Section 15. Quadrature Encoder Interface (QEI)

HIGHLIGHTS

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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 dsPIC33E/PIC24E devices.

Please consult the note at the beginning of the **"Quadrature Encoder Interface (QEI)"** 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

15.1 INTRODUCTION

The Quadrature Encoder Interface (QEI) module provides the interface to incremental encoders for obtaining mechanical position data. Quadrature encoders, also known as incremental encoders or optical encoders, detect position and speed of rotating motion systems. Quadrature encoders enable closed-loop control of motor control applications, such as Switched Reluctance (SR) and AC Induction Motors (ACIM).

A typical quadrature encoder includes a slotted wheel attached to the shaft of the motor and an Emitter/Detector module that senses the slots in the wheel. Typically, three output channels, Phase A (QEA), Phase B (QEB) and Index (INDX) provide information on the movement of the motor shaft, including distance and direction.

The two channels, Phase A (QEA) and Phase B (QEB), are typically 90º out of phase with respect to each other. The Phase A and Phase B channels have a unique relationship. If Phase A leads Phase B, the direction of the motor is deemed positive or forward. If Phase A lags Phase B, the direction of the motor is deemed negative or reverse. The Index pulse occurs once per mechanical revolution and is used as a reference to indicate an absolute position. Figure 15-1 illustrates the quadrature encoder interface signals.

The quadrature signals from the encoder can have four unique states (`01`, `00`, `10` and `11`) that reflect the relationship between QEA and QEB. Figure 15-1 illustrates these states for one count cycle. The order of the states get reversed when the direction of travel changes.

The quadrature decoder increments or decrements the 32-bit Up/Down Position Counter (POSCNT) for each change of state. The counter increments when QEA leads QEB and decrements when QEB leads QEA.

Figure 15-1: Quadrature Encoder Interface Signals

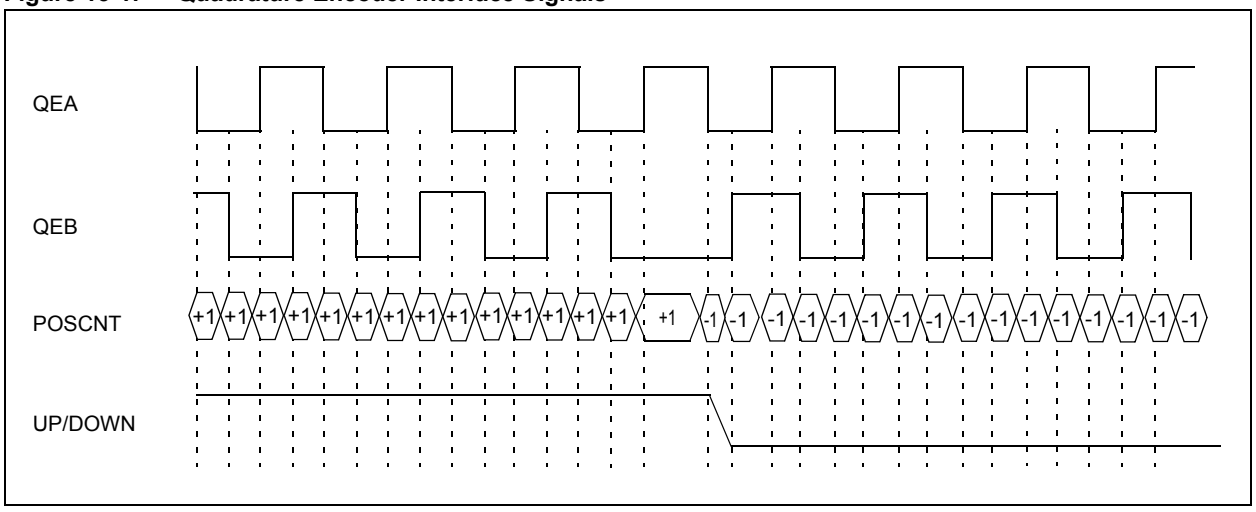


Table 15-1 shows the truth table that describes how the quadrature signals are decoded.

Table 15-1: Truth Table for Quadrature Encoder

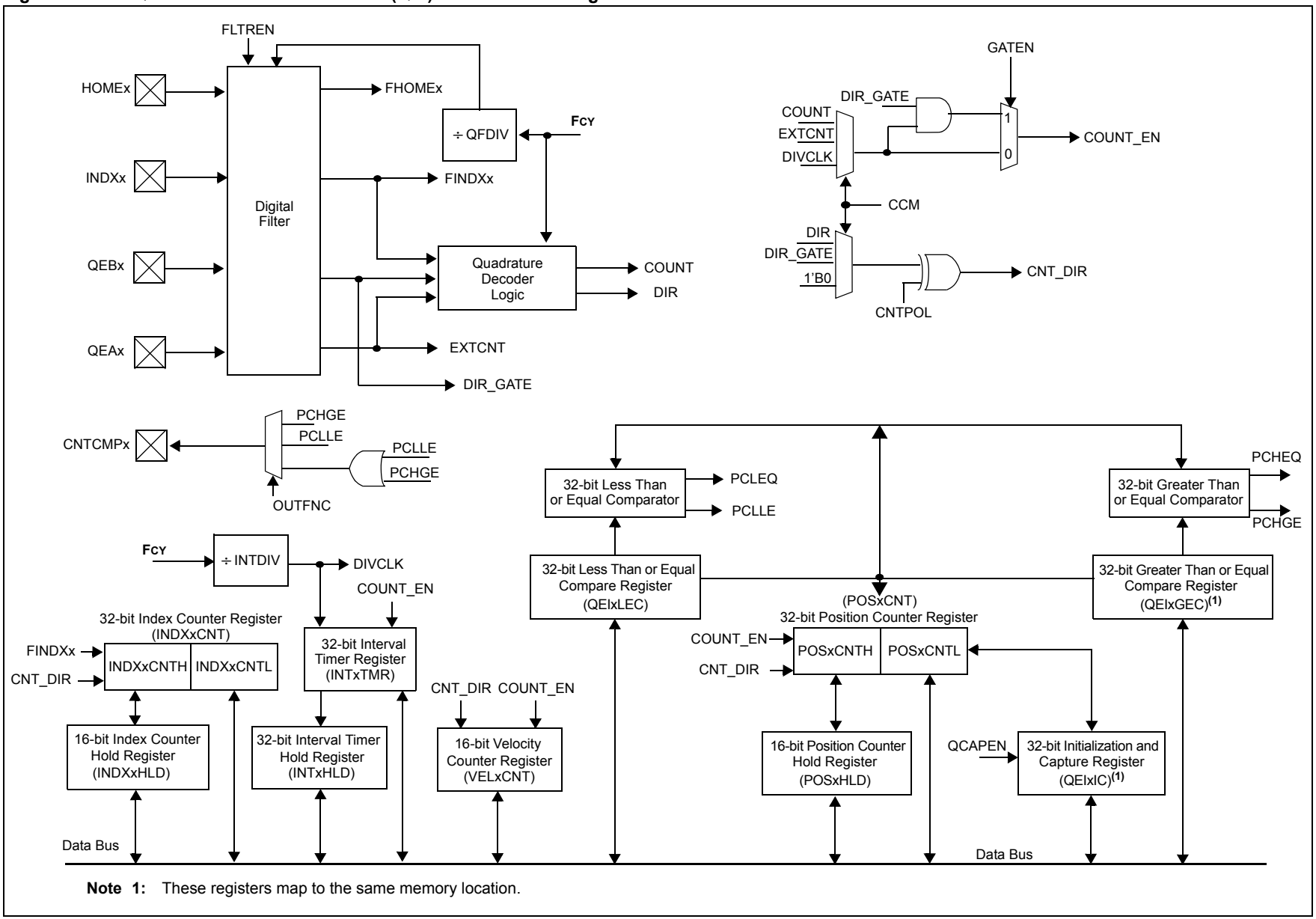
Current Quadrature State		Previous Quadrature State		Action
QA	QB	QA	QB	
1	1	1	1	No count or direction change
1	1	1	0	Count up
1	1	0	1	Count down
1	1	0	0	Invalid state change, ignore
1	0	1	1	Count down
1	0	1	0	No count or direction change
1	0	0	1	Invalid state change, ignore
1	0	0	0	Count up
0	1	1	1	Count up
0	1	1	0	Invalid state change, ignore
0	1	0	1	No count or direction change
0	1	0	0	Count down
0	0	1	1	Invalid state change, ignore
0	0	1	0	Count down
0	0	0	1	Count up
0	0	0	0	No count or direction change

Figure 15-2 illustrates the simplified block diagram of the QEI module. The QEI module consists of decoder logic to interpret the Phase A (QEA) and Phase B (QEB) signals, and an up/down counter to accumulate the count. The counter pulses are generated when the quadrature state changes. The count direction information must be maintained in a register until a direction change is detected. The module also includes digital noise filters, which condition the input signal.

The QEI module consists of the following major features:

- Four input pins: two phase signals, an index pulse and a home pulse
- Programmable digital noise filters on inputs
- Quadrature decoder providing counter pulses and count direction
- Count direction status
- x4 count resolution
- Index (INDX) pulse to reset the position counter
- General purpose 32-bit Timer/Counter mode
- Interrupts generated by QEI or counter events
- 16-bit velocity counter
- 32-bit position counter
- 32-bit index pulse counter
- 32-bit interval timer
- 32-bit position Initialization/Capture/Compare High Word register
- 32-bit position Initialization/Capture/Compare Low Word register
- 4X Quadrature Count mode
- External Up/Down Count mode
- External Gated Count mode
- External Gated Timer mode
- Interval Timer mode

Figure 15-2: Quadrature Encoder Interface (QEI) Module Block Diagram



Note 1: These registers map to the same memory location.

15.2 CONTROL AND STATUS REGISTERS

The following registers are associated with the QEI module:

- **QEIxCON: QEI Control Register**

  This register controls the QEI module operation.

- **QEIxIOC: QEI I/O Control Register**

  This register controls the input/output mode of the QEI module.

- **QEIxSTAT: QEI Status Register**

  This register provides the interrupt enable flag and status flag to indicate the status of the QEI module.

- **POSxCNTH: Position Counter High Word Register**

  This register is the high word of the position counter.

- **POSxCNTL: Position Counter Low Word Register**

  This register is the low word of the position counter.

- **POSxHLD: Position Counter Hold Register**

  This register holds the contents of the POSxCNTH register during the read or write operation.

- **VELxCNT: Velocity Counter Register**

  This register stores the velocity value.

- **INDXxCNTH: Index Counter High Word Register**

  This register is the high word of the index counter.

- **INDXxCNTL: Index Counter Low Word Register**

  This register is the low word of the index counter.

- **INDXxHLD: Index Counter Hold Register**

  This register holds the contents of the INDXxCNTH register during the read or write operation.

- **QEIxICH: Initialization/Capture High Word Register**

  This register is the high word of the QEIxIC register.

- **QEIxICL: Initialization/Capture Low Word Register**

  This register is the low word of the QEIxIC register.

- **QEIxLECH: Less Than or Equal Compare High Word Register**

  This register is the high word 16-bit less than or equal compare register.

- **QEIxLECL: Less Than or Equal Compare Low Word Register**

  This register is the low word 16-bit less than or equal compare register.

- **QEIxGECH: Greater Than or Equal Compare High Word Register**

  This register is the high word 16-bit greater than or equal compare register.

- **QEIxGECL: Greater Than or Equal Compare Low Word Register**

  This register is the low word 16-bit greater than or equal compare register.

- **INTxTMRH: Interval Timer High Word Register**

  This register is the high word of the Counter Pulse Interval Timer register.

- **INTxTMRL: Interval Timer Low Word Register**

  This register is the low word of the Counter Pulse Interval Timer register.

- **INTxHLDH: Interval Timer Hold High Word Register**

  This register holds the content of high word of the Interval Timer Hold register.

- **INTxHLDL: Interval Timer Hold Low Word Register**

  This register holds the content of low word of the Interval Timer Hold register.

Register 15-1: QEIxCON: QEI Control Register

R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QEIEN	—	QEISIDL	PIMOD<2:0>(1)			IMV<1:0>(2)	
bit 15							bit 8

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	INTDIV<2:0>(3)			CNTPOL	GATEN	CCM<1:0>	
bit 7							bit 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 15 **QEIEN:** Quadrature Encoder Interface Module Counter Enable bit
1 = Module counters are enabled
0 = Module counters are disabled, but SFRs can be read or written

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

bit 13 **QEISIDL:** Stop in Idle Mode bit
1 = Discontinue module operation when device enters Idle mode
0 = Continue module operation in Idle mode

bit 12-10 **PIMOD<2:0>:** Position Counter Initialization Mode Select bits(1)
111 = Reserved
110 = Modulo Count mode for position counter
101 = Resets the position counter when the position counter equals QEIxGEC register
100 = Second index event after home event initializes position counter with contents of QEIxIC register
011 = First index event after home event initializes position counter with contents of QEIxIC register
010 = Next index input event initializes the position counter with contents of QEIxIC register
001 = Every Index input event resets the position counter
000 = Index input event does not affect position counter

bit 9-8 **IMV<1:0>:** Index Match Value bits(2)
11 = Index match occurs when QEB = 1 and QEA = 1
10 = Index match occurs when QEB = 1 and QEA = 0
01 = Index match occurs when QEB = 0 and QEA = 1
00 = Index input event does not affect position counter

bit 7 **Unimplemented:** Read as '0'

bit 6-4 **INTDIV<2:0>:** Timer Input Clock Prescale Select bits (Interval timer, Main timer (position counter), velocity counter and index counter internal clock divider select)(3)
111 = 1:256 prescale value
110 = 1:64 prescale value
101 = 1:32 prescale value
100 = 1:16 prescale value
011 = 1:8 prescale value
010 = 1:4 prescale value
001 = 1:2 prescale value
000 = 1:1 prescale value

Note 1: When CCM = 10 or CCM = 11, all of the QEI counters operate as timers and the PIMOD<2:0> bits are ignored.

2: When CCM = 00 and QEA and QEB values match Index Match Value (IMV), the POSxCNTH and POSxCNTL registers are reset.

3: The selected clock rate should be at least twice the expected maximum quadrature count rate.

Register 15-1: QEIxCON: QEI Control Register (Continued)

bit 3 **CNTPOL:** Position and Index Counter/Timer Direction Select bit
1 = Counter direction is negative unless modified by external Up/Down signal
0 = Counter direction is positive unless modified by external Up/Down signal

bit 2 **GATEN:** External Count Gate Enable bit
1 = External gate signal controls position counter operation
0 = External gate signal does not affect position counter/timer operation

bit 1-0 **CCM<1:0>:** Counter Control Mode Selection bits
11 = Internal Timer mode
10 = External clock count with external Gate mode
01 = External clock count with external Up/Down mode
00 = Quadrature Encoder mode

Note 1: When CCM = 10 or CCM = 11, all of the QEI counters operate as timers and the PIMOD<2:0> bits are ignored.

2: When CCM = 00 and QEA and QEB values match Index Match Value (IMV), the POSxCNTH and POSxCNTL registers are reset.

3: The selected clock rate should be at least twice the expected maximum quadrature count rate.

Register 15-2: QEIxIOC: QEI I/O Control Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QCAPEN	FLTREN	QFDIV<2:0>			OUTFNC<1:0>		SWPAB
bit 15							bit 8

R/W-0	R/W-0	R/W-0	R/W-0	R-x	R-x	R-x	R-x
HOMPOL	IDXPOL	QEBPOL	QEAPOL	HOME	INDEX	QEB	QEA
bit 7							bit 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 15 **QCAPEN:** Position Counter Input Capture Enable bit
1 = HOMEx input event (positive edge) triggers a position capture event
0 = HOMEx input event (positive edge) does not trigger a position capture event

bit 14 **FLTREN:** QEA/QEB/INDX/HOMEx Digital Filter Enable bit
1 = Input Pin Digital filter is enabled
0 = Input Pin Digital filter is disabled (bypassed)

bit 13-11 **QFDIV<2:0>:** QEA/QEB/INDX/HOMEx Digital Input Filter Clock Divide Select bits
111 = 1:256 clock divide
110 = 1:64 clock divide
101 = 1:32 clock divide
100 = 1:16 clock divide
011 = 1:8 clock divide
010 = 1:4 clock divide
001 = 1:2 clock divide
000 = 1:1 clock divide

bit 10-9 **OUTFNC<1:0>:** QEI Module Output Function Mode Select bits
11 = The CNTCMPx pin goes high when POSxCNT ≤ QEIxLEC or POSxCNT ≥ QEIxGEC
10 = The CNTCMPx pin goes high when POSxCNT ≤ QEIxLEC
01 = The CNTCMPx pin goes high when POSxCNT ≥ QEIxGEC
00 = Output is disabled

bit 8 **SWPAB:** Swap QEA and QEB Inputs bit
1 = QEAx and QEBx are swapped prior to quadrature decoder logic
0 = QEAx and QEBx are not swapped

bit 7 **HOMPOL:** HOMEx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

bit 6 **IDXPOL:** INDXx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

bit 5 **QEBPOL:** QEBx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

bit 4 **QEAPOL:** QEAx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

Register 15-2: QEIxIOC: QEI I/O Control Register (Continued)

bit 3 **HOME:** Status of HOMEx Input Pin after Polarity Control bit (read-only)
1 = Pin is at logic '1', if HOMPOL bit is set to '0'
Pin is at logic '0', if HOMPOL bit is set to '1'
0 = Pin is at logic '0', if HOMPOL bit is set to '0'
Pin is at logic '1', if HOMPOL bit is set to '1'

bit 2 **INDEX:** Status of INDXx Input Pin after Polarity Control bit (Read-Only)
1 = Pin is at logic '1', if IDXPOL bit is set to '0'
Pin is at logic '0', if IDXPOL bit is set to '1'
0 = Pin is at logic '0', if IDXPOL bit is set to '0'
Pin is at logic '1', if IDXPOL bit is set to '1'

bit 1 **QEB:** Status of QEBx Input Pin after Polarity Control and SWPAB Pin Swapping bit (read-only)
1 = Physical pin QEB is at logic '1', if QEBPOL bit is set to '0' and SWPAB bit is set to '0'
Physical pin QEB is at logic '0', if QEBPOL bit is set to '1' and SWPAB bit is set to '0'
Physical pin QEA is at logic '1', if QEBPOL bit is set to '0' and SWPAB bit is set to '1'
Physical pin QEA is at logic '0', if QEBPOL bit is set to '1' and SWPAB bit is set to '1'

0 = Physical pin QEB is at logic '0', if QEBPOL bit is set to '0' and SWPAB bit is set to '0'
Physical pin QEB is at logic '1', if QEBPOL bit is set to '1' and SWPAB bit is set to '0'
Physical pin QEA is at logic '0', if QEBPOL bit is set to '0' and SWPAB bit is set to '1'
Physical pin QEA is at logic '1', if QEBPOL bit is set to '1' and SWPAB bit is set to '1'

bit 0 **QEA:** Status of QEAx Input Pin after Polarity Control and SWPAB Pin Swapping bit (read-only)
1 = Physical pin QEA is at logic '1', if QEAPOL bit is set to '0' and SWPAB bit is set to '0'
Physical pin QEA is at logic '0', if QEAPOL bit is set to '1' and SWPAB bit is set to '0'
Physical pin QEB is at logic '1', if QEAPOL bit is set to '0' and SWPAB bit is set to '1'
Physical pin QEB is at logic '0', if QEAPOL bit is set to '1' and SWPAB bit is set to '1'

0 = Physical pin QEA is at logic '0', if QEAPOL bit is set to '0' and SWPAB bit is set to '0'
Physical pin QEA is at logic '1', if QEAPOL bit is set to '1' and SWPAB bit is set to '0'
Physical pin QEB is at logic '0', if QEAPOL bit is set to '0' and SWPAB bit is set to '1'
Physical pin QEB is at logic '1', if QEAPOL bit is set to '1' and SWPAB bit is set to '1'

Register 15-3: QEIxSTAT: QEI Status Register

U-0	U-0	HS, R/C-0	R/W-0	HS, R/C-0	R/W-0	HS, R/C-0	R/W-0
—	—	PCHEQIRQ	PCHEQIEN	PCLEQIRQ	PCLEQIEN	POSOVIRQ	POSOVIEN
bit 15							bit 8

HS, R/C-0	R/W-0	HS, R/C-0	R/W-0	HS, R/C-0	R/W-0	HS, R/C-0	R/W-0
PCIIRQ(1)	PCIIEN	VELOVIRQ	VELOVIEN	HOMIRQ	HOMIEN	IDXIRQ	IDXIEN
bit 7							bit 0

Legend: C = Clearable bit		HS = Set in Hardware	
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 15-14 **Unimplemented:** Read as '0'

bit 13 **PCHEQIRQ:** Position Counter Greater Than or Equal Compare Status bit
1 = POSxCNT ≥ QEIxGEC
0 = POSxCNT < QEIxGEC

bit 12 **PCHEQIEN:** Position Counter Greater Than or Equal Compare Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 11 **PCLEQIRQ:** Position Counter Less Than or Equal Compare Status bit
1 = POSxCNT ≤ QEIxLEC
0 = POSxCNT > QEIxLEC

bit 10 **PCLEQIEN:** Position Counter Less Than or Equal Compare Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 9 **POSOVIRQ:** Position Counter Overflow Status bit
1 = Overflow has occurred
0 = No overflow has occurred

bit 8 **POSOVIEN:** Position Counter Overflow Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 7 **PCIIRQ:** Position Counter (Homing) Initialization Process Complete Status bit(1)
1 = POSxCNT was reinitialized
0 = POSxCNT was not reinitialized

bit 6 **PCIIEN:** Position Counter (Homing) Initialization Process Complete Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 5 **VELOVIRQ:** Velocity Counter Overflow Status bit
1 = Overflow has occurred
0 = No overflow has occurred

bit 4 **VELOVIEN:** Velocity Counter Overflow Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 3 **HOMIRQ:** Status Flag for Home Event Status bit
1 = Home event has occurred
0 = No Home event has occurred

Note 1: This status bit is only applicable to PIMOD<2:0> modes '011' and '100'.

Register 15-3: QEIxSTAT: QEI Status Register (Continued)

bit 2 **HOMIEN:** Home Input Event Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 1 **IDXIRQ:** Status Flag for Index Event Status bit
1 = Index event has occurred
0 = No Index event has occurred

bit 0 **IDXIEN:** Index Input Event Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

Note 1: This status bit is only applicable to PIMOD<2:0> modes '011' and '100'.

Register 15-4: POSxCNTH: Position Counter High Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
POSCNT<31:24>							
bit 15							bit 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
POSCNT<23:16>							
bit 7							bit 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 15-0 **POSCNT<31:16>:** High word used to form 32-bit Position Counter register (POSxCNT) bits

Register 15-5: POSxCNTL: Position Counter Low Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
POSCNT<15:8>							
bit 15							bit 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
POSCNT<7:0>							
bit 7							bit 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 15-0 **POSCNT<15:0>:** Low word used to form 32-bit Position Counter register (POSxCNT) bits

Register 15-6: POSxHLD: Position Counter Hold Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
POSHLD<15:8>							
bit 15							bit 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
POSHLD<7:0>							
bit 7							bit 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 15-0 **POSHLD<15:0>:** Hold register bits for reading and writing Position Counter High Word register (POSxCNTH) bits

Register 15-7: VELxCNT: Velocity Counter Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
VELCNT<15:8>							
bit 15							bit 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
VELCNT<7:0>							
bit 7							bit 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 15-0 **VELCNT<15:0>:** Velocity Counter bits

Register 15-8: INDXxCNTH: Index Counter High Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
INDXCNT<31:24>							
bit 15							bit 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
INDXCNT<23:16>							
bit 7							bit 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 15-0 **INDXCNT<31:16>:** High word used to form 32-bit Index Counter register (INDXxCNT) bits

Register 15-9: INDXxCNTL: Index Counter Low Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
INDXCNT<15:8>							
bit 15							bit 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
INDXCNT<7:0>							
bit 7							bit 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 15-0 **INDXCNT<15:0>:** Low word used to form 32-bit Index Counter register (INDXxCNT) bits

Register 15-10: INDXxHLD: Index Counter Hold Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
INDXHLD<15:8>							
bit 15							bit 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
INDXHLD<7:0>							
bit 7							bit 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 15-0 **INDXHLD<15:0>:** Hold register for reading and writing Index Counter High Word register (INDXxCNTH) bits

Register 15-11: QEIxICH: Initialization/Capture High Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QEIIC<31:24>							
bit 15							bit 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
QEIIC<23:16>							
bit 7							bit 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 15-0 **QEIIC<31:16>:** High word used to form 32-bit Initialization/Capture register (QEIxIC) bits

Register 15-12: QEIxICL: Initialization/Capture Low Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QEIIC<15:8>							
bit 15							bit 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
QEIIC<7:0>							
bit 7							bit 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 15-0 **QEIIC<15:0>:** Low word used to form 32-bit Initialization/Capture register (QEIxIC) bits

Register 15-13: QEIxLECH: Less Than or Equal Compare High Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QEILEC<31:24>							
bit 15							bit 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
QEILEC<23:16>							
bit 7							bit 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 15-0 **QEILEC<31:16>:** High word used to form 32-bit Less Than or Equal Compare register (QEIxLEC) bits

Register 15-14: QEIxLECL: Less Than or Equal Compare Low Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QEILEC<15:8>							
bit 15							bit 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
QEILEC<7:0>							
bit 7							bit 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 15-0 **QEILEC<15:0>:** Low word used to form 32-bit Less Than or Equal Compare register (QEIxLEC) bits

Register 15-15: QEIxGECH: Greater Than or Equal Compare High Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QEIGEC<31:24>							
bit 15							bit 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
QEIGEC<23:16>							
bit 7							bit 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 15-0 **QEIGEC<31:16>:** High word used to form 32-bit Greater Than or Equal Compare register (QEIxGEC) bits

Register 15-16: QEIxGECL: Greater Than or Equal Compare Low Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
QEIGEC<15:8>							
bit 15							bit 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
QEIGEC<7:0>							
bit 7							bit 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 15-0 **QEIGEC<15:0>:** Low word used to form 32-bit Greater Than or Equal Compare register (QEIxGEC) bits

Register 15-17: INTxTMRH: Interval Timer High Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
INTTMR<31:24>							
bit 15							bit 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
INTTMR<23:16>							
bit 7							bit 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 15-0 **INTTMR<31:16>:** High word used to form 32-bit Interval Timer register (INTxTMR) bits

Register 15-18: INTxTMRL: Interval Timer Low Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
INTTMR<15:8>							
bit 15							bit 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
INTTMR<7:0>							
bit 7							bit 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 15-0 **INTTMR<15:0>:** Low word used to form 32-bit Interval Timer register (INTxTMR) bits

Register 15-19: INTxHLDH: Interval Timer Hold High Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
INTHLD<31:24>							
bit 15							bit 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
INTHLD<23:16>							
bit 7							bit 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 15-0 **INTHLD<31:16>:** High word used to form 32-bit Interval Timer Hold register (INTxHLD) bits

Register 15-20: INTxHLDL: Interval Timer Hold Low Word Register

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
INTHLD<15:8>							
bit 15							bit 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
INTHLD<7:0>							
bit 7							bit 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 15-0 **INTHLD<15:0>:** Low word used to form 32-bit Interval Timer Hold register (INTxHLD) bits

15.3 MODULE DESCRIPTION

15.3.1 Position Counter

The position counter is 32 bits wide and is contained in two separate 16-bit registers: POSxCNTL and POSxCNTH. The counter counts the number of pulses generated by an encoder.

To read the counter during the counter operation, the user application should first read the least significant word (lsw) of the counter value from the POSxCNTL register. When the lsw is read first, the contents of POSxCNTH are automatically transferred into a hold register, POSxHLD. The user application can then read the POSxHLD register to get the most significant word (msw) of the counter value. The hold register (POSxHLD) ensures that the occurrence of a carry or borrow between the read operation does not affect the reading of a coherent 32-bit value.

To write a value to the POSxCNTL:POSxCNTH register pair, the user application should first write the msw to the POSxHLD register. When the lsw of the timer value is written to the POSxCNTL register, the contents of POSxHLD are automatically transferred to the POSxCNTH register. Thus, a coherent 32-bit value can be loaded into the position counter in a single clock cycle.

If the POSOVIEN bit in the QEI Status register (QEIxSTAT<8>) is set, and the position counter rolls over from 0x7FFFFFFF to 0x80000000, or from 0x80000000 to 0x7FFFFFFF, an interrupt will be generated.

The operating mode of the position counter is controlled by the CCM<1:0> bits in the QEI Control register (QEIxCON<1:0>). The position counter supports the following operating modes:

- Quadrature Count Mode
- External Count with External Up/Down Mode
- External Count with External Gate Mode
- Internal Timer Mode

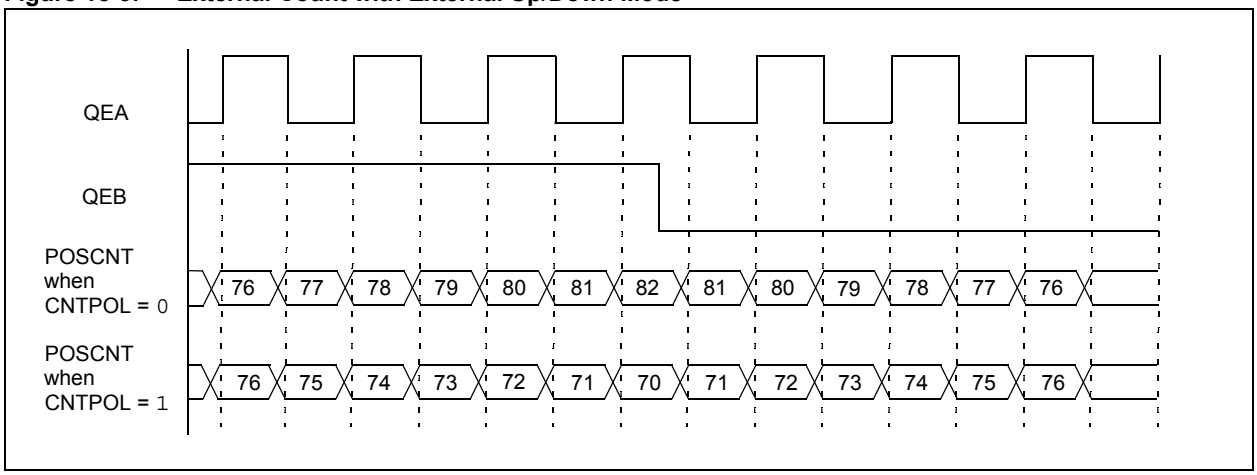
15.3.1.1 QUADRATURE COUNT MODE

In this mode, the QEA/EXTCNT and QEB/DIR/GATE inputs are decoded to generate count pulses and direction information to control the POSxCNT and VELxCNT. The INDXxCNT register counts when a valid edge is detected on INDX input. Figure 15-1 illustrates the timing diagram of the Quadrature Count mode operation.

15.3.1.2 EXTERNAL COUNT WITH EXTERNAL UP/DOWN MODE

In this mode, the QEA/EXTCNT input is considered as an external count signal, and the QEB/DIR/GATE input provides the count direction information. The count direction is positive unless overridden by the CNTPOL bit in the QEI Control register (QEIxCON<3>). Figure 15-3 illustrates the timing diagram of an External Count with External Up/Down mode operation.

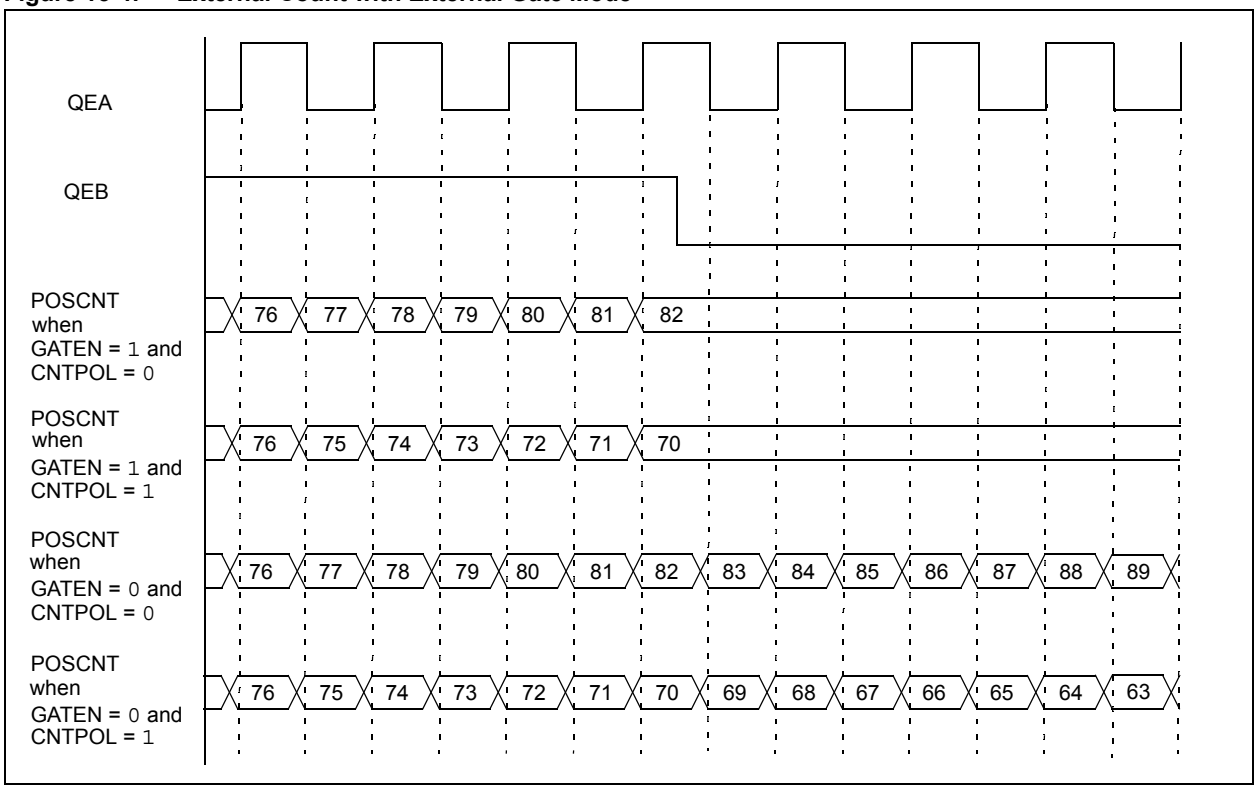
Figure 15-3: External Count with External Up/Down Mode



15.3.1.3 EXTERNAL COUNT WITH EXTERNAL GATE MODE

In this mode, the QEA/EXTCNT input is considered as an external count signal. If the GATEN bit in the QEI Control register (QEIxCON<2>) is set, and QEB/DIR/GATE = 0, the QEB/DIR/GATE input will inhibit the counter signal. If the GATEN bit is cleared, the gate signal does not affect the counter operation. The default count direction is positive. If the CNTPOL bit in the QEI Control register (QEIxCON<3>) is set, the count direction is negative. Figure 15-4 illustrates the timing diagram of an External Count with External Gate mode operation.

Figure 15-4: External Count with External Gate Mode

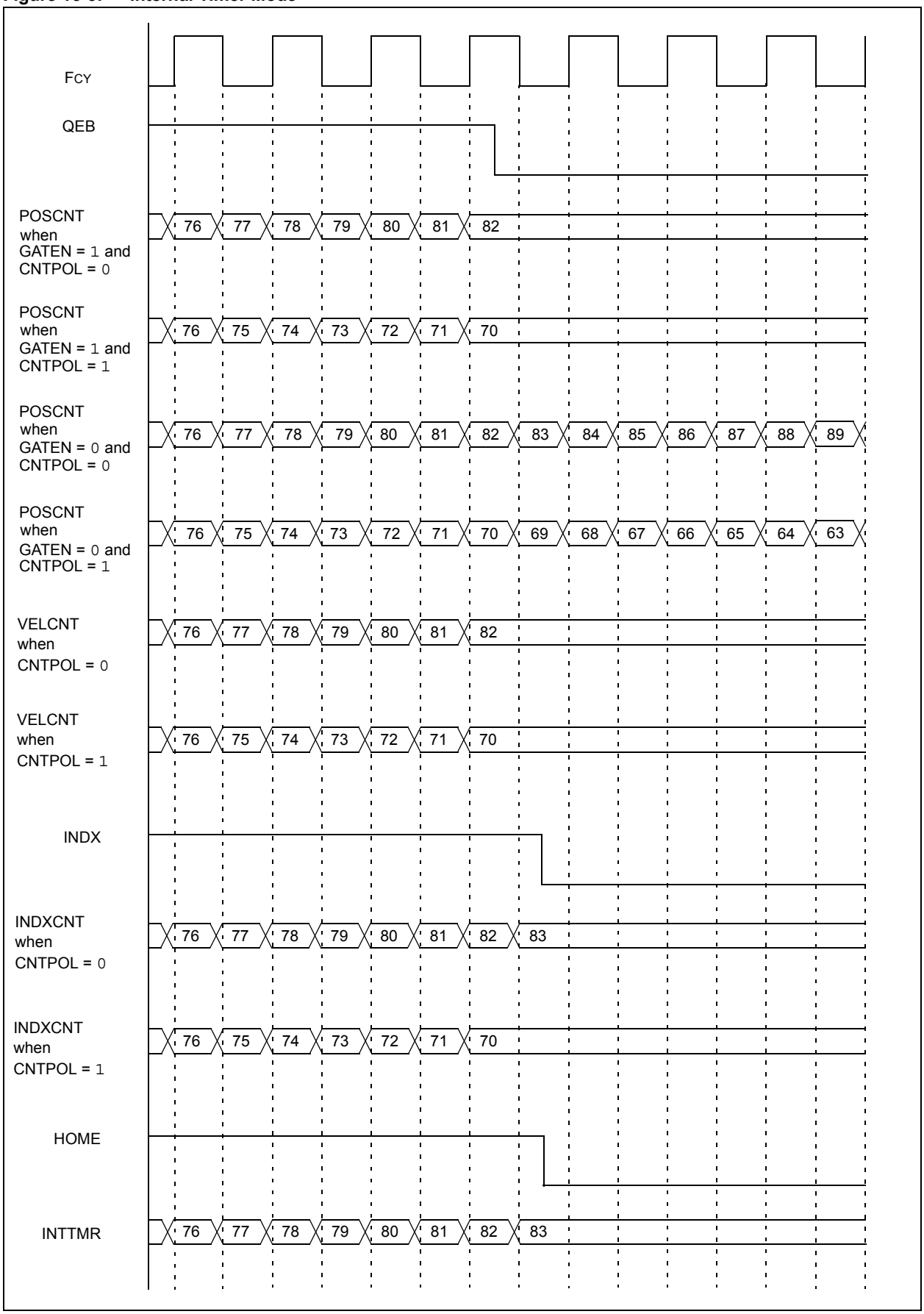


15.3.1.4 INTERNAL TIMER MODE

In this mode, the velocity, index and interval center of the position counter uses an internal clock as the count source. The internal clock is divided by the clock divider using the INTDIV<2:0> bits in the QEI Control register (QEIxCON<6:4>). If the GATEN bit in the QEI Control register (QEIxCON<2>) is set, and QEB/DIR/GATE = 0, the QEB/DIR/GATE input will inhibit the counter signal. If the GATEN bit is cleared, the gate signal does not affect the operation of the counter. The default count direction is positive. If the CNTPOL bit in the QEI Control register (QEIxCON<3>) is set, the count direction is negative. Figure 15-5 illustrates the timing diagram of an Internal Timer mode operation.

Note:	Although, the POSxCNT register allows byte accesses, reading from or writing to the POSxCNT register in Byte mode gives unpredictable results. As the hold register (POSxHLD) is only 16 bits wide, the operation in Byte mode is not recommended.

Figure 15-5: Internal Timer Mode

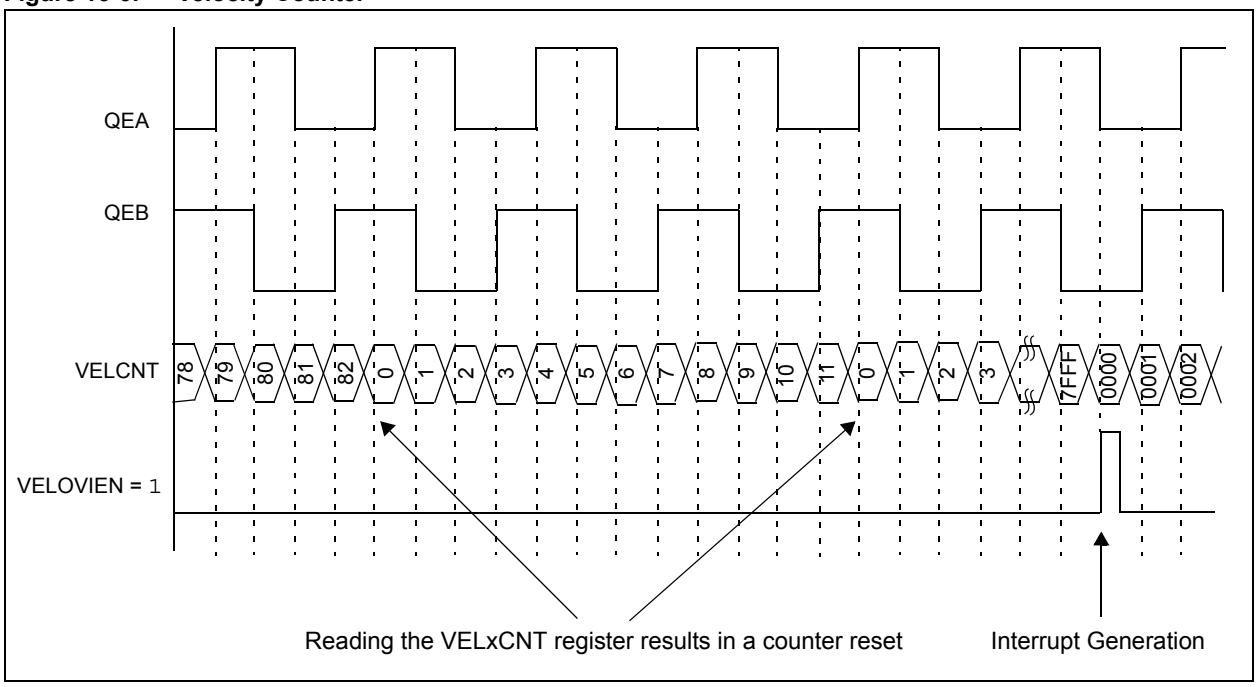


15.3.2 Velocity Counter

The Velocity Counter (VELxCNT) is a 16-bit wide register that increments or decrements based on the signal from the quadrature decoder logic. Reading this register results in a counter reset. The index input or any of the modes specified by the PIMOD<2:0> bits in the QEI Control register (QEIxCON<12:10>) does not affect the operation of the velocity counter. If the velocity counter rolls over from 0x7FFF to 0x8000, or from 0x8000 to 0x7FFF, and the VELOVIEN bit in the QEI Status register (QEIxSTAT<4>) is set, an interrupt will be generated. Figure 15-6 illustrates the timing diagram of the Velocity Counter operation.

Note:	The velocity counter specifies the distance traveled between the time interval of each sample. Reading the VELxCNT register results in counter reset. The user application should read the velocity counter at a rate of 1-4 kHz.

Figure 15-6: Velocity Counter



15.3.3 Index Counter

The Index Counter (INDXxCNT) is 32 bits wide and is contained in two separate 16-bit registers: INDXxCNTH and INDXxCNTL. It counts the index events and is incremented or decremented based on the direction output of the quadrature logic decoder (see Figure 15-2). For more information, refer to **15.3.7 "Index Event"**.

To read the index counter during the counter operation, the user application should first read the lsw of the counter value from the INDXxCNTL register. When the lsw is read first, the contents of the INDXxCNTH register are automatically transferred into a hold register, INDXxHLD. The user application can then read the INDXxHLD register to get the msw of the counter value.

To write a value to the INDXxCNTH:INDXxCNTL register pair, the user application should first write the msw to the INDXxHLD register. When the lsw of the index value is written to the INDXxCNTL register, the contents of the INDXxHLD register is automatically transferred to the INDXxCNTH register. Thus, a coherent 32-bit value can be loaded into the index counter in a single clock cycle.

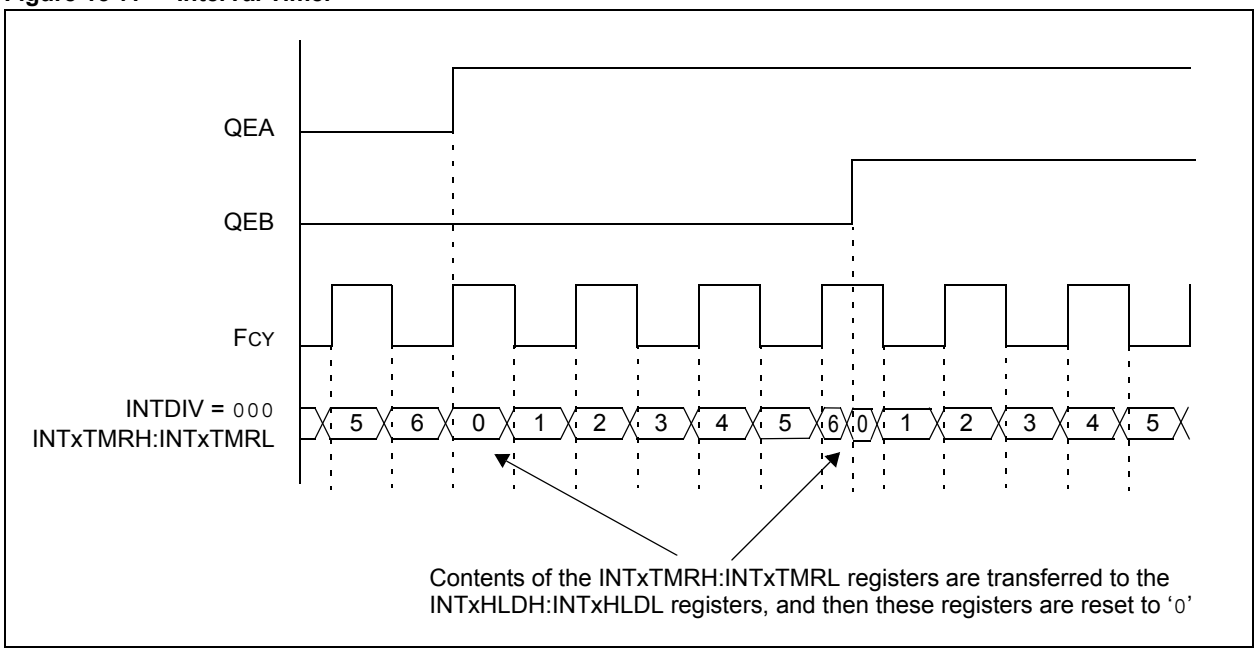
Note:	Although, the INDXxCNT register allows byte accesses, reading from or writing to the POSxCNT register in Byte mode gives unpredictable results. As the hold register (POSxHLD) is only 16 bits wide, the operation in Byte mode is not recommended.

15.3.4 Interval Timer

When a motor runs at a very low speed, the encoder does not generate enough pulses for accurate speed measurement. Therefore, instead of counting the number of pulses, the pulse duration can be measured. The 32-bit Interval Timer (INTxTMR) is used to measure the time interval between each decoded quadrature count pulse when the motor operates at a very low speed. The timer counts at a rate specified by the INTDIV<2:0> bits in the QEI Control register (QEIxCON<6:4>). The interval timer is cleared when the first count pulse is detected. When the next count pulse is detected, the current contents of the interval timer are transferred to the interval hold registers (INTxHLDH and INTxHLDL), the interval timer is cleared, and then the process repeats. The interval hold registers always contain the most recent completed timing measurements. Figure 15-7 illustrates the timing diagram of the Interval Timer operation.

Note:	If the INTxHLD register is read when a new position count pulse is detected, the contents of the INTxHLD register are not updated to avoid incoherent data reading.

Figure 15-7: Interval Timer



15.3.5 Initialization/Capture Register

The 32-bit Initialization/Capture register (QEIxIC) is a general purpose register that can be used to perform the following functions:

- Initialize the position counter
- Capture the contents of the position counter

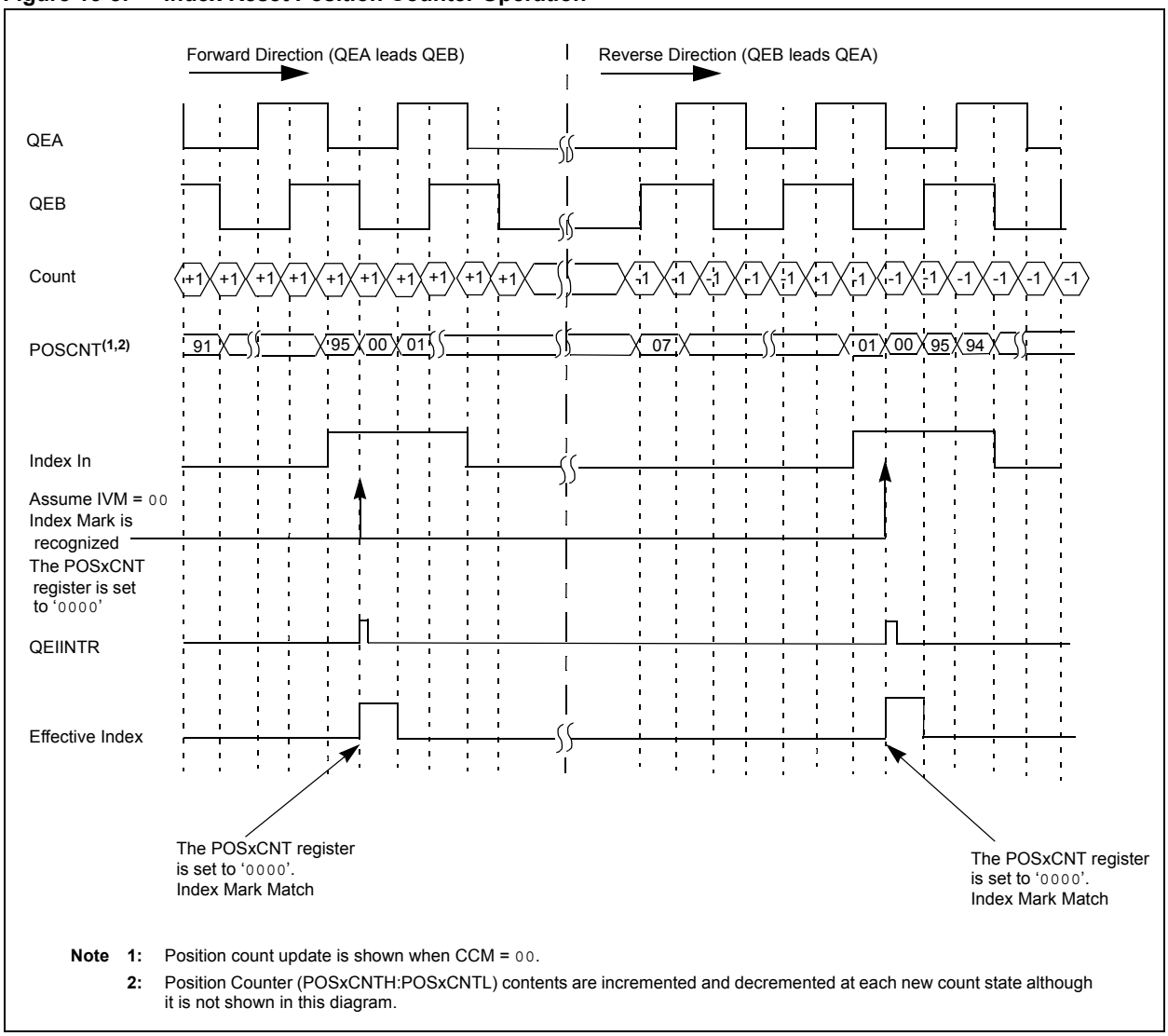
The QEIxIC register can perform only one of these tasks at a time, but the mode of operation can be changed during the operation. The selection is done by the PIMOD<2:0> bits of the QEI Control register (QEIxCON<12:10>). To initialize the Position Counter mode, the contents of QEIxIC register are loaded into the POSxCNT register based on the condition set by the PIMOD<2:0> bits.

In Capture mode, the input signal is used to capture the contents of the position register into the QEIxIC register. This register can be configured to define a travel boundary beyond which a fault is generated.

15.3.6 Position Comparator

The 32-bit Compare register and associated comparator allow the user application to compare the contents of the position counter to a specified value. The comparator provides two outputs: greater than or equal, and less than or equal. When a suitable condition is met, the comparator generates an interrupt by setting the PCHEQIRQ or PCLEQIRQ bit in the QEI Status register (QEIxSTAT<13> and QEIxSTAT<11>). The comparator output is available on the CNTCMPx pin. The selection of condition is made by the OUTFNC<1:0> bits of the QEI I/O Control register (QEIxIOC<10:9>). The comparator can also be used to reset the position counter when a match is detected. The selection is made by the PIMOD<2:0> bits of the QEI Control register (QEIxCON<12:10>). Figure 15-8 illustrates the index reset position counter operation.

Figure 15-8: Index Reset Position Counter Operation



Note 1: Position count update is shown when CCM = 00.

2: Position Counter (POSxCNTH:POSxCNTL) contents are incremented and decremented at each new count state although it is not shown in this diagram.

15.3.7 Index Event

The IMV<1:0> bits in the QEI Control register (QEIxCON<9:8>) specify the state of the QEA and QEB input signals required to acknowledge an index event. An index event is accepted when an index pulse occurs while the value of the QEA and QEB inputs match the condition set in the IMV<1:0> bits. This prevents further index events from being accepted until the index input signal is deasserted, and ensures that only one index event occurs for each index input pulse. Figure 15-8 illustrates the index reset position counter operation.

15.3.8 Position Counter Initialization Modes

By using the PIMOD<2:0> bits in the QEI Control register (QEIxCON<12:10>), the user application can specify how the position counter is initialized during the module operation.

- **Mode 0** - The position counter is unaffected by the index input.
- **Mode 1** - The position counter is cleared whenever an index input event is detected.
- **Mode 2** - The position counter is initialized with the contents of the QEIxIC register on the next detected index input event. When the index event occurs, the PIMOD<2:0> bits are cleared, and then the counter operates in Mode 0.
- **Mode 3** - The position counter is initialized with the contents of the QEIxIC register on the next detected index input event following the assertion of the home input. When an index event occurs following the home event, the PIMOD<2:0> bits are cleared, and then the counter operates in Mode 0.
- **Mode 4** - The position counter is initialized with the contents of the QEIxIC register on the second detected index input event following the assertion of the home input. When the second index event occurs following the home event, the PIMOD<2:0> bits are cleared, and then the counter operates in Mode 0.
- **Mode 5** - The position counter is cleared when the position counter value equals the QEIxIC register value.
- **Mode 6** - The position counter is loaded with the contents of the QEIxLEC register when the position counter value equals the QEIxGEC register value and a count up pulse is detected. The counter is loaded with the contents of the QEIxGEC register when the position counter value equals the QEIxLEC register value and a count down pulse is detected.
- **Mode 7** - Reserved; the position counter selects the default Mode 0 operation.

15.3.9 Digital Input Filter

The QEI module uses digital noise filters to reject noise on the incoming index and quadrature phase signals. These filters reject low-level noise and large, short duration noise spikes that typically occur in motor systems.

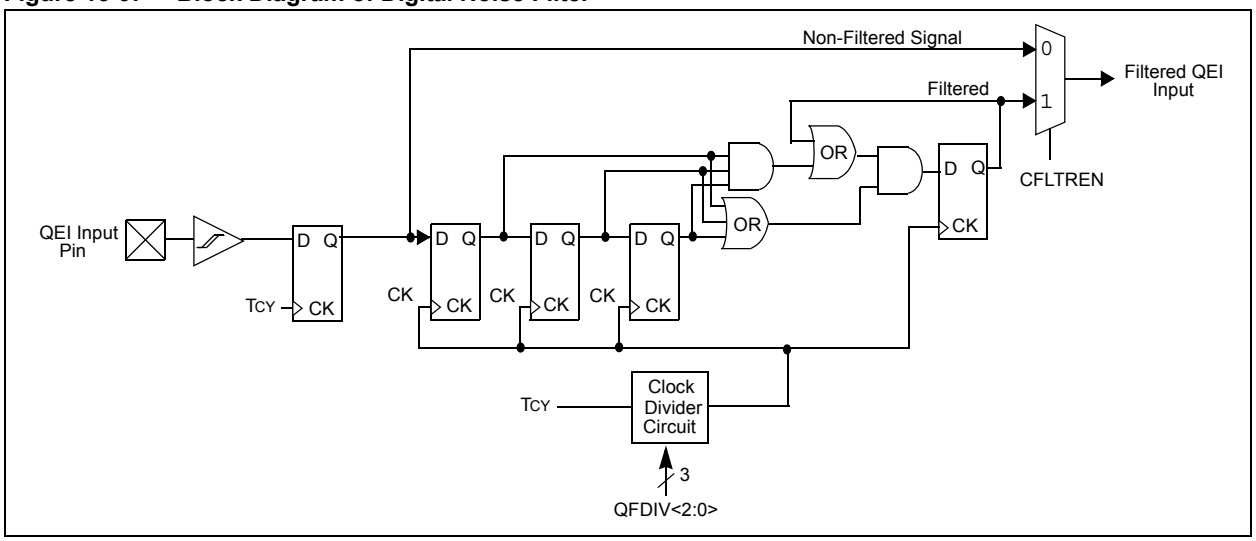
The filtered output signals can change only after an input level has the same value for three consecutive rising clock edges. The result is that short noise spikes between rising clock edges are ignored, and pulses shorter than two clock periods are rejected.

The filter clocks rate determines the low passband of the filter. A slower filter clock results in a passband rejecting lower frequencies.

The digital filter is enabled by setting the FLTREN bit in the QEI I/O Control register (QEIxIOC<14>). The QFDIV<2:0> bits in the QEI I/O Control register (QEIxIOC<13:11>) select the filter clock divider ratio for the clock signal.

Figure 15-9 illustrates the simplified block diagram of the digital noise filter.

Figure 15-9: Block Diagram of Digital Noise Filter



15.3.10 Interrupts

The following are the sources of QEI interrupts:

- Position counter overflow or underflow event
- Velocity counter overflow or underflow event
- Position counter initialization process complete
- Position counter greater than or equal compare interrupt
- Position counter less than or equal compare interrupt
- Index event interrupt
- Home event interrupt

The QEI Status register (QEIxSTAT) contains the individual interrupt enable bits and the corresponding interrupt status bits for each interrupt source. A status bit indicates that an interrupt request has occurred. The module reduces all of the QEI interrupts to a single interrupt signal to the interrupt controller module.

15.4 QEI OPERATION IN POWER-SAVING MODES

15.4.1 Sleep Mode

When the device enters Sleep mode, QEI operations cease. The POSxCNT register stops at the current value. The QEI does not respond to active signals on the QEA, QEB or INDX pins. The QEIxCON register remains unchanged.

15.4.2 Idle Mode

When the device enters Idle mode, the QEISIDL bit in the QEI Control register (QEIxCON<13>) determines whether the QEI module stops in Idle mode or continues to operate in Idle mode.

If QEICSIDL = 1, the QEI module enters into a power-saving mode and performs the same functions as in Sleep mode. If QEICSIDL = 0, the module does not enter into a power-saving mode and continues operation in Idle mode.

15.4.3 Doze Mode

The QEI operation in Doze mode is similar as in normal mode.

15.5 EFFECTS OF A RESET

A Reset forces module registers to their initial Reset state.

15.6 REGISTER MAP

A summary of the registers associated with the dsPIC33E/PIC24E family's Quadrature Encoder Interface (QEI) module is provided in Table 15-2.

Table 15-2: QEI Register Map

Name	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	All Resets
QEIxCON	QEIEN	—	QEISIDL	PIMOD<2:0>			IMV<1:0>		—	INTDIV<2:0>			CNTPOL	GATEN	CCM<1:0>		0x0000
QEIxIOC	QCAPEN	FLTREN	QFDIV<2:0>			OUTFNC<1:0>		SWPAB	HOMPOL	IDXPOL	QEBPOL	QEAPOL	HOME	INDEX	QEB	QEA	0x000X
QEIxSTAT	—	—	PCHEQIRQ	PCHEQIEN	PCLEQIRQ	PCLEQIEN	POSOVIRQ	POSOVIEN	PCIIRQ	PCIIEN	VELOVIRQ	VELOVIEN	HOMIRQ	HOMIEN	IDXIRQ	IDXIEN	0x0000
POSxCNTH	POSCNT<31:16>																0x0000
POSxCNTL	POSCNT<15:0>																0x0000
POSxHLD	POSHLD<15:0>																0x0000
VELxCNT	VELCNT<15:0>																0x0000
INDXxCNTH	INDXCNT<31:16>																0x0000
INDXxCNTL	INDXCNT<15:0>																0x0000
INDXxHLD	INDXHLD<15:0>																0x0000
QEIxICH	QEIIC<31:16>																0x0000
QEIxICL	QEIIC<15:0>																0x0000
QEIxLECH	QEILEC<31:16>																0x0000
QEIxLECL	QEILEC<15:0>																0x0000
QEIxGECH	QEIGEC<31:16>																0x0000
QEIxGECL	QEIGEC<15:0>																0x0000
INTxTMRH	INTTMR<31:16>																0x0000
INTxTMRL	INTTMR<15:0>																0x0000
INTxHLDH	INTHLD<31:16>																0x0000
INTxHLDL	INTHLD<15:0>																0x0000

Legend: x = unknown value on Reset, — = unimplemented, read as '0'. Reset values are shown in hexadecimal.

15.7 DESIGN TIPS

Question 1: ***How do I configure the software when hardware signals are interchanged?***

Answer: The HOMPOL, IDXPOL, QEBPOL and QEAPOL bits in the QEIxIOC register allow the user application to invert the polarity of their associated input signals. The SWPAB bit in the QEIxIOC, when set, swaps the QEA and QEB signals prior to their input into the quadrature decoder. Swapping of the signals reverses the direction of count. The OUTFNC<1:0> bits in the QEIxIOC register (QEIxIOC<10:9>) allow the user application to output the internal module state or the status of the position counter comparator on a device pin. The output timing is non-critical because the selected signal is used by the customer's application circuit, which is external to the device.

Question 2: ***How do I debug the software using the QEI module?***

Answer: The QEIxIOC register can be used to configure the external inputs and outputs of the QEI module.

When setting up or troubleshooting a motion control-based application, the HOME, INDEX, QEB and QEA status bits in the QEIxIOC register can be used to monitor the individual state of their associated inputs.

A sensor or signal can be connected to the Home input by setting the QCAPEN bit in the QEI I/O Control register (QEIxIOC<15>). When set, it allows the user application to capture the current position counter value and save it in the QEIxIC register. If the filter is enabled, the Home event is detected when a rising edge of the filtered Home signal occurs. When a Home event occurs, an interrupt generation can be enabled by setting the HOMIEN bit in the QEI Status register (QEIxSTAT<2>).

15.8 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 dsPIC33E/PIC24E device family, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to the QEI module are:

Title	Application Note #
Servo Control of a DC-Brush Motor	AN532
PIC18CXXX/PIC16CXXX DC Servomotor Application	AN696
Using the dsPIC30F for Vector Control of an ACIM	AN908

Note: Please visit the Microchip web site (www.microchip.com) for additional application notes and code examples for the dsPIC33E/PIC24E family of devices.

15.9 REVISION HISTORY

Revision A (June 2009)

This is the initial released version of this document.

Revision B (May 2010)

This version of the document includes the following updates:

- The document has been renamed from dsPIC33E Family Reference Manual to dsPIC33E/PIC24E Family Reference Manual
- Updated the QEIxCON: QEI Control Register (Register 15-1):
  - Renamed the register from QEICON to QEIxCON
  - Updated the PIMOD<12:10> = 111 definition
  - Changed the bit value definitions of CCM<1:0>
- Updated the QEIxIOC: QEI I/O Control Register (Register 15-2):
  - Renamed the register from QEIIOC to QEIxIOC
  - Updated the QCAPEN<15> = 0 definition
  - Changed the bit value definitions of OUTFNC<10:9>
  - Changed the bit value definitions of SWPAB<8>
  - Updated the bit name of QFDIV<13:11>, HOMPOL<7>, IDXPOL<6>, QEBPOL<5> and QEAPOL<4>
  - Updated the bit name and bit value definitions of HOME<3>, INDEX<2>, QEB<1> and QEA<0>
- Updated the QEIxSTAT: QEI Status Register (Register 15-3):
  - Renamed the register from QEISTAT to QEIxSTAT
  - Updated the bit name and bit value definitions of PCHEQIRQ<13>, PCLEQIRQ<11>, PCIIRQ<7>, HOMIRQ<3> and IDXIRQ<1>
  - Updated the bit name of PCHEQIEN<12>, PCLEQIEN<10> and IDXIEN<0>
  - Changed the bit value definitions of POSOVIRQ<9> and VELOVIRQ<5>
  - Add Note 1 to PCIIRQ<7> bit
- Updated the POSxCNTH: Position Counter High Word Register (Register 15-4):
  - Renamed the register from POSCNTH to POSxCNTH
  - Changed the bit name of POSCNTH to POSCNT and updated the definition
- Updated the POSxCNTL: Position Counter Low Word Register (Register 15-5):
  - Renamed the register from POSCNTL to POSxCNTL.
  - Changed the bit name of POSCNTL to POSCNT and updated the definition
- Updated the POSxHLD: Position Counter Hold Register (Register 15-6):
  - Renamed the register from POSHLDH to POSxHLD
  - Updated the bit definition of POSHLD<15:0>
- Updated the VELxCNT: Velocity Counter Register (Register 15-7):
  - Renamed the register from VELCNT to VELxCNT
  - Updated the bit name of VELCNT
- Updated the INDXxCNTH: Index Counter High Word Register (Register 15-8):
  - Renamed the register from IDXCNTH to INDXxCNTH
  - Changed the bit name of IDXCNTH to INDXCNT and updated the bit definition
- Updated the INDXxCNTL: Index Counter Low Word Register (Register 15-9):
  - Renamed the register from IDXCNTL to INDXxCNTL.
  - Changed the bit name and updated the definition of INDXCNT<15:0>
  - Changed the bit name of IDXCNTL to INDXCNT and updated the bit definition
- Updated the INDXxHLD: Index Counter Hold Register (Register 15-10):
  - Renamed the register from IDXHLDH to INDXxHLD
  - Changed the bit name of IDXHLDH to INDXxHLD and updated the bit definition

Revision B (May 2010) (Continued)

- Updated the QEIxICH: Initialization/Capture High Word Register (Register 15-11):
  - Renamed the register from ICCH to QEIxICH
  - Changed the bit name of ICCH to QEIIC and updated the bit definition
- Updated the QEIxICL: Initialization/Capture Low Word Register (Register 15-12):
  - Renamed the register from ICCL to QEIxICL
  - Changed the bit name of ICCL to QEIIC and updated the bit definition
- Added the QEIxLECH: Less Than or Equal Compare High Word Register (Register 15-13)
- Added the QEIxLECL: Less Than or Equal Compare Low Word Register (Register 15-14)
- Added the QEIxGECH: Greater Than or Equal Compare High Word Register (Register 15-15)
- Added the QEIxGECL: Greater Than or Equal Compare Low Word Register (Register 15-16)
- Updated the INTxTMRH: Interval Timer High Word Register (Register 15-17):
  - Renamed the register from INTTMRH to INTxTMRH
  - Changed the bit name of INTTMRH to INTTMR
- Updated the INTxTMRL: Interval Timer Low Word Register (Register 15-18):
  - Renamed the register from INTTMRL to INTxTMRL
  - Changed the bit name of INTTMRL to INTTMR
- Updated the INTxHLDH: Interval Timer Hold High Word Register (Register 15-19):
  - Renamed the register from INTHLDH to INTxHLDH
  - Changed the bit name of INTHLDH to INTHLD
- Updated the INTxHLDL: Interval Timer Hold Low Word Register (Register 15-20):
  - Renamed the register from INTHLDL to INTxHLDL
  - Changed the bit name of INTHLDL to INTHLD
- Deleted the CMPLH: Compare Register High Word and CMPLL: Compare Register Low Word registers
- All new register names and acronyms are updated throughout the document
- Updated all the timing diagrams in the document
- Updated the content in **15.3.7 “Index Event”**
- Updated the bulleted list in **15.3.10 “Interrupts”**
- Deleted UPDN pin in **15.4.1 “Sleep Mode”**
- Minor typographical and formatting corrections were made throughout the document

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