June 2009
Rev – 1.1

Photodetector Sensor Board SP1202S03RB User's Guide

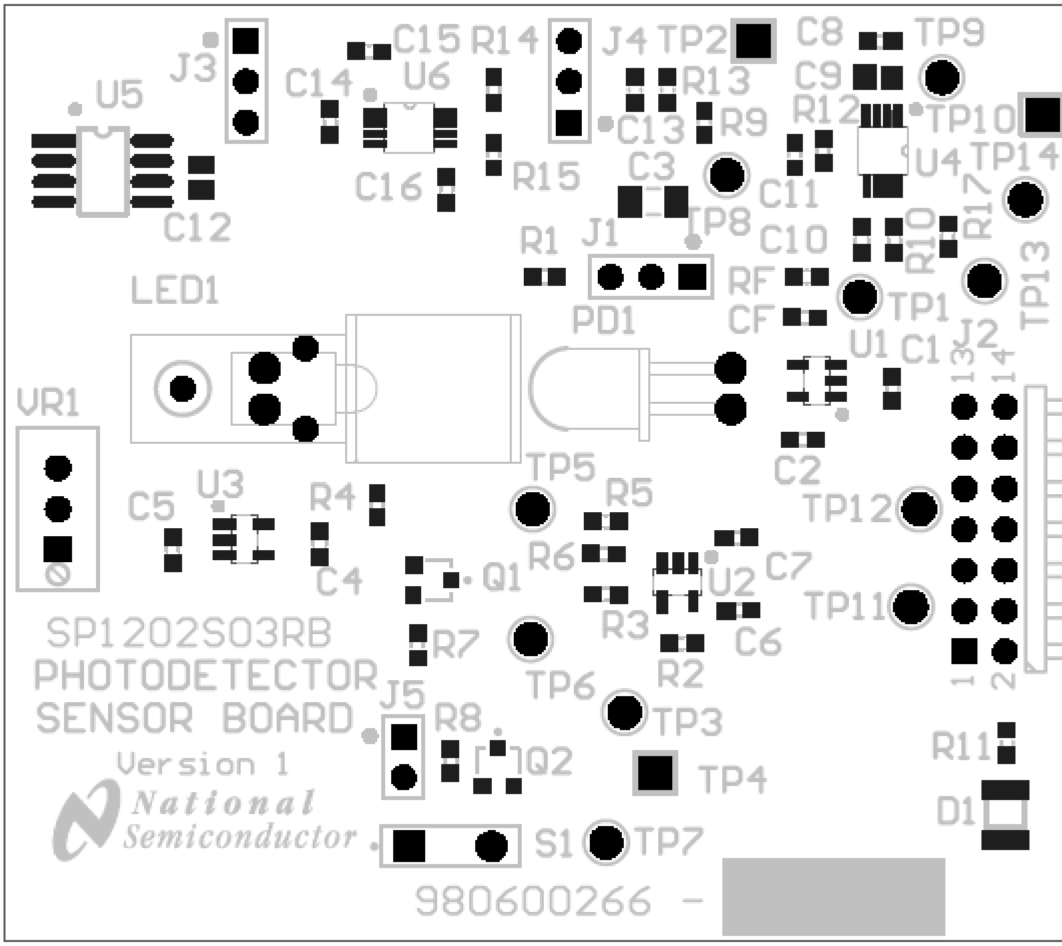


Table of Contents

1.0 Introduction

The Photodiode Sensor Board (SP1202S03RB), along with the Sensor Signal Path Control Panel (Sensor Panel) software and SPUSI2 USB Interface Dongle are designed to ease the design of circuits using various photodiodes with National's amplifiers and Analog-to-Digital converters (ADCs). Use the WEBENCH® Photodiode Sensor Designer to determine appropriate ICs and passives to achieve your signal path requirements: http://www.national.com/analog/webench/sensors/photodiode

See Figure 1 for component placement and Figure 2 for the example board schematic. The circuit for the photodiode sensor consists of a transimpedance amplifier (current to voltage converter) for operation in the photoconductive mode. Also, the board has circuitry to drive a light source (LED) which can be mounted in close proximity to the photodiode. The LED current can be either continuous or switched with the current level adjustable using a multi turn potentiometer.

The values for the LED driver are not calculated by Sensor Designer. The idea here is to provide a generic driver stage, allow the user to select a light source and adjust the current accordingly. The light source is not included in the kit. It should be chosen to be commensurate with the photodiode wavelength and optical sensitivity.

The outputs are a voltage output for the photocurrent (received optical power and a voltage output for the LED current (transmitted optical power).

2.0 Board Assembly

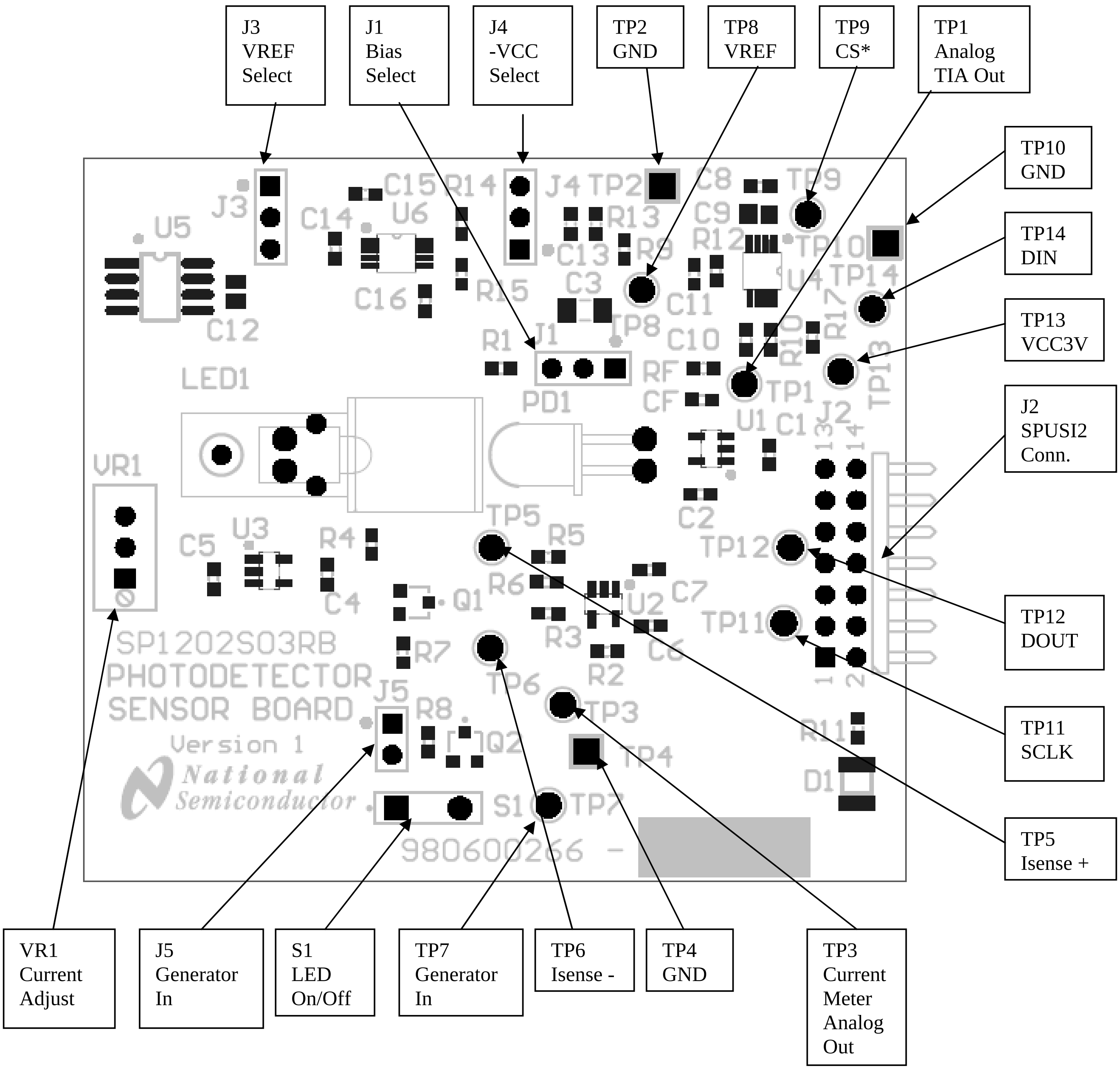
This Photodetector Sensor Board comes as a bare board that must be assembled. Refer to the example Bill of Materials for a description of component values. The values for the photodiode circuit are calculated using WEBENCH Sensor Designer. The values for the LED driver are not calculated by Sensor Designer.

3.0 Quick Start

Refer to *Figure 1* for locations of test points and major components. This Quick Start procedure provides 5V excitation for the sensor.

1. Place the J1 jumper across pins 2 & 3. This applies a negative 5VDC bias to the photodiode.
2. Place the J3 jumper across pins 2 & 3. This sets the ADC reference voltage to 4.096VDC.
3. Place the J4 jumper across pins 2 & 3. This sets the –VCC to -5VDC. Do not use this setting for an Op Amp that has a VCC of 5VDC or less.
4. Connect the Differential Pressure Sensor Board to the SPUSI2 board via 14-pin header J2.
5. Connect a USB cable between the SPUSI2 board and a PC USB port. GRN LED D1 on the Photodiode Sensor Board and D1 on the SPUSI2 board should come on if the PC is on.
6. If not already installed, install the Sensor Panel software on the PC. Run the software.

Figure 1. Component and Test Point Locations



4.0 Functional Description

The Photodiode Sensor Board component and test point locations are shown in *Figure 1*. The board schematic is shown in *Figure 2*.

4.1 Operational Modes

This board may be use in one of two modes: the Computer Mode using the SPUSI2 USB Interface Dongle or the Stand-Alone Mode without the use of the SPUSI2 USB Interface Dongle and a PC.

4.1.1 The Computer Mode

The board is intended for use in the Computer Mode, where a SPUSI2 board is used with it and the SPUSI2 board is connected to a PC via a USB port. Power to both boards is provided via USB.

4.1.2 The Stand-Alone Mode

The Stand-Alone Mode does not use the SPUSI2 board to capture data and upload it to a PC. To use the board this way, the user must provide +5V at pin 14 of header J2 as well as provide ADC clock and Chip Select signals to the ADC at pins 3 and 1, respectively, of J24. ADC data output is available at pin 5 of J2. Test Points may also be used to insert/read these signals. The range of frequencies for the ADC clock is 500KHZ to 1 MHz. The CS rate can be as low as desired, as but no faster than 17 times the ADC clock rate.

4.2 Signal Conditioning Circuitry

The output of the TIA (transimpedance amplifier) is on TP1. This is a voltage that is proportional to photocurrent. The values for RF and CF are calculated by the WEBENCH Sensor Designer. RF is determined by the full scale input voltage of the ADC and the maximum output photocurrent of the photodiode. CF is determined based on photodiode capacitance and an estimate of stray capacitance on the inverting input of OP Amp U1. The current flowing in the LED is measured and scaled by Op Amp U2 and appears on TP3. These voltages appear on the inputs of ADC U4. The digital output of the ADC appears on J2 Pin 5.

4.2.1 The Transimpedance Amplifier

In the photoconductive mode, the cathode of the photodiode is connected to the inverting pin of an op amp with the non inverting pin grounded. To maintain the virtual ground on the inverting pin, the op amp must provide current from its output through the RF to the photodiode.

So: $V_{out} = I_{PHOTODIODE} * RF$.

RF is determined by knowing the maximum photocurrent, sometimes referred to as $I_{SHORT\ CIRCUIT}$ of the photodiode, and the full scale input value of the ADC.

So: $RF = VFS/I_{SHORT\ CIRCUIT}$

Because the photodiode has capacitance, RF and C_{DIODE} form a pole in the noise gain transfer function. This can create stability issues and is compensated for by CF. WEBENCH Sensor Designer calculates the value of CF for a 45^{0} phase margin to insure stability.

4.2.2 Light Source

Provisions for a light source for test purposes are on the board.

The user can select an LED with appropriate wavelength and output power to compliment the photodiode selection. It may be necessary to modify component values in the LED driver to optimize performance.

S1 is provided as an ON/OFF control for the LED drive circuit. It controls the gate voltage of an NCH MOSFET. In the open position, the mosfet is conducting and the current source is enabled.

Also connected to the gate of the mosfet is a connector for a signal generator. A switching signal can be connected here to observe the transient response of the transimpedance amplifier. The rise times and switching frequencies are somewhat limited by the current source components and the mosfet switch so the user may want to install different components to achieve higher performance for the current source in this mode.

The current source consists of U3, Q1, VR1 and R7. The op amp will make sure the voltage at the CT of VR1 appears on the inverting pin. This voltage then appears across R7 (minimal V_{ON} for Q2). $I_{LED} = VR1_{CT}/R7$. Turning VR1 clockwise increases LED current. The differential amplifier U2 measures the current flowing in the LED by measuring the Voltage drop across R4. This voltage drop is scaled by the gain setting resistors.

$I_{LED} = Analog\_V2/(R3/(R2*R4))$

4.3 Power Supply

In the computer mode, power to this board is supplied through header J2 and ultimately from the host PC via USB. In most cases, the only voltage needed for the Photodetector Sensor board is the +5V from the USB connection.

The supply voltage source for the ADC (VREF on the schematic) is selected with J3 to be either the 4.1V from U5, or +5V from J2.

4.4 ADC Reference Circuitry

The single-ended ADC122S101 uses its supply voltage as its reference, so it is important that its supply voltage be stable and quiet. A 4.1V reference voltage is provided by U5, an accurate LM4120-4.1.

4.5 ADC clock

The ADC clock signal is provided external to the board at header J2. The frequency of this clock should be in the range of 500KHZ MHz to 1 MHz. A CS (Chip Select) signal is also required at J2. See the ADC data sheet for timing requirements.

4.6 Digital Data Output.

The digital output data from the ADC is available at 14-pin header J2. All digital signals to and from the ADC are present at this connector socket.

4.7 Power Requirements and Settings

Voltage and current requirements for the Photodetector Sensor Board are:

- Pin 14 of J2: +5.0V at **30 mA**
- Pins 2 and 4 of J2: Ground

With J4 connected from pin 2 to pin 3, the op amps in the circuit have a -5VDC on the -VCC terminals. This will yield a more accurate result for zero current flow in the LED and zero light level received in the photodiode. J4 pin 1 to pin 2 places GND on the –VCC pin.
The Photodiode can be reversed biased by connecting J1 from pin 2 to pin 3. This will reverse bias the photodiode by -5VDC and reduce the diode capacitance. This will reduce the effects of noise gain peaking due to capacitance on the inverting input of the transimpedance amplifier. J1 pin 1 to pin 2 connects the photodiode anode to GND.

5.0 Installing and Using the Photodetector Sensor Board

This Photodetector Sensor board requires power as described above.

5.1 Board Set-up

Refer to *Figure 1* for locations of connectors, test points and jumpers on the board.

1. Connect the Photodetector Sensor board to a SPUSI2 USB Interface Dongle.
2. Be sure all jumpers are in place per *Table 1*, below.

Table 1 - Jumper Default Positions		
Jumper	**Pins Shorted**	**FUNCTION**
J1	2-3	Neg. Photodiode Bias
J3	2 - 3	4.1V ADC Reference
J4	2 - 3	-5VDC for -VCC

3. Connect a USB cable to the SPUSI2 board and a PC.
4. Confirm that GRN LED D1 on the Photodetector Sensor board is on, indicating the presence of power to the board.
5. Be sure that the correct light source is installed in close proximity to the photodiode.
6. Be sure the current source values are chosen to drive the Light Source with the correct current levels.
7. For more accurate light power measurements it may be necessary to fashion a light shield to cover both the light source and the photodiode. Sufficient room around these two components has been provided for a light shield.

5.2 Quick Check of Analog Functions

Refer to *Figure 1* for locations of connectors and test points and jumpers on the board. If at any time the expected response is not obtained, see **Section 5.4** on Troubleshooting.

1. Perform steps 1 through 7 of Section 5.1.
2. Check for 5.0V on VCC and for 4.1V at TP8.
3. Check for -5V at J4 pin 3.
4. Turn S1 ON.
5. Monitor the voltage on TP3.
6. As the potentiometer is adjusted, the DC voltage on TP3 will vary. Verify the LED current is in the correct range.
7. As the potentiometer is adjusted, the voltage on TP1 should also vary based on the amount of light the source is generating.

This completes the quick check of the analog portion of the evaluation board.

5.3 Quick Check of Software and Computer Interface Operation

1. Perform steps 1 through 7 of Section 5.1.
2. Run the Sensor Panel software on the PC.
3. Select the SPI202S03RB Board.
4. Manually enter the following data:
   - Responsivity of the photodiode under test.
   - RF
   - Number of bits
   - Input Optical Power. This value is determined by setting the LED current, going to the LED datasheet and reading the power out at that LED current and at the photodiode wavelength.
   - Reference Voltage

   The software will measure the photocurrent of the photodiode and the LED current.

   The software knows the input power, calculates the received power and estimates the optical loss between the LED and the photodiode.

This completes the quick check of the software and computer interface.

5.4 Troubleshooting

If there is no output from the board, check the following:

- Be sure that the proper voltages and polarities are present.
- Be sure there is a clock signal at TP11 when trying to capture data.
- Be sure there is a voltage at TP3 that varies with light source current adjust.
- Be sure that the voltage on TP1 varies with light source current adjust.

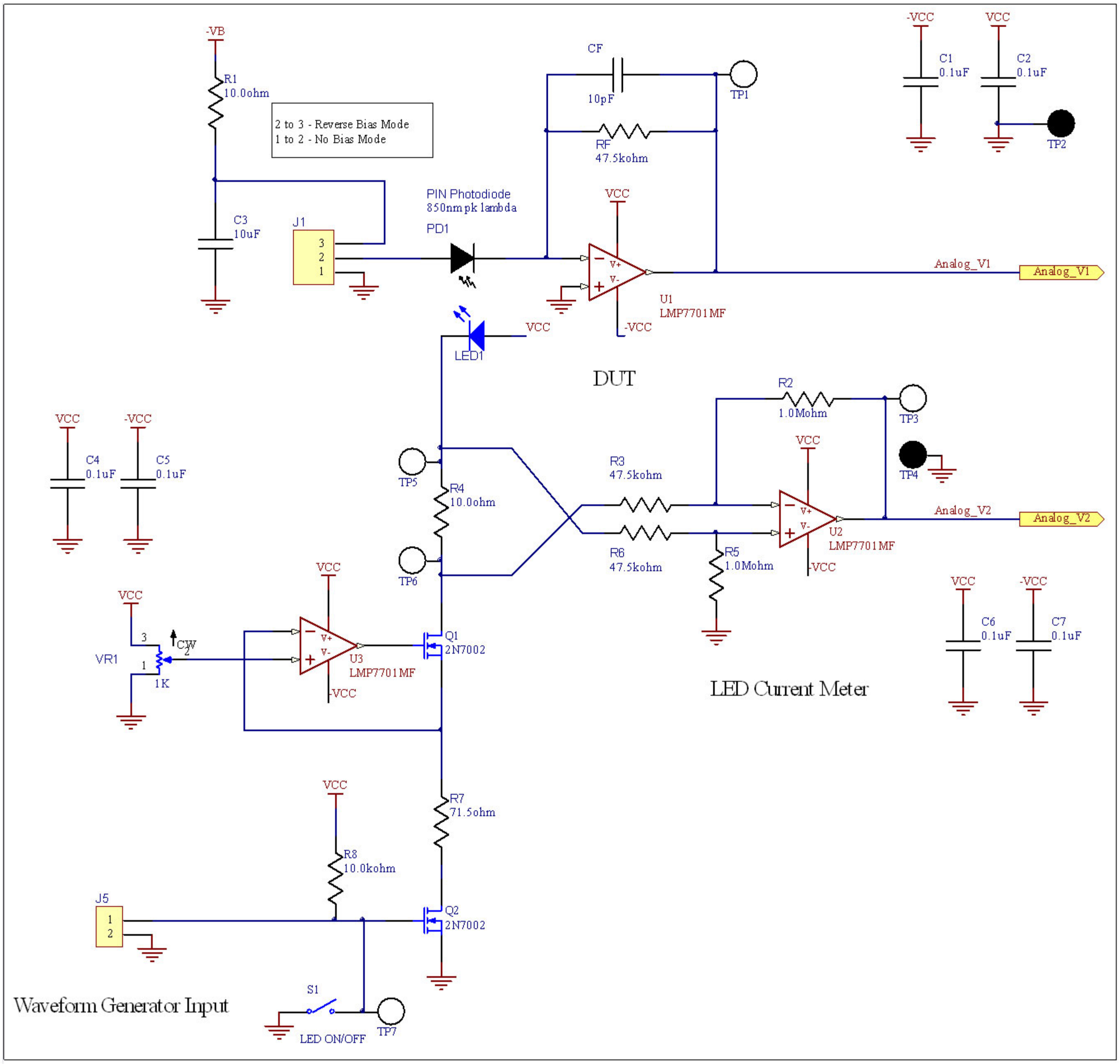
If the ADC output is zero or a single code, check the following:

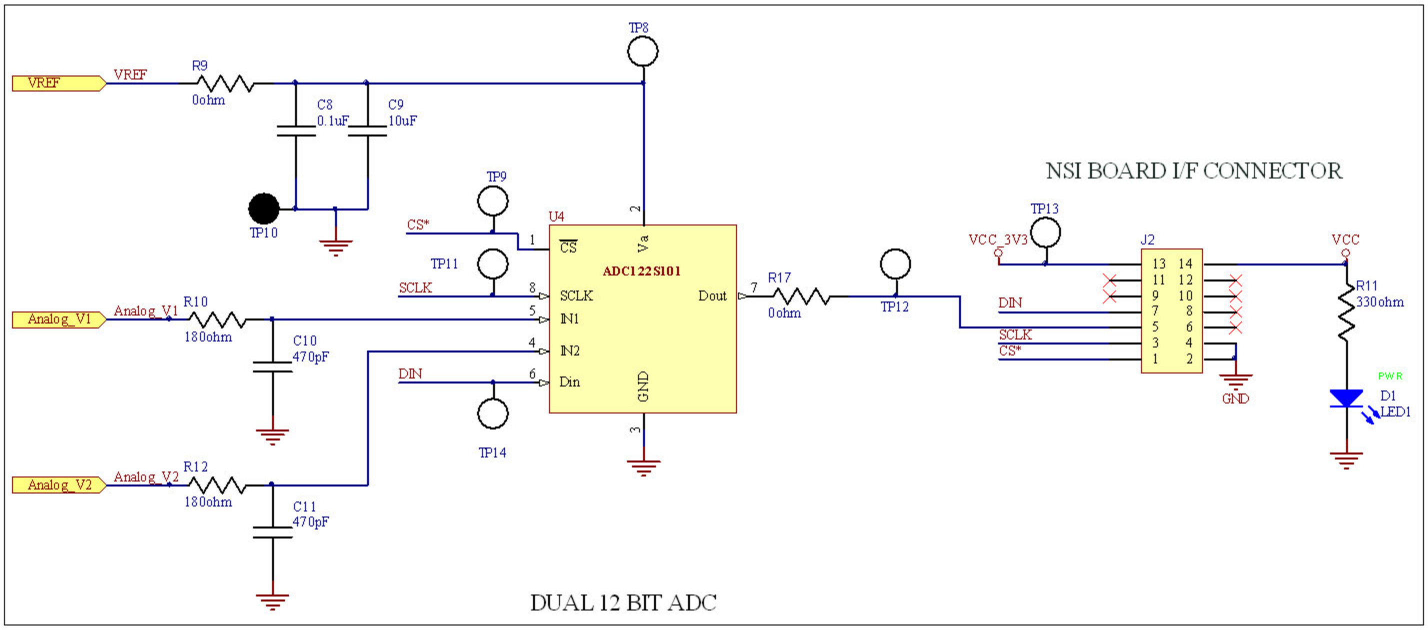
- Be sure that the proper voltages and polarities are present.
- Be sure that J2 is properly connected to a SPIUSI-2 USB Interface Dongle.

6.0 Board Specifications

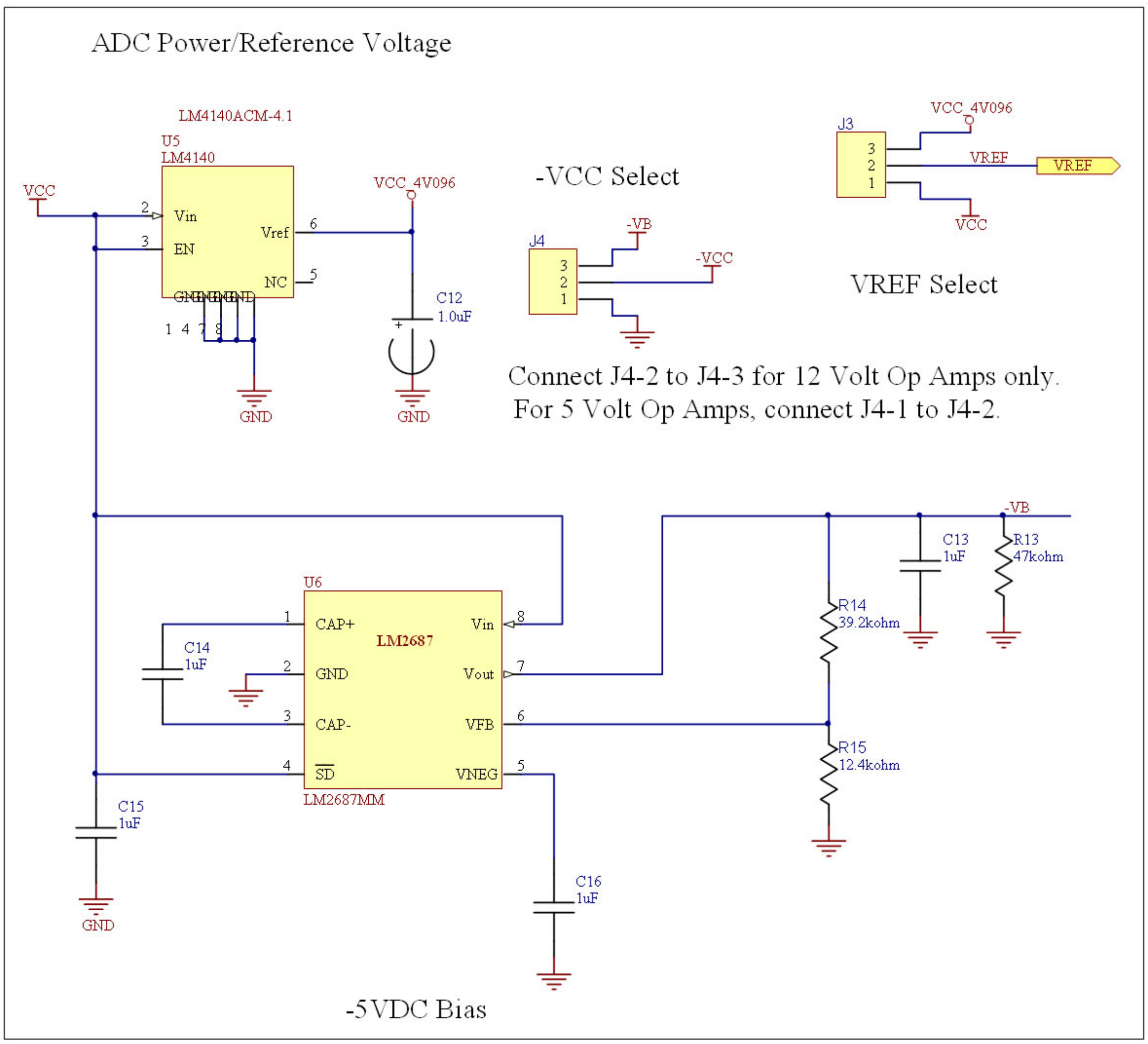
Board Size:	2.6" x 2.5" (6.6 cm x 6.35 cm)
Power Requirements:	+5V (30mA) at J2 pin 14

7.0 Example Hardware Schematic


-VB
R1
10.0ohm
2 to 3 - Reverse Bias Mode
1 to 2 - No Bias Mode
C3
10uF
J1
PIN Photodiode
850nm pk lambda
PD1
CF
10pF
RF
47.5kohm
TP1
VCC
-VCC
U1
LMP7701MF
Analog_V1
C1
0.1uF
C2
0.1uF
TP2
LED1
DUT
R2
1.0Mohm
TP3
TP4
R3
47.5kohm
R6
47.5kohm
R5
1.0Mohm
U2
LMP7701MF
Analog_V2
TP5
R4
10.0ohm
TP6
C4
0.1uF
C5
0.1uF
VR1
CW
1K
U3
LMP7701MF
Q1
2N7002
C6
0.1uF
C7
0.1uF
LED Current Meter
R7
71.5ohm
R8
10.0kohm
J5
Q2
2N7002
Waveform Generator Input
S1
LED ON/OFF
TP7



VREF
R9
0ohm
C8
0.1uF
C9
10uF
TP8
TP9
TP10
TP11
TP12
TP13
TP14
CS*
SCLK
DIN
U4
ADC122S101
CS
SCLK
IN1
IN2
Din
Va
Dout
GND
R17
0ohm
Analog_V1
R10
180ohm
C10
470pF
Analog_V2
R12
180ohm
C11
470pF
NSI BOARD I/F CONNECTOR
VCC_3V3
J2
CS*
GND
VCC
R11
330ohm
PWR
D1
LED1
DUAL 12 BIT ADC



ADC Power/Reference Voltage
LM4140ACM-4.1
U5
LM4140
VCC
Vin
EN
Vref
NC
VCC_4V096
C12
1.0uF
GND
-VCC Select
J4
-VB
-VCC
J3
VCC_4V096
VREF
VCC
VREF Select
Connect J4-2 to J4-3 for 12 Volt Op Amps only.
For 5 Volt Op Amps, connect J4-1 to J4-2.
U6
LM2687
CAP+
GND
CAP-
SD
Vin
Vout
VFB
VNEG
LM2687MM
C14
1uF
C15
1uF
C16
1uF
-VB
C13
1uF
R13
47kohm
R14
39.2kohm
R15
12.4kohm
-5VDC Bias

8.0 Example Bill of Materials

Bill of Materials

Photodetector Board

Project: PD_Ref_Des_Rev_B.PrjPCB

Variant: None

Creation Date: 9/24/2008 10:27:25

Print Date: 24-Sep-08 1:40:52 PM

REV B

National Semiconductor
The Sight & Sound of Information

Quantity	Designator	Description	Value	Footprint	Digikey_PN
7	C1, C2, C4, C5, C6, C7, C8	Capacitor	0.1uF	603	445-1317-1-ND
1	C3	Capacitor	10uF	1206	445-1391-1-ND
1	C9	Capacitor	10uF	805	587-1295-1-ND
2	C10, C11	Capacitor	470pF	603	445-1307-1-ND
1	C12	Polarized Capacitor	Value	0805L	478-3265-2-ND
4	C13, C14, C15, C16	Capacitor	1uF	603	445-1604-1-ND
1	CF	Capacitor	Sensor Designer	Sensor Designer	Sensor Designer
1	D1	LED, RED	User Specified	LED	
3	J1, J3, J4	Header, 3-Pin	HDR, 1x3	HDR1X3-A	S1011E-03-ND
1	J2	Header, 7-Pin, Dual row		HDR2X7H-B	
1	J5	Header, 2-Pin	HDR, 1x2	HDR1X2_A	WM6502-ND
1	LED1	Typical INFRARED GaAs LED		LED-1A	
1	PD1	Photo Diode, 900nm	SFH213	Photo-1A	475-1077-ND
2	Q1, Q2	N-Channel Enhancement Mode Vertical DMOS FET	2N7002	SOT23	2N7002CT-ND
1	RF	Resistor	Sensor Designer	Sensor Designer	Sensor Designer
2	R1, R4	Resistor	10.0ohm	603	541-10.0HCT-ND
2	R2, R5	Resistor	1.0Mohm	603	541-1.0MGCT-ND
2	R3, R6	Resistor	47.5kohm	603	541-47.5kHCT-ND
1	R7	Resistor	71.5ohm	603	541-71.5HCT-ND
1	R8	Resistor	10.0kohm	603	541-10.0kHCT-ND
2	R9, R17	Resistor	0ohm	603	541-0.0GTR-ND
2	R10, R12	Resistor	180ohm	603	541-180GCT-ND
1	R11	Resistor	330ohm	603	311-330GCT-ND
1	R13	Resistor	47kohm	603	541-47kGCT-ND
1	R14	Resistor	39.2kohm	603	541-39.2kHCT-ND
1	R15	Resistor	12.4kohm	603	541-12.4kHCT-ND
1	S1	Single-Pole, Single-Throw Switch		SPST-2	CKN6012-ND
11	TP1, TP3, TP5, TP6, TP7, TP8, TP9, TP11, TP12, TP13, TP14	Test Point	White	Testpoint Keystone 500x	5002K-ND
3	TP2, TP4, TP10	Test Point	Black	TEST POINT	5001K-ND
1	U1	Sensor Designer	Sensor Designer	Sensor Designer	Sensor Designer
2	U2, U3	Precision, CMOS Input, RRIO, Wide Supply Range Amplifiers	LMP7701MF	MF05A	LMP7701MFCT-ND
1	U4	2 Channel, 1 MSPS, 12-Bit A/D Converter	ADC122S101CIMM	MUA08A	ADC122S101CIMMCT-ND
1	U5	Precision Micropower Low Dropout Voltage Reference	LM4140ACM-4.1	SOIC8	LM4140BCM-4.1-ND
1	U6	Low Noise Regulated Switched Capacitor Voltage Inverter	LM2687MM	MUA08A	LM2687MMCT-ND
1	VR1	Potentiometer	1K	VR5_A	3250W-102-ND
3	Shunt	2 pin shunt			S9001-ND

APPENDIX

Summary Tables of Test Points and Connectors

Test Points on the Photodetector Sensor Board

Identifier	Name	Function
TP 1	Analog_V1	TIA Analog Output
TP 2	GND	Ground
TP 3	Analog_V2	Current Meter Analog Output
TP 4	GND	Ground
TP 5	Isense +	Current Sense Resistor +
TP 6	Isense -	Current Sense Resistor -
TP 7	J5 Pin 1	Waveform Generator Input
TP 8	VREF	ADC VDC
TP 9	CS*	CS* input for ADC
TP 10	GND	Ground
TP 11	SCLK	SCLK Input to ADC
TP 12	DOUT	SDATA output from ADC
TP 13	VCC_3V3	3.3VDC from SPUSI2 Board
TP 14	DIN	ADC DIN from SPUSI2 Board

J1 Jumper – Photodiode Bias Select

Shorted Positions	Results
1 - 2	GND on Photodiode Anode
2 - 3	-5VDC on Photodiode Anode

J3 Jumper - VADC_SEL

Shorted Positions	Results
1 - 2	+5V for ADC Supply and Reference Voltage
2 - 3	+4.1V for ADC Supply and Reference Voltage

J4 Jumper - -VCC Select

Shorted Positions	Results
1 - 2	-VCC = GND
2 - 3	-VCC = -5VDC

Summary Tables of Test Points and Connectors (cont'd)

J2 Connector - Connection to SPUSI2 Board

J2 Pin Number	Voltage or Signal
1	CS* input to ADC
2	Ground
3	SCLK input to ADC
4	Ground
5	SDATA output from ADC
6	no connection
7	DIN to ADC
8	no connection
9	no connection
10	no connection
11	no connection
12	no connection
13	+3.3V from SPUSI2 USB Interface Dongle
14	+5V from SPUSI2 USB Interface Dongle

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Interface	interface.ti.com	Medical	www.ti.com/medical
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