AN1309

Compensated Sensor Bar Graph Pressure Gauge

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INTRODUCTION

Compensated semiconductor pressure sensors such as the MPX2000 family are relatively easy to interface with digital systems. With these sensors and the circuitry described herein, pressure is translated into a 0.5 to 4.5 volt output range that is directly compatible with Microcomputer A/D inputs. The 0.5 to 4.5 volt range also facilitates interface with an LM3914, making Bar Graph Pressure Gauges relatively simple.
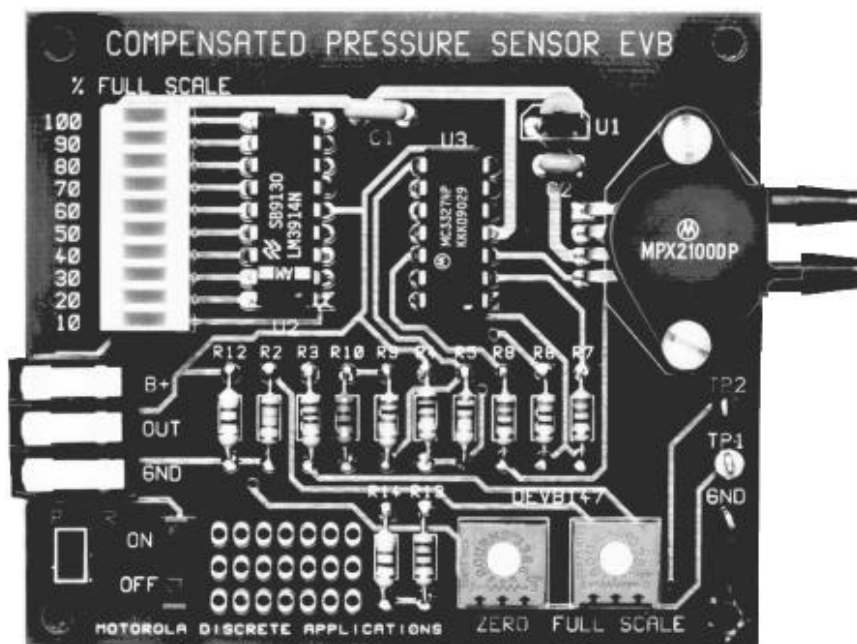

Figure 1. DEVB147 Compensated Pressure Sensor Evaluation Board

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EVALUATION BOARD DESCRIPTION

The information required to use evaluation board number DEVB147 follows, and a discussion of the design appears in the Design Considerations section.

FUNCTION

The evaluation board shown in Figure 1 is supplied with an MPX2100DP sensor and provides a 100 kPa full scale pressure measurement. It has two input ports. P1, the pressure port, is on the top side of the sensor and P2, a vacuum port, is on the bottom side. These ports can be supplied up to 100 kPa (15 psi) of pressure on P1 or up to 100 kPa of vacuum on P2, or a differential pressure up to 100 kPa between P1 and P2. Any of these sources will produce the same output.

The primary output is a 10 segment LED bar graph, which is labeled in increments of 10% of full scale, or 10 kPa with the MPX2100 sensor. An analog output is also provided. It nominally supplies 0.5 volts at zero pressure and 4.5 volts at full scale. Zero and full scale adjustments are made with potentiometers so labeled at the bottom of the board. Both adjustments are independent of one another.

ELECTRICAL CHARACTERISTICS

The following electrical characteristics are included as a guide to operation.

Characteristic	Symbol	Min	Typ	Max	Units
Power Supply Voltage	B+	6.8	—	13.2	dc Volts
Full Scale Pressure	P_{FS}	—	—	100	kPa
Overpressure	P_{MAX}	—	—	700	kPa
Analog Full Scale	V_{FS}	—	4.5	—	Volts
Analog Zero Pressure Offset	V_{OFF}	—	0.5	—	Volts
Analog Sensitivity	S_{AOUT}	—	40	—	mV/kPa
Quiescent Current	I_{CC}	—	40	—	mA
Full Scale Current	I_{FS}	—	160	—	mA

CONTENT

Board contents are described in the parts list shown in Table 1. A schematic and silk screen plot are shown in Figures 2 and 6. A pin by pin circuit description follows.

PIN-BY-PIN DESCRIPTION

B+:

Input power is supplied at the B+ terminal. Minimum input voltage is 6.8 volts and maximum is 13.2 volts. The upper limit is based upon power dissipation in the LM3914 assuming all 10 LED's are lit and ambient temperature is 25°C. The board will survive input transients up to 25 volts provided that average power dissipation in the LM3914 does not exceed 1.3 watts.

OUT:

An analog output is supplied at the OUT terminal. The signal it provides is nominally 0.5 volts at zero pressure and 4.5 volts at full scale. Zero pressure voltage is adjustable and set with R11. This output is designed to be directly connected to a microcomputer A/D channel, such as one of the E ports on an MC68HC11.

GND:

There are two ground connections. The ground terminal on the left side of the board is intended for use as the power supply return. On the right side of the board one of the test point terminals is also connected to ground. It provides a convenient place to connect instrumentation grounds.

TP1:

Test point 1 is connected to the LM3914's full scale reference voltage which sets the trip point for the uppermost LED segment. This voltage is adjusted via R1 to set full scale pressure.

TP2:

Test point 2 is connected to the +5.0 volt regulator output. It can be used to verify that supply voltage is within its 4.75 to 5.25 volt tolerance.

P1, P2:

Pressure and Vacuum ports P1 and P2 protrude from the sensor on the right side of the board. Pressure port P1 is on the top and vacuum port P2 is on the bottom. Neither port is labeled. Maximum safe pressure is 700 kPa.
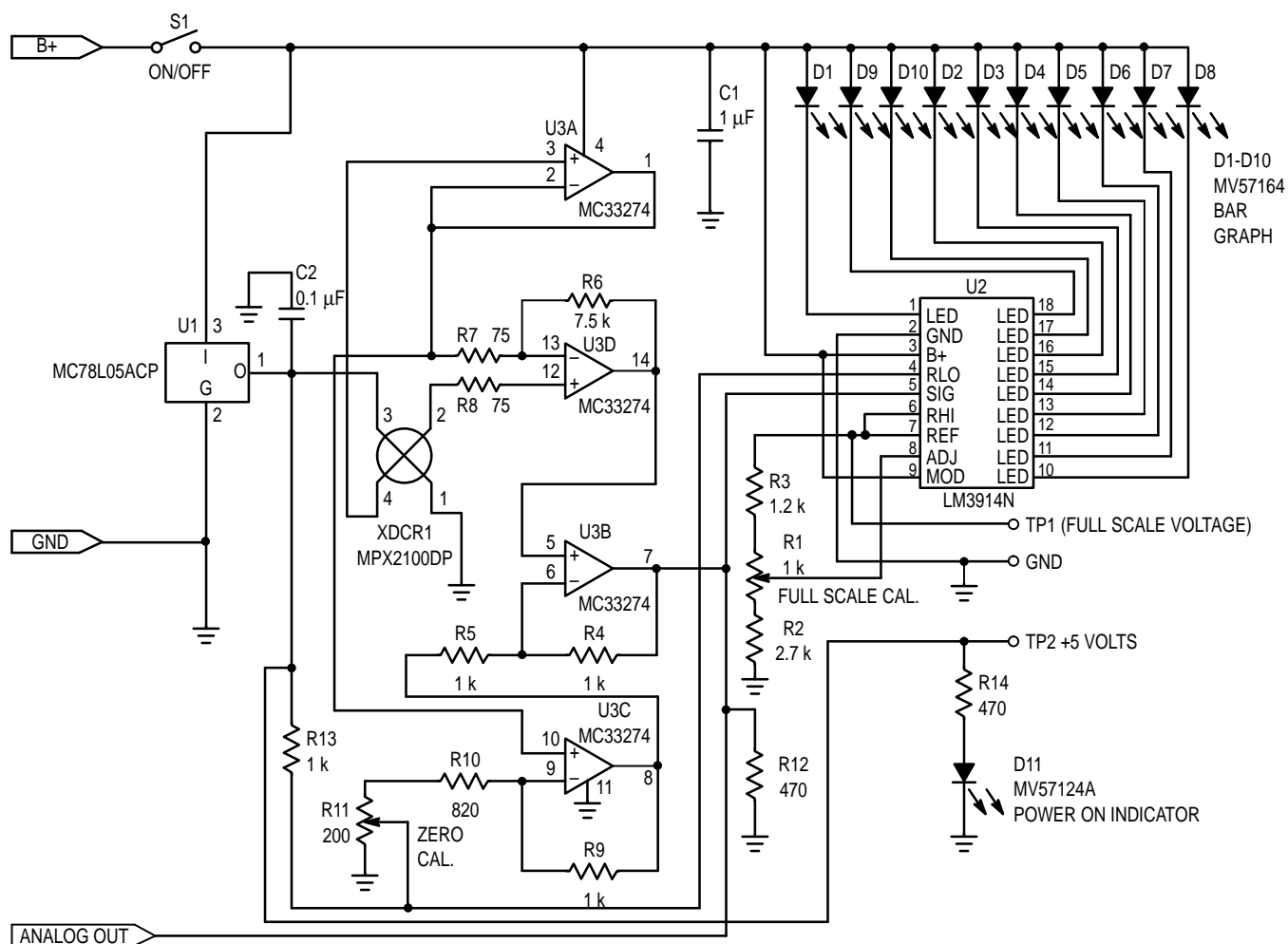
Figure 2. Compensated Pressure Sensor EVB Schematic

NOTE:
For zero pressure voltage independent
of sensor common mode R6/R7 = R2/R1
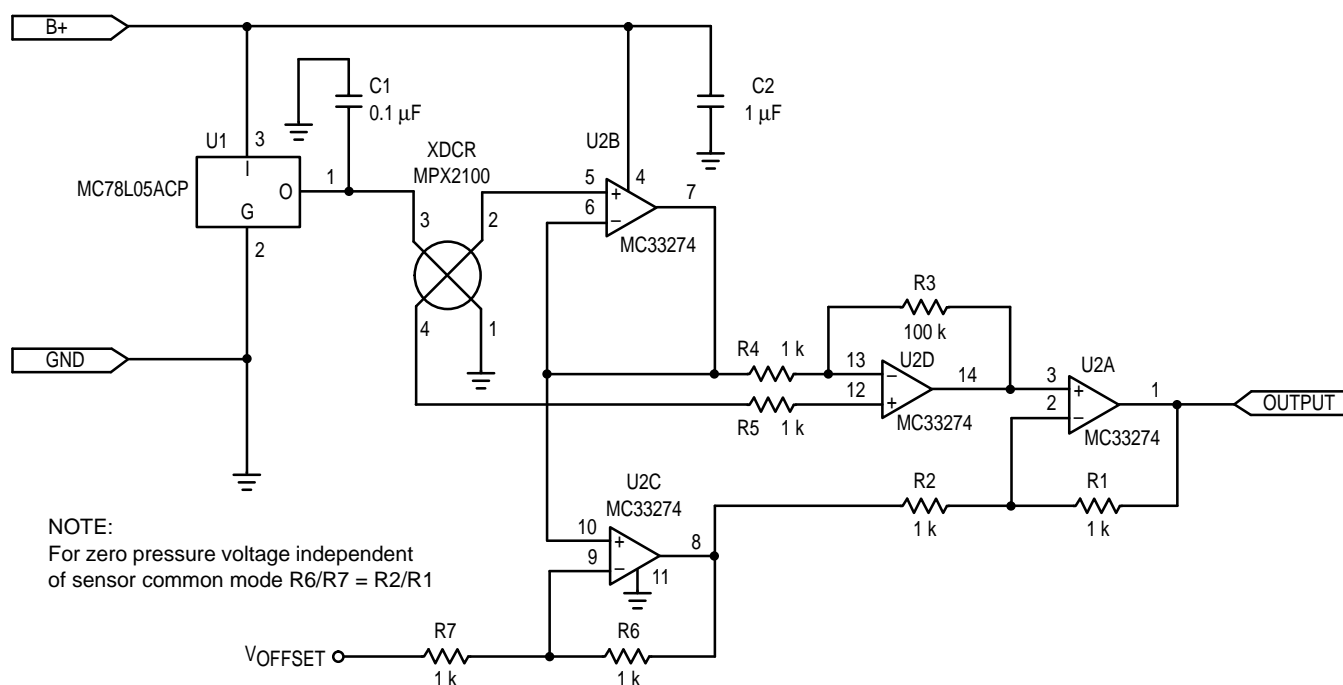
Figure 3. Compensated Sensor Interface

DESIGN CONSIDERATIONS

In this type of application the design challenge is how to take a relatively small DC coupled differential signal and produce a ground referenced output that is suitable for driving microcomputer A/D inputs. A user friendly interface circuit that will do this job is shown in Figure 3. It uses one quad op amp and several resistors to amplify and level shift the sensor's output. Most of the amplification is done in U2D which is configured as a differential amplifier. It is isolated from the sensor's positive output by U2B. The purpose of U2B is to prevent feedback current that flows through R3 and R4 from flowing into the sensor. At zero pressure the voltage from pin 2 to pin 4 on the sensor is zero volts. For example with the common mode voltage at 2.5 volts, the zero pressure output voltage at pin 14 of U2D is then 2.5 volts, since any other voltage would be coupled back to pin 13 via R3 and create a nonzero bias across U2D's differential inputs. This 2.5 volt zero pressure DC output voltage is then level translated to the desired zero pressure offset voltage (V_{OFFSET}) by U2C and U2A. To see how the level translation works, assume 0.5 volts at (V_{OFFSET}). With 2.5 volts at pin 10, pin 9 is also at 2.5 volts. This leaves 2.5 – 0.5 = 2.0 volts across R7. Since no current flows into pin 9, the same current flows through R6, producing 2.0 volts across R6 also. Adding the voltages (0.5 + 2.0 + 2.0) yields 4.5 volts at pin 8. Similarly 2.5 volts at pin 3 implies 2.5 volts at pin 2, and the drop across R2 is 4.5 V – 2.5 V = 2.0 volts. Again 2.0 volts across R2 implies an equal drop across R1, and the voltage at pin 1 is 2.5 V – 2.0 V = 0.5 volts. For this DC output voltage to be independent of the sensor's common mode voltage it is necessary to satisfy the condition that R6/R7 = R2/R1.

Gain is close but not exactly equal to R3/R4(R1/R2+1), which predicts 200.0 for the values shown in Figure 3. A more exact calculation can be performed by doing a nodal analysis, which yields 199.9. Cascading the gains of U2D and U2A

using standard op amp gain equations does not give an exact result, because the sensor's negative going differential signal at pin 4 subtracts from the DC level that is amplified by U2A.

The resulting 0.5 V to 4.5 V output from U2A is directly compatible with microprocessor A/D inputs. Tying this output to an LM3914 for a bar graph readout is also very straight forward. The block diagram that appears in Figure 4 shows the LM3914's internal architecture. Since the lower resistor in the input comparator chain is pinned out at R_{LO}, it is a simple matter to tie this pin to a voltage that is approximately equal to the interface circuit's 0.5 volt zero pressure output voltage. In Figure 2, this is accomplished by dividing down the 5.0 volt regulator's output voltage through R13 and adjustment pot R11. The voltage generated at R11's wiper is the offset voltage identified as V_{OFFSET} in Figure 3. Its source impedance is chosen to keep the total input impedance to U3C at approximately 1K. The wiper of R11 is also fed into R_{LO} for zeroing the bar graph.

The full scale measurement is set by adjusting the upper comparator's reference voltage to match the sensor's output at full pressure. An internal regulator on the LM3914 sets this voltage with the aid of resistors R2, R3, and adjustment pot R1 that are shown in Figure 2.

Five volt regulated power is supplied by an MC78L05. The LED's are powered directly from LM3914 outputs, which are set up as current sources. Output current to each LED is approximately 10 times the reference current that flows from pin 7 through R3, R1, and R2 to ground. In this design it is nominally (4.5 V/4.9K)10 = 9.2 mA.

Over a zero to 50°C temperature range combined accuracy for the sensor, interface and driver IC are +/– 10%. Given a 10 segment display total accuracy for the bar graph readout is approximately +/– (10 kPa +10%).

APPLICATION

Using the analog output to provide pressure information to a microcomputer is very straightforward. The output voltage range, which goes from 0.5 volts at zero pressure to 4.5 volts at full scale, is designed to make optimum use of microcomputer A/D inputs. A direct connection from the evaluation board analog output to an A/D input is all that is

required. Using the MC68HC11 as an example, the output is connected to any of the E ports, such as port E0 as shown in Figure 5. To get maximum accuracy from the A/D conversion, V_{REFH} is tied to 4.85 volts and V_{REFL} is tied to 0.3 volts by dividing down a 5.0 volt reference with 1% resistors.

CONCLUSION

Perhaps the most noteworthy aspect to the bar graph pressure gauge described here is the ease with which it can be designed. The interface between an MPX2000 series sensor and LM3914 bar graph display driver consists of one

quad op amp and a few resistors. The result is a simple and inexpensive circuit that is capable of measuring pressure, vacuum, or differential pressure with an output that is directly compatible to a microprocessor.
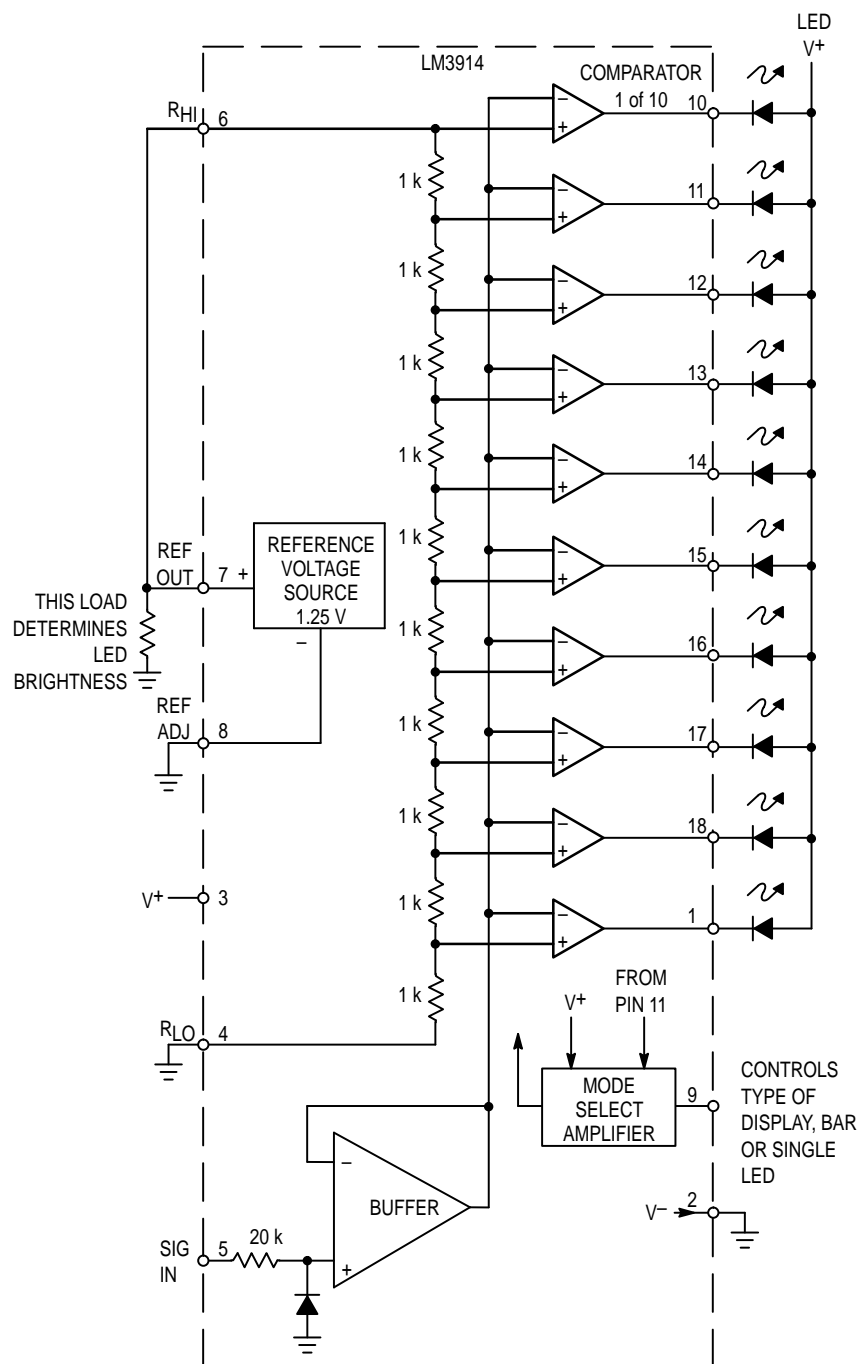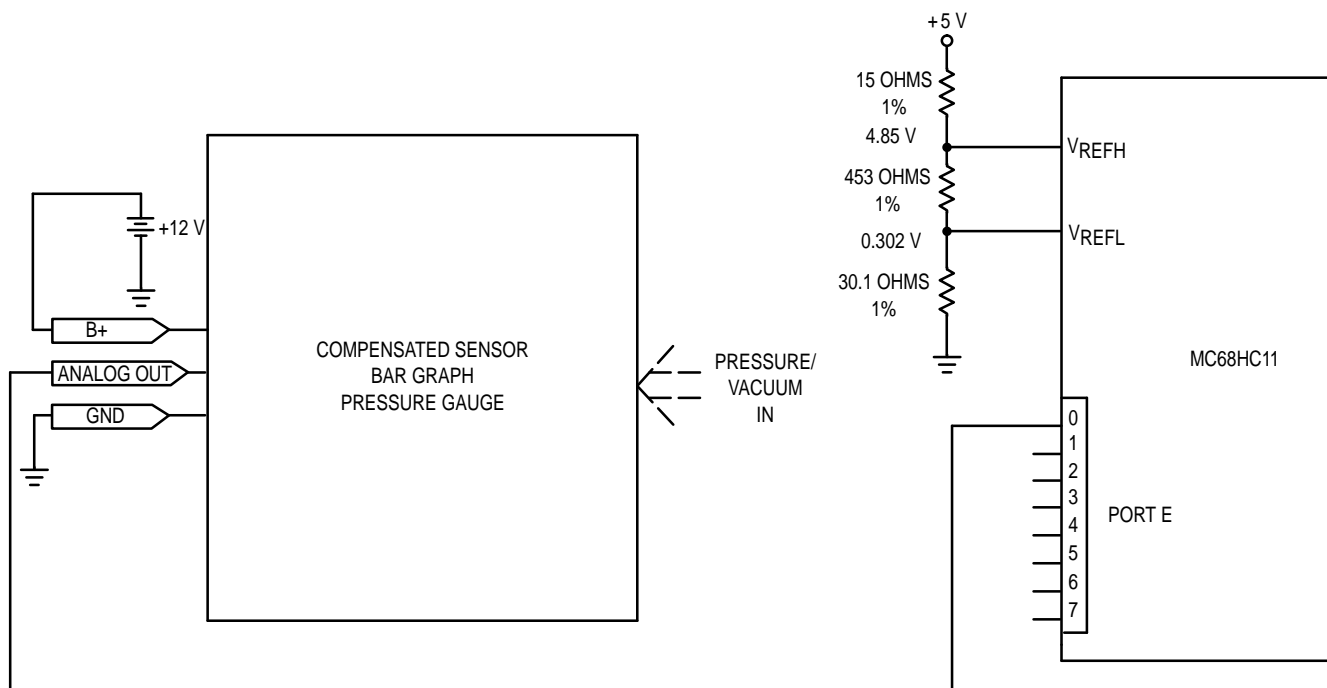
Figure 4. LM3914 Block Diagram
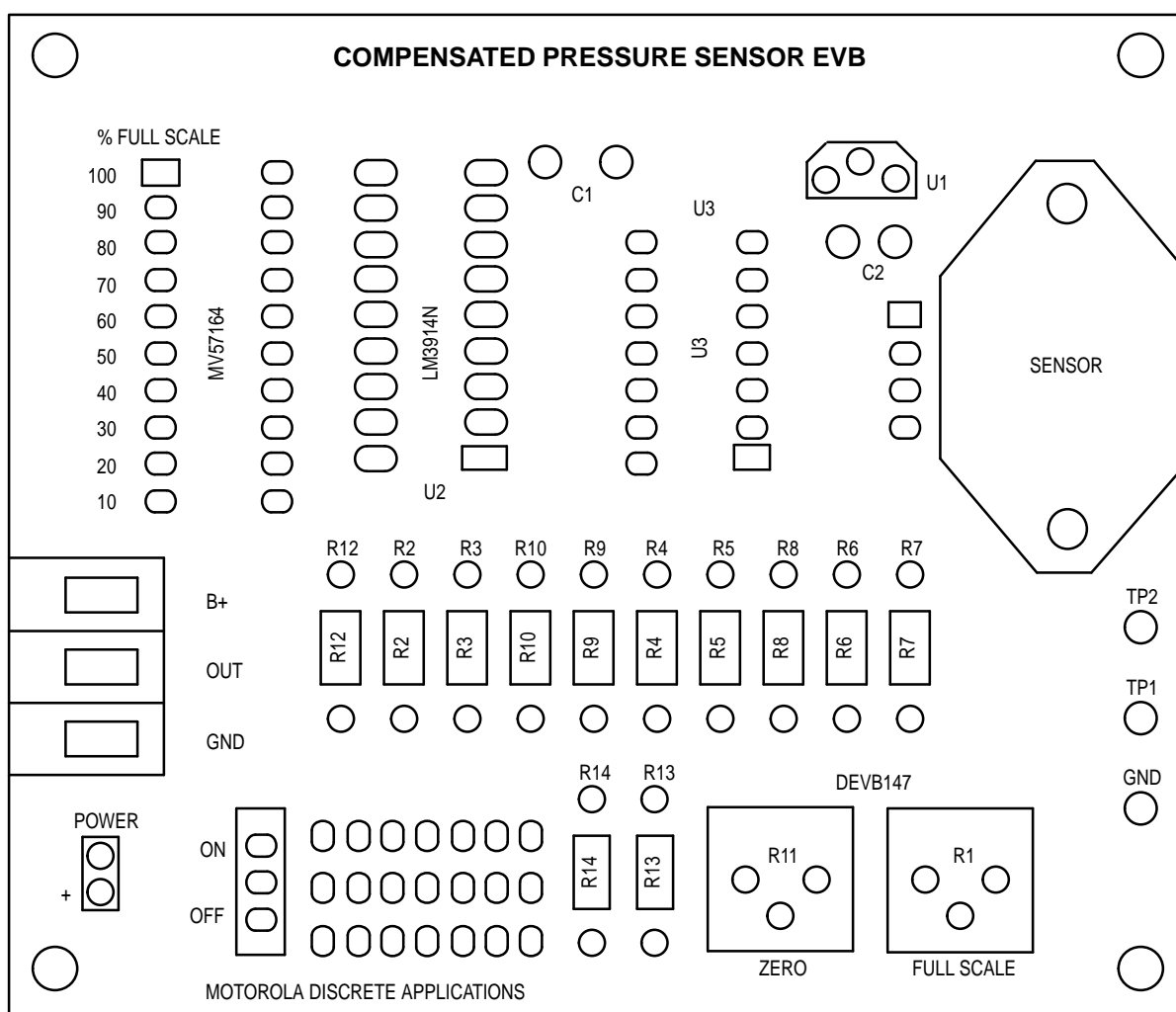
Figure 5. Application Example

Figure 6. Silk Screen

Table 1. Parts List

Designator	Qty.	Description	Value	Vendor	Part
C1	1	Ceramic Capacitor	1.0 µF		
C2	1	Ceramic Capacitor	0.1 µF		
D1-D10	1	Bar Graph LED		GI	MV57164
D11	1	LED		GI	MV57124A
R2	1	1/4 Watt Film Resistor	2.7K		
R3	1	1/4 Watt Film Resistor	1.2K		
R4, R5, R9, R13	4	1/4 Watt Film Resistor	1.0K		
R6	1	1/4 Watt Film Resistor	7.5K		
R7, R8	2	1/4 Watt Film Resistor	75		
R10	1	1/4 Watt Film Resistor	820		
R12, R14	2	1/4 Watt Film Resistor	470		
R1	1	Trimpot	1.0K	Bourns	3386P-1-102
R11	1	Trimpot	200	Bourns	3386P-1-201
S1	1	Switch		NKK	12SDP2
U1	1	5.0 V Regulator		Motorola	MC78L05ACP
U2	1	Bar Graph IC		National	LM3914N
U3	1	Op Amp		Motorola	MC33274P
XDCR1	1	Pressure Sensor		Motorola	MPX2100DP
—	1	Terminal Block		Augat	2SV03
—	1	Test Point Terminal (Black)		Components Corp.	TP1040100
—	1	Test Point Terminal (Red)		Components Corp.	TP1040102
—	1	Test Point Terminal (Yellow)		Components Corp.	TP1040104

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