Amplifying Signals with Low Common-Mode Voltage

Because the common-mode input range of the AD623 extends 0.1 V below ground, it is possible to measure small differential signals which have low, or no, common mode component. Figure 50 shows a thermocouple application where one side of the J-type thermocouple is grounded.

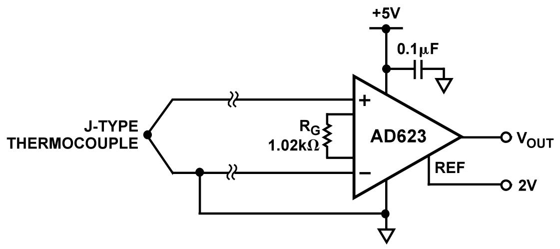

Figure 50. Amplifying Bipolar Signals with Low Common-Mode Voltage

Over a temperature range from –200°C to +200°C, the J-type thermocouple delivers a voltage ranging from –7.890 mV to 10.777 mV. A programmed gain on the AD623 of 100 (R_G = 1.02 kΩ) and a voltage on the AD623 REF pin of 2 V, results in the AD623's output voltage ranging from 1.110 V to 3.077 V relative to ground.

INPUT DIFFERENTIAL AND COMMON-MODE RANGE VS. SUPPLY AND GAIN

Figure 51 shows a simplified block diagram of the AD623. The voltages at the outputs of the amplifiers A1 and A2 are given by the equations

$$V_{A2} = V_{CM} + V_{DIFF}/2 + 0.6\ V + V_{DIFF} \times R_F/R_G$$
$$= V_{CM} + 0.6\ V + V_{DIFF} \times Gain/2$$

$$V_{A1} = V_{CM} - V_{DIFF}/2 + 0.6\ V - V_{DIFF} \times R_F/R_G$$
$$= V_{CM} + 0.6\ V - V_{DIFF} \times Gain/2$$

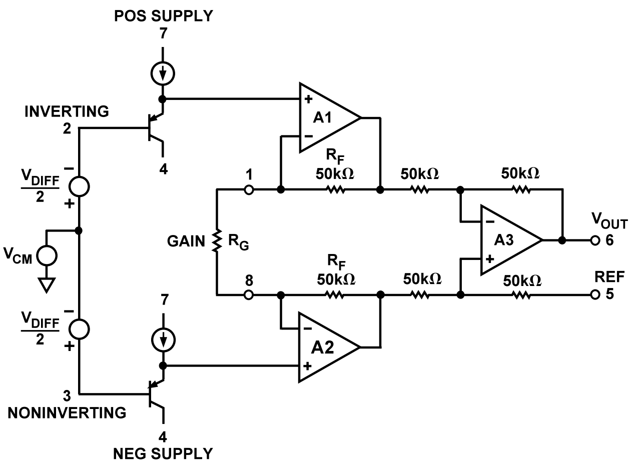

Figure 51. Simplified Block Diagram

The voltages on these internal nodes are critical in determining whether or not the output voltage will be clipped. The voltages V_{A1} and V_{A2} can swing from about 10 mV above the negative supply (V– or Ground) to within about 100 mV of the positive rail before clipping occurs. Based on this and from the above equations, the maximum and minimum input common-mode voltages are given by the equations

$$V_{CMMAX} = V+ -\ 0.7\ V - V_{DIFF} \times Gain/2$$

$$V_{CMMIN} = V- \ -0.590\ V + V_{DIFF} \times Gain/2$$

These equations can be rearranged to give the maximum possible differential voltage (positive or negative) for a particular common-mode voltage, gain, and power supply. Because the signals on A1 and A2, can clip on either rail, the maximum differential voltage will be the lesser of the two equations.

$$|V_{DIFFMAX}| = 2\ (V+ - 0.7\ V - V_{CM})/Gain$$

$$|V_{DIFFMAX}| = 2\ (V_{CM} - V- \ +0.590\ V)/Gain$$

However, the *range* on the differential input voltage range is also constrained by the output swing. So the range of V_{DIFF} may have to be lower according the equation.

$$Input\ Range \le Available\ Output\ Swing/Gain$$

For a bipolar input voltage with a common-mode voltage that is roughly half way between the rails, $V_{DIFFMAX}$ will be half the value that the above equations yield because the REF pin will be at midsupply. Note that the available output swing is given for different supply conditions in the Specifications section.

The equations can be rearranged to give the maximum gain for a fixed set of input conditions. Again, the maximum gain will be the lesser of the two equations.

$$Gain_{MAX} = 2\ (V+ - 0.7\ V - V_{CM})/V_{DIFF}$$
$$Gain_{MAX} = 2\ (V_{CM} - V- +0.590\ V)/V_{DIFF}$$

Again, we must ensure that the resulting gain times the input range is less than the available output swing. If this is not the case, the maximum gain is given by,

$$Gain_{MAX} = Available\ Output\ Swing/Input\ Range$$

Also for bipolar inputs (i.e., input range = 2 V_{DIFF}), the maximum gain will be half the value yielded by the above equations because the REF pin must be at midsupply.

The maximum gain and resulting output swing for different input conditions is given in Table IV. Output voltages are referenced to the voltage on the REF pin.

For the purposes of computation, it is necessary to break down the input voltage into its differential and common-mode component. So when one of the inputs is grounded or at a fixed voltage, the common-mode voltage changes as the differential voltage changes. Take the case of the thermocouple amplifier in Figure 50. The inverting input on the AD623 is grounded. So when the input voltage is –10 mV, the voltage on the noninverting input is –10 mV. For the purposes of signal swing calculations, this input voltage should be considered to be composed of a common-mode voltage of –5 mV (i.e., (+IN + –IN)/2) and a differential input voltage of –10 mV (i.e., +IN – –IN).