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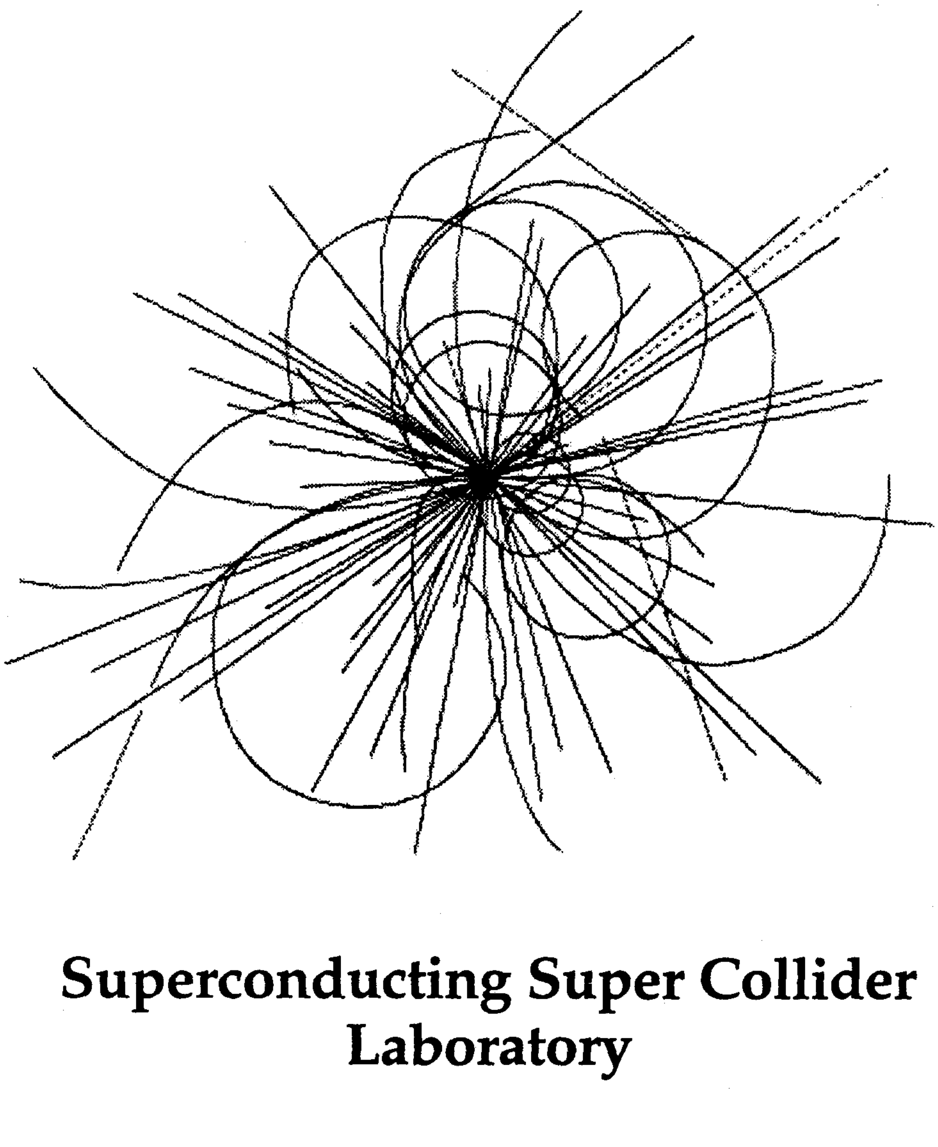

## Superconducting Super Collider Laboratory

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# Strain Gauge Pack in Process Measurement System for the Collider Quadrupole, Design and Technology Transfer*

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†Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

# STRAIN GAUGE PACK IN PROCESS MEASUREMENT SYSTEM FOR THE COLLIDER QUADRUPOLE, DESIGN AND TECHNOLOGY TRANSFER

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## INTRODUCTION

The in process measurement system that is described below was designed to monitor the strain gauge instrumentation collar pack during all phases of quadrupole magnet manufacture. The primary goal was to implement a monitoring system that incorporated standard measurement techniques while maintaining signal integrity. The flexibility and robustness required in a production environment were taken into account throughout the design and implementation. All major components were chosen from commercially available supplies. The driving software was chosen to provide a user friendly interface while keeping software development efforts to a minimum without sacrificing adaptability.

## MEASUREMENT CRITERIA AND TECHNIQUE

The gauges that are monitored with this system consist of sixteen (16) series connected 350Ω strain gages. An excitation current of 2.5mA is applied to the series circuit and the resulting voltage from the individual gauges is monitored using a digital multimeter. The goal of the measurement was to accurately resolve the measurement of the strain gauge to 10mΩ (0.010Ω). This level of accuracy corresponds to approximately 14μ-strain (or ≈20 PSI coil pre-stress). There were no significant data collection rates required for this system.

There are many sources of error that effect this level of accuracy. Some sources of error are digital multimeter (DMM) accuracy, current source noise, reference resistor accuracy, and thermoelectric effects. The DMM chosen for this system has a 10.5 part per million (ppm) accuracy which equates to approximately 4mΩ. The current source has a

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noise specification of 0.8μA which equates to approximately 2mΩ. The technique used required measurement of the current through a precision shunt resistor. The measurement of a shunt resistor was chosen because of the inaccuracies of the DMM involved in directly measuring the current, in addition to presenting problems in the implementation. The precision resistor chosen was a 350Ω (±0.001%) resistor with a 5ppm long term accuracy and a temperature coefficient of 5ppm/°C, which corresponds to ≈2mΩ (neglecting any change in temperature). Due to the number of connections and relays involved in this implementation there was an attempt to reduce any thermoelectric effects that may have been present. This was done by reversing the current in the series circuit and averaging the reading during the measurement. It should be noted that the inputs to the DMM were also switched so as to always be in the same region of the analog to digital converter therefore reducing any non-linearity effects of the DMM. This list of possible errors is not meant to be exhaustive but should reflect the primary sources of error that were addressed in the implementation.

## HARDWARE

The hardware chosen for this system was commercially available (see Table 1). Each component was chosen for its flexibility and/or accuracy. The majority of the components were available with an IEEE-488 option which made automation more convenient. A large and varied choice of plug in cards made the scanner an optimal choice for this implementation. Due to the characteristics of the low voltage scanner card, low contact resistance and long life, the card was selected for the primary multiplexing equipment. The DMM was chosen for its stability and long term (1 year) accuracy. Although the current source was not IEEE-488 compatible, the stability and noise specifications made this device a satisfactory choice. The computer chosen was based on an earlier implementation of the measurement system that utilized a similar computing platform.

**Table 1.** Major Hardware Components.

| NOMENCLATURE | MANUFACTURER | MODEL |
|---|---|---|
| Scanner | Keithley | 706 |
| DMM | Hewlett Packard | 3458 |
| Current Supply | Hewlett Packard | 6181 |
| Computer | Apple | Macintosh ci |

## SOFTWARE

The software was chosen for several reasons. Limited development time, no special programming expertise by designers, adaptability, excellent user interface, and flexible output formats made LabVIEW 2 by National Instruments a good choice. Many of the drivers for the hardware instruments existed and only minor modifications were required. The environment promoted the program adaptability that was needed. In addition, the superior user interface provided by this program allowed for reduced operator training and familiarity. The output was readily acceptable to many other presentation and analysis programs that are widely distributed in the Laboratory.

## PACKAGING

Due to the environment that this system was expected to be operated in, several steps were taken to shield and protect the system. A robust upright 19" rack was chosen to mount all equipment of the system. This, in combination with large casters, provided convenient maneuverability throughout the production floor. The cabinet was equipped with a large ventilation system to maintain temperate conditions. A multiple standard input uninterruptable power supply (UPS) was also installed to provide power conditioning and backup. All connections were made within an electromagnetic interference (EMI) shielded enclosure while maintaining good cable shielding and grounding techniques. Special attention was given to equipment supporting brackets. Maintenance and repair required accessibility and was provided for by slide mounts and hinged mounting where appropriate.

## CONCLUSION

While maintaining basic signal integrity, this implementation allowed for flexible use on the magnet production floor. It was easily transportable by technicians performing the monitoring function while providing easy, accurate data collection. The basic technique for measurement of the strain gauges was adhered to throughout the system implementation. The attention to detail, documentation, and readily available equipment selections has led to a highly maintainable system that has proven to be extremely flexible. This design has led to an implementation that monitors dipole strain gauge collar packs, end force transducers (bullets), and shell gauges in addition to quadrupole strain gauge collar packs.