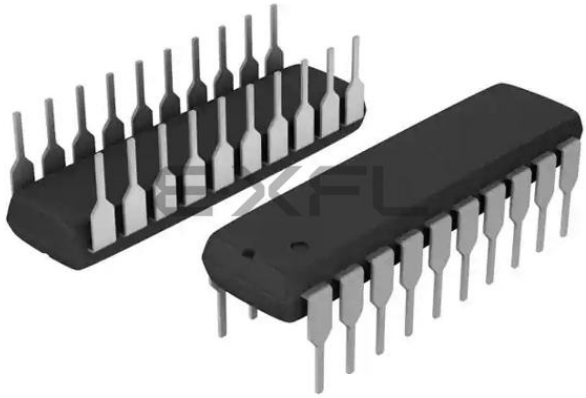

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Applications of "Embedded - Microcontrollers"

Details	
Product Status	Obsolete
Core Processor	8051
Core Size	8-Bit
Speed	20MHz
Connectivity	I²C, UART/USART
Peripherals	Brown-out Detect/Reset, LED, POR, PWM, WDT
Number of I/O	18
Program Memory Size	4KB (4K x 8)
Program Memory Type	OTP
EEPROM Size	-
RAM Size	128 x 8
Voltage - Supply (Vcc/Vdd)	2.7V ~ 6V
Data Converters	A/D 4x8b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Through Hole
Package / Case	20-DIP (0.300", 7.62mm)
Supplier Device Package	20-DIP
Purchase URL	https://www.e-xfl.com/product-detail/nxp-semiconductors/p87lpc768fn-112

PIN DESCRIPTIONS

MNEMONIC	PIN NO.	TYPE	NAME AND FUNCTION		
P0.0–P0.7	1, 13, 14, 16–20	I/O	**Port 0**: Port 0 is an 8-bit I/O port with a user-configurable output type. Port 0 latches are configured in the quasi-bidirectional mode and have either ones or zeros written to them during reset, as determined by the PRHI bit in the UCFG1 configuration byte. The operation of port 0 pins as inputs and outputs depends upon the port configuration selected. Each port pin is configured independently. Refer to the section on I/O port configuration and the DC Electrical Characteristics for details. The Keyboard Interrupt feature operates with port 0 pins. Port 0 also provides various special functions as described below.		
	1	O	**P0.0**	**CMP2**	Comparator 2 output.
		O		**PWM3**	Pulse Width Modulator 3 output.
	20	I	**P0.1**	**CIN2B**	Comparator 2 positive input B.
		O		**PWM0**	Pulse Width Modulator 0 output.
	19	I	**P0.2**	**CIN2A**	Comparator 2 positive input A.
		I		**BRAKE**	PWM brake input.
	18	I	**P0.3**	**CIN1B**	Comparator 1 positive input B.
		I		**AD0**	A/D channel 0 input.
	17	I	**P0.4**	**CIN1A**	Comparator 1 positive input A.
		I		**AD1**	A/D channel 1 input.
	16	I	**P0.5**	**CMPREF**	Comparator reference (negative) input.
		I		**AD2**	A/D channel 2 input.
	14	O	**P0.6**	**CMP1**	Comparator 1 output.
		I		**AD3**	A/D channel 3 input.
	13	I/O	**P0.7**	**T1**	Timer/counter 1 external count input or overflow output.
P1.0–P1.7	2–4, 8–12	I/O	**Port 1**: Port 1 is an 8-bit I/O port with a user-configurable output type, except for three pins as noted below. Port 1 latches are configured in the quasi-bidirectional mode and have either ones or zeros written to them during reset, as determined by the PRHI bit in the UCFG1 configuration byte. The operation of the configurable port 1 pins as inputs and outputs depends upon the port configuration selected. Each of the configurable port pins are programmed independently. Refer to the section on I/O port configuration and the DC Electrical Characteristics for details. Port 1 also provides various special functions as described below.		
	12	O	**P1.0**	**TxD**	Transmitter output for the serial port.
	11	I	**P1.1**	**RxD**	Receiver input for the serial port.
	10	I/O	**P1.2**	**T0**	Timer/counter 0 external count input or overflow output.
		I/O		**SCL**	I^2C serial clock input/output. When configured as an output, P1.2 is open drain, in order to conform to I^2C specifications.
	9	I	**P1.3**	**$\overline{\text{INT0}}$**	External interrupt 0 input.
		I/O		**SDA**	I^2C serial data input/output. When configured as an output, P1.3 is open drain, in order to conform to I^2C specifications.
	8	I	**P1.4**	**$\overline{\text{INT1}}$**	External interrupt 1 input.
	4	I	**P1.5**	**$\overline{\text{RST}}$**	External Reset input (if selected via EPROM configuration). 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 used as a port pin, P1.5 is a Schmitt trigger input only.
	3	O	**P1.6**	**PWM1**	Pulse Width Modulator 1 output
	2	O	**P1.7**	**PWM2**	Pulse Width Modulator 2 output

Analog Comparators

Two analog comparators are provided on the P87LPC768. Input and output options allow use of the comparators in a number of different configurations. Comparator operation is such that the output is a logical one (which may be read in a register and/or routed to a pin) when the positive input (one of two selectable pins) is greater than the negative input (selectable from a pin or an internal reference voltage). Otherwise the output is a zero. Each comparator may be configured to cause an interrupt when the output value changes.

Comparator Configuration

Each comparator has a control register, CMP1 for comparator 1 and CMP2 for comparator 2. The control registers are identical and are shown in Figure 4.

The overall connections to both comparators are shown in Figure 5. There are eight possible configurations for each comparator, as determined by the control bits in the corresponding CMPn register: CPn, CNn, and OEn. These configurations are shown in Figure 6. The comparators function down to a V_{DD} of 3.0V.

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

CMPn Address: ACh for CMP1, ADh for CMP2 Reset Value: 00h

Not Bit Addressable

7	6	5	4	3	2	1	0
—	—	CEn	CPn	CNn	OEn	COn	CMFn

BIT	SYMBOL	FUNCTION
CMPn.7, 6	—	Reserved for future use. Should not be set to 1 by user programs.
CMPn.5	CEn	Comparator enable. When set by software, the corresponding comparator function is enabled. Comparator output is stable 10 microseconds after CEn is first set.
CMPn.4	CPn	Comparator positive input select. When 0, CINnA is selected as the positive comparator input. When 1, CINnB is selected as the positive comparator input.
CMPn.3	CNn	Comparator negative input select. When 0, the comparator reference pin CMPREF is selected as the negative comparator input. When 1, the internal comparator reference V_{ref} is selected as the negative comparator input.
CMPn.2	OEn	Output enable. When 1, the comparator output is connected to the CMPn pin if the comparator is enabled (CEn = 1). This output is asynchronous to the CPU clock.
CMPn.1	COn	Comparator output, synchronized to the CPU clock to allow reading by software. Cleared when the comparator is disabled (CEn = 0).
CMPn.0	CMFn	Comparator interrupt flag. This bit is set by hardware whenever the comparator output COn changes state. This bit will cause a hardware interrupt if enabled and of sufficient priority. Cleared by software and when the comparator is disabled (CEn = 0).

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Figure 4. Comparator Control Registers (CMP1 and CMP2)

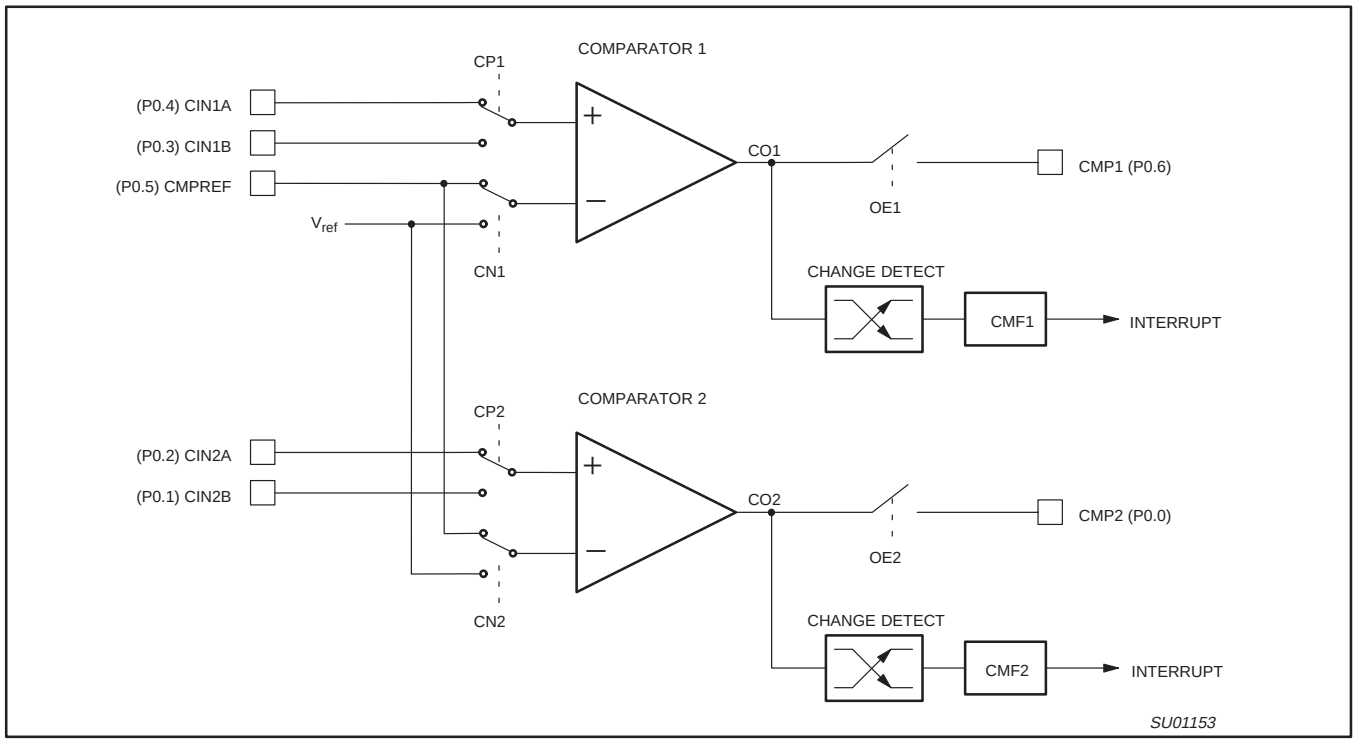

Figure 5. Comparator Input and Output Connections

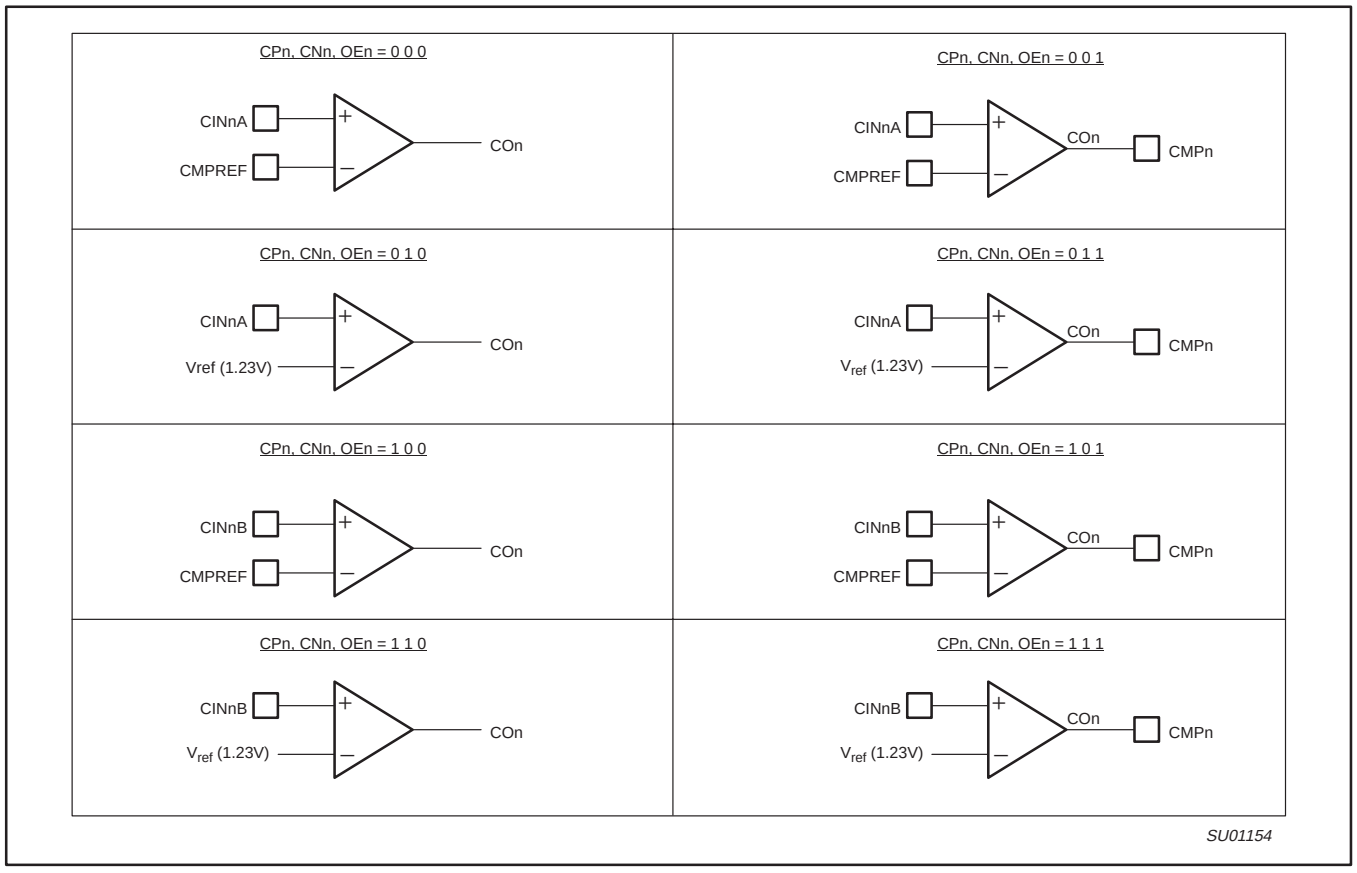

Figure 6. Comparator Configurations

CNSW0: Counter Shadow register 0

Addr: 0D1H

Reset Value: FFH

7	6	5	4	3	2	1	0
CNSW7	CNSW6	CNSW5	CNSW4	CNSW3	CNSW2	CNSW1	CNSW0

CNSW1: Counter Shadow register 1

Addr: 0D2H

Reset Value: FFH

7	6	5	4	3	2	1	0
Unused	Unused	Unused	Unused	Unused	Unused	CNSW9	CNSW8

The word “Shadow” in the above refers to the fact that writes are not into the register that controls the counter; rather they are into a holding register. As described below the transfer of data from this holding register, into the register which contains the actual reload value, is controlled by the user’s program.

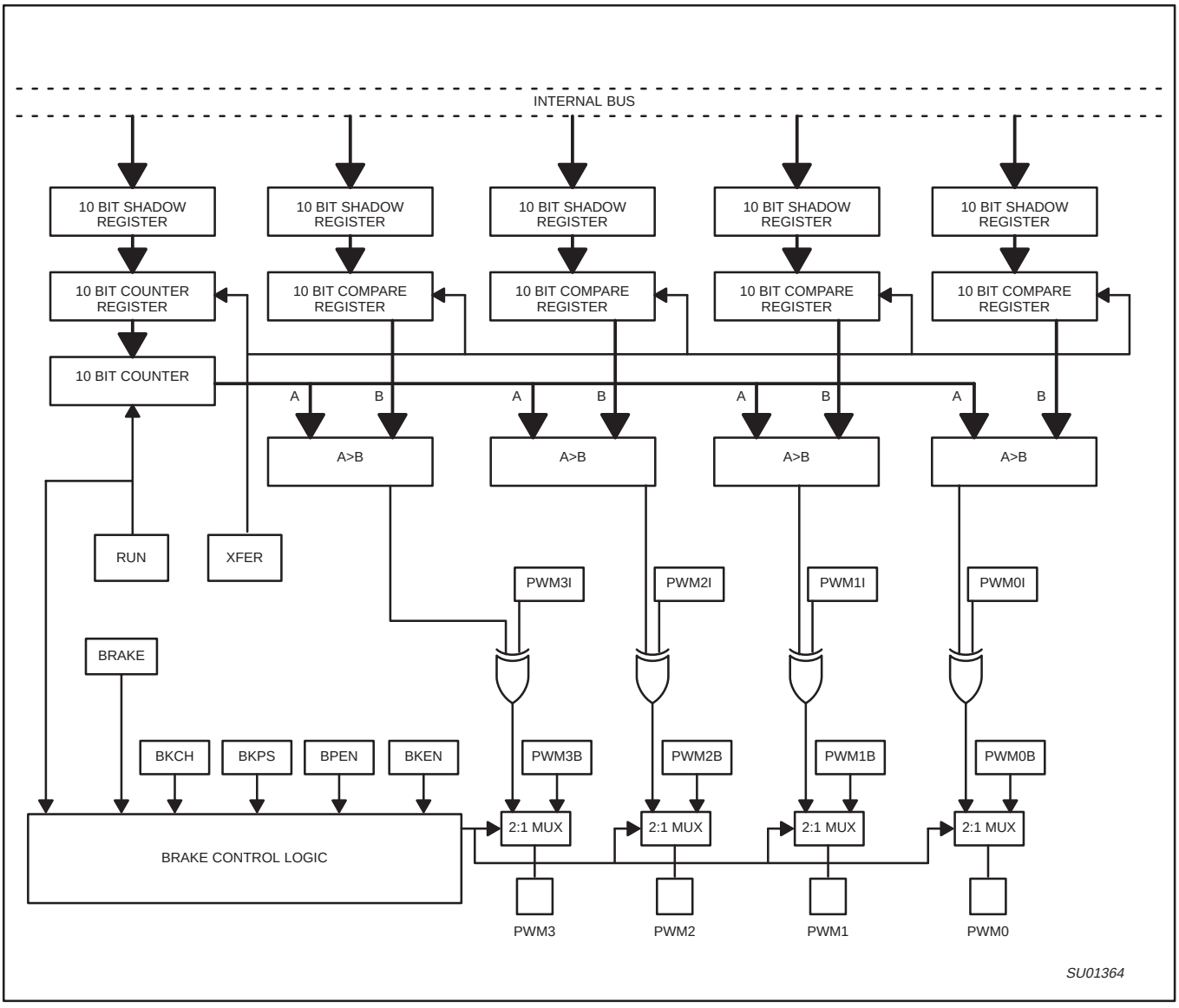

Figure 8. PWM Block Diagram

- Poll PWMCON0 to find that Transfer Bit PWMCON0.6 is “0”. When “0”:
- Write CNSW.(0:1) and CPSW.(0:4) for desired pulse widths and counter reload values
- Set PWMCON0 to Run and Transfer

Note that if a narrow pulse on the Brake Pin causes brake to be asserted, it may not be possible to go through the above code before the end of the pulse. In this case, in addition to the code shown, an external latch on the Brake Pin may be required to ensure that there is a smooth transition in going from brake to run.

The details for PWMCON1 are shown in the following table.

PWMCON1: PWM Control register 1

Addr: 0DBH

Reset Value: 00H

7	6	5	4	3	2	1	0
BKCH	BKPS	BPEN	BKEN	PWM3B	PWM2B	PWM1B	PWM0B

BIT	SYMBOL	FUNCTION
PWMCON1.7	BKCH	See table below
PWMCON1.6	BKPS	0= ”Brake” is asserted if P0.2(Brake Pin) is low.
		1= ”Brake” is asserted if P0.2(Brake Pin) is high.
PWMCON1.5	BPEN	See table below.
PWMCON1.4	BKEN	0= ”Brake” is never asserted.
		1= ”Brake” is enabled per table below.
PWMCON1.3	PWM3B	0= PWM3 is low, when Brake is asserted.
		1= PWM3 is high, when Brake is asserted.
PWMCON1.2	PWM2B	0= PWM2 is low, when Brake is asserted.
		1= PWM2 is high, when Brake is asserted.
PWMCON1.1	PWM1B	0= PWM1 is low, when Brake is asserted.
		1= PWM1 is high, when Brake is asserted.
PWMCON1.0	PWM0B	0= PWM0 is low, when Brake is asserted.
		1= PWM0 is high, when Brake is asserted.

BPEN	BKCH	BRAKE CONDITION
0	0	Always On, (Software Brake)
0	1	On when PWM not running (Brake Pin has no effect)
1	0	On when Brake Pin asserted (PWM run has no effect)
1	1	Not Allowed

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I²C Serial Interface

The I²C bus uses two wires (SDA and SCL) to transfer information between devices connected to the bus. The main features of the bus are:

- Bidirectional data transfer between masters and slaves.
- Serial addressing of slaves (no added wiring).
- Acknowledgment after each transferred byte.
- Multimaster bus.
- Arbitration between simultaneously transmitting masters without corruption of serial data on bus.

The I²C subsystem includes hardware to simplify the software required to drive the I²C bus. The hardware is a single bit interface which in addition to including the necessary arbitration and framing error checks, includes clock stretching and a bus timeout timer. The interface is synchronized to software either through polled loops or interrupts.

Refer to the application note AN422, entitled “Using the 8XC751 Microcontroller as an I²C Bus Master” for additional discussion of the 8xC76x I²C interface and sample driver routines.

The P87LPC768 I2C implementation duplicates that of the 87C751 and 87C752 except for the following details:

- The interrupt vector addresses for both the I²C interrupt and the Timer I interrupt.
- The I²C SFR addresses (I2CON, !2CFG, I2DAT).
- The location of the I²C interrupt enable bit and the name of the SFR it is located within (EI2 is Bit 0 in IEN1).
- The location of the Timer I interrupt enable bit and the name of the SFR it is located within (ETI is Bit 7 in IEN1).
- The I²C and Timer I interrupts have a settable priority.

Timer I is used to both control the timing of the I²C bus and also to detect a “bus locked” condition, by causing an interrupt when nothing happens on the I²C bus for an inordinately long period of time while a transmission is in progress. If this interrupt occurs, the program has the opportunity to attempt to correct the fault and resume I²C operation.

Six time spans are important in I²C operation and are insured by timer I:

- The MINIMUM HIGH time for SCL when this device is the master.
- The MINIMUM LOW time for SCL when this device is a master. This is not very important for a single-bit hardware interface like this one, because the SCL low time is stretched until the software responds to the I²C flags. The software response time normally meets or exceeds the MIN LO time. In cases where the software responds within MIN HI + MIN LO) time, timer I will ensure that the minimum time is met.
- The MINIMUM SCL HIGH TO SDA HIGH time in a stop condition.
- The MINIMUM SDA HIGH TO SDA LOW time between I²C stop and start conditions (4.7ms, see I²C specification).
- The MINIMUM SDA LOW TO SCL LOW time in a start condition.
- The MAXIMUM SCL CHANGE time while an I²C frame is in progress. A frame is in progress between a start condition and the following stop condition. This time span serves to detect a lack of software response on this device as well as external I²C problems. SCL “stuck low” indicates a faulty master or slave. SCL “stuck high” may mean a faulty device, or that noise induced onto the I²C bus caused all masters to withdraw from I²C arbitration.

The first five of these times are 4.7 ms (see I²C specification) and are covered by the low order three bits of timer I. Timer I is clocked by the P87LPC768 CPU clock. Timer I can be pre-loaded with one of four values to optimize timing for different oscillator frequencies. At lower frequencies, software response time is increased and will degrade maximum performance of the I²C bus. See special function register I2CFG description for prescale values (CT0, CT1).

The MAXIMUM SCL CHANGE time is important, but its exact span is not critical. The complete 10 bits of timer I are used to count out the maximum time. When I²C operation is enabled, this counter is cleared by transitions on the SCL pin. The timer does not run between I²C frames (i.e., whenever reset or stop occurred more recently than the last start). When this counter is running, it will carry out after 1020 to 1023 machine cycles have elapsed since a change on SCL. A carry out causes a hardware reset of the I²C interface and generates an interrupt if the Timer I interrupt is enabled. In cases where the bus hang-up is due to a lack of software response by this device, the reset releases SCL and allows I²C operation among other devices to continue.

Timer I is enabled to run, and will reset the I²C interface upon overflow, if the TIRUN bit in the I2CFG register is set. The Timer I interrupt may be enabled via the ETI bit in IEN1, and its priority set by the PTIH and PTI bits in the Ip1H and IP1 registers respectively.

I²C Interrupts

If I²C interrupts are enabled (EA and EI2 are both set to 1), an I²C interrupt will occur whenever the ATN flag is set by a start, stop, arbitration loss, or data ready condition (refer to the description of ATN following). In practice, it is not efficient to operate the I²C interface in this fashion because the I²C interrupt service routine would somehow have to distinguish between hundreds of possible conditions. Also, since I²C can operate at a fairly high rate, the software may execute faster if the code simply waits for the I²C interface.

Typically, the I²C interrupt should only be used to indicate a start condition at an idle slave device, or a stop condition at an idle master device (if it is waiting to use the I²C bus). This is accomplished by enabling the I²C interrupt only during the aforementioned conditions.

Reading I2CON

RDAT — The data from SDA is captured into “Receive DATa” whenever a rising edge occurs on SCL. RDAT is also available (with seven low-order zeros) in the I2DAT register. The difference between reading it here and there is that reading I2DAT clears DRDY, allowing the I²C to proceed on to another bit. Typically, the first seven bits of a received byte are read from I2DAT, while the 8th is read here. Then I2DAT can be written to send the Acknowledge bit and clear DRDY.

ATN — “ATteNtion” is 1 when one or more of DRDY, ARL, STR, or STP is 1. Thus, ATN comprises a single bit that can be tested to release the I²C service routine from a “wait loop.”

DRDY — “Data ReaDY” (and thus ATN) is set when a rising edge occurs on SCL, except at idle slave. DRDY is cleared by writing CDR = 1, or by writing or reading the I2DAT register. The following low period on SCL is stretched until the program responds by clearing DRDY.

I2CON Address: D8h Reset Value: 81h

Bit Addressable[1]

	7	6	5	4	3	2	1	0
READ	RDAT	ATN	DRDY	ARL	STR	STP	MASTER	—
WRITE	CXA	IDLE	CDR	CARL	CSTR	CSTP	XSTR	XSTP

BIT	SYMBOL	FUNCTION
I2CON.7	RDAT	Read: the most recently received data bit.
"	CXA	Write: clears the transmit active flag.
I2CON.6	ATN	Read: ATN = 1 if any of the flags DRDY, ARL, STR, or STP = 1.
"	IDLE	Write: in the I^2C slave mode, writing a 1 to this bit causes the I^2C hardware to ignore the bus until it is needed again.
I2CON.5	DRDY	Read: Data Ready flag, set when there is a rising edge on SCL.
"	CDR	Write: writing a 1 to this bit clears the DRDY flag.
I2CON.4	ARL	Read: Arbitration Loss flag, set when arbitration is lost while in the transmit mode.
"	CARL	Write: writing a 1 to this bit clears the CARL flag.
I2CON.3	STR	Read: Start flag, set when a start condition is detected at a master or non-idle slave.
"	CSTR	Write: writing a 1 to this bit clears the STR flag.
I2CON.2	STP	Read: Stop flag, set when a stop condition is detected at a master or non-idle slave.
"	CSTP	Write: writing a 1 to this bit clears the STP flag.
I2CON.1	MASTER	Read: indicates whether this device is currently as bus master.
"	XSTR	Write: writing a 1 to this bit causes a repeated start condition to be generated.
I2CON.0	—	Read: undefined.
"	XSTP	Write: writing a 1 to this bit causes a stop condition to be generated.

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Figure 9. I^2C Control Register (I2CON)

I2DAT Address: D9h Reset Value: xxh

Not Bit Addressable

	7	6	5	4	3	2	1	0
READ	RDAT	—	—	—	—	—	—	—
WRITE	XDAT	—	—	—	—	—	—	—

BIT	SYMBOL	FUNCTION
I2DAT.7	RDAT	Read: the most recently received data bit, captured from SDA at every rising edge of SCL. Reading I2DAT also clears DRDY and the Transmit Active state.
"	XDAT	Write: sets the data for the next transmitted bit. Writing I2DAT also clears DRDY and sets the Transmit Active state.
I2DAT.6–0	–	Unused.

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Figure 10. I^2C Data Register (I2DAT)

Checking ATN and DRDY

When a program detects ATN = 1, it should next check DRDY. If DRDY = 1, then if it receives the last bit, it should capture the data from RDAT (in I2DAT or I2CON). Next, if the next bit is to be sent, it should be written to I2DAT. One way or another, it should clear DRDY and then return to monitoring ATN. Note that if any of ARL, STR, or STP is set, clearing DRDY will not release SCL to high, so that the I^2C will not go on to the next bit. If a program detects ATN = 1, and DRDY = 0, it should go on to examine ARL, STR, and STP.

ARL "Arbitration Loss" is 1 when transmit Active was set, but this device lost arbitration to another transmitter. Transmit Active is cleared when ARL is 1. There are four separate cases in which ARL is set.

1. If the program sent a 1 or repeated start, but another device sent a 0, or a stop, so that SDA is 0 at the rising edge of SCL. (If the other device sent a stop, the setting of ARL will be followed shortly by STP being set.)

2. If the program sent a 1, but another device sent a repeated start, and it drove SDA low before SCL could be driven low. (This type of ARL is always accompanied by STR = 1.)

3. In master mode, if the program sent a repeated start, but another device sent a 1, and it drove SCL low before this device could drive SDA low.

4. In master mode, if the program sent stop, but it could not be sent because another device sent a 0.

STR "STaRt" is set to a 1 when an I^2C start condition is detected at a non-idle slave or at a master. (STR is not set when an idle slave becomes active due to a start bit; the slave has nothing useful to do until the rising edge of SCL sets DRDY.)

STP "SToP" is set to 1 when an I^2C stop condition is detected at a non-idle slave or at a master. (STP is not set for a stop condition at an idle slave.)

MASTER "MASTER" is 1 if this device is currently a master on the I^2C. MASTER is set when MASTRQ is 1 and the bus is not busy (i.e., if a start bit hasn't been received since reset or a "Timer I" time-out, or if a stop has been received since the last start). MASTER is cleared when ARL is set, or after the software writes MASTRQ = 0 and then XSTP = 1.

Writing I2CON

Typically, for each bit in an I^2C message, a service routine waits for ATN = 1. Based on DRDY, ARL, STR, and STP, and on the current bit position in the message, it may then write I2CON with one or more of the following bits, or it may read or write the I2DAT register.

CXA Writing a 1 to "Clear Xmit Active" clears the Transmit Active state. (Reading the I2DAT register also does this.)

Regarding Transmit Active

Transmit Active is set by writing the I2DAT register, or by writing I2CON with XSTR = 1 or XSTP = 1. The I^2C interface will only drive the SDA line low when Transmit Active is set, and the ARL bit will only be set to 1 when Transmit Active is set. Transmit Active is cleared by reading the I2DAT register, or by writing I2CON with CXA = 1. Transmit Active is automatically cleared when ARL is 1.

IDLE Writing 1 to "IDLE" causes a slave's I^2C hardware to ignore the I^2C until the next start condition (but if MASTRQ is 1, then a stop condition will cause this device to become a master).

CDR Writing a 1 to "Clear Data Ready" clears DRDY. (Reading or writing the I2DAT register also does this.)

CARL Writing a 1 to "Clear Arbitration Loss" clears the ARL bit.

CSTR Writing a 1 to "Clear STaRt" clears the STR bit.

CSTP Writing a 1 to "Clear SToP" clears the STP bit. Note that if one or more of DRDY, ARL, STR, or STP is 1, the low time of SCL is stretched until the service routine responds by clearing them.

XSTR Writing 1s to "Xmit repeated STaRt" and CDR tells the I^2C hardware to send a repeated start condition. This should only be at a master. Note that XSTR need not and should not be used to send an "initial" (non-repeated) start; it is sent automatically by the I^2C hardware. Writing XSTR = 1 includes the effect of writing I2DAT with XDAT = 1; it sets Transmit Active and releases SDA to high during the SCL low time. After SCL goes high, the I^2C hardware waits for the suitable minimum time and then drives SDA low to make the start condition.

XSTP Writing 1s to "Xmit SToP" and CDR tells the I^2C hardware to send a stop condition. This should only be done at a master. If there are no more messages to initiate, the service routine should clear the MASTRQ bit in I2CFG to 0 before writing XSTP with 1. Writing XSTP = 1 includes the effect of writing I2DAT with XDAT = 0; it sets Transmit Active and drives SDA low during the SCL low time. After SCL goes high, the I^2C hardware waits for the suitable minimum time and then releases SDA to high to make the stop condition.

Table 2. Interaction of TIRUN with SLAVEN, MASTRQ, and MASTER

SLAVEN, MASTRQ, MASTER	TIRUN	OPERATING MODE
All 0	0	The I^2C interface is disabled. Timer I is cleared and does not run. This is the state assumed after a reset. If an I^2C application wants to ignore the I^2C at certain times, it should write SLAVEN, MASTRQ, and TIRUN all to zero.
All 0	1	The I^2C interface is disabled.
Any or all 1	0	The I^2C interface is enabled. The 3 low-order bits of Timer I run for min-time generation, but the hi-order bits do not, so that there is no checking for I^2C being “hung.” This configuration can be used for very slow I^2C operation.
Any or all 1	1	The I^2C interface is enabled. Timer I runs during frames on the I^2C, and is cleared by transitions on SCL, and by Start and Stop conditions. This is the normal state for I^2C operation.

Table 3. CT1, CT0 Values

CT1, CT0	Min Time Count (Machine Cycles)	CPU Clock Max (for 100 kHz I^2C)	Timeout Period (Machine Cycles)
1 0	7	8.4 MHz	1023
0 1	6	7.2 MHz	1022
0 0	5	6.0 MHz	1021
1 1	4	4.8 MHz	1020

Interrupts

The P87LPC768 uses a four priority level interrupt structure. This allows great flexibility in controlling the handling of the P87LPC768's many interrupt sources. The P87LPC768 supports up to 13 interrupt sources.

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

Each interrupt source can be individually programmed to one of four priority levels by setting or clearing bits in the IP0, IP0H, IP1, and IP1H registers. 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. So, if two requests of different priority levels are received simultaneously, the request of higher priority level is serviced.

If requests of the same priority level are received simultaneously, 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 simultaneous requests of the same priority level.

Table 3 summarizes the interrupt sources, flag bits, vector addresses, enable bits, priority bits, arbitration ranking, and whether each interrupt may wake up the CPU from Power Down mode.

Table 4. Summary of Interrupts

Description	Interrupt Flag Bit(s)	Vector Address	Interrupt Enable Bit(s)	Interrupt Priority	Arbitration Ranking	Power Down Wakeup
External Interrupt 0	IE0	0003h	EX0 (IEN0.0)	IP0H.0, IP0.0	1 (highest)	Yes
Timer 0 Interrupt	TF0	000Bh	ET0 (IEN0.1)	IP0H.1, IP0.1	4	No
External Interrupt 1	IE1	0013h	EX1 (IEN0.2)	IP0H.2, IP0.2	7	Yes
Timer 1 Interrupt	TF1	001Bh	ET1 (IEN0.3)	IP0H.3, IP0.3	10	No
Serial Port Tx and Rx	TI & RI	0023h	ES (IEN0.4)	IP0H.4, IP0.4	12	No
Brownout Detect	BOF	002Bh	EBO (IEN0.5)	IP0H.5, IP0.5	2	Yes
I^2C Interrupt	ATN	0033h	EI2 (IEN1.0)	IP1H.0, IP1.0	5	No
KBI Interrupt	KBF	003Bh	EKB (IEN1.1)	IP1H.1, IP1.1	8	Yes
Comparator 2 interrupt	CMF2	0043h	EC2 (IEN1.2)	IP1H.2, IP1.2	11	Yes
Watchdog Timer	WDOVF	0053h	EWD (IEN0.6)	IP0H.6, IP0.6	3	Yes
A/D Converter	ADCI	005Bh	EAD (IEN1.4)	IP1H.4, IP1.4	6	Yes
Comparator 1 interrupt	CMF1	0063h	EC1 (IEN1.5)	IP1H.5, IP1.5	9	Yes
Timer 1 interrupt	–	0073h	ETI (IEN 1.7)	Ip1H.7, IP1.7	13 (lowest)	No

I/O Ports

The P87LPC768 has 3 I/O ports, port 0, port 1, and port 2. The exact number of I/O pins available depend upon the oscillator and reset options chosen. At least 15 pins of the P87LPC768 may be used as I/Os when a two-pin external oscillator and an external reset circuit are used. Up to 18 pins may be available if fully on-chip oscillator and reset configurations are chosen.

All but three I/O port pins on the P87LPC768 may be software configured to one of four types on a bit-by-bit basis, as shown in Table 4. These are: quasi-bidirectional (standard 80C51 port outputs), push-pull, open drain, and input only. Two configuration registers for each port choose the output type for each port pin.

Table 5. Port Output Configuration Settings

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

Quasi-Bidirectional Output Configuration

The default port output configuration for standard P87LPC768 I/O ports is the quasi-bidirectional output that is common on the 80C51 and most of its derivatives. This 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 pulled 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.

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

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

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

The quasi-bidirectional port configuration is shown in Figure 13.

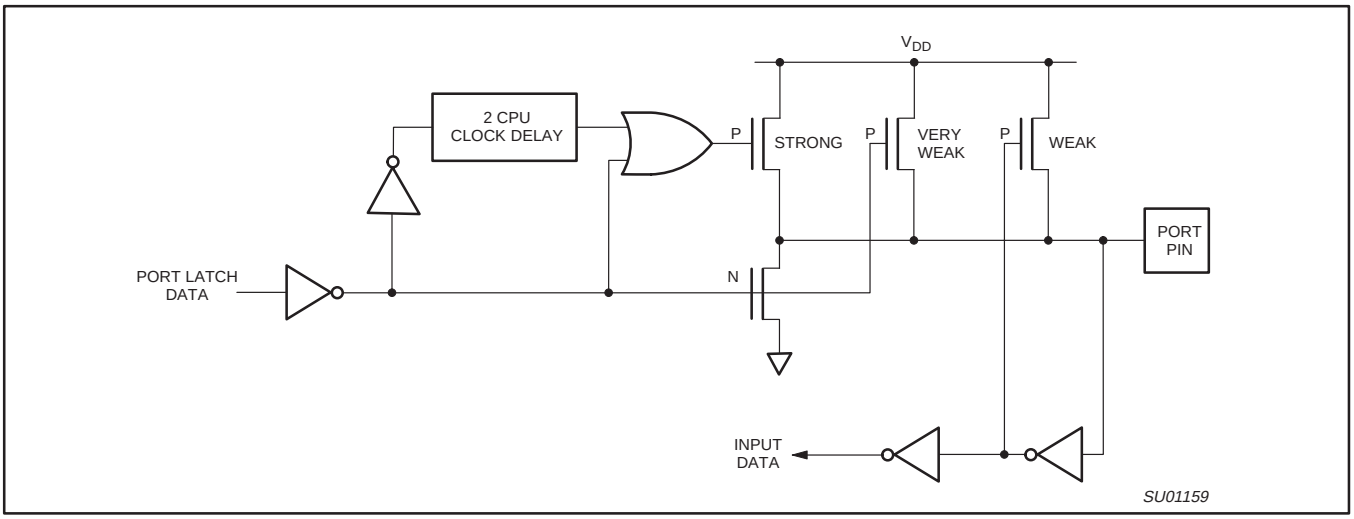

Figure 13. Quasi-Bidirectional Output

P2M1 Address: A4h Reset Value: 00h

Not Bit Addressable

7	6	5	4	3	2	1	0
P2S	P1S	P0S	ENCLK	ENT1	ENT0	(P2M1.1)	(P2M1.0)

BIT	SYMBOL	FUNCTION
P2M1.7	P2S	When P2S = 1, this bit enables Schmitt trigger inputs on Port 2.
P2M1.6	P1S	When P1S = 1, this bit enables Schmitt trigger inputs on Port 1.
P2M1.5	P0S	When P0S = 1, this bit enables Schmitt trigger inputs on Port 0.
P2M1.4	ENCLK	When ENCLK is set and the P87LPC768 is configured to use the on-chip RC oscillator, a clock output is enabled on the X2 pin (P2.0). Refer to the Oscillator section for details.
P2M1.3	ENT1	When set, the P.7 pin is toggled whenever Timer 1 overflows. The output frequency is therefore one half of the Timer 1 overflow rate. Refer to the Timer/Counters section for details.
P2M1.2	ENT0	When set, the P1.2 pin is toggled whenever Timer 0 overflows. The output frequency is therefore one half of the Timer 0 overflow rate. Refer to the Timer/Counterssection for details.
P2M1.1, P2M1.0	—	These bits, along with the matching bits in the P2M2 register, control the output configuration of P2.1 and P2.0 respectively, as shown in Table 4.

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Figure 16. Port 2 Mode Register 1 (P2M1)

Keyboard Interrupt (KBI)

The Keyboard Interrupt function is intended primarily to allow a single interrupt to be generated when any key is pressed on a keyboard or keypad connected to specific pins of the P87LPC768, as shown in Figure 17. This 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.

The P87LPC768 allows any or all pins of port 0 to be enabled to cause this interrupt. Port pins are enabled by the setting of bits in the KBI register, as shown in Figure 18. The Keyboard Interrupt Flag (KBF) in the AUXR1 register is set when any enabled pin is pulled low while the KBI interrupt function is active. An interrupt will generated if it has been enabled. Note that the KBF bit must be cleared by software.

Due to human time scales and the mechanical delay associated with keyswitch closures, the KBI feature will typically allow the interrupt service routine to poll port 0 in order to determine which key was pressed, even if the processor has to wake up from Power Down mode. Refer to the section on Power Reduction Modes for details.

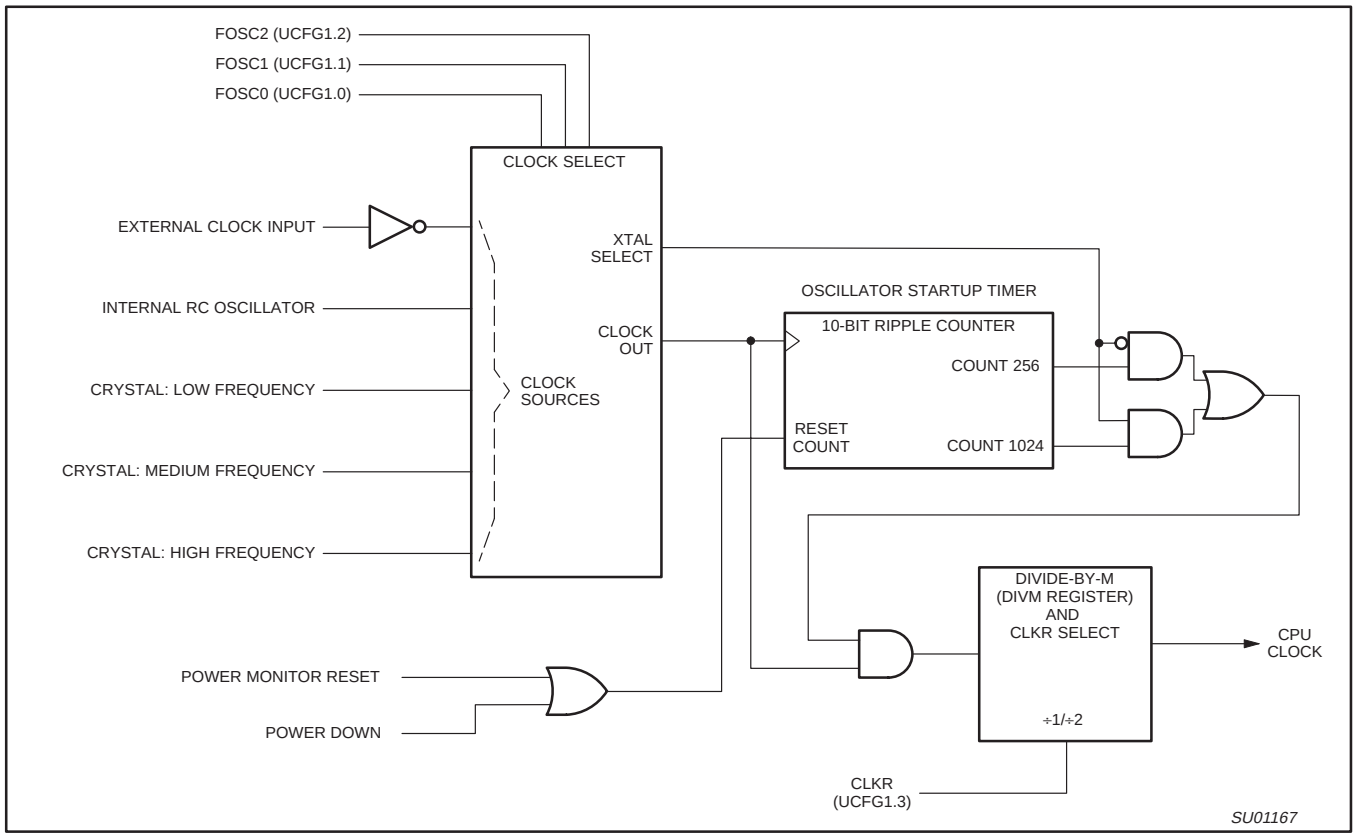

Figure 21. Block Diagram of Oscillator Control

CPU Clock Modification: CLKR and DIVM

For backward compatibility, the CLKR configuration bit allows setting the P87LPC768 instruction and peripheral timing to match standard 80C51 timing by dividing the CPU clock by two. Default timing for the P87LPC768 is 6 CPU clocks per machine cycle while standard 80C51 timing is 12 clocks per machine cycle. This division also applies to peripheral timing, allowing 80C51 code that is oscillator frequency and/or timer rate dependent. The CLKR bit is located in the EPROM configuration register UCFG1, described under EPROM Characteristics

In addition to this, the CPU clock may be divided down from the oscillator rate by a programmable divider, under program control. This function is controlled by the DIVM register. If the DIVM register is set to zero (the default value), the CPU will be clocked by either the unmodified oscillator rate, or that rate divided by two, as determined by the previously described CLKR function.

When the DIVM register is set to some value N (between 1 and 255), the CPU clock is divided by 2 * (N + 1). Clock division values from 4 through 512 are thus possible. This feature makes it possible to temporarily run the CPU at a lower rate, reducing power consumption, in a manner similar to Idle mode. By dividing the clock, the CPU can retain the ability to respond to events other than those that can cause interrupts (i.e. events that allow exiting the Idle mode) by executing its normal program at a lower rate. This can allow bypassing the oscillator startup 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.

Power Monitoring Functions

The P87LPC768 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.

Brownout Detection

The Brownout Detect function allows preventing the processor from failing in an unpredictable manner 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 by setting the BOI bit in the AUXR1 register (AUXR1.5).

The P87LPC768 allows selection of two Brownout levels: 2.5 V or 3.8 V. When V_{DD} drops below the selected voltage, the brownout detector triggers and remains active until V_{DD} is returns to a level above the Brownout Detect voltage. When Brownout Detect causes a processor reset, that reset remains active as long as V_{DD} remains below the Brownout Detect voltage. When Brownout Detect generates an interrupt, that interrupt occurs once as V_{DD} crosses from above to below the Brownout Detect voltage. For the interrupt to be processed, the interrupt system and the BOI interrupt must both be enabled (via the EA and EBO bits in IEN0).

When Brownout Detect is activated, the BOF flag in the PCON register is set so that the cause of processor reset may be determined by software. This flag will remain set until cleared by software.

Mode 0

Putting either Timer into Mode 0 makes it look like an 8048 Timer, which is an 8-bit Counter with a divide-by-32 prescaler. Figure 27 shows Mode 0 operation.

In this mode, the Timer register is configured as a 13-bit register. As the count rolls over from all 1s to all 0s, it sets the Timer interrupt flag TFn. The count input is enabled to the Timer when TRn = 1 and either GATE = 0 or $\overline{INTn}$ = 1. (Setting GATE = 1 allows the Timer to be controlled by external input $\overline{INTn}$, to facilitate pulse width measurements). TRn is a control bit in the Special Function Register TCON (Figure 26). The GATE bit is in the TMOD register.

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

Mode 0 operation is the same for Timer 0 and Timer 1. See Figure 27. There are two different GATE bits, one for Timer 1 (TMOD.7) and one for Timer 0 (TMOD.3).

TCON Address: 88h Reset Value: 00h

Bit Addressable

7	6	5	4	3	2	1	0
TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

BIT	SYMBOL	FUNCTION
TCON.7	TF1	Timer 1 overflow flag. Set by hardware on Timer/Counter overflow. Cleared by hardware when the interrupt is processed, or by software.
TCON.6	TR1	Timer 1 Run control bit. Set/cleared by software to turn Timer/Counter 1 on/off.
TCON.5	TF0	Timer 0 overflow flag. Set by hardware on Timer/Counter overflow. Cleared by hardware when the processor vectors to the interrupt routine, or by software.
TCON.4	TR0	Timer 0 Run control bit. Set/cleared by software to turn Timer/Counter 0 on/off.
TCON.3	IE1	Interrupt 1 Edge flag. Set by hardware when external interrupt 1 edge is detected. Cleared by hardware when the interrupt is processed, or by software.
TCON.2	IT1	Interrupt 1 Type control bit. Set/cleared by software to specify falling edge/low level triggered external interrupts.
TCON.1	IE0	Interrupt 0 Edge flag. Set by hardware when external interrupt 0 edge is detected. Cleared by hardware when the interrupt is processed, or by software.
TCON.0	IT0	Interrupt 0 Type control bit. Set/cleared by software to specify falling edge/low level triggered external interrupts.

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Figure 26. Timer/Counter Control Register (TCON)

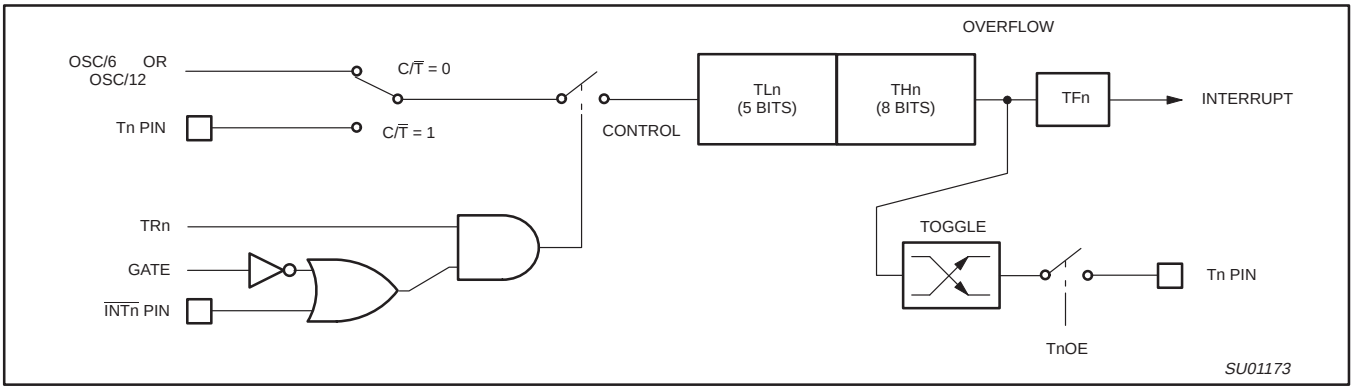

Figure 27. Timer/Counter 0 or 1 in Mode 0 (13-Bit Counter)

Baud Rates

The baud rate in Mode 0 is fixed: Mode 0 Baud Rate = CPU clock/6. The baud rate in Mode 2 depends on the value of bit SMOD1 in Special Function Register PCON. If SMOD1 = 0 (which is the value on reset), the baud rate is 1/32 of the CPU clock frequency. If SMOD1 = 1, the baud rate is 1/16 of the CPU clock frequency.

$$\text{Mode 2 Baud Rate} = \frac{1 + \text{SMOD1}}{32} \times \text{CPU clock frequency}$$

Using Timer 1 to Generate Baud Rates

When Timer 1 is used as the baud rate generator, the baud rates in Modes 1 and 3 are determined by the Timer 1 overflow rate and the value of SMOD1. The Timer 1 interrupt should be disabled in this application. The Timer itself can be configured for either “timer” or “counter” operation, and in any of its 3 running modes. In the most typical applications, it is configured for “timer” operation, in the auto-reload mode (high nibble of TMOD = 0010b). In that case the baud rate is given by the formula:

$$\text{Mode 1, 3 Baud Rate} = \frac{\text{CPU clock frequency}/\text{192 (or 96 if SMOD1 = 1)}}{256 - \text{(TH1)}}$$

Tables 6 and 7 list various commonly used baud rates and how they can be obtained using Timer 1 as the baud rate generator.

Table 10. Baud Rates, Timer Values, and CPU Clock Frequencies for SMOD1 = 0

Timer Count	Baud Rate					
	2400	4800	9600	19.2k	38.4k	57.6k
–1	0.4608	0.9216	* 1.8432	* 3.6864	* 7.3728	* 11.0592
–2	0.9216	1.8432	* 3.6864	* 7.3728	* 14.7456	
–3	1.3824	2.7648	5.5296	* 11.0592	–	–
–4	* 1.8432	* 3.6864	* 7.3728	* 14.7456	–	–
–5	2.3040	4.6080	9.2160	* 18.4320	–	–
–6	2.7648	5.5296	* 11.0592	–	–	–
–7	3.2256	6.4512	12.9024	–	–	–
–8	* 3.6864	* 7.3728	* 14.7456	–	–	–
–9	4.1472	8.2944	16.5888	–	–	–
–10	4.6080	9.2160	* 18.4320	–	–	–

Table 11. Baud Rates, Timer Values, and CPU Clock Frequencies for SMOD1 = 1

Timer Count	Baud Rate						
	2400	4800	9600	19.2k	38.4k	57.6k	115.2k
–1	0.2304	0.4608	0.9216	* 1.8432	* 3.6864	5.5296	* 11.0592
–2	0.4608	0.9216	* 1.8432	* 3.6864	* 7.3728	* 11.0592	–
–3	0.6912	1.3824	2.7648	5.5296	* 11.0592	16.5888	–
–4	0.9216	* 1.8432	* 3.6864	* 7.3728	* 14.7456	–	–
–5	1.1520	2.3040	4.6080	9.2160	* 18.4320	–	–
–6	1.3824	2.7648	5.5296	* 11.0592	–	–	–
–7	1.6128	3.2256	6.4512	12.9024	–	–	–
–8	* 1.8432	* 3.6864	* 7.3728	* 14.7456	–	–	–
–9	2.0736	4.1472	8.2944	16.5888	–	–	–
–10	2.3040	4.6080	9.2160	* 18.4320	–	–	–
–11	2.5344	5.0688	10.1376	–	–	–	–
–12	2.7648	5.5296	* 11.0592	–	–	–	–
–13	2.9952	5.9904	11.9808	–	–	–	–
–14	3.2256	6.4512	12.9024	–	–	–	–
–15	3.4560	6.9120	13.8240	–	–	–	–
–16	* 3.6864	* 7.3728	* 14.7456	–	–	–	–
–17	3.9168	7.8336	15.6672	–	–	–	–
–18	4.1472	8.2944	16.5888	–	–	–	–
–19	4.3776	8.7552	17.5104	–	–	–	–
–20	4.6080	9.2160	* 18.4320	–	–	–	–
–21	4.8384	9.6768	19.3536	–	–	–	–

NOTES TO TABLES 10 AND 11:
1. Tables 6 and 7 apply to UART modes 1 and 3 (variable rate modes), and show CPU clock rates in MHz for standard baud rates from 2400 to 115.2k baud.
2. Table 6 shows timer settings and CPU clock rates with the SMOD1 bit in the PCON register = 0 (the default after reset), while Table 7 reflects the SMOD1 bit = 1.
3. The tables show all potential CPU clock frequencies up to 20 MHz that may be used for baud rates from 9600 baud to 115.2k baud. Other CPU clock frequencies that would give only lower baud rates are not shown.
4. Table entries marked with an asterisk (*) indicate standard crystal and ceramic resonator frequencies that may be obtained from many sources without special ordering.

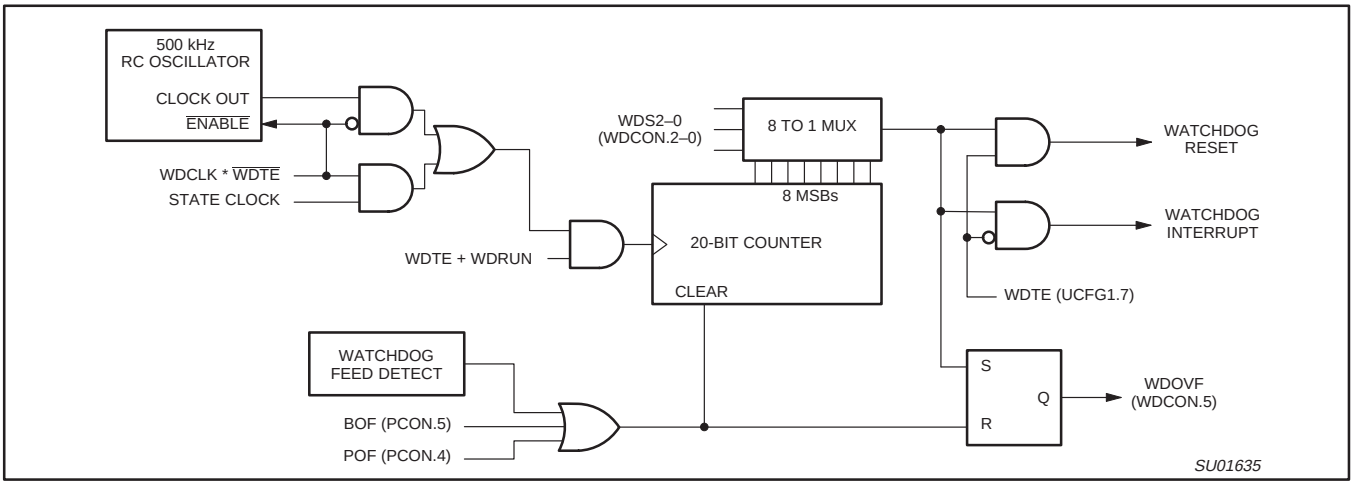

Figure 36. Block Diagram of the Watchdog Timer

WDCON Address: A7h

Not Bit Addressable

Reset Value:
- 30h for a watchdog reset.
- 10h for other rest sources if the watchdog is enabled via the WDTE configuration bit.
- 00h for other reset sources if the watchdog is disabled via the WDTE configuration bit.

7	6	5	4	3	2	1	0
—	—	WDOVF	WDRUN	WDCLK	WDS2	WDS1	WDS0

BIT	SYMBOL	FUNCTION
WDCON.7, 6	—	Reserved for future use. Should not be set to 1 by user programs.
WDCON.5	WDOVF	Watchdog timer overflow flag. Set when a watchdog reset or timer overflow occurs. Cleared when the watchdog is fed.
WDCON.4	WDRUN	Watchdog run control. The watchdog timer is started when WDRUN = 1 and stopped when WDRUN = 0. This bit is forced to 1 (watchdog running) if the WDTE configuration bit = 1.
WDCON.3	WDCLK	Watchdog clock select. The watchdog timer is clocked by CPU clock/6 when WDCLK = 1 and by the watchdog RC oscillator when WDCLK = 0. This bit is forced to 0 (using the watchdog RC oscillator) if the WDTE configuration bit = 1.
WDCON.2–0	WDS2–0	Watchdog rate select.

WDS2–0	Timeout Clocks	Minimum Time	Nominal Time	Maximum Time
0 0 0	8,192	10 ms	16 ms	23 ms
0 0 1	16,384	20 ms	32 ms	45 ms
0 1 0	32,768	41 ms	65 ms	90 ms
0 1 1	65,536	82 ms	131 ms	180 ms
1 0 0	131,072	165 ms	262 ms	360 ms
1 0 1	262,144	330 ms	524 ms	719 ms
1 1 0	524,288	660 ms	1.05 sec	1.44 sec
1 1 1	1,048,576	1.3 sec	2.1 sec	2.9 sec

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Figure 37. Watchdog Timer Control Register (WDCON)

Additional Features

The AUXR1 register contains several special purpose control bits that relate to several chip features. AUXR1 is described in Figure 38.

Software Reset

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

Dual Data Pointers

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

Specific instructions affected by the Data Pointer selection are:

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

Also, any instruction that reads or manipulates the DPH and DPL registers (the upper and lower bytes of the current DPTR) will be affected by the setting of DPS. The MOVX instructions have limited application for the P87LPC768 since the part does not have an external data bus. However, they may be used to access EPROM configuration information (see EPROM Characteristics section).

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

AUXR1 Address: A2h — Reset Value: 00h

Not Bit Addressable

7	6	5	4	3	2	1	0
KBF	BOD	BOI	LPEP	SRST	0	—	DPS

BIT	SYMBOL	FUNCTION
AUXR1.7	KBF	Keyboard Interrupt Flag. Set when any pin of port 0 that is enabled for the Keyboard Interrupt function goes low. Must be cleared by software.
AUXR1.6	BOD	Brown Out Disable. When set, turns off brownout detection and saves power. See Power Monitoring Functions section for details.
AUXR1.5	BOI	Brown Out Interrupt. When set, prevents brownout detection from causing a chip reset and allows the brownout detect function to be used as an interrupt. See the Power Monitoring Functions section for details.
AUXR1.4	LPEP	Low Power EPROM control bit. Allows power savings in low voltage systems. Set by software. Can only be cleared by power-on or brownout reset. See the Power Reduction Modes section for details.
AUXR1.3	SRST	Software Reset. When set by software, resets the P87LPC768 as if a hardware reset occurred.
AUXR1.2	—	This bit contains a hard-wired 0. Allows toggling of the DPS bit by incrementing AUXR1, without interfering with other bits in the register.
AUXR1.1	—	Reserved for future use. Should not be set to 1 by user programs.
AUXR1.0	DPS	Data Pointer Select. Chooses one of two Data Pointers for use by the program. See text for details.

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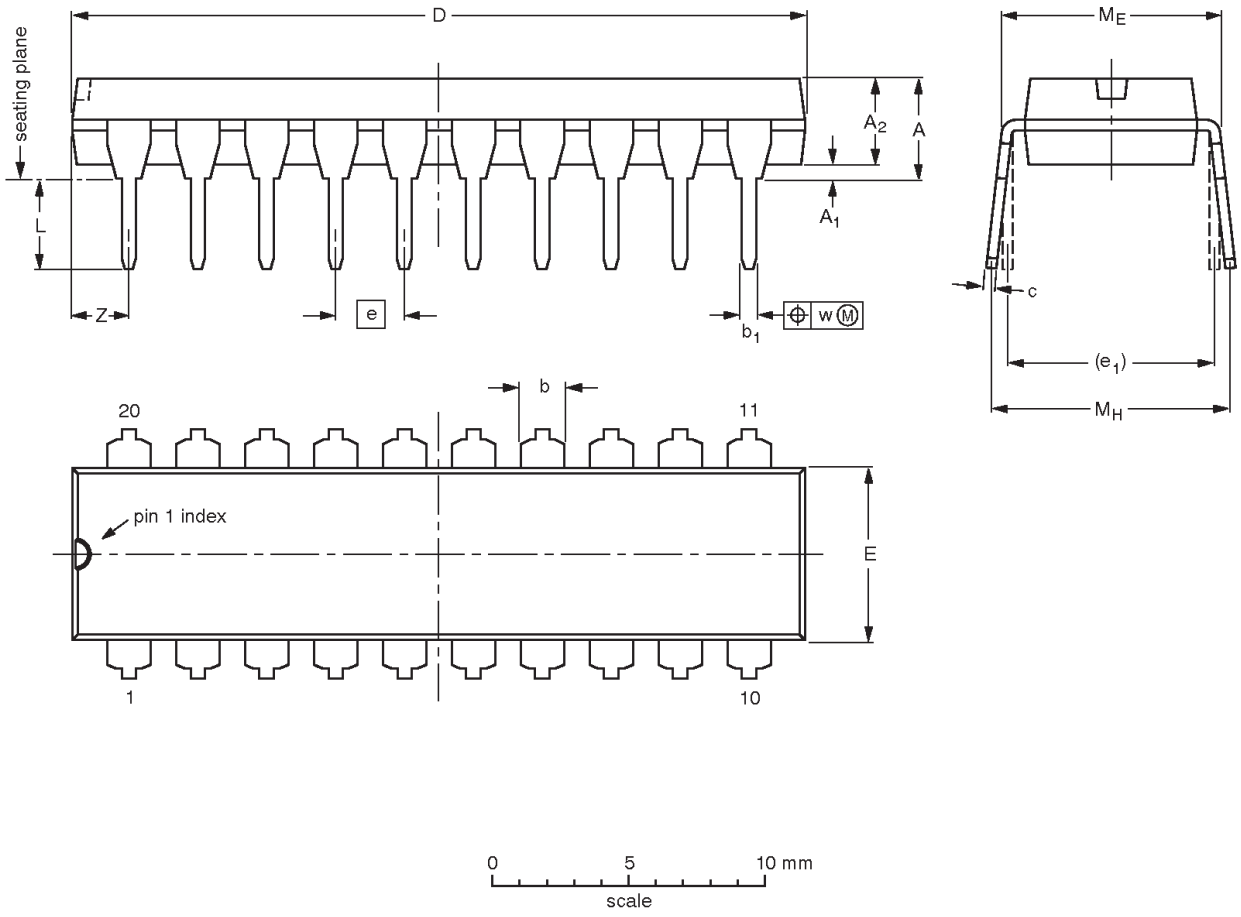
Figure 38. AUXR1 Register

DIP20: plastic dual in-line package; 20 leads (300 mil) **SOT146-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

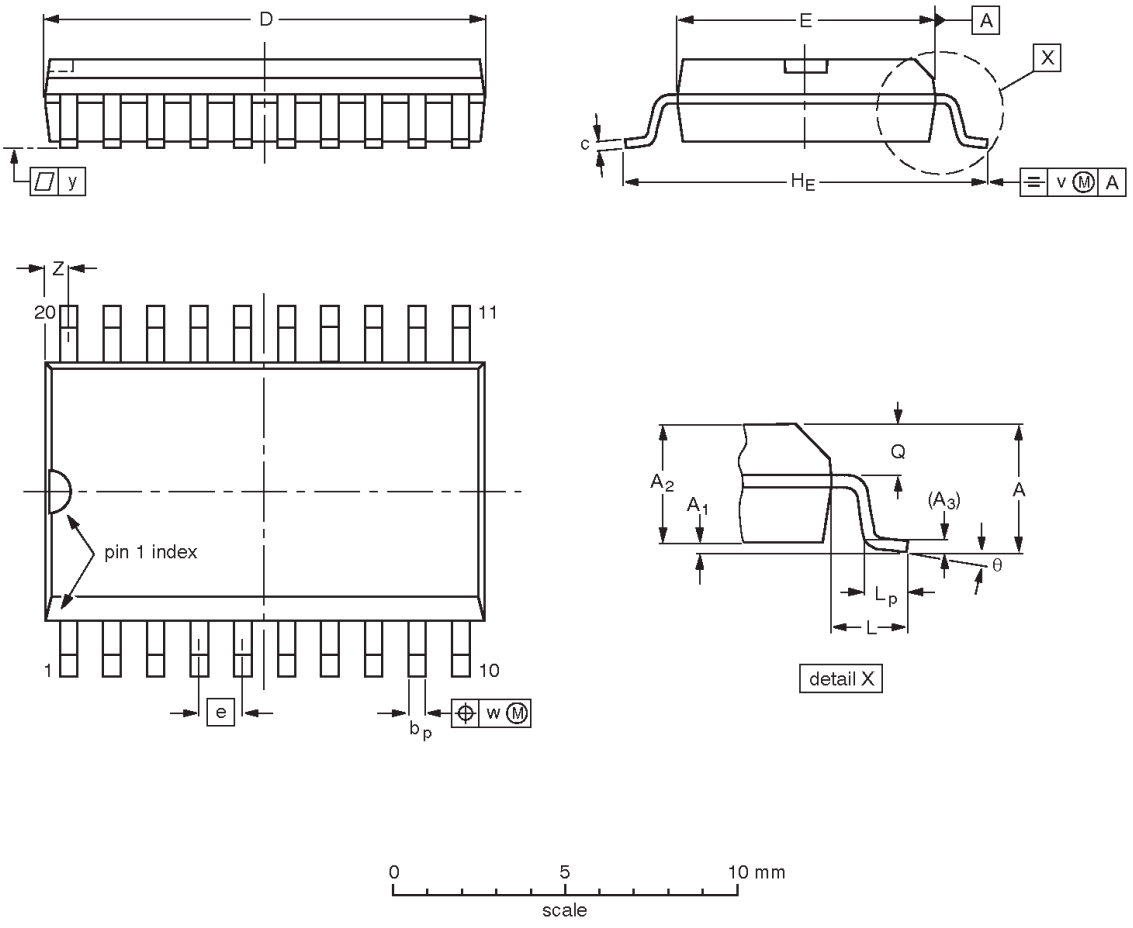
UNIT	A max.	A_1 min.	A_2 max.	b	b_1	c	D (1)	E (1)	e	e_1	L	M_E	M_H	w	Z (1) max.
mm	4.2	0.51	3.2	1.73 1.30	0.53 0.38	0.36 0.23	26.92 26.54	6.40 6.22	2.54	7.62	3.60 3.05	8.25 7.80	10.0 8.3	0.254	2.0
inches	0.17	0.020	0.13	0.068 0.051	0.021 0.015	0.014 0.009	1.060 1.045	0.25 0.24	0.10	0.30	0.14 0.12	0.32 0.31	0.39 0.33	0.01	0.078

Note

1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT146-1		MS-001	SC-603			~~95-05-24~~ 99-12-27

SO20: plastic small outline package; 20 leads; body width 7.5 mm **SOT163-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(1)}$	e	H_E	L	L_p	Q	v	w	y	$Z^{(1)}$	θ
mm	2.65	0.30 0.10	2.45 2.25	0.25	0.49 0.36	0.32 0.23	13.0 12.6	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.1 1.0	0.25	0.25	0.1	0.9 0.4	8^o 0^o
inches	0.10	0.012 0.004	0.096 0.089	0.01	0.019 0.014	0.013 0.009	0.51 0.49	0.30 0.29	0.050	0.419 0.394	0.055	0.043 0.016	0.043 0.039	0.01	0.01	0.004	0.035 0.016	

Note

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT163-1	075E04	MS-013				~~97-05-22~~ 99-12-27

REVISION HISTORY

Date	CPCN	Description
2002 Mar 12	9397 750 09558	– Added revision history – Updated Reset section
2001 Aug 06	9397 750 08661	Previous release