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Station C single wire control system - digital/analog converter

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STATION 'C' SINGLE WIRE CONTROL SYSTEM - DIGITAL/ANALOG CONVERTER

Station C (low energy separated beam) has been equipped with hardware required to implement a single-wire computerized control and monitoring system. This hardware, however, represents a semi single-wire system now commonly referred to as the 'cluster arrangement'. The purpose of this paper is to discuss the digital to analog convert (D/A) implemented in the station C cluster arrangement for achieving set-point control of experimental magnet power supplies. Design aspects of the D/A and certain considerations leading to the chosen design will be discussed.

Isolation

In the cluster arrangement of things all magnet power supplies are associated with a single remote receiver unit which has a single wire input, but then fans out to all power supplies. There is no inherent isolation between magnet power supplies in this situation, and therefore considerable thought was given to isolation of circuit grounds between power supplies and between the supplies and the remote receiver logic ground. It was determined that isolation must be achieved as undesirable ground loops could pose severe problems difficult to correct after design and construction.

Reference Voltage

Within the environment in which magnet power supplies operate, it is essential that the temperature coefficient of critical components such as a voltage reference be very low providing stability over a wide temperature range. From past experience the Power Supply Group has found this to be true and recommended that any D/A converter used compare temperature wise with the 0.0005%/^{o}C drift of the zenor voltage reference currently found in the low level amplifier control unit of the power supplies.

Commercial D/A Units

Considering commercial units, a distinct advantage that seems clear is that these units are readily available from various manufacturers and no design or construction time is required. However, for the application at hand and where a converter must be matched to existing equipment, there are several disadvantages to the commercial unit as noted below:

1. No inherent isolation is possible because all units would be common to a single power source, and to eliminate this it would be necessary to provide a separate power source for each D/A pushing the cost prohibitively high. Therefore, if a commercial unit were used, one would be forced to deal, perhaps unsuccessfully so, with possible ground loop problems.
2. Commercially available units in attractive price ranges were not available with output voltage ranges which would match the low level amplifier control unit. This required scaling of the output voltage or modification by the manufacturer. The latter of these proved unattractive cost wise, and scaling of the output also added additional cost to the unit since components used in scaling could not be allowed to degrade the performance of the D/A.
3. Units that were available in the desired price range of approximately $100.00 would likely require temperature controlled environment for the D/A reference to approach 0.0005%/^{o}C stability with temperature thus leading to additional cost.
4. It is necessary at times to connect magnet power supplies in series or in some form of series parallel combination in order to power certain magnets. In this situation, nonisolated commercial units with associated operational amplifiers could experience unacceptable common mode voltage conditions.

With this information in mind and realizing that the slow response time of the magnet power supply control loop (in the order of seconds) did not require high speed D/A operation, other alternatives were considered. In a discussion with R. Frankel it was suggested that perhaps the existing zenor reference could be utilized in designing a converter. After some investigation this was done.

Designed D/A

Conceding the time for design and construction, there are several advantages to having designed a converter rather than purchase one commercially. The advantages are:

1. Using reed relays to control the operation of a commercial ladder network provides complete isolation in the system. Being personally somewhat skeptical of employing reed relays, a few shielded units were purchased and tested with the results indeed verifying operations in excess of one million.
2. Standard R-2R type resistive ladder networks were found available at low cost with temperature coefficients considerably better than $100.00 could purchase in commercial converters.
3. The existing zenor reference with 0.0005%/°C temperature stability was utilized.
4. Expansion of the number of bits available from the converter can easily be obtained if required in the future, or for special applications.
5. The unit is easily repairable.

In application, the D/A converter means of set-point magnitude control has eliminated non-linearity due to potentiometer loading effects inherent previously. Also an attempt was made to significantly improve upon absolute setability. The degree to which setability is absolute (this is with respect to the control loop input signal) depends primarily upon, and is presently limited, by the precision and stability of certain discrete resistors in the circuitry. Through component selection absolute input setability can be realized to an accuracy of 0.025%FS, or the standard accuracy specified for the system using 12 bit converters.

One source of non-linearity still remains in the circuit as shown however. This is the loading of the zenor reference by the ladder network. Switching from all bits off to all 12 bits connected to the zenor reference, the zenor current is modulated by slightly more than one millampere which gives rise to varying drops in zenor voltage from unit to unit. Although this existed previously, it now hinders efforts to obtain absolute setability. In the future if this type of converter is retained, this non-linearity can be eliminated by invertion of the ladder network permitting constant loading of the zenor. Initially this has not been done because doing so will increase the drift with temperature of the output operational amplifier stage since the impedance to ground at the inverting input will not be constant and equal to the impedance to ground from the noninverting input--a condition for minimizing drift due to temperature. It is reasonable to expect that this can be done however, because for a $\pm 30^{\circ}C$ temperature change the 741K op amp will drift about 0.45 millivolts maximum according to specifications. The tolerable drift for 0.025% absolute accuracy of full scale is $\lesssim$2.44 millivolts (0 to -5V. control loop input signal).

It is anticipated that at the rate whereby magnet power supply settings are altered, the D/A converter will function reliably over a long period of time. Current material cost of this converter is approximately $60.00.

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CIRCUIT DIAGRAM — DIGITAL TO ANALOG CONVERTER