
Section 47. External Bus Interface (EBI)

HIGHLIGHTS

This section of the manual contains the following major topics:

47.1	Introduction	47-2
47.2	Control Registers	47-4
47.3	Interfacing to Various Devices	47-14
47.4	Bus Configuration	47-16
47.5	Device Configuration.....	47-17
47.6	Timing Diagrams	47-21
47.7	Effects Of Reset.....	47-24
47.8	Operation in Power-Saving Modes	47-24
47.9	Related Application Notes.....	47-25
47.10	Revision History	47-26

Note: This family reference manual section is meant to serve as a complement to device data sheets. Depending on the device variant, this manual section may not apply to all PIC32 devices.

Please consult the note at the beginning of the “**External Bus Interface (EBI)**” chapter in the current device data sheet to check whether this document supports the device you are using.

Device data sheets and family reference manual sections are available for download from the Microchip Worldwide Web site at: <http://www.microchip.com>

47.1 INTRODUCTION

The External Bus Interface (EBI) module provides a convenient, high-speed way to interface external parallel memory devices to the PIC32 family device.

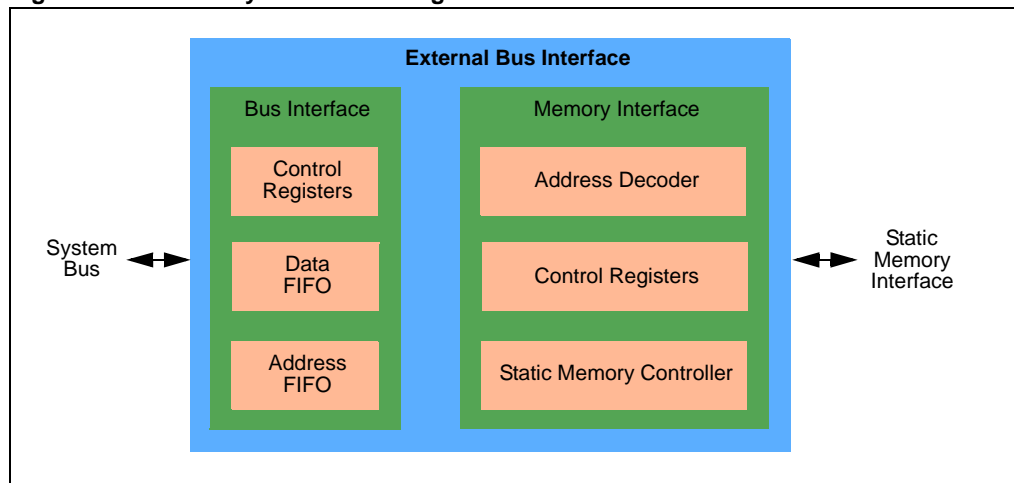
With the EBI module, it is possible to connect asynchronous SRAM and NOR Flash devices, as well as non-memory devices, such as camera sensors. The EBI module also supports Low-Cost Controllerless (LCC) Graphics devices.

The features of the EBI module depend on the particular PIC32 device and the pin count, as shown in Table 47-1.

Table 47-1: EBI Module Features

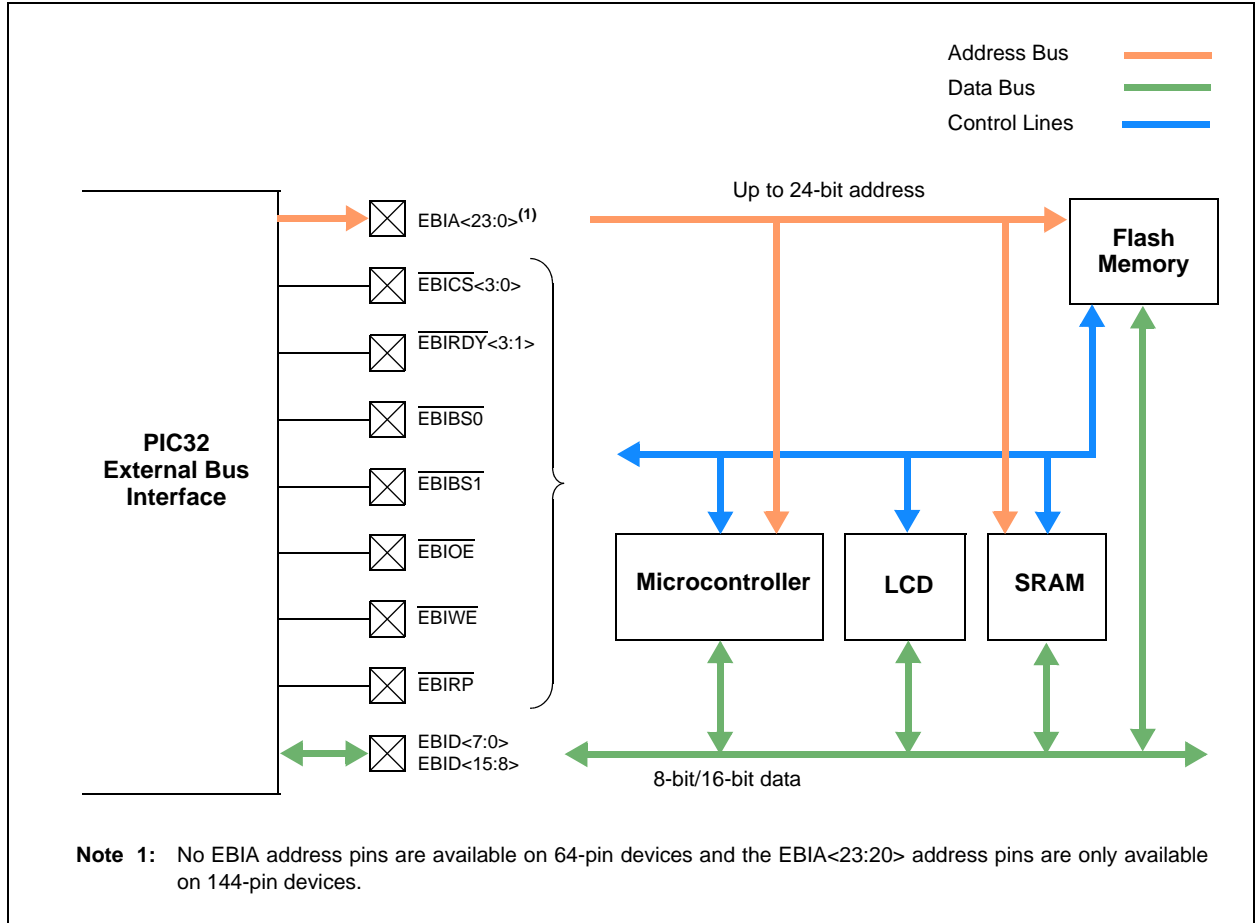
Feature	Number of Device Pins		
	100	124	144
Asynchronous SRAM	Y	Y	Y
Asynchronous NOR Flash	Y	Y	Y
Available address lines	20	20	24
8-bit data bus support	Y	Y	Y
16-bit data bus support	Y	Y	Y
Available Chip Selects	1	1	4
Timing mode sets	3	3	3
8-bit R/W from 16-bit bus	N	N	Y
Performance (MHz)	50	50	50
Non-memory device	Y	Y	Y

Figure 47-1: EBI System Block Diagram



Section 47. External Bus Interface (EBI)

Figure 47-2: EBI Module Pinout and Connections to External Devices



47.2 CONTROL REGISTERS

The EBI module for PIC32 devices contains the following Special Function Registers (SFRs):

- **EBICSx: External Bus Interface Chip Select Register (x = 0-3)**

This register contains the base address in physical memory for the selected external Device.

- **EBIMSKx: External Bus Interface Address Mask Register (x = 0-3)**

This register enables selection of the timing register set, as well as the Chip Select memory type and memory size.

- **EBISMTx: External Bus Interface Static Memory Timing Register (x = 0-2)**

This register can be used to configure the static memory timing.

- **EBIFTRPD: External Bus Interface Flash Timing Register**

This register defines the number of clock cycles to hold the external Flash memory in reset.

- **EBISMCON: External Bus Interface Static Memory Control Register**

This register can be used to define the static memory width for register sets 0-2, and to select Flash Reset/Power-down mode during a device Reset.

- **CFGEbIA: External Bus Interface Address Pin Configuration Register**

This register can be used to configure the address pins for the EBI module.

- **CFGEbIC: External Bus Interface Control Pin Configuration Register**

This register can be used to configure the control pins for the EBI module.

Table 47-2 and Table 47-3 provide a brief summary of the related EBI registers. Corresponding registers appear after the summary, followed by a detailed description of each bit.

Table 47-2: EBI SFR Summary

Register Name	Bit Range	Bit 31/15	Bit 30/14	Bit 29/13	Bit 28/12	Bit 27/11	Bit 26/10	Bit 25/9	Bit 24/8	Bit 23/7	Bit 22/6	Bit 21/5	Bit 20/4	Bit 19/3	Bit 118/2	Bit 17/1	Bit 16/0
EBICSx	31:16	CSADDR<15:0>															
	15:0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EBIMSKx	31:16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	15:0	—	—	—	—	—	REGSEL<2:0>			MEMTYPE<2:0>			MEMSIZE<4:0>				
EBISMTx	31:16	—	—	—	—	—	RDYMODE	PAGESIZE<1:0>	PAGEMODE	TPRC<3:0>					TBTA<2:0>		
	15:0	TWP<5:0>						TWR<1:0>		TAS<1:0>			TRC<5:0>				
EBIFTRPD	31:16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	15:0	—	—	—	—	TRPD<11:0>											
EBISMCON	31:16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	15:0	SMDWIDTH2<2:0>				SMDWIDTH1<2:0>			SMDWIDTH0<2:0>			—	—	—	—	—	SMRP

Legend: — = unimplemented, read as '0'.

Table 47-3: EBI Configuration Register Summary

Register Name	Bit Range	Bit 31/15	Bit 30/14	Bit 29/13	Bit 28/12	Bit 27/11	Bit 26/10	Bit 25/9	Bit 24/8	Bit 23/7	Bit 22/6	Bit 21/5	Bit 20/4	Bit 19/3	Bit 118/2	Bit 17/1	Bit 16/0
CFGEBIA	31:16	EBIPINEN	—	—	—	—	—	—	—	EBIA23EN	EBIA22EN	EBIA21EN	EBIA20EN	EBIA19EN	EBIA18EN	EBIA17EN	EBIA16EN
	15:0	EBIA15EN	EBIA14EN	EBIA13EN	EBIA12EN	EBIA11EN	EBIA10EN	EBIA9EN	EBIA8EN	EBIA7EN	EBIA6EN	EBIA5EN	EBIA4EN	EBIA3EN	EBIA2EN	EBIA1EN	EBIA0EN
CFGEBIC	31:16	—	EBI RDYINV3	EBI RDYINV2	EBI RDYINV1	—	EBI RDYEN3	EBI RDYEN2	EBI RDYEN1	—	—	—	—	—	—	EBI RDYLV1	EBIRPEN
	15:0	—	—	EBIWEEN	EBIOEEN	—	—	EBIBSEN1	EBIBSEN0	EBICSEN3	EBICSEN2	EBICSEN1	EBICSEN0	—	—	EBIDEN1	EBIDEN0

Legend: — = unimplemented, read as '0'.

PIC32 Family Reference Manual

Register 47-1: EBICSx: External Bus Interface Chip Select Register (x = 0-3)

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	CSADDR<15:8>							
23:16	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	CSADDR<7:0>							
15:8	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
7:0	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—

Legend:

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

-n = Value at POR

'1' = Bit is set

'0' = Bit is cleared

x = Bit is unknown

bit 31-16 **CSADDR<15:0>**: Base Address for Device bits

Address in physical memory, which will select the external device.

bit 15-0 **Unimplemented**: Read as '0'

Section 47. External Bus Interface (EBI)

Register 47-2: EBIMSKx: External Bus Interface Address Mask Register (x = 0-3)

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
23:16	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
15:8	U-0	U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0
	—	—	—	—	—	REGSEL<2:0>		
7:0	R/W-0	R/W-0	R/W-1	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	MEMTYPE<2:0>			MEMSIZE<4:0>				

Legend:

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

-n = Value at POR

'1' = Bit is set

'0' = Bit is cleared

x = Bit is unknown

bit 31-11 **Unimplemented:** Read as '0'

bit 10-8 **REGSEL<2:0>:** Timing Register Set for Chip Select 'x' bits

111 = Reserved

•
•
•

011 = Reserved

010 = Use EBITMGR2

001 = Use EBITMGR1

000 = Use EBITMGR0

bit 7-5 **MEMTYPE<2:0>:** Select Memory Type for Chip Select 'x' bits

111 = Reserved

•
•
•

011 = Reserved

010 = NOR-Flash

001 = SRAM

000 = Reserved

bit 4-0 **MEMSIZE<4:0>:** Select Memory Size for Chip Select 'x' bits

11111 = Reserved

•
•
•

01010 = Reserved

01001 = 16 MB

01000 = 8 MB

00111 = 4 MB

00110 = 2 MB

00101 = 1 MB

00100 = 512 KB

00011 = 256 KB

00010 = 128 KB

00001 = 64 KB (smaller memories alias within this range)

00000 = Chip Select is not used

PIC32 Family Reference Manual

Register 47-3: EBISMTx: External Bus Interface Static Memory Timing Register (x = 0-2)

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	U-0	U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0
	—	—	—	—	—	RDYMODE	PAGESIZE<1:0>	
23:16	R/W-0	R/W-0	R/W-1	R/W-0	R/W-0	R/W-1	R/W-0	R/W-0
	PAGEMODE	TPRC<3:0>				TBTA<2:0>		
15:8	R/W-0	R/W-0	R/W-1	R/W-1	R/W-0	R/W-0	R/W-0	R/W-1
	TWP<5:0>					TWR<1:0>		
7:0	R/W-0	R/W-1	R/W-0	R/W-0	R/W-1	R/W-1	R/W-0	R/W-0
	TAS<1:0>		TRC<5:0>					

Legend:

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

-n = Value at POR

'1' = Bit is set

'0' = Bit is cleared

x = Bit is unknown

bit 31-27 **Unimplemented:** Read as '0'

bit 26 **RDYMODE:** Data Ready Device Select bit

The device associated with register set 'x' is a data-ready device, and will use the READY pin.

1 = Ready input is used

0 = Ready input is not used

bit 25-24 **PAGESIZE<1:0>:** Page Size for Page Mode Device bits

11 = 32-word page

10 = 16-word page

01 = 8-word page

00 = 4-word page

bit 23 **PAGEMODE:** Memory Device Page Mode Support bit

1 = Device supports Page mode

0 = Device does not support Page mode

bit 22-19 **TPRC<3:0>:** Page Mode Read Cycle Time bits

Read cycle time is TPRC + 1 clock cycle.

bit 18-16 **TBTA<2:0>:** Data Bus Turnaround Time bits

Clock cycles (0-7) for static memory between read-to-write, write-to-read, and read-to-read when Chip Select changes.

bit 15-10 **TWP<5:0>:** Write Pulse Width bits

Write pulse width is TWP + 1 clock cycle.

bit 9-8 **TWR<1:0>:** Write Address/Data Hold Time bits

Number of clock cycles to hold address or data on the bus.

bit 7-6 **TAS<1:0>:** Write Address Setup Time bits

Clock cycles for address setup time. A value of '0' is only valid in the case of SSRAM.

bit 5-0 **TRC<5:0>:** Read Cycle Time bits

Read cycle time is TRC + 1 clock cycle.

Section 47. External Bus Interface (EBI)

Register 47-4: EBIFTRPD: External Bus Interface Flash Timing Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
23:16	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
15:8	U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
	—	—	—	—	TRPD<11:8>			
7:0	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x
	TRPD<7:0> ⁽¹⁾							

Legend:

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

-n = Value at POR

'1' = Bit is set

'0' = Bit is cleared

x = Bit is unknown

bit 31-12 **Unimplemented:** Read as '0'

bit 11-0 **TRPD<11:0>:** Flash Timing bits⁽¹⁾

These bits define the number of clock cycles to wait after resetting the external Flash memory before starting any read/write accesses.

Note 1: Please refer to the specific device data sheet for the actual reset values for these bits.

47

**External Bus
Interface (EBI)**

PIC32 Family Reference Manual

Register 47-5: EBISMCON: External Bus Interface Static Memory Control Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
23:16	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
15:8	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-1	R/W-0
	SMDWIDTH2<2:0>			SMDWIDTH1<2:0>			SMDWIDTH0<2:1>	
7:0	R/W-0	U-0	U-0	U-0	U-0	U-0	U-0	R/W-1
	SMDWIDTH0<0>	—	—	—	—	—	—	SMRP

Legend:

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

-n = Value at POR

'1' = Bit is set

'0' = Bit is cleared

x = Bit is unknown

bit 31-16 **Unimplemented:** Read as '0'

bit 15-13 **SMDWIDTH2<2:0>:** Static Memory Width for Register Set 2 bits

111 = Reserved

110 = Reserved

101 = Reserved

100 = 8 bits

011 = Reserved

010 = Reserved

001 = Reserved

000 = 16 bits

bit 12-10 **SMDWIDTH1<2:0>:** Static Memory Width for Register Set 1 bits

111 = Reserved

110 = Reserved

101 = Reserved

100 = 8 bits

011 = Reserved

010 = Reserved

001 = Reserved

000 = 16 bits

bit 9-7 **SMDWIDTH0<2:0>:** Static Memory Width for Register Set 0 bits

111 = Reserved

110 = Reserved

101 = Reserved

100 = 8 bits

011 = Reserved

010 = Reserved

001 = Reserved

000 = 16 bits

bit 6-1 **Unimplemented:** Read as '0'

bit 0 **SMRP:** Flash Reset/Power-down mode Select bit

After a Reset, the controller internally performs a power-down for Flash, and then sets this bit to '1'.

1 = Flash is taken out of Power-down mode

0 = Flash is forced into Power-down mode

Section 47. External Bus Interface (EBI)

Register 47-6: CFGEBIA: External Bus Interface Address Pin Configuration Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	R/W-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	EBIPINEN	—	—	—	—	—	—	—
23:16	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	EBIA23EN	EBIA22EN	EBIA21EN	EBIA20EN	EBIA19EN	EBIA18EN	EBIA17EN	EBIA16EN
15:8	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	EBIA15EN	EBIA14EN	EBIA13EN	EBIA12EN	EBIA11EN	EBIA10EN	EBIA9EN	EBIA8EN
7:0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	EBIA7EN	EBIA6EN	EBIA5EN	EBIA4EN	EBIA3EN	EBIA2EN	EBIA1EN	EBIA0EN

Legend:

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

-n = Value at POR

'1' = Bit is set

'0' = Bit is cleared

x = Bit is unknown

bit 31 **EBIPINEN:** EBI Pin Enable bit

1 = EBI controls access of pins shared with PMP

0 = Pins shared with EBI are available for general use

bit 30-24 **Unimplemented:** Read as '0'

bit 23-0 **EBIA23EN:EBIA0EN:** EBI Address Pin Enable bits

1 = The EBIAx pin is enabled for use by EBI

0 = The EBIAx pin has is available for general use

Note: When EBIMD = 1, the bits in this register are ignored and the pins are available for general use.

47

External Bus
Interface (EBI)

PIC32 Family Reference Manual

Register 47-7: CFGEBIC: External Bus Interface Control Pin Configuration Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	U-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0	R/W-0	R/W-0
	—	EBI RDYINV3	EBI RDYINV2	EBI RDYINV1	—	EBI RDYEN3	EBI RDYEN2	EBI RDYEN1
23:16	U-0	U-0	U-0	U-0	U-0	U-0	R/W-0	R/W-0
	—	—	—	—	—	—	EBIRDYLV	EBIRPEN
15:8	U-0	U-0	R/W-0	R/W-0	U-0	U-0	R/W-0	R/W-0
	—	—	EBIWEEN	EBIOEEN	—	—	EBIBSEN1	EBIBSEN0
7:0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	U-0	R/W-0	R/W-0
	EBICSEN3	EBICSEN2	EBICSEN1	EBICSEN0	—	—	EBIDEN1	EBIDEN0

Legend:

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

-n = Value at POR

'1' = Bit is set

'0' = Bit is cleared

x = Bit is unknown

bit 31 **Unimplemented:** Read as '0'

bit 30 **EBIRDYINV3:** EBIRDY3 Inversion Control bit

1 = Invert EBIRDY3 pin before use

0 = Do not invert EBIRDY3 pin before use

bit 29 **EBIRDYINV2:** EBIRDY2 Inversion Control bit

1 = Invert EBIRDY2 pin before use

0 = Do not invert EBIRDY2 pin before use

bit 28 **EBIRDYINV1:** EBIRDY1 Inversion Control bit

1 = Invert EBIRDY1 pin before use

0 = Do not invert EBIRDY1 pin before use

bit 27 **Unimplemented:** Read as '0'

bit 26 **EBIRDYEN3:** EBIRDY3 Pin Enable bit

1 = EBIRDY3 pin is enabled for use by the EBI module

0 = EBIRDY3 pin is available for general use

bit 25 **EBIRDYEN2:** EBIRDY2 Pin Enable bit

1 = EBIRDY2 pin is enabled for use by the EBI module

0 = EBIRDY2 pin is available for general use

bit 24 **EBIRDYEN1:** EBIRDY1 Pin Enable bit

1 = EBIRDY1 pin is enabled for use by the EBI module

0 = EBIRDY1 pin is available for general use

bit 23-18 **Unimplemented:** Read as '0'

bit 17 **EBIRDYLV:** EBIRDYx Pin Sensitivity Control bit

1 = Use level detect for EBIRDYx pins

0 = Use edge detect for EBIRDYx pins

bit 16 **EBIRPEN:** EBIRP Pin Sensitivity Control bit

1 = EBIRP pin is enabled for use by the EBI module

0 = EBIRP pin is available for general use

bit 15-14 **Unimplemented:** Read as '0'

bit 13 **EBIWEEN:** EBIWE Pin Enable bit

1 = EBIWE pin is enabled for use by the EBI module

0 = EBIWE pin is available for general use

Note: When EBIMD = 1, the bits in this register are ignored and the pins are available for general use.

Register 47-7: CFGEBIC: External Bus Interface Control Pin Configuration Register (Continued)

- bit 12 **EBIOEEN:** $\overline{\text{EBIOE}}$ Pin Enable bit
 1 = $\overline{\text{EBIOE}}$ pin is enabled for use by the EBI module
 0 = $\overline{\text{EBIOE}}$ pin is available for general use
- bit 11-10 **Unimplemented:** Read as '0'
- bit 9 **EBIBSEN1:** $\overline{\text{EBIBS1}}$ Pin Enable bit
 1 = $\overline{\text{EBIBS1}}$ pin is enabled for use by the EBI module
 0 = $\overline{\text{EBIBS1}}$ pin is available for general use
- bit 8 **EBIBSEN0:** $\overline{\text{EBIBS0}}$ Pin Enable bit
 1 = $\overline{\text{EBIBS0}}$ pin is enabled for use by the EBI module
 0 = $\overline{\text{EBIBS0}}$ pin is available for general use
- bit 7 **EBICSEN3:** $\overline{\text{EBICS3}}$ Pin Enable bit
 1 = $\overline{\text{EBICS3}}$ pin is enabled for use by the EBI module
 0 = $\overline{\text{EBICS3}}$ pin is available for general use
- bit 6 **EBICSEN2:** $\overline{\text{EBICS2}}$ Pin Enable bit
 1 = $\overline{\text{EBICS2}}$ pin is enabled for use by the EBI module
 0 = $\overline{\text{EBICS2}}$ pin is available for general use
- bit 5 **EBICSEN1:** $\overline{\text{EBICS1}}$ Pin Enable bit
 1 = $\overline{\text{EBICS1}}$ pin is enabled for use by the EBI module
 0 = $\overline{\text{EBICS1}}$ pin is available for general use
- bit 4 **EBICSEN0:** $\overline{\text{EBICS0}}$ Pin Enable bit
 1 = $\overline{\text{EBICS0}}$ pin is enabled for use by the EBI module
 0 = $\overline{\text{EBICS0}}$ pin is available for general use
- bit 3-2 **Unimplemented:** Read as '0'
- bit 1 **EBIDEN1:** EBI Data Upper Byte Pin Enable bit
 1 = EBID<15:8> pins are enabled for use by the EBI module
 0 = EBID<15:8> pins have reverted to general use
- bit 0 **EBIDEN0:** EBI Data Upper Byte Pin Enable bit
 1 = EBID<7:0> pins are enabled for use by the EBI module
 0 = EBID<7:0> pins have reverted to general use

Note: When EBIMD = 1, the bits in this register are ignored and the pins are available for general use.

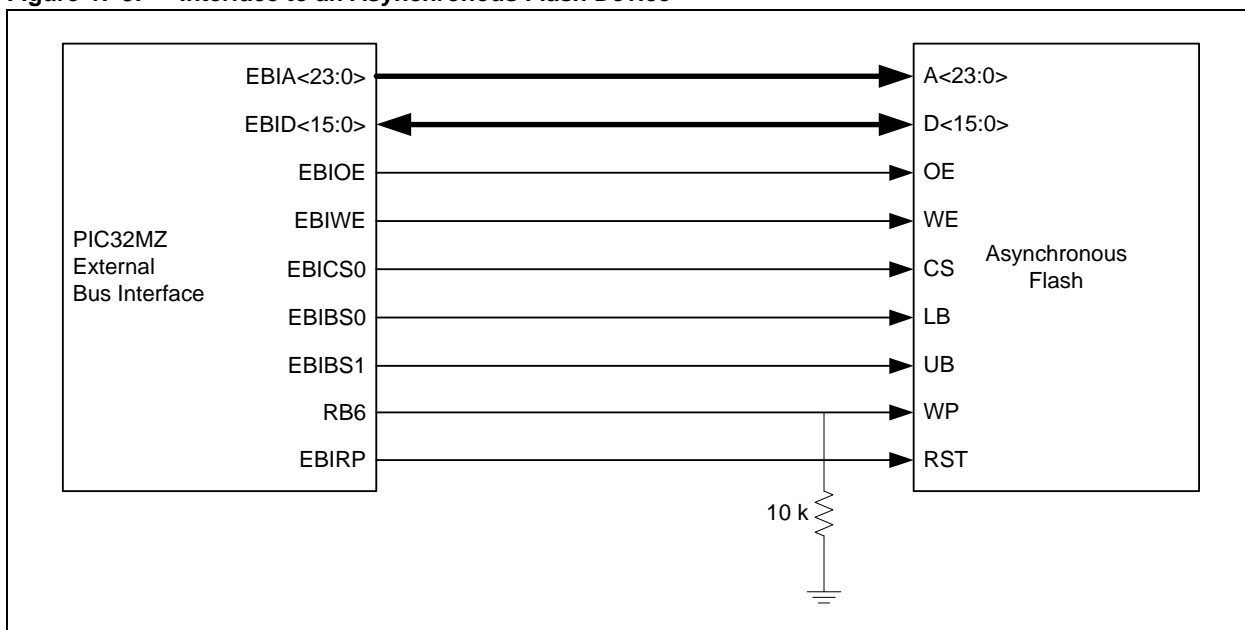
47.3 INTERFACING TO VARIOUS DEVICES

To provide support for a wide range of external devices, the EBI module can be configured to understand such things as the type, size, and bus width of each attached device. Since this configuration is determined on a Chip Select basis, when mixing devices on the EBI, similar devices should be on the same Chip Select line.

47.3.1 Interfacing to NOR Flash Memory

Figure 47-3 shows an example of connecting the EBI bus to an asynchronous NOR Flash device.

Figure 47-3: Interface to an Asynchronous Flash Device

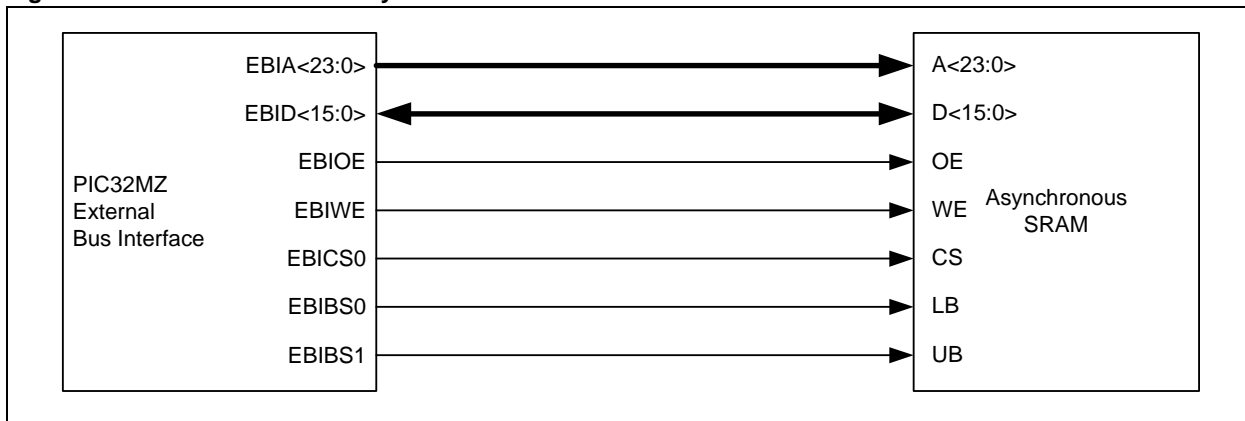


Note that the Write Protect (WP) pin on the Flash device is connected to a General Purpose I/O pin (RB6). This pin would not be under EBI control, hence it would be up to the user application to enable Flash writes prior to using the EBI to write the data, and disabling Flash writes when all writes are complete.

47.3.2 Interfacing to SRAM Memory

Figure 47-2 shows an example connecting the EBI bus to an Asynchronous SRAM memory device.

Figure 47-4: Interface to an Asynchronous SRAM Device



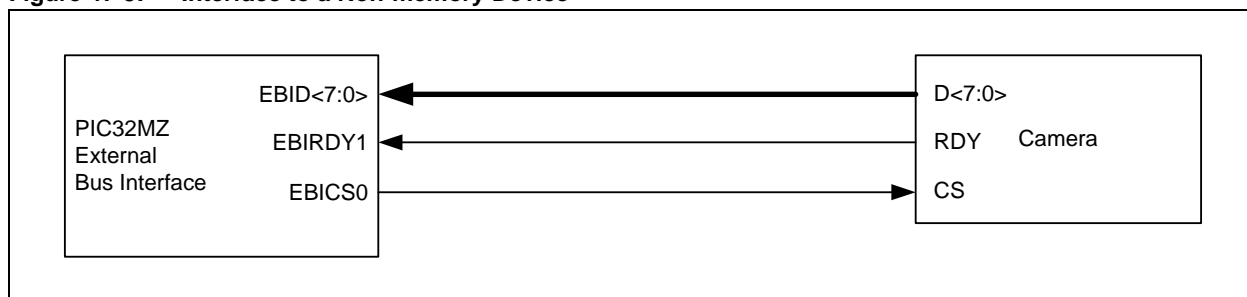
In the case of 8-bit memory devices, the Byte-Select (EBIBS) lines are not necessary and only EBID<7:0> would be connected. Two 8-bit memory devices can share the address and control lines, and only have separate data lines.

47.3.3 Interfacing to Non-Memory Devices

When non-memory devices are connected to the EBI bus, these devices provide a Ready line to indicate when valid data is on the data bus. This Ready line is connected to the EBIRDYx pin to connect to the EBI bus.

Figure 47-5 shows an example of connecting a non-Memory camera device to the EBI bus.

Figure 47-5: Interface to a Non-memory Device

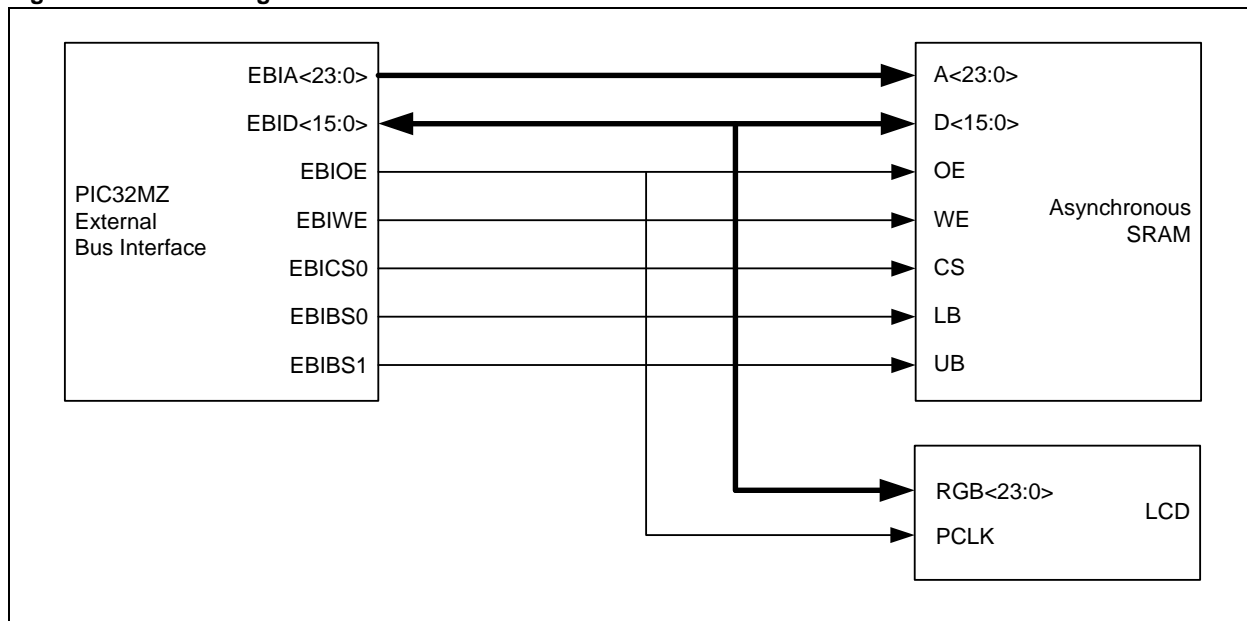


In this case, when the Chip Select line is asserted, the EBI bus would wait to read the data lines until the camera asserts the EBIRDY1 line.

47.3.4 Combining Devices on the EBI Bus

Figure 47-6 shows an example of sharing some elements of the EBI bus to achieve certain design purposes.

Figure 47-6: Sharing a Connection Between SRAM and a LCD



In this case, the SRAM serves as a memory buffer for the LCD. As the EBI goes through the data in the buffer, it is clocked into the LCD, permitting it to display the contents in memory.

47.4 BUS CONFIGURATION

47.4.1 Configuring Address Lines

The CFGEBIA register controls the number of EBIA lines in use and whether, overall, the EBI controls the address, data, and control lines, or if the lines are available for general use.

Each address line has an enable control in CFGEBIA. By setting the corresponding bit, the EBI controls that address line. Address bits in use should be contiguous.

The EBIPINEN bit (CFGEBIA<31>) determines control of the overall EBI lines. Setting the bit allows the EBI to control the corresponding pins. Clearing the bit allows the lines to be used for other purposes.

47.4.2 Configuring Control and Data Lines

The CFGEBIC register determines the settings for the EBICSx, EBIRDYx, EBIBSx, EBIWE, EBIOE, EBIRP, and EBIDx lines.

The EBICSEN0, EBICSEN1, EBICSEN2, and EBICSEN3 bits in the CFGEBIC register determine which EBICS lines are enabled. Setting a bit enables the corresponding EBICSx pin for EBI use. Clearing a bit disables the pin and allows it for general purpose use.

Three bits control the EBIRDYx lines, EBIRDYEN1, EBIRDYEN2, and EBIRDYEN3. When a bit is set, the corresponding EBIRDYx pin is enabled for use by the EBI module. Clearing a bit allows the EBIRDYx pin to be used for general use.

The EBIRDYINV1, EBIRDYINV2, and EBIRDYINV3 bits control the inversion of the EBIRDYx line prior to using it. When a bit is set, the EBIRDYx level will be inverted. When cleared, the signal is not inverted.

The final bit, EBIRDYLVL, determines whether the EBI module uses a level detect or an edge detect to determine when the EBIRDYx line is being asserted. Devices that have mixed assertion logic can thus be combined on the EBI bus by having separate EBIRDYx lines.

The EBIBSEN0, EBIBSEN1, EBIWEEN, EBIOEEN, and EBIRPEN bits control whether the EBIBSx, EBIWE, EBIOE, and EBIRP pins are enabled for use by the EBI module. The pins are enabled when the corresponding control bit is set, or available for general use when the bit is cleared.

The EBIDEN0 and EBIDEN1 bits control which 8-bit portion of the EBIDx bus is enabled. Setting EBIDEN1 enables EBID<15:8> for use by the EBI bus, and setting EBIDEN0 enables the EBID<7:0> lines. Clearing the bits disables the corresponding side of the bus and allows the pins to be used for general use. Note that only enabling EBID<15:8> does not guarantee that the bus will only use 8-bit transfers. If the design requires only 8-bit data transfers, use EBID<7:0>.

47.5 DEVICE CONFIGURATION

The basic configuration for each device or group of devices that will be using a particular Chip Select line includes:

- Configuring the base address of the device
- The type of device
- The size of the device
- The bus timing for the device

47.5.1 Base Address

Configuring the base address of a memory device is done through the EBICSx register. This register sets the beginning address in the PIC32 physical memory space where the device will appear. It is a 16-bit value, which allows the minimum device size (64 KB) to have contiguous locations in memory. In addition, it is not required to have larger memory devices appear lower in memory than smaller devices. For example, it is possible to have a 64 KB device at the start of EBI memory (0x20000000), adjacent to a 16 MB device, which would start at 0x20010000.

Example code for configuring the EBICSx registers to handle four memory devices is provided in [Example 47-1](#). This example maps a 1 MB device, followed by a 64 KB device, followed by another 1 MB device, and finally a 16 MB device.

Example 47-1:

```
/* Device 1: 1 MB Flash going from 0x20000000 to 0x200FFFFF */
EBICS0 = 0x20000000;
/* Device 2: 64 KB SRAM going from 0x20100000 to 0x2010FFFF */
EBICS1 = 0x20100000;
/* Device 3: 1 MB Flash going from 0x20110000 to 0x2020FFFF */
EBICS2 = 0x20110000;
/* Device 4: 16 MB SRAM going from 0x20210000 to 0x2120FFFF */
EBICS3 = 0x20210000;
```

47.5.2 Device Type

The EBI bus needs to know what type of device is attached to a particular chip select line. This is done through the MEMTYPE field in the EBIMSKx register of each Chip Select. There are two options available, NOR Flash (MEMTYPE = 0b010) and SRAM (MEMTYPE = 0b001). Non-memory devices would not require this to be set.

Example code for configuring the memory types for the devices previously listed in [Example 47-1](#) is shown in [Example 47-2](#).

Example 47-2:

```
EBIMSK0bits.MEMTYPE = 0b010; /* Device 1: NOR Flash */
EBIMSK1bits.MEMTYPE = 0b001; /* Device 2: SRAM */
EBIMSK2bits.MEMTYPE = 0b010; /* Device 3: NOR Flash */
EBIMSK3bits.MEMTYPE = 0b001; /* Device 4: SRAM */
```

47.5.3 Device Size

In addition to the type of memory device, the EBI bus needs to know the size of the attached device. The device size is configured by the MEMSIZE<4:0> (EBIMSKx<4:0>) bits.

The smallest memory size that can be accommodated by the EBI in a contiguous manner is 64 KB. Smaller devices would alias to that size, which results in gaps in the memory map.

Example code for configuring the device size for the devices listed in [Example 47-2](#) is shown in [Example 47-3](#).

Example 47-3:

```
EBIMSK0bits.MEMSIZE = 0b00101; /* Device 1: 1 MB */
EBIMSK1bits.MEMSIZE = 0b00001; /* Device 2: 64 KB */
EBIMSK2bits.MEMSIZE = 0b00101; /* Device 3: 1 MB */
EBIMSK3bits.MEMSIZE = 0b01001; /* Device 4: 16 MB */
```

47.5.4 Bus Timing

The EBI bus can handle a variety of memory timing requirements. There are three registers that configure the timing parameters, EBISMT0, EBISMT1, and EBISMT2. Identical memory devices should use the same EBISMTx register for timing purposes.

The REGSEL<2:0> bits (EBIMSKx<10:8>) are used to set which EBISMTx register will be used for each Chip Select line. Example code for setting up the bus timing is shown in [Example 47-4](#).

Example 47-4:

```
EBIMSK0bits.REGSEL = 0b000; /* Device 1: EBISMT0 */
EBIMSK1bits.REGSEL = 0b001; /* Device 2: EBISMT1 */
EBIMSK2bits.REGSEL = 0b000; /* Device 3: EBISMT0 */
EBIMSK3bits.REGSEL = 0b010; /* Device 4: EBISMT2 */
```

47.5.5 Configuring Bus Timing

Since devices have different timing considerations, it is necessary to configure the EBI bus to automatically handle those timing differences. By configuring the EBISMTx register, the bus will adjust read and write timings as needed.

If a device has a Ready pin, the RDYMODE bit (EBISMTx<26>) is set.

For devices with Page mode, the PAGEMODE bit (EBISMTx<23>) enables support for the device in the EBI module. Then, the PAGESIZE<1:0> bits (EBISMTx<25:24>) configure the Page Size so that the EBI knows how many words to write for each page.

The remaining bits in the EBISMTx register control how the EBI bus timing works. Refer to the diagrams in [47.6 “Timing Diagrams”](#) to see visual representations of the bus cycles, and where the timing parameters are needed. [Table 47-4](#) lists the individual timing parameters, and what they affect.

Table 47-4: Timing Parameters

Parameter	EBISMTx Register Bit Name	Description	Effect
tPRC	TPRC<3:0>	Page mode read cycle time.	Read cycle time is TPRC+1 clock cycles.
tBTA	TBTA<2:0>	Bus turnaround time.	Clock cycles (0-7) for read-to-write, write-to-read, and read-to-read (different CS) transitions.
tWP	TWP<5:0>	Write Pulse Width.	Write pulse width is TWP+1 clock cycles.
tWR	TWR<1:0>	Write address/data hold time.	Number of clock cycles to hold address or data on the bus.
tAS	TAS<1:0>	Write address setup time.	Clock cycles for address setup time. A value of '0' is only valid in case of SRAM.
tRC	TRC<5:0>	Read cycle time (non-Page mode memory).	Read cycle time is TRC + 1 clock cycles.
tRPD	TRPD<11:0>	Flash memory reset time.	Clock cycles after Flash reset before a read/write access.

Note: Clock cycles refers to system clock cycles, and is dependent on the speed of the SYSCLK when the system is running.

47.5.6 Reading and Writing to the EBI Module

Example 47-5 shows code that uses both reads and writes to SRAM attached to the EBI module. This example assumes a 200 MHz System Clock and that the TLB and MMU are set up correctly.

Example 47-5:

```
// Global Defines
#define SRAM_ADDR_CS0 0xC0000000
#define RAM_SIZE      2*1024*1024

int main(void)
{
    uint32_t loop;
    uint32_t *addr;
    uint32_t val;

    // Note: ISSI SRAM (IS64WV102416BLL). All of the parameters of the EBI
    // module are set up based on the timing of this RAM.

    // Enable address lines [0:17]
    // Controls access of pins shared with PMP
    CFGEBIA = 0x800FFFFF;

    // Enable write enable pin
    // Enable output enable pin
    // Enable byte select pin 0
    // Enable byte select pin 1
    // Enable Chip Select 0
    // Enable data pins [0:15]
    CFGEBIC = 0x00003313;

    // Connect CS0 to physical address
    EBICS0 = 0x20000000;

    // Memory size is set as 2 MB
    // Memory type is set as SRAM
    // Uses timing numbers in EBISMT0
    EBIMSK0 = 0x00000026;

    // Configure EBISMT0
    // ISSI device has read cycles time of 10 ns
    // ISSI device has address setup time of 0ns
    // ISSI device has address/data hold time of 2.5 ns
    // ISSI device has Write Cycle Time of 10 ns
    // Bus turnaround time is 0 ns
    // No page mode
    // No page size
    // No RDY pin
    EBISMT0 = 0x000029CA;

    // Keep default data width to 16-bits
    EBISMCON = 0x00000000;

    addr = (uint32_t *)SRAM_ADDR_CS0;
    // Write loop

    for (loop=0; loop < RAM_SIZE/4; loop++)
    {
        *addr++ = 0xAA55AA55;
    }

    // Read and verify loop
    addr = (uint32_t *)SRAM_ADDR_CS0;    // reset address to beginning

    for (loop=0 ; loop < RAM_SIZE/4; loop++)
    {
        val = *addr++;
        if (val != 0xAA55AA55)
        {
            return (0);    // Exit Failure
        }
    }

    return (1); // exit success
}
```

47.6 TIMING DIAGRAMS

47.6.1 Read/Write Access

Figure 47-7 shows the timing diagram of a read access. The EBI module checks the EBIRDYx pin after the tRC read access time. You need to ensure that the EBIRDYx signal is being driven with respect to the System Clock (SYSCLK). This avoids a possible race condition if EBIRDYx is driven by a different clock. When EBIRDYx is high, the EBI module latches the read data at the next rising clock edge.

Figure 47-7: Read Access of the Device with Ready Signal

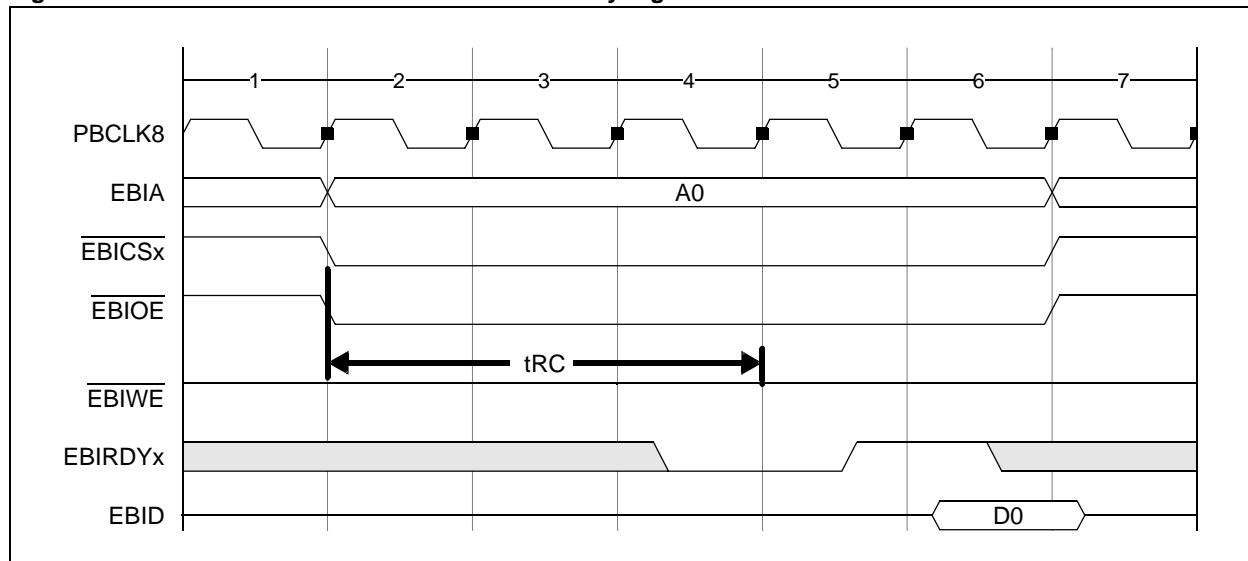
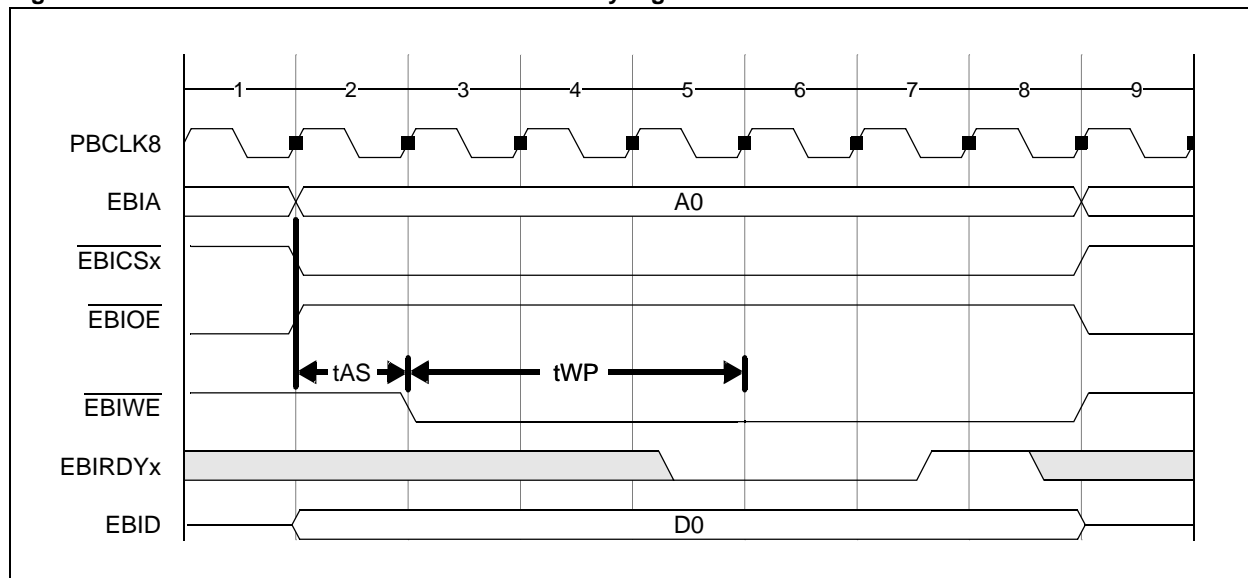


Figure 47-8 shows the timing diagram of a write access. The EBI module checks the EBIRDYx pin after a time equal to tAS(address setup time) + tWP(write period). When EBIRDYx is high, the write is finished. You need to ensure that the EBIRDYx signal is being driven with respect to the SYSCLK. This avoids a possible race condition if EBIRDYx is driven by a different clock.

Figure 47-8: Write Access of the Device with Ready Signal



47.6.2 Static Memory

The static memory timing diagrams assume an internal delay of two System Bus clock cycles, which is the delay for a cycle to be active on the bus to the clock cycle where the corresponding memory command is seen on the memory bus.

Figure 47-9 shows the timing for a SRAM and Flash read operation, where t_{RC} is the read cycle time.

Figure 47-9: SRAM and Flash Memory Read Timing

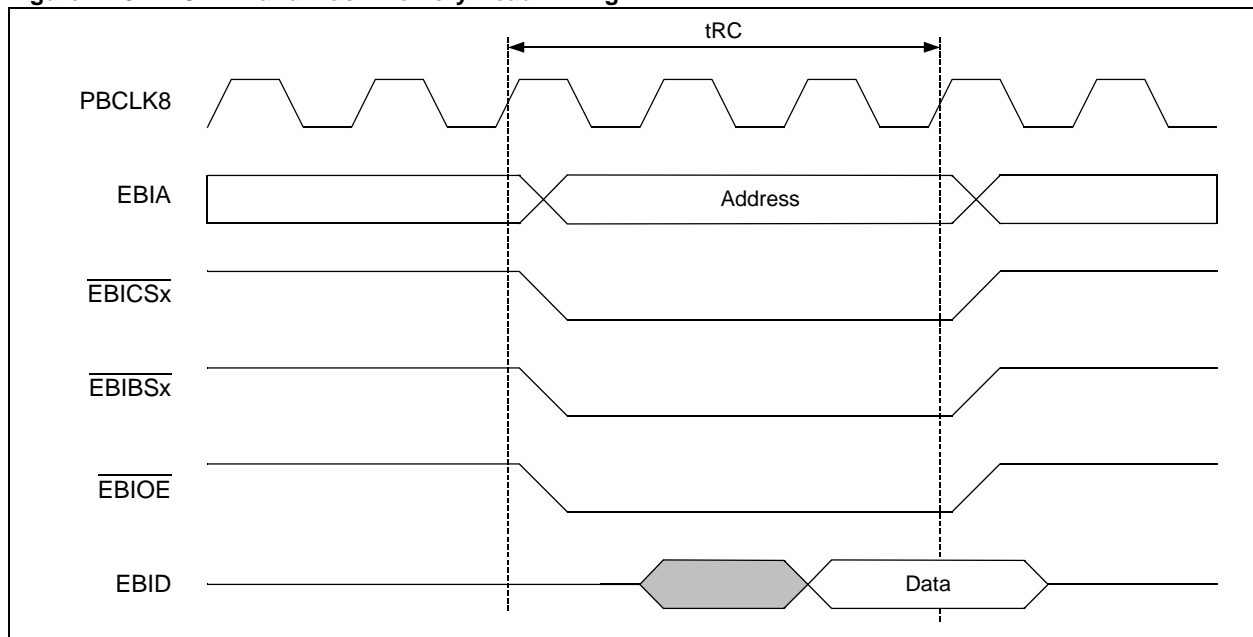
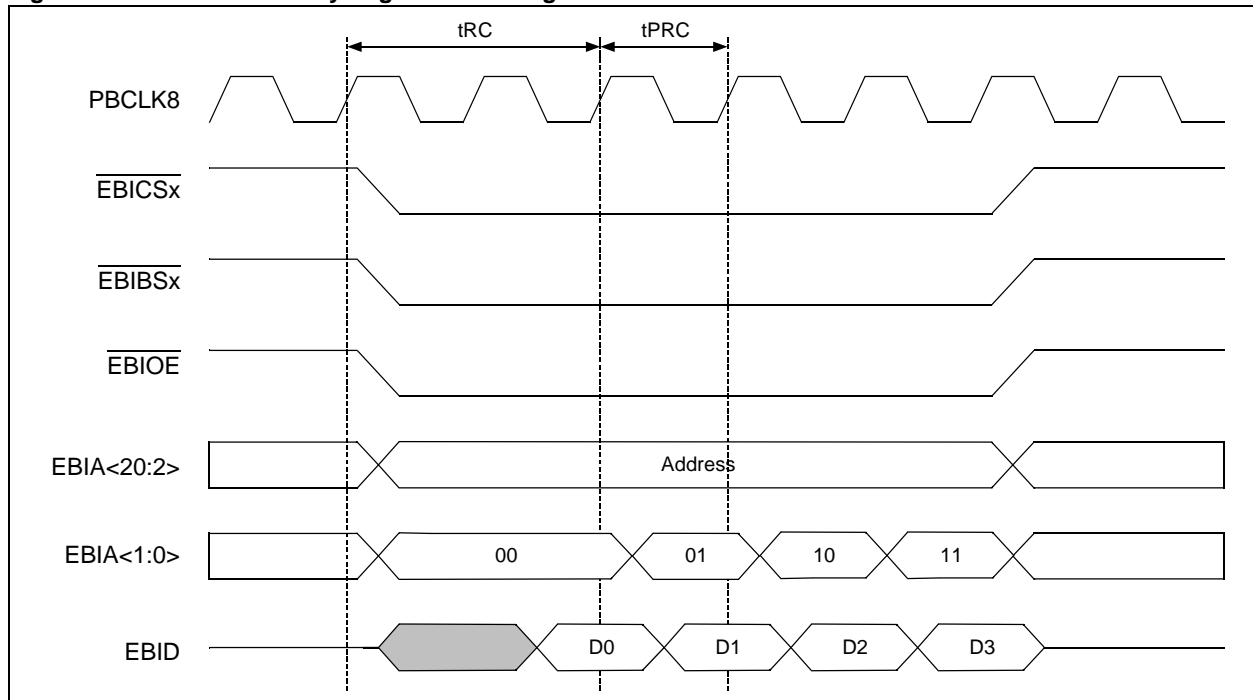


Figure 47-10 shows the Flash page read operation, where t_{RC} is the read cycle time and t_{PRC} is the page mode read cycle time.

Figure 47-10: Flash Memory Page Read Timing



Section 47. External Bus Interface (EBI)

Figure 47-11 shows the SRAM and Flash timing for a write operation, where t_{AS} is the address setup time, t_{WP} is the write pulse period, and t_{WR} is the write recovery time.

Figure 47-11: SRAM and Flash Write Timing

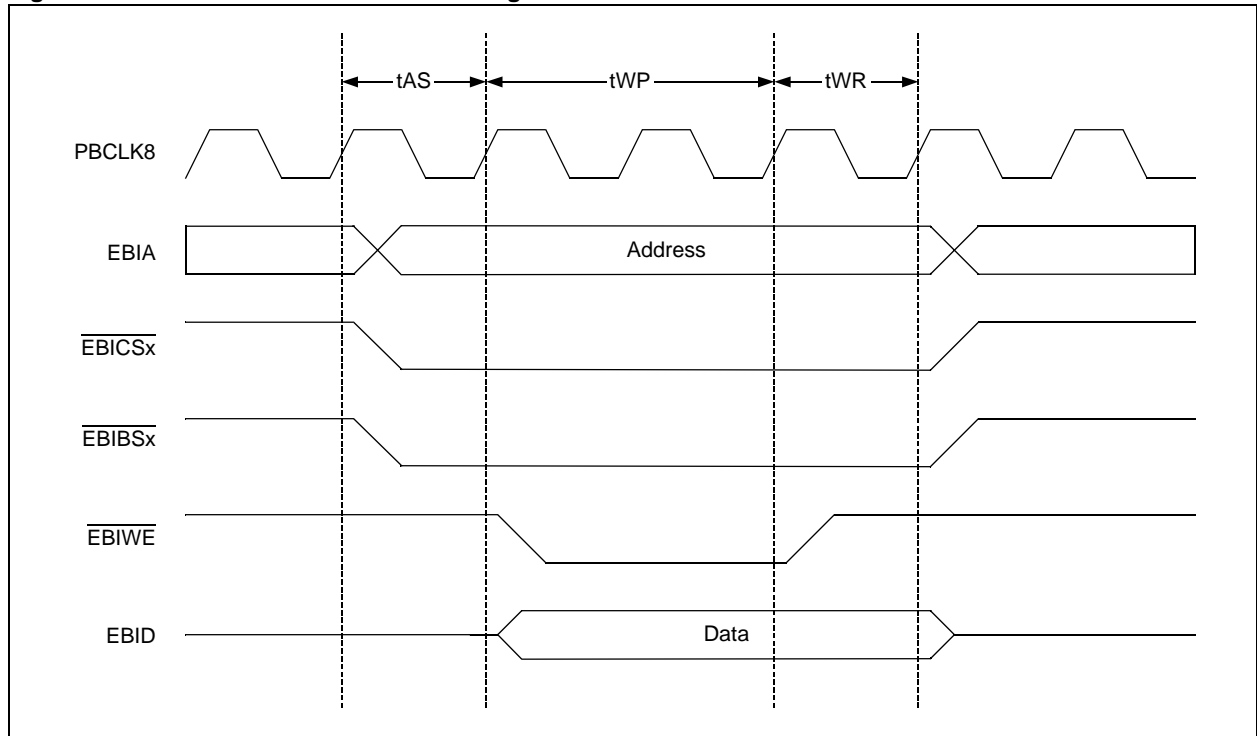
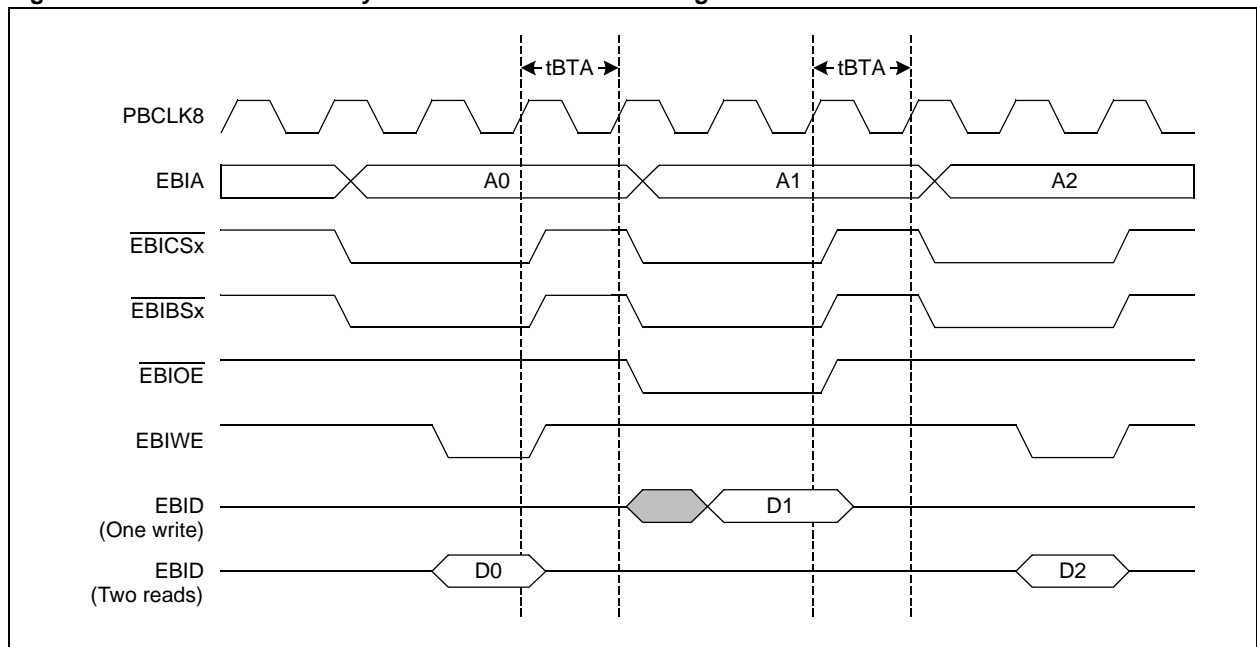


Figure 47-12 shows an example of inserting one idle clock for memory data bus turnaround time, where t_{BTA} is the number of idle clock cycles.

Figure 47-12: External Memory Data Bus Turnaround Timing



47.7 EFFECTS OF RESET

47.7.1 On Reset

All EBI module registers are forced to their reset states on a device Reset. In addition, the CFGEBIA and CFGEBIC registers are forced to their Reset states.

47.7.2 After Reset

The EBI module is not active, and must be initialized prior to accessing memory in the EBI address space. In addition, the Translation Lookaside Buffer (TLB) of the CPU must be set up prior to accessing any external device.

47.8 OPERATION IN POWER-SAVING MODES

47.8.1 Sleep Mode

When the device enters Sleep mode, the EBI module is disabled and placed into a low-power state where no clocking occurs in the module.

47.8.2 Idle Mode

When the device enters Idle mode, the EBI module continues to operate, and can execute transfers between internal and external memory.

47.8.3 Debug Mode

The behavior of the EBI module is unaltered in Debug mode.

47.9 RELATED APPLICATION NOTES

This section lists application notes that are related to this section of the manual. These application notes may not be written specifically for the PIC32 device family, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to the External Bus Interface (EBI) are:

Title	Application Note #
No related application notes at this time.	N/A

Note: Please visit the Microchip web site (www.microchip.com) for additional application notes and code examples for the PIC32 family of devices.

47.10 REVISION HISTORY

Revision A (November 2013)

This is the initial released version of this document.

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, KEELQ, KEELQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC³² logo, rPIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.


Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniscient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICtail, REAL ICE, rLAB, Select Mode, SQI, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2013, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

ISBN: 978-1-62077-645-2

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
= ISO/TS 16949 =

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://www.microchip.com/support>
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Hangzhou
Tel: 86-571-2819-3187
Fax: 86-571-2819-3189

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880-3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Dusseldorf
Tel: 49-2129-3766400

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Pforzheim
Tel: 49-7231-424750

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Venice
Tel: 39-049-7625286

Netherlands - Druenen
Tel: 31-416-690399
Fax: 31-416-690340

Poland - Warsaw
Tel: 48-22-3325737

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820