIGURE 6. TYPICAL OSCILLATOR CONNECTIONS**



**3.0 TRANSMIT AND RECEIVE DATA**

Each UART channel has a transmit holding register (THR) and a receive holding register (RHR). The THR and RHR registers are 16550 compatible so their access is limited to 8-bit format. The software driver must separately read the LSR content for the associated error flags before reading the data byte.

**3.1 FIFO DATA LOADING AND UNLOADING THROUGH THE UART CHANNEL REGISTERS, THR AND RHR.**

The THR and RHR register addresses for channel 0 to channel 7 is shown in Table 5 below. The THR and RHR for channels 0 to 7 are located at address 0x00, 0x10, 0x20, 0x30, 0x40, 0x50, 0x60 and 0x70 respectively. Transmit data byte is loaded to the THR when writing to that address and receive data is unloaded from the RHR register when reading that address. Both THR and RHR registers are 16C550 compatible in 8-bit format, so each bus operation can only write or read in bytes.

TABLE 5: TRANSMIT AND RECEIVE DATA REGISTER, 16C550 COMPATIBLE

THR and RHR Address Locations For CH0 to CH7 (16C550 Compatible)										
CH0	0x00	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH0	0x00	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH1	0x10	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH1	0x10	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH2	0x20	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH2	0x20	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH3	0x30	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH3	0x30	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH4	0x40	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH4	0x40	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH5	0x50	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH5	0x50	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH6	0x60	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH6	0x60	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH7	0x70	Write THR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
CH7	0x70	Read RHR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0

THRRHR1

**4.0 UART**

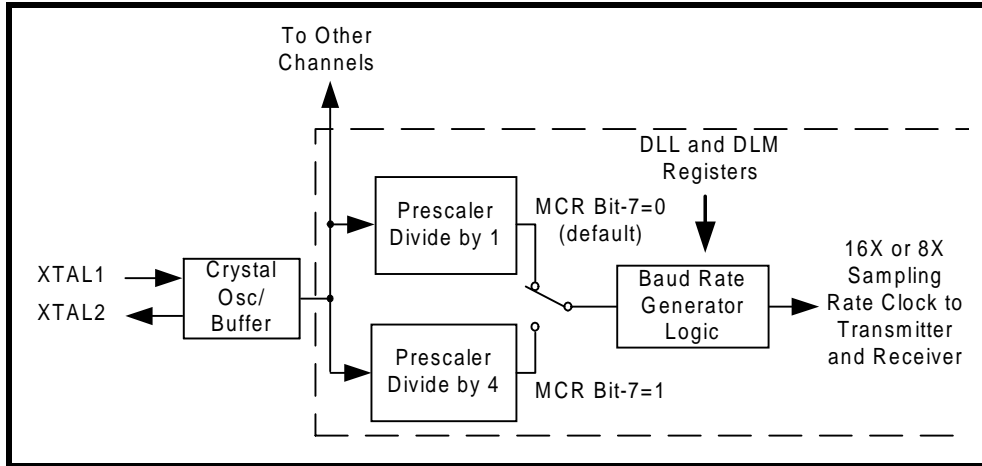
There are 8 UARTs [channel 7:0] in the 788. Each has its own 64-byte of transmit and receive FIFO, a set of 16550 compatible control and status registers, and a baud rate generator for individual channel data rate setting. Eight additional registers per UART were added for the EXAR enhanced features.

**4.1 PROGRAMMABLE BAUD RATE GENERATOR**

Each UART has its own Baud Rate Generator (BRG) with a prescaler 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  $(2^{16} - 1)$  to obtain a 16X or 8X sampling clock of the serial data rate. The sampling clock is used by the transmitter for data bit shifting and receiver for data sampling. The BRG divisor (DLL and DLM registers) defaults to a random value upon power up. Therefore, the BRG must be programmed during initialization to the operating data rate.

**FIGURE 7. BAUD RATE GENERATOR**



Programming the Baud Rate Generator Registers DLM and DLL provides the capability of selecting the operating data rate. Table 6 shows the standard data rates available with a 14.7456 MHz crystal or external clock at 16X clock rate. At 8X sampling rate, these

data rates would double. When using a non-standard data rate crystal or external clock, the divisor value can be calculated for channel 'N' with the following equation(s).

$$\text{divisor (decimal)} = (\text{XTAL1 clock frequency} / \text{prescaler}) / (\text{serial data rate} \times 16), \text{ WHEN } 8\text{XMODE-BIT N IS } 0$$

$$\text{divisor (decimal)} = (\text{XTAL1 clock frequency} / \text{prescaler}) / (\text{serial data rate} \times 8), \text{ WHEN } 8\text{XMODE-BIT N IS } 1$$

**TABLE 6: TYPICAL DATA RATES WITH A 14.7456 MHZ CRYSTAL OR EXTERNAL CLOCK AT 16X SAMPLING**

OUTPUT Data Rate MCR Bit-7=1	OUTPUT Data Rate MCR Bit-7=0	DIVISOR FOR 16x Clock (Decimal)	DIVISOR FOR 16x Clock (HEX)	DLM PROGRAM VALUE (HEX)	DLL PROGRAM VALUE (HEX)	DATA RATE ERROR (%)
100	400	2304	900	09	00	0
600	2400	384	180	01	80	0
1200	4800	192	C0	00	C0	0
2400	9600	96	60	00	60	0
4800	19.2k	48	30	00	30	0
9600	38.4k	24	18	00	18	0
19.2k	76.8k	12	0C	00	0C	0
38.4k	153.6k	6	06	00	06	0
57.6k	230.4k	4	04	00	04	0
115.2k	460.8k	2	02	00	02	0
230.4k	921.6k	1	01	00	01	0

**4.2 AUTOMATIC RTS/DTR HARDWARE FLOW CONTROL OPERATION**

Automatic RTS/DTR flow control is used to prevent data overrun to the local receiver FIFO. The RTS#/DTR# output pin is used to request remote unit to suspend/resume data transmission. The flow control features are individually selected to fit specific application requirement (see Figure 8):

- Select RTS (and CTS) or DTR (and DSR) through MCR bit-2.
- Enable auto RTS/DTR flow control using EFR bit-6.
- The auto RTS/DTR function must be started by asserting RTS/DTR# output pin (MCR bit-0 or 1 to logic 1 after it is enabled).

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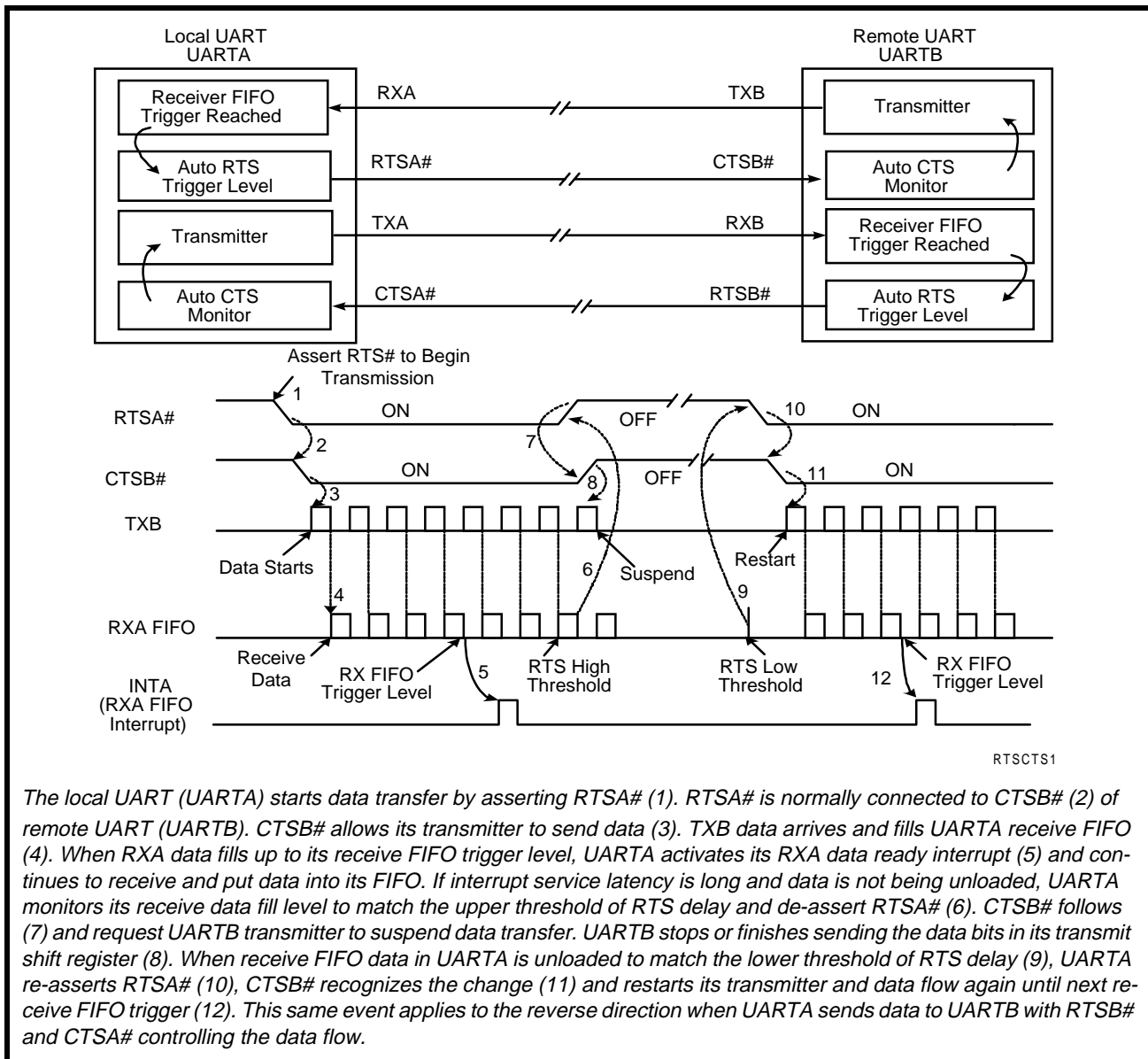
- Enable RTS/DTR interrupt through IER bit-6 (after setting EFR bit-4). The UART issues an interrupt when the RTS#/DTR# pin makes a transition: ISR bit-5 will be set to 1.
- Select Hysteresis values when used with programmable RX FIFO trigger levels

4.2.1 Auto CTS/DSR Flow Control

Automatic CTS/DSR flow control is used to prevent data overrun to the remote receiver FIFO. The CTS/DSR pin is monitored to suspend/restart local transmitter. The flow control features are individually selected to fit specific application requirement (see Figure 8):

- Select CTS (and RTS) or DSR (and DTR) through MCR bit-2.
- Enable auto CTS/DSR flow control using EFR bit-7.
- Enable CTS/DSR interrupt through IER bit-7 (after setting EFR bit-4). The UART issues an interrupt when the CTS#/DSR# pin makes a transition: ISR bit-5 will be set to 1, and UART will suspend TX transmissions as soon as the stop bit of the character in process is shifted out. Transmission is resumed after the CTS#/DSR# input returns to logic 0, indicating more data may be sent.

FIGURE 8. AUTO RTS/DTR AND CTS/DSR FLOW CONTROL OPERATION



The local UART (UARTA) starts data transfer by asserting RTS# (1). RTS# 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 RTS# (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 RTS# (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.

**4.3 INFRARED MODE**

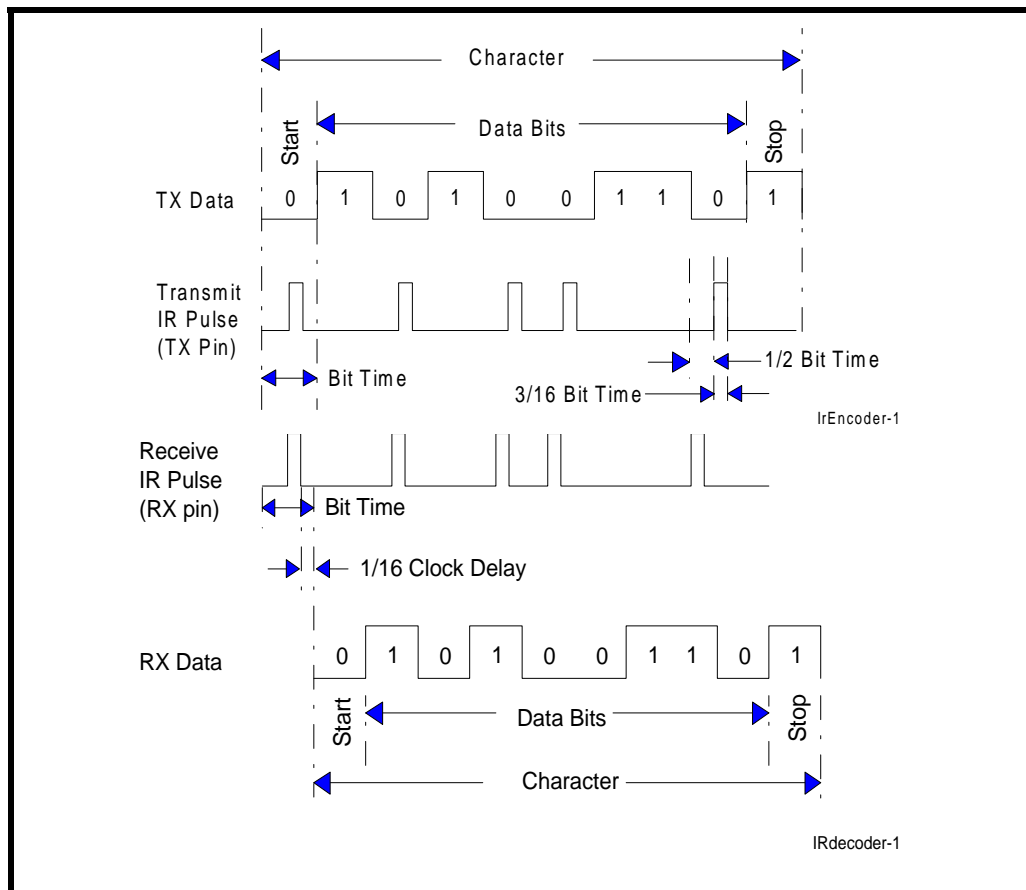
Each UART in the 788 includes the infrared encoder and decoder compatible to the IrDA (Infrared Data Association) version 1.0. The input pin ENIR conveniently activates all 8 UART channels to start up in the infrared mode. This global control pin enables the MCR bit-6 function in every UART channel register. After power up or a reset, the software can overwrite MCR bit-6 if so desired. ENIR and MCR bit-6 also disable the receiver while the transmitter is sending data. This prevents echoed data from reaching the receiver. The global activation ENIR pin prevents the infrared emitter from turning on and drawing large amount of current while the system is starting up. When the infrared feature is enabled, the transmit data outputs, TX[7:0], would idle at logic zero level.

Likewise, the RX [7:0] inputs assume an idle level of logic zero.

The infrared encoder sends out a 3/16 of a bit wide HIGH-pulse for each “0” bit in the transmit data stream. This signal encoding reduces the on-time of the infrared LED, hence reduces the power consumption. See Figure 9 below.

The infrared decoder receives the input pulse from the infrared sensing diode on RX pin. Each time it senses a light pulse, it returns a logic zero to the data bit stream. The decoder also accepts (when FCTR bit-4 = 1) an inverted IR-encoded input signal. This option supports active low instead of normal active high pulse from some infrared modules on the market.

**FIGURE 9. INFRARED TRANSMIT DATA ENCODING AND RECEIVE DATA DECODING**



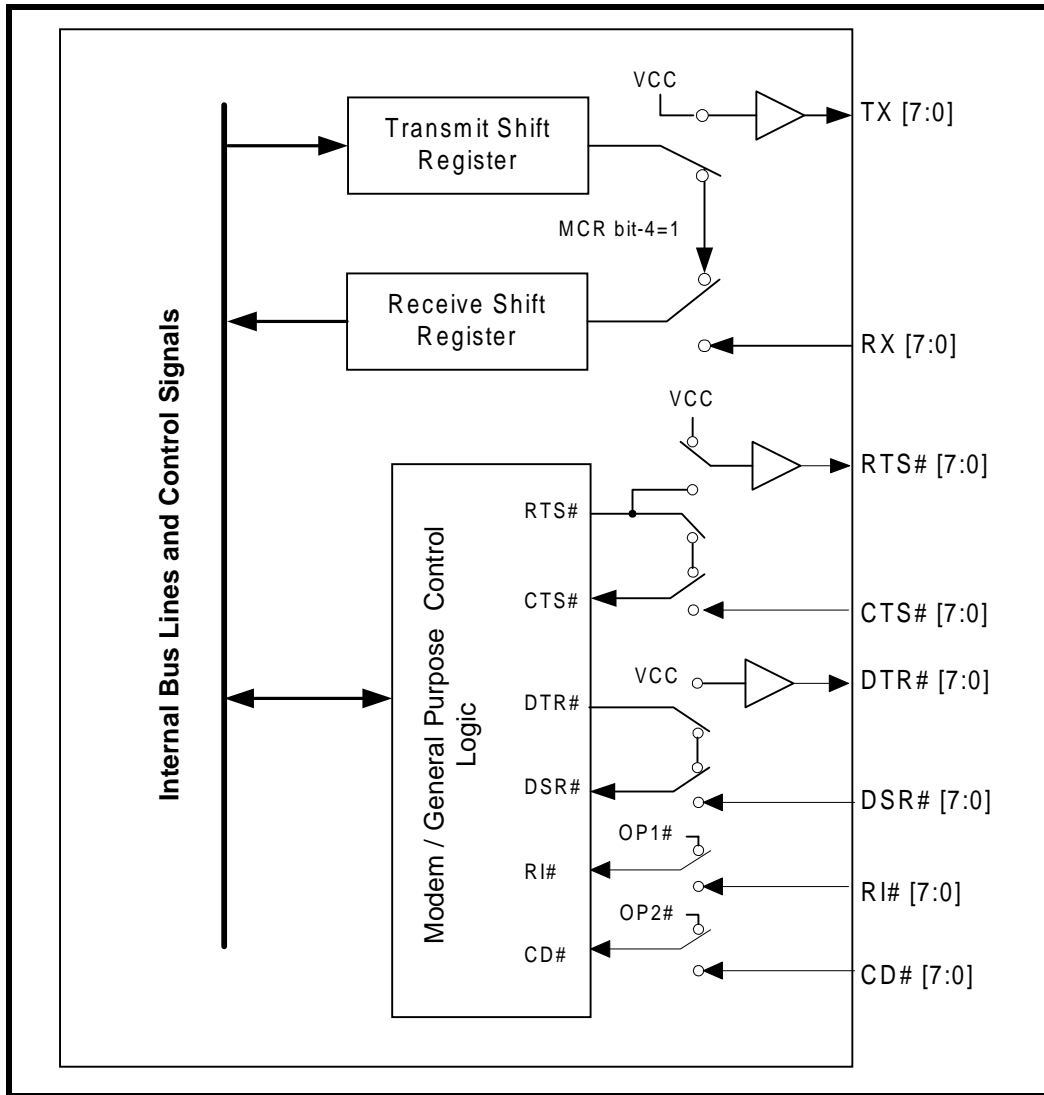
**4.4 INTERNAL LOOPBACK**

Each UART channel 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 10 shows how the modem port signals are re-configured. Transmit data from the trans-

mit 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 at logic 1 or mark condition while RTS# and DTR# are de-asserted, and CTS#, DSR# CD# and RI# inputs are ignored.



FIGURE 10. INTERNAL LOOP BACK



**4.5 UART CHANNEL CONFIGURATION REGISTERS AND ADDRESS DECODING.**

The 8 sets of UART configuration registers are decoded using address lines A4 to A7 as show below. Address lines A0 to A3 select the 16 registers in each channel.

The first 8 registers are 16550 compatible with EXAR enhanced feature registers located on the upper 8 addresses.

A7	A6	A5	A4	UART CHANNEL SELECTION
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7

**TABLE 7: UART CHANNEL CONFIGURATION REGISTERS.**

<u>ADDRESS</u>	<u>REGISTER</u>	<u>READ/WRITE</u>	<u>COMMENTS</u>
A3 A2 A1 A0			
<b>16550 COMPATIBLE</b>			
0 0 0 0	RHR - Receive Holding Reg THR - Transmit Holding Register	Read-only Write-only	LCR[7] = 0
0 0 0 0	DLL - Div Latch Low	Read/Write	LCR[7] = 1
0 0 0 1	DLM - Div Latch High	Read/Write	LCR[7] = 1
0 0 0 1	IER - Interrupt Enable Reg	Read/Write	LCR[7] = 0
0 0 1 0	ISR - Interrupt Status Reg FCR - FIFO Control Reg	Read-only Write-only	
0 0 1 1	LCR - Line Control Reg	Read/Write	
0 1 0 0	MCR - Modem Control Reg	Read/Write	
0 1 0 1	LSR - Line Status Reg reserved	Read-only Write-only	
0 1 1 0	MSR - Modem Status Reg reserved	Read-only Write-only	
0 1 1 1	SPR - Scratch Pad Reg	Read/Write	
<b>ENHANCED REGISTER</b>			
1 0 0 0	FCTR	Read/Write	
1 0 0 1	EFR - Enhanced Function Reg	Read/Write	
1 0 1 0	TXCNT - Transmit FIFO Level Counter TXTRG - Transmit FIFO Trigger Level	Read-only Write-only	
1 0 1 1	RXCNT - Receive FIFO Level Counter RXTRG - Receive FIFO Trigger Level	Read-only Write-only	
1 1 0 0	Xoff-1 - Xoff Character 1 Xchar	Write-only Read-only	Xon,Xoff Rcvd. Flags
1 1 0 1	Xoff-2 - Xoff Character 2 reserved	Write-only Read-only	
1 1 1 0	Xon-1 - Xon Character 1 reserved	Write-only Read-only	
1 1 1 1	Xon-2 - Xon Character 2 reserved	Write-only Read-only	

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TABLE 8: UART CHANNEL CONFIGURATION REGISTERS DESCRIPTION. SHADED BITS ARE ENABLED BY EFR BIT-4.

ADDRESS A3-A0	REG NAME	READ/ WRITE	BIT-7	BIT-6	BIT-5	BIT-4	BIT-3	BIT-2	BIT-1	BIT-0	COMMENT
0 0 0 0	RHR	R	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	LCR[7]=0
0 0 0 0	THR	W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	LCR[7]=0
0 0 0 0	DLL	R/W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	LCR[7]=1
0 0 0 1	DLM	R/W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	LCR[7]=1
0 0 0 1	IER	R/W	0/ CTS/DSR# Int. Enable	0/ RTS/DTR# Int. Enable	0/ Xon/Xoff/ Sp. Char. Int. Enable	0	Modem Status Int. Enable	RX Line Status Int. Enable	TX Empty Int. Enable	RX Data Int. Enable	
0 0 1 0	ISR	R	0/ FIFOs Enable	0/ FIFOs Enable	0/ Delta- Flow Cntl	0/ Xoff/spe- cial char	INT Source Bit-3	INT Source Bit-2	INT Source Bit-1	INT Source Bit-0	
0 0 1 0	FCR	W	0/ RXFIFO Trigger	0/ RXFIFO Trigger	0/ TXFIFO Trigger	0/ TXFIFO Trigger	DMA Mode	TX FIFO Reset	RX FIFO Reset	FIFOs Enable	
0 0 1 1	LCR	R/W	Divisor Enable	Set TX Break	Set Parity	Even Parity	Parity Enable	Stop Bits	Word Length Bit-1	Word Length Bit-0	
0 1 0 0	MCR	R/W	0/ BRG Prescaler	0/ IR Enable	0/ XonAny	Internal Lopback Enable	OP2 <sup>2</sup>	OP1 <sup>2</sup> / RTS/DTR Flow Sel	RTS# Pin Control	DTR# Pin Control	
0 1 0 1	LSR	R/W	RX FIFO ERROR	TSR Empty	THR Empty	RX Break	RX Fram- ing Error	RX Parity Error	RX Over- run	RX Data Ready	
0 1 1 0	MSR	R	CD	RI	DSR	CTS	Delta CD#	Delta RI#	Delta DSR#	Delta CTS#	
	MSR	W	0/ RS485 DLY-3	0/ RS485 DLY-2	0/ RS485 DLY-1	0/ RS485 DLY-0	Reserved	Reserved	Reserved	Reserved	
0 1 1 1	SPR	R/W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	User Data
1 0 0 0	FCTR	R/W	TRG Table Bit-1	TRG Table Bit-0	Auto RS485 Enable	Invert IR RX Input	RTS/DTR Hyst Bit-3	RTS/DTR Hyst Bit-2	RTS/DTR Hyst Bit-1	RTS/DTR Hyst Bit-0	
1 0 0 1	EFR	R/W	Auto CTS/DSR Enable	Auto RTS/DTR Enable	Special Char Select	Enable IER [7:4], ISR [5:4], FCR[5:4], MCR[7:5] MSR[7:4]	Software Flow Cntl Bit-3	Software Flow Cntl Bit-2	Software Flow Cntl Bit-1	Software Flow Cntl Bit-0	
1 0 1 0	TFCNT	R	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 0 1 0	TFTRG	W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 0 1 1	RFCNT	R	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 0 1 1	RFTRG	W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 1 0 0	XCHAR	R							Xon Det. Indicator	Xoff Det. Indicator	Self-clear after read
1 1 0 0	XOFF1	W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 1 0 1	XOFF2	W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 1 1 0	XON1	W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 1 1 1	XON2	W	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	

**NOTE 2:** MCR bits 2 and 3 (OP1 and OP2 outputs) are not available in the XR16L788. They are present for 16C550 compatibility during Internal loopback, see Figure 10.

**4.6 TRANSMITTER**

The transmitter section comprises of 64 bytes of FIFO, a byte-wide Transmit Holding Register (THR) and an 8-bit Transmit Shift Register (TSR). THR receives a data byte from the host (non-FIFO mode) or a data byte from the FIFO when the FIFO is enabled by FCR bit-0. TSR shifts out every data bit with the 16X or 8X internal clock. A bit time is 16 or 8 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 THR and TSR are reported in the Line Status Register (LSR bit-5 and bit-6).

**4.6.1 Transmit Holding Register (THR)**

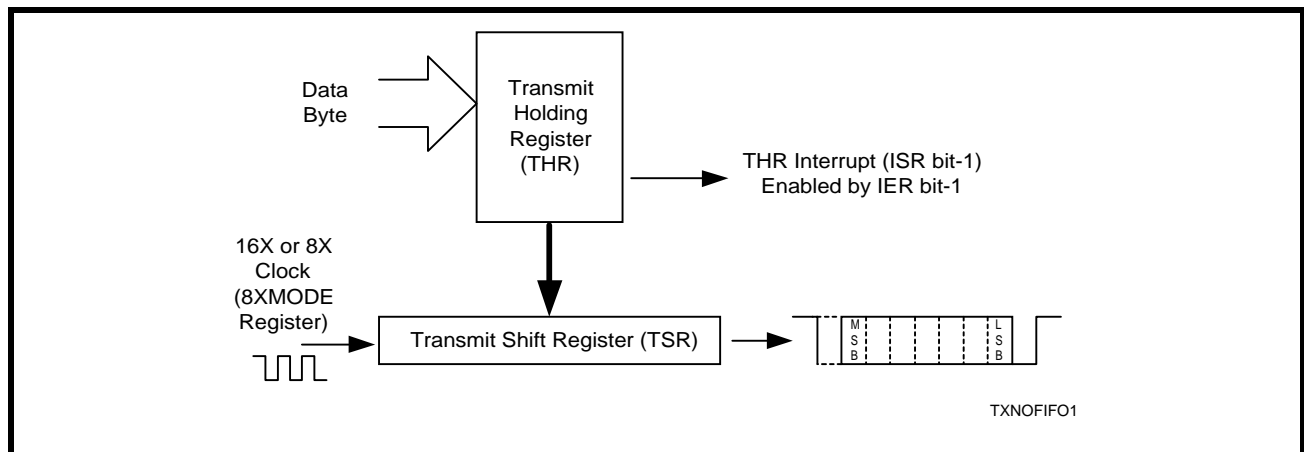
The transmit holding register is an 8-bit register providing a data interface to the host processor. The host

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 also the input register to the transmit FIFO of 64 bytes when FIFO operation is enabled by FCR bit-0. Every time a write operation is made to the transmit holding register, its FIFO data pointer is automatically bumped to the next sequential data location. A THR empty interrupt can be generated when IER bit-1 is set to logical 1.

**4.6.2 Transmitter Operation in non-FIFO**

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 11. TRANSMITTER OPERATION IN NON-FIFO MODE**



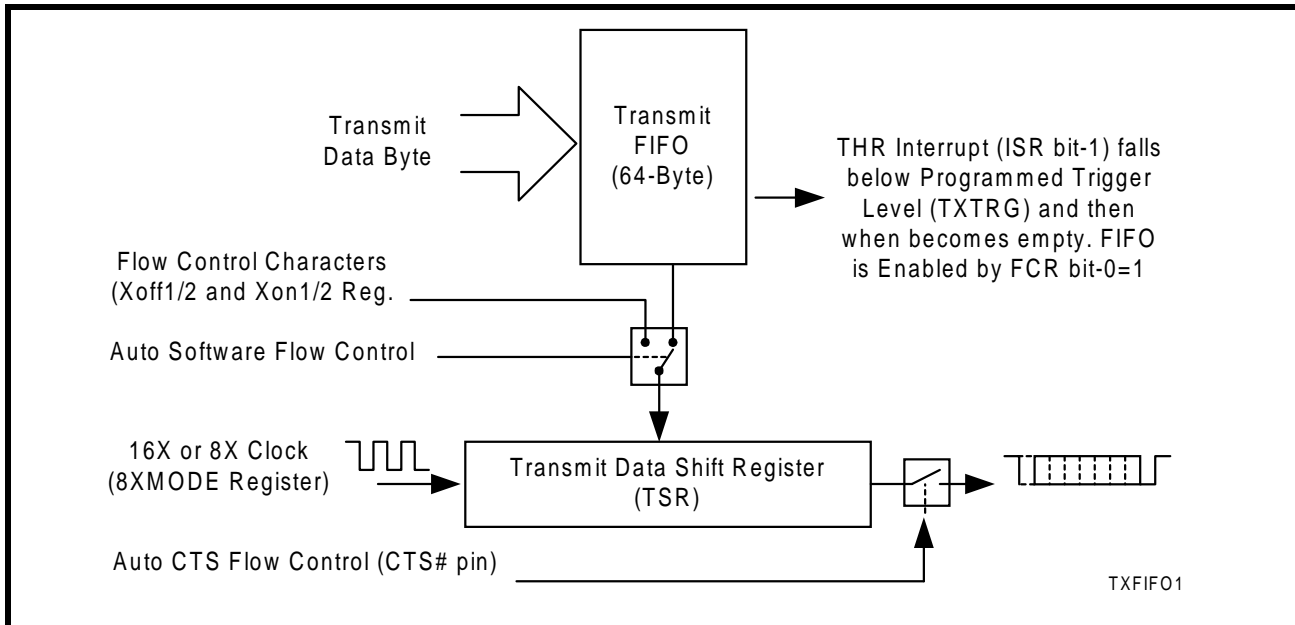
**4.6.3 Transmitter Operation in FIFO**

The host may fill the transmit FIFO with up to 64 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 amount of data in the FIFO falls below its programmed trigger level (see TXTRG register). The transmit empty interrupt is enabled by IER bit-1. The TSR flag (LSR bit-6) is set when TSR becomes completely empty. Furthermore, with the RS485 half-duplex direction control enabled (FCTR bit-5=1), the source of the transmit empty interrupt changes to TSR empty instead of THR empty. This is to ensure the RTS# output is not changed until the last stop bit of the last character is shifted out.

**4.6.4 Auto RS485 Operation**

The auto RS485 half-duplex direction control changes the behavior of the transmitter when enabled by FCTR bit-5. It de-asserts RTS# or DTR# after a specified delay indicated in MSR[7:4] following the last stop bit of the last character that has been transmitted. This helps in turning around the transceiver to receive the remote station's response. The delay optimizes the time needed for the last transmission to reach the farthest station on a long cable network before switching off the line driver. This delay prevents undesirable line signal disturbance that causes signal degradation. The auto RS485 half-duplex direction control also changes the transmitter empty interrupt to TSR empty instead of THR empty.

FIGURE 12. TRANSMITTER OPERATION IN FIFO AND FLOW CONTROL MODE



#### 4.7 RECEIVER

The receiver section contains an 8-bit Receive Shift Register (RSR) and a byte-wide Receive Holding Register (RHR). The RSR uses the 16X or 8X clock 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 (or 8X) clock rate. After 8 (or 4) clocks 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 1- 4. Upon unloading the receive data byte from RHR, the receive FIFO pointer is bumped and the error flags 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 function when receive data does not reach the receive FIFO trigger level. This time-out delay is 4 word lengths as defined by LCR[1,0] plus 12 bits time. The RHR interrupt is enabled by IER bit-0.

#### 4.8 REGISTERS

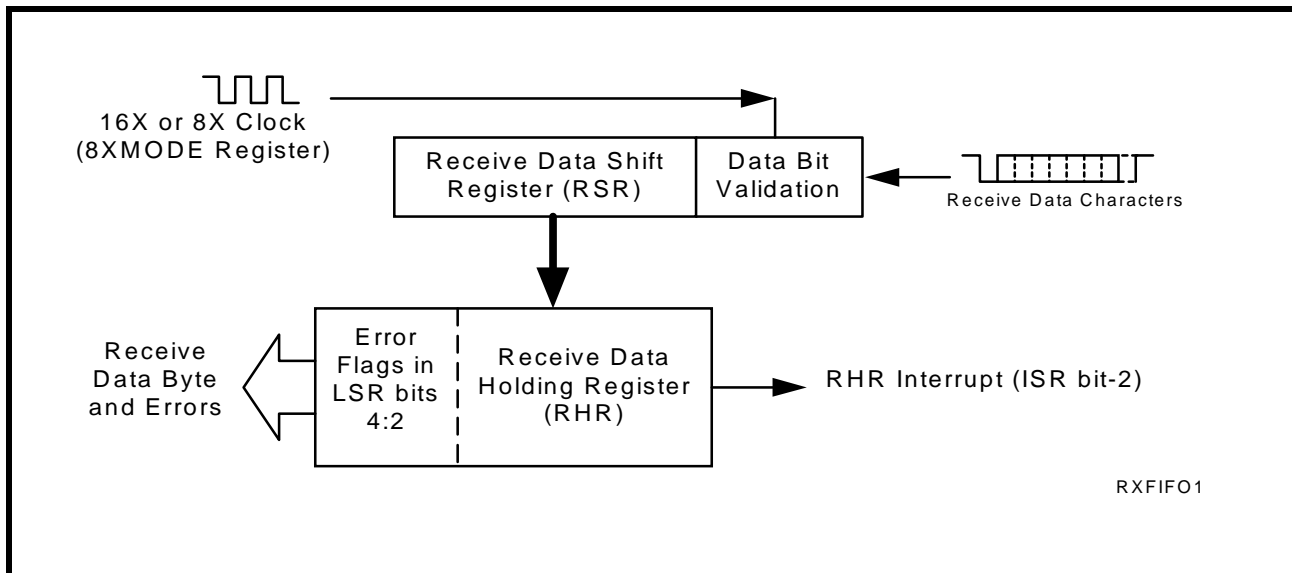
##### 4.8.1 Receive Holding Register (RHR)

The receive holding register is a 8-bit register that holds a receive data byte from the receive shift register (RSR). It provides the receive data interface to the host processor. The host reads the receive data byte on this register whenever a data byte is transferred from the RSR. RHR also part of the receive FIFO of 64 bytes by 11-bit wide, 3 extra bits are for the error flags to be in LSR register. When the FIFO is enabled by FCR bit-0, it acts as the first-out register of the FIFO as new data are put over the first-in register. Every time a read operation is made to the receive holding register, its FIFO data pointer is automatically bumped to the next sequential data location. Also, the error flags associated with the data byte are immediately updated onto the line status register (LSR) bits 1-4.

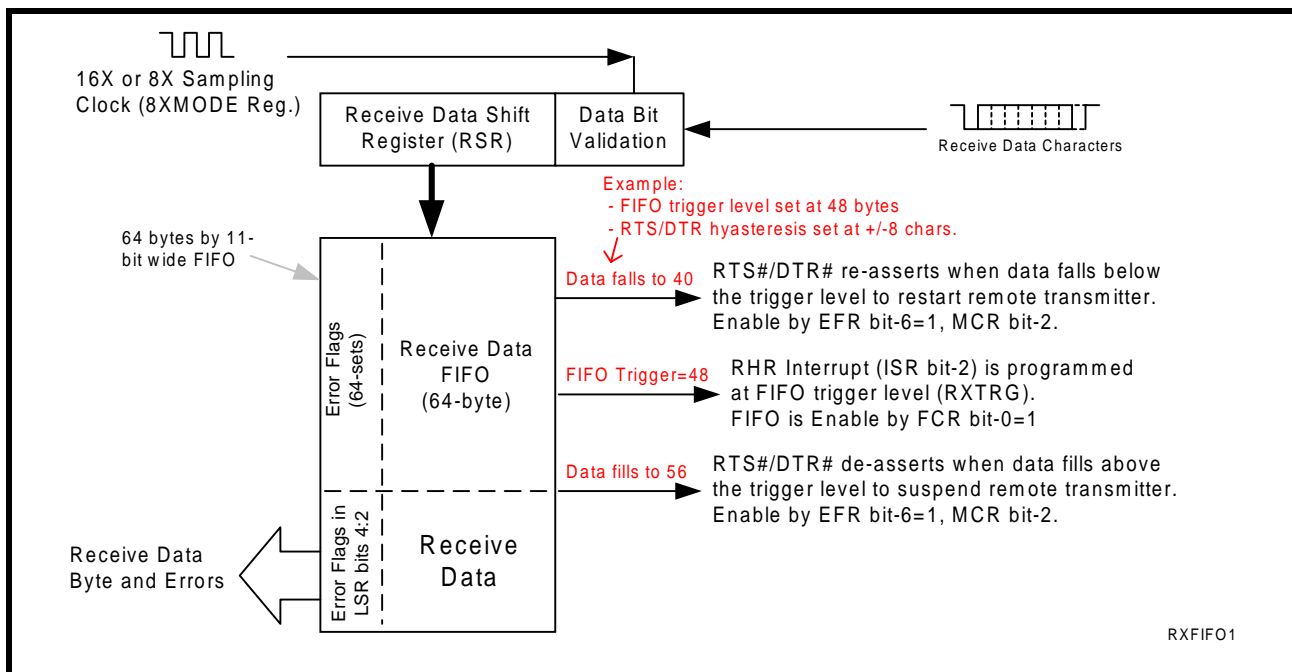
##### 4.8.2 Baud Rate Generator Divisors (DLL and DLM)

The Baud Rate Generator (BRG) is a 16-bit counter that generates the data rate for the transmitter and receiver. The rate is programmed through registers DLL and DLM which are only accessible when LCR bit-7 is set to logic 1. See Programmable Baud Rate Generator section for more detail.

**FIGURE 13. RECEIVER OPERATION IN NON-FIFO MODE**



**FIGURE 14. RECEIVER OPERATION IN FIFO AND FLOW CONTROL MODE**



**4.8.3 Interrupt Enable Register (IER)**

The Interrupt Enable Register (IER) masks the interrupts from receive data ready, transmit empty, line status and modem status registers. These interrupts are reported in the Interrupt Status Register (ISR) register and also encoded in INT (INT0-INT3) register in the Device Configuration Registers.

**4.9 IER VERSUS RECEIVE FIFO INTERRUPT MODE OPERATION**

When the receive FIFO (FCR BIT-0 = a logic 1) and receive interrupts (IER BIT-0 = logic 1) are enabled, the RHR interrupts (see ISR bits 3 and 4) status will reflect the following:

- A. The receive data available interrupts are issued to the host when the FIFO has reached the pro-

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grammed trigger level. It will be cleared when the FIFO drops below the programmed trigger level.

- B. FIFO level will be reflected in the ISR register when the FIFO trigger level is reached. Both the ISR register status bit and the interrupt will be cleared when the FIFO drops below the trigger level.
- C. The receive data ready bit (LSR BIT-0) is set as soon as a character is transferred from the shift register to the receive FIFO. It is reset when the FIFO is empty.

#### 4.10 IER VERSUS RECEIVE/TRANSMIT FIFO POLLED MODE OPERATION

When FCR BIT-0 equals a logic 1 for FIFO enable; resetting IER bits 0-3 enables the XR16L788 in the FIFO polled mode of operation. Since the receiver and transmitter have separate bits in the LSR either or both can be used in the polled mode by selecting respective transmit or receive control bit(s).

- A. LSR BIT-0 indicates there is data in RHR or RX FIFO.
- B. LSR BIT 1-4 provides the type of receive data errors encountered for the data byte in RHR, if any.
- C. LSR BIT-5 indicates THR is empty.
- D. LSR BIT-6 indicates when both the transmit FIFO and TSR are empty.
- E. LSR BIT-7 indicates the Or'ed function of errors in the RX FIFO.

#### IER[0]: RHR Interrupt Enable

The receive data ready interrupt will be issued when RHR has a data character in the non-FIFO mode or when the receive FIFO has reached the programmed trigger level in the FIFO mode.

Logic 0 = Disable the receive data ready interrupt. (default)

Logic 1 = Enable the receiver data ready interrupt.

#### IER[1]: THR Interrupt Enable

This interrupt is associated with bit-5 in the LSR register. An interrupt is issued whenever the THR becomes empty or when data in the FIFO falls below the programmed trigger level.

Logic 0 = Disable Transmit Holding Register empty interrupt. (default)

Logic 1 = Enable Transmit Holding Register empty interrupt.

#### IER[2]: Receive Line Status Interrupt Enable

Any of the LSR register bits 1,2,3 or 4 becomes active will generate an interrupt to inform the host con-

troller about the error status of the current data byte in FIFO.

Logic 0 = Disable the receiver line status interrupt. (default)

Logic 1 = Enable the receiver line status interrupt.

#### IER[3]: Modem Status Interrupt Enable

Logic 0 = Disable the modem status register interrupt. (default)

Logic 1 = Enable the modem status register interrupt.

#### IER[4]: Reserved.

#### IER[5]: Xoff Interrupt Enable (requires EFR bit-4=1)

Logic 0 = Disable the software flow control, receive Xoff interrupt. (default)

Logic 1 = Enable the software flow control, receive Xoff interrupt. See Software Flow Control section for details.

#### IER[6]: RTS# Output Interrupt Enable (requires EFR bit-4=1)

Logic 0 = Disable the RTS# interrupt. (default).

Logic 1 = Enable the RTS# interrupt. The UART issues an interrupt when the RTS# pin makes a transition.

#### IER[7]: CTS# Input Interrupt Enable (requires EFR bit-4=1)

Logic 0 = Disable the CTS# interrupt. (default).

Logic 1 = Enable the CTS# interrupt. The UART issues an interrupt when CTS# pin makes a transition.

#### 4.11 INTERRUPT STATUS REGISTER (ISR)

The UART provides multiple levels of prioritized interrupts to minimize external software interaction. The Interrupt Status Register (ISR) provides the user with six interrupt status bits. Performing a read cycle on the ISR will give the user the current highest pending interrupt level to be serviced, others queue up for next service. No other interrupts are acknowledged until the pending interrupt is serviced. The Interrupt Source Table, Table 9, shows the data values (bit 0-5) for the six prioritized interrupt levels and the interrupt sources associated with each of these interrupt levels.

##### 4.11.1 Interrupt Generation:

- LSR is by any of the LSR bits 1, 2, 3 and 4.
- RXRDY is by RX trigger level.
- RXRDY Time-out is by the a 4-char plus 12 bits delay timer if data doesn't reach FIFO trigger level.
- TXRDY is by LSR bit-5 (or bit-6 in auto RS485 control).

- MSR is by any of the MSR bits, 0, 1, 2 and 3.
  - Receive Xon/Xoff/Special character is by detection of a Xon, Xoff or Special character.
  - CTS#/DSR# is by a change of state on the input pin with auto flow control enabled, EFR bit-7, and depending on selection on MCR bit-2.
  - RTS#/DTR# is when its receiver changes the state of the output pin during auto RTS/DTR flow control enabled by EFR bit-6 and selection of MCR bit-2.
- 4.11.2 Interrupt Clearing:**
- LSR interrupt is cleared by a read to the LSR register.
  - RXRDY and RXRDY Time-out are cleared by reading data until FIFO falls below the trigger level.
  - TXRDY interrupt is cleared by a read to the ISR register.
  - MSR interrupt is cleared by a read to the MSR register.
  - Xon, Xoff or Special character interrupt is cleared by a read to ISR.
  - RTS#/DTR# and CTS#/DSR# status change interrupts are cleared by a read to the MSR register.

**TABLE 9: INTERRUPT SOURCE AND PRIORITY LEVEL**

PRIORITY LEVEL	ISR REGISTER STATUS BITS						SOURCE OF THE INTERRUPT+
	BIT-5	BIT-4	BIT-3	BIT-2	BIT-1	BIT-0	
1	0	0	0	1	1	0	LSR (Receiver Line Status Register)
2	0	0	0	1	0	0	RXRDY (Received Data Ready)
3	0	0	1	1	0	0	RXRDY (Receive Data Time-out)
4	0	0	0	0	1	0	TXRDY (Transmitter Holding Register Empty)
5	0	0	0	0	0	0	MSR (Modem Status Register)
6	0	1	0	0	0	0	RXRDY (Received Xon/Xoff or Special character)
7	1	0	0	0	0	0	CTS#/DSR#, RTS#/DTR# change of state
X	0	0	0	0	0	1	None (default)

**ISR[0]: Interrupt Status**

Logic 0 = An interrupt is pending and the ISR contents may be used as a pointer to the appropriate interrupt service routine.

Logic 1 = No interrupt pending. (default condition)

**ISR[3:1]: Interrupt Status**

These bits indicate the source for a pending interrupt at interrupt priority levels 1, 2, 3 and 4 (See Interrupt Source Table 9).

**ISR[5:4]: Interrupt Status**

These bits are enabled when EFR bit-4 is set to a logic 1. ISR bit-4 indicates that the receiver detected a data match of the Xon or Xoff character(s).

**NOTE:** Note that once set to a logic 1, the ISR bit-4 will stay a logic 1 until a Xon character is received. ISR bit-5 indicates that CTS#/DSR# or RTS#/DTR# has changed state.

**ISR[7:6]: FIFO Enable Status**

These bits are set to a logic 0 when the FIFOs are disabled. They are set to a logic 1 when the FIFOs are enabled.

**FIFO Control Register (FCR)**

This register is used to enable the FIFOs, clear the FIFOs, set the transmit/receive FIFO trigger levels, and select the DMA mode. The DMA, and FIFO modes are defined as follows:

**FCR BIT-0: TX and RX FIFO Enable**

Logic 0 = Disable the transmit and receive FIFO. (default).

Logic 1 = Enable the transmit and receive FIFOs. This bit must be set to logic 1 when other FCR bits are written or they will not be programmed.

**FCR[1]: RX FIFO Reset**

This bit is only active when FCR bit-0 is active.

Logic 0 = No receive FIFO reset. (default)

Logic 1 = Reset the receive FIFO pointers and FIFO level counter logic (the receive shift register is not cleared or altered). This bit will return to a logic 0 after resetting the FIFO.

**FCR[2]: TX FIFO Reset**

This bit is only active when FCR bit-0 is active.

Logic 0 = No transmit FIFO reset. (default)



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Logic 1 = Reset the transmit FIFO pointers and FIFO level counter logic (the transmit shift register is not cleared or altered). This bit will return to a logic 0 after resetting the FIFO.

**FCR[3]: DMA Mode Select**

This bit has no effect since TXRDY and RXRDY pins are not available in this device. It is provided for legacy software.

Logic 0 = Set DMA to mode 0. (default)

Logic 1 = Set DMA to mode 1.

**FCR[5:4]: Transmit FIFO Trigger Select**

(logic 0 = default, TX trigger level = one)

The FCTR Bits 6-7 are associated with these 2 bits by selecting one of the four tables. The 4 user select-

able trigger levels in 4 tables are supported for compatibility reasons. These 2 bits set the trigger level for the transmit FIFO interrupt. The UART will issue a transmit interrupt when the number of characters in the FIFO falls below the selected trigger level, or when it gets empty in case that the FIFO did not get filled over the trigger level on last re-load. Table 10 below shows the selections.

**FCTR[7:6]: Receive FIFO Trigger Select**

(logic 0 = default, RX trigger level =1)

The FCTR Bits 6-7 are associated with these 2 bits. These 2 bits are used to set the trigger level for the receiver FIFO interrupt. Table 10 shows the complete selections.

**TABLE 10: TRANSMIT AND RECEIVE FIFO TRIGGER LEVEL SELECTION**

FCTR BIT-7	FCTR BIT-6	FCR BIT-7	FCR BIT-6	FCR BIT-5	FCR BIT-4	RECEIVE TRIGGER LEVEL	TRANSMIT TRIGGER LEVEL	COMPATIBILITY
0	0	0 0 1 1	0 1 0 1	0	0	1 (default) 4 8 14	1 (default)	Table-A. 16C550, 16C2550, 16C2552, 16C554, 16C580 compatible.
0	1	0 0 1 1	0 1 0 1	0 0 1 1	0 1	8 16 24 28	16 8 24 30	Table-B. 16C650A compatible.
1	0	0 0 1 1	0 1 0 1	0 0 1 1	0 1	8 16 56 60	8 16 32 56	Table-C. 16C654 compatible.
1	1	X	X	X	X	Programmable	Programmable	Table-D. 16C850, 16c2850, 16C2852, 16C854, 16C864, 16C872 compatible.

**Line Control Register (LCR)**

The Line Control Register is used to specify the asynchronous data communication format. The word or character length, the number of stop bits, and the parity are selected by writing the appropriate bits in this register.

**LCR[1-0]: TX and RX Word Length Select**

These two bits specify the word length to be transmitted or received.

BIT-1	BIT-0	WORD LENGTH
0	0	5 (default)
0	1	6
1	0	7
1	1	8

**LCR[2]: TX and RX Stop-bit Length Select**

The length of stop bit is specified by this bit in conjunction with the programmed word length.

BIT-2	WORD LENGTH	STOP BIT LENGTH (BIT TIME(S))
0	5,6,7,8	1 (default)
1	5	1-1/2
1	6,7,8	2

**LCR[3]: TX and RX Parity Select**

Parity or no parity can be selected via this bit. The parity bit is a simple way used in communications for data integrity check. See Table 11 for parity selection summary below.

- Logic 0 = No parity.
- Logic 1 = A parity bit is generated during the transmission while the receiver checks for parity error of the data character received.

**LCR[4]: TX and RX Parity Select**

If the parity bit is enabled with LCR bit-3 set to a logic 1, LCR BIT-4 selects the even or odd parity format. Logic 0 = ODD Parity is generated by forcing an odd number of logic 1's in the transmitted character. The receiver must be programmed to check the same format. (default).

- Logic 1 = EVEN Parity is generated by forcing an even the number of logic 1's in the transmitted character. The receiver must be programmed to check the same format.

**LCR[5]: TX and RX Parity Select**

If the parity bit is enabled, LCR BIT-5 selects the forced parity format.

- LCR BIT-5 = logic 0, parity is not forced. (default)
- LCR BIT-5 = logic 1 and LCR BIT-4 = logic 0, parity bit is forced to a logical 1 for the transmit and receive data.
- LCR BIT-5 = logic 1 and LCR BIT-4 = logic 1, parity bit is forced to a logical 0 for the transmit and receive data.

**TABLE 11: PARITY SELECTION**

LCR BIT-5	LCR BIT-4	LCR BIT-3	PARITY SELECTION
X	X	0	No parity
0	0	1	Odd parity
0	1	1	Even parity
1	0	1	Force parity to mark, "1"
1	1	1	Forced parity to space, "0"

**LCR[6]: Transmit Break Enable**

- When enabled the Break control bit #causes a break condition to be transmitted (the TX output is forced to a "space", logic 0, state). This condition remains until disabled by setting LCR bit-6 to a logic 0.
- Logic 0 = No TX break condition. (default)
- Logic 1 = Forces the transmitter output (TX) to a "space", logic 0, for alerting the remote receiver of a line break condition.

**LCR[7]: Baud Rate Divisors Enable**
**Baud rate generator divisor (DLL/DLM) enable.**

- Logic 0 = Data registers are selected. (default)
- Logic 1 = Divisor latch registers are selected.

**Modem Control Register (MCR) or General Purpose Outputs Control.**

This register controls the serial interface signals with the modem or a peripheral device.

**Modem Control Register (MCR)**

The MCR register is used for controlling the modem interface signals or general purpose inputs/outputs.

**MCR[0]: DTR# Pins**

The DTR# pin may be used for automatic hardware flow control enabled by EFR bit-6 and MCR bit-2=1. If the modem interface is not used, this output may be used for general purpose.

- Logic 0 = Force DTR# output to a logic 1. (default)
- Logic 1 = Force DTR# output to a logic 0.

**MCR[1]: RTS# Pins**

The RTS# pin may be used for automatic hardware flow control by enabled by EFR bit-6 and MCR bit-2=0. If the modem interface is not used, this output may be used for general purpose.

- Logic 0 = Force RTS# output to a logic 1. (default)
- Logic 1 = Force RTS# output to a logic 0.

**MCR[2]: RTS/CTS or DTR/DSR for Auto Flow Control**

DTR# or RTS# auto hardware flow control select. This bit is in effect only when auto RTS/DTR is enabled by EFR bit-6.

- Logic 0 = RTS# (RX side) and CTS# (TX side) pins are used for auto hardware flow control.
- Logic 1 = DTR# (RX side) and DSR# (TX side) pins are used for auto hardware flow control.

**MCR[3]:**

Reserved. Logic zero is default.

**MCR[4]: Internal Loopback Enable**

- Logic 0 = Disable loopback mode. (default)
- Logic 1 = Enable local loopback mode, see loopback section and Figure 10.

**MCR[5]: Xon-Any Enable**

- Logic 0 = Disable Xon-Any function (for 16C550 compatibility). (default).
- Logic 1 = Enable Xon-Any function. In this mode any RX character received will enable Xon, resume data transmission.

**MCR[6]: Infrared Encoder/Decoder Enable**

The state of this bit depends on the sampled logic level of pin ENIR during power up, following a hardware reset or a soft-reset. Afterward user can override this bit for desired operation.

- Logic 0 = Enable the standard modem receive and transmit character interface.
- Logic 1 = Enable infrared IrDA receive and transmit inputs/outputs. While in this mode, the TX/RX output/input are routed to the infrared encoder/decoder. The data input and output levels will conform to the IrDA infrared interface requirement. As such, while in this mode the infrared TX output will be a logic 0 during idle data conditions. FCTR bit-4 may be selected to invert the RX input signal level going to the decoder for infrared modules that provide rather an inverted output.

**MCR[7]: Clock Prescaler Select**

- Logic 0 = Divide by one. The input clock from the crystal or external clock is fed directly to the Programmable Baud Rate Generator without further modification, i.e., divide by one. (default).
- Logic 1 = Divide by four. The prescaler divides the input clock from the crystal or external clock by four and feeds it to the Programmable Baud Rate Generator, hence, data rates become one fourth.

**Line Status Register (LSR)**

This register provides the status of data transfers between the UART and the host.

**LSR[0]: Receive Data Ready Indicator**

- Logic 0 = No data in receive holding register or FIFO. (default).
- Logic 1 = Data has been received and is saved in the receive holding register or FIFO.

**LSR[1]: Receiver Overrun Flag**

- Logic 0 = No overrun error. (default)
- Logic 1 = Overrun error. A data overrun error condition occurred in the receive shift register. This happens when additional data arrives while the FIFO is

full. In this case the previous data in the receive shift register is overwritten. Note that under this condition the data byte in the receive shift register is not transferred into the FIFO, therefore the data in the FIFO is not corrupted by the error.

**LSR[2]: Receive Data Parity Error Flag**

- Logic 0 = No parity error. (default)
- Logic 1 = Parity error. The receive character in RHR does not have correct parity information and is suspect. This error is associated with the character available for reading in RHR.

**LSR[3]: Receive Data Framing Error Flag**

- Logic 0 = No framing error. (default)
- Logic 1 = Framing error. The receive character did not have a valid stop bit(s). This error is associated with the character available for reading in RHR.

**LSR[4]: Receive Break Flag**

- Logic 0 = No break condition. (default)
- Logic 1 = The receiver received a break signal (RX was a logic 0 for one character frame time). In the FIFO mode, only one break character is loaded into the FIFO. The break indication remains until the RX input returns to the idle condition, "mark" or logic 1.

**LSR[5]: Transmit Holding Register Empty Flag**

This bit is the Transmit Holding Register Empty indicator. This bit indicates that the transmitter is ready to accept a new character for transmission. In addition, this bit causes the UART to issue an interrupt to the host when the THR interrupt enable is set. The THR bit is set to a logic 1 when the last data byte is transferred from the transmit holding register to the transmit shift register. The bit is reset to logic 0 concurrently with the data loading to the transmit holding register by the host. In the FIFO mode this bit is set when the transmit FIFO is empty; it is cleared when at least 1 byte is written to the transmit FIFO.

**LSR[6]: Transmit Shift Register Empty Flag**

This bit is the Transmit Shift Register Empty indicator. This bit is set to a logic 1 whenever the transmitter goes idle. It is set to logic 0 whenever either the THR or TSR contains a data character. In the FIFO mode this bit is set to one whenever the transmit FIFO and transmit shift register are both empty.

**LSR[7]: Receive FIFO Data Error Flag**

- Logic 0 = No FIFO error. (default)
- Logic 1 = An indicator for the sum of all error bits in the RX FIFO. At least one parity error, framing error or break indication is in the FIFO data. This bit clears when there is no more error(s) in the FIFO.

**Modem Status Register (MSR) - Read Only**

This register provides the current state of the modem interface signals, or other peripheral device that the UART is connected. Lower four bits of this register are used to indicate the changed information. These bits are set to a logic 1 whenever a signal from the modem changes state. These bits may be used as general purpose inputs/outputs when they are not used with modem signals.

**MSR[0]: Delta CTS# Input Flag**

- Logic 0 = No change on CTS# input (default).
- Logic 1 = The CTS# input has changed state since the last time it was monitored. A modem status interrupt will be generated if MSR interrupt is enabled (IER bit-3).

**MSR[1]: Delta DSR# Input Flag**

- Logic 0 = No change on DSR# input (default).
- Logic 1 = The DSR# input has changed state since the last time it was monitored. A modem status interrupt will be generated if MSR interrupt is enabled (IER bit-3).

**MSR[2]: Delta RI# Input Flag**

- Logic 0 = No change on RI# input (default).
- Logic 1 = The RI# input has changed from a logic 0 to a logic 1, ending of the ringing signal. A modem status interrupt will be generated if MSR interrupt is enabled (IER bit-3).

**MSR[3]: Delta CD# Input Flag**

- Logic 0 = No change on CD# input (default).
- Logic 1 = Indicates that the CD# input has changed state since the last time it was monitored. A modem status interrupt will be generated if MSR interrupt is enabled (IER bit-3).

**MSR[4]: CTS Input Status**

CTS# pin may function as automatic hardware flow control signal input if it is enabled and selected by Auto CTS (EFR bit-7) and RTS/CTS flow control select (MCR bit-2). Auto CTS flow control allows starting and stopping of local data transmissions based on the modem CTS# signal. A logic 1 on the CTS# pin will stop UART transmitter as soon as the current

character has finished transmission, and a logic 0 will resume data transmission. Normally MSR bit-4 bit is the compliment of the CTS# input. However in the loopback mode, this bit is equivalent to the RTS# bit in the MCR register. The CTS# input may be used as a general purpose input when the modem interface is not used.

**MSR[5]: DSR Input Status**

DSR# (active high, logical 1). This input may be used for auto DTR/DSR flow control function, see auto \hardware flow control section. Normally this bit is the compliment of the DSR# input. In the loopback mode, this bit is equivalent to the DTR# bit in the MCR register. The DSR# input may be used as a general purpose input when the modem interface is not used.

**MSR[6]: RI Input Status**

RI# (active high, logical 1). Normally this bit is the compliment of the RI# input. In the loopback mode this bit is equivalent to bit-2 in the MCR register. The RI# input may be used as a general purpose input when the modem interface is not used.

**MSR[7]: CD Input Status**

CD# (active high, logical 1). Normally this bit is the compliment of the CD# input. In the loopback mode this bit is equivalent to bit-3 in the MCR register. The CD# input may be used as a general purpose input when the modem interface is not used.

**Modem Status Register (MSR) - Write Only**

The upper four bits 4-7 of this register sets the delay in number of bits time for the auto RS485 turn around from transmit to receive.

**MSR [7:4]**

When Auto RS485 feature is enabled (FCTR bit-5=1) and RTS# output is connected to the enable input of a RS-485 transceiver. These 4 bits select from 0 to 15 bit-time delay after the end of the last stop-bit of the last transmitted character. This delay controls when to change the state of RTS# output. This delay is very useful in long-cable networks. Table 12 shows the selection. The bits are enabled by EFR bit-4.

TABLE 12: AUTO RS485 HALF-DUPLEX DIRECTION CONTROL DELAY FROM TRANSMIT-TO-RECEIVE

MSR[7]	MSR[6]	MSR[5]	MSR[4]	DELAY IN DATA BIT(S) TIME
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
9	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	10
1	0	1	1	11
1	1	0	0	12
1	1	0	1	13
1	1	1	0	14
1	1	1	1	15

**SCRATCH PAD REGISTER (SPR)**

This is a 8-bit general purpose register for the user to store temporary data. The content of this register is preserved during sleep mode but becomes 0xFF (default) after a reset or a power off-on cycle.

**FEATURE CONTROL REGISTER (FCTR)**

This register controls the UART enhanced functions that are not available on ST16C554 or ST16C654.

**FCTR [3:0] - Auto RTS/DTR Flow Control Hysteresis Select**

These bits select the auto RTS/DTR flow control hysteresis and only valid when TX and RX Trigger Table-D is selected (FCTR bit-6 and 7 are set to logic 1). The RTS/DTR hysteresis is referenced to the RX FIFO trigger level. After reset, these bits are set to logic 0 selecting the next FIFO trigger level for hardware flow control. Table 13 below shows the 16 selectable hysteresis levels.

**TABLE 13: 16 SELECTABLE HYSTERESIS LEVELS WHEN TRIGGER TABLE-D IS SELECTED**

FCTR Bit-3	FCTR Bit-2	FCTR Bit-1	FCTR Bit-0	RTS/DTR HYSTERESIS (CHARACTERS)
0	0	0	0	0
0	0	0	1	+/- 4
0	0	1	0	+/- 6
0	0	1	1	+/- 8
0	1	0	0	+/- 8
0	1	0	1	+/- 16
0	1	1	0	+/- 24
0	1	1	1	+/- 32
1	1	0	0	+/- 12
1	1	0	1	+/- 20
1	1	1	0	+/- 28
1	1	1	1	+/- 36
1	0	0	0	+/- 40
1	0	0	1	+/- 44
1	0	1	0	+/- 48
1	0	1	1	+/- 52

**FCTR[4]: Infrared RX Input Logic Select**

0 = Select RX input as active high encoded IrDA data, normal, (default).

1 = Select RX input as active low encoded IrDA data, inverted.

**FCTR[5]: Auto RS485 Enable**

Auto RS485 half duplex control enable/disable.

- 0 = Standard ST16C550 mode. Transmitter generates an interrupt when transmit holding register (THR) becomes empty. Transmit Shift Register (TSR) may still be shifting data bit out.
- 1 = Enable Auto RS485 half duplex direction control. RTS# output changes its logic level from 1 to 0 when finished sending the last stop bit of the last character out of the TSR register. It changes back to logic level 1 from 0 when a data byte is loaded into the THR or transmit FIFO. The change to logic 1 occurs prior sending the start-bit. It also changes the transmitter interrupt from transmit holding to transmit shift register (TSR) empty.

**FCTR[7:6]: TX and RX FIFO Trigger Table Select**

These 2 bits select the transmit and receive FIFO trigger level table A, B, C or D. When table A, B, or C is selected the auto RTS flow control trigger level is set to "next FIFO trigger level" for compatibility to ST16C550 and ST16C650 series. RTS/DTR# triggers on the next level of the RX FIFO trigger level, in another word, one FIFO level above and one FIFO level below. See in Table 10 for complete selection with FCR bit 4-5 and FCTR bit 6-7, i.e. if Table C is used on the receiver with RX FIFO trigger level set to 56 bytes, RTS/DTR# output will de-assert at 60 and re-assert at 16.

**Enhanced Feature Register (EFR)**

Enhanced features are enabled or disabled using this register. Bit 0-3 provide single or dual consecutive character software flow control selection (see Table 14). When the Xon1 and Xon2 and Xoff1 and Xoff2 modes are selected, the double 8-bit words are concatenated into two sequential characters. Caution: note that whenever changing the TX or RX flow control bits, always reset all bits back to logic 0 (disable) before programming a new setting.

TABLE 14: SOFTWARE FLOW CONTROL FUNCTIONS

EFR BIT-3 CONT-3	EFR BIT-2 CONT-2	EFR BIT-1 CONT-1	EFR BIT-0 CONT-0	TRANSMIT AND RECEIVE SOFTWARE FLOW CONTROL
0	0	0	0	No TX and RX flow control (default and reset)
0	0	X	X	No transmit flow control
1	0	X	X	Transmit Xon1/Xoff1
0	1	X	X	Transmit Xon2/Xoff2
1	1	X	X	Transmit Xon1 and Xon2/Xoff1 and Xoff2
X	X	0	0	No receive flow control
X	X	1	0	Receiver compares Xon1/Xoff1
X	X	0	1	Receiver compares Xon2/Xoff2
1	0	1	1	Transmit Xon1/ Xoff1, Receiver compares Xon1 or Xon2, Xoff1 or Xoff2
0	1	1	1	Transmit Xon2/Xoff2, Receiver compares Xon1 or Xon2, Xoff1 or Xoff2
1	1	1	1	Transmit Xon1 and Xon2/Xoff1 and Xoff2, Receiver compares Xon1 and Xon2/Xoff1 and Xoff2
0	0	1	1	No transmit flow control, Receiver compares Xon1 and Xon2/Xoff1 and Xoff2

**EFR BIT 0-3: Software Flow Control Select**

Combinations of software flow control can be selected by programming these bits.

**EFR[4]: Enhanced Function Bits Enable**

Enhanced function control bit. This bit enables the functions in IER bits 4-7, ISR bits 4-5, FCR bits 4-5, and MCR bits 5-7 to be modified. After modifying any enhanced bits, EFR bit-4 can be set to a logic 0 to latch the new values. This feature prevents legacy software from altering or overwriting the enhanced functions once set. Normally, it is recommended to leave it enabled, logic 1.

- Logic 0 = modification disable/latch enhanced features. IER bits 4-7, ISR bits 4-5, FCR bits 4-5, and MCR bits 5-7 are saved to retain the user settings. After a reset, the IER bits 4-7, ISR bits 4-5, FCR bits 4-5, and MCR bits 5-7 are set to a logic 0 to be compatible with ST16C554 mode. (default).
- Logic 1 = Enables the enhanced functions. When this bit is set to a logic 1 all enhanced features are enabled.

**EFR[5]: Special Character Detect Enable**

- Logic 0 = Special Character Detect Disabled. (default)
- Logic 1 = Special Character Detect Enabled. The UART compares each incoming receive character with data in Xoff-2 register. If a match exists, the received data will be transferred to FIFO and ISR

bit-4 will be set to indicate detection of the special character. Bit-0 corresponds with the LSB bit for the receive character. If flow control is set for comparing Xon1, Xoff1 (EFR [1:0]=10) then flow control and special character work normally. However, if flow control is set for comparing Xon2, Xoff2 (EFR[1:0]=01) then flow control works normally, but Xoff2 will not go to the FIFO, and will generate an Xoff interrupt and a special character interrupt.

**EFR[6]: AUTO RTS OR DTR FLOW CONTROL ENABLE**

RTS#/DTR# output may be used for hardware flow control by setting EFR bit-6 to logic 1. When Auto RTS/DTR is selected, an interrupt will be generated when the receive FIFO is filled to the programmed trigger level and RTS/DTR# will de-assert to a logic 1 at the next upper trigger or selected hysteresis level. RTS/DTR# will return to a logic 0 when FIFO data falls below the next lower trigger or selected hysteresis level (see FCTR bits 4-7). The RTS# or DTR# output must be asserted (logic 0) before the auto RTS/DTR can take effect. The selection for RTS# or DTR# is through MCR bit-2. RTS/DTR# pin will function as a general purpose output when hardware flow control is disabled.

- Logic 0 = Automatic RTS/DTR flow control is disabled. (default)
- Logic 1 = Enable Automatic RTS/DTR flow control.

**EFR[7]: Auto CTS Flow Control Enable**

Automatic CTS or DSR Flow Control.

- Logic 0 = Automatic CTS/DSR flow control is disabled. (default)
- Logic 1 = Enable Automatic CTS/DSR flow control. Transmission stops when CTS/DSR# pin de-asserts to logic 1. Transmission resumes when CTS/DRS# pin returns to a logic 0. The selection for CTS# or DSR# is through MCR bit-2.

**TFCNT[7:0]: Transmit FIFO Level Counter, read-only**

Transmit FIFO level byte count from 0x00 (zero) to 0x40 (64). This 8-bit register gives an indication of the number of characters in the transmit FIFO. The FIFO level Byte count register is read only. The user can take advantage of the FIFO level byte counter for faster data loading to the transmit FIFO., which reduces CPU bandwidth requirements.

**TXTRG [7:0]: Transmit FIFO Trigger Level, write only.**

An 8-bit value written to this register sets the TX FIFO trigger level from 0x00 (zero) to 0x40 (64). The TX FIFO trigger level generates an interrupt whenever the data level in the transmit FIFO falls below this preset trigger level.

**RFCNT[7:0]: Receive FIFO Level Counter, read only**

Receive FIFO level byte count from 0x00 (zero) to 0x40 (64). It gives an indication of the number of characters in the receive FIFO. The FIFO level byte count register is read only. The user can take advantage of the FIFO level byte counter for faster data unloading from the receiver FIFO, which reduces CPU bandwidth requirements.

**RXTRG[7:0]: Receive FIFO Trigger Level, write only**

An 8-bit value written to this register, sets the RX FIFO trigger level from 0x00 (zero) to 0x40 (64). The RX FIFO trigger level generates an interrupt whenever the receive FIFO level rises to this preset trigger level.

**TABLE 15: UART RESET CONDITIONS**

REGISTERS	RESET STATE
DLL	Bits 7-0 = 0xXX
DLM	Bits 7-0 = 0xXX
RHR	Bits 7-0 = 0xXX
THR	Bits 7-0 = 0xXX
IER	Bits 7-0 = 0x00
FCR	Bits 7-0 = 0x00
ISR	Bits 7-0 = 0x01
LCR	Bits 7-0 = 0x00
MCR	Bits 7-0 = 0x00
LSR	Bits 7-0 = 0x60
MSR	Bits 3-0 = logic 0 Bits 7-4 = logic levels of the inputs
SPR	Bits 7-0 = 0xFF
FCTR	Bits 7-0 = 0x00
EFR	Bits 7-0 = 0x00
TFCNT	Bits 7-0 = 0x00
TFTRG	Bits 7-0 = 0x00
RFCNT	Bits 7-0 = 0x00
RFTRG	Bits 7-0 = 0x00
XCHAR	Bits 7-0 = 0x00
XON1	Bits 7-0 = 0x00
XON2	Bits 7-0 = 0x00
XOFF1	Bits 7-0 = 0x00
XOFF2	Bits 7-0 = 0x00
I/O SIGNALS	RESET STATE
TX[ch-7:0]	Logic 1
IRTX[ch-7:0]	Logic 0
RTS#[ch-7:0]	Logic 1
DTR#[ch-7:0]	Logic 1



**ABSOLUTE MAXIMUM RATINGS**

Power Supply Range	7 Volts
Voltage at Any Pin	-0.5 to 7V
Operating Temperature	-40° to +85° C
Storage Temperature	-65° to +150° C
Package Dissipation	500 mW
Thermal Resistance (14x20x3.0mm 100-QFP)	$\theta$ -ja = 34°C/W , $\theta$ -jc = 9°C/W

**ELECTRICAL CHARACTERISTICS**

**DC ELECTRICAL CHARACTERISTICS**

TA=0° to 70°C (-40° to +85°C for industrial grade package), Vcc-3.3V and 5V +/-10% unless specified

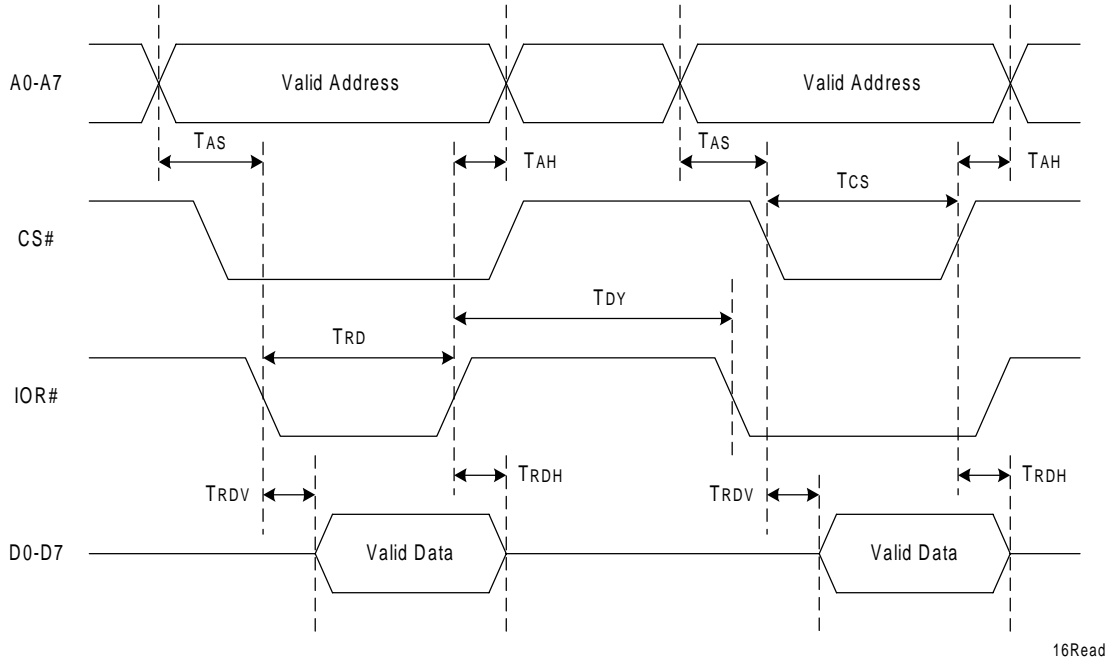
SYMBOL	PARAMETER	3.3V MIN	3.3 MAX	5V MIN	5V MAX	UNITS	CONDITION	NOTES
V <sub>IL</sub>	Input Low Voltage	-0.3	0.7	-0.5	0.8	V		
V <sub>IH</sub>	Input High Voltage	2.0		2.4		V		
V <sub>OL</sub>	Output Low Voltage		0.4		0.55	V	I <sub>out</sub> =6 mA	
V <sub>OH</sub>	Output High Voltage	2.0		2.4		V	I <sub>out</sub> =-2 mA	
I <sub>IL</sub>	Input Low Leakage Current		-10		-10	uA		
I <sub>IH</sub>	Input High Leakage Current		10		10	uA		
X1	Crystal/Clock input low level	-0.3	0.6	-0.5	0.6	V		
X1	Crystal/Clock input high level	2.4	6	3.0	6	V		
C <sub>IN</sub>	Input Pin Capacitance		5		5	pF		
I <sub>CC</sub>	Power Supply Current		5		5	mA	EXT Clock=2MHz A7-A0 at GND, all inputs at VCC or GND and outputs unloaded	
I <sub>SLEEP</sub>	Sleep Current		0.60		3.00	mA	Eight UARTs asleep. A7-A0 at GND, all inputs at VCC or GND and outputs unloaded.	20uA Typ.
R <sub>IN</sub>	Internal pull-up or pull-down resistance	3K	15K	3K	15K	Ohms		

**AC ELECTRICAL CHARACTERISTICS**

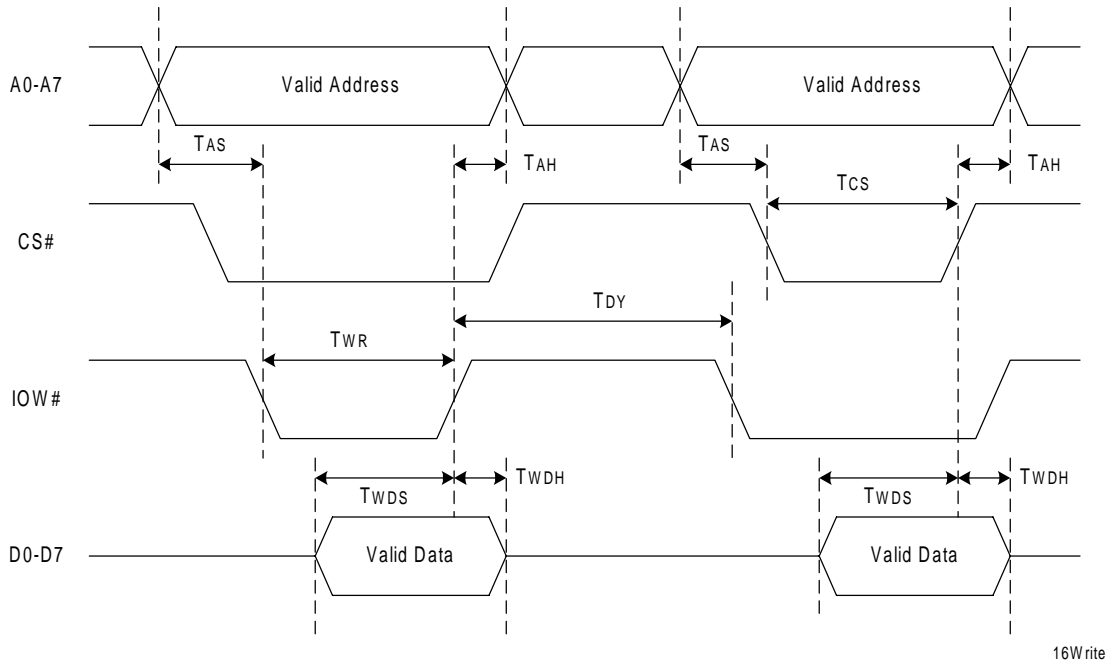
TA=0° to 70°C (-40° to +85°C for industrial grade package), Vcc=3.3V and 5V +/-10% unless specified.

SYMBOL	PARAMETER	3.3V MIN	3.3V MAX	5V MIN	5V MAX	UNITS	NOTES
T <sub>C1</sub> , T <sub>C2</sub>	Clock Pulse Period	10		8		ns	
T <sub>OSC</sub>	Oscillator Frequency		16		24	MHz	
T <sub>ECK</sub>	External Clock Frequency		33		50	MHz	
T <sub>AS</sub>	Address Setup (16 Mode)	10		5		ns	
T <sub>AH</sub>	Address Hold (16 Mode)	5		5		ns	
T <sub>CS</sub>	Chip Select Width (16 Mode)	50		30		ns	
T <sub>DY</sub>	Delay between CS# Active Cycles (16 Mode)	50		50		ns	
T <sub>RD</sub>	Read Strobe Width (16 Mode)	50		30		ns	
T <sub>WR</sub>	Write Strobe Width (16 Mode)	40		30		ns	
T <sub>RDV</sub>	Read Data Valid (16 Mode)	35		25		ns	
T <sub>WDS</sub>	Write Data Setup (16 Mode)	15		10		ns	
T <sub>RDH</sub>	Read Data Hold (16 Mode)		15		10	ns	
T <sub>WDH</sub>	Write Data Hold (16 Mode)	15		10		ns	
T <sub>ADS</sub>	Address Setup (68 Mode)	10		10		ns	
T <sub>ADH</sub>	Address Hold (68 Mode)	15		10		ns	
T <sub>RWS</sub>	R/W# Setup to CS# (68 Mode)	10		10		ns	
T <sub>RDA</sub>	Read Data Access (68 mode)	35		25		ns	
T <sub>RDH</sub>	Read Data Hold (68 mode)		15		10	ns	
T <sub>WDS</sub>	Write Data Setup (68 mode)	15		15		ns	
T <sub>WDH</sub>	Write Data Hold (68 Mode)	15		15		ns	
T <sub>RWH</sub>	CS# De-asserted to R/W# De-asserted (68 Mode)	10		10		ns	
T <sub>CSL</sub>	CS# Width (68 Mode)	50		40		ns	
T <sub>CSD</sub>	CS# Cycle Delay (68 Mode)	50		40		ns	
						ns	
T <sub>17D</sub>	Delay from IOW# to Modem Output		50		50	ns	
T <sub>18D</sub>	Delay to set Interrupt from Modem Input		50		35	ns	
T <sub>19D</sub>	Delay to reset Interrupt from IOR#		50		35	ns	
T <sub>RST</sub>	Reset Pulse	40		40		ns	

FIGURE 15. 16 MODE (INTEL) DATA BUS READ AND WRITE TIMING



16 Mode (Intel) Data Bus Read Timing



16 Mode (Intel) Data Bus Write Timing

**FIGURE 16. 68 MODE (MOTOROLA) DATA BUS READ AND WRITE TIMING**

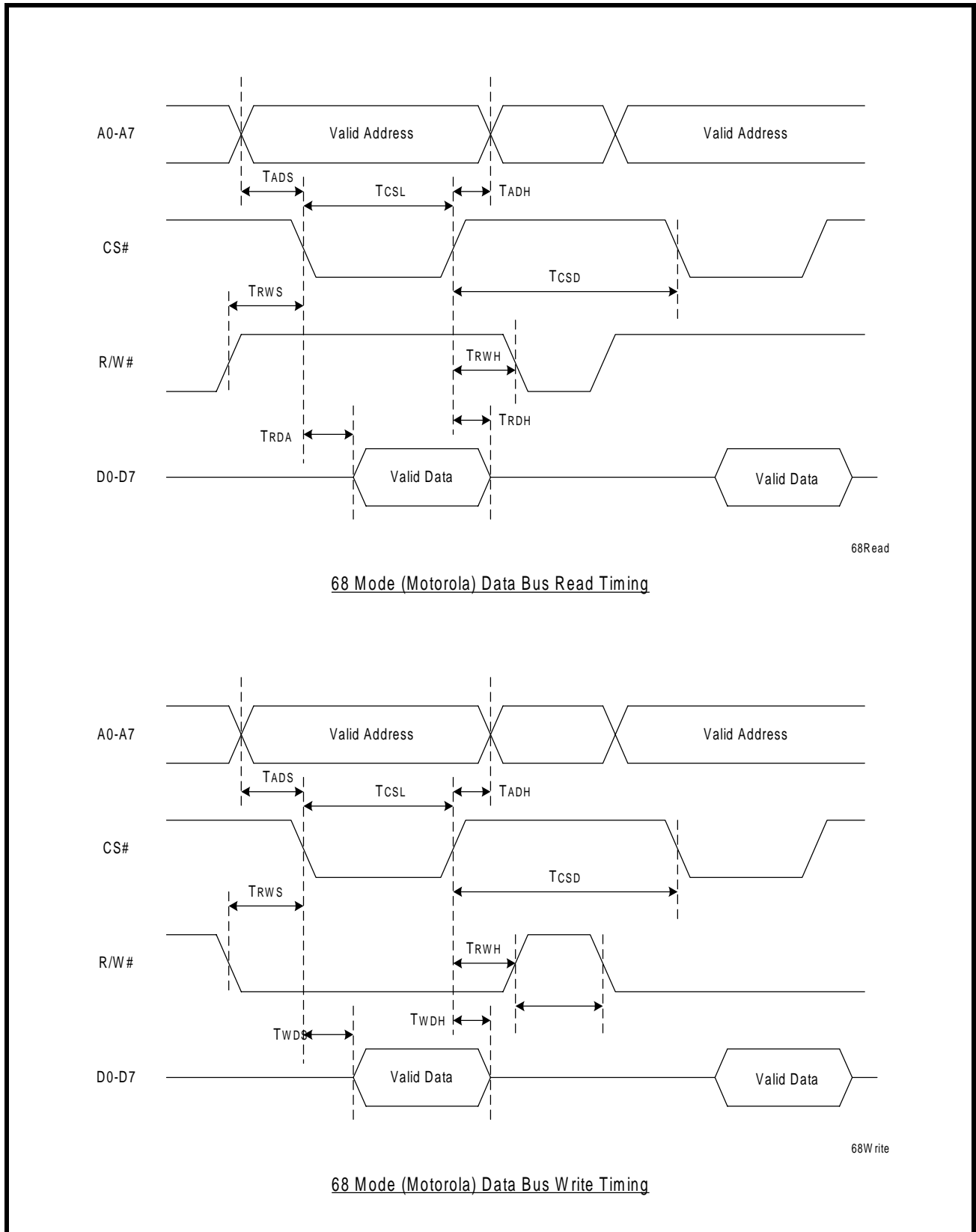


FIGURE 17. MODEM INPUT/OUTPUT PORT DELAY

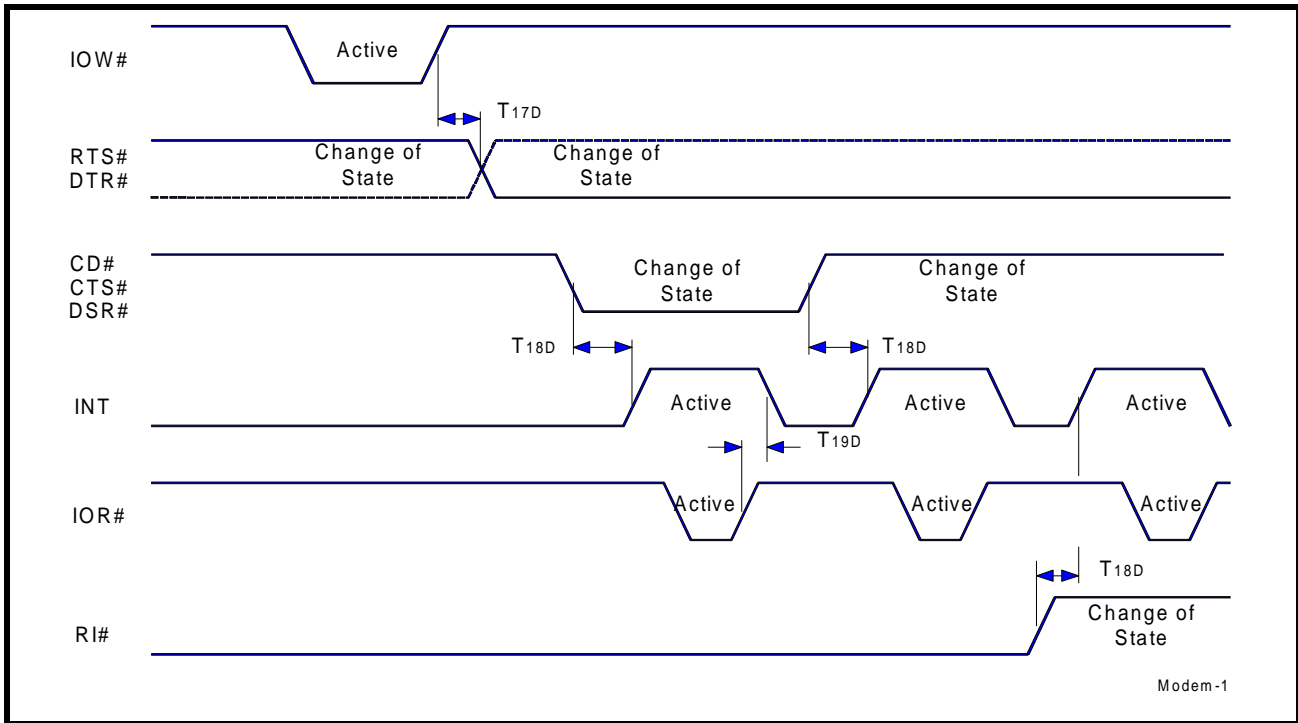
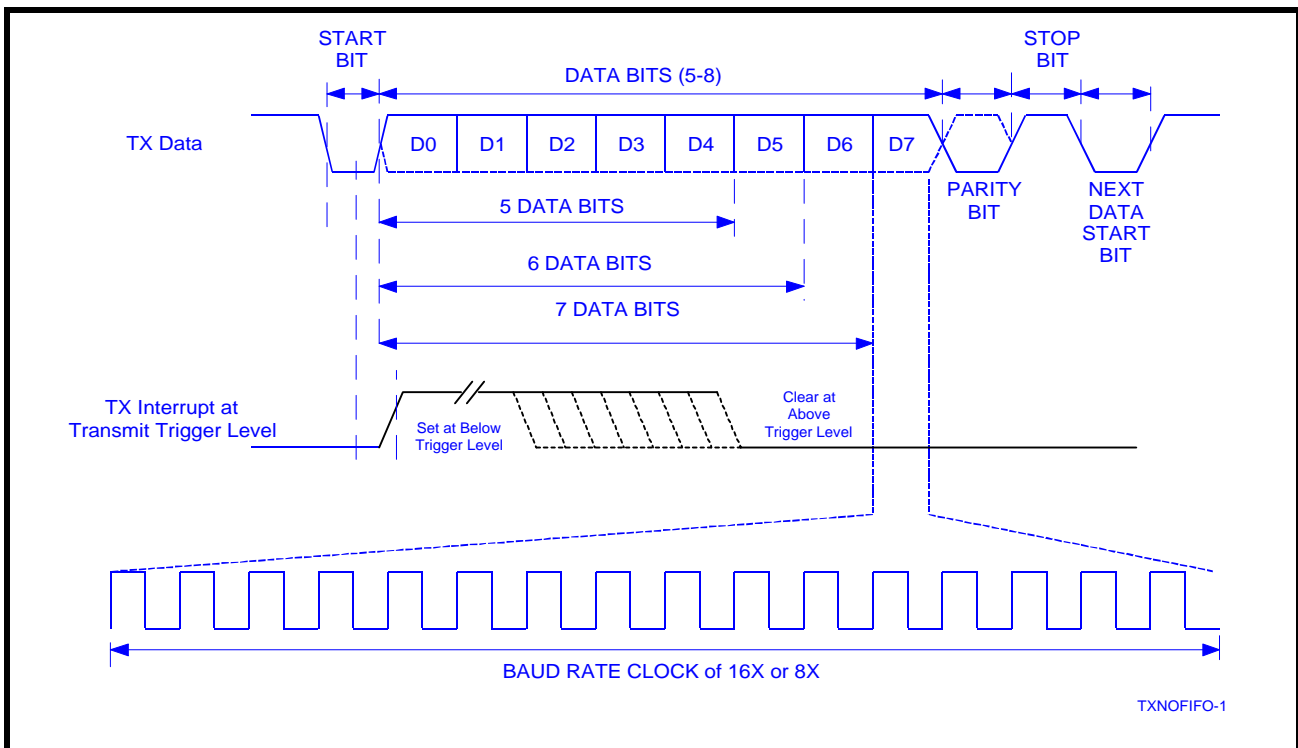
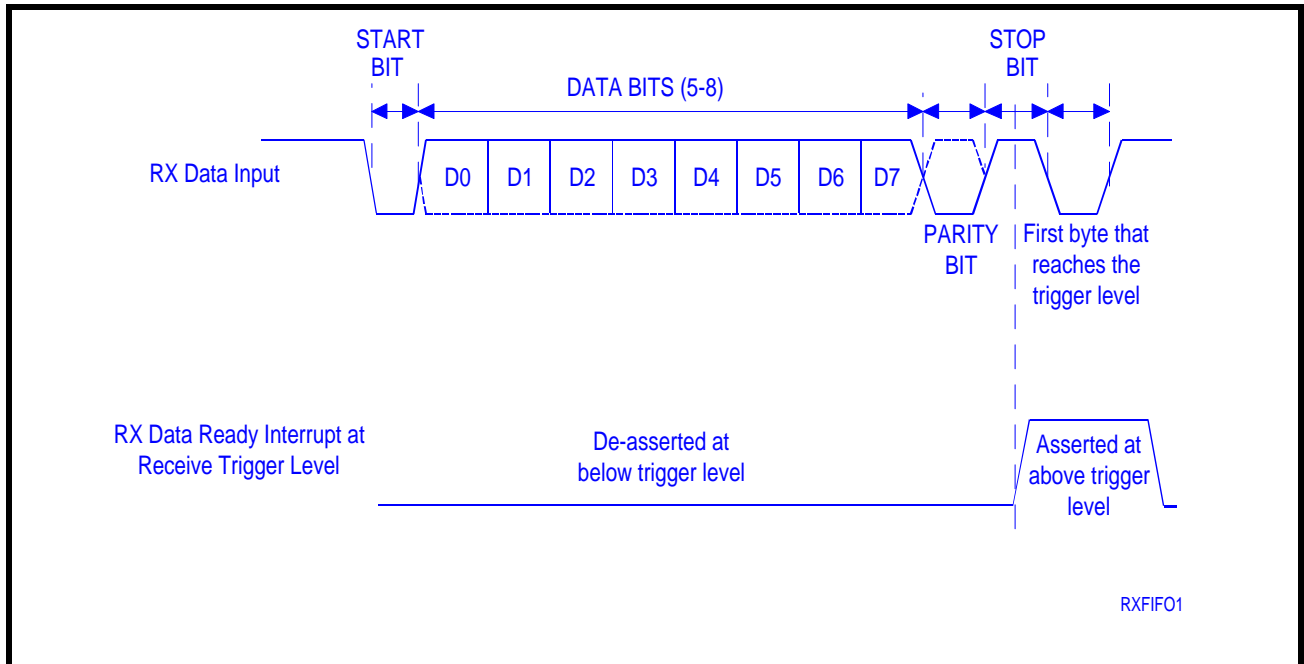


FIGURE 18. TRANSMIT DATA INTERRUPT AT TRIGGER LEVEL



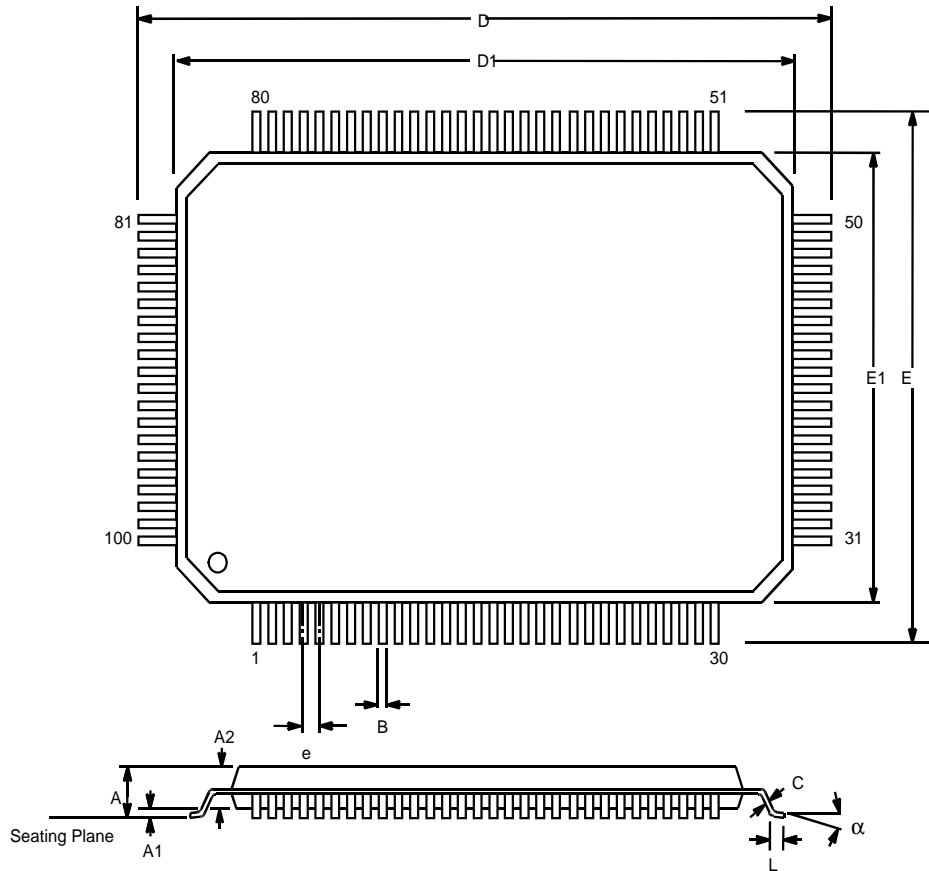
**FIGURE 19. RECEIVE DATA READY INTERRUPT AT TRIGGER LEVEL**



PACKAGE DIMENSIONS

100 LEAD PLASTIC QUAD FLAT PACK  
(14 mm x 20 mm, QFP)

Rev. 2.00



SYMBOL	1.95 mm Form			
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.102	0.134	2.60	3.40
A <sub>1</sub>	0.002	0.014	0.05	0.35
A <sub>2</sub>	0.100	0.120	2.55	3.05
B	0.009	0.015	0.22	0.38
C	0.005	0.009	0.13	0.23
D	0.931	0.951	23.65	24.15
D <sub>1</sub>	0.783	0.791	19.90	20.10
E	0.695	0.715	17.65	18.15
E <sub>1</sub>	0.547	0.555	13.90	14.10
e	0.0256 BSC		0.65 BSC	
L	0.026	0.037	0.65	0.95
α	0°	7°	0°	7°

Note: The control dimension is the millimeter column

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**REVISION HISTORY**

P1.0.0	Preliminary
P1.0.1	Corrected figure 2 pin diagram on pins 16 to 30 and 39.
P1.0.2	Corrected pins description (pin number) for TX3, RX6, DSR6# and 16/68#.
P1.0.3	Changed part number to XR16L788, added 5V spec and target timing, and corrected RX6 pin to be 39.
P1.0.4	Changed I <sub>cc</sub> to 5mA max. and I <sub>sleep</sub> current to 400uA max, clarified ENIR pin and MCR bits 2 and 6.
1.1.0	Updated Electrical Specification Tables. Added $\theta$ -ja and $\theta$ -jc values. Removed Preliminary designation.
1.1.1	changed V <sub>IL</sub> ( 0.8 to 0.7 max) and V <sub>IH</sub> (2.2 to 2.4 min) in electrical characteristics tables.
1.1.2	Changed I <sub>sleep</sub> max @ 3.3V from 0.40mA to 0.60 mA and @ 5V from 0.40 to 3.00mA
1.1.3	Deleted V <sub>OH</sub> @ I <sub>out</sub> =6mA. Changed condition on ICC from CLK=35MHz to "EXT Clock=2Mhz". Changed T <sub>RDA</sub> from min =30ns to 35ns. Changed max V <sub>OL</sub> @5V from 0.4 to 0.55V. Changed min V <sub>OH</sub> @5V from 4.0 to 2.4V.

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