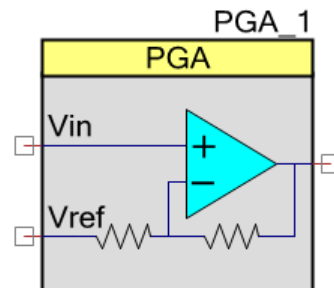


# Programmable Gain Amplifier (PGA)

2.0

## Features

- Gain steps from 1 to 50
- High input impedance
- Selectable input reference
- Adjustable power settings



## General Description

The PGA implements an opamp-based, non-inverting amplifier with user-programmable gain. This amplifier has high input impedance, wide bandwidth and selectable input voltage reference. It is derived from the switched capacitor/continuous time (SC/CT) block.

The gain can be between 1 (0 dB) and 50 (+34 dB). The gain can be selected using the configuration window or changed at run time using the provided API. The maximum bandwidth is limited by the gain-bandwidth product of the opamp and is reduced as the gain is increased. The input of the PGA operates from rail to rail, but the maximum input swing (difference between  $V_{in}$  and  $V_{ref}$ ) is limited to  $V_{DDA}/\text{Gain}$ . The output of the PGA is class A, and is rail to rail for sufficiently high load resistance.

The PGA is used when an input signal has insufficient amplitude. A PGA can be put in front of a comparator, ADC, or mixer to increase the amplitude of the signal to these components. The PGA can be used as a unity gain amplifier to buffer the inputs of lower impedance blocks, including Mixers or inverting PGAs. A unity gain PGA can also be used to buffer the output of a VDAC or reference.

## Input/Output Connections

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

### Vin – Analog

Vin is the input signal terminal.

## Vref – Analog \*

Vref is the input terminal for a reference signal.

The reference input can be connected to an external (to the component) reference or internal (to the component) V<sub>ss</sub> (ground). When the reference is connected externally, the routing resistance is added to the internal resistors, slightly decreasing the gain and increasing the gain tolerance.

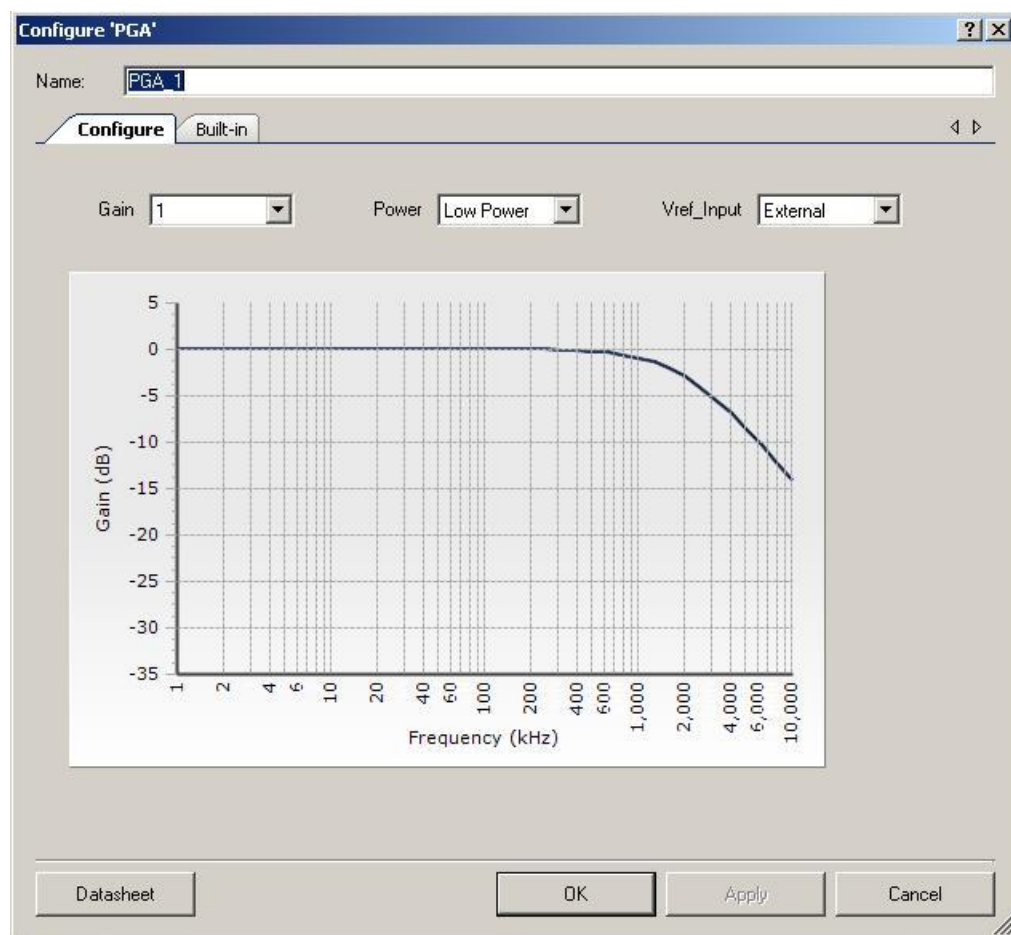
## Vout – Analog

Vout is the output voltage signal terminal. Vout is a function of (Vin – Vref) times the specified Gain:

$$V_{out} = V_{ref} + (V_{in} - V_{ref}) \times \text{Gain}$$

## Component Parameters

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



## Gain

This parameter sets the initial gain of the PGA. You can select the gain from the following set of allowed values: 1 (default), 2, 4, 8, 16, 24, 32, 48, and 50.

The following table shows the gain selection using Internal Resistors  $R_a$  and  $R_b$

| Gain | $R_b$ | $R_a$ |
|------|-------|-------|
| 1    | 0     | 40k   |
| 2    | 40k   | 40k   |
| 4    | 120k  | 40k   |
| 8    | 280k  | 40k   |
| 16   | 600k  | 40k   |
| 24   | 460k  | 20k   |
| 32   | 620k  | 20k   |
| 48   | 470k  | 10k   |
| 50   | 490k  | 10k   |

## Power

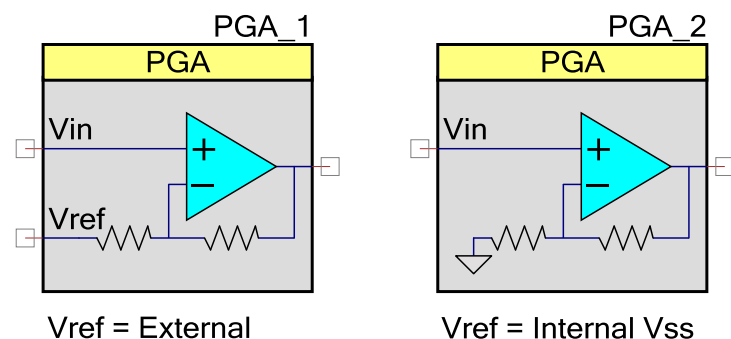
This parameter sets the initial drive power of the PGA. The power determines how fast the PGA reacts to changes in the input signal. There are four power settings: **Minimum Power**, **Low Power** (default), **Medium Power**, and **High Power**. A **Minimum Power** setting results in the slowest response time and a **High Power** setting results in the fastest response time.

## Vref\_Input

This parameter is used to select the input voltage reference. The options include:

- **Internal Vss** – A ground signal internal to the component provides the amplifier reference.
- **External** (default) – A signal on the Vref terminal provides the amplifier reference.

The symbol displayed in PSoC Creator changes depending on the reference input selected.

**Figure 1. PGA Configurations**


## 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 “PGA\_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 “PGA.”

| Function            | Description                                       |
|---------------------|---|
| PGA_Start()         | Starts the PGA                                    |
| PGA_Stop()          | Powers down the PGA                               |
| PGA_SetGain()       | Sets gain to predefined constants                 |
| PGA_SetPower()      | Sets drive power to one of four settings          |
| PGA_Sleep()         | Stops and saves the user configurations           |
| PGA_Wakeup()        | Restores and enables the user configurations      |
| PGA_Init()          | Initializes or restores default PGA configuration |
| PGA_Enable()        | Enables the PGA                                   |
| PGA_SaveConfig()    | Empty function. Provided for future use.          |
| PGA_RestoreConfig() | Empty function. Provided for future use.          |

## Global Variables

| Variable    | Description   |
|-------------|---|
| PGA_initVar | Indicates whether the PGA has been initialized. The variable is initialized to 0 and set to 1 the first time PGA_Start() is called. This allows the component to restart without reinitialization after the first call to the PGA_Start() routine.<br><br>If reinitialization of the component is required, then the PGA_Init() function can be called before the PGA_Start() or PGA_Enable() function. |

## void PGA\_Start(void)

- Description:** This is the preferred method to begin component operation. This function turns on the amplifier with the power and gain based on the settings provided during the configuration or the current values after PGA\_Stop() has been called.
- Parameters:** None
- Return Value:** None
- Side Effects:** None

## void PGA\_Stop(void)

- Description:** This function turns off PGA and enables its lowest power state.
- Parameters:** None
- Return Value:** None
- Side Effects:** None. Does not affect power or gain settings.

## void PGA\_SetPower(uint8 power)

- Description:** This function sets the drive power to one of four settings; minimum, low, medium, or high.
- Parameters:** uint8 power: See the following table for valid power settings.

| Power Setting | Notes                                      |
|---------------|--|
| PGA_MINPOWER  | Minimum active power and slowest slew rate |
| PGA_LOWPOWER  | Low power and slew rate                    |
| PGA_MEDPOWER  | Medium power and slew rate                 |
| PGA_HIGHPower | Highest active power and fastest slew rate |

- Return Value:** None
- Side Effects:** None



## void PGA\_SetGain(uint8 gain)

**Description:** This function sets the amplifier gain to a value between 1 and 50.

**Parameters:** uint8 gain: See the following table for valid gain settings.

| Gain Setting | Notes     |
|--------------|-----------|
| PGA_GAIN_01  | Gain = 1  |
| PGA_GAIN_02  | Gain = 2  |
| PGA_GAIN_04  | Gain = 4  |
| PGA_GAIN_08  | Gain = 8  |
| PGA_GAIN_16  | Gain = 16 |
| PGA_GAIN_24  | Gain = 24 |
| PGA_GAIN_32  | Gain = 32 |
| PGA_GAIN_48  | Gain = 48 |
| PGA_GAIN_50  | Gain = 50 |

**Return Value:** None

**Side Effects:** None

## void PGA\_Sleep(void)

**Description:** This is the preferred API to prepare the component for sleep. The PGA\_Sleep() API saves the current component state. Then it calls the PGA\_Stop() function and calls PGA\_SaveConfig() to save the hardware configuration.

Call the PGA\_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 PGA\_Wakeup(void)

- Description:** This is the preferred API to restore the component to the state when PGA\_Sleep() was called. The PGA\_Wakeup() function calls the PGA\_RestoreConfig() function to restore the configuration. If the component was enabled before the PGA\_Sleep() function was called, the PGA\_Wakeup() function will also re-enable the component.
- Parameters:** None
- Return Value:** None
- Side Effects:** Calling the PGA\_Wakeup() function without first calling the PGA\_Sleep() or PGA\_SaveConfig() function may produce unexpected behavior.

## void PGA\_Init(void)

- Description:** This function initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call PGA\_Init() because the PGA\_Start() API 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 PGA\_Enable(void)

- Description:** This function activates the hardware and begins component operation. It is not necessary to call PGA\_Enable() because the PGA\_Start() API calls this function, which is the preferred method to begin component operation.
- Parameters:** None
- Return Value:** None
- Side Effects:** None

## void PGA\_SaveConfig(void)

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

## void PGA\_RestoreConfig(void)

|                      |  |
|----------------------|--|
| <b>Description:</b>  | Empty function. Provided for future use. |
| <b>Parameters:</b>   | None                                     |
| <b>Return Value:</b> | None                                     |
| <b>Side Effects:</b> | 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 PGA 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.

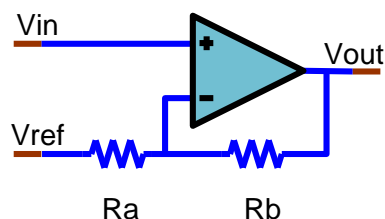
## Functional Description

The PGA is constructed from a generic SC/CT block. You can find details about this block in the applicable device datasheet and TRM, available on the [Cypress website](#). The gain is selected by adjusting two resistors, Ra and Rb (see [Figure 2. PGA Schematic](#)). Ra may be set to either 10 kΩ, 20 kΩ, or 40 kΩ. Rb is set between 0 kΩ and 1000 kΩ to generate the gain values selectable in either the parameter dialog or the PGA\_SetGain() function.

The block has a programmable capacitor in parallel with the feedback resistor, Rb. The value of the capacitor is configured for each gain selection to achieve guaranteed stability. Reassigning Rb values without also selecting the appropriate feedback capacitor value can result in PGA instability. Cypress strongly recommends that you use the provided APIs for gain changes.





**Figure 2. PGA Schematic**

The bandwidth of the PGA is determined by gain and power setting. Because of compensation capacitor and stability requirements, the bandwidth is somewhat reduced from the absolute maximum expected from the opamp's open loop gain-bandwidth.

## Resources

The PGA component uses one SC/CT analog 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 5LP (GCC) |            |
|---------------|--------------------|------------|----------------|------------|
|               | Flash Bytes        | SRAM Bytes | Flash Bytes    | SRAM Bytes |
| Default       | 228                | 22         | 332            | 5          |

## DC and AC Electrical Characteristics for PSoC 3

Specifications are valid for  $-40\text{ }^{\circ}\text{C} \leq T_A \leq 85\text{ }^{\circ}\text{C}$  and  $T_J \leq 100\text{ }^{\circ}\text{C}$ , except where noted.  
Specifications are valid for 1.71 V to 5.5 V, except where noted. Typical values are for  $T_A = 25\text{ }^{\circ}\text{C}$ .

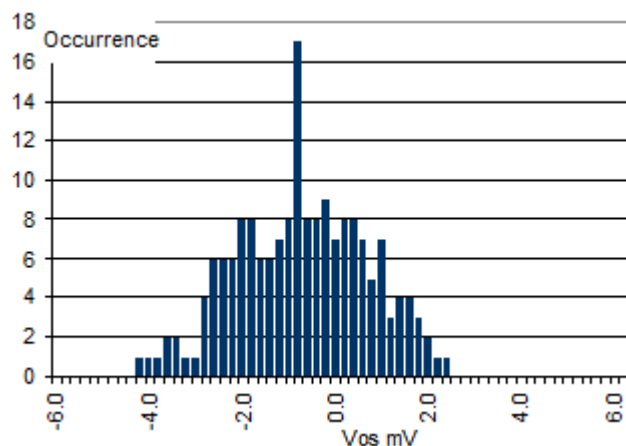
### DC Characteristics

| Parameter         | Description                                       | Conditions  | Min                     | Typ  | Max                     | Units    |
|-------------------|---|---|-------------------------|------|-------------------------|----------|
| V <sub>in</sub>   | Input voltage range                               | Power Mode = minimum  | V <sub>SSA</sub>        | -    | V <sub>DDA</sub>        | V        |
| V <sub>OS</sub>   | Input offset voltage                              | Power mode = high, gain = 1   | -                       | -    | 10                      | mV       |
| TCV <sub>OS</sub> | Temp. coeff. input offset voltage, absolute value | Power mode = high, gain = 1   | -                       | -    | ±30                     | μV/°C    |
| V <sub>onl</sub>  | DC output nonlinearity                            | Gain = 1  | -                       | -    | ±0.01                   | % of FSR |
| C <sub>IN</sub>   | Input capacitance                                 |   | -                       | -    | 7                       | pF       |
| V <sub>oh</sub>   | Output voltage swing                              | Power mode = high, gain = 1, R <sub>load</sub> = 100 kΩ to V <sub>DDA</sub> / 2 | V <sub>DDA</sub> - 0.15 | -    | -                       | V        |
| V <sub>ol</sub>   | Output voltage swing                              | Power mode = high, gain = 1, R <sub>load</sub> = 100 kΩ to V <sub>DDA</sub> / 2 | -                       | -    | V <sub>SSA</sub> + 0.15 | V        |
| V <sub>src</sub>  | Output voltage under load                         | I <sub>load</sub> = 250 μA, V <sub>DDA</sub> ≥ 2.7V, power mode = high          | -                       | -    | 300                     | mV       |
| Ge1               | Gain accuracy, deviation from nominal             | G = 1, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | -                       | 0.01 | 0.15                    | +/- %    |
| Ge2               |   | G = 2, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | -                       | 0.1  | 1.0                     |          |
| Ge4               |   | G = 4, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | -                       | 0.5  | 1.35                    |          |
| Ge8               |   | G = 8, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | -                       | 0.6  | 1.6                     |          |
| Ge16              |   | G = 16, V <sub>ref</sub> internally connected to V <sub>SS</sub>                | -                       | 0.7  | 2.5                     |          |
| Ge32              |   | G = 32, V <sub>ref</sub> internally connected to V <sub>SS</sub>                | -                       | 0.85 | 5.0                     |          |
| Ge50              |   | G = 50, V <sub>ref</sub> internally connected to V <sub>SS</sub>                | -                       | 2.1  | 5.0                     |          |
| Gd1               | Gain change versus temperature                    | G = 1, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | N/A                     | 1.2  | 2.5                     | ppm/°C   |
| Gd2               |   | G = 2, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | -                       | 8.6  | 20                      |          |
| Gd4               |   | G = 4, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | -                       | 13   | 29                      |          |
| Gd8               |   | G = 8, V <sub>ref</sub> internally connected to V <sub>SS</sub>                 | -                       | 15   | 35                      |          |
| Gd16              |   | G = 16, V <sub>ref</sub> internally connected to V <sub>SS</sub>                | -                       | 18   | 40                      |          |
| Gd32              |   | G = 32, V <sub>ref</sub> internally connected to V <sub>SS</sub>                | -                       | 38   | 75                      |          |

| Parameter       | Description                  | Conditions   | Min | Typ | Max  | Units |
|-----------------|------------------------------|--|-----|-----|------|-------|
| Gd50            |                              | G = 50, Vref internally connected to V <sub>SS</sub> | –   | 167 | 400  |       |
| PSSR            | Power supply rejection ratio |  | 48  | -   | -    | dB    |
| I <sub>DD</sub> | Operating current            | Power mode = high                                    | –   | 1.5 | 1.65 | mA    |

## Figures

Offset Voltage Histogram

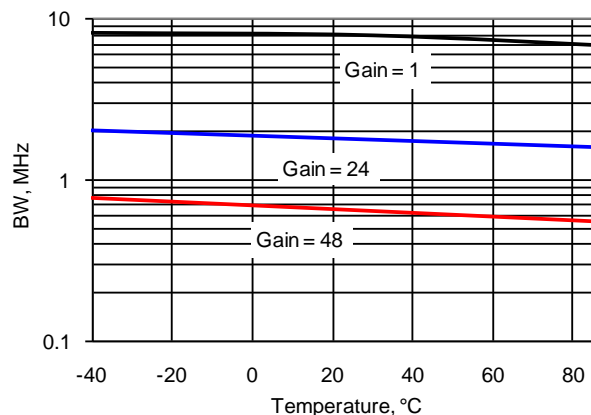


## AC Characteristics

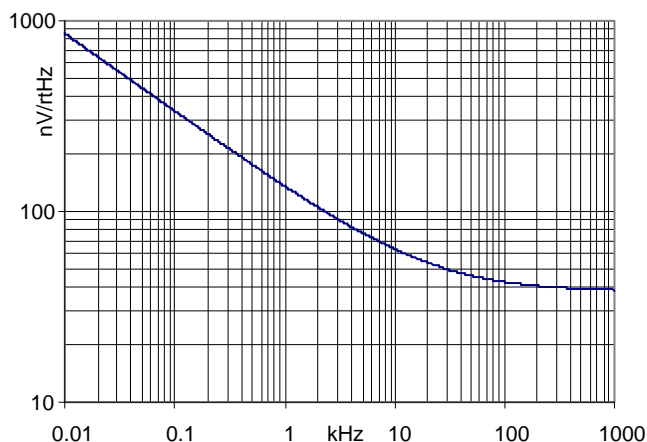
| Parameter      | Description         | Conditions   | Min  | Typ  | Max | Units     |
|----------------|---------------------|--|------|------|-----|-----------|
| BW1            | -3dB Bandwidth      | Power mode = high, gain = 1, input = 100 mV peak-to-peak | 6.7  | 8    | -   | MHz       |
| SR_G1          | Slew rate           | 20 - 80%, Gain = 1, P = High                             | 3.0  | 4.8  | N/A | V/μs      |
| SR_G16         |                     | 20 - 80%, Gain = 16, P = High                            | 0.5  | 0.87 | N/A | V/μs      |
| SR_G50         |                     | 20 - 80%, Gain = 50, P = High                            | 0.25 | 0.84 | N/A | V/μs      |
| e <sub>n</sub> | Input noise density | f = 100 kHz, P = High, V <sub>dda</sub> = 5V             | -    | 43   | -   | nV/sqrtHz |

## Figures

**Bandwidth versus Temperature,  
at Different Gain Settings, Power = High**



**Voltage noise,  $V_{DDA} = 5$  V, Power Mode = High**



## DC and AC Electrical Characteristics for PSoC 5LP

Specifications are valid for  $-40\text{ °C} \leq T_A \leq 85\text{ °C}$  and  $T_J \leq 100\text{ °C}$ , except where noted.  
Specifications are valid for 2.7 V to 5.5 V, except where noted. Typical values are for  $T_A = 25\text{ °C}$ .

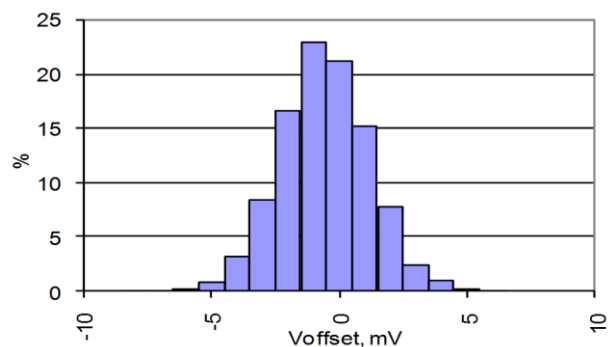
### DC Characteristics

| Parameter  | Description                                 | Conditions                  | Min       | Typ | Max       | Unit                         |
|------------|---|-----------------------------|-----------|-----|-----------|------------------------------|
| $V_{in}$   | Input voltage range                         | Power mode = minimum        | $V_{SSA}$ | —   | $V_{DDA}$ | V                            |
| $V_{os}$   | Input offset voltage                        | Power mode = high, gain = 1 | —         | —   | 20        | mV                           |
| $TCV_{os}$ | Input offset voltage drift with temperature | Power mode = high, gain = 1 | —         | —   | ±30       | $\mu\text{V}/^\circ\text{C}$ |
| $Ge_1$     | Gain error, gain = 1                        |                             | —         | —   | ±2        | %                            |
| $Ge_{16}$  | Gain error, gain = 16                       |                             | —         | —   | ±8        | %                            |
| $Ge_{50}$  | Gain error, gain = 50                       |                             | —         | —   | ±10       | %                            |

| Parameter        | Description                  | Conditions   | Min                     | Typ | Max                     | Units   |
|------------------|------------------------------|--|-------------------------|-----|-------------------------|---------|
| V <sub>ONL</sub> | DC output nonlinearity       | Gain =1  | –                       | –   | ±0.1                    | %of FSR |
| C <sub>IN</sub>  | Input capacitance            |  | –                       | –   | 7                       | pF      |
| V <sub>OH</sub>  | Output swing                 | Power mode = high, gain = 1, R <sub>LOAD</sub> = 100 kΩ to V <sub>DDA</sub> /2 | V <sub>DDA</sub> – 0.15 | –   | –                       | V       |
| V <sub>OL</sub>  | Output swing                 | Power mode = high, gain = 1, R <sub>LOAD</sub> = 100 kΩ to V <sub>DDA</sub> /2 | –                       | –   | V <sub>SSA</sub> + 0.15 | V       |
| V <sub>SRC</sub> | Output voltage under load    | I <sub>LOAD</sub> = 250 μA, power mode = high                                  | –                       | –   | 300                     | mV      |
| I <sub>DDA</sub> | Operating current            | Power mode = high  | –                       | 1.5 | 1.65                    | mA      |
| PSRR             | Power supply rejection ratio |  | 48                      | –   | –                       | dB      |

## Figures

Offset Voltage Histogram

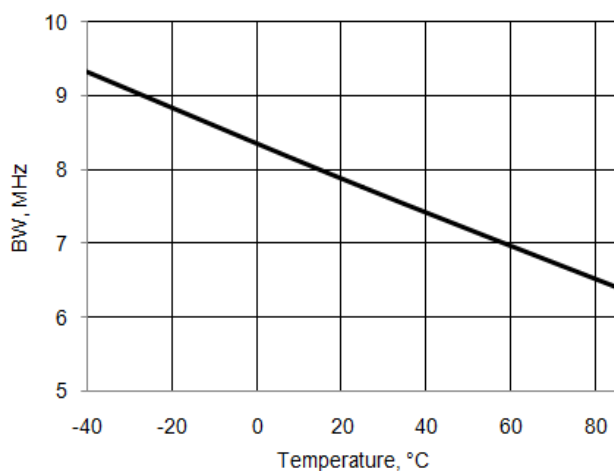


## AC Characteristics

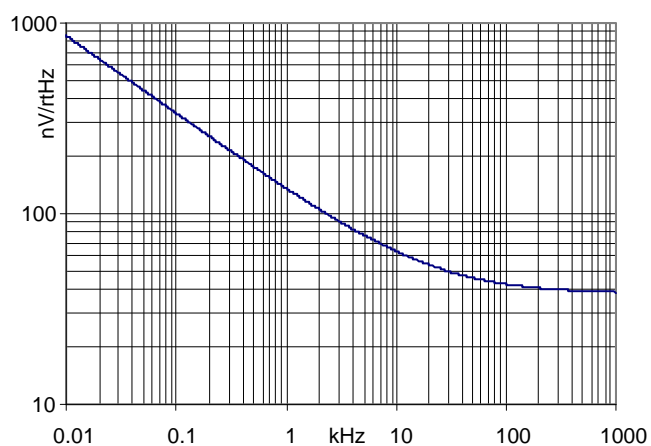
| Parameter | Description         | Conditions   | Min | Typ | Max | Units      |
|-----------|---------------------|--|-----|-----|-----|------------|
| BW1       | –3 dB bandwidth     | Power mode = high, gain = 1, non-inverting mode, $300\text{ mV} \leq V_{IN} \leq V_{DDA} - 1.2\text{ V}$ , $C_L \leq 25\text{ pF}$ | 6   | 8   | –   | MHz        |
| SR1       | Slew rate           | Power mode = high, gain = 1, 20% to 80%  | 3.0 | –   | –   | V/ $\mu$ s |
| $e_n$     | Input noise density | Power mode = high, $V_{DDA} = 5\text{ V}$ at 100 kHz   | –   | 43  | –   | nV/sqrtHz  |

## Figures

**Bandwidth versus Temperature,  
Gain = 1, Power Mode = High**



**Noise versus Frequency,  
 $V_{DDA} = 5\text{ V}$ , Power Mode = High**



## Component Changes

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

| Version | Description of Changes   | Reason for Changes / Impact   |
|---------|--|---|
| 2.0.c   | Minor datasheet edit.  | Fixed corrupted images/charts.  |
| 2.0.b   | Minor datasheet edit.  |   |
| 2.0.a   | Edited datasheet to remove references to PSoC 5.   | PSoC 5 has been replaced by the PSoC 5LP.   |
| 2.0     | Added variable Vdda support.   |   |
|         | Added MISRA Compliance section.  | The component does not have any specific deviations.  |
| 1.90    | Schematic and source file updates to use a single shared boost clock for all SC/CT block components. | A single shared clock will be used as boost clock by all SC/CT block components   |
|         | For low voltage VDDA operation uses a boost clock shared by all the SC/CT based components.          | Reduces the number of analog clocks required in the system for boost clocks. With this change a single boost clock is shared instead of using a separate clock for each SC/CT based component.  |
| 1.80    | Added PSoC 5LP support   |   |
|         | Changed resistor combination for Gain = 24   | Resistor values were incorrect  |
|         | Added all component APIs with the CYREENTRANT keyword  |   |
|         | Minor GUI updates  |   |
| 1.70.a  | Added DC and AC Electrical characteristics data for PSoC 5   |   |
| 1.70    | Changed PGA_Stop() API for PSoC 5  | Change required to prevent the component from impacting unrelated analog signals when stopped, when using PSoC 5.   |
|         | Updated PGA response graph   | Change required to dynamically resize graph to fit window and to add horizontal and vertical grids.   |
| 1.60    | Removed VDDA parameter from component customizer   | VDDA setting in the component is redundant and unnecessary for multiple components. The parameter was removed and the component queries the global setting for minimum VDDA in the DWR and automatically enables the pump when necessary. |
|         | Created configuration window to include frequency response graphs for an easier to use GUI.          | Previous configuration window did not provide enough information for ease of use.   |
|         | Corrected SetGain constants in the header file   | The constants provided for the SetGain API had incorrect values. These have been corrected.   |

| Version | Description of Changes                               | Reason for Changes / Impact  |
|---------|--|--|
|         | Added characterization data to datasheet             |  |
| 1.50    | Minor datasheet edits and updates                    |  |
|         | 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. |
|         | Removed Gain setting of 25.                          | The gain of 25 was too close to other values and therefore offered no value.   |
|         | Updated the symbol image and Configure dialog.       | These were updated to comply with corporate standards.   |
|         | Changed the names of the registers by adding "_REG." | Updated to comply with coding guidelines.  |
|         | Added specification table and graphic placeholders   | Data to be provided when characterization is complete.   |

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