CMOS single-chip 8-bit microcontrollers

83C51FA/83C51FB/ 83C51FC/80C51FA

DESCRIPTION

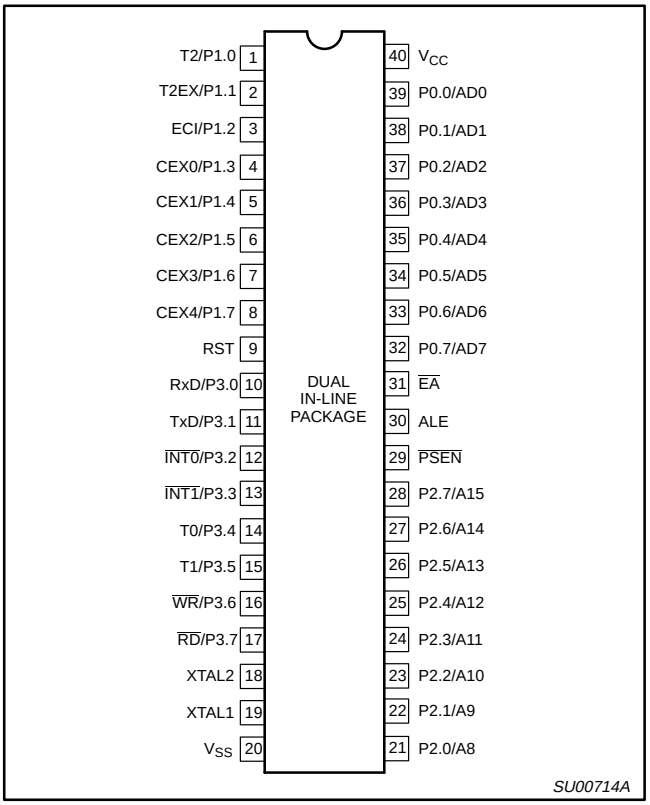
The 83C51FA/83C51FB/80C51FA Single-Chip 8-Bit Microcontroller is manufactured in an advanced CMOS process and is a derivative of the 80C51 microcontroller family. The 83C51FA/83C51FB/80C51FA has the same instruction set as the 80C51.

This device provides architectural enhancements that make it applicable in a variety of applications for general control systems. The 83C51FA contains 8k × 8 ROM memory (80C51FA ROMless version addresses up to 64k of external memory), the 83C51FB contains 16k × 8 ROM memory, the 83C51FC contains 32k × 8 ROM memory, a volatile 256 × 8 read/write data memory, four 8-bit I/O ports, three 16-bit timer/event counters, a Programmable Counter Array (PCA), a multi-source, four-priority-level, nested interrupt structure, an enhanced UART and on-chip oscillator and timing circuits. For systems that require extra capability, the 83C51FA/FB can be expanded using standard TTL compatible memories and logic.

Its added features make it an even more powerful microcontroller for applications that require pulse width modulation, high-speed I/O and up/down counting capabilities such as motor control. It also has a more versatile serial channel that facilitates multiprocessor communications.

See 87C51FA/87C51FB datasheet for EPROM/OTP specifications.

PIN CONFIGURATIONS



FEATURES

- 80C51 central processing unit
- Full static operation
- 8k × 8 ROM: 83C51FA;
  16k × 8 ROM: 83C51FB;
  32k × 8 ROM: 83C51FC
  ROMless: 80C51FA
  all capable of addressing external memory to 64k bytes
  - Two level program security system
  - 64 byte encryption array
- 256 × 8 RAM, expandable externally to 64k bytes
- Speed range up to 33MHz
- Three 16-bit timer/counters
  - T2 is an up/down counter
- 7 interrupt sources
- 4 level priority
- Programmable Counter Array (PCA)
  - High speed output
  - Capture/compare
  - Pulse Width Modulator
  - Watchdog Timer
- Four 8-bit I/O ports
- Full-duplex enhanced UART
  - Framing error detection
  - Automatic address recognition
- Power control modes
  - Idle mode
  - Power-down mode
- Once (On Circuit Emulation) Mode
- Five package styles
- Programmable clock out
- Low EMI (inhibit ALE)
- Second DPTR register (ROM only)
- Asynchronous port Reset

ORDERING INFORMATION

ROMless	ROM 8K × 8	ROM 16K × 8	ROM 32K × 8	TEMPERATURE RANGE °C AND PACKAGE	VOLTAGE RANGE (V)[1]	FREQ. (MHZ)	DWG. #
S80C51FA–4N40	S83C51FA–4N40	S83C51FB–4N40	S83C51FC–4N40	0 to +70, 40-Pin Plastic Dual In-line Pkg.	2.7 to 5.5[1]	3.5 to 16	SOT129-1
S80C51FA–4A44	S83C51FA–4A44	S83C51FB–4A44	S83C51FC–4A44	0 to +70, 44-Pin Plastic Leaded Chip Carrier	2.7 to 5.5[1]	3.5 to 16	SOT187-2
S80C51FA–4B44	S83C51FA–4B44	S83C51FB–4B44	S83C51FC–4B44	0 to +70, 44-Pin Plastic Quad Flat Pack	2.7 to 5.5[1]	3.5 to 16	SOT307-2
S80C51FA–5N40	S83C51FA–5N40	S83C51FB–5N40	S83C51FC–5N40	–40 to +85, 40-Pin Plastic Dual In-line Pkg.	2.7 to 5.5[1]	3.5 to 16	SOT129-1
S80C51FA–5A44	S83C51FA–5A44	S83C51FB–5A44	S83C51FC–5A44	–40 to +85, 44-Pin Plastic Leaded Chip Carrier	2.7 to 5.5[1]	3.5 to 16	SOT187-2
S80C51FA–5B44	S83C51FA–5B44	S83C51FB–5B44	S83C51FC–5B44	–40 to +85, 44-Pin Plastic Quad Flat Pack	2.7 to 5.5[1]	3.5 to 16	SOT307-2
S80C51FA–AN40	S83C51FA–AN40	S83C51FB–AN40	S83C51FC–AN40	0 to +70, 40-Pin Plastic Dual In-line Pkg.	5	3.5 to 24	SOT129-1
S80C51FA–AA44	S83C51FA–AA44	S83C51FB–AA44	S83C51FC–AA44	0 to +70, 44-Pin Plastic Leaded Chip Carrier	5	3.5 to 24	SOT187-2
S80C51FA–AB44	S83C51FA–AB44	S83C51FB–AB44	S83C51FC–AB44	0 to +70, 44-Pin Plastic Quad Flat Pack	5	3.5 to 24	SOT307-2
S80C51FA–BN40	S83C51FA–BN40	S83C51FB–BN40	S83C51FC–BN40	–40 to +85, 40-Pin Plastic Dual In-line Pkg.	5	3.5 to 24	SOT129-1
S80C51FA–BA44	S83C51FA–BA44	S83C51FB–BA44	S83C51FC–BA44	–40 to +85, 44-Pin Plastic Leaded Chip Carrier	5	3.5 to 24	SOT187-2
S80C51FA–BB44	S83C51FA–BB44	S83C51FB–BB44	S83C51FC–BB44	–40 to +85, 44-Pin Plastic Quad Flat Pack	5	3.5 to 24	SOT307-2
S80C51FA–IN40	S83C51FA–IN40	S83C51FB–IN40	S83C51FC–IN40	0 to +70, 40-Pin Plastic Dual In-line Pkg.	5	3.5 to 33	SOT129-1
S80C51FA–IA44	S83C51FA–IA44	S83C51FB–IA44	S83C51FC–IA44	0 to +70, 44-Pin Plastic Leaded Chip Carrier	5	3.5 to 33	SOT187-2
S80C51FA–IB44	S83C51FA–IB44	S83C51FB–IB44	S83C51FC–IB44	0 to +70, 44-Pin Plastic Quad Flat Pack	5	3.5 to 33	SOT307-2
S80C51FA–JN40	S83C51FA–JN40	S83C51FB–JN40	S83C51FC–JN40	–40 to +85, 40-Pin Plastic Dual In-line Pkg.	5	3.5 to 33	SOT129-1
S80C51FA–JA44	S83C51FA–JA44	S83C51FB–JA44	S83C51FC–JA44	–40 to +85, 44-Pin Plastic Leaded Chip Carrier	5	3.5 to 33	SOT187-2
S80C51FA–JB44	S83C51FA–JB44	S83C51FB–JB44	S83C51FC–JB44	–40 to +85, 44-Pin Plastic Quad Flat Pack	5	3.5 to 33	SOT307-2

NOTE:
1. S80C51FA devices are specified for 5V only.

BLOCK DIAGRAM

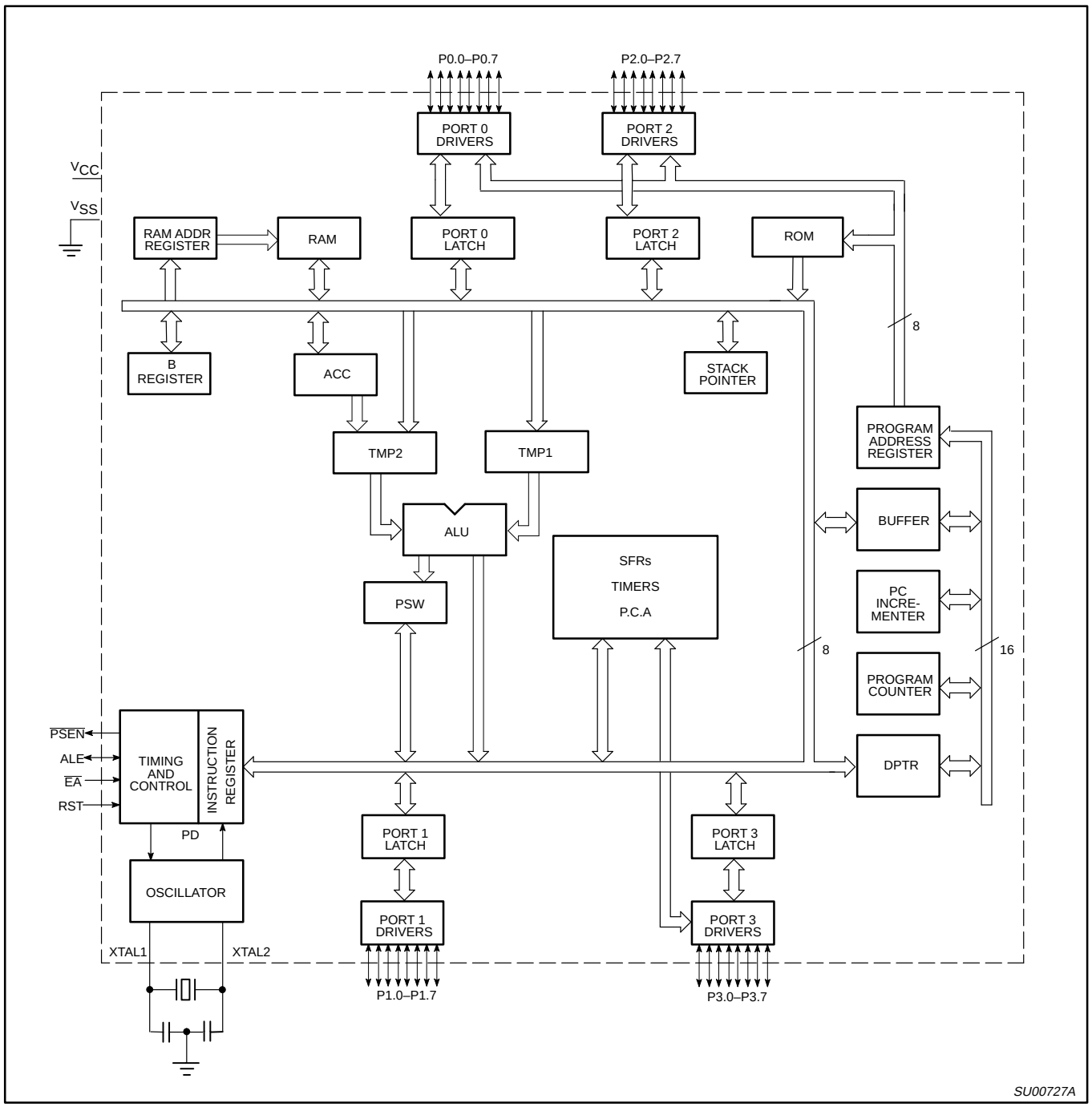


Table 1. 83C51FA/83C51FB/83C51FC/80C51FA Special Function Registers

SYMBOL	DESCRIPTION	DIRECT ADDRESS	BIT ADDRESS, SYMBOL, OR ALTERNATIVE PORT FUNCTION MSB							LSB	RESET VALUE
ACC*	Accumulator	E0H	E7	E6	E5	E4	E3	E2	E1	E0	00H
AUXR#	Auxiliary	8EH	–	–	–	–	–	–	–	AO	xxxxxxx0B
AUXR1#	Auxiliary 1 [3]	A2H	–	–	–	–	–	–	–	DPS0	xxxx0xx0B
B*	B register	F0H	F7	F6	F5	F4	F3	F2	F1	F0	00H
CCAP0H#	Module 0 Capture High	FAH									xxxxxxxxB
CCAP1H#	Module 1 Capture High	FBH									xxxxxxxxB
CCAP2H#	Module 2 Capture High	FCH									xxxxxxxxB
CCAP3H#	Module 3 Capture High	FDH									xxxxxxxxB
CCAP4H#	Module 4 Capture High	FEH									xxxxxxxxB
CCAP0L#	Module 0 Capture Low	EAH									xxxxxxxxB
CCAP1L#	Module 1 Capture Low	EBH									xxxxxxxxB
CCAP2L#	Module 2 Capture Low	ECH									xxxxxxxxB
CCAP3L#	Module 3 Capture Low	EDH									xxxxxxxxB
CCAP4L#	Module 4 Capture Low	EEH									xxxxxxxxB
CCAPM0#	Module 0 Mode	DAH	–	ECOM	CAPP	CAPN	MAT	TOG	PWM	ECCF	x0000000B
CCAPM1#	Module 1 Mode	DBH	–	ECOM	CAPP	CAPN	MAT	TOG	PWM	ECCF	x0000000B
CCAPM2#	Module 2 Mode	DCH	–	ECOM	CAPP	CAPN	MAT	TOG	PWM	ECCF	x0000000B
CCAPM3#	Module 3 Mode	DDH	–	ECOM	CAPP	CAPN	MAT	TOG	PWM	ECCF	x0000000B
CCAPM4#	Module 4 Mode	DEH	–	ECOM	CAPP	CAPN	MAT	TOG	PWM	ECCF	x0000000B
			DF	DE	DD	DC	DB	DA	D9	D8	
CCON*#	PCA Counter Control	D8H	CF	CR	–	CCF4	CCF3	CCF2	CCF1	CCF0	00x00000B
CH#	PCA Counter High	F9H									00H
CL#	PCA Counter Low	E9H									00H
CMOD#	PCA Counter Mode	D9H	CIDL	WDTE	–	–	–	CPS1	CPS0	ECF	00xxx000B
DPTR:	Data Pointer (2 bytes)										
DPH	Data Pointer High	83H									00H
DPL	Data Pointer Low	82H									00H
			AF	AE	AD	AC	AB	AA	A9	A8	
IE*	Interrupt Enable	A8H	EA	EC	ET2	ES	ET1	EX1	ET0	EX0	00H
			BF	BE	BD	BC	BB	BA	B9	B8	
IP*	Interrupt Priority	B8H	–	PPC	PT2	PS	PT1	PX1	PT0	PX0	x0000000B
			B7	B6	B5	B4	B3	B2	B1	B0	
IPH#	Interrupt Priority High	B7H	–	PPCH	PT2H	PSH	PT1H	PX1H	PT0H	PX0H	x0000000B
			87	86	85	84	83	82	81	80	
P0*	Port 0	80H	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0	FFH
			97	96	95	94	93	92	91	90	
P1*	Port 1	90H	CEX4	CEX3	CEX2	CEX1	CEX0	ECI	T2EX	T2	FFH
			A7	A6	A5	A4	A3	A2	A1	A0	
P2*	Port 2	A0H	AD15	AD14	AD13	AD12	AD11	AD10	AD9	AD8	FFH
			B7	B6	B5	B4	B3	B2	B1	B0	
P3*	Port 3	B0H	$\overline{RD}$	$\overline{WR}$	T1	T0	$\overline{INT1}$	$\overline{INT0}$	TxD	RxD	FFH
PCON#	Power Control	87H	SMOD1	SMOD0	–	POF[2]	GF1	GF0	PD	IDL	00xx0000B

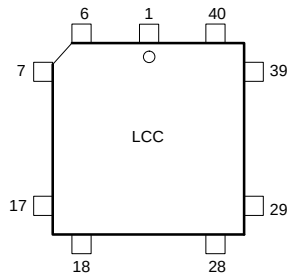
* SFRs are bit addressable.
\# SFRs are modified from or added to the 80C51 SFRs.
– Reserved bits.
1. Reset value depends on reset source.
2. Bit will not be affected by Reset.
3. Not available on 80C51FA (ROMless) at this time.

Table 1. 83C51FA/83C51FB/83C51FC/80C51FA Special Function Registers (Continued)

SYMBOL	DESCRIPTION	DIRECT ADDRESS	BIT ADDRESS, SYMBOL, OR ALTERNATIVE PORT FUNCTION MSB							LSB	RESET VALUE
			D7	D6	D5	D4	D3	D2	D1	D0	
PSW*	Program Status Word	D0H	CY	AC	F0	RS1	RS0	OV	–	P	00H
RACAP2H#	Timer 2 Capture High	CBH									00H
RACAP2L#	Timer 2 Capture Low	CAH									00H
SADDR#	Slave Address	A9H									00H
SADEN#	Slave Address Mask	B9H									00H
SBUF	Serial Data Buffer	99H									xxxxxxxxB
			9F	9E	9D	9C	9B	9A	99	98	
SCON*	Serial Control	98H	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI	00H
SP	Stack Pointer	81H									07H
			8F	8E	8D	8C	8B	8A	89	88	
TCON*	Timer Control	88H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	00H
			CF	CE	CD	CC	CB	CA	C9	C8	
T2CON*	Timer 2 Control	C8H	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/$\overline{T2}$	CP/$\overline{RL2}$	00H
T2MOD#	Timer 2 Mode Control	C9H	–	–	–	–	–	–	T2OE	DCEN	xxxxxx00B
TH0	Timer High 0	8CH									00H
TH1	Timer High 1	8DH									00H
TH2#	Timer High 2	CDH									00H
TL0	Timer Low 0	8AH									00H
TL1	Timer Low 1	8BH									00H
TL2#	Timer Low 2	CCH									00H
TMOD	Timer Mode	89H	GATE	C/$\overline{T}$	M1	M0	GATE	C/$\overline{T}$	M1	M0	00H

* SFRs are bit addressable.
\# SFRs are modified from or added to the 80C51 SFRs.
– Reserved bits.

PLASTIC LEADED CHIP CARRIER PIN FUNCTIONS



Pin	Function	Pin	Function	Pin	Function
1	NC*	16	P3.4/T0	31	P2.7/A15
2	P1.0/T2	17	P3.5/T1	32	$\overline{PSEN}$
3	P1.1/T2EX	18	P3.6/$\overline{WR}$	33	ALE
4	P1.2/ECI	19	P3.7/$\overline{RD}$	34	NC*
5	P1.3/CEX0	20	XTAL2	35	$\overline{EA}$
6	P1.4/CEX1	21	XTAL1	36	P0.7/AD7
7	P1.5/CEX2	22	V_{SS}	37	P0.6/AD6
8	P1.6/CEX3	23	NC*	38	P0.5/AD5
9	P1.7/CEX4	24	P2.0/A8	39	P0.4/AD4
10	RST	25	P2.1/A9	40	P0.3/AD3
11	P3.0/RxD	26	P2.2/A10	41	P0.2/AD2
12	NC*	27	P2.3/A11	42	P0.1/AD1
13	P3.1/TxD	28	P2.4/A12	43	P0.0/AD0
14	P3.2/$\overline{INT0}$	29	P2.5/A13	44	V_{CC}
15	P3.3/$\overline{INT1}$	30	P2.6/A14		

* DO NOT CONNECT

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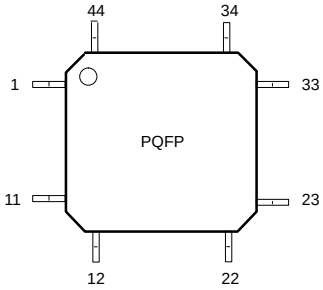
PLASTIC QUAD FLAT PACK PIN FUNCTIONS



Pin	Function	Pin	Function	Pin	Function
1	P1.5/CEX2	16	V_{SS}	31	P0.6/AD6
2	P1.6/CEX3	17	NC*	32	P0.5/AD5
3	P1.7/CEX4	18	P2.0/A8	33	P0.4/AD4
4	RST	19	P2.1/A9	34	P0.3/AD3
5	P3.0/RxD	20	P2.2/A10	35	P0.2/AD2
6	NC*	21	P2.3/A11	36	P0.1/AD1
7	P3.1/TxD	22	P2.4/A12	37	P0.0/AD0
8	P3.2/$\overline{INT0}$	23	P2.5/A13	38	V_{CC}
9	P3.3/$\overline{INT1}$	24	P2.6/A14	39	NC*
10	P3.4/T0	25	P2.7/A15	40	P1.0/T2
11	P3.5/T1	26	$\overline{PSEN}$	41	P1.1/T2EX
12	P3.6/$\overline{WR}$	27	ALE	42	P1.2/ECI
13	P3.7/$\overline{RD}$	28	NC*	43	P1.3/CEX0
14	XTAL2	29	$\overline{EA}$	44	P1.4/CEX1
15	XTAL1	30	P0.7/AD7		

* DO NOT CONNECT

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PIN DESCRIPTIONS

MNEMONIC	PIN NUMBER DIP	PIN NUMBER LCC	PIN NUMBER QFP	TYPE	NAME AND FUNCTION
V_{SS}	20	22	16	I	**Ground:** 0V reference.
V_{CC}	40	44	38	I	**Power Supply:** This is the power supply voltage for normal, idle, and power-down operation.
P0.0–0.7	39–32	43–36	37–30	I/O	**Port 0:** Port 0 is an open-drain, bidirectional I/O port. Port 0 pins that have 1s written to them float and can be used as high-impedance inputs. Port 0 is also the multiplexed low-order address and data bus during accesses to external program and data memory. In this application, it uses strong internal pull-ups when emitting 1s. Port 0 also outputs the code bytes during program verification. External pull-ups are required during program verification.
P1.0–P1.7	1–8	2–9	40–44, 1–3	I/O	**Port 1:** Port 1 is an 8-bit bidirectional I/O port with internal pull-ups. Port 1 pins that have 1s written to them are pulled high by the internal pull-ups and can be used as inputs. As inputs, port 1 pins that are externally pulled low will source current because of the internal pull-ups. (See DC Electrical Characteristics: I_{IL}). Port 1 also receives the low-order address byte during program memory verification. Alternate functions include:
	1	2	40	I/O	**T2 (P1.0):** Timer/Counter 2 external count input/Clockout (see Programmable Clock-Out)
	2	3	41	I	**T2EX (P1.1):** Timer/Counter 2 Reload/Capture/Direction Control
	3	4	42	I	**ECI (P1.2):** External Clock Input to the PCA
	4	5	43	I/O	**CEX0 (P1.3):** Capture/Compare External I/O for PCA module 0
	5	6	44	I/O	**CEX1 (P1.4):** Capture/Compare External I/O for PCA module 1
	6	7	1	I/O	**CEX2 (P1.5):** Capture/Compare External I/O for PCA module 2
	7	8	2	I/O	**CEX3 (P1.6):** Capture/Compare External I/O for PCA module 3
	8	9	3	I/O	**CEX4 (P1.7):** Capture/Compare External I/O for PCA module 4
P2.0–P2.7	21–28	24–31	18–25	I/O	**Port 2:** Port 2 is an 8-bit bidirectional I/O port with internal pull-ups. Port 2 pins that have 1s written to them are pulled high by the internal pull-ups and can be used as inputs. As inputs, port 2 pins that are externally being pulled low will source current because of the internal pull-ups. (See DC Electrical Characteristics: I_{IL}). Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that use 16-bit addresses (MOVX @DPTR). In this application, it uses strong internal pull-ups when emitting 1s. During accesses to external data memory that use 8-bit addresses (MOV @Ri), port 2 emits the contents of the P2 special function register.

PIN DESCRIPTIONS (Continued)

MNEMONIC	PIN NUMBER DIP	LCC	QFP	TYPE	NAME AND FUNCTION
P3.0–P3.7	10–17	11, 13–19	5, 7–13	I/O	**Port 3:** Port 3 is an 8-bit bidirectional I/O port with internal pull-ups. Port 3 pins that have 1s written to them are pulled high by the internal pull-ups and can be used as inputs. As inputs, port 3 pins that are externally being pulled low will source current because of the pull-ups. (See DC Electrical Characteristics: I_{IL}). Port 3 also serves the special features of the 80C51 family, as listed below:
	10	11	5	I	**RxD (P3.0):** Serial input port
	11	13	7	O	**TxD (P3.1):** Serial output port
	12	14	8	I	**$\overline{\text{INT0}}$ (P3.2):** External interrupt
	13	15	9	I	**$\overline{\text{INT1}}$ (P3.3):** External interrupt
	14	16	10	I	**T0 (P3.4):** Timer 0 external input
	15	17	11	I	**T1 (P3.5):** Timer 1 external input
	16	18	12	O	**$\overline{\text{WR}}$ (P3.6):** External data memory write strobe
	17	19	13	O	**$\overline{\text{RD}}$ (P3.7):** External data memory read strobe
RST	9	10	4	I	**Reset:** A high on this pin for two machine cycles while the oscillator is running, resets the device. An internal diffused resistor to V_{SS} permits a power-on reset using only an external capacitor to V_{CC}.
ALE	30	33	27	O	**Address Latch Enable:** Output pulse for latching the low byte of the address during an access to external memory. In normal operation, ALE is emitted at a constant rate of 1/6 the oscillator frequency, and can be used for external timing or clocking. Note that one ALE pulse is skipped during each access to external data memory. ALE can be disabled by setting SFR auxiliary.0. With this bit set, ALE will be active only during a MOVX instruction.
$\overline{\text{PSEN}}$	29	32	26	O	**Program Store Enable:** The read strobe to external program memory. When the 8XC51FX is executing code from the external program memory, $\overline{\text{PSEN}}$ is activated twice each machine cycle, except that two $\overline{\text{PSEN}}$ activations are skipped during each access to external data memory. $\overline{\text{PSEN}}$ is not activated during fetches from internal program memory.
$\overline{\text{EA}}$	31	35	29	I	**External Access Enable:** $\overline{\text{EA}}$ must be externally held low to enable the device to fetch code from external program memory locations 0000H and 7FFFH. If $\overline{\text{EA}}$ is held high, the device executes from internal program memory unless the program counter contains an address greater than 7FFFH. If security bit 1 is programmed, $\overline{\text{EA}}$ will be internally latched on Reset.
XTAL1	19	21	15	I	**Crystal 1:** Input to the inverting oscillator amplifier and input to the internal clock generator circuits.
XTAL2	18	20	14	O	**Crystal 2:** Output from the inverting oscillator amplifier.

NOTE:
To avoid “latch-up” effect at power-on, the voltage on any pin at any time must not be higher than V_{CC} + 0.5V or V_{SS} – 0.5V, respectively.

TIMER 2 OPERATION

Timer 2

Timer 2 is a 16-bit Timer/Counter which can operate as either an event timer or an event counter, as selected by C/T2* in the special function register T2CON (see Figure 1). Timer 2 has three operating modes:Capture, Auto-reload (up or down counting) ,and Baud Rate Generator, which are selected by bits in the T2CON as shown in Table 2.

Capture Mode

In the capture mode there are two options which are selected by bit EXEN2 in T2CON. If EXEN2=0, then timer 2 is a 16-bit timer or counter (as selected by C/T2* in T2CON) which, upon overflowing sets bit TF2, the timer 2 overflow bit. This bit can be used to generate an interrupt (by enabling the Timer 2 interrupt bit in the IE register/SFR table). If EXEN2= 1, Timer 2 operates as described above, but with the added feature that a 1- to -0 transition at external input T2EX causes the current value in the Timer 2 registers, TL2 and TH2, to be captured into registers RCAP2L and RCAP2H, respectively. In addition, the transition at T2EX causes bit EXF2 in T2CON to be set, and EXF2 like TF2 can generate an interrupt (which vectors to the same location as Timer 2 overflow interrupt. The Timer 2 interrupt service routine can interrogate TF2 and EXF2 to determine which event caused the interrupt). The capture mode is illustrated in Figure 2 (There is no reload value for TL2 and TH2 in this mode. Even when a capture event occurs from T2EX, the counter keeps on counting T2EX pin transitions or osc/12 pulses.).

Auto-Reload Mode (Up or Down Counter)

In the 16-bit auto-reload mode, Timer 2 can be configured (as either a timer or counter (C/T2* in T2CON)) then programmed to count up or down. The counting direction is determined by bit DCEN(Down Counter Enable) which is located in the T2MOD register (see Figure 3). When reset is applied the DCEN=0 which means Timer 2 will default to counting up. If DCEN bit is set, Timer 2 can count up or down depending on the value of the T2EX pin.

Figure 4 shows Timer 2 which will count up automatically since DCEN=0. In this mode there are two options selected by bit EXEN2 in T2CON register. If EXEN2=0, then Timer 2 counts up to 0FFFFH and sets the TF2 (Overflow Flag) bit upon overflow. This causes the Timer 2 registers to be reloaded with the 16-bit value in RCAP2L and RCAP2H.

The values in RCAP2L and RCAP2H are preset by software means. If EXEN2=1, then a 16-bit reload can be triggered either by an overflow or by a 1-to-0 transition at input T2EX. This transition also sets the EXF2 bit. The Timer 2 interrupt, if enabled, can be generated when either TF2 or EXF2 are 1.

In Figure 5 DCEN=1 which enables Timer 2 to count up or down. This mode allows pin T2EX to control the direction of count. When a logic 1 is applied at pin T2EX Timer 2 will count up. Timer 2 will overflow at 0FFFFH and set the TF2 flag, which can then generate an interrupt, if the interrupt is enabled. This timer overflow also causes the 16–bit value in RCAP2L and RCAP2H to be reloaded into the timer registers TL2 and TH2.

When a logic 0 is applied at pin T2EX this causes Timer 2 to count down. The timer will underflow when TL2 and TH2 become equal to the value stored in RCAP2L and RCAP2H. Timer 2 underflow sets the TF2 flag and causes 0FFFFH to be reloaded into the timer registers TL2 and TH2.

The external flag EXF2 toggles when Timer 2 underflows or overflows. This EXF2 bit can be used as a 17th bit of resolution if needed. The EXF2 flag does not generate an interrupt in this mode of operation.

(MSB) (LSB)

TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/$\overline{T2}$	CP/$\overline{RL2}$

Symbol	Position	Name and Significance
TF2	T2CON.7	Timer 2 overflow flag set by a Timer 2 overflow and must be cleared by software. TF2 will not be set when either RCLK or TCLK = 1.
EXF2	T2CON.6	Timer 2 external flag set when either a capture or reload is caused by a negative transition on T2EX and EXEN2 = 1. When Timer 2 interrupt is enabled, EXF2 = 1 will cause the CPU to vector to the Timer 2 interrupt routine. EXF2 must be cleared by software. EXF2 does not cause an interrupt in up/down counter mode (DCEN = 1).
RCLK	T2CON.5	Receive clock flag. When set, causes the serial port to use Timer 2 overflow pulses for its receive clock in modes 1 and 3. RCLK = 0 causes Timer 1 overflow to be used for the receive clock.
TCLK	T2CON.4	Transmit clock flag. When set, causes the serial port to use Timer 2 overflow pulses for its transmit clock in modes 1 and 3. TCLK = 0 causes Timer 1 overflows to be used for the transmit clock.
EXEN2	T2CON.3	Timer 2 external enable flag. When set, allows a capture or reload to occur as a result of a negative transition on T2EX if Timer 2 is not being used to clock the serial port. EXEN2 = 0 causes Timer 2 to ignore events at T2EX.
TR2	T2CON.2	Start/stop control for Timer 2. A logic 1 starts the timer.
C/$\overline{T2}$	T2CON.1	Timer or counter select. (Timer 2) 0 = Internal timer (OSC/12) 1 = External event counter (falling edge triggered).
CP/$\overline{RL2}$	T2CON.0	Capture/Reload flag. When set, captures will occur on negative transitions at T2EX if EXEN2 = 1. When cleared, auto-reloads will occur either with Timer 2 overflows or negative transitions at T2EX when EXEN2 = 1. When either RCLK = 1 or TCLK = 1, this bit is ignored and the timer is forced to auto-reload on Timer 2 overflow.

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Figure 1. Timer/Counter 2 (T2CON) Control Register

Table 2. Timer 2 Operating Modes

RCLK + TCLK	CP/$\overline{RL2}$	TR2	MODE
0	0	1	16-bit Auto-reload
0	1	1	16-bit Capture
1	X	1	Baud rate generator
X	X	0	(off)

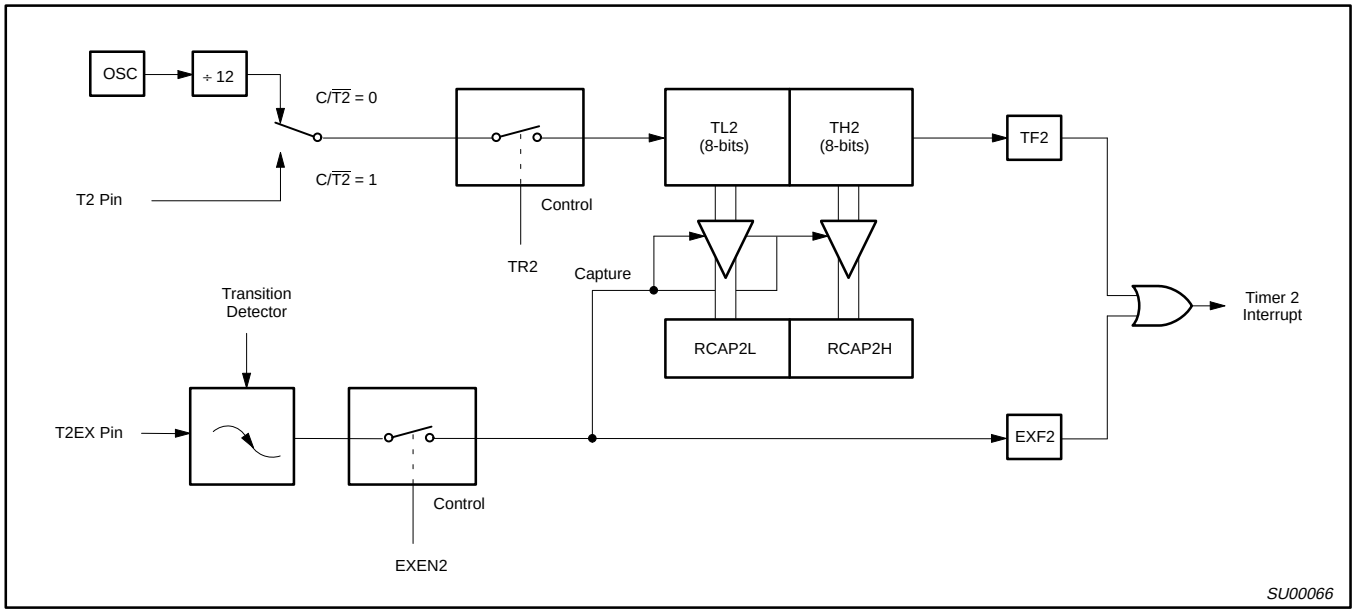

Figure 2. Timer 2 in Capture Mode

T2MOD Address = 0C9H Reset Value = XXXX XX00B

Not Bit Addressable

—	—	—	—	—	—	T2OE	DCEN
Bit 7	6	5	4	3	2	1	0

Symbol	Function
—	Not implemented, reserved for future use.*
T2OE	Timer 2 Output Enable bit.
DCEN	Down Count Enable bit. When set, this allows Timer 2 to be configured as an up/down counter.

* User software should not write 1s to reserved bits. These bits may be used in future 8051 family products to invoke new features. In that case, the reset or inactive value of the new bit will be 0, and its active value will be 1. The value read from a reserved bit is indeterminate.

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Figure 3. Timer 2 Mode (T2MOD) Control Register

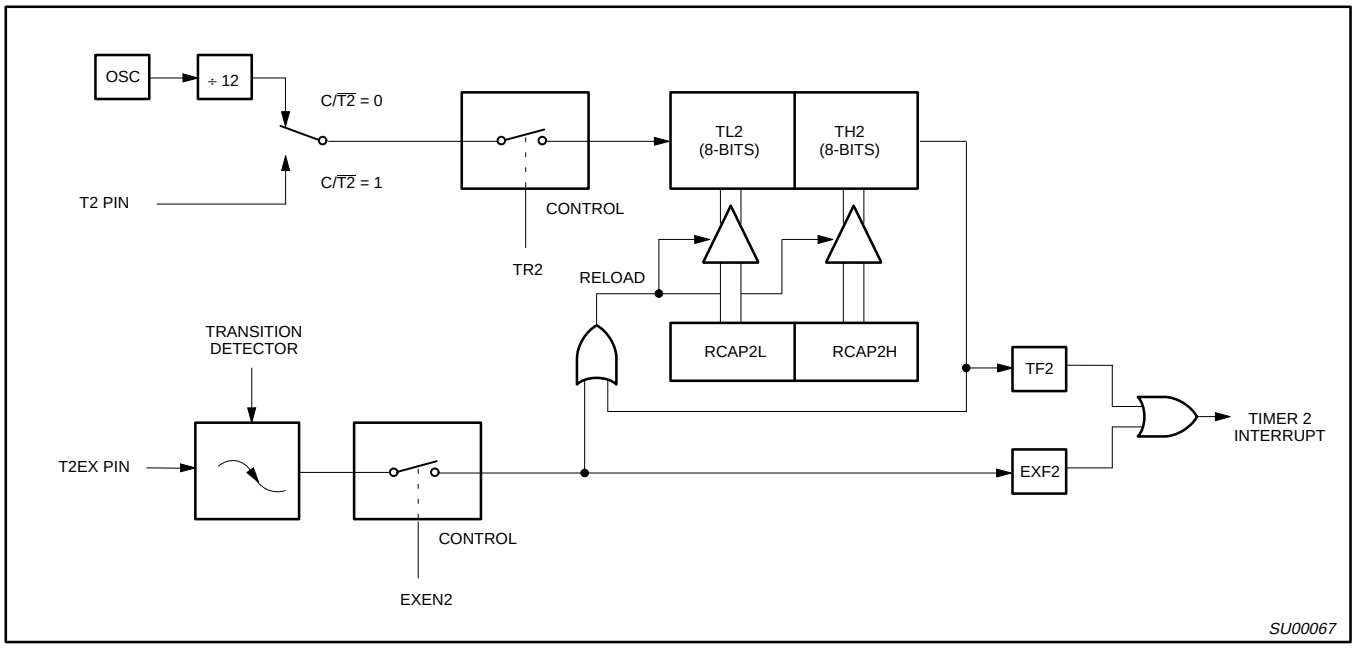

Figure 4. Timer 2 in Auto-Reload Mode (DCEN = 0)

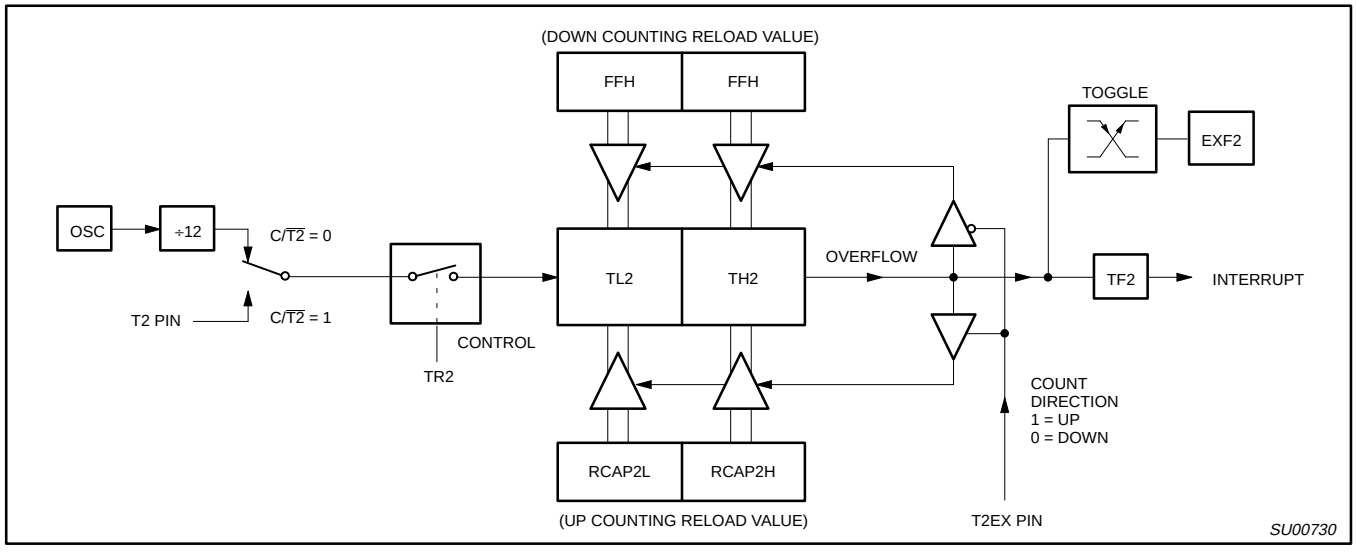

Figure 5. Timer 2 Auto Reload Mode (DCEN = 1)

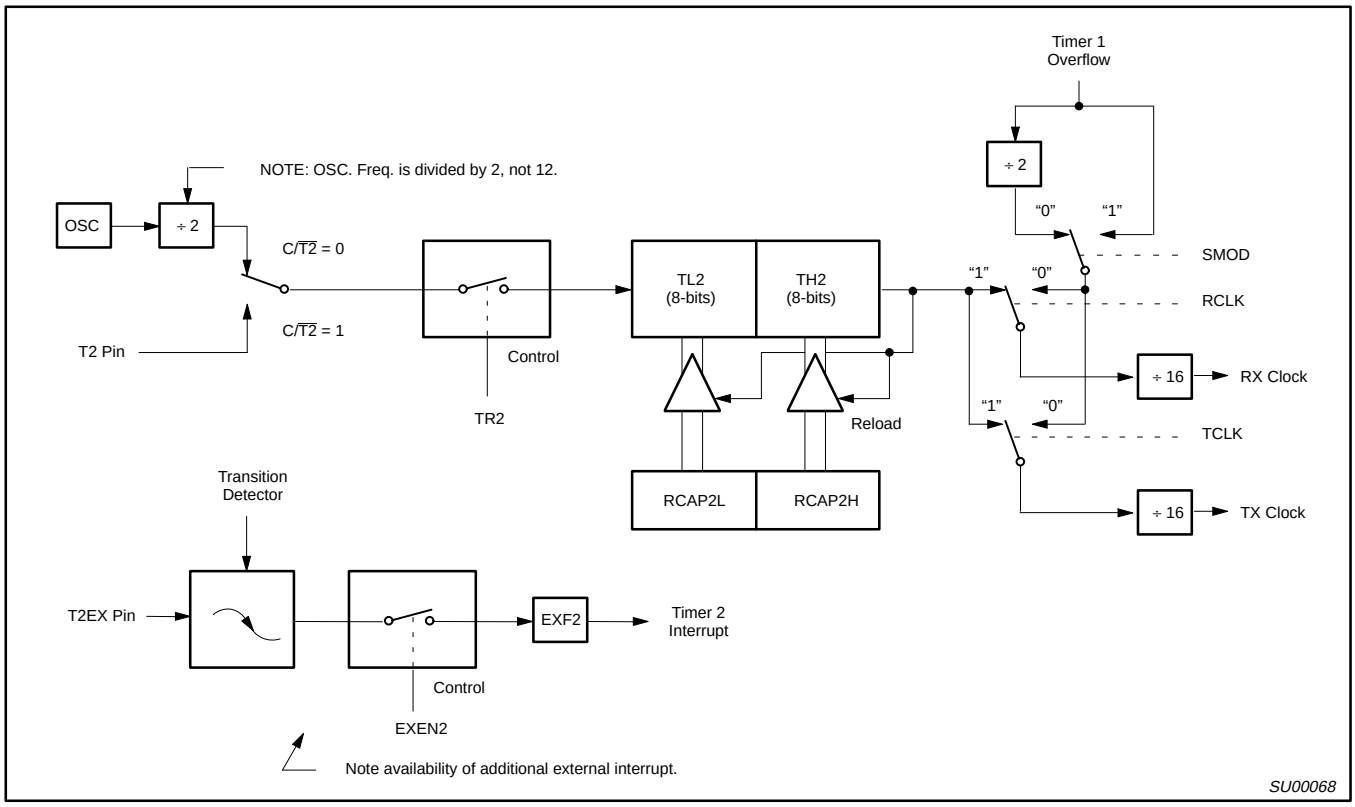

Figure 6. Timer 2 in Baud Rate Generator Mode

Table 3. Timer 2 Generated Commonly Used Baud Rates

Baud Rate	Osc Freq	Timer 2	
		RCAP2H	RCAP2L
375K	12MHz	FF	FF
9.6K	12MHz	FF	D9
2.8K	12MHz	FF	B2
2.4K	12MHz	FF	64
1.2K	12MHz	FE	C8
300	12MHz	FB	1E
110	12MHz	F2	AF
300	6MHz	FD	8F
110	6MHz	F9	57

Baud Rate Generator Mode

Bits TCLK and/or RCLK in T2CON (Table 2) allow the serial port transmit and receive baud rates to be derived from either Timer 1 or Timer 2. When TCLK= 0, Timer 1 is used as the serial port transmit baud rate generator. When TCLK= 1, Timer 2 is used as the serial port transmit baud rate generator. RCLK has the same effect for the serial port receive baud rate. With these two bits, the serial port can have different receive and transmit baud rates – one generated by Timer 1, the other by Timer 2.

Figure 6 shows the Timer 2 in baud rate generation mode. The baud rate generation mode is like the auto-reload mode,in that a rollover in TH2 causes the Timer 2 registers to be reloaded with the 16-bit value in registers RCAP2H and RCAP2L, which are preset by software.

The baud rates in modes 1 and 3 are determined by Timer 2's overflow rate given below:

$$\text{Modes 1 and 3 Baud Rates} = \frac{\text{Timer 2 Overflow Rate}}{16}$$

The timer can be configured for either "timer" or "counter" operation. In many applications, it is configured for "timer" operation (C/T2*=0). Timer operation is different for Timer 2 when it is being used as a baud rate generator.

Usually, as a timer it would increment every machine cycle (i.e., 1/12 the oscillator frequency). As a baud rate generator, it increments every state time (i.e., 1/2 the oscillator frequency). Thus the baud rate formula is as follows:

$$\text{Modes 1 and 3 Baud Rates} = \frac{\text{Oscillator Frequency}}{[32 \times [65536 - (\text{RCAP2H, RCAP2L})]]}$$

Where: (RCAP2H, RCAP2L)= The content of RCAP2H and RCAP2L taken as a 16-bit unsigned integer.

The Timer 2 as a baud rate generator mode shown in Figure 6, is valid only if RCLK and/or TCLK = 1 in T2CON register. Note that a rollover in TH2 does not set TF2, and will not generate an interrupt. Thus, the Timer 2 interrupt does not have to be disabled when Timer 2 is in the baud rate generator mode. Also if the EXEN2 (T2 external enable flag) is set, a 1-to-0 transition in T2EX (Timer/counter 2 trigger input) will set EXF2 (T2 external flag) but will not cause a reload from (RCAP2H, RCAP2L) to (TH2,TL2). Therefore when Timer 2 is in use as a baud rate generator, T2EX can be used as an additional external interrupt, if needed.

When Timer 2 is in the baud rate generator mode, one should not try to read or write TH2 and TL2. As a baud rate generator, Timer 2 is incremented every state time (osc/2) or asynchronously from pin T2; under these conditions, a read or write of TH2 or TL2 may not be accurate. The RCAP2 registers may be read, but should not be written to, because a write might overlap a reload and cause write and/or reload errors. The timer should be turned off (clear TR2) before accessing the Timer 2 or RCAP2 registers.

Table 3 shows commonly used baud rates and how they can be obtained from Timer 2.

Summary Of Baud Rate Equations

Timer 2 is in baud rate generating mode. If Timer 2 is being clocked through pin T2(P1.0) the baud rate is:

$$\text{Baud Rate} = \frac{\text{Timer 2 Overflow Rate}}{16}$$

If Timer 2 is being clocked internally , the baud rate is:

$$\text{Baud Rate} = \frac{f_{OSC}}{[32 \times [65536 - (\text{RCAP2H, RCAP2L})]]}$$

Where f_{OSC}= Oscillator Frequency

To obtain the reload value for RCAP2H and RCAP2L, the above equation can be rewritten as:

$$\text{RCAP2H, RCAP2L} = 65536 - \left(\frac{f_{OSC}}{32 \times \text{Baud Rate}}\right)$$

Timer/Counter 2 Set-up

Except for the baud rate generator mode, the values given for T2CON do not include the setting of the TR2 bit. Therefore, bit TR2 must be set, separately, to turn the timer on. see Table 4 for set-up of Timer 2 as a timer. Also see Table 5 for set-up of Timer 2 as a counter.

POWER OFF FLAG

The Power Off Flag (POF) is set by on-chip circuitry when the V_{CC} level on the 8XC51FA/83C51FB/83C51FC rises from 0 to 5V. The POF bit can be set or cleared by software allowing a user to determine if the reset is the result of a power-on or a warm start after powerdown. The V_{CC} level must remain above 3V for the POF to remain unaffected by the V_{CC} level.

Table 4. Timer 2 as a Timer

MODE	T2CON	
	INTERNAL CONTROL (Note 1)	EXTERNAL CONTROL (Note 2)
16-bit Auto-Reload	00H	08H
16-bit Capture	01H	09H
Baud rate generator receive and transmit same baud rate	34H	36H
Receive only	24H	26H
Transmit only	14H	16H

Table 5. Timer 2 as a Counter

MODE	TMOD	
	INTERNAL CONTROL (Note 1)	EXTERNAL CONTROL (Note 2)
16-bit	02H	0AH
Auto-Reload	03H	0BH

NOTES:
1. Capture/reload occurs only on timer/counter overflow.
2. Capture/reload occurs on timer/counter overflow and a 1-to-0 transition on T2EX (P1.1) pin except when Timer 2 is used in the baud rate generator mode.

OSCILLATOR CHARACTERISTICS

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier. The pins can be configured for use as an on-chip oscillator.

To drive the device from an external clock source, XTAL1 should be driven while XTAL2 is left unconnected. There are no requirements on the duty cycle of the external clock signal, because the input to the internal clock circuitry is through a divide-by-two flip-flop. However, minimum and maximum high and low times specified in the data sheet must be observed.

Reset

A reset is accomplished by holding the RST pin high for at least two machine cycles (24 oscillator periods), while the oscillator is running. To insure a good power-on reset, the RST pin must be high long enough to allow the oscillator time to start up (normally a few milliseconds) plus two machine cycles. At power-on, the voltage on V_{CC} and RST must come up at the same time for a proper start-up. Ports 1, 2, and 3 will asynchronously be driven to their reset condition when a voltage above V_{IH1} (min.) is applied to RESET.

Idle Mode

In the idle mode (see Table 6), the CPU puts itself to sleep while all of the on-chip peripherals stay active. The instruction to invoke the idle mode is the last instruction executed in the normal operating mode before the idle mode is activated. The CPU contents, the on-chip RAM, and all of the special function registers remain intact during this mode. The idle mode can be terminated either by any enabled interrupt (at which time the process is picked up at the interrupt service routine and continued), or by a hardware reset which starts the processor in the same manner as a power-on reset.

Power-Down Mode

To save even more power, a Power Down mode (see Table 6) can be invoked by software. In this mode, the oscillator is stopped and the instruction that invoked Power Down is the last instruction executed. The on-chip RAM and Special Function Registers retain their values until the Power Down mode is terminated.

Either a hardware reset or external interrupt can be used to exit from Power Down. Reset redefines all the SFRs but does not change the on-chip RAM. An external interrupt allows both the SFRs and the on-chip RAM to retain their values.

To properly terminate Power Down the reset or external interrupt should not be executed before V_{CC} is restored to its normal operating level and must be held active long enough for the oscillator to restart and stabilize (normally less than 10ms).

With an external interrupt, INT0 and INT1 must be enabled and configured as level-sensitive. Holding the pin low restarts the oscillator but bringing the pin back high completes the exit. Once the interrupt is serviced, the next instruction to be executed after RETI will be the one following the instruction that put the device into Power Down.

Design Consideration

- When the idle mode is terminated by a hardware reset, the device normally resumes program execution, from where it left off, up to two machine cycles before the internal rest algorithm takes control. On-chip hardware inhibits access to internal RAM in this event, but access to the port pins is not inhibited. To eliminate the possibility of an unexpected write when Idle is terminated by reset, the instruction following the one that invokes Idle should not be one that writes to a port pin or to external memory.

ONCE™ Mode

The ONCE (“On-Circuit Emulation”) Mode facilitates testing and debugging of systems using the 8XC51FA/FB without the 8XC51FA/FB/FC having to be removed from the circuit. The ONCE Mode is invoked by:

1. Pull ALE low while the device is in reset and $\overline{PSEN}$ is high;
2. Hold ALE low as RST is deactivated.

While the device is in ONCE Mode, the Port 0 pins go into a float state, and the other port pins and ALE and $\overline{PSEN}$ are weakly pulled high. The oscillator circuit remains active. While the 8XC51FA/FB is in this mode, an emulator or test CPU can be used to drive the circuit. Normal operation is restored when a normal reset is applied.

Programmable Clock-Out

The 8XC51FA/83C51FB has a new feature. A 50% duty cycle clock can be programmed to come out on P1.0. This pin, besides being a regular I/O pin, has two alternate functions. It can be programmed:

1. to input the external clock for Timer/Counter 2, or
2. to output a 50% duty cycle clock ranging from 61Hz to 4MHz at a 16MHz operating frequency.

To configure the Timer/Counter 2 as a clock generator, bit C/T2 (in T2CON) must be cleared and bit T20E in T2MOD must be set. Bit TR2 (T2CON.2) also must be set to start the timer.

The Clock-Out frequency depends on the oscillator frequency and the reload value of Timer 2 capture registers (RCAP2H, RCAP2L) as shown in this equation:

$$\frac{\text{Oscillator Frequency}}{4 \times (65536 - \text{RCAP2H, RCAP2L})}$$

In the Clock-Out mode Timer 2 roll-overs will not generate an interrupt. This is similar to when it is used as a baud-rate generator. It is possible to use Timer 2 as a baud-rate generator and a clock generator simultaneously. Note, however, that the baud-rate and the Clock-Out frequency will be the same.

Table 6. External Pin Status During Idle and Power-Down Mode

MODE	PROGRAM MEMORY	ALE	$\overline{PSEN}$	PORT 0	PORT 1	PORT 2	PORT 3
Idle	Internal	1	1	Data	Data	Data	Data
Idle	External	1	1	Float	Data	Address	Data
Power-down	Internal	0	0	Data	Data	Data	Data
Power-down	External	0	0	Float	Data	Data	Data

Programmable Counter Array (PCA)

The Programmable Counter Array is a special Timer that has five 16-bit capture/compare modules associated with it. Each of the modules can be programmed to operate in one of four modes: rising and/or falling edge capture, software timer, high-speed output, or pulse width modulator. Each module has a pin associated with it in port 1. Module 0 is connected to P1.3(CEX0), module 1 to P1.4(CEX1), etc. The basic PCA configuration is shown in Figure 7.

The PCA timer is a common time base for all five modules and can be programmed to run at: 1/12 the oscillator frequency, 1/4 the oscillator frequency, the Timer 0 overflow, or the input on the ECI pin (P1.2). The timer count source is determined from the CPS1 and CPS0 bits in the CMOD SFR as follows (see Figure 10):

CPS1	CPS0	PCA Timer Count Source
0	0	1/12 oscillator frequency
0	1	1/4 oscillator frequency
1	0	Timer 0 overflow
1	1	External Input at ECI pin

In the CMOD SFR are three additional bits associated with the PCA. They are CIDL which allows the PCA to stop during idle mode, WDTE which enables or disables the watchdog function on module 4, and ECF which when set causes an interrupt and the PCA overflow flag CF (in the CCON SFR) to be set when the PCA timer overflows. These functions are shown in Figure 8.

The watchdog timer function is implemented in module 4 (see Figure 17).

The CCON SFR contains the run control bit for the PCA and the flags for the PCA timer (CF) and each module (refer to Figure 11). To run the PCA the CR bit (CCON.6) must be set by software. The PCA is shut off by clearing this bit. The CF bit (CCON.7) is set when the PCA counter overflows and an interrupt will be generated if the ECF bit in the CMOD register is set, The CF bit can only be cleared by software. Bits 0 through 4 of the CCON register are the flags for the modules (bit 0 for module 0, bit 1 for module 1, etc.) and are set by hardware when either a match or a capture occurs. These flags also can only be cleared by software. The PCA interrupt system shown in Figure 9.

Each module in the PCA has a special function register associated with it. These registers are: CCAPM0 for module 0, CCAPM1 for module 1, etc. (see Figure 12). The registers contain the bits that control the mode that each module will operate in. The ECCF bit (CCAPMn.0 where n=0, 1, 2, 3, or 4 depending on the module) enables the CCF flag in the CCON SFR to generate an interrupt when a match or compare occurs in the associated module. PWM (CCAPMn.1) enables the pulse width modulation mode. The TOG bit (CCAPMn.2) when set causes the CEX output associated with the module to toggle when there is a match between the PCA counter and the module's capture/compare register. The match bit MAT (CCAPMn.3) when set will cause the CCFn bit in the CCON register to be set when there is a match between the PCA counter and the module's capture/compare register.

The next two bits CAPN (CCAPMn.4) and CAPP (CCAPMn.5) determine the edge that a capture input will be active on. The CAPN bit enables the negative edge, and the CAPP bit enables the positive edge. If both bits are set both edges will be enabled and a capture will occur for either transition. The last bit in the register ECOM (CCAPMn.6) when set enables the comparator function. Figure 13 shows the CCAPMn settings for the various PCA functions.

There are two additional registers associated with each of the PCA modules. They are CCAPnH and CCAPnL and these are the registers that store the 16-bit count when a capture occurs or a compare should occur. When a module is used in the PWM mode these registers are used to control the duty cycle of the output.

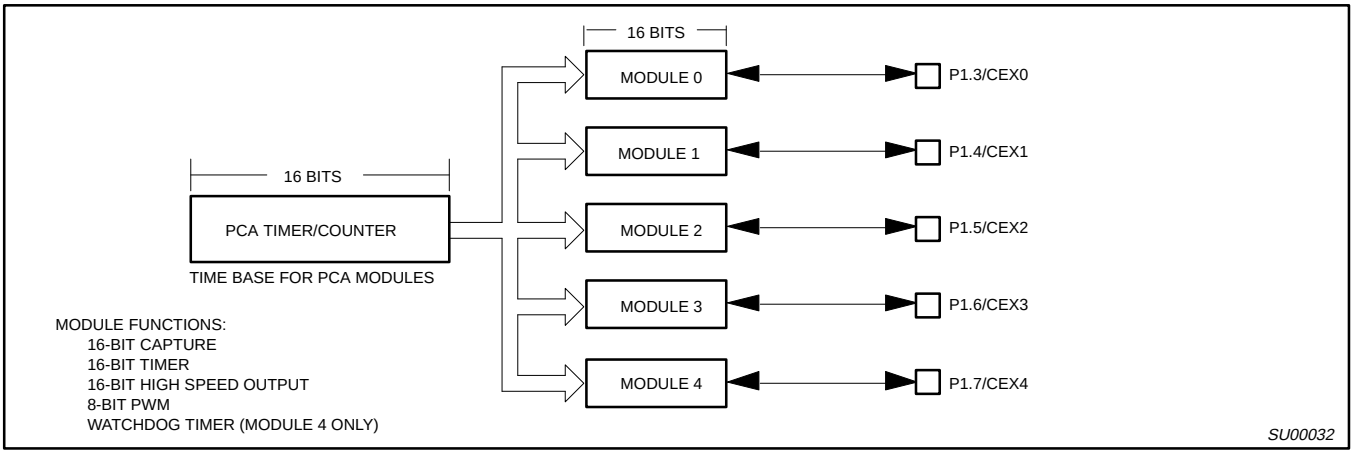

Figure 7. Programmable Counter Array (PCA)

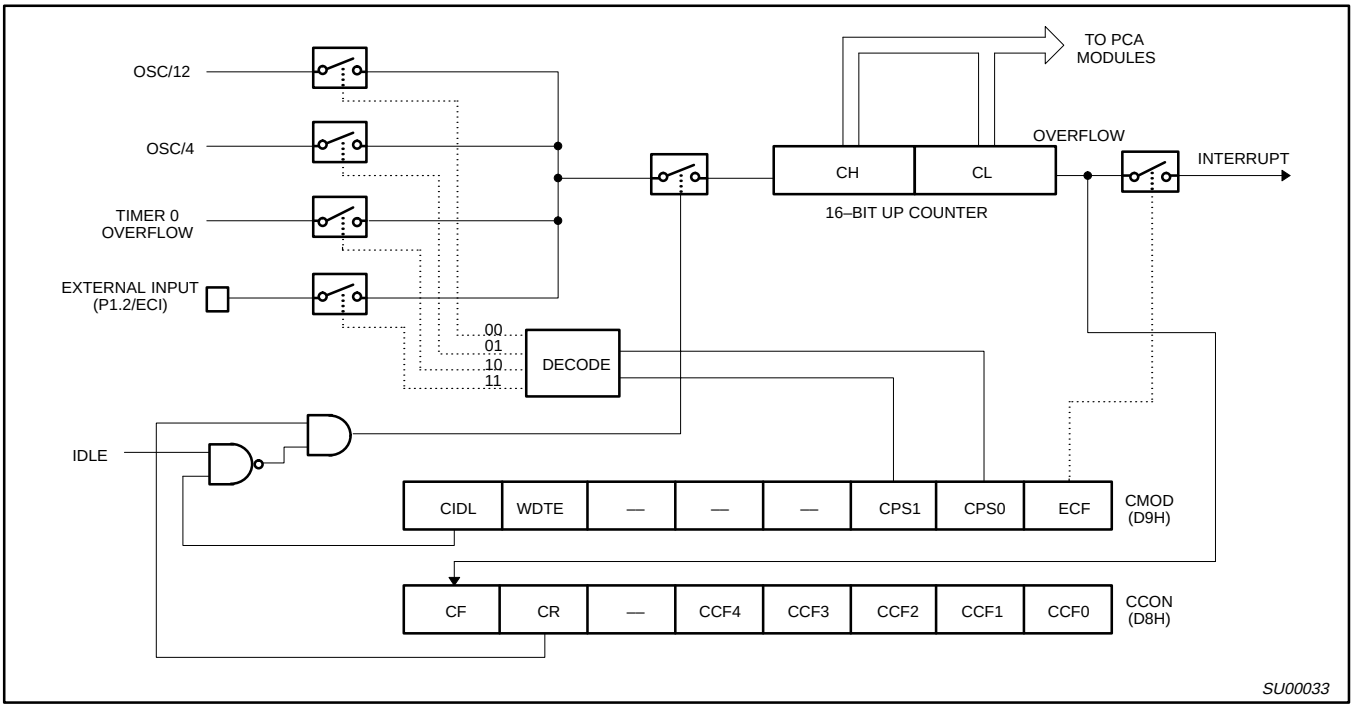

Figure 8. PCA Timer/Counter

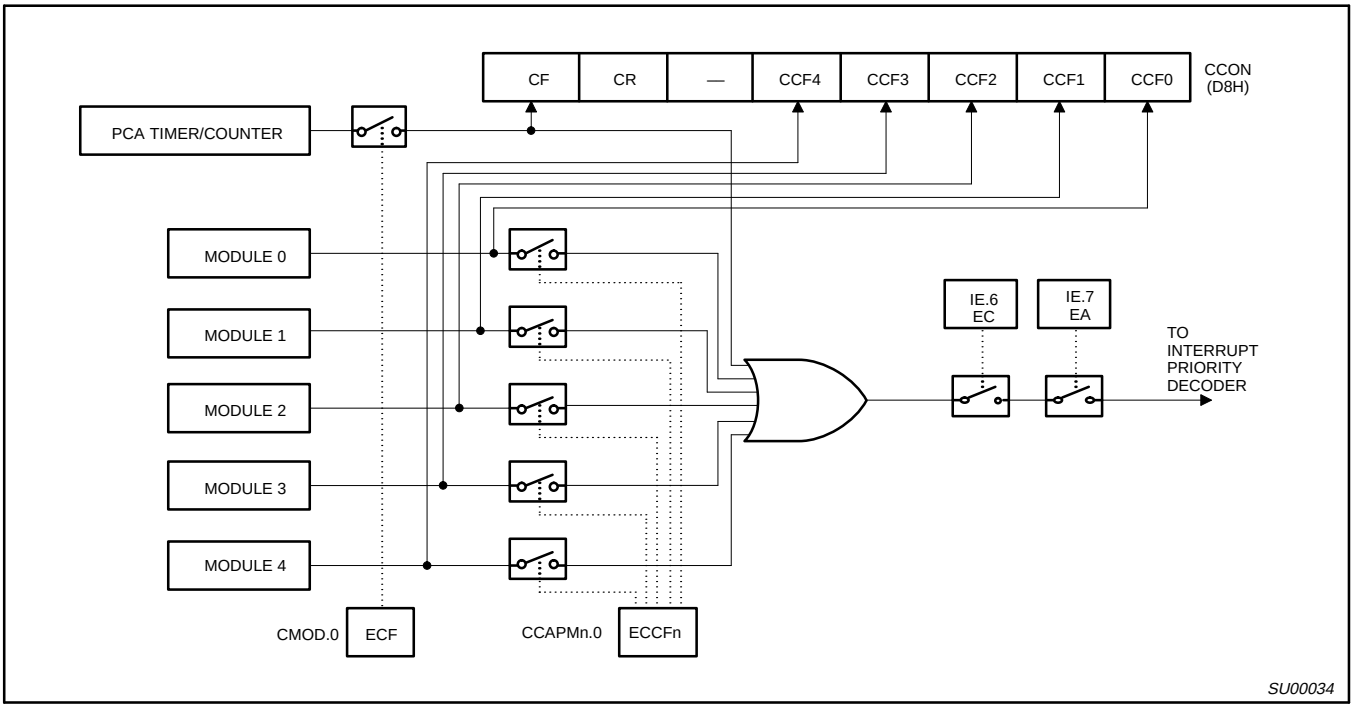

Figure 9. PCA Interrupt System

CMOD Address = OD9H Reset Value = 00XX X000B

Bit Addressable

CIDL	**WDTE**	**–**	**–**	**–**	**CPS1**	**CPS0**	**ECF**
Bit: 7	6	5	4	3	2	1	0

Symbol	Function
CIDL	Counter Idle control: CIDL = 0 programs the PCA Counter to continue functioning during idle Mode. CIDL = 1 programs it to be gated off during idle.
WDTE	Watchdog Timer Enable: WDTE = 0 disables Watchdog Timer function on PCA Module 4. WDTE = 1 enables it.
–	Not implemented, reserved for future use.*
CPS1	PCA Count Pulse Select bit 1.
CPS0	PCA Count Pulse Select bit 0.

CPS1	**CPS0**	**Selected PCA Input****	
0	0	0	Internal clock, $f_{OSC} \div 12$
0	1	1	Internal clock, $f_{OSC} \div 4$
1	0	2	Timer 0 overflow
1	1	3	External clock at ECI/P1.2 pin (max. rate = $f_{OSC} \div 8$)

ECF	PCA Enable Counter Overflow interrupt: ECF = 1 enables CF bit in CCON to generate an interrupt. ECF = 0 disables that function of CF.

NOTE:
* User software should not write 1s to reserved bits. These bits may be used in future 8051 family products to invoke new features. In that case, the reset or inactive value of the new bit will be 0, and its active value will be 1. The value read from a reserved bit is indeterminate.
** f_{OSC} = oscillator frequency

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Figure 10. CMOD: PCA Counter Mode Register

CCON Address = OD8H Reset Value = 00X0 0000B

Bit Addressable

CF	**CR**	**–**	**CCF4**	**CCF3**	**CCF2**	**CCF1**	**CCF0**
Bit: 7	6	5	4	3	2	1	0

Symbol	Function
CF	PCA Counter Overflow flag. Set by hardware when the counter rolls over. CF flags an interrupt if bit ECF in CMOD is set. CF may be set by either hardware or software but can only be cleared by software.
CR	PCA Counter Run control bit. Set by software to turn the PCA counter on. Must be cleared by software to turn the PCA counter off.
–	Not implemented, reserved for future use*.
CCF4	PCA Module 4 interrupt flag. Set by hardware when a match or capture occurs. Must be cleared by software.
CCF3	PCA Module 3 interrupt flag. Set by hardware when a match or capture occurs. Must be cleared by software.
CCF2	PCA Module 2 interrupt flag. Set by hardware when a match or capture occurs. Must be cleared by software.
CCF1	PCA Module 1 interrupt flag. Set by hardware when a match or capture occurs. Must be cleared by software.
CCF0	PCA Module 0 interrupt flag. Set by hardware when a match or capture occurs. Must be cleared by software.

NOTE:
* User software should not write 1s to reserved bits. These bits may be used in future 8051 family products to invoke new features. In that case, the reset or inactive value of the new bit will be 0, and its active value will be 1. The value read from a reserved bit is indeterminate.

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Figure 11. CCON: PCA Counter Control Register

CCAPMn Address CCAPM0 0DAH
CCAPM1 0DBH
CCAPM2 0DCH
CCAPM3 0DDH
CCAPM4 0DEH

Reset Value = X000 0000B

Not Bit Addressable

	–	ECOMn	CAPPn	CAPNn	MATn	TOGn	PWMn	ECCFn
Bit:	7	6	5	4	3	2	1	0

Symbol	Function
–	Not implemented, reserved for future use*.
ECOMn	Enable Comparator. ECOMn = 1 enables the comparator function.
CAPPn	Capture Positive, CAPPn = 1 enables positive edge capture.
CAPNn	Capture Negative, CAPNn = 1 enables negative edge capture.
MATn	Match. When MATn = 1, a match of the PCA counter with this module's compare/capture register causes the CCFn bit in CCON to be set, flagging an interrupt.
TOGn	Toggle. When TOGn = 1, a match of the PCA counter with this module's compare/capture register causes the CEXn pin to toggle.
PWMn	Pulse Width Modulation Mode. PWMn = 1 enables the CEXn pin to be used as a pulse width modulated output.
ECCFn	Enable CCF interrupt. Enables compare/capture flag CCFn in the CCON register to generate an interrupt.

NOTE:
*User software should not write 1s to reserved bits. These bits may be used in future 8051 family products to invoke new features. In that case, the reset or inactive value of the new bit will be 0, and its active value will be 1. The value read from a reserved bit is indeterminate.

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Figure 12. CCAPMn: PCA Modules Compare/Capture Registers

–	ECOMn	CAPPn	CAPNn	MATn	TOGn	PWMn	ECCFn	MODULE FUNCTION
X	0	0	0	0	0	0	0	No operation
X	X	1	0	0	0	0	X	16-bit capture by a positive-edge trigger on CEXn
X	X	0	1	0	0	0	X	16-bit capture by a negative trigger on CEXn
X	X	1	1	0	0	0	X	16-bit capture by a transition on CEXn
X	1	0	0	1	0	0	X	16-bit Software Timer
X	1	0	0	1	1	0	X	16-bit High Speed Output
X	1	0	0	0	0	1	0	8-bit PWM
X	1	0	0	1	X	0	X	Watchdog Timer

Figure 13. PCA Module Modes (CCAPMn Register)

PCA Capture Mode
To use one of the PCA modules in the capture mode either one or both of the CCAPM bits CAPN and CAPP for that module must be set. The external CEX input for the module (on port 1) is sampled for a transition. When a valid transition occurs the PCA hardware loads the value of the PCA counter registers (CH and CL) into the module's capture registers (CCAPnL and CCAPnH). If the CCFn bit for the module in the CCON SFR and the ECCFn bit in the CCAPMn SFR are set then an interrupt will be generated. Refer to Figure 14.

16-bit Software Timer Mode
The PCA modules can be used as software timers by setting both the ECOM and MAT bits in the modules CCAPMn register. The PCA timer will be compared to the module's capture registers and when a match occurs an interrupt will occur if the CCFn (CCON SFR) and the ECCFn (CCAPMn SFR) bits for the module are both set (see Figure 15).

High Speed Output Mode
In this mode the CEX output (on port 1) associated with the PCA module will toggle each time a match occurs between the PCA counter and the module's capture registers. To activate this mode the TOG, MAT, and ECOM bits in the module's CCAPMn SFR must be set (see Figure 16).

Pulse Width Modulator Mode
All of the PCA modules can be used as PWM outputs. Figure 17 shows the PWM function. The frequency of the output depends on the source for the PCA timer. All of the modules will have the same frequency of output because they all share the PCA timer. The duty cycle of each module is independently variable using the module's capture register CCAPLn. When the value of the PCA CL SFR is less than the value in the module's CCAPLn SFR the output will be low, when it is equal to or greater than the output will be high. When CL overflows from FF to 00, CCAPLn is reloaded with the value in CCAPHn. the allows updating the PWM without glitches. The PWM and ECOM bits in the module's CCAPMn register must be set to enable the PWM mode.

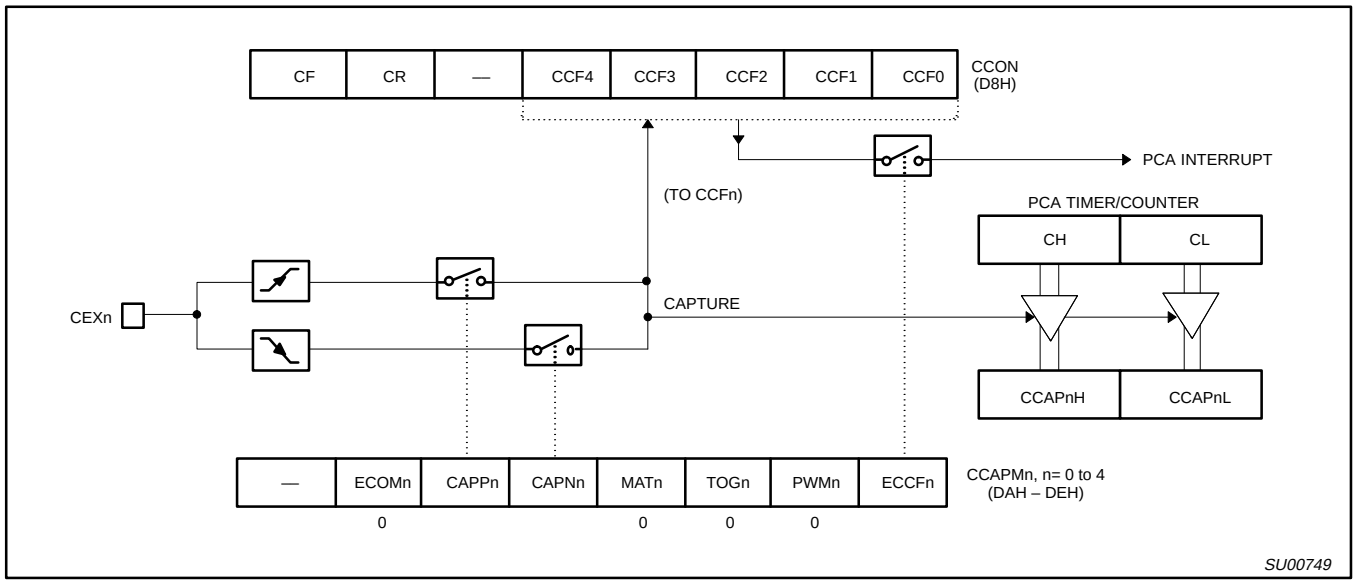

Figure 14. PCA Capture Mode

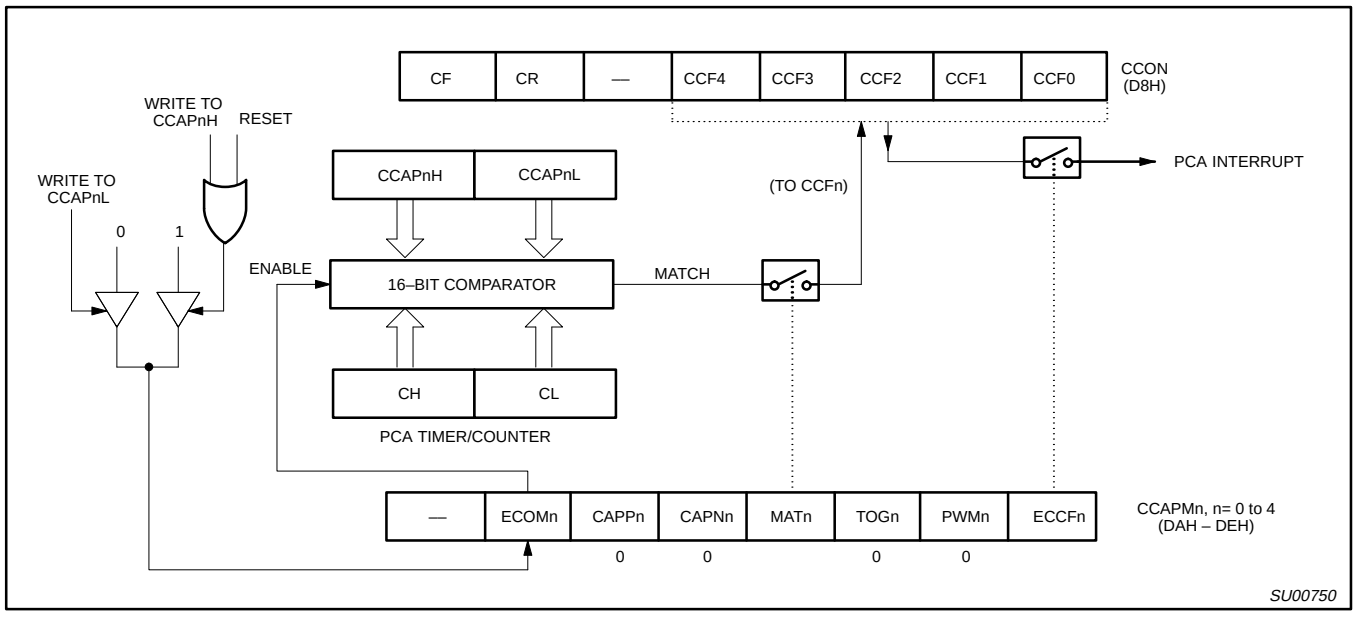

Figure 15. PCA Compare Mode

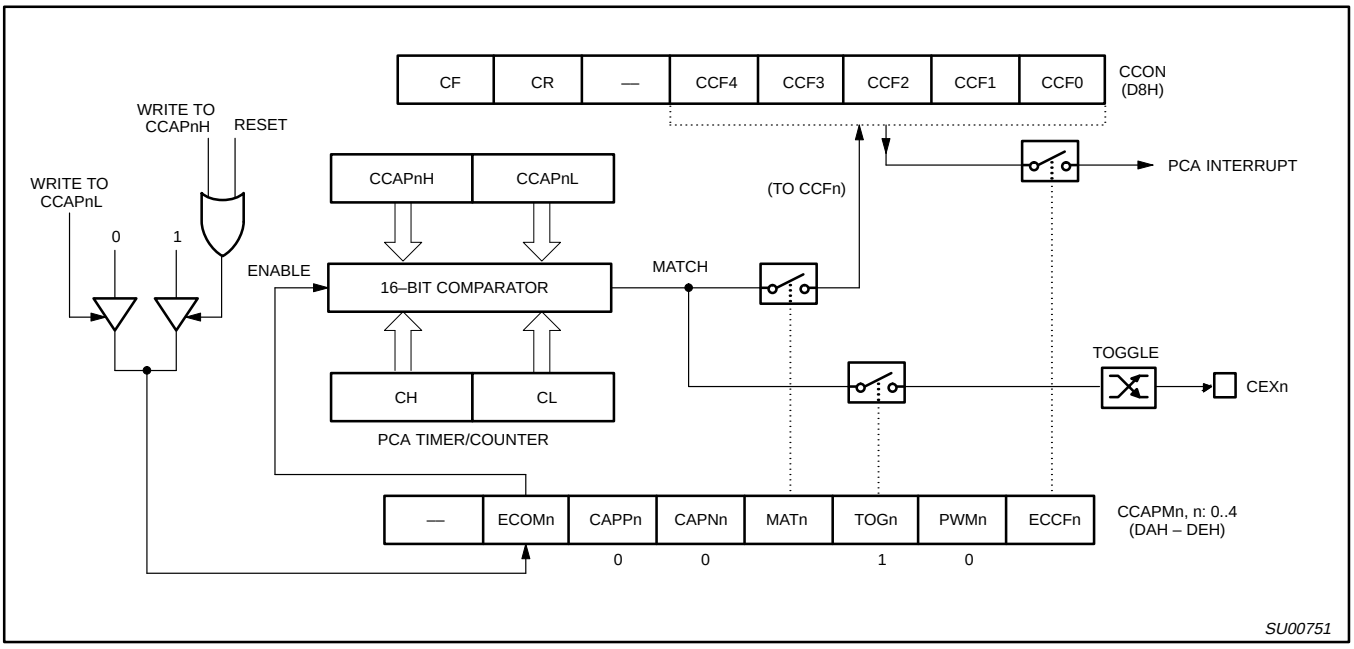

Figure 16. PCA High Speed Output Mode

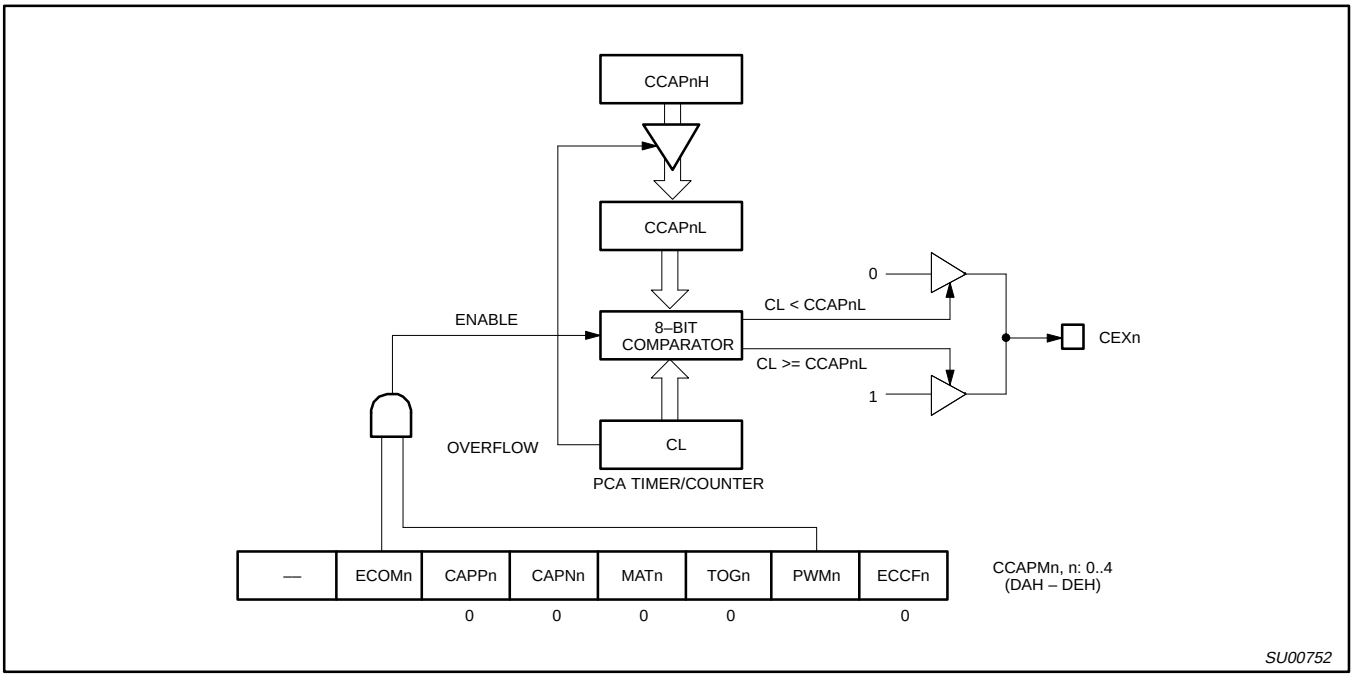

Figure 17. PCA PWM Mode

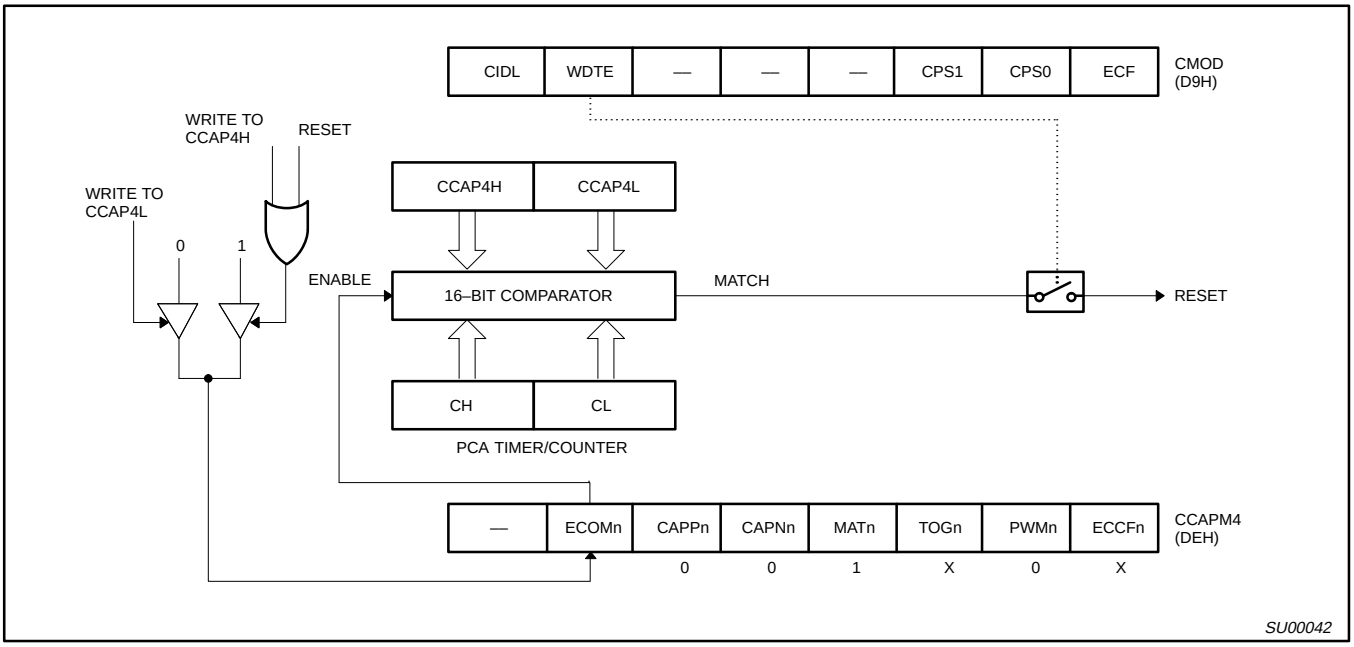

Figure 18. PCA Watchdog Timer

Enhanced UART

The UART operates in all of the usual modes that are described in the first section of *Data Handbook IC20, 80C51-Based 8-Bit Microcontrollers*. In addition the UART can perform framing error detect by looking for missing stop bits, and automatic address recognition. The 8XC51FA/83C51FB UART also fully supports multiprocessor communication as does the standard 80C51 UART.

When used for framing error detect the UART looks for missing stop bits in the communication. A missing bit will set the FE bit in the SCON register. The FE bit shares the SCON.7 bit with SM0 and the function of SCON.7 is determined by PCON.6 (SMOD0) (see Figure 19). If SMOD0 is set then SCON.7 functions as FE. SCON.7 functions as SM0 when SMOD0 is cleared. When used as FE SCON.7 can only be cleared by software. Refer to Figure 20.

Automatic Address Recognition

Automatic Address Recognition is a feature which allows the UART to recognize certain addresses in the serial bit stream by using hardware to make the comparisons. This feature saves a great deal of software overhead by eliminating the need for the software to examine every serial address which passes by the serial port. This feature is enabled by setting the SM2 bit in SCON. In the 9 bit UART modes, mode 2 and mode 3, the Receive Interrupt flag (RI) will be automatically set when the received byte contains either the “Given” address or the “Broadcast” address. The 9 bit mode requires that the 9th information bit is a 1 to indicate that the received information is an address and not data. Automatic address recognition is shown in Figure 21.

The 8 bit mode is called Mode 1. In this mode the RI flag will be set if SM2 is enabled and the information received has a valid stop bit following the 8 address bits and the information is either a Given or Broadcast address.

Mode 0 is the Shift Register mode and SM2 is ignored.

Using the Automatic Address Recognition feature allows a master to selectively communicate with one or more slaves by invoking the Given slave address or addresses. All of the slaves may be contacted by using the Broadcast address. Two special Function Registers are used to define the slave’s address, SADDR, and the address mask, SADEN. SADEN is used to define which bits in the SADDR are to b used and which bits are “don’t care”. The SADEN mask can be logically ANDed with the SADDR to create the “|Given” address which the master will use for addressing each of the slaves. Use of the Given address allows multiple slaves to be recognized while excluding others. The following examples will help to show the versatility of this scheme:

Slave 0	SADDR	=	1100 0000
	SADEN	=	1111 1101
	Given	=	1100 00X0
Slave 1	SADDR	=	1100 0000
	SADEN	=	1111 1110
	Given	=	1100 000X

In the above example SADDR is the same and the SADEN data is used to differentiate between the two slaves. Slave 0 requires a 0 in bit 0 and it ignores bit 1. Slave 1 requires a 0 in bit 1 and bit 0 is ignored. A unique address for Slave 0 would be 1100 0010 since slave 1 requires a 0 in bit 1. A unique address for slave 1 would be 1100 0001 since a 1 in bit 0 will exclude slave 0. Both slaves can be selected at the same time by an address which has bit 0 = 0 (for slave 0) and bit 1 = 0 (for slave 1). Thus, both could be addressed with 1100 0000.

In a more complex system the following could be used to select slaves 1 and 2 while excluding slave 0:

Slave 0	SADDR	=	1100 0000
	SADEN	=	1111 1001
	Given	=	1100 0XX0
Slave 1	SADDR	=	1110 0000
	SADEN	=	1111 1010
	Given	=	1110 0X0X
Slave 2	SADDR	=	1110 0000
	SADEN	=	1111 1100
	Given	=	1110 00XX

In the above example the differentiation among the 3 slaves is in the lower 3 address bits. Slave 0 requires that bit 0 = 0 and it can be uniquely addressed by 1110 0110. Slave 1 requires that bit 1 = 0 and it can be uniquely addressed by 1110 and 0101. Slave 2 requires that bit 2 = 0 and its unique address is 1110 0011. To select Slaves 0 and 1 and exclude Slave 2 use address 1110 0100, since it is necessary t make bit 2 = 1 to exclude slave 2.

The Broadcast Address for each slave is created by taking the logical OR of SADDR and SADEN. Zeros in this result are teated as don't-cares. In most cases, interpreting the don't-cares as ones, the broadcast address will be FF hexadecimal.

Upon reset SADDR (SFR address 0A9H) and SADEN (SFR address 0B9H) are leaded with 0s. This produces a given address of all "don't cares" as well as a Broadcast address of all "don't cares". this effectively disables the Automatic Addressing mode and allows the microcontroller to use standard 80C51 type UART drivers which do not make use of this feature.

SCON Address = 98H Reset Value = 0000 0000B

Bit Addressable

	SM0/FE	**SM1**	**SM2**	**REN**	**TB8**	**RB8**	**TI**	**RI**
Bit:	7	6	5	4	3	2	1	0

(SMOD0 = 0/1)*

Symbol	**Function**
FE	Framing Error bit. This bit is set by the receiver when an invalid stop bit is detected. The FE bit is not cleared by valid frames but should be cleared by software. The SMOD0 bit must be set to enable access to the FE bit.
SM0	Serial Port Mode Bit 0, (SMOD0 must = 0 to access bit SM0)
SM1	Serial Port Mode Bit 1

SM0	**SM1**	**Mode**	**Description**	**Baud Rate****
0	0	0	shift register	$f_{OSC}/12$
0	1	1	8-bit UART	variable
1	0	2	9-bit UART	$f_{OSC}/64$ or $f_{OSC}/32$
1	1	3	9-bit UART	variable

SM2	Enables the Automatic Address Recognition feature in Modes 2 or 3. If SM2 = 1 then RI will not be set unless the received 9th data bit (RB8) is 1, indicating an address, and the received byte is a Given or Broadcast Address. In Mode 1, if SM2 = 1 then RI will not be activated unless a valid stop bit was received, and the received byte is a Given or Broadcast Address. In Mode 0, SM2 should be 0.
REN	Enables serial reception. Set by software to enable reception. Clear by software to disable reception.
TB8	The 9th data bit that will be transmitted in Modes 2 and 3. Set or clear by software as desired.
RB8	In modes 2 and 3, the 9th data bit that was received. In Mode 1, if SM2 = 0, RB8 is the stop bit that was received. In Mode 0, RB8 is not used.
TI	Transmit interrupt flag. Set by hardware at the end of the 8th bit time in Mode 0, or at the beginning of the stop bit in the other modes, in any serial transmission. Must be cleared by software.
RI	Receive interrupt flag. Set by hardware at the end of the 8th bit time in Mode 0, or halfway through the stop bit time in the other modes, in any serial reception (except see SM2). Must be cleared by software.

NOTE:
*SMOD0 is located at PCON6.
**f_{OSC} = oscillator frequency

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Figure 19. SCON: Serial Port Control Register

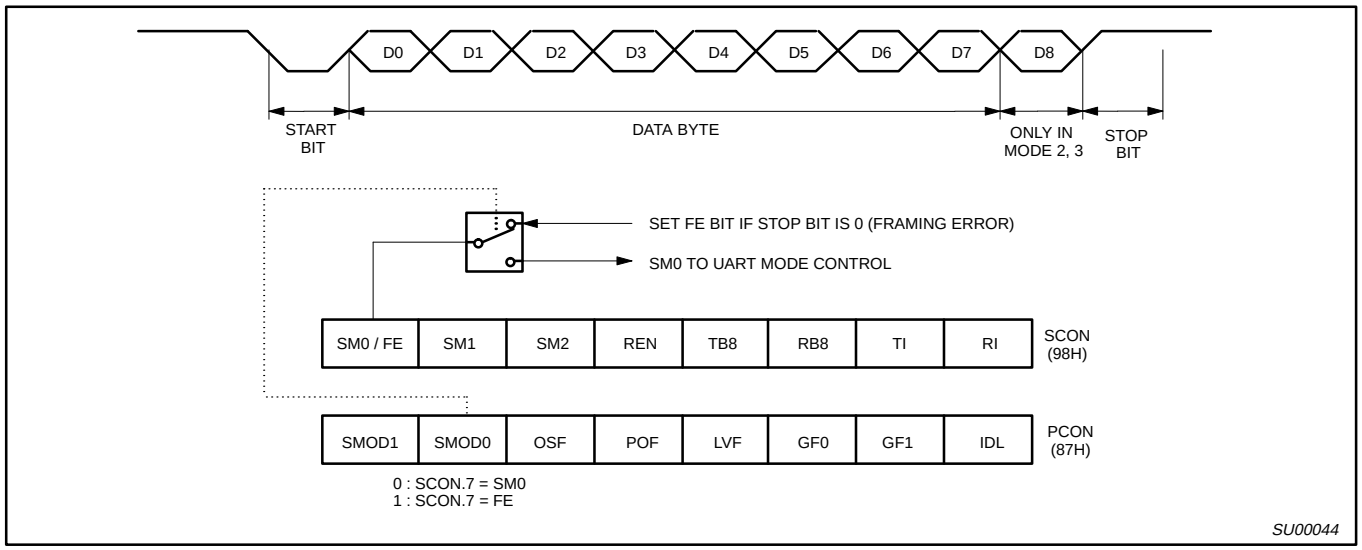

Figure 20. UART Framing Error Detection

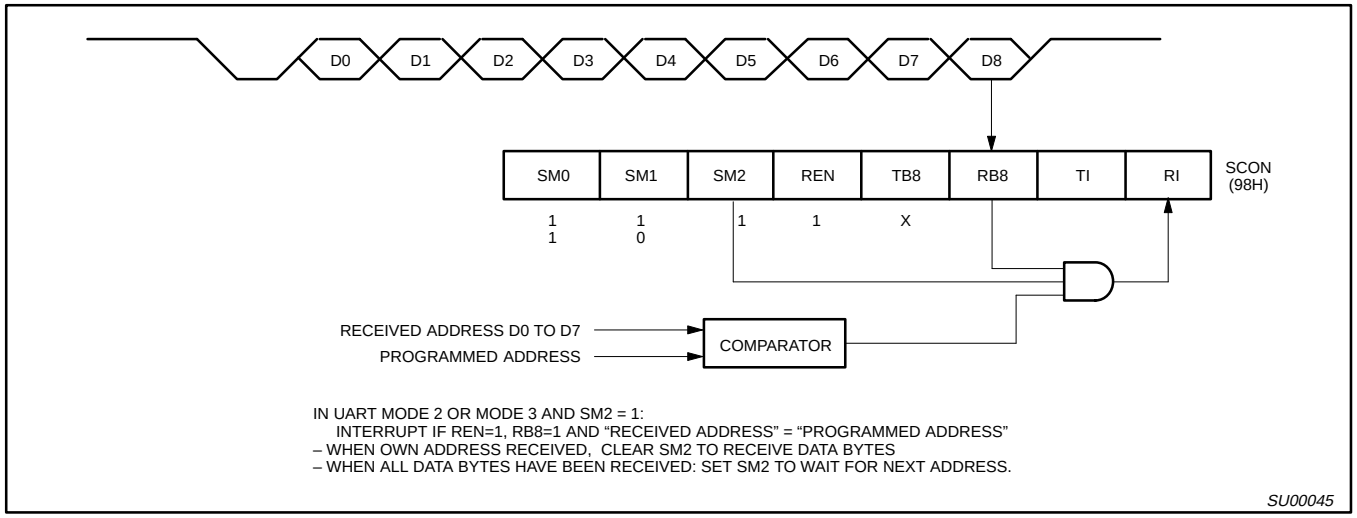

Figure 21. UART Multiprocessor Communication, Automatic Address Recognition

Interrupt Priority Structure

The 8XC51FA/FB has a 7-source four-level interrupt structure. There are 3 SFRs associated with the interrupts on the 8XC51FA/FB. They are the IE and IP. (See Figures 22 and 23.) In addition, there is the IPH (Interrupt Priority High) register that makes the four-level interrupt structure possible. The IPH is located at SFR address B7H. The structure of the IPH register and a description of its bits is shown below:

IPH (Interrupt Priority High) (B7H)

7	6	5	4	3	2	1	0
–	PPCH	PT2H	PSH	PT1H	PX1H	PT0H	PX0H

IPH.0 PX0H External interrupt 0 priority high
IPH.1 PT0H Timer 0 interrupt priority high
IPH.2 PX1H External interrupt 1 priority high
IPH.3 PT1H Timer 1 interrupt priority high
IPH.4 PSH Serial Port interrupt high
IPH.5 PT2H Timer 2 interrupt priority high
IPH.6 PPCH PCA interrupt priority high
IPH.7 — Not implemented

The function of the IPH SFR is simple and when combined with the IP SFR determines the priority of each interrupt. The priority of each interrupt is determined as shown in the following table:

PRIORITY BITS		INTERRUPT PRIORITY LEVEL
IPH.x	IP.x	
0	0	Level 0 (lowest priority)
0	1	Level 1
1	0	Level 2
1	1	Level 3 (highest priority)

The priority scheme for servicing the interrupts is the same as that for the 80C51, except there are four interrupt levels on the 8XC51FX rather than two as on the 80C51. An interrupt will be serviced as long as an interrupt of equal or higher priority is not already being serviced. If an interrupt of equal or higher level priority is being serviced, the new interrupt will wait until it is finished before being serviced. If a lower priority level interrupt is being serviced, it will be stopped and the new interrupt serviced. When the new interrupt is finished, the lower priority level interrupt that was stopped will be completed.

Table 7. Interrupt Table

SOURCE	POLLING PRIORITY	REQUEST BITS	HARDWARE CLEAR?	VECTOR ADDRESS
X0	1	IE0	N (L)[1] Y (T)[2]	03H
T0	2	TP0	Y	0BH
X1	3	IE1	N (L) Y (T)	13H
T1	4	TF1	Y	1BH
SP	5	R1, TI	N	23H
T2	6	TF2, EXF2	N	2BH
PCA	7	CF, CCFn n = 0–4	N	33H

NOTES:
1. L = Level activated
2. T = Transition activated

	7	6	5	4	3	2	1	0
IE (0A8H)	EA	EC	ET2	ES	ET1	EX1	ET0	EX0

Enable Bit = 1 enables the interrupt.
Enable Bit = 0 disables it.

BIT	SYMBOL	FUNCTION
IE.7	EA	Global disable bit. If EA = 0, all interrupts are disabled. If EA = 1, each interrupt can be individually enabled or disabled by setting or clearing its enable bit.
IE.6	EC	PCA interrupt enable bit.
IE.5	ET2	Timer 2 interrupt enable bit.
IE.4	ES	Serial Port interrupt enable bit.
IE.3	ET1	Timer 1 interrupt enable bit.
IE.2	EX1	External interrupt 1 enable bit.
IE.1	ET0	Timer 0 interrupt enable bit.
IE.0	EX0	External interrupt 0 enable bit.

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Figure 22. IE Registers

	7	6	5	4	3	2	1	0
IP (0B8H)	—	PPC	PT2	PS	PT1	PX1	PT0	PX0

Priority Bit = 1 assigns high priority
Priority Bit = 0 assigns low priority

BIT	SYMBOL	FUNCTION
IP.7	—	Not implemented, reserved for future use.
IP.6	PPC	PCA interrupt priority bit.
IP.5	PT2	Timer 2 interrupt priority bit.
IP.4	PS	Serial Port interrupt priority bit.
IP.3	PT1	Timer 1 interrupt priority bit.
IP.2	PX1	External interrupt 1 priority bit.
IP.1	PT0	Timer 0 interrupt priority bit.
IP.0	PX0	External interrupt 0 priority bit.

SU00572

Figure 23. IP Registers

Reduced EMI Mode

The AO bit (AUXR.0) in the AUXR register when set disables the ALE output.

8XC51FA/83C51FB/83C51FC Reduced EMI Mode

AUXR (8EH)

7	6	5	4	3	2	1	0
–	–	–	–	–	–	–	AO

AO: Turns off ALE output.

Dual DPTR

The dual DPTR structure (see Figure 24) is a way by which the 83C51FA, 83C51FB, and 83C51FC will specify the address of an external data memory location. (*NOTE: not available on 80C51FA [ROMless] at this time.) There are two 16-bit DPTR registers that address the external memory, and a single bit called DPS = AUSR1/bit0 that allows the program code to switch between them.

- New Register Name: AUXR1#
- SFR Address: A2H
- Reset Value: xxxxxxx0B

7	6	5	4	3	2	1	0
–	–	–	–	–	–	–	DPS

Where:
DPS = AUXR1/bit0 = Switches between DPTR0 and DPTR1.

Select Reg	DPS
DPTR0	0
DPTR1	1

The DPS bit status should be saved by software when switching between DPTR0 and DPTR1.

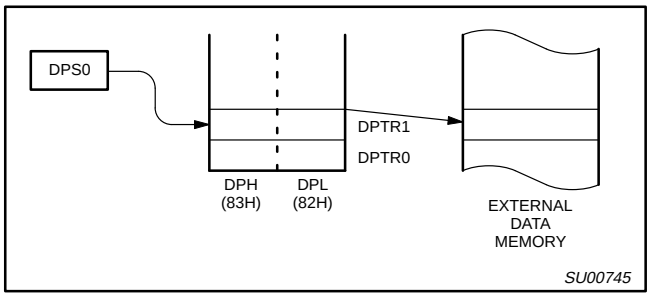


Figure 24.

DPTR Instructions

The instructions that refer to DPTR refer to the data pointer that is currently selected using the AUXR1/bit 0 register. The six instructions that use the DPTR are as follows:

INC DPTR	Increments the data pointer by 1
MOV DPTR, #data16	Loads the DPTR with a 16-bit constant
MOV A, @ A+DPTR	Move code byte relative to DPTR to ACC
MOVX A, @ DPTR	Move external RAM (16-bit address) to ACC
MOVX @ DPTR , A	Move ACC to external RAM (16-bit address)
JMP @ A + DPTR	Jump indirect relative to DPTR

The data pointer can be accessed on a byte-by-byte basis be specifying the Low or High byte in an instruction which accesses the SFRs. See application note AN458 for more details.

ABSOLUTE MAXIMUM RATINGS[1, 2, 3]

PARAMETER	RATING	UNIT
Operating temperature under bias	0 to +70 or –40 to +85	°C
Storage temperature range	–65 to +150	°C
Voltage on $\overline{EA}/V_{PP}$ pin to V_{SS}	0 to +13.0	V
Voltage on any other pin to V_{SS}	–0.5 to +6.5	V
Maximum I_{OL} per I/O pin	15	mA
Power dissipation (based on package heat transfer limitations, not device power consumption)	1.5	W

NOTES:
1. Stresses above 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 conditions other than those described in the AC and DC Electrical Characteristics section of this specification is not implied.
2. This product includes circuitry specifically designed for the protection of its internal devices from the damaging effects of excessive static charge. Nonetheless, it is suggested that conventional precautions be taken to avoid applying greater than the rated maxima.
3. Parameters are valid over operating temperature range unless otherwise specified. All voltages are with respect to V_{SS} unless otherwise noted.

DC ELECTRICAL CHARACTERISTICS

T_{amb} = 0°C to +70°C or –40°C to +85°C, V_{CC} = 2.7V to 5.5V ±10%, V_{SS} = 0V; (–4 and –5 devices; 16MHz devices except S80C51FA [ROMless])

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN	TYP[1]	MAX	
V_{IL}	Input low voltage	4.0V < V_{CC} < 5.5V	–0.5		$0.2V_{CC}$–0.1	V
		2.7V<V_{CC}< 4.0V	–0.5		0.7	V
V_{IH}	Input high voltage (ports 0, 1, 2, 3, $\overline{EA}$)		$0.2V_{CC}$+0.9		V_{CC}+0.5	V
V_{IH1}	Input high voltage, XTAL1, RST		$0.7V_{CC}$		V_{CC}+0.5	V
V_{OL}	Output low voltage, ports 1, 2, [8]	V_{CC} = 2.7V I_{OL} = 1.6mA[2]			0.4	V
V_{OL1}	Output low voltage, port 0, ALE, $\overline{PSEN}$[8, 7]	V_{CC} = 2.7V I_{OL} = 3.2mA[2]			0.4	V
V_{OH}	Output high voltage, ports 1, 2, 3 [3]	V_{CC} = 2.7V I_{OH} = –20µA	V_{CC} – 0.7			V
		V_{CC} = 4.5V I_{OH} = –30µA	V_{CC} – 0.7			V
V_{OH1}	Output high voltage (port 0 in external bus mode), ALE[9], $\overline{PSEN}$[3]	V_{CC} = 2.7V I_{OH} = –3.2mA	V_{CC} – 0.7			V
I_{IL}	Logical 0 input current, ports 1, 2, 3	V_{IN} = 0.4V	–1		–50	µA
I_{TL}	Logical 1-to-0 transition current, ports 1, 2, 3[6]	V_{IN} = 2.0V See note 4			–650	µA
I_{LI}	Input leakage current, port 0	0.45 < V_{IN} < V_{CC} – 0.3			±10	µA
I_{CC}	Power supply current (see Figure 32):	See note 5				
	Active mode @ 16MHz					
	83C51FA/FB/FC				15	mA
	80C51FA				32	mA
	Idle mode @ 16MHz					
	83C51FA/FB/FC				4	mA
	80C51FA				5	mA
	Power-down mode	T_{amb} = 0°C to 70°C		3	50	µA
		T_{amb} = –40°C to +85°C			75	µA
R_{RST}	Internal reset pull-down resistor		40		225	kΩ
C_{IO}	Pin capacitance[10] (except $\overline{EA}$)				15	pF

NOTES:

1. Typical ratings are not guaranteed. The values listed are at room temperature, 5V.
2. Capacitive loading on ports 0 and 2 may cause spurious noise to be superimposed on the V_{OL}s of ALE and ports 1 and 3. The noise is due to external bus capacitance discharging into the port 0 and port 2 pins when these pins make 1-to-0 transitions during bus operations. In the worst cases (capacitive loading > 100pF), the noise pulse on the ALE pin may exceed 0.8V. In such cases, it may be desirable to qualify ALE with a Schmitt Trigger, or use an address latch with a Schmitt Trigger STROBE input. I_{OL} can exceed these conditions provided that no single output sinks more than 5mA and no more than two outputs exceed the test conditions.
3. Capacitive loading on ports 0 and 2 may cause the V_{OH} on ALE and $\overline{PSEN}$ to momentarily fall below the V_{CC}–0.7 specification when the address bits are stabilizing.
4. Pins of ports 1, 2 and 3 source a transition current when they are being externally driven from 1 to 0. The transition current reaches its maximum value when V_{IN} is approximately 2V.
5. See Figures 33 through 36 for I_{CC} test conditions.
   Active mode: $I_{CC} = 0.9 \times FREQ. + 1.1mA$
   Idle mode: $I_{CC} = 0.18 \times FREQ. + 1.01mA$; See Figure 32.
6. This value applies to T_{amb} = 0°C to +70°C. For T_{amb} = –40°C to +85°C, I_{TL} = –750µA.
7. Load capacitance for port 0, ALE, and $\overline{PSEN}$ = 100pF, load capacitance for all other outputs = 80pF.
8. Under steady state (non-transient) conditions, I_{OL} must be externally limited as follows:
   Maximum I_{OL} per port pin: 15mA (*NOTE: This is 85°C specification.)
   Maximum I_{OL} per 8-bit port: 26mA
   Maximum total I_{OL} for all outputs: 71mA
   If I_{OL} exceeds the test condition, V_{OL} may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test conditions.
9. ALE is tested to V_{OH1}, except when ALE is off then V_{OH} is the voltage specification.
10. Pin capacitance is characterized but not tested. Pin capacitance is less than 25pF. Pin capacitance of ceramic package is less than 15pF (except $\overline{EA}$ is 25pF).

DC ELECTRICAL CHARACTERISTICS

T_{amb} = 0°C to +70°C or –40°C to +85°C, (–A, –B, –I, and –J devices; S80C51FA –4, –5); 5V ±10%; V_{SS} = 0V

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN	TYP[1]	MAX	
V_{IL}	Input low voltage	4.5V < V_{CC} < 5.5V	–0.5		$0.2V_{CC}$–0.1	V
V_{IH}	Input high voltage (ports 0, 1, 2, 3, $\overline{EA}$)		$0.2V_{CC}$+0.9		V_{CC}+0.5	V
V_{IH1}	Input high voltage, XTAL1, RST		$0.7V_{CC}$		V_{CC}+0.5	V
V_{OL}	Output low voltage, ports 1, 2, 3 [8]	V_{CC} = 4.5V I_{OL} = 1.6mA[2]			0.4	V
V_{OL1}	Output low voltage, port 0, ALE, $\overline{PSEN}$ [7, 8]	V_{CC} = 4.5V I_{OL} = 3.2mA[2]			0.4	V
V_{OH}	Output high voltage, ports 1, 2, 3 [3]	V_{CC} = 4.5V I_{OH} = –30µA	V_{CC} – 0.7			V
V_{OH1}	Output high voltage (port 0 in external bus mode), ALE[9], $\overline{PSEN}$[3]	V_{CC} = 4.5V I_{OH} = –3.2mA	V_{CC} – 0.7			V
I_{IL}	Logical 0 input current, ports 1, 2, 3	V_{IN} = 0.4V	–1		–50	µA
I_{TL}	Logical 1-to-0 transition current, ports 1, 2, 3[6]	V_{IN} = 2.0V See note 4			–650	µA
I_{LI}	Input leakage current, port 0	0.45 < V_{IN} < V_{CC} – 0.3			±10	µA
I_{CC}	Power supply current (see Figure 32): Active mode @ 16MHz[5] Idle mode @ 16MHz[5] Power-down mode	See note 5 T_{amb} = 0°C to 70°C T_{amb} = –40°C to +85°C		 3	 15 4 50 75	 µA µA µA µA
R_{RST}	Internal reset pull-down resistor		40		225	kΩ
C_{IO}	Pin capacitance[10] (except $\overline{EA}$)				15	pF

NOTES:

1. Typical ratings are not guaranteed. The values listed are at room temperature, 5V.
2. Capacitive loading on ports 0 and 2 may cause spurious noise to be superimposed on the V_{OL}s of ALE and ports 1 and 3. The noise is due to external bus capacitance discharging into the port 0 and port 2 pins when these pins make 1-to-0 transitions during bus operations. In the worst cases (capacitive loading > 100pF), the noise pulse on the ALE pin may exceed 0.8V. In such cases, it may be desirable to qualify ALE with a Schmitt Trigger, or use an address latch with a Schmitt Trigger STROBE input. I_{OL} can exceed these conditions provided that no single output sinks more than 5mA and no more than two outputs exceed the test conditions.
3. Capacitive loading on ports 0 and 2 may cause the V_{OH} on ALE and $\overline{PSEN}$ to momentarily fall below the V_{CC}–0.7 specification when the address bits are stabilizing.
4. Pins of ports 1, 2 and 3 source a transition current when they are being externally driven from 1 to 0. The transition current reaches its maximum value when V_{IN} is approximately 2V.
5. See Figures 33 through 36 for I_{CC} test conditions.
   Active mode: I_{CC} = 0.9 × FREQ. + 1.1mA
   Idle mode: I_{CC} = 0.18 × FREQ. +1.0mA; See Figure 32.
6. This value applies to T_{amb} = 0°C to +70°C. For T_{amb} = –40°C to +85°C, I_{TL} = –750µA.
7. Load capacitance for port 0, ALE, and $\overline{PSEN}$ = 100pF, load capacitance for all other outputs = 80pF.
8. Under steady state (non-transient) conditions, I_{OL} must be externally limited as follows:
   Maximum I_{OL} per port pin: 15mA (*NOTE: This is 85°C specification.)
   Maximum I_{OL} per 8-bit port: 26mA
   Maximum total I_{OL} for all outputs: 71mA
   If I_{OL} exceeds the test condition, V_{OL} may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test conditions.
9. ALE is tested to V_{OH1}, except when ALE is off then V_{OH} is the voltage specification.
10. Pin capacitance is characterized but not tested. Pin capacitance is less than 25pF. Pin capacitance of ceramic package is less than 15pF (except $\overline{EA}$ is 25pF).

AC ELECTRICAL CHARACTERISTICS

T_{amb} = 0°C to +70°C or –40°C to +85°C, V_{CC} = +2.7V to +5.5V (except S80C51FA V_{CC} = 5.0V ±10%), V_{SS} = 0V[1, 2, 3]

SYMBOL	FIGURE	PARAMETER	16MHz CLOCK		VARIABLE CLOCK		UNIT
			MIN	MAX	MIN	MAX	
$1/t_{CLCL}$	25	Oscillator frequency Speed versions : 4; 5			3.5	16	MHz
t_{LHLL}	25	ALE pulse width	85		$2t_{CLCL}$–40		ns
t_{AVLL}	25	Address valid to ALE low	22		t_{CLCL}–40		ns
t_{LLAX}	25	Address hold after ALE low	32		t_{CLCL}–30		ns
t_{LLIV}	25	ALE low to valid instruction in		150		$4t_{CLCL}$–100	ns
t_{LLPL}	25	ALE low to $\overline{PSEN}$ low	32		t_{CLCL}–30		ns
t_{PLPH}	25	$\overline{PSEN}$ pulse width	142		$3t_{CLCL}$–45		ns
t_{PLIV}	25	$\overline{PSEN}$ low to valid instruction in		82		$3t_{CLCL}$–105	ns
t_{PXIX}	25	Input instruction hold after $\overline{PSEN}$	0		0		ns
t_{PXIZ}	25	Input instruction float after $\overline{PSEN}$		37		t_{CLCL}–25	ns
t_{AVIV}	25	Address to valid instruction in		207		$5t_{CLCL}$–105	ns
t_{PLAZ}	25	$\overline{PSEN}$ low to address float		10		10	ns
Data Memory							
t_{RLRH}	26, 27	$\overline{RD}$ pulse width	275		$6t_{CLCL}$–100		ns
t_{WLWH}	26, 27	$\overline{WR}$ pulse width	275		$6t_{CLCL}$–100		ns
t_{RLDV}	26, 27	$\overline{RD}$ low to valid data in		147		$5t_{CLCL}$–165	ns
t_{RHDX}	26, 27	Data hold after $\overline{RD}$	0		0		ns
t_{RHDZ}	26, 27	Data float after $\overline{RD}$		65		$2t_{CLCL}$–60	ns
t_{LLDV}	26, 27	ALE low to valid data in		350		$8t_{CLCL}$–150	ns
t_{AVDV}	26, 27	Address to valid data in		397		$9t_{CLCL}$–165	ns
t_{LLWL}	26, 27	ALE low to $\overline{RD}$ or $\overline{WR}$ low	137	239	$3t_{CLCL}$–50	$3t_{CLCL}$+50	ns
t_{AVWL}	26, 27	Address valid to $\overline{WR}$ low or $\overline{RD}$ low	122		$4t_{CLCL}$–130		ns
t_{QVWX}	26, 27	Data valid to $\overline{WR}$ transition	13		t_{CLCL}–50		ns
t_{WHQX}	26, 27	Data hold after $\overline{WR}$	13		t_{CLCL}–50		ns
t_{QVWH}	27	Data valid to $\overline{WR}$ high	287		$7t_{CLCL}$–150		ns
t_{RLAZ}	26, 27	$\overline{RD}$ low to address float		0		0	ns
t_{WHLH}	26, 27	$\overline{RD}$ or $\overline{WR}$ high to ALE high	23	103	t_{CLCL}–40	t_{CLCL}+40	ns
External Clock							
t_{CHCX}	29	High time	20		20	t_{CLCL}–t_{CLCX}	ns
t_{CLCX}	29	Low time	20		20	t_{CLCL}–t_{CHCX}	ns
t_{CLCH}	29	Rise time		20		20	ns
t_{CHCL}	29	Fall time		20		20	ns
Shift Register							
t_{XLXL}	28	Serial port clock cycle time	750		$12t_{CLCL}$		ns
t_{QVXH}	28	Output data setup to clock rising edge	492		$10t_{CLCL}$–133		ns
t_{XHQX}	28	Output data hold after clock rising edge	8		$2t_{CLCL}$–117		ns
t_{XHDX}	28	Input data hold after clock rising edge	0		0		ns
t_{XHDV}	28	Clock rising edge to input data valid		492		$10t_{CLCL}$–133	ns

NOTES:
1. Parameters are valid over operating temperature range unless otherwise specified.
2. Load capacitance for port 0, ALE, and $\overline{PSEN}$ = 100pF, load capacitance for all other outputs = 80pF.
3. Interfacing the 83C51FA/FB/FC and 80C51FA to devices with float times up to 45ns is permitted. This limited bus contention will not cause damage to Port 0 drivers.
4. See application note AN457 for external memory interface.

AC ELECTRICAL CHARACTERISTICS

T_{amb} = 0°C to +70°C or –40°C to +85°C, V_{CC} = 5V ±10%, V_{SS} = 0V[1, 2, 3]

SYMBOL	FIGURE	PARAMETER	24MHz CLOCK		VARIABLE CLOCK[4]		33MHz CLOCK		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$1/t_{CLCL}$	25	Oscillator frequency Speed versions : A; B (24MHz) : I; J (33MHz)	3.5	24	3.5	33	 3.5	 33	MHz
t_{LHLL}	25	ALE pulse width	43		$2t_{CLCL}$–40		21		ns
t_{AVLL}	25	Address valid to ALE low	17		t_{CLCL}–25		5		ns
t_{LLAX}	25	Address hold after ALE low	17		t_{CLCL}–25				ns
t_{LLIV}	25	ALE low to valid instruction in		102		$4t_{CLCL}$–65		55	ns
t_{LLPL}	25	ALE low to $\overline{PSEN}$ low	17		t_{CLCL}–25		5		ns
t_{PLPH}	25	$\overline{PSEN}$ pulse width	80		$3t_{CLCL}$–45		45		ns
t_{PLIV}	25	$\overline{PSEN}$ low to valid instruction in		65		$3t_{CLCL}$–60		30	ns
t_{PXIX}	25	Input instruction hold after $\overline{PSEN}$	0		0		0		ns
t_{PXIZ}	25	Input instruction float after $\overline{PSEN}$		17		t_{CLCL}–25		5	ns
t_{AVIV}	25	Address to valid instruction in		128		$5t_{CLCL}$–80		70	ns
t_{PLAZ}	25	$\overline{PSEN}$ low to address float		10		10		10	ns
Data Memory									
t_{RLRH}	26, 27	$\overline{RD}$ pulse width	150		$6t_{CLCL}$–100		82		ns
t_{WLWH}	26, 27	$\overline{WR}$ pulse width	150		$6t_{CLCL}$–100		82		ns
t_{RLDV}	26, 27	$\overline{RD}$ low to valid data in		118		$5t_{CLCL}$–90		60	ns
t_{RHDX}	26, 27	Data hold after $\overline{RD}$	0		0		0		ns
t_{RHDZ}	26, 27	Data float after $\overline{RD}$		55		$2t_{CLCL}$–28		32	ns
t_{LLDV}	26, 27	ALE low to valid data in		183		$8t_{CLCL}$–150		90	ns
t_{AVDV}	26, 27	Address to valid data in		210		$9t_{CLCL}$–165		105	ns
t_{LLWL}	26, 27	ALE low to $\overline{RD}$ or $\overline{WR}$ low	75	175	$3t_{CLCL}$–50	$3t_{CLCL}$+50	40	140	ns
t_{AVWL}	26, 27	Address valid to $\overline{WR}$ low or $\overline{RD}$ low	92		$4t_{CLCL}$–75		45		ns
t_{QVWX}	26, 27	Data valid to $\overline{WR}$ transition	12		t_{CLCL}–30		0		ns
t_{WHQX}	26, 27	Data hold after $\overline{WR}$	17		t_{CLCL}–25		5		ns
t_{QVWH}	27	Data valid to $\overline{WR}$ high	162		$7t_{CLCL}$–130		80		ns
t_{RLAZ}	26, 27	$\overline{RD}$ low to address float		0		0		0	ns
t_{WHLH}	26, 27	$\overline{RD}$ or $\overline{WR}$ high to ALE high	17	67	t_{CLCL}–25	t_{CLCL}+25	5	55	ns
External Clock									
t_{CHCX}	29	High time	17		17	t_{CLCL}–t_{CLCX}			ns
t_{CLCX}	29	Low time	17		17	t_{CLCL}–t_{CHCX}			ns
t_{CLCH}	29	Rise time		5		5			ns
t_{CHCL}	29	Fall time		5		5			ns
Shift Register									
t_{XLXL}	28	Serial port clock cycle time	505		$12t_{CLCL}$		360		ns
t_{QVXH}	28	Output data setup to clock rising edge	283		$10t_{CLCL}$–133		167		ns
t_{XHQX}	28	Output data hold after clock rising edge	3		$2t_{CLCL}$–80				ns
t_{XHDX}	28	Input data hold after clock rising edge	0		0		0		ns
t_{XHDV}	28	Clock rising edge to input data valid		283		$10t_{CLCL}$–133		167	ns

NOTES:
1. Parameters are valid over operating temperature range unless otherwise specified.
2. Load capacitance for port 0, ALE, and $\overline{PSEN}$ = 100pF, load capacitance for all other outputs = 80pF.
3. Interfacing the 83C51FA/FB/FC and 80C51FA to devices with float times up to 45ns is permitted. This limited bus contention will not cause damage to Port 0 drivers.
4. Variable clock is specified for oscillator frequencies greater than 16MHz to 33MHz. For frequencies equal or less than 16MHz, see 16MHz “AC Electrial Characteristics”, page 3-52.

EXPLANATION OF THE AC SYMBOLS

Each timing symbol has five characters. The first character is always 't' (= time). The other characters, depending on their positions, indicate the name of a signal or the logical status of that signal. The designations are:

A – Address
C – Clock
D – Input data
H – Logic level high
I – Instruction (program memory contents)
L – Logic level low, or ALE
P – $\overline{\text{PSEN}}$
Q – Output data
R – $\overline{\text{RD}}$ signal
t – Time
V – Valid
W – $\overline{\text{WR}}$ signal
X – No longer a valid logic level
Z – Float

Examples: t_{AVLL} = Time for address valid to ALE low.
t_{LLPL} =Time for ALE low to $\overline{\text{PSEN}}$ low.

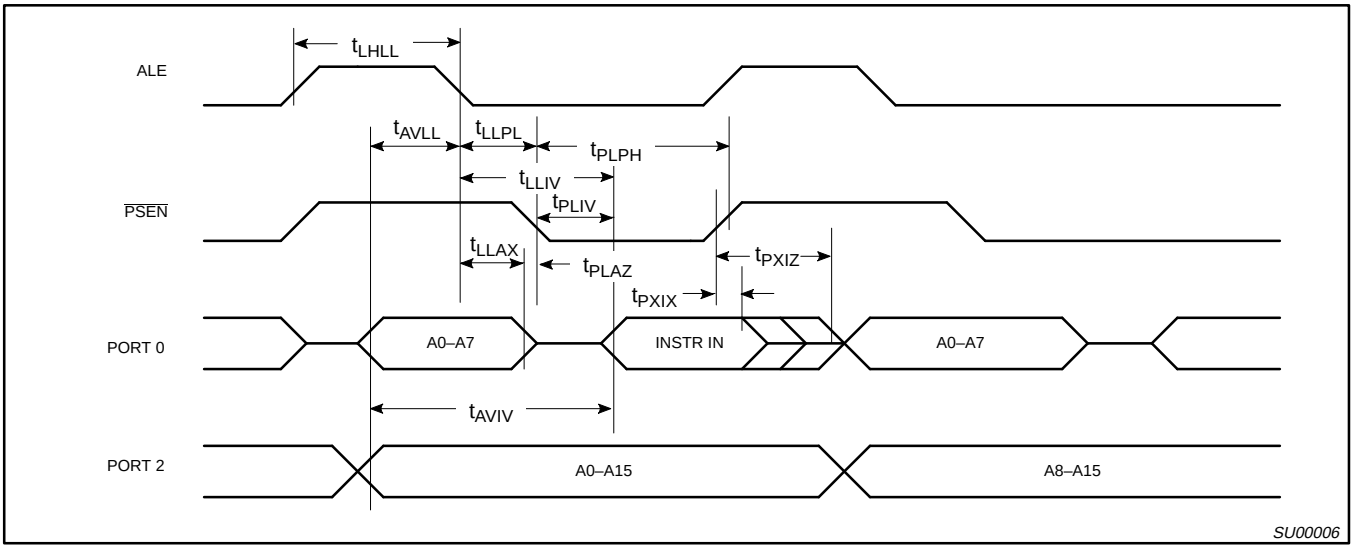


Figure 25. External Program Memory Read Cycle

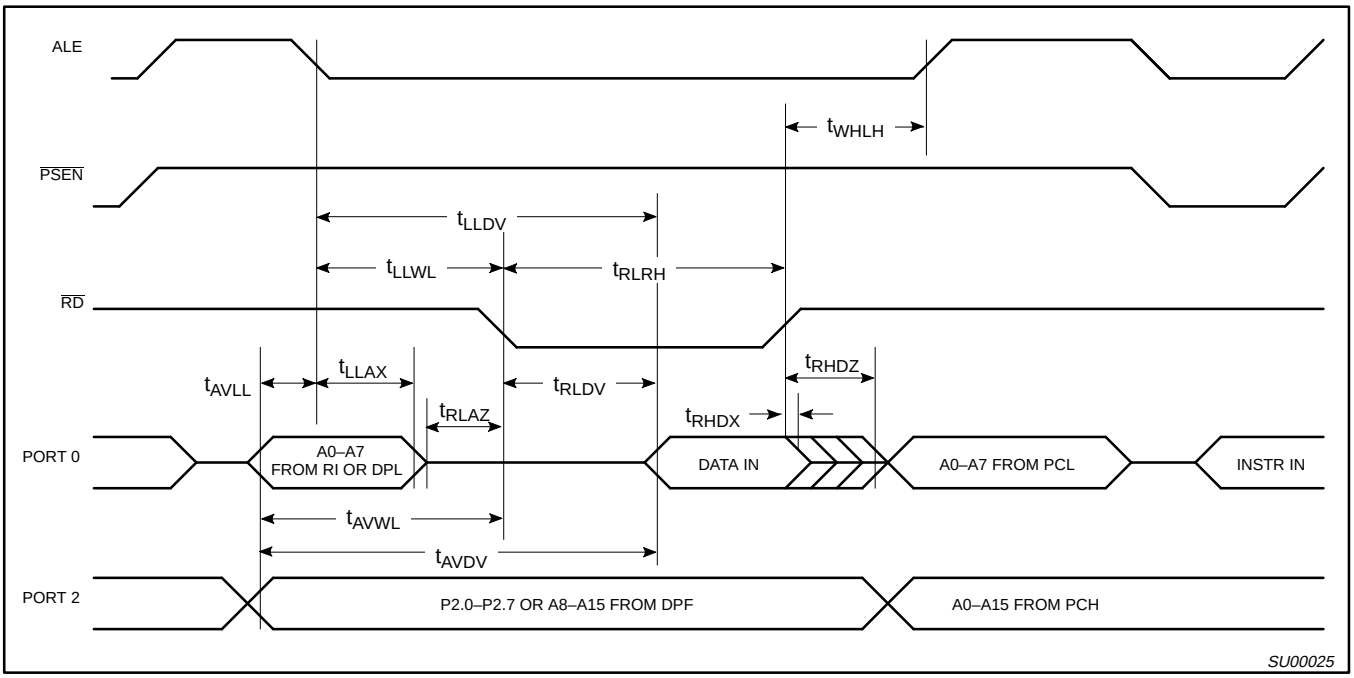


Figure 26. External Data Memory Read Cycle

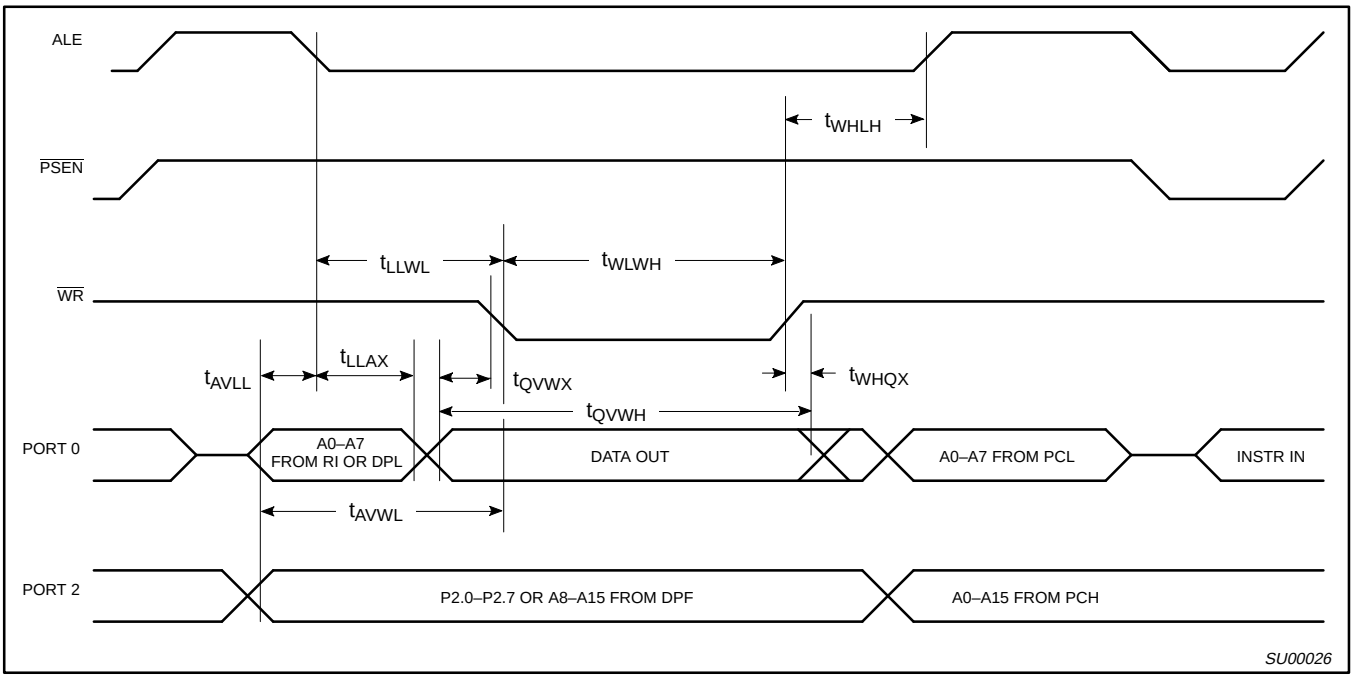


Figure 27. External Data Memory Write Cycle

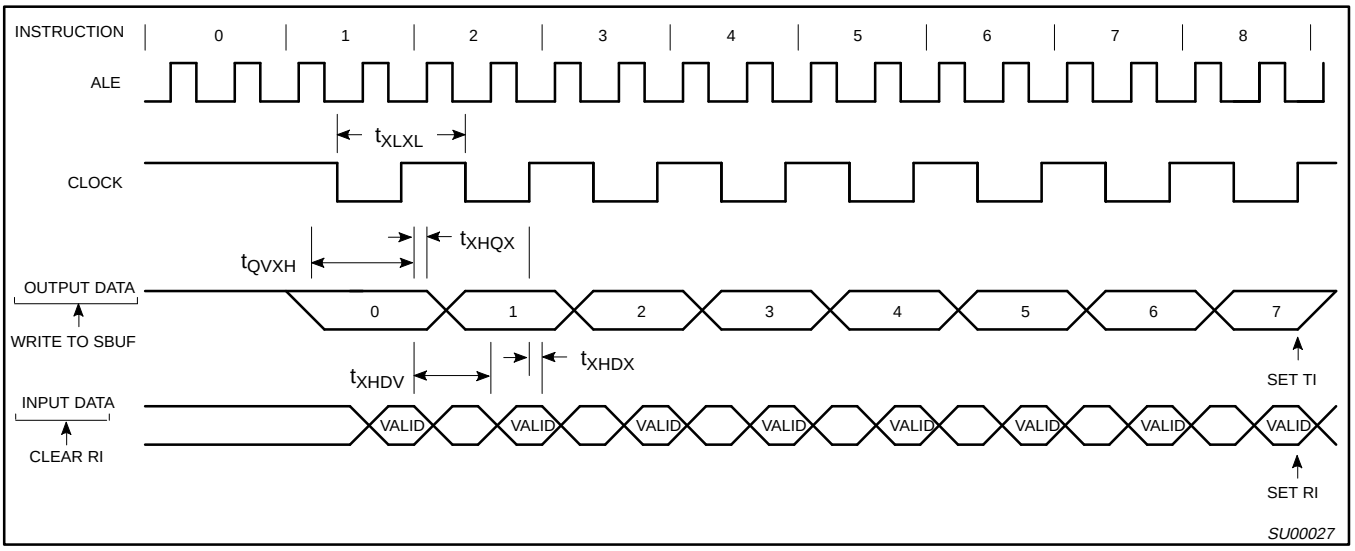


Figure 28. Shift Register Mode Timing

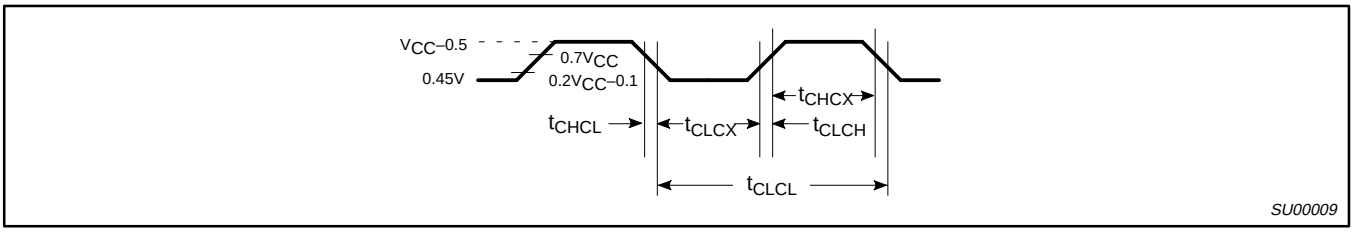
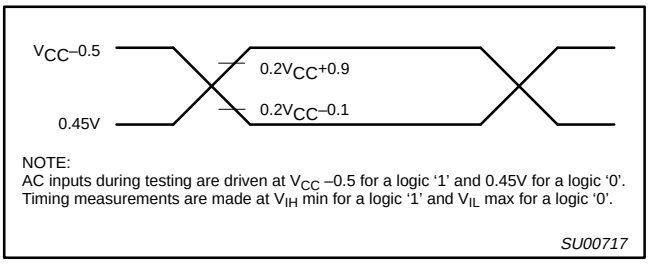


Figure 29. External Clock Drive



NOTE:
AC inputs during testing are driven at V_{CC} –0.5 for a logic '1' and 0.45V for a logic '0'. Timing measurements are made at V_{IH} min for a logic '1' and V_{IL} max for a logic '0'.

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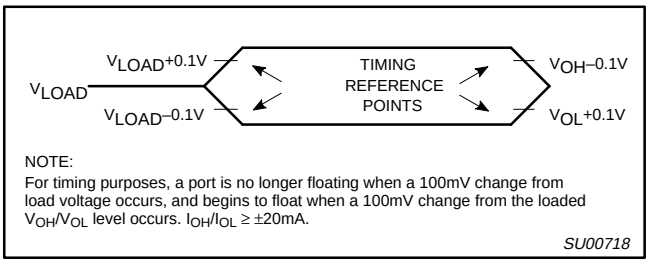
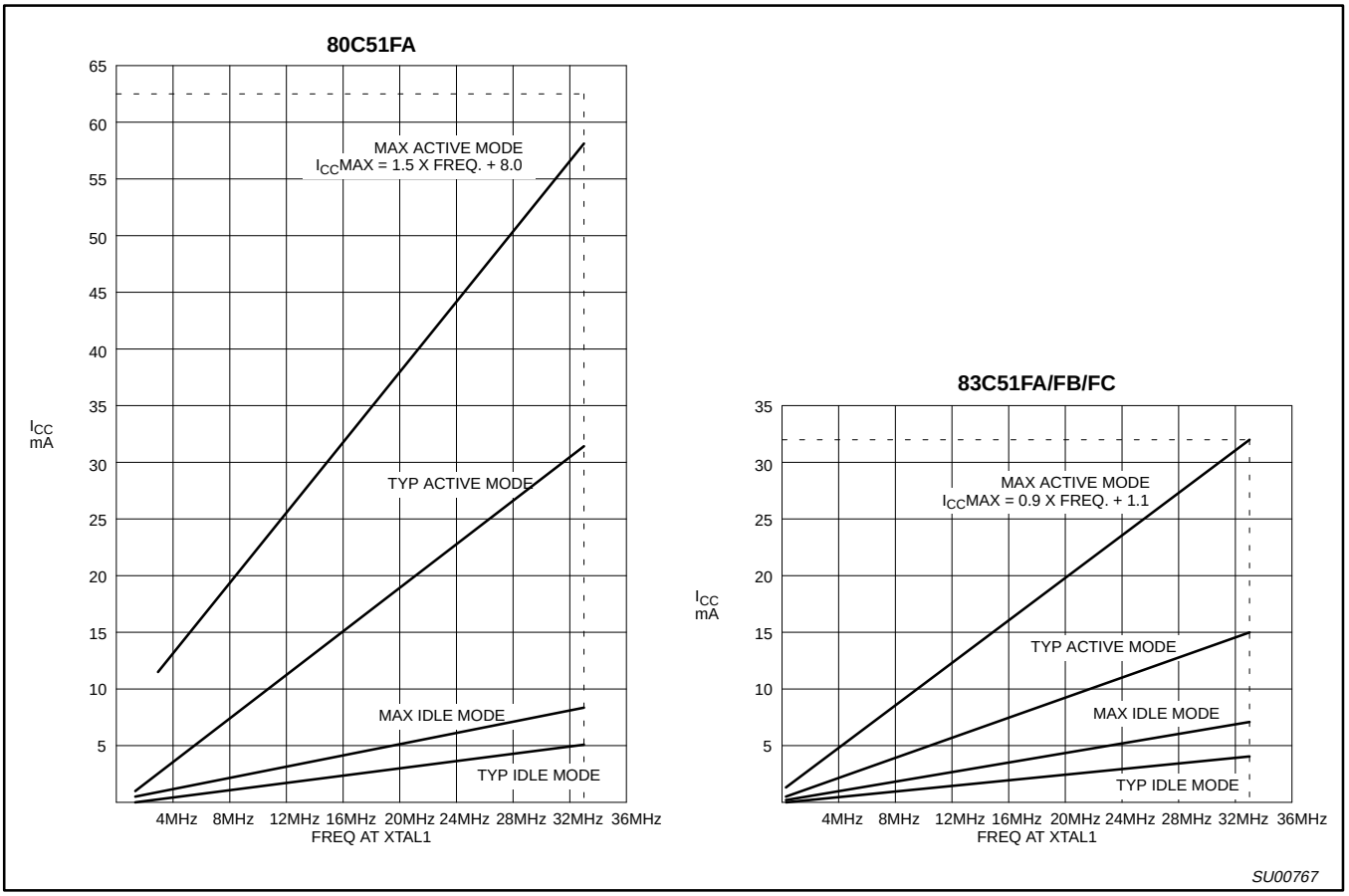
Figure 30. AC Testing Input/Output



NOTE:
For timing purposes, a port is no longer floating when a 100mV change from load voltage occurs, and begins to float when a 100mV change from the loaded V_{OH}/V_{OL} level occurs. $I_{OH}/I_{OL} \geq \pm 20$mA.

SU00718

Figure 31. Float Waveform



SU00767

Figure 32. I_{CC} vs. FREQ
Valid only within frequency specifications of the device under test

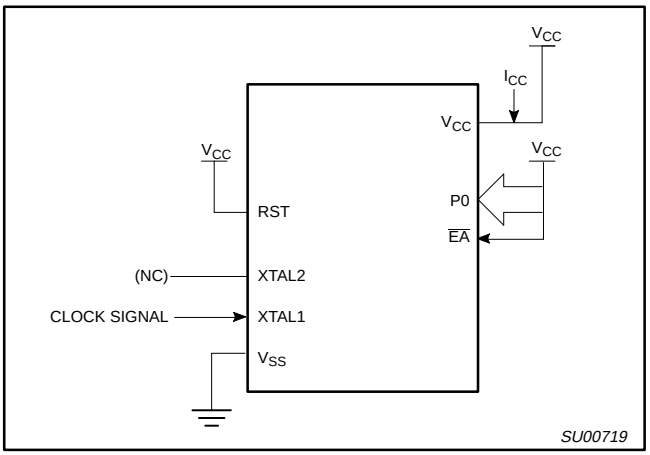


Figure 33. I_{CC} Test Condition, Active Mode
All other pins are disconnected

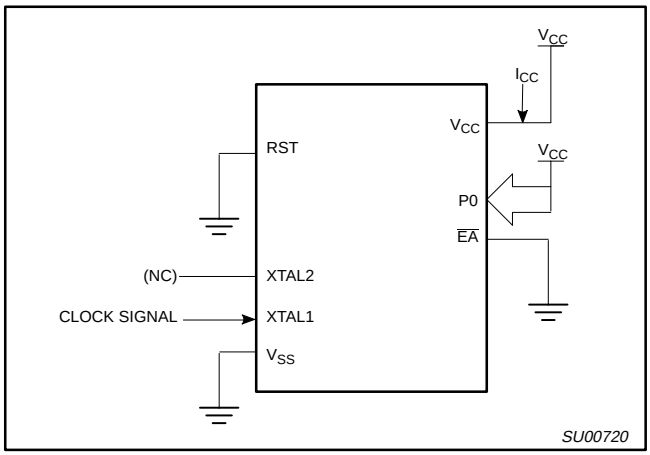


Figure 34. I_{CC} Test Condition, Idle Mode
All other pins are disconnected

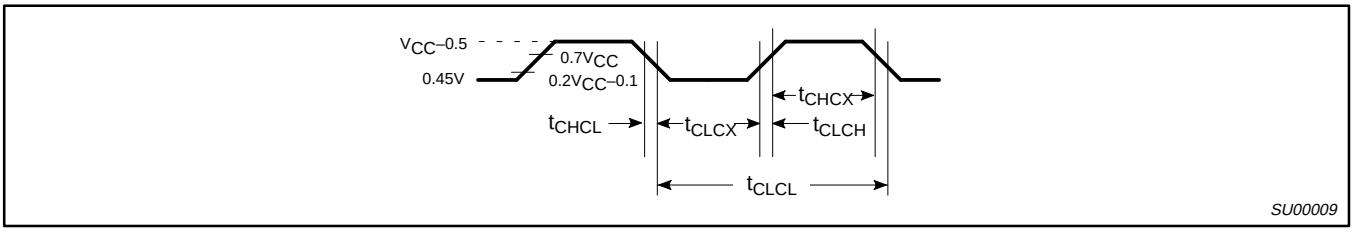


Figure 35. Clock Signal Waveform for I_{CC} Tests in Active and Idle Modes
$t_{CLCH} = t_{CHCL} = 5ns$

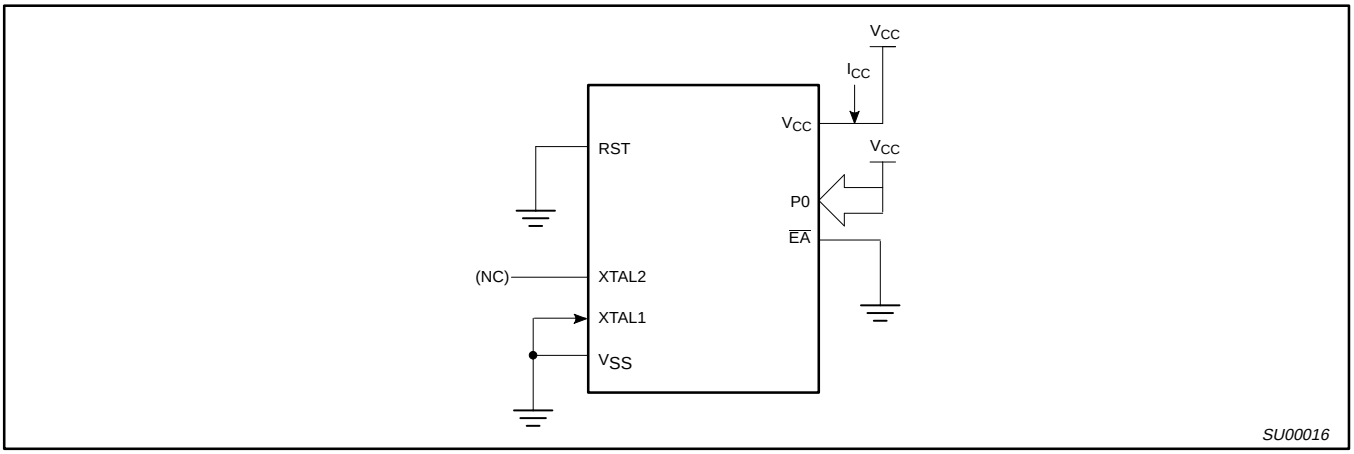


Figure 36. I_{CC} Test Condition, Power Down Mode
All other pins are disconnected. V_{CC} = 2V to 5.5V

Security Bits

With none of the security bits programmed the code in the program memory can be verified. If the encryption table is programmed, the code will be encrypted when verified. When only security bit 1 (see Table 8) is programmed, MOVC instructions executed from external program memory are disabled from fetching code bytes from the internal memory, EA is latched on Reset and all further programming of the EPROM is disabled. When security bits 1 and 2 are programmed, in addition to the above, verify mode is disabled.

Encryption Array

64 bytes of encryption array are initially unprogrammed (all 1s).

Table 8. Program Security Bits

PROGRAM LOCK BITS[1, 2]			
	SB1	SB2	PROTECTION DESCRIPTION
1	U	U	No Program Security features enabled. (Code verify will still be encrypted by the Encryption Array if programmed.)
2	P	U	MOVC instructions executed from external program memory are disabled from fetching code bytes from internal memory, $\overline{EA}$ is sampled and latched on Reset, and further programming of the EPROM is disabled.

NOTES:
1. P – programmed. U – unprogrammed.
2. Any other combination of the security bits is not defined.

83C51FA ROM CODE SUBMISSION

When submitting ROM code for the 83C51FA, the following must be specified:
1. 8k byte user ROM data
2. 64 byte ROM encryption key
3. ROM security bits.

ADDRESS	CONTENT	BIT(S)	COMMENT
0000H to 1FFFH	DATA	7:0	User ROM Data
2000H to 201FH	KEY	7:0	ROM Encryption Key FFH = no encryption
2020H	SEC	0	ROM Security Bit 1 0 = enable security 1 = disable security
2020H	SEC	1	ROM Security Bit 2 0 = enable security 1 = disable security

Security Bit 1: When programmed, this bit has two effects on masked ROM parts:
1. External MOVC is disabled, and
2. $\overline{EA}$ is latched on Reset.

Security Bit 2: When programmed, this bit inhibits Verify User ROM.

If the ROM Code file does not include the options, the following information must be included with the ROM code.

For each of the following, check the appropriate box, and send to Philips along with the code:

Security Bit #1: ☐ Enabled ☐ Disabled

Security Bit #2: ☐ Enabled ☐ Disabled

Encryption: ☐ No ☐ Yes If Yes, must send key file.

83C51FB ROM CODE SUBMISSION

When submitting ROM code for the 83C51FB, the following must be specified:

1. 16k byte user ROM data
2. 64 byte ROM encryption key
3. ROM security bits.

ADDRESS	CONTENT	BIT(S)	COMMENT
0000H to 3FFFH	DATA	7:0	User ROM Data
4000H to 401FH	KEY	7:0	ROM Encryption Key FFH = no encryption
4020H	SEC	0	ROM Security Bit 1 0 = enable security 1 = disable security
4020H	SEC	1	ROM Security Bit 2 0 = enable security 1 = disable security

Security Bit 1: When programmed, this bit has two effects on masked ROM parts:

1. External MOVC is disabled, and
2. $\overline{EA}$ is latched on Reset.

Security Bit 2: When programmed, this bit inhibits Verify User ROM.

If the ROM Code file does not include the options, the following information must be included with the ROM code.

For each of the following, check the appropriate box, and send to Philips along with the code:

Security Bit #1: ☐ Enabled ☐ Disabled

Security Bit #2: ☐ Enabled ☐ Disabled

Encryption: ☐ No ☐ Yes If Yes, must send key file.

83C51FC ROM CODE SUBMISSION

When submitting ROM code for the 83C51FC, the following must be specified:

1. 16k byte user ROM data
2. 64 byte ROM encryption key
3. ROM security bits.

ADDRESS	CONTENT	BIT(S)	COMMENT
0000H to 7FFFH	DATA	7:0	User ROM Data
8000H to 801FH	KEY	7:0	ROM Encryption Key FFH = no encryption
8020H	SEC	0	ROM Security Bit 1 0 = enable security 1 = disable security
8020H	SEC	1	ROM Security Bit 2 0 = enable security 1 = disable security

Security Bit 1: When programmed, this bit has two effects on masked ROM parts:

1. External MOVC is disabled, and
2. $\overline{EA}$ is latched on Reset.

Security Bit 2: When programmed, this bit inhibits Verify User ROM.

If the ROM Code file does not include the options, the following information must be included with the ROM code.

For each of the following, check the appropriate box, and send to Philips along with the code:

Security Bit #1: ☐ Enabled ☐ Disabled

Security Bit #2: ☐ Enabled ☐ Disabled

Encryption: ☐ No ☐ Yes If Yes, must send key file.