Signal conditioning circuitry for the RCO and HDO pressure sensors

INTRODUCTION

The signal conditioning circuitry described below has been especially designed for First Sensors RCO series pressure sensors. However it can be applied to all sensors with a Common Mode voltage which is half of the supply voltage ($V_{CM} \approx ½ V_S$), e.g. First Sensors HDO series. The RCO and HDO pressure sensors are calibrated and temperature compensated for span and offset. They offer a very economical method to sense pressures from 10 mbar up to 10 bar.

Many industrial systems have only one fairly unstable single voltage power supply available. This application note discusses a circuit which achieves nearly any required stable output signal by using unstable single or dual supply voltages. Further, it provides excellent performance and easy adjustment, requires little power and minimal board space and is low cost.

POWER SUPPLY OPTIONS

The universal circuitry shown in Figure 1 can be operated from single or dual power supplies. In either case certain voltage limitations do exist. These are mainly due to the output voltage swing, current consumption and power supply rejection of the used LT1014 quad amplifiers. Other amplifiers such as Rail to Rail versions can widen these limits.

Single supply operation
The circuitry requires a supply voltage of 7 to 30 V for correct operation.

Dual supply operation
When the circuitry is powered by dual supplies, the positive power supply must be between 7 and 30 V, while the negative voltage supply can be any negative voltage down to -22 V. However, the total voltage across the circuit must be limited to 30 V.

GENERAL DESCRIPTION

Referring to the schematic diagram of the universal signal conditioning circuitry shown in Figure 1, amplifier A1 is used to provide a regulated voltage for the pressure sensor. In this manner, the circuit becomes independent of supply variations, power supply noise and ripple. The voltage V_B will be 10 V when jumper J4 is left open, and 5 V when J4 is connected.

Note that in both cases the min. positive supply voltage must be at least 1.2 V higher than V_B or the chosen maximum V_{out}.

Amplifiers A3 and A4 are connected as an instrumentation amplifier and provide gain to the sensor output signal, V_{in}.

Amplifier A2, in conjunction with potentiometer R_O set the initial (zero-pressure) output voltage. The complete expression for the output voltage V_{out} is given by the following equation:

$$V_{out} = V_{in}\left[2\left(1+\frac{R_3}{R_{gain}}\right)\right]+V_{Ref} \qquad (1)$$

where

$$R_{gain} = R_S + R_G \qquad (2)$$

and V_{Ref} is the voltage as set by R_O.

Connection point V- can be connected to a negative power supply when available. The connection to V- allows the circuitry to run from a dual supply, thus giving the output the ability to swing to or below true ground. When a negative power supply is not used, the output of the circuitry at zero pressure will be 50 to 150 mV above ground. This small offset voltage can be further reduced to 30 to 80 mV by mounting a 2 kΩ resistor R_5 between output and ground. Also, when a negative power supply is not used, jumper J5 must be connected such that V- is connected to ground.

The polarity shown for the output voltage of the sensor is for a RCO gage/differential pressure sensor with the pressure applied to port B. By using jumpers J1, J2 and J3, a variety of combinations are possible for V_{Ref}, the output voltage that is to represent zero pressure. For example, it is possible to set the output voltage to change from 1 V at zero pressure to 5 V at full-scale pressure; or if dual supplies are available, to set the output to 0 V at zero pressure, to 5 V at full scale positive pressure and to -5 V for an equal but negative pressure (vacuum). Also, by using the proper jumper connections, it is possible to set the output to 5.0 V at zero pressure with swings to +10 V for positive pressure and to ground for negative pressure. Many other combinations are possible as well.

JUMPER CONNECTIONS

Jumper J4

This jumper simply controls the non-inverting gain of amplifier A1. With J4 open, the gain is 4 V/V and the voltage at the top of the bridge will be approximately 10 V. Leaving J4 open is the proper connection for all applications where V+ is 12 V or higher. For applications where V+ is between 8 V and 12 V, J4 should be connected. This will give A1 a gain of 2 V/V and hence V_B will be at approximately 5 V.

Jumpers J1 and J2

This network is a voltage divider, with 2.5 V at the top of the divider. Since R_1 and R_O are 10 kΩ, the range of the wiper arm voltage is easy to determine. With jumpers J1 and J2 open, the wiper arm will range from 0.83 V to 1.67 V and hence, this is also the range of adjustment for voltage V_{Ref} assuming jumper J3 is open. If J1 is shorted, the range of adjustment is now from 1.25 V to 2.5 V. If J2 is shorted and J1 left open, the range is from proximately 0.0 V to 1.25 V.

Jumper J3

With jumper J3 open, the gain of A2 is unity. With J3 shorted, the gain is 3 V/V. This jumper is only useful when it is desired to set V_{Ref} higher than 2.5 V, which is the maximum possible by using only J1 and J2. For example, if it is required to set V_{Ref} between 3.75 V and 7.5 V, the best adjustment is accomplished by jumpering J1and J3. If it is desired to set V_{Ref} at (or near) ground, jumpers J1 and J3 should be left open and J2 should be shorted.

Jumper J5

This jumper is used when operation is from a single supply. When a negative power supply is not used, jumper J5 must be included such that V- will be eliminated from operation. When jumper J5 is connected, V- will be connected to ground.

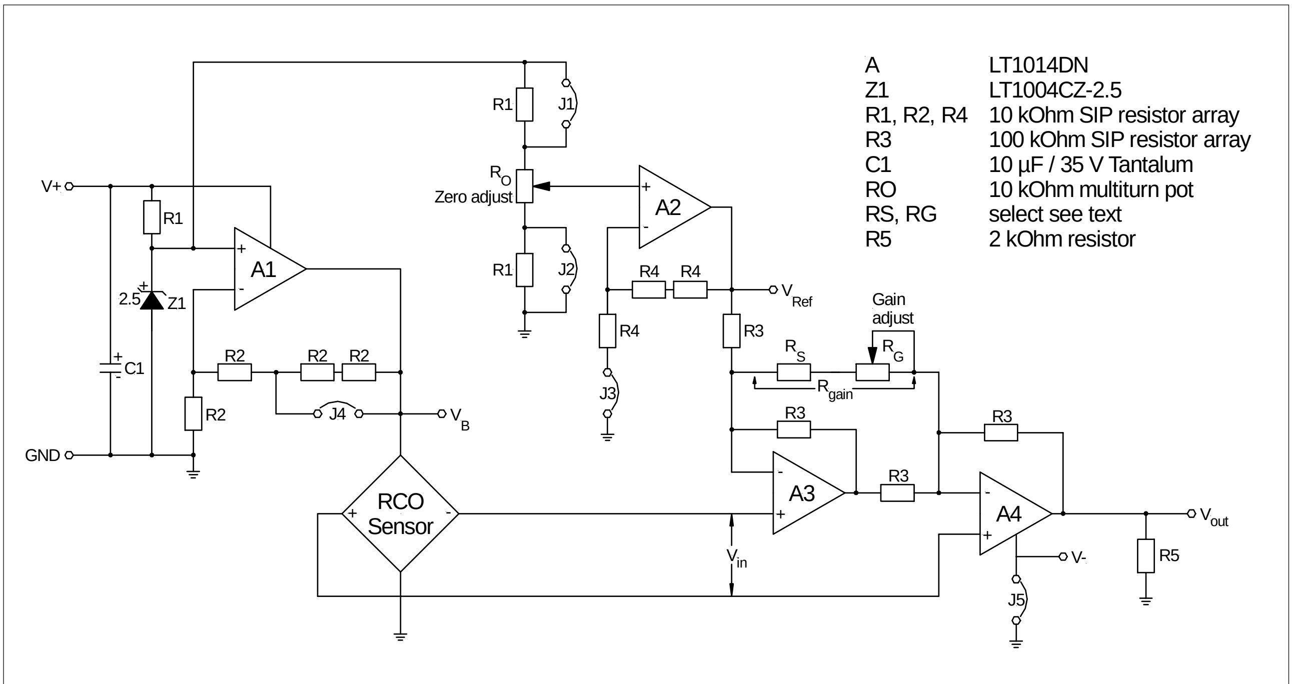

Figure 1: Signal conditioning circuitry for the RCO series pressure sensors

DESIGN EXAMPLE 1

Consider the need to measure a positive pressure from 0 to 100 psi and provide a 1 V to 6 V output, given a single 15 V supply.

Solution

We select a RCOP100D... sensor for this application. Pressure is applied to port B. Since a 15 V supply is available, J4 will be left open which will provide 10 V to the sensor. From the RCO data sheet, the output span for 100 psi input pressure is typ. 100 mV operating from a 12 V supply. Because the span is ratiometric to the supply voltage, the output for V_B=10 V supply will be 83.33 mV. Since the desired output span is 5 V (from 1 V to 6 V) the voltage gain required is 60 V/V. From equation (1) we get for the gain

$$A_V = \frac{\Delta V_{out}}{\Delta V_{in}} = 2\left(1 + \frac{R_3}{R_{gain}}\right)$$

For R_3=100 kΩ this equation is then solved for

$$R_{gain} = 3.448\ \text{k}\Omega$$

For the best adjustment range we will select R_S=3.24 kΩ and R_G to be a 500 Ω multiturn cermet pot.

Since the zero pressure output voltage V_R is to be 1 V, this is easily accommodated by leaving jumpers J1, J2, and J3 open but jumper J5 shorted. R_5 is not connected.

The final circuit design is shown in Fig. 2.

Adjustment procedure

1. With zero pressure applied, adjust R_O until V_{out} is 1.00 V.
2. Apply 100 psig and adjust R_O until the output is 6.00 V.
3. Repeat 1. and 2. if required.

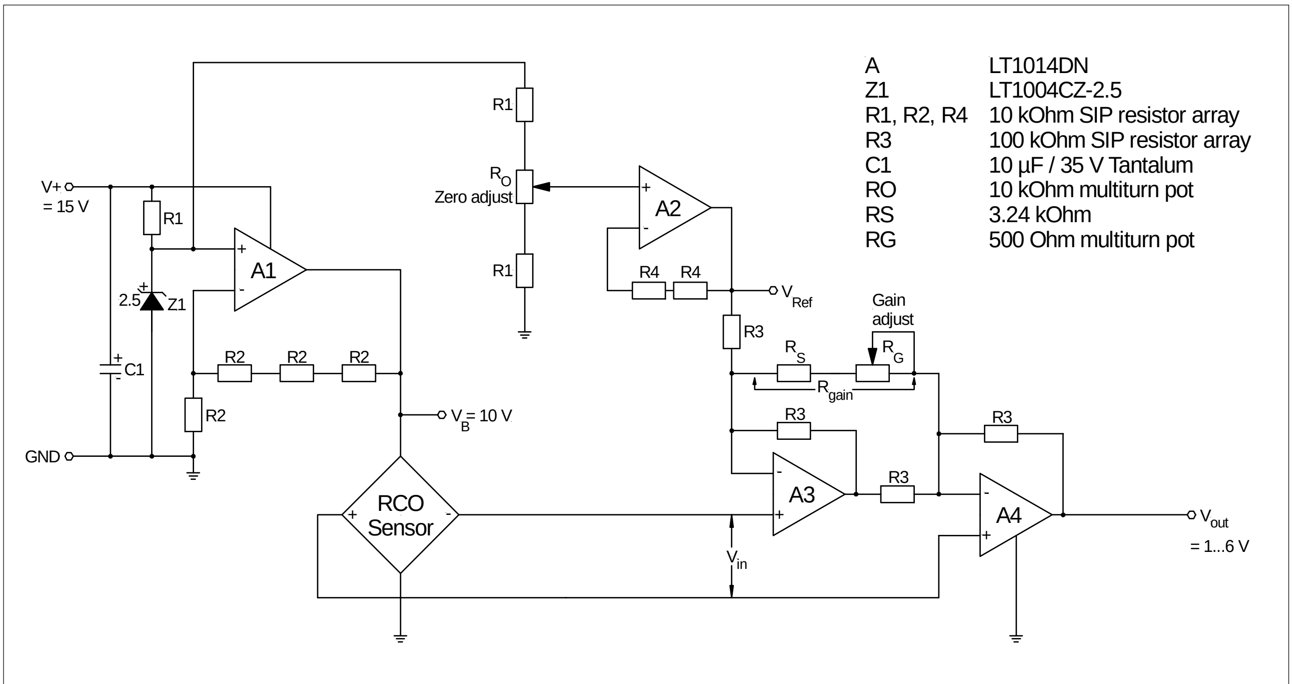

Figure 2: RCO signal conditioning circuitry for 1 V to 6 V output for 0 to 100 psi input pressure

DESIGN EXAMPLE 2

A dialysis machine must measure a pressure of ±500 mmHg. It is desired that the zero pressure output voltage is nominally at 5.0 V and provide an output change of ±2.5 V for this pressure input.
A +12 V supply is available.

Solution
We select a RCOP015D... sensor for this application. Pressure is applied to port B. Again, J4 will be left open to provide 10 V to the top of the sensor. From the RCO data sheet, the span at 12 V supply and 15 psi is typ. 90 mV. This equates to 0.5 mV/V per psi. Thus, at 10 V and 500 mmHg (9.67 psi) the output from the sensor bridge will be

$$V_{bridge} = \frac{90\text{ mV} \cdot 10\text{ V} \cdot 9.67\text{ psi}}{12\text{ V} \cdot 15\text{ psi}} = 48.35\text{ mV}$$

Because it is required that a 500 mmHg pressure provide an output voltage change of 2.5 V, the gain required is 51.7 V/V. Again, using the gain equation (1) with R_3=100 kΩ and solving for R_{gain} gives

$$R_{gain} = 4.024\text{ k}\Omega$$

To allow for approximately ±5 % gain adjustment from nominal, choose R_S = 3.74 kΩ and R_G to be a 500 Ω multiturn pot.

Since the zero pressure output required is 5.0 V, jumpers J1, J3 and J5 will be connected and jumper J2 will be left open. R_5 is not connected. In this manner, the wiper arm voltage of R_O can range from 1.25 V to 2.5 V and amplifier A2 provides a gain of 3 V/V. Thus, V_{Ref} can be adjusted from 3.75 V to 7.5 V.

The final circuit design is shown in Fig. 3.

Adjustment procedure

1. With zero pressure applied, adjust R_O until V_{out} is 5.00 V.
2. Apply +500 mmHg to port B and adjust R_O until the output is 7.50 V.
3. Apply +500 mmHg to port A and check if the output is 2.50 V.
4. Repeat 1. to 3. if required.

The 2.5 V output signal at -500 mmHg can be checked by applying +500 mmHg on port A of the RCOP015D... sensor. Thus, no vacuum is required.

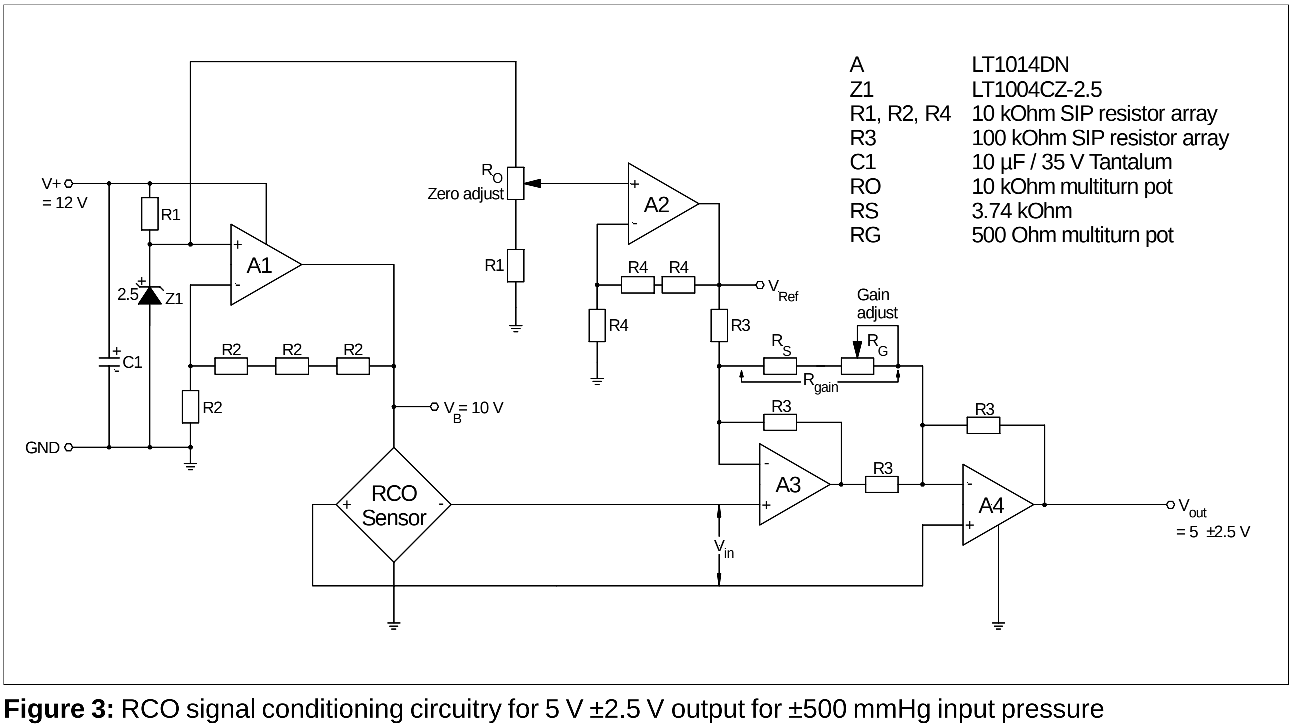

Figure 3: RCO signal conditioning circuitry for 5 V ±2.5 V output for ±500 mmHg input pressure

DESIGN EXAMPLE 3

In a portable respiration equipment a pressure of -25 mbar to +125 mbar needs to be measured. It is desired that the output voltage from the pressure sensor feeds an A/D converter working from a 5 V supply and with an analog input voltage of 0.5 to 5 V for the full pressure range. A 9 V battery supply is available.

Solution

We selected a RCOP001D... device for this application and accept a slightly worse linearity in the pressure range above 1 psi (69 mbar). Pressure is applied to port B. J4 needs to be closed for providing a 5 V supply to the top of the sensor. From the RCO data sheet the span for 0 to 1 psi is typ. 18 mV at 12 V supply. Thus, at 5 V and 125 mbar the output from the sensor bridge will be

$$V_{bridge} = \frac{18\text{ mV} \cdot 5\text{ V} \cdot 125\text{ mbar}}{12\text{ V} \cdot 69\text{ mbar}} = 13.59\text{ mV}$$

Because it is required that 125 mbar pressure provide 5 V output and -25 mbar provide 0.5 V the output voltage at zero pressure needs to be

$$V_{offset} = \frac{(5000\text{ mV} - 500\text{ mV}) \cdot 25\text{ mbar}}{125\text{ mbar} + 25\text{ mbar}} + 500\text{ mV}$$

$$V_{offset} = 1.25\text{ V}$$

The span for 0 to 125 mbar pressure will be 5.0 V-1.25 V=3.75 V. The gain required is 275.9 V/V. Using the gain equation (1) with R_3=100 kΩ gives

$$R_{gain} = 0.730\text{ k}\Omega$$

We choose a 680.1 Ω resistor for R_S and a 100 Ω multiturn pot for R_G.

Since the zero pressure output needs to be 1.25 V, jumpers J1, J2, J3 and J5 are left open. R_5 is not connected. While the wiper arm voltage can range from 0.83 V to 1.67 V and amplifier A2 provides a unity gain, the output offset voltage can be set to 1.25 V.

The final circuit design is shown in Fig. 4.

Adjustment procedure

1. With zero pressure applied, adjust R_O until V_{out} is 1.25 V.
2. Apply +125 mbar to port B and adjust R_O until the output is 5.00 V.
3. Apply +25 mbar to port A and check if the output is 0.50 V.
4. Repeat 1. to 3. if required.

The 0.5 V output signal at -25 mbar can be checked by applying +25 mbar on port A of the RCOP001D... sensor. Thus, no vacuum is required.

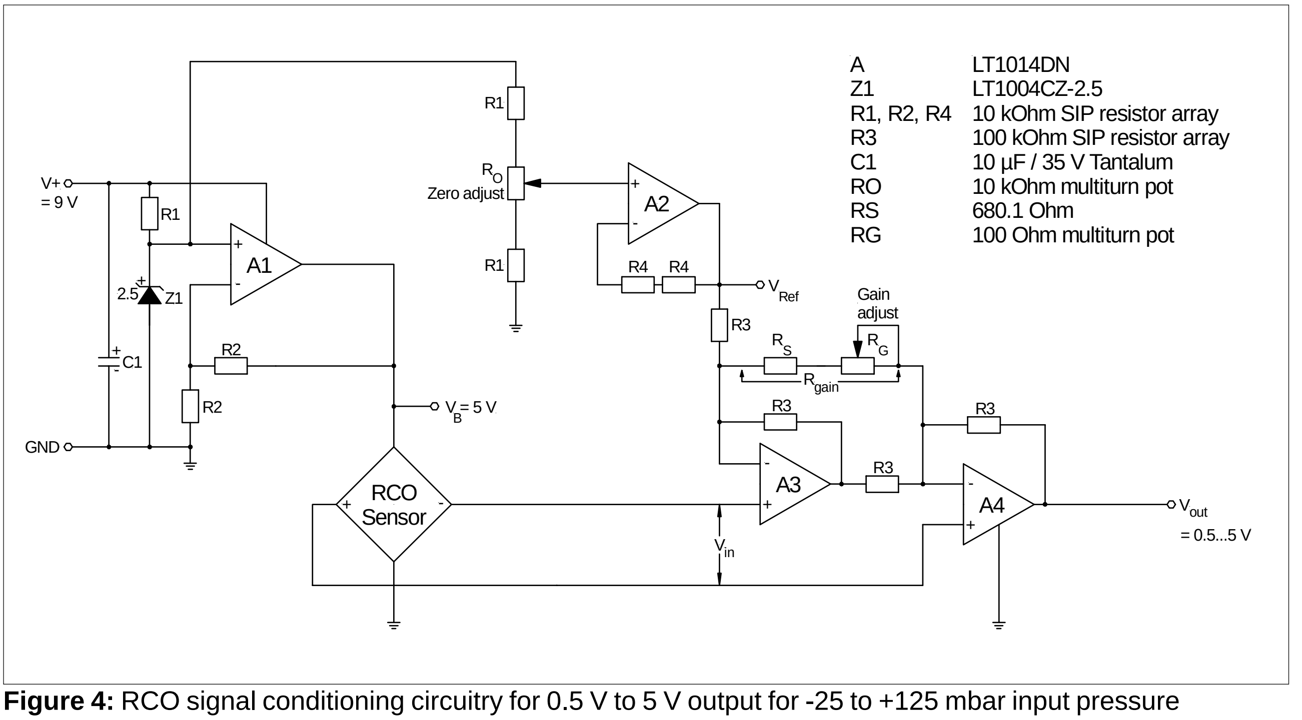

Figure 4: RCO signal conditioning circuitry for 0.5 V to 5 V output for -25 to +125 mbar input pressure