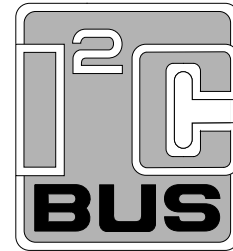


USER MANUAL



P89LPC932

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM

2002 Nov 22

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table of Contents**

General description	9
Pin configuration	9
Pin descriptions	12
Special Function Registers	15
Functional description	20
Enhanced CPU	20
Clocks	20
Clock definitions	20
Oscillator clock (OSCCLK)	20
Low speed oscillator option	20
Medium speed oscillator option	20
High speed oscillator option	20
Clock output	20
On-chip RC oscillator option	21
Watchdog oscillator option	21
External clock input option	21
Oscillator Clock (OSCCLK) wakeup delay	22
CPU Clock (CCLK) modification: DIVM register	22
Low power select	23
Memory organization	23
Data RAM arrangement	24
Interrupts	25
Interrupt priority structure	25
External Interrupt inputs	26
External Interrupt pin glitch suppression	26
I/O ports	28
Port configurations	28
Quasi-bidirectional output configuration	28
Open drain output configuration	29
Input-only configuration	30
Push-pull output configuration	30
Port 0 analog functions	30
Additional port features	31
Power monitoring functions	32
Brownout Detection	32
Power-on Detection	32
Power reduction modes	33
Reset	36
Reset vector	37
Timers/Counters 0 and 1	38
Mode 0	39
Mode 1	39
Mode 2	39

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

Mode 3	40
Mode 6	40
Timer Overflow toggle output	42
Real-time Clock/System Timer	43
Real-time Clock source	44
Changing RTCS1-0.	44
Real-time Clock interrupt/wake up	44
Reset sources affecting the Real-time Clock	45
Capture/Compare Unit (CCU)	46
CCU Clock (CCUCLK)	46
CCU Clock prescaling	46
Basic timer operation	46
Output compare	48
Input capture	49
PWM operation	50
Alternating Output Mode	52
Synchronized PWM register update	52
Halt	53
PLL operation	53
CCU interrupt structure	54
UART	58
Mode 0	58
Mode 1	58
Mode 2	58
Mode 3	58
SFR space	58
Baud Rate Generator and selection	58
Updating the BRGR1 and BRGR0 SFRs	59
Framing Error	60
Break Detect	60
More about UART Mode 0	61
More about UART Mode 1	62
More about UART Modes 2 and 3	63
Framing Error and RI in Modes 2 and 3 with SM2 = 1	63
Break Detect	63
Double buffering	64
Double buffering in different modes	64
Transmit interrupts with double buffering enabled (Modes 1, 2 and 3)	64
The 9th bit (bit 8) in double buffering (Modes 1, 2 and 3)	65
Multiprocessor communications	66
Automatic address recognition	66
I2C serial interface	68
I2C Data register	69
I2C Slave Address register	69
I2C Control register	69

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

I2C Status register	71
I2C SCL Duty Cycle registers I2SCLH and I2SCLL	71
I2C operation mode	72
Master Transmitter Mode	72
Master Receiver Mode	73
Slave Receiver Mode	74
Slave Transmitter Mode	74
Serial Peripheral Interface (SPI)	84
Typical SPI configurations	86
Configuring the SPI	87
Additional considerations for a slave	88
Additional considerations for a master	88
Mode change on SS	88
Write collision	89
Data mode	89
SPI clock prescaler select	91
Analog comparators	92
Comparator configuration	92
Internal reference voltage	93
Comparator interrupt	93
Comparators and power reduction modes	93
Comparator configuration example	94
Keypad interrupt (KBI)	95
Watchdog timer	97
Watchdog function	97
Feed sequence	97
Watchdog Control register (WDCON)	99
Watchdog Timer in Timer Mode	101
WDCLK = 0 and CPU power down	101
Switching of the Watchdog clock source	101
Additional features	102
Software reset	102
Dual Data Pointers	102
Data EEPROM	104
Data EEPROM read	104
Data EEPROM write	105
Hardware reset	105
Multiple writes to the DEEDAT register	105
Sequence of writes to DEECON and DEEDAT registers	105
Data EEPROM Row Fill	105
Data EEPROM Block Fill	105
Flash program memory	106
General description	106
Features	106
ISP & IAP capabilities of the LPC932	106

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

Flash organization.	106
Flash programming and erase	106
Boot ROM.	106
Power-On reset code execution	107
Hardware activation of the Boot Loader	107
In-System Programming (ISP)	107
Using the In-System Programming.	107
In-Application Programming method	112
User configuration bytes.	116
User security bytes.	117
Boot Vector.	117
Boot Status.	118
Index	119
Disclaimers	126
Licences	126
Contact information.	126

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****List of Figures**

28-Pin TSSOP Package	9
28-Pin PLCC Package	10
Logic symbol	10
Block diagram	11
Special Function Registers table.	15
On-chip RC oscillator TRIM register	21
Using the crystal oscillator.	21
Block diagram of oscillator control.	22
LPC932 memory map	23
On-chip data memory usage.	24
Interrupt priority level.	25
Summary of interrupts.	26
Interrupt sources, interrupt enables, and power down wake-up sources	27
Number of I/O pins available.	28
Port output configuration settings	28
Quasi-bidirectional output	29
Open drain output	29
Input -only	30
Push-pull output	30
Port output configuration	31
Brownout options.	32
Power reduction modes.	33
Power Control register (PCON).	34
Power Control register A (PCONA).	35
Block diagram of Reset.	36
Reset Sources register	37
Timer/Counter Mode Control register (TMOD)	38
Timer/Counter Auxiliary Mode Control register (TAMOD).	39
Timer/Counter Control register (TCON)	40
Timer/Counter 0 or 1 in Mode 0 (13-bit counter).	41
Timer/Counter 0 or 1 in Mode 1 (16-bit counter).	41
Timer/Counter 0 or 1 in Mode 2 (8-bit auto-reload).	41
Timer/Counter 0 Mode 3 (two 8-bit counters)	42
Timer/Counter 0 or 1 in Mode 6 (PWM auto-reload).	42
Real-time Clock/System Timer block diagram	43
Real-time Clock/System Timer clock sources.	44
RTCCON Register.	45
Capture Compare Unit block diagram.	46
CCU Prescaler Control register.	47
CCU Control register 0	48
Capture Compare Control register	49
Event delay counter for input capture	50
Asymmetrical PWM, downcounting.	51

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

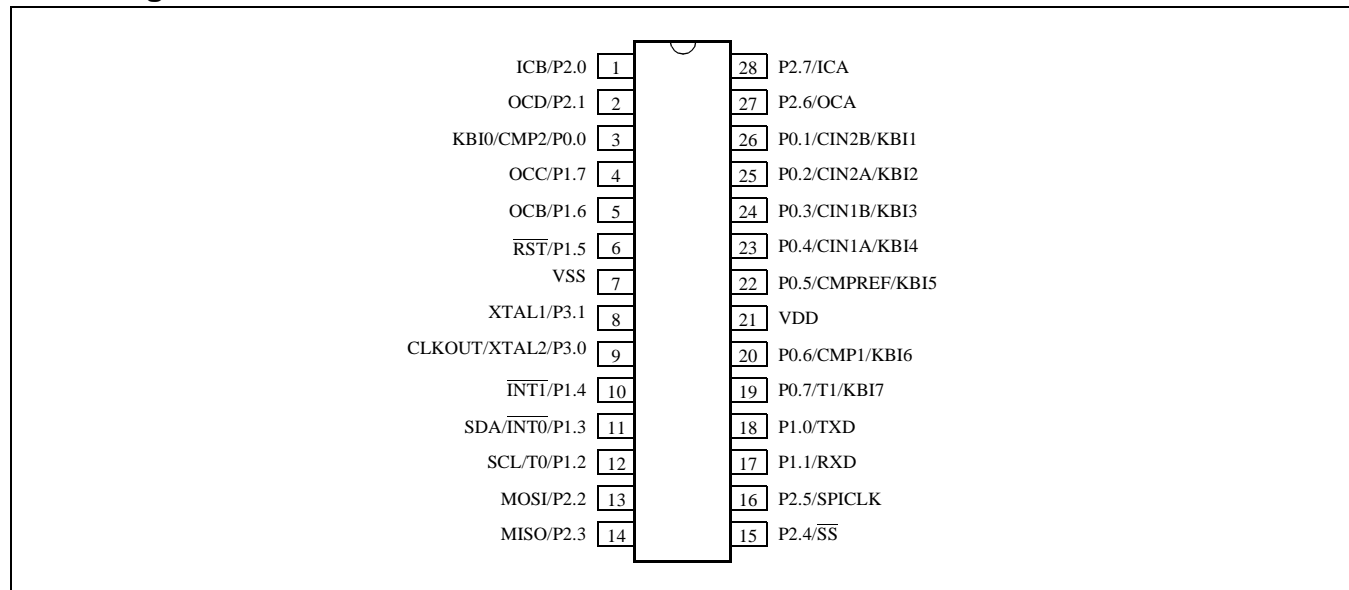
Symmetrical PWM.	51
Alternate Output Mode	52
Output Compare Pin Behavior	52
CCU Control register 1	53
Capture/Compare Unit interrupts	54
CCU Interrupt Status Encode register.	55
CCU Interrupt Flag register.	56
CCU Interrupt Control register.	57
SFR Locations for UARTs.	58
BRGCON register	59
Baud rate generation for UART (Modes 1, 3)	59
Baud rate generation for UART.	59
Serial Port Control register (SCON)	60
Serial Port Status register (SSTAT)	61
Serial Port Mode 0 (double buffering must be disabled)	62
Serial Port Mode 1 (only single transmit buffering case is shown)	62
Serial Port Mode 2 or 3 (only single transmit buffering case is shown).	63
FE and RI when SM2 = 1 in Modes 2 and 3.	63
Transmission with and without double buffering	65
I2C-bus configuration	68
I2C Data register	69
I2C Slave Address register	69
I2C Control register	70
I2C Status register.	71
I2C clock rates selection	71
Format in the Master Transmitter Mode	73
Format of Master Receiver Mode	73
A Master Receiver switches to Master Transmitter after sending Repeated Start	73
Format of Slave Receiver Mode	74
Format of Slave Transmitter Mode	75
I2C-bus serial interface block diagram	76
Master Transmitter Mode	77
Master Receiver Mode	78
Slave Receiver Mode	79
Slave Transmitter Mode	82
SPI block diagram	84
SPI Control register.	85
SPI Status register definition.	86
SPI Data register	86
SPI single master single slave configuration.	86
SPI dual device configuration, where either can be a master or a slave.	87
SPI single master multiple slaves configuration	87
SPI master and slave selection.	88
SPI slave transfer format with CPHA = 0	89
SPI slave transfer format with CPHA = 1	90

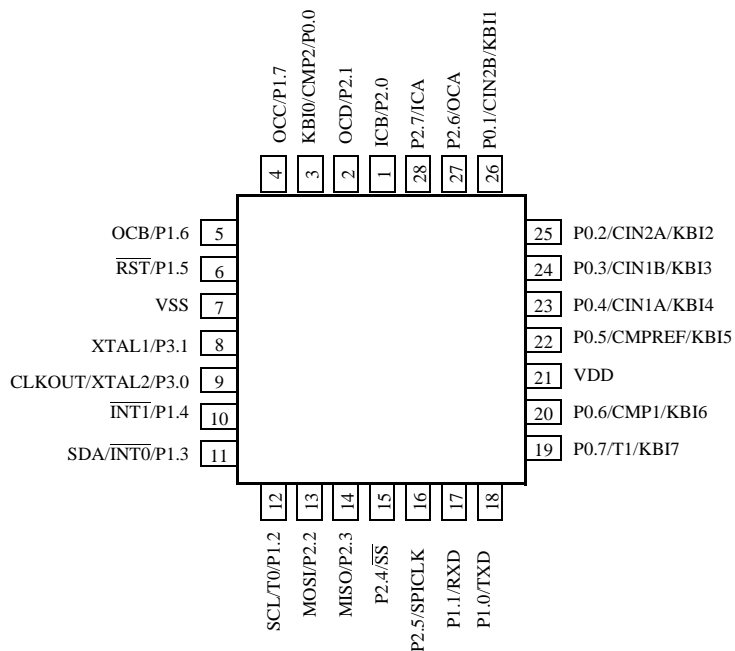
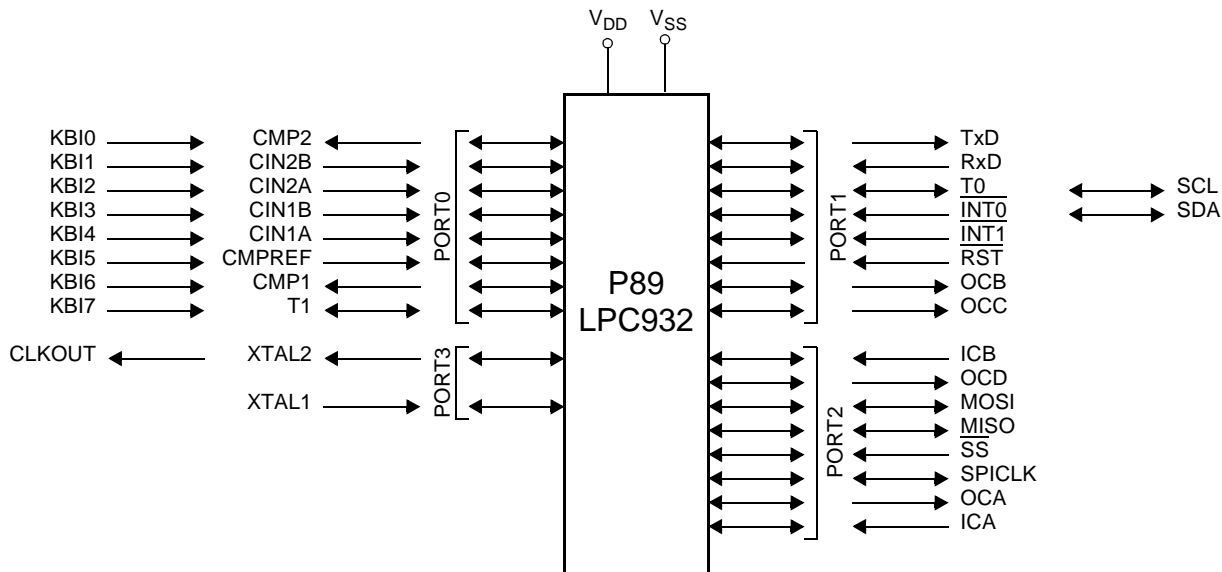
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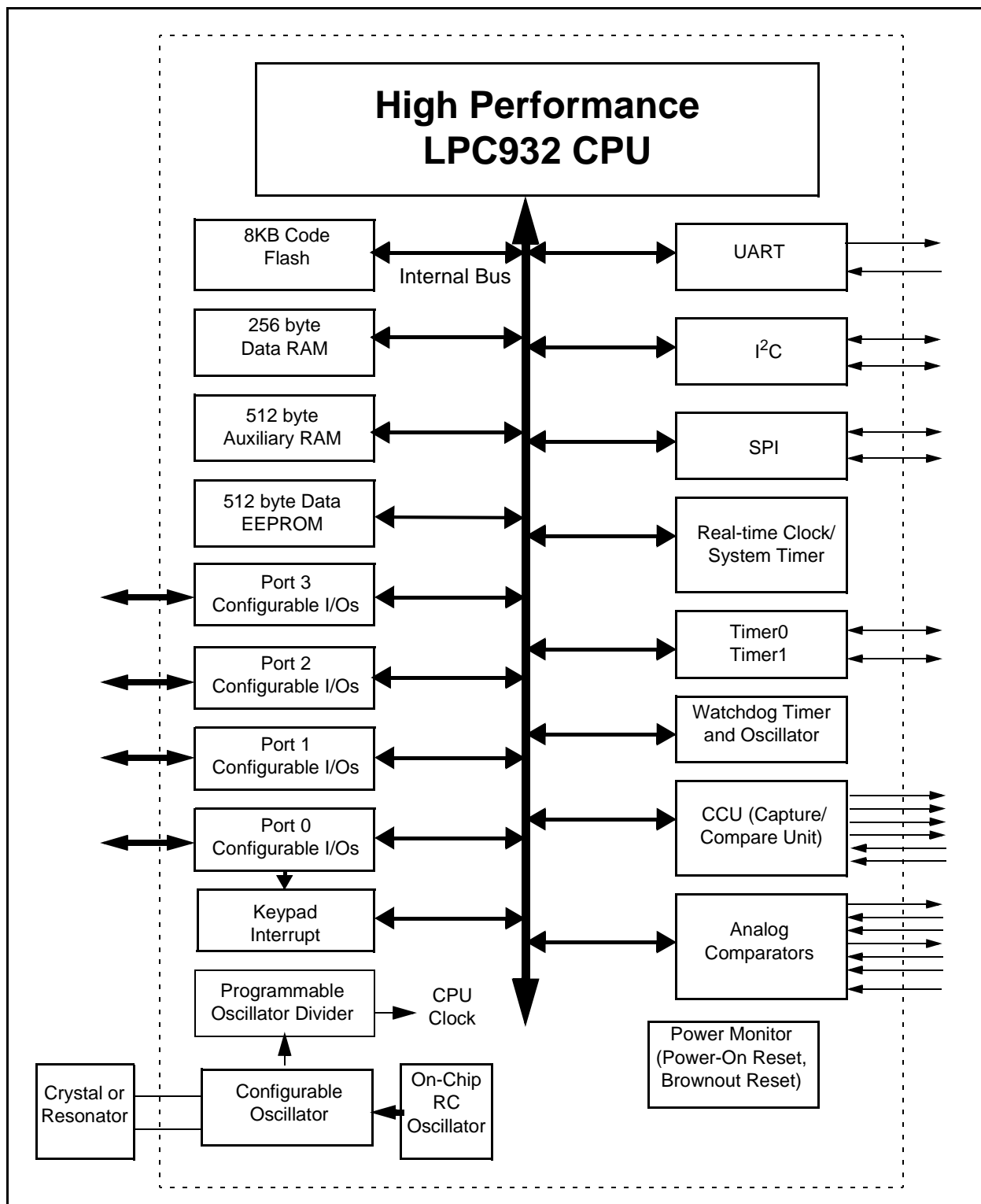
SPI master transfer format with CPHA = 0	90
SPI master transfer format with CPHA = 1	91
Comparator control registers (CMP1 and CMP2)	92
Comparator input and output connections	93
Comparator configurations	94
Keypad Pattern register.	95
Keypad Control register.	95
Keypad Interrupt Mask register (KBM)	96
Watchdog timer configuration	97
Watchdog Prescaler	98
Watchdog Timer Control register	99
Watchdog Timer in Watchdog Mode (WDTE = 1).	100
LPC932 Watchdog timeout values	100
Watchdog Timer in Timer Mode (WDTE = 0)	101
AUXR1 register	102
Data EEPROM Control register.	104
Forcing ISP Mode	107
In-System Programming (ISP) hex record formats	108
IAP function calls.	112
Flash User Configuration Byte 1 (UCFG1)	116
User sector Security Bytes (SEC0, ..., SEC7).	117
Boot Vector (BOOTVEC).	117
Boot Status (BOOTSTAT).	118

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****General description**

The LPC932 is a single-chip microcontroller designed for applications demanding high-integration, low cost solutions over a wide range of performance requirements. The LPC932 is based on a high performance processor architecture that executes instructions in two to four clocks, six times the rate of standard 80C51 devices. Many system level functions have been incorporated into the LPC932 in order to reduce component count, board space, and system cost.

Pin configuration**Figure 1: 28-Pin TSSOP Package**

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Figure 2: 28-Pin PLCC Package****Figure 3: Logic symbol**

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Figure 4:** Block diagram

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Pin descriptions**

MNEMONIC	PIN NO. for 28- PinDIP/ SSOP	TYPE	NAME AND FUNCTION
P0.0 - P0.7	3, 26, 25, 24, 23, 22, 20, 19	I/O	<p>Port 0: Port 0 is an 8-bit I/O port with a user-configurable output type. During reset Port 0 latches are configured in the input only mode with the internal pull-up disabled. The operation of port 0 pins as inputs and outputs depends upon the port configuration selected. Each port pin is configured independently. Refer to the section on I/O port configuration and the DC Electrical Characteristics in the Data Sheet for details.</p> <p>The Keypad Interrupt feature operates with port 0 pins.</p> <p>All pins have Schmitt triggered inputs.</p> <p>Port 0 also provides various special functions as described below.</p>
	3	I/O O I	<p>P0.0 Port 0 bit 0.</p> <p>CMP2 Comparator 2 output.</p> <p>KBI0 Keyboard Input 0.</p>
	26	I/O I I	<p>P0.1 Port 0 bit 1.</p> <p>CIN2B Comparator 2 positive input B.</p> <p>KBI1 Keyboard Input 1.</p>
	25	I/O I I	<p>P0.2 Port 0 bit 2.</p> <p>CIN2A Comparator 2 positive input A.</p> <p>KBI2 Keyboard Input 2.</p>
	24	I/O I I	<p>P0.3 Port 0 bit 3.</p> <p>CIN1B Comparator 1 positive input B.</p> <p>KBI3 Keyboard Input 3.</p>
	23	I/O I I	<p>P0.4 Port 0 bit 4.</p> <p>CIN1A Comparator 1 positive input A.</p> <p>KBI4 Keyboard Input 4.</p>
	22	I/O I I	<p>P0.5 Port 0 bit 5.</p> <p>CMPREF Comparator reference (negative) input.</p> <p>KBI5 Keyboard Input 5.</p>
	20	I/O O I	<p>P0.6 Port 0 bit 6.</p> <p>CMP1 Comparator 1 output.</p> <p>KBI6 Keyboard Input 6.</p>
	19	I/O I/O I	<p>P0.7 Port 0 bit 7.</p> <p>T1 Timer/counter 1 external count input or overflow output.</p> <p>KBI7 Keyboard Input 7.</p>
P1.0 - P1.7	18, 17, 12, 11, 10, 6, 5, 4	I/O (for P1.0- P1.4, P1.6- P1.7), I (for P1.5)	<p>Port 1: Port 1 is an 8-bit I/O port with a user-configurable output type, except for three pins as noted below. During reset Port 1 latches are configured in the input only mode with the internal pull-up disabled. The operation of the configurable port 1 pins as inputs and outputs depends upon the port configuration selected. Each of the configurable port pins are programmed independently. Refer to the section on I/O port configuration and the DC Electrical Characteristics in the Data Sheet for details. P1.2 - P1.3 are open drain when used as outputs. P1.5 is input only.</p> <p>All pins have Schmitt triggered inputs.</p> <p>Port 1 also provides various special functions as described below.</p>
	18	I/O O	<p>P1.0 Port 1 bit 0.</p> <p>TxD Transmitter output for the serial port.</p>

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

MNEMONIC	PIN NO. for 28- PinDIP/ SSOP	TYPE	NAME AND FUNCTION
	17	I/O I	P1.1 Port 1 bit 1. RxD Receiver input for the serial port.
	12	I/O I/O I/O	P1.2 Port 1 bit 2. (Open-drain when used as an output) T0 Timer/counter 0 external count input or overflow output. (Open-drain when used as outputs) SCL I ² C serial clock input/output.
	11	I I I/O	P1.3 Port 1 bit 3. (Open-drain when used as an output) INT0 External interrupt 0 input. SDA I ² C serial data input/output.
	10	I I	P1.4 Port 1 bit 4. INT1 External interrupt 1 input.
	6	I I	P1.5 Port 1 bit 5. (Input only) RST External Reset input during power-on or if selected via UCFG1. When functioning as a reset input a low on this pin resets the microcontroller, causing I/O ports and peripherals to take on their default states, and the processor begins execution at address 0. Also used during a power-on sequence to force In-System Programming mode.
	5	I/O O	P1.6 Port 1 bit 6. OCB Output Compare B.
	4	I/O O	P1.7 Port 1 bit 7. OCC Output Compare C.
P2.0 - P2.7	1, 2, 13, 14, 15, 16, 27, 28	I/O	Port 2: Port 2 is a 8-bit I/O port with a user-configurable output type. During reset Port 2 latches are configured in the input only mode with the internal pull-up disabled. The operation of port 2 pins as inputs and outputs depends upon the port configuration selected. Each port pin is configured independently. Refer to the section on I/O port configuration and the DC Electrical Characteristics in the Data Sheet for details. All pins have Schmitt triggered inputs. Port 2 also provides various special functions as described below.
	1	I/O I	P2.0 Port 2 bit 0. ICB Input capture B.
	2	I/O O	P2.1 Port 2 bit 1. OCD Output compare D.
	13	I/O I/O	P2.2 Port 2 bit 2. MOSI SPI master out slave in. When configured as master, this pin is output, when configured as slave, this pin is input.
	14	I/O I/O	P2.3 Port 2 bit 3. MISO SPI master in slave out. When configured as master, this pin is input, when configured as slave, this pin is output.
	15	I/O I	P2.4 Port 2 bit 4. SS SPI Slave select.
	16	I/O I/O	P2.5 Port 2 bit 5. SPICLK SPI clock. When configured as master, this pin is output, when configured as slave, this pin is input.
	27	I/O O	P2.6 Port 2 bit 6. OCA Output compare A

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

MNEMONIC	PIN NO. for 28- PinDIP/ SSOP	TYPE	NAME AND FUNCTION
	28	I/O	P2.7 Port 2 bit 7.
		I	ICA Input capture A
P3.0 - P3.1	9, 8	I/O	<p>Port 3: Port 3 is an 2-bit I/O port with a user-configurable output type. During reset Port 3 latches are configured in the input only mode with the internal pull-up disabled. The operation of port 3 pins as inputs and outputs depends upon the port configuration selected. Each port pin is configured independently. Refer to the section on I/O port configuration and the DC Electrical Characteristics in the Data Sheet for details.</p> <p>All pins have Schmitt triggered inputs.</p> <p>Port 3 also provides various special functions as described below:</p>
	9	I/O O O	<p>P3.0 Port 3 bit 0.</p> <p>XTAL2 Output from the oscillator amplifier (when a crystal oscillator option is selected via the FLASH configuration).</p> <p>CLKOUT CPU clock divided by 2 when enabled via SFR bit (ENCLK - TRIM.6). It can be used if the CPU clock is the internal RC oscillator, watchdog oscillator or external clock input, except when XTAL1/XTAL2 are used to generate clock source for the Real-time Clock/System Timer.</p>
	8	I/O I	<p>P3.1 Port 3 bit 1.</p> <p>XTAL1 Input to the oscillator circuit and internal clock generator circuits (when selected via the FLASH configuration). It can be a port pin if internal RC oscillator or watchdog oscillator is used as the CPU clock source, AND if XTAL1/XTAL2 are not used to generate the clock for the Real-time Clock/System Timer.</p>
V _{SS}	7	I	Ground: 0V reference.
V _{DD}	21	I	Power Supply: This is the power supply voltage for normal operation as well as Idle and Power down modes.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Special Function Registers****Note: Special Function Register (SFRs) accesses are restricted in the following ways:**

1. User must NOT attempt to access any SFR locations not defined.
2. Accesses to any defined SFR locations must be strictly for the functions for the SFRs.
3. SFR bits labeled '-', '0' or '1' can ONLY be written and read as follows:
 - '-' Unless otherwise specified, MUST be written with '0', but can return any value when read (even if it was written with '0'). It is a reserved bit and may be used in future derivatives.
 - '0' MUST be written with '0', and will return a '0' when read.
 - '1' MUST be written with '1', and will return a '1' when read.

Table 1: Special Function Registers table

Name	Description	SFR Address	Bit Functions and Addresses								Reset Value	
			MSB				LSB				Hex	Binary
ACC*	Accumulator	E0H	E7	E6	E5	E4	E3	E2	E1	E0	00H	00000000
AUXR1#	Auxiliary Function Register	A2H	CLKLP	EBRR	ENT1	ENT0	SRST	0	-	DPS	00H ¹	000000x0
B*	B Register	F0H	F7	F6	F5	F4	F3	F2	F1	F0	00H	00000000
BRGR0#§	Baud Rate Generator Rate Low	BEH									00H	00000000
BRGR1#§	Baud Rate Generator Rate High	BFH									00H	00000000
BRGCON#	Baud Rate Generator Control	BDH	-	-	-	-	-	-	SBRGS	BRGEN	00H [%]	xxxxxx00
CCCR#A	Capture Compare A Control Register	EAH	ICECA2	ICECA1	ICECA0	ICESA	ICNFA	FCOA	OCMA1	OCMA0	00H	00000000
CCCR#B	Capture Compare B Control Register	EBH	ICECB2	ICECB1	ICECB0	ICESB	ICNFB	FCOB	OCMB1	OCMB0	00H	00000000
CCCR#C	Capture Compare C Control Register	ECH	-	-	-	-	-	FCOC	OCMC1	OCMC0	00H	xxxxx000
CCCR#D	Capture Compare D Control Register	EDH	-	-	-	-	-	FCOD	OCMD1	OCMD0	00H	xxxxx000
CMP1#	Comparator 1 Control Register	ACH	-	-	CE1	CP1	CN1	OE1	CO1	CMF1	00H ¹	xx000000
CMP2#	Comparator 2 Control Register	ADH	-	-	CE2	CP2	CN2	OE2	CO2	CMF2	00H ¹	xx000000
DEECON#	Data EEPROM Control Register	F1H	EEIF	HVERR	ECTL1	ECTL0	-	-	-	EADR8	0EH	00001110
DEEDAT#	Data EEPROM Data Register	F2H									00H	00000000
DEEADR#	Data EEPROM Address Register	F3H									00H	00000000
DIVM#	CPU Clock Divide-by-M Control	95H									00H	00000000
DPTR	Data Pointer (2 bytes)											
DPH	Data Pointer High	83H									00H	00000000
DPL	Data Pointer Low	82H									00H	00000000
FMADRH#	Program Flash Address High	E7H									00H	00000000
FMADRL#	Program Flash Address Low	E6H									00H	00000000

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

Name	Description	SFR Address	Bit Functions and Addresses								Reset Value	
			MSB				LSB				Hex	Binary
FMCON#	Program Flash Control (Read)	E4H	BUSY	-	-	-	HVA	HVE	SV	OI	70H	01110000
	Program Flash Control (Write)		FMCMD.7	FMCMD.6	FMCMD.5	FMCMD.4	FMCMD.3	FMCMD.2	FMCMD.1	FMCMD.0		
FMDATA#	Program Flash Data	E5H									00H	00000000
I2ADR#	I ² C Slave Address Register	DBH	I2ADR.6	I2ADR.5	I2ADR.4	I2ADR.3	I2ADR.2	I2ADR.1	I2ADR.0	GC	00H	00000000
I2CON*#	I ² C Control Register	D8H	DF	DE	DD	DC	DB	DA	D9	D8	00H	x00000x0
I2DAT#	I ² C Data Register	DAH	-	I2EN	STA	STO	SI	AA	-	CRSEL		
I2SCLH#	Serial Clock Generator/SCL Duty Cycle Register High	DDH									00H	00000000
I2SCLL#	Serial Clock Generator/SCL Duty Cycle Register Low	DCH									00H	00000000
I2STAT#	I ² C Status Register	D9H	STA.4	STA.3	STA.2	STA.1	STA.0	0	0	0	F8H	11111000
ICRAH#	Input Capture A Register High	ABH									00H	
ICRAL#	Input Capture A Register low	AAH									00H	00000000
ICRBH#	Input Capture B Register High	AFH									00H	00000000
ICRBL#	Input Capture B Register Low	AEH									00H	00000000
IEN0*	Interrupt Enable 0	A8H	AF	AE	AD	AC	AB	AA	A9	A8		
			EA	EWDRT	EBO	ES/ESR	ET1	EX1	ET0	EX0	00H	00000000
IEN1*#	Interrupt Enable 1	E8H	EF	EE	ED	EC	EB	EA	E9	E8		
			EIEE	EST	-	ECCU	ESPI	EC	EKBI	EI2C	00H ¹	00x00000
IP0*	Interrupt Priority 0	B8H	BF	BE	BD	BC	BB	BA	B9	B8		
			-	PWDRT	PBO	PS/PSR	PT1	PX1	PT0	PX0	00H ¹	x0000000
IP0H#	Interrupt Priority 0 High	B7H	-	PWDRT H	PBOH	PSH/ PSRH	PT1H	PX1H	PT0H	PX0H	00H ¹	x0000000
IP1*#	Interrupt Priority 1	F8H	FF	FE	FD	FC	FB	FA	F9	F8		
			PIEE	PST	-	PCCU	PSPI	PC	PKBI	PI2C	00H ¹	00x00000
IP1H#	Interrupt Priority 1 High	F7H	PIEEH	PSTH	-	PCCUH	PSPIH	PCH	PKBIH	PI2CH	00H ¹	00x00000
KBCON#	Keypad Control Register	94H	-	-	-	-	-	-	PATN_S EL	KBIF	00H ¹	xxxxxx00
KBMASK#	Keypad Interrupt Mask Register	86H									00H	00000000
KBPATN#	Keypad Pattern Register	93H									FFH	11111111
OCRAH#	Output Compare A Register High	EFH									00H	00000000
OCRAL#	Output Compare A Register Low	EEH									00H	00000000
OCRBH#	Output Compare B Register High	FBH									00H	00000000
OCRBL#	Output Compare B Register Low	FAH									00H	00000000
OCRCH#	Output Compare C Register High	FDH									00H	00000000

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

Name		Description	SFR Address	Bit Functions and Addresses								Reset Value	
				MSB				LSB				Hex	Binary
OCRCL#	Output Compare C Register Low	FCH									00H	00000000	
OCRDH#	Output Compare D Register High	FFH									00H	00000000	
OCRDL#	Output Compare D Register Low	FEH									00H	00000000	
P0*	Port 0	80H	87	86	85	84	83	82	81	80	Note 1		
			T1/KB7	CMP1/KB6	CMPREF/KB5	CIN1A/KB4	CIN1B/KB3	CIN2A/KB2	CIN2B/KB1	CMP2/KB0			
P1*	Port 1	90H	97	96	95	94	93	92	91	90	Note 1		
			OCC	OCB	RST	INT1	INT0/SDA	T0/SCL	RxD	TxD			
P2*	Port 2	A0H	A7	A6	A5	A4	A3	A2	A1	A0	Note 1		
			ICA	OCA	SPICLK	SS	MISO	MOSI	OCD	ICB			
P3*	Port 3	B0H	B7	B6	B5	B4	B3	B2	B1	B0	Note 1		
			-	-	-	-	-	-	XTAL1	XTAL2			
P0M1#	Port 0 Output Mode 1	84H	(P0M1.7)	(P0M1.6)	(P0M1.5)	(P0M1.4)	(P0M1.3)	(P0M1.2)	(P0M1.1)	(P0M1.0)	FFH	11111111	
P0M2#	Port 0 Output Mode 2	85H	(P0M2.7)	(P0M2.6)	(P0M2.5)	(P0M2.4)	(P0M2.3)	(P0M2.2)	(P0M2.1)	(P0M2.0)	00H	00000000	
P1M1#	Port 1 Output Mode 1	91H	(P1M1.7)	(P1M1.6)	-	(P1M1.4)	(P1M1.3)	(P1M1.2)	(P1M1.1)	(P1M1.0)	FFH ¹	11111111	
P1M2#	Port 1 Output Mode 2	92H	(P1M2.7)	(P1M2.6)	-	(P1M2.4)	(P1M2.3)	(P1M2.2)	(P1M2.1)	(P1M2.0)	00H ¹	00000000	
P2M1#	Port 2 Output Mode 1	A4H	(P2M1.7)	(P2M1.6)	(P2M1.5)	(P2M1.4)	(P2M1.3)	(P2M1.2)	(P2M1.1)	(P2M1.0)	FFH	11111111	
P2M2#	Port 2 Output Mode 2	A5H	(P2M2.7)	(P2M2.6)	(P2M2.5)	(P2M2.4)	(P2M2.3)	(P2M2.2)	(P2M2.1)	(P2M2.0)	00H	00000000	
P3M1#	Port 3 Output Mode 1	B1H	-	-	-	-	-	-	(P3M1.1)	(P3M1.0)	03H ¹	xxxxxx11	
P3M2#	Port 3 Output Mode 2	B2H	-	-	-	-	-	-	(P3M2.1)	(P3M2.0)	00H ¹	xxxxxx00	
PCON#	Power Control Register	87H									00H	00000000	
			SMOD1	SMOD0	BOPD	BOI	GF1	GF0	PMOD1	PMOD0			
			RTCPD	DEEPPD	VCPD		I2PD	SPPD	SPD	CCUPD			
PCONA#	Power Control Register A	B5H									00H ¹	00000000	
PSW*	Program Status Wword	D0H	D7	D6	D5	D4	D3	D2	D1	D0	00H	00000000	
			CY	AC	F0	RS1	RS0	OV	F1	P			
PT0AD#	Port 0 Digital Input Disable	F6H	-	-	PT0AD.5	PT0AD.4	PT0AD.3	PT0AD.2	PT0AD.1	-	00H	xx00000x	
RSTSRC#	Reset Source Register	DFH	-	-	BOF	POF	R_BK	R_WD	R_SF	R_EX	Note 2		
RTCCON#	Real Time Clock Control	D1H	RTCF	RTCS1	RTCS0	-	-	-	ERTC	RTCEN	60H ^{1,5}	011xxx00	
RTCH#	Real Time Clock Register High	D2H									00H ⁵	00000000	
RTCL#	Real Time Clock Register Low	D3H									00H ⁵	00000000	
SADDR#	Serial Port Address Register	A9H									00H	00000000	
SADEN#	Serial Port Address Enable	B9H									00H	00000000	
SBUF	Serial Port Data Buffer Register	99H									xxH	xxxxxxxx	
SCON*	Serial Port Control	98H	9F	9E	9D	9C	9B	9A	99	98	00H	00000000	
			SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI			

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

Name		Description	SFR Address	Bit Functions and Addresses							Reset Value		
				MSB						LSB		Hex	Binary
SSTAT#	Serial Port Extended Status Register	BAH									00H	00000000	
			DBMOD	INTLO	CIDIS	DBISEL	FE	BR	OE	STINT			
SP	Stack Pointer	81H									07H	00000111	
SPCTL#	SPI Control Register	E2H	SSIG	SPEN	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	04H	00000100	
SPSTAT#	SPI Status Register	E1H	SPIF	WCOL	-	-	-	-	-	-	00H	00xxxxxx	
SPDAT#	SPI Data Register	E3H									00H	00000000	
TAMOD#	Timer 0 and 1 Auxiliary Mode	8FH	-	-	-	T1M2	-	-	-	T0M2	00H	xxx0xxx0	
											00H	00000000	
			8F	8E	8D	8C	8B	8A	89	88			
TCON*	Timer 0 and 1 Control	88H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	00H	00000000	
TCR20*#	CCU Control Register 0	C8H	PLEEN	HLTRN	HLTEN	ALTC	ALTB	TDIR2	TMOD21	TMOD20	00H	00000000	
TCR21#	CCU Control Register 1	F9H	TCOU2	-	-	-	PLLDV.3	PLLDV.2	PLLDV.1	PLLDV.0	00H	0xxx0000	
TH0	Timer 0 High	8CH									00H	00000000	
TH1	Timer 1 High	8DH									00H	00000000	
TH2#	CCU Timer High	CDH									00H	00000000	
TICR2#	CCU Interrupt Control Register	C9H	TOIE2	TOCIE2D	TOCIE2C	TOCIE2B	TOCIE2A	-	TICIE2B	TICIE2A	00H	00000x00	
TIFR2#	CCU Interrupt Flag Register	E9H	TOIF2	TOCF2D	TOCF2C	TOCF2B	TOCF2A	-	TICF2B	TICF2A	00H	00000x00	
TISE2#	CCU Interrupt Status Encode Register	DEH	-	-	-	-	-	ENCINT.2	ENCINT.1	ENCINT.0	00H	xxxxx000	
TL0	Timer 0 Low	8AH									00H	00000000	
TL1	Timer 1 Low	8BH									00H	00000000	
TL2#	CCU Timer Low	CCH									00H	00000000	
TMOD	Timer 0 and 1 Mode	89H	T1GATE	T1C/T	T1M1	T1M0	T0GATE	T0C/T	T0M1	T0M0	00H	00000000	
TOR2H#	CCU Reload Register High	CFH									00H	00000000	
TOR2L#	CCU Reload Register Low	CEH									00H	00000000	
TPCR2H#	Prescaler Control Register High	CBH	-	-	-	-	-	-	TPCR2H.1	TPCR2H.0	00H	xxxxxx00	
TPCR2L#	Prescaler Control Register Low	CAH	TPCR2L.7	TPCR2L.6	TPCR2L.5	TPCR2L.4	TPCR2L.3	TPCR2L.2	TPCR2L.1	TPCR2L.0	00H	00000000	
TRIM#	Internal Oscillator Trim Register	96H									Note 4		
			-	ENCLK	TRIM.5	TRIM.4	TRIM.3	TRIM.2	TRIM.1	TRIM.0			
WDCON#	Watchdog Control Register	A7H	PRE2	PRE1	PRE0	-	-	WDRUN	WDTOF	WDCLK	Notes 3,5		
WDL#	Watchdog Load	C1H									FFH	11111111	
WFEED1#	Watchdog Feed 1	C2H											
WFEED2#	Watchdog Feed 2	C3H											

Notes:

* SFRs are bit addressable.

SFRs are modified from or added to the 80C51 SFRs.

§ BRGR1 and BRGR0 must only be written if BRGEN in BRGCON SFR is '0'. If any of them is written if BRGEN = 1, result is unpredictable.

Unimplemented bits in SFRs (labeled '-') are X (unknown) at all times. Unless otherwise specified, '1's should not be written to these bits since they may be used for other purposes in future derivatives. The reset values shown for these bits are '0's

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

although they are unknown when read.

1. All ports are in input only mode after power-up.
2. The RSTSRC register reflects the cause of the LPC932 reset. Upon a power-up reset, all reset source flags are cleared except POF and BOF - the power-up reset value is xx110000.
3. After reset, the value is 111001x1, i.e., PRE2-PRE0 are all 1, WDRUN=1 and WDCLK=1. WDTOF bit is 1 after watchdog reset and is 0 after power-up reset. Other resets will not affect WDTOF.
4. On reset, the TRIM SFR is initialized with a factory preprogrammed value.
5. The only reset source that affects these SFRs is power-on reset.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM

P89LPC932

Functional description

Enhanced CPU

The LPC932 uses an enhanced 80C51 CPU which runs at 6 times the speed of standard 80C51 devices. A machine cycle consists of two CPU clock cycles, and most instructions execute in one or two machine cycles.

Clocks

Clock definitions

The LPC932 device has several internal clocks as defined below:

- OSCCLK - Input to the DIVM clock divider. OSCCLK is selected from one of four clock sources (see Figure 7) and can also be optionally divided to a slower frequency (see section "CPU Clock (CCLK) modification: DIVM register").

Note: f_{OSC} is defined as the OSCCLK frequency.

- CCLK - CPU clock; output of the DIVM clock divider. There are two CCLK cycles per machine cycle, and most instructions are executed in one to two machine cycles (two or four CCLK cycles).
- RCCLK - The internal 7.373 MHz RC oscillator output.
- PCLK - Clock for the various peripheral devices and is CCLK/2.

Oscillator clock (OSCCLK)

The LPC932 provides several user-selectable oscillator options in generating the CPU clock. This allows optimization for a range of needs from high precision to lowest possible cost. These options are configured when the FLASH is programmed and include an on-chip watchdog oscillator, an on-chip RC oscillator, an oscillator using an external crystal, or an external clock source. The crystal oscillator can be optimized for low, medium, or high frequency crystals covering a range from 20 kHz to 12 MHz.

Low speed oscillator option

This option supports an external crystal in the range of 20 kHz to 100 kHz. Ceramic resonators are also supported in this configuration.

Medium speed oscillator option

This option supports an external crystal in the range of 100 kHz to 4 MHz. Ceramic resonators are also supported in this configuration.

High speed oscillator option

This option supports an external crystal in the range of 4 MHz to 12 MHz. Ceramic resonators are also supported in this configuration.

Clock output

The LPC932 supports a user-selectable clock output function on the XTAL2 / CLKOUT pin when the crystal oscillator is not being used. This condition occurs if a different clock source has been selected (on-chip RC oscillator, watchdog oscillator, external clock input on X1) and if the Real-time Clock is not using the crystal oscillator as its clock source. This allows external devices to synchronize to the LPC932. This output is enabled by the ENCLK bit in the TRIM register.

The frequency of this clock output is 1/2 that of the CCLK. If the clock output is not needed in Idle mode, it may be turned off prior to entering Idle, saving additional power. Note: on reset, the TRIM SFR is initialized with a factory preprogrammed value. Therefore when setting or clearing the ENCLK bit, the user should retain the contents of bits 5:0 of the TRIM register. This can be done by reading the contents of the TRIM register (into the ACC for example), modifying bit 6, and writing this result back into the TRIM register. Alternatively, the "ANL direct" or "ORL direct" instructions can be used to clear or set bit 6 of the TRIM register.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****On-chip RC oscillator option**

The LPC932 has a 6-bit TRIM register that can be used to tune the frequency of the RC oscillator. During reset, the TRIM value is initialized to a factory pre-programmed value to adjust the oscillator frequency to 7.373 MHz, $\pm 2.5\%$. End user applications can write to the TRIM register to adjust the on-chip RC oscillator to other frequencies.

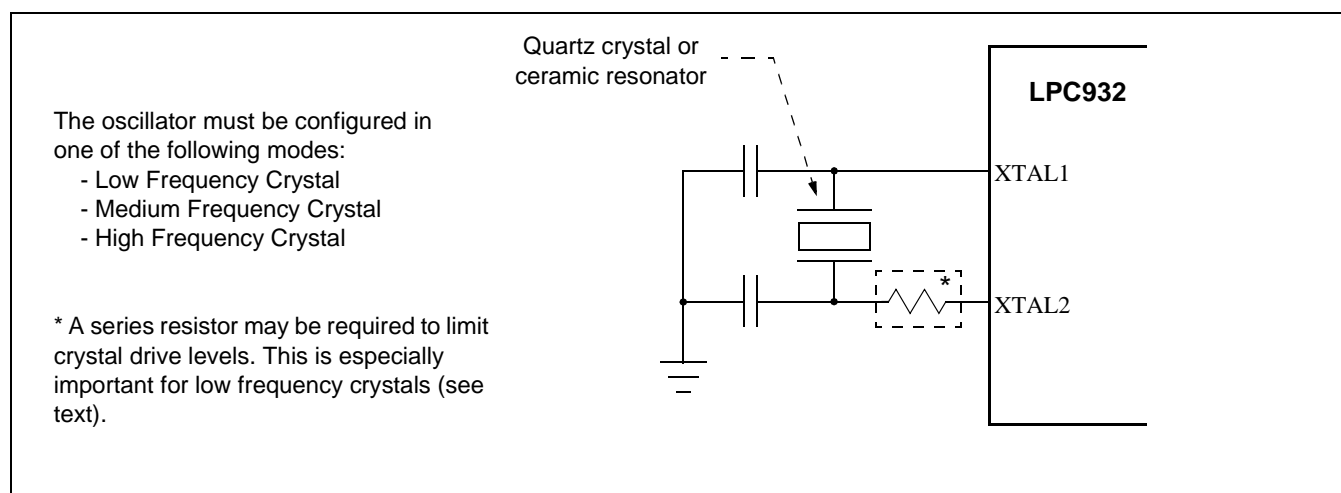
TRIM			7	6	5	4	3	2	1	0
Address: 96h			-	ENCLK	TRIM.5	TRIM.4	TRIM.3	TRIM.2	TRIM.1	TRIM.0
Not bit addressable										
Reset Source(s): Power-up only										
Reset Value: On power-up reset, ENCLK = 0, and TRIM.5-0 are loaded with the factory programmed value.										
BIT	SYMBOL	FUNCTION								
TRIM.7	-	Reserved.								
TRIM.6	ENCLK	When ENCLK =1, CCLK/ 2 is output on the XTAL2 pin (P3.0) provided that the crystal oscillator is not being used. When ENCLK=0, no clock output is enabled.								
TRIM.5-0		Trim value.								
Note: on reset, the TRIM SFR is initialized with a factory preprogrammed value. When setting or clearing the ENCLK bit, the user should retain the contents of bits 5:0 of the TRIM register. This can be done by reading the contents of the TRIM register (into the ACC for example), modifying bit 6, and writing this result back into the TRIM register. Alternatively, the "ANL direct" or "ORL direct" instructions can be used to clear or set bit 6 of the TRIM register.										

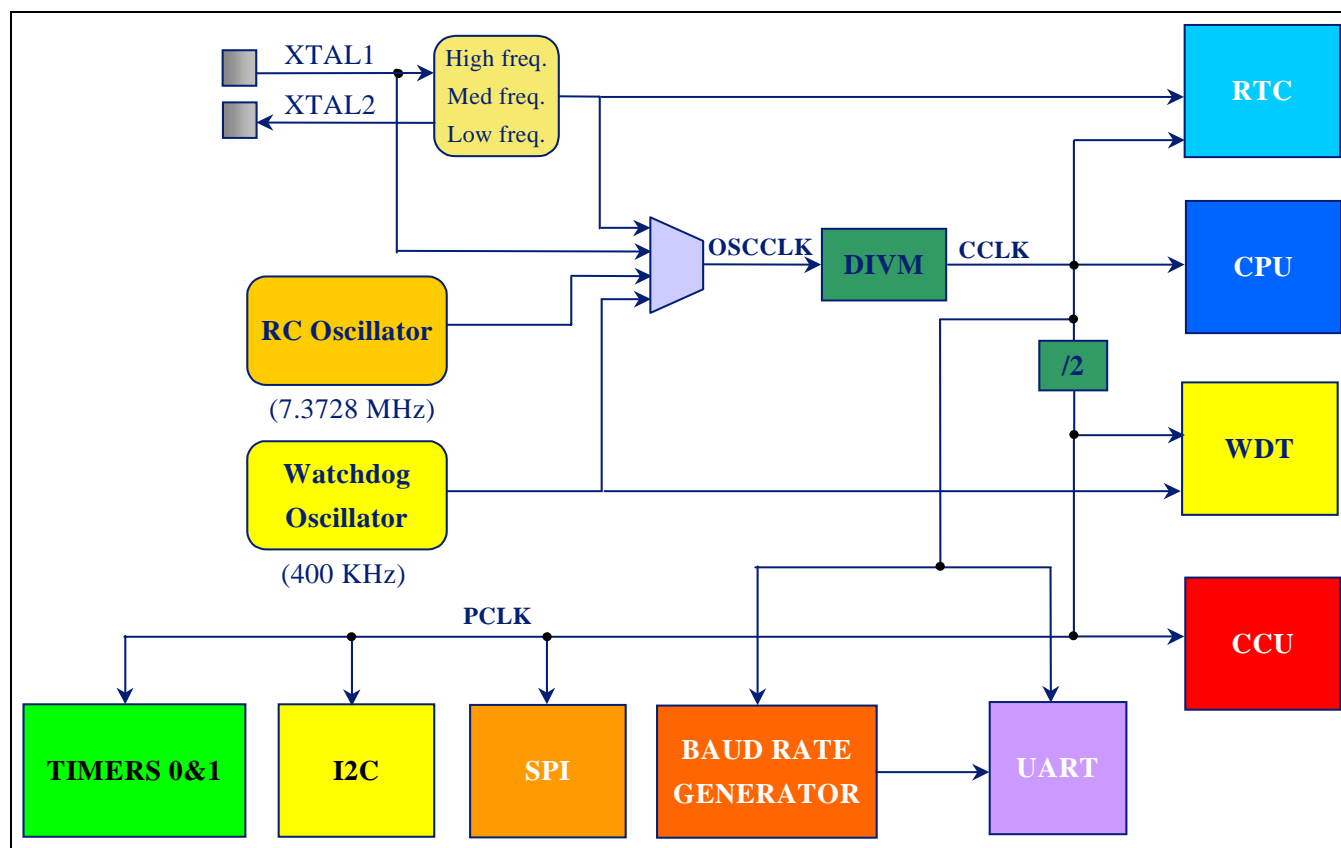
Figure 5: On-chip RC oscillator TRIM register**Watchdog oscillator option**

The watchdog has a separate oscillator which has a frequency of 400 kHz. This oscillator can be used to save power when a high clock frequency is not needed.

External clock input option

In this configuration, the processor clock is derived from an external source driving the XTAL1 / P3.1 pin. The rate may be from 0 Hz up to 12 MHz. The XTAL2 / P3.0 pin may be used as a standard port pin or a clock output.

**Figure 6: Using the crystal oscillator**

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Figure 7: Block diagram of oscillator control****Oscillator Clock (OSCCLK) wakeup delay**

The LPC932 has an internal wakeup timer that delays the clock until it stabilizes depending to the clock source used. If the clock source is any of the three crystal selections (low, medium or high frequencies) the delay is 992 OSCCLK cycles. If the clock source is either the internal RC oscillator, watchdog oscillator, or external clock, the delay is 224 OSCCLK cycles.

CPU Clock (CCLK) modification: DIVM register

The OSCCLK frequency can be divided down, by an integer, up to 256 times by configuring a dividing register, DIVM, to provide CCLK. This produces the CCLK frequency using the following formula:

$$\text{CCLK frequency} = f_{\text{OSC}} / (N+1)$$

Where: f_{OSC} is the frequency of OSCCLK

N is the value of DIVM.

Since N ranges in 0 - 255, the CCLK frequency can be in the range of f_{OSC} to $f_{\text{OSC}}/256$.

This feature makes it possible to temporarily run the CPU at a lower rate, reducing power consumption. By dividing the clock, the CPU can retain the ability to respond to events other than those that can cause interrupts (i.e. events that allow exiting the Idle mode) by executing its normal program at a lower rate. This can often result in lower power consumption than in Idle mode. This can allow bypassing the oscillator start-up time in cases where Power down mode would otherwise be used. The value of DIVM may be changed by the program at any time without interrupting code execution.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Low power select**

The LPC932 is designed to run at 12 MHz (CCLK) maximum. However, if CCLK is 8 MHz or slower, the CLKLP SFR bit (AUXR1.7) can be set to a '1' to lower the power consumption further. On any reset, CLKLP is '0' allowing highest performance. This bit can then be set in software if CCLK is running at 8 MHz or slower.

Memory organization

The LPC932 memory map is shown in Figure 8.

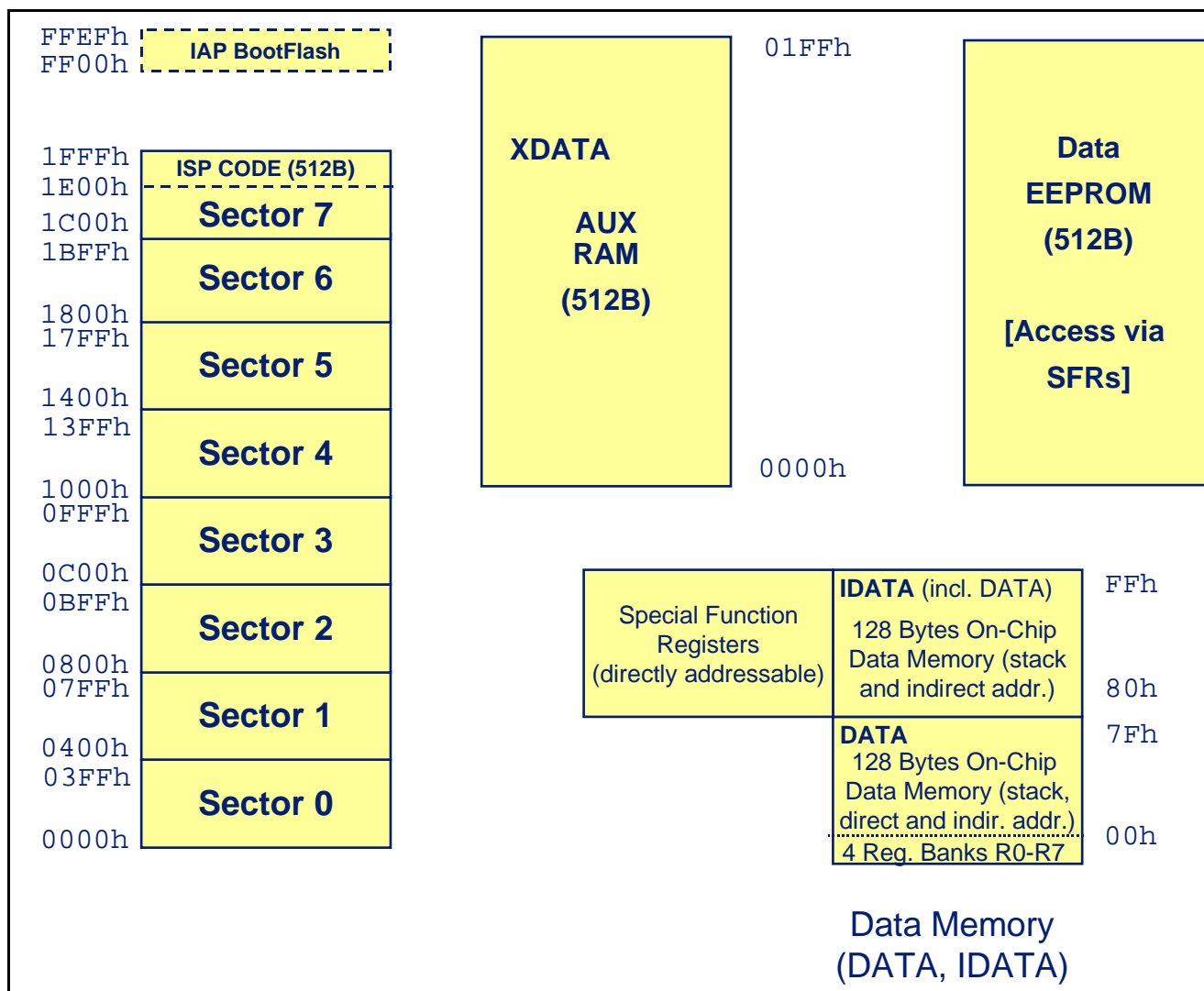


Figure 8: LPC932 memory map

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

The various LPC932 memory spaces are as follows:

DATA	128 bytes of internal data memory space (00h..7Fh) accessed via direct or indirect addressing, using instructions other than MOVX and MOVC. All or part of the Stack may be in this area.
IDATA	Indirect Data. 256 bytes of internal data memory space (00h:FFh) accessed via indirect addressing using instructions other than MOVX and MOVC. All or part of the Stack may be in this area. This area includes the DATA area and the 128 bytes immediately above it.
SFR	Special Function Registers. Selected CPU registers and peripheral control and status registers, accessible only via direct addressing.
XDATA	"External" Data or Auxiliary RAM. Duplicates the classic 80C51 64KB memory space addressed via the MOVX instruction using the DPTR, R0, or R1. All or part of this space could be implemented on-chip. The LPC932 has 512 bytes of on-chip XDATA memory.
CODE	64 KB of Code memory space, accessed as part of program execution and via the MOVC instruction. The LPC932 has 8 KB of on-chip Code memory.

The LPC932 also has 512 bytes of on-chip Data EEPROM that is accessed via SFRs (see section "Data EEPROM").

Data RAM arrangement

The 768 bytes of on-chip RAM is organized as follows:

Table 2: On-chip data memory usage.

Type	Data RAM	Size (Bytes)
DATA	Memory that can be addressed directly and indirectly	128
IDATA	Memory that can be addressed indirectly (includes DATA)	256
XDATA	Auxiliary ("External Data") on-chip memory that is accessed using the MOVX instructions	512

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Interrupts**

The LPC932 uses a four priority level interrupt structure. This allows great flexibility in controlling the handling of the LPC932's 15 interrupt sources.

Each interrupt source can be individually enabled or disabled by setting or clearing a bit in the interrupt enable registers IEN0 or IEN1. The IEN0 register also contains a global enable bit, EA, which enables all interrupts.

Each interrupt source can be individually programmed to one of four priority levels by setting or clearing bits in the interrupt priority registers IP0, IP0H, IP1, and IP1H. An interrupt service routine in progress can be interrupted by a higher priority interrupt, but not by another interrupt of the same or lower priority. The highest priority interrupt service cannot be interrupted by any other interrupt source. If two requests of different priority levels are received simultaneously, the request of higher priority level is serviced.

If requests of the same priority level are pending at the start of an instruction cycle, an internal polling sequence determines which request is serviced. This is called the arbitration ranking. Note that the arbitration ranking is only used for pending requests of the same priority level.

Table 4 summarizes the interrupt sources, flag bits, vector addresses, enable bits, priority bits, arbitration ranking, and whether each interrupt may wake up the CPU from a Power down mode.

Interrupt priority structure

There are four SFRs associated with the four interrupt levels: IP0, IP0H, IP1, IP1H. Every interrupt has two bits in IPx and IPxH (x = 0,1) and can therefore be assigned to one of four levels, as shown in Table 3.

Table 3: Interrupt priority level

Priority bits		Interrupt priority level
IPxH	IPx	
0	0	Level 0 (lowest priority)
0	1	Level 1
1	0	Level 2
1	1	Level 3 (highest priority)

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 4: Summary of interrupts**

Description	Interrupt flag bit(s)	Vector address	Interrupt enable bit(s)	Interrupt priority	Arbitration ranking	Power down wakeup
External Interrupt 0	IE0	0003h	EX0 (IEN0.0)	IP0H.0, IP0.0	1 (highest)	Yes
Timer 0 Interrupt	TF0	000Bh	ET0 (IEN0.1)	IP0H.1, IP0.1	4	No
External Interrupt 1	IE1	0013h	EX1 (IEN0.2)	IP0H.2, IP0.2	7	Yes
Timer 1 Interrupt	TF1	001Bh	ET1 (IEN0.3)	IP0H.3, IP0.3	10	No
Serial Port Tx and Rx ^{1,4}	TI & RI	0023h	ES/ESR (IEN0.4)	IP0H.4, IP0.4	13	No
Serial Port Rx ^{1,4}	RI					
Brownout Detect	BOF	002Bh	EBO (IEN0.5)	IP0H.5, IP0.5	2	Yes
Watchdog Timer/Real-time Clock	WDOVF/RTCF	0053h	EWDRT (IEN0.6)	IP0H.6, IP0.6	3	Yes
I ² C Interrupt	SI	0033h	EI2C (IEN1.0)	IP1H.0, IP1.0	5	No
KBI Interrupt	KBIF	003Bh	EKBI (IEN1.1)	IP1H.1, IP1.1	8	Yes
Comparators 1/2 interrupt	CMF1/CMF2	0043h	EC (IEN1.2)	IP1H.2, IP1.2	11	Yes
SPI interrupt	SPIF	004Bh	ESPI(IEN1.3)	IP1H.3, IP1.3	14	No
Capture/Compare Unit ²	See Note 2	005Bh	ECCU(IEN1.4)	IP1H.4, IP1.4	6	No
Reserved		0063h	(EN1.5)	IP1H.5, IP1.5	9	Yes
Serial Port Tx ³	TI	006Bh	EST (IEN1.6)	P1H.6, IP1.6	12	No
Data EEPROM write completed	EEPROM	0073h	EIEE(IEN1.7)	IP1H.7, IP1.7	15 (lowest)	No

1. SSTAT.5 = 0 selects combined Serial Port (UART) Tx and Rx interrupt; SSTAT.5 = 1 selects Serial Port Rx interrupt only (Tx interrupt will be different, see Note 3 below).

2. CCU interrupt has multiple sources. Any source in the TIFR2 SFR can cause a CCU interrupt.

3. This interrupt is used as Serial Port (UART) Tx interrupt if and only if SSTAT.5 = 1, and is disabled otherwise.

4. If SSTAT.0 = 1, the following Serial Port additional flag bits can cause this interrupt: FE, BR, OE

External Interrupt inputs

The LPC932 has two external interrupt inputs in addition to the Keypad Interrupt function. The two interrupt inputs are identical to those present on the standard 80C51 microcontrollers.

These external interrupts can be programmed to be level-triggered or edge-triggered by clearing or setting bit IT1 or IT0 in Register TCON. If ITn = 0, external interrupt n is triggered by a low level detected at the INTn pin. If ITn = 1, external interrupt n is edge triggered. In this mode if consecutive samples of the INTn pin show a high level in one cycle and a low level in the next cycle, interrupt request flag IEn in TCON is set, causing an interrupt request.

Since the external interrupt pins are sampled once each machine cycle, an input high or low level should be held for at least one machine cycle to ensure proper sampling. If the external interrupt is edge-triggered, the external source has to hold the request pin high for at least one machine cycle, and then hold it low for at least one machine cycle. This is to ensure that the transition is detected and that interrupt request flag IEn is set. IEn is automatically cleared by the CPU when the service routine is called.

If the external interrupt is level-triggered, the external source must hold the request active until the requested interrupt is generated. If the external interrupt is still asserted when the interrupt service routine is completed, another interrupt will be generated. It is not necessary to clear the interrupt flag IEn when the interrupt is level sensitive, it simply tracks the input pin level.

If an external interrupt is enabled when the LPC932 is put into Power down or Idle mode, the interrupt occurrence will cause the processor to wake up and resume operation. Refer to the section on Power Reduction Modes for details.

External Interrupt pin glitch suppression

Most of the LPC932 pins have glitch suppression circuits to reject short glitches (please refer to the 89LPC932 datasheet, AC Electrical Characteristics for glitch filter specifications). However, pins SDA/INT0/P1.3 and SCL/T0/P1.2 do not have the glitch suppression circuits. Therefore, INT1 has glitch suppression while INT0 does not.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM

P89LPC932

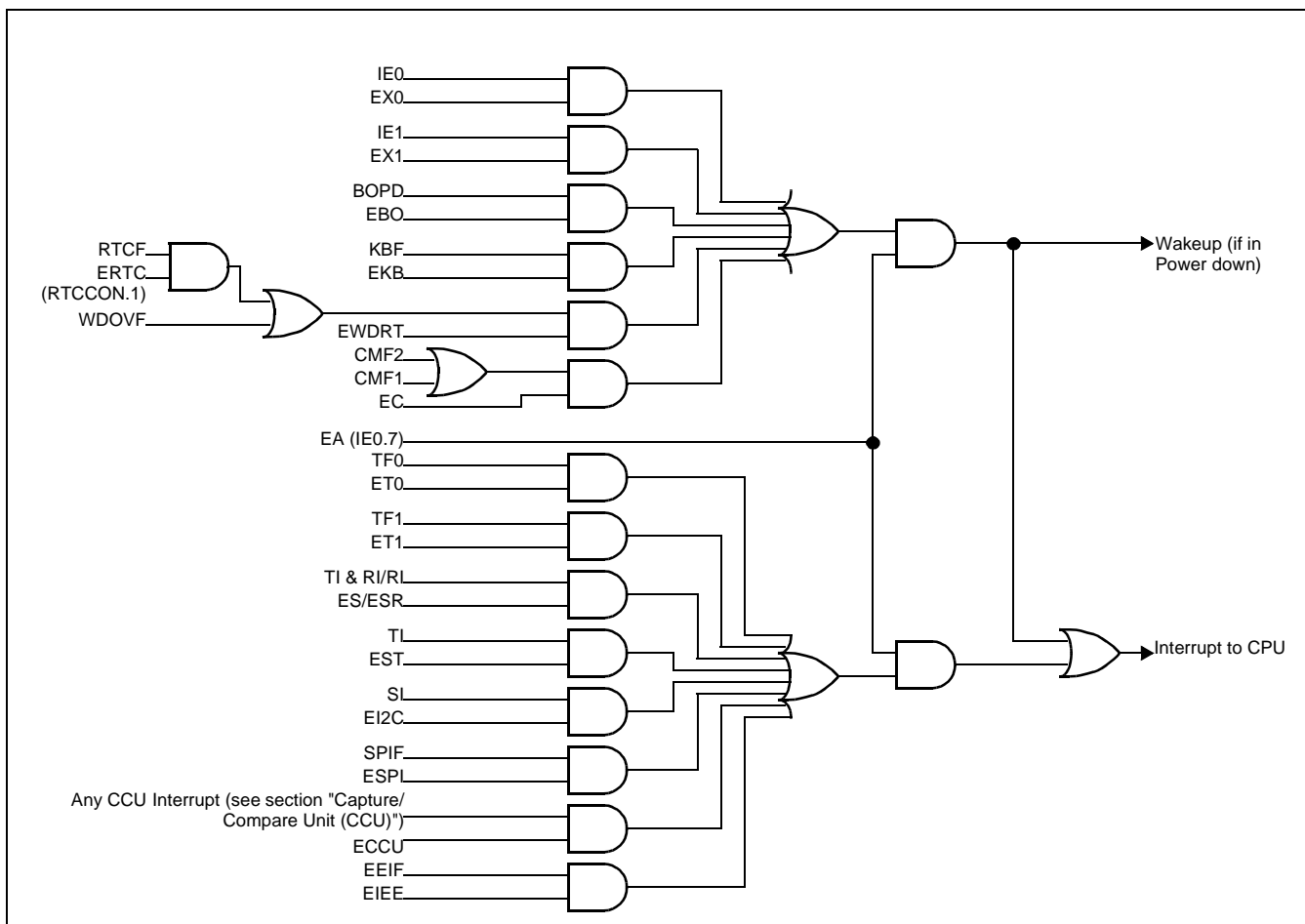


Figure 9: Interrupt sources, interrupt enables, and power down wake-up sources

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**I/O ports**

The LPC932 has 4 I/O ports: Port 0, Port 1, Port2, and Port 3. Ports 0, 1, and 2 are 8-bit ports and Port 3 is a 2-bit port. The exact number of I/O pins available depends upon the clock and reset options chosen (see Table 5).

Table 5: Number of I/O pins available.

Clock source	Reset option	Number of I/O pins
		28-pin package
On-chip oscillator or watchdog oscillator	No external reset (except during power-up)	26
	External $\overline{\text{RST}}$ pin supported	25
External clock input	No external reset (except during power-up)	25
	External $\overline{\text{RST}}$ pin supported	24
Low/medium/high speed oscillator (external crystal or resonator)	No external reset (except during power-up)	24
	External $\overline{\text{RST}}$ pin supported	23

Port configurations

All but three I/O port pins on the LPC932 may be configured by software to one of four types on a bit-by-bit basis, as shown in Table 6. These are: quasi-bidirectional (standard 80C51 port outputs), push-pull, open drain, and input-only. Two configuration registers for each port select the output type for each port pin.

P1.5 ($\overline{\text{RST}}$) can only be an input and cannot be configured.

P1.2 (SCL/T0) and P1.3 (SDA/ $\overline{\text{INT0}}$) may only be configured to be either input-only or open drain.

Table 6: Port output configuration settings

PxM1.y	PxM2.y	Port output mode
0	0	Quasi-bidirectional
0	1	Push-Pull
1	0	Input Only (High Impedance)
1	1	Open Drain

Quasi-bidirectional output configuration

Quasi-bidirectional outputs can be used both as an input and output without the need to reconfigure the port. This is possible because when the port outputs a logic high, it is weakly driven, allowing an external device to pull the pin low. When the pin is driven low, it is driven strongly and able to sink a large current. There are three pull-up transistors in the quasi-bidirectional output that serve different purposes.

One of these pull-ups, called the “very weak” pull-up, is turned on whenever the port latch for the pin contains a logic 1. This very weak pull-up sources a very small current that will pull the pin high if it is left floating.

A second pull-up, called the “weak” pull-up, is turned on when the port latch for the pin contains a logic 1 and the pin itself is also at a logic 1 level. This pull-up provides the primary source current for a quasi-bidirectional pin that is outputting a 1. If this pin is pulled low by an external device, the weak pull-up turns off, and only the very weak pull-up remains on. In order to pull the pin low under these conditions, the external device has to sink enough current to overpower the weak pull-up and pull the port pin below its input threshold voltage.

The third pull-up is referred to as the “strong” pull-up. This pull-up is used to speed up low-to-high transitions on a quasi-bidirectional port pin when the port latch changes from a logic 0 to a logic 1. When this occurs, the strong pull-up turns on for two CPU clocks quickly pulling the port pin high.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

The quasi-bidirectional port configuration is shown in Figure 10.

Although the LPC932 is a 3 V device most of the pins are 5 V-tolerant. If 5 V is applied to a pin configured in quasi-bidirectional mode, there will be a current flowing from the pin to V_{DD} causing extra power consumption. Therefore, applying 5 V to pins configured in quasi-bidirectional mode is discouraged.

A quasi-bidirectional port pin has a Schmitt-triggered input that also has a glitch suppression circuit.

(Please refer to the 89LPC932 datasheet, AC Electrical Characteristics for glitch filter specifications)

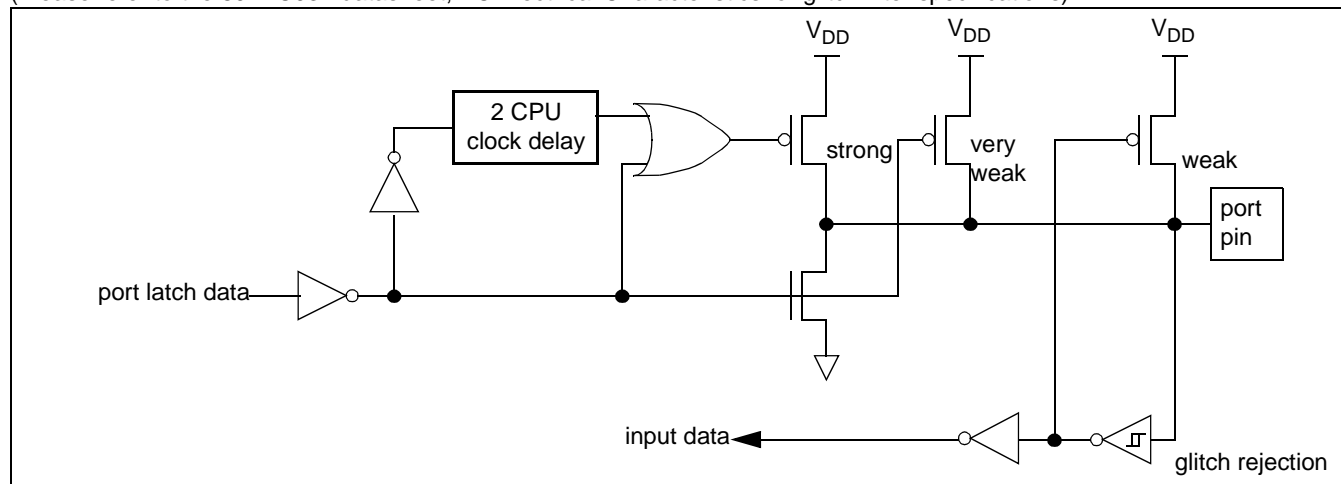


Figure 10: Quasi-bidirectional output

Open drain output configuration

The open drain output configuration turns off all pull-ups and only drives the pulldown transistor of the port pin when the port latch contains a logic 0. To be used as a logic output, a port configured in this manner must have an external pull-up, typically a resistor tied to V_{DD} . The pulldown for this mode is the same as for the quasi-bidirectional mode.

The open drain port configuration is shown in Figure 11.

An open drain port pin has a Schmitt-triggered input that also has a glitch suppression circuit.

Please refer to the 89LPC932 datasheet, AC Electrical Characteristics for glitch filter specifications).

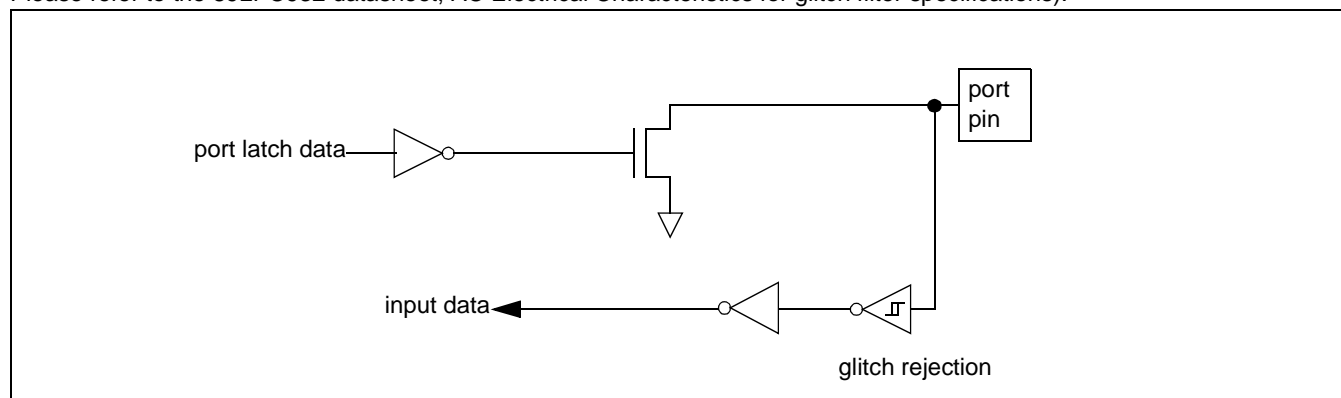
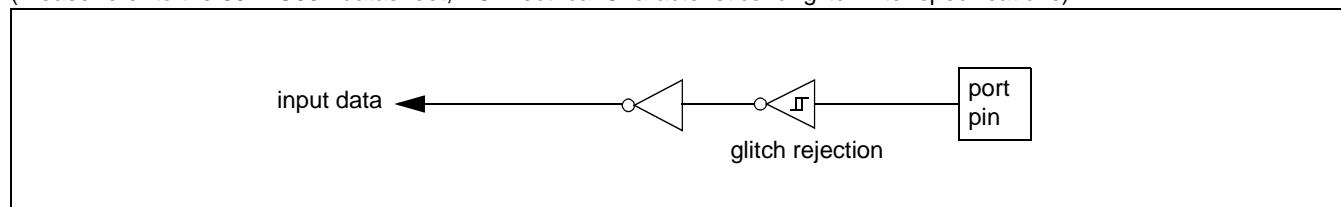


Figure 11: Open drain output

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Input-only configuration**

The input port configuration is shown in Figure 12. It is a Schmitt-triggered input that also has a glitch suppression circuit.

(Please refer to the 89LPC932 datasheet, AC Electrical Characteristics for glitch filter specifications)

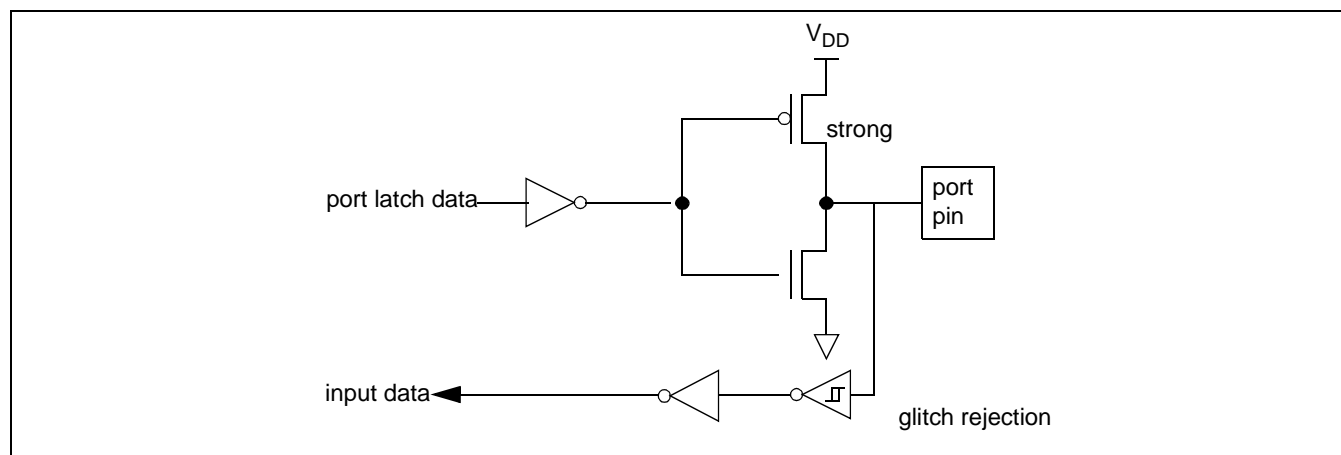
**Figure 12: Input -only****Push-pull output configuration**

The push-pull output configuration has the same pulldown structure as both the open drain and the quasi-bidirectional output modes, but provides a continuous strong pull-up when the port latch contains a logic 1. The push-pull mode may be used when more source current is needed from a port output.

The push-pull port configuration is shown in Figure 13.

A push-pull port pin has a Schmitt-triggered input that also has a glitch suppression circuit.

(Please refer to the 89LPC932 datasheet, AC Electrical Characteristics for glitch filter specifications)

**Figure 13: Push-pull output****Port 0 analog functions**

The LPC932 incorporates two Analog Comparators. In order to give the best analog performance and minimize power consumption, pins that are being used for analog functions must have both the digital outputs and digital inputs disabled.

Digital outputs are disabled by putting the port pins into the input-only mode as described in the Port Configurations section (see Table 6).

Digital inputs on Port 0 may be disabled through the use of the PT0AD register. Bits 1 through 5 in this register correspond to pins P0.1 through P0.5 of Port 0, respectively. Setting the corresponding bit in PT0AD disables that pin's digital input. Port bits that have their digital inputs disabled will be read as 0 by any instruction that accesses the port.

On any reset, PT0AD bits 1 through 5 default to '0's to enable the digital functions.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Table 7: Port output configuration**

Port pin	Configuration SFR bits		Alternate usage	Notes
	PxM1.y	PxM2.y		
P0.0	P0M1.0	P0M2.0	KBI0,CMP2	
P0.1	P0M1.1	P0M2.1	KBI1,CIN2B	Refer to section "Port 0 analog functions" for usage as analog inputs (CIN2B, CIN2A, CIN1B, CIN1A and CMPREF)
P0.2	P0M1.2	P0M2.2	KBI2,CIN2A	
P0.3	P0M1.3	P0M2.3	KBI3,CIN1B	
P0.4	P0M1.4	P0M2.4	KBI4,CIN1A	
P0.5	P0M1.5	P0M2.5	KBI5,CMPREF	
P0.6	P0M1.6	P0M2.6	KBI6,CMP1	
P0.7	P0M1.7	P0M2.7	KBI7,T1	
P1.0	P1M1.0	P1M2.0	TxD	
P1.1	P1M1.1	P1M2.1	RxD	
P1.2	P1M1.2	P1M2.2	T0,SCL	input-only or open-drain
P1.3	P1M1.3	P1M2.3	$\overline{\text{INT0}}$,SDA	input-only or open-drain
P1.4	P1M1.4	P1M2.4	$\overline{\text{INT1}}$	
P1.5	not configurable		$\overline{\text{RST}}$	Input only. Usage as general purpose input or $\overline{\text{RST}}$ is determined by User Configuration Bit RPD (UCFG1.6). Always a reset input during a power-on sequence.
P1.6	P1M1.6	P1M2.6	OCB	
P1.7	P1M1.7	P1M2.7	OCC	
P2.0	P2M1.0	P2M2.0	ICB	
P2.1	P2M1.1	P2M2.1	OCD	
P2.2	P2M1.2	P2M2.2	MOSI	
P2.3	P2M1.3	P2M2.3	MISO	
P2.4	P2M1.4	P2M2.4	$\overline{\text{SS}}$	
P2.5	P2M1.5	P2M2.5	SPICLK	
P2.6	P2M1.6	P2M2.6	OCA	
P2.7	P2M1.7	P2M2.7	ICA	
P3.0	P3M1.0	P3M2.0	XTAL2,CLKOUT	
P3.1	P3M1.1	P3M2.1	XTAL1	

Additional port features

After power-up, all pins are in Input-Only mode. **Please note that this is different from the LPC76x series of devices.**

- After power-up, all I/O pins except P1.5, may be configured by software.
- Pin P1.5 is input only. Pins P1.2 and P1.3 are configurable for either input-only or open drain.

Every output on the LPC932 has been designed to sink typical LED drive current. However, there is a maximum total output current for all ports which must not be exceeded. Please refer to the LPC932 Datasheet for detailed specifications.

All ports pins that can function as an output have slew rate controlled outputs to limit noise generated by quickly switching output signals. The slew rate is factory-set to approximately 10 ns rise and fall times.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Power monitoring functions**

The LPC932 incorporates power monitoring functions designed to prevent incorrect operation during initial power-on and power loss or reduction during operation. This is accomplished with two hardware functions: Power-on Detect and Brownout Detect.

Brownout Detection

The Brownout Detect function determines if the power supply voltage drops below a certain level. The default operation for a Brownout Detection is to cause a processor reset. However, it may alternatively be configured to generate an interrupt by setting the BOI (PCON.4) bit and the EBO (IEN0.5) bit.

Enabling and disabling of Brownout Detection is done via the BOPD (PCON.5) bit, bit field PMOD1-0 (PCON.1-0) and user configuration bit BOE (UCFG1.5). If BOE is in an unprogrammed state, brownout is disabled regardless of PMOD1-0 and BOPD. If BOE is in a programmed state, PMOD1-0 and BOPD will be used to determine whether Brownout Detect will be disabled or enabled. PMOD1-0 is used to select the power reduction mode. If PMOD1-0 = '11', the circuitry for the Brownout Detection is disabled for lowest power consumption. BOPD defaults to '0', indicating brownout detection is enabled on power-on if BOE is programmed.

If Brownout Detection is enabled, the operating voltage range for V_{DD} is 2.7 V-3.6 V, and the brownout condition occurs when V_{DD} falls below the Brownout trip voltage, V_{BO} (see D.C. Electrical Characteristics), and is negated when V_{DD} rises above V_{BO} . If Brownout Detection is disabled, the operating voltage range for V_{DD} is 2.4 V-3.6 V. If the LPC932 device is to operate with a power supply that can be below 2.7 V, BOE should be left in the unprogrammed state so that the device can operate at 2.4 V, otherwise continuous brownout reset may prevent the device from operating.

If Brownout Detect is enabled (BOE programmed, PMOD1-0 \neq '11', BOPD = 0), BOF (RSTSRC.5) will be set when a brownout is detected, regardless of whether a reset or an interrupt is enabled. BOF will stay set until it is cleared in software by writing '0' to the bit. Note that if BOE is unprogrammed, BOF is meaningless. If BOE is programmed, and a initial power-on occurs, BOF will be set in addition to the power-on flag (POF - RSTSRC.4).

For correct activation of Brownout Detect, certain V_{DD} rise and fall times must be observed. Please see the datasheet for specifications.

Table 8: Brownout options

BOE (UCFG1.5)	PMOD1-0 (PCON.1-0)	BOPD (PCON.5)	BOI (PCON.4)	EBO (IEN0.5)	EA (IEN0.7)	Description
0 (erased)	XX	X	X	X	X	Brownout disabled. V_{DD} operating range is 2.4 V-3.6 V.
1 (programmed)	11	X	X	X	X	
	\neq 11	1	X	X	X	Brownout disabled. V_{DD} operating range is 2.4 V-3.6 V. However, BOPD is default to '0' upon power-up.
		0	0	1	1	Brownout reset enabled. V_{DD} operating range is 2.7 V-3.6 V. Upon a brownout reset, BOF (RSTSRC.5) will be set to indicate the reset source. BOF can be cleared by writing '0' to the bit.
			1	1	1	Brownout interrupt enabled. V_{DD} operating range is 2.7 V-3.6 V. Upon a brownout interrupt, BOF (RSTSRC.5) will be set. BOF can be cleared by writing '0' to the bit.
				0	X	Both brownout reset and interrupt disabled. V_{DD} operating range is 2.4 V-3.6 V. However, BOF (RSTSRC.5) will be set when V_{DD} falls to the Brownout Detection trip point. BOF can be cleared by writing '0' to the bit.
				X	0	

Power-on Detection

The Power-On Detect has a function similar to the Brownout Detect, but is designed to work as power initially comes up, before the power supply voltage reaches a level where the Brownout Detect can function. The POF flag (RSTSRC.4) is set to indicate an initial power-on condition. The POF flag will remain set until cleared by software by writing '0' to the bit. Note that if BOE (UCFG1.5) is programmed, BOF (RSTSRC.5) will be set when POF is set. If BOE is unprogrammed, BOF is meaningless.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Power reduction modes**

The LPC932 supports three different power reduction modes as determined by SFR bits PCON.1-0 (see Table 9):

Table 9: Power reduction modes.

PMOD1 (PCON.1)	PMOD0 (PCON.0)	Description
0	0	Normal mode (default) - no power reduction.
0	1	Idle mode. The Idle mode leaves peripherals running in order to allow them to activate the processor when an interrupt is generated. Any enabled interrupt source or reset may terminate Idle mode.
1	0	<p>Power down mode: The Power down mode stops the oscillator in order to minimize power consumption. The LPC932 exits Power down mode via any reset, or certain interrupts - external pins $\overline{INT0}/\overline{INT1}$, brownout Interrupt, keyboard, Real-time Clock/System Timer), watchdog, and comparator trips. Waking up by reset is only enabled if the corresponding reset is enabled, and waking up by interrupt is only enabled if the corresponding interrupt is enabled and the EA SFR bit (IEN0.7) is set. In Power down mode the internal RC oscillator is disabled unless both the RC oscillator has been selected as the system clock AND the RTC is enabled. In Power down mode, the power supply voltage may be reduced to the RAM keep-alive voltage V_{RAM}. This retains the RAM contents at the point where Power down mode was entered. SFR contents are not guaranteed after V_{DD} has been lowered to V_{RAM}, therefore it is recommended to wake up the processor via Reset in this situation. V_{DD} must be raised to within the operating range before the Power down mode is exited. When the processor wakes up from Power down mode, it will start the oscillator immediately and begin execution when the oscillator is stable. Oscillator stability is determined by counting 1024 CPU clocks after start-up when one of the crystal oscillator configurations is used, or 256 clocks after start-up for the internal RC or external clock input configurations. Some chip functions continue to operate and draw power during Power down mode, increasing the total power used during Power down. These include:</p> <ul style="list-style-type: none"> • Brownout Detect • Watchdog Timer if WDCLK (WDCON.0) is '1'. • Comparators (Note: Comparators can be powered down separately with PCONA.5 set to '1' and comparators disabled); • Real-time Clock/System Timer (and the crystal oscillator circuitry if this block is using it, unless RTCPD, i.e., PCONA.7 is '1').
1	1	<p>Total power down mode: This is the same as Power down mode except that the Brownout Detection circuitry and the voltage comparators are also disabled to conserve additional power. Note that a brownout reset or interrupt will not occur. Voltage comparator interrupts and Brownout interrupt cannot be used as a wakeup source. The internal RC oscillator is disabled unless both the RC oscillator has been selected as the system clock AND the RTC is enabled. The following are the wakeup options supported:</p> <ul style="list-style-type: none"> • Watchdog Timer if WDCLK (WDCON.0) is '1'. Could generate Interrupt or Reset, either one can wake up the device • External interrupts $\overline{INT0}/\overline{INT1}$ • Keyboard Interrupt • Real-time Clock/System Timer (and the crystal oscillator circuitry if this block is using it, unless RTCPD, i.e., PCONA.7 is '1'). • Note: Using the internal RC-oscillator to clock the RTC during Power down may result in relatively high power consumption. Lower power consumption can be achieved by using an external low frequency clock when the Real-time Clock is running during Power down.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

PCON		7	6	5	4	3	2	1	0
Address: 87h		SMOD1	SMOD0	BOPD	BOI	GF1	GF0	PMOD1	PMOD0
Not bit addressable									
Reset Source(s): Any reset									
Reset Value: 00000000B									
BIT	SYMBOL	FUNCTION							
PCON.7	SMOD1	Double Baud Rate bit for the serial port (UART) when Timer 1 is used as the baud rate source. When 1, the Timer 1 overflow rate is supplied to the UART. When 0, the Timer 1 overflow rate is divided by two before being supplied to the UART. (See Figure 41)							
PCON.6	SMOD0	Framing Error Location: <ul style="list-style-type: none">- When 0, bit 7 of SCON is accessed as SM0 for the UART.- When 1, bit 7 of SCON is accessed as the framing error status (FE) for the UART. This bit also determines the location of the UART receiver interrupt RI (see description on RI in Figure 42).							
PCON.5	BOPD	Brownout Detect Power down. When 1, Brownout Detect is powered down and therefore disabled. When 0, Brownout Detect is enabled. (Note: BOPD must be '0' before any programming or erasing commands can be issued. Otherwise these commands will be aborted.)							
PCON.4	BOI	Brownout Detect Interrupt Enable. When 1, Brownout Detection will generate a interrupt . When 0, Brownout Detection will cause a reset.							
PCON.3	GF1	General Purpose Flag 1. May be read or written by user software, but has no effect on operation.							
PCON.2	GF0	General Purpose Flag 0. May be read or written by user software, but has no effect on operation.							
PCON.1-0	PMOD1-PMOD0	Power Reduction Mode (see section "Power reduction modes").							

Figure 14: Power Control register (PCON)

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

PCONA										
Address: B5H			7	6	5	4	3	2	1	0
Not bit addressable			RTCPD	DEEPD	VCPD	-	I2PD	SPPD	SPD	CCUPD
Reset Source(s): Any reset										
Reset Value: 0000000B										
BIT	SYMBOL	FUNCTION								
PCONA.7	RTCPD	Real-time Clock Power down: When '1', the internal clock to the Real-time Clock is disabled.								
PCONA.6	DEEPD	Data EEPROM Power down: When '1', the Data EEPROM is powered down. Note that in either Power down mode or Total Power down mode, the Data EEPROM will be powered down regardless of this bit.								
PCONA.5	VCPD	Analog Voltage Comparators Power down: When '1', the voltage comparators are powered down. User must disable the voltage comparators prior to setting this bit.								
PCONA.4	-	Not used. Reserved for future use.								
PCONA.3	I2PD	I ² C Power down: When '1', the internal clock to the I ² C is disabled. Note that in either Power down mode or Total Power down mode, the I ² C clock will be disabled regardless of this bit.								
PCONA.2	SPPD	SPI Power down: When '1', the internal clock to the SPI is disabled. Note that in either Power down mode or Total Power down mode, the SPI clock will be disabled regardless of this bit.								
PCONA.1	SPD	Serial Port (UART) Power down: When '1', the internal clock to the UART is disabled. Note that in either Power down mode or Total Power down mode, the UART clock will be disabled regardless of this bit.								
PCONA.0	CCUPD	Compare/Capture Unit (CCU) Power down: When '1', the internal clock to the CCU is disabled. Note that in either Power down mode or Total Power down mode, the CCU clock will be disabled regardless of this bit. (Note: This bit is overridden by the CCUDIS bit in FCFG1. If CCUDIS = 1, CCU is powered down.)								
NOTE: Brownout Detect Power down is located in PCON.5.										

Figure 15: Power Control register A (PCONA)

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Reset**

The P1.5/ $\overline{\text{RST}}$ pin can function as either an active low reset input or as a digital input, P1.5. The RPE (Reset Pin Enable) bit in UCFG1, when set to 1, enables the external reset input function on P1.5. When cleared, P1.5 may be used as an input pin.

NOTE: During a power-on sequence, The RPE selection is overridden and this pin will always function as a reset input. An external circuit connected to this pin should not hold this pin low during a Power-on sequence as this will keep the device in reset. After power-on this input will function either as an external reset input or as a digital input as defined by the RPE bit. Only a power-on reset will temporarily override the selection defined by RPE bit. Other sources of reset will not override the RPE bit.

Reset can be triggered from the following sources (see Figure 16):

- External reset pin (during power-on or if user configured via UCFG1);
- Power-on Detect;
- Brownout Detect;
- Watchdog Timer;
- Software reset;
- UART break detect reset.

For every reset source, there is a flag in the Reset Register, RSTSRC. The user can read this register to determine the most recent reset source. These flag bits can be cleared in software by writing a '0' to the corresponding bit. More than one flag bit may be set:

- During a power-on reset, both POF and BOF are set but the other flag bits are cleared.
- For any other reset, any previously set flag bits that have not been cleared will remain set.

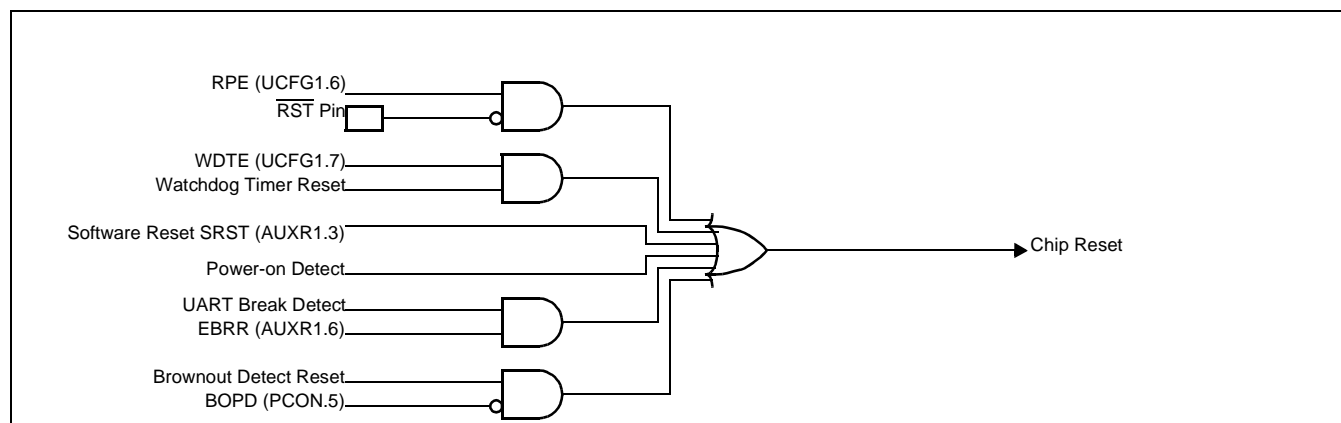


Figure 16: Block diagram of Reset

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

RSTSRC			7	6	5	4	3	2	1	0
Address: DFH			-	-	BOF	POF	R_BK	R_WD	R_SF	R_EX
Not bit addressable										
Reset Sources: Power-on only										
Reset Value: xx110000B (This is the power-on reset value. Other reset sources will set corresponding bits.)										
BIT	SYMBOL	FUNCTION								
RSTSRC.7-6	-	Reserved for future use. Should not be set to 1 by user programs.								
RSTSRC.5	BOF	Brownout Detect Flag. When Brownout Detect is activated, this bit is set. It will remain set until cleared by software by writing a '0' to the bit. (Note: On a Power-on reset, both POF and this bit will be set while the other flag bits are cleared.)								
RSTSRC.4	POF	Power-on Detect Flag. When Power-on Detect is activated, the POF flag is set to indicate an initial power-up condition. The POF flag will remain set until cleared by software by writing a '0' to the bit.. (Note: On a Power-on reset, both BOF and this bit will be set while the other flag bits are cleared.)								
RSTSRC.3	R_BK	Break detect reset. If a break detect occurs and EBRR (AUXR1.6) is set to '1', a system reset will occur. This bit is set to indicate that the system reset is caused by a break detect. Cleared by software by writing a '0' to the bit or on a Power-on reset.								
RSTSRC.2	R_WD	Watchdog Timer reset flag. Cleared by software by writing a '0' to the bit or a Power-on reset.(NOTE: UCFG1.7 must be = 1).								
RSTSRC.1	R_SF	Software reset Flag. Cleared by software by writing a '0' to the bit or a Power-on reset.								
RSTSRC.0	R_EX	External reset Flag. When this bit is '1', it indicates external pin reset. Cleared by software by writing a '0' to the bit or a Power-on reset. If \overline{RST} is still asserted after the Power-on reset is over, R_EX will be asserted.								

Figure 17: Reset Sources register**Reset vector**

- Following reset, the LPC932 will fetch instructions from either address 0000h or the Boot address. The Boot address is formed by using the Boot Vector as the high byte of the address and the low byte of the address =00h. The Boot address will be used if a UART break reset occurs or the non-volatile Boot Status bit (BOOTSTAT.0) = 1, or the device has been forced into ISP mode. Otherwise, instructions will be fetched from address 0000H.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Timers/Counters 0 and 1**

The LPC932 has two general-purpose counter/timers which are upward compatible with the 80C51 Timer 0 and Timer 1. Both can be configured to operate either as timers or event counters (see Figure 18). An option to automatically toggle the Tx pin upon timer overflow has been added.

In the "Timer" function, the register is incremented every PCLK.

In the "Counter" function, the register is incremented in response to a 1-to-0 transition on its corresponding external input pin (T0 or T1). The external input is sampled once during every machine cycle. When the pin is high during one cycle and low in the next cycle, the count is incremented. The new count value appears in the register during the cycle following the one in which the transition was detected. Since it takes 2 machine cycles (4 CPU clocks) to recognize a 1-to-0 transition, the maximum count rate is 1/4 of the CPU clock frequency. There are no restrictions on the duty cycle of the external input signal, but to ensure that a given level is sampled at least once before it changes, it should be held for at least one full machine cycle.

The "Timer" or "Counter" function is selected by control bits TnC/\bar{T} ($x = 0$ and 1 for Timers 0 and 1 respectively) in the Special Function Register TMOD. Timer 0 and Timer 1 have five operating modes (modes 0, 1, 2, 3 and 6), which are selected by bit-pairs ($TnM1$, $TnM0$) in TMOD and $TnM2$ in TAMOD. Modes 0, 1, 2 and 6 are the same for both Timers/Counters. Mode 3 is different. The operating modes are described later in this section.

TMOD		7	6	5	4	3	2	1	0
Address: 89h		T1GATE	T1C/ \bar{T}	T1M1	T1M0	T0GATE	T0C/ \bar{T}	T0M1	T0M0
Not bit addressable									
Reset Source(s): Any source									
Reset Value: 00000000B									
BIT	SYMBOL	FUNCTION							
TMOD.7	T1GATE	Gating control for Timer 1. When set, Timer/Counter is enabled only while the $\overline{INT1}$ pin is high and the TR1 control pin is set. When cleared, Timer 1 is enabled when the TR1 control bit is set.							
TMOD.6	T1C/ \bar{T}	Timer or Counter Selector for Timer 1. Cleared for Timer operation (input from CCLK). Set for Counter operation (input from T1 input pin).							
TMOD.5, 4	T1M1, T1M0	Mode Select for Timer 1. These bits are used with the T1M2 bit in the TAMOD register to determine the Timer 1 mode (see Figure 19).							
TMOD.3	T0GATE	Gating control for Timer 0. When set, Timer/Counter is enabled only while the $\overline{INT0}$ pin is high and the TR0 control pin is set. When cleared, Timer 0 is enabled when the TR0 control bit is set.							
TMOD.2	T0C/ \bar{T}	Timer or Counter Selector for Timer 0. Cleared for Timer operation (input from CCLK). Set for Counter operation (input from T0 input pin).							
TMOD.1, 0	T0M1, T0M0	Mode Select for Timer 0. These bits are used with the T0M2 bit in the TAMOD register to determine the Timer 0 mode (see Figure 19).							

Figure 18: Timer/Counter Mode Control register (TMOD)

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

TAMOD			7	6	5	4	3	2	1	0
Address: 8Fh			-	-	-	T1M2	-	-	-	T0M2
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: xxx0xxx0B										
BIT	SYMBOL	FUNCTION								
TAMOD.7-5	-	Reserved for future use. Should not be set to 1 by user programs.								
TAMOD.4	T1M2	Mode Select bit 2 for Timer 1. It is used with T1M1 and T1M0 in the TMOD register to determine Timer 1 mode.								
TAMOD.3-1	-	Reserved for future use. Should not be set to 1 by user programs.								
TAMOD.0	T0M2	Mode Select bit 2 for Timer 0. It is used with T0M1 and T0M0 in the TMOD register to determine Timer 0 mode.								
<u>TnM2-TnM0</u>		<u>Timer Mode</u>								
0 0 0		8048 Timer "TLn" serves as 5-bit prescaler.								
0 0 1		16-bit Timer/Counter "THn" and "TLn" are cascaded; there is no prescaler.								
0 1 0		8-bit auto-reload Timer/Counter. THn holds a value which is loaded into TLn when it overflows.								
0 1 1		Timer 0 is a dual 8-bit Timer/Counter in this mode. TL0 is an 8-bit Timer/Counter controlled by the standard Timer 0 control bits. TH0 is an 8-bit timer only, controlled by the Timer 1 control bits (see text). Timer 1 in this mode is stopped.								
1 0 0		Reserved. User must not configure to this mode.								
1 0 1		Reserved. User must not configure to this mode.								
1 1 0		PWM mode (see section "Mode 6").								
1 1 1		Reserved. User must not configure to this mode.								

Figure 19: Timer/Counter Auxiliary Mode Control register (TAMOD)**Mode 0**

Putting either Timer into Mode 0 makes it look like an 8048 Timer, which is an 8-bit Counter with a divide-by-32 prescaler. Figure 21 shows Mode 0 operation.

In this mode, the Timer register is configured as a 13-bit register. As the count rolls over from all 1s to all 0s, it sets the Timer interrupt flag TF_n. The count input is enabled to the Timer when TR_n = 1 and either TnGATE = 0 or INT_n = 1. (Setting TnGATE = 1 allows the Timer to be controlled by external input INT_n, to facilitate pulse width measurements). TR_n is a control bit in the Special Function Register TCON (Figure 20). The TnGATE bit is in the TMOD register.

The 13-bit register consists of all 8 bits of TH_n and the lower 5 bits of TL_n. The upper 3 bits of TL_n are indeterminate and should be ignored. Setting the run flag (TR_n) does not clear the registers.

Mode 0 operation is the same for Timer 0 and Timer 1. See Figure 21. There are two different GATE bits, one for Timer 1 (TMOD.7) and one for Timer 0 (TMOD.3).

Mode 1

Mode 1 is the same as Mode 0, except that all 16 bits of the timer register (TH_n and TL_n) are used. See Figure 22.

Mode 2

Mode 2 configures the Timer register as an 8-bit Counter (TL_n) with automatic reload, as shown in Figure 23. Overflow from TL_n not only sets TF_n, but also reloads TL_n with the contents of TH_n, which must be preset by software. The reload leaves TH_n unchanged. Mode 2 operation is the same for Timer 0 and Timer 1.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Mode 3**

When Timer 1 is in Mode 3 it is stopped. The effect is the same as setting TR1 = 0.

Timer 0 in Mode 3 establishes TL0 and TH0 as two separate 8-bit counters. The logic for Mode 3 on Timer 0 is shown in Figure 24. TL0 uses the Timer 0 control bits: T0C/T, T0GATE, TR0, INT0, and TF0. TH0 is locked into a timer function (counting machine cycles) and takes over the use of TR1 and TF1 from Timer 1. Thus, TH0 now controls the "Timer 1" interrupt.

Mode 3 is provided for applications that require an extra 8-bit timer. With Timer 0 in Mode 3, an LPC932 device can look like it has three Timer/Counters.

Note: When Timer 0 is in Mode 3, Timer 1 can be turned on and off by switching it into and out of its own Mode 3. It can still be used by the serial port as a baud rate generator, or in any application not requiring an interrupt.

Mode 6

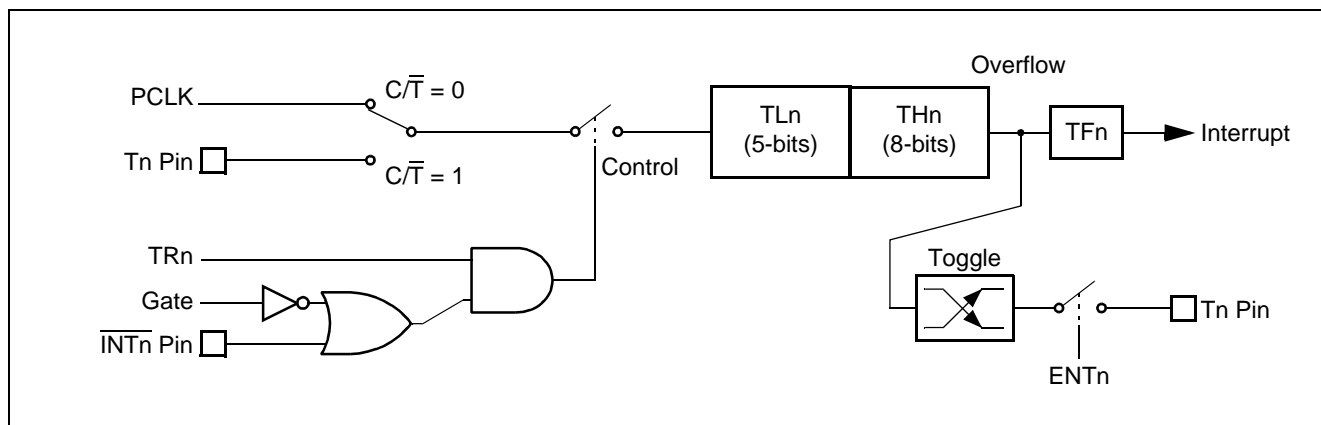
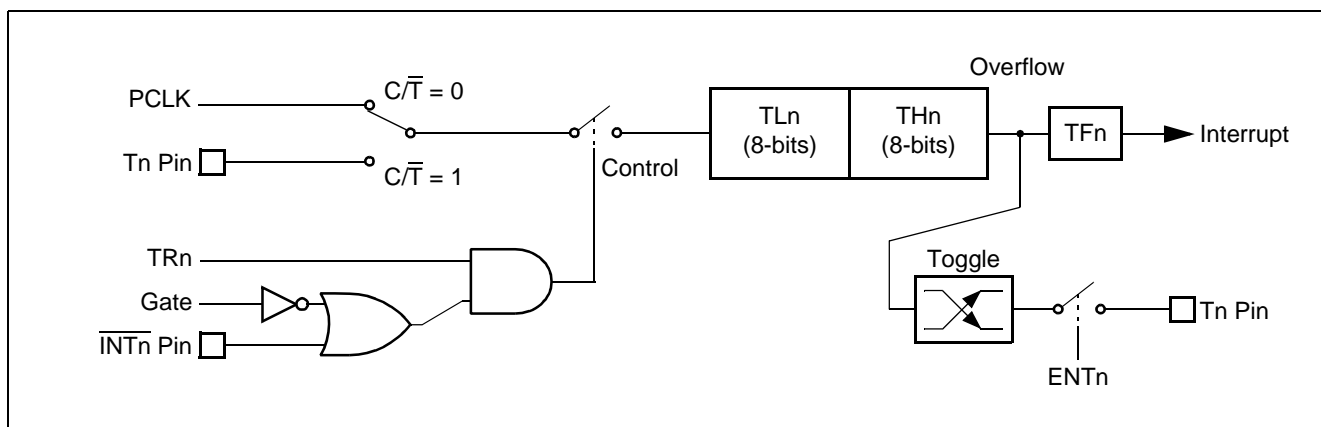
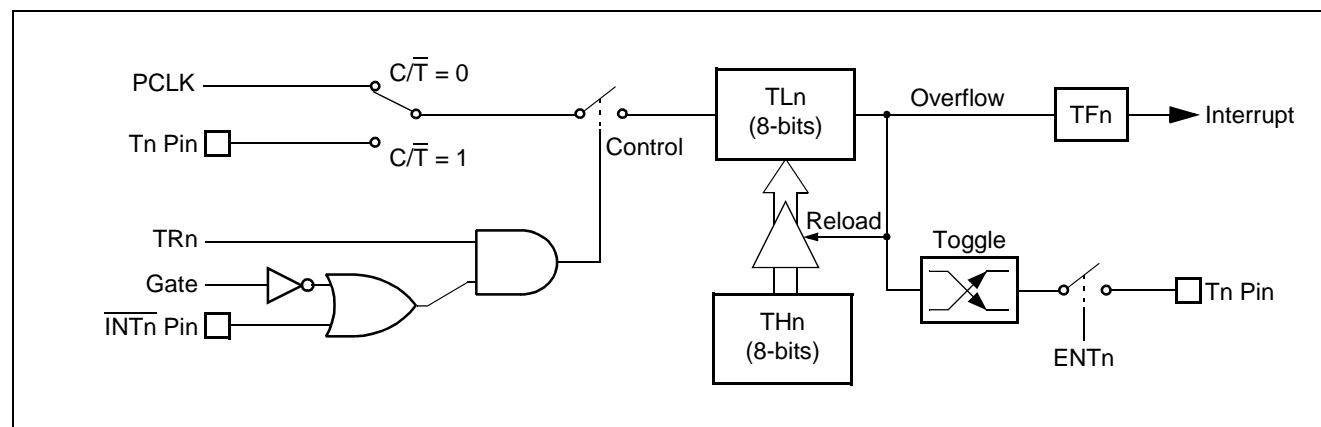
In this mode, the corresponding timer can be changed to a PWM with a full period of 256 timer clocks (see Figure 25). Its structure is similar to mode 2, except that:

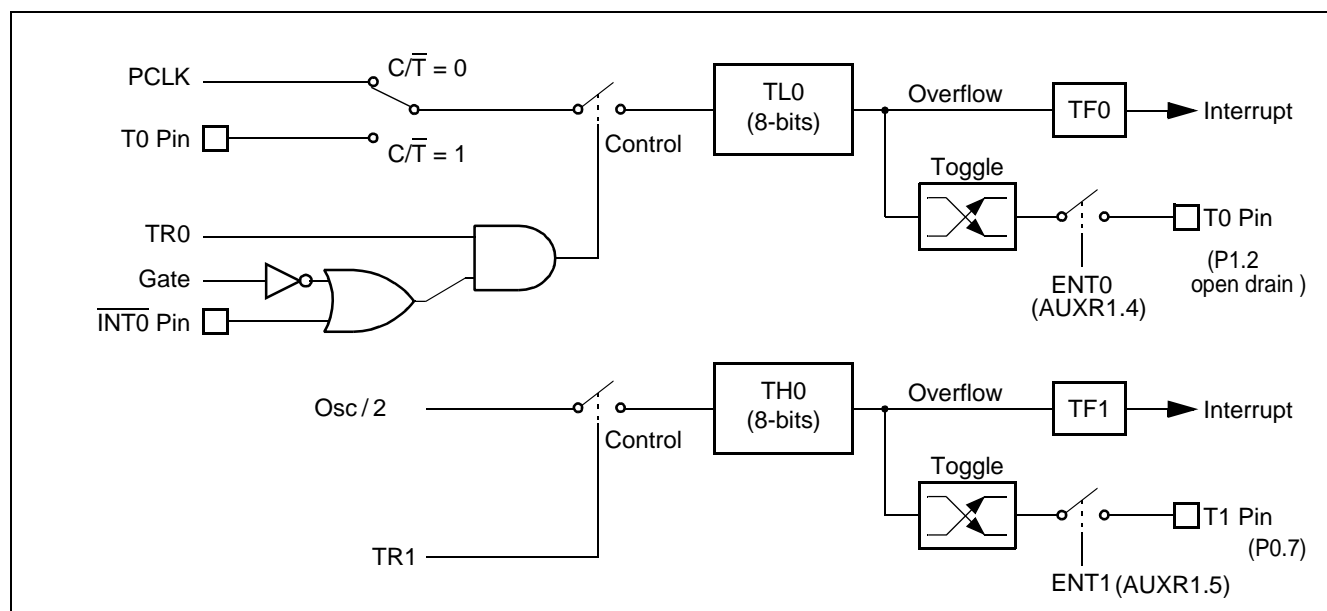
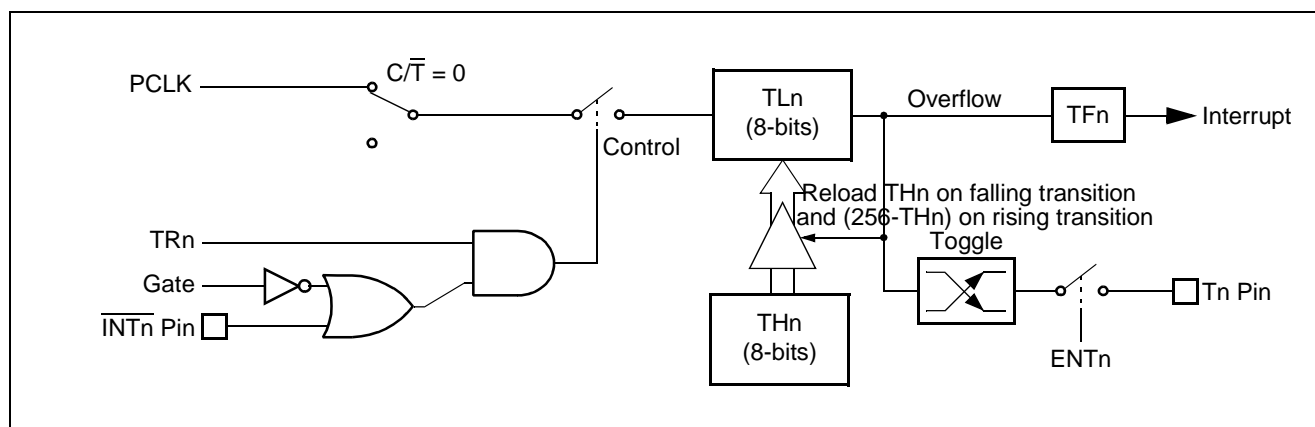
- TF_n (n = 0 and 1 for Timers 0 and 1 respectively) is set and cleared in hardware;
- The low period of the TF_n is in TH_n, and should be between 1 and 254, and;
- The high period of the TF_n is always 256-TH_n.
- Loading TH_n with 00h will force the Tx pin high, loading TH_n with FFh will force the Tx pin low.

Note that interrupt can still be enabled on the low to high transition of TF_n, and that TF_n can still be cleared in software like in any other modes.

TCON			7	6	5	4	3	2	1	0
Address: 88h			TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0
Bit addressable										
Reset Source(s): Any reset										
Reset Value: 0000000B										
BIT	SYMBOL	FUNCTION								
TCON.7	TF1	Timer 1 overflow flag. Set by hardware on Timer/Counter overflow. Cleared by hardware when the interrupt is processed, or by software (except in mode 6, see above, when it is cleared in hardware).								
TCON.6	TR1	Timer 1 Run control bit. Set/cleared by software to turn Timer/Counter 1 on/off.								
TCON.5	TF0	Timer 0 overflow flag. Set by hardware on Timer/Counter overflow. Cleared by hardware when the processor vectors to the interrupt routine, or by software. (except in mode 6, see above, when it is cleared in hardware)								
TCON.4	TR0	Timer 0 Run control bit. Set/cleared by software to turn Timer/Counter 0 on/off.								
TCON.3	IE1	Interrupt 1 Edge flag. Set by hardware when external interrupt 1 edge is detected. Cleared by hardware when the interrupt is processed, or by software.								
TCON.2	IT1	Interrupt 1 Type control bit. Set/cleared by software to specify falling edge/low level triggered external interrupts.								
TCON.1	IE0	Interrupt 0 Edge flag. Set by hardware when external interrupt 0 edge is detected. Cleared by hardware when the interrupt is processed, or by software.								
TCON.0	IT0	Interrupt 0 Type control bit. Set/cleared by software to specify falling edge/low level triggered external interrupts.								

Figure 20: Timer/Counter Control register (TCON)

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Figure 21: Timer/Counter 0 or 1 in Mode 0 (13-bit counter)****Figure 22: Timer/Counter 0 or 1 in Mode 1 (16-bit counter)****Figure 23: Timer/Counter 0 or 1 in Mode 2 (8-bit auto-reload)**

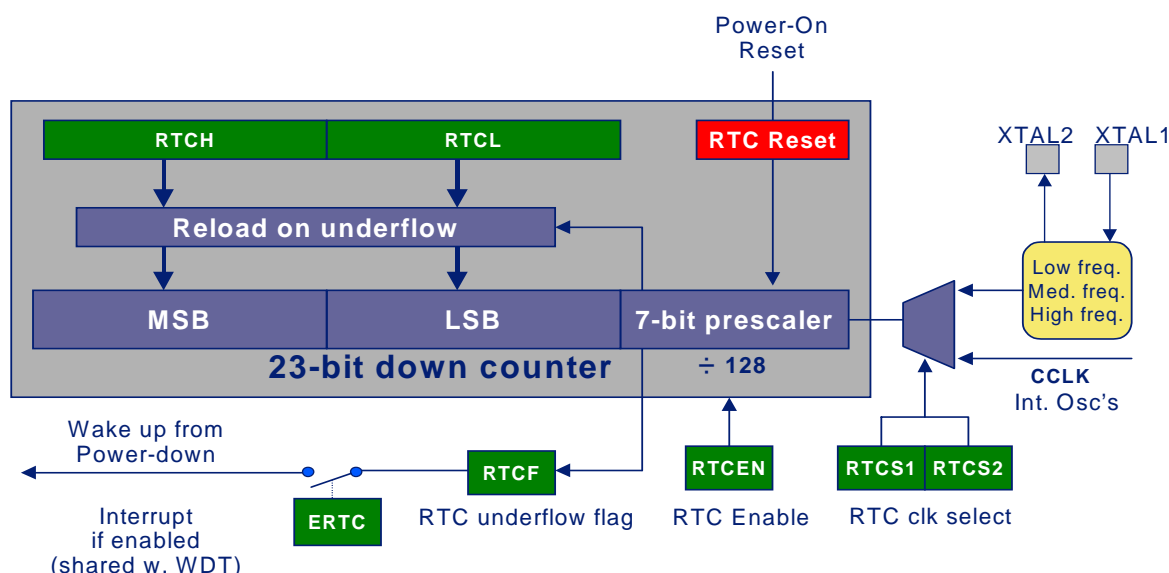
80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Figure 24: Timer/Counter 0 Mode 3 (two 8-bit counters)****Figure 25: Timer/Counter 0 or 1 in Mode 6 (PWM auto-reload)****Timer Overflow toggle output**

Timers 0 and 1 can be configured to automatically toggle a port output whenever a timer overflow occurs. The same device pins that are used for the T0 and T1 count inputs and PWM outputs are also used for the timer toggle outputs. This function is enabled by control bits ENT0 and ENT1 in the AUXR1 register, and apply to Timer 0 and Timer 1 respectively. The port outputs will be a logic 1 prior to the first timer overflow when this mode is turned on. In order for this mode to function, the C/\bar{T} bit must be cleared selecting PCLK as the clock source for the timer.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Real-time Clock/System Timer**

The LPC932 has a simple Real-time Clock/System Timer that allows a user to continue running an accurate timer while the rest of the device is powered down. The Real-time Clock can be an interrupt or a wake-up source (see Figure 9). The Real-time Clock is a 23-bit down counter. The clock source for this counter can be either the CPU clock (CCLK) or the XTAL1-2 oscillator, provided that the XTAL1-2 oscillator is not being used as the CPU clock. If the XTAL1-2 oscillator is used as the CPU clock, then the RTC will use CCLK as its clock source regardless of the state of the RTCS1:0 in the RTCCON register. There are three SFRs used for the RTC:

- RTCCON - Real-time Clock control.
- RTCH - Real-time Clock counter reload high (bits 22-15).
- RTCL - Real-time Clock counter reload low (bits 14-7).

**Figure 26:** Real-time Clock/System Timer block diagram

The Real-time Clock/System Timer can be enabled by setting the RTCEN (RTCCON.0) bit. The Real-time Clock is a 23-bit down counter (initialized to all 0's when RTCEN = 0) that is comprised of a 7-bit prescaler and a 16-bit loadable down counter. When RTCEN is written with '1', the counter is first loaded with (RTCH,RTCL,'1111111') and will count down. When it reaches all 0's, the counter will be reloaded again with (RTCH,RTCL,'1111111') and a flag - RTCF (RTCCON.7) - will be set.

Any write to RTCH and RTCL in-between the Real-time Clock reloading will not cause reloading of the counter. When the current count terminates, the contents of RTCH and RTCL will be loaded into the counter and the new count will begin. An immediate reload of the counter can be forced by clearing the RTCEN bit to '0' and then setting it back to '1'.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Real-time Clock source**

RTCS1-0 (RTCCON.6-5) are used to select the clock source for the RTC if either the Internal RC oscillator or the internal WD oscillator is used as the CPU clock. If the internal crystal oscillator or the external clock input on XTAL1 is used as the CPU clock, then the RTC will use CCLK as its clock source. .

Table 10: Real-time Clock/System Timer clock sources

RTCS1 (RTCCON.6)	RTCS0 (RTCCON.5)	FOSC2 (UCFG1.2)	FOSC1 (UCFG1.1)	FOSC0 (UCFG1.0)	RTC clock source	CPU clock source
x	x	0	0	0	CCLK	High frequency crystal
x	x	0	0	1	CCLK	Medium frequency crystal
x	x	0	1	0	CCLK	Low frequency crystal
0	0	0	1	1	High frequency crystal	Internal RC oscillator
0	1				Medium frequency crystal	
1	0				Low frequency crystal	
1	1				CCLK	
0	0	1	0	0	High frequency crystal	Watchdog oscillator
0	1				Medium frequency crystal	
1	0				Low frequency crystal	
1	1				CCLK	
x	x	1	0	1	undefined	undefined
x	x	1	1	0	undefined	undefined
x	x	1	1	1	CCLK	External clock input

Changing RTCS1-0

RTCS1-0 cannot be changed if the RTC is currently enabled (RTCCON.0 = 1). Setting RTCEN and updating RTCS1-0 may be done in a single write to RTCCON. However, if RTCEN = 1, this bit must first be cleared before updating RTCS1-0.

Real-time Clock interrupt/wake up

If ERTC (RTCCON.1), EWDRT (IEN1.0.6) and EA (IEN0.7) are set to '1', RTCF can be used as an interrupt source. This interrupt vector is shared with the watchdog timer. It can also be a source to wake up the device.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Reset sources affecting the Real-time Clock**

Only power-on reset will reset the Real-time Clock and its associated SFRs to their default state.

RTCCON		
Address: D1h		
Not bit addressable		
Reset Source(s): Power-up only		
Reset Value: 011xxx00B		
BIT	SYMBOL	FUNCTION
RTCCON.7	RTCF	Real-time Clock Flag. This bit is set to '1' when the 23-bit Real-time Clock reaches a count of '0'. It can be cleared in software.
RTCCON.6-5	RTCS1-0	Real-time Clock source select (see Table 10).
RTCCON.4-2	-	Reserved for future use. Should not be set to 1 by user programs.
RTCCON.1	ERTC	Real-time Clock interrupt enable. The Real-time Clock shares the same interrupt as the watchdog timer. Note that if the user configuration bit WDTE (UCFG1.7) is '0', the watchdog timer can be enabled to generate an interrupt. Users can read the RTCF (RTCCON.7) bit to determine whether the Real-time Clock caused the interrupt.
RTCCON.0	RTCEN	Real-time Clock enable. The Real-time Clock will be enabled if this bit is '1'. Note that this bit will not Power down the Real-time Clock. The RTCPD bit (PCONA.7) if set, will Power down and disable this block regardless of RTCEN.

Figure 27: RTCCON Register

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Capture/Compare Unit (CCU)**

This unit features:

- A 16-bit timer with 16-bit reload on overflow
- Selectable clock (CCUCLK), with a prescaler to divide the clock source by any integer between 1 and 1024.
- 4 Compare / PWM outputs with selectable polarity
- Symmetrical / Asymmetrical PWM selection
- 2 Capture inputs with event counter and digital noise rejection filter
- 7 interrupts with common interrupt vector (one Overflow, 2xCapture, 4xCompare),
- Safe 16-bit read/write via shadow registers.

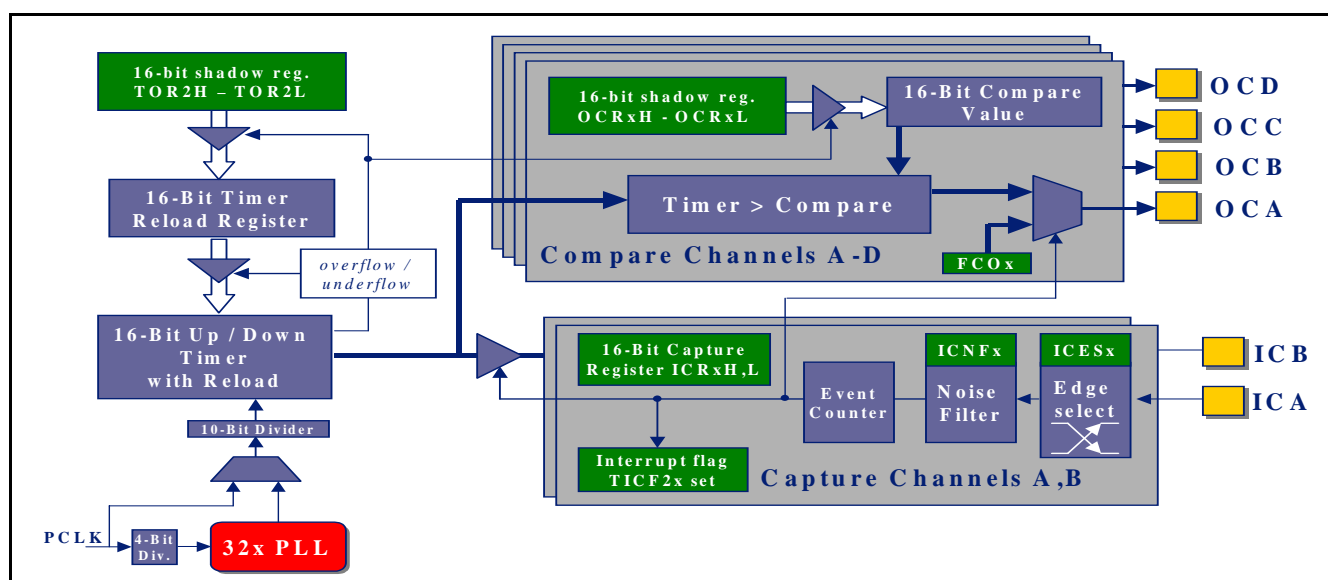


Figure 28: Capture Compare Unit block diagram

CCU Clock (CCUCLK)

The CCU runs on the CCUCLK, which can be either PCLK in basic timer mode or the output of a PLL (see Figure 28). The PLL is designed to use a clock source between 0.5 MHz to 1 MHz that is multiplied by 32 to produce a CCUCLK between 16 MHz and 32 MHz in PWM mode (asymmetrical or symmetrical). The PLL contains a 4-bit divider (PLLDV3:0 bits in the TCR21 register) to help divide PCLK into a frequency between 0.5 MHz and 1 MHz

CCU Clock prescaling

This CCUCLK can further be divided down by a prescaler. The prescaler is implemented as a 10-bit free-running counter with programmable reload at overflow. Writing a value to the prescaler will cause the prescaler to restart.

Basic timer operation

The Timer is a free-running up/down counter counting at the pace determined by the prescaler. The timer is started by setting the CCU Mode Select bits TMOD21 and TMOD20 in the CCU Control Register 0 (TCR20) as shown in the table in the TCR20 register description (Figure 30).

The CCU direction control bit, TDIR2, determines the direction of the count. TDIR2=0: Count up, TDIR2=1: Count down. If the timer counting direction is changed while the counter is running, the count sequence will be reversed in the CCUCLK cycle following the write of TDIR2. The timer can be written or read at any time and newly-written values will take effect when the prescaler overflows. The timer is accessible through two SFRs, TL2(low byte) and TH2(high byte). A third 16-bit SFR, TOR2H:TOR2L, determines the overflow reload value. TL2, TH2 and TOR2H, TOR2L will be 0 after a reset.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

Up-counting: When the timer contents are FFFFH, the next CCUCLK cycle will set the counter value to the contents of TOR2H:TOR2L.

Down-counting: When the timer contents are 0000H, the next CCUCLK cycle will set the counter value to the contents of TOR2H:TOR2L. During the CCUCLK cycle when the reload is performed, the CCU Timer Overflow Interrupt Flag (TOIF2) in the CCU Interrupt Flag Register (TIFR2) will be set, and, if the EA bit in the IEN0 register and ECCU bit in the IEN1 register (IEN1.4) are set, program execution will vector to the overflow interrupt. The user has to clear the interrupt flag in software by writing a logical '0' to it.

When writing to the reload registers, TOR2H and TOR2L, the values written are stored in two 8-bit shadow registers. In order to latch the contents of the shadow registers into TOR2H and TOR2L, the user must write a logical one to the CCU Timer Compare/Overflow Update bit TCOU2, in CCU Timer Control Register 1 (TCR21). The function of this bit depends on whether the timer is running in PWM mode or in basic timer mode. In basic timer mode, writing a one to TCOU2 will cause the values to be latched immediately and the value of TCOU2 will always read as zero. In PWM mode, writing a one to TCOU2 will cause the contents of the shadow registers to be updated on the next CCU Timer overflow. As long as the latch is pending, TCOU2 will read as one and will return to zero when the latching takes place. TCOU2 also controls the latching of the Output Compare registers OCR2A, OCR2B and OCR2C.

When writing to timer high byte, TH2, the value written is stored in a shadow register. When TL2 is written, the contents of TH2's shadow register is transferred to TH2 at the same time that TL2 gets updated. Thus, TH2 should be written prior to writing to TL2. If a write to TL2 is followed by another write to TL2, without TH2 being written in between, the value of TH2 will be transferred directly to the high byte of the timer.

If the 16-bitCCU Timer is to be used as an 8-bit timer, the user can write FFh (for upcounting) or 00h (for downcounting) to TH2. When TL2 is written, FFh:TH2 (for upcounting) and 00h (for downcounting) will be loaded to CCU Timer. The user will not need to rewrite TH2 again for an 8-bit timer operation unless there is a change in count direction.

When reading the timer, TL2 must be read first. When TL2 is read, the contents of the timer high byte are transferred to a shadow register in the same PCLK cycle as the read is performed. When TH2 is read, the contents of the shadow register are read instead. If a read from TL2 is followed by another read from TL2 without TH2 being read in between, the high byte of the timer will be transferred directly to TH2.

TPCR2H	
Address: CBH	7 6 5 4 3 2 1 0
Not bit addressable	- - - - - - TPCR2H.1 TPCR2H.0
Reset Source(s): Any reset	
Reset Value: xxxxxx00B	
TPCR2L	
Address: CAH	7 6 5 4 3 2 1 0
Not bit addressable	TPCR2L.7 TPCR2L.6 TPCR2L.5 TPCR2L.4 TPCR2L.3 TPCR2L.2 TPCR2L.1 TPCR2L.0

Figure 29: CCU Prescaler Control register

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**TCR20**

Address: C8h

Bit addressable

Reset Source(s): Any reset

Reset Value: 00000000B

7	6	5	4	3	2	1	0
PLLEN	HLTRN	HLTEN	ALTCD	ALTAB	TDIR2	TMOD21	TMOD20

BIT	SYMBOL	FUNCTION
TCR20.7	PLLEN	Phase Locked Loop Enable. When set to ,1 starts PLL operation. After the PLL is in lock this bit it will read back a one.
TCR20.6	HLTRN	PWM Halt. When set indicates a halt took place. In order to re-activate the PWM, the user must clear the HLTRN bit.
TCR20.5	HLTEN	PWM Halt Enable. When 1, a capture event as enabled for Input Capture A pin will immediately stop all activity on the PWM pins and set them to a predetermined state.
TCR20.4	ALTCD	PWM channel C/D alternately output enable. When this bit is set, the output of PWM channel C and D are alternately gated on every counter cycle.
TCR20.3	ALTAB	PWM channel A/B alternately output enable. When this bit is set, the output of PWM channel A and B are alternately gated on every counter cycle.
TCR20.2	TDIR2	Count direction of the CCU Timer. When 0, count up, when 1, count down.
TCR20.1-0	TMOD21 TMOD20	CCU Timer Mode Select.
	<u>TMOD21 ,TMOD20</u>	<u>CCU Timer Mode</u>
	00	Timer is stopped
	01	Basic timer function
	10	Asymmetrical PWM (uses PLL as clock source)
	11	Symmetrical PWM (uses PLL as clock source)

Figure 30: CCU Control register 0**Output compare**

The four output compare channels A, B, C and D are controlled through four 16-bit SFRs, OCRAH:OCRAL, OCRBH:OCRBL, OCRCH:OCRCL, OCRDH: OCRDL. Each output compare channel needs to be enabled in order to operate. The channel is enabled by selecting a Compare Output Action by setting the OCMx1:0 bits in the Capture Compare x Control Register – CCCRx (x=A, B, C, D). When a compare channel is enabled, the user will have to set the associated I/O pin to the desired output mode to connect the pin. (**Note:** The SFR bits for port pins P2.6, P1.6, P1.7, P2.1 must be set to '1' in order for the compare channel outputs to be visible at the port pins.) When the contents of TH2:TL2 match that of OCRxH:OCRxL, the Timer Output Compare Interrupt Flag - TOCFx is set in TIFR2. This happens in the CCUCLK cycle after the compare takes place. If EA and the Timer Output Compare Interrupt Enable bit – TOCIE2x (in TICR2 register), as well as ECCU bit in IEN1 are all set, the program counter will be vectored to the corresponding interrupt. The user must manually clear the bit by writing a '0' to it.

Two bits in OCCRx, the Output Compare x Mode bits OCMx1 and OCMx0 select what action is taken when a compare match occurs. Enabled compare actions take place even if the interrupt is disabled.

In order for a Compare Output Action to occur, the compare values must be within the counting range of the CCU timer.

When the compare channel is enabled, the I/O pin (which must be configured as an output) will be connected to an internal latch controlled by the compare logic. The value of this latch is zero from reset and can be changed by invoking a forced compare. A forced compare is generated by writing a '1' to the Force Compare x Output bit – FCOx bit in OCCRx. Writing a one to this bit generates a transition on the corresponding I/O pin as set up by OCMx1/OCMx0 without causing an interrupt. In basic timer operating mode the FCOx bits always read zero. (**Note:** This bit has a different function in PWM mode.) When an output compare

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

pin is enabled and connected to the compare latch, the state of the compare pin remains unchanged until a compare event or forced compare occurs.

CCCRx		
Address: CCCRA:EAh, CCCRB: EBh, CCCRC: ECh, CCCRD: EDh		
Not bit addressable		
Reset Source(s): Any reset	7	6
Reset Value: 00000000B	5	4
	3	2
	1	0
	ICECx2	ICECx1
	ICECx0	ICESx
	ICNFx	FCOx
	OCMx1	OCMx0
BIT	SYMBOL	FUNCTION
CCCRx.7	ICECx2	Capture Delay Setting Bit 2. Check Table 11 for details.
CCCRx.6	ICECx1	Capture Delay Setting Bit 1. Check Table 11 for details.
CCCRx.5	ICECx0	Capture Delay Setting Bit 0. Check Table 11 for details.
CCCRx.4	ICESx	Input Capture x Edge Select Bit. When 0: Negative edge triggers a capture, When 1: Positive edge triggers a capture.
CCCRx.3	ICNFx	Input Capture x Noise Filter Enable Bit. When 1, the capture logic needs to see four consecutive samples of the same value in order to recognize an edge as a capture event. The inputs are sampled every two CCLK periods regardless of the speed of the timer.
CCCRx.2	FCOx	Force Compare X Output Bit. When set, invoke a force compare.
CCCRx.1-0	OCMx1,OCMx0	Output Compare x Mode. See Table 12.

Figure 31: Capture Compare Control register

When the user writes to change the output compare value, the values written to OCRH2x and OCL2x are transferred to two 8-bit shadow registers. In order to latch the contents of the shadow registers into the capture compare register, the user must write a logical one to the CCU Timer Compare/Overflow Update bit TCOU2, in the CCU Control Register 1 - TCR21. The function of this bit depends on whether the timer is running in PWM mode or in basic timer mode. In basic timer mode, writing a one to TCOU2 will cause the values to be latched immediately and the value of TCOU2 will always read as zero. In PWM mode, writing a one to TCOU2 will cause the contents of the shadow registers to be updated on the next CCU Timer overflow. As long as the latch is pending, TCOU2 will read as one and will return to zero when the latch takes place. TCOU2 also controls the latching of all the Output Compare registers as well as the Timer Overflow Reload registers - TOR2.

Input capture

Input capture is always enabled. Each time a capture event occurs on one of the two input capture pins, the contents of the timer is transferred to the corresponding 16-bit input capture register ICRAH:ICRAL or ICRBH:ICRBL. The capture event is defined by the Input Capture Edge Select – ICESx bit (x being A or B) in the CCCRx register. The user will have to configure the associated I/O pin as an input in order for an external event to trigger a capture.

A simple noise filter can be enabled on the input capture input. When the Input Capture Noise Filter ICNFx bit is set, the capture logic needs to see four consecutive samples of the same value in order to recognize an edge as a capture event. The inputs are sampled every two CCLK periods regardless of the speed of the timer.

An event counter can be set to delay a capture by a number of capture events. The three bits ICECx2, ICECx1 and ICECx0 in the CCCRx register determine the number of edges the capture logic has to see before an input capture occurs.

When a capture event is detected, the Timer Input Capture x (x is A or B) Interrupt Flag – TIFC2x (TIFR2.1 or TIFR2.0) is set. If EA and the Timer Input Capture x Enable bit – TICIE2x (TICR2.1 or TICR2.0) is set as well as the ECCU (IEN1.4) bit is set, the program counter will be vectored to the corresponding interrupt. The interrupt flag must be cleared manually by writing a '0' to it.

When reading the input capture register, ICRxL must be read first. When ICRxL is read, the contents of the capture register high byte are transferred to a shadow register. When ICRxH is read, the contents of the shadow register are read instead. (If a read from ICRxL is followed by another read from ICRxL without ICRxH being read in between, the new value of the capture register high byte (from the last ICRxL read) will be in the shadow register.)

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Table 11: Event delay counter for input capture**

ICECx2 (CCCRx.7)	ICECx1 (CCCRx.6)	ICECx0 (CCCRx.5)	Delay (numbers of edges)
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	7
1	1	1	15

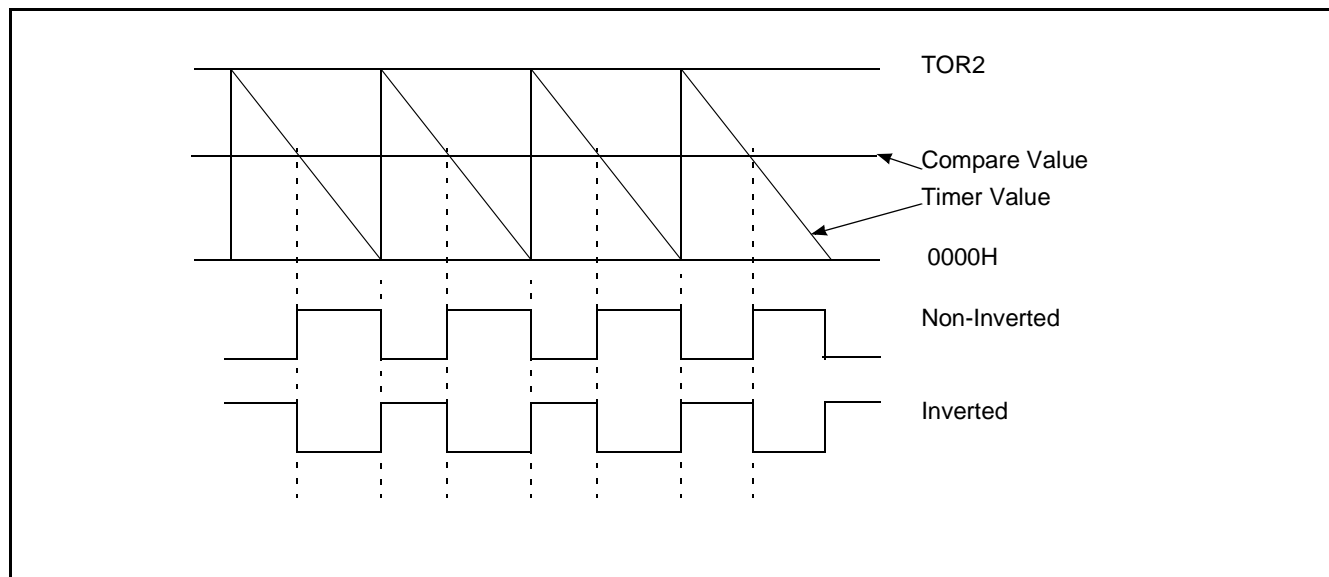
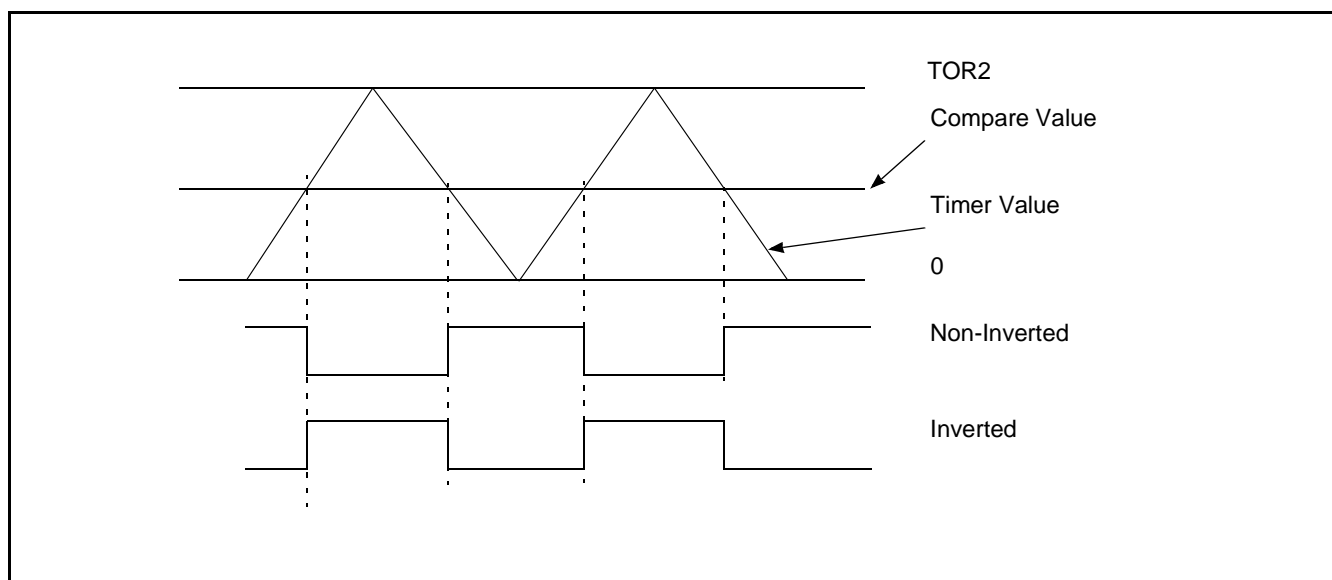
PWM operation

PWM Operation has two main modes, asymmetrical and symmetrical. These modes of timer operation are selected by writing 10H or 11H to TMOD21:TMOD20 as shown in section "Basic timer operation".

In asymmetrical PWM operation, the CCU Timer operates in downcounting mode regardless of the setting of TDIR2. In this case, TDIR2 will always read 1.

In symmetrical mode, the timer counts up/down alternately and the value of TDIR2 has no effect. The main difference from basic timer operation is the operation of the compare module, which in PWM mode is used for PWM waveform generation. Table 12 shows the behavior of the compare pins in PWM mode.

The user will have to configure the output compare pins as outputs in order to enable the PWM output. As with basic timer operation, when the PWM (compare) pins are connected to the compare logic, their logic state remains unchanged. However, since the bit FCO is used to hold the halt value, only a compare event can change the state of the pin.

**Figure 32: Asymmetrical PWM, downcounting****Figure 33: Symmetrical PWM**

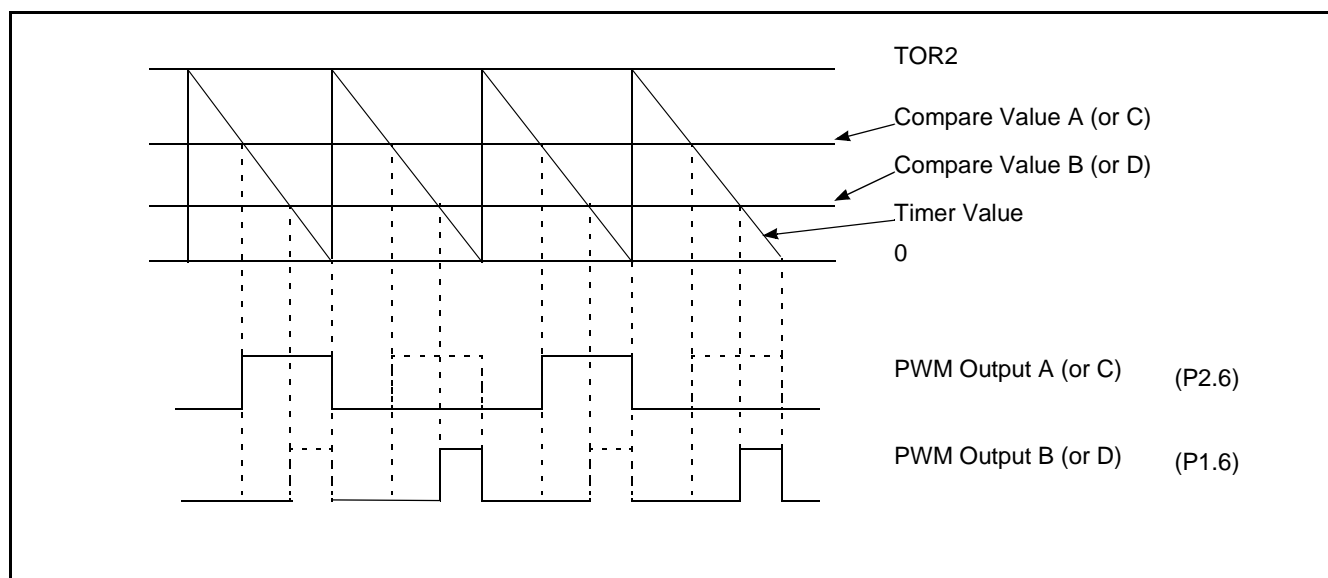
The CCU Timer Overflow interrupt flag is set when the counter changes direction at the top. For example, if TOR contains 01FFH, CCU Timer will count: ...01FEH, 01FFH, 01FEH,... The flag is set in the counter cycle after the change from TOR to TOR-1.

When the timer changes direction at the bottom, in this example, it counts ...,0001H, 0000H, 0001H,... The CCU Timer overflow interrupt flag is set in the counter CCUCLK cycle after the transition from 0001H to 0000H.

The status of the TDIR2 bit in TCR20 reflects the current counting direction. Writing to this bit while operating in symmetrical mode has no effect.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Alternating Output Mode**

In asymmetrical mode, the user can program PWM channels A/B and C/D as alternating pairs for bridge drive control. By setting ALTAB or ALTCD bits in TCR20, the output of these PWM channels are alternately gated on every counter cycle. This is shown in the following figure:

**Figure 34: Alternate Output Mode****Table 12: Output Compare Pin Behavior**

OCMx1 ¹ (CCCRx.1)	OCMx0 ¹ (CCCRx.0)	Output Compare pin behavior		
		Basic timer mode	Asymmetrical PWM	Symmetrical PWM
0	0	Output compare disabled. On power-on, this is the default state, and pins are configured as inputs.		
0	1	Set when compare in operation. Cleared on ² compare match.	Non-Inverted PWM. Set on ² compare match. Cleared on ² CCU Timer underflow.	Non-Inverted PWM. Cleared on ² compare match, upcounting. Set on ² compare match, downcounting.
1	0		Inverted PWM. Cleared on ² compare match. Set on ² CCU Timer underflow.	Inverted PWM. Set on ² compare match, upcounting. Cleared on ² compare match, downcounting.
1	1			

Note:
1. x = A, B, C, D
2. In this table, "on" means in the CCUCLK cycle after the event takes place.

Synchronized PWM register update

When the OCRx registers are written, a built in mechanism ensures that the value is not updated in the middle of a PWM pulse. This could result in an odd-length pulse. When the registers are written, the values are placed in two shadow registers, as is the case in basic timer operation mode. Writing to TCOU2 will cause the contents of the shadow registers to be updated on the next CCU Timer overflow. If OCRxH and/or OCRxL are read before the value is updated, the most currently written value is read.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Halt**

Setting the HLTEN bit in TCR20 enables the PWM Halt Function. When halt function is enabled, a capture event as enabled for the Input Capture A pin will immediately stop all activity on the PWM pins and set them to a predetermined state defined by FCOx bit. In PWM Mode, the FCOx bits in the CCCRx register hold the value the pin is forced to during halt. The value of the setting can be read back. The capture function and the interrupt will still operate as normal even if it has this added functionality enabled. When the PWM unit is halted, the timer will still run as normal. The HLTRN bit in TCR20 will be set to indicate that a halt took place. In order to re-activate the PWM, the user must clear the HLTRN bit. The user can force the PWM unit into halt by writing a logical one to HLTRN bit.

PLL operation

The PWM module features a Phase Locked Loop that can be used to generate a CCUCLK frequency between 16 MHz and 32 MHz. At this frequency the PWM module provides ultrasonic PWM frequency with 10-bit resolution provided that the crystal frequency is 1 MHz or higher (The PWM resolution is programmable up to 16 bits by writing to TOR2H:TOR2L). The PLL is fed an input signal of 0.5 - 1 MHz and generates an output signal of 32 times the input frequency. This signal is used to clock the timer. The user will have to set a divider that scales PCLK by a factor of 1-16. This divider is found in the SFR register TCR21. The PLL frequency can be expressed as follows:

$$\text{PLL frequency} = \text{PCLK} / (N+1)$$

Where: N is the value of PLLDV3:0.

Since N ranges in 0 - 15, the CCLK frequency can be in the range of PCLK to PCLK/16.

TCR21

Address: F9H

Not bit addressable

Reset Source(s): Any reset

Reset Value: 0xxx0000B

7

6

5

4

3

2

1

0

TCOU2	-	-	-	PLLDV.3	PLLDV.2	PLLDV.1	PLLDV.0
-------	---	---	---	---------	---------	---------	---------

BIT	SYMBOL	FUNCTION
TCR21.7	TCOU2	In basic timer mode, writing a '1' to TCOU2 will cause the values to be latched immediately and the value of TCOU2 will always read as '0'. In PWM mode, writing a '1' to TCOU2 will cause the contents of the shadow registers to be updated on the next CCU Timer overflow. As long as the latch is pending, TCOU2 will read as '1' and will return to '0' when the latching takes place. TCOU2 also controls the latching of the Output Compare registers OCRAx, OCRBx and OCRCx
TCR21.6-4	-	Reserved for future use. Should not be set to '1' by user program.
TCR21.3-0	PLLDV.3-0	PLL frequency divider.

Figure 35: CCU Control register 1

Setting the PLEN bit in TCR20 starts the PLL. When PLEN is set, it will not read back a one until the PLL is in lock. At this time, the PWM unit is ready to operate and the timer can be enabled. The following start-up sequence is recommended.

1. Set up the PWM module without starting the timer.
2. Calculate the right division factor so that the PLL receives an input clock signal of 500 kHz - 1 MHz. Write this value to PLLDV.
3. Set PLEN. Wait until the bit reads one.
4. Start the timer by writing a value to bits TMOD21, TMOD20.

When the timer runs from the PLL, the timer operates asynchronously to the rest of the microcontroller. Some restrictions apply:

- The user is discouraged from writing or reading the timer in asynchronous mode. The results may be unpredictable.
- Interrupts and flags are asynchronous. There will be delay as the event may not actually be recognized until some CCLK cycles later (for interrupts and reads).

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**CCU interrupt structure**

There are seven independent sources of interrupts in the CCU: timer overflow, captured input events on Input Capture blocks A/B, and compare match events on Output Compare blocks A through D. One common interrupt vector is used for the CCU service routine and interrupts can occur simultaneously in system usage. To resolve this situation, a priority encode function of the seven interrupt bits in TIFR2 SFR is implemented (after each bit is AND-ed with the corresponding interrupt enable bit in the TICR2 register). The order of priority is fixed as follows, from highest to lowest:

TOIF2
 TICF2A
 TICF2B
 TOCF2A
 TOCF2B
 TOCF2C
 TOCF2D

When any of the interrupt flags are set in the TIFR2 register, the three bits of output of the priority encoder (see Figure 36) will be available in CCU Timer Interrupt Status Encode (TISE2) register. Note that in order to generate an interrupt, the interrupt enable for the specific source, the CCU global interrupt enable bit (ECCU), and the global interrupt enable bit (EA), all need to be set,

An interrupt service routine for the CCU can be as follows:

1. Read the priority-encoded value from the TISE2 register to determine the interrupt source to be handled.
2. After the current (highest priority) event is serviced, write a '0' to the corresponding interrupt flag bit in the TIFR2 register to clear the flag.
3. Read the TISE2 register. If the priority-encoded interrupt source is '000', all CCU interrupts are serviced and a return from interrupt can occur. Otherwise, return to step 2 for the next interrupt.

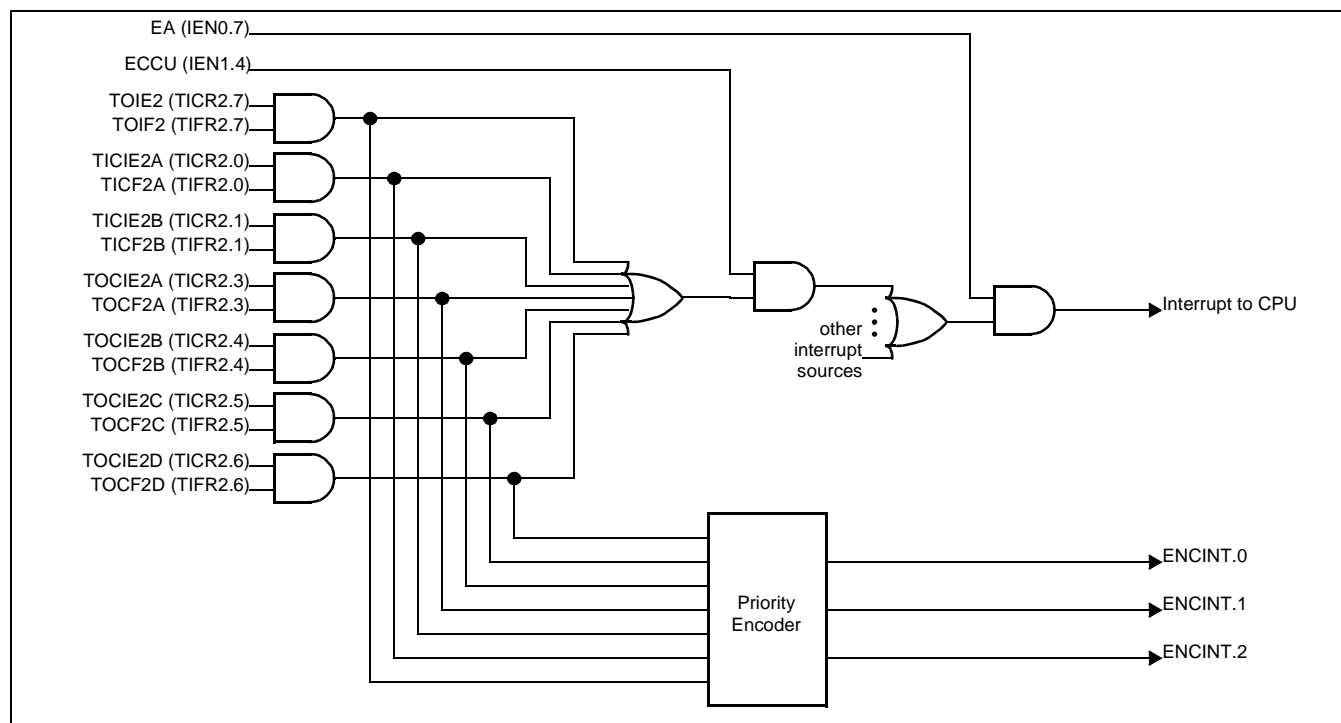


Figure 36: Capture/Compare Unit interrupts

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**TISE2**

Address: DEh

Not bit addressable

Reset Source(s): Any reset

Reset Value: xxxxx000B

7	6	5	4	3	2	1	0
-	-	-	-	-	ENCINT.2	ENCINT.1	ENCINT.0

BIT**SYMBOL****FUNCTION**

TISE2.7-3

-

Reserved for future use. Should not be set to '1' by user program.

TIFR2.2-0

ENCINT.2-0

CCU Interrupt Encode output. When multiple interrupts happen, more than one interrupt flag is set in CCU Interrupt Flag Register (TIFR2). The encoder output can be read to determine which interrupt is to be serviced. The user must write a '0' to clear the corresponding interrupt flag bit in the TIFR2 register after the corresponding interrupt has been serviced. Refer to Figure 38 for TIFR2 description.

ENCINT.2-0Interrupt Source

000

No interrupt pending.

001

Output Compare Event D interrupt (lowest priority).

010

Output Compare Event C interrupt.

011

Output Compare Event B interrupt.

100

Output Compare Event A interrupt.

101

Input Capture Event B interrupt.

110

Input Capture Event A interrupt.

Figure 37: CCU Interrupt Status Encode register

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

TIFR2

Address: E9H

Not bit addressable

Reset Source(s): Any reset

Reset Value: 00000x00B

7	6	5	4	3	2	1	0
TOIF2	TOCF2D	TOCF2C	TOCF2B	TOCF2A	-	TICF2B	TICF2A

BIT	SYMBOL	FUNCTION
TIFR2.7	TOIF2	CCU Timer Overflow Interrupt Flag bit. Set by hardware on CCU Timer overflow. Cleared by software.
TIFR2.6	TOCF2D	Output Compare Channel D Interrupt Flag Bit. Set by hardware when the contents of TH2:TL2 match that of OCRHD:OCRLD. Compare channel D must be enabled in order to generate this interrupt. If EA bit in IEN0, ECCU bit in IEN1 and TOCIE2D bit are all set, the program counter will vectored to the corresponding interrupt. Cleared by software.
TIFR2.5	TOCF2C	Output Compare Channel C Interrupt Flag Bit. Set by hardware when the contents of TH2:TL2 match that of OCRHC:OCRLC. Compare channel C must be enabled in order to generate this interrupt. If EA bit in IEN0, ECCU bit in IEN1 and TOCIE2C bit are all set, the program counter will vectored to the corresponding interrupt. Cleared by software.
TIFR2.4	TOCF2B	Output Compare Channel B Interrupt Flag Bit. Set by hardware when the contents of TH2:TL2 match that of OCRHB:OCRLB. Compare channel B must be enabled in order to generate this interrupt. If EA bit in IEN0, ECCU bit in IEN1 and TOCIE2B bit are set, the program counter will vectored to the corresponding interrupt. Cleared by software.
TIFR2.3	TOCF2A	Output Compare Channel A Interrupt Flag Bit. Set by hardware when the contents of TH2:TL2 match that of OCRHA:OCRLA. Compare channel A must be enabled in order to generate this interrupt. If EA bit in IEN0, ECCU bit in IEN1 and TOCIE2A bit are all set, the program counter will vectored to the corresponding interrupt. Cleared by software.
TIFR2.2	-	Reserved for future use. Should not be set to '1' by user program.
TIFR2.1	TICF2B	Input Capture Channel B Interrupt Flag Bit. Set by hardware when an input capture event is detected. Cleared by software.
TIFR2.0	TICF2A	Input Capture Channel A Interrupt Flag Bit. Set by hardware when an input capture event is detected. Cleared by software.

Figure 38: CCU Interrupt Flag register

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

TICR2										
Address: C9h										
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: 00000x00B										
BIT	SYMBOL	FUNCTION								
TICR2.7	TOIE2	CCU Timer Overflow Interrupt Enable bit.	7	6	5	4	3	2	1	0
TICR2.6	TOCIE2D	Output Compare Channel D Interrupt Enable Bit. If EA bit and this bit are set to 1, when compare channel D is enabled and the contents of TH2:TL2 match that of OCRHD:OCRLD, the program counter will vectored to the corresponding interrupt.	TOIE2	TOCIE2D	TOCIE2C	TOCIE2B	TOCIE2A	-	TICIE2B	TICIE2A
TICR2.5	TOCIE2C	Output Compare Channel C Interrupt Enable Bit. If EA bit and this bit are set to 1, when compare channel C is enabled and the contents of TH2:TL2 match that of OCRHC:OCRLC, the program counter will vectored to the corresponding interrupt.								
TICR2.4	TOCIE2B	Output Compare Channel B Interrupt Enable Bit. If EA bit and this bit are set to 1, when compare channel B is enabled and the contents of TH2:TL2 match that of OCRHB:OCRLB, the program counter will vectored to the corresponding interrupt.								
TICR2.3	TOCIE2A	Output Compare Channel A Interrupt Enable Bit. If EA bit and this bit are set to 1, when compare channel is enabled and the contents of TH2:TL2 match that of OCRHA:OCRLA, the program counter will vectored to the corresponding interrupt.								
TICR2.2	-	Reserved for future use. Should not be set to '1' by user program.								
TICR2.1	TICIE2B	Input Capture Channel B Interrupt Enable Bit. If EA bit and this bit all be set, when a capture event is detected, the program counter will vectored to the corresponding interrupt.								
TICR2.0	TICIE2A	Input Capture Channel A Interrupt Enable Bit. If EA bit and this bit all be set, when a capture event is detected, the program counter will vectored to the corresponding interrupt.								

Figure 39: CCU Interrupt Control register

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****UART**

The LPC932 has an enhanced UART that is compatible with the conventional 80C51 UART except that Timer 2 overflow cannot be used as a baud rate source. The LPC932 does include an independent Baud Rate Generator. The baud rate can be selected from the oscillator (divided by a constant), Timer 1 overflow, or the independent Baud Rate Generator. In addition to the baud rate generation, enhancements over the standard 80C51 UART include Framing Error detection, break detect, automatic address recognition, selectable double buffering and several interrupt options.

The UART can be operated in 4 modes:

Mode 0

Serial data enters and exits through RxD. TxD outputs the shift clock. 8 bits are transmitted or received, LSB first. The baud rate is fixed at 1/16 of the CPU clock frequency.

Mode 1

10 bits are transmitted (through TxD) or received (through RxD): a start bit (logical 0), 8 data bits (LSB first), and a stop bit (logical 1). When data is received, the stop bit is stored in RB8 in Special Function Register SCON. The baud rate is variable and is determined by the Timer 1 overflow rate or the Baud Rate Generator (see "Baud Rate Generator and selection" section).

Mode 2

11 bits are transmitted (through TxD) or received (through RxD): start bit (logical 0), 8 data bits (LSB first), a programmable 9th data bit, and a stop bit (logical 1). When data is transmitted, the 9th data bit (TB8 in SCON) can be assigned the value of 0 or 1. Or, for example, the parity bit (P, in the PSW) could be moved into TB8. When data is received, the 9th data bit goes into RB8 in Special Function Register SCON and the stop bit is not saved. The baud rate is programmable to either 1/16 or 1/32 of the CCLK frequency, as determined by the SMOD1 bit in PCON.

Mode 3

11 bits are transmitted (through TxD) or received (through RxD): a start bit (logical 0), 8 data bits (LSB first), a programmable 9th data bit, and a stop bit (logical 1). Mode 3 is the same as Mode 2 in all respects except baud rate. The baud rate in Mode 3 is variable and is determined by the Timer 1 overflow rate or the Baud Rate Generator (see "Baud Rate Generator and selection" section).

In all four modes, transmission is initiated by any instruction that uses SBUF as a destination register. Reception is initiated in Mode 0 by the condition RI = 0 and REN = 1. Reception is initiated in the other modes by the incoming start bit if REN = 1.

SFR space

The UART SFRs are at the following locations:

Table 13: SFR Locations for UARTs.

Register	Description	SFR Location
PCON	Power Control	87H
SCON	Serial Port (UART) Control	98H
SBUF	Serial Port (UART) Data Buffer	99H
SADDR	Serial Port (UART) Address	A9H
SADEN	Serial Port (UART) Address Enable	B9H
SSTAT	Serial Port (UART) Status	BAH
BRGR1	Baud Rate Generator Rate High Byte	BFH
BRGR0	Baud Rate Generator Rate Low Byte	BEH
BRGCON	Baud Rate Generator Control	BDH

Baud Rate Generator and selection

The LPC932 enhanced UART has an independent Baud Rate Generator. The baud rate is determined by a value programmed into the BRGR1 and BRGR0 SFRs. The UART can use either Timer 1 or the baud rate generator output as determined by BRGCON.2-1 (see Figure 41). Note that Timer T1 is further divided by 2 if the SMOD1 bit (PCON.7) is set. The independent Baud Rate Generator uses CCLK.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Updating the BRGR1 and BRGR0 SFRs**

The baud rate SFRs, BRGR1 and BRGR0 must only be loaded when the Baud Rate Generator is disabled (the BRGEN bit in the BRGCON register is '0'). This avoids the loading of an interim value to the baud rate generator. **(CAUTION: If either BRGR0 or BRGR1 is written when BRGEN = 1, the result is unpredictable.)**

Table 14: Baud rate generation for UART.

SCON.7 (SM0)	SCON.6 (SM1)	PCON.7 (SMOD1)	BRGCON.1 (SBRGS)	Receive/transmit baud rate for UART
0	0	X	X	CCLK/16
0	1	0	0	T1_rate/32
		1	0	T1_rate/16
		X	1	CCLK/((BRGR1,BRGR0)+16)
1	0	0	X	CCLK/32
		1	X	CCLK/16
1	1	0	0	T1_rate/32
		1	0	T1_rate/16
		X	1	CCLK/((BRGR1,BRGR0)+16)

BRGCON

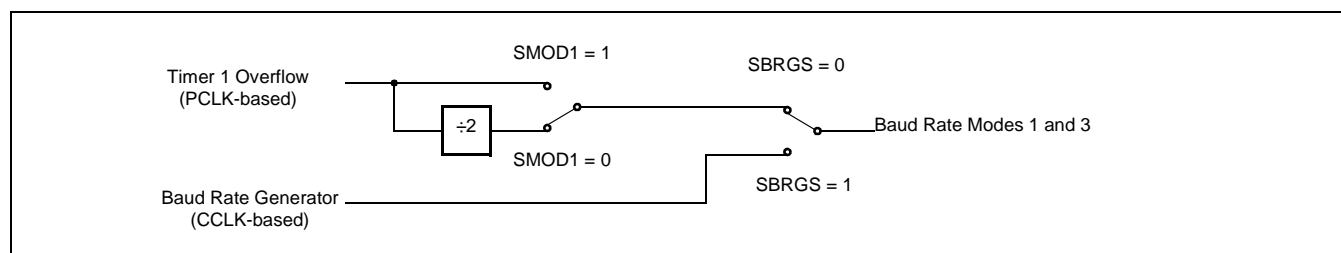
Address: BDh

Not bit addressable

Reset Source(s): Any reset

Reset Value: xxxxxx00B

BIT	SYMBOL	FUNCTION
BRGCON.7-2	-	Reserved for future use. Should not be set to 1 by user programs.
BRGCON.1	SBRGS	Select Baud Rate Generator as the source for baud rates to UART in modes 1 & 3 (see Table 14 for details)
BRGCON.0	BRGEN	Baud Rate Generator Enable. Enables the baud rate generator. BRGR1 and BRGR0 can only be written when BRGEN = 0.

Figure 40: BRGCON register**Figure 41: Baud rate generation for UART (Modes 1, 3)**

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Framing Error**

A Framing error occurs when the stop bit is sensed as a logic '0'. A Framing error is reported in the status register (SSTAT). In addition, if SMOD0 (PCON.6) is 1, Framing errors can be made available in SCON.7. If SMOD0 is 0, SCON.7 is SM0. It is recommended that SM0 and SM1 (SCON.7-6) are programmed when SMOD0 is '0'.

Break Detect

A break detect is reported in the status register (SSTAT). A break is detected when any 11 consecutive bits are sensed low. Since a break condition also satisfies the requirements for a framing error, a break condition will also result in reporting a framing error. Once a break condition has been detected, the UART will go into an idle state and remain in this idle state until a stop bit has been received. The break detect can be used to reset the device and force the device into ISP mode by setting the EBRR bit (AUXR1.6).

SCON			7	6	5	4	3	2	1	0
Address: 98h			SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI
Bit addressable										
Reset Source(s): Any reset										
Reset Value: 0000000B										
BIT	SYMBOL	FUNCTION								
SCON.7	SM0/FE	The use of this bit is determined by SMOD0 in the PCON register. If SMOD0 = 0, this bit is read and written as SM0, which with SM1, defines the serial port mode. If SMOD0 = 1, this bit is read and written as FE (Framing Error). FE is set by the receiver when an invalid stop bit is detected. Once set, this bit cannot be cleared by valid frames but is cleared by software. (Note: UART mode bits SM0 and SM1 should be programmed when SMOD0 is '0' - default mode on any reset.)								
SCON. 6	SM1	With SM0, defines the serial port mode (see table below).								
	<u>SM0, SM1</u>	<u>UART Mode</u> <u>UART 0 Baud Rate</u>								
	0 0	0: shift register CCLK/16 (default mode on any reset)								
	0 1	1: 8-bit UART Variable (see Table 14)								
	1 0	2: 9-bit UART CCLK/32 or CCLK/16								
SCON.5	SM2	3: 9-bit UART Variable (see Table 14)								
		Enables the multiprocessor communication feature in Modes 2 and 3. In Mode 2 or 3, if SM2 is set to 1, then RI will not be activated if the received 9th data bit (RB8) is 0. In Mode 0, SM2 should be 0. In Mode 1, SM2 must be 0.								
SCON.4	REN	Enables serial reception. Set by software to enable reception. Clear by software to disable reception.								
SCON.3	TB8	The 9th data bit that will be transmitted in Modes 2 and 3. Set or clear by software as desired.								
SCON.2	RB8	The 9th data bit that was received in Modes 2 and 3. In Mode 1 (SM2 must be 0), RB8 is the stop bit that was received. In Mode 0, RB8 is undefined.								
SCON.1	TI	Transmit interrupt flag. Set by hardware at the end of the 8th bit time in Mode 0, or at the the stop bit (see description of INTLO bit in SSTAT register) in the other modes. Must be cleared by software.								
SCON.0	RI	Receive interrupt flag. Set by hardware at the end of the 8th bit time in Mode 0, or approximately halfway through the stop bit time in Mode 1. For Mode 2 or Mode 3, if SMOD0, it is set near the middle of the 9th data bit (bit 8). If SMOD0 = 1, it is set near the middle of the stop bit (see SM2 - SCON.5 - for exceptions). Must be cleared by software.								

Figure 42: Serial Port Control register (SCON)

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****SSTAT**

Address: BAh

Not bit addressable

Reset Source(s): Any reset

Reset Value: 0000000B

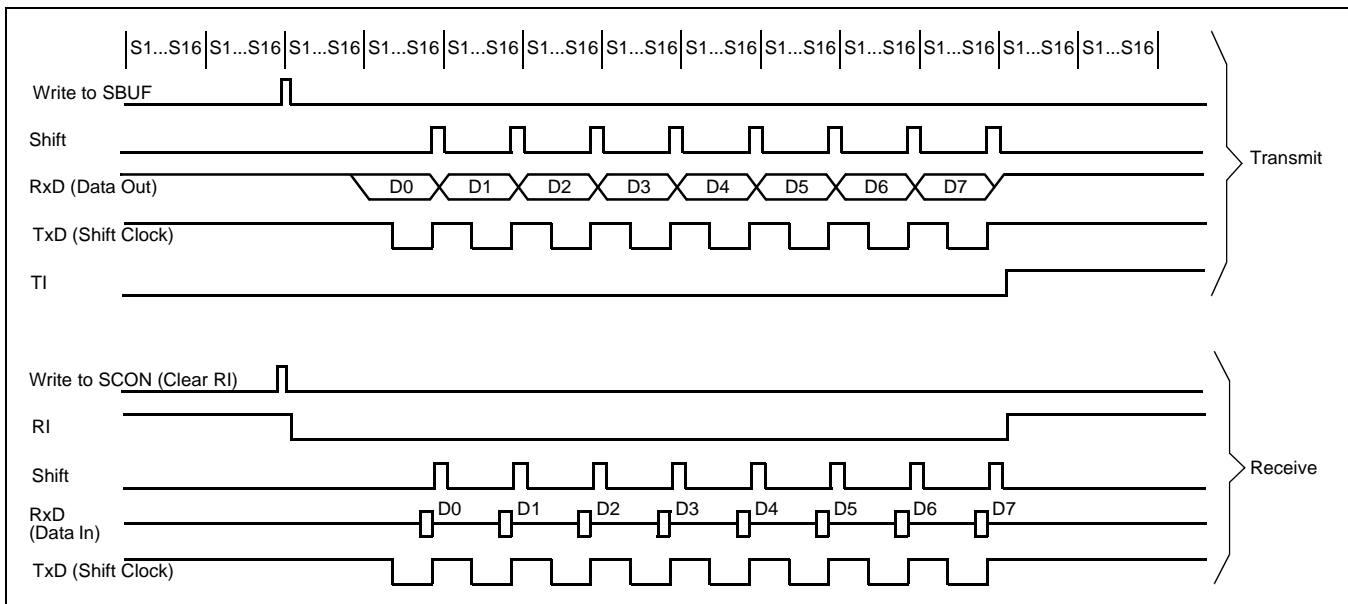
7	6	5	4	3	2	1	0
DBMOD	INTLO	CIDIS	DBISEL	FE	BR	OE	STINT

BIT	SYMBOL	FUNCTION
SSTAT.7	DBMOD	Double buffering mode. When set = 1 enables double buffering. Must be '0' for UART mode 0. In order to be compatible with existing 80C51 devices, this bit is reset to '0' to disable double buffering.
SSTAT.6	INTLO	Transmit interrupt position. When cleared = 0, the Tx interrupt is issued at the beginning of the stop bit. When set =1, the Tx interrupt is issued at end of the stop bit. Must be '0' for mode 0. Note that in the case of single buffering, if the Tx interrupt occurs at the end of a STOP bit, a gap may exist before the next start bit.
SSTAT.5	CIDIS	Combined Interrupt Disable. When set = 1, Rx and Tx interrupts are separate. When cleared = 0, the UART uses a combined Tx/Rx interrupt (like a conventional 80C51 UART). This bit is reset to '0' to select combined interrupts.
SSTAT.4	DBISEL	Double buffering transmit interrupt select. Used only if double buffering is enabled. This bit controls the number of interrupts that can occur when double buffering is enabled. When set, one transmit interrupt is generated after each character written to SBUF, and there is also one more transmit interrupt generated at the beginning (INTLO = 0) or the end (INTLO = 1) of the STOP bit of the last character sent (i.e., no more data in buffer). This last interrupt can be used to indicate that all transmit operations are over. When cleared = 0, only one transmit interrupt is generated per character written to SBUF. Must be '0' when double buffering is disabled. Note that except for the first character written (when buffer is empty), the location of the transmit interrupt is determined by INTLO. When the first character is written, the transmit interrupt is generated immediately after SBUF is written.
SSTAT.3	FE	Framing error flag is set when the receiver fails to see a valid STOP bit at the end of the frame. Cleared by software.
SSTAT.2	BR	Break Detect flag. A break is detected when any 11 consecutive bits are sensed low. Cleared by software.
SSTAT.1	OE	Overrun Error flag is set if a new character is received in the receiver buffer while it is still full (before the software has read the previous character from the buffer), i.e., when bit 8 of a new byte is received while RI in SCON is still set. Cleared by software.
SSTAT.0	STINT	Status Interrupt Enable. When set =1, FE, BR, or OE can cause an interrupt. The interrupt used is shared with RI (CIDIS = 1) or the combined TI/RI (CIDIS = 0). When cleared = 0, FE, BR, OE cannot cause an interrupt. (Note: FE, BR, or OE is often accompanied by a RI, which will generate an interrupt regardless of the state of STINT). Note that BR can cause a break detect reset if EBRR (AUXR1.6) is set to '1'.

Figure 43: Serial Port Status register (SSTAT)**More about UART Mode 0**

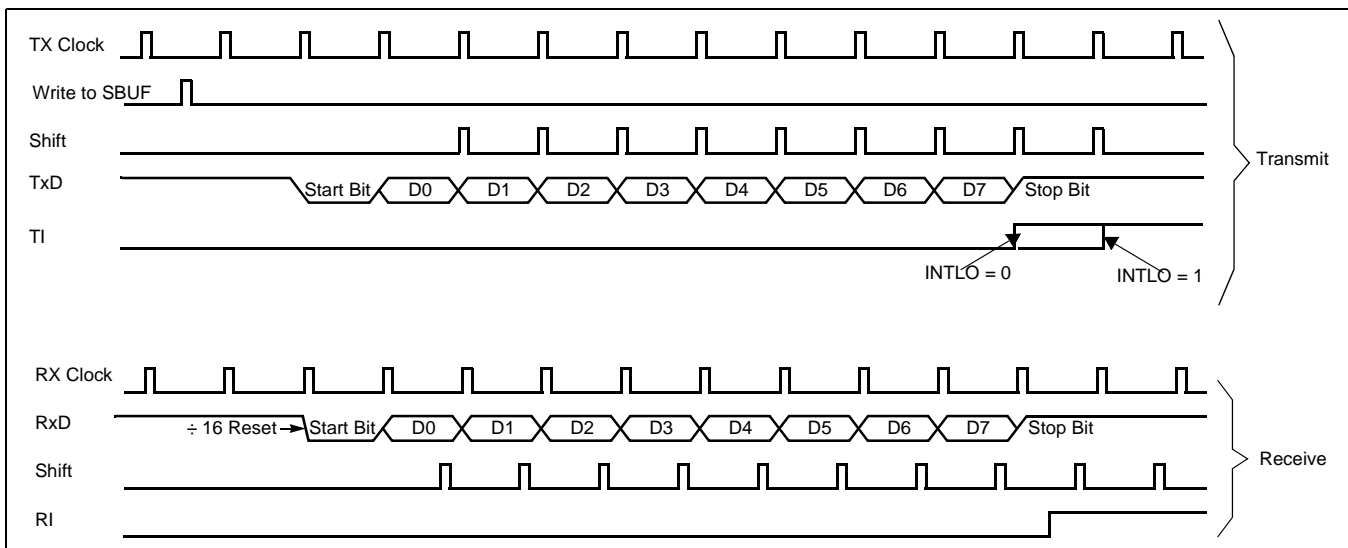
In Mode 0, a write to SBUF will initiate a transmission. At the end of the transmission, TI (SCON.1) is set, which must be cleared in software. Double buffering must be disabled in this mode.

Reception is initiated by clearing RI (SCON.0). Synchronous serial transfer occurs and RI will be set again at the end of the transfer. When RI is cleared, the reception of the next character will begin. Refer to Figure 44 for timing.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932
Figure 44: Serial Port Mode 0 (double buffering must be disabled)
More about UART Mode 1

Reception is initiated by detecting a 1-to-0 transition on RxD. RxD is sampled at a rate 16 times the programmed baud rate. When a transition is detected, the divide-by-16 counter is immediately reset. Each bit time is thus divided into 16 counter states. At the 7th, 8th, and 9th counter states, the bit detector samples the value of RxD. The value accepted is the value that was seen in at least 2 of the 3 samples. This is done for noise rejection. If the value accepted during the first bit time is not 0, the receive circuits are reset and the receiver goes back to looking for another 1-to-0 transition. This provides rejection of false start bits. If the start bit proves valid, it is shifted into the input shift register, and reception of the rest of the frame will proceed.

The signal to load SBUF and RB8, and to set RI, will be generated if, and only if, the following conditions are met at the time the final shift pulse is generated: RI = 0 and either SM2=0 or the received stop bit = 1. If either of these two conditions is not met, the received frame is lost. If both conditions are met, the stop bit goes into RB8, the 8 data bits go into SBUF, and RI is activated.


Figure 45: Serial Port Mode 1 (only single transmit buffering case is shown)

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****More about UART Modes 2 and 3**

Reception is the same as in Mode 1.

The signal to load SBUF and RB8, and to set RI, will be generated if, and only if, the following conditions are met at the time the final shift pulse is generated. (a) RI = 0, and (b) Either SM2 = 0, or the received 9th data bit = 1. If either of these conditions is not met, the received frame is lost, and RI is not set. If both conditions are met, the received 9th data bit goes into RB8, and the first 8 data bits go into SBUF.

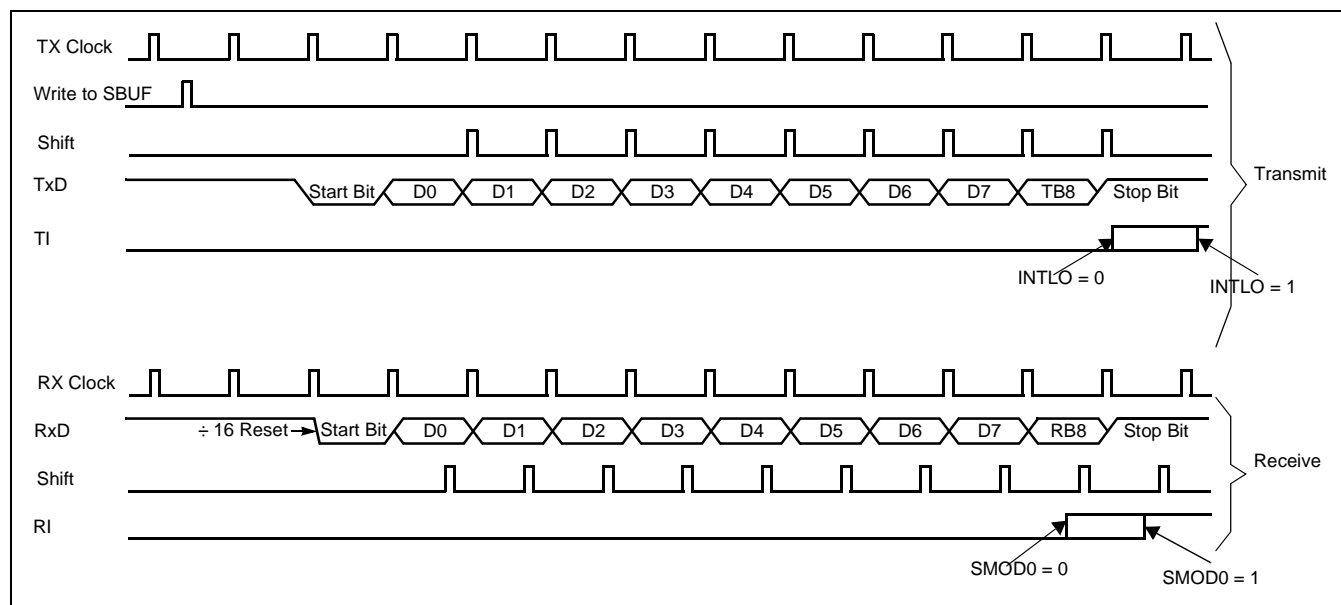


Figure 46: Serial Port Mode 2 or 3 (only single transmit buffering case is shown)

Framing Error and RI in Modes 2 and 3 with SM2 = 1

If SM2 = 1 in modes 2 and 3, RI and FE behaves as in the following table.

Table 15: FE and RI when SM2 = 1 in Modes 2 and 3.

Mode	PCON.6 (SMOD0)	RB8	RI	FE
2	0	0	No RI when RB8 = 0	Occurs during STOP bit
		1	Similar to Figure 46, with SMOD0 = 0, RI occurs during RB8, one bit before FE	Occurs during STOP bit
3	1	0	No RI when RB8 = 0	Will NOT occur
		1	Similar to Figure 46, with SMOD0 = 1, RI occurs during STOP bit	Occurs during STOP bit

Break Detect

A break is detected when 11 consecutive bits are sensed low and is reported in the status register (SSTAT). For Mode 1, this consists of the start bit, 8 data bits, and two stop bit times. For Modes 2 & 3, this consists of the start bit, 9 data bits, and one stop bit. The break detect bit is cleared in software or by a reset. The break detect can be used to reset the device and force the device into ISP mode. This occurs if the UART is enabled and the the EBRR bit (AUXR1.6) is set and a break occurs.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Double buffering**

The UART has a transmit double buffer that allows buffering of the next character to be written to SBUF while the first character is being transmitted. Double buffering allows transmission of a string of characters with only one stop bit between any two characters, provided the next character is written between the start bit and the stop bit of the previous character.

Double buffering can be disabled. If disabled (DBMOD, i.e. SSTAT.7 = 0), the UART is compatible with the conventional 80C51 UART. If enabled, the UART allows writing to SBUF while the previous data is being shifted out.

Double buffering in different modes

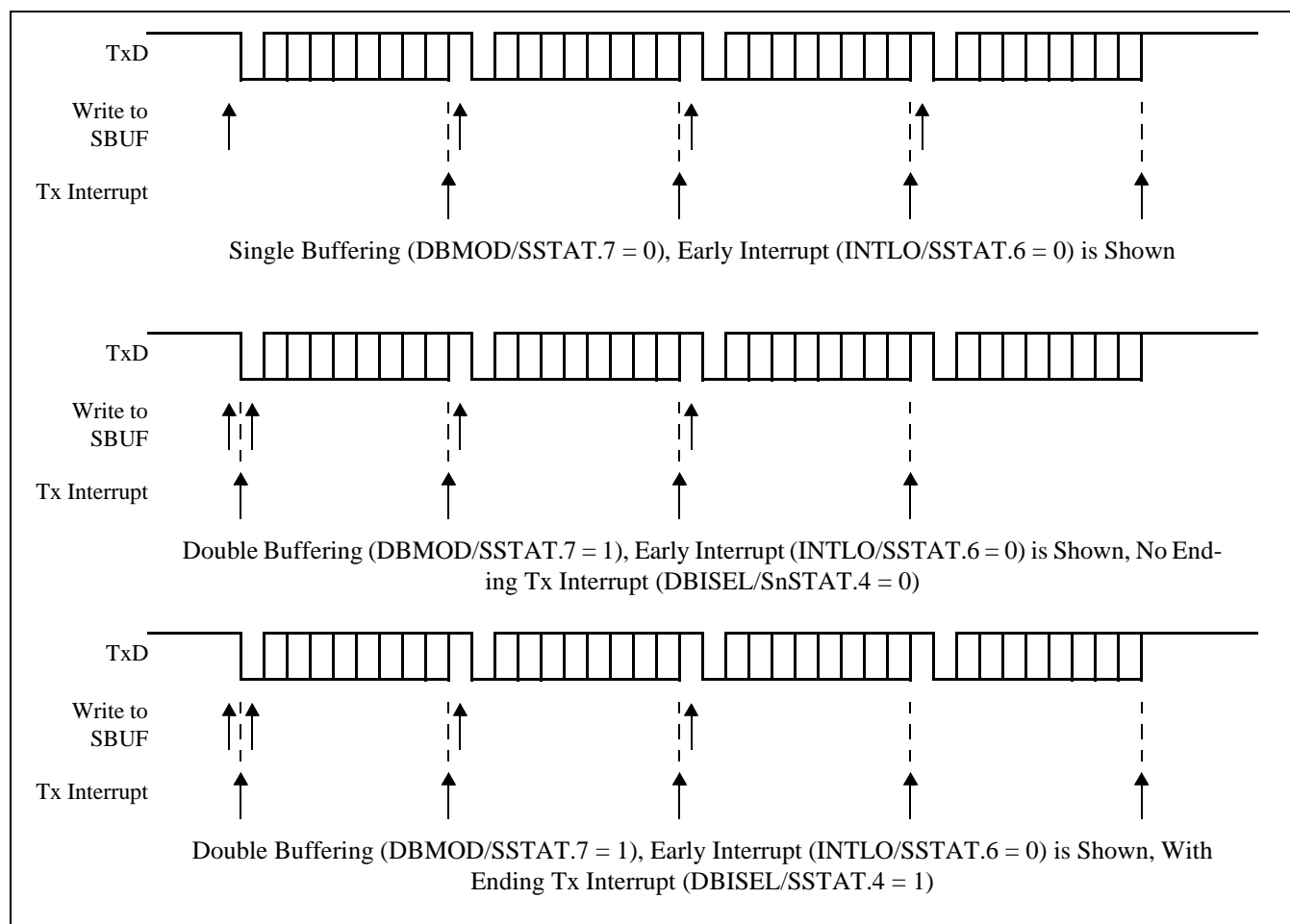
Double buffering is only allowed in Modes 1, 2 and 3. When operated in Mode 0, double buffering must be disabled (DBMOD = 0).

Transmit interrupts with double buffering enabled (Modes 1, 2 and 3)

Unlike the conventional UART, when double buffering is enabled, the Tx interrupt is generated when the double buffer is ready to receive new data. The following occurs during a transmission (assuming eight data bits):

1. The double buffer is empty initially.
 2. The CPU writes to SBUF.
 3. The SBUF data is loaded to the shift register and a Tx interrupt is generated immediately.
 4. If there is more data, go to 6, else continue on 5.
 5. If there is no more data, then:
 - If DBISEL is '0', no more interrupts will occur.
 - If DBISEL is '1' and INTLO is '0', a Tx interrupt will occur at the beginning of the STOP bit of the data currently in the shifter (which is also the last data).
 - If DBISEL is '1' and INTLO is '1', a Tx interrupt will occur at the end of the STOP bit of the data currently in the shifter (which is also the last data).
 6. If there is more data, the CPU writes to SBUF again. Then:
 - If INTLO is '0', the new data will be loaded and a Tx interrupt will occur at the beginning of the STOP bit of the data currently in the shifter.
 - If INTLO is '1', the new data will be loaded and a Tx interrupt will occur at the end of the STOP bit of the data currently in the shifter.
- Go to 3.

Note that if DBISEL is '1' and the CPU is writing to SBUF when the STOP bit of the last data is shifted out, there can be an uncertainty of whether a Tx interrupt is generated already with the UART not knowing whether there is any more data following.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Figure 47: Transmission with and without double buffering****The 9th bit (bit 8) in double buffering (Modes 1, 2 and 3)**

If double buffering is disabled (DBMOD, i.e. SSTAT.7 = 0), TB8 can be written before or after SBUF is written, provided TB8 is updated before that TB8 is shifted out. TB8 must not be changed again until after TB8 shifting has been completed, as indicated by the Tx interrupt.

If double buffering is enabled, TB8 MUST be updated before SBUF is written, as TB8 will be double-buffered together with SBUF data. The operation described in the section "Transmit interrupts with double buffering enabled (Modes 1, 2 and 3)" becomes as follows:

1. The double buffer is empty initially.
2. The CPU writes to TB8.
3. The CPU writes to SBUF.
4. The SBUF/TB8 data is loaded to the shift register and a Tx interrupt is generated immediately.
5. If there is more data, go to 7, else continue on 6.
6. If there is no more data, then:
 - If DBISEL is '0', no more interrupt will occur.
 - If DBISEL is '1' and INTLO is '0', a Tx interrupt will occur at the beginning of the STOP bit of the data currently in the shifter (which is also the last data).
 - If DBISEL is '1' and INTLO is '1', a Tx interrupt will occur at the end of the STOP bit of the data currently in the shifter (which is also the last data).
7. If there is more data, the CPU writes to TB8 again.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

8. The CPU writes to SBUF again. Then:

- If INTLO is '0', the new data will be loaded and a Tx interrupt will occur at the beginning of the STOP bit of the data currently in the shifter.
- If INTLO is '1', the new data will be loaded and a Tx interrupt will occur at the end of the STOP bit of the data currently in the shifter.

Go to 4.

Note that if DBISEL is '1' and the CPU is writing to SBUF when the STOP bit of the last data is shifted out, there can be an uncertainty of whether a Tx interrupt is generated already with the UART not knowing whether there is any more data following.

Multiprocessor communications

UART modes 2 and 3 have a special provision for multiprocessor communications. In these modes, 9 data bits are received or transmitted. When data is received, the 9th bit is stored in RB8. The UART can be programmed such that when the stop bit is received, the serial port interrupt will be activated only if RB8 = 1. This feature is enabled by setting bit SM2 in SCON. One way to use this feature in multiprocessor systems is as follows:

When the master processor wants to transmit a block of data to one of several slaves, it first sends out an address byte which identifies the target slave. An address byte differs from a data byte in that the 9th bit is 1 in an address byte and 0 in a data byte. With SM2 = 1, no slave will be interrupted by a data byte. An address byte, however, will interrupt all slaves, so that each slave can examine the received byte and see if it is being addressed. The addressed slave will clear its SM2 bit and prepare to receive the data bytes that follow. The slaves that weren't being addressed leave their SM2 bits set and go on about their business, ignoring the subsequent data bytes.

Note that SM2 has no effect in Mode 0, and must be '0' in Mode 1.

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.

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 be 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
```

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

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 to 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 treated as don't-cares. In most cases, interpreting the don't-cares as ones, the broadcast address will be FF hexadecimal. Upon reset SADDR and SADEN are loaded 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 UART drivers which do not make use of this feature.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**I²C serial interface**

The I²C-bus uses two wires, serial clock (SCL) and serial data (SDA) to transfer information between devices connected to the bus, and has the following features:

- Bidirectional data transfer between masters and slaves
- Multimaster bus (no central master)
- Arbitration between simultaneously transmitting masters without corruption of serial data on the bus
- Serial clock synchronization allows devices with different bit rates to communicate via one serial bus
- Serial clock synchronization can be used as a handshake mechanism to suspend and resume serial transfer
- The I²C-bus may be used for test and diagnostic purposes

A typical I²C-bus configuration is shown in Figure 48. Depending on the state of the direction bit (R/W), two types of data transfers are possible on the I²C-bus:

- Data transfer from a master transmitter to a slave receiver. The first byte transmitted by the master is the slave address. Next follows a number of data bytes. The slave returns an acknowledge bit after each received byte.
- Data transfer from a slave transmitter to a master receiver. The first byte (the slave address) is transmitted by the master. The slave then returns an acknowledge bit. Next follows the data bytes transmitted by the slave to the master. The master returns an acknowledge bit after all received bytes other than the last byte. At the end of the last received byte, a “not acknowledge” is returned. The master device generates all of the serial clock pulses and the START and STOP conditions. A transfer is ended with a STOP condition or with a repeated START condition. Since a repeated START condition is also the beginning of the next serial transfer, the I²C-bus will not be released.

The LPC932 device provides a byte-oriented I²C interface. It has four operation modes: Master Transmitter Mode, Master Receiver Mode, Slave Transmitter Mode and Slave Receiver Mode.

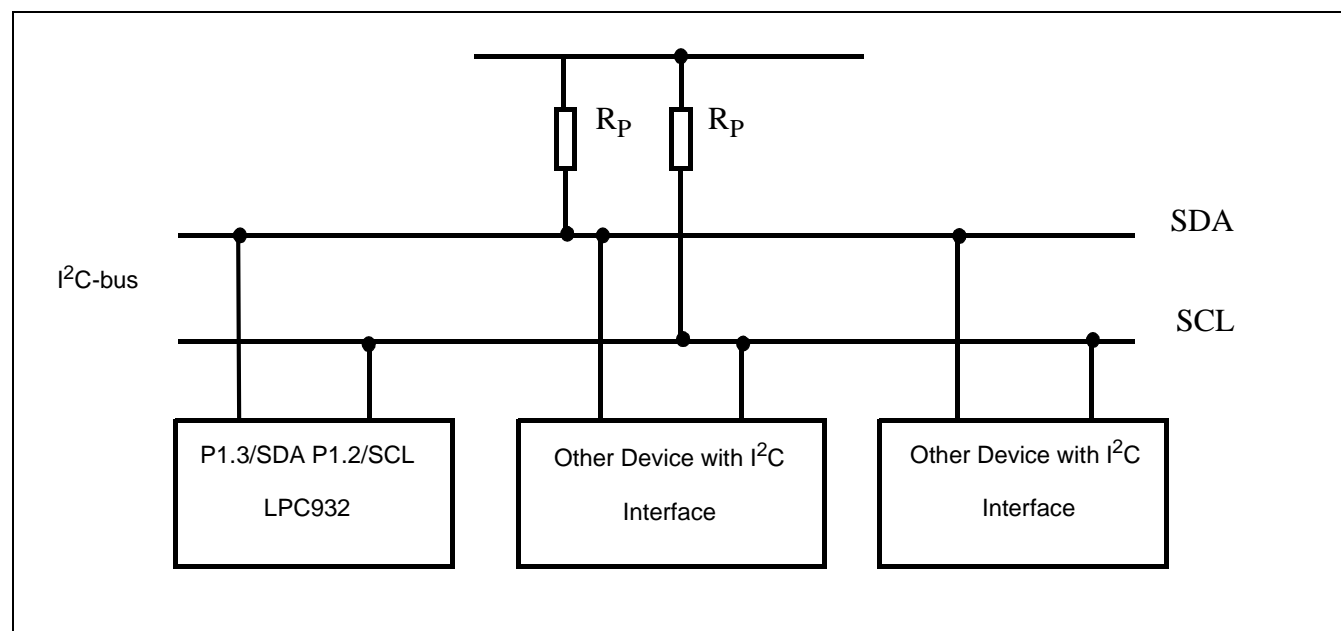


Figure 48: I²C-bus configuration

The LPC932 CPU interfaces with the I²C-bus through six Special Function Registers (SFRs): I2CON (I²C Control Register), I2DAT (I²C Data Register), I2STAT (I²C Status Register), I2ADR (I²C Slave Address Register), I2SCLH (SCL Duty Cycle Register High Byte), and I2SCLL (SCL Duty Cycle Register Low Byte).

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**I²C Data register**

I2DAT register contains the data to be transmitted or the data received. The CPU can read and write to this 8-bit register while it is not in the process of shifting a byte. Thus this register should only be accessed when the SI bit is set. Data in I2DAT remains stable as long as the SI bit is set. Data in I2DAT is always shifted from right to left: the first bit to be transmitted is the MSB (bit 7), and after a byte has been received, the first bit of received data is located at the MSB of I2DAT.

I2DAT									
Address: DAH									
Not bit addressable									
Reset Source(s): Any reset									
Reset Value: 0000000B									
		7	6	5	4	3	2	1	0
		I2DAT.7	I2DAT.6	I2DAT.5	I2DAT.4	I2DAT.3	I2DAT.2	I2DAT.1	I2DAT.0

Figure 49: I²C Data register**I²C Slave Address register**

I2ADR register is readable and writable, and is only used when the I²C interface is set to slave mode. In master mode, this register has no effect. The LSB of I2ADR is general call bit. When this bit is set, the general call address (00h) is recognized.

I2ADR										
Address: DBH										
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: 0000000B										
			7	6	5	4	3	2	1	0
			I2ADR.6	I2ADR.5	I2ADR.4	I2ADR.3	I2ADR.2	I2ADR.1	I2ADR.0	GC
BIT	SYMBOL	FUNCTION								
I2ADR7, 1	I2ADR.6, 0	7 bit own slave address. When in master mode, the contents of this register has no effect.								
I2ADR7.0	GC	General call bit. When set, the general call address (00H) is recognized, otherwise it is ignored.								

Figure 50: I²C Slave Address register**I²C Control register**

The CPU can read and write this register. There are two bits are affected by hardware: the SI bit and the STO bit. The SI bit is set by hardware and the STO bit is cleared by hardware.

CRSEL determines the SCL source when the I²C is in master mode. In slave mode this bit is ignored and the bus will automatically synchronize with any clock frequency up to 400 kHz from the master I²C device. When CRSEL = 1, the I²C interface uses the Timer1 overflow rate divided by 2 for the I²C clock rate. Timer 1 should be programmed by the user in 8 bit auto-reload mode (Mode 2).

$$\text{Data rate of I}^2\text{C} = \text{Timer overflow rate} / 2 = \text{PCLK} / (2 * (256 - \text{reload value})),$$

If fosc = 12 MHz, reload value is 0 - 255, so I²C data rate range is 11.72 Kbit/sec - 3000 Kbit/sec.

When CRSEL = 0, the I²C interface uses the internal clock generator based on the value of I2SCLL and I2CSC LH register. The duty cycle does not need to be 50%.

The STA bit is START flag. Setting this bit causes the I²C interface to enter master mode and attempt transmitting a START condition or transmitting a repeated START condition when it is already in master mode.

The STO bit is STOP flag. Setting this bit causes the I²C interface to transmit a STOP condition in master mode, or recovering from an error condition in slave mode.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

If the STA and STO are both set, then a STOP condition is transmitted to the I²C-bus if it is in master mode, and transmits a START condition afterwards. If it is in slave mode, an internal STOP condition will be generated, but it is not transmitted to the bus.

I2CON		
Address: D8h		
Bit addressable		
Reset Source(s): Any reset		
Reset Value: x00000x0B		
BIT	SYMBOL	FUNCTION
I2CON.7	-	Reserved for future use. Should not be set to 1 by user programs.
I2CON.6	I2EN	I ² C Interface Enable. When set, enables the I ² C interface. When clear, the I ² C function is disabled.
I2CON.5	STA	Start Flag. STA = 1: I ² C enters master mode, checks the bus and generates a START condition if the bus is free. If the bus is not free, it waits for a STOP condition (which will free the bus) and generates a START condition after a delay of a half clock period of the internal clock generator. When the I ² C interface is already in master mode and some data is transmitted or received, it transmits a repeated START condition. STA may be set at any time, it may also be set when the I ² C interface is in an addressed slave mode. STA = 0: no START condition or repeated START condition will be generated.
I2CON.4	STO	STOP Flag. STO = 1: In master mode, a STOP condition is transmitted to the I ² C-bus. When the bus detects the STOP condition, it will clear STO bit automatically. In slave mode, setting this bit can recover from an error condition. In this case, no STOP condition is transmitted to the bus. The hardware behaves as if a STOP condition has been received and it switches to "not addressed" Slave Receiver Mode. The STO flag is cleared by hardware automatically.
I2CON.3	SI	I ² C Interrupt Flag. This bit is set when one of the 25 possible I ² C states is entered. When EA bit and EI2C (IEN1.0) bit are both set, an interrupt is requested when SI is set.. Must be cleared by software by writing 0 to this bit.
I2CON.2	AA	The Assert Acknowledge Flag. When set to 1, an acknowledge (low level to SDA) will be returned during the acknowledge clock pulse on the SCL line on the following situations: (1)The "own slave address" has been received. (2)The general call address has been received while the general call bit(GC) in I2ADR is set. (3) A data byte has been received while the I ² C interface is in the Master Receiver Mode. (4)A data byte has been received while the I ² C interface is in the addressed Slave Receiver Mode When cleared to 0, an not acknowledge (high level to SDA) will be returned during the acknowledge clock pulse on the SCL line on the following situations: (1) A data byte has been received while the I ² C interface is in the Master Receiver Mode. (2) A data byte has been received while the I ² C interface is in the addressed Slave Receiver Mode.
I2CON.1	-	Reserved for future use. Should not be set to 1 by user programs.
I2CON.0	CRSEL	SCL clock selection. When set = 1, Timer1 overflow generates SCL, when cleared = 0, the internal SCL generator is used base on values of I2SCLH and I2SCLL.

Figure 51: I²C Control register

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****I²C Status register**

This is a read-only register. It contains the status code of I²C interface. The least three bits are always 0. There are 26 possible status codes. When the code is F8H, there is no relevant information available and SI bit is not set. All other 25 status codes correspond to defined I²C states. When any of these states entered, the SI bit will be set. Refer to Table 17 to Table 20 for details.

I2STAT		
Address: D9h		
Not bit addressable		
Reset Source(s): Any reset		
Reset Value: 11111000B		
BIT	SYMBOL	FUNCTION
I2STAT7, 3	STA.4, 0	I ² C the status code.
I2STAT2, 0	-	These three bits are not used and always set to 0.

Figure 52: I²C Status register**I²C SCL Duty Cycle registers I2SCLH and I2SCLL**

When the internal SCL generator is selected for the I²C interface by setting CRSEL = 0 in the I2CON register, the user must set values for registers I2SCLL and I2SCLH to select the data rate. I2SCLH defines the number of PCLK cycles for SCL = high, I2SCLL defines the number of PCLK cycles for SCL = low. The frequency is determined by the following formula:

$$\text{Bit Frequency} = f_{\text{PCLK}} / (2 * (\text{I2SCLH} + \text{I2SCLL}))$$

Where f_{PCLK} is the frequency of PCLK.

The values for I2SCLL and I2SCLH do not have to be the same; the user can give different duty cycle's for SCL by setting these two registers. However, the value of the register must ensure that the data rate is in the I²C data rate range of 0 - 400 kHz. Thus the values of I2SCLL and I2SCLH have some restrictions and values for both registers greater than 3 PCLKs are recommended.

Table 16: I²C clock rates selection

I2SCLL + I2SCLH	CRSEL	Bit data rate (Kbit/sec) at f_{osc}				
		7.373 MHz	3.6865 MHz	1.8433 MHz	12 MHz	6 MHz
6	0	-	307	154	-	-
7	0	-	263	132	-	-
8	0	-	230	115	-	375
9	0	-	205	102	-	333
10	0	369	184	92	-	300
15	0	246	123	61	400	200
25	0	147	74	37	240	120
30	0	123	61	31	200	100
50	0	74	37	18	120	60
60	0	61	31	15	100	50

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Table 16: I²C clock rates selection**

I2SCLL + I2SCLH	CRSEL	Bit data rate (Kbit/sec) at f _{OSC}				
		7.373 MHz	3.6865 MHz	1.8433 MHz	12 MHz	6 MHz
100	0	37	18	9	60	30
150	0	25	12	6	40	20
200	0	18	9	5	30	15
-	1	3.6 - 922 Kbps timer1 in mode 2	1.8 - 461 Kbps timer1 in mode 2	0.9 - 230 Kbps timer1 in mode 2	5.86 - 1500 Kbps timer1 in mode 2	2.93 - 750 Kbps timer1 in mode 2

I²C operation mode**Master Transmitter Mode**

In this mode data is transmitted from master to slave. Before the Master Transmitter Mode can be entered, I2CON must be initialized as follows:

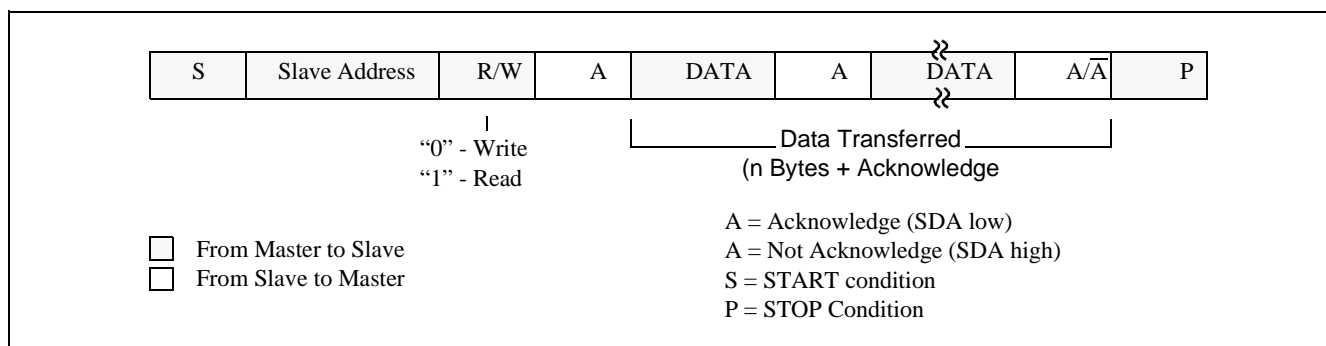
	7	6	5	4	3	2	1	0
I2CON (D8h)	-	I2EN	STA	STO	SI	AA	-	CRSEL
	-	1	0	0	0	x	-	bit rate

CRSEL defines the bit rate. I2EN must be set to 1 to enable the I²C function. If the AA bit is 0, it will not acknowledge its own slave address or the general call address in the event of another device becoming master of the bus and it can not enter slave mode. STA, STO, and SI bits must be cleared to 0.

The first byte transmitted contains the slave address of the receiving device (7 bits) and the data direction bit. In this case, the data direction bit (R/W) will be logic 0 indicating a write. Data is transmitted 8 bits at a time. After each byte is transmitted, an acknowledge bit is received. START and STOP conditions are output to indicate the beginning and the end of a serial transfer.

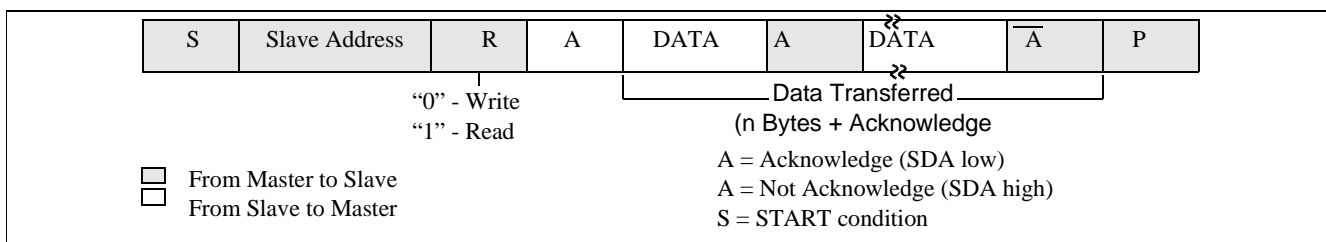
The I²C will enter Master Transmitter Mode by setting the STA bit. The I²C logic will send the START condition as soon as the bus is free. After the START condition is transmitted, the SI bit is set, and the status code in I2STAT should be 08h. This status code must be used to vector to an interrupt service routine where the user should load the slave address to I2DAT (Data Register) and data direction bit (SLA+W). The SI bit must be cleared before the data transfer can continue.

When the slave address and R/W bit have been transmitted and an acknowledgment bit has been received, the SI bit is set again, and the possible status codes are 18h, 20h, or 38h for the master mode or 68h, 78h, or 0B0h if the slave mode was enabled (setting AA = Logic 1). The appropriate action to be taken for each of these status codes is shown in Table 17.

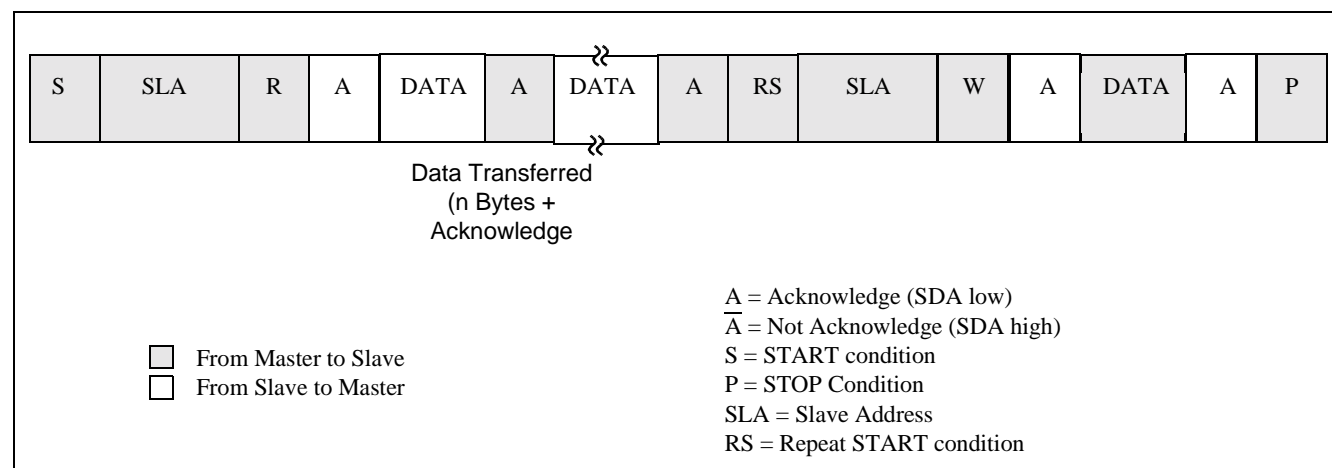
80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Figure 53: Format in the Master Transmitter Mode****Master Receiver Mode**

In the Master Receiver Mode, data is received from a slave transmitter. The transfer started in the same manner as in the Master Transmitter Mode. When the START condition has been transmitted, the interrupt service routine must load the slave address and the data direction bit to I²C Data Register (I2DAT). The SI bit must be cleared before the data transfer can continue.

When the slave address and data direction bit have been transmitted and an acknowledge bit has been received, the SI bit is set, and the Status Register will show the status code. For master mode, the possible status codes are 40H, 48H, or 38H. For slave mode, the possible status codes are 68H, 78H, or B0H. Refer to Table 18 for details.

**Figure 54: Format of Master Receiver Mode**

After a repeated START condition, I²C may switch to the Master Transmitter Mode.

**Figure 55: A Master Receiver switches to Master Transmitter after sending Repeated Start**

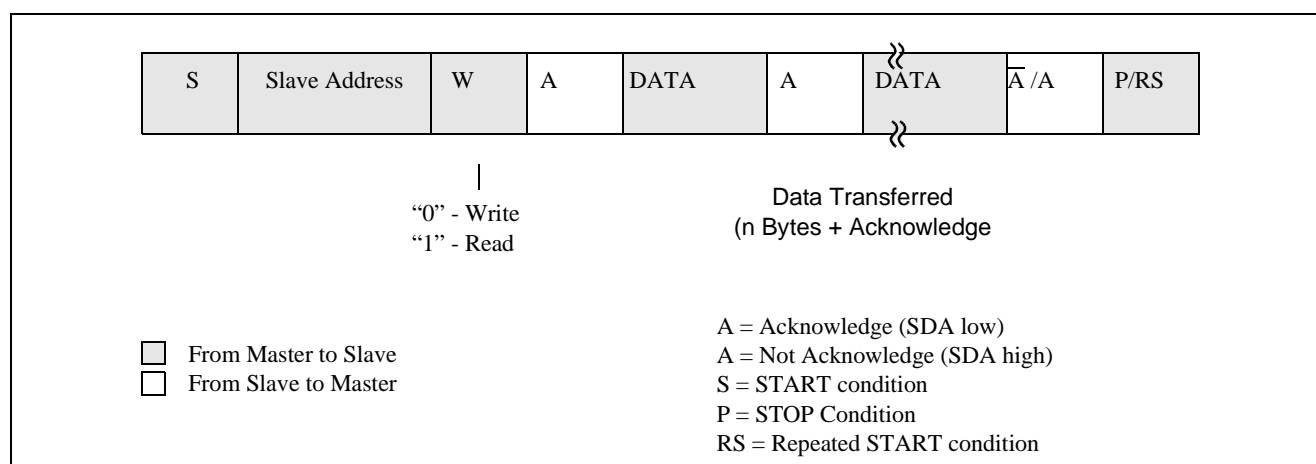
80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Slave Receiver Mode**

In the Slave Receiver Mode, data bytes are received from a master transmitter. To initialize the Slave Receiver Mode, the user should write the slave address to the Slave Address Register (I2ADR) and the I²C Control Register (I2CON) should be configured as follows:

	7	6	5	4	3	2	1	0
I2CON (D8h)	-	I2EN	STA	STO	SI	AA	-	CRSEL
	-	1	0	0	0	1	-	-

CRSEL is not used for slave mode. I2EN must be set = 1 to enable I²C function. AA bit must be set = 1 to acknowledge its own slave address or the general call address. STA, STO and SI are cleared to 0.

After I2ADR and I2CON are initialized, the interface waits until it is addressed by its own address or general address followed by the data direction bit which is 0(W). If the direction bit is 1(R), it will enter Slave Transmitter Mode. After the address and the direction bit have been received, the SI bit is set and a valid status code can be read from the Status Register(I2STAT). Refer to Table 19 for the status codes and actions.

**Figure 56: Format of Slave Receiver Mode****Slave Transmitter Mode**

The first byte is received and handled as in the Slave Receiver Mode. However, in this mode, the direction bit will indicate that the transfer direction is reversed. Serial data is transmitted via P1.3/SDA while the serial clock is input through P1.2/SCL. START and STOP conditions are recognized as the beginning and end of a serial transfer. In a given application, I²C may operate as a master and as a slave. In the slave mode, the I²C hardware looks for its own slave address and the general call address. If one of these addresses is detected, an interrupt is requested. When the microcontrollers wishes to become the bus master, the hardware waits until the bus is free before the master mode is entered so that a possible slave action is not interrupted. If bus arbitration is lost in the master mode, I²C switches to the slave mode immediately and can detect its own slave address in the same serial transfer.

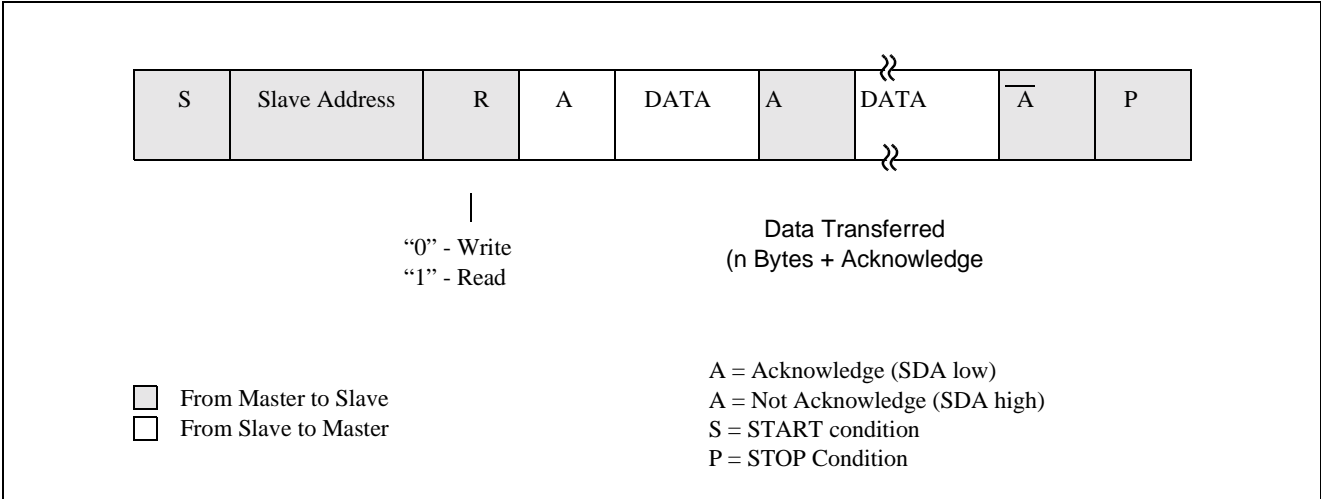
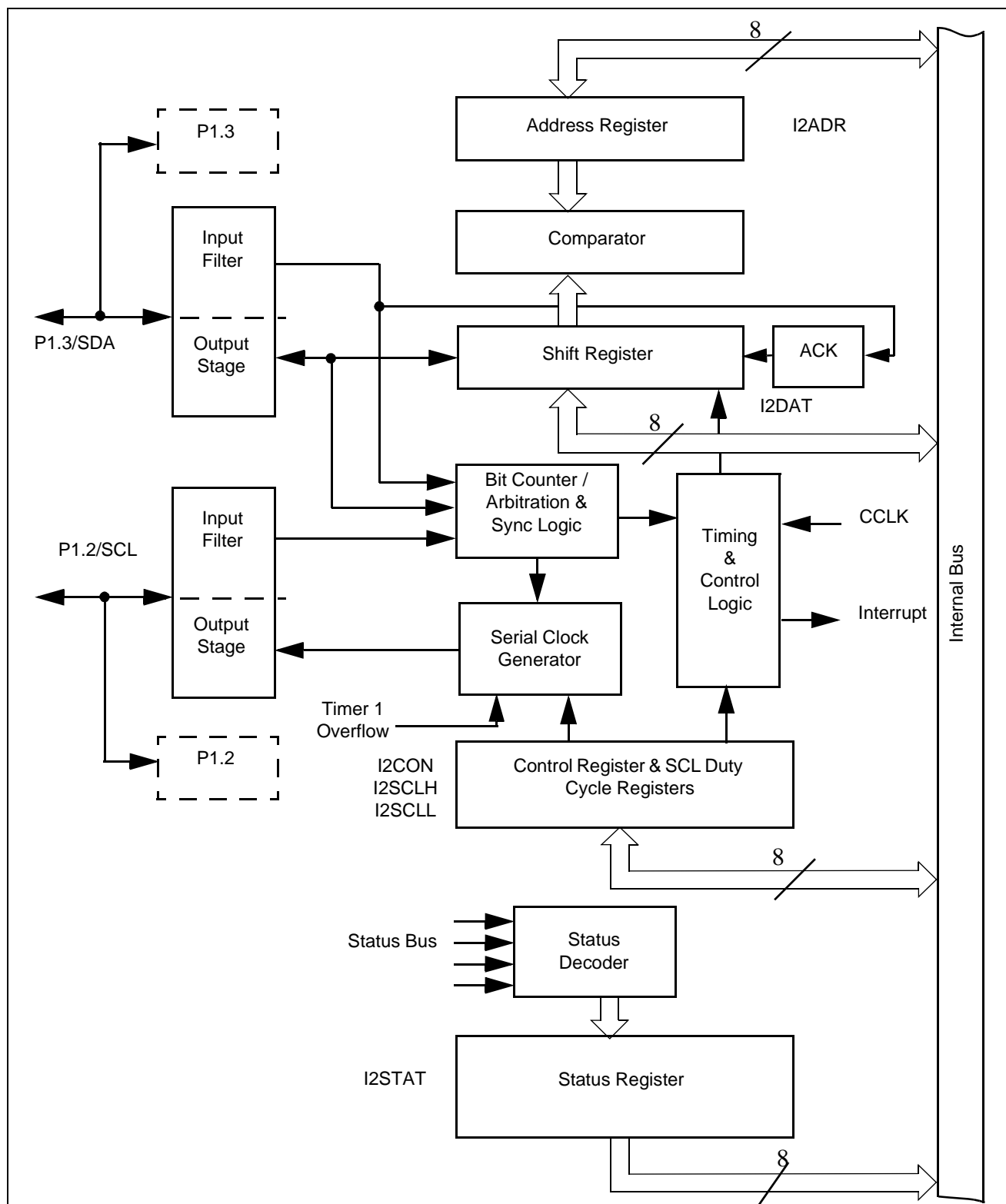


Figure 57: Format of Slave Transmitter Mode

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Figure 58: I²C-bus serial interface block diagram**

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 17: Master Transmitter Mode**

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
08H	A START condition has been transmitted	Load SLA+W	x	0	0	x	SLA+W will be transmitted; ACK bit will be received
10H	A repeat START condition has been transmitted	Load SLA+W or Load SLA+R	x	0	0	x	As above;SLA+W will be transmitted; I ² C switches to Master Receiver Mode
18h	SLA+W has been transmitted; ACK has been received	Load data byte or	0	0	0	x	Data byte will be transmitted; ACK bit will be received
		no I2DAT action or	1	0	0	x	Repeated START will be transmitted;
		no I2DAT action or	0	1	0	x	STOP condition will be transmitted; STO flag will be reset
		no I2DAT action	1	1	0	x	STOP condition followed by a START condition will be transmitted; STO flag will be reset.
20h	SLA+W has been transmitted;NOT-ACK has been received	Load data byte or	0	0	0	x	Data byte will be transmitted;ACK bit will be received
		no I2DAT action or	1	0	0	x	Repeated START will be transmitted;
		no I2DAT action or	0	1	0	x	STOP condition will be transmitted; STO flag will be reset
		no I2DAT action	1	1	0	x	STOP condition followed by a START condition will be transmitted; STO flag will be reset
28h	Data byte in I2DAT has been transmitted; ACK has been received	Load data byte or	0	0	0	x	Data byte will be transmitted; ACK bit will be received
		no I2DAT action or	1	0	0	x	Repeated START will be transmitted;
		no I2DAT action or	0	1	0	x	STOP condition will be transmitted; STO flag will be reset
		no I2DAT action	1	1	0	x	STOP condition followed by a START condition will be transmitted; STO flag will be reset

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 17: Master Transmitter Mode(Continued)**

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
30h	Data byte in I2DAT has been transmitted,NOT ACK hasbeen received	Load data byte or	0	0	0	x	Data byte will be transmitted; ACK bit will be received
		no I2DAT action or	1	0	0	x	Repeated START will be transmitted;
		no I2DAT action or	0	1	0	x	STOP condition will be transmitted; STO flag will be reset
		no I2DAT action	1	1	0	x	STOP condition followed by a START condition will be transmitted. STO flag will be reset.
38H	Arbitration lost in SLA+R/W or data bytes	No I2DAT action or	0	0	0	x	I ² C-bus will be released; not addressed slave will be entered
		No I2DAT action	1	0	0	x	A START condition will be transmitted when the bus becomes free.

Table 18: Master Receiver Mode

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
08H	A START condition has been transmitted	Load SLA+R	x	0	0	x	SLA+R will be transmitted; ACK bit will be received
10H	A repeat STARTcondition has been transmitted	Load SLA+R or	X	0	0	x	As above
		Load SLA+W	x	0	0	x	SLA+W will be transmitted; I ² C will be switches to Master Transmitter Mode
38H	Arbitration lost in NOT ACK bit	no I2DAT action or	0	0	0	x	I ² C will be released; it will enter a slave mode
		no I2DAT action	1	0	0	x	A START condition will be transmitted when the bus becomes free
40h	SLA+R has been transmitted;ACK has been received	no I2DAT action or	0	0	0	0	Data byte will be received; NOT ACK bit will be returned
		no I2DAT action or	0	0	0	1	Data byte will be received; ACK bit will be returned

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 18: Master Receiver Mode(Continued)**

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
48h	SLA+R has been transmitted; NOT ACK has been received	No I2DAT action or	1	0	0	x	Repeated START will be transmitted;
		no I2DAT action or	0	1	0	x	STOP condition will be transmitted; STO flag will be reset
		no I2DAT action or	1	1	0	x	STOP condition followed by a START condition will be transmitted; STO flag will be reset
50h	Data byte has been received; ACK has been returned	Read data byte	0	0	0	0	Data byte will be received; NOT ACK bit will be returned
		read data byte	0	0	0	1	Data byte will be received; ACK bit will be returned
58h	Data byte has been received; NACK has been returned	Read data byte or	1	0	0	x	Repeated START will be transmitted;
		read data byte or	0	1	0	x	STOP condition will be transmitted; STO flag will be reset
		read data byte	1	1	0	x	STOP condition followed by a START condition will be transmitted; STO flag will be reset

Table 19: Slave Receiver Mode

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
60H	Own SLA+W has been received; ACK has been received	no I2DAT action or	x	0	0	0	Data byte will be received and NOT ACK will be returned
		no I2DAT action	x	0	0	1	Data byte will be received and ACK will be returned
68H	Arbitration lost in SLA+R/Was master;Own SLA+W has been received, ACK returned	No I2DAT action or	x	0	0	0	Data byte will be received and NOT ACK will be returned
		no I2DAT action	x	0	0	1	Data byte will be received and ACK will be returned
70H	General call address(00H) has beenreceived, ACK has been returned	No I2DAT action or	x	0	0	0	Data byte will be received and NOT ACK will be returned
		no I2DAT action	x	0	0	1	Data byte will be received and ACK will be returned

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 19: Slave Receiver Mode(Continued)**

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
78H	Arbitration lost in SLA+R/W as master; General call addresshas been received, ACK bit has been returned	no I2DAT action or	x	0	0	0	Data byte will be received and NOT ACK will be returned
		no I2DAT action	x	0	0	1	Data byte will be received and ACK will be returned
80H	Previously addressed with own SLA address; Data has been received; ACK has been returned	Read data byte or	x	0	0	0	Data byte will be received and NOT ACK will be returned
		read data byte	x	0	0	1	Data byte will be received; ACK bit will be returned
88H	Previously addressed with own SLA address; Data has been received; NACK has been returned	Read data byte or	0	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or general address
		read data byte or	0	0	0	1	Switched to not addressed SLA mode; Own SLA will be recognized; general call address will be recognized if I2ADR.0=1
		read data byte or	1	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address. A START condition will be transmitted when the bus becomes free
		read data byte	1	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1. A START condition will be transmitted when the bus becomes free.
90H	Previously addressed with General call; Datahas been received; ACK has been returned	Read data byte or	x	0	0	0	Data byte will be received and NOT ACK will be returned
		read data byte	x	0	0	1	Data byte will be received and ACK will be returned

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 19: Slave Receiver Mode(Continued)**

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
98H	Previously addressed with General call; Data has been received; NACK has been returned	Read data byte	0	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address
		read data byte	0	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1.
		read data byte	1	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address. A START condition will be transmitted when the bus becomes free.
		read data byte	1	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1. A START condition will be transmitted when the bus becomes free.
A0H	A STOP condition or repeated START condition has been received while still addressed as SLA/ REC or SLA/TRX	No I2DAT action	0	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address
		no I2DAT action	0	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1.
		no I2DAT action	1	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address. A START condition will be transmitted when the bus becomes free.
		no I2DAT action	1	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1. A START condition will be transmitted when the bus becomes free.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Table 20: Slave Transmitter Mode**

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
A8h	Own SLA+R has been received; ACK has been returned	Load data byte or	x	0	0	0	Last data byte will be transmitted and ACK bit will be received
		load data byte	x	0	0	1	Data byte will be transmitted; ACK will be received
B0h	Arbitration lost in SLA+R/W as master; Own SLA+R has been received, ACK has been returned	Load data byte or	x	0	0	0	Last data byte will be transmitted and ACK bit will be received
		load data byte	x	0	0	1	Data byte will be transmitted; ACK bit will be received
B8H	Data byte in I2DAT has been transmitted; ACK has been received	Load data byte or	x	0	0	0	Last data byte will be transmitted and ACK bit will be received
		load data byte	x	0	0	1	Data byte will be transmitted; ACK will be received
C0H	Data byte in I2DAT has been transmitted; NACK has been received	No I2DAT action or	0	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address.
		no I2DAT action or	0	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1.
		no I2DAT action or	1	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address. A START condition will be transmitted when the bus becomes free.
		no I2DAT action	1	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1. A START condition will be transmitted when the bus becomes free.

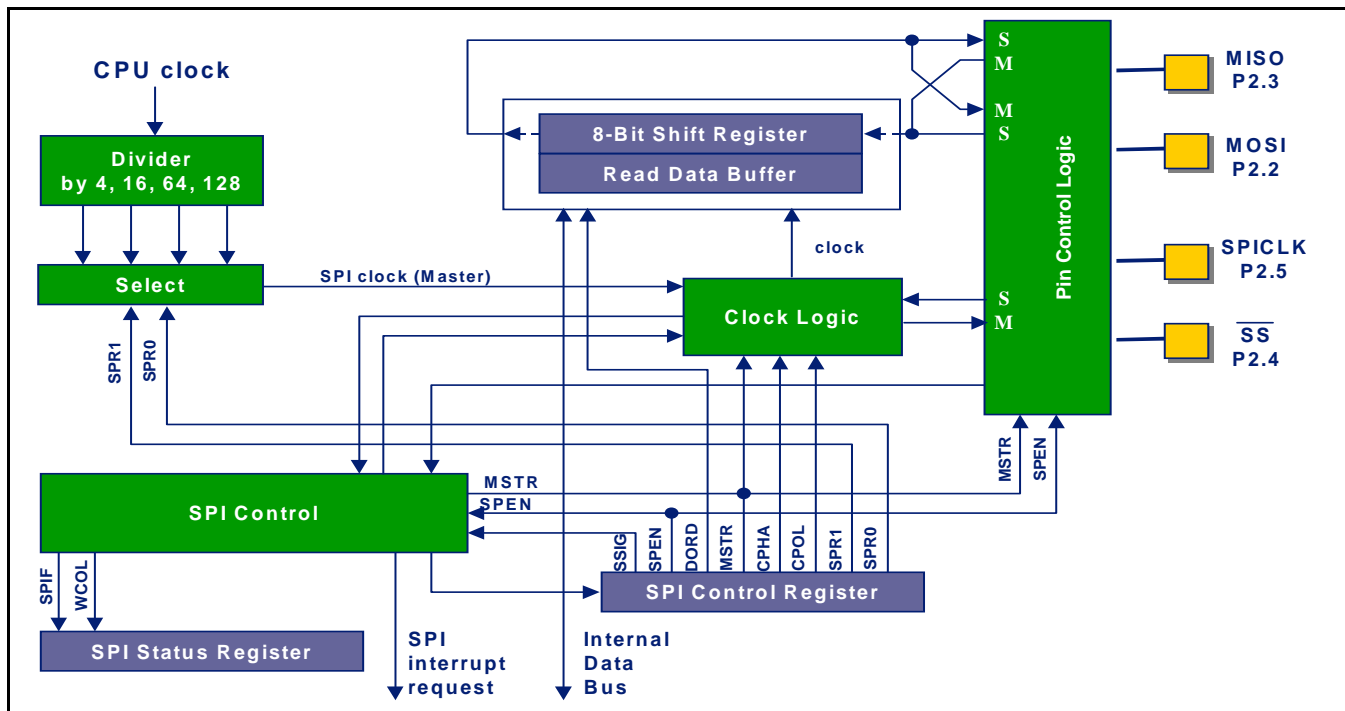
80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 20: Slave Transmitter Mode(Continued)**

Status code (I2STAT)	Status of the I ² C-bus hardware	Application software response					Next action taken by I ² C hardware
		to/from I2DAT	to I2CON				
			STA	STO	SI	AA	
C8H	Last data byte in I2DAT has been transmitted(AA=0); ACK has been received	No I2DAT action or	0	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address.
		no I2DAT action or	0	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1.
		no I2DAT action or	1	0	0	0	Switched to not addressed SLA mode; no recognition of own SLA or General call address. A START condition will be transmitted when the bus becomes free.
		no I2DAT action	1	0	0	1	Switched to not addressed SLA mode; Own slave address will be recognized; General call address will be recognized if I2ADR.0=1. A START condition will be transmitted when the bus becomes free.

For more information about the I²C interface, please refer to the I²C specification.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Serial Peripheral Interface (SPI)**

LPC932 provides another high-speed serial communication interface, the SPI interface. SPI is a full-duplex, high-speed, synchronous communication bus with two operation modes: Master mode and Slave mode. Up to 3 Mbit/s can be supported in either Master or Slave mode. It has a Transfer Completion Flag and Write Collision Flag Protection.

**Figure 59: SPI block diagram**

The SPI interface has four pins: SPICLK, MOSI, MISO and \overline{SS} :

- SPICLK, MOSI and MISO are typically tied together between two or more SPI devices. Data flows from master to slave on the MOSI (Master Out Slave In) pin and flows from slave to master on the MISO (Master In Slave Out) pin. The SPICLK signal is output in the master mode and is input in the slave mode. If the SPI system is disabled, i.e. SPEN (SPCTL.6) = 0 (reset value), these pins are configured for port functions.
 - \overline{SS} is the optional slave select pin. In a typical configuration, an SPI master asserts one of its port pins to select one SPI device as the current slave. An SPI slave device uses its \overline{SS} pin to determine whether it is selected. The \overline{SS} is ignored if any of the following conditions are true:
 - If the SPI system is disabled, i.e. SPEN (SPCTL.6) = 0 (reset value)
 - If the SPI is configured as a master, i.e., MSTR (SPCTL.4) = 1, and P2.4 is configured as an output (via the P2M1.4 and P2M2.4 SFR bits);
 - If the \overline{SS} pin is ignored, i.e. SSIG(SPCTL.7) bit = 1, this pin is configured for port functions.
- Note that even if the SPI is configured as a master (MSTR = 1), it can still be converted to a slave by driving the \overline{SS} pin low (if P2.4 is configured as input and SSIG = 0). Should this happen, the SPIF bit (SPSTAT.7) will be set (see section "Mode change on \overline{SS} ").

Typical connections are shown in Figures 63 - 65.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

SPCTL			7	6	5	4	3	2	1	0
Address: E2h			SSIG	SPEN	DORD	MSTR	CPOL	CPHA	SPR1	SPR0
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: 00000100B										
BIT	SYMBOL	FUNCTION								
SPCTL.7	SSIG	\overline{SS} IGNore. If set = 1, MSTR (bit 4) decides whether the device is a master or slave. If cleared = 0, the \overline{SS} pin decides whether the device is master or slave. The \overline{SS} pin can be used as a port pin (see Table 21).								
SPCTL.6	SPEN	SPI Enable. If set = 1, the SPI is enabled. If cleared = 0, the SPI is disabled and all SPI pins will be port pins..								
SPCTL.5	DORD	SPI Data ORDer.								
		1: The LSB of the data word is transmitted first.								
		0: The MSB of the data word is transmitted first.								
SPCTL.4	MSTR	Master/Slave mode Select (see Table 21).								
SPCTL.3	CPOL	SPI Clock Polarity (see Figures 66 - 69):								
		1: SPICLK is high when idle. The leading edge of SPICLK is the falling edge and the trailing edge is the rising edge.								
		0: SPICLK is low when idle. The leading edge of SPICLK is the rising edge and the trailing edge is the falling edge.								
SPCTL.2	CPHA	SPI CLock Phase select (see Figures 66 - 69):								
		1: Data is driven on the leading edge of SPICLK, and is sampled on the trailing edge.								
		0: Data is driven when SS is low (SSIG = 0) and changes on the trailing edge of SPICLK, and is sampled on the leading edge. (Note: If SSIG = 1, the operation is not defined.)								
SPCTL.1-0	SPR1-SPR0	SPI Clock Rate Select:								
	<u>SPR1-SPR0</u>	<u>SPI Clock Rate</u>								
	0 0	CCLK/4								
	0 1	CCLK/16								
	1 0	CCLK/64								
	1 1	CCLK/128								

Figure 60: SPI Control register

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****SPSTAT**

Address: E1h

Not bit addressable

Reset Source(s): Any reset

Reset Value: 00xxxxxB

7	6	5	4	3	2	1	0
SPIF	WCOL	-	-	-	-	-	-

BIT	SYMBOL	FUNCTION
SPSTAT.7	SPIF	SPI Transfer Completion Flag. When a serial transfer finishes, the SPIF bit is set and an interrupt is generated if both the ESPI (IEN1.3) bit and the EA bit are set. If \overline{SS} is an input and is driven low when SPI is in master mode, and SSIG = 0, this bit will also be set (see section "Mode change on SS"). The SPIF flag is cleared in software by writing '1' to this bit.
SPSTAT.6	WCOL	SPI Write Collision Flag. The WCOL bit is set if the SPI data register, SPDAT, is written during a data transfer (see section "Write collision"). The WCOL flag is cleared in software by writing '1' to this bit.
SPSTAT.5-0	-	Reserved for future use. Should not be set to 1 by user programs.

Figure 61: SPI Status register definition**SPDAT**

Address: E3h

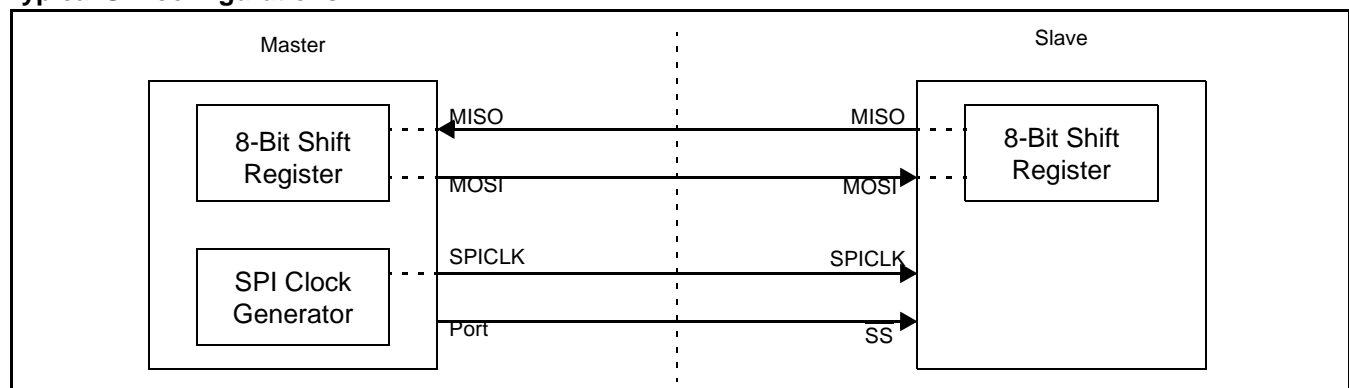
Not bit addressable

Reset Source(s): Any reset

Reset Value: 00000000B

7	6	5	4	3	2	1	0
MSB							LSB

BIT	SYMBOL	FUNCTION
SPD.7-0	-	Bit 7-0 of data transferred.

Figure 62: SPI Data register**Typical SPI configurations****Figure 63: SPI single master single slave configuration**

In Figure 63, SSIG (SPCTL.7) for the slave is '0', and \overline{SS} is used to select the slave. The SPI master can use any port pin (including P2.4/ \overline{SS}) to drive the \overline{SS} pin.

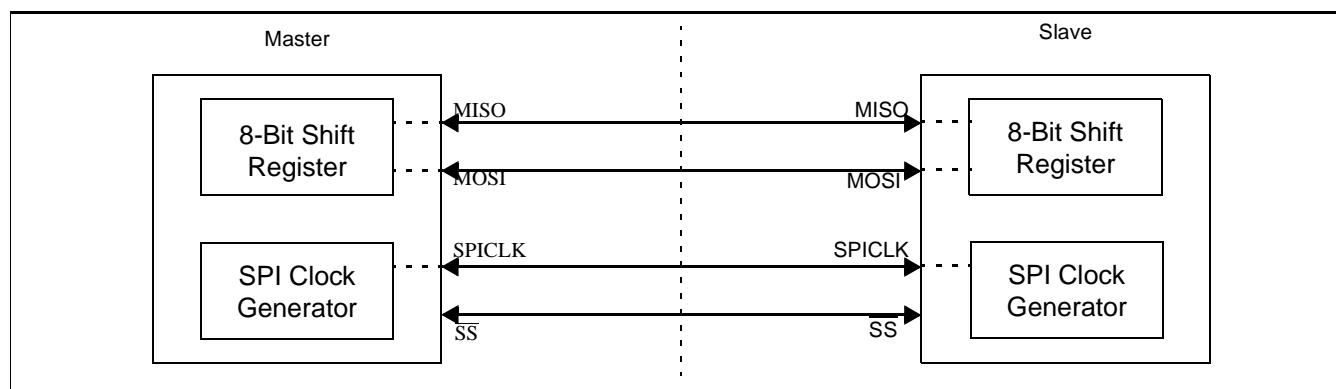
80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

Figure 64: SPI dual device configuration, where either can be a master or a slave.

Figure shows a case where two devices are connected to each other and either device can be a master or a slave. When no SPI operation is occurring, both can be configured as masters ($MSTR = 1$) with $SSIG$ cleared to 0 and P2.4 (\overline{SS}) configured in quasi-bidirectional mode. When a device initiates a transfer, it can configure P2.4 as an output and drive it low, forcing a mode change in the other device (see section "Mode change on \overline{SS} ") to slave.

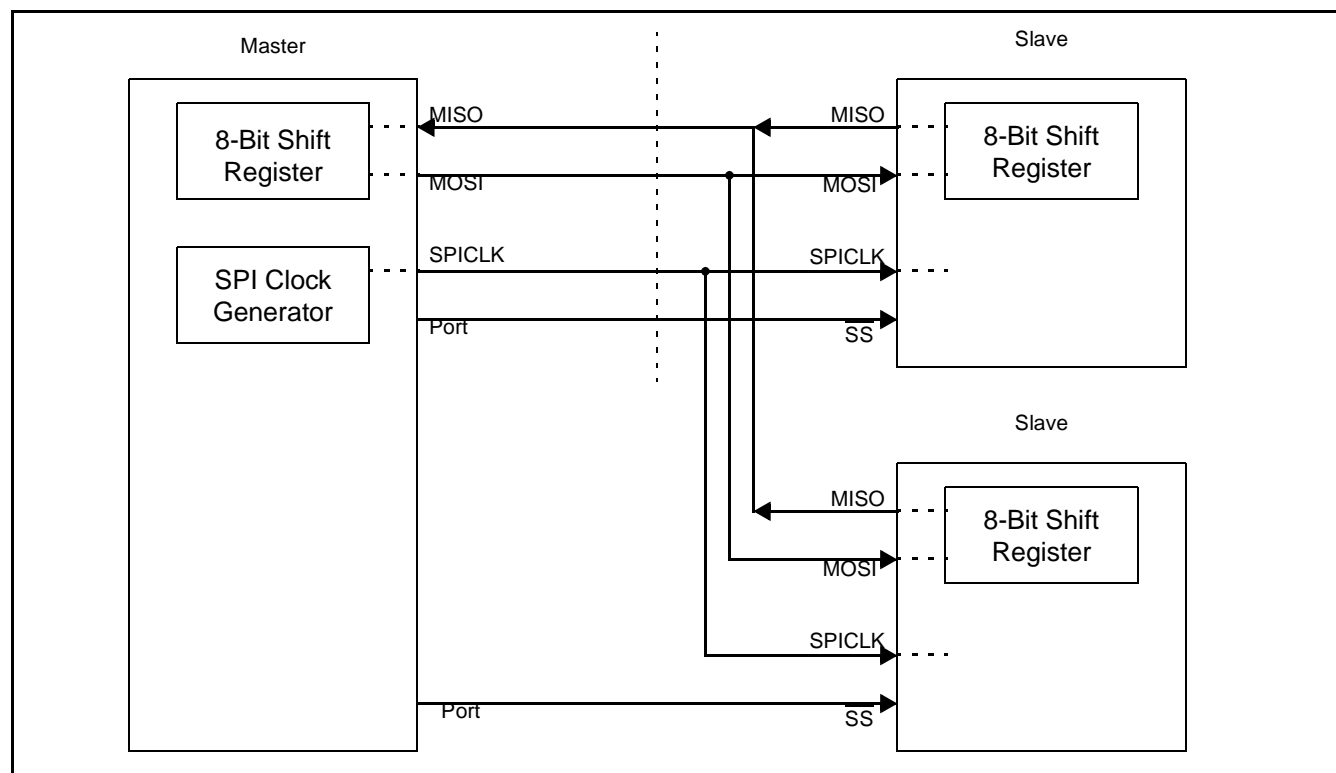


Figure 65: SPI single master multiple slaves configuration

In Figure 65, $SSIG$ (SPCTL.7) bits for the slaves are '0', and the slaves are selected by the corresponding \overline{SS} signals. The SPI master can use any port pin (including P2.4/ \overline{SS}) to drive the \overline{SS} pins.

Configuring the SPI

Table 21 shows configuration for the master/slave modes as well as usages and directions for the modes.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 21: SPI master and slave selection**

SPEN (SPCTL.6)	SSIG (SPCTL.7)	P2M2.4	\overline{SS} Pin	MSTR (SPCTL.4)	Master or Slave Mode	MISO	MOSI	SPICLK	Remarks
0	X	X	P2.4 ¹	X	SPI Disabled	P2.3 ¹	P2.2 ¹	P2.5 ¹	SPI disabled. P2.2, P2.3, P2.4, P2.5 are used as port pins.
1	0	X	0	0	Slave	output	input	input	Selected as slave.
1	0	X	1	0	Slave	Hi-Z	input	input	Not selected. MISO is high impedance to avoid bus contention.
1	0	0	0	1 (-> 0) ²	Slave	output	input	input	P2.4/ \overline{SS} is configured as an input or quasi-bidirectional pin. SSIG is 0. Selected externally as slave if \overline{SS} is selected and is driven low. The MSTR bit will be cleared to '0' when \overline{SS} becomes low.
1	0	0	1	1	Master	input	Hi-Z	Hi-Z	MOSI and SPICLK are at high impedance to avoid bus contention. Note that the user must pull-up or pull-down SPICLK (depending on CPOL - SPCTL.3) to avoid a floating SPICLK.
1	0	1	X	1	Master	input	output	output	MOSI and SPICLK are push-pull.
1	1	X	P2.4 ¹	0	Slave	output	input	input	
1	1	X	P2.4 ¹	1	Master	input	output	output	

1. Selected as a port function.

2. The MSTR bit changes to '0' automatically when \overline{SS} becomes low in input mode and SSIG is 0.**Additional considerations for a slave**

When CPHA equals zero, SSIG must be '0' and the \overline{SS} pin must be negated and reasserted between each successive serial byte. If the SPDAT register is written while \overline{SS} is active (low), a write collision error results. The operation is undefined if CPHA is '0' and SSIG is '1'.

When CPHA equals one, SSIG may be set to '1'. If SSIG = 0, the \overline{SS} pin may remain active low between successive transfers (can be tied low at all times). This format is sometimes preferred in systems having a single fixed master and a single slave driving the MISO data line.

Additional considerations for a master

In SPI, transfers are always initiated by the master. If the SPI is enabled (SPEN = 1) and selected as master, writing to the SPI data register by the master starts the SPI clock generator and data transfer. The data will start to appear on MOSI about one half SPI bit-time to one SPI bit-time after data is written to SPDAT.

Note that the master can select a slave by driving the \overline{SS} pin of the corresponding device low. Data written to the SPDAT register of the master is shifted out of the MOSI pin of the master to the MOSI pin of the slave, at the same time the data in SPDAT register in slave side is shifted out on MISO pin to the MISO pin of the master.

After shifting one byte, the SPI clock generator stops, setting the transfer completion flag (SPIF) and an interrupt will be created if the SPI interrupt is enabled (ESPI, or IEN1.3 = 1). The two shift registers in the master CPU and slave CPU can be considered as one distributed 16-bit circular shift register. When data is shifted from the master to the slave, data is also shifted in the opposite direction simultaneously. This means that during one shift cycle, data in the master and the slave are interchanged.

Mode change on \overline{SS}

If SPEN = 1, SSIG = 0 and MSTR = 1, the SPI is enabled in master mode. The \overline{SS} pin can be configured as an input or quasi-bidirectional (P2M2.4 = 0). In this case, another master can drive this pin low to select this device as an SPI slave and start sending data to it. To avoid bus contention, the CPU becomes a slave. As a result of the SPI becoming a slave, the MOSI and SPICLK pins are forced to be an input and MISO becomes an output.

2. The SPIF flag in SPSTAT is set, and if the SPI interrupt is enabled, an SPI interrupt will occur.

User software should always check the MSTR bit. If this bit is cleared by a slave select and the user wants to continue to use the SPI as a master, the user must reset the MSTR bit, otherwise it will stay in slave mode.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Write collision**

The SPI is single buffered in the transmit direction and double buffered in the receive direction. New data for transmission can not be written to the shift register until the previous transaction is complete. The WCOL (SPSTAT.6) bit is set to indicate data collision when the data register is written during transmission. In this case, the data currently being transmitted will continue to be transmitted, but the new data, i.e., the one causing the collision, will be lost.

While write collision is detected for both a master or a slave, it is uncommon for a master because the master has full control of the transfer in progress. The slave, however, has no control over when the master will initiate a transfer and therefore collision can occur.

For receiving data, received data is transferred into a parallel read data buffer so that the shift register is free to accept a second character. However, the received character must be read from the Data Register before the next character has been completely shifted in. Otherwise, the previous data is lost.

WCOL can be cleared in software by a write with a '1' to the bit.

Data mode

Clock Phase Bit (CPHA) allows user to set the edges for sampling and changing data. Clock Polarity bit CPOL allows user to set the clock polarity. Figures 66 - 69 show the different settings of Clock Phase bit CPHA.

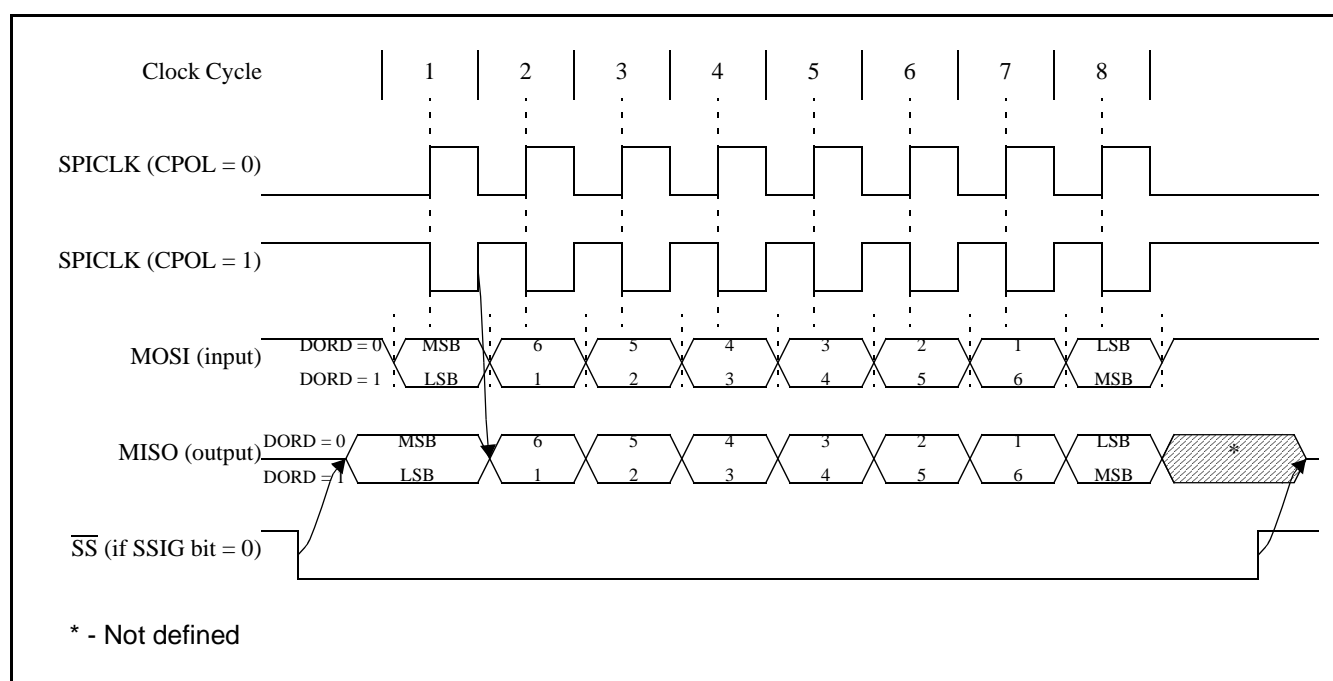
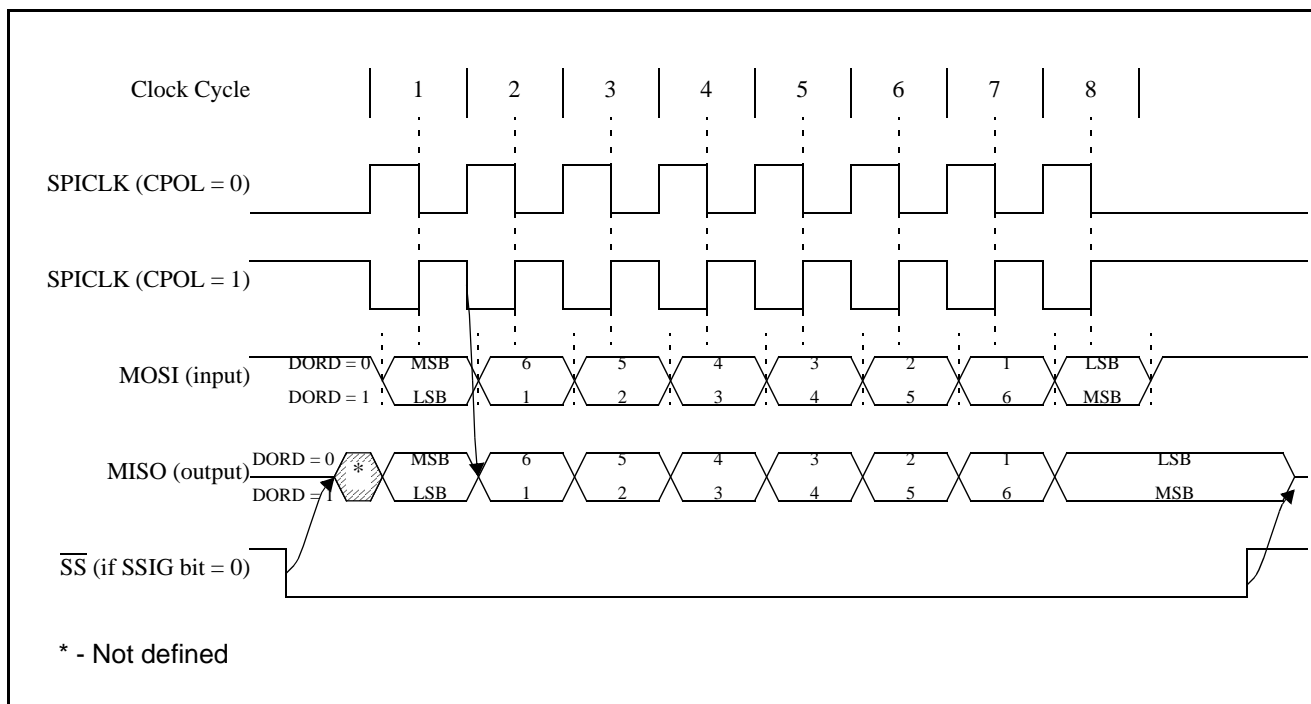
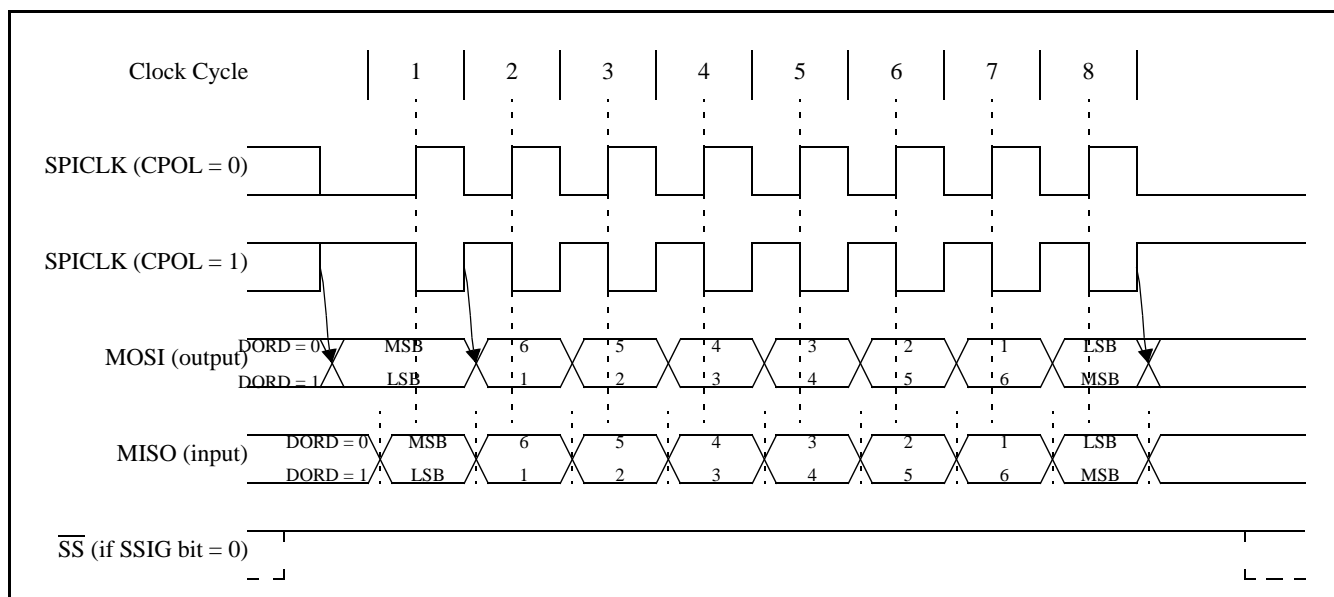
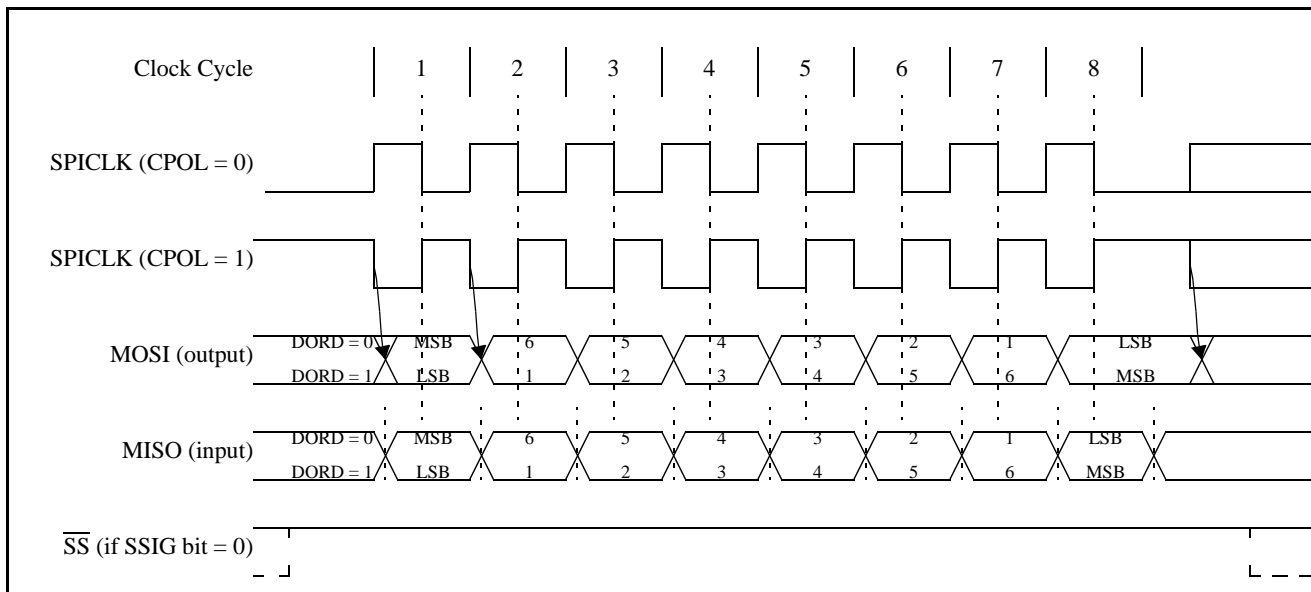


Figure 66: SPI slave transfer format with CPHA = 0

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Figure 67: SPI slave transfer format with CPHA = 1****Figure 68: SPI master transfer format with CPHA = 0**

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Figure 69: SPI master transfer format with CPHA = 1****SPI clock prescaler select**

The SPI clock prescaler selection uses the SPR1-SPR0 bits in the SPCTL register (see Figure 60).

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Analog comparators**

Two analog comparators are provided on the LPC932. Input and output options allow use of the comparators in a number of different configurations. Comparator operation is such that the output is a logical one (which may be read in a register and/or routed to a pin) when the positive input (one of two selectable pins) is greater than the negative input (selectable from a pin or an internal reference voltage). Otherwise the output is a zero. Each comparator may be configured to cause an interrupt when the output value changes.

Comparator configuration

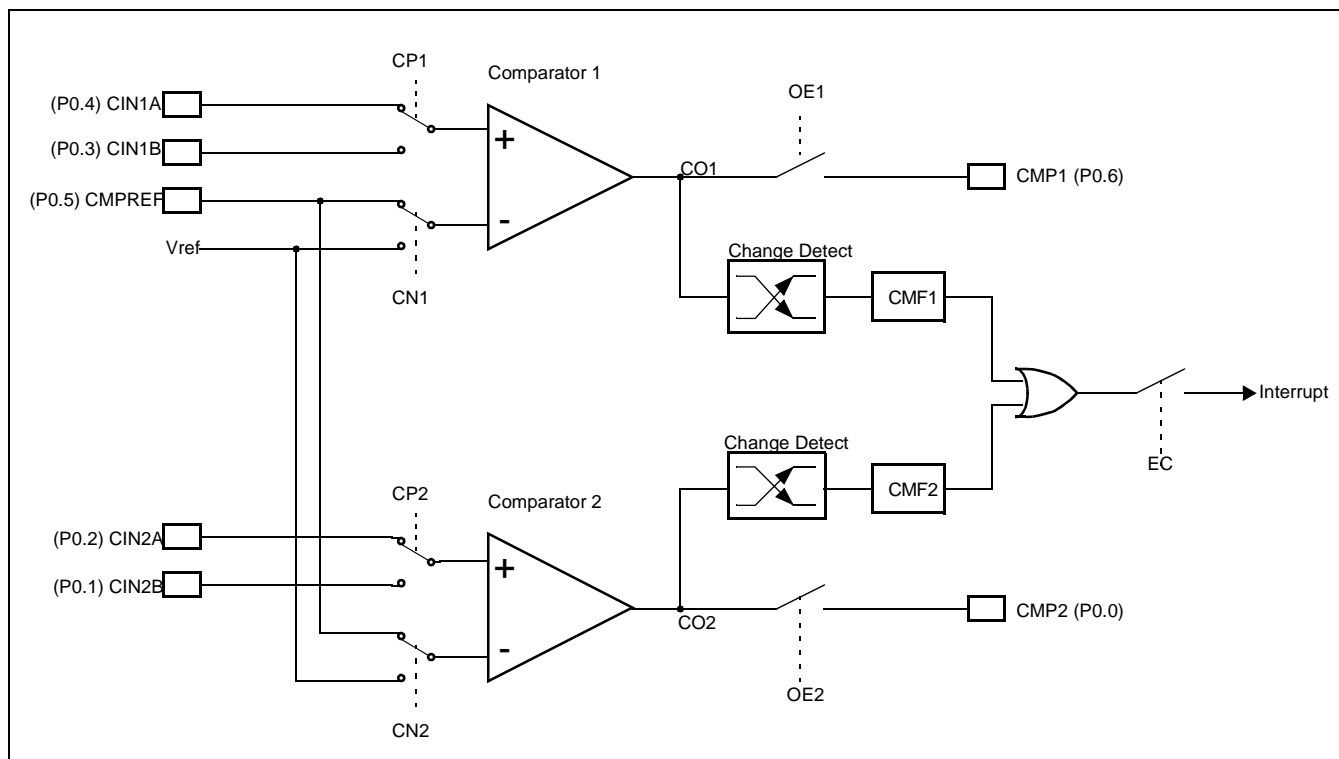
Each comparator has a control register, CMP1 for comparator 1 and CMP2 for comparator 2. The control registers are identical and are shown in Figure 70.

The overall connections to both comparators are shown in Figure 71. There are eight possible configurations for each comparator, as determined by the control bits in the corresponding CMPn register: CPn, CNn, and OEn. These configurations are shown in Figure 72.

When each comparator is first enabled, the comparator output and interrupt flag are not guaranteed to be stable for 10 microseconds. The corresponding comparator interrupt should not be enabled during that time, and the comparator interrupt flag must be cleared before the interrupt is enabled in order to prevent an immediate interrupt service.

CMPn		
Address: ACh for CMP1, ADh for CMP2		
	7	6 5 4 3 2 1 0
Not bit addressable	-	- CEn CPn CNn OEn COn CMFn
Reset Source(s): Any reset		
Reset Value: xx00000B		
BIT	SYMBOL	FUNCTION
CMPn.7, 6	-	Reserved for future use. Should not be set to 1 by user programs.
CMPn.5	CEn	Comparator enable. When set, the corresponding comparator function is enabled. Comparator output is stable 10 microseconds after CEn is set.
CMPn.4	CPn	Comparator positive input select. When 0, CINnA is selected as the positive comparator input. When 1, CINnB is selected as the positive comparator input.
CMPn.3	CNn	Comparator negative input select. When 0, the comparator reference pin CMPREF is selected as the negative comparator input. When 1, the internal comparator reference, Vref, is selected as the negative comparator input.
CMPn.2	OEn	Output enable. When 1, the comparator output is connected to the CMPn pin if the comparator is enabled (CEn = 1). This output is asynchronous to the CPU clock.
CMPn.1	COn	Comparator output, synchronized to the CPU clock to allow reading by software.
CMPn.0	CMFn	Comparator interrupt flag. This bit is set by hardware whenever the comparator output COn changes state. This bit will cause a hardware interrupt if enabled. Cleared by software.

Figure 70: Comparator control registers (CMP1 and CMP2)

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Figure 71: Comparator input and output connections****Internal reference voltage**

An internal reference voltage, V_{ref} , may supply a default reference when a single comparator input pin is used. Please refer to the Datasheet for specifications.

Comparator interrupt

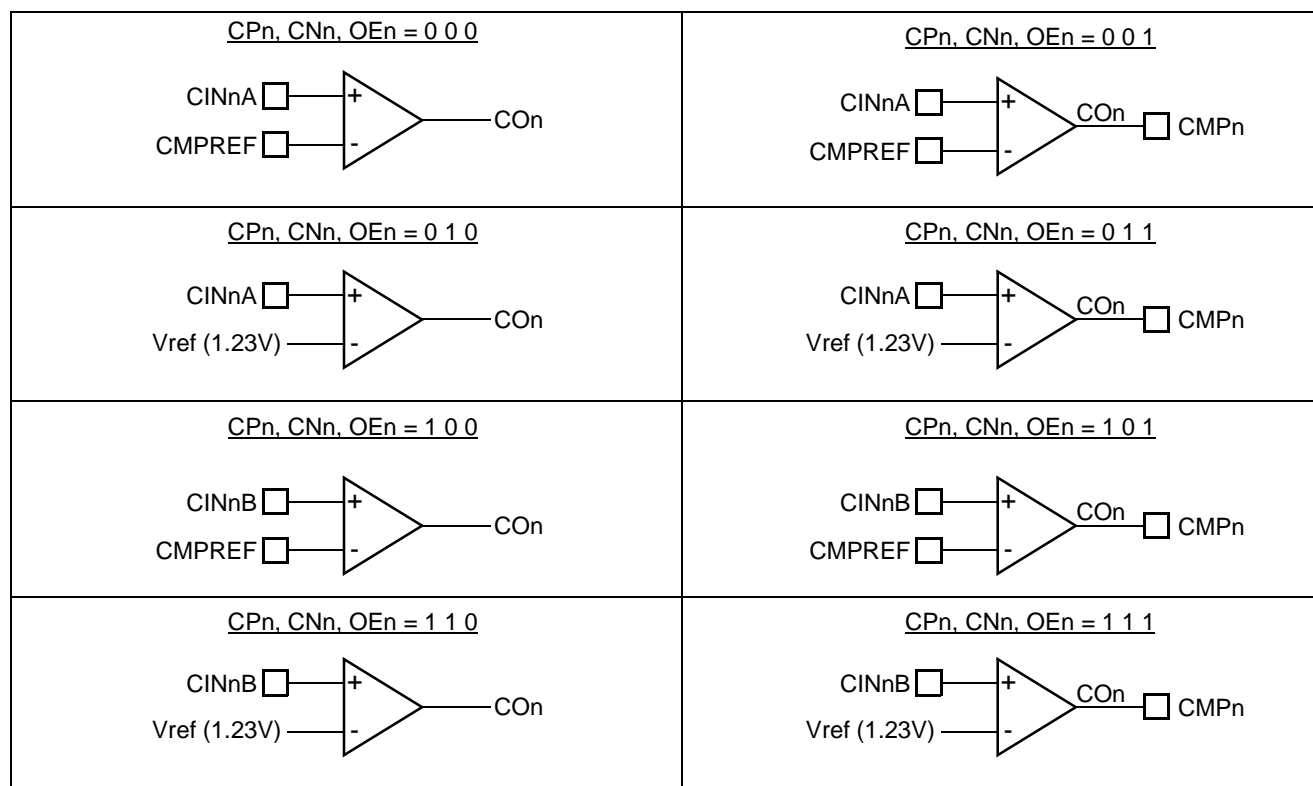
Each comparator has an interrupt flag CMF_n contained in its configuration register. This flag is set whenever the comparator output changes state. The flag may be polled by software or may be used to generate an interrupt. The two comparators use one common interrupt vector. The interrupt will be generated when the interrupt enable bit EC in the $IEN1$ register is set and the interrupt system is enabled via the EA bit in the $IEN0$ register. If both comparators enable interrupts, after entering the interrupt service routine, the user will need to read the flags to determine which comparator caused the interrupt.

Comparators and power reduction modes

Either or both comparators may remain enabled when Power down or Idle mode is activated, but both comparators are disabled automatically in Total Power down mode.

If a comparator interrupt is enabled (except in Total Power down mode), a change of the comparator output state will generate an interrupt and wake up the processor. If the comparator output to a pin is enabled, the pin should be configured in the push-pull mode in order to obtain fast switching times while in Power down mode. The reason is that with the **oscillator** stopped, the temporary strong pull-up that normally occurs during switching on a quasi-bidirectional port pin does not take place.

Comparators consume power in Power down and Idle modes, as well as in the normal operating mode. This should be taken into consideration when system power consumption is an issue. To minimize power consumption, the user can Power down the comparators by disabling the comparators and setting $PCONA.5$ to '1', or simply putting the device in Total Power down mode.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Figure 72: Comparator configurations****Comparator configuration example**

The code shown below is an example of initializing one comparator. Comparator 1 is configured to use the CIN1A and CMPREF inputs, outputs the comparator result to the CMP1 pin, and generates an interrupt when the comparator output changes.

CMPINIT:

```

MOV    PT0AD,#030h    ; Disable digital INPUTS on pins that are used for analog functions: CIN1A, CMPREF.
ANL    P0M2,#0CFh     ; Disable digital OUTPUTS on pins that are used
ORL    P0M1,#030h     ; for analog functions: CIN1A, CMPREF.
MOV    CMP1,#024h     ; Turn on comparator 1 and set up for:
                        ; - Positive input on CIN1A.
                        ; - Negative input from CMPREF pin.
                        ; - Output to CMP1 pin enabled.

CALL   delay10us      ; The comparator has to start up for at least 10 microseconds before use.
ANL    CMP1,#0FEh     ; Clear comparator 1 interrupt flag.
SETB   EC             ; Enable the comparator interrupt. The priority is left at the current value.
SETB   EA             ; Enable the interrupt system (if needed).
RET                                ; Return to caller.

```

The interrupt routine used for the comparator must clear the interrupt flag (CMF1 in this case) before returning.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Keypad interrupt (KBI)**

The Keypad Interrupt function is intended primarily to allow a single interrupt to be generated when Port 0 is equal to or not equal to a certain pattern. This function can be used for bus address recognition or keypad recognition. The user can configure the port via SFRs for different tasks.

There are three SFRs used for this function. The Keypad Interrupt Mask Register (KBMASK) is used to define which input pins connected to Port 0 are enabled to trigger the interrupt. The Keypad Pattern Register (KBPATN) is used to define a pattern that is compared to the value of Port 0. The Keypad Interrupt Flag (KBIF) in the Keypad Interrupt Control Register (KBICON) is set when the condition is matched while the Keypad Interrupt function is active. An interrupt will be generated if it has been enabled by setting the EKBI bit in IEN1 register and EA = 1. The PATN_SEL bit in the Keypad Interrupt Control Register (KBICON) is used to define equal or not-equal for the comparison.

In order to use the Keypad Interrupt as an original KBI function like in the 87LPC76x series, the user needs to set KBPATN = 0FFh and PATN_SEL = 1 (not equal), then any key connected to Port0 which is enabled by KBMASK register is will cause the hardware to set KBIF = 1 and generate an interrupt if it has been enabled. The interrupt may be used to wake up the CPU from Idle or Power down modes. This feature is particularly useful in handheld, battery powered systems that need to carefully manage power consumption yet also need to be convenient to use.

In order to set the flag and and cause an interrupt, the pattern on Port 0 must be held longer than 6 CCLKs.

KBPATN			7	6	5	4	3	2	1	0
Address: 93h			KBPATN.7	KBPATN.6	KBPATN.5	KBPATN.4	KBPATN.3	KBPATN.2	KBPATN.1	KBPATN.0
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: 11111111B										
BIT	SYMBOL	FUNCTION								
KBPATN.7-0	-	Pattern bit 7 - bit 0								

Figure 73: Keypad Pattern register

KBICON			7	6	5	4	3	2	1	0
Address: 94h			-	-	-	-	-	-	PATN_SEL	KBIF
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: xxxxxx00B										
BIT	SYMBOL	FUNCTION								
KBICON.7-2	-	Reserved								
KBICON.1	PATN_SEL	Pattern Matching Polarity selection. When set, Port 0 has to be equal to the user-defined Pattern in KBPATN to generate the interrupt. When clear, Port 0 has to be not equal to the value of KBPATN register to generate the interrupt.								
KBICON.0	KBIF	Keypad Interrupt Flag. Set when Port 0 matches user defined conditions specified in KBPATN, KBMASK, and PATN_SEL. Needs to be cleared by software by writing "0".								

Figure 74: Keypad Control register

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

KBMASK			7	6	5	4	3	2	1	0
Address: 86h			KBMASK.7	KBMASK.6	KBMASK.5	KBMASK.4	KBMASK.3	KBMASK.2	KBMASK.1	KBMASK.0
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: 00000000B										
BIT	SYMBOL	FUNCTION								
KBMASK.7	-	When set, enables P0.7 as a cause of a Keypad Interrupt.								
KBMASK.6	-	When set, enables P0.6 as a cause of a Keypad Interrupt.								
KBMASK.5	-	When set, enables P0.5 as a cause of a Keypad Interrupt.								
KBMASK.4	-	When set, enables P0.4 as a cause of a Keypad Interrupt.								
KBMASK.3	-	When set, enables P0.3 as a cause of a Keypad Interrupt.								
KBMASK.2	-	When set, enables P0.2 as a cause of a Keypad Interrupt.								
KBMASK.1	-	When set, enables P0.1 as a cause of a Keypad Interrupt.								
KBMASK.0	-	When set, enables P0.0 as a cause of a Keypad Interrupt.								
Note: the Keypad Interrupt must be enabled in order for the settings of the KBMASK register to be effective.										

Figure 75: Keypad Interrupt Mask register (KBM)

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Watchdog timer**

The watchdog timer subsystem protects the system from incorrect code execution by causing a system reset when it underflows as a result of a failure of software to feed the timer prior to the timer reaching its terminal count. The watchdog timer can only be reset by a power-on reset.

Watchdog function

The watchdog timer has an on-chip 400 kHz oscillator. When the watchdog is enabled, it can run from the watchdog oscillator or from PCLK (refer to Figure 76) by configuring the WDCLK bit in the Watchdog Control Register WDCON. When the watchdog feature is enabled, the timer must be fed regularly by software in order to prevent it from resetting the CPU.

There are four SFRs used for the watchdog function: Watchdog Control Register(WDCON), Watchdog Load Register(WDL), and Watchdog Feed Registers, WFEED1 and WFEED2.

There are two SFR bits in Flash configuration byte UCFG1 that are related to watchdog configuration: the Watchdog Timer Enable bit, (WDTE), and the Watchdog Safety Enable bit, (WDSE). Refer to the following table for details about these two bits.

Table 22: Watchdog timer configuration

WDTE (UCFG1.7)	WDSE (UCFG1.4)	FUNCTION
0	x	The watchdog is disabled. The timer can be used as an internal timer and can be used to generate an interrupt. WDSE has no effect.
1	0	The watchdog is enabled. The user can set WDCLK to choose the clock source.
1	1	The watchdog is enabled, along with additional safety features: 1. WDCLK is forced to 1 (using watchdog oscillator) 2. WDCON and WDL register can only be written once 3. WDRUN is forced to 1

Figure 78 shows the watchdog timer in watchdog mode. It consists of a programmable 13-bit prescaler, and an 8-bit down counter. The down counter is clocked (decrement) by a tap taken from the prescaler. The clock source for the prescaler is either the PCLK or watchdog oscillator selected by the WDCLK bit in the WDCON register. (Note that switching of the clock sources will not take effect immediately - see section "Switching of the Watchdog clock source").

When the watchdog feature is disabled, it can be used as an interval timer and may generate an interrupt.

The watchdog asserts the watchdog reset when the watchdog count underflows and the watchdog is enabled. When the watchdog is enabled, writing to WDL or WDCON must be followed by a feed sequence for the new values to take effect.

If a watchdog reset occurs, the internal reset is active for at least one watchdog clock cycle (PCLK or the watchdog oscillator clock). If CCLK is still running, code execution will begin immediately after the reset cycle. If the processor was in Power down mode, the watchdog reset will start the oscillator and code execution will resume after the oscillator is stable.

Feed sequence

The watchdog timer control register and the 8-bit down counter (Figure 78) are not directly loaded by the user. The user writes to the WDCON and the WDL SFRs. At the end of a feed sequence, the values in the WDCON and WDL SFRs are loaded to the control register and the 8-bit down counter. Before the feed sequence, any new values written to these two SFRs will not take effect. To avoid a watchdog reset, the watchdog timer needs to be fed (via a special sequence of software action called the feed sequence) prior to reaching an underflow.

To feed the watchdog, two write instructions must be sequentially executed successfully. Between the two write instructions, SFR reads are allowed, but writes are not allowed. The instructions should move A5H to the WFEED1 register and then 5AH to the WFEED2 register. An incorrect feed sequence will cause an immediate watchdog reset. The program sequence to feed the watchdog timer is as follows:

```
CLR    EA                      ; disable interrupt
MOV    WFEED1,#0A5h           ; do watchdog feed part 1
```

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

```

MOV    WFEED2,#05Ah      ; do watchdog feed part 2
SETB   EA                ; enable interrupt

```

This sequence assumes that the LPC932 interrupt system is enabled and there is a possibility of an interrupt request occurring during the feed sequence. If an interrupt was allowed to be serviced and the service routine contained any SFR writes, it would trigger a watchdog reset. If it is known that no interrupt could occur during the feed sequence, the instructions to disable and re-enable interrupts may be removed.

In watchdog mode (WDTE = 1), writing the WDCON register must be IMMEDIATELY followed by a feed sequence to load the WDL to the 8-bit down counter, and the WDCON to the shadow register. If writing to the WDCON register is not immediately followed by the feed sequence, a watchdog reset will occur.

For example: setting WDRUN = 1:

```

MOV    ACC,WDCON          ; get WDCON
SETB   ACC.2              ; set WD_RUN=1
MOV    WDL,#0FFh          ; New count to be loaded to 8-bit down counter
CLR    EA                 ; disable interrupt
MOV    WDCON,ACC          ; write back to WDCON (after the watchdog is enabled, a feed must occur
                          ; immediately)

MOV    WFEED1,#0A5h       ; do watchdog feed part 1
MOV    WFEED2,#05Ah       ; do watchdog feed part 2
SETB   EA                 ; enable interrupt

```

In timer mode (WDTE = 0), WDCON is loaded to the control register every CCLK cycle (no feed sequence is required to load the control register), but a feed sequence **is required** to load from the WDL SFR to the 8-bit down counter before a time-out occurs.

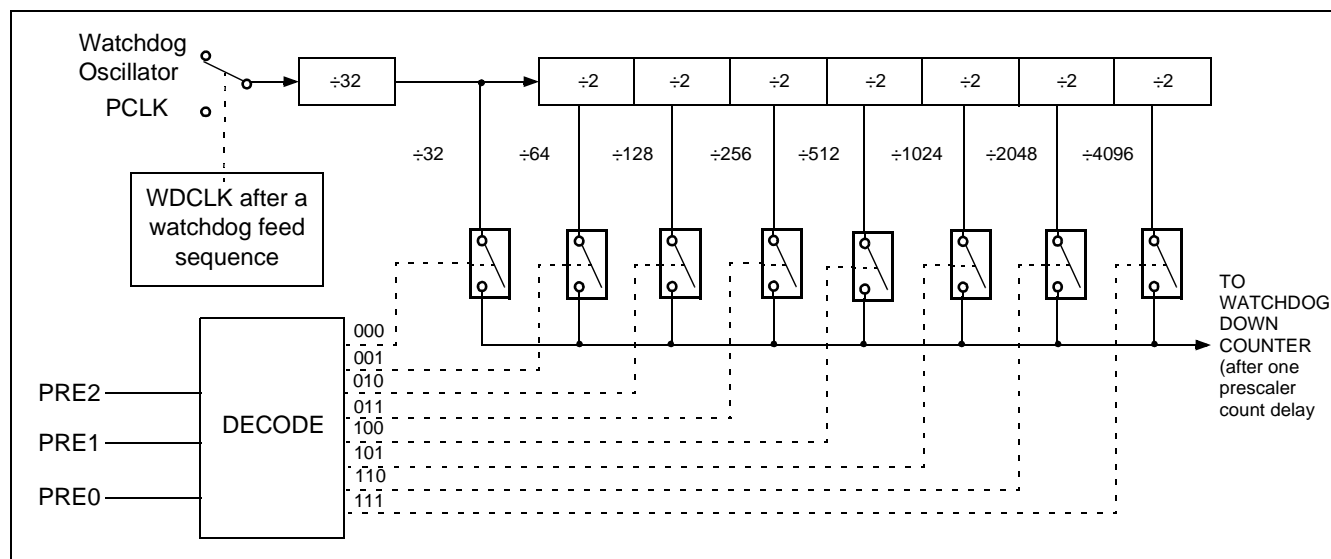


Figure 76: Watchdog Prescaler

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Watchdog Control register (WDCON)**

WDCON			7	6	5	4	3	2	1	0
Address: A7h			PRE2	PRE1	PRE0	-	-	WDRUN	WDTOF	WDCLK
Not bit addressable										
Reset Source(s): See reset value below										
Reset Value: 111xx1?1B			(Note: WDCON.7,6,5,2,0 - set to '1' any reset; WDCON.1 - cleared to '0' on Power-on reset, set to '1' on watchdog reset, not affected by any other reset)							
BIT	SYMBOL	FUNCTION								
WDCON.7-5	PRE2-PRE0	Clock Prescaler Tap Select. Refer to Table 23 for detail.								
WDCON.4-3	-	Reserved for future use. Should not be set to 1 by user program.								
WDCON.2	WDRUN	Watchdog Run Control. The watchdog timer is started when WDRUN = 1 and stopped when WDRUN = 0. This bit is forced to 1 (watchdog running) if both WDTE and WDSE are set to 1.								
WDCON.1	WDTOF	Watchdog Timer Time-Out Flag. This bit is set when the 8-bit down counter underflows. In watchdog mode, a feed sequence will clear this bit. It can also be cleared by writing '0' to this bit in software.								
WDCON.0	WDCLK	Watchdog input clock select. When set the watchdog oscillator is selected. When cleared, PCLK is selected. (If the CPU is powered down, the watchdog is disabled if WDCLK = 0, see section "WDCLK = 0 and CPU power down"). (Note: If both WDTE and WDSE are set to 1, this bit is forced to 1.) Refer to section "Switching of the Watchdog clock source" for details.								

Figure 77: Watchdog Timer Control register

The number of watchdog clocks before timing out is calculated by the following equations:

$$tclks = (2^{(5+PRE)} + 1)(WDL + 1)$$

where:

- PRE is the value of prescaler (PRE2-PRE0) which can be the range 0-7, and;
- WDL is the value of watchdog load register which can be the range of 0-255.

The minimum number of tclks is:

$$tclks = (2^{(5+0)} + 1)(0 + 1) = 33$$

$$tclks = (2^{(5+PRE)} + 1)(WDL + 1)$$

The maximum number of tclks is:

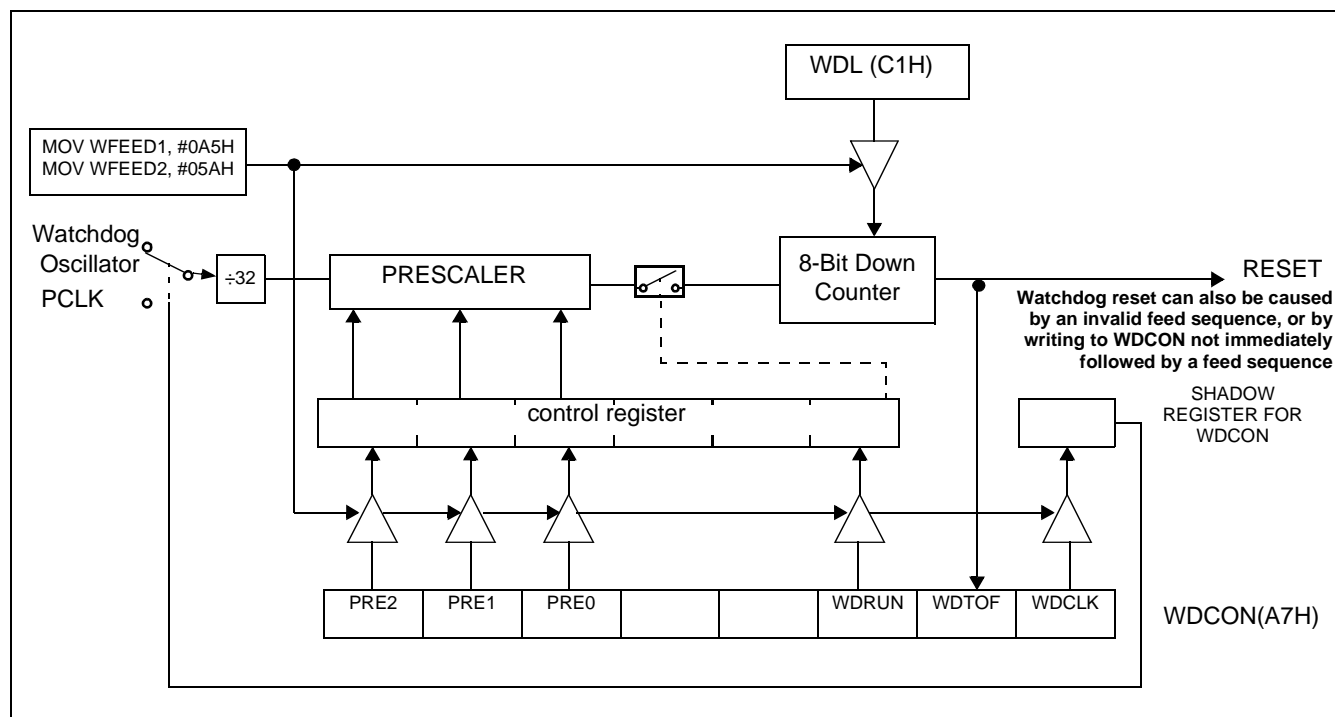
$$tclks = (2^{(5+7)} + 1)(255 + 1) = 1,048,832$$

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

The following table shows sample LPC932 timeout values.

Table 23: LPC932 Watchdog timeout values

PRE2-PRE0	WDL in decimal)	Timeout Period (in watchdog clock cycles)	Watchdog Clock Source	
			400 kHz Watchdog Oscillator Clock (Normal)	12 MHz CCLK (6 MHz CCLK/2 Watchdog Clock)
000	0	33	82.5 μ s	5.50 μ s
	255	8,193	20.5 ms	1.37 ms
001	0	65	162.5 μ s	10.8 μ s
	255	16,385	41.0 ms	2.73 ms
010	0	129	322.5 μ s	21.5 μ s
	255	32,769	81.9 ms	5.46 ms
011	0	257	642.5 μ s	42.8 μ s
	255	65,537	163.8 ms	10.9 ms
100	0	513	1.28 ms	85.5 μ s
	255	131,073	327.7 ms	21.8 ms
101	0	1,025	2.56 ms	170.8 μ s
	255	262,145	655.4 ms	43.7 ms
110	0	2,049	5.12 ms	341.5 μ s
	255	524,289	1.31 s	87.4 ms
111	0	4097	10.2 ms	682.8 μ s
	255	1,048,577	2.62 s	174.8 ms

**Figure 78: Watchdog Timer in Watchdog Mode (WDTE = 1)**

80C51 8-bit microcontroller with two-clock core

8 KB 3 V low-power Flash with 512-byte data EEPROM

P89LPC932

Watchdog Timer in Timer Mode

Figure 79 shows the Watchdog Timer in Timer Mode. In this mode, any changes to WDCON are written to the shadow register after one watchdog clock cycle. A watchdog underflow will set the WDTOF bit. If IEN0.6 is set, the watchdog underflow is enabled to cause an interrupt. WDTOF is cleared by writing a '0' to this bit in software. When an underflow occurs, the contents of WDL is reloaded into the down counter and the watchdog timer immediately begins to count down again.

A feed is necessary to cause WDL to be loaded into the down counter before an underflow occurs. Incorrect feeds are ignored in this mode.

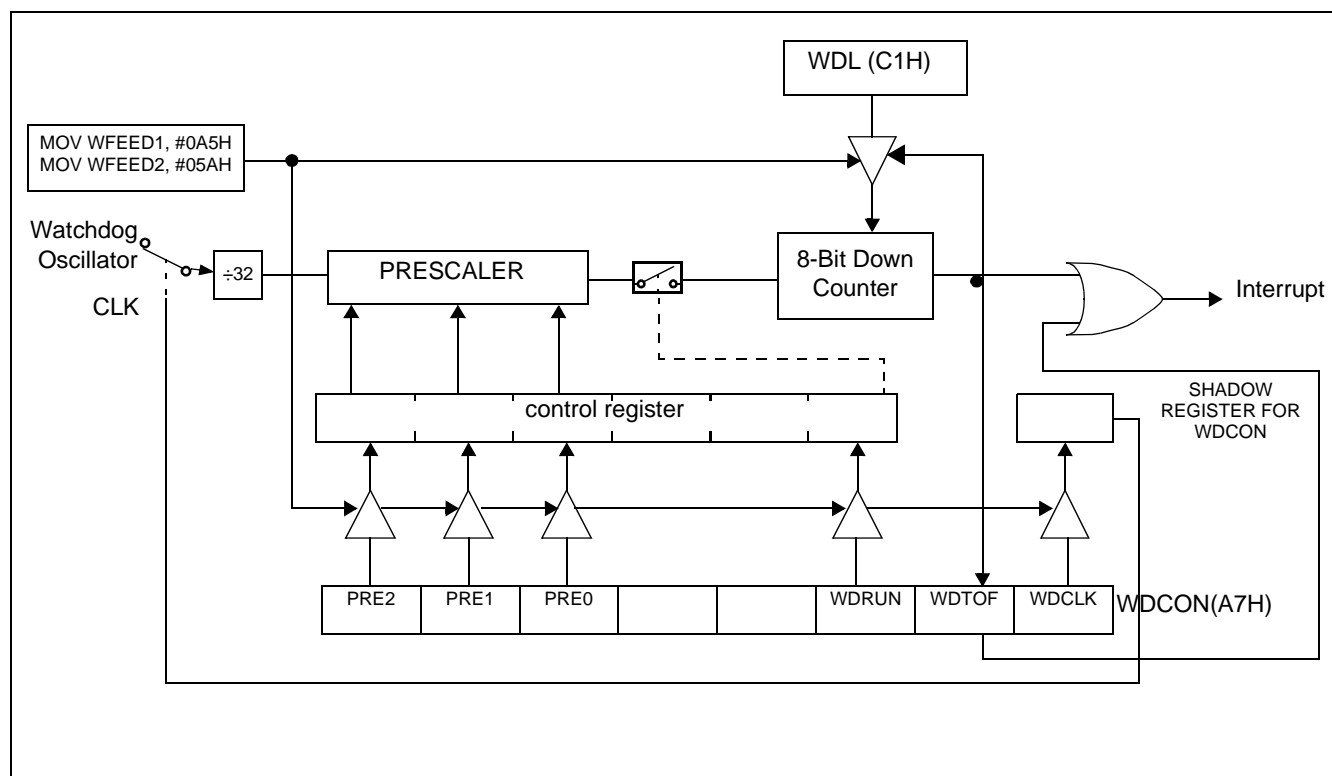


Figure 79: Watchdog Timer in Timer Mode (WDTE = 0)

WDCLK = 0 and CPU power down

If WDCLK is '0', PCLK is selected as the watchdog clock. If the CPU is powered down (PMOD1, i.e., PCON.1, is '1'), PCLK is not running and therefore the watchdog is disabled.

Switching of the Watchdog clock source

After changing WDCLK (WDCON.0), switching of the clock source will not immediately take effect. As shown in Figure 78, the selection is loaded after a watchdog feed sequence. In addition, due to clock synchronization logic, it can take two old clock cycles before the old clock source is deselected, and then an additional two new clock cycles before the new clock source is selected.

Since the prescaler starts counting immediately after a feed, switching clocks can cause some inaccuracy in the prescaler count. The inaccuracy could be as much as 2 old clock source counts plus a 2 new clock cycles.

Note: When switching clocks, it is important that the old clock source is left enabled for 2 clock cycles after the feed completes. Otherwise, the watchdog may become disabled when the old clock source is disabled. For example, suppose PCLK (WCLK=0) is the current clock source. After WCLK is set to '1', the program should wait at least two PCLK cycles (4 CCLKs) after the feed completes before going into Power down mode. Otherwise, the watchdog could become disabled when CCLK turns off. The watchdog oscillator will never become selected as the clock source unless CCLK is turned on again first.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Additional features**

The AUXR1 register contains several special purpose control bits that relate to several chip features. AUXR1 is described in Figure 80.

AUXR1			7	6	5	4	3	2	1	0
Address: A2h			CLKLP	EBRR	ENT1	ENT0	SRST	0	-	DPS
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: 000000x0B										
BIT	SYMBOL	FUNCTION								
AUXR1.7	CLKLP	Clock Low Power Select. When set, reduces power consumption in the clock circuits. Can be used when the clock frequency is 8 MHz or less. After reset this bit is cleared to support up to 12 MHz operation.								
AUXR1.6	EBRR	UART Break Detect Reset Enable. If '1', UART Break Detect will cause a chip reset and force the device into ISP mode.								
AUXR1.5	ENT1	When set, the P0.7 pin is toggled whenever Timer1 overflows. The output frequency is therefore one half of the Timer1 overflow rate. Refer to the Timer/Counters section for details.								
AUXR1.4	ENT0	When set the P1.2 pin is toggled whenever Timer0 overflows. The output frequency is therefore one half of the Timer0 overflow rate. Refer to the Timer/Counters section for details.								
AUXR1.3	SRST	Software Reset. When set by software, resets the LPC932 as if a hardware reset occurred.								
AUXR1.2	0	This bit contains a hard-wired 0. Allows toggling of the DPS bit by incrementing AUXR1, without interfering with other bits in the register.								
AUXR1.1	-	Not used. Allowable to set to a "1" .								
AUXR1.0	DPS	Data Pointer Select. Chooses one of two Data Pointers.								

Figure 80: AUXR1 register**Software reset**

The SRST bit in AUXR1 gives software the opportunity to reset the processor completely, as if an external reset or watchdog reset had occurred. If a value is written to AUXR1 that contains a 1 at bit position 3, all SFRs will be initialized and execution will resume at program address 0000. Care should be taken when writing to AUXR1 to avoid accidental software resets.

Dual Data Pointers

The dual Data Pointers (DPTR) adds to the ways in which the processor can specify the address used with certain instructions. The DPS bit in the AUXR1 register selects one of the two Data Pointers. The DPTR that is not currently selected is not accessible to software unless the DPS bit is toggled.

Specific instructions affected by the Data Pointer selection are:

- INC DPTR Increments the Data Pointer by 1.
- JMP @A+DPTR Jump indirect relative to DPTR value.
- MOV DPTR, #data16 Load the Data Pointer with a 16-bit constant.
- MOVCA, @A+DPTR Move code byte relative to DPTR to the accumulator.

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

- MOVXA, @DPTR Move data byte the accumulator to data memory relative to DPTR.
- MOVX @DPTR, A Move data byte from data memory relative to DPTR to the accumulator.

Also, any instruction that reads or manipulates the DPH and DPL registers (the upper and lower bytes of the current DPTR) will be affected by the setting of DPS. The MOVX instructions have limited application for the LPC932 since the part does not have an external data bus. However, they may be used to access Flash configuration information (see Flash Configuration section) or auxiliary data (XDATA) memory.

Bit 2 of AUXR1 is permanently wired as a logic 0. This is so that the DPS bit may be toggled (thereby switching Data Pointers) simply by incrementing the AUXR1 register, without the possibility of inadvertently altering other bits in the register.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Data EEPROM**

The LPC932 has 512 bytes of on-chip Data EEPROM that can be used to save configuration parameters. The Data EEPROM is SFR based, byte readable, byte writable, and erasable (via row fill and sector fill). The user can read, write, and fill the memory via three SFRs and one interrupt:

- Address Register (DEEADR) is used for address bits 7-0 (bit 8 is in the DEECON register).
- Control Register (DEECON) is used for address bit 8, setup operation mode, and status flag bit (see Table 81).
- Data Register (DEEDAT) is used for writing data to, or reading data from, the Data EEPROM.

DEECON			7	6	5	4	3	2	1	0
Address: F1h			EEIF	HVERR	ECTL.1	ECTL.0	-	-	-	EADR8
Not bit addressable										
Reset Source(s): Any reset										
Reset Value: 0x00xxx0B										
BIT	SYMBOL	FUNCTION								
DEECON.7	EEIF	Data EEPROM interrupt flag. Set when a read or write finishes, reset by software.								
DEECON.6	-	Reserved for future use. Should not be set to 1 by user program.								
DEECON.5-4	ECTL.1, ECTL.0	Operation mode selection.								
	00	Byte read / write mode								
	10	Row (64 bytes) fill								
	11	Block fill (512 bytes)								
DEECON.3-1	-	Reserved for future use. Should not be set to 1 by user program.								
DEECON.0	EADR8	Most significant address (bit 8) of the Data EEPROM. EADR7-0 are in DEEADR.								

Figure 81: Data EEPROM Control register

Byte Mode: In this mode data can be read and written to one byte at a time. Data is in the DEEDAT register and the address is in the DEEADR register.

Row Fill: In this mode the addressed row (64 bytes, with address DEEADR.5-0 ignored) is filled with the DEEDAT pattern. To erase the entire row to 00h or program the entire row to FFh, write 00h or FFh to DEEDAT prior to row fill.

Block Fill: In this mode all 512 bytes are filled with the DEEDAT pattern. To erase the block to 00h or program the block to FFh, write 00h or FFh to DEEDAT prior to the block fill. Prior to using this command EADR8 must be set = 1.

In any mode, after the operation finishes, the hardware will set EEIF bit. An interrupt can be enabled via the IEN1.7 bit. If IEN1.7 and the EA bits are set, it will generate an interrupt request. The EEIF bit is cleared by software.

Data EEPROM read

A byte can be read via polling or interrupt:

1. Write to DEECON with ECTL1-0 (DEECON.5-4) = '00' and correct bit 8 address to EADR8. (Note that if the correct values are already written to DEECON, there is no need to write to this register.)
2. Without writing to the DEEDAT register, write address bits 7-0 to DEEADR.
3. If both the EIEE (IEN1.7) bit and the EA (IEN0.7) bit are '1's, wait for the Data EEPROM interrupt then read/poll the EEIF (DEECON.7) bit until it is set to '1'. If EIEE or EA is '0', the interrupt is disabled, only polling is enabled.
4. Read the Data EEPROM data from the DEEDAT SFR.

Note that if DEEDAT is written prior to a write to DEEADR (if DEECON.5-4 = '00'), a Data EEPROM write operation will commence. The user must take caution that such cases do not occur during a read. An example is if the Data EEPROM is read

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM**

in an interrupt service routine with the interrupt occurring in the middle of a Data EEPROM cycle. The user should disable interrupts during a Data EEPROM write operation (see section "Data EEPROM write").

Data EEPROM write

A byte can be written via polling or interrupt:

1. Write to DEECON with ECTL1-0 (DEECON.5-4) = '00' and correct bit 8 address to EADR8. (Note that if the correct values are already written to DEECON, there is no need to write to this register.)
2. Write the data to the DEEDAT register.
3. Write address bits 7-0 to DEEADR.
4. If both the EIEE (IEN1.7) bit and the EA (IEN0.7) bit are '1's, wait for the Data EEPROM interrupt then read/poll the EEIF (DEECON.7) bit until it is set to '1'. If EIEE or EA is '0', the interrupt is disabled and only polling is enabled. When EEIF is '1', the operation is complete and data is written.

As a write to the DEEDAT register followed by a write to the DEEADR register will automatically set off a write (if DEECON.5-4 = '00'), the user must take great caution in a write to the DEEDAT register. It is strongly recommended that the user disables interrupts prior to a write to the DEEDAT register and enable interrupts after all writes are over. An example is as follows:

```
CLR    EA                ; disable interrupt
MOV    DEEDAT,@R0        ; write data pattern
MOV    DEEADR,@R1        ; write address the data pattern is to be written to
SETB   EA                ; enable interrupt, if IEN1.7 (EIEE) bit is set, wait for interrupt and poll the
                        ; DEECON.7 (EEIF) bit.
```

Hardware reset.

During any hardware reset, including watchdog and system timer reset, the state machine that "remembers" a write to the DEEDAT register will be initialized. If a write to the DEEDAT register occurs followed by a hardware reset, a write to the DEEADR register without a prior write to the DEEDAT register will result in a read cycle.

Multiple writes to the DEEDAT register

If there are multiple writes to the DEEDAT register before a write to the DEEADR register, the last data written to the DEEDAT register will be written to the corresponding address.

Sequence of writes to DEECON and DEEDAT registers

A write to the DEEDAT register is considered a valid write (i.e., will trigger the state machine to "remember" a write operation is to commence) if DEECON.5-4 = '00'. If these mode bits are already '00' and address bit 8 is correct, there is no need to write to the DEECON register prior to a write to the DEEDAT register.

Data EEPROM Row Fill

A row (8 bytes) can be filled with a predetermined data pattern via polling or interrupt:

1. Write to DEECON with ECTL1-0 (DEECON.5-4) = '10' and correct bit 8 address to EADR8. (Note that if the correct values are already written to DEECON, there is no need to write to this register.)
2. Write the fill pattern to the DEEDAT register. (Note that if the correct values are already written to DEEDAT, there is no need to write to this register.)
3. Write address bits 7-0 to DEEADR. Note that address bits 5-0 are ignored.
4. If both the EIEE (IEN1.7) bit and the EA (IEN0.7) bit are '1's, wait for the Data EEPROM interrupt then read/poll the EEIF (DEECON.7) bit until it is set to '1'. If EIEE or EA is '0', the interrupt is disabled and only polling is enabled. When EEIF is '1', the operation is complete and row is filled with the DEEDAT pattern.

Data EEPROM Block Fill

The Data EEPROM array can be filled with a predetermined data pattern via polling or interrupt:

1. Write to DEECON with ECTL1-0 (DEECON.5-4) = '11'. Set bit EADR8 = 1.
2. Write the fill pattern to the DEEDAT register.
3. Write any address to DEEADR. Note that the entire address is ignored in a block fill operation.
4. If both the EIEE (IEN1.7) bit and the EA (IEN0.7) bit are '1's, wait for the Data EEPROM interrupt then read/poll the EEIF (DEECON.7) bit until it is set to '1'. If EIEE or EA is '0', the interrupt is disabled and only polling is enabled. When EEIF is '1', the operation is complete.

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM

P89LPC932**Flash program memory****General description**

The LPC932 Flash memory provides in-circuit electrical erasure and programming. The Flash can be read and written as bytes. The Chip Erase operation will erase the entire program memory. The Sector and Page Erase functions can erase any Flash sector (1 KB) or page (64 bytes). In-System Programming and standard parallel programming are both available. On-chip erase and write timing generation contribute to a user-friendly programming interface. The LPC932 Flash reliably stores memory contents even after 10,000 erase and program cycles. The cell is designed to optimize the erase and programming mechanisms. The LPC932 uses VDD as a supply voltage to perform the Program/Erase algorithms.

Features

- Internal fixed boot ROM, containing low-level In-Application Programming (IAP) routines
- User programs can call these routines to perform In-Application Programming (IAP).
- Default loader providing In-System Programming via the serial port, located in upper end of user program memory.
- Boot vector allows user provided Flash loader code to reside anywhere in the Flash memory space, providing flexibility to the user.
- Programming and erase over the full operating voltage range
- Read/Programming/Erase using ISP/IAP
- Any flash program/erase operation in 2 ms
- Parallel programming with industry-standard commercial programmers
- Programmable security for the code in the Flash for each sector.
- 10,000 minimum erase/program cycles for each byte.
- 10-year minimum data retention.

ISP & IAP capabilities of the LPC932**Flash organization**

The LPC932 program memory consists of eight 1 KB sectors. Each sector can be further divided into 64-byte pages. In addition to sector erase and page erase, a 64-byte page register is included which allows from 1 to 64 bytes of a given page to be programmed at the same time, substantially reducing overall programming time. An In-Application Programming (IAP) interface is provided to allow the end user's application to erase and reprogram the user code memory. In addition, erasing and reprogramming of user-programmable bytes including UCFG1, the Boot Status Bit, and the Boot Vector is supported. As shipped from the factory, the upper 512 bytes of user code space contains a serial In-System Programming (ISP) routine allowing for the device to be programmed in circuit through the serial port.

Flash programming and erase

There are three methods of erasing or programming of the Flash memory that may be used. First, the Flash may be programmed or erased in the end-user application by calling low-level routines through a common entry point. Second, the on-chip ISP boot loader may be invoked. This ISP boot loader will, in turn, call low-level routines through the same common entry point that can be used by the end-user application. Third, the Flash may be programmed or erased using the parallel method by using a commercially available EPROM programmer which supports this device. This device does not provide for direct verification of code memory contents. Instead this device provides a 32-bit CRC result on either a sector or a page,.

Boot ROM

When the microcontroller programs its own Flash memory, all of the low level details are handled by code that is contained in a 256 byte Boot ROM that is separate from the Flash memory. A user program simply calls the common entry point in the Boot ROM with appropriate parameters to accomplish the desired operation. Boot ROM operations include operations such as erase

80C51 8-bit microcontroller with two-clock core

8 KB 3 V low-power Flash with 512-byte data EEPROM

P89LPC932

sector, erase page, program page, CRC, program security bit, etc. The Boot ROM occupies the program memory space at the top of the address space from FF00 to FFFF hex, thereby not conflicting with the user program memory space.

Power-On reset code execution

The LPC932 contains two special Flash elements: the BOOT VECTOR and the Boot Status Bit. Following reset, the LPC932 examines the contents of the Boot Status Bit. If the Boot Status Bit is set to zero, power-up execution starts at location 0000H, which is the normal start address of the user's application code. When the Boot Status Bit is set to a value other than zero, the contents of the Boot Vector is used as the high byte of the execution address and the low byte is set to 00H. The factory default setting is 01EH, corresponds to the address 1E00H for the default ISP boot loader. This boot loader is pre-programmed at the factory into this address space and can be erased by the user. **Users who wish to use this loader should take cautions to avoid erasing the 1KB sector from 1C00H to 1FFFH. Instead, the page erase function can be used to erase the eight 64-byte pages located from 1C00H to 1DFFH.** A custom boot loader can be written with the Boot Vector set to the custom boot loader, if desired.

Hardware activation of the Boot Loader

The boot loader can also be executed by forcing the device into ISP mode during a power-on sequence (see Figure 82). This is accomplished by powering up the device with the reset pin initially held low and holding the pin low for a fixed time after VDD rises to its normal operating value. This is followed by three, and only three, properly timed low-going pulses. Fewer or more than three pulses will result in the device not entering ISP mode. Timing specifications may be found in the datasheet for this device.

This has the same effect as having a non-zero status byte. This allows an application to be built that will normally execute the user code but can be manually forced into ISP operation. If the factory default setting for the Boot Vector (1EH) is changed, it will no longer point to the factory pre-programmed ISP boot loader code. If this happens, the only way it is possible to change the contents of the Boot Vector is through the parallel programming method, provided that the end user application does not contain a customized loader that provides for erasing and reprogramming of the Boot Vector and Boot Status Bit. After programming the Flash, the status byte should be programmed to zero in order to allow execution of the user's application code beginning at address 0000H.

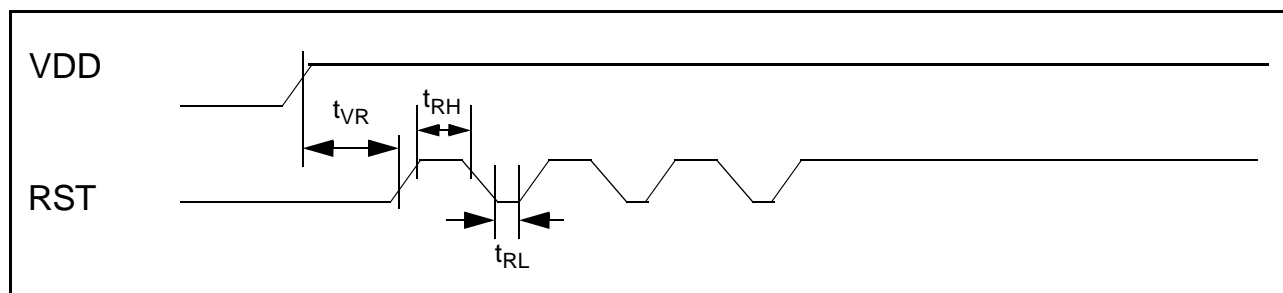


Figure 82: Forcing ISP Mode

In-System Programming (ISP)

In-System Programming is performed without removing the microcontroller from the system. The In-System Programming facility consists of a series of internal hardware resources coupled with internal firmware to facilitate remote programming of the LPC932 through the serial port. This firmware is provided by Philips and embedded within each LPC932 device. The Philips In-System Programming facility has made in-circuit programming in an embedded application possible with a minimum of additional expense in components and circuit board area. The ISP function uses five pins. Only a small connector needs to be available to interface your application to an external circuit in order to use this feature.

Using the In-System Programming

The ISP feature allows for a wide range of baud rates to be used in your application, independent of the oscillator frequency. It is also adaptable to a wide range of oscillator frequencies. This is accomplished by measuring the bit-time of a single bit in a received character. This information is then used to program the baud rate in terms of timer counts based on the oscillator fre-

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932

quency. The ISP feature requires that an initial character (an uppercase U) be sent to the LPC932 to establish the baud rate. The ISP firmware provides auto-echo of received characters. Once baud rate initialization has been performed, the ISP firmware will only accept Intel Hex-type records. Intel Hex records consist of ASCII characters used to represent hexadecimal values and are summarized below:

```
:NNAAAARRDD..DDCC<crLf>
```

In the Intel Hex record, the “NN” represents the number of data bytes in the record. The LPC932 will accept up to 64 (40H) data bytes. The “AAAA” string represents the address of the first byte in the record. If there are zero bytes in the record, this field is often set to 0000. The “RR” string indicates the record type. A record type of “00” is a data record. A record type of “01” indicates the end-of-file mark. In this application, additional record types will be added to indicate either commands or data for the ISP facility. The maximum number of data bytes in a record is limited to 64 (decimal). ISP commands are summarized in Table 24 . As a record is received by the LPC932, the information in the record is stored internally and a checksum calculation is performed. The operation indicated by the record type is not performed until the entire record has been received. Should an error occur in the checksum, the LPC932 will send an “X” out the serial port indicating a checksum error. If the checksum calculation is found to match the checksum in the record, then the command will be executed. In most cases, successful reception of the record will be indicated by transmitting a “.” character out the serial port

Table 24: In-System Programming (ISP) hex record formats

Record type	Command/data function
00	Program User Code Memory Page :nnaaa00dd..ddcc Where: nn = number of bytes to program aaaa = page address dd..dd = data bytes cc = checksum Example: :100000000102030405006070809cc
01	Read Version Id :00xxxx01cc Where: xxxx = required field but value is a “don’t care” cc = checksum Example: :00000001cc

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 24: In-System Programming (ISP) hex record formats**

Record type	Command/data function																																
02	<p>Miscellaneous Write Functions</p> <p>:02xxxx02ssddcc</p> <p>Where:</p> <p>xxxx = required field but value is a "don't care"</p> <p>ss = subfunction code</p> <p>dd = data</p> <p>cc = checksum</p> <p>Subfunction codes:</p> <table> <tr><td>00</td><td>= UCFG1</td></tr> <tr><td>01</td><td>= reserved</td></tr> <tr><td>02</td><td>= Boot Vector</td></tr> <tr><td>03</td><td>= Status Byte</td></tr> <tr><td>04</td><td>= reserved</td></tr> <tr><td>05</td><td>= reserved</td></tr> <tr><td>06</td><td>= reserved</td></tr> <tr><td>07</td><td>= reserved</td></tr> <tr><td>08</td><td>= Security Byte 0</td></tr> <tr><td>09</td><td>= Security Byte 1</td></tr> <tr><td>0A</td><td>= Security Byte 2</td></tr> <tr><td>0B</td><td>= Security Byte 3</td></tr> <tr><td>0C</td><td>= Security Byte 4</td></tr> <tr><td>0D</td><td>= Security Byte 5</td></tr> <tr><td>0E</td><td>= Security Byte 6</td></tr> <tr><td>0F</td><td>= Security Byte 7</td></tr> </table> <p>Example:</p> <p>:020000020347cc</p>	00	= UCFG1	01	= reserved	02	= Boot Vector	03	= Status Byte	04	= reserved	05	= reserved	06	= reserved	07	= reserved	08	= Security Byte 0	09	= Security Byte 1	0A	= Security Byte 2	0B	= Security Byte 3	0C	= Security Byte 4	0D	= Security Byte 5	0E	= Security Byte 6	0F	= Security Byte 7
00	= UCFG1																																
01	= reserved																																
02	= Boot Vector																																
03	= Status Byte																																
04	= reserved																																
05	= reserved																																
06	= reserved																																
07	= reserved																																
08	= Security Byte 0																																
09	= Security Byte 1																																
0A	= Security Byte 2																																
0B	= Security Byte 3																																
0C	= Security Byte 4																																
0D	= Security Byte 5																																
0E	= Security Byte 6																																
0F	= Security Byte 7																																

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 24: In-System Programming (ISP) hex record formats**

Record type	Command/data function																																						
03	<p>Miscellaneous Read Functions</p> <p>:01xxxx03sscc</p> <p>Where</p> <p>xxxx = required field but value is a “don't care”</p> <p>ss = subfunction code</p> <p>cc = checksum</p> <p>Subfunction codes:</p> <table> <tr><td>00</td><td>= UCFG1</td></tr> <tr><td>01</td><td>= reserved</td></tr> <tr><td>02</td><td>= Boot Vector</td></tr> <tr><td>03</td><td>= Status Byte</td></tr> <tr><td>04</td><td>= reserved</td></tr> <tr><td>05</td><td>= reserved</td></tr> <tr><td>06</td><td>= reserved</td></tr> <tr><td>07</td><td>= reserved</td></tr> <tr><td>08</td><td>= Security Byte 0</td></tr> <tr><td>09</td><td>= Security Byte 1</td></tr> <tr><td>0A</td><td>= Security Byte 2</td></tr> <tr><td>0B</td><td>= Security Byte 3</td></tr> <tr><td>0C</td><td>= Security Byte 4</td></tr> <tr><td>0D</td><td>= Security Byte 5</td></tr> <tr><td>0E</td><td>= Security Byte 6</td></tr> <tr><td>0F</td><td>= Security Byte 7</td></tr> <tr><td>10</td><td>= Manufacturer Id</td></tr> <tr><td>11</td><td>= Device Id</td></tr> <tr><td>12</td><td>= Derivative Id</td></tr> </table> <p>Example:</p> <p>:0100000312cc</p>	00	= UCFG1	01	= reserved	02	= Boot Vector	03	= Status Byte	04	= reserved	05	= reserved	06	= reserved	07	= reserved	08	= Security Byte 0	09	= Security Byte 1	0A	= Security Byte 2	0B	= Security Byte 3	0C	= Security Byte 4	0D	= Security Byte 5	0E	= Security Byte 6	0F	= Security Byte 7	10	= Manufacturer Id	11	= Device Id	12	= Derivative Id
00	= UCFG1																																						
01	= reserved																																						
02	= Boot Vector																																						
03	= Status Byte																																						
04	= reserved																																						
05	= reserved																																						
06	= reserved																																						
07	= reserved																																						
08	= Security Byte 0																																						
09	= Security Byte 1																																						
0A	= Security Byte 2																																						
0B	= Security Byte 3																																						
0C	= Security Byte 4																																						
0D	= Security Byte 5																																						
0E	= Security Byte 6																																						
0F	= Security Byte 7																																						
10	= Manufacturer Id																																						
11	= Device Id																																						
12	= Derivative Id																																						

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Table 24: In-System Programming (ISP) hex record formats**

Record type	Command/data function
04	Erase Sector/Page :03xxxx04ssaaaacc Where: xxxx = required field but value is a "don't care" aaaa = sector/page address ss = 01 erase sector = 00 erase page cc = checksum Example: :03000004010000F8
05	Read Sector CRC :01xxxx05aacc Where: xxxx = required field but value is a "don't care" aa = sector address high byte cc = checksum Example: :0100000504F6cc
06	Read Global CRC :00xxxx06cc Where: xxxx = required field but value is a "don't care" cc = checksum Example: :00000006FA
07	Direct Load of Baud Rate :02xxxx07HHLLcc Where: xxxx = required field but value is a "don't care" HH = high byte of timer LL = low byte of timer cc = checksum Example: :02000007FFFFcc

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**Table 24: In-System Programming (ISP) hex record formats**

Record type	Command/data function
08	Full Chip Erase :00xxxx08cc Where: xxxx = required field but value is a "don't care" cc = checksum Example: :00000008cc

In-Application Programming method

Several In-Application Programming (IAP) calls are available for use by an application program to permit selective erasing and programming of Flash sectors, pages, security bits, configuration bytes, and device id. All calls are made through a common interface, PGM_MTP. The programming functions are selected by setting up the microcontroller's registers before making a call to PGM_MTP at FF00H. The IAP calls are shown in Table 25.

Table 25: IAP function calls

IAP function	IAP call parameters
Program User Code Page	Input parameters: ACC = 00h R3 = number of bytes to program R4 = page address (MSB) R5 = page address (LSB) R7 = pointer to data buffer in RAM Return parameter(s): R7 = status Carry = set on error, clear on no error
Read Version Id	Input parameters: ACC = 01h Return parameter(s): R7 = IAP code version id

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 25: IAP function calls**

IAP function	IAP call parameters
Misc. Write	Input parameters: ACC = 02h R5 = data to write R7 = register address 00 = UCFG1 01 = reserved 02 = Boot Vector 03 = Status Byte 04 = reserved 05 = reserved 06 = reserved 07 = reserved 08 = Security Byte 0 09 = Security Byte 1 0A = Security Byte 2 0B = Security Byte 3 0C = Security Byte 4 0D = Security Byte 5 0E = Security Byte 6 0F = Security Byte 7 Return parameter(s): R7 = status Carry = set on error, clear on no error

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 25: IAP function calls**

IAP function	IAP call parameters
Misc. Read	Input parameters: ACC = 03h R7 = register address 00 = UCFG1 01 = reserved 02 = Boot Vector 03 = Status Byte 04 = reserved 05 = reserved 06 = reserved 07 = reserved 08 = Security Byte 0 09 = Security Byte 1 0A = Security Byte 2 0B = Security Byte 3 0C = Security Byte 4 0D = Security Byte 5 0E = Security Byte 6 0F = Security Byte 7 Return parameter(s): R7 = register data if no error, else error status Carry = set on error, clear on no error
Erase Sector/Page	Input parameters: ACC = 04h R7 = 70H (erase page) or 71H (erase sector) R4 = sector/page address (MSB) R5 = sector/page address (LSB) Return parameter(s): R7 = status Carry = set on error, clear on no error

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****Table 25: IAP function calls**

IAP function	IAP call parameters
Read Sector CRC	Input parameters: ACC = 05h R7 = sector address Return parameter(s): R4 = CRC bits 31:24 R5 = CRC bits 23:16 R6 = CRC bits 15:8 R7 = CRC bits 7:0 (if no error) R7 = error status (if error) Carry = set on error, clear on no error
Read Global CRC	Input parameters: ACC = 06h Return parameter(s): R4 = CRC bits 31:24 R5 = CRC bits 23:16 R6 = CRC bits 15:8 R7 = CRC bits 7:0 (if no error) R7 = error status (if error) Carry = set on error, clear on no error
Read User Code	Input parameters: ACC = 07h R4 = address (MSB) R5 = address (LSB) Return parameter(s): R7 = data

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM
P89LPC932**User configuration bytes**

A number of user-configurable features of the LPC932 must be defined at power-up and therefore cannot be set by the program after start of execution. These features are configured through the use of an Flash byte UCFG1 shown in Figure 83.

UCFG1		7	6	5	4	3	2	1	0
Address: xxxh		WDTE	RPE	BOE	WDSE	-	FOSC2	FOSC1	FOSC0
Unprogrammed value: 63h									
BIT	SYMBOL	FUNCTION							
UCFG1.7	WDTE	Watchdog timer enable. When set =1, enables the watchdog timer. The timer may still be used to generate an interrupt. Refer to Table 22 for details.							
UCFG1.6	RPE	Reset pin enable. When set =1, enables the reset function of pin P1.5. When cleared, P1.5 may be used as an input pin. NOTE: During a power-up sequence, the RPE selection is overridden and this pin will always functions as a reset input. After power-up the pin will function as defined by the RPE bit. Only a power-up reset will temporarily override the selection defined by RPE bit. Other sources of reset will not override the RPE bit.							
UCFG1.5	BOE	Brownout Detect Enable (see section "Brownout Detection").							
UCFG1.4	WDSE	Watchdog Safety Enable bit. Refer to Table 22 for details.							
UCFG1.3	-	Reserved (should remain unprogrammed at zero).							
UCFG1.2-0	FOSC2-FSOC0	CPU oscillator type select. See section "Clocks" section for additional information. Combinations other than those shown below should not be used. They are reserved for future use.							
	<u>FOSC2-FOSC0</u>	<u>Oscillator Configuration</u>							
	1 1 1	External clock input on XTAL1.							
	1 0 0	Watchdog Oscillator, 400 kHz (+20/ -30% tolerance).							
	0 1 1	Internal RC oscillator, 7.373 MHz \pm 2.5%.							
	0 1 0	Low frequency crystal, 20 kHz to 100 kHz.							
	0 0 1	Medium frequency crystal or resonator, 100 kHz to 4 MHz.							
	0 0 0	High frequency crystal or resonator, 4 MHz to 12 MHz.							
Factory default value for UCFG1 is set for watchdog disabled, reset pin enabled, brownout detect enabled, and using the internal RC oscillator									

Figure 83: Flash User Configuration Byte 1 (UCFG1)

80C51 8-bit microcontroller with two-clock core**P89LPC932****8 KB 3 V low-power Flash with 512-byte data EEPROM****User security bytes**

There are eight user sector Security Bytes (SEC0, ..., SEC7), each corresponding to one sector and having the following bit assignments:

SECx	7	6	5	4	3	2	1	0
Address: xxxh	-	-	-	-	-	GEDISx	SPEDISx	MOVCDISx
Unprogrammed value: 00h								
BIT	SYMBOL	FUNCTION						
SECx.7-3	-	Reserved (should remain unprogrammed at zero).						
SECx.2	GEDISx	Disables ISP/IAP global erase for sector x. This bit and sector x is erased when a 'global' erase command is issued from the programmer interface. This bit and sector x CANNOT be erased in ISP or IAP modes. To erase these the device must be removed from the application and put in a parallel programmer.s						
SECx.1	SPEDISx	Disables program and erase of all or part of sector x. This bit and sector x are erased when a 'global' erase command is issued in ISP/IAP mode, or from the parallel programmer interface.						
SECx.0	MOVCDISx	Disables the MOVC command for sector x. Any MOVC that attempts to read a byte in a MOVC protected sector will return invalid data. This bit can only be erased when sector x is erased.						

Figure 84: User sector Security Bytes (SEC0, ..., SEC7)**Boot Vector**

BOOTVEC	7	6	5	4	3	2	1	0
Address: xxxh	-	-	-	BOOTV4	BOOTV3	BOOTV2	BOOTV1	BOOTV0
Unprogrammed value: 00h								
BIT	SYMBOL	FUNCTION						
BOOTVEC.7-5	-	Reserved (should remain unprogrammed at zero).						
BOOTVEC.4-0	-	Boot Vector. If the Boot Vector is selected as the reset address, the LPC932 will start execution at an address comprised of 00H in the lower eight bits and this BOOTVEC as the upper bits after a reset. (See section "Reset vector").						

Figure 85: Boot Vector (BOOTVEC)

80C51 8-bit microcontroller with two-clock core
8 KB 3 V low-power Flash with 512-byte data EEPROM

P89LPC932

Boot Status

BOOTSTAT		7	6	5	4	3	2	1	0
Address: xxxxh		-	-	-	-	-	-	-	BSB
Unprogrammed value: 00h									
BIT	SYMBOL	FUNCTION							
BOOTSTAT.7-1	-	Reserved (should remain unprogrammed at zero).							
BOOTSTAT.0	BSB	Boot Status Bit. If programmed to '1', the LPC932 will always start execution at an address comprised of 00H in the lower eight bits and BOOTVEC as the upper bits after a reset. (See section "Reset vector").							

Figure 86: Boot Status (BOOTSTAT)

INDEX

A

Analog comparators 30, 92
 configuration 92
 configuration example 94
 enabling 92
 internal reference voltage 93
 interrupt 93
 power reduction modes 93, 94
Analog comparators and power reduction 30

B

Block diagram 11
Brownout detection 32
 enabling and disabling 32
 operating range 32
 options 32
 rise and fall times of V_{DD} 32

C

Capture Compare Unit 46
 basic timer operation 46
 clock prescaling 46
 input capture 49
 interrupt structure 54
 output compare 48
 output compare pin behavior 52
 PLL operation 53
 PWM
 alternating output mode 52
 asymmetrical operation 50
 halt 53
 operation 50
 register update synchronization 52
 symmetrical operation 50
CaptureCompare Unit 46
Clock
 CPU clock 20

- CPU divider (DIVM) 22
- definitions 20
- external input option 21
- output 20
- PCLK 20
- RCCLK 20
- wakeup delay 22

D

Data EEPROM

- block fill 105
- byte mode 104
- hardware reset 105
- multiple writes to the DEEDAT register 105
- reading 104
- row fill 105
- sequence of writes to DEECON and DEEDAT registers 105
- writing 105

Dual Data Pointers 102

E

EEPROM 104

F

FLASH 106

- Boot Status 118
- Boot Vector 117
- Bootrom 106
- features 106
- hardware activation of the boot loader 107
- in-application programming (IAP) 112
- ISP 107
- ISP & IAP capabilities 106
- organization 106
- power-on reset code execution 107
- programming and erasure 106

I

I2C serial interface

- clock rate selection for common frequencies 71
- master receiver mode 73
- master receiver states 78
- master transmitter mode 72
- master transmitter states 77
- slave receiver mode 74
- slave receiver states 79

Interrupts 25

- arbitration ranking 25
- edge-triggered 26
- external input pin glitch suppression 26
- external inputs 26
- keypad 26
- priority structure 25

K

Keypad interrupt (KBI) 95

L

Low power (LPEP) 23

M

Memory

- Code 24
- Data 24
- IDATA 24
- organization 23
- XDATA 24

O

Oscillator

- high speed option 20
- low speed option 20
- medium speed option 20

RC option 21
watchdog (WDT) option 21

P

Pin

configuration
 28-pin PLCC package 9
 28-pin TSSOP package 9
descriptions 12

Ports

additional features 31
I/O 28
input only configuration 30
open drain output configuration 29
Port 0 12
Port 0 analog functions 30
Port 1 12
Port 2 13
Port 3 14
push-pull output configuration 30
quasi-bidirectional output configuration 28

Power monitoring functions 32

Power reduction modes 33

normal mode 33
power down mode (partial) 33

Power-down mode (total) 33

Power-on detection 32

R

Real time clock 43

clock sources 44
interrupt/wake up 44

Reset 36

enabling the external reset input pin 36, 116
software reset 102
sources 36
UART break-detect, ISP entry 37

S**Serial Peripheral Interface (SPI) 84****SFR**

AUXR1 102
BRGCON 59
CCCRx 49
CMPn 92
DEECON 104
I2ADR 69
I2CON 70
I2DAT 69
I2SCLH 71
I2SCLL 71
I2STAT 71
KBCON 95
KBMASK 96
KBPATN 95
PCON 34
PCONA 35
PT0AD 30
RSTSRC 37
RTCCON 45
SCON 60
SPCTL 85
SPDAT 86
SPSTAT 86
SSTAT 61
TAMOD 39
TCON 40
TCR20 48
TCR21 53
TICR2 57
TIFR2 56
TISE2 55
TMOD 38
TPCR2H 47
TPCR2L 47
TRIM 19, 20, 21
UCFG1 116
WDCON 99

Special Function Registers (SFRs), table of 15**SPI**

additional considerations for the master 88
additional considerations for the slave 88

- clock prescaler select 91
- configurations 86
- configuring 87
- data mode 89
- mode change on SS 88
- write collision 89

T

Timer/counters 38

- mode 0 39
- mode 1 39
- mode 2 (8-bit auto reload) 39
- mode 3 (seperates TL0 & TH0) 40
- mode 6 (8-bit PWM) 40
- toggle output 42

U

UART 58

- automatic address recognition 66
- baud rate generator 58
- BRGR1 and BRGR0, updating 59
- double buffering in 9-bit mode 65
- double buffering in different modes 64
- framing error 60, 63
- mode 0 61
- mode 0 (shift register) 58
- mode 1 62
- mode 1 (8-bit variable baud rate) 58
- mode 2 63
- mode 2 (9-bit fixed baud rate) 58
- mode 3 63
- mode 3 (9-bit variable baud rate) 58
- multiprocessor communications 66
- SFR locations. 58
- status register 61
- transmit interrupts with double buffering enabled (modes 1, 2 and 3) 64

User Configuration Byte (UCFG1) 116, 117

W

Watchdog timer 97

 switching of watchdog clock source 101

 timer mode 101

 watchdog function 97

 watchdog timeout values 100

 WDCLK = 0 and CPU power down 101

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8 KB 3 V low-power Flash with 512-byte data EEPROM**P89LPC932****DISCLAIMERS**

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