SERIAL COMMUNICATION

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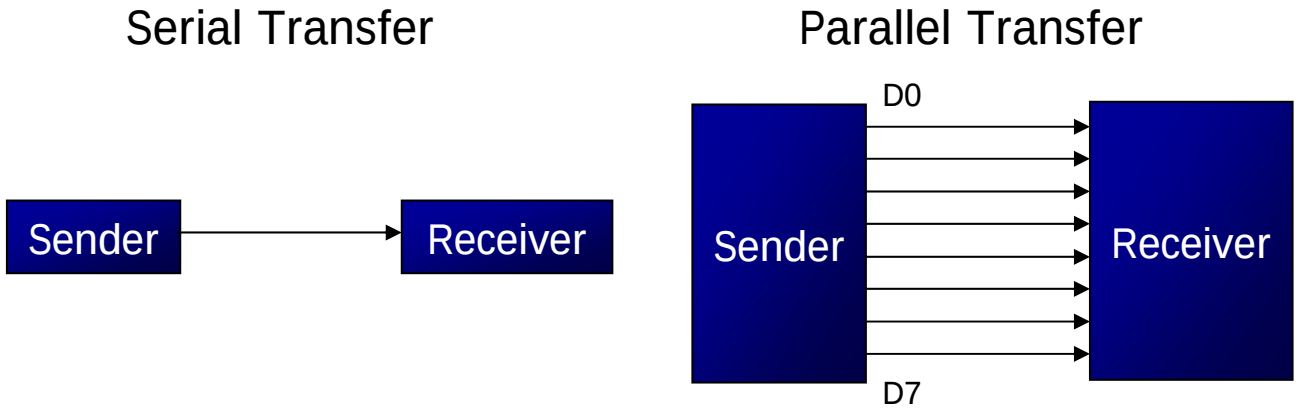
BASICS OF SERIAL COMMUNICA-TION

- Computers transfer data in two ways:
  - Parallel
    - Often 8 or more lines (wire conductors) are used to transfer data to a device that is only a few feet away
  - Serial
    - To transfer to a device located many meters away, the serial method is used
    - The data is sent one bit at a time



BASICS OF SERIAL COMMUNICA-TION (cont')

- At the transmitting end, the byte of data must be converted to serial bits using parallel-in-serial-out shift register
- At the receiving end, there is a serial-in-parallel-out shift register to receive the serial data and pack them into byte
- When the distance is short, the digital signal can be transferred as it is on a simple wire and requires no modulation
- If data is to be transferred on the telephone line, it must be converted from 0s and 1s to audio tones
  - This conversion is performed by a device called a *modem*, "Modulator/demodulator"

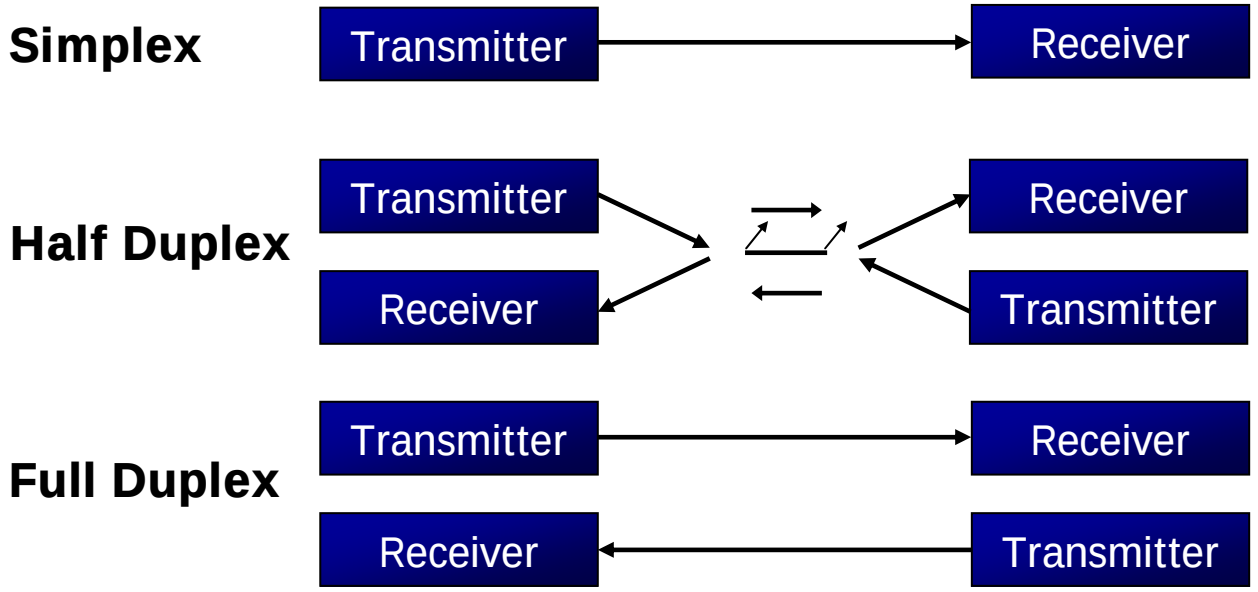
BASICS OF SERIAL COMMUNICA-TION (cont')

- Serial data communication uses two methods
  - *Synchronous* method transfers a block of data at a time
  - *Asynchronous* method transfers a single byte at a time
- It is possible to write software to use either of these methods, but the programs can be tedious and long
  - There are special IC chips made by many manufacturers for serial communications
    - UART (universal asynchronous Receiver-transmitter)
    - USART (universal synchronous-asynchronous Receiver-transmitter)

BASICS OF SERIAL COMMUNICA-TION

Half- and Full-Duplex Transmission

- If data can be transmitted and received, it is a *duplex* transmission
  - If data transmitted one way a time, it is referred to as *half duplex*
  - If data can go both ways at a time, it is *full duplex*
- This is contrast to *simplex* transmission



BASICS OF SERIAL COMMUNICA-TION

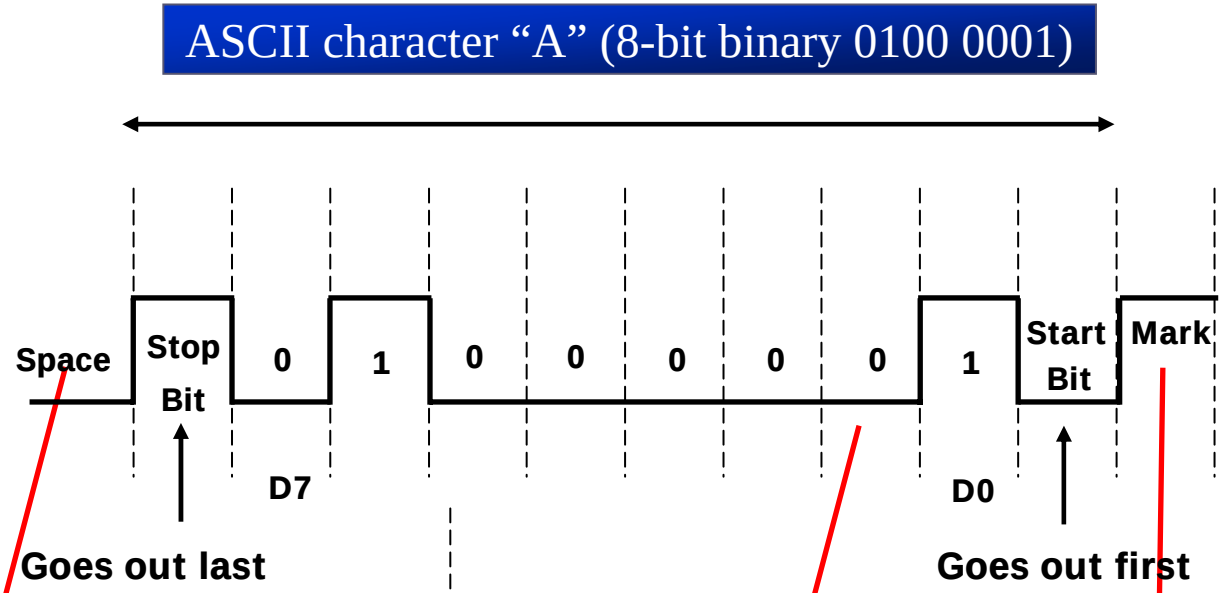
Start and Stop Bits

- A *protocol* is a set of rules agreed by both the sender and receiver on
  - How the data is packed
  - How many bits constitute a character
  - When the data begins and ends
- Asynchronous serial data communication is widely used for character-oriented transmissions
  - Each character is placed in between start and stop bits, this is called *framing*
  - Block-oriented data transfers use the synchronous method
- The start bit is always one bit, but the stop bit can be one or two bits

BASICS OF SERIAL COMMUNICA-TION

Start and Stop Bits (cont')

- The start bit is always a 0 (low) and the stop bit(s) is 1 (high)



The 0 (low) is referred to as *space*

The transmission begins with a start bit followed by D0, the LSB, then the rest of the bits until MSB (D7), and finally, the one stop bit indicating the end of the character

When there is no transfer, the signal is 1 (high), which is referred to as *mark*

SERIAL COMMUNICA-TION PROGRAMMING (cont')

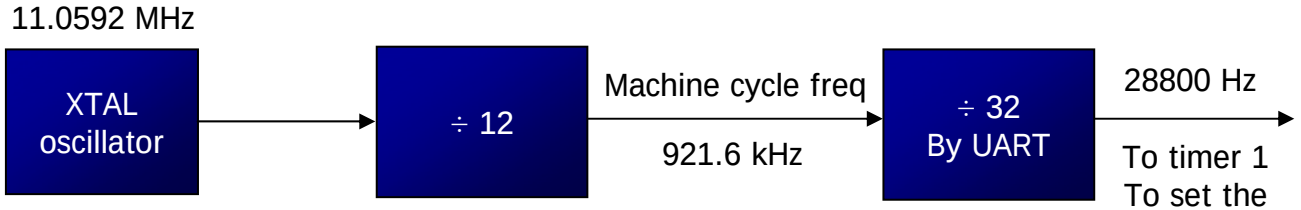
With XTAL = 11.0592 MHz, find the TH1 value needed to have the following baud rates. (a) 9600 (b) 2400 (c) 1200

Solution:

The machine cycle frequency of 8051 = 11.0592 / 12 = 921.6 kHz, and 921.6 kHz / 32 = 28,800 Hz is frequency by UART to timer 1 to set baud rate.

(a) 28,800 / 3 = 9600 where -3 = FD (hex) is loaded into TH1
(b) 28,800 / 12 = 2400 where -12 = F4 (hex) is loaded into TH1
(c) 28,800 / 24 = 1200 where -24 = E8 (hex) is loaded into TH1

Notice that dividing 1/12 of the crystal frequency by 32 is the default value upon activation of the 8051 RESET pin.



Baud Rate	TH1 (Decimal)	TH1 (Hex)
9600	-3	FD
4800	-6	FA
2400	-12	F4
1200	-24	E8

TF is set to 1 every 12 ticks, so it functions as a frequency divider

SERIAL COMMUNICA-TION PROGRAMMING

SBUF Register

- SBUF is an 8-bit register used solely for serial communication
  - For a byte data to be transferred via the TxD line, it must be placed in the SBUF register
    - The moment a byte is written into SBUF, it is framed with the start and stop bits and transferred serially via the TxD line
  - SBUF holds the byte of data when it is received by 8051 RxD line
    - When the bits are received serially via RxD, the 8051 deframes it by eliminating the stop and start bits, making a byte out of the data received, and then placing it in SBUF

```
MOV SBUF,#'D'   ;load SBUF=44h, ASCII for 'D'
MOV SBUF,A      ;copy accumulator into SBUF
MOV A,SBUF      ;copy SBUF into accumulator
```

SERIAL COMMUNICA-TION PROGRAMMING

SCON Register

- SCON is an 8-bit register used to program the start bit, stop bit, and data bits of data framing, among other things

SM0	SM1	SM2	REN	TB8	RB8	TI	RI

SM0	SCON.7	Serial port mode specifier
SM1	SCON.6	Serial port mode specifier
SM2	SCON.5	Used for multiprocessor communication
REN	SCON.4	Set/cleared by software to enable/disable reception
TB8	SCON.3	Not widely used
RB8	SCON.2	Not widely used
TI	SCON.1	Transmit interrupt flag. Set by HW at the begin of the stop bit mode 1. And cleared by SW
RI	SCON.0	Receive interrupt flag. Set by HW at the begin of the stop bit mode 1. And cleared by SW

Note: *Make SM2, TB8, and RB8 =0*

SERIAL COMMUNICA-TION PROGRAMMING

SCON Register (cont')

- SM0, SM1
  - They determine the framing of data by specifying the number of bits per character, and the start and stop bits

SM0	SM1	
0	0	Serial Mode 0
0	**1**	**Serial Mode 1, 8-bit data, 1 stop bit, 1 start bit**
1	0	Serial Mode 2
1	1	Serial Mode 3

Only mode 1 is of interest to us

- SM2
  - This enables the multiprocessing capability of the 8051

SERIAL COMMUNICA-TION PROGRAMMING

SCON Register (cont')

- REN (receive enable)
  - It is a bit-adressable register
    - When it is high, it allows 8051 to receive data on RxD pin
    - If low, the receiver is disable
- TI (transmit interrupt)
  - When 8051 finishes the transfer of 8-bit character
    - It raises TI flag to indicate that it is ready to transfer another byte
    - TI bit is raised at the beginning of the stop bit
- RI (receive interrupt)
  - When 8051 receives data serially via RxD, it gets rid of the start and stop bits and places the byte in SBUF register
    - It raises the RI flag bit to indicate that a byte has been received and should be picked up before it is lost
    - RI is raised halfway through the stop bit

SERIAL COMMUNICA-TION PROGRAMMING

Programming Serial Data Transmitting

- In programming the 8051 to transfer character bytes serially
  1. TMOD register is loaded with the value 20H, indicating the use of timer 1 in mode 2 (8-bit auto-reload) to set baud rate
  2. The TH1 is loaded with one of the values to set baud rate for serial data transfer
  3. The SCON register is loaded with the value 50H, indicating serial mode 1, where an 8-bit data is framed with start and stop bits
  4. TR1 is set to 1 to start timer 1
  5. TI is cleared by `CLR TI` instruction
  6. The character byte to be transferred serially is written into SBUF register
  7. The TI flag bit is monitored with the use of instruction `JNB TI,xx` to see if the character has been transferred completely
  8. To transfer the next byte, go to step 5

SERIAL COMMUNICA-TION PROGRAMMING

Programming Serial Data Transmitting (cont')

Write a program for the 8051 to transfer letter "A" serially at 4800 baud, continuously.

Solution:

```
        MOV  TMOD,#20H  ;timer 1,mode 2(auto reload)
        MOV  TH1,#-6    ;4800 baud rate
        MOV  SCON,#50H  ;8-bit, 1 stop, REN enabled
        SETB TR1        ;start timer 1
AGAIN:  MOV  SBUF,#"A"  ;letter "A" to transfer
HERE:   JNB  TI,HERE    ;wait for the last bit
        CLR  TI         ;clear TI for next char
        SJMP AGAIN      ;keep sending A
```

SERIAL COMMUNICA-TION PROGRAMMING

Programming Serial Data Transmitting (cont')

Write a program for the 8051 to transfer "YES" serially at 9600 baud, 8-bit data, 1 stop bit, do this continuously

Solution:

```
        MOV  TMOD,#20H  ;timer 1,mode 2(auto reload)
        MOV  TH1,#-3    ;9600 baud rate
        MOV  SCON,#50H  ;8-bit, 1 stop, REN enabled
        SETB TR1        ;start timer 1
AGAIN:  MOV  A,#"Y"     ;transfer "Y"
        ACALL TRANS
        MOV  A,#"E"     ;transfer "E"
        ACALL TRANS
        MOV  A,#"S"     ;transfer "S"
        ACALL TRANS
        SJMP AGAIN      ;keep doing it
;serial data transfer subroutine
TRANS:  MOV  SBUF,A     ;load SBUF
HERE:   JNB  TI,HERE    ;wait for the last bit
        CLR  TI         ;get ready for next byte
         RET
```

SERIAL COMMUNICA-TION PROGRAMMING

Importance of TI Flag

- The steps that 8051 goes through in transmitting a character via TxD
  1. The byte character to be transmitted is written into the SBUF register
  2. The start bit is transferred
  3. The 8-bit character is transferred on bit at a time
  4. The stop bit is transferred
     - It is during the transfer of the stop bit that 8051 raises the TI flag, indicating that the last character was transmitted
  5. By monitoring the TI flag, we make sure that we are not overloading the SBUF
     - If we write another byte into the SBUF before TI is raised, the untransmitted portion of the previous byte will be lost
  6. After SBUF is loaded with a new byte, the TI flag bit must be forced to 0 by `CLR TI` in order for this new byte to be transferred

SERIAL COMMUNICA-TION PROGRAMMING

Importance of TI Flag (cont')

- By checking the TI flag bit, we know whether or not the 8051 is ready to transfer another byte
  - It must be noted that TI flag bit is raised by 8051 itself when it finishes data transfer
  - It must be cleared by the programmer with instruction `CLR TI`
  - If we write a byte into SBUF before the TI flag bit is raised, we risk the loss of a portion of the byte being transferred
- The TI bit can be checked by
  - The instruction `JNB TI,xx`
  - Using an interrupt

SERIAL COMMUNICA-TION PROGRAMMING

Programming Serial Data Receiving

- In programming the 8051 to receive character bytes serially
  1. TMOD register is loaded with the value 20H, indicating the use of timer 1 in mode 2 (8-bit auto-reload) to set baud rate
  2. TH1 is loaded to set baud rate
  3. The SCON register is loaded with the value 50H, indicating serial mode 1, where an 8-bit data is framed with start and stop bits
  4. TR1 is set to 1 to start timer 1
  5. RI is cleared by `CLR RI` instruction
  6. The RI flag bit is monitored with the use of instruction `JNB RI,xx` to see if an entire character has been received yet
  7. When RI is raised, SBUF has the byte, its contents are moved into a safe place
  8. To receive the next character, go to step 5

SERIAL COMMUNICA-TION PROGRAMMING

Programming Serial Data Receiving (cont')

Write a program for the 8051 to receive bytes of data serially, and put them in P1, set the baud rate at 4800, 8-bit data, and 1 stop bit

Solution:

```
        MOV  TMOD,#20H  ;timer 1,mode 2(auto reload)
        MOV  TH1,#-6    ;4800 baud rate
        MOV  SCON,#50H  ;8-bit, 1 stop, REN enabled
        SETB TR1        ;start timer 1
HERE:   JNB  RI,HERE    ;wait for char to come in
        MOV  A,SBUF     ;saving incoming byte in A
        MOV  P1,A       ;send to port 1
        CLR  RI         ;get ready to receive next
                        ;byte
        SJMP HERE       ;keep getting data
```

SERIAL COMMUNICA-TION PROGRAMMING

Programming Serial Data Receiving (cont')

Example 10-5

Assume that the 8051 serial port is connected to the COM port of IBM PC, and on the PC, we are using the terminal.exe program to send and receive data serially. P1 and P2 of the 8051 are connected to LEDs and switches, respectively. Write an 8051 program to (a) send to PC the message "We Are Ready", (b) receive any data send by PC and put it on LEDs connected to P1, and (c) get data on switches connected to P2 and send it to PC serially. The program should perform part (a) once, but parts (b) and (c) continuously, use 4800 baud rate.

Solution:

```
        ORG   0
        MOV   P2,#0FFH    ;make P2 an input port
        MOV   TMOD,#20H   ;timer 1, mode 2
        MOV   TH1,#0FAH   ;4800 baud rate
        MOV   SCON,#50H   ;8-bit, 1 stop, REN enabled
        SETB  TR1         ;start timer 1
        MOV   DPTR,#MYDATA ;load pointer for message
H_1:    CLR   A
        MOV   A,@A+DPTR   ;get the character
...
```

SERIAL COMMUNICA-TION PROGRAMMING

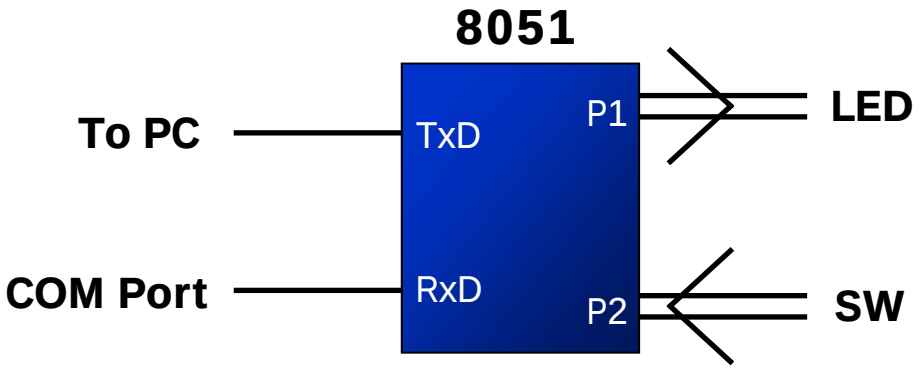
Programming Serial Data Receiving (cont')

Example 10-5 (cont')

```
        JZ   B_1          ;if last character get out
        ACALL SEND        ;otherwise call transfer
        INC  DPTR         ;next one
        SJMP H_1          ;stay in loop
B_1:    MOV  a,P2         ;read data on P2
        ACALL SEND        ;transfer it serially
        ACALL RECV        ;get the serial data
        MOV  P1,A         ;display it on LEDs
        SJMP B_1          ;stay in loop indefinitely
;----serial data transfer. ACC has the data------
SEND:   MOV  SBUF,A       ;load the data
H_2:    JNB  TI,H_2       ;stay here until last bit
                          ;gone
        CLR  TI           ;get ready for next char
        RET               ;return to caller
;----Receive data serially in ACC----------------
RECV:   JNB  RI,RECV      ;wait here for char
        MOV  A,SBUF       ;save it in ACC
        CLR  RI           ;get ready for next char
        RET               ;return to caller
...
```

Example 10-5 (cont')

```
;-----The message---------------
MYDATA: DB   "We Are Ready",0
        END
```



SERIAL COMMUNICA-TION PROGRAMMING

Importance of RI Flag

- In receiving bit via its RxD pin, 8051 goes through the following steps
  1. It receives the start bit
     - Indicating that the next bit is the first bit of the character byte it is about to receive
  2. The 8-bit character is received one bit at time
  3. The stop bit is received
     - When receiving the stop bit 8051 makes RI = 1, indicating that an entire character byte has been received and must be picked up before it gets overwritten by an incoming character

SERIAL COMMUNICA-TION PROGRAMMING

Importance of RI Flag (cont')

(cont')

4. By checking the RI flag bit when it is raised, we know that a character has been received and is sitting in the SBUF register
   - We copy the SBUF contents to a safe place in some other register or memory before it is lost
5. After the SBUF contents are copied into a safe place, the RI flag bit must be forced to 0 by `CLR RI` in order to allow the next received character byte to be placed in SBUF
   - Failure to do this causes loss of the received character

SERIAL COMMUNICA-TION PROGRAMMING

Importance of RI Flag (cont')

- By checking the RI flag bit, we know whether or not the 8051 received a character byte
  - If we failed to copy SBUF into a safe place, we risk the loss of the received byte
  - It must be noted that RI flag bit is raised by 8051 when it finish receive data
  - It must be cleared by the programmer with instruction `CLR RI`
  - If we copy SBUF into a safe place before the RI flag bit is raised, we risk copying garbage
- The RI bit can be checked by
  - The instruction `JNB RI,xx`
  - Using an interrupt

SERIAL COMMUNICA-TION PROGRAMMING

Doubling Baud Rate

- There are two ways to increase the baud rate of data transfer
  - To use a higher frequency crystal
  - To change a bit in the PCON register

The system crystal is fixed

- PCON register is an 8-bit register
  - When 8051 is powered up, SMOD is zero
  - We can set it to high by software and thereby double the baud rate

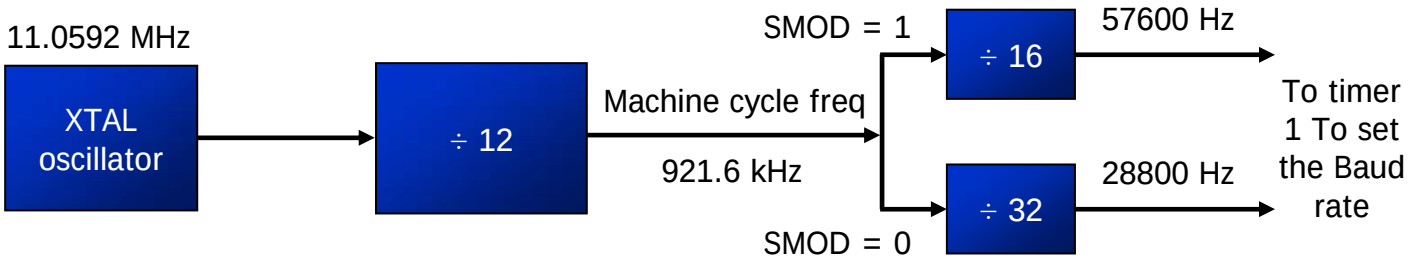
SMOD	--	--	--	GF1	GF0	PD	IDL

It is not a bit-addressable register

```
MOV  A,PCON     ;place a copy of PCON in ACC
SETB ACC.7      ;make D7=1
MOV  PCON,A     ;changing any other bits
```

SERIAL COMMUNICA-TION PROGRAMMING

Doubling Baud Rate (cont')



Baud Rate comparison for SMOD=0 and SMOD=1

TH1	(Decimal)	(Hex)	SMOD=0	SMOD=1
	-3	FD	9600	19200
	-6	FA	4800	9600
	-12	F4	2400	4800
	-24	E8	1200	2400

SERIAL COMMUNICA-TION PROGRAMMING

Doubling Baud Rate (cont')

Example 10-6

Assume that XTAL = 11.0592 MHz for the following program, state (a) what this program does, (b) compute the frequency used by timer 1 to set the baud rate, and (c) find the baud rate of the data transfer.

```
        MOV   A,PCON      ;A=PCON
        MOV   ACC.7       ;make D7=1
        MOV   PCON,A      ;SMOD=1, double baud rate
                          ;with same XTAL freq.
        MOV   TMOD,#20H   ;timer 1, mode 2
        MOV   TH1,-3      ;19200 (57600/3 =19200)
        MOV   SCON,#50H   ;8-bit data, 1 stop bit, RI
                          ;enabled
        SETB  TR1         ;start timer 1
        MOV   A,#"B"      ;transfer letter B
A_1:    CLR   TI          ;make sure TI=0
        MOV   SBUF,A      ;transfer it
H_1:    JNB   TI,H_1      ;stay here until the last
                          ;bit is gone
        SJMP  A_1         ;keep sending "B" again
```

SERIAL COMMUNICA-TION PROGRAMMING

Doubling Baud Rate (cont')

Example 10-6 (cont')

Solution:

```
(a) This program transfers ASCII letter B (01000010
    binary) continuously
(b) With XTAL = 11.0592 MHz and SMOD = 1 in the
    above program, we have:

11.0592 / 12 = 921.6 kHz machine cycle frequency.
921.6 / 16 = 57,600 Hz frequency used by timer 1
to set the baud rate.
57600 / 3 = 19,200, the baud rate.
```

Find the TH1 value (in both decimal and hex) to set the baud rate to each of the following. (a) 9600 (b) 4800 if SMOD=1. Assume that XTAL 11.0592 MHz

Solution:

With XTAL = 11.0592 and SMOD = 1, we have timer frequency = 57,600 Hz.

(a) 57600 / 9600 = 6; so TH1 = -6 or TH1 = FAH

(b) 57600 / 4800 = 12; so TH1 = -12 or TH1 = F4H

SERIAL COMMUNICA-TION PROGRAMMING

Doubling Baud Rate (cont')

Example 10-8
Find the baud rate if TH1 = -2, SMOD = 1, and XTAL = 11.0592 MHz. Is this baud rate supported by IBM compatible PCs?

Solution:
With XTAL = 11.0592 and SMOD = 1, we have timer frequency = 57,600 Hz. The baud rate is 57,600/2 = 28,800. This baud rate is not supported by the BIOS of the PCs; however, the PC can be programmed to do data transfer at such a speed. Also, HyperTerminal in Windows supports this and other baud rates.

SERIAL COMMUNICA-TION PROGRAMMING

Doubling Baud Rate (cont')

Example 10-10

Write a program to send the message "The Earth is but One Country" to serial port. Assume a SW is connected to pin P1.2. Monitor its status and set the baud rate as follows:
SW = 0, 4800 baud rate
SW = 1, 9600 baud rate
Assume XTAL = 11.0592 MHz, 8-bit data, and 1 stop bit.

Solution:

```
        SW    BIT P1.2
        ORG   0H          ;starting position
MAIN:
        MOV   TMOD,#20H
        MOV   TH1,#-6     ;4800 baud rate (default)
        MOV   SCON,#50H
        SETB  TR1
        SETB  SW          ;make SW an input
S1:     JNB   SW,SLOWSP   ;check SW status
        MOV   A,PCON      ;read PCON
        SETB  ACC.7       ;set SMOD high for 9600
        MOV   PCON,A      ;write PCON
        SJMP  OVER        ;send message
.....
```

SERIAL COMMUNICA-TION PROGRAMMING

Doubling Baud Rate (cont')

```
.....

SLOWSP:
        MOV   A,PCON      ;read PCON
        SETB  ACC.7       ;set SMOD low for 4800
        MOV   PCON,A      ;write PCON
OVER:   MOV   DPTR,#MESS1 ;load address to message
FN:     CLR   A
        MOVC  A,@A+DPTR   ;read value
        JZ    S1          ;check for end of line
        ACALL SENDCOM     ;send value to serial port
        INC   DPTR        ;move to next value
        SJMP  FN          ;repeat
;------------
SENDCOM:
        MOV   SBUF,A      ;place value in buffer
HERE:   JNB   TI,HERE     ;wait until transmitted
        CLR   TI          ;clear
        RET               ;return

;------------
MESS1: DB "The Earth is but One Country",0
        END
```