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APPLICATION NOTE 3484

Upgrading from Mechanical Potentiometers to Digital Pots

Digital pots have many advantages over their mechanical counterparts, including lower system cost, improved reliability, and greater system flexibility. This article describes advantages and disadvantages, and presents a summary of the comparison.

Mechanical pots (potentiometers) are variable resistors that have long been used to trim offset and gains, set LCD contrast voltages, adjust power supplies - just to name a few of the numerous applications. Using a screwdriver to make an analog adjustment is quickly becoming archaic. It is costly to implement and prone to human error. In today's competitive market, replacing a mechanical pot with a digital pot can be a big advantage. A digital pot adds robustness to the product, and streamlines the manufacturing process by eliminating the expensive and problematical manual production adjustments. It can easily result in lower cost and increased assembly throughput. Digital pots are often the perfect alternative, but there are some things one must consider in determining if a design is suitable for such an upgrade.

Resolution

A mechanical pot has theoretically infinite resolution. In practice, however, the effective resolution is determined by the skill level of the pot adjuster. Skill level varies from person to person, and from day to day, so the effective resolution may be quite poor. A 1-turn pot is very susceptible to adjuster jitter, whereas a 10-turn pot minimizes the concern.

A digital pot cannot offer infinite resolution, but it can offer a resolution that appears to be continuous by selecting a high enough resolution pot for the given application. In addition, the resolution is fully specified, repeatable, and guaranteed.

Limitations

In a mechanical pot, the wiper contacts a resistive element and is moved along its length to vary resistance. The wiper contact and the overall connectivity of the resistive element must be preserved over the life of the product to insure reliable operation. Mechanical pots are readily available in environmentally sealed packages to protect the wiper, but that feature comes with increased cost. Also, because of the actual mechanical connection involved, they are ultimately susceptible to vibration, shock, humidity, and pressure.

A digital pot can offer a more reliable, higher quality solution. However, it is not without its own limitations that must be considered.

In a digital pot, the wiper and pot connections are limited to the bounds of the power-supply rails. Some designs may accommodate a 2.7 to 5.5V supply, while other designs may accommodate ±15V. In any case, the pot connections must be within the operating rails of the IC. Often the design can be altered to insure that the pot connections are within the power-supply rails, or a simple resistor divider could be used.

Digital pots are available in both volatile and nonvolatile options. In the volatile case, once power is removed from the device, the pot adjustment is lost. Thus, it is necessary to store the setting information in an external EEPROM, flash, or another form of nonvolatile memory. Conversely, there are also nonvolatile pots that include this memory on-chip, typically as EEPROM, to save the settings after power is turned off.

In addition, it is necessary to power a digital pot for adjustment and operation. The resistive elements are not available for use in an unpowered state.

When comparing the cost of a mechanical pot cost to that of a digital pot, it is important to consider all of the actual costs incurred. By adding the cost of assembly, the labor associated with the physical adjustment, and the potential warranty costs, the digital pot will almost always be the less expensive solution. In applications that require multiple digital pots, the cost advantage is even greater. See **Table 1** for further comparisons between digital and mechanical pots.

Table 1. Digital Pots vs. Mechanical Pots

Feature	Digital Pot	Mechanical Pot
Resolution	32 to 256 steps are available at this time.	Theoretically, this is infinite, though limited by the skill level of the pot adjuster.
Common-mode limitations	This is presently limited to the power-supply rails.	This is limited to the breakdown voltages of the wiper/dielectric.
Unpowered operation	This only functions when power is applied to the device.	These are functional without power, though utility may be limited.
Durability	The number of adjustment cycles is infinite, though nonvolatile devices may have EEPROM-write limitation.	The number of adjustment cycles is finite, and depend on the manufacturer/design.
Environmental concerns	Generally, these are very durable.	Depending on the design, some are very susceptible to vibration, shock, humidity, and pressure.
Setting retention	The setting is retained with the use of either external or included EEPROM/flash memory.	The setting is retained without power. More permanent retention can be obtained by the use of a glue dab, which is difficult to remove for subsequent adjustments.
Adjustment procedure	A 2-or 3-wire serial digital interface typically allows a MCU (or user) to adjust the pot. Also available are increment/ decrement interfaces that do not require MCU intervention.	Typically a screwdriver is used to adjust the pot until the desired set point is read on a voltmeter or similar.
In-use pot adjustment	The MCU or user can adjust the pot as desired during operation. This can be helpful in automatically adjusting references, thresholds, etc.	If the set screw is not glued, a screwdriver may be used to adjust the pot manually.
Scaling	Linear and log are available.	Linear and log are available.
Temperature correction	Several digital pot designs include a temperature sensor and NV memory to provide a lookup-table-adjusted pot output over temperature.	Temperature-based adjustment is not possible.
Cost	The cost of the pot, plus the savings from eliminating a manual adjustment procedure and from lower rework/lower warranty repair cost, results in an overall cost savings.	Mechanical pots are inexpensive. However, the total overall cost will be higher due to the labor needed to make the adjustment, the possibility of adjustment error, and the cost of warranty repairs.

Conclusion

In almost all cases, replacing a mechanical pot with a digital pot will yield advantages and improvements to the end product. The total solution costs will be lower, with improved reliability and a more robust manufacturing process. An additional benefit is the software, and therefore potentially automated, control of the adjustment or setting in the system. This yields more flexibility, extended features, and additional functionality.

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