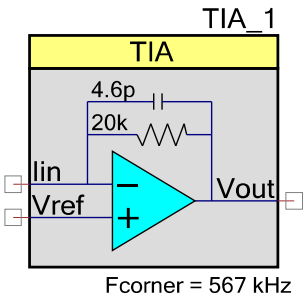
Trans-Impedance Amplifier (TIA)
1.60

Features



- Selectable conversion gain
- Selectable corner frequency
- Compensated 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 photo-diodes. The conversion gain of the TIA is expressed in ohms, with the available range between 20 K and 1.0 Megohms. Current output sensors, such as photo-diodes 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.

Iin – Analog

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

Note This terminal name is `Iin` (capital `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 Rfb is resistive feedback:

$$Vout = Vref - Iin * Rfb$$ **Equation 1**

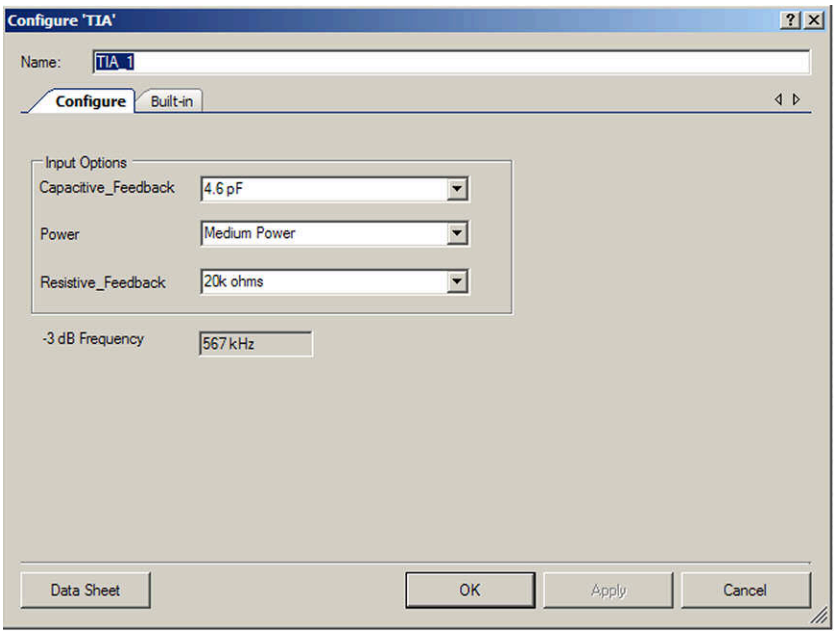
Positive (from source) currents result in output voltage, which is negative with respect to Vref.

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

Parameters and Setup

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

Figure 1. Configure TIA 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, Low, Medium (default), and High. 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 upon Resistor Feedback, Capacitive Feedback value and Power setting.

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.

	Digital Blocks					API Memory (Bytes)		
Analog Blocks	Datapaths	Macro cells	Status Registers	Control Registers	Counter7	Flash	RAM	Pins (per External I/O)
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
void TIA_Start(void)	Powers up the TIA.
void TIA_Stop(void)	Powers down the TIA.
void TIA_SetPower(uint8 power)	Setsdrive power to one of four levels.
void TIA_SetResFB(uint8 res_feedback)	Sets the resistive feedback to one of 8 values.
void TIA_SetCapFB(uint8 cap_feedback)	Sets the capacitive feedback to one of 4 values.
void TIA_Sleep(void)	Stops and saves the user configurations.
void TIA_Wakeup(void)	Restores and enables the user configurations.
void TIA_Init(void)	Initializes or restores default TIA configuration.
void TIA_Enable(void)	Enables the TIA.
void TIA_SaveConfig(void)	Empty function. Provided for future usage.
void TIA_RestoreConfig(void)	Empty function. Provided for future usage.

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 the 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: Turns off the TIA block.

Note This API is not recommended for use on PSoC 3 ES2 and PSoC 5 ES1 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 (e.g. unpredictably bad results from analog components) when the component utilizing that resource is stopped. It is recommended that this component should be powered up (by calling the TIA_Start() routine) at all times. Do not call the TIA_Stop() function.

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 table below 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 table below 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 usage.

Parameters: None

Return Value: None

Side Effects: None

void TIA_RestoreConfig(void)

Description: Empty function. Provided for future usage.

Parameters: None

Return Value: None

Side Effects: None

Sample Firmware Source Code

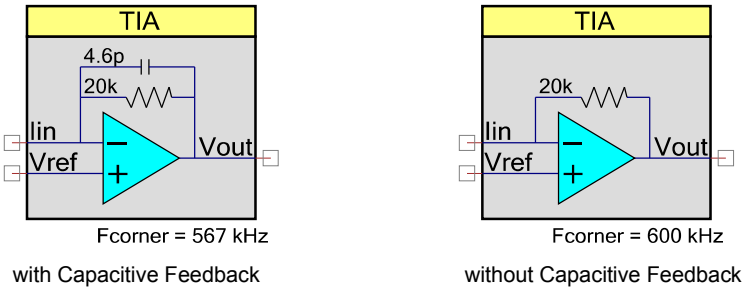
PSoC Creator provides numerous example projects that include schematics and example code in the Find Example Project dialog. For component-specific examples, open the dialog from the Component Catalog or an instance of the component in a schematic. For general examples, open the dialog from the Start 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

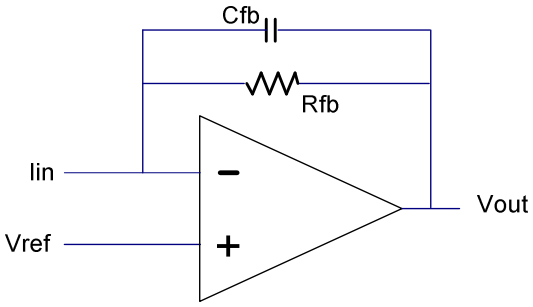
The TIA is constructed from a generic SC/CT block. The topology is an opamp with a selectable feedback resistor from the output to the inverting input. Optionally, a selectable feedback capacitor can also be connected between the output and the inverting input. See the following for TIA configurations.

Figure 2: TIA Configurations



The output voltage is controlled by adjusting the Rfb feedback resistor. (See the following figure.) Rfb may be set to one of 8 values, between 20k and 1000k ohms, selectable in either the parameter dialog or the using the TIA_SetResFB() API function.

Figure 3: TIA Schematic



The DC output level can be adjusted by adding current to the Iin 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 may 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:

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

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°C, V_{dda} = 5.0V, Power HIGH, Op-Amp bias LOW, output referenced to 1.024V.

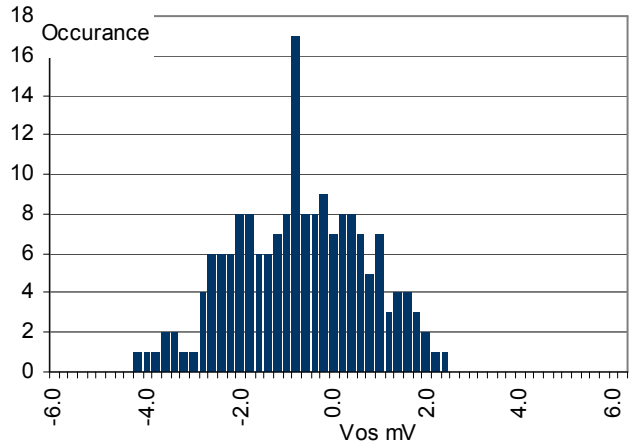
Note Characteristic data table will be updated following silicon characterization.

TIA DC Specifications

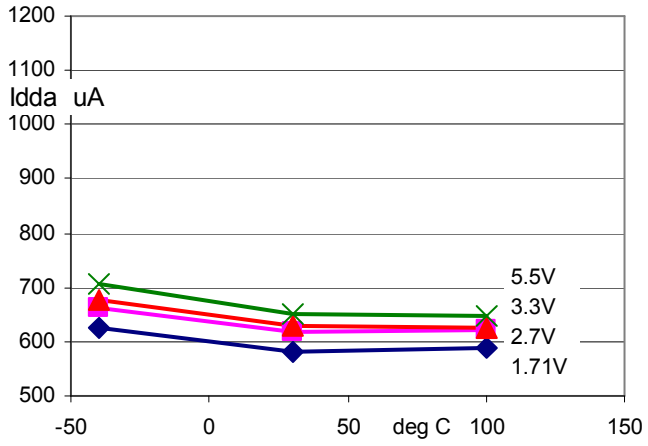
Parameter	Description	Conditions	Min	Typ	Max	Units
V_{IOFF}	Input offset voltage		–	3.5	10	mV
Rconv	Conversion resistance	R = 20K; 40 pF load	15	–	27	kΩ
		R = 30K; 40 pF load	22.5	–	40.5	kΩ
		R = 40K; 40 pF load	30	–	54	kΩ
		R = 80K; 40 pF load	60	–	108	kΩ
		R = 120K; 40 pF load	90	–	162	kΩ
		R = 250K;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

Figures

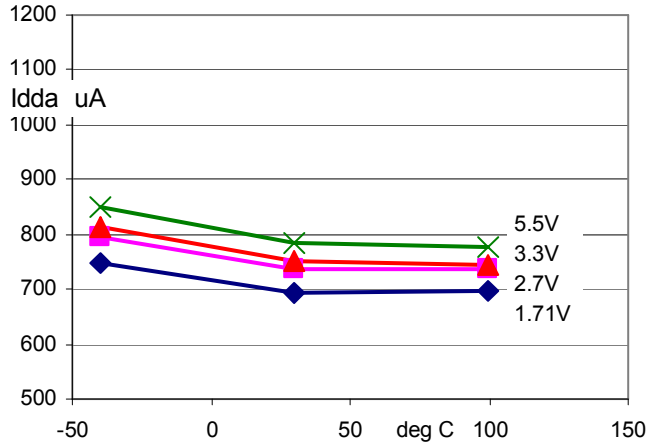
Histogram offset



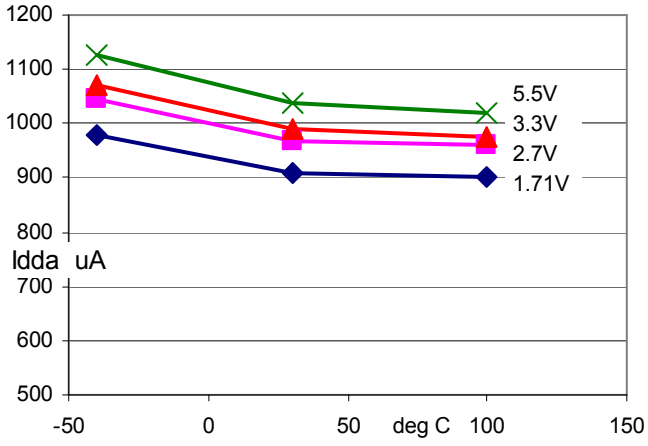
Typical Operating Current vs Temp, Power = Minimum



Typical Operating Current vs Temp, Power = Low



Typical Operating Current vs Temp, Power = High

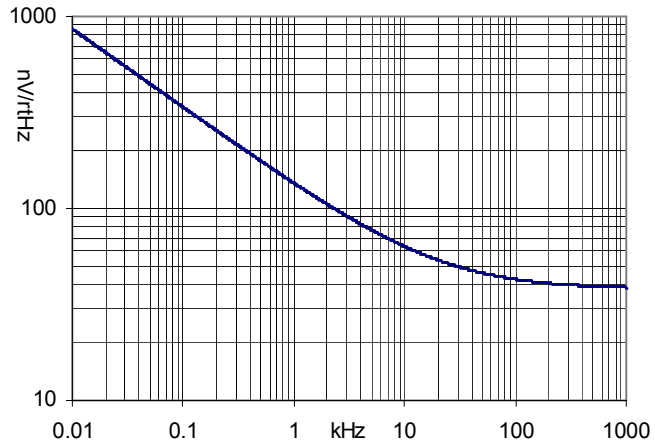


TIA AC Specifications

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, Vdda = 5.0V, 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
1.60	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 shall auto-recognize voltage setting and set 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 80kOhm 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 ES3 silicon and PSoC 5 ES2 silicon or later.	The charge pump clock was not being enabled properly and therefore SC blocks were not working.