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POTENTIOMETERS FOR POSITION READOUT

J. A. Curtiss

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Accelerator Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

AGS DIVISION TECHNICAL NOTE

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The table below lists percent resolution available as a function of the number of bits in A/D converter applications.

Resolution	Each Increment	Expressed as Percent
one part per thousand	1/1000	0.1
10-Bit A/D	1/1024	0.098
11-Bit A/D	1/2048	0.049
12-Bit A/D	1/4096	0.0244
13-Bit A/D	1/8192	0.0122
14-Bit A/D	1/16,384	0.0061

Position readout potentiometers at the AGS have traditionally been 10-turn 10 K wirewound A-series Helipots in plastic cases. Two considerations have prompted a further look at these readout devices. First, it is possible on some types of drive systems to greatly simplify the mechanical arrangement by utilizing a single-turn pot. Secondly, there is some question about the accuracy with which device position is presently known.

The output voltage provided by a wirewound potentiometer is quantized by its very construction. The pot may be viewed as a multiposition switch which makes contact with very many junctions of a resistor string. The resolution available increases with the number of junctions available, or the number of wire turns on the pot. The theoretical resolution[1] of a wirewound potentiometer, a measure of the sensitivity to which the output ratio may be adjusted, is the reciprocal of the number of turns of wire in the resistance winding expressed as a percentage. Beckman A-series 10-turn 10 K pots commonly used at the AGS have 8.842 $\pm$ 5% turns, or a theoretical resolution of (1/8842) $\times$ 100 = 0.011%.

Comparing the table presented in the first paragraph of this paper to the above derived theoretical resolution of 0.011% indicates that our existing pots are, as components, capable of position readouts of up to 13-bit-equivalent accuracy. This is twice the accuracy of our 12-bit datacon system capability, and four times the 11-bit accuracy we customarily employ since we apply only + 10 volts and read position with a $\pm$ 10 volt converter.

The present H20 electrostatic septum is equipped with Beckman 7600 series 10 K pots. From catalog data, their theoretical resolution is 0.012%, an almost exact match for a 13-bit A/D converter. If applied with a 14-bit A/D converter, the converter output will jump by two binary bits every time the pot wiper leaves one wire and switches to another.

As presently arranged, the 14-bit converter reads $\pm$ 10 volts while only + 10 volts is applied to the pot. We thus employ the 14-bit converter as a 13-bit converter anyway. The same accuracy could be obtained by using a 12-bit + 5 volt converter and applying + 10 volts to the readout pot. While the device is retracted, the A/D would read full scale with 100% overrange applied (the A/D's are rated for this), while in the region of interest we obtain 13-bit precision. A further simplification leading to more confidence in this critical position data would be individual converters dedicated to the upstream and downstream pots, eliminating signal multiplexing. By the way, this level of precision matches the noise level of the most precise Lambda 10-volt supply available.

Single turn wirewound potentiometers can be used to simplify the mechanical portion of a position readout system. For a 10-bit (one part per thousand) system, a 10 K Beckman model 5310 is adequate, providing a theoretical resolution of 0.073%. For greater position accuracy a three-inch diameter Beckman model 5710 is required. The theoretical resolution of a 10 K pot is listed as 0.031%, while it improves to 0.022% for a 100 K pot. The 10 K variety is thus adequate for the 0.049% resolution of an 11-bit A/D, while the 100 K single-turn pot is mandatory for the 0.0244% resolution provided by a 12-bit A/D.

The three-inch 5710 pots are provided in a servo style case at about $25 each, while the 10-bit model 5310 is available for $12 in Beckman's familiar black plastic case. Our ten-turn pots use the same type plastic case. The AGS has never lost a pot due to radiation damage of the plastic case.

As indicated by the foregoing, the application of wirewound pots is limited by their characteristic resolution. Wirewound pots are customarily employed in radiation areas, but the SEB interim switchyard will baptize a new style pot with infinite resolution.

Cermet pots have been used for some time in circuit trimming applications. Cermet resistance elements start as a mixture of precious metals and glass in a liquid carrier, screened onto a steatite base. The unit is fired at 2000 F fusing the ceramic-metallic resistance element into the ceramic substrate. The resulting pot has a resistance and linearity at least as good as wirewound and is stable under high power dissipation and high temperature operation. Plastic cases are adequate, since, reiterating, we have never lost a pot due to radiation damage.

The single-turn cermet pot most attractive for our use would be the Beckman Series 6600, providing an 0.15% minimum practical independent linearity (a measure of linearity which does not constrain endpoints). Series 6600 pots cost about $50 each. A quantity will be obtained and used as transverse and skew readouts for the electrostatic splitter and Lambertson magnet to be employed in the SEB Interim Switchyard. In the meantime, a single pot will be mounted in a radiation area and motor-driven to obtain zero-order data on mechanical life in a radiation environment.

References

1. Variable Resistive Components Institute (VRCI) Standard T-210.

Distr:

AGS & EP&S Staff
G. Bagley
Dept. Admin.