Characterization of a pulsed mode high voltage power supply for nuclear detectors

A B Ghazali¹, T S Ahmad¹ and N A Abdullah²
¹Universiti Tenaga Nasional (UNITEN); ²Malaysian Nuclear Agency, MOSTI

Email: Abakar@uniten.edu.my

Abstract. This paper discusses the characterization of a pulsed mode high voltage power supply (HVPS) using LT1073 chip. The pulsed modulated signal generated from this chip is amplified using a step-up ferrite core transformer of 1:20 turn ratio and then further multiplied and converted into DC high voltage output using a diode-capacitor arrangement. The circuit is powered by a 9V alkaline battery but regulated at 5V supply. It was found that the output for this setup is 520V, 87 μA with 10% load regulation. This output is suitable to operate a pancake-type GM detector, typically model LND 7317 where the plateau is from 475V to 675V. It was also found that when a β-source with intensity of 120 cps is used, the power consumption of the circuit is 5V, 10.1 mA only. When the battery was left ‘on’ for 40 hours continuously, the battery’s voltage has dropped to 6.9V, meaning that the 5V supply as well as 520V output is still maintained. It is noted that the minimum output voltage of 475V has reached when the regulated supply has reduced to 4.6V and consequently the 9V battery dropped to 6.5V, and this had happened after approximately 3 days of continuous operation. The power efficiency for this circuitry was found to be 89.5%. This result has far better in performance since the commercial portable equipment of this type has normally specified that not less than 8 hours continuous operation only. On the circuit design for this power supply, it was found that the enveloped frequency is 133 Hz with approximately 50% duty cycle. The modulated frequency during ‘on’ state was found to be 256 KHz in which the majority of power consumption is required.

1. Introduction

The challenge to reduce energy consumption in instrumentation design, especially on portable equipment has never stopped. This includes selection and reduction in number of hardware components, such as the semiconductor chips and to improve the control strategy during software development. A power supply (PS) to drive electronic circuitry in the equipment plays a very important role in order to make the equipment functioning as required. This PS should be designed with high efficiency so that unwanted power lost in the components used for this power supply is minimal. A well-known design is to use a switched mode PS where the output is regulated using duty cycle control at optimal frequency to switch the transistors to fully on and off, so that very little resistive losses between input and the load [1]. Other method in the design is called pulsed mode PS where the duty cycle control is used to drive a power transistor that connected to an ignition coil so that a high transient that due to the release of coil’s energy during switching off the transistor is created. This transient is then amplified and rectified by a step up transformer and the diode-capacitor circuit to obtain a DC output and this approach has been used for example by Bicron scintillation counter [2]. The later design is applied in this article where a micropower DC/DC converter, LT1073 chip is used to function as an oscillator as well as a regulator. In this report, a 9V battery is converted into 520V PS for operating a nuclear detector and a characterization of this PS is discussed here.

2. Circuit design

The circuit diagram for this HVPS is shown in Figure 1 and Figure 2 is used. The transistor Q1 collector of U1 (pin 3) is connected to the primary winding of 1:20 step-up ferrite core transformer to produce a modulated signal of 256 KHz for about 50% duty cycle with enveloped frequency of 133 Hz. This duty cycle as well as the HV output are controlled by the feedback voltage at pin 8 of U1 obtained from a potential divider of R2, 100KΩ and R3, 40MΩ
resistors. Pin numbers 6 and 7 are used for weak battery indicator and they do not consider in this circuit. After 20x amplification of signal from the transformer, it is then rectified and converted to direct current (dc) output at point D. The diodes D2,..., D4 and capacitors, C2,..., C4 arrangement as shown will get the HV output of \(2V_{p+} + V_{p-}\) where \(V_p\) is the peak voltage in either positive or negative cycle of the waveform [4]. The output ripple due to the envelope frequency is reduced by a low pass filter of R4 and C5 before connected to a GM detector. The load regulation for this circuit was also performed by connecting the HV output to a number of resistor’s values as the load and this will determine the power efficiency.

![Figure 1. HV circuitry using LT1073 chip](image1)

![Figure 2. Block diagram of LT1073 chip](image2)

**3. Result and discussion**

A typical result with the prescribed feedback voltage to LT1073 chip is shown in Figure 3 where the modulated signal at point A is obtained from the chip that connected to the primary winding of the step-up transformer. Capacitor C3 in Figure 1 acts as an ac coupling and this signal is rectified by diode D3 to get 320V rms. The ac voltage that sitting of dc voltage at point C is further rectified by diode D4 and capacitor C4 to obtain the HV output of 520V dc at point D with ripple of \(15V_{pp}\) 133 Hz. This ripple is then reduced to \(5V_{pp}\) by low pass filter of R4 and C5.

![Image of results](image3)

(a) Points A (yellow-packet) and B (green-rectified)
A load regulation for this portable HVPS was conducted by connecting a number of resistor values as the load. The result is shown in Figure 4 where the output of 520V (no load) has dropped to 468V (10% regulation) at about 87 μA of load current. This amount of current is more than adequate since an average current required to produce a pulse is in the range of pA only [5]. The current flow from 5V regulator to this HVPS circuit was also measured and found that to be 10.1 mA. It means that the circuit efficiency in term of power delivery is \((520\text{V} \times 87 \mu\text{A})/(5\text{V} \times 10.1\text{ mA}) = 89.5\%\).

Figure 4. Load regulation responses for discrete load values from 5 MΩ to 50 MΩ

The 9V battery’s life span was also monitored, initially for 40 hours continuous operation. A LND 7317 GM detector is connected to this HVPS output as shown in Figure 5 (a) where a β-source radionuclide is placed near to the detector. The pulses as shown in Figures 5 (b) and (c) were obtained from the detector and a pulse shaper respectively. For radiation intensity of 120 pulses per second (cps), it was found that the battery’s voltage has dropped to 6.9V, meaning that the 5V supply as well as 520V output is still maintained. Note that the minimum plateau of this detector (475V) has reached when the regulated supply had reduced to 4.6V and consequently the 9V battery dropped to 6.5V, and this has happened after approximately 3 days of continuous operation.
4. Conclusion
This article has shown that a LT1073 IC is suitable for HVPS design to operate a nuclear detector used for portable equipment, such as a survey meter. It is also shown that a pulsed mode power supply has very good power efficiency and this is in comparable to a good performance of a switching mode power supply.

5. References
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