ANALOG DEVICES

Circuit Note
CN-0233

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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

Design and Integration Files

Schematics, Layout Files, Bill of Materials

CIRCUIT FUNCTION AND BENEFITS

Industrial and instrumentation systems, as well as programmable logic controllers (PLCs) and distributed control systems (DCS), must often control outputs, which can be both current controlled (4 mA to 20 mA), and voltage controlled (up to ±10 V). Typically, such designs also need to be isolated from the local system controller to protect against ground loops and also to ensure robustness against external events. Traditional solutions use discrete ICs for both power and digital isolation.

When multichannel isolation is needed, the cost and space of providing discrete solutions becomes a big disadvantage. Solutions based on opto-isolators typically have reasonable output regulation but require additional external components, thereby increasing board area. Power modules are often bulky and may provide poor output regulation. The circuit in Figure 1 is based on the ADuM347x family of isolators (ADuM3470, ADuM3471, ADuM3472, ADuM3473, ADuM3474) and

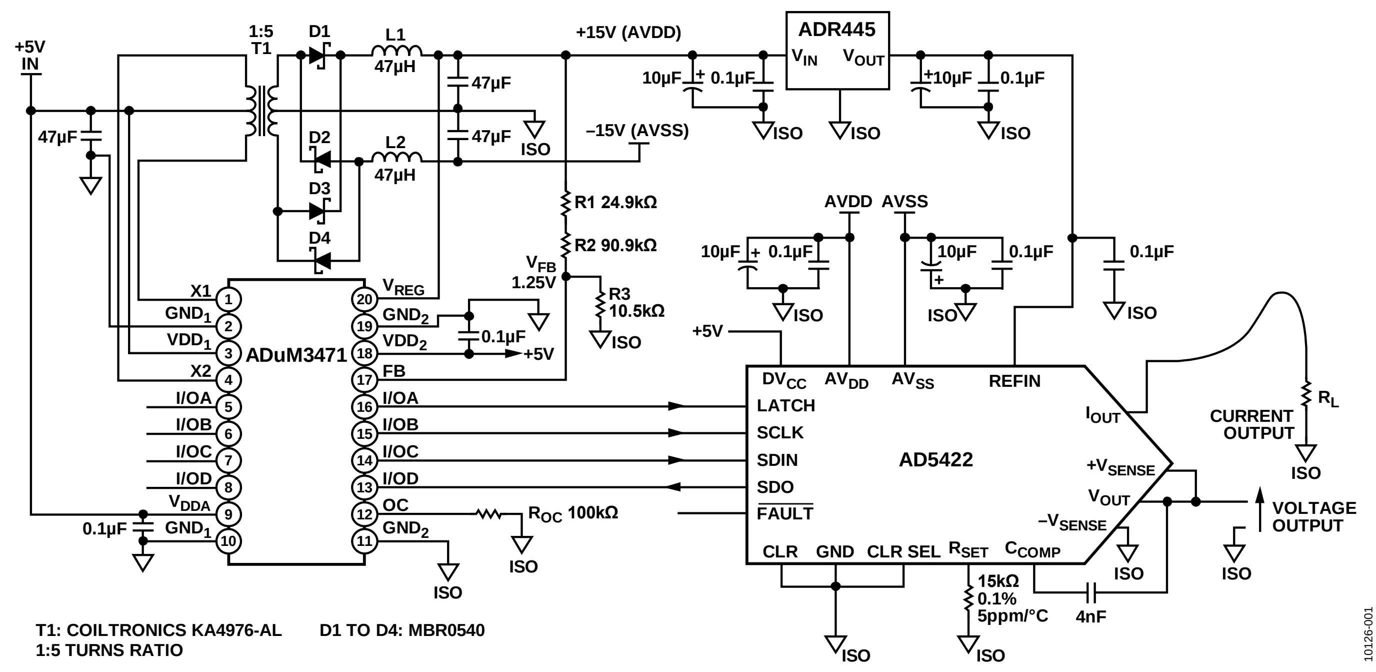

Figure 1. Isolated 16-Bit Current and Voltage Output DAC with Isolated Power Supplies.

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 www.analog.com
Fax: 781.461.3113

integrates digital isolation, as well as the PWM-controlled power regulation circuitry along with associated feedback isolation. External transformers are used to transfer power across the isolation barrier. The AD5422 16-bit DAC provides the current and voltage outputs.

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 20 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 of 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 drivers (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 setpoint 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 −26.3 V. 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.

The AD5422 integral nonlinearity (INL) was tested using both linear supplies and the isolated dc-to-dc switching supplies to ensure no loss in system accuracy was incurred because of the switching supplies. Figure 2 shows the INL for the linear supplies and Figure 3 for the switching supplies. There is no noticeable performance loss when using the switching supply as compared to the linear supply.

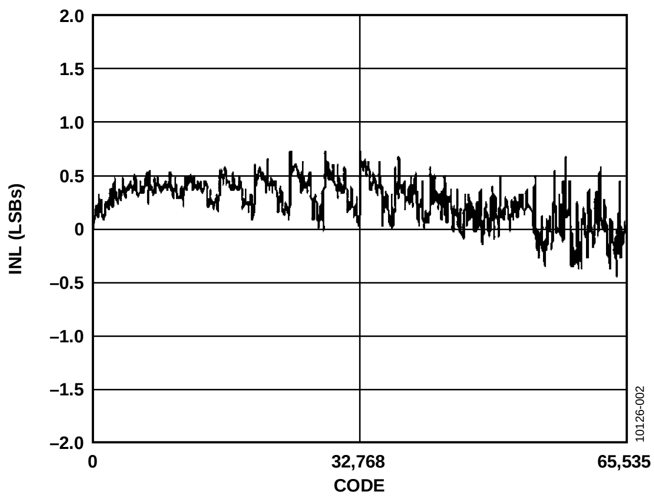

Figure 2. Measured INL of Circuit for ±10V Output Range Using Linear Supplies .

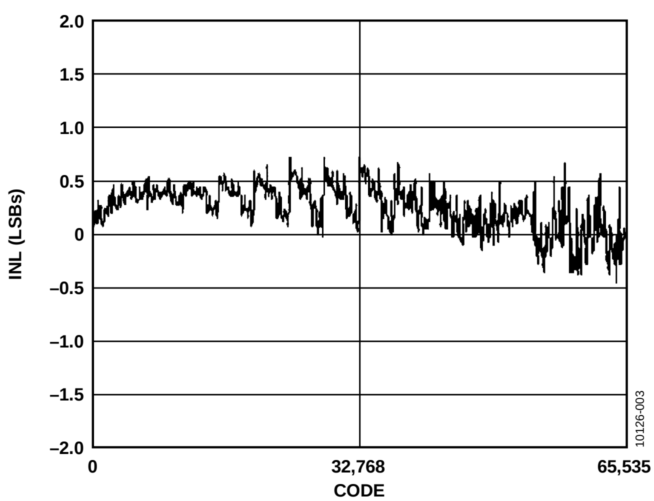

Figure 3. Measured INL of Circuit for ±10V Output Range Using Switching Supplies .

The average output noise was also tested and compared over time when using a linear supply and switching supply, as shown in Figure 4. Note that there is a slight offset in output noise measured over time. This offset can be attributed to a combination of dc PSRR due to the difference in linear negative supply versus the unregulated switching supply, as well as a contribution due to the drift in the reference during the time between the two measurements.

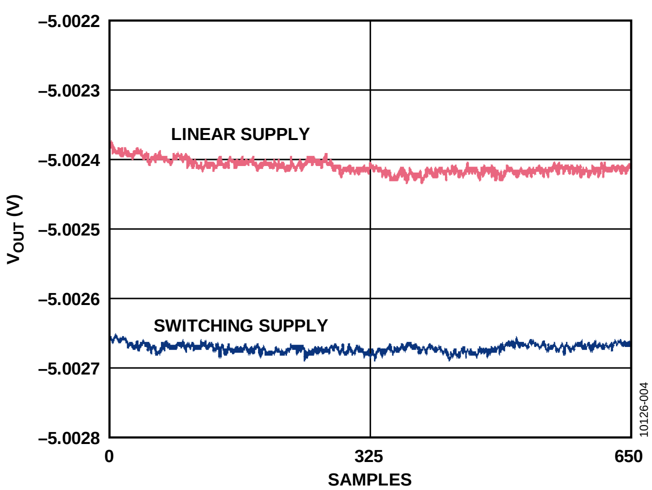

Figure 4. Measured Average DAC Output Noise for Linear and Switching Supplies with DAC Output Set at −5 V on ±10 V Output Range (1 LSB = 0.0003 V), 650 Samples.

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-AD5422EBZ circuit board and the EVAL-ADuM3471EBZ connected together as shown in Figure 5. To ensure the isolation paths were tested fully, the ground, power, and data tracks between the controller and the AD5422 device were cut, and the signals were routed through the ADuM3471 evaluation board.

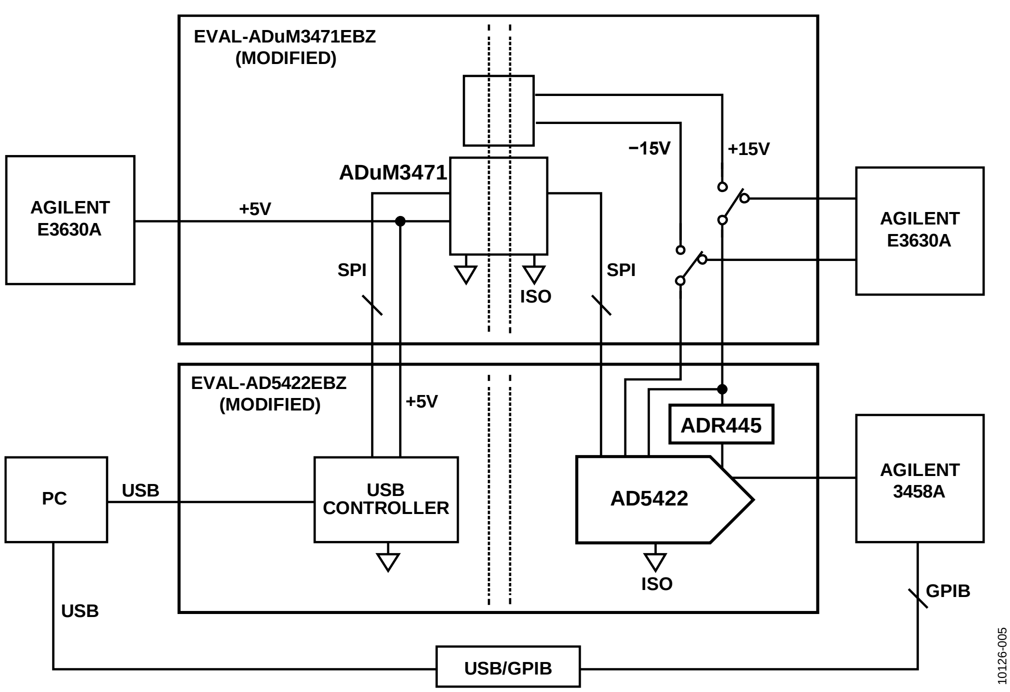

Figure 5. Functional Block Diagram of Test Setup Showing Evaluation Board Connections

Equipment Used to Collect Test Data

- PC with a USB port and Windows® XP, Windows Vista®, (32-bit), or Windows 7 (32-bit)
- EVAL-AD5422EBZ (modified)
- EVAL-ADuM3471EBZ (modified)
- Evaluation software for AD5422 board.
- Power supply: +5 V
- Power supply: ±15 V, Agilent E3630A or equivalent
- Agilent 3458A, 8.5 digit meter or equivalent
- National Instruments GPIB to USB-B interface and cable

Setup and Test

The circuit was tested and verified by connecting both the ADuM3471 evaluation board and the AD5422 evaluation board, as shown in Figure 5.

The double supply was set up as a positive and negative supply on the ADuM3471 evaluation board by changing the transformer to a 1:5 turns ratio transformer (Coilcraft KA4976-AL). Other changes were removing the 0 Ω resistors from R24 and R22 to R23 and R21. Short-circuiting R23 instead of R24 makes the +7.5 V/6 V pin of J6 become the −15 V supply. Short-circuiting R21 instead of R22 connects the transformer center tap to the ground plane instead of the node where L3, C20, and C27 are connected.

Figure 16 of UG-197 shows which resistors should be short-circuited and open-circuited for the double supply or positive and negative supply configurations. Note: See user guide UG-197 for detailed information on these hardware changes.

The AD5422 evaluation board was modified to allow the digital control signals to pass through the ADuM3471 evaluation board. This allows the full data isolation path to the AD5422 to be fully tested.

The INL and noise data were obtained by inputting the DAC data to the AD5422 evaluation board from the PC and reading the results from the 3485A meter using the GPIB/USB interface. The AD5422 evaluation board software was used to generate the data to the DAC.

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-014 Tutorial, *Basic DAC Architectures I: String DACs and Thermometer (Fully Decoded) DACs*, Analog Devices.

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

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

10/11—Rev. 0: Initial Version