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"[Embedded - Microcontrollers](#)" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

### Applications of "[Embedded - Microcontrollers](#)"

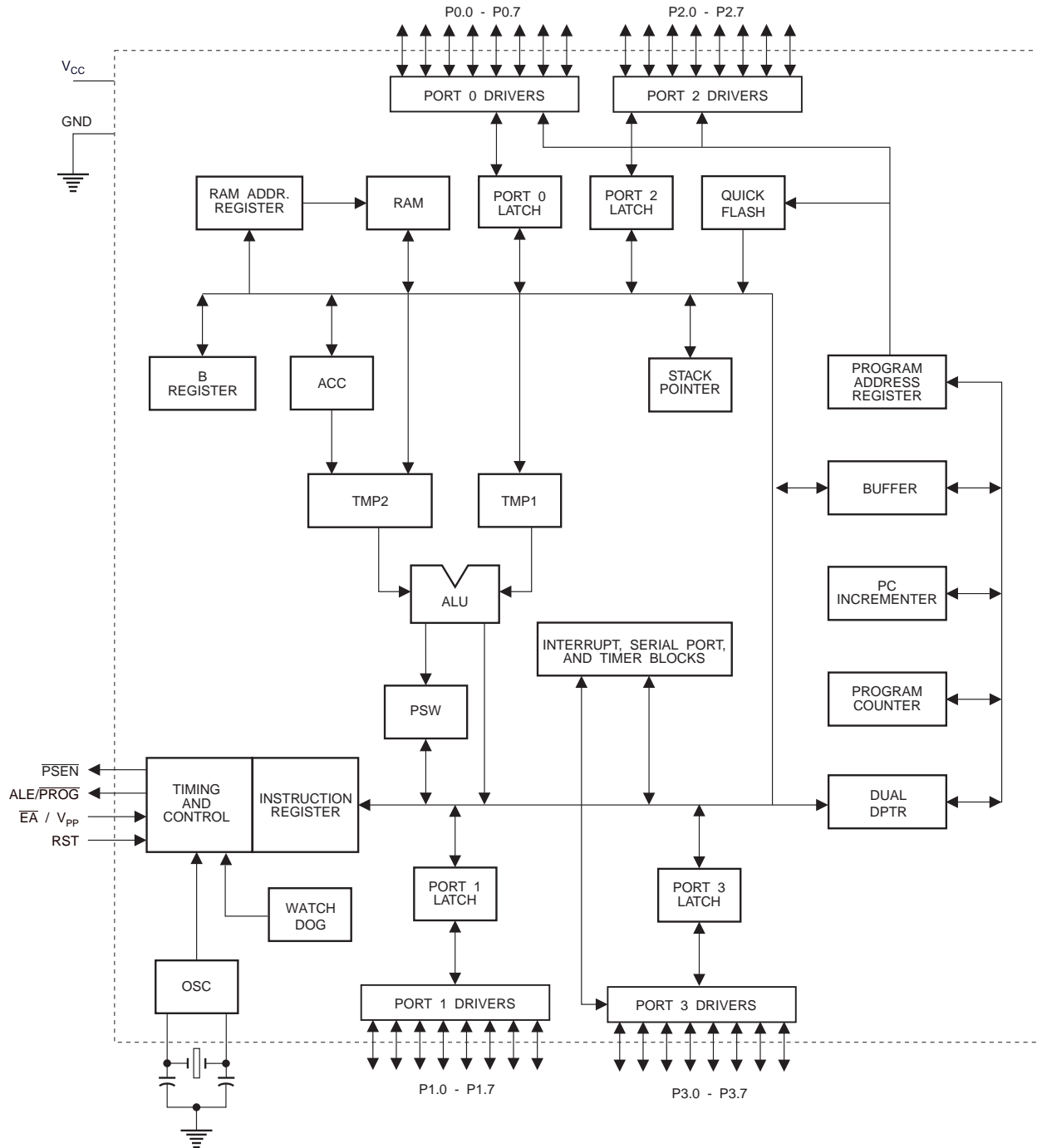
#### Details

Product Status	Obsolete
Core Processor	8051
Core Size	8-Bit
Speed	24MHz
Connectivity	UART/USART
Peripherals	WDT
Number of I/O	32
Program Memory Size	32KB (32K x 8)
Program Memory Type	OTP Quick FLASH
EEPROM Size	-
RAM Size	512 x 8
Voltage - Supply (Vcc/Vdd)	4V ~ 6V
Data Converters	-
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C
Mounting Type	Surface Mount
Package / Case	44-LCC (J-Lead)
Supplier Device Package	44-PLCC (16.6x16.6)
Purchase URL	<a href="https://www.e-xfl.com/product-detail/microchip-technology/at87f51rc-24ji">https://www.e-xfl.com/product-detail/microchip-technology/at87f51rc-24ji</a>

user programmed by a conventional nonvolatile memory programmer. A total of 512 bytes of internal RAM are available in the AT87F51RC. The 256-byte expanded internal RAM is accessed via MOVX instructions after clearing bit 1 in the SFR located at address 8EH. The other 256-byte RAM segment is accessed the same way as the Atmel

AT89-series and other 8052-compatible products. By combining a versatile 8-bit CPU with QuickFlash on a monolithic chip, the Atmel AT87F51RC is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

## Block Diagram



The AT87F51RC provides the following standard features: 32K bytes of QuickFlash, 512 bytes of RAM, 32 I/O lines, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT87F51RC is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next external interrupt or hardware reset.

## Pin Description

### VCC

Supply voltage.

### GND

Ground.

### Port 0

Port 0 is an 8-bit open drain bidirectional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-impedance inputs.

Port 0 can also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode, P0 has internal pullups.

Port 0 also receives the code bytes during QuickFlash programming and outputs the code bytes during program verification. External pullups are required during program verification.

### Port 1

Port 1 is an 8-bit bidirectional I/O port with internal pullups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins, they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current ( $I_{IL}$ ) because of the internal pullups.

In addition, P1.0 and P1.1 can be configured to be the timer/counter 2 external count input (P1.0/T2) and the timer/counter 2 trigger input (P1.1/T2EX), respectively, as shown in the following table.

Port 1 also receives the low-order address bytes during QuickFlash programming and verification.

Port Pin	Alternate Functions
P1.0	T2 (external count input to Timer/Counter 2), clock-out
P1.1	T2EX (Timer/Counter 2 capture/reload trigger and direction control)

### Port 2

Port 2 is an 8-bit bidirectional I/O port with internal pullups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins, they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current ( $I_{IL}$ ) because of the internal pullups.

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, Port 2 uses strong internal pullups when emitting 1s. During accesses to external data memory that use 8-bit addresses (MOVX @ RI), Port 2 emits the contents of the P2 Special Function Register.

Port 2 also receives the high-order address bits and some control signals during QuickFlash programming and verification.

### Port 3

Port 3 is an 8-bit bidirectional I/O port with internal pullups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins, they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current ( $I_{IL}$ ) because of the pullups.

Port 3 also serves the functions of various special features of the AT87F51RC, as shown in the following table.

Port 3 also receives some control signals for QuickFlash programming and verification.

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	$\overline{\text{INT1}}$ (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.6	$\overline{\text{WR}}$ (external data memory write strobe)
P3.7	$\overline{\text{RD}}$ (external data memory read strobe)

### RST

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device. This pin drives High for 96 oscillator periods after the Watchdog times out. The DISRTO bit in SFR AUXR (address 8EH) can be used to disable this feature. In the default state of bit DISTRO, the RESET HIGH out feature is enabled.

### ALE/PROG

Address Latch Enable is an output pulse for latching the low byte of the address during accesses to external

memory. This pin is also the program pulse input ( $\overline{\text{PROG}}$ ) during QuickFlash programming.

In normal operation, ALE is emitted at a constant rate of 1/6 the oscillator frequency and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external data memory.

If desired, ALE operation can be disabled by setting bit 0 of SFR location 8EH. With the bit set, ALE is active only during a MOVX or MOVC instruction. Otherwise, the pin is weakly pulled high. Setting the ALE-disable bit has no effect if the microcontroller is in external execution mode.

#### **$\overline{\text{PSEN}}$**

Program Store Enable is the read strobe to external program memory.

When the AT87F51RC is executing code from 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.

#### **$\overline{\text{EA/VPP}}$**

External Access Enable.  $\overline{\text{EA}}$  must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed,  $\overline{\text{EA}}$  will be internally latched on reset.

$\overline{\text{EA}}$  should be strapped to  $V_{\text{CC}}$  for internal program executions.

This pin also receives the 12-volt programming enable voltage ( $V_{\text{PP}}$ ) during QuickFlash programming.

#### **XTAL1**

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

#### **XTAL2**

Output from the inverting oscillator amplifier.

**Table 1.** AT87F51RC SFR Map and Reset Values

0F8H								0FFH
0F0H	B 00000000							0F7H
0E8H								0EFH
0E0H	ACC 00000000							0E7H
0D8H								0DFH
0D0H	PSW 00000000							0D7H
0C8H	T2CON 00000000	T2MOD XXXXXX00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000		0CFH
0C0H								0C7H
0B8H	IP XX000000							0BFH
0B0H	P3 11111111							0B7H
0A8H	IE 0X000000							0AFH
0A0H	P2 11111111		AUXR1 XXXXXXX0				WDRST XXXXXXX	0A7H
98H	SCON 00000000	SBUF XXXXXXXX						9FH
90H	P1 11111111							97H
88H	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000	AUXR XXX00000	8FH
80H	P0 11111111	SP 00000111	DP0L 00000000	DP0H 00000000	DP1L 00000000	DP1H 00000000	PCON 0XXX0000	87H

## Special Function Registers

A map of the on-chip memory area called the Special Function Register (SFR) space is shown in Table 1.

Note that not all of the addresses are occupied, and unoccupied addresses may not be implemented on the chip. Read accesses to these addresses will in general return random data, and write accesses will have an indeterminate effect.

User software should not write 1s to these unlisted locations, since they may be used in future products to invoke

new features. In that case, the reset or inactive values of the new bits will always be 0.

**Timer 2 Registers:** Control and status bits are contained in registers T2CON (shown in Table 2) and T2MOD (shown in Table 4) for Timer 2. The register pair (RCAP2H, RCAP2L) are the Capture/Reload registers for Timer 2 in 16-bit capture mode or 16-bit auto-reload mode.

**Interrupt Registers:** The individual interrupt enable bits are in the IE register. Two priorities can be set for each of the six interrupt sources in the IP register.

**Table 2.** T2CON – Timer/Counter 2 Control Register

T2CON Address = 0C8H

Reset Value = 0000 0000B

Bit Addressable

Bit	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T $\overline{2}$	CP/RL $\overline{2}$
	7	6	5	4	3	2	1	0

Symbol	Function
TF2	Timer 2 overflow flag set by a Timer 2 overflow and must be cleared by software. TF2 will not be set when either RCLK = 1 or TCLK = 1.
EXF2	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	Receive clock enable. When set, causes the serial port to use Timer 2 overflow pulses for its receive clock in serial port Modes 1 and 3. RCLK = 0 causes Timer 1 overflow to be used for the receive clock.
TCLK	Transmit clock enable. When set, causes the serial port to use Timer 2 overflow pulses for its transmit clock in serial port Modes 1 and 3. TCLK = 0 causes Timer 1 overflows to be used for the transmit clock.
EXEN2	Timer 2 external enable. 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	Start/Stop control for Timer 2. TR2 = 1 starts the timer.
C/ $\overline{T2}$	Timer or counter select for Timer 2. C/ $\overline{T2}$ = 0 for timer function. C/ $\overline{T2}$ = 1 for external event counter (falling edge triggered).
CP/ $\overline{RL2}$	Capture/Reload select. CP/ $\overline{RL2}$ = 1 causes captures to occur on negative transitions at T2EX if EXEN2 = 1. CP/ $\overline{RL2}$ = 0 causes automatic reloads to occur when Timer 2 overflows or negative transitions occur at T2EX when EXEN2 = 1. When either RCLK or TCLK = 1, this bit is ignored and the timer is forced to auto-reload on Timer 2 overflow.

**Table 3a. AUXR: Auxiliary Register**

AUXR	Address = 8EH	Reset Value = XXX00X00B						
	Not Bit Addressable							
	–	–	–	WDIDLE	DISRTO	–	EXTRAM	DISALE
Bit	7	6	5	4	3	2	1	0
–	Reserved for future expansion							
DISALE	Disable/Enable ALE							
	DISALE	Operating Mode						
	0	ALE is emitted at a constant rate of 1/6 the oscillator frequency						
	1	ALE is active only during a MOVX or MOVC instruction						
EXTRAM	Internal External RAM (00H-FFH) access using MOVX @ Ri/DPTR							
	EXTRAM	Operating Mode						
	0	Internal ERAM (00H-FFH) access using MOVX @ Ri/DPTR						
	1	External data memory access						
DISTRO	Disable/Enable Reset out							
	DISRTO							
	0	Reset pin is driven High after WDT times out						
	1	Reset pin is input only						
WDIDLE	Disable/Enable WDT in IDLE mode							
	WDIDLE							
	0	WDT continues to count in IDLE mode						
	1	WDT halts counting in IDLE mode						

**Dual Data Pointer Registers:** To facilitate accessing both internal and external data memory, two banks of 16-bit Data Pointer Registers are provided: DP0 at SFR address locations 82H-83H and DP1 at 84H-85H. Bit DPS = 0 in SFR AUXR1 selects DP0 and DPS = 1 selects DP1. The user should always initialize the DPS bit to the appropriate

value before accessing the respective Data Pointer Register.

**Power Off Flag:** The Power Off Flag (POF) is located at bit 4 (PCON.4) in the PCON SFR. POF is set to “1” during power up. It can be set and rest under software control and is not affected by reset.

**Table 3b. AUXR1: Auxiliary Register 1**

AUXR1	Address = A2H	Reset Value = XXXXXXXX0B							
	Not Bit Addressable								
		–	–	–	–	–	–	DPS	
Bit		7	6	5	4	3	2	1	0
–	Reserved for future expansion								
DPS	Data Pointer Register Select								
	DPS								
	0	Selects DPTR Registers DP0L, DP0H							
	1	Selects DPTR Registers DP1L, DP1H							

## Memory Organization

MCS-51 devices have a separate address space for Program and Data Memory. Up to 64K bytes each of external Program and Data Memory can be addressed.

### Program Memory

If the  $\overline{EA}$  pin is connected to GND, all program fetches are directed to external memory.

On the AT87F51RC, if  $\overline{EA}$  is connected to  $V_{CC}$ , program fetches to addresses 0000H through 7FFFH are directed to internal memory and fetches to addresses 8000H through FFFFH are to external memory.

### Data Memory

The AT87F51RC has internal data memory that is mapped into four separate segments: the lower 128 bytes of RAM, upper 128 bytes of RAM, 128 bytes special function register (SFR) and 256 bytes expanded RAM (ERAM).

The four segments are:

1. The Lower 128 bytes of RAM (addresses 00H to 7FH) are directly and indirectly addressable.
2. The Upper 128 bytes of RAM (addresses 80H to FFH) are indirectly addressable only.
3. The Special Function Registers, SFRs, (addresses 80H to FFH) are directly addressable only.
4. The 256-byte expanded RAM (ERAM, 00H-FFH) is indirectly accessed by MOVX instructions, and with the EXTRAM bit cleared.

The Lower 128 bytes can be accessed by either direct or indirect addressing. The Upper 128 bytes can be accessed by indirect addressing only. The Upper 128 bytes occupy the same address space as the SFR. This means they have the same address, but are physically separate from the SFR space.

When an instruction accesses an internal location above address 7FH, the CPU knows whether the access is to the upper 128 bytes of data RAM or to SFR space by the addressing mode used in the instruction. Instructions that use direct addressing access SFR space. For example:

```
MOV 0A0H, # data
```

accesses the SFR at location 0S0H (which is P2). Instructions that use indirect addressing access the Upper 128 bytes of data RAM. For example:

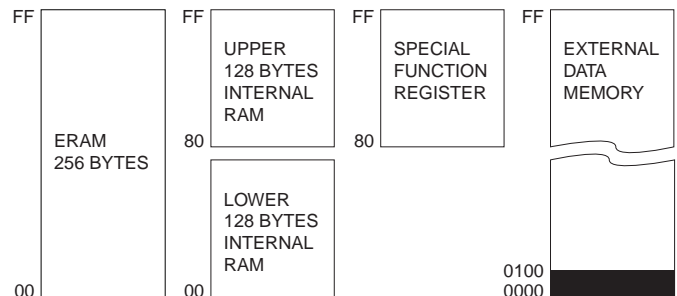
```
MOV@R0, # data
```

where R0 contains 0A0H, accesses the data byte at address 0A0H, rather than P2 (whose address is 0A0H).

Note that stack operations are examples of indirect addressing, so the upper 128 bytes of data RAM are available as stack space.

The 256 bytes of ERAM can be accessed by indirect addressing, with EXTRAM bit cleared and MOVX instructions. This part of memory is physically located on-chip, logically occupying the first 256 bytes of external data memory.

**Figure 1.** Internal and External Data Memory Address (with EXTRAM = 0)



With EXTRAM = 0, the ERAM is indirectly addressed, using the MOVX instruction in combination with any of the registers R0, R1 of the selected bank or DPTR. An access to ERAM will not affect ports P0, P2, P3.6 ( $\overline{WR}$ ), and P3.7 ( $\overline{RD}$ ). For example, with EXTRAM = 0,

```
MOVX@R0, # data
```

where R0 contains 0A0H, accesses the ERAM at address 0A0H rather than external memory. An access to external data memory locations higher than FFH (i.e. 0100H to FFFFH) will be performed with the MOVX DPTR instructions in the same way as in the standard MCS-51, i.e., with P0 and P2 as data/address bus, and P3.6 and P3.7 as write and read timing signals. Refer to Figure 1.

With EXTRAM = 1, MOVX @ Ri and MOVX@DPTR will be similar to the standard MCS-51. MOVX@Ri will provide an 8-bit address multiplexed with data on Port 0 and any output port pins can be used to output higher-order address bits. This is to provide the external paging capability. MOVX@DPTR will generate a 16-bit address. Port 2 outputs the high-order 8 address bits (the contents of DP0H), while Port 0 multiplexes the low-order 8 address bits (the contents of DP0L) with data. MOVX @ Ri and MOVX@DPTR will generate either read or write signals on P3.6 ( $\overline{WR}$ ) and P3.7 ( $\overline{RD}$ ).

The stack pointer (SP) may be located anywhere in the 256 bytes RAM (lower and upper RAM) internal data memory. The stack may not be located in the ERAM.

the transition was detected. Since two machine cycles (24 oscillator periods) are required to recognize a 1-to-0 transition, the maximum count rate is 1/24 of the oscillator frequency. To ensure that a given level is sampled at least once before it changes, the level should be held for at least one full machine cycle.

## Capture Mode

In the capture mode, two options are selected by bit EXEN2 in T2CON. If EXEN2 = 0, Timer 2 is a 16-bit timer or counter which upon overflow sets bit TF2 in T2CON. This bit can then be used to generate an interrupt. If EXEN2 = 1, Timer 2 performs the same operation, but a 1-to-0 transition at external input T2EX also causes the cur-

rent value in TH2 and TL2 to be captured into RCAP2H and RCAP2L, respectively. In addition, the transition at T2EX causes bit EXF2 in T2CON to be set. The EXF2 bit, like TF2, can generate an interrupt. The capture mode is illustrated in Figure 2.

## Auto-Reload (Up or Down Counter)

Timer 2 can be programmed to count up or down when configured in its 16-bit auto-reload mode. This feature is invoked by the DCEN (Down Counter Enable) bit located in the SFR T2MOD (see Table 5). Upon reset, the DCEN bit is set to 0 so that timer 2 will default to count up. When DCEN is set, Timer 2 can count up or down, depending on the value of the T2EX pin.

**Figure 2. Timer in Capture Mode**

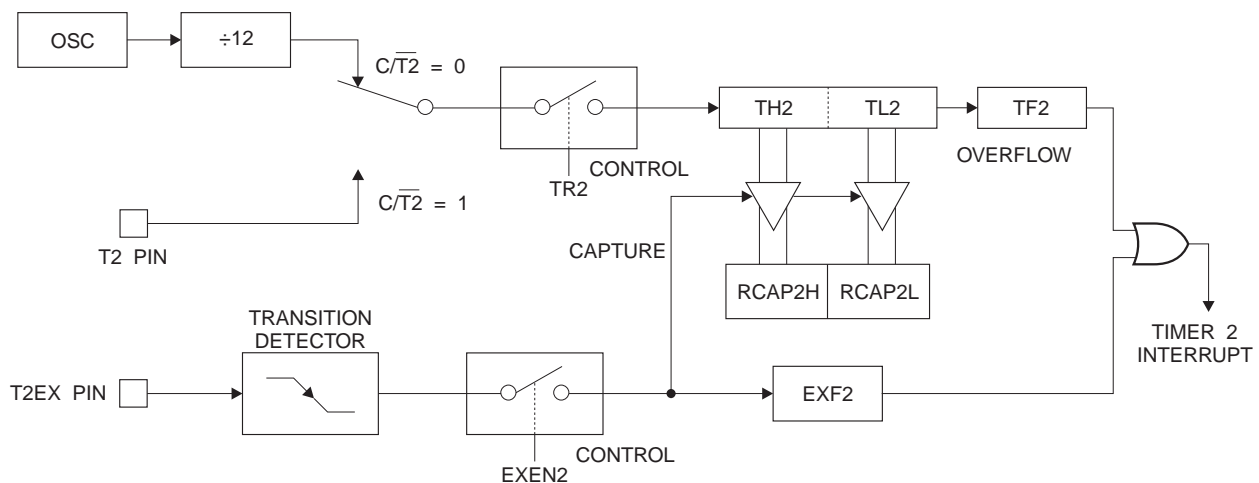


Figure 3 shows Timer 2 automatically counting up when DCEN=0. In this mode, two options are selected by bit EXEN2 in T2CON. If EXEN2 = 0, Timer 2 counts up to 0FFFFH and then sets the TF2 bit upon overflow. The overflow also causes the timer registers to be reloaded with the 16-bit value in RCAP2H and RCAP2L. The values in Timer in Capture Mode RCAP2H and RCAP2L are preset by software. If EXEN2 = 1, a 16-bit reload can be triggered either by an overflow or by a 1-to-0 transition at external input T2EX. This transition also sets the EXF2 bit. Both the TF2 and EXF2 bits can generate an interrupt if enabled.

Setting the DCEN bit enables Timer 2 to count up or down, as shown in Figure 3. In this mode, the T2EX pin controls

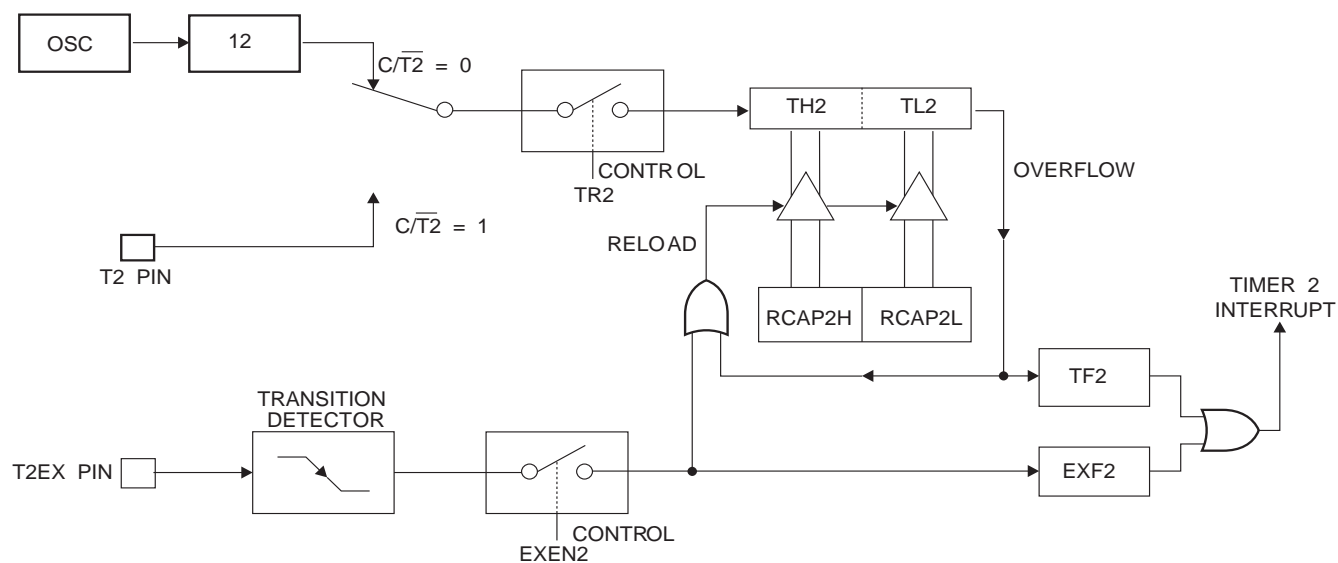
the direction of the count. A logic 1 at T2EX makes Timer 2 count up. The timer will overflow at 0FFFFH and set the TF2 bit. This overflow also causes the 16-bit value in RCAP2H and RCAP2L to be reloaded into the timer registers, TH2 and TL2, respectively.

A logic 0 at T2EX makes Timer 2 count down. The timer underflows when TH2 and TL2 equal the values stored in RCAP2H and RCAP2L. The underflow sets the TF2 bit and causes 0FFFFH to be reloaded into the timer registers.

The EXF2 bit toggles whenever Timer 2 overflows or underflows and can be used as a 17th bit of resolution. In this operating mode, EXF2 does not flag an interrupt.



**Figure 3.** Timer 2 Auto Reload Mode (DCEN = 0)

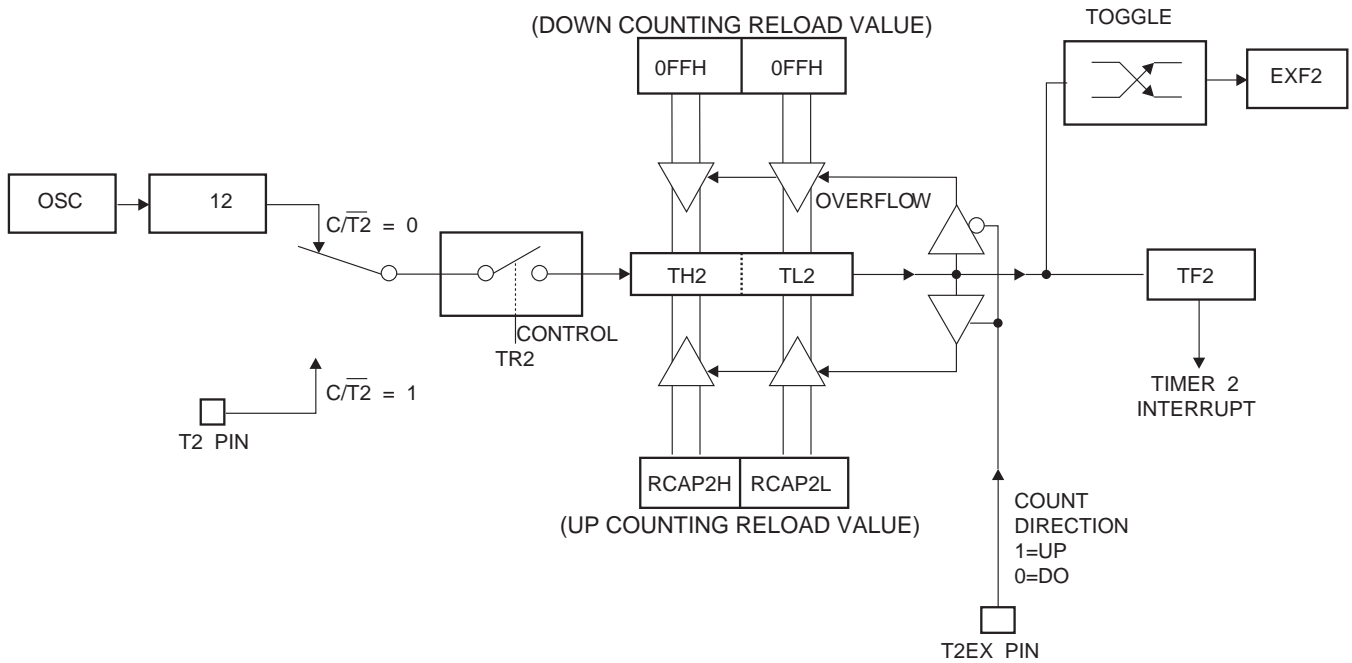


**Table 5.** T2MOD—Timer 2 Mode Control Register

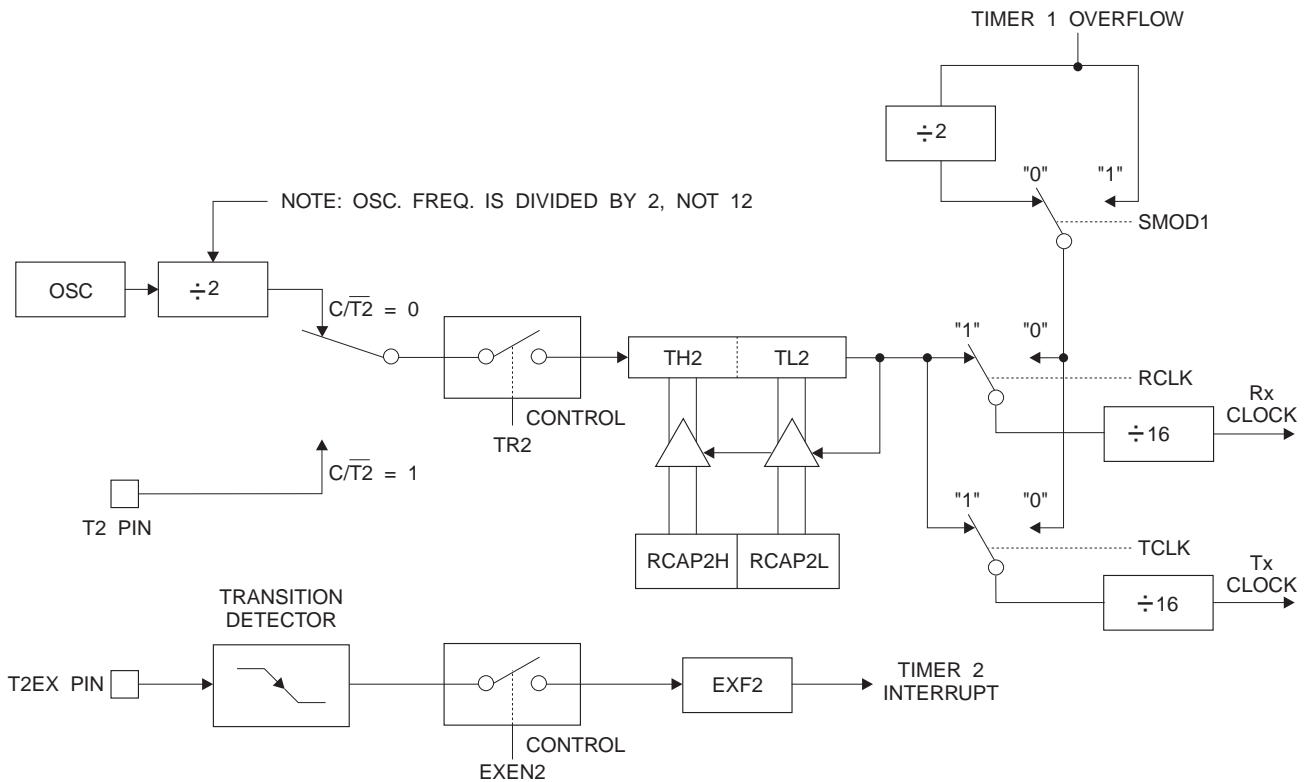
T2MOD Address = 0C9H						Reset Value = XXXX XX00B	
Not Bit Addressable							
Bit	–	–	–	–	–	T2OE	DCEN
	7	6	5	4	3	2	1

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

**Figure 4.** Timer 2 Auto Reload Mode (DCEN = 1)



**Figure 5.** Timer 2 in Baud Rate Generator Mode



## Baud Rate Generator

Timer 2 is selected as the baud rate generator by setting TCLK and/or RCLK in T2CON (Table 2). Note that the baud rates for transmit and receive can be different if Timer 2 is used for the receiver or transmitter and Timer 1 is used for the other function. Setting RCLK and/or TCLK puts Timer 2 into its baud rate generator mode, as shown in Figure 5.

The baud rate generator mode is similar to 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 according to the following equation.

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

The Timer can be configured for either timer or counter operation. In most applications, it is configured for timer operation ( $CP/\overline{T2} = 0$ ). The timer operation is different for Timer 2 when it is used as a baud rate generator. Normally, as a timer, it increments every machine cycle (at 1/12 the oscillator frequency). As a baud rate generator, however, it

increments every state time (at 1/2 the oscillator frequency). The baud rate formula is given below.

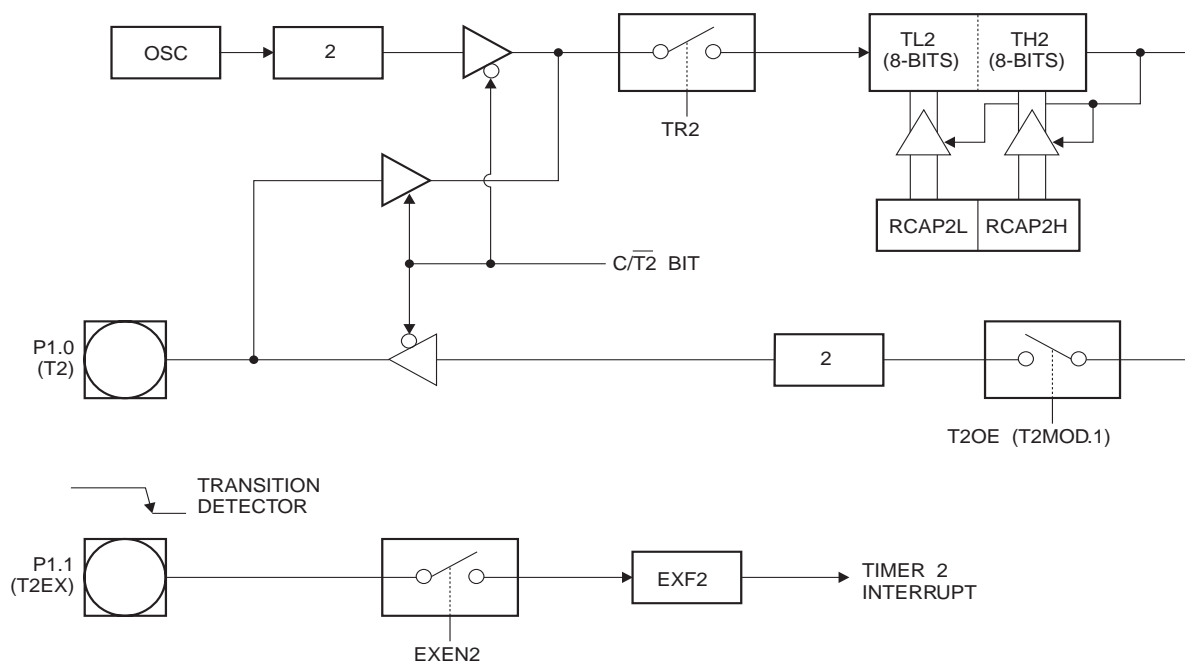
$$\frac{\text{Modes 1 and 3}}{\text{Baud Rate}} = \frac{\text{Oscillator Frequency}}{32 \times [65536 - \text{RCAP2H}, \text{RCAP2L}]}$$

where (RCAP2H, RCAP2L) is the content of RCAP2H and RCAP2L taken as a 16-bit unsigned integer.

Timer 2 as a baud rate generator is shown in Figure 5. This figure is valid only if RCLK or TCLK = 1 in T2CON. Note that a rollover in TH2 does not set TF2 and will not generate an interrupt. Note too, that if EXEN2 is set, a 1-to-0 transition in T2EX will set EXF2 but will not cause a reload from (RCAP2H, RCAP2L) to (TH2, TL2). Thus when Timer 2 is in use as a baud rate generator, T2EX can be used as an extra external interrupt.

Note that when Timer 2 is running ( $TR2 = 1$ ) as a timer in the baud rate generator mode, TH2 or TL2 should not be read from or written to. Under these conditions, the Timer is incremented every state time, and the results of a read or write 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.

**Figure 6.** Timer 2 in Clock-Out Mode



## Programmable Clock Out

A 50% duty cycle clock can be programmed to come out on P1.0, as shown in Figure 6. This pin, besides being a regular I/O pin, has two alternate functions. It can be programmed to input the external clock for Timer/Counter 2 or to output a 50% duty cycle clock ranging from 61 Hz to 4 MHz at a 16 MHz operating frequency.

To configure the Timer/Counter 2 as a clock generator, bit C/T2 (T2CON.1) must be cleared and bit T2OE (T2MOD.1) must be set. Bit TR2 (T2CON.2) starts and stops 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 the following equation.

$$\text{Clock-Out Frequency} = \frac{\text{Oscillator Frequency}}{4 \times [65536 - (\text{RCAP2H}, \text{RCAP2L})]}$$

In the clock-out mode, Timer 2 roll-overs will not generate an interrupt. This behavior is similar to when Timer 2 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 clock-out frequencies cannot be determined independently from one another since they both use RCAP2H and RCAP2L.

### Interrupts

The AT87F51RC has a total of six interrupt vectors: two external interrupts ( $\overline{\text{INT0}}$  and  $\overline{\text{INT1}}$ ), three timer interrupts (Timers 0, 1, and 2), and the serial port interrupt. These interrupts are all shown in Figure 7.

Each of these interrupt sources can be individually enabled or disabled by setting or clearing a bit in Special Function Register IE. IE also contains a global disable bit, EA, which disables all interrupts at once.

Note that Table 5 shows that bit position IE.6 is unimplemented. In the AT87F51RC, bit position IE.5 is also unimplemented. User software should not write 1s to these bit positions, since they may be used in future AT89 products.

Timer 2 interrupt is generated by the logical OR of bits TF2 and EXF2 in register T2CON. Neither of these flags is cleared by hardware when the service routine is vectored to. In fact, the service routine may have to determine whether it was TF2 or EXF2 that generated the interrupt, and that bit will have to be cleared in software.

The Timer 0 and Timer 1 flags, TF0 and TF1, are set at S5P2 of the cycle in which the timers overflow. The values are then polled by the circuitry in the next cycle. However,

the Timer 2 flag, TF2, is set at S2P2 and is polled in the same cycle in which the timer overflows.

**Table 6.** Interrupt Enable (IE) Register

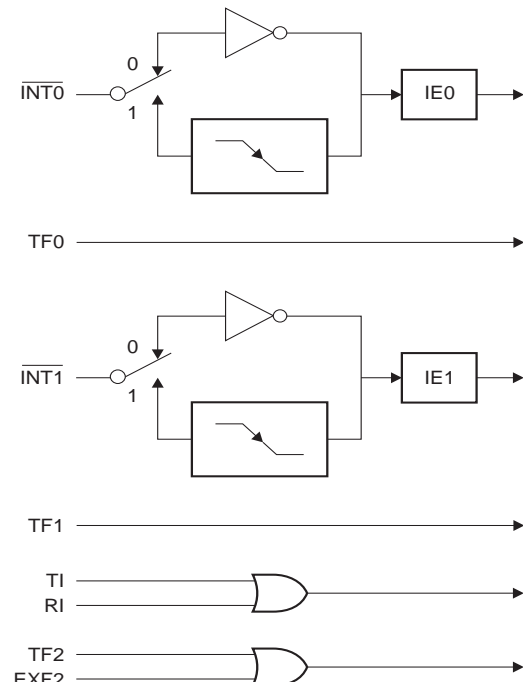
(MSB)				(LSB)			
EA	—	ET2	ES	ET1	EX1	ET0	EX0
Enable Bit = 1 enables the interrupt.							
Enable Bit = 0 disables the interrupt.							

Symbol	Position	Function
EA	IE.7	Disables all interrupts. If EA = 0, no interrupt is acknowledged. If EA = 1, each interrupt source is individually enabled or disabled by setting or clearing its enable bit.
—	IE.6	Reserved.
ET2	IE.5	Timer 2 interrupt enable bit.
ES	IE.4	Serial Port interrupt enable bit.
ET1	IE.3	Timer 1 interrupt enable bit.
EX1	IE.2	External interrupt 1 enable bit.
ET0	IE.1	Timer 0 interrupt enable bit.
EX0	IE.0	External interrupt 0 enable bit.

User software should never write 1s to unimplemented bits, because they may be used in future AT89 products.

**Figure 7.** Interrupt Sources



## Oscillator Characteristics

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier that can be configured for use as an on-chip oscillator, as shown in Figure 8. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven, as shown in Figure 9. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

## Idle Mode

In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special functions registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset.

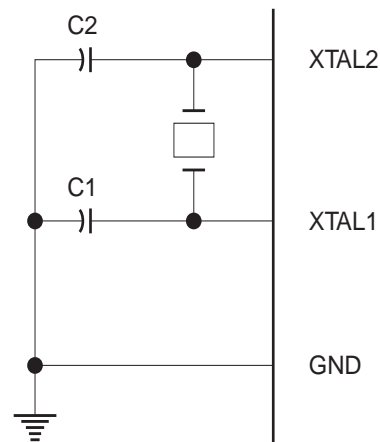
Note that when idle mode is terminated by a hardware reset, the device normally resumes program execution from where it left off, up to two machine cycles before the internal reset algorithm takes control. On-chip hardware inhibits access to internal RAM in this event, but access to the port pins is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

## Power-down Mode

In the power down mode, the oscillator is stopped, and the instruction that invokes 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. Exit from power down can be initiated either by a hardware reset or by an enabled external interrupt. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before  $V_{CC}$  is restored to

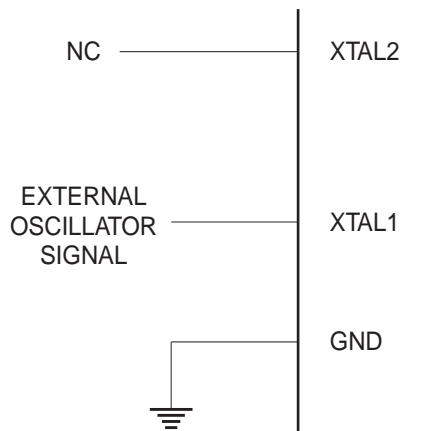
its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

**Figure 8.** Oscillator Connections



Note: C1, C2 = 30 pF  $\pm$  10 pF for Crystals  
= 40 pF  $\pm$  10 pF for Ceramic Resonators

**Figure 9.** External Clock Drive Configuration



**Table 7.** Status of External Pins During Idle and Power-down Modes

Mode	Program Memory	ALE	$\overline{PSEN}$	PORT0	PORT1	PORT2	PORT3
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

## Program Memory Lock Bits

The AT87F51RC has three lock bits that can be left unprogrammed (U) or can be programmed (P) to obtain the additional features listed in the following table.

**Table 8.** Lock Bit Protection Modes

Program Lock Bits				Protection Type
	LB1	LB2	LB3	
1	U	U	U	No program lock features.
2	P	U	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 QuickFlash memory is disabled.
3	P	P	U	Same as mode 2, but verify is also disabled.
4	P	P	P	Same as mode 3, but external execution is also disabled.

When lock bit 1 is programmed, the logic level at the  $\overline{EA}$  pin is sampled and latched during reset. If the device is powered up without a reset, the latch initializes to a random value and holds that value until reset is activated. The latched value of  $\overline{EA}$  must agree with the current logic level at that pin in order for the device to function properly.

## Programming the QuickFlash

The AT87F51RC is shipped with the on-chip QuickFlash memory array ready to be programmed. The programming interface needs a high-voltage (12-volt) program enable signal and is compatible with conventional third-party Flash or EPROM programmers.

The AT87F51RC code memory array is programmed byte-by-byte.

**Programming Algorithm:** Before programming the AT87F51RC, the address, data, and control signals should

be set up according to the QuickFlash programming mode table and Figure 10 and Figure 11. To program the AT87F51RC, take the following steps:

1. Input the desired memory location on the address lines.
2. Input the appropriate data byte on the data lines.
3. Activate the correct combination of control signals.
4. Raise  $\overline{EA}/V_{PP}$  to 12V.
5. Pulse ALE/ $\overline{PROG}$  once to program a byte in the QuickFlash array or the lock bits. The byte-write cycle is self-timed and typically takes no more than 50  $\mu$ s. Repeat steps 1 through 5, changing the address and data for the entire array or until the end of the object file is reached.

**Data Polling:** The AT87F51RC features  $\overline{Data}$  Polling to indicate the end of a write cycle. During a write cycle, an attempted read of the last byte written will result in the complement of the written data on P0.7. Once the write cycle has been completed, true data is valid on all outputs, and the next cycle may begin. Data Polling may begin any time after a write cycle has been initiated.

**Ready/Busy:** The progress of byte programming can also be monitored by the RDY/ $\overline{BSY}$  output signal. P3.0 is pulled low after ALE goes high during programming to indicate  $\overline{BUSY}$ . P3.0 is pulled high again when programming is done to indicate READY.

**Program Verify:** If lock bits LB1 and LB2 have not been programmed, the programmed code data can be read back via the address and data lines for verification. The lock bits cannot be verified directly. Verification of the lock bits is achieved by observing that their features are enabled.

**Reading the Signature Bytes:** The signature bytes are read by the same procedure as a normal verification of locations 000H, 100H, and 200H, except that P3.6 and P3.7 must be pulled to a logic low. The values returned are as follows.

- (000H) = 1EH indicates manufactured by Atmel
- (100H) = 87H indicates 87F family
- (200H) = 07H indicates 87F51RC

## Programming Interface

Every code byte in the QuickFlash array can be programmed by using the appropriate combination of control signals. The write operation cycle is self-timed and once initiated, will automatically time itself to completion.

All major programming vendors offer worldwide support for the Atmel microcontroller series. Please contact your local programming vendor for the appropriate software revision.

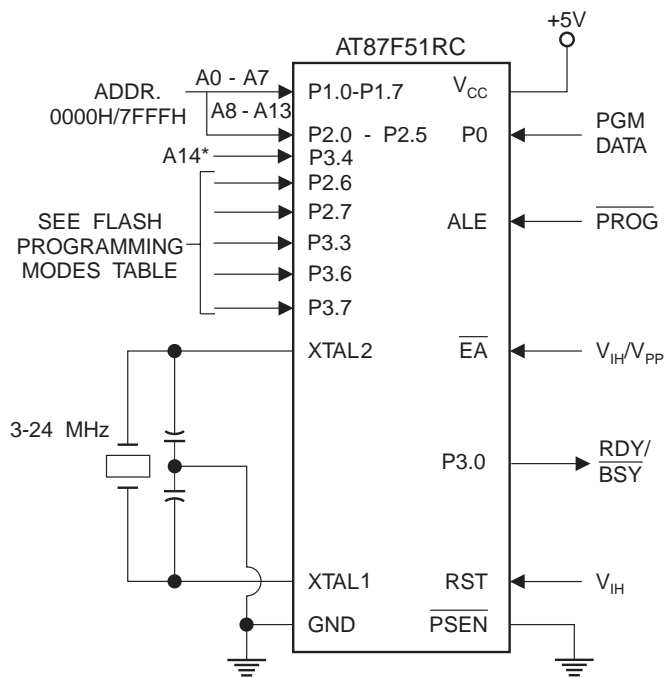
**Table 9.** QuickFlash Programming Modes

Mode	V <sub>CC</sub>	RST	PSEN	ALE/ PROG	EA/ V <sub>PP</sub>	P2.6	P2.7	P3.3	P3.6	P3.7	P0.7-0 Data	P3.4	P2.5-0	P1.7-0
												Address		
Write Code Data	5 V	H	L		12 V	L	H	H	H	H	D <sub>IN</sub>	A14	A13-8	A7-0
Read Code Data	5 V	H	L	H	H	L	L	L	H	H	D <sub>OUT</sub>	A14	A13-8	A7-0
Write Lock Bit 1	6.5 V	H	L		12 V	H	H	H	H	H	X	X	X	X
Write Lock Bit 2	6.5 V	H	L		12 V	H	H	H	L	L	X	X	X	X
Write Lock Bit 3	6.5 V	H	L		12 V	H	L	H	H	L	X	X	X	X
Read Lock Bits														
1, 2, 3	5 V	H	L	H	H	H	H	L	H	L	D2, 3, 4	X	X	X
Read Atmel ID	5 V	H	L	H	H	L	L	L	L	L	1EH	X	X	000H
Read Device ID	5 V	H	L	H	H	L	L	L	L	L	87H	X	X	100H
Read Device ID	5 V	H	L	H	H	L	L	L	L	L	07H	X	X	200H

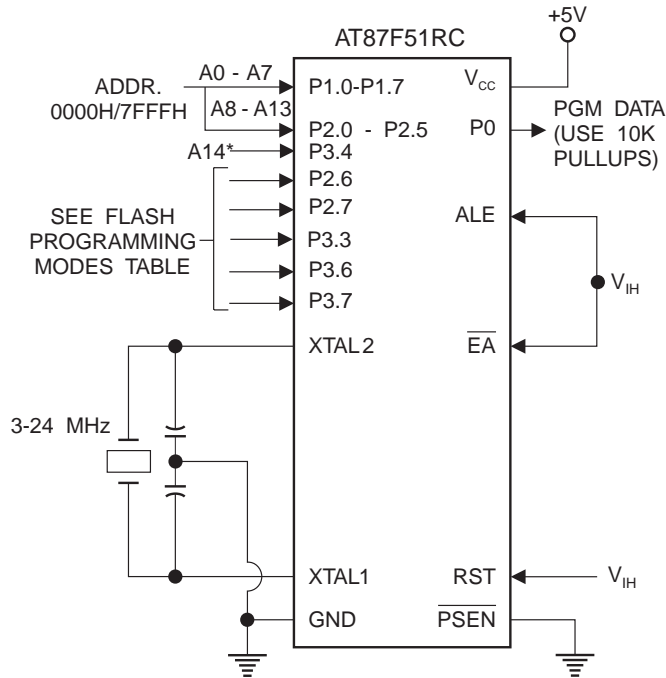
Notes: 1. Each Prog/pulse is 200 ns for Write Code Data and 100 ms for Write Lock Bits.

2. RDY/BSY signal is output on P3.0 during programming.

**Figure 10.** Programming the QuickFlash Memory



**Figure 11.** Verifying the QuickFlash Memory



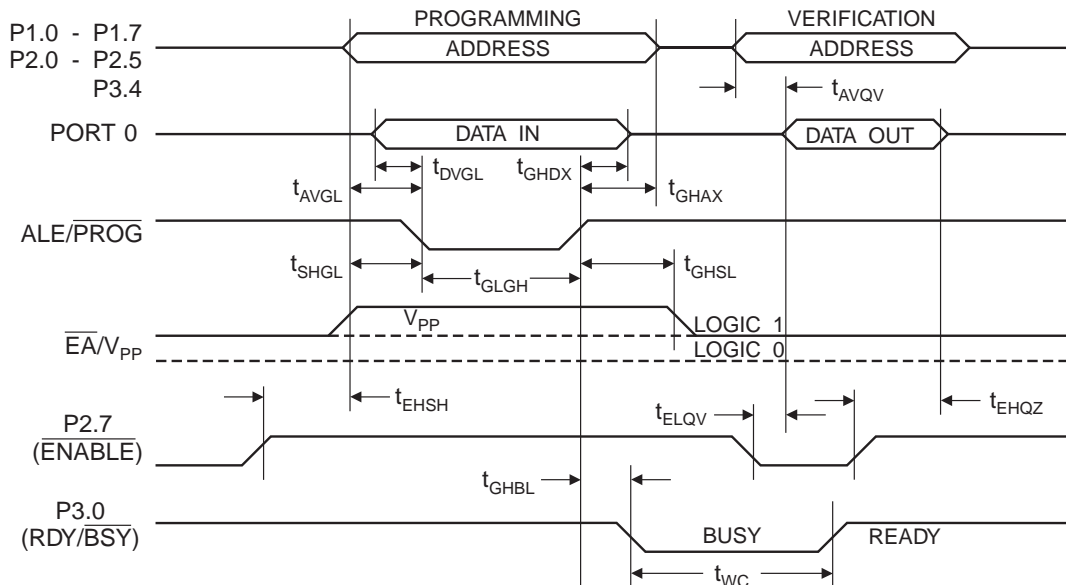
\*Programming address line A14 (P3.4) is not the same as the external memory address line A14 (P2.6).

## QuickFlash Programming and Verification Characteristics

$T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $V_{CC} = 5.0 \pm 10\%$

Symbol	Parameter	Min	Max	Units
$V_{PP}$	Programming Supply Voltage	11.5	12.0	V
$I_{PP}$	Programming Supply Current		10	mA
$I_{CC}$	$V_{CC}$ Supply Current		30	mA
$1/t_{CLCL}$	Oscillator Frequency	3	24	MHz
$t_{AVGL}$	Address Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
$t_{GHAX}$	Address Hold after $\overline{PROG}$	$48t_{CLCL}$		
$t_{DVGL}$	Data Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
$t_{GHDX}$	Data Hold after $\overline{PROG}$	$48t_{CLCL}$		
$t_{EHS}$	P2.7 ( $\overline{ENABLE}$ ) High to $V_{PP}$	$48t_{CLCL}$		
$t_{SHGL}$	$V_{PP}$ Setup to $\overline{PROG}$ Low	10		$\mu\text{s}$
$t_{GHSL}$	$V_{PP}$ Hold after $\overline{PROG}$	10		$\mu\text{s}$
$t_{GLGH}$	$\overline{PROG}$ Width	0.2	1	$\mu\text{s}$
$t_{AVQV}$	Address to Data Valid		$48t_{CLCL}$	
$t_{ELQV}$	$\overline{ENABLE}$ Low to Data Valid		$48t_{CLCL}$	
$t_{EHQZ}$	Data Float after $\overline{ENABLE}$	0	$48t_{CLCL}$	
$t_{GHBL}$	$\overline{PROG}$ High to $\overline{BUSY}$ Low		1.0	$\mu\text{s}$
$t_{WC}$	Byte Write Cycle Time		80	$\mu\text{s}$

## QuickFlash Programming and Verification Waveforms





## Absolute Maximum Ratings\*

Operating Temperature.....	-55°C to +125°C
Storage Temperature .....	-65°C to +150°C
Voltage on Any Pin with Respect to Ground .....	-1.0V to +7.0V
Maximum Operating Voltage .....	6.6V
DC Output Current.....	15.0 mA

**\*NOTICE:** Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

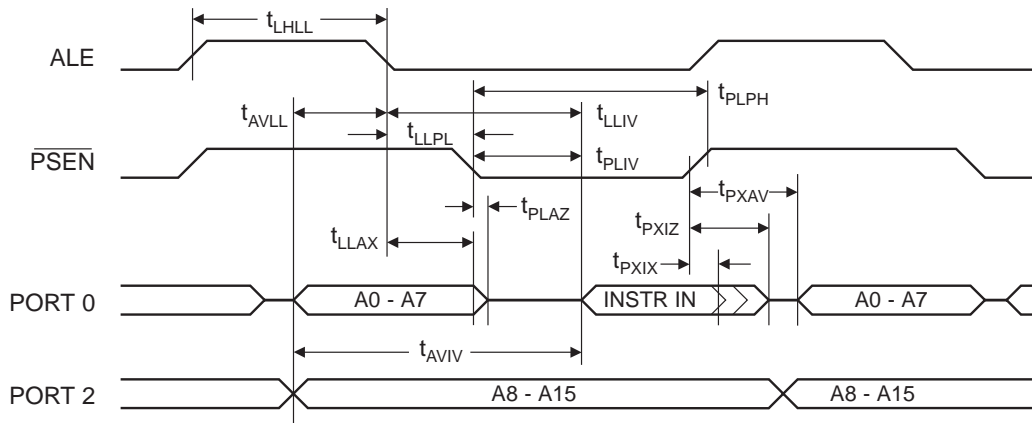
## DC Characteristics

The values shown in this table are valid for  $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  and  $V_{CC} = 5.0\text{V} \pm 20\%$ , unless otherwise noted.

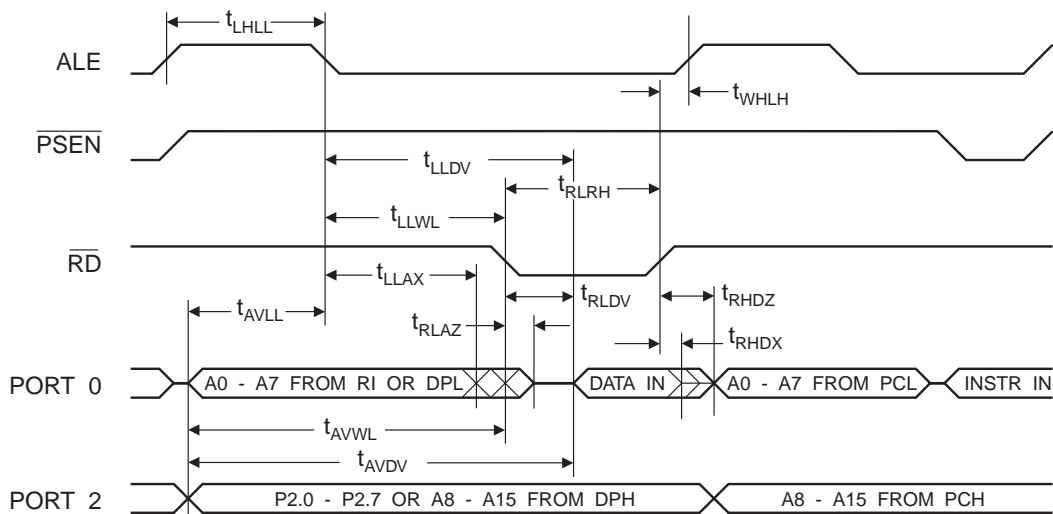
Symbol	Parameter	Condition	Min	Max	Units
$V_{IL}$	Input Low-voltage	(Except $\overline{EA}$ )	-0.5	$0.2 V_{CC} - 0.1$	V
$V_{IL1}$	Input Low-voltage ( $\overline{EA}$ )		-0.5	$0.2 V_{CC} - 0.3$	V
$V_{IH}$	Input High-voltage	(Except XTAL1, RST)	$0.2 V_{CC} + 0.9$	$V_{CC} + 0.5$	V
$V_{IH1}$	Input High-voltage	(XTAL1, RST)	$0.7 V_{CC}$	$V_{CC} + 0.5$	V
$V_{OL}$	Output Low-voltage <sup>(1)</sup> (Ports 1,2,3)	$I_{OL} = 1.6 \text{ mA}$		0.45	V
$V_{OL1}$	Output Low-voltage <sup>(1)</sup> (Port 0, ALE, $\overline{PSEN}$ )	$I_{OL} = 3.2 \text{ mA}$		0.45	V
$V_{OH}$	Output High-voltage (Ports 1,2,3, ALE, $\overline{PSEN}$ )	$I_{OH} = -60 \mu\text{A}$ , $V_{CC} = 5\text{V} \pm 10\%$	2.4		V
		$I_{OH} = -25 \mu\text{A}$	$0.75 V_{CC}$		V
		$I_{OH} = -10 \mu\text{A}$	$0.9 V_{CC}$		V
$V_{OH1}$	Output High-voltage (Port 0 in External Bus Mode)	$I_{OH} = -800 \mu\text{A}$ , $V_{CC} = 5\text{V} \pm 10\%$	2.4		V
		$I_{OH} = -300 \mu\text{A}$	$0.75 V_{CC}$		V
		$I_{OH} = -80 \mu\text{A}$	$0.9 V_{CC}$		V
$I_{IL}$	Logical 0 Input Current (Ports 1,2,3)	$V_{IN} = 0.45\text{V}$		-50	$\mu\text{A}$
$I_{TL}$	Logical 1 to 0 Transition Current (Ports 1,2,3)	$V_{IN} = 2\text{V}$ , $V_{CC} = 5\text{V} \pm 10\%$		-650	$\mu\text{A}$
$I_{LI}$	Input Leakage Current (Port 0, $\overline{EA}$ )	$0.45 < V_{IN} < V_{CC}$		$\pm 10$	$\mu\text{A}$
RRST	Reset Pull-down Resistor		50	300	$\text{K}\Omega$
$C_{IO}$	Pin Capacitance	Test Freq. = 1 MHz, $T_A = 25^{\circ}\text{C}$		10	pF
$I_{CC}$	Power Supply Current	Active Mode, 12 MHz		25	mA
		Idle Mode, 12 MHz		6.5	mA
	Power-down Mode <sup>(1)</sup>	$V_{CC} = 6\text{V}$		100	$\mu\text{A}$
		$V_{CC} = 3\text{V}$		40	$\mu\text{A}$

- Notes: 1. Under steady state (non-transient) conditions,  $I_{OL}$  must be externally limited as follows:  
Maximum  $I_{OL}$  per port pin: 10 mA  
Maximum  $I_{OL}$  per 8-bit port:  
Port 0: 26 mA      Ports 1, 2, 3: 15 mA  
Maximum total  $I_{OL}$  for all output pins: 71 mA  
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.
2. Minimum  $V_{CC}$  for Power-down is 2V.

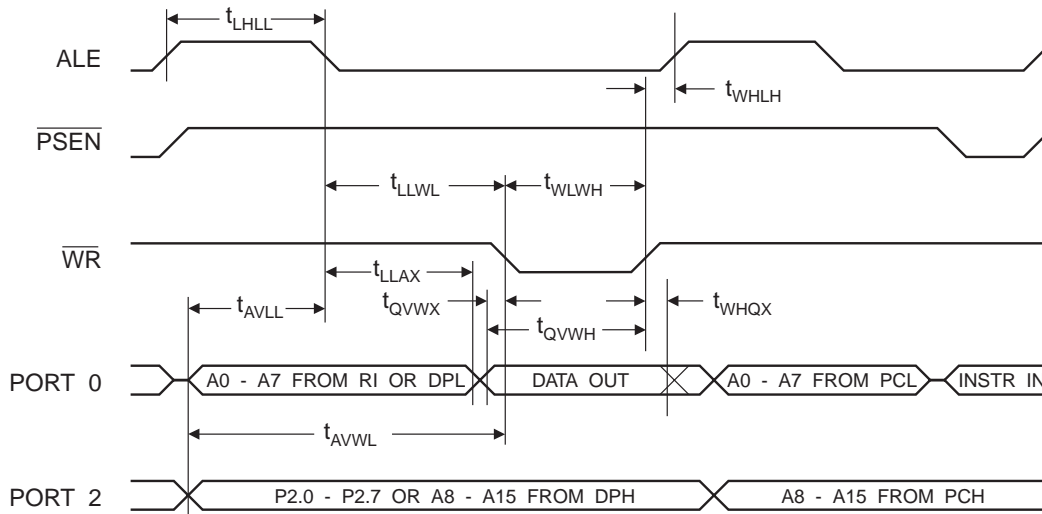
## External Program Memory Read Cycle



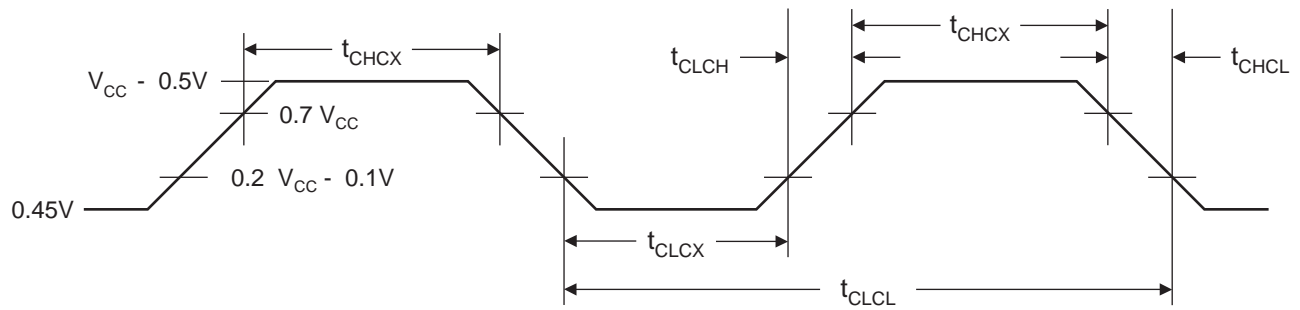
## External Data Memory Read Cycle



## External Data Memory Write Cycle



## External Clock Drive Waveforms



## External Clock Drive

Symbol	Parameter	Min	Max	Units
$1/t_{CLCL}$	Oscillator Frequency	0	24	MHz
$t_{CLCL}$	Clock Period	41.6		ns
$t_{CHCX}$	High Time	15		ns
$t_{CLCX}$	Low Time	15		ns
$t_{CLCH}$	Rise Time		20	ns
$t_{CHCL}$	Fall Time		20	ns

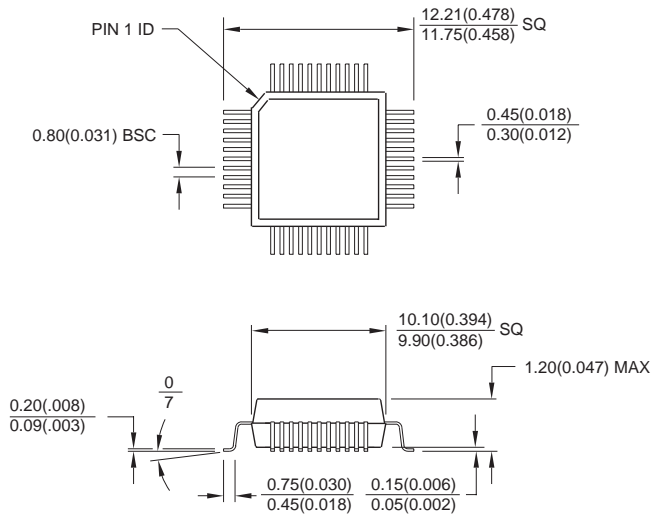
## Ordering Information

Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range
12	5V $\pm$ 20%	AT87F51RC-12AC	44A	Commercial (0° C to 70° C)
		AT87F51RC-12JC	44J	
		AT87F51RC-12PC	40P6	
		AT87F51RC-12AI	44A	Industrial (-40° C to 85° C)
		AT87F51RC-12JI	44J	
		AT87F51RC-12PI	40P6	
16	5V $\pm$ 20%	AT87F51RC-16AC	44A	Commercial (0° C to 70° C)
		AT87F51RC-16JC	44J	
		AT87F51RC-16PC	40P6	
		AT87F51RC-16AI	44A	Industrial (-40° C to 85° C)
		AT87F51RC-16JI	44J	
		AT87F51RC-16PI	40P6	
20	5V $\pm$ 20%	AT87F51RC-20AC	44A	Commercial (0° C to 70° C)
		AT87F51RC-20JC	44J	
		AT87F51RC-20PC	40P6	
		AT87F51RC-20AI	44A	Industrial (-40° C to 85° C)
		AT87F51RC-20JI	44J	
		AT87F51RC-20PI	44Q	
24	5V $\pm$ 20%	AT87F51RC-24AC	44A	Commercial (0° C to 70° C)
		AT87F51RC-24JC	44J	
		AT87F51RC-24PC	40P6	
		AT87F51RC-24AI	44A	Industrial (-40° C to 85° C)
		AT87F51RC-24JI	44J	
		AT87F51RC-24PI	40P6	

Package Type	
<b>44A</b>	44-lead, Thin Plastic Gull Wing Quad Flatpack (TQFP)
<b>44J</b>	44-lead, Plastic J-Leaded Chip Carrier (PLCC)
<b>40P6</b>	40-lead, 0.600" Wide, Plastic Dual Inline Package (PDIP)

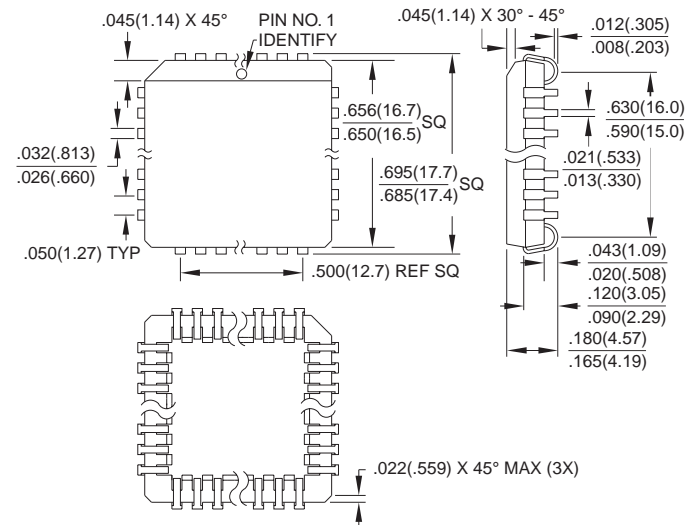
## Packaging Information

**44A**, 44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP)  
Dimensions in Millimeters and (Inches)\*



\*Controlling dimension: millimeters

**44J**, 44-lead, Plastic J-Leaded Chip Carrier (PLCC)  
Dimensions in Inches and (Millimeters)



**40P6**, 40-lead, 0.600" Wide, Plastic Dual Inline Package (PDIP)  
Dimensions in Inches and (Millimeters)  
JEDEC STANDARD MS-011 AC

