Low-Cost PicoAmpere Meter for GEM Detectors

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The objective of my project at CERN was to participate in the development and test of a picoampere current measuring box for HV lines which measures extremely low currents, down to 1pA, while keeping the complexity and cost of the box to the minimum possible.

The group I was working with had previously introduced an Active Voltage Divider (AVD) which divides a negative high voltage supply into constant, low impedance output voltage lines to GEM foils as shown in Figure 1. The I²C protocol is employed such that online readout from the AVD box to SRS is possible. Thus, the final user can constantly monitor temperature, humidity, and GEM voltages.

The scope of the picoampere measuring box is to enable current measurement of each of the high voltage cables in the figure below. This box must also contain an I²C interface such that online readout via cable to SRS is possible.

![Figure 1 – System Block Diagram](image)

The principle behind this picoampere meter is the linearity of the logarithmic current versus voltage characteristic of a silicon diode. The test diode was a BF245 MOSFET connected as a diode. The first step in this project was to confirm that this I-V curve is linear in the required range, i.e. 1pA to 1mA. Also, we had to confirm that the temperature coefficient for the transistor is constant, and equal to $-2mV/°C$. Figure 2 shows the extracted characteristic for the BF245C diode.
It was observed that the input lines to the box contain a 50 Hz pickup since each wire acts as an antenna. This 50 Hz signal was suppressed by adding a second order low pass filter which I developed and tested using discrete components. The circuit diagram and bode plot are shown in Figures 3 and 4 respectively.

![Figure 2 - BF245C I-V Characteristic](image)

![Figure 3 - Low Pass Filter Circuit Diagram](image)

![Figure 4 –Filter Bode Magnitude/Phase Plot](image)
The principle behind this current measuring box was applied to the PICO box. The PICO box was built to allow the measurement of ultra-weak currents which are read from the anode strips of a GEM or MicroMega detector.

The avalanche pulses from these detectors may typically consist of 1 to 10 femto Coulomb of charge. Therefore, by using a very small charge integrating capacitor in parallel with the diode, an order of hundred such pulses per second are sufficient to generate a weak current in the order of 1 picoampere or more and this can be measured with the PICO box.

The PICO box contains an analogue logarithmic meter with two selectable ranges: 100nA and 10μA so that high counting rates on the detector, say 100 pulses per second when one uses high intensity radioactive sources, can be equally measured with the PICO box.

So far this kind of measurement was only possible with very expensive instrumentation. The PICO will be a cheap utility for detector developers of the RD51 collaboration. The PICO box is still under development and the final objective is to be able to improve sensitivity down to 10 femtoampere.

My task in the PICO box project was to develop part of the circuit using discrete components and test the operation of the box. The low pass filter for the first picoampere meter was also included in this box.

Part of my job at CERN was to learn new software tools for schematic design and 3D modelling. I used Altium Designer to create the schematics for both boxes, which will be used to create the PCB for the final box, and Sketchup to create a 3D model of the final appearance of the first box so that one can determine the ideal position for the components and connectors in the box which will affect the PCB design.

The figures below illustrate the 3D models for the PicoAmpere Measuring Box and the PICO box. The measurements obtained using 3D modelling are essential when installing the connectors in the actual box, so that the connectors are aligned to the pads on the PCB.
Figure 5 – PicoAmpere Measuring Box 3D model

Figure 6 – PICO Box 3D model