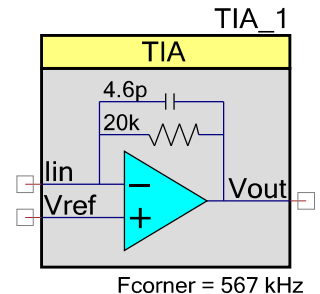


Trans-Impedance Amplifier (TIA)

1.70

Features

- Selectable conversion gain
- Selectable corner frequency
- Compensation for capacitive input sources
- Adjustable power settings
- Selectable input reference voltage



General Description

The Trans-Impedance Amplifier (TIA) component provides an opamp-based current to voltage conversion amplifier with resistive gain and user-selected bandwidth. It is derived from the SC/CT block.

The TIA is used to convert an external current to a voltage. Typical applications include the measurement of sensors with current outputs such as photodiodes. The conversion gain of the TIA is expressed in ohms, with the available range between 20 kΩ and 1.0 MΩ. Current output sensors, such as photodiodes, often have substantial output capacitance. This requires shunt feedback capacitance in the TIA in order to guarantee stability. The TIA has a programmable feedback capacitor to meet this need and provide bandwidth limiting to reduce broadband noise.

Input/Output Connections

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

lin – Analog

The lin is the input signal terminal. It is the sum of currents from the global inputs, which may include signals from a current output DAC.

Note This terminal name is `Iin` (uppercase i) **not** `lin` (lowercase l).

Vref – Analog

Vref is the input terminal for a reference signal. The reference may be an internal reference, internal VDAC value, or external signal.

Vout – Analog

Vout is the output signal terminal. Vout is determined by the following equation, where R_{FB} is resistive feedback:

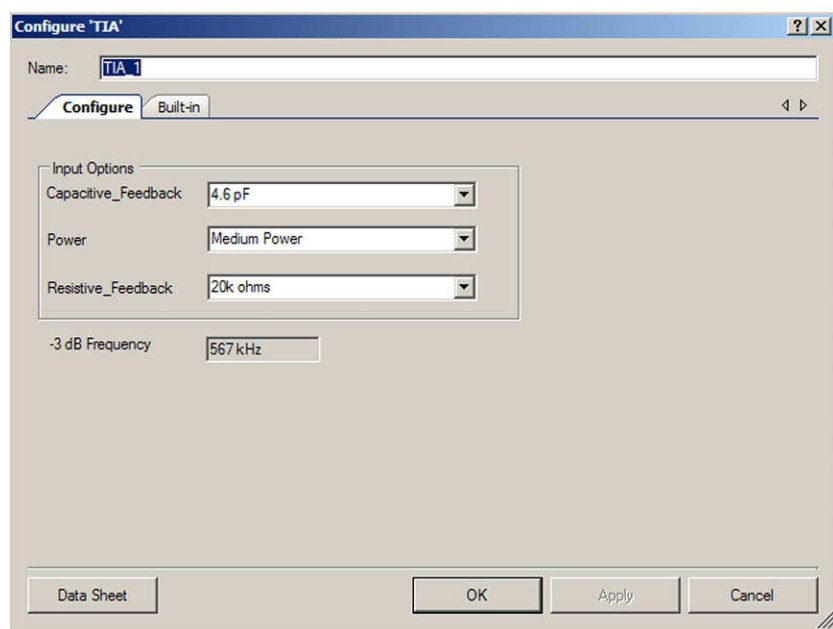
$$V_{out} = V_{ref} - I_{in} \times R_{fb}$$

Positive (from source) currents result in output voltage that is negative with respect to Vref.

Negative (into source) currents result in output voltage that is positive with respect to Vref.

Component Parameters

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



Capacitive_Feedback

This sets the capacitive feedback for the TIA. The capacitive feedback can be set to **None**, **1.3 pF**, **3.3 pF**, or **4.6 pF** (default). The –3 dB frequency for the TIA is calculated from the product of the values of resistive and capacitive feedback components.

Power

This sets the initial drive power of the TIA. The power determines the speed with which the TIA reacts to changes in the input signal. There are four power settings; **Minimum Power**, **Low**



Power, Medium Power (default), and **High Power**. The **Minimum Power** setting results in the slowest response time and **High Power** the fastest. **Minimum** and **Low Power** settings have reduced drive currents and are not suitable for the lower values of feedback resistor.

Resistive_Feedback

This sets the nominal resistive feedback for the TIA. The resistive feedback may be selected from the following set of allowed values (in ohms): 20k (default), 30k, 40k, 80k, 120k, 250k, 500k, and 1000k.

-3 db Frequency

This combobox is used to display the calculated value of bandwidth. This value depends on **Resistor_Feedback**, **Capacitive_Feedback** values and **Power** settings.

Placement

There are no placement specific options.

Resources

The TIA uses one SC/CT block. Typically, the Vref input is routed from a voltage reference, a VDAC output, or an externally supplied reference on a GPIO.

| Analog Blocks | Digital Blocks | | | | | API Memory (Bytes) | | Pins (per External I/O) |
|------------------------|----------------|-------------|------------------|-------------------|----------|--------------------|-----|-------------------------|
| | Datapaths | Macro cells | Status Registers | Control Registers | Counter7 | Flash | RAM | |
| 1 SC/CT Fixed HW block | N/A | N/A | N/A | N/A | N/A | 352 | 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 “TIA_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 “TIA.”



| Function | Description |
|---------------------|---|
| TIA_Start() | Powers up the TIA. |
| TIA_Stop() | Powers down the TIA. |
| TIA_SetPower() | Sets drive power to one of four levels. |
| TIA_SetResFB() | Sets the resistive feedback to one of eight values. |
| TIA_SetCapFB() | Sets the capacitive feedback to one of four values. |
| TIA_Sleep() | Stops and saves the user configurations. |
| TIA_Wakeup() | Restores and enables the user configurations. |
| TIA_Init() | Initializes or restores default TIA configuration. |
| TIA_Enable() | Enables the TIA. |
| TIA_SaveConfig() | Empty function. Provided for future use. |
| TIA_RestoreConfig() | Empty function. Provided for future use. |

Global Variables

| Variable | Description |
|-------------|---|
| TIA_initVar | Indicates whether the TIA has been initialized. The variable is initialized to 0 and set to 1 the first time TIA_Start() is called. This allows the component to restart without reinitialization after the first call to the TIA_Start() routine. If reinitialization of the component is required, then the TIA_Init() function can be called before the TIA_Start() or TIA_Enable() function. |

void TIA_Start(void)

Description: Performs all of the required initialization for the component and enables power to the amplifier. The first time the routine is executed, the resistive and capacitive feedback and amplifier power are set based on the values provided during configuration. When called to restart the TIA following a TIA_Stop() call, the current component parameter settings are retained.

Parameters: None

Return Value: None

Side Effects: None



void TIA_Stop(void)

Description: Powers down TIA to its lowest power state and disables output.

Note This API is not recommended for use on PSoC 3 ES2 and PSoC 5 silicon. These devices have a defect that causes connections to several analog resources to be unreliable when not powered. The unreliability manifests itself in silent failures (for example, unpredictably bad results from analog components) when the component using that resource is stopped. When using this silicon, all analog components in a design should be powered up (by calling their respective _Start() APIs, for instance TIA_Start()) at all times. Do not call the TIA_Stop() APIs.

Parameters: None

Return Value: None

Side Effects: Does not affect power, resistive or capacitive feedback settings

void TIA_SetPower(uint8 power)

Description: 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 |
|---------------|--|
| TIA_MINPOWER | Minimum active power and slowest reaction time |
| TIA_LOWPOWER | Low power and speed |
| TIA_MEDPOWER | Medium power and speed |
| TIA_HIGHPower | Highest active power and fastest reaction time |

Return Value: None

Side Effects: None

(void) TIA_SetResFB(uint8 res_feedback)

Description: Set the amplifier resistive feedback value.

Parameters: uint8 res_feedback: See the following table for valid resistive feedback settings.

| Gain Setting | Notes |
|------------------------|---------------------------|
| TIA_RES_FEEDBACK_20K | Feedback resistor = 20k |
| TIA_RES_FEEDBACK_30K | Feedback resistor = 30k |
| TIA_RES_FEEDBACK_40K | Feedback resistor = 40k |
| TIA_RES_FEEDBACK_80K | Feedback resistor = 80k |
| TIA_RES_FEEDBACK_120K | Feedback resistor = 120k |
| TIA_RES_FEEDBACK_250K | Feedback resistor = 250k |
| TIA_RES_FEEDBACK_500K | Feedback resistor = 500k |
| TIA_RES_FEEDBACK_1000K | Feedback resistor = 1000k |

Return Value: None

Side Effects: None

(void) TIA_SetCapFB(uint8 cap_feedback)

Description: Set the amplifier capacitive feedback value.

Parameters: uint8 cap_feedback: See the following table for valid capacitive feedback settings.

| Gain Setting | Notes |
|------------------------|-----------------------------|
| TIA_CAP_FEEDBACK_NONE | No capacitive feedback |
| TIA_CAP_FEEDBACK_1_3PF | Feedback capacitor = 1.3 pF |
| TIA_CAP_FEEDBACK_3_3PF | Feedback capacitor = 3.3 pF |
| TIA_CAP_FEEDBACK_4_6PF | Feedback capacitor = 4.6 pF |

Return Value: None

Side Effects: None

void TIA_Sleep(void)

Description: This is the preferred API to prepare the component for sleep. The TIA_Sleep() function saves the current component state. Then it calls the TIA_Stop() function and calls TIA_SaveConfig() to save the hardware configuration.

Call the TIA_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 TIA_Wakeup(void)

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

Parameters: None

Return Value: None

Side Effects: Calling the TIA_Wakeup() function without first calling the TIA_Sleep() or TIA_SaveConfig() function may produce unexpected behavior.

void TIA_Init(void)

Description: Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call TIA_Init() because the TIA_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 TIA_Enable(void)

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

Parameters: None

Return Value: None

Side Effects: None



void TIA_SaveConfig(void)

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

void TIA_RestoreConfig(void)

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

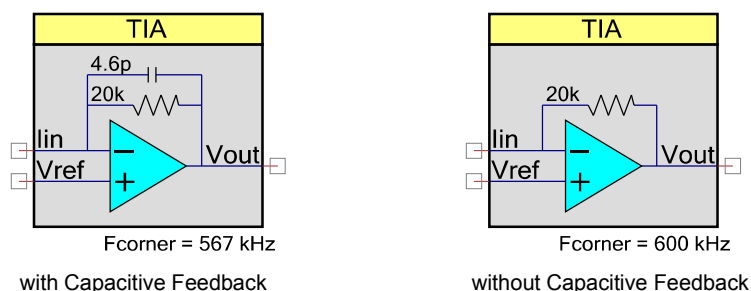
Sample Firmware Source Code

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.

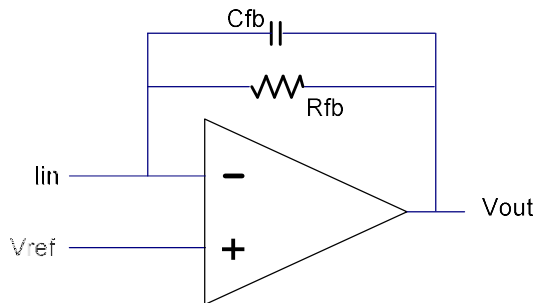
Functional Description

The TIA is constructed from a generic SC/CT block. The topology is an opamp with a selectable feedback resistor from the output to the inverting input. Optionally, a selectable feedback capacitor can also be connected between the output and the inverting input. [Figure 1](#) shows the two possible TIA configurations.

Figure 1. TIA Configurations

The output voltage is controlled by adjusting the Rfb feedback resistor (see [Figure 2](#)). Rfb can be set to one of 8 values, between 20k and 1000k ohms, selectable in either the parameter dialog or using the TIA_SetResFB() API function.

Figure 2. TIA Schematic



The DC output level can be adjusted by adding current to the lin terminal. Positive current (into the terminal) pushes the output negative; negative current (pulling current from the terminal) pushes the output positive. The source of the current can be an internal DAC.

The amplifier bandwidth is determined by the interaction between the feedback resistor Rfb and the selection of the capacitor in parallel with Rfb. The capacitive feedback value Cfb can be set to one of four values in either the parameter dialog or by using the TIA_SetCapFB() API function.

The –3 dB frequency for the amplifier is:

$$\text{Freq} - 3 \text{ dB} = 1/(2\pi R_{fb} C_{fb})$$

DC and AC Electrical Characteristics

The following values indicate expected performance and are based on initial characterization data. Unless otherwise specified in the tables below, all $T_A = 25^\circ\text{C}$, $V_{DDA} = 5.0 \text{ V}$, High Power, Opamp bias low, output referenced to 1.024 V.

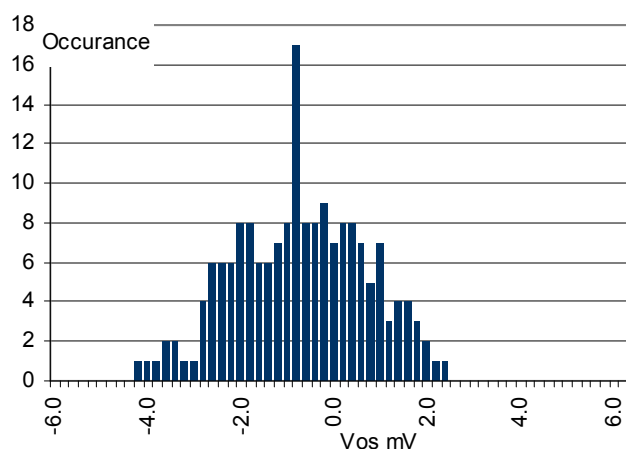
Note The characteristic data tables will be updated following silicon characterization.

TIA DC Specifications

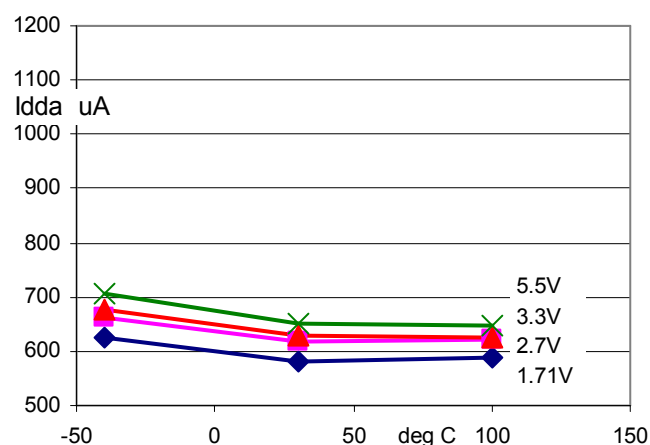
| Parameter | Description | Conditions | Min | Typ | Max | Units |
|------------|-----------------------|----------------------|------|-----|------|------------|
| V_{IOFF} | Input offset voltage | | – | 3.5 | 10 | mV |
| Rconv | Conversion resistance | R = 20k; 40-pF load | 15 | – | 27 | k Ω |
| | | R = 30k; 40-pF load | 22.5 | – | 40.5 | k Ω |
| | | R = 40k; 40-pF load | 30 | – | 54 | k Ω |
| | | R = 80k; 40-pF load | 60 | – | 108 | k Ω |
| | | R = 120k; 40-pF load | 90 | – | 162 | k Ω |
| | | R = 250k; 40-pF load | 187 | – | 338 | k Ω |
| | | R = 500k; 40-pF load | 375 | – | 675 | k Ω |
| | | R = 1M; 40 pF load | 750 | – | 1350 | k Ω |
| | Quiescent current | | – | 0.9 | 2.0 | mA |

Figures

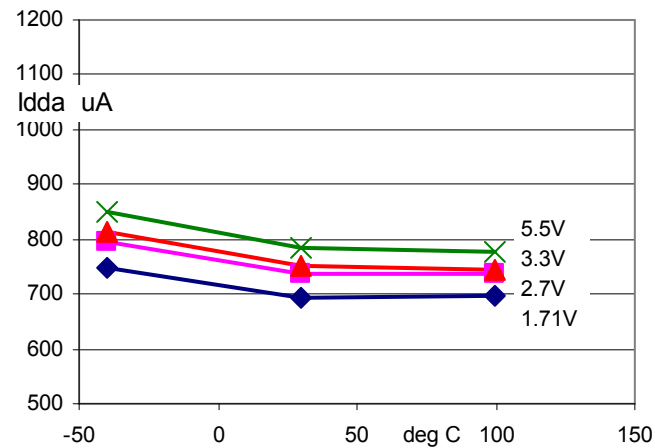
Histogram offset



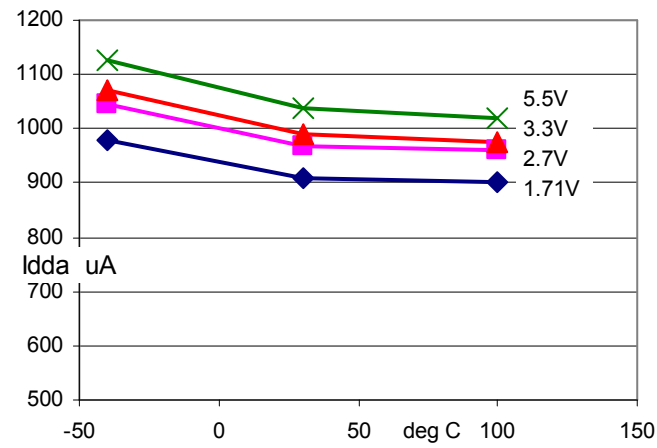
Typical Operating Current versus Temp, Power = Minimum



Typical Operating Current versus Temp, Power = Low



Typical Operating Current versus Temp, Power = High

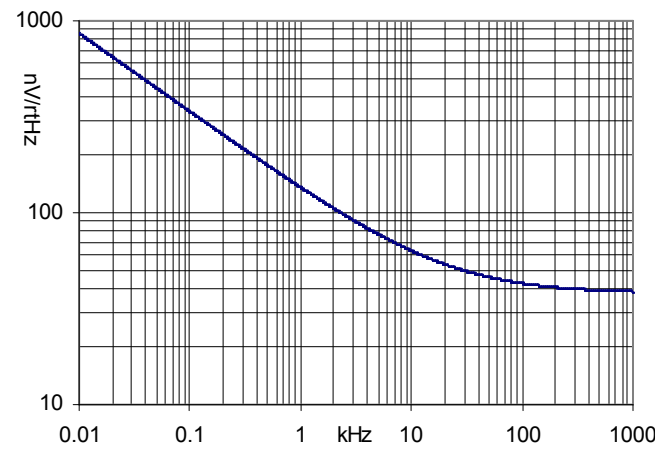


TIA AC Specifications

| Parameter | Description | Conditions | Min | Typ | Max | Units |
|-----------|-------------------------|-----------------------|------|-----|-----|-------|
| BW | Input bandwidth (−3 dB) | R = 20k; −20-pF load | 1600 | – | – | kHz |
| | | R = 120k; −20-pF load | 240 | – | – | kHz |
| | | R = 1M; −20-pF load | 25 | – | – | kHz |
| | | R = 20k; −40-pF load | 1500 | – | – | kHz |
| | | R = 120k; −40-pF load | 240 | – | – | kHz |
| | | R = 1M; −40-pF load | 25 | – | – | kHz |

Figures

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



Note More specifications at other voltages and graphs will 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 |
|---------|---|---|
| 1.70 | TIA_Stop() API modified for PSoC 5 | Changes required to prevent the component from impacting unrelated analog signals when stopped on PSoC 5 |
| | Added Debug window support | |
| | Added backward compatibility for register defines | To provide backward compatibility for TIA_1_10. |
| 1.60 | Updated the Configure dialog. | Created a customized interface. Added calculated bandwidth to customizer to support Bandwidth display. |
| | Removed Min-vdda parameter | Parameter for min Vdda is not required. Component will auto-recognize the voltage setting and set the block-internal switch pump accordingly. |
| | Updated TIA component symbol | TIA component symbol is updated to reflect Resistive Feedback, Capacitive Feedback, Fcorner value. |
| | Added characterization data to the 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. |
| | TIA parameter Pull-down values are reordered in the ascending order. | The TIA parameter pull-down values are not in ascending order. The 80k ohm comes after 1000k ohm. Reordered the values accordingly. |
| | Changed the minus symbol to be the same length as horizontal stroke in the '+' character. | Updated the minus symbol to meet the industry standard. |
| | Updated a conditional statement to properly enable the charge pump clock for PSoC 3 Production silicon and PSoC 5 ES2 silicon or later. | The charge pump clock was not being enabled properly and therefore SC blocks were not working. |

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