

MSP430F2274 Transimpedance Amplifier (TIDM-TIA) User's Guide

1 Introduction

This manual describes the TIDM-TIA hardware and how to use it. The TIDM-TIA uses a MSP430F2274 microcontroller to convert the current produced by a photodiode into a voltage. The TIDM-TIA converts current to voltage by using one of the MSP430F2274's integrated op-amps and an external feedback resistor. This voltage is then sampled by the ADC on the MSP430F2274 and converted to a 10-bit value. Resulting conversion values can then be used to turn the LED on or off based on simple logic. Other GPIO pins are also available to use externally. The entire process of the TIA is indicated in [Figure 1](#).

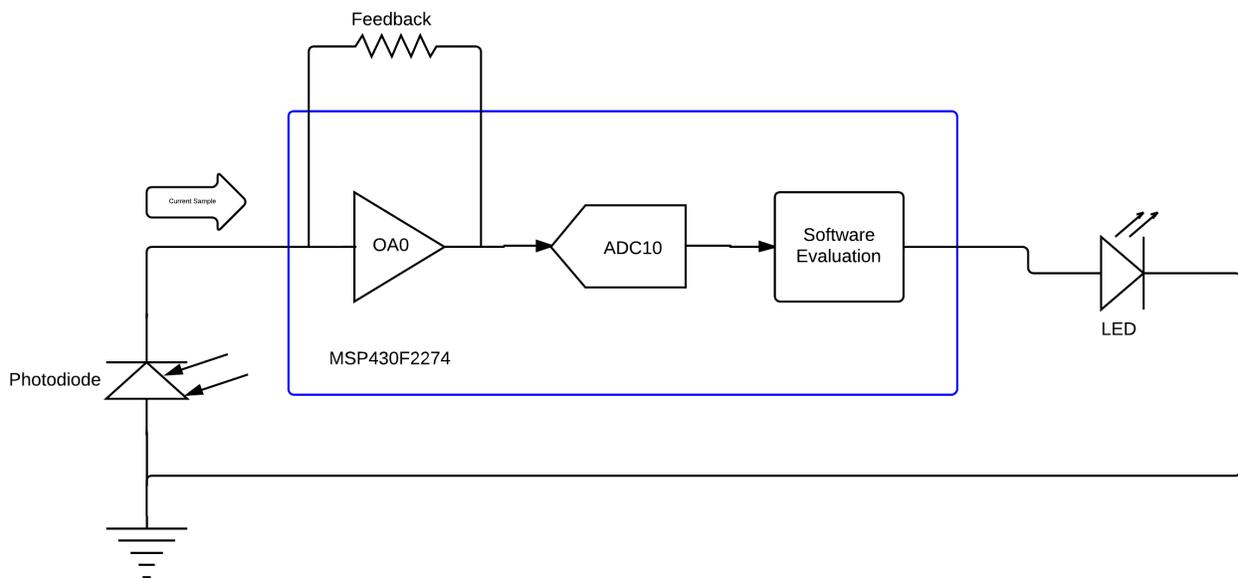


Figure 1. TIA Block Diagram

The TIDM-TIA is programmable and powered by a 4-wire JTAG connection or by an external source through an external voltage pin.

Find more information on the [MSP430F2274 datasheet](#).

For more information on transimpedance amplifiers and their properties, see the Transimpedance Considerations for High-Speed Amplifiers and Compensate Transimpedance Amplifiers Intuitively resources in [Section 6](#).

2 Acronyms, Terms, and Definitions

ADC— Analog-to-Digital Converter

CCS— Texas Instruments' Code Composer Studio

GPIO— General-Purpose Input/Output

JTAG— Joint Test Action Group

LED— Light Emitting Diode

OA— General Purpose Operational Amplifier

Op-Amp— Operational Amplifier

TI— Texas Instruments

TIA— Transimpedance Amplifier

TIDM-TIA— The name of this reference design

Blue-wire— Patch wires added to a circuit board to correct issues or change design.

3 Hardware Description

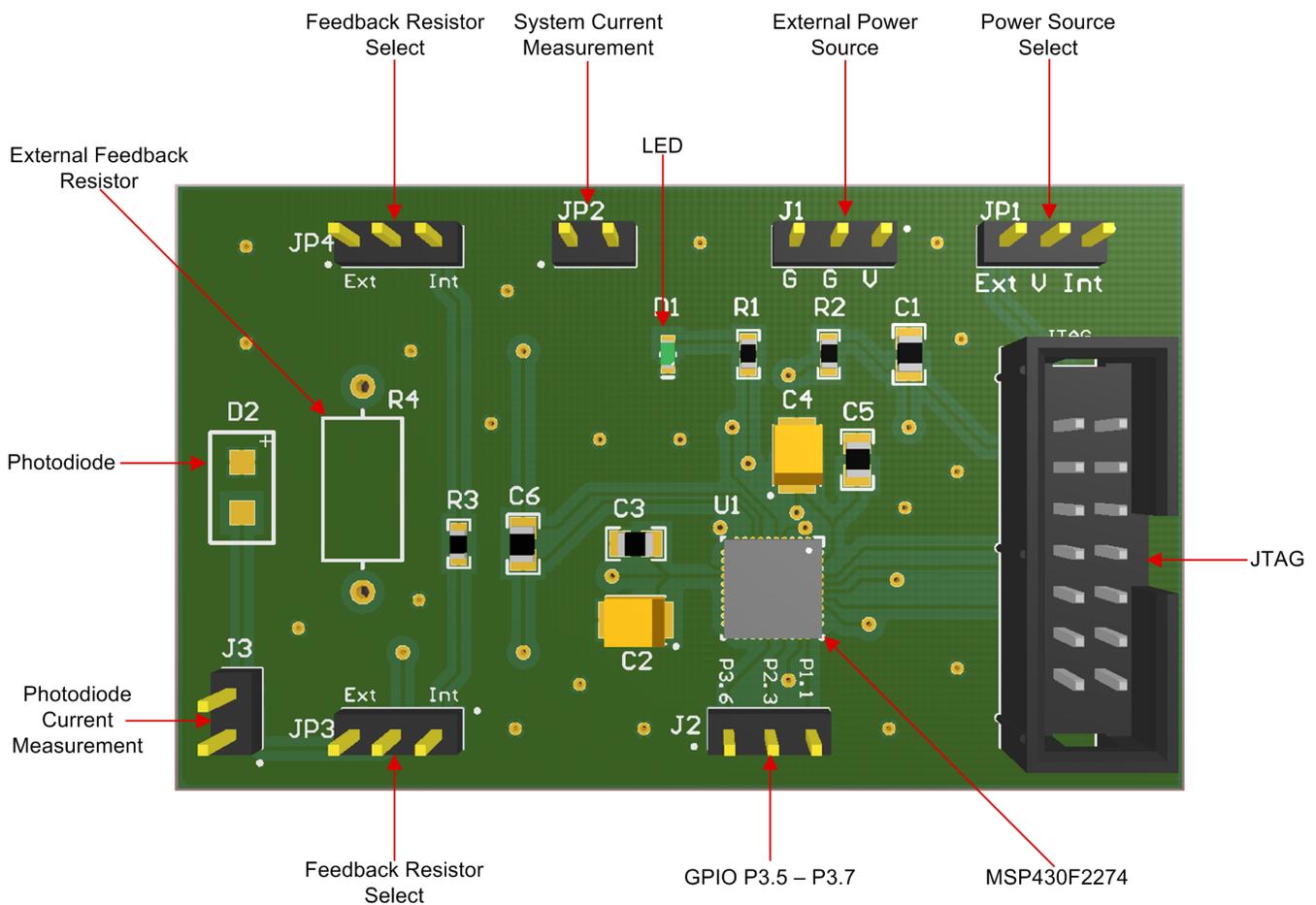


Figure 2. TIA Hardware Description

3.1 JTAG Connector

The part number of the 14-pin JTAG connector is SBH11-PBPC-D07-ST-BK from Sullins Connector Solutions.

The JTAG header provides a 4-wire method of programming and powering the TIDM-TIA. A MSP-FET430UIF can be used to program and debug the TIDM-TIA.

3.2 Powering the TIDM-TIA

Use the power select jumper (JP1) to switch between JTAG and external power sources for the board. Placing a jumper between pins *V* and *Int* allows power to come from the JTAG connection. Placing a jumper between pins *V* and *Ext* allows the board to be powered by applying voltage to pin *V* on the J1 jumper just to the left of JP1. A voltage of 3.3 V is recommended, but voltages can range from 1.8 to 3.6 V for the MSP430F2274.

By default, power by the JTAG connection should be selected. Do not apply voltage to J1 when powering the TIDM-TIA by JTAG.

3.3 Measuring Current Consumption

The current consumed by the TIDM-TIA can easily be measured by connecting an ammeter between the two pins of jumper JP2. When not measuring the current, leave a connection between these two pins.

3.4 Photodiode

The part number of the photodiode is SFH 2701 from OSRAM Opto Semiconductors Inc. Find more information on the [SFH 2701 datasheet](#).

The photodiode is the key component to the TIDM-TIA as it creates a current to be manipulated. The magnitude of the current depends on both the intensity of light hitting its active sensor and the wavelength of that light. Wavelengths between 400 and 1050 nm affect the photodiode. Currents from -0.1 to -100 μA can be obtained depending on the light hitting the photodiode. With indoor lighting, current output can range from around -0.1 to around -8 μA depending on the light source's proximity. Sunlight causes the photodiode to output currents of -30 μA and lower depending on the brightness of the day.

To measure the current produced by the photodiode, connect an ammeter between both pins of jumper JP5. This measurement helps when choosing an external feedback resistor (explained in [Section 3.5.2](#)).

This photodiode can also be replaced for similar designs. For example, a photodiode optimized to be sensitive to infrared light may be used with similar board functionality. To use a different photodiode, remove the SFH 2701 and blue-wire a new photodiode to its solder pads.

3.5 Feedback Resistors

3.5.1 Onboard Feedback Resistor

The TIDM-TIA has an onboard 2.37-M Ω feedback resistor connected between the inverting input of the integrated op-amp and its output. This feedback resistor provides the gain across the op-amp. Default gain with the onboard feedback resistor is very high and optimized for low-light, indoor situations where the photodiode only produces -0.1 to -1.5 μA of current. The feedback resistor helps convert the current from the photodiode into a voltage readable by the ADC. Output voltage is calculated using [Equation 1](#):

$$V_{\text{out}} = -(I_{\text{photo}} \times R_{\text{F}})$$

where

- I_{photo} is the current from the photodiode
- R_{F} is the resistance of the feedback resistor.

(1)

3.5.2 External Feedback Resistor

The TIDM-TIA also has an option to use an external feedback resistor for a different voltage gain. [Figure 3](#) shows the functionality of jumpers JP3 and JP4 with regards to selecting a feedback resistor.

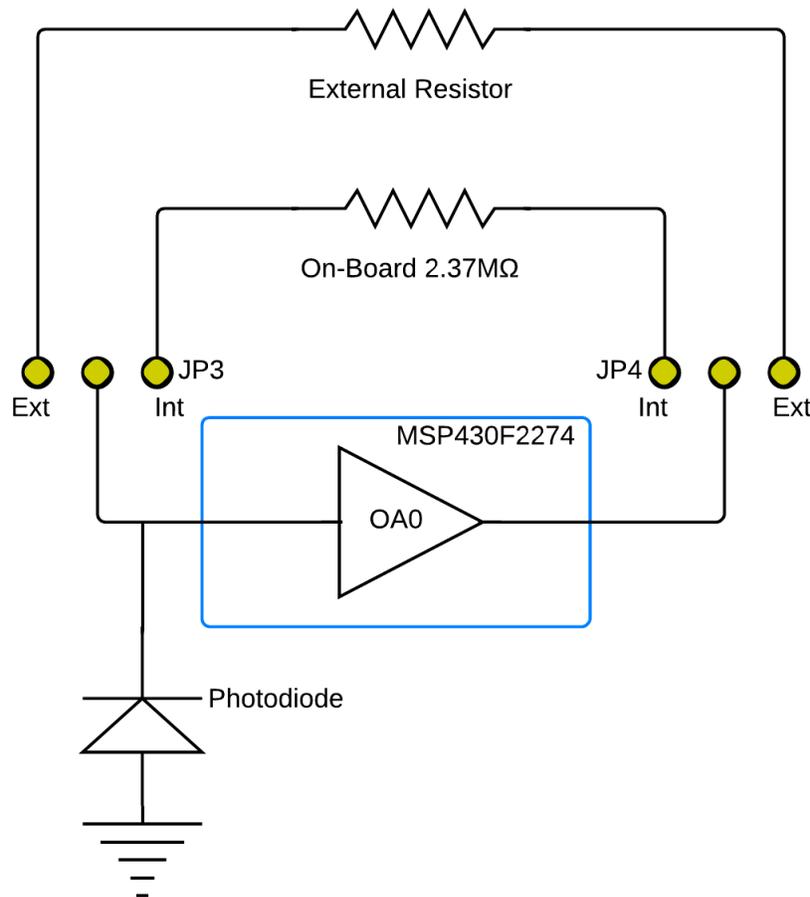


Figure 3. Feedback Resistor Jumpers

By default, there is a jumper connecting the *Int* and middle pins of JP3 and JP4 to use the onboard feedback resistor. Connecting the *Ext* and middle pins of both JP3 and JP4 allows for the use of an external feedback resistor. An external resistor can be connected to the TIDM-TIA board by blue-wiring a resistor to the R4 location on the board at the two holes. Knowing a target output voltage and measuring the current from the photodiode makes it possible to use [Equation 1](#) to select a proper feedback resistor.

3.5.3 Feedback Capacitor

Using an external resistor may result in a noisier output signal because there is a noise reducing capacitor calibrated for the onboard feedback resistor's resistance. Selecting a feedback capacitor value is determined by Equation 2 (see the MSP430F2274 datasheet for details).

$$C_F = \frac{1 + \sqrt{8\pi R_F C_i f_{GBW}}}{4\pi R_F f_{GBW}}$$

where

- R_F is the feedback resistance
- C_i is 10 pF
- f_{GBW} is the gain-bandwidth product of the op-amp (determined by its slew rate mode) (2)

In general, a larger feedback capacitance will result in a slightly smaller bandwidth.

For more information on selecting a feedback capacitor, see the *Transimpedance Considerations for High-Speed Amplifiers* and *Compensate Transimpedance Amplifiers Intuitively* resources in Section 6.

3.6 Operational Amplifier

The TIDM-TIA uses the MSP430F2274's integrated op-amp with a feedback resistor to provide the current-to-voltage conversion. Using the op-amp is preferred to simply feeding the photodiode's current across a resistor. A lone feedback resistor has a tradeoff between a large gain and a small response time. Using the onboard op-amp with a feedback resistor allows for a faster response time, large gain, and better signal-to-noise ratio of output signals. There is also a feedback capacitor added across the feedback resistor. Its job is to act as a low-pass filter, reducing noise and oscillation created by the op-amp (see Section 3.5.3 for details on changing the capacitor). The complete circuit involving the op-amp can be seen in Figure 4 where IS1 simulates the photodiode as a current source.

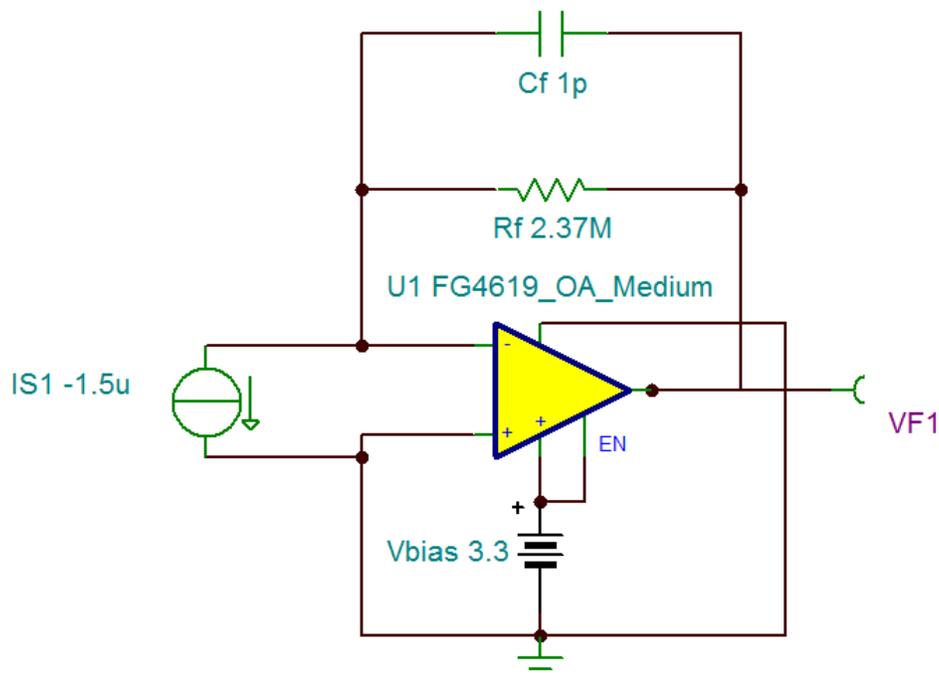


Figure 4. Operational Amplifier Circuit

The transfer function of the output is then seen in Equation 3:

$$V_{OUT} = -\frac{R_F}{1 + SC_F R_F} \times I_{PK} \tag{3}$$

As mentioned in the previous section, the TIDM-TIA has a feedback resistor with a resistance of 2.37 MΩ. This combination of photodiode, feedback resistor, and op-amp should provide the ideal output voltage seen in SPICE simulations in Figure 5. Currents created by the photodiode range from 0 to -1.5 μA, which are used as test values.

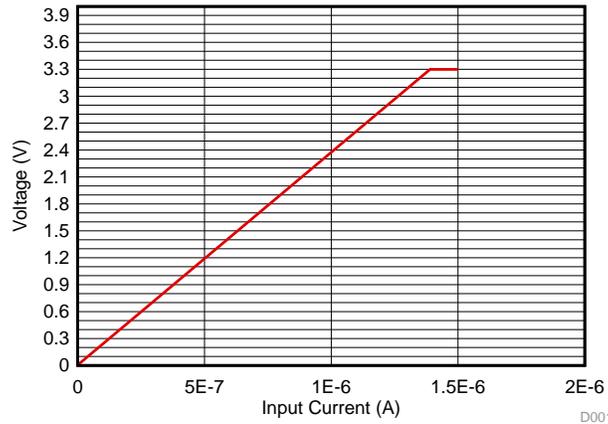


Figure 5. TIA SPICE Simulation

The Tina-TI SPICE model of the op-amp is available on the MSP430F2274 product web page. Characterization data for the photodiode current versus op-amp output voltage can be seen in Figure 6. Results are close to expected output.

NOTE: This output will change if using an external feedback resistor or different photodiode.

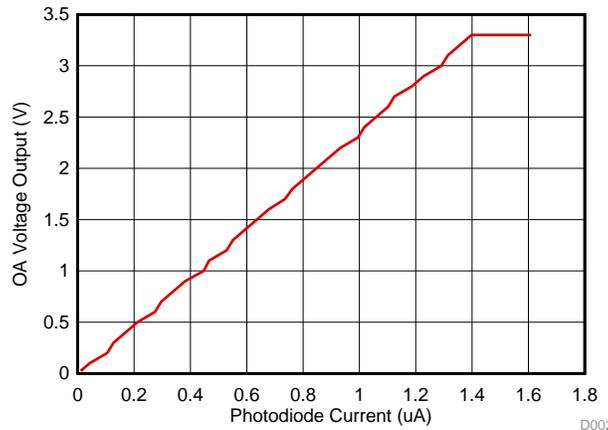


Figure 6. Op-Amp Voltage Output Characterization

For more information on the characteristics of the operational amplifier, see the [MSP430F2274 datasheet](#).

3.7 Analog-to-Digital Converter

The 10-bit ADC inside the MSP430F2274 converts voltage at the output of the op-amp into a 10-bit value. Both components are connected to each other inside the MSP430F2274. By default, the ADC uses reference voltages of 0 V (GND) and 3.3 V (V_{CC}) for its samples in single-channel, single-conversion mode, which is configured in software and can be changed for the different operations of the ADC. However, channel A1 of the ADC is the only channel the op-amp output is connected to by default.

See the [MSP430F2274 user's guide](#) for more information on the ADC.

3.8 GPIO Pins

On the TIDM-TIA, P1.0 from the MSP430F2274 controls the onboard LED. The LED turns on when the photodiode provides a dark reading and turns off for a bright reading. Whether a reading is "dark" or "bright" is determined by the conversion value from the ADC.

The TIDM-TIA also offers access to three GPIO pins on the MSP430F2274. Pins P1.1, P2.3, and P3.6 are all available to use through jumper J2. See the [MSP430F2274 user's guide](#) for more information on these pins.

5 Bills of Materials

Table 1. BOM

DESIGNATOR	DESCRIPTION	COMMENT	QUANTITY	MANUFACTURER	MANUFACTURER PART NUMBER	SUPPLIER	SUPPLIER PART NUMBER	FOOTPRINT
C1	CAP, CERM, 0.01 μ F, 250 V, \pm 10%, X7R, 0805	DNP	1	Taiyo Yuden	QMK212B7103KG-T	Digi-Key	587-1271-1-ND	0805_HV
C2, C4	CAP, TA, 10 μ F, 10 V, \pm 20%, 2.5 Ω , SMD	293D106X0010B2TE3	2	Vishay Sprague	293D106X0010B2TE3	Digi-Key	718-1119-1-ND	3528-21
C3, C5	CAP, CERM, 0.1 μ F, 25 V, \pm 10%, X7R, 0805	08053C104KAT2A	2	AVX Corporation	08053C104KAT2A	Digi-Key	478-3755-1-ND	0805_HV
C6	CAP, CERM, 1 pF, 50 V, \pm 25%, COG/NPO, 0805	08055A1R0CAT2A	1	AVX Corporation	08055A1R0CAT2A	Digi-Key	478-1292-1-ND	0805_HV
D1	LED, Green, SMD	LG L29K-G2J1-24-Z	1	OSRAM Opto Semiconductors Inc	LG L29K-G2J1-24-Z	Digi-Key	475-2709-1-ND	LG L29K_GREEN
D2	OSRAM Photodiode	SFH 2701	1	OSRAM Opto Semiconductors Inc	SFH 2701	Digi-Key	475-2967-X-ND	SFH 2701 - 1206
J1, J2, JP1, JP3, JP4	Header, 100 mil, 3x1, Gold, TH	TSW-103-07-G-S	5	Samtec Inc	TSW-103-07-G-S	Digi-Key	SAM1029-03-ND	TSW-103-07-G-S
J3, JP2	Header, 100 mil, 2x1, Gold, TH	TSW-102-07-G-S	2	Samtec Inc	TSW-102-07-G-S	Digi-Key	SAM1029-02-ND	TSW-102-07-G-S
JTAG	Header (shrouded), 100 mil, 7x2, Gold, TH	SBH11-PBPC-D07-ST-BK	1	Sullins Connector Solutions	SBH11-PBPC-D07-ST-BK	Digi-Key	S9170-ND	CONN_SBH11-PBPC-D07-ST-BK
R1	RES, 560 Ω , 5%, 0.1 W, 0603	CRCW0603560RJNEA	1	Vishay Dale	CRCW0603560RJNEA	Digi-Key	541-560GCT-ND	0603
R2	RES, 47 k Ω , 5%, 0.1 W, 0603	CRCW060347K0JNEA	1	Vishay Dale	CRCW060347K0JNEA	Digi-Key	541-47KGCT-ND	0603
R3	RES, 2.37 M Ω , 1%, 0.1 W, 0603	CRCW06032M37FKEA	1	Vishay Dale	CRCW06032M37FKEA	Digi-Key	541-2.37MHCT-ND	0603
R4	RES	DNP	1					External Resistor
U1	16-bit Ultra-Low-Power Microcontroller, 32-KB Flash, 1-K RAM, RHA0040B	MSP430F2274IRHA	1	Texas Instruments	MSP430F2274IRHAT	Digi-Key	296-21459-1-ND	RHA0040B

6 References

1. MSP430F2274: [Product Folder](#)
2. MSP-FET430UIF: [Tool Folder](#)
3. OSRAM SFH 2701 ([PDF](#))
4. Compensate Transimpedance Amplifiers Intuitively ([SBOA055A](#))
5. Transimpedance Considerations for High-Speed Amplifiers ([SBOA122](#))
6. TIDM-TIA: [Design Folder](#)

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