DESIGN FAQs

Frequently Asked Questions:

DIGITAL POTENTIOMETERS

Roger Allan, Contributing Editor

Q. What is a digital potentiometer?

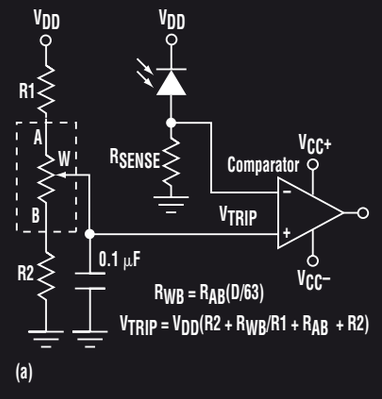
A. A conventional potentiometer or "pot" is an analog device used to vary, or control, the amount of current that flows through an electronic circuit. It's a mechanical device with a wiper that's used to select the value of the variable resistance desired. A digital potentiometer is either a volatile or nonvolatile device. The former consists of resistors or resistor arrays. It also has other electronic circuit elements like switches, logic gates, multiplexers, and data converters. A nonvolatile device additionally includes memory in the form of EEPROM or a one-time programmable (fuse link) memory. A digital potentiometer can be used to calibrate system tolerances or dynamically control system parameters. Nonvolatile memory parts retain the wiper-setting values after a power cycle from off to on. In addition, fuse link parts offer a one-time program trimmer feature.

Q. What's the primary advantage of a digital potentiometer compared to an analog potentiometer?

A. Digital potentiometers are excellent cost-effective replacements for mechanical potentiometers because of their robustness. They also have excellent settability, better resolution, and lower noise levels. They're more stable over time. And, their resistance values drift minimally, are more reliable, and allow for remote control. Other advantages include smaller physical size, a lower temperature coefficient of resistance, more resistance range options, and numerous packages to choose from. Since it is a digital device, a designer has the option of using it in either volatile or nonvolatile memory configurations as well.

Q. What are the various digital-potentiometer applications?

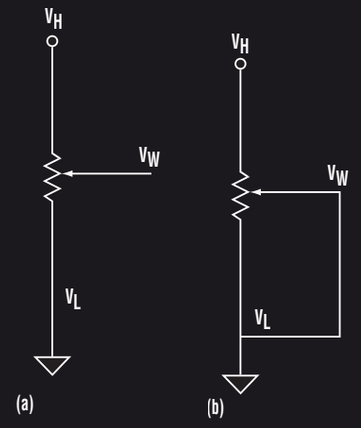
A. Digital potentiometers can be used as a variable low-pass filter, a programmable-gain amplifier, a programmable oscillator, a voltage-to-current converter, and a programmable rise- and fall-time waveform controller. They also can be used for precision calibration of set point thresholds, sensor trimming, LCD bias trimming, audio attenuation, adjustable power supplies, motor-control overcurrent trip setting, and offset trimming *(Fig. 1)*.



1. Digital potentiometers can be used in a variety of applications, including setting a precision threshold (a), a set point or threshold calibration (b), a trimming voltage reference (c), or a programmable inverting gain amplifier (d).

Q. When designing with digital potentiometers, is the potentiometer configuration important?

A. Yes. There are two types of potentiometer configurations: a three-terminal configuration *(Fig. 2a)* and a two-terminal configuration *(Fig. 2b)*. When connected in a true potentiometer configuration, a three-terminal setup normally gives designers maximum control over the load on the wiper by having the wiper connected to a high-impedance node. This keeps the current flowing through the wiper low. On the other hand, connecting a digital potentiometer in a two-terminal configuration means the wiper may have to carry large current loads. This is particularly true when the wiper is closest to the potentiometer's high side



2. Potentiometers can be configured with three terminals (a) or two terminals (b).

and is connected to the low side, which is grounded. Depending on the voltage applied to the potentiometer and the wiper's resistance value, designers must be careful not to exceed the maximum current ratings flowing into and out of V_H and V_W under these conditions.

Q. Is the digital potentiometer a one-for-one replacement for an analog potentiometer? If not, what are the restrictions?

A. No, a digital potentiometer isn't a one-for-one replacement for an analog potentiometer. There are limitations. Designers must ensure that both voltage and current levels are below the maximum ratings specified in the data sheet.

Normally, a digital potentiometer is connected on one side *(Fig. 2a, again)* to the V_{DD} power-supply line and on the other side *(Fig 2b, again)* to the V_{SS} line (which can be connected to ground), with the wiper side output (W) available in between. The larger voltage of either A or B must be greater than the value of V_{SS} or ground. Except for some specific models that are rated for operation greater than 5 V, voltages across the wiper to the V_{DD} or V_{SS} line, as well as between V_{DD} and V_{SS}, must not exceed 5 V.

The maximum current is limited by three boundaries at a given resistance setting: the maximum rated operating voltage, the power dissipation rating (which becomes a factor at low resistance values), and the maximum current-handling capabilities of the internal switches. At zero scale with minimum wiper resistance, 20 mA is the maximum allowable intermittent limit imposed by the switches. Figure 3

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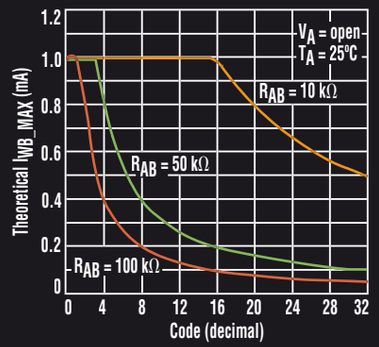

3. This graph shows the typical maximum current between the wiper terminal and Ground as a function of code values.

shows typical graphs of maximum current between the wiper terminal and Ground as a function of code values.

Q. How important is the operating-voltage range in designing with a digital potentiometer?

A. The operating-voltage range is critical. Digital potentiometers must have a rating that's consistent with the voltage ratings in which the conventional analog potentiometer is used. Most digital potentiometers are limited to 5-V operation. However, some are available for ±5-, ±15-, 12-, and 30-V operation.

Q. Can the power be shut off and turned back on in a nonvolatile digital potentiometer so it can be considered refreshed?

A. No. That only refreshes the register logic, not the EEPROM. Data will have to be reloaded again before its rated retention time—usually after at least 10 years—to put a fresh charge onto the EEPROM cell.

Q. What are the common failure modes of digital potentiometers?

A. Because it is a digital device, latch-up conditions can occur on a digital potentiometer's end terminals A and B when the prescribed power-up sequence with respect to V_{DD}, V_{SS}, the potentiometer terminals, and Ground isn't followed. Device failure also can occur if a 5-V-rated digital potentiometer is subjected to more than 5 V (either across the potentiometer's end terminals A and B or between the wiper, W, and either A or B). Applying V_{DD} first is recommended, then V_{SS}, with respect to Ground. The order of application between the ends of the digital potentiometer (A and B) and the wiper terminal (W) is not important, but they should be powered up last. ED Online 10505

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PRODUCT Q&As

ANALOG DEVICES' DIGITAL POTENTIOMETERS DELIVER INDUSTRY-LEADING PERFORMANCE, FUNCTIONALITY, AND RELIABILITY

Now you can choose digital potentiometers from the industry's broadest portfolio and get the best resolution for the best value. Analog Devices' proven technology meets the demands of the toughest environments, including applications for the automotive, consumer, and industrial markets. ADI's integrated-circuit digital potentiometers provide the same variable resistance setting offered by mechanical potentiometers while reducing or eliminating the labor required to set the wiper position. These digital devices use a digital controller with a serial interface to set the wiper position. As a result, these potentiometers can be placed next to sensitive analog circuitry, eliminating electrical noise pickup due to the mechanical potentiometer's remote front panel routing. To browse our extensive portfolio of digital potentiometers, including the products featured below, visit *www.analog.com/digitalpots*.

AD5290: Compact +30-V/±15-V 256-Position Digital Potentiometer

Developed on ADI's new iCMOS™ industrial process technology, the AD5290 delivers an unbeatable combination of features and performance in an ultrasmall package size. This device performs the same electronic adjustment function as traditional mechanical potentiometers or variable resistors, but with the enhanced resolution needed for high-voltage designs and the benefits of complete digital control. The AD5290 also provides superior temperature-coefficient performance and solid-state reliability.

AD5251/AD5252/AD5253/AD5254: Nonvolatile Dual- and Quad-Channel I^2C-Compatible Digital Potentiometers

The AD525x family of dual and quad 6- and 8-bit resolution digital potentiometers is ideal for I^2C-controlled applications in network equipment power-supply margining applications. The AD5254 is a quad-channel, digitally controlled variable resistor (VR) with a resolution of 256 positions. Additional user memory locations are available to store constants and serial numbers. The AD5254's versatile programming via a microcontroller allows multiple modes of operation and adjustment including direct mode, increment, and decrement mode in a single step or in 6-dB steps.

AD5258/AD5259: Nonvolatile, I^2C-Compatible, 64/256-Position Digital Potentiometers

The AD5258/AD5259 family of digital potentiometers delivers the necessary resolution for optimal image fidelity required on larger LCD panels. Many LCD panel manufacturers have begun using digital potentiometers to replace aging, less capable mechanical potentiometer designs. In addition to improved performance, the AD5258/AD5259 eliminate the need for time-consuming physical adjustments that increase the risk of mechanical failure due to vibration and/or human error.