

Loved to. Roland F.

1. INTRODUCTION

1.1 DESCRIPTION

The TMS 9902A Asynchronous Communications Controller (ACC) is a peripheral device designed for use with the Texas Instruments 9900 family of microprocessors. The TMS 9902A is fabricated using N-channel, silicon gate, MOS technology. The TMS 9902A is TTL-compatible on all inputs and outputs, including the power supply (+5 V) and single-phase clock. This controller provides the interface between a microprocessor and a serial, asynchronous, communications channel. The ACC performs the timing and data serialization and deserialization functions, facilitating microprocessor control of the asynchronous channel. The TMS 9902A ACC accepts *EIA Standard RS-232-C* protocol.

1.2 KEY FEATURES

- Compatible with TMS 9900 and TMS 9995
- Low cost, serial, asynchronous interface
- Programmable, five-to-eight-bit, I/O character length
- Programmable 1, 1½, and 2 stop bits
- Even, odd, or no parity
- Fully programmable data rate generation
- Interval timer with resolution from 64 to 16,320 microseconds
- TTL-compatibility, including power supply
- Standard 18-pin plastic or ceramic package
- N-channel, silicon gate technology

1.3 TYPICAL APPLICATION

Figure 1 shows a general block diagram of a system incorporating a TMS 9902A ACC. Following is a tutorial discussion of this application. Subsequent sections of this Data Manual detail most aspects of the ACC use.

The TMS 9902A interfaces with the CPU through the *communications register unit* (CRU). The CRU interface consists of five address select lines (S0-S4), chip enable (\overline{CE}), and three CRU lines (CRUIN, CRUOUT, CRUCLK). An additional input to the CPU is the ACC interrupt line (\overline{INT}). The TMS 9902A occupies 32 bits of CRU space; each of the 32 bits are selected individually by processor address lines A10-A14, which are connected to the ACC select lines S0-S4, respectively. Chip enable (\overline{CE}) is generated by decoding address lines A0-A9 for CRU cycles. Under certain conditions the TMS 9902A causes interrupts. The interrupt logic shown in Figure 1 can be a TMS 9901.

The ACC interfaces to the asynchronous communications channel on five lines: request to send (\overline{RTS}), data set ready (DSR), clear to send (CTS), serial transmit data (XOUT), and serial receive data (RIN). The request to send (\overline{RTS}) goes active (LOW) whenever the transmitter is activated. However, before data transmission begins, the clear to send (CTS) input must be active. The data set ready (DSR) input does not affect the receiver or transmitter. When DSR or CTS changes level, an interrupt is generated.

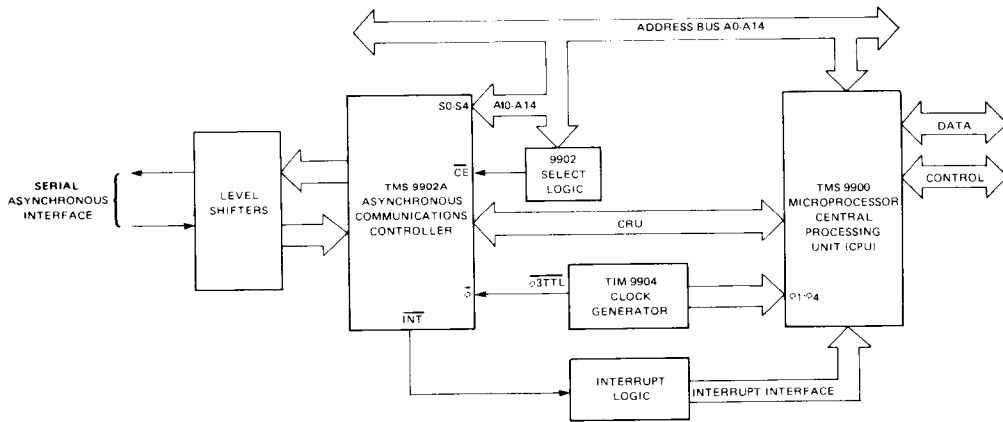


FIGURE 1. TYPICAL APPLICATION, TMS 9902A ASYNCHRONOUS COMMUNICATION CONTROLLER (ACC)

2. ARCHITECTURE

The controller is designed to provide a low cost, serial, asynchronous interface to the 9900 family of microprocessors. The TMS 9902A ACC, diagrammed in Figure 2, has five main subsections: CRU interface, transmitter section, receiver section, interval timer, and interrupt section.

2.1 CRU INTERFACE

The CRU is the means by which the CPU communicates with the TMS 9902A ACC. The ACC occupies 32 bits CRU read and write space. Figure 3 illustrates CRU interfaces between a TMS 9902A and 9900, 9981 and 9995 CRU's. The CRU lines are tied directly to each other as shown. The least significant bits of the address bus are connected to the select lines. In a TMS 9900 CPU system A14-A10 are connected to S4-S0 respectively. The most significant address bits are decoded to select the TMS 9902A via the chip enable (\overline{CE}) signal. When \overline{CE} is inactive (HIGH), the CRU interface of the 9902A is disabled.

Figure 3(c) illustrates a TMS 9995 CRU interface. The $\overline{WE}/\overline{CRUCLK}$ line from the 9995 needs to be inverted for the 9902A. The A10-A14 lines are connected to S0-S4 respectively on the 9902. Selection of the 9902 is possible utilizing the A0-A5 lines in conjunction with the \overline{MEMEN} line.

NOTE

When \overline{CE} is inactive (HIGH) the 9902A sets its CRUIN pin to high impedance and disables CRUCLK from coming on chip. This means the CRUIN line can be used as an OR-tied bus. The 9902A is still able to see the select lines even when \overline{CE} is high.

For those unfamiliar with the CRU concept, the following is a discussion of how to build a CRU interface. The CRU is a bit addressable, synchronous, serial interface over which a single instruction can transfer between one and 32 bits serially. Each one of the bits of the CRU space has a unique address and can be read and written to. During multi-bit CRU transfers, the CRU address is incremented at the beginning of each CRU cycle to point to the next consecutive CRU bit.

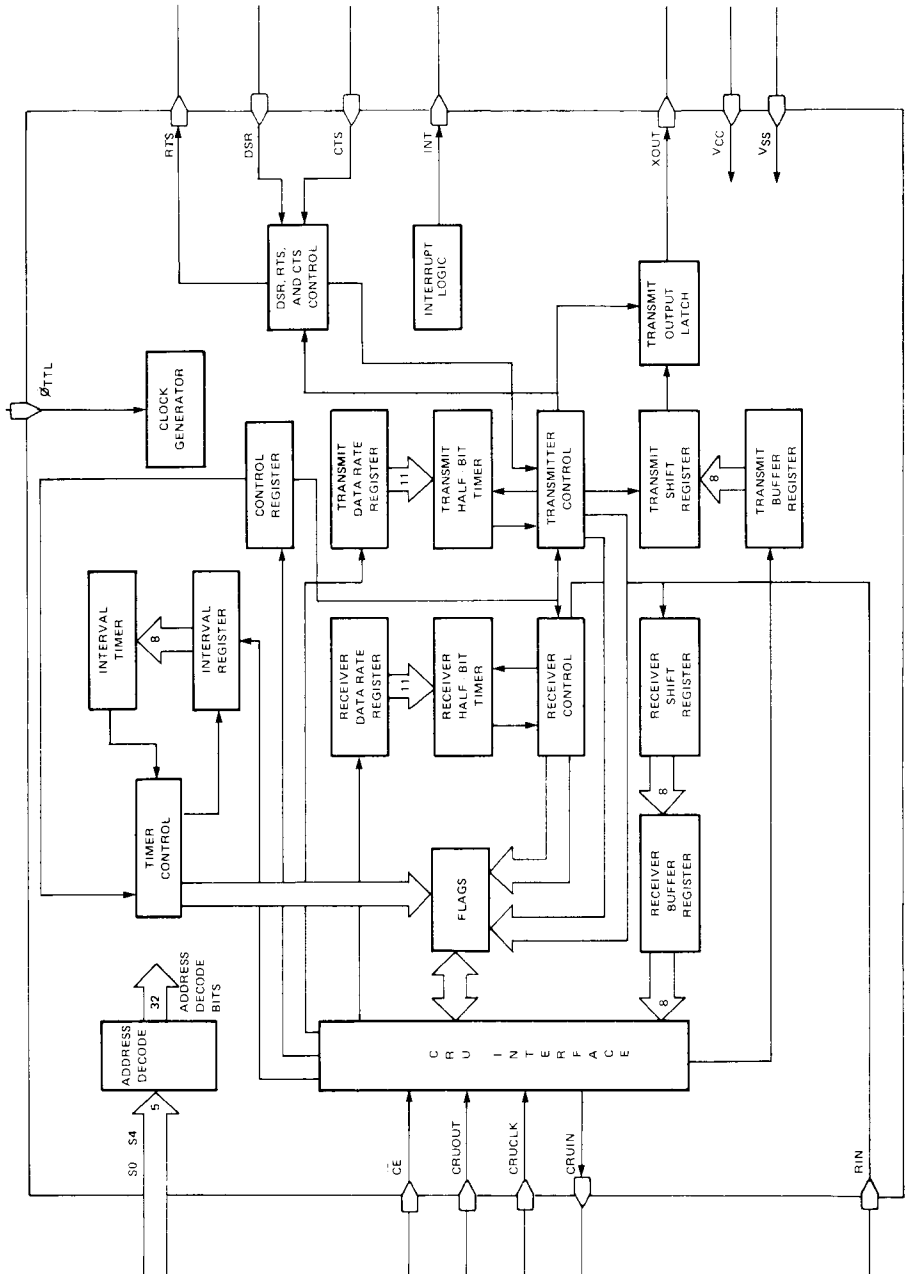
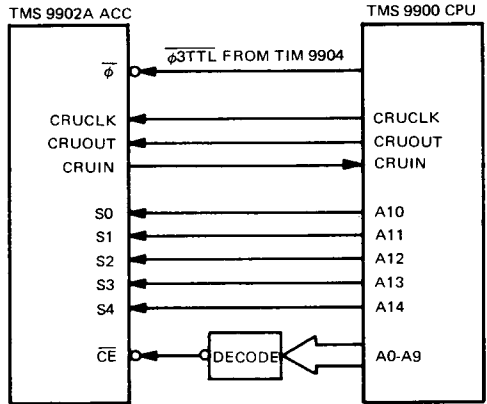
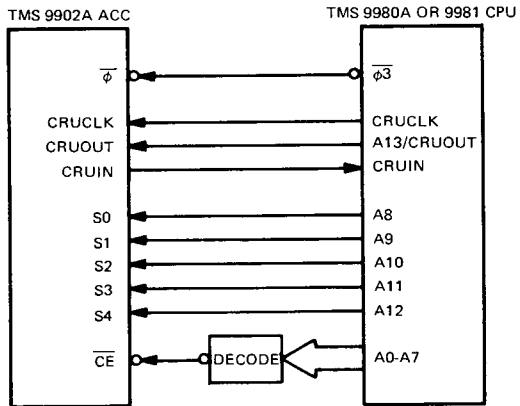


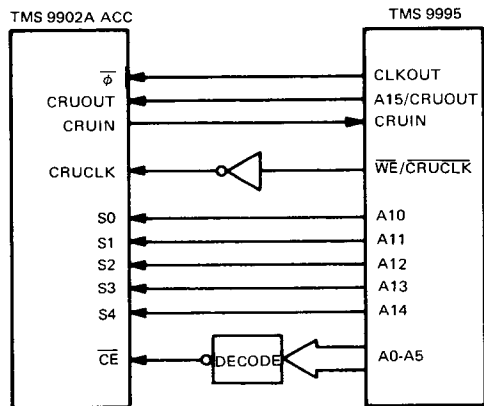
FIGURE 2. TMS 9902A ASYNCHRONOUS COMMUNICATIONS CONTROLLER (ACC) BLOCK DIAGRAM



(A) TMS 9900 CRU



(B) TMS 9981 CRU



(C) TMS 9995 CRU

FIGURE 3 – TMS 9902A CRU INTERFACES

When a TMS 9900 series CPU executes a CRU Instruction, the processor uses the contents of Workspace Register 12 as a base address. (Refer to the 9900 Microprocessor Data Manual for a complete discussion on how CRU addresses are derived.) The CRU address is brought out on the 15-bit address bus; this means that the least significant bit of R12 is not brought out of the CPU. During CRU cycles, the memory control lines (MEMEN, WE, and DBIN) are all inactive; MEMEN being inactive (HIGH) indicates the address is not a memory address and therefore is a CRU address or external instruction code. Also, when MEMEN is inactive (HIGH) and a valid address is present, address bits A0-A2 must all be zero to constitute a valid CRU address. If address bits A0-A2 are other than all zeroes, they are indicating an external instruction code. In summary, address bits A3-A14 contain the CRU address to be decoded; address bits A0-A2 must be zero; and MEMEN must be inactive (HIGH) to indicate a CRU cycle.

2.1.1 CPU Output For CRU

The TMS 9902A ACC occupies 32 bits of output CRU space, of which 23 bits are used: 31 and 21-0. These 23 bits are employed by the CPU to communicate command and control information to the TMS 9902A. Table 1 shows the mapping between CRU address select (S lines) and ACC functions. Each CRU addressable output bit on the ACC is described in detail following Table 1.

TABLE 1
TMS 9902A ACC OUTPUT SELECT BIT ASSIGNMENTS

ADDRESS ₂					ADDRESS ₁₀	NAME	DESCRIPTION
S0	S1	S2	S3	S4			
1	1	1	1	1	31	RESET	Reset device
					30-22		Not used
1	0	1	0	1	21	DSCENB	Data Set Status Change Interrupt Enable
1	0	1	0	0	20	TIMENB	Timer Interrupt Enable
1	0	0	1	1	19	XBIENB	Transmitter Interrupt Enable
1	0	0	1	0	18	RIENB	Receiver Interrupt Enable
1	0	0	0	1	17	BRKON	Break On
1	0	0	0	0	16	RTSON	Request to Send On
0	1	1	1	1	15	TSTMD	Test Mode
0	1	1	1	0	14	LDCTRL	Load Control Register
0	1	1	0	1	13	LDIR	Load Interval Register
0	1	1	0	0	12	LRDR	Load Receiver Data Rate Register
0	1	0	1	1	11	LXDR	Load Transmit Data Rate Register
					10-0		Control, Interval, Receive Data Rate, Transmit Data Rate, and Transmit Buffer Registers

Bit 31 (RESET) --

Reset. Writing a one or zero to bit 31 causes the device to reset, consequently disabling all interrupts, initializing the transmitter and receiver, setting RTS inactive (HIGH), setting all register load control flags (LDCTRL, LDIR, LRDR, and LXDR) to a logic one level, and resetting the BREAK flag. No other input or output operations should be performed for 11 ϕ clock cycles after issuing the RESET command.

Bit 30-Bit 22 --

Not used.

INTERRUPT ENABLE	SELECT BIT	INTERRUPT FLAG	INTERRUPT ENABLED
DSCENB	21	DSCH	DSCINT
TIMENB	20	TIMELP	TIMINT
XBIENB	19	XBRE	XINT
RIENB	18	RBRL	RINT

Bit 21 (DSCENB) –	Data Set Change Interrupt Enable. Writing a one to bit 21 causes the $\overline{\text{INT}}$ output to be active (LOW) whenever DSCH (Data Set Status Change) is a logic one. Writing a zero to bit 21 causes DSCH interrupts to be disabled. Writing either a one or zero to bit 21 causes DSCH to reset. (Refer also to Section 2.5.)
Bit 20 (TIMENB) –	Timer Interrupt Enable. Writing a one to bit 20 causes the $\overline{\text{INT}}$ output to be active whenever TIMELP (Timer Elapsed) is a logic one. Writing a zero to bit 20 causes TIMELP interrupts to be disabled. Writing either a one or zero to bit 20 causes TIMELP and TIMERR (Timer Error) to reset. (Refer also to Sections 2.4 and 2.5.)
Bit 19 (XBIENB) –	Transmit Buffer Interrupt Enable. Writing a one to bit 19 causes the $\overline{\text{INT}}$ output to be active whenever XBRE (Transmit Buffer Register Empty) is a logic one. Writing a zero to bit 19 causes XBRE interrupts to be disabled. The state of XBRE is not affected by writing to bit 19. (Refer also to Sections 2.2 and 2.5.)
Bit 18 (RIENB) –	Receiver Interrupt Enable. Writing a one to bit 18 causes the $\overline{\text{INT}}$ output to be active whenever RBRL (Receiver Buffer Register Loaded) is a logic one. Writing a zero to bit 18 disables RBRL interrupts. Writing either a one or zero to bit 18 causes RBRL to reset. (Refer also to Sections 2.3 and 2.5.)
Bit 17 (BRKON) –	Break On. Writing a one to bit 17 causes the XOUT (Transmitter Serial Data Output) to go to a logic zero whenever the transmitter is active and the Transmit Buffer Register (SBR) and the Transmit Shift Register (XSR) are empty. While BRKON is set, loading of characters into the XBR is inhibited. Writing a zero to bit 17 causes BRKON to reset and the transmitter to resume normal operation.
Bit 16 (RTSON) –	Request To Send On. Writing a one to bit 16 causes the $\overline{\text{RTS}}$ output to be active (LOW). Writing a zero to bit 16 causes $\overline{\text{RTS}}$ to go to a logic one after the XSR (Transmit Shift Register) and XBR (Transmit Buffer Register) are empty, and BRKON is reset. Thus, the $\overline{\text{RTS}}$ output does not become inactive (HIGH) until <i>after</i> character transmission is completed.
Bit 15 (TSTMD) –	Test Mode. Writing a one to bit 15 causes $\overline{\text{RTS}}$ to be internally connected to $\overline{\text{CTS}}$, XOUT to be internally connected to RIN, $\overline{\text{DSR}}$ to be internally held LOW, and the Interval Timer to operate 32 times its normal rate. Writing a zero to bit 15 re-enables normal device operation. There seldom is reason to enter the test mode under normal circumstances, but this function is useful for diagnostic and inspection purposes.
Bits 14-11 –	Register Load Control Flags. Output bits 14-11 determine which of the five registers are loaded when writing to bits 10-0. The flags are prioritized as shown in Table 2.

TABLE 2
TMS 9902A ACC REGISTER LOAD SELECTION

REGISTER LOAD CONTROL FLAG STATUS				REGISTER ENABLED
LDCTRL	LDIR	LRDR	LXDR	
1	X	X	X	Control Register
0	1	X	X	Interval Register
0	0	1	X	Receive Data Rate Register *
0	0	X	1	Transmit Data Rate Register *
0	0	0	0	Transmit Buffer Register

* If both LRDR and LXDR bits are set, both registers are loaded, assuming LDCTRL and LDIR are disabled; if only one of the registers is to be loaded, only that register bit is set, and the other register bit reset.

Bit 14 (LDCTRL) –	Load Control Register. Writing a one to bit 14 causes LDCTRL to be set to a logic one. When LDCTRL = 1, any data written to bits 0-7 is directed to the Control Register. Note that LDCTRL is also set to a logic one when a one or zero is written to bit 31 (RESET). Writing a zero to bit 14 causes LDCTRL to reset to a logic zero, disabling loading of the Control Register. LDCTRL is also automatically reset to logic zero when a datum is written to bit 7 of the Control Register. Reset normally occurs as the last bit is written when loading the Control Register with a LDCR instruction.
Bit 13 (LDIR) –	Load Interval Register. Writing a one to bit 13 causes LDIR to set to a logic one. When LDIR = 1 and LDCTRL = 0, any data written to bits 0-7 is directed to the Interval Register. Note that LDIR is also set to a logic one when a datum is written to bit 31 (RESET); however, Interval Register loading is not enabled until LDCTRL is set to a logic zero. Writing a zero to bit 13 causes LDIR to be reset to logic zero, disabling loading of the Interval Register. LDIR is also automatically reset to logic zero when a datum is written to bit 7 of the Interval Register. Reset normally occurs as the last bit is written when loading the Interval Register with a LDCR instruction.
Bit 12 (LRDR) –	Load Receive Data Rate Register. Writing a one to bit 12 causes LRDR to set to a logic one. When LRDR = 1, LDIR = 0, and LDCTRL = 0. Any data written to bits 0-10 is directed to the Receive Data Rate Register. Note that LRDR is also set to a logic one when a datum is written to bit 31 (RESET); however, Receive Data Rate Register loading is not enabled until LDCTRL and LDIR are set to a logic zero. Writing a zero bit to 12 causes LRDR to reset to a logic zero, disabling loading of the Receive Data Rate Register. LRDR is also automatically reset to logic zero when a datum is written to bit 10 of the Receive Data Rate Register. Reset normally occurs as the last bit is written when loading the Receive Data Rate Register with a LDCR instruction.
Bit 11 (LXDR) –	Load Transmit Data Rate Register. Writing a one to bit 11 causes LXDR to set to a logic one. When LXDR = 1, LDIR = 0, and LDCTRL = 0, any data written to bits 0-10 is directed to the Transmit Data Rate Register. Note that loading of both the Receive and Transmit Data Rate Registers is enabled when LDCTRL = 0, LDIR = 0, LRDR = 1, and LXDR = 1; thus these two registers may be loaded simultaneously when data is received and transmitted at the same rate. LXDR is also set to a logic one when a datum is written to bit 31 (RESET); however, Transmit Data Rate Register loading is not enabled until LDCTRL and LDIR are at logic zero. Writing a zero to bit 11 causes LXDR to reset to logic zero, consequently disabling loading of the Transmit Data Rate Register. Since bit 11 is the next bit addressed after loading the Transmit Data Rate Register, the register may be loaded and the LXDR flag reset with a single LDCR instruction in which 12 bits (Bits 0-11) are written and zero written to Bit 11.
Bits 14-11 (All Zeroes) –	Load Transmit Buffer Register. See Section 2.1.2.5.
Bits 10-0 (Data) –	Data. Information written to bits 10-0 is loaded into the controlling registers as indicated by LDCTRL, LDIR, LRDR, and LXDR (see Table 2). The different register bits are described in Section 2.1.2 below.

2.1.2 Registers

2.1.2.1 Control Register

The Control Register is loaded to select character length, device clock operation, parity, and the number of stop bits for the transmitter; control register loading occurs when LDCTRL is active (see Table 2). Table 3 shows the bit address assignments for the Control Register.

**TABLE 3
CONTROL REGISTER BIT ADDRESS ASSIGNMENTS**

ADDRESS ₁₀	NAME	DESCRIPTION
7	SBS1	} ← Stop Bit Select
6	SBS2	
5	PENB	Parity Enable
4	PODD	Odd Parity Select
3	CLK4M	φ Input Divide Select
2	—	Not Used
1	RCL1	} ← Character Length Select
0	RCL0	

7	6	5	4	3	2	1	0
SBS1	SBS2	PENB	PODD	CLK4M	NOT USED	RCL1	RCL0

MSB

LSB

Bits 7 and 6
(SBS1 and SBS2) –

Stop Bit Selection. The number of stop bits to be appended to each transmitter character is selected by bits 7 and 6 of the Control Register as shown below. The receiver only tests for a single stop bit, regardless of the status of bits 7 and 6.

STOP BIT SELECTION

SBS1 BIT 7	SBS2 BIT 6	NUMBER OF TRANSMITTED STOP BITS
0	0	1½
0	1	2
1	0	1
1	1	1

Bits 5 and 4
(PENB and PODD) –

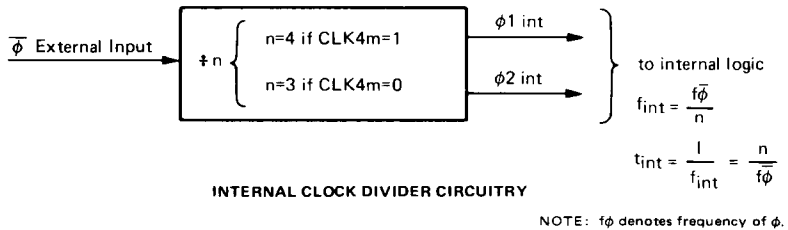
Parity Selection. The type of parity generated for transmission and detected for reception is selected by bits 5 and 4 of the Control Register as shown below. When parity is enabled (PENB = 1), the parity bit is transmitted and received in addition to the number of bits selected for the character length. Odd parity is such that the total number of ones in the character and parity bit, exclusive of stop bit(s), are odd. For even parity, the total number of ones are even.

PARITY SELECTION

PENB BIT 5	PODD BIT 4	PARITY
0	0	None
0	1	None
1	0	Even
1	1	Odd

Bit 3 (CLK4M) –

$\bar{\phi}$ Input Divide Select. The $\bar{\phi}$ input to the ACC is used to generate internal dynamic logic clocking and to establish the time base for the Interval Timer Transmitter, and Receiver. The $\bar{\phi}$ input is internally divided by either 3 or 4 to generate the two-phase internal clocks required for MOS logic, and to establish the basic internal operating frequency (f_{int}) and internal clock period (t_{int}). When bit 3 of the Control Register is set to a logic one (CLK4M = 1), $\bar{\phi}$ is internally divided by 4, and when CLK4M = 0, $\bar{\phi}$ is divided by 3. For example, when $\bar{\phi}$ = 3 MHz, as in a standard 3 MHz TMS 9900 system, and CLK4M = 0, $\bar{\phi}$ is internally divided by 3 to generate an internal clock period t_{int} of 1 μ s. The figure below shows the operation of the internal clock divider circuitry. The internal clock frequency should be no greater than 1.1 MHz; thus, when $\bar{\phi}$ > 3.3 MHz, CLK4M should be set to a logic one.



Bits 1 and 0
(RCL1 and RCL0) –

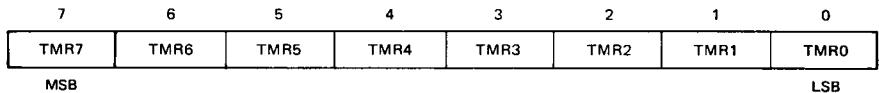
Character Length Select. The number of data bits in each transmitted and received character is determined by bits 1 and 0 of the Control Register as shown below:

CHARACTER LENGTH SELECTION

RCL1 BIT 1	RCL0 BIT 0	CHARACTER LENGTH
0	0	5 Bits
0	1	6 Bits
1	0	7 Bits
1	1	8 Bits

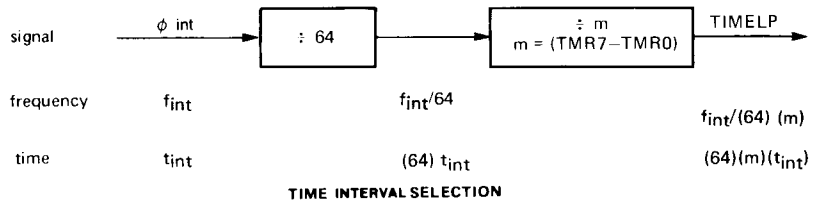
2.1.2.2 Interval Register

The Interval Register is enabled for loading when LDCTRL = 0 and LDIR = 1 (see Table 2). The Interval Register is used to select the rate at which interrupts are generated by the TMS 9902A Interval Timer. The figure below shows the bit assignments for the Interval Register when enabling for loading.



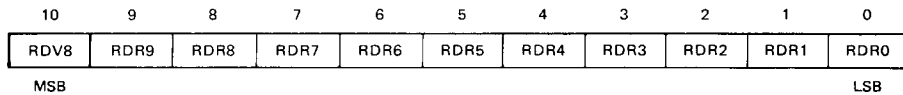
INTERVAL REGISTER BIT ADDRESS ASSIGNMENTS

The figure below illustrates the establishment of the interval for the Interval Timer. For example, if the Interval Register is loaded with a value of 80_{16} (128_{10}) the interval at which Timer Interrupts are generated is t_{int} . $t_{int} \cdot 64 \cdot M = (1 \mu s) (64) (128) = 8.192 \text{ ms}$ when $t_{int} = 1 \mu s$. $t_{int} = n/f\phi$ where $n = 4$ if $CLK4M = 1$, 3 if $CLK4M = 0$.



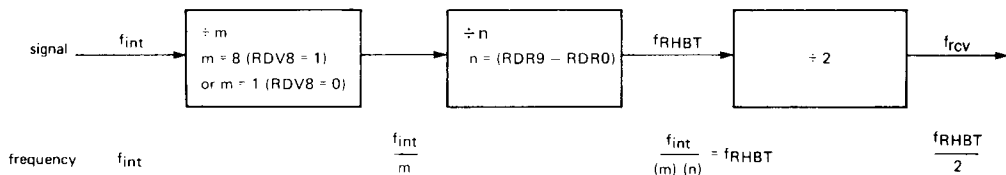
2.1.2.3 Receive Data Rate Register

The Receive Data Rate Register (RDR) is enabled for loading when $LDCTRL = 0$, $LDIR = 0$, and $LRDR = 1$ (see Table 2). The Receive Data Rate Register is used to select the bit rate at which data is received. The diagram shows the bit address assignments for the Receive Data Rate Register when enabled for loading.



RECEIVE DATA RATE REGISTER BIT ADDRESS ASSIGNMENTS

The diagram below illustrates the manner in which the receive data rate is established. Basically, two programmable counters are used to determine the interval for half the bit period of receive data. The first counter divides the internal system clock frequency (f_{int}) by either 8 ($RDV8 = 1$) or 1 ($RDV8 = 0$). The second counter has ten stages and may be programmed to divide its input signal by any value from 1 ($RDR9 - RDR0 = 0000000001$) to 1023 ($RDR9 - RDR0 = 1111111111$). The frequency of the output of the second counter (f_{RHBT}) is double the receive-data rate. For example, assume the Receive Data Rate Register is loaded with a value of 11000111000 ; $RDV8 = 1$, and $RDR9 - RDR0 = 1000111000 = 238_{16} = 568_{10}$. Thus, for $f_{int} = 1 \text{ MHz}$, (see Control Register, bit 3) the receive data rate is $f_{rcv} = [(1 \times 10^6 \div 8) \div 568] \div 2 = 110.04 \text{ bits per second}$.

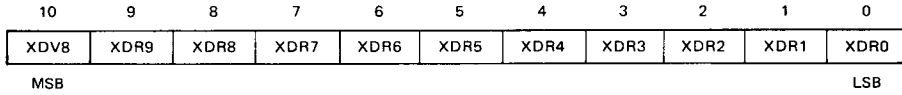


Quantitatively, the receive-data rate f_{rcv} is described by the following algebraic expression:

$$f_{rcv} = \frac{f_{RHBT}}{2} = \frac{f_{int}}{(2)(m)(n)} = \frac{f_{int}}{(2)(8RDV8)(RDR9 - RDR0)}$$

2.1.2.4 Transmit Data Rate Register

The Transmit Data Rate Register (XDR) is enabled for loading when LDCTRL = 0, LDIR = 0, and LXDR = 1 (see Table 2). The Transmit Data Rate Register is used to select the data for the transmitter. The figure below shows the bit address assignments for the Transmit Data Rate Register when enabled for loading.



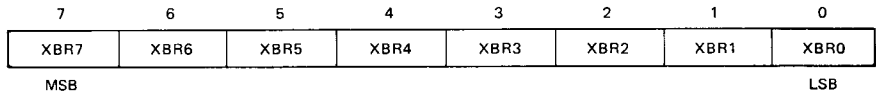
The transmit data rate is selected with the Transmit Data Rate Register in the same manner the receive data rate is selected with the Receive Data Rate Register. The algebraic expression for the Transmit Data Rate f_{xmt} is

$$f_{xmt} = \frac{f_{XHBT}}{2} = \frac{f_{int}}{(2)(8^{XDV8})(XDR9 - XDR0)}$$

For example, if the Transmit Data Rate Register is loaded with a value of 00110100001, XDV8 = 0, and XDR9 - XDR0 = 1A116 = 41710. If $f_{int} = 1$ MHz, the transmit data rate = $f_{xmt} = [(1 \times 10^6 \div 1) \div 417] \div 2 = 1199.0$ bits per second.

2.1.2.5 Transmit Buffer Register

The transmit Buffer Register (XBR) is enabled for loading when LDCTRL = 0, LDIR = 0, LRDR = 0, LXDR = 0, and BRKON = 0 (see Table 2). The Transmit Buffer Register is used to store the next character to be transmitted. When the transmitter is active, the contents of the Transmit Buffer Register are transferred to the Transmit Shift Register (XSR) each time the previous character has been completely transmitted (XSR becomes empty). The bit address assignments for the Transmit Buffer Register are shown below:



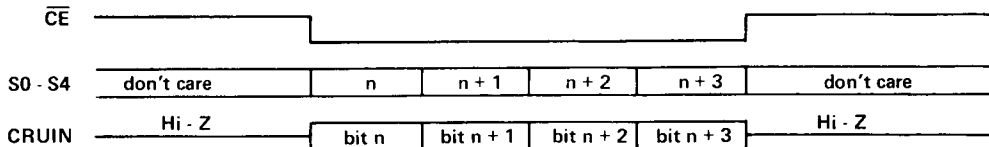
TRANSMIT BUFFER REGISTER BIT ADDRESS ASSIGNMENTS

All eight bits should be transferred into the register, regardless of the selected character length. The extraneous high order bits will be ignored for transmission purposes; however, loading of bit 7 is internally detected, which causes the Transmit Buffer Register Empty (XBRE) status flag to reset.

2.1.3 Input To CPU For CRU

The ACC occupies 32 bits of input CRU space. The CPU reads the 32 bits from the ACC to sense the status of the device. Table 4 shows the mapping between CRU bit address and ACC read data. Each CRU addressable read bit is described following Table 5.

Status and data information is read from the ACC using \overline{CE} , S0-S4, and CRUIN. The following figure illustrates the relationship of the signals used to access four bits of data from the ACC.



ACC DATA ACCESS SIGNAL TIMING

TABLE 4. CRU OUTPUT BIT ADDRESS ASSIGNMENTS

31	RESET	27	NOT USED	23	22	21	20	19	18	17	16								
		DSCENB	TIMENB	XBIENB	RIENB	BRKON	RTSON												
15	TSTMD	LDCTRL	LDIR	LDR	LXDR	CONTROL, INTERVAL, RECEIVE DATA RATE, TRANSMIT DATA RATE, AND TRANSMIT BUFFER REGISTERS													
						CONTROL REGISTER													
						SBS2	PENB	PODD	CLK4M	RCL1	RCL0								
						Stop Bits			Parity			Character Length							
						00	1-1/2	none	$f_{mt} =$			00	5						
						01	2	10	even	$f_p/(3 \cdot CLK4M)$			01	6					
						1X	1	11	odd				10	7					
												11	8						
						INTERVAL REGISTER													
						TMR7	TMR6	TMR5	TMR4	TMR3	TMR2	TMR1	TMR0						
						$T_{trvl} = t_{mt} \times 64 \times \text{TMR}$													
						RECEIVE DATA RATE REGISTER													
						RDR9	RDR8	RDR7	RDR6	RDR5	RDR4	RDR3	RDR2	RDR1	RDR0				
						$f_{rev} = f_{mt} \div 8 \text{RDV8} \div \text{RDR} \div 2$													
						TRANSMIT DATA RATE REGISTER													
						XDV8	XDR9	XDR8	XDR7	XDR6	XDR5	XDR4	XDR3	XDR2	XDR1	XDR0			
						$f_{emt} = f_{mt} \div 8 \text{XDV8} \div \text{XDR} \div 2$													
						TRANSMIT BUFFER REGISTER													
						XBR7	XBR6	XBR5	XBR4	XBR3	XBR2	XBR1	XBR0						

NOTE 1: Loading of the bit indicated by [hatched box] causes the load control flag for that register to reset automatically.

TABLE 5
TMS 9902A ACC INPUT SELECT BIT ASSIGNMENTS

ADDRESS ₂					ADDRESS ₁₀	NAME	DESCRIPTION
S0	S1	S2	S3	S4			
1	1	1	1	1	31	INT	Interrupt
1	1	1	1	0	30	FLAG	Register Load Control Flag Set
1	1	1	0	1	29	DSCH	Data Set Status Change
1	1	1	0	0	28	CTS	Clear to Send
1	1	0	1	1	27	DSR	Data Set Ready
1	1	0	1	0	26	RTS	Request to Send
1	1	0	0	1	25	TIMELP	Timer Elapsed
1	1	0	0	0	24	TIMERR	Timer Error
1	0	1	1	1	23	XSRE	Transmit Shift Register Empty
1	0	1	1	0	22	XBRE	Transmit Buffer Register Empty
1	0	1	0	1	21	RBRL	Receive Buffer Register Loaded
1	0	1	0	0	20	DSCINT	Data Set Status Change Interrupt (DSCH · DSCENB)
1	0	0	1	1	19	TIMINT	Timer Interrupt (TIMELP · TIMENB)
1	0	0	1	0	18	—	Not Used (always = 0)
1	0	0	0	1	17	XBINT	Transmitter Interrupt (XBRE · XBIENB)
1	0	0	0	0	16	RBINT	Receiver Interrupt (RBRL · RIENB)
0	1	1	1	1	15	RIN	Receive Input
0	1	1	1	0	14	RSBD	Receive Start Bit Detect
0	1	1	0	1	13	RFBD	Receive Full Bit Detect
0	1	1	0	0	12	RFER	Receive Framing Error
0	1	0	1	1	11	ROVER	Receive Overrun Error
0	1	0	1	0	10	RPER	Receive Parity Error
0	1	0	0	1	9	RCVERR	Receive Error
0	1	0	0	0	8	—	Not Used (always = 0)
					7-0	RBR7 · RBR0	Receive Buffer Register (Received Data)

Bit 31 (INT) —

INT = DSCINT (Data Set Status Change Interrupt) + TIMINT (Timer Interrupt) + XBINT (Transmitter Interrupt) + RBINT (Receiver Interrupt). The interrupt output (INT) is active (LOW) when this status signal is a logic one. (Refer also to Section 2.6.)

Bit 30 (FLAG) —

FLAG = LDCTRL + LDIR + LRDR + LXDR + BRKON. When any of the register load control flags or BRKON is set, FLAG = 1 (see Section 2.1.1).

Bit 29 (DSCH) —

Data Set Status Change. DSCH is set when the $\overline{\text{DSR}}$ or $\overline{\text{CTS}}$ input changes state. To ensure recognition of the state change, $\overline{\text{DSR}}$ or $\overline{\text{CTS}}$ must remain stable in its new state for a minimum of two internal clock cycles. DSCH is reset by an output to bit 21 (DSCENB).

Bit 28 (CTS) —

Clear To Send. The CTS signal indicates the inverted status of the $\overline{\text{CTS}}$ device input.

Bit 27 (DSR) —

Data Set Ready. The DSR signal indicates the inverted status of the $\overline{\text{DSR}}$ device input.

Bit 26 (RTS) —

Request To Send. The RTS signal indicates the inverted status of the $\overline{\text{RTS}}$ device output.

Bit 25 (TIMELP) —

Timer Elapsed. TIMELP is set each time the Interval Timer decrements to 0. TIMELP is reset by an output to bit 20 (TIMENB).

Bit 24 (TIMERR) –	Timer Error. TIMERR is set whenever the Interval Timer decrements to 0 and TIMELP (Timer Elapsed) is already set, indicating that the occurrence of TIMELP was not recognized and cleared by the CPU before subsequent intervals elapsed. TIMERR is reset by an output to bit 20 (TIMENB, Timer Interrupt Enable).
Bit 23 (XSRE) –	Transmit Shift Register Empty. When XSRE = 1, no data is currently being transmitted and the XOUT output is at logic one unless BRKON (see Section 2.1.1) is set. When XSRE = 0, transmission of data is in progress.
Bit 22 (XBRE) –	Transmit Buffer Register Empty. When XBRE = 1, the Transmit Buffer Register does not contain the next character to be transmitted. XBRE is set each time the contents of the Transmit Buffer Register are transferred to the Transmit Shift Register, XBRE is reset by an output to bit 7 of the Transmit Buffer Register (XBR7), indicating that a character has been loaded.
Bit 21 (RBRL) –	Receive Buffer Register Loaded. RBRL is set when a complete character has been assembled in the Receive Shift Register, and the character is transferred to the Receive Buffer Register. RBRL is reset by an output to bit 18 (RIENB, Receiver Interrupt Enable).
Bit 20 (DSCINT) –	Data Set Status Change Interrupt. DSCINT = DSCH (Data Set Status Change) AND DSCENB (Data Set Status Change Interrupt Enable). DSCINT indicates the presence of an enabled interrupt caused by the changing of state of DSR or \overline{CTS} .
Bit 19 (TIMINT) –	Timer Interrupt. TIMINT = TIMELP (Timer Elapsed) AND TIMENB (Timer Interrupt Enable). TIMINT indicates the presence of an enabled interrupt caused by the interval timer.
Bit 17 (XBINT) –	Transmitter Interrupt. XBINT = XBRE (Transmit Buffer Register Empty) AND XBIENB (Transmit Buffer Interrupt Enable). XBINT indicates the presence of an enabled interrupt caused by the transmitter.
Bit 16 (RBINT) –	Receiver Interrupt. RBINT = RBRL (Receive Buffer Register Loaded) AND RIENB (Receiver Interrupt Enable). RBINT indicates the presence of an enabled interrupt caused by the receiver.
Bit 15 (RIN) –	Receive Input. RIN indicates the status of the RIN input to the device.
Bit 14 (RSBD) –	Receive Start Bit Detect. RSBD is set a half bit time after the 1-to-0 transition of RIN, indicating the start bit of a character. If RIN is not still 0 at such time RSBD is reset. Otherwise, RSBD remains true until the complete character has been received. This bit is normally used only for testing purposes.
Bit 13 (RFBD) –	Receive Full Bit Detect. RFBD is set one bit time after RSBD is set to indicate the sample point for the first data bit of the received character. RFBD is reset when the character has been completely received. This bit is normally used only for testing purposes.
Bit 12 (RFER) –	Receive Framing Error. RFER is set when a character is received in which the stop bit, which should be a logic one, is a logic zero. RFER should only be reset when RBRL (Receive Buffer Register Loaded) is a one. RFER is reset when a character with the correct stop bit is received.
Bit 11 (ROVER) –	Receive Overrun Error. ROVER is set when a new character is received before the RBRL (Receive Buffer Register Loaded) flag is reset, indicating that the CPU failed to read the previous character and reset RBRL before the present character is completely received. ROVER is reset when a character is received. RBRL is reset when the character is transferred to the Receive Buffer Register.
Bit 10 (RPER) –	Receive Parity Error. RPER is set when a character is received in which the parity is incorrect. RPER is reset when a character with correct parity is received.

Bit 9 (RCVERR) –

Receive Error. RCVERR = RFER (Receive Framing Error) + ROVER (Receive Overrun Error) + RPER (Receive Parity Error). The RCVERR signal indicates the presence of an error in the most recently received character.

Bit 7-Bit 0
(RBR7-RBR0) –

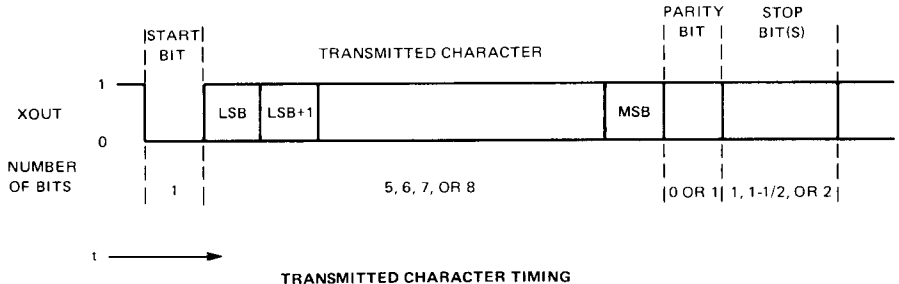
Receive Buffer Register. The Receive Buffer Register contains the most recently received character. For character lengths of fewer than eight bits, the character is right-justified, with unused most significant bit(s) all zero(es). The presence of valid data in the Receive Buffer Register is indicated when RBRL (Receive Buffer Register Loaded) is a logic one.

2.2 TRANSMITTER OPERATION

The operation of the transmitter is diagrammed in Figure 4. The transmitter is initialized by issuing the RESE command (output to bit 31), which causes the internal signals XSRE (Transmit Shift Register Empty) and XBR (Transmit Buffer Register Empty) to set, and BRKON to reset. Device outputs RTS and XOUT are set, placing the transmitter in its idle state. When RTSON (Request-to-Send On) is set by the CPU, the $\overline{\text{RTS}}$ output becomes active (LOW) and the transmitter becomes active when the CTS input goes LOW.

2.2.1 Data Transmission

If the Transmit Buffer Register contains a character, transmission begins. The contents of the Transmit Buffer Register are transferred to the Transmit Shift Register, causing XSRE to reset and XBRE to set. The first bit transmitted (start bit) is always a logic zero. Subsequently, the character is shifted out LSB first. Only the number of bits specified by RCL1 and RCL0 (character length select) of the Control Register are shifted. If parity is enabled, the correct parity bit is next transmitted. Finally the stop bit(s) selected by SBS1 and SBS0 of the Control Register are transmitted. Stop bits are always logic one. XSRE is set to indicate that no transmission is in progress, and the transmitter again tests XBRE to determine if the CPU has yet loaded the next character. The timing for a transmitted character is shown below.



2.2.2 BREAK Transmission

The BREAK message is transmitted only if $\text{XBRE} = 1$, $\overline{\text{CTS}} = 0$, and $\text{BRKON} = 1$. After transmission of the BREAK message begins, loading of the Transmit Buffer Register is inhibited and XOUT is reset. When BRKON is reset by the CPU, XOUT is set and normal operation continues. It is important to note that characters loaded into the Transmit Buffer Register are transmitted prior to the BREAK message, regardless of whether or not the character has been loaded into the Transmit Shift Register before BRKON is set. Any character to be transmitted subsequent to transmission of the BREAK message may not be loaded into the Transmit Buffer Register until after BRKON is reset.

2.2.3 Transmission Termination

Whenever $\text{XSRE} = 1$ and $\text{BRKON} = 0$, the transmitter is idle with XOUT set to one. If RTSON is reset at this time, the $\overline{\text{RTS}}$ device output will go inactive (HIGH), disabling further data transmission until RTSON is again set. $\overline{\text{RTS}}$ will not go inactive, however, until any characters loaded into the Transmit Buffer Register prior to resetting RTSON are transmitted and $\text{BRKON} = 0$.

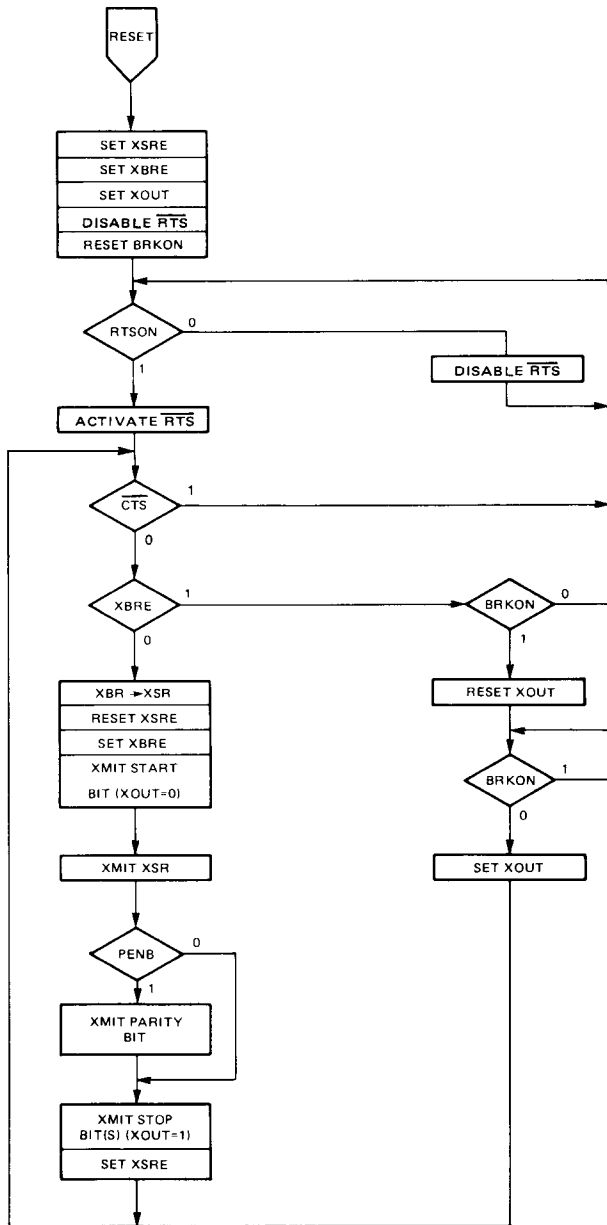


FIGURE 4. TMS 9902A TRANSMITTER OPERATION

2.3 RECEIVER OPERATION.

2.3.1 Receiver Initialization

Operation of the TMS 9902A receiver is diagrammed in Figure 5. The receiver is initialized whenever the CPU issues the RESET command. The RBRL (Receive Buffer Register Loaded) flag is reset to indicate that no character currently in the Receive Buffer Register, and the RSBD (Receive Start Bit Detect) and RFBD (Receive Full Bit Detect) flags are reset. The receiver remains in the inactive state until a one-to-zero transition is detected on the RIN device input.

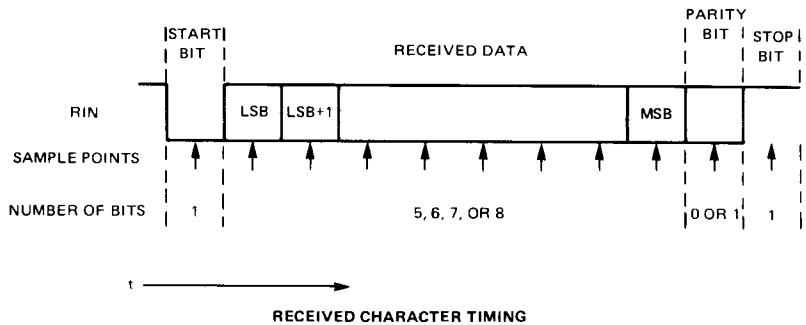
2.3.2 Start Bit Detection

The receiver delays a half bit time and again samples RIN to ensure that a valid start bit has been detected. RIN = 0 after the half-bit delay, RSBD is set and data reception begins. If RIN = 1, no data reception occurs.

2.3.3 Data Reception

In addition to verifying the valid start bit, the half-bit delay after the one-to-zero transition also establishes the sample point for all subsequent data bits in a valid received character. Theoretically, the sample point is in the center of each bit cell, thus maximizing the limits of acceptable distortion of data cells. After the first full bit delay, the least significant data bit is received and RFBD is set. The receiver continues to delay one-bit intervals and samples RIN until the selected number of bits are received. If parity is enabled, one additional bit is read for parity. After an additional bit delay, the received character is transferred to the Receive Buffer Register, RBRL is set, ROVER (Receive Overrun Error) and RPER (Receive Parity Error) are loaded with appropriate values, and RIN is tested for a valid stop bit. If RIN = 1, the stop bit is valid. RFER (Receive Framing Error), RSBD, and RFBD are reset, and the receiver waits for the next start bit to begin reception of the next character.

If RIN = 0 when the stop bit is sampled, RFER is set to indicate the occurrence of a framing error. RSBD and RFBD are reset, but sampling for the start bit of the next character does not begin until RIN = 1. The timing for a received character is depicted below.



2.4 INTERVAL TIMER OPERATION

A flowchart of the operation of the Interval Timer is shown in Figure 6. Execution of the RESET command by the CPU causes TIMELP (Timer Elapsed) and TIMERR (Timer Error) to reset and LDIR (Load Interval Register) to set. Resetting LDIR causes the contents of the Interval Register to be loaded into the Interval Timer, thus beginning the selected time interval. The timer is decremented every 64 internal clock cycles (every two internal clock cycles when in Test Mode) until it reaches zero, at which time the Interval Timer is reloaded by the Interval Register and TIMELP is set. If TIMELP was already set, TIMERR is set to indicate that TIMELP was not cleared by the CPU before the next time period elapsed. Each time LDIR is reset, the contents of the Interval Register are loaded into the Interval Timer, thus restarting the timer (refer also to Section 2.1.2.2).

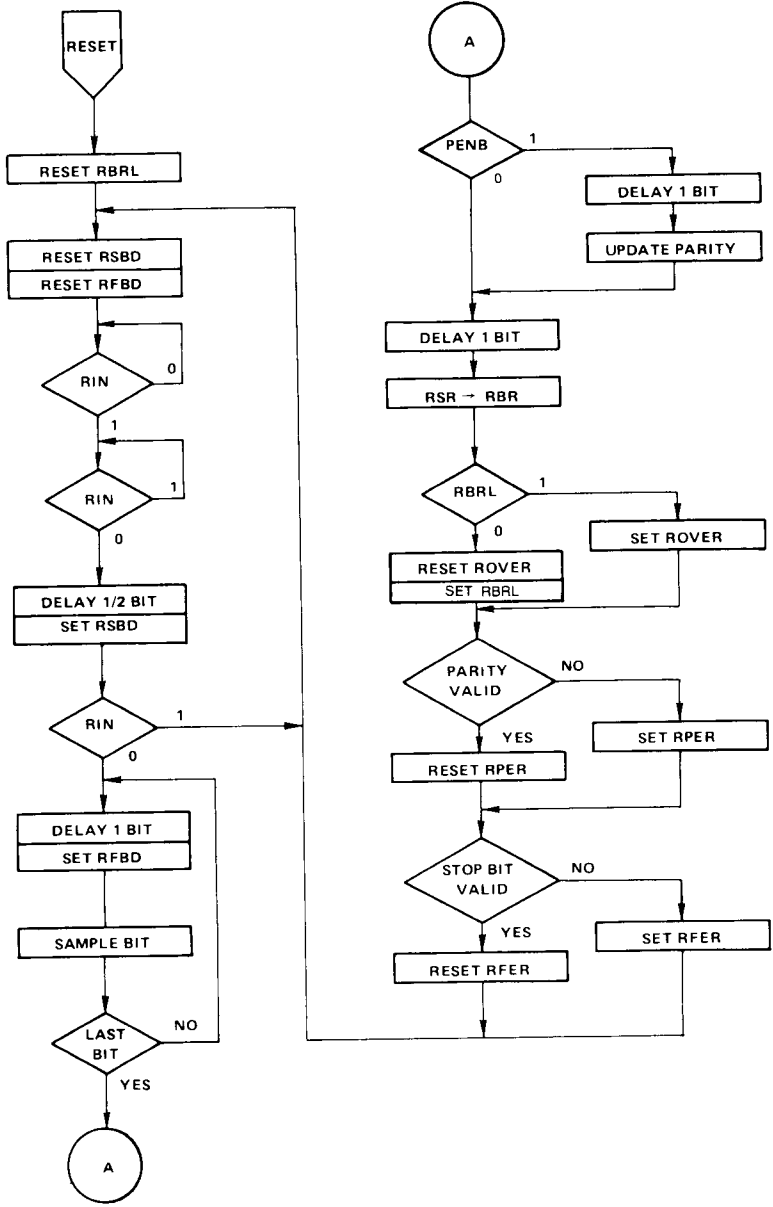


FIGURE 5. TMS 9902A RECEIVER OPERATION

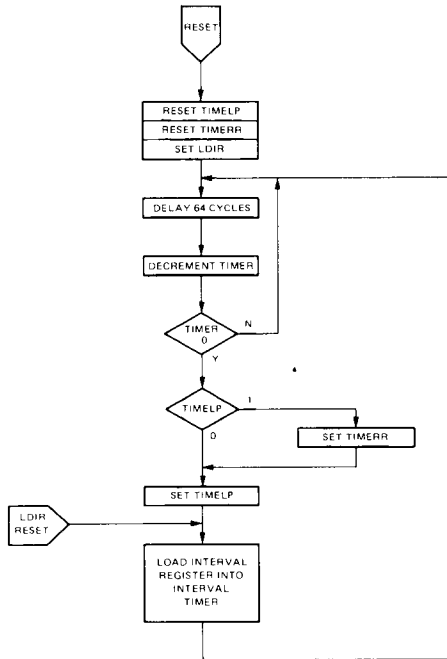
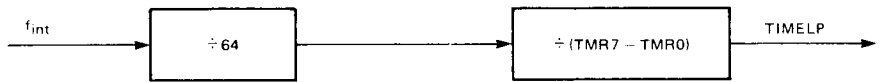


FIGURE 6. TMS 9902A INTERVAL TIMER OPERATION



INTERVAL TIMER SELECTION

2.5 INTERRUPTS

The interrupt output ($\overline{\text{INT}}$) is active (LOW) when any of the following conditions occurs and the corresponding interrupt has been enabled on the TMS 9902A by the CPU:

- (1) $\overline{\text{DSR}}$ or $\overline{\text{CTS}}$ changes levels (DSCN = 1)
- (2) A character has been received and stored in the Receive Buffer Register (RBRL = 1)
- (3) The Transmit Buffer Register is empty (XBRE = 1)
- (4) The selected time interval has elapsed (TIMELP = 1)

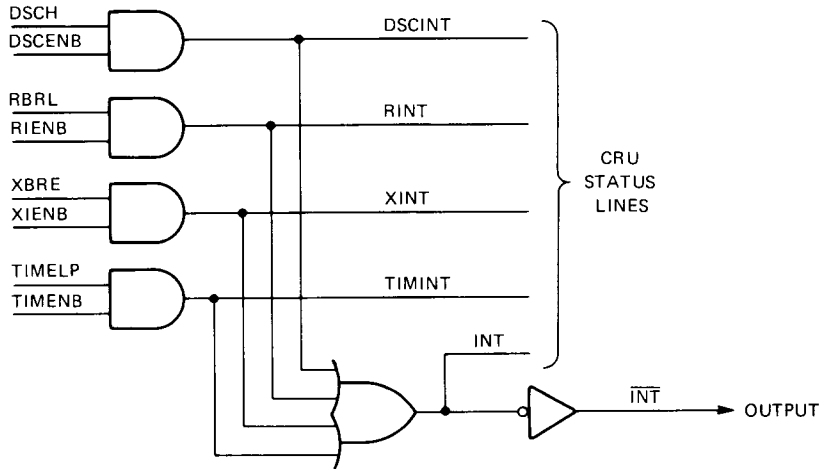


FIGURE 7. $\overline{\text{INT}}$ OUTPUT GENERATION

Figure 7 illustrates the logical equivalent of the ACC interrupt section. Table 6 lists the actions necessary to clear those conditions of the TMS 9902A that cause interrupts.

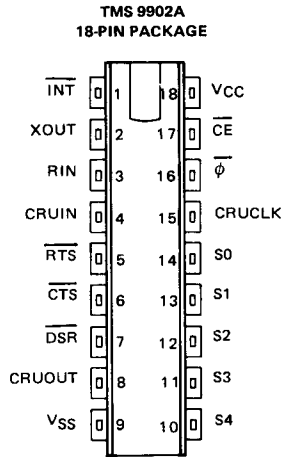
TABLE 6
TMS 9902A INTERRUPT CLEARING

MNEMONIC	CAUSE	ACTION TO RESET
DSCINT	$\overline{\text{CTS}}$ or $\overline{\text{DSR}}$ change state	Write a bit to DSCENB (bit 21)*
RINT	Receive Buffer Full	Write a bit to RIENB (bit 18)*
XINT	Transmit Buffer Register Empty	Load Transmit Buffer
TIMINT	Timer Elapsed	Write a bit to TIMENB (bit 20)*

* Writing a zero to clear the interrupt will clear the interrupt and disable further interrupts.

2.6 TMS 9902A TERMINAL ASSIGNMENTS AND FUNCTIONS

SIGNATURE	PIN	I/O	DESCRIPTION
$\overline{\text{INT}}$	1	O	Interrupt – when active (LOW), the $\overline{\text{INT}}$ output indicates that at least one of the interrupt conditions has occurred.
XOUT	2	O	Transmitter Serial Data Output line – XOUT, remains inactive (HIGH) when TMS 9902A is not transmitting.
RIN	3	I	Receiver Serial Data Input Line – RCV must be held in the inactive (HIGH) state when not receiving data. A transition from HIGH to LOW activates the receiver circuitry.
CRUIN	4	O	Serial data output pin from TMS 9902A to CRUIN input pin of the CPU.
$\overline{\text{RTS}}$	5	O	Request-to-Send output from TMS 9902A to modem. $\overline{\text{RTS}}$ is enabled by the CPU and remains active (LOW) during transmission from the TMS 9902A.
$\overline{\text{CTS}}$	6	I	Clear-to-Send input from modem to TMS 9902A. When active (LOW), it enables the transmitter section of TMS 9902A.
$\overline{\text{DSR}}$	7	I	Data Set Ready input from modem to TMS 9902A. $\overline{\text{DSR}}$ generates an interrupt when it changes state.
CRUOUT	8	I	Serial data input line to TMS 9902A from CRUOUT line of the CPU.
VSS	9	I	Ground reference voltage.
S4 (LSB)	10	I	Address Select Lines. The data bit being accessed by the CPU interface is specified by the 5-bit code appearing on S0-S4.
S3	11	I	
S2	12	I	
S1	13	I	
S0	14	I	
CRUCLK	15	I	CRU Clock. When active (HIGH), indicates valid data on the CRUOUT line for the 9902A.
ϕ	16	I	TTL Clock.
$\overline{\text{CE}}$	17	I	Chip Enable – when $\overline{\text{CE}}$ is inactive (HIGH), TMS 9902A CRU interface is disabled. CRUIN remains at high impedance when $\overline{\text{CE}}$ is inactive (HIGH).
VCC	18	I	Supply voltage (+5 V nominal).



3. DEVICE APPLICATION

This section describes the software interface between the CPU and the ACC and discusses some of the design considerations in the use of this device for asynchronous communications applications.

3.1 DEVICE INITIALIZATION

The ACC is initialized by the RESET command from the CPU (output bit 31), followed by loading the Control, Interval, Receive Data Rate, and Transmit Data Rate registers. Assume that the value to be loaded into the CRU Base Register (register 12) in order to point to bit 0 is 004016. In this application characters have seven bits of data plus even parity and one stop bit. The ϕ input to the ACC is a 3 MHz signal. The ACC divides this signal frequency by three to generate an internal clock frequency of 1 MHz. An interrupt is generated by the Interval Timer every 1.6 milliseconds when timer interrupts are enabled. The transmitter operates at a data rate of 300 bits per second, and the receiver operates at 1200 bits per second.

NOTE

To operate both the transmitter and receiver at 300 bits per second, delete the "LDCR @RDR,11" instruction (see below). The "LDCR @XDR,12" instruction will cause both data rate registers to be loaded and LRDR and LXDR to reset.

3.1.1 Initialization Program

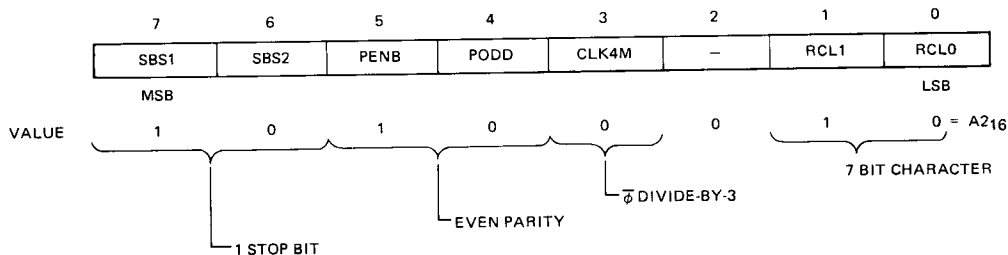
The initialization program for the configuration described above is shown below. The RESET command disables all interrupts, initializes all controllers, and sets the four register load control flags (LDCTRL, LDIR, LRDR, and LXDR). Loading the last bit of each of the registers causes the load control flag to reset automatically.

	LI	R12,>40	INITIALIZE CRU BASE
	SBO	31	RESET COMMAND
	LDCR	@ CNTRL,8	LOAD CONTROL AND RESET LDCTRL
	LDCR	@ INTVL,8	LOAD INTERVAL AND RESET LDIR
	LDCR	@ RDR,11	LOAD RDR AND RESET LRDR
	LDCR	@ XDR,12	LOAD XDR AND RESET LXDR
	.	.	.
	.	.	.
CNTR	BYTE	>A2	
INTVL	BYTE	1600/64	
RDR	DATA	>1A1	
XDR	DATA	>4D0	

The RESET command initializes all subcontrollers, disables interrupts, and sets LDCTRL, LDIR, LRDR, and LXDR, enabling loading of the control register.

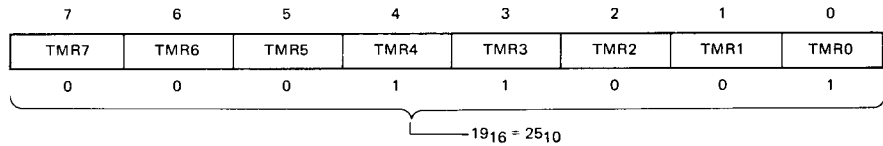
3.1.2 Control Register

The options listed in Table 3 in Section 2.1.2.1 are selected by loading the value shown below.



3.1.3 Interval Register

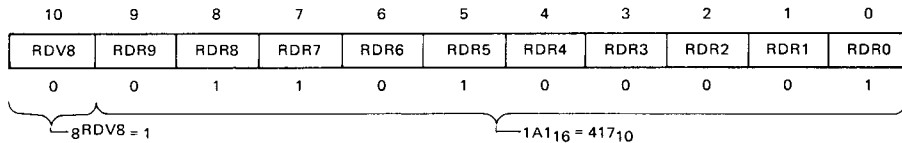
To set up the Interval Register to generate an interrupt every 1.6 milliseconds, load the value into the Interval Register to specify the number of 64-microsecond increments in the total interval desired.



$$25 \times 64 \text{ MICROSECONDS} = 1.6 \text{ MILLISECONDS}$$

3.1.4 Receive Data Rate Register

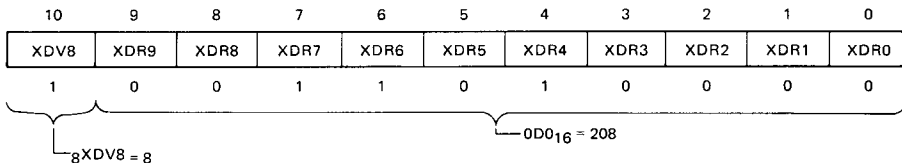
To set the data rate for the receiver to 1200 bits per second, load the value into the Receive Data Rate Register shown below:



$$10^6 \div 1 \div 417 \div 2 = 1199.04 \text{ BITS PER SECOND}$$

3.1.5 Transmit Data Rate Register

To program the data rate for the transmitter for 300 bits per second, load the following value into the Transmit Data Rate Register.



$$1 \times 10^6 \div 8 \div 208 \div 2 = 300.48 \text{ BITS PER SECOND}$$

3.2 DATA TRANSMISSION

The subroutine shown below demonstrates a simple loop for transmitting a block of data.

	LI	R0, LISTAD	INITIALIZE LIST POINTER
	LI	R1, COUNT	INITIALIZE BLOCK COUNT
	LI	R12, CRUBAS	INITIALIZE CRU BASE
	SBO	16	TURN ON TRANSMITTER
XMTLP	TB	22	WAIT FOR XBRE = 1
	JNE	XMTLP	
	LDCR	*R0+,8	LOAD CHARACTER INCREMENT POINTER
			RESET XBRE
	DEC	R1	DECREMENT COUNT
	JNE	XMTLP	LOOP IF NOT COMPLETE
	SBZ	16	TURN OFF TRANSMITTER

After initializing the list pointer, block count, and CRU base address, RTSON is set to cause the transmitter and the $\overline{\text{RTS}}$ output to become active. Data transmission does not begin, however, until the $\overline{\text{CTS}}$ input becomes active. After the final character is loaded into the Transmit Buffer Register, RTSON is reset. The transmitter and the $\overline{\text{RTS}}$ output do not become inactive until the final character is transmitted.

3.3 DATA RECEPTION

The following software will cause a block of data to be received and stored in memory.

CARRET	BYTE	>0D	
RCVBLK	LI	R2, RCVLST	INITIALIZE LIST COUNT
	LI	R3, MXRCNT	INITIALIZE MAX COUNT
	LI	R4, CARRET	SET UP END OF BLOCK CHARACTER
RCVLP	TB	21	WAIT FOR RBRL = 1
	JNE	RCVLP	
	STCR	*R2,8	STORE CHARACTER
	SBZ	18	RESET RBRL
	DEC	R3	DECREMENT COUNT
	JEQ	RCVEND	END IF COUNT = 0
	CB	*R2+,R4	COMPARE TO EOB CHARACTER, INCREMENT POINTER
	JNE	RCVLP	LOOP IF NOT COMPLETE
RCVEND	RT		END OF SUBROUTINE

3.4 REGISTER LOADING AFTER INITIALIZATION

The Control, Interval, and Data Rate registers may be reloaded after initialization. For example, it may be desirable to change the interval of the timer. Assume that the interval is to be changed to 10.24 milliseconds; the instruction sequence is:

	SBO	13	SET LOAD CONTROL FLAG
	LDCR	@ INTVL2,8	LOAD REGISTER, RESET FLAG
	.	.	.
	.	.	.
INTVL2	BYTE	10240/64	

When transmitter interrupts are enabled, caution should be exercised to ensure that a transmitter interrupt does not occur while the load control flag is set. For example, if a transmitter interrupt occurs between execution of the "SBO 13" and the next instruction, the Transmit Buffer is not enabled for loading when the Transmitter Interrupt service routine is entered because the LDIR flag is set. This situation may be avoided by the following sequence:

	BLWP	@ITVCHG	CALL SUBROUTINE
	.	.	.
	.	.	.
ITVCPC	LIMI	0	MASK ALL INTERRUPTS
	MOV	@24(R13),R12	LOAD CRU BASE ADDRESS
	SBO	13	SET FLAG
	LDCR	@ INTVL2,8	LOAD REGISTER AND RESET FLAG
	RTWP		RESTORE MASK AND RETURN
	.	.	.
	.	.	.
ITVCHG	DATA	ACCWP, ITVCPC	
INTVL2	BYTE	10240/64	

In this case all interrupts are masked, ensuring that all interrupts are disabled while the load control flag is set

3.5 INTERFACE TO A DATA TERMINAL

Following is a discussion of the TMS 9902A interface to a TI Model 733 data terminal as implemented on the TM 990/100M microcomputer module. Figure 8 diagrams the hardware interface, and Table 7 lists the software interface. The 733 data terminal is an ASCII-code, serial asynchronous, EIA device equipped with a keyboard, thermal printer, and digital cassette tape.

3.5.1 Hardware Interface

The hardware interface between the TMS 9902A and the 733 data terminal is shown in Figure 8. The asynchronous communication conforms to *EIA Standard RS-232-C*. The 75188 and 75189 perform the necessary level shifting between TTL levels and RS-232-C levels. The ACC chip enable ($\overline{9902SEL}$) signal comes from decode circuitry which looks at A0-A9 on CRU cycles. The interrupt output (\overline{INT}) of the TMS 9902A is sent to the TMS 9901 for prioritization and encoding. When the 9902A is communicating with a terminal, the RTS pin can be connected to the CTS pin because the terminal will always be in the clear-to-send (\overline{CTS}) condition.

Figure 9 diagrams the hardware interface of a TMS 9995 to an ASR 733 Data Terminal utilizing a TMS 9902A. This schematic is very similar to the TMS 9900 interface diagram. $\overline{WE/CRUCLK}$ must be inverted before connecting to CRUCLK input on the TMS 9902A.

3.5.2 Software

The software required to initialize, read from, and write to the TMS 9902A ACC is listed in Table 7. These routines are taken directly from TIBUG (TM 990/402-1), which is the monitor that runs on the TM 990/100M boards. The coding shown is part of a routine entered because of a power-up reset. Before this section of code was entered, not shown, R12 is set to the correct value of the TMS 9902A CRU base address. The baud rate is detected by measuring the start bit length when an "A" is entered via the keyboard. The variable COUNT is incremented every time the SPLOOP is executed. When a zero is seen at 9902A bit 15 (RIN), the start bits are finished being received. The value of COUNT is then compared against a table of known values in TABLE to determine the baud rate.

TIBUG assumes that all 1200-baud data terminals are TI Model 733 data terminals. The TI Model 733 communicates at 1200 baud, but prints at 300 baud; this means that bits travel the communications line at 1200 baud, but the spacing between characters is 300 baud. A wait loop is included in the write character routine to handle this spacing requirement. The TIBUG T command is used to indicate that a 1200 baud terminal is true 1200 baud; i.e., not TI 733.

This code is taken from the middle of TIBUG; thus constructs and symbols are used which are not defined here. Lines 261 and 262 of the code contain XOP calls. The READ opcode is really a call to XOP 13 and the MESSAGE opcode is a call to XOP 14, which, in turn, calls XOP 12. This can be figured out if the assembled code for these opcodes is examined. Following is a list of EQU statements that appear at the beginning of TIBUG but are not shown here:

COUNT	EQU	3
POINT	EQU	7
LINK	EQU	11
CRUBAS	EQU	12

Once again, these values could easily be obtained by looking at the assembled code for the statement in which the symbol is used.

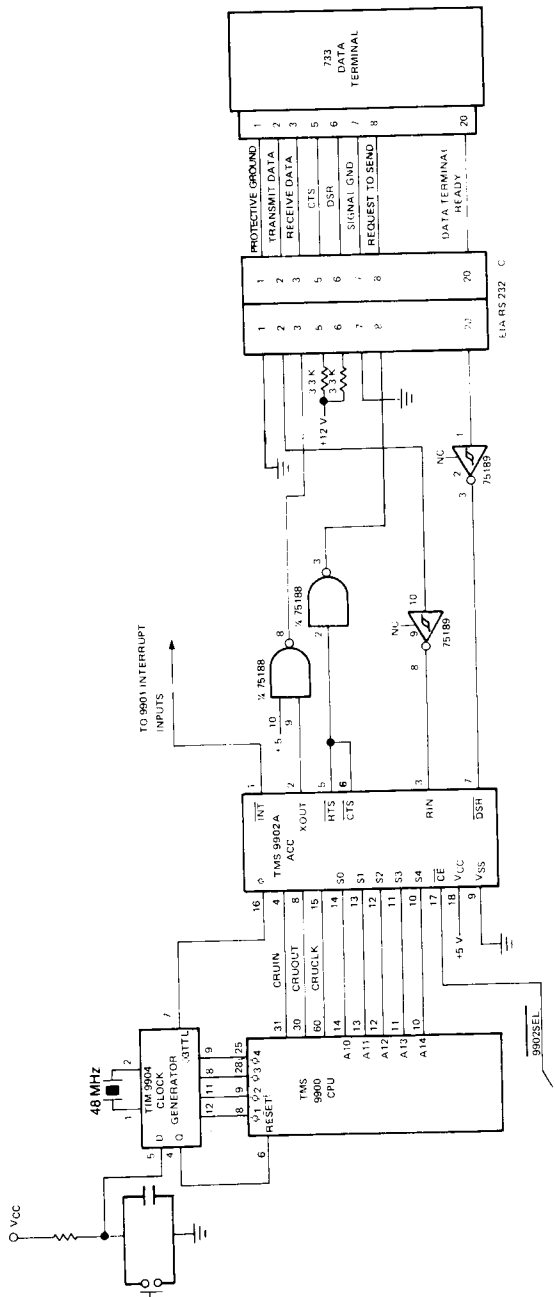


FIGURE 8. TMS 9900/9902A INTERFACE TO AN ASR 733 DATA TERMINAL

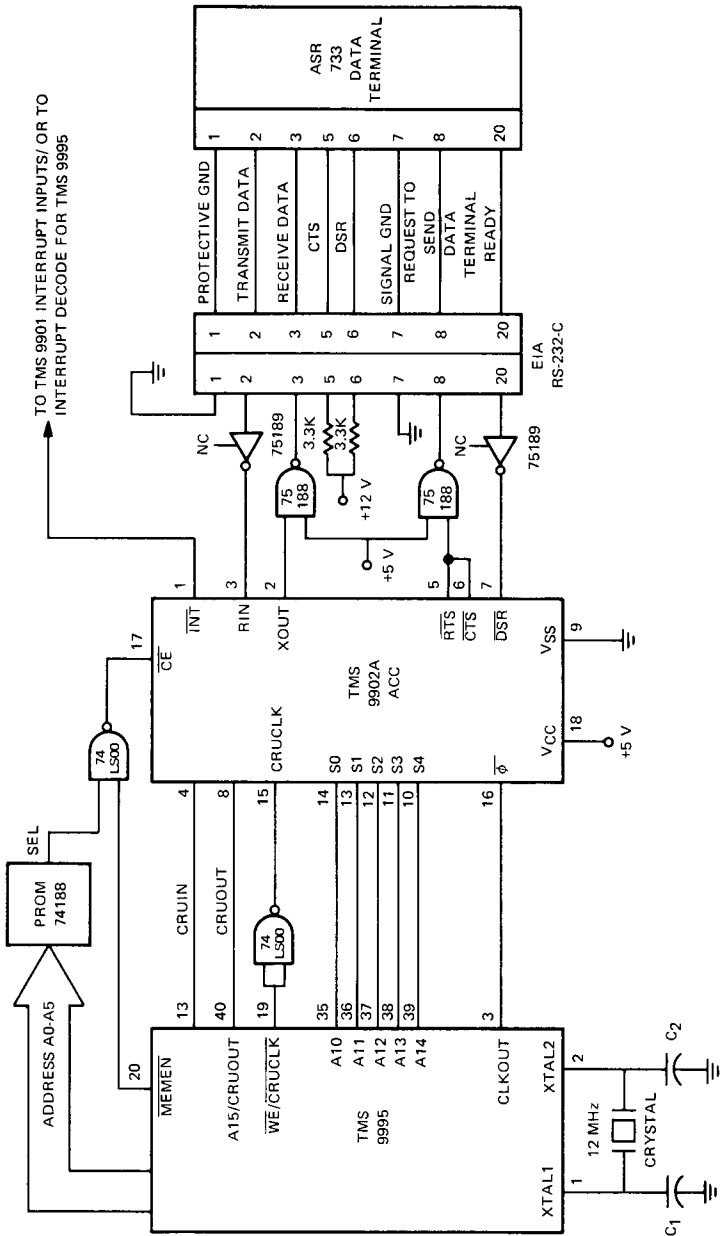


FIGURE 9. TMS 9901 INTERRUPT INPUTS/ OR TO INTERRUPT DECODE FOR TMS 9902A INTERFACE TO A 733 DATA TERMINAL

TABLE 7
TMS 9902A SOFTWARE

TIBUG
COMMAND SEARCH AND SYSTEM INZ

STATEMENT NO.	ADDRESS (HEX)	ASSEMBLED CODE		
0231			*	
0232			* INITIALIZE TMS9902 FOR:	*BAUD RATE
0233			*	*7 BITS/CHARACTER
0234			*	*EVEN PARITY
0235			*	*2 STOP BITS
0236			*	*POLLED OPERATION
0237			*	
0238	015E 1D1F		SBO 31	RESET TMS9902 UART
0239	0160 3220		LDCR @CR,8	INITIALIZE TMS9902 CONTROL REG
	0162 01A4			
0240	0164 1E0D		SBZ 13	DO NOT INT INTERVAL REG
0241	0166 04C3		CLR COUNT	RESET LOOP COUNT
0242	0168 1F0F	TSTSP	TB 15	SPACE?
0243	016A 13FE		JEQ TSTSP	NO, JUMP BACK
0244	016C 0583	SPLLOOP	INC COUNT	TIME THE START BIT
0245	016E 1F0F		TB 15	FALL OUT ON A MARK
0246	0170 16FD		JNE SPLLOOP	
0247			*	
0248			* TABLE SEARCH FOR BAUD RATE	
0249			*	
0250	0172 0207		LI POINT, TABLE	SET POINTER TO TABLE
	0174 0194			
0251	0176 8DC3	BDLOOP	C COUNT,*POINT+	MATCH?
0252	0178 1202		JLE MATCH	YES, SET BAUD RATE
0253	017A 05C7		INCT POINT	NO, UPDATE POINTER
0254	017C 10FC		JMP BDLOOP	
0255	017E	MATCH	EQU \$	
0256	017E 3317		LDCR *POINT,12	INT. REC./XMT. DATA RATE
0257	0180 C1D7		MOV *POINT,POINT	
0258	0182 0287		CI POINT,>1A0	1200 BAUD ?
	0184 01A0			
0259	0186 1602		JNE BANNER	LEAVE ASR FLAG ALONE
0260	0188 0720		SETO @ASR	SET 733ASR FLAG
	018A FFF4			
0261	018C 2F45	BANNER	READ CHAR	
0262	018E 2FA0		MSG @LOGON	PRINT LOG ON MESSAGE
	0190 022B			
0263	0192 10DC		JMP JMMONT	TO TOP OF MONITOR
0264	0194 0040	TABLE	DATA >40,>D0	2400 BAUD
	0196 00D0			
0265	0198 0070		DATA >70,>1A0	1200 BAUD
	019A 01A0			
0266	019C 0200		DATA >200,>4D0	300 BAUD
	019E 04D0			
0267	01A0 0400		DATA >400,>638	110 BAUD
	01A2 0638			
0268	01A4 62	CR	BYTE >62	

TIBUG

TABLE 7 (Continued)

*** WRITE CHARACTER ***

```

0290 *****
0291 * WRITE CHARACTER -- XOP R,12
0292 *                                     --- NORMAL RETURN
0293 *
0294 * TRANSMIT THE CHARACTER IN THE LEFT BYTE OF
0295 * USER REGISTER R. IF THE CHARACTER IS A
0296 * CARRIAGE RETURN, THE ROUTINE WAITS 200 MSEC FOR
0297 * THE CARRIAGE TO RETURN. IF THE TERMINAL IS
0298 * A 733ASR AS DENOTED IN THE T COMMAND, EACH
0299 * CHARACTER IS PADDED WITH 25 MSEC TO REDUCE
0300 * THE TRANSFER RATE TO 300 BAUD.
0301 *****
0302 01B6 020A WENTRY LI R10,3750
      01B8 0EA6
0303 01BA 020C LI CRUBAS,>80 SET CRU BASE REG.
      01BC 0080
0304 01BE 1D10 SBO 16 SET RTSON
0305 01C0 1F16 TB 22 TRANSMIT BUFFER REG. EMPTY?
0306 01C2 16F9 JNE WENTRY NO, WAIT UNTIL IT IS
0307 01C4 321B LDCR *LINK,8 CHARACTER TO UART
0308 01C6 D2DB MOVB *LINK,LINK
0309 01C8 1E10 SBZ 16 RESET RTSON
0310 01CA 098B SRL LINK,8
0311 01CC 028B CI LINK,>000D CARRIAGE RETURN
      01CE 000D
0312 01D0 1608 JNE ASR733 NO, SKIP
0313 01D2 0A3A SLA R10,3
0314 01D4 1F16 WLOOP1 TB 22 WAIT FOR XMISSION TO END
0315 01D6 16FE JNE WLOOP1
0316 01D8 1F17 TB 23
0317 01DA 16FC JNE WLOOP1
0318 01DC 060A WLOOP2 DEC R10 WAIT LOOP
0319 01DE 16FE JNE WLOOP2
0320 01E0 0380 RTWP
0321 01E2 C2E0 ASR733 MOV @DUMPPFG,LINK IN DUMP ROUTINE ?
      01E4 FFF6
0322 01E6 1303 JEQ WEXIT YES,IGNORE ASR FLAG
0323 01E8 C2E0 MOV @ASR,LINK ASR733 ?
      01EA FFF4
0324 01EC 16F3 JNE WLOOP1 YES, WAIT 3 NULLS
0325 01EE 0380 WEXIT RTWP

```

TIBUG

*** READ CHARACTER ***

```

0271 *****
0272 * READ CHARACTER -- XOP R,13
0273 *                                     -- NORMAL RETURN
0274 *
0275 * READ WAITS FOR A CHARACTER TO BE ASSEMBLED IN
0276 * THE UART. THE CHARACTER IS PLACED IN THE LEFT
0277 * BYTE OF USER REGISTER R. THE RIGHT BYTE IS
0278 * ZEROED. ALL ERRORS ARE IGNORED.
0279 *****
0280 *
0281 01A6 020C RENTRY LI CRUBAS,>80 SET CRU BASE REG.
      01A8 0080
0282 01AA 1F15 TB 21 RECEIVE BUFFER REG. FULL?
0283 01AC 16FC JNE RENTRY NO, LOOP
0284 01AE 04DB CLR *LINK
0285 01B0 361B STCR *LINK,8
0286 01B2 1E12 SBZ 18
0287 01B4 0380 RTWP

```

4. TMS 9902A ELECTRICAL SPECIFICATIONS

4.1 ABSOLUTE MAXIMUM RATINGS OVER OPERATING FREE-AIR TEMPERATURE RANGE (UNLESS OTHERWISE NOTED)*

Supply voltage, V_{CC}	-0.3 V to 10 V
All inputs and output voltages	-0.3 V to 10 V
Continuous power dissipation	0.55 W
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C

* Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the "Recommended Operating Conditions" section of this specification is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

4.2 RECOMMENDED OPERATING CONDITIONS

PARAMETER	TMS 9902A			TMS 9902A-40			TMS 9902ANA			UNIT	
	MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX		
Supply voltage, V_{CC}	4.75	5	5.25	4.75	5	5.25	4.75	5	5.25	V	
Supply voltage, V_{SS}	0			0			0			V	
High-level input voltage, V_{IH}	2		V_{CC}	2		V_{CC}	2		2.2	V_{CC}	V
Low-level input voltage, V_{IL}	$V_{SS}-0.3$		0.8	$V_{SS}-0.3$		0.8	$V_{SS}-0.3$		0.6	0.8	V
Operating free-air temperature, T_A	0		70	0		70	-40		85	°C	

4.3 ELECTRICAL CHARACTERISTICS OVER FULL RANGE OF RECOMMENDED OPERATING CONDITIONS (UNLESS OTHERWISE NOTED)*

PARAMETER	TEST CONDITIONS	TMS 9902A		TMS 9902A-40		TMS 9902ANA		UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		MIN
V_{OH} High-level output voltage	$I_{OH} = -100 \mu A$	2.4	V_{CC}	2.4	V_{CC}	2.4	2.4	V_{CC}	V
	$I_{OH} = -200 \mu A$	2.2	V_{CC}	2.2	V_{CC}	2.2	V_{CC}	V_{CC}	
V_{OL} Low-level output voltage	$I_{OL} = 3.2 \text{ mA}$	V_{SS}	0.4	V_{SS}	0.4	V_{SS}	0.4	V_{SS}	V
I_L Input current (any input)	$V_I = 0 \text{ V to } V_{CC}$	± 10		± 10		± 10		± 10	μA
$I_{CC(AV)}$ Average supply current from V_{CC}	$t_{c(\phi)} = 330 \text{ ns}$, $T_A = 70^\circ C$	100		100		100		100	mA
C_i Small signal input capacitance	$f = 1 \text{ MHz}$	15		15		10		10	pF
C_o Large signal input capacitance		20		20		20		20	

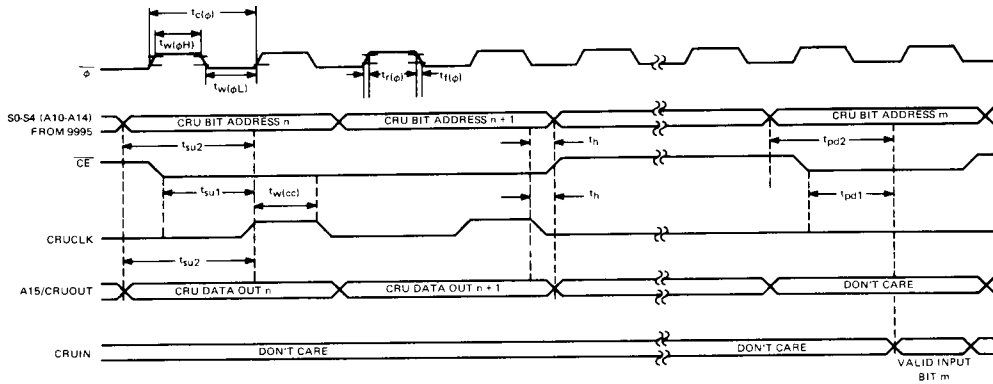
* All voltages are referenced to V_{SS} .

4.4 TIMING REQUIREMENTS OVER FULL RANGE OF OPERATING CONDITIONS

PARAMETER		TMS 9902A			TMS 9902A-40			TMS 9902ANA			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$t_{c(\phi)}$	Clock cycle time	300	333	667	240	250	360	300	333	667	ns
$t_{r(\phi)}$	Clock rise time			30			30			12	ns
$t_{f(\phi)}$	Clock fall time			30			30			12	ns
$t_{w(\phi H)}$	Clock pulse width (high level)	.45 t_c		.85 t_c	.45 t_c		.85 t_c	.45 t_c		.85 t_c	ns
$t_{w(\phi L)}$	Clock pulse width (low level)	.15 t_c		.55 t_c	.15 t_c		.55 t_c	.15 t_c		.55 t_c	ns
t_{su1}	Setup time for CE before CRUCLK			150			150			150 180	ns
t_{su2}	Setup time for S0-S4, CRUOUT before CRUCLK			180			180			180 220	ns
t_h	Hold time for CE, S0-S4, or CRUOUT after CRUCLK			25			25			25	ns
t_{wcc}	CRUCLK pulse width			.37 t_c			.37 t_c			.37 t_c 100	ns

4.5 SWITCHING CHARACTERISTICS OVER FULL RANGE OF RECOMMENDED OPERATING CONDITIONS

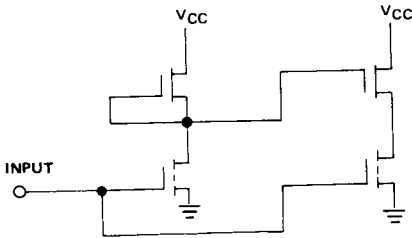
PARAMETER		TEST CONDITIONS	TMS 9902A			TMS 9902A-40			TMS 9902ANA			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_{pd1}	Propagation delay, CE to valid CRUIN	$C_L = 100 \text{ pF}$			240			165			400	ns
t_{pd2}	Propagation delay, S0-S4 to valid CRUIN				260			185			400	ns



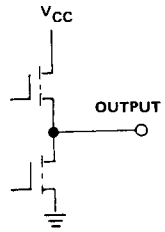
NOTE: ALL SWITCHING TIMES ARE ASSUMED TO BE AT 10% OR 90% VALUES.

SWITCHING CHARACTERISTICS

EQUIVALENT OF I/O INPUTS



EQUIVALENT OF I/O OUTPUTS

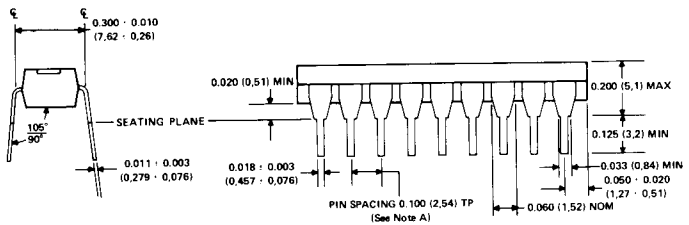
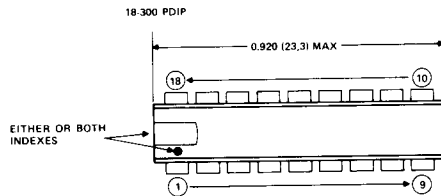
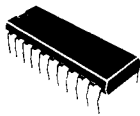


INPUT AND OUTPUT EQUIVALENTS

5. MECHANICAL SPECIFICATIONS

TMS 9902A NL

18 pin plastic packages



NOTES: A. Each pin centerline is located within 0.010 (0.26) of its true longitudinal position.
 B. All linear dimensions are in inches and parenthetically in millimeters. Inch dimensions govern.