

### Circuits from the Lab™ Reference Circuits

Circuits from the Lab™ reference circuits are engineered and tested for quick and easy system integration to help solve today's analog, mixed-signal, and RF design challenges. For more information and/or support, visit [www.analog.com/CN0202](http://www.analog.com/CN0202).

| Devices Connected/Referenced |  |
|------------------------------|--|
| AD5750                       | Industrial Current/Voltage Output Driver with Programmable Ranges              |
| AD5662                       | 16-Bit nanoDAC® Digital-to-Analog Converter in SOT-23                          |
| ADR444                       | Ultralow Noise, 4.096V LDO XFET Voltage Reference with Current Sink and Source |

## Flexible, High Accuracy, Low Drift, PLC/DCS Analog Output Module

### EVALUATION AND DESIGN SUPPORT

#### Circuit Evaluation Boards

[CN-0202 Circuit Evaluation Board \(EVAL-CN0202-SDPZ\)](#)

[System Demonstration Platform \(EVAL-SDP-CB1Z\)](#)

#### Design and Integration Files

[Schematics, Layout Files, Bill of Materials](#)

### CIRCUIT FUNCTION AND BENEFITS

The circuit shown in Figure 1 provides a full function, flexible, programmable analog output solution that meets most requirements for programmable logic controller (PLC) and distributed control system (DCS) applications. The AD5662 low power (0.75 mW @ 5 V), rail-to-rail output, 16-bit nanoDAC® converter and the AD5750 industrial current/voltage output driver are well matched with respect to input and output voltage ranges, as well as reference voltage requirements. The ADR444

low drift (3 ppm/°C maximum for B-grade), high initial accuracy (0.04% maximum for B-grade), and low noise (1.8  $\mu$ V p-p typical, 0.1 Hz to 10 Hz) provides the reference voltage for both the AD5750 and AD5662 and guarantees ultralow noise, high accuracy, and low temperature drift for the circuit. This circuit provides all the typical voltage and current output ranges with 16-bit resolution and no missing codes, 0.05% linearity, and less than 0.2% total output error.

The circuit also contains key features for industrial applications, such as on-chip output fault detection and protection (short circuit, undervoltage output, open circuit current output, and overtemperature), CRC checking to prevent packet error (PEC), and flexible power-up options, making it an ideal choice for robust industrial control systems. No external precision resistors or calibration routines

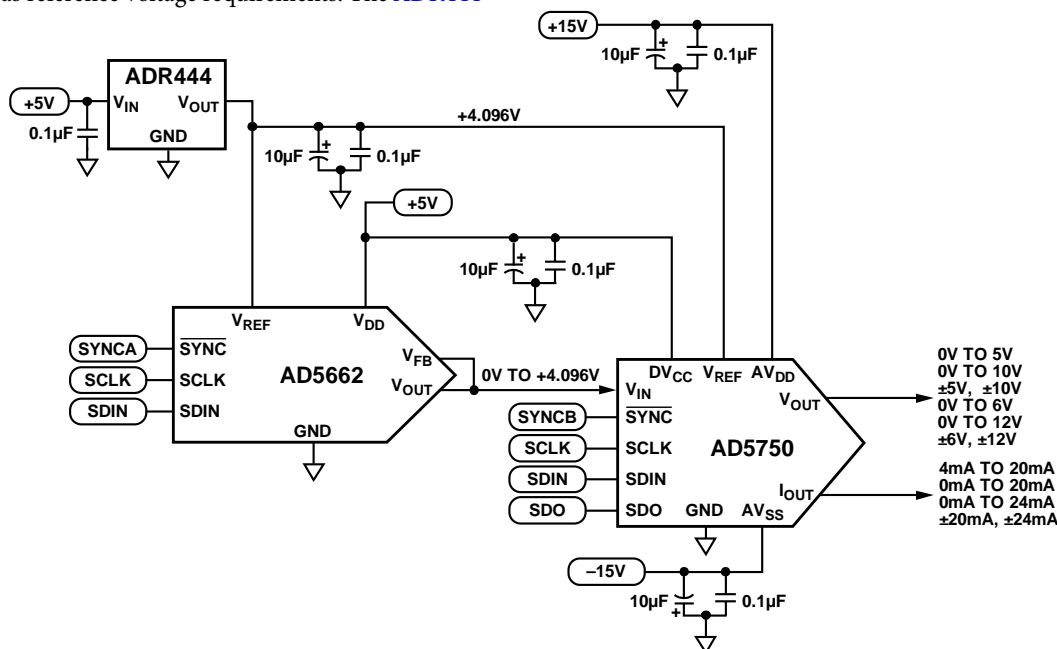


Figure 1. Basic Analog Output Circuit for Single Channel (Simplified Schematic, All Connections and Protection Circuits Not Shown)

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#### Rev.0

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are needed to maintain consistent performance in mass production, thereby making it ideal for PLC or DCS modules.

## CIRCUIT DESCRIPTION

The [AD5750/AD5750-1](#) are both single-channel, low cost, precision voltage/current output drivers developed to meet the requirements of industrial process control applications. The voltage output range can be programmed for the standard output ranges for PLC and DCS applications: 0 V to 5 V, 0 V to 10 V, -5 V to +5 V, and -10 V to +10 V. A 20% overrange setting is also provided for the standard ranges, giving the following options: 0 V to 6 V, 0 V to 12 V, -6 V to +6 V, and -12 V to +12 V.

The current output, which is provided on a separate pin, can be programmed for the ranges of 4 mA to 20 mA, 0 mA to 20 mA, -20 mA to +20 mA, 0 mA to 24 mA, and -24 mA to +24 mA. The unipolar ranges have a 2% overrange setting. Because the [AD5750/AD5750-1](#) current output can either source or sink current, it can interface to a wide variety of sensors or actuators. The voltage and current output pins can be tied together to configure the end system as a single-channel output if desired.

The [AD5662](#) is a single channel, low cost, low power, rail-to-rail voltage buffered output nanoDAC® device. The [AD5662](#) guarantees  $\pm 1$  LSB DNL under a wide range of reference voltages that can vary from 0.75 V to the  $V_{DD}$  supply so that the [AD5750](#) and the [AD5662](#) can operate from a common reference source of 4.096 V, provided by the [ADR444](#). The whole system will benefit from the ultralow noise and low temperature coefficient of [ADR444](#). The [ADR44x](#) family of references are ideal for driving either the reference or the power input of converters because they can source and sink current. The [AD5662](#) also incorporates a power-on reset circuit to ensure that the DAC output powers up to either midscale or zero and remains there until a valid write takes place.

Devices for PLC and DCS applications generally need ESD protection and overvoltage protection much higher than the formal recommend specifications. The [AD5750](#) has integrated ESD protection diodes internal to each pin that can prevent damage from a 3 kV transient (Human Body Model). However, the industrial control environment can subject I/O circuits to much higher transients. External 30 V, 600 W transient voltage suppressors (TVS), a 50 mA, 30 V PolySwitch, and power Schottky diodes are built into the [EVAL-CN0202-SDPZ](#) circuit board to provide higher voltage ESD protection, 50 mA overcurrent, and 30 V overvoltage protection. The optional external protection circuits are not shown in the simplified schematic of Figure 1 but can be found in the detailed schematic (EVAL-CN0202-SDPZ-SCH pdf file) in the CN0202 Design Support package: [www.analog.com/CN0202-DesignSupport](http://www.analog.com/CN0202-DesignSupport).

The circuit must be constructed on a multilayer PC board with a large area ground plane. Proper layout, grounding, and decoupling techniques must be used to achieve optimum performance (see [Tutorial MT-031, Grounding Data Converters and Solving the Mystery of "AGND" and "DGND,"](#) and [Tutorial MT-101, Decoupling Techniques](#)).

## Measurements

Integral nonlinearity (INL), differential nonlinearity (DNL), and output error are the most important specifications for PLC, DCS, and other process control systems. The [AD5750](#) has highly flexible and configurable output ranges that can be tailored to meet the needs of the application. Measurements of INL, DNL, and output error for the circuit are shown in Figure 2, Figure 3, and Figure 4, respectively. This data was taken at 25°C in the 0 V to 5 V voltage output mode. The test results for all the other ranges are listed in Table 1.

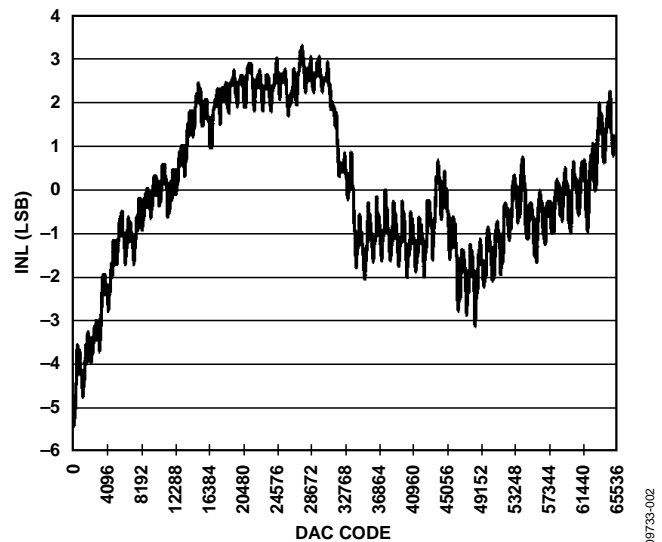


Figure 2. INL for 0 V to 5 V Output Range

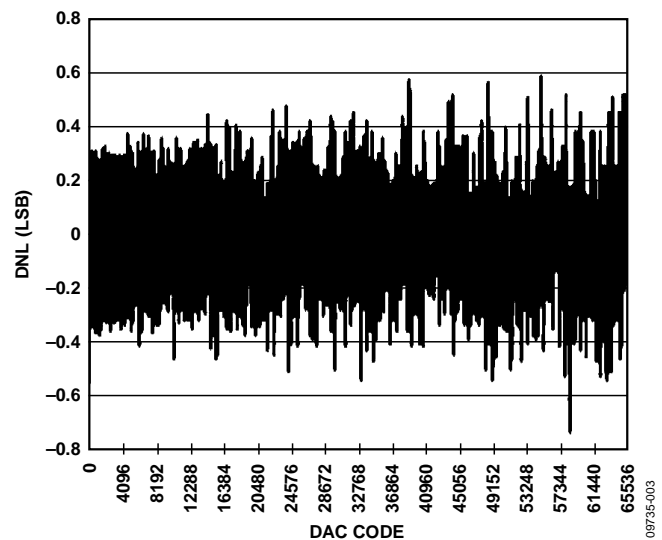


Figure 3. DNL for 0 V to 5 V Output Range

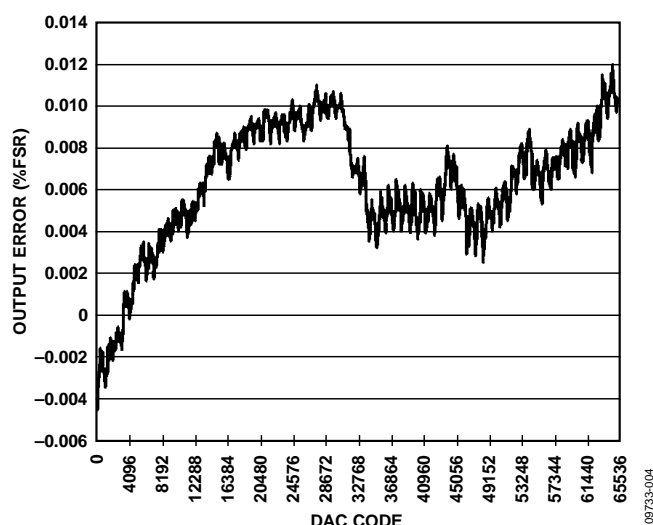


Figure 4. Output Error for 0 V to 5 V Output Range

The test results shown in Table 1 were made at 25°C using the [EVAL-CN0202-SDPZ](#) board powered by an Agilent E3631A dc supply and measured with an Agilent 34401A digital multimeter.

Note that the output ranges 0 mA to 20.4 mA and 0 mA to 24.5 mA are both designed to be trimmed by the customer to precisely match the 0 mA to 20 mA and 0 mA to 24 mA ranges. The 1.54% FSR output error measurement in the 0 mA to 20.4 mA range includes the gain error, which should be removed by customer calibration.

Table 1. Test Results for All Output Ranges

| Range               | Current Sense Resistor | INL (LSB) | Linearity (%FSR) | Ouput Error (%FSR) |
|---------------------|------------------------|-----------|------------------|--------------------|
| 0 V to 5 V          | Don't care             | 3.5       | 0.009            | 0.02               |
| 0 V to 10 V         | Don't care             | 3.3       | 0.007            | 0.03               |
| –5 V to +5 V        | Don't care             | 3.6       | 0.008            | 0.13               |
| –10 V to +10 V      | Don't care             | 3.5       | 0.008            | 0.12               |
| 0 V to 6 V          | Don't care             | 3.6       | 0.008            | 0.03               |
| 0 V to 12 V         | Don't care             | 5.3       | 0.008            | 0.09               |
| –6 V to +6 V        | Don't care             | 3.3       | 0.008            | 0.15               |
| –12 V to +12 V      | Don't care             | 3.3       | 0.008            | 0.15               |
| –2.5 V to +2.5 V    | Don't care             | 3.6       | 0.008            | 0.13               |
| 4 mA to 20 mA       | Internal               | 4.1       | 0.008            | 0.10               |
| 4 mA to 20 mA       | External               | 4.1       | 0.010            | 0.08               |
| 0 mA to 20 mA       | Internal               | 3.7       | 0.008            | 0.05               |
| 0 mA to 20 mA       | External               | 4.9       | 0.011            | 0.03               |
| 0 mA to 24 mA       | Internal               | 3.7       | 0.009            | 0.04               |
| 0 mA to 24 mA       | External               | 4.7       | 0.012            | 0.03               |
| –20 mA to +20 mA    | Internal               | 4.1       | 0.006            | 0.14               |
| –20 mA to +20 mA    | External               | 3.7       | 0.006            | 0.12               |
| –24 mA to +24 mA    | Internal               | 3.9       | 0.006            | 0.14               |
| –24 mA to +24 mA    | External               | 3.3       | 0.005            | 0.12               |
| 3.92 mA to +20.4 mA | Internal               | 4.4       | 0.010            | 0.20               |
| 0 mA to +20.4 mA    | Internal               | 3.6       | 0.008            | 1.54               |
| 0 mA to +24.5 mA    | Internal               | 5.1       | 0.008            | 1.43               |

## COMMON VARIATIONS

This circuit describes one implementation of a family of driver and DAC products, from which various devices can be selected to achieve desired performance. 12-bit to 16-bit resolution is the regular requirement for PLC and DCS applications. For applications not requiring 16-bit resolution, the [AD5620](#) (12-bit), and [AD5640](#) (14-bit) are available, but have internal references.

For multichannel applications, the [AD5623R](#) (12-bit), [AD5643R](#) (14-bit), and [AD5663R](#) (16-bit) are dual nanoDAC devices, and the [AD5624R](#) (12-bit), [AD5644R](#) (14-bit), and [AD5664R](#) (16-bit) are quad nanoDAC devices.

The [AD5750-1](#) driver is pin-compatible with the [AD5750](#) and can accept a 0 V to 2.5 V input range when used with a 1.25 V reference. The [AD5751](#) is a unipolar analog output driver and can supply a 40 V output using a 50 V AVDD supply.

## CIRCUIT EVALUATION AND TEST

### Equipment Needed (Equivalents Can Be Substituted)

- System Demonstration Platform ([EVAL-SDP-CB1Z](#))
- CN-0202 Circuit Evaluation Board ([EVAL-CN0202-SDPZ](#))
- CN-0202 Evaluation Software
- Software for controlling external test measurement equipment (not included on CD)
- Agilent 34401A, 6.5 Digit Digital Multimeter
- Agilent E3631A 0 V to 6 V/5 A;  $\pm 25$  V/1 A Triple Output DC Power Supply
- PC (Windows® 2000 or Windows XP) with USB interface
- National Instruments GPIB to USB-B interface and cable

## Getting Started

Load the evaluation software by placing the CN0202 Evaluation Software disc in the CD drive of the PC. Using My Computer, locate the drive that contains the evaluation software disc and open the Readme file. Follow the instructions contained in the Readme file for installing and using the evaluation software.

## Functional Block Diagram

Figure 5 shows a functional block diagram of the test setup. The pdf file “EVAL-CN0202-SDPZ-SCH” contains the detailed circuit schematics for the CN-0202 evaluation board. This file is contained in the CN-0202 Design Support Package:

[www.analog.com/CN0202-DesignSupport](http://www.analog.com/CN0202-DesignSupport).

## Setup

Connect the 120-pin connector on the [EVAL-CN0202-SDPZ](#) circuit board to the connector marked “CON A” or “CON B” on the [EVAL-SDP-CB1Z](#) evaluation (SDP) board. Nylon hardware should be used to firmly secure the two boards, using the holes provided at the ends of the 120-pin connectors. After successfully setting the dc output supply to +15 V, –15 V and +6 V output, turn the power supply off.

With power to the supply off, connect a +15 V power supply to pin of CN1 marked “+15 V”, a –15 V power supply to the pin of CN1 marked “–15 V”, and “GND” to the pin of CN1 marked “GND”. Connect +6 V to CN2 the same way. Turn on the power supply and then connect the USB cable with the SDP board to the USB port on the PC. Note: Do not connect the USB cable to the mini USB connector on the SDP board before turning on the dc power supply for the [EVAL-CN0202-SDPZ](#).

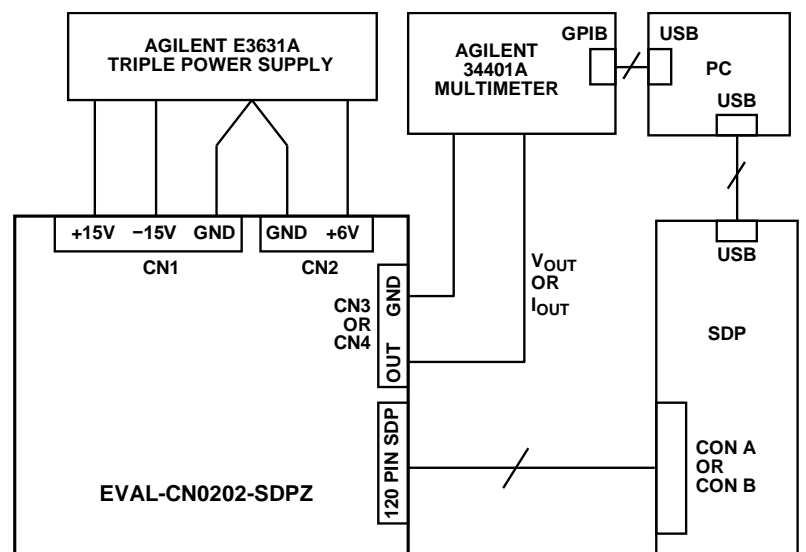


Figure 5. Test Setup Functional Block Diagram

Table 2. Jumper Settings for EVAL-CN0202-SDPZ (Bolded Values Are Default Settings)

| Jumper | Descriptions                                   | Setting                        | Function   |
|--------|--|--------------------------------|--|
| JP1    | Sets the address of <a href="#">AD5750</a>     | Shorting Pin1 with Pin2        | Address of AD5750 : b'001                          |
|        |  | <b>Shorting Pin3 with Pin2</b> | <b>Address of AD5750 : b'000</b>                   |
| JP2    | Sets the external compensation capacitor       | Shorting                       | Adding 1 nF Compensation Capacitor                 |
|        |  | <b>Opening</b>                 | <b>Removing 1 nF Compensation Capacitor</b>        |
| JP3    | VSENSE+ Setting                                | <b>Shorting</b>                | <b>Shorting VSENSE+ with VOUT internally</b>       |
|        |  | Opening                        | VSENSE+ has no connection with VOUT internally     |
| JP4    | VSENSE– Setting                                | <b>Shorting</b>                | <b>Shorting VSENSE– with GND internally</b>        |
|        |  | Opening                        | VSENSE– has no connection with GND internally      |
| JP5    | Shorts the VOUT and IOUT pins                  | Shorting                       | Shorts VOUT and IOUT together.                     |
|        |  | <b>Opening</b>                 | <b>VOUT and IOUT have no connection internally</b> |
| JP6    | Sets the CLEAR Mode for <a href="#">AD5750</a> | Shorting                       | Clears to midscale                                 |
|        |  | <b>Opening</b>                 | <b>Clears to zero scale</b>                        |

### Test

After setting up the test equipment, connect the pin of CN3 marked “VOUT” or the pin of CN4 marked “IOUT” to the input of the Agilent 34401A. Make sure that the cable connection on the front panel of the Agilent 34401A is correct, depending on the different input signal type (current or voltage). Testing the INL, DNL, and total error will take a considerable amount of time because all of the [AD5660-1](#) 16-bit DAC levels must be set and measured by the 34401A.

The software provided on the CD allows the DAC codes to be set by the PC. An automatic test program is necessary to step through the codes and analyze the data. This is not provided on the CD but must be implemented by the customer to correspond to the requirements of the particular multimeter used in the test setup.

In the test configuration shown in Figure 5, the GPIB output of the 34401A multimeter interfaces to a second USB port on the PC using the National Instruments GPIB to USB-B interface and cable. This allows the multimeter readings corresponding to each code to be loaded into an Excel spreadsheet on the PC. The data is then analyzed for INL, DNL, and total error using industry-standard definitions.

For more details on the definitions and how to calculate the INL, DNL, and total error from the measured data, see the "TERMINOLOGY" section of the [AD5662 data sheet](#) and also the following reference: *Data Conversion Handbook*, "Testing Data Converters," Chapter 5, Analog Devices.

### LEARN MORE

CN-0202 Design Support Package:

<http://www.analog.com/CN0202-DesignSupport>

Slattery, Colm, Derrick Hartmann, and Li Ke, "PLC Evaluation Board Simplifies Design of Industrial Process Control Systems." *Analog Dialogue* (April 2009).

CN-0063 Circuit Note, *16-Bit Fully Isolated Voltage Output Module Using the AD5662 DAC, ADuM1401 Digital Isolator, and External Amplifiers*, Analog Devices.

CN-0064 Circuit Note, *16-Bit Fully Isolated 4 mA to 20 mA Output Module Using the AD5662 DAC, ADuM1401 Digital Isolator, and External Amplifiers*, Analog Devices.

CN-0065 Circuit Note, *16-Bit Fully Isolated Output Module Using the AD5422 Single Chip Voltage and Current Output DAC and the ADuM1401 Digital Isolator*, Analog Devices.

CN-0066 Circuit Note, *Fully Isolated Input Module Based on the AD7793 24-Bit  $\Sigma$ - $\Delta$  ADC and the ADuM5401 Digital Isolator*, Analog Devices.

CN-0067 Circuit Note, *Fully Isolated Input Module Based on the AD7793 24-Bit  $\Sigma$ - $\Delta$  ADC, the ADuM5401 Digital Isolator, and a High Performance In-Amp*, Analog Devices.

CN-0097 Circuit Note, *Simplified 12-Bit Voltage and 4 mA-to-20 mA Output Solution Using the AD5412*, Analog Devices.

CN-0209 Circuit Note, *Fully Programmable Universal Analog Front End for Process Control Applications*, Analog Devices.

MT-031 Tutorial, *Grounding Data Converters and Solving the Mystery of “AGND” and “DGND”*, Analog Devices.

MT-101 Tutorial, *Decoupling Techniques*, Analog Devices.

Kester, Walt. *Practical Design Techniques for Sensor Signal Conditioning, Analog Devices*, 1999, ISBN 0-916550-20-6

Kester, Walt. *Data Conversion Handbook*, Chapter 5, Analog Devices.

### **Data Sheets and Evaluation Boards**

CN-0202 Circuit Evaluation Board (EVAL-CN0202-SDPZ)

System Demonstration Platform (EVAL-SDP-CB1Z)

AD5750 Data Sheet

AD5750 Evaluation Board

AD5662 Data Sheet

AD5662 Evaluation Board

### **REVISION HISTORY**

9/11—Revision 0: Initial Version

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