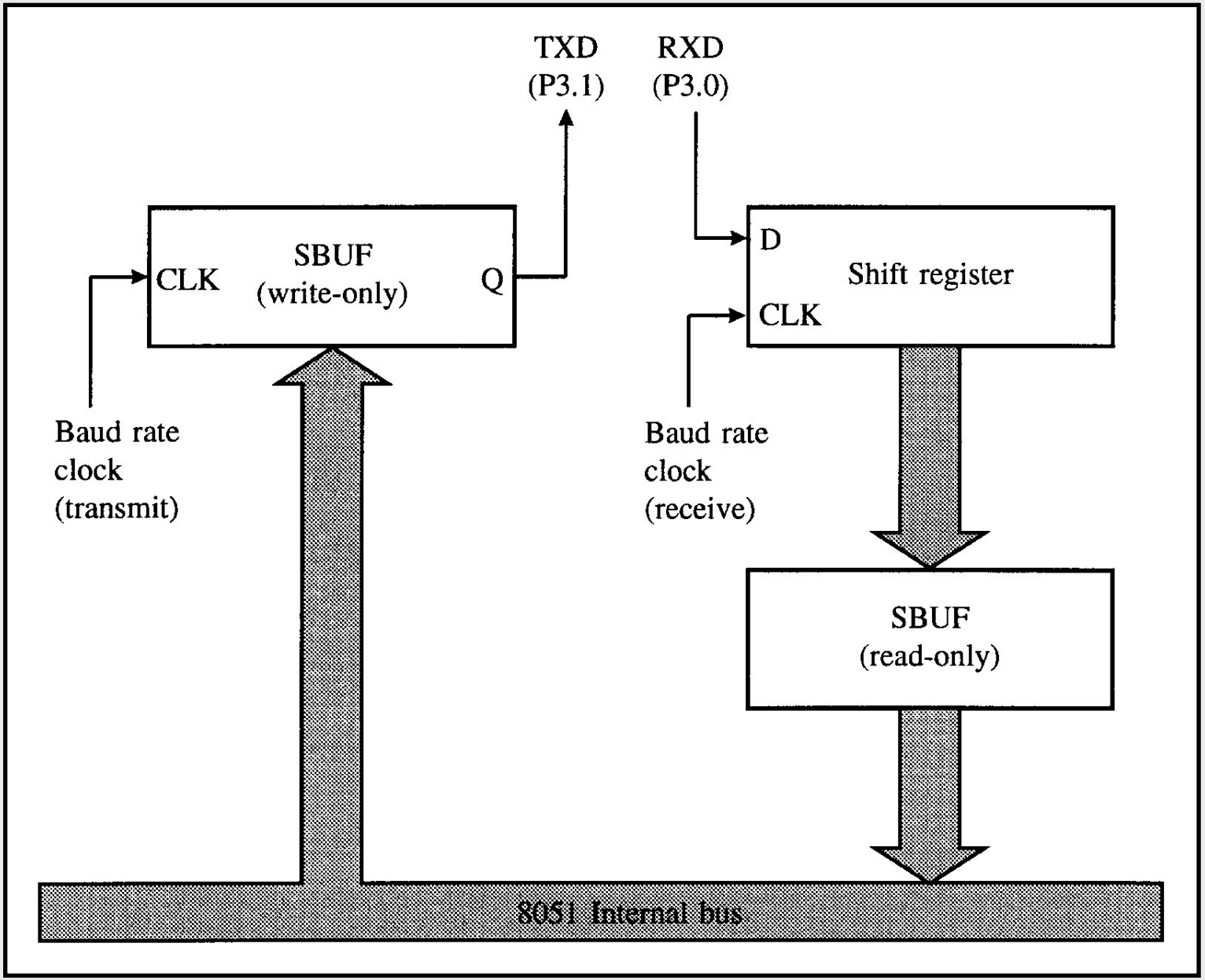
8051 serial port operation

introduction

- output data : parallel-to-serial conversion
- input data : serial-to-parallel conversion
- hardware access by TXD, and RXD bits
- full-duplex operation
- receive buffering
- software access by SBUF, and SCON
- frequency of operation can be fixed (on-chip oscillator) or variable (Timer 1 should be programmed accordingly)

serial port block diagram



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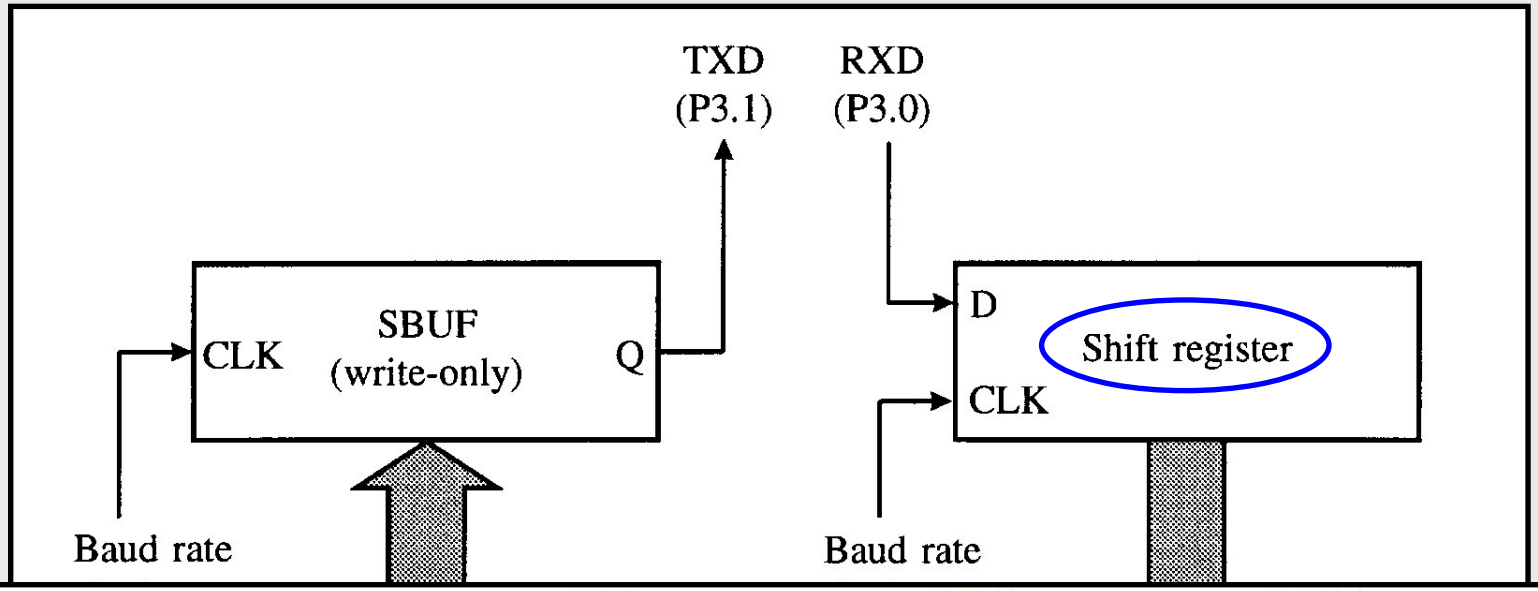

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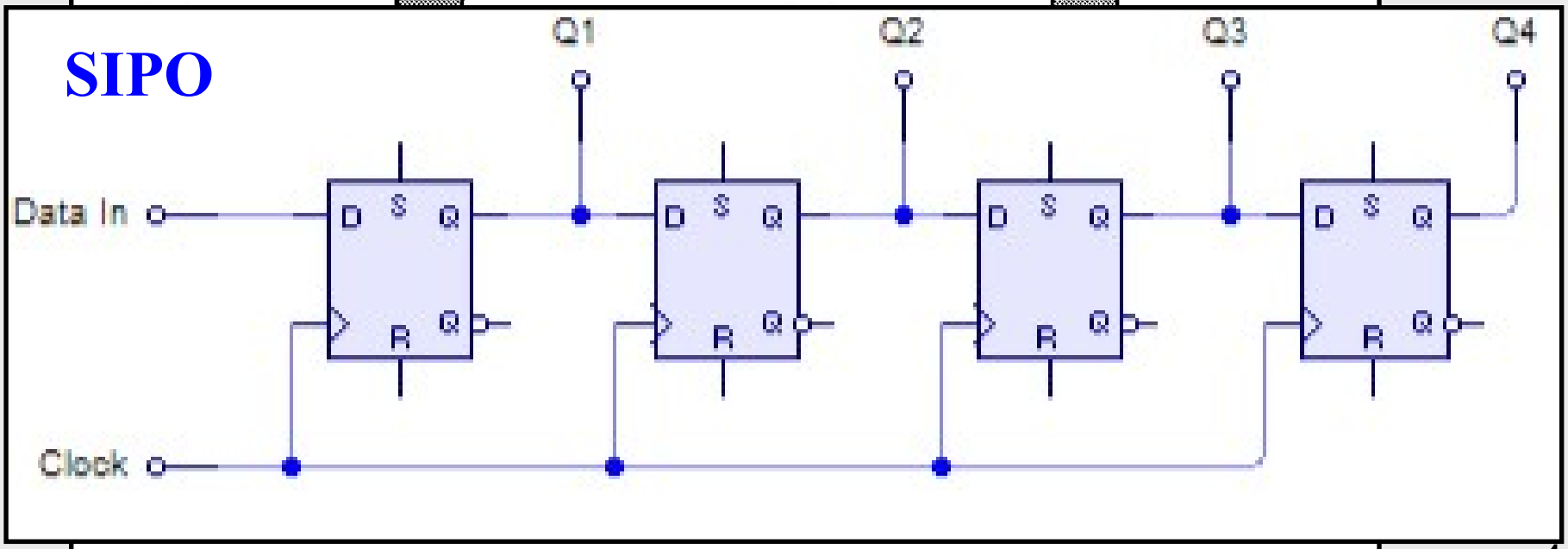

Serial port CONtrol register

SCON (serial port control) register summary

BIT	SYMBOL	ADDRESS	DESCRIPTION
SCON.7	SM0	9FH	Serial port mode bit 0 (see Table 5–2)
SCON.6	SM1	9EH	Serial port mode bit 1 (see Table 5–2)
SCON.5	SM2	9DH	Serial port mode bit 2. Enables multiprocessor communications in modes 2 & 3; RI will not be activated if received 9th bit is 0
SCON.4	REN	9CH	Receiver enable. Must be set to receive characters
SCON.3	TB8	9BH	Transmit bit 8. 9th bit transmitted in modes 2 and 3; set/cleared by software
SCON.2	RB8	9AH	Receive bit 8. 9th bit received
SCON.1	TI	99H	Transmit interrupt flag. Set at end of character transmission; cleared by software
SCON.0	RI	98H	Receive interrupt flag. Set at end of character reception; cleared by software

Serial port modes

SM0	SM1	MODE	DESCRIPTION	BAUD RATE
0	0	0	Shift register	Fixed (oscillator frequency ÷ 12)
0	1	1	8-bit UART	Variable (set by timer)
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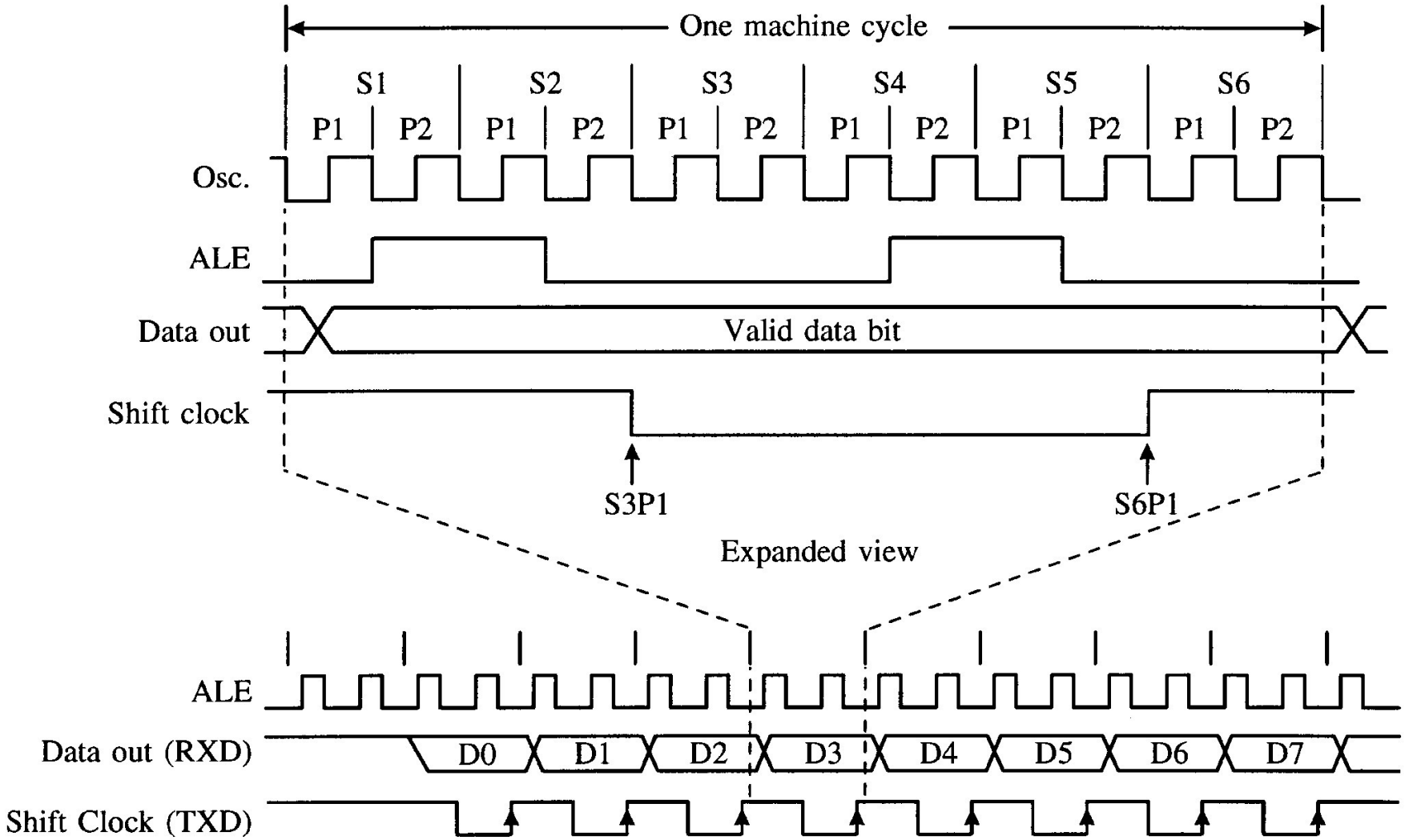
8-bit shift register (mode 0)

- serial data enter and exit through RXD
- TXD outputs the shift clock
- 8-bit transmission (LSB first)
- baud rate is fixed at 1/12 oscillator frequency

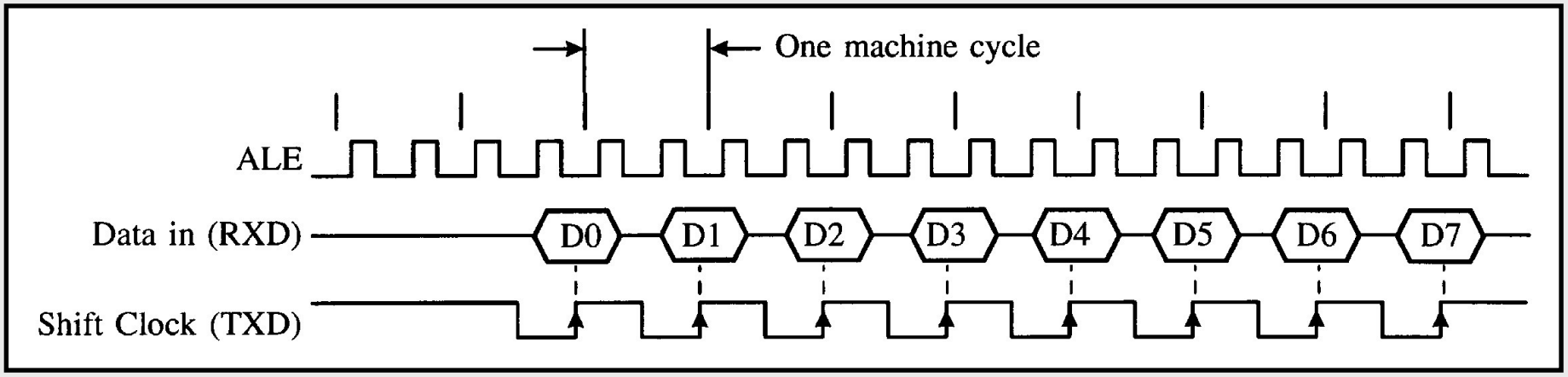
8-bit shift register (mode 0) (transmit)



initiated by any instruction that writes to SBUF

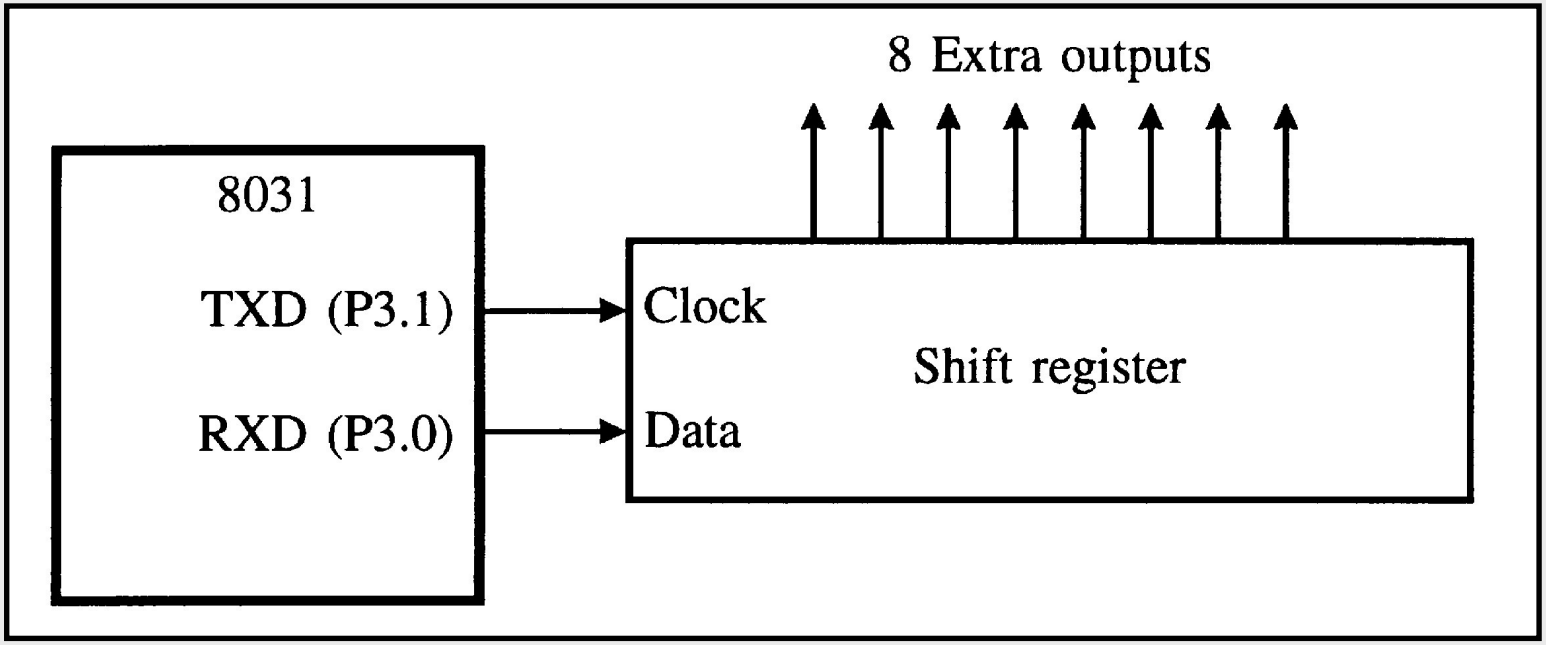
8-bit shift register (mode 0) (receive)

Receiption enabled : REN = 1, and RI = 0



- set REN at the beginning of program (initialize)
- clear RI (begin data input operation)
- clock pulses on TXD, data clocked in RXD

expanding output capability of 8051



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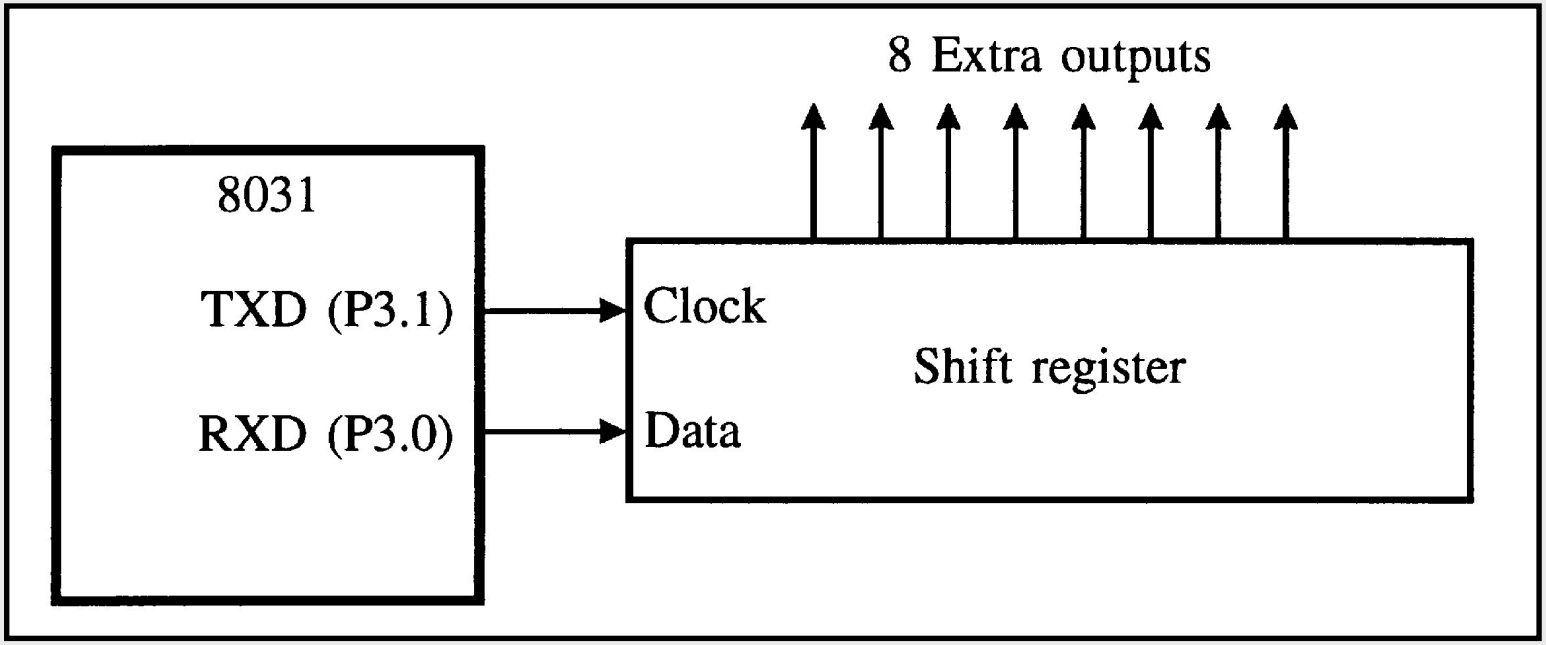
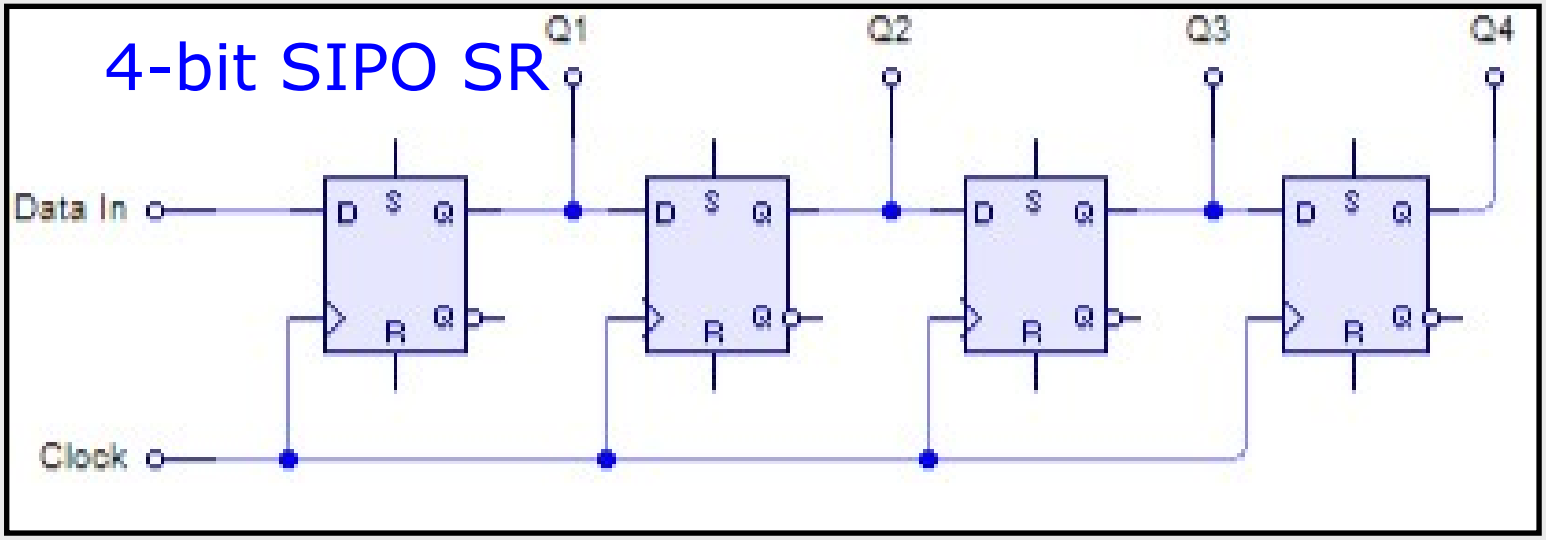
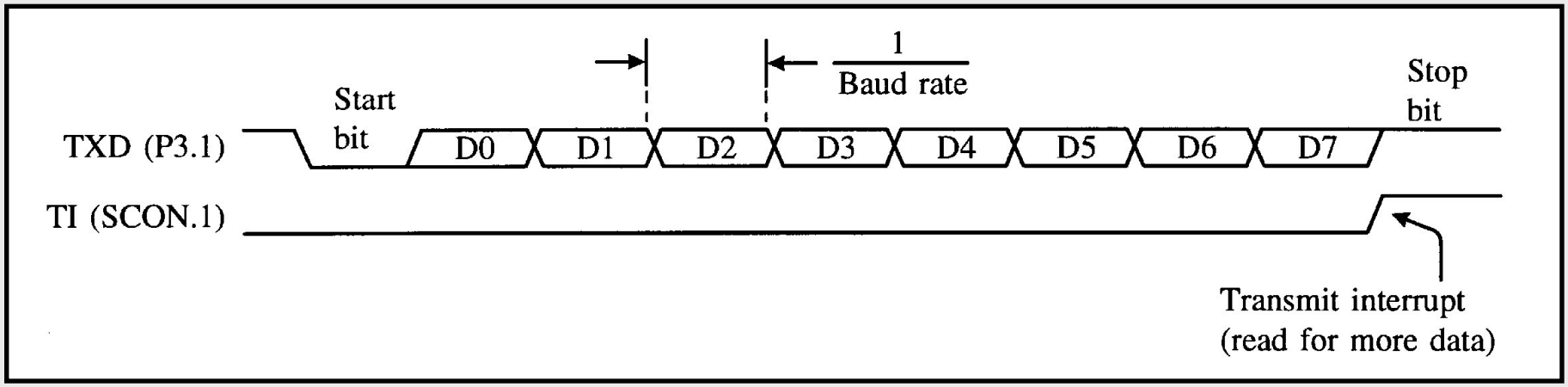




8-bit UART with variable baud rate (mode 1)

- Universal Asynchronous Receiver/Transmitter
- each character has start bit (low), stop bit (high)
- parity bit may be used between last bit & stop bit
- parallel-to-serial conversion for output data
- serial-to-parallel conversion for input data
- 10 bits are transmitted on TXD
- 10 bits are received on RXD
- stop bit goes into RB8 in SCON (receive mode)

8-bit UART with variable baud rate (mode 1)



- transmission is initiated by writing to SBUF
- TI is set with stop bit on TXD
- reception is initiated with 1-to-0 transmission on RXD

8-bit UART with variable baud rate (mode 1)

- false start bit detection on the receiver side by requiring a stop bit after eight counts following a 1-to-0 transition
- else receiver is assumed to be triggered by noise and returns to idle state
- if no problem, stop bit is clocked into RB8
- SBUF gets loaded with 8 data bits
- RI is set

- when RI = 0 AND
- SM2 = 1 & stop bit = 1 OR SM2 = 0

Serial port modes

SM0	SM1	MODE	DESCRIPTION	BAUD RATE
0	0	0	Shift register	Fixed (oscillator frequency ÷ 12)
0	1	1	8-bit UART	Variable (set by timer)
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multiprocessor communication

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9-bit UART with fixed baud rate (mode 2)

- 9-bit UART with fixed baud rate
- 11 bits are transmitted and received
- 9^{th} data bit is programmable (e.g. parity bit)
- on transmission, 9^{th} bit is placed in TB8
- on receivement, 9^{th} bit is placed in RB8
- baud rate is either 1/32 or 1/64 of on-chip oscillator frequency

9-bit UART with variable baud rate (mode 3)

- similar to mode 2, but baud rate is programmable and provided by timer

initialization and accessing serial port registers

receiver enable

```
SETB    REN
```

```
MOV     SCON, #xxx1xxxxB
```

9th data bit

- loaded into TB8 by software for transmission
- received bit is written on RB8

even parity on 9th data bit

```
MOV     C, P
MOV     TB8, C
MOV     SBUF, A
```

odd parity on 9th data bit

```
MOV     C, P
CPL     C
MOV     TB8, C
MOV     SBUF, A
```

initialization and accessing serial port registers

even parity on 8th data bit

```
CLR     ACC.7       ; ensure MSB clear
MOV     C, P        ; copy to C
MOV     ACC.7, C    ; even parity into MSB
MOV     SBUF, A     ; send {7bits+even parity}
```

interrupt flags (RI, TI)

- set by hardware
- cleared by software

initialization and accessing serial port registers

even parity on 8th data bit

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CLR     ACC.7      ; ensure MSB clear
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```

interrupt flags (RI, TI)

- set by hardware
- cleared by software

receive buffer full

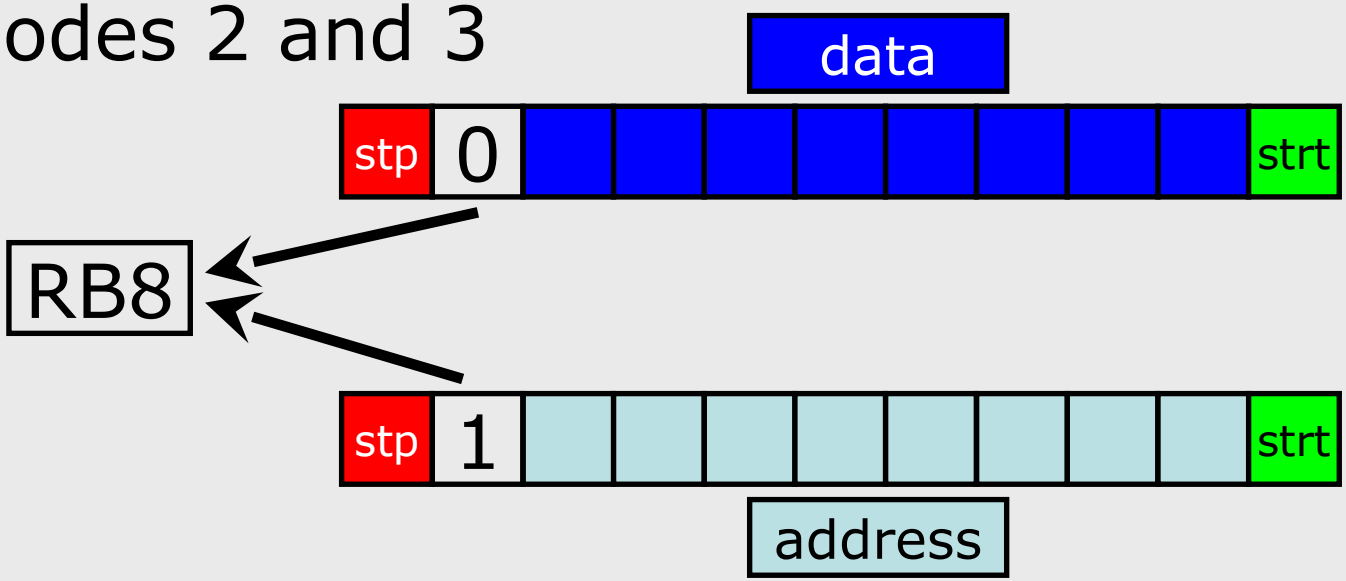
```
WAIT:  JNB   RI, WAIT
       CLR   RI
       MOV   A, SBUF
```

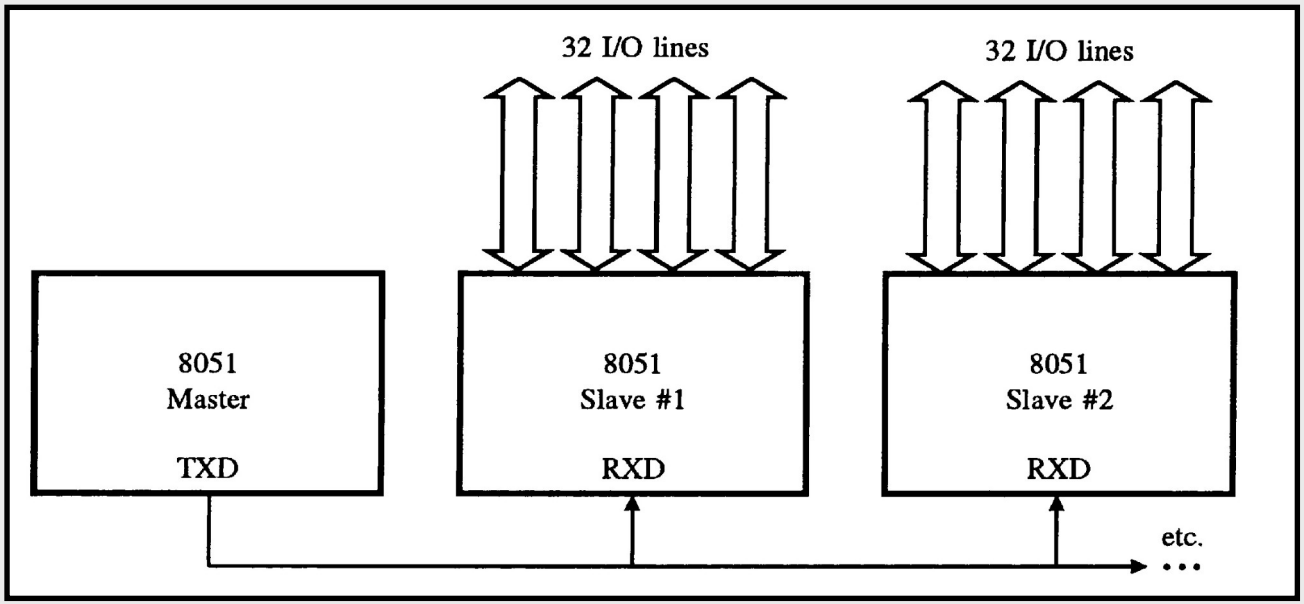
transmit buffer empty

```
WAIT:  JNB   TI, WAIT
       CLR   TI
       MOV   SBUF, A
```

multiprocessor communications

- for modes 2 and 3





addressed slave clears its SM2 bit

serial port baud rates

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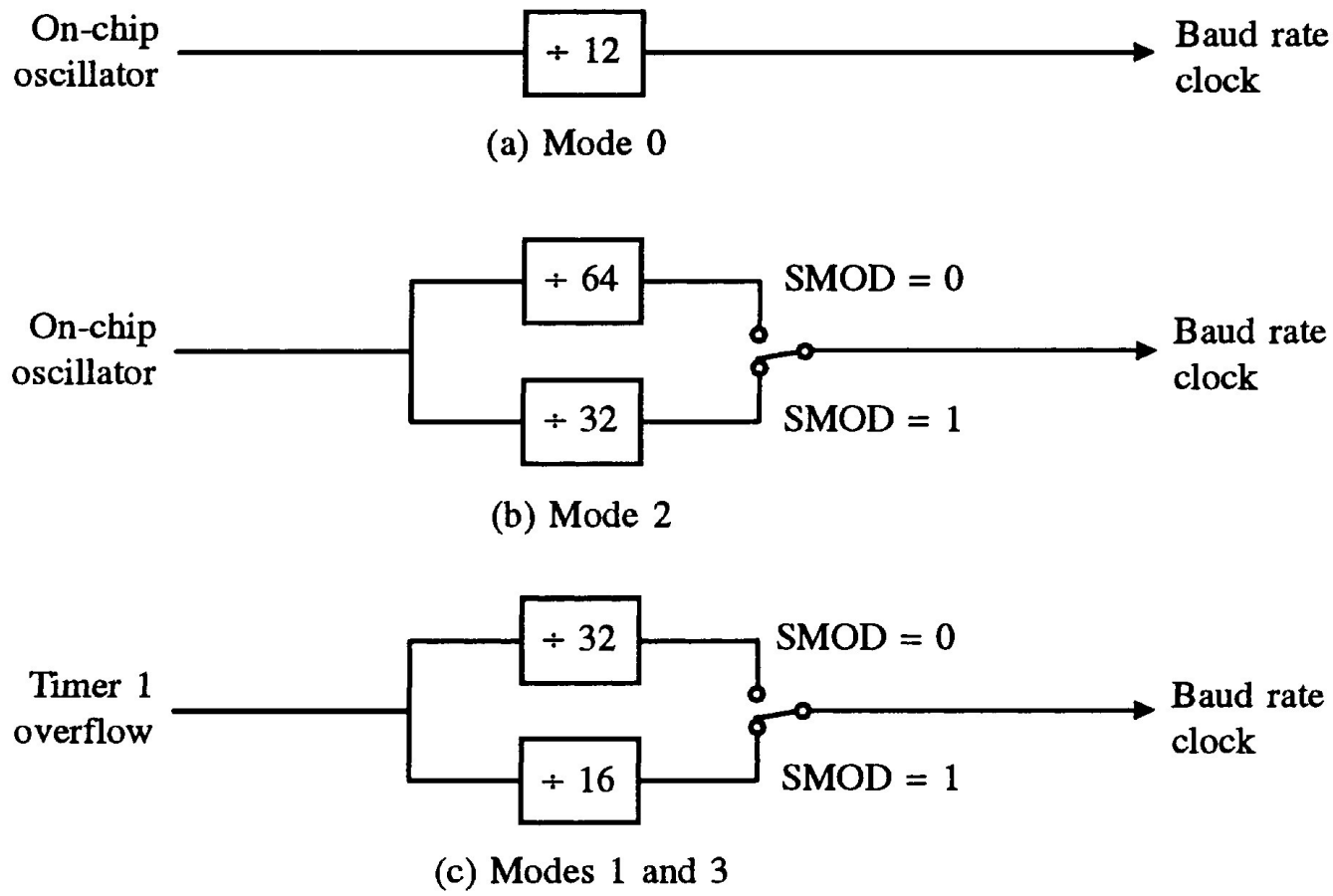

bit 7 of PCON is SMOD bit

setting SMOD = 1 doubles the baud rate

SMOD is zero default by system reset

serial port baud rates (cont'd)

PCON is not bit-addressable

```
MOV     A, PCON     ; get current value
SETB    ACC.7       ; set bit 7 (SMOD)
MOV     PCON, A     ; write value back
```

- baud rates in modes 1 and 3 are determined by timer overflow rate

Baud rate summary

BAUD RATE	CRYSTAL FREQUENCY	SMOD	TH1 RELOAD VALUE	ACTUAL BAUD RATE	ERROR
9600	12.000 MHz	1	−7 (F9H)	8923	7%
2400	12.000 MHz	0	−13 (F3H)	2404	0.16%
1200	12.000 MHz	0	−26 (E6H)	1202	0.16%
19200	11.059 MHz	1	−3 (FDH)	19200	0
9600	11.059 MHz	0	−3 (FDH)	9600	0
2400	11.059 MHz	0	−12 (F4H)	2400	0
1200	11.059 MHz	0	−24 (E8H)	1200	0

5% error is tolerable due to *rounding*

initializing the serial port (example)

- 8-bit UART at 2400 baud (timer 1 to provide baud clock rate) (assume 12 MHz crystal oscillator)

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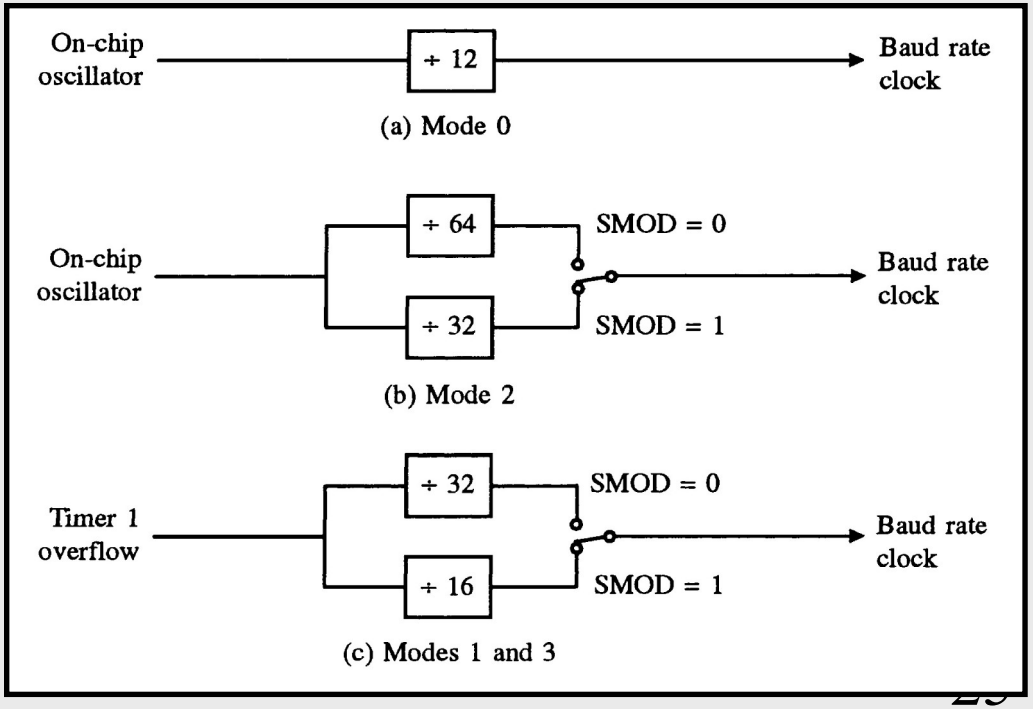

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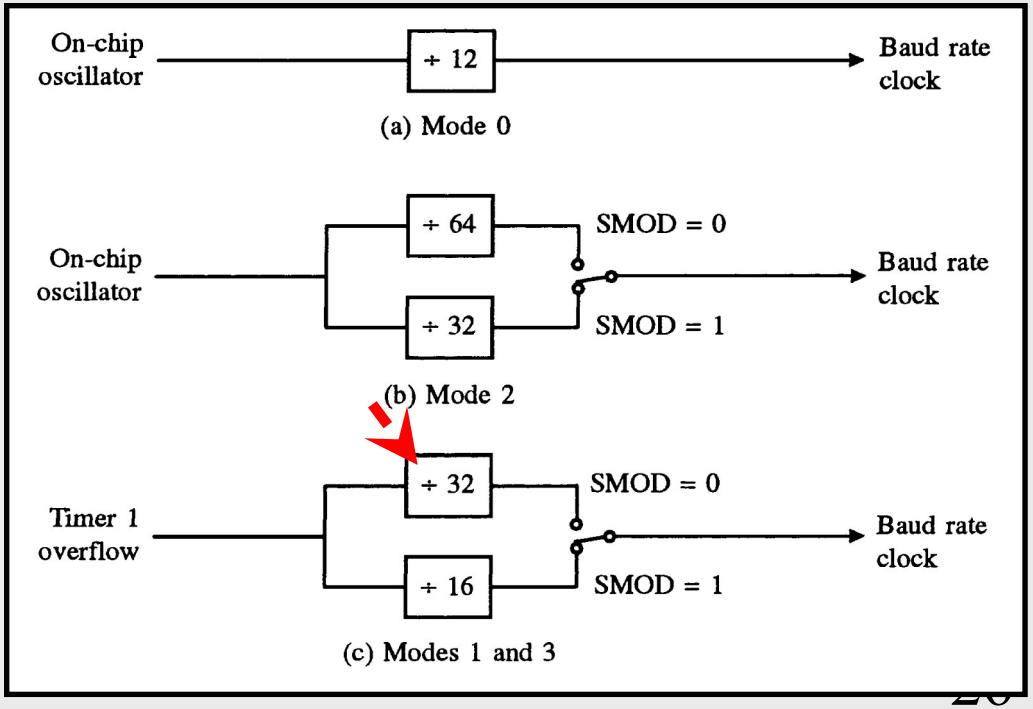

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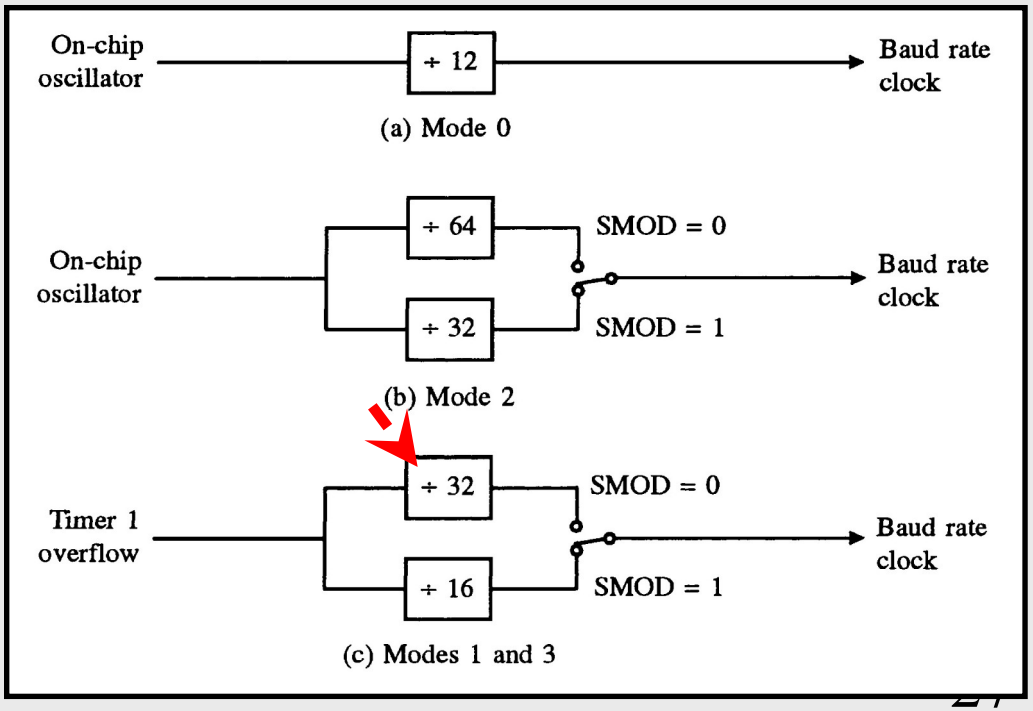
2400 = T1OR / 32 *(SMOD = 0)*



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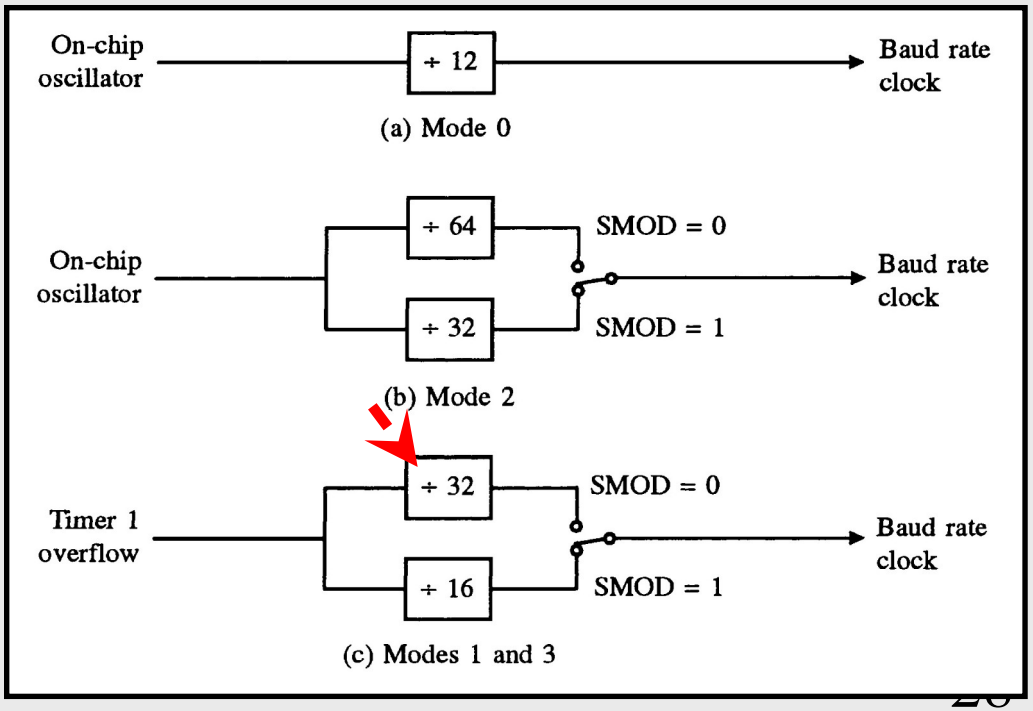

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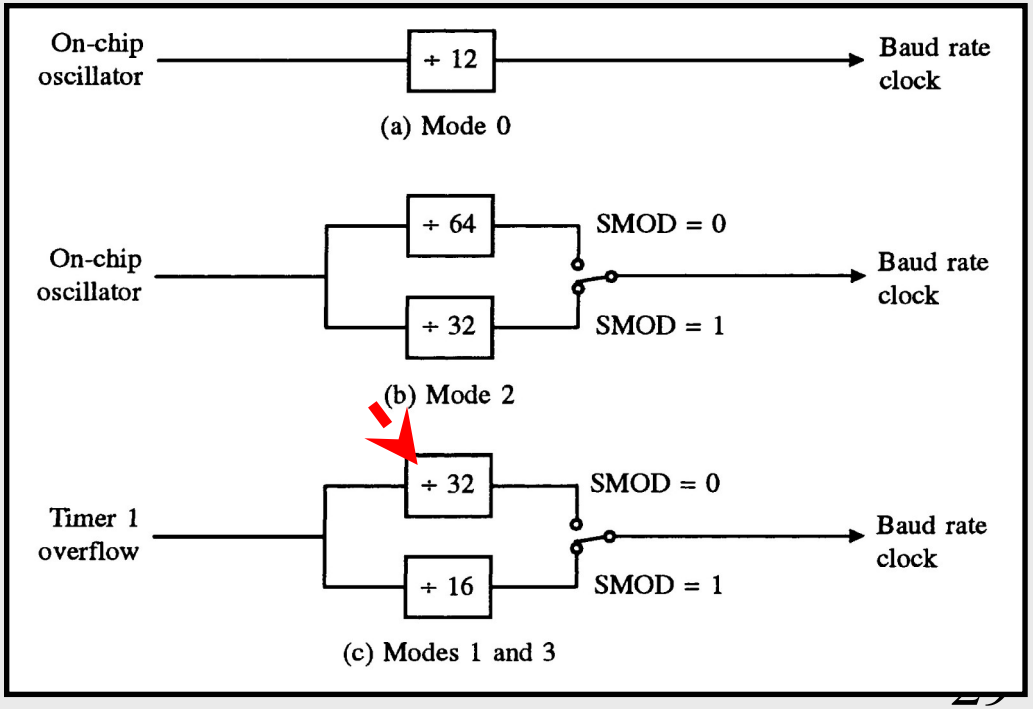
Timer 1 clocked at 1 MHz



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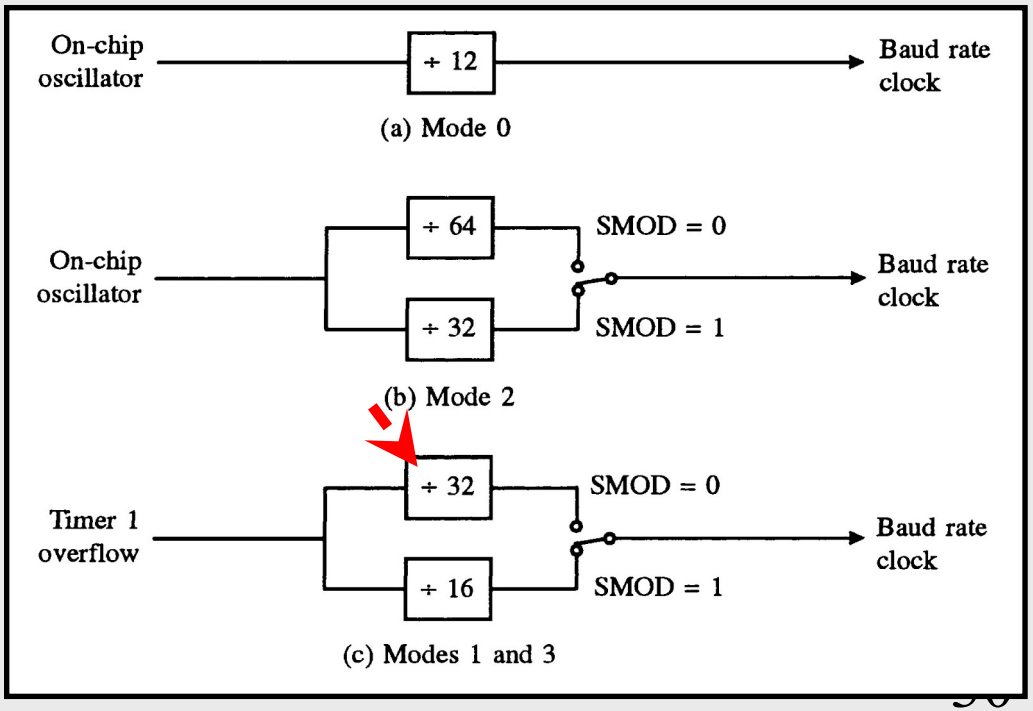
Timer 1 clocked at 1 MHz

# of reload = 1000000 / 76800



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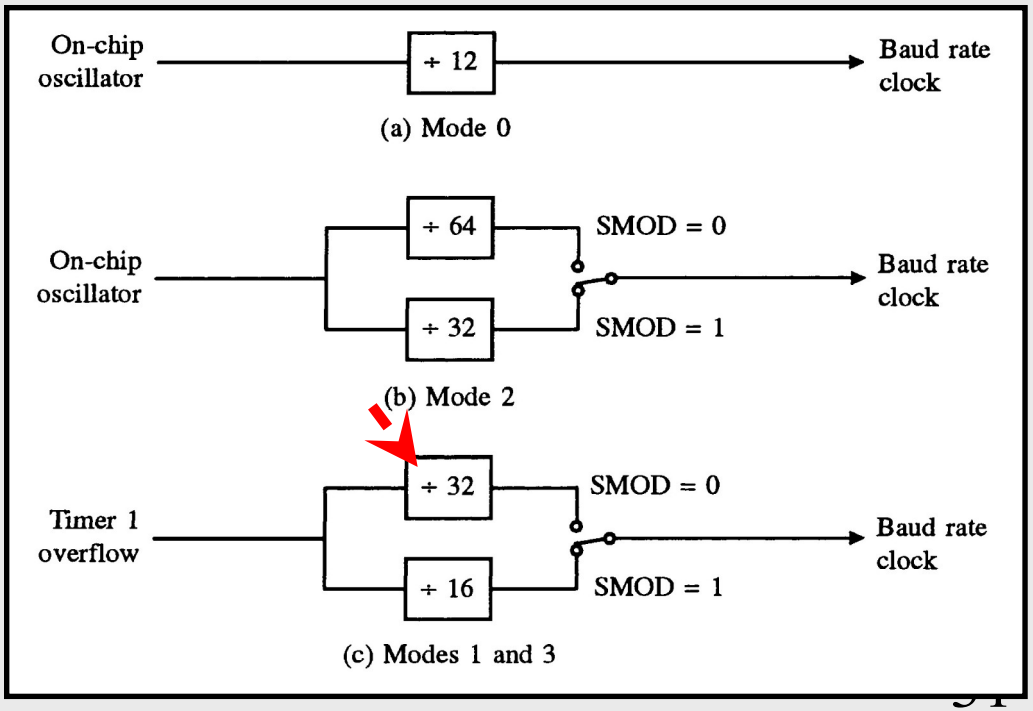
Timer 1 clocked at 1 MHz

# of reload = 1000000 / 76800

# of reload = 13,02 ~ **13**



initializing the serial port (example)

- enable receive mode REN = 1
- indicate that transmit buffer is empty TI = 1
- set timer 1 to 8-bit autoreload mode (with proper TH1)

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	SM0	SM1	SM2	REN	TB8	RB8	TI	RI
SCON:	0	1	0	1	0	0	1	0
	GTE	C/T	M1	M0	GTE	C/T	M1	M0
TMOD:	0	0	1	0	0	0	0	0
	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0
TCON:	0	1	0	0	0	0	0	0
TH1:	1	1	1	1	0	0	1	1

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TMOD:	0	0	1	0	0	0	0	0
	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0
TCON:	0	1	0	0	0	0	0	0
TH1:	1	1	1	1	0	0	1	1

```
INIT:   MOV     SCON, #52H   ; serial port, mode 1
        MOV     TMOD, #20H   ; timer 1, mode 2
        MOV     TH1, #-13    ; reload for 2400 baud
        SETB    TR1          ; start timer 1
```

output character subroutine (example)

- OUTCHR subroutine that transmits 7-bit ASCII code on accumulator with 8th bit as odd-parity (return from subroutine by keeping the accumulator value intact)

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```
OUTCHR: MOV   C, P        ; parity in C flag
        CPL   C           ; odd-parity
        MOV   ACC.7, C    ; add to character code
AGAIN:  JNB   TI, AGAIN   ; empty check
        CLR   TI          ; TI rdy, clear TI flag
        MOV   SBUF, A     ; send character
        CLR   ACC.7       ; strip-off parity
        RET               ; return from subr.
```

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```

```
MOV     A, # 'Z'
CALL    OUTCHR
(continue)
```

more general version

input character subroutine (example)

- INCHR subroutine that receives 7-bit ASCII character and expects 8th bit as odd-parity to set the carry flag if there is an error on parity

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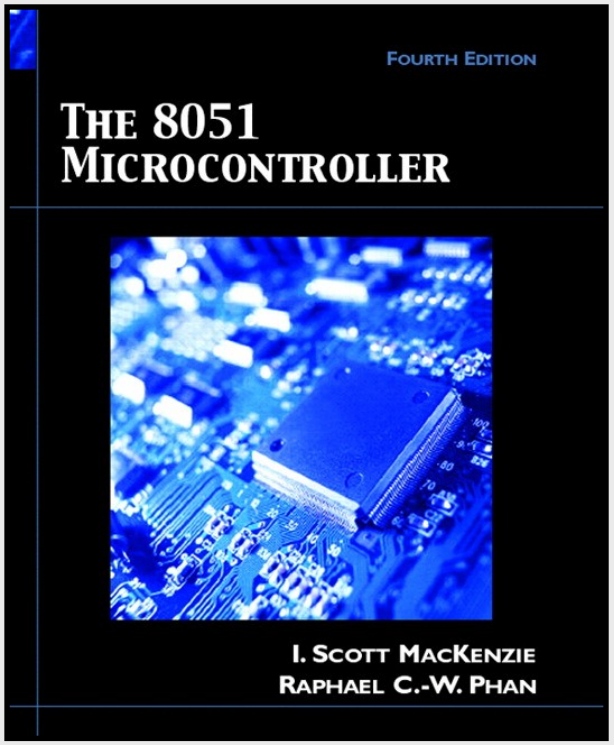
```
INCHR:  JNB     RI, $       ; wait for character
        CLR     RI          ; clear flag
        MOV     A, SBUF     ; read character into A
        MOV     C, P        ; P set for odd-parity
        CPL     C           ; check for error
        CLR     ACC.7       ; strip-off parity
        RET
```

summary

- serial port operation modes
- baud rate calculation for serial operation
- setting up serial port for UART

references



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