Use Digitally Controlled Potentiometer To Adjust Voltage Reference Output

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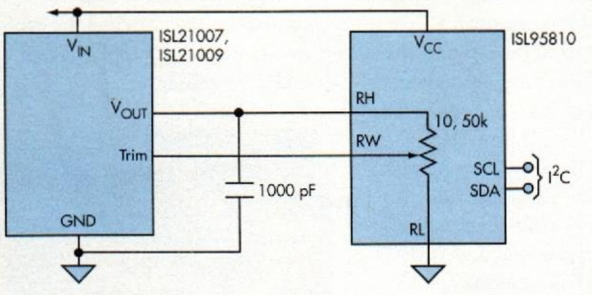
The output voltage of a voltage reference device can be adjusted using a digitally controlled potentiometer (DCP) without significantly changing the device's temperature coefficient (TC), which describes how the output voltage changes as the operating temperature changes. Some voltage references include a trim pin for fine-tuning V_{OUT} using a DCP. However, even parts without a trim pin can be adjusted using a DCP.

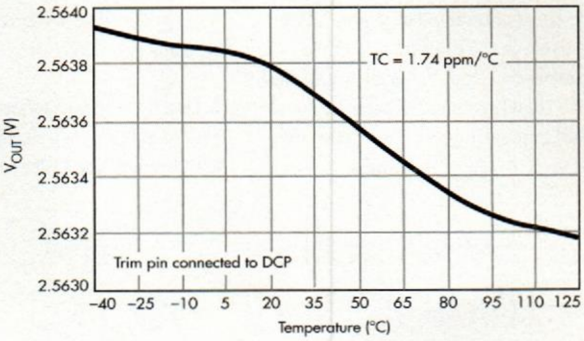
First, consider the case of a voltage reference that does have a trim pin. Generally, the trim input is internally biased by a resistor divider. The trim pin can also be driven externally by using the DCP. As long as the DCP's resistance is significantly lower than that of the trim divider, the voltage reference can be varied to obtain a V_{OUT} within a range of the nominal value specified on the data sheet. Ideally, the DCP resistance is about one-tenth the resistance at the trim pin, so DCP resistance will dominate the voltage reference device, and external biasing will achieve the desired output voltage adjustment.

A low-noise DCP with a lower-power I^2C bus equipped with 256 taps, along with resistor elements and CMOS switches, is an ideal choice. One example is the ISL95810. The I^2C bus interface controls the wiper position. The user can write directly to the associated volatile wiper register (WR) and nonvolatile initial value register (IVR). The content of the WR controls the wiper position. At power-up, the device recalls the contents of the DCP's initial value register to the wiper register.

The DCP's high terminal (RH) is connected to the V_{OUT} pin of a voltage reference containing a trim pin—for example, an ISL21007 or ISL21009 *(Fig. 1)*. The DCP's wiper terminal (RW) is connected to the reference's trim pin. The DCP's low terminal (RL) is connected to ground, and the output voltage is adjusted by writing to the wiper register. The trim pin resistance of the ISL21007 is 625 kΩ, and the ISL95810 is available in 10-kΩ and 50-kΩ versions. As a result, the DCP resistance will dominate the voltage reference, which will be externally biased to achieve the required output voltage adjustment. The reference's output will vary up to nominal V_{OUT} ±2.5% as the trim pin is swept from 0 to V_{OUT} using the DCP.



1. If the voltage reference has a trim pin, the digitally controlled potentiometer can externally bias the reference to provide an adjustable output.



2. This graph shows the change in the reference's output voltage as the temperature changes when connected to a DCP.

For the ISL21007-25 and ISL21009-25, which have a nominal output of 2.50 V, the ±2.5% trim works out to a range of 0.125 V. Using a DCP with 256 taps, therefore, creates a step size of 488 µV for changes in the output. When the trim pin is floating at room temperature, its voltage is half the nominal V_{OUT}, driven by the internal voltage divider. For instance, for the above references, the trim pin voltage is 1.25 V since the nominal output voltage is 2.50 V.

The temperature coefficient is calculated using the reference voltage measured over the specified temperature range by the industry-standard "box" method:

$$TC = \frac{\left(V_{REFmax} - V_{REFmin}\right)\left(T_{max} - T_{min}\right)}{V_{REFnominal}}$$

The TC when the voltage reference is connected to the DCP for V_{OUT} adjustment and when the trim pin is floating are approximately the same in value, 1.7 ppm/°C. Figure 2 shows the change in output voltage over temperature as the trim pin is adjusted using the DCP, when the V_{OUT} pin of the reference is connected to the RH pin of the DCP.

The trim pin should be left floating when no output voltage adjustment is desired. Many voltage reference devices do not

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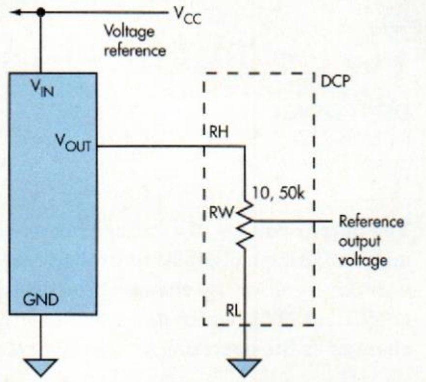
have a trim pin. But as noted earlier, a DCP can be used to adjust their V_{OUT} as well. The adjustment can be in the range from 0 to V_{OUT}, with the increments of the adjustment depending on the device's nominal V_{OUT} and the DCP used.

Figure 3 shows the connection between the DCP and the voltage reference device. The DCP's RH is connected to the V_{OUT} pin, while RL is connected to ground. For example, using the ISL60002-25, a three-pin SOT-23 with a nominal V_{OUT} of 2.50 V, and the ISL95810, which has 256 taps, V_{OUT} can be adjusted in increments of approximately 9.7 mV from 0 to V_{OUT} (nominal).

Another device without a trim pin, the ISL21400, incorporates a precision voltage reference combined with a temperature sensor whose output voltage varies linearly with temperature. It allows users to program the output over temperature with a choice of three gain values. Using a DCP allows further adjustment for desired precision levels. To adjust the V_{OUT} of multiple devices, dual and quad devices can be employed.



3. Even if the voltage reference doesn't have a trim pin, the digitally controlled potentiometer can be used to adjust the device's output.

Two AA Cells Power Class D Amp To Produce Huge Audio Volume

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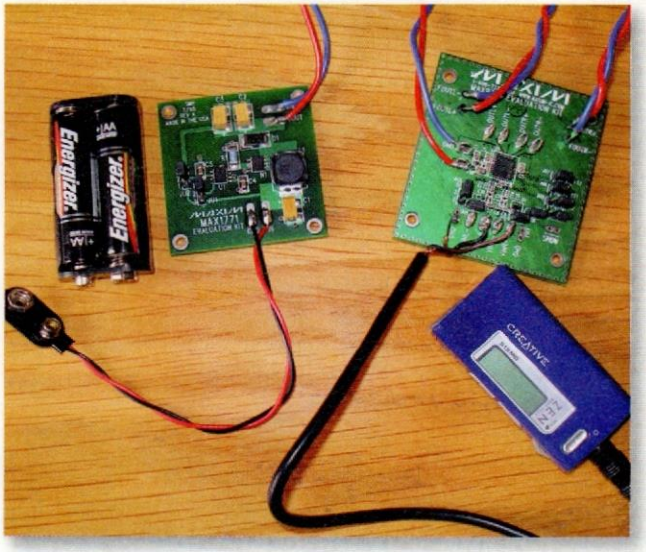
Class D audio amplifiers like the MAX9704 offer almost 90% efficiency, but they need 10 V to operate. For battery-operated systems, that would require a large number of batteries wired in series. You can avoid bulky battery packs by incorporating a switched-mode boost converter like the MAX1771, which generates 12 V from inputs as low as 2 V and delivers output currents up to 2 A. A battery-operated class D amplifier can then run off a pair of AA cells.



Powered by a switching converter operating from two AA cells, this class D amplifier (right-hand board) delivers 6 W of speaker power for as long as four hours.

You can create such a system using evaluation boards (EVkits) available for both the class D amplifier and the boost converter. Simply wire them together and connect two AA alkaline cells, an MP3 player for the audio source, and a pair (in this example) of Celestion Ditton 44 loudspeakers *(see the figure)*. The output power is limited by the MAX1771 EVkit, but the class D amplifier uses the total available power, estimated at 6 W, very efficiently. The volume from this simple circuit is excellent, and the two AA cells have an estimated battery life of over four hours.

The main limitation on power output is the MAX1771 EVkit, whose maximum output current at 6 V is 0.5 A. The kit can be modified to deliver as much as 2 A, which boosts the power output (at 6 V) to 24 W. Two AA batteries can support this power output as before, but perhaps not for four hours.

This technique can also provide uninterrupted audio in an automobile, allowing entertainment to continue at full volume while the engine is being cranked. That capability will be of increasing interest if a proposed law takes affect requiring car engines to stop at traffic lights and then restart when the accelerator is depressed. The voltage from a 12-V battery dips to as low as 6 V when the car is cranked during cold conditions, and that drop in supply voltage can have a substantial effect on the audio amplifier.

Rear-seat applications can also benefit from this circuit, because DVD players initiate a relatively long reset period when their power supply is interrupted. DVD-based navigation systems need protection from supply dropouts as well.

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