



P89LPC915/916/917

8-bit microcontrollers with accelerated two-clock 80C51 core
2 kB 3 V Flash with 8-bit A/D converter

Rev. 04 — 17 December 2004

Product data

1. General description

The P89LPC915/916/917 are single-chip microcontrollers in low-cost 14-pin and 16-pin packages, 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 P89LPC915/916/917 in order to reduce component count, board space, and system cost.

2. Features

- 2 kB byte-erasable Flash code memory organized into 256-byte sectors and 16-byte pages. Single-byte erasing allows any byte(s) to be used as non-volatile data storage.
- 256-byte RAM data memory.
- Two 16-bit counter/timers. Timer 0 (and Timer 1 - P89LPC917) may be configured to toggle a port output upon timer overflow or to become a PWM output.
- 23-bit system timer that can also be used as a Real-Time clock.
- 4-input multiplexed 8-bit A/D converter/single DAC output. Two analog comparators with selectable reference.
- Enhanced UART with fractional baud rate generator, break detect, framing error detection, automatic address detection and versatile interrupt capabilities.
- SPI communication port (P89LPC916).
- Internal RC oscillator option allows operation without external oscillator components. The RC oscillator (factory calibrated to $\pm 1\%$) option is selectable and fine tunable.
- 2.4 V to 3.6 V V_{DD} operating range. I/O pins are 5 V tolerant (may be pulled up or driven to 5.5 V).
- Up to 14 I/O pins when using internal oscillator and reset options (P89LPC916, P89LPC917).

3. Additional features

- 14-pin (P89LPC915) and 16-pin (P89LPC916, P89LPC917) TSSOP packages.
- A high performance 80C51 CPU provides instruction cycle times of 111 ns to 222 ns for all instructions except multiply and divide when executing at 18 MHz. This is six times the performance of the standard 80C51 running at the same clock frequency. A lower clock frequency for the same performance results in power savings and reduced EMI.



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- In-Application Programming (IAP-Lite) and byte erase allows code memory to be used for non-volatile data storage.
- Serial Flash In-Circuit Programming (ICP) allows simple production coding with commercial EPROM programmers. Flash security bits prevent reading of sensitive application programs.
- Watchdog timer with separate on-chip oscillator, requiring no external components. The Watchdog prescaler is selectable from 8 values.
- Low-voltage reset (Brownout detect) allows a graceful system shutdown when power fails. May optionally be configured as an interrupt.
- Idle and two different power-down reduced power modes. Improved wake-up from Power-down mode (a low interrupt input starts execution). Typical power-down current is 1 μA (total power-down with voltage comparators disabled).
- Active-LOW reset. On-chip power-on reset allows operation without external reset components. A reset counter and reset glitch suppression circuitry prevent spurious and incomplete resets. A software reset function is also available.
- Programmable port output configuration options: quasi-bidirectional, open drain, push-pull, input-only.
- Port 'input pattern match' detect. Port 0 may generate an interrupt when the value of the pins match or do not match a programmable pattern.
- LED drive capability (20 mA) on all port pins. A maximum limit is specified for the entire chip.
- Controlled slew rate port outputs to reduce EMI. Outputs have approximately 10 ns minimum ramp times.
- Only power and ground connections are required to operate the P89LPC915/916/917 when internal reset option is selected.
- Four interrupt priority levels.
- Five (P89LPC916), six (P89LPC915), or seven (P89LPC917) keypad interrupt inputs.
- Second data pointer.
- Schmitt trigger port inputs.
- Emulation support.

4. Ordering information

Table 1: Ordering information

Type number	Package		
	Name	Description	Version
P89LPC915FDH	TSSOP14	plastic thin shrink small outline package; 14 leads; body width 4.4 mm	SOT402-1
P89LPC915HDH	TSSOP14	plastic thin shrink small outline package; 14 leads; body width 4.4 mm	SOT402-1
P89LPC916FDH	TSSOP16	plastic thin shrink small outline package; 16 leads; body width 4.4 mm	SOT403-1
P89LPC917FDH	TSSOP16	plastic thin shrink small outline package; 16 leads; body width 4.4 mm	SOT403-1

4.1 Ordering options

Table 2: Ordering options^[1]

Type number	Temperature range	Frequency
P89LPC915HDH	-40 °C to +125 °C	0 MHz to 18 MHz
P89LPC915FDH	-40 °C to +85 °C	
P89LPC916FDH		
P89LPC917FDH		

[1] Please contact your local Philips sales office for availability of extended temperature (-40 °C to +125 °C) versions of the P89LPC916 and P89LPC917 devices.

5. Block diagram

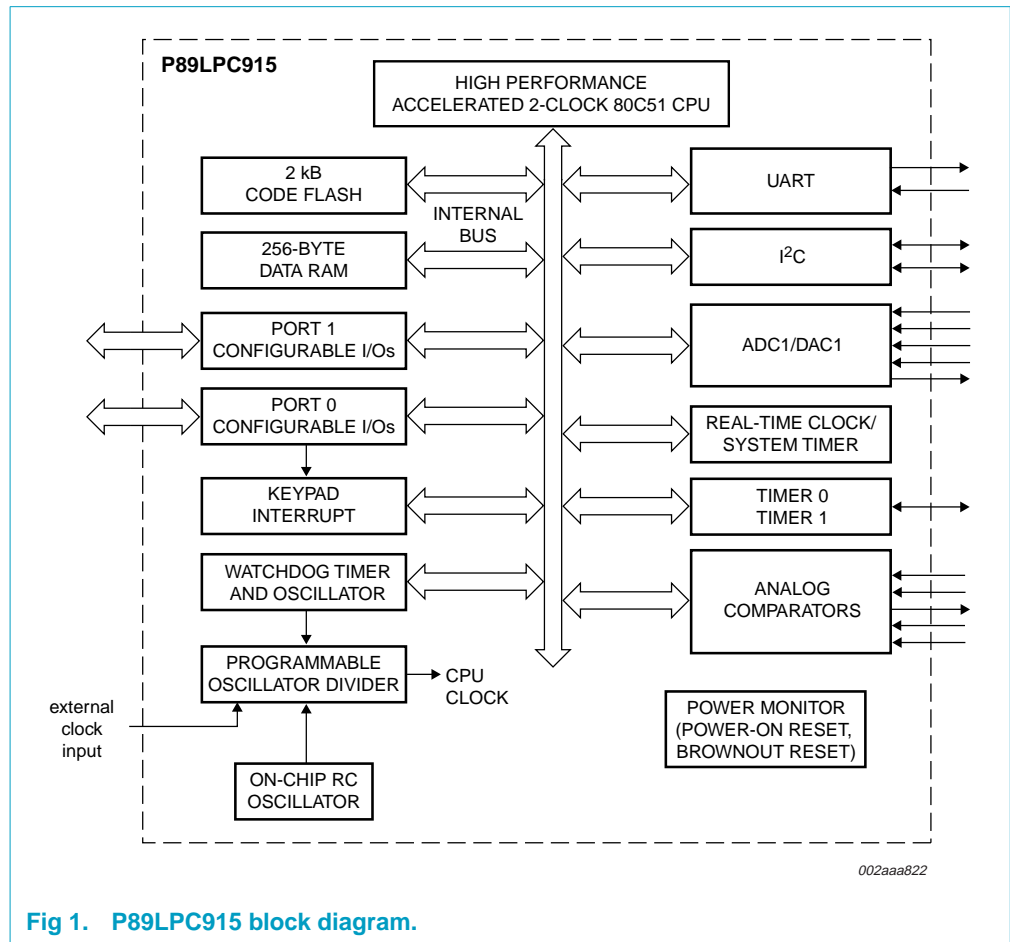


Fig 1. P89LPC915 block diagram.

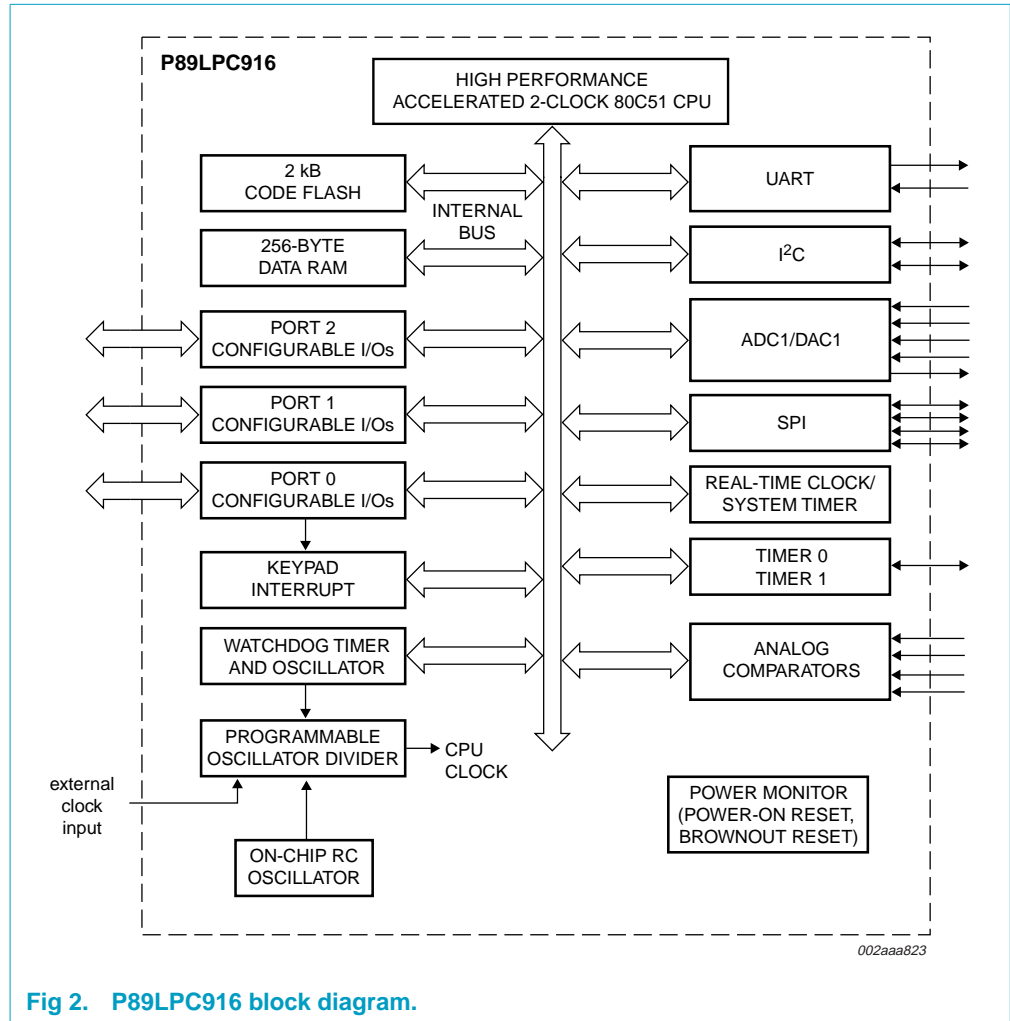


Fig 2. P89LPC916 block diagram.

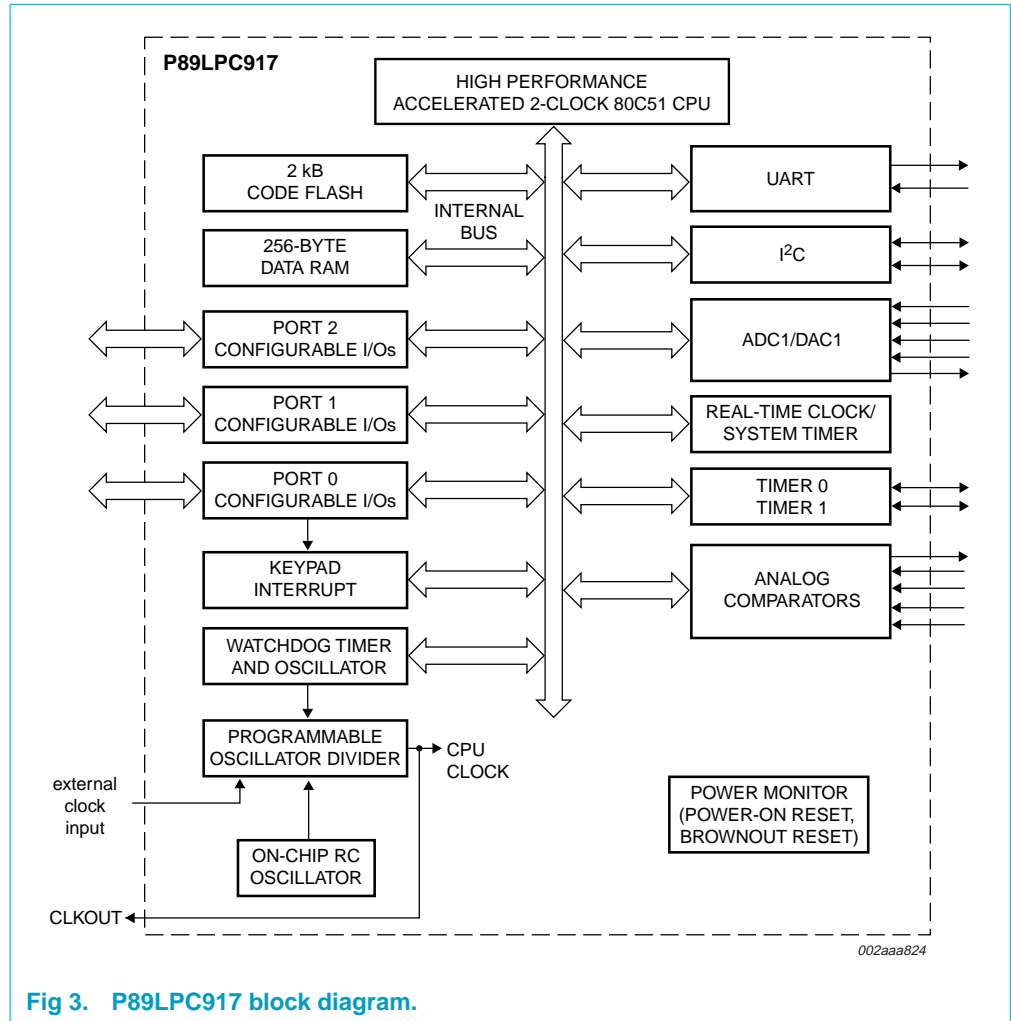
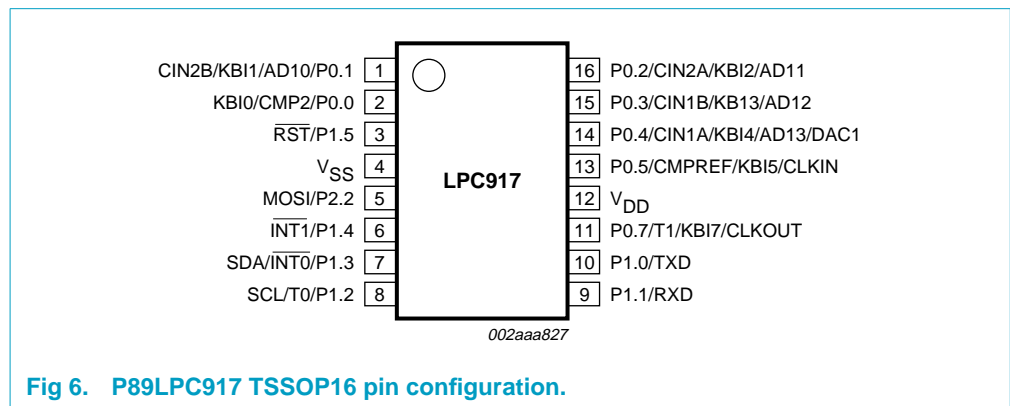
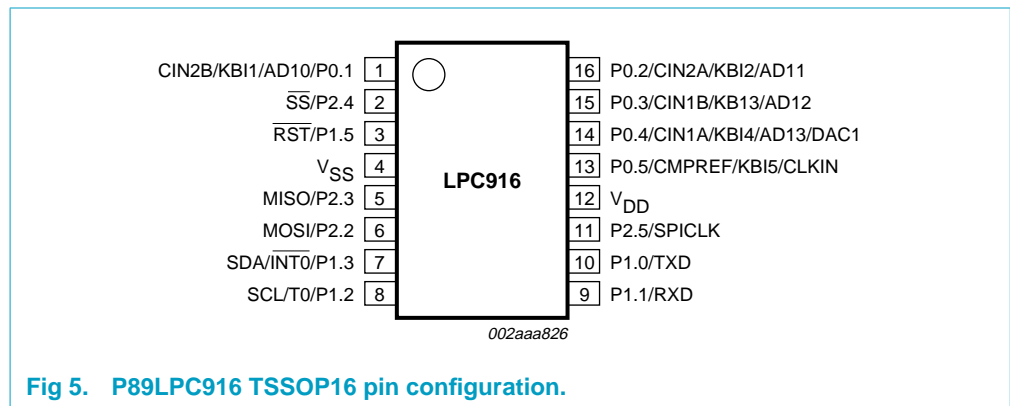
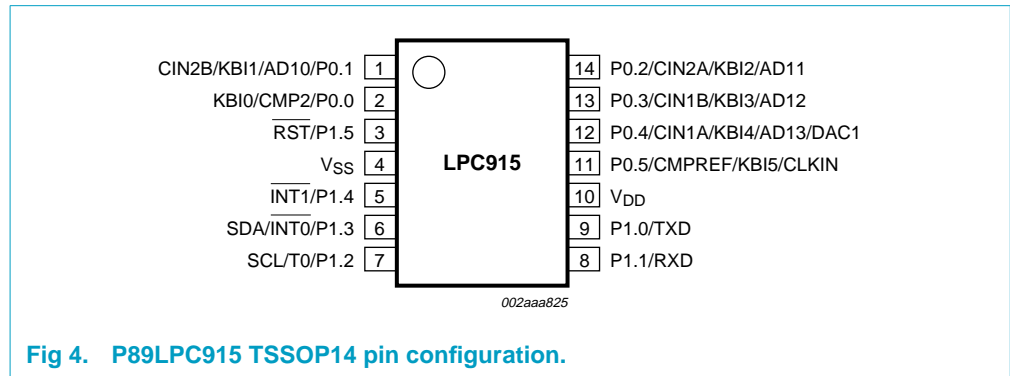


Fig 3. P89LPC917 block diagram.

6. Pinning information

6.1 Pinning



6.2 Pin description

Table 3: P89LPC915 pin description

Symbol	Pin	Type	Description
P0.0 to P0.5		I/O	<p>Port 0: Port 0 is a 6-bit I/O port with user-configurable outputs. 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 Section 9.12.1 “Port configurations” and Table 13 “DC electrical characteristics” 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>
	2	I/O	P0.0 — Port 0 bit 0.
		I	CMP2 — Comparator 2 output.
		I	KB10 — Keyboard input 0.
	1	I/O	P0.1 — Port 0 bit 1.
		I	CIN2B — Comparator 2 positive input B.
		I	KB11 — Keyboard input 1.
		I	AD10 — A/D channel 1, input 0
	14	I/O	P0.2 — Port 0 bit 2.
		I	CIN2A — Comparator 2 positive input A.
		I	KB12 — Keyboard input 2.
		I	AD11 — A/D channel 1, input 1
	13	I/O	P0.3 — Port 0 bit 3.
		I	CIN1B — Comparator 1 positive input B.
		I	KB13 — Keyboard input 3.
		I	AD12 — A/D channel 1, input 2.
	12	I/O	P0.4 — Port 0 bit 4.
		I	CIN1A — Comparator 1 positive input A.
		I	KB14 — Keyboard input 4.
		I	AD13 — A/D channel 1, input 3.
		O	DAC1 — Digital to analog converter 1 output.
	11	I/O	P0.5 — Port 0 bit 5.
		I	CMPREF — Comparator reference (negative) input.
		I	KB15 — Keyboard input 5.
		I	CLKIN — External clock input.

Table 3: P89LPC915 pin description...continued

Symbol	Pin	Type	Description
P1.0 to P1.5		I/O (P1.2); I (P1.5)	<p>Port 1: Port 1 is a 6-bit I/O port with user-configurable outputs. During reset Port 1 latches are configured in the input only mode with the internal pull-up disabled. The operation of the inputs and outputs depends upon the port configuration selected. Refer to Section 9.12.1 "Port configurations" and Table 13 "DC electrical characteristics" for details. P1.2 is an open drain when used as an output. 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>
	9	I/O O	<p>P1.0 — Port 1 bit 0</p> <p>TxD — Serial port transmitter data.</p>
	8	I/O I	<p>P1.1 — Port 1 bit 0</p> <p>RxD — Serial port receiver data.</p>
	7	I/O I/O I/O	<p>P1.2 — Port 1 bit 2. (Open drain when used as an output.)</p> <p>T0 — Timer/counter 0 external count input, overflow output, or PWM output.</p> <p>SCL — I²C-bus serial clock input/output.</p>
	6	I/O I/O I/O	<p>P1.3 — Port 1 bit 2. (Open drain when used as an output.)</p> <p>INT0 — External interrupt 0 input.</p> <p>SDA — I²C-bus serial data input/output.</p>
	5	I/O I/O	<p>P1.4 — Port 1 bit 2.</p> <p>INT1 — External interrupt 1 input.</p>
	3	I I	<p>P1.5 — Port 1 bit 5. (Input only.)</p> <p>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. When using an oscillator frequency above 12 MHz, the reset input function of P1.5 must be enabled. An external circuit is required to hold the device in reset at power-up until V_{DD} has reached its specified level. When system power is removed V_{DD} will fall below the minimum specified operating voltage. When using an oscillator frequency above 12 MHz, in some applications, an external brownout detect circuit may be required to hold the device in reset when V_{DD} falls below the minimum specified operating voltage. Also used during a power-on sequence to force In-System Programming mode.</p>
V _{SS}	4	I	Ground: 0 V reference.
V _{DD}	10	I	Power Supply: This is the power supply voltage for normal operation as well as Idle and Power-down modes.

Table 4: P89LPC916 pin description

Symbol	Pin	Type	Description
P0.1 to P0.5		I/O	<p>Port 0: Port 0 is a 5-bit I/O port with user-configurable outputs. 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 Section 9.12.1 “Port configurations” and Table 13 “DC electrical characteristics” 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>
1		I/O	P0.1 — Port 0 bit 1.
		I	CIN2B — Comparator 2 positive input B.
		I	KBI1 — Keyboard input 1.
		I	AD10 — A/D channel 1, input 0
16		I/O	P0.2 — Port 0 bit 2.
		I	CIN2A — Comparator 2 positive input A.
		I	KBI2 — Keyboard input 2.
		I	AD11 — A/D channel 1, input 1
15		I/O	P0.3 — Port 0 bit 3.
		I	CIN1B — Comparator 1 positive input B.
		I	KBI3 — Keyboard input 3.
		I	AD12 — A/D channel 1, input 2.
14		I/O	P0.4 — Port 0 bit 4.
		I	CIN1A — Comparator 1 positive input A.
		I	KBI4 — Keyboard input 4.
		I	AD13 — A/D channel 1, input 3.
		O	DAC1 — Digital to analog converter 1 output.
13		I/O	P0.5 — Port 0 bit 5.
		I	CMPREF — Comparator reference (negative) input.
		I	KBI5 — Keyboard input 5.
		I	CLKIN — External clock input.

Table 4: P89LPC916 pin description...continued

Symbol	Pin	Type	Description
P1.0 to P1.5		I/O (P1.2); I (P1.5)	<p>Port 1: Port 1 is a 5-bit I/O port with user-configurable outputs. During reset Port 1 latches are configured in the input only mode with the internal pull-up disabled. The operation of the P1.2 input and outputs depends upon the port configuration selected. Refer to Section 9.12.1 "Port configurations" and Table 13 "DC electrical characteristics" for details. P1.2 is an open drain when used as an output. 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>
	10	I/O	P1.0 — Port 1 bit 0
		O	TxD — Serial port transmitter data.
	9	I/O	P1.1 — Port 1 bit 0
		I	RxD — Serial port receiver data.
	8	I/O	P1.2 — Port 1 bit 2. (Open drain when used as an output.)
		I/O	T0 — Timer/counter 0 external count input, overflow output, or PWM output.
		I/O	SCL — I ² C-bus serial clock input/output.
	7	I/O	P1.3 — Port 1 bit 2. (Open drain when used as an output.)
		I/O	INT0 — External interrupt 0 input.
		I/O	SDA — I ² C-bus serial data input/output.
	3	I	P1.5 — Port 1 bit 5. (Input only.)
		I	<p>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. When using an oscillator frequency above 12 MHz, the reset input function of P1.5 must be enabled. An external circuit is required to hold the device in reset at power-up until V_{DD} has reached its specified level. When system power is removed V_{DD} will fall below the minimum specified operating voltage. When using an oscillator frequency above 12 MHz, in some applications, an external brownout detect circuit may be required to hold the device in reset when V_{DD} falls below the minimum specified operating voltage. Also used during a power-on sequence to force In-System Programming mode.</p>

Table 4: P89LPC916 pin description...continued

Symbol	Pin	Type	Description
P2.2 to P2.5		I/O	<p>Port 2: Port 2 is a 4-bit I/O port having user-configurable output types. During reset Port 1 latches are configured in the input only mode with the internal pull-up disabled. The operation of the P2 input and outputs depends upon the port configuration selected. Refer to Section 9.12.1 “Port configurations” and Table 13 “DC electrical characteristics” for details.</p> <p>All pins have Schmitt triggered inputs.</p> <p>Port 2 also provides various special functions as described below:</p>
	6	I/O	P2.2 — Port 2 bit 2.
		O	MOSI — SPI master out slave in. When configured as a master this pin is an output. When configured as a slave, this pin is an input.
	5	I/O	P2.3 — Port 2 bit 3.
		I	MISO — SPI master in slave out. When configured as a master this pin is an input. When configured as a slave, this pin is an output.
	2	I/O	P2.4 — Port 2 bit 4.
		I/O	SS — SPI Slave select.
	11	I/O	P2.5 — Port 2 bit 5.
		I/O	SPICLK — When configured as a master this pin is an output. When configured as a slave, this pin is an input.
V _{SS}	4	I	Ground: 0 V reference.
V _{DD}	12	I	Power Supply: This is the power supply voltage for normal operation as well as Idle and Power-down modes.

Table 5: P89LPC917 pin description

Symbol	Pin	Type	Description
P0.0 to P0.5		I/O	<p>Port 0: Port 0 is a 7-bit I/O port with user-configurable outputs. 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 Section 9.12.1 “Port configurations” and Table 13 “DC electrical characteristics” 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>
	2	I/O	P0.0 — Port 0 bit 0.
		I	CMP2 — Comparator 2 output.
		I	KBI0 — Keyboard input 0.
	1	I/O	P0.1 — Port 0 bit 1.
		I	CIN2B — Comparator 2 positive input B.
		I	KBI1 — Keyboard input 1.
		I	AD10 — A/D channel 1, input 0
	16	I/O	P0.2 — Port 0 bit 2.
		I	CIN2A — Comparator 2 positive input A.
		I	KBI2 — Keyboard input 2.
		I	AD11 — A/D channel 1, input 1
	15	I/O	P0.3 — Port 0 bit 3.
		I	CIN1B — Comparator 1 positive input B.
		I	KBI3 — Keyboard input 3.
		I	AD12 — A/D channel 1, input 2.
	14	I/O	P0.4 — Port 0 bit 4.
		I	CIN1A — Comparator 1 positive input A.
		I	KBI4 — Keyboard input 4.
		I	AD13 — A/D channel 1, input 3.
		O	DAC1 — Digital to analog converter 1 output.
	13	I/O	P0.5 — Port 0 bit 5.
		I	CMPREF — Comparator reference (negative) input.
		I	KBI5 — Keyboard input 5.
		I	CLKIN — External clock input.
	11	I/O	P0.7 — Port 0 bit 7.
		I	T1 — Timer/counter 1 external count input, overflow output, or PWM output.
		I	KBI7 — Keyboard input 7.
		I	CLKOUT — Clock output.

Table 5: P89LPC917 pin description...continued

Symbol	Pin	Type	Description
P1.0 to P1.5		I/O (P1.2); I (P1.5)	<p>Port 1: Port 1 is a 6-bit I/O port with user-configurable outputs. During reset Port 1 latches are configured in the input only mode with the internal pull-up disabled. The operation of the outputs depends upon the port configuration selected. Refer to Section 9.12.1 “Port configurations” and Table 13 “DC electrical characteristics” for details. P1.2 and P1.3 are open drain when used as outputs. P1.5 is input only. All pins have Schmitt triggered inputs.</p> <p>Port 1 also provides various special functions as described below:</p>
	10	I/O	P1.0 — Port 1 bit 0.
		O	TxD — Serial port transmitter data.
	9	I/O	P1.1 — Port 1 bit 1.
		I	RxD — Serial port receiver data.
	8	I/O	P1.2 — Port 1 bit 2. (Open drain when used as an output.)
		I/O	T0 — Timer/counter 0 external count input, overflow, or PWM output.
		I/O	SCL — I ² C-bus serial clock input/output.
	7	I/O	P1.3 — Port 1 bit 3. (Open drain when used as an output.)
		I/O	INT0 — External interrupt 0 input.
		I/O	SDA — I ² C-bus serial data input/output.
	6	I/O	P1.4 — Port 1 bit 4.
		I/O	INT1 — External interrupt 1 input.
	3	I	P1.5 — Port 1 bit 5. (Input only.)
		I	<p>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. When using an oscillator frequency above 12 MHz, the reset input function of P1.5 must be enabled. An external circuit is required to hold the device in reset at power-up until V_{DD} has reached its specified level. When system power is removed V_{DD} will fall below the minimum specified operating voltage. When using an oscillator frequency above 12 MHz, in some applications, an external brownout detect circuit may be required to hold the device in reset when V_{DD} falls below the minimum specified operating voltage. Also used during a power-on sequence to force In-System Programming mode.</p>
P2.2	5	I/O	<p>Port 2: Port 2.2 is a single-bit I/O port with a user-configurable output. During reset the Port 2.2 latch is configured in the input only mode with the internal pull-up disabled. The operation of the output depends upon the port configuration selected. Refer to Section 9.12.1 “Port configurations” and Table 13 “DC electrical characteristics” for details.</p> <p>This pin has a Schmitt triggered input.</p>
V _{SS}	4	I	Ground: 0 V reference.
V _{DD}	12	I	Power Supply: This is the power supply voltage for normal operation as well as Idle and Power-down modes.

7. Logic symbols

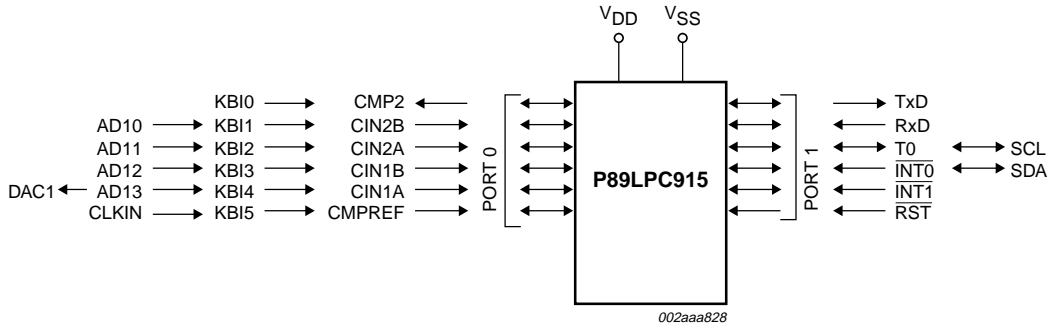


Fig 7. P89LPC915 logic symbol.

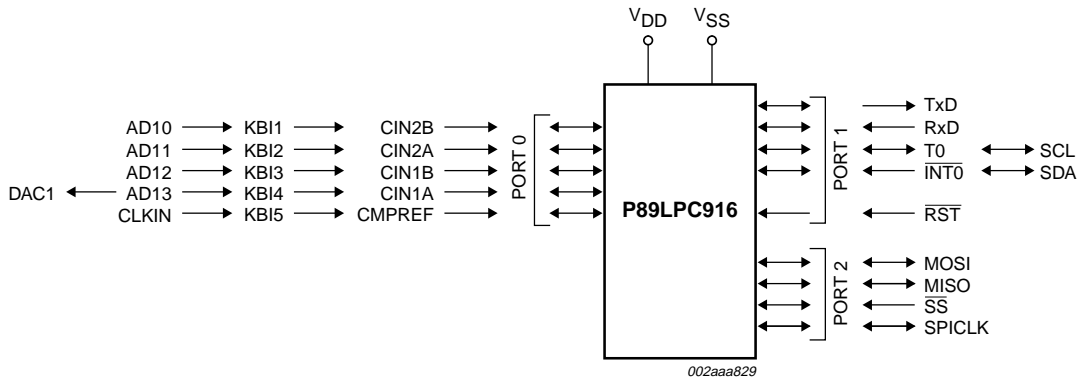


Fig 8. P89LPC916 logic symbol.

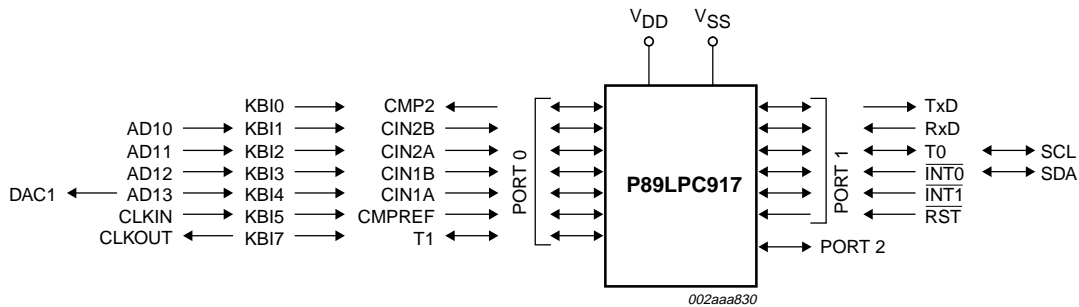


Fig 9. P89LPC917 logic symbol.

7.1 Product comparison

Table 6 highlights the differences between these three devices. For a complete list of device features, please see Section 2 “Features” on page 1.

Table 6: Product comparison

Type number	Comp 2 output	SPI	T1 PWM output	CLKOUT	$\overline{\text{INT1}}$	KBI
P89LPC915	X	-	-	-	X	6
P89LPC916	-	X	-	-	-	5
P89LPC917	X	-	X	X	X	7

8. Special function registers

Remark: Special Function Registers (SFRs) accesses are restricted in the following ways:

- User must **not** attempt to access any SFR locations not defined.
- Accesses to any defined SFR locations must be strictly for the functions for the SFRs.
- 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 7: P89LPC915 Special function registers

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value	
			MSB				LSB				Hex	Binary
Bit address			E7	E6	E5	E4	E3	E2	E1	E0		
ACC*	Accumulator	E0H									00	00000000
ADCON1	A/D control register 1	97H	ENBI1	ENADCI 1	TMM1	EDGE1	ADC11	ENADC1	ADCS11	ADCS10	00	00000000
ADINS	A/D input select	A3H	ADI13	ADI12	ADI11	ADI10	-	-	-	-	00	00000000
ADMODA	A/D mode register A	C0H	BNDI1	BURST1	SCC1	SCAN1	-	-	-	-	00	00000000
ADMODB	A/D mode register B	A1H	CLK2	CLK1	CLK0	-	ENDAC1	-	BSA1	-	00	000x0000
AD1BH	A/D_1 boundary high register	C4H									FF	11111111
AD1BL	A/D_1 boundary low register	BCH									00	00000000
AD1DAT0	A/D_1 data register 0	D5H									00	00000000
AD1DAT1	A/D_1 data register 1	D6H									00	00000000
AD1DAT2	A/D_1 data register 2	D7H									00	00000000
AD1DAT3	A/D_1 data register 3	F5H									00	00000000
AUXR1	Auxiliary function register	A2H	CLKLP	EBRR	-	ENT0	SRST	0	-	DPS	00	000000x0
Bit address			F7	F6	F5	F4	F3	F2	F1	F0		
B*	B register	F0H									00	00000000
BRGR0 ^[2]	Baud rate generator rate low	BEH									00	00000000
BRGR1 ^[2]	Baud rate generator rate high	BFH									00	00000000
BRGCON	Baud rate generator control	BDH	-	-	-	-	-	-	SBRGS	BRGEN	00 ^[2]	xxxxxx00
CMP1	Comparator 1 control register	ACH	-	-	CE1	CP1	CN1	-	CO1	CMF1	00 ^[1]	xx000000
CMP2	Comparator 2 control register	ADH	-	-	CE2	CP2	CN2	OE2	CO2	CMF2	00 ^[1]	xx000000
DIVM	CPU clock divide-by-M control	95H									00	00000000
DPTR	Data pointer (2 bytes)											
DPH	Data pointer high	83H									00	00000000
DPL	Data pointer low	82H									00	00000000
FMADRH	Program Flash address high	E7H	-	-	-	-	-	-			00	00000000
FMADRL	Program Flash address low	E6H									00	00000000

Table 7: P89LPC915 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value		
											Hex	Binary	
FMCON	Program Flash Control (Read)	E4H	BUSY	-	-	-	HVA	HVE	SV	OI	70	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									00	00000000	
I2ADR	I ² C-bus slave address register	DBH	I2ADR.6	I2ADR.5	I2ADR.4	I2ADR.3	I2ADR.2	I2ADR.1	I2ADR.0	GC	00	00000000	
			Bit address	DF	DE	DD	DC	DB	DA	D9	D8		
I2CON*	I ² C-bus control register	D8H	-	I2EN	STA	STO	SI	AA	-	CRSEL	00	x0000x0	
I2DAT	I ² C-bus data register	DAH											
I2SCLH	Serial clock generator/SCL duty cycle register high	DDH									00	00000000	
I2SCLL	Serial clock generator/SCL duty cycle register low	DCH									00	00000000	
I2STAT	I ² C-bus status register	D9H	STA.4	STA.3	STA.2	STA.1	STA.0	0	0	0	F8	11111000	
			Bit address	AF	AE	AD	AC	AB	AA	A9	A8		
IEN0*	Interrupt enable 0	A8H	EA	EWDRT	EBO	ES/ESR	ET1	EX1	ET0	EX0	00	00000000	
			Bit address	EF	EE	ED	EC	EB	EA	E9	E8		
IEN1*	Interrupt enable 1	E8H	EAD	EST	-	-	-	EC	EKBI	EI2C	00 ^[1]	00x00000	
			Bit address	BF	BE	BD	BC	BB	BA	B9	B8		
IPO*	Interrupt priority 0	B8H	-	PWDRT	PBO	PS/PSR	PT1	PX1	PT0	PX0	00 ^[1]	x0000000	
IP0H	Interrupt priority 0 high	B7H	-	PWDRT H	PBOH	PSH/ PSRH	PT1H	PX1H	PT0H	PX0H	00 ^[1]	x0000000	
			Bit address	FF	FE	FD	FC	FB	FA	F9	F8		
IP1*	Interrupt priority 1	F8H	PAD	PST	-	-	-	PC	PKBI	PI2C	00 ^[1]	00x00000	
IP1H	Interrupt priority 1 high	F7H	PADH	PSTH	-	-	-	PCH	PKBIH	PI2CH	00 ^[1]	00x00000	
KBCON	Keypad control register	94H	-	-	-	-	-	-	PATN _SEL	KBIF	00 ^[1]	xxxxxx00	
KBMASK	Keypad interrupt mask register	86H									00	00000000	
KBPATN	Keypad pattern register	93H									FF	11111111	

Table 7: P89LPC915 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value	
			MSB							LSB	Hex	Binary
		Bit address	87	86	85	84	83	82	81	80		
P0*	Port 0	80H	-	-	CMPREF /KBI5	CIN1A /KBI4	CIN1B /KBI3	CIN2A /KBI2	CIN2B /KBI1	CMP2 /KBI0		[1]
		Bit address	97	96	95	94	93	92	91	90		
P1*	Port 1	90H	-	-	RST	INT1	INT0/ SDA	T0/SCL	RXD	TXD		[1]
P0M1	Port 0 output mode 1	84H	-	-	(P0M1.5)	(P0M1.4)	(P0M1.3)	(P0M1.2)	(P0M1.1)	(P0M1.0)	FF ^[1]	11111111
P0M2	Port 0 output mode 2	85H	-	-	(P0M2.5)	(P0M2.4)	(P0M2.3)	(P0M2.2)	(P0M2.1)	(P0M2.0)	00 ^[1]	00000000
P1M1	Port 1 output mode 1	91H	-	-	-	(P1M1.4)	(P1M1.3)	(P1M1.2)	(P1M1.1)	(P1M1.0)	D3 ^[1]	11x1xx11
P1M2	Port 1 output mode 2	92H	-	-	-	(P1M2.4)	(P1M2.3)	(P1M2.2)	(P1M2.1)	(P1M2.0)	00 ^[1]	00x0xx00
PCON	Power control register	87H	SMOD1	SMOD0	BOPD	BOI	GF1	GF0	PMOD1	PMOD0	00	00000000
PCONA	Power control register A	B5H	RTCPD	-	VCPD	ADPD	I2PD	-	SPD	-	00 ^[1]	00000000
		Bit address	D7	D6	D5	D4	D3	D2	D1	D0		
PSW*	Program status word	D0H	CY	AC	F0	RS1	RS0	OV	F1	P	00	00000000
PT0AD	Port 0 digital input disable	F6H	-	-	PT0AD.5	PT0AD.4	PT0AD.3	PT0AD.2	PT0AD.1	-	00	xx00000x
RSTSRC	Reset source register	DFH	-	-	BOF	POF	R_BK	R_WD	R_SF	R_EX		[3]
RTCCON	Real-time clock control	D1H	RTCF	RTCS1	RTCS0	-	-	-	ERTC	RTCEN	60 ^{[1][6]}	011xxx00
RTCH	Real-time clock register high	D2H									00 ^[6]	00000000
RTCL	Real-time clock register low	D3H									00 ^[6]	00000000
SADDR	Serial port address register	A9H									00	00000000
SADEN	Serial port address enable	B9H									00	00000000
SBUF	Serial Port data buffer register	99H									xx	xxxxxxxx
		Bit address	9F	9E	9D	9C	9B	9A	99	98		
SCON*	Serial port control	98H	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI	00	00000000
SSTAT	Serial port extended status register	BAH	DBMOD	INTLO	CIDIS	DBISEL	FE	BR	OE	STINT	00	00000000
SP	Stack pointer	81H									07	00000111
TAMOD	Timer 0 and 1 auxiliary mode	8FH	-	-	-	-	-	-	-	T0M2	00	xxx0xxx0
		Bit address	8F	8E	8D	8C	8B	8A	89	88		
TCON*	Timer 0 and 1 control	88H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	00	00000000

Table 7: P89LPC915 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value		
			MSB				LSB				Hex	Binary	
TH0	Timer 0 high	8CH										00	00000000
TH1	Timer 1 high	8DH										00	00000000
TL0	Timer 0 low	8AH										00	00000000
TL1	Timer 1 low	8BH										00	00000000
TMOD	Timer 0 and 1 mode	89H	T1GATE	T1C/T	T1M1	T1M0	T0GATE	T0C/T	T0M1	T0M0		00	00000000
TRIM	Internal oscillator trim register	96H	RCCLK	-	TRIM.5	TRIM.4	TRIM.3	TRIM.2	TRIM.1	TRIM.0		[5] [6]	
WDCON	Watchdog control register	A7H	PRE2	PRE1	PRE0	-	-	WDRUN	WDTOF	WDCLK		[4] [6]	
WDL	Watchdog load	C1H										FF	11111111
WFEED1	Watchdog feed 1	C2H											
WFEED2	Watchdog feed 2	C3H											

[1] All ports are in input only (high impedance) state after power-up.

[2] BRGR1 and BRGR0 must only be written if BRGEN in BRGCON SFR is logic 0. If any are written while BRGEN = 1, the result is unpredictable.

[3] The RSTSRC register reflects the cause of the P89LPC915/916/917 reset. Upon a power-up reset, all reset source flags are cleared except POF and BOF; the power-on reset value is xx110000.

[4] After reset, the value is 111001x1, i.e., PRE[2:0] are all logic 1, WDRUN = 1 and WDCLK = 1. WDTOF bit is logic 1 after Watchdog reset and is logic 0 after power-on reset. Other resets will not affect WDTOF.

[5] On power-on reset, the TRIM SFR is initialized with a factory preprogrammed value. Other resets will not cause initialization of the TRIM register.

[6] The only reset source that affects these SFRs is power-on reset

Table 8: P89LPC916 Special function registers

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value	
			MSB				LSB				Hex	Binary
	Bit address		E7	E6	E5	E4	E3	E2	E1	E0		
ACC*	Accumulator	E0H									00	00000000
ADCON1	A/D control register 1	97H	ENBI1	ENADCI 1	TMM1	EDGE1	ADC11	ENADC1	ADCS11	ADCS10	00	00000000
ADINS	A/D input select	A3H	ADI13	ADI12	ADI11	ADI10	-	-	-	-	00	00000000
ADMODA	A/D mode register A	C0H	BNDI1	BURST1	SCC1	SCAN1	-	-	-	-	00	00000000
ADMODB	A/D mode register B	A1H	CLK2	CLK1	CLK0	-	ENDAC1	-	BSA1	-	00	000x0000
AD1BH	A/D_1 boundary high register	C4H									FF	11111111
AD1BL	A/D_1 boundary low register	BCH									00	00000000
AD1DAT0	A/D_1 data register 0	D5H									00	00000000
AD1DAT1	A/D_1 data register 1	D6H									00	00000000
AD1DAT2	A/D_1 data register 2	D7H									00	00000000
AD1DAT3	A/D_1 data register 3	F5H									00	00000000
AUXR1	Auxiliary function register	A2H	CLKLP	EBRR	-	ENT0	SRST	0	-	DPS	00	000000x0
	Bit address		F7	F6	F5	F4	F3	F2	F1	F0		
B*	B register	F0H									00	00000000
BRGR0 ^[2]	Baud rate generator rate low	BEH									00	00000000
BRGR1 ^[2]	Baud rate generator rate high	BFH									00	00000000
BRGCON	Baud rate generator control	BDH	-	-	-	-	-	-	SBRGS	BRGEN	00 ^[2]	xxxxxx00
CMP1	Comparator 1 control register	ACH	-	-	CE1	CP1	CN1	-	CO1	CMF1	00 ^[1]	xx000000
CMP2	Comparator 2 control register	ADH	-	-	CE2	CP2	CN2	OE2	CO2	CMF2	00	xx000000
DIVM	CPU clock divide-by-M control	95H									00	00000000
DPTR	Data pointer (2 bytes)											
DPH	Data pointer high	83H									00	00000000
DPL	Data pointer low	82H									00	00000000
FMADRH	Program Flash address high	E7H	-	-	-	-	-	-			00	00000000
FMADRL	Program Flash address low	E6H									00	00000000

Table 8: P89LPC916 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value	
											Hex	Binary
FMCON	Program Flash Control (Read)	E4H	BUSY	-	-	-	HVA	HVE	SV	OI	70	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									00	00000000
I2ADR	I ² C-bus slave address register	DBH	I2ADR.6	I2ADR.5	I2ADR.4	I2ADR.3	I2ADR.2	I2ADR.1	I2ADR.0	GC	00	00000000
			Bit address	DF	DE	DD	DC	DB	DA	D9	D8	
I2CON*	I ² C-bus control register	D8H	-	I2EN	STA	STO	SI	AA	-	CRSEL	00	x0000x0
I2DAT	I ² C-bus data register	DAH										
I2SCLH	Serial clock generator/SCL duty cycle register high	DDH									00	00000000
I2SCLL	Serial clock generator/SCL duty cycle register low	DCH									00	00000000
I2STAT	I ² C-bus status register	D9H	STA.4	STA.3	STA.2	STA.1	STA.0	0	0	0	F8	11111000
			Bit address	AF	AE	AD	AC	AB	AA	A9	A8	
IEN0*	Interrupt enable 0	A8H	EA	EWDRT	EBO	ES/ESR	ET1	-	ET0	EX0	00	00000000
			Bit address	EF	EE	ED	EC	EB	EA	E9	E8	
IEN1*	Interrupt enable 1	E8H	EAD	EST	-	-	ESPI	EC	EKBI	EI2C	00 ^[1]	00x00000
			Bit address	BF	BE	BD	BC	BB	BA	B9	B8	
IPO*	Interrupt priority 0	B8H	-	PWDRT	PBO	PS/PSR	PT1	-	PT0	PX0	00 ^[1]	x0000000
IP0H	Interrupt priority 0 high	B7H	-	PWDRT H	PBOH	PSH/ PSRH	PT1H	-	PT0H	PX0H	00 ^[1]	x0000000
			Bit address	FF	FE	FD	FC	FB	FA	F9	F8	
IP1*	Interrupt priority 1	F8H	PAD	PST	-	-	PSPI	PC	PKBI	PI2C	00 ^[1]	00x00000
IP1H	Interrupt priority 1 high	F7H	PADH	PSTH	-	-	PSPIH	PCH	PKBIH	PI2CH	00 ^[1]	00x00000
KBCON	Keypad control register	94H	-	-	-	-	-	-	PATN _SEL	KBIF	00 ^[1]	xxxxxx00
KBMASK	Keypad interrupt mask register	86H									00	00000000
KBPATN	Keypad pattern register	93H									FF	11111111

Table 8: P89LPC916 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value	
			MSB							LSB	Hex	Binary
		Bit address	87	86	85	84	83	82	81	80		
P0*	Port 0	80H	-	-	CMPREF /KBI5	CIN1A /KBI4	CIN1B /KBI3	CIN2A /KBI2	CIN2B /KBI1	-		[1]
		Bit address	97	96	95	94	93	92	91	90		
P1*	Port 1	90H	-	-	RST	-	INT0/SDA	T0/SCL	RXD	TXD		[1]
		Bit address	97	96	95	94	93	92	91	90		
P2*	Port 2	A0H	-	-	SPICLK	SS	MISO	MOSI	-	-		[1]
P0M1	Port 0 output mode 1	84H	-	-	(P0M1.5)	(P0M1.4)	(P0M1.3)	(P0M1.2)	(P0M1.1)	-	FF ^[1]	11111111
P0M2	Port 0 output mode 2	85H	-	-	(P0M2.5)	(P0M2.4)	(P0M2.3)	(P0M2.2)	(P0M2.1)	-	00 ^[1]	00000000
P1M1	Port 1 output mode 1	91H	-	-	-	-	(P1M1.3)	(P1M1.2)	(P1M1.1)	(P1M1.0)	D3 ^[1]	11x1xx11
P1M2	Port 1 output mode 2	92H	-	-	-	-	(P1M2.3)	(P1M2.2)	(P1M2.1)	(P1M2.0)	00 ^[1]	00x0xx00
P2M1	Port 2 output mode 1	A4H	-	-	(P2M1.5)	(P2M1.4)	(P2M1.3)	(P2M1.2)	-	-	FF ^[1]	11111111
P2M2	Port 2 output mode 2	A5H	-	-	(P2M2.5)	(P2M2.4)	(P2M2.3)	(P2M2.2)	-	-	00 ^[1]	00000000
PCON	Power control register	87H	SMOD1	SMOD0	BOPD	BOI	GF1	GF0	PMOD1	PMOD0	00	00000000
PCONA	Power control register A	B5H	RTCPD	-	VCPD	ADPD	I2PD	SPPD	SPD	-	00 ^[1]	00000000
		Bit address	D7	D6	D5	D4	D3	D2	D1	D0		
PSW*	Program status word	D0H	CY	AC	F0	RS1	RS0	OV	F1	P	00	00000000
PT0AD	Port 0 digital input disable	F6H	-	-	PT0AD.5	PT0AD.4	PT0AD.3	PT0AD.2	PT0AD.1	-	00	xx00000x
RSTSRC	Reset source register	DFH	-	-	BOF	POF	R_BK	R_WD	R_SF	R_EX		[3]
RTCCON	Real-time clock control	D1H	RTCF	RTCS1	RTCS0	-	-	-	ERTC	RTCEN	60 ^[1] [6]	011xxx00
RTCH	Real-time clock register high	D2H									00 ^[6]	00000000
RTCL	Real-time clock register low	D3H									00 ^[6]	00000000
SADDR	Serial port address register	A9H									00	00000000
SADEN	Serial port address enable	B9H									00	00000000
SBUF	Serial Port data buffer register	99H									xx	xxxxxxxx
		Bit address	9F	9E	9D	9C	9B	9A	99	98		
SCON*	Serial port control	98H	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI	00	00000000
SSTAT	Serial port extended status register	BAH	DBMOD	INTLO	CIDIS	DBISEL	FE	BR	OE	STINT	00	00000000

Table 8: P89LPC916 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value		
			MSB				LSB				Hex	Binary	
SP	Stack pointer	81H										07	00000111
SPCTL	SPI control register	E2H	SSIG	SPEN	DORD	MSTR	CPOL	CPHA	SPR1	SPR0		04	00000100
SPSTAT	SPI status register	E1H	SPIF	WCOL	-	-	-	-	-	-		00	00xxxxxx
SPDAT	SPI data register	E3H										00	00000000
TAMOD	Timer 0 and 1 auxiliary mode	8FH	-	-	-	-	-	-	-	T0M2		00	xxx0xxx0
		Bit address	8F	8E	8D	8C	8B	8A	89	88			
TCON*	Timer 0 and 1 control	88H	TF1	TR1	TF0	TR0	-	-	IE0	IT0		00	00000000
TH0	Timer 0 high	8CH										00	00000000
TH1	Timer 1 high	8DH										00	00000000
TL0	Timer 0 low	8AH										00	00000000
TL1	Timer 1 low	8BH										00	00000000
TMOD	Timer 0 and 1 mode	89H	T1GATE	T1C/T	T1M1	T1M0	T0GATE	T0C/T	T0M1	T0M0		00	00000000
TRIM	Internal oscillator trim register	96H	RCCLK	-	TRIM.5	TRIM.4	TRIM.3	TRIM.2	TRIM.1	TRIM.0		[5] [6]	
WDCON	Watchdog control register	A7H	PRE2	PRE1	PRE0	-	-	WDRUN	WDTOF	WDCLK		[4] [6]	
WDL	Watchdog load	C1H										FF	11111111
WFEED1	Watchdog feed 1	C2H											
WFEED2	Watchdog feed 2	C3H											

[1] All ports are in input only (high impedance) state after power-up.

[2] BRGR1 and BRGR0 must only be written if BRGEN in BRGCON SFR is logic 0. If any are written while BRGEN = 1, the result is unpredictable.

[3] The RSTSRC register reflects the cause of the P89LPC915/916/917 reset. Upon a power-up reset, all reset source flags are cleared except POF and BOF; the power-on reset value is xx110000.

[4] After reset, the value is 111001x1, i.e., PRE[2:0] are all logic 1, WDRUN = 1 and WDCLK = 1. WDTOF bit is logic 1 after Watchdog reset and is logic 0 after power-on reset. Other resets will not affect WDTOF.

[5] On power-on reset, the TRIM SFR is initialized with a factory preprogrammed value. Other resets will not cause initialization of the TRIM register.

[6] The only reset source that affects these SFRs is power-on reset.

Table 9: P89LPC917 Special function registers

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value	
			MSB				LSB				Hex	Binary
	Bit address		E7	E6	E5	E4	E3	E2	E1	E0		
ACC*	Accumulator	E0H									00	00000000
ADCON1	A/D control register 1	97H	ENBI1	ENADCI 1	TMM1	EDGE1	ADC11	ENADC1	ADCS11	ADCS10	00	00000000
ADINS	A/D input select	A3H	ADI13	ADI12	ADI11	ADI10	-	-	-	-	00	00000000
ADMODA	A/D mode register A	C0H	BNDI1	BURST1	SCC1	SCAN1	-	-	-	-	00	00000000
ADMODB	A/D mode register B	A1H	CLK2	CLK1	CLK0	-	ENDAC1	-	BSA1	-	00	000x0000
AD1BH	A/D_1 boundary high register	C4H									FF	11111111
AD1BL	A/D_1 boundary low register	BCH									00	00000000
AD1DAT0	A/D_1 data register 0	D5H									00	00000000
AD1DAT1	A/D_1 data register 1	D6H									00	00000000
AD1DAT2	A/D_1 data register 2	D7H									00	00000000
AD1DAT3	A/D_1 data register 3	F5H									00	00000000
AUXR1	Auxiliary function register	A2H	CLKLP	EBRR	ENT1	ENT0	SRST	0	-	DPS	00	000000x0
	Bit address		F7	F6	F5	F4	F3	F2	F1	F0		
B*	B register	F0H									00	00000000
BRGR0 ^[2]	Baud rate generator rate low	BEH									00	00000000
BRGR1 ^[2]	Baud rate generator rate high	BFH									00	00000000
BRGCON	Baud rate generator control	BDH	-	-	-	-	-	-	SBRGS	BRGEN	00 ^[2]	xxxxxx00
CMP1	Comparator 1 control register	ACH	-	-	CE1	CP1	CN1	-	CO1	CMF1	00 ^[1]	xx000000
CMP2	Comparator 2 control register	ADH	-	-	CE2	CP2	CN2	OE2	CO2	CMF2	00 ^[1]	xx000000
DIVM	CPU clock divide-by-M control	95H									00	00000000
DPTR	Data pointer (2 bytes)											
DPH	Data pointer high	83H									00	00000000
DPL	Data pointer low	82H									00	00000000
FMADRH	Program Flash address high	E7H	-	-	-	-	-	-			00	00000000
FMADRL	Program Flash address low	E6H									00	00000000

Table 9: P89LPC917 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value		
											Hex	Binary	
FMCON	Program Flash Control (Read)	E4H	BUSY	-	-	-	HVA	HVE	SV	OI	70	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									00	00000000	
I2ADR	I ² C-bus slave address register	DBH	I2ADR.6	I2ADR.5	I2ADR.4	I2ADR.3	I2ADR.2	I2ADR.1	I2ADR.0	GC	00	00000000	
			Bit address	DF	DE	DD	DC	DB	DA	D9	D8		
I2CON*	I ² C-bus control register	D8H	-	I2EN	STA	STO	SI	AA	-	CRSEL	00	x0000x0	
I2DAT	I ² C-bus data register	DAH											
I2SCLH	Serial clock generator/SCL duty cycle register high	DDH									00	00000000	
I2SCLL	Serial clock generator/SCL duty cycle register low	DCH									00	00000000	
I2STAT	I ² C-bus status register	D9H	STA.4	STA.3	STA.2	STA.1	STA.0	0	0	0	F8	11111000	
			Bit address	AF	AE	AD	AC	AB	AA	A9	A8		
IEN0*	Interrupt enable 0	A8H	EA	EWDRT	EBO	ES/ESR	ET1	EX1	ET0	EX0	00	00000000	
			Bit address	EF	EE	ED	EC	EB	EA	E9	E8		
IEN1*	Interrupt enable 1	E8H	EAD	EST	-	-	-	EC	EKBI	EI2C	00 ^[1]	00x00000	
			Bit address	BF	BE	BD	BC	BB	BA	B9	B8		
IPO*	Interrupt priority 0	B8H	-	PWDRT	PBO	PS/PSR	PT1	PX1	PT0	PX0	00 ^[1]	x0000000	
IP0H	Interrupt priority 0 high	B7H	-	PWDRT H	PBOH	PSH/ PSRH	PT1H	PX1H	PT0H	PX0H	00 ^[1]	x0000000	
			Bit address	FF	FE	FD	FC	FB	FA	F9	F8		
IP1*	Interrupt priority 1	F8H	PAD	PST	-	-	-	PC	PKBI	PI2C	00 ^[1]	00x00000	
IP1H	Interrupt priority 1 high	F7H	PADH	PSTH	-	-	-	PCH	PKBIH	PI2CH	00 ^[1]	00x00000	
KBCON	Keypad control register	94H	-	-	-	-	-	-	PATN _SEL	KBIF	00 ^[1]	xxxxxx00	
KBMASK	Keypad interrupt mask register	86H									00	00000000	
KBPATN	Keypad pattern register	93H									FF	11111111	

Table 9: P89LPC917 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value		
			MSB							LSB	Hex	Binary	
			Bit address	87	86	85	84	83	82	81	80		
P0*	Port 0	80H	T1/KBI7/ CLKOUT	-	CMPREF /KBI5	CIN1A /KBI4	CIN1B /KBI3	CIN2A /KBI2	CIN2B /KBI1	CMP2 /KBI0			[1]
			Bit address	97	96	95	94	93	92	91	90		
P1*	Port 1	90H	-	-	RST	INT1	INT0/ SDA	T0/SCL	RXD	TXD			[1]
P0M1	Port 0 output mode 1	84H	(P0M1.7)	-	(P0M1.5)	(P0M1.4)	(P0M1.3)	(P0M1.2)	(P0M1.1)	(P0M1.0)	FF ^[1]	11111111	
P0M2	Port 0 output mode 2	85H	(P0M2.7)	-	(P0M2.5)	(P0M2.4)	(P0M2.3)	(P0M2.2)	(P0M2.1)	(P0M2.0)	00 ^[1]	00000000	
P1M1	Port 1 output mode 1	91H	-	-	-	(P1M1.4)	(P1M1.3)	(P1M1.2)	(P1M1.1)	(P1M1.0)	D3 ^[1]	11x1xx11	
P1M2	Port 1 output mode 2	92H	-	-	-	(P1M2.4)	(P1M2.3)	(P1M2.2)	(P1M2.1)	(P1M2.0)	00 ^[1]	00x0xx00	
PCON	Power control register	87H	SMOD1	SMOD0	BOPD	BOI	GF1	GF0	PMOD1	PMOD0	00	00000000	
PCONA	Power control register A	B5H	RTCPD	-	VCPD	ADPD	I2PD	-	SPD	-	00 ^[1]	00000000	
			Bit address	D7	D6	D5	D4	D3	D2	D1	D0		
PSW*	Program status word	D0H	CY	AC	F0	RS1	RS0	OV	F1	P	00	00000000	
PT0AD	Port 0 digital input disable	F6H	-	-	PT0AD.5	PT0AD.4	PT0AD.3	PT0AD.2	PT0AD.1	-	00	xx00000x	
RSTSRC	Reset source register	DFH	-	-	BOF	POF	R_BK	R_WD	R_SF	R_EX			[3]
RTCCON	Real-time clock control	D1H	RTCF	RTCS1	RTCS0	-	-	-	ERTC	RTCEN	60 ^{[1][6]}	011xxx00	
RTCH	Real-time clock register high	D2H									00 ^[6]	00000000	
RTCL	Real-time clock register low	D3H									00 ^[6]	00000000	
SADDR	Serial port address register	A9H									00	00000000	
SADEN	Serial port address enable	B9H									00	00000000	
SBUF	Serial Port data buffer register	99H									xx	xxxxxxxx	
			Bit address	9F	9E	9D	9C	9B	9A	99	98		
SCON*	Serial port control	98H	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI	00	00000000	
SSTAT	Serial port extended status register	BAH	DBMOD	INTLO	CIDIS	DBISEL	FE	BR	OE	STINT	00	00000000	
SP	Stack pointer	81H									07	00000111	
TAMOD	Timer 0 and 1 auxiliary mode	8FH	-	-	-	T1M2	-	-	-	T0M2	00	xxx0xxx0	
			Bit address	8F	8E	8D	8C	8B	8A	89	88		
TCON*	Timer 0 and 1 control	88H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	00	00000000	

Table 9: P89LPC917 Special function registers...continued

* indicates SFRs that are bit addressable.

Name	Description	SFR addr.	Bit functions and addresses								Reset value	
			MSB				LSB				Hex	Binary
TH0	Timer 0 high	8CH									00	00000000
TH1	Timer 1 high	8DH									00	00000000
TL0	Timer 0 low	8AH									00	00000000
TL1	Timer 1 low	8BH									00	00000000
TMOD	Timer 0 and 1 mode	89H	T1GATE	T1C/T	T1M1	T1M0	T0GATE	T0C/T	T0M1	T0M0	00	00000000
TRIM	Internal oscillator trim register	96H	RCCLK	ENCLK	TRIM.5	TRIM.4	TRIM.3	TRIM.2	TRIM.1	TRIM.0	[5]	[6]
WDCON	Watchdog control register	A7H	PRE2	PRE1	PRE0	-	-	WDRUN	WDTOF	WDCLK	[4]	[6]
WDL	Watchdog load	C1H									FF	11111111
WFEED1	Watchdog feed 1	C2H										
WFEED2	Watchdog feed 2	C3H										

[1] All ports are in input only (high impedance) state after power-up.

[2] BRGR1 and BRGR0 must only be written if BRGEN in BRGCON SFR is logic 0. If any are written while BRGEN = 1, the result is unpredictable.

[3] The RSTSRC register reflects the cause of the P89LPC915/916/917 reset. Upon a power-up reset, all reset source flags are cleared except POF and BOF; the power-on reset value is xx110000.

[4] After reset, the value is 111001x1, i.e., PRE[2:0] are all logic 1, WDRUN = 1 and WDCLK = 1. WDTOF bit is logic 1 after Watchdog reset and is logic 0 after power-on reset. Other resets will not affect WDTOF.

[5] On power-on reset, the TRIM SFR is initialized with a factory preprogrammed value. Other resets will not cause initialization of the TRIM register.

[6] The only reset source that affects these SFRs is power-on reset.

9. Functional description

Remark: Please refer to the *P89LPC915/916/917 User's Manual* for a more detailed functional description.

9.1 Enhanced CPU

The P89LPC915/916/917 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.

9.2 Clocks

9.2.1 Clock definitions

The P89LPC915/916/917 device has several internal clocks as defined below:

OSCCLK — Input to the DIVM clock divider. OSCCLK is selected from one of three clock sources (see [Figure 10](#)) and can also be optionally divided to a slower frequency (see [Section 9.7 “CPU Clock \(CCLK\) modification: DIVM register”](#)).

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

CCLK — CPU clock; output of the 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

9.2.2 CPU clock (OSCCLK)

The P89LPC915/916/917 provide 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, and an external clock input.

9.2.3 Clock output (P89LPC917)

The P89LPC917 supports a user selectable clock output function on the CLKOUT pin. This allows external devices to synchronize to the P89LPC917. This output is enabled by the ENCLK bit in the TRIM register. The frequency of this clock output is $\frac{1}{2}$ 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.

9.3 On-chip RC oscillator option

The P89LPC915/916/917 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, $\pm 1\%$ at room temperature. End-user applications can write to the TRIM register to adjust the on-chip RC oscillator to other frequencies.

9.4 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.

9.5 External clock input option

In this configuration, the processor clock is derived from an external source driving the CLKIN pin. The rate may be from 0 Hz up to 18 MHz. **When using an oscillator frequency above 12 MHz, the reset input function of P1.5 must be enabled. An external circuit is required to hold the device in reset at power-up until V_{DD} has reached its specified level. When system power is removed V_{DD} will fall below the minimum specified operating voltage. When using an oscillator frequency above 12 MHz, in some applications, an external brownout detect circuit may be required to hold the device in reset when V_{DD} falls below the minimum specified operating voltage.**

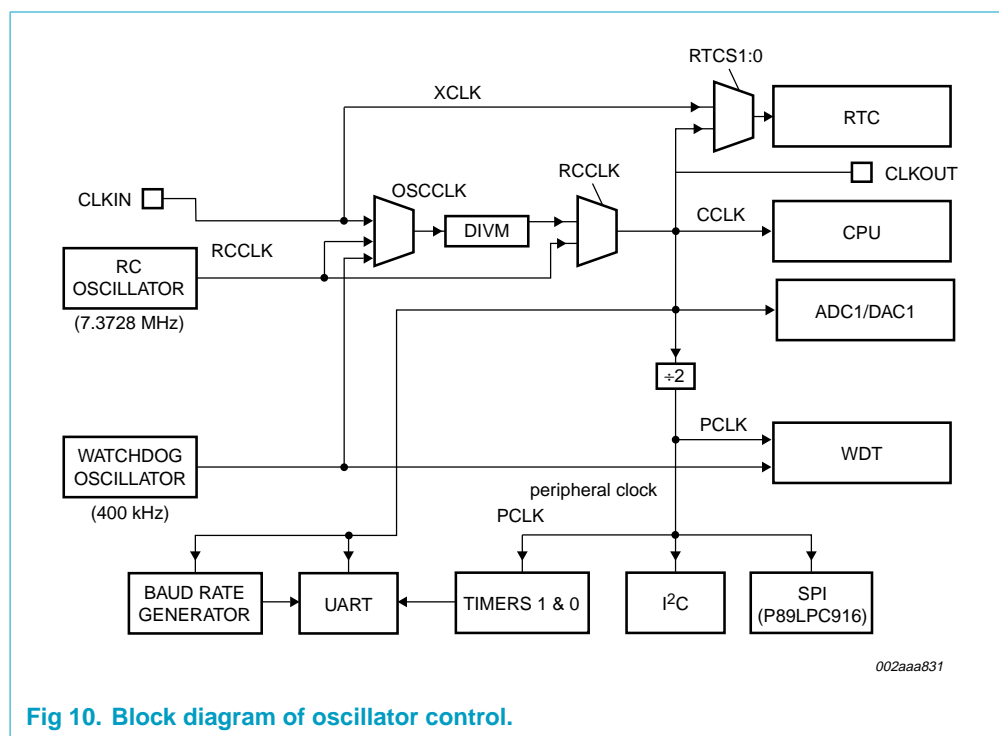


Fig 10. Block diagram of oscillator control.

9.6 CPU Clock (CCLK) wake-up delay

The P89LPC915/916/917 has an internal wake-up timer that delays the clock until it stabilizes. The delay is 224 OSCCLK cycles plus 60 to 100 μ s.

9.7 CPU Clock (CCLK) modification: DIVM register

The OSCCLK frequency can be divided down up to 510 times by configuring a dividing register, DIVM, to generate CCLK. 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 that would not exit Idle mode by executing its normal program at a lower rate. This can also 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.

9.8 Low power select

The P89LPC915/916/917 are designed to run at 18 MHz (CCLK) maximum. However, if CCLK is 8 MHz or slower, the CLKLP SFR bit (AUXR1.7) can be set to logic 1 to lower the power consumption further. On any reset, CLKLP is logic 0 allowing highest performance access. This bit can then be set in software if CCLK is running at 8 MHz or slower.

9.9 A/D converter

9.9.1 General description

The P89LPC915/916/917 has an 8-bit, 4-channel multiplexed successive approximation analog-to-digital converter. A block diagram of the A/D converter is shown in Figure 11. The A/D consists of a 4-input multiplexer which feeds a sample-and-hold circuit providing an input signal to one of two comparator inputs. The control logic in combination with the successive approximation register (SAR) drives a digital-to-analog converter which provides the other input to the comparator. The output of the comparator is fed to the SAR.

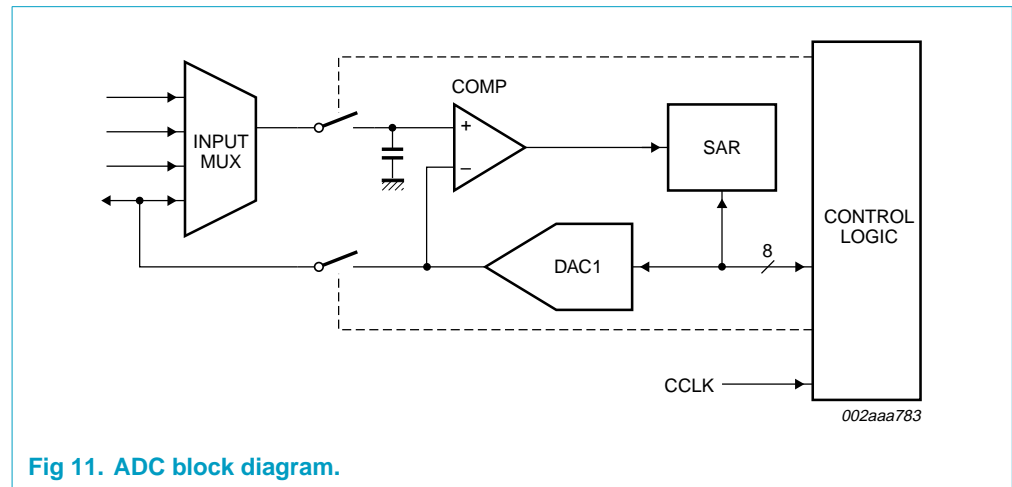


Fig 11. ADC block diagram.

9.9.2 Features

- An 8-bit, 4-channel multiplexed input, successive approximation A/D converter
- Four A/D result registers
- Six operating modes
 - Fixed channel, single conversion mode
 - Fixed channel, continuous conversion mode
 - Auto scan, single conversion mode
 - Auto scan, continuous conversion mode
 - Dual channel, continuous conversion mode
 - Single step mode
- Three conversion start modes
 - Timer triggered start
 - Start immediately
 - Edge triggered
- 8-bit conversion time of $\geq 3.9 \mu\text{s}$ at an ADC clock of 3.3 MHz
- Interrupt or polled operation
- Boundary limits interrupt
- DAC output to a port pin with high output impedance
- Clock divider
- Power-down mode

9.9.3 A/D operating modes

Fixed channel, single conversion mode: A single input channel can be selected for conversion. A single conversion will be performed and the result placed in the result register which corresponds to the selected input channel. An interrupt, if enabled, will be generated after the conversion completes.

Fixed channel, continuous conversion mode: A single input channel can be selected for continuous conversion. The results of the conversions will be sequentially placed in the four result registers. An interrupt, if enabled, will be generated after every four conversions. Additional conversion results will again cycle through the four result registers, overwriting the previous results. Continuous conversions continue until terminated by the user.

Auto scan, single conversion mode: Any combination of the four input channels can be selected for conversion. A single conversion of each selected input will be performed and the result placed in the result register which corresponds to the selected input channel. An interrupt, if enabled, will be generated after all selected channels have been converted. If only a single channel is selected this is equivalent to single channel, single conversion mode.

Auto scan, continuous conversion mode: Any combination of the four input channels can be selected for conversion. A conversion of each selected input will be performed and the result placed in the result register which corresponds to the selected input channel. An interrupt, if enabled, will be generated after all selected

channels have been converted. The process will repeat starting with the first selected channel. Additional conversion results will again cycle through the four result registers, overwriting the previous results. Continuous conversions continue until terminated by the user.

Dual channel, continuous conversion mode: This is a variation of the auto scan continuous conversion mode where conversion occurs on two user-selectable inputs. The result of the conversion of the first channel is placed in result register, AD1DAT0. The result of the conversion of the second channel is placed in result register, AD1DAT1. The first channel is again converted and its result stored in AD1DAT2. The second channel is again converted and its result placed in AD1DAT3. An interrupt is generated, if enabled, after every set of four conversions (two conversions per channel).

Single step mode: This special mode allows 'single-stepping' in an auto scan conversion mode. Any combination of the four input channels can be selected for conversion. After each channel is converted, an interrupt is generated, if enabled, and the A/D waits for the next start condition. May be used with any of the start modes.

9.9.4 Conversion start modes

Timer triggered start: An A/D conversion is started by the overflow of Timer 0. Once a conversion has started, additional Timer 0 triggers are ignored until the conversion has completed. The Timer triggered start mode is available in all A/D operating modes.

Start immediately: Programming this mode immediately starts a conversion. This start mode is available in all A/D operating modes.

Edge triggered: (P89LPC915/917) An A/D conversion is started by rising or falling edge of P1.4. Once a conversion has started, additional edge triggers are ignored until the conversion has completed. The edge triggered start mode is available in all A/D operating modes.

9.9.5 Boundary limits interrupt

The A/D converters have both a high and low boundary limit register. After the four MSBs have been converted, these four bits are compared with the four MSBs of the boundary high and low registers. If the four MSBs of the conversion are outside the limit an interrupt will be generated, if enabled. If the conversion result is within the limits, the boundary limits will again be compared after all 8 bits have been converted. An interrupt will be generated, if enabled, if the result is outside the boundary limits. The boundary limit may be disabled by clearing the boundary limit interrupt enable.

9.9.6 DAC output to a port pin with high output impedance

The A/D converter's DAC block can be output to a port pin. In this mode, the AD1DAT3 register is used to hold the value fed to the DAC. After a value has been written to AD1DAT3, the DAC output will appear on the channel 3 pin.

9.9.7 Clock divider

The A/D converter requires that its internal clock source be in the range of 500 kHz to 3.3 MHz to maintain accuracy. A programmable clock divider that divides the clock from 1 to 8 is provided for this purpose.

9.9.8 Power-down and Idle mode

In Idle mode the A/D converter, if enabled, will continue to function and can cause the device to exit Idle mode when the conversion is completed if the A/D interrupt is enabled. In Power-down mode or Total power-down mode, the A/D does not function. If the A/D is enabled, it will consume power. Power can be reduced by disabling the A/D.

9.10 Memory organization

The various P89LPC915/916/917 memory spaces are as follows:

- DATA
256 bytes of internal data memory space (00h:FFh) accessed via direct or indirect addressing, using instructions other than MOVX and MOVC. All or part of the Stack may be in this area.
- SFR
Special Function Registers. Selected CPU registers and peripheral control and status registers, accessible only via direct addressing.
- CODE
64 kB of Code memory space, accessed as part of program execution and via the MOVC instruction. The P89LPC915/916/917 has 2 kB of on-chip Code memory.

9.11 Interrupts

The P89LPC915/916/917 uses a four priority level interrupt structure. This allows great flexibility in controlling the handling of the many interrupt sources.

The P89LPC915 and P89LPC917 support 13 interrupt sources: external interrupts 0 and 1, timers 0 and 1, serial port Tx, serial port Rx, combined serial port Rx and Tx, brownout detect, Watchdog/Real-Time clock, I2C, keyboard, comparators 1 and 2, and the A/D converter.

The P89LPC916 supports 14 interrupt sources: external interrupt 0, timers 0 and 1, serial port Tx, serial port Rx, combined serial port Rx and Tx, brownout detect, Watchdog/Real-Time clock, I2C, keyboard, comparators 1 and 2, SPI, and the A/D converter.

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 disable bit, EA, which disables 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 IPO, IPOH, 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 pending at the start of an instruction, the request of higher priority level is serviced.

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

9.11.1 External interrupt inputs

The P89LPC915 and P89LPC917 have two external interrupt inputs as well as the Keypad Interrupt function. The P89LPC916 has one external interrupt input as well as the Keypad Interrupt function. These external 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 setting or clearing bit IT1 or IT0 in Register TCON.

In edge-triggered mode, if successive samples of the $\overline{\text{INTn}}$ pin show a HIGH in one cycle and a LOW in the next cycle, the interrupt request flag IEn in TCON is set, causing an interrupt request.

If an external interrupt is enabled when the P89LPC915/916/917 is put into Power-down or Idle mode, the interrupt will cause the processor to wake-up and resume operation. Refer to [Section 9.14 "Power reduction modes"](#) for details.

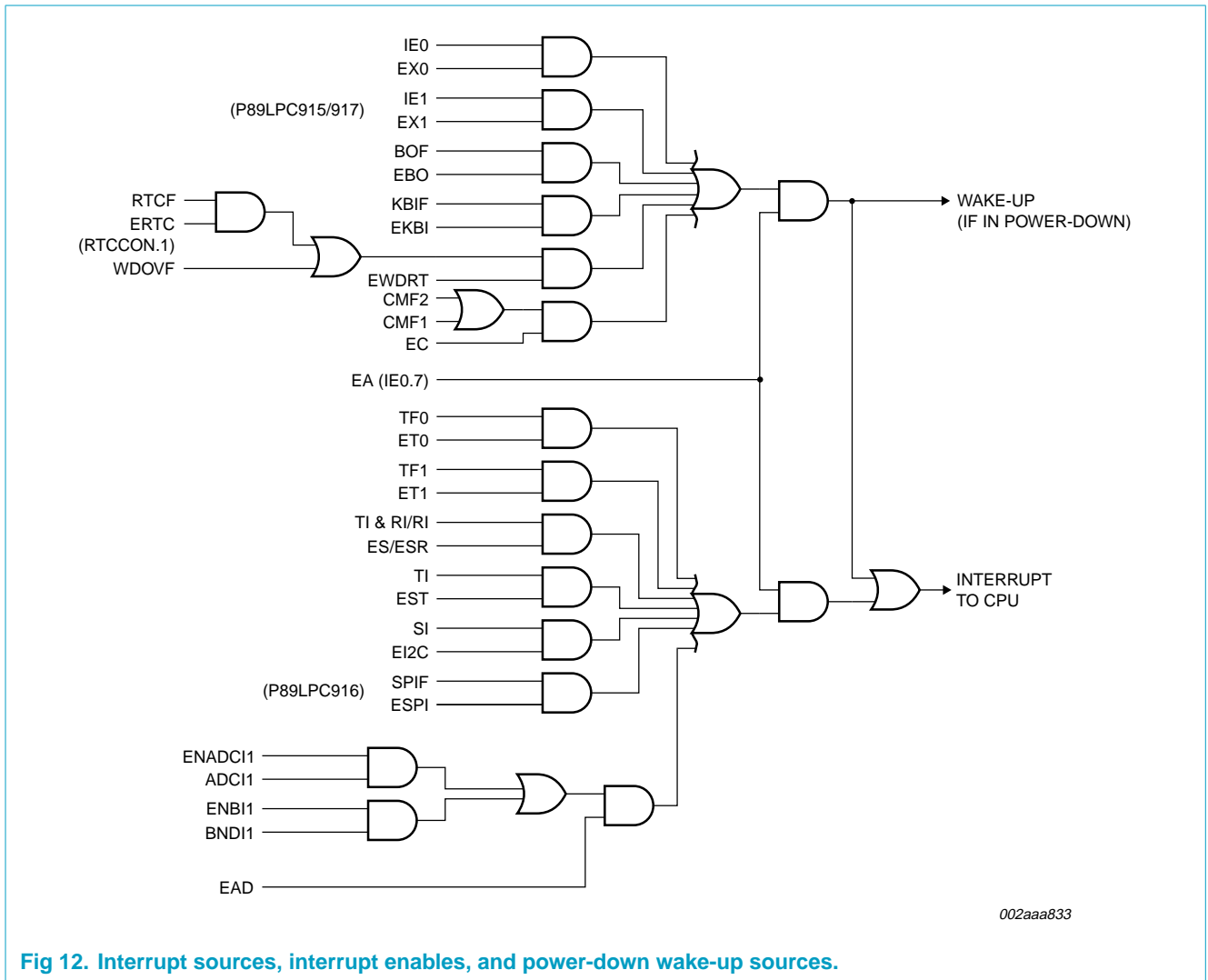


Fig 12. Interrupt sources, interrupt enables, and power-down wake-up sources.

9.12 I/O ports

The P89LPC916 and P89LPC917 devices have three I/O ports: Port 0, Port 1, and Port 2. The exact number of I/O pins available depends on the clock and reset options chosen, as shown in [Table 10](#).

Table 10: Number of I/O pins available (P89LPC916, P89LPC917)

Clock source	Reset option	Number of I/O pins (16-pin package)
RC oscillator or Watchdog oscillator	No external reset (except during power-up)	14
	External $\overline{\text{RST}}$ pin supported	13
External clock input	No external reset (except during power-up)	13
	External $\overline{\text{RST}}$ pin supported ^[1]	12

[1] Required for operation above 12 MHz.

The P89LPC915 has 2 I/O ports: Port 0, and Port 1. The exact number of I/O pins available depends on the reset option chosen, as shown in [Table 11](#).

Table 11: Number of I/O pins available (P89LPC915)

Clock source	Reset option	Number of I/O pins (14-pin package)
RC oscillator or Watchdog oscillator	No external reset (except during power-up)	12
	External $\overline{\text{RST}}$ pin supported	11
External clock input	No external reset (except during power-up)	11
	External $\overline{\text{RST}}$ pin supported ^[1]	10

[1] Required for operation above 12 MHz.

9.12.1 Port configurations

Except as listed below, every I/O pin on the P89LPC915/916/917 may be configured by software to one of four types on a bit-by-bit basis. 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.

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

9.12.2 Quasi-bidirectional output configuration

Quasi-bidirectional output type can be used as both 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 fairly large current. These features are somewhat similar to an open-drain output except that there are three pull-up transistors in the quasi-bidirectional output that serve different purposes.

The P89LPC915/916/917 is a 3 V device, but the pins are 5 V-tolerant. In quasi-bidirectional mode, if a user applies 5 V on the pin, there will be a current flowing from the pin to V_{DD} , causing extra power consumption. Therefore, applying 5 V in quasi-bidirectional mode is discouraged.

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

9.12.3 Open-drain output configuration

The open-drain output configuration turns off all pull-ups and only drives the pull-down transistor of the port driver 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} .

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

9.12.4 Input-only configuration

The input-only port configuration has no output drivers. It is a Schmitt triggered input that also has a glitch suppression circuit.

9.12.5 Push-pull output configuration

The push-pull output configuration has the same pull-down 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. A push-pull port pin has a Schmitt triggered input that also has a glitch suppression circuit.

9.12.6 Port 0 analog functions

The P89LPC915/916/917 incorporates two Analog Comparators. In order to give the best analog function performance and to minimize power consumption, pins that are being used for analog functions must have the digital outputs and digital inputs disabled.

Digital outputs are disabled by putting the port output into the Input-Only (high impedance) mode as described in [Section 9.12.4 "Input-only configuration"](#).

Digital inputs on Port 0 may be disabled through the use of the PT0AD register. On any reset, the PT0AD bits default to logic 0s to enable digital functions.

9.12.7 Additional port features

After power-up, all pins are in Input-Only mode. After power-up all I/O pins except P1.5, may be configured by software.

- Pin P1.5 is input only.
- SCL/T0/P1.2 and SDA/ $\overline{\text{INT0}}$ /P1.3 may only be configured to be either input-only or open drain.

Every output on the P89LPC915/916/917 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 [Table 13 “DC electrical characteristics”](#) for detailed specifications.

All port 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.

9.13 Power monitoring functions

The P89LPC915/916/917 incorporates power monitoring functions designed to prevent incorrect operation during initial power-up and power loss or reduction during operation. This is accomplished with two hardware functions: Power-on detect and Brownout detect.

9.13.1 Brownout detection

The Brownout detect function determines if the power supply voltage drops below a certain level. The default operation is for a Brownout detection to cause a processor reset, however, it may alternatively be configured to generate an interrupt.

Brownout detection may be enabled or disabled in software.

If Brownout detection is enabled, the brownout condition occurs when V_{DD} falls below the brownout trip voltage, V_{BO} (see [Table 13 “DC electrical characteristics”](#)), and is negated when V_{DD} rises above V_{BO} . If the P89LPC915/916/917 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.

For correct activation of Brownout detect, the V_{DD} rise and fall times must be observed. Please see [Table 13 “DC electrical characteristics”](#) for specifications.

9.13.2 Power-on detection

The Power-on detect has a function similar to the Brownout detect, but is designed to work as power comes up initially, before the power supply voltage reaches a level where Brownout detect can work. The POF flag in the RSTSRC register is set to indicate an initial power-up condition. The POF flag will remain set until cleared by software.

9.14 Power reduction modes

The P89LPC915/916/917 supports three different power reduction modes. These modes are Idle mode, Power-down mode, and total Power-down mode.

9.14.1 Idle mode

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.

9.14.2 Power-down mode

The Power-down mode stops the oscillator in order to minimize power consumption. The P89LPC915/916/917 exits Power-down mode via any reset, or certain interrupts. 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 highly recommended to wake up the processor via reset in this case. V_{DD} must be raised to within the operating range before the Power-down mode is exited.

Some chip functions continue to operate and draw power during Power-down mode, increasing the total power used during power-down. These include: Brownout detect, Watchdog Timer, Comparators (note that Comparators can be powered-down separately), and Real-Time Clock (RTC)/System Timer. The internal RC oscillator is disabled unless both the RC oscillator has been selected as the system clock **and** the RTC is enabled.

9.14.3 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. The internal RC oscillator is disabled unless both the RC oscillator has been selected as the system clock **and** the RTC is enabled. If the internal RC oscillator is used to clock the RTC during Power-down, there will be high power consumption. Please use an external low frequency clock to achieve low power with the Real-Time Clock running during Power-down.

9.15 Reset

The P1.5/ \overline{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 logic 1, enables the external reset input function on P1.5. When cleared, P1.5 may be used as an input pin.

Remark: During a power-up 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-up this input will function either as an external reset input or as a digital input 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.

Reset can be triggered from the following sources:

- External reset pin (during power-up or if user configured via UCFG1. This option must be used for an oscillator frequency above 12 MHz.)
- Power-on detect
- Brownout detect
- Watchdog Timer
- Software reset
- UART break character 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 logic 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, previously set flag bits that have not been cleared will remain set.

9.16 Timers/counters 0 and 1

The P89LPC915/916/917 devices have two general purpose counter/timers which are upward compatible with the standard 80C51 Timer 0 and Timer 1. An option to automatically toggle the T0 pin upon timer overflow has been added. In addition an option to toggle the T1 pin upon overflow has been added on the P89LPC917. In the 'Timer' function, the register is incremented every machine cycle. In the 'Counter' function, the register of Timer 0 is incremented in response to a 1-to-0 transition at its external input pin. This external input is sampled once very machine cycle.

Timer 0 has five operating modes (modes 0, 1, 2, 3, and 6).

Timer 1 has four operating modes (modes 0, 1, 2, and 3), except on the P89LPC917 where Timer 1 also has mode 6. Modes 0, 1, and 2 are the same for both Timers/Counters. Mode 3 is different.

9.16.1 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. In this mode, the Timer register is configured as a 13-bit register. Mode 0 operation is the same for Timer 0 and Timer 1.

9.16.2 Mode 1

Mode 1 is the same as Mode 0, except that all 16 bits of the timer register are used.

9.16.3 Mode 2

Mode 2 configures the Timer register as an 8-bit Counter with automatic reload. Mode 2 operation is the same for Timer 0 and Timer 1.

9.16.4 Mode 3

When Timer 1 is in Mode 3 it is stopped. Timer 0 in Mode 3 forms two separate 8-bit counters and is provided for applications that require an extra 8-bit timer. When Timer 1 is in Mode 3 it can still be used by the serial port as a baud rate generator.

9.16.5 Mode 6

In this mode, the corresponding timer can be changed to a PWM with a full period of 256 timer clocks.

9.16.6 Timer overflow toggle output

Timer 0 (and Timer 1 on the P89LPC917) can be configured to automatically toggle the timer output pin, Tx, whenever a timer overflow occurs. The same device pin that is used for the count input is also used for the timer toggle output. The port output will be a logic 1 prior to the first timer overflow when this mode is turned on.

9.17 Real-Time clock/system timer

The P89LPC915/916/917 devices have a simple Real-Time clock 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 a wake-up or an interrupt source. The Real-Time clock is a 23-bit down counter comprised of a 7-bit prescaler and a 16-bit loadable down counter. When it reaches all logic 0s, the counter will be reloaded again and the RTCF flag will be set.

The clock source for this counter can either be the CPU clock (CCLK) or the external clock input, provided that the external clock input is not being used as the CPU clock. If the external clock input is used as the CPU clock, then the RTC will use CCLK as its clock source.

Only power-on reset will reset the Real-Time clock and its associated SFRs to the default state.

9.18 UART

The P89LPC915/916/917 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 P89LPC915/916/917 does include an independent Baud Rate Generator. The baud rate can be selected from CCLK (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, automatic address recognition, selectable double buffering and several interrupt options. The UART can be operated in 4 modes: shift register, 8-bit UART, 9-bit UART, and CCLK/32 or CCLK/16.

9.18.1 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 $\frac{1}{16}$ of the CPU clock frequency.

9.18.2 Mode 1

10 bits are transmitted (through TxD) or received (through RxD): a start bit (logic 0), 8 data bits (LSB first), and a stop bit (logic 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 (described in [Section 9.18.5 "Baud rate generator and selection"](#)).

9.18.3 Mode 2

11 bits are transmitted (through TxD) or received (through RxD): start bit (logic 0), 8 data bits (LSB first), a programmable 9th data bit, and a stop bit (logic 1). When data is transmitted, the 9th data bit (TB8 in SCON) can be assigned the value of logic 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, while the stop bit is not saved. The baud rate is programmable to either $\frac{1}{16}$ or $\frac{1}{32}$ of the CCLK frequency, as determined by the SMOD1 bit in PCON.

9.18.4 Mode 3

11 bits are transmitted (through TxD) or received (through RxD): a start bit (logic 0), 8 data bits (LSB first), a programmable 9th data bit, and a stop bit (logic 1). In fact, 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 (described in [Section 9.18.5 "Baud rate generator and selection"](#)).

9.18.5 Baud rate generator and selection

The P89LPC915/916/917 has an independent Baud Rate Generator. The baud rate is determined by a baud-rate preprogrammed into the BRGR1 and BRGR0 SFRs which together form a 16-bit baud rate divisor value that works in a similar manner as Timer 1. If the baud rate generator is used, Timer 1 can be used for other timing functions.

The UART can use either Timer 1 or the baud rate generator output (see [Figure 13](#)). Note that Timer T1 is further divided by 2 if the SMOD1 bit (PCON.7) is cleared. The independent Baud Rate Generator uses CCLK.

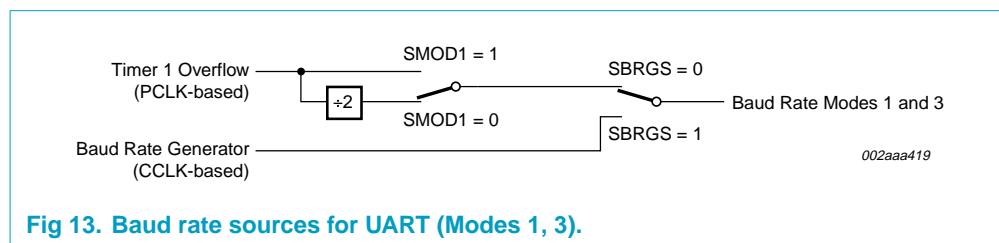


Fig 13. Baud rate sources for UART (Modes 1, 3).

9.18.6 Framing error

Framing error is reported in the status register (SSTAT). In addition, if SMOD0 (PCON.6) is logic 1, framing errors can be made available in SCON.7, respectively. If SMOD0 is logic 0, SCON.7 is SM0. It is recommended that SM0 and SM1 (SCON.7:6) are set up when SMOD0 is logic 0.

9.18.7 Break detect

Break detect is reported in the status register (SSTAT). A break is detected when 11 consecutive bits are sensed LOW. The break detect can be used to reset the device.

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

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

Unlike the conventional UART, in double buffering mode, the Tx interrupt is generated when the double buffer is ready to receive new data.

9.18.10 The 9th bit (bit 8) in double buffering (Modes 1, 2 and 3)

If double buffering is disabled TB8 can be written before or after SBUF is written, as long as TB8 is updated some time before that bit is shifted out. TB8 must not be changed until the bit is shifted out, 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.

9.19 I²C-bus serial interface

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

- Bi-directional data transfer between masters and slaves
- Multi master 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 14](#). The P89LPC915/916/917 device provides a byte-oriented I²C-bus interface that supports data transfers up to 400 kHz.

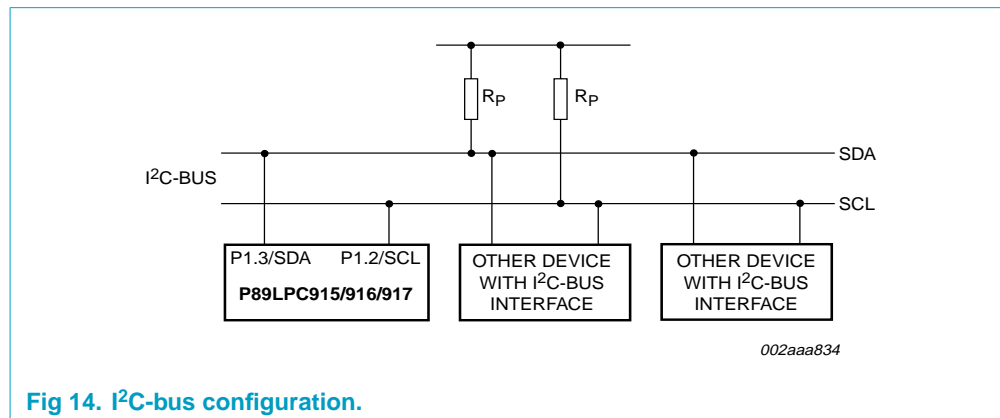


Fig 14. I²C-bus configuration.

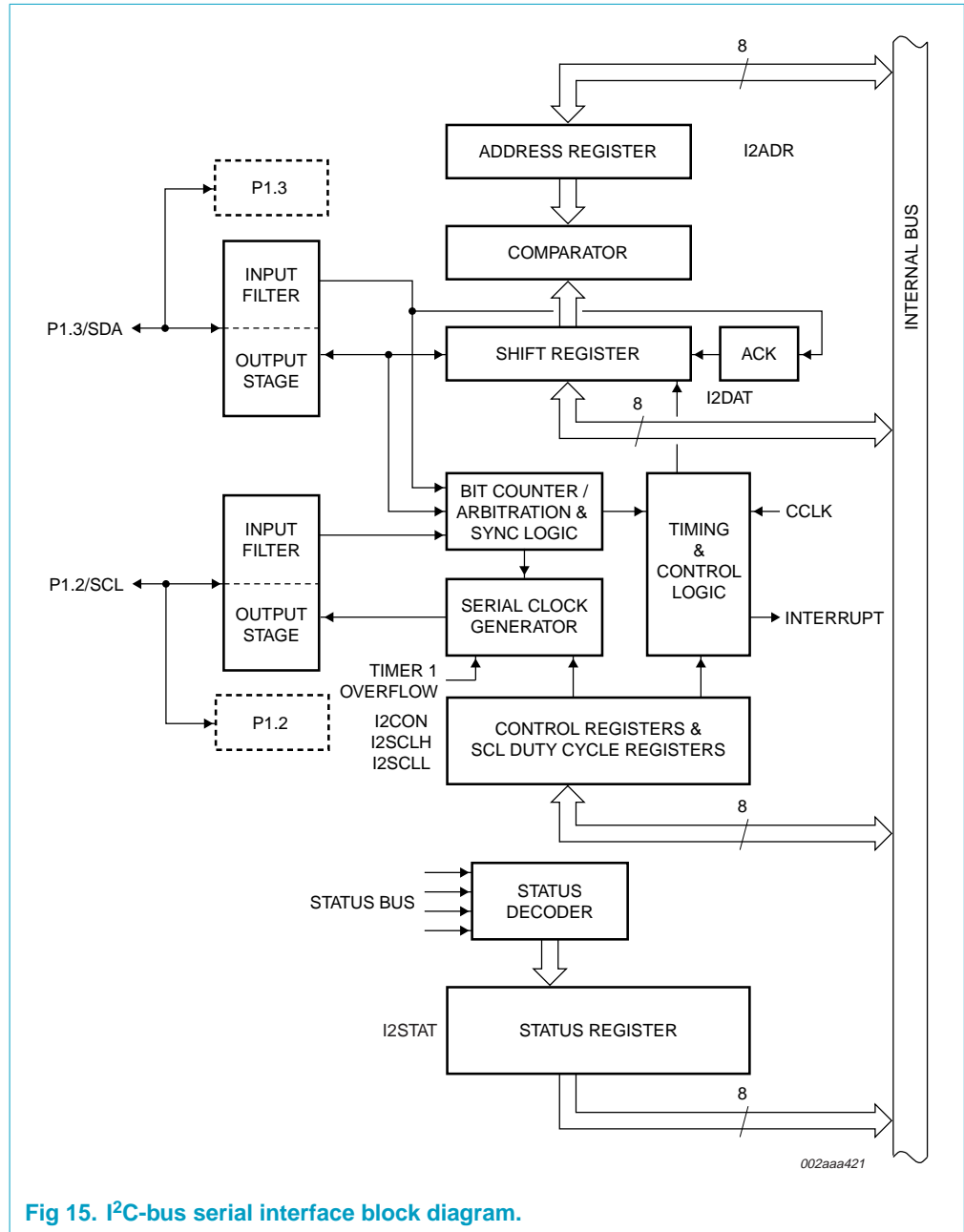


Fig 15. I²C-bus serial interface block diagram.

9.20 Serial Peripheral Interface (SPI - P89LPC916)

The P89LPC916 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 4.5 Mbit/s can be supported in either Master or 3.0 Mbit/s in Slave mode. It has a Transfer Completion Flag and Write Collision Flag Protection.

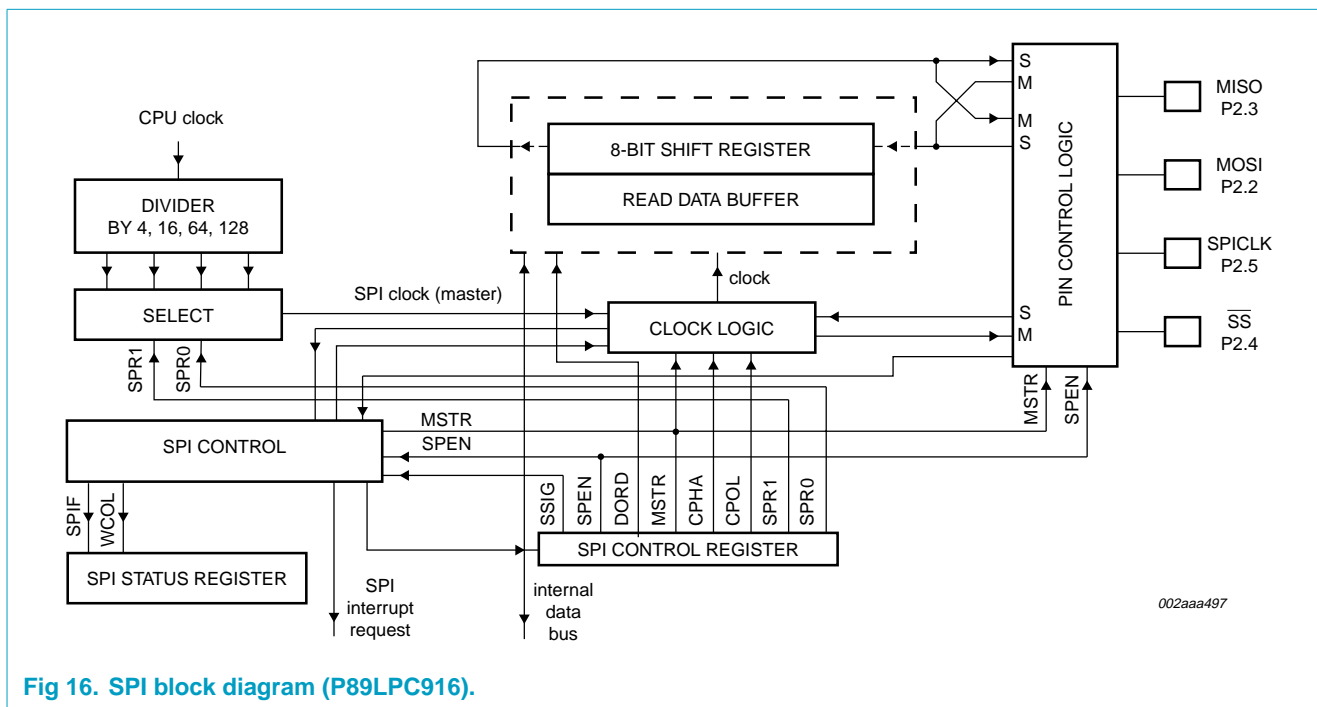


Fig 16. SPI block diagram (P89LPC916).

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 MOSI (Master Out Slave In) pin and flows from slave to master on 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.

Typical connections are shown in [Figure 17](#), [18](#), and [19](#).

9.20.1 Typical SPI configurations

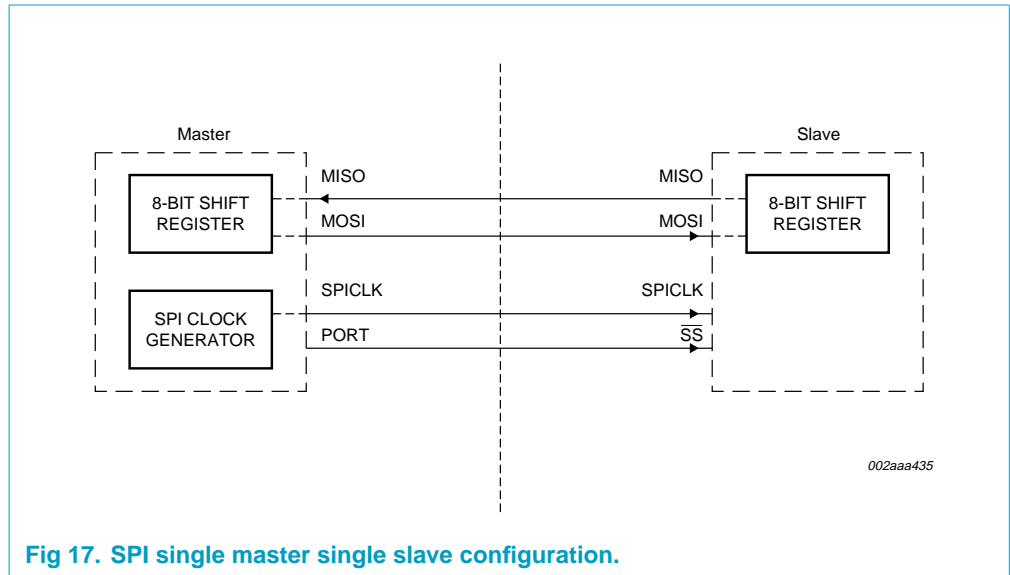


Fig 17. SPI single master single slave configuration.

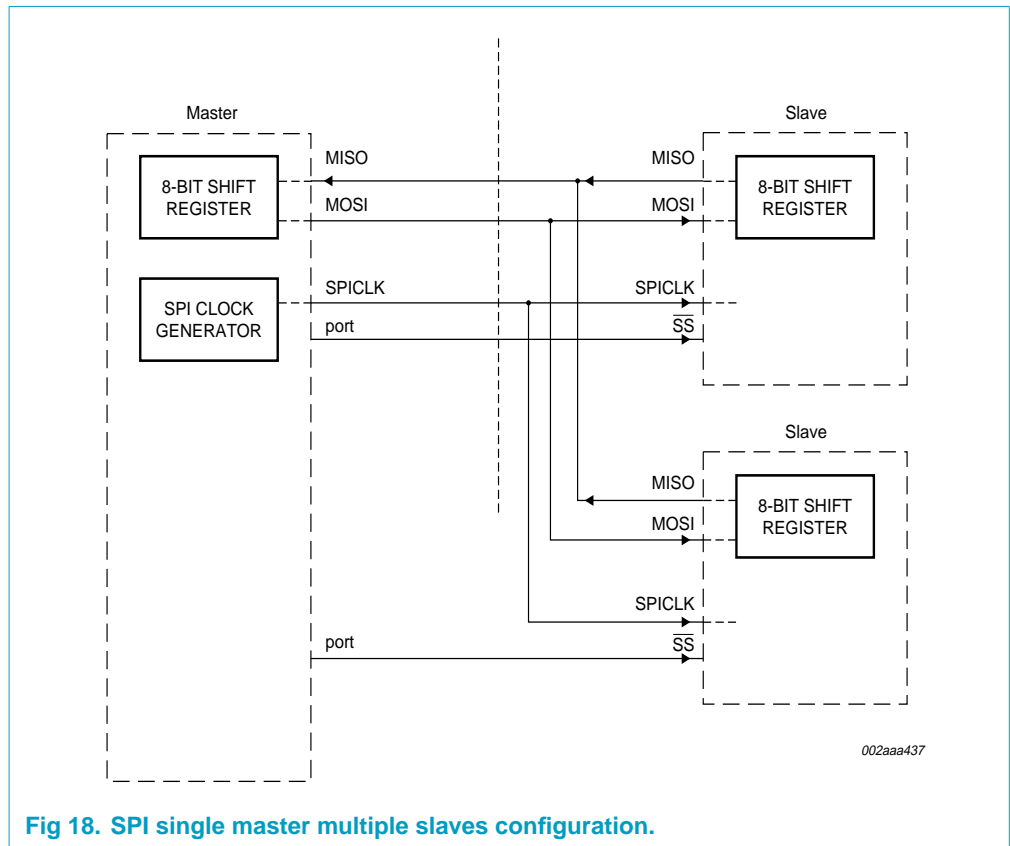
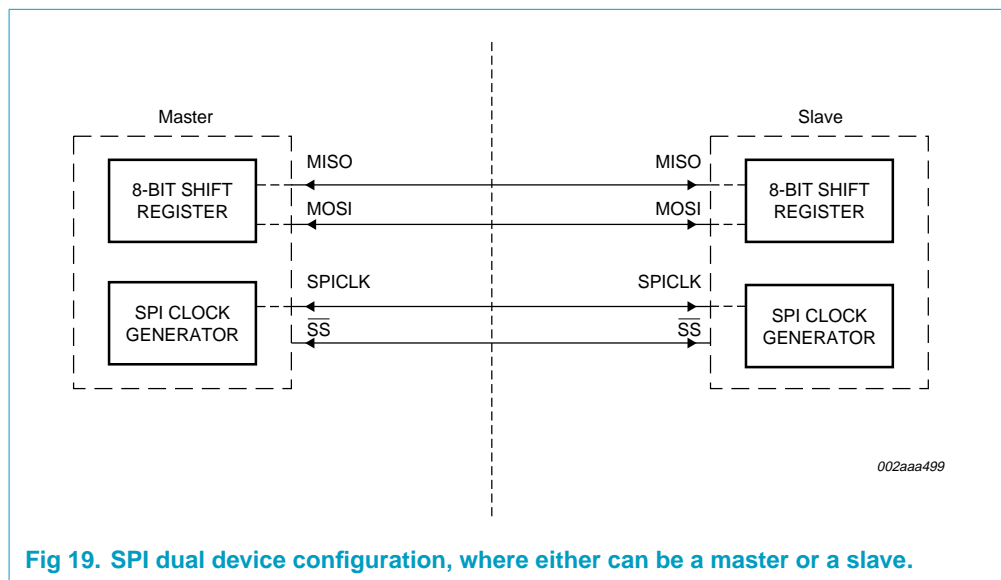


Fig 18. SPI single master multiple slaves configuration.



9.21 Analog comparators

Two analog comparators are provided on the P89LPC915/916/917. Input and output options allow use of the comparators in a number of different configurations. Comparator operation is such that the output is a logic 1 when the positive input 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 1 may be output to a port pin.

The overall connections to both comparators are shown in **Figure 20**. The comparators function to $V_{DD} = 2.4$ V.

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.

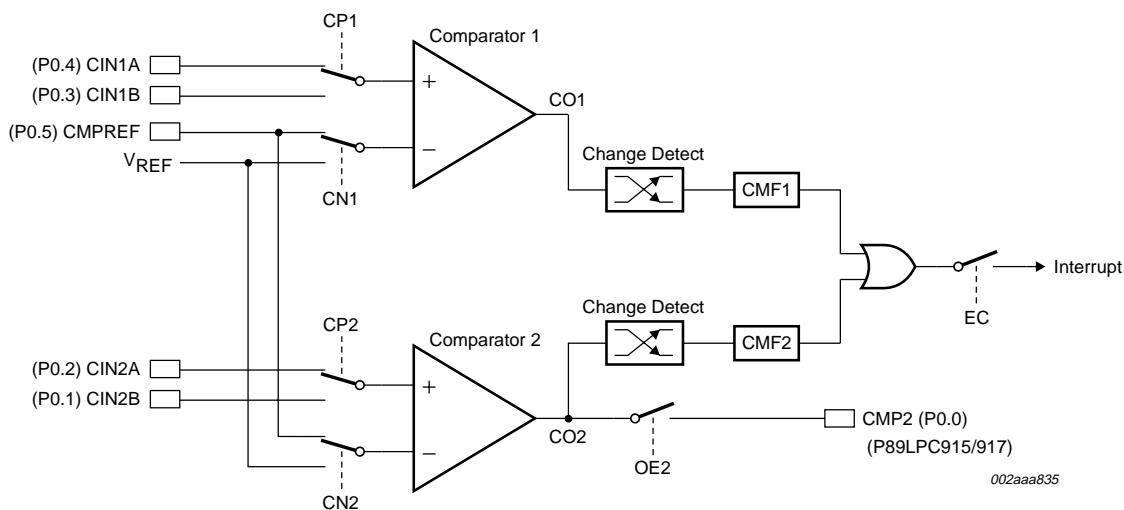


Fig 20. Comparator input and output connections.

9.22 Internal reference voltage

An internal reference voltage generator may supply a default reference when a single comparator input pin is used. The value of the internal reference voltage, referred to as V_{REF} , is 1.23 V ± 10 %.

9.23 Comparator interrupt

Each comparator has an interrupt flag 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. If both comparators enable interrupts, after entering the interrupt service routine, the user needs to read the flags to determine which comparator caused the interrupt.

Possible comparator configurations are shown in [Figure 20](#).

9.24 Comparator 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 fact should be taken into account when system power consumption is an issue. To minimize power consumption, the user can disable the comparators via PCONA.5, or put the device in Total Power-down mode.

9.25 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.

The Keypad Interrupt Mask Register (KBMASK) is used to define which input pins connected to Port 0 can 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 (KBCON) is set when the condition is matched while the Keypad Interrupt function is active. An interrupt will be generated if enabled. The PATN_SEL bit in the Keypad Interrupt Control Register (KBCON) is used to define equal or not-equal for the comparison.

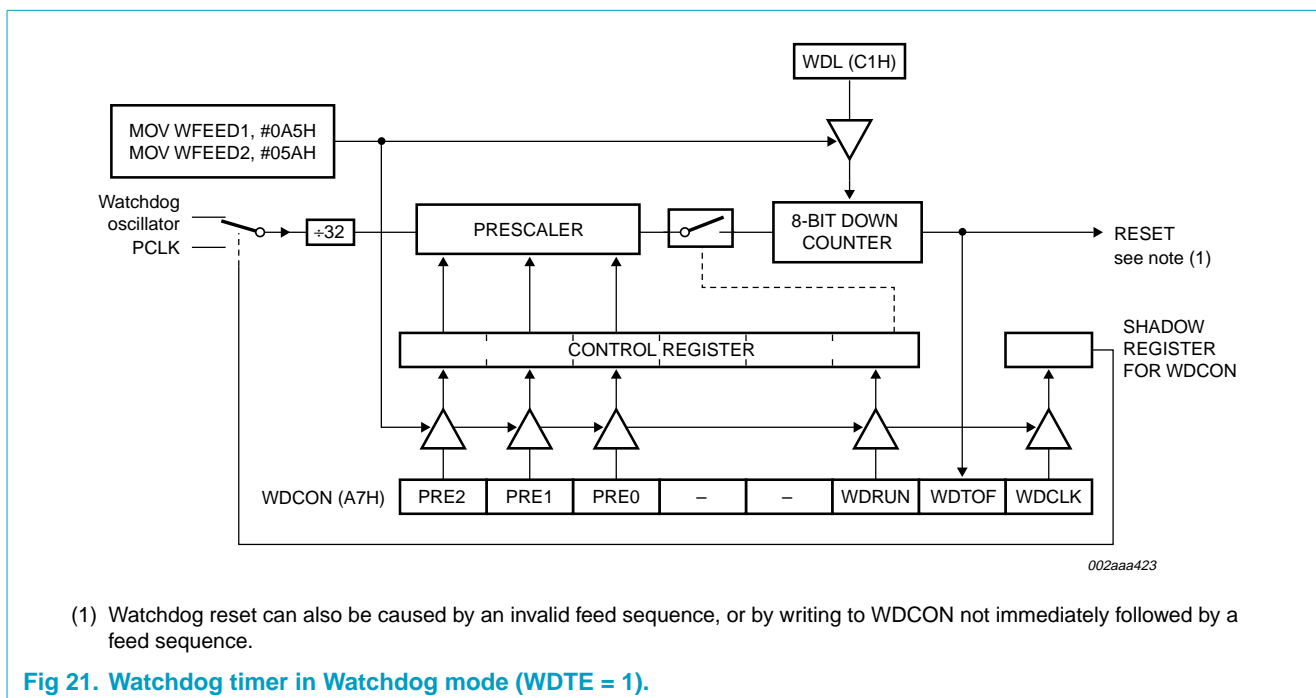
In order to use the Keypad Interrupt as an original KBI function like in 87LPC76x series, the user needs to set KBPATN = 0FFH and PATN_SEL = 1 (not equal), then any key connected to Port 0 which is enabled by the KBMASK register will cause the hardware to set KBIF and generate an interrupt if it has 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 cause an interrupt, the pattern on Port 0 must be held longer than six CCLKs.

9.26 Watchdog timer

The Watchdog timer causes a system reset when it underflows as a result of a failure to feed the timer prior to the timer reaching its terminal count. It consists of a programmable 12-bit prescaler, and an 8-bit down counter. The down counter is decremented by a tap taken from the prescaler. The clock source for the prescaler is either the PCLK or the nominal 400 kHz Watchdog oscillator. The Watchdog timer

can only be reset by a power-on reset. When the Watchdog feature is disabled, it can be used as an interval timer and may generate an interrupt. Figure 21 shows the Watchdog timer in Watchdog mode. Feeding the Watchdog requires a two-byte sequence. If PCLK is selected as the Watchdog clock and the CPU is powered-down, the Watchdog is disabled. The Watchdog timer has a time-out period that ranges from a few μ s to a few seconds. Please refer to the *P89LPC915/916/917 User's Manual* for more details.



9.27 Additional features

9.27.1 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. Care should be taken when writing to AUXR1 to avoid accidental software resets.

9.27.2 Dual data pointers

The dual Data Pointers (DPTR) provides two different Data Pointers to specify the address used with certain instructions. The DPS bit in the AUXR1 register selects one of the two Data Pointers. Bit 2 of AUXR1 is permanently wired as a logic 0 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.

9.28 Flash program memory

9.28.1 General description

The P89LPC915/916/917 Flash memory provides in-circuit electrical erasure and programming. The Flash can be erased, read, and written as bytes. The Sector and Page Erase functions can erase any Flash sector (256 bytes) or page (16 bytes). The

Chip Erase operation will erase the entire program memory. In-Circuit Programming using standard commercial programmers is available. In addition, In-Application Programming (IAP-Lite) and byte erase allows code memory to be used for non-volatile data storage. On-chip erase and write timing generation contribute to a user-friendly programming interface. The P89LPC915/916/917 Flash reliably stores memory contents even after 100,000 erase and program cycles. The cell is designed to optimize the erase and programming mechanisms. The P89LPC915/916/917 uses V_{DD} as the supply voltage to perform the Program/Erase algorithms.

9.28.2 Features

- Programming and erase over the full operating voltage range.
- Byte-erase allowing code memory to be used for data storage.
- Read/Programming/Erase using ICP.
- Any flash program operation in 4 ms.
- Programming with industry-standard commercial programmers.
- Programmable security for the code in the Flash for each sector.
- More than 100,000 minimum erase/program cycles for each byte.
- 10-year minimum data retention.

9.28.3 Flash organization

The P89LPC915/916/917 program memory consists of eight 256-byte sectors. Each sector can be further divided into sixteen 16-byte pages. In addition to sector erase, page erase, and byte erase, a 16-byte page register is included which allows from 1 to 16 bytes of a given page to be programmed at the same time, substantially reducing overall programming time. In addition, erasing and reprogramming of user-programmable configuration bytes including UCFG1, the Boot Status Bit, and the Boot Vector is supported.

9.28.4 Flash programming and erasing

Different methods of erasing or programming of the Flash are available. The Flash may be programmed or erased in the end-user application (IAP-Lite) under control of the application's firmware. Another option is to use the In-Circuit Programming (ICP) mechanism. This ICP system provides for programming through a serial clock-serial data interface 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 the entire 2 kB of user code space.

9.28.5 In-circuit programming (ICP)

In-Circuit Programming is performed without removing the microcontroller from the system. The In-Circuit Programming facility consists of internal hardware resources to facilitate remote programming of the P89LPC915/916/917 through a two-wire serial interface. The Philips In-Circuit Programming facility has made in-circuit programming in an embedded application, using commercially available programmers, possible with a minimum of additional expense in components and circuit board area. The ICP function uses five pins. Only a small connector (with V_{DD} ,

V_{SS} , \overline{RST} , clock, and data signals) needs to be available to interface your application to a commercial programmer in order to use this feature. Additional details may be found in the *P89LPC915/916/917 User's Manual*.

9.28.6 In-application programming (IAP-Lite)

In-Application Programming is performed in the application under the control of the microcontroller's firmware. The IAP-Lite facility consists of internal hardware resources to facilitate programming and erasing. The Philips In-Application Programming Lite has made in-application programming in an embedded application possible without additional components. This is accomplished through the use of four SFRs consisting of a control/status register, a data register, and two address registers. Additional details may be found in the *P89LPC915/916/917 User's Manual*.

9.28.7 Using flash as data storage

The Flash code memory array of this device supports **individual** byte erasing and programming. Any byte in the code memory array may be read using the MOVC instruction, provided that the sector containing the byte has not been secured (a MOVC instruction is not allowed to read code memory contents of a secured sector). Thus any byte in a non-secured sector may be used for non-volatile data storage.

9.28.8 User configuration bytes

Some user-configurable features of the P89LPC915/916/917 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 the Flash byte UCFG1. Please see the *P89LPC915/916/917 User's Manual* for additional details.

9.28.9 User sector security bytes

There are eight User Sector Security Bytes, each corresponding to one sector. Please see the *P89LPC915/916/917 User's Manual* for additional details.

10. Limiting values

Table 12: Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).^[1]

Symbol	Parameter	Conditions	Min	Max	Unit
$T_{amb(bias)}$	operating bias ambient temperature		-55	+125	°C
T_{stg}	storage temperature range		-65	+150	°C
V_n	voltage on any pin to V_{SS}		-0.5	+5.5	V
$I_{OH(I/O)}$	high-level output current per I/O pin		-	8	mA
$I_{OL(I/O)}$	low-level output current per I/O pin		-	20	mA
$I_{I/O(tot)(max)}$	maximum total I/O current		-	120	mA
$P_{tot(pack)}$	total power dissipation per package	based on package heat transfer, not device power consumption	-	1.5	W

[1] The following applies to Limiting values:

- Stresses above those listed under **Table 12** may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any conditions other than those described in **Table 13 “DC electrical characteristics”**, **Table 14 “AC characteristics”** and **Table 15 “AC characteristics”** of this specification are not implied.
- This product includes circuitry specifically designed for the protection of its internal devices from the damaging effects of excessive static charge. Nonetheless, it is suggested that conventional precautions be taken to avoid applying greater than the rated maximum.
- Parameters are valid over operating temperature range unless otherwise specified. All voltages are with respect to V_{SS} unless otherwise noted.

11. Static characteristics

Table 13: DC electrical characteristics
 $V_{DD} = 2.4\text{ V to }3.6\text{ V unless otherwise specified.}$
 $T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C for industrial, }-40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C extended, unless otherwise specified.}$

Symbol	Parameter	Conditions	Min	Typ ^[1]	Max	Unit
$I_{DD(\text{oper})}$	power supply current, operating	3.6 V; 12 MHz	[2] -	7	13	mA
		3.6 V; 18 MHz	[2] -	11	16	mA
$I_{DD(\text{idle})}$	power supply current, Idle mode	3.6 V; 12 MHz	[2] -	3.6	4.8	mA
		3.6 V; 18 MHz	[2] -	4	6	mA
$I_{DD(\text{PD})}$	power supply current, Power-down mode, voltage comparators powered-down	3.6 V, industrial	[2] -	45	70	μA
		3.6 V, extended	[2] -	-	150	μA
$I_{DD(\text{TPD})}$	power supply current, total Power-down mode	3.6 V, industrial	[2] -	< 0.1	5	μA
		3.6 V, extended	[2] -	-	50	μA
$(dV_{DD}/dt)_r$	V_{DD} rise rate		-	-	2	mV/ μs
$(dV_{DD}/dt)_f$	V_{DD} fall rate		-	-	50	mV/ μs
V_{RAM}	RAM keep-alive voltage		1.5	-	-	V
$V_{\text{th(HL)}}$	negative-going threshold voltage (Schmitt trigger input)		$0.22V_{DD}$	$0.4V_{DD}$	-	V
$V_{\text{th(LH)}}$	positive-going threshold voltage (Schmitt trigger input)		-	$0.6V_{DD}$	$0.7V_{DD}$	V
V_{hys}	hysteresis voltage		-	$0.2V_{DD}$	-	V
V_{OL}	low-level output voltage, all ports	$I_{\text{OL}} = 20\text{ mA}$	-	0.6	1.0	V
		$I_{\text{OL}} = 10\text{ mA}$	-	0.3	0.5	V
		$I_{\text{OL}} = 3.2\text{ mA}$	-	0.2	0.3	V
V_{OH}	high-level output voltage, all ports	$I_{\text{OH}} = -8\text{ mA}$; push-pull mode	$V_{DD} - 1$	-	-	V
		$I_{\text{OH}} = -3.2\text{ mA}$; push-pull mode	$V_{DD} - 0.7$	$V_{DD} - 0.4$	-	V
		$I_{\text{OH}} = -20\text{ }\mu\text{A}$; quasi-bidirectional mode	$V_{DD} - 0.3$	$V_{DD} - 0.2$	-	V
C_{ig}	input-ground capacitance		[3] -	-	15	pF
I_{IL}	logical 0 input current, all ports	$V_{\text{IN}} = 0.4\text{ V}$	[4] -	-	-80	μA
I_{LI}	input leakage current, all ports	$V_{\text{IN}} = V_{\text{IL}}$ or V_{IH}	[5] -	-	± 10	μA
I_{TL}	logical 1-to-0 transition current, all ports	$V_{\text{IN}} = 2.0\text{ V}$ at $V_{DD} = 3.6\text{ V}$	[6][7] -30	-	-450	μA
R_{RST}	internal reset pull-up resistor		10	-	30	k Ω
V_{BO}	brownout trip voltage with BOV = 1, BOPD = 0	$2.4\text{ V} < V_{DD} < 3.6\text{ V}$	2.40	-	2.70	V

Table 13: DC electrical characteristics...*continued* $V_{DD} = 2.4\text{ V to }3.6\text{ V unless otherwise specified.}$ $T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C for industrial, }-40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C extended, unless otherwise specified.}$

Symbol	Parameter	Conditions	Min	Typ ^[1]	Max	Unit
V_{REF}	band gap reference voltage		1.11	1.23	1.34	V
$TC_{(VREF)}$	band gap temperature coefficient		-	10	20	ppm/ °C

- [1] Typical ratings are not guaranteed. The values listed are at room temperature, 3 V.
- [2] The $I_{DD(oper)}$, $I_{DD(idle)}$, and $I_{DD(PD)}$ specifications are measured using an external clock with the following functions disabled: comparators, brownout detect, ADC, I²C-bus, UART, SPI, and Watchdog timer.
- [3] Pin capacitance is characterized but not tested.
- [4] Measured with port in quasi-bidirectional mode.
- [5] Measured with port in high-impedance mode.
- [6] Ports in quasi-bidirectional mode with weak pull-up (applies to all port pins with pull-ups)
- [7] Port pins source a transition current when used in quasi-bidirectional mode and externally driven from logic 1 to logic 0. This current is highest when V_{IN} is approximately 2 V.

12. Dynamic characteristics

Table 14: AC characteristics
 $V_{DD} = 2.4\text{ V to }3.6\text{ V}$, unless otherwise specified.

 $T_{amb} = -40\text{ °C to }+85\text{ °C}$ for industrial, $-40\text{ °C to }+125\text{ °C}$ extended, unless otherwise specified.^[1]

Symbol	Parameter	Conditions	Variable clock		$f_{osc} = 12\text{ MHz}$		Unit
			Min	Max	Min	Max	
f_{RCOSC}	internal RC oscillator frequency (nominal $f = 7.3728\text{ MHz}$) trimmed to $\pm 1\%$ at $T_{amb} = 25\text{ °C}$	industrial	7.189	7.557	7.189	7.557	MHz
		extended	7.004	7.741	7.004	7.741	MHz
f_{WDOSC}	internal Watchdog oscillator frequency (nominal $f = 400\text{ kHz}$)		320	520	320	520	kHz

External clock input

f_{osc}	oscillator frequency	$V_{DD} = 2.4\text{ V to }3.6\text{ V}$	0	12	-	-	MHz
t_{CLCL}	clock cycle	see Figure 27	83	-	-	-	ns
f_{CLKP}	CLKLP active frequency		0	8	-	-	MHz
t_{CHCX}	high time	see Figure 27	22	$t_{CLCL} - t_{CLCX}$	22	-	ns
t_{CLCX}	low time	see Figure 27	22	$t_{CLCL} - t_{CHCX}$	22	-	ns
t_{CLCH}	rise time	see Figure 27	-	8	-	8	ns
t_{CHCL}	fall time	see Figure 27	-	8	-	8	ns

Glitch filter

	glitch rejection, P1.5/ \overline{RST} pin		-	50	-	50	ns
	signal acceptance, P1.5/ \overline{RST} pin		125	-	125	-	ns
	glitch rejection, any pin except P1.5/ \overline{RST}		-	15	-	15	ns
	signal acceptance, any pin except P1.5/ \overline{RST}		50	-	50	-	ns

Shift register (UART mode 0)

t_{XLXL}	serial port clock cycle time	see Figure 26	$16t_{CLCL}$	-	1333	-	ns
t_{QVXH}	output data set-up to clock rising edge	see Figure 26	$13t_{CLCL}$	-	1083	-	ns
t_{XHQX}	output data hold after clock rising edge	see Figure 26	-	$t_{CLCL} + 20$	-	103	ns
t_{XHDX}	input data hold after clock rising edge	see Figure 26	-	0	-	0	ns
t_{DVXH}	input data valid to clock rising edge	see Figure 26	150	-	150	-	ns

Table 14: AC characteristics...continued

 $V_{DD} = 2.4\text{ V to }3.6\text{ V}$, unless otherwise specified. $T_{amb} = -40\text{ °C to }+85\text{ °C}$ for industrial, $-40\text{ °C to }+125\text{ °C}$ extended, unless otherwise specified.^[1]

Symbol	Parameter	Conditions	Variable clock		$f_{osc} = 12\text{ MHz}$		Unit
			Min	Max	Min	Max	
SPI interface							
f_{SPI}	Operating frequency						
	2.0 MHz (Slave)		0	$CCLK/6$	0	2.0	MHz
	3.0 MHz (Master)		-	$CCLK/4$	-	-	MHz
t_{SPICYC}	Cycle time	see Figure 22, 23, 24, 25					
	2.0 MHz (Slave)		$6/CCLK$	-	500	-	ns
	3.0 MHz (Master)		$4/CCLK$	-	-	-	ns
$t_{SPILEAD}$	Enable lead time (Slave)	see Figure 24, 25					
	2.0 MHz		250	-	250	-	ns
t_{SPILAG}	Enable lag time (Slave)	see Figure 24, 25					
	2.0 MHz		250	-	250	-	ns
$t_{SPICLKH}$	SPICLK high time	see Figure 22, 23, 24, 25					
	Master		$2/CCLK$	-	340	-	ns
	Slave		$3/CCLK$	-	190	-	ns
$t_{SPICLKL}$	SPICLK low time	see Figure 22, 23, 24, 25					
	Master		$2/CCLK$	-	340	-	ns
	Slave		$3/CCLK$	-	190	-	ns
t_{SPIDSU}	Data set-up time (Master or Slave)	see Figure 22, 23, 24, 25	100	-	100	-	ns
t_{SPIDH}	Data hold time (Master or Slave)	see Figure 22, 23, 24, 25	100	-	100	-	ns
t_{SPIA}	Access time (Slave)	see Figure 24, 25	0	120	0	120	ns
t_{SPIDIS}	Disable time (Slave)	see Figure 24, 25					
	2.0 MHz		0	240	-	240	ns
t_{SPIDV}	Enable to output data valid	see Figure 22, 23, 24, 25					
	2.0 MHz		0	240	-	240	ns
	3.0 MHz		0	167	-	167	ns
t_{SPIOH}	Output data hold time	see Figure 22, 23, 24, 25	0	-	0	-	ns

Table 14: AC characteristics...continued

 $V_{DD} = 2.4\text{ V to }3.6\text{ V}$, unless otherwise specified. $T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C}$ for industrial, $-40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$ extended, unless otherwise specified.^[1]

Symbol	Parameter	Conditions	Variable clock		$f_{osc} = 12\text{ MHz}$		Unit
			Min	Max	Min	Max	
t_{SPIR}	Rise time	see Figure 22, 23, 24, 25					
	SPI outputs (SPICLK, MOSI, MISO)		-	100	-	100	ns
	SPI inputs (SPICLK, MOSI, MISO, \overline{SS})		-	2000	-	2000	ns
t_{SPIF}	Fall time	see Figure 22, 23, 24, 25					
	SPI outputs (SPICLK, MOSI, MISO)		-	100	-	100	ns
	SPI inputs (SPICLK, MOSI, MISO, \overline{SS})		-	2000	-	2000	ns

[1] Parameters are valid over operating temperature range unless otherwise specified. Parts are tested to 2 MHz, but are guaranteed to operate down to 0 Hz.

Table 15: AC characteristics $V_{DD} = 3.0\text{ V to }3.6\text{ V}$, unless otherwise specified. $T_{amb} = -40\text{ °C to }+85\text{ °C}$ for industrial, $-40\text{ °C to }+125\text{ °C}$ extended, unless otherwise specified.^[1]

Symbol	Parameter	Conditions	Variable clock		$f_{osc} = 18\text{ MHz}$		Unit
			Min	Max	Min	Max	
f_{RCOSC}	internal RC oscillator frequency (nominal $f = 7.3728\text{ MHz}$) trimmed to $\pm 1\%$ at $T_{amb} = 25\text{ °C}$	industrial	7.189	7.557	7.189	7.557	MHz
		extended	7.004	7.741	7.004	7.741	MHz
f_{WDOSC}	internal Watchdog oscillator frequency (nominal $f = 400\text{ kHz}$)		320	520	320	520	kHz

External clock input

f_{osc}	oscillator frequency		[1] 0	18	-	-	MHz
t_{CLCL}	clock cycle	see Figure 27	55	-	-	-	ns
f_{CLKP}	CLKLP active frequency		0	8	-	-	MHz
t_{CHCX}	high time	see Figure 27	22	$t_{CLCL} - t_{CLCX}$	22	-	ns
t_{CLCX}	low time	see Figure 27	22	$t_{CLCL} - t_{CHCX}$	22	-	ns
t_{CLCH}	rise time	see Figure 27	-	5	-	5	ns
t_{CHCL}	fall time	see Figure 27	-	5	-	5	ns

Glitch filter

	glitch rejection, P1.5/ \overline{RST} pin		-	50	-	50	ns
	signal acceptance, P1.5/ \overline{RST} pin		125	-	125	-	ns
	glitch rejection, any pin except P1.5/ \overline{RST}		-	15	-	15	ns
	signal acceptance, any pin except P1.5/ \overline{RST}		50	-	50	-	ns

Shift register (UART mode 0)

t_{XLXL}	serial port clock cycle time	see Figure 26	$16t_{CLCL}$	-	888	-	ns
t_{QVXH}	output data set-up to clock rising edge	see Figure 26	$13t_{CLCL}$	-	722	-	ns
t_{XHQX}	output data hold after clock rising edge	see Figure 26	-	$t_{CLCL} + 20$	-	103	ns
t_{XHDX}	input data hold after clock rising edge	see Figure 26	-	0	-	0	ns
t_{DVXH}	input data valid to clock rising edge	see Figure 26	150	-	150	-	ns

SPI interface

f_{SPI}	Operating frequency						
	3.0 MHz (Slave)		0	$CCLK/6$	0	3	MHz
	4.5 MHz (Master)		-	$CCLK/4$	-	4.5	MHz
t_{SPICYC}	Cycle time	see Figure 22, 23, 24, 25					
	3.0 MHz (Slave)		$6/CCLK$	-	333	-	ns
	4.5 MHz (Master)		$4/CCLK$	-	222	-	ns

Table 15: AC characteristics...continued

 $V_{DD} = 3.0\text{ V to }3.6\text{ V}$, unless otherwise specified. $T_{amb} = -40\text{ °C to }+85\text{ °C}$ for industrial, $-40\text{ °C to }+125\text{ °C}$ extended, unless otherwise specified.^[1]

Symbol	Parameter	Conditions	Variable clock		$f_{osc} = 18\text{ MHz}$		Unit
			Min	Max	Min	Max	
t _{SPILEAD}	Enable lead time (Slave)	see Figure 24, 25					
	3.0 MHz		250	-	250	-	ns
t _{SPILAG}	Enable lag time (Slave)	see Figure 24, 25					
	3.0 MHz		250	-	250	-	ns
t _{SPICLKH}	SPICLK high time	see Figure 22, 23, 24, 25					
	Master		$\frac{2}{CCLK}$	-	111	-	ns
	Slave		$\frac{3}{CCLK}$	-	167	-	ns
t _{SPICLKL}	SPICLK low time	see Figure 22, 23, 24, 25					
	Master		$\frac{2}{CCLK}$	-	111	-	ns
	Slave		$\frac{3}{CCLK}$	-	167	-	ns
t _{SPIDSU}	Data set-up time (Master or Slave)	see Figure 22, 23, 24, 25	100	-	100	-	ns
t _{SPIDH}	Data hold time (Master or Slave)	see Figure 22, 23, 24, 25	100	-	100	-	ns
t _{SPIA}	Access time (Slave)	see Figure 24, 25	0	80	0	80	ns
t _{SPIDIS}	Disable time (Slave)	see Figure 24, 25					
	3.0 MHz		0	160	-	160	ns
t _{SPIDV}	Enable to output data valid	see Figure 22, 23, 24, 25					
	3.0 MHz		0	160	-	160	ns
	4.5 MHz		0	111	-	111	ns
t _{SPIOH}	Output data hold time	see Figure 22, 23, 24, 25	0	-	0	-	ns
t _{SPIR}	Rise time	see Figure 22, 23, 24, 25					
	SPI outputs (SPICLK, MOSI, MISO)		-	100	-	100	ns
	SPI inputs (SPICLK, MOSI, MISO, SS)		-	2000	-	2000	ns

Table 15: AC characteristics...continued

$V_{DD} = 3.0\text{ V to }3.6\text{ V}$, unless otherwise specified.

$T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C}$ for industrial, $-40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$ extended, unless otherwise specified.^[1]

Symbol	Parameter	Conditions	Variable clock		$f_{osc} = 18\text{ MHz}$		Unit
			Min	Max	Min	Max	
t_{SPIF}	Fall time	see Figure 22, 23, 24, 25					
	SPI outputs (SPICLK, MOSI, MISO)		-	100	-	100	ns
	SPI inputs (SPICLK, MOSI, MISO, \overline{SS})		-	2000	-	2000	ns

- [1] Parameters are valid over operating temperature range unless otherwise specified. Parts are tested to 2 MHz, but are guaranteed to operate down to 0 Hz.
- [2] When using an oscillator frequency above 12 MHz, the reset input function of P1.5 must be enabled. An external circuit is required to hold the device in reset at power-up until V_{DD} has reached its specified level. When system power is removed V_{DD} will fall below the minimum specified operating voltage. When using an oscillator frequency above 12 MHz, in some applications, an external brownout detect circuit may be required to hold the device in reset when V_{DD} falls below the minimum specified operating voltage.

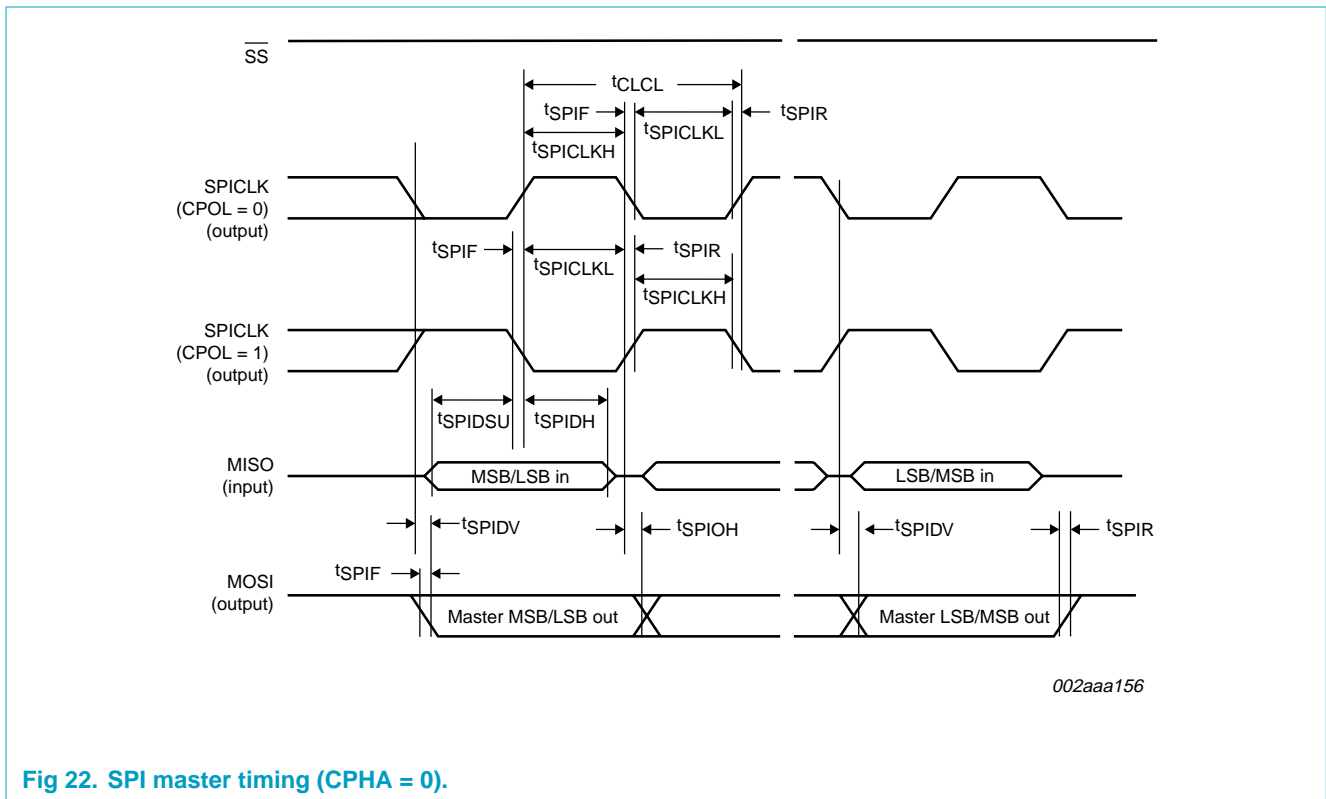


Fig 22. SPI master timing (CPHA = 0).

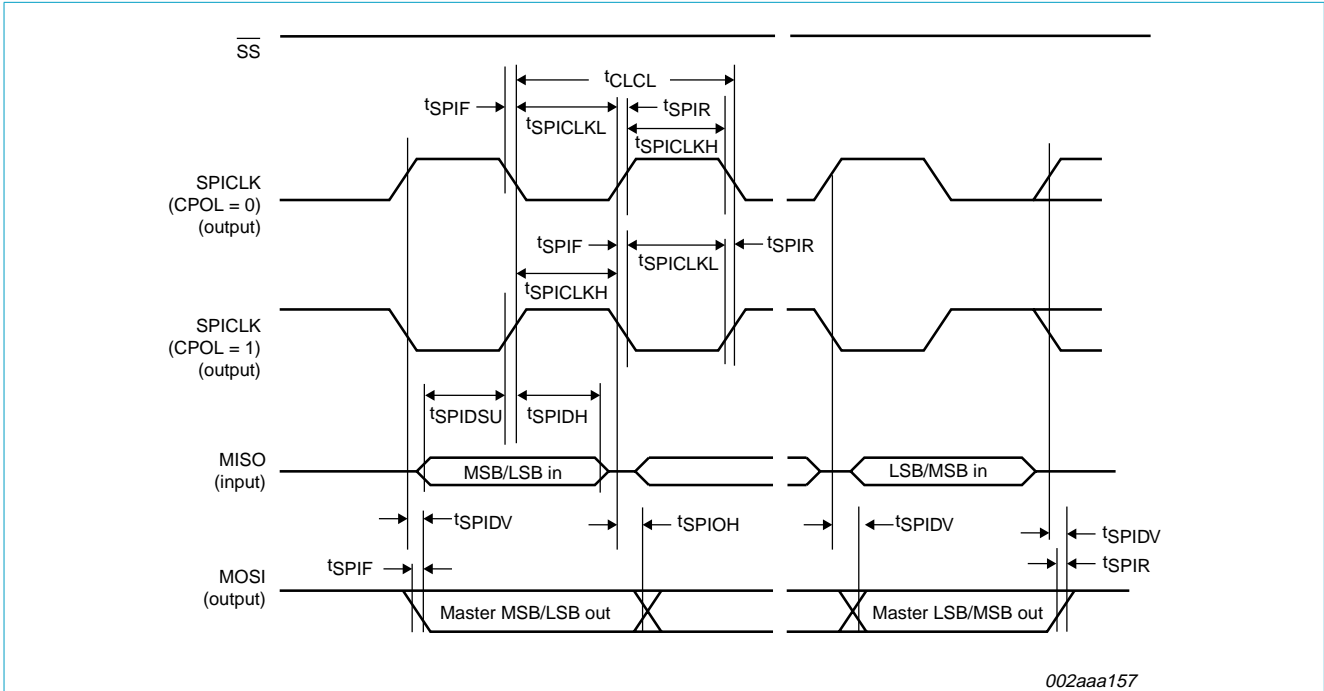


Fig 23. SPI master timing (CPHA = 1).

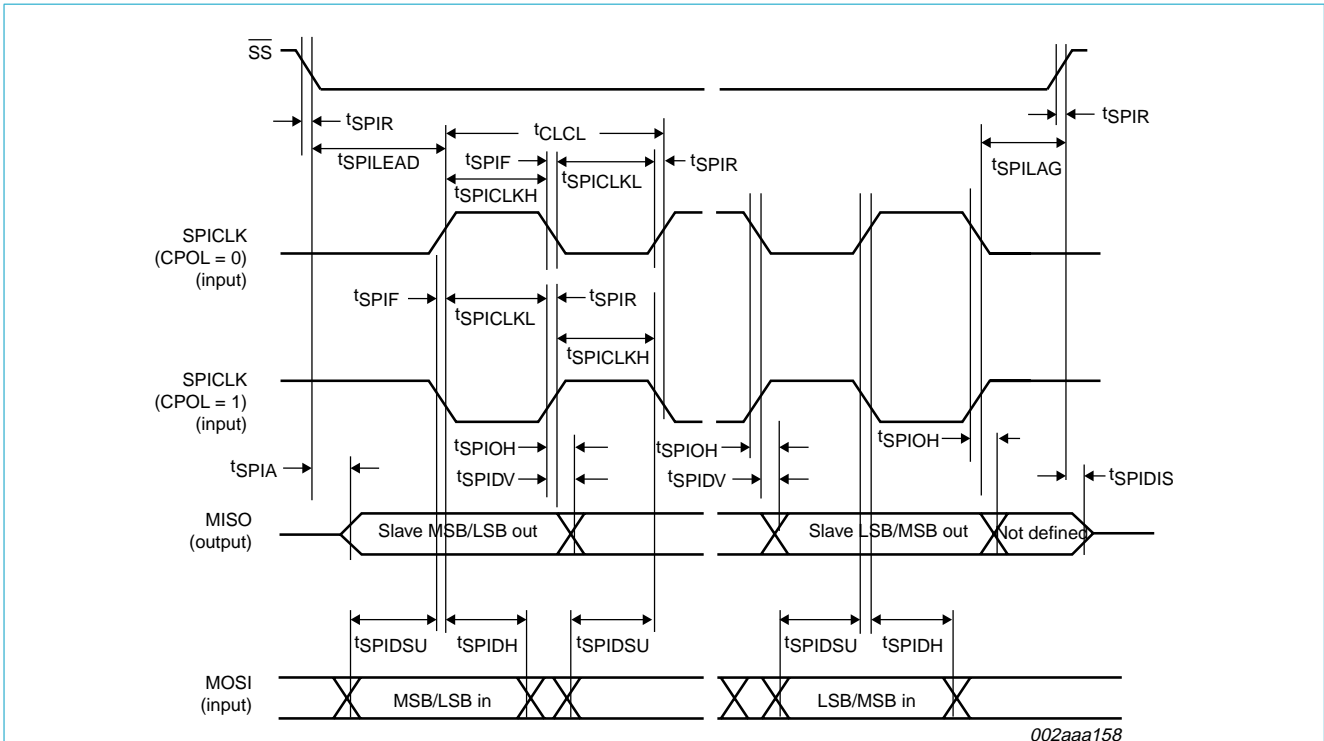


Fig 24. SPI slave timing (CPHA = 0).

13. Comparator electrical characteristics

Table 16: Comparator electrical characteristics

$V_{DD} = 2.4\text{ V to }3.6\text{ V}$, unless otherwise specified.

$T_{amb} = -40\text{ °C to }+85\text{ °C}$ for industrial, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IO}	offset voltage comparator inputs		-	-	± 20	mV
V_{CR}	common mode range comparator inputs		0	-	$V_{DD} - 0.3$	V
CMRR	common mode rejection ratio		[1]	-	-50	dB
	response time		-	250	500	ns
	comparator enable to output valid		-	-	10	μs
I_{IL}	input leakage current, comparator	$0 < V_{IN} < V_{DD}$	-	-	± 10	μA

[1] This parameter is characterized, but not tested in production.

14. Package outline

TSSOP14: plastic thin shrink small outline package; 14 leads; body width 4.4 mm

SOT402-1

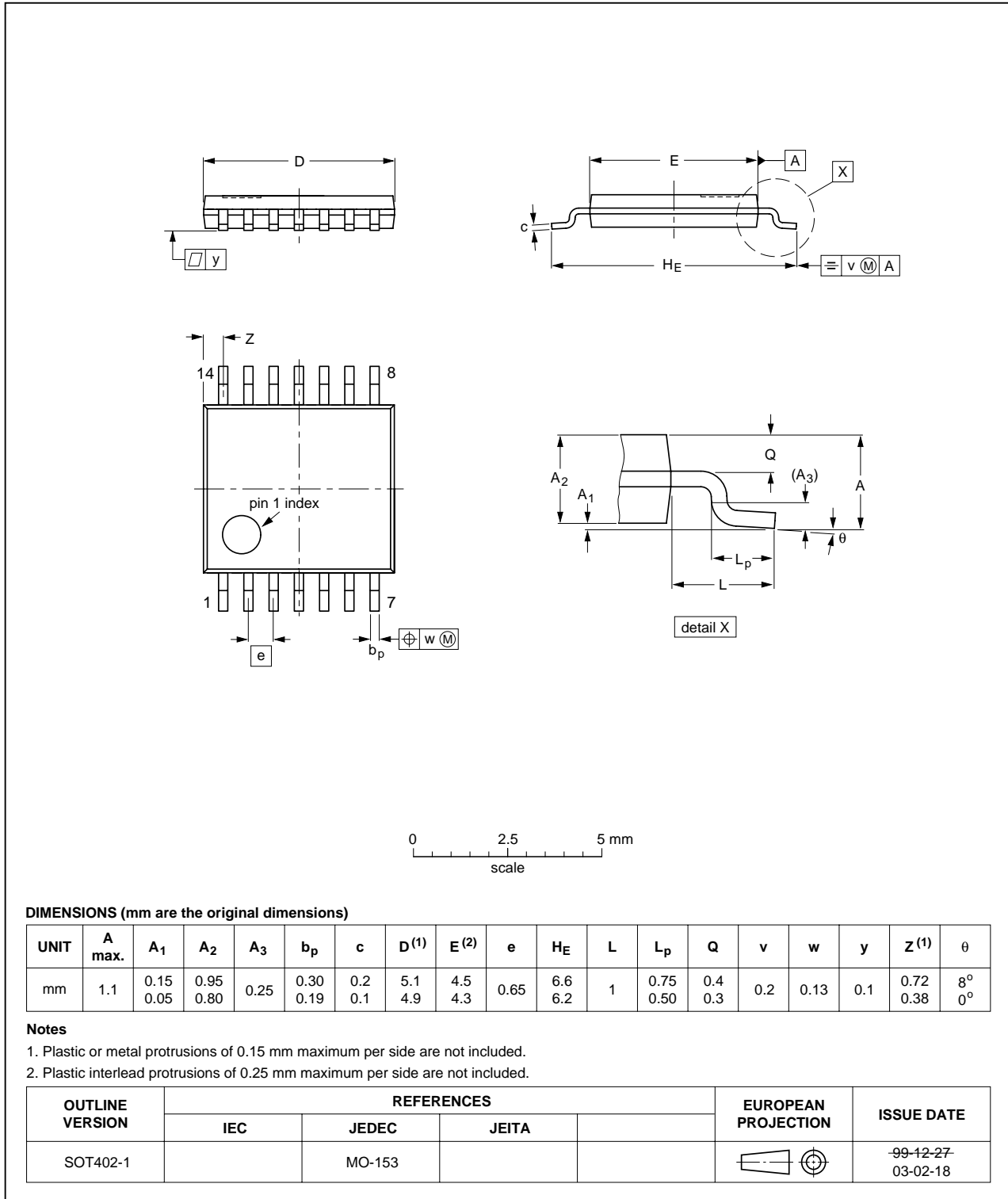


Fig 28. SOT402-1 (TSSOP14).

TSSOP16: plastic thin shrink small outline package; 16 leads; body width 4.4 mm

SOT403-1

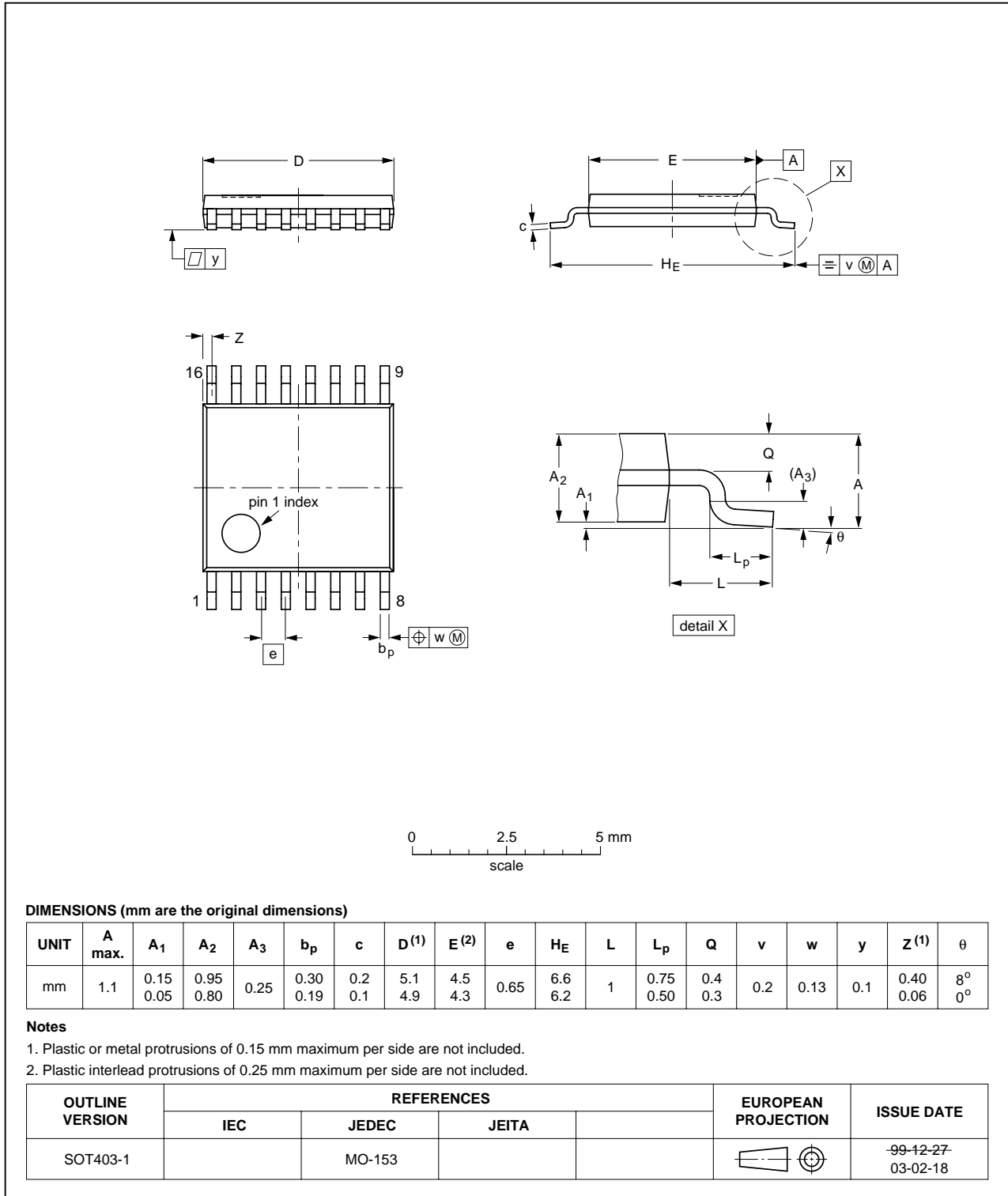


Fig 29. SOT403-1 (TSSOP16).

15. Revision history

Table 17: Revision history

Rev	Date	CPCN	Description
04	20041217	-	Product data (9397 750 14397) Modifications: <ul style="list-style-type: none">• Added extended temperature device (P89LPC915HDH).• Added 18 MHz information.
03	20040701	-	Preliminary data (9397 750 13522)
02	20040512	-	Preliminary data (9397 750 13278)
01	20040408	-	Preliminary data (9397 750 12986)

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Level	Data sheet status ^[1]	Product status ^{[2][3]}	Definition
I	Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
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