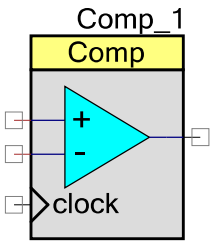
Comparator (Comp)

1.90

Features



- Low input offset
- User controlled offset calibration
- Multiple speed modes
- Low-power mode
- Output routable to digital logic blocks or pins
- Selectable output polarity
- Configurable operation mode during Sleep

General Description

The Comparator (Comp) component provides a hardware solution to compare two analog input voltages. The output can be sampled in software or digitally routed to another component. Three speed levels are provided to allow you to optimize for speed or power consumption. A reference or external voltage can be connected to either input.

You can also invert the output of the comparator using the Polarity parameter.

When to Use a Comparator

The Comparator can provide a fast comparison between two voltages, compared to using an ADC. Although an ADC can be used with software to compare multiple voltage levels, applications requiring fast response or little software intervention are good candidates for this comparator. Some example applications include CapSense®, power supplies, or simple translation from an analog level to a digital signal.

A common configuration is to create an adjustable comparator by connecting a voltage DAC to the negative input terminal.

Input/Output Connections

This section describes the input and output connections for the Comp. An asterisk (*) in the list of I/Os states that the I/O may be hidden on the symbol under the conditions listed in the description of that I/O.

Positive Input – Analog

This input is usually connected to the voltage that is being compared. This input can be routed to GPIOs or to a selection of internal references.

Negative Input – Analog

This input is usually connected to the reference voltage. This input can be routed to GPIOs or to a selection of internal references.

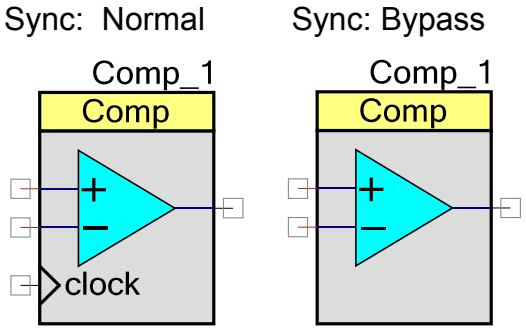
Comparator Out – Digital Output

The output of the comparison. For noninverting configuration, this output goes high when the positive input voltage is greater than the negative input voltage. If the polarity is set to inverting, the output will go high when the negative input voltage is greater than the positive input voltage, in this case one inverter from an UDB block is used in order to inverts the comparator's output signal. The output can be routed to other component digital inputs such as interrupts, timers, etc.

clock – Digital Input *

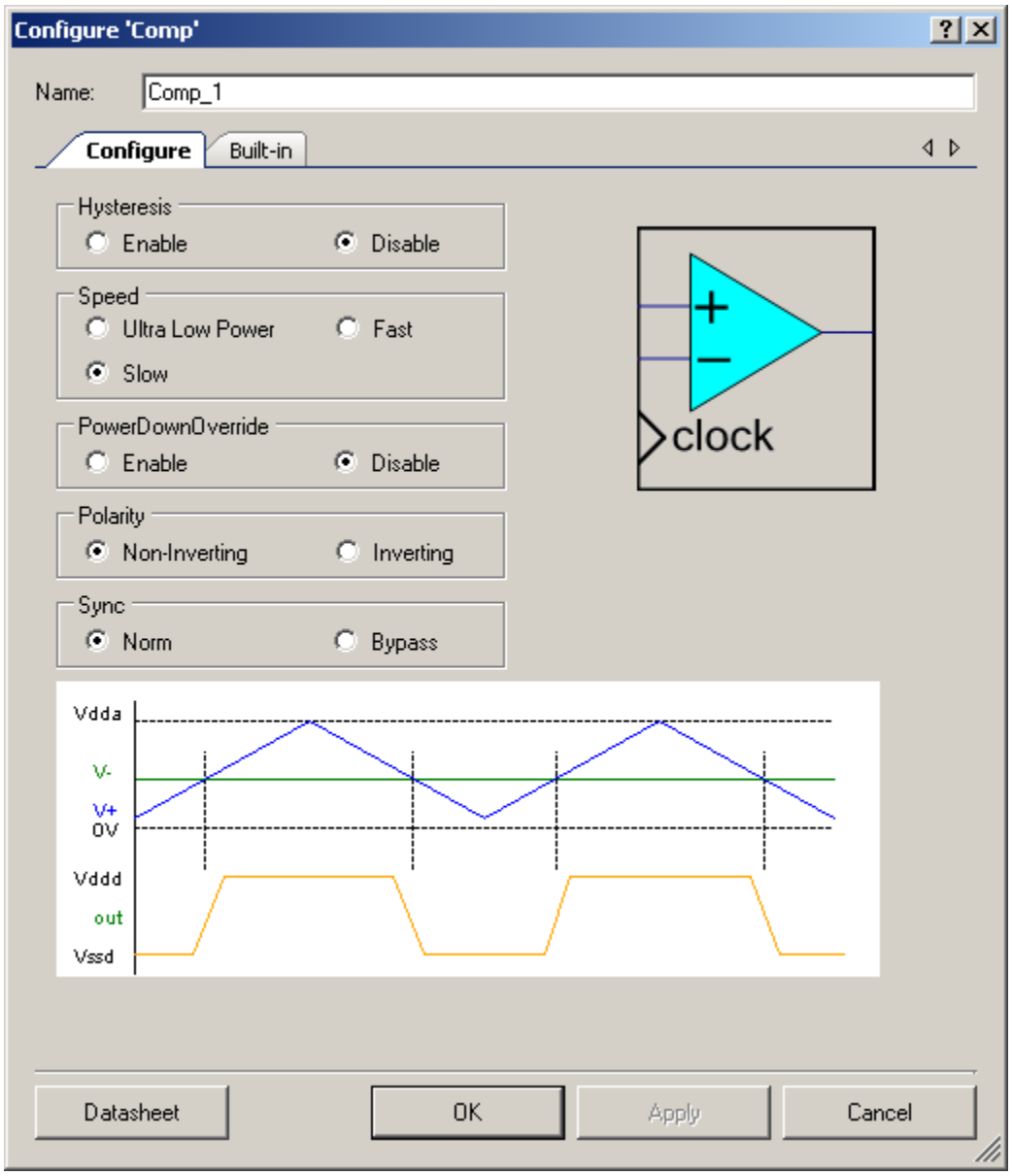
The clock input synchronizes the comparator output to the rising edge of the clock when the **Sync** parameter is set to **Normal**. This forces the comparator output to be sampled on the rising edge of the clock.

When the **Sync** parameter is set to **Bypass,** the output is not synchronized with bus clock on rising edge and synchronized to the bus clock on falling edge. In this case the clock input terminal no longer displayed on the component symbol.



Component Parameters

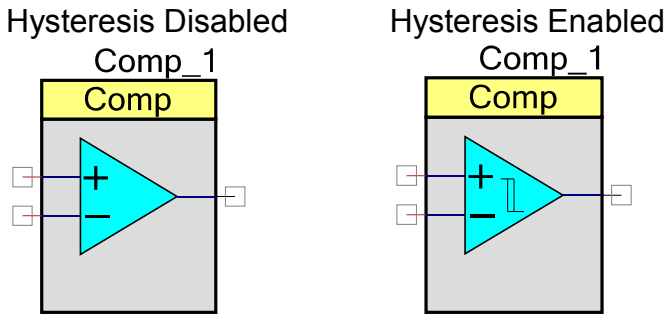
Drag a Comparator onto your design and double-click it to open the **Configure** dialog.



The Comparator provides the following parameters.

Hysteresis

This parameter allows you to add approximately 10 mV of hysteresis to the comparator. This helps to ensure that slowly moving voltages or slightly noisy voltages will not cause the output of the comparator to oscillate when the two input voltages are near equal.



Speed

This parameter provides a way for the user to optimize speed verses power consumption.

Speed Options	Description
Ultra Low Power	Use this setting for very low power applications.
Slow (default)	Use this setting for signals requiring response times slower than 80 ns.
Fast	Use this setting for signals requiring response times faster than 80 ns.

PowerDownOverride

Enabling the power down override parameter causes the comparator to stay active during Sleep mode. When the **PowerDownOverride** option is enabled, the customizer automatically sets the power mode to Ultra Low Power and remaining power options become unavailable. This is because Ultra Low Power is the only valid power mode for the comparator in Sleep mode.

Note Don't use the inverted output in this mode.

Note This parameter is not valid for PSoC 5 silicon and the GUI option is unavailable. For PSoC 3 and PSoC 5 LP silicon, this feature is supported and the GUI option is available.

Polarity

This parameter allows you to invert the output of the comparator. This is useful for peripherals that require an inverted signal from the comparator. The sampled signal state returned by the software API and the comparator output seen by the power manager (see the *System Reference Guide* section on Alt Active and Sleep) is not affected by this parameter.

Note Inversion logic for comparator is implemented using UDBs.

Polarity Options	Description
Inverting	Output goes high when positive input is less than the negative input
Non-Inverting (default)	Output goes high when positive input is greater than negative input

Sync

This parameter selects between synchronizing the output with a clock and connecting through asynchronous set/synchronous to the bus clock reset flop. When **Norm** is selected, the output will change on the rising edge of the clock input. When Bypass is selected, the output will set immediately and reset on the rising edge of the bus clock.

Sync Options	Description
Norm (default)	Sync the comparator output with the clock input.
Bypass	Connect the analog comparator output through asynchronous set/synchronous to the bus clock reset flop.

Application Programming Interface

Application Programming Interface (API) routines allow you to configure the component using software. The following table lists the interface to each function. The subsequent sections cover each function in more detail.

By default, PSoC Creator assigns the instance name “Comp_1” to the first instance of a component in a given design. You can rename the instance to any unique value that follows the syntactic rules for identifiers. The instance name becomes the prefix of every global function name, variable, and constant symbol. For readability, the instance name used in the following table is “Comp.”

Function	Description
Comp_Start()	Initializes the Comparator with default customizer values.
Comp_Stop()	Turns off the Comparator.
Comp_SetSpeed()	Sets speed of the Comparator.
Comp_ZeroCal()	Zeros the input offset of the Comparator.
Comp_GetCompare()	Returns compare result.
Comp_LoadTrim()	Writes a value to the Comparator trim register.
Comp_Sleep()	Stops Comparator operation and saves the user configuration.
Comp_Wakeup()	Restores and enables the user configuration.
Comp_Init()	Initializes or restores default Comparator configuration.
Comp_Enable()	Enables the Comparator.

Function	Description
Comp_SaveConfig()	Empty function. Provided for future use.
Comp_RestoreConfig()	Empty function. Provided for future use.
Comp_PwrDwnOverrideEnable()	Enables Comparator operation in sleep mode. Only valid for PSoC 3 silicon.
Comp_PwrDwnOverrideDisable()	Disables Comparator operation in sleep mode. Only valid for PSoC 3 silicon.

Global Variables

Variable	Description
Comp_initVar	Indicates whether the Comparator has been initialized. The variable is initialized to 0 and set to 1 the first time Comp_Start() is called. This allows the component to restart without reinitialization after the first call to the Comp_Start() routine. If reinitialization of the component is required, then the Comp_Init() function can be called before the Comp_Start() or Comp_Enable() function.

void Comp_Start(void)

Description: This is the preferred method to begin component operation. Comp_Start() sets the initVar variable, calls the Comp_Init() function, and then calls the Comp_Enable() function.

Parameters: None

Return Value: None

Side Effects: If the initVar variable is already set, this function only calls the Comp_Enable() function.

void Comp_Stop(void)

Description: Disables and powers down the comparator.

Note This API is not recommended for use on PSoC 3 ES2 and PSoC 5 silicon. These devices have a defect that causes connections to several analog resources to be unreliable when not powered. The unreliability manifests itself in silent failures (for example, unpredictably bad results from analog components) when the component using that resource is stopped. When using this silicon, all analog components in a design should be powered up (by calling their respective _Start() APIs, for instance Comp_Start()) at all times. Do not call the Comp_Stop() APIs.

Parameters: None

Return Value: None

Side Effects: None

void Comp_SetSpeed(uint8 speed)

Description: This function selects one of three speed modes for the comparator. The comparator power consumption increases for the faster speed modes.

Parameters: uint8 speed: Speed parameter, see the following table for valid settings.

Speed Options	Description
Comp_LOWPOWER	Use this setting for very low power applications
Comp_SLOWSPEED	Use this setting for signals requiring response times slower than 80 ns
Comp_HIGHSPEED	Use this setting for signals requiring response times faster than 80 ns

Return Value: None

Side Effects: None

uint16 Comp_ZeroCal(void)

Description: Performs custom calibration of the input offset to minimize error for a specific set of conditions: comparator reference voltage, supply voltage, and operating temperature.

A reference voltage in the range at which the comparator will be used must be applied to the negative input of the comparator while the offset calibration is performed. The comparator component must be configured for Fast or Slow operation when calibration is performed. The calibration process will not work correctly if the comparator is configured in Low Power mode.

Parameters: None

Return Value: uint16: The value from the comparator trim register after the offset calibration is complete.

This value has the same format as the input parameter for the Comp_LoadTrim() API routine. Refer to the *PSoC® 3, PSoC® 5 Architecture TRM* for a description of the comparator trim register.

Side Effects: During the calibration procedure, the comparator output may behave erratically.

During the calibration procedure, the analog routing switches for the comparator positive input are reconfigured. This reconfiguration may affect the analog signal routing for other components that are connected to the comparator positive input.

When calibration is complete, all routing and comparator configuration registers are restored to the state they were in before calibration occurred.

uint8 Comp_GetCompare(void)

Description: This function returns a nonzero value when the voltage connected to the positive input is greater than the negative input voltage. This value is not affected by the Polarity parameter. This value always reflects a noninverted state.

Parameters: None

Return Value: uint8: Comparator output state. Nonzero value when the positive input voltage is greater than the negative input voltage; otherwise, the return value is zero.

Side Effects: None

void Comp_LoadTrim(uint16 trimVal)

Description: This function writes a value into the comparator trim register.

Parameters: uint16 trimVal: Value to be stored in the comparator trim register.

This value has the same format as the parameter returned by the Comp_ZeroCal() API routine. Refer to the *PSoC® 3, PSoC® 5 Architecture TRM* for a description of the comparator trim register.

Return Value: None

Side Effects: None

void Comp_SaveConfig(void)

Description: This function saves the component configuration and nonretention registers. It also saves the current component parameter values, as defined in the Configure dialog or as modified by appropriate APIs. This function is called by the Comp_Sleep() function.

Parameters: None

Return Value: None

Side Effects: Empty function. Implemented for future usage. No effect by calling this function.

void Comp_RestoreConfig(void)

Description: This function restores the component configuration and nonretention registers. It also restores the component parameter values to what they were prior to calling the Comp_Sleep() function.

Parameters: None

Return Value: None

Side Effects: Empty function. Implemented for future use. No effect by calling this function.

void Comp_Sleep(void)

Description: This is the preferred routine to prepare the component for sleep. The Comp_Sleep() routine saves the current component state. Then it calls the Comp_Stop() function and calls Comp_SaveConfig() to save the hardware configuration.

Call the Comp_Sleep() function before calling the CyPmSleep() or the CyPmHibernate() function. Refer to the PSoC Creator *System Reference Guide* for more information about power management functions.

Parameters: None

Return Value: None

Side Effects: In the inverting mode of comparator, the output is implemented using UDB. Hence, the comparator output level is high when this sleep API is called and it does not go to sleep.

void Comp_Wakeup(void)

Description: This is the preferred routine to restore the component to the state when Comp_Sleep() was called. The Comp_Wakeup() function calls the Comp_RestoreConfig() function to restore the configuration. If the component was enabled before the Comp_Sleep() function was called, the Comp_Wakeup() function will also re-enable the component.

Parameters: None

Return Value: None

Side Effects: Calling the Comp_Wakeup() function without first calling the Comp_Sleep() or Comp_SaveConfig() function may produce unexpected behavior.

void Comp_PwrDwnOverrideEnable(void)

Description: This is the power-down override feature. This function allows the component to stay active during sleep mode. Before calling this API, the Comp_SetPower() API should be called with the Comp_LOWPOWER parameter to set the comparator power mode to Ultra Low Power. This is because Ultra Low Power is the only valid power mode for the comparator in Sleep mode.

The Comp_PwrDwnOverrideEnable() function is not valid for PSoC 5 silicon. It is available for PSoC 3 and PSoC 5 LP silicon.

Parameters: None

Return Value: None

Side Effects: None

void Comp_PwrDwnOverrideDisable(void)

Description: This is the power-down override feature. This function allows the comparator to stay inactive during sleep mode. This API is not valid for PSoC 5 silicon. It is available for PSoC 3 and PSoC 5 LP silicon.

Parameters: None

Return Value: None

Side Effects: None

void Comp_Init(void)

Description: Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call Comp_Init() because the Comp_Start() routine calls this function and is the preferred method to begin component operation.

Parameters: None

Return Value: None

Side Effects: All registers will be set to values according to the customizer Configure dialog.

void Comp_Enable(void)

Description: Activates the hardware and begins component operation. It is not necessary to call Comp_Enable() because the Comp_Start() routine calls this function, which is the preferred method to begin component operation.

Parameters: None

Return Value: None

Side Effects: None

Sample Firmware Source Code

PSoC Creator provides numerous example projects that include schematics and example code in the Find Example Project dialog. For component-specific examples, open the dialog from the Component Catalog or an instance of the component in a schematic. For general examples, open the dialog from the Start Page or **File** menu. As needed, use the **Filter Options** in the dialog to narrow the list of projects available to select.

Refer to the “Find Example Project” topic in the PSoC Creator Help for more information.

Functional Description

The Comparator is functionally a high-gain high-bandwidth differential amplifier (an opamp with the compensation removed). The comparator is trimmed at the factory to achieve low input offset voltage. It can be trimmed at runtime in the customer's code to achieve improved input offset voltage precision at a specific point. Hysteresis is enabled by adding offsetting currents to the input stage. The nominal hysteresis is 10 mV (33 mV maximum), which is enough to be significantly larger than the sum of any input self noise of the comparator and internal routing interference.

Input offset voltage is normally specified as the absolute value of the difference between the two inputs when the output of the Comparator switches state.

Resources

The analog comparator component uses one analog comparator block.

API Memory Usage

The component memory usage varies significantly, depending on the compiler, device, number of APIs used and component configuration. The following table provides the memory usage for all APIs available in the given component configuration.
The measurements have been done with the associated compiler configured in Release mode with optimization set for Size. For a specific design the map file generated by the compiler can be analyzed to determine the memory usage.

Configuration	PSoC 3 (Keil_PK51)		PSoC 5 (GCC)		PSoC 5LP (GCC)	
	Flash Bytes	SRAM Bytes	Flash Bytes	SRAM Bytes	Flash Bytes	SRAM Bytes
Default	512	2	540	12	584	5

DC and AC Electrical Characteristics

Specifications are valid for –40 °C ≤ T_A ≤ 85 °C and T_J ≤ 100 °C, except where noted.
Specifications are valid for 1.71 V to 5.5 V, except where noted.

Comparator DC Specifications

Parameter	Description	Conditions	Min	Typ	Max	Units
V_{IOFF}	Input offset voltage in fast mode	Factory trim	–	2.0	10	mV
	Input offset voltage in slow mode	Factory trim	–	2.0	10	mV

Parameter	Description	Conditions	Min	Typ	Max	Units
V_{IOFF}	Input offset voltage in fast mode[1]	Custom trim	–	1.0	4.0	mV
	Input offset voltage in slow mode[1]	Custom trim	–	1.0	4.0	mV
V_{IOFF}	Input offset voltage in ultra low-power mode		–	12	–	mV
V_{HYST}	Hysteresis	Hysteresis enable mode	–	10	33	mV
V_{ICM}	Input common mode voltage	High current / fast mode	0	–	V_{DDA} – 0.1	V
		Low current / slow mode	0	–	V_{DDA}	V
		Ultra low power mode	0	–	V_{DDA} – 0.9	V
CMRR	Common mode rejection ratio		30	50	–	dB
I_{CMP}	High current mode/fast mode[2]		–	250	400	µA
	Low current mode/slow mode[2]		–	40	100	µA
	Ultra low-power mode[2]		–	6.0	–	µA

[1] The recommended procedure for using a custom trim value for the on-chip comparators can be found in the TRM.
[2] Based on device characterization (Not production tested).

Comparator AC Specifications

Parameter	Description	Conditions	Min	Typ	Max	Units
T_{RESP}	Response time, high current mode[1]	50-mV overdrive, measured pin-to-pin	–	80	110	ns
	Response time, low current mode[1]	50-mV overdrive, measured pin-to-pin	–	155	200	ns
	Response time, ultra low-power mode[1]	50-mV overdrive, measured pin-to-pin	–	55	–	µs

[1] Based on device characterization (Not production tested).

Component Changes

This section lists the major changes in the component from the previous version.

Version	Description of Changes	Reason for Changes / Impact
1.90	Updated comparator trim register masks for PSoC3, PSoC5LP or later.	To support zero calibration procedure for this chips.

Version	Description of Changes	Reason for Changes / Impact
	Updated ZeroCal() API.	In order to decrease function execution time.
	Adding support Panther LP silicon.	
1.80		Per creator 2.0 public release requirement.
1.70	Comp_Stop() API changes for PSoC 5.	Change required to prevent the component from impacting unrelated analog signals when stopped, when used with PSoC 5.
	Fixed an issue with using comparator as wakeup source for Sleep and Alt Active modes.	Comparator was not configured correctly in previous version to use it as a wakeup source for Sleep and Alt Active modes.
	Changed Comp_SetSpeed() API to set the comparator trim values based on the speed settings.	Comparator Trim values were not properly set based on the speed settings in the previous version of the component.
	Comparator GUI updates	To force the power mode to Ultra Low power when PowerDownOverride option is enabled.
1.60	Updated configuration window with an accurate waveform including hysteresis.	Previous configuration window did not provide enough information for ease of use.
	Corrected Hysteresis enable bit setting implementation	The meaning of the enable hysteresis bit was flipped. This has been corrected to correctly enable hysteresis on all versions of silicon
	Added characterization data to datasheet.	
	Minor datasheet edits and updates.	
1.50.a	Added Known Problems and Solutions to datasheet	To provide a workaround for hysteresis problem in PSoC 3 ES2 silicon.
1.50	Added Sleep/Wakeup and Init/Enable APIs.	To support low power modes, as well as to provide common interfaces to separate control of initialization and enabling of most components.
	Updated Configure dialog with customized interface.	The updated Configure dialog makes it easier to use. There is also a preview of how the component will change based on various selections.
	Added Power Down Override parameter to the Configure dialog.	To allow configuration of Comparator to operate during sleep mode.
	Added Comp_PwrDwnOverrideEnable()/ Comp_PwrDwnOverrideDisable() APIs.	To allow the component to stay active/inactive during sleep mode.