

Analog Engineer's Circuit

Transimpedance Amplifier Circuit with MSP430™ Smart Analog Combo



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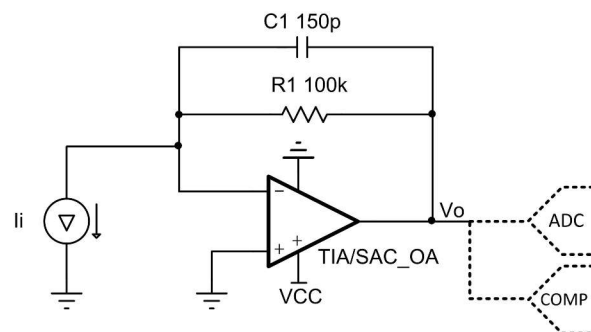
Design Goals

Input		Output		BW	Supply	
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	f_p	V_{cc}	V_{ee}
0 A	30 μ A	0.2V	3.2V	10 kHz	3.3V	0V

Design Description

Some MSP430™ microcontrollers (MCUs) contain configurable integrated signal chain elements such as op-amps, DACs, and programmable gain stages. These elements make up a peripheral called the smart analog combo (SAC). For information on the different types of SACs and how to leverage their configurable analog signal chain capabilities, see the [MSP430 MCUs Smart Analog Combo](#) video. To get started with your design, download the [MSP430 Transimpedance Amplifier Circuit Design Files](#).

The transimpedance op amp circuit configuration converts an input current source into an output voltage. The current to voltage gain is based on the feedback resistance. The circuit can maintain a constant voltage bias across the input source as the input current changes, which benefits many sensors. The characteristics of the Transimpedance Amplifier (TIA) module in [MSP430FR2311](#) make it especially suited for this functionality; however, this circuit can also be implemented with the [MSP430FR2311](#), or with the [MSP430FR2355](#) with additional built-in DAC and PGA capabilities. The output of these integrated amplifiers can be sampled directly by the on-board ADC or monitored by the on-board comparator for further processing inside the MCU.



Design Notes

- An op amp with low input bias current reduces DC errors.
- A bias voltage can be added to the non-inverting input to set the output voltage for 0-A input currents. The integrated 12-bit DAC in MSP430FR2355 SAC_L3 can be used for this purpose.
- Operate within the linear output voltage swing (see A_{oI} specification) to minimize non-linearity errors.
- If the fix is implemented with the MSP430FR2311, this circuit can be realized by the TransImpedance Amplifier (TIA) module, or by the SAC_L1.
- If the fix is implemented with the MSP430FR2355 SAC_L3, the op-amp should be configured in general-purpose mode.

- The [MSP430 Transimpedance Amplifier Circuit Design Files](#) include code examples showing how to properly initialize the peripherals.

Design Steps

- Select the gain resistor.

$$R_1 = \frac{V_{oMax} - V_{oMin}}{I_{iMax}} = \frac{3.2V - 0.2V}{30\mu A} = 100k\Omega$$

- Select the feedback capacitor to meet the circuit bandwidth.

$$C_1 \leq \frac{1}{2 \times \pi \times R_1 \times f_p}$$

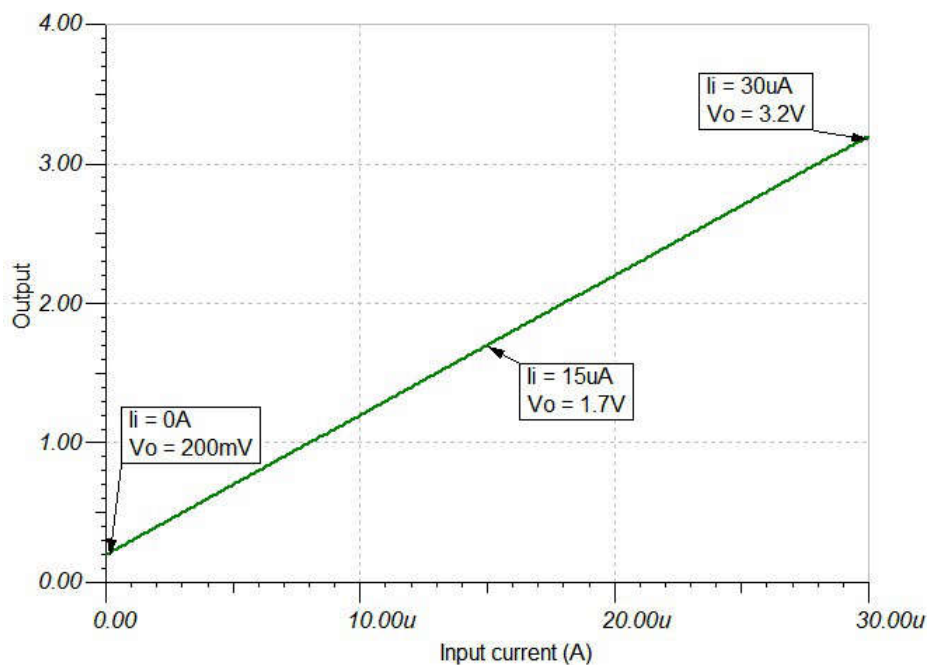
$$C_1 \leq \frac{1}{2 \times \pi \times 100k\Omega \times 10kHz} \leq 159pF \approx 150pF \text{ (Standard Value)}$$

- Calculate the necessary op amp gain bandwidth (GBW) for the circuit to be stable.

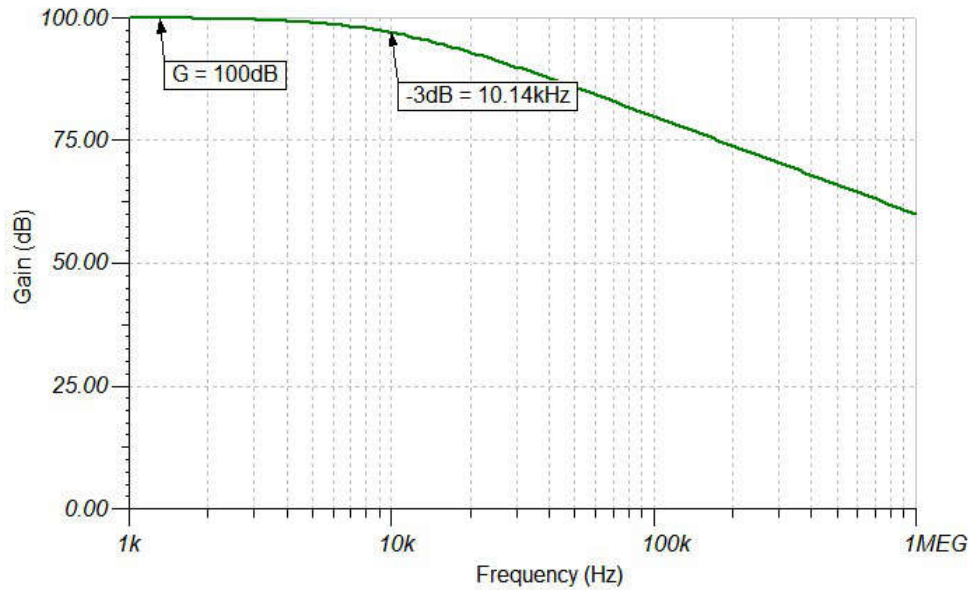
$$GBW > \frac{C_{in} + C_1}{2 \times \pi \times R_1 \times C_1^2} > \frac{7pF + 150pF}{2 \times \pi \times 100k\Omega \times (150pF)^2} > 11.10kHz$$

Design Simulations

DC Simulation Results



AC Simulation Results



Target Applications

- [Smoke and Heat Detectors](#)
- [Gas Detectors](#)
- [Motion Detectors](#)
- [Pulse Oximeters](#)
- [Blood Glucose Monitors](#)

Design References

1. Texas Instruments, [MSP430 Transimpedance Amplifier](#), code examples and SPICE simulation files
2. Texas Instruments, [MSP430FR2311 16MHz integrated analog microcontroller with 3.75KB FRAM, Op Amp, TIA, comparator with DAC, 10-bit ADC](#), product page
3. Texas Instruments, [MSP430 MCUs Smart Analog Combo](#), video



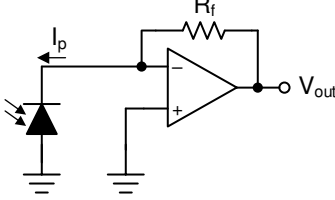
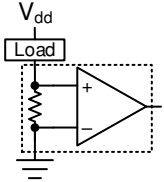
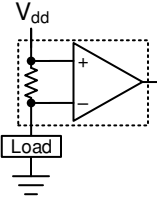
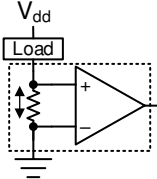

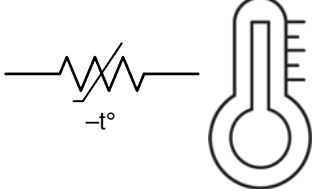
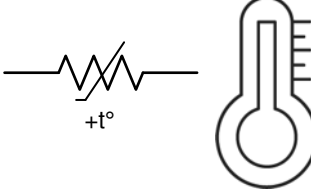
Design Featured Op Amp

MSP430FR2311 Transimpedance Amplifier	
V_{CC}	2.0V to 3.6V
V_{CM}	-0.1V to $V_{CC}/2V$
V_{out}	Rail-to-rail
V_{os}	$\pm 5mV$
A_{OL}	100dB
I_q	350 μA (high-speed mode)
	120 μA (low-power mode)
I_b	5pA (TSSOP-16 with OA-dedicated pin input)
	50pA (TSSOP-20 and VQFN-16)
UGBW	5MHz (high-speed mode)
	1.8MHz (low-power mode)
SR	4V/ μs (high-speed mode)
	1V/ μs (low-power mode)
Number of channels	1
	MSP430FR2311

Design Alternate Op Amp

MSP430FRxx Smart Analog Combo		
	MSP430FR2311 SAC_L1	MSP430FR2355 SAC_L3
V_{CC}	2.0V to 3.6V	
V_{CM}	-0.1V to $V_{CC} + 0.1V$	
V_{out}	Rail-to-rail	
V_{os}	$\pm 5mV$	
AOL	100dB	
I_q	350 μA (high-speed mode)	
	120 μA (low-power mode)	
I_b	50pA	
UGBW	4MHz (high-speed mode)	2.8MHz (high-speed mode)
	1.4MHz (low-power mode)	1MHz (low-power mode)
SR	3V/ μs (high-speed mode)	
	1V/ μs (low-power mode)	
Number of channels	1	4
	MSP430FR2311	MSP430FR2355

Related MSP430 Circuits

<p>Low-noise and long-range PIR sensor conditioner circuit</p> 	<p>Bridge amplifier circuit</p> 	<p>Transimpedance amplifier circuit</p> 
<p>Single-supply, low-side, unidirectional current-sensing circuit</p> 	<p>High-side current sensing with discrete difference amplifier circuit</p> 	<p>Low-side, bidirectional current-sensing circuit</p> 
<p>Half-wave rectifier circuit</p> 	<p>Temperature sensing with NTC thermistor circuit</p> 	<p>Temperature sensing with PTC thermistor circuit</p> 

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (March 2020) to Revision B (October 2024) Page

- Updated the format for tables, figures, and cross-references throughout the document 1
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Changes from Revision * (December 2019) to Revision A (March 2020) Page

- Added *Related MSP430 Circuits* section.....1
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