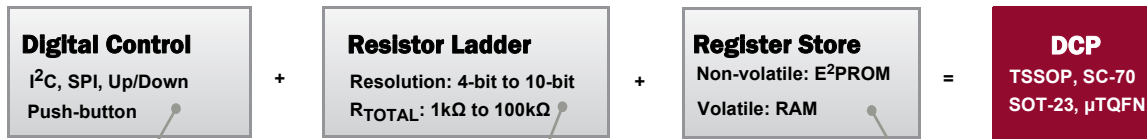


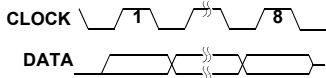
Digital Control Potentiometers Offer Hidden Benefits for Many Designs

AN1699  
Rev 0.00  
February 17, 2014



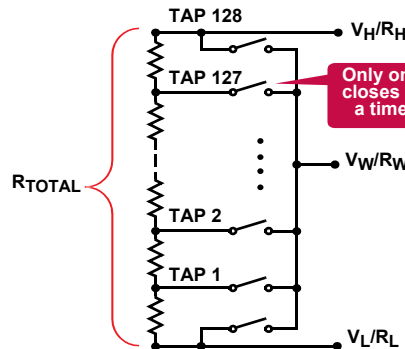
**Digital Control**

Digital control allows the user to select each switch in a "make-before-break" mode, transferring the potential to the wiper.



**Resistor Ladder**

The resistor array is comprised of individual resistors connected in series. There are electronic switches (taps) at each resistor junction, which have a common output node called a wiper (VW/RW). Each physical end of the array is described as a terminal and referred to as VGH/RH and VL/RL, and the resistance between the terminals is referred to as RTOTAL.



**Register Store**

DCP wiper position is stored in a register. When power is reset, a volatile DCP typically sets the wiper position to midscale or zero-scale at power-up. When the power is cycled for a nonvolatile DCP, the last value stored in the EEPROM register is recalled, which loads the initial wiper value during power-up.

**ACCESS CONTROL REGISTER (ACR)**

VOL	SHDN	WIP	0	0	0	0	0
-----	------	-----	---	---	---	---	---

DCP = Digitally Controlled Potentiometer  
Tap = Switch position on resistor string  
RTOTAL = Total Resistance  
Wiper (VW/RW) = DCP output node

Just about any application you can name these days needs ICs that are smaller, highly integrated, and less expensive. Innovations and advancements in digital control potentiometers (DCPs) fit right into these requirements. DCPs are now ideal design choices for controlling backlighting in video products, or for volume control in audio products, among other applications because they now deliver significant flexibility at lower costs than ever. 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. 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's a little bit 'hidden,' but worth looking at.

The benefit is the flexibility. A DCP allows you to set the voltage on the ends 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, you add resistance in series, and as a result improve the resolution of the DCP for a specific application, depending on its requirements. Flexibility is a big plus here, varying the voltage across the fixed resistance mean. For example, the DCP can be used in the feedback path of an amplifier.

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.

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.

Another improvement we are seeing from DCPs is stable temperatures. 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/°C. Basically, the performance limitation is gone.

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 it's an excellent choice for an application like an audio system. Secondly, outputs of either DACs or DCPs can be found with an output buffer to drive impedance loads, but it's more usual to find a DCP with a simple resistance at the output.

Control interfaces are another issue. A DCP can provide push-button controls or up-down controls, I<sup>2</sup>C 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.

Top uses for DCPs now: in pressure, temperature and laser sensors; to trim voltages on voltage regulators; in power supply modules to regulate voltage; and for adjusting analog signals for digital systems.

## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
  2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
  3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
  4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
  5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.  
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.  
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.  
Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
  6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
  7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
  8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
  9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
  10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
  11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
  12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.  
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



### SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

**Renesas Electronics America Inc.**  
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.  
Tel: +1-408-432-8888, Fax: +1-408-434-5351

**Renesas Electronics Canada Limited**  
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3  
Tel: +1-905-237-2004

**Renesas Electronics Europe Limited**  
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K  
Tel: +44-1628-651-700, Fax: +44-1628-651-804

**Renesas Electronics Europe GmbH**  
Arcadiastrasse 10, 40472 Düsseldorf, Germany  
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

**Renesas Electronics (China) Co., Ltd.**  
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China  
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

**Renesas Electronics (Shanghai) Co., Ltd.**  
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China  
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

**Renesas Electronics Hong Kong Limited**  
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong  
Tel: +852-2265-6688, Fax: +852-2886-9022

**Renesas Electronics Taiwan Co., Ltd.**  
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan  
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

**Renesas Electronics Singapore Pte. Ltd.**  
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949  
Tel: +65-6213-0200, Fax: +65-6213-0300

**Renesas Electronics Malaysia Sdn.Bhd.**  
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia  
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

**Renesas Electronics India Pvt. Ltd.**  
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India  
Tel: +91-80-67208700, Fax: +91-80-67208777

**Renesas Electronics Korea Co., Ltd.**  
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea  
Tel: +82-2-558-3737, Fax: +82-2-558-5338