
Section 48. Comparator with Blanking

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 PIC24F devices.

Please consult the note at the beginning of the “**Comparator**” 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>

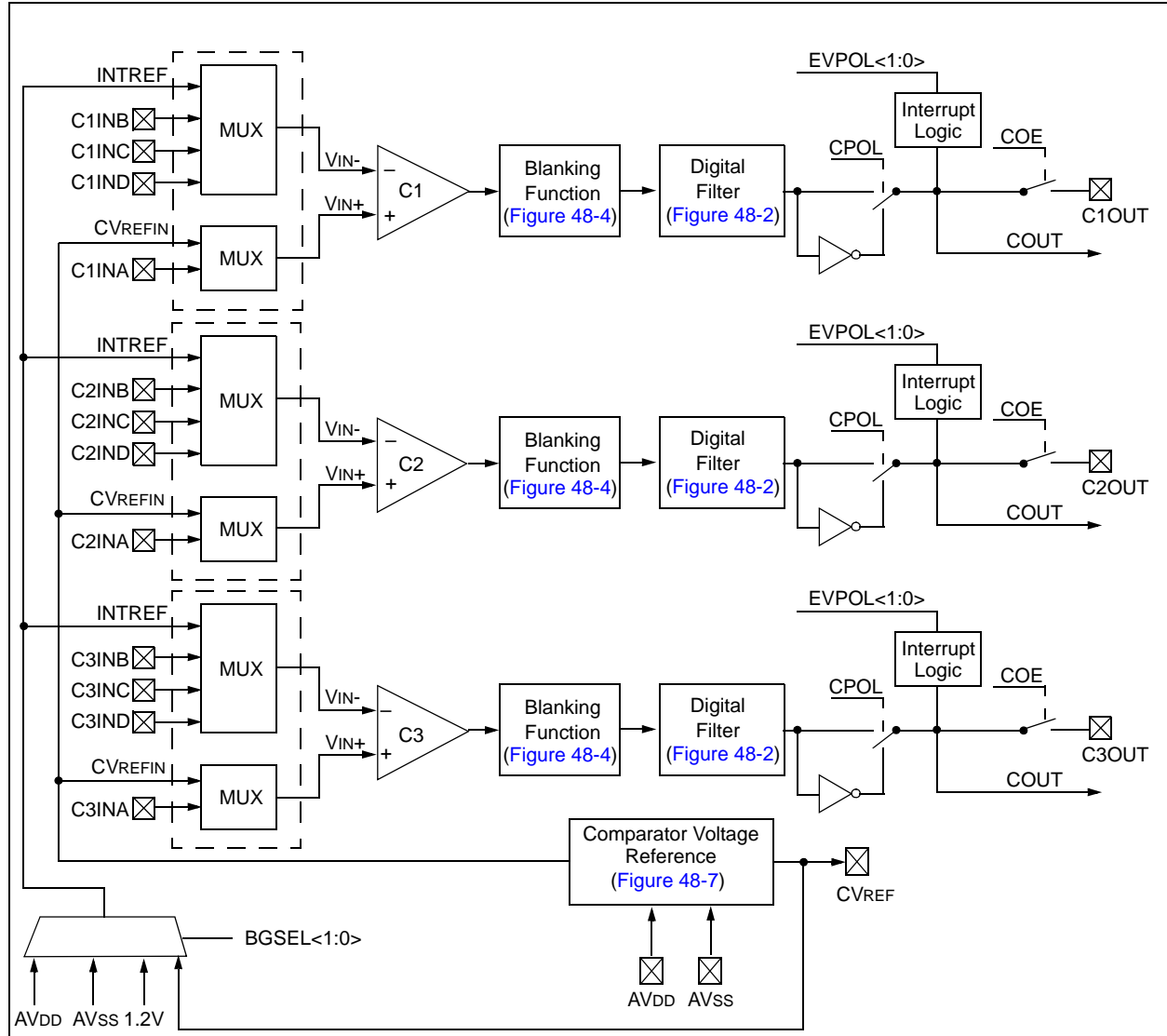
48.1 INTRODUCTION

The PIC24F Comparator with Blanking module provides multiple comparators that can be configured in different ways. Individual comparator options are specified by the Comparator with Blanking module's Special Function Register (SFR) control bits. The SFRs control bits associated with Comparator with Blanking module allow users to:

- Select the edge for trigger and interrupt generation
- Select low-power control
- Configure the comparator voltage reference and band gap
- Configure output blanking and masking

The comparator operating mode is determined by the input selections (that is, whether the input voltage is compared to a second input voltage, to an internal voltage band gap reference, or to an internal reference voltage). The internal reference voltage is generated by a resistor ladder network that is configured by the Comparator Voltage Reference Control register (CVRCON) (see [Register 48-6](#)).

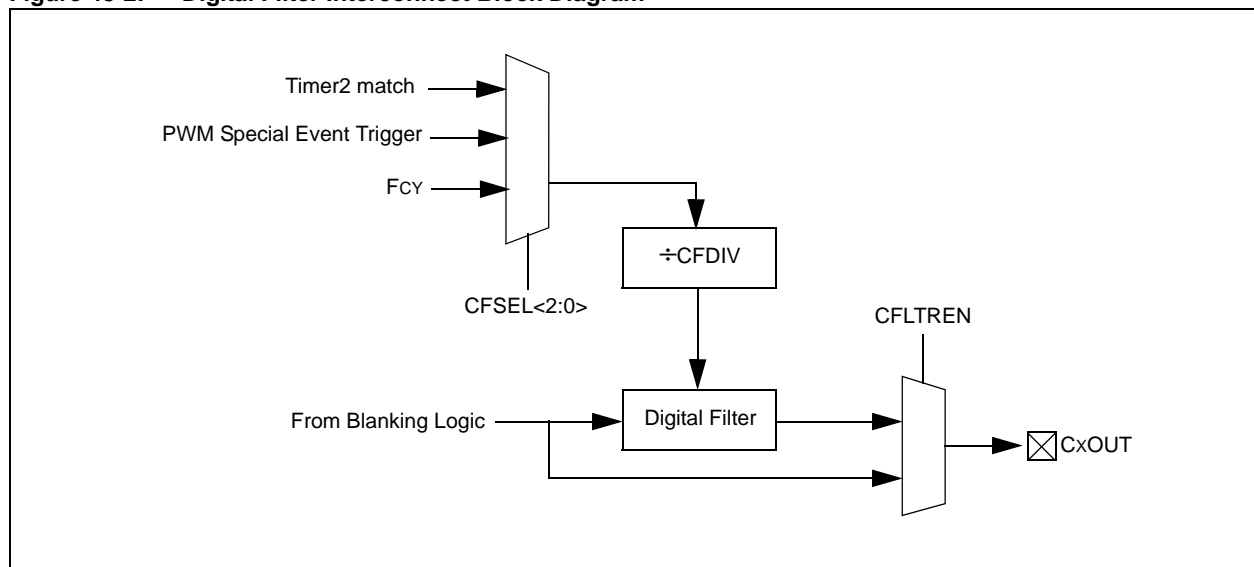
Figure 48-1: Input Selection Logic Block Diagram



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**Comparator with
Blanking**

Figure 48-2: Digital Filter Interconnect Block Diagram



48.2 COMPARATOR REGISTERS

The Comparator with Blanking module uses the following six registers:

- **CMSTAT: Comparator Status Register**

This register enables control over the operation of all comparators when the device enters Idle mode. In addition, it provides the status of all comparator results, as well as all of the comparator outputs and event bits, which are replicated as read-only bits in the CMSTAT register.

- **CMxCON: Comparator Control Register** (where x = 1, 2, or 3)

This register allows the application program to enable, configure and interact with the individual comparators.

- **CMxMSKSR: Comparator Mask Source Select Control Register**

This register allows the application program to select sources for the inputs for the blanking function.

- **CMxMSKCON: Comparator Mask Gating Control Register**

This register allows the application program to specify the blank function logic.

- **CMxFLTR: Comparator Filter Control Register**

This register enables comparator filter configuration.

- **CVRCON: Comparator Voltage Reference Control Register**

This register allows the application program to enable, configure and interact with the comparator internal voltage reference generator (for more information, see [48.6 “Comparator Voltage Reference Generator”](#)).

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Register 48-1: CMSTAT: Comparator Status Register

| | | | | | | | |
|--------|-----|-----|-----|-----|-------|-------|-------|
| R/W-0 | U-0 | U-0 | U-0 | U-0 | R-0 | R-0 | R-0 |
| CMSIDL | — | — | — | — | C3EVT | C2EVT | C1EVT |
| bit 15 | | | | | | bit 8 | |
| U-0 | U-0 | U-0 | U-0 | U-0 | R-0 | R-0 | R-0 |
| — | — | — | — | — | C3OUT | C2OUT | C1OUT |
| 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 **CMSIDL:** Stop in Idle Mode bit
 1 = Discontinue operation of all comparators when device enters Idle mode
 0 = Continue operation of all comparators in Idle mode
- bit 14-11 **Unimplemented:** Read as '0'
- bit 10 **C3EVT:** Comparator 3 Event Status bit
 1 = Comparator event occurred
 0 = Comparator event did not occur
- bit 9 **C2EVT:** Comparator 2 Event Status bit
 1 = Comparator event occurred
 0 = Comparator event did not occur
- bit 8 **C1EVT:** Comparator 1 Event Status bit
 1 = Comparator event occurred
 0 = Comparator event did not occur
- bit 7-3 **Unimplemented:** Read as '0'
- bit 2 **C3OUT:** Comparator 3 Output Status bit
 When CPOL = 0:
 1 = VIN+ > VIN-
 0 = VIN+ < VIN-
 When CPOL = 1:
 1 = VIN+ < VIN-
 0 = VIN+ > VIN-
- bit 1 **C2OUT:** Comparator 2 Output Status bit
 When CPOL = 0:
 1 = VIN+ > VIN-
 0 = VIN+ < VIN-
 When CPOL = 1:
 1 = VIN+ < VIN-
 0 = VIN+ > VIN-
- bit 0 **C1OUT:** Comparator 1 Output Status bit
 When CPOL = 0:
 1 = VIN+ > VIN-
 0 = VIN+ < VIN-
 When CPOL = 1:
 1 = VIN+ < VIN-
 0 = VIN+ > VIN-

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Register 48-2: CMxCON: Comparator Control Register

| | | | | | | | |
|--------|-------|-------|-------|-----|-----|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R-0 |
| CON | COE | CPOL | CLPWR | — | — | CEVT | COUT |
| bit 15 | | | | | | | bit 8 |

| | | | | | | | |
|------------|-------|-----|-------|-----|-----|----------|-------|
| R/W-0 | R/W-0 | U-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 |
| EVPOL<1:0> | | — | CREF | — | — | CCH<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 **CON:** Comparator Enable bit
 1 = Comparator is enabled
 0 = Comparator is disabled
- bit 14 **COE:** Comparator Output Enable bit
 1 = Comparator output is present on the CxOUT pin
 0 = Comparator output is internal only
- bit 13 **CPOL:** Comparator Output Polarity Select bit
 1 = Comparator output is inverted
 0 = Comparator output is not inverted
- bit 12 **CLPWR:** Comparator Low Power Mode Select bit
 1 = Comparator operates in low-power mode
 0 = Comparator does not operate in low-power mode
- bit 11-10 **Unimplemented:** Read as '0'
- bit 9 **CEVT:** Comparator Event bit
 1 = Comparator event according to EVPOL<1:0> settings occurred; disables future triggers and interrupts until the bit is cleared
 0 = Comparator event did not occur
- bit 8 **COUT:** Comparator Output bit
 When CPOL = 0 (non-inverted polarity):
 1 = VIN+ > VIN-
 0 = VIN+ < VIN-
 When CPOL = 1 (inverted polarity):
 1 = VIN+ < VIN-
 0 = VIN+ > VIN-
- bit 7-6 **EVPOL<1:0>:** Trigger/Event/Interrupt Polarity Select bits
 11 = Trigger/Event/Interrupt generated on any change of the comparator output (while CEVT = 0)
 10 = Trigger/Event/Interrupt generated only on high to low transition of the polarity-selected comparator output (while CEVT = 0)
 If CPOL = 1 (inverted polarity):
 Low-to-high transition of the comparator output
 If CPOL = 0 (non-inverted polarity):
 High-to-low transition of the comparator output
 01 = Trigger/Event/Interrupt generated only on low to high transition of the polarity-selected comparator output (while CEVT = 0)
 If CPOL = 1 (inverted polarity):
 High-to-low transition of the comparator output
 If CPOL = 0 (non-inverted polarity):
 Low-to-high transition of the comparator output
 00 = Trigger/Event/Interrupt generation is disabled

Register 48-2: CMxCON: Comparator Control Register

| | |
|---------|--|
| bit 5 | Unimplemented: Read as '0' |
| bit 4 | CREF: Comparator Reference Select bit (VIN+ input) 1 = VIN+ input connects to internal CVREFIN voltage 0 = VIN+ input connects to CxINA pin |
| bit 3-2 | Unimplemented: Read as '0' |
| bit 1-0 | CCH<1:0>: Comparator Channel Select bits 11 = VIN- input of comparator connects to INTREF 10 = VIN- input of comparator connects to CxIND pin 01 = VIN- input of comparator connects to CxINC pin 00 = VIN- input of comparator connects to CxINB pin |

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Register 48-3: CMxMSKSRCC: Comparator Mask Source Select Control Register

| | | | | | | | |
|--------|-----|-----|-----|--------------|-------|-------|------|
| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | RW-0 |
| — | — | — | — | SELSRCC<3:0> | | | |
| 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 |
| SELSRCB<3:0> | | | | SELSRCA<3:0> | | | |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11-8 **SELSRCC<3:0>:** Mask C Input Select bits

1111 = FLTA

1110 = Reserved

1101 = Reserved

1100 = Reserved

1011 = Reserved

1010 = Reserved

1001 = Reserved

1000 = Reserved

0111 = Reserved

0110 = Reserved

0101 = PWM1H3

0100 = PWM1L3

0011 = PWM1H2

0010 = PWM1L2

0001 = PWM1H1

0000 = PWM1L1

bit 7-4 **SELSRCB<3:0>:** Mask B Input Select bits

1111 = FLTA

1110 = Reserved

1101 = Reserved

1100 = Reserved

1011 = Reserved

1010 = Reserved

1001 = Reserved

1000 = Reserved

0111 = Reserved

0110 = Reserved

0101 = PWM1H3

0100 = PWM1L3

0011 = PWM1H2

0010 = PWM1L2

0001 = PWM1H1

0000 = PWM1L1

Register 48-3: CMxMSKSRCA: Comparator Mask Source Select Control Register (Continued)

bit 3-0 **SELSRCA<3:0>**: Mask A Input Select bits

1111 = FLTA
1110 = Reserved
1101 = Reserved
1100 = Reserved
1011 = Reserved
1010 = Reserved
1001 = Reserved
1000 = Reserved
0111 = Reserved
0110 = Reserved
0101 = PWM1H3
0100 = PWM1L3
0011 = PWM1H2
0010 = PWM1L2
0001 = PWM1H1
0000 = PWM1L1

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Register 48-4: CMxMSKCON: Comparator Mask Gating 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 |
| HLMS | — | OCEN | OCNEN | OBEN | OBNEN | OAEN | OANEN |
| 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 |
| NAGS | PAGS | ACEN | ACNEN | ABEN | ABNEN | AAEN | AANEN |
| 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 **HLMS:** High or Low Level Masking Select bits
1 = The masking (blanking) function will prevent any asserted ('0') comparator signal from propagating
0 = The masking (blanking) function will prevent any asserted ('1') comparator signal from propagating
- bit 14 **Unimplemented:** Read as '0'
- bit 13 **OCEN:** OR Gate C Input Inverted Enable bit
1 = MCI is connected to OR gate
0 = MCI is not connected to OR gate
- bit 12 **OCNEN:** OR Gate C Input Inverted Enable bit
1 = Inverted MCI is connected to OR gate
0 = Inverted MCI is not connected to OR gate
- bit 11 **OBEN:** OR Gate B Input Inverted Enable bit
1 = MBI is connected to OR gate
0 = MBI is not connected to OR gate
- bit 10 **OBNEN:** OR Gate B Input Inverted Enable bit
1 = Inverted MBI is connected to OR gate
0 = Inverted MBI is not connected to OR gate
- bit 9 **OAEN:** OR Gate A Input Enable bit
1 = MAI is connected to OR gate
0 = MAI is not connected to OR gate
- bit 8 **OANEN:** OR Gate A Input Inverted Enable bit
1 = Inverted MAI is connected to OR gate
0 = Inverted MAI is not connected to OR gate
- bit 7 **NAGS:** Negative AND Gate Output Select
1 = Inverted ANDI is connected to OR gate
0 = Inverted ANDI is not connected to OR gate
- bit 6 **PAGS:** Positive AND Gate Output Select
1 = ANDI is connected to OR gate
0 = ANDI is not connected to OR gate
- bit 5 **ACEN:** AND Gate A1 C Input Inverted Enable bit
1 = MCI is connected to AND gate
0 = MCI is not connected to AND gate
- bit 4 **ACNEN:** AND Gate A1 C Input Inverted Enable bit
1 = Inverted MCI is connected to AND gate
0 = Inverted MCI is not connected to AND gate
- bit 3 **ABEN:** AND Gate A1 B Input Enable bit
1 = B input enabled as input to AND gate A1
0 = B input disabled as input to AND gate A1

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Register 48-4: CMxMSKCON: Comparator Mask Gating Control Register (Continued)

| | |
|-------|---|
| bit 2 | ABNEN: AND Gate A1 B Input Inverted Enable bit 1 = Inverted MBI is connected to AND gate 0 = Inverted MBI is not connected to AND gate |
| bit 1 | AAEN: AND Gate A1 A Input Enable bit 1 = MAI is connected to AND gate 0 = MAI is not connected to AND gate |
| bit 0 | AANEN: AND Gate A1 A Input Inverted Enable bit 1 = Inverted MAI is connected to AND gate 0 = Inverted MAI is not connected to AND gate |

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Register 48-5: CMxFLTR: Comparator Filter Control Register

| | | | | | | | |
|--------|-----|-----|-----|-----|-----|-------|-----|
| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | I-0 |
| — | — | — | — | — | — | — | — |
| 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 |
| — | CFSEL<2:0> | | | CFLTREN | CFDIV<2:0> | | |
| 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 15-7 **Unimplemented:** Read as '0'

bit 6-4 **CFSEL<2:0>:** Comparator Filter Input Clock Select bits

111 = Reserved

110 = Reserved

101 = Reserved

100 = Reserved

011 = Reserved⁽¹⁾

010 = Timer2 Match ⁽¹⁾

001 = PWM Special Event Trigger⁽¹⁾

000 = Instruction Clock (Fcy)⁽¹⁾

bit 3 **CFLTREN:** Comparator Output Digital Filter Enable bit

1 = Digital filter enabled

0 = Digital filter disabled

bit 2-0 **CFDIV<2:0>:** Comparator Output Filter Clock Divide Select bits

111 = Clock Divide 1:128

110 = Clock Divide 1:64

101 = Clock Divide 1:32

100 = Clock Divide 1:16

011 = Clock Divide 1:8

010 = Clock Divide 1:4

001 = Clock Divide 1:2

000 = Clock Divide 1:1

Note 1: For more information, refer to the specific device data sheet.

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Register 48-6: CVRCON: Comparator Voltage Reference Control Register

| | | | | | | | |
|--------|----------------------|-------|-------|----------|---------|------------|-------|
| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
| — | — | — | — | — | VREFSEL | BGSEL<1:0> | |
| 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 |
| CVREN | CVROE ⁽¹⁾ | CVRR | CVRSS | CVR<3:0> | | | |
| 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 15-11 **Unimplemented:** Read as '0'

bit 10 **VREFSEL:** Voltage Reference Select bit

1 = CVREFIN = CVREF pin

0 = CVREFIN is generated by the resistor network

bit 9-8 **BGSEL<1:0>:** Band Gap Reference Source Select bits

11 = INTREF = CVREF pin

10 = INTREF = 1.2V (nominal)

01 = INTREF = AVDD

00 = INTREF = AVDD

bit 7 **CVREN:** Comparator Voltage Reference Enable bit

1 = Comparator voltage reference circuit powered on

0 = Comparator voltage reference circuit powered down

bit 6 **CVROE:** Comparator Voltage Reference Output Enable bit⁽¹⁾

1 = Voltage level is output on CVREF pin

0 = Voltage level is disconnected from CVREF pin

bit 5 **CVRR:** Comparator Voltage Reference Range Selection bit

1 = CVRSRC/24 step size

0 = CVRSRC/32 step size

bit 4 **CVRSS:** Comparator Voltage Reference Source Selection bit

1 = Comparator voltage reference source, CVRSRC = AVDD – AVSS

0 = Comparator voltage reference source, CVRSRC = AVDD – AVSS

bit 3-0 **CVR<3:0>:** Comparator Voltage Reference Value Selection bits

When CVRR = 1:

$$CVREFIN = (CVR<3:0>/24) \cdot (CVRSRC)$$

When CVRR = 0:

$$CVREFIN = 1/4 \cdot (CVRSRC) + (CVR<3:0>/32) \cdot (CVRSRC)$$

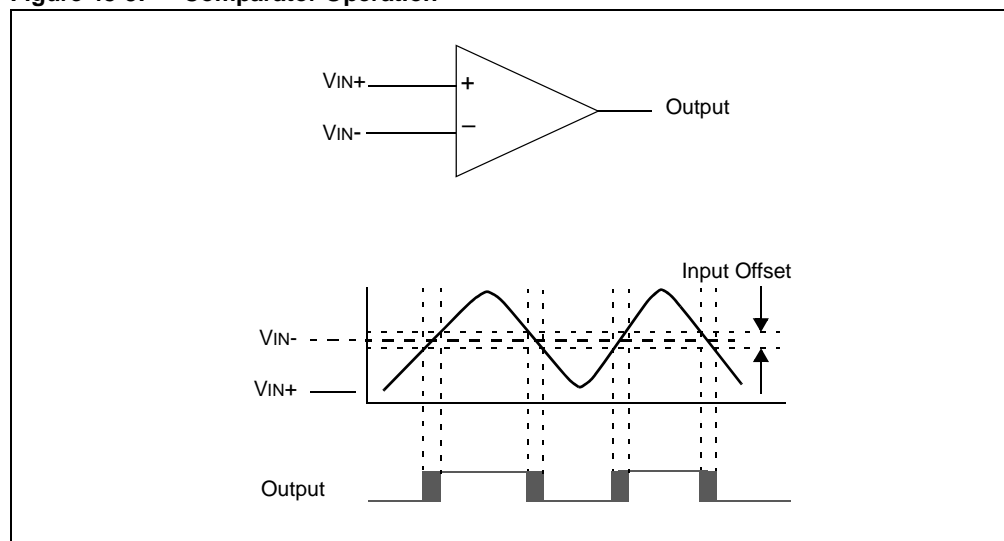
Note 1: The CVROE bit overrides the TRIS bit setting.

48.3 COMPARATOR OPERATION

The operation of a typical comparator, along with the relationship between the analog input levels and the digital output is illustrated in Figure 48-3. Depending on the comparator operating mode, the monitored analog signal is compared to either an external or internal voltage reference.

In Figure 48-3, the V_{IN-} is a fixed voltage. The analog signal present at V_{IN+} is compared to the reference signal at V_{IN-} , and the digital output of the comparator is created by the difference between the two signals. When V_{IN+} is less than V_{IN-} , the output of the comparator is a digital low level. When V_{IN+} is greater than V_{IN-} , the output of the comparator is a digital high level. The shaded areas of the output represent the area of uncertainty due to input offsets and response time. The polarity of the comparator output can be inverted, so that it is a digital low level when V_{IN+} is greater than V_{IN-} .

Figure 48-3: Comparator Operation



Input offset represents the range of voltage levels within which the comparator trip point can occur. The output can switch at any point within this offset range. Response time is the minimum time required for the comparator to recognize a change in input levels.

Each of the comparators can be configured to use the same or different reference sources. For example, one comparator can use an external reference while the others use the internal reference. For more information on operation of comparator voltage references, see 48.6 “Comparator Voltage Reference Generator”.

48.4 COMPARATOR CONFIGURATION

Each of the comparators in the Comparator with Blanking module is configured independently by various control bits in the following registers:

- Comparator Status register (CMSTAT) ([Register 48-1](#))
- Comparator Control register (CMxCON) ([Register 48-2](#))
- Comparator Mask Source Control register (CMxMSKSRC) ([Register 48-3](#))
- Comparator Mask Gating Control register (CMxMSKCON) ([Register 48-4](#))
- Comparator Filter Control register (CMxFLTR) ([Register 48-5](#))
- Comparator Voltage Reference Control register (CVRCON) ([Register 48-6](#))

48.4.1 Comparator Enable/Disable

The comparator under control may be enabled or disabled using the corresponding CON bit (CMxCON<15>). When the comparator is disabled (CON = 0), the corresponding trigger and interrupt generation is also disabled.

It is recommended to first configure the CMxCON register with all bits to the desired value, and then set the CON bit (CMxCON<15>).

48.4.2 Comparator Output Blanking Function

In many power control and motor control applications, there are periods of time in which the inputs to the analog comparator are known to be invalid. The blanking (masking) function enables the user to ignore the comparator output during predefined periods of time. In this document, the terms 'masking' and 'blanking' are used interchangeably.

[Figure 48-4](#) illustrates a block diagram of the comparator blanking circuitry. A blanking circuit is associated with each analog comparator.

Each comparator's blanking function has three user selectable inputs:

- MAI (Mask A Input)
- MBI (Mask B Input)
- MCI (Mask C Input)

The MAI, MBI and MCI signal sources are selected through the SELSRCA<3:0>, SELSRCB<3:0> and SELSRCC<3:0> bit fields in the CMxMSKSRC registers.

The MAI, MBI and the MCI signals are fed into an AND-OR function block, which enables the user to construct a blanking (masking) signal from these inputs.

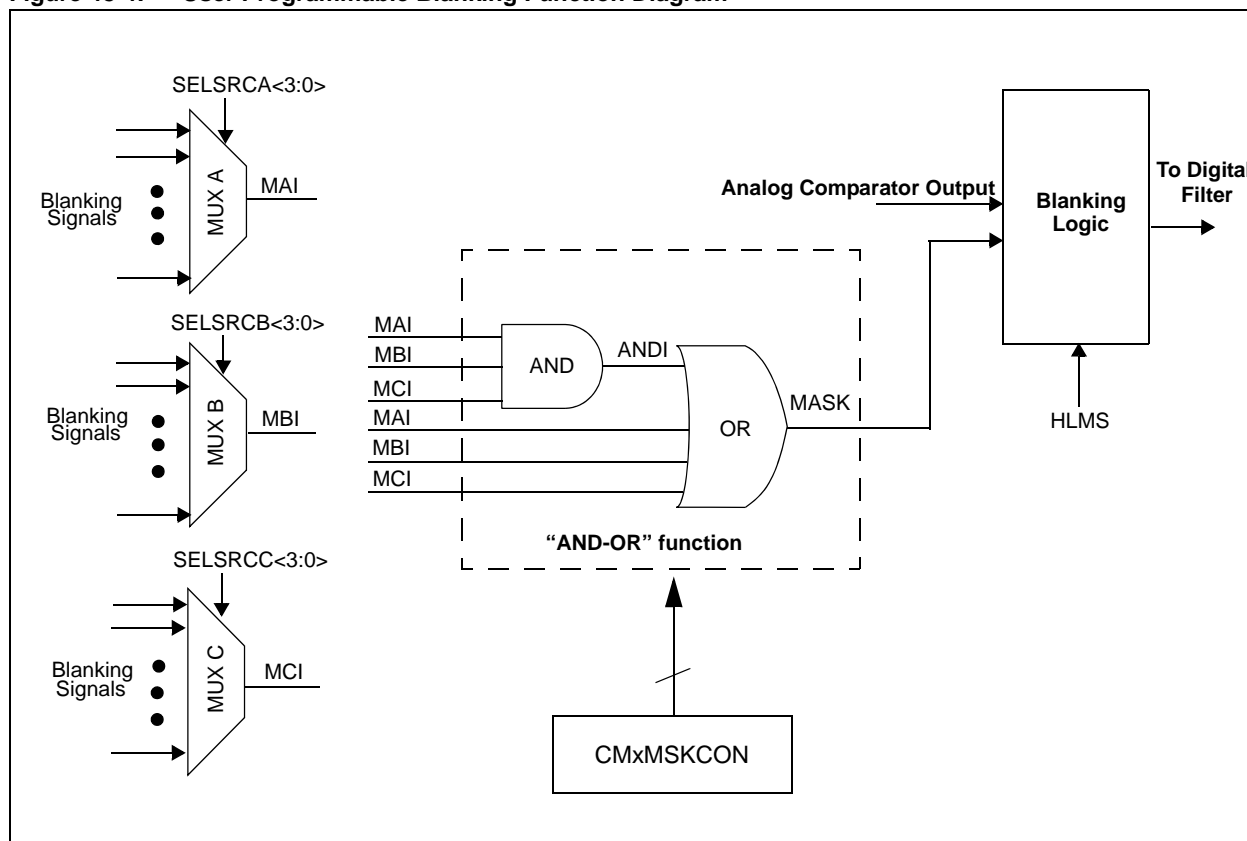
The blanking (masking) function is disabled following a system Reset.

The HLMS bit (CMxMSKCON<15>) configure the masking logic to operate properly depending on the default (deasserted) state of the comparators.

If the comparator is configured for 'positive logic' so that a '0' represents a deasserted state and the comparator output is a '1' when it is asserted, the HLMS bit should be set to '0' so that the blanking function (assuming the blanking function is active) will prevent the '1' signal of the comparator from propagating through the module.

If the comparator is configured for 'negative logic' so that a '1' represents a deasserted state and the comparator output is a '0' when it is asserted, the HLMS bit should be set to a '1' so that the blanking function (assuming blanking function is active) will prevent the '0' signal of the comparator from propagating through the module.

Figure 48-4: User Programmable Blanking Function Diagram



48.4.3 Digital Output Filter

In many motor and power control applications, the analog comparator input signals can be corrupted by the large electromagnetic fields generated by the associated external switching power transistors. Corruption of the analog input signals to the comparator can cause unwanted comparator output transitions. The programmable digital output filter can minimize the effects of input signal corruption.

The digital filter requires three consecutive input samples to be similar before the output of the filter can change state. Assuming the current state is '0', a string of inputs such as '001010110111' will only yield an output state of '1' at the end of the example sequence after the three consecutive '1's. Similarly, a sequence of three consecutive '0's are required before the output will change to a zero state.

Because of the requirement of three similar consecutive states for the filter, the chosen digital filter clock period must be one-third or less than the maximum desired comparator response time.

The digital filter is enabled by setting the CFLTREN bit (CMxFLTR<3>). The CFDIV<2:0> bits (CMxFLTR<2:0>) select the clock divider ratio for the clock signal input to the digital filter block. The CFSEL<2:0> bits (CMxFLTR<6:4>) select the desired clock source for the digital filter. The digital filter is disabled (bypassed) following a system Reset.

48.4.4 Comparator Polarity Selection

To provide maximum flexibility, the output of the comparator may be inverted using the CPOL bit (CMxCON<13>). This is functionally identical to reversing the inverting and non-inverting inputs of the comparator for a particular mode.

The CPOL bit (CMxCON<13>) should be changed only when the comparator is disabled (CON = 0). Internal logic will prevent the generation of any corresponding triggers or interrupts when CON = 0. The logic allows both the CON and CPOL bits to be set with a single register write.

48.4.5 Event Polarity Selection

In addition to a programmable comparator output polarity, the Comparator with Blanking module also allows software selection for trigger/interrupt edge polarity through the EVPOL<1:0> bits (CMxCON<7:6>). This feature allows independent control of the comparator output, as seen on any external pins, and the trigger/interrupt generation.

Note: The corresponding comparator must be enabled (CON = 1) for the specific trigger/interrupt generation to be enabled.

48.4.6 Comparator Reference Input Selection

The input to the non-inverting input of the comparator, also known as the reference input, can be selected between the following settings:

- CxINA pin (CON = 1, CREF = 0)
- Internal CVREF voltage (CON = 1, CREF = 1)

48.4.7 Comparator Channel Selection

The input to the inverting input of the comparator, also known as the channel input, can be selected between the following settings:

- CxINB pin (CON = 1, CCH<1:0> = 'b00)
- CxINC pin (CON = 1, CCH<1:0> = 'b01)
- CxIND pin (CON = 1, CCH<1:0> = 'b10)
- Band Gap Reference (CON = 1, CCH<1:0> = 'b11). The source of the band gap reference can be selected by the user-assigned application through the BGSEL<1:0> bits (CVRCON<9:8>).

48.4.8 Low-Power Selection

Depending on the capabilities of the comparator modules, this interface provides a low-power mode selection bit, CLPWR (CMxCON<12>). Using this bit, a user can trade-off power consumption for the speed of the comparator.

When CLPWR = 0, the Standard Power mode is active. When CLPWR = 1, the low-power setting of the corresponding comparator is enabled.

Note: The comparator power setting should not be changed while CON = 1.

48.4.9 Comparator Event Status Bit

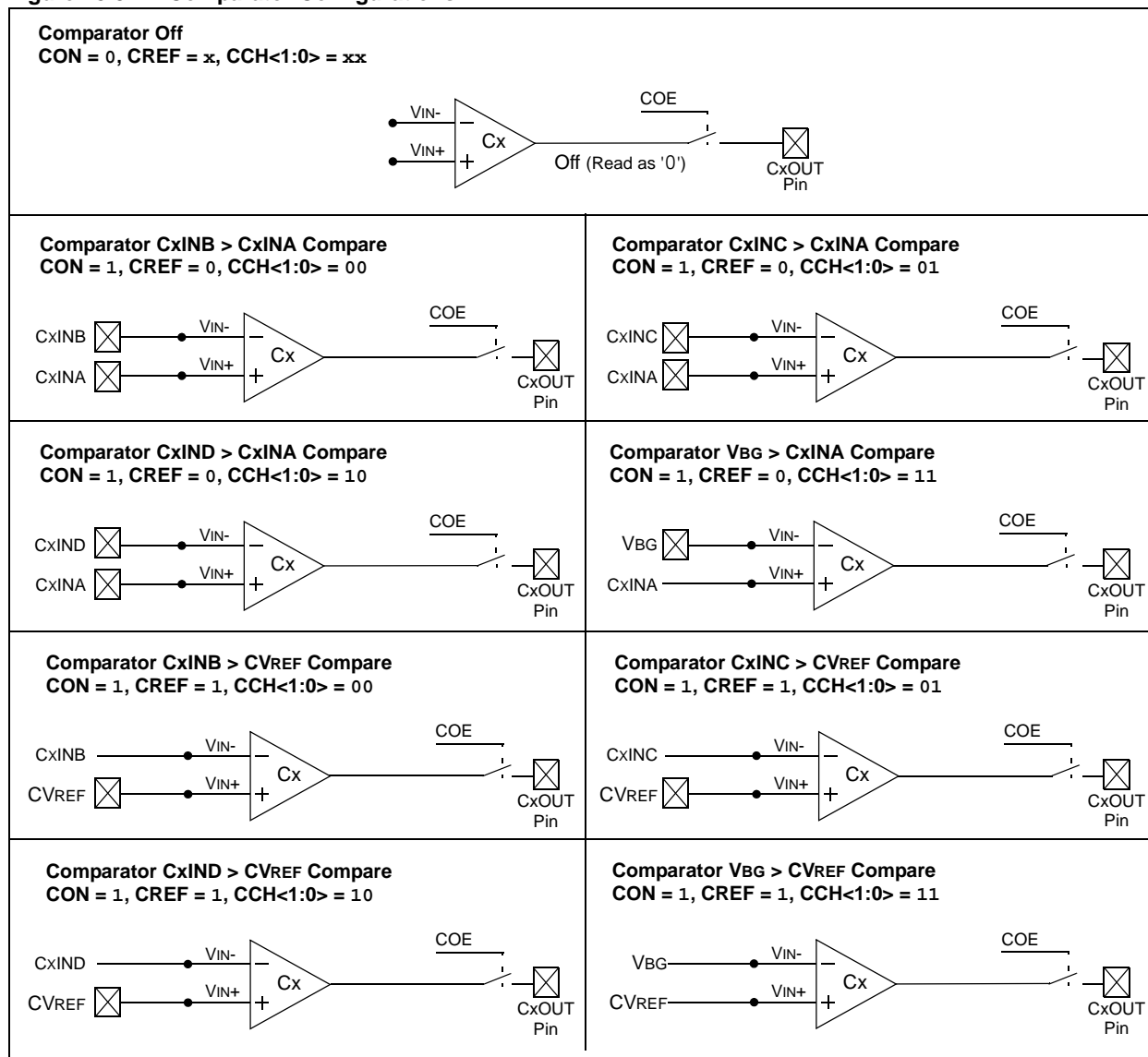
The Comparator Event Status (CEVT) bit (CMxCON<9>) reflects whether or not the comparator has gone through the preconfigured event. After the bit is set, all future triggers and interrupts from the corresponding comparator will be blocked until the user-assigned application clears the CEVT bit. Clearing the CEVT bit begins rearming the trigger. Once the CEVT bit is cleared, it takes an extra CPU cycle for the comparator triggers to be fully rearmed.

48.4.10 Status Register

To provide an overview of all comparator results, the comparator output bits, CxOUT (CMxCON<8>) and the event bits, CxEVT (CMxCON<9>) are replicated as status bits in the CMSTAT register.

These bits are read-only and can be altered only by manipulating the corresponding CMxCON register or the comparator input signals. Figure 48-5 illustrates the comparator configurations.

Figure 48-5: Comparator Configurations



48.5 COMPARATOR INTERRUPTS

The Comparator Interrupt Flag (CMIF) bit (IFS1<2>) is set when the synchronized output value of any of the comparator changes with respect to the last read value. The following bits can be read by the user application to detect an event:

- **C1EVT** – Comparator 1 Event bit (CMSTAT<8>)
- **C2EVT** – Comparator 2 Event bit (CMSTAT<9>)
- **C3EVT** – Comparator 3 Event bit (CMSTAT<10>)

User-assigned software can read the CxEVT and CxOUT bits to determine the change that occurred. Because it is possible to write a '1' to this register, a simulated interrupt can be software initiated. Both the CMIF and CxEVT bits must be reset by clearing them in software. These bits can be cleared in the Interrupt Service Routine (ISR). For more information, refer to the **Section 8. "Interrupts"** (DS39707) in the *"PIC24F Family Reference Manual"*.

Note: The comparison required for generating interrupts is based on the current comparator state and the last read value of the comparator outputs. Reading the C1OUT, C2OUT and C3OUT bits in the CMxCON register will update the values used for the interrupt generation.

48.5.1 Interrupt Operation During Sleep Mode

If a comparator is enabled and the PIC24F device is placed in Sleep mode, the comparator remains active. If the Comparator interrupt is enabled in the Interrupt module, it remains functional. Under these conditions, a comparator interrupt event will wake-up the device from Sleep mode.

Each operational comparator consumes additional current. To minimize power consumption in Sleep mode, turn off the comparators before entering Sleep mode by disabling the CON bit (CMxCON<15>). If the device wakes up from Sleep mode, the contents of the CMxCON register are not affected. For more information on Sleep mode, refer to **Section 10. "Power-Saving Features"** (DS39698) in the *"PIC24F Family Reference Manual"*.

48.5.2 Interrupt Operation During Idle Mode

The comparator remains active in Idle mode. Comparator interrupt operation during Idle mode is controlled by the Comparator Idle Mode (CMIDL) bit (CMSTAT<15>). If CMIDL = 0, normal interrupt operation continues. If CMIDL = 1, the comparator continues to operate, but it does not generate interrupts.

For more information on Idle mode, refer to **Section 10. "Power-Saving Features"** (DS39698) in the *"PIC24F Family Reference Manual"*.

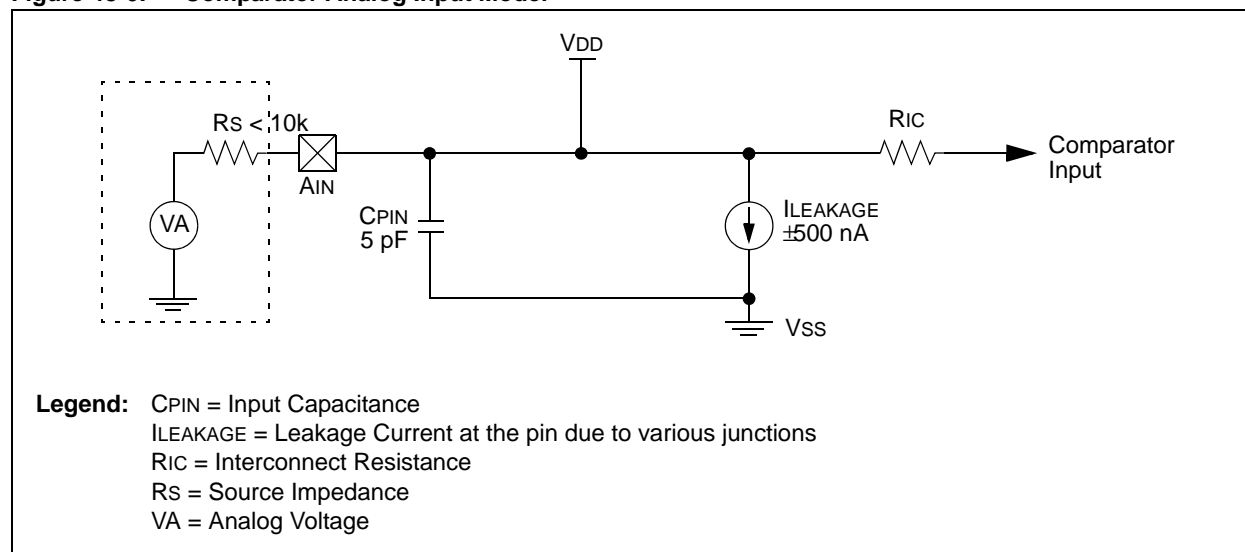
48.5.3 Effects of a Reset State

A device Reset forces the CMxCON register to its Reset state, causing the comparator modules to be turned off (CON = 0). However, the input pins multiplexed with analog input sources are configured as analog inputs by default on device Reset. The I/O configuration for these pins is determined by the setting of the ADxPCFGL or ADxPCFGH register. Therefore, device current is minimized when analog inputs are present at Reset time.

48.5.4 Analog Input Connection Considerations

A simplified circuit for an analog input is illustrated in [Figure 48-6](#). A maximum source impedance of 10 kΩ is recommended for the analog sources. Any external component connected to an analog input pin, such as a capacitor or a Zener diode, should have little leakage current.

Figure 48-6: Comparator Analog Input Model



48.6 COMPARATOR VOLTAGE REFERENCE GENERATOR

The internal comparator voltage reference is derived from a 16-tap resistor ladder network that provides a selectable voltage level, as illustrated in Figure 48-7. This resistor network generates the internal voltage reference for the analog comparators.

This voltage generator network is managed by the Comparator Voltage Reference Control (CVRCON) register (see Register 48-6) through these control bits:

- **CVREN** – Comparator Voltage Reference Enable bit (CVRCON<7>)
This control bit enables the voltage reference circuit.
- **CVROE** – Comparator Voltage Reference Output Enable bit (CVRCON<6>)
This control bit enables the reference voltage to be placed on the CVREF pin. When enabled, this bit overrides the corresponding TRIS bit setting.
- **VREFSEL** – Voltage Reference Select bit (CVRCON<10>)
This control bit specifies whether the reference source is external (VREF+), or it is obtained from the 4-bit DAC output.
- **CVRSS** – Comparator Voltage Reference Source Selection bit (CVRCON<4>)
This control bit specifies that the source (CVRSRC) for the voltage reference circuit is either the device voltage supply (AVDD and AVSS) or an external reference (VREF+ and VREF-).
- **CVRR** – Comparator Voltage Reference Range Selection bit (CVRCON<5>)
This control bit selects one of the two voltage ranges covered by the 16-tap resistor ladder network:
 - 0 CVRSRC to 0.67 CVRSRC
 - 0.25 CVRSRC to 0.75 CVRSRC

The range selected also determines the voltage increments available from the resistor ladder taps (see 48.6.1 “Configuring the Comparator Voltage Reference”).

- **CVR<3:0>** – Comparator Voltage Reference Value Selection bits (CVRCON<3:0>)
These bits designate the resistor ladder tap position.

Table 48-1 lists the voltage at each tap for both ranges with CVRSRC = 3.3V.

Figure 48-7: Comparator Voltage Reference Block Diagram

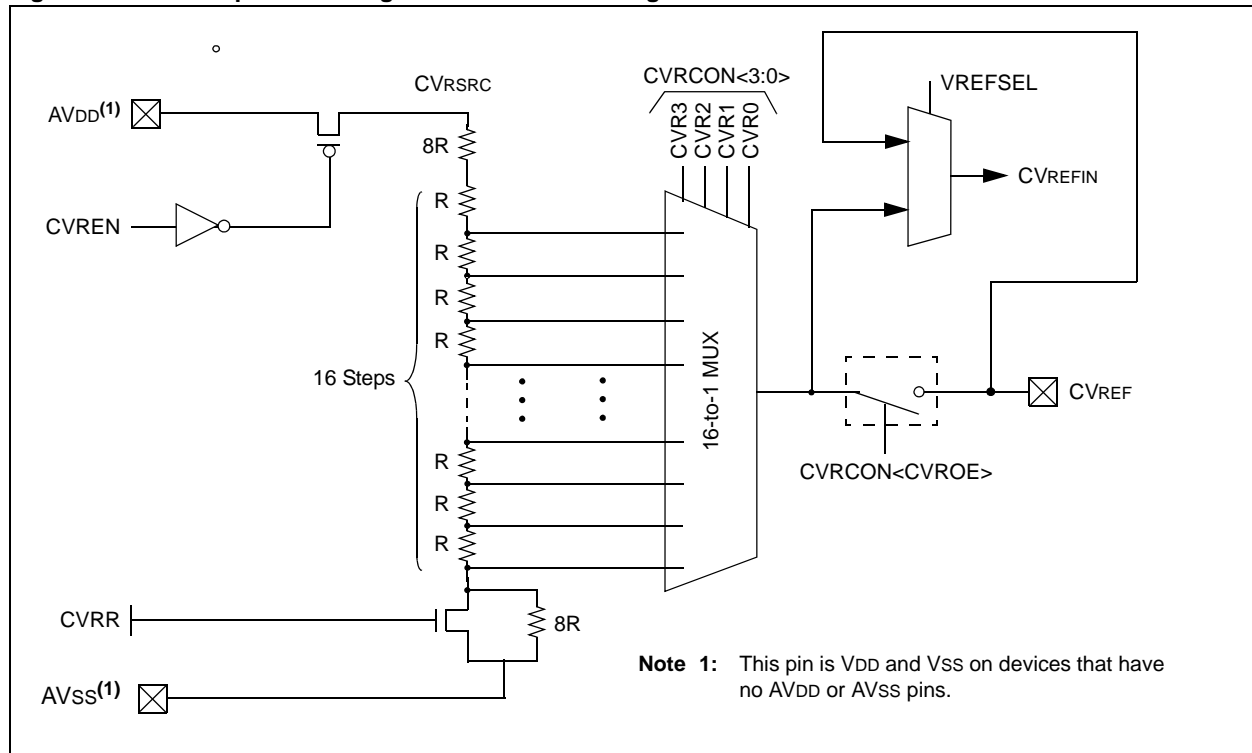


Table 48-1: Typical Voltage Reference with CVRSRC = 3.3V

| CVR<3:0> | Tap | Voltage Reference | |
|----------|-----|-------------------|----------|
| | | CVRR = 0 | CVRR = 1 |
| 0000 | 0 | 0.83V | 0.00V |
| 0001 | 1 | 0.93V | 0.14V |
| 0010 | 2 | 1.03V | 0.28V |
| 0011 | 3 | 1.13V | 0.41V |
| 0100 | 4 | 1.24V | 0.55V |
| 0101 | 5 | 1.34V | 0.69V |
| 0110 | 6 | 1.44V | 0.83V |
| 0111 | 7 | 1.55V | 0.96V |
| 1000 | 8 | 1.65V | 1.10V |
| 1001 | 9 | 1.75V | 1.24V |
| 1010 | 10 | 1.86V | 1.38V |
| 1011 | 11 | 1.96V | 1.51V |
| 1100 | 12 | 2.06V | 1.65V |
| 1101 | 13 | 2.17V | 1.79V |
| 1110 | 14 | 2.27V | 1.93V |
| 1111 | 15 | 2.37V | 2.06V |

48.6.1 Configuring the Comparator Voltage Reference

The voltage range selected by the CVRR bit (CVRCON<5>) determines the size of the steps selected by the CVR<3:0> bits (CVRCON<3:0>). One range (CVRR = 0) provides finer resolution by offering smaller voltage increments for each step. The equations used to calculate the comparator voltage reference are as follows:

If CVRR = 1:

$$\text{Voltage Reference} = ((\text{CVR}<3:0>)/24) * (\text{CVRSRC})$$

If CVRR = 0:

$$\text{Voltage Reference} = (\text{CVRSRC}/4) + ((\text{CVR}<3:0>)/32) * (\text{CVRSRC})$$

48.6.2 Voltage Reference Accuracy/Error

The full voltage reference range cannot be realized because the transistors on the top and bottom of the resistor ladder network, as shown in [Figure 48-7](#), keep the voltage reference from approaching the reference source rails. The voltage reference is derived from the reference source; therefore, the voltage reference output changes with fluctuations in the reference source. For reference voltage accuracy, refer to the “**Electrical Characteristics**” chapter of the specific device data sheet.

48.6.3 Operation During Sleep Mode

When the device wakes up from Sleep mode through an interrupt or a Watchdog Timer time-out, the contents of the CVRCON register are not affected. To minimize current consumption in Sleep mode, the voltage reference should be disabled.

48.6.4 Effects of a Reset

A device Reset has the following effects:

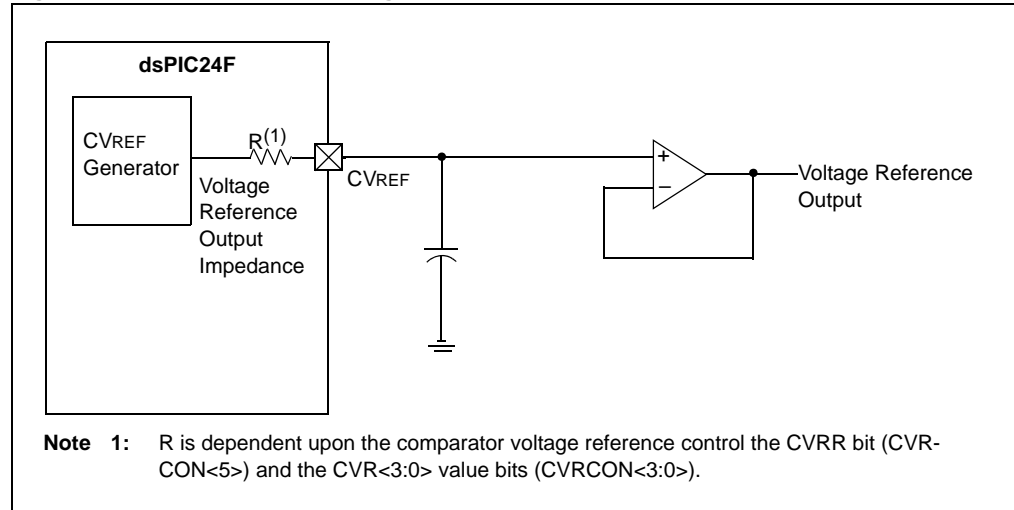
- Disables the voltage reference by clearing the CVREN bit (CVRCON<7>)
- Disconnects the reference from the CVREF pin by clearing the CVROE bit (CVRCON<6>)
- Selects the high-voltage range by clearing the CVRR bit (CVRCON<5>)
- Clears the CVR value bits (CVRCON<3:0>)

48.6.5 Connection Considerations

The voltage reference generator operates independently of the Comparator with Blanking module. The output of the reference generator is connected to the CVREF pin if the CVROE bit (CVRCON<6>) is set. Enabling the voltage reference output onto the I/O when it is configured as a digital input will increase current consumption. Configuring the port associated with CVREF as a digital output, with CVRSS enabled, will also increase current consumption.

The CVREF output pin can be used as a simple Digital-to-Analog output with limited drive capability. Due to this limited current drive capability, a buffer must be used on the voltage reference output for external connections to CVREF. Figure 48-8 illustrates a buffering technique example.

Figure 48-8: Comparator Voltage Reference Output Buffer Example



48.7 REGISTER MAP

A summary of the Special Function Registers (SFRs) associated with the Comparator with Blanking module is provided in [Table 48-2](#).

Table 48-2: Comparator Register Map

| File 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 |
|-----------|--------|--------|--------|--------|--------------|---------|------------|-------|--------------|------------|-------|-------|--------------|------------|----------|-------|------------|
| CMSTAT | CMSIDL | — | — | — | — | C3EVT | C2EVT | C1EVT | — | — | — | — | — | C3OUT | C2OUT | C1OUT | 0000 |
| CMxCON | CON | COE | CPOL | CLPWR | — | — | CEVT | COUT | EVPOL<1:0> | | — | CREF | — | — | CCH<1:0> | | 0000 |
| CMxMSKSRC | — | — | — | — | SELSRCC<3:0> | | | | SELSRCB<3:0> | | | | SELSRCA<3:0> | | | | 0000 |
| CMxMSKCON | HLMS | — | OCEN | OCNEN | OBEN | OBNEN | OAEN | OANEN | NAGS | PAGS | ACEN | ACNEN | ABEN | ABNEN | AAEN | AANEN | 0000 |
| CMxFLTR | — | — | — | — | — | — | — | — | — | CFSEL<2:0> | | | CFLTREN | CFDIV<2:0> | | | 0000 |
| CVRCON | — | — | — | — | — | VREFSEL | BGSEL<1:0> | | CVREN | CVROE | CVRR | CVRSS | CVR<3:0> | | | | 0000 |

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

Note 1: Not all bits are available for all devices. Please refer to the specific device data sheet for details.

48.8 DESIGN TIPS

Question 1: *Why is my voltage reference not what I expect?*

Answer: Any variation of the voltage reference source will translate directly onto the CVREF pin. Also, ensure that you have correctly calculated the voltage divider, which generates the voltage reference.

Question 2: *Why is my voltage reference not at the expected level when I connect CVREF into a low-impedance circuit?*

Answer: The voltage reference module is not intended to drive large loads. A buffer must be used between the CVREF pin and the load of the PIC24F device (see [Figure 48-8](#)).

48.9 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 PIC24F device family, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to the Comparator with Blanking module are:

| Title | Application Note # |
|---|--------------------|
| Make a Delta-Sigma Converter Using a Microcontroller's Analog Comparator Module | AN700 |
| A Comparator Based Slope ADC | AN863 |

Note: Visit the Microchip web site (www.microchip.com) for additional application notes and code examples for the PIC24F family of devices.

48.10 REVISION HISTORY

Revision A (December 2010)

This is the initial released version of this document.

NOTES:

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