Design and Fabrication of a High Voltage Distribution Box

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Abstract

This report discusses the design and fabrication of a high voltage distribution box for use in a cosmic ray detector. Specifically, the distribution box was required to take in two high voltage ($\simeq$1800V) supply lines connected with BNC plugs, and output eight lines, also using BNC plugs (four inputs connected to each input). The box also needed to be shielded to reduce noise production in the voltage signals. The design was realized using a 3" $\times$ 3" $\times$ 6" metal electronics box, which kept the design as compact as possible.

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1 Introduction and Design Criteria

The high voltage distribution box was part of a cosmic ray detector system. Specifically, the box distributed the two high voltage DC signals from a power supply into eight outputs, one for each photomultiplier tube used in the detector. The tubes were attached to paddle scintillators arranged into a circle, and the entire assembly was mounted vertically, like a windmill. The detector is to be used for long term data collection of muon events, and will be displayed in the Physics Building at the University of Saskatchewan.

1.1 Design Criteria

The primary constraint on the design was its need to handle DC voltages of up to 2000V. This was necessary in order to drive the eight photomultiplier tubes that the box would supply. Photomultiplier tubes are high voltage, low current devices, so large current handling was not a great concern. The handling of large voltages translated into the need for sufficiently thick insulation on the hot wires in the box, while the low current demands allowed for smaller gauge wire to be used without concern for overheating the wires and damaging the insulation.

A secondary requirement was to keep the design as compact as possible. This was necessary because of the space needed for the other components of the cosmic ray detector on its stand. As well, the input and output voltage ports needed to connect to standard BNC high voltage connection plugs, so high voltage BNC ports were needed in the design.

2 Design and Fabrication

The design for the actual box was done using *qcad*, an open source CAD program. The box was designed to be as simple as possible: the two input plugs were placed on one 3" $\times$ 6" side, and the eight output plugs were placed in two rows of four on the opposite 3" $\times$ 6" side of the box. The holes for the plugs were D-shaped to keep the BNC ports from rotating once they were installed; this made the machining process complex enough that it needed to be done by experienced personnel. The machining of the D-holes was performed by the Physics Department's Machining Shop. The schematic drawings for the D-holes and their placement are included in the Appendix.

Once the box was machined, the inner surface was sanded to remove all traces of paint. This ensured that the lock washers for the BNC plugs made solid electrical contacts with the box, which acted as a common ground for all of the ports. Grounding the shell of the box also acted to make the shielding of the coaxial RG47 cable continuous, which helped to reduce noise injection into the lines.

The BNC ports were manufactured by KINGS, part no. 1704-1. They used a lock washer and a threaded nut to attach to the wall of the box. Inside the box, the high voltage connection point on the plugs was a slot designed to accept 14 or 16 gauge wire that could be soldered into place. In order to connect one input port to four output ports, five wires needed to be spliced together. The four output wires, each approximately 2" long, were spliced into a pigtail and soldered together, and a fifth 1" wire was soldered onto the pigtail, leading off in the opposite direction. The splice point was then wrapped in at least four layers of standard black electrical tape to prevent it from shorting against the walls of the box. Two sets of five spliced wires were created and used in the

box. Once the wires were installed and the plugs were properly connected, the box was closed and fastened shut using the supplied screws.

The layout of the plugs was arranged as logically as possible. Viewed from above, with the two input plugs on top and the eight output plugs on the bottom, the left input plug connects to the four leftmost output plugs and the right input plug connects to the four rightmost output plugs. In other words, each input plug connects to the four closest output plugs.

3 Testing

The most critical concern for the box was that there were no shorts from the high voltage lines to the grounded box. This was tested using the continuity tester function on a digital multimeter. One lead was held against the sheath of one of the ports while the other was held against the inner pin of each BNC plug in turn. No continuity was detected, as desired.

The second test was that all of the ports shared a common ground. This required that continuity existed between the outer sheaths of all 10 BNC plugs on the box. Continuity was detected between all of the plug sheaths, as desired.

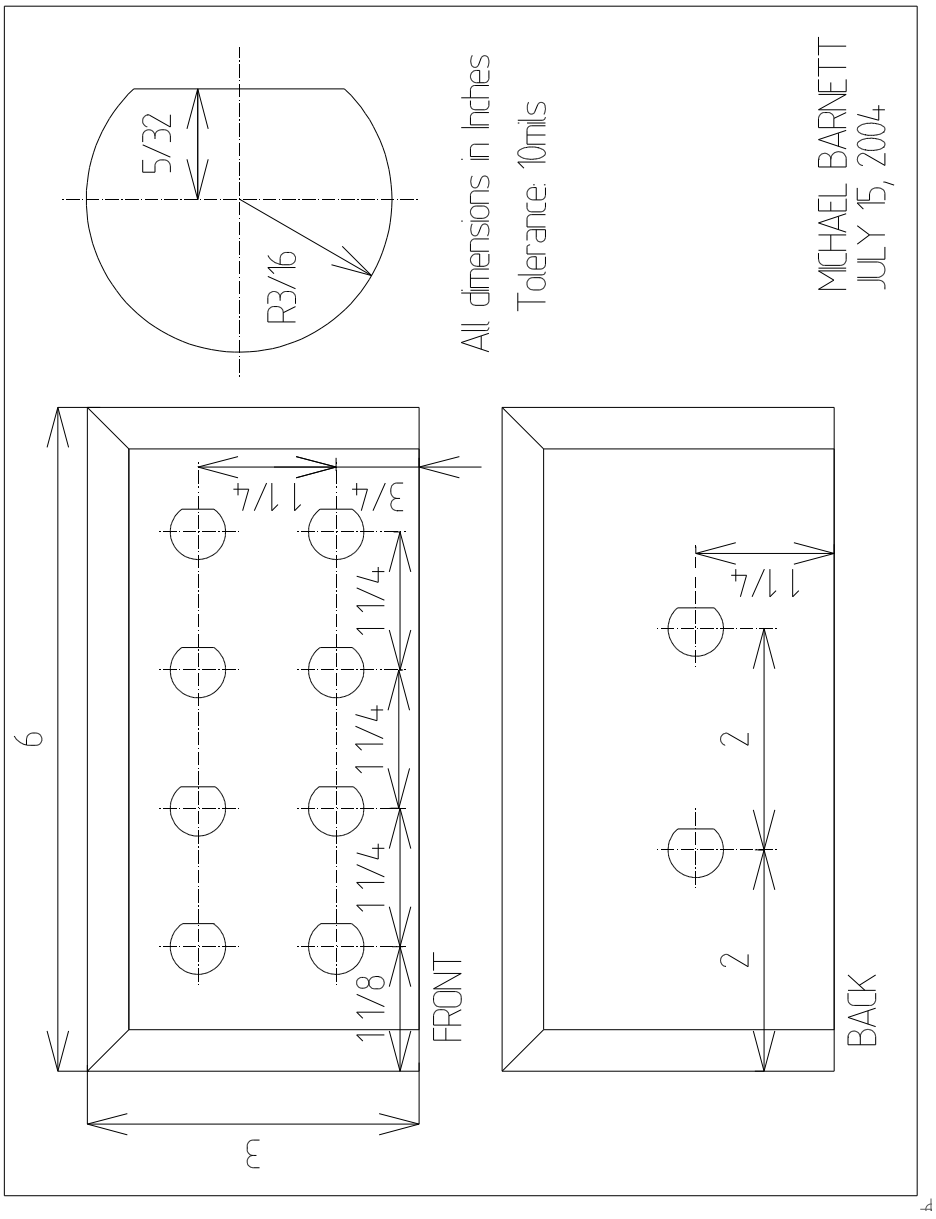
The third test was that there was continuity between the high voltage pins from each input plug to its four output plugs, and that there was no continuity between the two input plug pins. Both results were as desired.

Once the box had been tested for continuity and shorts, the box was attached to a high voltage supply. The output plugs were left unused, and the supply was slowly powered up to 1800V, the optimal operating voltage. The supply maintained power, as desired (i.e. no fuse was blown). The final test was to attach several photomultiplier tubes to the distribution box, and to attach the tubes' signal ports to an oscilloscope. Once the supply voltage was raised above approximately 1600V, signal pulses were observed on the oscilloscope. This indicated that the photomultiplier tubes were receiving the correct voltages, and thus that the distribution box was behaving correctly.

4 Discussion and Maintenance Needs

The high voltage distribution box functioned as desired, and was small enough to be unobtrusive in the final layout of the cosmic ray detector system. The primary concern for the long term maintenance of the distribution box is the possibility of a short developing between the internal high voltage wires and the grounded shell of the box. All connections were soldered and then taped to minimize the chance of a connection breaking and a wire falling against the surface of the box. There is no need for any periodic maintenance on the distribution box; it was designed to function as a sealed unit.

Appendix


5/32
R3/16
All dimensions in Inches
Tolerance: 10mils
MICHAEL BARNETT
JULY 15, 2004
1 1/4
3/4
1 1/4
1 1/4
1 1/4
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6
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FRONT
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