Boo-Ree Multimedia Inc.

HIGH PERFORMANCE 8BIT RISC CPU BASED
GRAPHIC IMAGE & VOICE PRODUCT

USERS MANUAL SPECIFICATION

BMC513

RISC 80C51
8-BIT CMOS MICROCONTROLLER

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Scope of this Revision

Every attempt has been made to ensure a consistent and implemental specification. Implementations should ensure compliance with this revision.

Revision History

Revision	Date	Comments
1.00	2010.08	1st released version for customer's development
1.10	2011.04	Add 80QFP-1420 package
1.20	2011.07	Add explanation of IVCON0 and IVCON1 in more details. Fix errata.
1.30	2012.03	Add External Main Oscillator Electrical Characteristics.
1.40	2012.04	Correct the errorta

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1 INTRODUCTION

The BMC513 combines a powerful RISC 8051-based micro-controller with a hardwired high quality ADPCM voice codec, called ***BRAC***® to simply play voice or sound at the sampling frequency of up to 48KHz and with hardwired JPEG like graphic image decoder, called ***BRJPEG***®. And its 384KBytes embedded e-FLASH memory and richer peripherals will reduce the chip count on your system resulting in manufacturing cost-down and early time-to-market. In addition, In-house software development tool kit (***Power Studio***: Compiler & Debugger) and hardware In-circuit emulator, called ***PowerICE***, will make your development much faster and easier.

1.1 FEATURES

Fast 8-bit RISC 8051 core MCU

- Advanced RISC B51core using 1-clocks per instruction
- Dual DPTRs (Data Pointer Registers) for fast block move

Hardwired ADPCM Voice Codec

- Embedded own ADPCM Codec(BRAC®) with a dedicated DMA
  - ✓ Selectable sampling frequency from 4KHz to 48KHz
  - ✓ Built-in Low Pass Filter & 3 times up-sampling
  - ✓ 3-bit / 4-bit data compression
- Volume control with mute feature
- Automatic DMA access to external Serial Flash (up to 1Gbit)
- IBB(Input Bit stream Buffer) mode for direct playback of voice data in X-RAM
- Voice Recording

Hardwired BRJPEG Decoder

- Embedded own DCT based Image decoder
  - ✓ 128x128 10 frame decoding @12MHz
  - ✓ 192x192 10 frame decoding @24MHz
- Built-in processing engines for image decoding
  - ✓ Variable length decoding engine
  - ✓ Inverse DCT engine
- Support additional MAC/MUL/ADD/SUM instructions with up to 16 data input

VDMA

- Two dimensional DMA engine with on the fly additional functions
  - ✓ Color space conversion from YCbCr to RGB
  - ✓ Mixing foreground and background images
  - ✓ Alpha blending with 4444 and 5551 formats
- Local I80LCD channel to read/write RGB data to/from external frame memory

Memories

- 384KBytes embedded NOR Flash Memory(e-FLASH) for program and data
  - ✓ Sector Endurance: 10,000 Cycles
  - ✓ Greater than 10 years Data Retention
  - ✓ This memory is protected from writing after reset.
- 256Bytes On-chip data SRAM(I-RAM)
- 4KBytes On-chip Extended data SRAM(X-RAM)
- Up to 1Gbits, Serial NOR Flash externally expandable

JTAG Interface

- On-Chip Debug and In-System Programming through JTAG

In-house Development Tools

- Power Studio v1.2(SDK: Software Development Kit), and In-Circuit Emulator (***PowerICE***)
- Support IAR Compiler

In-house Mass-Production Tools (Gang Writer)
- ***PowerWriter*** : Gang writer with 8 Sockets(68QFN/80QFP, plus JTAG) and USB interface to Host PC

ADC
- 6(80QFP)/4(68QFN) channels 10-bit
- Max. 20uS conversion time, Max 50K SPS @3MHz ADC conversion clock
- Programmable input clock frequency

1 channel 10-bit D/A Converter

Serial Flash Controller
- Master-only interface with dual DMA functions
- BSPI clock is configurable. (Max. F_{SYS})
- BSPI is mainly used for external serial flash
- BSPI on-the-fly function by a dedicated DMA (high-speed data read even during voice Playback)

UART
- Supports 5-bit, 6-bit, 7-bit, or 8-bit serial data transmit/receive (TX/RX)
- Supports external clocks for the UART operation
- Programmable baud rate
- Supports IrDA 1.0
- Loopback mode for testing
- Insertion of one or two Stop bits per frame
- Parity checking
- LSB first

RTC
- Time information (seconds/minutes/hours) directly in BCD code
- Calendar information (date/month/year/day of the week) directly in BCD code up to year 9999
- Leap year generator
- Wake-up signal generation: support on the STOP mode
- Alarm interrupt
- Cyclic interrupt: the interrupt cycle may be 1/512, 1/256, 1/64, 1/16, 1/4, 1/2, and 1 second

USB Device
- Fully Compliant to USB 2.0 full-speed specification (maximum 12Mbps)
- Complete Device Configuration
- Compatible with both OpenHCI and Intel UHCI Standards
- Support 5 Endpoints (1 Control Endpoint, 4 Data Endpoints with logical endpoint numbering
- EP0: 16 Bytes Control/Status Endpoint
- EP1/2: 64 Bytes Data Endpoint (IN/OUT) supporting automatic double buffering
- EP3/4: 16 Bytes Data Endpoint (IN/OUT) supporting automatic double buffering
- Supports Bulk Data Transfer
- CRC16 Generation and CRC5/CRC16 Checking
- Suspend/Resume Control
- On-Chip USB Transceiver

Timers with Pulse Width Modulation (PWM)
- 3 channels 16-bit Programmable Timers
- Interval Mode, Toggle Mode, Capture Mode or PWM Mode
- 3 PWM output, Timer output and Capture Input
- Supports external clock sources

SPI
- Full-duplex, 3-wire or 4-wire Synchronous Data Transfer
- Support Master and Slave operation
- Serial clock with programmable polarity and phase
- Baud rate clock selectable in Master mode
- MSB First or LSB First Data Transfer
- Support 1 Byte / 2 Byte operation

Watchdog Timer
- 8-bit Timer with pre-scaler.
- If an overflow of watchdog timer is generated, a reset is issued.

I80LCD Interface
- Support parallel/serial external LCD interfaces
  - ✓ 8-bit, 9-bit, 16-bit, 18-bit parallel I80 interface
  - ✓ 3-wire, 4-wire serial interface
- Support VDMA local bus interface

LCD Controller/Driver
- 32(80QFP)/30(68QFN) segments and 4 common terminals
- 1/2, 1/3 and 1/4 duty selectable
- 16 level LCD contrast control by software
- LCD display data memory registers

Other Features
- 30 programmable interrupt sources (10(80QFP)/8(68QFN) external interrupt sources)
- Low power consumption

Low Voltage Reset (LVR)
- Criteria voltage: 2.0V

On-Chip Regulator
- VDD to 1.8V conversion
- VDD to 3.3V conversion

Clock Circuit
- External crystal: 4MHz ~ 12MHz
- External resonator: 4MHz ~ 8MHz
- Internal typ. 16MHz oscillator
- External crystal: 32.768KHz
- Internal typ. 32.768KHz oscillator
- On chip PLL: Max 48MHz

Power Down Mode
- IDLE: only CPU clock stops
- STOP: selected system clock and CPU clock stop

Operating Frequency
- Max. 24MHz

Operating Voltages
- 2.2V to 5.5V at 4 – 12MHz

Operating Temperature Range
- -40℃ ~ 85℃

I/O and Package type
- 61(80QFP)/51(68QFN) GPIOs
- 68-pin (8x8 mm) QFN
- 80-pin (14x20 mm) QFP

SMART option
- RDP (Flash Read Protection)
- HDP (Flash Program Protection)

1.2 Device Summary

Table 1-1. Playback Duration

[Unit: sec]

	Major Sampling Rate by using 384KBytes (Maximum)						
Compression	4 KHz	6.4 KHz	8 KHz	16 KHz	22 KHz	32 KHz	44.1 KHz
3-bit	256	160	128	64	46.5	32	23.2
4-bit	192	120	96	48	34.9	24	17.4

Note: external serial flash is recommended to be used for longer voice playback duration.

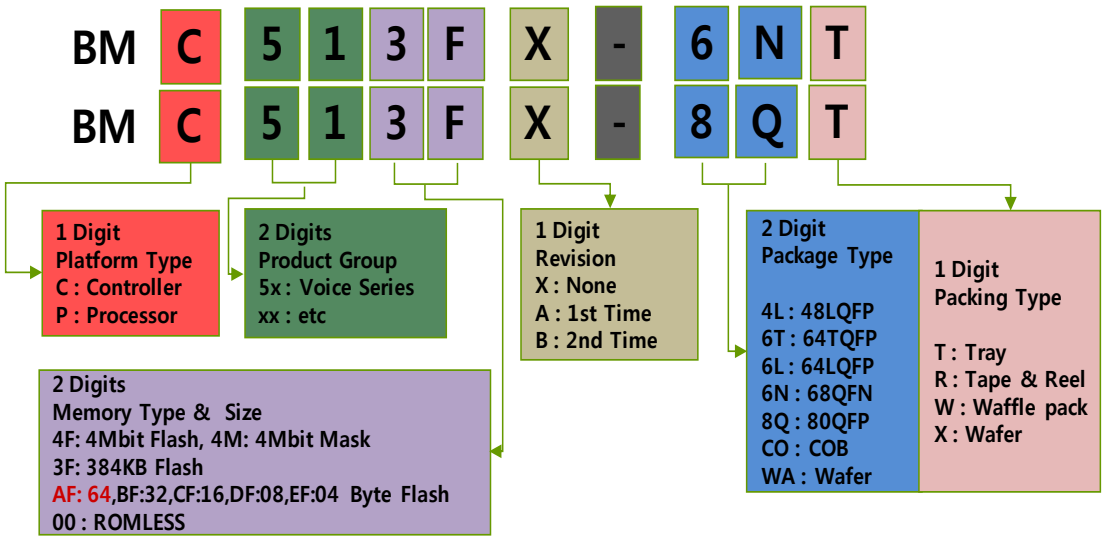
Table 1-2. Device Summary

Part Number	ROM (e-FLASH)	SRAM	ADC (bit x ch)	DAC	ADPCM Codec	GPIO	Schedule
BMC51A	64KBytes	6KB	10 x 6	1 (12bit)	Y	40	Available now
BMC513	384Kbytes	4KB	10 x 6	1 (10bit)	Y	51	Available now

Table 1-3. Ordering Number and Standard Marking

	BMC51x's Ordering Number List		
Package	Ordering Number	Standard Marking	Description
64LQFP	BMC51AFX-6LT	BMC51AFX-6LT	Refer to Table 1.4
68QFN	BMC513FX-6NT	BMC513FX-6NT	
80QFP	BMC513FX-8QT	BMC513FX-8QT	

Table 1-4. Example of Ordering Number Structure



1.3 Block Diagram

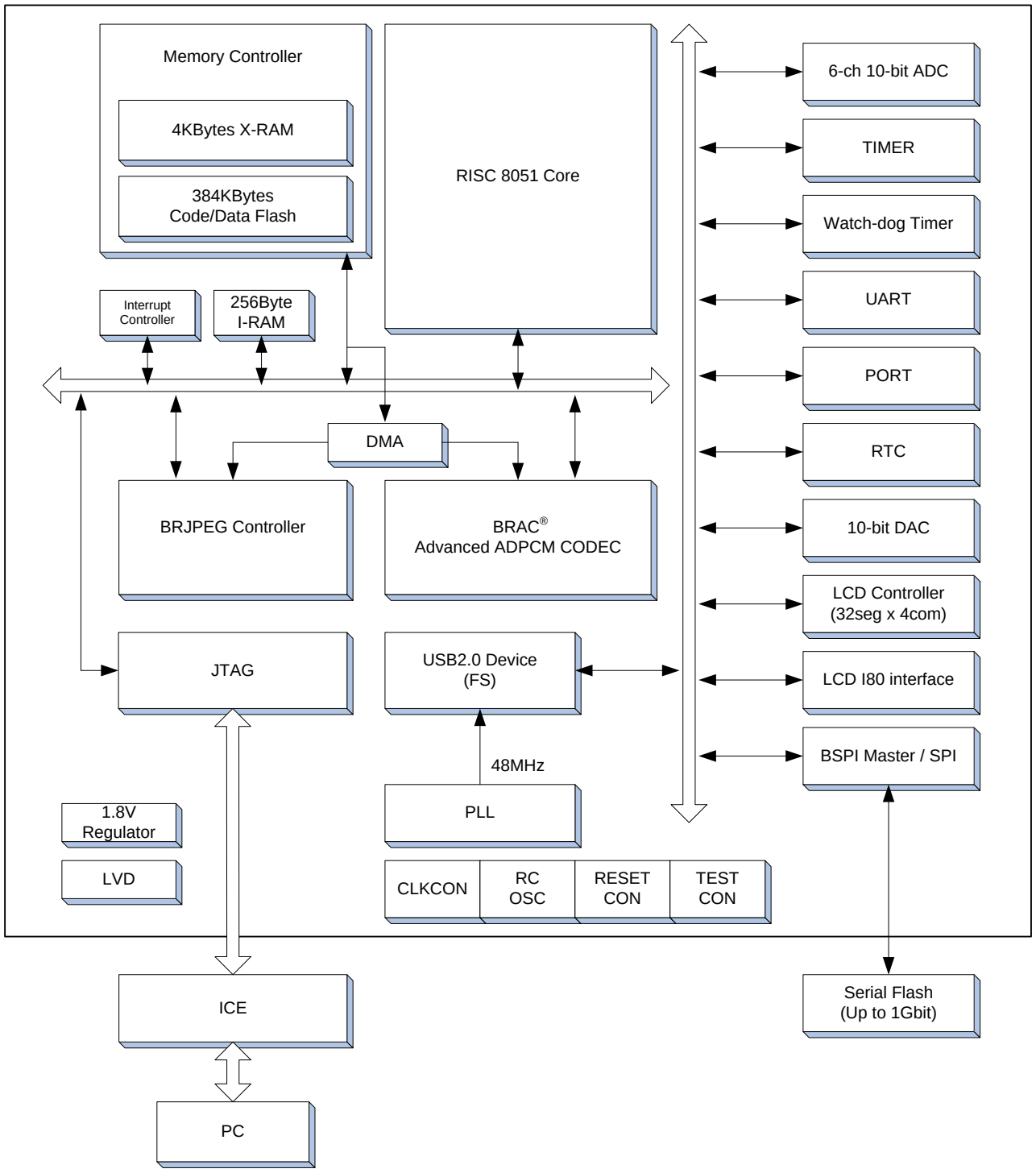


Figure 1-1. Block Diagram

1.4 Pin Assignment

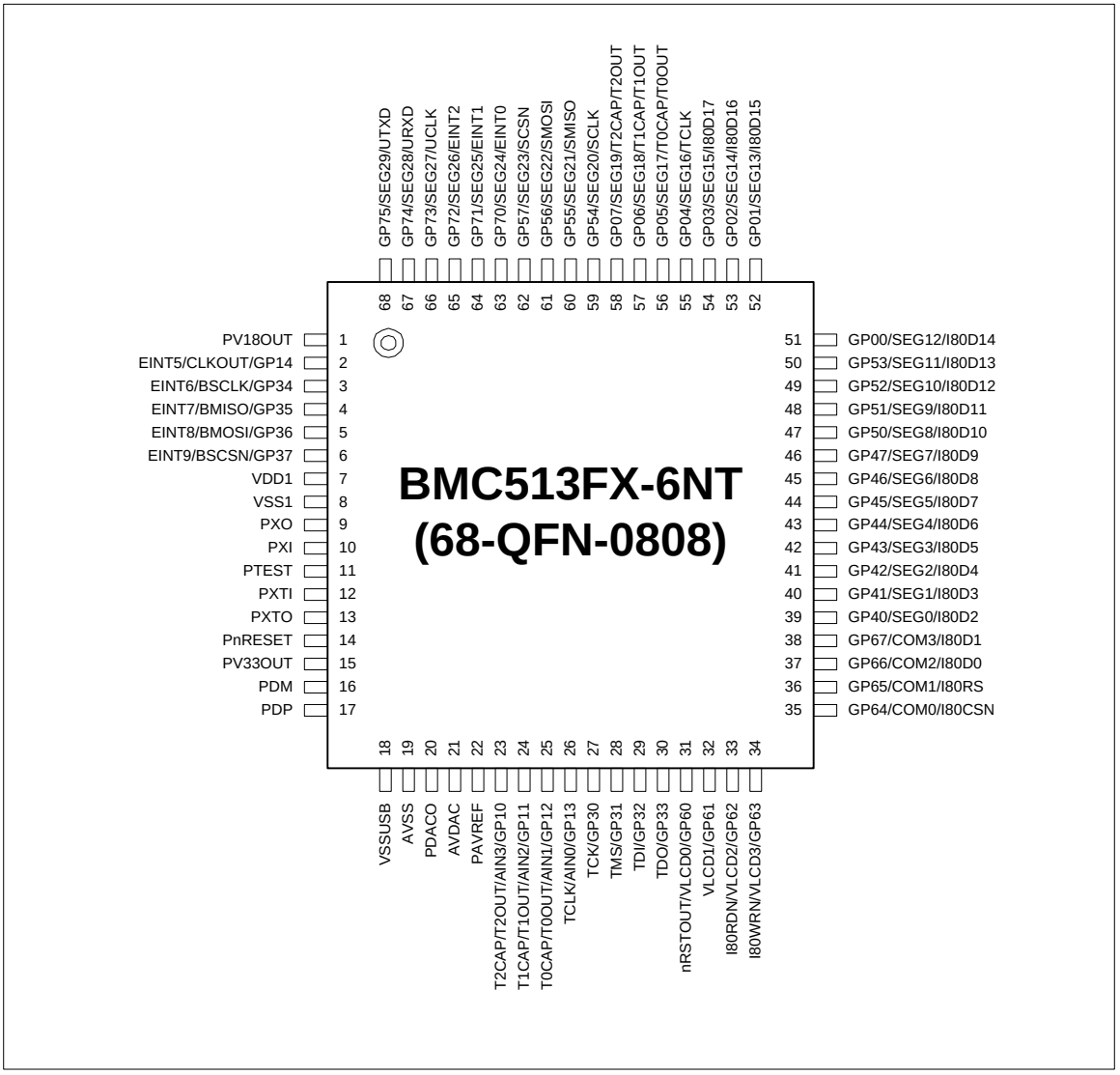


Figure 1-2. 68-QFN Pin Assignment

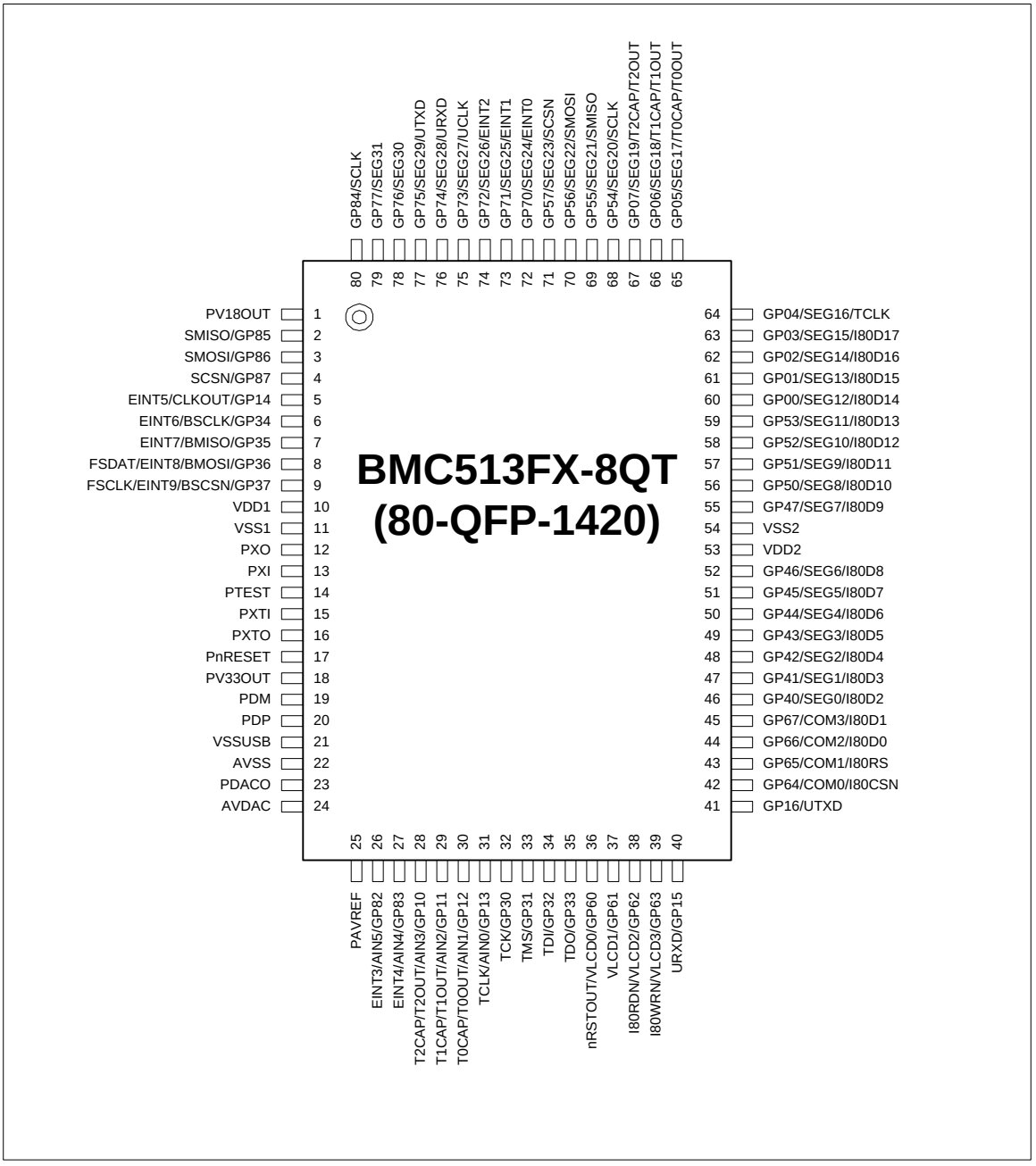


Figure 1-3. 80-QFP Pin Assignment

1.5 Pin Descriptions

Pin		Pin Name	Function	Default	Pull-up/dn @RESET	I/O State @RESET
80Pin	68Pin					
1	1	PV18OUT	V18OUT (1.8V)	V18OUT	-	O
2	-	**PGP85**	GP85/SMISO	GP85	Pull-up	I
3	-	**PGP86**	GP86/SMOSI	GP86	Pull-up	I
4	-	**PGP87**	GP87/SCSN	GP87	Pull-up	I
5	2	PGP14	GP14/CLKOUT/EINT5	GP14	-	I
6	3	PGP34	GP34/BSCLK/EINT6	GP34	Pull-up	I
7	4	PGP35	GP35/BSMISO/EINT7	GP35	-	I
8	5	PGP36	GP36/BSMOSI/EINT8	GP36	-	I
9	6	PGP37	GP37/BSCSN/EINT9	GP37	-	I
10	7	VDD1	VDD	VDD	-	Power
11	8	VSS1	VSS	VSS	-	Ground
12	9	PXO	XO	XO	-	O
13	10	PXI	XI	XI	-	I
14	11	PTEST	TEST	TEST	Pull-dn	I
15	12	PXTI	XTI	XTI	-	I
16	13	PXTO	XTO	XTO	-	O
17	14	PnRESET	nRESET	nRESET	Pull-up	I
18	15	PV33OUT	V33OUT	V33OUT	-	O
19	16	PDM	DM	DM	-	AB
20	17	PDP	DP	DP	-	AB
21	18	VSSUSB	VSSUSB	VSSUSB		Ground
22	19	AVSS	AVSS	AVSS	-	Ground
23	20	PDACO	DACO	DACO	-	O
24	21	AVDAC	AVDAC (3.3V)	AVDAC	-	Power
25	22	PAVREF	AVREF	AVREF	-	I
26	-	**PGP82**	GP82/AIN5/EINT3	GP82	Pull-up	I
27	-	**PGP83**	GP83/AIN4/EINT4	GP83	Pull-up	I
28	23	PGP10	GP10/AIN3/T2CAP/T2OUT	GP10	-	I
29	24	PGP11	GP11/AIN2/T1CAP/T1OUT	GP11	-	I
30	25	PGP12	GP12/AIN1/T0CAP/T0OUT	GP12	-	I
31	26	PGP13	GP13/AIN0/TCLK	GP13	-	I
32	27	PGP30	GP30/TCK	GP30	Pull-up	I
33	28	PGP31	GP31/TMS	GP31	Pull-up	I
34	29	PGP32	GP32/TDI	GP32	-	I
35	30	PGP33	GP33/TDO	GP33	-	I
36	31	PGP60	GP60/VLCD0/nRSTOUT	nRSTOUT	-	O
37	32	PGP61	GP61/VLCD1	GP61	-	I
38	33	PGP62	GP62/VLCD2/I80RDN	GP62	-	I
39	34	PGP63	GP63/VLCD3/I80WRN	GP63	-	I
40	-	**PGP15**	GP15/URXD	GP15	Pull-up	I
41	-	**PGP16**	GP16/UTXD	GP16	Pull-up	I
42	35	PGP64	GP64/COM0/I80CSN	GP64	-	I
43	36	PGP65	GP65/COM1/I80RS	GP65	-	I
44	37	PGP66	GP66/COM2/I80D0	GP66	-	I
45	38	PGP67	GP67/COM3/I80D1	GP67	-	I
46	39	PGP40	GP40/SEG0/I80D2	GP40	-	I
47	40	PGP41	GP41/SEG1/I80D3	GP41	-	I
48	41	PGP42	GP42/SEG2/I80D4	GP42	-	I
49	42	PGP43	GP43/SEG3/I80D5	GP43	-	I
50	43	PGP44	GP44/SEG4/I80D6	GP44	-	I
51	44	PGP45	GP45/SEG5/I80D7	GP45	-	I
52	45	PGP46	GP46/SEG6/I80D8	GP46	-	I
53	-	**VDD2**	VDD	VDD	-	Power
54	-	**VSS2**	VSS	VSS	-	Ground
55	46	PGP47	GP47/SEG7/I80D9	GP47	-	I
56	47	PGP50	GP50/SEG8/I80D10	GP50	-	I
57	48	PGP51	GP51/SEG9/I80D11	GP51	-	I

Pin		Pin Name	Function	Default	Pull-up/dn @RESET	I/O State @RESET
80Pin	68Pin					
58	49	PGP52	GP52/SEG10/I80D12	GP52	-	I
59	50	PGP53	GP53/SEG11/I80D13	GP53	-	I
60	51	PGP00	GP00/SEG12/I80D14	GP00	-	I
61	52	PGP01	GP01/SEG13/I80D15	GP01	-	I
62	53	PGP02	GP02/SEG14/I80D16	GP02	-	I
63	54	PGP03	GP03/SEG15/I80D17	GP03	-	I
64	55	PGP04	GP04/SEG16/TCLK	GP04	-	I
65	56	PGP05	GP05/SEG17/T0CAP/T0OUT	GP05	-	I
66	57	PGP06	GP06/SEG18/T1CAP/T1OUT	GP06	-	I
67	58	PGP07	GP07/SEG19/T1CAP/T2OUT	GP07	-	I
68	59	PGP54	GP54/SEG20/SCLK	GP54	-	I
69	60	PGP55	GP55/SEG21/SMISO	GP55	-	I
70	61	PGP56	GP56/SEG22/SMOSI	GP56	-	I
71	62	PGP57	GP57/SEG23/SCSN	GP57	-	I
72	63	PGP70	GP70/SEG24/EINT0	GP70	-	I
73	64	PGP71	GP71/SEG25/EINT1	GP71	-	I
74	65	PGP72	GP72/SEG26/EINT2	GP72	-	I
75	66	PGP73	GP73/SEG27/UCLK	GP73	-	I
76	67	PGP74	GP74/SEG28/URXD	GP74	-	I
77	68	PGP75	GP75/SEG29/UTXD	GP75	-	I
78	-	**PGP76**	GP76/SEG30	GP76	Pull-up	I
79	-	**PGP77**	GP77/SEG31	GP77	Pull-up	I
80	-	**PGP84**	GP84/SCLK	GP84	Pull-up	I

Miscellaneous

Name	I/O	Description
XI XO	I O	Clock Input / Output (Max. 12MHz) Connect these oscillation pins to crystal oscillators.
XTI XTO	I O	32.768 KHz clock Input / Output.
nRESET	I	Chip Reset Signal (active “Low”) This PnRESET pin contains an internal pull up resistor 250kΩ. Setting this pin to low level initialize the internal state of the device. Thereafter, setting the input to high release the reset status. The BMC513 waits for the system clock to be stable, and then set PC to the reset interrupt vector. Internal Reset is generated after clock stabilization
nRSTOUT	O	External Device reset control nRSTOUT: Pin RESET, LVD Reset, SW Reset, WDT Reset
CLKOUT	O	Clock Output signal. The CLKOSEL bits in CLKCON register configure the clock output mode among Main OSC clock, Sub OSC clock, Internal 16MHz main OSC clock, Internal 32KHz sub OSC clock, RTC clock output, PLL output clock and etc.
TEST	I	Factory test input pin. NOTE: ***This pin should be connected to Ground.***

External Interrupt (10pins)

Name	I/O	Description
EINT0 ~ EINT9	I	External Interrupt input pins, The valid edge for EINT0 to EINT9 can be selected through the EINTMODx register. When these are not used for interrupts, these can be used as normal pins.

JTAG System Interface (4pins)

Name	I/O	Description
TDO	O	ICE TDO The default function of this pin is JTAG TDO pin and user program can change this pin as normal GPIO when ICE is not connected.
TDI	I	ICE TDI The default function of this pin is JTAG TDI pin and user program can change this pin as normal GPIO when ICE is not connected.
TCK	I	ICE TCK The default function of this pin is JTAG TCK pin and user program can change this pin as normal GPIO when ICE is not connected.
TMS	I	ICE TMS The default function of this pin is JTAG TMS pin and user program can change this pin as normal GPIO when ICE is not connected.

UART Interface (3pins)

Name	I/O	Description
UCLK	I	External Clock Source for UART
URXD	I	Receive Data Input for UART
UTXD	O	Transmit Data Output for UART

Serial Flash Interface (4pins)

Name	I/O	Description
BSCSN	O	Serial Flash Chip Select
BSCLK	O	Serial Flash Clock
BMOSI	O	Serial Data Output
BMISO	I	Serial Data Input

ADC Interface (7pins)

Name	I/O	Description
AIN0 ~ AIN5	AI	Analog Input pins for 6-channel(Range: 0.0V ~ AVREF value), 10-bit A/D converter.
AVREF	AI	ADC Reference Top Voltage. Normally, the max value of AVREF = VDD

DAC Interface (1pins)

Name	I/O	Description
DACO	AO	Analog output of DAC

SPI Interface (4pins)

Name	I/O	Description
SCLK	IO	SPI Clock. When configured as master, this pin is an output, When configured as slave, this pin is an input.
SMISO	IO	SPI master-in/slave-out. When configured as master, this pin is an input, When configured as slave, this pin is an output.
SMOSI	IO	SPI master-out/slave-in. When configured as master, this pin is an output, When configured as slave, this pin is an input.
SCSN	IO	SPI slave select. When configured as master, this pin is an output, When configured as slave, this pin is an input.

Timer Interface (4pins)

Name	I/O	Description
TCLK	I	External Clock Source for Timer 0, Timer 1 and Timer 2
T0CAP/T0OUT	IO	Timer 0 Capture input / Timer 0 16-bit PWM mode output or counter match toggle output
T1CAP/T1OUT	IO	Timer 1 Capture input / Timer 1 16-bit PWM mode output or counter match toggle output
T2CAP/T2OUT	IO	Timer 2 Capture input / Timer 2 16-bit PWM mode output or counter match toggle output

I80LCD Interface (22pins)

Name	I/O	Description
I80RS	O	Register selection output
I80CSN	O	Chip select output
I80WRN	O	Write strobe output
I80RDN	O	Read strobe output
I80D0 ~ I80D17	IO	Data input/output

LCD Controller / Driver (40pins)

Name	I/O	Description
SEG[31:0]	O	LCD segment signal outputs
COM[3:0]	O	LCD common signal outputs
VLCD0 ~ VLCD3	I	LCD Bias pins

USB Interface (2pins)

Name	I/O	Description
DP	AB	DATA(+) for USB device.
DM	AB	DATA(-) for USB device.

GPIOs (61pins)

Name	I/O	Description
GP00 ~ GP07	IO	8-Bit CMOS tri-state I/O port. 2mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P0MOD0 and P0MOD1 registers.
GP10 ~ GP16	IO	7-Bit CMOS tri-state I/O port. 4mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P1MOD0 and P1MOD1 registers.
GP30 ~ GP37	IO	8-Bit CMOS tri-state I/O port. 4mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P3MOD0 and P3MOD1 registers.
GP40 ~ GP47	IO	8-Bit CMOS tri-state I/O port. 2mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P4MOD0 and P4MOD1 registers.
GP50 ~ GP57	IO	8-Bit CMOS tri-state I/O port. 2mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P5MOD0 and P5MOD1 registers.
GP60 ~ GP66	IO	8-Bit CMOS tri-state I/O port. 2/4mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P6MOD0 and P6MOD1 registers.
GP70 ~ GP77	IO	8-Bit CMOS tri-state I/O port. 2mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P7MOD0 and P7MOD1 registers.
GP82 ~ GP87	IO	6-Bit CMOS tri-state I/O port. 4mA output driving current capability. Each bit can be set individually as either any data transfer purpose or specific alternative function defined by the P8MOD0 and P8MOD1 registers.

Power

Name	I/O	Description
VDD1, VDD2	P	Digital Power 2.2 V ~ 5.5V
V18OUT	O	Digital Power 1.8V output from internal LDO. **Connected to GND through 1uF capacitor**
V33OUT	O	Digital Power 3.3V output from internal LDO. **Connected to GND through 1uF capacitor**
AVDAC	P	Analog Power Supply For DAC (Connected to PV33OUT)
VSS1, VSS2	G	Digital Ground
VSSUSB	G	USB PHY Ground
AVSS	G	Analog Ground (for ADC and DAC)

2 MEMORY ORGANIZATION

There are three kinds of memory areas: 384KBytes e-FLASH, 4KBytes X-RAM and 256Bytes I-RAM. Figure 2-1 shows the memory organization of the BMC513. I-RAM includes 4 banks of 8 working registers and can be available as stack area. X-RAM is 4KBytes and can be used for the data memory and code memory also. The total size of e-FLASH for the BMC513 is 384KBytes and can be used for the data memory and code memory. X-RAM and e-FLASH are separated physically but are mapped into the same memory space together logically depending on the register values of XRAMB and ROMB in terms of code memory space and data memory space. The register XRAMB and ROMB choose the BANK depending on it's value. The BANK 0 of e-FLASH is the basic BANK for code memory space and is mapped to the address 0x0000 ~ 0x7FFF regardless of the XRAMB and ROMB. And X-RAM is also the basic data memory and is mapped to the address 0x8000 ~ 0x8FFF also. The detail conceptual block diagram and its explanation are described in Chapter 2.1 and Chapter 2.2.

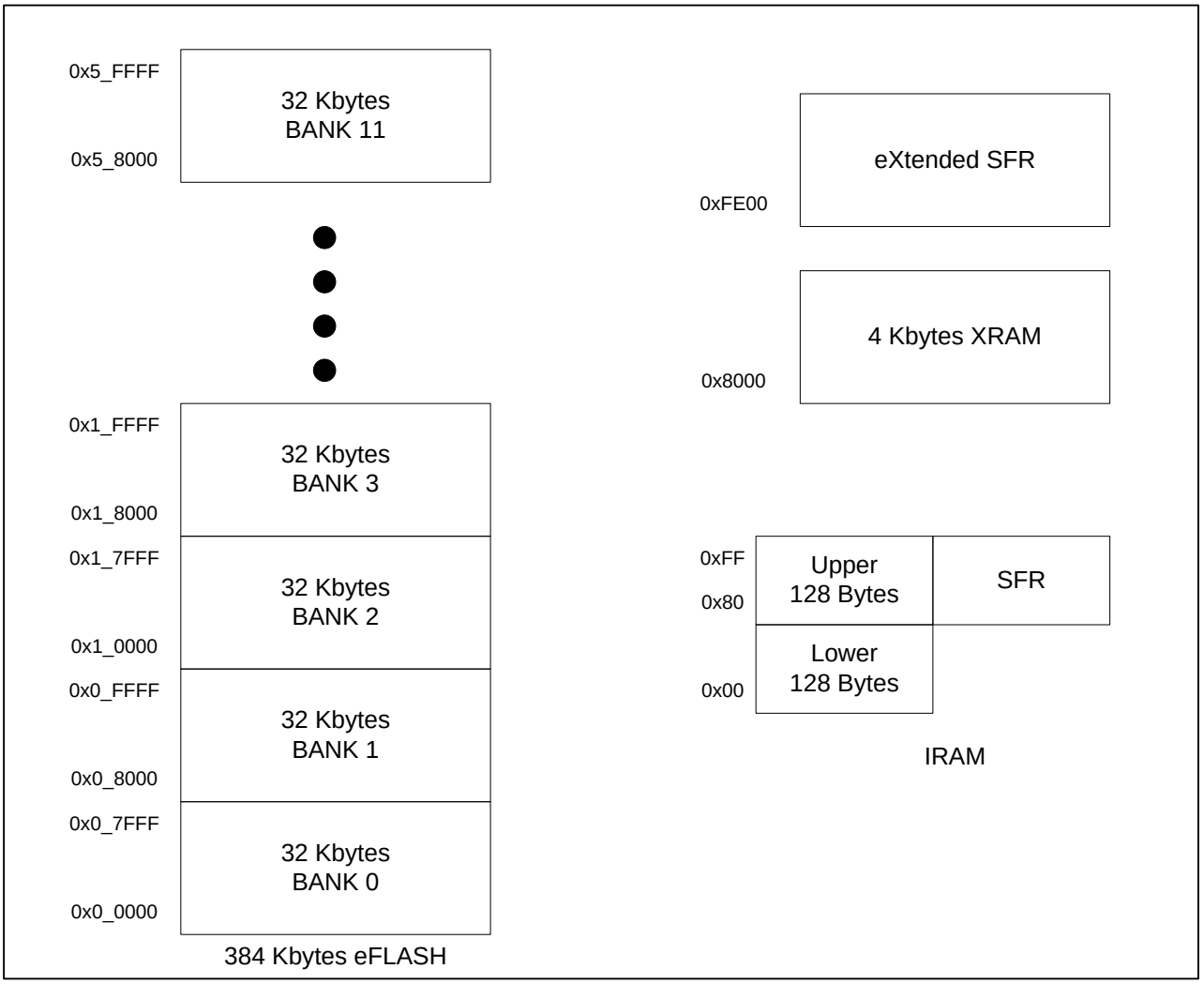


Figure 2-1. Memory Organization of the BMC513

2.1 Code Memory

After reset, CPU begins execution from location 0x0000. CPU can access using MOVC instruction in code memory.

Table 2-1. Code Memory Map

Logical Address Range	ROMB Value	Descriptions
0x00000 ~ 0x07FFF	X	Bank 0 (32 KB) This range includes the default boot code area in e-FLASH memory and all the contents are downloaded and burned normally by JTAG ICE.
0x08000 ~ 0x0FFFF	0	Bank 1 (32 KB)
0x08000 ~ 0x0FFFF	1	Bank 2 (32 KB)
0x08000 ~ 0x0FFFF	2 ~ 10	Bank 3 ~ Bank 11 (32 KB each per Bank)
0x8000 ~ 0x8FFF	31	X-RAM (4 KB) This area is mapped to 4 KB X-RAM and program can be copied to this area to be executed. For example, the e-FLASH burning program can be executed in this area.

'X' means don't care.

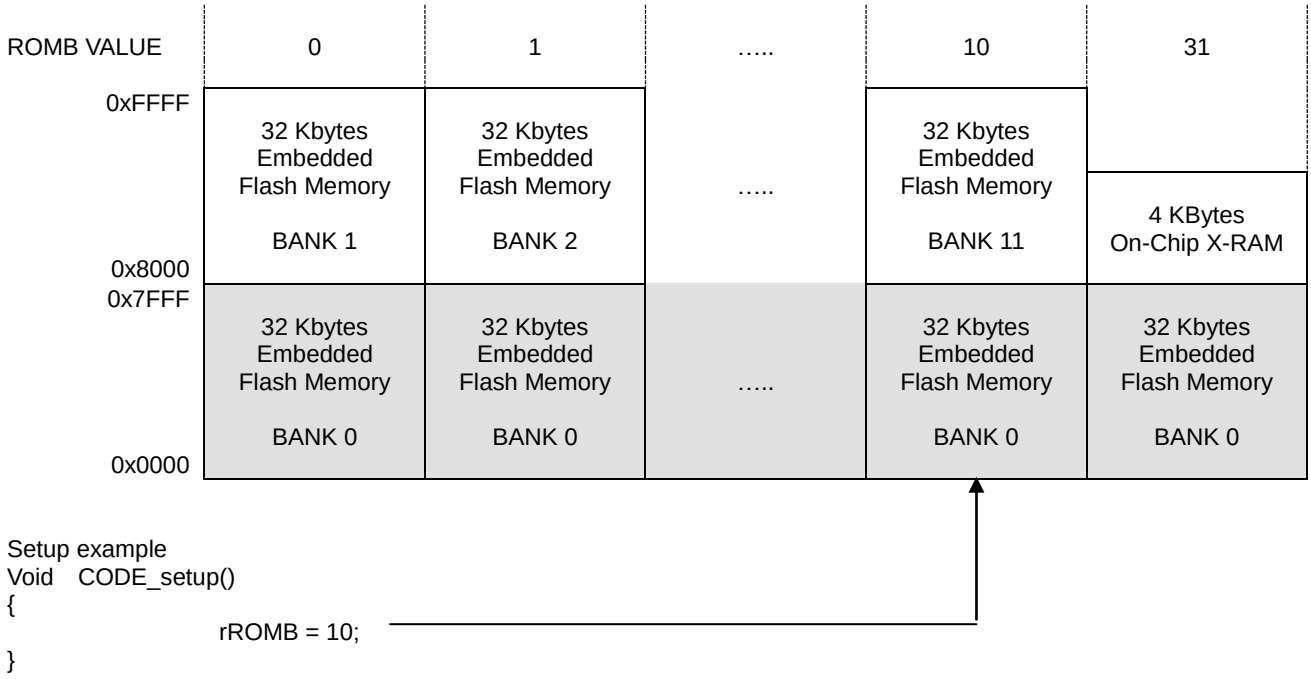


Figure 2-2. Code Space Memory Structure

2.2 Data Memory

Table 2-2. Data Memory Map

Logical Address Range	XRAMB	Descriptions
0x0000 ~ 0x7FFF	0 ~ 11	BANK0 ~ 11 Embedded FLASH 32KB Depending on the XRAMB, any of e-FLASH can be accessed through this area. Default XRAMB is zero.
0x8000 ~ 0x97FF	X	X-RAM On-chip X-RAM 4KB X-RAM is always assigned to this area regardless of XRAMB. Even when the value of ROMB is 31, this X-RAM can be accessed through this address range.

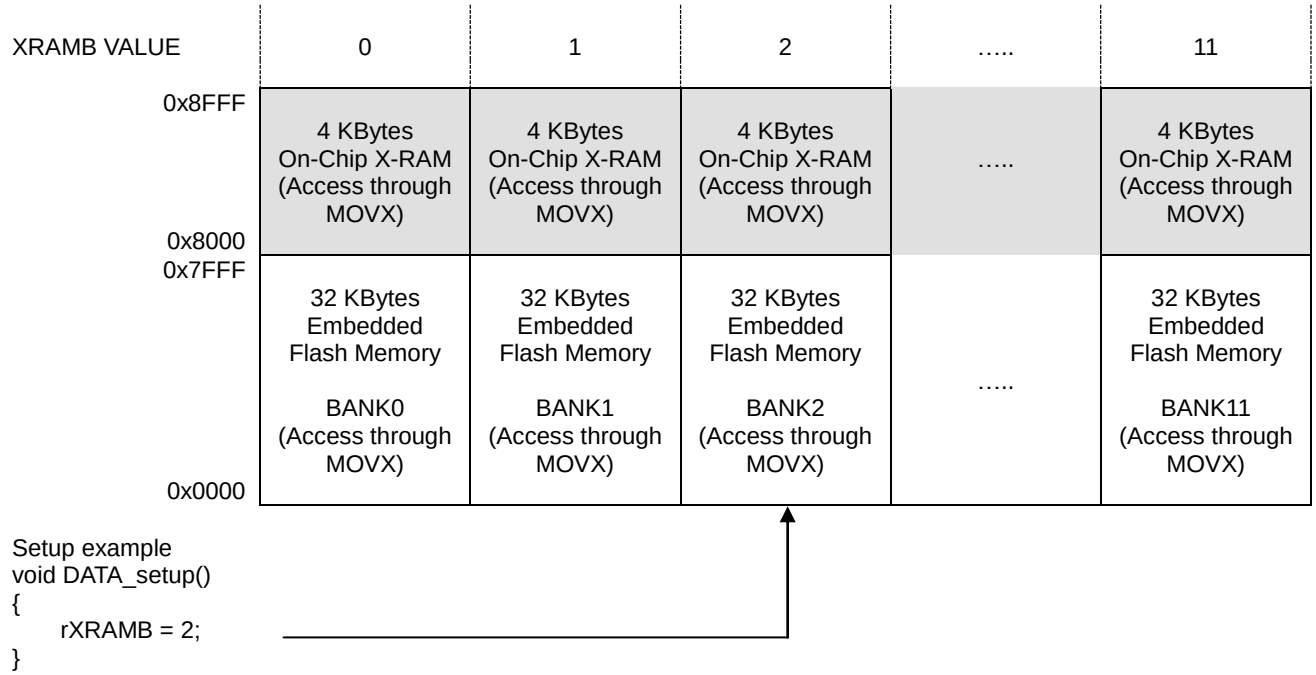


Figure 2-3. Data Space Memory Structure

Accesses to data memory can use either MOVX @DPTR or MOVX @Ri.

2.3 I-RAM

I-RAM (Figure 2-4) consists of:

- 128 Bytes of I-RAM accessible through direct or indirect addressing mode (0x00 – 0x7F).
- Upper 128 Bytes of I-RAM accessible through indirect addressing mode (0x80 – 0xFF) and this area can be available as stack area.
- 128 Bytes of special function registers (SFRs) accessible through direct addressing mode (0x80 – 0xFF).

Although the SFRs and the upper 128 Bytes of I-RAM share the same address range, the actual address space is separate and is differentiated by the type of addressing. Direct addressing accesses the SFRs, indirect addressing accesses the upper 128 Bytes of I-RAM.

The lowest 32 Bytes of the lower 128 Bytes are grouped into 4 banks of 8 registers. Program instructions call out these registers as R0 through R7. Two bits in the PSW select which register bank are in use.

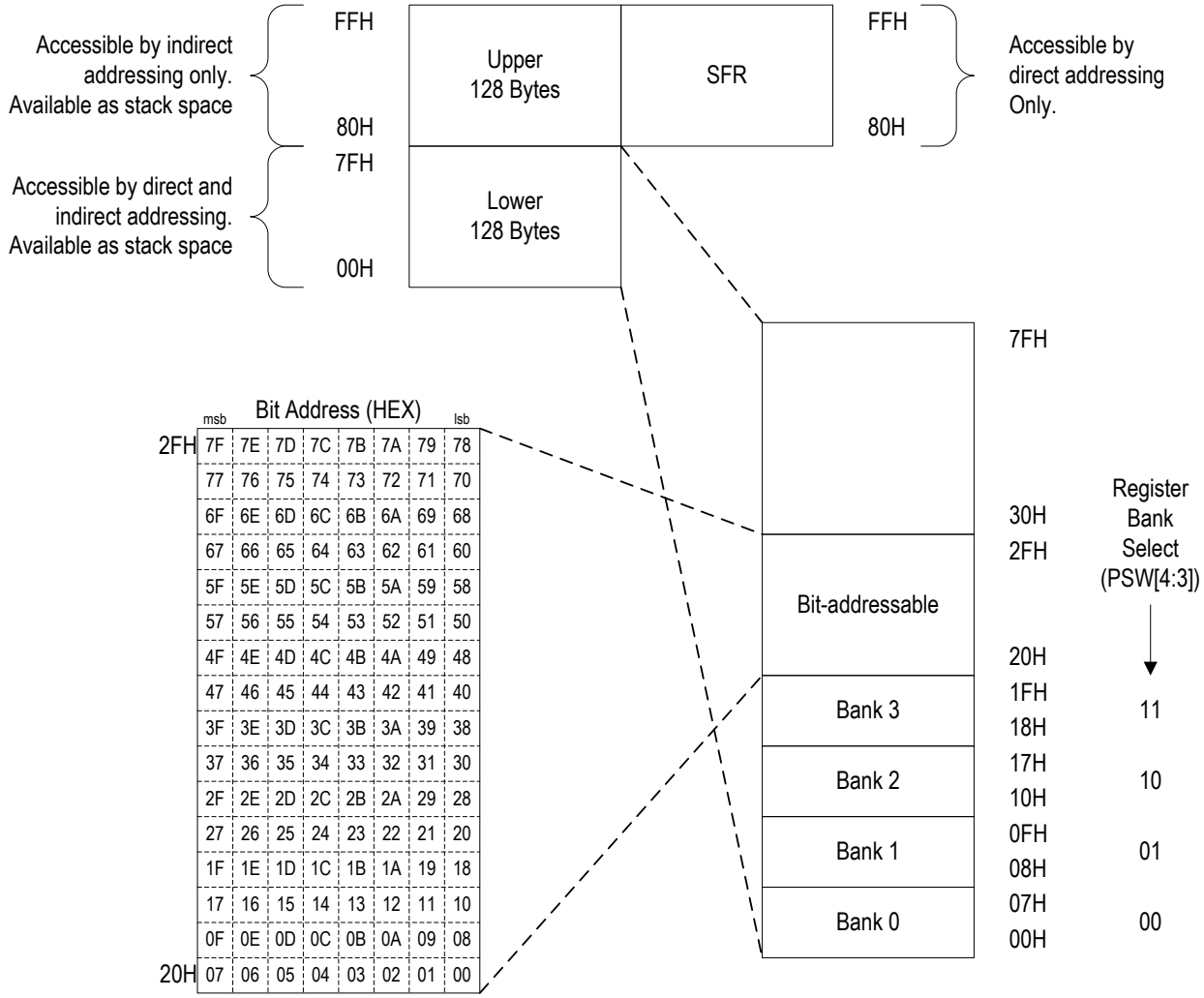


Figure 2-4. I-RAM Memory Structure

2.4 SFR (Special Function Register) Map

The BMC513 employs dual data pointers to accelerate data/program memory block moves. It maintains the data pointers as DPTR0 at SFR location 0x82 and 0x83. It is not necessary to modify code to use DPTR0. The BMC513 adds a second data pointer (DPTR1) at SFR location 0x84 and 0x85. The DPTR select bit in the bit 0 of DPSEL selects the active pointers. When DPSEL=0, instruction/data that use the DPTR will use DP0L and DP0H. When DPSEL=1, instruction/data that use the DPTR will use DP1L and DP1H. All DPTR related instruction/data use the currently selected data pointer. To switch the active pointer, toggle the DPSEL bit. Using dual data pointers provides significantly increased efficiency when moving large blocks of data.

The special function registers (SFRs) control several of the features of the BMC513.

Table 2-3. Special Function Register Map

Higher Nibble (Hex) →

	8	9	A	B	C	D	E	F
0	P0* 0000 0000	P1* 0000 0000	P2* xxxx xxxx	P3* 0000 0000	P4* 0000 0000	PSW* 0000 0000	ACC* 0000 0000	B* 0000 0000
1	SP 0000 0111	GIE 0000 0000	ROMB 0000 0000	USBFA 0000 0000	USBEP2CSR2 0000 0000	USBEP3WC1 0000 0000	ADCON0 0000 0000	UCON0 0000 0000
2	DP0L 0000 0000	IE0 0000 0000	XRAMB 0000 0000	USBPM 0000 0000	USBEP2CSR3 0000 0000	USBEP3WC2 0000 0000	ADCON1 0111 0000	UCON1 0000 0000
3	DP0H 0000 0000	IP0 0000 0000	CLKCON 0001 0000	USBIPEND 0000 0000	USBEP3CSR0 0000 0001	USBEP4WC1 0000 0000	ADAT0 00xx 0000	UTRSTAT 0001 1001
4	DP1L 0000 0000	IE1 0000 0000	SMCLKCON 0111 1000	USBINTEN 1001 1111	USBEP3CSR1 0000 0100	USBEP4WC2 0000 0000	ADAT1 xxxx xxxx	UERSTAT 0000 0000
5	DP1H 0000 0000	IP1 0000 0000	CLK_EN0 0000 0001	USBFN_L 0000 0000	USBEP3CSR2 0000 0000	USBEP0FIFO xxxx xxxx	ADREF 0000 0000	UINTCON 0000 0000
6	DPSEL 0000 0000	IE2 0000 0000	CLK_EN1 0000 0000	USBFN_H 0000 0000	USBEP3CSR3 0000 0000	USBEP1FIFO xxxx xxxx	ADREFCMP 1111 1111	UBAUD 0010 0000
7		IP2 0000 0000	PCON 0010 0000	USBEP0CSR0 0000 0001	USBEP4CSR0 0000 0001	USBEP2FIFO xxxx xxxx		URXBUF xxxx xxxx
8	P5* 0000 0000	P6* 0000 0000	RSTCON 0000 0000	P7* 0000 0000	USBEP4CSR1 0000 0100	USBEP3FIFO xxxx xxxx	P8[*1] 0000 0000	UTXBUF xxxx xxxx
9		IE3 0000 0000	RSTSTAT 0000 0001	USBPE0CSR1 0000 0000	USBEP4CSR2 0000 0000	USBEP4FIFO xxxx xxxx		Reserved
A		IP3 0000 0000	SYSCFG 0000 0000	USBEP1CSR0 0000 0001	USBEP4CSR3 0000 0000	USBEPLNUM1 0010 0001		Reserved
B			IVCON0 0001 0011	USBEP1CSR1 0000 0100	USBEP0WC 0000 0000	USBEPLNUM2 0100 0011		Reserved
C			IVCON1 0000 0000	USBEP1CSR2 0000 0000	USBEP1WC1 0000 0000	USBNAKCON1 0000 0000	WDTCON 0000 0011	SPIMOD 0100 0000
D			WKUPSTAT 0000 0000	USBEP1CSR3 0000 0000	USBEP1WC2 0000 0000	USBNAKCON2 0000 0000	WCNTCLK 0000 1111	SPICK 0000 0000
E			PLLCON0 0000 1010	USBEP2CSR0 0000 0001	USBEP2WC1 0000 0000	USBNAKEN 0000 0000	WDTCNT xxxx xxxx	SPIDATA0 xxxx xxxx
F			PLLCON1 1010 0000	USBEP2CSR1 0000 0100	USBEP2WC2 0000 0000	USBCONF 0000 0000	WDTREF 1111 1111	SPIDATA1 xxxx xxxx

*1: These registers are only available in 80-QFP package. User must not access these registers in 68-QFN package.

Table 2-4. Extended Special Function Register Map 1

Upper Address (Hex) ⟶

	FE0	FE1	FE2	FE3	FE4	FE5	FE6
0	T0CON 0000 0000	T2CON 0000 0000	LCON 0000 1100	DISP_MEM0 xxxx xxxx	JTAGOFF 0000 0000	P3MOD0 0000 0000	P8MOD0[*1] 0000 0000
1	T0DATA0 1111 1111	T2DATA0 1111 1111	LCNST 0000 0000	DISP_MEM1 xxxx xxxx	EINTMOD0 0000 0000	P3MOD1 0000 0000	P8MOD1[*1] 0000 0000
2	T0DATA1 1111 1111	T2DATA1 1111 1111	LCKSEL 0000 1111	DISP_MEM2 xxxx xxxx	EINTMOD1 0000 0000	P3PUD0 0000 1010	P8PUD0[*1] 1010 0000
3	T0CNT0 1111 1111	T2CNT0 1111 1111	-	DISP_MEM3 xxxx xxxx	EINTMOD2 0000 0000	P3PUD1 0000 0010	P8PUD1[*1] 1010 1010
4	T0CNT1 1111 1111	T2CNT1 1111 1111	-	DISP_MEM4 xxxx xxxx	EINTMOD3 0000 0000	P4MOD0 0000 0000	-
5	T0PDR0 0000 0001	T2PDR0 0000 0001	-	DISP_MEM5 xxxx xxxx	EINTEN0 0000 0000	P4MOD1 0000 0000	-
6	T0PDR1 0000 0000	T2PDR1 0000 0000	-	DISP_MEM6 xxxx xxxx	EINTEN1 0000 0000	P4PUR 0000 0000	-
7	-	-	-	DISP_MEM7 xxxx xxxx	EINTPND0 0000 0000	P5MOD0 0000 0000	-
8	T1CON 0000 0000	-	-	DISP_MEM8 xxxx xxxx	EINTPND1 0000 00000	P5MOD1 0000 0000	-
9	T1DATA0 1111 1111	-	-	DISP_MEM9 xxxx xxxx	P0MOD0 0000 0000	P5PUR 0000 0000	-
A	T1DATA1 1111 1111	-	-	DISP_MEM10 xxxx xxxx	P0MOD1 0000 0000	P6MOD0 0000 0000	-
B	T1CNT0 1111 1111	-	-	DISP_MEM11 xxxx xxxx	P0PUR 0000 0000	P6MOD1 0000 0000	-
C	T1CNT1 1111 1111	-	-	DISP_MEM12 xxxx xxxx	P1MOD0 0000 0000	P6PUR 0000 0000	-
D	T1PDR0 0000 0001	-	-	DISP_MEM13 xxxx xxxx	P1MOD1 0000 0000	P7MOD0 0000 0000	-
E	T1PDR1 0000 0001	-	-	DISP_MEM14 xxxx xxxx	P1PUD0 0000 0000	P7MOD1 0000 0000	-
F	-	-	-	Reserved	P1PUD1 0010 1000	P7PUR 1100 0000	-

*1: These registers are only available in 80-QFP package. User must not access these registers in 68-QFN package.

Table 2-5. Extended Special Function Register Map 2

Upper Address (Hex) ⟶

	FF0	FF1	FF2	FF3	FF4
0	BRAC_CTRL 0000 0000	BRAC_ENC_CTRL 0000 0000	SFCTRL 0000 0010	-	BRJPEG_BUF_PTR_L xxxx xxxx
1	BRAC_CTRL2 0000 0000	BRAC_ENC_SAMPLE_L xxxx xxxx	SFPORT xxxx xxxx	-	BRJPEG_BUF_PTR_H xxxx xxxx
2	BRAC_INT_EN 0000 0000	BRAC_ENC_SAMPLE_H xxxx xxxx	SFDMA_CTRL 0000 0000	-	BRJPEG_TABLE_PTR_L xxxx xxxx
3	BRAC_INT_PEND 0000 0000	BRAC_ENC_RESULT xxxx xxxx	SFDMA_START_ADRL xxxx xxxx	-	BRJPEG_TABLE_PTR_H xxxx xxxx
4	BRAC_START_ADRL xxxx xxxx	-	SFDMA_START_ADRM xxxx xxxx	-	BRJPEG_IBB_PTR_L xxxx xxxx
5	BRAC_START_ADRM xxxx xxxx	-	SFDMA_START_ADRH xxxx xxxx	-	BRJPEG_IBB_PTR_M xxxx xxxx
6	BRAC_START_ADRH xxxx xxxx	-	SFDMA_RXBUF xxxx xxxx	-	BRJPEG_IBB_PTR_H xxxx xxxx
7	BRAC_SIZEL 0000 0000	-	SFDMA_TSIZE 0000 0000	-	BRJPEG_IBB_XRAM_PTR xxxx xxxx
8	BRAC_SIZEM 0000 0000	DAC_CTL 0000 1100	SFDMA_X_BASE_L xxxx xxxx	-	BRJPEG_GET_BUFFER_L xxxx xxxx
9	BRAC_SIZEH 0000 0000	DACOUT_L 0000 0000	SFDMA_X_BASE_H xxxx xxxx	-	BRJPEG_GET_BUFFER_M xxxx xxxx
A	BRAC_IBB_READ_PTR 0000 0000	DACOUT_H 0000 0000	SFCTRL2 0000 0000	-	BRJPEG_GET_BUFFER_H xxxx xxxx
B	BRAC_CMD_ADDR xxxx xxxx	VOLUME 1111 1111	-	-	BRJPEG_BITS_LEFT xxxx xxxx
C	BRAC_CMD_DATA xxxx xxxx	DCOL 0000 0000	-	-	BRJPEG_GET_PEEK_L xxxx xxxx
D	BRAC_BUFF xxxx xxxx	DCOH 0000 0000	-	-	BRJPEG_GET_PEEK_H xxxx xxxx
E	BRAC_CTRL3 0000 0000	-	-	-	BRJPEG_QP_Y xxxx xxxx
F	-	-	-	-	BRJPEG_QP_C xxxx xxxx

Table 2-6. Extended Special Function Register Map 3

Upper Address (Hex) ⟶

	FF5	FF6	FF7	FF8	FF9	FFA
0	BRJPEG_PREV_DC_Y_L xxxx xxxx	BRJPEG_IDCT_ACC_0 xxxx xxxx	-	RTCCON0 0000 0000	-	FCON_CTRL 0000 0000
1	BRJPEG_PREV_DC_Y_H xxxx xxxx	BRJPEG_IDCT_ACC_1 xxxx xxxx	-	RTCCON1 0000 0000	-	FCON_STAT 0000 0000
2	BRJPEG_PREV_DC_CB_L xxxx xxxx	BRJPEG_IDCT_ACC_2 xxxx xxxx	-	BCDSEC xxxx xxxx	-	FCON_ADDR_L xxxx xxxx
3	BRJPEG_PREV_DC_CB_H xxxx xxxx	BRJPEG_IDCT_ACC_3 xxxx xxxx	-	BCDMIN xxxx xxxx	-	FCON_ADDR_M xxxx xxxx
4	BRJPEG_PREV_DC_CR_L xxxx xxxx	-	-	BCDHOUR xxxx xxxx	-	FCON_ADDR_H xxxx xxxx
5	BRJPEG_PREV_DC_CR_H xxxx xxxx	-	-	BCDDATE xxxx xxxx	-	FCON_WDATA_L xxxx xxxx
6	BRJPEG_CFG 0000 0000	-	-	BCDDAY xxxx xxxx	-	FCON_WDATA_H_EN xxxx xxxx
7	BRJPEG_BUFSEL xxxx xxxx	-	-	BCDMON xxxx xxxx	-	FCON_CTRL2 0000 0000
8	BRJPEG_CMD 0000 0000	-	-	BCDYEARL xxxx xxxx	-	FCON_WP_L 1111 1111
9	BRJPEG_IE 0000 0000	-	-	BCDYEARH xxxx xxxx	-	FCON_WP_H 0000 1111
A	BRJPEG_ICLR 0000 0000	-	-	RTCALM 0000 0000	-	-
B	BRJPEG_ST 0000 0000	-	-	ALMSEC 0000 0000	-	-
C	BRJPEG_VLD_MODE xxxx xxxx	-	-	ALMMIN 0000 0000	-	-
D	BRJPEG_IDCT_MODE xxxx xxxx	-	-	ALMHOUR 0000 0000	-	-
E	-	-	-	ALMDATE 0000 0000	-	-
F	-	-	-	-	-	-

Table 2-7. Extended Special Function Register Map 4

Upper Address (Hex) ⟶

	FFB	FFC	FFD	FFE	FFF
0	-	I80LCD_TP_W0 xxxx xxxx	I80LCD_CFG_0 0000 0000	VDMA_CFG_0 0000 0000	VDMA_FG_H_OFFSET xxxx xxxx
1	-	I80LCD_TP_W1 xxxx xxxx	I80LCD_CFG_1 0000 0000	VDMA_CFG_1 0000 0000	VDMA_FG_V_OFFSET xxxx xxxx
2	-	I80LCD_TP_W2 xxxx xxxx	I80LCD_DATA_0 xxxx xxxx	VDMA_H_LEN xxxx xxxx	VDMA_FG_H_LEN xxxx xxxx
3	-	I80LCD_TP_W3 xxxx xxxx	I80LCD_DATA_1 xxxx xxxx	VDMA_V_LEN xxxx xxxx	VDMA_FG_V_LEN xxxx xxxx
4	-	I80LCD_TP_W4 xxxx xxxx	I80LCD_DATA_2 xxxx xxxx	VDMA_DST_H_WIDTH_L xxxx xxxx	VDMA_FG_H_WIDTH_L xxxx xxxx
5	-	I80LCD_TP_W5 xxxx xxxx	I80LCD_DATA_3 xxxx xxxx	VDMA_DST_H_WIDTH_H xxxx xxxx	VDMA_FG_H_WIDTH_H xxxx xxxx
6	-	I80LCD_TP_W6 xxxx xxxx	I80LCD_DATA_4 xxxx xxxx	VDMA_DST_ADDR_L xxxx xxxx	VDMA_FG_ADDR_L xxxx xxxx
7	-	I80LCD_TP_R0 xxxx xxxx	I80LCD_DATA_5 xxxx xxxx	VDMA_DST_ADDR_H xxxx xxxx	VDMA_FG_ADDR_M xxxx xxxx
8	-	I80LCD_TP_R1 xxxx xxxx	I80LCD_CMD 0000 0000	VDMA_BG_H_WIDTH_L xxxx xxxx	VDMA_FG_ADDR_H xxxx xxxx
9	-	I80LCD_TP_R2 xxxx xxxx	I80LCD_IE 0000 0000	VDMA_BG_H_WIDTH_H xxxx xxxx	VDMA_CMD 0000 0000
A	-	I80LCD_TP_R3 xxxx xxxx	I80LCD_ICLR 0000 0000	VDMA_BG_ADDR_L xxxx xxxx	VDMA_IE 0000 0000
B	-	I80LCD_TP_R4 xxxx xxxx	I80LCD_ST 0000 0000	VDMA_BG_ADDR_M xxxx xxxx	VDMA_ICLR 0000 0000
C	-	-	-	VDMA_BG_ADDR_H xxxx xxxx	VDMA_ST 0000 0000
D	-	-	-	-	VDMA_RGB_R xxxx xxxx
E	-	-	-	-	VDMA_RGB_G xxxx xxxx
F	-	-	-	-	VDMA_RGB_B xxxx xxxx

CPU Control Registers

Name	Add.	R/W	Description	Page
SP	0x81	R/W	Stack Pointer	3-1
DP0L	0x82	R/W	Lower Byte of Data Pointer 0	3-1
DP0H	0x83	R/W	Higher Byte of Data Pointer 0	3-1
DP1L	0x84	R/W	Lower Byte of Data Pointer 1	3-1
DP1H	0x85	R/W	Higher Byte of Data Pointer 1	3-2
DPSEL	0x86	R/W	Select DPTR 0/1 register	3-2
PSW	0xD0	R/W	Program Status Word	3-2
ACC	0xE0	R/W	Accumulator	3-2
B	0xF0	R/W	B Register	3-2

Interrupt Control Registers

Name	Add.	R/W	Description	Page
GIE	0x91	R/W	Global Interrupt Enable	5-7
IE0	0x92	R/W	Interrupt Enable 0	5-7
IP0	0x93	R/W	Interrupt Priority 0 Register	5-7
IE1	0x94	R/W	Interrupt Enable 1	5-7
IP1	0x95	R/W	Interrupt Priority 1 Register	5-7
IE2	0x96	R/W	Interrupt Enable 2	5-8
IP2	0x97	R/W	Interrupt Priority 2 Register	5-8
IE3	0x99	R/W	Interrupt Enable 3	5-8
IP3	0x9A	R/W	Interrupt Priority 3 Register	5-8

System Control Registers

Name	Add.	R/W	Description	Page
ROMB	0xA1	R/W	ROM Bank Selection	4-14
XRAMB	0xA2	R/W	Data Memory Bank Selection	4-14
CLKCON	0xA3	R/W	Clock Control Register 0	4-14
SMCLKCON	0xA4	R/W	Smart Clock Control Register	4-15
CLK_EN0	0xA5	R/W	Clock Enable Register 0	4-15
CLK_EN1	0xA6	R/W	Clock Enable Register 1	4-16
PCON	0xA7	R/W	Power Control Register	4-16
RSTCON	0xA8	W	Reset Control Register	4-16
RSTSTAT	0xA9	R	Reset Source Status Register	4-16
SYSCFG	0xAA	R/W	System Configuration Register	4-17
IVCON0	0xAB	R/W	IVC Control Register 0	4-17
IVCON1	0xAC	R/W	IVC Control Register 1	4-17
WKUPSTAT	0xAD	R/W	Wakeup Source Status Register	4-17
PLLCON0	0xAE	R/W	PLL control Register 0	4-18
PLLCON1	0xAF	R/W	PLL control Register 1	4-18

USB Device Control Registers

Name	Add.	R/W	Description	Page
USBFA	0xB1	-	USB Function Address Register	14-6
USBPM	0xB2	-	USB Power Management Register	14-6
USBIPEND	0xB3	-	USB Interrupt Pending Register	14-7
USBINTEN	0xB4	-	USB Interrupt Enable Register	14-8
USBFN_L	0xB5	-	USB Frame Number Register L	14-8
USBFN_H	0xB6	-	USB Frame Number Register H	14-8
USBEP0CSR0	0xB7	-	USB EP0 Common Status Register 0	14-8
USBEP0CSR1	0xB9	-	USB EP0 Common Status Register 1	14-9
USBEP1CSR0	0xBA	-	USB EP1 Common Status Register 0	14-10
USBEP1CSR1	0xBB	-	USB EP1 Common Status Register 1	14-10
USBEP1CSR2	0xBC	-	USB EP1 Common Status Register 2	14-11

USBEP1CSR3	0xBD	-	USB EP1 Common Status Register 3	14-12
USBEP2CSR0	0xBE	-	USB EP2 Common Status Register 0	14-10
USBEP2CSR1	0xBF	-	USB EP2 Common Status Register 1	14-10
USBEP2CSR2	0xC1	-	USB EP2 Common Status Register 2	14-11
USBEP2CSR3	0xC2	-	USB EP2 Common Status Register 3	14-12
USBEP3CSR0	0xC3	-	USB EP3 Common Status Register 0	14-10
USBEP3CSR1	0xC4	-	USB EP3 Common Status Register 1	14-10
USBEP3CSR2	0xC5	-	USB EP3 Common Status Register 2	14-11
USBEP3CSR3	0xC6	-	USB EP3 Common Status Register 3	14-12
USBEP4CSR0	0xC7	-	USB EP4 Common Status Register 0	14-10
USBEP4CSR1	0xC8	-	USB EP4 Common Status Register 1	14-10
USBEP4CSR2	0xC9	-	USB EP4 Common Status Register 2	14-11
USBEP4CSR3	0xCA	-	USB EP4 Common Status Register 3	14-12
USBEP0WC	0xCB	-	USB EP0 Write Count Register	14-13
USBEP1WC1	0xCC	-	USB EP1 Write Count Register 1	14-13
USBEP1WC2	0xCD	-	USB EP1 Write Count Register 2	14-13
USBEP2WC1	0xCE	-	USB EP2 Write Count Register 1	14-13
USBEP2WC2	0xCF	-	USB EP2 Write Count Register 2	14-13
USBEP3WC1	0xD1	-	USB EP3 Write Count Register 1	14-13
USBEP3WC2	0xD2	-	USB EP3 Write Count Register 2	14-13
USBEP4WC1	0xD3	-	USB EP4 Write Count Register 1	14-13
USBEP4WC2	0xD4	-	USB EP4 Write Count Register 2	14-13
USBEP0FIFO	0xD5	-	USB EP0 FIFO	14-14
USBEP1FIFO	0xD6	-	USB EP1 FIFO	14-14
USBEP2FIFO	0xD7	-	USB EP2 FIFO	14-14
USBEP3FIFO	0xD8	-	USB EP3 FIFO	14-14
USBEP4FIFO	0xD9	-	USB EP4 FIFO	14-14
USBEPLNUM1	0xDA	-	USB EP Logical Number Control Register 1	14-14
USBEPLNUM2	0xDB	-	USB EP Logical Number Control Register 2	14-14
USBNAKCON1	0xDC	-	USB EP NAK Control Register 1	14-14
USBNAKCON2	0xDD	-	USB EP NAK Control Register 2	14-15
USBNAKEN	0xDE	-	USB EP NAK Enable Register	14-15
USBCONF	0xDF	-	USB Configuration Register	14-15

ADC Control Registers

Name	Add.	R/W	Description	Page
ADCON0	0xE1	R/W	ADC Control Register 0	13-6
ADCON1	0xE2	R/W	ADC Control Register 1	13-6
ADAT0	0xE3	R	AD Conversion Lower Result Register	13-7
ADAT1	0xE4	R	AD Conversion Higher Result Register	13-7
ADREF	0xE5	R/W	ADC Reference Register	13-7
ADREFCMP	0xE6	R/W	ADC Reference Compare Register	13-7

WDT Control Registers

Name	Add.	R/W	Description	Page
WDTCON	0xEC	R/W	WDT Control Register	12-5
WCNTCLK	0xED	R/W	WDT Counter Pre-Scale value register	12-5
WDTCNT	0xEE	R	WDT Counter	12-5
WDTREF	0xEF	R/W	WDT Reference Value	12-5

UART Control Registers

Name	Add.	R/W	Description	Page
UCON0	0xF1	R/W	UART Control Register 0	10-10
UCON1	0xF2	R/W	UART Control Register 1	10-10
UTRSTAT	0xF3	R/W	UART TX/RX Status Register	10-11
UERSTAT	0xF4	R/W	UART RX Error Status Register	10-11
UINTCON	0xF5	R/W	UART Interrupt Enable / Pending Register	10-12

UBAUD	0xF6	R/W	UART Baud Rate Divisor Register	10-12
URXBUF	0xF7	R	UART Receive Buffer	10-12
UTXBUF	0xF8	W	UART Transmit Buffer	10-12

SPI Control Registers

Name	Add.	R/W	Description	Page
SPIMOD	0xFC	R/W	SPI Mode Register	9-9
SPICK	0xFD	R/W	SPI Baud Rate counter clock select Register	9-9
SPIDATA0	0xFE	R/W	SPI Transmit / Receive Buffer 0	9-9
SPIDATA1	0xFF	R/W	SPI Transmit / Receive Buffer 1	9-10

Timer Control Registers

Name	Add.	R/W	Description	Page
T0CON	0xFE00	R/W	Timer 0 Control Register	11-7
T0DATA0	0xFE01	R/W	Timer 0 Reference Data Register 0	11-7
T0DATA1	0xFE02	R/W	Timer 0 Reference Data Register 1	11-7
T0CNT0	0xFE03	R/W	Timer 0 Lower Down Counter	11-7
T0CNT1	0xFE04	R/W	Timer 0 Upper Down Counter	11-7
T0PDR0	0xFE05	R/W	Timer 0 PWM Data Register 0	11-7
T0PDR1	0xFE06	R/W	Timer 0 PWM Data Register 1	11-7
T1CON	0xFE08	R/W	Timer 1 Control Register	11-7
T1DATA0	0xFE09	R/W	Timer 1 Reference Data Register 0	11-7
T1DATA1	0xFE0A	R/W	Timer 1 Reference Data Register 1	11-7
T1CNT0	0xFE0B	R/W	Timer 1 Lower Down Counter	11-7
T1CNT1	0xFE0C	R/W	Timer 1 Upper Down Counter	11-7
T1PDR0	0xFE0D	R/W	Timer 1 PWM Data Register 0	11-7
T1PDR1	0xFE0E	R/W	Timer 1 PWM Data Register 1	11-7
T2CON	0xFE10	R/W	Timer 2 Control Register	11-7
T2DATA0	0xFE11	R/W	Timer 2 Reference Data Register 0	11-7
T2DATA1	0xFE12	R/W	Timer 2 Reference Data Register 1	11-7
T2CNT0	0xFE13	R/W	Timer 2 Lower Down Counter	11-7
T2CNT1	0xFE14	R/W	Timer 2 Upper Down Counter	11-7
T2PDR0	0xFE15	R/W	Timer 2 PWM Data Register 0	11-7
T2PDR1	0xFE16	R/W	Timer 2 PWM Data Register 1	11-7

LCD (COM/SEG) Controller/Driver Registers

Name	Add.	R/W	Description	Page
LCON	0xFE20	R/W	LCD Control Register	18-16
LCNST	0xFE21	R/W	LCD Contrast Control Register	18-16
LCKSEL	0xFE22	R/W	LCD Clock Select Register	18-16
DISP_MEM0	0xFE30	R/W	Display Memory 0	18-3
DISP_MEM1	0xFE31	R/W	Display Memory 1	18-3
DISP_MEM2	0xFE32	R/W	Display Memory 2	18-3
DISP_MEM3	0xFE33	R/W	Display Memory 3	18-3
DISP_MEM4	0xFE34	R/W	Display Memory 4	18-3
DISP_MEM5	0xFE35	R/W	Display Memory 5	18-3
DISP_MEM6	0xFE36	R/W	Display Memory 6	18-3
DISP_MEM7	0xFE37	R/W	Display Memory 7	18-3
DISP_MEM8	0xFE38	R/W	Display Memory 8	18-3
DISP_MEM9	0xFE39	R/W	Display Memory 9	18-3
DISP_MEM10	0xFE3A	R/W	Display Memory 10	18-3
DISP_MEM11	0xFE3B	R/W	Display Memory 11	18-3
DISP_MEM12	0xFE3C	R/W	Display Memory 12	18-3
DISP_MEM13	0xFE3D	R/W	Display Memory 13	18-3
DISP_MEM14	0xFE3E	R/W	Display Memory 14	18-3
DISP_MEM15	0xFE3F	R/W	Display Memory 15	18-3

GPIOs Control Registers

Name	Add.	R/W	Description	Page
P0	0x80	R/W	General Purpose I/O 0	19-6
P1	0x90	R/W	General Purpose I/O 1	19-6
P2	0xA0	R/W	Reserved for standard 8051.	19-6
P3	0xB0	R/W	General Purpose I/O 3	19-6
P4	0xC0	R/W	General Purpose I/O 4	19-6
P5	0x88	R/W	General Purpose I/O 5	19-6
P6	0x98	R/W	General Purpose I/O 6	19-6
P7	0xB8	R/W	General Purpose I/O 7	19-6
P8*1	0xE8	R/W	General Purpose I/O 8	19-7
JTAGOFF	0xFE40	R/W	JTAG port control Register	19-7
EINTMOD0	0xFE41	R/W	External Interrupt Control Register 0	19-7
EINTMOD1	0xFE42	R/W	External Interrupt Control Register 1	19-7
EINTMOD2	0xFE43	R/W	External Interrupt Control Register 2	19-7
EINTMOD3	0xFE44	R/W	External Interrupt Control Register 3	19-8
EINTEN0	0xFE45	R/W	External Interrupt Enable Register 0	19-8
EINTEN1	0xFE46	R/W	External Interrupt Enable Register 1	19-8
EINTPND0	0xFE47	W	External Interrupt Pending Register 0	19-8
EINTPND1	0xFE48	W	External Interrupt Pending Register 1	19-9
P0MOD0	0xFE49	R/W	GP00 ~ GP01 Mode Control Register 0	19-10
P0MOD1	0xFE4A	R/W	GP02 ~ GP03 Mode Control Register 1	19-10
P0PUR	0xFE4B	R/W	PORT 0 Pull-Up Control Register	19-10
P1MOD0	0xFE4C	R/W	GP10 ~ GP13 Mode Control Register 0	19-11
P1MOD1	0xFE4D	R/W	GP14 ~ GP17 Mode Control Register 1	19-11
P1PUD0	0xFE4E	R/W	PORT 1 Pull-Up/Down Control Register 0	19-11
P1PUD1	0xFE4F	R/W	PORT 1 Pull-Up/Down Control Register 1	19-11
P3MOD0	0xFE50	R/W	GP30 ~ GP33 Mode Control Register 0	19-12
P3MOD1	0xFE51	R/W	GP34 ~ GP37 Mode Control Register 1	19-12
P3PUD0	0xFE52	R/W	PORT 3 Pull-Up/Down Control Register 0	19-12
P3PUD1	0xFE53	R/W	PORT 3 Pull-Up/Down Control Register 1	19-12
P4MOD0	0xFE54	R/W	GP40 ~ GP43 Mode Control Register 0	19-13
P4MOD1	0xFE55	R/W	GP44 ~ GP47 Mode Control Register 1	19-13
P4PUR	0xFE56	R/W	PORT 4 Pull-Up Control Register 0	19-13
P5MOD0	0xFE57	R/W	GP50 ~ GP53 Mode Control Register 0	19-14
P5MOD1	0xFE58	R/W	GP54 ~ GP57 Mode Control Register 1	19-14
P5PUR	0xFE59	R/W	PORT 5 Pull-Up Control Register 0	19-14
P6MOD0	0xFE5A	R/W	GP60 ~ GP63 Mode Control Register 0	19-15
P6MOD1	0xFE5B	R/W	GP64 ~ GP67 Mode Control Register 1	19-15
P6PUR	0xFE5C	R/W	PORT 6 Pull-Up Control Register 0	19-15
P7MOD0	0xFE5D	R/W	GP70 ~ GP73 Mode Control Register 0	19-16
P7MOD1	0xFE5E	R/W	GP74 ~ GP77 Mode Control Register 1	19-16
P7PUR	0xFE5F	R/W	PORT 7 Pull-Up Control Register 0	19-16
P8MOD0*1	0xFE60	R/W	GP10 ~ GP13 Mode Control Register 0	19-17
P8MOD1*1	0xFE61	R/W	GP14 ~ GP17 Mode Control Register 1	19-17
P8PUD0*1	0xFE61	R/W	PORT 1 Pull-Up/Down Control Register 0	19-17
P8PUD1*1	0xFE63	R/W	PORT 1 Pull-Up/Down Control Register 1	19-17

*1: These registers are only available in 80-QFP package. User must not access these registers in 68-QFN package.

BRAC® Control Registers

Name	Add.	R/W	Description	Page
BRAC_CTRL	0xFF00	R/W	Control Register for BRAC®	6-12
BRAC_CTRL2	0xFF01	R/W	Control Register2 for BRAC®	6-12
BRAC_INT_EN	0xFF02	R/W		6-12
BRAC_INT_PEND	0xFF03	R/W		6-12
BRAC_START_ADRL	0xFF04	W	Low Byte of BRAC® Start Address for decoding compressed data.	6-13
BRAC_START_ADRM	0xFF05	W	Middle Byte of BRAC® Start Address for decoding compressed data.	6-13

BRAC_START_ADRH	0xFF06	W	High Byte of BRAC® Start Address for decoding compressed data	6-13
BRAC_SIZEL	0xFF07	W	The data amount to be read from internal e-FLASH or external serial FLASH	6-13
BRAC_SIZEM	0xFF08	W	The data amount to be read from internal e-FLASH or external serial FLASH	6-13
BRAC_SIZEH	0xFF09	W	The data amount to be read from internal e-FLASH or external serial FLASH	6-13
BRAC_IBB_READ_PTR	0xFF0A	R/W	IBB Read Pointer for Channel 0	6-13
BRAC_CMD_ADDR	0xFF0B	R/W	Command address for BRAC® Decoding and Encoding	6-13
BRAC_CMD_DATA	0xFF0C	R/W	Command data for BRAC® Decoding and Encoding	6-13
BRAC_BUFF	0xFF0D	W	Buffer for BRAC® Decoding	6-14
BRAC_CTRL3	0xFF0E	R/W	Control Register3 for BRAC	6-14
BRAC_ENC_CTRL	0xFF10	R	BRAC Encoder Status Register	6-15
BRAC_ENC_SAMPLE_L	0xFF11	W	BRAC Encoder Sample Low Register	6-15
BRAC_ENC_SAMPLE_H	0xFF12	W	BRAC Encoder Sample High Register	6-15
BRAC_ENC_RESULT	0xFF13	R	BRAC Encoder Result Register	6-15
DAC_CTL	0xFF18	R/W	DAC Control Register	6-15
DACOUT_L	0xFF19	R/W	DAC Low Output Register	6-15
DACOUT_H	0xFF1A	R/W	DAC High Output Register	6-15
VOLUME	0xFF1B	W	Volume Control Register in Decoding Mode. Auto Gain Control Register in Encoding Mode	6-16
DCO_L	0xFF1C	W	DCO Low Register	6-16
DCO_H	0xFF1D	W	DCO High Register	6-16

Serial Flash Control Registers

Name	Add.	R/W	Description	Page
SFCTRL	0xFF20	R/W	SF Control register(For CPU mode only)	7-5
SFPORT	0xFF21	R/W	SF Receive/Transmit Buffer(For CPU mode only)	7-5
SFDMA_CTRL	0xFF22	R/W	SFDMA Control Register	7-5
SFDMA_START_ADRL	0xFF23	W	SFDMA Start Address Low	7-5
SFDMA_START_ADRM	0xFF24	W	SFDMA Start Address Middle	7-5
SFDMA_START_ADRH	0xFF25	W	SFDMA Start Address High	7-5
SFDMA_RXBUF	0xFF26	R	SFDMA Rx Buffer	7-5
SFDMA_TSIZE	0xFF27	R/W	SFDMA Transfer Size	7-6
SFDMA_X_BASE_L	0xFF28	W	SFDMA Target XRAM Base Address Low	7-6
SFDMA_X_BASE_H	0xFF29	W	SFDMA Target XRAM Base Address High	7-6
SFCTRL2	0xFF2A	R/W	SF Control register 2	7-6

BRJPEG® Decoder Control Registers

Name	Add.	R/W	Description	Page
BRJPEG_BUF_PTR_L	0xFF40	R/W	Low byte of XRAM buffer base address	8-7
BRJPEG_BUF_PTR_H	0xFF41	R/W	High byte of XRAM buffer base address	8-7
BRJPEG_TABLE_PTR_L	0xFF42	R/W	Low byte of constant table base address in internal eFlash	8-7
BRJPEG_TABLE_PTR_H	0xFF43	R/W	High byte of constant table base address in internal eFlash	8-7
BRJPEG_IBB_PTR_L	0xFF44	R/W	Low byte of video input bit stream buffer address	8-7
BRJPEG_IBB_PTR_M	0xFF45	R/W	Middle byte of video input bit stream buffer address	8-7
BRJPEG_IBB_PTR_H	0xFF46	R/W	High byte of video input bit stream buffer address	8-7
BRJPEG_IBB_XRAM_PTR	0xFF47	R/W	Video input bit stream buffer offset address in XRAM IBB mode	8-7
BRJPEG_GET_BUFFER_L	0xFF48	R/W	Low byte of intermediate bit stream buffer	8-8
BRJPEG_GET_BUFFER_M	0xFF49	R/W	Middle byte of intermediate bit stream buffer	8-8
BRJPEG_GET_BUFFER_H	0xFF4A	R/W	High byte of intermediate bit stream buffer	8-8
BRJPEG_BITS_LEFT	0xFF4B	R/W	Number of valid bits in GET_BUFFER	8-8
BRJPEG_GET_PEEK_L	0xFF4C	R/W	Low byte of the get_bits/peek_bits result	8-8
BRJPEG_GET_PEEK_H	0xFF4D	R/W	High byte of the get_bits/peek_bits result	8-8
BRJPEG_QP_Y	0xFF4E	R/W	Quantization scale for luminance component	8-8

BRJPEG_QP_C	0xFF4F	R/W	Quantization scale for chrominance component	8-8
BRJPEG_PREV_DC_Y_L	0xFF50	R/W	Low byte of previous DC value for Y component	8-8
BRJPEG_PREV_DC_Y_H	0xFF51	R/W	High byte of previous DC value for Y component	8-8
BRJPEG_PREV_DC_CB_L	0xFF52	R/W	Low byte of previous DC value for Cb component	8-8
BRJPEG_PREV_DC_CB_H	0xFF53	R/W	High byte of previous DC value for Cb component	8-9
BRJPEG_PREV_DC_CR_L	0xFF54	R/W	Low byte of previous DC value for Cr component	8-9
BRJPEG_PREV_DC_CR_H	0xFF55	R/W	High byte of previous DC value for Cr component	8-9
BRJPEG_CFG	0xFF56	R/W	Configuration	8-9
BRJPEG_BUF_SEL	0xFF57	R/W	Input/Output buffer selection for processing engines	8-9
BRJPEG_CMD	0xFF58	R/W	Command	8-10
BRJPEG_IE	0xFF59	R/W	Interrupt enable	8-10
BRJPEG_ICLR	0xFF5A	W	Interrupt clear	8-10
BRJPEG_ST	0xFF5B	R/W	Status	8-10
BRJPEG_VLD_MODE	0xFF5C	R/W	Mode setting for the VLD engine	8-10
BRJPEG_IDCT_MODE	0xFF5D	R/W	Mode setting for the IDCT engine	8-11
BRJPEG_IDCT_ACC_0	0xFF60	R/W	Accumulator byte 0 (LSB) in IDCT engine	8-11
BRJPEG_IDCT_ACC_1	0xFF61	R/W	Accumulator byte 1 in IDCT engine	8-11
BRJPEG_IDCT_ACC_2	0xFF62	R/W	Accumulator byte 2 in IDCT engine	8-11
BRJPEG_IDCT_ACC_3	0xFF63	R/W	Accumulator byte 3 (MSB) in IDCT engine	8-11

RTC Control Registers

Name	Add.	R/W	Description	Page
RTCCON0	0xFF80	R/W	RTC Control Register 0	15-5
RTCCON1	0xFF81	R/W	RTC Control Register 1	15-5
BCDSEC	0xFF82	R/W	BCD Second bits	15-5
BCDMIN	0xFF83	R/W	BCD Minute bits	15-5
BCDHOUR	0xFF84	R/W	BCD Hour bits	15-6
BCDDATE	0xFF85	R/W	BCD Date bits	15-6
BCDDAY	0xFF86	R/W	BCD Day of a week bits	15-6
BCDMON	0xFF87	R/W	BCD Month bits	15-6
BCDYEARL	0xFF88	R/W	BCD Year lower bits	15-6
BCDYEARH	0xFF89	R/W	BCD Year upper bits	15-6
RTCALM	0xFF8A	R/W	ALARM Control Register	15-7
ALMSEC	0xFF8B	R/W	ALARM Second Data bits. (BCD value)	15-7
ALMMIN	0xFF8C	R/W	ALARM Minute Data bits. (BCD value)	15-7
ALMHOUR	0xFF8D	R/W	ALARM Hour Data bits. (BCD value)	15-7
ALMDATE	0xFF8E	R/W	ALARM Date Data bits. (BCD value)	15-7

Embedded Flash Control Registers

Name	Add.	R/W	Description	Page
FCON_CTRL	0xFFA0	R/W	FCON Control Register	20-4
FCON_STAT	0xFFA1	R	Status Register	20-4
FCON_ADDR_L	0xFFA2	R/W	Address Low	20-4
FCON_ADDR_M	0xFFA3	R/W	Address Middle	20-4
FCON_ADDR_H	0xFFA4	R/W	Address High and Write Start Register	20-4
FCON_WDATA_L	0xFFA5	R/W	Write Data Low	20-4
FCON_WDATA_H_EN	0xFFA6	R/W	Write Data High and Write Enable Register	20-4
FCON_WP_L	0xFFA8	R/W	Program/Sector_Erase Protect Low Register	20-5
FCON_WP_H	0xFFA9	R/W	Program/Sector_Erase Protect High Register	20-5

I80 I/F Registers

Name	Add.	R/W	Description	Page
I80LCD_TP_W0	0xFFC0	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN low in LCD write operation becomes I80LCD_TP_W0	17-11
I80LCD_TP_W1	0xFFC1	R/W	Number of HCLK cycles from LCD_RS to LCD_WRN low in LCD write operation becomes I80LCD_TP_W1	17-11
I80LCD_TP_W2	0xFFC2	R/W	Number of HCLK cycles from LCD_RS to LCD_D valid output in LCD write operation becomes I80LCD_TP_W2	17-11
I80LCD_TP_W3	0xFFC3	R/W	Number of HCLK cycles from LCD_RS to LCD_WRN high - 1 in LCD write operation becomes I80LCD_TP_W3 + 1	17-11
I80LCD_TP_W4	0xFFC4	R/W	Number of HCLK cycles from LCD_RS to LCD_D high-impedance - 1 in LCD write operation becomes I80LCD_TP_W4 + 1	17-11
I80LCD_TP_W5	0xFFC5	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN high in LCD write operation becomes I80LCD_TP_W5 + 1	17-11
I80LCD_TP_W6	0xFFC6	R/W	Number of HCLK cycles for single LCD write operation becomes I80LCD_TP_W6 + 1	17-11
I80LCD_TP_R0	0xFFC7	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN low in LCD read operation becomes I80LCD_TP_R0	17-11
I80LCD_TP_R1	0xFFC8	R/W	Number of HCLK cycles from LCD_RS to LCD_RDN low in LCD read operation becomes I80LCD_TP_R1	17-12
I80LCD_TP_R2	0xFFC9	R/W	Number of HCLK cycles from LCD_RS to LCD_RDN high in LCD read operation becomes I80LCD_TP_R2 + 1	17-12
I80LCD_TP_R3	0xFFCA	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN high in LCD read operation becomes I80LCD_TP_R3 + 1	17-12
I80LCD_TP_R4	0xFFCB	R/W	Number of cycles for single LCD read operation becomes I80LCD_TP_R4 + 1	17-12
I80LCD_CFG_0	0xFFD0	R/W	Configuration byte 0	17-12
I80LCD_CFG_1	0xFFD1	R/W	Configuration byte 1	17-13
I80LCD_DATA_0	0xFFD2	R/W	Data buffer byte 0	17-13
I80LCD_DATA_1	0xFFD3	R/W	Data buffer byte 1	17-13
I80LCD_DATA_2	0xFFD4	R/W	Data buffer byte 2	17-13
I80LCD_DATA_3	0xFFD5	R/W	Data buffer byte 3	17-13
I80LCD_DATA_4	0xFFD6	R/W	Data buffer byte 4	17-13
I80LCD_DATA_5	0xFFD7	R/W	Data buffer byte 5	17-13
I80LCD_CMD	0xFFD8	R/W	Command	17-14
I80LCD_IE	0xFFD9	R/W	Interrupt enable	17-14
I80LCD_ICLR	0xFFDA	R/W	Interrupt clear	17-14
I80LCD_ST	0xFFDB	R/W	Status	17-14

VDMA Control Registers

Name	Add.	R/W	Description	Page
VDMA_CFG_0	0xFFE0	R/W	Configuration byte 0	16-4
VDMA_CFG_1	0xFFE1	R/W	Configuration byte 1	16-4
VDMA_H_LEN	0xFFE2	R/W	Horizontal length – 1 for the background and destination moving area	16-4
VDMA_V_LEN	0xFFE3	R/W	Vertical length – 1 for the background and destination moving area	16-4
VDMA_DST_H_WIDTH_L	0xFFE4	R/W	Low byte of the horizontal width of the destination frame	16-5
VDMA_DST_H_WIDTH_H	0xFFE5	R/W	High byte of the horizontal width of the destination frame	16-5
VDMA_DST_ADDR_L	0xFFE6	R/W	Low byte of the destination area starting address	16-5
VDMA_DST_ADDR_H	0xFFE7	R/W	High byte of the destination area starting address	16-5
VDMA_BG_H_WIDTH_L	0xFFE8	R/W	Low byte of the horizontal width of the background source frame	16-5
VDMA_BG_H_WIDTH_H	0xFFE9	R/W	High byte of the horizontal width of the background source frame	16-5
VDMA_BG_ADDR_L	0xFFEA	R/W	Low byte of the background source area starting address	16-5
VDMA_BG_ADDR_M	0xFFEB	R/W	Middle byte of the background source area starting address	16-5
VDMA_BG_ADDR_H	0xFFEC	R/W	High byte of the background source area starting address	16-5
VDMA_FG_H_OFFSET	0xFFF0	R/W	Horizontal offset of the foreground area	16-5
VDMA_FG_V_OFFSET	0xFFF1	R/W	Vertical offset of the foreground area	16-5
VDMA_FG_H_LEN	0xFFF2	R/W	Horizontal length – 1 for foreground moving area	16-6
VDMA_FG_V_LEN	0xFFF3	R/W	Vertical length – 1 for foreground moving area	16-6
VDMA_FG_H_WIDTH_L	0xFFF4	R/W	Low byte of the horizontal width of the foreground source frame	16-6
VDMA_FG_H_WIDTH_H	0xFFF5	R/W	High byte of the horizontal width of the foreground source frame	16-6
VDMA_FG_ADDR_L	0xFFF6	R/W	Low byte of the foreground source area starting address	16-6
VDMA_FG_ADDR_M	0xFFF7	R/W	Middle byte of the foreground source area starting address	16-6
VDMA_FG_ADDR_H	0xFFF8	R/W	High byte of the foreground source area starting address	16-6
VDMA_CMD	0xFFF9	R/W	Command	16-6
VDMA_IE	0xFFFA	R/W	Interrupt enable	16-6
VDMA_ICLR	0xFFFB	R/W	Interrupt clear	16-6
VDMA_ST	0xFFFC	R/W	Status	16-7
VDMA_RGB_R	0xFFFD	R/W	VDMA _RGB Red value	16-7
VDMA_RGB_G	0xFFFE	R/W	VDMA_RGB Green value	16-7
VDMA_RGB_B	0xFFFF	R/W	VDMA_RGB Blue value	16-7

NOTES:

3 INSTRUCTION SET

All BMC513 instructions are binary code compatible and perform the same functions as they do with the standard 8051. The effects of these instructions on bits, flags, and other status functions are identical to the standard 8051. However, the timing of the instructions is different, in terms of the number of clocks per instruction cycles and timing within the instruction cycle.

3.1 REGISTER DESCRIPTION FOR CPU

Summary

Name	Add.	R/W	Description	Reset
SP	0x81	R/W	Stack Pointer	0x07
DP0L	0x82	R/W	Lower Byte of Data Pointer 0	0x00
DP0H	0x83	R/W	Higher Byte of Data Pointer 0	0x00
DP1L	0x84	R/W	Lower Byte of Data Pointer 1	0x00
DP1H	0x85	R/W	Higher Byte of Data Pointer 1	0x00
DPSEL	0x86	R/W	Select DPTR 0/1 register	0x00
PSW	0xD0	R/W	Program Status Word	0x00
ACC	0xE0	R/W	Accumulator	0x00
B	0xF0	R/W	B Register	0x00

SP (0x81)

Name	Bit	R/W	Description	Reset
SP	7:0	R/W	Stack Pointer. On PUSH/CALL: before Increment, on POP/RET: after Decrement. Available only by internal 256 bytes SRAM (I-RAM). The SP is initialized to 07H after a reset. This means the internal data addressed after 08H is used as stack.	0x07

DP0L (0x82)

Name	Bit	R/W	Description	Reset
DP0L	7:0	R/W	Lower Byte of Data Pointer 0. If DPSEL = 0, this register is available.	0x00

DP0H (0x83)

Name	Bit	R/W	Description	Reset
DP0H	7:0	R/W	Higher Byte of Data Pointer 0 If DPSEL = 0, this register is available.	0x00

DP1L (0x84)

Name	Bit	R/W	Description	Reset
DP1L	7:0	R/W	Lower Byte of Data Pointer 1. If DPSEL = 1, this register is available.	0x00

DP1H (0x85)

Name	Bit	R/W	Description	Reset
DP1H	7:0	R/W	Higher Byte of Data Pointer 1 If DPSEL = 1, this register is available.	0x00

DPSEL (0x86)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
DPSEL	0	R/W	Select DPTR 0/1 register 0: DPTR0, 1: DPTR1	0

PSW (0xD0)

Name	Bit	R/W	Description	Reset
CY	7	R/W	Carry Flag	0
AC	6	R/W	Auxiliary Carry Flag	0
F0	5	R/W	Flag0 available to the user for general purpose.	0
RS	4:3	R/W	00: Register Bank 0 (0x00 ~ 0x07) 01: Register Bank 1 (0x08 ~ 0x0F) 10: Register Bank 2 (0x10 ~ 0x17) 11: Register Bank 3 (0x18 ~ 0x1F)	00
OV	2	R/W	Overflow Flag	0
F1	1	R/W	Flag1 available to the user for general purpose.	0
P	0	R/W	Parity Flag Set/Cleared by hardware each instruction cycle to indicate an odd/even number of '1' bits in the accumulator	0

ACC (0xE0)

Name	Bit	R/W	Description	Reset
ACC	7:0	R/W	Accumulator	0x00

B (0xF0)

Name	Bit	R/W	Description	Reset
B	7:0	R/W	B Register	0x00

3.2 PSW

The PSW (Program Status Word) contains several status bits that reflect the current state of the CPU. The PSW resides in SFR space at 0xD0. It contains the CY (Carry) bit, the AC (Auxiliary Carry) for BCD operations, the two registers bank select bits (RS), the OV (Overflow), the P (Parity), and a F0/F1 (user defined status flag). The CY serves the functions of a carry bit in arithmetic operations, also serves as the accumulator (A) for a number of Boolean operations. Auxiliary carry flag (AC) is set when the last arithmetic operation resulted in a carry into (during addition) or borrows from (during subtraction) the high order nibble. The bits of RS are used to select one of the four register banks. A number of instructions refer to these I-RAM locations as R0 through R7. Overflow flag (OV) is set when the last arithmetic operation resulted in a carry (addition), borrow (subtraction), or overflow (multiply or divide).

The Parity bit reflects the number of 1s in the Accumulator: P=1 if Accumulator contains an odd number of 1s (Odd Parity Check). Thus the number of 1s in the Accumulator plus P is always even.

3.3 Instruction Types

The register and operand notations for instructions are follows:

Table 3-1. Operand Notations

Dir	Direct address
A	8-bit accumulator
PC	16-bit program counter
DPTR	16-bit [DPxH:DPxL] of the currently selected data pointer register
Rn	Register R0 ~ R7 of the currently selected register bank
@Ri	8-bit internal I-RAM location (00H ~ FFH) addressed indirectly through R0 or R1
bit	direct addressed bit in I-RAM (20H ~ 2FH) or SFR (80H ~ FFH)
rel	Signed (two's complement) 8-bit offset byte, used by SJMP and all conditional umps, Range -128 to +127 bytes relative to first byte of the following instruction
addr16	16-bit destination address, used by LCALL and LJMP, a branch can be anywhere within the 64KB code memory address space
addr11	11-bit destination address, used by ACALL and AJMP, a branch can be within the same 2KB page of code memory as the first byte of the following instruction.
#imm	8-bit constant included in instruction
#imm16	16-bit constant included in instruction

3.3.1 Data Transfer Instructions

Data transfer instructions are available for moving data around SFR, internal I-RAM, X-RAM and e-FLASH area.

The MOV instruction allows data to be transferred between any internal I-RAM spaces or SFR locations and between accumulator to internal I-RAM spaces or SFR locations. Remember the Upper 128 bytes of internal I-RAM can be accessed only by indirect addressing and SFR space only by direct addressing.

The stack pointer resides in internal I-RAM. The PUSH instruction increment the SP, then copies the byte into the stack. The POP instruction fetches the byte from the stack, and then decrement the SP. PUSH and POP use only direct addressing to identify the byte being saved or restored, but the stack itself is accessed by indirect addressing using the SP register. This means the stack can go into the upper 128, but not SFR space.

The Data Transfer instructions include a 16-bit MOV that can be used to initialize the Data Pointer (DPTRx, x=0, 1) for look-up tables in e-FLASH, or for X-RAM accesses.

The XCH, XCHD can be used to facilitate data manipulations.

MOVX instruction is used to access the internal X-RAM and e-FLASH area. Only indirect addressing can be used. The choice whether to use a one-byte address, @Ri, where Ri can be either R0 or R1 of the selected register bank, or a two-byte address, @DPTR. MOVC instructions are available for reading lookup tables in internal X-RAM or e-FLASH memory.

Table 3-2. Mnemonic and Operand of Data Transfer Instrunctions

Mnemonic & Operand		Operation & Funtions			Opcode (HEX)	PSW					
						CY	AC	F0	RS	OV	P
MOV	A, #imm	A	←	imm	74	•	•	•	•	•	↔
MOV	A, @Ri	A	←	(Ri)	E6,E7	•	•	•	•	•	↔
MOV	A, Rn	A	←	Rn	E8 ~ EF	•	•	•	•	•	↔
MOV	A, Dir	A	←	Dir	E5	•	•	•	•	•	↔
MOV	@Ri, A	(Ri)	←	A	F6,F7	•	•	•	•	•	•
MOV	@Ri, #imm	(Ri)	←	imm	76,77	•	•	•	•	•	•
MOV	@Ri, Dir	(Ri)	←	Dir	A6,A7	•	•	•	•	•	•
MOV	Rn, A	Rn	←	A	F8 ~ FF	•	•	•	•	•	•
MOV	Rn, Dir	Rn	←	Dir	A8 ~ AF	•	•	•	•	•	•
MOV	Rn, #imm	Rn	←	imm	78 ~ 7F	•	•	•	•	•	•
MOV	Dir, A	Dir	←	A	F5	•	•	•	•	•	•
MOV	Dir, #imm	Dir	←	imm	75	•	•	•	•	•	←
MOV	Dir, @Ri	Dir	←	(Ri)	86,87	•	•	•	•	•	←
MOV	Dir, Rn	Dir	←	Rn	88 ~ 8F	•	•	•	•	•	←
MOV	Dir1, Dir2	Dir1	←	Dir2	85	•	•	•	•	•	←
MOV	DPTR, #imm16	DPTR	←	imm16	90	•	•	•	•	•	•
MOVC	A, @A+DPTR	A	←	(A+DPTR)	93	•	•	•	•	•	↔
MOVC	A, @A+PC	PC A	← ←	PC + 1 (A+PC)	83	•	•	•	•	•	↔
MOVX	A, @DPTR	A	←	DPTR	E0	•	•	•	•	•	↔
MOVX	A, @Ri	A	←	(Ri)	E2,E3	•	•	•	•	•	↔
MOVX	@DPTR, A	(DPTR)	←	A	F0	•	•	•	•	•	•
MOVX	@Ri, A	(Ri)	←	A	F2,F3	•	•	•	•	•	•
XCH	A, @Ri	A	↔	(Ri)	C6,C7	•	•	•	•	•	↔
XCH	A, Rn	A	↔	Rn	C8~CF	•	•	•	•	•	↔
XCH	A, Dir	A	↔	Dir	C5	•	•	•	•	•	↔
XCHD	A, @Ri	A_{3-0}	↔	$(Ri)_{3-0}$	D6,D7	•	•	•	•	•	↔
PUSH	Dir	SP (SP)	← ←	SP + 1 Dir	C0	•	•	•	•	•	•
POP	Dir	Dir SP	← ←	SP SP - 1	D0	•	•	•	•	•	•

'←': If destination address are E0H (Accumulator), it is set or cleared.

Table 3-2 is Mnemonic and Operand description of each data transfer instruction. Each function and effects on PSW are also described. The symbol '•' means 'no effect to PSW' and the symbol '↔' means 'can effect to PSW'.

3.3.2 Arithmetic Instructions

These instructions are addition, subtraction, decimal adjustment, increment, decrement, multiplication, and division between two operands. The accesses of addition and subtraction are by all addressing mode except indexed addressing. The I-RAM space can be incremented or decremented without going through the accumulator.

The MUL AB instruction multiplies the Accumulator by the B-register and puts the product into the concatenated B and Accumulator registers. The DIV AB instruction divides the Accumulator by the data in the B-register and leaves the 8-bit quotient in the Accumulator, and the remainder in the B-register.

The DA A instruction is for BCD (Binary Coded Decimal) arithmetic operations. In BCD arithmetic, ADD and ADDC instruction should always be followed by a DA A operation, to ensure that the result is also in BCD. DA A will not convert a binary number to BCD. The DA A operation produces a meaningful result only as the second step in the addition of two BCD bytes.

Table 3-3 is Mnemonic and operand description of each arithmetic instruction. Each function and effects on PSW are also described. The symbol '•' means 'no effect t PSW', the symbol '↔' means 'can effect to PSW', and '0' means 'always force to '0'.

Table 3-3. Mnemonic and Operand of Arithmetic Instructions

Mnemonic & Operand		Operation & Funtions			Opcode (HEX)	PSW					
						CY	AC	F0	RS	OV	P
ADD	A, #imm	A	←	A + imm	24	↔	↔	•	•	↔	↔
ADD	A, @Ri	A	←	A + (Ri)	26,27	↔	↔	•	•	↔	↔
ADD	A, Rn	A	←	A + Rn	28 ~ 2F	↔	↔	•	•	↔	↔
ADD	A, Dir	A	←	A + Dir	25	↔	↔	•	•	↔	↔
ADDC	A, #imm	A	←	A + imm + CY	34	↔	↔	•	•	↔	↔
ADDC	A, @Ri	A	←	A + (Ri) + CY	36,37	↔	↔	•	•	↔	↔
ADDC	A, Rn	A	←	A + Rn + CY	38 ~ 3F	↔	↔	•	•	↔	↔
ADDC	A, Dir	A	←	A + Dir + CY	35	↔	↔	•	•	↔	↔
SUBB	A, #imm	A	←	A – imm – CY	94	↔	↔	•	•	↔	↔
SUBB	A, @Ri	A	←	A – (Ri) – CY	96,97	↔	↔	•	•	↔	↔
SUBB	A, Rn	A	←	A – Rn – CY	98 ~ 9F	↔	↔	•	•	↔	↔
SUBB	A, Dir	A	←	A – Dir – CY	95	↔	↔	•	•	↔	↔
INC	A	A	←	A + 1	04	•	•	•	•	•	↔
INC	@Ri	(Ri)	←	(Ri) + 1	06,07	•	•	•	•	•	•
INC	Rn	Rn	←	Rn + 1	08 ~ 0F	•	•	•	•	•	•
INC	Dir	Dir	←	Dir + 1	05	•	•	•	•	•	←
INC	DPTR	DPTR	←	DPTR + 1	A3	•	•	•	•	•	•
DEC	A	A	←	A – 1	14	•	•	•	•	•	↔
DEC	@Ri	(Ri)	←	(Ri) – 1	16,17	•	•	•	•	•	•
DEC	Rn	Rn	←	Rn – 1	18 ~ 1F	•	•	•	•	•	•
DEC	Dir	Dir	←	Dir – 1	15	•	•	•	•	•	←
DA	A	A	←	Da(A)	D4	↔	•	•	•	•	↔
MUL	AB	AB	←	A x B	A4	0	•	•	•	↔	↔
DIV	AB	AB	←	A / B	84	0	•	•	•	↔	↔

'←': If destination address are E0H (Accumulator), it is set or cleared.

3.3.3 Unconditional Branch Instructions

The Unconditional Branch instructions are three format, 'SJMP, LJMP, AJMP'. The SJMP instruction encodes the destination address as a relative offset. The instruction is 2-bytes long, consisting of the opcode and the relative offset byte. The jump distance is limited to a range of -128 to +127 bytes relative to the instruction following the SJMP. The LJMP instruction encodes the destination address as a 16-bit constant. The instruction is 3-bytes long, consisting of the opcode and two address bytes. The destination address can be anywhere in the 64KB code memory space. The AJMP instruction encodes the destination address as an 11-bit constant. The instruction is 2-bytes long, consisting of the opcode, which itself contains 3 of 11 address bits, followed by another type containing the low 8-bits of the destination address. Hence the destination has to be within the same 2KB block as the instruction following the AJMP.

The JMP @A + DPTR instruction supports case jumps. The destination address is computed at execution time as the sum of the 16-bit DPTR register and the Accumulator. Typically, DPTR is set up with address of a jump table, and the Accumulator is given an index to the table.

Table 3-4 is Mnemonic and operand description of unconditional branch instruction. Each function and effects on PSW are also described. As shown in the table, any instruction related subroutine call can not effects on PSW.

Table 3-4. Mnemonic and Operand of Unconditional Branch Instructions

Mnemonic & Operand	Operation & Funtions	Opcode (HEX)	PSW					
			CY	AC	F0	RS	OV	P
AJMP add11	PC_{10_0} ← addr11	01,21, 41,61, 81,A1, C1,E1	•	•	•	•	•	•
JMP @A + DPTR	PC ← A + DPTR	73	•	•	•	•	•	•
SJMP rel	PC ← PC + rel	80	•	•	•	•	•	•
LJMP addr16	PC ← addr16	02	•	•	•	•	•	•
NOP	No operation	00	•	•	•	•	•	•

3.3.4 Boolean Instructions

The Boolean Instructions are single-bit processing functions. The I-RAM (20H ~ 2FH) contains 128 addressable bits (00H ~ 7FH), and the SFR space (address ends in 000b, that 0H or 8H) can support up to 128 other addressable bits (80H ~ FFH). The instructions that access these bits are conditional branches, move, set, clear, complement, OR, and AND instructions. All bit accesses are by direct addressing

Table 3-5 is Mnemonic and operand description of each Boolean instruction. Each function and effects on PSW are also described. The symbol '•' means 'no effect to PSW' and the symbol '↔' means 'can effect to PSW', and the symbol '0' means 'force to 0'.

Table 3-5. Mnemonic and Operand of Boolean Instructions

Mnemonic & Operand	Operation & Funtions	Opcode (HEX)	PSW					
			CY	AC	F0	RS	OV	P
ANL C, bit	CY ← CY & bit	82	↔	•	•	•	•	•
ANL C, /bit	CY ← CY & !bit	B0	↔	•	•	•	•	•
CLR C	CY ← '0'	C3	↔	•	•	•	•	•
CLR bit	bit ← '0'	C2	•	•	•	•	•	←
CPL C	CY ← !CY	B3	↔	•	•	•	•	•
CPL bit	bit ← !bit	B2	•	•	•	•	•	←
MOV C, bit	CY ← bit	A2	↔	•	•	•	•	•
MOV bit, C	bit ← CY	92	•	•	•	•	•	←
ORL C, bit	CY ← CY | bit	72	↔	•	•	•	•	•
ORL C, /bit	CY ← CY | !bit	A0	↔	•	•	•	•	•
SETB C	CY ← '1'	D3	↔	•	•	•	•	•
SETB bit	bit ← '1'	D2	•	•	•	•	•	←

'←': If destination address are E0H (Accumulator), it is set or cleared.

3.3.5 Subroutine Call Instructions

The LCALL instruction uses the 16-bit address format, and the subroutine can be anywhere in the 64KB code memory space. The ACALL instruction uses the 11-bit address format and the subroutine must be in the same 2KByte clock as the instruction following the ACALL. Subroutines should end with a RET instruction, which returns execution to the instruction following the CALL, RETI is used to return from interrupt service routine. The only difference between RET and RETI is that RETI tells the interrupt control system that the interrupt in progress is done.

Table 3-6 is Mnemonic and operand description of instructions related to the subroutine call. Each function and effects on PSW are also described. As shown in the table, any instruction related subroutine call can not effects on PSW.

Table 3-6. Mnemonic and Operand of Instructions related to the Subroutine Call

Mnemonic & Operand	Operation & Funtions	Opcode (HEX)	PSW					
			CY	AC	F0	RS	OV	P
ACALL add11	PC ← PC + 2 SP ← SP + 1 (SP) ← PC_{low} SP ← SP + 1 (SP) ← PC_{high} $PC_{10\ 0}$ ← addr11	11,31, 51,71, 91,B1, D1,F1	•	•	•	•	•	•
LCALL addr16	PC ← PC + 3 SP ← SP + 1 (SP) ← PC_{low} SP ← SP + 1 (SP) ← PC_{high} $PC_{10\ 0}$ ← addr16	12	•	•	•	•	•	•
RET	PC_{high} ← (SP) SP ← SP – 1 PC_{low} ← (SP) SP ← SP - 1	22	•	•	•	•	•	•
RETI	PC_{high} ← SP) SP ← SP – 1 PC_{low} ← (SP) SP ← SP - 1	32	•	•	•	•	•	•

3.3.6 Conditional Branch Instructions

All of these Jumps specify the destination address by the relative offset method, and so are limited to a jump distance of -128 to +127 bytes from the following the conditional jump instruction. Since no ZERO bit is in the PSW, the JZ and JNZ instructions test the Accumulator data instead of PSW.

The DJNZ (Decrement and Jump If Not Zero) instruction is for loop control. To execute a loop N times load a counter byte with N and terminate the loop with a DJNZ to the beginning of the loop. The CJNE (Compare and Jump if Not Equal) instruction can also be used for loop control. Two bytes are specified in the operand field of the instruction. The jump is executed only if the two bytes are not equal. Another application of this instruction is in “greater than, less than” comparisons. The two bytes in the operand field are taken as unsigned integers. If the first is less than the second, then the CY is set. If the first is greater than the second, the CY is cleared.

Table 3-7 is Mnemonic and operand description of each conditional branch instruction. Each function and effects on PSW are also described. The symbol ‘•’ means ‘no effect to PSW’, the symbol ‘↔’ means ‘can effect to PSW’.

Table 3-7. Mnemonic and Operand of Conditional Branch Instructions

Mnemonic & Operand		Operation & Funtions	Opcode (HEX)	PSW					
				CY	AC	F0	RS	OV	P
JB	bit, rel	If bit = 1, PC ← PC + rel	20	•	•	•	•	•	•
JBC	bit, rel	If bit = 1, PC ← PC + rel bit ← ‘0’	10	•	•	•	•	•	←
JC	rel	If CY = 1, PC ← PC + rel	40	•	•	•	•	•	•
JNB	bit, rel	If bit = 0, PC ← PC + rel	30	•	•	•	•	•	•
JNC	rel	If CY = 0, PC ← PC + rel	50	•	•	•	•	•	•
JZ	rel	If A = 0, PC ← PC + rel	60	•	•	•	•	•	•
JNZ	rel	If A != 0, PC ← PC + rel	70	•	•	•	•	•	•
CJNE	@Ri, #imm, rel	If (Ri) != imm PC ← PC + rel CY ← ‘1’:(Ri) < imm CY ← ‘0’:(Ri) >= imm	B6, B7	↔	•	•	•	•	•
CJNE	A, #imm, rel	If A != imm PC ← PC + rel CY ← ‘1’:A < imm CY ← ‘0’:A >= imm	B4	↔	•	•	•	•	•
CJNE	A, Dir, rel	If A != Dir PC ← PC + rel CY ← ‘1’:A < Dir CY ← ‘0’:A >= Dir	B5	↔	•	•	•	•	•
CJNE	Rn, #imm, rel	If Rn != imm PC ← PC + rel CY ← ‘1’:Rn < imm CY ← ‘0’:Rn >= imm	B8 ~ BF	↔	•	•	•	•	•
DJNZ	Dir, rel	Dir ← Dir - 1 If Dir != ‘0’ PC ← PC + rel	D5	•	•	•	•	•	•
DJNZ	Rn, rel	Rn ← Rn – 1 If Rn != ‘0’ PC ← PC + rel	D8 ~ DF	•	•	•	•	•	•

‘←’: If destination addresses are E0H (Accumulator), it is set or cleared.

3.3.7 Logical Instructions

The instructions that perform Boolean operations (AND, OR, XOR, NOT) on bytes perform the operation on a bit-by-bit basis. CLR (clear), CPL (complement), SWAP, Rotate (RL, RLC, RR, RRC) instructions manipulate the Accumulator. The Rotate instructions shift the Accumulator 1 bit to the left or right. For a left rotation, the MSB rolls into the LSB position. For a right rotation, the LSB rolls into the MSB position. The SWAP instruction interchanges the high and low nibbles within the Accumulator. This is a useful operation in BCD manipulations.

Table 3-8 is Mnemonic and operand description of each logical instruction. Each function and effects on PSW are also described. The symbol '•' means 'no effect to PSW', the symbol '↔' means 'can effect to PSW'.

Table 3-8. Mnemonic and Operand of Logical Instructions

Mnemonic & Operand		Operation & Funtions			Opcode (HEX)	PSW					
						CY	AC	F0	RS	OV	P
ANL	A, #imm	A	←	A & imm	54	•	•	•	•	•	↔
ANL	A, @Ri	A	←	A & (Ri)	56,57	•	•	•	•	•	↔
ANL	A, Rn	A	←	A & Rn	58 ~ 5F	•	•	•	•	•	↔
ANL	A, Dir	A	←	A & Dir	55	•	•	•	•	•	↔
ANL	Dir, #imm	Dir	←	Dir & imm	53	•	•	•	•	•	←
ANL	Dir, A	Dir	←	Dir & A	52	•	•	•	•	•	•
ORL	A, #imm	A	←	A | imm	44	•	•	•	•	•	↔
ORL	A, @Ri	A	←	A | (Ri)	46,47	•	•	•	•	•	↔
ORL	A, Rn	A	←	A | Rn	48 ~ 4F	•	•	•	•	•	↔
ORL	A, Dir	A	←	A | Dir	45	•	•	•	•	•	↔
ORL	Dir, #imm	Dir	←	Dir | imm	43	•	•	•	•	•	←
ORL	Dir, A	Dir	←	Dir | A	42	•	•	•	•	•	•
XRL	A, #imm	A	←	A ^ imm	64	•	•	•	•	•	↔
XRL	A, @Ri	A	←	A ^ (Ri)	66,67	•	•	•	•	•	↔
XRL	A, Rn	A	←	A ^ Rn	68 ~ 6F	•	•	•	•	•	↔
XRL	A, Dir	A	←	A ^ Dir	65	•	•	•	•	•	↔
XRL	Dir, #imm	Dir	←	Dir ^ imm	63	•	•	•	•	•	←
XRL	Dir, A	Dir	←	Dir ^ A	62	•	•	•	•	•	•
CLR	A	A	←	'0'	E4	•	•	•	•	•	↔
CPL	A	A	←	!A	F4	•	•	•	•	•	•
SWAP	A	A_{7_4}	←	A_{3_0}	C4	•	•	•	•	•	•
RL	A	A_{n+1} A_0	<< =	A_n (n=0 ~ 6) A_7	23	•	•	•	•	•	•
RLC	A	A_{n+1} CY A_0	<< = =	A_n (n=0 ~ 6) A_7 CY	33	↔	•	•	•	•	↔
RR	A	A_{n+1} A_0	>> =	A_n (n=0 ~ 6) A_7	03	•	•	•	•	•	•
RRC	A	A_{n+1} A_7 CY	>> = =	A_n (n=0 ~ 6) CY A_0	13	↔	•	•	•	•	↔

'←': If destination address are E0H (Accumulator), it is set or cleared.

3.4 Instruction Set Summary

The BMC513 is fully binary compatible with the standard 8051 instruction set. The difference between the BMC513 and the standard 8051 is the number of cycles required to execute an instruction.

F_{SYS} = 10MHz, The execution time of NOP is 50ns.

Detailed Data Transfer Instruction Summary
( ) : In this case, destination is internal flash area.

Data Transfer Instruction		Bytes	Maximum Clock Cycles	
			Standard 8051	**BMC513**
MOV	A ,#imm	2	12	**2**
MOV	A, @Ri	1	12	**2**
MOV	A, Rn	1	12	**1**
MOV	A, Dir	2	12	**2**
MOV	@Ri, A	1	12	**2**
MOV	@Ri, #imm	2	12	**2**
MOV	@Ri, Dir	2	24	**3**
MOV	Rn, A	1	12	**1**
MOV	Rn, Dir	2	24	**3**
MOV	Rn, #imm	2	12	**2**
MOV	Dir, A	2	12	**2**
MOV	Dir, #imm	3	24	**3**
MOV	Dir, @Ri	2	24	**3**
MOV	Dir, Rn	2	24	**2**
MOV	Dir1, Dir2	3	24	**3**
MOV	DPTR, #imm16	3	24	**3**
MOVC	A, @A+DPTR	1	24	**4**
MOVC	A, @A+PC	1	24	**4**
MOVX	A, @DPTR	1	24	**3**
MOVX	A, @Ri	1	24	**3**
MOVX	@DPTR, A	1	24	**3(4)**
MOVX	@Ri, A	1	24	**3(4)**
XCH	A, @Ri	1	12	**3**
XCH	A, Rn	1	12	**2**
XCH	A, Dir	2	12	**3**
XCHD	A, @Ri	1	12	**3**
PUSH	Dir	2	24	**3**
POP	Dir	2	24	**2**

Detailed Arithmetic Instruction Summary

Arithmetic Instruction		Bytes	Maximum Clock Cycles	
			Standard 8051	**BMC513**
ADD	A, #imm	2	12	**2**
ADD	A, @Ri	1	12	**2**
ADD	A, Rn	1	12	**1**
ADD	A, Dir	2	12	**2**
ADDC	A, #imm	2	12	**2**
ADDC	A, @Ri	1	12	**2**
ADDC	A, Rn	1	12	**1**
ADDC	A, Dir	2	12	**2**
SUBB	A, #imm	2	12	**2**
SUBB	A, @Ri	1	12	**2**
SUBB	A, Rn	1	12	**1**
SUBB	A, Dir	2	12	**2**
INC	A	1	12	**1**
INC	@Ri	1	12	**3**
INC	Rn	1	12	**2**
INC	Dir	2	12	**3**

INC	DPTR	1	24	**1**
DEC	A	1	12	**1**
DEC	@Ri	1	12	**3**
DEC	Rn	1	12	**2**
DEC	Dir	2	12	**3**
DA	A	1	12	**1**
MUL	AB	1	48	**1**
DIV	AB	1	48	**11**

Detailed Unconditional Branch Instruction Summary

Unconditional Branch Instruction		Bytes	Maximum Clock Cycles	
			Standard 8051	**BMC513**
AJMP	add11	2	24	**3**
JMP	@A+DPTR	1	24	**3**
SJMP	rel	2	24	**3**
LJMP	add16	3	24	**3**
NOP		1	12	**1**

Detailed Boolean Instruction Summary

Boolean Instruction		Bytes	Maximum Clock Cycles	
			Standard 8051	**BMC513**
ANL	C, bit	2	24	**2**
ANL	C, /bit	2	24	**2**
ORL	C, bit	2	24	**2**
ORL	C, /bit	2	24	**2**
CLR	C	1	12	**1**
CLR	bit	2	12	**3**
CPL	C	1	12	**1**
CPL	bit	2	12	**3**
SETB	C	1	12	**1**
SETB	bit	2	12	**3**
MOV	C, bit	2	12	**2**
MOV	bit, C	2	24	**3**

Detailed Subroutine Call Instruction Summary

Subroutine Call Instruction		Bytes	Maximum Clock Cycles	
			Standard 8051	**BMC513**
ACALL	add11	2	24	**3**
LCALL	add16	3	24	**3**
RET		1	24	**4**
RETI		1	24	**4**

Detailed Conditional Branch Instruction Summary
( ) : In this case, jump is not taken.

Conditional Branch Instruction		Bytes	Maximum Clock Cycles	
			Standard 8051	**BMC513**
JB	bit, rel	3	24	**4(3)**
JNB	bit, rel	3	24	**4(3)**
JBC	bit, rel	3	24	**4(3)**
JC	rel	2	24	**3(2)**
JNC	rel	2	24	**3(2)**
JZ	rel	2	24	**3(2)**
JNZ	rel	2	24	**3(2)**
CJNE	@Ri, #imm, rel	3	24	**4(3)**
CJNE	A, #imm, rel	3	24	**4(3)**
CJNE	A, Dir, rel	3	24	**4(3)**
CJNE	Rn, #imm, rel	3	24	**4(3)**
DJNZ	Dir, rel	3	24	**4(3)**
DJNZ	Rn, rel	2	24	**3(2)**

Detailed Logical Instruction Summary

Logical Instruction		Bytes	Maximum Clock Cycles	
			Standard 8051	**BMC513**
ANL	A, #imm	2	12	**2**
ANL	A, @Ri	1	12	**2**
ANL	A, Rn	1	12	**1**
ANL	A, Dir	2	12	**2**
ANL	Dir, #imm	3	24	**3**
ANL	Dir, A	2	12	**3**
ORL	A, #imm	2	12	**2**
ORL	A, @Ri	1	12	**2**
ORL	A, Rn	1	12	**1**
ORL	A, Dir	2	12	**2**
ORL	Dir, #imm	3	24	**3**
ORL	Dir, A	2	12	**3**
XRL	A, #imm	2	12	**2**
XRL	A, @Ri	1	12	**2**
XRL	A, Rn	1	12	**1**
XRL	A, Dir	2	12	**2**
XRL	Dir, #imm	3	24	**3**
XRL	Dir, A	2	12	**3**
CLR	A	1	12	**1**
CPL	A	1	12	**1**
SWAP	A	1	12	**1**
RL	A	1	12	**1**
RLC	A	1	12	**1**
RR	A	1	12	**1**
RRC	A	1	12	**1**

NOTES:

4 SYSTEM CONTROLLER

4.1 OVERVIEW

The system controller consists of three parts: reset management, system clock management, and system power management control. The system clock management logic can generate the required system clock signals. There is a PLL to generate internal clocks for USB. Software program can control the operation frequency of the PLLs, internal clock sources and either enable or disable the clock to reduce the power consumption.

The BMC513 has various power-down modes to keep optimal power consumption for a given task. The power-down modes consists of three modes: General Clock Gating mode, IDLE mode and STOP mode.

General Clock Gating mode is used to control the ON/OFF of clocks for internal peripherals in the BMC513. User can optimize the power consumption of the BMC513 using this General Clock Gating mode by supplying clocks for peripherals that are necessary for a certain application.

4.2 FEATURES

- Include on-chip PLL
- Include on-chip 16MHz Main oscillator
- Include on-chip 32.768KHz Sub oscillator
- Independent clock ON and OFF control to reduce power consumption
- Supports power-down mode: Power clock gating, IDLE and STOP mode to optimize the power consumption.
- Wake-up by one of external interrupt, WDT wake-up, USB wake-up and RTC alarm wake-up. (STOP mode Only)

4.3 OPERATION

4.3.1 RESET MANAGEMENT

RESET Types

The BMC513 processor has four types of resets and reset controller can place the system into the predefined states with one of the following resets.

- Pin RESET(PnRESET): Uncompromised, unmask-able, and complete reset, it is generated when PnRESET pin is asserted.
- Software RESET(SWRST): Software can initialize the internal state by writing the RSTCON register.
- Watchdog RESET(WDTRST): The watchdog timer monitors the devices state and generates the watchdog reset when the state is abnormal.
- Low Voltage Detect RESET(LVDRST): When V_{DD} is changed in condition for LVD operation in the normal operation mode, reset occurs.

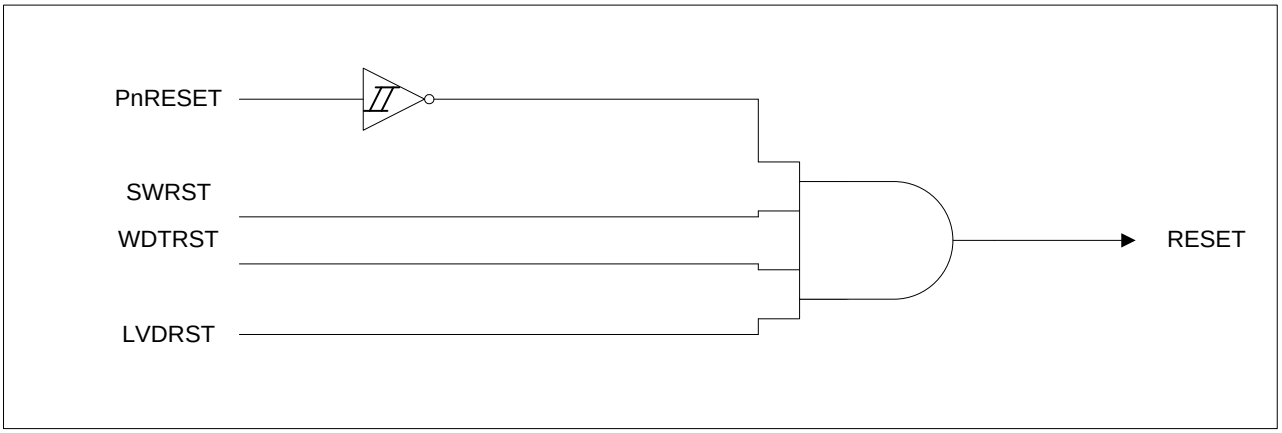


Figure 4-1. RESET source of the BMC513

1. When LVD circuit detects V_{DD} below V_{LVD}, reset is generated.
2. When Watch-dog timer overflow is occurred, reset is generated.
3. PnRESET pin is issued to low, reset is generated.
4. Chip reset occurs when it writes “0xB” into RSTCON register.

PIN RESET (PnRESET)

Pin reset is invoked when the PnRESET pin is asserted and all units in the system (**except RTC block**) are initialized to known states. When the unmaskable PnRESET pin is asserted as “low”, the internal hardware reset signal is generated. Upon assertion of PnRESET, the BMC513 enters into reset sate regardless of the previous state. The internal oscillator stabilization time is 6.1ms.

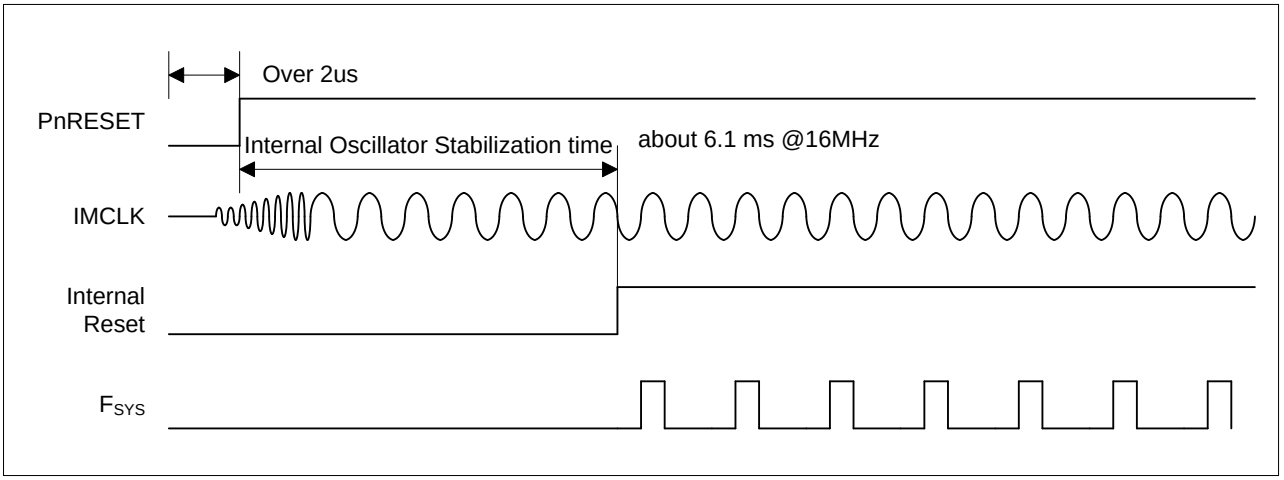


Figure 4-2. Pin Reset Sequence

LVD RESET (LVDRST)

The Low Voltage Detect Circuit (LVD) is built on the BMC513 to generate a system reset. When LVD circuit detects V_{DD} below V_{LVD}, reset is generated. The internal oscillator stabilization time is 2ms.

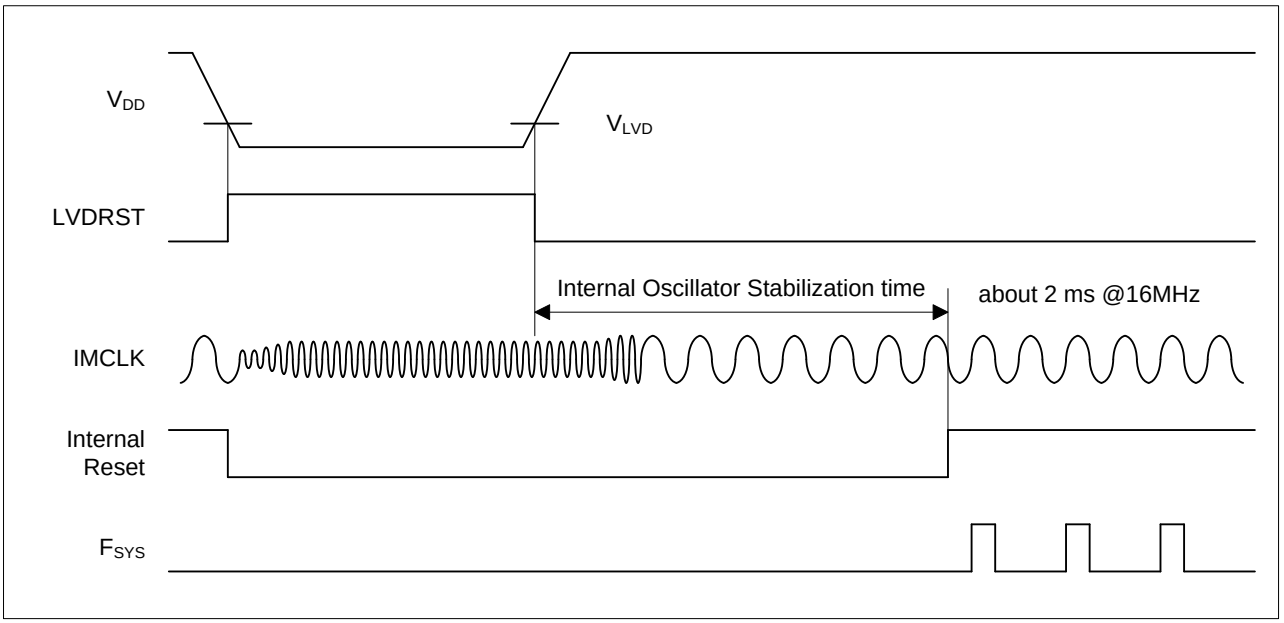


Figure 4-3. LVD Reset Sequence

Software RESET

Software can initialize the device state itself when it writes “0xB” to RSTCON register.

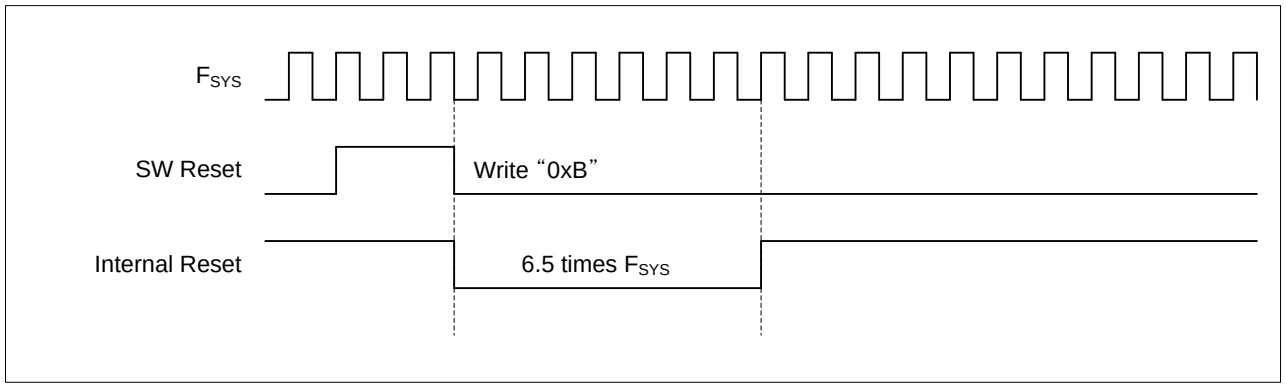


Figure 4-4. Software Reset Timing

Watchdog RESET

Watchdog reset is invoked timer overflows under the condition that both watchdog timer and reset are enabled.

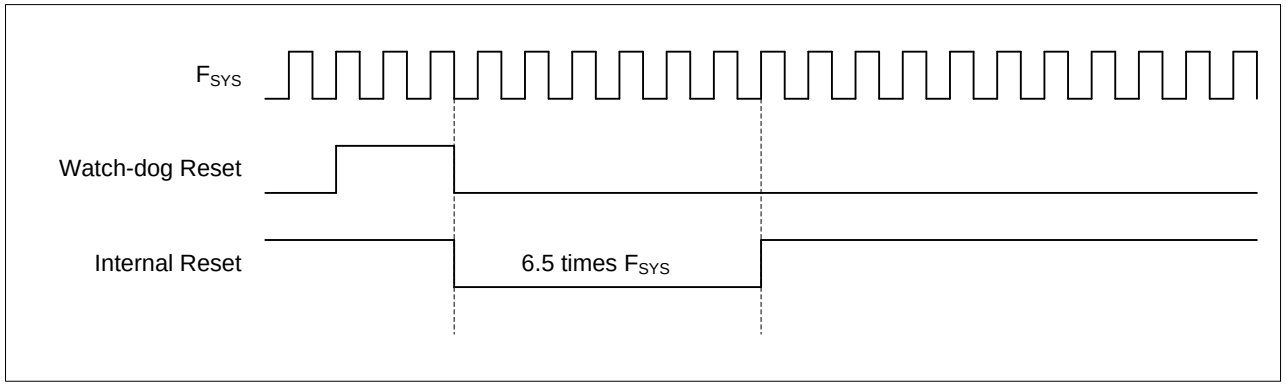


Figure 4-5. Watchdog Reset Timing

4.3.2 CLOCK MANAGEMENT

Overview

Figure 4-6 show a block diagram of the clock architecture. The main clock source comes from an external oscillator (EMCLK), an internal 16M main oscillator clock (IMCLK), PLL output clock (PLLCLK), an external sub oscillator (ESCLK) or an internal 32K sub oscillator clock (ISCLK).

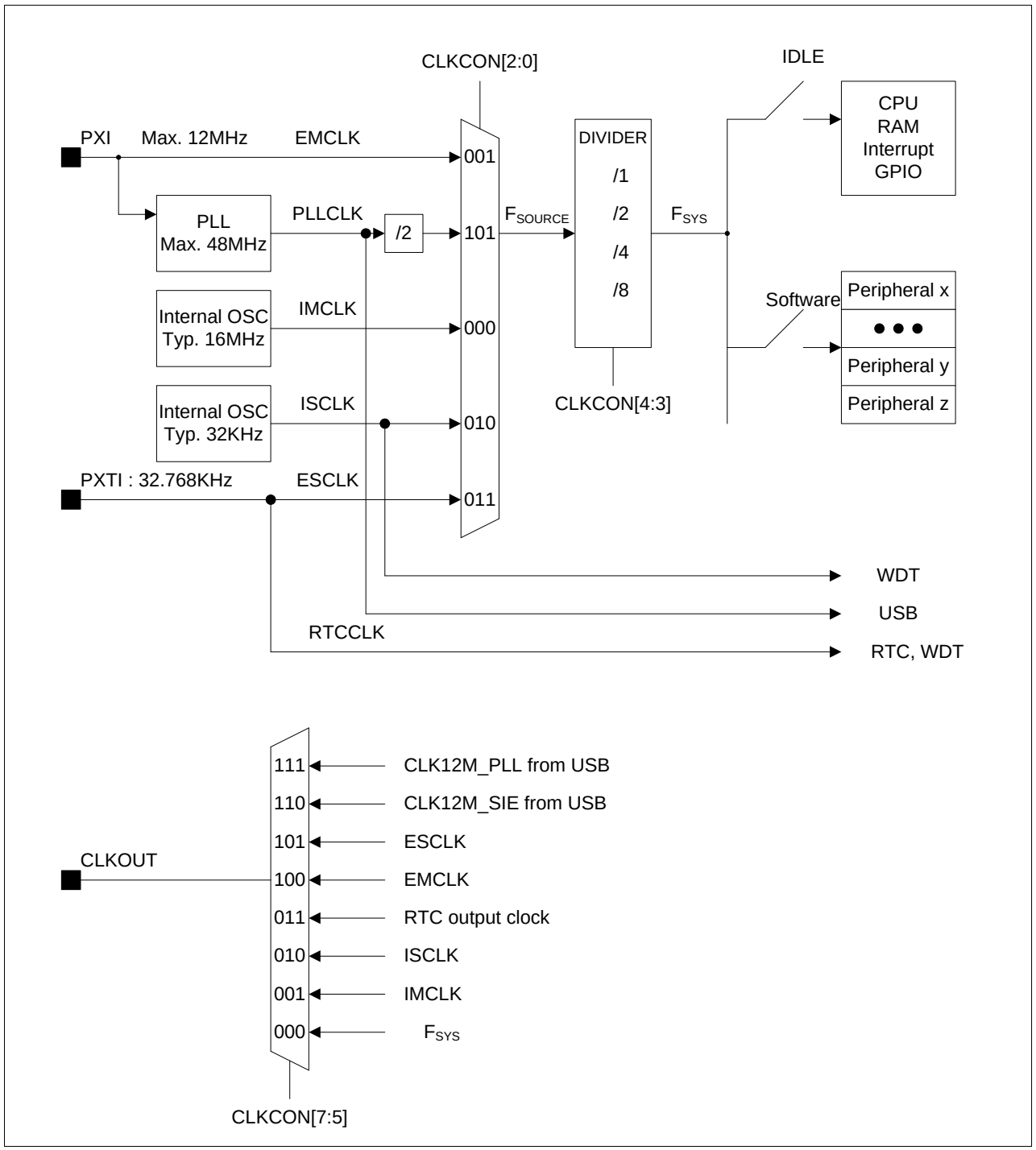


Figure 4-6. Clock generator block diagram

The RTC working clock is generated by PXTI (RTCCLK). The frequency is 32.768KHz.

IMCLK: INTERNAL MAIN CLOCK 16MHz

IMCLK means an internal main clock 16MHz.

The internal 16MHz oscillator supplies the clock to the F_{SOURCE} when CLKSRC field in CLKCON register is “000b”. Enabling and disabling the internal 16MHz oscillator is possible by controlling Int16MOSCdis bit in SYSCFG register. User should check Int16MOSCstable bit in SYSCFG register when IMCLK is used for the F_{SOURCE}. The IMCLK can’t be used for PLL input.

After reset, IMCLK is enabled by default and can be used for F_{SOURCE} by default.

EMCLK: EXTERNAL MAIN CLOCK 4 ~ 12MHz

EMCLK means an external main clock. The frequency range of external clock oscillator is allowed from 4MHz to 12MHz.

When the resonators (from 4MHz to 8MHz) and load capacitors are used as the external oscillator (not recommended), they have to be placed as close to the processor as possible in order to have the stable clock and minimize the stabilization time. The value of load capacitor should be chosen according to the external oscillator.

EMCLK can be used for the F_{SOURCE} or PLL input source. It can be disabled or enabled by controlling MAIN_OSC_DIS bit in SYSCFG register. User should check MAIN_OSC_STABLE bit in SYSCFG register when EMCLK is used for the F_{SOURCE}.

After reset, EMCLK is enabled.

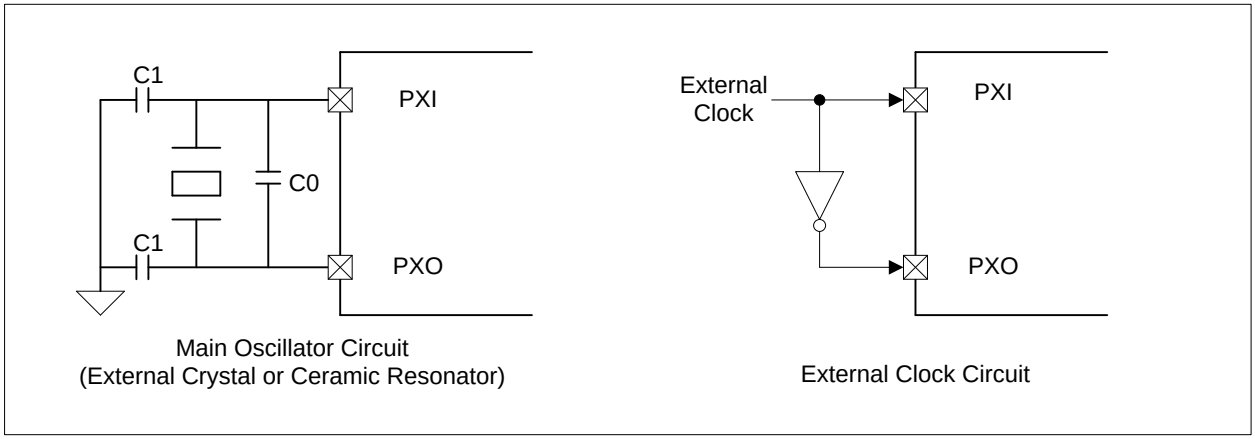


Figure 4-7. Main Oscillator Circuit

ISCLK: INTERNAL SUB CLOCK 32.768KHz

ISCLK means an internal sub-clock 32.768KHz. ISCLK can be used for the F_{SOURCE}. It is not impossible to use as PLL input source. The internal 32.768KHz oscillator is used for wakeup of watch dog timer as a clock source in STOP mode. It can be optionally enabled or not.

ISCLK cannot be used for the RTC working clock.

After reset, ISCLK is enabled.

ESCLK: EXTERNAL SUB CLOCK 32.768KHz

ESCLK means an external sub-clock 32.768KHz. ESCLK can be used for the F_{SOURCE}. It is not impossible to use as PLL input source. It can be disabled by S/W

ESCLK can be used for the RTC working clock and watch dog timer clock source.

PLL

The PLL (Phase-Locked-Loop) frequency synthesizer is constructed in CMOS in single monolithic structure. The PLL has frequency multiplication capabilities for the output clock frequency (PLLCLK) based on the input clock frequency (EMCLK) by the following equation.

$$PLLCLK = EMCLK * (MDIV[5:0] +8) / (PDIV[3:0]+2) / (2^{SDIV[1:0]})$$

Where,

MDIV: the value for Main Divider
PDIV: the value for Pre Divider
SDIV: the value for Post Scaler

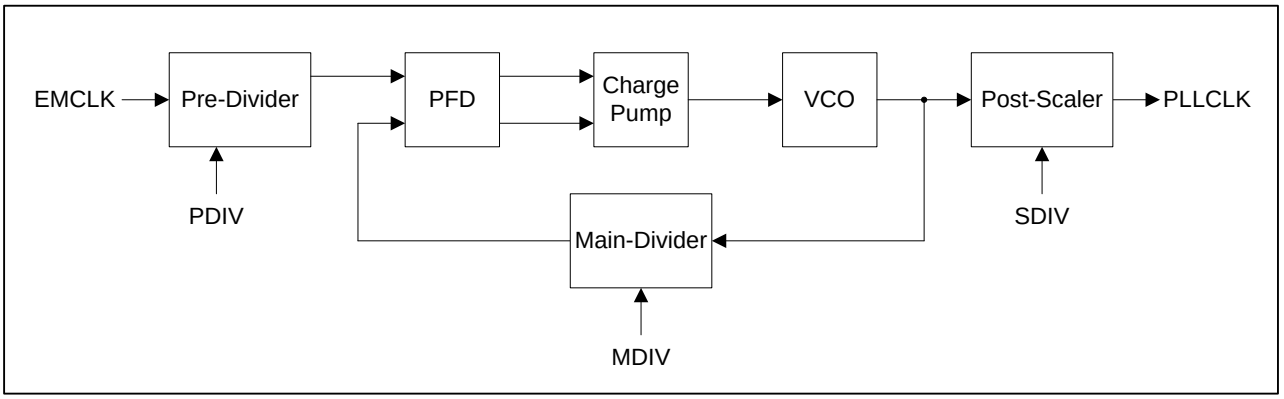


Figure 4-8. PLL Block Diagram

MDIV, PDIV and SDIV are the values for programmable dividers (see the register description).

The PLL consists of a Phase/Frequency Detector (PFD), a Charge Pump, a Voltage Controlled Oscillator (VCO), a pre-divider, a main-divider and post scaler as depicted in Figure 4-8 above.

PLL generates clock sources for USB and F_{SOURCE}.

Changing PLL Settings in Normal Operation

During the operation of the BMC513 in NORMAL mode, if the operation frequency wants to be changed by writing the PMS value, the sequences are as follows:

1. Enable an external main oscillator (EMCLK) by controlling MAIN_OSC_DIS bit in CLKCON register.
2. Checking an external main oscillator stable by monitoring MAIN_OSC_STABLE bit in SYSCFG register.
3. Changes PMS value in PLLCON0 and PLLCON1 register.
4. Enable PLL by controlling PLL_EN bit in PLLCON0 register
5. Checking a PLL stable by monitoring PLL_STABLE bit in PLLCON0 register. (300us Lock-up time)
6. If PLL is stable, set CLKSRC fields in CLKCON register to “101b”, and then F_{SOURCE} is fed from PLLCLK/2.

Clock Source Selection

Clock input source (F_{SOURCE}) can use EMCLK(PXI), ESCLK(PXTI), PLLCLK, IMCLK(internal 16MHz OSC, default) or ISCLK(internal 32K OSC) as its clock source by setting CLKCON[2:0] only after stabilization. Otherwise, it might bring the chip into unexpected status of operations.
Especially, when using PLLCLK as clock source, must use EMCLK as PLL clock input.

Figure 4-9 shows system clock source change timing diagram. Other case is same operation.

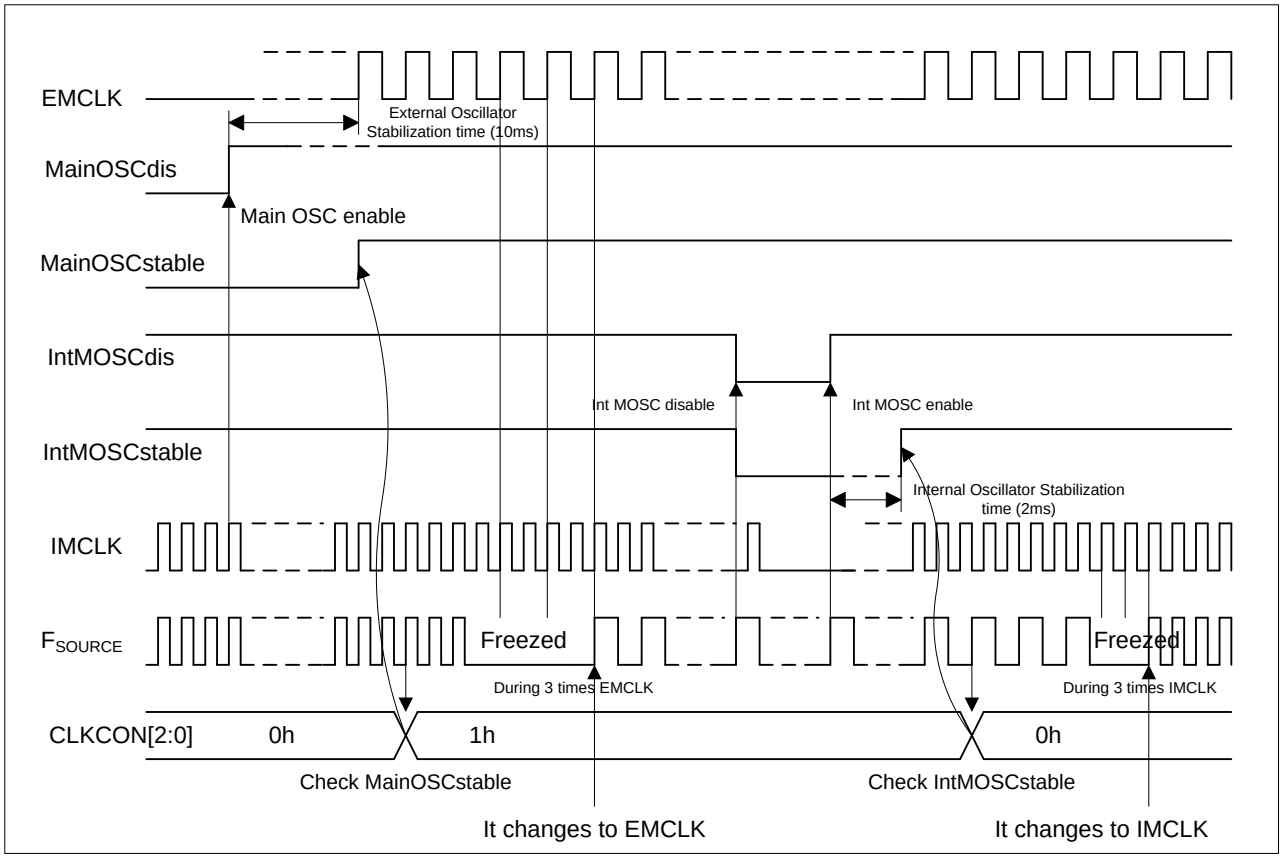


Figure 4-9. The case that changes clock source

How to control clock source:

After Reset, system is running by IMCLK

Using ESCLK

```
rSYSCFG = 0;                    // enable external Sub-Oscillator
rCLKCON = 0x1B;                 // FSOURCE = ESCLK, FSYS = FSOURCE
```

Using ISCLK

```
rSYSCFG = 0;                    // enable internal Sub-Oscillator
rCLKCON = 0x1A;                 // FSOURCE = ISCLK, FSYS = FSOURCE
```

Using IMCLK

```
rSYSCFG = 0;                    // enable internal Main-Oscillator
While (!(rSYSCFG & 0x80));      // wait internal Main-Oscillator stable
rCLKCON = 0x10;                 // FSOURCE = IMCLK, FSYS = FSOURCE / 2
```

Using EMCLK

```
rSYSCFG = 0;                    // enable external Main-Oscillator
While (!(rSYSCFG & 0x40));      // wait external Main-Oscillator stable

rCLKCON = 0x19;                 // FSOURCE = EMCLK, FSYS = FSOURCE
                                // or
rSMCLKCON = 0xF7;               // Flash Access 1 wait, ONE_CACHE_EN
rCLKCON = 0x18;                 // FSOURCE = EMCLK, FSYS = FSOURCE / 2
```

Using PLLCLK

```
rSYSCFG = 0;                    // enable external Main-Oscillator
While (!(rSYSCFG & 0x40));      // wait external Main-Oscillator stable

                                // PLL output frequency = 48MHz
rPLLCON1 = (0x28<<2) + 0x0;     // MDIV = 0x28, SDIV = 0x0
rPLLCON0 = PLL_EN + 0xA;        // PDIV = 0xA, PLL enable
While (!(rPLLCON0 & 0x80));     // wait PLL stable

rPCON = rPCON & 0xBF;           // EF_WAIT_MODE = 0
rSMCLKCON = 0xFA;               // Flash Access 2 wait, ONE_CACHE_EN = 1
rCLKCON = 0x1D;                 // FSOURCE = PLLCLK/2, FSYS = FSOURCE = 24MHz
```

4.3.3 POWER MANAGEMENT

The power management block controls system clocks by software for the reduction of power consumption of the BMC513. The BMC513 has three power-down modes

Power Saving Mode State Diagram

Figure 4-10 shows Power saving mode state with either Entering or Exiting condition. In general, the entering conditions (CMD) are set to PCON register by CPU.

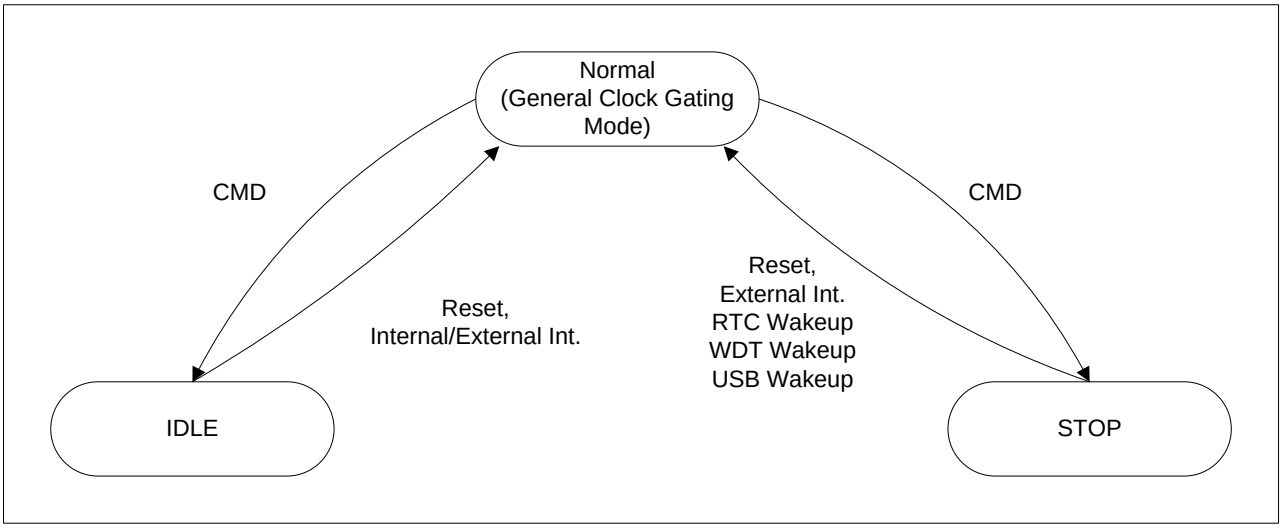


Figure 4-10. Power-down mode State Diagram

General Clock Gating Mode (Normal Mode)

In General Clock Gating mode, both On and OFF of clock gating of the individual clock source of each block are performed by controlling each corresponding clock source enable bit of CLK_EN0 and CLK_EN1 registers. The Clock Gating is applied instantly whenever the corresponding bit (or bits) is changed.

IDLE Mode

In IDLE mode, clock to CPU is in stop.

Idle mode is invoked when the IDLE Mode bit of PCON is set to '1'. In IDLE mode, CPU operations are halted while some peripherals remain active. During IDLE mode, the internal clock is gated away from the CPU, but all peripherals remain active.

There are two ways to release IDLE mode:

1. Execute a reset. All system and peripheral control registers (except RTC block) are reset to their default values. If interrupts are masked, a reset is the only way to release IDLE mode.
2. Activate any enabled interrupt, causing IDLE mode to be released.

How to Enter into IDLE mode:

```
orl     PCON, #01H
nop
nop
nop
```

Because the next instruction just after IDLE mode entrance will also be executed, the next instruction of IDLE MUST be "NOP" instruction.

STOP Mode

STOP mode is invoked when the STOP Mode bit of PCON is set to '1'. In STOP mode, the operation of the CPU and all peripherals except RTC and WDT (If WAKEEN bit is set to '1' for using wakeup feature) are halted. That is, the external main oscillator and internal 16MHz main oscillator are stopped (Stopping oscillator circuit is optional for the necessary of faster oscillation stabilization time. See MAIN_OSCEN_STOP and INT_MOSCEN_STOP bits in SYSCFG register). The supply current is reduced. External sub oscillator and internal 32KHz sub oscillator are configurable. The clock supply to F_{SOURCE} is disconnected in entry of STOP mode and connected in exit of STOP mode. All system functions stop when the clock "freezes", but data stored in the internal register file is retained.

Table 4-1. IP status on Normal and STOP mode

	Normal mode	STOP mode
External Main Oscillator (EMCLK)	Configurable (MAIN_OSC_DIS bit of SYSCFG register)	Configurable (MAIN_OSCEN_STOP bit of SYSCFG register)
Internal 16MHz Main Oscillator (IMCLK)	Configurable(INT_MOSC_DIS bit of SYSCFG register)	Configurable(INT_MOSCEN_STOP bit of SYSCFG register)
PLL (PLLCLK)	Configurable (PLL_EN bit of PLLCON0 register)	STOP
ADC	Configurable	STOP
DAC	Configurable	STOP
USB	Configurable	Enter SUSPEND mode

How to Enter into STOP mode:

```
anl     IVCON0, #0DEH    ; disable LVD circuit
orl     PCON, #02H
nop
nop
nop
```

Because the next instruction just after STOP mode entrance will also be executed, the next instruction of STOP MUST be "NOP" instruction.

Following operation will be executed before entering STOP mode

1. LVD circuit should be disabled. (Mandatory): LVD circuit will be automatically enabled when wakeup is generated except reset source, and then LVD circuit checks the voltage level. If voltage level is over V_{LVD}, STOP mode will be released. If not, LVD reset is generated.
2. If system is using the PLLCK for F_{SOURCE}, should change it to IMCLK or EMCLK before entering STOP mode. Because PLLCLK will be stopped in STOP mode.
3. When any of external interrupts are used as Wakeup sources, bits of registers (EINTEN0 and EINTEN1) related to the external interrupts should be only enabled. Otherwise, it might cause unexpected system malfunction.
4. Disable JTAG function. (Optional)
5. Internal 3.3V LDO Power down (Optional)
6. Disable USB PHY pull-up. (Optional)
7. Disable Internal 32K sub-oscillator (Optional)
8. Disable External 32K sub-oscillator (Optional)
9. If system is using the EMCLK for FSOURCE, make internal 16M main oscillator (IMCLK) disable to reduce current before entering STOP mode. (Optional)
10. If system is using the IMCLK for FSOURCE, make external main oscillator (EMCLK) disable to reduce current before entering STOP mode. (Optional)

There are several ways to release STOP mode

1. Execute a reset. All system and peripheral control register (except RTC block) are reset to their default values.
2. WDT Wakeup. WDT counting overflow by when WAKEEN bit in WDTCON register is set to "1" in STOP mode causes STOP mode to be released.
3. RTC wakeup. In STOP mode, the RTC ALARM feature causes STOP mode to be released. If any of RTC related Interrupts are enabled, after the release, RTC ALARM interrupt takes.
4. External Interrupt.
5. USB Wakeup

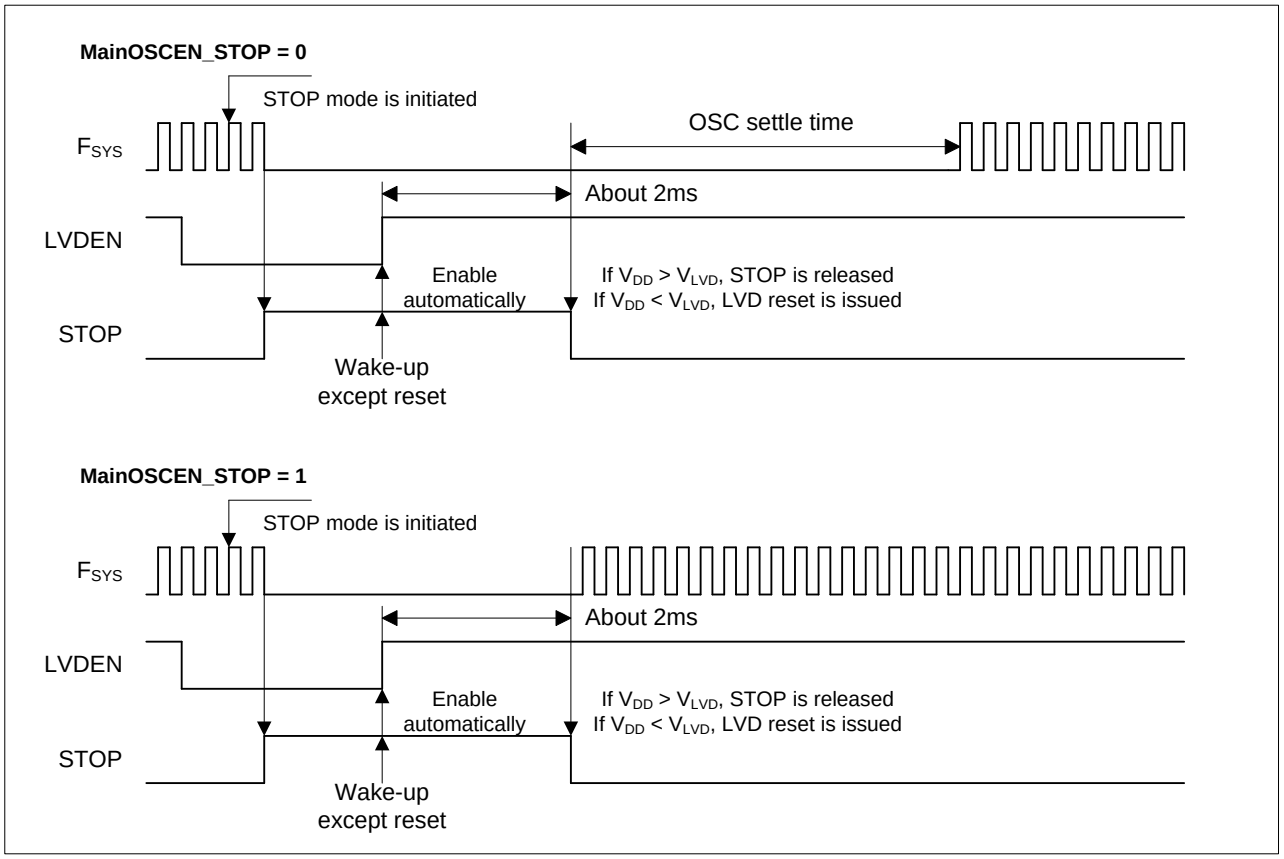


Figure 4-11. Entering STOP mode and Exiting STOP mode (Wake-up)

4.4 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
ROMB	0xA1	R/W	ROM Bank Selection	0x00
XRAMB	0xA2	R/W	Data Memory Bank Selection	0x00
CLKCON	0xA3	R/W	System Clock Control Register	0x10
SMCLKCON	0xA4	R/W	Smart Clock Control Register	0xF0
CLK_EN0	0xA5	R/W	Peripheral Clock Enable Register 0	0x01
CLK_EN1	0xA6	R/W	Peripheral Clock Enable Register 1	0x00
PCON	0xA7	R/W	Power Control Register	0x20
RSTCON	0xA8	W	Reset Control Register	0x00
RSTSTAT	0xA9	R	Reset Source Status Register	0x00
SYSCFG	0xAA	R/W	System Configuration Register	0x08
IVCON0	0xAB	R/W	IVC Control Register 0	0x13
IVCON1	0xAC	R/W	IVC Control Register 1	0x00
WKUPSTAT	0xAD	R/W	Wakeup Source Status Register	0x00
PLLCON0	0xAE	R/W	PLL Control Register 0	0x0A
PLLCON1	0xAF	R/W	PLL Control Register 1	0xA0

ROMB (0xA1)

Name	Bit	R/W	Description	Reset
RSVD	7:5	R	Reserved. Always read as '0'	-
ROMB	4:0	R/W	ROM Bank Selection Immediately after the changing of ROMB, the fetch of next instruction loads code from the new BANKn selected by ROMB. Bank0: 0x0000 ~ 0x07FFF (32KB) Bank(this value + 1): 0x08000 ~ 0x0FFFF (32KB per Bank)	0x00

XRAMB (0xA2)

Name	Bit	R/W	Description	Reset
RSVD	7:5	R	Reserved. Always read as '0'	-
XRAMB	4:0	R/W	e-FLASH 32KBytes Bank Selector. If this value 0, Select Bank 0 0x0000 ~ 0x7FFF : e-FLASH area 0x8000 ~ 0x8FFF : X-RAM area	0x00

CLKCON (0xA3)

This register will be only reset by PnRESET or LVDRST. This register configures the source clock and the division ratio of clock. The operation speed of clock can be slower to reduce the overall power consumption, if application does not require full performance.

Name	Bit	R/W	Description	Reset
CLKO	7:5	R/W	Select source clock with CLKOUT pad (GP14) 111: CLK12M_PLL from USB 110: CLK12M_SIE from USB 101: ESCLK 100: EMCLK 011: RTC output clock 010: ISCLK 001: IMCLK 000: F_{SYS}	000
CLKDIV	4:3	R/W	System clock divisor select. 00: $F_{SYS} = F_{SOURCE} / 8$ 01: $F_{SYS} = F_{SOURCE} / 4$ 10: $F_{SYS} = F_{SOURCE} / 2$ 11: $F_{SYS} = F_{SOURCE} / 1$	10
CLKSRC	2:0	R/W	System source (F_{SOURCE}) clock select. 000: IMCLK (Internal Main-Clock, Typ. 16MHz) 001: EMCLK (External Main-Clock, 4 ~ 12MHz, Using PXI and PXO) 010: ISCLK (Internal Sub-Clock, Typ. 32.768KHz) 011: ESCLK (External Sub-Clock 32.768KHz, Using PXTI and PXTO) 101: PLLCLK / 2 (Output from PLL)	000

SMCLKCON (0xA4)

This register will be only reset by PnRESET or LVDRST. The smart clock control register, which controls input clock of VDMA, I80 LCD, BRJPEG and BRAC and also controls a number of wait clocks, is used for low-power and performance enhancement.

Name	Bit	R/W	Description	Reset
SMCLK_EN_VDMA	7	R/W	Smart Clock Enable for VDMA block	1
SMCLK_EN_I80LCD	6	R/W	Smart Clock Enable for I80 LCD block	1
SMCLK_EN_JPEG	5	R/W	Smart Clock Enable for BRJPEG block	1
SMCLK_EN_BRAC	4	R/W	Smart Clock Enable for BRAC block	1
FLASH_WAIT_CNT	3:2	R/W	Flash Read Wait Count register. When EF_WAIT_MODE of PCON is '0' : All Flash Area -> 0: 0-wait, 1: 1-wait, 2: 2-wait, 3: Reserved When EF_WAIT_MODE of PCON is '1' : 0x00000 ~ 0x0FFFF area -> 0: 0-wait, 1: 0-wait, 2: 1-wait, 3: Reserved 0x10000 ~ 0x5FFFF area -> 0: 0-wait, 1: 1-wait, 2: 2-wait, 3: Reserved **This bit should be set to 2 when F_{SYS} is greater than 20MHz and set to 1 when F_{SYS} is greater than 10MHz. (If user want to use PLLCLK or IMCLK as clock source, should think these bit value)**	00
ONE_CACHE_EN	1	R/W	One Cache Enable for CPU performance enhancement and low power flash access.	0
RSVD	0	R/W	Reserved. **Don't make this bit set to '1' to avoid anything unexpected.**	0

CLK_EN0 (0xA5)

F_{SYS} to supply each peripheral is frozen when bit of this register is set to '0".

Name	Bit	R/W	Description	Reset
U0_CKEN	7	R/W	Control F_{SYS} into UART 0 block 0: disable, 1: enable	0
T2_CKEN	6	R/W	Control F_{SYS} into Timer 2 block 0: disable, 1: enable	0
T1_CKEN	5	R/W	Control F_{SYS} into Timer 1 block 0: disable, 1: enable	0
T0_CKEN	4	R/W	Control F_{SYS} into Timer 0 block 0: disable, 1: enable	0
SPI_CKEN	3	R/W	Control F_{SYS} into SPI block 0: disable, 1: enable	0
ADC_CKEN	2	R/W	Control F_{SYS} into ADC block 0: disable, 1: enable	0
RTC_CKEN	1	R/W	Control F_{SYS} into RTC block. Even if this bit is set to 0, RTC counter is alive if RTCCLK is running. 0: disable, 1: enable	0
WDT_CKEN	0	R/W	Control F_{SYS} into WDT block 0: disable, 1: enable	1

CLK_EN1 (0xA6)

F_{SYS} to supply each peripheral is frozen when bit of this register is set to '0".

Name	Bit	R/W	Description	Reset
LCD_CKEN	7	R/W	Control F_{SYS} into LCD block 0 : disable, 1 : enable	0
VDMA_CKEN	6	R/W	Control F_{SYS} into VDMA block 0 : disable, 1 : enable	0
I80LCD_CKEN	5	R/W	Control F_{SYS} into I80LCD block 0 : disable, 1 : enable	0
JPEG_CKEN	4	R/W	Control F_{SYS} into BRJPEG block 0 : disable, 1 : enable	0
FLASH_CKEN	3	R/W	Flash control block's clock enable bit 0 : disable, 1 : enable	0
BRAC_CKEN	2	R/W	Control F_{SYS} or F_{SYS}/2 into BRAC@ block 0: disable, 1: enable	0
RSVD	1	-	Reserved	0
U11_CKEN	0	R/W	Control F_{SYS} into USB Device block 0: disable, 1: enable	0

PCON (0xA7)

Name	Bit	R/W	Description	Reset
USBPHYPUPEN	7	R/W	USB PHY Pull-UP enable 0: disable, 1: enable	0
EF_WAIT_MODE	6	R/W	Controls internal flash wait mode. Flash read wait count is determined by SMCLKCON.FLASH_WAIT_CNT. But when this bit is set, the wait count of 0x0000 ~0xFFFF flash area is decremented by 1. Refer to SMCLKCON FLASH_WAIT_CNT bits.	0
LDO33_PD	5	R/W	3.3V LDO Power Down 0 : Normal Operation 1 : Power-Down	1
RSVD	4:2	-	Reserved	-
STOP	1	R/W	Full System Stop with Oscillator. Stop mode can be released by PIN Reset, LVD Reset, Power-on Reset, External pin wake-up signal, USB wake-up or RTC wake-up. 0: Disable, 1: Enable	0
IDLE	0	R/W	Disable clock only provided to CPU, It can be released by interrupt of each peripheral and external interrupt. 0: Disable, 1: Enable	0

RSTCON (0xA8)

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
RTCRST	4	W	RTC reset by software. Set this bit to '1' before starting RTC. This bit is automatically cleared.	0
SWRST	3:0	W	If this field has "B", then the system will restart.	0

RSTSTAT (0xA9)

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
LVDRST	3	R	Reset by LVD	0
WDTRST	2	R	Reset by Watchdog timer	0
SWRST	1	R	Reset by Software	0
PINRST	0	R	Reset by PnRESET	0

SYSCFG (0xAA)

Name	Bit	R/W	Description	Reset
INT_MOSC_STABLE	7	R	Internal 16MHz Oscillator stable flag 0: Internal 16MHz Oscillator is unstable 1: Internal 16MHz Oscillator is stable	0
MAIN_OSC_STABLE	6	R	Main Oscillator stable flag 0: Main Oscillator is unstable, 1: Main Oscillator is stable	0
INT_MOSCEN_STOP	5	R/W	Internal 16MHz Main Oscillator enable bit in STOP mode 0: disable in STOP mode, 1: Enable in STOP mode	0
MAIN_OSCEN_STOP	4	R/W	External Main Oscillator enable bit in STOP mode 0: disable in STOP mode, 1: Enable in STOP mode	0
INT_32K_OSC_DIS	3	R/W	Internal 32KHz Oscillator enable control 0: enable, 1: disable	1
INT_MOSC_DIS	2	R/W	Internal 16MHz Oscillator enable control 0: enable, 1: disable	0
SUB_OSC_DIS	1	R/W	Sub Oscillator(PXTI) enable control 0: enable, 1: disable	0
MAIN_OSC_DIS	0	R/W	Main Oscillator (PXI) enable control 0: enable, 1: disable	0

IVCON0 (0xAB)

BLD(Battery Level Detector) is to check the level of Input power(VDD),which will be set by fields of BLD_SEL and set '1' of BLDOUT field of IVCON1 Register when VDD goes below the level set by BLD_SEL.
ISTOP field sets the SUB-IVC driving capability to minimize leakage current in STOP mode.
LVR(Low Voltage Reset) will reset the CHIP automatically when VDD goes below values set by LVR_SEL field.

Name	Bit	R/W	Description	Reset
BLD_SEL	7:6	R/W	BLD Level selection bits: each value ±0.2V tolerance. **Be careful with the order of bit values.** 00: 3.08V, 11 : 2.77V, 10 : 2.43V, 01 : 2.23V	00
BLD_EN	5	R/W	Battery Level Detector(BLD) Enable 0 : disable, 1 : enable	0
ISTOP	4:3	R/W	Control IVC driving capability in STOP mode 11: weakest, smallest ~~ 00: strongest, largest	10
LVR_SEL	2:1	R/W	Low Voltage Reset (LVR) Level selection bits **Be careful with the order of bit values.** 00 : 2.051V, 11 : 2.000V, 10 : 1.951V, 01 : 1.905V	01
LVR_EN	0	R/W	LVR Enable 0 : disable, 1 : enable	1

IVCON1 (0xAC)

IVCON1 mainly turns on and off IVC (Internal Voltage Control block) by fields[4:0] in special purpose.
However, it's used only by CHIP Maker in chip test mode. Those fields should be remained as they are.

BLDOUT field will be set '1' when VDD goes below the conditions set by IVCCON0.

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
BLDOUT	5	R	BLD(Battery Level Detector) output signal	0
RSVD	4:0	R/W	Reserved for factory test. **Don't make these bits set to '1' to avoid anything unexpected.**	0

WKUPSTAT (0xAD)

The field [7:4] of this register indicates which source is used for changing system state into normal mode from STOP mode. The field [7:4] of this register can be cleared by writing '1' per bit or by entering into STOP mode.

Name	Bit	R/W	Description	Reset
USB_WKUP	7	R/W	Wake-up by USB from STOP mode	0
EINT_WKUP	6	R/W	Wake-up by External Interrupt from STOP mode	0
RTC_WKUP	5	R/W	Wake-up by RTC from STOP mode	0
WDT_WKUP	4	R/W	Wake-up by Watchdog timer from STOP mode	0
RSVD	3:0	-	Reserved	-

PLLCON0 (0xAE)

PLL control, PLLCLK = EMCLK * (MDIV[5:0] +8) / (PDIV[3:0]+2) / ($2^{SDIV[1:0]}$)
The output frequency of the PLL is determined by the value PDIV, MDIV and SDIV fields. The reset value of PDIV, MDIV and SDIV generates 48MHz output frequency when input PXI is 12MHz. When PLL_EN bit is set, PLL clock will be generated after 300us (lockup time) when PXI is 12MHz. Especially, you want to use over 24MHz PLL clock for F_{SOURCE}, the fields CLKDIV in CLKCON register should be set over F_{SOURCE}/2. **This register will be only reset by PnRESET or LVDRST**.

Name	Bit	R/W	Description	Reset
PLL_STABLE	7	R	0: PLL unstable, 1: PLL stable	0
RSVD	6:5	-	Reserved	-
PLL_EN	4	R/W	0: PLL disable, 1: PLL enable	0
PDIV	3:0	R/W	PLL P value These bits can't be set "0"	0xA

PLLCON1 (0xAF)

This register will be only reset by PnRESET or LVDRST.

Name	Bit	R/W	Description	Reset
MDIV	7:2	R/W	PLL M value These bits can't be set 0	0x28
SDIV	1:0	R/W	PLL S value	0

Note: Although there is the equation for choosing PLL value, we strongly recommended only the values in the PLL value recommendation Table 4-2 below. If you have to use other value, please contact to us.

Table 4-2. PLL value Recommendation

FIN(MHz)	Target PLLCLK(MHz)	PDIV(decimal)	MDIV(decimal)	SDIV(decimal)
4	8	2	24	2
	12	2	40	2
	16	2	24	1
	20	2	32	1
	24	2	40	1
	48	2	40	0
6	8	4	24	2
	12	4	40	2
	16	4	24	1
	20	4	32	1
	24	4	40	1
	48	4	40	0
8	8	6	24	2
	12	6	40	2
	16	6	24	1
	20	6	32	1
	24	6	40	1
	48	6	40	0
12	12	10	40	2
	16	10	24	1
	20	10	32	1
	24	10	40	1
	48	10	40	0

5 INTERRUPT STRUCTURE

5.1 OVERVIEW

The BMC513 interrupt controller has a total of 28 interrupt sources. Each Interrupt request can be generated by internal function blocks or external interrupt pins.

Figure 5-1 shows how the IEx, IPx registers and the polling sequence work together to determine which interrupt will be served.

After reset, the CPU begins execution from location 0x0000. Each interrupt causes the CPU to jump to that location, where it commences execution of the service routine. If any interrupt is assigned to location 0x0003 and it is going to be used, its service routine must begin at location 0x0003. If the interrupt is not going to be used, its service location is available as general purpose program memory. The interrupt service locations are spaced at 8-byte intervals. If an interrupt service routine is short enough, it can reside entirely within that 8-byte interval. Longer service routines can use a jump instruction to skip over subsequent interrupt location, if other interrupt are in use.

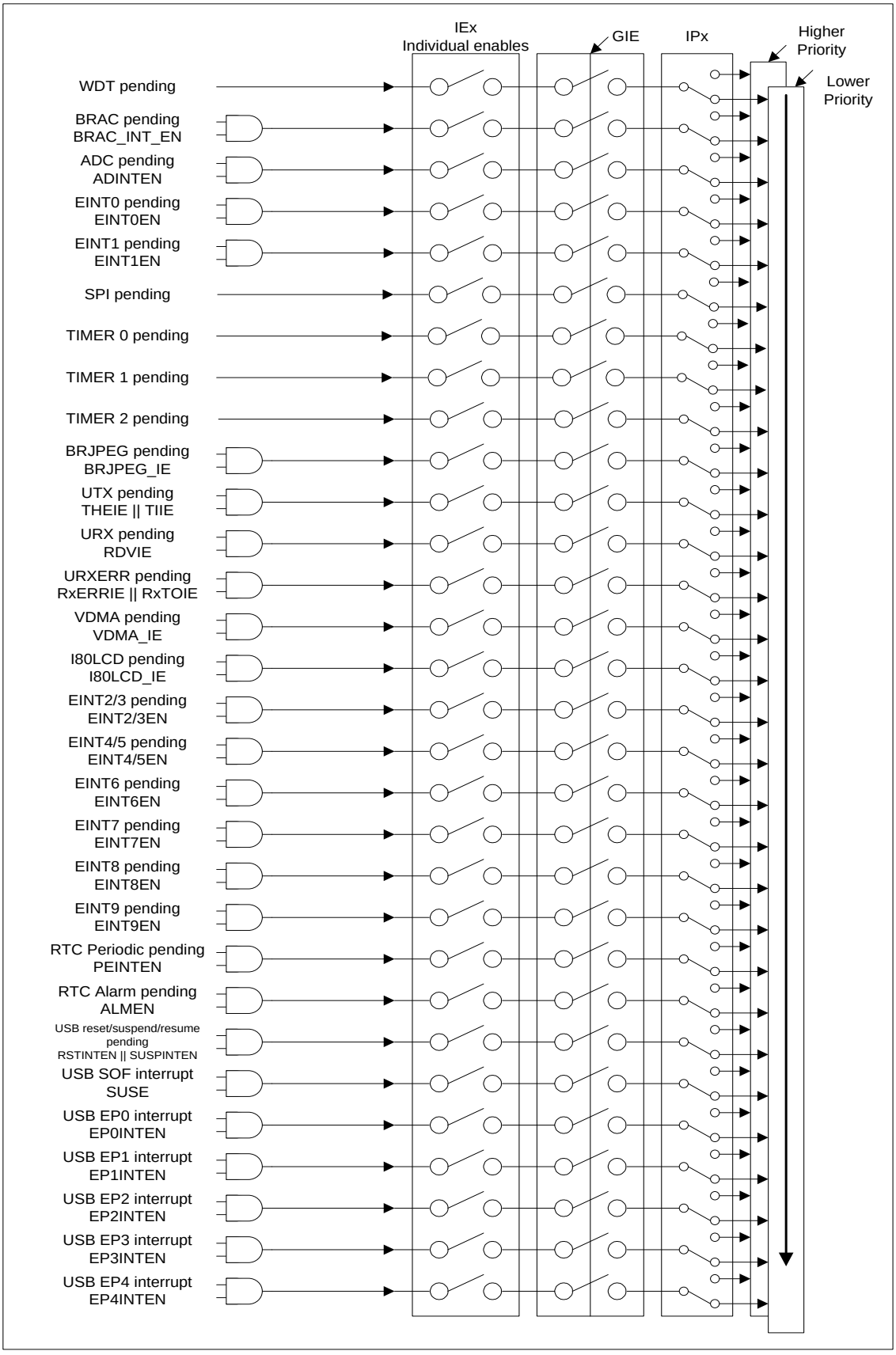


Figure 5-1. Interrupt Control System

5.2 Interrupt Priority

Each interrupt source can also be individually programmed to one of two priority levels by setting or clearing a bit in Special Function Register IPx. A low-priority interrupt can itself be interrupted by a high-priority interrupt, but not by another low-priority interrupt. A high-priority interrupt can't be interrupted by any other interrupt source.

If two requests of different priority levels are received simultaneously, the request of higher priority level is serviced. If requests of the same priority level are received simultaneously, smaller number of default priority value is serviced. Table 5-1 describes Interrupt Default Priority just after reset:

Table 5-1. Interrupt Default Priority

Default Priority (IPx = 0 or IPx = 1)	Source	Vector Address
	RESET	0000H
0 (Highest)	WDT Interrupt	0003H
1	BRAC® Interrupt	000BH
2	ADC Interrupt	0013H
3	External Interrupt 0	001BH
4	External Interrupt 1	0023H
5	SPI Interrupt	002BH
6	Timer 0 Interrupt	0033H
7	Timer 1 Interrupt	003BH
8	Timer 2 Interrupt	0043H
9	BRJPEG Interrupt	004BH
10	UART TX Interrupt	0053H
11	UART RX Interrupt	005BH
12	UART RX Error Interrupt	0063H
13	VDMA Interrupt	006BH
14	I80 Interrupt	0073H
15	External Interrupt 2/3	007BH
16	External Interrupt 4/5	0083H
17	External Interrupt 6	008BH
18	External Interrupt 7	0093H
19	External Interrupt 8	009BH
20	External Interrupt 9	00A3H
21	RTC Periodic interrupt	00ABH
22	RTC ALARM interrupt	00B3H
23	USB Device Reset/Suspend/Resume interrupt	00BBH
24	USB Device SOF interrupt	00C3H
25	USB Device Endpoint 0 interrupt	00CBH
26	USB Device Endpoint 1 interrupt	00D3H
27	USB Device Endpoint 2 interrupt	00DBH
28	USB Device Endpoint 3 interrupt	00E3H
29	USB Device Endpoint 4 interrupt	00EBH

5.3 Interrupt Handling

The interrupt flags are sampled at the end of instruction cycle. When an interrupt occurs, only the Program Counter is automatically pushed on to the stack area, not the PSW or any other registers.

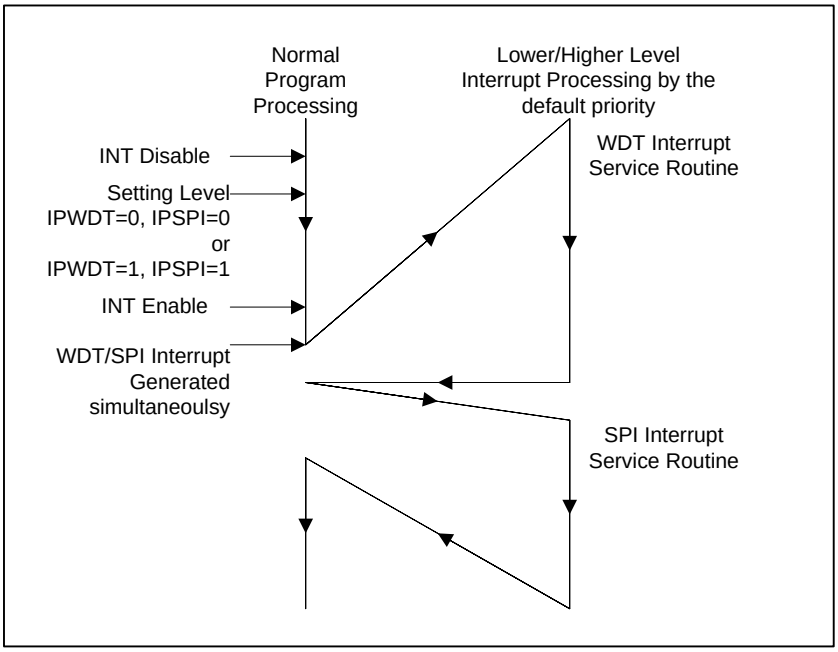


Figure 5-2. Handling Same Level of Interrupts

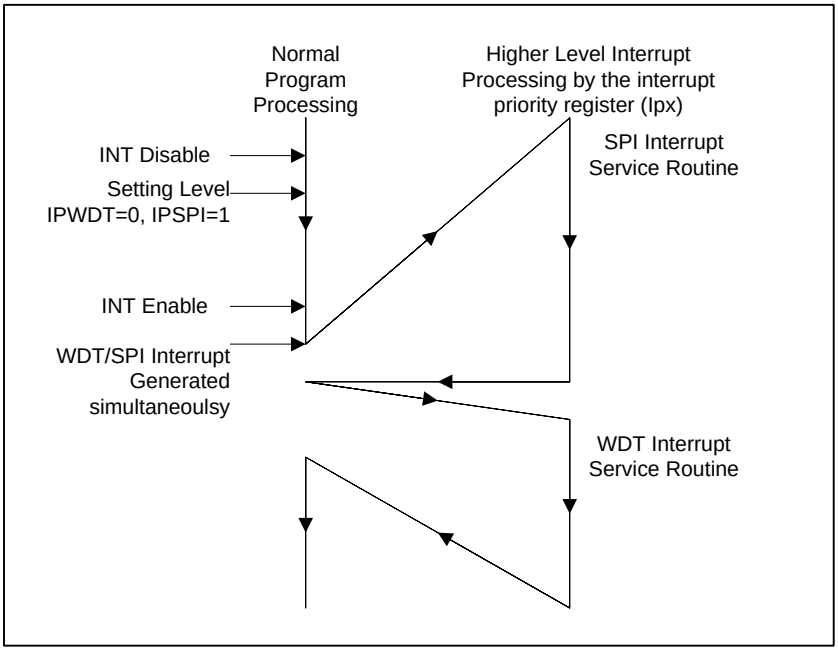


Figure 5-3. Handling Different Level of Interrupt (Higher Level is first issued)

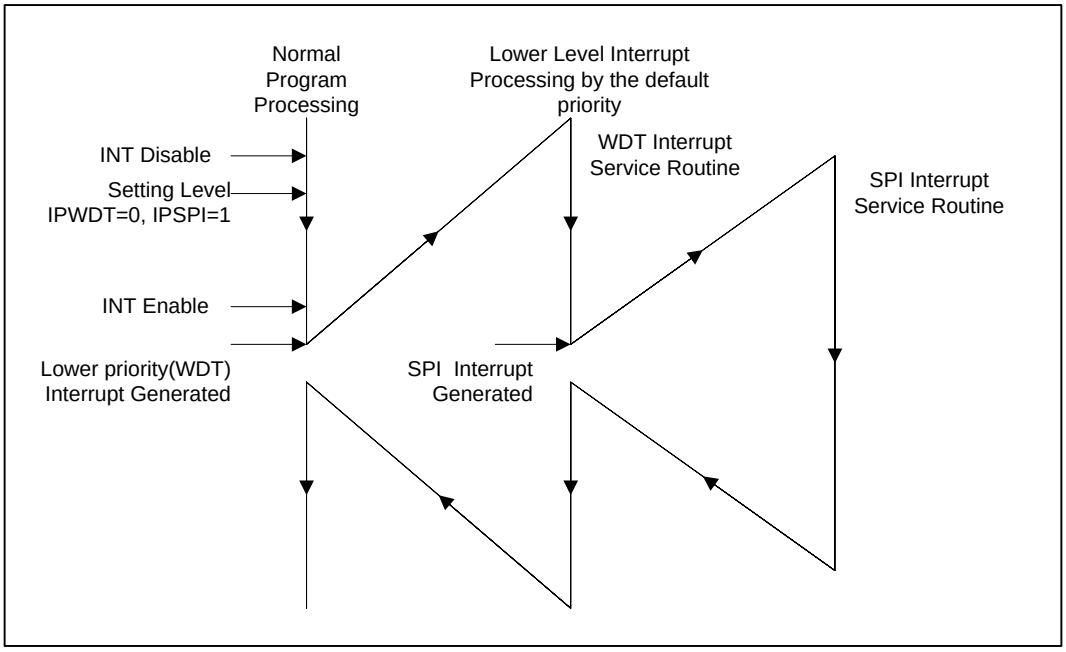


Figure 5-4. Handling Different Level Interrupts (Lower Level is first issued)

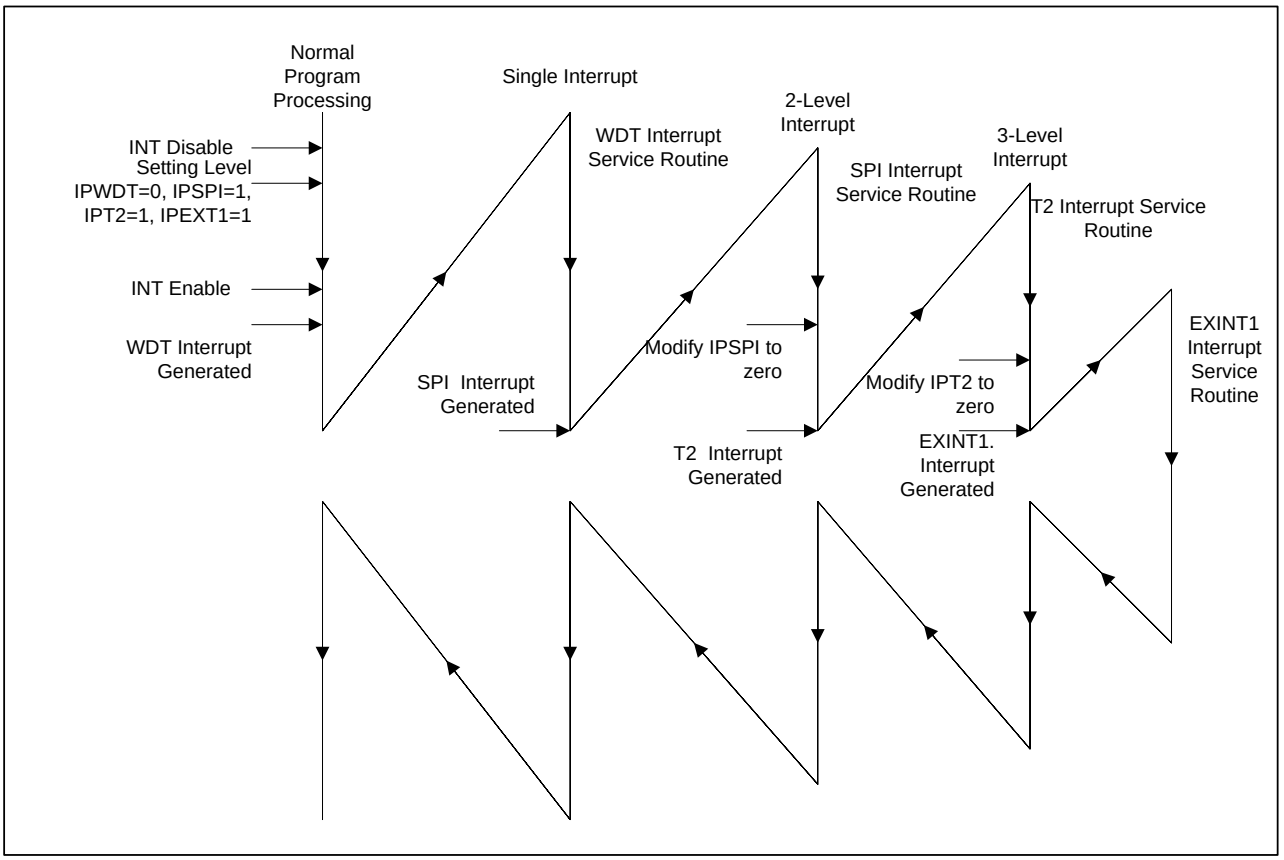


Figure 5-5. Handling Multiple Level Interrupts

5.4 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
GIE	0x91	R/W	Global Interrupt Enable	0x00
IE0	0x92	R/W	Interrupt Enable 0	0x00
IP0	0x93	R/W	Interrupt Priority 0 Register	0x00
IE1	0x94	R/W	Interrupt Enable 1	0x00
IP1	0x95	R/W	Interrupt Priority 1 Register	0x00
IE2	0x96	R/W	Interrupt Enable 2	0x00
IP2	0x97	R/W	Interrupt Priority 2 Register	0x00
IE3	0x99	R/W	Interrupt Enable 3	0x00
IP3	0x9A	R/W	Interrupt Priority 3 Register	0x00

GIE (0x91)

Name	Bit	R/W	Description	Reset
GIE	7	R/W	Global Interrupt Enable. 0: Disable All interrupt, 1: Enable All interrupt	0
RSVD	6:0	R	Reserved	0x00

IE0 (0x92)

Name	Bit	R/W	Description		Reset
IET1	7	R/W	0: Disable Timer 1 interrupt	1: Enable Timer 1 interrupt	0
IET0	6	R/W	0: Disable Timer 0 interrupt	1: Enable Timer 0 interrupt	0
IESPI	5	R/W	0: Disable SPI interrupt	1: Enable SPI interrupt	0
IEEXT1	4	R/W	0: Disable External interrupt 1	1: Enable External interrupt 1	0
IEEXT0	3	R/W	0: Disable External interrupt 0	1: Enable External interrupt 0	0
IEADC	2	R/W	0: Disable ADC interrupt	1: Enable ADC interrupt	0
IEBRAC	1	R/W	0: Disable BRAC® interrupt	1: Enable BRAC® interrupt	0
IEWDT	0	R/W	0: Disable Watch-dog timer interrupt	1: Enable Watch-dog timer interrupt	0

IP0 (0x93)

Interrupt Priority 0 register. IP0, IP1, IP2, and IP3 contain information for interrupt priority. Each IPx register value determines the priority of the corresponding interrupt source.
Default Priority: IPWDT > IPBRAC ···· IPU1TX > IPUSBEP4

Name	Bit	R/W	Description	Reset
IPT1	7	R/W	0: Lower priority level, 1: Higher priority level	0
IPT0	6	R/W	0: Lower priority level, 1: Higher priority level	0
IPSPI	5	R/W	0: Lower priority level, 1: Higher priority level	0
IPEXT1	4	R/W	0: Lower priority level, 1: Higher priority level	0
IPEXT0	3	R/W	0: Lower priority level, 1: Higher priority level	0
IPADC	2	R/W	0: Lower priority level, 1: Higher priority level	0
IPBRAC	1	R/W	0: Lower priority level, 1: Higher priority level	0
IPWDT	0	R/W	0: Lower priority level, 1: Higher priority level	0

IE1 (0x94)

Name	Bit	R/W	Description		Reset
IEEXT2_3	7	R/W	0: Disable External interrupt 2/3	1: Enable External interrupt 2/3	0
IEI80LCD	6	R/W	0: Disable I80LCD interrupt	1: Enable I80LCD interrupt	0
IEVDMA	5	R/W	0: Disable VDMA interrupt	1: Enable VDMA interrupt	0
IEURXERR	4	R/W	0: Disable UART RX Error interrupt	1: Enable UART RX Error interrupt	0
IEURX	3	R/W	0: Disable UART Receive interrupt	1: Enable UART Receive interrupt	0
IEUTX	2	R/W	0: Disable UART Transmit interrupt	1: Enable UART Transmit interrupt	0
IEBRJPEG	1	R/W	0: Disable JPEG interrupt	1: Enable JPEG interrupt	0
IET2	0	R/W	0: Disable Timer 2 interrupt	1: Enable Timer 2 interrupt	0

IP1 (0x95)

Name	Bit	R/W	Description	Reset
IPEXT2_3	7	R/W	0: Lower priority level, 1: Higher priority level	0
IPI80LCD	6	R/W	0: Lower priority level, 1: Higher priority level	0
IPVDMA	5	R/W	0: Lower priority level, 1: Higher priority level	0
IPURXERR	4	R/W	0: Lower priority level, 1: Higher priority level	0
IPURX	3	R/W	0: Lower priority level, 1: Higher priority level	0
IPUTX	2	R/W	0: Lower priority level, 1: Higher priority level	0
IPBRJPEG	1	R/W	0: Lower priority level, 1: Higher priority level	0
IPT2	0	R/W	0: Lower priority level, 1: Higher priority level	0

IE2 (0x96)

Name	Bit	R/W	Description	Reset
IEUSBRST	7	R/W	0: Disable USB reset/suspend/resume interrupt 1: Enable USB reset/suspend/resume interrupt	0
IERTCALM	6	R/W	0: Disable RTC ALARM interrupt 1: Enable RTC ALARM interrupt	0
IERTCPRI	5	R/W	0: Disable RTC Periodic interrupt 1: Enable RTC Periodic interrupt	0
IEEXT9	4	R/W	0: Disable External interrupt 9 1: Enable External interrupt 9	0
IEEXT8	3	R/W	0: Disable External interrupt 8 1: Enable External interrupt 8	0
IEEXT7	2	R/W	0: Disable External interrupt 7 1: Enable External interrupt 7	0
IEEXT6	1	R/W	0: Disable External interrupt 6 1: Enable External interrupt 6	0
IEEXT4_5	0	R/W	0: Disable External interrupt 4/5 1: Enable External interrupt 4/5	0

IP2 (0x97)

Name	Bit	R/W	Description	Reset
IPUSBRST	7	R/W	0: Lower priority level, 1: Higher priority level	0
IPRTCALM	6	R/W	0: Lower priority level, 1: Higher priority level	0
IPRTCPRI	5	R/W	0: Lower priority level, 1: Higher priority level	0
IPEXT9	4	R/W	0: Lower priority level, 1: Higher priority level	0
IPEXT8	3	R/W	0: Lower priority level, 1: Higher priority level	0
IPEXT7	2	R/W	0: Lower priority level, 1: Higher priority level	0
IPEXT6	1	R/W	0: Lower priority level, 1: Higher priority level	0
IPEXT4_5	0	R/W	0: Lower priority level, 1: Higher priority level	0

IE3 (0x99)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
IEUSBEP4	5	R/W	0: Disable RTC Periodic interrupt 1: Enable RTC Periodic interrupt	0
IEUSBEP3	4	R/W	0: Disable External interrupt 7 1: Enable External interrupt 7	0
IEUSBEP2	3	R/W	0: Disable External interrupt 6 1: Enable External interrupt 6	0
IEUSBEP1	2	R/W	0: Disable External interrupt 5 1: Enable External interrupt 5	0
IEUSBEP0	1	R/W	0: Disable External interrupt 4 1: Enable External interrupt 4	0
IEUSBSOF	0	R/W	0: Disable External interrupt 3 1: Enable External interrupt 3	0

IP3 (0x9A)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
IPUSBEP4	5	R/W	0: Lower priority level, 1: Higher priority level	0
IPUSBEP3	4	R/W	0: Lower priority level, 1: Higher priority level	0
IPUSBEP2	3	R/W	0: Lower priority level, 1: Higher priority level	0
IPUSBEP1	2	R/W	0: Lower priority level, 1: Higher priority level	0
IPUSBEP0	1	R/W	0: Lower priority level, 1: Higher priority level	0
IPUSBSOF	0	R/W	0: Lower priority level, 1: Higher priority level	0

6 BRAC® CODEC

The BMC513 has Audio decoder/encoder (Embedded hardwired ADPCM based Voice Codec).

6.1 FEATURES

- 3/4 bit decoder
- 3/4 bit encoder
- 3-up interpolation filter
- DMA for internal e-FLASH and external serial FLASH
- Sampling Frequency Generation by DCO (Digital Controller Oscillator)

6.2 OPERATION

Voice Encoding (Compressing) sequence using Power Studio

All the voice data to be played should be stored in flash memory. The voice data can be stored into internal flash memory (e-FLASH) or external serial flash memory. Each of flash memory can be distinguished by the value of DATA_SRC in BRAC_CTRL2 register.

Before playing the voice data in the user program, user should prepare the compressed voice data and store it into flash memory as follows. For more details, please refer to Power Studio User's Manual.

This example is the default samples included in Power Studio.
Open the project. (Project -> Open project… -> SimpleVoice/SimpleVoice.prj)
If the default project (SimpleVoice) is opened, then step 1 to 3 in the following procedure can be skipped.

1. Prepare the waveform (.wav file) to be encoded.
2. Include the waveform into Wav File Folder in the project through "Add files to project" in Project Menu.
3. Edit the waveform (Cut, Paste, Delete, Copy) and test it with Play, Stop and re-sampling command in tool bar.
4. Build -> "Build Brac" in Menu.
   A. Choose the order of waveform and Compression ratio (3bit, 4bit).
   B. All the information for this compression is stored into 2 files with the name of "project_name.brc" and "project_name.h", which are located in the chosen directory.
   C. Fill the blank in Memory start address of BRAC Data
   D. Press "Build" button. If any error, check the size of compressed voice data.
5. Download the compressed data ("project_name.brc" into e-FLASH.
   A. Tools -> "Brac Data Writing" in Menu.
   B. Choose type of flash memory (internal e-FLASH or external Serial Flash
   C. Type the same address as the start address (written in 4-C step) in the range of the chosen flash memory (for this example, 0x7FFF). "-1" of End address means "Download all the data to the end of file."
   D. Download and verify.

File Format of project_name.h

Let's assume the name of waveform files are as follows:

```
/* 0*/    "chord_16K_mono.wav"
/* 1*/    "ding_16K_mono.wav"
/* 2*/    "notify_16K_mono.wav"
/* 3*/    "ringin_8K_mono.wav"
```

```
/* 4*/      “ringout_8K_mono.wav”
/* 5*/      “tada_16K_mono.wav”
/* 6*/      “Chimes_16K_mono.wav”
/* 7*/      “chinese_part_16_mono0.wav”
/* 8*/      “chinese_part_16_mono0_3.wav”
/* 9*/      “number_0.wav”
/*10*/      “number_1.wav”
/*11*/      “number_2.wav”
/*12*/      “number_3.wav”
/*13*/      “number_4.wav”
/*14*/      “number_5.wav”
/*15*/      “number_6.wav”
/*16*/      “number_7.wav”
/*17*/      “number_8.wav”
/*18*/      “number_9.wav”
/*19*/      “number_10.wav”
```

The generated header file for BRAC® includes the enumeration of file name, the start address and the size of each compressed voice data.

```
#if     1       // only English file name cane be enumerated.
enum {
                _chord_16K_mono,                        //16000Hz, 4Bit
                _ding_16K_mono,                         //16000Hz, 4Bit
                _notify_16K_mono,                       // 8000Hz, 4Bit
                _ringin_8K_mono,                        // 8000Hz, 4Bit
                _ringout_8K_mono,                       // 8000Hz, 4Bit
                _tata_16K_mono,                         //16000Hz, 4Bit
                _Chimes_16K_mono,                       //16000Hz, 4Bit
                _chinese_part_16_mono0,                 //16000Hz, 4Bit
                _chinese_part_16_mono0_3,               //16000Hz, 4Bit
                _number_0,                              //16000Hz, 4Bit
                _number_1,                              //16000Hz, 4Bit
                _number_2,                              //16000Hz, 4Bit
                _number_3,                              //16000Hz, 4Bit
                _number_4,                              //16000Hz, 4Bit
                _number_5,                              //16000Hz, 4Bit
                _number_6,                              //16000Hz, 4Bit
                _number_7,                              //16000Hz, 4Bit
                _number_8,                              //16000Hz, 4Bit
                _number_9,                              //16000Hz, 4Bit
                _number_10,                             //16000Hz, 4Bit
};
#endif

Const struct _FileInfo {
                char            *FileName;
                unsigned int    Fs;
                unsigned char   Nbit;
} FileInfo[] = {
                /* 0*/      {“chord_16K_mono.wav”, 16000, 4},
                /* 1*/      {“ding_16K_mono.wav”, 16000, 4},
                /* 2*/      {“notify_16K_mono.wav”, 16000, 4},
                /* 3*/      {“ringin_8K_mono.wav”, 8000, 4},
                /* 4*/      {“ringout_8K_mono.wav”, 8000, 4},
                /* 5*/      {“tada_16K_mono.wav”, 16000, 4},
                /* 6*/      {“Chimes_16K_mono.wav”, 16000, 4},
                /* 7*/      {“chinese_part_16_mono0.wav”, 16000, 4},
                /* 8*/      {“Chinese_part_16_mono0_3.wav”, 16000, 4},
                /* 9*/      {“number_0.wav”, 16000, 4},
                /*10*/      {“number_1.wav”, 16000, 4},
                /*11*/      {“number_2.wav”, 16000, 4},
                /*12*/      {“number_3.wav”, 16000, 4},
                /*13*/      {“number_4.wav”, 16000, 4},
                /*14*/      {“number_5.wav”, 16000, 4},
                /*15*/      {“number_6.wav”, 16000, 4},
```

```
                /*16*/      {“number_7.wav”, 16000, 4},
                /*17*/      {“number_8.wav”, 16000, 4},
                /*18*/      {“number_9.wav”, 16000, 4},
                /*19*/      {“number_10.wav”, 16000, 4},
}

const unsigned char FilePos[] = {
                        //  addrh addrm addrl sizeh sizel
                /* 0*/      0x01, 0x00, 0x00, 0x22, 0x6b,
                /* 1*/      0x01, 0x22, 0x6c, 0x1c, 0xad,
                /* 2*/      0x01, 0x3f, 0x1a, 0x2a, 0x5c,
                /* 3*/      0x01, 0x69, 0x77, 0x0e, 0x2c,
                /* 4*/      0x01, 0x77, 0xa4, 0x07, 0x56,
                /* 5*/      0x01, 0x7e, 0xfb, 0x3c, 0xb9,
                /* 6*/      0x01, 0xbb, 0xb5, 0x13, 0xc5,
                /* 7*/      0x01, 0xcf, 0x7b, 0xea, 0x96,
                /* 8*/      0x02, 0xba, 0x12, 0xea, 0x96,
                /* 9*/      0x03, 0xa4, 0xa9, 0x0f, 0xa3,
                /*10*/      0x03, 0xb4, 0x4d, 0x0c, 0xef,
                /*11*/      0x03, 0xc1, 0x3d, 0x0c, 0x3c,
                /*12*/      0x03, 0xcd, 0x7a, 0x0d, 0x75,
                /*13*/      0x03, 0xda, 0xf0, 0x0e, 0x6b,
                /*14*/      0x03, 0xe9, 0x5c, 0x0e, 0xeb,
                /*15*/      0x03, 0xf8, 0x48, 0x0d, 0x7e,
                /*16*/      0x04, 0x05, 0xc7, 0x0b, 0xcb,
                /*17*/      0x04, 0x11, 0x93, 0x0a, 0xf7,
                /*18*/      0x04, 0x1c, 0x8b, 0x10, 0x10,
                /*19*/      0x04, 0x2c, 0x9c, 0x08, 0x2f
}
```

The voice compressed data can be stored into any address of flash memory. User can define the address in the Power Development Studio tool. For this example, it is assumed that the address starts from 0x7FFF.

The **FileInfo** information includes **the string data of waveform file name**, **sampling frequency** and **compression format**.

The **FilePos** information includes **the start address and the size** of each voice compressed data. These data are required to play the voice for the BMC513. The address is consisted of three byte and the size is two bytes.

[select the range of waveform by mouse drag] > [Wave / create new waveform with select].

If the 3-bit compression is selected, then higher compression algorithm is selected and the file size of compression data becomes smaller than 4-bit compression. And to provide the compression type, the selected compression algorithm is listed in FileInfo variables.

The lower sampling frequency causes the smaller compressed data. But in this case, the quality of voice sound can be degraded so that careful editing the wave file is required.

Decoding the compressed voice data

Sentence Index	C Programming

	void PlayNext();
	{
	int PlayAddr;
	const UCHAR*fPos; // Pointer variable of FilePos[]
	
	PlayAddr = _chord_16k_mono * 5; // Let’s Play _chord_16K_mono

A	Setting BRAC_CTRL2
	fPos = FilePos + PlayAddr;

B	rBRAC_START_ADRH = *fPos++; // Set the Start Address
	rBRAC_START_ADRM = *fPos++; // of BRAC® Compressed Data
	rBRAC_START_ADRL = *fPos++;
	
	rBRAC_SIZEM = *fPos++; // Set Size of BRAC® Compressed Data
	rBRAC_SIZEL = *fPos++;

C	rDCOH = 0x02; // Set DCO Value
	rDCOL = 0x0C; // Fs=16KHz, F_{SOURCE}=12Mhz, Upsampling

D	If (FileInfo[_chord_16k_mono] == 4)
	rBRAC_CTRL = 0x81 // 4 Bit BRAC® Starts
	Else
	rBRAC_CTRL = 0x89 // 3 Bit

	}

This sample code describes how to play a voice "_chord_16K_mono". To play the voice,

1. BRAC initialization is done like Sentence Index A.
2. BRAC Start Address and the size like Sentence Index B.
3. DCO_VAL like Sentence Index C.
4. Depending on the compressed data, BRAC® Starting Command is set. In the above case, the voice data "_chord_16K_mono " is compressed into 4 Bit. So the 4-Bit compression is selected like Sentence Index E.

Using Interrupt Service routine for BRAC® decoding

BRAC® decoding starts immediately after the setting of BRAC_CTRL as 0x81 or 0x89. And the end of BRAC® decoding can be detected by "polling" or "interrupt" method. The **polling** means BMC513 should check the BRAC_SIZEx register whether it's value becomes zero or not. Zero value means all the BRAC® data is decoded and no more data is remained to be played. But this operation requires the operational load of the BMC513 and spends more power. Instead of this, the **interrupt** method is simple and easy to check the end of BRAC® decoding.

Sentence Index	C Programming
A	void BracDmaInt() interrupt 1 // using interrupt service routine "1"
	{
B	rBRAC_INT_PEND |= BRAC_PEND;
	PlayNext(); }
	void BracDmaTest() {
C	rIE0 |= IEBRAC; rGIE = 0x80;
	PlayNext(); }

BRAC® interrupt is assigned to Interrupt 1 as like Sentence Index A. The syntax "interrupt 1" gives the interrupt information to the C compiler and the interrupt vector table is generated automatically at address 0x0B by C compiler. And the interrupt should be enabled like Sentence Index C in the initialization routine. And in the interrupt service routine, the interrupt pending vector should be cleared like Index B.

Playing Mute

If there needs mute period between two waveforms, then MUTE command can be used for it. The mute period can be calculated with BRAC_SIZEx and DCOL/DCOH.

Ex) For 1 seconds muting, Assumption: F_{SOURCE} = 12MHz, and upsampling
DCO_VAL = 0x20C (16KHz)
BRAC_SIZE = 1 / Sampling Time
= 1 / (1 / 16000)
= 16000 = 0x3e80

Sentence Index	C Programming

A	rBRAC_SIZEM = 0x3e; // Set Size of MUTE period
	rBRAC_SIZEL = 0x80
	
	rDCOH = 0x2;
	
	rDCOL = 0x0C;
	
	rBRAC_CTRL = 0x40; // MUTE Command

DCO (Selecting the sampling frequency for playing)

The BMC513 can generate all kinds of sampling frequency depending on the value of DCOL/DCOH register. So, the proper DCOL/DCOH is selected depending on the waveform sampling frequency. The value of DCOL/DCOH can be calculated as follows.

{rDCOH, rDCOL} = Fs * 2^{17} * 3 / Fin for upsampling output Given Fs=16KHz and F_{SOURCE}=12MHz, then rDCOH = 0x2, rDCOL = 0x0C
{rDCOH, rDCOL} = Fs * 2^{17} / Fin for non-upsampling output Given Fs=16KHz and F_{SOURCE}=12MHz, then {rDCOH, rDCOL} = 0xAE

Fs is the desired output sampling frequency. And F_{SOURCE} is the operating frequency (described in chapter 4).

DC level shifting and Pause Operation

When the BMC513 is reset or power on, the DAC output signal has zero Voltage. But the DAC output pin should have VOmax/2 offset before playing a waveform. For this operation, the BMC513 supports the DC level shifting by hardware. The basic concept of DC level shifting is as Figure 6-1.

Duration Time = 1024 / Fs(Sampling Frequency)

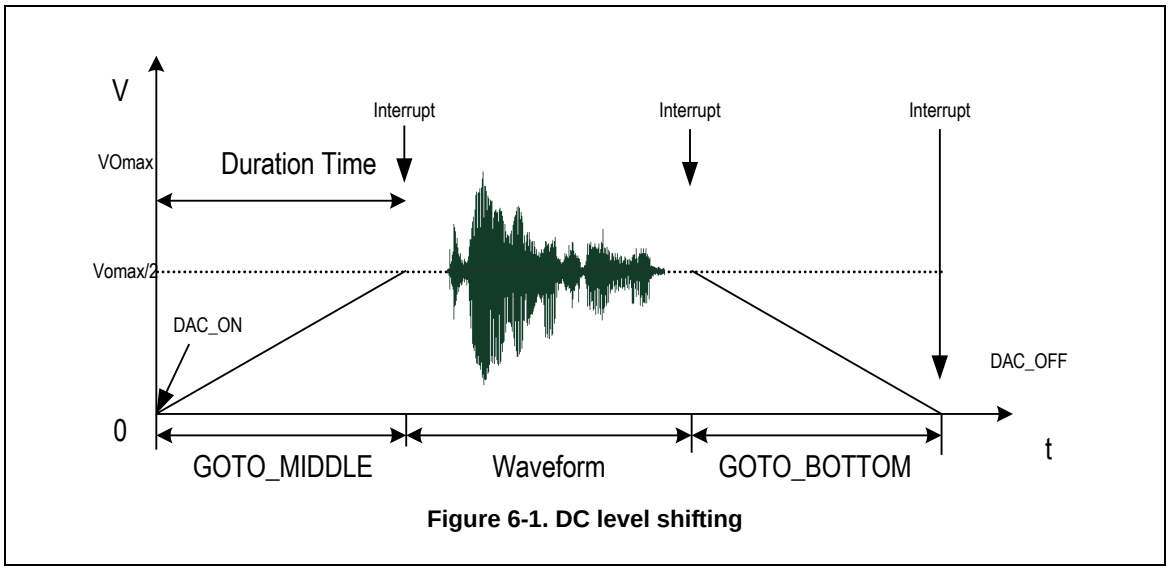


Figure 6-1. DC level shifting

Before playing a waveform, GOTO_MIDDLE should be issued like sentence index A in the following table

Sentence Index	C Programming

A	rDCOH = 0x0;
	rDCOL = 0x80;
	
	BRAC_CTRL = 0x20; // GOTO_MIDDLE

After the end of playing waveforms, if the BMC513 don't need to play any more waveform, then the voltage of DAC is better go to bottom (Zero Volt) with command with GOTO_BOTTOM.

The speed of increment and decrement depends on the value of DCOL/DCOH. The calculation of this value is same as normal waveform.

Playing normal PCM data

The BMC513 supports the direct output of PCM data to DAC. The control sequence of sine wave is as follows.

Sentence Index	C Programming

A	const char BracDirectPcm_Sine[] =
	{
	0x00, 0xf0, 0x18, 0x0f, 0x13, 0x47, 0xa8, 0x65,
	0x6a, 0x64, 0x87, 0x7d, 0xff, 0x87, 0x7d, 0x64,
	0x67, 0x6a, 0xa8, 0x15, 0x47, 0x0f, 0xf3, 0x18,
	0x00, 0x00, 0xe7, 0xf0, 0xec, 0xb8, 0x57, 0x9a,
	0x95, 0x9c, 0x78, 0x82, 0x00, 0x78, 0x82, 0x9c,
	0x98, 0x95, 0x57, 0xea, 0xb8, 0xf0, 0x0c, 0xe7,
	0x00, 0xf0, 0x18, 0x0f, 0x13, 0x47, 0xa8, 0x65,
	0x6a, 0x64, 0x87, 0x7d, 0xff, 0x87, 0x7d, 0x64,
	0x67, 0x6a, 0xa8, 0x15, 0x47, 0x0f, 0xf3, 0x18,
	0x00, 0x00, 0xe7, 0xf0, 0xec, 0xb8, 0x57, 0x9a,
	0x95, 0x9c, 0x78, 0x82, 0x00, 0x78, 0x82, 0x9c,
	0x98, 0x95, 0x57, 0xea, 0xb8, 0xf0, 0x0c, 0xe7,
	0x00, 0xf0, 0x18, 0x0f, 0x13, 0x47, 0xa8, 0x65,
	0x6a, 0x64, 0x87, 0x7d, 0xff, 0x87, 0x7d, 0x64,
	0x67, 0x6a, 0xa8, 0x15, 0x47, 0x0f, 0xf3, 0x18,
	0x00, 0x00, 0xe7, 0xf0, 0xec, 0xb8, 0x57, 0x9a,
	0x95, 0x9c, 0x78, 0x82, 0x00, 0x78, 0x82, 0x9c,
	0x98, 0x95, 0x57, 0xea, 0xb8, 0xf0, 0x0c, 0xe7
	}

	rBRAC_SIZEM = 0;
	rBRAC_SIZEL = 0x2f; // should be size – 1
	
	rBRAC_START_ADRH = 0;
	rBRAC_START_ADRM = (UCHAR)(((UINT)BracDirectPcm_Sine&0xff00)>>8);
	rBRAC_START_ADRL = (UCHAR)((UINT)BracDirectPcm_Sine&0xff);

B	rBRAC_CTRL = 0x87;

The PCM output is very simple. The size and the address of PCM sample is set first and BRAC_CTRL is set as 0x87.

The PCM data can be stored in any position of memory. This means the data can be located in the area of program memory or data memory. Above example shows the data is stored in program memory as the variable type of “const char”.

The format of PCM sample is 12 bit and all the data should be concatenated. The following program shows how to generate the PCM samples of sine table. The byte order can be easily understood.

Sentence Index	C Programming

	For(i=0; i<0x2000; i+=2)
	{
	ddd = (unsigned short)(sin(i*1.0*PI/16.0)*0x7fff);
	fprintf(fp, “%c”, (ddd&0xff0)>>4);
	
	ddd1 = (unsigned short)(sin((i+1)*1.0*PI/16.0)*0x7fff);
	fprintf(fp, “%c”, ((ddd&0xf000)>>12) + (ddd1&0xf0));
	fprintf(fp, “%c”, ((ddd1&0xff00)>>8));
	}

Reducing the total size of compressed data

If the total size of compress data is larger than the allowed memory space, then programmer should decrease its size. **Power Studio** provides two kinds of scheme for this.

1. Resample the voice data into lower sampling frequency
   [Open Waveform] > [Wave / Re-sampling] > [Select Sampling Frequency]
2. Split the wave into several waves and remove the mute period between the waves.

Ex)

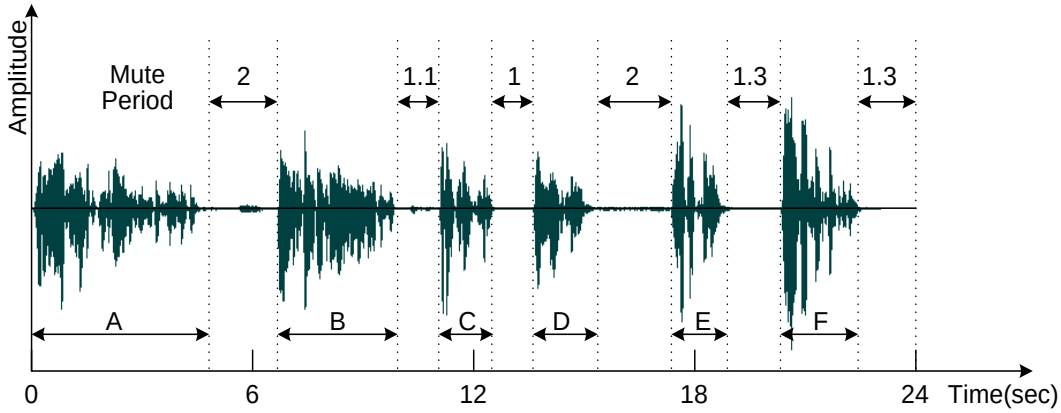


Figure 6-2. The Playing Time of the Waveform

As Figure 6-2, the playing time of the waveform is about 24 seconds and the total sum of mute period is over 8.7 seconds. If the waveform is split into 6 waveforms(A,B,C,D,E and F) which are compressed separately and mute period is replaced with MUTE command, then about 36% of voice data can be reduced.

Volume Control

The BMC513 has digital volume and it can be controlled through register “VOLUME”. It effects immediately after setting. Therefore, during the sound output from the BMC513, changing the level of volume with the big difference value compared to the previous one may cause noise.

Digital Low pass filtering and Upsampling

The BMC513 has digital low pass filter inside of the chip called “upsampling” function. This low pass filter up-samples three times from original waveform, which means the sound quality is improved a lot without the implementation of analog filter outside of the chip. Even though programmer selects the upsampling function, the voice data don’t need to be changed. But if up-sampling function is selected, then the BRAC_DCO_VALx should be set with 3 times larger value than the original value.

Sentence Index	C Programming

	#define UPSAMPLING
	
	#ifdef UPSAMPLING
	rDAC_CTL = 1; // 3x up-sampling On
	#else
	rDAC_CTL = 3; // 3x up-sampling Off
	#endif

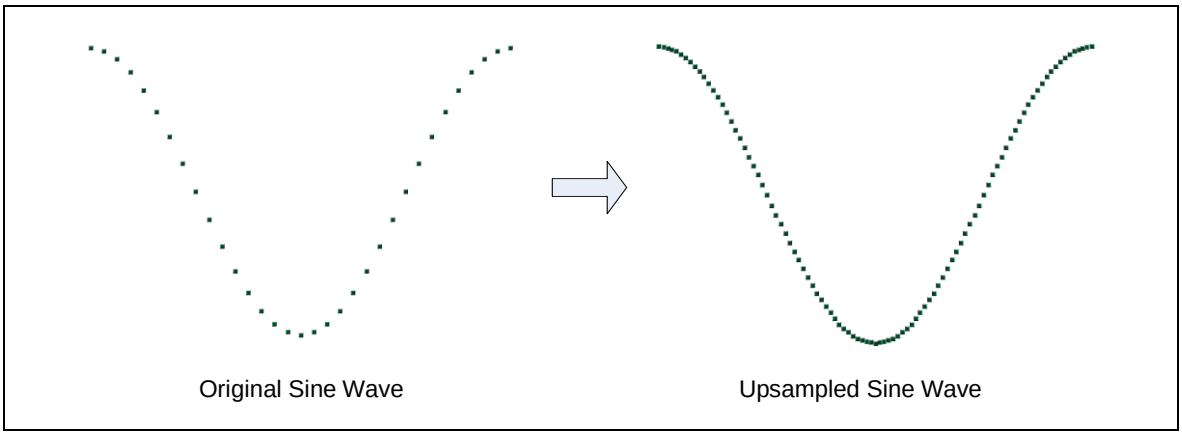


Figure 6-3. 3x Up-sampling

IBB (Input Bit stream Buffer) Mode

The BMC513 supports BRAC data read from X-RAM instead of voice data memories. This is very useful for NAND flash devices because of direct playback in X-RAM. In other words, BRAC DMA reads BRAC data from X-RAM instead of e-FLASH or external serial flash.

The size of IBB for each channel is 256 Bytes. For this mode, some of X-RAM area should be reserved for IBB mode. And the start address of IBB can be set by lower 13 bit of BRAC_START_ADR at each channel.

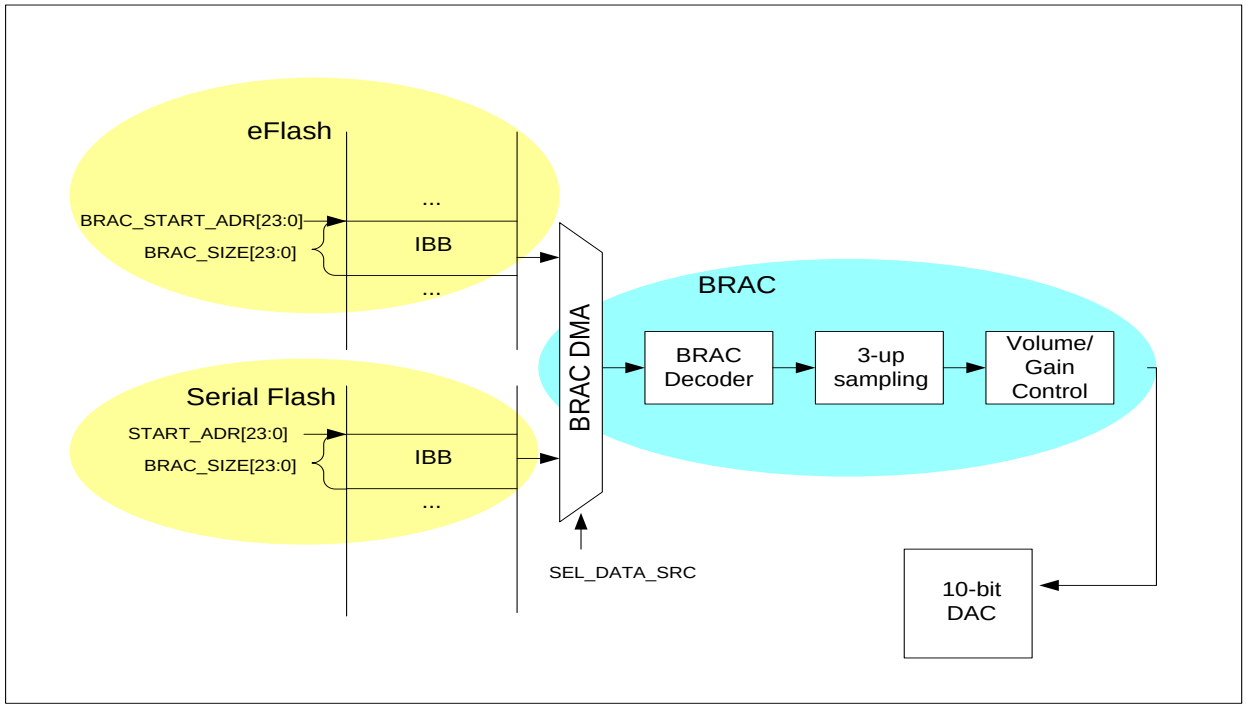


Figure 6-4. BRAC Decoder Decoding Scheme(Normal Play Mode)

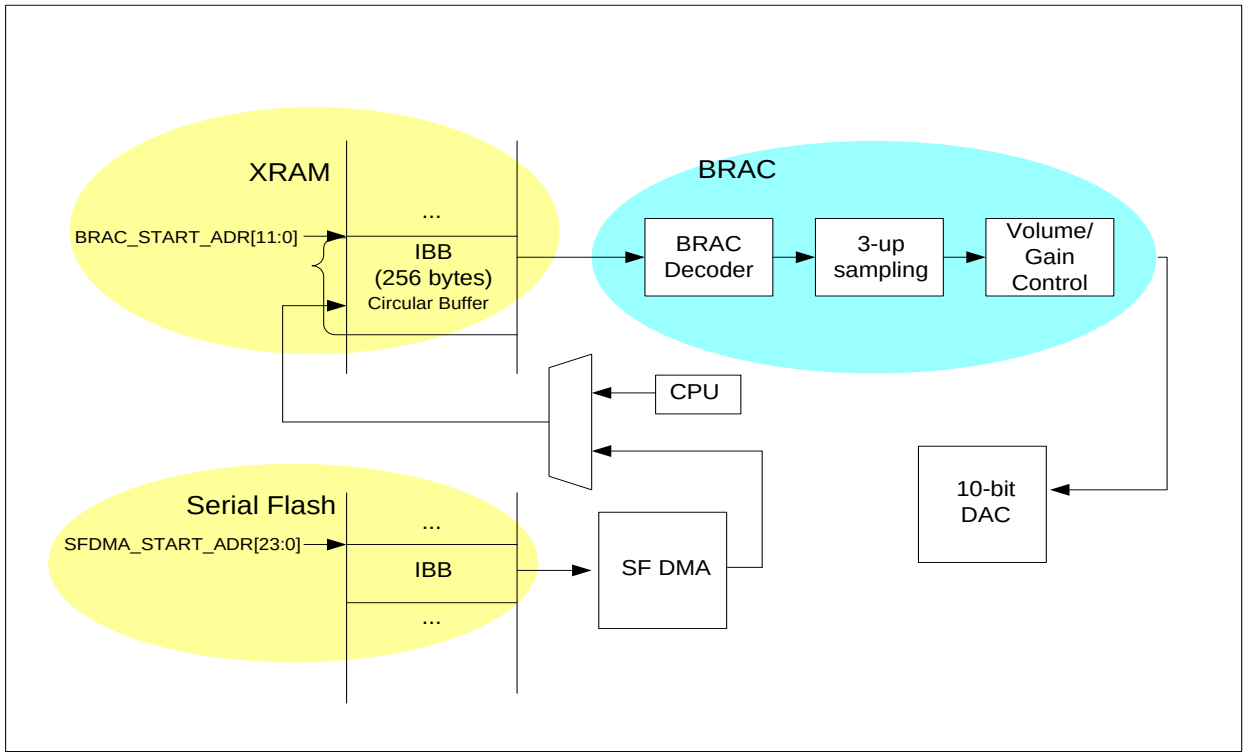


Figure 6-5. BRAC Decoder Decoding Scheme(IBB Play Mode)

6.3 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
BRAC_CTRL	0xFF00	R/W	Control Register for BRAC®	0x00
BRAC_CTRL2	0xFF01	R/W	Control Register2 for BRAC®	0x00
BRAC_INT_EN	0xFF02	R/W	BRAC® Interrupt enable Register	0x00
BRAC_INT_PEND	0xFF03	R/W	BRAC® Interrupt pending Register	0x00
BRAC_START_ADRL	0xFF04	W	Low Byte of BRAC® Start Address for decoding compressed data.	Undef.
BRAC_START_ADRM	0xFF05	W	Middle Byte of BRAC® Start Address for decoding compressed data.	Undef.
BRAC_START_ADRH	0xFF06	W	High Byte of BRAC® Start Address for decoding compressed data	Undef.
BRAC_SIZEL	0xFF07	W	The data amount to be read from internal e-FLASH or external serial FLASH	0x00
BRAC_SIZEM	0xFF08	W	The data amount to be read from internal e-FLASH or external serial FLASH	0x00
BRAC_SIZEH	0xFF09	W	The data amount to be read from internal e-FLASH or external serial FLASH	0x00
BRAC_IBB_READ_PTR	0xFF0A	R	IBB Read Pointer for Channel 0	0x00
BRAC_CMD_ADDR	0xFF0B	R/W	Command address for BRAC® Decoding and Encoding	Undef.
BRAC_CMD_DATA	0xFF0C	R/W	Command data for BRAC® Decoding and Encoding	Undef.
BRAC_BUFF	0xFF0D	W	Buffer for BRAC® Decoding	Undef.
BRAC_CTRL3	0xFF0E	R/W	Control Register3 for BRAC®	0x00
BRAC_ENC_CTRL	0xFF10	R	BRAC® Encoder Status Register	0x00
BRAC_ENC_SAMPLE_L	0xFF11	W	BRAC® Encoder Sample Low Register	Undef.
BRAC_ENC_SAMPLE_H	0xFF12	W	BRAC® Encoder Sample High Register	Undef.
BRAC_ENC_RESULT	0xFF13	R	BRAC® Encoder Result Register	Undef.
DAC_CTL	0xFF18	R/W	DAC Control Register	0x0C
DACOUT_L	0xFF19	R/W	DAC Low Output Register	0x00
DACOUT_H	0xFF1A	R/W	DAC High Output Register	0x00
VOLUME	0xFF1B	W	Volume Control Register in Decoding Mode. Auto Gain Control Register in Encoding Mode	0xFF
DCOL	0xFF1C	W	DCO Low Register	0x00
DCOH	0xFF1D	W	DCO High Register	0x00

Note) These registers have to be accessed using **MOVX** instruction.

BRAC_CTRL (0xFF00)

Name	Bit	R/W	Description	Reset
DMA_EN	7	R/W	1: Enable DMA operation This bit must set to '1' for audio playing	0
SIL_EN	6	R/W	1: Silence Start , size with BRAC_SIZEx **This bit generates interrupt when operation is completed.**	0
GO_MID	5	R/W	1: Bring the Output DAC level to VOmax/2 from zero **This bit generates interrupt when operation is completed.**	0
GO_BOT	4	R/W	1: Bring the Output DAC level to zero from VOmax/2 **This bit generates interrupt when operation is completed.**	0
B3BIT_EN	3	R/W	0: Enable 4bit BRAC® Decoding 1: Enable 3bit BRAC® Decoding	0
RSVD	2	R	Reserved	0
DIR_PCM_EN	1	R/W	1: Enable Direct PCM output	0
BRAC_EN	0	R/W	1: Start the BRAC® Decoding **This bit generates interrupt when operation is completed.** **SIL_EN, GO_MID, GO_BOT and BRAC_EN bits should be asserted exclusively. Only one bit should be asserted at one time.**	0

BRAC_CTRL2 (0xFF01)

BRAC Control Register 2

Name	Bit	R/W	Description	Reset
XRAM_IBB_EN	7	R/W	XRAM IBB Enable bit. 1 : BRAC raw data is from XRAM pointed by BRAC_START_ADR 0 : BRAC raw data is from internal Flash or serial Flash.	00
RSVD	6:2	R/W	Reserved	0
ENC_MODE	1	R/W	BRAC Encoding Mode Enable 0: BRAC decoding, 1: BRAC encoding BRAC encoding is initialized when 1 is written to this bit. This bit should be set whenever BRAC encoding starts.	0
DATA_SRC	0	R/W	This bit determines where the BRAC raw data resides. 1 : External serial FLASH data used for BRAC decoding. 0 : Internal embedded FLASH used for BRAC decoding.	0

BRAC_INT_EN (0xFF02)

BRAC Interrupt Mask register

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
IBB_MASK	1	R/W	IBB half empty interrupt enable register 1 : Enable, 0 : Disable	0
BRAC_MASK	0	R/W	BRAC interrupt enable register 1 : Enable, 0 : Disable	0

BRAC_INT_PEND (0xFF03)

BRAC Interrupt Pending register

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
IBB_PEND	1	R/W	IBB half empty interrupt pending register IBB half empty interrupt makes this bit 1. When this bit is set, pending bit is cleared.	0
BRAC_PEND	0	R/W	BRAC interrupt pending register. BRAC interrupt makes this bit 1. When this bit is set, pending bit is cleared.	0

BRAC_START_ADRL (0xFF04), BRAC_START_ADRM (0xFF05), BRAC_START_ADRH (0xFF06)

BRAC_START_ADR[23:0] registers is increasing by 1 after starting BRAC® decoding automatically.

Name	Bit	R/W	Description	Reset
STARTADRL	7:0	W	The start address bit [7:0] for BRAC® decoding	Undef.

Name	Bit	R/W	Description	Reset
STARTADRM	7:0	W	The start address bit [15:8] for BRAC® decoding	Undef.

Name	Bit	R/W	Description	Reset
STARTADRH	7:0	W	The start address bit [23:16] for BRAC® decoding	Undef.

BRAC_SIZEL (0xFF07), BRAC_SIZEM (0xFF08), BRAC_SIZEH (0xFF09)

BRAC_SIZE[23:0] registers is automatically decreasing by 1 after starting BRAC® decoding.

Name	Bit	R/W	Description	Reset
SIZEL	7:0	W	Data size to be read from e-FLASH or external Serial FLASH. This is concatenated with SIZEH and SIZEM.	0x00

Name	Bit	R/W	Description	Reset
SIZEM	7:0	W	Data size to be read from e-FLASH or external Serial FLASH. This is concatenated with SIZEH and SIZEL.	0x00

Name	Bit	R/W	Description	Reset
SIZEH	7:0	W	Data size to be read from e-FLASH or external Serial FLASH. This is concatenated with SIZEM and SIZEL.	0x00

BRAC_IBB_READ_PTR (0xFF0A)

Name	Bit	R/W	Description	Reset
RD_PTR	7:0	R	BRAC DMA read pointer. CPU should observe this register before CPU writes BRAC data to IBB area not to overwrite BRAC data. If the half of IBB is consumed, interrupt is generated.	0x00

BRAC_CMD_ADDR (0xFF0B)

Command address for BRAC Decoding/Encoding

Name	Bit	R/W	Description	Reset
CMD_ADDR	7:0	R/W	Reserved	Undef.

BRAC_CMD_DATA (0xFF0C)

Command value for BRAC Decoding/Encoding

Name	Bit	R/W	Description	Reset
BRAC_DATA	7:0	R/W	Reserved	Undef.

BRAC_BUFF (0xFF0D)

Name	Bit	R/W	Description	Reset
BRAC_BUFF	7:0	W	Buffer for BRAC® Decoding Voice data is stored to this buffer by CPU. This buffer is used only when CPU mode. CPU mode is NOT recommended.	Undef.

BRAC_CTRL3 (0xFF0E)

Name	Bit	R/W	Description	Reset
RSVD	7:0	R/W	Reserved for test.	Undef.

BRAC_ENC_CTRL (0xFF10)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
BRAC_ENC_BUSY	0	R	1 : BRAC Encoder is under running, 0 : BRAC is idle.	Undef.

BRAC_ENC_SAMPLE_L (0xFF11)

Name	Bit	R/W	Description	Reset
SAMPLE_L	7:4	R/W	Encoding PCM Sample Lower Bits. BRAC Encoding starts when this bit is written. Then this register should be written after SAMPLE_H is written.	Undef.
RSVD	3:0	-	Reserved	-

BRAC_ENC_SAMPLE_H (0xFF12)

Name	Bit	R/W	Description	Reset
SAMPLE_H	7:0	R	Encoding PCM Sample Upper Bits. This should be signed number.	Undef.

BRAC_ENC_RESULT (0xFF13)

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
RESULT	3:0	R	Encoding Result Data	Undef.

DAC_CTL (0xFF18)

DAC Control Register

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
DAC_PDN	3	R/W	Internal DAC goes to power down when this bit is set to ‘1’. 0: DAC is operating, 1: DAC power down	1
VOL_DIS	2	R/W	Volume value has maximum when this bit is set to ‘1’. 0: Enable volume control, 1: Disable volume control	1
D3_UP_DIS	1	R/W	0: Enable 3x up-sampling, 1: Disable 3x up-sampling	0
DAC_EN	0	R/W	0: Disable DAC, 1: Enable DAC When this bit is set to ‘1’, the data outputs to DACO	0

DACOUT_L (0xFF19)

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
DACOUT_L	1:0	R/W	Output Data for DAC[1:0]. This is concatenated with DACOUT_H. This Register should be written before DACOUT_H and should not be written during decoding because this value affects Vout of DAC.	0x0

DACOUT_H (0xFF1A)

Name	Bit	R/W	Description	Reset
DACOUT_H	7:0	R/W	Output Data for DAC[9:2]. This is concatenated with DACOUT_L. This register should not be written during decoding because this value affects Vout of DAC.	0x00

VOLUME (0xFF1B)

Name	Bit	R/W	Description	Reset
Volume	7:0	W	[Decoding Mode] - Volume 0x00: Mute, 0xFF: Max Volume [Encoding Mode] – AGC_GAIN Value: (upper 4-bit) + (lower 4-bit/16)	0xFF

*VOmax: Maximum Output Voltage of DAC

DCOL (0xFF1C)
DCOH (0xFF1D)

This register selects BRAC Sampling rates at decoding and ADC auto sample rate at encoding.
Encoding/Decoding is paused by writing 0 to this register.

Fs(sampling Frequency when 3-up sampling mode) = F_{SOURCE} * (DCO_VAL/2^{17}) * ⅓

Example) Fs =10KHz, F_{SOURCE} = 4MHz → DCO_VAL = 0x3d7 and up-sampling

Name	Bit	R/W	Description	Reset
DCO_L	7:0	W	DCO lower value	0x00

Name	Bit	R/W	Description	Reset
DCO_H	7:0	W	DCO higher value	0x00

7 SERIAL FLASH CONTROLLER

7.1 FEATURES

- External Serial Flash controller with BSPI signals.
- Dedicated Read DMA(SFDMA) for transferring from serial flash to XRAM
- Dedicated SPI signals (BSPI) for the access of external serial flash.

7.2 PIN DESCRIPTION

Table 7-1. BSPI Pin Description

GPIO	Pin Name	Function	Type
GP34	BSCLK	Serial Flash Clock	O
GP35	BMISO	Serial Data Input	I
GP36	BMOSI	Serial Data Output	O
GP37	BSCSN	Serial Flash Chip Select	O

7.3 BLOCK DIAGRAM

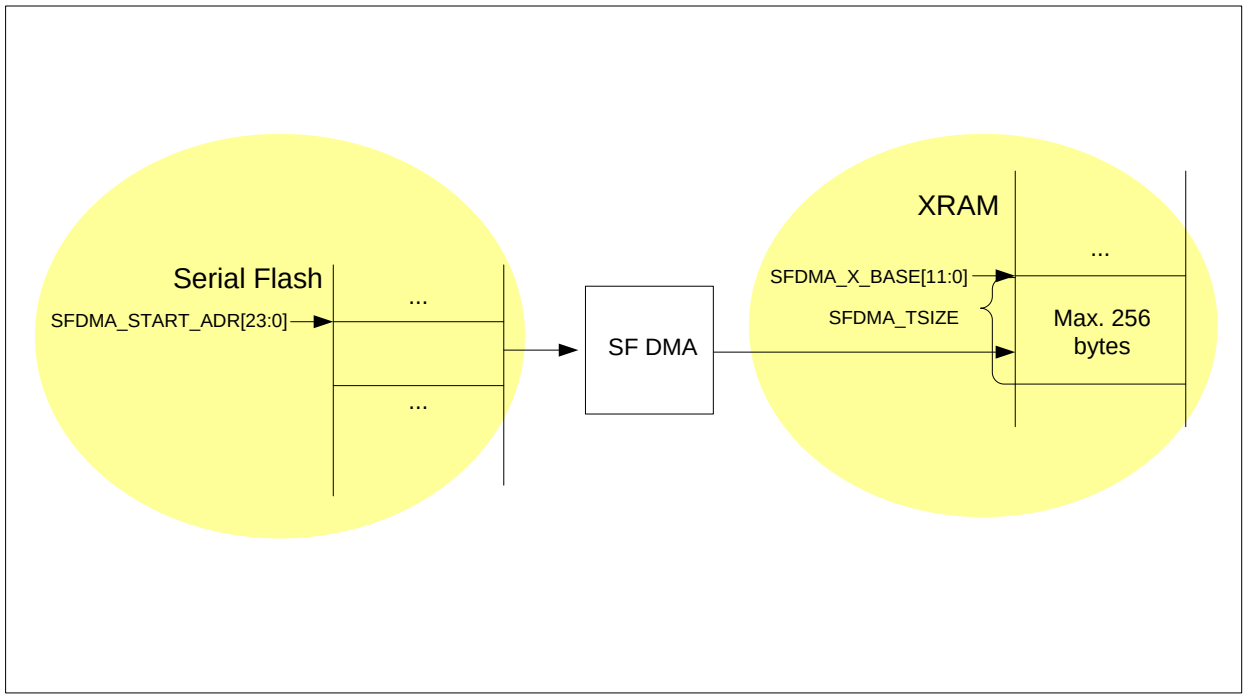


Figure 7-1. SFCON Block Diagram

7.4 OPERATION

CPU access by SFCTRL and SFPORT

BSPI CSN (BSCSN) signal is controlled by CPU in software GPIO control. When BSPI_CSN bit of SFCTRL register is written 0 and if there's no master which is using BSPI, CPU come to have the right to use BSPI port. After CPU finishes the use of BSPI, BSPI_CSN bit of SFCTRL register should be written to 1. **If not, other masters which want to use BSPI cannot access BSPI permanently.**

SFDMA is strongly recommended except SPI Erase/Programming by CPU when high speed serial read operation is required.

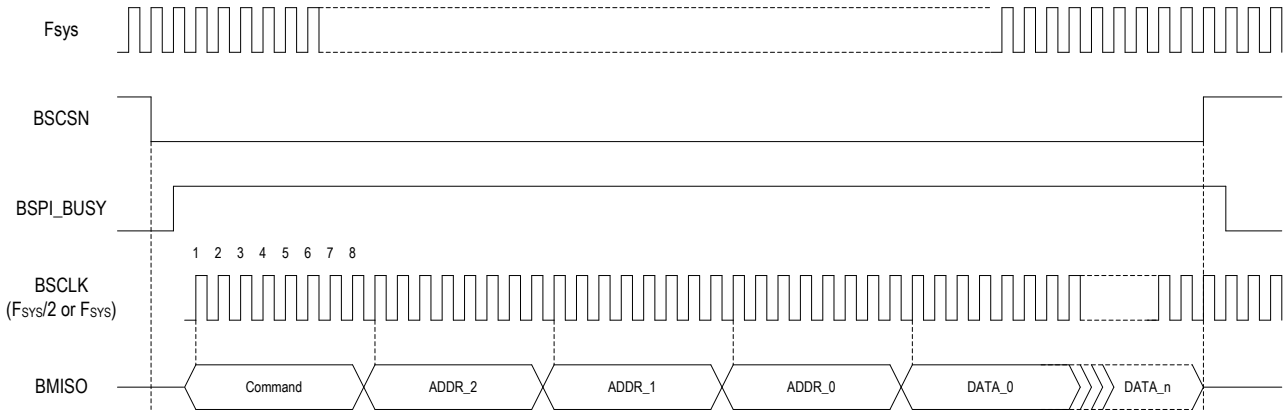


Figure 7-2. Timing Diagram of read operation from external serial FLASH

SFDMA (Serial Flash Read DMA)

The SFCON supports a dedicated DMA to read data from external serial flash to XRAM. This feature is absolutely useful to continuously read data up to 256 bytes during voice playback. SFDMA can transfer data without CPU intervention from external serial flash to XRAM. In this case, SFDMA operation has no relation to sampling rate of voice playback.

The usage of BRDMA is as follows.

1. Set SFDMA_START_ADRL/M/H ,TSIZE and X_BASE
2. BRDMA_CTRL = 0x3
3. While (BRDMA_CTRL & 0x01)
4. Trasfer to XRAM is done.

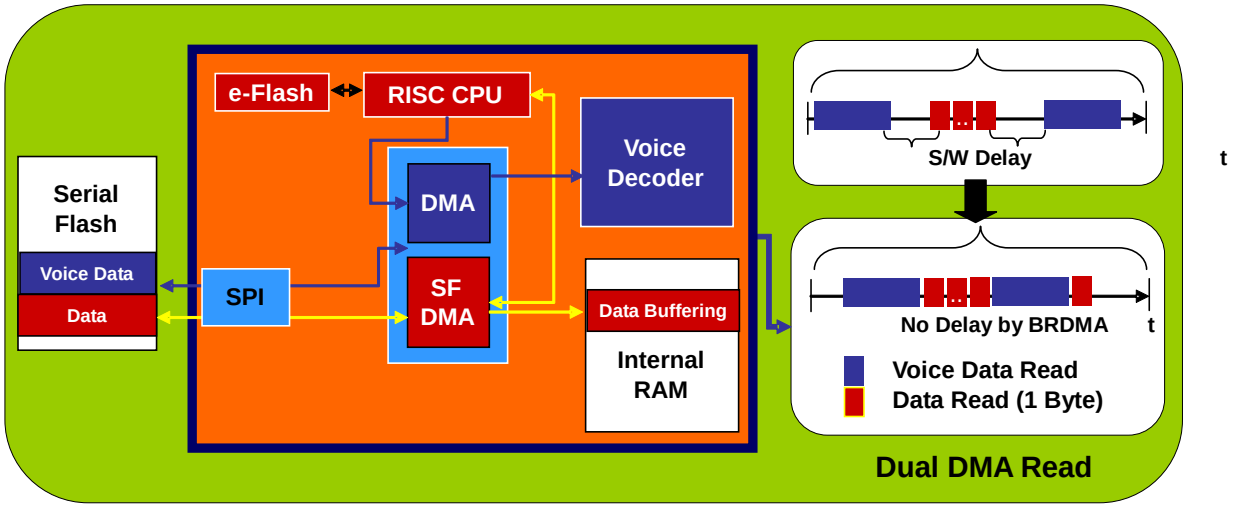


Figure 7-3. Application of voice Playing

7.5 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
SFCTRL	0xFF20	R/W	SF Control register(For CPU mode only)	0x02
SFPORT	0xFF21	R/W	SF Receive/Transmit Buffer(For CPU mode only)	Undef.
SFDMA_CTRL	0xFF22	R/W	SFDMA Control Register	0x00
SFDMA_START_ADRL	0xFF23	W	SFDMA Start Address Low	Undef.
SFDMA_START_ADRM	0xFF24	W	SFDMA Start Address Middle	Undef.
SFDMA_START_ADRH	0xFF25	W	SFDMA Start Address High	Undef.
SFDMA_RXBUF	0xFF26	R	SFDMA Rx Buffer	Undef.
SFDMA_TSIZE	0xFF27	R/W	SFDMA Transfer Size	0x00
SFDMA_X_BASE_L	0xFF28	W	SFDMA Target XRAM Base Address Low	Undef.
SFDMA_X_BASE_H	0xFF29	W	SFDMA Target XRAM Base Address High	Undef.
SFCTRL2	0xFF2A	R/W	SF Control register 2	0x00

Note) These registers have to be accessed using **MOVX** instruction.

SFCTRL (0xFF20)

This register is only for CPU mode.

Name	Bit	R/W	Description	Reset
RSVD	7:3	R	Reserved	-
SF_RS	2	W	When it is set to '1', BSPI read operation starts. This bit is cleared automatically just after writing.	0
SF_CSN	1	R/W	SPI chip select signal. When both this bit and SF_BUSY bit are '0', external SF_CSN pin goes to '0'.	1
SF_BUSY	0	R	It is flag that BSPI operation is running 0: idle, 1: busy	0

SFPORT (0xFF21)

This register is only for CPU mode.

Name	Bit	R/W	Description	Reset
SF_PORT	7:0	R/W	[Write] MSB in this register goes out through BSPI_MOSI port firstly. [Read] The value is inputted through BSPI_MISO MSB firstly.	Undef.

SFDMA_CTRL (0xFF22)

Name	Bit	R/W	Description	Reset
RSVD	7:3	-	Reserved	-
SFDMA_CPU_MODE	2	R/W	0 : BRDMA automatically stores serial flash data to XRAM. 1 : XRAM is NOT written by BRDMA.	0
SFDMA_AUTO_INC	1	R/W	1 : BRDMA_START_ADR is automatically incremented.	0
SFDMA_EN	0	R/W	BRDMA starts when this bit is set. And this bit is cleared when DMA transfer operation is done.	0

SFDMA_START_ADRL (0xFF23)
SFDMA_START_ADRM (0xFF24)
SFDMA_START_ADRH (0xFF25)

Name	Bit	R/W	Description	Reset
ADDR_L	7:0	W	BRDMA Start Address	Undef.

Name	Bit	R/W	Description	Reset
ADDR_M	7:0	W	BRDMA Start Address	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:3	-	Reserved	-
ADDR_H	2:0	W	BRDMA Start Address	Undef.

SFDMA_RXBUF (0xFF26)

This is used for CPU mode.

Name	Bit	R/W	Description	Reset
RXBUF	7:0	W	BRDMA Read Buffer	Undef.

SFDMA_TSIZE (0xFF27)

Name	Bit	R/W	Description	Reset
TSIZE	7:0	W	(TSIZE+1) bytes are transferred to XRAM from Serial Flash.	Undef.

SFDMA_XBASE_L (0xFF28)

Name	Bit	R/W	Description	Reset
BASE_L	7:0	W	XRAM base lower address	Undef.

SFDMA_XBASE_H (0xFF29)

Name	Bit	R/W	Description	Reset
BASE_H	7:0	W	XRAM base higher address	Undef.

SFCTRL2 (0xFF2A)

Name	Bit	R/W	Description	Reset
RSVD	7:5	R	Reserved	-
SF_4BYTE_ADDR	4	R/W	When this bit is set to '1', serial flash address is 4 bytes.	0
SF_BANK_ADDR	3:1	R/W	Bank address for 128Mbits (16Mbytes) blocks. This bits are used when the serial flash greater than 128Mbits is needed. This bits are valid only when SF_4BYTE_ADDR bit is set.	000
SF_FAST_MODE	0	R/W	This bit selects the speed of SPI clock 1 : SF clock = F_{SYS} 0 : SF clock = F_{SYS}/2	0

8 BRJPEG DECODER

8.1 OVERVIEW

The BMC513 has a BRJPEG decoder to decode graphic image bit streams which are encoded by Boo-Ree's own PC based software encoder.

8.2 FEATURES

- Embedded own DCT based image decoder
  - ✓ 128x128 10 frame decoding @12MHz
  - ✓ 192x192 10 frame decoding @24MHz
- Built-in processing engines for image decoding
  - ✓ Variable length decoding(VLD) engine
  - ✓ Inverse discrete cosine transform(IDCT) engine
- Variable length decoding(VLD) engine
  - ✓ Bit processing
  - ✓ Huffman decoding
  - ✓ Run-length decoding
  - ✓ Inverse quantization(IQ)
- Inverse DCT engine
  - ✓ 16-bit multiplier and 32-bit accumulator supporting 4-point and 8-point DCT
  - ✓ Clipping circuit
  - ✓ Support additional MAC/MUL/ADD/SUM instructions with up to 16 data input

8.3 OPERATION

Figure 8-1 on the next page shows BRJPEG Decoder decoding scheme. BRJPEG Decoder has two hardwired engines, VLD and IDCT. VLD engine consists of bit processor (BP), variable length decoder (VLD) and inverse quantizer (IQ). Bit processor reads the bit stream data from input bit-stream buffer (IBB) in internal e-FLASH, external serial flash or XRAM. The Huffman codes extracted from BP are decoded by VLD and IQ with the table information in e-FLASH. And the output is sent to the one of BUF01 and BUF23 in XRAM. IDCT engine reads the VLD engine output from BUF01 or BUF23, performs 2-D IDCT and clipping, and saves the result to the one of BUF0, BUF2, BUF4, and BUF5. Then VDMA takes the decoded YCbCr data, does the color space conversion from YCbCr to RGB on the fly, and sends RGB data to the I80LCD controller for display.

For the maximum performance, BRJPEG decoder provides ping-pong buffers for both VLD engine and IDCT engine. VLD engine can select one of BUF01 and BUF23 for its output. IDCT engine can select the input data from one of BUF01 and BUF23 and the output data from one of BUF4 and BUF5. 6 buffers may need for the maximum throughput.

For the minimum memory usage, only BUF01 (BUF0 and BUF1) is needed. VLD engine sends the output to the BUF01, and then IDCT engine read the input from BUF01 and send its output to BUF0.

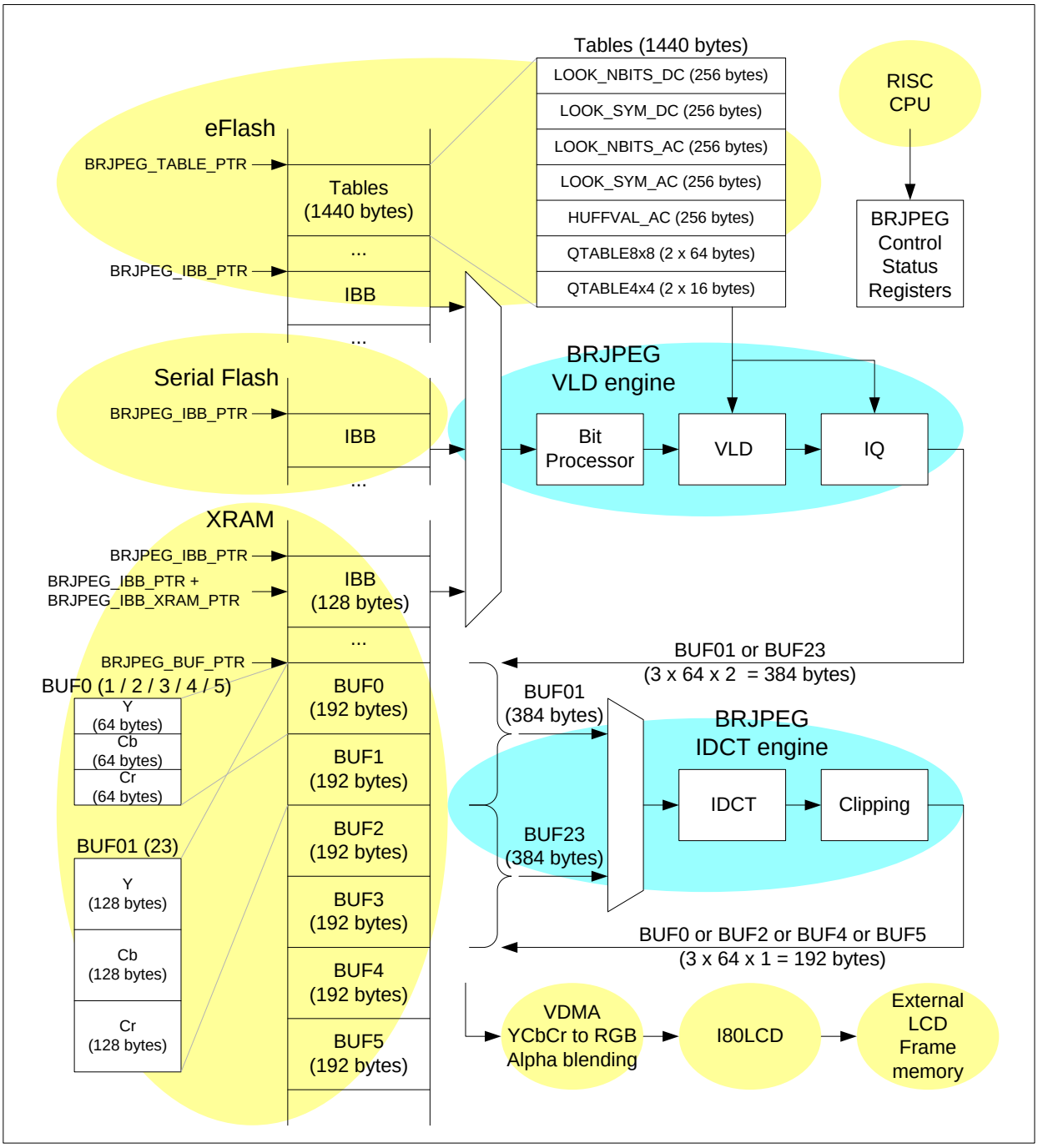


Figure 8-1. BRJPEG Decoder Decoding Scheme

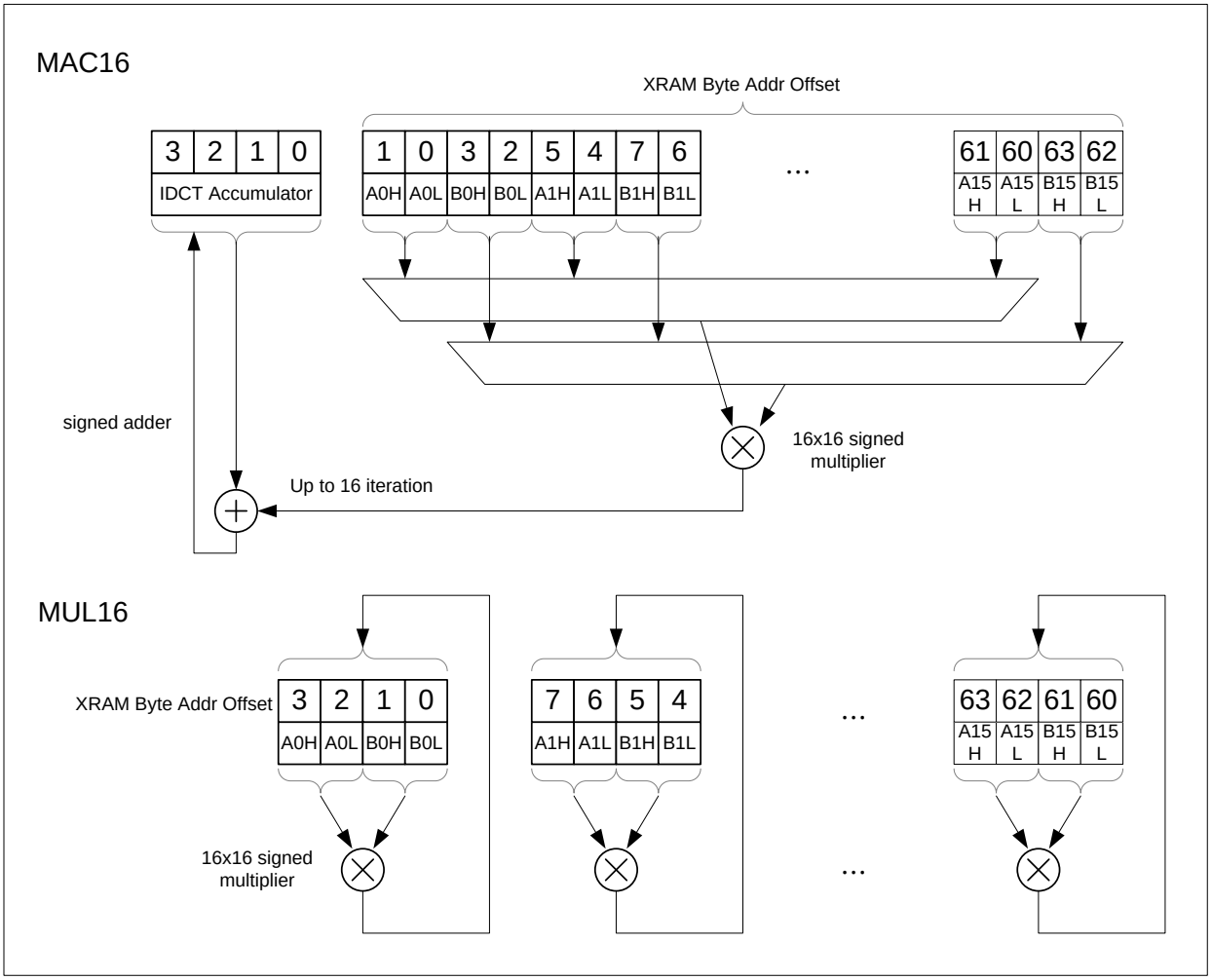


Figure 8-2. IDCT engine operation for MAC16 and MUL16 instructions

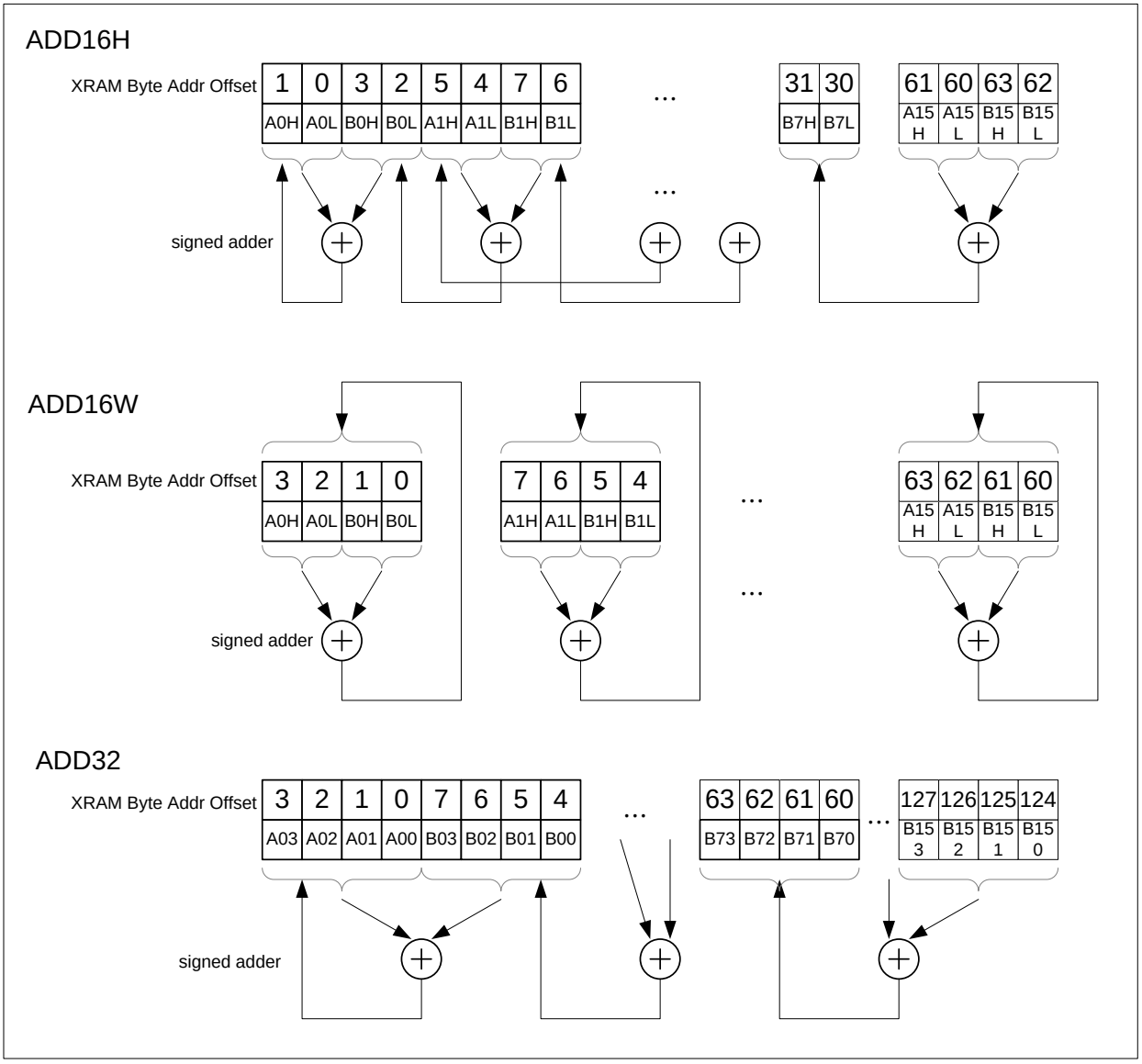


Figure 8-3. IDCT engine operation for ADD16H, ADD16W and ADD32 instructions

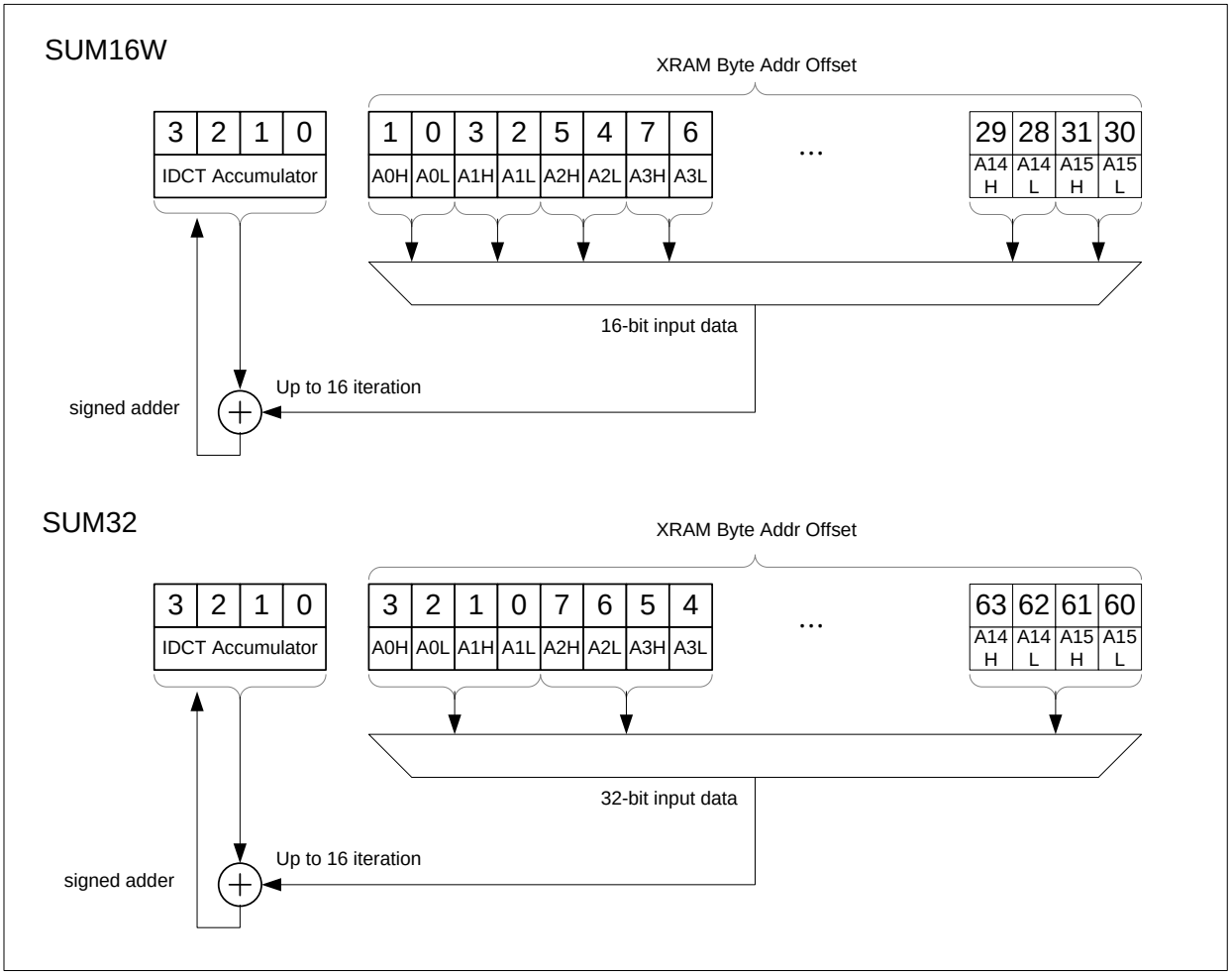


Figure 8-4. IDCT engine operation for SUM16W and SUM32 instructions

8.4 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
BRJPEG_BUF_PTR_L	0xFF40	R/W	Low byte of XRAM buffer base address	Undef.
BRJPEG_BUF_PTR_H	0xFF41	R/W	High byte of XRAM buffer base address	Undef.
BRJPEG_TABLE_PTR_L	0xFF42	R/W	Low byte of constant table base address in internal e-FLASH	Undef.
BRJPEG_TABLE_PTR_H	0xFF43	R/W	High byte of constant table base address in internal e-FLASH	Undef.
BRJPEG_IBB_PTR_L	0xFF44	R/W	Low byte of video input bit stream buffer address	Undef.
BRJPEG_IBB_PTR_M	0xFF45	R/W	Middle byte of video input bit stream buffer address	Undef.
BRJPEG_IBB_PTR_H	0xFF46	R/W	High byte of video input bit stream buffer address	Undef.
BRJPEG_IBB_XRAM_PTR	0xFF47	R/W	Video input bit stream buffer offset address in XRAM IBB mode	Undef.
BRJPEG_GET_BUFFER_L	0xFF48	R/W	Low byte of intermediate bit stream buffer	Undef.
BRJPEG_GET_BUFFER_M	0xFF49	R/W	Middle byte of intermediate bit stream buffer	Undef.
BRJPEG_GET_BUFFER_H	0xFF4A	R/W	High byte of intermediate bit stream buffer	Undef.
BRJPEG_BITS_LEFT	0xFF4B	R/W	Number of valid bits in GET_BUFFER	Undef.
BRJPEG_GET_PEEK_L	0xFF4C	R/W	Low byte of the get_bits/peek_bits result	Undef.
BRJPEG_GET_PEEK_H	0xFF4D	R/W	High byte of the get_bits/peek_bits result	Undef.
BRJPEG_QP_Y	0xFF4E	R/W	Quantization scale for luminance component	Undef.
BRJPEG_QP_C	0xFF4F	R/W	Quantization scale for chrominance component	Undef.
BRJPEG_PREV_DC_Y_L	0xFF50	R/W	Low byte of previous DC value for Y component	Undef.
BRJPEG_PREV_DC_Y_H	0xFF51	R/W	High byte of previous DC value for Y component	Undef.
BRJPEG_PREV_DC_CB_L	0xFF52	R/W	Low byte of previous DC value for Cb component	Undef.
BRJPEG_PREV_DC_CB_H	0xFF53	R/W	High byte of previous DC value for Cb component	Undef.
BRJPEG_PREV_DC_CR_L	0xFF54	R/W	Low byte of previous DC value for Cr component	Undef.
BRJPEG_PREV_DC_CR_H	0xFF55	R/W	High byte of previous DC value for Cr component	Undef.
BRJPEG_CFG	0xFF56	R/W	Configuration	0x0
BRJPEG_BUFSEL	0xFF57	R/W	Input / Output buffer selection for processing engines	Undef.
BRJPEG_CMD	0xFF58	R/W	Command	0x0
BRJPEG_IE	0xFF59	R/W	Interrupt enable	0x0
BRJPEG_ICLR	0xFF5A	W	Interrupt clear	0x0
BRJPEG_ST	0xFF5B	R/W	Status	0x0
BRJPEG_VLD_MODE	0xFF5C	R/W	Mode setting for the VLD engine	Undef.
BRJPEG_IDCT_MODE	0xFF5D	R/W	Mode setting for the IDCT engine	Undef.
RESERVED	0xFF5E	-	Reserved	-
RESERVED	0xFF5F	-	Reserved	-
BRJPEG_IDCT_ACC_0	0xFF60	R/W	Accumulator byte 0 (LSB) in IDCT engine	Undef.
BRJPEG_IDCT_ACC_1	0xFF61	R/W	Accumulator byte 1 in IDCT engine	Undef.
BRJPEG_IDCT_ACC_2	0xFF62	R/W	Accumulator byte 2 in IDCT engine	Undef.
BRJPEG_IDCT_ACC_3	0xFF63	R/W	Accumulator byte 3 (MSB) in IDCT engine	Undef.

Note) These registers have to be accessed using **MOVX** instruction.

BRJPEG_BUF_PTR_L (0xFF40), BRJPEG_BUF_PTR_H (0xFF41)

BRJPEG_BUF_PTR[11:0] register is the base address pointer for the XRAM buffers, which are used by the processing engines to save the intermediate data and pass the input and output data. For the minimum performance, two 192-byte buffers (BUF0/BUF1) are needed. For the maximum performance, six 192-byte buffers (BUF0 to BUF5) are needed.

Name	Bit	R/W	Description	Reset
BUF_PTR_L	7:0	R/W	Bits[7:0] of XRAM buffer base address	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
BUF_PTR_H	3:0	R/W	Bits[11:8] of XRAM buffer base address	Undef.

BRJPEG_TABLE_PTR_L (0xFF42), BRJPEG_TABLE_PTR_H (0xFF43)

BRJPEG_TABLE_PTR[15:0] register is the base address pointer for the constant tables in internal Flash. Seven constant tables should be located in predefined order in internal flash from this base address pointer. This address pointer should be assigned less than 0xFA60 to access 1440 byte constant tables within 16-bit address domain.

Name	Bit	R/W	Description	Reset
TABLE_PTR_L	7:0	R/W	Bits[7:0] of constant table base address in internal eFlash	Undef.

Name	Bit	R/W	Description	Reset
TABLE_PTR_H	7:0	R/W	Bits[15:8] of constant table base address in internal eFlash	Undef.

BRJPEG_IBB_PTR_L (0xFF44), BRJPEG_IBB_PTR_M (0xFF45), BRJPEG_IBB_PTR_H (0xFF46)

BRJPEG_IBB_PTR[23:0] register is the video input bit stream buffer (IBB) pointer. For the internal eFlash IBB and serial flash IBB, this register is incremented according to the bit stream parsing by VLD engine. But for the XRAM IBB, this register is the base address register and the BRJPEG_IBB_XRAM_PTR[6:0] is the offset register and incremented.

Name	Bit	R/W	Description	Reset
IBB_PTR_L	7:0	R/W	Bits[7:0] of video input bit stream buffer	Undef.

Name	Bit	R/W	Description	Reset
IBB_PTR_M	7:0	R/W	Bits[15:8] of video input bit stream buffer	Undef.

Name	Bit	R/W	Description	Reset
IBB_PTR_H	7:0	R/W	Bits[23:16] of video input bit stream buffer	Undef.

BRJPEG_IBB_XRAM_PTR (0xFF47)

BRJPEG_IBB_XRAM_PTR[6:0] register is the video input bit stream buffer (IBB) offset address pointer in XRAM IBB mode. BRJPEG_IBB_PTR[11:0] + BRJPEG_IBB_XRAM_PTR[6:0] is the XRAM IBB address. Only BRJPEG_IBB_XRAM_PTR is incremented and wrapped around 128 bytes.

Name	Bit	R/W	Description	Reset
RSVD	7	-	Reserved	-
IBB_XRAM_PTR	6:0	R/W	Video input bit stream buffer offset address in XRAM IBB mode	Undef.

BRJPEG_GET_BUFFER_L (0xFF48), BRJPEG_GET_BUFFER_M (0xFF49), BRJPEG_GET_BUFFER_H (0xFF4A)

BRJPEG_IBB_PTR[23:0] register is the intermediate bit stream buffer to access more than 8bits from IBB.

Name	Bit	R/W	Description	Reset
GET_BUFFER_L	7:0	R/W	Bits[7:0] of intermediate bit stream buffer	Undef.

Name	Bit	R/W	Description	Reset
GET_BUFFER_M	7:0	R/W	Bits[15:8] of intermediate bit stream buffer	Undef.

Name	Bit	R/W	Description	Reset
GET_BUFFER_H	7:0	R/W	Bits[23:16] of intermediate bit stream buffer	Undef.

BRJPEG_BITS_LEFT (0xFF4B)

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
BITS_LEFT	4:0	R/W	Number of valid bits in GET_BUFFER	Undef.

BRJPEG_GET_PEEK_L (0xFF4C), BRJPEG_GET_PEEK_H (0xFF4D)

BRJPEG_GET_PEEK[15:0] register is the result of get_bits or peek_bits command in BRJPEG_VLD_MODE register.

Name	Bit	R/W	Description	Reset
GET_PEEK_L	7:0	R	Bits[7:0] of the get_bits/peek_bits result	Undef.

Name	Bit	R/W	Description	Reset
GET_PEEK_H	7:0	R	Bits[15:8] of the get_bits/peek_bits result	Undef.

BRJPEG_QP_Y (0xFF4E)

Name	Bit	R/W	Description	Reset
QP_Y	7:0	R/W	Quantization scale for luminance component	Undef.

BRJPEG_QP_C (0xFF4F)

Name	Bit	R/W	Description	Reset
QP_C	7:0	R/W	Quantization scale for chrominance component	Undef.

BRJPEG_PREV_DC_Y_L (0xFF50), BRJPEG_PREV_DC_Y_H (0xFF51)

BRJPEG_PREV_DC_Y[12:0] register keeps the previous DC value for Y component.

Name	Bit	R/W	Description	Reset
PREV_DC_Y_L	7:0	R/W	Bits[7:0] of previous DC value for Y component	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
PREV_DC_Y_H	4:0	R/W	Bits[12:8] of previous DC value for Y component	Undef.

BRJPEG_PREV_DC_CB_L (0xFF52), BRJPEG_PREV_DC_CB_H (0xFF53)

BRJPEG_PREV_DC_CB[12:0] register keeps the previous DC value for Cb component.

Name	Bit	R/W	Description	Reset
PREV_DC_CB_L	7:0	R/W	Bits[7:0] of previous DC value for Cb component	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
PREV_DC_CB_H	4:0	R/W	Bits[12:8] of previous DC value for Cb component	Undef.

BRJPEG_PREV_DC_CR_L (0xFF54), BRJPEG_PREV_DC_CR_H (0xFF55)

BRJPEG_PREV_DC_CR[12:0] register keeps the previous DC value for Cr component.

Name	Bit	R/W	Description	Reset
PREV_DC_CR_L	7:0	R/W	Bits[7:0] of previous DC value for Cr component	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
PREV_DC_CR_H	4:0	R/W	Bits[12:8] of previous DC value for Cr component	Undef.

BRJPEG_CFG (0xFF56)

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
IBB_TYPE	4:3	R/W	Memory type of IBB 00: Internal eFlash 01: External serial flash 10: XRAM 11: Reserved	00
RSVD	2	R/W	Reserved	0
DC_PREDICTION	1	R/W	DC prediction mode in quantized DC coefficients 0: disable DC prediction, 1: enable DC prediction	0
BLOCK_TYPE	0	R/W	Block size for VLD/IQ/IDCT 0: 4x4, 1: 8x8	0

BRJPEG_BUFSEL (0xFF57)

BRJPEG_BUFSEL defines which XRAM buffers are used by VLD or IDCT.

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
IDCT_OUT	3:2	R/W	IDCT output buffer selection for 3x64x1bytes. 00: BUF0, 01: BUF2, 02: BUF4, 03: BUF5	Undef.
IDCT_IN	1	R/W	IDCT input buffer selection for 3x64x2bytes 0: BUF01, 1: BUF23	Undef.
VLD_OUT	0	R/W	VLD output buffer or IQ input/output buffer selection for 3x64x2 bytes 0: BUF01, 1: BUF23	Undef.

BRJPEG_CMD (0xFF58)

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
IDCT_EN	1	R/W	IDCT enable command. When set, it is not cleared until the IDCT operation is done. IDCT operation is defined by BRJPEG_IDCT_MODE register. 0: idle, 1: enable(W)/busy(R)	0
VLD_EN	0	R/W	VLD enable command. When set, it is not cleared until the VLD operation is done. VLD operation is defined by BRJPEG_VLD_MODE register. 0: idle, 1: enable(W)/busy(R)	0

BRJPEG_IE (0xFF59)

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
IDCT_DONE_IE	1	R/W	IDCT done interrupt enable 0: disable, 1: enable	0
VLD_DONE_IE	0	R/W	VLD done interrupt enable 0: disable, 1: enable	0

BRJPEG_ICLR (0xFF5A)

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
IDCT_DONE_ICLR	1	W	IDCT done interrupt clear by writing 1	0
VLD_DONE_ICLR	0	W	VLD done interrupt clear by writing 1	0

BRJPEG_ST (0xFF5B)

Name	Bit	R/W	Description	Reset
IDCT_DONE_ST	1	R/W	IDCT done status. This bit can be set by writing 1. 0: idle, 1: done(R)/set(W)	0
VLD_DONE_ST	0	R/W	VLD done status. This bit can be set by writing 1. 0: idle, 1: done(R)/set(W)	0

BRJPEG_VLD_MODE (0xFF5C)

BRJPEG_VLD_MODE register defines which operation will be done by VLD engine.

Name	Bit	R/W	Description	Reset
VLD_OP	7:5	R/W	VLD operation selection 000: VLD_IQ 001: VLD 010: IQ 011: RESERVED 100: GET_BITS 101: PEEK_BITS 110: DROP_BITS 111: FILL_BUFFER	Undef.
VLD_BITS	4:0	R/W	Number of bits for GET_BITS, PEEK_BITS, DROP_BITS and FILL_BUFFER operations	Undef.

BRJPEG_IDCT_MODE (0xFF5D)

BRJPEG_IDCT_MODE register defines which operation will be done by IDCT engine.

Name	Bit	R/W	Description	Reset
IDCT_OP	7:5	R/W	IDCT operation selection 000: 2D-IDCT and Clipping 001: MAC16 010: MUL16 011: ADD16H 100: ADD16W 101: ADD32 110: SUM16W 111: SUM32	Undef.
IDCT_SAT_DIS	4	R/W	IDCT accumulator saturation disable 0: saturation enable, 1: saturation disable	Undef
IDCT_NOOP	3:0	R/W	Number of operations for MAC16, MUL16, ADD16H, ADD16W, ADD32, SUM16W, SUM32	Undef.

BRJPEG_IDCT_ACC_0 (0xFF60), BRJPEG_IDCT_ACC_1 (0xFF61), BRJPEG_IDCT_ACC_2 (0xFF62), BRJPEG_IDCT_ACC_3 (0xFF63)

BRJPEG_IDCT_ACC[31:0] register is the accumulator for the IDCT operations.

Name	Bit	R/W	Description	Reset
IDCT_ACC_0	7:0	R/W	Bits[7:0] of the accumulator in IDCT engine	Undef.

Name	Bit	R/W	Description	Reset
IDCT_ACC_1	7:0	R/W	Bits[15:8] of the accumulator in IDCT engine	Undef.

Name	Bit	R/W	Description	Reset
IDCT_ACC_2	7:0	R/W	Bits[23:16] of the accumulator in IDCT engine	Undef.

Name	Bit	R/W	Description	Reset
IDCT_ACC_3	7:0	R/W	Bits[31:24] of the accumulator in IDCT engine	Undef.

NOTES:

9 SPI

9.1 OVERVIEW

Serial Peripheral Interface (SPI) of the BMC513 can interface the serial data transfer. During SPI transfer, data is simultaneously transmitted (shifted out serially) and received (shifted in serially). It can operate as master or slave device in 3-wire or 4-wire modes. All SPI input/output pins are multiplexed with GPIOs.

9.2 FEATURES

- Full-duplex, 3-wire or 4-wire Synchronous Data Transfer
- Support Master and Slave operation
- Serial clock with programmable polarity and phase
- Baud rate clock selectable in Master mode
- MSB First or LSB First Data Transfer
- Support 1 Byte / 2 Byte operation

9.3 PIN DESCRIPTION

Table 9-1. SPI PIN Description

GPIO	Pin Name	Function	Type
GP54	SCLK	SPI Clock. When configured as master, this pin is an output, When configured as slave, this pin is an input.	IO
GP55	SMISO	SPI master-in/slave-out. When configured as master, this pin is an input, When configured as slave, this pin is an output.	IO
GP56	SMOSI	SPI master-out/slave-in. When configured as master, this pin is an output, When configured as slave, this pin is an input.	IO
GP57	SCSN	SPI slave select. When configured as master, this pin is an output, When configured as slave, this pin is an input.	IO

9.4 BLOCK DIAGRAM

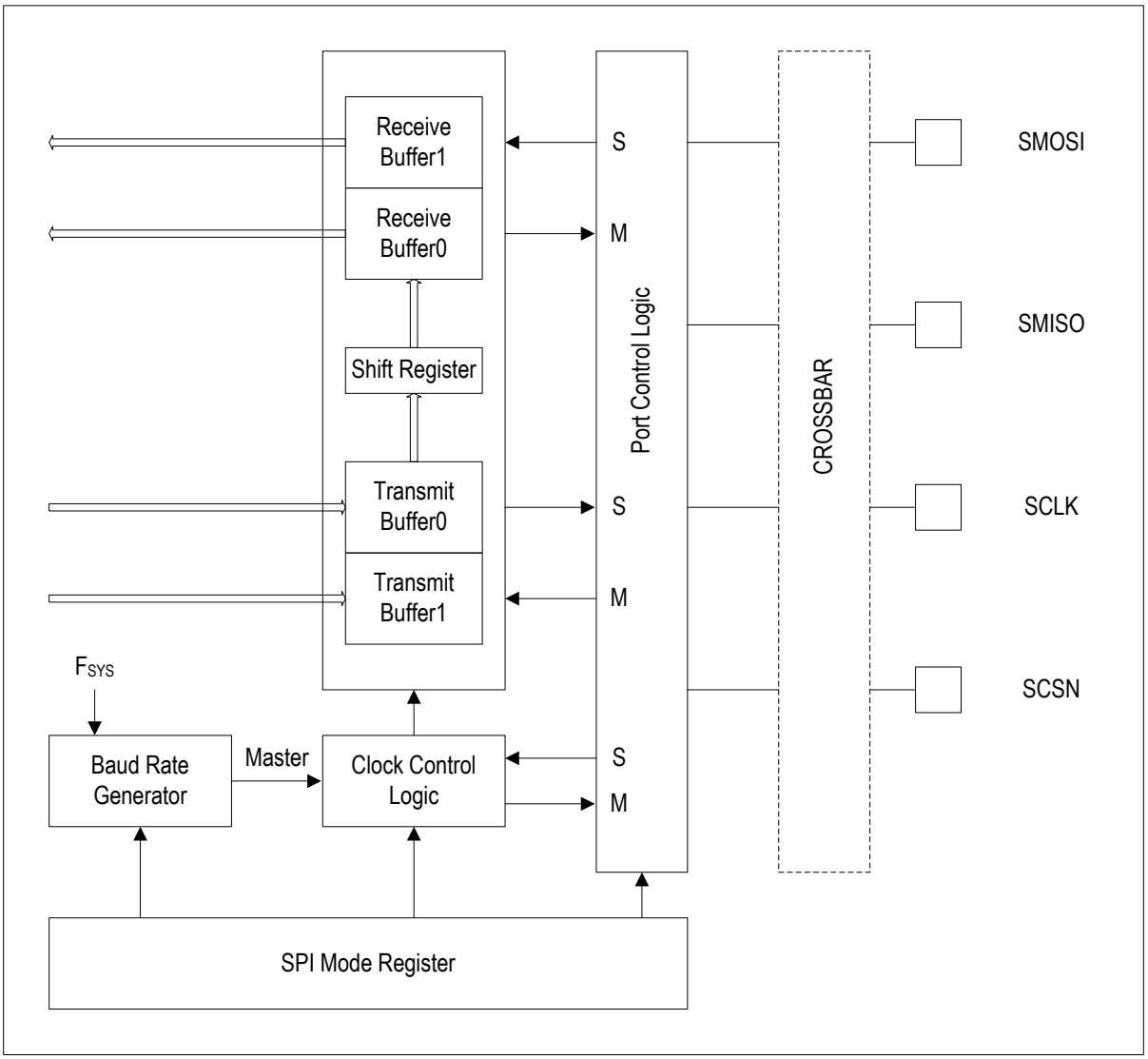


Figure 9-1. SPI Block Diagram

9.5 OPERATION

The four signals used by SPI (MOSI, MISO, SCK, SCSN) are described below.

Master Out, Slave In (MOSI)

The master-out, slave-in (MOSI) signal is an output from a master device and an input to a slave device. It is used to serially transfer data from the master to the slave. This signal is an output when SPI is operating as a master and an input when SPI is operating as a slave.

Master in, Slave Out (MISO)

The master-in, slave-out (MISO) signal is an output from a slave device and an input to the master device. It is used to serially transfer data from the slave to the master. This signal is an input when SPI is operating as a master and an output when SPI is operation as a slave

Serial Clock (SCK)

The serial clock (SCK) signal is an output from a master device and an input to a slave device. It is used to synchronize the transfer of data between the master and the slave on the MOSI and MISO lines. SPI generates this signal when operating as a master. In slave mode SPI receive this signal from a master. The SCKPHA and SCKPOL in SPIMOD register and the CKSEL in SPICK control the shape and rate of SCK. The CKSEL provide several possible clock rates when the SPI is in master mode. In slave mode, the SPI will operate at the rate of the incoming SCK as long as ***it does not exceed the maximum bit rate***. There are also four possible combinations of SCK phase and polarity with respect to the serial data. The SPI data transfer formats are shown in Figure 9-4. ***To prevent glitches on SCK from disrupting the interface, SCKPHA, SCKPOL, and CKSEL should be set up before the interface is enabled.***

Slave Select (SCSN)

The slave select (SCSN) signal is an output from a master device and an input to a slave device. It is used when the SSMD bit in SPIMOD is set to logic 1.

Master Mode Operation

A SPI master device initiates all data transfers on a SPI bus. SPI is placed in master mode by clearing the SLVEN bit in SPIMOD register. Writing a byte of data to the SPI data register (SPIDATA) when in master mode writes to the transmit buffer. The byte in the transmit buffer is immediately moved to the shift register, and a data transfer begins. The SPI master immediately shifts out the data serially on the MOSI line while providing the serial clock on SCK. During operating, a next data don't have to be written into the SPIDATA. If interrupts are enabled, an interrupt request is generated at the end of transfer. While the SPI master transfers data to a slave on the MOSI line, the SPI slave device simultaneously transfers the contents of its shift register to the SPI master on the MISO line in a full-duplex operation. Therefore, the interrupt serves as both a transmit-complete and receive-data-ready.

Slave Mode Operation

When SPI is enabled and not configured as a master, it will operate as a SPI salve. As a slave, byte are shifted in through the MOSI pin and out through the MISO pin by a master device controlling the SCK signal. A bit counter in the SPI logic counts SCK edges. When 8 bits have been shifted through the shift register, operation is finished. A slave device cannot initiate transfers. ***Data to be transferred to the master device should be pre-loaded into shift register by writing a data to SPIDATA***.

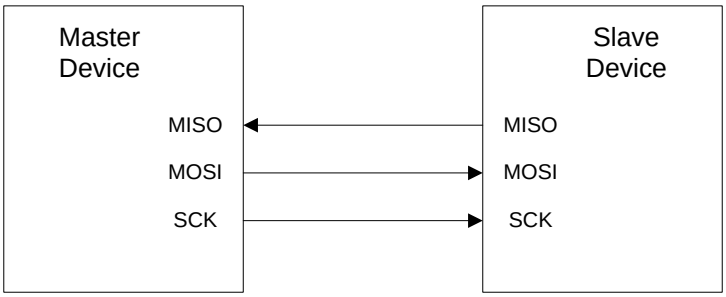


Figure 9-2. 3-Wire Master-Slave Interconnection

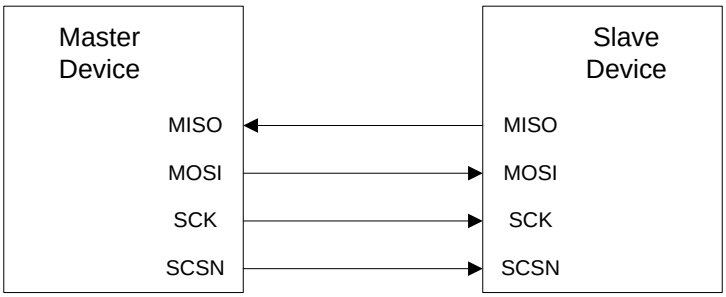


Figure 9-3. 4-Wire Master-Slave Interconnection

Timing Diagram

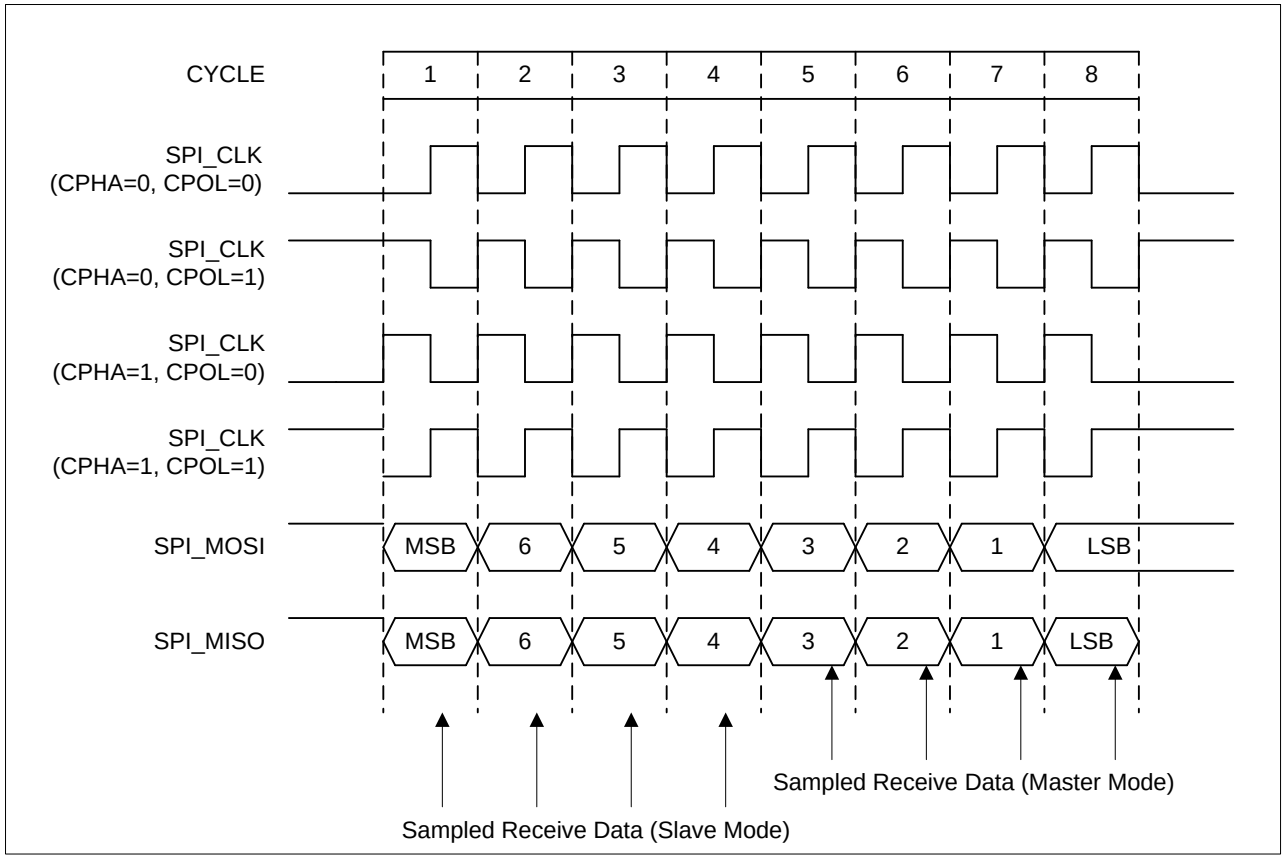


Figure 9-4. SPI Transfer Format

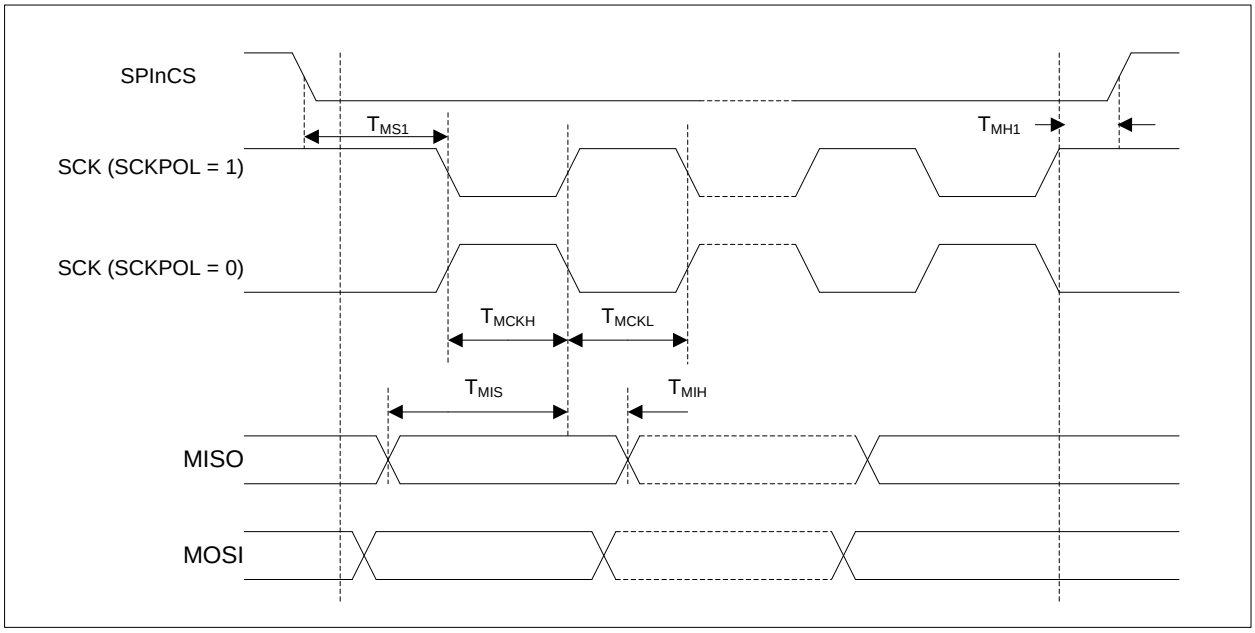


Figure 9-5. 4-Wire SPI Master Timing (SCKPHA=0)

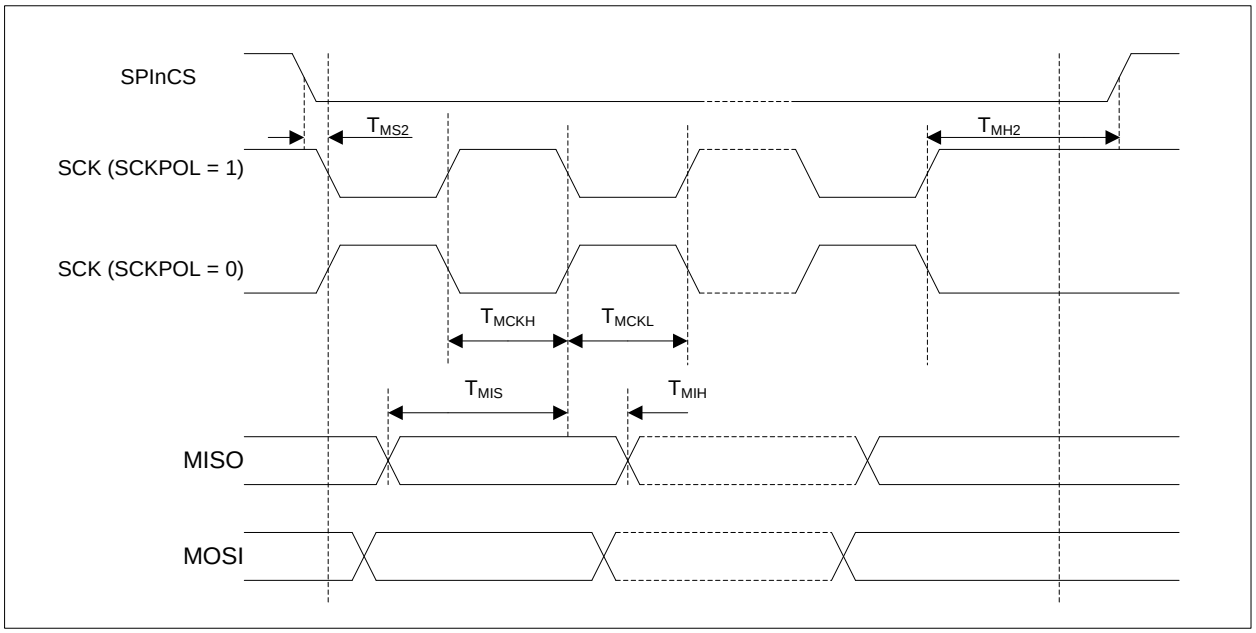


Figure 9-6. 4-Wire SPI Master Timing (SCKPHA=1)

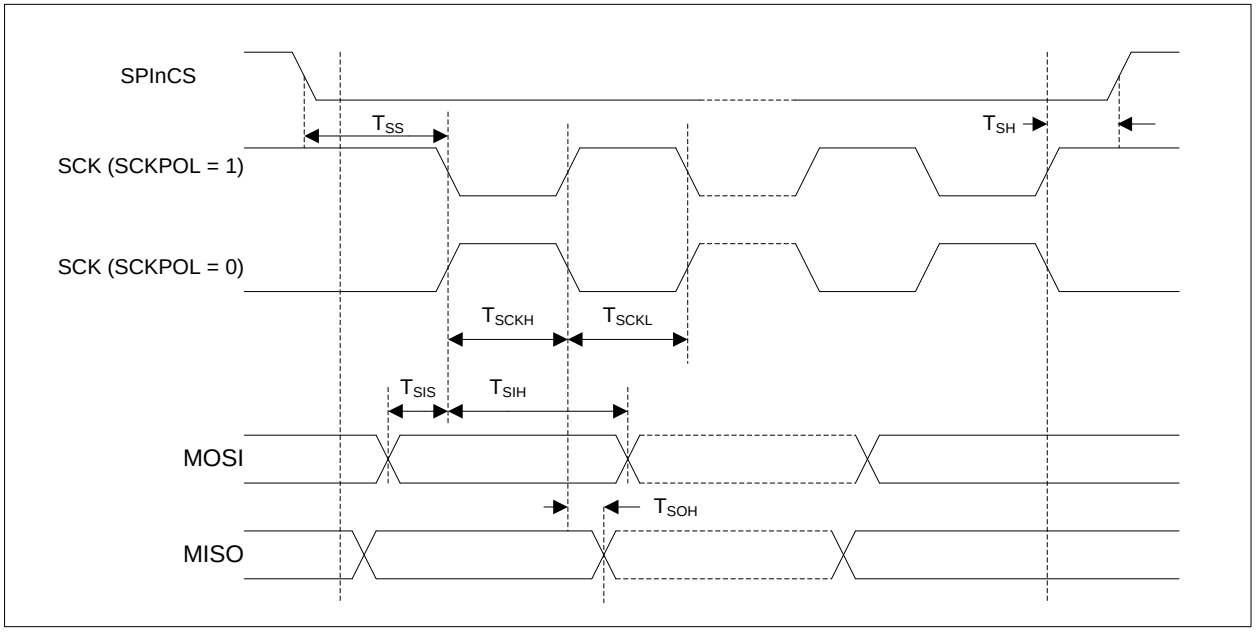


Figure 9-7. 4-Wire SPI Slave Timing (SCKPHA=0)

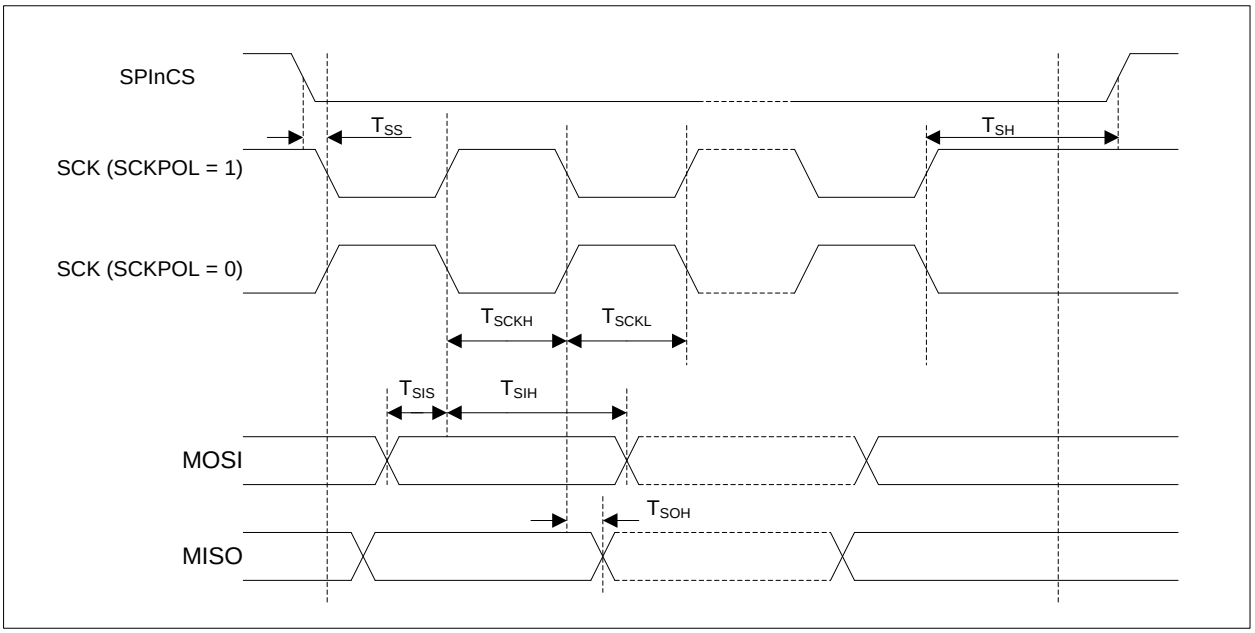


Figure 9-8. 4-Wire SPI Slave Timing (SCKPHA=1)

SPI Timing Parameters

Parameter	Description	Min	Max	Units
Master Mode Timing *(See Figure 9-5 and Figure 9-6)				
T_{MS1}	SCSN falling to first SCK edge	4 * T_{FSYS}		ns
T_{MH1}	Last SCK edge to SCSN rising	1 * T_{FSYS}	2 * T_{FSYS}	ns
T_{MS2}	SCSN falling to first SCK edge	1 * T_{FSYS}	2 * T_{FSYS}	ns
T_{MH2}	Last SCK edge to SCSN rising	4 * T_{FSYS}		ns
T_{MCKH}	SCK High Time	2 * T_{FSYS}		ns
T_{MCKL}	SCK Low Time	3 * T_{FSYS}		ns
T_{MIS}	MISO Valid to SCK Shift Edge	1 * T_{FSYS}		ns
T_{MIH}	SCK shift Edge to MISO change	0		ns
Slave Mode Timing *(See Figure 9-7 and Figure 9-8)				
T_{SS}	SCSN falling to first SCK edge	2 * T_{FSYS}		ns
T_{SH}	Last SCK edge to SCSN rising	2 * T_{FSYS}		ns
T_{SCKH}	SCK High Time	2 * T_{FSYS}		ns
T_{SCKL}	SCK Low Time	2 * T_{FSYS}		ns
T_{SIS}	MOSI Valid to SCK Sample edge	2 * T_{FSYS}		ns
T_{SIH}	SCK shift Edge to MOSI change	1 * T_{FSYS}		ns
T_{SOH}	SCK shift Edge to MISO change		4 * T_{FSYS}	ns

9.6 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
SPIMOD	0xFC	R/W	SPI Mode Register	0x40
SPICK	0xFD	R/W	SPI Baud Rate counter clock select Register	0x00
SPIDATA0	0xFE	R/W	SPI Transmit and Receive Data	Undef.
SPIDATA1	0xFF	R/W	SPI Transmit and Receive Data	Undef.

SPIMOD (0xFC)

Name	Bit	R/W	Description	Reset
SPI_INTPEND	7	R/W	SPI Interrupt Pending If the IESPI in the IE0 register is enabled and GIE is enabled, an interrupt is requested when this bit is set to '1'. User can clear this bit by writing '1' to this bit.	0
SPI_SSMD	6	R/W	SPI Slave Select Enable 0: SCSN signal is not routed to a port pin 1: SCSN signal is mapped as an output/input	1
SPI_SCKPHA	5	R/W	SPI Clock Phase 0: Data centered on first edge of SCK period. 1: Data centered on second edge of SCK period.	0
SPI_SCKPOL	4	R/W	SPI Clock Polarity. 0: SCK line low in idle state. 1: SCK line high in idle state.	0
SPI_SLVEN	3	R/W	SPI Master/Slave Mode 0: Master Mode, 1: Slave Mode	0
SPI_DIR	2	R/W	SPI Data Direction 0: MSB first, 1: LSB first	0
SPI_MODE	1	R/W	SPI Operation Mode 0: Receive-only mode, 1: Receive/Transmit mode	0
SPI_EN	0	R/W	0: Disable SPI operation, 1: Enable SPI operation	0

SPICK (0xFD)

SPI Baud rate counter clock select register. BaudRate = F_{SYS}/ CntValue

Name	Bit	R/W	Description			Reset
SPI_BUSY	7	R	This bit is set to logic 1 when a SPI transfer is in progress (Master or Slave mode) 0: SPI idle, 1: SPI Busy			0
SPI_2BYTE	6	R/W	1 Byte or 2 Byte selection 0: 1 Byte(8-bit) operation mode, 1: 2 Byte operation mode			0
RSVD	5:4	R	Reserved			000
SPI_CKSEL	3:0	R/W	0000	CntValue = 4095,	BaudRate = 12 MHz / 4095 ≒ 2.93 Kbps	0000
			0001	CntValue = 2500,	BaudRate ≒ 4.8 Kbps	
			0010	CntValue = 1250,	BaudRate ≒ 9.6 Kbps	
			0011	CntValue = 1000,	BaudRate ≒ 12 Kbps	
			0100	CntValue = 500,	BaudRate ≒ 24 Kbps	
			0101	CntValue = 250,	BaudRate ≒ 48 Kbps	
			0110	CntValue = 125,	BaudRate ≒ 96 Kbps	
			0111	CntValue = 50,	BaudRate ≒ 240 Kbps	
			1000	CntValue = 25,	BaudRate ≒ 480 Kbps	
			1001	CntValue = 12,	BaudRate ≒ 1 Mbps	
			1010	CntValue = 10,	BaudRate ≒ 1.2 Mbps	
			1011	CntValue = 5,	BaudRate ≒ 2.4 Mbps	
			1100	CntValue = 4,	BaudRate ≒ 3 Mbps	

SPIDATA0 (0xFE)

Name	Bit	R/W	Description	Reset
SPIDATA0	7:0	R/W	SPI Transmit and Receive Data 0. This register is used transmit and receive SPI data. Writing data to SPIDATA0 places the data into transmit buffer and shift register and initiates (starts) a transfer when in Master Mode. A read of SPIDATA0 returns the contents of the receive buffer. When in master mode, Receive operation can only be possible to write any data (i.e. any dummy data) into this register even if Receive operation is only required.	Undef.

SPIDATA1 (0xFF)

Name	Bit	R/W	Description	Reset
SPIDATA1	7:0	R/W	SPI Transmit and Receive Data 1. This register is used transmit and receive SPI data in Double Byte Mode which Two-Byte bit of SPICK register is set. In Double Byte Mode, this register should be set before the SPIDATA0 is transmitted. A read of SPIDATA1 returns the contents of the receive buffer.	Undef.

PROGRAMMING TIP:

Transmit and receive setup example procedure, with a description of each step is shown below.

Setup Procedure	Description
void SPI_setup() {	
rCLK_EN0 |= 0x08;	1) Enable SPI operation clock.
rP3MOD1 = 0xAA;	2) Set P3MOD1 register for SPI operation.
rIE0 |= 0x20;	3) Enable SPI interrupt
rGIE = 0x80;	4) Enable Global interrupt
rSPICK = 0x4C;	5) Set SPICK register to select the baud rate “3Mbps” Set 2 Byte operation mode
rSPIMOD = 0x72;	6) SPIMOD.6 = 1: Enable SPI interrupt SPI_SCKPHA = 1, SPI_SCKPOL = 1 SPIMOD.3 = 0; Master Mode. In this case SCLK pin is operation as output. SPIMOD.2 = 0: MSB first SPIMOD.1 = 1: Receive/Transmit mode
######	# At this time, slave device should be enabled before master device is enabled
rSPIMOD |= 0x1;	SPIMOD.0 = 1: Enable SPI operation
rSPIDATA1 = 0xA3	7) Write the second transmit data to rSPIDATA1.
rSPIDATA0 = 0x75;	8) Write the transmit data to rSPIDATA0. Then an internal baud rate clock is generated to start transmit/receive. After transmit/receive have been finished, SPI interrupt (INTSPI) is generated in 1 byte operation mode
}	

10 UART

10.1 OVERVIEW

Universal Asynchronous Receiver and Transmitter (UART) of the BMC513 provide one asynchronous serial I/O ports. The UART can support bit rates up to 115Kbps using system clock. UART input and output pins are multiplexed with GPIOs.

The BMC513's UART includes programmable baud rates, infrared (IR) transmit/receive, one or two stop bit insertion, 5-bit, 6-bit, 7-bit or 8-bit data width and parity checking.

UART contains a baud-rate generator, transmitter, receiver and a control unit. The baud-rate generator can be clocked by F_{SYS}, EXTUCLK, $F_{SYS}/2$, $F_{SYS}/4$, $F_{SYS}/8$ or $F_{SYS}/16$ clock.

Transmit data is written first to transmit buffer register (Holding register). From there, it is copied to the transmit shifter and then shifted out by the transmit data pin, UTXD. Received data is shifted in by the receive data pin, URXD. It is then copied from the shifter to the receive buffer register when one data byte has been received.

10.2 FEATURES

- Supports 5-bit, 6-bit, 7-bit, or 8-bit serial data transmit/receive (TX/RX)
- Supports external clocks for the UART operation
- Programmable baud rate
- Supports IrDA 1.0
- Loopback mode for testing
- IInsertion of one or two Stop bits per frame
- Parity checking

10.3 PIN DESCRIPTION

Table 10-1. UART PIN Description

GPIO1	Pin Name	Function	Type
GP73	UCLK	External Clock Source for UART	I
GP74	URXD	Receive Data Input for UART	I
GP75	UTXD	Transmit Data Output for UART	O

10.4 BLOCK DIAGRAM

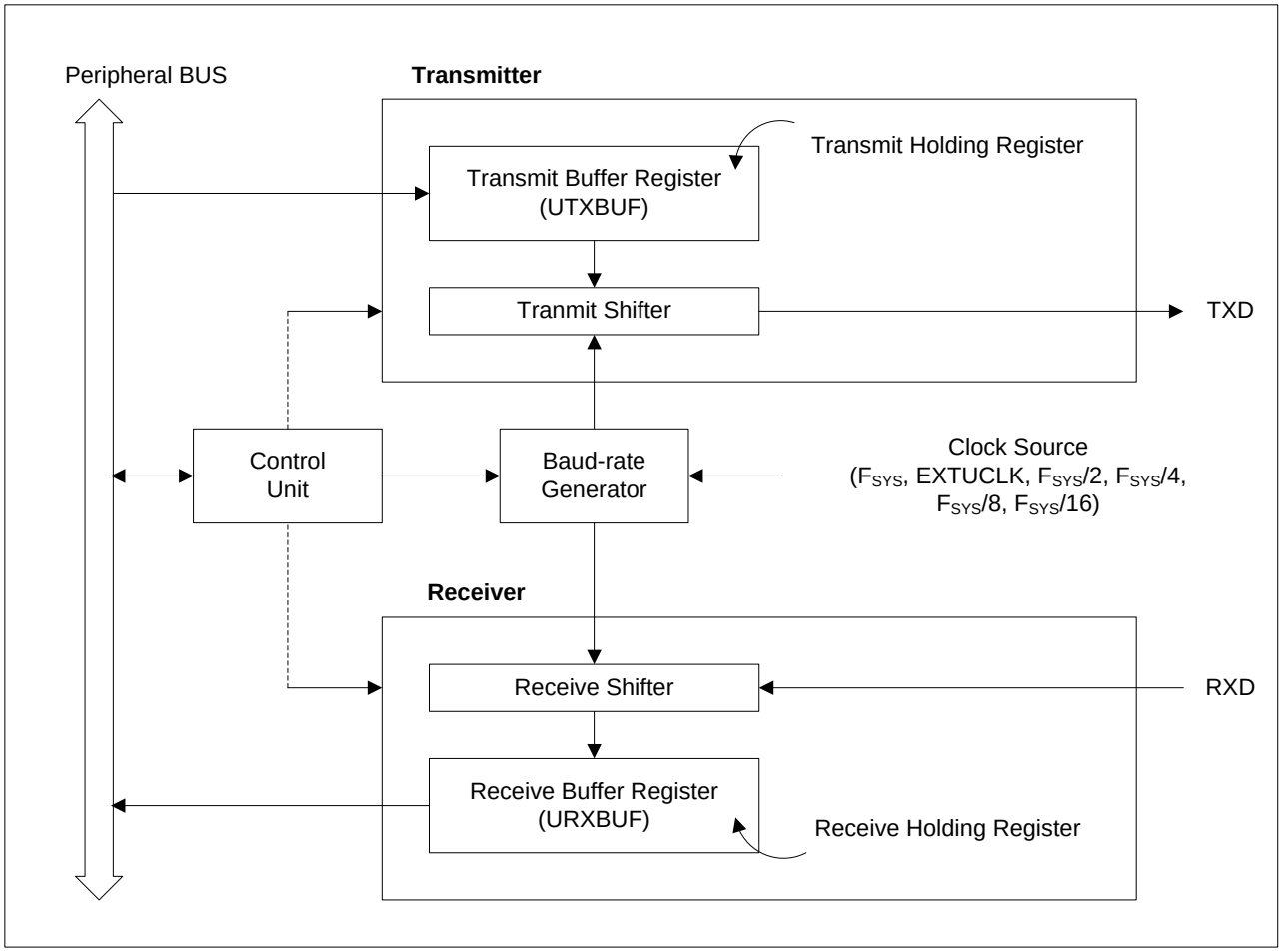


Figure 10-1. UART Block Diagram

10.5 OPERATION

The following sections describe the UART operations that include data transmission, data reception, interrupt generation, baud-rate generation, Loopback mode, and infrared mode.

Transmission

The data frame for transmission is programmable. It consists of a start bit, 5 to 8 data bits, an optional parity bit and 1 to 2 stop bits, which can be specified by the control register (UCON). The transmitter can also produce the break condition, which forces the serial output to logic ‘0’ for one frame transmission time. This block transmits break signals after the present transmission word is transmitted completely. After transmission of the break signal, it continuously transmits data into the UTXBUF (Tx holding register).

Reception

Like the transmission, the data frame for reception is also programmable. It consists of a start bit, 5 to 8 data bits, an optional parity bit and 1 to 2 stop bits in the control register (UCON). The receiver can detect overrun error, parity error, frame error and break condition, each of which can set an error flag.

- The overrun error indicates that new data has overwritten the old data before the old data has been read.
- The parity error indicates that the receiver has detected an unexpected parity condition.
- The frame error indicates that the received data does not have a valid stop bit.
- The break condition indicates that the URXD input is held in the logic ‘0’ for duration of longer than one frame transmission time.

Interrupt Request Generation

UART of the BMC513 has eight status (Tx/Rx/Error) signals: Overrun error, Parity error, Frame error, Break, Receive buffer data valid, Transmit buffer empty, and Transmit shifter empty, all of which are specified by the corresponding UART status register (UTRSTAT and UERSTAT).

The overrun error, parity error, frame error and break condition are referred to as the receive error status. Each of which can cause the receive error status interrupt request, if the receive-error-status-interrupt-enable bit is set to '1' in the interrupt register, UINTCON. When a receive-error-status-interrupt-request is detected, the signal causing the request can be identified by reading the value of UERSTAT.

When the receiver transfers the data in the receive shifter to the receive buffer register, Rx interrupt is generated if the receive mode in control register, UCON, is selected.

Transferring data from the transmit holding register to the transmit will cause Tx interrupt.

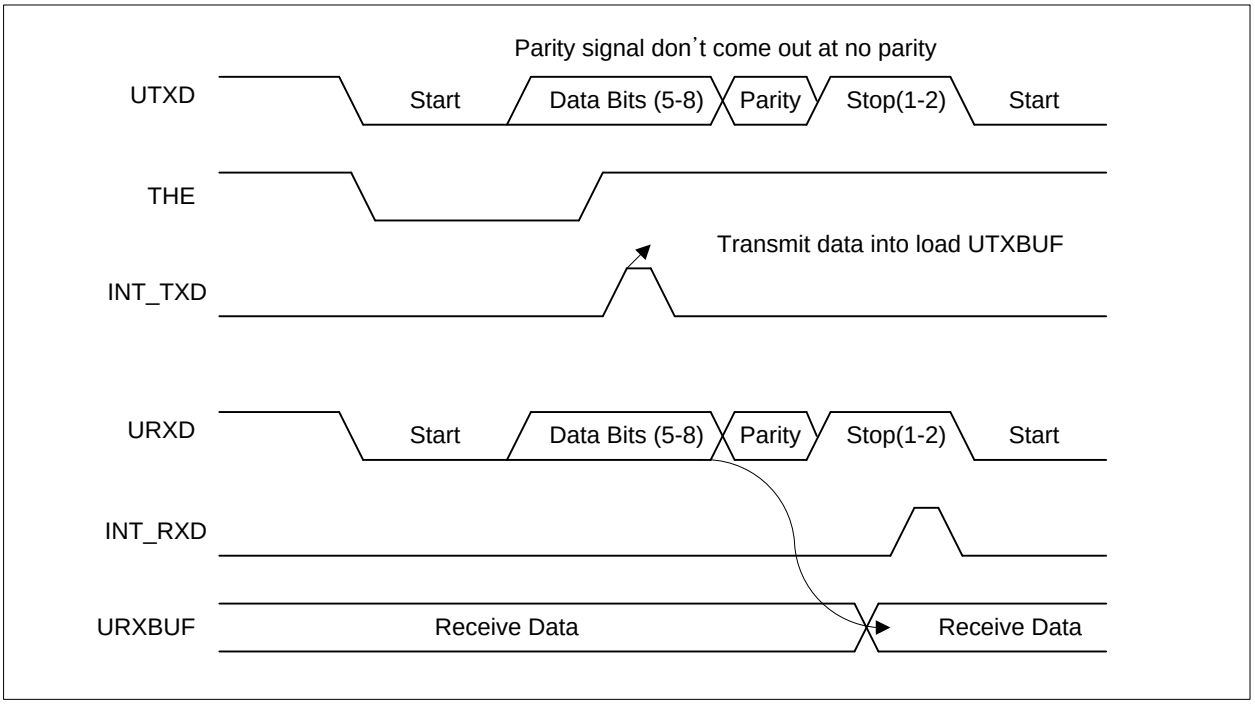


Figure 10-2. UART Interrupt Timing Diagram

Baud-rate Generation

Baud-rate generator of UART provides the serial clock for the transmitter and the receiver. The source clock for the baud-rate generator can be selected with one of internal system clock, F_{SYS}, EXTUCLK, $F_{SYS}/2$, $F_{SYS}/4$, $F_{SYS}/8$ or $F_{SYS}/16$. In other words, dividend is selectable by setting Clock Selection of UCON1.

Baud Rate CLK = (Source CLK) / ((CNT0+1) x 16)
(Source CLK : F_{SYS}, EXTUCLK, $F_{SYS}/2$, $F_{SYS}/4$, $F_{SYS}/8$ or $F_{SYS}/16$)

EXTUCLK are sampled by F_{SYS}. But their clock and F_{SYS} is asynchronous clock. So they may not be sampled at exact time. So, it is recommended to use EXTUCLK under $F_{SYS}/2$.

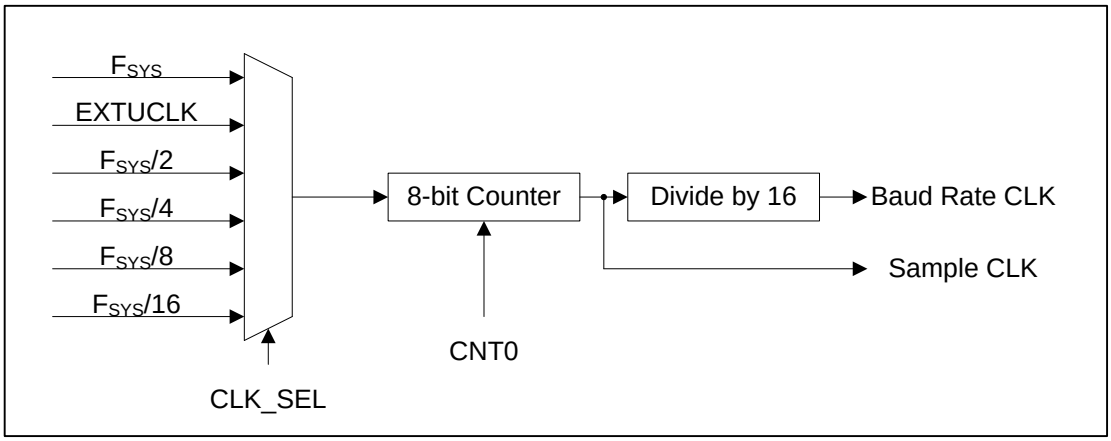


Figure 10-3. Baud Rate Generator

Table 10-2. Baud Rate Examples of UART

Frequency	Wanted Baud Rate	Real Baud Rate	UBAUD value (Decimal)	Error Ratio (%)
F_{SYS} = 11.0592MHz	4800	4800	143	0
	9600	9600	71	0
	19200	19200	35	0
	38400	38400	17	0
	57600	57600	11	0
	115200	115200	5	0
F_{SYS} = 12MHz	4800	4808	155	0.16
	9600	9615	77	0.15
	19200	19231	38	0.16
	38400	37500	19	2.34
	57600	57692	12	0.16

Loopback Mode

The UART provides a test mode referred to as the Loopback mode, to aid in isolating faults in the communication link. This mode structurally enables the connection of URXD and UTXD in the UART. In this mode, therefore, transmitted data is received to the receiver, via URXD. This feature allows the processor to verify the internal transmit and to receive the data path. This mode can be selected by setting the loopback bit in the UART control register (UCON0).

Infrared (IR) Mode

The UART supports infrared (IR) transmission and reception, which can be selected by setting the Infrared-mode bit in the UART control register, UCON1. In IR mode, the transmit period is pulsed at a rate of 3/16 that of the normal serial transmit rate (when the transmit data value in the UTXBUF register is '0'). In IR receive mode, the receiver must detect the 3/16 pulsed period to recognize a '0' value in the receiver buffer register, URXBUF, as the IR receive data.

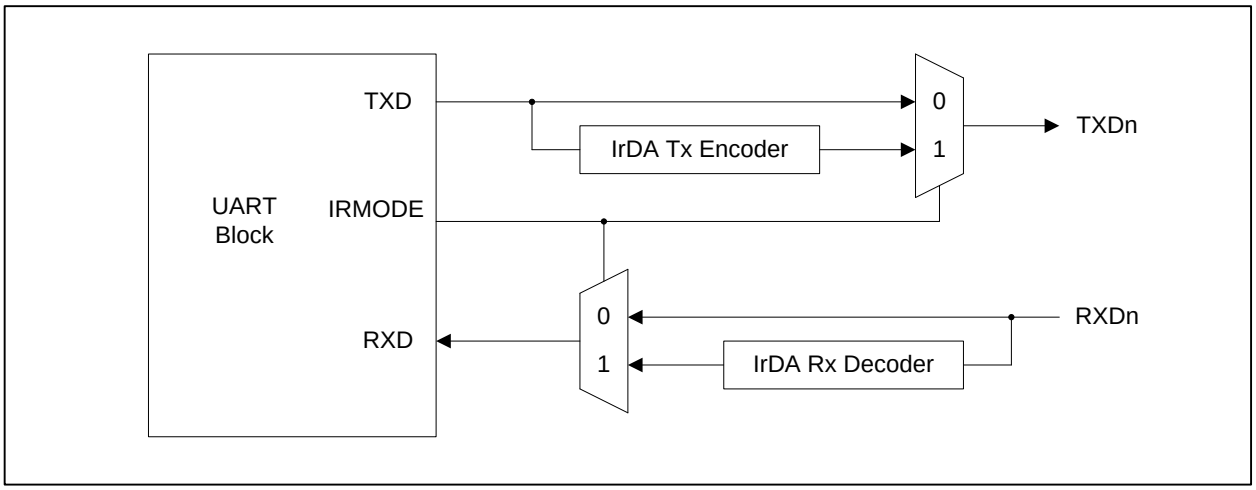


Figure 10-4. IrDA Function Block Diagram

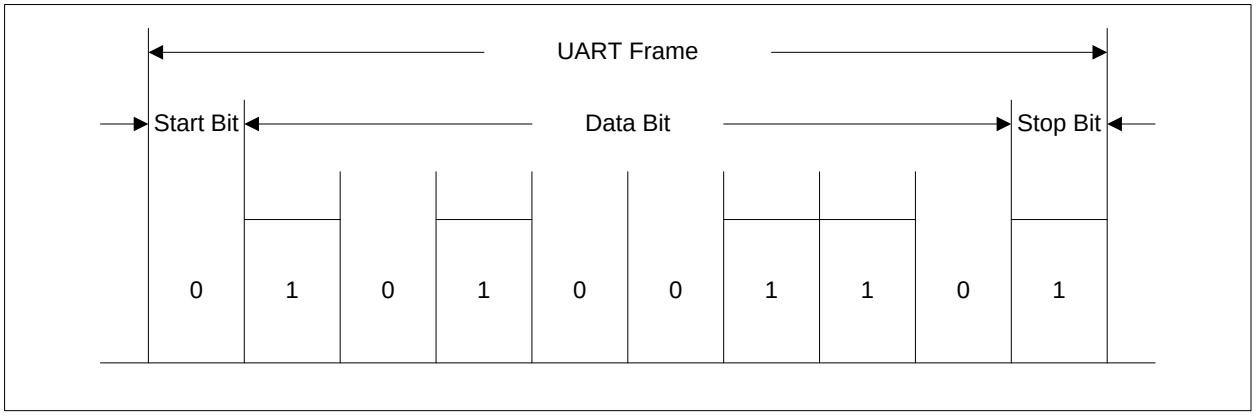


Figure 10-5. UART Frame Structure

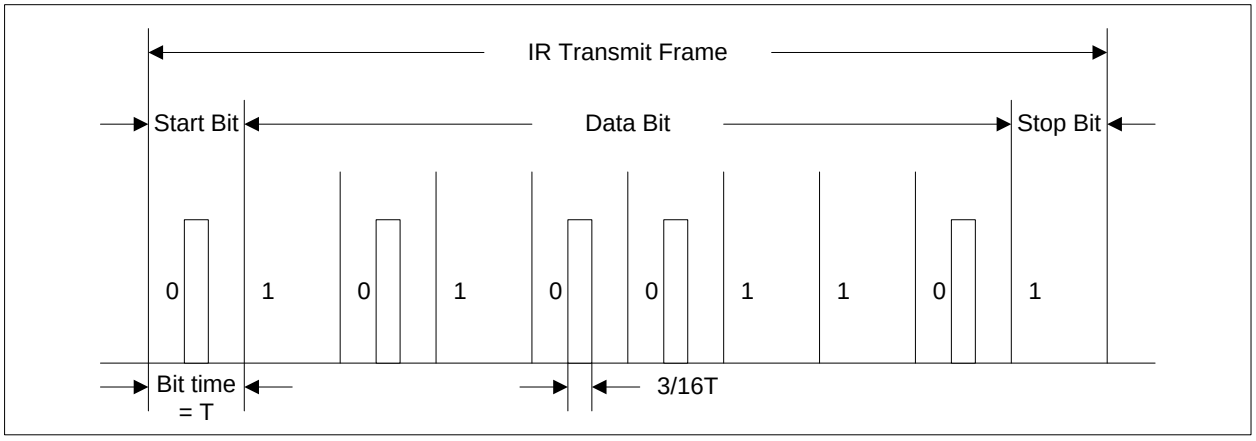


Figure 10-6. Infrared Tx Frame Timing Diagram

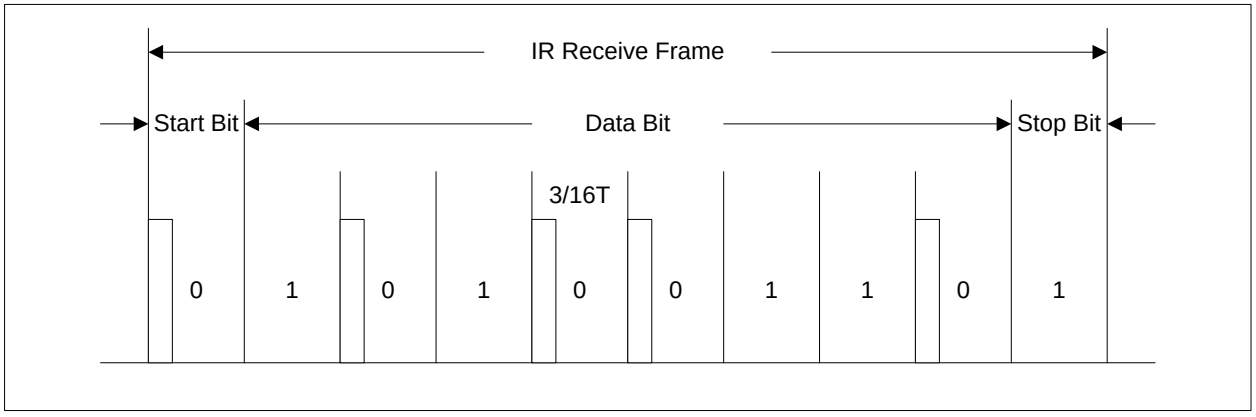


Figure 10-7. Infrared Rx Frame Timing Diagram

10.6 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
UCON0	0xF1	R/W	UART Control Register 0	0x00
UCON1	0xF2	R/W	UART Control Register 1	0x00
UTRSTAT	0xF3	R/W	UART TX/RX Status Register	0x19
UERSTAT	0xF4	R/W	UART RX Error Status Register	0x00
UINTCON	0xF5	R/W	UART Interrupt Enable / Pending Register	0x00
UBAUD	0xF6	R/W	UART Baud Rate Divisor Register	0x20
URXBUF	0xF7	R	UART Receive Buffer	Undef.
UTXBUF	0xF8	W	UART Transmit Buffer	Undef.
Reserved	0xF9	R/W	**User can't access these registers, if access, it might cause unexpected operation.**	0x00
Reserved	0xFA	R/W		0x00
Reserved	0xFB	R/W		0x00

UCON0 (0xF1)

Name	Bit	R/W	Description		Reset
PMD	7:5	R/W	Parity mode		000
			0XX	No parity	
			100	Odd parity	
			101	Even parity	
			110	Parity is forced/checked as a '1'	
			111	Parity is forced/checked as a '0'	
LOOPB	4	R/W	Setting this bit to '1' causes the UART to enter Loop-back mode. In this mode, the transmit data output (UTXD) keeps '1' and UTXBUF is internally connected to the receive data register (URXBUF). This mode is provided for test purposes only. For normal operation, this bit should always be '0'.		0
ECHO	3	R/W	Echo mode enable 0: Disable echo test 1: Enable echo test (RX data is sent not only RXBUF but also TX port directly, so TXBUF data will not be transmitted)		0
SBR	2	R/W	Setting this bit causes the UART to send a break. A break is defined as a continuous Low level signal on the transmit data output with the duration of more than one frame transmission time.		0
RMODE	1	R/W	0: Disable Receive mode, 1: Enable Receive mode		0
TMODE	0	R/W	0: Disable Transmit mode, 1: Enable Transmit mode		0

UCON1 (0xF2)

Name	Bit	R/W	Description	Reset
RSVD	7	-	Reserved	0
UBAUDCLK	6:4	R/W	Clock Source Selection 000: F_{SYS} 001: EXTUCLK 010: $F_{SYS}/2$ 011: $F_{SYS}/4$ 100: $F_{SYS}/8$ 101: $F_{SYS}/16$ Other value: Reserved	000
IRMODE	3	R/W	0: Normal operation mode 1: Infrared TX/RX mode	0
WL	2:1	R/W	Word Length 00: 5bits, 01: 6bits, 10: 7bits, 11: 8bits	00
STB	0	R/W	Number of stop bits 0: One stop bit per frame, 1: Two stop bit per frame	0

UTRSTAT (0xF3)

Name	Bit	R/W	Description	Reset
RSVD	7:5	R	Reserved	-
Transmit Buffer Empty (THE)	4	R	This bit is set to '1' automatically when transmit buffer register is empty regardless of shift register. If THEIE bit in UINTCON register is '1' and this bit is '1', TX interrupt Request will be generated. 0: The buffer register is not empty 1: Empty This bit is cleared automatically by writing transmit data into transmit buffer register (UTXBUF).	1
Transmitter Empty (TXIDLE)	3	R	This bit is set to '1' automatically when the transmit buffer register has no valid data to transmit and the transmit shift register is empty. If TIIE in UINTCON register is '1' and this bit is '1', TX interrupt Request will be generated. 0: Not empty 1: Transmit (transmit buffer & shift register) empty	1
RSVD	2	R	Reserved	-
Receive Data Valid (RDV)	1	R	This bit is set to '1' automatically whenever receive buffer register contains valid data, received over the URXD port 0: Empty 1: The buffer register has a received data This bit is cleared automatically by reading URXBUF.	0
Receive IDLE(RXIDLE)	0	R	This bit is only for CPU to monitor the receive state of UART. This bit indicates that RX operation is in active	1

UERSTAT (0xF4)

All bits of UERSTAT register are automatically cleared to '0' when this register is read.

Name	Bit	R/W	Description	Reset
RSVD	7:4	R	Reserved	-
Overrun Error (OER)	3	R	This bit is set to '1' automatically whenever a overrun error occurs during receive operation. When URXBUF has a previous valid data, but a new received data is going to be written into URXBUF. 0: No overrun error during receive 1: Overrun error (Interrupt is requested)	0
Parity Error (PER)	2	R	This bit is set to '1' automatically whenever a parity error occurs during receive operation. 0: No parity error during receive 1: Parity error (Interrupt is requested)	0
Frame Error (FER)	1	R	This bit is set to '1' automatically whenever a frame error occurs during receive operation. A frame error occurs when a '0' is detected instead of the stop bit(s). 0: No frame error during receive 1: Frame error (Interrupt is requested)	0
Break Signal Detected (BKD)	0	R	This bit is set to '1' automatically to indicate that a break signal has been received 0: No break receive 1: Break receive (Interrupt is requested)	0

UINTCON (0xF5)

These bits, in conjunction with the IEURX, IEURXERR and IEUTX in the IE1 register, enables UART interrupts.

Name	Bit	R/W	Description	Reset
URXERRINTPEND	7	R/W	RX ERROR Interrupt Pending Register. This bit is cleared by setting '1'. 0: Non-pending, 1: Pending	0
URXINTPEND	6	R/W	RX Interrupt Pending Register. This bit is cleared by setting '1'. 0: Non-pending, 1: Pending	0
UTXINTPEND	5	R/W	TX Interrupt Pending Register. This bit is cleared by setting '1'. 0: Non-pending, 1: Pending	0
TIIE	4	R/W	Transmit empty Interrupt Enable. 0: Disable 1: Enable	0
THEIE	3	R/W	Transmit Buffer empty Interrupt Enable. 0: Disable 1: Enable	0
RXERRIE	2	R/W	Enable the UART to generate an interrupt upon an exception, such as a break, frame error, parity error, or overrun error during a Rx operation 0: Do not generate receive error status interrupt. 1: Generates receive error status interrupt	0
RSVD	1	R/W	Reserved. **Don't make this bit set to '1' to avoid anything unexpected.**	0
RDVIE	0	R/W	Receive Data Valid Interrupt Enable 0: Disable 1: Enable	0

UBAUD (0xF6)

Baud Rate Out = (Select CLK) / ((CNT0+1) x 16)

Name	Bit	R/W	Description	Reset
CNT0	7:0	R/W	Time constant value CNT0[7:0]	0x20

URXBUF (0xF7)

Name	Bit	R/W	Description	Reset
RXBUF	7:0	R	Receive Data	Undef.

UTXBUF (0xF8)

Name	Bit	R/W	Description	Reset
TXBUF	7:0	W	Transmit Data	Undef.

PROGRAMMINT TIP:

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
void UART_NONFIFO_setup() {	
rCLK_EN0 |= 0x80;	1) Enable UART operation clock.

rP7MOD1 = 0x0F;	2) Set P7MOD1 register for UART operation.
	Using GP1: rP1PUD0 = 0x00; // pullup disable
	rP1MOD1 = 0x3C;

rIE1 |= 0x04;	3) Enable UART TX interrupt
rGIE = 0x80;	4) Enable Global interrupt
rUBAUD = 12;	5) Baud Rate: 57600 (PXI = 12MHz)
rUINTCON = 0x18;	6) TXIDLE/THE interrupt enable
rUCON1 = 0x06;	7) Clock source: F_{SYS} 8 bit word length, 1 stop bit per frame
rUCON0 = 0x01	8) No parity, Transmit enable At this time, interrupt will be generated, because Transmit holding buffer is empty. Some data should write to rUTXBUF in UART TX interrupt service routine.
}	

11 Timers

11.1 OVERVIEW

The BMC513 have three 16-bit timers (Timer 0, 1, and 2). Timers have Pulse Width Modulation (PWM) function, capture function and timer output pins. All timers have a clock divider independently. All timers' input/output pins are multiplexed with GPIO pins.

The timer down count register (TnCNT) will be decreased when the timer is enabled. The timer time-out value register (TnDATA) is to be loaded into the TCNTn register.

11.2 FEATURES

- 3 Programmable Timers
- Interval Mode, Toggle Mode, PWM Mode and Capture Mode
- 3 Programmable duty control of output wave form(PWM) and Timer output

11.3 PIN DESCRIPTION

Table 11-1. Timers PIN Description

GPIO1	GPIO2	Pin Name	Function	Type
GP13	GP04	TCLK	External Clock Source for Timer 0, Timer 1 and Timer 2	I
GP12	GP05	T0CAP/T0OUT	Timer 0 Capture Input Timer 0 16-bit PWM mode output or counter match toggle output	I O
GP11	GP06	T1CAP/T1OUT	Timer 1 Capture Input Timer 1 16-bit PWM mode output or counter match toggle output	I O
GP10	GP07	T2CAP/T2OUT	Timer 2 Capture Input Timer 2 16-bit PWM mode output or counter match toggle output	I O

11.4 BLOCK DIAGRAM

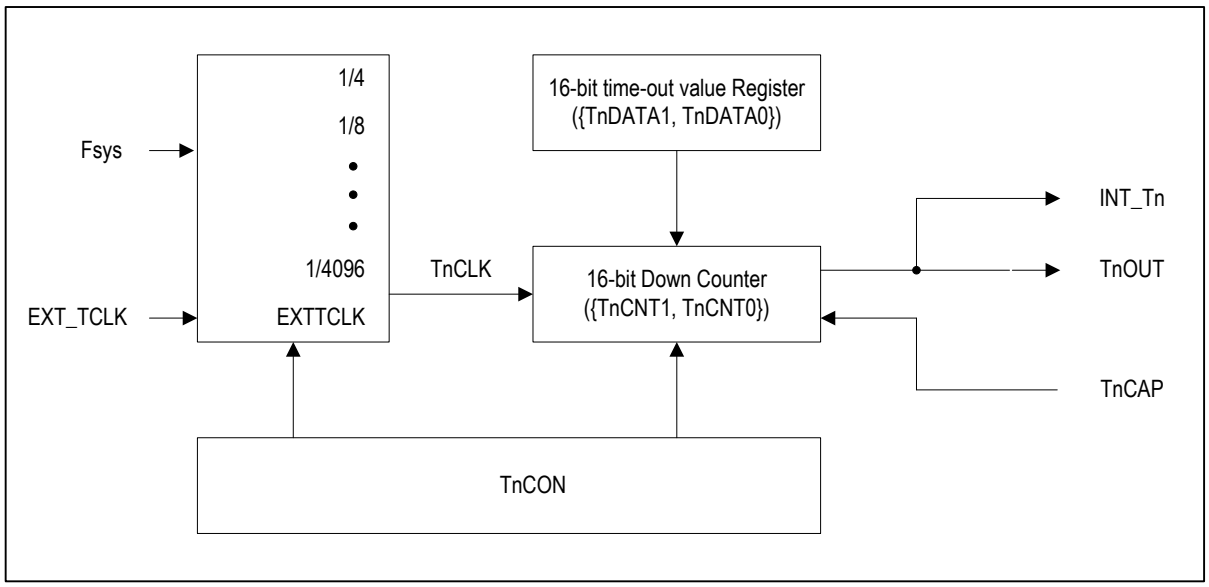


Figure 11-1. Timers Block Diagram.

11.5 OPERATION

When TnDATA is set, it loads a data value (TnDATA0) into count register (TnCNT). When a timer is enabled, it begins decrement of the count register value (TnCNT). When the TnCNT reaches to ‘0’, the associated interrupt is generated. The base value (TnDATA) is then reloaded to the TnCNT, and the timer continues decrement of its TnCNT unless each timer disable. If timer is disabled, you can write a new base value into its register (TnDATA) during decrement of its TnCNT.

PWM Mode

The interrupt is generated by MATEN and OVFEN. TnOUT goes to high at starting of counter and then TnOUT goes to low when TnDATA is equal to TnCNT.

In PWM mode, the timer pulse continues to toggle whenever timer count value is same as the PWM data register and the timer pulse return to initial value whenever a time-out occurs. The PWM pulse is output directly at the TnOUT. Using PWM mode, you can achieve a flexible timer clock range which flexible duty.

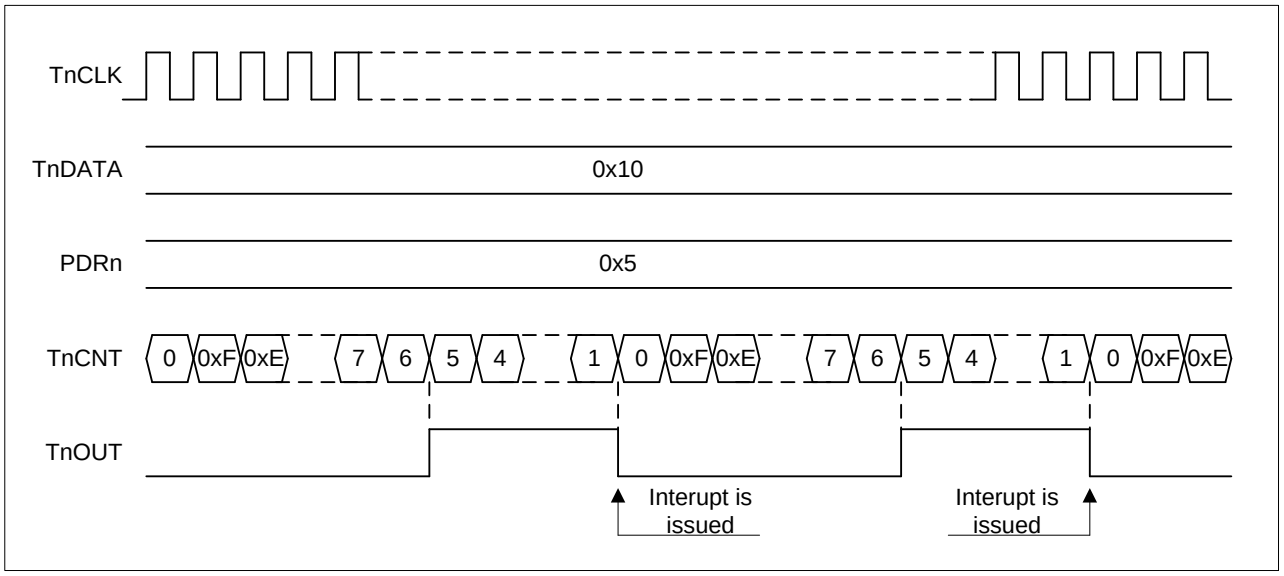


Figure 11-2. Example of Timer Operation in PWM Mode

Interval Mode

In Interval Mode, a timer continues to toggle whenever a timer reference register(TnDAT) value is same as a timer count register (TnCNT). An interrupt request is generated whenever the level of the timer output signal is inverted (that is, when the level toggles).

In Interval Mode, a timer generates one-shot pulse of timer clock duration whenever a time-out occurs. This pulse generates a time-out interrupt that directly output at the timer's configured output pin (TnOUT)

Toggle Mode

In toggle mode, the timer pulse continues to toggle whenever a time-out occurs. An interrupt request is generated whenever the level of the timer output signal is inverted (that is, when the level toggles). The toggle pulse is output directly at the configured output pin. Using toggle mode, you can achieve a flexible timer clock range which 50% duty.

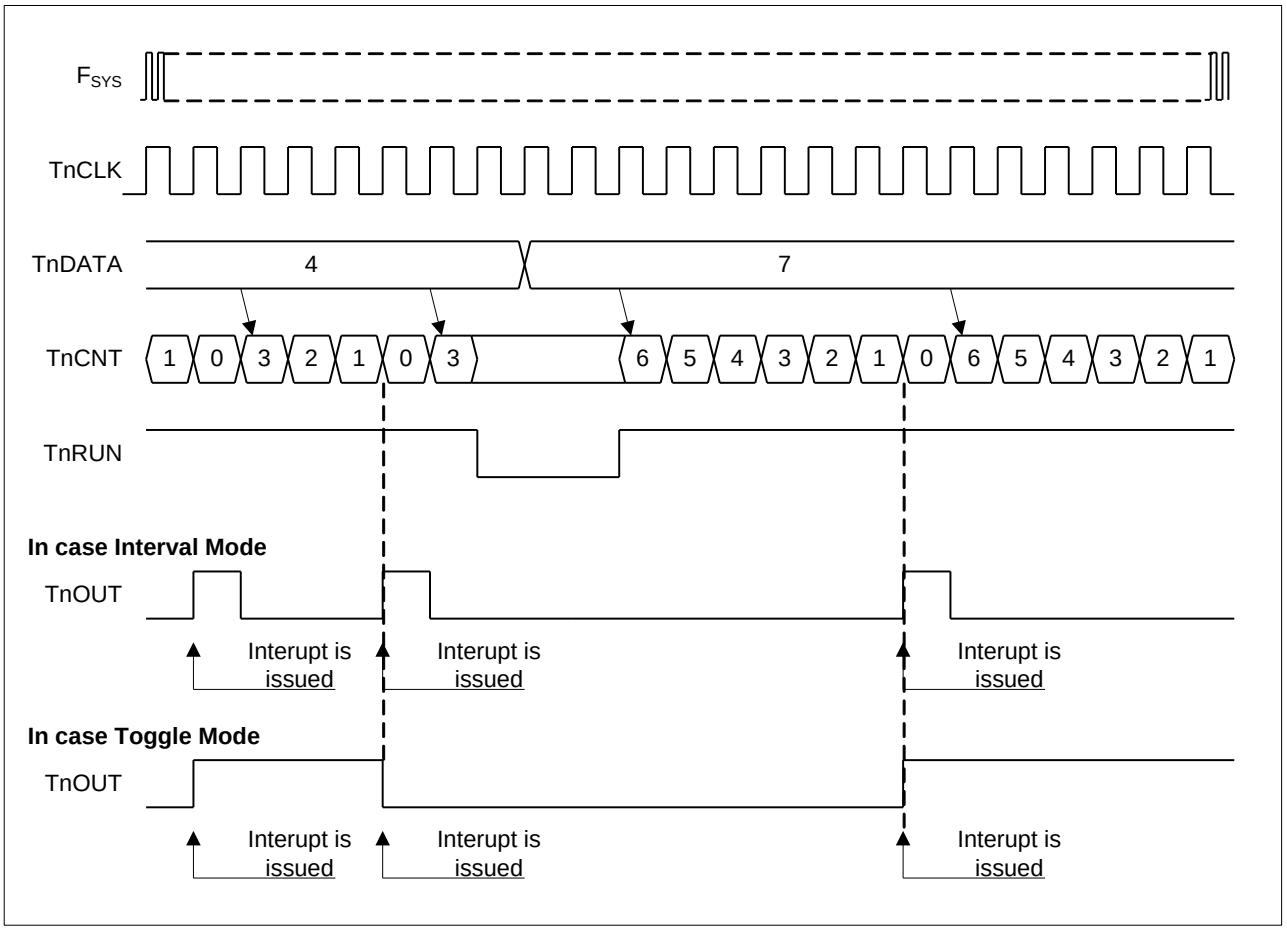


Figure 11-3. Example of Timer Operation in Interval and Toggle Mode

Capture Mode

In Capture Mode, the interrupt is generated whenever TnCAP pin is issued. Capture interrupt enable bit isn't existence and TnOUT is not coming out.

In capture mode, the interrupt is generated whenever rising edge of TnCAP pin is detected. An interrupt request and a capture trigger are generated at switching the active rising edge of a TnCAP pin. At the same time, the value of a counter is stored to the temporary register. And reading TnCNT by CPU, the temporary register value will be read out to the CPU. If a new capture trigger is generated before the value of TnCNT is read, the value of temporary can be rewritten. So, new value will be read out when CPU read TnCNT register. TnCAP is shared with TnOUT pin.

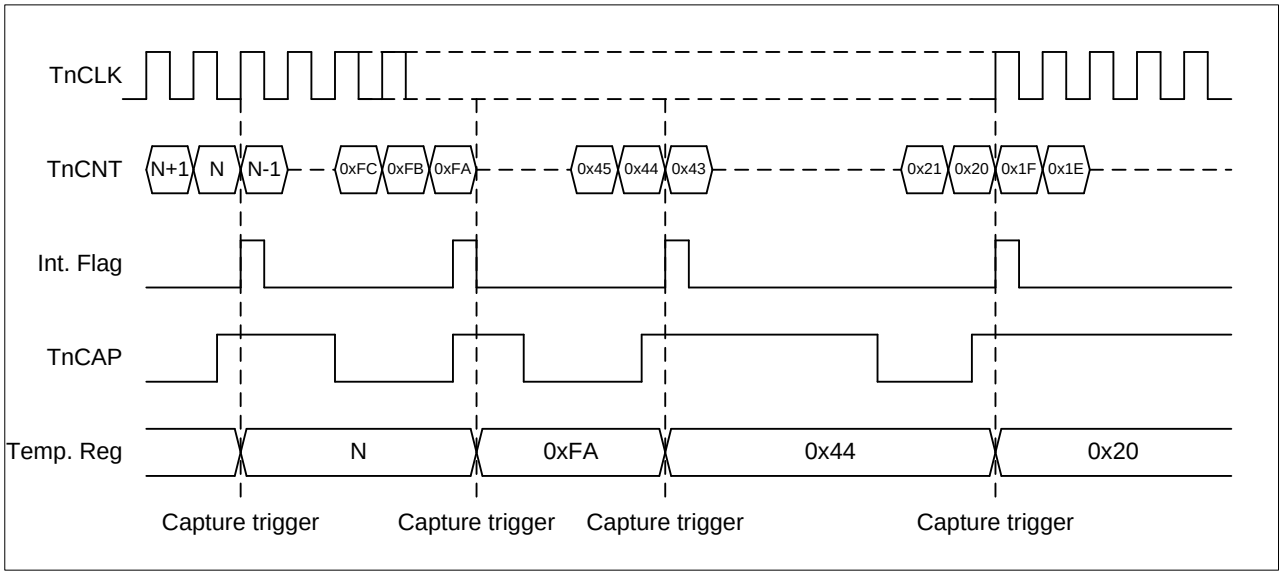


Figure 11-4. Example of Timer Operation in Capture Mode

11.6 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
T0CON	0xFE00	R/W	Timer 0 Control Register	0x00
T0DATA0	0xFE01	R/W	Timer 0 Reference Data Register 0	0xFF
T0DATA1	0xFE02	R/W	Timer 0 Reference Data Register 1	0xFF
T0CNT0	0xFE03	R/W	Timer 0 Lower Counter	0xFF
T0CNT1	0xFE04	R/W	Timer 0 Upper Counter	0xFF
T0PDR0	0xFE05	R/W	Timer 0 PWM Data Register 0	0x01
T0PDR1	0xFE06	R/W	Timer 0 PWM Data Register 1	0x00
T1CON	0xFE08	R/W	Timer 1 Control Register	0x00
T1DATA0	0xFE09	R/W	Timer 1 Reference Data Register 0	0xFF
T1DATA1	0xFE0A	R/W	Timer 1 Reference Data Register 1	0xFF
T1CNT0	0xFE0B	R/W	Timer 1 Lower Counter	0xFF
T1CNT1	0xFE0C	R/W	Timer 1 Upper Counter	0xFF
T1PDR0	0xFE0D	R/W	Timer 1 PWM Data Register 0	0x01
T1PDR1	0xFE0E	R/W	Timer 1 PWM Data Register 1	0x00
T2CON	0xFE10	R/W	Timer 2 Control Register	0x00
T2DATA0	0xFE11	R/W	Timer 2 Reference Data Register 0	0xFF
T2DATA1	0xFE12	R/W	Timer 2 Reference Data Register 1	0xFF
T2CNT0	0xFE13	R/W	Timer 2 Lower Counter	0xFF
T2CNT1	0xFE14	R/W	Timer 2 Upper Counter	0xFF
T2PDR0	0xFE15	R/W	Timer 2 PWM Data Register 0	0x01
T2PDR1	0xFE16	R/W	Timer 2 PWM Data Register 1	0x00

Note) These registers have to be accessed using **MOVX** instruction.

TnCON (T0CON: 0xFE00, T1CON: 0xFE08, T2CON: 0xFE10)

Name	Bit	R/W	Description		Reset
TnCLK_SEL	7:4	R/W	Timer n counting clock select TnCLK = F_{SYS} / $2^{(n+2)}$ (n= 0~10), When n=11, TnCLK = External Timer clock (<= F_{SYS}/2)		0000
TnMOD_SEL	3:2	R/W	00	Interval Mode.	00
			01	Toggle Mode	
			10	PWM Mode	
			11	Capture Rising Mode	
TnINTPEND	1	R/W	Timer n Interrupt Pending If the IETn in the IE0 and IE1 register is enabled and GIE is enabled, an interrupt is requested when this bit is set to '1'. User can clear this bit by writing '1' to this bit.		0
TnRUN	0	R/W	0: Disable Timer n, 1: Enable Timer n		0

TnDATA0 (T0DATA0: 0xFE01, T1DATA0: 0xFE09, T2DATA0: 0xFE11)

Timer 0/1/2 reference data value = {TnDATA1[7:0], TnDATA0[7:0]}.

Name	Bit	R/W	Description	Reset
TnDATA0	7:0	R/W	Timer 0/1/2 reference data register 0.	0xFF

TnDATA1 (T0DATA1: 0xFE02, T1DATA1: 0xFE0A, T2DATA1: 0xFE12)

Name	Bit	R/W	Description	Reset
TnDATA1	7:0	R/W	Timer 0/1/2 reference data register 1.	0xFF

TnCNT0 (T0CNT0: 0xFE03, T1CNT0: 0xFE0B, T2CNT0: 0xFE13)

Timer 0/1/2 counter = {TnCNT1[7:0], TnCNT0[7:0]}

Name	Bit	R/W	Description	Reset
TnCNT0	7:0	R/W	Timer 0/1/2 Count register 0.	0xFF

TnCNT1 (T0CNT1: 0xFE04, T1CNT1: 0xFE0C, T2CNT1: 0xFE14)

Name	Bit	R/W	Description	Reset
TnCNT1	7:0	R/W	Timer 0/1/2 Count register 1.	0xFF

TnPDR0 (T0PDR0: 0xFE05, T1PDR0: 0xFE0D, T2PDR0: 0xFE15)

Timer 0/1/2 PWM value = {TnPDR1[7:0], TnPDR0[7:0]}

Name	Bit	R/W	Description	Reset
TnPDR0	7:0	R/W	Timer 0/1/2 PWM Data register 0. This register must not have zero value, and will be written any value in PWM mode.	0x01

TnPDR1 (T0PDR1: 0xFE06, T1PDR1: 0xFE0E, T2PDR1: 0xFE16)

Name	Bit	R/W	Description	Reset
TnPDR1	7:0	R/W	Timer 0/1/2 PWM Data register 1. This register will be written any value in PWM mode.	0x00

PROGRAMMINT TIP:

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
void TIMER0_setup() {	
rCLK_EN0 |= 0x10;	1) Enable TIMER 0 operation clock.
rP1MOD0 = 0x30;	2) Set P1MOD0 register for TIMER 0 operation. Using GP0: rP0MOD1 = 0x0C;
rIE0 |= 0x40; rGIE = 0x80;	3) Enable TIMER 0 interrupt 4) Enable Global interrupt

rT0DATA0 = 0x03;
rT0DATA1 = 0xE8;
rT0CON = 0x90;
	5) [7:4]: select counting clock source ($F_{SYS}/2^{11}$)
	Interval mode, Start timer

}	

12 WDT

12.1 OVERVIEW

The watchdog timer is used to prevent the system from locking-up (for example in infinite software loops). If the software does not write to the watchdog during the programmed time, then it can generate an internal reset.

12.2 FEATURES

- 8-bit Timer with pre-scaler.
- If an overflow of watchdog timer is generated, a reset is issued when WAKEEN is disabled, or WAKE-UP is issued when enabled.

12.3 BLOCK DIAGRAM

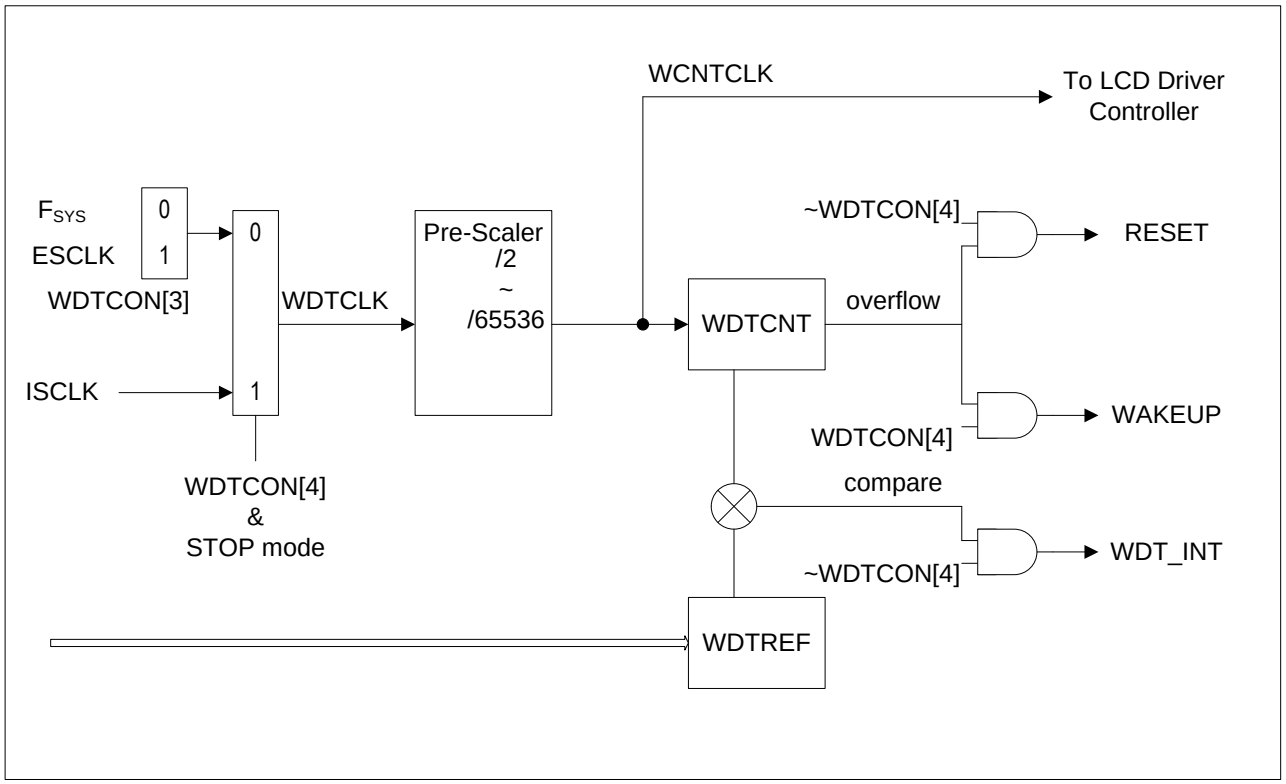


Figure 12-1. WDT Block Diagram.

12.4 OPERATION

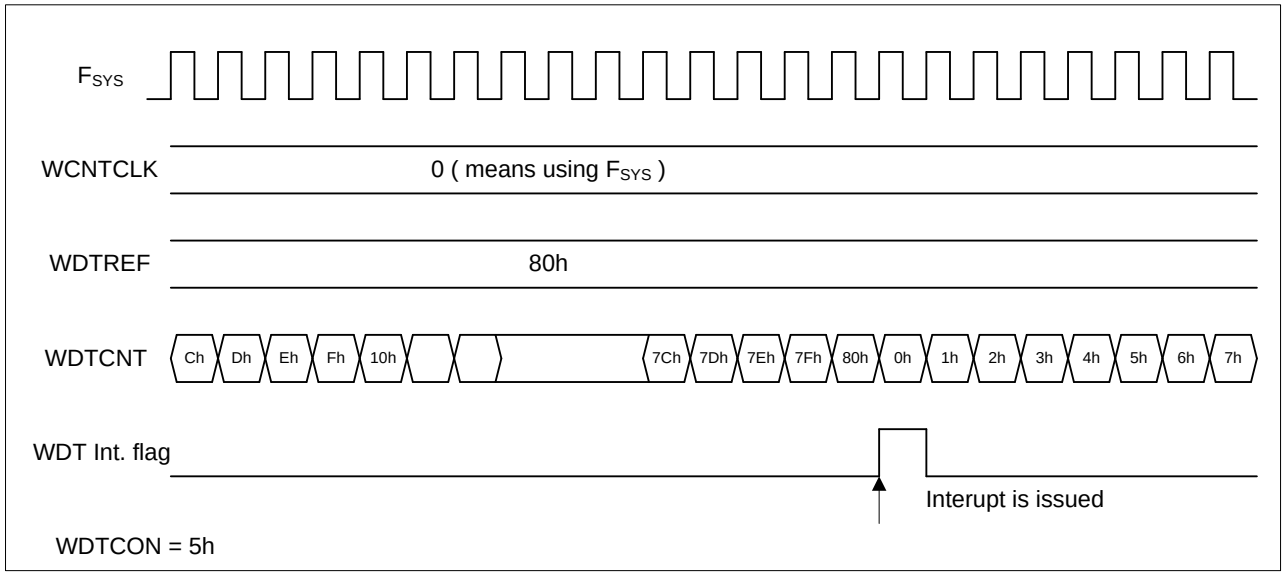


Figure 12-2. WDT Timing Diagram with interrupt.

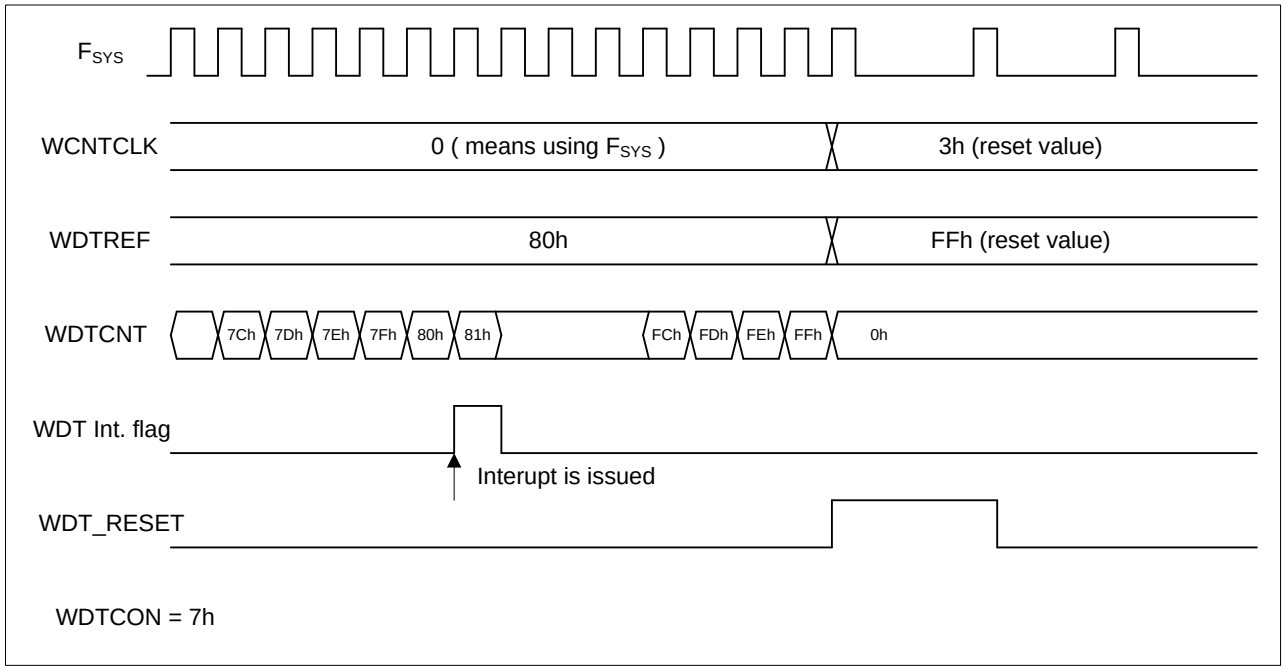


Figure 12-3. WDT Timing Diagram with interrupt and reset

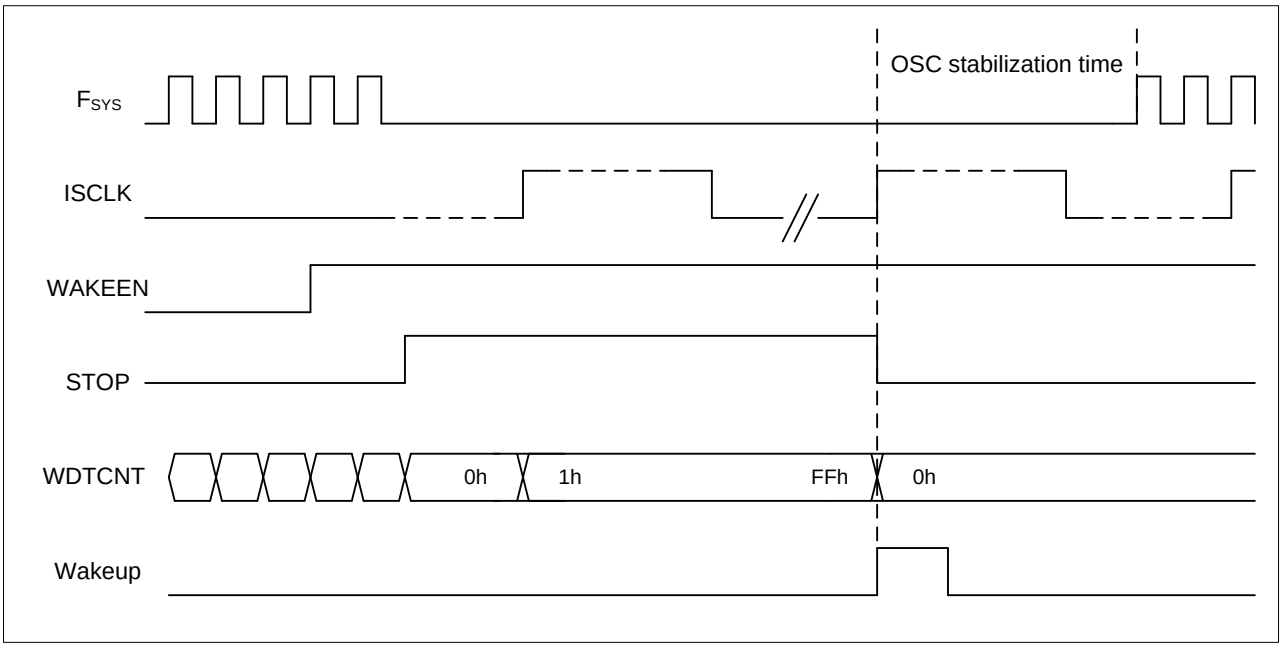


Figure 12-4. WDT Timing diagram with WAKEEN on STOP mode

12.5 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
WDTCON	0xEC	R/W	WDT Control Register	0x03
WCNTCLK	0xED	R/W	WDT Counter Pre-scale value register	0x0F
WDTCNT	0xEE	R	WDT Counter	Undef.
WDTREF	0xEF	R/W	WDT Reference Value	0xFF

WDTCON (0xEC)

Name	Bit	R/W	Description		Reset
RSVD	7	-	Reserved		-
WINTPEND	6	R/W	WDT Interrupt Pending If the IEWDT in the IE0 register is enabled and GIE is enabled, an interrupt is requested when this bit is set to '1'. User can clear this bit by writing '1' to this bit.		0
WCNTCLR	5	R/W	0: Not effect, 1: Clear Watch-dog Counter This bit is automatically cleared by hardware.		0
WDTWAKEEN	4	R/W	Enable Wake-up function. When this bit is set to '1', other WDT function is ignored. This function is only available on STOP mode. WDT is operating by using internal RC oscillator clock. WDTCNT reach overflow that goes to wake-up operation. 0: Disable, 1: Enable		0
WDTCLK	3	R/W	Select Pre-Scale input source clock 0: F_{SYS}, 1: ESCLK(32.768KHz sub oscillator clock)		0
WDT_SEL	2:1	R/W	00	Interrupt / Reset all disable	01
			01	Interrupt Disable and Reset Enable WDTCNT is only used as overflow reset	
			10	Interrupt Enable and Reset Disable In this case, it is used as timer/counter. That is, interrupt occurs when WDTCNT value get equals to WDTREF value, and then WDTCNT value is cleared to re-start same operation of counting. No reset occurs.	
			11	Interrupt / Reset all Enable Reset: WDTCNT overflow Interrupt: WDTCNT is equal to WDTREF Watch-dog timer interrupt occurs when WDTCNT is equal to WDTREF, and future more WDTCNT continuously counts to reach overflow that goes to reset operation.	
WDTEN	0	R/W	0: Disable Watch-dog Timer, 1: Enable Watch-dog Timer		1

WCNTCLK (0xED)

Name	Bit	R/W	Description	Reset
RSVD	7:4	R	Reserved	0x0
WCNTCLK	3:0	R/W	Select WDT counter source clock WCNTCK = Select Clock/ $2^{(n+1)}$, n = 0 ~ 15, This value=15, F_{SYS}=12MHz : WCNTCK = 12 MHz / 2^{16} ≒ 183 Hz	1111

WDTCNT (0xEE)

Name	Bit	R/W	Description	Reset
WDTCNT	7:0	R	Watch-dog Timer Counter	Undef.

WDTREF (0xEF)

Name	Bit	R/W	Description	Reset
WDTREF	7:0	R/W	Watch-dog timer reference value Watch-dog timer interrupt condition is WDTCNT=WDTREF at WDTEN.	0xFF

Watchdog timer counter clock Frequency

F_{SYS} = 12MHz, WDTREF = 0xFF			
WCNTCLK	Counter Clock	Freq.	Overflow time
0000	12 MHz / 2 = 6 MHz	167 ns	167 ns * 256 ≒ 42.75 us
0001	12 MHz / 4 = 3 MHz	333 ns	333 ns * 256 ≒ 85.25 us
0010	12 MHz / 8 = 1.5 MHz	667 ns	667 ns * 256 ≒ 170.75 us
0011	12 MHz / 16 = 750 KHz	1.33 us	1.33 us * 256 ≒ 340.48 us
0100	12 MHz / 32 = 375 KHz	2.67 us	2.67 us * 256 ≒ 683.52 us
0101	12 MHz / 64 = 187.5 KHz	5.33 us	5.33 us * 256 ≒ 1.36 ms
0110	12 MHz / 128 = 93.8 KHz	10.66 us	10.66 us * 256 ≒ 2.73 ms
0111	12 MHz / 256 = 46.9 KHz	21.32 us	21.32 us * 256 ≒ 5.46 ms
1000	12 MHz / 512 = 23.4 KHz	42.7 us	42.7 us * 256 ≒ 10.93 ms
1001	12 MHz / 1024 = 11.7 KHz	85.47 us	85.47 us * 256 ≒ 21.88 ms
1010	12 MHz / 2048 = 5.86 KHz	170.65 us	170.65 us * 256 ≒ 43.69 ms
1011	12 MHz / 4096 = 2.93 KHz	342.3 us	342.3 us * 256 ≒ 87.63 ms
1100	12 MHz / 8192 = 1.46 KHz	684.93 us	684.93 us * 256 ≒ 175.34 ms
1101	12 MHz / 16384 = 732 Hz	1.37 ms	1.37 ms * 256 ≒ 350.72 ms
1110	12 MHz / 32768 = 366 Hz	2.73 ms	2.73 ms * 256 ≒ 698.88 ms
1111	12 MHz / 65536 = 183 Hz	5.46 ms	5.46 ms * 256 ≒ 1.398 s

13 ADC Controller

13.1 OVERVIEW

The 10-bit A/D Converter (ADC) module uses successive approximation logic to convert analog levels entering at one of the eight input channels to equivalent 10-bit digital values. The analog input level must lie between the AVREF and AVSS values.

13.2 FEATURES

- Max 50K sampling per second with 3MHz
- Programmable input clock frequency
- 6-channel 10bit ADC
- If Key scan or other ADC functions need to be used, while ADC is in recording mode, firstly the wanted function must be placed in ADC interrupt service routine and secondly after the wanted function finishes, ADC operation should be returned to the previous recording mode.

13.3 PIN DESCRIPTION

Table 13-1. ADC PIN Description

GPIO	Pin Name	Function	TYPE
GP8[2] GP8[3] GP1[0] GP1[1] GP1[2] GP1[3]	ADIN[5:0]	Analog Input pins for 6-channel(Range: 0.0V ~ AVREF value)	I
-	AVREF	ADC Reference Top Voltage. Normally, the max value of AVREF = VDD	I

13.4 BLOCK DIAGRAM

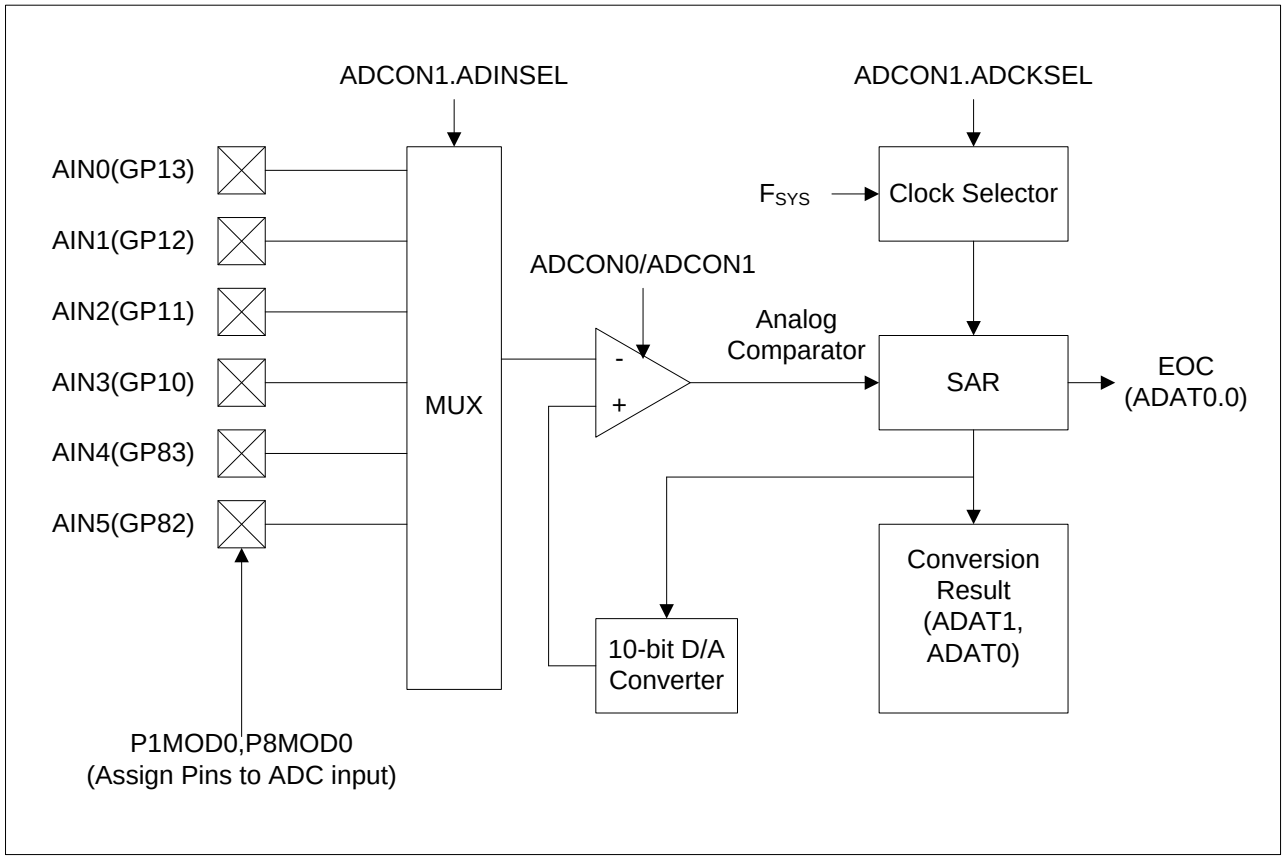


Figure 13-1. ADC Block Diagram

13.5 OPERATION

A/D Conversion Time

The A/D conversion process requires 4 steps (4 clock edges) to convert each bit and 10 clocks to set-up A/D conversion. Therefore, total of 50 clocks are required to complete a 10-bit conversion.

When the F_{SYS} frequency is 24MHz and the pre-scale value 1, total 10-bit conversion time is given:

A/D Conversion frequency = 24MHz / 8 = 3MHz
4 clocks/bit + 10bits + setup time = 50 clocks, 50 clocks * 333ns $\fallingdotseq$ 20 μs

Normal Mode

Performing AD Conversion according to STC bit enable of ADCON0 register. When ADRDY bit is '1' and STC bit set to '1', the AD Conversion will be started. And then the AD Conversion is completed, STC is automatically cleared. If users want to AD Conversion again, user should set STC bit to '1'. If ADINTEN bit in ADCON0 register is '1', the interrupt will be generated whenever the AD Conversion is completed.

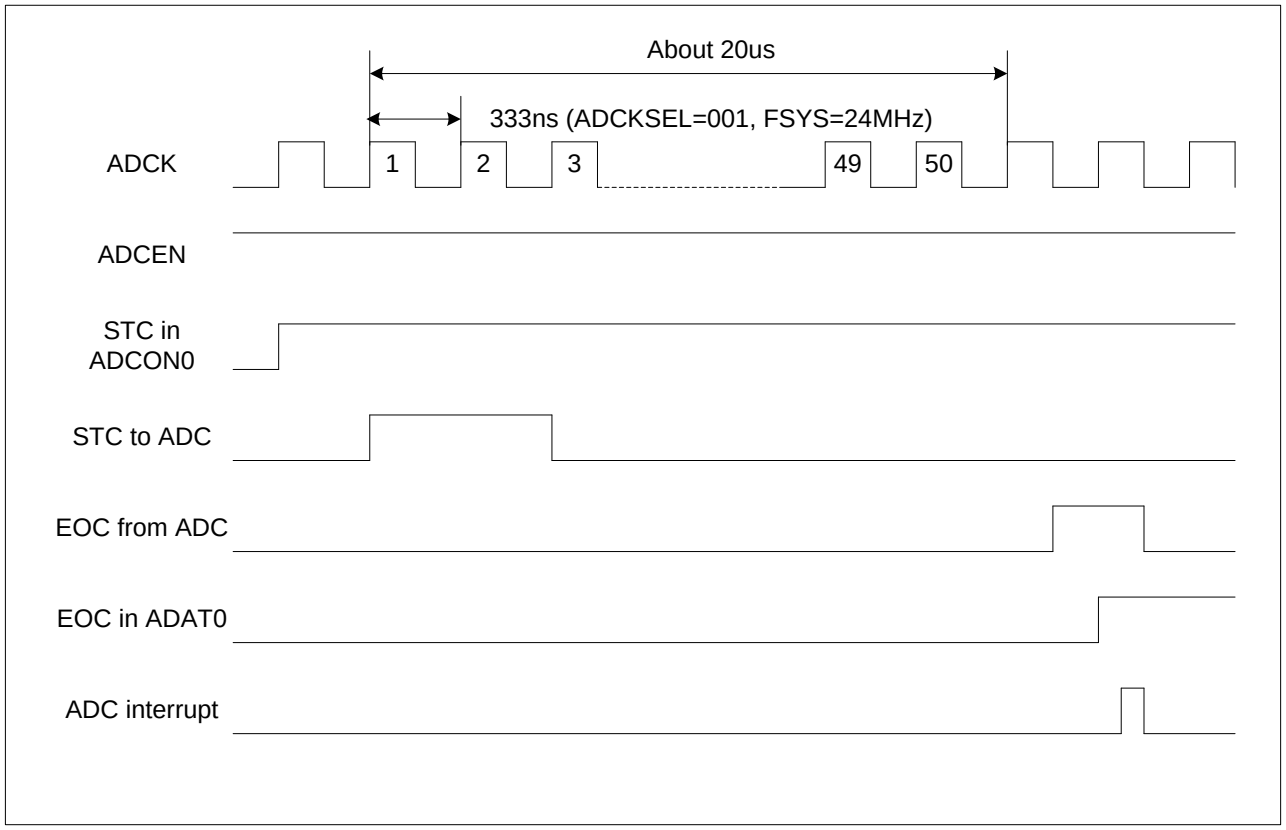


Figure 13-2. Operation of A/D Conversion

Infinite Mode

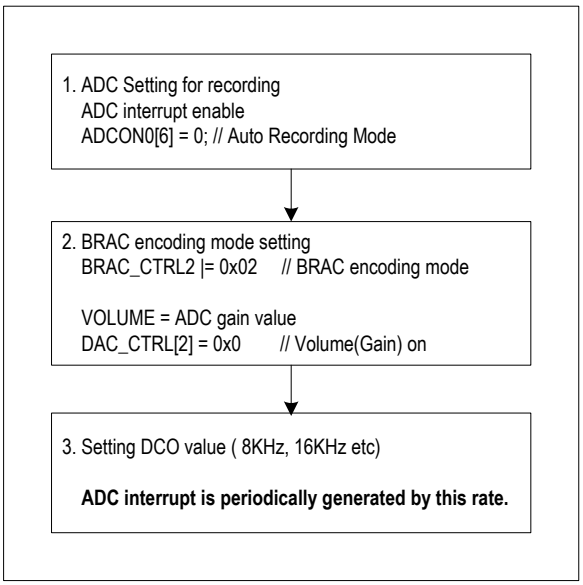
When ADRDY bit is '1' and STC bit set to '1', the AD Conversion will be started. And then the AD Conversion operation is executed continuously until clearing STC bit to '0' by software. To finish the AD Conversion is completed, ADCEN bit or STC bit clear to '0'. If ADINTEN bit in ADCON0 register is '1', the interrupt will be generated whenever the AD Conversion is completed.

Compare Mode

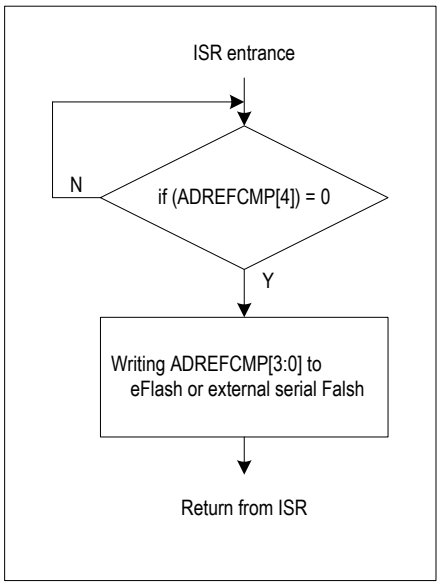
When ADRDY bit is ‘1’ and STC bit set to ‘1’, the AD Conversion will be started. And then the AD Conversion operation is executed continuously until clearing STC bit to ‘0’. To finish the AD Conversion is completed, ADCEN bit or STC bit clear to ‘0’. If ADINTEN bit in ADCON0 register is ‘1’, the interrupt will be generated whenever a conversion result value in ADAT1 is the same as ADREF value according to ADREFCMP register. Using this mode can check AD input voltage range

Voice Recording by BRAC encoding

Both ADC controller and BRAC encoder periodically generates encoded sample from PCM data which is capture from internal 10-bit ADC. CPU task is only transferring encoded voice data (ADREFCMP[3:0]) to internal or external storage device. ADC recording mode setting and ISR flowchart is as follows.



< Auto Recording Mode Setting >



< ADC ISR(Interrupt Service Routine) >

13.6 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
ADCON0	0xE1	R/W	ADC Control Register 0	0x00
ADCON1	0xE2	R/W	ADC Control Register 1	0x70
ADAT0	0xE3	R	AD Conversion Lower Result Register	Undef.
ADAT1	0xE4	R	AD Conversion Higher Result Register	Undef.
ADREF	0xE5	R/W	ADC Reference Register	0x00
ADREFCMP	0xE6	R/W	ADC Reference Compare Register	0xFF

ADCON0 (0xE1)

Name	Bit	R/W	Description		Reset
STC	7	R/W	AD conversion start bit 0: Not affect, 1: ADC start Only in Normal mode (ADMOD=00), this bit is automatically cleared by hardware when AD conversion has completed. The actual AD conversion can be delayed to synchronize with the selected ADC clock period (ADCKSEL).		0
RECORD_CON	6	R/W	This bit is effective when Recording mode 0: Auto Recording Mode. ADC Data is automatically transferred to BRAC encoder and start encoding. 1: Manual Recording Mode. ADC Data should be transferred by CPU.		0
INT_PEND	5	R/W	ADC interrupt pending register. ADC interrupt set this bit. When this bit is set by CPU, pending bit is cleared.		0
EXTAVREF	4	R/W	0: Using Internal AVREF 1: Using External AVREF		0
ADMOD	3:2	R/W	00	Normal mode. Performing AD conversion once according STC enable.	00
			01	Infinite mode. While ADCEN=1 with STC enable, ADC is performed constantly in the same cycle of ADIN and ADCK, and Interrupt can be occurred on every ADC cycle when ADINTEN was set to '1'.	
			10	Compare mode. While ADCEN=1 by STC enable, ADC is performed constantly in same cycle of ADIN and ADCK, and then interrupt can be occurred if ADAT[9:2] = ADREF[7:0].	
			11	Recording mode During ADCEN=1, Performing AD conversion only once according to each recording request. In this time STC bit should be zero because it will be automatically enabled and then disabled.	
ADINTEN	1	R/W	0: Disable ADC interrupt, 1: Enable ADC interrupt This bit, in conjunction with IEADC in the IE0 register, enables ADC interrupts.		0
ADCEN	0	R/W	0: Disable ADC operation, 1: Enable ADC operation This bit should not be written during AD conversion.		0

ADCON1 (0xE2)

Name	Bit	R/W	Description		Reset
RSVD	7	R	Reserved		0
ADCKSEL	6:4	R/W	ADC source clock selector (ADCK). Internal ADC supports maximum 50 KSPS at 3 MHz.		111
			111	ADCK = F_{SYS} / 2^9, 24MHz / 512 = 46.875 KHz, F_{SYS} = 24MHz	
			110	ADCK = F_{SYS} / 2^8, 24MHz / 256 = 93.75 KHz	
			101	ADCK = F_{SYS} / 2^7, 24MHz / 128 = 187.5 KHz	
			100	ADCK = F_{SYS} / 2^6, 24MHz / 64 = 375 KHz	
			011	ADCK = F_{SYS} / 2^5, 24MHz / 32 = 750 KHz	
			010	ADCK = F_{SYS} / 2^4, 24MHz / 16 = 1.5 MHz	
			001	ADCK = F_{SYS} / 2^3, 24MHz / 8 = 3 MHz	
			000	Reserved (should not be set to this value)	
RSVD	3	R	Reserved		0
ADINSEL	2:0	R/W	ADC input channel select 000: ADIN0, 001: ADIN1, 010: ADIN2, 011: ADIN3, 100: ADIN4, 101: ADIN5		000

ADAT0 (0xE3)

Name	Bit	R/W	Description	Reset
RSVD	7:6	R	Reserved	00
ADATA0	5:4	R	AD conversion result [1:0]	Undef.
RSVD	3:2	R	Reserved	00
ADRDY	1	R	AD Conversion Ready indication 0: ADC preparing, 1: ADC Ready When ADCEN is set to '1', ADC source clock selected by ADCKSEL is supplied to ADC. ADC operation will be ready after 3 clocks are supplied. ADRDY is a flag bit of this readiness. Once the ADC gets into ready state, while the ADCK is supplying, the ADC is always in ready status so that it is not necessary to check ADRDY bit again. When ADCEN bit in ADCON0 is cleared to 0, ADRDY is cleared to 0 as well.	0
EOC	0	R	AD Conversion Completion Indication 0: ADC on-going, 1: ADC complete The EOC bit indicates the end of conversion process that is started by STC=1 or recording request. End of conversion can be notified by either setting EOC bit or the ADC interrupt. EOC bit is automatically cleared as below: In ADMOD=0 (Normal mode) or ADMOD=3 (Recording mode), EOC is cleared by reading ADATA0. In ADMOD=1(Infinite mode) or ADMOD=2(Compare mode), EOC is automatically cleared by hardware.	0

ADAT1 (0xE4)

Name	Bit	R/W	Description	Reset
ADATA1	7:0	R	AD conversion result [9:2]	Undef.

ADREF (0xE5)

Name	Bit	R/W	Description	Reset
ADREF	7:0	R/W	When ADC Compare mode, if ADREF[ADREFCMP] = ADAT1, Interrupt is occurred. When ADC Recording mode, recorded data is stored in this register. Upper Recorded Data = {~AD result[9], AD result[8:2]}	0x00

ADREFCMP (0xE6) (Normal Mode)

Name	Bit	R/W	Description	Reset
ADREFCMP	7:0	R/W	This register is used to compare to certain conversion bit.	0xFF

ADREFCMP (0xE6) (Recording Mode)

Name	Bit	R/W	Description	Reset
AD1_0	7:6	R	AD result[1:0]	Undef
RSVD	5	R	Reserved	0
ENC_BUSY	4	R	0 : BRAC Encoding is done, 1 : Under BRAC Encoding	Undef.
ENC_RESULT	3:0	R	Encoding Result	Undef.

NOTES:

14 USB CONTROLLER

14.1 OVERVIEW

USB products are easy to use for end users. Electrical details, such as bus termination, are isolated from end users and plug and play is supported. There are other merits for users; Self-identifying peripherals, automatic mapping function to driver, auto-configuration, dynamically attach and detach and reconfiguration, and so on.

14.2 FEATURES

- Fully Compliant to USB 2.0 full-speed specification (maximum 12Mbps)
- Complete Device Configuration
- Compatible with both OpenHCI and Intel UHCI Standards
- Support 5 Endpoints (1 Control Endpoint, 4 Data Endpoints with logical endpoint numbering)
- EP0: 16 Bytes Control/Status Endpoint
- EP1/2: 64 Bytes Data Endpoint (IN/OUT) supporting automatic double buffering
- EP3/4: 16 Bytes Data Endpoint (IN/OUT) supporting automatic double buffering
- Supports Bulk Data Transfer
- CRC16 Generation and CRC5/CRC16 Checking
- Suspend/Resume Control
- On-Chip USB Transceiver

Table 14-1. Summary of Endpoint

Endpoint	Description
Endpoint 0	16 Bytes FIFO Does not support double-buffering Bidirectional endpoint for control transfer
Endpoint 1/2	64 Bytes FIFO Configurable FIFO size Supports double-buffering IN/OUT configurable Bulk/Interrupt/Isochronous Support logical endpoint feature
Endpoint 3/4	16 Bytes FIFO Configurable FIFO size Supports double-buffering IN/OUT configurable Bulk/Interrupt/Isochronous Support logical endpoint feature

14.3 PIN DESCRIPTION

Table 14-2. USB PIN Description

Pin Name	Function	I/O Type	Note
DP	DATA(+) for USB device.	IO	
DM	DATA(-) for USB device.	IO	

14.4 BLOCK DIAGRAM

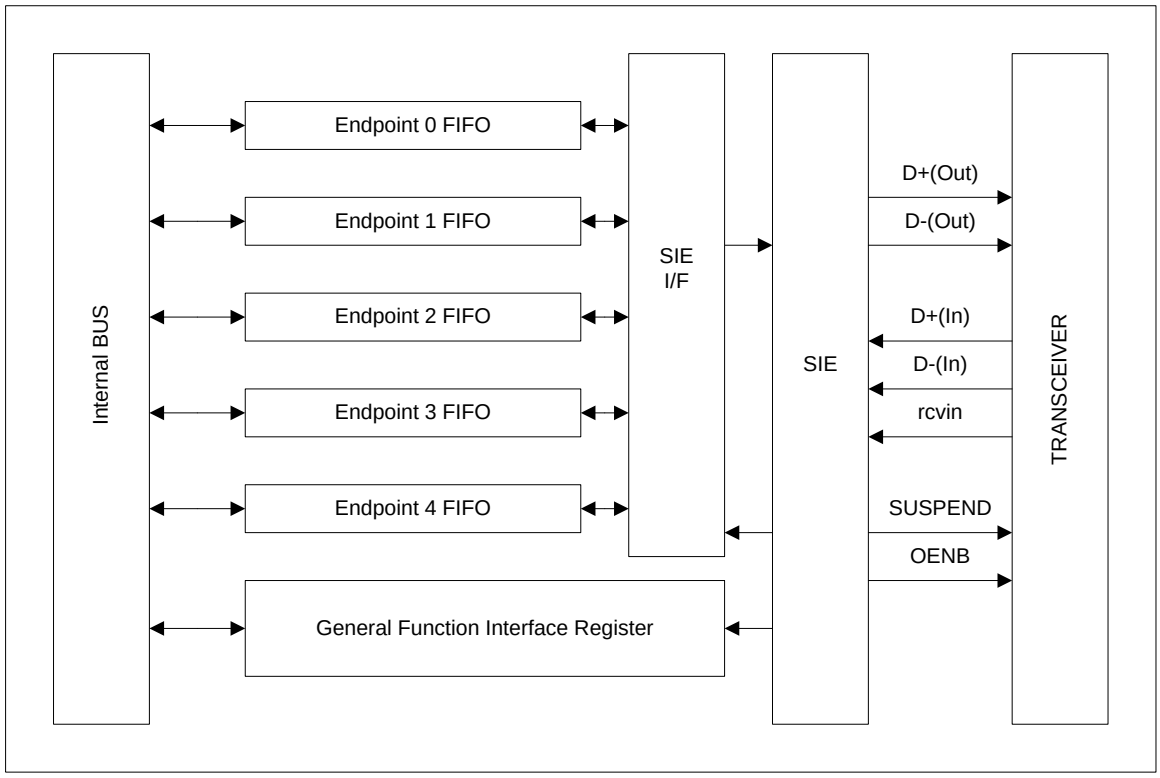


Figure 14-1. USB Device Block Diagram

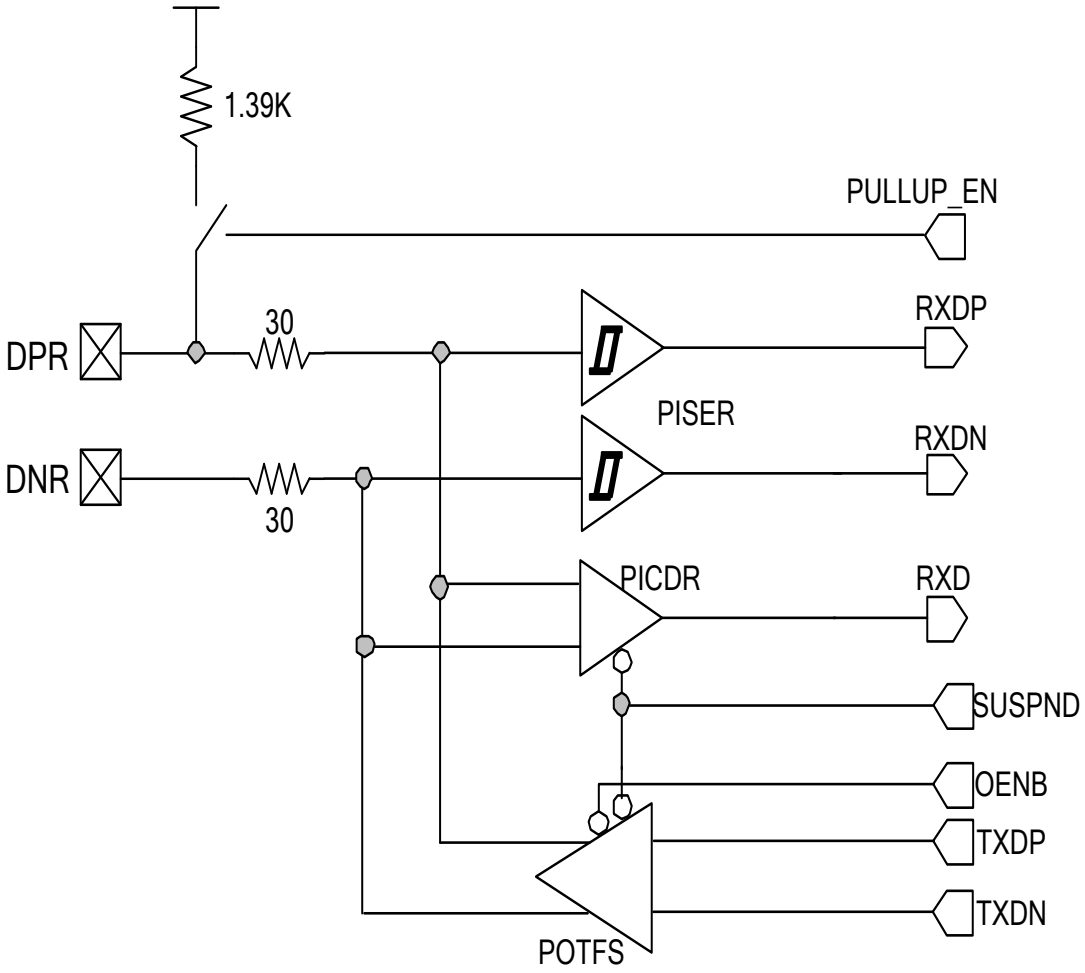


Figure 14-2. USB Transceiver Block Diagram

PULLUP_EN: USBPHYUPEN bit of PCON register in SYSTEM CONTROLLER.

14.5 OPERATION

Endpoint Architecture

USB core has totally 5 endpoints: one is endpoint 0 (EP0), and the others are endpoint 1 ~ 6. All endpoints except endpoint 0 can be double buffered in order to support best transfer speed.

In case of USB core without double buffering functionality, if it has not finished loading data into the endpoint buffer when the next IN token arrives, the CPU it sends a NAK handshake in response to the IN token. This means that the host should send an IN token at a later time to receive valid data from the USB device.

However, USB core of the BMC513 can load the next packet of bulk data while the previous packet is being transferred over USB. This is accomplished by double buffering. This function is always enabled and does not support triple or quadruple buffering.

Therefore, in the case Endpoint 1, for maximum transfer speed, you need to define 32 bytes of endpoint size in your descriptor information and configure 32 bytes of physical size by setting MAXP in USBEP1CSR0 register as 0100b.

USBEPnCSR2[1:0] bits indicates the status of double buffering in OUT endpoint: 00b means that there is no packets in double buffer, 01b means that 1 packet is existed in buffers, and 11b means that buffer is full

USBEPnCSR3[1:0] bits indicates the status of double buffering in IN endpoint: 00b means that there is no packets in buffers, 10b means that 1 packet is existed in buffers, and 11b means that buffers is full.

Logical Endpoint Feature

In USB core of the BMC513, logical endpoint capability allows a number of physical endpoints in the device to support a larger number of data pipes at logical endpoints requested by a host. This is done by re-assigning physical endpoints to support the logical endpoint requested by the host.

14.6 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
USBFA	0xB1	-	USB Function Address Register	0x00
USBPM	0xB2	-	USB Power Management Register	0x00
USBIPEND	0xB3	-	USB Interrupt Pending Register	0x00
USBINTEN	0xB4	-	USB Interrupt Enable Register	0x80
USBFN_L	0xB5	-	USB Frame Number Register L	0x00
USBFN_H	0xB6	-	USB Frame Number Register H	0x00
USBEP0CSR0	0xB7	-	USB EP0 Common Status Register 0	0x01
USBEP0CSR1	0xB9	-	USB EP0 Common Status Register 1	0x00
USBEP1CSR0	0xBA	-	USB EP1 Common Status Register 0	0x01
USBEP1CSR1	0xBB	-	USB EP1 Common Status Register 1	0x04
USBEP1CSR2	0xBC	-	USB EP1 Common Status Register 2	0x00
USBEP1CSR3	0xBD	-	USB EP1 Common Status Register 3	0x00
USBEP2CSR0	0xBE	-	USB EP2 Common Status Register 0	0x01
USBEP2CSR1	0xBF	-	USB EP2 Common Status Register 1	0x04
USBEP2CSR2	0xC1	-	USB EP2 Common Status Register 2	0x00
USBEP2CSR3	0xC2	-	USB EP2 Common Status Register 3	0x00
USBEP3CSR0	0xC3	-	USB EP3 Common Status Register 0	0x01
USBEP3CSR1	0xC4	-	USB EP3 Common Status Register 1	0x04
USBEP3CSR2	0xC5	-	USB EP3 Common Status Register 2	0x00
USBEP3CSR3	0xC6	-	USB EP3 Common Status Register 3	0x00
USBEP4CSR0	0xC7	-	USB EP4 Common Status Register 0	0x01
USBEP4CSR1	0xC8	-	USB EP4 Common Status Register 1	0x04
USBEP4CSR2	0xC9	-	USB EP4 Common Status Register 2	0x00
USBEP4CSR3	0xCA	-	USB EP4 Common Status Register 3	0x00
USBEP0WC	0xCB	-	USB EP0 Write Count Register	0x00
USBEP1WC1	0xCC	-	USB EP1 Write Count Register 1	0x00
USBEP1WC2	0xCD	-	USB EP1 Write Count Register 2	0x00
USBEP2WC1	0xCE	-	USB EP2 Write Count Register 1	0x00
USBEP2WC2	0xCF	-	USB EP2 Write Count Register 2	0x00
USBEP3WC1	0xD1	-	USB EP3 Write Count Register 1	0x00
USBEP3WC2	0xD2	-	USB EP3 Write Count Register 2	0x00
USBEP4WC1	0xD3	-	USB EP4 Write Count Register 1	0x00
USBEP4WC2	0xD4	-	USB EP4 Write Count Register 2	0x00
USBEP0FIFO	0xD5	-	USB EP0 FIFO	Undef.
USBEP1FIFO	0xD6	-	USB EP1 FIFO	Undef.
USBEP2FIFO	0xD7	-	USB EP2 FIFO	Undef.
USBEP3FIFO	0xD8	-	USB EP3 FIFO	Undef.
USBEP4FIFO	0xD9	-	USB EP4 FIFO	Undef.
USBEPLNUM1	0xDA	-	USB EP Logical Number Control Register 1	0x21
USBEPLNUM2	0xDB	-	USB EP Logical Number Control Register 2	0x43
USBNAKCON1	0xDC	-	USB EP NAK Control Register 1	0x00
USBNAKCON2	0xDD	-	USB EP NAK Control Register 2	0x00
USBNAKEN	0xDE	-	USB EP NAK Enable Register	0x00
USBCONF	0xDF	-	USB Configuration Register	0x00

R: Read
W: Write
S: SET
C: Clear

USBFA (0xB1)

Name	Bit	CPU	USB	Description	Reset
USBAUP	7	S	R/C	USB Address Update The CPU sets this bit whenever it updates the USB Function Address Field in this register. The USBFAF is used after the Status phase of a Control transfer, which is signaled by the clearing of the DEND bit in the Endpoint 0 CSR	0
USBFAF	6:0	R/W	R	USB Function Address Field. The CPU writes the address to these bits.	0x00

USBPM (0xB2)

Name	Bit	CPU	USB	Description	Reset
USBISOU	7	R/W	R	ISO Update Used for ISO mode only. If set, USB waits for a SOF token from the time USBINRDY was set to send the packet. If an IN token is received before a SOF token, then a zero length data packet will be sent	0
RSVD	6	-	-	Reserved	-
USBRST	3	R	S	ReSeT The USB set this bit if reset signaling is received from the host. This bit remains set as long as reset signaling persists on the bus. 0: Normal operation, 1: Reset received state	0
USBRESUM	2	R/W	R	RESUme Mode The CPU sets this bit for a duration of 10ms (maximum of 15ms) to initiate a resume signaling. The CPU generates resume signaling while this bit is set in suspend mode 0: Normal or suspend state 1: Resume signal generation in suspend state	0
USBSUSM	1	R/C	R/W	SUSpend Mode This bit is set by the USB when it enters suspend mode. It is cleared under the following conditions: 1. The CPU clears the USB RESUM bit (bit2 of this register), to end resume signaling. 2. The CPU reads USB interrupt Pending register for the USB resume interrupt. 0: Normal operation, 1: Suspend state	0
USBSUSE	0	R/W	R	SUSpend Enable. 0: Disable Suspend mode, 1: Enable Suspend mode	0

USBIPEND (0xB3)

The CPU will be written a “1” to clear each pending bit.

Name	Bit	CPU	USB	Description	Reset
USBRSTPEND	7	R/C	S	ReSeT interrupt PENDing The USB sets this bit, when it receives reset signaling. 0: No reset interrupt, 1: Reset interrupt generated	0
USBRESPEND	6	R/C	S	RESume interrupt PENDing The USB sets this bit, when it receive resume signaling, while in suspend mode. If the resume is due to a USB reset, then the CPU is first interrupted with a Resume Interrupt. Once the clocks resume and the SE0 condition persists for 3ms, USB RESET interrupt will be asserted. 0: No resume interrupt, 1: Resume interrupt generated	0
USBSUSPEND	5	R/C	S	SUSpend interrupt PENDing The USB sets this bit when it receives suspend signaling. This bit is set whenever there is no activity for 3ms on the bus. Thus, if the CPU does not stop the clock after the first suspend interrupt, it will be continue to be interrupted every 3ms as long as there is no activity on the USB bus. 0: No suspend interrupt, 1: Suspend interrupt generated	0
USBEP4PEND	4	R/C	S	EndPoint N interrupt PENDing **For Bulk Endpoints:** The USB sets this bit under the following conditions: 1. IINRDY bit is cleared 2. FIFO is flushed 3. OSTSTALL/ISTSTALL is set 4. ORDY bit is set **For ISO Endpoints:** The USB sets this bit under the following conditions: 1. IUNDER bit is set 2. IINRDY bit is cleared 3. FIFO is flushed 4. OSTSTALL/ISTSTALL is set This conditions are mutually exclusive. 0: No EP N Interrupt, 1: EP N interrupt generated (N = 1, 2, 3, 4)	0
USBEP3PEND	3	R/C	S		0
USBEP2PEND	2	R/C	S		0
USBEP1PEND	1	R/C	S		0
USBEP0PEND	0	R/C	S	EndPoint 0 interrupt PENDing This bit corresponds to endpoint 0 interrupt. The USB sets this bit under the following conditions: 1. ORDY bit is set 2. INRDY bit is cleared 3. STSTALL bit is set 4. SETEND bit is set 5. DEND bit is cleared (Indicates End of control transfer) 0: No EP0 Interrupt, 1: EP0 interrupt generated	0

USBINTEN (0xB4)

Name	Bit	CPU	USB	Description	Reset
USBRSTINTEN	7	R/W	R	Reset Interrupt Enable 0: Disable, 1: Enable	1
RSVD	6	-	-	Reserved	-
USBSUSPINTEN	5	R/W	R	Suspend Interrupt Enable 0: Disable, 1: Enable	0
USBEP4INTEN	4	R/W	R	Endpoint 4 Interrupt Enable 0: Disable, 1: Enable	0
USBEP3INTEN	3	R/W	R	Endpoint 3 Interrupt Enable 0: Disable, 1: Enable	0
USBEP2INTEN	2	R/W	R	Endpoint 2 Interrupt Enable 0: Disable, 1: Enable	0
USBEP1INTEN	1	R/W	R	Endpoint 1 Interrupt Enable 0: Disable, 1: Enable	0
USBEP0INTEN	0	R/W	R	Endpoint 0 Interrupt Enable 0: Disable, 1: Enable	0

USBFN_L (0xB5), USBFN_H (0xB6)

These registers maintain the Frame Number within SOF packet. Frame Number within SOF packet is 11 bits.

Name	Bit	CPU	USB	Description	Reset
FN_L	7:0	R	W	Frame Number[7:0] from SOF packet	0x00

Name	Bit	CPU	USB	Description	Reset
RSVD	7:3	-	-	Reserved	-
FN_H	2:0	R	W	Frame Number[10:8] from SOF packet	0

USBEP0CSR0 (0xB7)

Name	Bit	CPU	USB	Description	Reset
MAXPSET	7	W	-	0: MAXP isn't overwritten when CPU writes any value to USBEPnCSR0 register 1: MAXP is overwritten.	0
RSVD	6:2	-	-	Reserved	-
MAXP	1:0	R/W	R	MAXP size value If MAXP is 00, then MAXP is 8 bytes If MAXP is 01, then MAXP is 8 bytes If MAXP is 10, then MAXP is 16 bytes	0x1

USBEP0CSR1 (0xB9)

Name	Bit	CPU	USB	Description	Reset
EP0_SVSET	7	W	-	SerViced SETup end The CPU writes a “1” to this bit to clear SETEND 0: No operation 1: SETEND bit clear	0
EP0_SVORDY	6	W	-	SerViced Out ReaDY The CPU writes a “1” to this bit to clear ORDY 0: No operation 1: ORDY bit clear	0
EP0_SDSTALL	5	R/W	C	SenD STALL The CPU writes a “1” to this bit at the same time it clears ORDY, if it decodes an invalid token. The USB issues a STALL handshake to the current control transfer. The CPU writes a “0 to end the STALL condition 0: Normal operation state 1: Go to stall token transmit state	0
EP0_SETEND	4	R	S	SETup END This bit is read only bit. The USB sets this bit when a control transfer ends before DEND is set. The CPU clears this bit by writing a “1” to the SVSET bit. When the USB sets this bit, an interrupt is generated to the CPU. When such a condition occurs, the USB flushes the FIFO, and invalidates CPU access to the FIFO. When CPU access to the FIFO is invalidated, this bit is cleared. 0: Normal operation state 1: Setup end stage	0
EP0_DEND	3	R/S	C	Data END The CPU sets this bit 1. After loading the last packet of data into the FIFO, at the same time INRDY is set. 2. While it clears ORDY after unloading the last packet of data 3. For a zero length data phase, when it clears ORDY and sets INRDY. 0: Not dataend state 1: Dataend stage	0
EP0_STSTALL	2	R/C	S	SenT STALL The USB sets this bit if a control transaction is ended due to a protocol violation. An interrupt is generated when this bit is set. 0: No stall token is transmitted 1: Control transaction is ended due to a protocol violation	0
EP0_INRDY	1	R/S	C	IN packet ReaDY The CPU sets this bit after writing a packet of data into endpoint 0 FIFO. The USB clears this bit once the packet has been successfully sent to the host. An interrupt is generated when the USB clears this bit, so the CPU can load the next packet. For a zero length data phase, the CPU sets INRDY and DEND at the same time 0: Not yet loaded packet to EP0 FIFO, or in OUT mode 1: Loading packet to EP0 FIFO completed	0
EP0_ORDY	0	R	S	Out packet ReaDY This bit a read-only bit. The USB sets this bit once a valid token is written to the FIFO. An interrupt is generated when the USB sets this bit. The CPU clears this bit by writing a “1” to the SVORDY. 0: Not received packet, or in IN mode 1: Received packet from host	0

USBEP1CSR0 (0xBA), USBEP2CSR0 (0xBE), USBEP3CSR0 (0xC3), USBEP4CSR0 (0xC7)

Name	Bit	CPU	USB	Description	Reset
MAXPSET	7	W	-	0: MAXP isn't overwritten when CPU writes any value to USBEPnCSR0 register 1: MAXP is overwritten.	0
RSVD	6:4	-	-	Reserved	-
MAXP	3:0	R/W	R	MAXP size value If MAXP is 0000, then MAXP is 8 bytes If MAXP is 0001, then MAXP is 8 bytes If MAXP is 0010, then MAXP is 16 bytes If MAXP is 0011, then MAXP is 24 bytes If MAXP is 0100, then MAXP is 32 bytes If MAXP is 0101, then MAXP is 40 bytes If MAXP is 0110, then MAXP is 48 bytes If MAXP is 0111, then MAXP is 56 bytes If MAXP is 1000, then MAXP is 64 bytes Note: 1. EP3CSR0 and EP4CSR0 have up to 16 bytes. 2. If you want to use double buffering of EP1, you should set 0100b in this field. You set 1000b in this field, cannot use double buffering.	0x1

USBEP1CSR1 (0xBB), USBEP2CSR1 (0xBF), USBEP3CSR1 (0xC4), USBEP4CSR1 (0xC8)

Name	Bit	CPU	USB	Description	Reset
RSVD	7:5	-	-	Reserved	-
EP_IATCLR	4	R/W	-	In mode, AuTo CLeaR This bit is valid only when endpoint N is set to IN. If set, whenever the CPU writes MAXP data in endpoint N FIFO, IINRDY will automatically be set without any intervention from CPU. If the CPU writes less than MAXP data, then IINRDY bit has to be set by the CPU automatically. 0: No operation 1: Auto clearing IINRDY when MAXP-sized packet loaded	0
EP_IISO	3	R/W	-	In mode, ISO mode This bit is valid only when endpoint N is set to IN. 0: Endpoint N will be Bulk mode 1: Endpoint N will be ISO mode	0
EP_MODE	2	R/W	-	In/out MODE selection 0: Transfer direction will be OUT 1: Transfer direction will be IN	1
EP_OATCLR	1	R/W	-	Out mode, AuTo CLeaR This bit is valid only when endpoint N is set to OUT. If set, whenever the CPU unloads last data in endpoint N FIFO, OORDY will automatically be cleared without any intervention from CPU. 0: No operation 1: Auto clearing ORDY when FIFO data unloaded	0
EP_OISO	0	R/W	-	Out mode, ISO mode This bit is valid only when endpoint N is set to OUT. 0: Endpoint N will be Bulk mode 1: Endpoint N will be ISO mode	0

USBEP1CSR2 (0xBC), USBEP2CSR2 (0xC1), USBEP3CSR2 (0xC5), USBEP4CSR2 (0xC9)

This register is available on OUT endpoint.

Name	Bit	CPU	USB	Description	Reset
EP_OCLTOG	7	W	R	Out mode, Clear data TOGgle This bit is valid only when endpoint N is set to OUT. When the CPU writes a “1” to this bit, the data toggle sequence bit is reset to DATA0. 0: No operation, 1:Data toggle flag set to 0	0
EP_OSTSTALL	6	R/C	S	Out mode, SenT STALL This bit is valid only when endpoint N is set to OUT. The USB sets this bit when an OUT token is ended with a STALL handshake. The USB issues a stall handshake to the host if it sends more than MAXP data for the OUT token. 0: No operation, 1: Stall handshake transmitted	
EP_OSDSTALL	5	R/W	R	Out mode, SenD STALL This bit is valid only when endpoint N is set to OUT. The CPU writes a “1” to issue a STALL handshake to the USB. The CPU clears this bit to end the STALL condition. 0: No operation, 1: Stall handshake transmit state	0
EP_OFFLUSH	4	R/W	C	Out mode, Fifo FLUSH This bit is valid only when endpoint N is set to OUT. The CPU writes a “1” to flush the FIFO. This bit can be set only when OORDY is set. The packet due to be unloaded by the CPU will be flushed. 0: No operation, 1: FIFO flush	0
EP_ODERR	3	R	S	Out mode, Data ERRor This bit is valid only when endpoint N is set to OUT ISO. This bit should be sampled with OORDY. When set, it indicates the data packet due to be unloaded by the CPU has an error (either bit stuffing or CRC). If two packets are loaded into the FIFO, and the second packet has an error, then this bit gets set only after the first packet is unloaded. This is automatically cleared when OORDY gets cleared. 0: Normal operation, 1: Data error (ISO)	0
EP_OOVER	2	R/C	S	Out mode, fifo OVER run This bit is valid only when endpoint N is set to OUT ISO. This bit is set if the CPU is not able to load an OUT ISO packet into the FIFO. 0: Normal operation, 1: Data received at FIFO full state (ISO)	0
EP_OFFULL	1	R	S	Out mode, fifo FULL This bit is valid only when endpoint N is set to OUT. Indicate no more packets can be accepted. If USBEPnCSR2[1:0] is 00 = No packet in FIFO 01 = 1 packet in FIFO 11 = 2 packets of MAXP =< 1/2 FIFO or 1 packet of MAXP > FIFO size 0: Normal operation, 1: FIFO full state	0
EP_OORDY	0	R/C	S	Out mode, Out packet ReaDY This bit is valid only when endpoint N is set to OUT. The USB sets this bit once it has loaded a packet of data into the FIFO. Once the CPU reads the FIFO for the entire packet, this bit should be cleared by the CPU. 0: Not received data packet, 1: Received data packet from host	0

USBEP1CSR3 (0xBD), USBEP2CSR3 (0xC2), USBEP3CSR3 (0xC6), USBEP4CSR3 (0xCA)

This register is available on IN endpoint.

Name	Bit	CPU	USB	Description	Reset
RSVD	7	-	-	Reserved	-
EP_ICLTOG	6	W	R/C	In mode, Clear data TOGgle This bit is valid only when endpoint N is set to IN. When the CPU writes a “1” to this bit, the data toggle bit is cleared. This is a write-only register. 0: No operation, 1: Data toggle flag set to 0	0
EP_ISTSTALL	5	R/C	S	In mode, SenT STALL This bit is valid only when endpoint N is set to IN. The USB sets this bit when a STALL handshake is issued to an IN token, due to the CPU setting SEND STALL bit. When the USB issues a STALL handshake, IINRDY is cleared. 0: No operation, 1: Stall handshake transmitted	
EP_ISDSTALL	4	R/W	R	In mode, SenD STALL This bit is valid only when endpoint N is set to IN. The CPU writes a 1 to this bit to issue a STALL handshake to the USB. The CPU clears this bit to end the STALL condition. 0: No operation, 1: Stall handshake transmit state	0
EP_IFFLUSH	3	R/W	C	In mode, Fifo FLUSH This bit is valid only when endpoint N is set to IN. The CPU sets this bit if it intends to flush the IN FIFO. This bit is cleared by the USB when the FIFO is flushed. The CPU is interrupted when this happens. If a token is in progress, the USB waits until the transmission is complete before the FIFO is flushed. If two packets are loaded into the FIFO, only the top-most packet (one that was intended to be sent to the host) is flushed, and the corresponding IINRDY bit for that packet is cleared. 0: No operation, 1: FIFO flush	0
EP_IUNDER	2	R/C	S	In mode, UNDER run This bit is valid only when endpoint N is set to IN ISO. The USB sets this bit when in ISO mode, an IN token is received and the IINRDY bit is not set. The USB sends a zero length data packet for such conditions, and the next packet that is loaded into the FIFO is flushed. 0: No operation, 1: Received IN token but not ready (ISO)	0
EP_INEMP	1	R	S	In mode, fifo Not EMPty This bit is valid only when endpoint N is set to IN. Indicate there is at least one packet of data in FIFO. If USBEPnCSR3[1:0] is 10 = 1 packet in FIFO 11 = 2 packets of MAXP =< 1/2 FIFO or 1 packet of MAXP > FIFO size 0: No data packet in FIFO 1: there is at least one packet of data in FIFO	0
EP_IINRDY	0	R/S	C	In mode, IN packet ReaDY This bit is valid only when endpoint N is set to IN. The CPU sets this bit, after writing a packet of data into the FIFO. The USB clears this bit once the packet has been successfully sent to the host. An interrupt is generated when the USB clears this bit, so the CPU can load the next packet. While this bit is set, the CPU will not be able to write to the FIFO. If the SEND STALL bit is set by the CPU, this bit cannot be set. 0: Not ready for IN operation, 1: Ready for IN operation	0

USBEP0WC (0xCB)

When ORDY in USBEP0CSR1 register is set for OUT endpoints, this register maintains the byte-count number of data in FIFO due to be unloaded by the CPU

Name	Bit	CPU	USB	Description	Reset
RSVD	7:5	-	-	Reserved	-
WRTCNT1	4:0	R	W	The byte-count number of data in FIFO due to be unloaded by the CPU.	0x00

USBEP1WC1 (0xCC), USBEP2WC1 (0xCE)

When OORDY in USBEPnCSR2 register is set for OUT endpoints, this register maintains the byte-count number of data in FIFO due to be unloaded by the CPU

Name	Bit	CPU	USB	Description	Reset
RSVD	7	-	-	Reserved	-
WRTCNT1	6:0	R	W	The byte-count number of data first-saved in FIFO due to be firstly unloaded by the CPU, when there are two packets of MAXP =< 1/2 FIFO size (USBEPnCSR2[1:0] is 11b). Otherwise, In case there is one packet in FIFO (USBEPnCSR2[1:0] is 01b), it means the byte-count number of data in FIFO due to be unloaded by the CPU.	0x00

USBEP1WC2 (0xCD), USBEP2WC2 (0xCF)

When OORDY in USBEPnCSR2 register is set for OUT endpoints, this register maintains the byte-count number of data in FIFO due to be unloaded by the CPU

Name	Bit	CPU	USB	Description	Reset
RSVD	7	-	-	Reserved	-
WRTCNT2	6:0	R	W	The byte-count number of data second-saved in FIFO due to be secondly unloaded by the CPU, when there are two packets of MAXP =< 1/2 FIFO size (USBEPnCSR2[1:0] is 11b). In case USBEPnCSR2[1:0] is 00b or 01b, 0x00 is displayed on this fields.	0x00

USBEP3WC1 (0xD1), USBEP4WC1 (0xD3)

When OORDY in USBEPnCSR2 register is set for OUT endpoints, this register maintains the byte-count number of data in FIFO due to be unloaded by the CPU

Name	Bit	CPU	USB	Description	Reset
RSVD	7:5	-	-	Reserved	-
WRTCNT1	4:0	R	W	The byte-count number of data first-saved in FIFO due to be firstly unloaded by the CPU, when there are two packets of MAXP =< 1/2 FIFO size (USBEPnCSR2[1:0] is 11b). Otherwise, In case there is one packet in FIFO (USBEPnCSR2[1:0] is 01b), it means the byte-count number of data in FIFO due to be unloaded by the CPU.	0x00

USBEP3WC2 (0xD2), USBEP4WC2 (0xD4)

When OORDY in USBEPnCSR2 register is set for OUT endpoints, this register maintains the byte-count number of data in FIFO due to be unloaded by the CPU

Name	Bit	CPU	USB	Description	Reset
RSVD	7:5	-	-	Reserved	-
WRTCNT2	4:0	R	W	The byte-count number of data second-saved in FIFO due to be secondly unloaded by the CPU, when there are two packets of MAXP =< 1/2 FIFO size (USBEPnCSR2[1:0] is 11b). In case USBEPnCSR2[1:0] is 00b or 01b, 0x00 is displayed on this fields.	0x00

USBEP0FIFO (0xD5)

Name	Bit	CPU	USB	Description	Reset
EPFIFO	7:0	R/W	R/W	FIFO which is used for data IN/OUT	Undef.

USBEP1FIFO (0xD6)

Name	Bit	CPU	USB	Description	Reset
EPFIFO	7:0	R/W	R/W	FIFO which is used for data IN/OUT	Undef.

USBEP2FIFO (0xD7)

Name	Bit	CPU	USB	Description	Reset
EPFIFO	7:0	R/W	R/W	FIFO which is used for data IN/OUT	Undef.

USBEP3FIFO (0xD8)

Name	Bit	CPU	USB	Description	Reset
EPFIFO	7:0	R/W	R/W	FIFO which is used for data IN/OUT	Undef.

USBEP4FIFO (0xD9)

Name	Bit	CPU	USB	Description	Reset
EPFIFO	7:0	R/W	R/W	FIFO which is used for data IN/OUT	Undef.

USBEPLNUM1 (0xDA)

This register holds the endpoint numbers to indicate each physical endpoint and the default number is the same as physical one. You can change endpoint number from 5 to 15 by setting this register

Name	Bit	CPU	USB	Description	Reset
LNUMEP2	7:4	R/W	R	These bits express logical EP number. So, Endpoint 2 (default) is able to be changed to other EP number from 5 to 15	0x2
LNUMEP1	3:0	R/W	R	These bits express logical EP number. So, Endpoint 1 (default) is able to be changed to other EP number from 5 to 15.	0x1

USBEPLNUM2 (0xDB)

Name	Bit	CPU	USB	Description	Reset
LNUMEP4	7:4	R/W	R	These bits express logical EP number. So, Endpoint 4 (default) is able to be changed to other EP number from 5 to 15.	0x4
LNUMEP3	3:0	R/W	R	These bits express logical EP number. So, Endpoint 3 (default) is able to be changed to other EP number from 5 to 15.	0x3

USBNAKCON1 (0xDC)

Name	Bit	CPU	USB	Description	Reset
NAKEP2	7:4	R/W	-	2nd EPx Address to transmit NAK, Do not set 0.	0x0
NAKEP1	3:0	R/W	-	1st EPx Address to transmit NAK, Do not set 0.	0x0

NOTE: You can set each USBNAKCON1 and USBNAKCON2 registers separately.
Do not set NAKEP1 and NAKEP2 to “0”. Setting with 0 will lead to error on EP0

H/W will send NAK packet if the EP number matched with the one in NAKEP1 and NAKEP2 even though EP is already configured in USBEPxCSRx and USBEPLOGNUMx.

USBNAKCON2 (0xDD)

Name	Bit	CPU	USB	Description	Reset
NAKEP4	7:4	R/W	-	4th EPx Address to transmit NAK, Do not set 0.	
NAKEP3	3:0	R/W	-	3rd EPx Address to transmit NAK, Do not set 0.	0x0

NOTE: You can set each USBNAKCON1 and USBNAKCON2 registers separately.
Do not set NAKEP3 and NAKEP4 to "0". Setting with 0 will lead to error on EP0

H/W will send NAK packet if the EP number matched with the one in NAKEP3 and NAKEP4 even though EP is already configured in USBEPxCSRx and USBEPLOGNUMx.

USBNAKEN (0xDE)

Name	Bit	CPU	USB	Description	Reset
RSVD	7:2	-	-	Reserved	-
NAKEN2	1	R/W	-	If you set this bit, H/W will send NAK packet as a response from IN packet to all endpoints involved in USBEPNAKCON2 register. 0: NAK disable, 1: NAK enable	0
NAKEN1	0	R/W	-	If you set this bit, H/W will send NAK packet as a response from IN packet to all endpoints involved in USBEPNAKCON1 register. 0: NAK disable, 1: NAK enable	0

USBCONF (0xDF)

Name	Bit	CPU	USB	Description	Reset
INTSOF_SEL	7	R/W	-	User can select SOF interrupt or CRC error interrupt for USB SOF interrupt source. 0: SOF interrupt, 1: CRC error interrupt	0
SEND_NAK	6	R/W	-	Sending NAK operation This bit will be reset whenever SOF packet is received. 0: Normal operation 1: NAK response to USB host's IN/OUT/SETUP packet	0
WAKE_EN	5	R/W	-	USB Wakeup disable. The BMC513 enters to USB suspend mode whenever STOP is enabled. In this time, the BMC513 can release from USB suspend mode when D+ level is low. 0: Wakeup function disable, 1: Wakeup function enable	0
SET_SUSP	4	R/W	-	For power down mode in another mode except USB mode, this bit is used. 0: No operation 1: Suspend will be issued to USB host	0
CLK_48M_EN	3	R/W	-	0: disable, 1: enable	0
DP_DM_DIR	2	R/W	-	User can select to drive D+ and D- line by software or USB(hardware) 0: D+/D- are set to bi-direction (driven by USB) 1: D+/D- are set to output only (driven by Software)	0
DPVALUE	1	R/W	-	This bit is used when user only want to drive D+ line by software in force. 0: if DP_DM_DIR = 1, D+ drives low 1: If DP_DM_DIR = 1, D+ drives high	0
DMVALUE	0	R/W	-	This bit is used when user only want to drive D- line by software in force. 0: if DP_DM_DIR = 1, D- drives low 1: If DP_DM_DIR = 1, D- drives high	0

PROGRAMMING TIP:

15 RTC

15.1 OVERVIEW

The data of RTC includes second, minute, hour, date, day of the week, month and year. The RTC units works with an external 32.768KHz crystal (ESCLK) from PXTI pin and also can perform the alarm function. Please refer to Figure 15-2 using s/w code.

15.2 FEATURES

- Time information (seconds/minutes/hours) directly in BCD code
- Calendar information (date/month/year/day of the week) directly in BCD code up to year 9999
- Leap year generator
- Alarm interrupt (**Wake-up signal generation to exit from STOP mode**)
  - ✓ This interrupt can be set by sec unit
  - ✓ 1 sec is the shortest time to be set
- Cyclic interrupt: the interrupt cycle may be 1/512, 1/256, 1/64, 1/16, 1/4, 1/2, and 1 second

15.3 BLOCK DIAGRAM

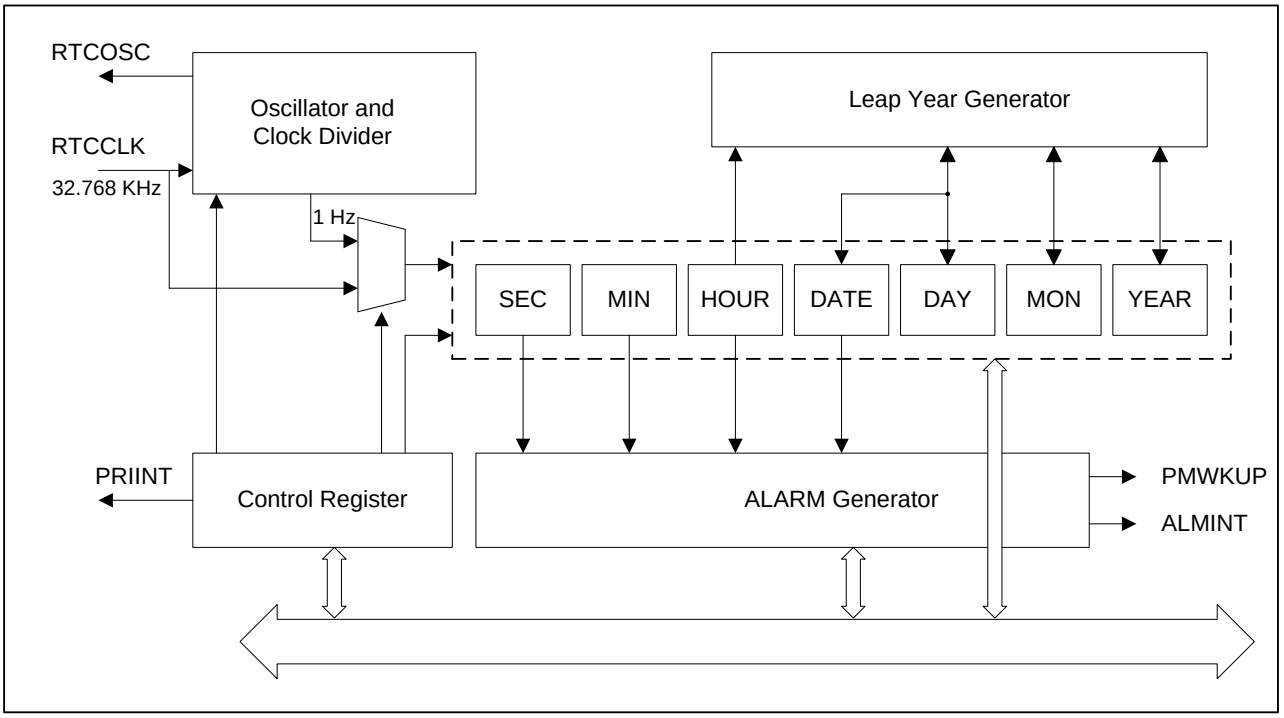


Figure 15-1. RTC Block Diagram

15.4 OPERATION

RTC_RST bit of RSTCON register (System Controller) goes "HIGH" to "LOW" for resetting RTC block. After that, RTC block should be activated.

LEAP YEAR GENERATOR

The leap year generator can determine the last date of each month out of 28, 29, 30 or 31, based on data from BCDDATE, BCDMON, BCDYEARL, and BCDYEARH. This block considers leap year in deciding the last date. A 16 bit counter can just represent four BCD digits, so it can decide whether any year is a leap year or not.

READ/WRITE BCD REGISTERS

Bit 0 (BCDMOD) of the RTCCON0 register must be set high in order to write the BCD register in RTC block. When BCDMOD=0 or START=1, the CPU can't write a data into BCD registers. The CPU must be clear BCDMOD bit after writing data into BCD registers. If not, BCD registers do not run even though START bit is set to 1.

An one second error when the CPU reads data from BCD counters and this cause the change of the higher time units. When the CPU reads data from the BCD counters, another time unit may be changed if BCDSEC register is overflowed. The reading sequence of the BCD counters is BCDYEARH/L, BCDMON, BCDDATE, BCDHOUR, BCDMIN, and BCDSEC. It is required to read it again from BCDYEARH to BCDSEC if BCDSEC is zero.

ALARM function

The RTC generation alarm signal at specified time in the STOP mode or normal mode. In normal mode, the alarm interrupt is activated and in the STOP mode wake-up signal is activated. The RTC alarm register, RTCALM, determines the alarm enable and the condition of the alarm time setting

RTCALM					ALARM Interrupt Condition
4	3	2	1	0	
0	-	-	-	-	Not generate Interrupt
1	0	0	0	0	Not generate Interrupt
1	0	0	0	1	ALMSEC == BCDSEC
1	0	0	1	0	ALMMIN == BCDMIN, BCDSEC == 0
1	0	0	1	1	ALMMIN == BCDMIN, ALMSEC == BCDSEC
1	0	1	0	0	ALMHOUR = BCDHOUR, BCDMIN == 0, BCDSEC == 0
1	0	1	0	1	ALMHOUR = BCDHOUR, ALMSEC == BCDSEC
1	0	1	1	0	ALMHOUR = BCDHOUR, ALMMIN == BCDMIN, BCDSEC == 0
1	0	1	1	1	ALMHOUR = BCDHOUR, ALMMIN == BCDMIN, ALMSEC == BCDSEC
1	1	0	0	0	ALMDATE = BCDDATE, BCDHOUR == 0, BCDMIN == 0, BCDSEC == 0
1	1	0	0	1	ALMDATE = BCDDATE, ALMSEC == BCDSEC
1	1	0	1	0	ALMDATE = BCDDATE, ALMMIN == BCDMIN, BCDSEC == 0
1	1	0	1	1	ALMDATE = BCDDATE, ALMMIN == BCDMIN, ALMSEC == BCDSEC
1	1	1	0	0	ALMDATE = BCDDATE, ALMHOUR = BCDHOUR, BCDMIN == 0, BCDSEC == 0
1	1	1	0	1	ALMDATE = BCDDATE, ALMHOUR = BCDHOUR, ALMSEC == BCDSEC
1	1	1	1	0	ALMDATE = BCDDATE, ALMHOUR = BCDHOUR, ALMMIN == BCDMIN, BCDSEC == 0
1	1	1	1	1	ALMDATE = BCDDATE, ALMHOUR = BCDHOUR, ALMMIN == BCDMIN, ALMSEC == BCDSEC

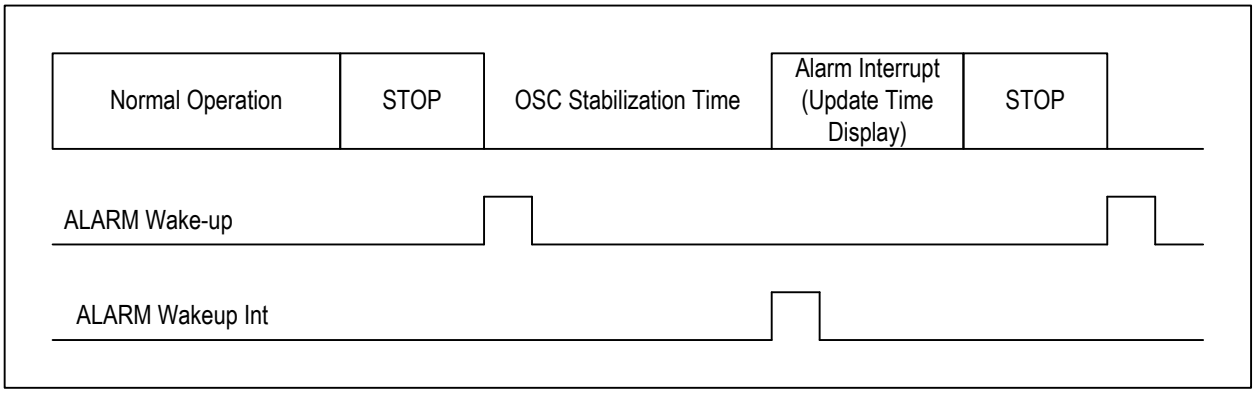


Figure 15-2. Basic RTC operation

15.5 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	RTC_RST
RTCCON0	0xFF80	R/W	RTC Control Register 0	0x00
RTCCON1	0xFF81	R/W	RTC Control Register 1	0x00
BCDSEC	0xFF82	R/W	BCD Second bits	Undef.
BCDMIN	0xFF83	R/W	BCD Minute bits	Undef.
BCDHOUR	0xFF84	R/W	BCD Hour bits	Undef.
BCDDATE	0xFF85	R/W	BCD Date bits	Undef.
BCDDAY	0xFF86	R/W	BCD Day of a Week bits	Undef.
BCDMON	0xFF87	R/W	BCD Month bits	Undef.
BCDYEARL	0xFF88	R/W	BCD Year lower bits	Undef.
BCDYEARH	0xFF89	R/W	BCD Year upper bits	Undef.
RTCALM	0xFF8A	R/W	ALARM control register	0x00
ALMSEC	0xFF8B	R/W	ALARM Second Data register. (BCD value)	0x00
ALMMIN	0xFF8C	R/W	ALARM Minute Data register. (BCD value)	0x00
ALMHOUR	0xFF8D	R/W	ALARM Hour Data register. (BCD value)	0x00
ALMDATE	0xFF8E	R/W	ALARM Date Data register. (BCD value)	0x00

Note) These registers have to be accessed using **MOVX** instruction.

RTCCON0 (0xFF80)

RTC_CNTSEL, RTC_CLKSEL, and RTC_CLKRST bits are used for testing. In normal operation, these bits have to be cleared to '0'.

Name	Bit	R/W	Description	RTC_RST
RSVD	7:5	R	Reserved	000
RTC_CNTSEL	4	R/W	BCD count select 0: Merge BCD counters 1: Reserved (Separate BCD counters)	0
RTC_CLKSEL	3	R/W	BCD clock select 0: PXTI(RTCCLK) $1/2^{15}$ divided clock (1Hz) 1: Reserved(PXTI)	0
RTC_CLKRST	2	R/W	RTC clock divider reset 0: No Reset 1: Reserved (Reset)	0
RTC_BCDMOD	1	R/W	BCD counter MODify. The CPU can write a value into the BCDxxx counters when this bit is set to '1'. This bit should be cleared after setting any value by the CPU.	0
RTC_STARTB	0	R/W	RTC start bit. This bit controls to run the BCD counters. The CPU can't modify the BCDxxx counters during running RTC (STARTB = '0'). 0: RTC running 1: RTC no running	0

RTCCON1 (0xFF81)

Name	Bit	R/W	Description	RTC_RST
RSVD	7:3	R	Reserved	0x0
PEINTPEND	4	R/W	Periodic Interrupt Pending If the IERTCPRI in the IE2 and PEINTEN in this register is enabled and GIE is enabled, an interrupt is requested when this bit is set to '1'. User can clear this bit by writing '1' to this bit.	0
PEINTS	3:1	R/W	Periodic interrupt select 000: No Periodic interrupt generated 001: Periodic interrupt generated every 1/512 second 010: Periodic interrupt generated every 1/256 second 011: Periodic interrupt generated every 1/64 second 100: Periodic interrupt generated every 1/16 second 101: Periodic interrupt generated every 1/4 second 110: Periodic interrupt generated every 1/2 second 111: Periodic interrupt generated every 1 second	000
PEINTEN	0	R/W	Periodic Interrupt Enable 0: Not generate interrupt with the period designated by the PEINTS. 1: Generate interrupt with the period designated by the PEINTS	0

BCDSEC (0xFF82)

Name	Bit	R/W	Description	RTC_RST
RSVD	7	R	Reserved	0
BCDSEC	6:0	R/W	BCD value for second bits. [6:4] bit is from 0 to 5, [3:0] bit is from 0 to 9	Undef.

BCDMIN (0xFF83)

Name	Bit	R/W	Description	RTC_RST
RSVD	7	R	Reserved	0
BCDMIN	6:0	R/W	BCD value for minute bits. [6:4] bit is from 0 to 5, [3:0] bit is from 0 to 9	Undef.

BCDHOUR (0xFF84)

Name	Bit	R/W	Description	RTC_RST
RSVD	7:6	R	Reserved	00
BCDHOUR	5:0	R/W	BCD value for hour bits. [5:4] bit is from 0 to 2, [3:0] bit is from 0 to 9	Undef.

BCDDATE (0xFF85)

Name	Bit	R/W	Description	RTC_RST
RSVD	7:6	R	Reserved	00
BCDDATE	5:0	R/W	BCD value for date bits. From 0 to 28, 29, 30, 31 (decimal: 01 ~ 31) [5:4] bit is from 0 to 3, [3:0] bit is from 0 to 9	Undef.

BCDDAY (0xFF86)

Name	Bit	R/W	Description	RTC_RST
RSVD	7:3	R	Reserved	0x0
BCDDAY	2:0	R/W	BCD value for day of a week bits. [2:0] bit is from 0 to 6. 000: Sunday, 001: Monday, 010: Tuesday, 011: Wednesday, 100: Thursday, 101: Friday, 110: Saturday	Undef.

BCDMON (0xFF87)

Name	Bit	R/W	Description	RTC_RST
RSVD	7:5	R	Reserved	000
BCDMON	4:0	R/W	BCD value for month bits. [4] bit is from 0 to 1, [3:0] bit is from 0 to 9	Undef.

BCDYEARL (0xFF88)

Name	Bit	R/W	Description	RTC_RST
BCDYEARL	7:0	R/W	BCD value for lower of year bits. From 0 to 99	Undef.

BCDYEARH (0xFF89)

Name	Bit	R/W	Description	RTC_RST
BCDYEARH	7:0	R/W	BCD value for upper of year bits. From 0 to 99	Undef.

RTCALM (0xFF8A)

Name	Bit	R/W	Description	RTC_RST
RSVD	7	R	Reserved	-
WKUP_PEND	6	R/W	Alarm Wake-up Pending from STOP mode If the IERTCALM in the IE2 is enabled and GIE is enabled, a wakeup signal and interrupt will be requested when this bit is set to '1'. User can clear this bit by writing '1' to this bit. In the STOP mode, this bit is available.	0
ALM_PEND	5	R/W	Alarm Interrupt Pending If the IERTCALM in the IE2 is enabled and GIE is enabled, an interrupt is requested when this bit is set to '1'. User can clear this bit by writing '1' to this bit. In the STOP mode, this bit is not available.	0
ALM_EN	4	R/W	ALARM global enable bit 0: Disable, 1: Enable	0
DATE_EN	3	R/W	Date ALARM enable bit 0: Disable, 1: Enable	0
HOUR_EN	2	R/W	Hour ALARM enable bit 0: Disable, 1: Enable	0
MIN_EN	1	R/W	Minute ALARM enable bit 0: Disable, 1: Enable	0
SEC_EN	0	R/W	Second ALARM enable bit 0: Disable, 1: Enable	0

ALMSEC (0xFF8B)

Name	Bit	R/W	Description	RTC_RST
RSVD	7	R	Reserved	0
ALMSEC	6:0	R/W	BCD value for ALARM second bits. [6:4] bit is from 0 to 5, [3:0] bit is from 0 to 9	0x00

ALMMIN (0xFF8C)

Name	Bit	R/W	Description	RTC_RST
RSVD	7	R	Reserved	0
ALMMIN	6:0	R/W	BCD value for ALARM minute bits. [6:4] bit is from 0 to 5, [3:0] bit is from 0 to 9	0x00

ALMHOUR (0xFF8D)

Name	Bit	R/W	Description	RTC_RST
RSVD	7:6	R	Reserved	00
ALMHOUR	5:0	R/W	BCD value for ALARM hour bits. [5:4] bit is from 0 to 2, [3:0] bit is from 0 to 9	0x00

ALMDATE (0xFF8E)

Name	Bit	R/W	Description	RTC_RST
RSVD	7:6	R	Reserved	00
ALMDATE	5:0	R/W	BCD value for ALARM date bits. From 0 to 28, 29, 30, 31 (decimal: 01 ~ 31) [5:4] bit is from 0 to 3, [3:0] bit is from 0 to 9	0x00

NOTES:

16 VDMA

The BMC513 has a VDMA for 2-dimensional data movement.

16.1 FEATURES

- Two dimensional DMA engine with on the fly additional functions
  - ✓ Color space conversion from YCbCr to RGB
  - ✓ Mixing foreground and background images
  - ✓ Alpha blending supporting 4444 and 5551 formats
- Local I80LCD channel to read/write RGB data to/from external frame memory

16.2 BLOCK DIAGRAM

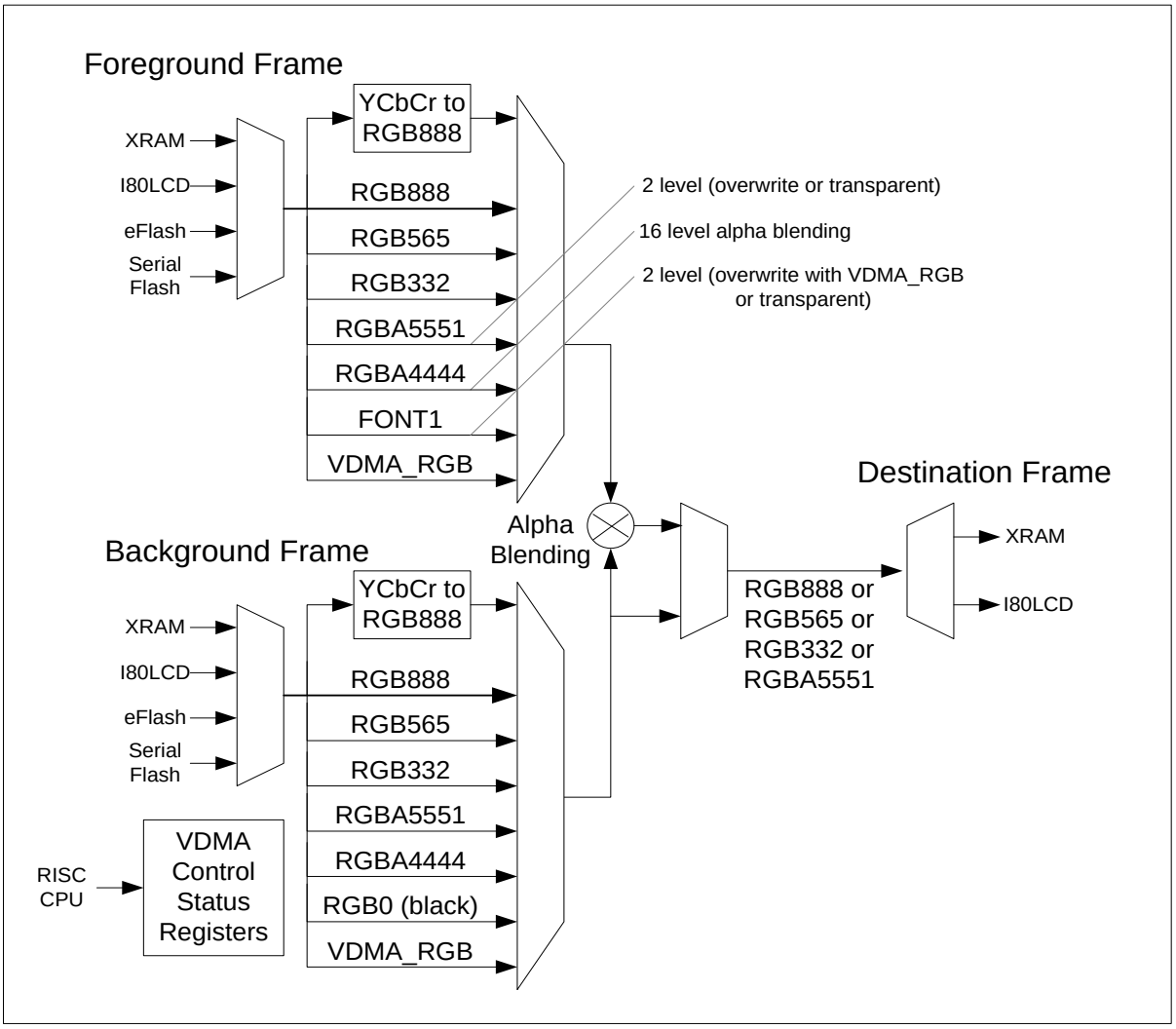


Figure 16-1. VDMA Block Diagram

16.3 OPERATION

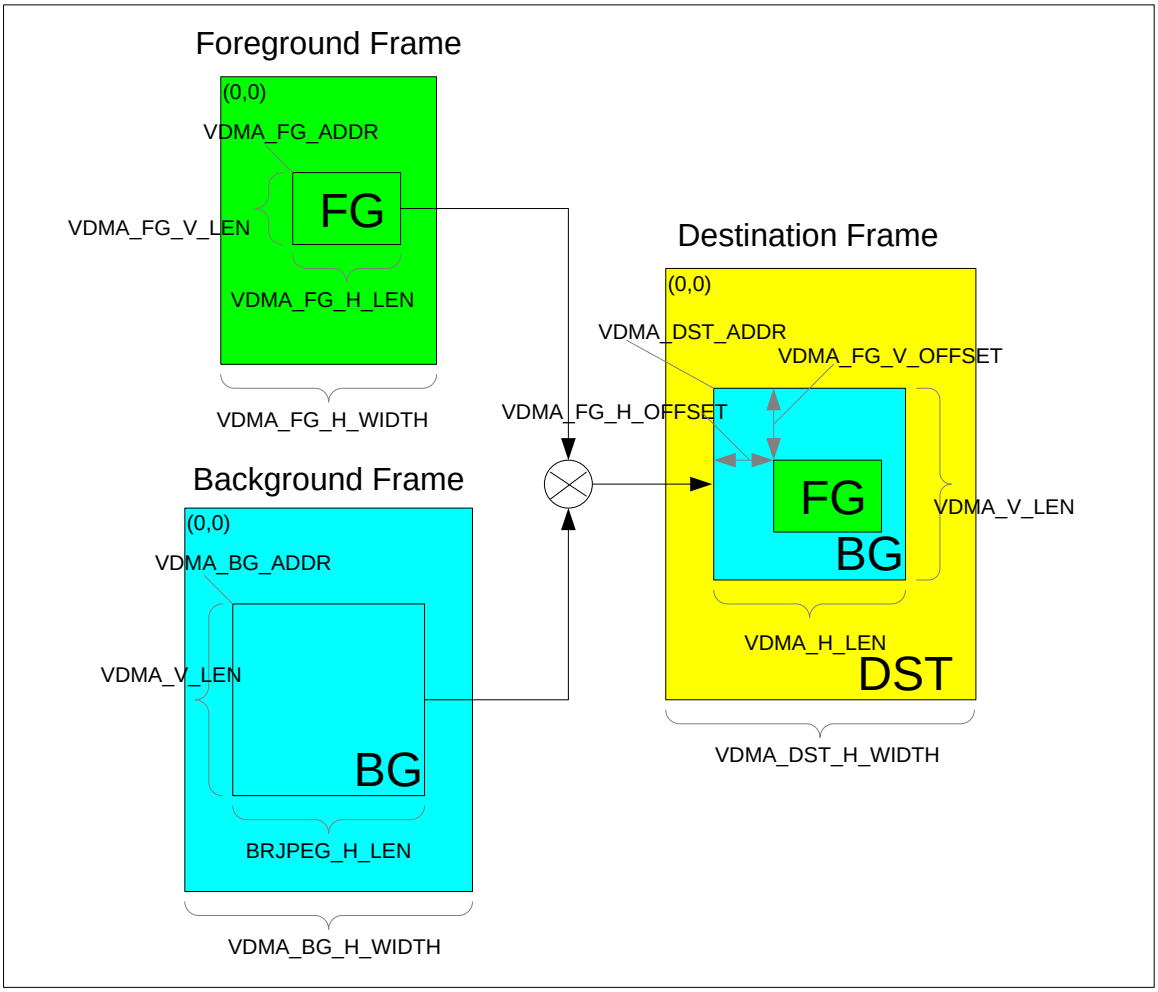


Figure 16-2. VDMA 2-D Frame Structure

16.4 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
VDMA_CFG_0	0xFFE0	R/W	Configuration byte 0	0x0
VDMA_CFG_1	0xFFE1	R/W	Configuration byte 1	0x0
VDMA_H_LEN	0xFFE2	R/W	Horizontal length – 1 for the background and destination moving area	Undef.
VDMA_V_LEN	0xFFE3	R/W	Vertical length – 1 for the background and destination moving area	Undef.
VDMA_DST_H_WIDTH_L	0xFFE4	R/W	Low byte of the horizontal width of the destination frame	Undef.
VDMA_DST_H_WIDTH_H	0xFFE5	R/W	High byte of the horizontal width of the destination frame	Undef.
VDMA_DST_ADDR_L	0xFFE6	R/W	Low byte of the destination area starting address	Undef.
VDMA_DST_ADDR_H	0xFFE7	R/W	High byte of the destination area starting address	Undef.
VDMA_BG_H_WIDTH_L	0xFFE8	R/W	Low byte of the horizontal width of the background source frame	Undef.
VDMA_BG_H_WIDTH_H	0xFFE9	R/W	High byte of the horizontal width of the background source frame	Undef.
VDMA_BG_ADDR_L	0xFFEA	R/W	Low byte of the background source area starting address	Undef.
VDMA_BG_ADDR_M	0xFFEB	R/W	Middle byte of the background source area starting address	Undef.
VDMA_BG_ADDR_H	0xFFEC	R/W	High byte of the background source area starting address	Undef.
RESERVED	0xFFED	-	Reserved	-
RESERVED	0xFFEE	-	Reserved	-
RESERVED	0xFFEF	-	Reserved	-
VDMA_FG_H_OFFSET	0xFFF0	R/W	Horizontal offset of the foreground area	Undef.
VDMA_FG_V_OFFSET	0xFFF1	R/W	Vertical offset of the foreground area	Undef.
VDMA_FG_H_LEN	0xFFF2	R/W	Horizontal length – 1 for foreground moving area	Undef.
VDMA_FG_V_LEN	0xFFF3	R/W	Vertical length – 1 for foreground moving area	Undef.
VDMA_FG_H_WIDTH_L	0xFFF4	R/W	Low byte of the horizontal width of the foreground source frame	Undef.
VDMA_FG_H_WIDTH_H	0xFFF5	R/W	High byte of the horizontal width of the foreground source frame	Undef.
VDMA_FG_ADDR_L	0xFFF6	R/W	Low byte of the foreground source area starting address	Undef.
VDMA_FG_ADDR_M	0xFFF7	R/W	Middle byte of the foreground source area starting address	Undef.
VDMA_FG_ADDR_H	0xFFF8	R/W	High byte of the foreground source area starting address	Undef.
VDMA_CMD	0xFFF9	R/W	Command	0x0
VDMA_IE	0xFFFA	R/W	Interrupt enable	0x0
VDMA_ICLR	0xFFFB	R/W	Interrupt clear	0x0
VDMA_ST	0xFFFC	R/W	Status	0x0
VDMA_RGB_R	0xFFFD	R/W	VDMA _RGB Red value	Undef.
VDMA_RGB_G	0xFFFE	R/W	VDMA_RGB Green value	Undef.
VDMA_RGB_B	0xFFFF	R/W	VDMA_RGB Blue value	Undef.

Note) These registers have to be accessed using **MOVX** instruction.

VDMA_CFG_0 (0xFFE0)

Name	Bit	R/W	Description	Reset
VDMA_BG_RGB	7:5	R/W	VDMA background color components 000: YCbCr 001: RGB888 010: RGB565 011: RGB332 100: RGBA5551. 1-bit alpha is ignored. 101: RGBA4444. 4-bit alpha is ignored. 110: RGB0 (0, 0, 0). Black background color. 111: VDMA_RGB register	000
VDMA_BG_SRC	4:3	R/W	VDMA background source memory 00: XRAM 01: I80LCD 10: Internal eFlash 11: External serial flash Set this field to XRAM if this field is not required for the operation.	00
VDMA_DST_RGB	2:1	R/W	VDMA background color components 00: RGB888 01: RGB565 10: RGB332 11: RGBA5551	00
VDMA_DST	0	R/W	VDMA destination memory 0: XRAM, 1: I80LCD	0

VDMA_CFG_1 (0xFFE1)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
VDMA_FG_RGB	5:3	R/W	VDMA foreground color components 000: YCbCr 001: RGB888 010: RGB565 011: RGB332 100: RGBA5551. 1-bit alpha blending is applied. 101: RGBA4444. 4-bit alpha blending is applied. 110: 1-bit plane 111: VDMA_RGB register	000
VDMA_FG_SRC	2:1	R/W	VDMA foreground source memory 00: XRAM 01: I80LCD 10: Internal eFlash 11: External serial flash Set this field to XRAM if this field is not required for the operation.	00
VDMA_BLEND_EN	0	R/W	VDMA blending enable 0: disable. Only background image is moved to the destination memory. 1: enable. Foreground and background images are blended and moved to the destination memory.	0

VDMA_H_LEN (0xFFE2)

Name	Bit	R/W	Description	Reset
VDMA_H_LEN	7:0	R/W	Horizontal length – 1 for the background and destination moving area	Undef.

VDMA_V_LEN (0xFFE3)

Name	Bit	R/W	Description	Reset
VDMA_V_LEN	7:0	R/W	Vertical length – 1 for the background and destination moving area	Undef.

VDMA_DST_H_WIDTH_L (0xFFE4), VDMA_DST_H_WIDTH_H (0xFFE5)

VDMA_DST_H_WIDTH[8:0] register keeps the horizontal image frame width of the destination.

Name	Bit	R/W	Description	Reset
VDMA_DST_H_WIDTH_L	7:0	R/W	Bits[7:0] of the horizontal width of the destination frame	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
VDMA_DST_H_WIDTH_H	0	R/W	Bit[8] of the horizontal width of the destination frame	Undef.

VDMA_DST_ADDR_L (0xFFE6), VDMA_DST_ADDR_H (0xFFE7)

VDMA_DST_ADDR[11:0] register is the destination memory address if it is XRAM.

Name	Bit	R/W	Description	Reset
VDMA_DST_ADDR_L	7:0	R/W	Bits[7:0] of the destination area starting address	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
VDMA_DST_ADDR_H	3:0	R/W	Bits[11:8] of the destination area starting address	Undef.

VDMA_BG_H_WIDTH_L (0xFFE8), VDMA_BG_H_WIDTH_H (0xFFE9)

VDMA_BG_H_WIDTH[8:0] register keeps the horizontal image frame width of the background source.

Name	Bit	R/W	Description	Reset
VDMA_BG_H_WIDTH_L	7:0	R/W	Bits[7:0] of the horizontal width of the background source frame	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
VDMA_BG_H_WIDTH_H	0	R/W	Bit[8] of the horizontal width of the background source frame	Undef.

VDMA_BG_ADDR_L (0xFFEA), VDMA_BG_ADDR_M (0xFFEB), VDMA_BG_ADDR_H (0xFFEC)

VDMA_BG_ADDR[23:0] register is the background source image address.

Name	Bit	R/W	Description	Reset
VDMA_BG_ADDR_L	7:0	R/W	Bits[7:0] of the background source area starting address	Undef.

Name	Bit	R/W	Description	Reset
VDMA_BG_ADDR_M	7:0	R/W	Bits[15:8] of the background source area starting address	Undef.

Name	Bit	R/W	Description	Reset
VDMA_BG_ADDR_H	7:0	R/W	Bits[23:16] of the background source area starting address	Undef.

VDMA_FG_H_OFFSET (0xFFF0)

Name	Bit	R/W	Description	Reset
VDMA_FG_H_OFFSET	7:0	R/W	Horizontal offset of the foreground area	Undef.

VDMA_FG_V_OFFSET (0xFFF1)

Name	Bit	R/W	Description	Reset
VDMA_FG_V_OFFSET	7:0	R/W	Vertical offset of the foreground area	Undef.

VDMA_FG_H_LEN (0xFFF2)

Name	Bit	R/W	Description	Reset
VDMA_FG_H_LEN	7:0	R/W	Horizontal length – 1 for foreground moving area	Undef.

VDMA_FG_V_LEN (0xFFF3)

Name	Bit	R/W	Description	Reset
VDMA_FG_V_LEN	7:0	R/W	Vertical length – 1 for the foreground moving area	Undef.

VDMA_FG_H_WIDTH_L (0xFFF4), VDMA_FG_H_WIDTH_H (0xFFF5)

VDMA_FG_H_WIDTH[8:0] register keeps the horizontal image frame width of the foreground source.

Name	Bit	R/W	Description	Reset
VDMA_FG_H_WIDTH_L	7:0	R/W	Bits[7:0] of the horizontal width of the foreground source frame	Undef.

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
VDMA_FG_H_WIDTH_H	0	R/W	Bit[8] of the horizontal width of the foreground source frame	Undef.

VDMA_FG_ADDR_L (0xFFF6), VDMA_FG_ADDR_M (0xFFF7), VDMA_FG_ADDR_H (0xFFF8)

VDMA_FG_ADDR[23:0] register is the foreground source image address.

Name	Bit	R/W	Description	Reset
VDMA_FG_ADDR_L	7:0	R/W	Bits[7:0] of the foreground source area starting address	Undef.

Name	Bit	R/W	Description	Reset
VDMA_FG_ADDR_M	7:0	R/W	Bits[15:8] of the foreground source area starting address	Undef.

Name	Bit	R/W	Description	Reset
VDMA_FG_ADDR_H	7:0	R/W	Bits[23:16] of the foreground source area starting address	Undef.

VDMA_CMD (0xFFF9)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
VDMA_ EN	0	R/W	VDMA enable command. When set, it is not cleared until the VDMA operation is done. 0: idle, 1: enable(W)/busy(R)	0

VDMA_IE (0xFFFA)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
VDMA_ DONE_IE	0	R/W	VDMA done interrupt enable 0: disable, 1: enable	0

VDMA_ICLR (0xFFFB)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
VDMA_ DONE_ICLR	0	W	VDMA done interrupt clear by writing 1	0

VDMA_ST (0xFFFC)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
VDMA_ DONE_ST	0	R/W	VDMA done status. This bit can be set by writing 1. 0: idle, 1: done(R)/set(W)	0

VDMA_RGB_R (0xFFFD), VDMA_RGB_G (0xFFFE), VDMA_RGB_B (0xFFFF)

VDMA_RGB register is RGB color register for background image.

Name	Bit	R/W	Description	Reset
VDMA_RGB_R	7:0	R/W	VDMA _RGB Red value	Undef.

Name	Bit	R/W	Description	Reset
VDMA_RGB_G	7:0	R/W	VDMA _RGB Green value	Undef.

Name	Bit	R/W	Description	Reset
VDMA_RGB_B	7:0	R/W	VDMA _RGB Blue value	Undef.

NOTES:

17 I80LCD INTERFACE

The BMC513 has an 8080-series interface for LCD.

17.1 FEATURES

- Support parallel/serial external LCD interfaces
  - ✓ 8-bit, 9-bit, 16-bit, 18-bit parallel I80 interface
  - ✓ 3-wire, 4-wire serial interface
- Support VDMA local bus interface

17.2 PIN DESCRIPTION

Table 17-1. I80 LCD Interface PIN Description

GPIO	Pin Name	Function	Type
GP6[5]	I80RS	Register selection output	O
GP6[4]	I80CSN	Chip select output	O
GP6[3]	I80WRN	Write strobe output	O
GP6[2]	I80RDN	Read strobe output	O
GP0[3:0] GP5[3:0] GP4[7:0] GP6[7:6]	I80D[17:0]	Data Input / Output	IO

17.3 OPERATION

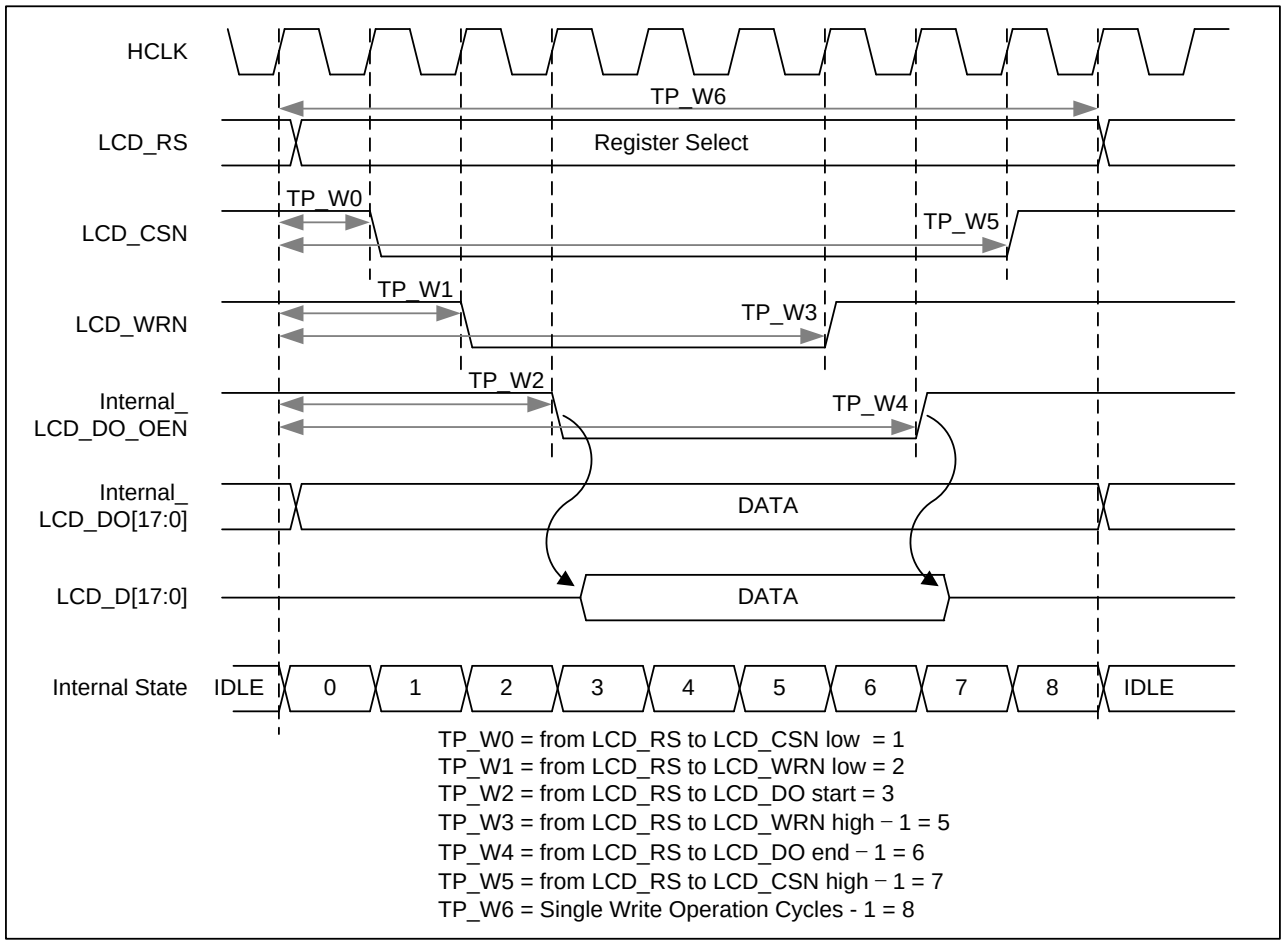


Figure 17-1. I80LCD single write timing parameters

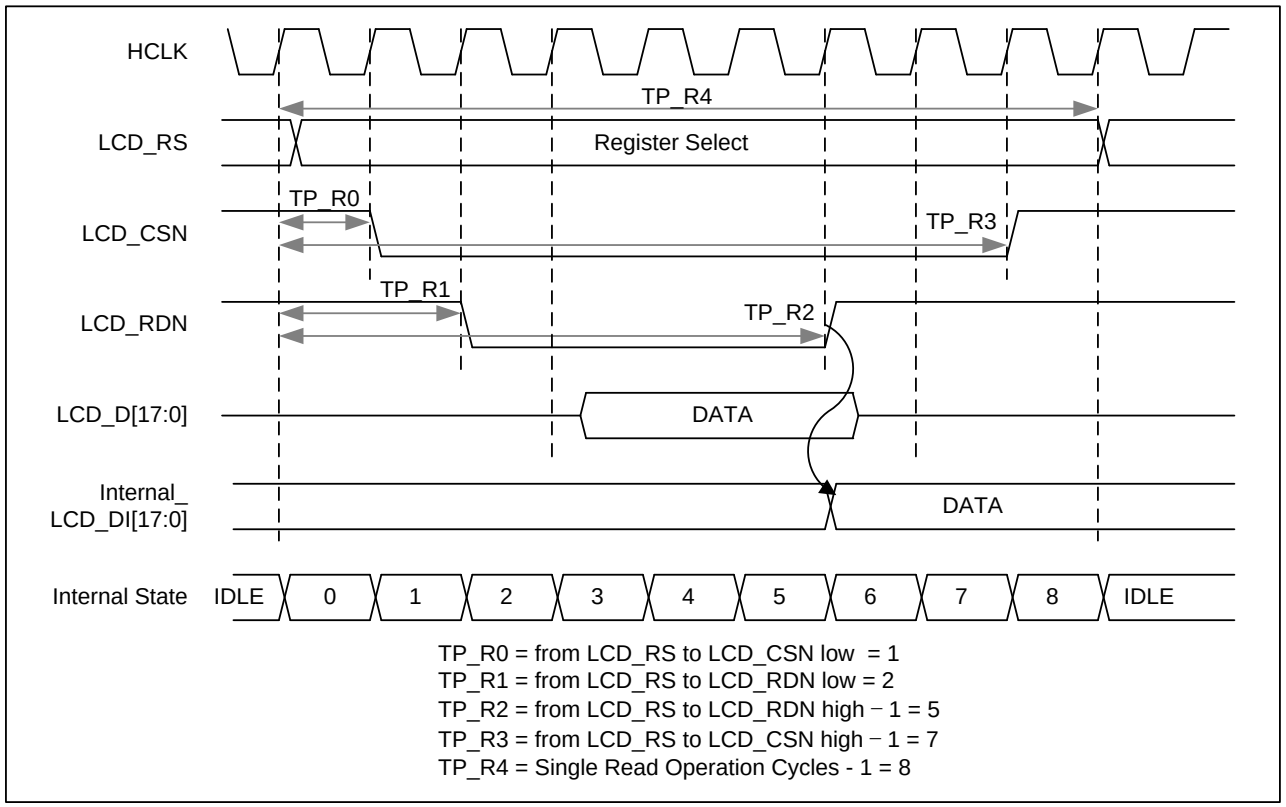


Figure 17-2. I80LCD single read timing parameters

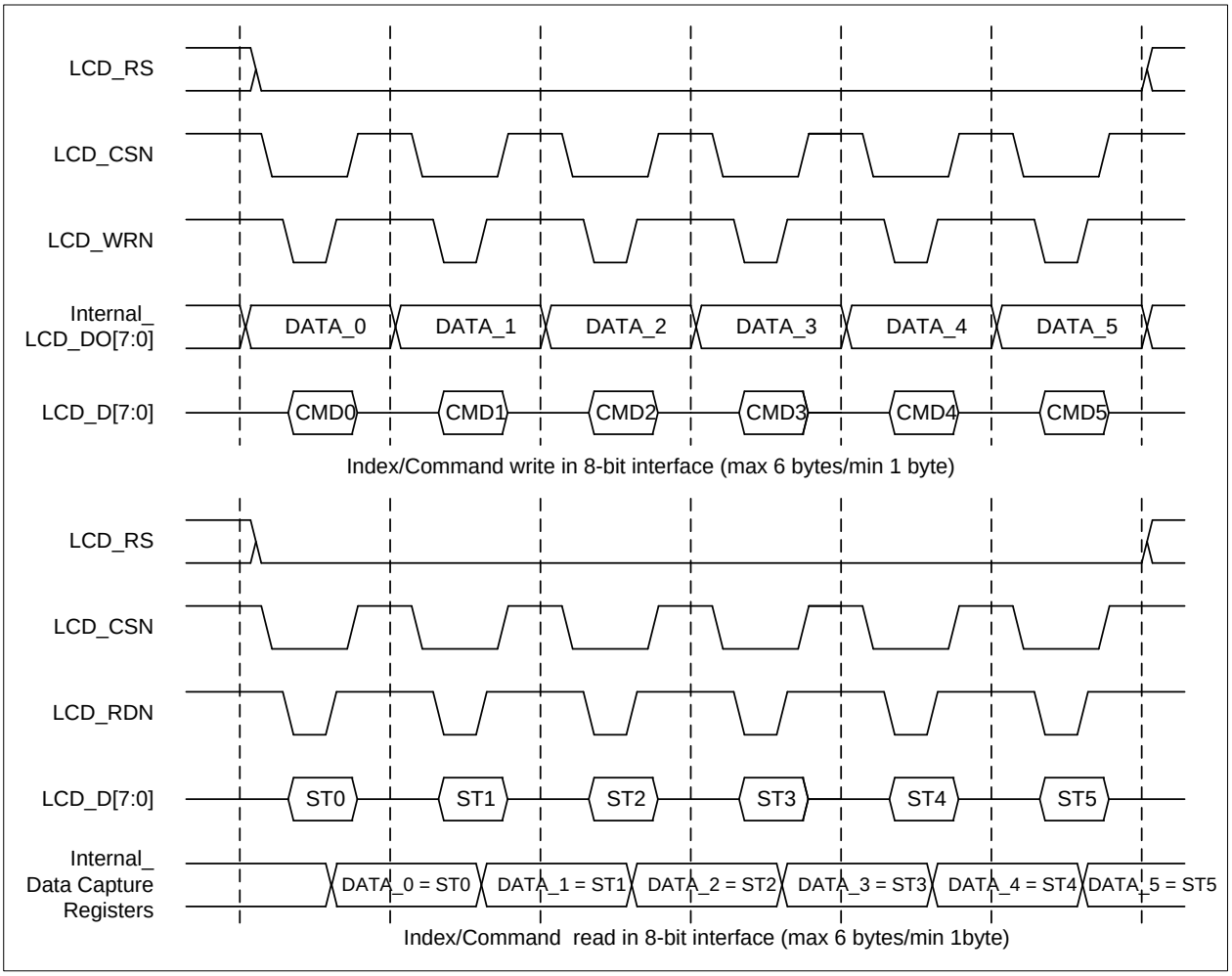


Figure 17-3. I80LCD 8-bit interface for Index/Command transfer

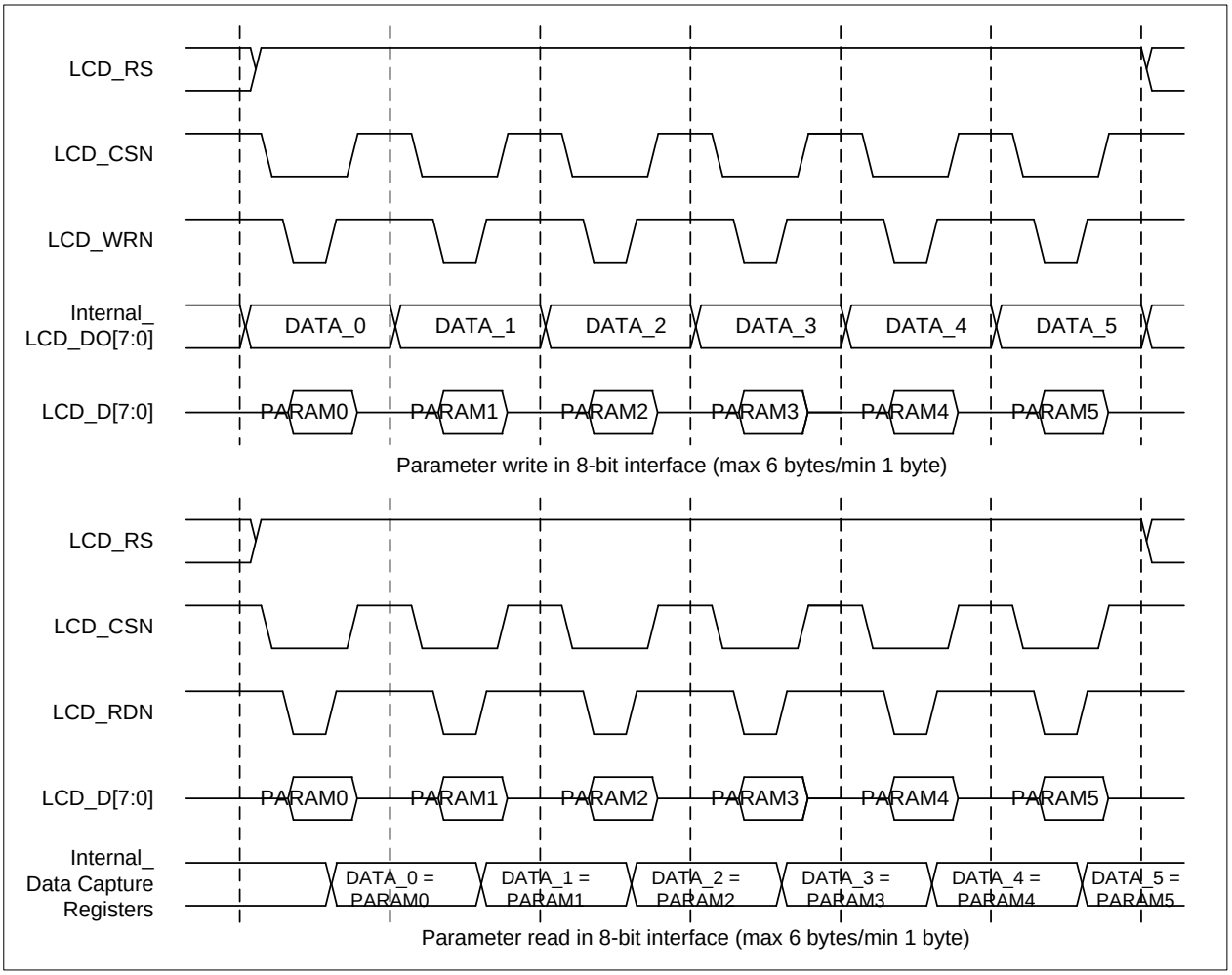


Figure 17-4. I80LCD 8-bit interface for Parameter transfer

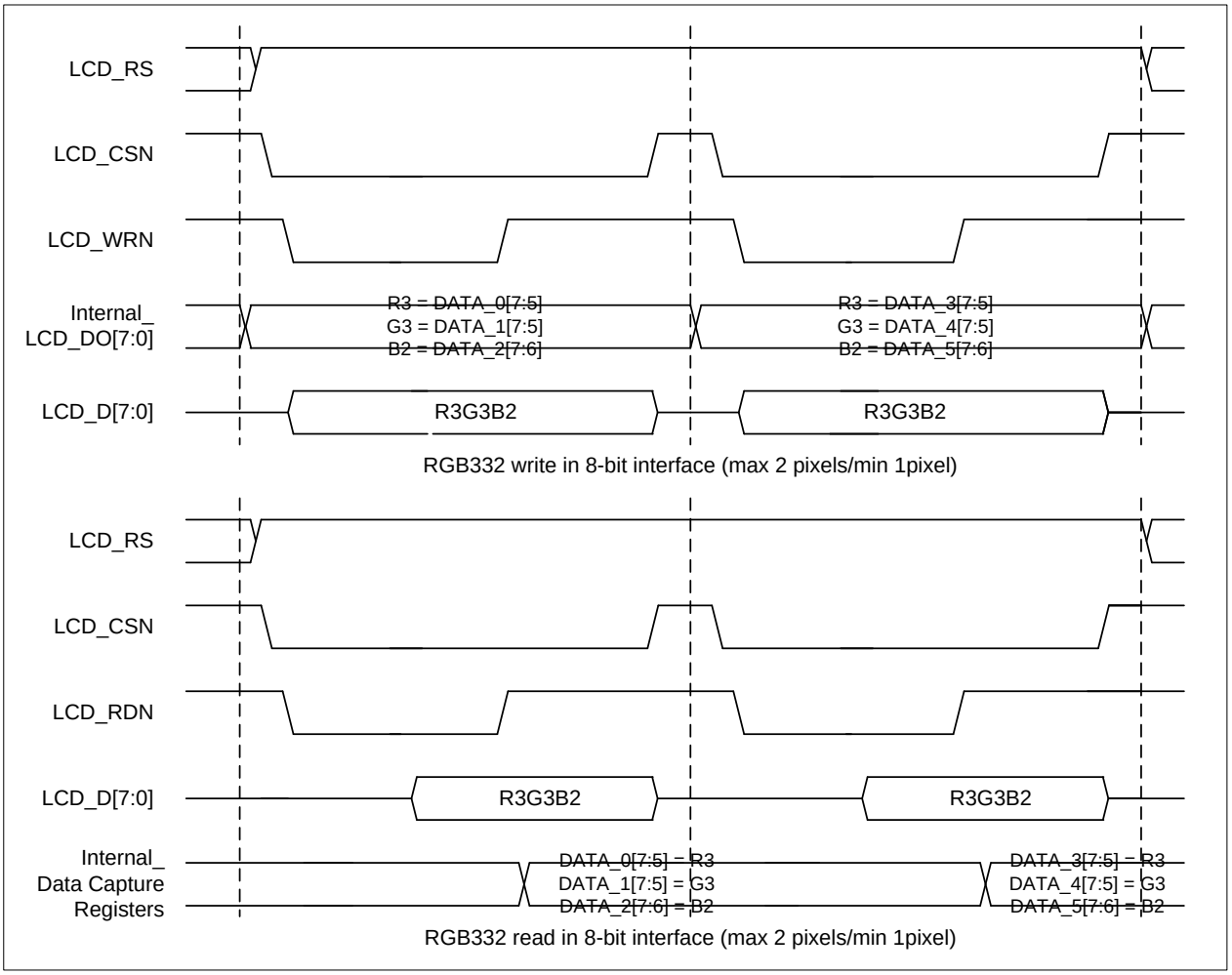


Figure 17-5. I80LCD 8-bit interface for RGB332 transfer

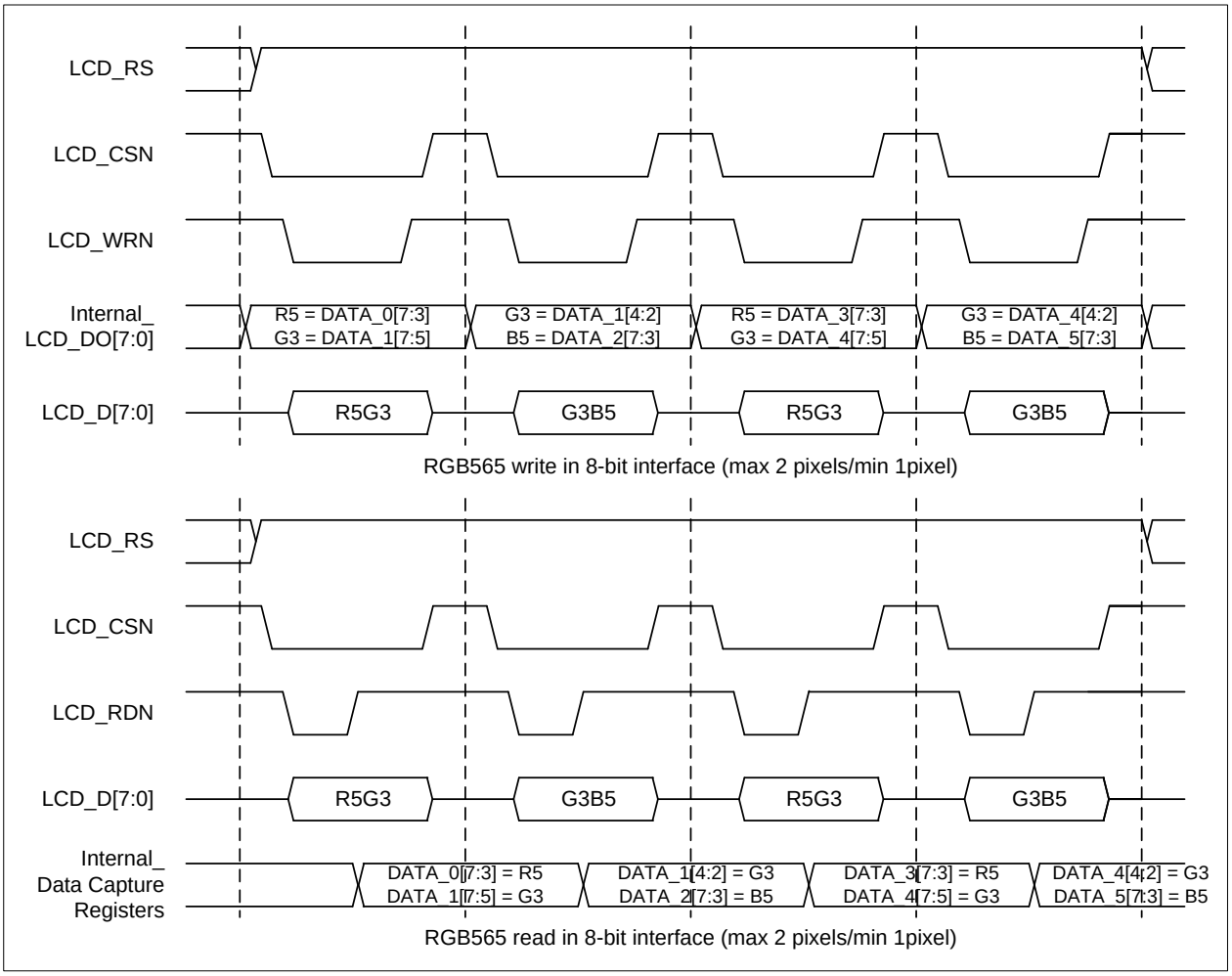


Figure 17-6. I80LCD 8-bit interface for RGB565 transfer

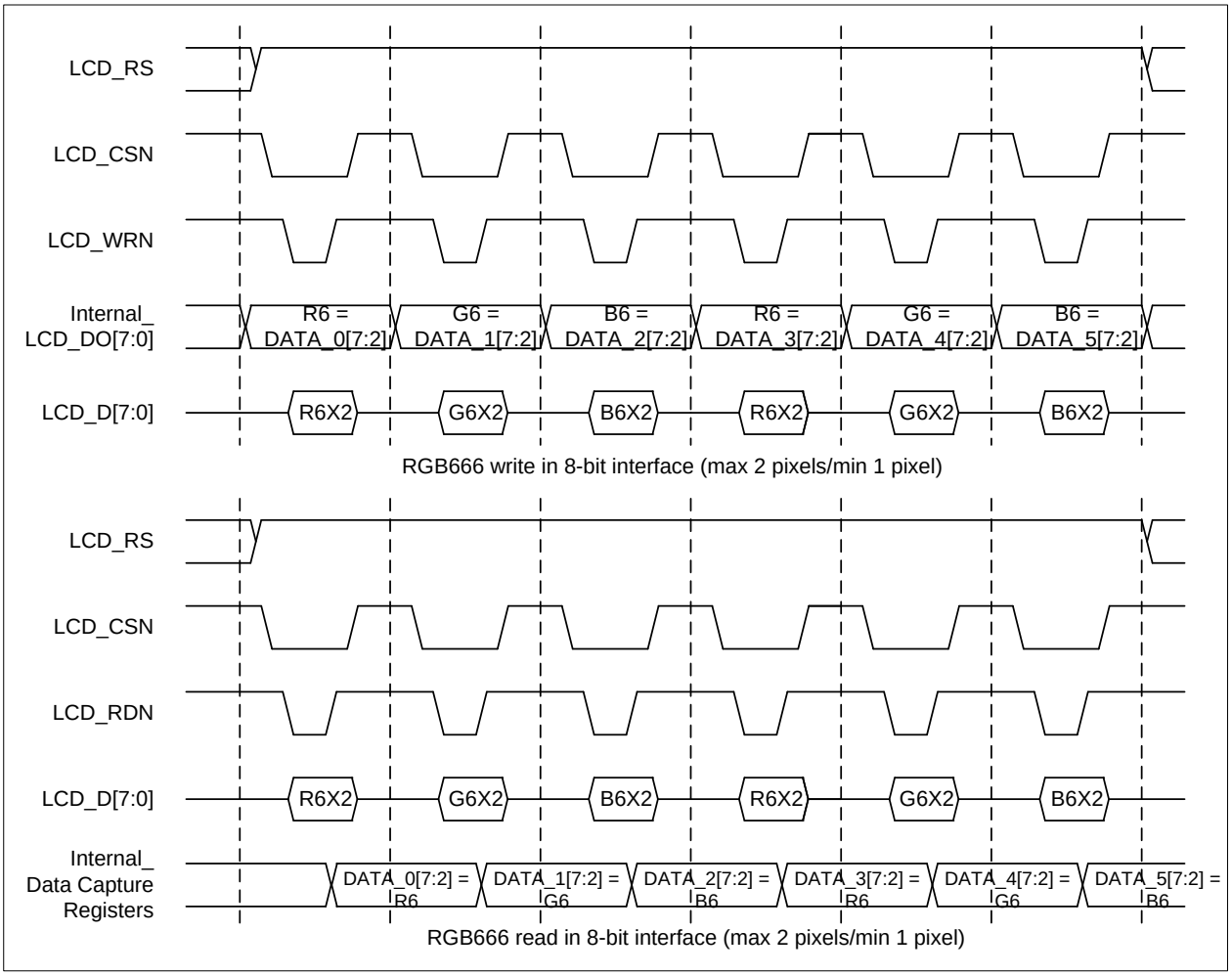


Figure 17-7. I80LCD 8-bit interface for RGB666 transfer

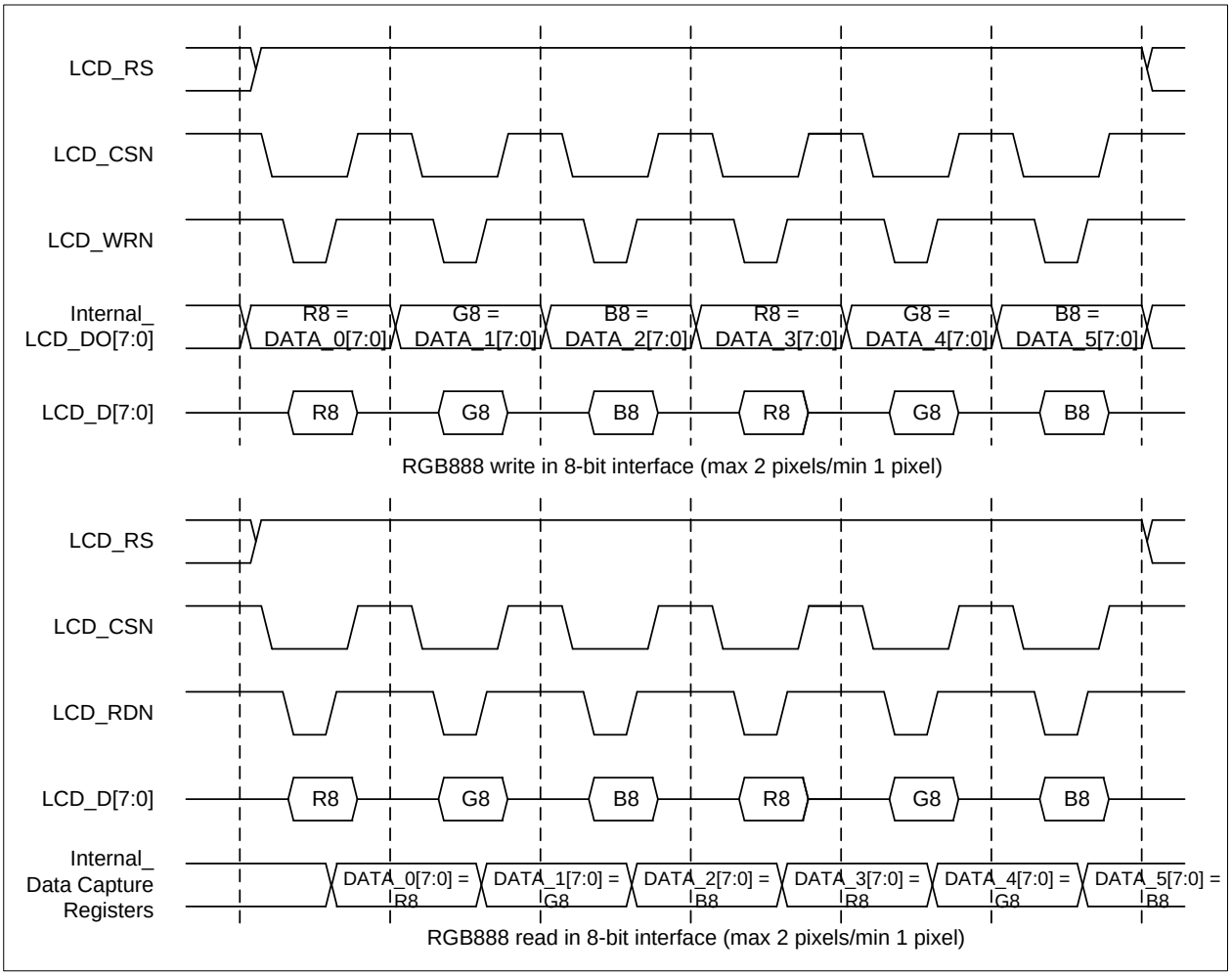


Figure 17-8. I80LCD 8-bit interface for RGB888 transfer

17.4 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
I80LCD_TP_W0	0xFFC0	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN low in LCD write operation becomes I80LCD_TP_W0	Undef.
I80LCD_TP_W1	0xFFC1	R/W	Number of HCLK cycles from LCD_RS to LCD_WRN low in LCD write operation becomes I80LCD_TP_W1	Undef.
I80LCD_TP_W2	0xFFC2	R/W	Number of HCLK cycles from LCD_RS to LCD_D valid output in LCD write operation becomes I80LCD_TP_W2	Undef.
I80LCD_TP_W3	0xFFC3	R/W	Number of HCLK cycles from LCD_RS to LCD_WRN high in LCD write operation becomes I80LCD_TP_W3 + 1	Undef.
I80LCD_TP_W4	0xFFC4	R/W	Number of HCLK cycles from LCD_RS to LCD_D high-impedance in LCD write operation becomes I80LCD_TP_W4 + 1	Undef.
I80LCD_TP_W5	0xFFC5	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN high in LCD write operation becomes I80LCD_TP_W5 + 1	Undef.
I80LCD_TP_W6	0xFFC6	R/W	Number of HCLK cycles for single LCD write operation becomes I80LCD_TP_W6 + 1	Undef.
I80LCD_TP_R0	0xFFC7	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN low in LCD read operation becomes I80LCD_TP_R0	Undef.
I80LCD_TP_R1	0xFFC8	R/W	Number of HCLK cycles from LCD_RS to LCD_RDN low in LCD read operation becomes I80LCD_TP_R1	Undef.
I80LCD_TP_R2	0xFFC9	R/W	Number of HCLK cycles from LCD_RS to LCD_RDN high in LCD read operation becomes I80LCD_TP_R2 + 1	Undef.
I80LCD_TP_R3	0xFFCA	R/W	Number of HCLK cycles from LCD_RS to LCD_CSN high in LCD read operation becomes I80LCD_TP_R3 + 1	Undef.
I80LCD_TP_R4	0xFFCB	R/W	Number of cycles for single LCD read operation becomes I80LCD_TP_R4 + 1	Undef.
RESERVED	0xFFCC		Reserved	-
RESERVED	0xFFCD		Reserved	-
RESERVED	0xFFCE		Reserved	-
RESERVED	0xFFCF		Reserved	-
I80LCD_CFG_0	0xFFD0	R/W	Configuration byte 0	0x0
I80LCD_CFG_1	0xFFD1	R/W	Configuration byte 1	0x0
I80LCD_DATA_0	0xFFD2	R/W	Data buffer byte 0	Undef.
I80LCD_DATA_1	0xFFD3	R/W	Data buffer byte 1	Undef.
I80LCD_DATA_2	0xFFD4	R/W	Data buffer byte 2	Undef.
I80LCD_DATA_3	0xFFD5	R/W	Data buffer byte 3	Undef.
I80LCD_DATA_4	0xFFD6	R/W	Data buffer byte 4	Undef.
I80LCD_DATA_5	0xFFD7	R/W	Data buffer byte 5	Undef.
I80LCD_CMD	0xFFD8	R/W	Command	0x0
I80LCD_IE	0xFFD9	R/W	Interrupt enable	0x0
I80LCD_ICLR	0xFFDA	R/W	Interrupt clear	0x0
I80LCD_ST	0xFFDB	R/W	Status	0x0

Note) These registers have to be accessed using **MOVX** instruction.

I80LCD_TP_W0 (0xFFC0)

Name	Bit	R/W	Description	Reset
RSVD	7:3	-	Reserved	-
TP_W0	2:0	R/W	Number of starting cycle of LCD_CSN low in LCD write operation becomes I80LCD_TP_W0	Undef.

I80LCD_TP_W1 (0xFFC1)

Name	Bit	R/W	Description	Reset
RSVD	7:3	-	Reserved	-
TP_W1	2:0	R/W	Number of starting cycle of LCD_WRN low in LCD write operation becomes I80LCD_TP_W1	Undef.

I80LCD_TP_W2 (0xFFC2)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
TP_W2	5:0	R/W	Number of starting cycle of LCD_D output active in LCD write operation becomes I80LCD_TP_W2	Undef.

I80LCD_TP_W3 (0xFFC3)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
TP_W3	5:0	R/W	Number of ending cycle of LCD_WRN low in LCD write operation becomes I80LCD_TP_W3 + 1	Undef.

I80LCD_TP_W4 (0xFFC4)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
TP_W4	5:0	R/W	Number of ending cycle of LCD_D output active in LCD write operation becomes I80LCD_TP_W4 + 1	Undef.

I80LCD_TP_W5 (0xFFC5)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
TP_W5	5:0	R/W	Number of ending cycle of LCD_CSN low in LCD write operation becomes I80LCD_TP_W5 + 1	Undef.

I80LCD_TP_W6 (0xFFC6)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
TP_W6	5:0	R/W	Number of cycles for one LCD write operation becomes I80LCD_TP_W6 + 1	Undef.

I80LCD_TP_R0 (0xFFC7)

Name	Bit	R/W	Description	Reset
RSVD	7:3	-	Reserved	-
TP_R0	2:0	R/W	Number of starting cycle of LCD_CSN low in LCD read operation becomes I80LCD_TP_R0	Undef.

I80LCD_TP_R1 (0xFFC8)

Name	Bit	R/W	Description	Reset
RSVD	7:3	-	Reserved	-
TP_R1	2:0	R/W	Number of starting cycle of LCD_RDN low in LCD read operation becomes I80LCD_TP_R1	Undef.

I80LCD_TP_R2 (0xFFC9)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
TP_R2	5:0	R/W	Number of ending cycle of LCD_RDN low in LCD read operation becomes I80LCD_TP_R2 + 1	Undef.

I80LCD_TP_R3 (0xFFCA)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
I80LCD_TP_R3	5:0	R/W	Number of ending cycle of LCD_CSN low in LCD read operation becomes I80LCD_TP_R3 + 1	Undef.

I80LCD_TP_R4 (0xFFCB)

Name	Bit	R/W	Description	Reset
RSVD	7:6	-	Reserved	-
TP_R4	5:0	R/W	Number of cycles for one LCD read operation becomes I80LCD_TP_R4 + 1	Undef.

I80LCD_CFG_0 (0xFFD0)

Name	Bit	R/W	Description	Reset
RGB_2PIXEL_PACK	7	R/W	This bit defines two pixel packing method when I80LCD_RGB_N_PIXEL is high for two pixel mode 0: no packing. 2 pixels in 8 bytes. (R0/G0, B0/X, R1/G1, B1/X) 1: packing. 2 pixels in 6 bytes. (R0/G0, B0/R1, G1/B1)	0
RGB_N_PIXEL	6	R/W	Number of RGB pixels to read or write for each I80LCD enable 0: 1 pixel. 1: 2 pixel.	0
RGB_TYPE	5:4	R/W	External LCD RGB type 00: RGB332 01: RGB565 10: RGB666 11: RGB888	00
IF_BYTE_MAPPING	3:2	R/W	Internal byte mapping for external LCD interface data pins 00: use [15:0] for 16 bit interface. Use [7:0] for 8 bit interface. 01: use [17:2] for 16 bit interface. Use [17:10] for 8 bit interface. 10: use [16:9, 7:0] for 16 bit interface. Use [16:9] for 8 bit interface. 11: use [17:10, 8:1] for 16 bit interface. Use [8:1] for 8 bit interface.	00
IF_BITS	1:0	R/W	Number of external LCD parallel data pins 00: 8 bits, 01: 9 bits, 10: 16 bits, 11: 18 bits	00

I80LCD_CFG_1 (0xFFD1)

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
RS_INV	4	R/W	I80LCD_RS output is inverted if this bit is set.	0
CPU_WAIT_EN	3	R/W	CPU wait enable not to use the interrupt or polling scheme. 0: disable, 1: enable If this bit is disabled SW should check or guarantee the completion of the current command before issuing the next command.	0
SPI_LINE	2	R/W	Number of SPI lines for serial SPI type interface 0: 3 lines, 1: 4 lines	0
SPI_EN	1	R/W	External LCD interface type 0: parallel I80 type, 1: serial SPI type	0
I_P_BIT_LEN	0	R/W	Number of bytes for each index/parameter of external LCD device 0: 1 byte, 1: 2 bytes	0

I80LCD_DATA_0 (0xFFD2)

Name	Bit	R/W	Description	Reset
DATA_0	7:0	R/W	Data buffer byte 0	Undef.

I80LCD_DATA_1 (0xFFD3)

Name	Bit	R/W	Description	Reset
DATA_1	7:0	R/W	Data buffer byte 1	Undef.

I80LCD_DATA_2 (0xFFD4)

Name	Bit	R/W	Description	Reset
DATA_2	7:0	R/W	Data buffer byte 2	Undef.

I80LCD_DATA_3 (0xFFD5)

Name	Bit	R/W	Description	Reset
DATA_3	7:0	R/W	Data buffer byte 3	Undef.

I80LCD_DATA_4 (0xFFD6)

Name	Bit	R/W	Description	Reset
DATA_4	7:0	R/W	Data buffer byte 4	Undef.

I80LCD_DATA_5 (0xFFD7)

Name	Bit	R/W	Description	Reset
DATA_5	7:0	R/W	Data buffer byte 5	Undef.

I80LCD_CMD (0xFFD8)

Name	Bit	R/W	Description	Reset
N_TRAN	7:5	R/W	Number of I80LCD transactions. It is different depending on the data type. Index/Parameter: (transfer bytes >> I80LCD_I_P_BIT_LEN) – 1 RGB data: (transfer bytes >> I80LCD_RGB_N_PIXEL)/3 -1	Undef.
KEEP_CSN_LOW	4	R/W	I80LCD_CSN is kept low after the transaction is done when this bit is set.	Undef.
CMD_WR	3	R/W	0: read transaction, 1: write transaction	Undef.
CMD_TYPE	2:1	R/W	I80LCD transaction type. 00: Index, 01: Parameter, 10: RGB data, 11: VDMA	Undef.
I80LCD_ EN	0	R/W	I80LCD enable command. When set, it is not cleared until the I80LCD operation is done. 0: idle, 1: enable(W)/busy(R)	0

I80LCD_IE (0xFFD9)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
DONE_IE	0	R/W	I80LCD done interrupt enable 0: disable, 1: enable	0

I80LCD_ICLR (0xFFDA)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
DONE_ICLR	0	W	I80LCD done interrupt clear by writing 1	0

I80LCD_ST (0xFFDB)

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
BUSY_ST	1	R	I80LCD busy status. 0: idle, 1: busy	0
DONE_ST	0	R/W	I80LCD done status. This bit can be set by writing 1. 0: idle, 1: done(R)/set(W)	0

18 LCD DRIVER CONTROLLER

18.1 OVERVIEW

The LCD driver controller has 4-com x 32-segment drivers so that a maximum of 128 segments (panel) are controllable. Each segment is controlled by a corresponding bit in the LCD Display Memory Register.

18.2 FEATURES

The following is the distinctive features that are described in detail in this user's manual:

- LCD controller/driver
- Display Memory (0xFE30–0xFE3E) Registers contain the data to be displayed on the LCD
- 32 segment output pins (SEG0–SEG31)
- 4 common output pins (COM0–COM3)
- 4 LCD operating power supply pins (VLCD0– VLCD3)
- LCD bias by internal or external voltage dividing resistors
- Programmable bias voltage level selector
- Supports bias and duty mode for each corresponding operation
- Programmable frame clock generator

18.3 PIN DESCRIPTION

Table 18-1. LCD PIN Description

GPIO	Pin Name	Function	Type
GP6[7:4]	COM[3:0]	Appropriate voltage level for COM driver signal	O
GP7[7:0] GP5[7:4] GP0[7:0] GP5[3:0] GP4[7:0]	SEG[31:0]	Appropriate voltage level for SEG driver signal	O
GP6[3:0]	VLCD[3:0]	LCD bias circuit pin	I

NOTE: If any PINs of COM[3:0], SEG[31:0] and VLCD[3:0] are not used, Not-used PINs must be set as GPIO ports using GPn Mode Control Register (PnMODn).

18.4 BLOCK DIAGRAM

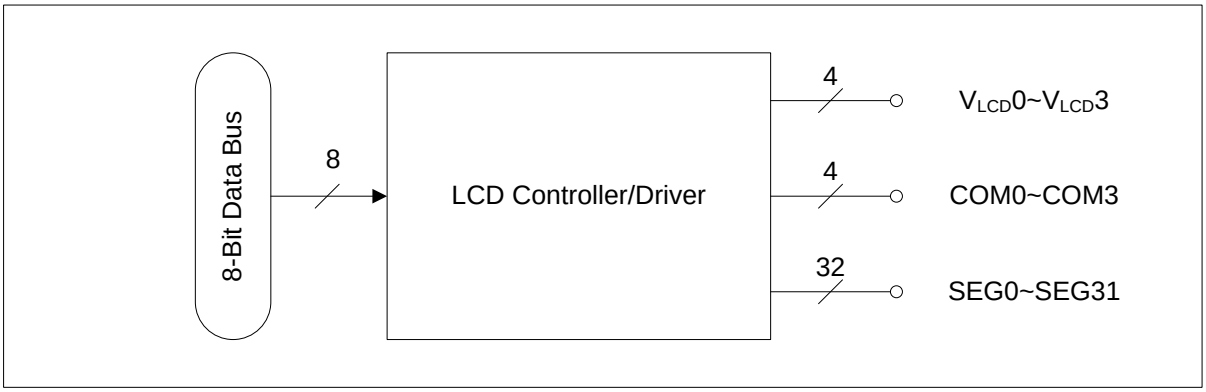


Figure 18-1. LCD Controller Top Block Diagram

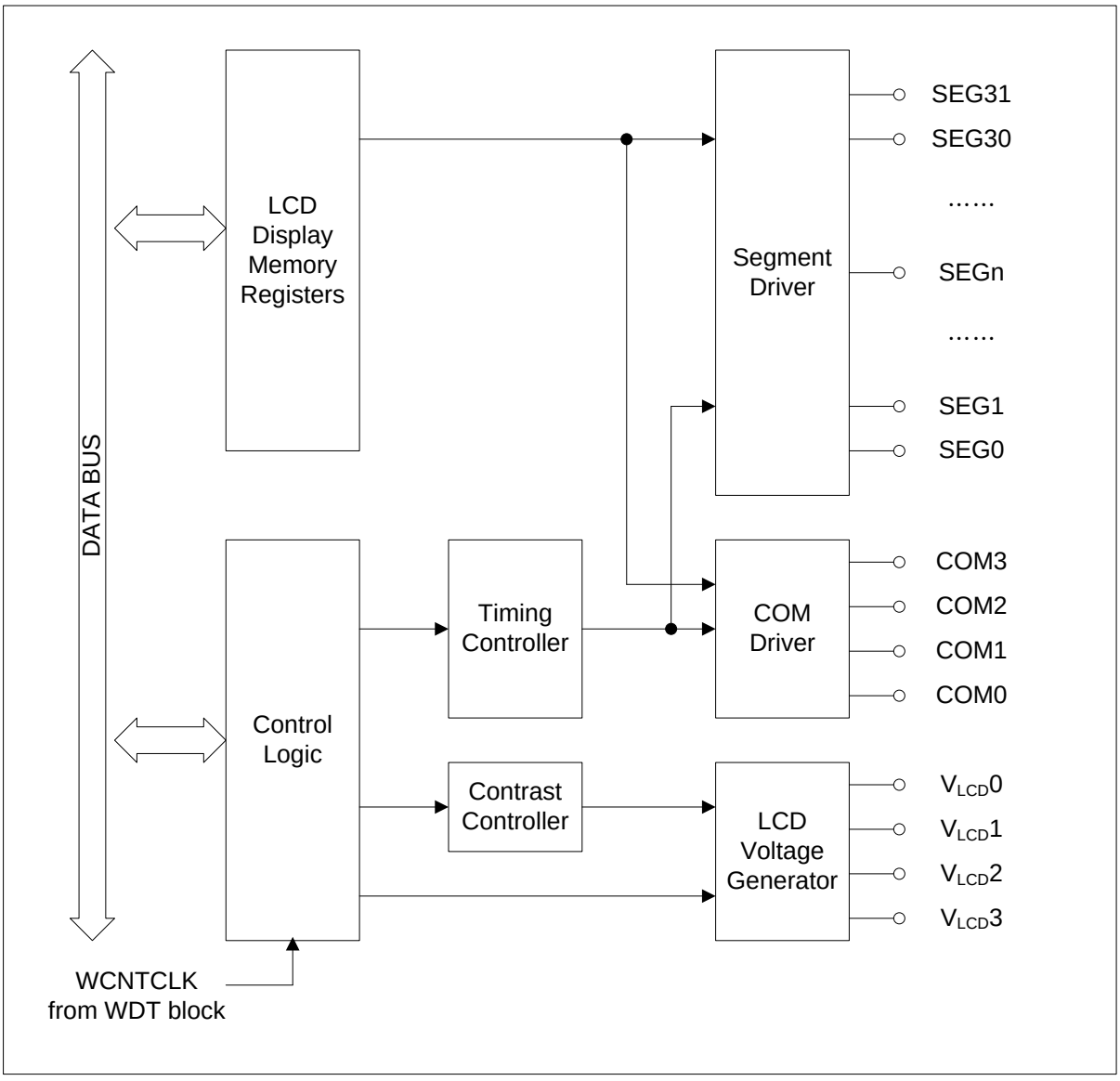


Figure 18-2. LCD Controller Block Diagram

18.5 OPERATION

Bit settings in the LCD control register (LCON) and LCKSEL, determine the LCD frame frequency (source clock from WDT block), duty and bias, and the segment pins used for display output. When a external sub-oscillator (ESCLK, WDTCON[3] = 1) is selected, the LCD display is enabled even during stop and idle mode.

The LCD control register LCON turns the LCD display on and off. LCD data stored in the display RAM locations are transferred to the segment signal pins automatically without program control.

LCD RAM ADDRESS AREA

RAM addresses FF30H – FF3FH are used as LCD data memory. When the bit value of a display segment is "1", the LCD display is turned on; when the bit value is "0", the display is turned off.

Display RAM data are sent out through segment pins SEG0–SEG31 using a direct memory access (DMA) method that is synchronized with the f_{LCD} signal. RAM addresses in this location that are not used for LCD display can be allocated to general-purpose use.

Table 18-2. 4COM x 30SEG Display Memory Organization

	7	6	5	4	3	2	1	0
	COM3	COM2	COM1	COM0	COM3	COM2	COM1	COM0
FE30H	SEG1COM3	SEG1COM2	SEG1COM1	SEG1COM0	SEG0COM3	SEG0COM2	SEG0COM1	SEG0COM0
FE31H	SEG3COM3	SEG3COM2	SEG3COM1	SEG3COM0	SEG2COM3	SEG2COM2	SEG2COM1	SEG2COM0
FE32H	SEG5COM3	SEG5COM2	SEG5COM1	SEG5COM0	SEG4COM3	SEG4COM2	SEG4COM1	SEG4COM0
FE33H	SEG7COM3	SEG7COM2	SEG7COM1	SEG7COM0	SEG6COM3	SEG6COM2	SEG6COM1	SEG6COM0
FE34H	SEG9COM3	SEG9COM2	SEG9COM1	SEG9COM0	SEG8COM3	SEG8COM2	SEG8COM1	SEG8COM0
FE35H	SEG11COM3	SEG11COM2	SEG11COM1	SEG11COM0	SEG10COM3	SEG10COM2	SEG10COM1	SEG10COM0
FE36H	SEG13COM3	SEG13COM2	SEG13COM1	SEG13COM0	SEG12COM3	SEG12COM2	SEG12COM1	SEG12COM0
FE37H	SEG15COM3	SEG15COM2	SEG15COM1	SEG15COM0	SEG14COM3	SEG14COM2	SEG14COM1	SEG14COM0
FE38H	SEG17COM3	SEG17COM2	SEG17COM1	SEG17COM0	SEG16COM3	SEG16COM2	SEG16COM1	SEG16COM0
FE39H	SEG19COM3	SEG19COM2	SEG19COM1	SEG19COM0	SEG18COM3	SEG18COM2	SEG18COM1	SEG18COM0
FE3AH	SEG21COM3	SEG21COM2	SEG21COM1	SEG21COM0	SEG20COM3	SEG20COM2	SEG20COM1	SEG20COM0
FE3BH	SEG23COM3	SEG23COM2	SEG23COM1	SEG23COM0	SEG22COM3	SEG22COM2	SEG22COM1	SEG22COM0
FE3CH	SEG25COM3	SEG25COM2	SEG25COM1	SEG25COM0	SEG24COM3	SEG24COM2	SEG24COM1	SEG24COM0
FE3DH	SEG27COM3	SEG27COM2	SEG27COM1	SEG27COM0	SEG26COM3	SEG26COM2	SEG26COM1	SEG26COM0
FE3EH	SEG29COM3	SEG29COM2	SEG29COM1	SEG29COM0	SEG28COM3	SEG28COM2	SEG28COM1	SEG28COM0
FE3FH	SEG31COM3	SEG31COM2	SEG31COM1	SEG31COM0	SEG30COM3	SEG30COM2	SEG30COM1	SEG30COM0

FRAME FREQUENCY

The LCD clock signal, LCDCK, determines the frequency of COM signal scanning of each segment output. This is also referred to as the 'frame frequency'. Since LCDCK is generated by the watchdog timer block and its frequency is selected with values of LCKSEL register.

The LCD display can continue to operate during idle and stop modes if an external sub oscillator is used as the watch timer source when it is enabled.

Table 18-3. Frame Frequency

	WDTCON[3]=0, F_{SYS} = 12 MHz	WDTCON[3]=1, PXTI = 32.768 KHz
LCKSEL	LCDCK = Frame Frequency (f_{LCD})	LCDCK = Frame Frequency (f_{LCD})
0000	12 MHz / 16 = 750 KHz	32.768 KHz / 16 = 2048 Hz
0001	12 MHz / 32 = 375 KHz	32.768 KHz / 32 = 1025 Hz
0010	12 MHz / 64 = 187.5 KHz	32.768 KHz / 64 = 512 Hz
0011	12 MHz / 128 = 93.8 KHz	32.768 KHz / 128 = 256 Hz
0100	12 MHz / 256 = 46.9 KHz	32.768 KHz / 256 = 128 Hz
0101	12 MHz / 512 = 23.4 KHz	32.768 KHz / 512 = 64 Hz
0110	12 MHz / 1024 = 11.7 KHz	32.768 KHz / 1024 = 32 Hz
0111	12 MHz / 2048 = 5.86 KHz	32.768 KHz / 2048 = 16 Hz
1000	12 MHz / 4096 = 2.93 KHz	32.768 KHz / 4096 = 8 Hz
1001	12 MHz / 8192 = 1.46 KHz	32.768 KHz / 8192 = 4 Hz
1010	12 MHz / 16384 = 732 Hz	32.768 KHz / 16384 = 2 Hz
1011	12 MHz / 32768 = 366 Hz	32.768 KHz / 32768 = 1 Hz
1100	12 MHz / 65536 = 183 Hz	Never set
1101	12 MHz / 131072 = 91.55 Hz	Never set
1110	12 MHz / 262144 = 45.78 Hz	Never set
1111	12 MHz / 524288 = 22.89 Hz	Never set

LCD VOLTAGE DRIVING METHOD

Voltage Generator or based on positive supply voltage applied V_{LCD}, it generates the voltage levels for the timing and control logic to produce the COM and SEG waveforms.

The LCD display is turned on only when the voltage difference between the common and segment signals is greater than V_{LCD}. The LCD display is turned off when the difference between the common and segment signal voltage is less than V_{LCD}. The turn-on voltage, + V_{LCD} or - VLCD, is generated only when both signals are the selected signals of the bias. Table 18-4 shows LCD drive voltages for static mode, 1/2 bias and 1/3 bias.

Table 18-4. LCD Drive voltage Values

LCD Power Supply	Static Mode	1/2 Bias	1/3 Bias
$V_{LCD}0$	V_{LCD}	V_{LCD}	V_{LCD}
$V_{LCD}1$	-	1/2 V_{LCD}	2/3 V_{LCD}
$V_{LCD}2$	-	1/2 V_{LCD}	1/3 V_{LCD}
$V_{LCD}3$	-	1/2 V_{LCD}	1/3 V_{LCD}
Vss	0V	0V	0V

NOTE: The LCD panel display may deteriorate if a DC voltage is applied that lies between the common and segment signal voltage. Therefore, always drive the LCD panel with AC voltage.

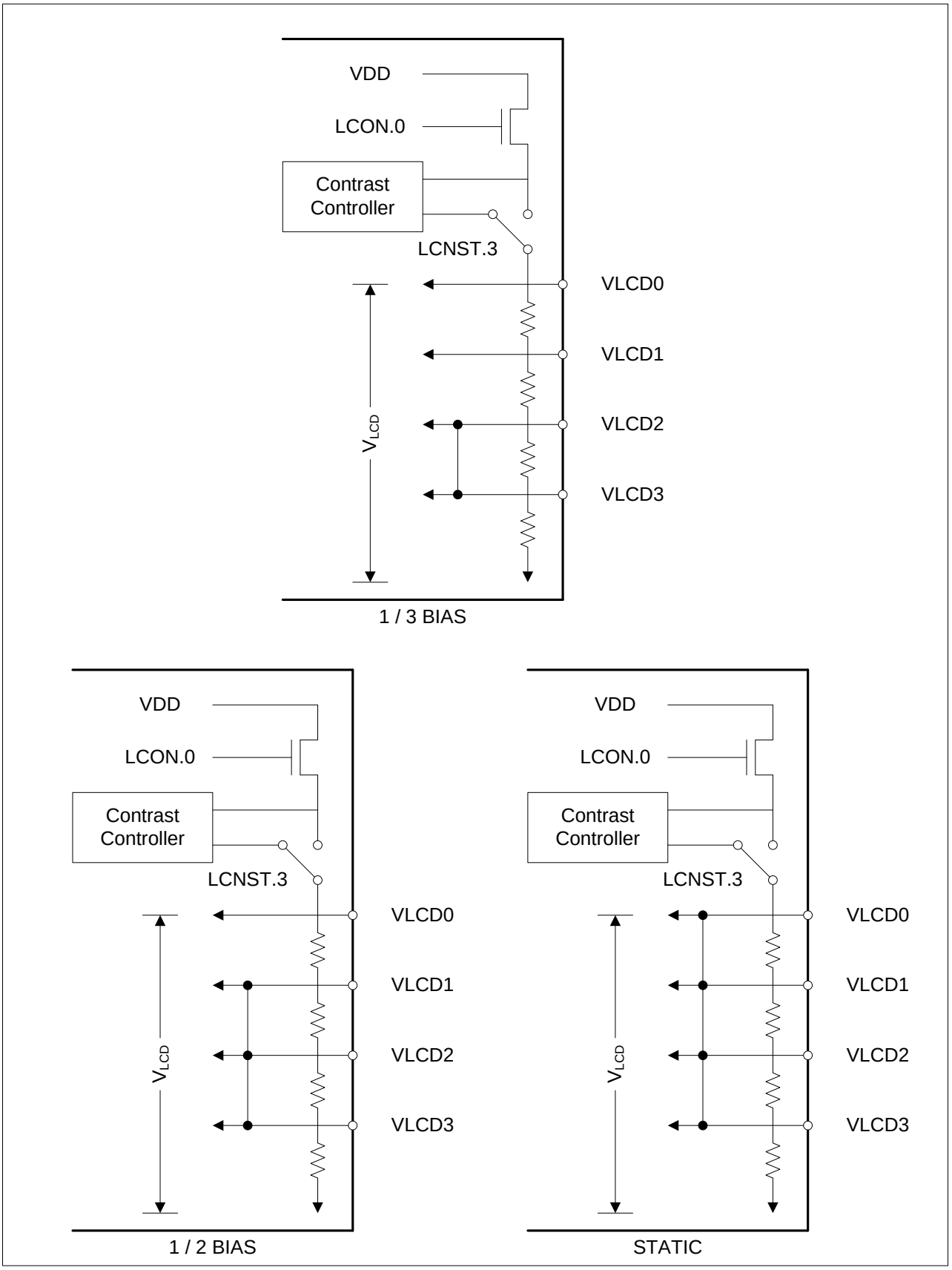


Figure 18-3. Voltage Dividing Internal Resistor Circuit Diagram

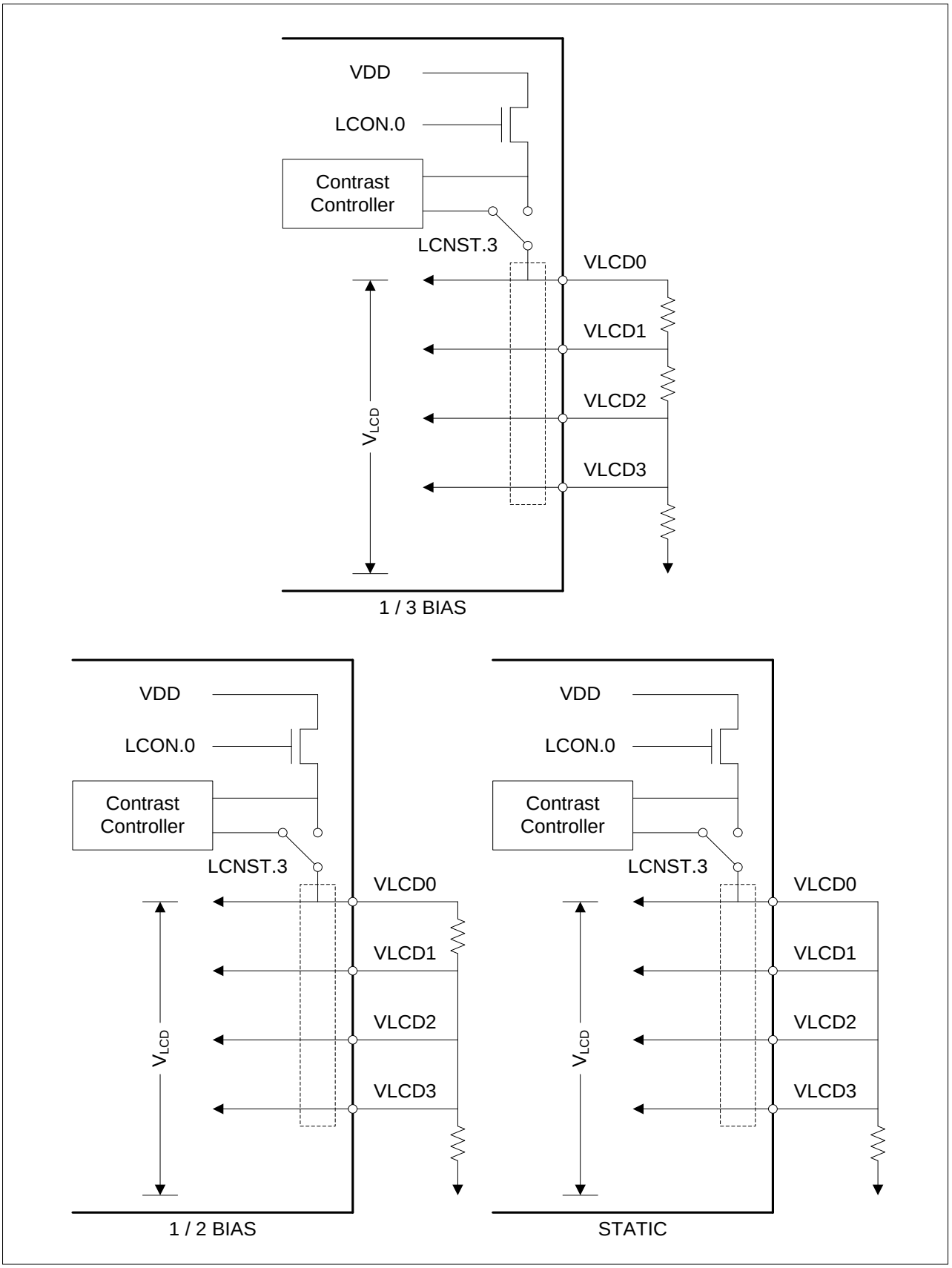


Figure 18-4. Voltage Dividing External Resistor Circuit Diagram

LCD OUTPUT SIGNAL WAVEFORM

If the LCD is supplied with DC power, the LCD element undergoes a chemical change causing a deterioration of the element. Therefore, the LCD controller has a built-in AC circuit to drive the LCD with a two-frame AC waveform. The LCD controller supports several operation modes with different numbers of COM and different biasing levels.

- 1/1 Duty (1 COM), 1/1 Bias
- 1/2 Duty (2 COM), 1/2 Bias
- 1/3 Duty (3 COM), 1/2 Bias
- 1/3 Duty (3 COM), 1/3 Bias
- 1/4 Duty (4 COM), 1/3 Bias

Static Mode

The AC timing diagram of COM/SEG signals under static mode is described as below:

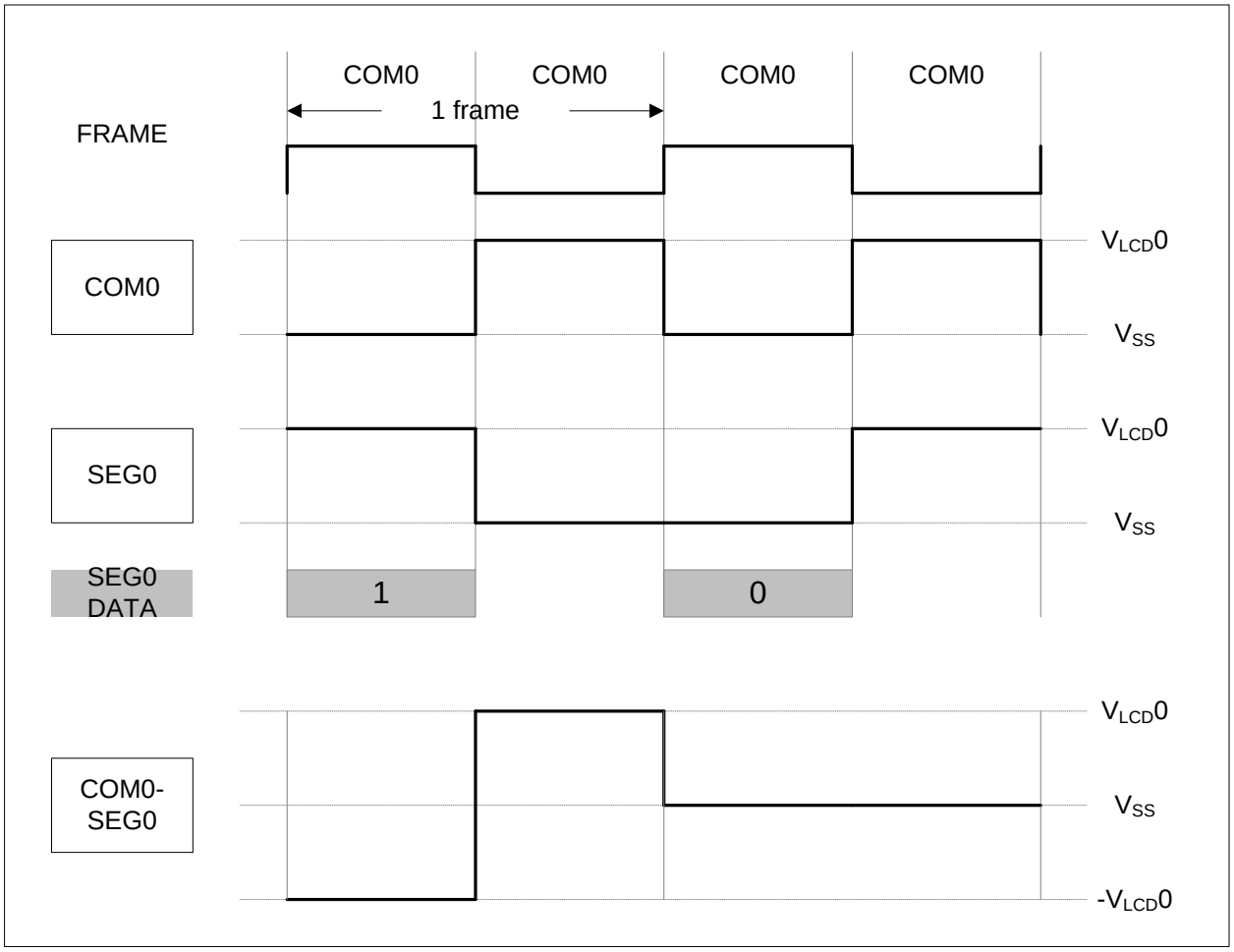


Figure 18-5. COM/SEG Signal in Static Mode

1/2 Duty, 1/2 Bias Mode

The AC timing diagram of COM/SEG signals under 1/2 duty 1/2 bias mode is described as below:

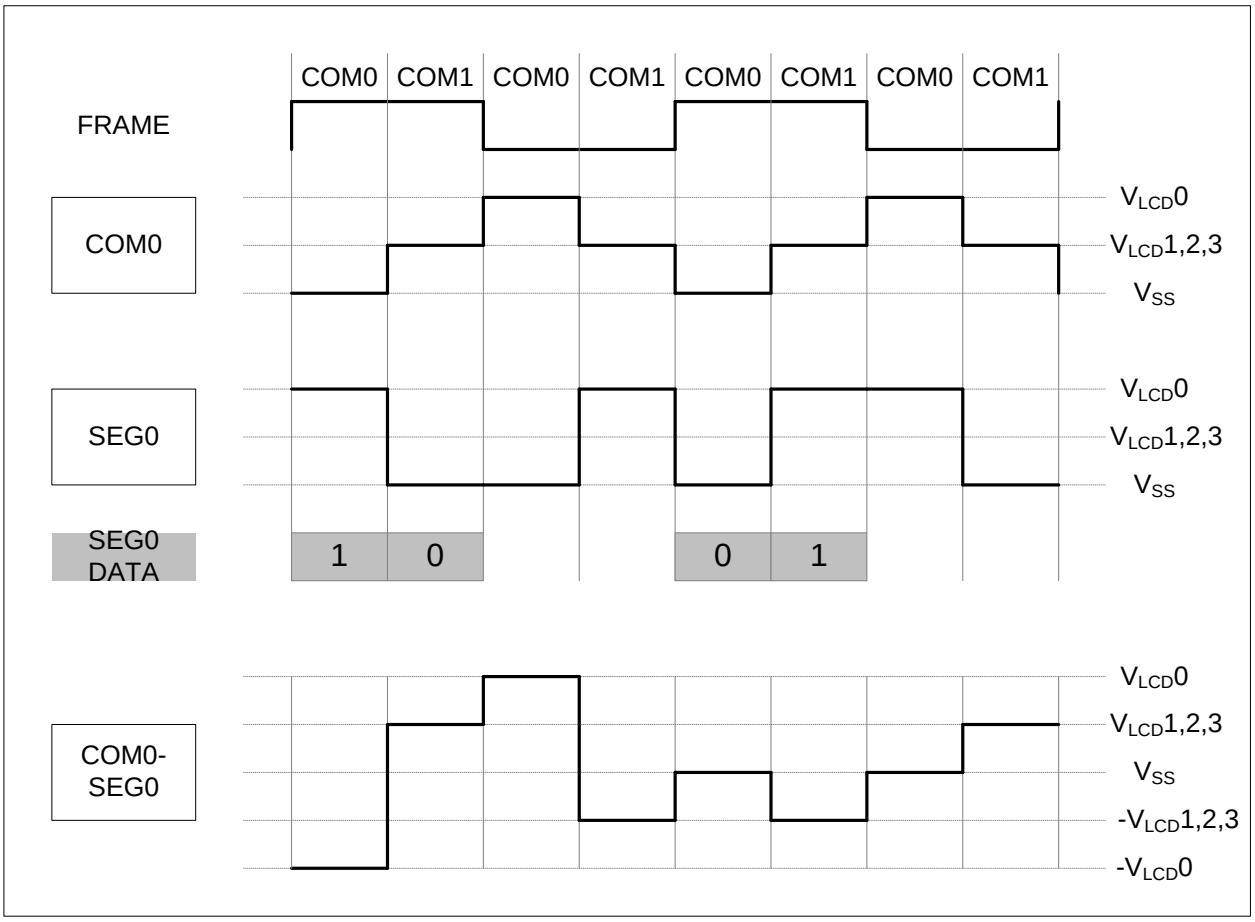


Figure 18-6. COM/SEG Signal in 1/2 Duty and 1/2 Bias Mode

1/3 Duty, 1/2 Bias Mode

The AC timing diagram of COM/SEG signals under 1/3 duty 1/2 bias mode is described as below:

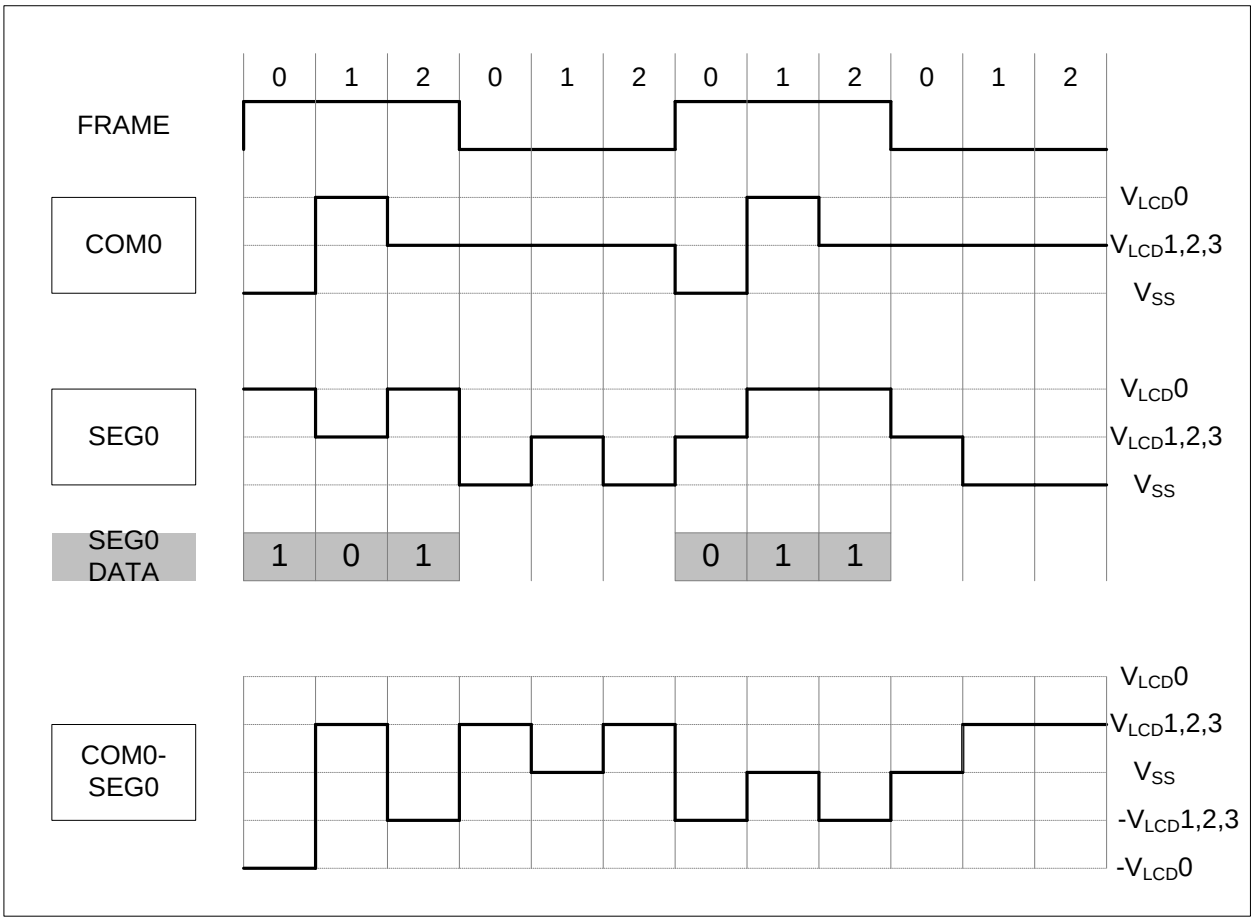


Figure 18-7. COM/SEG Signal in 1/3 Duty and 1/2 Bias Mode

1/3 Duty, 1/3 Bias Mode

The AC timing diagram of COM/SEG signals under 1/3 duty 1/3 bias mode is described as below:

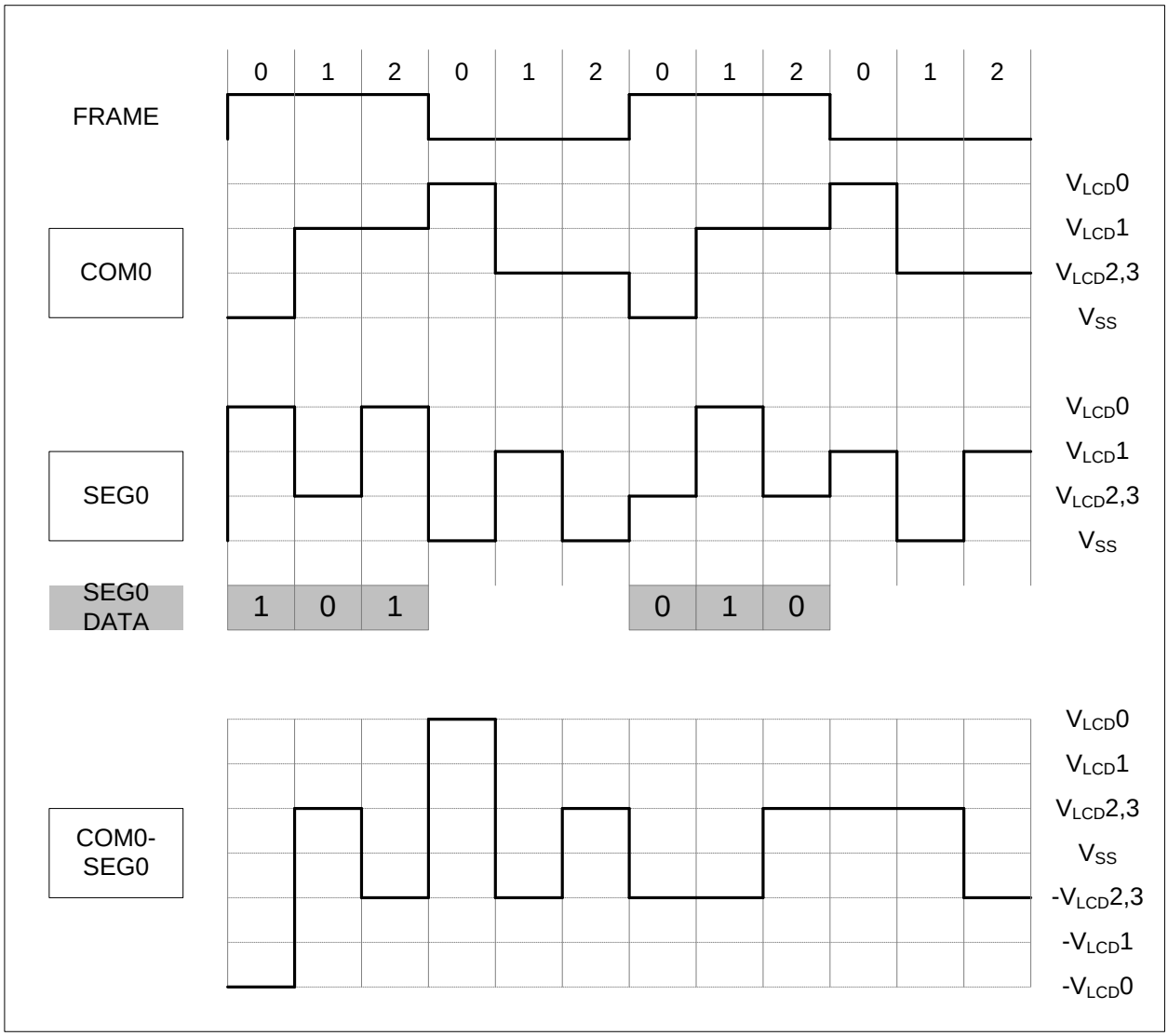


Figure 18-8. COM/SEG Signal in 1/3 Duty and 1/3 Bias Mode

1/4 Duty, 1/3 Bias Mode

The AC timing diagram of COM/SEG signals under 1/4 duty 1/3 bias mode is described as below:

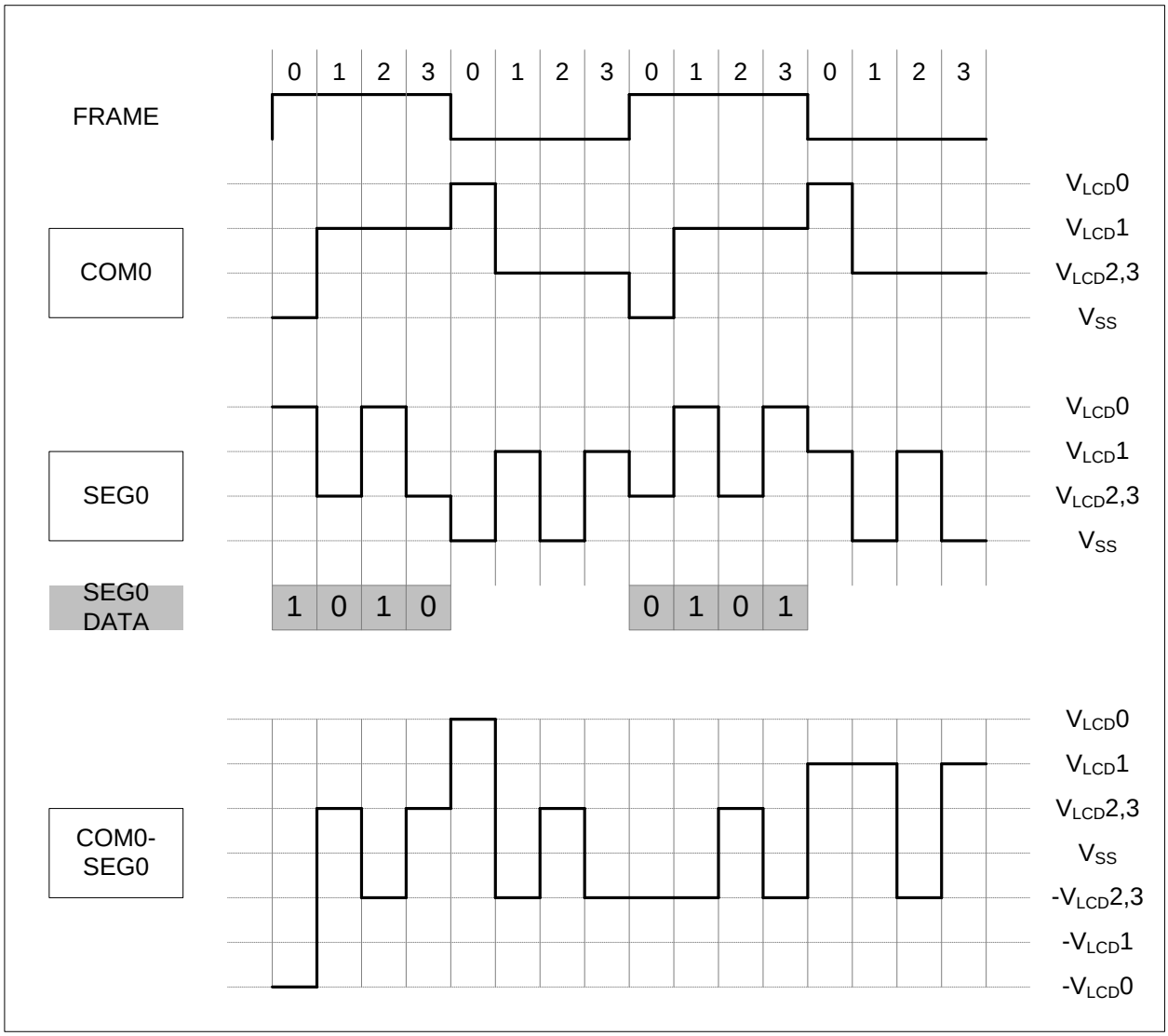


Figure 18-9. COM/SEG Signal in 1/4 Duty and 1/3 Bias Mode

18.6 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
LCON	0xFE20	R/W	LCD Control Register	0x0C
LCNST	0xFE21	R/W	LCD Contrast Control Register	0x00
LCKSEL	0xFE22	R/W	LCD Clock Select Register	0x0F
DISP_MEM0	0xFE30	R/W	Display Memory 0	Undef.
DISP_MEM1	0xFE31	R/W	Display Memory 1	Undef.
DISP_MEM2	0xFE32	R/W	Display Memory 2	Undef.
DISP_MEM3	0xFE33	R/W	Display Memory 3	Undef.
DISP_MEM4	0xFE34	R/W	Display Memory 4	Undef.
DISP_MEM5	0xFE35	R/W	Display Memory 5	Undef.
DISP_MEM6	0xFE36	R/W	Display Memory 6	Undef.
DISP_MEM7	0xFE37	R/W	Display Memory 7	Undef.
DISP_MEM8	0xFE38	R/W	Display Memory 8	Undef.
DISP_MEM9	0xFE39	R/W	Display Memory 9	Undef.
DISP_MEM10	0xFE3A	R/W	Display Memory 10	Undef.
DISP_MEM11	0xFE3B	R/W	Display Memory 11	Undef.
DISP_MEM12	0xFE3C	R/W	Display Memory 12	Undef.
DISP_MEM13	0xFE3D	R/W	Display Memory 13	Undef.
DISP_MEM14	0xFE3E	R/W	Display Memory 14	Undef.
DISP_MEM15[*1]	0xFE3F	R/W	Display Memory 15	Undef.

Note) These registers have to be accessed using **MOVX** instruction.

*1: This register is only available in 80-QFP package. User must not access this register in 68-QFN package.

LCON (0xFE20)

Name	Bit	R/W	Description	Reset
RSVD	7:5	-	Reserved	-
BIAS	4:3	R/W	0: 1/2 bias, 1: 1/3 bias	0x1
DUTY	2:1	R/W	0: 1/2 duty, 1: 1/3 duty, 2: 1/4 duty	0x2
DISP_EN	0	R/W	Display Enable 0 : Disable, 1 : Enable	0x0

LCNST (0xFE21)

Name	Bit	R/W	Description	Reset
CNST_LEVEL	7:4	R/W	Contrast Level 0: 1/16 step (dimmest level) 1: 2/16 step … 14: 15/16 step 15: 16/16 step (brightest level)	0x0
CNST_EN	3	R/W	LCD Contrast Enable Bit	0
DIM_EN	2	R/W	Normal/Diminish LCD dividing resistor 0 : Normal, 1 : Diminish resistor enable	0
RSVD	1:0	R	RSVD	0

LCKSEL (0xFE22)

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
CKSEL	3:0	R/W	FRAME Clock Select Refer to FRAME FREQUENCY description.	0x0F

NOTES:

19 GPIO

19.1 OVERVIEW

The BMC513 has 61(80QFP)/51(68QFN) programmable I/O ports. I/O port mode registers select either function's port or GPIO.

This section also describes how to change the functionality of multiplexed pins. These pins can function at the system level as a GPIO signal, or they can be assigned a signal function dedicated to an integrated peripheral device. Each GPIO can be configured as either an input or an output. The GPIO ports also can be connected to the internal interrupt controller to generate an interrupt from input signals.

19.2 FEATURES

- PORT 0 (GP0): 8-bit Input / Output Port
- PORT 1 (GP1): 7(5)-bit Input / Output Port
- PORT 3 (GP3): 8-bit Input / Output Port
- PORT 4 (GP4): 8-bit Input / Output Port
- PORT 5 (GP5): 8-bit Input / Output Port
- PORT 6 (GP6): 8-bit Input / Output Port
- PORT 7 (GP7): 8(6)-bit Input / Output Port
- PORT 8 (GP8): 6-bit input / Output Port

19.3 BLOCK DIAGRAM

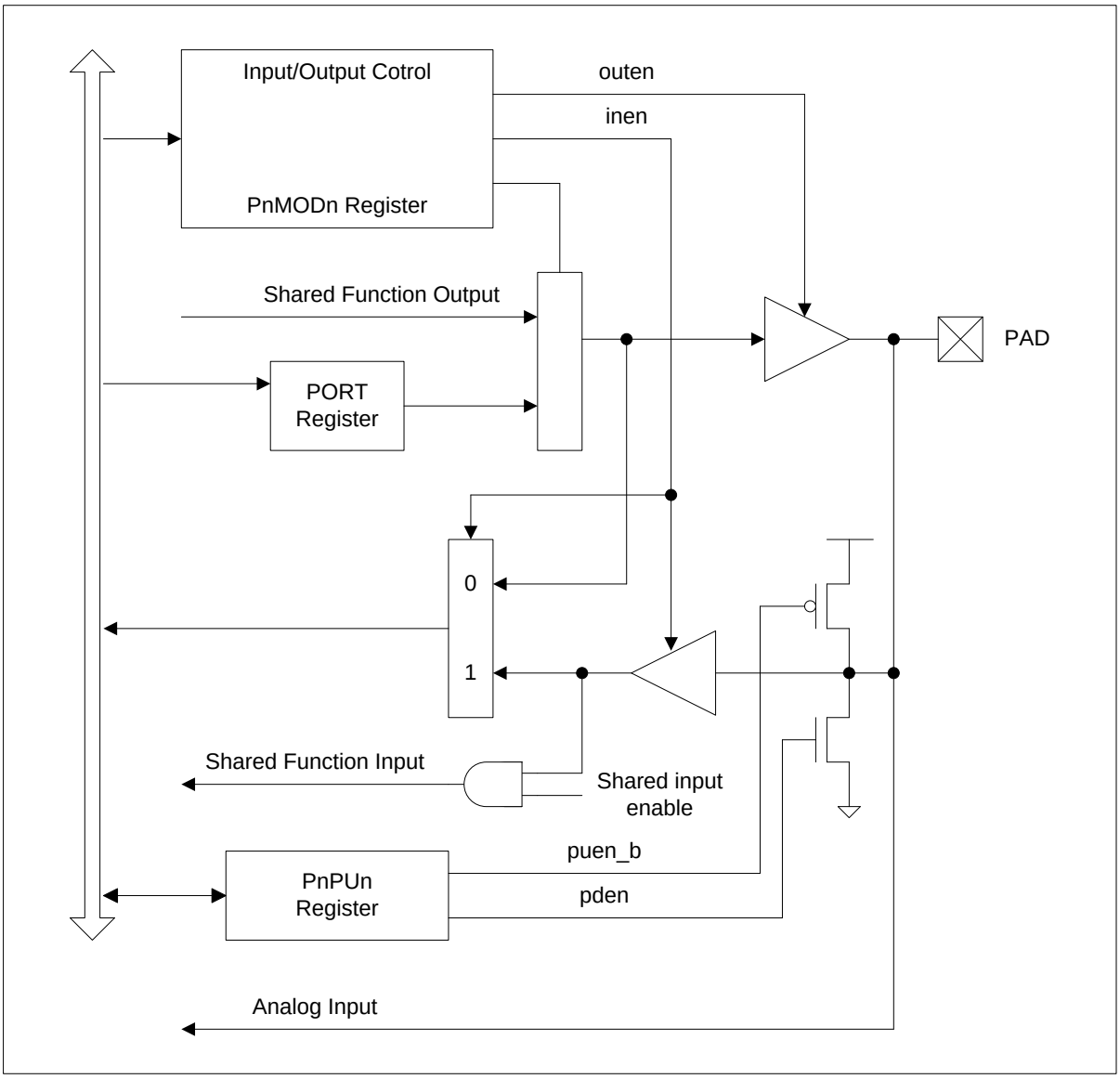


Figure 19-1. GPIO Block Diagram

19.4 PORT CONFIGURATION

B: Bidirectional, I: Input, O: Output

Table 19-1. GPIO 0 Configuration

PORT 0	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP07	GP07-Input	GP07-Output	SEG19 (O)	T2CAP (I) / T2OUT (O)
GP06	GP06-Input	GP06-Output	SEG18 (O)	T1CAP (I) / T1OUT (O)
GP05	GP05-Input	GP05-Output	SEG17 (O)	T0CAP (I) / T0OUT (O)
GP04	GP04-Input	GP04-Output	SEG16 (O)	TCLK (I)
GP03	GP03-Input	GP03-Output	SEG15 (O)	I80D17 (B)
GP02	GP02-Input	GP02-Output	SEG14 (O)	I80D16 (B)
GP01	GP01-Input	GP01-Output	SEG13 (O)	I80D15 (B)
GP00	GP00-Input	GP00-Output	SEG12 (O)	I80D14 (B)

Table 19-2. GPIO 1 Configuration

PORT 1	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP16[*1]	GP16-Input	GP16-Output	-	UTXD (O)
GP15[*1]	GP15-Input	GP15-Output	-	URXD(I)
GP14	GP14-Input	GP14-Output	CLKOUT (O)	EINT5 (I)
GP13	GP13-Input	GP13-Output	AIN0 (I)	TCLK (I)
GP12	GP12-Input	GP12-Output	AIN1 (I)	T0CAP (I) / T0OUT (O)
GP11	GP11-Input	GP11-Output	AIN2 (I)	T1CAP (I) / T1OUT (O)
GP10	GP10-Input	GP10-Output	AIN3 (I)	T2CAP (I) / T2OUT (O)

*1: These are only available in 80-QFP.

Table 19-3. GPIO 3 Configuration

PORT 3	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP37	GP37-Input	GP37-Output	BSCSN (O)	EINT9 (I)
GP36	GP36-Input	GP36-Output	BMOSI (O)	EINT8 (I)
GP35	GP35-Input	GP35-Output	BMISO (I)	EINT7 (I)
GP34	GP34-Input	GP34-Output	BSCLK (O)	EINT6 (I)
GP33	GP33-Input	GP33-Output	-	-
GP32	GP32-Input	GP32-Output	-	-
GP31	GP31-Input	GP31-Output	-	-
GP30	GP30-Input	GP30-Output	-	-

Table 19-4. GPIO 4 Configuration

PORT 4	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP47	GP47-Input	GP47-Output	SEG7 (O)	I80D9 (B)
GP46	GP46-Input	GP46-Output	SEG6 (O)	I80D8 (B)
GP45	GP45-Input	GP45-Output	SEG5 (O)	I80D7 (B)
GP44	GP44-Input	GP44-Output	SEG4 (O)	I80D6 (B)
GP43	GP43-Input	GP43-Output	SEG3 (O)	I80D5 (B)
GP42	GP42-Input	GP42-Output	SEG2 (O)	I80D4 (B)
GP41	GP41-Input	GP41-Output	SEG1 (O)	I80D3 (B)
GP40	GP40-Input	GP40-Output	SEG0 (O)	I80D2 (B)

Table 19-5. GPIO 5 Configuration

PORT 5	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP57	GP57-Input	GP57-Output	SEG23 (O)	SCSN (B)
GP56	GP56-Input	GP56-Output	SEG22 (O)	SMOSI (B)
GP55	GP55-Input	GP55-Output	SEG21 (O)	SMISO (B)
GP54	GP54-Input	GP54-Output	SEG20 (O)	SCLK (B)
GP53	GP53-Input	GP53-Output	SEG11 (O)	I80D13 (B)
GP52	GP52-Input	GP52-Output	SEG10 (O)	I80D12 (B)
GP51	GP51-Input	GP51-Output	SEG9 (O)	I80D11 (B)
GP50	GP50-Input	GP50-Output	SEG8 (O)	I80D10 (B)

Table 19-6. GPIO 6 Configuration

PORT 6	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP67	GP67-Input	GP67-Output	COM3 (O)	I80D1 (B)
GP66	GP66-Input	GP66-Output	COM2 (O)	I80D0 (B)
GP65	GP65-Input	GP65-Output	COM1 (O)	I80RS (O)
GP64	GP64-Input	GP64-Output	COM0 (O)	I80CSN (O)
GP63	GP63-Input	GP63-Output	VLC3 (O)	I80WRN (O)
GP62	GP62-Input	GP62-Output	VLC2 (O)	I80RDN (O)
GP61	GP61-Input	GP61-Output	VLC1 (O)	
GP60	GP60-Input	GP60-Output	VLC0 (O)	nRSTOUT(O)(Default)

Table 19-7. GPIO 7 Configuration

PORT 7	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP77[*1]	GP77-Input	GP77-Output	SEG31 (O)	-
GP76[*1]	GP76-Input	GP76-Output	SEG30 (O)	-
GP75	GP75-Input	GP75-Output	SEG29 (O)	UTXD (O)
GP74	GP74-Input	GP74-Output	SEG28 (O)	URXD (I)
GP73	GP73-Input	GP73-Output	SEG27 (O)	UCLK (I)
GP72	GP72-Input	GP72-Output	SEG26 (O)	EINT2 (I)
GP71	GP71-Input	GP71-Output	SEG25 (O)	EINT1 (I)
GP70	GP70-Input	GP70-Output	SEG24 (O)	EINT0 (I)

*1: These are only available in 80-QFP.

Table 19-8. GPIO 8 Configuration

PORT 8	Selectable Functions (Shared Function)			
	00 (Default)	01	10	11
GP87	GP87-Input	GP87-Output	-	SCSN (B)
GP86	GP86-Input	GP86-Output	-	SMOSI (B)
GP85	GP85-Input	GP85-Output	-	SMISO (B)
GP84	GP84-Input	GP84-Output	-	SCLK (B)
GP83	GP83-Input	GP83-Output	AIN4 (I)	EINT4 (I)
GP82	GP82-Input	GP82-Output	AIN5 (I)	EINT3 (I)

GP8 is only available in 80-QFP.

19.5 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
P0	0x80	R/W	General Purpose I/O 0	0x00
P1	0x90	R/W	General Purpose I/O 1	0x00
P2	0xA0	R/W	Reserved for standard 8051.	0x00
P3	0xB0	R/W	General Purpose I/O 3	0x00
P4	0xC0	R/W	General Purpose I/O 4	0x00
P5	0x88	R/W	General Purpose I/O 5	0x00
P6	0x98	R/W	General Purpose I/O 6	0x00
P7	0xB8	R/W	General Purpose I/O 7	0x00
P8	0xE8	R/W	General Purpose I/O 8. User can't access this register in 68-QFN, if access, it might cause unexpected operation.	0x00
JTAGOFF	0xFE40	R/W	JTAG port control Register	0x00
EINTMOD0	0xFE41	R/W	External Interrupt Control Register 0 (for 0/1)	0x00
EINTMOD1	0xFE42	R/W	External Interrupt Control Register 1 (for 2/5)	0x00
EINTMOD2	0xFE43	R/W	External Interrupt Control Register 2 (for 6/7)	0x00
EINTMOD3	0xFE44	R/W	External Interrupt Control Register 3 (for 8/9)	0x00
EINTEN0	0xFE45	R/W	External Interrupt Enable Register 0	0x00
EINTEN1	0xFE46	R/W	External Interrupt Enable Register 1	0x00
EINTPND0	0xFE47	R/W	External Interrupt Pending Register 0	0x00
EINTPND1	0xFE48	R/W	External Interrupt Pending Register 1	0x00
P0MOD0	0xFE49	R/W	GP00 ~ GP03 Mode Control Register 0	0x00
P0MOD1	0xFE4A	R/W	GP04 ~ GP07 Mode Control Register 1	0x00
P0PUR	0xFE4B	R/W	PORT 0 Pull-Up Control Register	0x00
P1MOD0	0xFE4C	R/W	GP10 ~ GP13 Mode Control Register 0	0x00
P1MOD1	0xFE4D	R/W	GP14 ~ GP16 Mode Control Register 1	0x00
P1PUD0	0xFE4E	R/W	PORT 1 Pull-Up/Down Control Register 0	0x00
P1PUD1	0xFE4F	R/W	PORT 1 Pull-Up/Down Control Register 1	0x28
P3MOD0	0xFE50	R/W	GP30 ~ GP33 Mode Control Register 0	0x00
P3MOD1	0xFE51	R/W	GP34 ~ GP37 Mode Control Register 1	0x00
P3PUD0	0xFE52	R/W	PORT 3 Pull-Up/Down Control Register 0	0x0A
P3PUD1	0xFE53	R/W	PORT 3 Pull-Up/Down Control Register 1	0x02
P4MOD0	0xFE54	R/W	GP40 ~ GP43 Mode Control Register 0	0x00
P4MOD1	0xFE55	R/W	GP44 ~ GP47 Mode Control Register 1	0x00
P4PUR	0xFE56	R/W	PORT 4 Pull-Up Control Register 0	0x00
P5MOD0	0xFE57	R/W	GP50 ~ GP53 Mode Control Register 0	0x00
P5MOD1	0xFE58	R/W	GP54 ~ GP57 Mode Control Register 1	0x00
P5PUR	0xFE59	R/W	PORT 5 Pull-Up Control Register 0	0x00
P6MOD0	0xFE5A	R/W	GP60 ~ GP63 Mode Control Register 0	0x03
P6MOD1	0xFE5B	R/W	GP64 ~ GP67 Mode Control Register 1	0x00
P6PUR	0xFE5C	R/W	PORT 6 Pull-Up Control Register 0	0x00
P7MOD0	0xFE5D	R/W	GP70 ~ GP73 Mode Control Register 0	0x00
P7MOD1	0xFE5E	R/W	GP74 ~ GP77 Mode Control Register 1	0x00
P7PUR	0xFE5F	R/W	PORT 7 Pull-Up Control Register 0	0xC0
P8MOD0	0xFE60	R/W	GP82 ~ GP83 Mode Control Register 0	0x00
P8MOD1	0xFE60	R/W	GP84 ~ GP87 Mode Control Register 1	0x00
P8PUD0	0xFE60	R/W	PORT 8 Pull-Up/Down Control Register 0	0xA0
P8PUD1	0xFE60	R/W	PORT 8 Pull-Up/Down Control Register 1	0xAA

Note) These registers except P0 ~ P7 registers have to be accessed using **MOVX** instruction.
User can't access P8xxx registers in 68-QFN, If access, it might cause unexpected operation.

In the BMC513, most of the pins are multiplexed pins. So, it is determined, by PnMODn register, which function is selected for each pin. If ports are configured as output ports, data can be written to the corresponding bit of Pn. Or if configured as input ports, the data can be read from the corresponding bit of Pn.

When PnPUDn are configured as pull-up or pull-down, it will be enabled 1us later.

P0 (0x80)

Name	Bit	R/W	Description	Reset
P0	7:0	R/W	General Purpose I/O 0 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

P1 (0x90)

Name	Bit	R/W	Description	Reset
P1	6:0	R/W	General Purpose I/O 1 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

[6:5] fields are only available in 80-QFP.

P3 (0xB0)

Name	Bit	R/W	Description	Reset
P3	7:0	R/W	General Purpose I/O 3 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

P4 (0xC0)

Name	Bit	R/W	Description	Reset
P4	7:0	R/W	General Purpose I/O 4 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

P5 (0x88)

Name	Bit	R/W	Description	Reset
P5	7:0	R/W	General Purpose I/O 5 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

P6 (0x98)

Name	Bit	R/W	Description	Reset
P6	7:0	R/W	General Purpose I/O 6 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

P7 (0xB8)

Name	Bit	R/W	Description	Reset
P7	7:0	R/W	General Purpose I/O 7 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

[7:6] fields are only available in 80-QFP.

P8 (0xE8)

Name	Bit	R/W	Description	Reset
P8	7:2	R/W	General Purpose I/O 8 Each of these pins can be used as either any data transfer purpose or specific alternative function defined by user	0x00

This register is only available in 80-QFP.

JTAGOFF (0xFE40)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
JTAGOFF	0	R/W	If this bit is 0, GP30, GP31, GP32 and GP33 are activated as JTAG PORT independent of P3MOD0 Value. 0: Enable JTAG Port, 1: Disable JTAG Port	0

EINTMOD0 (0xFE41)

External interrupt mode register 0. When is set as interrupt pin, its input go through noise filter by using EINTxCON bit and generates interrupt. If it is set as normal general I/O port, noise filter does not affect data flow.

Name	Bit	R/W	Description	Reset
RSVD	7	R/W	Reserved	-
EINT1CON	6:4	R/W	External interrupt request input for GP71 [6] – 0: filtering off, 1: filtering on [5:4] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0
RSVD	3	R/W	Reserved	-
EINT0CON	2:0	R/W	External interrupt request input for GP70 [2] – 0: filtering off, 1: filtering on [1:0] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0

EINTMOD1 (0xFE42)

Name	Bit	R/W	Description	Reset
RSVD	7	R/W	Reserved	-
EINT4_5CON	6:4	R/W	External interrupt request input for GP83 and GP14 [6] – 0: filtering off, 1: filtering on [5:4] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0
RSVD	3	R/W	Reserved	-
EINT2_3CON	2:0	R/W	External interrupt request input for GP72 and GP82 [2] – 0: filtering off, 1: filtering on [1:0] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0

EINTMOD2 (0xFE43)

Name	Bit	R/W	Description	Reset
RSVD	7	R/W	Reserved	-
EINT7CON	6:4	R/W	External interrupt request input for GP35 [6] – 0: filtering off, 1: filtering on [5:4] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0
RSVD	3	R/W	Reserved	-
EINT6CON	2:0	R/W	External interrupt request input for GP34 [2] – 0: filtering off, 1: filtering on [1:0] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0

EINTMOD3 (0xFE44)

Name	Bit	R/W	Description	Reset
RSVD	7	R/W	Reserved	-
EINT9CON	6:4	R/W	External interrupt request input for GP37 [6] – 0: filtering off, 1: filtering on [5:4] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0
RSVD	3	R/W	Reserved	-
EINT8CON	2:0	R/W	External interrupt request input for GP36 [2] – 0: filtering off, 1: filtering on [1:0] – 00: Reserved(never used), 01: rising edge detection 10: falling edge detection, 11: both edge detection	0x0

EINTEN0 (0xFE45)

Name	Bit	R/W	Description	Reset
EINT7EN	7	R/W	Enable external Interrupt 7 0: Disable, 1: Enable	0
EINT6EN	6	R/W	Enable external Interrupt 6 0: Disable, 1: Enable	0
EINT5EN	5	R/W	Enable external Interrupt 5 0: Disable, 1: Enable	0
RSVD	4	-	User can't access this register, if access, it might cause unexpected operation.	-
RSVD	3	-	User can't access this register, if access, it might cause unexpected operation.	-
EINT2EN	2	R/W	Enable external Interrupt 2 0: Disable, 1: Enable	0
EINT1EN	1	R/W	Enable external Interrupt 1 0: Disable, 1: Enable	0
EINT0EN	0	R/W	Enable external Interrupt 0 0: Disable, 1: Enable	0
NOTE: Must clear each pending bit before setting this register.				

EINTEN1 (0xFE46)

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
EINT9EN	1	R/W	Enable external Interrupt 9 0: Disable, 1: Enable	0
EINT8EN	0	R/W	Enable external Interrupt 8 0: Disable, 1: Enable	0
NOTE: Must clear each pending bit before setting this register.				

EINTPND0 (0xFE47)

This bit is cleared by writing "1" to each bit.

Name	Bit	R/W	Description	Reset
EINT7PND	7	R/W	Enable external Interrupt 7 Pending	0
EINT6PND	6	R/W	Enable external Interrupt 6 Pending	0
EINT5PND	5	R/W	Enable external Interrupt 5 Pending	0
RSVD	4	-	Reserved	-
RSVD	3	-	Reserved	-
EINT2PND	2	R/W	Enable external Interrupt 2 Pending	0
EINT1PND	1	R/W	Enable external Interrupt 1 Pending	0
EINT0PND	0	R/W	Enable external Interrupt 0 Pending	0

EINTPND1 (0xFE48)

This bit is cleared by writing “1” to each bit.

Name	Bit	R/W	Description	Reset
RSVD	7:2	-	Reserved	-
EINT9PND	1	R/W	Enable external Interrupt 9 Pending	0
EINT8PND	0	R/W	Enable external Interrupt 8 Pending	0

P0MOD0 (0xFE49)

Name	Bit	R/W	Description		Reset
GP03MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG15 (O)	11: I80D17 (B)	
GP02MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG14 (O)	11: I80D16 (B)	
GP01MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG13 (O)	11: I80D15 (B)	
GP00MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG12 (O)	11: I80D14 (B)	

P0MOD1 (0xFE4A)

Name	Bit	R/W	Description		Reset
GP07MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG19 (O)	11: T2CAP (I) / T2OUT (O)	
GP06MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG18 (O)	11: T1CAP (I) / T1OUT (O)	
GP05MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG17 (O)	11: T0CAP (I) / T0OUT (O)	
GP04MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG16 (O)	11: TCLK (I)	

P0PUR (0xFE4B)

Name	Bit	R/W	Description	Reset
GP07PU	7	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP06PU	6	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP05PU	5	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP04PU	4	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP03PU	3	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP02PU	2	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP01PU	1	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP00PU	0	R/W	0: Pull-up Disable, 1: Pull-up Enable	0

P1MOD0 (0xFE4C)

Name	Bit	R/W	Description		Reset
GP13MOD	7:6	R/W	00: Input	01: Output	00
			10: AIN0 (I)	11: TCLK (I)	
GP12MOD	5:4	R/W	00: Input	01: Output	00
			10: AIN1 (I)	11: T0CAP (I) / T0OUT (O)	
GP11MOD	3:2	R/W	00: Input	01: Output	00
			10: AIN2 (I)	11: T1CAP (I) / T1OUT (O)	
GP10MOD	1:0	R/W	00: Input	01: Output	00
			10: AIN3 (I)	11: T2CAP (I) / T2OUT (O)	

P1MOD1 (0xFE4D)

User must not access GP16MOD and GP15MOD fields in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description		Reset
RSVD	7:6	-	Reserved		-
GP16MOD	5:4	R/W	00: Input	01: Output	00
			10: Reserved	11: UTXD (O)	
GP15MOD	3:2	R/W	00: Input	01: Output	00
			10: Reserved	11: URXD (I)	
GP14MOD	1:0	R/W	00: Input	01: Output	00
			10: CLKOUT (O)	11: EINT5 (I)	

P1PUD0 (0xFE4E)

Name	Bit	R/W	Description		Reset
GP13PUD	7:6	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP12PUD	5:4	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP11PUD	3:2	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP10PUD	1:0	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	

P1PUD1 (0xFE4F)

User must not access GP16PUD and GP15PUD fields in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description		Reset
RSVD	7:6	-	Reserved		-
GP16PUD	5:4	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
GP15PUD	3:2	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
GP14PUD	1:0	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	

P3MOD0 (0xFE50)

Name	Bit	R/W	Description		Reset
GP33MOD	7:6	R/W	00: Input	01: Output	00
			10: Reserved	11: Reserved	
GP32MOD	5:4	R/W	00: Input	01: Output	00
			10: Reserved	11: Reserved	
GP31MOD	3:2	R/W	00: Input	01: Output	00
			10: Reserved	11: Reserved	
GP30MOD	1:0	R/W	00: Input	01: Output	00
			10: Reserved	11: Reserved	

Notice) When reset, PGP3[0](TCK), PGP3[1](TMS), PGP3[2](TDI) is used as JTAG input pins and PGP3[3] is used as JTAG output pin. P3MOD0 register is effective only when JTAGOFF register is 1.

P3MOD1 (0xFE51)

Name	Bit	R/W	Description		Reset
GP37MOD	7:6	R/W	00: Input	01: Output	00
			10: BSCSN (O)	11: EINT9 (I)	
GP36MOD	5:4	R/W	00: Input	01: Output	00
			10: BMOSI (B)	11: EINT8 (I)	
GP35MOD	3:2	R/W	00: Input	01: Output	00
			10: BMISO (B)	11: EINT7 (I)	
GP34MOD	1:0	R/W	00: Input	01: Output	00
			10: BSCLK (O)	11: EINT6 (I)	

P3PUD0 (0xFE52)

Name	Bit	R/W	Description		Reset
GP33PUD	7:6	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP32PUD	5:4	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP31PUD	3:2	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
GP30PUD	1:0	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	

P3PUD1 (0xFE53)

Name	Bit	R/W	Description		Reset
GP37PUD	7:6	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP36PUD	5:4	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP35PUD	3:2	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	00
			10: Pull-up enabled	11: Don't use (Never set)	
GP34PUD	1:0	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	

P4MOD0 (0xFE54)

Name	Bit	R/W	Description		Reset
GP43MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG3 (O)	11: I80D5 (B)	
GP42MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG2 (O)	11: I80D4 (B)	
GP41MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG1 (O)	11: I80D2 (B)	
GP40MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG0 (O)	11: I80D2 (B)	

P4MOD1 (0xFE55)

Name	Bit	R/W	Description		Reset
GP47MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG7 (O)	11: I80D9 (B)	
GP46MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG6 (O)	11: I80D8 (B)	
GP45MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG5 (O)	11: I80D7 (B)	
GP44MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG4 (O)	11: I80D6 (B)	

P4PUR (0xFE56)

Name	Bit	R/W	Description	Reset
GP47PU	7	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP46PU	6	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP45PU	5	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP44PU	4	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP43PU	3	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP42PU	2	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP41PU	1	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP40PU	0	R/W	0: Pull-up Disable, 1: Pull-up Enable	0

P5MOD0 (0xFE57)

Name	Bit	R/W	Description		Reset
GP53MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG11 (O)	11: I80D13 (B)	
GP52MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG10 (O)	11: I80D12 (B)	
GP51MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG9 (O)	11: I80D11 (B)	
GP50MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG8 (O)	11: I80D10 (B)	

P5MOD1 (0xFE58)

Name	Bit	R/W	Description		Reset
GP57MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG23 (O)	11: SCSN (B)	
GP56MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG22 (O)	11: SMOSI (B)	
GP55MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG21 (O)	11: SMISO (B)	
GP54MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG20 (O)	11: SCLK (B)	

P5PUR (0xFE59)

Name	Bit	R/W	Description	Reset
GP57PU	7	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP56PU	6	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP55PU	5	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP54PU	4	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP53PU	3	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP52PU	2	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP51PU	1	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP50PU	0	R/W	0: Pull-up Disable, 1: Pull-up Enable	0

P6MOD0 (0xFE5A)

Name	Bit	R/W	Description		Reset
GP63MOD	7:6	R/W	00: Input	01: Output	00
			10: VLC3 (O)	11: I80WRN (O)	
GP62MOD	5:4	R/W	00: Input	01: Output	00
			10: VLC2 (O)	11: I80RDN (O)	
GP61MOD	3:2	R/W	00: Input	01: Output	00
			10: VLC1 (O)	11: Reserved	
GP60MOD	1:0	R/W	00: Input	01: Output	11
			10: VLC0 (O)	11: nRSTOUT(O)	

P6MOD1 (0xFE5B)

Name	Bit	R/W	Description		Reset
GP67MOD	7:6	R/W	00: Input	01: Output	00
			10: COM3 (O)	11: I80D1 (B)	
GP66MOD	5:4	R/W	00: Input	01: Output	00
			10: COM2 (O)	11: I80D0 (B)	
GP65MOD	3:2	R/W	00: Input	01: Output	00
			10: COM1 (O)	11: I80RS (O)	
GP64MOD	1:0	R/W	00: Input	01: Output	00
			10: COM0 (O)	11: I80CSN (O)	

P6PUR (0xFE5C)

Name	Bit	R/W	Description	Reset
GP67PU	7	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP66PU	6	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP65PU	5	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP64PU	4	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP63PU	3	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP62PU	2	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP61PU	1	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP60PU	0	R/W	0: Pull-up Disable, 1: Pull-up Enable	0

P7MOD0 (0xFE5D)

Name	Bit	R/W	Description		Reset
GP73MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG27 (O)	11: UCLK (I)	
GP72MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG26 (O)	11: EINT2 (I)	
GP71MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG25 (O)	11: EINT1 (I)	
GP70MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG24 (O)	11: EINT0 (I)	

P7MOD1 (0xFE5E)

User must not access GP77MOD and GP76MOD fields in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description		Reset
GP77MOD	7:6	R/W	00: Input	01: Output	00
			10: SEG31 (O)	11: Reserved	
GP76MOD	5:4	R/W	00: Input	01: Output	00
			10: SEG30 (O)	11: Reserved	
GP75MOD	3:2	R/W	00: Input	01: Output	00
			10: SEG29 (O)	11: UTXD (O)	
GP74MOD	1:0	R/W	00: Input	01: Output	00
			10: SEG28 (O)	11: URXD (I)	

P7PUR (0xFE5F)

User must not access GP77PU and GP76PU fields in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description	Reset
GP77PU	7	R/W	0: Pull-up Disable, 1: Pull-up Enable	1
GP76PU	6	R/W	0: Pull-up Disable, 1: Pull-up Enable	1
GP75PU	5	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP74PU	4	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP73PU	3	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP72PU	2	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP71PU	1	R/W	0: Pull-up Disable, 1: Pull-up Enable	0
GP70PU	0	R/W	0: Pull-up Disable, 1: Pull-up Enable	0

P8MOD0 (0xFE60)

User must not access this register in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description		Reset
GP83MOD	7:6	R/W	00: Input	01: Output	00
			10: AIN4 (I)	11: EINT4 (I)	
GP82MOD	5:4	R/W	00: Input	01: Output	00
			10: AIN5 (I)	11: EINT3 (I)	
RSVD	3:0	-	-		00

P8MOD1 (0xFE61)

User must not access this register in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description		Reset
GP87MOD	7:6	R/W	00: Input	01: Output	00
			10: Reserved	11: SCSN (B)	
GP86MOD	5:4	R/W	00: Input	01: Output	00
			10: Reserved	11: SMOSI (B)	
GP85MOD	3:2	R/W	00: Input	01: Output	00
			10: Reserved	11: SMISO (B)	
GP84MOD	1:0	R/W	00: Input	01: Output	00
			10: Reserved	11: SCLK(B)	

P8PUD0 (0xFE62)

User must not access this register in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description		Reset
GP83PUD	7:6	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
GP82PUD	5:4	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
RSVD	3:0	-	-		00

P8PUD1 (0xFE63)

User must not access this register in 68-QFN, If access, it might cause unexpected operation.

Name	Bit	R/W	Description		Reset
GP87PUD	7:6	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
GP86PUD	5:4	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
GP85PUD	3:2	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	
GP84PUD	1:0	R/W	00: Pull-Up/Down disabled	01: Pull-down enabled	10
			10: Pull-up enabled	11: Don't use (Never set)	

NOTES:

20 EMBEDDED FLASH CONTROL

20.1 OVERVIEW

This block is used for programming/erase on internal flash.
Figure 20-1 Shows sector mapping within the 384KB embedded flash.

Physical Start Address	Sector Number	
0x5_FE00	Sector 767(512B)	64KB
…	…	
0x5_0000	Sector 640(512B)	
0x4_FE00	Sector 639(512B)	64KB
…	…	
0x4_0000	Sector 512(512B)	
0x3_FE00	Sector 511(512B)	64KB
…	…	
0x3_0000	Sector 384(512B)	
0x2_FE00	Sector 383(512B)	64KB
…	…	
0x2_0000	Sector 256(512B)	
0x1_FE00	Sector 255(512B)	64KB
…	…	
0x1_0000	Sector 128(512B)	
0x0_FE00	Sector 127(512B)	64KB
0x0_FC00	Sector 126(512B)	
…	…	
0x0_0200	Sector 001(512B)	
0x0_0000	Sector 000(512B)	

Figure 20-1. Sector Mapping within the BMC513 embedded flash

20.2 FEATURES

The BMC513 consists of one 3072Kbits (384Kbytes) e-FLASH (embedded NOR flash). Main feature is as follows:

- Auto Timing Generation for internal flash programming/erase
- Small Sector Erase Capability
  - ✓ Uniform 512 Byte sectors (Total 768 sectors)
- Fast Chip/Sector Erase
  - ✓ Sector Erase Time: 8.0ms typ.
  - ✓ Chip Erase Time: 50.0ms typ. (Not supported by CPU)
  - ✓ Byte Program Time: 25μs typ.

20.3 OPERATION

Embedded Flash Controller is simple to use. Here is sector erase/program example C-code. sector_erase() function erases one sector and sector_program() function write 512bytes to a sector. The argument “sec_num” is sector number from 0 to 767. And “buf” is 512 bytes array pointer.

Corresponding FCON_WP register bit should be set before sector erase/program.

```
#define   F_PROGRAM          2
#define   F_SECTOR_ERASE     0

void sector_erase(int sec_num) {

        FCON_CTRL               = F_SECTOR_ERASE;
        FCON_ADDR_H             = (unsigned char)((sec_num>>8) & 0xff);
        FCON_ADDR_M             = (unsigned char)(sec_num & 0xff);
        FCON_ADDR_L             = 0x00;     // Any value is O.K. This can be skipped.
        FCON_WDATA_H_EN         = 0x1;      // Any value is O.K. Start to erase.
        while (FCON_STAT);          // Wait until sector erase is done.

}

void sector_program(int sec_num, unsigned char *buf) {

        int       addr;

        FCON_CTRL         = F_PROGRAM;

        FCON_ADDR_H   = (unsigned char)((sec_num>>8) & 0xff);
        FCON_ADDR_M   = (unsigned char)(sec_num & 0xff);
        FCON_ADDR_L    = 0x00;     // Program from 0x00. Other value except 0 can be used.

        for (addr=0;addr<512;addr+=2) {
                FCON_WDATA_L            = buf[addr];
                FCON_WDATA_H_EN      = buf[addr+1];   // Start to program.
                // Flash Address is automatically incremented after programming.
                while (FCON_STAT);                          // Wait until sector erase is done.
        }
}
```

20.4 REGISTER DESCRIPTION

SUMMARY

Name	Add.	R/W	Description	Reset
FCON_CTRL	0xFFA0	R/W	Flash Control Register	0
FCON_STAT	0xFFA1	R	Status Register	0
FCON_ADDR_L	0xFFA2	R/W	Address Low	Undef.
FCON_ADDR_M	0xFFA3	R/W	Address Middle	Undef.
FCON_ADDR_H	0xFFA4	R/W	Address High and Write Start Register	Undef.
FCON_WDATA_L	0xFFA5	R/W	Write Data Low	Undef.
FCON_WDATA_H_EN	0xFFA6	R/W	Write Data High and Write Enable Register	Undef
RSVD	0xFFA7	R	Reserved	0
FCON_WP_L	0xFFA8	R/W	Program/Sector_Erase Protect Low Register	0xff
FCON_WP_H	0xFFA9	R/W	Program/Sector_Erase Protect High Register	0x0f

Note) These registers have to be accessed using **MOVX** instruction.

FCON_CTRL (0xFFA0)

Name	Bit	R/W	Description	Reset
RSVD	7:3	-	Reserved	-
RESET	2	R/W	Flash Reset.	0
PROG_MODE	1	R/W	1 : Program, 0 : Sector Erase When sector erase mode, {FCON_ADDR_H and FCON_ADDR_M} pair is sector number. This controller does not support Chip Erase.	0
RSVD	0	-	RSVD	-

FCON_STAT (0xFFA1)

Name	Bit	R/W	Description	Reset
RSVD	7:1	-	Reserved	-
FCON_BUSY	0	R	This register indicates the status of FCON. 1 : Flash write is in progress 0 : Flash write is done.	0

FCON_ADDR_L (0xFFA2)

Name	Bit	R/W	Description	Reset
ADDR_L	7:0	R/W	Flash Program Address(Half Word Address). Internal flash is composed of 16-bit data. Then this register can address 512 bytes (1 sector) data. When sector erase, this register has no effect. **This register is auto-incremented during Flash Programming.**	Undef.

FCON_ADDR_M (0xFFA3)

Name	Bit	R/W	Description	Reset
ADDR_L	7:0	R/W	Flash Program/Erase Middle Address (Half Word Address).	Undef.

FCON_ADDR_H (0xFFA4)

Name	Bit	R/W	Description	Reset
ADDR_H	7:0	R/W	Flash Program/Erase High Address (Half Word Address).	Undef.

FCON_WDATA_L (0xFFA5)

Name	Bit	R/W	Description	Reset
WDTA_L	7:0	R/W	Flash Program Lower Write Data	Undef.

FCON_WDATA_H_EN (0xFFA6)

Name	Bit	R/W	Description	Reset
WDTA_H	7:0	R/W	Flash Program Upper Write Data and Write Enable Register. When this register is written, Flash Write Operation starts. **Flash Erase/Program does NOT proceed when corresponding protection bit is set.**	Undef.

FCON_WP_L (0xFFA8)

Name	Bit	R/W	Description	Reset
WP_L	7:0	R/W	Flash Program/Erase Protection Low Register Each bit protect 32K blocks of internal flash. 1 : Protected, 0 : Not Protected Bit 0 : 0x00000 ~ 0x07FFF Bit 1 : 0x08000 ~ 0x0FFFF Bit 2 : 0x10000 ~ 0x17FFF Bit 3 : 0x18000 ~ 0x1FFFF Bit 4 : 0x20000 ~ 0x27FFF Bit 5 : 0x28000 ~ 0x2FFFF Bit 6 : 0x30000 ~ 0x37FFF Bit 7 : 0x38000 ~ 0x3FFFF	0xFF

FCON_WP_H (0xFFA9)

Name	Bit	R/W	Description	Reset
RSVD	7:4	-	Reserved	-
WP_H	3:0	R/W	Flash Program/Erase Protection Low Register Each bit protect 32K blocks of internal flash. Bit 0 : 0x40000 ~ 0x47FFF Bit 1 : 0x48000 ~ 0x4FFFF Bit 2 : 0x50000 ~ 0x57FFF Bit 3 : 0x58000 ~ 0x5FFFF	0x0F

NOTES:

21 ELECTRICAL DATA

Table 21-1. Absolute Maximum Ratings

(T_A = 25 ℃)

Parameter	Symbol	Conditions	Rating	Unit
Supply voltage	V_{DD}	-	-0.3 to +6.0	V
Input voltage	V_I	Ports 0 - 8	-0.3 to V_{DD} + 0.3	
Output voltage	V_O	-	-0.3 to V_{DD} + 0.3	
Output current high	I_{OH}	One I/O pin active	-15	mA
		ALL I/O pins active	-60	
Output current low	I_{OL}	One I/O pin active	+30 (Peak Value)	
		Total pin current for ports	+100 (Peak Value)	
Operating temperature	T_A	-	-40 to +85	℃
Storage temperature	T_{STG}	-	-65 to +150	

Table 21-2. DC Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, V_{DD} = 2.2 V to 5.5 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Operating voltage	V_{DD}	PXI = 4 ~ 12MHz, PXTI = 32.768KHz F_{SYS} = 24MHz (using PLL)	2.2	-	5.5	V
Input high voltage	V_{IH1}	All input pins except for V_{IH2}	0.8V_{DD}	-	V_{DD}	
	V_{IH2}	PXI, PXTI	V_{DD}-0.1	-	V_{DD}	
Input low voltage	V_{IL1}	All input pins except for V_{IL2}	-	-	0.2V_{DD}	
	V_{IL2}	PXI, PXTI	-	-	0.1	
Output high voltage	V_{OH1}	V_{DD} = 4.5V to 5.5 V, I_{OH} = -2 mA PGP0, PGP4, PGP5, PGP6[6:4], PGP7	V_{DD}-1.0	-	-	
	V_{OH2}	V_{DD} = 4.5V to 5.5 V, I_{OH} = -4 mA PGP1, PGP3, PGP6[3:0], PGP8	V_{DD}-1.0	-	-	
Output low voltage	V_{OL1}	V_{DD} = 4.5V to 5.5 V, I_{OL} = 2 mA PGP0, PGP4, PGP5, PGP6[6:4], PGP7	-	-	1.0	
	V_{OL2}	V_{DD} = 4.5V to 5.5 V, I_{OL} = 4 mA PGP1, PGP3, PGP6[3:0], PGP8	-	-	1.0	
Input high leakage current	I_{LIH1}	V_{IN} = V_{DD} All input pins except PTEST, I_{LIH2}	-	-	3	μA
	I_{LIH2}	V_{IN} = V_{DD} PXI, PXTI	-	-	20	
Input low leakage current	I_{LIL1}	V_{IN} = 0V All input pins except PnRESET, I_{LIL2}	-	-	-3	
	I_{LIL2}	V_{IN} = 0V PXI, PXTI	-	-	-20	
Output high leakage current	I_{LOH}	V_{OUT} = V_{DD} All output pins	-	-	3	
Output low leakage current	I_{LOL}	V_{OUT} = 0V All output pins	-	-	-3	
LCD voltage dividing resistor	R_{LCD1}	T_A = 25 ℃, LCNST.2 = "0"	40	60	80	kΩ
	R_{LCD2}	T_A = 25 ℃, LCNST.2 = "1"	20	30	40	
Oscillator feedback resistor	R_{OSC1}	V_{DD} = 5V, T_A = 25 ℃ PXI = V_{DD}, PXO = 0 V	420	850	1700	
	R_{OSC2}	V_{DD} = 5V, T_A = 25 ℃ PXTI = V_{DD}, PXTO = 0 V	2200	4500	9000	
Pull-up resistor	R_{L1}	V_{IN} = 0V, V_{DD} = 5V, T_A = 25 ℃	25	50	100	

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
		PGP0, PGP1, PGP3 ~ PGP8				
		V_{IN} = 0V, V_{DD} = 3.3V, T_A = 25 ℃ PGP0, PGP1, PGP3 ~ PGP8	50	100	150	
	R_{L2}	V_{IN} = 0V, V_{DD} = 5V, T_A = 25 ℃ PnRESET	150	250	400	
		V_{IN} = 0V, V_{DD} = 3.3V, T_A = 25 ℃ PnRESET	300	500	700	
Pull-down resistor	R_{L3}	V_{IN} = 5V, V_{DD} = 5V, T_A = 25 ℃ PGP1, PGP3	25	50	100	
		V_{IN} = 3.3V, V_{DD} = 3.3V, T_A = 25 ℃ PGP1, PGP3, PGP8	50	100	150	
	R_{L4}	V_{IN} = 5V, V_{DD} = 5V, T_A = 25 ℃ PTEST	25	50	100	
		V_{IN} = 3.3V, V_{DD} = 3.3V, T_A = 25 ℃ PTEST	50	100	150	
Middle output voltage (V_{DD} = V_{LCD0})	V_{LCD1}	V_{DD} = 2.4V to 5.5V, 1/3 Bias LCD clock = 0Hz	$0.67V_{DD}$-0.2	$0.67V_{DD}$	$0.67V_{DD}$ +0.2	V
	V_{LCD2}		$0.33V_{DD}$-0.2	$0.33V_{DD}$	$0.33V_{DD}$ +0.2	
$\|V_{LCD}$ - COMi$\|$ Voltage drop (i = 0 – 3)	V_{DC}	-15 μA per common pin	-	-	120	mV
$\|V_{LCD}$ - SEGi$\|$ Voltage drop (i = 0 – 31)	V_{DS}	-15 μA per segment pin	-	-	120	
Supply current(1)	I_{DD1}(2)	Normal Operating mode: V_{DD} = 5V EMCLK = 12MHz, ESCLK = 32.768KHz IMCLK = 16MHz, ISCLK = 32.768KHz Crystal oscillator C1 = C2 = 22pF	-	6	12	mA
	I_{DD21}(2)	IDLE mode: V_{DD} = 5V EMCLK = 12MHz, ESCLK = 32.768KHz IMCLK = 16MHz, ISCLK = 32.786KHz Crystal oscillator C1 = C2 = 22pF	-	4	8	
	I_{DD22}	Sub-IDLE mode: V_{DD} = 5V EMCLK = Disable, ESCLK= 32.768KHz IMCLK = Disable, ISCLK = 32.768KHz Crystal oscillator C1 = C2 = 22pF	-	0.3	1	
	I_{DD31}(3)	STOP mode: V_{DD} = 5V EMCLK = Disable, ESCLK= Disable IMCLK = Disable, ISCLK = Disable	-	0.6	6.0	μA
	I_{DD32}	Sub-STOP mode: V_{DD} = 5V EMCLK = Disable, ESCLK= Disable IMCLK = Disable, ISCLK = 32.768KHz	-	0.8		

NOTE:

(1) Supply current does not include current drawn through internal pull-up/down resistors, LCD voltage dividing resistors, and external output current loads.

(2) I_{DD1} and I_{DD2} include a power consumption of external sub clock oscillation, internal main clock oscillation and internal sub clock oscillation.

(3) I_{DD3} is the current when the external main, external sub, internal main and internal sub clock oscillation stops.

Table 21-3. AC Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, V_{DD} = 2.2 V to 5.5 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
External interrupt input high, low width (PGP7[2:0], PGP8[3:2], PGP14, PGP3[7:4])	t_{INTH},t_{INTL}	All external interrupt pins,	500	-	-	ns
PnRESET input low width	t_{RSL}	Input	5	-	-	μs

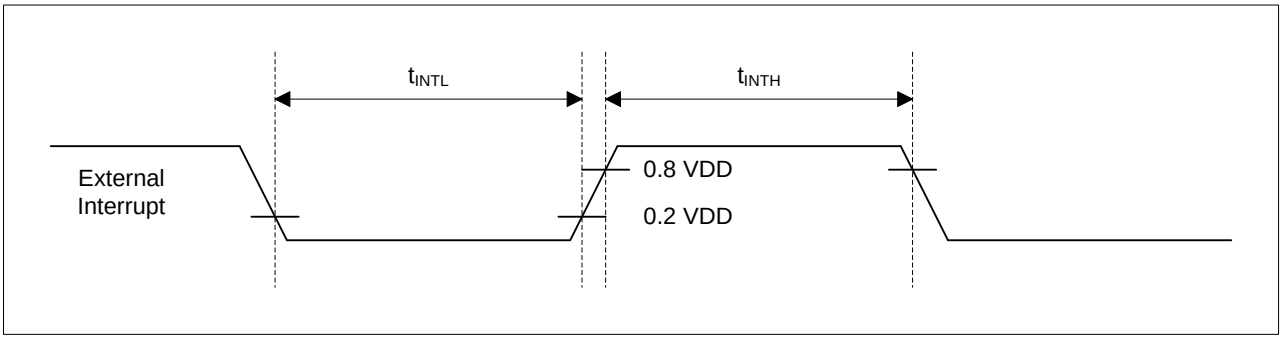


Figure 21-1. Input Timing for External Interrupts

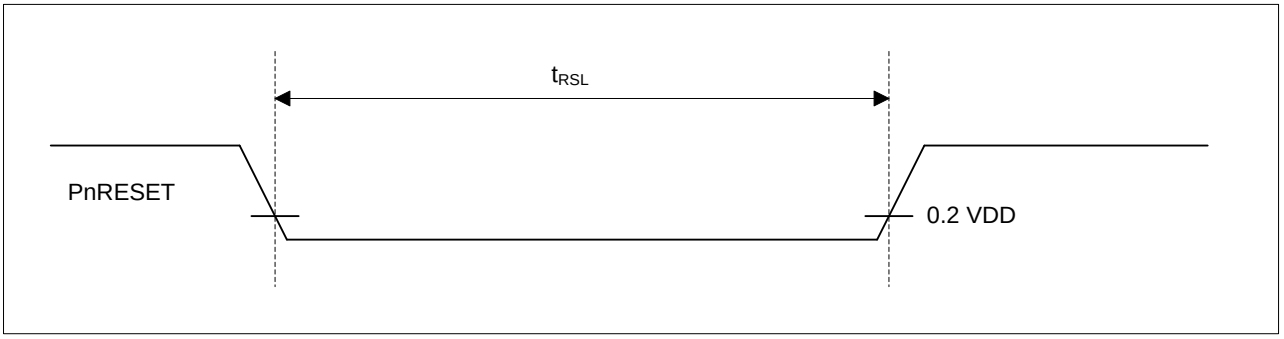


Figure 21-2. Input Timing for PnRESET

Table 21-4. Input/Output Capacitance

(T_A = -40 ℃ to +85 ℃, V_{DD} = 0 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input capacitance	C_{IN}	1 MHz; unmeasured pins are returned to V_{SS}	-	-	10	pF
Output capacitance	C_{OUT}					
I/O capacitance	C_{IO}					

Table 21-5. A/D Converter Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, V_{DD} = 2.7 V to 5.5 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Resolution	-	-	-	10	-	bit
Integral linearity error	ILE	VDD = 5.120 V VSS = 0 V	-	-	±2	LSB
Differential linearity error	DLE			-	±1	
Offset error of top	EOT			-	±10	
Offset error of bottom	EOB			-	±10	
Conversion time(1)	T_{CON}	-	20	-	-	μs
Analog input voltage	V_{IAN}	-	V_{SS}	-	V_{DD}	V
Analog input impedance	R_{AN}	-	2	1000	-	MΩ
Analog input current	I_{ADIN}	V_{DD} = 5 V	-	-	10	μA
Analog block current(2)	I_{ADC}	V_{DD} = 5 V	-	0.5	1.5	mA
		V_{DD} = 5 V When power down mode	-	100	500	nA

NOTES:

(1) 'Conversion time' is the time required from the moment a conversion operation starts until it ends.

(2) I_{ADC} is an operation current during A/D converter.

Table 21-6. D/A Converter Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, AV_{DAC} = 3.0 V to 3.6 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Differential Non-Linearity	DNL	AV_{DAC} = 3.3V, FCLK = 100KHz	-	-	±1.0	LSB
Integral Non-Linearity	INL		-	-	±7.0	LSB
Output Voltage Range	Vout		0.05	-	A_{VDAC} – 0.2	V
Supply Current	I_{OP}		-	2.6	-	mA
Power Down Current	I_{STP}		-	-	1	μA

Table 21-7. External Oscillator Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, V_{DD} = 2.2 V to 5.5 V)

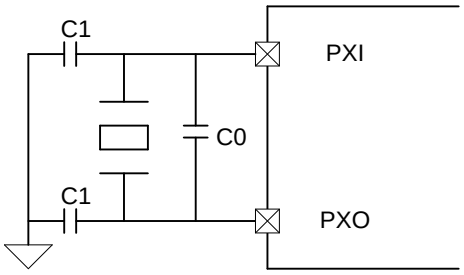
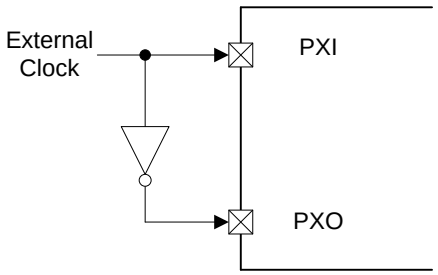
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
External Main Oscillator(EMCLK) Frequency	EM_{FREQ}	V_{DD} = 5V, T_A = 25℃	1	-	24	MHz
Stabilization time	T_{STA}	V_{DD} = 5V, T_A = 25℃	-	-	70	ms
Crystal/resonator/ceramic			1	-	24	MHz
External clock			1	-	24	MHz
Capacitance	C0	Option Shunt Cap. If user wants to use small SMD type crystal, this cap should be needed.	3	5	10	pF
	C1	-	-	18	-	pF

Table 21-8. Internal Oscillator Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, V_{DD} = 2.2 V to 5.5 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Internal Main Oscillator(IMCLK) Frequency	IM_{FREQ}	V_{DD} = 5V, T_A = 25℃	13	16	19	MHz
Internal Sub Oscillator(ISCLK) Frequency	IS_{FREQ}	V_{DD} = 5V, T_A = 25℃	26.2	32.768	39.3	KHz

Table 21-9. Low Voltage Reset Electrical Characteristics

(T_A = -40 ℃ to +85 ℃)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Voltage of LVR	V_{LVR}	IVCON0.LVR_SEL = 2'b00	1.951	2.051	2.151	V
		IVCON0.LVR_SEL = 2'b01	1.805	1.905	2.005	
		IVCON0.LVR_SEL = 2'b10	1.851	1.951	2.051	
		IVCON0.LVR_SEL = 2'b11	1.9	2.0	2.1	
Voltage of BLD	V_{BLD}	IVCON0.BLD_SEL = 2'b00	2.88	3.08	3.28	V
		IVCON0.BLD_SEL = 2'b01	2.03	2.23	2.43	
		IVCON0.BLD_SEL = 2'b10	2.23	2.43	2.63	
		IVCON0.BLD_SEL = 2'b11	2.57	2.77	2.97	
V_{DD} voltage rising time	t_R	-	10	-	-	μs
V_{DD} voltage off time	t_{OFF}	-	0.5	-	-	S
Hysteresis LVR	ΔV	-	-	10	100	mV
Current consumption	I_{LVR}	V_{DD} = 5 V	-	30	60	μA

Figure 21-3. LVR (Low Voltage Reset) Timing

Table 21-10. LCD Contrast Controller Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, V_{DD} = 2.4 V to 5.5 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Resolution	-	-	-	-	4	Bits
Linearity	R_{LIN}	V_{DD} = 5 V	-	-	±150	mV
Max Output Voltage	V_{LPP}	V_{LCD0} = V_{DD} = 5V LCNST = 0xF8	4.9	-	V_{LCD0}	V

Table 21-11. Internal Flash ROM Electrical Characteristics

(T_A = -40 ℃ to +85 ℃, V_{DD} = 2.2 V to 5.5 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Programming Time (1)	Ftp	V_{DD} = 5 V, T_A = 25℃	20	25	30	μs
Chip Erasing Time (2)	Ftp1		32	50	70	ms
Sector Erasing Time (3)	Ftp2		4	8	12	ms
Read frequency	f_R		-	-	12	MHz
Number of Writing/Erasing	FN_{WE}	-	-	-	10,000(4)	Times

NOTES:
(1) The programming time is the time during which 2 byte (16-bit) is programmed. Not allowed one byte program
(2) The chip erasing time is the time during which entire program memory is erased
(3) The sector erasing time is the time during which all 512 byte block is erased
(4) The chip erasing is available in Tool Program Mode only.

22 MECHANICAL DATA

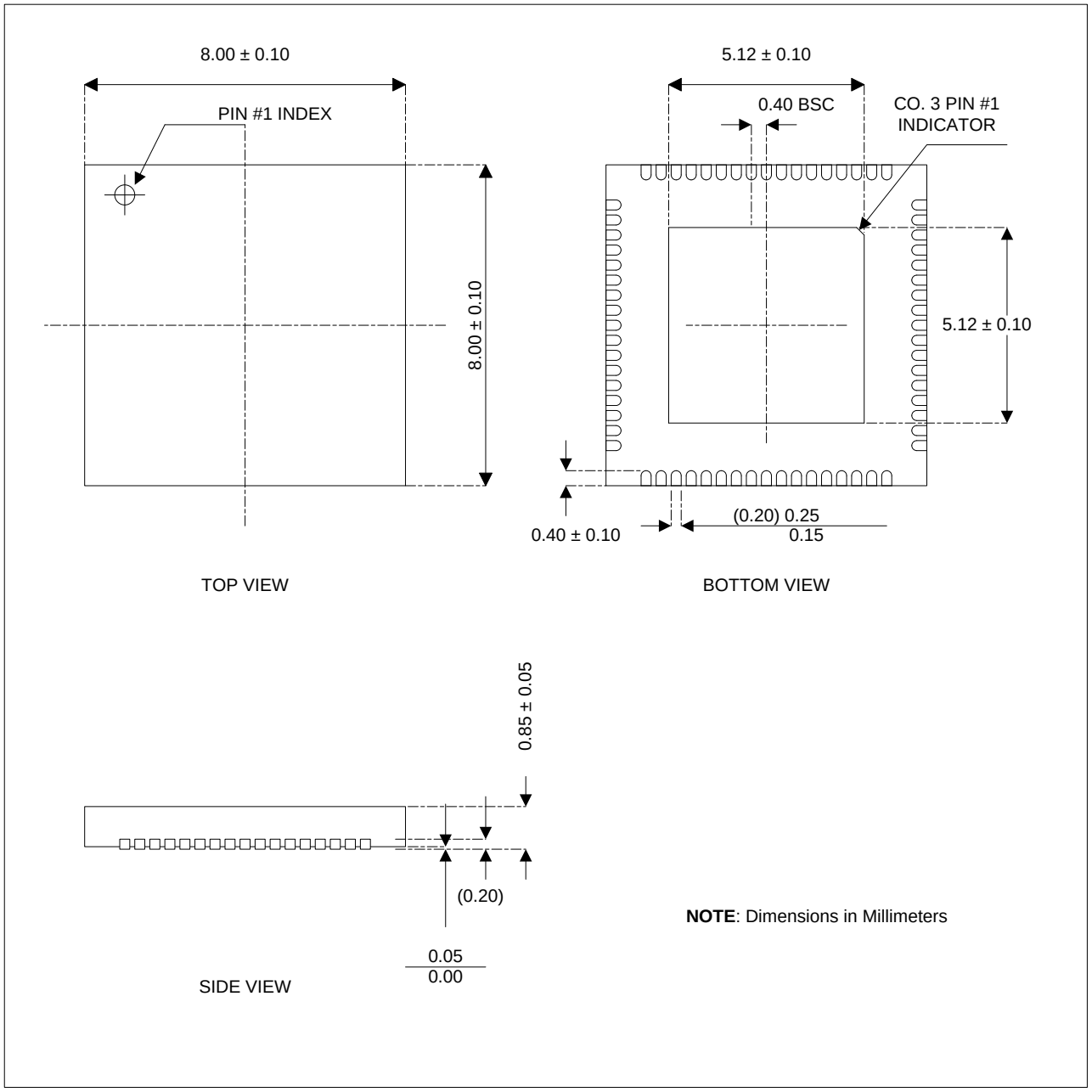


Figure 22-1. 68-QFN Package Dimension

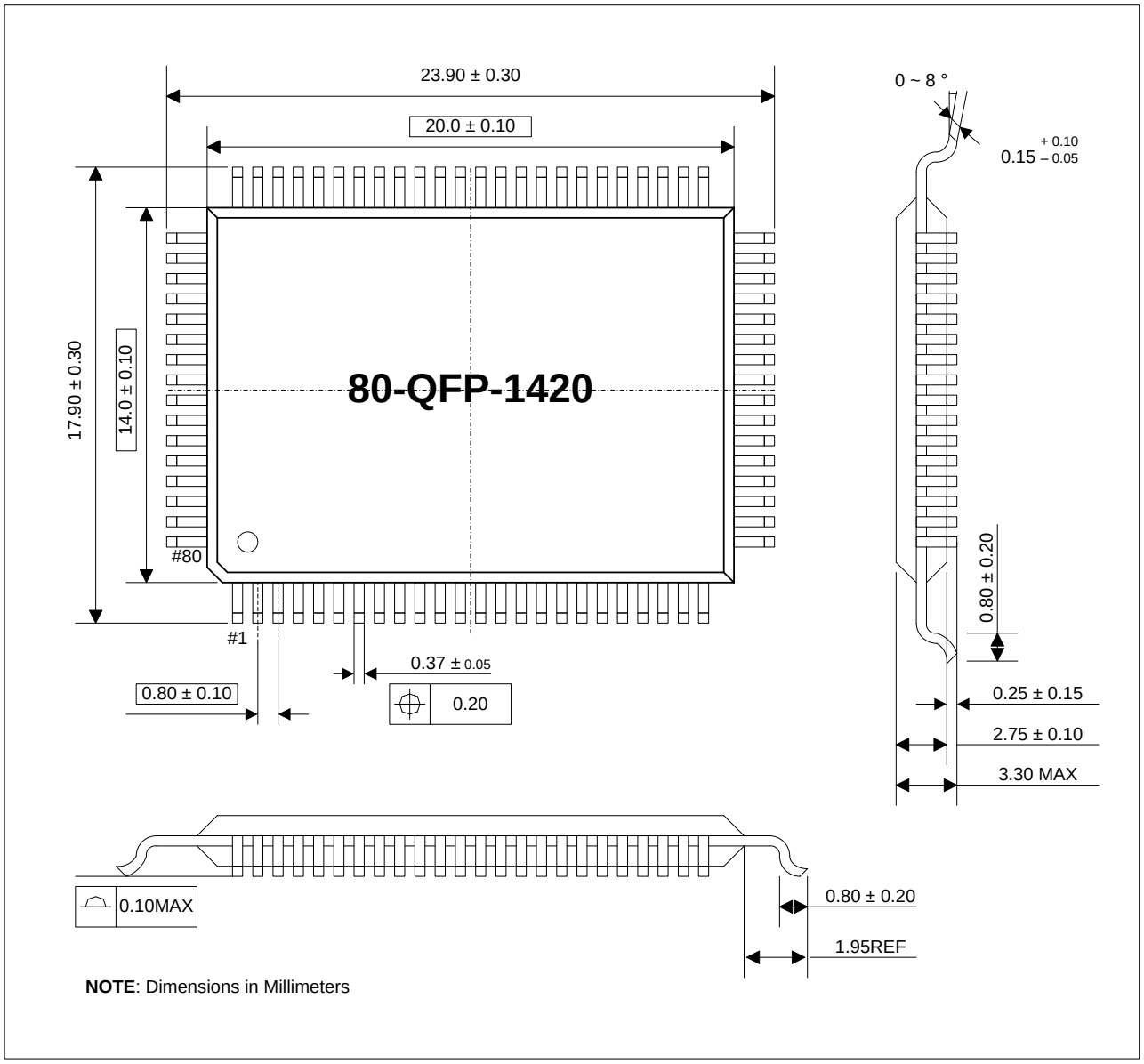


Figure 22-2. 80-QFP Package Dimension