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Industry Smallest Package UART with 2.25V to 5.5V Operation, Intel/Motorola Data Bus Interfaces Select and Exclusive PowerSave Feature

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- Small 32-QFN Package of 5x5x0.9mm
- Wide Range Supply Voltage Operation of 2.25V to 5.5V
- Intel/Motorola Data Bus Select
- PowerSave Reduces Sleep Mode Current down to 30uA*
- Automatic RTS/CTS Hardware Flow Control
- Automatic Xon/Xoff software flow control
- 16-byte Transmit/Receive FIFO to Reduce Bandwidth Requirements of External CPU
- Wireless Infrared Encoder and Decoder
- Full Modem Interface (TXD, RXD, RTS, CTS, DTR, DSR, RI, CD)
- Pb-Free, RoHS Compliant Versions Offered

Applications

- Handheld Appliances
- Battery Operated Instruments
- Portable Appliances
- CDMA Cellular Phones
- Cellular Base Stations
- Telecommunications Network Routers
- Industrial Automation Controls

Description

This dual-channel product family is highly integrated and built for small board space, low voltage and high bandwidth requirements found in a variety of handheld and battery operated applications. These include Point-of-Sale (POS) terminals, tablets and notepads, CDMA cellular phones, expansion modules, instrumentation, cellular base stations, wireless infrared appliances, and industrial automation controls.

The series consists of four devices: [XR16L2450](#), [XR16L2550](#), [XR16L2551](#) and [XR16L2552](#). Each has two independently controlled UART channels and operates over a broad range power source of 2.25V to 5.5V with 5V tolerant inputs.

Specifications

CH	2
CPUInterface	Intel or Motorola
Data Rate@5/3.3/2.5V	3.1/1.8/1.0
Tx/RxFIFO(Bytes)	16/16
Tx/RxFIFOCtrs	No
Tx/RxFIFOINT Trig	No/ 4 Levels
AutoRTS/CTS	Yes
IrDaSup	Yes
5VTollInputs	Yes
Sup V	2.25-5.5
Pkgs	QFN-32, TQFP-48

Documents**▶ Datasheets**

[Datasheet Version 1.1.3 May 2007 901.93 KB](#)

▶ Application Notes

[DAN-138, Exar's XR16L2550 Compared to TI's TL16C752B Version 1.0.0 November 2003 69.59 KB](#)

[DAN-176, Power-Save Feature: Sleep Current Down to 15•A Version 1.0.0 August 2004 42.54 KB](#)



The XR16L2551 uniquely offers a very small 32-QFN, 5x5x0.9mm, package with PowerSave feature to conserve power down to less than 30uA* of current consumption. These attributes are a perfect combination for tight space and/or battery operated designs. The PowerSave feature eliminates the need for two external octal transceivers to reduce board space requirement and lower overall system costs. The XR16L2551 also offers a pin select for Intel or Motorola data bus interface to reduce hardware design cycle.

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► [Quality Manual](#)

► [Quarterly Quality & Reliability Report](#)

► [RoHS-Green Solutions](#)



The XR16L2550, XR16L2551 and XR16L2552 have 16-byte of TX and RX FIFOs for larger data buffering and provide automatic hardware (RTS/CTS) or software (Xon/Xoff) flow control to eliminate receiver data overflow and wasteful re-transmissions. In addition, the devices include the wireless infrared encoder/decoder for wireless communications. The XR16L2450 has one byte of TX and RX FIFO as its predecessor, the ST16C2450, but with lower operating voltage and 5V tolerant inputs. The 4 devices are pin and function compatible with their previous 5V series.

For UART technical support or to obtain an IBIS model for this product, please email [Exar's UART Technical Support group](#).

► **Schematics**

[PCI Eval Board Schematic Version 1.1.0](#)
[July 2007](#)
[167.82 KB](#)

[ISA Eval Board Schematic Version 1.4.0](#)
[August 2007](#)
[109.05 KB](#)

► **Evaluation Board Manuals**

[Evaluation Board User's Manual Version 1.3.0](#)
[August 2003](#)
[24.69 KB](#)

Part Number	Pkg Code	RoHS	Min Temp. (°C)	Max Temp. (°C)	Status	Buy Now	Order Samples
XR16L2551IL	QFN32		-40	85	Active	<input type="checkbox"/>	<input type="checkbox"/>
XR16L2551IL-F	QFN32		-40	85	Active	<input type="checkbox"/>	<input type="checkbox"/>
XR16L2551IM-F	TQFP48		-40	85	Active	<input type="checkbox"/>	<input type="checkbox"/>

Part Status Legend

Active - the part is released for sale, standard product.

EOL (End of Life) - the part is no longer being manufactured, there may or may not be inventory still in stock.

CF (Contact Factory) - the part is still active but customers should check with the factory for availability. Longer lead-times may apply.

PRE (Pre-introduction) - the part has not been introduced or the part number is an early version available for sample only.

OBS (Obsolete) - the part is no longer being manufactured and may not be ordered.

NRND (Not Recommended for New Designs) - the part is not recommended for new designs.

GENERAL DESCRIPTION

The XR16L2551 (L2551) is a low voltage dual universal asynchronous receiver and transmitter (UART) with 5 Volt tolerant inputs. The device includes additional capability over the ST16C2550: Intel and Motorola data bus interface selection, hardware and software flow control, infrared encoder/decoder, sleep mode and a PowerSave mode for battery operation. The L2551's enhanced register set is compatible to the ST16C2550 and XR16L2550. It supports the Exar's enhanced features of 16 bytes of TX and RX FIFOs and a complete modem interface. Onboard registers provide the user with operational status and data error tags. An internal loopback capability allows onboard diagnostics. Independent programmable baud rate generator is provided in each channel to support data rates up to 3.125 Mbps.

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

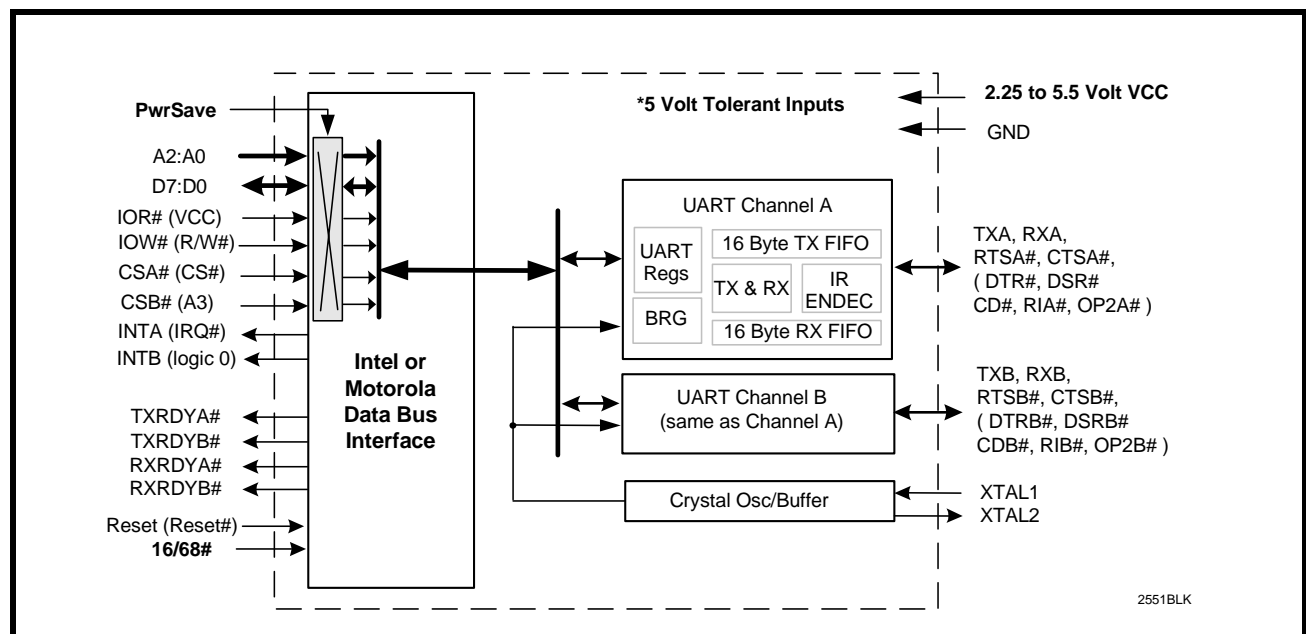
APPLICATIONS

- Battery Operated Instruments
- Data Port Adapters
- Handheld Appliances
- Radio Frequency Data Modems
- Base Stations
- USB Hubs
- Industrial Automation Controls

FEATURES

- **2.25 to 5.5 Volt Operation**
- **5 Volt Tolerant Inputs**
- **Intel or Motorola Bus Interface Select (16/68#) pin**
- Pin-to-pin compatible to XR16L2751CM
- Two Independent UARTs
 - Up to 3.125 Mbps at 5V, 2 Mbps at 3.3V, and 1 Mbps at 2.5V with external clock input
 - Up to 1.5 Mbps at 5V, 1.25 Mbps at 3.3V and 1 Mbps at 2.5V with crystal clock input
 - 16 bytes of Transmit and Receive FIFOs
 - **Automatic RTS/CTS hardware flow control**
 - **Automatic Xon/Xoff software flow control**
 - **Wireless infrared encoder/decoder**
 - Receive FIFO trigger levels select
 - Programmable character lengths (5, 6, 7 or 8) with even, odd, forced or no parity
 - Full Modem Interface (CTS#, RTS#, DSR#, DTR#, RI#, CD#) in the 48-TQFP package
- **Sleep Mode with PowerSave feature for battery operation**
- Industrial Temperature range
- **Tiny 32-QFN, no lead package (5x5x0.9mm)**
- 48-TQFP Package

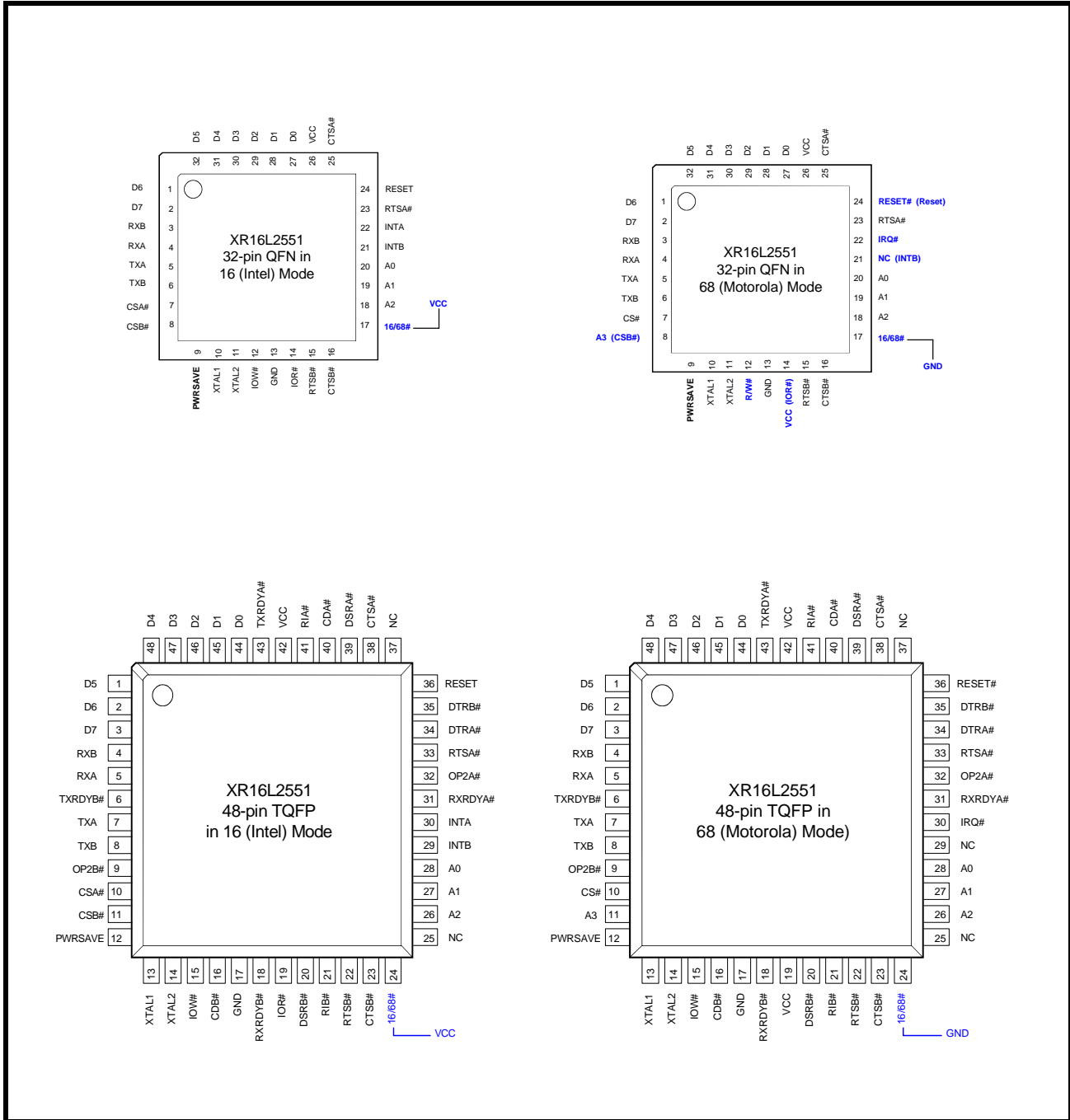
FIGURE 1. XR16L2551 BLOCK DIAGRAM



XR16L2551

LOW VOLTAGE DUART WITH POWERSAVE

FIGURE 2. PIN OUT ASSIGNMENT



ORDERING INFORMATION

PART NUMBER	PACKAGE	OPERATING TEMPERATURE RANGE	DEVICE STATUS
XR16L2551IL	32-Lead QFN	-40°C to +85°C	Active
XR16L2551IM	48-Lead TQFP	-40°C to +85°C	Active

PIN DESCRIPTIONS

Pin Description

NAME	32-QFN PIN #	48-TQFP PIN #	TYPE	DESCRIPTION
DATA BUS INTERFACE				
A2 A1 A0	18 19 20	26 27 28	I	Address data lines [2:0]. These 3 address lines select one of the internal registers in UART channel A/B during a data bus transaction.
D7 D6 D5 D4 D3 D2 D1 D0	2 1 32 31 30 29 28 27	3 2 1 48 47 46 45 44	IO	Data bus lines [7:0] (bidirectional).
IOR# (VCC)	14	19	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 is not used and should be connected to VCC.
IOW# (R/W#)	12	15	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.
CSA# (CS#)	7	10	I	When 16/68# pin is at logic 1, this input is chip select A (active low) to enable channel A in the device. When 16/68# pin is at logic 0, this input becomes the chip select (active low) for the Motorola bus interface.
CSB# (A3)	8	11	I	When 16/68# pin is at logic 1, this input is chip select B (active low) to enable channel B in the device. When 16/68# pin is at logic 0, this input becomes address line A3 which is used for channel selection in the Motorola bus interface. Input logic 0 selects channel A and logic 1 selects channel B.
INTA (IRQ#)	22	30	O	When 16/68# pin is at logic 1 for Intel bus interface, this output becomes channel A interrupt output. The output state is defined by the user through the software setting of MCR[3]. INTA is set to the active mode and OP2A# output to a logic 0 when MCR[3] is set to a logic 1. INTA is set to the three state mode and OP2A# to a logic 1 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 device interrupt output (active low, open drain). An external pull-up resistor is required for proper operation.

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Pin Description

NAME	32-QFN PIN #	48-TQFP PIN #	TYPE	DESCRIPTION
INTB (NC)	21	29	O	When 16/68# pin is at logic 1 for Intel bus interface, this output becomes channel B interrupt output. The output state is defined by the user and through the software setting of MCR[3]. INTB is set to the active mode and OP2B# output to a logic 0 when MCR[3] is set to a logic 1. INTB is set to the three state mode and OP2B# to a logic 1 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 is not used and will stay at logic zero level. Leave this output unconnected.
TXRDYA#	-	43	O	UART channel A Transmitter Ready (active low). The output provides the TX FIFO/THR status for transmit channel A. If it is not used, leave it unconnected.
RXRDYA#	-	31	O	UART channel A Receiver Ready (active low). This output provides the RX FIFO/RHR status for receive channel A. If it is not used, leave it unconnected.
TXRDYB#	-	6	O	UART channel B Transmitter Ready (active low). The output provides the TX FIFO/THR status for transmit channel B. If it is not used, leave it unconnected.
RXRDYB#	-	18	O	UART channel B Receiver Ready (active low). This output provides the RX FIFO/RHR status for receive channel B. If it is not used, leave it unconnected.
MODEM OR SERIAL I/O INTERFACE				
TXA	5	7	O	UART channel A Transmit Data. If it is not used, leave it unconnected.
RXA	4	5	I	UART channel A Receive Data. Normal receive data input must idle at logic 1 condition. If it is not used, tie it to VCC or pull it high via a 100k ohm resistor.
RTSA#	23	33	O	UART channel A Request-to-Send (active low) or general purpose output. If it is not used, leave it unconnected.
CTSA#	25	38	I	UART channel A Clear-to-Send (active low) or general purpose input. This input should be connected to VCC when not used.
DTRA#	-	34	O	UART channel A Data-Terminal-Ready (active low) or general purpose output. If it is not used, leave it unconnected.
DSRA#	-	39	I	UART channel A Data-Set-Ready (active low) or general purpose input. This input should be connected to VCC when not used. This input has no effect on the UART.
CDA#	-	40	I	UART channel A Carrier-Detect (active low) or general purpose input. This input should be connected to VCC when not used. This input has no effect on the UART.
RIA#	-	41	I	UART channel A Ring-Indicator (active low) or general purpose input. This input should be connected to VCC when not used. This input has no effect on the UART.

Pin Description

NAME	32-QFN PIN #	48-TQFP PIN #	TYPE	DESCRIPTION
OP2A#	-	32	O	Output Port 2 Channel A - The output state is defined by the user and through the software setting of MCR[3]. INTA is set to the active mode and OP2A# output to a logic 0 when MCR[3] is set to a logic 1. INTA is set to the three state mode and OP2A# to a logic 1 when MCR[3] is set to a logic 0. This output should not be used as a general output else it will disturb the INTA output functionality. If it is not used at all, leave it unconnected.
TXB	6	8	O	UART channel B Transmit Data. If it is not used, leave it unconnected.
RXB	3	4	I	UART channel B Receive Data. Normal receive data input must idle at logic 1 condition. If it is not used, tie it to VCC or pull it high via a 100k ohm resistor.
RTSB#	15	22	O	UART channel B Request-to-Send (active low) or general purpose output. If it is not used, leave it unconnected.
CTSB#	16	23	I	UART channel B Clear-to-Send (active low) or general purpose input. This input should be connected to VCC when not used.
DTRB#	-	35	O	UART channel B Data-Terminal-Ready (active low) or general purpose output. If it is not used, leave it unconnected.
DSRB#	-	20	I	UART channel B Data-Set-Ready (active low) or general purpose input. This input should be connected to VCC when not used. This input has no effect on the UART.
CDB#	-	16	I	UART channel B Carrier-Detect (active low) or general purpose input. This input should be connected to VCC when not used. This input has no effect on the UART.
RIB#	-	21	I	UART channel B Ring-Indicator (active low) or general purpose input. This input should be connected to VCC when not used. This input has no effect on the UART.
OP2B#	-	9	O	Output Port 2 Channel B - The output state is defined by the user and through the software setting of MCR[3]. INTB is set to the active mode and OP2B# output to a logic 0 when MCR[3] is set to a logic 1. INTB is set to the three state mode and OP2B# to a logic 1 when MCR[3] is set to a logic 0. This output should not be used as a general output else it will disturb the INTB output functionality. If it is not used, leave it unconnected.
ANCILLARY SIGNALS				
XTAL1	10	13	I	Crystal or external clock input.
XTAL2	11	14	O	Crystal or buffered clock output.
16/68#	17	24	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.

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Pin Description

NAME	32-QFN PIN #	48-TQFP PIN #	TYPE	DESCRIPTION
PwrSave	9	12	I	PowerSave (active high). This feature isolates the L2551'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 PowerSave Feature section for details.
RESET (RESET#)	24	36	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 channel A and B. 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	26	42	Pwr	2.25V to 5.5V power supply. All inputs are 5V tolerant.
GND	13	17	Pwr	Power supply common, ground.
GND	Center Pad	N/A	Pwr	The center pad on the backside of the 32-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.
N.C.	-	25, 37		No Connection. These pins are not connected internally. But if there is a possibility of migrating to the XR16L2751 for future needs, please refer to the XR16L2751 datasheet to determine if these pins should be connected to VCC or GND.

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

1.0 PRODUCT DESCRIPTION

The XR16L2551 (L2551) provides serial asynchronous receive data synchronization, parallel-to-serial and serial-to-parallel data conversions for both the transmitter and receiver sections. These functions are necessary for converting the serial data stream into parallel data that is required with digital data systems. Synchronization for the serial data stream is accomplished by adding start and stop bits to the transmit data to form a data character (character orientated protocol). Data integrity is ensured by attaching a parity bit to the data character. The parity bit is checked by the receiver for any transmission bit errors. The electronic circuitry to provide all these functions is fairly complex especially when manufactured on a single integrated silicon chip. The L2551 represents such an integration with greatly enhanced features. The L2551 is fabricated with an advanced CMOS process.

Transmit and Receive FIFOs (16 Bytes each)

The L2551 is an upward solution that provides a dual UART capability with 16 bytes of transmit and receive FIFO memory, instead of none in the 16C2450. The L2551 is designed to work with high speed modems and shared network environments, that require fast data processing time. Increased performance is realized in the L2551 by the transmit and receive FIFO's. This allows the external processor to handle more networking tasks within a given time. For example, the ST16C2450 without a receive FIFO, will require unloading of the RHR in 93 microseconds (This example uses a character length of 11 bits, including start/stop bits at 115.2 Kbps). This means the external CPU will have to service the receive FIFO less than every 100 microseconds. However with the 16 byte FIFO in the L2551, the data buffer will not require unloading/loading for 1.53 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 4 selectable receive FIFO trigger interrupt levels is uniquely provided for maximum data throughput performance especially when operating in a multi-channel environment. The FIFO memory greatly reduces the bandwidth requirement of the external controlling CPU, increases performance, and reduces power consumption.

Data Bus Interface, Intel or Motorola Type

The L2551 provides a single host interface for the 2 UARTs and supports Intel or Motorola microprocessor (CPU) data bus interface. The Intel bus compatible interface allows direct interconnect to Intel compatible type of CPUs using IOR#, IOW# and CSA# or CSB# inputs for data bus operation. The Motorola bus compatible interface instead uses the R/W#, CS# and A3 signals for data bus transactions. Few data bus interface signals change their functions depending on user's selection, see pin description for details. The Intel and Motorola bus interface selection is made through the 16/68# pin (pin 24 for 48-TQFP package and pin 17 for 32-QFN package).

Enhanced Features

The XR16L2551 integrates the functions of 2 enhanced 16C550 Universal Asynchronous Receiver and Transmitter (UART). Its features set is compatible to the XR16L2550 device but offers Intel or Motorola data bus interface and PowerSave to isolate the data bus interface during Sleep mode. Each UART is independently controlled having its own set of device configuration registers. The configuration registers set is 16550 UART compatible for control, status and data transfer. Additionally, each UART channel has automatic RTS/CTS hardware flow control, automatic Xon/Xoff and special character software flow control, 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 3.125 Mbps at 5V with a 50 MHz external clock.

The rich feature set of the L2551 is available through internal registers. Selectable receive FIFO trigger levels, selectable TX and RX baud rates, and modem interface controls are all standard features. Following a power on reset or an external reset (and operating in 16 or Intel Mode), the L2551 is functionally and software compatible with the previous generation ST16C2450 and ST16C2550.

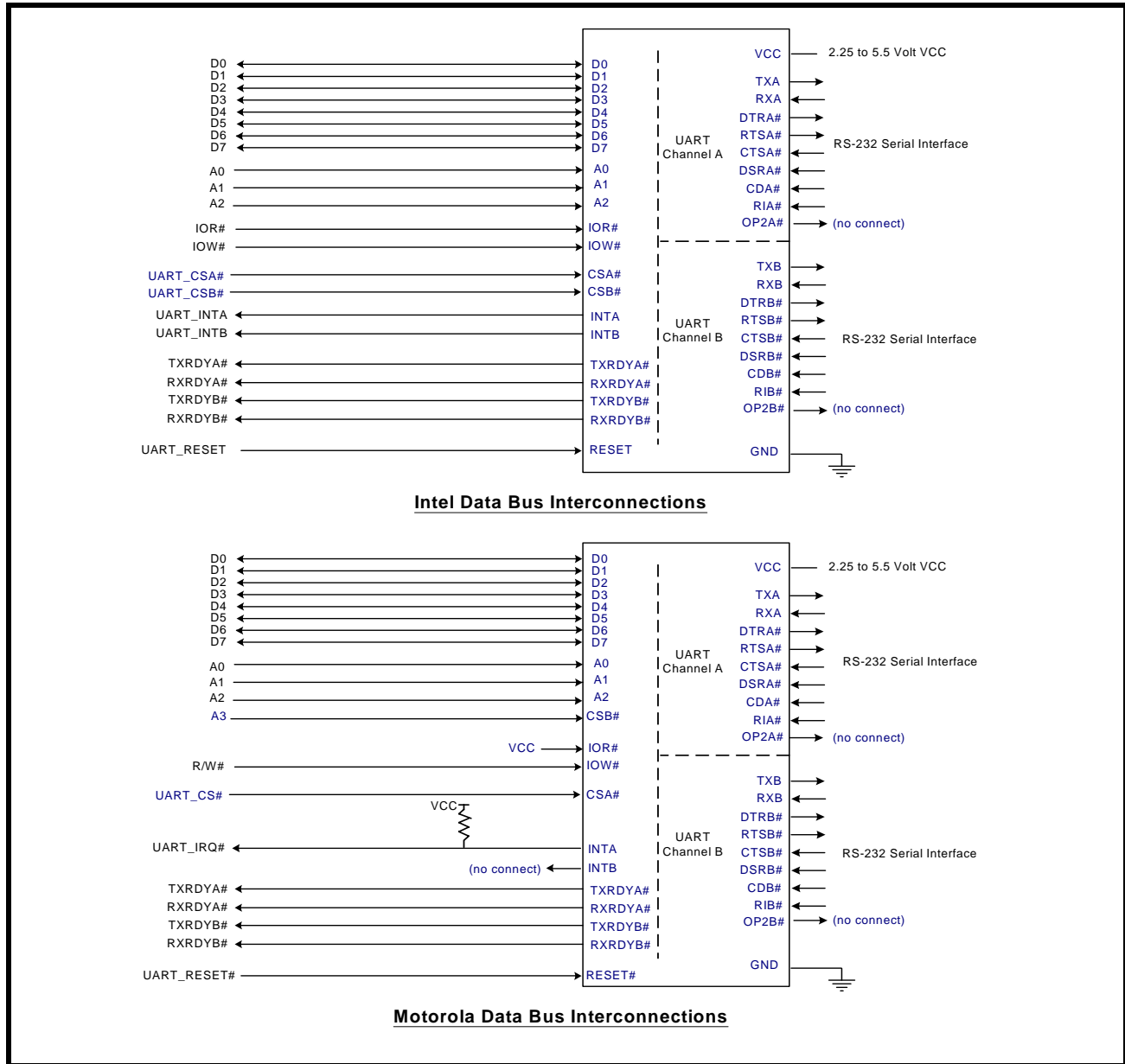
LOW VOLTAGE DUART WITH POWERSAVE

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 L2551 data interface supports the Intel compatible types of CPUs and it is compatible to the industry standard 16C550 UART. No clock (oscillator nor external clock) is required to operate a data bus transaction. Each bus cycle is asynchronous using CSA/B#, IOR# and IOW# or CS#, R/W# and A3 inputs. Both UART channels share the same data bus for host operations. A typical data bus interconnection for Intel and Motorola mode is shown in **Figure 3**.

FIGURE 3. XR16L2751 TYPICAL INTEL/MOTOROLA DATA BUS INTERCONNECTIONS



2.2 5-Volt Tolerant Inputs

The L2551 can accept up to 5V inputs even when operating at 3.3V or 2.5V. But note that if the L2551 is operating at 2.5V, its V_{OH} may not be high enough to meet the requirements of the V_{IH} of a CPU or a serial transceiver that is operating at 5V.

2.3 Device Reset

The RESET or RESET# input resets the internal registers and the serial interface outputs in both channels to their default state (see [Table 14](#)). An active high pulse of at least 40 ns duration will be required to activate the reset function in the device.

2.4 Device Identification and Revision

The L2551 provides a Device Identification code and a Device Revision code to distinguish the part from other devices and revisions. To read the identification code from the part, it is required to set the baud rate generator registers DLL and DLM both to 0x00. Now reading the content of the DLM will provide 0x02 to indicate L2551 and reading the content of DLL will provide the revision of the part; for example, a reading of 0x01 means revision A.

2.5 Channel A and B Selection

The UART provides the user with the capability to bi-directionally transfer information between an external CPU and an external serial communication device. A logic 0 on chip select pins, CSA# or CSB#, allows the user to select UART channel A or B to configure, send transmit data and/or unload receive data to/from the UART. Selecting both UARTs can be useful during power up initialization to write to the same internal registers, but do not attempt to read from both uarts simultaneously. Individual channel select functions are shown in [Table 1](#).

TABLE 1: CHANNEL A AND B SELECT IN 16 MODE

CSA#	CSB#	FUNCTION
1	1	UART de-selected
0	1	Channel A selected
1	0	Channel B selected
0	0	Channel A and B selected

During Motorola Bus Mode (16/68# pin connected to GND), the package interface pins are configured for connection with Motorola, and other popular microprocessor bus types. In this mode the L2551 decodes an additional address, A3, to select one of the UART ports. The A3 address decode function is used only when in the Motorola Bus Mode. [See Table 2](#).

Channel A and B Internal Registers

TABLE 2: CHANNEL A AND B SELECT IN 68 MODE

CS#	A3	FUNCTION
1	N/A	UART de-selected
0	0	Channel A selected
0	1	Channel B selected

Each UART channel in the L2551 has a standard register set for controlling, monitoring and data loading and unloading. The configuration register set is compatible to those already available in the standard single 16C550. 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), and a user accessible scratch pad register (SPR).

2.6 DMA Mode

The device does not support direct memory access. The DMA Mode (a legacy term) in this document doesn't mean "direct memory access" but refers to data block transfer operation. The DMA mode affects the state of the RXRDY# A/B and TXRDY# A/B output pins. The transmit and receive FIFO trigger levels provide additional flexibility to the user for block mode operation. The LSR bits 5-6 provide an indication when the transmitter is

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empty or has an empty location(s) for more data. The user can optionally operate the transmit and receive FIFO in the DMA mode (FCR bit-3=1). When the transmit and receive FIFO are enabled and the DMA mode is disabled (FCR bit-3 = 0), the L2551 is placed in single-character mode for data transmit or receive operation. When DMA mode is enabled (FCR bit-3 = 1), the user takes advantage of block mode operation by loading or unloading the FIFO in a block sequence determined by the programmed trigger level. The following table show their behavior. Also see [Figure 20](#) through [Figure 25](#).

TABLE 3: TXRDY# AND RXRDY# OUTPUTS IN FIFO AND DMA MODE

PINS	FCR BIT-0=0 (FIFO DISABLED)	FCR BIT-0=1 (FIFO ENABLED)	
		FCR Bit-3 = 0 (DMA Mode Disabled)	FCR Bit-3 = 1 (DMA Mode Enabled)
RXRDY# A/B	0 = 1 byte. 1 = no data.	0 = at least 1 byte in FIFO 1 = FIFO empty.	1 to 0 transition when FIFO reaches the trigger level, or time-out occurs. 0 to 1 transition when FIFO empties.
TXRDY# A/B	0 = THR empty. 1 = byte in THR.	0 = FIFO empty. 1 = at least 1 byte in FIFO.	0 = FIFO has at least 1 empty location. 1 = FIFO is full.

2.7 INTA and INTB Outputs

The INTA and INTB interrupt output changes according to the operating mode and enhanced features setup. [Table 4](#) and [Table 5](#) summarize the operating behavior for the transmitter and receiver. Also see [Figure 20](#) through [Figure 25](#).

TABLE 4: INTA AND INTB PINS OPERATION FOR TRANSMITTER

	FCR BIT-0 = 0 (FIFO DISABLED)	FCR BIT-0 = 1 (FIFO ENABLED)
INTA/B Pin	0 = a byte in THR 1 = THR empty	0 = at least 1 byte in FIFO 1 = FIFO empty

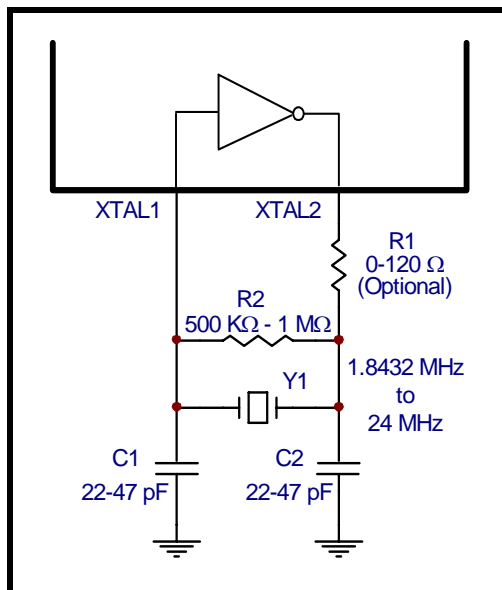
TABLE 5: INTA AND INTB PIN OPERATION FOR RECEIVER

	FCR BIT-0 = 0 (FIFO DISABLED)	FCR BIT-0 = 1 (FIFO ENABLED)
INTA/B Pin	0 = no data 1 = 1 byte	0 = FIFO below trigger level 1 = FIFO above trigger level

2.8 Crystal Oscillator or External Clock Input

The L2551 includes an on-chip oscillator (XTAL1 and XTAL2) to produce a clock for both UART sections in the device. The CPU data bus does not require this clock for bus operation. The crystal oscillator provides a system clock to the Baud Rate Generators (BRG) section found in each of the UART. XTAL1 is the input to the oscillator or external clock buffer input with XTAL2 pin being the output. Please note that the input XTAL1 is not 5V tolerant and so the maximum at the pin should be VCC. For programming details, see “Programmable Baud Rate Generator.”

FIGURE 4. TYPICAL OSCILLATOR CONNECTIONS

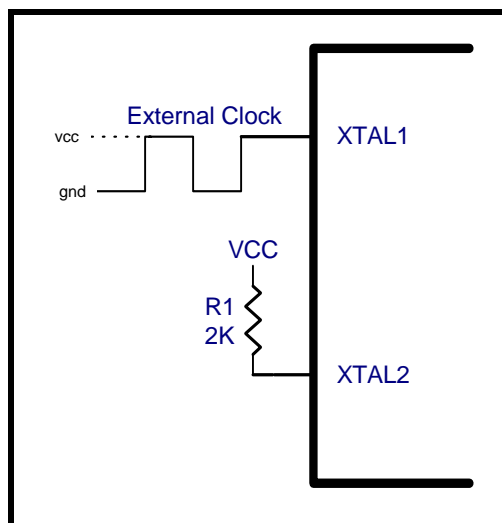


The on-chip oscillator is designed to use an industry standard microprocessor crystal (parallel resonant, fundamental frequency with 10-22 pF capacitance load, ESR of 20-120 ohms and 100 ppm frequency tolerance) connected externally between the XTAL1 and XTAL2 pins (see **Figure 4**), with an external 500 kΩ to 1 MΩ resistor across it. Alternatively, an external clock can be connected to the XTAL1 pin to clock the internal baud rate generator for standard or custom rates. Typical oscillator connections are shown in **Figure 4**. For further reading on oscillator circuit please see application note DAN108 on EXAR's web site.

2.9 Programmable Baud Rate Generator

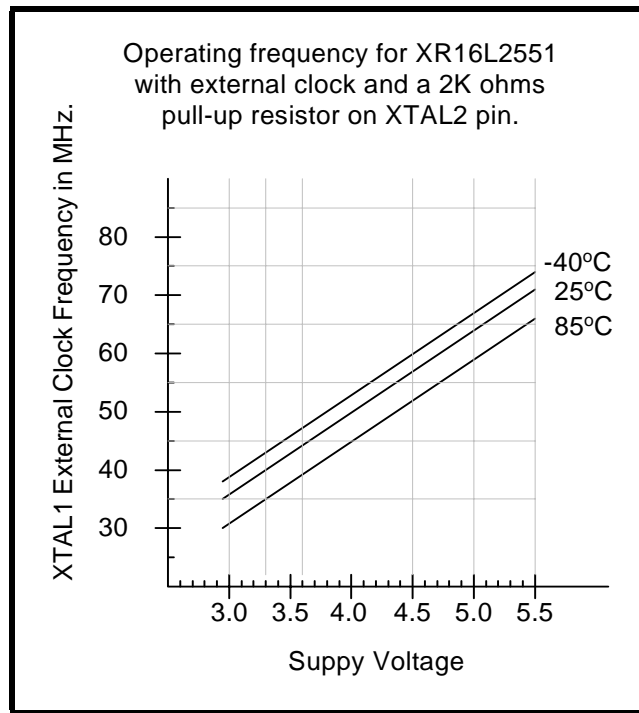
A single baud rate generator is provided for the transmitter and receiver, allowing independent TX/RX channel control. The programmable Baud Rate Generator is capable of operating with a crystal frequency of up to 24 MHz. However, with an external clock input on XTAL1 pin and a 2K ohms pull-up resistor on XTAL2 pin (as shown in **Figure 5**) it can extend its operation up to 50 MHz (3.125Mbps serial data rate) at room temperature and 5.0V.

FIGURE 5. EXTERNAL CLOCK CONNECTION FOR EXTENDED DATA RATE



To obtain maximum data rate, it is necessary to use full rail swing on the clock input. See external clock operating frequency over power supply voltage chart in **Figure 6**.

FIGURE 6. OPERATING FREQUENCY CHART. REQUIRES A 2K OHMS PULL-UP RESISTOR ON XTAL2 PIN TO INCREASE OPERATING SPEED



The L2551 divides the basic external clock by 16. The basic 16X clock provides table rates to support standard and custom applications using the same system design. The Baud Rate Generator divides the input 16X clock by any divisor from 1 to $2^{16} - 1$. The rate table is configured via the DLL and DLM internal register functions. Customized Baud Rates can be achieved by selecting the proper divisor values for the MSB and LSB sections of baud rate generator.

Table 6 shows the standard data rates available with a 14.7456 MHz crystal or external clock at 16X sampling rate. When using a non-standard frequency crystal or external clock, the divisor value can be calculated for DLL/DLM with the following equation.

$$\text{divisor (decimal)} = (\text{XTAL1 clock frequency}) / (\text{serial data rate} \times 16)$$

TABLE 6: TYPICAL DATA RATES WITH A 14.7456 MHZ CRYSTAL OR EXTERNAL CLOCK

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 (%)
400	2304	900	09	00	0
2400	384	180	01	80	0
4800	192	C0	00	C0	0
9600	96	60	00	60	0
19.2k	48	30	00	30	0
38.4k	24	18	00	18	0
76.8k	12	0C	00	0C	0
153.6k	6	06	00	06	0
230.4k	4	04	00	04	0
460.8k	2	02	00	02	0
921.6k	1	01	00	01	0

2.10 Transmitter

The transmitter section comprises of an 8-bit Transmit Shift Register (TSR) and 16 bytes of FIFO which includes a byte-wide Transmit Holding Register (THR). TSR shifts out every data bit with the 16X internal clock. A bit time is 16 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).

2.10.1 Transmit Holding Register (THR) - Write Only

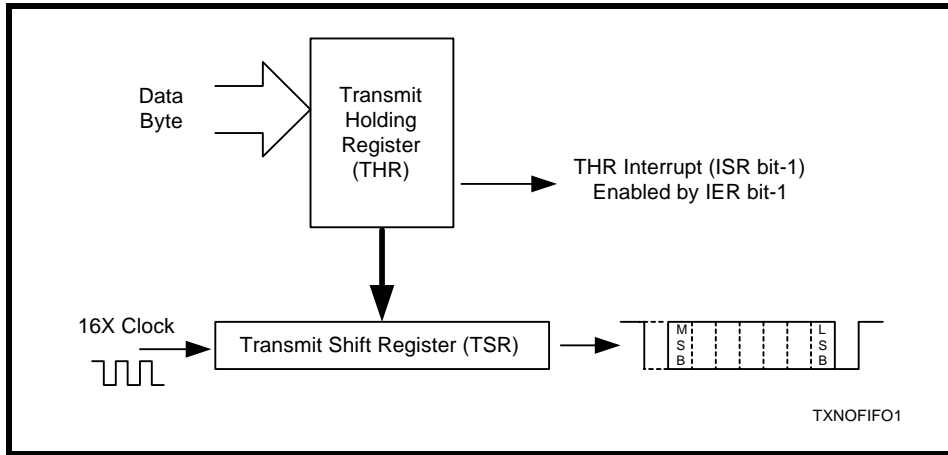
The transmit holding register is an 8-bit register providing a data interface to the host processor. The host writes transmit data byte to the THR to be converted into a serial data stream including start-bit, data bits, parity-bit and stop-bit(s). The least-significant-bit (Bit-0) becomes first data bit to go out. The THR is the input register to the transmit FIFO of 16 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.

2.10.2 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.

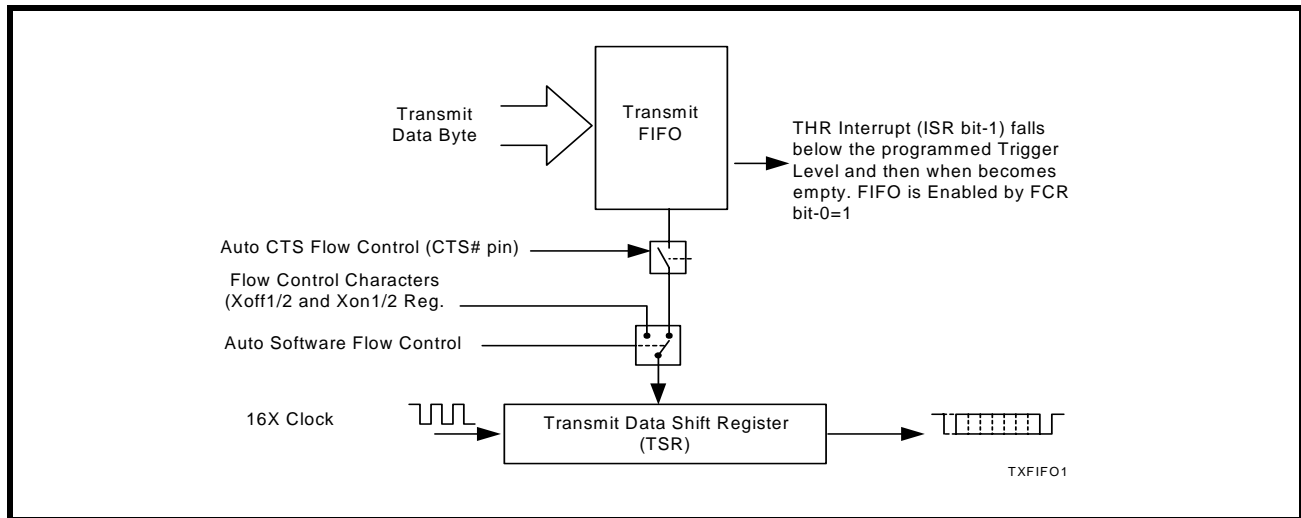
2.10.3 Transmitter Operation in FIFO Mode

FIGURE 7. TRANSMITTER OPERATION IN NON-FIFO MODE



The host may fill the transmit FIFO with up to 16 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 transmit empty interrupt is enabled by IER bit-1. The TSR flag (LSR bit-6) is set when the FIFO and the TSR become empty.

FIGURE 8. TRANSMITTER OPERATION IN FIFO AND FLOW CONTROL MODE



2.11 Receiver

The receiver section contains an 8-bit Receive Shift Register (RSR) and 16 bytes of FIFO which includes a byte-wide Receive Holding Register (RHR). The RSR uses the 16X 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. After 8 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 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.

2.11.1 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 16 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 9. RECEIVER OPERATION IN NON-FIFO MODE

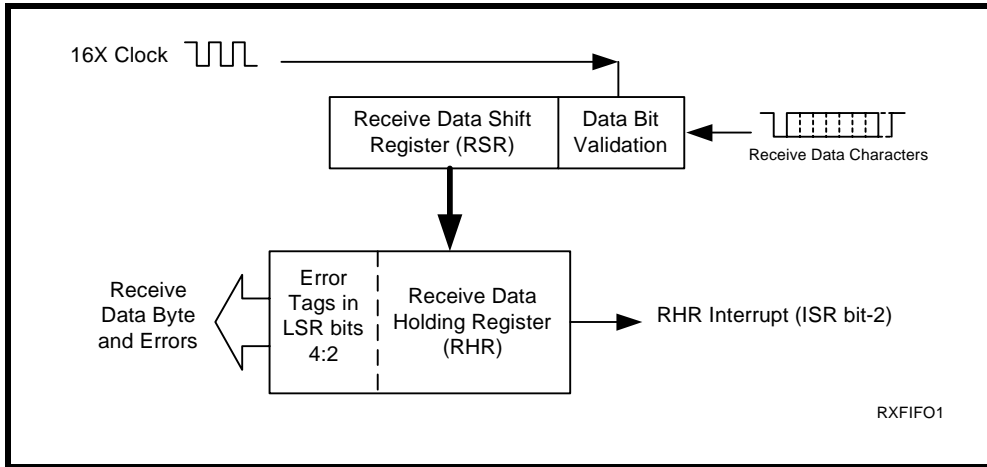
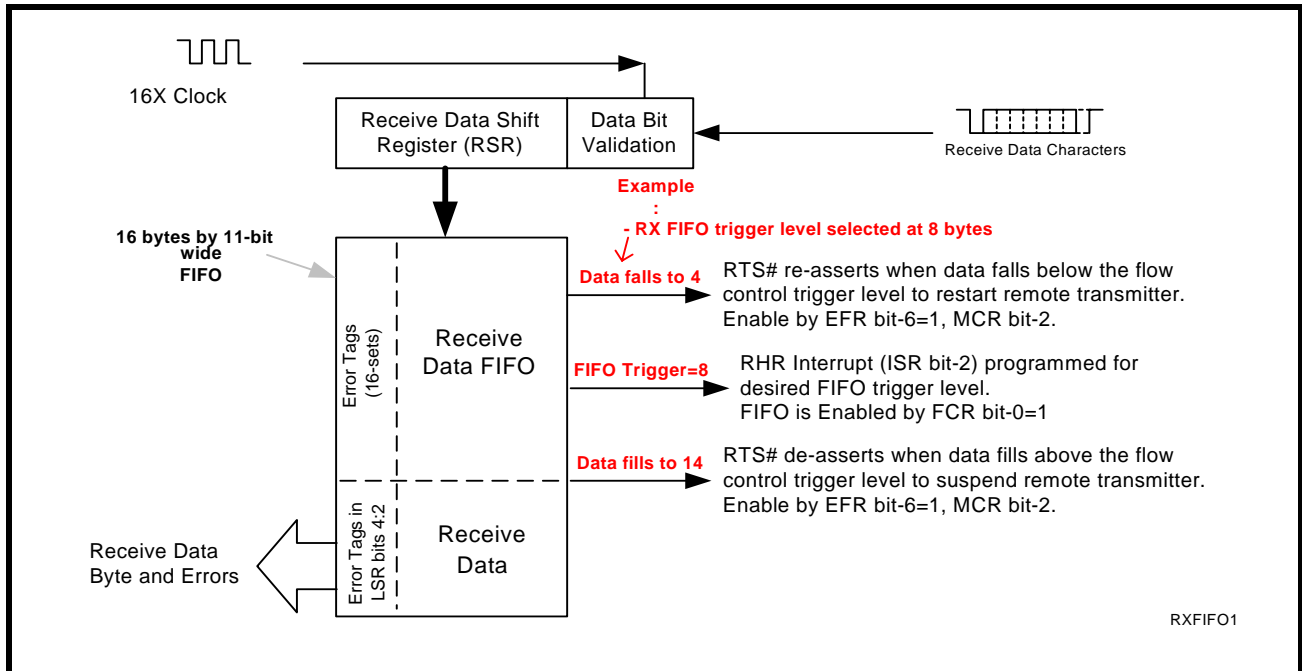


FIGURE 10. RECEIVER OPERATION IN FIFO AND AUTO RTS FLOW CONTROL MODE



2.12 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 11**):

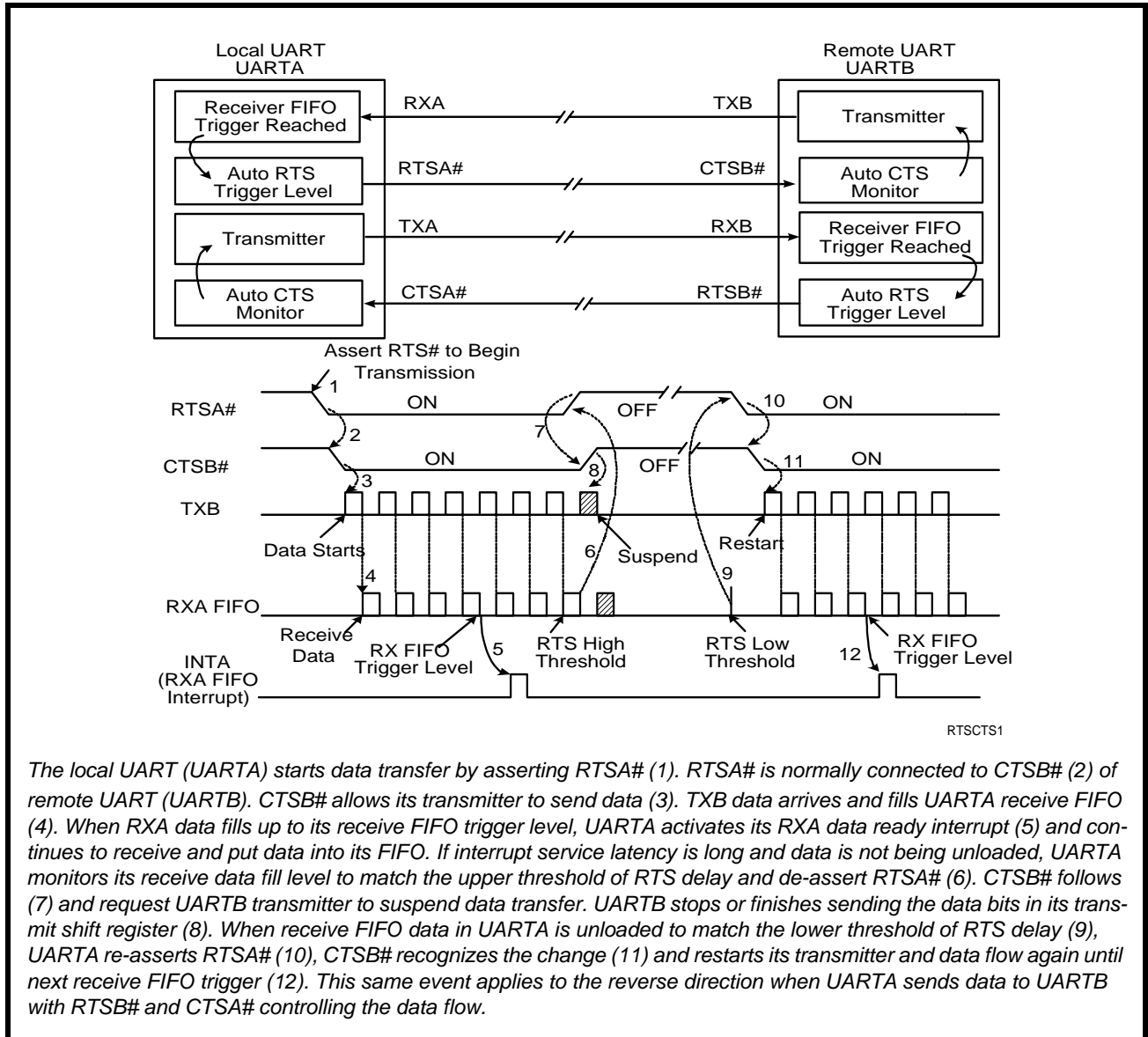
- Enable auto RTS flow control using EFR bit-6.
- The auto RTS function must be started by asserting RTS# output pin (MCR bit-1 to logic 1 after it is enabled).
- Enable RTS interrupt through IER bit-6 (after setting EFR bit-4). The UART issues an interrupt when the RTS# pin makes a transition from low to high: ISR bit-5 will be set to logic 1.

2.13 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 11**):

- Enable auto CTS flow control using EFR bit-7.
- Enable CTS interrupt through IER bit-7 (after setting EFR bit-4). The UART issues an interrupt when the CTS# pin is de-asserted (logic 1): 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 (logic 0), indicating more data may be sent.

FIGURE 11. AUTO RTS AND CTS FLOW CONTROL OPERATION



XR16L2551

LOW VOLTAGE DUART WITH POWERSAVE

2.14 Auto Xon/Xoff (Software) Flow Control

When software flow control is enabled (See Table 13), the L2551 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 L2551 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 L2551 will monitor the receive data stream for a match to the Xon-1,2 character. If a match is found, the L2551 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 13) and suspend/resume transmissions. When double 8-bit Xon/Xoff characters are selected, the L2551 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 overflowing and flow control needs to be executed, the L2551 automatically sends an Xoff message (when enabled) via the serial TX output to the remote modem. The L2551 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 programmed trigger level. To clear this condition, the L2551 will transmit the programmed Xon-1,2 characters as soon as receive FIFO is less than one trigger level below the programmed trigger level. See Table 7 below.

TABLE 7: 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)
1	1	1*	0
4	4	4*	1
8	8	8*	4
14	14	14*	8

* 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 8-bit word length, no parity and 1 stop bit setting.

2.15 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 L2551 compares each incoming receive character with Xoff-2 data. If a match exists, the received data will be transferred to 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.

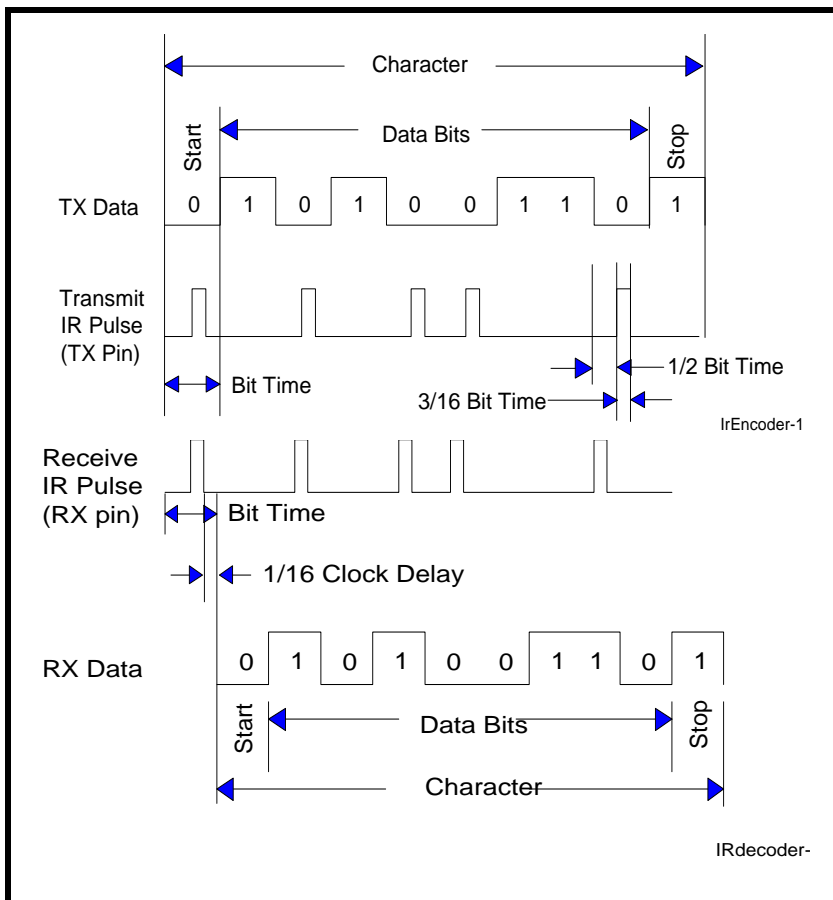
2.16 Infrared Mode

The L2551 UART includes the infrared encoder and decoder compatible to the IrDA (Infrared Data Association) version 1.0. 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. This signal encoding reduces the on-time of the infrared LED, hence reduces the power consumption. See **Figure 12** below.

The infrared encoder and decoder are enabled by setting MCR register bit-6 to a ‘1’. When the infrared feature is enabled, the transmit data output, TX, idles at logic zero level. Likewise, the RX input assumes an idle level of logic zero from a reset and power up, see **Figure 12**.

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 12. INFRARED TRANSMIT DATA ENCODING AND RECEIVE DATA DECODING



2.17 Sleep Mode with Auto Wake-Up and PowerSave Feature

The L2551 supports low voltage system designs, hence, a sleep mode with auto wake-up and PowerSave feature is included to reduce power consumption when the device is not actively used.

2.17.1 Sleep Mode

All of these conditions must be satisfied for the L2551 to enter sleep mode:

- no interrupts pending for both channels of the L2551 (ISR bit-0 = 1)
- divisor is a non-zero value (ie. DLL = 0x1)
- sleep mode of both channels are enabled (IER bit-4 = 1)
- modem inputs are not toggling (MSR bits 0-3 = 0)
- RX input pins are idling at a logic 1

The L2551 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 L2551 resumes normal operation by any of the following when PowerSave mode is disabled:

- a receive data start bit transition (logic 1 to 0)
- 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 L2551 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 L2551 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 channel A or B. The L2551 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. The number of characters lost during the restart also depends on your operating data rate. More characters are lost when operating at higher data rate. Also, it is important to keep RX A/B inputs idling at logic 1 or “marking” condition during sleep mode to avoid receiving a “break” condition upon the restart. This may 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 designer can use a 47k-100k ohm pull-up resistor on the RXA and RXB pins.

2.17.2 PowerSave Feature

If the address lines, data bus lines, IOW#, IOR#, CSA#, CSB#, and modem input lines remain steady when the L2551 is in sleep mode, the maximum current will be in the microamp range as specified in the DC Electrical Characteristics on [page 36](#). If the input lines are floating or are toggling while the L2551 is in sleep mode, the current can be up to 100 times more. If not using the PowerSave feature, then 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 PowerSave feature is enabled (pin 12 of the 48-TQFP or pin 9 of the 32-QFN is 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 L2551 enters PowerSave mode when the PWRSAVE pin is connected to VCC and the L2551 is in sleep mode (see Sleep Mode section above).

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

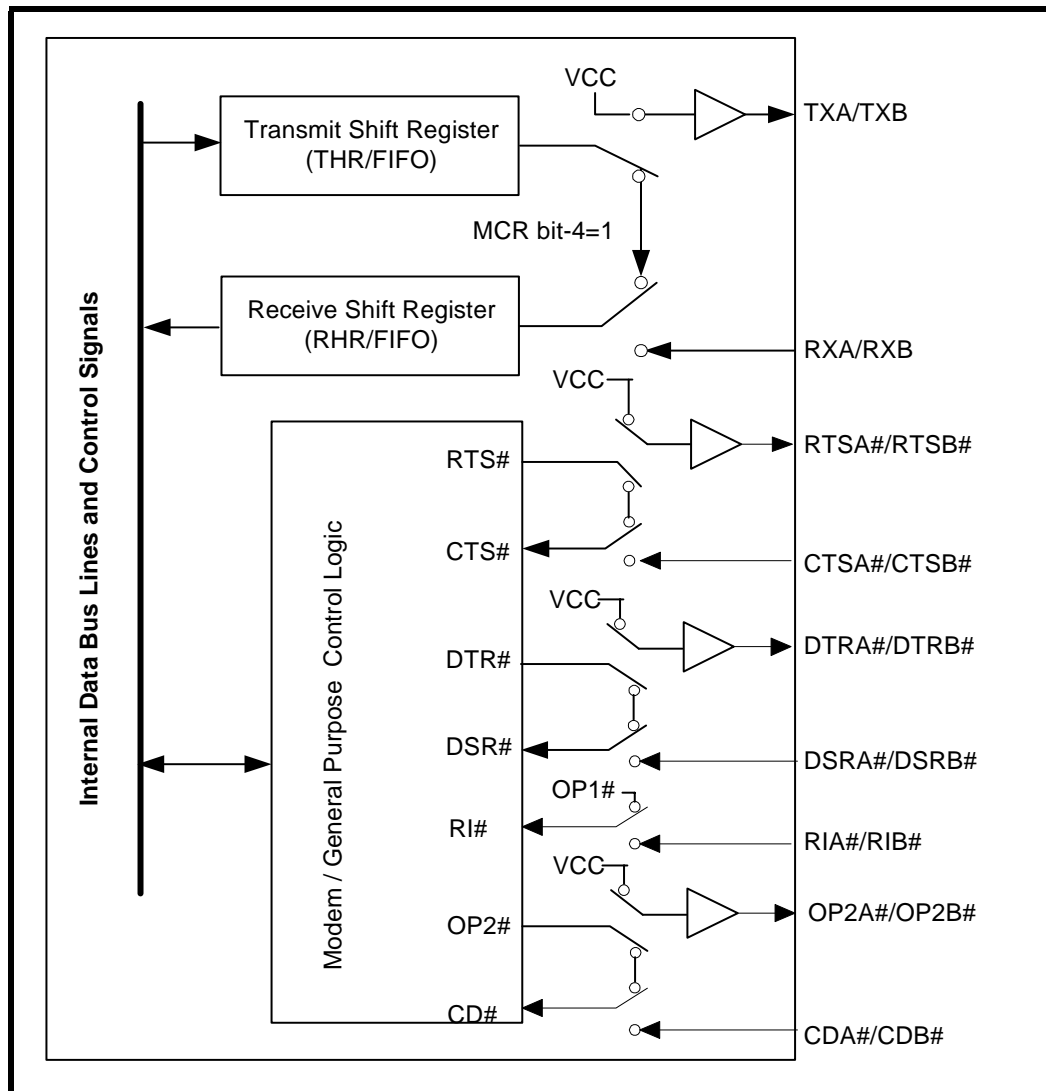
- a receive data start bit transition (logic 1 to 0)
- a change of logic state on any of the modem or general purpose serial inputs: CTS#, DSR#, CD#, RI#

The L2551 will return to the PowerSave mode automatically after a read to the MSR (to reset the modem inputs) and all interrupting conditions have been serviced and cleared. The L2551 will stay in the PowerSave mode of operation until it is disabled by setting IER bit-4 to a logic 0 and/or the PowerSave pin is connected to GND.

2.18 Internal Loopback

The L2551 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 13** 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 at logic 1 or mark condition while RTS# and DTR# are de-asserted, and CTS#, DSR# CD# and RI# inputs are ignored. Caution: the RX input pins must be held to a logic 1 during loopback test else upon exiting the loopback test the UART may detect and report a false “break” signal. Also, Auto RTS/CTS is not supported during internal loopback.

FIGURE 13. INTERNAL LOOP BACK IN CHANNEL A AND B



LOW VOLTAGE DUART WITH POWERSAVE
3.0 UART INTERNAL REGISTERS

Each of the UART channel in the L2551 has its own set of configuration registers selected by address lines A0, A1 and A2 with CSA# or CSB# selecting the channel. The registers are 16C550 compatible. The complete register set is shown on **Table 8** and **Table 9**....INTERNAL Register descriptions

TABLE 8: UART CHANNEL A AND B UART INTERNAL REGISTERS

A2,A1,A0 ADDRESSES	REGISTER	READ/WRITE	COMMENTS
16C550 COMPATIBLE REGISTERS			
0 0 0	RHR - Receive Holding Register THR - Transmit Holding Register	Read-only Write-only	LCR[7] = 0
0 0 0	DLL - Div Latch Low Byte	Read/Write	LCR[7] = 1, LCR ≠ 0xBF
0 0 1	DLM - Div Latch High Byte	Read/Write	
0 0 0	DREV - Device Revision	Read/Write	LCR[7] = 1, LCR ≠ 0xBF, DLL = 0x00, DLM = 0x00
0 0 1	DVID - Device ID	Read/Write	
0 0 1	IER - Interrupt Enable Register	Read/Write	LCR[7] = 0
0 1 0	ISR - Interrupt Status Register FCR - FIFO Control Register	Read-only Write-only	LCR ≠ 0xBF
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 Reserved	Read-only Write-only	
1 1 0	MSR - Modem Status Register Reserved	Read-only Write-only	
1 1 1	SPR - Scratch Pad Register	Read/Write	
ENHANCED REGISTERS			
0 1 0	EFR - Enhanced Function Register	Read/Write	LCR = 0xBF
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	

TABLE 9: INTERNAL REGISTERS DESCRIPTION. SHADED BITS ARE ENABLED WHEN EFR BIT-4=1

ADDRESS A2-A0	REG NAME	READ/ WRITE	BIT-7	BIT-6	BIT-5	BIT-4	BIT-3	BIT-2	BIT-1	BIT-0	COMMENT
16C550 Compatible Registers											
0 0 0	RHR	RD	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	LCR[7] = 0
0 0 0	THR	WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
0 0 1	IER	RD/WR	0/ CTS Int. Enable	0/ RTS Int. Enable	0/ Xoff Int. Enable	0/ Sleep Mode Enable	Modem Stat. Int. Enable	RXLine Stat. Int. Enable	TX Empty Int Enable	RX Data Int. Enable	
0 1 0	ISR	RD	FIFOs Enabled	FIFOs Enabled	0/ INT Source Bit-5	0/ INT Source Bit-4	INT Source Bit-3	INT Source Bit-2	INT Source Bit-1	INT Source Bit-0	LCR ≠ 0xBF
0 1 0	FCR	WR	RXFIFO Trigger	RXFIFO Trigger	0	0	DMA Mode Enable	TX FIFO Reset	RX FIFO Reset	FIFOs Enable	
0 1 1	LCR	RD/WR	Divisor Enable	Set TX Break	Set Par- ity	Even Parity	Parity Enable	Stop Bits	Word Length Bit-1	Word Length Bit-0	
1 0 0	MCR	RD/WR	0/ BRG Pres- caler	0/ IR Mode ENable	0/ XonAny	Internal Loop- back Enable	OP2#/ INT Output Enable	Rsvd (OP1#)	RTS# Output Control	DTR# Output Control	LCR ≠ 0xBF
1 0 1	LSR	RD	RX FIFO Global Error	THR & TSR Empty	THR Empty	RX Break	RX Fram- ing Error	RX Parity Error	RX Over- run Error	RX Data Ready	
1 1 0	MSR	RD	CD# Input	RI# Input	DSR# Input	CTS# Input	Delta CD#	Delta RI#	Delta DSR#	Delta CTS#	
1 1 1	SPR	RD/WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
Baud Rate Generator Divisor											
0 0 0	DLL	RD/WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	LCR[7] = 1 LCR ≠ 0xBF
0 0 1	DLM	RD/WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
0 0 0	DREV	RD	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	LCR[7]=1 DLL=0x00 DLM=0x00
0 0 1	DVID	RD	0	0	0	0	0	0	1	0	

TABLE 9: INTERNAL REGISTERS DESCRIPTION. SHADED BITS ARE ENABLED WHEN EFR BIT-4=1

ADDRESS A2-A0	REG NAME	READ/ WRITE	BIT-7	BIT-6	BIT-5	BIT-4	BIT-3	BIT-2	BIT-1	BIT-0	COMMENT
Enhanced Registers											
0 1 0	EFR	RD/WR	Auto CTS Enable	Auto RTS Enable	Special Char Select	Enable IER [7:4], ISR [5:4], FCR[5:4], MCR[7:5]	Soft- ware Flow Cntl Bit-3	Soft- ware Flow Cntl Bit-2	Soft- ware Flow Cntl Bit-1	Soft- ware Flow Cntl Bit-0	LCR=0xBF
1 0 0	XON1	RD/WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 0 1	XON2	RD/WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 1 0	XOFF1	RD/WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	
1 1 1	XOFF2	RD/WR	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0	

4.0 INTERNAL REGISTER DESCRIPTIONS

4.1 Receive Holding Register (RHR) - Read- Only

SEE "RECEIVER" ON PAGE 14.

4.2 Transmit Holding Register (THR) - Write-Only

SEE "TRANSMITTER" ON PAGE 13.

4.3 Interrupt Enable Register (IER) - Read/Write

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).

4.3.1 IER versus Receive FIFO Interrupt Mode Operation

When the receive FIFO (FCR BIT-0 = 1) and receive interrupts (IER BIT-0 = 1) are enabled, the RHR interrupts (see ISR bits 2 and 3) status will reflect the following:

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

4.3.2 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 XR16L2551 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 indicates an overrun error has occurred and that data in the FIFO may not be valid.
- C. LSR BIT 2-4 provides the type of receive data errors encountered for the data byte in RHR, if any.
- D. LSR BIT-5 indicates Transmit FIFO is empty.
- E. LSR BIT-6 indicates when both the transmit FIFO and TSR are empty.
- F. LSR BIT-7 indicates a data error in at least one character 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 bit enables the Transmit Ready interrupt which is issued whenever the Transmit FIFO becomes empty. If the Transmit FIFO is empty when this bit is enabled, an interrupt will be generated.

- Logic 0 = Disable Transmit Ready interrupt (default).
- Logic 1 = Enable Transmit Ready interrupt.

IER[2]: Receive Line Status Interrupt Enable

If any of the LSR register bits 1, 2, 3 or 4 is a logic 1, it will generate an interrupt to inform the host controller about the error status of the current data byte in FIFO. LSR bit-1 generates an interrupt immediately when the character has been received. LSR bits 2-4 generate an interrupt when the character with errors is read out of the 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]: Sleep Mode Enable (requires EFR bit-4 = 1)

- Logic 0 = Disable Sleep Mode (default).
- Logic 1 = Enable Sleep Mode. See Sleep Mode section for further details.

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 from low to high.

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 from low to high.

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4.4 Interrupt Status Register (ISR) - Read-Only

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 are queued up to be serviced next. No other interrupts are acknowledged until the pending interrupt is serviced. The Interrupt Source Table, [Table 10](#), shows the data values (bit 0-5) for the interrupt priority levels and the interrupt sources associated with each of these interrupt levels.

4.4.1 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 a 4-char plus 12 bits delay timer.
- TXRDY is by TX FIFO empty.
- MSR is by any of the MSR bits 0, 1, 2 and 3.
- Receive Xoff/Special character is by detection of a Xoff or Special character.
- CTS# is when its transmitter toggles the input pin (from low to high) during auto CTS flow control.
- RTS# is when its receiver toggles the output pin (from low to high) during auto RTS flow control.

4.4.2 Interrupt Clearing:

- LSR interrupt is cleared by a read to the LSR register (but flags and tags not cleared until character(s) that generated the interrupt(s) has been emptied or cleared from FIFO).
- RXRDY interrupt is cleared by reading data until FIFO falls below the trigger level.
- RXRDY Time-out interrupt is cleared by reading RHR.
- TXRDY interrupt is cleared by a read to the ISR register or writing to THR.
- MSR interrupt is cleared by a read to the MSR register.
- Xoff interrupt is cleared by a read to ISR or when Xon character(s) is received.
- Special character interrupt is cleared by a read to ISR or after the next character is received.
- RTS# and CTS# flow control interrupts are cleared by a read to the MSR register.

TABLE 10: INTERRUPT SOURCE AND PRIORITY LEVEL

PRIORITY LEVEL	ISR REGISTER STATUS BITS						SOURCE OF 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	1	1	0	0	RXRDY (Receive Data Time-out)
3	0	0	0	1	0	0	RXRDY (Received Data Ready)
4	0	0	0	0	1	0	TXRDY (Transmit Ready)
5	0	0	0	0	0	0	MSR (Modem Status Register)
6	0	1	0	0	0	0	RXRDY (Received Xoff or Special character)
7	1	0	0	0	0	0	CTS#, RTS# change of state
-	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 (See Interrupt Source [Table 10](#)).

ISR[4]: Xoff or Special Character Interrupt Status

This bit is enabled when EFR bit-4 is set to a logic 1. ISR bit-4 indicates that the receiver detected a data match of the Xoff character(s). If this is an Xoff interrupt, it can be cleared by a read to the ISR or when an Xon character is received. If it is a special character interrupt, it will automatically clear after the next character is received.

ISR[5]: RTS#/CTS# Interrupt Status

This bit is enabled when EFR bit-4 is set to a logic 1. ISR bit-5 indicates that the CTS# or RTS# has changed state from low to high.

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.

4.5 FIFO Control Register (FCR) - Write-Only

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[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 a '1'.

- 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 a '1'.

- Logic 0 = No transmit FIFO reset (default).
- 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

Controls the behavior of the TXRDY# and RXRDY# pins. See DMA operation section for details.

- Logic 0 = Normal Operation (default).
- Logic 1 = DMA Mode.

FCR[5:4]: Reserved

FCR[7:6]: Receive FIFO Trigger Select

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

These 2 bits are used to set the trigger level for the receive FIFO. The UART will issue a receive interrupt when the number of the characters in the FIFO crosses the trigger level. **Table 11** shows the complete selections.

TABLE 11: RECEIVE FIFO TRIGGER LEVEL SELECTION

FCR BIT-7	FCR BIT-6	RECEIVE TRIGGER LEVEL	COMPATIBILITY
0	0	1 (default)	16C550, 16C2550, 16C2552, 16C554, 16C580 compatible.
0	1	4	
1	0	8	
1	1	14	

4.6 Line Control Register (LCR) - Read/Write

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 12** 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 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[5] = logic 0, parity is not forced (default).
- LCR[5] = logic 1 and LCR[4] = logic 0, parity bit is forced to a logical 1 for the transmit and receive data.
- LCR[5] = logic 1 and LCR[4] = logic 1, parity bit is forced to a logical 0 for the transmit and receive data.

TABLE 12: 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 (DLL/DLM) Enable

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

4.7 Modem Control Register (MCR) or General Purpose Outputs Control - Read/Write

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

MCR[0]: DTR# Output

The DTR# pin is a modem control output. If the modem interface is not used, this output may be used as a general purpose output.

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

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MCR[1]: RTS# Output

The RTS# pin is a modem control output. If the modem interface is not used, this output may be used as a general purpose output.

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

MCR[2]: Reserved

OP1# is not available as an output pin on the L2551. But it is available for use during Internal Loopback Mode. In the Loopback Mode, this bit is used to write the state of the modem RI# interface signal.

MCR[3]: OP2# Output / INT Output Enable

This bit enables and disables the operation of INT, interrupt output. If INT output is not used, OP2# can be used as a general purpose output. This bit does not affect the IRQ# output during Motorola mode.

- Logic 0 = INT (A-B) outputs disabled (three state mode) and OP2# output set to a logic 1 (default).
- Logic 1 = INT (A-B) outputs enabled (active mode) and OP2# output set to a logic 0.

MCR[4]: Internal Loopback Enable

- Logic 0 = Disable loopback mode (default).
- Logic 1 = Enable local loopback mode, see loopback section and [Figure 13](#).

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 resume transmit operation. The RX character will be loaded into the RX FIFO, unless the RX character is an Xon or Xoff character and the L2551 is programmed to use the Xon/Xoff flow control.

MCR[6]: Infrared Encoder/Decoder Enable

- Logic 0 = Enable the standard modem receive and transmit input/output interface. (Default)
- Logic 1 = Enable infrared IrDA receive and transmit inputs/outputs. The TX/RX output/input are routed to the infrared encoder/decoder. The data input and output levels conform to the IrDA infrared interface requirement. While in this mode, the infrared TX output will be a logic 0 during idle data conditions.

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.

4.8 Line Status Register (LSR) - Read Only

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. An interrupt will be generated immediately if LSR interrupt is enabled (IER bit-2).

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. If the LSR interrupt is enabled (IER bit-2), an interrupt will be generated when the character is in the 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. If the LSR interrupt is enabled (IER bit-2), an interrupt will be generated when the character is in the 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 at least 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. If the LSR interrupt is enabled (IER bit-2), an interrupt will be generated when the character is in the RHR.

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 the transmit FIFO contains at least 1 byte.

LSR[6]: THR and TSR Empty Flag

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 a logic 1 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 = A global 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.

4.9 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.

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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

Normally this 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

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

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

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.

4.10 Scratch Pad Register (SPR) - Read/Write

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.

4.11 Baud Rate Generator Registers (DLL and DLM) - Read/Write

The Baud Rate Generator (BRG) is a 16-bit counter that generates the data rate for the transmitter. The rate is programmed through registers DLL and DLM which are only accessible when LCR bit-7 is set to '1'. **SEE "PROGRAMMABLE BAUD RATE GENERATOR" ON PAGE 11.** for more details.

4.12 Device Identification Register (DVID) - Read Only

This register contains the device ID (0x02 for XR16L2551). Prior to reading this register, DLL and DLM should be set to 0x00.

4.13 Device Revision Register (DREV) - Read Only

This register contains the device revision information. For example, 0x01 means revision A. Prior to reading this register, DLL and DLM should be set to 0x00.

4.14 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 13**). 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.

EFR[3:0]: Software Flow Control Select

Single character and dual sequential characters software flow control is supported. Combinations of software flow control can be selected by programming these bits.

TABLE 13: 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[4]: Enhanced Function Bits Enable

Enhanced function control bit. This bit enables IER bits 4-7, ISR 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, and MCR bits 5-7 are saved to retain the user settings. After a reset, the IER bits 4-7, ISR bits 4-5, and MCR bits 5-7 are set to a logic 0 to be compatible with ST16C550 mode (default).
- Logic 1 = Enables the above-mentioned register bits to be modified by the user.

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 receive 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 of 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, if enabled via IER bit-5. Special character interrupts are cleared automatically after the next received character.

EFR[6]: Auto RTS Flow Control Enable

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

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

EFR[7]: Auto CTS Flow Control Enable

Automatic CTS Flow Control.

- Logic 0 = Automatic CTS flow control is disabled (default).
- Logic 1 = Enable Automatic CTS flow control. Data transmission stops when CTS# input de-asserts to logic 1. Data transmission resumes when CTS# returns to a logic 0.

4.15 Software Flow Control Registers (XOFF1, XOFF2, XON1, XON2) - Read/Write

These registers are used as the programmable software flow control characters XOFF1, XOFF2, XON1, and XON2. For more details, see [Table 7](#).

TABLE 14: UART RESET CONDITIONS FOR CHANNEL A AND B

REGISTERS	RESET STATE
DLM	Bits 7-0 = 0xXX
DLL	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 inverted
SPR	Bits 7-0 = 0xFF
EFR	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	Logic 1
OP2#	Logic 1
RTS#	Logic 1
DTR#	Logic 1
RXRDY#	Logic 1
TXRDY#	Logic 0
INT	Three-State Condition

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ABSOLUTE MAXIMUM RATINGS

Power Supply Range	7 Volts
Voltage at Any Pin	GND-0.3 V to +5.5 V
Operating Temperature	-40° to +85°C
Storage Temperature	-65° to +150°C
Package Dissipation	500 mW

TYPICAL PACKAGE THERMAL RESISTANCE DATA (MARGIN OF ERROR: ± 15%)

Thermal Resistance (48-TQFP)	theta-ja =59°C/W, theta-jc = 16°C/W
Thermal Resistance (32-QFN)	theta-ja = 33°C/W, theta-jc = 22°C/W

ELECTRICAL CHARACTERISTICS
DC ELECTRICAL CHARACTERISTICS

Unless otherwise noted: TA=-40° to +85°C, Vcc is 2.25 to 5.5V

SYMBOL	PARAMETER	2.5V LIMITS		3.3V LIMITS		5.0V LIMITS		UNITS	CONDITIONS
		MIN	MAX	MIN	MAX	MIN	MAX		
V _{ILCK}	Clock Input Low Level	-0.3	0.2	-0.3	0.6	-0.5	0.6	V	
V _{IHCK}	Clock Input High Level	2.0	5.5	2.4	5.5	3.0	5.5	V	
V _{IL}	Input Low Voltage	-0.3	0.6	-0.3	0.8	-0.5	0.8	V	
V _{IH}	Input High Voltage	2.0	5.5	2.0	5.5	2.2	5.5	V	
V _{OL}	Output Low Voltage		0.4		0.4		0.4	V	I _{OL} = 6 mA I _{OL} = 4 mA I _{OL} = 2 mA
V _{OH}	Output High Voltage	1.8		2.0		2.4		V	I _{OH} = -6 mA I _{OH} = -1 mA I _{OH} = -400 uA
I _{IL}	Input Low Leakage Current		±10		±10		±10	uA	
I _{IH}	Input High Leakage Current		±10		±10		±10	uA	
C _{IN}	Input Pin Capacitance		5		5		5	pF	
I _{CC}	Power Supply Current		1		1.3		3	mA	
I _{SLEEP} I _{PWRSV}	Sleep Current/ Powersave Current		6		15		30	uA	See Test 1

Test 1: The following inputs must remain steady at VCC or GND state to minimize sleep current: A0-A2, D0-D7, IOR#, IOW# (R/W#), CSA# (CS#), CSB# (A3) and all modem inputs. Also, RXA and RXB inputs must idle at logic 1 state while asleep. Floating inputs may result in sleep currents in the mA range. For Powersave, the UART internally isolates all of these inputs therefore not requiring them to remain steady.

AC ELECTRICAL CHARACTERISTICS

Unless otherwise noted: $T_A = -40^{\circ}$ to $+85^{\circ}$ C, V_{CC} is 2.25V to 5.5V,

70 pF load where applicable

SYMBOL	PARAMETER	LIMITS 2.5		LIMITS 3.3		LIMITS 5.0		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
-	Crystal Frequency		16		20		24	MHz
CLK	External Clock Low/High Time	31		17		10		ns
OSC	External Clock Frequency		16		30		50	MHz
T_{AS}	Address Setup Time (16 Mode)	10		10		10		ns
T_{AH}	Address Hold Time (16 Mode)	10		10		10		ns
T_{CS}	Chip Select Width (16 Mode)	150		75		50		ns
T_{RD}	IOR# Strobe Width (16 Mode)	150		75		50		ns
T_{DY}	Read Cycle Delay (16 Mode)	150		75		50		ns
T_{RDV}	Data Access Time (16 Mode)		125		70		45	ns
T_{DD}	Data Disable Time (16 Mode)	0	45	0	30	0	30	ns
T_{WR}	IOW# Strobe Width (16 Mode)	150		75		50		ns
T_{DY}	Write Cycle Delay (16 Mode)	150		75		50		ns
T_{DS}	Data Setup Time (16 Mode)	25		20		15		ns
T_{DH}	Data Hold Time (16 Mode)	15		10		10		ns
T_{ADS}	Address Setup (68 Mode)	10		10		10		ns
T_{ADH}	Address Hold (68 Mode)	10		10		10		ns
T_{RWS}	R/W# Setup to CS# (68 Mode)	10		10		10		ns
T_{RDA}	Read Data Access (68 mode)		125		70		45	ns
T_{RDH}	Read Data Disable (68 mode)		45		30		30	ns
T_{WDS}	Write Data Setup (68 mode)	25		20		15		ns
T_{WDH}	Write Data Hold (68 Mode)	15		10		10		ns
T_{RWH}	R/W# Hold (68 Mode)	15		10		10		ns
T_{CSL}	CS# Width (68 Mode)	150		75		50		ns
T_{CSD}	CS# Cycle Delay (68 Mode)	150		75		50		ns
T_{WDO}	Delay From IOW# To Output		150		75		50	ns
T_{MOD}	Delay To Set Interrupt From MODEM Input		150		75		50	ns
T_{RSI}	Delay To Reset Interrupt From IOR#		150		75		50	ns

LOW VOLTAGE DUART WITH POWERSAVE

AC ELECTRICAL CHARACTERISTICS

Unless otherwise noted: TA=-40° to +85°C, Vcc is 2.25V to 5.5V,
70 pF load where applicable

SYMBOL	PARAMETER	LIMITS 2.5		LIMITS 3.3		LIMITS 5.0		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
T _{SSI}	Delay From Stop To Set Interrupt		1		1		1	Bclk
T _{RRi}	Delay From IOR# To Reset Interrupt		150		75		50	ns
T _{SI}	Delay From Stop To Interrupt		150		75		50	ns
T _{INT}	Delay From Initial INT Reset To Transmit Start	8	24	8	24	8	24	Bclk
T _{WRI}	Delay From IOW# To Reset Interrupt		150		75		50	ns
T _{SSR}	Delay From Stop To Set RXRDY#		1		1		1	Bclk
T _{RR}	Delay From IOR# To Reset RXRDY#		150		75		50	ns
T _{WT}	Delay From IOW# To Set TXRDY#		150		75		50	ns
T _{SRT}	Delay From Center of Start To Reset TXRDY#		8		8		8	Bclk
T _{RST}	Reset Pulse Width	40		40		40		ns
N	Baud Rate Divisor	1	2 ¹⁶ -1	1	2 ¹⁶ -1	1	2 ¹⁶ -1	-
Bclk	Baud Clock	16X of data rate						Hz

FIGURE 14. CLOCK TIMING

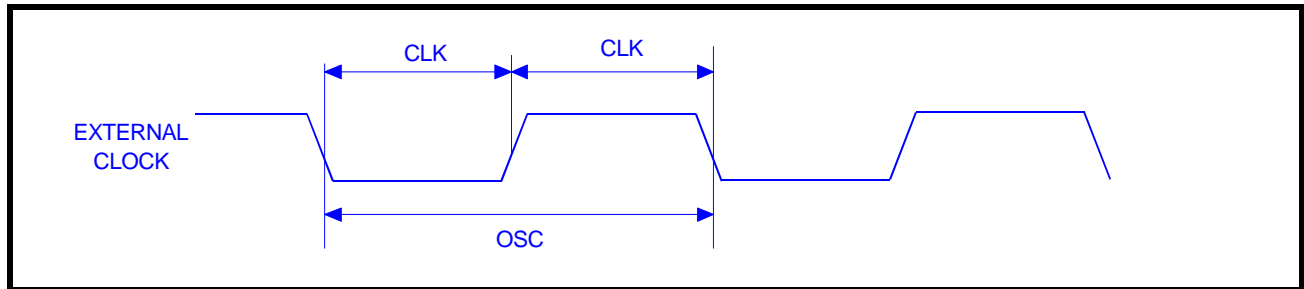


FIGURE 15. MODEM INPUT/OUTPUT TIMING FOR CHANNELS A & B

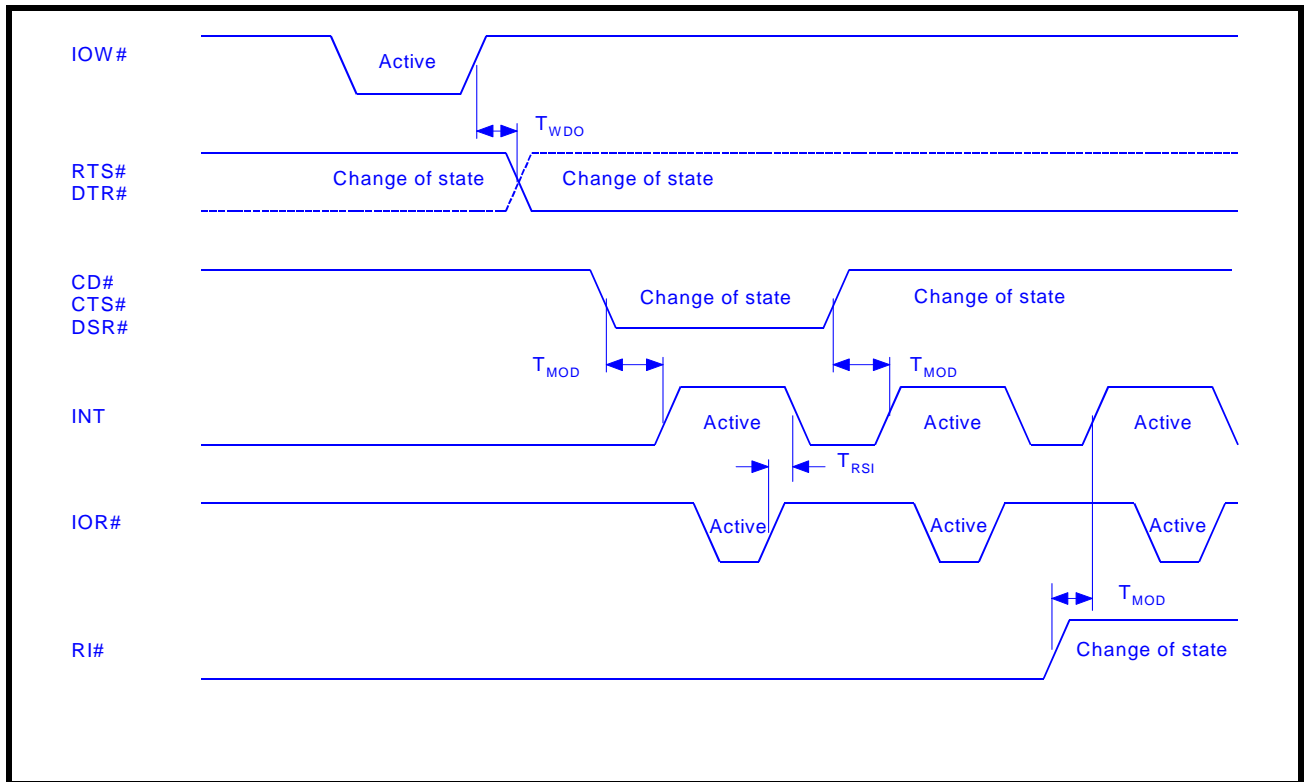
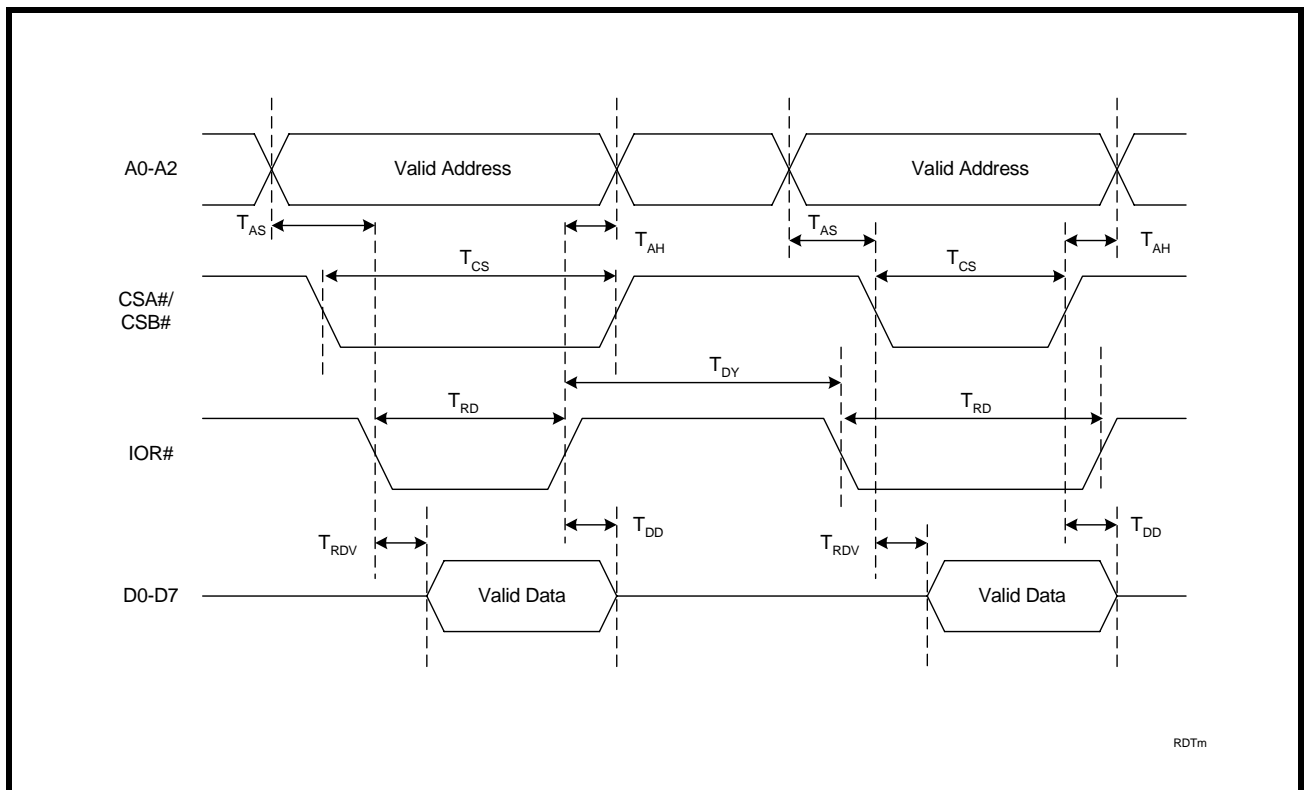


FIGURE 16. 16 MODE (INTEL) DATA BUS READ TIMING



RDTm

FIGURE 17. 16 MODE (INTEL) DATA BUS WRITE TIMING

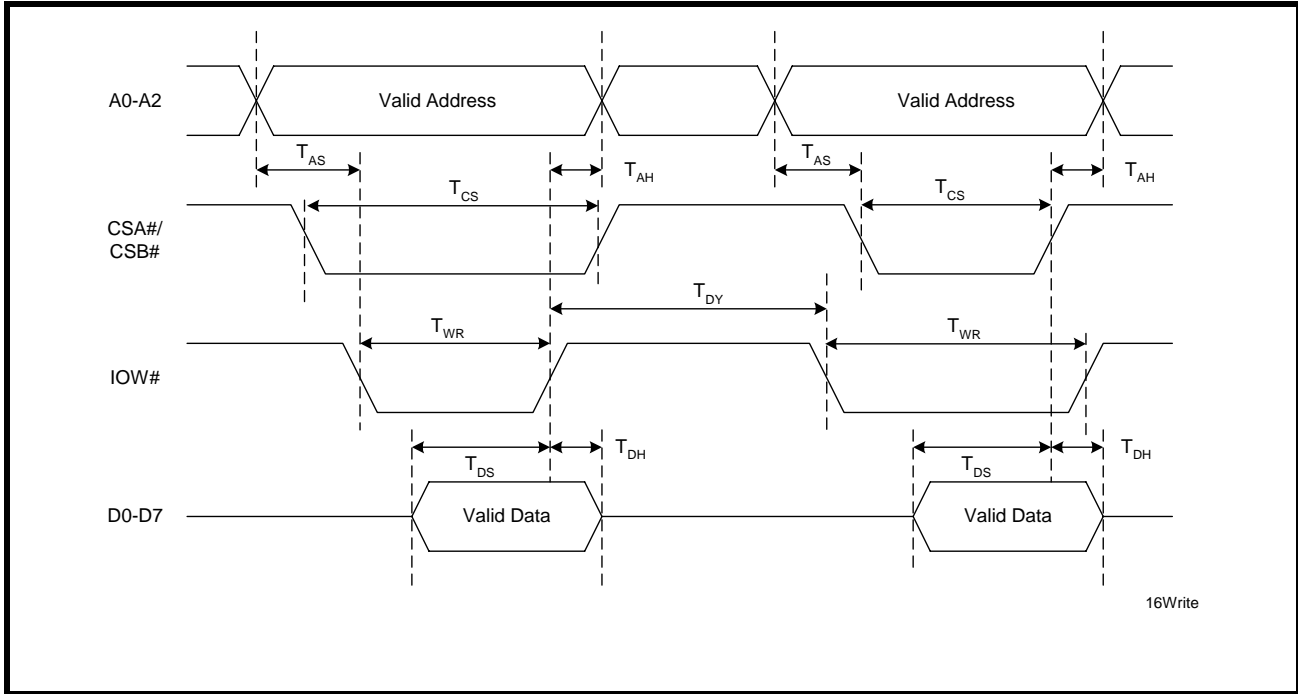


FIGURE 18. 68 MODE (MOTOROLA) DATA BUS READ TIMING

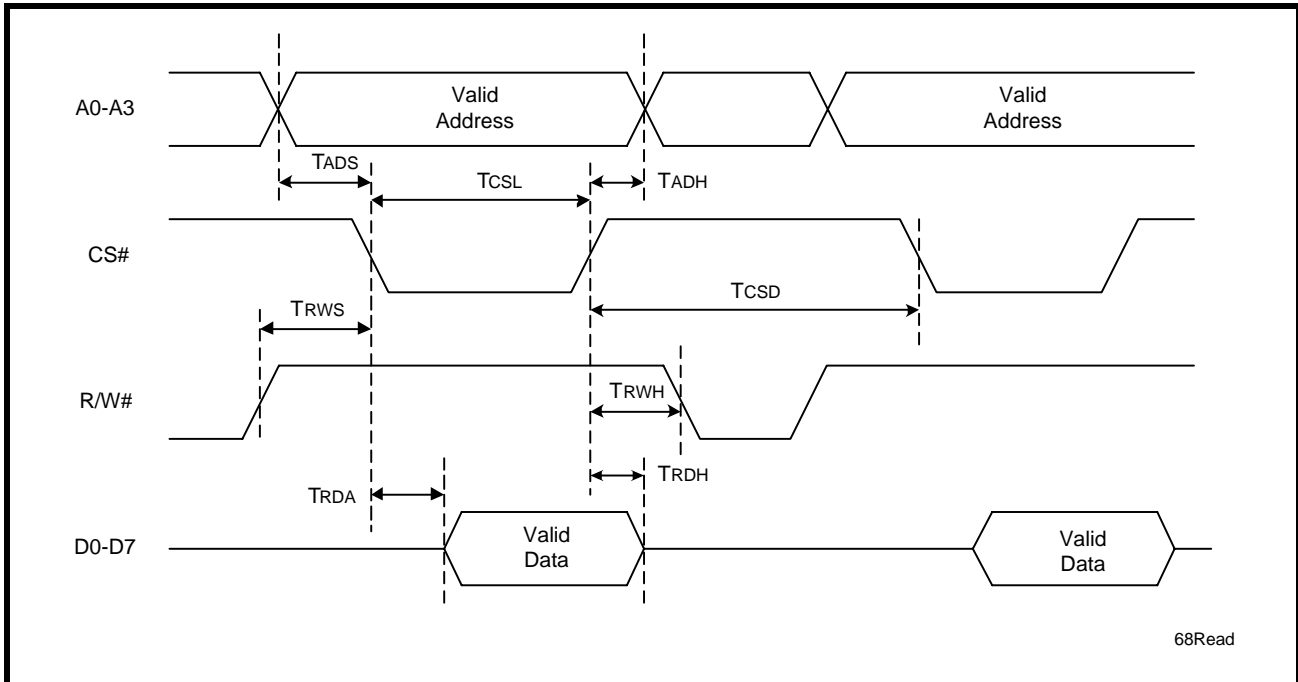


FIGURE 19. 68 MODE (MOTOROLA) DATA BUS WRITE TIMING

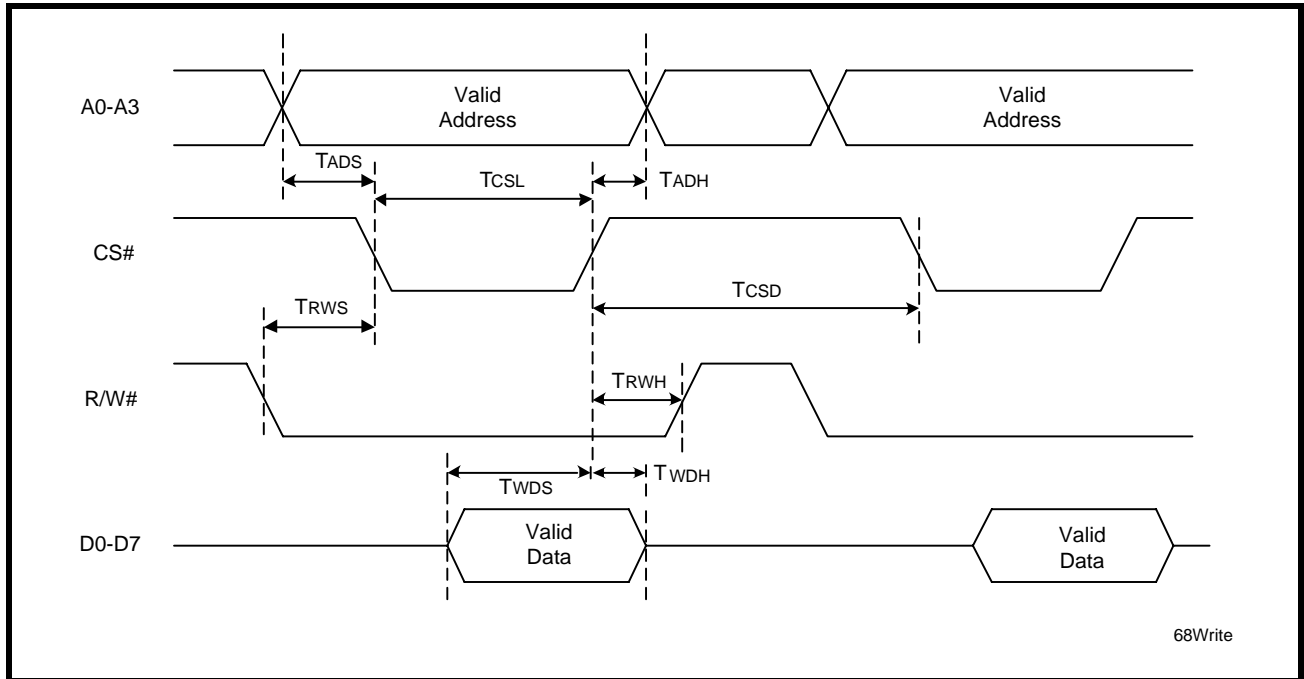


FIGURE 20. RECEIVE READY & INTERRUPT TIMING [NON-FIFO MODE] FOR CHANNELS A & B

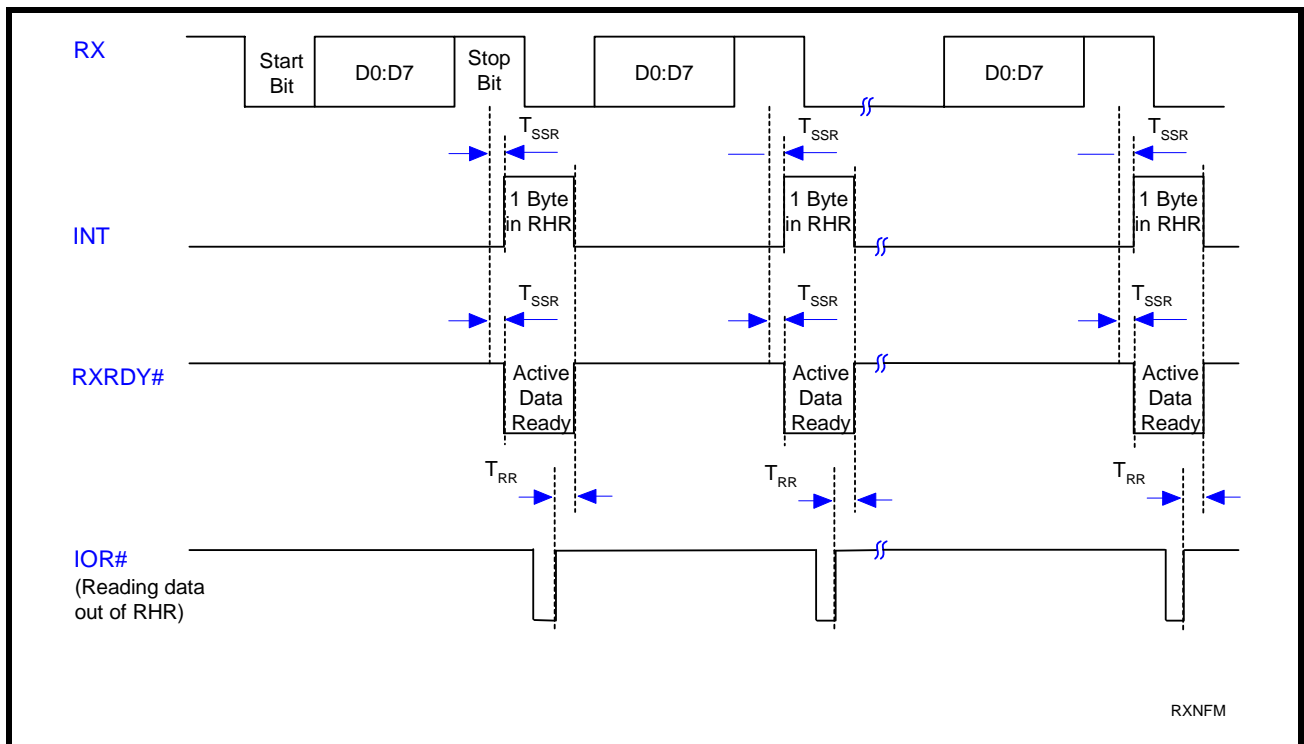


FIGURE 21. TRANSMIT READY & INTERRUPT TIMING [NON-FIFO MODE] FOR CHANNELS A & B

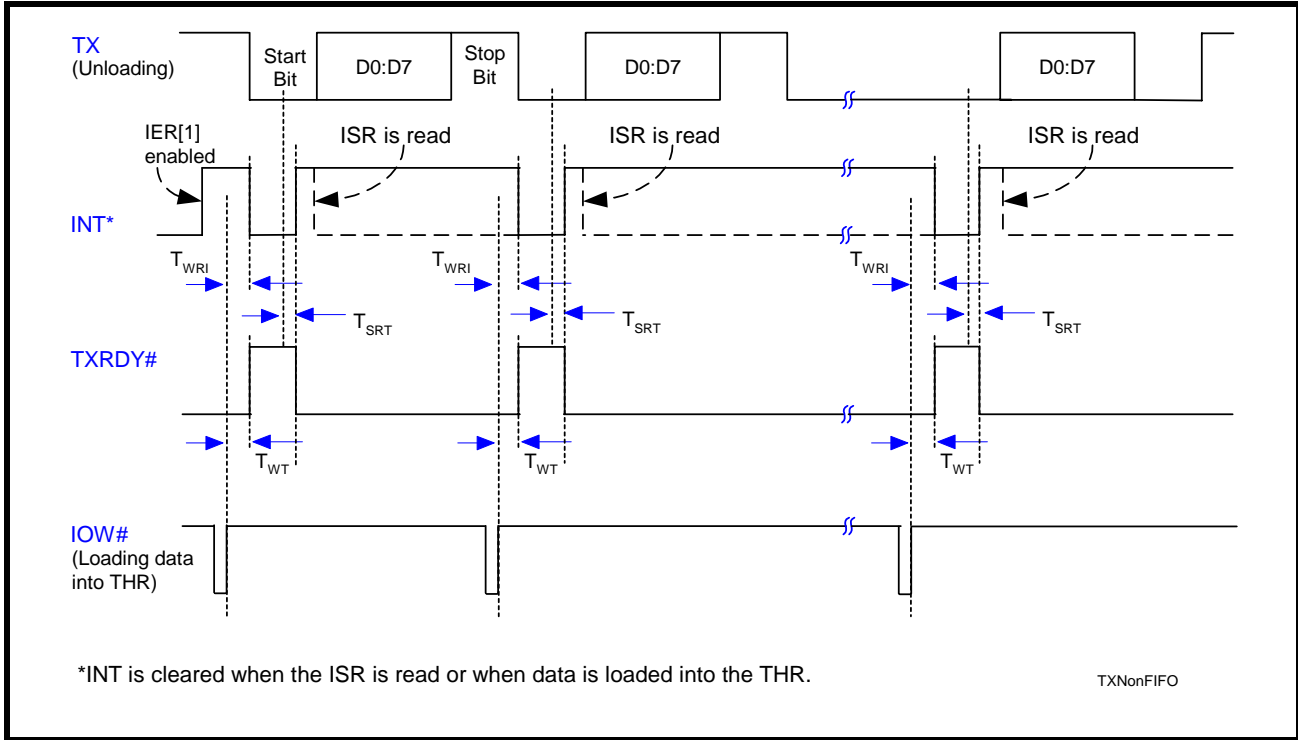


FIGURE 22. RECEIVE READY & INTERRUPT TIMING [FIFO MODE, DMA DISABLED] FOR CHANNELS A & B

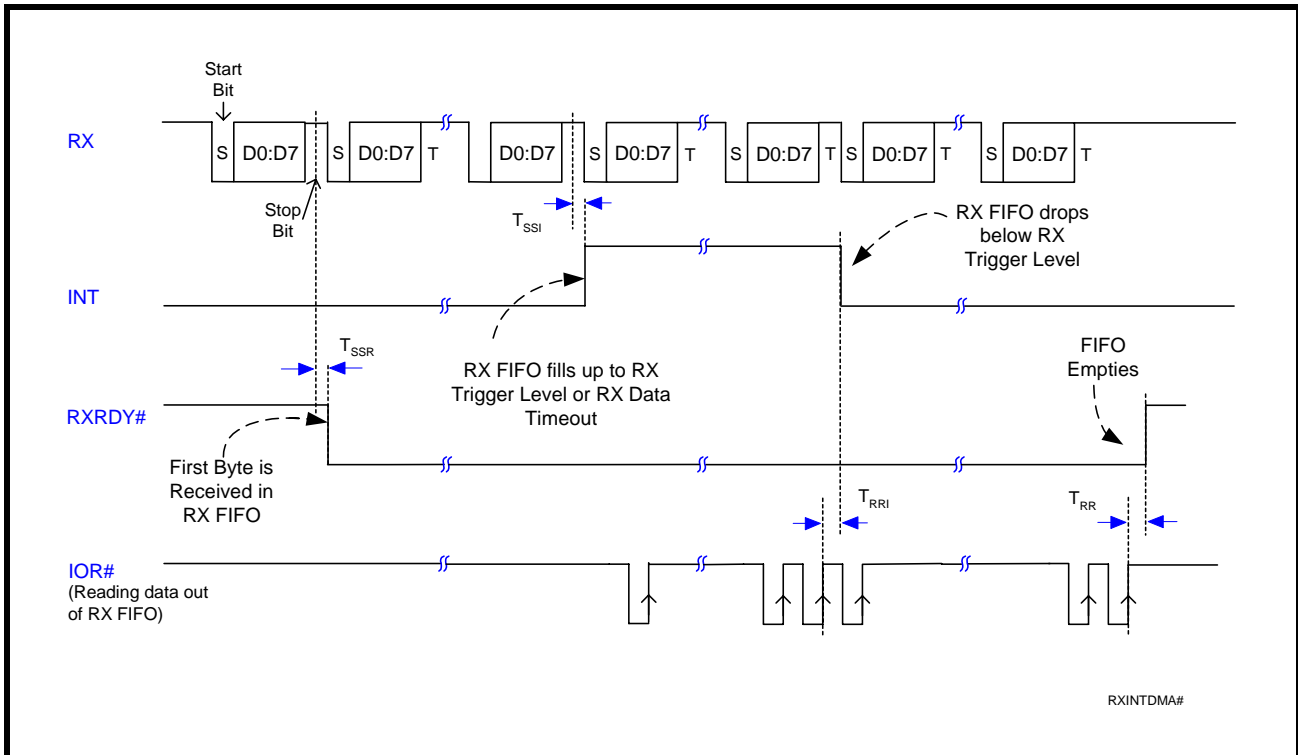


FIGURE 23. RECEIVE READY & INTERRUPT TIMING [FIFO MODE, DMA ENABLED] FOR CHANNELS A & B

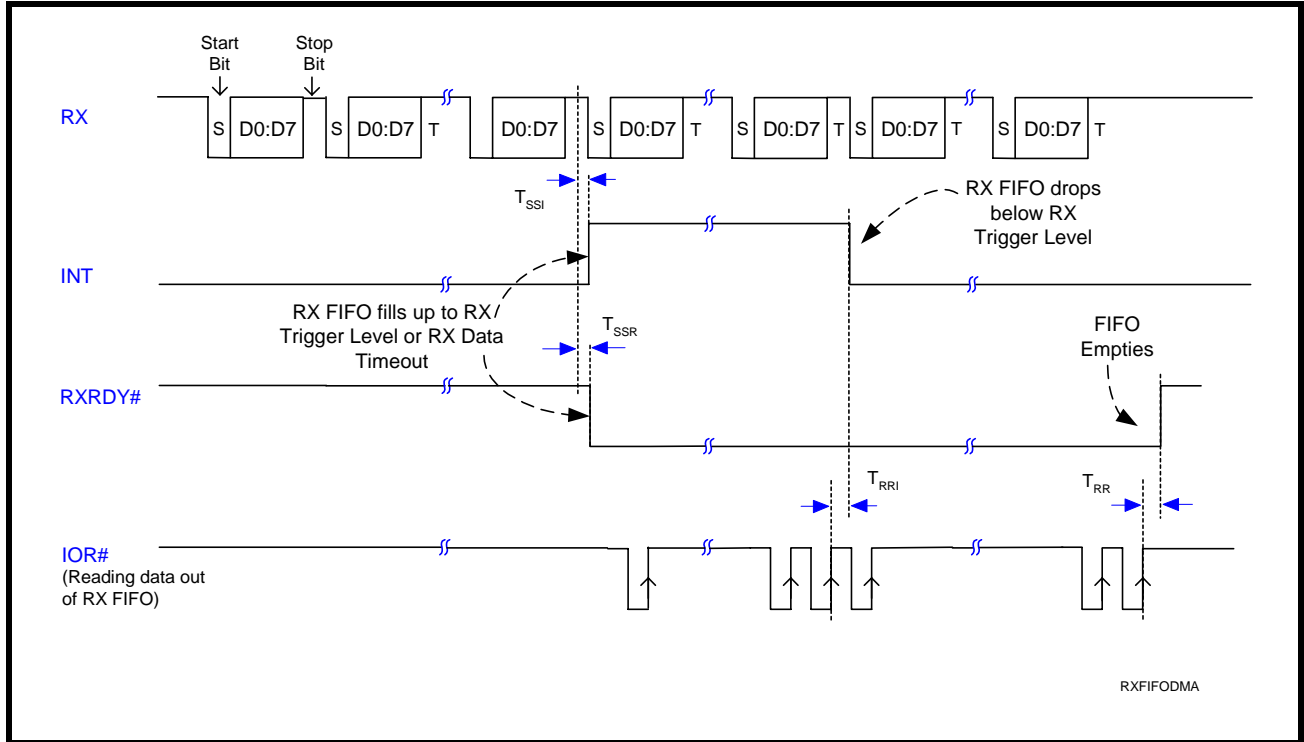


FIGURE 24. TRANSMIT READY & INTERRUPT TIMING [FIFO MODE, DMA MODE DISABLED] FOR CHANNELS A & B

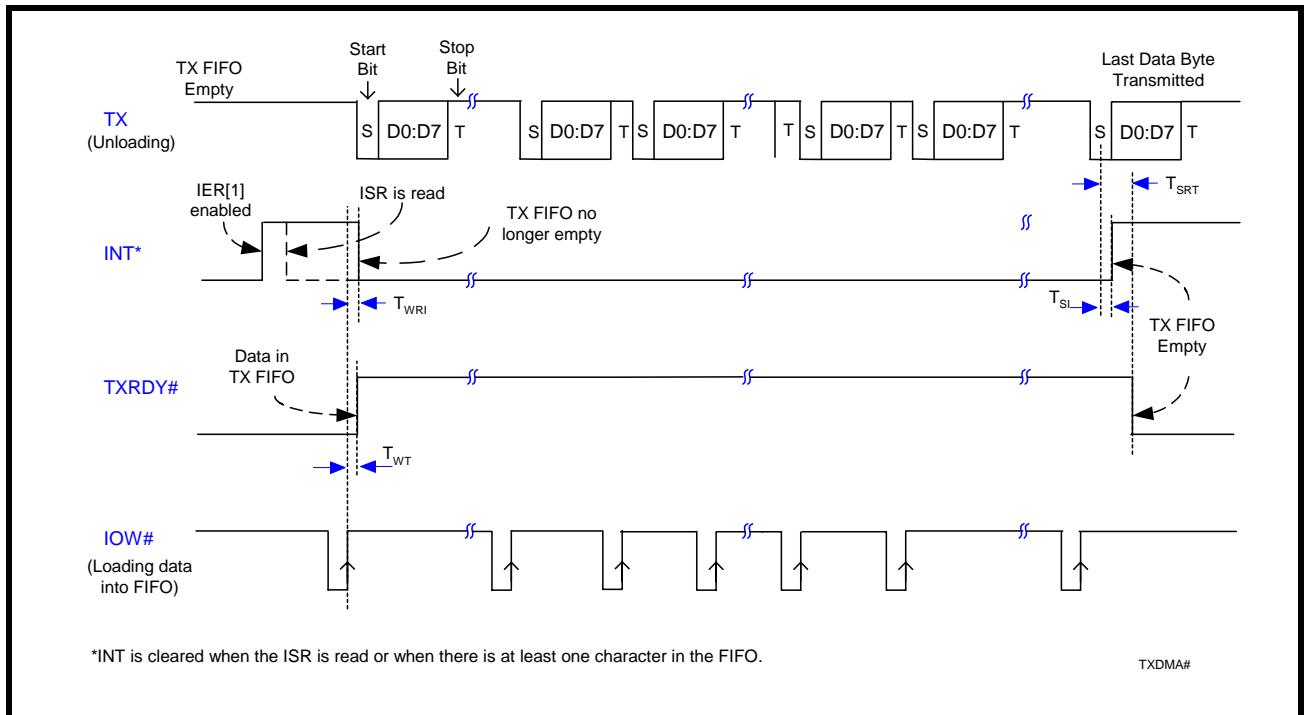
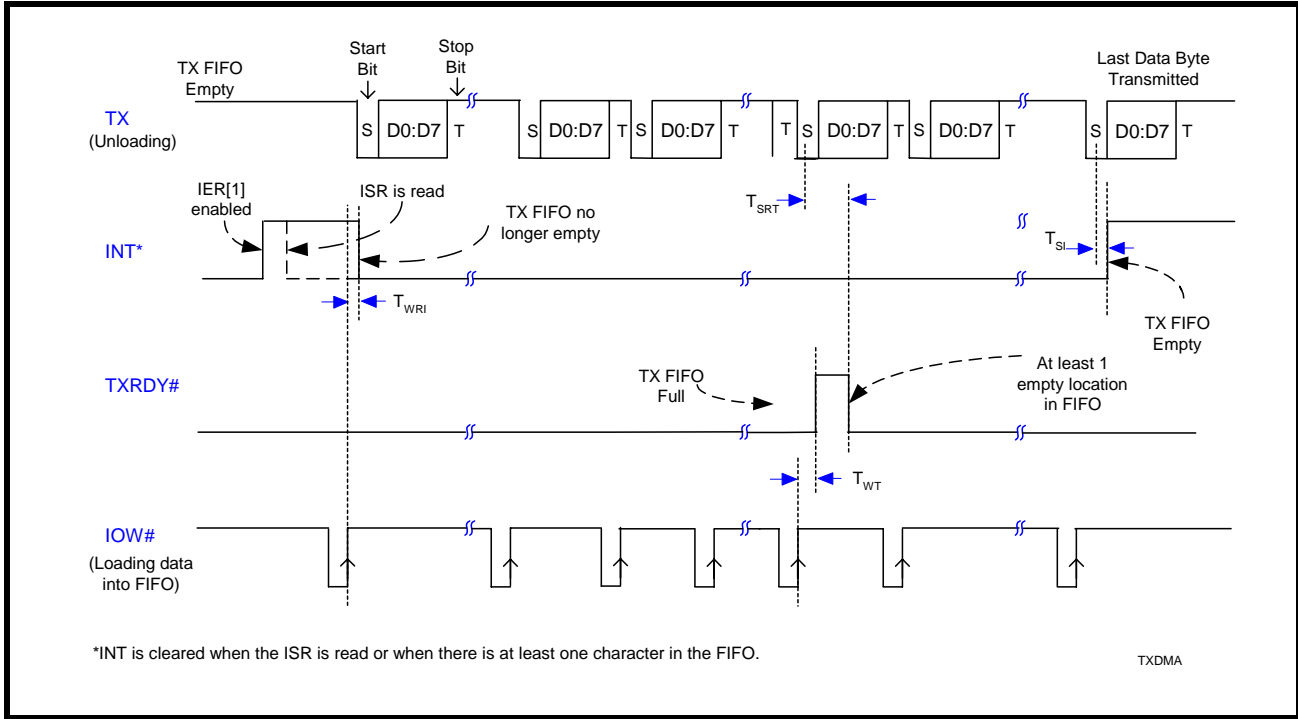
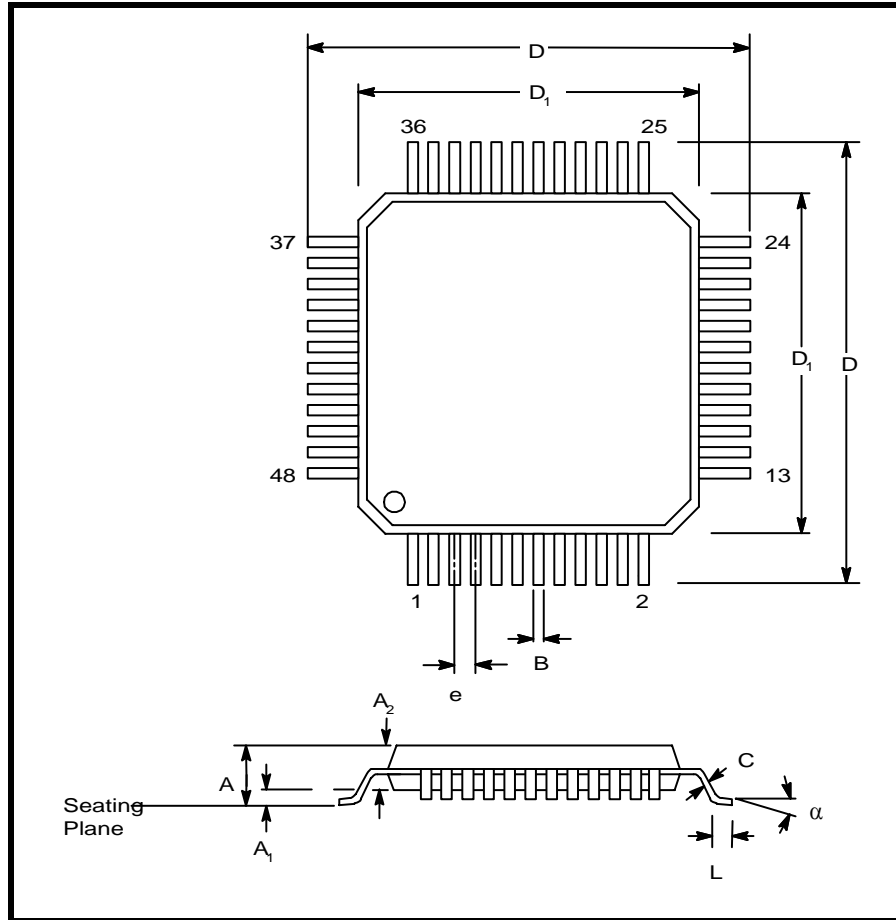


FIGURE 25. TRANSMIT READY & INTERRUPT TIMING [FIFO MODE, DMA MODE ENABLED] FOR CHANNELS A & B



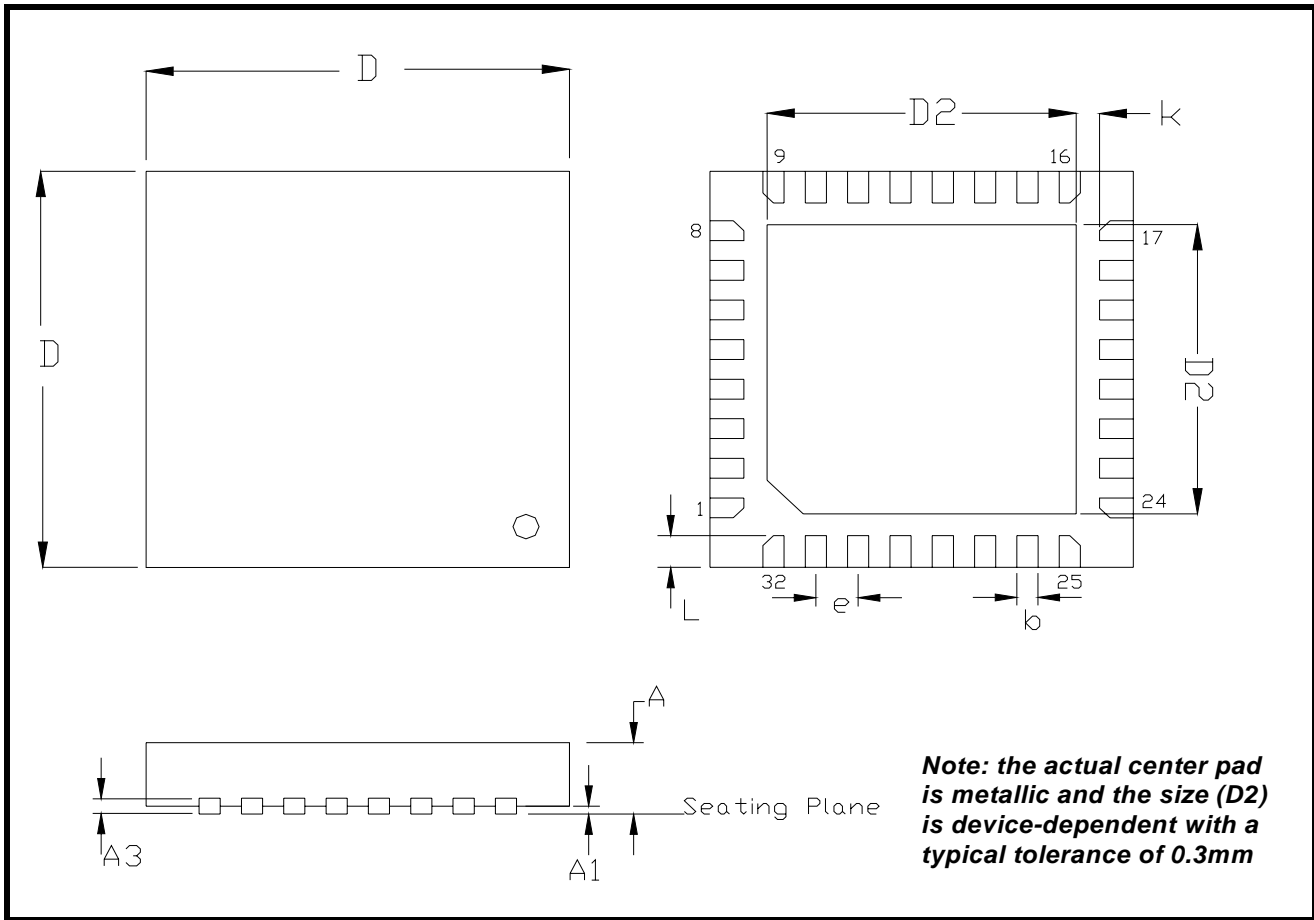
PACKAGE DIMENSIONS (48 PIN TQFP - 7 X 7 X 1 mm)



Note: The control dimension is the millimeter column

SYMBOL	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.039	0.047	1.00	1.20
A1	0.002	0.006	0.05	0.15
A2	0.037	0.041	0.95	1.05
B	0.007	0.011	0.17	0.27
C	0.004	0.008	0.09	0.20
D	0.346	0.362	8.80	9.20
D1	0.272	0.280	6.90	7.10
e	0.020 BSC		0.50 BSC	
L	0.018	0.030	0.45	0.75
a	0°	7°	0°	7°

PACKAGE DIMENSIONS (32 PIN QFN - 5 X 5 X 0.9 mm)



Note: The control dimension is in millimeter.

SYMBOL	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.031	0.039	0.80	1.00
A1	0.000	0.002	0.00	0.05
A3	0.006	0.010	0.15	0.25
D	0.193	0.201	4.90	5.10
D2	0.138	0.150	3.50	3.80
b	0.007	0.012	0.18	0.30
e	0.0197 BSC		0.50 BSC	
L	0.012	0.020	0.35	0.45
k	0.008	-	0.20	-

REVISION HISTORY

DATE	REVISION	DESCRIPTION
November 2002	P1.0.0	Preliminary Datasheet.
March 2003	P1.0.1	Updated AC Electrical Characteristics. Updated register set with enhanced features.
May 2003	P1.0.2	Added patent number to first page. Added 32 pin QFN package dimensions.
June 2003	P1.0.3	Added Device Status to Ordering Information.
July 2003	P1.0.4	Updated AC Electrical Characteristics.
September 2003	1.0.0	Final Production Release. Updated 5V tolerance information.
September 2004	1.1.0	Corrected 32-QFN package dimension descriptions. Added GND center pad pin description. Added Device Revision and Device ID registers and descriptions.
May 2005	1.1.1	Updated the Data Access Time (T_{RDV} and T_{RDA}) in AC Electrical Characteristics.
April 2006	1.1.2	Updated the "Voltage at Any Pin" to "GND-0.3 V to +5.5 V." SEE "ABSOLUTE MAXIMUM RATINGS" ON PAGE 36.
May 2007	1.1.3	Updated the QFN package drawing and added the parameter "k".

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