AN-1412
APPLICATION NOTE

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4 mA to 20 mA Process Control Loop Using the AD5662 DAC

CIRCUIT FUNCTION AND BENEFITS

In many process control applications, 2-wire current transmitters are often used to transmit analog signals through noisy environments. These current transmitters use a zero-scale signal current of 4 mA and a full-scale signal current of 20 mA—therefore the designation: 4 mA to 20 mA converter. The circuit described in this application note provides a low power current transmitter with 16-bit resolution and monotonicity, which is powered directly from the 4 mA to 20 mA control loop power supply and consumes less than 4 mA. Transmitters requiring more than 4 mA cannot be powered directly from the loop power supply and, therefore, require an additional supply.

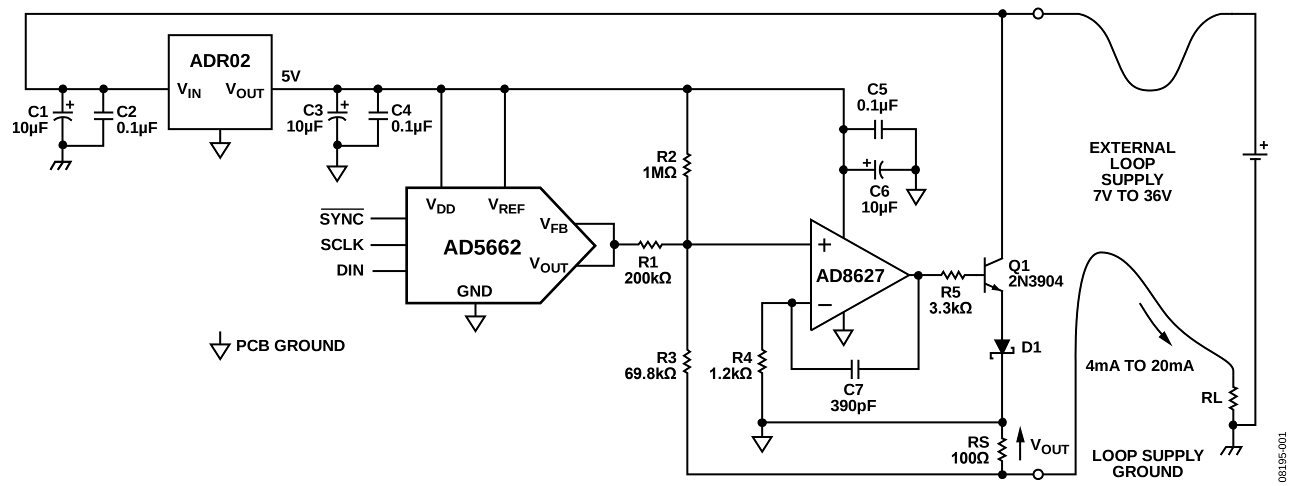

Figure 1. Programmable 4 mA to 20 mA Process Controller (Simplified Schematic)

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REVISION HISTORY

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CIRCUIT DESCRIPTION

This circuit provides a programmable output current of 4 mA to 20 mA using the AD5662 *nano*DAC® converter as a controller.

The loop current is sensed by measuring the voltage, V_{OUT}, which is dropped across RS. If the digital-to-analog converter (DAC) output is 0 V, a current of

$$\frac{V_{REF}}{R2} = \frac{5\ V}{1\ M\Omega} = 5\ \mu A \quad (1)$$

flows through R2 and R3, forcing the printed circuit board (PCB) ground to be 349 mV more positive than the voltage measured at the load side of RS. The RS voltage of 349 mV corresponds to a loop current of

$$\frac{V_{OUT}}{RS} = \frac{349\ mV}{100\ \Omega} = 3.49\ mA \quad (2)$$

When the DAC outputs a full-scale voltage of 5 V, the current through R2 is

$$\frac{V_{REF}}{R2} = \frac{5\ V}{1\ M\Omega} = 5\ \mu A \quad (3)$$

The current through R1 is

$$\frac{V_{REF}}{R1} = \frac{5\ V}{200\ k\Omega} = 25\ \mu A \quad (4)$$

Therefore, the current through R3 is

$$\frac{V_{REF}}{R2} + \frac{V_{REF}}{R1} = 5\ \mu A + 25\ \mu A = 30\ \mu A \quad (5)$$

The R3 current forces the voltage, V_{OUT}, across RS to equal

$$30\ \mu A \times 69.8\ k\Omega = 2.09\ V \quad (6)$$

The feedback loop around the AD8627 forces the voltage at its noninverting input to equal the PCB ground voltage. The output current is, therefore, directly proportional to the digital code. The AD8627 regulates the DAC output current to satisfy the current summation at its noninverting node. The output current is calculated using the following equation:

$$I_{OUT} = \frac{1}{RS}\left(\left(V_{DAC} \times \frac{R3}{R1}\right) + \left(V_{REF} \times \frac{R3}{R2}\right)\right) \quad (7)$$

For the values shown in Figure 1,

$$I_{OUT} = (0.266\ \mu A \times D) + 3.49\ mA \quad (8)$$

where $0 \leq D \leq 65{,}535$. D represents the input code in decimals.

This circuit gives a full-scale output current of 20.9 mA when the AD5662 digital code equals 0xFFFF. Likewise, the output current of the AD5662 is 3.49 mA when the digital code equals 0x0000. The extended current range (3.49 mA to 20.9 mA) allows the user to calibrate the 4 mA to 20 mA range by using software and the 16-bit resolution of the AD5662. The Schottky diode is required in this circuit to prevent loop supply power-on transients from pulling the noninverting input of the AD8627 more than 300 mV below its inverting input. The Schottky diode must be able to handle at least the 20 mA full loop load.

Biasing for the controller is provided by the ADR02 precision 5 V reference, and the circuit requires no external trims because of the tight initial output voltage tolerance of the ADR02 and the low supply current of both the AD8627 and the AD5662.

The limits on the allowable loop power supply are set by the ADR02 minimum input voltage (7 V) and maximum input voltage (36 V). The 2N3904 (Q1 in Figure 1) maximum allowable power dissipation at 25°C is 625 mW; therefore a higher power transistor must be used if the loop supply exceeds about 30 V. Power dissipation in the 2N3904 can be reduced by adding an appropriate voltage dropping resistor in series with its collector.

COMMON VARIATIONS

The basic circuit is flexible and can accommodate a number of different references, voltage output DACs, and op amps. Considerations are reference accuracy, DAC resolution, and amplifier offset voltage. The prime requirement is that the total circuit must operate on the loop supply voltage and require less than 4 mA of quiescent current (for a DAC code of 0x0000).

REFERENCE

Voltage Reference Wizard Design Tool

AN08195-0-7/16(B)