ANALOG DEVICES

Circuit Note

CN-0233

Circuits from the Lab® Reference Designs

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Devices Connected/Referenced	
ADuM3471	Quad Isolator with Integrated Transformer Driver and PWM Controller.
AD5422	16-Bit Current Source and Voltage Output DAC
ADR445	Precision 5.0 V Reference

16-Bit Isolated Industrial Voltage and Current Output DAC with Isolated DC-to-DC Supplies

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

- **CN0233 Circuit Evaluation Board (EVAL-CN0233-SDPZ)**
- **System Demonstration Platform (EVAL-SDP-CB1Z)**

Design and Integration Files

- **Schematics, Layout Files, Bill of Materials**

CIRCUIT FUNCTION AND BENEFITS

The circuit in Figure 1 provides 16-bit fully isolated ±10 V and 4 mA-to-20 mA outputs suitable for programmable logic controllers (PLCs) and distributed control systems (DCSs).

The circuit uses digital isolation, as well as PWM-controlled power regulation circuitry along with associated feedback isolation. External transformers are used to transfer power across the isolation barrier, and the entire circuit operates on a single +5 V supply located on the primary side. This solution is superior to isolated power modules, which are often bulky and may provide poor output regulation.

Digital isolators are superior to opto-isolators especially when multichannel isolation is needed. The integrated design isolates the circuit from the local system controller to protect against ground loops and also to ensure robustness against external events often encountered in harsh industrial environments.

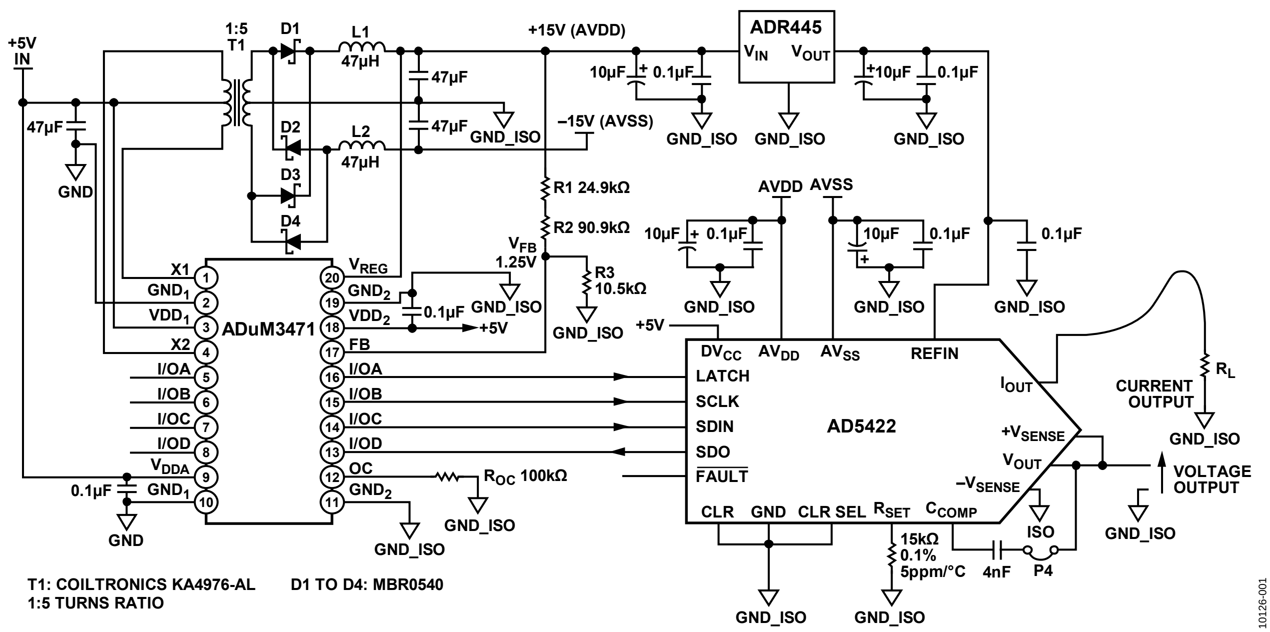

Figure 1. Isolated 16-Bit Current and Voltage Output DAC with Isolated Power Supplies

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CIRCUIT DESCRIPTION

The AD5422 is a fully integrated, fully programmable 16-bit voltage and current output DAC, capable of programming ranges from 4 mA to 20 mA, 0 mA to 24 mA, 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V. The voltage output headroom is typically 1 V, and the current output needs about 2.5 V headroom. This means that the 20 mA current output can drive a load up to approximately 600 Ω with a 15 V supply.

The ADuM347x devices are quad-channel digital isolators with an integrated PWM controller and low impedance transformer driver outputs (X1 and X2). The only additional components required for an isolated dc-to-dc converter are a transformer and simple full-wave diode rectifier. The devices provide up to 2 W of regulated, isolated power when supplied from a 5.0 V or 3.3 V input. This eliminates the need for a separate isolated dc-to-dc converter.

The *i*Coupler chip-scale transformer technology is used to isolate the logic signals, and the integrated transformer driver with isolated secondary side control provides high efficiency for the isolated dc-to-dc converter. The internal oscillator frequency is adjustable from 200 kHz to 1 MHz and is determined by the value of R_{OC}. For R_{OC} = 100 kΩ, the switching frequency is 500 kHz.

The ADuM3471 regulation is from the positive 15 V supply. The feedback for regulation is from the divider network (R1, R2, R3). The resistors are chosen such that the feedback voltage is 1.25 V when the output voltage is 15 V. The feedback voltage is compared with the ADuM3471 internal feedback voltage of 1.25 V. Regulation is achieved by varying the duty cycle of the PWM signals driving the external transformer.

The negative supply is loosely regulated, and for light loads can be as high as −23 V. This is within the maximum operating value of −26.4 V specification for the AD5422. With nominal loads greater than 1 kΩ, the additional power dissipation due to the larger unregulated negative supply voltage is not a problem. In applications that require higher compliance voltages or where very low power dissipation is required, a different power supply design should be considered.

This circuit was tested with the ADR445 5 V, high precision, low drift (3 ppm/°C maximum for B grade) external reference. This allows total system errors of less than 0.1% to be achieved over the industrial temperature range (−40°C to +85°C).

The AD5422 has a high precision integrated internal reference with a drift of 10 ppm/°C maximum. If this reference is used rather than the external reference, only 0.065% additional error is incurred across the industrial temperature range.

Test Data and Results

The AD5422 differential nonlinearity (DNL) was tested to ensure no loss in system accuracy was incurred because of the switching supplies. Figure 2 shows the DNL for a ±10V range. The result shows less than 0.5 LSB DNL error.

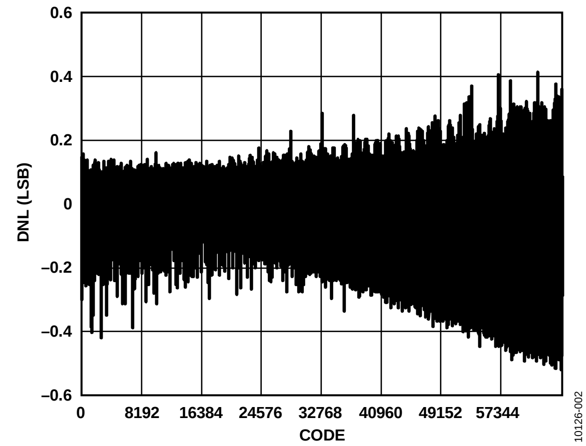

Figure 2. Measured DNL of Circuit for ±10 V Output Range

The average output noise was also tested and measured over time, as shown in Figure 3. The total drift is approximately 75 µV, corresponding to only 0.25 LSB.

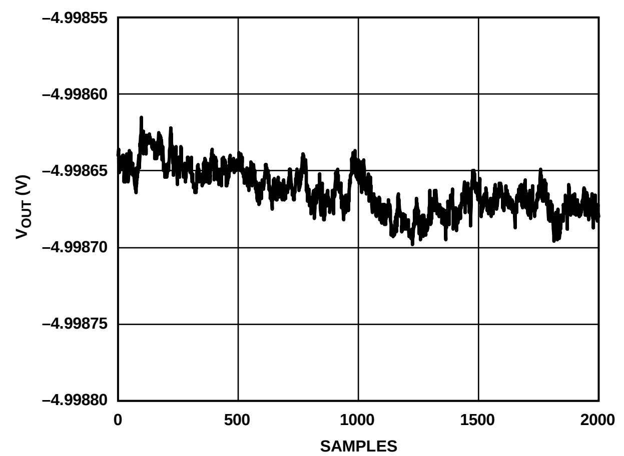

Figure 3. Measured Average DAC Output Noise with DAC Output Set at −5 V on ±10 V Output Range, Vertical Scale: 50 µV/div (1 LSB = 305 µV), 2000 Samples

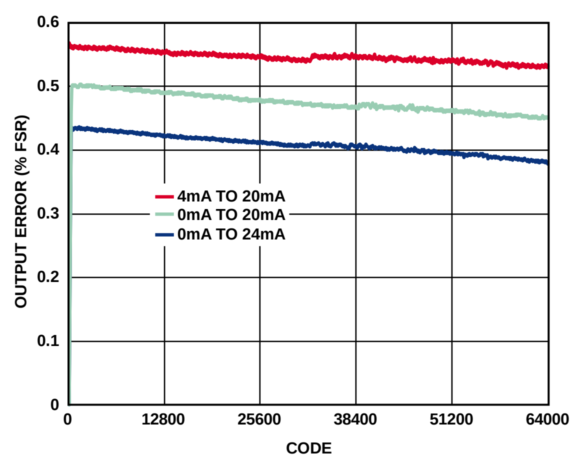

Figure 4. Measured Error (% FSR) For Current Output Ranges

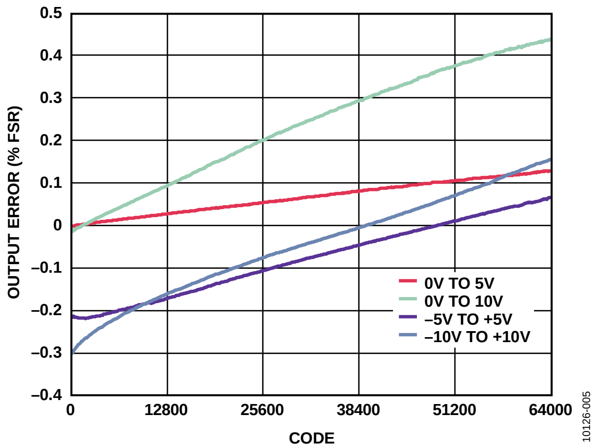

Figure 5. Measured Error (% FSR) for Voltage Output Ranges

Actual error data from the circuit is shown in Figure 4 and Figure 5. The total error in the output current and voltage (% FSR) is calculated by taking the difference between the ideal output and the measured output, dividing by the FSR, and multiplying the result by 100. An error of less than 0.5% FSR error is achieved in both the current and voltage output modes as shown in Figure 4 and Figure 5, respectively.

If the V_{OUT} pin must drive large capacitive loads up to 1 µF, a 3.9 nF capacitor can be connected between the V_{OUT} pin and the C_{COMP} pin of the AD5422 by connecting the P4 pins on the board using a jumper. However, the addition of this capacitor reduces the bandwidth of the output amplifier, increasing the settling time.

COMMON VARIATIONS

This circuit is proven to work well with good stability and accuracy with component values shown. Where the application needs only the 4 mA to 20 mA current output, a single supply scheme can be used. In this case, the positive AVCC supply can be as large as 26.4 V and, therefore, the output compliance is 26.4 V – 2.5 V = 23.9 V. With an output current of 20 mA, a load resistance as high as 1 kΩ is possible.

For applications not requiring 16-bit resolution, the 12-bit AD5412 is available.

The ADuM347x isolators (ADuM3470, ADuM3471, ADuM3472, ADuM3473, ADuM3474) provide four independent isolation channels in a variety of input/output channel configurations. These devices are also available with either a maximum data rate of 1 Mbps (A grade) or 25 Mbps (C grade).

CIRCUIT EVALUATION AND TEST

This circuit was tested using the EVAL-CN0233-SDPZ circuit board and the EVAL-SDP-CB1Z connected together as shown in Figure 6.

Equipment Used to Collect Test Data

- PC with a USB port and Windows® XP, Windows Vista®, (32-bit), or Windows 7 (32-bit)
- EVAL-CN0233-SDPZ
- EVAL-SDP-CB1Z
- Power supply: +6 V wall wart, Agilent E3630A, or equivalent
- Agilent 3458A, 8.5 digit multimeter or equivalent
- National Instruments GPIB to USB-B interface and cable (only required for capturing analog data from the DAC and transferring it to the PC).

Setup and Test

The circuit was tested and verified by connecting both the EVAL-CN0233-SDPZ evaluation board and the EVAL-SDP-CB1Z evaluation board, as shown in Figure 6.

The CN-0233 Evaluation Software is used to capture the data from the EVAL-CN0233-SDPZ circuit board using the setup seen in Figure 6. Details regarding the use of the software can be found in the CN-0233 Software User Guide.

The DNL, noise data, and actual FSR error were obtained by inputting the DAC data to the EVAL-CN0233-SDPZ evaluation board using EVAL-SDP-CB1Z board connected to the PC and reading the voltage or current output results from the 3485 multimeter. The GPIB/USB interface was used to transfer the data to the PC for analysis. The CN0233 Evaluation Software was used to generate the data to the DAC.

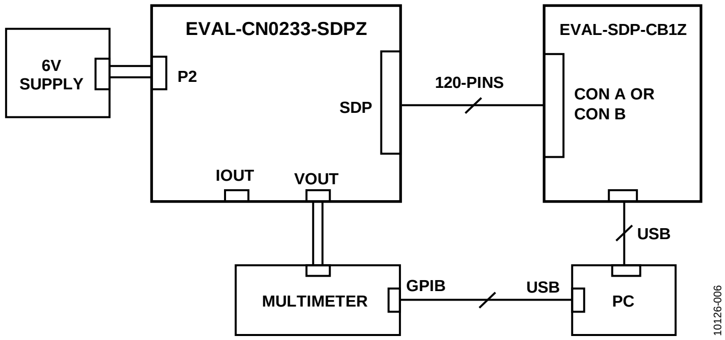

Figure 6. Functional Block Diagram of Test Setup Showing Evaluation Board Connections

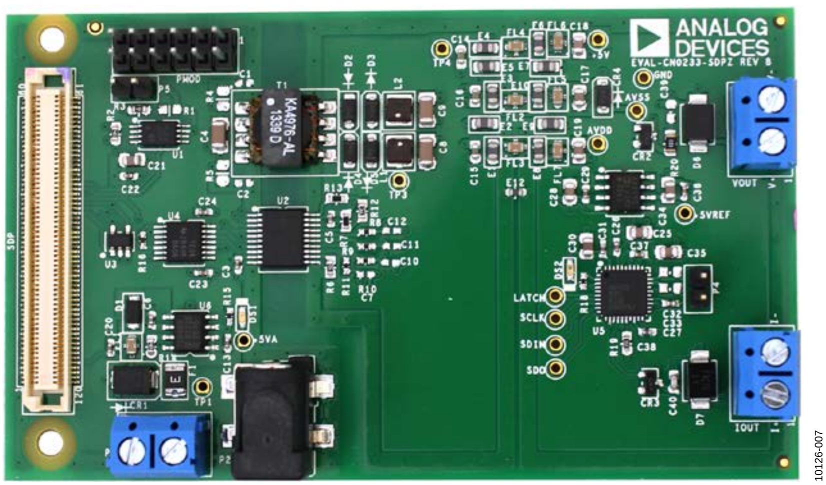

Figure 7. EVAL-CN0233-SDPZ PC Board Photo

LEARN MORE

CN-0233 Design Support Package: http://www.analog.com/CN0233-DesignSupport

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.

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MT-015 Tutorial, *Basic DAC Architectures II: Binary DACs*, Analog Devices.

MT-016 Tutorial, *Basic DAC Architectures III: Segmented DACs*, Analog Devices.

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

Wayne, Scott. iCoupler® *Digital Isolators Protect RS-232, RS-485, and CAN Buses in Industrial, Instrumentation, and Computer Applications. Analog Dialogue* (October 2005).

Ardizzoni, John. *A Practical Guide to High-Speed Printed-Circuit-Board Layout*, *Analog Dialogue* 39-09, September 2005.

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

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

Data Sheets and Evaluation Boards

EVAL-CN0233-SDPZ

EVAL-SDP-CB1Z

AD5422 Data Sheet

AD5422 Evaluation Board (EVAL-AD5422EBZ)

ADuM3471 Data Sheet

ADuM3471 Evaluation Board (EVAL-ADuM3471EBZ)

UG-197 User Guide for ADuM3471 Evaluation Board

ADR445 Data Sheet

REVISION HISTORY

3/14—Rev. 0 to Rev. A

Changes to Circuit Function and Benefits Section and Figure 1 1
Changes to Circuit Description Section and Figure 2; Added Test Data and Results Section and Figure 4, Renumbered Sequentially; Replaced Figure 3 2
Added Figure 5; Changes to Circuit Evaluation and Test Section, Equipment Used to Collect Test Data Section, and Setup and Test Section 3
Changes to Figure 6; Added Figure 7 4

10/11—Revision 0: Initial Version