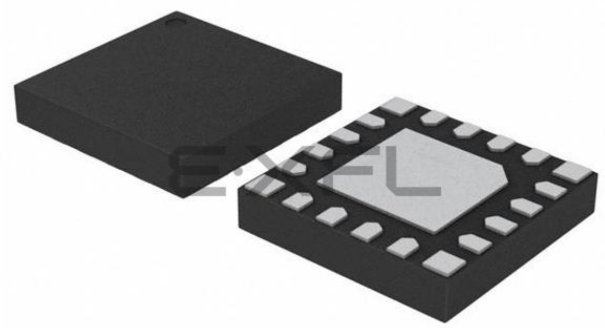

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"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable 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	Active
Core Processor	CIP-51 8051
Core Size	8-Bit
Speed	25MHz
Connectivity	SMBus (2-Wire/I²C), SPI, UART/USART
Peripherals	Brown-out Detect/Reset, Cap Sense, POR, PWM, Temp Sensor, WDT
Number of I/O	16
Program Memory Size	8KB (8K x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	512 x 8
Voltage - Supply (Vcc/Vdd)	1.8V ~ 3.6V
Data Converters	A/D 9x12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	20-UFQFN Exposed Pad
Supplier Device Package	20-QFN (3x3)
Purchase URL	https://www.e-xfl.com/product-detail/silicon-labs/c8051f990-c-gm

List of Tables

1.5. SAR ADC with 16-bit Auto-Averaging Accumulator and Autonomous Low Power Burst Mode

C8051F99x-C8051F98x devices have a 300 ksps, 10-bit or 75 ksps 12-bit successive-approximation-register (SAR) ADC with integrated track-and-hold and programmable window detector. ADC0 also has an autonomous low power Burst Mode which can automatically enable ADC0, capture and accumulate samples, then place ADC0 in a low power shutdown mode without CPU intervention. It also has a 16-bit accumulator that can automatically average the ADC results, providing an effective 11, 12, or 13 bit ADC result without any additional CPU intervention.

The ADC can sample the voltage at select GPIO pins (see Figure 1.17) and has an on-chip attenuator that allows it to measure voltages up to twice the voltage reference. Additional ADC inputs include an on-chip temperature sensor, the VDD supply voltage, and the internal digital supply voltage.

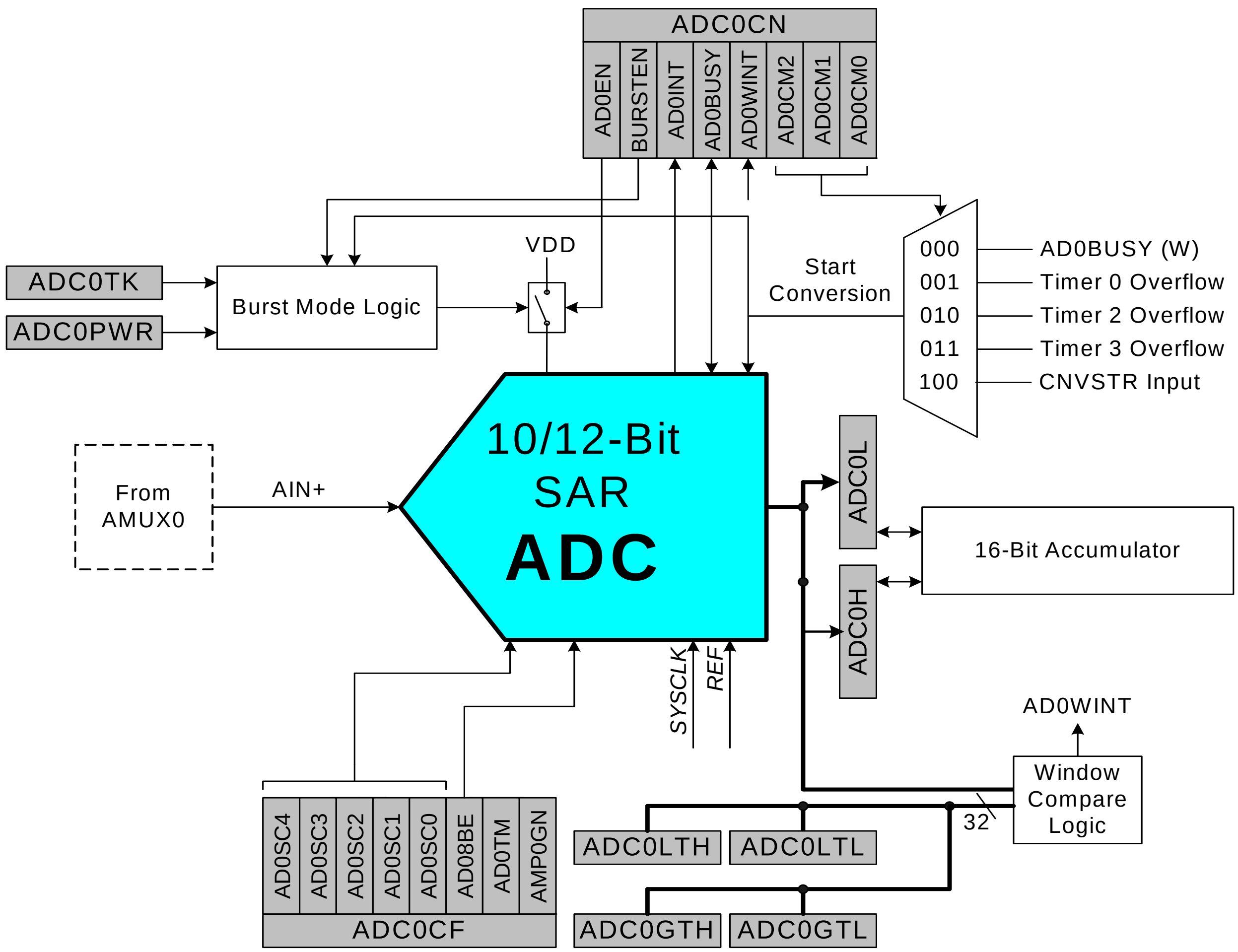

Figure 1.16. ADC0 Functional Block Diagram

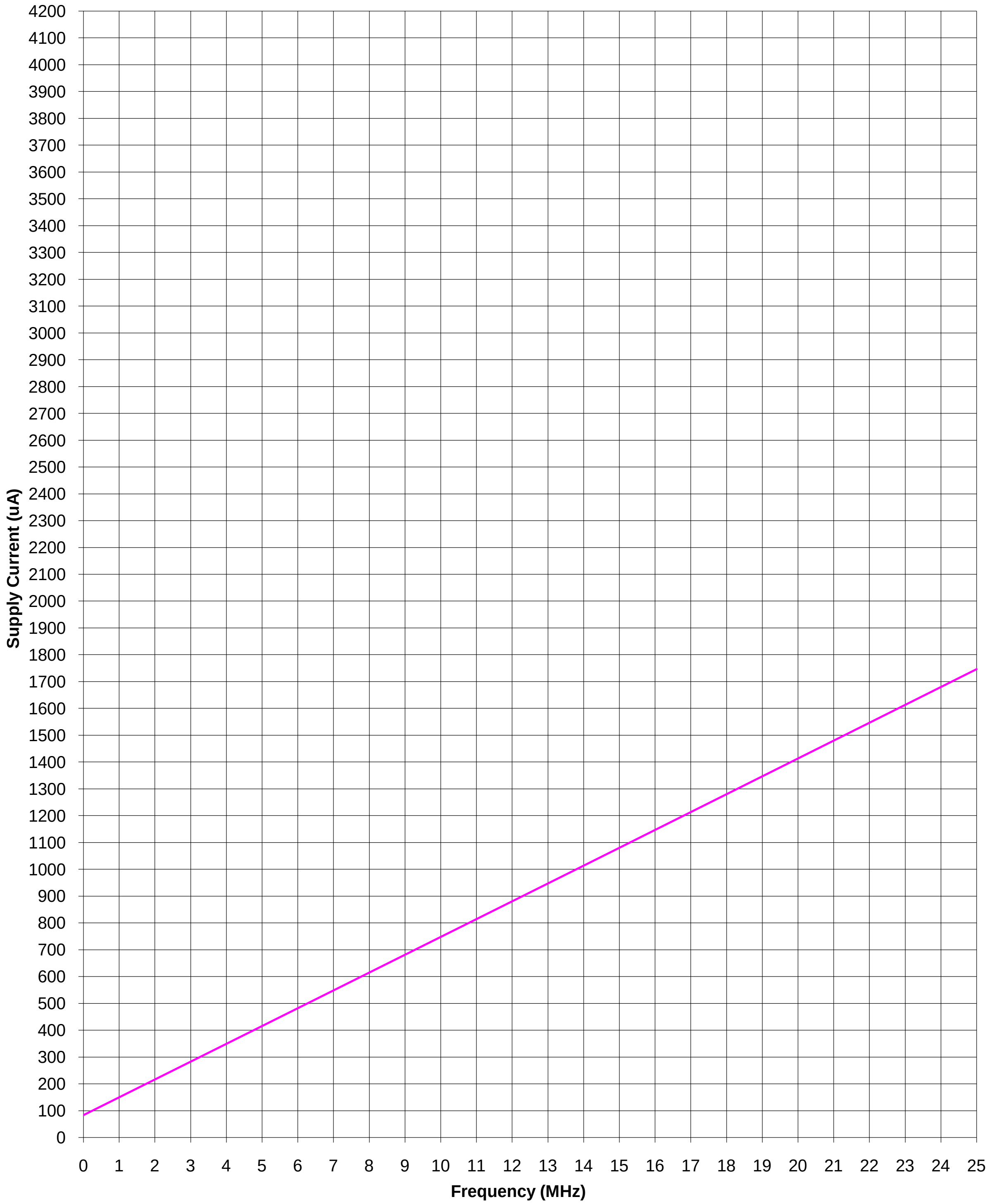

Figure 4.2. Idle Mode Current (External CMOS Clock)

Table 4.12. Voltage Reference Electrical Characteristics

V_{DD} = 1.8 to 3.6 V, **–**40 to +85 °C unless otherwise specified.

Parameter	Conditions	Min	Typ	Max	Units
Internal High-Speed Reference (REFSL[1:0] = 11)					
Output Voltage	–40 to +85 °C, V_{DD} = 1.8–3.6 V	1.62	1.65	1.68	V
VREF Turn-on Time		—	—	1.5	µs
Supply Current	Normal Power Mode Low Power Mode	— —	260 140	— —	µA
External Reference (REFSL[1:0] = 00, REFOE = 0)					
Input Voltage Range		0	—	V_{DD}	V
Input Current	Sample Rate = 300 ksps; VREF = 3.0 V	—	5.25	—	µA

SFR Definition 5.3. ADC0AC: ADC0 Accumulator Configuration

Bit	7	6	5	4	3	2	1	0
Name	AD012BE	AD0AE	AD0SJST[2:0]			AD0RPT[2:0]		
Type	R/W	W	R/W			R/W		
Reset	0	0	0	0	0	0	0	0

SFR Page = 0x0; SFR Address = 0xBA

Bit	Name	Function
7	AD012BE	**ADC0 12-Bit Mode Enable.** Enables 12-bit Mode on C8051F980/6 and C8051F990/6 devices. 0: 12-bit Mode Disabled. 1: 12-bit Mode Enabled.
6	AD0AE	**ADC0 Accumulate Enable.** Enables multiple conversions to be accumulated when burst mode is disabled. 0: ADC0H:ADC0L contain the result of the latest conversion when Burst Mode is disabled. 1: ADC0H:ADC0L contain the accumulated conversion results when Burst Mode is disabled. Software must write 0x0000 to ADC0H:ADC0L to clear the accumulated result. This bit is write-only. Always reads 0b.
5:3	AD0SJST[2:0]	**ADC0 Accumulator Shift and Justify.** Specifies the format of data read from ADC0H:ADC0L. 000: Right justified. No shifting applied. 001: Right justified. Shifted right by 1 bit. 010: Right justified. Shifted right by 2 bits. 011: Right justified. Shifted right by 3 bits. 100: Left justified. No shifting applied. All remaining bit combinations are reserved.
2:0	AD0RPT[2:0]	**ADC0 Repeat Count.** Selects the number of conversions to perform and accumulate in Burst Mode. This bit field must be set to 000 if Burst Mode is disabled. 000: Perform and Accumulate 1 conversion. 001: Perform and Accumulate 4 conversions. 010: Perform and Accumulate 8 conversions. 011: Perform and Accumulate 16 conversions. 100: Perform and Accumulate 32 conversions. 101: Perform and Accumulate 64 conversions. All remaining bit combinations are reserved.

SFR Definition 5.10. ADC0LTH: ADC0 Less-Than High Byte

Bit	7	6	5	4	3	2	1	0
Name	AD0LT[15:8]							
Type	R/W							
Reset	0	0	0	0	0	0	0	0

SFR Page = 0x0; SFR Address = 0xC6

Bit	Name	Function
7:0	AD0LT[15:8]	**ADC0 Less-Than High Byte.** Most Significant Byte of the 16-bit Less-Than window compare register.

SFR Definition 5.11. ADC0LTL: ADC0 Less-Than Low Byte

Bit	7	6	5	4	3	2	1	0
Name	AD0LT[7:0]							
Type	R/W							
Reset	0	0	0	0	0	0	0	0

SFR Page = 0x0; SFR Address = 0xC5

Bit	Name	Function
7:0	AD0LT[7:0]	**ADC0 Less-Than Low Byte.** Least Significant Byte of the 16-bit Less-Than window compare register.
Note: In 8-bit mode, this register should be set to 0x00.		

SFR Definition 6.2. IREF0CF: Current Reference Configuration

Bit	7	6	5	4	3	2	1	0
Name	PWMEN					PWMSS[2:0]		
Type	R/W	R/W	R/W	R/W	R/W	R/W		
Reset	0	0	0	0	0	0	0	0

SFR Page = All; SFR Address = 0xB9

Bit	Name	Function
7	PWMEN	**PWM Enhanced Mode Enable.** Enables the PWM Enhanced Mode. 0: PWM Enhanced Mode disabled. 1: PWM Enhanced Mode enabled.
6:3	Unused	Read = 0000b, Write = don't care.
2:0	PWMSS[2:0]	**PWM Source Select.** Selects the PCA channel to use for the fine-tuning control signal. 000: CEX0 selected as fine-tuning control signal. 001: CEX1 selected as fine-tuning control signal. 010: CEX2 selected as fine-tuning control signal. All Other Values: Reserved.

6.2. IREF0 Specifications

See Table 4.13 on page 62 for a detailed listing of IREF0 specifications.

10.1. Program Memory

The CIP-51 core has a 64 kB program memory space. The C8051F99x-C8051F98x devices implement 8 kB (C8051F980/1/6/7, C8051F990/1/6/7), 4 kB (C8051F982/3/8/9), or 2 kB (C8051F985) of this program memory space as in-system, re-programmable Flash memory, organized in a contiguous block from addresses 0x0000 to 0x1FFF (8 kB devices), 0x0FFF (4 kB devices), or 0x07FF (2 kB devices). The last byte of this contiguous block of addresses serves as the security lock byte for the device. Any addresses above the lock byte are reserved.

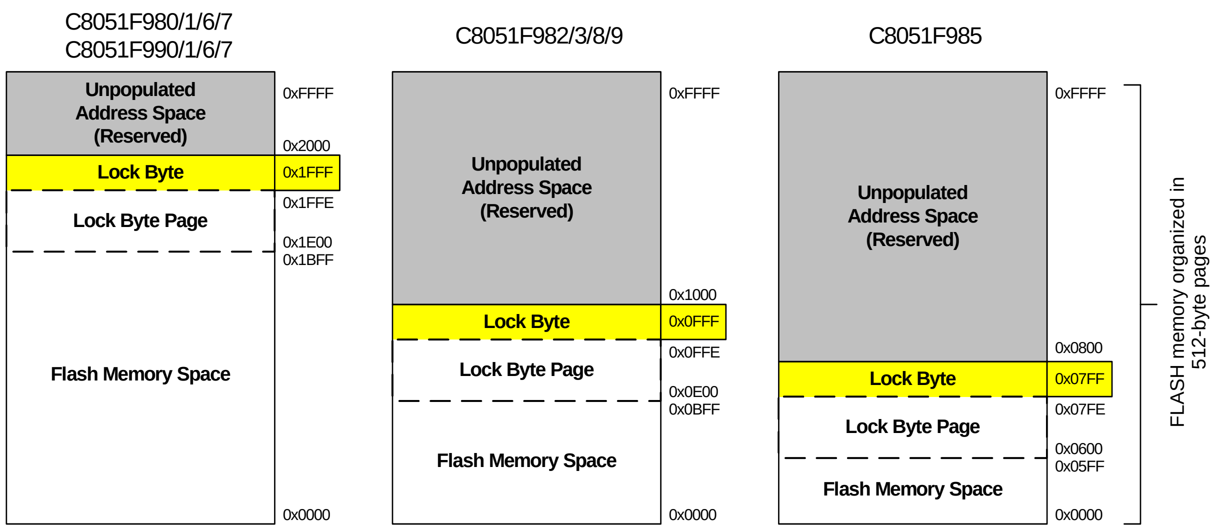

Figure 10.2. Flash Program Memory Map

10.1.1. MOVX Instruction and Program Memory

The MOVX instruction in an 8051 device is typically used to access external data memory. On the C8051F99x-C8051F98x devices, the MOVX instruction is normally used to read and write on-chip XRAM, but can be re-configured to write and erase on-chip Flash memory space. MOVC instructions are always used to read Flash memory, while MOVX write instructions are used to erase and write Flash. This Flash access feature provides a mechanism for the C8051F99x-C8051F98x to update program code and use the program memory space for non-volatile data storage. Refer to Section “14. Flash Memory” on page 150 for further details.

10.2. Data Memory

The C8051F99x-C8051F98x device family include 512 bytes of RAM data memory. 256 bytes of this memory is mapped into the internal RAM space of the 8051. The remainder of this memory is on-chip “external” memory. The data memory map is shown in Figure 10.1 for reference.

10.2.1. Internal RAM

There are 256 bytes of internal RAM mapped into the data memory space from 0x00 through 0xFF. The lower 128 bytes of data memory are used for general purpose registers and scratch pad memory. Either direct or indirect addressing may be used to access the lower 128 bytes of data memory. Locations 0x00 through 0x1F are addressable as four banks of general purpose registers, each bank consisting of eight byte-wide registers. The next 16 bytes, locations 0x20 through 0x2F, may either be addressed as bytes or as 128 bit locations accessible with the direct addressing mode.

The upper 128 bytes of data memory are accessible only by indirect addressing. This region occupies the same address space as the Special Function Registers (SFR) but is physically separate from the SFR

SFR Definition 15.2. PMU0FL: Power Management Unit Flag[1,2]

Bit	7	6	5	4	3	2	1	0
Name								CS0WK
Type	R	R	R	R	R	R	R	R/W
Reset	0	0	0	0	0	0	0	Varies

SFR Page = 0x0; SFR Address = 0xCE

Bit	Name	Description	Write	Read
7:1	Unused	**Unused**	Don’t Care.	0000000b
0	CS0WK	**CS0 Wake-up Source Enable and Flag**	0: Disable wake-up on CS0 event. 1: Enable wake-up on CS0 event.	Set to 1 if CS0 event caused the last wake-up.

Notes:
1. The Low Power Internal Oscillator cannot be disabled and the MCU cannot be placed in Suspend or Sleep Mode if any wake-up flags are set to 1. Software should clear all wake-up sources after each reset and after each wake-up from Suspend or Sleep Modes.
2. PMU0 requires two system clocks to update the wake-up source flags after waking from Suspend mode. The wake-up source flags will read ‘0’ during the first two system clocks following the wake from Suspend mode.

16.5. CRC0 Bit Reverse Feature

CRC0 includes hardware to reverse the bit order of each bit in a byte as shown in Figure 16.2. Each byte of data written to CRC0FLIP is read back bit reversed. For example, if 0xC0 is written to CRC0FLIP, the data read back is 0x03. Bit reversal is a useful mathematical function used in algorithms such as the FFT.

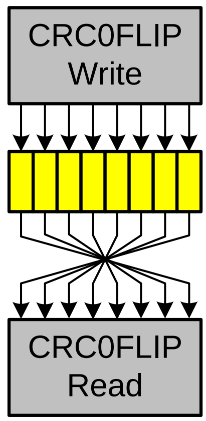

Figure 16.2. Bit Reverse Register

SFR Definition 16.6. CRC0FLIP: CRC0 Bit Flip

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Name	CRC0FLIP[7:0]							
Type	R/W							
Reset	0	0	0	0	0	0	0	0

SFR Page = All; SFR Address = 0x9C

Bit	Name	Function
7:0	CRC0FLIP[7:0]	**CRC0 Bit Flip.** Any byte written to CRC0FLIP is read back in a bit-reversed order, i.e. the written LSB becomes the MSB. For example: If 0xC0 is written to CRC0FLIP, the data read back will be 0x03. If 0x05 is written to CRC0FLIP, the data read back will be 0xA0.

18. Reset Sources

Reset circuitry allows the controller to be easily placed in a predefined default condition. On entry to this reset state, the following occur:

- CIP-51 halts program execution
- Special Function Registers (SFRs) are initialized to their defined reset values
- External Port pins are forced to a known state
- Interrupts and timers are disabled

All SFRs are reset to the predefined values noted in the SFR descriptions. The contents of RAM are unaffected during a reset; any previously stored data is preserved as long as power is not lost. Since the stack pointer SFR is reset, the stack is effectively lost, even though the data on the stack is not altered.

The Port I/O latches are reset to 0xFF (all logic ones) in open-drain mode. Weak pullups are enabled during and after the reset. For power-on resets, the $\overline{RST}$ pin is high-impedance with the weak pull-up off until the device exits the reset state. For V_{DD} Monitor resets, the $\overline{RST}$ pin is driven low until the device exits the reset state.

On exit from the reset state, the program counter (PC) is reset, and the system clock defaults to an internal oscillator. Refer to Section "19. Clocking Sources" on page 188 for information on selecting and configuring the system clock source. The Watchdog Timer is enabled with the system clock divided by 12 as its clock source (Section "26.4. Watchdog Timer Mode" on page 311 details the use of the Watchdog Timer). Program execution begins at location 0x0000.

Important Note: On device reset or upon waking up from Sleep mode, address 0x0000 of external memory may be overwritten by an indeterminate value. The indeterminate value is 0x00 in most situations. A dummy variable should be placed at address 0x0000 in external memory to ensure that the application firmware does not store any data that needs to be retained during sleep or reset at this memory location.

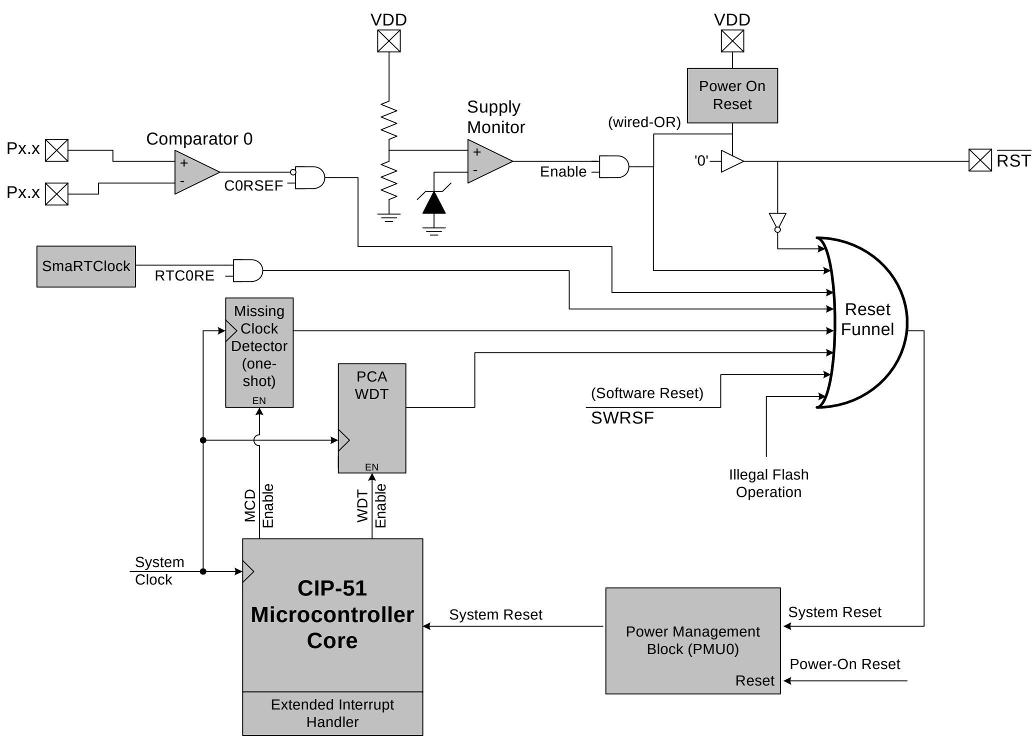

Figure 18.1. Reset Sources

19. Clocking Sources

C8051F99x-C8051F98x devices include a programmable precision internal oscillator, an external oscillator drive circuit, a low power internal oscillator, and a SmaRTClock real time clock oscillator. The precision internal oscillator can be enabled/disabled and calibrated using the OSCICN and OSCICL registers, as shown in Figure 19.1. The external oscillator can be configured using the OSCXCN register. The low power internal oscillator is automatically enabled and disabled when selected and deselected as a clock source. SmaRTClock operation is described in the SmaRTClock oscillator chapter.

The system clock (SYSCLK) can be derived from the precision internal oscillator, external oscillator, low power internal oscillator, low power internal oscillator divided by 8, or SmaRTClock oscillator. The global clock divider can generate a system clock that is 1, 2, 4, 8, 16, 32, 64, or 128 times slower that the selected input clock source. Oscillator electrical specifications can be found in the Electrical Specifications Chapter.

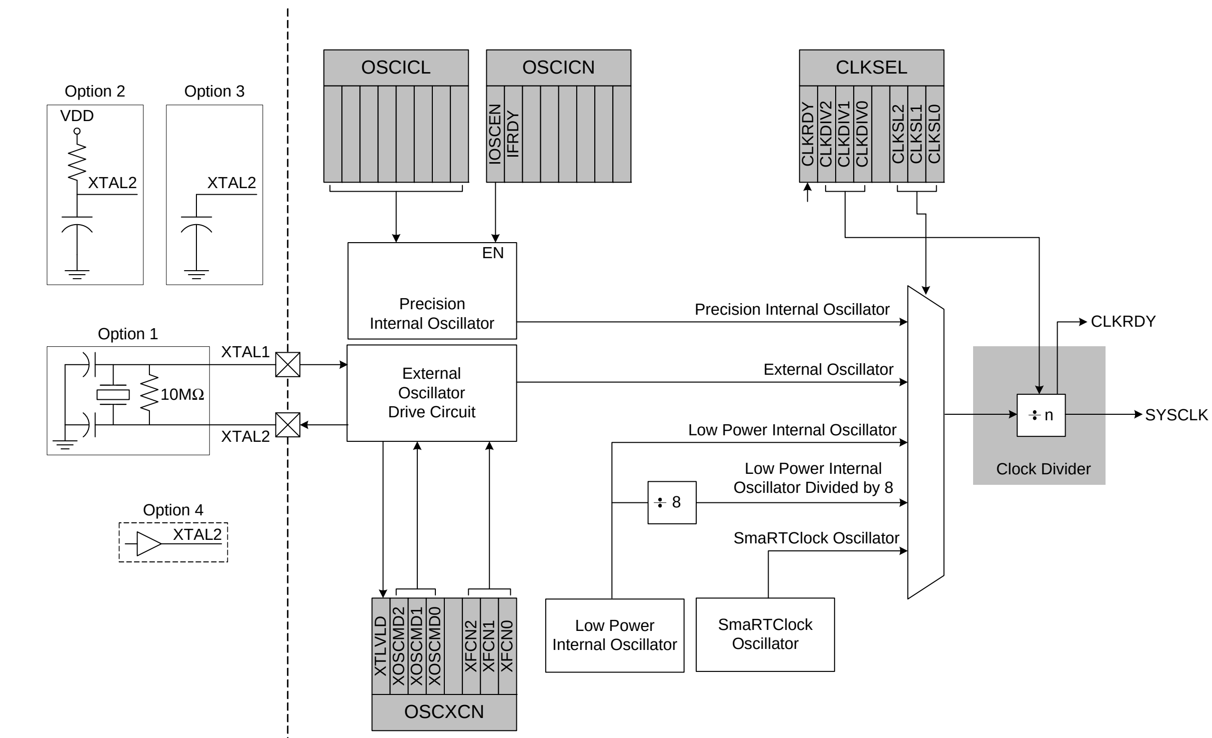

Figure 19.1. Clocking Sources Block Diagram

The proper way of changing the system clock when both the clock source and the clock divide value are being changed is as follows:

If switching from a fast “undivided” clock to a slower “undivided” clock:

1. Change the clock divide value.
2. Poll for CLKRDY > 1.
3. Change the clock source.

If switching from a slow “undivided” clock to a faster “undivided” clock:

1. Change the clock source.
2. Change the clock divide value.
3. Poll for CLKRDY > 1.

SFR Definition 19.2. OSCICN: Internal Oscillator Control

Bit	7	6	5	4	3	2	1	0
Name	IOSCEN	IFRDY	Reserved[5:0]					
Type	R/W	R	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	Varies	Varies	Varies	Varies	Varies	Varies

SFR Page = 0x0; SFR Address = 0xB2

Bit	Name	Function
7	IOSCEN	**Internal Oscillator Enable.** 0: Internal oscillator disabled. 1: Internal oscillator enabled.
6	IFRDY	**Internal Oscillator Frequency Ready Flag.** 0: Internal oscillator is not running at its programmed frequency. 1: Internal oscillator is running at its programmed frequency.
5:0	Reserved	Must perform read-modify-write.

Notes:
1. Read-modify-write operations such as ORL and ANL must be used to set or clear the enable bit of this register.
2. OSCBIAS (REG0CN.4) must be set to 1 before enabling the precision internal oscillator.

20.1.2. Using RTC0ADR and RTC0DAT to Access SmaRTClock Internal Registers

The SmaRTClock internal registers can be read and written using RTC0ADR and RTC0DAT. The RTC0ADR register selects the SmaRTClock internal register that will be targeted by subsequent reads or writes. Recommended instruction timing is provided in this section. If the recommended instruction timing is not followed, then BUSY (RTC0ADR.7) should be checked prior to each read or write operation to make sure the SmaRTClock Interface is not busy performing the previous read or write operation. A SmaRTClock Write operation is initiated by writing to the RTC0DAT register. Below is an example of writing to a SmaRTClock internal register.

1. Poll BUSY (RTC0ADR.7) until it returns 0 or follow recommended instruction timing.
2. Write 0x05 to RTC0ADR. This selects the internal RTC0CN register at SmaRTClock Address 0x05.
3. Write 0x00 to RTC0DAT. This operation writes 0x00 to the internal RTC0CN register.

A SmaRTClock Read operation is initiated by setting the SmaRTClock Interface Busy bit. This transfers the contents of the internal register selected by RTC0ADR to RTC0DAT. The transferred data will remain in RTC0DAT until the next read or write operation. Below is an example of reading a SmaRTClock internal register.

1. Poll BUSY (RTC0ADR.7) until it returns 0 or follow recommended instruction timing.
2. Write 0x05 to RTC0ADR. This selects the internal RTC0CN register at SmaRTClock Address 0x05.
3. Write 1 to BUSY. This initiates the transfer of data from RTC0CN to RTC0DAT.
4. Poll BUSY (RTC0ADR.7) until it returns 0 or follow recommend instruction timing.
5. Read data from RTC0DAT. This data is a copy of the RTC0CN register.

Note: The RTC0ADR and RTC0DAT registers will retain their state upon a device reset.

20.1.3. RTC0ADR Short Strobe Feature

Reads and writes to indirect SmaRTClock registers normally take 7 system clock cycles. To minimize the indirect register access time, the Short Strobe feature decreases the read and write access time to 6 system clocks. The Short Strobe feature is automatically enabled on reset and can be manually enabled/disabled using the SHORT (RTC0ADR.4) control bit.

Recommended Instruction Timing for a single register read with short strobe enabled:

```
mov RTC0ADR, #095h
nop
nop
nop
mov A, RTC0DAT
```

Recommended Instruction Timing for a single register write with short strobe enabled:

```
mov RTC0ADR, #095h
mov RTC0DAT, #000h
nop
```

20.1.4. SmaRTClock Interface Autoread Feature

When Autoread is enabled, each read from RTC0DAT initiates the next indirect read operation on the SmaRTClock internal register selected by RTC0ADR. Software should set the BUSY bit once at the beginning of each series of consecutive reads. Software should follow recommended instruction timing or check if the SmaRTClock Interface is busy prior to reading RTC0DAT. Autoread is enabled by setting AUTORD (RTC0ADR.6) to logic 1.

Registers XBR0, XBR1, and XBR2 are used to assign the digital I/O resources to the physical I/O Port pins. Note that when the SMBus is selected, the Crossbar assigns both pins associated with the SMBus (SDA and SCL); when either UART is selected, the Crossbar assigns both pins associated with the UART (TX and RX). UART0 pin assignments are fixed for bootloading purposes: UART TX0 is always assigned to P0.4; UART RX0 is always assigned to P0.5. Standard Port I/Os appear contiguously after the prioritized functions have been assigned.

Notes:

1. The Crossbar must be enabled (XBARE = 1) before any Port pin is used as a digital output. Port output drivers are disabled while the Crossbar is disabled.
2. When SMBus is selected in the Crossbar, the pins associated with SDA and SCL will automatically be forced into open-drain output mode regardless of the PnMDOUT setting.
3. SPI0 can be operated in either 3-wire or 4-wire modes, depending on the state of the NSSMD1-NSSMD0 bits in register SPI0CN. The NSS signal is only routed to a Port pin when 4-wire mode is selected. When SPI0 is selected in the Crossbar, the SPI0 mode (3-wire or 4-wire) will affect the pinout of all digital functions lower in priority than SPI0.
4. For given XBRn, PnSKIP, and SPInCN register settings, one can determine the I/O pin-out of the device using Figure 21.3.
5. On 20-pin devices, P1.4 should be skipped in the Crossbar. It is not available as a device pin.

22.5.2. Read Sequence (Master)

During a read sequence, an SMBus master reads data from a slave device. The master in this transfer will be a transmitter during the address byte, and a receiver during all data bytes. The SMBus interface generates the START condition and transmits the first byte containing the address of the target slave and the data direction bit. In this case the data direction bit (R/W) will be logic 1 (READ). Serial data is then received from the slave on SDA while the SMBus outputs the serial clock. The slave transmits one or more bytes of serial data.

If hardware ACK generation is disabled, the ACKRQ is set to 1 and an interrupt is generated after each received byte. Software must write the ACK bit at that time to ACK or NACK the received byte.

With hardware ACK generation enabled, the SMBus hardware will automatically generate the ACK/NACK, and then post the interrupt. **It is important to note that the appropriate ACK or NACK value should be set up by the software prior to receiving the byte when hardware ACK generation is enabled.**

Writing a 1 to the ACK bit generates an ACK; writing a 0 generates a NACK. Software should write a 0 to the ACK bit for the last data transfer, to transmit a NACK. The interface exits Master Receiver Mode after the STO bit is set and a STOP is generated. The interface will switch to Master Transmitter Mode if SMB0-DAT is written while an active Master Receiver. Figure 22.6 shows a typical master read sequence. Two received data bytes are shown, though any number of bytes may be received. Notice that the ‘data byte transferred’ interrupts occur at different places in the sequence, depending on whether hardware ACK generation is enabled. The interrupt occurs **before** the ACK with hardware ACK generation disabled, and **after** the ACK when hardware ACK generation is enabled.

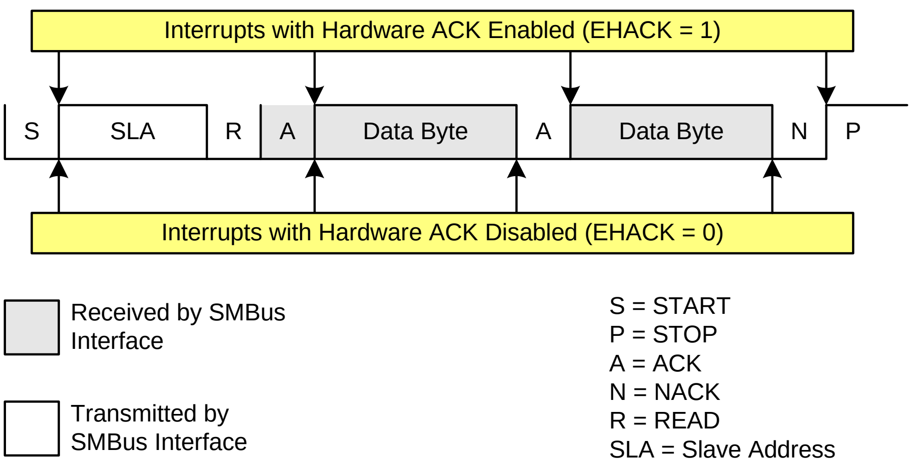

Figure 22.6. Typical Master Read Sequence

SFR Definition 25.6. TH0: Timer 0 High Byte

Bit	7	6	5	4	3	2	1	0
Name	TH0[7:0]							
Type	R/W							
Reset	0	0	0	0	0	0	0	0

SFR Page = 0x0; SFR Address = 0x8C

Bit	Name	Function
7:0	TH0[7:0]	**Timer 0 High Byte.** The TH0 register is the high byte of the 16-bit Timer 0.

SFR Definition 25.7. TH1: Timer 1 High Byte

Bit	7	6	5	4	3	2	1	0
Name	TH1[7:0]							
Type	R/W							
Reset	0	0	0	0	0	0	0	0

SFR Page = 0x0; SFR Address = 0x8D

Bit	Name	Function
7:0	TH1[7:0]	**Timer 1 High Byte.** The TH1 register is the high byte of the 16-bit Timer 1.

26.3.1. Edge-triggered Capture Mode

In this mode, a valid transition on the CEXn pin causes the PCA to capture the value of the PCA counter/timer and load it into the corresponding module's 16-bit capture/compare register (PCA0CPLn and PCA0CPHn). The CAPPn and CAPNn bits in the PCA0CPMn register are used to select the type of transition that triggers the capture: low-to-high transition (positive edge), high-to-low transition (negative edge), or either transition (positive or negative edge). When a capture occurs, the Capture/Compare Flag (CCFn) in PCA0CN is set to logic 1. An interrupt request is generated if the CCFn interrupt for that module is enabled. The CCFn bit is not automatically cleared by hardware when the CPU vectors to the interrupt service routine, and must be cleared by software. If both CAPPn and CAPNn bits are set to logic 1, then the state of the Port pin associated with CEXn can be read directly to determine whether a rising-edge or falling-edge caused the capture.

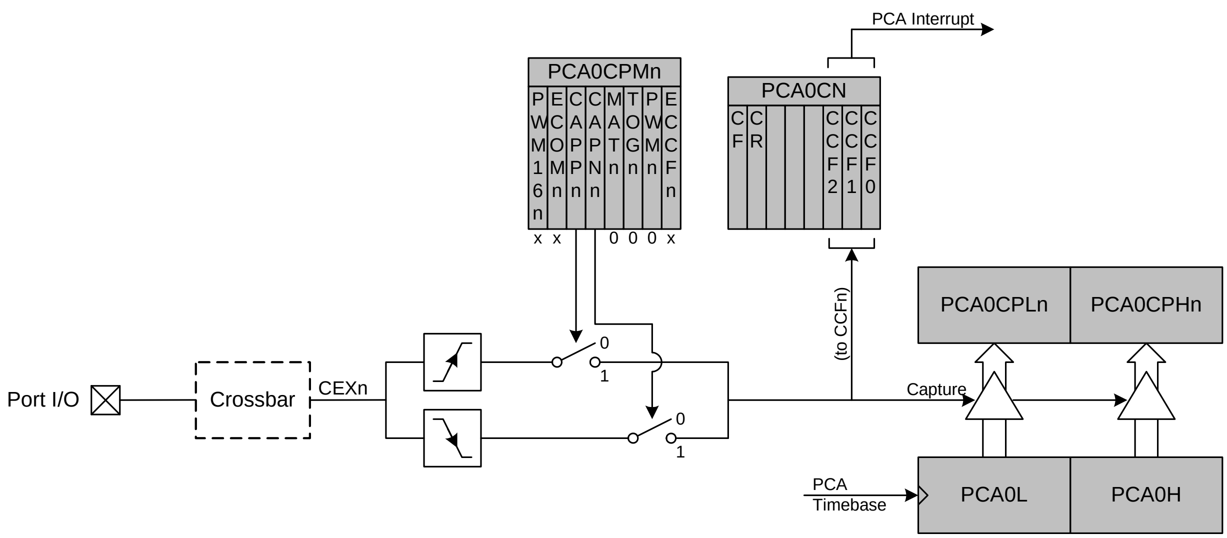

Figure 26.4. PCA Capture Mode Diagram

Note: The CEXn input signal must remain high or low for at least 2 system clock cycles to be recognized by the hardware.