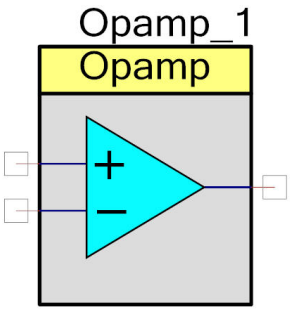
# PSoC 4 Operational Amplifier (Opamp)

1.10




## 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 to a 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 PSoC 4200 BLE devices the Comparator can operate in the 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*

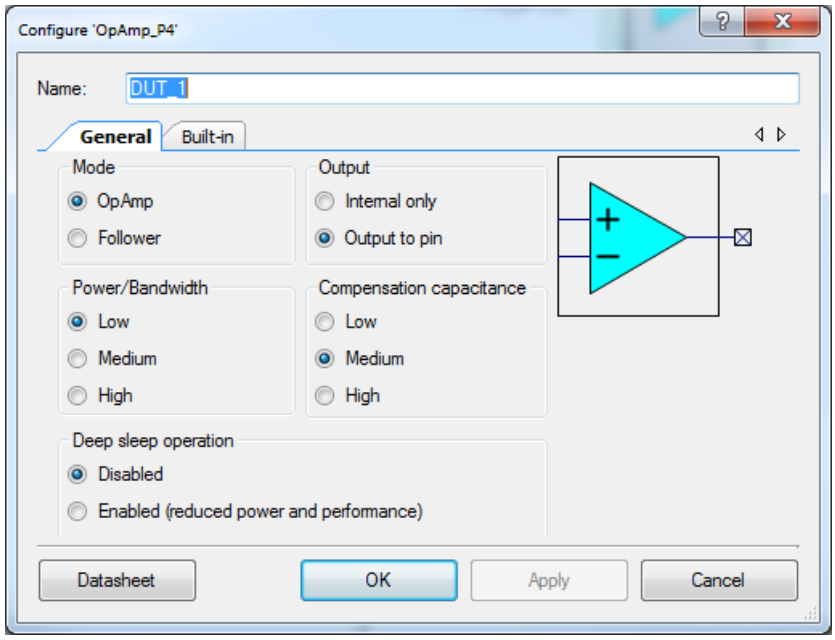
When the Opamp component is configured in Opamp Mode, this I/O is the normal inverting input. When the Opamp is configured in Follower Mode, this I/O is hard-connected to the output and the I/O is unavailable.

## 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

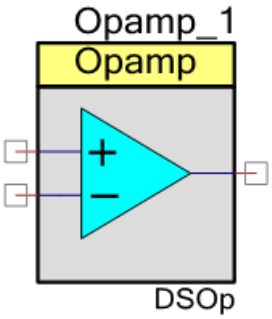
This parameter selects an output mode: Internal only – internal connections or Output to pin – connection to pin (external).

### 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 available for PSoC 4200 BLE devices only. It enables the component operation in Deep Sleep mode. If this option is enabled, a "DSOp" label will be displayed under the symbol.




**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 is 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 boost must be turned on when the supply is less than 2.7 volts and off if the supply is more than 4 volts.

**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. Call the Sleep() function before calling the CySysPmDeepSleep() or the CySysPmHibernate() functions. The "Deep sleep operation" option has an influence on this function implementation.

**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. The "Deep sleep operation" option has an influence on this function implementation.

**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 of the Compensation option

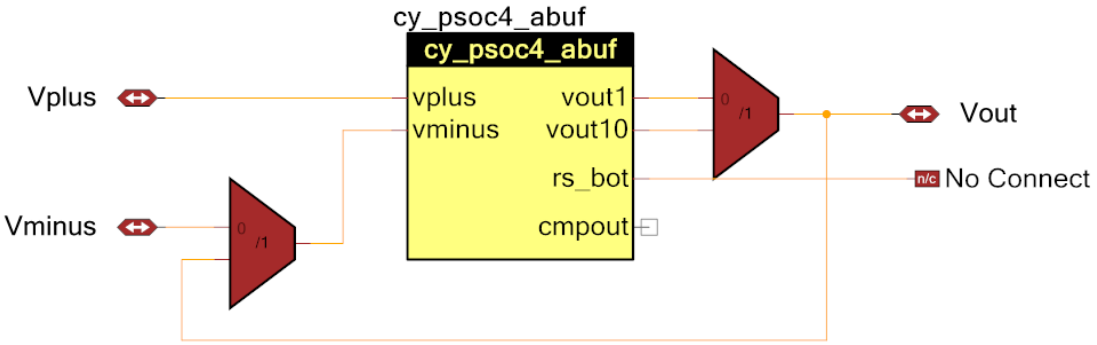
There are recommended settings for the Compensation option:

| 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.

## Block Diagram and Configuration

The component uses cy_psoc4_abuf primitive.




## 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.

## DC Specifications

| Parameter | Description | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{DD}$ | Opamp Block current. No load. | | – | – | – | – |
| $I_{DD\_HI}$ | Power = high | | – | 1000 | 1300 | µA |
| $I_{DD\_MED}$ | Power = medium | | – | 320 | 500 | µA |
| $I_{DD\_LOW}$ | Power = low | | – | 250 | 350 | µA |
| $I_{DD}$ | Opamp Block current. VDD = 1.8 V. No load. | For PSoC 4200 BLE family | – | – | – | – |
| $I_{DD\_HI}$ | Power = high | For PSoC 4200 BLE family | – | 1000 | 1300 | µA |
| $I_{DD\_MED}$ | Power = medium | For PSoC 4200 BLE family | – | 500 | – | µA |
| $I_{DD\_LOW}$ | Power = low | For PSoC 4200 BLE family | – | 250 | 350 | µA |
| $I_{DD\_HI}$ | Power = high | For PSoC 4100M/ PSoC 4200M | – | 1100 | 1850 | µA |

| Parameter | Description | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{DD\_MED}$ | Power = medium | For PSoC 4100M/ PSoC 4200M | – | 550 | 950 | µA |
| $I_{DD\_LOW}$ | Power = low | For PSoC 4100M/ PSoC 4200M | – | 150 | 350 | µA |
| $I_{OUT\_MAX}$ | $V_{DDA} \geq 2.7$ V, 500 mV from rail | | – | – | – | – |
| $I_{OUT\_MAX\_HI}$ | Power = high | | 10 | – | – | mA |
| $I_{OUT\_MAX\_MID}$ | Power = medium | | 10 | – | – | mA |
| $I_{OUT\_MAX\_LO}$ | Power = low | | – | 5 | – | mA |
| $I_{OUT}$ | $V_{DDA}$ = 1.71 V, 500 mV from rail | | – | – | – | – |
| $I_{OUT\_MAX\_HI}$ | Power = high | | 4 | – | – | mA |
| $I_{OUT\_MAX\_MID}$ | Power = medium | | 4 | – | – | mA |
| $I_{OUT\_MAX\_LO}$ | Power = low | | – | 2 | – | mA |
| $V_{IN}$ | Charge pump on, $V_{DDA} \geq 2.7$ V | | –0.05 | – | VDDA – 0.2 | V |
| $V_{CM}$ | Charge pump on, $V_{DDA} \geq 2.7$ V | | –0.05 | – | VDDA – 0.2 | V |
| $V_{OUT}$ | $V_{DDA} \geq 2.7$ V | | – | – | – | |
| $V_{OUT\_1}$ | Power = high, $I_{LOAD}$=10 mA | | 0.5 | – | VDDA – 0.5 | V |
| $V_{OUT\_2}$ | Power = high, $I_{LOAD}$=1 mA | | 0.2 | – | VDDA – 0.2 | V |
| $V_{OUT\_3}$ | Power = medium, $I_{LOAD}$=1 mA | | 0.2 | – | VDDA – 0.2 | V |
| $V_{OUT\_4}$ | Power = low, $I_{LOAD}$=0.1mA | | 0.2 | – | VDDA – 0.2 | V |
| $V_{OS}$ | Offset voltage | High mode | 1 | ±0.5 | 1 | mV |
| $V_{OS}$ | Offset voltage | Medium mode | – | ±1 | – | mV |
| $V_{OS}$ | Offset voltage | Low mode | – | ±2 | – | mV |
| $V_{OS\_DR}$ | Offset voltage drift | High mode | –10 | ±3 | 10 | µV/C |
| $V_{OS\_DR}$ | Offset voltage drift | Medium mode | – | ±10 | – | µV/C |
| $V_{OS\_DR}$ | Offset voltage drift | Low mode | – | ±10 | – | µV/C |
| CMRR | DC | VDDD = 3.6 V | 70 | 80 | – | dB |
| CMRR | DC | For PSoC 4200 BLE family<br>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<br>VDDD = 3.6 V | 60 | 70 | – | dB |
| PSRR | At 1 kHz, 100 mV ripple | VDDD = 3.6 V | 70 | 85 | – | dB |

## AC Specifications

| Parameter | Description | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| GBW | Load = 20 pF, 0.1 mA. $V_{DDA}$ = 2.7 V | | – | – | – | – |
| GBW_HI | Power = high | | 6 | – | – | MHz |
| GBW_MED | Power = medium | | 4 | – | – | MHz |
| GBW_LO | Power = low | | 2 | – | – | MHz |
| GBW_LO | Power = low | For PSoC 4200 BLE family, PSoC 4100M/PSoC 4200M | – | 1 | – | MHz |
| Noise | | | – | – | – | – |
| $V_{N1}$ | Input referred, 1 Hz - 1GHz, power = high | | – | 94 | – | µVrms |
| $V_{N2}$ | Input referred, 1 kHz, power = high | | – | 72 | – | nV/rtHz |
| $V_{N3}$ | Input referred, 10kHz, power = high | | – | 28 | – | nV/rtHz |
| $V_{N4}$ | Input referred, 100kHz, power = high | | – | 15 | – | nV/rtHz |
| $C_{LOAD}$ | Stable up to maximum load. Performance specs at 50 pF. | | – | – | 125 | pF |
| Slew_rate | Cload = 50 pF, Power = High, $V_{DDA} \geq 2.7$ 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 | – | 25 | – | µSec |
| Deep-Sleep Mode (For PSoC 4200 BLE family; only guaranteed for VDDA > 2.5 V) | | | | | | |
| GBW_DS | Gain bandwidth product | | – | 50 | – | kHz |
| IDD_DS | Current | | – | 15 | – | µA |
| 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; only guaranteed for VDDA ≥ 2.7 V)<br>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 | |

| Parameter | Description | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| IDD_MED_M2 | Mode 2, Medium current | 25 °C | - | 60 | uA | |
| IDD_LOW_M2 | Mode 2, Low current | 25 °C | - | 15 | uA | |
| 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 | |
| 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_M2 | 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_M! | 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 | |
| IOU_MED_M2 | Mode 2, Medium current | Output is 0.5 V to VDDA-0.5 V | - | 1 | mV | |
| IOU_LOW_M2 | Mode 2, Low current | Output is 0.5 V to VDDA-0.5 V | - | 0.5 | mV | |

# Component Changes

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

| Version | Description of Changes | Reason for Changes / Impact |
|---|---|---|
| 1.10.c | Edited the datasheet. | Updated Offset voltage and Offset voltage drift parameter names into DC Specifications table.<br>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 | |