Section 20. Comparator Voltage Reference

HIGHLIGHTS

This section of the manual contains the following major topics:

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 **"Comparator Voltage Reference"** 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

20.1 INTRODUCTION

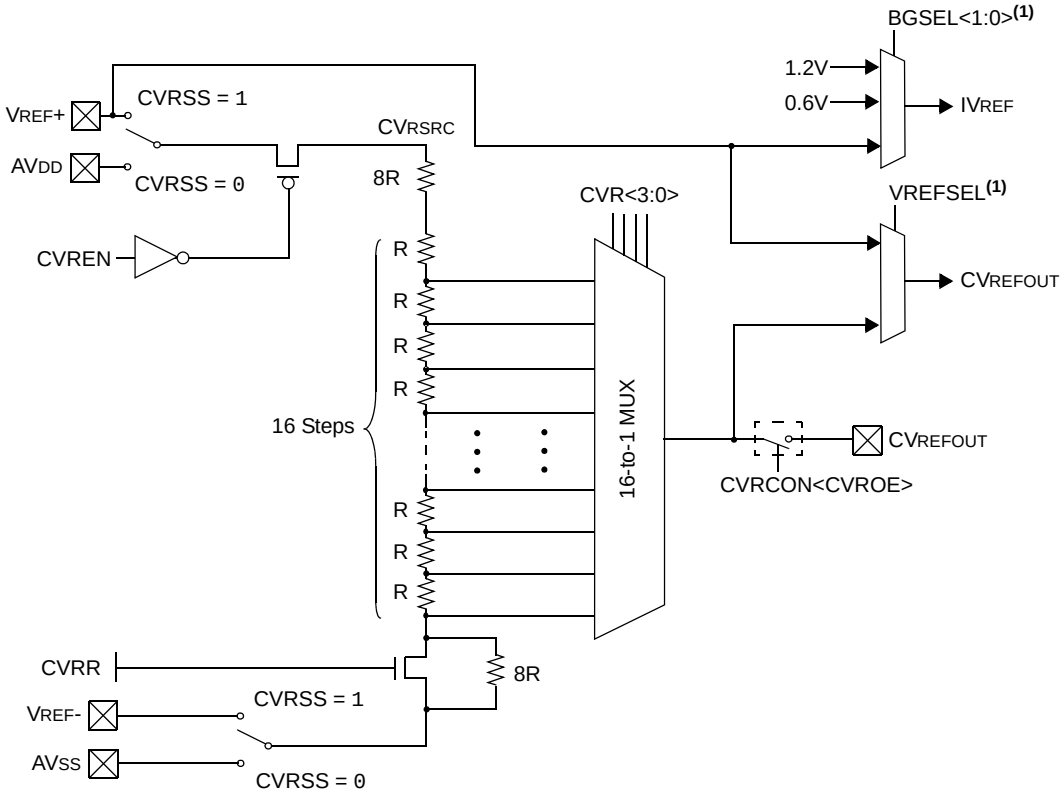
The Comparator Voltage Reference module is a 16-tap, resistor ladder network that provides a selectable reference voltage. Although its primary purpose is to provide a reference for the analog comparators, it also may be used independently of them.

A block diagram of the module is illustrated in Figure 20-1. The resistor ladder is segmented to provide two ranges of voltage reference values and has a power-down function to conserve power when the reference is not used. The module's supply reference can be provided from either device VDD/VSS or an external voltage reference. The module output is available for the comparators and typically available for pin output. For more information, refer to the specific device data sheet.

The Comparator Voltage Reference has the following features:

- High and low range selection
- Sixteen output levels available for each range
- Internally connected to comparators to conserve device pins
- Output can be connected to a pin

Figure 20-1: Comparator Voltage Reference Block Diagram



Note 1: These bits are not available on all devices. On such devices, CVREF is generated by the resistor network and IVREF is connected to 1.2V. Refer to the specific device data sheet for availability.

20.2 COMPARATOR VOLTAGE REFERENCE CONTROL REGISTER

Register 20-1: CVRCON: Comparator Voltage Reference 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	U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-1
	ON(1)	—	—	—	—	VREFSEL(2)	BGSEL<1:0>(2)	
7:0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	—	CVROE	CVRR	CVRSS	CVR<3:0>			

Legend:			
R = readable bit	W = writable bit	P = programmable	r = reserved bit
U = unimplemented bit, read as '0'	-n = bit value at POR: ('0', '1', x = unknown)		

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

bit 15 **ON:** Comparator Voltage Reference On bit(1)
- 1 = Module is enabled, setting this bit does not affect other bits in the register.
- 0 = Module is disabled and does not consume current. Clearing this bit does not affect the other bits in the register

bit 14-11 **Unimplemnted:** Read as '0'

bit 10 **VREFSEL:** Voltage Reference Select bit(2)
- 1 = $CV_{REF} = V_{REF+}$
- 0 = CV_{REF} is generated by the resistor network

bit 9-8 **BGSEL<1:0>:** Band Gap Reference Source bits(2)
- 11 = $IV_{REF} = V_{REF+}$
- 10 = Reserved
- 01 = IV_{REF} = 0.6V (nominal, default)
- 00 = IV_{REF} = 1.2V (nominal)

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

bit 6 **CVROE:** CV_{REFOUT} Enable bit
- 1 = Voltage level is output on CV_{REFOUT} pin
- 0 = Voltage level is disconnected from CV_{REFOUT} pin

bit 5 **CVRR:** CV_{REF} Range Selection bit
- 1 = 0 to 0.67 CV_{RSRC}, with $CV_{RSRC}/24$ step size
- 0 = 0.25 CV_{RSRC} to 0.75 CV_{RSRC}, with $CV_{RSRC}/32$ step size

bit 4 **CVRSS:** CV_{REF} Source Selection bit
- 1 = Comparator voltage reference source, $CV_{RSRC} = (V_{REF+}) – (V_{REF-})$
- 0 = Comparator voltage reference source, $CV_{RSRC} = AV_{DD} – AV_{SS}$

bit 3-0 **CVR<3:0>:** CV_{REF} Value Selection $0 \leq CVR<3:0> \leq 15$ bits

When CVRR = 1:

$CV_{REF} = (CVR<3:0>/24) \bullet (CV_{RSRC})$

When CVRR = 0:

$CV_{REF} = 1/4 \bullet (CV_{RSRC}) + (CVR<3:0>/32) \bullet (CV_{RSRC})$

Note 1: When using 1:1 PBCLK divisor, the user's software should not read/write the peripheral's SFRs in the SYSCLK cycle immediately following the instruction that clears the module's ON bit.

2: These bits are not available on all devices and the reset value is '0' for devices without these bits. Refer to the specific device data sheet for availability.

20.3 OPERATION

20.3.1 CVREF Output

The Comparator Voltage Reference module is controlled through the CVRCON register (Register 20-1). This module provides two ranges of output voltage, each with 16 distinct levels. The range to be used is selected by the CVRR bit (CVRCON<5>). The primary difference between the ranges is the size of the steps selected by the CVREF value selection bits, CVR<3:0>, with one range offering finer resolution and the other offering a wider range of output voltage. The typical output voltages are listed in Table 20-1.

The equations used to calculate the CVREF output are as follows:

If CVRR = 1: Voltage Reference = ((CVR<3:0>)/24) x (CVRSRC)

If CVRR = 0: Voltage Reference = (CVRSRC/4) + ((CVR<3:0>)/32) x (CVRSRC)

The CVREF Source Voltage (CVRSRC) can come from either VDD and VSS, or the external VREF+ and VREF- pins that are multiplexed with I/O pins. The voltage source is selected by the CVRSS bit (CVRCON<4>). The voltage reference is output to the CVREFOUT pin by setting the CVROE bit (CVRCON<6>); this overrides the corresponding TRIS bit setting.

The settling time of the Comparator Voltage Reference module must be considered when changing the CVREF output. For more information, refer to the specific device data sheet.

Table 20-1: Typical Voltage Reference in Volts (CVRSRC = 3.3)

CVR<3:0>	Voltage Reference	
	CVRR = 0 (CVRCON<5>)	CVRR = 1 (CVRCON<5>)
0	0.83V	0.00V
1	0.93V	0.14V
2	1.03V	0.28V
3	1.13V	0.41V
4	1.24V	0.55V
5	1.34V	0.69V
6	1.44V	0.83V
7	1.55V	0.96V
8	1.65V	1.10V
9	1.75V	1.24V
10	1.86V	1.38V
11	1.96V	1.51V
12	2.06V	1.65V
13	2.17V	1.79V
14	2.27V	1.93V
15	2.37V	2.06V

20.3.2 CVREF Output Considerations

The full range of voltage reference cannot be realized due to the construction of the module. The transistors on the top and bottom of the resistor ladder network (Figure 20-1) 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 that source. Refer to the product data sheet for the electrical specifications. Table 20-2 contains the typical output impedances for the Comparator Voltage Reference module.

Table 20-2: Typical CVREF Output Impedance in kilohms

CVR<3:0>	Voltage Reference	
	CVRR = 0 (CVRCON<5>)	CVRR = 1 (CVRCON<5>)
0	12k	0.5k
1	13k	1.9k
2	13.8k	3.7k
3	14.4k	5.3k
4	15k	6.7k
5	15.4k	7.9k
6	15.8k	9k
7	15.9k	9.9k
8	16k	10.7k
9	15.9k	11.3k
10	15.8k	11.7k
11	15.4k	11.9k
12	15k	12k
13	14.4k	11.9k
14	13.8k	11.7k
15	12.9k	11.3k

20.3.3 IVREF Output

The Comparator Voltage Reference module provides selection for the internal voltage reference. The Band Gap Reference Source Select bits (BGSEL<1:0>) allow voltage selection of 1.2V or 0.6V, which is generated internally. Refer to the specific device data sheet for the IVREF specifications.

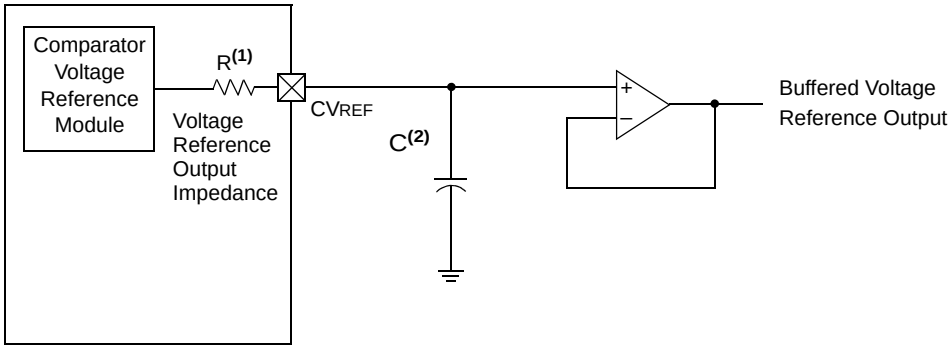
20.4 INTERRUPTS

There are no Interrupt configuration registers or bits for the Comparator Voltage Reference module. The module does not generate interrupts.

20.5 I/O PIN CONTROL

The Comparator Voltage Reference module can output to a pin. When the module is enabled and CVROE (CVRCON<6>) is '1', the output driver for the CVREFOUT pin is disabled and the CVREF voltage is available at the pin. For operation, the TRIS bit corresponding to the CVREFOUT pin must be a '1'. This disables the digital Input mode for the pin and prevents undesired current draw resulting from applying an analog voltage to a digital input pin. The output buffer has very limited drive capability. An external buffer amplifier is recommended for any application that uses the CVREF voltage externally. An output capacitor may be used to reduce output noise. Use of an output capacitor will increase settling time (see Figure 20-2).

Figure 20-2: Comparator Voltage Reference Output Buffer Example



Note 1: R is dependent on the Comparator Voltage Reference Control bits CVRR (CVRCON<5>) and CVR<3:0> (CVRCON<3:0>). For more information, see Table 20-2.

2: Use of an output capacitor will increase settling time. Capacitor value selection is dependent on the CVR<3:0> and CVRR settings, and the frequency to be attenuated.

20.6 OPERATION IN POWER-SAVING AND DEBUG MODES

20.6.1 Operation in Sleep Mode

The Comparator Voltage Reference module continues to operate in Sleep mode. The CVRCON register is not affected when the device enters or wakes from Sleep mode. If the CVREF voltage is not used in Sleep mode, the module can be disabled by clearing the ON bit (CVRCON<15>) prior to entering Sleep mode to save power.

20.6.2 Operation in Idle Mode

The Comparator Voltage Reference module continues to operate in Idle mode. The CVRCON register is not affected when the device enters or exits Idle mode. There is no provision to automatically disable the module in Idle mode. If the CVREF voltage is not used in Idle mode, the module can be disabled by clearing the ON bit (CVRCON<15>) prior to entering Idle mode to save power.

20.6.3 Operation in Debug Mode

The Comparator Voltage Reference module continues to operate while the device is in Debug mode. The module does not support Freeze mode.

20.7 EFFECTS OF RESETS

All Resets disable the voltage reference by forcing all bits in the CVRCON register to '0'.

20.8 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 PIC32 family device family, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to the Comparator Voltage Reference module are:

Title	Application Note #
Related application notes are not available.	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.

20.9 REVISION HISTORY

Revision A (October 2007)

This is the initial released version of this document.

Revision B (October 2007)

Updated document to remove Confidential status.

Revision C (April 2008)

Revised status to Preliminary; Revised U-0 to r-x.

Revision D (June 2008)

Revised Figure 20-1; Change Reserved bits from “Maintain as” to “Write”; Added Note to ON bit (CVRCON Register).

Revision E (August 2010)

This revision includes the following updates:

- Updated the Comparator Voltage Reference Block Diagram (see Figure 20-1)
- Added notes regarding the INV, SET, and CLR registers to the Oscillators SFR Summary (see Table 20-1)
- Updated the Comparator Voltage Reference Control Register (see Register 20-1)
- Removed the CVRCONINV, CVRCONSET, and CVRCONCLR registers
- Removed 20.3.3 “Initialization”
- Added new section **20.3.3 “IVREF Output”**
- Removed Table 20-4: Pins Associated with a Comparator
- Removed 20.8 “Design Tips”
- Minor corrections to formatting and text were incorporated throughout the document

Revision F (May 2011)

This revision includes the following updates:

- Updated the Comparator Voltage Reference Block Diagram (see Figure 20-1)
- Removed the Comparator Voltage Reference SFR Summary (Table 20-1) and related text
- Updated the BGSEL<1:0> bit value for ‘10’ to Reserved and modified the Notes in the CVRCON register (see Register 20-1)
- Updated the allowable voltage reference selections in **20.3.3 “IVREF Output”**
- Minor updates to text and formatting were incorporated throughout the document

NOTES:

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.

Trademarks

Printed on recycled paper.

ISBN: 978-1-61341-127-8

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
ISO/TS 16949:2002

Microchip received ISO/TS-16949:2002 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, KEELOQ® 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

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
Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

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

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

Santa Clara
Santa Clara, CA
Tel: 408-961-6444
Fax: 408-961-6445

Toronto
Mississauga, Ontario,
Canada
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: 86-10-8528-2100
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 - Hong Kong SAR
Tel: 852-2401-1200
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: 86-755-8203-2660
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: 91-20-2566-1512
Fax: 91-20-2566-1513

Japan - Yokohama
Tel: 81-45-471- 6166
Fax: 81-45-471-6122

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: 886-3-6578-300
Fax: 886-3-6578-370

Taiwan - Kaohsiung
Tel: 886-7-213-7830
Fax: 886-7-330-9305

Taiwan - Taipei
Tel: 886-2-2500-6610
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 - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

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

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

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

UK - Wokingham
Tel: 44-118-921-5869
Fax: 44-118-921-5820

02/18/11