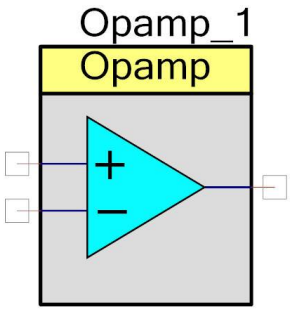
PSoC 4 Operational Amplifier (Opamp)

1.20



Features

- Follower or Opamp configuration
- Rail-to-rail inputs and output
- Output direct low resistance connection to pin
- 1mA or 10mA output current
- Internal connection for follower

General Description

The Opamp operates as an off-the-shelf operation amplifier. A direct connection is made between the Opamp output and a dedicated GPIO pin for a low output resistance. Two output modes (Internal only and Output to pin) are provided to drive internal or external signals respectively. The Output to pin may drive both internal (SAR Component) and external signals. The user also has control of different overall power levels that provide a tradeoff between power and bandwidth.

For all devices, except PSoC 4100/PSoC 4200, the Opamp can operate in Deep Sleep power mode.

Note External resistors are required to perform amplification.

When to Use the Opamp

The following is a list of common use cases for the Opamp Component:

- Gain for SAR ADC
- High impedance buffer for SAR ADC
- General purpose signal amplifier
- Active filter

Input/Output Connections

This section describes various input and output connections for the Opamp.

Positive Input – Analog Input

When the Opamp is configured in follower Mode, this I/O is the voltage input. If the Opamp is configured in Opamp Mode, this I/O acts as the standard Opamp noninverting input.

Negative Input – Analog Input*

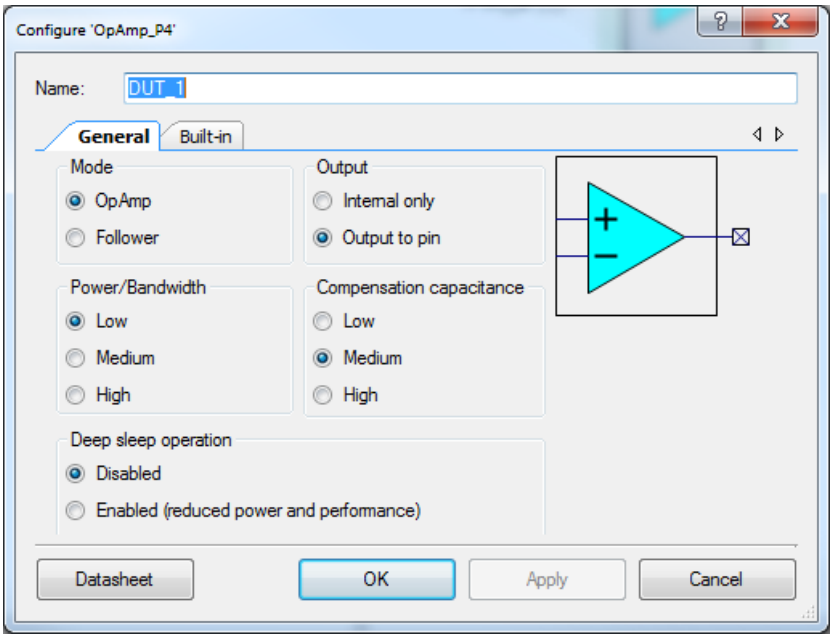
When the Opamp Component is configured in Opamp Mode, this I/O is the normal inverting input. When the Opamp is configured in Follower Mode, this I/O is hard-connected to the output and the I/O is unavailable.

Vout – Analog output

The output can be directly connected to a pin and/or routed to an internal load using the Output parameter. The drive strength is selectable as either Output to pin or Internal only. Connections to pins require the Output to pin setting. Internal connections can operate with either the Internal only or Output to pin setting, but should normally be configured for Internal only.

Component Parameters

Drag Opamp onto your design and double-click it to open the Configure dialog.



The Opamp provides the following parameters:

Mode

This parameter allows you to select between two configurations: **Opamp** and **Follower**. **Opamp** is the default configuration. In this mode, all three terminals are available for connection. In the follower mode, the inverting input is internally connected to the output to create a voltage follower.

Power/Bandwidth

The Opamp works over a wide range of operating currents. Higher operating current increases the Opamp bandwidth. The **Power/Bandwidth** parameter allows you to select the power level: High, Medium, and Low.

Output

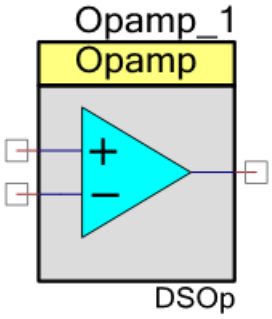
This parameter selects an output mode: Internal only – internal connections or Output to pin – connection to pin (external).

Compensation

The opamp offers three compensation settings: Low, Med and High. This allows reducing the compensation (hence increase the bandwidth) when the Opamp's loop gain is reduced.

Deep sleep operation

This parameter is not available for PSoC 4100/PSoC 4200 devices. It enables the Component operation in Deep Sleep mode. If this option is enabled, a "DSOp" label will be displayed under the symbol. If two Opamps of the same CTB/CTBm block are used in the project, both must have the same Deep Sleep settings.



Note Only dedicated pins may be used for operation in Deep Sleep mode.

Note For correct operation in Deep Sleep mode, the V_{DDA} must be larger than 2.5 V. The boost pump does not operate in Deep Sleep mode.

Application Programming Interface

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

By default, PSoC Creator assigns the instance name "Opamp_1" to the first instance of a Component in a given design. You can rename it 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 "Opamp"

Functions

Function	Description
Opamp_Start()	Performs all of the required initialization for the Component and enables power to the block.
Opamp_Stop()	Turns off the Opamp block.
Opamp_Init()	Initializes or restores the Component according to the customizer Configure dialog settings.
Opamp_Enable()	Activates the hardware and begins Component operation.
Opamp_SetPower()	Sets the drive power to one of three settings; LOW_POWER, MED_POWER, HIGH_POWER.
Opamp_PumpControl()	Turn the boost pump on or off.
Opamp_Sleep()	This is the preferred API to prepare the Component for sleep.
Opamp_Wakeup()	This is the preferred API to restore the Component to the state when Opamp_Sleep() was called.

void Opamp_Start(void)

Description: Performs all of the required initialization for the Component and enables power to the block. The first time the routine is executed, the Power level, Mode, and Output mode are set. When called to restart the Opamp following a Stop() call, the current Component parameter settings are retained.

Parameters: None

Return Value: None

Side Effects: None

void Opamp_Stop(void)

Description: Turn off the Opamp block.

Parameters: None

Return Value: None

Side Effects: Does not affect the Opamp mode or power settings

void Opamp_Init(void)

Description: Initializes or restores the Component according to the customizer Configure dialog settings. It is not necessary to call Init() because the Start() API calls this function and is the preferred method to begin the Component operation.

Parameters: None

Return Value: None

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

void Opamp_Enable(void)

Description: Activates the hardware and begins the Component operation. It is not necessary to call Enable() because the Start() API calls this function, which is the preferred method to begin Component operation.

Parameters: None

Return Value: None

Side Effects: None

void Opamp_SetPower(uint32 power)

Description: Sets the opamp to one of three power levels..

Parameters: (uint32) power: Power levels. See table below.

Parameter Value	Description
Opamp_LOW_POWER	Lowest active power.
Opamp_MED_POWER	Medium power.
Opamp_HIGH_POWER	Highest active power.

Return Value: None

void Opamp_PumpControl(uint32 onOff)

Description: Allows the user to turn the Opamp's boost pump on or off. By Default the Opamp_Start() function turns on the pump. Use this command to turn it off. The charge pump must be turned on to provide rail-to-rail input common mode. Each opamp has a charge pump that can be controlled individually. The pump can be turned off for low input range levels. When the pump is turned off, the pump supply will be shorted to vdda. Shutting off the charge pump allows the opamp to achieve low power modes.

Parameters: (uint32) onOff: Control the pump. See the table below.

Parameter Value	Description
Opamp_PUMP_OFF	Turn off the pump
Opamp_PUMP_ON	Turn on the pump

Return Value: None

Side Effects: Turning this pump off will reduce the Opamp input range by 1.8 volts or (Vssa to (Vdda – 1.8 volts)).

void Opamp_Sleep(void)

Description: This is the preferred API to prepare the Component for sleep. The Sleep() API saves the current Component state and stops the Component. Call the Sleep() function before calling the CySysPmDeepSleep() or the CySysPmHibernate() functions. If the "Deep sleep operation" is enabled then this function does nothing and the Component continues to operate during low power state.

Parameters: None

Return Value: None

Side Effects: None

void Opamp_Wakeup(void)

Description: This is the preferred API to restore the Component to the state when Sleep() is called. If the Component has been enabled before the Sleep() function is called, the Wakeup() function will also re-enable the Component. If the "Deep sleep operation" is enabled then this function does nothing because the Component operates during low power state as well as in active state.

Parameters: None

Return Value: None

Side Effects: Calling the Wakeup() function without first calling the Sleep() function may produce unexpected behavior.

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.

MISRA Compliance

This section describes the MISRA-C:2004 compliance and deviations for the Component. There are two types of deviations defined:

- project deviations – deviations that are applicable for all PSoC Creator Components
- specific deviations – deviations that are applicable only for this Component

This section provides information on the Component-specific deviations. The project deviations are described in the MISRA Compliance section of the *System Reference Guide* along with information on the MISRA compliance verification environment.

The Opamp Component has the following specific deviations:

MISRA-C: 2004 Rule	Rule Class (Required/Advisory)	Rule Description	Description of Deviation(s)
19.7	A	A function is used in preference to a function-like macro.	Deviated since function-like macros are used to allow more efficient code.

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 the Release mode with an optimization set for Size. For a specific design, the map file generated by the compiler can be analyzed to determine the memory usage.

PSoC 4 (GCC)

Configuration		Flash Bytes	SRAM Bytes
Deep sleep operation	Disabled	240	9
	Enabled	188	8

Functional Description

This Component is a basic operational amplifier. You may configure power, output strength, and interconnect the Opamp to other Components. Low resistive connections are made from the Opamp to three selected pins to provide the optimal performance.

Using the Compensation option

There are recommended settings for the Compensation option:

Loop Gain	Load Capacitance	
	Less than 50 pF	50pF to 125 pF
1-6	Medium	High
7 or more	Low	Medium

These settings are applicable for the Output to pin setting, which is capable to drive a pin. 125 pF is the maximum load capacitance for this output.

Placement

Each Opamp is directly connected to specific GPIOs along with being connected to the internal fabric. The Output connection to a GPIO requires the use of the directly connected pin. Refer to the device datasheet for the part being used for the specific physical pin connections.

Registers

See the chip Technical Reference Manual (TRM) for more information about the registers.

Component Debug Window

PSoC Creator allows viewing debug information about the Components in the design. Each Component window lists the memory and registers for the instance. For detailed hardware registers descriptions, refer to the appropriate device technical reference manual. For detailed UDB registers descriptions used in the Component, refer to the Registers section of this datasheet.

To open the Component Debug window:

1. Make sure the debugger is running or in break mode.
2. Choose **Windows > Components…** from the **Debug** menu.
3. In the Component Window Selector dialog, select the Component instances to view and click **OK**.

The selected Component Debug window(s) will open within the debugger framework. Refer to the "Component Debug Window" topic in the PSoC Creator Help for more information.

Resources

The Opamp uses one of the opamp (Constant Time Block – mini (CTBm)) blocks in PSoC 4. No other resources are required.

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.

Note Final characterization data for the PSoC Analog Coprocessor device is not available at this time. Once the data is available, the Component datasheet will be updated on the Cypress web site.

DC Specifications

Parameter	Description	Conditions	Min	Typ	Max	Units
IDD	Opamp Block current. No load.		–	–	–	–
IDD_HI	Power = high		–	1000	1300	µA
IDD_MED	Power = medium		–	320	500	µA
IDD_LOW	Power = low		–	250	350	µA
IDD	Opamp Block current. VDD = 1.8 V. No load.	For PSoC 4200 BLE family	–	–	–	–
IDD_HI	Power = high	For PSoC 4200 BLE family	–	1000	1300	µA
IDD_MED	Power = medium	For PSoC 4200 BLE family	–	500	–	µA
IDD_LOW	Power = low	For PSoC 4200 BLE family	–	250	350	µA
IDD_HI	Power = high	For PSoC 4100M/ PSoC 4200M/ PSoC 4200L/PSoC 4100S	–	1100	1850	µA
IDD_MED	Power = medium	For PSoC 4100M/ PSoC 4200M/ PSoC 4200L/PSoC 4100S	–	550	950	µA
IDD_LOW	Power = low	For PSoC 4100M/ PSoC 4200M/ PSoC 4200L/PSoC 4100S	–	150	350	µA
IOUT_MAX	VDDA ≥ 2.7 V, 500 mV from rail		–	–	–	–
IOUT_MAX_HI	Power = high		10	–	–	mA
IOUT_MAX_MID	Power = medium		10	–	–	mA

Parameter	Description	Conditions	Min	Typ	Max	Units
IOUT_MAX_LO	Power = low		–	5	–	mA
IOUT	VDDA = 1.71 V, 500 mV from rail		–	–	–	–
IOUT_MAX_HI	Power = high		4	–	–	mA
IOUT_MAX_MID	Power = medium		4	–	–	mA
IOUT_MAX_LO	Power = low		–	2	–	mA
VIN	Charge pump on, VDDA ≥ 2.7 V		–0.05	–	VDDA – 0.2	V
VCM	Charge pump on, VDDA ≥ 2.7 V		–0.05	–	VDDA – 0.2	V
VOUT	VDDA ≥ 2.7 V		–	–	–	
VOUT_1	Power = high, Iload=10 mA		0.5	–	VDDA – 0.5	V
VOUT_2	Power = high, Iload=1 mA		0.2	–	VDDA – 0.2	V
VOUT_3	Power = medium, Iload=1 mA		0.2	–	VDDA – 0.2	V
VOUT_4	Power = low, Iload=0.1mA		0.2	–	VDDA – 0.2	V
VOS	Offset voltage	High mode	–1	±0.5	1	mV
VOS	Offset voltage	Medium mode	–	±1	–	mV
VOS	Offset voltage	Low mode	–	±2	–	mV
VOS_DR	Offset voltage drift	High mode	–10	±3	10	µV/C
VOS_DR	Offset voltage drift	Medium mode	–	±10	–	µV/C
VOS_DR	Offset voltage drift	Low mode	–	±10	–	µV/C
Cload	Stable up to maximum load. Performance specs at 50 pF.		–	–	125	pF
CMRR	DC	VDDD = 3.6 V	70	80	–	dB
CMRR	DC	For PSoC 4200 BLE family VDDD = 3.6 V, High-Power Mode	65	70	–	dB
CMRR	DC Common mode rejection ratio. High Power mode. Common Model Voltage Range from 0.5V to VDDA - 0.5V.	For PSoC 4100M/ PSoC 4200M/ PSoC 4200L VDDD = 3.6 V	60	70	–	dB
PSRR	At 1 kHz, 100 mV ripple	VDDD = 3.6 V	70	85	–	dB
Deep-Sleep Mode (For PSoC 4200 BLE family; only guaranteed for VDDA > 2.5 V)						
IDD_DS	Current		–	15	–	µA

Parameter	Description	Conditions	Min	Typ	Max	Units
Vos_DS	Offset voltage		–	5	–	mV
Vos_dr_DS	Offset voltage drift		–	20	–	µV/°C
Vout_DS	Output voltage		0.2	–	VDD–0.2	V
Vcm_DS	Common mode voltage		0.2	–	VDD–1.8	V
Deep-Sleep Mode (For PSoC 4100M/PSoC 4200M/ PSoC 4200L/PSoC 4100S; only guaranteed for VDDA ≥ 2.7 V) Mode 2 is lowest current range. Mode 1 has higher GBW.						
IDD_HI_M1	Mode 1, High current	25 °C	-	1400	-	uA
IDD_MED_M1	Mode 1, Medium current	25 °C	-	700	-	uA
IDD_LOW_M1	Mode 1, Low current	25 °C	-	200	-	uA
IDD_HI_M2	Mode 2, High current	25 °C	-	120	-	uA
IDD_MED_M2	Mode 2, Medium current	25 °C	-	60	-	uA
IDD_LOW_M2	Mode 2, Low current	25 °C	-	15	-	uA
VOS_HI_M1	Mode 1, High current	With trim 25 °C, 0.2 V to VDDA-1.5 V	-	5	-	mV
VOS_MED_M1	Mode 1, Medium current	With trim 25 °C, 0.2 V to VDDA-1.5 V	-	5	-	mV
VOS_LOW_M1	Mode 1, Low current	With trim 25 °C, 0.2 V to VDDA-1.5 V	-	5	-	mV
VOS_HI_M2	Mode 2, High current	With trim 25 °C, 0.2 V to VDDA-1.5 V	-	5	-	mV
VOS_MED_M2	Mode 2, Medium current	With trim 25 °C, 0.2 V to VDDA-1.5 V	-	5	-	mV
VOS_LOW_M2	Mode 2, Low current	With trim 25 °C, 0.2 V to VDDA-1.5 V	-	5	-	mV
IOUT_HI_M1	Mode 1, High current	Output is 0.5 V to VDDA-0.5 V	-	10	-	mV
IOUT_MED_M1	Mode 1, Medium current	Output is 0.5 V to VDDA-0.5 V	-	10	-	mV
IOUT_LOW_M1	Mode 1, Low current	Output is 0.5 V to VDDA-0.5 V	-	4	-	mV
IOUT_HI_M2	Mode 2, High current	Output is 0.5 V to VDDA-0.5 V	-	1	-	mV
IOUT_MED_M2	Mode 2, Medium current	Output is 0.5 V to VDDA-0.5 V	-	1	-	mV
IOUT_LOW_M2	Mode 2, Low current	Output is 0.5 V to VDDA-0.5 V	-	0.5	-	mV

AC Specifications

Parameter	Description	Conditions	Min	Typ	Max	Units
GBW	Load = 20 pF, 0.1 mA. VDDA = 2.7 V		–	–	–	–
GBW_HI	Power = high		6	–	–	MHz
GBW_MED	Power = medium		4	–	–	MHz
GBW_MED	Power = medium	For PSoC 4100S	3	–	–	MHz
GBW_LO	Power = low		2	–	–	MHz
GBW_LO	Power = low	For PSoC 4200 BLE family, PSoC 4100M/PSoC 4200M/ PSoC 4200L/PSoC 4100S	–	1	–	MHz
Noise			–	–	–	–
VN1	Input referred, 1 Hz - 1GHz, power = high	Not applicable for PSoC 4100S	–	94	–	µVrms
VN2	Input referred, 1 kHz, power = high		–	72	–	nV/rtHz
VN3	Input referred, 10kHz, power = high		–	28	–	nV/rtHz
VN4	Input referred, 100kHz, power = high		–	15	–	nV/rtHz
Slew_rate	Cload = 50 pF, Power = High, VDDA ≥ 2.7 V		6	–	–	V/µsec
T_op_wake	From disable to enable, no external RC dominating		–	300	–	µSec
T_op_wake	From disable to enable, no external RC dominating	PSoC 4100M/PSoC 4200M/ PSoC 4200L/PSoC 4100S	–	25	–	µSec
Deep-Sleep Mode (For PSoC 4200 BLE family; only guaranteed for VDDA > 2.5 V)						
GBW_DS	Gain bandwidth product	Not applicable for PSoC 4100S	–	50	–	kHz
Deep-Sleep Mode (For PSoC 4100M/PSoC 4200M/PSoC 4200L/PSoC 4100S; only guaranteed for VDDA ≥ 2.7 V) Mode 2 is lowest current range. Mode 1 has higher GBW.						
GBW_HI_M1	Mode 1, High current	20-pF load, no DC load 0.2 V to VDDA-1.5 V	-	4	-	MHz
GBW_MED_M1	Mode 1, Medium current	20-pF load, no DC load 0.2 V to VDDA-1.5 V	-	2	-	MHz
GBW_LOW_M1	Mode 1, Low current	20-pF load, no DC load 0.2 V to VDDA-1.5 V	-	0.5	-	MHz
GBW_HI_M2	Mode 2, High current	20-pF load, no DC load 0.2 V to VDDA-1.5 V	-	0.5	-	MHz
GBW_MED_M2	Mode 2, Medium current	20-pF load, no DC load 0.2 V to VDDA-1.5 V	-	0.2	-	MHz
GBW_LOW_M2	Mode 2, Low current	20-pF load, no DC load 0.2 V to VDDA-1.5 V	-	0.1	-	MHz

Component Changes

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

Version	Description of Changes	Reason for Changes / Impact
1.20.c	Edited datasheet.	Added final characterization data for PSoC 4100S device.
1.20.b	Updated the Opamp_PumpControl function description.	Make the datasheet more clear.
1.20.a	Edited datasheet.	Final characterization data for PSoC 4000S, PSoC 4100S and PSoC Analog Coprocessor devices is not available at this time. Once the data is available, the Component datasheet will be updated on the Cypress web site.
1.20	Added support for PSoC Analog Coprocessor devices.	New device support.
	Edited the datasheet.	Updated Component Parameters section with clarification of the deep sleep operation.
1.10.d	Edited the datasheet.	Minor corrections in parameters naming (AC Specifications section). Updated DC and AC Electrical Characteristics section with PSoC 4200L data.
1.10.c	Edited the datasheet.	Updated Offset voltage and Offset voltage drift parameter names into DC Specifications table. Updated DC and AC Electrical Characteristics section with PSoC 4100M/ PSoC 4200M data.
1.10.b	Edited the datasheet.	Added CMRR parameter values for PSoC 4200 BLE devices.
1.10.a	Edited the datasheet.	Added information that for correct operation in deep sleep mode, V_{DDA} must be larger than 2.5 V.
1.10	Added the Deep sleep operation parameter to control Component availability in Deep Sleep mode.	Updates to support PSoC 4200 BLE devices.
	Updated API Memory usage and MISRA compliance sections.	
	Removed references to SaveConfig() and RestoreConfig() APIs because they are empty.	
	Changed output mode parameters from “1mA” and “10mA” to “Internal only” and “Output to pin” respectively.	
1.0.a	Updated datasheet.	Corrected specs to match device datasheet.
1.0	First release	