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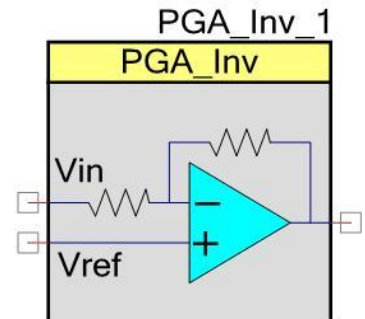
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# Inverting Programmable Gain Amplifier (PGA\_Inv)

2.0

## Features

- Gain steps from  $-1$  to  $-49$
- High input impedance
- Adjustable power settings



## General Description

The Inverting Programmable Gain Amplifier (PGA\_Inv) component implements an opamp-based inverting amplifier with user-programmable gain. It is derived from the switched capacitor/continuous time (SC/CT) block.

The inverting gain can be between  $-1.0$  (0 dB) and  $-49.0$  (+33.8 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 of the opamp and is reduced as the gain is increased. The input of the PGA\_Inv 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\_Inv is class A, and is rail to rail for sufficiently high load resistance.

The PGA\_Inv is used when an input signal has insufficient amplitude and the preferred output polarity is the inverse of the input. A PGA\_Inv can be placed in front of a comparator, ADC, or mixer to increase the signal amplitude. A unity gain PGA\_Inv following another gain stage or buffer can be used to generate differential outputs.

## Input/Output Connections

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

$V_{in}$  is the input signal terminal.

### Vref – Analog

$V_{ref}$  is the input terminal for a reference signal. The reference input has a high impedance and may be connected to fixed reference (for example,  $V_{DDA}/2$ ), VDACC8 output, or routed to a pin.

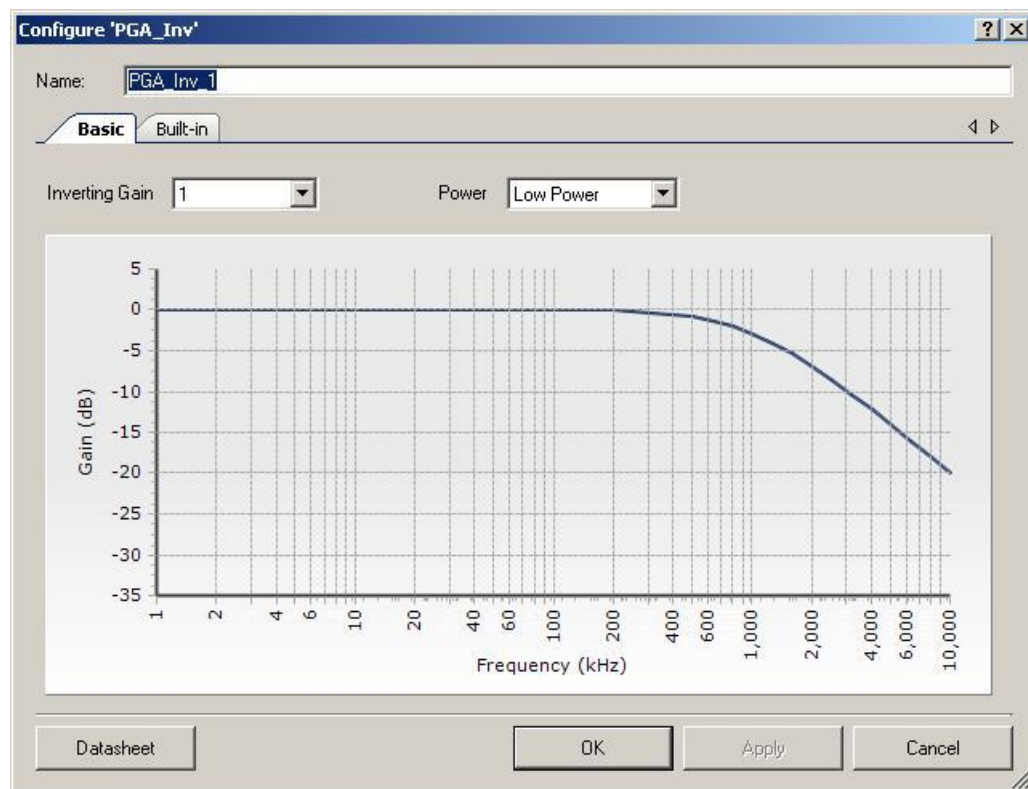
## Vout – Analog

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

$$V_{out} = V_{ref} + (V_{in} - V_{ref}) \times \text{Gain} \quad \text{where Gain is a negative value}$$

## Component Parameters

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



## Inverting\_Gain

This parameter is used to set the default gain of the amplifier. The allowable inverting gains provided are: -1 (default), -3, -7, -15, -22, -24, -31, -47, and -49.

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

Gain	$R_b$	$R_a$
-1	40	40k
-3	120k	40k
-7	280k	40k

Gain	R <sub>b</sub>	R <sub>a</sub>
-15	600k	40k
-22	880k	40k
-24	480k	20k
-31	620k	20k
-47	470k	10k
-49	490k	10k

## Power

This sets the initial drive power of the PGA\_Inv. The **Power** setting determines the speed with which the PGA\_Inv responds to changes in the input signal. There are four power settings: **Minimum Power**, **Low Power** (default), **Medium Power**, and **High Power**. A **Low Power** setting results in the slowest response time and a **High Power** setting results in the fastest response time. The **Power** setting can be set at run time using the PGA\_Inv\_SetPower() API.

## 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\_Inv\_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 “PGA\_Inv.”

Function	Description
PGA_Inv_Start()	Starts the PGA_Inv.
PGA_Inv_Stop()	Powers down the PGA_Inv.
PGA_Inv_SetGain()	Sets gain to predefined constants.
PGA_Inv_SetPower()	Sets drive power to one of four settings.
PGA_Inv_Sleep()	Stops and saves the user configurations.
PGA_Inv_Wakeup()	Restores and enables the user configurations.

Function	Description
PGA_Inv_Init()	Initializes or restores default PGA_Inv configuration.
PGA_Inv_Enable()	Enables the PGA_Inv.
PGA_Inv_SaveConfig()	Empty function. Provided for future use.
PGA_Inv_RestoreConfig()	Empty function. Provided for future use.

## Global Variables

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

## void PGA\_Inv\_Inv\_Start(void)

**Description:** Turns on the PGA\_Inv and sets the power level.

**Parameters:** None

**Return Value:** None

**Side Effects:** None

## void PGA\_Inv\_Stop(void)

**Description:** Turns off PGA\_Inv and enables its lowest power state.

**Parameters:** None

**Return Value:** None

**Side Effects:** None. Does not affect power or gain settings.

**void PGA\_Inv\_SetGain(uint8 gain)**

**Description:** Sets gain of amplifier between –1 and –49. The table below shows the valid gain settings.

**Parameters:** uint8 gain: Sets the gain to a specific value. See table below for valid gain settings.

Gain Setting	Notes
PGA_Inv_GAIN_01	Gain = –1
PGA_Inv_GAIN_03	Gain = –3
PGA_Inv_GAIN_07	Gain = –7
PGA_Inv_GAIN_15	Gain = –15
PGA_Inv_GAIN_22	Gain = –22
PGA_Inv_GAIN_24	Gain = –24
PGA_Inv_GAIN_31	Gain = –31
PGA_Inv_GAIN_47	Gain = –47
PGA_Inv_GAIN_49	Gain = –49

**Return Value:** None

**Side Effects:** None

**void PGA\_Inv\_SetPower(uint8 power)**

**Description:** Sets the drive power to one of four settings: minimum, low, medium, or high.

**Parameters:** uint8 power: Sets the power level to one of four settings: minimum, low, medium, or high.

Power Setting	Notes
PGA_Inv_MINPOWER	Minimum active power and slowest slew rate
PGA_Inv_LOWPOWER	Low power and slew rate
PGA_Inv_MEDPOWER	Medium power and slew rate
PGA_Inv_HIGHPOWER	Highest active power and fastest slew rate

**Return Value:** None

**Side Effects:** None

## void PGA\_Inv\_Sleep(void)

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

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

## void PGA\_Inv\_Init(void)

- Description:** Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call PGA\_Inv\_Init() because the PGA\_Inv\_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 PGA\_Inv\_Enable(void)

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

## void PGA\_Inv\_SaveConfig(void)

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

## void PGA\_Inv\_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\_Inv component does not have any specific deviations.

## 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

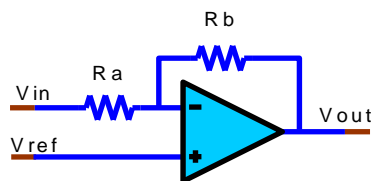
The PGA\_Inv is constructed from a generic SC/CT block. The gain is selected by adjusting two resistors; Ra and Rb (see [Figure 1](#)). Ra may be set to either 20k or 40k ohms, depending on





selected gain.  $R_b$  may be set between 20k and 1000k ohms, to generate the possible gain values selectable in either the **Configure** dialog or the `PGA_Inv_SetGain()` function.

**Figure 1. PGA\_Inv Schematic**



The block has a programmable capacitor in parallel with the feedback resistor,  $R_b$ . The capacitor value is configured for each gain selection to achieve guaranteed stability. Reassigning  $R_b$  values without also selecting the appropriate feedback capacitor value may result in PGA\_Inv instability. You are strongly advised to use the provided APIs for gain changes.

The input resistance of the PGA\_Inv is finite. The gain accuracy is dependent on the routing resistance between the source and the  $V_{in}$  input. The gain specifications accommodate the nominal variation in the routing resistance.

## Resources

The PGA\_Inv 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	206	22	304	5

## DC and AC Electrical Characteristics for PSoC 3

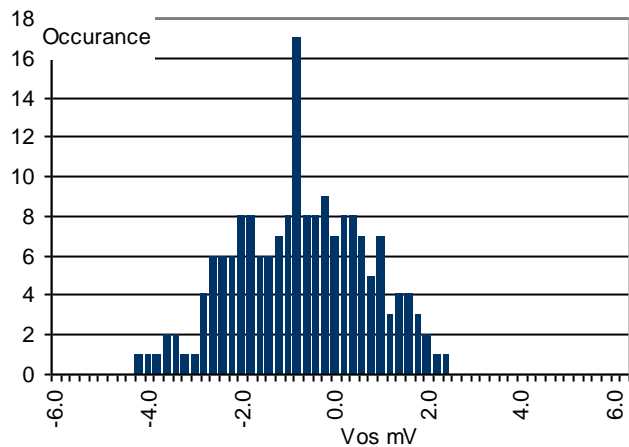
Specifications are valid for  $-40\text{ }^{\circ}\text{C} \leq T_A \leq 85\text{ }^{\circ}\text{C}$  and  $T_J \leq 100\text{ }^{\circ}\text{C}$ , except where noted. Specifications are valid for 1.71 V to 5.5 V, except where noted. Typical values are for  $T_A = 25\text{ }^{\circ}\text{C}$ .

### DC Characteristics

Parameter	Description	Conditions	Min	Typ	Max	Units
$V_{IN}$	Input voltage range	Power mode = minimum	$V_{SSA}$	–	$V_{DDA}$	V
$V_{OS}$	Input offset voltage	Power mode = high, gain = 1, $V_{DDA} = 5\text{ V}$	–	–	10	mV
$TCV_{OS}$	Input offset voltage drift with temperature	Power mode = high, gain = 1, $V_{DDA} = 5\text{ V}$	–	–	$\pm 30$	$\mu\text{V}/^{\circ}\text{C}$
$Ge_1$	Gain error, gain = 1	$V_{DDA} = 5\text{ V}$	–	–	$\pm 0.15$	%
$Ge_{15}$	Gain error, gain = 15	$V_{DDA} = 5\text{ V}$	–	–	$\pm 2.5$	%
$Ge_{49}$	Gain error, gain = 49	$V_{DDA} = 5\text{ V}$	–	–	$\pm 5$	%
$V_{ONL}$	DC output nonlinearity	Gain = 1	–	–	$\pm 0.01$	% of FSR
$R_{IN}$	Input resistance		35	–	–	$\text{M}\Omega$
$C_{IN}$	Input capacitance		–	–	7	pF
$V_{OH}, V_{OL}$	Output voltage swing	Power mode = high, gain = 1, $R_{LOAD} = 100\text{ k}\Omega$ to $V_{DDA}/2$	$V_{DDA} - 0.15$	–	$V_{SSA} + 0.15$	V
$V_{src}$	Output voltage under load	$I_{load} = 250\text{ }\mu\text{A}$ , $V_{dda} \geq 2.7\text{ V}$ , power mode = high	–	–	300	mV
$I_{DD}$	Operating current	Power mode = high	–	1.5	1.65	mA
PSRR	Power supply rejection ratio		48	–	–	dB

## Figures

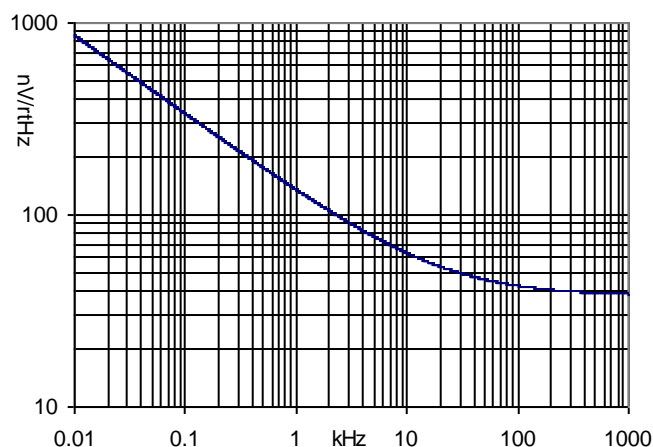
Histogram Input Offset Voltage



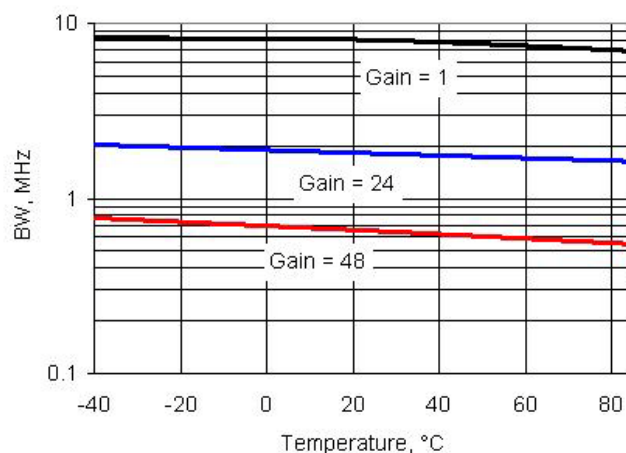
## AC Characteristics

Parameter	Description	Conditions	Min	Typ	Max	Units
BW1	–3 dB bandwidth	Power mode = high, gain = 1, input = 100mV peak-to-peak	6.7	8	–	MHz
SR1	Slew rate	Power mode = high, gain = 1, 20% to 80%	3	–	–	V/μs
e <sub>n</sub>	Input noise density	Power mode = high, V <sub>DDA</sub> = 5 V, at 100 kHz	–	43	–	nV/sqrtHz

## Figures

Voltage noise,  $V_{DDA} = 5.0V$ , Power = High

Bandwidth vs. Temperature, at Different Gain Settings, Power Mode = High



## DC and AC Electrical Characteristics for PSoC 5LP

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 2.7 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
$V_{IN}$	Input voltage range	Power mode = minimum	$V_{SSA}$	–	$V_{DDA}$	V
$V_{OS}$	Input offset voltage	Power mode = high, gain = 1, $V_{DDA} = 5\text{ V}$	–	–	20	mV
$TCV_{OS}$	Input offset voltage drift with temperature	Power mode = high, gain = 1, $V_{DDA} = 5\text{ V}$	–	–	$\pm 30$	$\mu\text{V}/^{\circ}\text{C}$
$Ge1$	Gain error, gain = 1	$V_{DDA} = 5\text{ V}$	–	$\pm 2.5$	$\pm 5.5$	%
$Ge15$	Gain error, gain = 15	$V_{DDA} = 5\text{ V}$	–	$\pm 8$	$\pm 11.5$	%
$Ge49$	Gain error, gain = 49	$V_{DDA} = 5\text{ V}$	–	$\pm 13$	$\pm 19.5$	%
$Gd1$	Gain drift, gain = 1		–	$\pm 95$	$\pm 200$	$\text{ppm}/^{\circ}\text{C}$
$Gd15$	Gain drift, gain = 15		–	$\pm 115$	$\pm 250$	$\text{ppm}/^{\circ}\text{C}$
$Gd49$	Gain drift, gain = 49		–	$\pm 350$	$\pm 850$	$\text{ppm}/^{\circ}\text{C}$
$V_{ONL}$	DC output nonlinearity	Gain = 1	–	–	$\pm 0.1$	% of FSR

Parameter	Description	Conditions	Min	Typ	Max	Units
V <sub>OH</sub> , 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>DDA</sub> – 0.15	–	V <sub>SSA</sub> + 0.15	V
C <sub>in</sub>	Input capacitance		-	-	7	pF
V <sub>src</sub>	Output voltage under load	I <sub>load</sub> = 250 μA, power mode = high	-	-	300	mV
I <sub>DD</sub>	Operating current	Power mode = high	–	1.5	1.65	mA
PSRR	Power supply rejection ratio		48	-	–	dB

## AC Characteristics

Parameter	Description	Conditions	Min	Typ	Max	Units
BW1	–3 dB bandwidth	Power mode = high, gain = 1, V <sub>DDA</sub> = 5 V	3.1	–	–	MHz
SR1	Slew rate	Power mode = high, gain = 1, 20% to 80%	3	–	–	V/μs
e <sub>n</sub>	Input noise density	Power mode = high, V <sub>DDA</sub> = 5 V, at 100 kHz	-	43	-	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
2.0.c	Minor datasheet edits.	
2.0.b	Minor datasheet edits.	
2.0.a	Edited datasheet to remove references to PSoC 5.	PSoC 5 has been replaced by the PSoC 5LP.
2.0	Added variable V <sub>dda</sub> support.	
	Added MISRA Compliance section.	The component does not have any specific deviations.
1.90	For low voltage V <sub>DDA</sub> 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.

Version	Description of Changes	Reason for Changes / Impact
	Added PSoC 5LP support	
1.80	Added all component APIs with the CYREENTRANT.	
	Minor GUI updates	
	PGA_Inv_Stop() API modified for PSoC 5	Change required to prevent the component from impacting unrelated analog signals when stopped, when using PSoC 5.
1.70	Updated PGA_Inv response graph	Change required to dynamically resize graph to fit window and to add horizontal and vertical grids.
	Added DC and AC electrical characteristics data for PSoC 5	
	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.
1.60	Configuration window created to include Frequency response graphs a better ease of use GUI.	Previous configuration window did not provide enough information for ease of use.
	SetGain constants corrected in the header file	The constants provided for the SetGain API had incorrect values. These have been corrected.
	Added characterization data to datasheet	
	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.
1.50	Removed Gain setting of 23.	The gain of 23 was too close to 22 and 24 and therefore offered no value.
	Updated the symbol and Configure dialog.	These were updated to comply with corporate standards.

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