

# DESIGN NOTES

## LTC1451/52/53: 12-Bit Rail-to-Rail Micropower DACs in an SO-8 Design Note 96

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The LTC<sup>®</sup>1451, LTC1452 and LTC1453 are complete, single supply, rail-to-rail voltage output 12-bit digital-to-analog (DAC) converters. They include an output buffer amplifier and a space saving SPI compatible three-wire serial interface. There is also a data output pin that allows daisy-chaining multiple DACs. These DACs use a proprietary architecture which guarantees a DNL (Differential Nonlinearity) error of less than 0.5LSB. The typical DNL error is about 0.2LSB as shown in Figure 1. There is a built-in power-on reset that resets the output to zero scale. The output amplifier can swing to within 5mV of  $V_{CC}$  when unloaded and can source or sink 5mA even at a 4.5V supply. These DACs come in an 8-pin PDIP and SO-8 package.

### 5V and 3V Operation

The LTC1451 has an on-board reference of 2.048V and a nominal output swing of 4.095V. It operates from a single 4.5V to 5.5V supply dissipating 2mW ( $I_{CC(TYP)} = 400\mu A$ ).

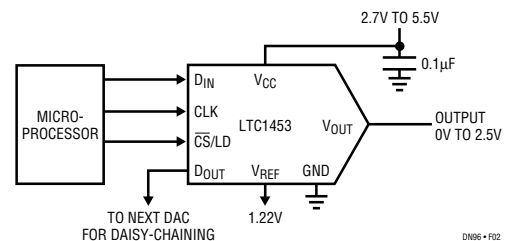
The LTC1452 is a multiplying DAC with no on-board reference and a full-scale output of twice the reference input. It operates from a single supply that can range from 2.7V to 5.5V. It dissipates 1.125mW ( $I_{CC(TYP)} = 225\mu A$ ) at a 5V supply and a mere 0.5mW ( $I_{CC(TYP)} = 160\mu A$ ) at a 3V supply.

The LTC1453 has a 1.22V on-board reference and a convenient full scale of 2.5V. It can operate on a single supply with a wide range of 2.7V to 5.5V as shown in Figure 2. It dissipates 0.75mW ( $I_{CC(TYP)} = 220\mu A$ ) at a 3V supply. The digital inputs can swing above  $V_{CC}$  for easy interfacing with 5V logic.

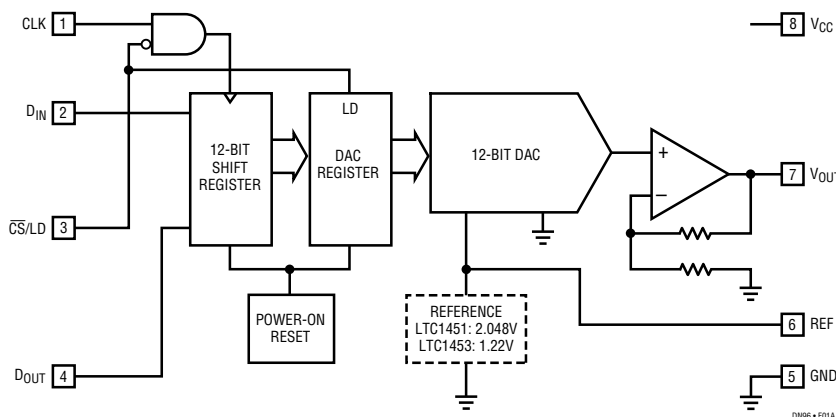
### True Rail-to-Rail Output

The output rail-to-rail amplifier can source or sink 5mA over the entire operating temperature range while pulling to within 300mV of the positive supply voltage or ground. The output swings to within a few millivolts of either

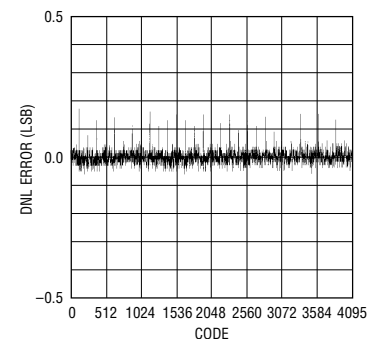
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**Figure 2. The 3V LTC1453 is SPI Compatible and Talks to Both 5V and 3V Processors**



**Figure 1. Proprietary Architecture Guarantees Excellent DNL**



supply rail when unloaded and has an equivalent output resistance of  $50\Omega$  when driving to either rail. The output can drive a capacitive load of up to  $1000\text{pF}$  without oscillating.

### Wide Range of Applications

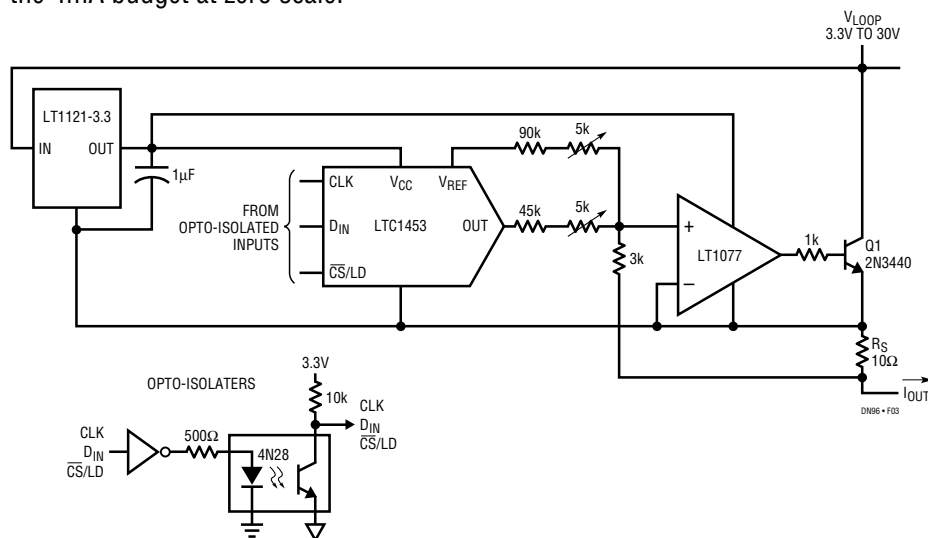
Some of the applications for this family include digital calibration, industrial process control, automatic test equipment, cellular telephones and portable battery-powered applications where low supply current is essential. Figure 3 shows how to use an LTC1453 to make an opto-isolated digitally controlled  $4\text{mA}$  to  $20\text{mA}$  process controller. The controller circuitry, including the opto-isolator, is powered by the loop voltage that can have a wide range of  $3.3\text{V}$  to  $30\text{V}$ . The  $1.22\text{V}$  reference output of the LTC1453 is used for the  $4\text{mA}$  offset current and  $V_{\text{OUT}}$  is used for the digitally controlled  $0\text{mA}$  to  $16\text{mA}$  current.  $R_S$  is a sense resistor and the LT<sup>®</sup>1077 op amp modulates the transistor Q1 to provide the  $4\text{mA}$  to  $20\text{mA}$  current through this resistor. The potentiometers allow for offset and full-scale adjustment. The control circuitry consumes well under the  $4\text{mA}$  budget at zero scale.

### Flexibility, True Rail-to-Rail Performance and Micropower; All In a Tiny SO-8

The LTC1451, LTC1452 and LTC1453 are the most flexible micropower, stand alone DACs that offer true rail-to-rail performance. This flexibility along with the tiny SO-8 package allows these parts to be used in a wide range of applications where size, power, DNL and single supply operation are important.

**Table 1. LTC Serial Voltage Output DACs**

Part	V <sub>CC</sub> Range	Reference	Full Scale	I <sub>CC</sub>
LTC1451	4.5V to 5.5V	2.048V-Internal	4.095V	400 $\mu\text{A}$ at 5V
LTC1452	2.7V to 5.5V	External	2 $\times$ REF	225 $\mu\text{A}$ at 5V
LTC1453	2.7V to 5.5V	1.22V-Internal	2.5V	250 $\mu\text{A}$ at 3V
LTC1257	4.75V to 15.75V	2.048V-Internal (2.5V to 12V-External)	2.048V (2.5V to 12V)	350 $\mu\text{A}$ at 5V



**Figure 3. 4mA to 20mA Process Controller Has 3.3V Minimum Loop Voltage**

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