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ELECTRONIC ENGINEERING

Construction of High Voltage Power Supply Unit for GM Counter

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Abstract— **High Voltage Power Supply Unit is essential for nuclear radiation detection or counting system. A high voltage power supply unit that is suitable to use with GM (Geiger Muller) counter is constructed with locally available components. The constructed high voltage unit is based on push-pull mode and it is acceptable for low-level primary voltage (2V to 10.19V) and delivers it at high-level secondary voltage (105V to 514V) of transformer. To avoid the insulation problem at the transformer secondary coil, a voltage multiplying circuit is used. The desired voltage is rectified and multiplied by voltage multiplier unit provides 3055V (-3 kV) DC at approximately 1mA output current.**

Keywords— **high voltage power supply unit, GM (Geiger Muller) counter, oscillator, frequency divider, push-pull mode, transformer, voltage multiplier**

I. INTRODUCTION

High Voltage (H.V) power supply is required by a nuclear instrumentation to produce an electrical signal when a radiation enters its detector. The signal can be in the form of pulse or current and its magnitude depends on the intensity of radiation around the detector. It also depends on the voltage across the positive and negative terminals of the detector. In both gaseous and solid counters, charged particles liberated by ionization can be collected at boundary electrodes under an applied High potential electric field. There are mainly two types of HVPS in the nuclear field: those for very low current (up to 100µA) used for biasing semiconductor detectors and gas-filled detectors and those able to deliver higher currents needed when working with photomultiplier tubes. Fig.1 shows HVPS system for GM counter, type of gas filled detector. The High Voltage Power Supply unit in present work is constructed with oscillator, JK flip-flop, push-pull driver transistors, step-up transformer, regulated voltage power supply, variable voltage regulator and voltage multiplier. A regulated power supply provides 12V DC to operate oscillator, flip-flop and driver transistors. Oscillator converts electrical energy in the form of DC to electrical energy in the form of AC. Flip-flop acts as alternator and frequency divider. Driver transistors switch the high current required to provide appreciable power to step-up transformer. Compact size, low power consumption and low cost are the major advantages over conventional E.H.T design. This unit can provide (~3kV) DC at 1mA output current by varying the High Voltage output control adjustment. The block diagram of the typical radiation detection for GM tube is as shown in Fig. 2.

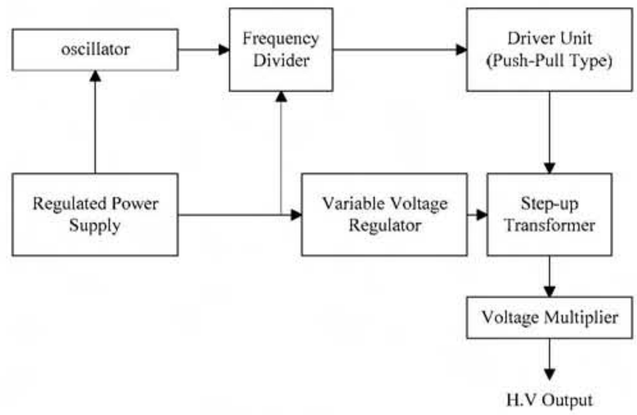

Fig. 1 Block diagram of high voltage unit

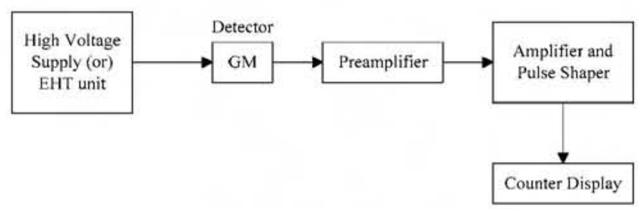

Fig. 2 Typical radiation detection system

II. INTRODUCTION OVERVIEW OF CONSTRUCTION OF HIGH VOLTAGE POWER SUPPLY UNIT

A. Oscillator

Oscillator is a circuit that produces a repetitive waveform on its output with only the DC supply voltage as an input. A repetitive input signal is not required. Oscillators are used to generate required frequencies and timing signals. Essentially an oscillator converts electrical energy in the form of DC to electrical energy in the form of AC. A basic oscillator consists of an amplifier for gain (either discrete transistor or operational amplifier) and a positive feedback circuit that produces phase shift and provide attenuation.

1) 4011 NAND Gate as an Oscillator: The phase shift I.C oscillator produces a frequency of 3kHz and it consists of two NAND gates. The function of the phase shift oscillator (or) square wave oscillator is as follows: First, assume logic "1" at point a. Therefore, logic "0" will be obtained at point b and time constant is $T_1 = R_1C_1$. Similarly, point c will be "1" with the time constant $T_2=R_2C_2$ respectively. Therefore, point a and point b, point b and point c are 180 out of phase of $R_1C_1 = R_2C_2 = RC$, the frequency of oscillation is

$$f = \frac{1}{2RC}$$

In this design, R = 150k and C=1nF

$$f = \frac{1}{2\times150k\times1n}$$

f = 3.33 kHz (~3kHz)

B. 4027 JK Flip-Flop used as Frequency Divider

There are two modes in a dual JK flip-flop, clocked and direct. In the clocked mode, the direct set and clear inputs remain at ground. The inputs to the J and K lines decide what the flip-flop is going to do. If the J and K remain grounded, the clocking does nothing. If J is positive and K grounded, the clocking forces Q positive and to ground. If J is grounded and K positive, the clocking forces Q to ground positive. If both J and K are positive, the clocking alternates the Q and states. In the direct mode, a positive set input forces Q positive and to ground. A positive reset input forces Q to ground and positive. Both set and reset inputs simultaneously go positive, both Q and will also go positive. This is usually a disallowed state. The actual operation doesn't happen until the positive edge ground to positive transition of the clock. The output signals will change state while the input signal is going positive since it is used a positive edge triggered JK flip-flop. The output Q and are out-of-phase. Since it takes two input clock pulses to produce one output cycle, the output signal frequency is the half of the input signal frequency. Therefore, it can be used as a frequency divider and is also called a T (or) Toggle flip-flop.

C. Push-Pull Driver Transistor

The function of the driver transistor is to deliver a specified amount of power to its load.

In this high voltage supply, the two transistors (C1383) are used as driver transistors. C1383 transistor is NPN Si, AF power amplifier. Its rating should not be exceeded above the following data.

- Collector to emitter voltage BV_{CE}= 50V
- Collector to base voltage BV_{CB}= 60V
- Base to emitter voltage BV_{EB} = 5V
- Maximum collector current I_C = 1A
- Maximum Device power dissipation PD watts = 1W (Heat sink) (or) 0.75W
- Frequency in MHz f = 200 MHz
- Current gain h_{FE} = 120 min

These two transistors are connected in push-pull amplifier form. By connecting two transistors in push-pull, it is possible to increase the power output that obtainable from a single stage. The two input signals applied to the base terminals of the two transistors must be equal in magnitude but of the positive phase. Each transistor conducts at all times and, as a result of the input signals, the collector current in one transistor increases when thata in the other decreases. Each transistor supplies one half of the power output delivered to the load. A push-pull amplifier has the added advantage of reduced non-linear distortion. If one of these transistors would have a better h_{FE} it would take over the whole current and it would burn. To avoid this problem, a resistor is to be inserted in series with base.

D. Selection of Constructed H.V Transformer

To avoid the insulation problem at the transformer secondary coil, voltage multiplying circuit will be used. For safe operation, the transformer secondary voltage should not exceed 600V. The specification of constructed transformer parameters is as follows:

Specification of Constructed Transformer Design

Iron core size in inches

- Width -0.65inch
- Stack height -1.006inch
- Cross-sectional area - 0.654inch
- Core-type -EI type
- Primary winding
- Current -800mA
- Voltage -12V AC
- Power -9.6 W
- Number of turns -288turns
- SWG -23

- Secondary winding
- Current -17.4mA
- Voltage -500V AC
- Power -8.7 W
- Number of turns -6000 turns
- SWG -43

E. Regulated Power Supply

The block diagram of a regulated power supply is shown in Fig. 3. The secondary voltage (18V) of the transformer is connected to the Bridge rectifiers. Rectifiers convert the AC input voltage to a pulsating DC voltage. Thus, rectifier is also called converter circuit. Filter eliminates the fluctuations in the rectified voltage and produces a relatively smooth DC voltage. The filter capacitor 1000μF/25V and 0.1μF/50V are provided in unregulated portion of the circuit. The function of a regulated power supply is to provide the necessary DC voltage and current with low level of ripple and with regulation. It must provide a stable DC output voltage, irrespective of changes in the main input voltage and of changes in the load current. A +12V, 1A regulated power supply unit requires in this system. The three-terminal IC regulator LM 7812 is used for positive voltage output.

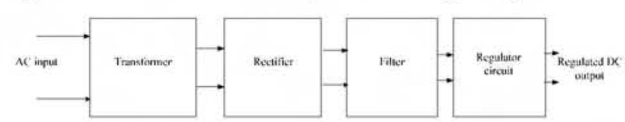

Fig. 3 Block diagram of a regulated power supply