Choosing Digital Control Potentiometers for Precision Control Applications

Introduction

Digital control potentiometers (DCPs) provide a flexible alternative to DACs in many control and signal-adjustment applications. This application note explains how DCPs improve design flexibility, simplify calibration, and enable fine adjustment of analog signals while reducing component count.

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1. Digital Control Potentiometer Overview

Most applications require ICs that are smaller, highly integrated, and less expensive. Innovations and advancements in digital control potentiometers (DCPs) fit right into these requirements.

DCPs are ideal design choices for controlling backlighting in video products, volume control in audio products, and other applications because they provide significant flexibility at lower cost than ever before.

Even better, DCP manufacturers have taken advantage of process technology improvements to deliver temperature performance improvements and integrated on-chip non-volatile memory. All these improvements make DCPs an alternative to DACs in many handheld and portable applications.

Figure 1 illustrates the basic architecture of a DCP. A DCP consists of a resistor ladder with multiple selectable tap points and a common output node known as the wiper (VW/RW). The resistance between the end terminals is referred to as RTOTAL. Digital control logic selects the active tap position, allowing the output voltage or resistance to be adjusted electronically.

The resistor array is comprised of individual resistors connected in series. Electronic switches are located at each resistor junction, and only one switch is typically active at a time. The selected tap connects the corresponding voltage potential to the wiper output, enabling precise adjustment of the output level. Digital control typically supports interfaces such as I²C, SPI, and Up/Down control inputs.

Some DCPs also incorporate charge pumps that allow the output to swing between dual supplies while the input remains within a single-supply range. Additionally, certain devices support operation from ±5V or ±15V supplies, providing flexibility for a wide variety of analog signal-conditioning applications

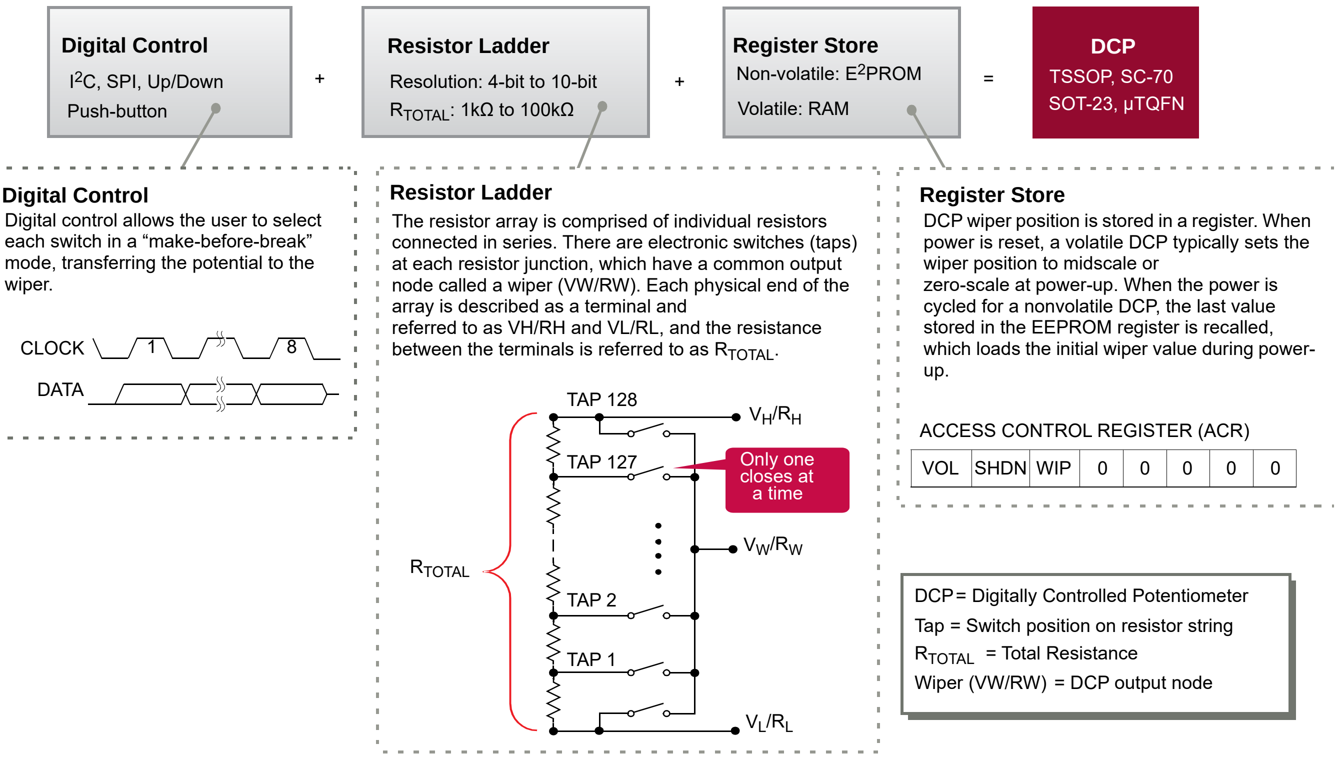

Figure 1. DCP Architecture

2. Resolution Flexibility

DACs provide fixed resolutions in 8-bit through 24-bit versions where output voltages span between the supply voltages in known increments. DCPs, while limited in the number of total taps at 1024 (or 10 bits), offer a different kind of benefit. It is a little bit hidden, but worth looking at. The benefit is the flexibility.

A DCP provides the ability to define the voltage applied to each end of the potentiometer. If the voltage is set on the rails, then the resolution of the output is equal to the number of taps. On the other hand, if the ends are set to a span of half the supply, then the output resolution benefits by the same factor of two.

In effect, the addition of series resistance can improve DCP resolution when the application's operating range is limited. This flexibility is a significant advantage because the voltage span across the fixed resistance can be adjusted to suit the application. For example, the DCP can be used in the feedback path of an amplifier.

This ability to improve effective resolution over a limited operating range is one of the key advantages of a DCP compared with a fixed-resolution DAC.

3. Nonvolatile Memory and Power-Up Behavior

Adding memory is another feature that makes DCPs attractive. The typical solution has been to add an external EEPROM to hold onto critical information in case of a power failure or interruption.

DCPs with added non-volatile memory can conveniently store basic information such as wiper position. Identification, calibration and other data also can now be stored right there with the DCP simply by choosing a DCP with more EEPROM cells.

Some DCPs also incorporate charge pumps so the output can swing between dual supplies, while the input remains between ground and a single supply. Additionally, there are DCPs that operate on a single ±5V or ±15V supply.

4. Temperature Performance

Another improvement in modern DCPs is enhanced temperature stability. Temperature performance used to be a limitation for DCPs, but is no longer.

Process technology improvements let DCPs provide 50ppm/degrees Centigrade of change in end-to-end resistance. Since most DCPs are used as voltage dividers, it makes sense to look at resistances as relative, so the meaningful comparison is relative differences versus temperature. In this comparison, the temperature performance is approximately 4ppm/degrees C. Basically, the performance limitation is gone.

5. DCPs Versus DACs

As DCP features have improved, designers of consumer electronics equipment or telecommunications systems have been able to consider using DCPs in place of DACs. The decision involves comparing the temperature performance, memory (or lack of it), and flexibility, or rigidity, of a DCP compared with a DAC.

Those comparisons are blurring now that the performance of DCPs is improving so much. For example, both provide linear steps, but the DCP also can use logarithmic steps, therefore, DCPs are an excellent choice for applications such as audio systems.

Outputs of either DACs or DCPs can be found with an output buffer to drive low impedance loads, but a simple resistive output is more typical of DCPs. Control interfaces are another issue. A DCP can provide push-button controls or up-down controls, I^2C and/or SPI interfaces, whereas DACs typically only support serial and parallel inputs.

DACs do have some fundamental advantages in some applications, where absolute precision is an overarching objective. DCPs can store their own calibration information, directly set the gate bias for proper functioning in an application like a base station, and dynamically adjust to include data from other sources, such as temperature sensors.

6. Typical Applications

Top uses for DCPs now include:

- Pressure sensors
- Temperature sensors
- Laser sensors
- Trimming voltages on voltage regulators
- Attenuate analog signals to digital system levels

7. Conclusion

DCPs are now an ideal design choice for control and adjustment applications because they deliver significant flexibility at a lower cost. Improvements in temperature performance and integrated on-chip non-volatile memory make DCPs an alternative to DACs in many handheld and portable applications, while DACs remain advantageous where absolute precision is the overarching objective.

8. Revision History

Revision	Date	Description
1.00	Aug 7, 2026	▪ Applied the latest template. ▪ Updated the title. ▪ Reorganized document.
0.00	Feb 17, 2014	Initial release.

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