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MAX1450 Evaluation Kit

_____*General Description*

The MAX1450 evaluation kit (EV kit) demonstrates silicon piezoresistive sensor calibration and temperature compensation using the MAX1450. The kit includes an assembled and tested PC board with a Lucas NovaSensor® pressure sensor calibrated at room temperature. It also supports several popular pressure-sensor packages. The board uses multiturn potentiometers and configuration switches to calibrate and temperature-compensate a sensor to 1% accuracy.

_____*Component List*

DESIGNATION	QTY	DESCRIPTION
C1, C2, C3	3	0.1µF ceramic capacitors
C4	1	0.01µF ceramic capacitor
D1	1	6.2V, 500mW, surface-mount zener diode
JU1, JU2	0	Open
P1, P2	2	4-pin headers
P3, P4	2	10-pin headers
R1–R5	5	1MΩ ±5% resistors (1206)
R6, R8–R11	0	Open
SW1	1	Five-position SPST dip switch
S1	1	Sensor site 1 Lucas NovaSensor NPH-8-100GH (TO-8, 100kPa gauge) Other possible sensors: Sentir AP-301 (modified TO-5) or IC sensors models 10/20/30/40 (TO-8)
S2	0	Sensor site 2 Sensym SDX and ISO series, IC sensors LP series, or Lucas NovaSensor NPI series
U1	1	Maxim MAX1450CAP (20-pin SSOP)
VR1, VR2, VR3	3	50kΩ trim potentiometers
VR4	1	500kΩ trim potentiometer (supplied but not mounted)
VR5	1	100kΩ trim potentiometer
None	1	PC board
None	1	MAX1450 EV kit data sheet
None	1	MAX1450 data sheet

_____*Features*

♦ **Proven PC Board Layout**

♦ **Convenient Test Points Provided On-Board**

♦ **Includes Calibrated (at room temperature) Lucas NovaSensor Pressure Sensor**

♦ **Fully Assembled and Tested**

♦ **Supports Many Popular Sensor Packages**

_____*Ordering Information*

PART	TEMP. RANGE	IC PACKAGE
MAX1450EVKIT	-40°C to +125°C	20 SSOP

_____*Quick Start*

Use the quick-start procedure to evaluate initial factory calibration accuracy or to modify the calibration settings. Before recalibrating the MAX1450, you should test the precalibrated EV board. Supply power to the PC board and measure the output voltage as a function of pressure and temperature. As shipped from the factory, the EV kit has been calibrated at room temperature but not compensated over temperature.

Required Equipment
• Precision regulated power supply capable of providing +5.000V

• Multimeter with at least five significant digits

• 0–15psi gauge pneumatic pressure controller/calibrator

Initial Setup
The four-pin sensor connector (P2) can be used to probe the four sensor nodes: sensor excitation (IN+), sensor ground (IN-), sensor positive output (OUT+), and sensor negative output (OUT-). This connector may also serve as a means of wiring to an alternate sensor. Connector P2 allows the user to supply power to the board, and to measure output voltage and sensor excitation voltage.

Room Temperature Bench Test
The board's output is ratiometric to the supply; therefore, supply voltage must be set accurately to minimize measurement error.

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Evaluates: MAX1450

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Connect the negative power-supply terminal to the analog connector pin labeled VSS. Connect the positive power-supply terminal to the analog connector pin labeled VDD. Connect the DVM to the analog connector pin labeled VOUT; the ground return should be connected to the VSS pin.

IMPORTANT: To avoid problems with ground loops and noise, connect all equipment to the same AC circuit and **use one common earth ground**. If the power supply has a programmable current limit, set it to about 10mA. Adjust the supply voltage to +5.000V, measuring the voltage at test point VDD with respect to test point VSS. There should be no connection to the sensor pressure port. Since the sensor supplied is a gauge type, the output voltage at connector P2 should read approximately 0.5V.

Room Temperature Pressure Test

Carefully remove the plastic sensor protector (if supplied) and connect a silicone pressure tube to the sensor pressure port. Grasp the sensor, not the PC board, while fitting the tube in place. Perform any required pressure controller initialization/calibration procedures, then vent the system. At 0psig, the output voltage should read between 0.49V and 0.51V. Perform a few pressure cycles (0–15psi with supplied sensor) to minimize hysteresis effects. Apply full-scale pressure and confirm that the output reads between 4.49V and 4.51V. Test at intermediate pressures to measure for pressure linearity errors.

Detailed Description of Hardware

The MAX1450 EV kit performs analog calibration and temperature compensation of a silicon piezoresistive sensor. The board is shipped fully assembled and tested, with a calibrated Lucas Novasensor. Three sensor connection sites are provided: S1, S2, and P1. The board operates with a 5V nominal supply voltage. Since its output is ratiometric (proportional) to the supply voltage, it is critical to maintain a precise supply voltage during test. The nominal calibrated output voltage range will be 0.5V (at minimum pressure) to 4.5V (at maximum pressure). Other output voltage ranges are also possible, within the common-mode output range of the MAX1450.

Replacing the Sensor

The MAX1450 may be used to calibrate and temperature-compensate a wide variety of pressure sensor types; however, some sensors may require additional external circuitry. This EV kit is designed for bulk micromachined silicon piezoresistive pressure sensors. See Table 1. Connector P1 will accept any generic sensor configured as a four-wire closed Wheatstone bridge. It is most useful with sensors that require off-board mounting, such as those that have large threaded pressure ports. This connector may also be used as a sensor test point. Sensor sites S1 and S2 provide several overlapping footprints for popular metal, plastic, and ceramic sensors, which use a slip tube as a pressure port. See the *Component List* for models that are accepted at these sites. Only one sensor may be installed at a time. Sensor sites S1 and S2 are not provided for accommodating differential pressure-sensing applications that require two pressure sensors.

Power Requirements

The MAX1450 EV kit operates with a nominal supply voltage of +5V and requires about 5mA of supply current, including the sensor. The supply may vary between +4.5V and +5.5V, and a 6.2V zener diode has been added across the power-supply lines (VDD and VSS) to protect the MAX1450. Connector P2 is provided for connecting power, as well as for measuring the output voltage and sensor excitation voltage.

Calibration and Temperature-Compensation Procedure

The MAX1450 EV kit can correct four common types of sensor errors: offset, full-span output (FSO), offset tempco, and FSO tempco. The user may choose which parameters to correct depending on the sensor behavior, operating temperature range, and desired accuracy. Sensor calibration corrects the offset and FSO errors at a single temperature. Temperature compensation, which is optional, minimizes offset and FSO error drifts with changes in temperature, and will require an environmental chamber. To correct offset and FSO errors over a range of temperatures, use the offset tempco (VR1, OFTC) and FSO tempco (VR4, FSOTC) potentiometers.

Since the PC board is not conformal coated, the environmental chamber must not allow condensation to take place. If condensation occurs, bake the PC board at +125°C (with no power applied) for a minimum of one hour. The circuit may behave erratically if moisture condenses on the PC board due to weak ionic paths affecting high-impedance nodes on the board. The electronics should be conformal coated in any application where moisture condensation may occur.

Put the board in an environmental chamber and test the board over any temperatures between -40°C and +125°C. First perform one or two full excursions of temperature and pressure to minimize hysteresis errors.

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Table 1. Sensor Requirements for EV Kit

PARAMETER	VALUE	DESCRIPTION
Bridge Resistance	5kΩ (typ)	Sensor input impedance at +25°C
Resistance Tempco	TCR > |TCS|	The sensor input impedance tempco must exceed the absolute value of the sensor pressure-sensitivity tempco.
Pressure Sensitivity	~10 to 30 mV/V/FSO	Differential output FSO, per volt of sensor excitation
Sensitivity Tempco	TCS < 0	The sensitivity tempco must be negative.
Sensor Offset	$|V_{OFFSET}|$ < 100mV	The sensor offset voltage (absolute value) at minimum gain must be less than about 100mV. At higher gains, the offset must be proportionately smaller.
Offset Tempco	|OTC| < |TCS|	The absolute value of the sensor offset tempco must be less than the absolute value of its sensitivity tempco, when both are expressed in terms of the sensor's FSO.

Most of the error after compensation is due to sensor drift and nonrepeatable behavior. To understand the source of these errors, monitor the low-level sensor output using the P1 sensor connector to separate sensor errors from MAX1450 errors. To avoid attenuating the sensor output signal, take this measurement using a multimeter with an input impedance >10MΩ.

Required Equipment
- Precision regulated power supply capable of providing +5.000V
- Multimeter with at least five significant digits
- 0–15psi gauge pneumatic pressure controller/calibrator
- Dry air or nitrogen
- Noncondensing environmental chamber capable of handling -40°C to +125°C

Initial Setup
Trim potentiometer VR4 (FSOTC) is required only when compensating over temperature. Installing VR4 may perturb previous calibration setpoints. Begin with the switches and potentiometers as shown in Table 2.

Connect the sensor to a pressure source and test for leaks. Connect the EV kit to a +5V power source. Since output voltage is ratiometric to the power supply, an accurate power-supply setting is required. If the power supply has a programmable current limit, set it to about 10mA. Current consumption should not exceed 5mA.

Calibration Procedure
This procedure describes how to calibrate at a single temperature. The following example is designed to calibrate a sensor with a nominal output voltage of 0.5V at P_{MIN} and an output voltage of 4.5V at P_{MAX}; thus, the ideal FSO will be 4V.

Choosing PGA Gain Setting
1) Set the temperature to T1 and allow sufficient soak time.
2) Confirm that the supply voltage is correct.
3) Set the pressure to P_{MIN}.
4) Adjust VR3 (FSO trim) until V_{BDRIVE} (Vbdr, BDRV) is approximately 2.0V.
5) Measure the differential sensor output (INP - INM).
6) Set the pressure to P_{MAX}; remeasure (INP - INM).
7) Calculate the sensor FSO.
8) Divide the ideal FSO (4V) by the sensor FSO to calculate the ideal PGA gain required.
9) Choose the PGA gain setting that is closest to the calculated ideal gain.
10) Program the PGA gain chosen using the three programming switches (SW1-1, SW1-2, SW1-3).

Example:
1) Set the temperature to T1 and allow it to soak.
2) Confirm the supply voltage.
3) Set the pressure to P_{MIN}.
4) Adjust VR3 until V_{BDRIVE} = 2.42V.
5) Measure (INP - INM) at P_{MIN} to be -0.011V.
6) Measure (INP - INM) at P_{MAX} to be 0.056V.
7) Calculate sensor FSO to be 0.067V.
8) Calculate the ideal gain to be 4 / 0.067 = 59.7V/V.
9) Determine the closest available gain setting to be 65 (PGA value is 1).
10) Set the PGA to 001 (binary), close SW1-1 (LSB), open SW1-2, and open SW1-3.

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Table 2. Initial Settings

PARAMETER	FUNCTION	INITIAL SETTING	DESCRIPTION
SW1-1	PGA LSB	Off (open)	Minimum gain
SW1-2	PGA NSB	Off (open)	Minimum gain
SW1-3	PGA MSB	Off (open)	Minimum gain
SW1-4	Offset Sign	On (closed)	Sign bit is set to positive.
SW1-5	Offset TC Sign	On (closed)	Sign bit is set to positive.
VR1	Offset TC Adjust	Fully CCW	No offset TC correction is performed. V_{OFFSET}, pin 9 = 0.
VR2	Offset Adjust	Fully CCW	No offset correction is added. V_{OFFTC}, pin 8 = 0.
VR3	FSO Adjust	Approximately midscale	Sets initial V_{ISRC} to ~2.5V.
VR4	FSO TC Adjust	Do not install VR4 unless compensating over temperature.	No FSO TC adjustment
VR5	R_{ISRC} Adjust	Approximately midscale	Sets initial R_{ISRC} to ~ 50kΩ.

Determining and Setting the Ideal Sensor Excitation Voltage at T1

1) Set the pressure to P_{MIN}.

2) Measure the output voltage (V_{OUT}) at P_{MIN}.

3) If $V_{OUT} > 0.5V$, open SW1-4 (SOF); if $V_{OUT} < 0.5V$, close SW1-4.

4) Adjust VR2 (OFST trim) until V_{OUT} is 0.5V.

5) Set the pressure to P_{MAX}, and measure V_{OUT} at P_{MAX}.

6) Calculate the uncorrected FSO as follows: V_{OUT} at P_{MAX} - V_{OUT} at P_{MIN}.

7) Calculate the FSO error as follows: uncorrected FSO / ideal FSO.

8) Set the pressure to P_{MIN}, and measure V_{BDRIVE} (uncorrected V_{BDRIVE}).

9) Determine the ideal V_{BDRIVE} as follows: uncorrected V_{BDRIVE} / FSO error.

10) Using VR3 (FSO trim), set V_{ISRC} (pin 17) to ideal V_{BDRIVE}.

11) Using VR5 (R_{ISRC} trim), set V_{BDRIVE} to ideal V_{BDRIVE}.

Example:

1) Set the pressure to P_{MIN}.

2) Measure V_{OUT} at P_{MIN} to be 0.987V.

3) Open SW1-4 (the voltage at OFFSET, pin 9, is subtracted from the output).

4) Adjust VR2 until V_{OUT} at P_{MIN} = 0.503V.

5) Set the pressure to P_{MAX}, then measure V_{OUT} at P_{MAX} to be 4.742V.

6) Calculate the uncorrected FSO as follows: 4.742 - 0.503 = 4.239V.

7) Calculate the FSO error as follows: 4.239 / 4 = 1.0597 (approximately 6% too high).

8) Measure V_{BDRIVE} as 2.42V (uncorrected V_{BDRIVE}).

9) Calculate ideal V_{BDRIVE} as follows: 2.42 / 1.0597 = 2.284V.

10) Adjust VR3 until V_{ISRC} = 2.284V.

11) Adjust VR5 until V_{BDRIVE} = 2.284V.

Setting Offset Voltage at T1

1) Set VR2 fully CCW (V_{OFFSET}, pin 9 = 0).

2) Set the pressure to P_{MIN}.

3) Measure the output voltage V_{OUT} at P_{MIN}.

4) If $V_{OUT} > 0.5V$, open SW1-4; if $V_{OUT} < 0.5V$, close SW1-4.

5) Adjust VR2 until V_{OUT} is 0.5V.

Example:

1) Set VR2 fully CCW.

2) Set the pressure to P_{MIN}.

3) Measure V_{OUT} P_{MIN} to be 0.387V.

4) Close SW1-4 (the voltage at OFFSET, pin 9, is added to the output).

5) Adjust VR2 until V_{OUT} at P_{MIN} = 0.496V.

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Offset and FSO calibration (at T1) is now complete. Remeasure the EV kit's output voltage (V_{OUT}) at both P_{MIN} and P_{MAX}. If required, make small readjustments to FSO and to offset using their respective adjusting potentiometers. If large errors are observed (~ 0.5% or greater), recalibrate from step 1.

Temperature-Compensation Procedure

Accuracy may be improved by measuring offset and FSO errors at a second temperature T2 (T2 > T1). The FSOTC and OFFTC potentiometers will be used to compensate for the drift in offset and FSO.

Compensating FSO TC Error at T2

1) Increase the temperature to T2 and allow sufficient soak time.

2) Confirm that the supply voltage is correct.

3) Set the pressure to P_{MIN}.

4) Measure V_{BDRIVE} (uncorrected V_{BDRIVE} at T2).

5) Compare this uncorrected V_{BDRIVE} with the ideal V_{BDRIVE} at T1 (see *Determining and Setting the Ideal Sensor Excitation Voltage at T1*). If the uncorrected V_{BDRIVE} is less than or equal to the ideal V_{BDRIVE} at T1, the sensor cannot be compensated and you should abort the procedure. If it is greater than the ideal V_{BDRIVE}, the sensor can be compensated and you may proceed.

6) Measure V_{OUT} at P_{MIN}.

7) Set the pressure to P_{MAX}, and measure V_{OUT} at P_{MAX}.

8) Calculate the uncorrected FSO as follows: V_{OUT} at P_{MAX} - V_{OUT} at P_{MIN}.

9) Calculate the FSO error as follows: uncorrected FSO / ideal FSO.

10) Set the pressure to P_{MIN}, and remeasure V_{BDRIVE} (uncorrected V_{BDRIVE}).

11) Determine the ideal V_{BDRIVE} as follows: uncorrected V_{BDRIVE} / FSO error.

12) Using VR4 (FSO TC trim), set V_{BDRIVE} to ideal V_{BDRIVE}.

Example:

1) Increase the temperature to T2 and allow sufficient soak time.

2) Confirm that the supply voltage is correct.

3) Set the pressure to P_{MIN}.

4) Measure the uncorrected V_{BDRIVE} at T2 as 2.961V.

5) Since it is greater than 2.284V, we can proceed.

6) Measure V_{OUT} at P_{MIN} to be 0.6V.

7) Set the pressure to P_{MAX}, and measure V_{OUT} at P_{MAX} to be 4.72V.

8) Calculate the uncorrected FSO as follows: 4.72 - 0.6 = 4.12V.

9) Calculate FSO error as follows: 4.12 / 4 = 1.03 (approximately 3% too high).

10) Set the pressure to P_{MIN}, and remeasure V_{BDRIVE} (uncorrected V_{BDRIVE}).

11) Determine the ideal V_{BDRIVE} as follows: 2.961 / 1.03 = 2.875V.

12) Adjust VR4 (FSO TC trim) until V_{BDRIVE} = 2.875V.

Compensating Offset TC Error at T2

1) Set the pressure to P_{MIN}.

2) Measure V_{OUT} at P_{MIN}.

3) Calculate the offset TC error as follows: V_{OUT} at P_{MIN} - 0.5.

4) Calculate the delta V_{BDRIVE} as follows: ideal V_{BDRIVE} at T2 - ideal V_{BDRIVE} at T1.

5) Calculate the offset TC correction factor as follows: offset TC error / (1.15 · delta V_{BDRIVE}).

6) If offset TC error is positive, set SW1-5 to open (negative offset TC correction); if it is negative, close SW1-5.

7) Calculate V_{OFFTC} as follows: offset TC correction factor · V_{BDRIVE} at T2.

8) Measure the voltage at OFFTC (pin 8), and adjust VR1 to the value V_{OFFTC}.

Example:

1) Set the pressure to P_{MIN}.

2) Measure V_{OUT} at P_{MIN} to be 0.75V.

3) Calculate the offset TC error as follows: 0.75 - 0.5 = +0.25V.

4) Calculate delta V_{BDRIVE} as follows: 2.875 - 2.284 = +0.591V.

5) Calculate offset TC correction factor as follows: 0.25 / (1.15 · 0.591) = 0.368 (+36.7% of V_{BDRIVE}).

6) Since offset TC correction factor is positive, open SW1-5.

7) Calculate V_{OFFTC} as 0.368 · 2.875 = 1.058V.

8) Adjust VR1 until V_{OFFTC} = 1.058V.

Final Offset Readjustment at T2

1) Set VR2 fully CCW (V_{OFFSET}, pin 9 = 0).

2) Set the pressure to P_{MIN}.

3) Measure the output voltage (V_{OUT}) at P_{MIN}.

4) If V_{OUT} > 0.5V, open SW1-4; if V_{OUT} < 0.5V, close SW1-4.

5) Adjust VR2 until V_{OUT} is 0.5V.

   Example:

   1) Set VR2 fully CCW.

   2) Set the pressure to P_{MIN}.

   3) Measure V_{OUT} at P_{MIN} to be 0.05V (saturated).

   4) Close SW1-4 (add an offset voltage to the output).

   5) Adjust VR2 until V_{OUT} at P_{MIN} = 0.504V.

Calibration and temperature compensation are now complete. Temperature compensation is linear and has been optimized at the two chosen temperature points, T1 and T2. The EV kit can now be evaluated at other intermediate temperature points to determine the magnitude of nonlinear temperature errors that the MAX1450 cannot compensate. Consider the MAX1457, MAX1459, or MAX1478 for improved accuracy and manufacturability.

Frequently Asked Questions

- **The sensor voltage and/or output voltage jump erratically. How can I correct this?**

  This is caused by moisture condensation in the test oven. Purge with dry air or nitrogen.

- **The output of the board is noisy. How can I correct this?**

  Keep the sensor wires as short as possible, especially when operating at high gain settings. Add a bypass capacitor across the sensor output lines. If using an external sensor, connect shielded cables between the sensor and the MAX1450.

- **Will Maxim make custom modifications to the MAX1450 to better suit my application?**

  Yes. The MAX1450 can be modified for an N R E fee and/or a production order commitment. Contact the factory for details.

- **What can I do to minimize sensor repeatability errors on the EV kit?**

  Sensor parameters may change over time or during shipment. The sensor offset is notorious for drifting over time. A sensor "wake-up" is recommended before precise calibration measurements can be taken. This wake-up should include several full-temperature excursions, combined with full-scale pressure excursions.

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Figure 1. MAX1450 EV Kit Schematic

*R8, R9, R10 ARE SHORTED WITH
A PC BOARD TRACE.
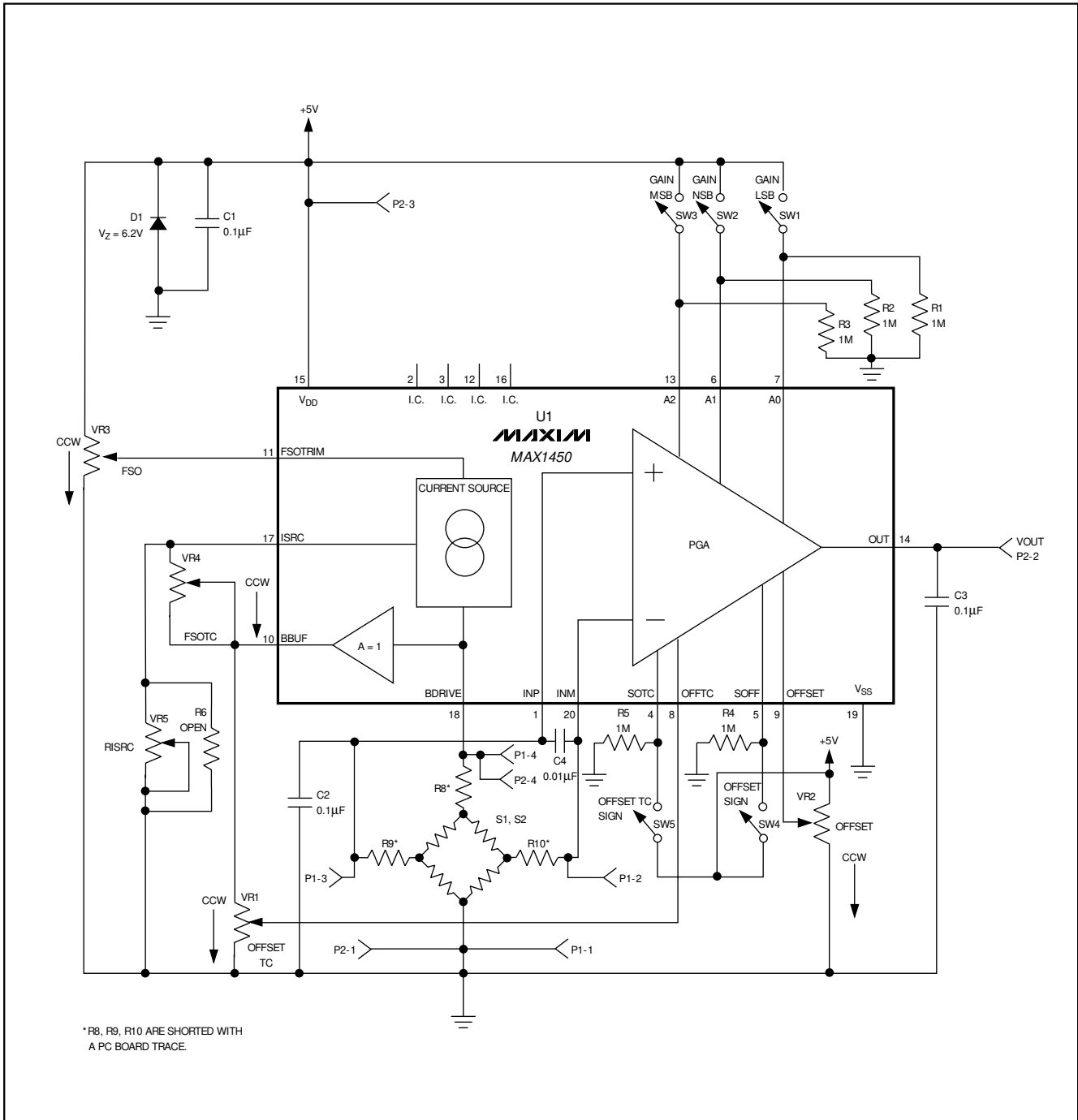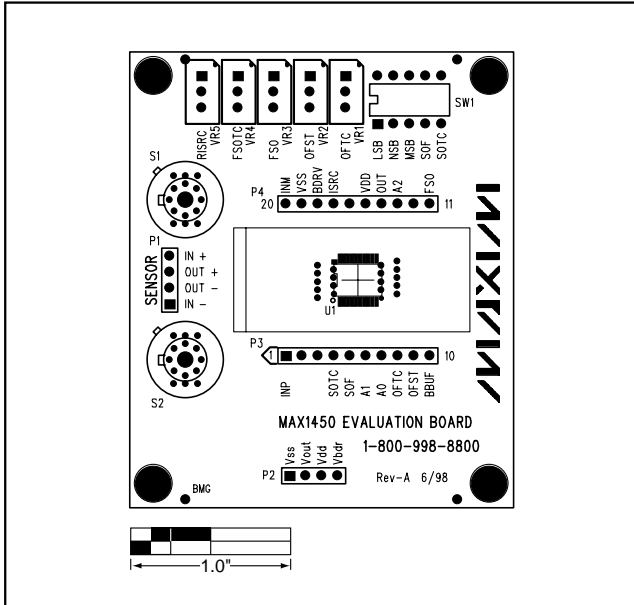
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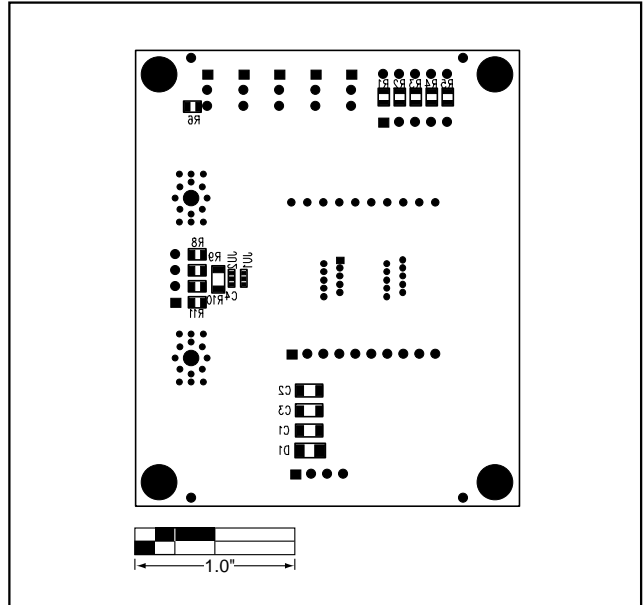Figure 2. MAX1450 EV Kit Component Placement Guide—Component Side

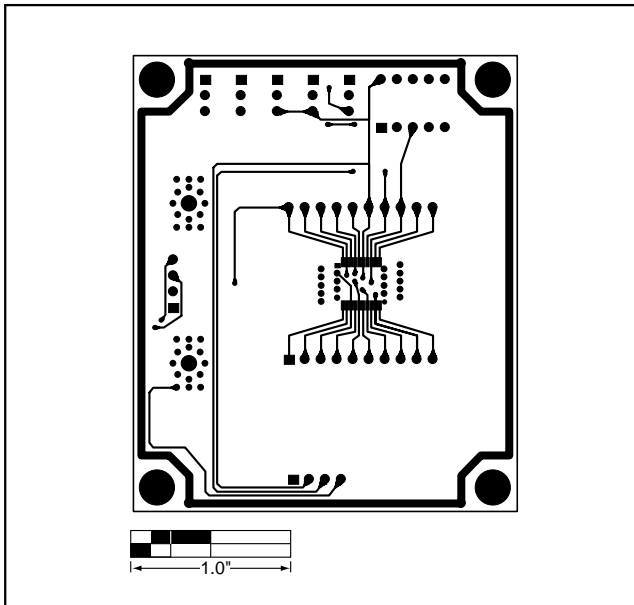Figure 3. MAX1450 EV Kit Component Placement Guide—Solder Side

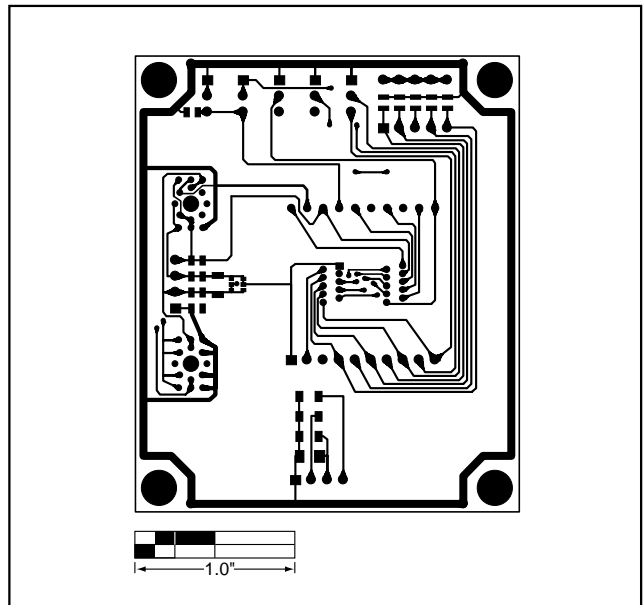Figure 4. MAX1450 EV Kit PC Board Layout—Component Side

Figure 5. MAX1450 EV Kit PC Board Layout—Solder Side

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