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Article

Digital potentiometers and digital-to-analog converters in tasks for tuning of active RC-filters

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Abstract:
The most popular schemes of digital potentiometers (DP) and digital-to-analog converters (DAC) are considered. DP and DAC use how elements of parameter adjustment of active RC-filters. The circuits of the DAC on the Kelvin-Varley divider, the Kelvin divider based on the R-2R matrix, and the architecture of the DAC with a segmented circuit are shown. The internal structure of DP an Analog Devices and Intersil company is shown, and also the DP switching circuits in a tunable low-pass filter and a band-pass filter, a programmable inverting amplifier and a voltage regulator are presented.

Keywords: active RC-filter, digital tuning elements, digital potentiometer, digital-to-analog converter, low-pass filter, band-pass filter, inverting amplifier, voltage regulator.

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1. Introduction

Active RC-filters (ARCF) are widely used in radio engineering, measuring equipment and automation [1-3]. The implementation of high-precision analog signal conversion in frequency selection devices requires the use of precision elements or calibration procedures using electronic components with controlled characteristics [4-21]. Digital-to-analog converter (DAC) [22-26] or digital potentiometer (DP) [27-38] can be selected as adjustment elements.

The purpose of the article is a brief overview of digital elements for tuning of characteristics in active RC-filters – DAC and DP.

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2. Digital-to-analog converters

The DACs in the ARCF are used as controlled signal dividers. Fig. 1 shows two types of segmented DAC with voltage output. The architecture in Fig. 1a is called the Kelvin-Varley divider and consists of two or more "string DACs" [25]. Since there are buffers between the first and second stages, the DAC of the second stage is not an input, and the resistors in this chain do not have to be of the same rating as the resistors in the other. However, all the resistors in each circuit must be equal to each other, otherwise the DAC will not be linear. Buffer amplifiers (BU) are biased and this can cause non-monotony in the DAC. In a simpler configuration of the Kelvin-Varley divider [25] (Fig. 1a), the "A" DAC is always "lower" (with a lower potential) than the "B" DAC, and an additional tap labeled "A" on the LSB line DAC is not required. Data decoding is performed by only two priority encoders. Instead of using a second resistor chain, you can use a binary DAC to generate the three lowest bits, as shown on Fig. 1b. It is very difficult to produce high-resolution R-2R ladder circuits. Therefore, it is quite common to make a high-resolution DAC with a relay circuit for low-order bits, and a different structure [25] for two to five high-order bits.

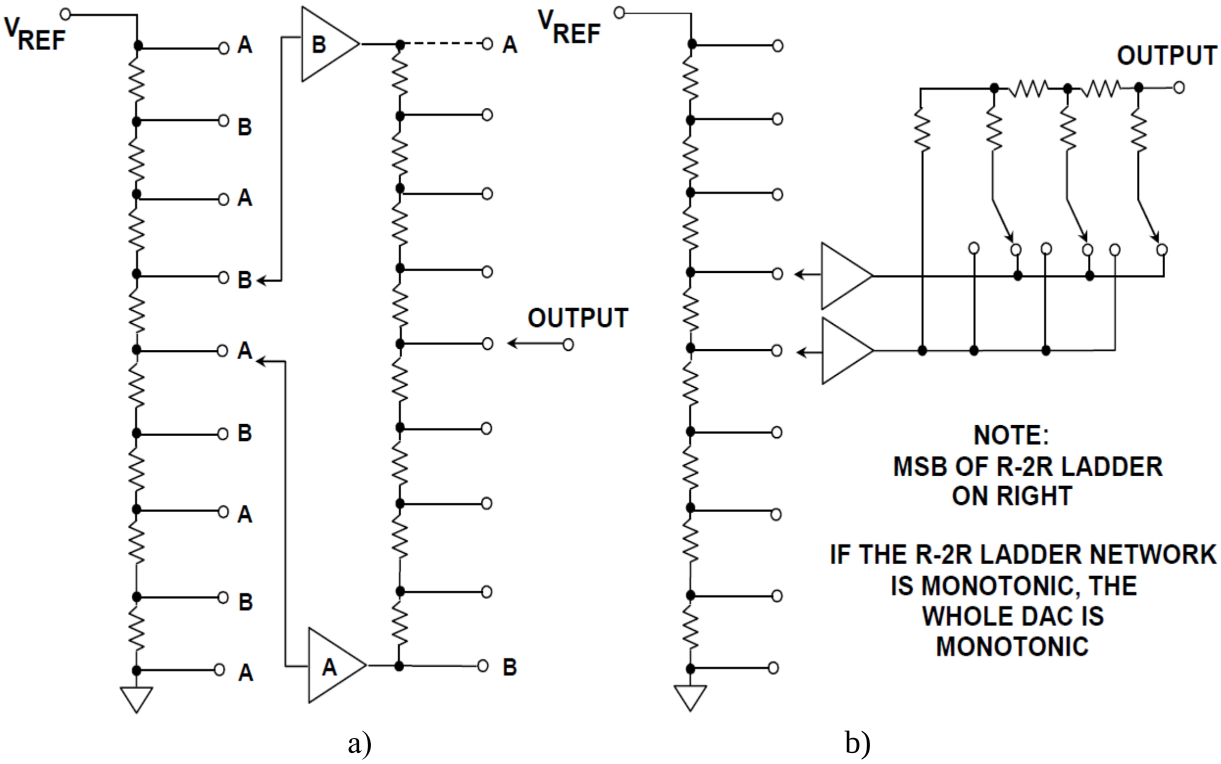

Fig. 1 Kelvin-Varley divider (a), Kelvin divider, and R-2R resistor matrix (b) [25]

Figure 2 shows an unbuffered version of the segmented-circuit DAC architecture. This version is more thought-out in concept (and, of course, can be manufactured based on CMOS processes that produce resistors and switches, so it can also be cheaper) [25].

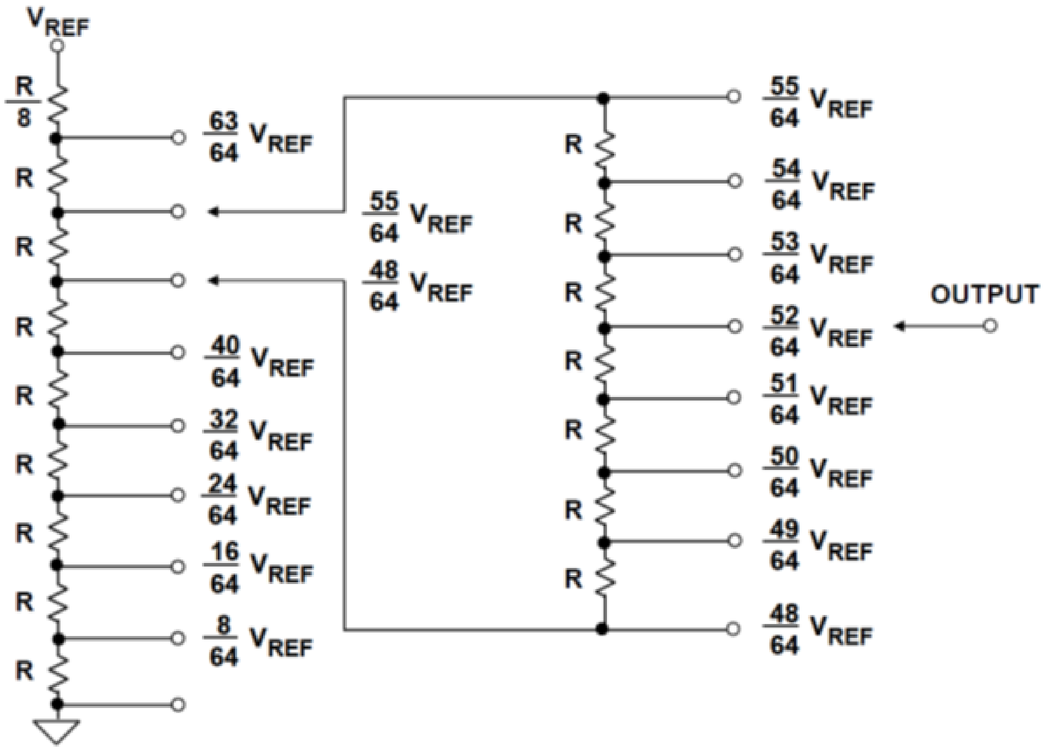

Fig. 2 Segmented unbuffered string DACs [25, 26]

Here (Fig. 2) the resistors in the two chains should be equal, except that the upper resistor in the MSB chain should be less (1/2 kΩ from the values of the others), and the LSB chain has resistors of 2 kΩ – 1 kΩ, but not 2 kΩ [25, 26].

3. Digital potentiometers

DP is an adjustment element in ARCF and allow performing about 50 thousand adjustments before failure [29]. Previously, the ARCF used mechanical potentiometers (MP), which have, at best, several thousand adjustments. Since the MP is subject to mechanical wear, they lose to the DP in terms of reliability [29].

Figure 3 present the internal structure of the DP [29-30].

The DP of Analog Devices range offers excellent performance over a wide range of industrial temperatures. These compact devices, sometimes called digital pot, RDAC, or digiPOT, can be used to calibrate system errors or dynamically adjust parameters. DPs, such as the AD5123 and AD5143 (Fig. 4) [33] have non-volatile memory, 128 / 256 adjustment positions, a small tolerance deviation from the nominal resistance, and a low temperature coefficient, which simplifies the creation of applications with an open feedback loop or applications where the tolerance values need to be matched.

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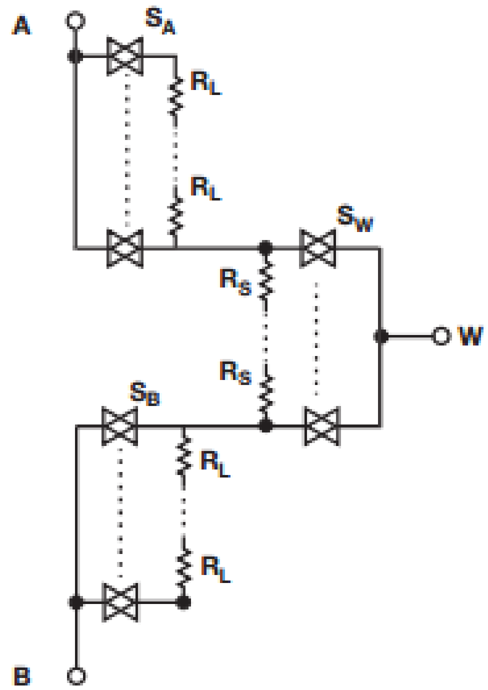

Fig. 3 Internal structure of DP [30]

DPs of ADI digiPOT+ AD5270/AD5271/AD5272/AD5274 are single-channel, contain 1024-/256-position resistors with digital control, through-pass resistor tolerance error of less than 1%, and programmable memory [32].

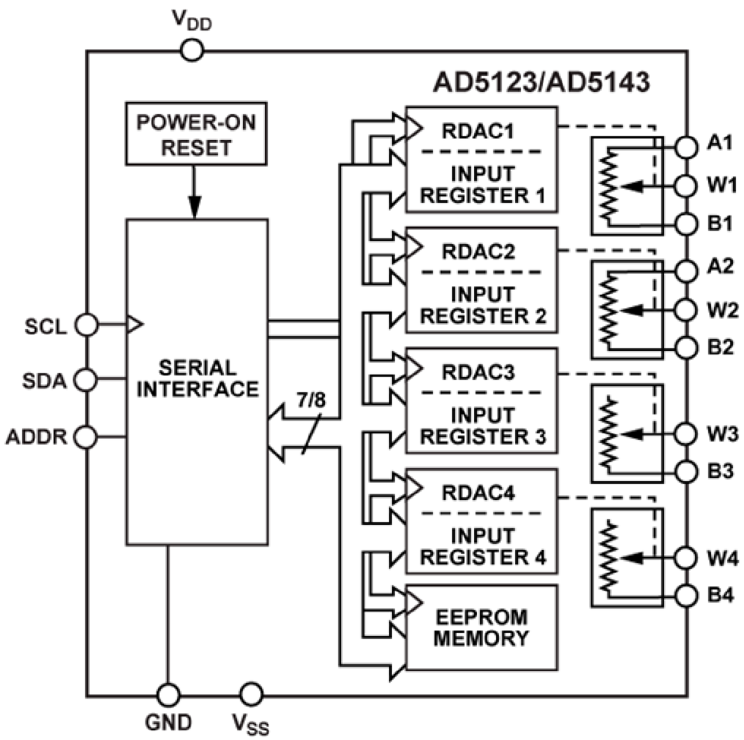

Fig. 4 Functional block diagram of the AD5123 and AD5143 [32]

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Figure 5 shows three examples of DPs that are manufactured in small packages [33].

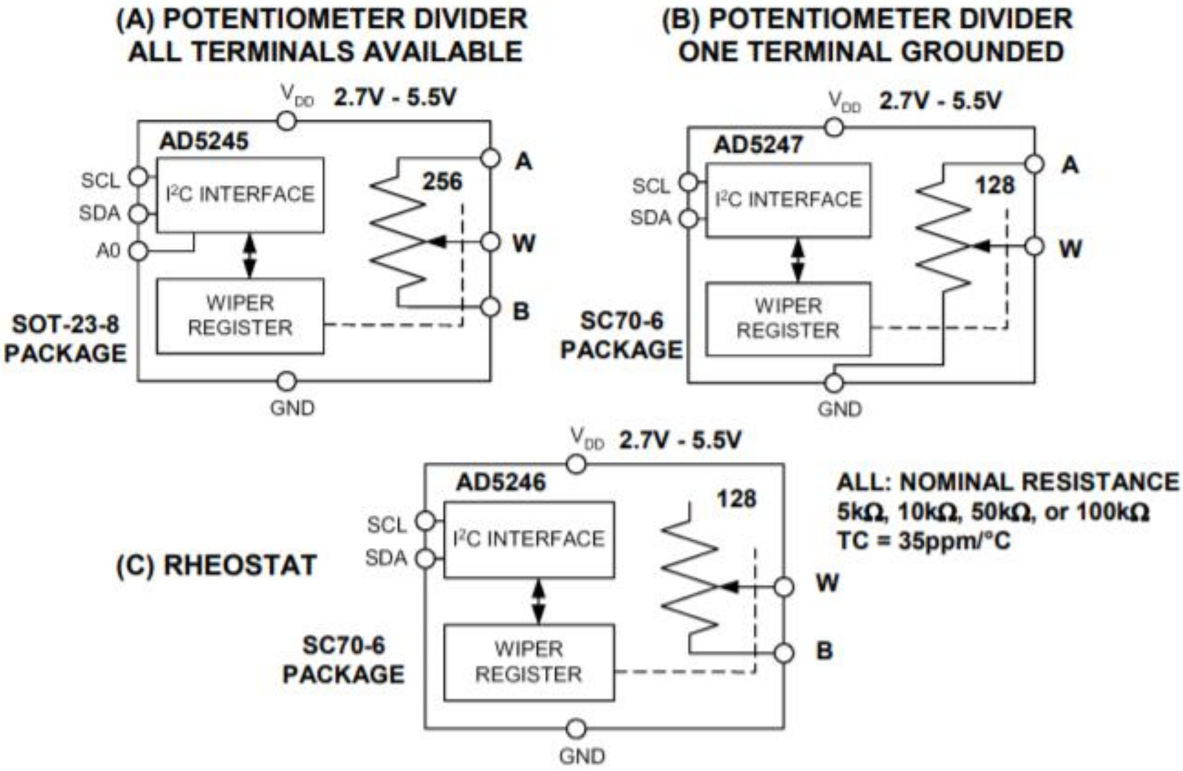
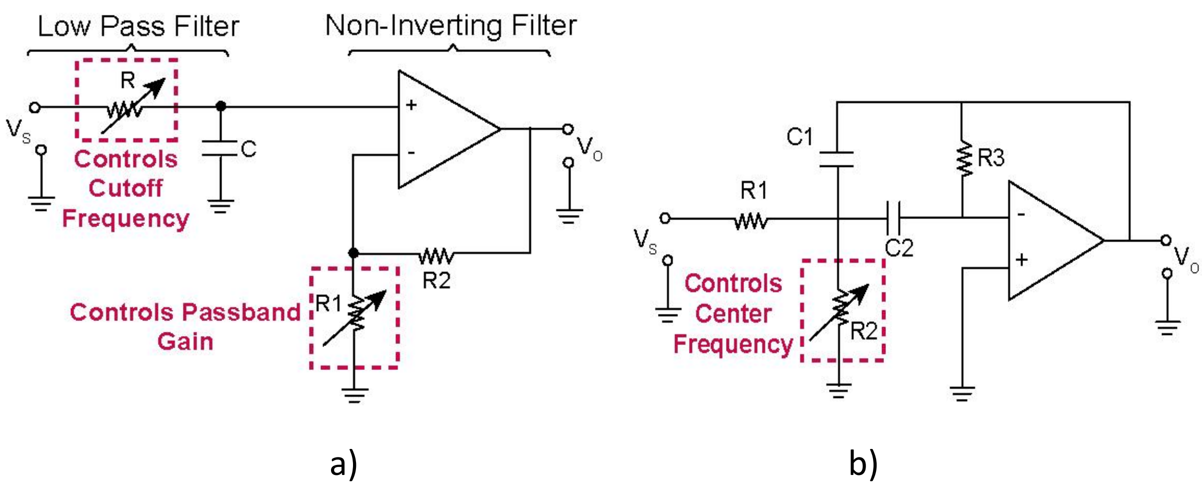


Fig. 5 The DP usage examples [33]

On Fig. 6 presented the options for using the DP in a low-pass filter and a band-pass filter, inverting amplifiers, and voltage regulators [37-38].



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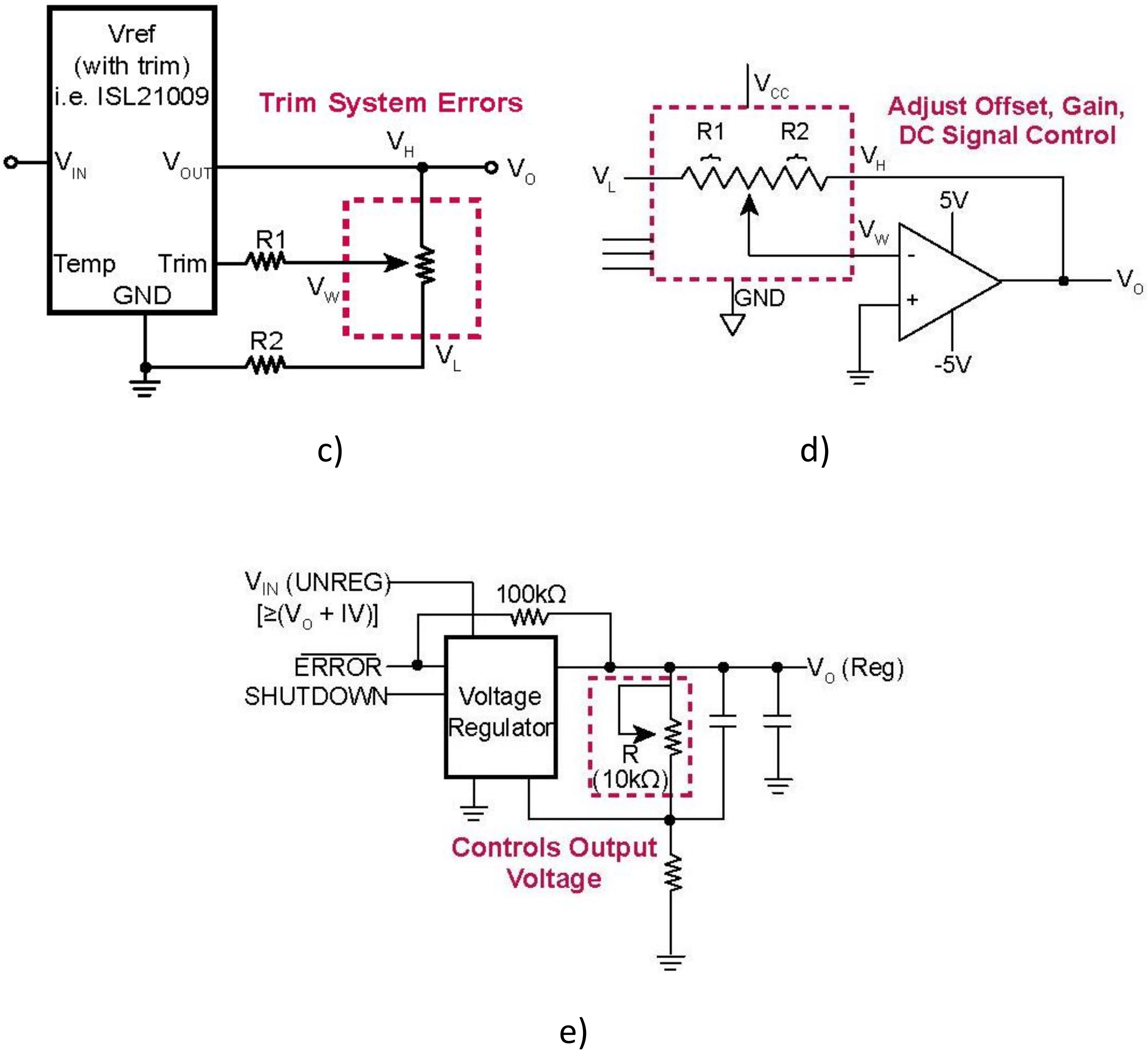

Fig. 6 Programmable low-pass filter and gain unit (a), programmable band-pass filter (b), reference voltage source (c), programmable inverting amplifier (d), programmable voltage regulator (e).

4. Conclusion

The attention of developers of analog devices is drawn to the fact that today the DP and DAC are effectively used as controlled signal dividers, as well as elements of the adjustment of ARCF. Examples include DP switching circuits in the low-pass filter and band-pass filter, inverting amplifiers and voltage regulators.

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