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

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.

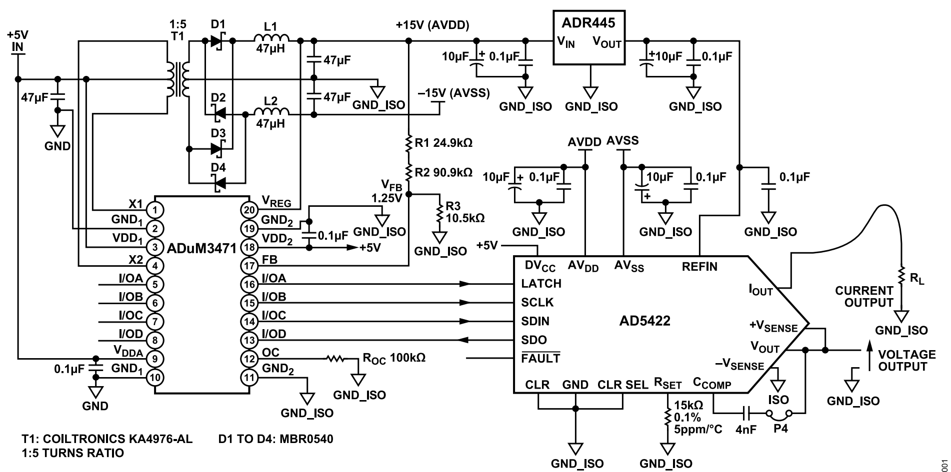

Figure 1. Isolated 16-Bit Current and Voltage Output DAC with Isolated Power Supplies

TABLE OF CONTENTS

REVISION HISTORY

12/23—Revision B: Initial Version

Converted Document from CN-0233 to AN-2564... 1

Deleted Circuit Evaluation and Test Section, Equipment Used to Collect Test Data Section, Setup and Test Section, Learn More Section, and Data Sheets and Evaluation Boards Section..................................4

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 ADuM3471internal 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 un-regulated 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.

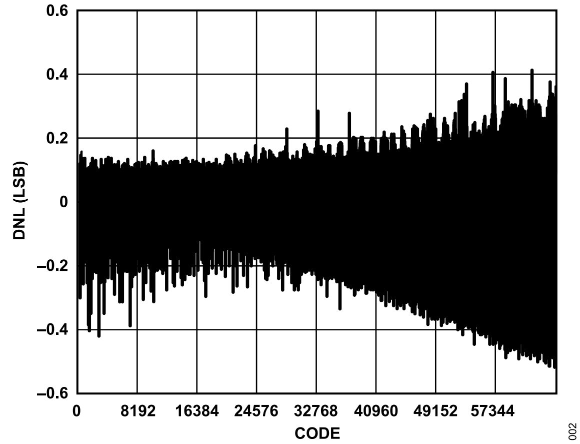

Figure 2. Measured DNL of Circuit for ±10 V Output Range

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.

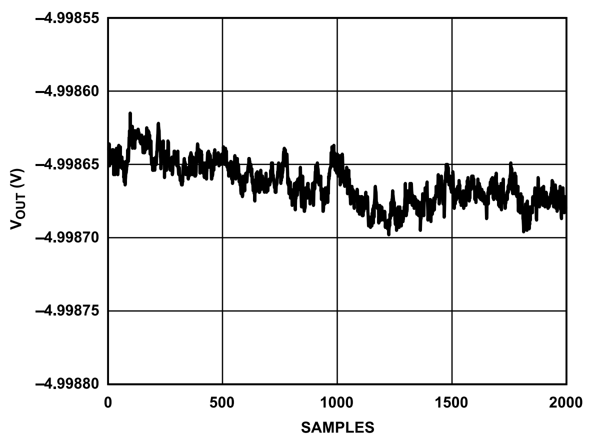

Figure 3. Measured Average DAC Output Noise with DAC Output Set at −5 V on ±10 V Output Range, Vertical Scale: 50 µV/div (1 LSB = 305 µV), 2000 Samples

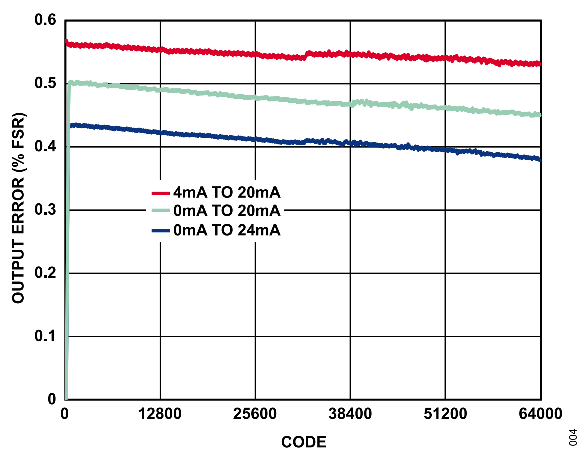

Figure 4. Measured Error (% FSR) For Current Output Ranges

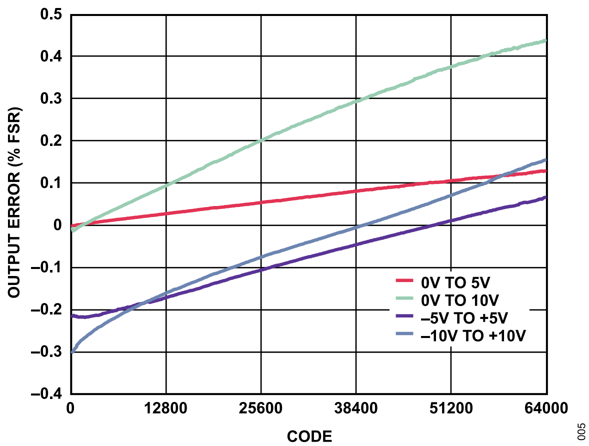

Figure 5. Measured Error (% FSR) for Voltage Output Ranges

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).