

AN1322

Applying Semiconductor Sensors to Bar Graph Pressure Gauges

Prepared by: Warren Schultz
Discrete Applications Engineering

INTRODUCTION

Bar Graph displays are noted for their ability to very quickly convey a relative sense of how much of something is present. They are particularly useful in process monitoring applications where quick communication of a relative value is more important than providing specific data.

Designing bar graph pressure gauges based upon semiconductor pressure sensors is relatively straightforward. The sensors can be interfaced to bar graph display drive IC's, microcomputers and MC33161 voltage monitors. Design examples for all three types are included.

BAR GRAPH DISPLAY DRIVER

Interfacing semiconductor pressure sensors to a bar graph display IC such as an LM3914 is very similar to microcomputer interface. The same 0.5 to 4.5 V analog signal that a microcomputer's A/D converter wants to see is also quite suitable for driving an LM3914. In Figure 1, this interface is provided by dual op amp U2 and several resistors.

The op amp interface amplifies and level shifts the sensor's output. To see how this amplifier works, simplify it by grounding the output of voltage divider R3, R5. If the common mode voltage at pins 2 and 4 of the sensor is 4.0 V, then pin 2 of U2A and pin 6 of U2B are also at 4.0 V. This puts 4.0 V across R6. Assuming that the current in R4 is equal to the current in R6, $323 \mu\text{A} \cdot 100 \text{ ohms}$ produces a 32 mV drop across R4 which adds to the 4.0 V at pin 2. The output voltage at pin 1 of U2A is, therefore, 4.032 V. This puts $4.032 - 4.0 \text{ V}$ across R2, producing 43 μA . The same current flowing through R1 again produces a voltage drop of 4.0 V, which sets the output at zero. Substituting a divider output greater than zero into this calculation reveals that the zero pressure output voltage is equal to the output voltage of divider R3, R5. For this DC output voltage to be independent of the sensor's common mode voltage, it is necessary to satisfy the condition that $R1/R2 = R6/R4$.

Gain can be determined by assuming a differential output at the sensor and going through the same calculation. To do this assume 100 mV of differential output, which puts pin 2 of

U2A at 3.95 V, and pin 6 of U2B at 4.05 V. Therefore, 3.95 V is applied to R6, generating 319 μA . This current flowing through R4 produces 31.9 mV, placing pin 1 of U2A at $3950 \text{ mV} + 31.9 \text{ mV} = 3982 \text{ mV}$. The voltage across R2 is then $4050 \text{ mV} - 3982 \text{ mV} = 68 \text{ mV}$, which produces a current of 91 μA that flows into R1. The output voltage is then $4.05 \text{ V} + (91 \mu\text{A} \cdot 93.1\text{k}) = 12.5 \text{ V}$. Dividing 12.5 V by the 100 mV input yields a gain of 125, which provides a 4.0 V span for 32 mV of full scale sensor output.

Setting divider R3, R5 at 0.5 V results in a 0.5 V to 4.5 V output that is easily tied to an LM3914. The block diagram that appears in Figure 2 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 V zero pressure output voltage. Returning to Figure 1, this is accomplished by using the zero pressure offset voltage that is generated at the output of divider R3, R5.

Again looking at Figure 1, full scale 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 R7, R9, and adjustment pot R8.

Eight volt regulated power is supplied by an MC78L08. 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 R7, R8, and R9 to ground. In this design it is nominally $(4.5 \text{ V}/4.9 \text{ k})10 = 9.2 \text{ mA}$.

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

This circuit can be simplified by substituting an MPX5100 integrated sensor for the MPX2100 and the op amp interface. The resulting schematic is shown in Figure 3. In this case zero reference for the bar graph is provided by dividing down the 5 V regulator with R4, R1 and adjustment pot R6. The voltage at the wiper of R6 is adjusted to match the sensor's zero pressure offset voltage. It is connected to R_{LO} to zero the bar graph.

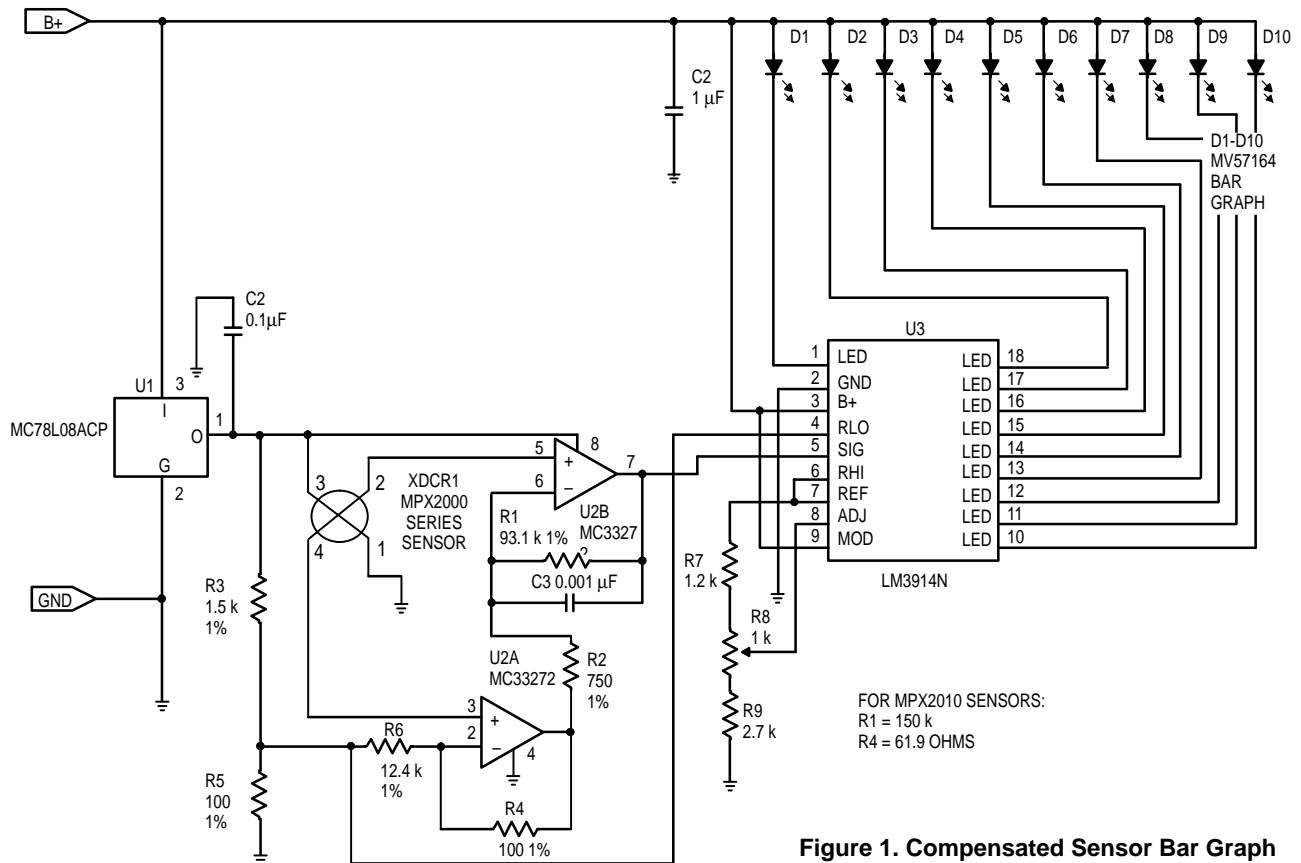


Figure 1. Compensated Sensor Bar Graph Pressure Gauge

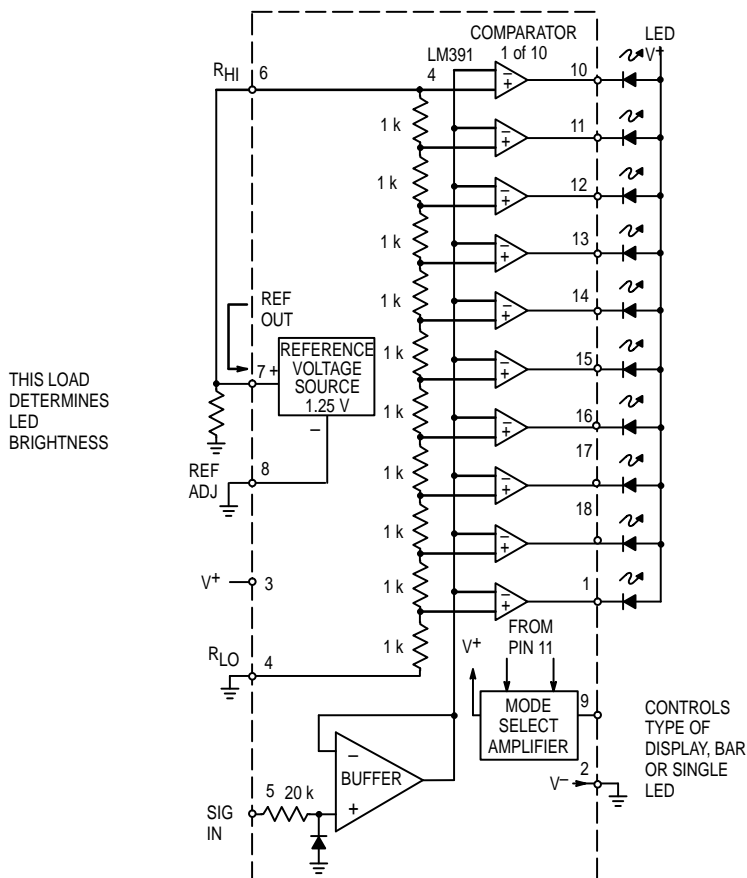


Figure 2. LM3914 Block Diagram

Figure 4. Microcomputer Bar Graph Pressure Gauge

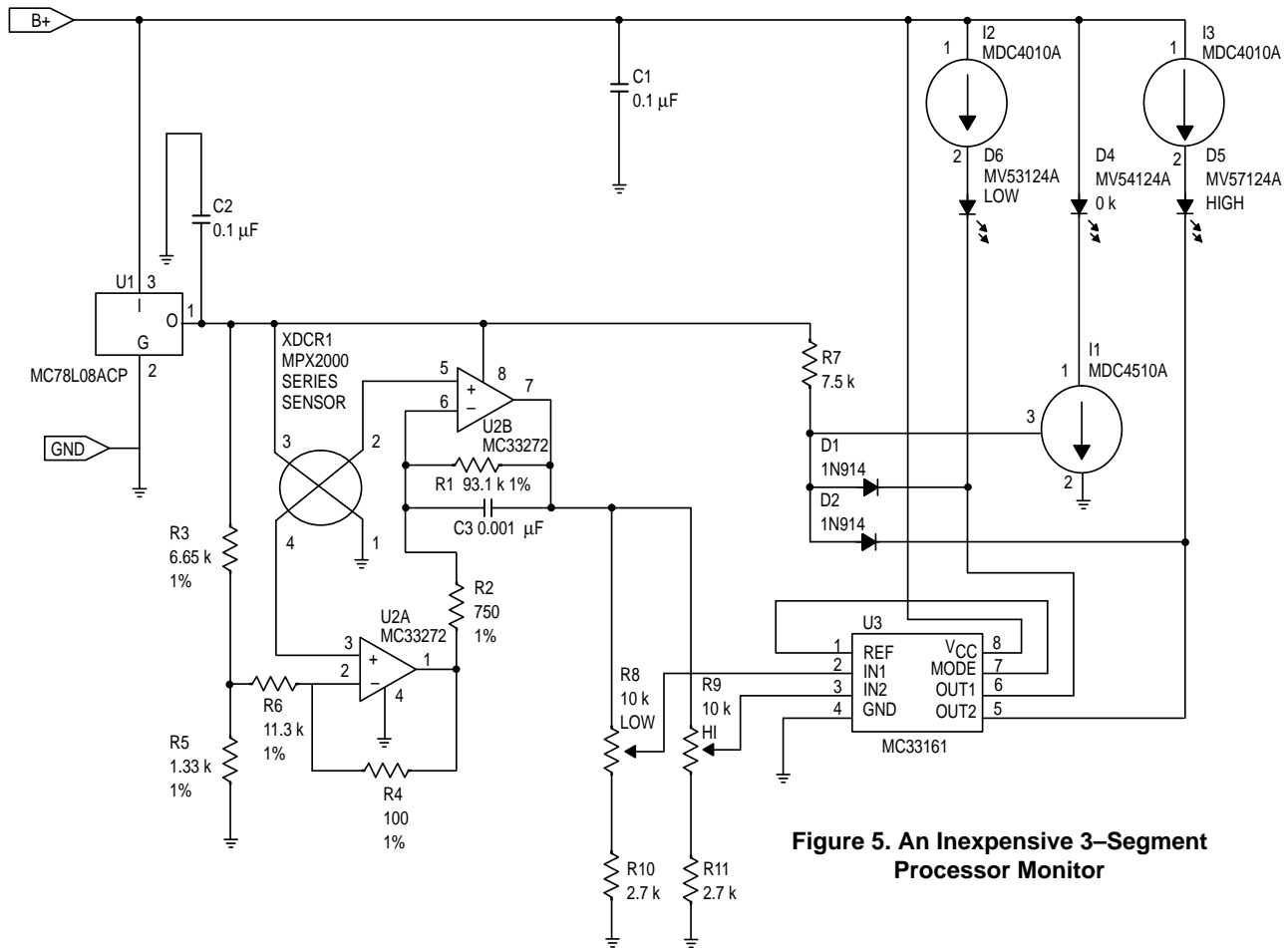


Figure 5. An Inexpensive 3-Segment Processor Monitor

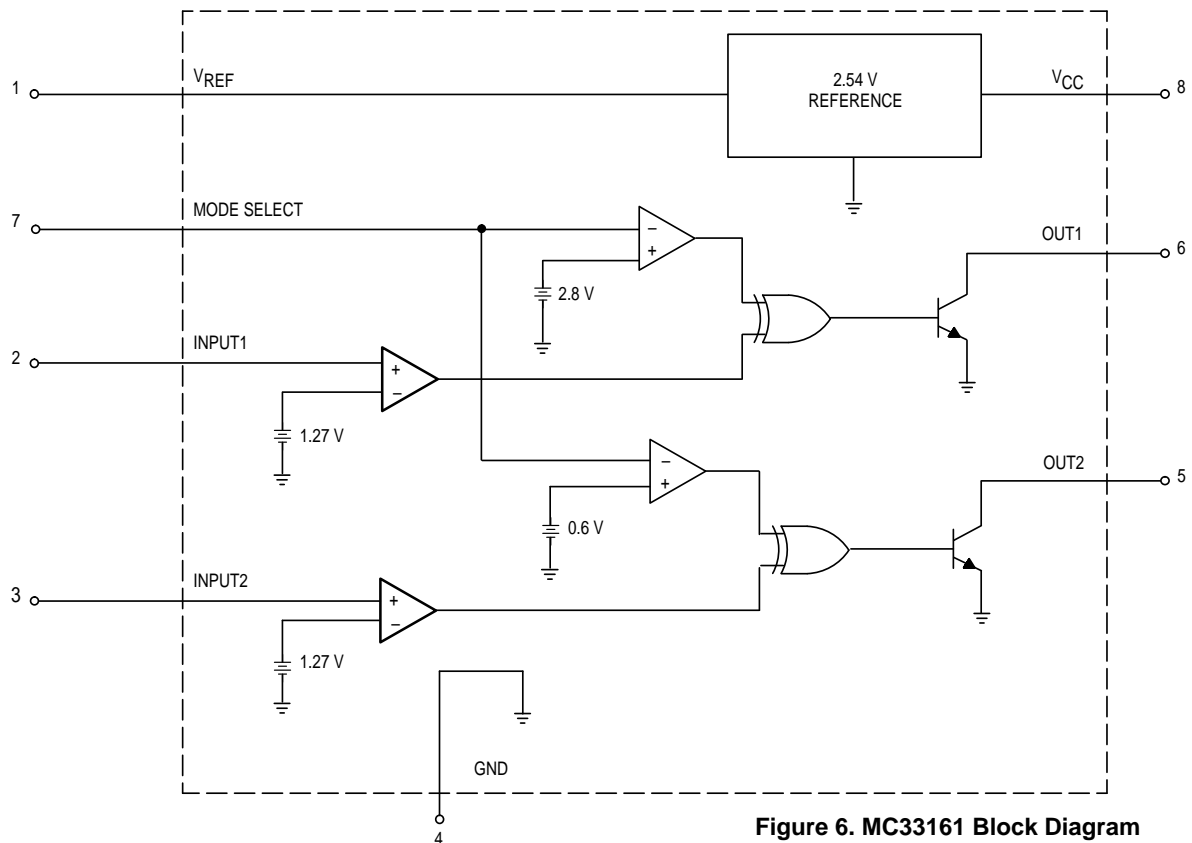


Figure 6. MC33161 Block Diagram

MICROCOMPUTER BAR GRAPH

Microcomputers with internal A/D converters such as an MC68HC05B5 lend themselves to easily creating bar graphs. Using the A/D converter to measure the sensor's analog output voltage and output ports to individually switch LED's makes a relatively straightforward pressure gauge. This type of design is facilitated by a new MDC4510A gated current sink. The MDC4510A takes one of the processor's logic outputs and switches 10 mA to an LED. One advantage of this approach is that it is very flexible regarding the number of segments that are used, and has the availability through software to independently adjust scaling factors for each segment. This approach is particularly useful for process monitoring in systems where a microprocessor is already in place.

Figure 4 shows a direct connection from an MPX5100 sensor to the microcomputer. Similar to the previous example, an MPX2000 series sensor with the op amp interface that is shown in Figure 1 can be substituted for the MPX5100. In this case the op amp interface's output at pin 7 ties to port PD5, and its supply needs to come from a source greater than 6.5 V.

PROCESS MONITOR

For applications where an inexpensive HIGH-LOW-OK process monitor is required, the circuit in Figure 5 does a good job. It uses an MC33161 Universal Voltage Monitor and the same analog interface previously described to indicate high, low or in-range pressure.

A block diagram of the MC33161 is illustrated in Figure 6. By tying pin 1 to pin 7 it is set up as a window detector. Whenever input 1 exceeds 1.27 V, two logic ones are placed at the inputs of its exclusive OR gate, turning off output 1. Therefore this output is on unless the lower threshold is exceeded. When 1.27 V is exceeded on input 2, just the opposite occurs. A single logic one appears at its exclusive OR gate, turning on output 2. These two outputs drive LED's through MDC4010A 10 mA current sources to indicate low pressure and high pressure.

Returning to Figure 5, an in-range indication is developed by turning on current source I1 whenever both the high and low outputs are off. This function is accomplished with a discrete gate made from D1, D2 and R7. Its output feeds the

input of switched current source I1, turning it on with R7 when neither D1 nor D2 is forward biased.


Thresholds are set independently with R8 and R9. They sample the same 4.0 V full scale span that is used in the other examples. However, zero pressure offset is targeted for 1.3 V. This voltage was chosen to approximate the 1.27 V reference at both inputs, which avoids throwing away the sensor's analog output signal to overcome the MC33161's input threshold. In addition, R10 and R11 are selected such that at full scale output, ie., 5.3 V on pin 7, the low side of the pots is nominally at 1.1 V. This keeps the minimum input just below the comparator thresholds of 1.27 V, and maximizes the resolution available from adjustment pots R8 and R9. When level adjustment is not desired, R8 – R11 can be replaced by a simpler string of three fixed resistors.

CONCLUSION

The circuits that have been shown here are intended to make simple, practical and cost effective bar graph pressure gauges. Their application involves a variety of trade-offs that can be matched to the needs of individual applications. In general, the most important trade-offs are the number of segments required and processor utilization. If the system in which the bar graph is used already has a microprocessor with unused A/D channels and I/O ports, tying MDC4510A current sources to the unused output ports is a very cost effective solution. On a stand-alone basis, the MC33161 based process monitor is the most cost effective where only 2 or 3 segments are required. Applications that require a larger number of segments are generally best served by one of the circuits that uses a dedicated bar graph display.

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