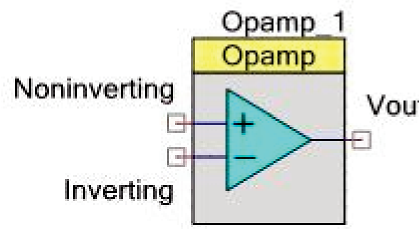
Operational Amplifier (Opamp)

1.90

Features



- Follower or Opamp configuration
- Unity gain bandwidth > 3.0 MHz
- Input offset voltage 2.0 mV max
- Rail-to-rail inputs and output
- Output direct low resistance connection to pin
- 25-mA output current
- Programmable power and bandwidth
- Internal connection for follower (saves pin)

General Description

The Opamp component provides a low-voltage, low-power operational amplifier and may be internally connected as a voltage follower. The inputs and output may be connected to internal routing nodes, directly to pins, or a combination of internal and external signals. The Opamp is suitable for interfacing with high-impedance sensors, buffering the output of voltage DACs, driving up to 25 mA; and building active filters in any standard topology.

Input/Output Connections

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

Noninverting – Analog

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

Inverting – Analog *

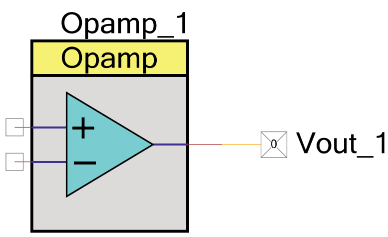
When the Opamp component is configured for Opamp mode, this I/O is the normal inverting input. When the Opamp is configured for Follower mode, this I/O is hard-connected to the output and the I/O is unavailable.

Vout – Analog

The output is directly connected to a pin. It can drive 25 mA and can be connected to internal loads using the analog routing fabric. When used for internal routing, the output remains connected to the pin.

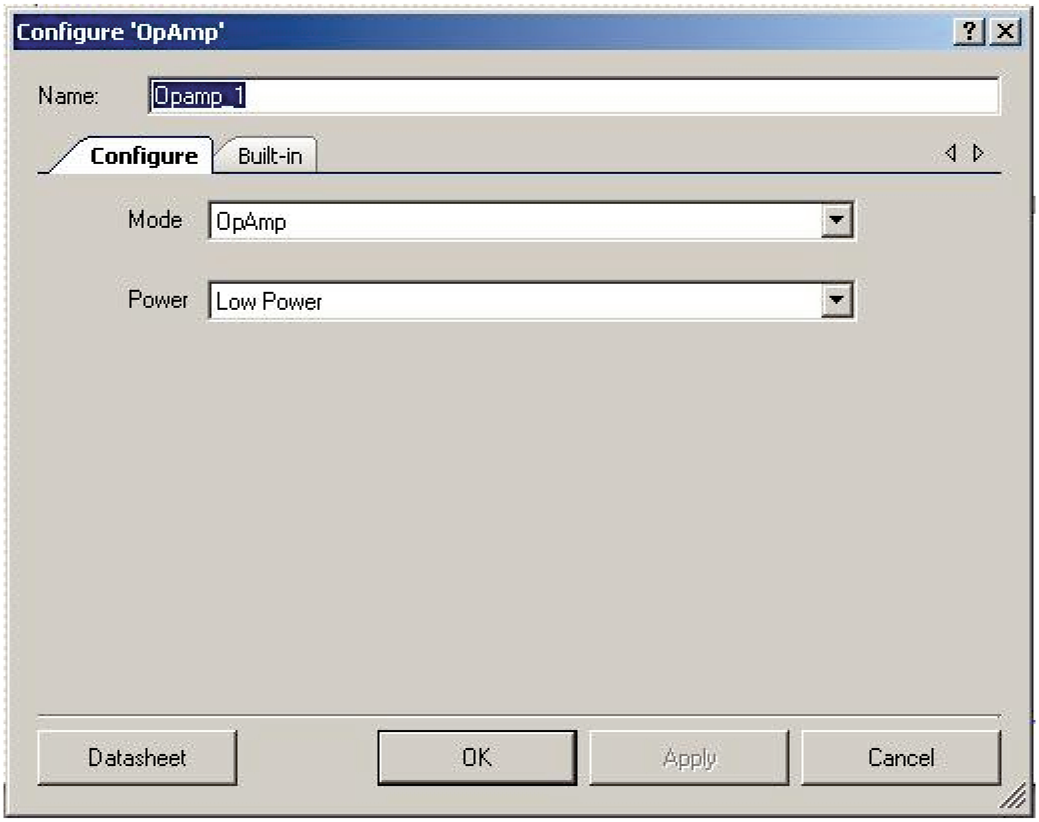
Schematic Macro Information

The default Opamp in the Component Catalog is a schematic macro using an Opamp component with default settings. The Opamp component is connected to an analog Pin component named Vout_1.



Component Parameters

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

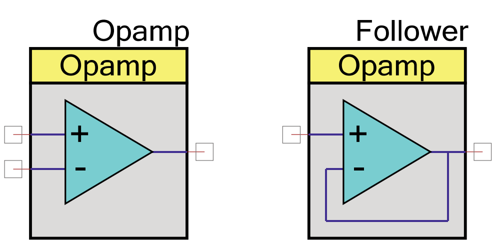


The Opamp has the following parameters:

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 follower mode, the inverting input is internally connected to the output to create a voltage follower.

Figure 1. Configuration Options



Power

The Opamp works over a wide range of operating currents. Higher operating current increases Opamp bandwidth. The **Power** parameter allows you to select the power level:

- In **High Power** and **Med Power** modes, the output is a class AB stage, enabling direct drive of high output currents.
- In **Low Power** mode, the output is a class A stage with limited current drive.
- In **Low Power Over Compensated** (LPOC) mode, the output is a class A stage.

  For PSoC 3 Production silicon, the LPOC mode is used for low-power transimpedance amplifiers (TIAs). This mode has the same drive capability as low power, but includes added compensation for circuit topologies with higher than normal input capacitance, as seen in photo sensors and other current-output sensors of various types.

  Wider-bandwidth TIAs can be implemented using the medium or high-power settings. In this case, exercise the usual care in dealing with compensation for capacitively loaded sources.

Note The above description of LPOC mode is correct for PSoC 3 Production silicon only.

Placement

Each Opamp is directly connected to specific GPIOs.

	Noninverting Input	Inverting Input	Output
opamp_0	P0[2]	P0[3]	P0[1]
opamp_1	P3[5]	P3[4]	P3[6]
opamp_2	P0[4]	P0[5]	P0[0]
opamp_3	P3[3]	P3[2]	P3[7]

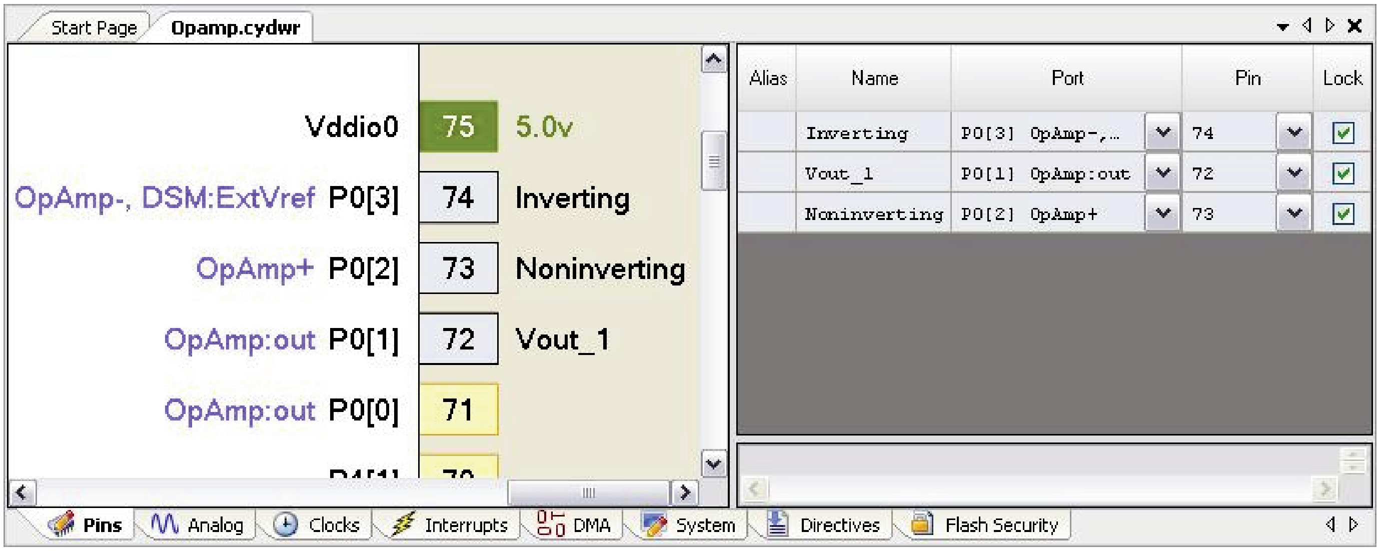
Refer to the device datasheet for the part being used for the specific physical pin connections.

Input signals may use the analog global routing buses in addition to the dedicated input pins. Using the direct connections uses fewer internal routing resources and results in lower route resistance and capacitance. The output pin associated with each specific location will always be driven by the Opamp, when enabled.

Ports P0[3] and P3[2] are also used for connection to a capacitor for bypassing the bandgap reference supplied to the ADC, for a reference output, or for an input from an external reference. When these reference connections are used, routing to the Opamp inverting inputs must be done through the analog global routing buses.

Figure 2 shows one example of how the Opamp may be connected using the Design-Wide Resources Pin Editor.

Figure 2. Example Placement



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.”

Function	Description
Opamp_Start()	Turns on the Opamp and sets the power level to the value chosen during the parameter selection.
Opamp_Stop()	Disables Opamp (power down).
Opamp_SetPower()	Sets the power level.
Opamp_Sleep()	Stops and saves the user configuration.
Opamp_Wakeup()	Restores and enables the user configuration.
Opamp_Init()	Initializes or restores default Opamp configuration.
Opamp_Enable()	Enables the Opamp.
Opamp_SaveConfig()	Empty function. Provided for future use.
Opamp_RestoreConfig()	Empty function. Provided for future use.

Global Variables

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

void Opamp_Start(void)

Description: Turns on the Opamp and sets the power level to the value chosen during the parameter selection.

Parameters: None

Return Value: None

Side Effects: None

void Opamp_Stop(void)

Description: Turns off the Opamp and enable its lowest power state.

Parameters: None

Return Value: None

Side Effects: None

void Opamp_SetPower(uint8 power)

Description: Sets the power level.

Parameters: uint8 power: Sets the power level to one of four settings: LPOC, Low, Medium, or High.

Power Setting	Notes
Opamp_LPOCPOWER	Least power, compensated for TIA
Opamp_LOWPOWER	Least power, reduced bandwidth
Opamp_MEDPOWER	Medium bandwidth
Opamp_HIGHPOWER	Highest bandwidth

Return Value: None

Side Effects: None

void Opamp_Sleep(void)

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

Call the Opamp_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: None

void Opamp_Wakeup(void)

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

Parameters: None

Return Value: None

Side Effects: Calling the Opamp_Wakeup() function without first calling the Opamp_Sleep() or Opamp_SaveConfig() function may produce unexpected behavior.

void Opamp_Init(void)

Description: Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call Opamp_Init() because the Opamp_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 Opamp_Enable(void)

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

Parameters: None

Return Value: None

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

void Opamp_SaveConfig(void)

Description:	Empty function. Provided for future use.
Parameters:	None
Return Value:	None
Side Effects:	None

void Opamp_RestoreConfig(void)

Description:	Empty function. Provided for future use.
Parameters:	None
Return Value:	None
Side Effects:	None

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 component-specific deviations. 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 does not have any specific deviations.

Sample Firmware Source Code

PSoC Creator provides many 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.

Resources

The Opamp component uses one Opamp Fixed block per instance. When used in the Opamp mode with external components (that is, not routing the output through the analog globals), no routing resources are used.

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 5LP (GCC)	
	Flash Bytes	SRAM Bytes	Flash Bytes	SRAM Bytes
Default	130	2	198	5

DC and AC Electrical Characteristics for PSoC 3

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.

DC Characteristics

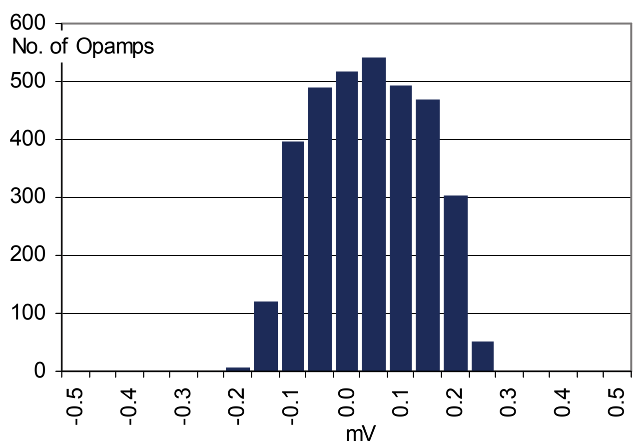
Parameter	Description	Conditions	Min	Typ[1]	Max	Units
V_I	Input voltage range		V_{SSA}	–	V_{DDA}	V
V_{IOFF}	Input offset voltage	Temp = –40 °C to +70 °C	–	0.5	2	mV
TCVos	Input offset voltage drift with temperature	Power mode = high	–	±12	±30	µV/°C
Avol	Open-loop gain	Power mode = high	90	–	–	dB
Ge1	Gain error, unity gain buffer mode	R_{LOAD} = 1 kΩ	–	–	±0.1	%

1. The values are for T_A = 25 °C, V_{DDA} = 5.0 V, Power = High, output referenced to analog ground, V_{SSA} except where noted.

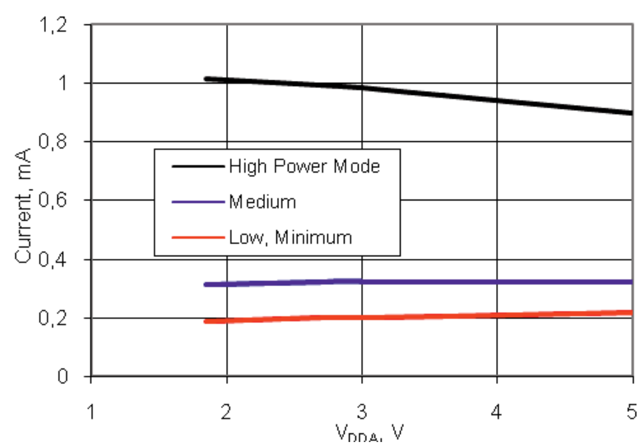
Parameter	Description	Conditions	Min	Typ[1]	Max	Units
R_{IN}	Input resistance	Positive gain, noninverting input	–	–	–	MΩ
C_{IN}	Input capacitance	Routing from pin	–	–	18	pF
V_O	Output voltage range	1 mA, source or sink, power mode = high	V_{SSA} + 0.05	–	V_{DDA} – 0.05	V
		100 K to V_{DDA}/2, G = 1	–	–	–	V
I_{OUT}	Output current, source or sink	V_{SSA} + 500 mV ≤ V_{OUT} ≤ V_{DDA} – 500 mV, V_{DDA} > 2.7 V	25	–	–	mA
		V_{SSA} + 500 mV ≤ Vout ≤ V_{DDA} – 500 mV, 1.7 V = V_{DDA} ≤ 2.7 V	16	–	–	mA
I_{DD}	Quiescent current	Power mode = min	–	200	270	µA
		Power mode = low	–	250	400	µA
		Power mode = med	–	330	950	µA
		Power mode = high	–	1000	2500	µA
CMRR	Common mode rejection ratio		80	–	–	dB
PSRR	Power supply rejection ratio	V_{DDA} ≥ 2.7 V	85	–	–	dB
		V_{DDA} ≤ 2.7 V	70	-	-	

Figures

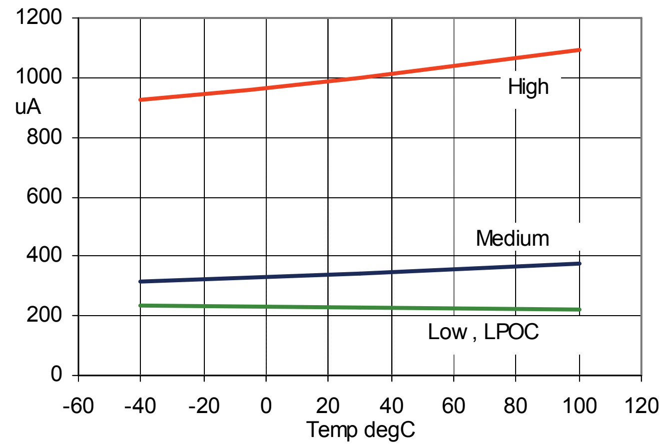
Histogram Input Offset Voltage
T = 25 ° C, V_{DDA} = 5.0 V



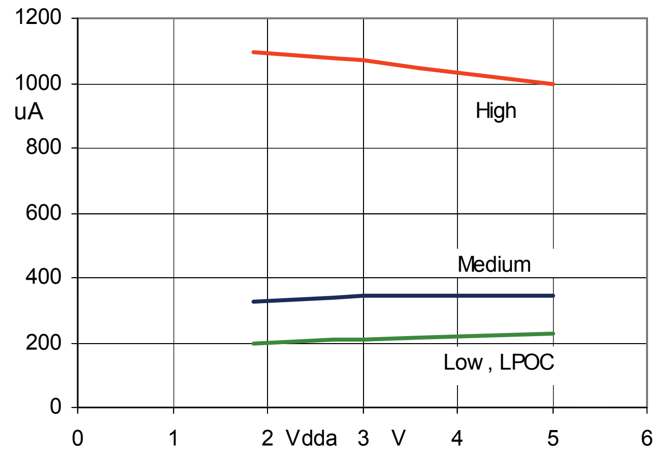
Opamp Operating Current versus V_{DDA}, and Power Mode



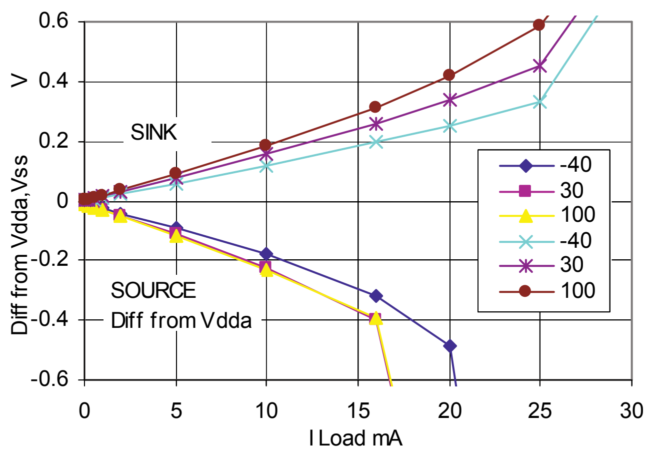
Operating Current versus Temperature, V_{DD} = 5.0 V



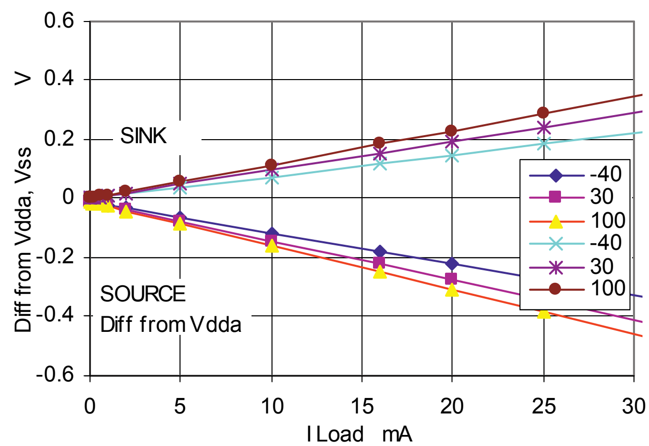
Operating Current versus Voltage T = 25 °C



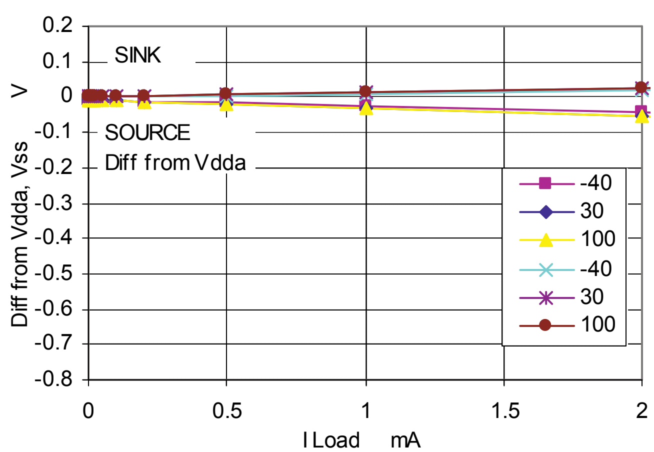
Output Voltage versus Load Current, V_{DDA} = 1.71 V, Power = High



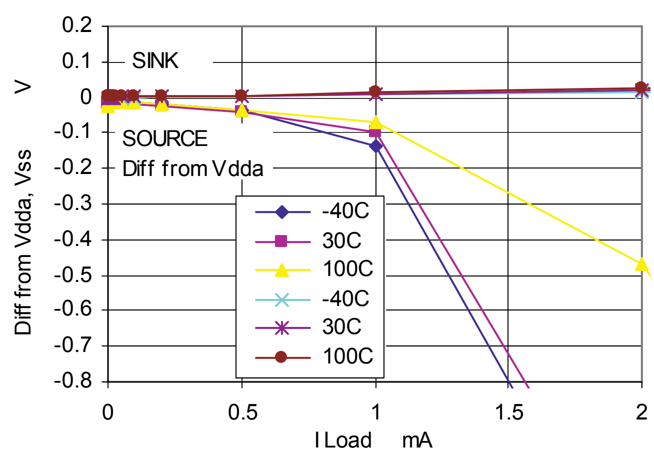
Output Voltage versus Load Current, V_{DDA} = 5.0 V, Power = High



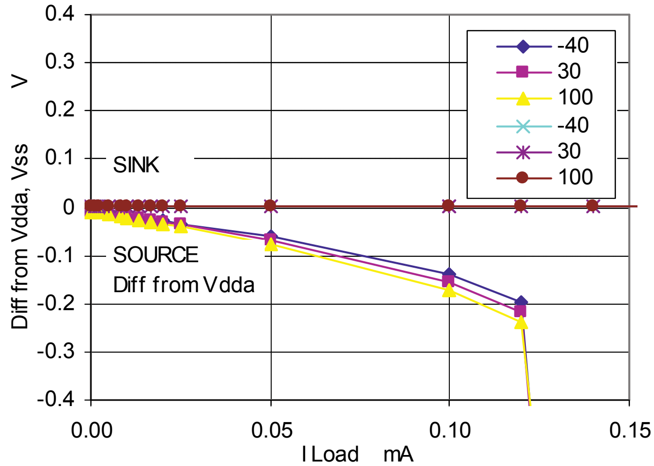
Output Voltage versus Load Current, V_{DDA} = 2.7 V, Power = Med



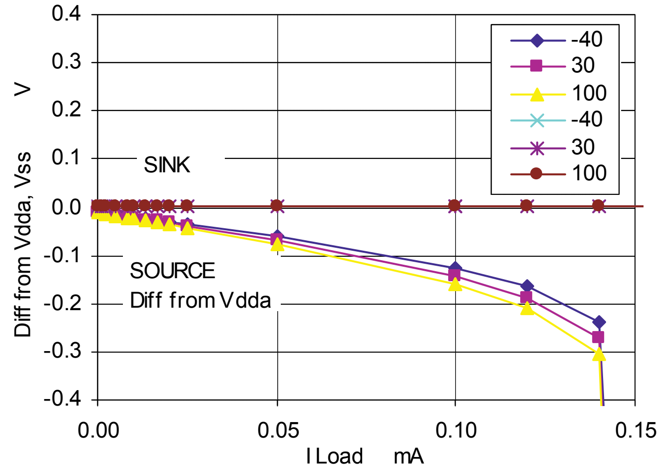
Output Voltage versus Load Current V_{DDA} = 5.0 V, Power = Medium



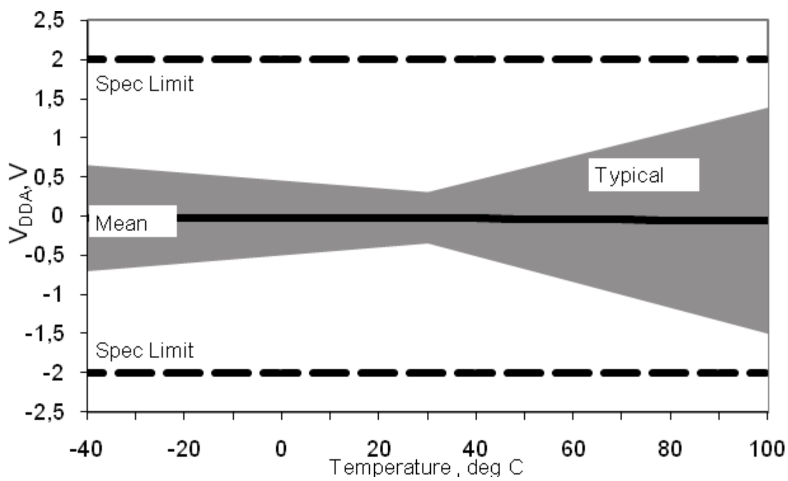
Output Voltage versus Load Current,
V_{DDA} = 2.7 V, Power = Low



Output Voltage versus Load Current,
V_{DDA} = 5.0 V, Power = Low



Input Offset Voltage versus Temperature
Power = High, V_{DDA} = 5.0 V



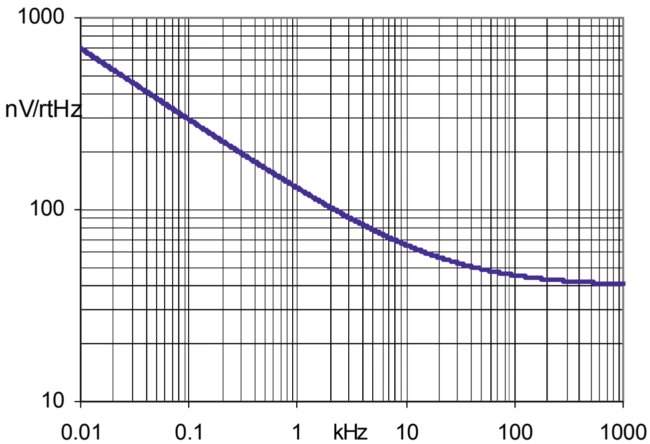
AC Characteristics

Parameter	Description	Conditions	Min	Typ	Max	Units
GBW	Gain-bandwidth product	Power mode = minimum, 100 mV pk-pk, 15-pF load	1	5.4	–	MHz
		Power mode = low, 100 mV pk-pk, 15-pF load	2	5.1	–	MHz
		Power mode = medium, 100 mV pk-pk, 15-pF load	1	3.5	–	MHz
		Power mode = high, 100 mV pk-pk, 200-pF load	3	8	–	MHz

Parameter	Description	Conditions	Min	Typ	Max	Units
SR	Slew Rate	Power mode = low, 15-pF load	1.1	2.4	–	V/µs
		Power mode = medium, 15-pF load	0.9	1.4	–	V/µs
		Power mode = high, 200-pF load	3	4.3	–	V/µs
e_n	Input noise density	Power mode = high, V_{DDA} = 5 V, at 100 kHz	–	45	–	nV/sqrtHz

Figures

Input Voltage Noise Density
T = 25 °C, V_{DDA} = 5.0 V, Power = high



DC and AC Electrical Characteristics for PSoC 5LP

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.

DC Characteristics

Parameter	Description	Conditions	Min	Typ	Max	Units
V_I	Input voltage range		V_{SSA}	–	V_{DDA}	V
V_{OS}	Input offset voltage	Operating temperature > 70 °C	–	–	3	mV
		Operating temperature –40 °C to 70 °C	–	–	2	mV
TCVos	Input offset voltage drift with temperature		–	±12	±30	µV/°C
Ge1	Gain error, unity gain buffer mode	R_{LOAD} = 1 kΩ	–	–	±0.1	%

Parameter	Description	Conditions	Min	Typ	Max	Units
C_{IN}	Input capacitance	Routing from pin	–	–	18	pF
V_O	Output voltage range	1 mA, source or sink	V_{SSA} + 0.05	–	V_{DDA} – 0.05	V
I_{OUT}	Output current, source or sink	V_{SSA} + 500 mV ≤ Vout ≤ V_{DDA} – 500 mV	10	–	–	mA
I_{DD}	Quiescent current	V_{SSA} + 50 mV ≤ V_{OUT} ≤ V_{DDA} – 500 mV	–	1	2.5	mA
CMRR	Common mode rejection ratio		80	–	–	dB
PSRR	Power supply rejection ratio		75	–	–	dB

AC Characteristics

Parameter	Description	Conditions	Min	Typ	Max	Units
GBW	Gain-bandwidth product	200 pF load	3	–	–	MHz
SR	Slew Rate	200 pF load	3	–	–	V/µs
e_n	Input noise density	V_{DDA} = 5 V, at 100 kHz	–	45	–	nV/sqrtHz

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.a	Edited datasheet to remove references to PSoC 5.	PSoC 5 has been replaced by the PSoC 5LP.
1.90	Added MISRA Compliance section.	The component does not have any specific deviations.
1.80	Added PSoC 5LP support.	
	Added all APIs with the CYREENTRANT keyword when they are included in the .cyre file.	Not all APIs are truly reentrant. Comments in the component API source files indicate which functions are candidates. This change is required to eliminate compiler warnings for functions that are not reentrant used in a safe way: protected from concurrent calls by flags or Critical Sections.

Version	Description of Changes	Reason for Changes / Impact
	Input offset voltage vs Temperature graph updated in the datasheet to include x and y axis labels.	Labels needs to be added to the axes.
	Minor datasheet edits.	Improve readability.
1.70.a	Added PSoC 5 DC and AC characteristics	
1.70	Removed Low Power mode DRC error for PSoC 3 Production	Low power mode is supported in PSoC 3 Production
	Implemented DRC error to allow only High Power mode for PSoC 5	Only High Power mode is supported in PSoC 5
	Edited Opamp_SetPower() API to allow only High Power mode for PSoC 5	
	Debug window support added	New feature added
1.60	Added a GUI Configuration Editor	For easier use a GUI has been added to set the two parameters from a drop down
	Added characterization data to datasheet	
	Minor datasheet edits and updates	
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.