# DACx1001 Enables Ultra High-Precision Closed-Loop Control System Design

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High-performance control-loop applications demand high-resolution, monotonicity, fast settling, ultra-low glitch, and low noise. The DAC11001A, DAC91001, and DAC81001 (DACx1001) provide highly competitive specifications for such designs. In addition, the DACx1001 provide uniform code-to-code glitch across all codes.

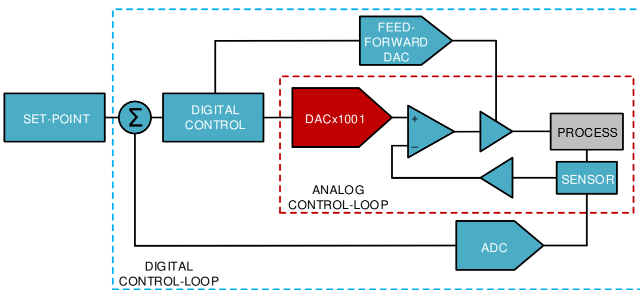


**Figure 1. Feedback Control Loop**

## Introduction

Precision control is a core requirement in the field of precision engineering and manufacturing such as semiconductor and optical manufacturing, precision analog output modules, inertial navigation, spectrometers, laser markers, and lab and field instrumentation. These applications include high-precision closed-loop control systems that are often a combination of digital and analog control loops. They control various types of actuators such as DC motors, piezoelectric transducers, electrostatic and electromagnetic actuators, and so forth. Every type of actuator requires specific driving methods and associated design challenges. In addition, precision control systems have key requirements such as precision, speed, and robustness. The DACx1001 family of ultra high-performance digital-to-analog converters (DAC) provides a state-of-the-art feature set to address the demands of the new and current generation high-precision control systems.

## Requirements of a Control System

As shown in Figure 1, a precision DAC typically finds application in the analog loop of a multi-loop control system. In some cases, the DAC is used for set point generation outside the control loop. The analog loop is designed for achieving best control speed and resolution, while the digital loop ensures the overall accuracy and advanced loop compensation. Figure 2 shows a simplified schematic of an analog control loop using DACx1001. The selection of the reference buffers and the output buffer for DACx1001 is key to achieving the required settling time, noise, and stability. High bandwidth reference buffers ensure low overshoot at the reference inputs of the DAC during code change. Refer to the *20/18/16-Bit, Low-Noise, Ultra-Low THD, Fast-Settling High-Voltage Output DACs Data Sheet* for guidance on buffer selection. Table 1 shows the driving method and the key DAC performance requirements for different types of actuators. The key performance of high-precision control systems is generally defined by speed, precision, loop bandwidth, steady-state error, and loop stability. You can translate these requirements to DAC specifications as described in the following sections.

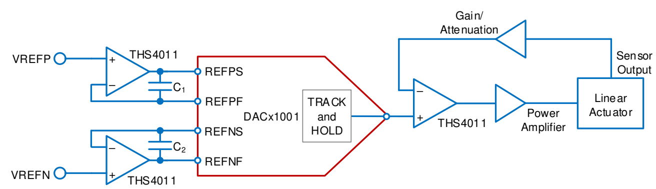


**Figure 2. DACx1001 Control Loop Schematic**

**Table 1. Actuators and Performance**

| ACTUATOR TYPE | DRIVING METHOD | KEY REQUIREMENTS |
|---|---|---|
| DC Motor / Galvano motor | Voltage or current | Resolution, glitch |
| Piezo transducer | Voltage | Resolution, settling time, glitch |
| Electrostatic deflection | Voltage | Resolution, settling time |
| Electromagnetic deflection | Current | Resolution, settling time |
| Crystal oscillator | Voltage | Resolution, noise |

*Resolution* defines the smallest control step for the system. A high-resolution DAC minimizes the steady-state error and enhances the flatness of the control response. DACx1001 are available in 20-bit, 18-bit, and 16-bit resolutions.

*Linearity* defines the stability and the steady-state error of the system. A DAC with monotonic output response makes the system stable. DACx1001 provide guaranteed monotonicity and uniform differential non-linearity (DNL) across all codes and all output ranges. Figure 3 shows the DNL versus Code plot of the DAC11001A. The DACx1001 offer excellent integral non-linearity (INL) of less than ±4 LSB (max) across all ranges and less than ±2 LSB (max) in specified temperature ranges, at 20-bit resolution.

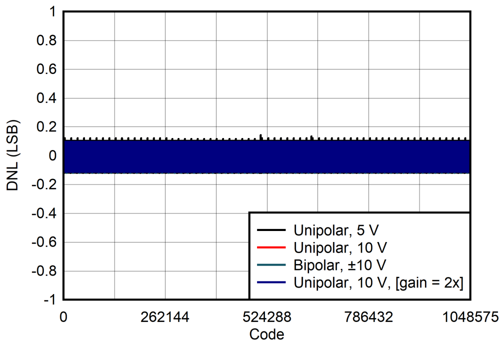


**Figure 3. DAC11001A DNL versus Digital Code**

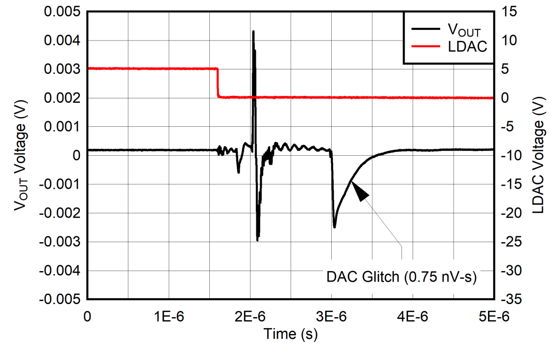


**Figure 5. Code-to-code Glitch**

*Settling Time* decides the bandwidth of the control loop and the ability of the loop to respond to a change in the set point as well as to recover from external disturbances. Figure 4 shows the settling behavior of DAC11001A for a 100-code step with ±1LSB settling error at 20-bit.

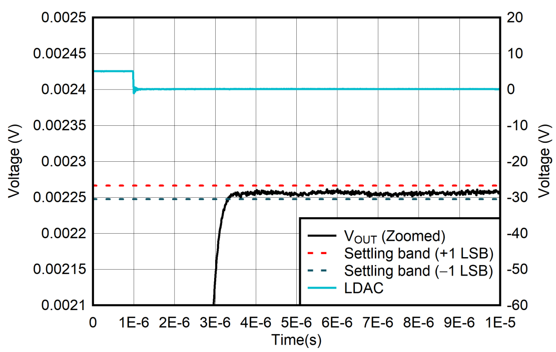


**Figure 4. DAC11001A Output Settling**

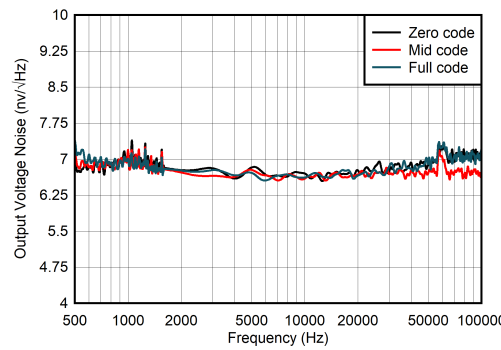


**Figure 6. Noise Density**

*Glitch:* Mechanical actuators like DC motors and piezoelectric transducers tend to vibrate when the DAC exhibits a large code-to-code glitch. The DACx1001 provide an integrated track-and-hold (TnH) circuit that filters out the code-to-code glitch of the DAC. The hold time for the TnH is also configurable, which allows the DAC to reach faster update rates up to 1 MHz. Figure 5 shows the typical glitch behavior of DACx1001. The typical major carry transition glitch energy of DACx1001 is as low as 0.75 nV-s.

*Noise:* For sensitive components like crystal oscillators and optical control systems, low-noise is a key requirement. The DACx1001 provides a very low typical noise density of 7 nV/√Hz. Figure 6 shows the noise density plot for DACx1001.

## DACx1001

The 20-bit DAC11001A, 18-bit DAC91001, and 16-bit DAC81001 are highly accurate, low-noise, voltage-output, single-channel, digital-to-analog converters (DACs). The DACx1001 are specified monotonic by design, and offer excellent linearity. The DACx1001 use a versatile 4–wire serial interface that operates at clock rates of up to 50 MHz. The DACx1001 are specified over the industrial temperature range of –40°C to +125°C.

## Conclusion

Advancements in manufacturing and instrumentation technologies demand ultra-high-performance closed loop system implementation. The DACx1001 family of DACs provides a highly competitive feature set to make the control loop designs achieve high-precision, speed, and robustness across wide operating conditions.

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