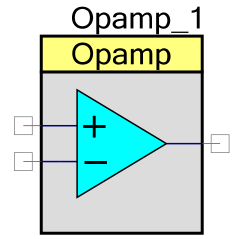
Operational Amplifier (Opamp)

1.60



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 constructing 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.

Non-Inverting – 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 non-inverting input.

Inverting – Analog *

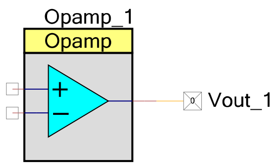
When the Opamp component is configured for Opamp mode, this I/O is the normal inverting input. When the Opamp is configured for Follower mode, this I/O is hard-connected to the output and the I/O is unavailable.

Vout – Analog

The output is directly connected to a pin. It is capable of driving 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

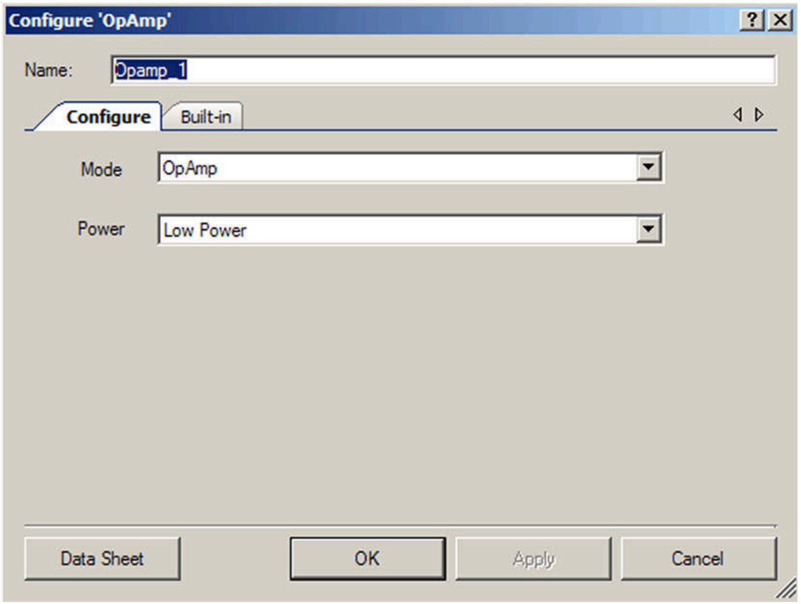
The default Opamp in the Component Catalog is a schematic macro using an Opamp component with default settings. The Opamp component is connected to an analog Pin component named Vout_1.



Parameters and Setup

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

Figure 1 Configure Opamp Dialog

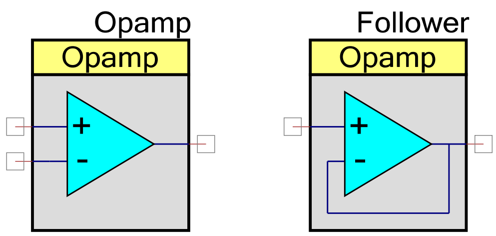


The Opamp has the following parameters:

Mode

This parameter allows you to select between two configurations: "Opamp" and "Follower". In Opamp 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. Opamp is the default configuration.

Figure 2 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 and Medium power modes, the output is a class AB stage, enabling direct drive of substantial 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 ES3 silicon, the LPOC mode is used for low-power transimpedance amplifiers (TIAs). This mode has the same drive capability as low power, but includes additional compensation for circuit topologies with higher than normal input capacitance as is often 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 ES3 silicon only. For PSoC 3 ES2 silicon, LPOC mode is not supported; High Power mode should be used instead. For PSoC 3 ES2 silicon, the High Power setting enables the 1.024 V Vref on the positive input. Any design with an Opamp that requires this Vref must include at least one Opamp that uses this High Power mode setting.

Placement

Each Opamp is directly connected to specific GPIOs.

	Non-inverting 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]

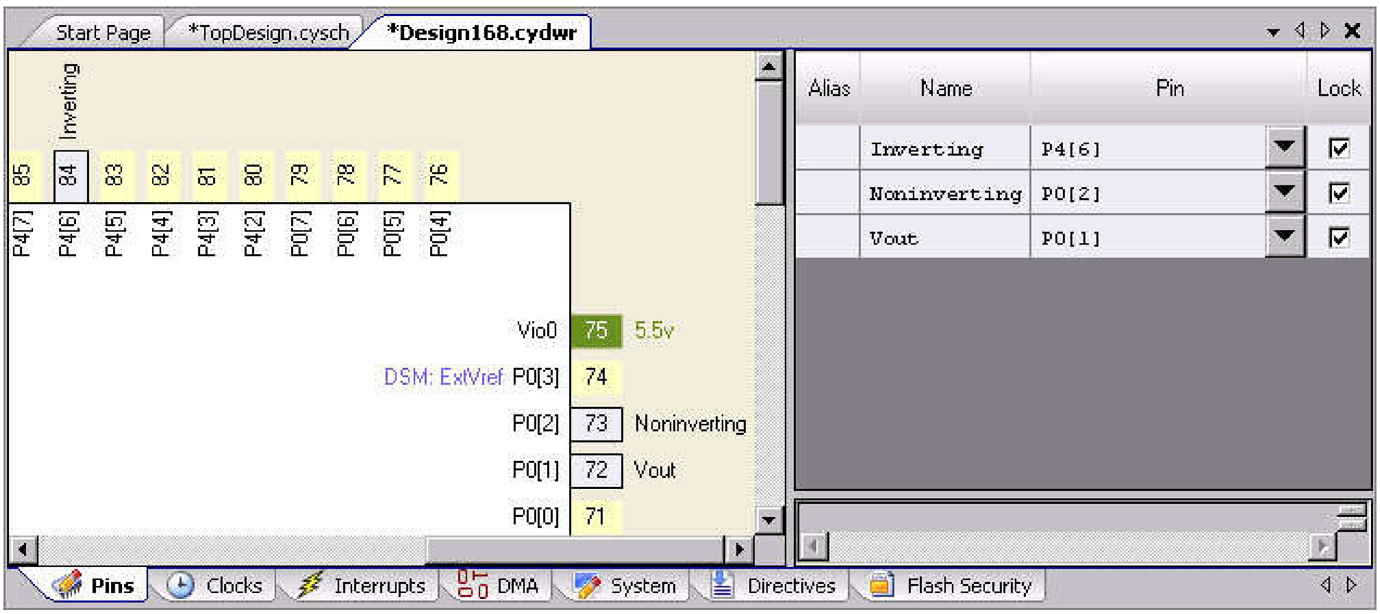
Refer to the device data sheet for the part being used for the specific physical pin connections.

Input signals may use the analog global routing buses in addition to the dedicated input pins. Using the direct connections utilizes 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.

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

Figure 3 Example placement



Resources

The Opamp component uses one Opamp resource 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.

	Digital Blocks					API Memory (Bytes)		
Analog Blocks	Datapaths	Macro cells	Status Registers	Control Registers	Counter7	Flash	RAM	Pins (per External I/O)
1 Opamp fixed block	N/A	N/A	N/A	N/A	N/A	202	2	3

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
void Opamp_Start(void)	Turns on the Opamp and sets the power level to the value chosen during the parameter selection.
void Opamp_Stop(void)	Disable Opamp (power down)
void Opamp_SetPower(uint8 power)	Set the power level.
void Opamp_Sleep(void)	Stops and saves the user configuration.
void Opamp_Wakeup(void)	Restores and enables the user configuration.
void Opamp_SaveConfig(void)	Empty function. Provided for future usage.
void Opamp_RestoreConfig(void)	Empty function. Provided for future usage.
void Opamp_Init(void)	Initializes or restores default Opamp configuration.
void Opamp_Enable(void)	Enables the Opamp.

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	
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 _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_SaveConfig(void)

Description: Empty function. Provided for future usage.

Parameters: None

Return Value: None

Side Effects: None

void Opamp_RestoreConfig(void)

Description: Empty function. Provided for future usage.

Parameters: None

Return Value: None

Side Effects: None

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.

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.

DC and AC Electrical Characteristics

The following values are based on characterization data. Specifications are valid for -40° C ≤ T_A ≤ 85° C and T_J ≤ 100° C except where noted. Unless otherwise specified in the tables below, all Typical values are for T_A = 25° C, Vdda = 5.0 V, Power = High, output referenced to analog ground, Vssa.

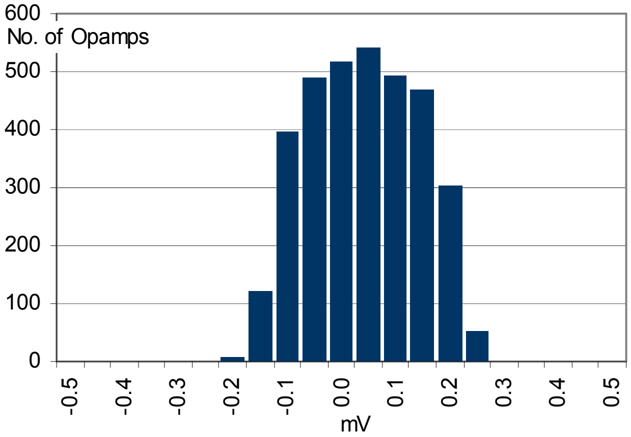
5.0 V/3.3 V DC Electrical Characteristics

Data collection is currently in progress. This table will be updated in a future release.

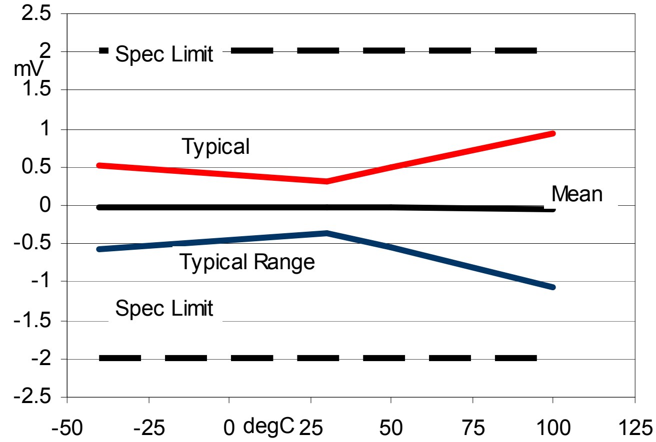
Parameter	Description	Conditions	Min	Typ	Max	Units
Vi	Input voltage range		V_{SSA}	–	V_{DDA}	V
Vioff	Input offset voltage	Power mode = minimum	–	0.5	2	mV
		Power mode = low	–	TBD	TBD	mV
		Power mode = medium	–	TBD	TBD	mV
		Power mode = high	–	TBD	TBD	mV
TCVos	Input offset voltage drift with temperature	Power mode = high	–	±12	–	µV/°C
Avol	Open-loop gain	Power mode = high	TBD	TBD	–	dB
Ge1	Gain error, unity gain buffer mode	Rload = 1 kΩ	–	–	±0.1	%
Rin	Input resistance	Positive gain, noninverting input	TBD	–	–	MΩ
Cin	Input capacitance	Routing from pin	–	TBD	TBD	pF
Vo	Output voltage range	1 mA, source or sink, power mode = high	V_{SSA} + 0.05	–	V_{DDA} – 0.05	V
		100 K to Vdda / 2, G = 1	TBD	–	TBD	V
Iout	Output current, source or sink	V_{SSA} + 500 mV ≤ Vout ≤ 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
Idd	Quiescent current	Power mode = min	–	TBD	TBD	µA
		Power mode = low	–	TBD	TBD	µA
		Power mode = med	–	TBD	TBD	µA
		Power mode = high	–	900	2000	µA
CMRR	Common mode rejection ratio		80	–	–	dB
PSRR	Power supply rejection ratio		TBD	–	–	dB

Figures

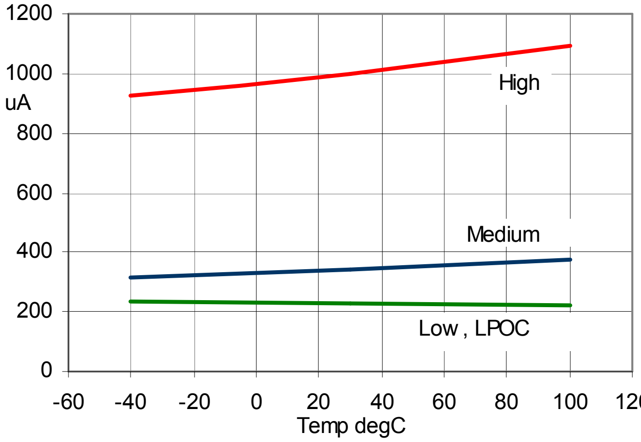
Histogram Input Offset Voltage
T=25C, Vdda=5.0V



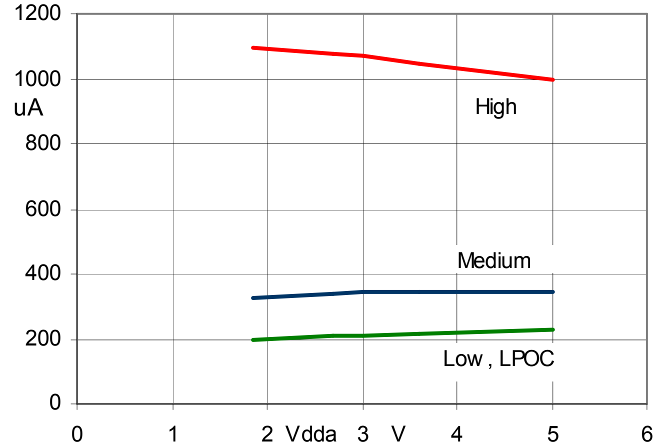
Input Offset Voltage vs Temperature
Power=High, Vdda=5.0V



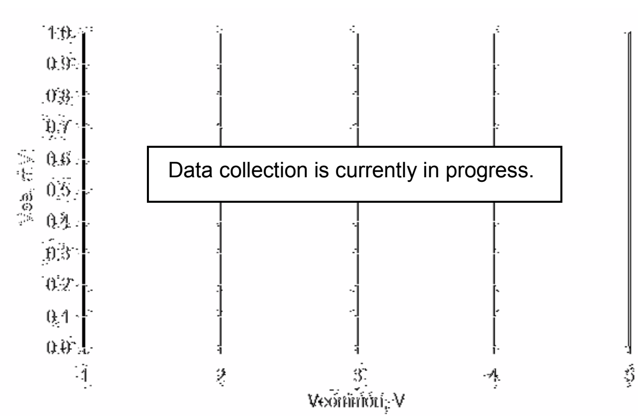
Operating current vs temp, Vdd=5.0V



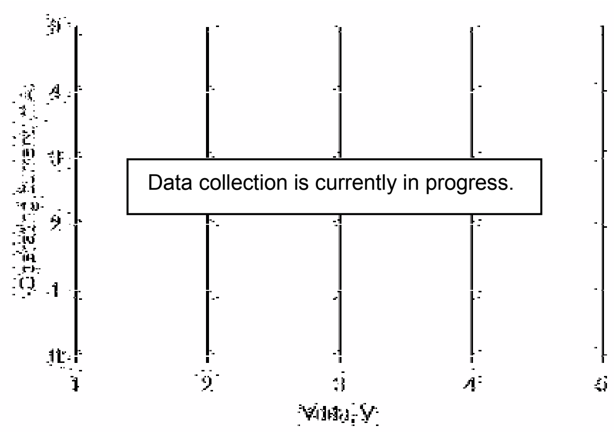
Operating current vs voltage T=25C



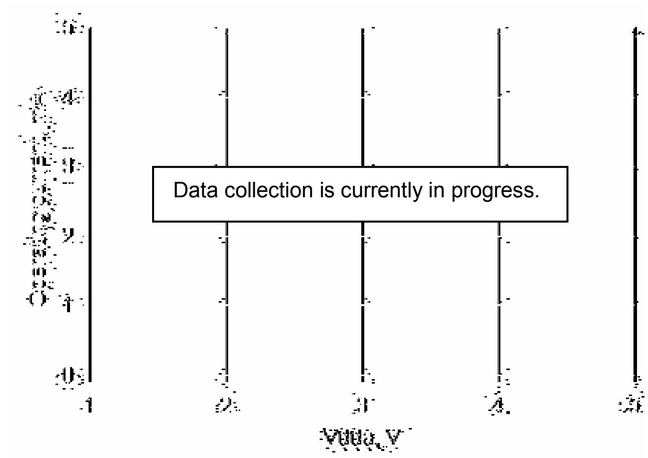
Opamp Voffset vs Common Mode Voltage and
Temperature, Power Mode = High



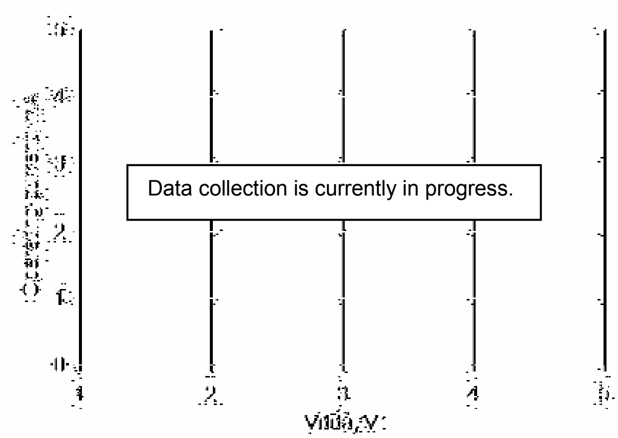
Opamp Operating Current vs Vdda,
Power Mode = Minimum



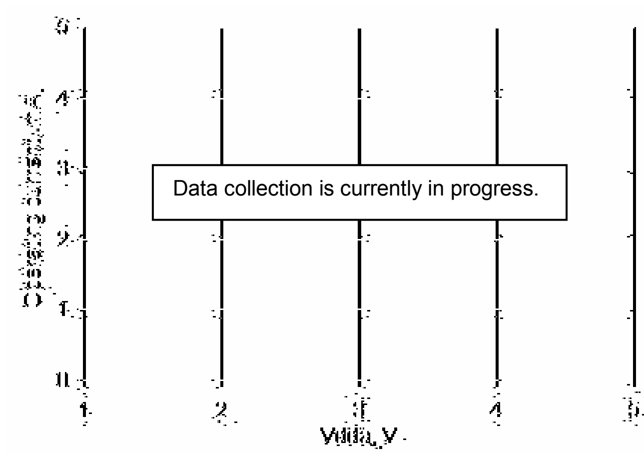
Opamp Operating Current vs Vdda,
Power Mode = Low



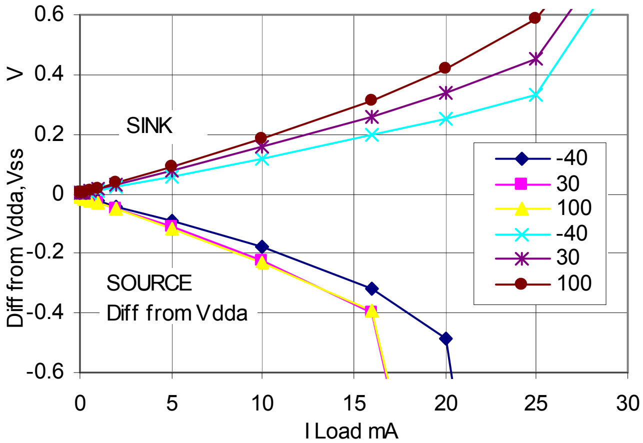
Opamp Operating Current vs Vdda,
Power Mode = Medium



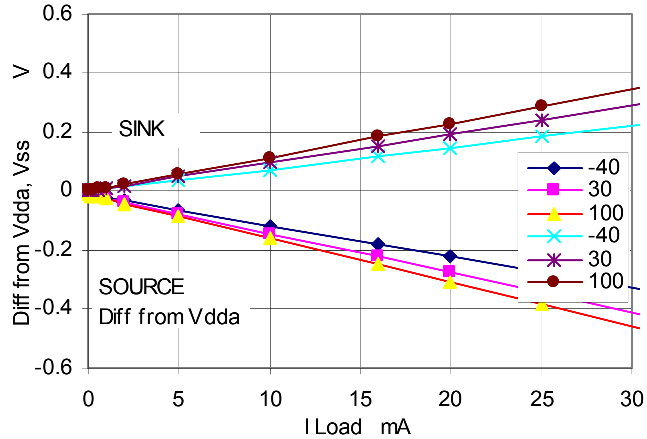
Opamp Operating Current vs Vdda,
Power Mode = High



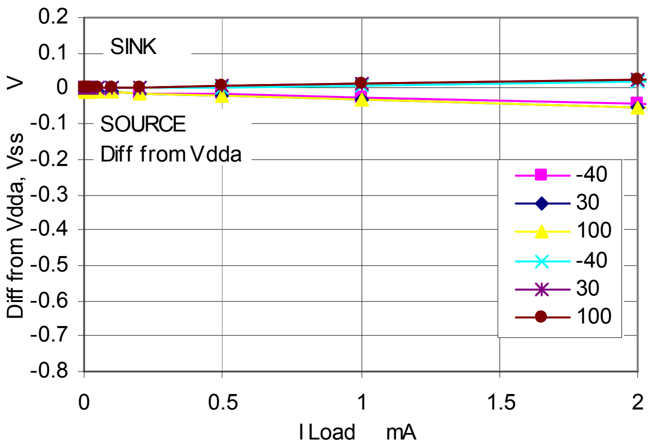
Output voltage vs load current,
Vdda=1.71V, P=High



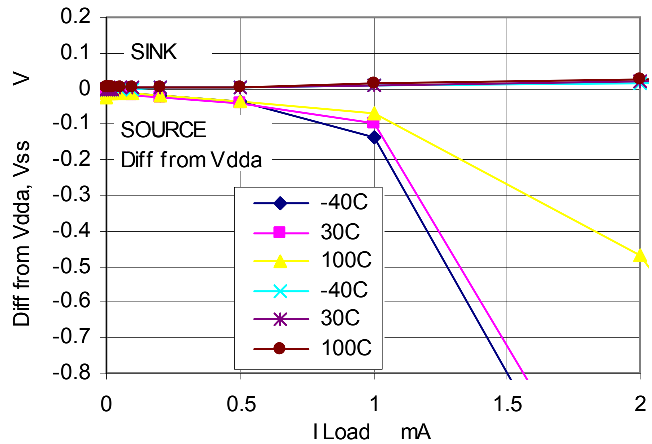
Output voltage vs load current,
Vdda=5.0V, Power=High



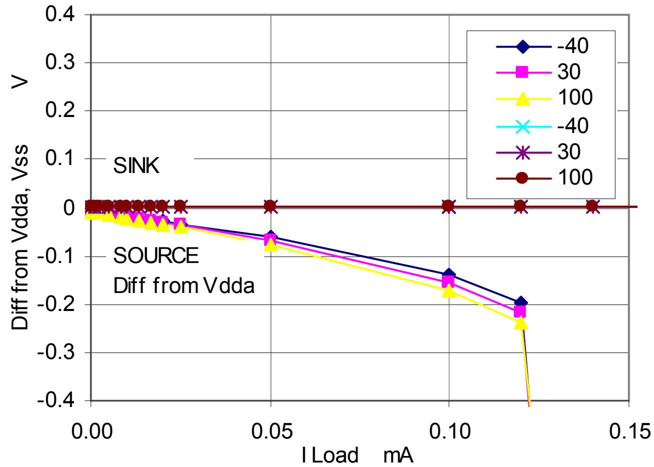
Output voltage vs load current,
Vdda=2.7V, P=Med



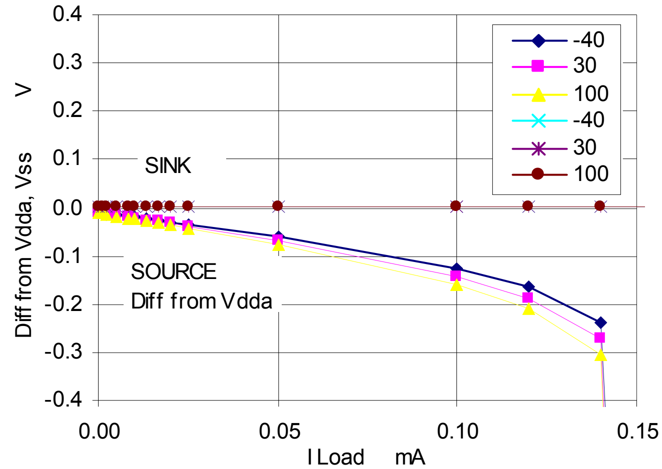
Output voltage vs load current
Vdda=5.0V, Power=Medium



Output voltage vs load current,
Vdda=2.7V, P=Low



Output voltage vs load current,
Vdda=5.0V, P=Low



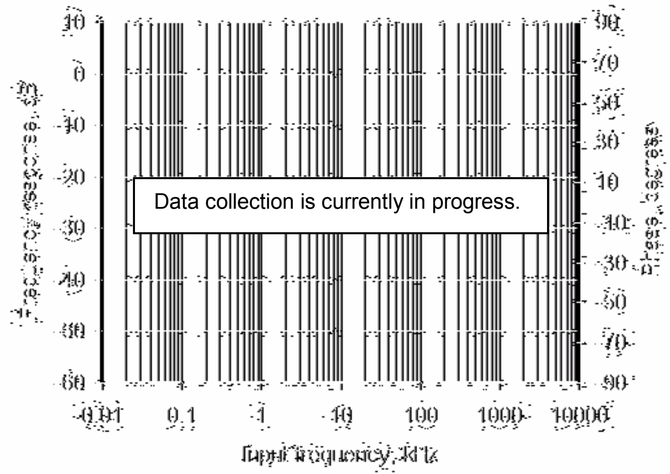
5.0 V/3.3 V AC Electrical Characteristics

Data collection is currently in progress. This table will be updated in a future release.

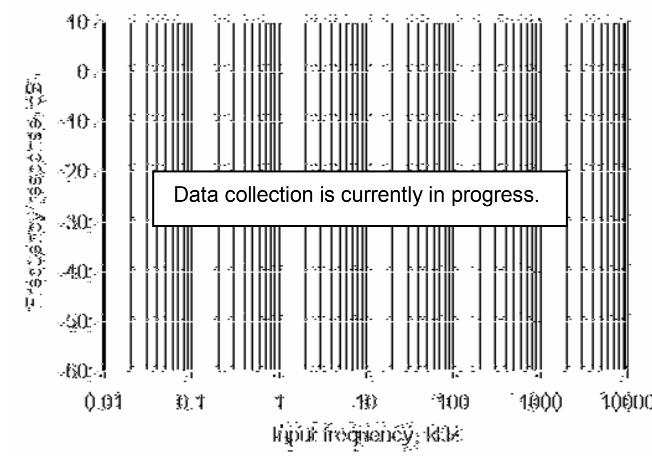
Parameter	Description	Conditions	Min	Typ	Max	Units
GBW	Gain-bandwidth product	Power mode = minimum, 100 mV pk-pk, 15 pF load	TBD	TBD	–	MHz
		Power mode = low, 100 mV pk-pk, 15 pF load	TBD	TBD	–	MHz
		Power mode = medium, 100 mV pk-pk, 15 pF load	TBD	TBD	–	MHz
		Power mode = high, 100 mV pk-pk, 200 pF load	3	TBD	–	MHz
SR	Slew Rate	Power mode = minimum, 15 pF load	TBD	TBD	–	V/µs
		Power mode = low, 15 pF load	TBD	TBD	–	V/µs
		Power mode = medium, 15 pF load	TBD	TBD	–	V/µs
		Power mode = high, 200 pF load	3	TBD	–	V/µs
e_n	Input noise density	Power mode = high, Vdda = 5 V, at 100 kHz	–	45	–	nV/sqrtHz

Figures

Open Loop Gain and Phase vs Frequency and Temperature, Power Mode = High, Cl = 15 Pf, Vdda = 5V



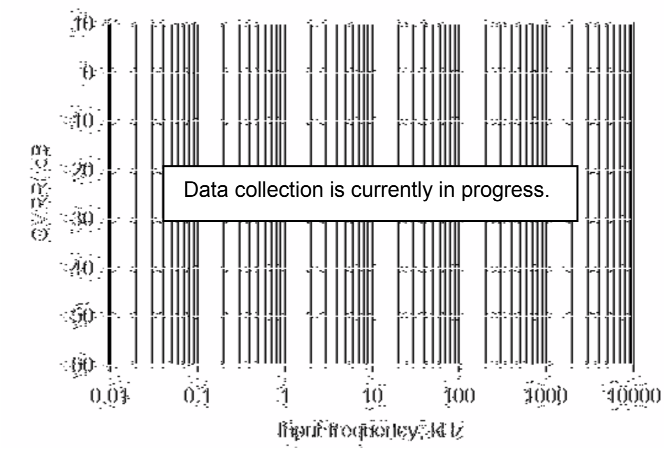
Opamp Closed Loop Frequency Response, Gain = 1, Vdda = 5V



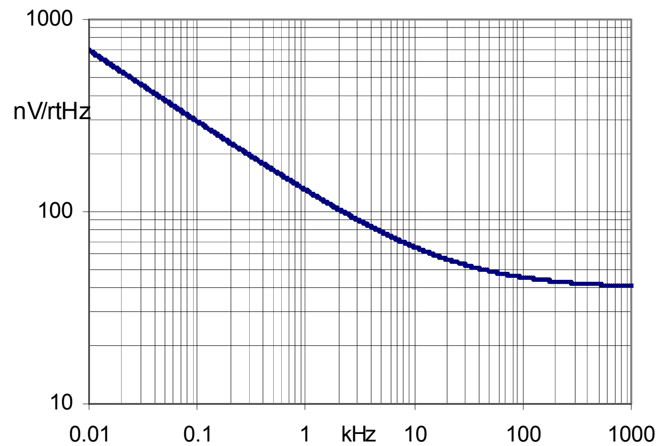
Opamp Closed Loop Frequency Response, Gain = 10, Vdda = 5V

Opamp test Circuit for Gain = 10

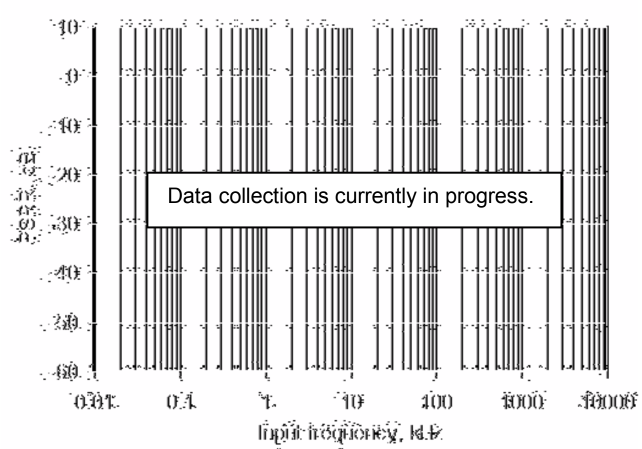
Opamp CMRR vs Frequency



Input Voltage Noise Density
T=25C, Vdda = 5.0V, P=high



Opamp PSRR vs Frequency



Note More specifications at other voltages and graphs may be added after characterization.

Component Changes

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

Version	Description of Changes	Reason for Changes / Impact
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	

Version	Description of Changes	Reason for Changes / Impact
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.