Wireless Voice Flash MCU

HT66FV240

Revision: V1.40 Date: December 15, 2016

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Features

CPU Features

- Operating Voltage
  - f_{SYS}= 4MHz: 2.2V~5.5V
  - f_{SYS}= 8MHz: 2.4V~5.5V
  - f_{SYS}=16MHz: 3.6V~5.5V
- Up to 0.25μs instruction cycle with 16MHz system clock at V_{DD}=5V
- Power down and wake-up functions to reduce power consumption
- Oscillator Type
  - External 16MHz Crystal – HXT
  - External 32.768kHz Crystal – LXT
  - Internal 32kHz RC – LIRC
- Multi-mode operation: NORMAL, SLOW, IDLE and SLEEP
- All instructions executed in one to three instruction cycles
- Table read instructions
- 115 powerful instructions
- 8-level subroutine nesting
- Bit manipulation instruction

Peripheral Features

- Program Memory: 4K×16
- Data Memory: 384×8
- True EEPROM Memory: 128×8
- Watchdog Timer function
- Up to 28 bidirectional I/O lines
- Software controlled 4-SCOM lines LCD driver with 1/2 bias
- Two external interrupt lines shared with I/O pins
- Multiple Timer Modules for time measure, input capture, compare match output, PWM output function or single pulse output function
- Serial Interfaces Module – SIM for SPI or I^2C
- Dual Time-Base functions for generation of fixed time interrupt signals
- Serial Peripheral Interface – SPIA
- 8-channel 12-bit resolution A/D converter
- In Application Programming function – IAP
- DMA function via SPIA interface for external data transfer
- G.711 standard compander
- Programmable sampling rate for audio recording / audio playback
- Pre-Amp(OPA) for Microphone input
- High performance 16-bit PCM A/D Converter
- Class AB power amplifier for speaker driving

- High performance 16-bit audio D/A converter
- Digital volume control for audio playback function
- Digital Programmable Gain Amplifier – PGA
- Low Voltage Reset function
- Low Voltage Detect function
- Flash program memory can be re-programmed up to 100,000 times
- Flash program memory data retention > 10 years
- True EEPROM data memory can be re-programmed up to 1,000,000 times
- True EEPROM data memory data retention > 10 years
- Package type: 48-pin LQFP

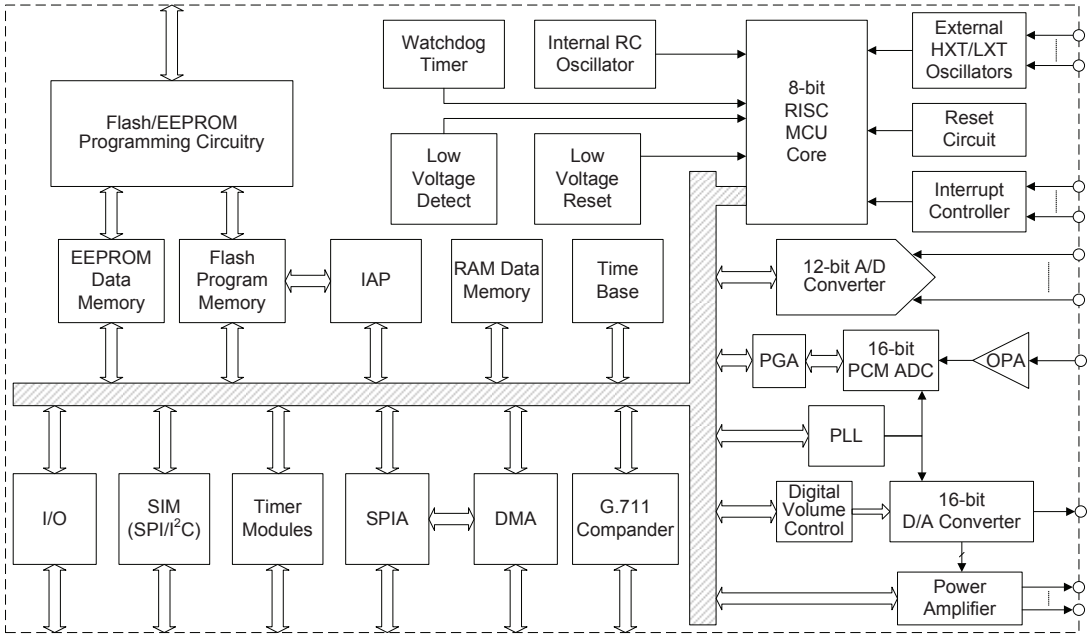
General Description

The device is a Flash Memory A/D type 8-bit high performance RISC architecture microcontroller which is designed for wireless voice product applications. It integrates a 16-bit PCM ADC, 16-bit DAC, Power Amplifier, G.711 Compander, DMA processing unit combined with an 8-bit microcontroller. The 16-bit PCM A/D Converter and D/A Converter in the device operate at a sampling rate of 8/12/16 KHz for the Microphone input/Speaker output. For the D/A Converter, the device has a digital programmable gain amplifier. The gain range is from -32dB to +6dB. For the PCM A/D Converter input, the digital gain range is from 0dB to 19.5dB.

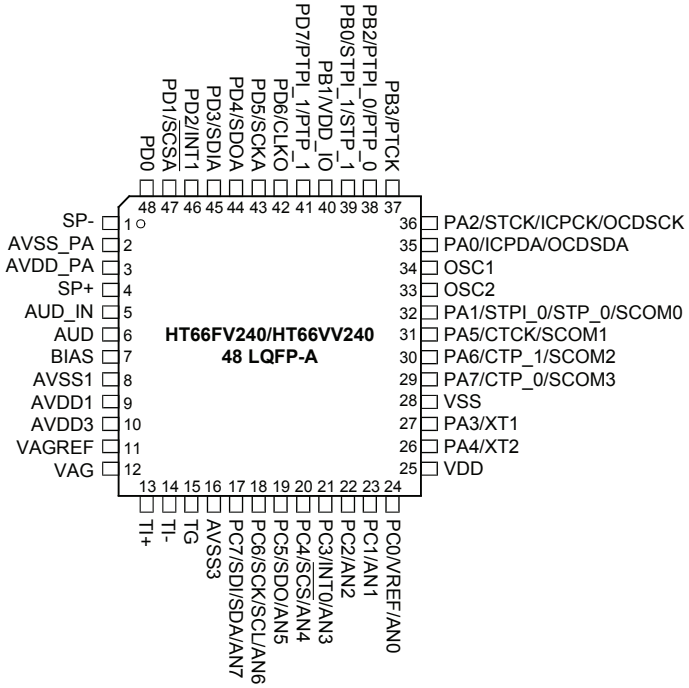
Multiple and extremely flexible Timer Modules provide timing, pulse generation and PWM generation functions. Communication with the outside world is catered for by including fully integrated SPI or I^2C interface functions, two popular interfaces which provide designers with a means of easy communication with external peripheral hardware. Protective features such as an internal Watchdog Timer, Low Voltage Reset and Low Voltage Detector coupled with excellent noise immunity and ESD protection ensure that reliable operation is maintained in hostile electrical environments.

A full choice of HXT, LXT and LIRC oscillator functions are provided including a fully integrated system oscillator. The ability to operate and switch dynamically between a range of operating modes using different clock sources gives users the ability to optimise microcontroller operation and minimise power consumption.

Block Diagram



Pin Assignment



Note: The OCDSDA and OCDSCK pins are the OCDS dedicated pins and only available for the HT66VV240 device which is the OCDS EV chip for the HT66FV240 device.

Pin Descriptions

With the exception of the power pins and some relevant transformer control pins, all pins on these devices can be referenced by their Port name, e.g. PA0, PA1 etc, which refer to the digital I/O function of the pins. However these Port pins are also shared with other function such as the Analog to Digital Converter, Timer Module pins etc. The function of each pin is listed in the following table, however the details behind how each pin is configured is contained in other sections of the datasheet.

Pad Name	Function	OPT	I/T	O/T	Description
PA0/ICPDA/ OCDSDA	PA0	PAWU PAPU	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	ICPDA	—	ST	CMOS	ICP Data/Address line
	OCDSDA	—	ST	CMOS	OCDS Data/Address line, for EV chip only.
PA1/STPI_0/ STP_0/SCOM0	PA1	PAWU PAPU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	STPI_0	PAS0 IFS	ST	—	STM capture input
	STP_0	PAS0	—	CMOS	STM output
	SCOM0	PAS0	—	SCOM	LCD common output
PA2 /STCK/ ICPCK/OCDSCK	PA2	PAWU PAPU	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	STCK	PAS0	ST	—	STM clock input
	ICPCK	—	ST	CMOS	ICP Clock pin
	OCDSCK	—	ST	—	OCDS Clock pin, for EV chip only.
PA3/XT1	PA3	PAWU PAPU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	XT1	PAS0	LXT	—	LXT oscillator pin
PA4/XT2	PA4	PAWU PAPU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	XT2	PAS1	—	LXT	LXT oscillator pin
PA5/CTCK/ SCOM1	PA5	PAWU PAPU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	CTCK	PAS1	ST	—	CTM clock input
	SCOM1	PAS1	—	SCOM	LCD common output
PA6/CTP_1/ SCOM2	PA6	PAWU PAPU PAS3	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	CTP_1	PAS1	—	CMOS	CTM output
	SCOM2	PAS1	—	SCOM	LCD common output
PA7/CTP_0/ SCOM3	PA7	PAWU PAPU PAS3	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up.
	CTP_0	PAS1	—	CMOS	CTM output
	SCOM3	PAS1	—	SCOM	LCD common output

Pad Name	Function	OPT	I/T	O/T	Description
PB0/STPI_1/ STP_1	PB0	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	STPI_1	PBS0 IFS	ST	—	STM capture input
	STP_1	PBS0	—	CMOS	STM output
PB1/VDD_IO	PB1	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	VDD_IO	PBS0	PWR	—	PD0~PD7 I/O power for level shift
PB2/PTPI_0/ PTP_0	PB2	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	PTPI_0	PBS0 IFS	ST	—	PTM capture input
	PTP_0	PBS0	—	CMOS	PTM output
PB3/PTCK	PB3	PBPU	ST	CMOS	General purpose I/O. Register enabled pull-up
	PTCK	—	ST	—	PTM clock/capture input
PC0/VREF/AN0	PC0	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	VREF	PCS0	AN	—	A/D Converter reference input
	AN0	PCS0	AN	—	A/D Converter analog input
PC1/AN1	PC1	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	AN1	PCS0	AN	—	A/D Converter analog input
PC2/AN2	PC2	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	AN2	PCS0	AN	—	A/D Converter analog input
PC3/INT0/AN3	PC3	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	INT0	PCS0 INTEG INTC0	ST	—	External Interrupt 0
	AN3	PCS0	AN	—	A/D Converter analog input
PC4/$\overline{SCS}$/AN4	PC4	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	$\overline{SCS}$	PCS1	ST	CMOS	SPI slave select
	AN4	PCS1	AN	—	A/D Converter analog input
PC5/SDO/AN5	PC5	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SDO	PCS1	—	CMOS	SPI data output
	AN5	PCS1	AN	—	A/D Converter analog input
PC6/SCK/SCL/ AN6	PC6	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SCK	PCS1	ST	CMOS	SPI serial clock
	SCL	PCS1	ST	NMOS	I^2C clock line
	AN6	PCS1	AN	—	A/D Converter analog input
PC7/SDI/SDA/ AN7	PC7	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SDI	PCS1	ST	—	SPI data input
	SDA	PCS1	ST	NMOS	I^2C data line
	AN7	PCS1	AN	—	A/D Converter analog input

Pad Name	Function	OPT	I/T	O/T	Description
PD0	PD0	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-up
PD1/$\overline{SCSA}$	PD1	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	$\overline{SCSA}$	PDS0	ST	CMOS	SPIA slave select
PD2/INT1	PD2	PDPU	ST	CMOS	General purpose I/O. Register enabled pull-up
	INT1	INTEG INTC0	ST	—	External Interrupt 1
PD3/SDIA	PD3	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SDIA	PDS0	ST	—	SPIA data input
PD4/SDOA	PD4	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SDOA	PDS1	—	CMOS	SPIA data output
PD5/SCKA	PD5	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SCKA	PDS1	ST	CMOS	SPIA serial clock
PD6/CLKO	PD6	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	CLKO	PDS1	—	CMOS	HXT oscillator output with buffer
PD7/PTPI_1/ PTP_1	PD7	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	PTPI_1	PDS1 IFS	ST	—	PTM capture input
	PTP_1	PDS1	—	CMOS	PTM output
OSC1	OSC1	—	HXT	—	HXT oscillator pin
OSC2	OSC2	—	—	HXT	HXT oscillator pin
VDD	VDD	—	PWR	—	Positive power supply
VSS	VSS	—	PWR	—	Negative power supply, ground.
SP+	SP+	—	—	AO	Power amplifier output
SP-	SP-	—	—	AO	Power amplifier output
AUD_IN	AUD_IN	—	AN	—	Power amplifier input
BIAS	BIAS	—	—	AO	Power amplifier voltage bias reference
AUD	AUD	—	—	AO	D/A converter output
AVDD1	AVDD1	—	PWR	—	Audio D/A converter positive power supply
AVDD_PA	AVDD_PA	—	PWR	—	Audio Power Amplifier positive power supply
AVSS1	AVSS1	—	PWR	—	Audio D/A converter negative power supply
AVSS_PA	AVSS_PA	—	PWR	—	Audio Power Amplifier negative power supply
AVDD3	AVDD3	—	PWR	—	Audio PCM A/D converter positive power supply
VAGREF	VAGREF	—	—	AO	PCM A/D converter analog ground reference voltage This pin should be left open or connected a bypass capacitor to ground.
VAG	VAG	—	—	AO	PCM A/D converter analog ground voltage This pin should be connected a bypass capacitor to ground.

Pad Name	Function	OPT	I/T	O/T	Description
TI+	TI+	—	AN	—	Operational Amplifier non-inverting input
TI-	TI-	—	AN	—	Operational Amplifier inverting input
TG	TG	—	—	AO	Operational Amplifier gain setting output
AVSS3	AVSS3	—	PWR	—	Audio PCM A/D converter negative power supply

Legend: I/T: Input type
O/T: Output type
OPT: Optional by configuration option (CO) or register option
PWR: Power
CO: Configuration option
ST: Schmitt Trigger input
AN: Analog input
AO: Analog output;
CMOS: CMOS output
NMOS: NMOS output
SCOM: Software controlled LCD COM
HXT: High frequency crystal oscillator
LXT: Low frequency crystal oscillator

Absolute Maximum Ratings

Supply Voltage ..... V_{SS}−0.3V to V_{SS}+6.0V
Input Voltage ..... V_{SS}−0.3V to V_{DD}+0.3V
Storage Temperature..... -50˚C to 125˚C
Operating Temperature..... -40˚C to 85˚C
I_{OL} Total 80mA
I_{OH} Total ..... -80mA
Total Power Dissipation 500mW

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to these devices. Functional operation of these devices at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect devices reliability.

D.C. Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	f_{SYS}=4MHz	2.2	—	5.5	V
			f_{SYS}=8MHz	2.4	—	5.5	V
			f_{SYS}=16MHz	3.6	—	5.5	V
V_{DD_IO}	I/O Port D Supply Voltage	—	—	2.2	—	V_{DD}	V
I_{DD}	Operating Current (HXT)	3V	f_{SYS}=f_H/2, No load, all peripherals off, WDT enable	—	1.2	2.0	mA
		5V		—	3.2	4.8	mA
		3V	f_{SYS}=f_H/4, No load, all peripherals off, WDT enable	—	0.9	1.3	mA
		5V		—	2.6	3.9	mA
		3V	f_{SYS}=f_H/8, No load, all peripherals off, WDT enable	—	0.8	1.2	mA
		5V		—	2.3	3.5	mA
		3V	f_{SYS}=f_H/16, No load, all peripherals off, WDT enable	—	0.7	1.05	mA
		5V		—	2.1	3.15	mA
		3V	f_{SYS}=f_H/32, No load, all peripherals off, WDT enable	—	0.69	1.04	mA
		5V		—	2.05	3.08	mA
		3V	f_{SYS}=f_H/64, No load, all peripherals off, WDT enable	—	0.67	1.01	mA
		5V		—	2.01	3.0	mA
	Operating Current (LXT)	3V	f_{SYS}=f_{SUB}=f_{LXT}, LXTSP=0 No load, all peripherals off, WDT enable	—	10	20	μA
		5V		—	30	50	μA
		3V	f_{SYS}=f_{SUB}=f_{LXT}, LXTSP=1 No load, all peripherals off, WDT enable	—	10	20	μA
		5V		—	40	60	μA
	Operating Current (LIRC)	3V	f_{SYS}=f_{SUB}=f_{LIRC} No load, all peripherals off, WDT enable	—	10	20	μA
		5V		—	30	50	μA
I_{STB}	Standby Current (IDLE0 Mode)	3V	LXT on, LXTSP=0 No load, all peripherals off, WDT enable	—	4	8	μA
		5V		—	6	12	μA
		3V	LXT on, LXTSP=1 No load, all peripherals off, WDT enable	—	5	10	μA
		5V		—	7	14	μA
	Standby Current (IDLE0 Mode)	3V	LIRC on No load, all peripherals off, WDT enable	—	1.3	3.0	μA
		5V		—	2.2	5.0	μA
	Standby Current (IDLE1 Mode)	3V	f_{SYS}=f_H/4=4MHz No load, all peripherals off, WDT enable	—	0.6	1.2	mA
		5V		—	1.6	3.2	mA
		3V	f_{SYS}=f_H/2=8MHz No load, all peripherals off, WDT enable	—	0.7	1.4	mA
		5V		—	1.8	3.6	mA
		5V	f_{SYS}=f_H=16MHz No load, all peripherals off, WDT enable	—	2.0	4.0	mA
	Standby Current (Sleep Mode)	3V	LIRC off No load, all peripherals off, WDT disable	—	0.1	1.0	μA
		5V		—	0.3	2.0	μA
	Standby Current (Sleep Mode)	3V	LIRC on No load, all peripherals off, WDT enable	—	1.3	5.0	μA
		5V		—	2.2	10	μA

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{IL}	Input Low Voltage for I/O Ports or Input Pins	5V	—	0	—	1.5	V
		—	—	0	—	$0.2V_{DD}$	V
	Input Low Voltage for I/O Port D (Supplied by VDD_IO)	5V	—	0	—	1.5	V
		—	—	0	—	$0.2V_{DD\_IO}$	V
V_{IH}	Input High Voltage for I/O Ports or Input Pins	5V	—	3.5	—	5.0	V
		—	—	$0.8V_{DD}$	—	V_{DD}	V
	Input High Voltage for I/O Port D (Supplied by VDD_IO)	5V	—	3.5	—	5.0	V
		—	—	$0.8V_{DD\_IO}$	—	V_{DD_IO}	V
I_{OL}	Sink Current for I/O Port (Except I/O Port D and CLKO pins)	3V	$V_{OL} = 0.1V_{DD}$	8	16	—	mA
		5V	$V_{OL} = 0.1V_{DD}$	16	32	—	mA
	Sink Current for I/O Port D	3V	$V_{OL} = 0.1V_{DD}$	2	4	—	mA
		5V	$V_{OL} = 0.1V_{DD}$	5	10	—	mA
	Sink Current for CLKO Pin	5V	$V_{OL} = 0.1V_{DD}$	10.5	14	—	mA
		3V	$V_{OL} = 0.1V_{DD}$	2	3	—	mA
I_{OH}	Source Current for I/O Port (Except I/O Port D and CLKO pins)	3V	$V_{OH} = 0.9V_{DD}$	-3.75	-7.5	—	mA
		5V	$V_{OH} = 0.9V_{DD}$	-7.5	-15	—	mA
	Source Current for I/O Port D	3V	$V_{OH} = 0.9V_{DD}$	-1	-2	—	mA
		5V	$V_{OH} = 0.9V_{DD}$	-2.5	-5	—	mA
	Source Current for CLKO Pin	5V	$V_{OH} = 0.9V_{DD}$	6	8	—	mA
		3V	$V_{OH} = 0.9V_{DD}$	3	4	—	mA
R_{PH}	Pull-high Resistance for I/O Ports	3V	—	20	60	100	kΩ
		5V	—	10	30	50	kΩ

A.C. Characteristics

Ta=25°C

Symbol	Parameter	Test Condition		Min.	Typ.	Max.	Unit
		V_{DD}	Condition				
f_{HXT}	High Speed Crystal Oscillator Clock (HXT)	2.2~5.5V	—	—	16	—	MHz
f_{LXT}	Low Speed Crystal Oscillator Clock (LXT)	—	—	—	32.768	—	kHz
f_{LIRC}	Low Speed RC Oscillator Clock (LIRC)	5V	Ta = 25°C	-10%	32	+10%	kHz
		2.2V~5.5V	Ta = -40°C to 85°C	-50%	32	+60%	kHz
t_{TCK}	xTCK pin Minimum Input Pulse Width	—	—	0.3	—	—	μs
t_{TPI}	STPI_n, PTPI_n pin Minimum Input Pulse Width	—	—	0.3	—	—	μs
t_{INT}	Interrupt Pin Minimum Input Pulse Width	—	—	10	—	—	μs
t_{SST}	System Start-up Timer Period (Wake-up from Power Down Mode, f_{SYS} off)	—	$f_{SYS} = f_H = f_{HXT}$	128	—	—	t_{SYS}
		—	$f_{SYS} = f_{SUB} = f_{LXT}$	1024	—	—	t_{SYS}
		—	$f_{SYS} = f_{SUB} = f_{LIRC}$	2	—	—	t_{SYS}
	System Start-up Timer period (SLOW Mode → NORMAL Mode) (NORMAL Mode → SLOW Mode)	—	$f_{SYS} = f_{SUB} \rightarrow f_{HXT}$ or $f_H = f_{HXT}$, f_{HXT} off → on	1024	—	—	t_{HXT}
		—	$f_{SYS} = f_H \rightarrow f_{LXT}$ or $f_{SUB} = f_{LIRC} \rightarrow f_{LXT}$, f_{LXT} off → on	1024	—	—	t_{LXT}
		—	$f_{SYS} = f_H \rightarrow f_{LIRC}$ or $f_{SUB} = f_{LXT} \rightarrow f_{LIRC}$, f_{LIRC} off → on	2	—	—	t_{LIRC}
	System Start-up Timer Period (Wake-up from Power Down Mode, f_{SYS} on)	—	—	2	—	—	t_{SYS}
	System Start-up Timer Period (WDT Hardware Reset)	—	—	0	—	—	t_{SYS}
t_{RSTD}	System Reset Delay Time (Power-on Reset, MCD Reset LVR Hardware/Software Reset, WDTC/RSTC Software Reset)	—	—	25	50	100	ms
	System Reset Delay Time (WDT Hardware Reset)	—	—	8.3	16.7	33.3	ms
t_{EERD}	EEPROM Read Time	—	—	—	2	4	t_{SYS}
t_{EEWR}	EEPROM Write Time	—	—	—	2	4	ms

Note: $t_{SYS} = 1/f_{SYS}$

A/D Converter Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
AV_{DD}	A/D Converter Operating Voltage	—	$AV_{DD}=V_{DD}$	2.7	—	5.5	V
V_{ADI}	A/D Converter Input Voltage	—	—	0	—	V_{DD}/V_{REF}	V
V_{REF}	A/D Converter Reference Voltage	—	—	2	—	V_{DD}+0.1V	V
DNL	Differential Non-linearity	3V	$V_{REF}=V_{DD}$, t_{ADCK} =0.5μs	—	—	±3	LSB
		5V					
INL	Integral Non-linearity	3V	$V_{REF}=V_{DD}$, t_{ADCK} =0.5μs	—	—	±4	LSB
		5V					
I_{ADC}	Additional Current Consumption for A/D Converter Enable	3V	No load, t_{ADCK} =0.5μs	—	1.0	2.0	mA
		5V		—	1.5	3.0	mA
t_{ADCK}	A/D Converter Clock Period	—	—	0.5	—	10	μs
t_{ADC}	A/D Conversion Time (A/D Sample and Hold Time)	—	—	—	16	—	t_{ADCK}
t_{ON2ST}	A/D Converter On-to-Start Time	—	—	4	—	—	μs

LVD/LVR Electrical Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{LVR}	Low Voltage Reset Voltage	—	LVR Enable, voltage select 2.1V	Typ. - 5%	2.1	Typ. + 5%	V
			LVR Enable, voltage select 2.55V		2.55		
			LVR Enable, voltage select 3.15V		3.15		
			LVR Enable, voltage select 3.8V		3.8		
V_{LVD}	Low Voltage Detector Voltage	—	LVD Enable, voltage select 2.0V	Typ. - 5%	2.0	Typ. + 5%	V
			LVD Enable, voltage select 2.2V		2.2		
			LVD Enable, voltage select 2.4V		2.4		
			LVD Enable, voltage select 2.7V		2.7		
			LVD Enable, voltage select 3.0V		3.0		
			LVD Enable, voltage select 3.3V		3.3		
			LVD Enable, voltage select 3.6V		3.6		
			LVD Enable, voltage select 4.0V		4.0		
V_{BG}	Bandgap Reference Voltage	—	—	Typ. - 5%	1.04	Typ. + 5%	V
I_{OP}	LVDLVR Operating Current	5V	LVD/LVR Enable, VBGEN=0	—	20	25	μA
			LVD/LVR Enable, VBGEN=1	—	180	200	μA
t_{BGS}	V_{BG} Turn on Stable Time	—	No load	—	—	150	μs
t_{LVDS}	LVDO stable time	—	For LVR enable, VBGEN=0, LVD off→on	—	—	15	μs
		—	For LVR disable, VBGEN=0, LVD off→on	—	—	150	μs
t_{LVR}	Minimum Low Voltage Width to Reset	—	—	120	240	480	μs
t_{LVD}	Minimum Low Voltage Width to Interrupt	—	—	60	120	240	μs

16-bit PCM A/D Converter Electrical Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		VDD	Conditions				
AV_{DD3}	16-bit PCM A/D Converter Operating Voltage	—	—	2.4	—	5.5	V
SNR	Signal to Noise Ratio	2.4V~5.5V	Note	—	70	—	dB
Fs	Sampling Rate	—	—	8	12	16	kHz
t_{ADC_RESB}	Minimum A/D Converter Reset Pulse Width	—	—	100	—	—	μs

D/A Converter Electrical Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		VDD	Conditions				
AV_{DD1}	16-bit Audio D/A Converter Operating Voltage	—	—	2.2	—	5.5	V
THD+N	THD+N(Note)	3V	10kΩ Load	—	-55	—	dB

Note: sine wave input @ 1kHz, -6dB.

Power Amplifier Electrical Characteristics

Ta=25°C

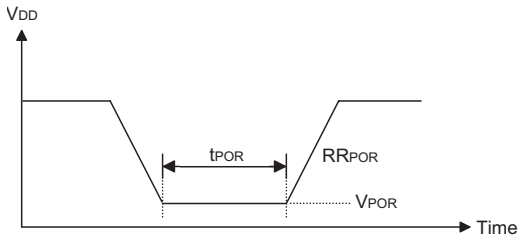
Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		VDD	Conditions				
AV_{DD_PA}	Audio Power Amplifier Operating Voltage	—	—	2.2	—	5.5	V
THD+N	THD+N(Note)	3V	8Ω Load	—	-51	—	dB
P_{OUT}	Output Power	3V	8Ω Load, THD=1%	—	410	—	mW
		5V	8Ω Load, THD=1%	—	1200	—	mW

Note: sine wave input @ 1kHz, -6dB.

Power-on Reset Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{POR}	V_{DD} Start Voltage to Ensure Power-on Reset	—	—	—	—	100	mV
RR_{POR}	V_{DD} Raising Rate to Ensure Power-on Reset	—	—	0.035	—	—	V/ms
t_{POR}	Minimum Time for V_{DD} Stays at V_{POR} to Ensure Power-on Reset	—	—	1	—	—	ms



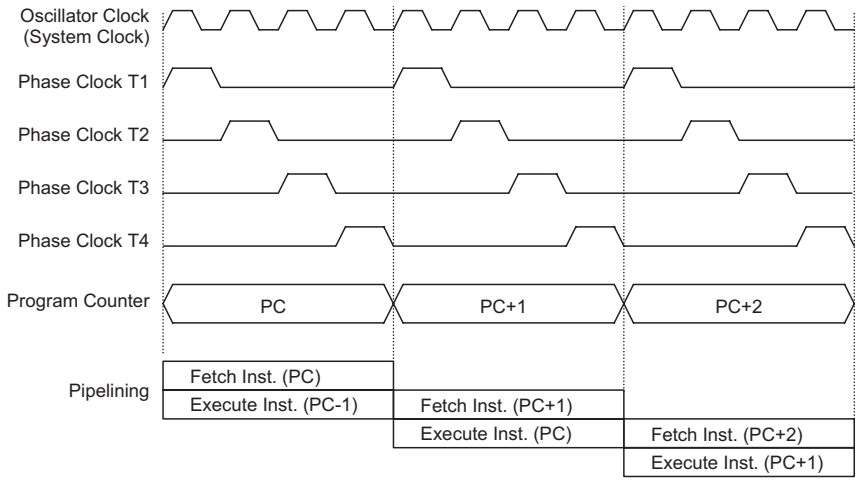
System Architecture

A key factor in the high-performance features of the Holtek range of microcontrollers is attributed to their internal system architecture. The range of devices take advantage of the usual features found within RISC microcontrollers providing increased speed of operation and enhanced performance. The pipelining scheme is implemented in such a way that instruction fetching and instruction execution are overlapped, hence instructions are effectively executed in one cycle, with the exception of branch or call instructions. An 8-bit wide ALU is used in practically all instruction set operations, which carries out arithmetic operations, logic operations, rotation, increment, decrement, branch decisions, etc. The internal data path is simplified by moving data through the Accumulator and the ALU. Certain internal registers are implemented in the Data Memory and can be directly or indirectly addressed. The simple addressing methods of these registers along with additional architectural features ensure that a minimum of external components is required to provide a functional I/O and A/D control system with maximum reliability and flexibility. This makes these devices suitable for low-cost, high-volume production for controller applications.

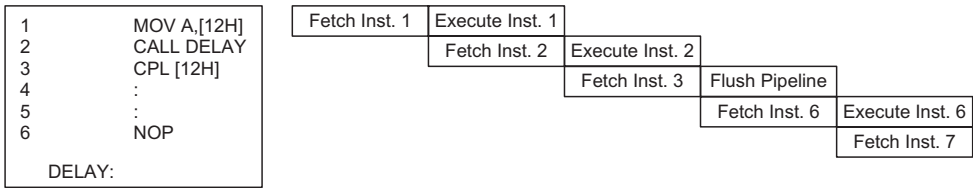
Clocking and Pipelining

The main system clock, derived from either a HXT, LXT, or LIRC oscillator is subdivided into four internally generated non-overlapping clocks, T1~T4. The Program Counter is incremented at the beginning of the T1 clock during which time a new instruction is fetched. The remaining T2~T4 clocks carry out the decoding and execution functions. In this way, one T1~T4 clock cycle forms one instruction cycle. Although the fetching and execution of instructions takes place in consecutive instruction cycles, the pipelining structure of the microcontroller ensures that instructions are effectively executed in one instruction cycle. The exception to this are instructions where the contents of the Program Counter are changed, such as subroutine calls or jumps, in which case the instruction will take one more instruction cycle to execute.

For instructions involving branches, such as jump or call instructions, two machine cycles are required to complete instruction execution. An extra cycle is required as the program takes one cycle to first obtain the actual jump or call address and then another cycle to actually execute the branch. The requirement for this extra cycle should be taken into account by programmers in timing sensitive applications.



System Clocking and Pipelining



Instruction Fetching

Program Counter

During program execution, the Program Counter is used to keep track of the address of the next instruction to be executed. It is automatically incremented by one each time an instruction is executed except for instructions, such as "JMP" or "CALL" that demand a jump to a non-consecutive Program Memory address. Only the lower 8 bits, known as the Program Counter Low Register, are directly addressable by the application program.

When executing instructions requiring jumps to non-consecutive addresses such as a jump instruction, a subroutine call, interrupt or reset, etc., the microcontroller manages program control by loading the required address into the Program Counter. For conditional skip instructions, once the condition has been met, the next instruction, which has already been fetched during the present instruction execution, is discarded and a dummy cycle takes its place while the correct instruction is obtained.

Program Counter	
High Byte	**Low Byte (PCL)**
PC11~PC8	PC7~PC0

Program Counter

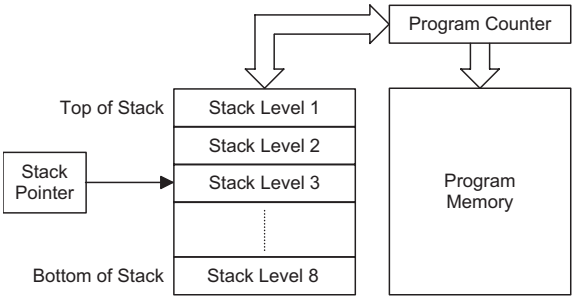
The lower byte of the Program Counter, known as the Program Counter Low register or PCL, is available for program control and is a readable and writeable register. By transferring data directly into this register, a short program jump can be executed directly; however, as only this low byte is available for manipulation, the jumps are limited to the present page of memory that is 256 locations. When such program jumps are executed it should also be noted that a dummy cycle will be inserted. Manipulating the PCL register may cause program branching, so an extra cycle is needed to pre-fetch.

Stack

This is a special part of the memory which is used to save the contents of the Program Counter only. The stack has multiple levels and is neither part of the data nor part of the program space, and is neither readable nor writeable. The activated level is indexed by the Stack Pointer, and is neither readable nor writeable. At a subroutine call or interrupt acknowledge signal, the contents of the Program Counter are pushed onto the stack. At the end of a subroutine or an interrupt routine, signaled by a return instruction, RET or RETI, the Program Counter is restored to its previous value from the stack. After a device reset, the Stack Pointer will point to the top of the stack.

If the stack is full and an enabled interrupt takes place, the interrupt request flag will be recorded but the acknowledge signal will be inhibited. When the Stack Pointer is decremented, by RET or RETI, the interrupt will be serviced. This feature prevents stack overflow allowing the programmer to use the structure more easily. However, when the stack is full, a CALL subroutine instruction can still be executed which will result in a stack overflow. Precautions should be taken to avoid such cases which might cause unpredictable program branching.

If the stack is overflow, the first Program Counter save in the stack will be lost.



Arithmetic and Logic Unit – ALU

The arithmetic-logic unit or ALU is a critical area of the microcontroller that carries out arithmetic and logic operations of the instruction set. Connected to the main microcontroller data bus, the ALU receives related instruction codes and performs the required arithmetic or logical operations after which the result will be placed in the specified register. As these ALU calculation or operations may result in carry, borrow or other status changes, the status register will be correspondingly updated to reflect these changes. The ALU supports the following functions:

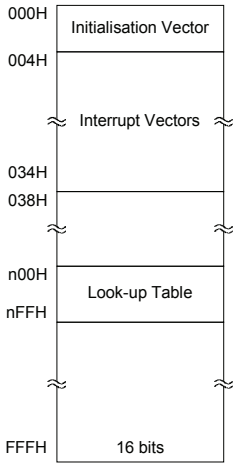
- Arithmetic operations:
  ADD, ADDM, ADC, ADCM, SUB, SUBM, SBC, SBCM, DAA
  LADD, LADDM, LADC, LADCM, LSUB, LSUBM, LSBC, LSBCM, LDAA
- Logic operations:
  AND, OR, XOR, ANDM, ORM, XORM, CPL, CPLA
  LAND, LOR, LXOR, LANDM, LORM, LXORM, LCPL, LCPLA
- Rotation:
  RRA, RR, RRCA, RRC, RLA, RL, RLCA, RLC
  LRRA, LRR, LRRCA, LRRC, LRLA, LRL, LRLCA, LRLC
- Increment and Decrement:
  INCA, INC, DECA, DEC
  LINCA, LINC, LDECA, LDEC
- Branch decision:
  JMP, SZ, SZA, SNZ, SIZ, SDZ, SIZA, SDZA, CALL, RET, RETI
  LSZ, LSZA, LSNZ, LSIZ, LSDZ, LSIZA, LSDZA

Flash Program Memory

The Program Memory is the location where the user code or program is stored. For these devices series the Program Memory are Flash type, which means it can be programmed and re-programmed a large number of times, allowing the user the convenience of code modification on the same device. By using the appropriate programming tools, these Flash devices offer users the flexibility to conveniently debug and develop their applications while also offering a means of field programming and updating.

Structure

The Program Memory has a capacity of 4K×16 bits. The Program Memory is addressed by the Program Counter and also contains data, table information and interrupt entries. Table data, which can be setup in any location within the Program Memory, is addressed by a separate table pointer registers.



Program Memory Structure

Special Vectors

Within the Program Memory, certain locations are reserved for the reset and interrupts. The location 000H is reserved for use by these devices reset for program initialisation. After a device reset is initiated, the program will jump to this location and begin execution.

Look-up Table

Any location within the Program Memory can be defined as a look-up table where programmers can store fixed data. To use the look-up table, the table pointer must first be setup by placing the address of the look up data to be retrieved in the table pointer register, TBLP and TBHP. These registers define the total address of the look-up table.

After setting up the table pointer, the table data can be retrieved from the Program Memory using the corresponding table read instruction such as “TABRD [m]” or “TABRDL [m]” respectively when the memory [m] is located in sector 0. If the memory [m] is located in other sectors, the data can be retrieved from the program memory using the corresponding extended table read instruction such as “LTABRD [m]” or “LTABRDL [m] ”respectively. When the instruction is executed, the lower order table byte from the Program Memory will be transferred to the user defined Data Memory register [m] as specified in the instruction. The higher order table data byte from the Program Memory will be transferred to the TBLH special register. Any unused bits in this transferred higher order byte will be read as "0".

The accompanying diagram illustrates the addressing data flow of the look-up table.

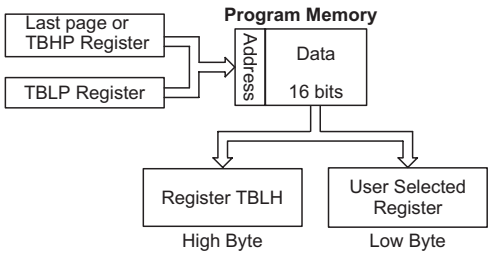


Table Program Example

The accompanying example shows how the table pointer and table data is defined and retrieved from the device. This example uses raw table data located in the last page which is stored there using the ORG statement. The value at this ORG statement is "0F00H" which refers to the start address of the last page within the 4K Program Memory of the device. The table pointer low byte register is setup here to have an initial value of "06H". This will ensure that the first data read from the data table will be at the Program Memory address "0F06H" or 6 locations after the start of the last page. Note that the value for the table pointer is referenced to the first address of the page that TBHP pointed if the "TABRD [m]" instruction is being used. The high byte of the table data which in this case is equal to zero will be transferred to the TBLH register automatically when the "TABRD [m] instruction is executed.

Because the TBLH register is a read/write register and can be restored, care should be taken to ensure its protection if both the main routine and Interrupt Service Routine use table read instructions. If using the table read instructions, the Interrupt Service Routines may change the value of the TBLH and subsequently cause errors if used again by the main routine. As a rule it is recommended that simultaneous use of the table read instructions should be avoided. However, in situations where simultaneous use cannot be avoided, the interrupts should be disabled prior to the execution of any main routine table-read instructions. Note that all table related instructions require two instruction cycles to complete their operation.

Table Read Program Example

```
tempreg1 db ?      ; temporary register #1
tempreg2 db ?      ; temporary register #2
 :
mov  a,06h         ; initialise low table pointer - note that this address is referenced
mov  tblp,a        ; to the last page or the page that tbhp pointed
mov  a,07h         ; initialise high table pointer
mov  tbhp,a
:
tabrd   tempreg1   ; transfers value in table referenced by table pointer data at program
                   ; memory address "0F06H" transferred to tempreg1 and TBLH
dec  tblp          ; reduce value of table pointer by one
tabrd   tempreg2   ; transfers value in table referenced by table pointer data at program
                   ; memory address "0F05H" transferred to tempreg2 and TBLH in this
                   ; example the data "1AH" is transferred to tempreg1 and data "0FH" to
                   ; register tempreg2
:
org  0F00h         ; sets initial address of program memory
dc   00Ah, 00Bh, 00Ch, 00Dh, 00Eh, 00Fh, 01Ah, 01Bh
:
```

In Circuit Programming – ICP

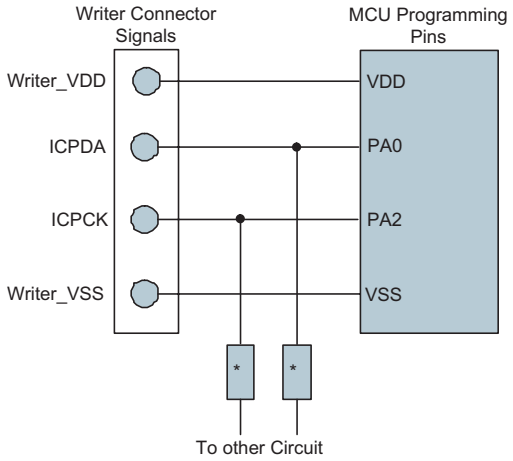
The provision of Flash type Program Memory provides the user with a means of convenient and easy upgrades and modifications to their programs on the same device.

As an additional convenience, Holtek has provided a means of programming the microcontroller in-circuit using a 4-pin interface. This provides manufacturers with the possibility of manufacturing their circuit boards complete with a programmed or un-programmed microcontroller, and then programming or upgrading the program at a later stage. This enables product manufacturers to easily keep their manufactured products supplied with the latest program releases without removal and re-insertion of the device.

Holtek Writer Pins	MCU Programming Pins	Pin Description
ICPDA	PA0	Programming Serial Data/Address
ICPCK	PA2	Programming Clock
VDD	VDD	Power Supply
VSS	VSS	Ground

The Program Memory and EEPROM data memory can be programmed serially in-circuit using this 4-wire interface. Data is downloaded and uploaded serially on a single pin with an additional line for the clock. Two additional lines are required for the power supply. The technical details regarding the in-circuit programming of the device are beyond the scope of this document and will be supplied in supplementary literature.

During the programming process, the user must take care of the ICPDA and ICPCK pins for data and clock programming purposes to ensure that no other outputs are connected to these two pins.



Note: * may be resistor or capacitor. The resistance of * must be greater than 1k or the capacitance of * must be less than 1nF.

On-Chip Debug Support – OCDS

There is an EV chip named HT66VV240 which is used to emulate the real MCU device named HT66FV240. The EV chip device also provides the "On-Chip Debug" function to debug the real MCU device during development process. The EV chip and real MCU devices, HT66VV240 and HT66FV240, are almost functional compatible except the "On-Chip Debug" function. Users can use the EV chip device to emulate the real MCU device behaviors by connecting the OCDSDA and OCDSCK pins to the Holtek HT-IDE development tools. The OCDSDA pin is the OCDS Data/Address input/output pin while the OCDSCK pin is the OCDS clock input pin. When users use the EV chip device for debugging, the corresponding pin functions shared with the OCDSDA and OCDSCK pins in the real MCU device will have no effect in the EV chip. However, the two OCDS pins which are pin-shared with the ICP programming pins are still used as the Flash Memory programming pins for ICP. For more detailed OCDS information, refer to the corresponding document named "Holtek e-Link for 8-bit MCU OCDS User's Guide".

Holtek e-Link Pins	EV Chip OCDS Pins	Pin Description
OCDSDA	OCDSDA	On-Chip Debug Support Data/Address input/output
OCDSCK	OCDSCK	On-Chip Debug Support Clock input
VDD	VDD	Power Supply
VSS	VSS	Ground

In Application Programming – IAP

This device offers IAP function to update data or application program to flash ROM. Users can define any ROM location for IAP, but there are some features which user must notice in using IAP function.

- Erase Block: 256 words/block
- Writing: 4 words/time
- Reading: 1 word/time

In Application Program Control Registers

The Address register, FARL and FARH, the Data registers, FD0L/FD0H, FD1L/FD1H, FD2L/FD2H and FD3L/FD3H, and the Control registers, FC0, FC1 and FC2, are the corresponding Flash access registers located in Data Memory sector 1 for IAP. If using the indirect addressing method to access the FC0, FC1 and FC2 registers, all read and write operations to the registers must be performed using the Indirect Addressing Register, IAR1 or IAR2, and the Memory Pointer pair, MP1L/MP1H or MP2L/MP2H. Because the FC0, FC1 and FC2 control registers are located at the address of 50H~52H in Data Memory sector 1, the desired value ranged from 50H to 52H must first be written into the MP1L or MP2L Memory Pointer low byte and the value "01H" must also be written into the MP1H or MP2H Memory Pointer high byte.

Register Name	Bit							
	7	6	5	4	3	2	1	0
FC0	CFWEN	FMOD2	FMOD1	FMOD0	FWPEN	FWT	FRDEN	FRD
FC1	D7	D6	D5	D4	D3	D2	D1	D0
FC2	—	—	—	—	—	—	—	CLWB
FARL	A7	A6	A5	A4	A3	A2	A1	A0
FARH	—	—	—	—	A11	A10	A9	A8
FD0L	D7	D6	D5	D4	D3	D2	D1	D0
FD0H	D15	D14	D13	D12	D11	D10	D9	D8
FD1L	D7	D6	D5	D4	D3	D2	D1	D0
FD1H	D15	D14	D13	D12	D11	D10	D9	D8
FD2L	D7	D6	D5	D4	D3	D2	D1	D0
FD2H	D15	D14	D13	D12	D11	D10	D9	D8
FD3L	D7	D6	D5	D4	D3	D2	D1	D0
FD3H	D15	D14	D13	D12	D11	D10	D9	D8

IAP Registers List

- **FC0 Register**

Bit	7	6	5	4	3	2	1	0
Name	CFWEN	FMOD2	FMOD1	FMOD0	FWPEN	FWT	FRDEN	FRD
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	1	1	0	0	0	0

Bit 7 **CFWEN**: Flash Memory Write enable control
0: Flash memory write function is disabled
1: Flash memory write function has been successfully enabled
When this bit is cleared to 0 by application program, the Flash memory write function is disabled. Note that writing a "1" into this bit results in no action. This bit is used to indicate that the Flash memory write function status. When this bit is set to 1 by hardware, it means that the Flash memory write function is enabled successfully. Otherwise, the Flash memory write function is disabled as the bit content is zero.

Bit 6~4 **FMOD2~FMOD0**: Mode selection
000: Write program memory
001: Block erase program memory
010: Reserved
011: Read program memory
10x: Reserved
110: FWEN mode – Flash memory Write function Enabled mode
111: Reserved

Bit 3 **FWPEN**: Flash memory Write Procedure Enable control
0: Disable
1: Enable
When this bit is set to 1 and the FMOD field is set to "110", the IAP controller will execute the "Flash memory write function enable" procedure. Once the Flash memory write function is successfully enabled, it is not necessary to set the FWPEN bit any more.

Bit 2 **FWT**: Flash memory Write Initiate control
0: Do not initiate Flash memory write or Flash memory write process is completed
1: Initiate Flash memory write process
This bit is set by software and cleared by hardware when the Flash memory write process is completed.

Bit 1 **FRDEN**: Flash memory Read Enable control
0: Flash memory read disable
1: Flash memory read enable

Bit 0 **FRD**: Flash memory Read Initiate control
0: Do not initiate Flash memory read or Flash memory read process is completed
1: Initiate Flash memory read process
This bit is set by software and cleared by hardware when the Flash memory read process is completed.

- **FC1 Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: Whole chip reset pattern
When user writes a specific value of "55H" to this register, it will generate a reset signal to reset whole chip.

- **FC2 Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	—	CLWB
R/W	—	—	—	—	—	—	—	R/W
POR	—	—	—	—	—	—	—	0

Bit 7~1 Unimplemented, read as 0.

Bit 0 **CLWB**: Flash memory Write Buffer Clear control
0: Do not initiate Write Buffer Clear process or Write Buffer Clear process is completed
1: Initiate Write Buffer Clear process
This bit is set by software and cleared by hardware when the Write Buffer Clear process is completed.

- **FARL Register**

Bit	7	6	5	4	3	2	1	0
Name	A7	A6	A5	A4	A3	A2	A1	A0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 Flash Memory Address bit 7 ~ bit 0

- **FARH Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	A11	A10	A9	A8
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as 0.

Bit 3~0 Flash Memory Address bit 11 ~ bit 0

- **FD0L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The first Flash Memory data bit 7 ~ bit 0

- **FD0H Register**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The first Flash Memory data bit 15 ~ bit 8

- **FD1L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The second Flash Memory data bit 7 ~ bit 0

- **FD1H Register**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The second Flash Memory data bit 15 ~ bit 8

- **FD2L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The third Flash Memory data bit 7 ~ bit 0

- **FD2H Register**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The third Flash Memory data bit 15 ~ bit 8

- **FD3L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The fourth Flash Memory data bit 7 ~ bit 0

- **FD3H Register**

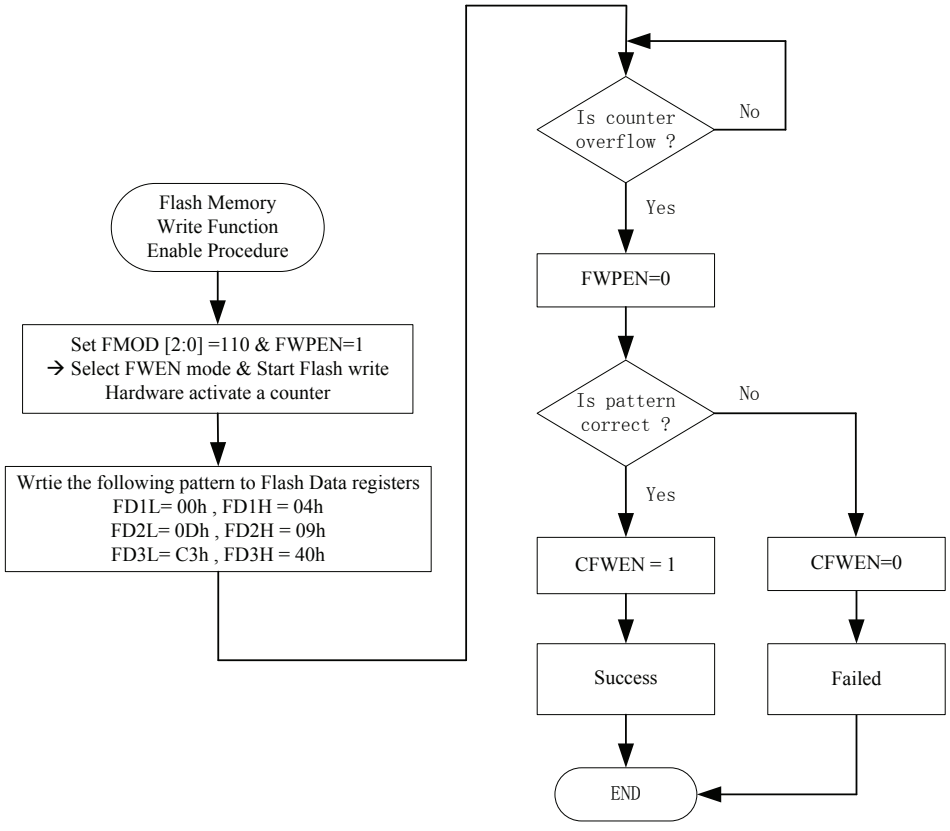
Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 The fourth Flash Memory data bit 15 ~ bit 8

Flash Memory Write Function Enable Procedure

In order to allow users to change the Flash memory data through the IAP control registers, users must first enable the Flash memory write operation by the following procedure:

- Write "110" into the FMOD2~FMOD0 bits to select the FWEN mode.
- Set the FWPEN bit to "1". The step 1 and step 2 can be executed simultaneously.
- The pattern data with a sequence of 00H, 04H, 0DH, 09H, C3H and 40H must be written into the FD1L, FD1H, FD2L, FD2H, FD3L and FD3H registers respectively.
- A counter with a time-out period of 300μs will be activated to allow users writing the correct pattern data into the FD1L/FD1H ~ FD3L/FD3H register pairs. The counter clock is derived from LIRC oscillator.
- If the counter overflows or the pattern data is incorrect, the Flash memory write operation will not be enabled and users must again repeat the above procedure. Then the FWPEN bit will automatically be cleared to 0 by hardware.
- If the pattern data is correct before the counter overflows, the Flash memory write operation will be enabled and the FWPEN bit will automatically be cleared to 0 by hardware. The CFWEN bit will also be set to 1 by hardware to indicate that the Flash memory write operation is successfully enabled.
- Once the Flash memory write operation is enabled, the user can change the Flash ROM data through the Flash control register.
- To disable the Flash memory write operation, the user can clear the CFWEN bit to 0.



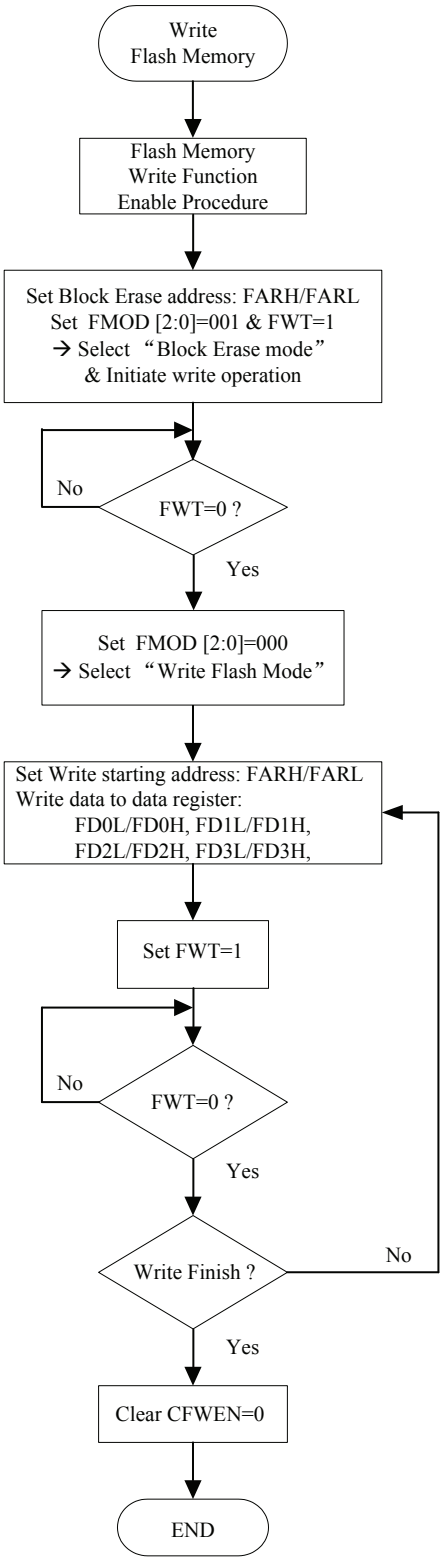
Flash Memory Write Function Enable Procedure

Flash Memory Write Procedure

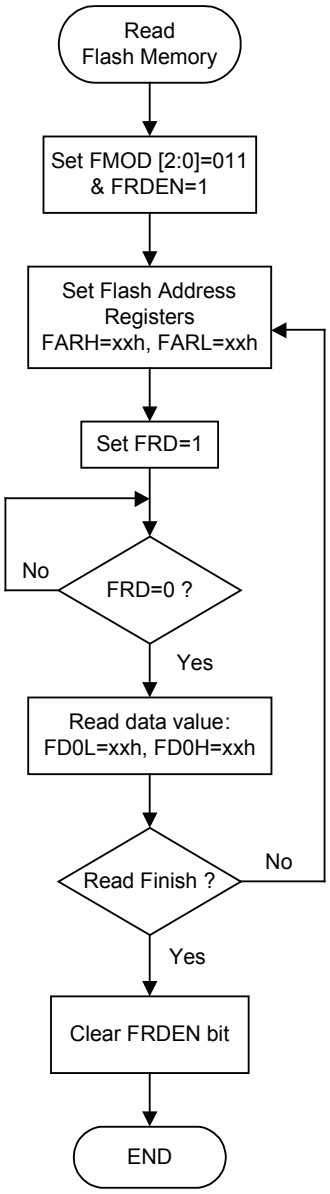
After the Flash memory write function is successfully enabled through the preceding IAP procedure, users must first erase the corresponding Flash memory block and then initiate the Flash memory write operation. Since the number of the block erase operation is 256 words per block, the available block erase address is only specified by FARH register and the content in the FARL register is not used to specify the block address.

Erase Block	FARH [3:0]	FARL [7:0]
0	0000	xxxx xxxx
1	0001	xxxx xxxx
2	0010	xxxx xxxx
3	0011	xxxx xxxx
4	0100	xxxx xxxx
5	0101	xxxx xxxx
6	0110	xxxx xxxx
7	0111	xxxx xxxx
8	1000	xxxx xxxx
9	1001	xxxx xxxx
10	1010	xxxx xxxx
11	1011	xxxx xxxx
12	1100	xxxx xxxx
13	1101	xxxx xxxx
14	1110	xxxx xxxx
15	1111	xxxx xxxx

"x": don't care



Write Flash Memory Procedure



Read Flash Memory Procedure

Note: When the FWT or FRD bit is set to 1, the MCU is stopped.

Data Memory

The Data Memory is an 8-bit wide RAM internal memory and is the location where temporary information is stored.

Divided into two types, the first of Data Memory is an area of RAM where special function registers are located. These registers have fixed locations and are necessary for correct operation of the device. Many of these registers can be read from and written to directly under program control, however, some remain protected from user manipulation. The second area of Data Memory is reserved for general purpose use. All locations within this area are read and write accessible under program control.

Switching between the different Data Memory sectors is achieved by properly setting the Memory Pointers to correct value.

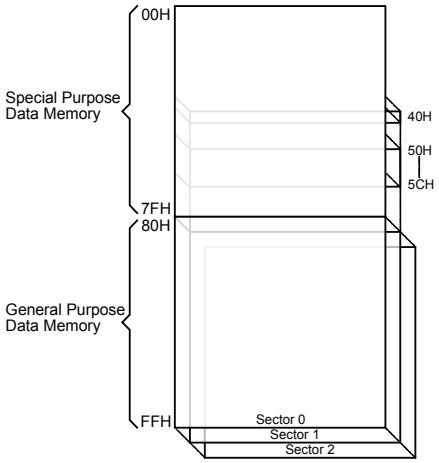
Structure

The Data Memory is subdivided into several sectors, all of which are implemented in 8-bit wide Memory. Each of the Data Memory sectors is categorized into two types, the Special Purpose Data Memory and the General Purpose Data Memory.

The address range of the Special Purpose Data Memory for the device is from 00H to 7FH while the address range of the General Purpose Data Memory is from 80H to FFH.

Type		Sector 0	Sector 1	Sector 2
Special Purpose Data Memory	Start Address	00H	00H	—
	End Address	7FH	7FH	—
	Capacity-bytes	128	128	—
General Purpose Data Memory	Start Address	80H	80H	80H
	End Address	FFH	FFH	FFH
	Capacity-bytes	128	128	128

Data Memory Summary



Data Memory Structure

General Purpose Data Memory

All microcontroller programs require an area of read/write memory where temporary data can be stored and retrieved for use later. It is this area of RAM memory that is known as General Purpose Data Memory. This area of Data Memory is fully accessible by the user programing for both reading and writing operations. By using the bit operation instructions individual bits can be set or reset under program control giving the user a large range of flexibility for bit manipulation in the Data Memory.

Special Purpose Data Memory

This area of Data Memory is where registers, necessary for the correct operation of the microcontroller, are stored. Most of the registers are both readable and writeable but some are protected and are readable only, the details of which are located under the relevant Special Function Register section. Note that for locations that are unused, any read instruction to these addresses will return the value "00H".

	Bank 0	Bank 1 ~ Bank 2
00H	IAR0	
01H	MP0	
02H	IAR1	
03H	MP1L	
04H	MP1H	
05H	ACC	
06H	PCL	
07H	TBLP	
08H	TBLH	
09H	TBHP	
0AH	STATUS	
0BH		
0CH	IAR2	
0DH	MP2L	
0EH	MP2H	
0FH		
10H	INTC0	
11H		
12H	PA	
13H	PAC	
14H	PAPU	
15H	PAWU	
16H		
17H	RSTFC	
18H		
19H		
1AH	PB	
1BH	PBC	
1CH	PBPU	
1DH	PSCR	
1EH	TB0C	
1FH	TB1C	
20H	SCC	
21H		
22H	HXTC	
23H	LXTC	
24H		
25H	RSTC	
26H	CTRL	
27H	CTMC0	
28H	CTMC1	
29H	CTMDL	
2AH	CTMDH	
2BH	CTMAL	
2CH	CTMAH	
2DH	CTMRP	
2EH	LVDC	
2FH	LVRC	
30H	STMC0	
31H	STMC1	
32H	STMDL	
33H	STMDH	
34H	STMAL	
35H	STMAH	
36H	STMRP	
37H	INTEG	
38H	INTC1	
39H	INTC2	
3AH	INTC3	
3BH	MFI0	
3CH	MFI1	
3DH	MFI2	
3EH	MFI3	
3FH	SCOMC	

	Bank 0	Bank 1	Bank 2
40H		EEC	
41H	EEA		
42H	EED		
43H	PTMC0		
44H	PTMC1		
45H	PTMDL		
46H	PTMDH		
47H	PTMAL		
48H	PTMAH		
49H	PTMRPL		
4AH	PTMRPH		
4BH			
4CH			
4DH	WDTC		
4EH	PCPU		
4FH	PC		
50H	PCC	FC0	
51H	PDPU	FC1	
52H	PD	FC2	
53H	PDC	FARL	
54H	ADRL	FARH	
55H	ADRH	FD0L	
56H	ADCR0	FD0H	
57H	ADCR1	FD1L	
58H	PAS0	FD1H	
59H	PAS1	FD2L	
5AH	PBS0	FD2H	
5BH	PCS0	FD3L	
5CH	PCS1	FD3H	
5DH	PDS0		
5EH	PDS1		
5FH	IFS		
60H	SIMTOC		
61H	SIMC0		
62H	SIMC1		
63H	SIMD		
64H	SIMA/SIMC2		
65H	SPIAC0		
66H	SPIAC1		
67H	SPIAD		
68H	SPIADMAC		
69H	SPIA_DMA_LEN		
6AH	SPIA_DMA_ADDR		
6BH	SPIA_DMA_RW_P		
6CH			
6DH			
6EH			
6FH	USVC		
70H	PGAC		
71H	RECPLAC		
72H	COMPANDC		
73H	RECDL		
74H	RECDH		
75H	PLADL		
76H	PLADH		
77H			
≈	≈	≈	≈
7FH			

: Unused, read as 00H

Special Purpose Data Memory Structure

Special Function Register Description

Most of the Special Function Register details will be described in the relevant functional section. However, several registers require a separate description in this section.

Indirect Addressing Registers – IAR0, IAR1, IAR2

The Indirect Addressing Registers, IAR0, IAR1 and IAR2, although having their locations in normal RAM register space, do not actually physically exist as normal registers. The method of indirect addressing for RAM data manipulation uses these Indirect Addressing Registers and Memory Pointers, in contrast to direct memory addressing, where the actual memory address is specified. Actions on the IAR0, IAR1 and IAR2 registers will result in no actual read or write operation to these registers but rather to the memory location specified by their corresponding Memory Pointers, MP0, MP1L/MP1H or MP2L/MP2H. Acting as a pair, IAR0 and MP0 can together access data only from Sector 0 while the IAR1 register together with MP1L/MP1H register pair and IAR2 register together with MP2L/MP2H register pair can access data from any Data Memory sector. As the Indirect Addressing Registers are not physically implemented, reading the Indirect Addressing Registers indirectly will return a result of "00H" and writing to the registers indirectly will result in no operation.

Memory Pointers – MP0, MP1H/MP1L, MP2H/MP2L

Five Memory Pointers, known as MP0, MP1L, MP1H, MP2L and MP2H, are provided. These Memory Pointers are physically implemented in the Data Memory and can be manipulated in the same way as normal registers providing a convenient way with which to address and track data. When any operation to the relevant Indirect Addressing Registers is carried out, the actual address that the microcontroller is directed to is the address specified by the related Memory Pointer. MP0, together with Indirect Addressing Register, IAR0, are used to access data from Sector 0, while MP1L/MP1H together with IAR1 and MP2L/MP2H together with IAR2 are used to access data from all data sectors according to the corresponding MP1H or MP2H register. Direct Addressing can be used in all data sectors using the corresponding instruction which can address all available data memory space.

Indirect Addressing Program Example

```
data .section data
adres1 db ?
adres2 db ?
adres3 db ?
adres4 db ?
block  db ?
code .section at 0 code
org 00h
start:
mov a,04h             ; setup size of block
mov block,a
mov a,offset adres1   ; Accumulator loaded with first RAM address
mov mp0,a             ; setup memory pointer with first RAM address
loop:
clr IAR0              ; clear the data at address defined by MP0
inc mp0               ; increment memory pointer
sdz block             ; check if last memory location has been cleared
jmp loop
continue:
     :
```

The important point to note here is that in the example shown above, no reference is made to specific RAM addresses.

Accumulator – ACC

The Accumulator is central to the operation of any microcontroller and is closely related with operations carried out by the ALU. The Accumulator is the place where all intermediate results from the ALU are stored. Without the Accumulator it would be necessary to write the result of each calculation or logical operation such as addition, subtraction, shift, etc., to the Data Memory resulting in higher programming and timing overheads. Data transfer operations usually involve the temporary storage function of the Accumulator; for example, when transferring data between one user defined register and another, it is necessary to do this by passing the data through the Accumulator as no direct transfer between two registers is permitted.

Program Counter Low Register – PCL

To provide additional program control functions, the low byte of the Program Counter is made accessible to programmers by locating it within the Special Purpose area of the Data Memory. By manipulating this register, direct jumps to other program locations are easily implemented. Loading a value directly into this PCL register will cause a jump to the specified Program Memory location, however, as the register is only 8-bit wide, only jumps within the current Program Memory page are permitted. When such operations are used, note that a dummy cycle will be inserted.

Look-up Table Registers – TBLP, TBHP, TBLH

These three special function registers are used to control operation of the look-up table which is stored in the Program Memory. TBLP and TBHP are the table pointer and indicates the location where the table data is located. Their value must be setup before any table read commands are executed. Their value can be changed, for example using the "INC" or "DEC" instructions, allowing for easy table data pointing and reading. TBLH is the location where the high order byte of the table data is stored after a table read data instruction has been executed. Note that the lower order table data byte is transferred to a user defined location.

Status Register – STATUS

This 8-bit register contains the zero flag (Z), carry flag (C), auxiliary carry flag (AC), overflow flag (OV), SC flag, CZ flag, power down flag (PDF), and watchdog time-out flag (TO). These arithmetic/logical operation and system management flags are used to record the status and operation of the microcontroller.

With the exception of the TO and PDF flags, bits in the status register can be altered by instructions like most other registers. Any data written into the status register will not change the TO or PDF flag. In addition, operations related to the status register may give different results due to the different instruction operations. The TO flag can be affected only by a system power-up, a WDT time-out or by executing the "CLR WDT" or "HALT" instruction. The PDF flag is affected only by executing the "HALT" or "CLR WDT" instruction or during a system power-up.

The Z, OV, AC, C, SC and CZ flags generally reflect the status of the latest operations.

- C is set if an operation results in a carry during an addition operation or if a borrow does not take place during a subtraction operation; otherwise C is cleared. C is also affected by a rotate through carry instruction.
- AC is set if an operation results in a carry out of the low nibbles in addition, or no borrow from the high nibble into the low nibble in subtraction; otherwise AC is cleared.
- Z is set if the result of an arithmetic or logical operation is zero; otherwise Z is cleared.
- OV is set if an operation results in a carry into the highest-order bit but not a carry out of the highest-order bit, or vice versa; otherwise OV is cleared.
- PDF is cleared by a system power-up or executing the "CLR WDT" instruction. PDF is set by executing the "HALT" instruction.
- TO is cleared by a system power-up or executing the "CLR WDT" or "HALT" instruction. TO is set by a WDT time-out.
- SC is the result of the "XOR" operation which is performed by the OV flag and the MSB of the current instruction operation result.
- CZ is the operational result of different flags for different instuctions. Refer to register definitions for more details.

In addition, on entering an interrupt sequence or executing a subroutine call, the status register will not be pushed onto the stack automatically. If the contents of the status registers are important and if the subroutine can corrupt the status register, precautions must be taken to correctly save it.

STATUS Register

Bit	7	6	5	4	3	2	1	0
Name	SC	CZ	TO	PDF	OV	Z	AC	C
R/W	R	R	R	R	R/W	R/W	R/W	R/W
POR	x	x	0	0	x	x	x	x

"x": unknown

Bit 7 **SC**: The result of the "XOR" operation which is performed by the OV flag and the MSB of the instruction operation result.

Bit 6 **CZ**: The the operational result of different flags for different instuctions.

For SUB/SUBM/LSUB/LSUBM instructions, the CZ flag is equal to the Z flag.

For SBC/ SBCM/ LSBC/ LSBCM instructions, the CZ flag is the "AND" operation result which is performed by the previous operation CZ flag and current operation zero flag. For other instructions, the CZ flag willl not be affected.

Bit 5 **TO**: Watchdog Time-out flag
0: After power up ow executing the "CLR WDT" or "HALT" instruction
1: A watchdog time-out occurred

Bit 4 **PDF**: Power down flag
0: After power up ow executing the "CLR WDT" instruction
1: By executing the "HALT" instructin

Bit 3 **OV**: Overflow flag
0: No overflow
1: An operation results in a carry into the highest-order bit but not a carry out of the highest-order bit or vice versa

Bit 2 **Z**: Zero flag
0: The result of an arithmetic or logical operation is not zero
1: The result of an arithmetic or logical operation is zero

Bit 1 **AC**: Auxiliary flag
0: No auxiliary carry
1: An operation results in a carry out of the low nibbles, in addition, or no borrow from the high nibble into the low nibble in substraction

Bit 0 **C**: Carry flag
0: No carry-out
1: An operation results in a carry during an addition operation or if a borrow does not take place during a subtraction operation

The "C" flag is also affected by a rotate through carry instruction.

EEPROM Data Memory

The device contains an area of internal EEPROM Data Memory. EEPROM, which stands for Electrically Erasable Programmable Read Only Memory, is by its nature a non-volatile form of re-programmable memory, with data retention even when its power supply is removed. By incorporating this kind of data memory, a whole new host of application possibilities are made available to the designer. The availability of EEPROM storage allows information such as product identification numbers, calibration values, specific user data, system setup data or other product information to be stored directly within the product microcontroller. The process of reading and writing data to the EEPROM memory has been reduced to a very trivial affair.

EEPROM Data Memory Structure

The EEPROM Data Memory capacity is 128×8 bits. Unlike the Program Memory and RAM Data Memory, the EEPROM Data Memory is not directly mapped into memory space and is therefore not directly addressable in the same way as the other types of memory. Read and Write operations to the EEPROM are carried out in single byte operations using an address and data register in sector 0 and a single control register in sector 1.

EEPROM Registers

Three registers control the overall operation of the internal EEPROM Data Memory. These are the address register, EEA, the data register, EED and a single control register, EEC. As both the EEA and EED registers are located in sector 0, they can be directly accessed in the same was as any other Special Function Register. The EEC register, however, being located in sector 1, can be read from or written to indirectly using the MP1H/MP1L or MP2H/MP2L Memory Pointer pair and Indirect Addressing Register, IAR1 or IAR2. Because the EEC control register is located at address 40H in sector 1, the Memory Pointer low byte register, MP1L or MP2L, must first be set to the value 40H and the Memory Pointer high byte register, MP1H or MP2H, set to the value, 01H, before any operations on the EEC register are executed.

Register Name	Bit							
	7	6	5	4	3	2	1	0
EEA	—	EEA6	EEA5	EEA4	EEA3	EEA2	EEA1	EEA0
EED	D7	D6	D5	D4	D3	D2	D1	D0
EEC	—	—	—	—	WREN	WR	RDEN	RD

EEPROM Registers List

EEA Register

Bit	7	6	5	4	3	2	1	0
Name	—	EEA6	EEA5	EEA4	EEA3	EEA2	EEA1	EEA0
R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	0	0	0	0	0	0	0

Bit 7 Unimplemented, read as 0.

Bit 6~0 **EEA6~EEA0**: Data EEPROM address bit 6~bit0

EED Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: Data EEPROM data bit 7~bit0

EEC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	WREN	WR	RDEN	RD
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as 0.

Bit 3 **WREN**: Data EEPROM write enable
0: Disable
1: Enable
This is the Data EEPROM Write Enable Bit which must be set high before Data EEPROM write operations are carried out. Clearing this bit to zero will inhibit Data EEPROM write operations.

Bit 2 **WR**: EEPROM write control
0: Write cycle has finished
1: Activate a write cycle
This is the Data EEPROM Write Control Bit and when set high by the application program will activate a write cycle. This bit will be automatically reset to zero by the hardware after the write cycle has finished. Setting this bit high will have no effect if the WREN has not first been set high.

Bit 1 **RDEN**: Data EEPROM read enable
0: Disable
1: Enable
This is the Data EEPROM Read Enable Bit which must be set high before Data EEPROM read operations are carried out. Clearing this bit to zero will inhibit Data EEPROM read operations.

Bit 0 **RD**: EEPROM read control
0: Read cycle has finished
1: Activate a read cycle
This is the Data EEPROM Read Control Bit and when set high by the application program will activate a read cycle. This bit will be automatically reset to zero by the hardware after the read cycle has finished. Setting this bit high will have no effect if the RDEN has not first been set high.

Note: The WREN, WR, RDEN and RD can not be set to "1" at the same time in one instruction. The WR and RD can not be set to "1" at the same time.

Reading Data from the EEPROM

To read data from the EEPROM, the read enable bit, RDEN, in the EEC register must first be set high to enable the read function. The EEPROM address of the data to be read must then be placed in the EEA register. If the RD bit in the EEC register is now set high, a read cycle will be initiated. Setting the RD bit high will not initiate a read operation if the RDEN bit has not been set. When the read cycle terminates, the RD bit will be automatically cleared to zero, after which the data can be read from the EED register. The data will remain in the EED register until another read or write operation is executed. The application program can poll the RD bit to determine when the data is valid for reading.

Writing Data to the EEPROM

To write data to the EEPROM, the EEPROM address of the data to be written must first be placed in the EEA register and the data placed in the EED register. Then the write enable bit, WREN, in the EEC register must first be set high to enable the write function. After this, the WR bit in the EEC register must be immediately set high to initiate a write cycle. These two instructions must be executed consecutively. The global interrupt bit EMI should also first be cleared before implementing any write operations, and then set again after the write cycle has started. Note that setting the WR bit high will not initiate a write cycle if the WREN bit has not been set. As the EEPROM write cycle is controlled using an internal timer whose operation is asynchronous to microcontroller system clock, a certain time will elapse before the data will have been written into the EEPROM. Detecting when the write cycle has finished can be implemented either by polling the WR bit in the EEC register or by using the EEPROM interrupt. When the write cycle terminates, the WR bit will be automatically cleared to zero by the microcontroller, informing the user that the data has been written to the EEPROM. The application program can therefore poll the WR bit to determine when the write cycle has ended.

Write Protection

Protection against inadvertent write operation is provided in several ways. After the device is powered on, the Write Enable bit in the control register will be cleared preventing any write operations. Also at power-on the Memory Pointer high byte register, MP1H, will be reset to zero, which means that Data Memory sector 0 will be selected. As the EEPROM control register is located in sector 1, this adds a further measure of protection against spurious write operations. During normal program operation, ensuring that the Write Enable bit in the control register is cleared will safeguard against incorrect write operations.

EEPROM Interrupt

The EEPROM write interrupt is generated when an EEPROM write cycle has ended. The EEPROM interrupt must first be enabled by setting the DEE bit in the relevant interrupt register. However, as the EEPROM is contained within a Multi-function Interrupt, the associated multi-function interrupt enable bit must also be set. When an EEPROM write cycle ends, the DEF request flag and its associated multi-function interrupt request flag will both be set. If the global, EEPROM and Multi-function interrupts are enabled and the stack is not full, a jump to the associated Multi-function Interrupt vector will take place. When the interrupt is serviced only the Multi-function interrupt flag will be automatically reset, the EEPROM interrupt flag must be manually reset by the application program.

Programming Considerations

Care must be taken that data is not inadvertently written to the EEPROM. Protection can be Periodic by ensuring that the Write Enable bit is normally cleared to zero when not writing. Also the Memory Pointer high byte register could be normally cleared to zero as this would inhibit access to sector 1 where the EEPROM control register exist. Although certainly not necessary, consideration might be given in the application program to the checking of the validity of new write data by a simple read back process. When writing data the WR bit must be set high immediately after the WREN bit has been set high, to ensure the write cycle executes correctly. The global interrupt bit EMI should also be cleared before a write cycle is executed and then re-enabled after the write cycle starts. Note that the device should not enter the IDLE or SLEEP mode until the EEPROM read or write operation is totally complete. Otherwise, the EEPROM read or write operation will fail.

Programming Example

- **Reading data from the EEPROM − polling method**

```
MOV  A, EEPROM_ADRES      ; user defined address
MOV  EEA, A
MOV  A, 040H              ; setup memory pointer low byte MP1L
MOV  MP1L, A              ; MP1L points to EEC register
MOV  A, 01H               ; setup Memory Pointer high byte MP1H
MOV  MP1H, A
SET  IAR1.1               ; set RDEN bit, enable read operations
SET  IAR1.0               ; start Read Cycle - set RD bit
BACK:
SZ   IAR1.0               ; check for read cycle end
JMP  BACK
CLR  IAR1                 ; disable EEPROM write
CLR  MP1H
MOV  A, EED               ; move read data to register
MOV  READ_DATA, A
```

- **Writing Data to the EEPROM − polling method**

```
MOV  A, EEPROM_ADRES      ; user defined address
MOV  EEA, A
MOV  A, EEPROM_DATA       ; user defined data
MOV  EED, A
MOV  A, 040H              ; setup memory pointer low byte MP1L
MOV  MP1L, A              ; MP1L points to EEC register
MOV  A, 01H               ; setup Memory Pointer high byte MP1H
MOV  MP1H, A
CLR  EMI
SET  IAR1.3               ; set WREN bit, enable write operations
SET  IAR1.2               ; start Write Cycle - set WR bit
SET  EMI
BACK:
SZ   IAR1.2               ; check for write cycle end
JMP  BACK
CLR  IAR1                 ; disable EEPROM write
CLR  MP1H
```

Oscillator

Various oscillator types offer the user a wide range of functions according to their various application requirements. The flexible features of the oscillator functions ensure that the best optimisation can be achieved in terms of speed and power saving. Oscillator selections and operation are selected through a combination of application program and relevant control registers.

Oscillator Overview

In addition to being the source of the main system clock the oscillators also provide clock sources for the Watchdog Timer and Time Base Interrupts. External oscillators requiring some external components as well as fully integrated internal oscillator, requiring no external components, are provided to form a wide range of both fast and slow system oscillators. All oscillator options are selected through register programming. The higher frequency oscillators provide higher performance but carry with it the disadvantage of higher power requirements, while the opposite is of course true for the lower frequency oscillators. With the capability of dynamically switching between fast and slow system clock, the device has the flexibility to optimize the performance/power ratio, a feature especially important in power sensitive portable applications.

Type	Name	Freq.	Pins
External High Speed Crystal	HXT	16 MHz	OSC1/OSC2
External Low Speed Crystal	LXT	32.768 kHz	XT1/XT2
Internal Low Speed RC	LIRC	32 kHz	—

Oscillator Types

System Clock Configurations

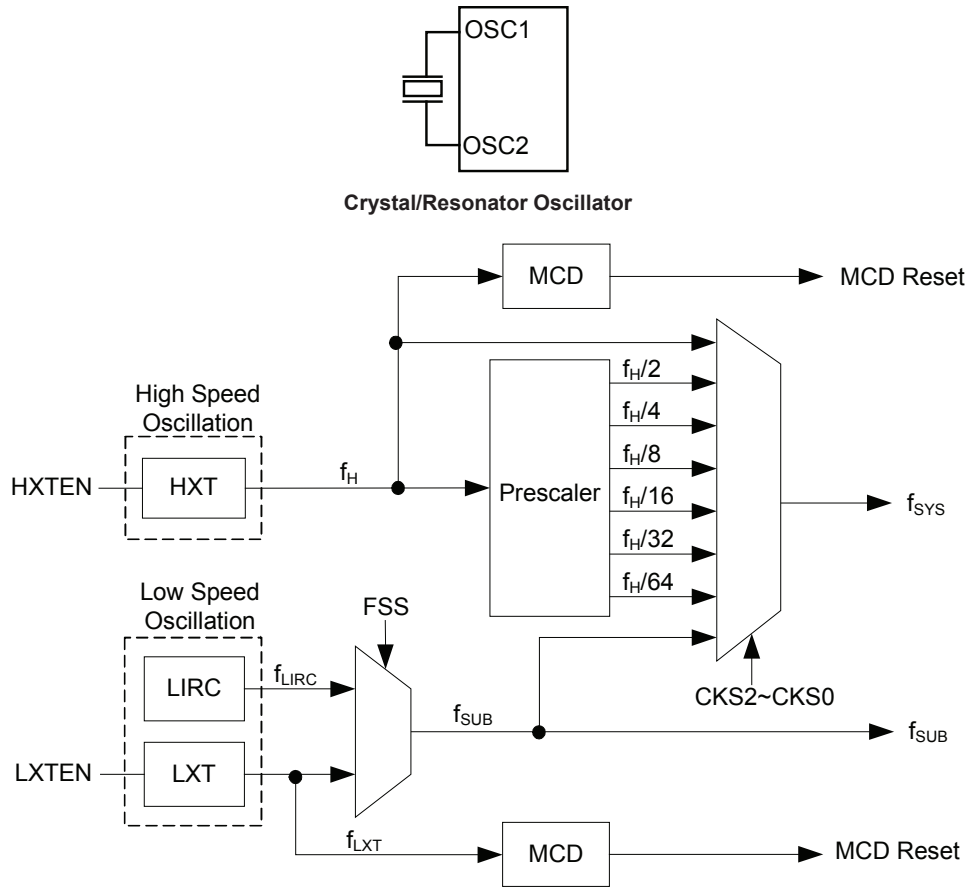
There are three methods of generating the system clock, one high speed oscillator and two low speed oscillators. The high speed oscillator is the external crystal/ceramic oscillator. The two low speed oscillators are the internal 32 kHz RC oscillator and the external 32.768 kHz crystal oscillator. Selecting whether the low or high speed oscillator is used as the system oscillator is implemented using the CKS2~CKS0 bits in the SCC register and as the system clock can be dynamically selected.

The actual source clock used for the low speed oscillators is chosen via the FSS bit in the SCC register. The frequency of the slow speed or high speed system clock is determined using the CKS2~CKS0 bits in the SCC register. Note that two oscillator selections must be made namely one high speed and one low speed system oscillators. It is not possible to choose a no-oscillator selection for either the high or low speed oscillator.

External Crystal/Ceramic Oscillator – HXT

The External Crystal/Ceramic System Oscillator is the high frequency oscillator, which is the default oscillator clock source after power on. For most crystal oscillator configurations, the simple connection of a crystal across OSC1 and OSC2 will create the necessary phase shift and feedback for oscillation, without requiring external capacitors.

For oscillator stability and to minimise the effects of noise and crosstalk, it is important to ensure that the crystal and any associated resistors and capacitors along with interconnecting lines are all located as close to the MCU as possible.



Crystal/Resonator Oscillator

System Clock Configurations

External 32.768 kHz Crystal Oscillator – LXT

The External 32.768 kHz Crystal System Oscillator is one of the low frequency oscillator choices, which is selected via a software control bit, FSS. This clock source has a fixed frequency of 32.768 kHz and requires a 32.768 kHz crystal to be connected between pins XT1 and XT2. The external resistor and capacitor components connected to the 32.768 kHz crystal are necessary to provide oscillation. For applications where precise frequencies are essential, these components may be required to provide frequency compensation due to different crystal manufacturing tolerances. After the LXT oscillator is enabled by setting the LXTEN bit to 1, there is a time delay associated with the LXT oscillator waiting for it to start-up.

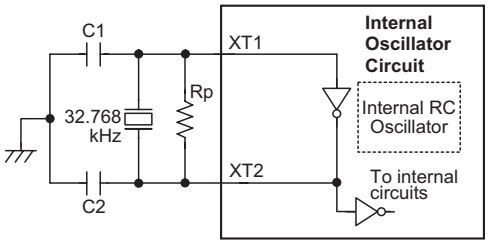
When the microcontroller enters the SLEEP or IDLE Mode, the system clock is switched off to stop microcontroller activity and to conserve power. However, in many microcontroller applications it may be necessary to keep the internal timers operational even when the microcontroller is in the SLEEP or IDLE Mode. To do this, another clock, independent of the system clock, must be provided.

However, for some crystals, to ensure oscillation and accurate frequency generation, it is necessary to add two small value external capacitors, C1 and C2. The exact values of C1 and C2 should be selected in consultation with the crystal or resonator manufacturer's specification. The external parallel feedback resistor, Rp, is required.

The pin-shared software control bits determine if the XT1/XT2 pins are used for the LXT oscillator or as I/O pins.

- If the LXT oscillator is not used for any clock source, the XT1/XT2 pins can be used as normal I/O pins.
- If the LXT oscillator is used for any clock source, the 32.768 kHz crystal should be connected to the XT1/XT2 pins.

For oscillator stability and to minimise the effects of noise and crosstalk, it is important to ensure that the crystal and any associated resistors and capacitors along with interconnecting lines are all located as close to the MCU as possible.



Note: 1. Rp, C1 and C2 are required.
2. Although not shown pins have a parasitic capacitance of around 7pF.

External LXT Oscillator

LXT Oscillator Low Power Function

The LXT oscillator can function in one of two modes, the Speed-Up Mode and the Low-Power Mode. The mode selection is executed using the LXTSP bit in the LXTC register

LXTSP	LXT Operating Mode
0	Low Power
1	Speed up

When the LXTSP bit is set to high, the LXT Quick Start Mode will be enabled. In the Speed-Up Mode the LXT oscillator will power up and stabilise quickly. However, after the LXT oscillator has fully powered up, it can be placed into the Low-Power Mode by clearing the LXTSP bit to zero and the oscillator will continue to run bit with reduced current consumption. It is important to note that the LXT operating mode switching must be properly controlled before the LXT oscillator clock is selected as the system clock source. Once the LXT oscillator clock is selected as the system clock source using the CKS bit field and FSS bit in the SCC register, the LXT oscillator operating mode can not be changed.

It should be note, that no matter what condition the LXTSP is set to, the LXT oscillator will always function normally. The only difference is that it will take more time to start up if in the Low Power Mode.

Internal 32kHz Oscillator – LIRC

The Internal 32 kHz System Oscillator is one of the low frequency oscillator choices, which is selected via a software control bit, FSS. It is a fully integrated RC oscillator with a typical frequency of 32 kHz at 5V, requiring no external components for its implementation. Device trimming during the manufacturing process and the inclusion of internal frequency compensation circuits are used to ensure that the influence of the power supply voltage, temperature and process variations on the oscillation frequency are minimised. As a result, at a power supply of 5V and at a temperature of 25˚C degrees, the fixed oscillation frequency of 32 kHz will have a tolerance within 10%.

Supplementary Oscillators

The low speed oscillators, in addition to providing a system clock source are also used to provide a clock source to two other device functions. These are the Watchdog Timer and the Time Base Interrupts.

Operating Modes and System Clocks

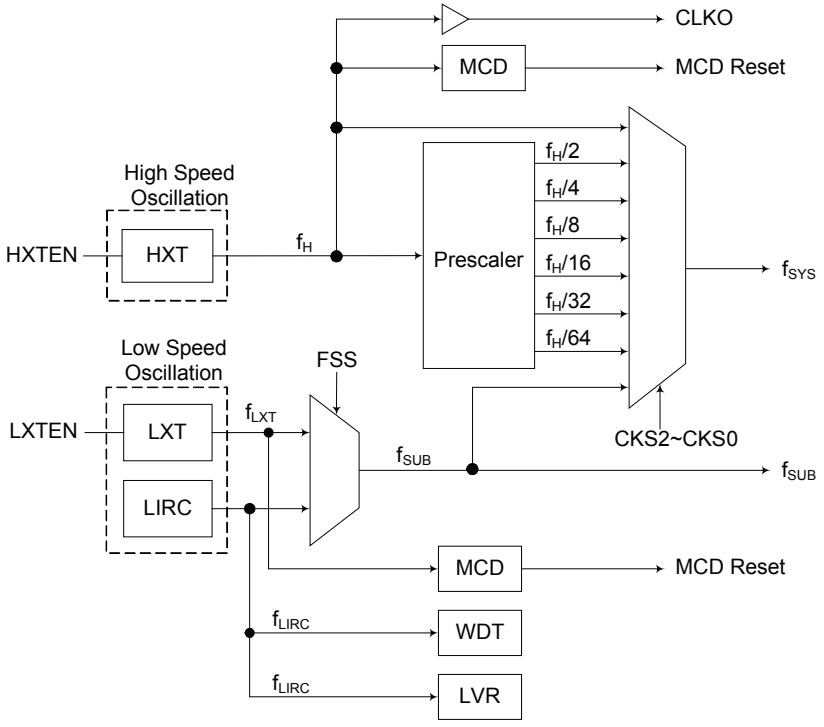
Present day applications require that their microcontrollers have high performance but often still demand that they consume as little power as possible, conflicting requirements that are especially true in battery powered portable applications. The fast clocks required for high performance will by their nature increase current consumption and of course vice-versa, lower speed clocks reduce current consumption. As Holtek has provided these devices with both high and low speed clock sources and the means to switch between them dynamically, the user can optimise the operation of their microcontroller to achieve the best performance/power ratio.

System Clocks

The device has different clock sources for both the CPU and peripheral function operation. By providing the user with a wide range of clock selections using register programming, a clock system can be configured to obtain maximum application performance.

The main system clock, can come from either a high frequency, f_H, or low frequency, f_{SUB}, source, and is selected using the CKS2~CKS0 bits in the SCC register. The high speed system clock is sourced from an HXT oscillator. The low speed system clock source can be sourced from the internal clock f_{SUB}. If f_{SUB} is selected then it can be sourced by either the LXT or LIRC oscillators, selected via configuring the FSS bit in the SCC register. The other choice, which is a divided version of the high speed system oscillator has a range of $f_H/2$~$f_H/64$.

The CLKO signal which is derived from the HXT oscillator is shared with an I/O line and can be sent out to the external pin which is determined by the corresponding pin-shared function selection bits. The CLKO output slew rate can be programmed using the SR1 and SR0 bits in the CTRL register.



System Clock Configurations

Note: When the system clock source f_{SYS} is switched to f_{SUB} from f_H, the high speed oscillation can be stopped to conserve the power or continue to oscillate to provide the clock source, f_H~$f_H/64$, for peripheral circuit to use, which is determined by configuring the corresponding high speed oscillator enable control bit.

System Operation Modes

There are six different modes of operation for the microcontroller, each one with its own special characteristics and which can be chosen according to the specific performance and power requirements of the application. There are two modes allowing normal operation of the microcontroller, the NORMAL Mode and SLOW Mode. The remaining four modes, the SLEEP, IDLE0, IDLE1 and IDLE2 Mode are used when the microcontroller CPU is switched off to conserve power.

Operation Mode	CPU	Register Setting			f_{SYS}	f_H	f_{SUB}	f_{LIRC}
		FHIDEN	FSIDEN	CKS2~CKS0				
NORMAL	On	x	x	000~110	f_H~f_H/64	On	On	On
SLOW	On	x	x	111	f_{SUB}	On/Off (1)	On	On
IDLE0	Off	0	1	000~110	Off	Off	On	On
				111	On			
IDLE1	Off	1	1	x	On	On	On	On
IDLE2	Off	1	0	000~110	On	On	Off	On
				111	Off			
SLEEP	Off	0	0	x	Off	Off	Off	On/Off (2)

Note: 1. The f_H clock will be switched on or off by configuring the corresponding oscillator enable bit in the SLOW mode.

2. The f_{LIRC} clock can be switched on or off which is controlled by the WDT function being enabled or disabled.

NORMAL Mode

As the name suggests this is one of the main operating modes where the microcontroller has all of its functions operational and where the system clock is provided by the high speed oscillator. This mode operates allowing the microcontroller to operate normally with a clock source will come from the high speed oscillator, HXT oscillator. Although a high speed oscillator is used, running the microcontroller at a divided clock ratio reduces the operating current.

SLOW Mode

This is also a mode where the microcontroller operates normally although now with a slower speed clock source. The clock source used will be from f_{SUB}. The f_{SUB} clock is derived from either the LIRC or LXT oscillator.

SLEEP Mode

The SLEEP Mode is entered when an HALT instruction is executed and when the FHIDEN and FSIDEN bit are low. In the SLEEP mode the CPU will be stopped. However the f_{SUB} clock can still continue to operate if the WDT function is enabled.

IDLE0 Mode

The IDLE0 Mode is entered when an HALT instruction is executed and when the FSIDEN bit in the SCC register is high and the FHIDEN bit in the SCC register is low. In the IDLE0 Mode the CPU will be switched off but the low speed oscillator will be turned on to drive some peripheral functions.

IDLE1 Mode

The IDLE1 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is high and the FSIDEN bit in the SCC register is high. In the IDLE1 Mode the CPU will be switched off but both the high and low speed oscillators will be turned on to provide a clock source to keep some peripheral functions operational.

IDLE2 Mode

The IDLE2 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is high and the FSIDEN bit in the SCC register is low. In the IDLE2 Mode the CPU will be switched off but the high speed oscillator will be turned on to provide a clock source to keep some peripheral functions operational.

Missing Clock Detector Function – MCD

There is a Missing Clock Detector, MCD, in this device. The MCD is used to detect the high speed HXT or low speed LXT oscillator operation when the corresponding oscillator is enabled and selected as the system clock. If the oscillator is enabled to be used as the system clock and no clock cycle is detected by the MCD in a certain period of time, it means that the oscillator does not oscillate successfully and then the MCD will generate a signal to reset the microcontroller.

Control Registers

The registers, SCC, HXTC and LXTC, are used to control the system clock and the corresponding oscillator configurations.

Register Name	Bit							
	7	6	5	4	3	2	1	0
CTRL	—	—	—	—	—	—	SR1	SR0
SCC	CKS2	CKS1	CKS0	—	—	FSS	FHIDEN	FSIDEN
HXTC	—	—	—	—	—	—	HXTF	HXTEN
LXTC	—	—	—	—	—	LXTSP	LXTF	LXTEN

System Operating Mode Control Registers List

CTRL Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	SR1	SR0
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as 0.

Bit 1~0 **SR1~SR0**: CLKO pin slew rate selection
00: 0 ns
01: 10 ns
10: 15 ns
11: 20 ns

SCC Register

Bit	7	6	5	4	3	2	1	0
Name	CKS2	CKS1	CKS0	—	—	FSS	FHIDEN	FSIDEN
R/W	R/W	R/W	R/W	—	—	R/W	R/W	R/W
POR	0	1	0	—	—	0	0	0

Bit 7~5 **CKS2~CKS0**: System clock selection
000: f_H
001: $f_H/2$
010: $f_H/4$
011: $f_H/8$
100: $f_H/16$
101: $f_H/32$
110: $f_H/64$
111: f_{SUB}
These three bits are used to select which clock is used as the system clock source. In addition to the system clock source directly derived from f_H or f_{SUB}, a divided version of the high speed system oscillator can also be chosen as the system clock source.

Bit 4~3 Unimplemented, read as 0.

Bit 2 **FSS**: Low Frequency clock selection
0: LIRC
1: LXT

Bit 1 **FHIDEN**: High Frequency oscillator control when CPU is switched off
0: Disable
1: Enable
This bit is used to control whether the high speed oscillator is activated or stopped when the CPU is switched off by executing an "HALT" instruction.

Bit 0 **FSIDEN**: Low Frequency oscillator control when CPU is switched off
0: Disable
1: Enable
This bit is used to control whether the low speed oscillator is activated or stopped when the CPU is switched off by executing an "HALT" instruction. The LIRC oscillator is controlled by this bit together with the WDT function enable control when the LIRC is selected to be the low speed oscillator clock source or the WDT function is enabled respectively. If this bit is cleared to 0 but the WDT function is enabled, the LIRC oscillator will also be enabled.

HXTC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	HXTF	HXTEN
R/W	—	—	—	—	—	—	R	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as 0.

Bit 1 **HXTF**: HXT oscillator stable flag
0: HXT unstable
1: HXT stable
This bit is used to indicate whether the HXT oscillator is stable or not. When the HXTEN bit is set to 1 to enable the HXT oscillator, the HXTF bit will first be cleared to 0 and then set to 1 after the HXT oscillator is stable.

Bit 0 **HXTEN**: HXT oscillator enable control
0: Disable
1: Enable

LXTC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	LXTSP	LXTF	LXTEN
R/W	—	—	—	—	—	RW	R	R/W
POR	—	—	—	—	—	0	0	0

Bit 7~3 Unimplemented, read as 0.

Bit 2 **LXTSP**: LXT oscillator speed-up control
0: Disable – Low power
1: Enable – Speed up
This bit is used to control whether the LXT oscillator is operating in the low power or quick start mode. When the LXTSP bit is set to 1, the LXT oscillator will oscillate quickly but consume more power. If the LXTSP bit is cleared to 0, the LXT oscillator will consume less power but take longer time to stablise. It is important to note that this bit can not be changed after the LXT oscillator is selected as the system clock source using the CKS2~CKS0 and FSS bits in the SCC register.

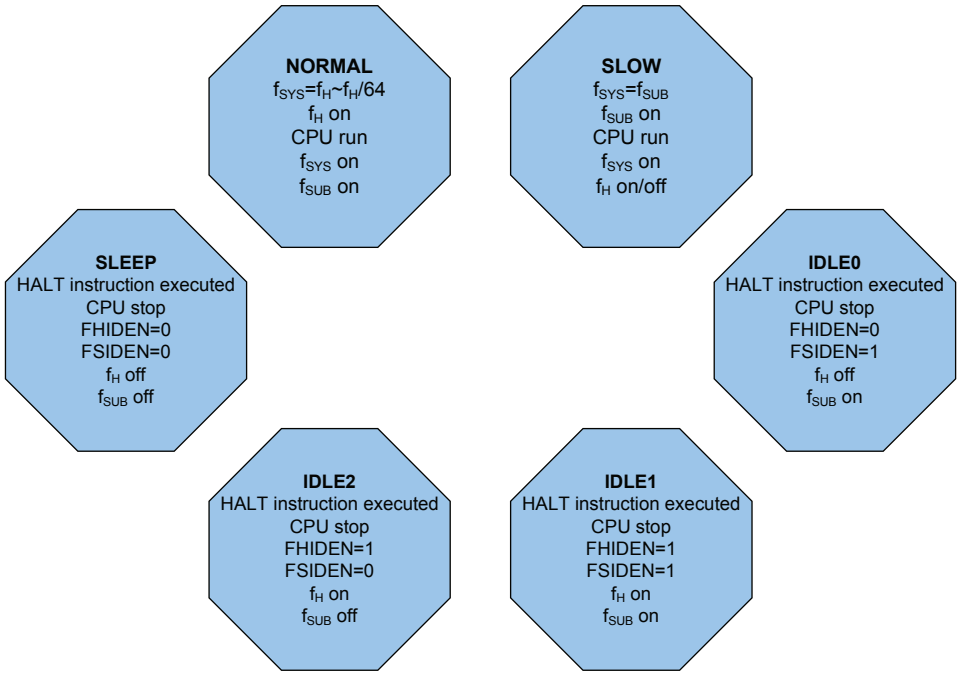
Bit 1 **LXTF**: LXT oscillator stable flag
0: LXT unstable
1: LXT stable
This bit is used to indicate whether the LXT oscillator is stable or not. When the LXTEN bit is set to 1 to enable the LXT oscillator, the LXTF bit will first be cleared to 0 and then set to 1 after the LXT oscillator is stable.

Bit 0 **LXTEN**: LXT oscillator enable control
0: Disable
1: Enable

Operating Mode Switching

The device can switch between operating modes dynamically allowing the user to select the best performance/power ratio for the present task in hand. In this way microcontroller operations that do not require high performance can be executed using slower clocks thus requiring less operating current and prolonging battery life in portable applications.

In simple terms, Mode Switching between the NORMAL Mode and SLOW Mode is executed using the CKS2~CKS0 bits in the SCC register while Mode Switching from the NORMAL/SLOW Modes to the SLEEP/IDLE Modes is executed via the HALT instruction. When an HALT instruction is executed, whether the device enters the IDLE Mode or the SLEEP Mode is determined by the condition of the FHIDEN and FSIDEN bits in the SCC register.



NORMAL Mode to SLOW Mode Switching

When running in the NORMAL Mode, which uses the high speed system oscillator, and therefore consumes more power, the system clock can switch to run in the SLOW Mode by set the CKS2~CKS0 bits to "111" in the SCC register. This will then use the low speed system oscillator which will consume less power. Users may decide to do this for certain operations which do not require high performance and can subsequently reduce power consumption.

The SLOW Mode is sourced from the LXT or LIRC oscillator determined by the FSS bit in the SCC register and therefore requires this oscillator to be stable before full mode switching occurs.

SLOW Mode to NORMAL Mode Switching

In SLOW mode the system clock is derived from f_{SUB}. When system clock is switched back to the NORMAL mode from f_{SUB}, the CKS2~CKS0 bits should be set to "000" ~"110" and then the system clock will respectively be switched to f_H~ $f_H/64$.

However, if f_H is not used in SLOW mode and thus switched off, it will take some time to re-oscillate and stabilise when switching to the NORMAL mode from the SLOW Mode. This is monitored using the HXTF bit in the HXTC register. The time duration required for the high speed system oscillator stabilization is specified in the A.C. characteristics.

Entering the SLEEP Mode

There is only one way for the device to enter the SLEEP Mode and that is to execute the "HALT" instruction in the application program with both the FHIDEN and FSIDEN bits in the SCC register equal to "0". In this mode all the clocks and functions will be switched off except the WDT function. When this instruction is executed under the conditions described above, the following will occur:

- The system clock will be stopped and the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag PDF will be set, and WDT timeout flag TO will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled.

Entering the IDLE0 Mode

There is only one way for the device to enter the IDLE0 Mode and that is to execute the "HALT" instruction in the application program with the FSIDEN bit in the SCC register equal to "1" and the FHIDEN bit in the SCC register equal to "0". When this instruction is executed under the conditions described above, the following will occur:

- The f_H clock will be stopped and the application program will stop at the "HALT" instruction, but the f_{SUB} clock will be on.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag PDF will be set, and WDT timeout flag TO will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled.

Entering the IDLE1 Mode

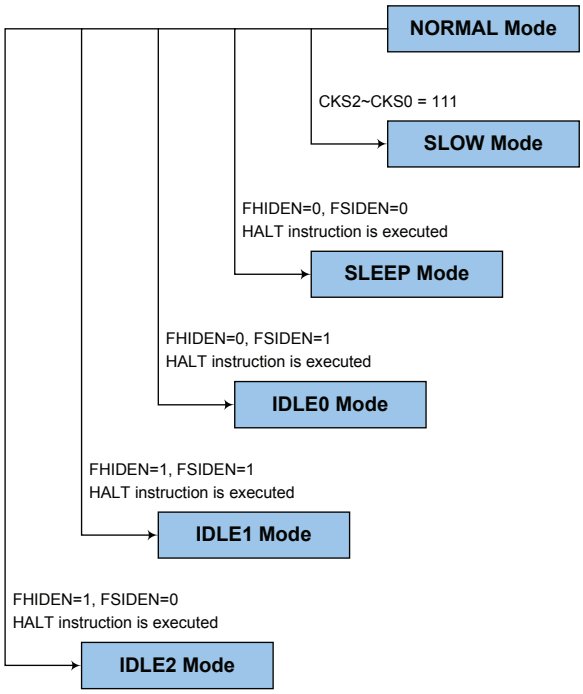
There is only one way for the device to enter the IDLE1 Mode and that is to execute the "HALT" instruction in the application program with both the FHIDEN and FSIDEN bits in the SCC register equal to "1". When this instruction is executed under the conditions described above, the following will occur:

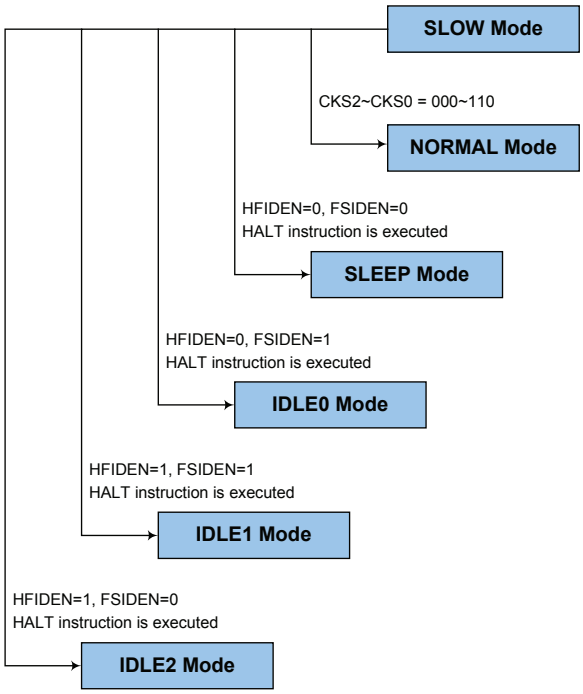
- The f_H and f_{SUB} clocks will be on but the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag PDF will be set, and WDT timeout flag TO will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled.

Entering the IDLE2 Mode

There is only one way for the device to enter the IDLE2 Mode and that is to execute the "HALT" instruction in the application program with the FHIDEN bit in the SCC register equal to "1" and the FSIDEN bit in the SCC register equal to "0". When this instruction is executed under the conditions described above, the following will occur:

- The f_H clock will be on but the f_{SUB} clock will be off and the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag PDF will be set, and WDT timeout flag TO will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled.


NORMAL Mode
CKS2~CKS0 = 111
SLOW Mode
FHIDEN=0, FSIDEN=0
HALT instruction is executed
SLEEP Mode
FHIDEN=0, FSIDEN=1
HALT instruction is executed
IDLE0 Mode
FHIDEN=1, FSIDEN=1
HALT instruction is executed
IDLE1 Mode
FHIDEN=1, FSIDEN=0
HALT instruction is executed
IDLE2 Mode


SLOW Mode
CKS2~CKS0 = 000~110
NORMAL Mode
HFIDEN=0, FSIDEN=0
HALT instruction is executed
SLEEP Mode
HFIDEN=0, FSIDEN=1
HALT instruction is executed
IDLE0 Mode
HFIDEN=1, FSIDEN=1
HALT instruction is executed
IDLE1 Mode
HFIDEN=1, FSIDEN=0
HALT instruction is executed
IDLE2 Mode

Standby Current Considerations

As the main reason for entering the SLEEP or IDLE Mode is to keep the current consumption of the device to as low a value as possible, perhaps only in the order of several micro-amps except in the IDLE1 and IDLE2 Mode, there are other considerations which must also be taken into account by the circuit designer if the power consumption is to be minimised. Special attention must be made to the I/O pins on the device. All high-impedance input pins must be connected to either a fixed high or low level as any floating input pins could create internal oscillations and result in increased current consumption. This also applies to devices which have different package types, as there may be unbonbed pins. These must either be setup as outputs or if setup as inputs must have pull-high resistors connected.

Care must also be taken with the loads, which are connected to I/O pins, which are setup as outputs. These should be placed in a condition in which minimum current is drawn or connected only to external circuits that do not draw current, such as other CMOS inputs. Also note that additional standby current will also be required if the LIRC oscillator has enabled.

In the IDLE1 and IDLE 2 Mode the high speed oscillator is on, if the peripheral function clock source is derived from the high speed oscillator, the additional standby current will also be perhaps in the order of several hundred micro-amps.

Wake-up

To minimise power consumption the device can enter the SLEEP or any IDLE Mode, where the CPU will be switched off. However, when the device is woken up again, it will take a considerable time for the original system oscillator to restart, stablise and allow normal operation to resume.

After the system enters the SLEEP or IDLE Mode, it can be woken up from one of various sources listed as follows:

- An external falling edge on Port A
- A system interrupt
- A WDT overflow

When the device executes the "HALT" instruction, the PDF flag will be set to 1. The PDF flag will be cleared to 0 if the device experiences a system power-up or executes the clear Watchdog Timer instruction. If the system is woken up by a WDT overflow, a Watchdog Timer reset will be initiated and the TO flag will be set to 1. The TO flag is set if a WDT time-out occurs and causes a wake-up that only resets the Program Counter and Stack Pointer, other flags remain in their original status.

Each pin on Port A can be setup using the PAWU register to permit a negative transition on the pin to wake up the system. When a Port A pin wake-up occurs, the program will resume execution at the instruction following the "HALT" instruction. If the system is woken up by an interrupt, then two possible situations may occur. The first is where the related interrupt is disabled or the interrupt is enabled but the stack is full, in which case the program will resume execution at the instruction following the "HALT" instruction. In this situation, the interrupt which woke up the device will not be immediately serviced, but wukk rather be serviced later when the related interrupt is finally enabled or when a stack level becomes free. The other situation is where the related interrupt is enabled and the stack is not full, in which case the regular interrupt response takes place. If an interrupt request flag is set high before entering the SLEEP or IDLE Mode, the wake-up function of the related interrupt will be disabled.

Watchdog Timer

The Watchdog Timer is provided to prevent program malfunctions or sequences from jumping to unknown locations, due to certain uncontrollable external events such as electrical noise.

Watchdog Timer Clock Source

The Watchdog Timer clock source is provided by the internal RC oscillator, f_{LIRC}. The LIRC internal oscillator has an approximate frequency of 32 kHz and this specified internal clock period can vary with V_{DD}, temperature and process variations. The Watchdog Timer source clock is then subdivided by a ratio of 2^8 to 2^{18} to give longer timeouts, the actual value being chosen using the WS2~WS0 bits in the WDTC register.

Watchdog Timer Control Register

A single register, WDTC, controls the required timeout period as well as the enable/disable operation. This register controls the overall operation of the Watchdog Timer.

WDTC Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	WE4	WE3	WE2	WE1	WE0	WS2	WS1	WS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	0	1	1

Bit 7~3 **WE4~WE0**: WDT function enable control
10101: Disabled
01010: Enabled
Other values: Reset MCU
If these bits are changed due to adverse environmental conditions, the microcontroller will be reset. The reset operation will be activated after 2~3 LIRC clock cycles and the WRF bit in the RSTFC register will be set to 1.

Bit 2~0 **WS2~WS0**: WDT time-out period selection
000: $2^8/f_{LIRC}$
001: $2^{10}/f_{LIRC}$
010: $2^{12}/f_{LIRC}$
011: $2^{14}/f_{LIRC}$
100: $2^{15}/f_{LIRC}$
101: $2^{16}/f_{LIRC}$
110: $2^{17}/f_{LIRC}$
111: $2^{18}/f_{LIRC}$
These three buts determine the division ratio of the watchdog timer source clock, which in turn determines the time-out period.

RSTFC Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	LRF	WRF
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	x	0	0

"x": unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: Reset control register software reset flag
Described elsewhere.

Bit 2 **LVRF**: LVR function reset flag
Described elsewhere.

Bit 1 **LRF**: LVR control register software reset flag
Described elsewhere.

Bit 0 **WRF**: WDT control register software reset flag
0: Not occurred
1: Occurred
This bit is set to 1 by the WDT control register software reset and cleared by the application program. Note that this bit can only be cleared to 0 by the application program.

Watchdog Timer Operation

The Watchdog Timer operates by providing a device reset when its timer overflows. This means that in the application program and during normal operation the user has to strategically clear the Watchdog Timer before it overflows to prevent the Watchdog Timer from executing a reset. This is done using the clear watchdog instruction. If the program malfunctions for whatever reason, jumps to an unknown location, or enters an endless loop, the clear instruction will not be executed in the correct manner, in which case the Watchdog Timer will overflow and reset the device. With regard to the Watchdog Timer enable/disable function, there are five bits, WE4~WE0, in the WDTC register to offer the enable/disable control and reset control of the Watchdog Timer. The WDT function will be disabled when the WE4~WE0 bits are set to a value of 10101B while the WDT function will be enabled if the WE4~WE0 bits are equal to 01010B. If the WE4~WE0 bits are set to any other values, other than 01010B and 10101B, it will reset the device after 2~3 f_{LIRC} clock cycles. After power on these bits will have a value of 01010B.

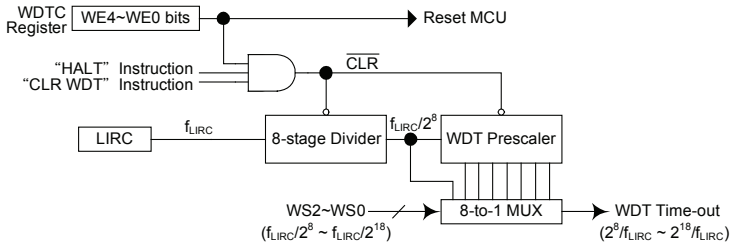
WE4 ~ WE0 Bits	WDT Function
10101B	Disable
01010B	Enable
Any other value	Reset MCU

Watchdog Timer Enable/Disable Control

Under normal program operation, a Watchdog Timer time-out will initialise a device reset and set the status bit TO. However, if the system is in the SLEEP or IDLE Mode, when a Watchdog Timer time-out occurs, the TO bit in the status register will be set and only the Program Counter and Stack Pointer will be reset. Three methods can be adopted to clear the contents of the Watchdog Timer. The first is a WDT reset, which means a certain value except 01010B and 10101B written into the WE4~WE0 field, the second is using the Watchdog Timer software clear instruction and the third is via a HALT instruction.

There is only one method of using software instruction to clear the Watchdog Timer. That is to use the single "CLR WDT" instruction to clear the WDT contents.

The maximum time out period is when the 2^{18} division ratio is selected. As an example, with a 32 kHz LIRC oscillator as its source clock, this will give a maximum watchdog period of around 8 second for the 2^{18} division ratio, and a minimum timeout of 7.8ms for the 2^8 division ration.



Watchdog timer

Reset and Initialisation

A reset function is a fundamental part of any microcontroller ensuring that the device can be set to some predetermined condition irrespective of outside parameters. The most important reset condition is after power is first applied to the microcontroller. In this case, internal circuitry will ensure that the microcontroller, after a short delay, will be in a well defined state and ready to execute the first program instruction. After this power-on reset, certain important internal registers will be set to defined states before the program commences. One of these registers is the Program Counter, which will be reset to zero forcing the microcontroller to begin program execution from the lowest Program Memory address.

In addition to the power-on reset, another reset exists in the form of a Low Voltage Reset, LVR, where a full reset is implemented in situations where the power supply voltage falls below a certain threshold. Another type of reset is when the Watchdog Timer overflows and resets the microcontroller. All types of reset operations result in different register conditions being setup.

Reset Functions

There are five ways in which a microcontroller reset can occur, through events occurring both internally and externally.

Power-on Reset

The most fundamental and unavoidable reset is the one that occurs after power is first applied to the microcontroller. As well as ensuring that the Program Memory begins execution from the first memory address, a power-on reset also ensures that certain other registers are preset to known conditions. All the I/O port and port control registers will power up in a high condition ensuring that all pins will be first set to inputs.

Note: t_{RSTD} is power-on delay, typical time=50ms

Power-On Reset Timing Chart

Internal Reset Control

There is an internal reset control register, RSTC, which is used to provide a reset when the device operates abnormally due to the environmental noise interference. If the content of the RSTC register is set to any value other than 01010101B or 10101010B, it will reset the device after 2~3 f_{LIRC} clock cycles. After power on the register will have a value of 01010101B.

RSTC7 ~ RSTC0 Bits	Reset Function
01010101B	No operation
10101010B	No operation
Any other value	Reset MCU

Internal Reset Function Control

- **RSTC Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	RSTC7	RSTC6	RSTC5	RSTC4	RSTC3	RSTC2	RSTC1	RSTC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	1	0	1

Bit 7~0 **RSTC7~RSTC0**: Reset function control
01010101: No operation
10101010: No operation
Other values: Reset MCU
If these bits are changed due to adverse environmental conditions, the microcontroller will be reset. The reset operation will be activated after 2~3 LIRC clock cycles and the RSTF bit in the RSTFC register will be set to 1.

- **RSTFC Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	LRF	WRF
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	x	0	0

"x": unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: Reset control register software reset flag
0: Not occurred
1: Occurred
This bit is set to 1 by the RSTC control register software reset and cleared by the application program. Note that this bit can only be cleared to 0 by the application program.

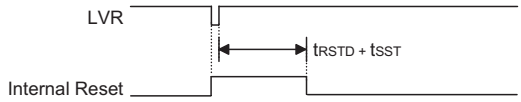
Bit 2 **LVRF**: LVR function reset flag
Described elsewhere.

Bit 1 **LRF**: LVR control register software reset flag
Described elsewhere.

Bit 0 **WRF**: WDT control register software reset flag
Described elsewhere.

Low Voltage Reset – LVR

The microcontroller contains a low voltage reset circuit in order to monitor the supply voltage of the device. The LVR function is always enabled with a specific LVR voltage, V_{LVR}. If the supply voltage of the device drops to within a range of 0.9V~V_{LVR} such as might occur when changing the battery, the LVR will automatically reset the device internally and the LVRF bit in the RSTFC register will also be set to 1. For a valid LVR signal, a low supply voltage, i.e., a voltage in the range between 0.9V~ V_{LVR} must exist for a time greater than that specified by t_{LVR} in the LVD/LVR characteristics. If the low supply voltage state does not exceed this value, the LVR will ignore the low supply voltage and will not perform a reset function. The actual V_{LVR} value can be selected by the LVS bits in the LVRC register. If the LVS7~LVS0 bits have any other value, which may perhaps occur due to adverse environmental conditions such as noise, the LVR will reset the device after 2~3 f_{LIRC} clock cycles. When this happens, the LRF bit in the RSTFC register will be set to 1. After power on the register will have the value of 01010101B. Note that the LVR function will be automatically disabled when the device enters the power down mode.



Note: t_{RSTD} is power-on delay, typical time=50ms

Low Voltage Reset Timing Chart

- **LVRC Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	LVS7	LVS6	LVS5	LVS4	LVS3	LVS2	LVS1	LVS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	1	0	1

Bit 7~0 **LVS7~LVS0**: LVR voltage select
01010101: 2.1V
00110011: 2.55V
10011001: 3.15V
10101010: 3.8V
Other values: Generates a MCU reset – register is reset to POR value

When an actual low voltage condition occurs, as specified by one of the four defined LVR voltage value above, an MCU reset will generated. The reset operation will be activated after 2~3 f_{LIRC} clock cycles. In this situation the register contents will remain the same after such a reset occurs.

Any register value, other than the four defined register values above, will also result in the generation of an MCU reset. The reset operation will be activated after 2~3 f_{LIRC} clock cycles. However in this situation the register contents will be reset to the POR value.

- **RSTFC Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	LRF	WRF
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	x	0	0

"x": unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: Reset control register software reset flag
Described elsewhere.

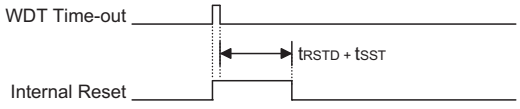
Bit 2 **LVRF**: LVR function reset flag
0: Not occurred
1: Occurred
This bit is set to 1 when a specific low voltage reset condition occurs. Note that this bit can only be cleared to 0 by the application program.

Bit 1 **LRF**: LVR control register software reset flag
0: Not occurred
1: Occurred
This bit is set to 1 by the LVRC control register contains any undefined LVR voltage register values. This in effect acts like a software-reset function. Note that this bit can only be cleared to 0 by the application program.

Bit 0 **WRF**: WDT control register software reset flag
Described elsewhere.

Watchdog Time-out Reset during Normal Operation

The Watchdog time-out Reset during normal operation is the same as the hardware Low Voltage Reset except that the Watchdog time-out flag TO will be set to "1".

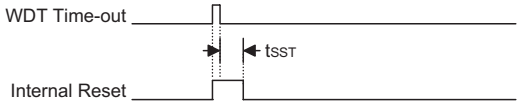


Note: t_{RSTD} is power-on delay, typical time=16.7ms

WDT Time-out Reset during Normal Operation Timing Chart

Watchdog Time-out Reset during SLEEP or IDLE Mode

The Watchdog time-out Reset during SLEEP or IDLE Mode is a little different from other kinds of reset. Most of the conditions remain unchanged except that the Program Counter and the Stack Pointer will be cleared to "0" and the TO flag will be set to "1". Refer to the A.C. Characteristics for t_{SST} details.



WDT Time-out Reset during SLEEP or IDLE Mode Timing Chart

Reset Initial Conditions

The different types of reset described affect the reset flags in different ways. These flags, known as PDF and TO are located in the status register and are controlled by various microcontroller operations, such as the SLEEP or IDLE Mode function or Watchdog Timer. The reset flags are shown in the table:

TO	PDF	Reset Function
0	0	Power-on reset
u	u	LVR reset during NORMAL or SLOW Mode operation
1	u	WDT time-out reset during NORMAL or SLOW Mode operation
1	1	WDT time-out reset during IDLE or SLEEP Mode operation

"u" stands for unchanged

The following table indicates the way in which the various components of the microcontroller are affected after a power-on reset occurs.

Item	Reset Function
Program Counter	Reset to zero
Interrupts	All interrupts will be disabled
WDT, Time Base	Clear after reset, WDT begins counting
Timer Modules	Timer Modules will be turned off
Input/Output Ports	I/O ports will be setup as inputs
Stack pointer	Stack pointer will point to the top of the stack

The different kinds of resets all affect the internal registers of the microcontroller in different ways. To ensure reliable continuation of normal program execution after a reset occurs, it is important to know what condition the microcontroller is in after a particular reset occurs. The following table describes how each type of reset affects the microcontroller internal registers.

Register	Reset (Power On)	LVR Reset (Normal Operation)	WDT Time-out (Normal Operation)	WDT Time-out (IDLE or SLEEP)*
IAR0	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
MP0	0000 0000	0000 0000	0000 0000	uuuu uuuu
IAR1	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
MP1L	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP1H	0000 0000	0000 0000	0000 0000	uuuu uuuu
ACC	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
PCL	0000 0000	0000 0000	0000 0000	0000 0000
TBLP	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBLH	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBHP	---- xxxx	---- uuuu	---- uuuu	---- uuuu
STATUS	--00 xxxx	--uu uuuu	--uu uuuu	--uu uuuu
IAR2	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
MP2L	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP2H	0000 0000	0000 0000	0000 0000	uuuu uuuu
INTC0	-000 0000	-000 0000	-000 0000	-uuu uuuu
PA	1111 1111	1111 1111	1111 1111	uuuu uuuu
PAC	1111 1111	1111 1111	1111 1111	uuuu uuuu
PAPU	0000 0000	0000 0000	0000 0000	uuuu uuuu
PAWU	0000 0000	0000 0000	0000 0000	uuuu uuuu
RSTFC	---- 0x00	---- uuuu	---- uuuu	---- uuuu
PB	---- 1111	---- 1111	---- 1111	---- uuuu
PBC	---- 1111	---- 1111	---- 1111	---- uuuu
PBPU	---- 0000	---- 0000	---- 0000	---- uuuu
PSCR	---- --00	---- --00	---- --00	---- --uu
TBC0	0--- -000	0--- -000	0--- -000	u--- -uuu
TBC1	0--- -000	0--- -000	0--- -000	u--- -uuu
SCC	010- -000	010- -000	010- -000	uuu- -uuu
HXTC	---- --01	---- --01	---- --01	---- --uu
LXTC	---- -000	---- -000	---- -000	---- -uuu
RSTC	0101 0101	0101 0101	0101 0101	uuuu uuuu
CTRL	---- --00	---- --00	---- --00	---- --uu
CTMC0	0000 0---	0000 0---	0000 0---	uuuu u---
CTMC1	0000 0000	0000 0000	0000 0000	uuuu uuuu
CTMDL	0000 0000	0000 0000	0000 0000	uuuu uuuu
CTMDH	0000 0000	0000 0000	0000 0000	uuuu uuuu
CTMAL	0000 0000	0000 0000	0000 0000	uuuu uuuu
CTMAH	0000 0000	0000 0000	0000 0000	uuuu uuuu
CTMRP	0000 0000	0000 0000	0000 0000	uuuu uuuu
LVDC	--00 -000	--00 -000	--00 -000	--uu -uuu
LVRC	0101 0101	0101 0101	0101 0101	uuuu uuuu
STMC0	0000 0---	0000 0---	0000 0---	uuuu u---
STMC1	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMDL	0000 0000	0000 0000	0000 0000	uuuu uuuu

Register	Reset (Power On)	LVR Reset (Normal Operation)	WDT Time-out (Normal Operation)	WDT Time-out (IDLE or SLEEP)*
STMDH	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMAL	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMAH	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMRP	0000 0000	0000 0000	0000 0000	uuuu uuuu
INTEG	---- 0000	---- 0000	---- 0000	---- uuuu
INTC1	0000 0000	0000 0000	0000 0000	uuuu uuuu
INTC2	0000 0000	0000 0000	0000 0000	uuuu uuuu
INTC3	--00 --00	--00 --00	--00 --00	--uu --uu
MFI0	--00 --00	--00 --00	--00 --00	--uu --uu
MFI1	--00 --00	--00 --00	--00 --00	--uu --uu
MFI2	--00 --00	--00 --00	--00 --00	--uu --uu
MFI3	0000 0000	0000 0000	0000 0000	uuuu uuuu
LCDC	-000 ----	-000 ----	-000 ----	-uuu ----
EEA	-000 0000	-000 0000	-000 0000	-uuu uuuu
EED	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTMC0	0000 0---	0000 0---	0000 0---	uuuu u---
PTMC1	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTMDL	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTMDH	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTMAL	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTMAH	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTMRPL	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTMRPH	0000 0000	0000 0000	0000 0000	uuuu uuuu
WDTC	0101 0011	0101 0011	0101 0011	uuuu uuuu
PCPU	0000 0000	0000 0000	0000 0000	uuuu uuuu
PC	1111 1111	1111 1111	1111 1111	uuuu uuuu
PCC	1111 1111	1111 1111	1111 1111	uuuu uuuu
PDPU	0000 0000	0000 0000	0000 0000	uuuu uuuu
PD	1111 1111	1111 1111	1111 1111	uuuu uuuu
PDC	1111 1111	1111 1111	1111 1111	uuuu uuuu
ADRL (ADRFS=0)	xxxx ----	xxxx ----	xxxx ----	uuuu ----
ADRL (ADRFS=1)	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
ADRH (ADRFS=0)	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
ADRH (ADRFS=1)	---- xxxx	---- uuuu	---- uuuu	---- uuuu
ADCR0	0110 -000	0110 -000	0110 -000	uuuu –uuu
ADCR1	-000 -000	-000 -000	-000 -000	-uuu –uuu
PAS0	0000 0000	0000 0000	0000 0000	uuuu uuuu
PAS1	0000 0000	0000 0000	0000 0000	uuuu uuuu
PBS0	0000 0000	0000 0000	0000 0000	uuuu uuuu
PCS0	0000 0000	0000 0000	0000 0000	uuuu uuuu
PCS1	0000 0000	0000 0000	0000 0000	uuuu uuuu
PDS0	0000 0000	0000 0000	0000 0000	uuuu uuuu
PDS1	0000 0000	0000 0000	0000 0000	uuuu uuuu
IFS	--00 00--	--00 00--	--00 00--	--uu uu--
SIMTOC	0000 0000	0000 0000	0000 0000	uuuu uuuu
SIMC0	111- 0000	111- 0000	111- 0000	uuu- uuuu
SIMC1	1000 0001	1000 0001	1000 0001	uuuu uuuu

Register	Reset (Power On)	LVR Reset (Normal Operation)	WDT Time-out (Normal Operation)	WDT Time-out (IDLE or SLEEP)*
SIMD	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
SIMA	0000 0000	0000 0000	0000 0000	uuuu uuuu
SPIC0	111- --00	111- --00	111- --00	uuu- --uu
SPIC1	--00 0000	--00 0000	--00 0000	--uu uuuu
SPID	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
SPIADMAC	0--- 0000	0--- 0000	0--- 0000	u--- uuuu
SPIA_DMA_LEN	-011 1111	-011 1111	-011 1111	-uuu uuuu
SPIA_DMA_ADDR	1000 0000	1000 0000	1000 0000	1uuu uuuu
SPIA_DMA_RW_P	1000 0000	1000 0000	1000 0000	uuuu uuuu
USVC	0000 0000	0000 0000	0000 0000	uuuu uuuu
PGAC	0000 0000	0000 0000	0000 0000	uuuu uuuu
RECPLAC	0000 -000	0000 -000	0000 -000	uuuu -000
COMPANDC	---- 0000	---- 0000	---- 0000	---- uuuu
RECDL	0000 0000	0000 0000	0000 0000	uuuu uuuu
RECDH	0000 0000	0000 0000	0000 0000	uuuu uuuu
PLADL	0000 0000	0000 0000	0000 0000	uuuu uuuu
PLADH	0000 0000	0000 0000	0000 0000	uuuu uuuu
EEC	---- 0000	---- 0000	---- 0000	---- uuuu
FC0	0000 0000	0000 0000	0000 0000	uuuu uuuu
FC1	0000 0000	0000 0000	0000 0000	uuuu uuuu
FC2	---- ---0	---- ---0	---- ---0	---- ---u
FARL	0000 0000	0000 0000	0000 0000	uuuu uuuu
FARH	---- 0000	---- 0000	---- 0000	---- uuuu
FD0L	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD0H	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD1L	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD1H	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD2L	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD2H	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD3L	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD3H	0000 0000	0000 0000	0000 0000	uuuu uuuu

Note: "u" stands for unchanged
"x" stands for "unknown"
"-" stands for unimplemented

Input/Output Ports

Holtek microcontrollers offer considerable flexibility on their I/O ports. With the input or output designation of every pin fully under user program control, pull-high selections for all ports and wake-up selections on certain pins, the user is provided with an I/O structure to meet the needs of a wide range of application possibilities.

These devices provide bidirectional input/output lines labeled with port names PA~PD These I/O ports are mapped to the RAM Data Memory with specific addresses as shown in the Special Purpose Data Memory table. All of these I/O ports can be used for input and output operations. For input operation, these ports are non-latching, which means the inputs must be ready at the T2 rising edge of instruction "MOV A, [m]", where m denotes the port address. For output operation, all the data is latched and remains unchanged until the output latch is rewritten.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PAWU	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
PA	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0
PAC	PAC7	PAC6	PAC5	PAC4	PAC3	PAC2	PAC1	PAC0
PAPU	PAPU7	PAPU6	PAPU5	PAPU4	PAPU3	PAPU2	PAPU1	PAPU0
PB	—	—	—	—	PB3	PB2	PB1	PB0
PBC	—	—	—	—	PBC3	PBC2	PBC1	PBC0
PBPU	—	—	—	—	PBPU3	PBPU2	PBPU1	PBPU0
PC	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0
PCC	PCC7	PCC6	PCC5	PCC4	PCC3	PCC2	PCC1	PCC0
PCPU	PCPU7	PCPU6	PCPU5	PCPU4	PCPU3	PCPU2	PCPU1	PCPU0
PD	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0
PDC	PDC7	PDC6	PDC5	PDC4	PDC3	PDC2	PDC1	PDC0
PDPU	PDPU7	PDPU6	PDPU5	PDPU4	PDPU3	PDPU2	PDPU1	PDPU0

I/O Registers List

"—": Unimplemented, read as "0".

PAn/PBn/PCn/PDn: I/O Port Data bit
0: Data 0
1: Data 1

Pull-high Resistors

Many product applications require pull-high resistors for their switch inputs usually requiring the use of an external resistor. To eliminate the need for these external resistors, all I/O pins, when configured as an input have the capability of being connected to an internal pull-high resistor. These pull-high resistors are selected using registers PAPU~PDPU, and are implemented using weak PMOS transistors.

PAPU Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PAPU7	PAPU6	PAPU5	PAPU4	PAPU3	PAPU2	PAPU1	PAPU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 I/O Port A bit 7 ~ bit 0 Pull-high Control
0: Disable
1: Enable

PBPU Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	—	—	—	—	PBPU3	PBPU2	PBPU1	PBPU0
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 "—" Unimplemented, read as 0

Bit 3~0 I/O Port B bit 3 ~ bit 0 Pull-high Control
0: Disable
1: Enable

PCPU Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PCPU7	PCPU6	PCPU5	PCPU4	PCPU3	PCPU2	PCPU1	PCPU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 I/O Port C bit 7 ~ bit 0 Pull-high Control
0: Disable
1: Enable

PDPU Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PDPU7	PDPU6	PDPU5	PDPU4	PDPU3	PDPU2	PDPU1	PDPU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 I/O Port D bit 7 ~ bit 0 Pull-high Control
0: Disable
1: Enable

Port A Wake-up

The HALT instruction forces the microcontroller into the SLEEP or IDLE Mode which preserves power, a feature that is important for battery and other low-power applications. Various methods exist to wake-up the microcontroller, one of which is to change the logic condition on one of the Port A pins from high to low. This function is especially suitable for applications that can be woken up via external switches. Each pin on Port A can be selected individually to have this wake-up feature using the PAWU register.

PAWU Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 I/O Port A bit 7 ~ bit 0 wake-up function Control
0: Disable
1: Enable

I/O Port Control Registers

Each Port has its own control register, known as PAC~PDC, which controls the input/output configuration. With this control register, each I/O pin with or without pull-high resistors can be reconfigured dynamically under software control. For the I/O pin to function as an input, the corresponding bit of the control register must be written as a "1". This will then allow the logic state of the input pin to be directly read by instructions. When the corresponding bit of the control register is written as a "0", the I/O pin will be setup as a CMOS output. If the pin is currently setup as an output, instructions can still be used to read the output register.

However, it should be noted that the program will in fact only read the status of the output data latch and not the actual logic status of the output pin.

PAC Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PAC7	PAC6	PAC5	PAC4	PAC3	PAC2	PAC1	PAC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	1	1	1	1	1	1	1	1

Bit 7~0 I/O Port A bit 7 ~ bit 0 Input/Output Control
0: Output
1: Input

PBC Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	—	—	—	—	PBC3	PBC2	PBC1	PBC0
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	1	1	1	1

Bit 7~4 "—" Unimplemented, read as 0
Bit 3~0 I/O Port B bit 3 ~ bit 0 Input/Output Control
0: Output
1: Input

PCC Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PCC7	PCC6	PCC5	PCC4	PCC3	PCC2	PCC1	PCC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	1	1	1	1	1	1	1	1

Bit 7~0 I/O Port C bit 7 ~ bit 0 Input/Output Control
0: Output
1: Input

PDC Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PDC7	PDC6	PDC5	PDC4	PDC3	PDC2	PDC1	PDC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	1	1	1	1	1	1	1	1

Bit 7~0 I/O Port D bit 7 ~ bit 0 Input/Output Control
0: Output
1: Input

Pin-shared Functions

The flexibility of the microcontroller range is greatly enhanced by the use of pins that have more than one function. Limited numbers of pins can force serious design constraints on designers but by supplying pins with multi-functions, many of these difficulties can be overcome. For these pins, the desired function of the multi-function I/O pins is selected by a series of registers via the application program control.

Pin-shared Function Selection Registers

The device includes Port "x" output function Selection register "n", labeled as PxSn, and Input Function Selection register, labeled as IFS, which can select the desired functions of the multi-function pins.

When the pin-shared input function is selected to be used, the corresponding input and output functions selection should be properly managed. For example, if the I²C SDA line is used, the corresponding output pin-shared function should be configured as the SDI/SDA function by configuring the PxSn register and the SDA signal intput should be properly selected using the IFS register. However, if the external interrupt function is selected to be used, the relevant output pin-shared function should be selected as an I/O function and the interrupt input signal should be selected.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PAS0	PAS07	PAS06	PAS05	PAS04	PAS03	PAS02	PAS01	PAS00
PAS1	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	PAS11	PAS10
PBS0	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00
PCS0	PCS07	PCS06	PCS05	PCS04	PCS03	PCS02	PCS01	PCS00
PCS1	PCS17	PCS16	PCS15	PCS14	PCS13	PCS12	PCS11	PCS10
PDS0	PDS07	PDS06	PDS05	PDS04	PDS03	PDS02	PDS01	PDS00
PDS1	PDS17	PDS16	PDS15	PDS14	PDS13	PDS12	PDS11	PDS10
IFS	—	—	IFS5	IFS4	IFS3	IFS2	—	—

Pin-shared Function Selection Registers List

- **PAS0 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PAS07	PAS06	PAS05	PAS04	PAS03	PAS02	PAS01	PAS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PAS07~PAS06**: PA3 pin function selection
00/01/10: PA3
11: XT1

Bit 5~4 **PAS05~PAS04**: PA2 pin function selection
00/01/10/11: PA2/STCK

Bit 3~2 **PAS03~PAS02**: PA1 pin function selection
00/10: PA1/STPI_0
01: STP_0
11: SCOM0

Bit 1~0 **PAS01~PAS00**: PA0 pin function selection
00/01/10/11: PA0

- **PAS1 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	PAS11	PAS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PAS17~PAS16**: PA7 pin function selection
00/10: PA7
01: CTP_0
11: SCOM3

Bit 5~4 **PAS15~PAS14**: PA6 pin function selection
00/10: PA6
01: CTP_1
11: SCOM2

Bit 3~2 **PAS13~PAS12**: PA5 pin function selection
00/01/10: PA5/CTCK
11: SCOM1

Bit 1~0 **PAS11~PAS10**: PA4 pin function selection
00/01/10: PA4
11: XT2

- **PBS0 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PBS07~PBS06**: PB3 pin function selection
00/01/10/11: PB3/PTCK

Bit 5~4 **PBS05~PBS04**: PB2 pin function selection
00/10/11: PB2/PTPI_0
01: PTP_0

Bit 3~2 **PBS03~PBS02**: PB1 pin function selection
00/01/10: PB1
11: VDD_IO

Bit 1~0 **PBS01~PBS00**: PB0 pin function selection
00/10/11: PB0/STPI_1
01: STP_1

- **PCS0 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PCS07	PCS06	PCS05	PCS04	PCS03	PCS02	PCS01	PCS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PCS07~PCS06**: PC3 pin function selection
00/01/10: PC3/INT0
11: AN3

Bit 5~4 **PCS05~PCS04**: PC2 pin function selection
00/01/10: PC2
11: AN2

Bit 3~2 **PCS03~PCS02**: PC1 pin function selection
00/01/10: PC1
11: AN1

Bit 1~0 **PCS01~PCS00**: PC0 pin function selection
00/01/10: PC0
11: AN0/VREF

- **PCS1 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PCS17	PCS16	PCS15	PCS14	PCS13	PCS12	PCS11	PCS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PCS17~PCS16**: PC7 pin function selection
00/10: PC7
01: SDI/SDA
11: AN7

Bit 5~4 **PCS15~PCS14**: PC6 pin function selection
00/10: PC6
01: SCK/SCL
11: AN6

Bit 3~2 **PCS13~PCS12**: PC5 pin function selection
00/10: PC5
01: SDO
11: AN5

Bit 1~0 **PCS11~PCS10**: PC4 pin function selection
00/10: PC4
01: $\overline{SCS}$
11: AN4

- **PDS0 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PDS07	PDS06	PDS05	PDS04	PDS03	PDS02	PDS01	PDS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PDS07~PDS06**: PD3 pin function selection
00/10/11: PD3
01: SDIA

Bit 5~4 **PDS05~PDS04**: PD2 pin function selection
00/01/10/11: PD2/INT1

Bit 3~2 **PDS03~PDS02**: PD1 pin function selection
00/10/11: PD1
01: $\overline{\text{SCSA}}$

Bit 1~0 **PDS01~PDS00**: PD0 pin function selection
00/01/10/11: PD0

- **PDS1 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PDS17	PDS16	PDS15	PDS14	PDS13	PDS12	PDS11	PDS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PDS17~PDS16**: PD7 pin function selection
00/10/11: PD7/PTPI_1
01: PTP_1

Bit 5~4 **PDS15~PDS14**: PD6 pin function selection
00/10/11: PD6
01: CLKO

Bit 3~2 **PDS13~PDS12**: PD5 pin function selection
00/10/11: PD5
01: SCKA

Bit 1~0 **PDS11~PDS10**: PD4 pin function selection
00/10/11: PD4
01: SDOA

- **IFS Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	—	—	IFS5	IFS4	IFS3	IFS2	—	—
R/W	—	—	R/W	R/W	R/W	R/W	—	—
POR	—	—	0	0	0	0	—	—

Bit 7~6 "—" Unimplemented, read as 0

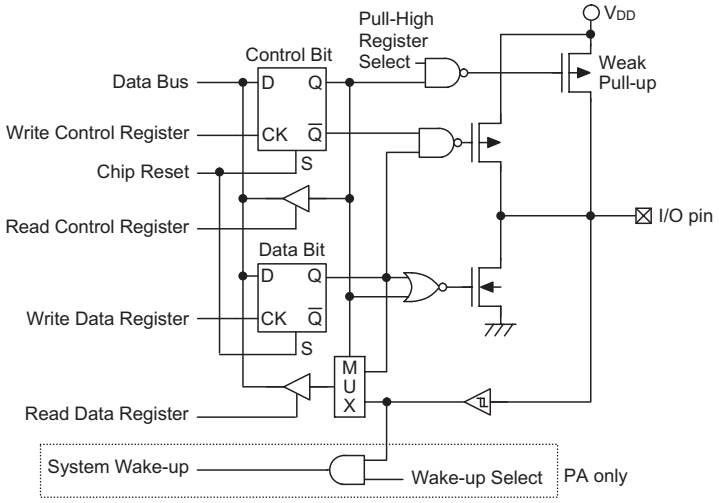
Bit 5~4 **IFS5~IFS4**: PTPI input source pin selection
00: PTPI_0
01/10/11: PTPI_1

Bit 3~2 **IFS3~IFS2**: STPI input source pin selection
00: STPI_0
01/10/11: STPI_1

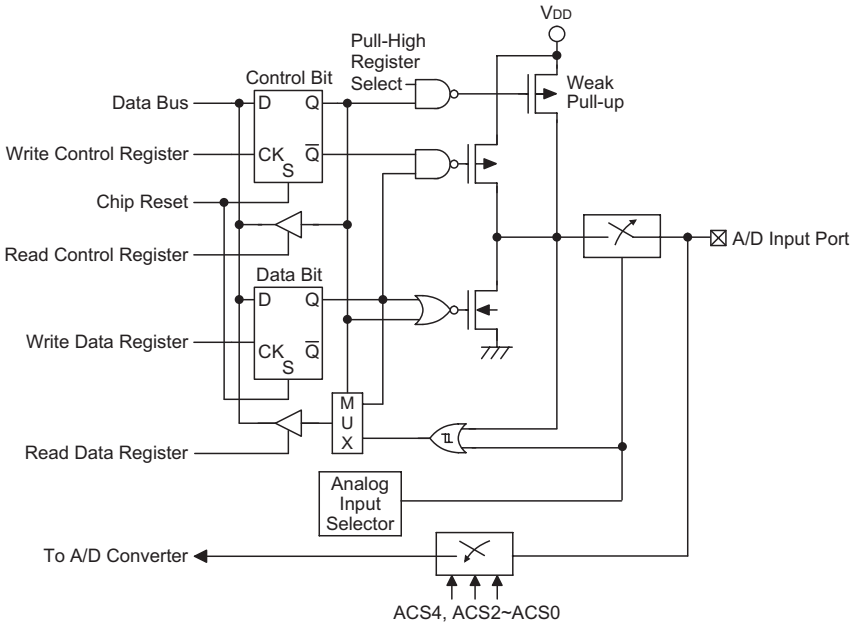
Bit 1~0 "—" Unimplemented, read as 0

I/O Pin Structures

The accompanying diagrams illustrate the internal structures of some generic I/O pin types. As the exact logical construction of the I/O pin will differ from these drawings, they are supplied as a guide only to assist with the functional understanding of the I/O pins. The wide range of pin-shared structures does not permit all types to be shown.



Generic Input/Output Structure



A/D Input/Output Structure

Programming Considerations

Within the user program, one of the things first to consider is port initialisation. After a reset, all of the I/O data and port control registers will be set to high. This means that all I/O pins will be defaulted to an input state, the level of which depends on the other connected circuitry and whether pull-high selections have been chosen. If the port control registers are then programmed to setup some pins as outputs, these output pins will have an initial high output value unless the associated port data registers are first programmed. Selecting which pins are inputs and which are outputs can be achieved byte-wide by loading the correct values into the appropriate port control register or by programming individual bits in the port control register using the "SET [m].i" and "CLR [m].i" instructions. Note that when using these bit control instructions, a read-modify-write operation takes place. The microcontroller must first read in the data on the entire port, modify it to the required new bit values and then rewrite this data back to the output ports.

Port A has the additional capability of providing wake-up functions. When the device is in the SLEEP or IDLE Mode, various methods are available to wake the device up. One of these is a high to low transition of any of the Port A pins. Single or multiple pins on Port A can be setup to have this function.

Timer Modules – TM

One of the most fundamental functions in any microcontroller devices is the ability to control and measure time. To implement time related functions the device includes several Timer Modules, generally abbreviated to the name TM. The TMs are multi-purpose timing units and serve to provide operations such as Timer/Counter, Input Capture, Compare Match Output and Single Pulse Output as well as being the functional unit for the generation of PWM signals. Each of the TMs has two interrupts. The addition of input and output pins for each TM ensures that users are provided with timing units with a wide and flexible range of features.

The common features of the different TM types are described here with more detailed information provided in the individual Compact, Standard and Periodic TM sections.

Introduction

The device contains three TMs and each individual TM cab be categorised as a certain type, namely Compact Type TM, Standard Type TM or Periodic Type TM. Although similar in nature, the different TM types vary in their feature complexity. The common features to all of the Compact, Standard and Periodic TMs will be described in this section and the the detailed operation regarding each of the TM types will be described in separate sections. The main features and differences between the three types of TMs are summarised in the accompanying table.

TM Function	CTM	STM	PTM
Timer/Counter	√	√	√
Input Capture	—	√	√
Compare Match Output	√	√	√
PWM Channels	1	1	1
Single Pulse Output	—	1	1
PWM Alignment	Edge	Edge	Edge
PWM Adjustment Period & Duty	Duty or Period	Duty or Period	Duty or Period

TM Function Summary

TM Operation

The different types of TM offer a diverse range of functions, from simple timing operations to PWM signal generation. The key to understanding how the TM operates is to see it in terms of a free running count-up counter whose value is then compared with the value of pre-programmed internal comparators. When the free running count-up counter has the same value as the pre-programmed comparator, known as a compare match situation, a TM interrupt signal will be generated which can clear the counter and perhaps also change the condition of the TM output pin. The internal TM counter is driven by a user selectable clock source, which can be an internal clock or an external pin.

TM Clock Source

The clock source which drives the main counter in each TM can originate from various sources. The selection of the required clock source is implemented using the xTCK2~xTCK0 bits in the xTM control registers, where "x" can stand for C, S or P. The clock source can be a ratio of the system clock, f_{SYS}, or the internal high clock, f_H, the f_{SUB} clock source or the external xTCK pin. The xTCK pin clock source is used to allow an external signal to drive the TM as an external clock source for event counting.

TM Interrupts

The Compact, Standard or Periodic type TM has two internal interrupt, one for each of the internal comparator A or comparator P, which generate a TM interrupt when a compare match condition occurs. When a TM interrupt is generated, it can be used to clear the counter and also to change the state of the TM output pin.

TM External Pins

Each of the TMs, irrespective of what type, has one or three TM input pins, with the label xTCK and xTPI_n respectively. The TM input pin, xTCK, is essentially a clock source for the TM and is selected using the xTCK2~xTCK0 bits in the xTMC0 register. This external TM input pin allows an external clock source to drive the internal TM. The TM input pin can be chosen to have either a rising or falling active edge. The STCK and PTCK pins are also used as the external trigger input pin in single pulse output mode for the STM and PTM respectively.

The other TM input pin, STPI_n and PTPI_n, is the capture input whose active edge can be a rising edge, a falling edge or both rising and falling edges and the active edge transition type is selected using the STIO1~STIO0 or PTIO1~PTIO0 bits in the STMC1 or PTMC1 register respectively. There is another capture input, PTCK, for PTM capture input mode, which can be used as the external trigger input source except the PTPI pin.

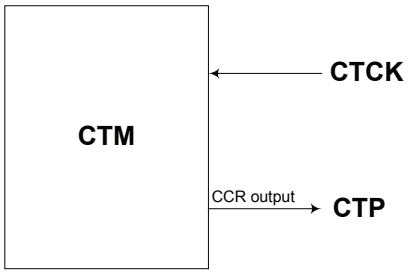
The TMs each have two output pins known as the name, xTP, with a "_n" suffix. The "_n" suffix indicates that they are from a TM with multiple output pins which is selected using the corresponding pin-shared function selection bits described in the Pin-shared Function section. When the TM is in the Compare Match Output Mode, these pins can be controlled by the TM to switch to a high or low level or to toggle when a compare match situation occurs. The external xTP output pin is also the pin where the TM generates the PWM output waveform. As the TM output pins are pin-shared with other functions, the TM output function must first be setup using relevant pin-shared function selection register.

CTM	STM	PTM
CTCK CTP_0, CTP_1	STCK, STPI_0, STPI_1 STP_0, STP_1	PTCK, PTPI_0, PTPI_1 PTP_0, PTP_1

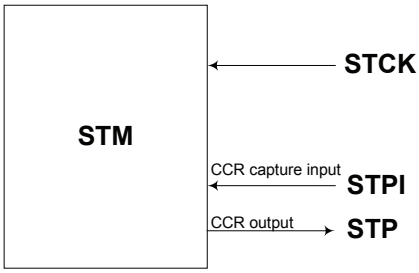
TM External Pins

TM Input/Output Pin Control Register

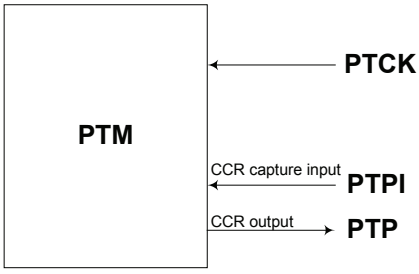
Selecting to have a TM input/output or whether to retain its other shared function is implemented using the relevant pin-shared function selection registers, with the corresponding selection bits in each pin-shared function register corresponding to a TM input/output pin. Configuring the selection bits correctly will setup the corresponding pin as a TM input/output. The details of the pin-shared function selection are described in the pin-shared function section.



CTM Function Pin Control Block Diagram



STM Function Pin Control Block Diagram

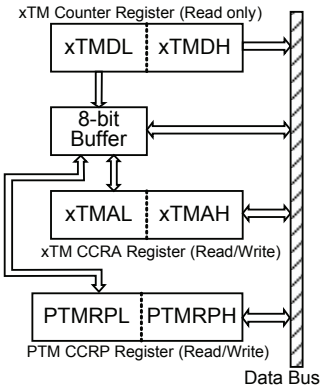


PTM Function Pin Control Block Diagram

Programming Considerations

The TM Counter Registers and the Capture/Compare CCRA and CCRP registers, all have a low and high byte structure. The high bytes can be directly accessed, but as the low bytes can only be accessed via an internal 8-bit buffer, reading or writing to these register pairs must be carried out in a specific way. The important point to note is that data transfer to and from the 8-bit buffer and its related low byte only takes place when a write or read operation to its corresponding high byte is executed.

As the CCRA and CCRB registers are implemented in the way shown in the following diagram and accessing these register pairs is carried out in a specific way as described above, it is recommended to use the "MOV" instruction to access the CCRA and CCRP low byte registers, named xTMAL and PTMRPL, using the following access procedures. Accessing the CCRA or CCRB low byte registers without following these access procedures will result in unpredictable values.

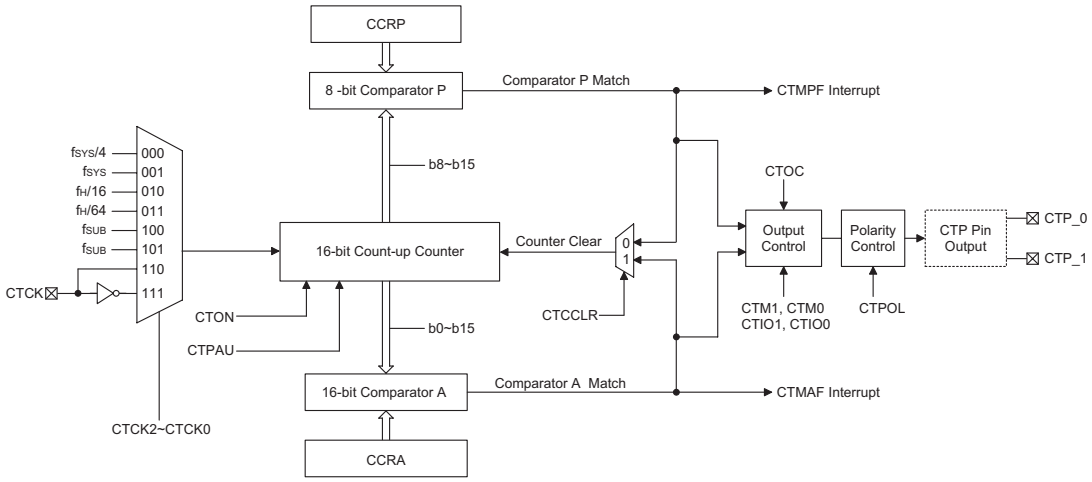


The following steps show the read and write procedures:

- Writing Data to CCRA or CCRP
  - Step 1. Write data to Low Byte xTMAL or PTMRPL
    – note that here data is only written to the 8-bit buffer.
  - Step 2. Write data to High Byte xTMAH or PTMRPH
    – here data is written directly to the high byte registers and simultaneously data is latched from the 8-bit buffer to the Low Byte registers.
- Reading Data from the Counter Registers and CCRA or CCRP
  - Step 1. Read data from the High Byte xTMDH, xTMAH or PTMRPH
    – here data is read directly from the High Byte registers and simultaneously data is latched from the Low Byte register into the 8-bit buffer.
  - Step 2. Read data from the Low Byte xTMDL, xTMAL or PTMRPL
    – this step reads data from the 8-bit buffer.

Compact Type TM – CTM

Although the simplest form of the TM types, the Compact TM type still contains three operating modes, which are Compare Match Output, Timer/Event Counter and PWM Output modes. The Compact TM can also be controlled with an external input pin and can drive two external output pins. These two external output pins can be the same signal or the inverse signal.



Compact Type TM Block Diagram

Compact TM Operation

The Compact TM core is a 16-bit count-up counter which is driven by a user selectable internal or external clock source. There are also two internal comparators with the names, Comparator A and Comparator P. These comparators will compare the value in the counter with CCRP and CCRA registers. The CCRP is eight bits wide whose value is compared with the highest eight bits in the counter while the CCRA is sixteen-bit wide and therefore compares with all counter bits.

The only way of changing the value of the 16-bit counter using the application program, is to clear the counter by changing the CTON bit from low to high. The counter will also be cleared automatically by a counter overflow or a compare match with one of its associated comparators. When these conditions occur, a TM interrupt signal will also usually be generated. The Compact Type TM can operate in a number of different operational modes, can be driven by different clock sources including an input pin and can also control an output pin. All operating setup conditions are selected using relevant internal registers.

Compact Type TM Register Description

Overall operation of the Compact TM is controlled using a series of registers. A read only register pair exists to store the internal counter 16-bit value, while a read/write register pair exists to store the internal 16-bit CCRA value. The CTMRP register is used to store the 8-bit CCRP bits. The remaining two registers are control registers which setup the different operating and control modes.

Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
CTMC0	CTPAU	CTCK2	CTCK1	CTCK0	CTON	—	—	—
CTMC1	CTM1	CTM0	CTIO1	CTIO0	CTOC	CTPOL	CTDPX	CTCCLR
CTMDL	D7	D6	D5	D4	D3	D2	D1	D0
CTMDH	D15	D14	D13	D12	D11	D10	D9	D8
CTMAL	D7	D6	D5	D4	D3	D2	D1	D0
CTMAH	D15	D14	D13	D12	D11	D10	D9	D8
CTMRP	CTRP7	CTRP6	CTRP5	CTRP4	CTRP3	CTRP2	CTRP1	CTRP0

16-bit Compact TM Registers List

CTMDL Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 CTM Counter Low Byte Register bit 7 ~ bit 0
CTM 16-bit Counter bit 7 ~ bit 0

CTMDH Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 CTM Counter High Byte Register bit 7 ~ bit 0
CTM 16-bit Counter bit 15 ~ bit 8

CTMAL Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 CTM CCRA Low Byte Register bit 7 ~ bit 0
CTM 16-bit CCRA bit 7 ~ bit 0

CTMAH Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 CTM CCRA High Byte Register bit 7 ~ bit 0
CTM 16-bit CCRA bit 15 ~ bit 8

CTMC0 Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	CTPAU	CTCK2	CTCK1	CTCK0	CTON	—	—	—
R/W	R/W	R/W	R/W	R/W	R/W	—	—	—
POR	0	0	0	0	0	—	—	—

Bit 7 **CTPAU**: CTM Counter Pause control
0: Run
1: Pause
The counter can be paused by setting this bit high. Clearing the bit to zero restores normal counter operation. When in a Pause condition the TM will remain powered up and continue to consume power. The counter will retain its residual value when this bit changes from low to high and resume counting from this value when the bit changes to a low value again.

Bit 6~4 **CTCK2~CTCK0**: Select CTM Counter clock
000: $f_{SYS}/4$
001: f_{SYS}
010: $f_H/16$
011: $f_H/64$
100: f_{SUB}
101: f_{SUB}
110: CTCK rising edge clock
111: CTCK falling edge clock
These three bits are used to select the clock source for the TM. The external pin clock source can be chosen to be active on the rising or falling edge. The clock source f_{SYS} is the system clock, while f_H and f_{SUB} are other internal clocks, the details of which can be found in the oscillator section.

Bit 3 **CTON**: CTM Counter On/Off control
0: Off
1: On
This bit controls the overall on/off function of the TM. Setting the bit high enables the counter to run while clearing the bit disables the TM. Clearing this bit to zero will stop the counter from counting and turn off the TM which will reduce its power consumption. When the bit changes state from low to high the internal counter value will be reset to zero, however when the bit changes from high to low, the internal counter will retain its residual value until the bit returns high again. If the TM is in the Compare Match Output Mode then the TM output pin will be reset to its initial condition, as specified by the CTOC bit, when the CTON bit changes from low to high.

Bit 2~0 Unimplemented, read as "0"

CTMC1 Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	CTM1	CTM0	CTIO1	CTIO0	CTOC	CTPOL	CTDPX	CTCCLR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **CTM1~CTM0**: Select CTM Operating Mode
00: Compare Match Output Mode
01: Undefined
10: PWM Mode
11: Timer/Counter Mode

These bits setup the required operating mode for the TM. To ensure reliable operation the TM should be switched off before any changes are made to the CTM1 and CTM0 bits. In the Timer/Counter Mode, the TM output pin control will be disabled.

Bit 5~4 **CTIO1~CTIO0**: Select CTM external pin CTP_n function

Compare Match Output Mode
00: No change
01: Output low
10: Output high
11: Toggle output

PWM Output Mode
00: PWM output inactive state
01: PWM output active state
10: PWM output
11: Undefined

Timer/Counter Mode
Unused

These two bits are used to determine how the TM output pin changes state when a certain condition is reached. The function that these bits select depends upon in which mode the TM is running.

In the Compare Match Output Mode, the CTIO1 and CTIO0 bits determine how the TM output pin changes state when a compare match occurs from the Comparator A. The TM output pin can be setup to switch high, switch low or to toggle its present state when a compare match occurs from the Comparator A. When the bits are both zero, then no change will take place on the output. The initial value of the TM output pin should be setup using the CTOC bit in the CTMC1 register. Note that the output level requested by the CTIO1 and CTIO0 bits must be different from the initial value setup using the CTOC bit otherwise no change will occur on the TM output pin when a compare match occurs. After the TM output pin changes state, it can be reset to its initial level by changing the level of the CTON bit from low to high.

In the PWM Mode, the CTIO1 and CTIO0 bits determine how the TM output pin changes state when a certain compare match condition occurs. The PWM output function is modified by changing these two bits. It is necessary to only change the values of the CTIO1 and CTIO0 bits only after the TM has been switched off. Unpredictable PWM outputs will occur if the CTIO1 and CTIO0 bits are changed when the TM is running.

Bit 3 **CTOC**: CTM CTP_n Output control

Compare Match Output Mode
0: Initial low
1: Initial high

PWM Output Mode
0: Active low
1: Active high

This is the output control bit for the TM output pin. Its operation depends upon whether TM is being used in the Compare Match Output Mode or in the PWM Mode. It has no effect if the TM is in the Timer/Counter Mode. In the Compare Match Output Mode it determines the logic level of he TM output pin before a compare match occurs. In the PWM Mode it determines if the PWM signal is active high or active low.

Bit 2 **CTPOL**: CTM CTP_n Output polarity control
0: Non-inverted
1: Inverted

This bit controls the polarity of the CTP_n output pin. When the bit is set high the TM output pin will be inverted and not inverted when the bit is zero. It has no effect if the TM is in the Timer/Counter Mode.

Bit 1 **CTDPX**: CTM PWM duty/period control
0: CCRP – period; CCRA – duty
1: CCRP – duty; CCRA – period

This bit determines which of the CCRA and CCRP registers are used for period and duty control of the PWM waveform.

Bit 0 **CTCCLR**: CTM Counter Clear condition selection
0: Comparator P match
1: Comparator A match

This bit is used to select the method which clears the counter. Remember that the Compact TM contains two comparators, Comparator A and Comparator P, either of which can be selected to clear the internal counter. With the CTCCLR bit set high, the counter will be cleared when a compare match occurs from the Comparator A. When the bit is low, the counter will be cleared when a compare match occurs from the Comparator P or with a counter overflow. A counter overflow clearing method can only be implemented if the CCRP bits are all cleared to zero. The CTCCLR bit is not used in the PWM Mode.

CTMRP Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	CTRP7	CTRP6	CTRP5	CTRP4	CTRP3	CTRP2	CTRP1	CTRP0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **CTRP7~CTRP0**: CTM CCRP 8-bit register, compared with the CTM counter bit 15~bit 8
Comparator P match period =
0: 65536 CTM clocks
1~255: (1~255) x 256 CTM clocks

These eight bits are used to setup the value on the internal CCRP 8-bit register, which are then compared with the internal counter's highest eight bits. The result of this comparison can be selected to clear the internal counter if the CTCCLR bit is set to zero. Setting the CTCCLR bit to zero ensures that a compare match with the CCRP values will reset the internal counter. As the CCRP bits are only compared with the highest eight counter bits, the compare values exist in 256 clock cycle multiples. Clearing all eight bits to zero is in effect allowing the counter to overflow at its maximum value.

Compact Type TM Operation Modes

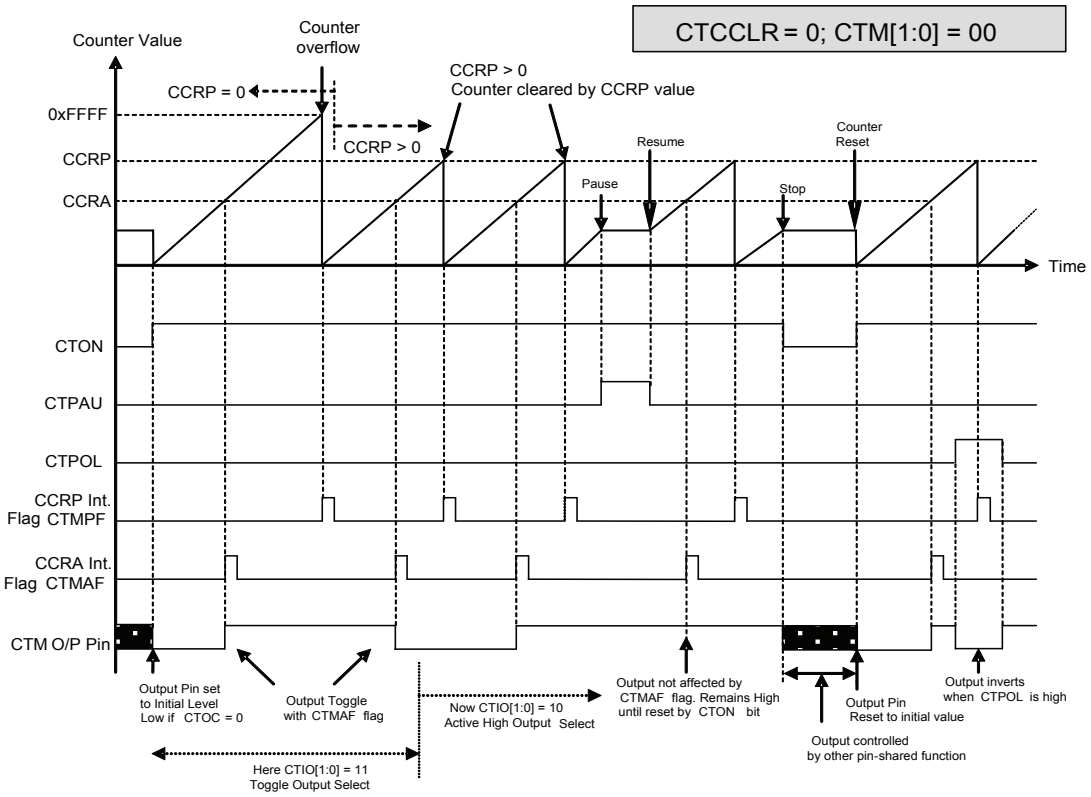
The Compact Type TM can operate in one of three operating modes, Compare Match Output Mode, PWM Mode or Timer/Counter Mode. The operating mode is selected using the CTM1 and CTM0 bits in the CTMC1 register.

Compare Match Output Mode

To select this mode, bits CTM1 and CTM0 in the CTMC1 register, should be set to "00" respectively. In this mode once the counter is enabled and running it can be cleared by three methods. These are a counter overflow, a compare match from Comparator A and a compare match from Comparator P. When the CTCCLR bit is low, there are two ways in which the counter can be cleared. One is when a compare match occurs from Comparator P, the other is when the CCRP bits are all zero which allows the counter to overflow. Here both CTMAF and CTMPF interrupt request flags for the Comparator A and Comparator P respectively, will both be generated.

If the CTCCLR bit in the CTMC1 register is high then the counter will be cleared when a compare match occurs from Comparator A. However, here only the CTMAF interrupt request flag will be generated even if the value of the CCRP bits is less than that of the CCRA registers. Therefore when CTCCLR is high no CTMPF interrupt request flag will be generated. If the CCRA bits are all zero, the counter will overflow when its reaches its maximum 16-bit, FFFF Hex, value, however here the CTMAF interrupt request flag will not be generated.

As the name of the mode suggests, after a comparison is made, the TM output pin will change state. The TM output pin condition however only changes state when a CTMAF interrupt request flag is generated after a compare match occurs from Comparator A. The CTMPF interrupt request flag, generated from a compare match occurs from Comparator P, will have no effect on the TM output pin. The way in which the TM output pin changes state are determined by the condition of the CTIO1 and CTIO0 bits in the CTMC1 register. The TM output pin can be selected using the CTIO1 and CTIO0 bits to go high, to go low or to toggle from its present condition when a compare match occurs from Comparator A. The initial condition of the TM output pin, which is setup after the CTON bit changes from low to high, is setup using the CTOC bit. Note that if the CTIO1 and CTIO0 bits are zero then no pin change will take place.

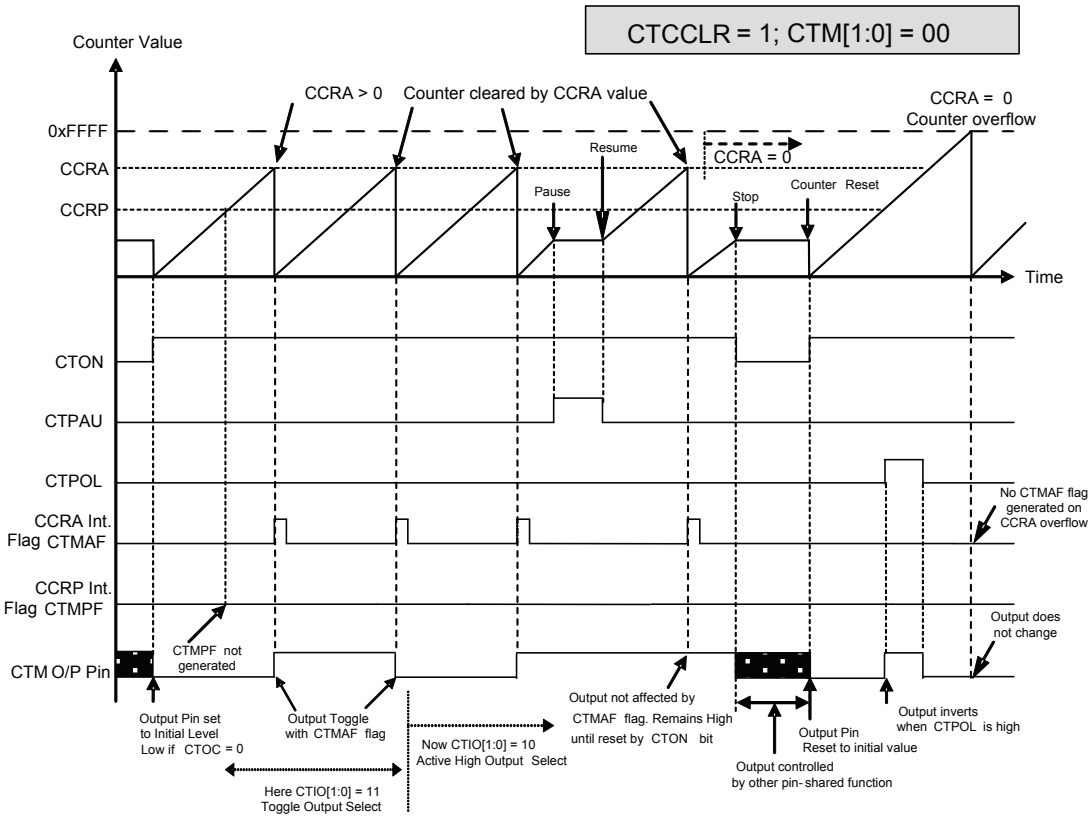


Compare Match Output Mode – CTCCLR=0

Note: 1. With CTCCLR = 0 a Comparator P match will clear the counter

2. The TM output pin controlled only by CTMAF flag

3. The output pin is reset to its initial state by CTON bit rising edge



Compare Match Output Mode – CTCCLR=1

Note: 1. With CTCCLR = 1, a Comparator A match will clear the counter

2. The TM output pin is controlled only by CTMAF flag

3. The TM output pin is reset to initial state by CTON rising edge

4. The CTMPF flags is not generated when CTCCLR = 1

Timer/Counter Mode

To select this mode, bits CTM1 and CTM0 in the CTMC1 register should be set to 11 respectively. The Timer/Counter Mode operates in an identical way to the Compare Match Output Mode generating the same interrupt flags. The exception is that in the Timer/Counter Mode the TM output pin is not used. Therefore the above description and Timing Diagrams for the Compare Match Output Mode can be used to understand its function. As the TM output pin is not used in this mode, the pin can be used as a normal I/O pin or other pin-shared function.

PWM Output Mode

To select this mode, bits CTM1 and CTM0 in the CTMC1 register should be set to 10 respectively. The PWM function within the TM is useful for applications which require functions such as motor control, heating control, illumination control etc. By providing a signal of fixed frequency but of varying duty cycle on the TM output pin, a square wave AC waveform can be generated with varying equivalent DC RMS values.

As both the period and duty cycle of the PWM waveform can be controlled, the choice of generated waveform is extremely flexible. In the PWM mode, the CTCCLR bit has no effect on the PWM operation. Both of the CCRA and CCRP registers are used to generate the PWM waveform, one register is used to clear the internal counter and thus control the PWM waveform frequency, while the other one is used to control the duty cycle. Which register is used to control either frequency or duty cycle is determined using the CTDPX bit in the CTMC1 register. The PWM waveform frequency and duty cycle can therefore be controlled by the values in the CCRA and CCRP registers.

An interrupt flag, one for each of the CCRA and CCRP, will be generated when a compare match occurs from either Comparator A or Comparator P. The CTOC bit in the CTMC1 register is used to select the required polarity of the PWM waveform while the two CTIO1 and CTIO0 bits are used to enable the PWM output or to force the TM output pin to a fixed high or low level. The CTPOL bit is used to reverse the polarity of the PWM output waveform.

16-bit CTM, PWM Mode, Edge-aligned Mode, CTDPX=0

CCRP	1~255	0
Period	CCRPx256	65536
Duty	CCRA	

If f_{SYS} = 16MHz, TM clock source is $f_{SYS}/4$, CCRP = 2 and CCRA = 128,

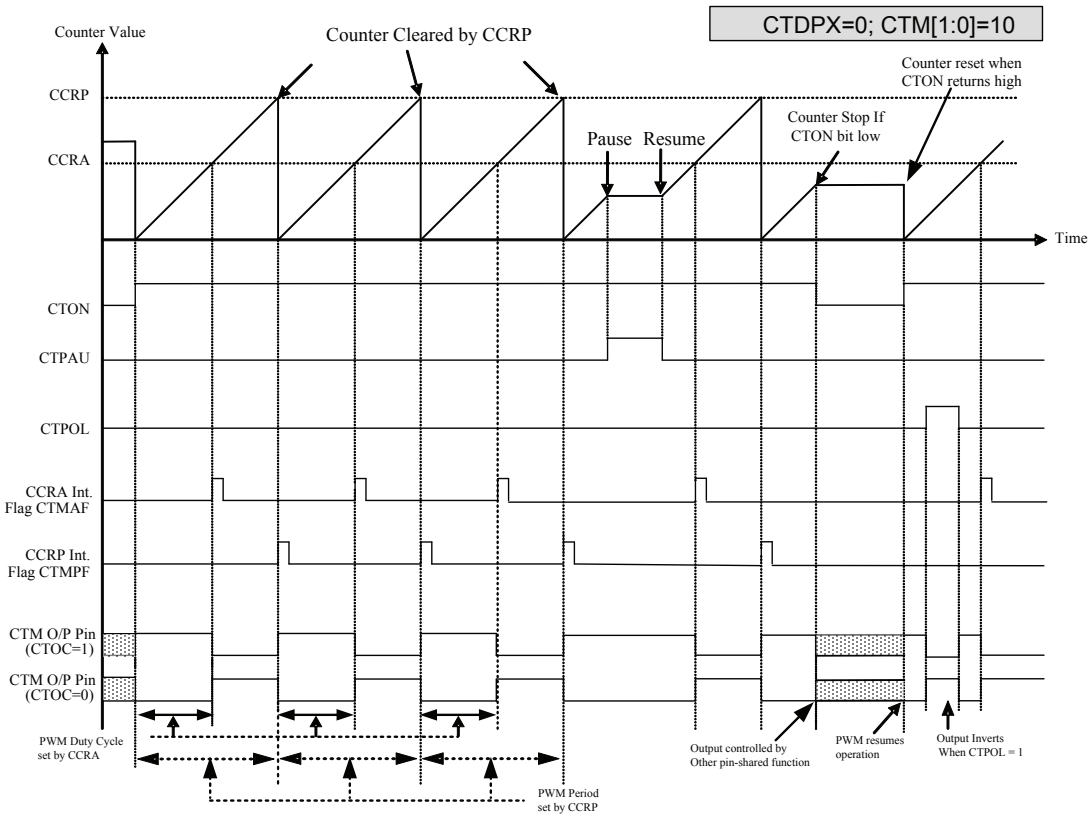
The CTM PWM output frequency = ($f_{SYS}/4$) / (2x256) = $f_{SYS}/2048$ = 7.8125 kHz, duty = 128/(2x256)= 25%.

If the Duty value defined by the CCRA register is equal to or greater than the Period value, then the PWM output duty is 100%.

16-bit CTM, PWM Mode, Edge-aligned Mode, CTDPX=1

CCRP	1~255	0
Period	CCRA	CCRA
Duty	CCRPx256	65536

The PWM output period is determined by the CCRA register value together with the TM clock while the PWM duty cycle is defined by the CCRP register value except when the CCRP value is equal to 0.



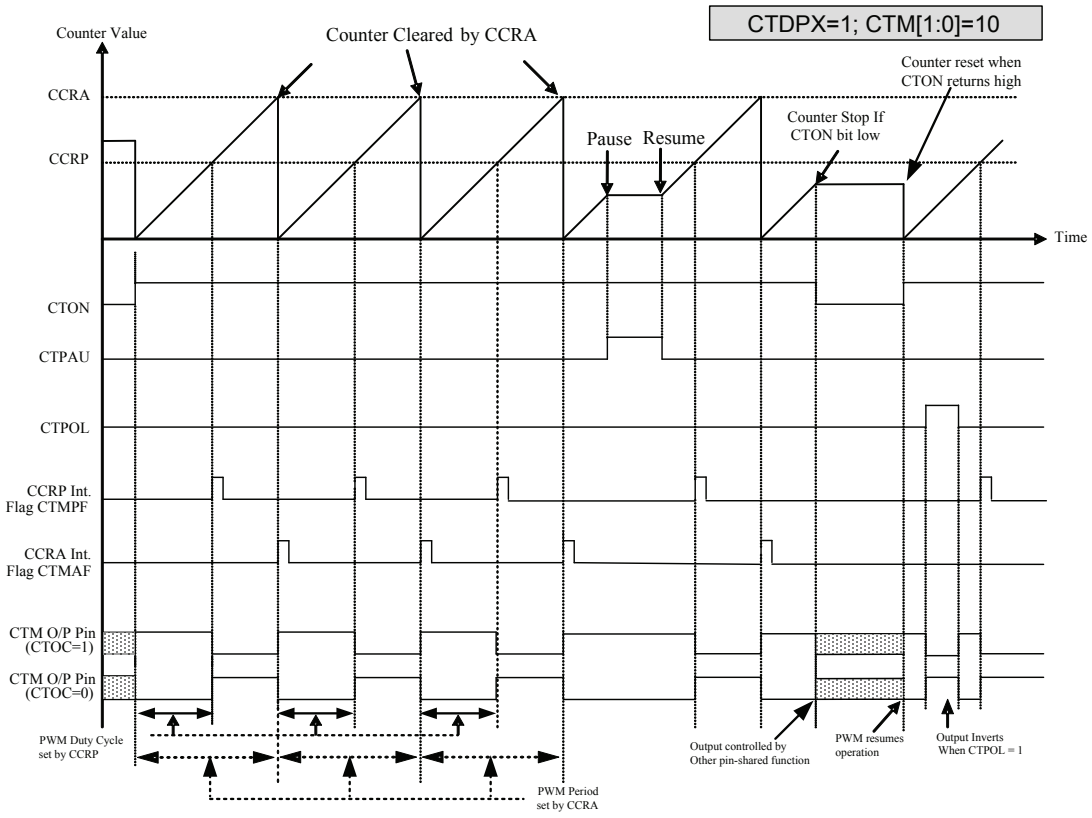
PWM Mode – CTDPX=0

Note: 1. Here CTDPX = 0 - Counter cleared by CCRP

2. A counter clear sets PWM Period

3. The internal PWM function continues even when CTIO1, CTIO0 = 00 or 01

4. The CTCCLR bit has no influence on PWM operation



PWM Mode – CTDPX=1

Note: 1. Here CTDPX = 1 – Counter cleared by CCRA

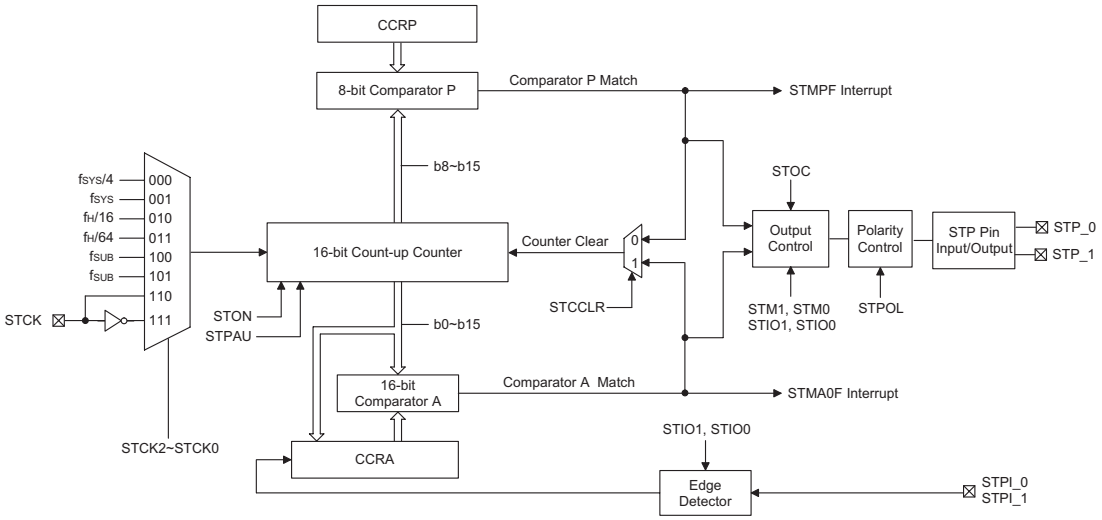
2. A counter clear sets PWM Period

3. The internal PWM function continues even when CTIO [1:0] = 00 or 01

4. The CTCCLR bit has no influence on PWM operation

Standard Type TM – STM

The Standard Type TM contains five operating modes, which are Compare Match Output, Timer/ Event Counter, Capture Input, Single Pulse Output and PWM Output modes. The Standard TM can also be controlled with two external input pin and can drive two external output pins.



Standard Type TM Block Diagram

Standard TM Operation

The size of Standard TM is 16-bit wide and its core is a 16-bit count-up counter which is driven by a user selectable internal or external clock source. There are also two internal comparators with the names, Comparator A and Comparator P. These comparators will compare the value in the counter with CCRP and CCRA registers. The CCRP comparator is 8-bit wide whose value is compared the with highest 8 bits in the counter while the CCRA is the sixteen bits and therefore compares all counter bits.

The only way of changing the value of the 16-bit counter using the application program, is to clear the counter by changing the STON bit from low to high. The counter will also be cleared automatically by a counter overflow or a compare match with one of its associated comparators. When these conditions occur, a TM interrupt signal will also usually be generated. The Standard Type TM can operate in a number of different operational modes, can be driven by different clock sources including an input pin and can also control an output pin. All operating setup conditions are selected using relevant internal registers.

Standard Type TM Register Description

Overall operation of the Standard TM is controlled using a series of registers. A read only register pair exists to store the internal counter 16-bit value, while a read/write register pair exists to store the internal 16-bit CCRA value. The STMRP register is used to store the 8-bit CCRP bits. The remaining two registers are control registers which setup the different operating and control modes.

Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
STMC0	STPAU	STCK2	STCK1	STCK0	STON	—	—	—
STMC1	STM1	STM0	STIO1	STIO0	STOC	STPOL	STDPX	STCCLR
STMDL	D7	D6	D5	D4	D3	D2	D1	D0
STMDH	D15	D14	D13	D12	D11	D10	D9	D8
STMAL	D7	D6	D5	D4	D3	D2	D1	D0
STMAH	D15	D14	D13	D12	D11	D10	D9	D8
STMRP	STRP7	STRP6	STRP5	STRP4	STRP3	STRP2	STRP1	STRP0

16-bit Standard TM Registers List

STMDL Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 STM Counter Low Byte Register bit 7 ~ bit 0
STM 16-bit Counter bit 7 ~ bit 0

STMDH Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 STM Counter High Byte Register bit 7 ~ bit 0
STM 16-bit Counter bit 15 ~ bit 8

STMAL Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 STM CCRA Low Byte Register bit 7 ~ bit 0
STM 16-bit CCRA bit 7 ~ bit 0

STMAH Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 STM CCRA High Byte Register bit 7 ~ bit 0
STM 16-bit CCRA bit 15 ~ bit 8

STMC0 Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	STPAU	STCK2	STCK1	STCK0	STON	—	—	—
R/W	R/W	R/W	R/W	R/W	R/W	—	—	—
POR	0	0	0	0	0	—	—	—

Bit 7 **STPAU**: STM Counter Pause control
0: Run
1: Pause
The counter can be paused by setting this bit high. Clearing the bit to zero restores normal counter operation. When in a Pause condition the TM will remain powered up and continue to consume power. The counter will retain its residual value when this bit changes from low to high and resume counting from this value when the bit changes to a low value again.

Bit 6~4 **STCK2~STCK0**: Select STM Counter clock
000: $f_{SYS}/4$
001: f_{SYS}
010: $f_H/16$
011: $f_H/64$
100: f_{SUB}
101: f_{SUB}
110: STCK rising edge clock
111: STCK falling edge clock
These three bits are used to select the clock source for the TM. The external pin clock source can be chosen to be active on the rising or falling edge. The clock source f_{SYS} is the system clock, while f_H and f_{SUB} are other internal clocks, the details of which can be found in the oscillator section.

Bit 3 **STON**: STM Counter On/Off control
0: Off
1: On
This bit controls the overall on/off function of the TM. Setting the bit high enables the counter to run while clearing the bit disables the TM. Clearing this bit to zero will stop the counter from counting and turn off the TM which will reduce its power consumption. When the bit changes state from low to high the internal counter value will be reset to zero, however when the bit changes from high to low, the internal counter will retain its residual value until the bit returns high again. If the TM is in the Compare Match Output Mode then the TM output pin will be reset to its initial condition, as specified by the STOC bit, when the STON bit changes from low to high.

Bit 2~0 Unimplemented, read as "0"

STMC1 Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	STM1	STM0	STIO1	STIO0	STOC	STPOL	STDPX	STCCLR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **STM1~STM0**: Select STM Operating Mode
00: Compare Match Output Mode
01: Capture Input Mode
10: PWM Mode or Single Pulse Output Mode
11: Timer/Counter Mode

These bits setup the required operating mode for the TM. To ensure reliable operation the TM should be switched off before any changes are made to the STM1 and STM0 bits. In the Timer/Counter Mode, the TM output pin control will be disabled.

Bit 5~4 **STIO1~STIO0**: Select STM external pin STP_n or STPI_n function

Compare Match Output Mode
00: No change
01: Output low
10: Output high
11: Toggle output

PWM Output Mode/Single Pulse Output Mode
00: PWM output inactive state
01: PWM output active state
10: PWM output
11: Single Pulse Output

Capture Input Mode
00: Input capture at rising edge of STPI_n
01: Input capture at falling edge of STPI_n
10: Input capture at rising/falling edge of STPI_n
11: Input capture disabled

Timer/Counter Mode
Unused

These two bits are used to determine how the TM output pin changes state when a certain condition is reached. The function that these bits select depends upon in which mode the TM is running.

In the Compare Match Output Mode, the STIO1 and STIO0 bits determine how the TM output pin changes state when a compare match occurs from the Comparator A. The TM output pin can be setup to switch high, switch low or to toggle its present state when a compare match occurs from the Comparator A. When the bits are both zero, then no change will take place on the output. The initial value of the TM output pin should be setup using the STOC bit in the STMC1 register. Note that the output level requested by the STIO1 and STIO0 bits must be different from the initial value setup using the STOC bit otherwise no change will occur on the TM output pin when a compare match occurs. After the TM output pin changes state, it can be reset to its initial level by changing the level of the STON bit from low to high.

In the PWM Mode, the STIO1 and STIO0 bits determine how the TM output pin changes state when a certain compare match condition occurs. The PWM output function is modified by changing these two bits. It is necessary to only change the values of the STIO1 and STIO0 bits only after the TM has been switched off. Unpredictable PWM outputs will occur if the STIO1 and STIO0 bits are changed when the TM is running.

Bit 3 **STOC**: STM STP_n Output control

Compare Match Output Mode
0: Initial low
1: Initial high

PWM Output Mode/Single Pulse Output Mode
0: Active low
1: Active high

This is the output control bit for the TM output pin. Its operation depends upon whether TM is being used in the Compare Match Output Mode or in the PWM Mode/ Single Pulse Output Mode. It has no effect if the TM is in the Timer/Counter Mode. In the Compare Match Output Mode it determines the logic level of he TM output pin before a compare match occurs. In the PWM Mode/Single Pulse Output Mode it determines if the PWM signal is active high or active low.

Bit 2 **STPOL**: STM STP_n Output polarity control
0: Non-inverted
1: Inverted

This bit controls the polarity of the STP_n output pin. When the bit is set high the TM output pin will be inverted and not inverted when the bit is zero. It has no effect if the TM is in the Timer/Counter Mode.

Bit 1 **STDPX**: STM PWM duty/period control
0: CCRP – period; CCRA – duty
1: CCRP – duty; CCRA – period

This bit determines which of the CCRA and CCRP registers are used for period and duty control of the PWM waveform.

Bit 0 **STCCLR**: STM Counter Clear condition selection
0: Comparator P match
1: Comparator A match

This bit is used to select the method which clears the counter. Remember that the Compact TM contains two comparators, Comparator A and Comparator P, either of which can be selected to clear the internal counter. With the STCCLR bit set high, the counter will be cleared when a compare match occurs from the Comparator A. When the bit is low, the counter will be cleared when a compare match occurs from the Comparator P or with a counter overflow. A counter overflow clearing method can only be implemented if the CCRP bits are all cleared to zero. The STCCLR bit is not used in the PWM Output, Single Pulse Output or Capture Input Mode.

STMRP Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	STRP7	STRP6	STRP5	STRP4	STRP3	STRP2	STRP1	STRP0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **STRP7~STRP0**: STM CCRP 8-bit register, compared with the STM counter bit 15~bit 8
Comparator P match period =
0: 65536 STM clocks
1~255: (1~255) x 256 STM clocks

These eight bits are used to setup the value on the internal CCRP 8-bit register, which are then compared with the internal counter's highest eight bits. The result of this comparison can be selected to clear the internal counter if the STCCLR bit is set to zero. Setting the STCCLR bit to zero ensures that a compare match with the CCRP values will reset the internal counter. As the CCRP bits are only compared with the highest eight counter bits, the compare values exist in 256 clock cycle multiples. Clearing all eight bits to zero is in effect allowing the counter to overflow at its maximum value.

Standard Type TM Operation Modes

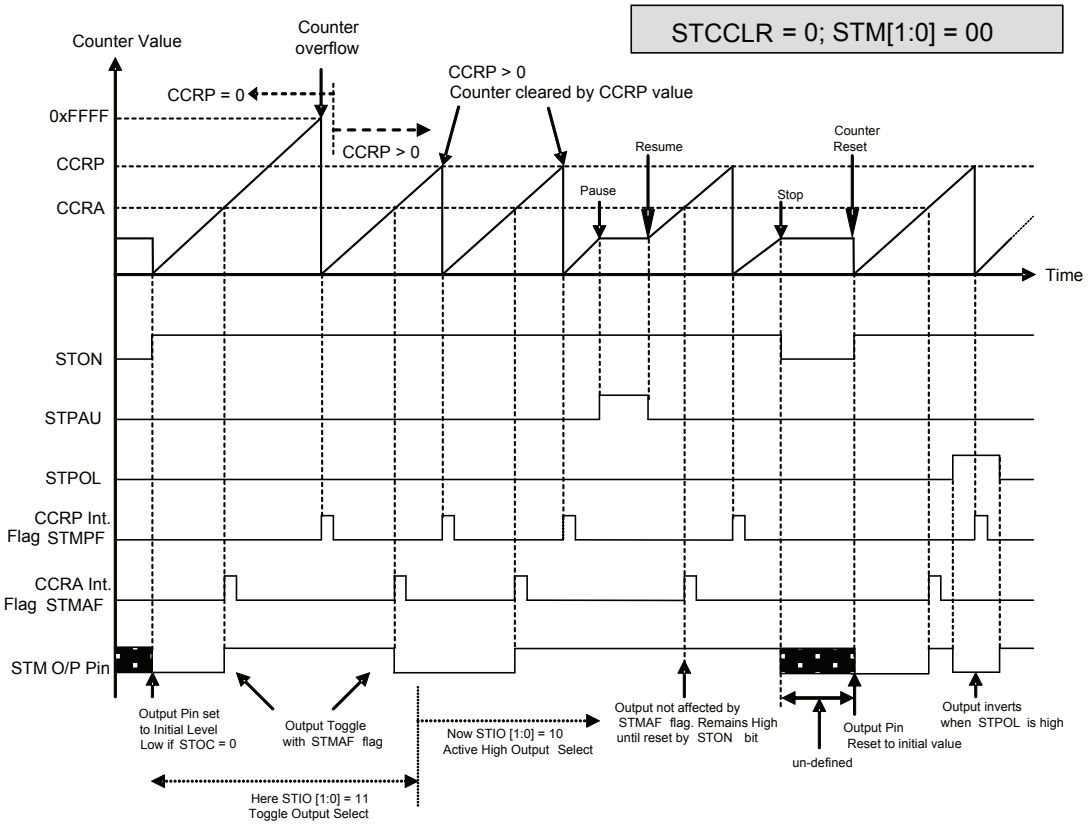
The Standard Type TM can operate in one of five operating modes, Compare Match Output Mode, PWM Output Mode, Single Pulse Output Mode, Capture Input Mode or Timer/Counter Mode. The operating mode is selected using the STM1 and STM0 bits in the STMC1 register.

Compare Match Output Mode

To select this mode, bits STM1 and STM0 in the STMC1 register, should be set to 00 respectively. In this mode once the counter is enabled and running it can be cleared by three methods. These are a counter overflow, a compare match from Comparator A and a compare match from Comparator P. When the STCCLR bit is low, there are two ways in which the counter can be cleared. One is when a compare match from Comparator P, the other is when the CCRP bits are all zero which allows the counter to overflow. Here both STMAF and STMPF interrupt request flags for Comparator A and Comparator P respectively, will both be generated.

If the STCCLR bit in the STMC1 register is high then the counter will be cleared when a compare match occurs from Comparator A. However, here only the STMAF interrupt request flag will be generated even if the value of the CCRP bits is less than that of the CCRA registers. Therefore when STCCLR is high no STMPF interrupt request flag will be generated. In the Compare Match Output Mode, the CCRA can not be set to "0".

As the name of the mode suggests, after a comparison is made, the TM output pin, will change state. The TM output pin condition however only changes state when a STMAF interrupt request flag is generated after a compare match occurs from Comparator A. The STMPF interrupt request flag, generated from a compare match occurs from Comparator P, will have no effect on the TM output pin. The way in which the TM output pin changes state are determined by the condition of the STIO1 and STIO0 bits in the STMC1 register. The TM output pin can be selected using the STIO1 and STIO0 bits to go high, to go low or to toggle from its present condition when a compare match occurs from Comparator A. The initial condition of the TM output pin, which is setup after the STON bit changes from low to high, is setup using the STOC bit. Note that if the STIO1 and STIO0 bits are zero then no pin change will take place.

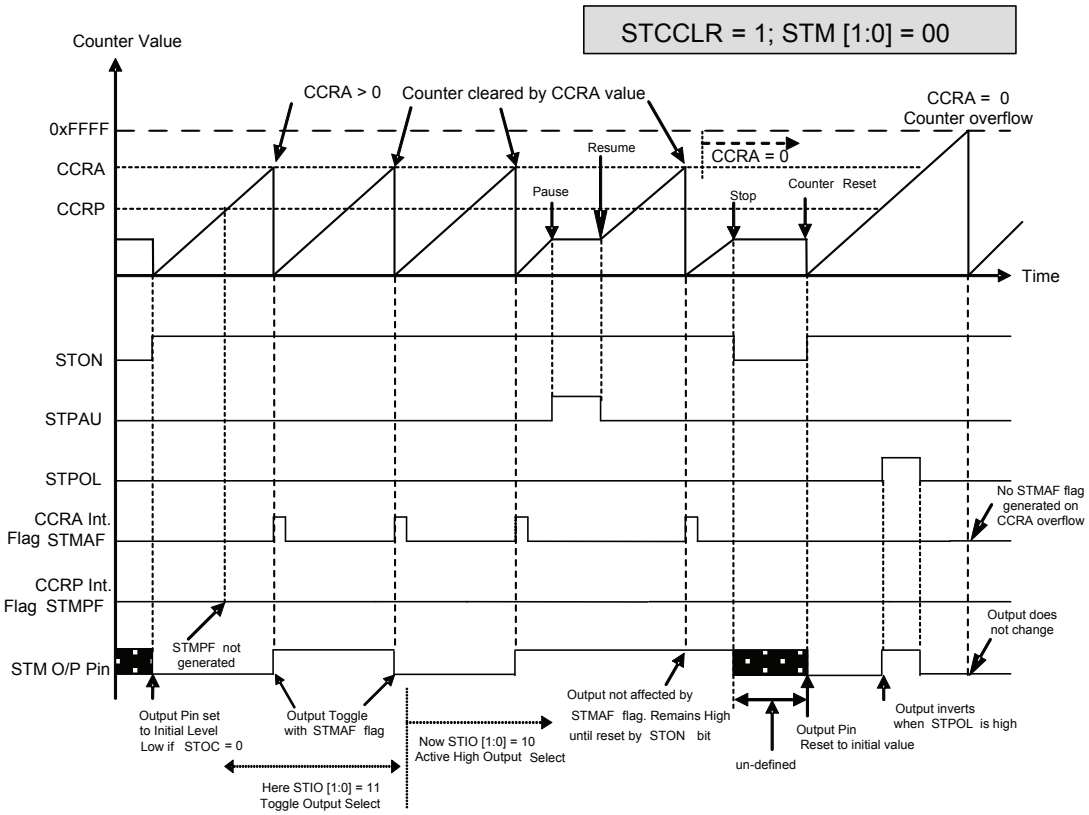


Compare Match Output Mode – STCCLR=0

Note: 1. With STCCLR=0 a Comparator P match will clear the counter

2. The STM output pin is controlled only by the STMAF flag

3. The output pin is reset to itsinitial state by a STON bit rising edge



Compare Match Output Mode – STCCLR=1

Note: 1. With STCCLR=1 a Comparator A match will clear the counter

2. The STM output pin is controlled only by the STMAF flag

3. The output pin is reset to its initial state by a STON bit rising edge

4. A STMPF flag is not generated when STCCLR=1

Timer/Counter Mode

To select this mode, bits STM1 and STM0 in the STMC1 register should be set to 11 respectively. The Timer/Counter Mode operates in an identical way to the Compare Match Output Mode generating the same interrupt flags. The exception is that in the Timer/Counter Mode the TM output pin is not used. Therefore the above description and Timing Diagrams for the Compare Match Output Mode can be used to understand its function. As the TM output pin is not used in this mode, the pin can be used as a normal I/O pin or other pin-shared function.

PWM Output Mode

To select this mode, bits STM1 and STM0 in the STMC1 register should be set to 10 respectively and also the STIO1 and STIO0 bits should be set to 10 respectively. The PWM function within the TM is useful for applications which require functions such as motor control, heating control, illumination control etc. By providing a signal of fixed frequency but of varying duty cycle on the TM output pin, a square wave AC waveform can be generated with varying equivalent DC RMS values.

As both the period and duty cycle of the PWM waveform can be controlled, the choice of generated waveform is extremely flexible. In the PWM mode, the STCCLR bit has no effect as the PWM period. Both of the CCRA and CCRP registers are used to generate the PWM waveform, one register is used to clear the internal counter and thus control the PWM waveform frequency, while the other one is used to control the duty cycle. Which register is used to control either frequency or duty cycle is determined using the STDPX bit in the STMC1 register. The PWM waveform frequency and duty cycle can therefore be controlled by the values in the CCRA and CCRP registers.

An interrupt flag, one for each of the CCRA and CCRP, will be generated when a compare match occurs from either Comparator A or Comparator P. The STOC bit in the STMC1 register is used to select the required polarity of the PWM waveform while the two STIO1 and STIO0 bits are used to enable the PWM output or to force the TM output pin to a fixed high or low level. The STPOL bit is used to reverse the polarity of the PWM output waveform.

16-bit STM, PWM Mode, Edge-aligned Mode, STDPX=0

CCRP	1~255	0
Period	CCRPx256	65536
Duty	CCRA	

If f_{SYS} = 16MHz, TM clock source is $f_{SYS}/4$, CCRP = 2 and CCRA = 128,

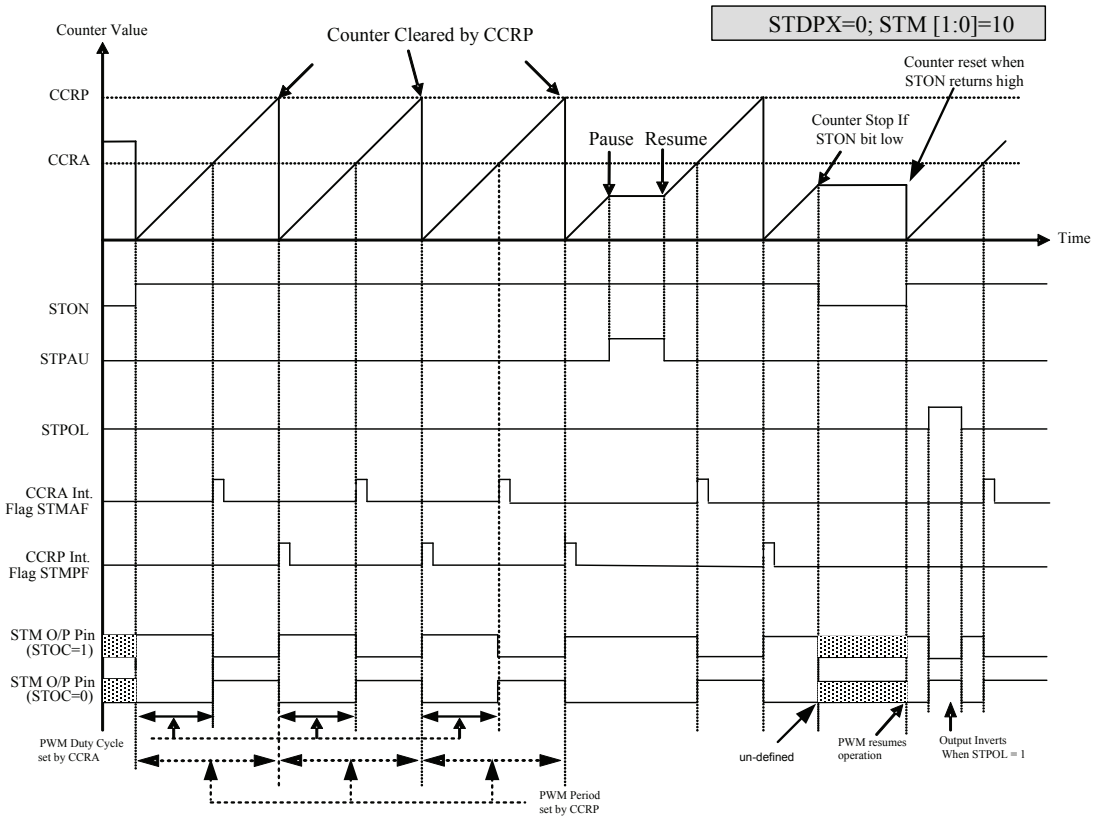
The STM PWM output frequency = $(f_{SYS}/4) / (2x256) = f_{SYS}/2048$ = 7.8125 kHz, duty = 128/(2x256)= 25%.

If the Duty value defined by the CCRA register is equal to or greater than the Period value, then the PWM output duty is 100%.

16-bit STM, PWM Mode, Edge-aligned Mode, STDPX=1

CCRP	1~255	0
Period	CCRA	CCRA
Duty	CCRPx256	65536

The PWM output period is determined by the CCRA register value together with the TM clock while the PWM duty cycle is defined by the CCRP register value except when the CCRP value is equal to 0.



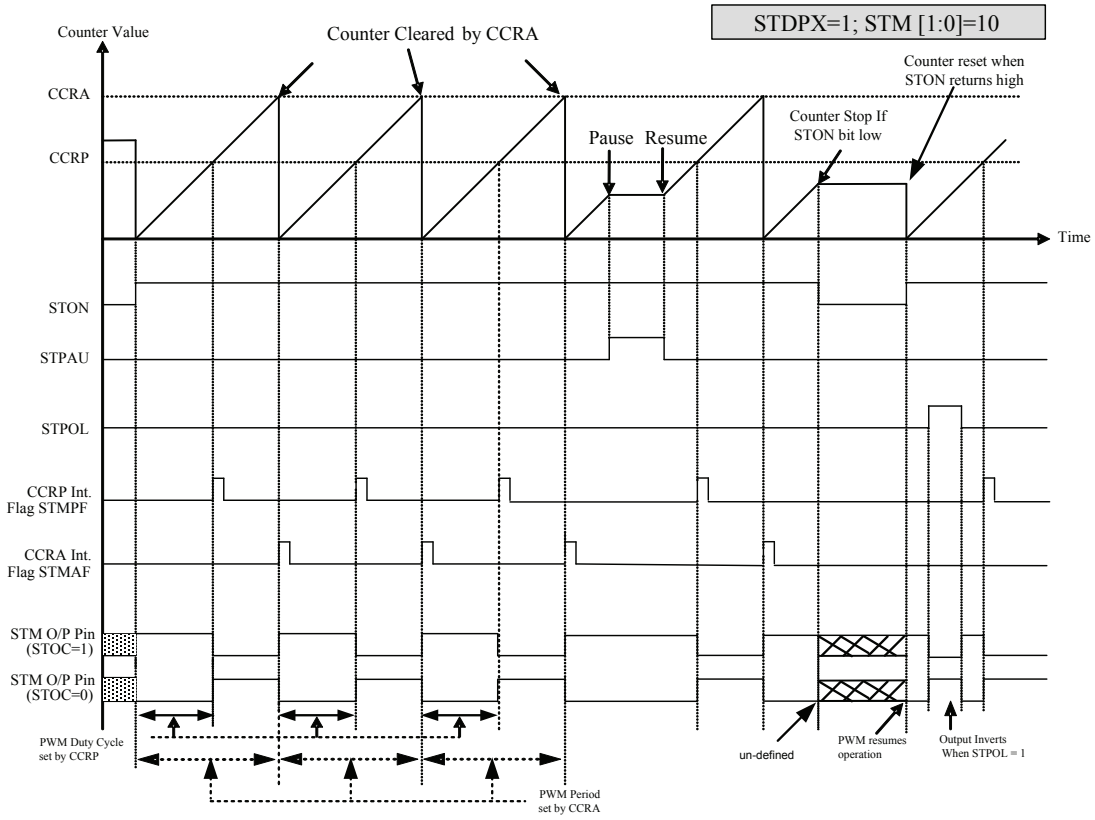
PWM Mode – STDPX = 0

Note: 1. Here STDPX=0 – Counter cleared by CCRP

2. A counter clear sets the PWM Period

3. The internal PWM function continues running even when STIO [1:0] = 00 or 01

4. The STCCLR bit has no influence on PWM operation



PWM Mode – STDPX = 1

Note: 1. Here STDPX=1 – Counter cleared by CCRA

2. A counter clear sets the PWM Period

3. The internal PWM function continues even when STIO [1:0] = 00 or 01

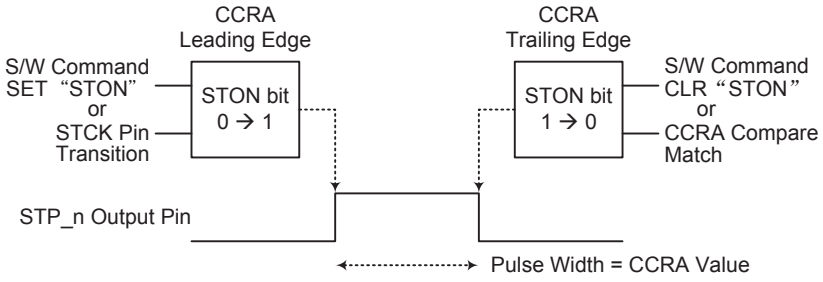
4. The STCCLR bit has no influence on PWM operation

Single Pulse Output Mode

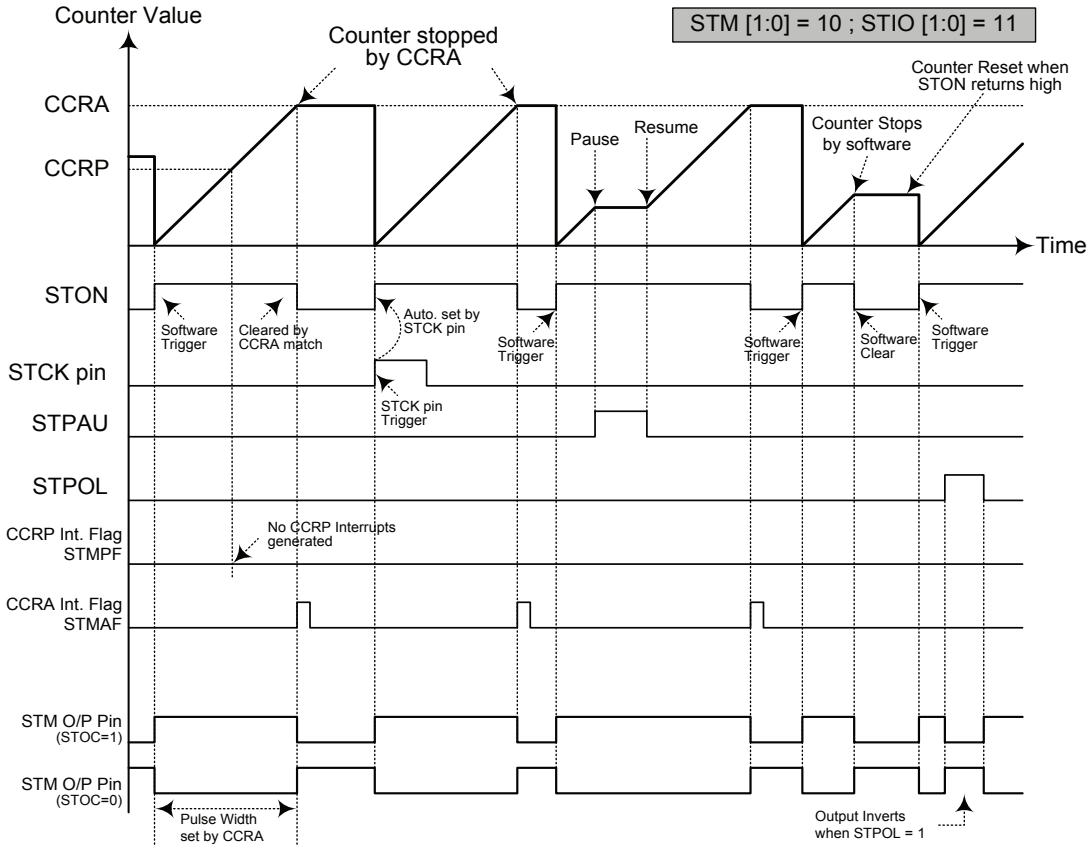
To select this mode, bits STM1 and STM0 in the STMC1 register should be set to 10 respectively and also the STIO1 and STIO0 bits should be set to 11 respectively. The Single Pulse Output Mode, as the name suggests, will generate a single shot pulse on the TM output pin.

The trigger for the pulse output leading edge is a low to high transition of the STON bit, which can be implemented using the application program. However in the Single Pulse Mode, the STON bit can also be made to automatically change from low to high using the external STCK pin, which will in turn initiate the Single Pulse output. When the STON bit transitions to a high level, the counter will start running and the pulse leading edge will be generated. The STON bit should remain high when the pulse is in its active state. The generated pulse trailing edge will be generated when the STON bit is cleared to zero, which can be implemented using the application program or when a compare match occurs from Comparator A.

However a compare match from Comparator A will also automatically clear the STON bit and thus generate the Single Pulse output trailing edge. In this way the CCRA value can be used to control the pulse width. A compare match from Comparator A will also generate a TM interrupt. The counter can only be reset back to zero when the STON bit changes from low to high when the counter restarts. In the Single Pulse Mode CCRP is not used. The STCCLR and STDPX bits are not used in this Mode.



Single Pulse Generation



Single Pulse Mode

Note: 1. Counter stopped by CCRA

2. CCRP is not used

3. The pulse triggered by the STCK pin or by setting the STON bit high

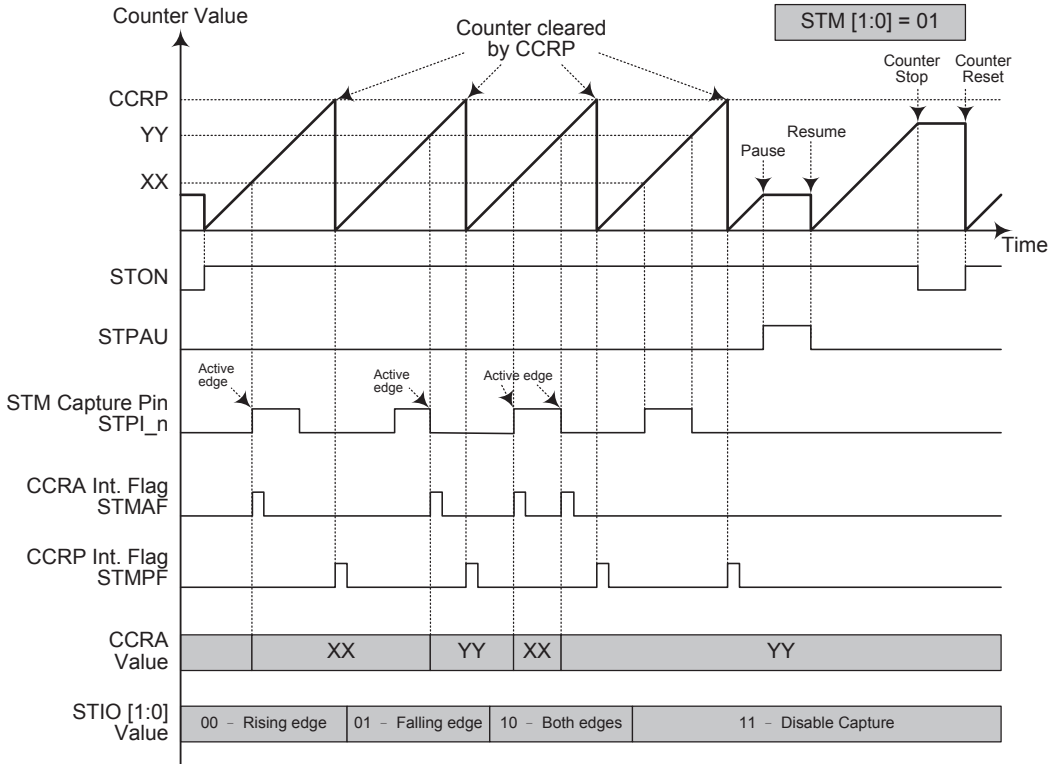
4. A STCK pin active edge will automatically set the STON bit high.

5. In the Single Pulse Mode, STIO [1:0] must be set to "11" and can not be changed.

Capture Input Mode

To select this mode bits STM1 and STM0 in the STMC1 register should be set to 01 respectively. This mode enables external signals to capture and store the present value of the internal counter and can therefore be used for applications such as pulse width measurements. The external signal is supplied on the STPI_n pin, whose active edge can be a rising edge, a falling edge or both rising and falling edges; the active edge transition type is selected using the STIO1 and STIO0 bits in the STMC1 register. The counter is started when the STON bit changes from low to high which is initiated using the application program.

When the required edge transition appears on the STPI_n pin the present value in the counter will be latched into the CCRA registers and a TM interrupt generated. Irrespective of what events occur on the STPI_n pin the counter will continue to free run until the STON bit changes from high to low. When a CCRP compare match occurs the counter will reset back to zero; in this way the CCRP value can be used to control the maximum counter value. When a CCRP compare match occurs from Comparator P, a TM interrupt will also be generated. Counting the number of overflow interrupt signals from the CCRP can be a useful method in measuring long pulse widths. The STIO1 and STIO0 bits can select the active trigger edge on the STPI_n pin to be a rising edge, falling edge or both edge types. If the STIO1 and STIO0 bits are both set high, then no capture operation will take place irrespective of what happens on the STPI_n pin, however it must be noted that the counter will continue to run. The STCCLR and STDPX bits are not used in this Mode.

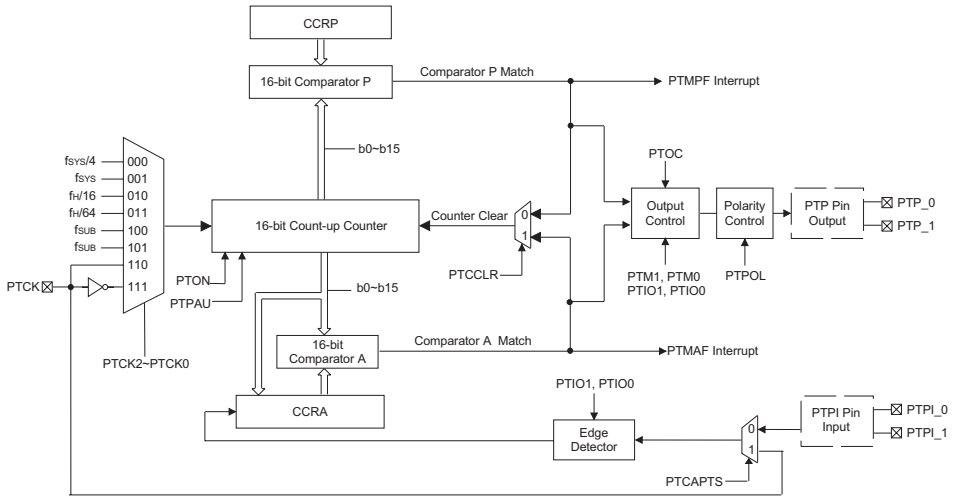


Capture Input Mode

Note: 1. STM [1:0] = 01 and active edge set by the STIO [1:0] bits
2. A TM Capture input pin active edge transfers the counter value to CCRA
3. STCCLR bit not used
4. No output function -- STOC and STPOL bits are not used
5. CCRP determines the counter value and the counter has a maximum count value when CCRP is equal to zero.

Periodic Type TM – PTM

The Periodic Type TM contains five operating modes, which are Compare Match Output, Timer/ Event Counter, Capture Input, Single Pulse Output and PWM Output modes. The Periodic TM can also be controlled with three external input pins and can drive two external output pins.



Periodic Type TM Block Diagram

Periodic TM Operation

The size of Periodic TM is 16-bit wide and its core is a 16-bit count-up counter which is driven by a user selectable internal or external clock source. There are also two internal comparators with the names, Comparator A and Comparator P. These comparators will compare the value in the counter with CCRP and CCRA registers. The CCRP or CCRA comparator is 16-bit wide whose value is compared with all counter bits.

The only way of changing the value of the 16-bit counter using the application program is to clear the counter by changing the PTON bit from low to high. The counter will also be cleared automatically by a counter overflow or a compare match with one of its associated comparators. When these conditions occur, a TM interrupt signal will also usually be generated. The Periodic Type TM can operate in a number of different operational modes, can be driven by different clock sources including an input pin and can also control the output pins. All operating setup conditions are selected using relevant internal registers.

Periodic Type TM Register Description

Overall operation of the Periodic TM is controlled using a series of registers. A read only register pair exists to store the internal counter 16-bit value, while two read/write register pairs exist to store the internal 16-bit CCRA and CCRP value. The remaining two registers are control registers which setup the different operating and control modes.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PTMC0	PTPAU	PTCK2	PTCK1	PTCK0	PTON	—	—	—
PTMC1	PTM1	PTM0	PTIO1	PTIO0	PTOC	PTPOL	PTCAPTS	PTCCLR
PTMDL	D7	D6	D5	D4	D3	D2	D1	D0
PTMDH	D15	D14	D13	D12	D11	D10	D9	D8
PTMAL	D7	D6	D5	D4	D3	D2	D1	D0
PTMAH	D15	D14	D13	D12	D11	D10	D9	D8
PTMRPL	PTRP7	PTRP6	PTRP5	PTRP4	PTRP3	PTRP2	PTRP1	PTRP0
PTMRPH	PTRP15	PTRP14	PTRP13	PTRP12	PTRP11	PTRP10	PTRP9	PTRP8

Periodic TM Registers List

PTMDL Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 PTM Counter Low Byte Register bit 7 ~ bit 0
PTM 16-bit Counter bit 7 ~ bit 0

PTMDH Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 PTM Counter High Byte Register bit 7 ~ bit 0
PTM 16-bit Counter bit 15 ~ bit 8

PTMAL Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 PTM CCRA Low Byte Register bit 7 ~ bit 0
PTM 16-bit CCRA bit 7 ~ bit 0

PTMAH Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 PTM CCRA High Byte Register bit 7 ~ bit 0
PTM 16-bit CCRA bit 15 ~ bit 8

PTMRPL Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PTRP7	PTRP6	PTRP5	PTRP4	PTRP3	PTRP2	PTRP1	PTRP0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 PTRP7~PTRP0: PTM CCRP Low Byte Register bit 7 ~ bit 0
PTM 16-bit CCRP bit 7 ~ bit 0

PTMRPH Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PTRP15	PTRP14	PTRP13	PTRP12	PTRP11	PTRP10	PTRP9	PTRP8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 PTRP15~PTRP8: PTM CCRP High Byte Register bit 7 ~ bit 0
PTM 16-bit CCRP bit 15 ~ bit 8

PTMC0 Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PTPAU	PTCK2	PTCK1	PTCK0	PTON	—	—	—
R/W	R/W	R/W	R/W	R/W	R/W	—	—	—
POR	0	0	0	0	0	—	—	—

Bit 7 **PTPAU**: PTM Counter Pause control
0: Run
1: Pause
The counter can be paused by setting this bit high. Clearing the bit to zero restores normal counter operation. When in a Pause condition the TM will remain powered up and continue to consume power. The counter will retain its residual value when this bit changes from low to high and resume counting from this value when the bit changes to a low value again.

Bit 6~4 **PTCK2~PTCK0**: Select PTM Counter clock
000: $f_{SYS}/4$
001: f_{SYS}
010: $f_H/16$
011: $f_H/64$
100: f_{SUB}
101: f_{SUB}
110: PTCK rising edge clock
111: PTCK falling edge clock
These three bits are used to select the clock source for the TM. The external pin clock source can be chosen to be active on the rising or falling edge. The clock source f_{SYS} is the system clock, while f_H and f_{SUB} are other internal clocks, the details of which can be found in the oscillator section.

Bit 3 **PTON**: PTM Counter On/Off control
0: Off
1: On
This bit controls the overall on/off function of the TM. Setting the bit high enables the counter to run while clearing the bit disables the TM. Clearing this bit to zero will stop the counter from counting and turn off the TM which will reduce its power consumption. When the bit changes state from low to high the internal counter value will be reset to zero, however when the bit changes from high to low, the internal counter will retain its residual value until the bit returns high again. If the TM is in the Compare Match Output Mode then the TM output pin will be reset to its initial condition, as specified by the PTOC bit, when the PTON bit changes from low to high.

Bit 2~0 Unimplemented, read as "0"

PTMC1 Register

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	PTM1	PTM0	PTIO1	PTIO0	PTOC	PTPOL	PTCAPTS	PTCCLR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PTM1~PTM0**: Select PTM Operating Mode
00: Compare Match Output Mode
01: Capture Input Mode
10: PWM Mode or Single Pulse Output Mode
11: Timer/Counter Mode
These bits setup the required operating mode for the TM. To ensure reliable operation the TM should be switched off before any changes are made to the PTM1 and PTM0 bits. In the Timer/Counter Mode, the TM output pin control will be disabled.

Bit 5~4 **PTIO1~PTIO0**: Select PTM external pin PTP_n, PTPI_n or PTCK function
Compare Match Output Mode
00: No change
01: Output low
10: Output high
11: Toggle output
PWM Output Mode/Single Pulse Output Mode
00: PWM output inactive state
01: PWM output active state
10: PWM output
11: Single Pulse Output
Capture Input Mode
00: Input capture at rising edge of PTPI_0/PTPI_1 or PTCK
01: Input capture at falling edge of PTPI_0/PTPI_1 or PTCK
10: Input capture at rising/falling edge of PTPI_0/PTPI_1 or PTCK
11: Input capture disabled

Timer/Counter Mode
Unused

These two bits are used to determine how the TM output pin changes state when a certain condition is reached. The function that these bits select depends upon in which mode the TM is running.

In the Compare Match Output Mode, the PTIO1 and PTIO0 bits determine how the TM output pin changes state when a compare match occurs from the Comparator A. The TM output pin can be setup to switch high, switch low or to toggle its present state when a compare match occurs from the Comparator A. When the bits are both zero, then no change will take place on the output. The initial value of the TM output pin should be setup using the PTOC bit in the PTMC1 register. Note that the output level requested by the PTIO1 and PTIO0 bits must be different from the initial value setup using the PTOC bit otherwise no change will occur on the TM output pin when a compare match occurs. After the TM output pin changes state, it can be reset to its initial level by changing the level of the PTON bit from low to high.

In the PWM Mode, the PTIO1 and PTIO0 bits determine how the TM output pin changes state when a certain compare match condition occurs. The PWM output function is modified by changing these two bits. It is necessary to only change the values of the PTIO1 and PTIO0 bits only after the TM has been switched off. Unpredictable PWM outputs will occur if the PTIO1 and PTIO0 bits are changed when the TM is running.

Bit 3 **PTOC**: PTM PTP_n Output control

Compare Match Output Mode
0: Initial low
1: Initial high

PWM Output Mode/Single Pulse Output Mode
0: Active low
1: Active high

This is the output control bit for the TM output pin. Its operation depends upon whether TM is being used in the Compare Match Output Mode or in the PWM Mode/ Single Pulse Output Mode. It has no effect if the TM is in the Timer/Counter Mode. In the Compare Match Output Mode it determines the logic level of he TM output pin before a compare match occurs. In the PWM Mode/Single Pulse Output Mode it determines if the PWM signal is active high or active low.

Bit 2 **PTPOL**: PTM PTP_n Output polarity control
0: Non-inverted
1: Inverted

This bit controls the polarity of the PTP_n output pin. When the bit is set high the TM output pin will be inverted and not inverted when the bit is zero. It has no effect if the TM is in the Timer/Counter Mode.

Bit 1 **PTCAPTS**: PTM Capture Triiger Source selection
0: From PTP_n, PTPI_n or PTCK pin
1: From PTCK pin

Bit 0 **PTCCLR**: PTM Counter Clear condition selection
0: Comparator P match
1: Comparator A match

This bit is used to select the method which clears the counter. Remember that the Compact TM contains two comparators, Comparator A and Comparator P, either of which can be selected to clear the internal counter. With the PTCCLR bit set high, the counter will be cleared when a compare match occurs from the Comparator A. When the bit is low, the counter will be cleared when a compare match occurs from the Comparator P or with a counter overflow. A counter overflow clearing method can only be implemented if the CCRP bits are all cleared to zero. The PTCCLR bit is not used in the PWM Output, Single Pulse Output or Capture Input Mode.

Periodic Type TM Operation Modes

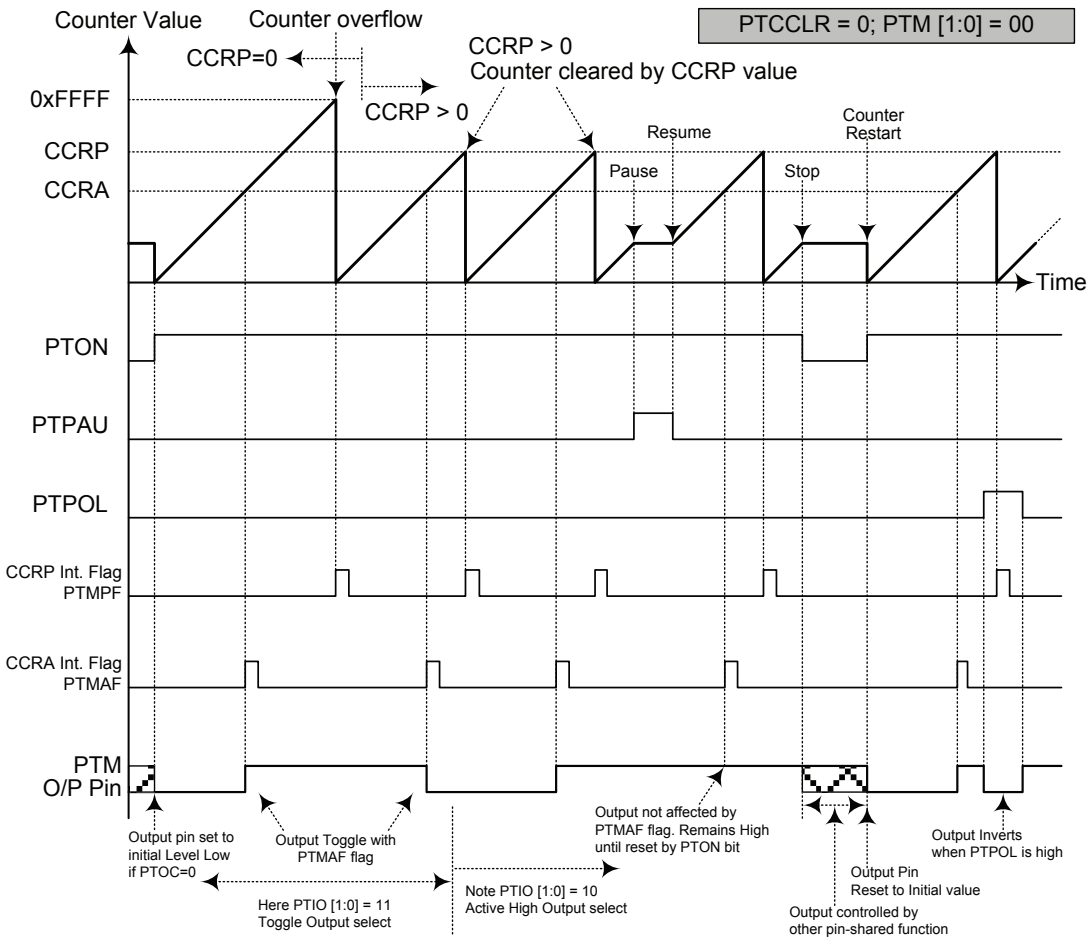
The Periodic Type TM can operate in one of five operating modes, Compare Match Output Mode, PWM Output Mode, Single Pulse Output Mode, Capture Input Mode or Timer/Counter Mode. The operating mode is selected using the PTM1 and PTM0 bits in the PTMC1 register.

Compare Match Output Mode

To select this mode, bits PTM1 and PTM0 in the PTMC1 register, should be set to 00 respectively. In this mode once the counter is enabled and running it can be cleared by three methods. These are a counter overflow, a compare match from Comparator A and a compare match from Comparator P. When the PTCCLR bit is low, there are two ways in which the counter can be cleared. One is when a compare match from Comparator P, the other is when the CCRP bits are all zero which allows the counter to overflow. Here both PTMAF and PTMPF interrupt request flags for Comparator A and Comparator P respectively, will both be generated.

If the PTCCLR bit in the PTMC1 register is high then the counter will be cleared when a compare match occurs from Comparator A. However, here only the PTMAF interrupt request flag will be generated even if the value of the CCRP bits is less than that of the CCRA registers. Therefore when PTCCLR is high no PTMPF interrupt request flag will be generated. In the Compare Match Output Mode, the CCRA can not be set to "0".

As the name of the mode suggests, after a comparison is made, the TM output pin will change state. The TM output pin condition however only changes state when a PTMAF interrupt request flag is generated after a compare match occurs from Comparator A. The PTMPF interrupt request flag, generated from a compare match occurs from Comparator P, will have no effect on the TM output pin. The way in which the TM output pin changes state are determined by the condition of the PTIO1 and PTIO0 bits in the PTMC1 register. The TM output pin can be selected using the PTIO1 and PTIO0 bits to go high, to go low or to toggle from its present condition when a compare match occurs from Comparator A. The initial condition of the TM output pin, which is setup after the PTON bit changes from low to high, is setup using the PTOC bit. Note that if the PTIO1 and PTIO0 bits are zero then no pin change will take place.

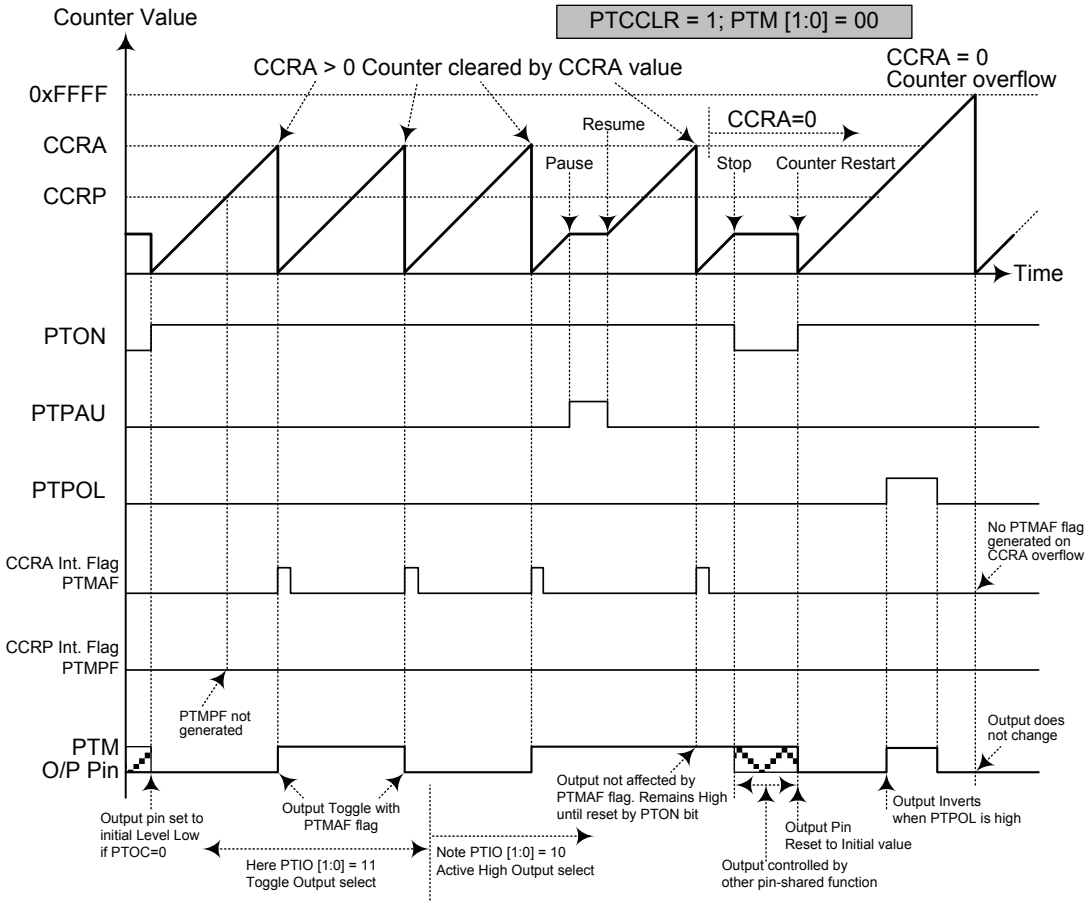


Compare Match Output Mode – PTCCLR = 0

Note: 1. With PTCCLR=0, a Comparator P match will clear the counter

2. The TM output pin is controlled only by the PTMAF flag

3. The output pin is reset to its initial state by a PTON bit rising edge



Compare Match Output Mode – PTCCLR = 1

Note: 1. With PTCCLR=1, a Comparator A match will clear the counter

2. The TM output pin is controlled only by the PTMAF flag

3. The output pin is reset to its initial state by a PTON bit rising edge

4. A PTMPF flag is not generated when PTCCLR =1

Timer/Counter Mode

To select this mode, bits PTM1 and PTM0 in the PTMC1 register should be set to 11 respectively. The Timer/Counter Mode operates in an identical way to the Compare Match Output Mode generating the same interrupt flags. The exception is that in the Timer/Counter Mode the TM output pin is not used. Therefore the above description and Timing Diagrams for the Compare Match Output Mode can be used to understand its function. As the TM output pin is not used in this mode, the pin can be used as a normal I/O pin or other pin-shared function.

PWM Output Mode

To select this mode, bits PTM1 and PTM0 in the PTMC1 register should be set to 10 respectively and also the PTIO1 and PTIO0 bits should be set to 10 respectively. The PWM function within the TM is useful for applications which require functions such as motor control, heating control, illumination control, etc. By providing a signal of fixed frequency but of varying duty cycle on the TM output pin, a square wave AC waveform can be generated with varying equivalent DC RMS values.

As both the period and duty cycle of the PWM waveform can be controlled, the choice of generated waveform is extremely flexible. In the PWM mode, the PTCCLR bit has no effect as the PWM period. Both of the CCRP and CCRA registers are used to generate the PWM waveform, one register is used to clear the internal counter and thus control the PWM waveform frequency, while the other one is used to control the duty cycle. The PWM waveform frequency and duty cycle can therefore be controlled by the values in the CCRA and CCRP registers.

An interrupt flag, one for each of the CCRA and CCRP, will be generated when a compare match occurs from either Comparator A or Comparator P. The PTOC bit in the PTMC1 register is used to select the required polarity of the PWM waveform while the two PTIO1 and PTIO0 bits are used to enable the PWM output or to force the TM output pin to a fixed high or low level. The PTPOL bit is used to reverse the polarity of the PWM output waveform.

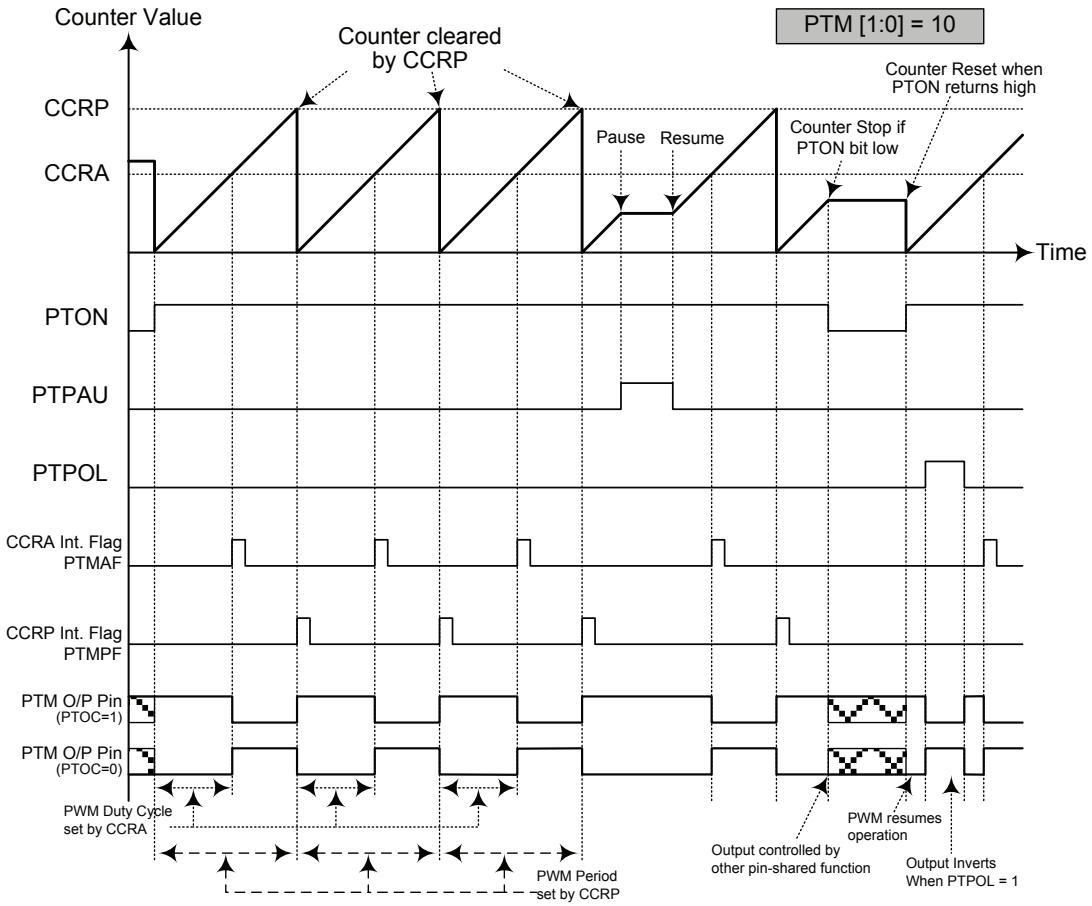
16-bit PTM, PWM Mode,

Period		Duty
CCRP = 0	CCRP = 1~65535	CCRA
65536	1~65535	

If f_{SYS}=16MHz, TM clock source select $f_{SYS}/4$, CCRP=512 and CCRA=128,

The PTM PWM output frequency = ($f_{SYS}/4$)/512 = $f_{SYS}/2048$ = 7.8125kHz, duty=128/512=25%,

If the Duty value defined by the CCRA register is equal to or greater than the Period value, then the PWM output duty is 100%.



PWM Mode

Note: 1. The counter is cleared by CCRP.

2. A counter clear sets the PWM Period

3. The internal PWM function continues running even when PTIO [1:0] = 00 or 01

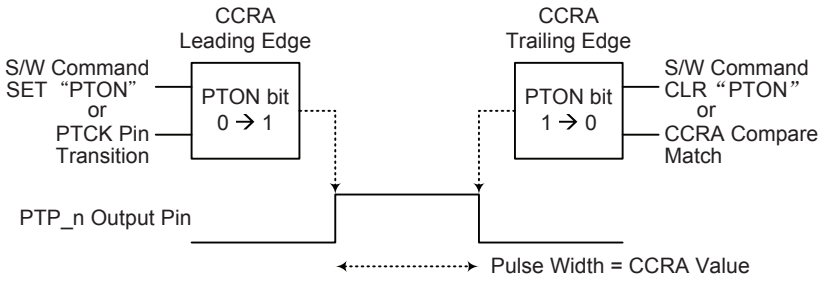
4. The PTCCLR bit has no influence on PWM operation

Single Pulse Output Mode

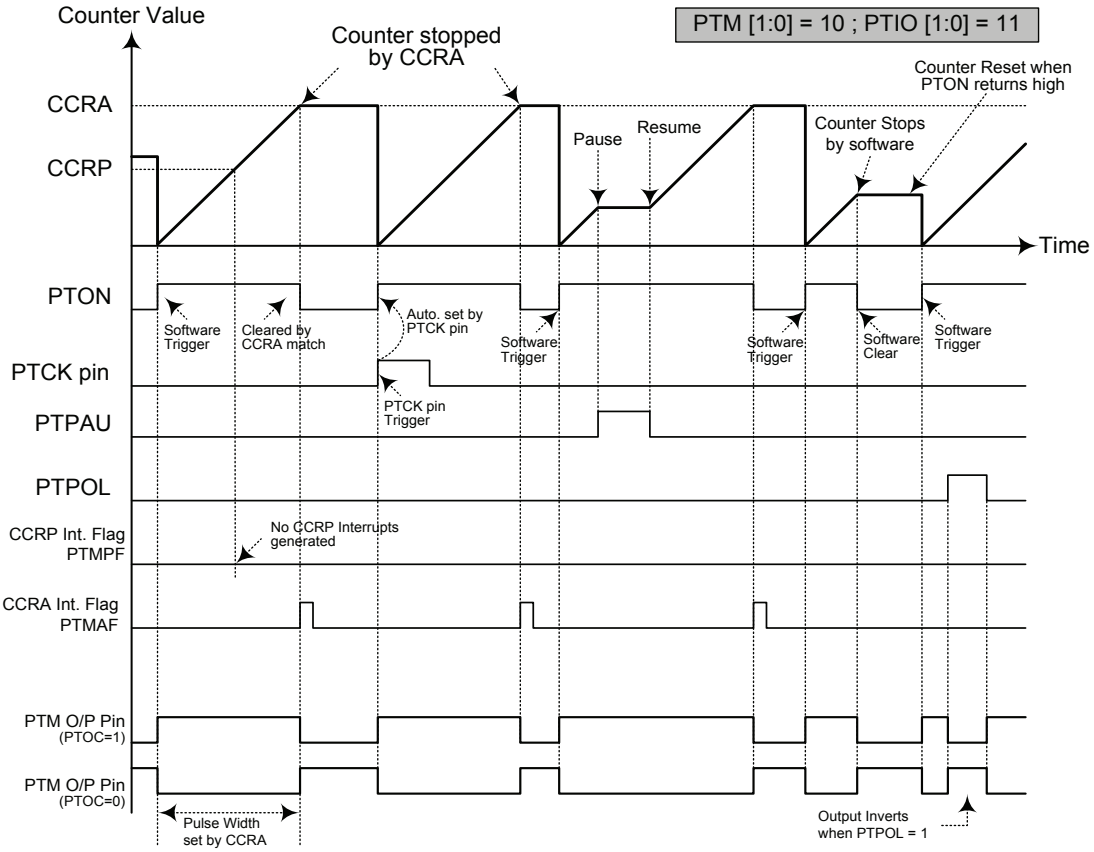
To select this mode, bits PTM1 and PTM0 in the PTMC1 register should be set to 10 respectively and also the PTIO1 and PTIO0 bits should be set to 11 respectively. The Single Pulse Output Mode, as the name suggests, will generate a single shot pulse on the TM output pin.

The trigger for the pulse output leading edge is a low to high transition of the PTON bit, which can be implemented using the application program. However in the Single Pulse Mode, the PTON bit can also be made to automatically change from low to high using the external PTCK pin, which will in turn initiate the Single Pulse output. When the PTON bit transitions to a high level, the counter will start running and the pulse leading edge will be generated. The PTON bit should remain high when the pulse is in its active state. The generated pulse trailing edge will be generated when the PTON bit is cleared to zero, which can be implemented using the application program or when a compare match occurs from Comparator A.

However a compare match from Comparator A will also automatically clear the PTON bit and thus generate the Single Pulse output trailing edge. In this way the CCRA value can be used to control the pulse width. A compare match from Comparator A will also generate a TM interrupt. The counter can only be reset back to zero when the PTON bit changes from low to high when the counter restarts. In the Single Pulse Mode CCRP is not used. The PTCCLR is not used in this Mode.



Single Pulse Generation



Single Pulse Mode

Note: 1. Counter stopped by CCRA

2. CCRP is not used

3. The pulse triggered by the PTCK pin or by setting the PTON bit high

4. A PTCK pin active edge will automatically set the PTON bit high.

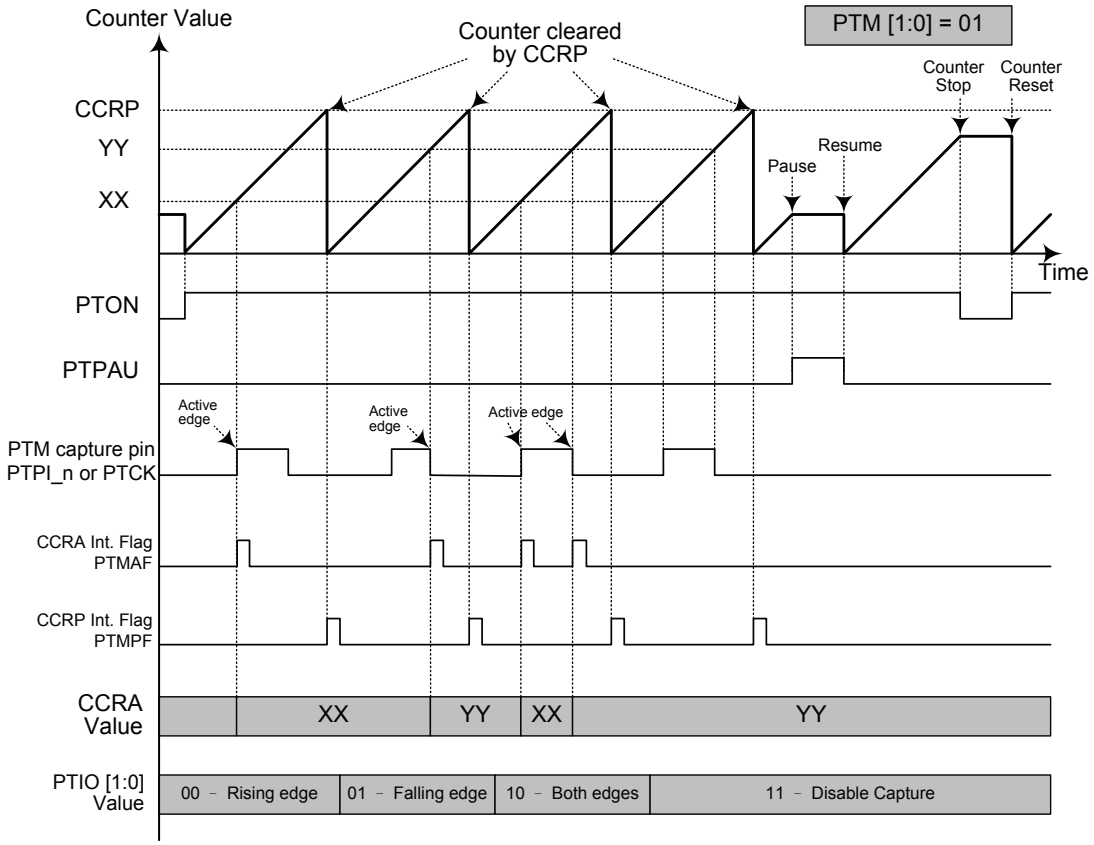
5. In the Single Pulse Mode, PTIO [1:0] must be set to "11" and can not be changed.

Capture Input Mode

To select this mode bits PTM1 and PTM0 in the PTMC1 register should be set to 01 respectively. This mode enables external signals to capture and store the present value of the internal counter and can therefore be used for applications such as pulse width measurements. The external signal is supplied on the PTPI_0/PTPI_1 or PTCK pin, selected by the PTCAPTS bit in the PTMC1 register. The input pin active edge can be either a rising edge, a falling edge or both rising and falling edges; the active edge transition type is selected using the PTIO1 and PTIO0 bits in the PTMC1 register. The counter is started when the PTON bit changes from low to high which is initiated using the application program.

When the required edge transition appears on the PTPI_0/PTPI_1 or PTCK pin the present value in the counter will be latched into the CCRA registers and a TM interrupt generated. Irrespective of what events occur on the PTPI_0/PTPI_1 or PTCK pin the counter will continue to free run until the PTON bit changes from high to low. When a CCRP compare match occurs the counter will reset back to zero; in this way the CCRP value can be used to control the maximum counter value. When a CCRP compare match occurs from Comparator P, a TM interrupt will also be generated. Counting the number of overflow interrupt signals from the CCRP can be a useful method in measuring long pulse widths. The PTIO1 and PTIO0 bits can select the active trigger edge on the PTPI_0/PTPI_1 or PTCK pin to be a rising edge, falling edge or both edge types. If the PTIO1 and PTIO0 bits are both set high, then no capture operation will take place irrespective of what happens on the PTPI_0/PTPI_1 or PTCK pin, however it must be noted that the counter will continue to run.

As the PTPI_0/PTPI_1 or PTCK pin is pin shared with other functions, care must be taken if the TM is in the Input Capture Mode. This is because if the pin is setup as an output, then any transitions on this pin may cause an input capture operation to be executed. The PTCCLR, PTOC and PTPOL bits are not used in this Mode.



Capture Input Mode

Note: 1. PTM [1:0] = 01 and active edge set by the PTIO [1:0] bits

2. A TM Capture input pin active edge transfers the counter value to CCRA

3. PTCCLR bit not used

4. No output function – PTOC and PTPOL bits are not used

5. CCRP determines the counter value and the counter has a maximum count value when CCRP is equal to zero.

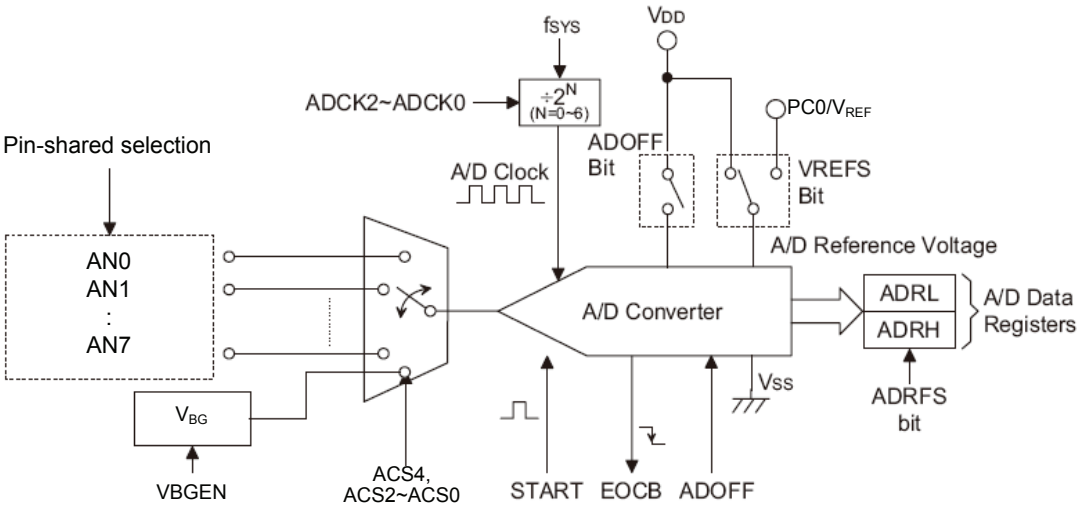
Analog to Digital Converter

The need to interface to real world analog signals is a common requirement for many electronic systems. However, to properly process these signals by a microcontroller, they must first be converted into digital signals by A/D converters. By integrating the A/D conversion electronic circuitry into the microcontroller, the need for external components is reduced significantly with the corresponding follow-on benefits of lower costs and reduced component space requirements.

A/D Overview

The devices contain a multi-channel analog to digital converter which can directly interface to external analog signals, such as that from sensors or other control signals and convert these signals directly into either a 12-bit digital value.

The accompanying block diagram shows the internal structure of the A/D converter together with its associated registers.



A/D Converter Structure

A/D Converter Register Description

Overall operation of the A/D converter is controlled using four registers. A read only register pair exists to store the A/D Converter data 12-bit value. The remaining two registers are control registers which setup the operating and control function of the A/D converter.

Register Name	Bit							
	7	6	5	4	3	2	1	0
ADRL (ADRFS=0)	D3	D2	D1	D0	—	—	—	—
ADRL (ADRFS=1)	D7	D6	D5	D4	D3	D2	D1	D0
ADRH (ADRFS=0)	D11	D10	D9	D8	D7	D6	D5	D4
ADRH (ADRFS=1)	—	—	—	—	D11	D10	D9	D8
ADCR0	START	EOCB	ADOFF	ACS4	—	ACS2	ACS1	ACS0
ADCR1	—	VBGEN	ADRFS	VREFS	—	ADCK2	ADCK1	ADCK0

A/D Converter Registers List

A/D Converter Data Registers – ADRL, ADRH

As the device contains an internal 12-bit A/D converter, it requires two data registers to store the converted value. These are a high byte register, known as ADRH, and a low byte register, known as ADRL. After the conversion process takes place, these registers can be directly read by the microcontroller to obtain the digitised conversion value. As only 12 bits of the 16-bit register space is utilised, the format in which the data is stored is controlled by the ADRFS bit in the ADCR1 register as shown in the accompanying table. D0~D11 are the A/D conversion result data bits. Any unused bits will be read as zero.

ADRFS	ADRH								ADRL							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	0	0	0	0
1	0	0	0	0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

A/D Converter Data Registers

A/D Converter Control Registers – ADCR0, ADCR1

To control the function and operation of the A/D converter, three or four control registers known as ADCR0 and ADCR1 are provided. These 8-bit registers define functions such as the selection of which analog channel is connected to the internal A/D converter, the digitised data format, the A/D clock source as well as controlling the start function and monitoring the A/D converter end of conversion status. The ACS2~ACS0 and ACS4 bits in the ADCR0 register define the A/D Converter input channel number. As the device contains only one actual analog to digital converter hardware circuit, each of the individual 8 analog inputs must be routed to the converter. It is the function of the ACS4 and ACS2~ACS0 bits to determine which analog channel input pins or internal Bandgap reference voltage is actually connected to the internal A/D converter.

The relevant pin-shared function selection bits determine which pins on I/O Ports are used as analog inputs for the A/D converter input and which pins are not to be used as the A/D converter input. When the pin is selected to be an A/D input, its original function whether it is an I/O or other pin-shared function will be removed. In addition, any internal pull-high resistor connected to the pin will be automatically removed if the pin is selected to be an A/D converter input.

- **ADCR0 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	START	EOCB	ADOFF	ACS4	—	ACS2	ACS1	ACS0
R/W	R/W	R	R/W	R/W	—	R/W	R/W	R/W
POR	0	1	1	0	—	0	0	0

Bit 7 **START**: Start the A/D Conversion
0→1→0: Start
0→1: Reset the A/D converter and set EOCB to "1"
This bit is used to initiate an A/D conversion process. The bit is normally low but if set high and then cleared low again, the A/D converter will initiate a conversion process. When the bit is set high, the A/D converter will be reset.

Bit 6 **EOCB**: End of A/D Conversion flag
0: A/D conversion ended
1: A/D conversion in progressReset the A/D converter and set EOCB to "1"
This read only flag is used to indicate when an A/D conversion process has completed. When the conversion process is running, the bit will be high.

Bit 5 **ADOFF**: A/D Converter power On/Off control
0: A/D converter powered on
1: A/D converter powered off
This bit controls the power to the A/D internal function. This bit should be cleared to zero to enable the A/D comverter. If the bit is set high, then the A/D converter will be switched off reducing the device power consumption. As the A/D converter will consume a limited amount of power, even when not executing a voncersion, this may be an important consideration in power sensitive battery powered applications.
Note: 1. It is recommended to set ADOFF=1 before entering IDLE/SLEEP Mode for savong power.
2. ADOFF=1 will power down the A/D Converter.

Bit 4 **ACS4**: Select Internal Bandgap reference voltage as A/D converter input control
0: Disable
1: Enable
This bit enables the internal Bandgap reference voltage to be connected to the A/D converter. The VBGEN bit must first have been set to enable the Bandgap reference voltage to be used by the A/D converter. When the ACS4 bit is set high, the Bandgap reference voltage will be routed to the A/D converter and other A/D input channels will be disconnected.

Bit 3 Unimplemented, read as "0"

Bit 2~0 **ACS2~ACS0**: Select A/D input channel (when ACS4 is "0")
000: AN0
001: AN1
010: AN2
011: AN3
100: AN4
101: AN5
110: AN6
111: AN7
These bits are the A/D input channel selection bits. As there is only one internal hardware A/D converter, each of the eight A/D inputs must be routed to the internal converter using these bits. If bit ACS4 is set high, then the internal Bandgap reference voltage will be routed to the A/D converter.

- **ADCR1 Register**

Register Name	Bit							
	7	6	5	4	3	2	1	0
Name	—	VBGEN	ADRFS	VREFS	—	ADCK2	ADCK1	ADCK0
R/W	—	R	R/W	R/W	—	R/W	R/W	R/W
POR	—	0	0	0	—	0	0	0

Bit 7 Unimplemented, read as "0"

Bit 6 **VBGEN**: Internal Bandgap reference voltage enable control
0: Disable
1: Enable
This bit controls the internal Bandgap circuit on/off function to the A/D converter. When the bit is set high, the bandgap reference voltage can be used by the A/D converter. If the Bandgap reference voltage is not used by the A/D converter and the LVD/LVR function is disabled, then the bandgap reference circuit will be automatically switched off to conserve power. When the Bandgap reference voltage is switched on for use by the A/D converter, a time, t_{BG}, should be allowed for the Bandgap circuit to stabilise before implementing an A/D conversion.

Bit 5 **ADRFS**: A/D Converter data format control
0: A/D converter data MSB is in ADRH bit 7, LSB is in ADRL bit 4.
1: A/D converter data MSB is in ADRH bit 3, LSB is in ADRL bit 0.
This bit controls the format of the 12-bit converted A/D value in the two A/D data registers. Details are provided in the A/D data register section.

Bit 4 **VREFS**: A/D converter reference voltage selection control
0: Internal A/D converter power
1: VREF pin
This bit is used to select the reference voltage for the A/D converter. If the bit is high, then the A/D converter reference voltage is supplied on the external VREF pin. If the bit is low, then the internal A/D converter reference voltage is used which is taken from the A/D converter power supply pin.

Bit 3 Unimplemented, read as "0"

Bit 2~0 **ADCK2~ADCK0**: A/D clock source selection
000: f_{SYS}
001: $f_{SYS}/2$
010: $f_{SYS}/4$
011: $f_{SYS}/8$
100: $f_{SYS}/16$
101: $f_{SYS}/32$
110: $f_{SYS}/64$
111: Undefined
These bits are used to select the clock source for the A/D converter.

A/D Operation

The START bit in the ADCR0 register is used to start and reset the A/D converter. When the microcontroller sets this bit from low to high and then low again, an analog to digital conversion cycle will be initiated. When the START bit is brought from low to high but not low again, the EOCB bit in the ADCR0 register will be set high and the analog to digital converter will be reset. It is the START bit that is used to control the overall start operation of the internal analog to digital converter.

The EOCB bit in the ADCR0 register is used to indicate when the analog to digital conversion process is complete. This bit will be automatically set to 0 by the microcontroller after a conversion cycle has ended. In addition, the corresponding A/D interrupt request flag will be set in the interrupt control register, and if the interrupts are enabled, an appropriate internal interrupt signal will be generated. This A/D internal interrupt signal will direct the program flow to the associated A/D internal interrupt address for processing. If the A/D internal interrupt is disabled, the microcontroller can be used to poll the EOCB bit in the ADCR0 register to check whether it has been cleared as an alternative method of detecting the end of an A/D conversion cycle.

The clock source for the A/D converter, which originates from the system clock f_{SYS}, can be chosen to be either f_{SYS} or a subdivided version of f_{SYS}. The division ratio value is determined by the ADCK2~ADCK0 bits in the ADCR1 register.

Although the A/D clock source is determined by the system clock f_{SYS}, and by bits ADCK2~ADCK0, there are some limitations on the maximum A/D clock source speed that can be selected. As the recommended range of permissible A/D clock period, t_{ADCK}, is from 0.5μs to 10μ, care must be taken for system clock frequencies. For example, as the system clock operates at a frequency of 16MHz, the ADCK2~ADCK0 bits should not be set to 000, 001 or 010. Doing so will give A/D clock periods that are less than the minimum A/D clock period which may result in inaccurate A/D conversion values. Refer to the following table for examples, where values marked with an asterisk * show where, depending upon the device, special care must be taken, as the values may be less than the specified minimum A/D Clock Period.

f_{SYS}	A/D Clock Period (t_{ADCK})							
	ADCK[2:0] = 000 (f_{SYS})	ADCK[2:0] = 001 ($f_{SYS}/2$)	ADCK[2:0] = 010 ($f_{SYS}/4$)	ADCK[2:0] = 011 ($f_{SYS}/8$)	ADCK[2:0] = 100 ($f_{SYS}/16$)	ADCK[2:0] = 101 ($f_{SYS}/62$)	ADCK[2:0] = 110 ($f_{SYS}/64$)	ADCK[2:0] = 111
16 MHz	62.5ns *	125ns *	250ns *	500ns	1μs	2μs	4μs	Undefined

A/D Clock Period Examples

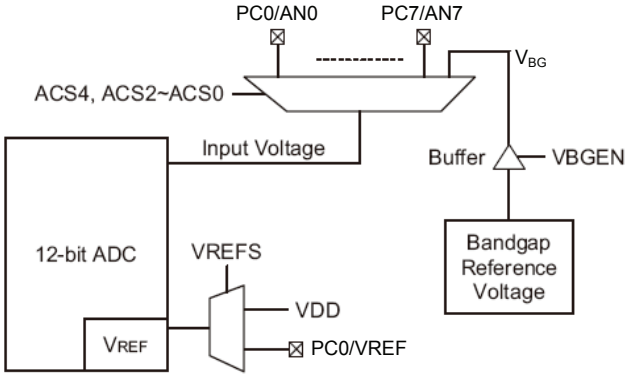
Controlling the power on/off function of the A/D converter circuitry is implemented using the ADOFF bit in the ADCR0 register. This bit must be zero to power on the A/D converter. When the ADOFF bit is cleared to zero to power on the A/D converter internal circuitry a certain delay, as indicated in the timing diagram, must be allowed before an A/D conversion is initiated. Even if no pins are selected for use as A/D inputs, if the ADOFF bit is zero then some power will still be consumed. In power conscious applications it is therefore recommended that the ADOFF is set high to reduce power consumption when the A/D converter function is not being used.

The reference voltage supply to the A/D Converter can be supplied from either the positive power supply pin, VDD, or from an external reference sources supplied on pin VREF. The desired selection is made using the VREFS and relecant pin-shared function selection bits. As the VREF pin is pin-shared with other functions, when the VREFS bit is set high and the relevant pin-shared function selection bits are selected as the VREF function, the VREF pin function will be selected and therefore other pin functions will be disabled.

A/D Input Pins

All of the A/D analog input pins are pin-shared with the I/O pins on Port C as well as other functions. The corresponding selection bits in the PCS0 and PCS1 registers, determine whether the input pins are setup as A/D converter analog inputs or whether they have other functions. If the corresponding pin is setup to be an A/D converter input, the original pin functions will be disabled. In this way, pins can be changed under program control to change their function between A/D inputs and other functions. All pull-high resistors, which are setup through register programming, will be automatically disconnected if the pins are setup as A/D inputs. Note that it is not necessary to first setup the A/D pin as an input in the port control register to enable the A/D input as when the relevant A/D input function selection bits enable an A/D input, the status of the port control register will be overridden.

The A/D converter has its own reference voltage pin, VREF, however the reference voltage can also be supplied from the power supply pin, a choice which is made through the VREFS bit in the ADCR1 register. The analog input values must not be allowed to exceed the value of V_{REF}.



A/D Input Structure

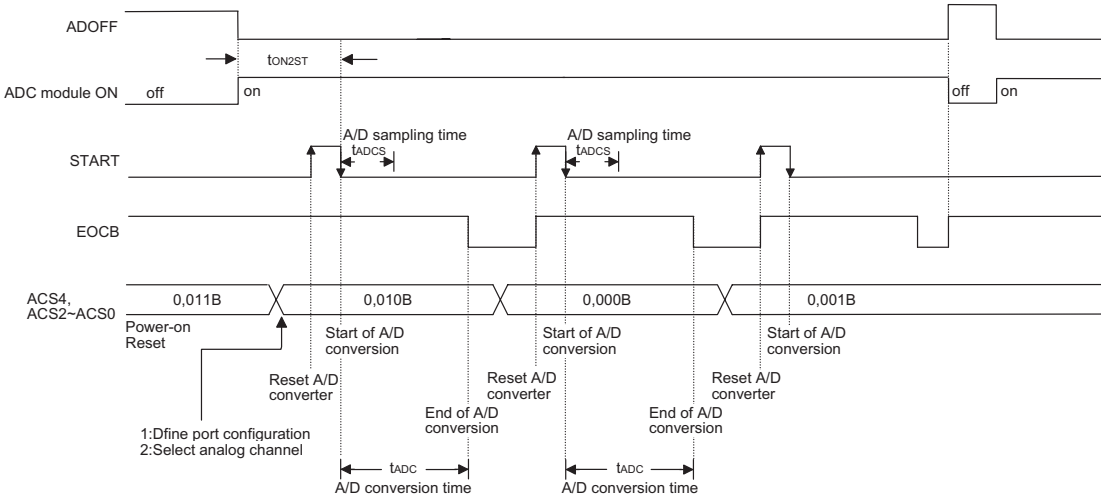
Summary of A/D Conversion Steps

The following summarises the individual steps that should be executed in order to implement an A/D conversion process.

- Step 1
  Select the required A/D conversion clock by correctly programming bits ADCK2~ADCK0 in the ADCR1 register.
- Step 2
  Enable the A/D by clearing the ADOFF bit in the ADCR0 register to zero.
- Step 3
  Select which channel is to be connected to the internal A/D converter by correctly programming the ACS4 and ACS2~ACS0 bits which are also contained in the ADCR0 register.
- Step 4
  Select which pins are to be used as A/D inputs and configure them by correctly programming the corresponding pin-shared function selection registers.
- Step 5
  If the interrupts are to be used, the interrupt control registers must be correctly configured to ensure the A/D converter interrupt function is active. The master interrupt control bit, EMI, and the A/D converter interrupt bit, ADE, must both be set high to do this.
- Step 6
  The analog to digital conversion process can now be initialised by setting the START bit in the ADCR0 register from low to high and then low again. Note that this bit should have been originally cleared to zero.
- Step 7
  To check when the analog to digital conversion process is complete, the EOCB bit in the ADCR0 register can be polled. The conversion process is complete when this bit goes low. When this occurs the A/D data register ADRL and ADRH can be read to obtain the conversion value. As an alternative method, if the interrupts are enabled and the stack is not full, the program can wait for an A/D interrupt to occur.

Note: When checking for the end of the conversion process, if the method of polling the EOCB bit in the ADCR0 register is used, the interrupt enable step above can be omitted.

The accompanying diagram shows graphically the various stages involved in an analog to digital conversion process and its associated timing. After an A/D conversion process has been initiated by the application program, the microcontroller internal hardware will begin to carry out the conversion, during which time the program can continue with other functions. The time taken for the A/D conversion is 16 t_{ADCK} where t_{ADCK} is equal to the A/D clock period.



A/D Conversion Timing

Programming Considerations

During microcontroller operations where the A/D converter is not being used, the A/D internal circuitry can be switched off to reduce power consumption, by setting bit ADOFF high in the ADCR0 register. When this happens, the internal A/D converter circuits will not consume power irrespective of what analog voltage is applied to their input lines. If the A/D converter input lines are used as normal I/Os, then care must be taken as if the input voltage is not at a valid logic level, then this may lead to some increase in power consumption.

A/D Transfer Function

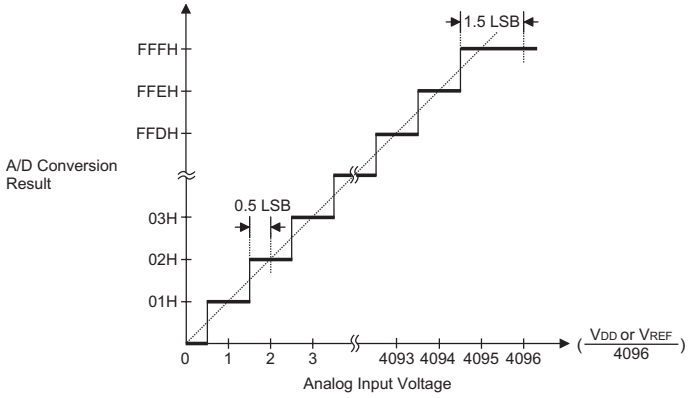
As the devices contain a 12-bit A/D converter, its full-scale converted digitised value is equal to FFFH. Since the full-scale analog input value is equal to the V_{DD} or V_{REF} voltage, this gives a single bit analog input value of V_{DD} or V_{REF} divided by 4096.

$$1\ LSB = (V_{DD} \text{ or } V_{REF}) \div 4096$$

The A/D Converter input voltage value can be calculated using the following equation:

$$\text{A/D input voltage} = \text{A/D output digital value} \times (V_{DD} \text{ or } V_{REF}) \div 4096$$

The diagram shows the ideal transfer function between the analog input value and the digitised output value for the A/D converter. Except for the digitised zero value, the subsequent digitised values will change at a point 0.5 LSB below where they would change without the offset, and the last full scale digitised value will change at a point 1.5 LSB below the V_{DD} or V_{REF} level.



Ideal A/D Transfer Function

A/D Programming Examples

The following two programming examples illustrate how to setup and implement an A/D conversion. In the first example, the method of polling the EOCB bit in the ADCR0 register is used to detect when the conversion cycle is complete, whereas in the second example, the A/D interrupt is used to determine when the conversion is complete.

Example: using an EOCB polling method to detect the end of conversion

```
clr ADE                ; disable ADC interrupt
mov a,03H
mov ADCR1,a            ; select fSYS/8 as A/D clock and switch off VBG voltage
clr ADOFF
mov a,03H              ; setup PCS0 to configure pin AN0
mov PCS0,a
mov a,00H
mov ADCR0,a            ; enable and connect AN0 channel to A/D converter
:
start_conversion:
clr START              ; high pulse on start bit to initiate conversion
set START              ; reset A/D
clr START              ; start A/D
:
polling_EOC:
sz  EOCB               ; poll the ADCR0 register EOCB bit to detect end of A/D conversion
jmp polling_EOC        ; continue polling
:
mov a,ADRL             ; read low byte conversion result value
mov ADRL_buffer,a      ; save result to user defined register
mov a,ADRH             ; read high byte conversion result value
mov ADRH_buffer,a      ; save result to user defined register
:
jmp start_conversion   ; start next A/D conversion
```

Example: using the interrupt method to detect the end of conversion

```
clr ADE                ; disable ADC interrupt
mov a,03H
mov ADCR1,a            ; select fSYS/8 as A/D clock and switch off VBG voltage
clr ADOFF
mov a,03h              ; setup PCS0 to configure pin AN0
mov PCS0,a
mov a,00h
mov ADCR0,a            ; enable and connect AN0 channel to A/D converter
:
Start_conversion:
clr START              ; high pulse on START bit to initiate conversion
set START              ; reset A/D
clr START              ; start A/D
clr ADF                ; clear ADC interrupt request flag
set ADE                ; enable ADC interrupt
set EMI                ; enable global interrupt
:
:
ADC_ISR:               ; ADC interrupt service routine
mov acc_stack,a        ; save ACC to user defined memory
mov a,STATUS
mov status_stack,a     ; save STATUS to user defined memory
:
mov a, ADRL            ; read low byte conversion result value
mov adrl_buffer,a      ; save result to user defined register
mov a, ADRH            ; read high byte conversion result value
mov adrh_buffer,a      ; save result to user defined register
:
EXIT_INT_ISR:
mov a,status_stack
mov STATUS,a           ; restore STATUS from user defined memory
mov a,acc_stack        ; restore ACC from user defined memory
reti
```

Serial Interface Module – SIM

These devices contain a Serial Interface Module, which includes both the four-line SPI interface or two-line I^2C interface types, to allow an easy method of communication with external peripheral hardware. Having relatively simple communication protocols, these serial interface types allow the microcontroller to interface to external SPI or I^2C based hardware such as sensors, Flash or EEPROM memory, etc. The SIM interface pins are pin-shared with other I/O pins and therefore the SIM interface functional pins must first be selected using the corresponding pin-shared function selection bits. As both interface types share the same pins and registers, the choice of whether the SPI or I^2C type is used is made using the SIM operating mode control bits, named SIM2~SIM0, in the SIMC0 register. These pull-high resistors of the SIM pin-shared I/O pins are selected using pull-high control registers when the SIM function is enabled and the corresponding pins are used as SIM input pins.

SPI Interface

The SPI interface is often used to communicate with external peripheral devices such as sensors, Flash or EEPROM memory devices, etc. Originally developed by Motorola, the four line SPI interface is a synchronous serial data interface that has a relatively simple communication protocol simplifying the programming requirements when communicating with external hardware devices.

The communication is full duplex and operates as a slave/master type, where the devices can be either master or slave. Although the SPI interface specification can control multiple slave devices from a single master, these devices provided only one $\overline{SCS}$ pin. If the master needs to control multiple slave devices from a single master, the master can use I/O pin to select the slave devices.

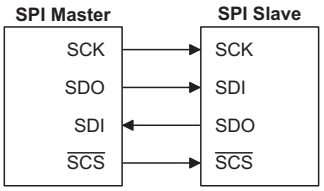
SPI Interface Operation

The SPI interface is a full duplex synchronous serial data link. It is a four line interface with pin names SDI, SDO, SCK and $\overline{SCS}$ Pins SDI and SDO are the Serial Data Input and Serial Data Output lines, SCK is the Serial Clock line and $\overline{SCS}$ is the Slave Select line. As the SPI interface pins are pin-shared with normal I/O pins and with the I2C function pins, the SPI interface pins must first be selected by configuring the pin-shared function selection bits and setting the correct bits in the SIMC0 and SIMC2 registers. After the desired SPI configuration has been set it can be disabled or enabled using the SIMEN bit in the SIMC0 register. Communication between devices connected to the SPI interface is carried out in a slave/master mode with all data transfer initiations being implemented by the master. The Master also controls the clock signal. As the device only contains a single $\overline{SCS}$ pin only one slave device can be utilized. The $\overline{SCS}$ pin is controlled by software, set CSEN bit to 1 to enable $\overline{SCS}$ pin function, set CSEN bit to 0 the $\overline{SCS}$ pin will be placed into I/O pin or other pin-shared functions.

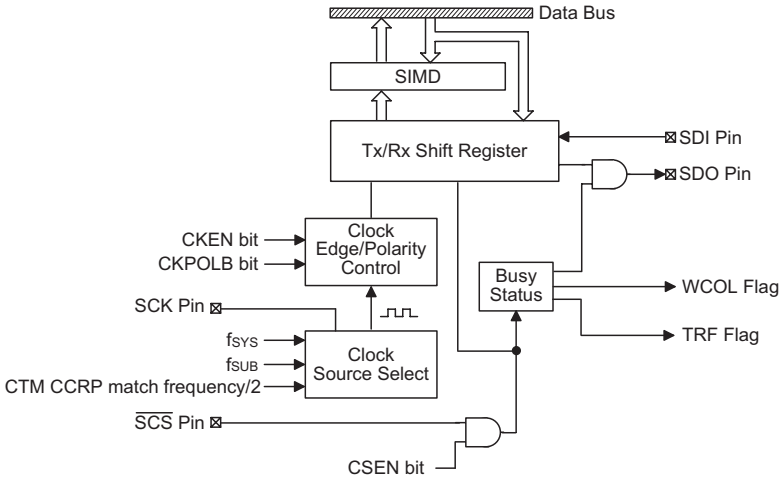
The SPI function in this device offers the following features:

- Full duplex synchronous data transfer
- Both Master and Slave modes
- LSB first or MSB first data transmission modes
- Transmission complete flag
- Rising or falling active clock edge

The status of the SPI interface pins is determined by a number of factors such as whether the device is in the master or slave mode and upon the condition of certain control bits such as CSEN and SIMEN.



SPI Master/Slave Connection



SPI Block Diagram

SPI Registers

There are three internal registers which control the overall operation of the SPI interface. These are the SIMD data register and two registers SIMC0 and SIMC2. Note that the SIMC1 register is only used by the I²C interface.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SIMC0	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
SIMD	D7	D6	D5	D4	D3	D2	D1	D0
SIMC2	D7	D6	CKPOLB	CKEG	MLS	CSEN	WCOL	TRF

SPI Registers List

- **SIMD Register**

The SIMD register is used to store the data being transmitted and received. The same register is used by both the SPI and I²C functions. Before the device writes data to the SPI bus, the actual data to be transmitted must be placed in the SIMD register. After the data is received from the SPI bus, the device can read it from the SIMD register. Any transmission or reception of data from the SPI bus must be made via the SIMD register.

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

There are also two control registers for the SPI interface, SIMC0 and SIMC2. Note that the SIMC2 register also has the name SIMA which is used by the I²C function. The SIMC1 register is not used by the SPI function, only by the I²C function. Register SIMC0 is used to control the enable/disable function and to set the data transmission clock frequency. Register SIMC2 is used for other control functions such as LSB/MSB selection, write collision flag, etc.

SIMC0 Register

Bit	7	6	5	4	3	2	1	0
Name	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
R/W	R/W	R/W	R/W	—	R/W	R/W	R/W	R/W
POR	1	1	1	—	0	0	0	0

Bit 7~5 **SIM2~SIM0**: SIM Operating Mode Control
000: SPI master mode; SPI clock is f_{SYS}/4
001: SPI master mode; SPI clock is f_{SYS}/16
010: SPI master mode; SPI clock is f_{SYS}/64
011: SPI master mode; SPI clock is f_{SUB}
100: SPI master mode; SPI clock is CTM CCRP match frequency/2
101: SPI slave mode
110: I²C slave mode
111: Non SIM function
These bits setup the overall operating mode of the SIM function. As well as selecting if the I²C or SPI function, they are used to control the SPI Master/Slave selection and the SPI Master clock frequency. The SPI clock is a function of the system clock but can also be chosen to be sourced from CTM. If the SPI Slave Mode is selected then the clock will be supplied by an external Master device.

Bit 4 Unimplemented, read as "0"

Bit 3~2 **SIMDEB1~SIMDEB0**: I²C Debounce Time Selection
00: No debounce
01: 2 system clock debounce
1x: 4 system clock debounce

Bit 1 **SIMEN**: SIM Enable Control
0: Disable
1: Enable
The bit is the overall on/off control for the SIM interface. When the SIMEN bit is cleared to zero to disable the SIM interface, the SDI, SDO, SCK and $\overline{SCS}$, or SDA and SCL lines will lose their SPI or I²C function and the SIM operating current will be reduced to a minimum value. When the bit is high the SIM interface is enabled. The SIM configuration option must have first enabled the SIM interface for this bit to be effective.If the SIM is configured to operate as an SPI interface via the SIM2~SIM0 bits, the contents of the SPI control registers will remain at the previous settings when the SIMEN bit changes from low to high and should therefore be first initialised by the application program. If the SIM is configured to operate as an I²C interface via the SIM2~SIM0 bits and the SIMEN bit changes from low to high, the contents of the I²C control bits such as HTX and TXAK will remain at the previous settings and should therefore be first initialised by the application program while the relevant I²C flags such as HCF, HAAS, HBB, SRW and RXAK will be set to their default states.

Bit 0 **SIMICF**: SIM Incomplete Flag
0: SIM incomplete condition not occurred
1: SIM incomplete condition occured
This bit is only available when the SIM is configured to operate in an SPI slave mode. If the SPI operates in the slave mode with the SIMEN and CSEN bits both being set to 1 but the $\overline{SCS}$ line is pulled high by the external master device before the SPI data transfer is completely finished, the SIMICF bit will be set to 1 together with the TRF bit. When this condition occurs, the corresponding interrupt will occur if the interrupt function is enabled. However, the TRF bit will not be set to 1 if the SIMICF bit is set to 1 by software application program.

SIMC2 Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	CKPOLB	CKEG	MLS	CSEN	WCOL	TRF
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 Undefined bits

These bits can be read or written by the application program.

Bit 5 **CKPOLB**: SPI clock line base condition selection

0: The SCK line will be high when the clock is inactive.

1: The SCK line will be low when the clock is inactive.

The CKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCK line will be low when the clock is inactive. When the CKPOLB bit is low, then the SCK line will be high when the clock is inactive.

Bit 4 **CKEG**: SPI SCK clock active edge type selection

CKPOLB=0

0: SCK is high base level and data capture at SCK rising edge

1: SCK is high base level and data capture at SCK falling edge

CKPOLB=1

0: SCK is low base level and data capture at SCK falling edge

1: SCK is low base level and data capture at SCK rising edge

The CKEG and CKPOLB bits are used to setup the way that the clock signal outputs and inputs data on the SPI bus. These two bits must be configured before data transfer is executed otherwise an erroneous clock edge may be generated. The CKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCK line will be low when the clock is inactive. When the CKPOLB bit is low, then the SCK line will be high when the clock is inactive. The CKEG bit determines active clock edge type which depends upon the condition of CKPOLB bit.

Bit 3 **MLS**: SPI data shift order

0: LSB first

1: MSB first

This is the data shift select bit and is used to select how the data is transferred, either MSB or LSB first. Setting the bit high will select MSB first and low for LSB first.

Bit 2 **CSEN**: SPI $\overline{\text{SCS}}$ pin control

0: Disable

1: Enable

The CSEN bit is used as an enable/disable for the $\overline{\text{SCS}}$ pin. If this bit is low, then the $\overline{\text{SCS}}$ pin will be disabled and placed into I/O pin or other pin-shared functions. If the bit is high, the $\overline{\text{SCS}}$ pin will be enabled and used as a select pin.

Bit 1 **WCOL**: SPI write collision flag

0: No collision

1: Collision

The WCOL flag is used to detect whether a data collision has occurred or not. If this bit is high, it means that data has been attempted to be written to the SIMD register duting a data transfer operation. This writing operation will be ignored if data is being transferred. This bit can be cleared by the application program.

Bit 0 **TRF**: SPI Transmit/Receive complete flag

0: SPI data is being transferred

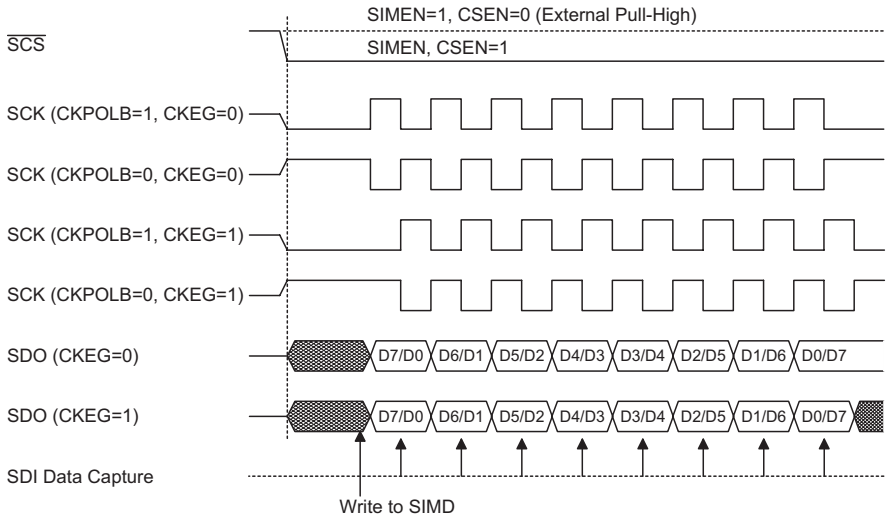
1: SPI data transfer is completed

The TRF bit is the Transmit/Receive Complete flag and is set to 1 automatically when an SPI data transfer is completed, but must cleared to 0 by the application program. It can be used to generate an interrupt.

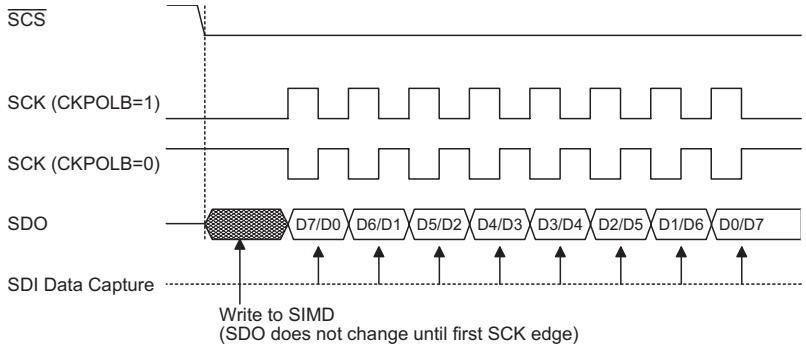
SPI Communication

After the SPI interface is enabled by setting the SIMEN bit high, then in the Master Mode, when data is written to the SIMD register, transmission/reception will begin simultaneously. When the data transfer is complete, the TRF flag will be set automatically, but must be cleared using the application program. In the Slave Mode, when the clock signal from the master has been received, any data in the SIMD register will be transmitted and any data on the SDI pin will be shifted into the SIMD register. The master should output a $\overline{SCS}$ signal to enable the slave devices before a clock signal is provided. The slave data to be transferred should be well prepared at the appropriate moment relative to the $\overline{SCS}$ signal depending upon the configurations of the CKPOLB bit and CKEG bit. The accompanying timing diagram shows the relationship between the slave data and $\overline{SCS}$ signal for various configurations of the CKPOLB and CKEG bits.

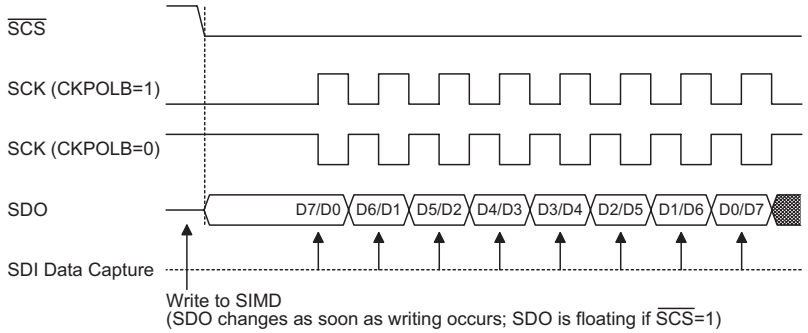
The SPI will continue to function even in the IDLE Mode.



SPI Master Mode Timing

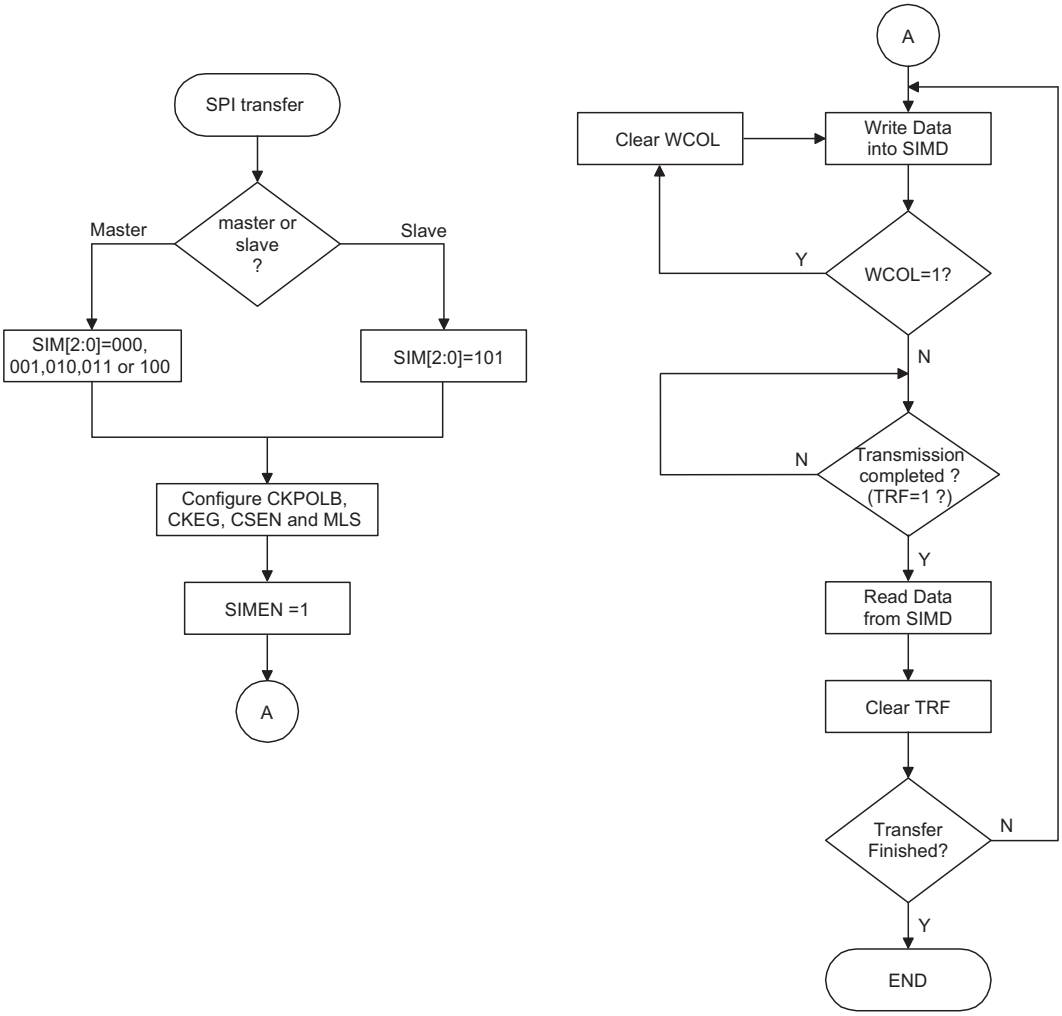


SPI Slave Mode Timing – CKEG=0



Note: For SPI slave mode, if SIMEN=1 and CSEN=0, SPI is always enabled and ignores the $\overline{SCS}$ level.

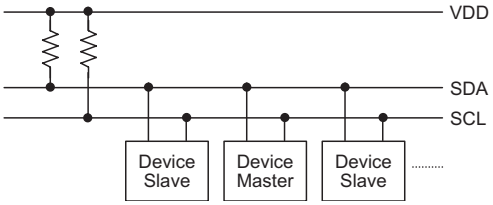
SPI Slave Mode Timing – CKEG=1



SPI Transfer Control Flowchart

I²C Interface

The I²C interface is used to communicate with external peripheral devices such as sensors, EEPROM memory etc. Originally developed by Philips, it is a two line low speed serial interface for synchronous serial data transfer. The advantage of only two lines for communication, relatively simple communication protocol and the ability to accommodate multiple devices on the same bus has made it an extremely popular interface type for many applications.

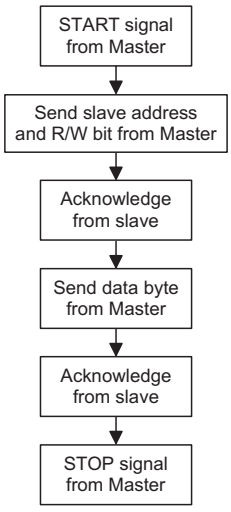


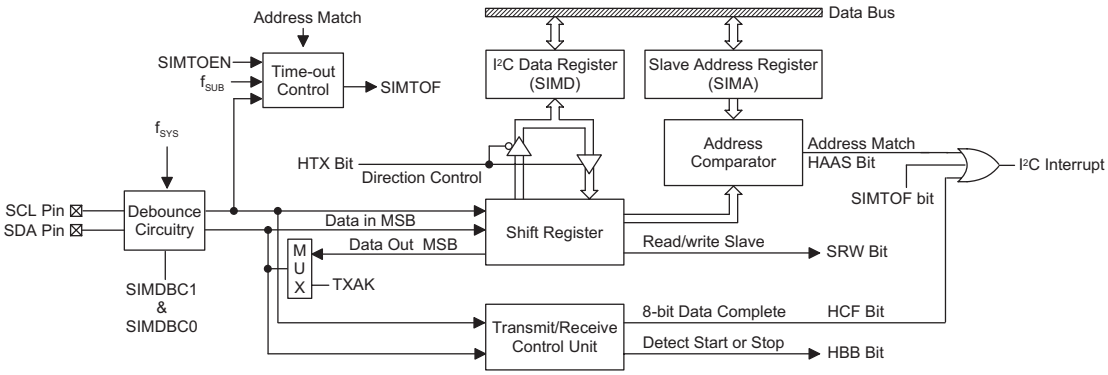
I²C Master/Slave Bus Connection

I²C Interface Operation

The I²C serial interface is a two line interface, a serial data line, SDA, and serial clock line, SCL. As many devices may be connected together on the same bus, their outputs are both open drain types. For this reason it is necessary that external pull-high resistors are connected to these outputs. Note that no chip select line exists, as each device on the I²C bus is identified by a unique address which will be transmitted and received on the I²C bus.

When two devices communicate with each other on the bidirectional I²C bus, one is known as the master device and one as the slave device. Both master and slave can transmit and receive data, however, it is the master device that has overall control of the bus. For these devices, which only operate in slave mode, there are two methods of transferring data on the I²C bus, the slave transmit mode and the slave receive mode.





I²C Block Diagram

The SIMDEB1 and SIMDEB0 bits determine the debounce time of the I²C interface. This uses the system clock to in effect add a debounce time to the external clock to reduce the possibility of glitches on the clock line causing erroneous operation. The debounce time, if selected, can be chosen to be either 2 or 4 system clocks. To achieve the required I²C data transfer speed, there exists a relationship between the system clock, f_{SYS}, and the I²C debounce time. For either the I²C Standard or Fast mode operation, users must take care of the selected system clock frequency and the configured debounce time to match the criterion shown in the following table.

I²C Debounce Time Selection	I²C Standard Mode (100kHz)	I²C Fast Mode (400kHz)
No Devounce	f_{SYS} > 2 MHz	f_{SYS} > 5 MHz
2 system clock debounce	f_{SYS} > 4 MHz	f_{SYS} > 10 MHz
4 system clock debounce	f_{SYS} > 8 MHz	f_{SYS} > 20 MHz

I²C Minimum f_{SYS} Frequency

I²C Registers

There are three control registers associated with the I2C bus, SIMC0, SIMC1 and SIMA, and one data register, SIMD. The SIMD register, which is shown in the above SPI section, is used to store the data being transmitted and received on the I²C bus. Before the microcontroller writes data to the I²C bus, the actual data to be transmitted must be placed in the SIMD register. After the data is received from the I²C bus, the microcontroller can read it from the SIMD register. Any transmission or reception of data from the I2C bus must be made via the SIMD register.

Note that the SIMA register also has the name SIMC2 which is used by the SPI function. Bit SIMEN and bits SIM2~SIM0 in register SIMC0 are used by the I²C interface.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SIMC0	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
SIMC1	HCF	HAAS	HBB	HTX	TXAK	SRW	IAMWU	RXAK
SIMD	D7	D6	D5	D4	D3	D2	D1	D0
SIMA	IICA6	IICA5	IICA4	IICA3	IICA2	IICA1	IICA0	D0

I²C Registers List

SIMD Register

The SIMD register is used to store the data being transmitted and received. The same register is used by both the SPI and I²C functions. Before the device writes data to the I²C bus, the actual data to be transmitted must be placed in the SIMD register. After the data is received from the I²C bus, the device can read it from the SIMD register. Any transmission or reception of data from the I²C bus must be made via the SIMD register.

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

SIMA Register

The SIMA register is also used by the SPI interface but has the name SIMC2. The SIMA register is the location where the 7-bit slave address of the slave device is stored. Bits 7~1 of the SIMA register define the device slave address. Bit 0 is not defined.

When a master device, which is connected to the I²C bus, sends out an address, which matches the slave address in the SIMA register, the slave device will be selected. Note that the SIMA register is the same register address as SIMC2 which is used by the SPI interface.

Bit	7	6	5	4	3	2	1	0
Name	IICA6	IICA5	IICA4	IICA3	IICA2	IICA1	IICA0	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~1 **IICA6~IICA0**: I²C slave address
IICA6~IICA0 is the I²C slave address bit 6 ~ bit 0

Bit 0 Undefined bit
The bit can be read or written by the application program.

There are also two control registers for the I²C interface, SIMC0 and SIMC1. The register SIMC0 is used to control the enable/disable function and to set the data transmission clock frequency.The SIMC1 register contains the relevant flags which are used to indicate the I²C communication status.

SIMC0 Register

Bit	7	6	5	4	3	2	1	0
Name	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
R/W	R/W	R/W	R/W	—	R/W	R/W	R/W	R/W
POR	1	1	1	—	0	0	0	0

Bit 7~5 **SIM2~SIM0**: SIM Operating Mode Control
000: SPI master mode; SPI clock is f_{SYS} /4
001: SPI master mode; SPI clock is f_{SYS} /16
010: SPI master mode; SPI clock is f_{SYS} /64
011: SPI master mode; SPI clock is f_{SUB}
100: SPI master mode; SPI clock is CTM CCRP match frequency/2
101: SPI slave mode
110: I²C slave mode
111: Non SIM function
These bits setup the overall operating mode of the SIM function. As well as selecting if the I²C or SPI function, they are used to control the SPI Master/Slave selection and the SPI Master clock frequency. The SPI clock is a function of the system clock but can also be chosen to be sourced from CTM. If the SPI Slave Mode is selected then the clock will be supplied by an external Master device.

Bit 4 Unimplemented, read as "0"

Bit 3~2 **SIMDEB1~SIMDEB0**: I²C Debounce Time Selection
00: No debounce
01: 2 system clock debounce
1x: 4 system clock debounce

Bit 1 **SIMEN**: SIM Enable Control
0: Disable
1: Enable
The bit is the overall on/off control for the SIM interface. When the SIMEN bit is cleared to zero to disable the SIM interface, the SDI, SDO, SCK and $\overline{SCS}$, or SDA and SCL lines will lose their SPI or I²C function and the SIM operating current will be reduced to a minimum value. When the bit is high the SIM interface is enabled. The SIM configuration option must have first enabled the SIM interface for this bit to be effective.If the SIM is configured to operate as an SPI interface via the SIM2~SIM0 bits, the contents of the SPI control registers will remain at the previous settings when the SIMEN bit changes from low to high and should therefore be first initialised by the application program. If the SIM is configured to operate as an I²C interface via the SIM2~SIM0 bits and the SIMEN bit changes from low to high, the contents of the I²C control bits such as HTX and TXAK will remain at the previous settings and should therefore be first initialised by the application program while the relevant I²C flags such as HCF, HAAS, HBB, SRW and RXAK will be set to their default states.

Bit 0 **SIMICF**: SIM Incomplete Flag
0: SIM incomplete condition not occurred
1: SIM incomplete condition occured
This bit is only available when the SIM is configured to operate in an SPI slave mode. If the SPI operates in the slave mode with the SIMEN and CSEN bits both being set to 1 but the $\overline{SCS}$ line is pulled high by the external master device before the SPI data transfer is completely finished, the SIMICF bit will be set to 1 together with the TRF bit. When this condition occurs, the corresponding interrupt will occur if the interrupt function is enabled. However, the TRF bit will not be set to 1 if the SIMICF bit is set to 1 by software application program.

SIMC1 Register

Bit	7	6	5	4	3	2	1	0
Name	HCF	HAAS	HBB	HTX	TXAK	SRW	IAMWU	RXAK
R/W	R	R	R	R/W	R/W	R/W	R/W	R
POR	1	0	0	0	0	0	0	1

Bit 7 **HCF**: I²C Bus data transfer completion flag
0: Data is being transferred
1: Completion of an 8-bit data transfer
The HCF flag is the data transfer flag. This flag will be zero when data is being transferred. Upon completion of an 8-bit data transfer the flag will go high and an interrupt will be generated.

Bit 6 **HAAS**: I²C Bus data transfer completion flag
0: Not address match
1: Address match
The HAAS flag is the address match flag. This flag is used to determine if the slave device address is the same as the master transmit address. If the addresses match then this bit will be high, if there is no match then the flag will be low.

Bit 5 **HBB**: I²C Bus busy flag
0: I²C Bus is not busy
1: I²C Bus is busy
The HBB flag is the I²C busy flag. This flag will be "1" when the I²C bus is busy which will occur when a START signal is detected. The flag will be set to "0" when the bus is free which will occur when a STOP signal is detected.

Bit 4 **HTX**: I²C slave device transmitter/receiver selection
0: Slave device is the receiver
1: Slave device is the transmitter

Bit 3 **TXAK**: I²C bus transmit acknowledge flag
0: Slave send acknowledge flag
1: Slave does not send acknowledge flag
The TXAK bit is the transmit acknowledge flag. After the slave device receipt of 8-bits of data, this bit will be transmitted to the bus on the 9th clock from the slave device. The slave device must always set TXAK bit to "0" before further data is received.

Bit 2 **SRW**: I²C slave read/write flag
0: Slave device should be in receive mode
1: Slave device should be in transmit mode
The SRW flag is the I²C Slave Read/Write flag. This flag determines whether the master device wishes to transmit or receive data from the I²C bus. When the transmitted address and slave address is match, that is when the HAAS flag is set high, the slave device will check the SRW flag to determine whether it should be in transmit mode or receive mode. If the SRW flag is high, the master is requesting to read data from the bus, so the slave device should be in transmit mode. When the SRW flag is zero, the master will write data to the bus, therefore the slave device should be in receive mode to read this data.

Bit 1 **IAMWU**: I²C Address Match Wake-Up control
0: Disable
1: Enable – must be cleared by the application program after wake-up
This bit should be set to 1 to enable the I²C address match wake up from the SLEEP or IDLE Mode. If the IAMWU bit has been set before entering either the SLEEP or IDLE mode to enable the I²C address match wake up, then this bit must be cleared by the application program after wake-up to ensure correction device operation.

Bit 0 **RXAK**: I²C bus receive acknowledge flag
0: Slave receives acknowledge flag
1: Slave does not receive acknowledge flag
The RXAK flag is the receiver acknowledge flag. When the RXAK flag is "0", it means that a acknowledge signal has been received at the 9th clock, after 8 bits of data have been transmitted. When the slave device in the transmit mode, the slave device checks the RXAK flag to determine if the master receiver wishes to receive the next byte. The slave transmitter will therefore continue sending out data until the RXAK flag is "1". When this occurs, the slave transmitter will release the SDA line to allow the master to send a STOP signal to release the I²C Bus.

I²C Bus Communication

Communication on the I²C bus requires four separate steps, a START signal, a slave device address transmission, a data transmission and finally a STOP signal. When a START signal is placed on the I²C bus, all devices on the bus will receive this signal and be notified of the imminent arrival of data on the bus. The first seven bits of the data will be the slave address with the first bit being the MSB. If the address of the slave device matches that of the transmitted address, the HAAS bit in the SIMC1 register will be set and an I²C interrupt will be generated. After entering the interrupt service routine, the slave device must first check the condition of the HAAS and SIMTOF bit to determine whether the interrupt source originates from an address match or from the completion of an 8-bit data transfer or I²C time-out. During a data transfer, note that after the 7-bit slave address has been transmitted, the following bit, which is the 8th bit, is the read/write bit whose value will be placed in the SRW bit. This bit will be checked by the slave device to determine whether to go into transmit or receive mode. Before any transfer of data to or from the I²C bus, the microcontroller must initialise the bus, the following are steps to achieve this:

- **Step 1**

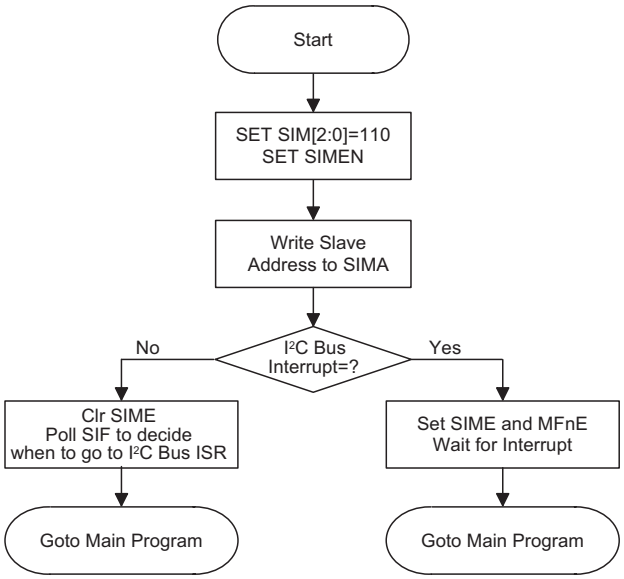
  Set the SIM2~SIM0 bits to "110" and SIMEN bit to "1" in the SIMC0 register to enable the I²C bus.

- **Step 2**

  Write the slave address of the device to the I²C bus address register SIMA.

- **Step 3**

  Set the SIME and SIM Muti-Function interrupt enable bit of the interrupt control register to enable the SIM interrupt and Multi-function interrupt.



I²C Bus Initialisation Flow Chart

I²C Bus Start Signal

The START signal can only be generated by the master device connected to the I²C bus and not by the slave device. This START signal will be detected by all devices connected to the I²C bus. When detected, this indicates that the I²C bus is busy and therefore the HBB bit will be set. A START condition occurs when a high to low transition on the SDA line takes place when the SCL line remains high.

I²C Slave Address

The transmission of a START signal by the master will be detected by all devices on the I²C bus. To determine which slave device the master wishes to communicate with, the address of the slave device will be sent out immediately following the START signal. All slave devices, after receiving this 7-bit address data, will compare it with their own 7-bit slave address. If the address sent out by the master matches the internal address of the microcontroller slave device, then an internal I²C bus interrupt signal will be generated. The next bit following the address, which is the 8th bit, defines the read/write status and will be saved to the SRW bit of the SIMC1 register. The slave device will then transmit an acknowledge bit, which is a low level, as the 9th bit. The slave device will also set the status flag HAAS when the addresses match.

As an I²C bus interrupt can come from two sources, when the program enters the interrupt subroutine, the HAAS bit and SIMTOF bit should be examined to see whether the interrupt source has come from a matching slave address or from the completion of a data byte transfer or I²C time-out. When a slave address is matched, the devices must be placed in either the transmit mode and then write data to the SIMD register, or in the receive mode where it must implement a dummy read from the SIMD register to release the SCL line.

I²C Bus Read/Write Signal

The SRW bit in the SIMC1 register defines whether the slave device wishes to read data from the I²C bus or write data to the I²C bus. The slave device should examine this bit to determine if it is to be a transmitter or a receiver. If the SRW flag is "1" then this indicates that the master device wishes to read data from the I²C bus, therefore the slave device must be setup to send data to the I²C bus as a transmitter. If the SRW flag is "0" then this indicates that the master wishes to send data to the I²C bus, therefore the slave device must be setup to read data from the I²C bus as a receiver.

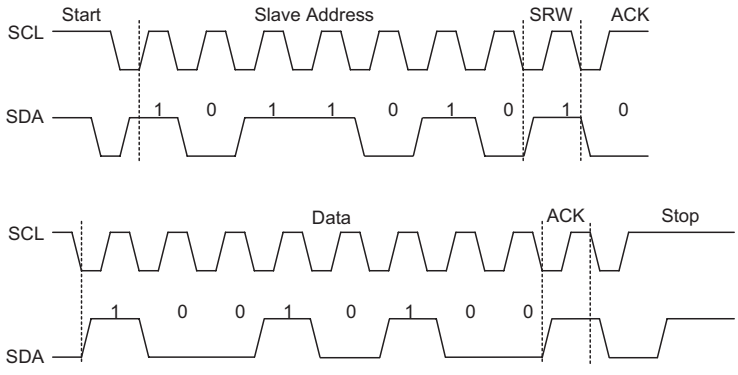
I²C Bus Slave Address Acknowledge Signal

After the master has transmitted a calling address, any slave device on the I²C bus, whose own internal address matches the calling address, must generate an acknowledge signal. The acknowledge signal will inform the master that a slave device has accepted its calling address. If no acknowledge signal is received by the master then a STOP signal must be transmitted by the master to end the communication. When the HAAS flag is high, the addresses have matched and the slave device must check the SRW flag to determine if it is to be a transmitter or a receiver. If the SRW flag is high, the slave device should be setup to be a transmitter so the HTX bit in the SIMC1 register should be set to "1". If the SRW flag is low, then the microcontroller slave device should be setup as a receiver and the HTX bit in the SIMC1 register should be set to "0".

I²C Bus Data and Acknowledge Signal

The transmitted data is 8-bits wide and is transmitted after the slave device has acknowledged receipt of its slave address. The order of serial bit transmission is the MSB first and the LSB last. After receipt of 8-bits of data, the receiver must transmit an acknowledge signal, level "0", before it can receive the next data byte. If the slave transmitter does not receive an acknowledge bit signal from the master receiver, then the slave transmitter will release the SDA line to allow the master to send a STOP signal to release the I²C Bus. The corresponding data will be stored in the SIMD register. If setup as a transmitter, the slave device must first write the data to be transmitted into the SIMD register. If setup as a receiver, the slave device must read the transmitted data from the SIMD register.

When the slave receiver receives the data byte, it must generate an acknowledge bit, known as TXAK, on the 9th clock. The slave device, which is setup as a transmitter will check the RXAK bit in the SIMC1 register to determine if it is to send another data byte, if not then it will release the SDA line and await the receipt of a STOP signal from the master.

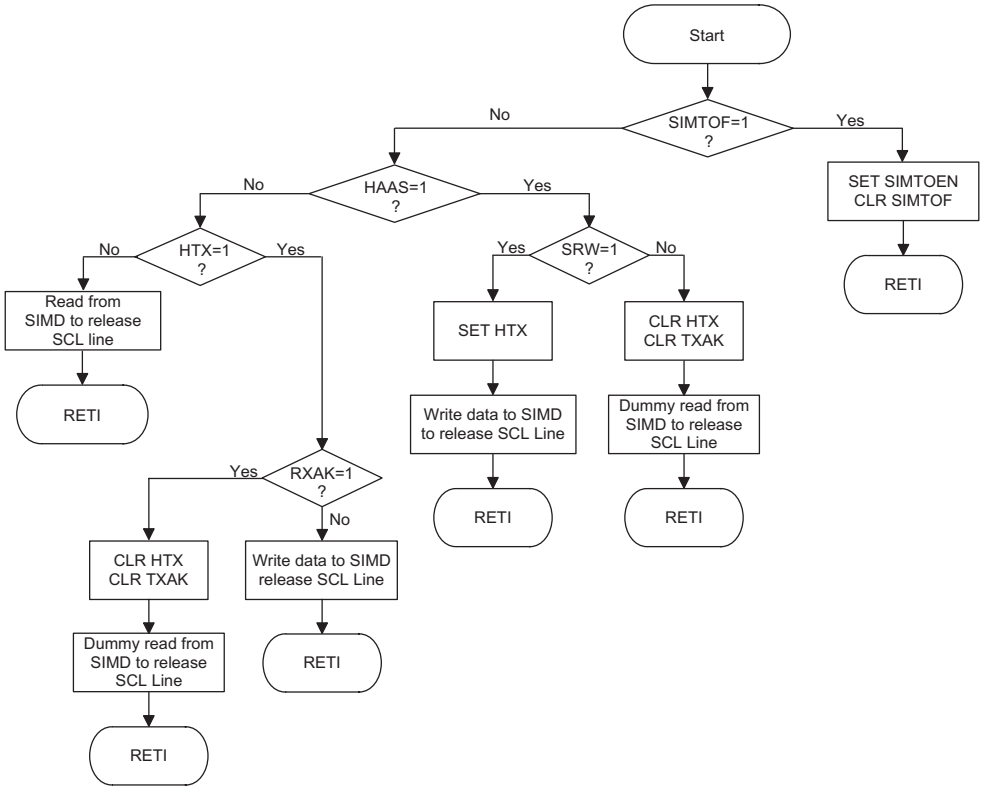


S=Start (1 bit)
SA=Slave Address (7 bits)
SR=SRW bit (1 bit)
M=Slave device send acknowledge bit (1 bit)
D=Data (8 bits)
A=ACK (RXAK bit for transmitter, TXAK bit for receiver 1 bit)
P=Stop (1 bit)

S	SA	SR	M	D	A	D	A	----------	S	SA	SR	M	D	A	D	A	----------	P

I²C Communication Timing Diagram

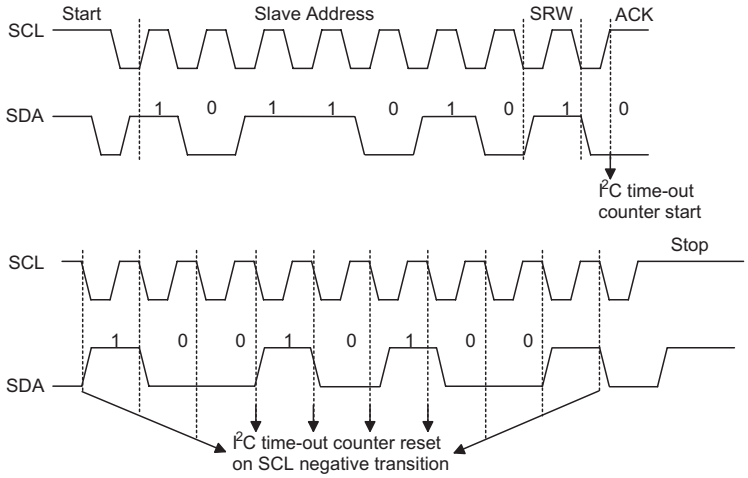
Note: *When a slave address is matched, the device must be placed in either the transmit mode and then write data to the SIMD register, or in the receive mode where it must implement a dummy read from the SIMD register to release the SCL line.



I²C Bus ISR Flow Chart

I²C Time-out Control

In order to reduce the I²C lockup problem due to reception of erroneous clock sources, a time-out function is provided. If the clock source connected to the I²C bus is not received for a while, then the I²C circuitry and registers will be reset after a certain time-out period. The time-out counter starts to count on an I²C bus "START" & "address match"condition, and is cleared by an SCL falling edge. Before the next SCL falling edge arrives, if the time elapsed is greater than the time-out period specified by the SIMTOC register, then a time-out condition will occur. The time-out function will stop when an I²C "STOP" condition occurs.



I²C Time-out Diagram

When an I²C time-out counter overflow occurs, the counter will stop and the I2CTOEN bit will be cleared to zero and the I2CTF bit will be set high to indicate that a time-out condition has occurred. The time-out condition will also generate an interrupt which uses the I²C interrrupt vector. When an I²C time-out occurs, the I²C internal circuitry will be reset and the registers will be reset into the following condition:

Register	After I²C Time-out
SIMD, SIMA, SIMC0	No change
SIMC1	Reset to POR condition

I²C Register after Time-out

The I2CTOF flag can be cleared by the application program. There are 64 time-out period selections which can be selected using the I2CTOS bits in the SIMTOC register. The time-out duration is calculated by the formula: ((1~64) × (32/f_{SUB})). This gives a time-out period which ranges from about 1ms to 64ms.

SIMTOC Register

Bit	7	6	5	4	3	2	1	0
Name	SIMTOEN	SIMTOF	SIMTOS5	SIMTOS4	SIMTOS3	SIMTOS2	SIMTOS1	SIMTOS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **SIMTOEN**: I²C Time-out control
0: Disable
1: Enable

Bit 6 **SIMTOF**: I²C Time-out flag
0: No time-out occurred
1: Time-out occurred

Bit 5~0 **SIMTOS5~SIMTOS0**: I²C Time-out period selection
I²C Time-out clock source is $f_{SUB}/32$

I²C Time-out period is equal to $(\text{I2CTOS}[5:0]+1)\times\frac{32}{f_{SUB}}$

Serial Interface – SPIA

The device contains an independent SPI function. It is important not to confuse this independent SPI function with the additional one contained within the combined SIM function, which is described in another section of this datasheet. This independent SPI function will carry the name SPIA to distinguish it from the other one in the SIM.

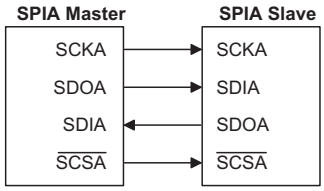
This SPIA interface is often used to communicate with external peripheral devices such as sensors, Flash or EEPROM memory devices, etc. Originally developed by Motorola, the four line SPI interface is a synchronous serial data interface that has a relatively simple communication protocol simplifying the programming requirements when communicating with external hardware devices.

The communication is full duplex and operates as a slave/master type, where the device can be either master or slave. Although the SPIA interface specification can control multiple slave devices from a single master, this device is provided only one $\overline{\text{SCSA}}$ pin. If the master needs to control multiple slave devices from a single master, the master can use I/O pins to select the slave devices.

SPIA Interface Operation

The SPIA interface is a full duplex synchronous serial data link. It is a four line interface with pin names SDIA, SDOA, SCKA and $\overline{\text{SCSA}}$ Pins SDIA and SDOA are the Serial Data Input and Serial Data Output lines, SCKA is the Serial Clock line and $\overline{\text{SCSA}}$ is the Slave Select line. As the SPIA interface pins are pin-shared with other functions, the SPIA interface pins must first be selected by configuring the corresponding selection bits in the pin-shared function selection registers. The SPIA interface function is disabled or enabled using the SPIAEN bit in the SPIAC0 register. Communication between devices connected to the SPIA interface is carried out in a slave/master mode with all data transfer initiations being implemented by the master. The master also controls the clock/signal. As the device only contains a single $\overline{\text{SCSA}}$ pin only one slave device can be utilised.

The $\overline{\text{SCSA}}$ pin is controlled by the application program, set the the SACSEN bit to "1" to enable the $\overline{\text{SCSA}}$ pin function and clear the SACSEN bit to "0" to place the $\overline{\text{SCSA}}$ pin into an I/O function.

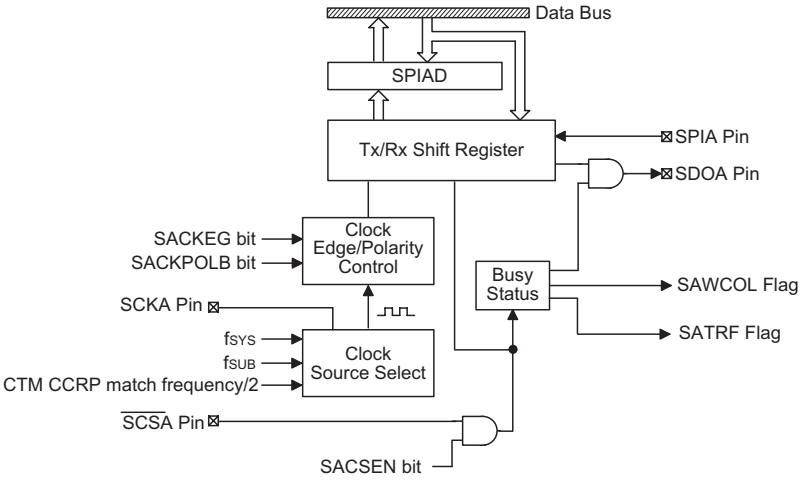


SPIA Master/Slave Connection

The SPIA Serial Interface function includes the following features:

- Full-duplex synchronous data transfer
- Both Master and Slave mode
- LSB first or MSB first data transmission modes
- Transmission complete flag
- Rising or falling active clock edge

The status of the SPIA interface pins is determined by a number of factors such as whether the device is in the master or slave mode and upon the condition of certain control bits such as SACSEN and SPIAEN.



SPIA Block Diagram

SPIA Registers

There are three internal registers which control the overall operation of the SPIA interface. These are the SIMD data register and two registers SPIAC0 and SPIAC1.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SPIAC0	SASPI2	SASPI1	SASPI0	—	—	—	SPIAEN	SPIAICF
SPIAC1	—	—	SACKPOLB	SACKEG	SAMLS	SACSEN	SAWCOL	SATRF
SPIAD	D7	D6	D5	D4	D3	D2	D1	D0

SPIA Registers List

SPIAD Register

The SPIAD register is used to store the data being transmitted and received. Before the device writes data to the SPIA bus, the actual data to be transmitted must be placed in the SPIAD register. After the data is received from the SPIA bus, the device can read it from the SPIAD register. Any transmission or reception of data from the SPIA bus must be made via the SPIA register.

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

There are also two control registers for the SPIA interface, SPIAC0 and SPIAC1. Register SPIAC0 is used to control the enable/disable function and to set the data transmission clock frequency. Register SPIAC1 is used for other control functions such as LSB/MSB selection, write collision flag, etc.

SPIAC0 Register

Bit	7	6	5	4	3	2	1	0
Name	SASPI2	SASPI1	SASPI0	—	—	—	SPIAEN	SPIAICF
R/W	R/W	R/W	R/W	—	—	—	R/W	R/W
POR	1	1	1	—	—	—	0	0

Bit 7~5 **SASPI2~SASPI0**: SPIA Master/Slave clock select
000: SPIA master mode with clock f_{SYS} /4
001: SPIA master mode with clock f_{SYS} /16
010: SPIA master mode with clock f_{SYS} /64
011: SPIA master mode with clock f_{SUB}
100: SPIA master mode with clock CTM CCRP match frequency/2
101: SPIA slave mode
11x: Reserved

Bit 4~2 Unimplemented, read as "0"

Bit 1 **SPIAEN**: SPIIA Enable Control
0: Disable
1: Enable
The bit is the overall on/off control for the SPIA interface. When the SPIAEN bit is cleared to zero to disable the SPIA interface, the SDIA, SDOA, SCKA and $\overline{SCSA}$ lines will lose the SPI function and the SPIA operating current will be reduced to a minimum value. When the bit is high the SPIA interface is enabled.

Bit 0 **SPIAICF**: SPIA Incomplete Flag
0: SPIA incomplete condition not occurred
1: SPIA incomplete condition occured
This bit is only available when the SPIA is configured to operate in an SPIA slave mode. If the SPIA operates in the slave mode with the SPIAEN and SACSEN bits both being set to 1 but the $\overline{SCSA}$ line is pulled high by the external master device before the SPIA data transfer is completely finished, the SPIAICF bit will be set to 1 together with the SATRF bit. When this condition occurs, the corresponding interrupt will occur if the interrupt function is enabled. However, the SATRF bit will not be set to 1 if the SPIAICF bit is set to 1 by software application program.

SPIAC1 Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	SACKPOLB	SACKEG	SAMLS	SACSEN	SAWCOL	SATRF
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **SACKPOLB**: SPIA clock line base condition selection
0: The SCKA line will be high when the clock is inactive.
1: The SCKA line will be low when the clock is inactive.
The SACKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCKA line will be low when the clock is inactive. When the SACKPOLB bit is low, then the SCKA line will be high when the clock is inactive.

Bit 4 **SACKEG**: SPIA SCKA clock active edge type selection
SACKPOLB=0
0: SCKA is high base level and data capture at SCKA rising edge
1: SCKA is high base level and data capture at SCKA falling edge
SACKPOLB=1
0: SCKA is low base level and data capture at SCKA falling edge
1: SCKA is low base level and data capture at SCKA rising edge

The SACKEG and SACKPOLB bits are used to setup the way that the clock signal outputs and inputs data on the SPIA bus. These two bits must be configured before data transfer is executed otherwise an erroneous clock edge may be generated. The SACKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCKA line will be low when the clock is inactive. When the SACKPOLB bit is low, then the SCKA line will be high when the clock is inactive. The SACKEG bit determines active clock edge type which depends upon the condition of SACKPOLB bit.

Bit 3 **SAMLS**: SPIA data shift order
0: LSB first
1: MSB first

This is the data shift select bit and is used to select how the data is transferred, either MSB or LSB first. Setting the bit high will select MSB first and low for LSB first.

Bit 2 **SACSEN**: SPIA $\overline{\text{SCSA}}$ pin control
0: Disable
1: Enable

The SACSEN bit is used as an enable/disable for the $\overline{\text{SCSA}}$ pin. If this bit is low, then the $\overline{\text{SCSA}}$ pin function will be disabled and can be placed into I/O pin or other pin-shared functions. If the bit is high, the $\overline{\text{SCSA}}$ pin will be enabled and used as a select pin.

Bit 1 **SAWCOL**: SPIA write collision flag
0: No collision
1: Collision

The SAWCOL flag is used to detect whether a data collision has occurred or not. If this bit is high, it means that data has been attempted to be written to the SPIAD register duting a data transfer operation. This writing operation will be ignored if data is being transferred. This bit can be cleared by the application program.

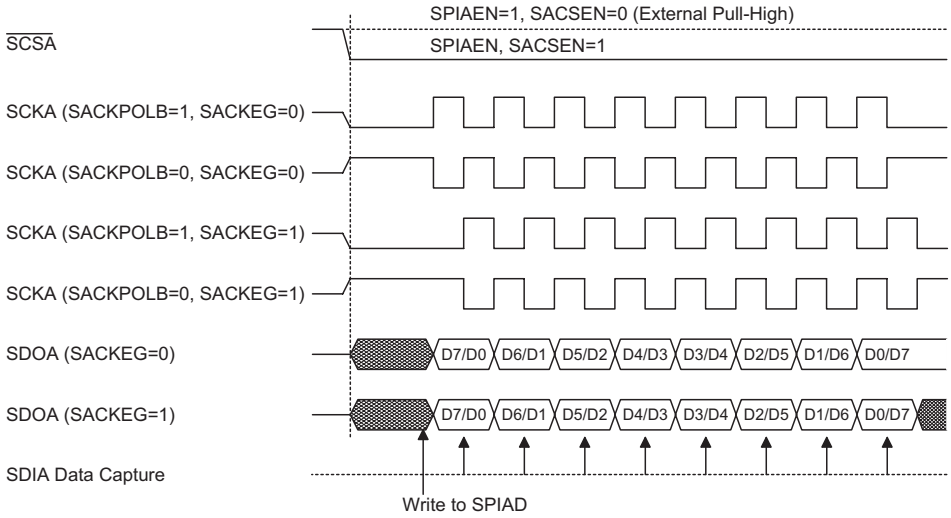
Bit 0 **SATRF**: SPIA Transmit/Receive complete flag
0: SPIA data is being transferred
1: SPIA data transfer is completed

The SATRF bit is the Transmit/Receive Complete flag and is set to 1 automatically when an SPIA data transfer is completed, but must cleared to 0 by the application program. It can be used to generate an interrupt.

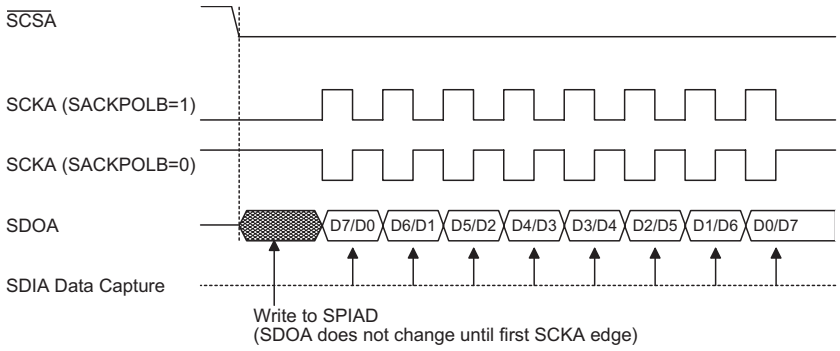
SPIA Communication

After the SPIA interface is enabled by setting the SPIAEN bit high, then in the Master Mode, when data is written to the SPIAD register, transmission/reception will begin simultaneously. When the data transfer is complete, the SATRF flag will be set automatically, but must be cleared using the application program. In the Slave Mode, when the clock signal from the master has been received, any data in the SPIAD register will be transmitted and any data on the SDIA pin will be shifted into the SPIAD registers.

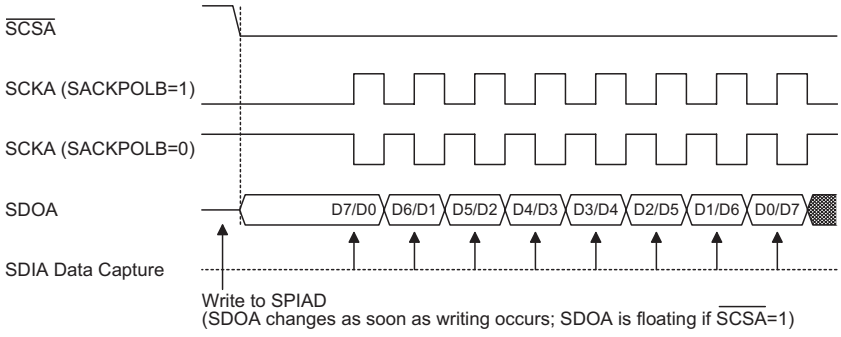
The master should output a $\overline{\text{SCSA}}$ signal to enable the slave device before a clock signal is provided. The slave data to be transferred should be well prepared at the appropriate moment relative to the $\overline{\text{SCSA}}$ signal depending upon the configurations of the SACKPOLB bit and SACKEG bit. The accompanying timing diagram shows the relationship between the slave data and $\overline{\text{SCSA}}$ signal for various configurations of the SACKPOLB and SACKEG bits. The SPIA will continue to function if the SPIA clock source is active.



SPIA Master Mode Timing

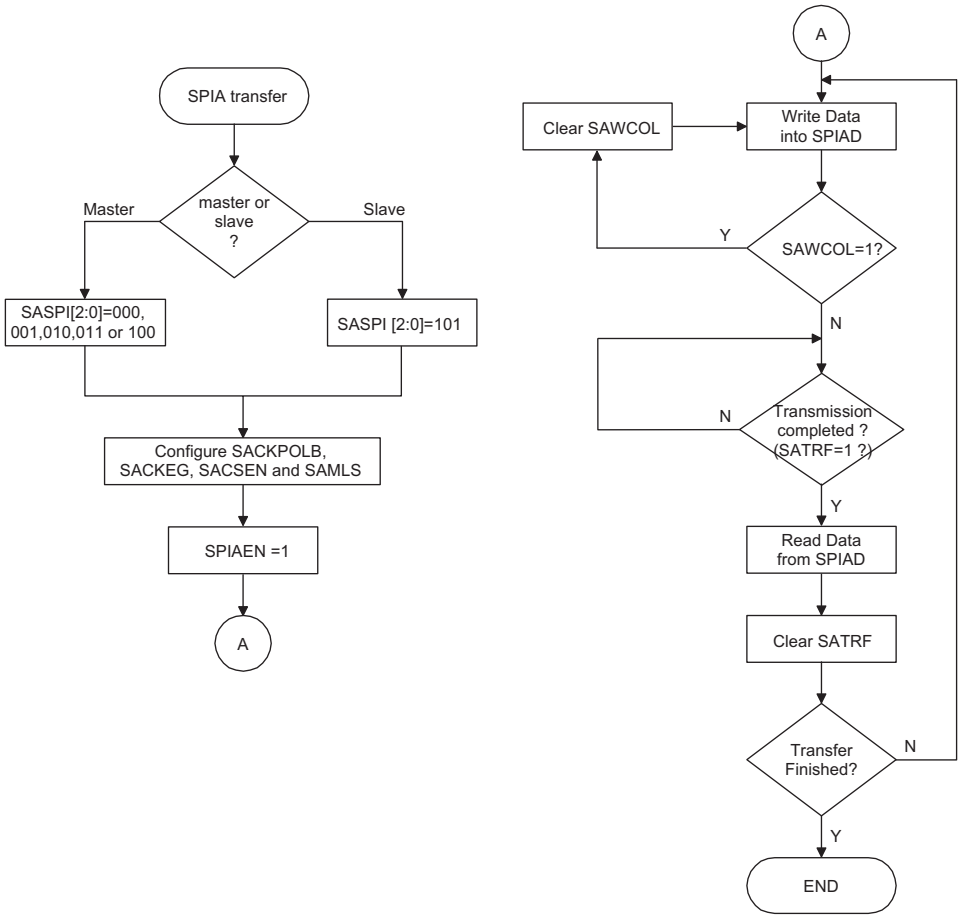


SPIA Slave Mode Timing – SACKEG=0



Note: For SPIA slave mode, if SPIAEN=1 and SACSEN=0, SPIA is always enabled and ignores the $\overline{SCSA}$ level.

SPIA Slave Mode Timing – SACKEG=1



SPIA Transfer Control Flowchart

SPIA Bus Enable/Disable

To enable the SPIA bus, set SACSEN=1 and $\overline{SCSA}$ =0, then wait for data to be written into the SPIAD (TXRX buffer) register. For the Master Mode, after data has been written to the SPIAD (TXRX buffer) register, then transmission or reception will start automatically. When all the data has been transferred the SATRF bit should be set. For the Slave Mode, when clock pulses are received on SCKA, data in the TXRX buffer will be shifted out or data on SDIA will be shifted in.

To Disable the SPIA bus SCKA, SDIA, SDOA, $\overline{SCSA}$ will become I/O pins or other pin-shared functions.

SPIA Operation

All communication is carried out using the 4-line interface for either Master or Slave Mode.

The SACSEN bit in the SPIAC1 register controls the overall function of the SPIA interface. Setting this bit high will enable the SPIA interface by allowing the $\overline{SCSA}$ line to be active, which can then be used to control the SPIA interface. If the SACSEN bit is low, the SPIA interface will be disabled and the $\overline{SCSA}$ line will be an I/O pin or other pin-shared functions and can therefore not be used for control of the SPIA interface. If the SACSEN bit and the SPIAEN bit in the SPIAC0 register are set high, this will place the SDIA line in an I/O pin or other pin-shared functions and the SDOA line high. If in Master Mode the SCKA line will be either high or low depending upon the clock polarity selection bit SACKPOLB in the SPIAC1 register. If in Slave Mode the SCKA line will be in an I/O pin or other pin-shared functions. If SPIAEN is low then the bus will be disabled and $\overline{SCSA}$, SDIA, SDOA and SCKA pins will all become I/O pins or other pin-shared functions. In the Master Mode the Master will always generate the clock signal. The clock and data transmission will be initiated after data has been written into the SPIAD register. In the Slave Mode, the clock signal will be received from an external master device for both data transmission and reception. The following sequences show the order to be followed for data transfer in both Master and Slave Mode.

Master Mode

- **Step 1**

  Select the clock source and Master mode using the SASPI2~SASPI0 bits in the SPIAC0 control register

- **Step 2**

  Setup the SACSEN bit and setup the SAMLS bit to choose if the data is MSB or LSB shifted first, this must be same as the Slave device.

- **Step 3**

  Setup the SPIAEN bit in the SPIAC0 control register to enable the SPIA interface.

- **Step 4**

  For write operations: write the data to the SPIAD register, which will actually place the data into the TXRX buffer. Then use the SCKA and $\overline{SCSA}$ lines to output the data. After this go to step 5.

  For read operations: the data transferred in on the SDIA line will be stored in the TXRX buffer until all the data has been received at which point it will be latched into the SPIAD register.

- **Step 5**

  Check the SAWCOL bit if set high then a collision error has occurred so return to step 4. If equal to zero then go to the following step.

- **Step 6**

  Check the SATRF bit or wait for a SPIA serial bus interrupt.

- **Step 7**

  Read data from the SPIAD register.

- **Step 8**

  Clear SATRF.

- **Step 9**

  Go to step 4.

Slave Mode

- **Step 1**

  Select the SPI Slave mode using the SASPI2~SASPI0 bits in the SPIAC0 control register

- **Step 2**

  Setup the SACSEN bit and setup the SAMLS bit to choose if the data is MSB or LSB shifted first, this setting must be the same with the Master device.

- **Step 3**

  Setup the SPIAEN bit in the SPIAC0 control register to enable the SPIA interface.

- **Step 4**

  For write operations: write the data to the SPIAD register, which will actually place the data into the TXRX buffer. Then wait for the master clock SCKA and $\overline{\text{SCSA}}$ signal. After this, go to step 5.

  For read operations: the data transferred in on the SDIA line will be stored in the TXRX buffer until all the data has been received at which point it will be latched into the SPIAD register.

- **Step 5**

  Check the SAWCOL bit if set high then a collision error has occurred so return to step 4. If equal to zero then go to the following step.

- **Step 6**

  Check the SATRF bit or wait for a SPIA serial bus interrupt.

- **Step 7**

  Read data from the SPIAD register.

- **Step 8**

  Clear SATRF.

- **Step 9**

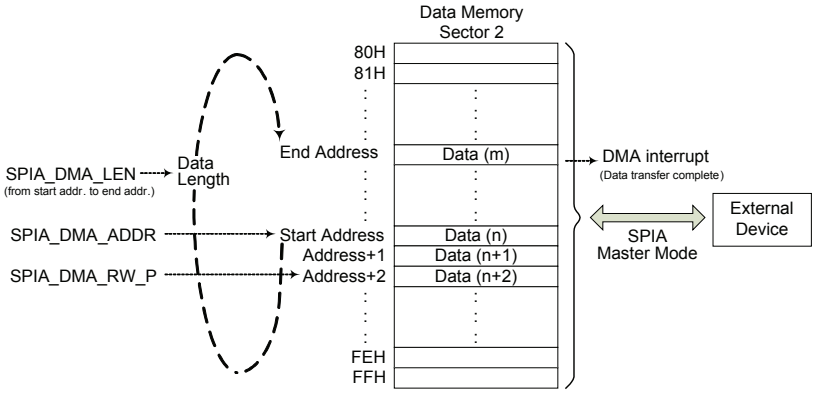
  Go to step 4.

Error Detection

The SAWCOL bit in the SPIAC1 register is provided to indicate errors during data transfer. The bit is set by the SPIA serial Interface but must be cleared by the application program. This bit indicates a data collision has occurred which happens if a write to the SPIAD register takes place during a data transfer operation and will prevent the write operation from continuing.

Direct Memory Access – DMA

The device contains a Direct Memory Access, DMA, controller which is used for direct data exchange with external devices without using the MCU resources. This assumes that the data to be transferred is prepared and ready. The DMA controller exchanges the data with the external device using the independent Serial Interface. This has the name SPIA and is described in another section. The SPIA name is used to distinguish it from other SPI interface which exists in the Serial Interface Module, SIM. The data to be transmitted by the DMA controller must first be written into Data Memory Sector 2. The received data will also be stored in Data Memory Sector 2. After the DMA data transfer is completed, a DMA interrupt will be generated if the corresponding interrupt control is enabled.



DMA Using SPIA Interface

DMA Controller

The DMA controller implements data exchange with external devices using the SPIA interface setup in the master mode. If there is data to be transmitted to an external device, the data needs to be first written into the Data Memory Sector 2. The SPIA related registers must also be properly configured to set it up as an SPIA master device. Then the corresponding DMA configurations such as the DMA transfer start address and data length should be specified. After the configurations described above are setup, the DMA transfer start bit can be set from 0 to 1 to activate the DMA transfer.

The DMA transfer start address can be set from 80H to FFH in Data Memory Sector 2 and the transfer data length can be from 1 to 128 bytes. The DMA transfer current address is specified by the read-only DMA address pointer which will be automatically incremented by 1 after each data byte is successfully transferred on the SPIA interface. When the address is greater than the maximum available address, FFH, and the desired DMA data transfer has not completed, the address will be wrapped around to the start address, 80H. Then the current address pointer will continue to be incremented by 1 until the desired DMA data transfer has completed.

After the desired data transaction has completed, a DMA interrupt will be generated if the corresponding DMA interrupt control is enabled. The enable control bit, DMA_ON, will not be cleared to 0 automatically by hardware so must therefore be cleared to 0 by the application program after the current DMA data transfer has finished. Note that the DMA_ON bit must be set from 0 to 1 if the next DMA data transaction is necessary to be re-initiated after the current data transfer has completed. For another DMA transfer to take place the DMA_ON bit must be cleared to zero and again set high. If the DMA_ON bit remains high, further DMA data transfers will not be re-initiated.

DMA Registers

There are four registers related to the DMA data transfer, which control the overall DMA data transfer operation. A DMA control register exists to store the DMA related error flags together with the DMA enable control and mode select. There is a data length register which is used to store the overall DMA data transfer length. There is also an address register together with a read-only address pointer which are used to manage the data address during the DMA data transfer operation.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SPIA_DMAC	DMA_ON	—	—	—	DMA_HALTERR	DMA_STERR	DMA_FST	DMA_ERROR
SPIA_DMA_LEN	—	DL6	DL5	DL4	DL3	DL2	DL1	DL0
SPIA_DMA_ADDR	DA7	DA6	DA5	DA4	DA3	DA2	DA1	DA0
SPIA_DMA_RW_P	DP7	DP6	DP5	DP4	DP3	DP2	DP1	DP0

DMA Registers List

SPIADMAC Register

Bit	7	6	5	4	3	2	1	0
Name	DMA_ON	—	—	—	DMA_HALTERR	DMA_STERR	DMA_FST	DMA_ERROR
R/W	R/W	—	—	—	R	R	R/W	R
POR	0	—	—	—	0	0	0	0

Bit 7 **DMA_ON**: DMA enable control
0 → 1: DMA enabled
1 → 0: DMA disable
Before using the DMA data transfer function the SPIA interface should first be properly configured to be in the master mode together with its other related configurations. After this the DMA data transfer will be activated when the DMA_ON bit is set from 0 to 1 if the corresponding DMA configurations are also properly setup. Note that this bit should be cleared to 0 by the application program after the whole DMA data transfer is completed.

Bit 6~4 Unimplemented, read as "0"

Bit 3 **DMA_HALTERR**: DMA HALT error flag
0: No HALT instruction is executed during a DMA operation
1: HALT instruction is executed during a DMA operation
This bit is set to 1 by the hardware when the MCU executes a HALT instruction during a DMA operation. This bit can be cleared to 0 by the application program or automatically cleared to 0 when the DMA_ON bit is re-set from 0 to 1. The DMA data transfer will immediately be terminated and the address pointer will remain unchanged if the MCU executes a HALT instruction during the DMA operation. This will result in the DMA_HALTERR bit being set to 1.

Bit 2 **DMA_STERR**: DMA Start error flag
0: No Start error occurs during a DMA operation
1: Start error occurs during a DMA operation
This bit is set to 1 by the hardware if the DMA_ON or SPIAEN bit is cleared to 0 to stop the DMA transfer when the DMA transfer is operating. This bit can be cleared to 0 by the application program or automatically cleared to 0 when the DMA_ON bit is re-set from 0 to 1. When the DMA_STERR bit is set to 1, the DMA error interrupt will be generated if the corresponding interrupt is enabled.

If the DMA_ON bit is cleared to 0 during the DMA operation, the current DMA data byte transfer will not immediately be terminated until the current byte transfer is finished. The address pointer will then be incremented by one. Then overall DMA data transfer will be terminated and the DMA_STERR bit will be set to 1. However, if the SPIAEN bit is cleared to 0 during the DMA operation, the current data byte transfer will immediately be terminated and the address pointer will be incremented by one followed by the DMA_STERR bit being set to 1.

Bit 1 **DMA_FST**: DMA transfer mode select
0: Normal mode
1: Fast mode

Bit 0 **DMA_ERROR**: DMA Write error flag
0: No write error occurs during a DMA operation
1: Write error occurs during a DMA operation

This bit is set to 1 by the hardware if the MCU writes a data byte into a certain location in Data memory Sector 2, during a time where data is being transferred to the external device via the SPIA interface. This bit can be cleared to 0 by the application program or automatically cleared to 0 when the DMA_ON bit is re-set from 0 to 1. When the DMA_ERROR bit is set to 1, a DMA error interrupt will be generated if the corresponding interrupt is enabled.

The MCU write operation will be ignored and the DMA controller will continue to transfer data with the DMA_ERROR bit being set to 1 when the same Data Memory address is accessed by the DMA transfer and the MCU write access.

SPIA_DMA_LEN Register

Bit	7	6	5	4	3	2	1	0
Name	—	DL6	DL5	DL4	DL3	DL2	DL1	DL0
R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	0	1	1	1	1	1	1

Bit 7 Unimplemented, read as "0"

Bit 6~0 **DL6~DL0**: DMA data transfer length
DMA data transfer length = [DL6 ~ DL0] + 1
DMA data transfer length can be from 1 to 128 byte.

SPIA_DMA_ADDR Register

Bit	7	6	5	4	3	2	1	0
Name	DA7	DA6	DA5	DA4	DA3	DA2	DA1	DA0
R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	1	0	0	0	0	0	0	0

Bit 7 **DA7**: MSB of the DMA address, fixed as "1"

Bit 6~0 **DA6~DA0**: DMA data transfer start address
DMA data transfer start address can be from 80H to FFH.

SPIA_DMA_RW_P Register

Bit	7	6	5	4	3	2	1	0
Name	DP7	DP6	DP5	DP4	DP3	DP2	DP1	DP0
R/W	R	R	R	R	R	R	R	R
POR	1	0	0	0	0	0	0	0

Bit 7~0 **DP7~DP0**: DMA data transfer current address pointer
DMA data transfer start address can be from 80H to FFH.

DMA Data Transfer using SPIA Interface

When there is data to be transferred by the DMA controller, the data has to first be written into Data Memory Sector 2. The SPIA interface master mode is used to transfer the data stored in the Data Memory Sector 2 and therefore the corresponding SPIA registers should be properly configured. The DMA relevant registers should also be setup before the DMA_ON bit is correctly initiated. After the DMA_ON is set from 0 to 1, the data which has been written into Data Memory Sector 2 will automatically be transmitted via the SDOA line to the external device while data from the external device will be received on the SDIA line. After the whole data transaction has finished, a DMA interrupt will be generated if the relevant interrupt function is enabled. The DMA_ON bit should be cleared to 0 by the application program.

When the DMA data transfer is activated and one byte of data has completely transferred using the SPIA master mode, the SPIA transfer complete flag, SATRF, will be set to 1 and an SPIA complete transfer interrupt will be generated if the related interrupt control is enabled. Then the data byte at the same time received from the SDIA line will be moved into Data Memory Sector 2. After this the DMA address pointer will be incremented by one and the SATRF flag will be cleared to 0 automatically and the next data byte will be loaded into the SPIA data register, SPIAD, in preparation for the next data byte transfer.

DMA Error Management

When data is transferring via the DMA controller, three types of errors may occur. These errors are DMA HALT error, DMA Start error and DMA Write error. When the DMA data is transferring and the MCU executes a HALT instruction, the DMA HALT error condition will occur.

If a DMA HALT error occurs, the current DMA data transfer will immediately be terminated, the address pointer will remain unchanged and the corresponding error flag, DMA_HALTERR, will be set to 1.

When the DMA_ON or SPIAEN bit is cleared to 0 to stop a presently executing DMA transfer, a DMA Start error condition will occur and the DMA error interrupt request will be generated. If a DMA Start error occurs due to the DMA operation being disabled by clearing the DMA_ON bit to 0, the current DMA data byte transfer will not immediately be terminated until the current byte transfer is finished. The address pointer will then be incremented by one and the corresponding error flag, DMA_STERR, will be set to 1. However, if a DMA Start error occurs due to the SPIA interface being disabled by clearing the SPIAEN bit to 0, the current DMA data transfer will immediately be terminated, the address pointer will be incremented by one and the DMA_STERR bit will set to 1.

When the MCU writes a data byte into a certain location in Data Memory Sector 2, during a time in which data is being transferred to the external device via the SPIA interface, a DMA Write error condition will occur and a DMA error interrupt request will be generated. If a DMA Write error occurs, the MCU write operation will be ignored, the DMA controller will continue to transfer data and the DMA_ERROR bit will be set to 1.

Note that any of these error flags will be set to 1 by the hardware when the corresponding error condition occurs and will be cleared to 0 by the application program or automatically cleared when the DMA_ON bit is re-set from 0 to 1.

DMA Interrupt

There are two kinds of DMA interrupts, the DMA transfer interrupt and DMA error interrupt. The DMA transfer interrupt will occur when the whole of the DMA data is completely transferred while the DMA error interrupt will occur when the corresponding error condition occurs. The corresponding DMA interrupts must be enabled along with the EMI being enabled.

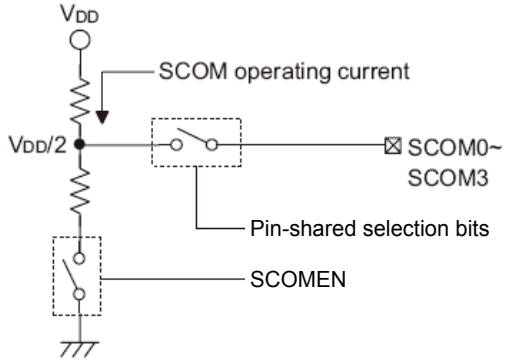
SCOM Function for LCD

The device has the capability of driving external LCD panels. The common pins for LCD driving, SCOM0~SCOM3, are pin shared with the I/O pins. The LCD signals (COM and SEG) are generated using the application program.

LCD Operation

An external LCD panel can be driven using this device by configuring the I/O pins as common pins and using other output ports lines as segment pins. The LCD driver function is controlled using the SCOMC register which in addition to controlling the overall on/off function also controls the bias voltage setup function. This enables the LCD COM driver to generate the necessary $V_{DD}/2$ voltage levels for LCD 1/2 bias operation.

The SCOMEN bit in the SCOMC register is the overall master control for the LCD driver. The LCD SCOMn pin is selected to be used for LCD driving by the corresponding pin-shared function selection bits. Note that the Port Control register does not need to first setup the pins as outputs to enable the LCD driver operation.



LCD COM Bias

LCD Bias Control

The LCD COM driver enables a range of selections to be provided to suit the requirement of the LCD panel which is being used. The bias resistor choice is implemented using the ISEL1 and ISEL0 bits in the SCOMC register.

SCOMC Register

Bit	7	6	5	4	3	2	1	0
Name	—	ISEL1	ISEL0	SCOMEN	—	—	—	—
R/W	—	R/W	R/W	R/W	—	—	—	—
POR	—	0	0	0	—	—	—	—

Bit 7 Unimplemented, read as "0"

Bit 6~5 **ISEL1~ISEL0**: Select SCOM typical bias current (V_{DD}=5V)
00: 25μA
01: 50μA
10: 100μA
11: 200μA

Bit 4 **SCOMEN**: SCOM Function enable control
0: Disable
1: Enable

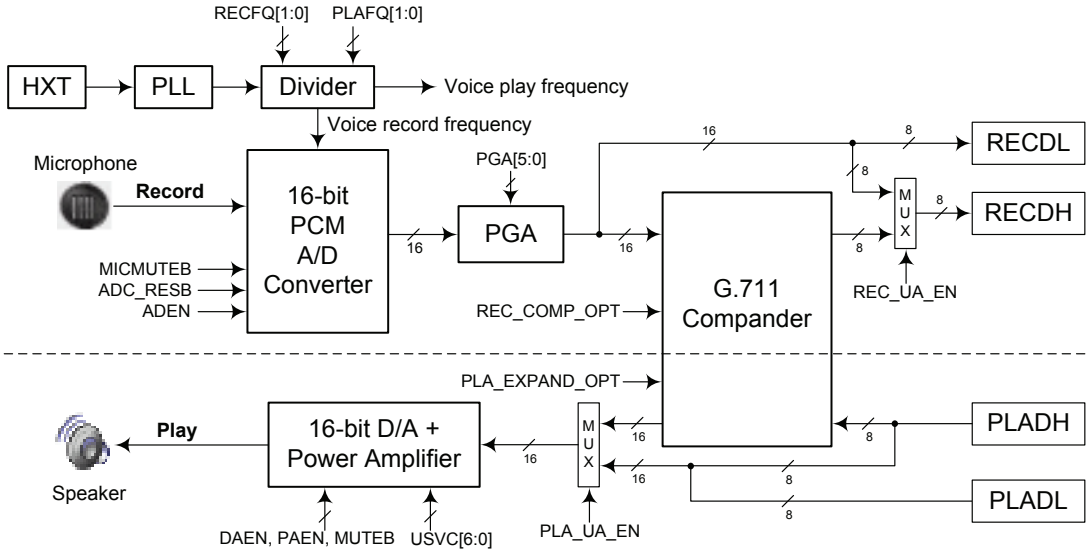
Bit 3~0 Unimplemented, read as "0"

Voice Controller

The device contains a highly flexible and full featured voice controller to manage the voice recording and voice playback operations. On the recording side is 16-bit A/D converter and programmable gain control amplifier for the microphone input signal processing. To manage the problem of signals with large dynamic ranges and reduce memory storage requirements, there is the option to compress the digitised recorded data using the fully integrated compander function. Both μ-law and a-law algorithms can be selected as the compression technique.

On the playback side there is a fully integrated 16-bit D/A converter complete with volume control. A power amplifier offers the possibility of directly driving external speakers. If the recorded data has been compressed, the internal compander will decode the recorded digitised data before being transmitted to the D/A converter for conversion to an analog signal.

An external crystal provides the oscillator source for the internal Phase Locked Loop, PLL, which offers a wide range of recording and playback frequencies.



Voice Controller Block Diagram

PLL Operation

The voice recording and playback clock are derived from a fully integrated PLL circuit. There is no individual enable control bit for the PLL operation. The PLL circuit is controlled by several control bits including the ADEN, ADC_RESB and DAEN bits together with the corresponding voice record and play interrupt enable control bits, RECE and PLAYE. The PLL circuit will be disabled if the related control bits are all cleared to 0 or if the device enters the power down mode. Otherwise, the PLL circuit will be enabled when any of the related control bits are set to 1. After the PLL is enabled and has stabilised, the clock output is further divided by a specific ratio determined by the recording and playing clock frequency selection bits, RECFQ and PLAFQ bit fields. It is recommended that the same frequency is used for both voice recording and playback.

Note that the PLL circuit is enabled by the voice record or play interrupt enable control bits even if the voice recording or playing function is not enabled. This is because the voice recording or playing frequency source can also be used as a general purpose time base when the recording or playing function is not enabled.

Device Power Down	ADEN	ADC_RESB	DAEN	RECE	PLAE	PLL Circuit
Yes	x	x	x	x	x	Disabled
No	0	0	0	0	0	Disabled
	1	x	x	x	x	Enabled
	x	1	x	x	x	
	x	x	1	x	x	
	x	x	x	1	x	
	x	x	x	x	1	

Voice Recording Operation

The voice input from the external microphone is recorded by sampling with a specific recording frequency. This frequency is selected by the RECFQ1 and RECFQ0 bits and then digitised by a 16-bit PCM A/D converter. The 16-bit digitised PCM value is then amplified by a PGA which has a programmable gain, the value of which is setup using the PGA [5:0] bits.

The 16-bit PCM data can be stored in two different ways, direct data storage or first compressed and then stored. This is determined by the REC_UA_EN bit. If the REC_UA_EN bit is cleared to zero, the G.711 Compander compressor function will be disabled and the 16-bit PCM data will be directly stored in the RECDH and RECDL register pair. If the REC_UA_EN bit is set high, the 16-bit PCM data will be first compressed and encoded into 8-bit data using a μ-law or a-law algorithm and then stored into in the RECDH register. The compression type selection is selected by the REC_COMP_OPT bit. The RECDH/RECDL register pair should be read with a fixed frequency, i.e. the voice recording sample rate, which is determined using the RECFQ [1:0] bits. The voice record interrupt request will be generated with a specific frequency, which is known as the voice recording sample rate.

Voice Playing Operation

The voice data located in the PLADH and PLADL register pair can be output with a specific play frequency to the external speaker using the 16-bit D/A converter and a power amplifier whose volume control is setup using the USVC [6:0] bits. The 16-bit voice data in the PLADH and PLADL registers can be directly sent to the D/A converter if the PLA_UA_EN bit is cleared to 0 to disable the G.711 Compander expander function. If the PLA_UA_EN bit is set to 1, the 8-bit data in the PLADH register will be expanded and decoded into 16-bit data using either a μ-law or a-law algorithm. The algorithm selection is determined using the PLA_EXPAND_OPT bit. This expanded 16-bit data will then be transmitted to the 16-bit D/A converter and power amplifier for playback. The volume control can be adjusted using the relevant bits. The PLADH/PLADL register pair should be setup with a fixed frequency, which will be what determines the voice playing sample rate. This is setup using the PLAFQ [1:0] bits. The voice play interrupt request will be generated with a specific frequency, which is known as the voice playing sample rate.

Voice Controller Registers

The overall voice record and play functions are controlled using a series of registers. Four control registers exist to control the 16-bit PCM A/D converter, PGA, G.711 Compander, 16-bit D/A converter and power amplifier functions together with the microphone and speaker mute control. Two data register pairs exist to store the data which is recorded and to be played.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PGAC	MICMUTEB	ADC_ RESB	PGA5	PGA4	PGA3	PGA2	PGA1	PGA0
RECPLAC	RECFQ1	RECFQ0	PLAFQ1	PLAFQ0	—	ADEN	PAEN	DAEN
COMPANDC	—	—	—	—	REC_ COMP_OPT	PLA_ EXPAND_OPT	REC_ UA_EN	PLA_ UA_EN
USVC	MUTEB	USVC6	USVC5	USVC4	USVC3	USVC2	USVC1	USVC0
RECDL	R_D7	R_D6	R_D5	R_D4	R_D3	R_D2	R_D1	R_D0
RECDH	R_D15	R_D14	R_D13	R_D12	R_D11	R_D10	R_D9	R_D8
PLADL	P_D7	P_D6	P_D5	P_D4	P_D3	P_D2	P_D1	P_D0
PLADH	P_D15	P_D14	P_D13	P_D12	P_D11	P_D10	P_D9	P_D8

Voice Controller Registers List

PGAC Register

Bit	7	6	5	4	3	2	1	0
Name	MICMUTEB	ADC_RESB	PGA5	PGA4	PGA3	PGA2	PGA1	PGA0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **MICMUTEB**: Microphone Mute control
0: Mute microphone input
1: Enable microphone input

Bit 6 **ADC_RESB**: 16-bit PCM A/D converter reset control
0: PCM A/D converter in reset condition
1: PCM A/D converter in normal operation

This bit is used to control the 16-bit PCM A/D converter reset function. The PCM A/D converter will be reset when any MCU reset condition occurs or if the ADC_RESB bit is cleared to 0 by the application program. Note that the PCM A/D converter should be reset for at least 100μs by clearing the ADC_RESB bit to 0 to successfully reset the PCM A/D converter after it is enabled by setting the ADEN bit to 1.

Bit 5~0 **PGA5~PGA0**: PGA gain control
000000: Gain ≈ 0 dB
000001: Gain ≈ 0.5 dB
000010: Gain ≈ 1.0 dB
000011: Gain ≈ 1.5 dB
: :
100110: Gain ≈ 19.0 dB
100111: Gain ≈ 19.5 dB
101000: Gain ≈ 19.5 dB
: :
111111: Gain ≈ 19.5 dB

These bits are used to control the PGA gain which ranges from 0dB~19.5dB. The PGA is a digital amplifier used to amplify the 16-bit data that comes from the PCM A/D converter.

RECPLAC Register

Bit	7	6	5	4	3	2	1	0
Name	RECFQ1	RECFQ0	PLAFQ1	PLAFQ0	—	ADEN	PAEN	DAEN
R/W	R/W	R/W	R/W	R/W	—	R/W	R/W	R/W
POR	0	0	0	0	—	0	0	0

Bit 7~6 **RECFQ1~RECFQ0**: Recording frequency selection
00: 8 kHz
01: 16 kHz
10: 12 kHz
11: 24 kHz

Bit 5~4 **PLAFQ1~PLAFQ0**: Playing frequency selection
00: 8 kHz
01: 16 kHz
10: 12 kHz
11: 24 kHz

Bit 3 Unimplemented, read as "0"

Bit 2 **ADEN**: 16-bit PCM A/D converter Enable control
0: Disable
1: Enable
This bit is used to control the 16-bit PCM A/D converter enable function. After the PCM A/D converter is enabled by setting the ADEN bit to 1, it is recommended to clear the ADC_RESB bit to 0 for at least 100μs to successfully complete the PCM A/D converter reset procedure.

Bit 1 **PAEN**: Power Amplifier Enable control
0: Disable
1: Enable

Bit 0 **DAEN**: 16-bit D/A converter Enable control
0: Disable
1: Enable
Note that the PLL circuit, 16-bit PCM A/D converter, 16-bit D/A converter and power amplifier will all be disabled when the MCU enters the Power down Mode.

COMPANDC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	REC_ COMP_OPT	PLA_ EXPAND_OPT	REC_ UA_EN	PLA_ UA_EN
R/W	—	—	—	—	—	R/W	R/W	R/W
POR	—	—	—	—	—	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3 **REC_COMP_OPT**: Record Compressing algorithm select
0: μ-law
1: a-law

Bit 2 **PLA_EXPAND_OPT**: Play Expanding algorithm select
0: μ-law
1: a-law

Bit 1 **REC_UA_EN**: Record Compressor Enable control
0: Disable
1: Enable
This bit is used to control the record compressor function. When this bit is cleared to 0, the record compressor will be disabled and the 16-bit recorded data will be stored in the RECDH and RECDL registers without compression. If this bit is set to 1, the record compressor will be enabled and the 16-bit recorded data will be compressed into an 8-bit encoded data in μ-law or a-law algorithm determined using the corresponding algorithm selection bit. After compression this encoded data will be stored in the RECDH register.

Bit 0 **PLA_UA_EN**: Play Expander Enable control
0: Disable
1: Enable
This bit is used to control the play expander function. When this bit is cleared to 0, the play expander will be disabled and the 16-bit data which is stored in the PLADH and PLADL registers will be sent to the D/A converter without being expanded. If this bit is set to 1, the play expander will be enabled and the 8-bit encoded data stored in the PLADH register will be expanded into 16-bit decoded data using a μ-law or a-law algorithm determined using the corresponding algorithm selection bit. After decoding the data will be sent to the D/A converter and played.

USVC Register

Bit	7	6	5	4	3	2	1	0
Name	MUTEB	USVC6	USVC5	USVC4	USVC3	USVC2	USVC1	USVC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **MUTEB**: Speaker Mute control
0: Mute speaker output
1: Enable speaker output
This bit is used to enable the speaker function. When this bit is cleared to 0, the speaker function will be disabled. The D/A converter and power amplifier will also be disabled.

Bit 6~0 **USVC6~USVC0**: Speaker volume control
000_1100: Gain ≈ 6.0 dB
000_1011: Gain ≈ 5.5 dB
000_1010: Gain ≈ 5.0 dB
000_1001: Gain ≈ 4.5 dB
000_1000: Gain ≈ 4.0 dB
000_0111: Gain ≈ 3.5 dB
000_0110: Gain ≈ 3.0 dB
000_0101: Gain ≈ 2.5 dB
000_0100: Gain ≈ 2.0 dB
000_0011: Gain ≈ 1.5 dB
000_0010: Gain ≈ 1.0 dB
000_0001: Gain ≈ 0.5 dB
000_0000: Gain ≈ 0.0 dB
111_1111: Gain ≈ -0.5 dB
111_1110: Gain ≈ -1.0 dB
111_1101: Gain ≈ -1.5 dB
111_1100: Gain ≈ -2.0 dB
111_1011: Gain ≈ -2.5 dB
111_1010: Gain ≈ -3.0 dB
111_1001: Gain ≈ -3.5 dB
111_1000: Gain ≈ -4.0 dB
111_0111: Gain ≈ -4.5 dB
111_0110: Gain ≈ -5.0 dB
111_0101: Gain ≈ -5.5 dB
111_0100: Gain ≈ -6.0 dB
111_0011: Gain ≈ -6.5 dB
111_0010: Gain ≈ -7.0 dB
111_0001: Gain ≈ -7.5 dB
111_0000: Gain ≈ -8.0 dB
110_1111: Gain ≈ -8.5 dB
110_1110: Gain ≈ -9.0 dB
110_1101: Gain ≈ -9.5 dB

110_1100: Gain ≈ -10.0 dB
110_1011: Gain ≈ -10.5 dB
110_1010: Gain ≈ -11.0 dB
110_1001: Gain ≈ -11.5 dB
110_1000: Gain ≈ -12.0 dB
110_0111: Gain ≈ -13.0 dB
110_0110: Gain ≈ -14.0 dB
110_0101: Gain ≈ -15.0 dB
110_0100: Gain ≈ -16.0 dB
110_0011: Gain ≈ -17.0 dB
110_0010: Gain ≈ -18.0 dB
110_0001: Gain ≈ -19.0 dB
110_0000: Gain ≈ -20.0 dB
101_1111: Gain ≈ -21.0 dB
101_1110: Gain ≈ -22.0 dB
101_1101: Gain ≈ -23.0 dB
101_1100: Gain ≈ -24.0 dB
101_1011: Gain ≈ -25.0 dB
101_1010: Gain ≈ -26.0 dB
101_1001: Gain ≈ -27.0 dB
101_1000: Gain ≈ -28.0 dB
101_0111: Gain ≈ -29.0 dB
101_0110: Gain ≈ -30.0 dB
101_0101: Gain ≈ -31.0 dB
101_0100: Gain ≈ -32.0 dB
Others: Reserved

These bits are used to control the output volume which ranges from -32dB~6dB.

RECDL Register

Bit	7	6	5	4	3	2	1	0
Name	R_D7	R_D6	R_D5	R_D4	R_D3	R_D2	R_D1	R_D0
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 **R_D7~R_D0**: Recorded data low byte register bit 7~bit 0

This register is used to store the 16-bit recorded PCM data low byte.

RECDH Register

Bit	7	6	5	4	3	2	1	0
Name	R_D15	R_D14	R_D13	R_D12	R_D11	R_D10	R_D9	R_D8
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 **R_D15~R_D8**: Recorded data high byte register bit 7~bit 0

This register is used to store the 16-bit PCM data high byte when the REC_UA_EN bit is cleared to 0. If the REC_UA_EN bit is set to 1, this register is used to store the 8-bit compressed μ-law or a-law data.

PLADL Register

Bit	7	6	5	4	3	2	1	0
Name	P_D7	P_D6	P_D5	P_D4	P_D3	P_D2	P_D1	P_D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **P_D7~P_D0**: Play data low byte register bit 7~bit 0
This register is used to store the 16-bit PCM play data low byte

PLADH Register

Bit	7	6	5	4	3	2	1	0
Name	P_D15	P_D14	P_D13	P_D12	P_D11	P_D10	P_D9	P_D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **P_D15~P_D8**: Played data high byte register bit 7~bit 0
This register is used to store the 16-bit PCM play data high byte data when the PLA_UA_EN bit is cleared to 0. If the PLA_UA_EN bit is set to 1, this register is used to store the 8-bit compressed μ-law or a-law data which will be expanded to 16-bit PCM data and then played.

Interrupts

Interrupts are an important part of any microcontroller system. When an external event or an internal function such as a Timer Module or an A/D converter requires microcontroller attention, their corresponding interrupt will enforce a temporary suspension of the main program allowing the microcontroller to direct attention to their respective needs. The device contains several external interrupt and internal interrupts functions. The external interrupts are generated by the action of the external INT0 and INT1 pins, while the internal interrupts are generated by various internal functions such as the TMs, Time Base, LVD, EEPROM, SIM, Voice Play/Record, DMA and the A/D converter, etc.

Interrupt Registers

Overall interrupt control, which basically means the setting of request flags when certain microcontroller conditions occur and the setting of interrupt enable bits by the application program, is controlled by a series of registers, located in the Special Purpose Data Memory, as shown in the accompanying table. The number of registers depends upon the device chosen but fall into three categories. The first is the INTC0~INTC3 registers which setup the primary interrupts, the second is the MFI0~MFI3 registers which setup the Multi-function interrupts. Finally there is an INTEG register to setup the external interrupt trigger edge type.

Each register contains a number of enable bits to enable or disable individual interrupts as well as interrupt flags to indicate the presence of an interrupt request. The naming convention of these follows a specific pattern. First is listed an abbreviated interrupt type, then the (optional) number of that interrupt followed by either an "E" for enable/disable bit or "F" for request flag.

Function	Enable Bit	Request Flag	Notes
Global	EMI	—	—
INTn Pins	INTnE	INTnF	n = 0 ~ 1
Voice Play	PLAYE	PLAYF	—
Voice Record	RECE	RECF	—
Multi-function	MFnE	MFnF	n = 0 ~ 3
A/D Converter	ADE	ADF	—
Time Base	TBnE	TBnF	n = 0 ~ 1
DMA Transfer	DMAE	DMAF	—
DMA Error	DMAERRE	DMAERRF	—
LVD	LVE	LVF	—
EEPROM write operation	DEE	DEF	—
SIM	SIME	SIMF	—
SPIA	SPIAE	SPIAF	—
CTM	CTMPE	CTMPF	—
	CTMAE	CTMAF	
STM	STMPE	STMPF	—
	STMAE	STMAF	
PTM	PTMPE	PTMPF	—
	PTMAE	PTMAF	

Interrupt Register Bit Naming Conventions

Register Name	Bit							
	7	6	5	4	3	2	1	0
INTEG	—	—	—	—	INT1S1	INT1S0	INT0S1	INT0S0
INTC0	—	RECF	PLAYF	INT0F	RECE	PLAYE	INT0E	EMI
INTC1	MF3F	MF2F	MF1F	MF0F	MF3E	MF2E	MF1E	MF0E
INTC2	INT1F	TB1F	TB0F	ADF	INT1E	TB1E	TB0E	ADE
INTC3	—	—	DMAERRF	DMAF	—	—	DMAERRE	DMAE
MFI0	—	—	CTMAF	CTMPF	—	—	CTMAE	CTMPE
MFI1	—	—	STMAF	STMPF	—	—	STMAE	STMPE
MFI2	—	—	PTMAF	PTMPF	—	—	PTMAE	PTMPE
MFI3	SPIAF	SIMF	DEF	LVF	SPIAE	SIME	DEE	LVE

Interrupt Registers List

INTEG Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	INT1S1	INT1S0	INT0S1	INT0S0
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3~2 **INT1S1~INT1S0**: Interrupt edge control for INT1 pin
- 00: Disable
- 01: Rising edge
- 10: Falling edge
- 11: Rising and falling edges

Bit 1~0 **INT0S1~INT0S0**: Interrupt edge control for INT0 pin
- 00: Disable
- 01: Rising edge
- 10: Falling edge
- 11: Rising and falling edges

INTC0 Register

Bit	7	6	5	4	3	2	1	0
Name	—	RECF	PLAYF	INT0F	RECE	PLAYE	INT0E	EMI
R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	0	0	0	0	0	0	0

Bit 7 Unimplemented, read as "0"
Bit 6 **RECF**: Voice Record interrupt request flag
0: no request
1: interrupt request
Bit 5 **PLAYF**: Voice Play interrupt request flag
0: no request
1: interrupt request
Bit 4 **INT0F**: INT0 interrupt request flag
0: no request
1: interrupt request
Bit 3 **RECE**: Voice Record interrupt control
0: Disable
1: Enable
Bit 2 **PLAYE**: Voice Play interrupt control
0: Disable
1: Enable
Bit 1 **INT0E**: INT0 interrupt control
0: Disable
1: Enable
Bit 0 **EMI**: Global interrupt control
0: Disable
1: Enable

INTC1 Register

Bit	7	6	5	4	3	2	1	0
Name	MF3F	MF2F	MF1F	MF0F	MF3E	MF2E	MF1E	MF0E
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **MF3F**: Multi-function 3 interrupt request flag
0: no request
1: interrupt request
Bit 6 **MF2F**: Multi-function 2 interrupt request flag
0: no request
1: interrupt request
Bit 5 **MF1F**: Multi-function 1 interrupt request flag
0: no request
1: interrupt request
Bit 4 **MF0F**: Multi-function 0 interrupt request flag
0: no request
1: interrupt request
Bit 3 **MF3E**: Multi-function 3 interrupt control
0: Disable
1: Enable
Bit 2 **MF2E**: Multi-function 2 interrupt control
0: Disable
1: Enable
Bit 1 **MF1E**: Multi-function 1 interrupt control
0: Disable
1: Enable
Bit 0 **MF0E**: Multi-function 0 interrupt control
0: Disable
1: Enable

INTC2 Register

Bit	7	6	5	4	3	2	1	0
Name	INT1F	TB1F	TB0F	ADF	INT1E	TB1E	TB0E	ADE
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **INT1F**: INT1 interrupt request flag
0: No request
1: Interrupt request

Bit 6 **TB1F**: Time Base 1 interrupt request flag
0: No request
1: Interrupt request

Bit 5 **TB0F**: Time Base 0 interrupt request flag
0: No request
1: Interrupt request

Bit 4 **ADF**: A/D Converter interrupt request flag
0: No request
1: Interrupt request

Bit 3 **INT1E**: INT1 interrupt control
0: Disable
1: Enable

Bit 2 **TB1E**: Time Base 1 interrupt control
0: Disable
1: Enable

Bit 1 **TB0E**: Time Base 0 interrupt control
0: Disable
1: Enable

Bit 0 **ADE**: A/D Converter interrupt control
0: Disable
1: Enable

INTC3 Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	DMAERRF	DMAF	—	—	DMAERRE	DMAE
R/W	—	—	R/W	R/W	—	—	R/W	R/W
POR	—	—	0	0	—	—	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **DMAERRF**: DMA Error interrupt request flag
0: No request
1: Interrupt request

Bit 5 **DMAF**: DMA transfer interrupt request flag
0: No request
1: Interrupt request

Bit 3~2 Unimplemented, read as "0"

Bit 1 **DMAERRE**: DMA Error interrupt control
0: Disable
1: Enable

Bit 0 **DMAE**: DMA Transfer interrupt control
0: Disable
1: Enable

MFI0 Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	CTMAF	CTMPF	—	—	CTMAE	CTMPE
R/W	—	—	R/W	R/W	—	—	R/W	R/W
POR	—	—	0	0	—	—	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **CTMAF**: CTM Comparator A match Interrupt request flag
0: No request
1: Interrupt request

Bit 4 **CTMPF**: CTM Comparator P match Interrupt request flag
0: No request
1: Interrupt request

Bit 3~2 Unimplemented, read as "0"

Bit 1 **CTMAE**: CTM Comparator A match Interrupt control
0: Disable
1: Enable

Bit 0 **CTMPE**: CTM Comparator P match Interrupt control
0: Disable
1: Enable

MFI1 Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	STMAF	STMPF	—	—	STMAE	STMPE
R/W	—	—	R/W	R/W	—	—	R/W	R/W
POR	—	—	0	0	—	—	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **STMAF**: STM Comparator A match Interrupt request flag
0: No request
1: Interrupt request

Bit 4 **STMPF**: STM Comparator P match Interrupt request flag
0: No request
1: Interrupt request

Bit 3~2 Unimplemented, read as "0"

Bit 1 **STMAE**: STM Comparator A match Interrupt control
0: Disable
1: Enable

Bit 0 **STMPE**: STM Comparator P match Interrupt control
0: Disable
1: Enable

MFI2 Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	PTMAF	PTMPF	—	—	PTMAE	PTMPE
R/W	—	—	R/W	R/W	—	—	R/W	R/W
POR	—	—	0	0	—	—	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **PTMAF**: PTM Comparator A match Interrupt request flag
0: No request
1: Interrupt request

Bit 4 **PTMPF**: PTM Comparator P match Interrupt request flag
0: No request
1: Interrupt request

Bit 3~2 Unimplemented, read as "0"

Bit 1 **PTMAE**: PTM Comparator A match Interrupt control
0: Disable
1: Enable

Bit 0 **PTMPE**: PTM Comparator P match Interrupt control
0: Disable
1: Enable

MFI3 Register

Bit	7	6	5	4	3	2	1	0
Name	SPIAF	SIMF	DEF	LVF	SPIAE	SIME	DEE	LVE
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **SPIAF**: SPIA Interrupt request flag
0: No request
1: Interrupt request

Bit 6 **SIMF**: SIM Interrupt request flag
0: No request
1: Interrupt request

Bit 5 **DEF**: Data EEPROM Interrupt request flag
0: No request
1: Interrupt request

Bit 4 **LVF**: LVD Interrupt request flag
0: No request
1: Interrupt request

Bit 3 **SPIAE**: SPIA Interrupt control
0: Disable
1: Enable

Bit 2 **SIME**: SIM Interrupt control
0: Disable
1: Enable

Bit 1 **DEE**: Data EEPROM Interrupt control
0: Disable
1: Enable

Bit 0 **LVE**: LVD Interrupt control
0: Disable
1: Enable

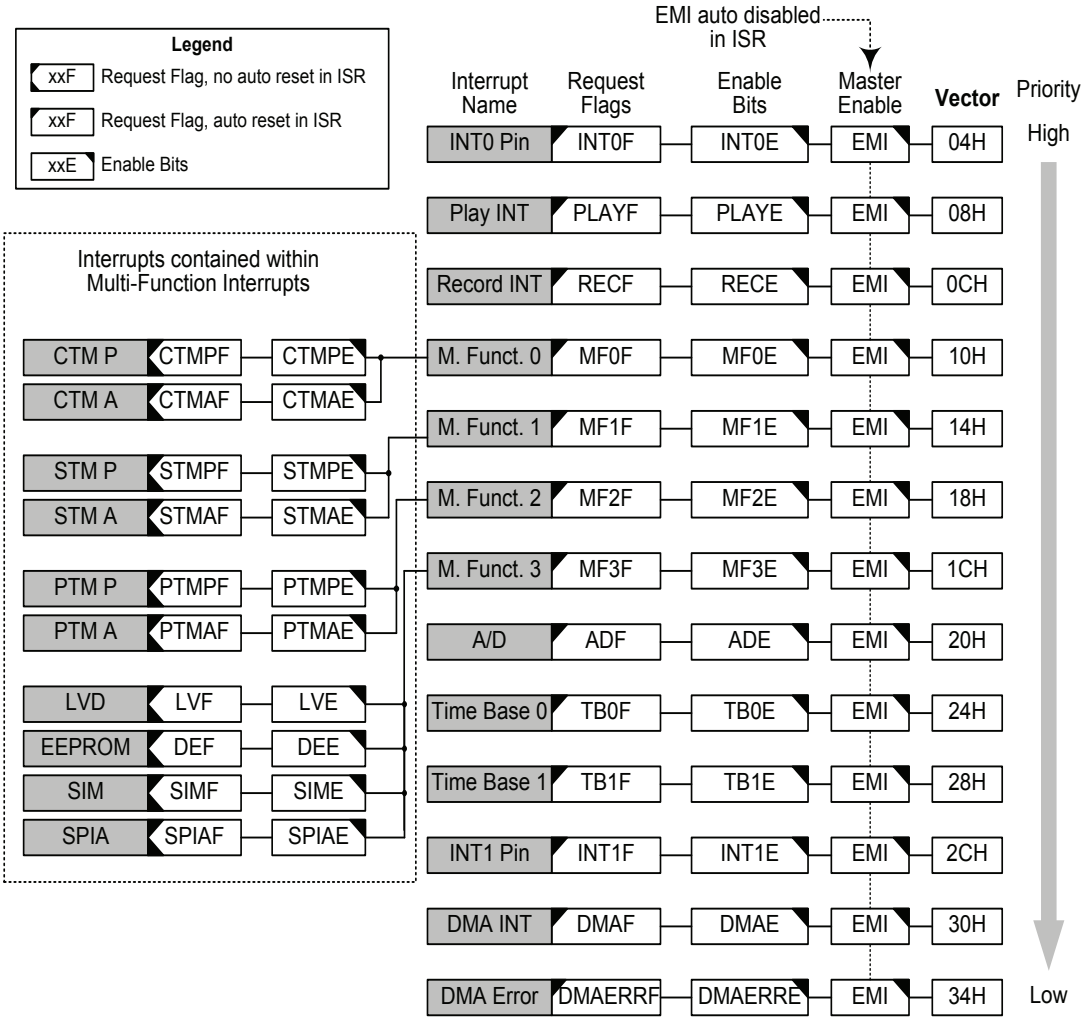
Interrupt Operation

When the conditions for an interrupt event occur, such as a TM Comparator P or Comparator A or A/D conversion completion, etc, the relevant interrupt request flag will be set. Whether the request flag actually generates a program jump to the relevant interrupt vector is determined by the condition of the interrupt enable bit. If the enable bit is set high then the program will jump to its relevant vector; if the enable bit is zero then although the interrupt request flag is set an actual interrupt will not be generated and the program will not jump to the relevant interrupt vector. The global interrupt enable bit, if cleared to zero, will disable all interrupts.

When an interrupt is generated, the Program Counter, which stores the address of the next instruction to be executed, will be transferred onto the stack. The Program Counter will then be loaded with a new address which will be the value of the corresponding interrupt vector. The microcontroller will then fetch its next instruction from this interrupt vector. The instruction at this vector will usually be a JMP which will jump to another section of program which is known as the interrupt service routine. Here is located the code to control the appropriate interrupt. The interrupt service routine must be terminated with a RETI, which retrieves the original Program Counter address from the stack and allows the microcontroller to continue with normal execution at the point where the interrupt occurred.

The various interrupt enable bits, together with their associated request flags, are shown in the accompanying diagrams with their order of priority. Some interrupt sources have their own individual vector while others share the same multi-function interrupt vector. Once an interrupt subroutine is serviced, all other interrupts will be blocked, as the global interrupt enable bit, EMI bit will be cleared automatically. This will prevent any further interrupt nesting from occurring. However, if other interrupt requests occur during this interval, although the interrupt will not be immediately serviced, the request flag will still be recorded.

If an interrupt requires immediate servicing while the program is already in another interrupt service routine, the EMI bit should be set after entering the routine to allow interrupt nesting. If the stack is full, the interrupt request will not be acknowledged, even if the related interrupt is enabled, until the Stack Pointer is decremented. If immediate service is desired, the stack must be prevented from becoming full. In case of simultaneous requests, the accompanying diagram shows the priority that is applied. All of the interrupt request flags when set will wake-up the device if it is in SLEEP or IDLE Mode, however to prevent a wake-up from occurring the corresponding flag should be set before the device is in SLEEP or IDLE Mode.



Interrupt Scheme

External Interrupt

The external interrupts are controlled by signal transitions on the pins INT0~INT1. An external interrupt request will take place when the external interrupt request flags, INT0F~INT1F, are set, which will occur when a transition, whose type is chosen by the edge select bits, appears on the external interrupt pins. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and respective external interrupt enable bit, INT0E~INT1E, must first be set. Additionally the correct interrupt edge type must be selected using the INTEG register to enable the external interrupt function and to choose the trigger edge type. As the external interrupt pins are pin-shared with I/O pins, they can only be configured as external interrupt pins and the external interrupt pin is selected by the corresponding pin-shared function selection bits. The pin must also be setup as an input by setting the corresponding bit in the port control register. When the interrupt is enabled, the stack is not full and the correct transition type appears on the external interrupt pin, a subroutine call to the external interrupt vector, will take place. When the interrupt is serviced, the external interrupt request flags, INT0F~INT1F, will be automatically reset and the EMI bit will be automatically cleared to disable other interrupts. Note that any pull-high resistor selections on the external interrupt pins will remain valid even if the pin is used as an external interrupt input.

The INTEG register is used to select the type of active edge that will trigger the external interrupt. A choice of either rising or falling or both edge types can be chosen to trigger an external interrupt. Note that the INTEG register can also be used to disable the external interrupt function.

Voice Play Interrupt

The Voice Play interrupt is controlled by a dedicated voice-play timer whose time-out frequency is determined by the PLAFQ1 and PLAFQ0 bits in the RECPLAC register. When the timer with specific frequency time-out occurs, the voice play interrupt request will take place and the relevant request flag will be set. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and voice play interrupt enable bit, PLAYE, must first be set. When the interrupt is enabled, the stack is not full and the voice play timer time-out occurs, a subroutine call to the voice play interrupt vector will take place. When the interrupt is serviced, the voice play interrupt request flag will be automatically reset and the EMI bit will also be automatically cleared to disable other interrupts.

Voice Record Interrupt

The Voice Record interrupt is controlled by a dedicated voice-record timer whose time-out frequency is determined by the RECFQ1 and RECFQ0 bits in the RECPLAC register. When the voice-record timer with specific frequency time-out occurs, the voice record interrupt request will take place and the relevant request flag will be set. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and voice record interrupt enable bit, RECE, must first be set. When the interrupt is enabled, the stack is not full and the voice record timer time-out occurs, a subroutine call to the voice record interrupt vector will take place. When the interrupt is serviced, the voice record interrupt request flag will be automatically reset and the EMI bit will also be automatically cleared to disable other interrupts.

Multi-function Interrupt

Within the device there are up to four Multi-function interrupts. Unlike the other independent interrupts, these interrupts have no independent source, but rather are formed from other existing interrupt sources, namely the TM interrupts, LVD interrupt, EEPROM write operation interrupt, SIM and SPIA interface interrupts.

A Multi-function interrupt request will take place when any of the Multi-function interrupt request flags MFnF are set. The Multi-function interrupt flags will be set when any of their included functions generate an interrupt request flag. To allow the program to branch to its respective interrupt vector address, when the Multi-function interrupt is enabled and the stack is not full, and either one of the interrupts contained within each of Multi-function interrupt occurs, a subroutine call to one of the Multi-function interrupt vectors will take place. When the interrupt is serviced, the related Multi-Function request flag will be automatically reset and the EMI bit will be automatically cleared to disable other interrupts.

However, it must be noted that, although the Multi-function Interrupt request flags will be automatically reset when the interrupt is serviced, the request flags from the original source of the Multi-function interrupts will not be automatically reset and must be manually reset by the application program.

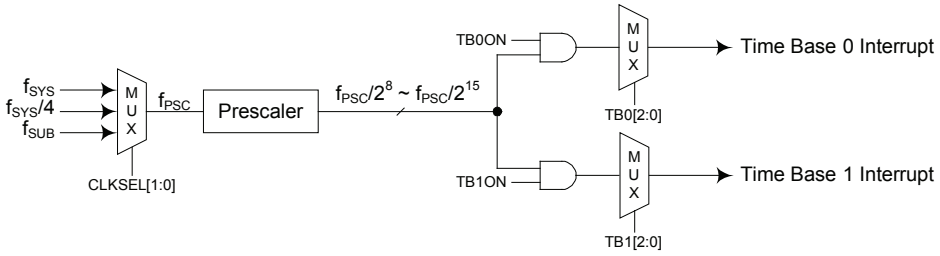
A/D Converter Interrupt

The A/D Converter Interrupt is controlled by the termination of an A/D conversion process. An A/D Converter Interrupt request will take place when the A/D Converter Interrupt request flag, ADF, is set, which occurs when the A/D conversion process finishes. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and A/D Interrupt enable bit, ADE, must first be set. When the interrupt is enabled, the stack is not full and the A/D conversion process has ended, a subroutine call to the A/D Converter Interrupt vector, will take place. When the interrupt is serviced, the A/D Converter Interrupt flag, ADF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

Time Base Interrupt

The function of the Time Base Interrupt is to provide regular time signal in the form of an internal interrupt. It is controlled by the overflow signal from its internal timer. When this happens its interrupt request flag, TBnF, will be set. To allow the program to branch to its respective interrupt vector addresses, the global interrupt enable bit, EMI and Time Base enable bit, TBnE, must first be set. When the interrupt is enabled, the stack is not full and the Time Base overflows, a subroutine call to its respective vector location will take place. When the interrupt is serviced, the interrupt request flag, TBnF, will be automatically reset and the EMI bit will be cleared to disable other interrupts.

The purpose of the Time Base Interrupt is to provide an interrupt signal at fixed time periods. Its clock source, f_{PSC}, originates from the internal clock source f_{SYS}, $f_{SYS}/4$ or f_{SUB} and then passes through a divider, the division ratio of which is selected by programming the appropriate bits in the TB0C and TB1C registers to obtain longer interrupt periods whose value ranges. The clock source which in turn controls the Time Base interrupt period is selected using the CLKSEL1 and CLKSEL0 bits in the PSCR register.



Time Base Interrupts

PSCR Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CLKSEL1	CLKSEL0
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 unimplemented, read as "0"

Bit 1~0 **CLKSEL1~CLKSEL0**: Prescaler clock source selection
00: f_{SYS}
01: $f_{SYS}/4$
1x: f_{SUB}

TB0C Register

Bit	7	6	5	4	3	2	1	0
Name	TB0ON	—	—	—	—	TB02	TB01	TB00
R/W	R/W	—	—	—	—	R/W	R/W	R/W
POR	0	—	—	—	—	0	0	0

Bit 7 **TB0ON**: Time Base 0 Enable Control
0: Disable
1: Enable

Bit 6~3 unimplemented, read as "0"

Bit 2~0 **TB02~TB00**: Time Base 0 time-out division ratio selection
000: $2^8/f_{PSC}$
001: $2^9/f_{PSC}$
010: $2^{10}/f_{PSC}$
011: $2^{11}/f_{PSC}$
100: $2^{12}/f_{PSC}$
101: $2^{13}/f_{PSC}$
110: $2^{14}/f_{PSC}$
111: $2^{15}/f_{PSC}$

TB1C Register

Bit	7	6	5	4	3	2	1	0
Name	TB1ON	—	—	—	—	TB12	TB11	TB10
R/W	R/W	—	—	—	—	R/W	R/W	R/W
POR	0	—	—	—	—	0	0	0

Bit 7 **TB1ON**: Time Base 1 Enable Control
0: Disable
1: Enable

Bit 6~3 unimplemented, read as "0"

Bit 2~0 **TB12~TB10**: Time Base 1 time-out period selection
000: $2^8/f_{PSC}$
001: $2^9/f_{PSC}$
010: $2^{10}/f_{PSC}$
011: $2^{11}/f_{PSC}$
100: $2^{12}/f_{PSC}$
101: $2^{13}/f_{PSC}$
110: $2^{14}/f_{PSC}$
111: $2^{15}/f_{PSC}$

DMA Transfer Interrupt

The DMA Transfer Interrupt is controlled by the termination of a DMA transfer process. A DMA Transfer Interrupt request will take place when the DMA data Transfer Interrupt request flag, DMAF, is set, which occurs when the DMA data transfer process finishes. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and DMA Transfer Interrupt enable bit, DMAE, must first be set. When the interrupt is enabled, the stack is not full and the DMA transfer process has ended, a subroutine call to the DMA Transfer Interrupt vector, will take place. When the interrupt is serviced, the DMA Transfer Interrupt flag, DMAF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

DMA Error Interrupt

The DMA Error Interrupt is controlled by a DMA error occurrence. A DMA Error Interrupt request will take place when the DMA Error Interrupt request flag, DMAERRF, is set, which occurs when a DMA error occurs. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and DMA Error Interrupt enable bit, DMAERRE, must first be set. When the interrupt is enabled, the stack is not full and a DMA Error occurred, a subroutine call to the DMA Error Interrupt vector, will take place. When the interrupt is serviced, the DMA Error Interrupt flag, DMAERRF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

Serial Interface Module Interrupt

The Serial Interface Module Interrupt, also known as the SIM interrupt, is contained within the Multi-function Interrupt. A SIM Interrupt request will take place when the SIM Interrupt request flag, SIMF or I^2C address match or I^2C time-out, is set, which occurs when a byte of data has been received or transmitted by the SIM interface. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, the Serial Interface Interrupt enable bit, SIME, and Muti-function interrupt enable bit must first be set. When the interrupt is enabled, the stack is not full and any of these situations occur, a subroutine call to the respective Multi-function Interrupt vector, will take place. When the Serial Interface Interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts, however only the Multi-function interrupt request flag will be also automatically cleared. As the SIMF flag will not be automatically cleared, it has to be cleared by the application program.

SPIA Interface Interrupt

The SPIA Interface Module Interrupt is contained within the Multi-function Interrupt. A SPIA Interrupt request will take place when the SPIA Interrupt request flag, SPIAF, is set, which occurs when a byte of data has been received or transmitted by the SPIA interface. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, the Serial Interface Interrupt enable bit, SPIAE, and Muti-function interrupt enable bit must first be set. When the interrupt is enabled, the stack is not full and a byte of data has been transmitted or received by the SPIA interface, a subroutine call to the respective Multi-function Interrupt vector, will take place. When the SPIA Interface Interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts, however only the Multi-function interrupt request flag will be also automatically cleared. As the SPIAF flag will not be automatically cleared, it has to be cleared by the application program.

LVD Interrupt

The Low Voltage Detector Interrupt is contained within the Multi-function Interrupt. An LVD Interrupt request will take place when the LVD Interrupt request flag, LVF, is set, which occurs when the Low Voltage Detector function detects a low power supply voltage. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, Low Voltage Interrupt enable bit, LVE, and associated Multi-function interrupt enable bit, must first be set. When the interrupt is enabled, the stack is not full and a low voltage condition occurs, a subroutine call to the Multi-function Interrupt vector, will take place. When the Low Voltage Interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts. However, only the Multi-function interrupt request flag will be also automatically cleared. As the LVF flag will not be automatically cleared, it has to be cleared by the application program.

EEPROM Interrupt

The EEPROM Write Interrupt is contained within the Multi-function Interrupt. An EEPROM Write Interrupt request will take place when the EEPROM Write Interrupt request flag, DEF, is set, which occurs when an EEPROM Write cycle ends. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, EEPROM Write Interrupt enable bit, DEE, and associated Multi-function interrupt enable bit must first be set. When the interrupt is enabled, the stack is not full and an EEPROM Write cycle ends, a subroutine call to the respective Multi-function Interrupt vector will take place. When the EEPROM Write Interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts. However, only the Multi-function interrupt request flag will be automatically cleared. As the DEF flag will not be automatically cleared, it has to be cleared by the application program.

TM Interrupt

The Compact, Standard and Periodic TMs have two interrupts, one comes from the comparator A match situation and the other comes from the comparator P match situation. All of the TM interrupts are contained within the Multi-function Interrupts. For all of the TM types there are two interrupt request flags and two enable control bits. A TM interrupt request will take place when any of the TM request flags are set, a situation which occurs when a TM comparator P or A match situation happens.

To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, respective TM Interrupt enable bit, and relevant Multi-function Interrupt enable bit, MFnE, must first be set. When the interrupt is enabled, the stack is not full and a TM comparator match situation occurs, a subroutine call to the relevant Multi-function Interrupt vector locations, will take place. When the TM interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts. However, only the related MFnF flag will be automatically cleared. As the TM interrupt request flags will not be automatically cleared, they have to be cleared by the application program.

Interrupt Wake-up Function

Each of the interrupt functions has the capability of waking up the microcontroller when in the SLEEP or IDLE Mode. A wake-up is generated when an interrupt request flag changes from low to high and is independent of whether the interrupt is enabled or not. Therefore, even though these devices are in the SLEEP or IDLE Mode and its system oscillator stopped, situations such as external edge transitions on the external interrupt pins, a low power supply voltage or comparator input change may cause their respective interrupt flag to be set high and consequently generate an interrupt. Care must therefore be taken if spurious wake-up situations are to be avoided. If an interrupt wake-up function is to be disabled then the corresponding interrupt request flag should be set high before the device enters the SLEEP or IDLE Mode. The interrupt enable bits have no effect on the interrupt wake-up function.

Programming Considerations

By disabling the relevant interrupt enable bits, a requested interrupt can be prevented from being serviced, however, once an interrupt request flag is set, it will remain in this condition in the interrupt register until the corresponding interrupt is serviced or until the request flag is cleared by the application program.

Where a certain interrupt is contained within a Multi-function interrupt, then when the interrupt service routine is executed, as only the Multi-function interrupt request flags, MFnF, will be automatically cleared, the individual request flag for the function needs to be cleared by the application program.

It is recommended that programs do not use the "CALL" instruction within the interrupt service subroutine. Interrupts often occur in an unpredictable manner or need to be serviced immediately. If only one stack is left and the interrupt is not well controlled, the original control sequence will be damaged once a CALL subroutine is executed in the interrupt subroutine.

Every interrupt has the capability of waking up the microcontroller when it is in the SLEEP or IDLE Mode, the wake up being generated when the interrupt request flag changes from low to high. If it is required to prevent a certain interrupt from waking up the microcontroller then its respective request flag should be first set high before enter SLEEP or IDLE Mode.

As only the Program Counter is pushed onto the stack, then when the interrupt is serviced, if the contents of the accumulator, status register or other registers are altered by the interrupt service program, their contents should be saved to the memory at the beginning of the interrupt service routine.

To return from an interrupt subroutine, either a RET or RETI instruction may be executed. The RETI instruction in addition to executing a return to the main program also automatically sets the EMI bit high to allow further interrupts. The RET instruction however only executes a return to the main program leaving the EMI bit in its present zero state and therefore disabling the execution of further interrupts.

Low Voltage Detector – LVD

Each device has a Low Voltage Detector function, also known as LVD. This enabled the device to monitor the power supply voltage, V_{DD}, and provide a warning signal should it fall below a certain level. This function may be especially useful in battery applications where the supply voltage will gradually reduce as the battery ages, as it allows an early warning battery low signal to be generated. The Low Voltage Detector also has the capability of generating an interrupt signal.

LVD Register

The Low Voltage Detector function is controlled using a single register with the name LVDC. Three bits in this register, VLVD2~VLVD0, are used to select one of eight fixed voltages below which a low voltage condition will be determined. A low voltage condition is indicated when the LVDO bit is set. If the LVDO bit is low, this indicates that the V_{DD} voltage is above the preset low voltage value. The LVDEN bit is used to control the overall on/off function of the low voltage detector. Setting the bit high will enable the low voltage detector. Clearing the bit to zero will switch off the internal low voltage detector circuits. As the low voltage detector will consume a certain amount of power, it may be desirable to switch off the circuit when not in use, an important consideration in power sensitive battery powered applications.

LVDC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	LVDO	LVDEN	—	VLVD2	VLVD1	VLVD0
R/W	—	—	R	R/W	—	R/W	R/W	R/W
POR	—	—	0	0	—	0	0	0

Bit 7~6 unimplemented, read as "0"

Bit 5 **LVDO**: LVD output flag
0: No Low Voltage Detected
1: Low Voltage Detected

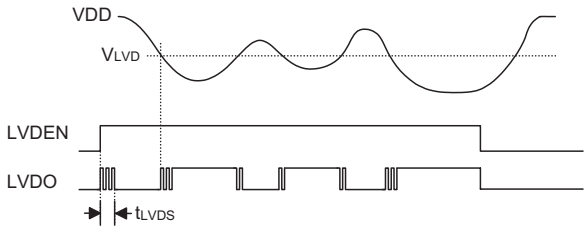
Bit 4 **LVDEN**: Low Voltage Detector Enable control
0: Disable
1: Enable

Bit 3 unimplemented, read as "0"

Bit 2~0 **VLVD2~VLVD0**: LVD Voltage selection
000: 2.0V
001: 2.2V
010: 2.4V
011: 2.7V
100: 3.0V
101: 3.3V
110: 3.6V
111: 4.0V

LVD Operation

The Low Voltage Detector function operates by comparing the power supply voltage, V_{DD}, with a pre-specified voltage level stored in the LVDC register. This has a range of between 2.0V and 4.0V. When the power supply voltage, V_{DD}, falls below this pre-determined value, the LVDO bit will be set high indicating a low power supply voltage condition. The Low Voltage Detector function is supplied by a reference voltage which will be automatically enabled. When the device is powered down the low voltage detector will remain active if the LVDEN bit is high. After enabling the Low Voltage Detector, a time delay t_{LVDS} should be allowed for the circuitry to stabilise before reading the LVDO bit. Note also that as the V_{DD} voltage may rise and fall rather slowly, at the voltage nears that of V_{LVD}, there may be multiple bit LVDO transitions.

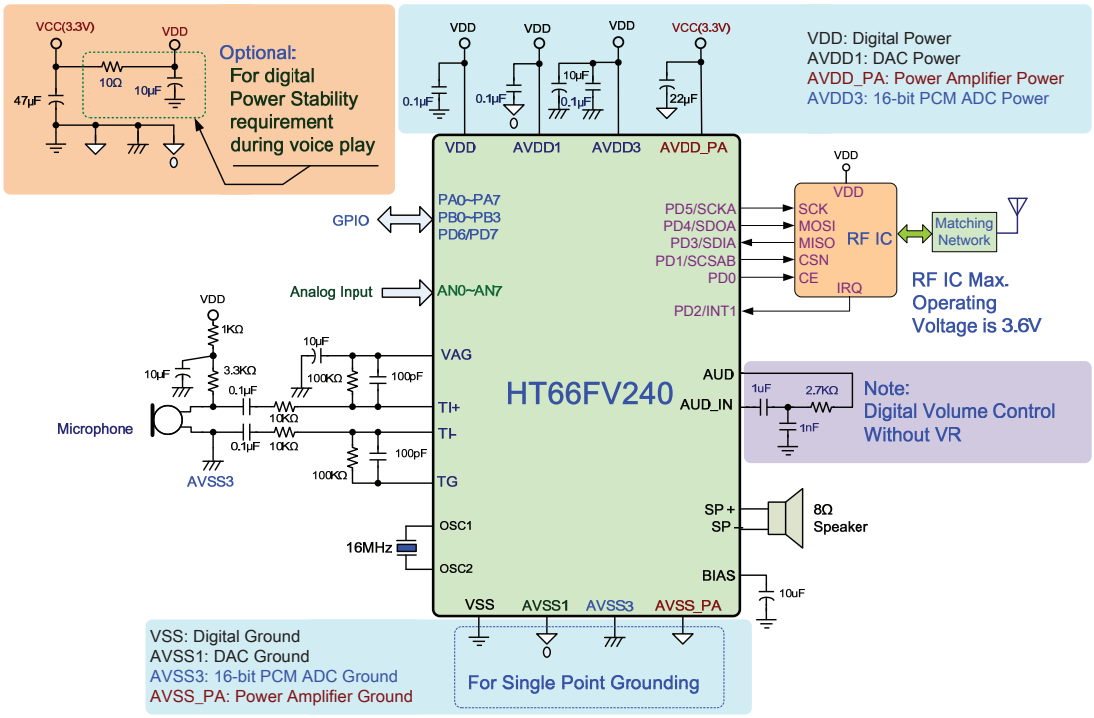


LVD Operation

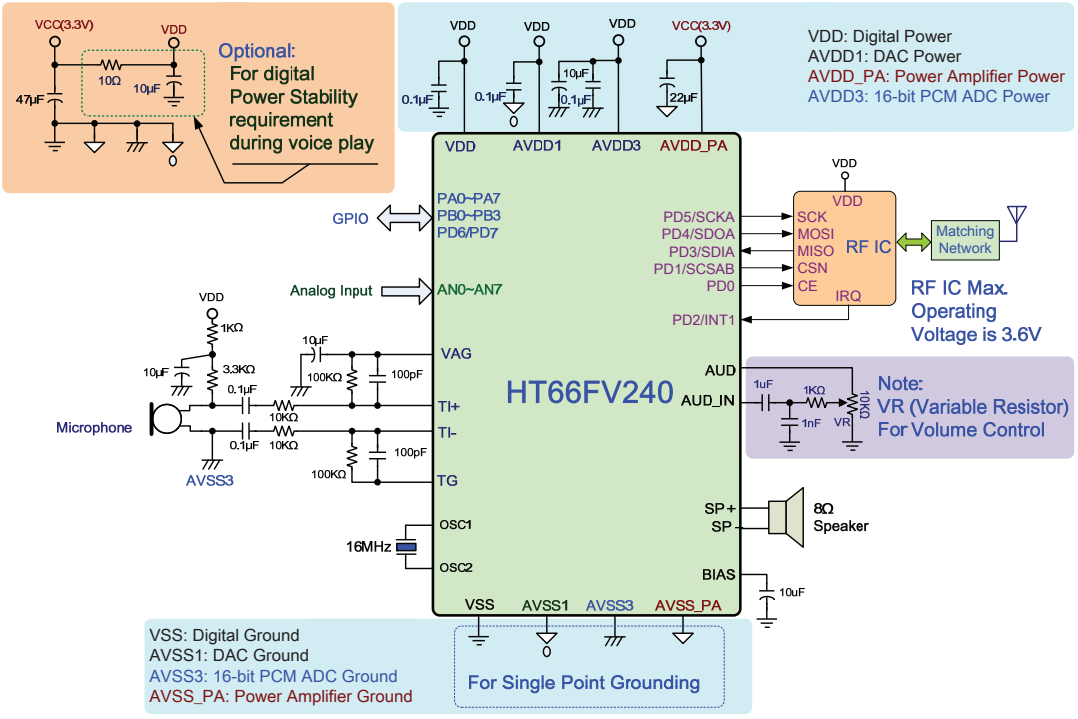
The Low Voltage Detector also has its own interrupt which is contained within one of the Multi-function interrupts, providing an alternative means of low voltage detection, in addition to polling the LVDO bit. The interrupt will only be generated after a delay of t_{LVD} after the LVDO bit has been set high by a low voltage condition. When the device is powered down the Low Voltage Detector will remain active if the LVDEN bit is high. In this case, the LVF interrupt request flag will be set, causing an interrupt to be generated if V_{DD} falls below the preset LVD voltage. This will cause the device to wake-up from the SLEEP or IDLE Mode, however if the Low Voltage Detector wake up function is not required then the LVF flag should be first set high before the device enters the SLEEP or IDLE Mode.

Application Circuits

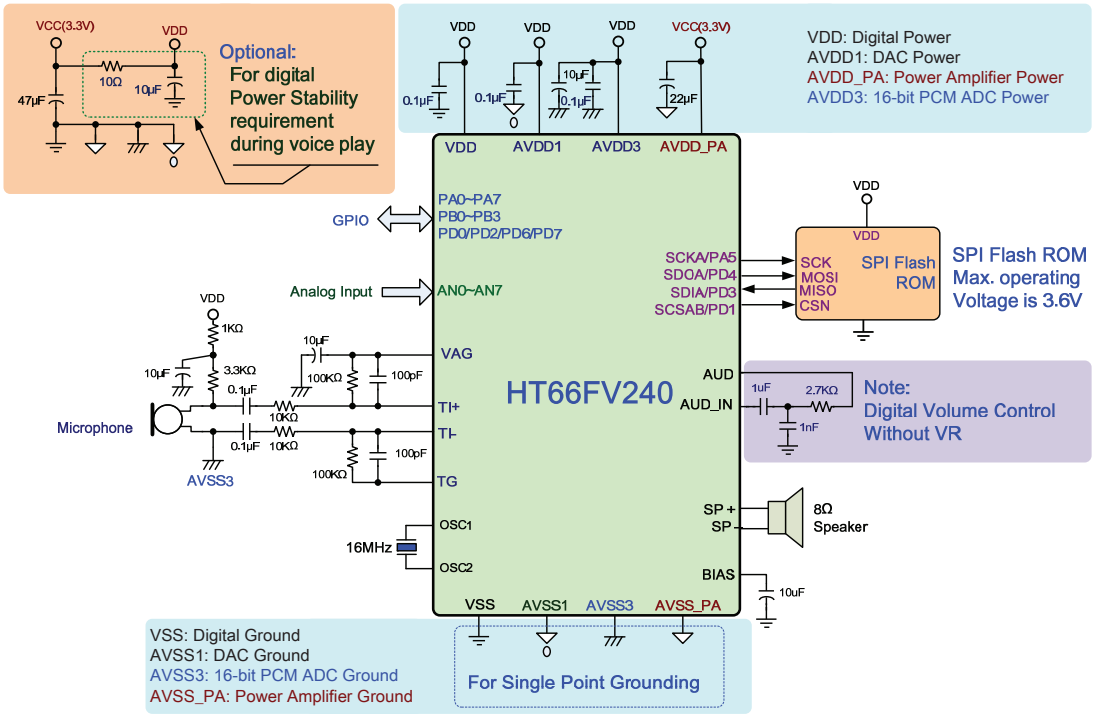
Wireless Voice Application Circuit (3V) − 1



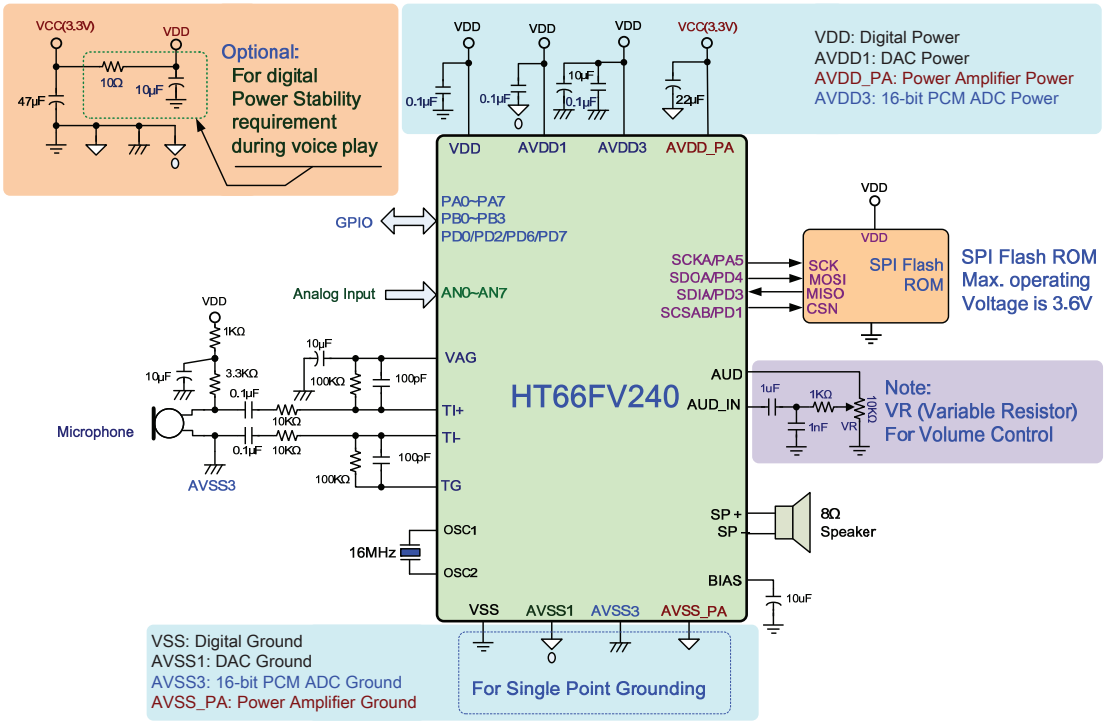
Wireless Voice Application Circuit (3V) − 2



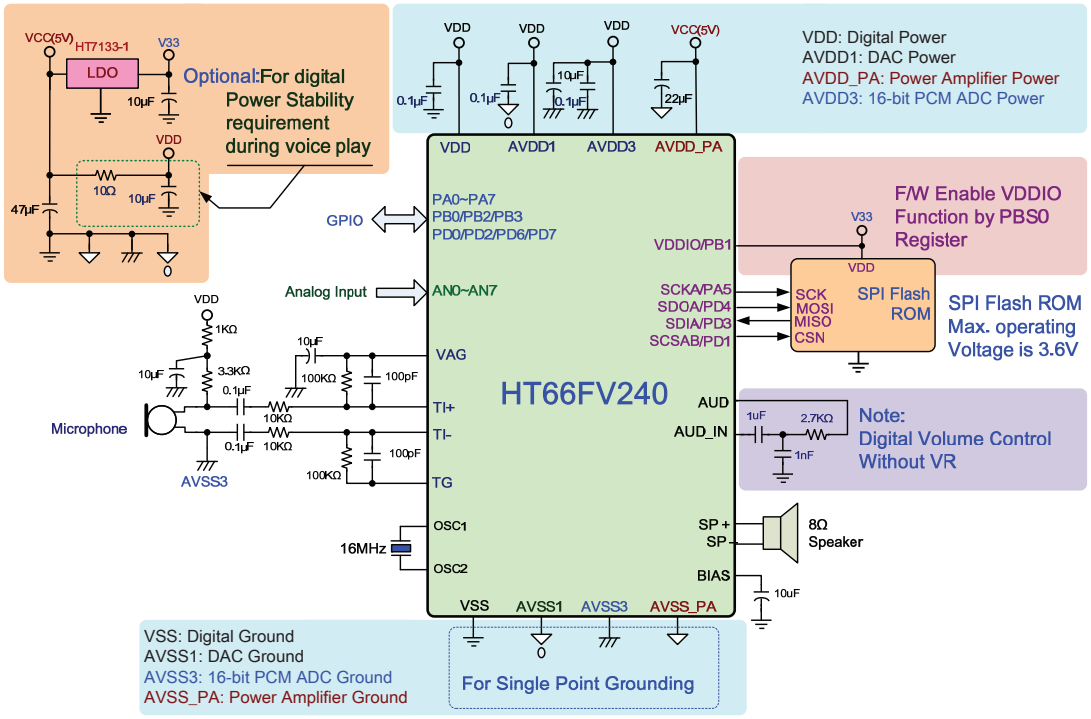
Record/Play Voice Application Circuit (3V) − 1



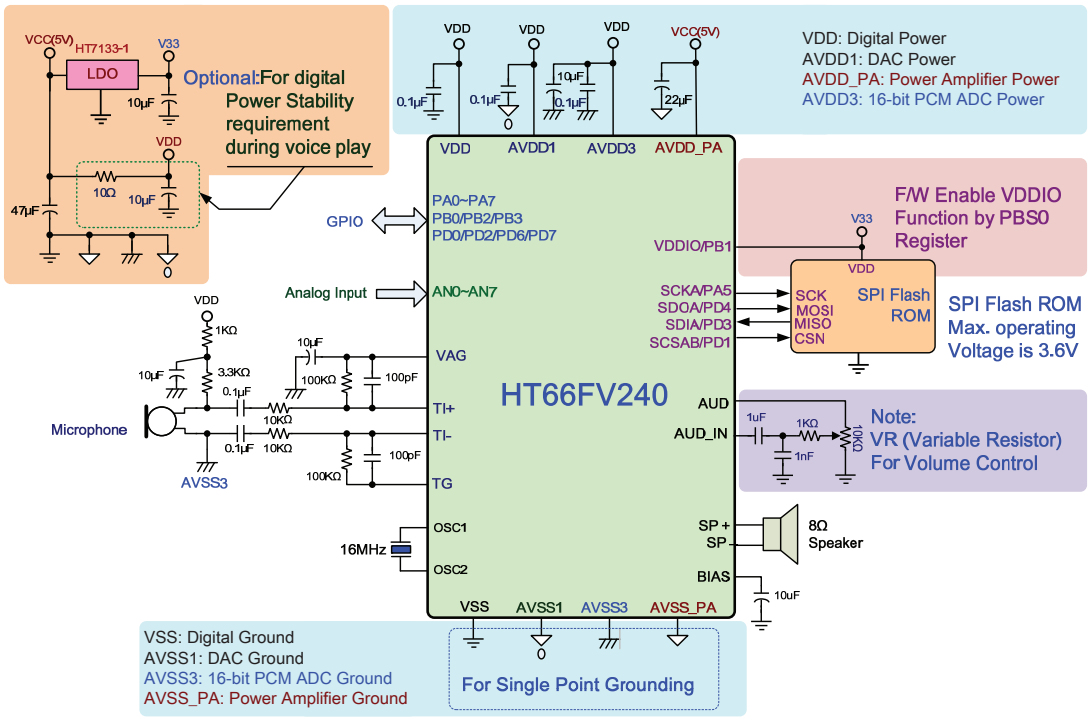
Record/Play Voice Application Circuit (3V) − 2



Record/Play Voice Application Circuit (5V) − 1



Record/Play Voice Application Circuit (5V) − 2



Instruction Set

Introduction

Central to the successful operation of any microcontroller is its instruction set, which is a set of program instruction codes that directs the microcontroller to perform certain operations. In the case of Holtek microcontroller, a comprehensive and flexible set of over 60 instructions is provided to enable programmers to implement their application with the minimum of programming overheads.

For easier understanding of the various instruction codes, they have been subdivided into several functional groupings.

Instruction Timing

Most instructions are implemented within one instruction cycle. The exceptions to this are branch, call, or table read instructions where two instruction cycles are required. One instruction cycle is equal to 4 system clock cycles, therefore in the case of an 8MHz system oscillator, most instructions would be implemented within 0.5μs and branch or call instructions would be implemented within 1μs. Although instructions which require one more cycle to implement are generally limited to the JMP, CALL, RET, RETI and table read instructions, it is important to realize that any other instructions which involve manipulation of the Program Counter Low register or PCL will also take one more cycle to implement. As instructions which change the contents of the PCL will imply a direct jump to that new address, one more cycle will be required. Examples of such instructions would be “CLR PCL” or “MOV PCL, A”. For the case of skip instructions, it must be noted that if the result of the comparison involves a skip operation then this will also take one more cycle, if no skip is involved then only one cycle is required.

Moving and Transferring Data

The transfer of data within the microcontroller program is one of the most frequently used operations. Making use of several kinds of MOV instructions, data can be transferred from registers to the Accumulator and vice-versa as well as being able to move specific immediate data directly into the Accumulator. One of the most important data transfer applications is to receive data from the input ports and transfer data to the output ports.

Arithmetic Operations

The ability to perform certain arithmetic operations and data manipulation is a necessary feature of most microcontroller applications. Within the Holtek microcontroller instruction set are a range of add and subtract instruction mnemonics to enable the necessary arithmetic to be carried out. Care must be taken to ensure correct handling of carry and borrow data when results exceed 255 for addition and less than 0 for subtraction. The increment and decrement instructions such as INC, INCA, DEC and DECA provide a simple means of increasing or decreasing by a value of one of the values in the destination specified.

Logical and Rotate Operation

The standard logical operations such as AND, OR, XOR and CPL all have their own instruction within the Holtek microcontroller instruction set. As with the case of most instructions involving data manipulation, data must pass through the Accumulator which may involve additional programming steps. In all logical data operations, the zero flag may be set if the result of the operation is zero. Another form of logical data manipulation comes from the rotate instructions such as RR, RL, RRC and RLC which provide a simple means of rotating one bit right or left. Different rotate instructions exist depending on program requirements. Rotate instructions are useful for serial port programming applications where data can be rotated from an internal register into the Carry bit from where it can be examined and the necessary serial bit set high or low. Another application which rotate data operations are used is to implement multiplication and division calculations.

Branches and Control Transfer

Program branching takes the form of either jumps to specified locations using the JMP instruction or to a subroutine using the CALL instruction. They differ in the sense that in the case of a subroutine call, the program must return to the instruction immediately when the subroutine has been carried out. This is done by placing a return instruction "RET" in the subroutine which will cause the program to jump back to the address right after the CALL instruction. In the case of a JMP instruction, the program simply jumps to the desired location. There is no requirement to jump back to the original jumping off point as in the case of the CALL instruction. One special and extremely useful set of branch instructions are the conditional branches. Here a decision is first made regarding the condition of a certain data memory or individual bits. Depending upon the conditions, the program will continue with the next instruction or skip over it and jump to the following instruction. These instructions are the key to decision making and branching within the program perhaps determined by the condition of certain input switches or by the condition of internal data bits.

Bit Operations

The ability to provide single bit operations on Data Memory is an extremely flexible feature of all Holtek microcontrollers. This feature is especially useful for output port bit programming where individual bits or port pins can be directly set high or low using either the "SET [m].i" or "CLR [m].i" instructions respectively. The feature removes the need for programmers to first read the 8-bit output port, manipulate the input data to ensure that other bits are not changed and then output the port with the correct new data. This read-modify-write process is taken care of automatically when these bit operation instructions are used.

Table Read Operations

Data storage is normally implemented by using registers. However, when working with large amounts of fixed data, the volume involved often makes it inconvenient to store the fixed data in the Data Memory. To overcome this problem, Holtek microcontrollers allow an area of Program Memory to be setup as a table where data can be directly stored. A set of easy to use instructions provides the means by which this fixed data can be referenced and retrieved from the Program Memory.

Other Operations

In addition to the above functional instructions, a range of other instructions also exist such as the "HALT" instruction for Power-down operations and instructions to control the operation of the Watchdog Timer for reliable program operations under extreme electric or electromagnetic environments. For their relevant operations, refer to the functional related sections.

Instruction Set Summary

The instructions related to the data memory access in the following table can be used when the desired data memory is located in Data Memory sector 0.

Table Conventions

x: Bits immediate data
m: Data Memory address
A: Accumulator
i: 0~7 number of bits
addr: Program memory address

Mnemonic	Description	Cycles	Flag Affected
Arithmetic			
ADD A,[m]	Add Data Memory to ACC	1	Z, C, AC, OV, SC
ADDM A,[m]	Add ACC to Data Memory	1Note	Z, C, AC, OV, SC
ADD A,x	Add immediate data to ACC	1	Z, C, AC, OV, SC
ADC A,[m]	Add Data Memory to ACC with Carry	1	Z, C, AC, OV, SC
ADCM A,[m]	Add ACC to Data memory with Carry	1Note	Z, C, AC, OV, SC
SUB A,x	Subtract immediate data from the ACC	1	Z, C, AC, OV, SC, CZ
SUB A,[m]	Subtract Data Memory from ACC	1	Z, C, AC, OV, SC, CZ
SUBM A,[m]	Subtract Data Memory from ACC with result in Data Memory	1Note	Z, C, AC, OV, SC, CZ
SBC A,x	Subtract immediate data from ACC with Carry	1	Z, C, AC, OV, SC, CZ
SBC A,[m]	Subtract Data Memory from ACC with Carry	1	Z, C, AC, OV, SC, CZ
SBCM A,[m]	Subtract Data Memory from ACC with Carry, result in Data Memory	1Note	Z, C, AC, OV, SC, CZ
DAA [m]	Decimal adjust ACC for Addition with result in Data Memory	1Note	C
Logic Operation			
AND A,[m]	Logical AND Data Memory to ACC	1	Z
OR A,[m]	Logical OR Data Memory to ACC	1	Z
XOR A,[m]	Logical XOR Data Memory to ACC	1	Z
ANDM A,[m]	Logical AND ACC to Data Memory	1Note	Z
ORM A,[m]	Logical OR ACC to Data Memory	1Note	Z
XORM A,[m]	Logical XOR ACC to Data Memory	1Note	Z
AND A,x	Logical AND immediate Data to ACC	1	Z
OR A,x	Logical OR immediate Data to ACC	1	Z
XOR A,x	Logical XOR immediate Data to ACC	1	Z
CPL [m]	Complement Data Memory	1Note	Z
CPLA [m]	Complement Data Memory with result in ACC	1	Z
Increment & Decrement			
INCA [m]	Increment Data Memory with result in ACC	1	Z
INC [m]	Increment Data Memory	1Note	Z
DECA [m]	Decrement Data Memory with result in ACC	1	Z
DEC [m]	Decrement Data Memory	1Note	Z
Rotate			
RRA [m]	Rotate Data Memory right with result in ACC	1	None
RR [m]	Rotate Data Memory right	1Note	None
RRCA [m]	Rotate Data Memory right through Carry with result in ACC	1	C
RRC [m]	Rotate Data Memory right through Carry	1Note	C
RLA [m]	Rotate Data Memory left with result in ACC	1	None
RL [m]	Rotate Data Memory left	1Note	None
RLCA [m]	Rotate Data Memory left through Carry with result in ACC	1	C
RLC [m]	Rotate Data Memory left through Carry	1Note	C

Mnemonic	Description	Cycles	Flag Affected
Data Move			
MOV A,[m]	Move Data Memory to ACC	1	None
MOV [m],A	Move ACC to Data Memory	1Note	None
MOV A,x	Move immediate data to ACC	1	None
Bit Operation			
CLR [m].i	Clear bit of Data Memory	1Note	None
SET [m].i	Set bit of Data Memory	1Note	None
Branch Operation			
JMP addr	Jump unconditionally	2	None
SZ [m]	Skip if Data Memory is zero	1Note	None
SZA [m]	Skip if Data Memory is zero with data movement to ACC	1Note	None
SZ [m].i	Skip if bit i of Data Memory is zero	1Note	None
SNZ [m]	Skip if Data Memory is not zero	1Note	None
SNZ [m].i	Skip if bit i of Data Memory is not zero	1Note	None
SIZ [m]	Skip if increment Data Memory is zero	1Note	None
SDZ [m]	Skip if decrement Data Memory is zero	1Note	None
SIZA [m]	Skip if increment Data Memory is zero with result in ACC	1Note	None
SDZA [m]	Skip if decrement Data Memory is zero with result in ACC	1Note	None
CALL addr	Subroutine call	2	None
RET	Return from subroutine	2	None
RET A,x	Return from subroutine and load immediate data to ACC	2	None
RETI	Return from interrupt	2	None
Table Read Operation			
TABRD [m]	Read table to TBLH and Data Memory	2Note	None
TABRDL [m]	Read table (last page) to TBLH and Data Memory	2Note	None
ITABRD [m]	Increment table pointer TBLP first and Read table to TBLH and Data Memory	2Note	None
ITABRDL [m]	Increment table pointer TBLP first and Read table (last page) to TBLH and Data Memory	2Note	None
Miscellaneous			
NOP	No operation	1	None
CLR [m]	Clear Data Memory	1Note	None
SET [m]	Set Data Memory	1Note	None
CLR WDT	Clear Watchdog Timer	1	TO, PDF
SWAP [m]	Swap nibbles of Data Memory	1Note	None
SWAPA [m]	Swap nibbles of Data Memory with result in ACC	1	None
HALT	Enter power down mode	1	TO, PDF

Note: 1. For skip instructions, if the result of the comparison involves a skip then up to three cycles are required, if no skip takes place only one cycle is required.
2. Any instruction which changes the contents of the PCL will also require 2 cycles for execution.
3. For the "CLR WDT" instruction the TO and PDF flags may be affected by the execution status. The TO and PDF flags are cleared after the "CLR WDT" instructions is executed. Otherwise the TO and PDF flags remain unchanged.

Extended Instruction Set

The extended instructions are used to support the full range address access for the data memory. When the accessed data memory is located in any data memory sections except sector 0, the extended instruction can be used to access the data memory instead of using the indirect addressing access to improve the CPU firmware performance.

Mnemonic	Description	Cycles	Flag Affected
Arithmetic			
LADD A,[m]	Add Data Memory to ACC	2	Z, C, AC, OV, SC
LADDM A,[m]	Add ACC to Data Memory	2Note	Z, C, AC, OV, SC
LADC A,[m]	Add Data Memory to ACC with Carry	2	Z, C, AC, OV, SC
LADCM A,[m]	Add ACC to Data memory with Carry	2Note	Z, C, AC, OV, SC
LSUB A,[m]	Subtract Data Memory from ACC	2	Z, C, AC, OV, SC, CZ
LSUBM A,[m]	Subtract Data Memory from ACC with result in Data Memory	2Note	Z, C, AC, OV, SC, CZ
LSBC A,[m]	Subtract Data Memory from ACC with Carry	2	Z, C, AC, OV, SC, CZ
LSBCM A,[m]	Subtract Data Memory from ACC with Carry, result in Data Memory	2Note	Z, C, AC, OV, SC, CZ
LDAA [m]	Decimal adjust ACC for Addition with result in Data Memory	2Note	C
Logic Operation			
LAND A,[m]	Logical AND Data Memory to ACC	2	Z
LOR A,[m]	Logical OR Data Memory to ACC	2	Z
LXOR A,[m]	Logical XOR Data Memory to ACC	2	Z
LANDM A,[m]	Logical AND ACC to Data Memory	2Note	Z
LORM A,[m]	Logical OR ACC to Data Memory	2Note	Z
LXORM A,[m]	Logical XOR ACC to Data Memory	2Note	Z
LCPL [m]	Complement Data Memory	2Note	Z
LCPLA [m]	Complement Data Memory with result in ACC	2	Z
Increment & Decrement			
LINCA [m]	Increment Data Memory with result in ACC	2	Z
LINC [m]	Increment Data Memory	2Note	Z
LDECA [m]	Decrement Data Memory with result in ACC	2	Z
LDEC [m]	Decrement Data Memory	2Note	Z
Rotate			
LRRA [m]	Rotate Data Memory right with result in ACC	2	None
LRR [m]	Rotate Data Memory right	2Note	None
LRRCA [m]	Rotate Data Memory right through Carry with result in ACC	2	C
LRRC [m]	Rotate Data Memory right through Carry	2Note	C
LRLA [m]	Rotate Data Memory left with result in ACC	2	None
LRL [m]	Rotate Data Memory left	2Note	None
LRLCA [m]	Rotate Data Memory left through Carry with result in ACC	2	C
LRLC [m]	Rotate Data Memory left through Carry	2Note	C
Data Move			
LMOV A,[m]	Move Data Memory to ACC	2	None
LMOV [m],A	Move ACC to Data Memory	2Note	None
Bit Operation			
LCLR [m].i	Clear bit of Data Memory	2Note	None
LSET [m].i	Set bit of Data Memory	2Note	None

Mnemonic	Description	Cycles	Flag Affected
Branch			
LSZ [m]	Skip if Data Memory is zero	2Note	None
LSZA [m]	Skip if Data Memory is zero with data movement to ACC	2Note	None
LSNZ [m]	Skip if Data Memory is not zero	2Note	None
LSZ [m].i	Skip if bit i of Data Memory is zero	2Note	None
LSNZ [m].i	Skip if bit i of Data Memory is not zero	2Note	None
LSIZ [m]	Skip if increment Data Memory is zero	2Note	None
LSDZ [m]	Skip if decrement Data Memory is zero	2Note	None
LSIZA [m]	Skip if increment Data Memory is zero with result in ACC	2Note	None
LSDZA [m]	Skip if decrement Data Memory is zero with result in ACC	2Note	None
Table Read			
LTABRD [m]	Read table to TBLH and Data Memory	3Note	None
LTABRDL [m]	Read table (last page) to TBLH and Data Memory	3Note	None
LITABRD [m]	Increment table pointer TBLP first and Read table to TBLH and Data Memory	3Note	None
LITABRDL [m]	Increment table pointer TBLP first and Read table (last page) to TBLH and Data Memory	3Note	None
Miscellaneous			
LCLR [m]	Clear Data Memory	2Note	None
LSET [m]	Set Data Memory	2Note	None
LSWAP [m]	Swap nibbles of Data Memory	2Note	None
LSWAPA [m]	Swap nibbles of Data Memory with result in ACC	2	None

Note: 1. For these extended skip instructions, if the result of the comparison involves a skip then up to four cycles are required, if no skip takes place two cycles is required.

2. Any extended instruction which changes the contents of the PCL register will also require three cycles for execution.

Instruction Definition

ADC A,[m] Add Data Memory to ACC with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

ADCM A,[m] Add ACC to Data Memory with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

ADD A,[m] Add Data Memory to ACC

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

ADD A,x Add immediate data to ACC

Description The contents of the Accumulator and the specified immediate data are added. The result is stored in the Accumulator.

Operation ACC ← ACC + x

Affected flag(s) OV, Z, AC, C, SC

ADDM A,[m] Add ACC to Data Memory

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

AND A,[m] Logical AND Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical AND operation. The result is stored in the Accumulator.

Operation ACC ← ACC "AND" [m]

Affected flag(s) Z

AND A,x Logical AND immediate data to ACC

Description Data in the Accumulator and the specified immediate data perform a bit wise logical AND operation. The result is stored in the Accumulator.

Operation ACC ← ACC "AND" x

Affected flag(s) Z

ANDM A,[m] Logical AND ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical AND operation. The result is stored in the Data Memory.

Operation [m] ← ACC "AND" [m]

Affected flag(s) Z

CALL addr Subroutine call

Description Unconditionally calls a subroutine at the specified address. The Program Counter then increments by 1 to obtain the address of the next instruction which is then pushed onto the stack. The specified address is then loaded and the program continues execution from this new address. As this instruction requires an additional operation, it is a two cycle instruction.

Operation Stack ← Program Counter + 1
Program Counter ← addr

Affected flag(s) None

CLR [m] Clear Data Memory

Description Each bit of the specified Data Memory is cleared to 0.

Operation [m] ← 00H

Affected flag(s) None

CLR [m].i Clear bit of Data Memory

Description Bit i of the specified Data Memory is cleared to 0.

Operation [m].i ← 0

Affected flag(s) None

CLR WDT Clear Watchdog Timer

Description The TO, PDF flags and the WDT are all cleared.

Operation WDT cleared
TO ← 0
PDF ← 0

Affected flag(s) TO, PDF

CPL [m] Complement Data Memory

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa.

Operation [m] ← $\overline{[m]}$

Affected flag(s) Z

CPLA [m] Complement Data Memory with result in ACC

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa. The complemented result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC ← $\overline{[m]}$

Affected flag(s) Z

DAA [m] Decimal-Adjust ACC for addition with result in Data Memory

Description Convert the contents of the Accumulator value to a BCD (Binary Coded Decimal) value resulting from the previous addition of two BCD variables. If the low nibble is greater than 9 or if AC flag is set, then a value of 6 will be added to the low nibble. Otherwise the low nibble remains unchanged. If the high nibble is greater than 9 or if the C flag is set, then a value of 6 will be added to the high nibble. Essentially, the decimal conversion is performed by adding 00H, 06H, 60H or 66H depending on the Accumulator and flag conditions. Only the C flag may be affected by this instruction which indicates that if the original BCD sum is greater than 100, it allows multiple precision decimal addition.

Operation [m] ← ACC + 00H or
[m] ← ACC + 06H or
[m] ← ACC + 60H or
[m] ← ACC + 66H

Affected flag(s) C

DEC [m] Decrement Data Memory

Description Data in the specified Data Memory is decremented by 1.

Operation [m] ← [m] − 1

Affected flag(s) Z

DECA [m] Decrement Data Memory with result in ACC

Description Data in the specified Data Memory is decremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC ← [m] − 1

Affected flag(s) Z

HALT Enter power down mode

Description This instruction stops the program execution and turns off the system clock. The contents of the Data Memory and registers are retained. The WDT and prescaler are cleared. The power down flag PDF is set and the WDT time-out flag TO is cleared.

Operation TO ← 0
PDF ← 1

Affected flag(s) TO, PDF

INC [m] Increment Data Memory

Description Data in the specified Data Memory is incremented by 1.

Operation [m] ← [m] + 1

Affected flag(s) Z

INCA [m] Increment Data Memory with result in ACC

Description Data in the specified Data Memory is incremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC ← [m] + 1

Affected flag(s) Z

JMP addr Jump unconditionally

Description The contents of the Program Counter are replaced with the specified address. Program execution then continues from this new address. As this requires the insertion of a dummy instruction while the new address is loaded, it is a two cycle instruction.

Operation Program Counter ← addr

Affected flag(s) None

MOV A,[m] Move Data Memory to ACC

Description The contents of the specified Data Memory are copied to the Accumulator.

Operation ACC ← [m]

Affected flag(s) None

MOV A,x Move immediate data to ACC

Description The immediate data specified is loaded into the Accumulator.

Operation ACC ← x

Affected flag(s) None

MOV [m],A Move ACC to Data Memory

Description The contents of the Accumulator are copied to the specified Data Memory.

Operation [m] ← ACC

Affected flag(s) None

NOP No operation

Description No operation is performed. Execution continues with the next instruction.

Operation No operation

Affected flag(s) None

OR A,[m] Logical OR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical OR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″OR″ [m]

Affected flag(s) Z

OR A,x Logical OR immediate data to ACC

Description Data in the Accumulator and the specified immediate data perform a bitwise logical OR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″OR″ x

Affected flag(s) Z

ORM A,[m] Logical OR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical OR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″OR″ [m]

Affected flag(s) Z

RET Return from subroutine

Description The Program Counter is restored from the stack. Program execution continues at the restored address.

Operation Program Counter ← Stack

Affected flag(s) None

RET A,x Return from subroutine and load immediate data to ACC

Description The Program Counter is restored from the stack and the Accumulator loaded with the specified immediate data. Program execution continues at the restored address.

Operation Program Counter ← Stack
ACC ← x

Affected flag(s) None

RETI Return from interrupt

Description The Program Counter is restored from the stack and the interrupts are re-enabled by setting the EMI bit. EMI is the master interrupt global enable bit. If an interrupt was pending when the RETI instruction is executed, the pending Interrupt routine will be processed before returning to the main program.

Operation Program Counter ← Stack
EMI ← 1

Affected flag(s) None

RL [m] Rotate Data Memory left

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← [m].7

Affected flag(s) None

RLA [m] Rotate Data Memory left with result in ACC

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← [m].7

Affected flag(s) None

RLC [m] Rotate Data Memory left through Carry

Description The contents of the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← C
C ← [m].7

Affected flag(s) C

RLCA [m] Rotate Data Memory left through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into the bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← C
C ← [m].7

Affected flag(s) C

RR [m] Rotate Data Memory right

Description The contents of the specified Data Memory are rotated right by 1 bit with bit 0 rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← [m].0

Affected flag(s) None

RRA [m] Rotate Data Memory right with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated right by 1 bit with bit 0 rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← [m].0

Affected flag(s) None

RRC [m] Rotate Data Memory right through Carry

Description The contents of the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← C
C ← [m].0

Affected flag(s) C

RRCA [m] Rotate Data Memory right through Carry with result in ACC

Description: Data in the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation:
ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← C
C ← [m].0

Affected flag(s): C

SBC A,[m] Subtract Data Memory from ACC with Carry

Description: The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation: ACC ← ACC − [m] − C

Affected flag(s): OV, Z, AC, C, SC, CZ

SBC A, x Subtract immediate data from ACC with Carry

Description: The immediate data and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation: ACC ← ACC - [m] - $\overline{C}$

Affected flag(s): OV, Z, AC, C, SC, CZ

SBCM A,[m] Subtract Data Memory from ACC with Carry and result in Data Memory

Description: The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation: [m] ← ACC − [m] − C

Affected flag(s): OV, Z, AC, C, SC, CZ

SDZ [m] Skip if decrement Data Memory is 0

Description: The contents of the specified Data Memory are first decremented by 1. If the result is 0 the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation:
[m] ← [m] − 1
Skip if [m]=0

Affected flag(s): None

SDZA [m] Skip if decrement Data Memory is zero with result in ACC

Description: The contents of the specified Data Memory are first decremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation:
ACC ← [m] − 1
Skip if ACC=0

Affected flag(s): None

SET [m] Set Data Memory

Description Each bit of the specified Data Memory is set to 1.

Operation [m] ← FFH

Affected flag(s) None

SET [m].i Set bit of Data Memory

Description Bit i of the specified Data Memory is set to 1.

Operation [m].i ← 1

Affected flag(s) None

SIZ [m] Skip if increment Data Memory is 0

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation [m] ← [m] + 1
Skip if [m]=0

Affected flag(s) None

SIZA [m] Skip if increment Data Memory is zero with result in ACC

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m] + 1
Skip if ACC=0

Affected flag(s) None

SNZ [m].i Skip if Data Memory is not 0

Description If the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.

Operation Skip if [m].i ≠ 0

Affected flag(s) None

SNZ [m] Skip if Data Memory is not 0

Description If the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.

Operation Skip if [m]≠ 0

Affected flag(s) None

SUB A,[m] Subtract Data Memory from ACC

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC − [m]

Affected flag(s) OV, Z, AC, C, SC, CZ

SUBM A,[m] Subtract Data Memory from ACC with result in Data Memory

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC − [m]

Affected flag(s) OV, Z, AC, C, SC, CZ

SUB A,x Subtract immediate data from ACC

Description The immediate data specified by the code is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC − x

Affected flag(s) OV, Z, AC, C, SC, CZ

SWAP [m] Swap nibbles of Data Memory

Description The low-order and high-order nibbles of the specified Data Memory are interchanged.

Operation [m].3~[m].0 ↔ [m].7~[m].4

Affected flag(s) None

SWAPA [m] Swap nibbles of Data Memory with result in ACC

Description The low-order and high-order nibbles of the specified Data Memory are interchanged. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC.3~ACC.0 ← [m].7~[m].4
ACC.7~ACC.4 ← [m].3~[m].0

Affected flag(s) None

SZ [m] Skip if Data Memory is 0

Description If the contents of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation Skip if [m]=0

Affected flag(s) None

SZA [m] Skip if Data Memory is 0 with data movement to ACC

Description The contents of the specified Data Memory are copied to the Accumulator. If the value is zero, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m]
Skip if [m]=0

Affected flag(s) None

SZ [m].i Skip if bit i of Data Memory is 0

Description If bit i of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation Skip if [m].i=0

Affected flag(s) None

TABRD [m] Read table (current page) to TBLH and Data Memory

Description The low byte of the program code (current page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

TABRDL [m] Read table (last page) to TBLH and Data Memory

Description The low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

ITABRD [m] Increment table pointer low byte first and read table to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the program code addressed by the table pointer (TBHP and TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

ITABRDL [m] Increment table pointer low byte first and read table (last page) to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

XOR A,[m] Logical XOR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical XOR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″XOR″ [m]

Affected flag(s) Z

XORM A,[m] Logical XOR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical XOR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″XOR″ [m]

Affected flag(s) Z

XOR A,x Logical XOR immediate data to ACC

Description Data in the Accumulator and the specified immediate data perform a bitwise logical XOR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″XOR″ x

Affected flag(s) Z

Extended Instruction Definition

The extended instructions are used to directly access the data stored in any data memory sections.

LADC A,[m] Add Data Memory to ACC with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

LADCM A,[m] Add ACC to Data Memory with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

LADD A,[m] Add Data Memory to ACC

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

LADDM A,[m] Add ACC to Data Memory

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

LAND A,[m] Logical AND Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical AND operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″AND″ [m]

Affected flag(s) Z

LANDM A,[m] Logical AND ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical AND operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″AND″ [m]

Affected flag(s) Z

LCLR [m] Clear Data Memory

Description Each bit of the specified Data Memory is cleared to 0.

Operation [m] ← 00H

Affected flag(s) None

LCLR [m].i Clear bit of Data Memory

Description Bit i of the specified Data Memory is cleared to 0.

Operation [m].i ← 0

Affected flag(s) None

LCPL [m] Complement Data Memory

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa.

Operation $[m] \leftarrow \overline{[m]}$

Affected flag(s) Z

LCPLA [m] Complement Data Memory with result in ACC

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa. The complemented result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow \overline{[m]}$

Affected flag(s) Z

LDAA [m] Decimal-Adjust ACC for addition with result in Data Memory

Description Convert the contents of the Accumulator value to a BCD (Binary Coded Decimal) value resulting from the previous addition of two BCD variables. If the low nibble is greater than 9 or if AC flag is set, then a value of 6 will be added to the low nibble. Otherwise the low nibble remains unchanged. If the high nibble is greater than 9 or if the C flag is set, then a value of 6 will be added to the high nibble. Essentially, the decimal conversion is performed by adding 00H, 06H, 60H or 66H depending on the Accumulator and flag conditions. Only the C flag may be affected by this instruction which indicates that if the original BCD sum is greater than 100, it allows multiple precision decimal addition.

Operation $[m] \leftarrow ACC + 00H$ or
$[m] \leftarrow ACC + 06H$ or
$[m] \leftarrow ACC + 60H$ or
$[m] \leftarrow ACC + 66H$

Affected flag(s) C

LDEC [m] Decrement Data Memory

Description Data in the specified Data Memory is decremented by 1.

Operation $[m] \leftarrow [m] - 1$

Affected flag(s) Z

LDECA [m] Decrement Data Memory with result in ACC

Description Data in the specified Data Memory is decremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow [m] - 1$

Affected flag(s) Z

LINC [m] Increment Data Memory

Description Data in the specified Data Memory is incremented by 1.

Operation $[m] \leftarrow [m] + 1$

Affected flag(s) Z

LINCA [m] Increment Data Memory with result in ACC

Description Data in the specified Data Memory is incremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow [m] + 1$

Affected flag(s) Z

LMOV A,[m] Move Data Memory to ACC

Description The contents of the specified Data Memory are copied to the Accumulator.

Operation ACC ← [m]

Affected flag(s) None

LMOV [m],A Move ACC to Data Memory

Description The contents of the Accumulator are copied to the specified Data Memory.

Operation [m] ← ACC

Affected flag(s) None

LOR A,[m] Logical OR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical OR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″OR″ [m]

Affected flag(s) Z

LORM A,[m] Logical OR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical OR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″OR″ [m]

Affected flag(s) Z

LRL [m] Rotate Data Memory left

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← [m].7

Affected flag(s) None

LRLA [m] Rotate Data Memory left with result in ACC

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← [m].7

Affected flag(s) None

LRLC [m] Rotate Data Memory left through Carry

Description The contents of the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← C
C ← [m].7

Affected flag(s) C

LRLCA [m] Rotate Data Memory left through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into the bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← C
C ← [m].7

Affected flag(s) C

LRR [m] Rotate Data Memory right

Description The contents of the specified Data Memory are rotated right by 1 bit with bit 0 rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← [m].0

Affected flag(s) None

LRRA [m] Rotate Data Memory right with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated right by 1 bit with bit 0 rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← [m].0

Affected flag(s) None

LRRC [m] Rotate Data Memory right through Carry

Description The contents of the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← C
C ← [m].0

Affected flag(s) C

LRRCA [m] Rotate Data Memory right through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← C
C ← [m].0

Affected flag(s) C

LSBC A,[m] Subtract Data Memory from ACC with Carry

Description The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC − [m] − C

Affected flag(s) OV, Z, AC, C, SC, CZ

LSBCM A,[m] Subtract Data Memory from ACC with Carry and result in Data Memory

Description The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC − [m] − C

Affected flag(s) OV, Z, AC, C, SC, CZ

LSDZ [m] Skip if decrement Data Memory is 0

Description The contents of the specified Data Memory are first decremented by 1. If the result is 0 the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation [m] ← [m] − 1
Skip if [m]=0

Affected flag(s) None

LSDZA [m] Skip if decrement Data Memory is zero with result in ACC

Description The contents of the specified Data Memory are first decremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation ACC ← [m] − 1
Skip if ACC=0

Affected flag(s) None

LSET [m] Set Data Memory

Description Each bit of the specified Data Memory is set to 1.

Operation [m] ← FFH

Affected flag(s) None

LSET [m].i Set bit of Data Memory

Description Bit i of the specified Data Memory is set to 1.

Operation [m].i ← 1

Affected flag(s) None

LSIZ [m] Skip if increment Data Memory is 0

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation [m] ← [m] + 1
Skip if [m]=0

Affected flag(s) None

LSIZA [m] Skip if increment Data Memory is zero with result in ACC

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m] + 1
Skip if ACC=0

Affected flag(s) None

LSNZ [m].i Skip if Data Memory is not 0

Description If the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.

Operation Skip if [m].i ≠ 0

Affected flag(s) None

LSNZ [m] Skip if Data Memory is not 0

Description If the content of the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.

Operation Skip if [m] ≠ 0

Affected flag(s) None

LSUB A,[m] Subtract Data Memory from ACC

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC − [m]

Affected flag(s) OV, Z, AC, C, SC, CZ

LSUBM A,[m] Subtract Data Memory from ACC with result in Data Memory

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC − [m]

Affected flag(s) OV, Z, AC, C, SC, CZ

LSWAP [m] Swap nibbles of Data Memory

Description The low-order and high-order nibbles of the specified Data Memory are interchanged.

Operation [m].3~[m].0 ↔ [m].7~[m].4

Affected flag(s) None

LSWAPA [m] Swap nibbles of Data Memory with result in ACC

Description The low-order and high-order nibbles of the specified Data Memory are interchanged. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC.3~ACC.0 ← [m].7~[m].4
ACC.7~ACC.4 ← [m].3~[m].0

Affected flag(s) None

LSZ [m] Skip if Data Memory is 0

Description If the contents of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation Skip if [m]=0

Affected flag(s) None

LSZA [m] Skip if Data Memory is 0 with data movement to ACC

Description The contents of the specified Data Memory are copied to the Accumulator. If the value is zero, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m]
Skip if [m]=0

Affected flag(s) None

LSZ [m].i Skip if bit i of Data Memory is 0

Description If bit i of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation Skip if [m].i=0

Affected flag(s) None

LTABRD [m] Read table (current page) to TBLH and Data Memory

Description The low byte of the program code (current page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LTABRDL [m] Read table (last page) to TBLH and Data Memory

Description The low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LITABRD [m] Increment table pointer low byte first and read table to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the program code addressed by the table pointer (TBHP and TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LITABRDL [m] Increment table pointer low byte first and read table (last page) to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LXOR A,[m] Logical XOR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical XOR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″XOR″ [m]

Affected flag(s) Z

LXORM A,[m] Logical XOR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical XOR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″XOR″ [m]

Affected flag(s) Z

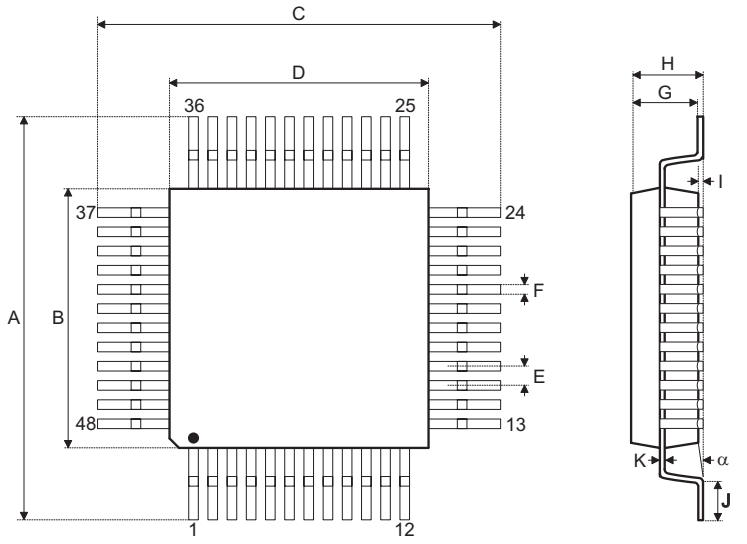
Package Information

Note that the package information provided here is for consultation purposes only. As this information may be updated at regular intervals users are reminded to consult the Holtek website for the latest version of the Package/Carton Information.

Additional supplementary information with regard to packaging is listed below. Click on the relevant section to be transferred to the relevant website page.

- Further Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- Packing Meterials Information
- Carton information

48-pin LQFP (7mm×7mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.354 BSC	—
B	—	0.276 BSC	—
C	—	0.354 BSC	—
D	—	0.276 BSC	—
E	—	0.020 BSC	—
F	0.007	0.009	0.011
G	0.053	0.055	0.057
H	—	—	0.063
I	0.002	—	0.006
J	0.018	0.024	0.030
K	0.004	—	0.008
α	0°	—	7°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	9.00 BSC	—
B	—	7.00 BSC	—
C	—	9.00 BSC	—
D	—	7.00 BSC	—
E	—	0.50 BSC	—
F	0.17	0.22	0.27
G	1.35	1.40	1.45
H	—	—	1.60
I	0.05	—	0.15
J	0.45	0.60	0.75
K	0.09	—	0.20
α	0°	—	7°