Power consumption comparison in three experimental circuits for radiation detection

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Abstract. Geiger Mueller tube is a longstanding device to detect gamma ray in its range and it still preferred in many radiation detection devices due to robustness in rough environment. The high voltage supply to support Geiger Mueller activation needs a transformer in order to operate. This paper will discuss the effectiveness of the transformer to get satisfactory and stable high voltage. The transformers were winded manually in few sets with limited size of the bobbin and ferrite core. The transformers were applied into three different circuits to analyse the high voltage. The result of the effectiveness of the transformer and the high voltage of the circuit were discussed.

1. Introduction
Safety is the most important issue when it comes to any kind of work place. The greatest issue in radiation exposure environment is the accuracy of the radiation detection device. In the past years, several studies have reported, including the study on oil insulating systems to investigate the high energy ionizing radiation phenomenon emitted by the electrical discharge, showed that the event occurred when the free electrons knocked out of the valence coating and positive ions that have lost these electrons and, also introducing argon bubbles [1]. Meanwhile, the research on high voltage transformer had been done with extremely low frequency electromagnetic radiation (160KVA and 250KVA) to investigate the effect of exposing it to selected students. The findings demonstrate that the increasing in heart pulse, arterial blood pressure and tympanic temperature but decreasing in blood oxygen saturation [2]. Besides that, in order to achieve an ideal scintillator design, the research work on scintillation and optical characteristics of ZnO:Sc based have been conducted to get the high time resolution [3]. With 13.6 pA system noise current, this high time resolution is suitable for sub-nanosecond pulsed radiation detection [3]. As highlighted in a portable radiation detector application, a study concerning configuration of a sensor interface integrated circuit system has been performed. The study found that the high bias voltage of commercial silicon-photomultiplier detector could be driven by the proposed radiation detector system in mobile application [4]. In another study, by using 193 nm ArF excimer laser on nano-graphite electrical contacts on both diamond surfaces, the researchers created a radiation detector from a plate of high quality polycrystalline chemical vapour deposition diamond. These works proved that electrodes made by laser graphitisation are Ohmic electrically contacts [5]. Similarly in Geiger counter device, one of the oldest radiation detectors where numerous studies have been reported in a lot of papers till recent years. This common device is using Geiger Mueller (GM) tube, the oldest radiation detector which is simpler in design and robust in
most environment. Compare to ion chamber, GM counters are more sensitive in monitoring low levels of contamination [6]. There are two points considered as an important topic in the latest invention of GM tube. According to [7], besides the improvements in manufacturing, the halogen-quenched GM tubes also of significant concern. There are large volume of published studies regarding the performance and effectiveness of the Geiger counter. Previous studies have reported that researchers have investigated GM counter with several methods including Monte Carlo [8][9] and correlation technique [10]. This paper will share the process of how to build and assemble all the components and devices to produce three circuits of high voltage and effectiveness of transformers ratio winding towards high voltage. Finally, the establishment of three type of circuits that are able to produce 450V-550V high voltage, where one of them to be chosen as part of the low cost survey meter.

2. Methodology

As shown in Figure 1, it is important to realize that certain requirement needs to be occupied for the purpose of GM counter to be functioning. The most important thing is high voltage supply so that the GM tube can be activated. Along with the product of stress and inter electrode distance, the entering ionizing radiation must be able to start the avalanche of a self-maintaining mechanism that leads to the break down [11]. Numerous studies have revealed that GM tube still on demand and a number of studies show the important of stable, low cost and efficiency of the high voltage supply [12].

![Figure 1. Block diagram of the radiation detection device.](image)

The first process starts with the circuit design. There are three designs as shown in Figure 2, Figure 3 and Figure 4 that have been used in this study. The first one is a high voltage (HV) circuit using two coils transformer and Figure 3 is using three coils transformer. Meanwhile the third circuit not using transformer but inductance. First and foremost, all the components needed must be available. Normally it is quite difficult to get all the components to be there even a resistor.

Then, all components were assembled on breadboard before being transferred to strip board. At the same time, the transformers were winded using manual winder, as depicted below. Not to be forgotten, the size of transformer is limited into RM8 only since there is no other size obtainable and the ratio of the coils as shown in the Table 1 and Table 2. Once the result of HV can be accepted, the components were assembled into strip board. The acceptable HV, ranging from 450 volts to 550 volts, ever since the GM tube (LND7121) working at these point values. This process will be repeated if the result not achievable especially the transformer coils ratio. The flow of the process was depicted in Figure 5.
Figure 2. High voltage circuit with 2 coils ratio.

Figure 3. High voltage circuit with three coils ratio.

Figure 4. High voltage circuit with inductance without transformer.
Figure 5. The flow of the assembling components from breadboard into strip board and the result.

3. Result and discussion
The resulting high voltage for each transformer configurations were shown in Table 1 to Table 3. Based on these results, it can be seen that the transformer application in the circuit needs more improvement. Both first and second circuits gave unpredicted results. Even the three coils ratio be able to produce 524 volts but this configuration is unstable and even drop between 0 to 290 volts. On the hand, it is obvious from the third table, that the HV circuit with inductance shows stable and good HV results. Even though the current is quite high compare to others, this circuit is the best solution at the moment. The plotted graph for voltage current and power for each circuit also depicted in Figure 6 to Figure 8.
Table 1. Current, high voltage and power for Circuit 1.

| Transformer Configuration | Resistance (Ohm) | HV value (V) | Current (Amp) | Power (W) |
|---------------------------|------------------|-------------|--------------|-----------|
| 10:1200                   | 0.7:78.7         | Drop        | 0            | -         |
| 20:1200                   | 1.2:72.2         | 300         | 0.207        | 62.100    |
| 30:1015                   | 1.8:66.2         | 694         | 0.037        | 25.678    |
| 40:1100                   | 2.2:65.6         | 600         | 0.034        | 20.400    |
| 50:1050                   | 2.6:70.1         | 925         | 0.029        | 26.825    |
| 50:700                    | 2.5:37.7         | 747         | 0.051        | 38.097    |
| 50:650                    | 2.5:35.3         | 871         | 0.031        | 27.001    |
| 50:600                    | 2.5:31.7         | 768         | 0.030        | 23.040    |

Table 2. Current, high voltage and power for Circuit 2.

| Transformer Configuration | Resistance (Ohm) | HV value (V) | Current (Amp) | **Power (kW) |
|---------------------------|------------------|-------------|--------------|-------------|
| 5:5:1100                  | 0.5:0.5:63       | 704*        | 1.564        | 1.1011      |
| 10:10:1000                | 0.7:0.7:62       | 352*        | 1.562        | 0.5498      |
| 15:15:1020                | 1.3:1.3:64       | 334*        | 1.562        | 0.5217      |
| 20:20:1200                | 1.1:1.1:70       | 743*        | 1.563        | 1.1613      |
| 25:25:1050                | 1.6:1.6:60       | 524*        | 1.563        | 0.8190      |

*the value drop between 0-290V  **Starting power before drop

Table 3. Current, high voltage and power for Circuit 3.

| Transformer Configuration | Resistance (Ohm) | HV value (V) | Current (Amp) | Power (W) |
|---------------------------|------------------|-------------|--------------|-----------|
| Nil                       | 19.95k           | 241         | 0.08         | 19.28     |
| Nil                       | 17.66k           | 255         | 0.09         | 22.95     |
| Nil                       | 11.04k           | 305         | 0.11         | 33.55     |
| Nil                       | 6.29k            | 355         | 0.14         | 49.70     |
| Nil                       | 2.77k            | 405         | 0.18         | 72.90     |
| Nil                       | 3.8              | 455         | 0.24         | 109.20    |
Figure 6. Plotted voltages for Circuit 1, Circuit 2 and Circuit 3.

Figure 7. Plotted current for Circuit 1, Circuit 2 and Circuit 3.

Figure 8. Plotted power for Circuit 1, Circuit 2 and Circuit 3.
In summary, large variations in high voltage values are exposed and the circuits with transformer configurations shown the unachievable high voltage value. The main findings suggest that in general the circuit with inductance element indicate that the circuit be able to produce the required voltage.

4. References

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