AN ELECTRONIC LEVEL SYSTEM FOR ROTATING MAGNETS*

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Summary

The recent installation of the MICRO-BETA system on C.E.S.R. has required that several of the quadrupole focusing magnets near the interaction region be rotated about the beam axis in a highly reproducible manner. This rotation is required in order to compensate for the solenoid field present in the interaction region. An inexpensive gravity direction sensor with electronic read-out was developed using commercially available components. The range, cost, accuracy, and stability of these level systems will be described.

Introduction

The solenoidal magnetic field at the interaction point in an electron-positron storage ring is very desirable in order to momentum analyze the particles from the various interactions in the detector. This same field will however cause a mixing of horizontal and vertical betatron oscillations unless compensated. Such mixing will waste useful aperture, decrease the luminosity and make the machine difficult to control.

One way to compensate for the solenoid field is to physically rotate all or some of the the quadrupole magnets near the interaction point. In the recently installed Micro-Beta focusing system on C.E.S.R. the first three focusing magnets on each side of the primary interaction region were rotated by angles of about five degrees.[1],[2]

Previous systems which also rotated some of the quadrupoles had exposed the necessity of very accurate control of the magnet angles. The environment includes very high magnetic fields and normal laboratory temperature variations. Most of the schemes that had been tried suffered from either backlash/lack of sensitivity problems or lack of memory in the event of a power outage. A system was required which had sufficient stability and sensitivity as well as yielding an absolute angular position readout after a power outage. Such a system could also relax the requirements on the magnet moving mechanism in terms of angular rigidity.

* This research was supported by the National Science Foundation.

Description of System

An inexpensive gravity sensing electrolytic transducer has been designed and is manufactured by The Fredricks Company. The device is built in a glass vial half filled with a conducting electrolytic fluid with three electrodes typically as shown in figure 1.[3],[4]

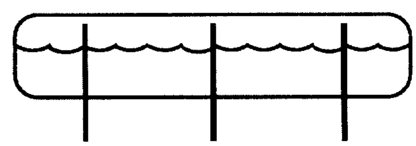

Figure 1

As the device is tilted the electrical resistance between A and B is not equal to the resistance between B and C. It can be seen that arbitrarily high sensitivity can be achieved at a sacrifice of angular dynamic range. A D.C. bridge cannot be used because of obvious electrolytic plating. In order to take advantage of the potential sensitivity, an A.C. bridge using synchronous detection is utilized to measure the ratio of the A-B resistance to the B-C resistance. An oscillator/synchronous detector module manufactured by Schaevitz Engineering was utilized.[5] This module was designed for use with an LVDT but the addition of the blocking capacitors and the audio transformer (to avoid any possibility of DC current flow) yielded a completely satisfactory driver circuit. The level readout circuit is shown in figure 2.

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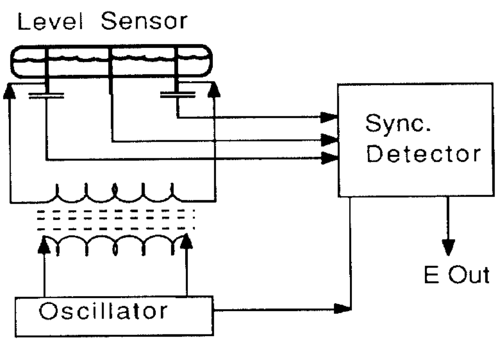

Figure 2

The electrolytic conducting fluid used in the level transducers has a high thermal coefficient of resistance as well as a reasonably high thermal coefficient of expansion. The result of both these factors is a large temperature coefficient of the level output signal. This output error will however be zero at the null or zero angle position.

In order to avoid this temperature induced error the device was mounted in a large thermal mass which was temperature regulated as shown in figure 3.

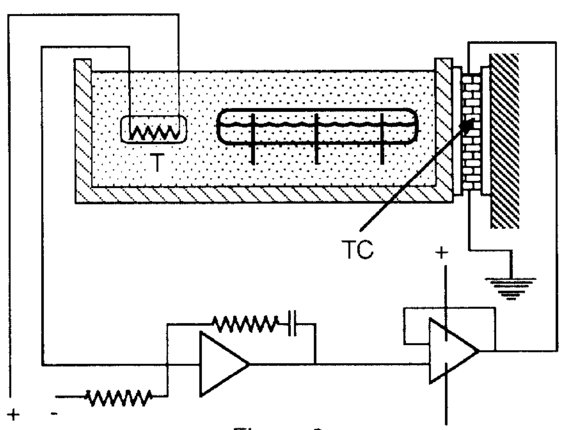

Figure 3

The thermistor T, is placed in intimate thermal contact with the level transducer by virtue of potting the assembly in thermally conducting epoxy. The resistance of T is compared to a fixed reference resistor and a voltage proportional to the temperature difference is generated. This signal is amplified and drives a thermoelectric heater/cooler (TC) which heats or cools the transducer case relative to the mounting bracket.

The specifications of the various components as well as approximate costs are as follows:

Transducer---

Manufacturer	Fredericks Co.Model #0714
Approx. Cost	$30.00
Dynamic Range	±12 degrees
Temp. Coeff.	0.4%/deg.C

Bridge Circuit---

Manufacturer	Schaevitz Eng., Model #SMS/GPM-109A
Approx. Cost	$160.00
Output range	±10 volts DC
Stability	0.1% of full scale
Temp. Coeff.	0.04%/deg.C

Thermistor--

Temp. Coeff.	4.5%/deg.C
Approx. Cost	$5.00

Thermoelectric Cooler---

Manufacturer	MELCOR, Trenton,N. J. Model #CP1.0-63-06L
Approx. Cost	$14.00
Output Power	14 Watts

Audio Transformer---

Approx. Cost	$8.00

Results

Calculations had shown that the maximum required rotation range of several of the quadrupoles was ±5 degrees and the required accuracy in the most severe case was ±100 micro-radians or ±0.0057 degrees. This accuracy requirement was independent of the angle.

Several of the level devices have been operating for about one year. Some of them are in a D.C. magnetic field of one Tesla. The temperature variations of the environment are ± several degrees centigrade.

Four quadrupole magnets have been monitored for month long periods of time. During this time the magnets were not intentionally rotated.The rotated angle and the measured angle variation for the magnets were as follows:

Magnet #1)	2.50 degrees	±0.0058 degrees
Magnet #2)	2.49 degrees	±0.0025 degrees
Magnet #3)	2.46 degrees	±0.0025 degrees
Magnet #4)	2.16 degrees	±0.0035 degrees

There was some indication that magnet #1 had accidentally been moved during the month by someone standing on it.

Conclusion

The system described has been in operation for one year. The stability and reproduceability have been ±0.006 degrees which is entirely satisfactory for our needs and certainly much better than was available with previous systems. The cost per channel is of the order of $200.00 and could be much less in large quantities.

Other systems have been built using different sensor models. One has a dynamic range of ±25 degrees and the other measures X and Y tilt independently using a five electrode transducer and synchronous detectors operating at two different frequencies on each of the two axis.

References

[1] S. W. Herb et.al.,this conference, paper M17.

[2] D. Rubin, this conference, paper X40.

[3] The Fredericks Company, Huntingdon Valley, PA 19006

[4] J. Westphal et. al., Rev. of Scientific Instruments 54, 415 (1983)

[5] Schaevitz Engineering, Camden, N. J. 08101