Muon Hunter kit notes for CERN HST 2016
High voltage measurement

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1 Introduction

There is more than one way to measure the high voltage produced by the kit. This description is about measuring the high voltage using a multimeter and a simple potential divider model. This can be useful to set the voltage required for the Geiger-Müller tubes. It is a practical that students can do with appropriate supervision. It requires to measure high voltage so training on measuring high voltages safely is mandatory for students to undertake measurements like this.

If one tries to measure the high voltage at the HV test points using a multimeter, a typical DMM[1] will load the circuit. It will display a lower voltage than the actual value. If the output impedance of the circuit was a fixed value this would require the use of a simple potential divider equation and the voltage could be calculated from this. However, the output impedance of this circuit depends on the setting on the RV_1 resistor that determines the oscillator frequency and the current flowing through the high voltage transistor and the L_1 inductor.

Therefore to measure the high voltage with more accuracy a range of voltage measurements should be made. From these measurements a range of output impedances can be determined. After a linear regression, a formula can be determined to calculate the actual high voltage produced by the kit.

2 Theory of measurement

A series of measurement pairs should be made.

Notations: Z_{out} is the output impedance of the circuit. V_0 is the voltage produced by the circuit. V_{HV} is the voltage measured at the HV test point. V_{GM+} is the voltage measured at the + terminal of the Geiger-Müller tube.

First we measure V_{HV} with a multimeter of known internal resistance Z_{meter}.

$$V_{HV} = V_0 \frac{Z_{meter}}{Z_{out} + Z_{meter}} \quad (1)$$

Secondly we measure V_{GM+}.

$$V_{GM+} = V_0' \frac{Z_{meter}}{Z_{out} + Z_{meter} + 4.8M\Omega} \quad (2)$$

Assuming $V_0' = V_0$[2], (1)/(2) gives:

$$Z_{out} = \frac{Z_{meter}(V_{GM+} - V_{HV}) + 4.8V_{GM+}}{V_{HV} - V_{GM+}}$$

Knowing Z_{out} and using (1), V_0 can be calculated.

$$V_0 = V_{HV} \frac{Z_{out} + Z_{meter}}{Z_{meter}}$$

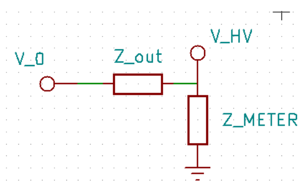

Figure 1: V_{HV} measurement

[1] A typical input resistance value is $10M\Omega$, but it can range from $10M\Omega$ to $1000M\Omega$ in most of the cases, so check your meter first.

[2] See section 5.

After measuring a series of V_{HV} and V_{GM+} point pairs an experimental, linear relationship can be established between V_{HV} and V_0 using linear regression.

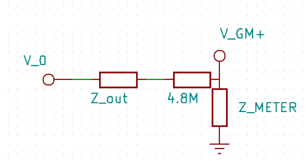

Figure 2: V_{GM+} measurement

3 Measurements

3.1

Start with RV_1 being in one of the extreme positions.

3.2

Measure the voltage at the HV test point. V_{HV}

3.3

Measure the voltage at the + terminal of the GM tube. V_{GM+}

3.4

Calculate Z_{out} and V_0 using the formula. Adjust RV_1 and repeat for about 15 point pairs.

4 Example data

$V_{HV}(V)$	$V_{GM+}(V)$	$Z_{out}(M\Omega)$	$V_0(V)$
420	312	3.87	582
396	295	4.02	555
358	263	3.29	476
321	237	3.54	435
283	206	2.84	363
267	195	3.00	347
251	183	2.92	324
226	163	2.42	281
213	153	2.24	261
196	142	2.62	247
180	130	2.48	225
167	119	1.90	199
151	107	1.67	176
134	96	2.13	162
128	92	2.26	157

Table 1: High voltage calibration

The linear regression for the whole range gives the following formula ($R^2 = 0.9984$):

$$V_0 = 1.481V_{HV} - 45.04$$

The linear regression for the marked $476 - 281$ STS-5 range gives the following formula ($R^2 = 0.9968$):

$$V_0 = 1.495V_{HV} - 54.12$$

5 Limitations

We assumed in section 2 that $V_0 = V_0'$. However, loading the circuit at two different places changes the oscillator frequency slightly differently, that in return has an effect on the high voltage generated. This effect was measured to have a less than a 1% effect on the voltage measured.