MOTOROLA
SEMICONDUCTOR
APPLICATION NOTE

T-65-03

AN961

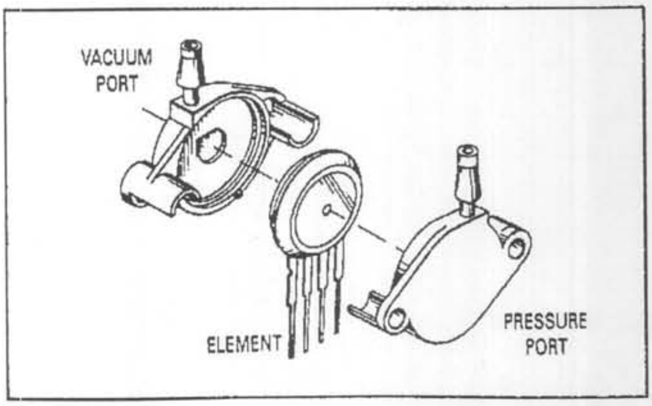
Interfacing The MPX2000 Series Silicon Pressure Sensors

Prepared by
Gene Swensen, Sensor Engineering
Semiconductor Products Sector

INTRODUCTION

The MPX Series of monolithic, on-chip compensated, silicon pressure sensors offer highly stable performance over the temperature range of −40° to 125°C, providing an ideal solution for users who choose to achieve temperature compensated performance without the cost and burden of part-by-part temperature characterization.

The MPX2000 Series of silicon pressure sensors are temperature compensated, calibrated versions of the standard MPX10, MPX50, MPX100 and MPX200 uncalibrated devices. Designated MPX2010 thru MPX2200 these sensors complement the standard line of pressure ranges of 10 kPa thru 200 kPa. As with their companion devices, the MPX2000 Series sensors are available as unported elements and as ported assemblies suitable for pressure, vacuum and differential pressure measurements. Refer to MPX2010 thru MPX2200 Data Sheets for dimensional and port-configuration suffix information.



MPX2000 Series calibrated, temperature compensated silicon pressure sensors are available as unported elements, vacuum ported, pressure ported, or supplied with two ports for differential measurements.

Figure 1.

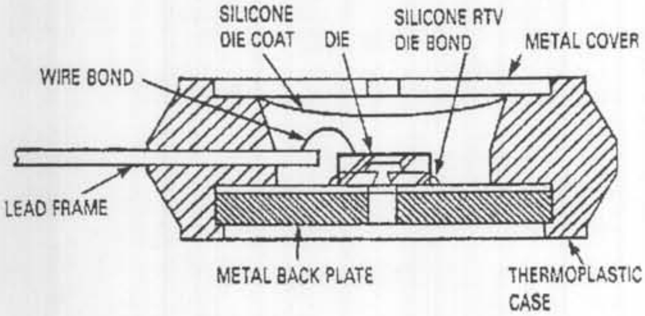


Figure 2 shows the cross section of the Motorola MPX pressure sensor die in the chip carrier package. A silicone gel isolates the die surface and wire bonds from harsh environments, while allowing the pressure signal to be transmitted to the silicon diaphragm.

Figure 2. MPX Differential Pressure Sensor Element Cross Section

ON CHIP CALIBRATION AND COMPENSATION

Calibration and temperature compensation are achieved on-chip with two diffused thermistors and ten thin-film resistors, all of which are deposited on the periphery of the substrate. Five resistors and both thermistors are laser trimmed to ensure compliance with the published specifications. Resistors R_{off1} and R_{off2} in Figure 4 serve as a voltage divider to zero the offset voltage with zero pressure applied. Thermistors R_{TCoff1} and R_{TCoff2} are selected to stabilize the initial value of offset over temperature. R_{s1} equals R_{s2} to assure symmetry; these values combined with R_p establish span calibration and compensation over temperature.

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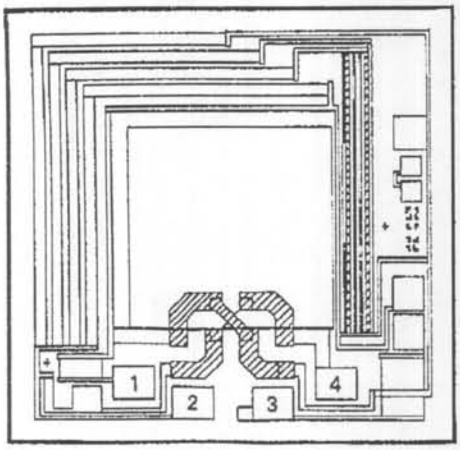
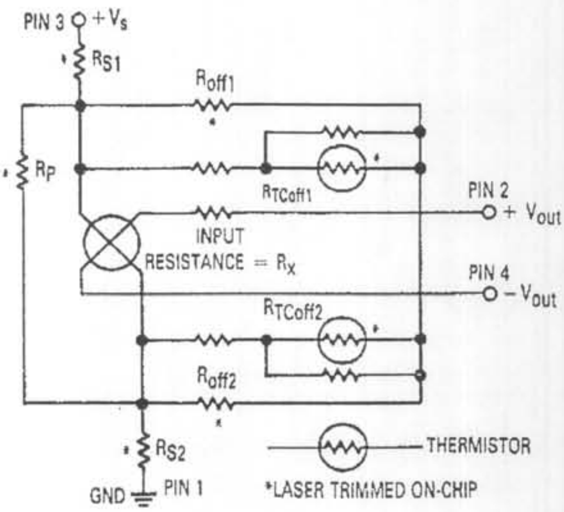


Monolithic pressure sensor chip, showing diaphragm, shear stress strain gage, thin-film resistor circuitry and pin out.

Figure 3. Monolithic Pressure Sensor Chip



Five laser-trimmed resistors and two thermistors calibrate the sensor for offset, span, and symmetry as well as provide temperature compensation.

Figure 4. Temperature Compensated Pressure Sensor Circuit

PERFORMANCE CHARACTERISTICS

MPX2000 Series Pressure Sensors are designed to provide an output of 4 mV/V Excitation with full-scale pressure applied, or 40 mV at the recommended excitation of 10 Vdc. Variations in span, linearity, offset and hysteresis will modify this output within the limits of the Operating Characteristics listed on the Data Sheet. The magnitude of these variations will be affected by the initial trimmed values and the device performance over a specified temperature range. The circuit designer should have a full understanding of MPX2000 performance characteristics as weighed against his design requirements prior to selecting an interface circuit design approach. Shown in Figures 5, 6 and 7, are the MPX2000 worst-case performance windows at 25°C, 0° to 85°C, and −40° to 125°C respectively.

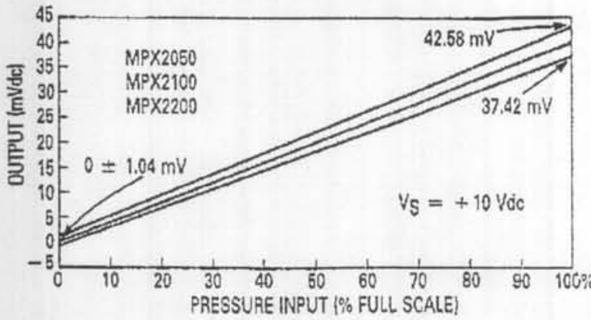


Figure 5. Output versus Pressure Differential Performance Window at 25°C

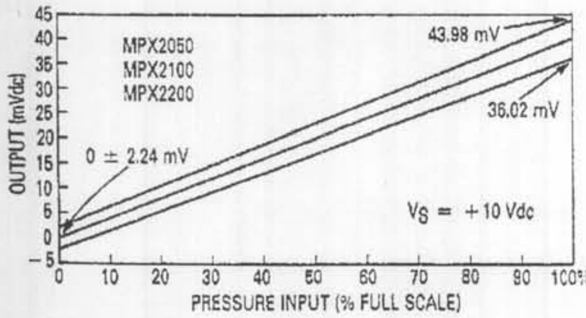


Figure 6. Output versus Pressure Differential Performance Window at 0°C to 85°C

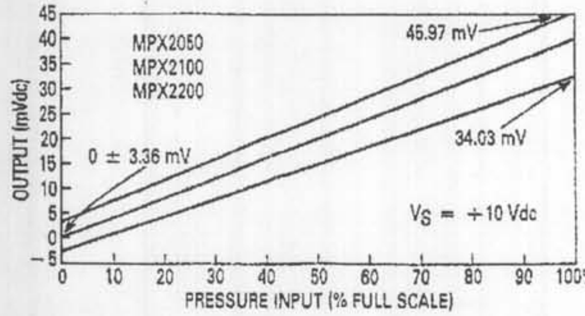


Figure 7. Output versus Pressure Differential Performance Window at −40°C to 125°C

IMPROVED PERFORMANCE CHARACTERISTICS

Many design requirements specify initial values of offset and span more precise than those values offered by the MPX2000 series sensors. With the addition of simple circuitry to fine-tune the offset and span, worst-case performance can be improved considerably and will comply with those limits exhibited in Figures 8, 9 and 10.

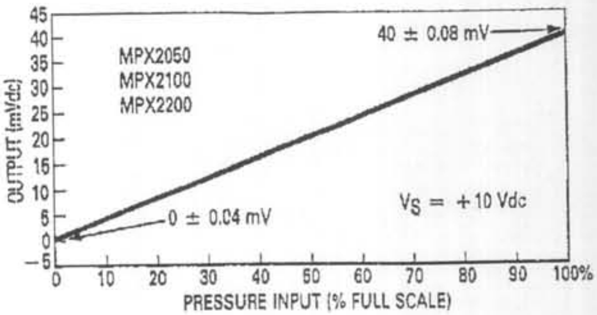


Figure 8. Improved Performance Characteristics. Output versus Pressure Differential Performance Window at 25°C.

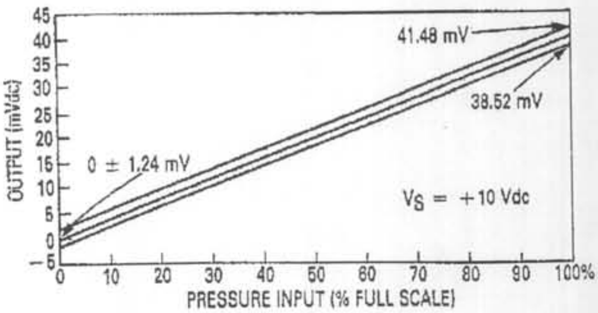


Figure 9. Improved Performance Characteristics. Output versus Pressure Differential Performance Window at 0°C to 85°C.

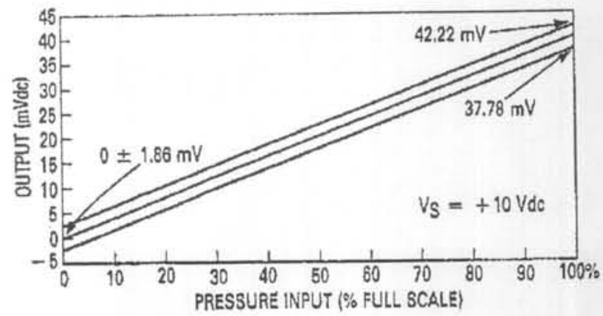
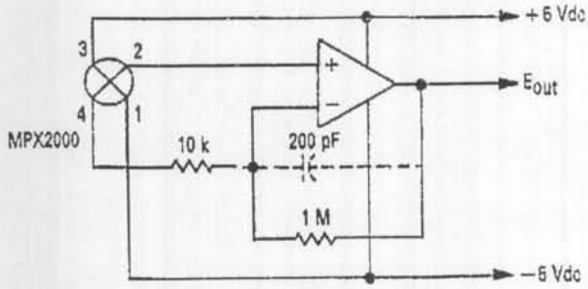


Figure 10. Improved Performance Characteristics. Output versus Pressure Differential Performance Window at −40°C to 125°C.

Figure 11. Interface Circuits

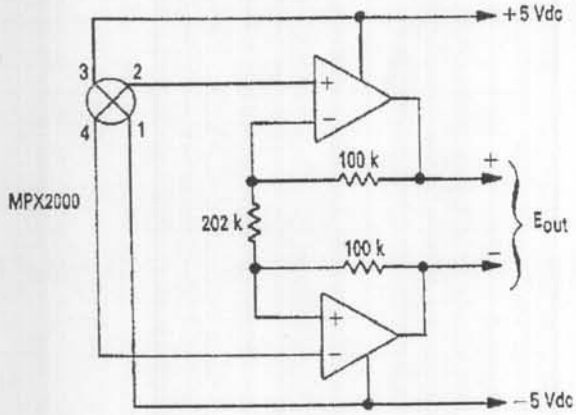
Circuits a) thru f) are compatible with the Performance Characteristics Curves shown in Figures 5, 6 and 7.



a) Simple Pressure to Voltage Converter. Split Supply.

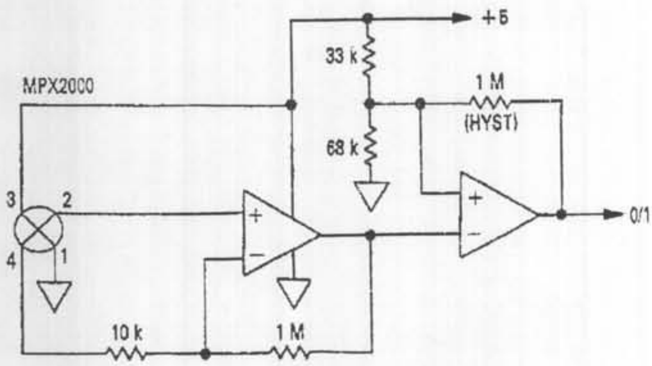
Output referenced to ground. E_O = ± 4 Vdc with full-scale pressure (vacuum) applied.

*Use 200 pF where board layout has not been optimized to reduce parasitic oscillations.



b) Differential Output. Split Supply.

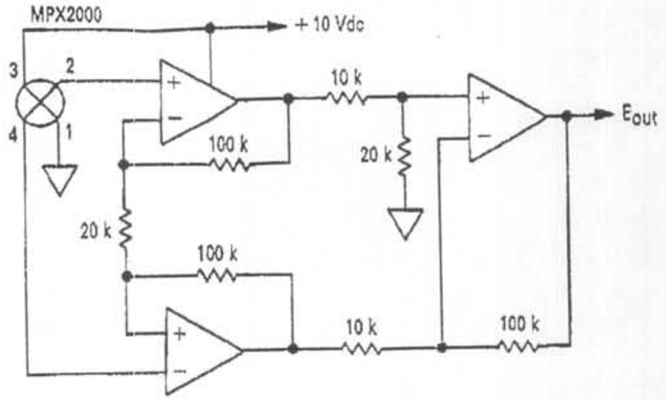
Output (+) referenced to Output (−). E_O = 0.0 Vdc at zero pressure applied. +4 Vdc to −4 Vdc output with full-scale pressure (+) or vacuum (−) applied.



c) Single-ended Supply, TTL or CMOS Logic Compatible Comparator.

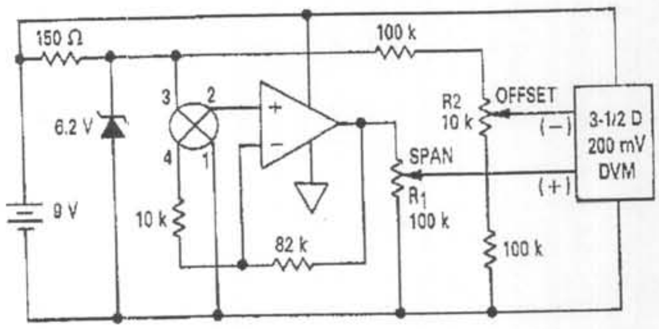
Output switches low at 55% full-scale input; switches high at 45% input. 1 M Hysteresis resistor may be removed or value changed according to user requirements.

Figure 11 (continued)



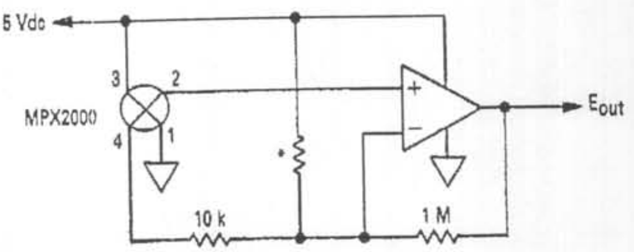
d) Single-ended Supply, Ground Referenced Output.

E_O = 8 Vdc with 100% pressure applied. Circuit is ratiometric. Output is 80% V_{CC} with 100% pressure applied.



e) Battery Operated, DVM Compatible Manometer.

Full-scale output equals 200 mV; use R1 to scale conversion units, R2 to adjust Offset.



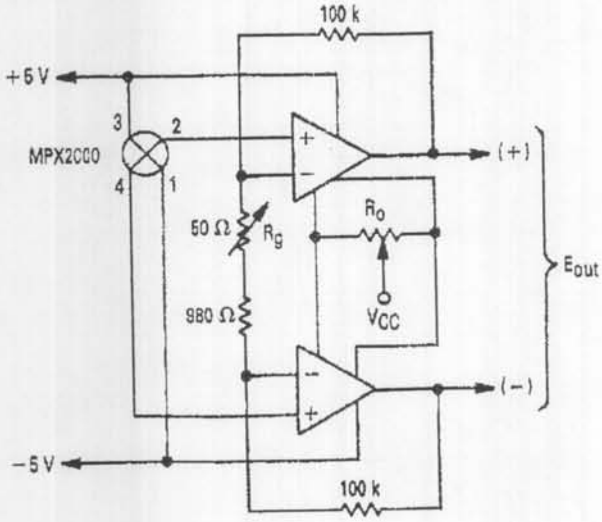
f) 5 V, Single-ended Supply, Pedestal Referenced Output.

E_O is +4 Vdc plus Pedestal Voltage with full-scale pressure applied.

*Select for desired pedestal. (≅ 100 k = 1 V)

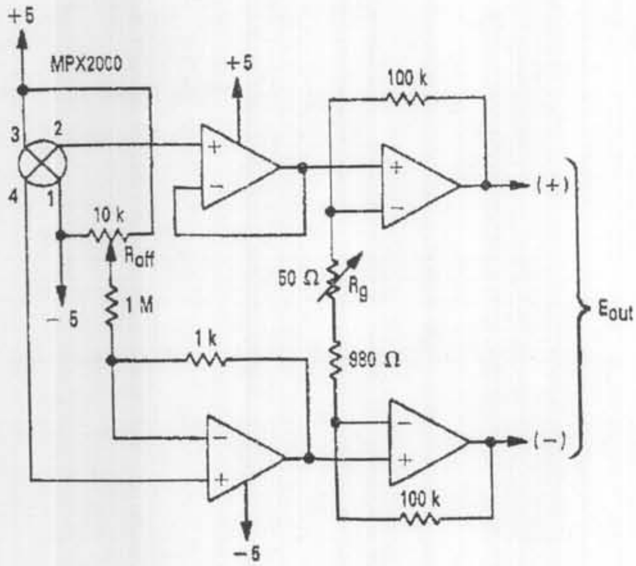
Figure 12. Interface Circuits

Circuits a) thru f) are compatible with Performance Characteristic Curves shown in Figures 8, 9 and 10.



a) Precision, Dual Op-Amp Pressure-to-Voltage Converter.

Set SPAN with R_g, then set OFFSET with R_o. Differential output is ± 8 Vdc with full pressure (vacuum) applied.

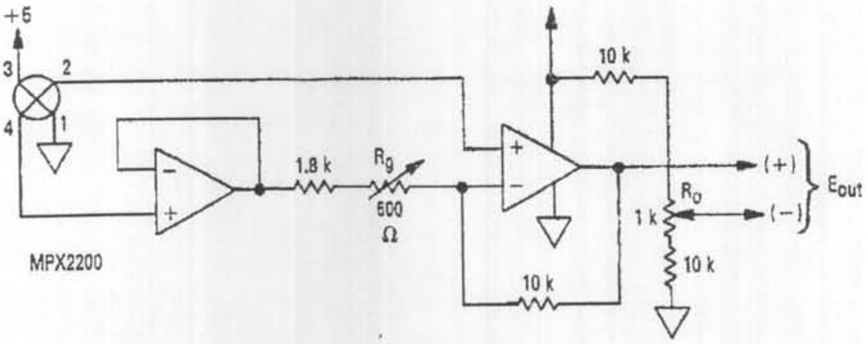


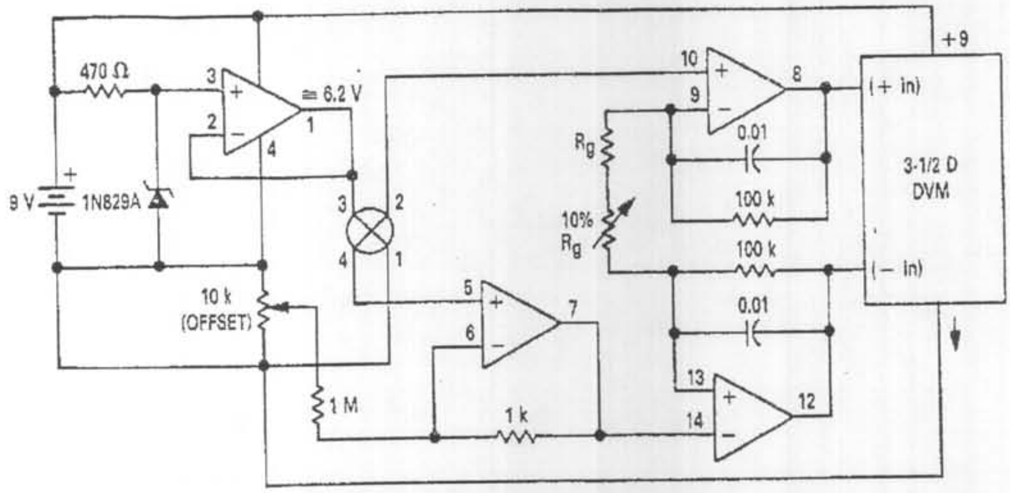
b) Precision Pressure-to-Voltage Converter using Quad Op-Amp.

DVM or μP compatible input. Set SPAN with R_g, then OFFSET with R_{off}. Differential output is ± 8 Vdc with full-scale pressure (vacuum) applied.

Figure 12 (continued)

c) **200 kPa to 200 mV Converter.**
1 mV/kPa for microprocessor input, or read directly from 3-1/2 Digit DVM. Set R_g for SPAN and then R_o for OFFSET.



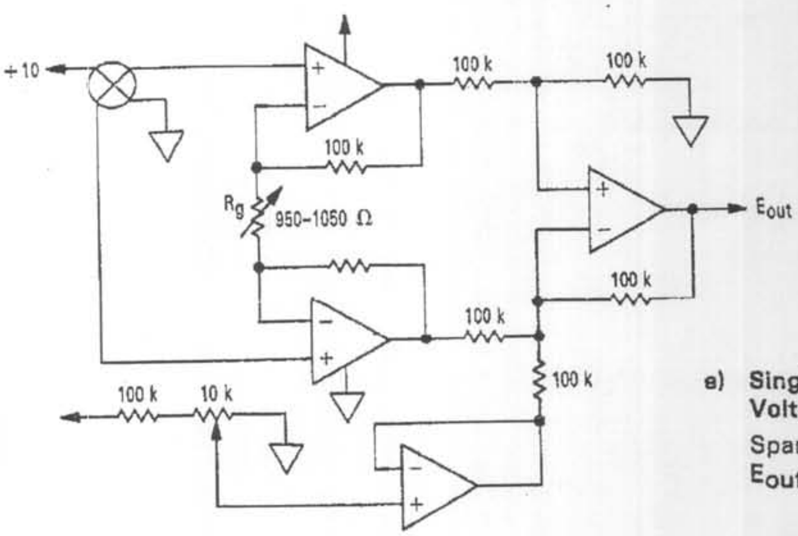


d) **Precision Portable Manometer.**
Better than ±.5% accuracy over normal ambient range using metal-film resistors and similar accuracy rated DVM. Use R_g + 10% R_g to set span and accomplish conversion ratio.

EXAMPLE: Determine R_g using an MPX2050P sensor to measure and display 0–199.9 mm/Hg.

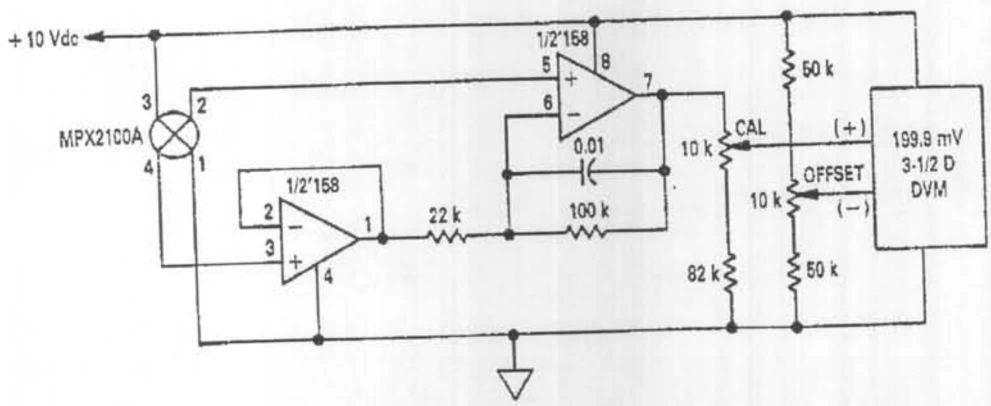
1. Required scale factor is 1 mm/Hg = 1 mV to DVM.
2. XDCR scale factor is 4 mV/V/50 kPa or 80 μV/V/kPa. Excitation V is 6.2 V; so XDCR scale factor is 6.2 x 80 = 496 μV/kPa.
3. Convert mm/Hg to kPa (1 kPa = 7.50062 mm/H_g).
4. Convert total span to kPa. (199.9/7.50062 = 26.65 kPa)
5. Determine XDCR output at full scale. (496 μV x 26.65 = 13.218 mV)
6. Amplifier Gain required is: (199.9 mV/13.218 mV) = 15.123 V/V.
7. $A_V = \frac{2\ R_{fb}}{R_g} + 1$ so $A_V - 1 = \frac{200\ \text{k}}{X} = 14.161$ k

   To select practical values let R_g = 13 k and (R_g) = 2 k.



e) **Single Supply, Ground Referenced, Pressure-to-Voltage Converter.**
Span and Offset controls are independent.
E_{out} is +8 Vdc with full scale pressure applied.

Figure 12 (continued)



f) **Barometer — Displays in kPa.**

Calibration Procedures

A) Vacuum Reference Procedure.

With a full vacuum applied, adjust the OFFSET pot for 00.00 displayed. With vacuum removed, adjust CAL for local barometric pressure.

B) Two-point Procedure with no Vacuum Reference.

Record the displayed reading and local pressure. With a change in local pressure, record the new local pressure and displayed reading. Adjust CAL in the proper direction so that the change in displayed reading equals the change in local pressure. Repeat as necessary. Now adjust OFFSET so that the displayed reading equals local pressure.

Conversion Factor: 100 kPa = 29.529 in/H_g

COMPONENT SELECTION

While sensor performance will remain within the limits of the windows specified in this document, care must be taken to assure that circuit performance will not degrade the apparent output of the device. Select the operational amplifier according to the temperature, drift, noise and stability requirements of your design goal. Select resistors appropriate to the temperature environment. Use metal-film resistors for extended temperature range operation. Use temperature compensated reference diodes or appropriately rated regulators where generation of the excitation voltage is integral to the packaged assembly. Determine that the support circuitry will meet the performance requirements of your design over temperature independent of the sensor.

MOUNTING TECHNIQUES

Refer to Applications Note AN936, "Mounting Techniques, Lead Forming, and Testing of Motorola's MPX Series Pressure Sensors."

Lead forming and mounting techniques, if not properly applied, may contribute large offsets and further degradation of sensor performance, especially over temperature. Thoroughly understand the mechanical handling and mounting ground rules prior to finalizing the mechanical portions of your design.

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