A Compact High Voltage Module for Biasing of PIN Photodiode in Dosimetry Applications

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ABSTRACT

A compact High Voltage (HV) module for generating 100V DC output has been developed for biasing of PIN photodiode detector used in dosimetry applications. Two different approaches have been used in designing the HV circuit. In the first case, the circuit employs a low noise, constant frequency pulse width modulating (PWM) boost converter with an inductor operating in discontinuous current mode. Charge pump converters are used to further increase the voltage levels. In the second case an autotransformer is used as the switching element with the PWM boost converter. The compact design, low noise and low current consumption are the stringent requirement of such supplies. The present modules have been developed using through-hole leaded components. The compactness and noise performance can the further improved if SMD components are used. The designed supply modules have good line and load regulation.

1. INTRODUCTION

The high voltage has immense applications like varactor diode biasing in TV tuners, set-top boxes, LCD power supply, Avalanche photodiode biasing and biasing of PIN photodiode detectors used in dosimeters. Designing such circuits for compactness, low noise and low current consumption is a tedious job, especially when used for biasing of PIN Photodiodes in dosimetry applications. The PIN photodiode when used in dosimetry applications for gamma radiation measurements, the gamma photons interact with the detector material and produce e-h pairs [1]. Maximum photons interaction takes place in the I-region of the detector. These e-h pairs are then swept by the applied field and converted into a current pulse. The number of pulses per unit time is proportional to the radiation intensity. The detection efficiency is a function of thickness of detection medium (the I-region) which in turn depends upon the applied reverse bias. The detector signal amplitude thus increases with increased detector bias till the PIN diode achieves full depletion [2]. The detector capacitance reduces due to increased I-region thickness with the increasing detector bias. This reduces the capacitive noise components of the detector. The signal to noise ratio is thus greatly improved when the detector is operated in fully depleted mode at high detector bias. To fully deplete the I-region of the PIN photodiode of 500 micron thickness used in our applications, reverse bias of approximately 100 V is required. Since the output of PIN diodes is very small and vulnerable to noisy pick-ups, the bias supply should have low noise levels. We have developed an HV module which is capable of generating +100 VDC output with +5 VDC input. The module is compact, has very low noise and has good line and load regulations. The compactness and noise performance can be further improved if SMD components are used instead of through hole leaded components.

2. OPERATION

The figure-1 below depicts the block diagram of high voltage module for generating +100 VDC from +5 VDC at input. IC MAX5026 is employed as DC-DC converter which is a constant frequency, low noise boost converter. It operates from 3 V to 11 V switches at 500 kHz and is capable of generating 36 V at output. Figure-2 shows the photograph of the fabricated prototype HV module based on the inductor as switching element. Figure –3 shows the prototype HV module based on the autotransformer as switching element. IC MAX5026 operates in discontinuous mode in order to reduce the switching noise at the output. Also switching times have been slowed to reduce the high frequency spikes that are otherwise present in most of the cases.

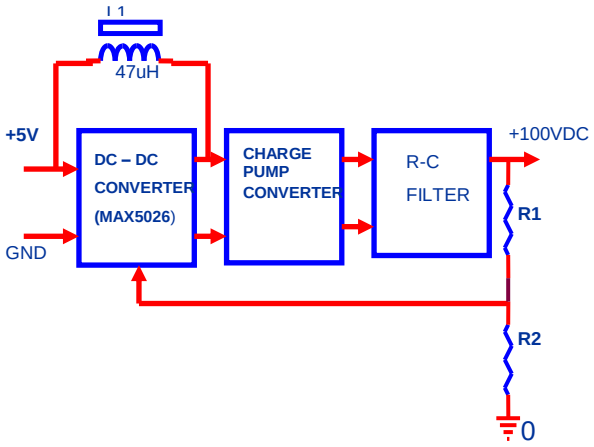

Fig 1. Block schematic of HV Module

Slower switching times reduce the high frequency di/dt and dv/dt rates which minimize radiated and coupled noise to surrounding circuits through current loops and capacitances between PCB traces or component pins.

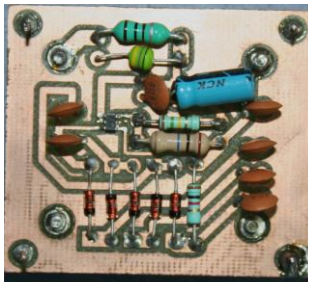

Figure - 2. Prototype HV Module (Inductor based)

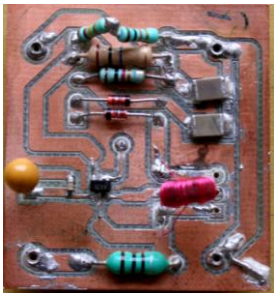

Figure - 3. Prototype HV Module (Auto-transformer based)

The output from the MAX5026 is 36 V. Using a two stage charge pump converter, the output is nearly tripled. More stages of charge pump converter can be added to get higher outputs. The diodes used in the charge pump converter must be high speed Schottkey type as MAX5026 switching frequency is 500 kHz. To minimize the noise in the output, an R-C filter [3] is used at the output stage. The resistance divider formed by R_1 and R_2 provides feedback for regulating the circuit output. The resistance values of the divider are calculated as.

$$V_{out} = \{1.25 (R_1 + R_2)\} / R_2$$

Or

$$R_1 = R_2 \{(V_{out} / 1.25) - 1\}$$

R1 should be fixed to a high value say 10MΩ, and R2 should be calculated

We have used 10MΩ for R_2 and corresponding value of R_3 is 130KΩ to get 100V output.

3. RESULTS

The output of the High Voltage (HV) module is 100 VDC at +5 VDC input. The noise in the output is about 70 mVrms. AC coupled waveform at the output of the HV module is shown in figure -4 and figure-5 to show the noise output for inductor based and autotransformer based designs respectively. The noise can be further reduced by providing larger R-C filter in the output and taking care in PCB designing and providing ground planes.

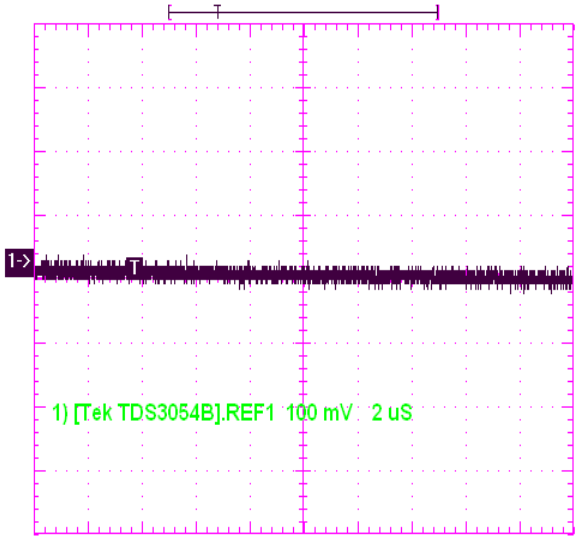

Figure -4. Noise in the output voltage of HV Module (Inductor based). The measurements are carried out using the Tektronix Oscilloscope (DSO 3054B) with probe of input impedance 10MΩ.

The change in output voltage for various loads has been measured. The result is shown in figure-6. It is seen that the supply module has good load regulation for low current load (as in PIN diodes). The load regulation is calculated to be 0.2% at load currents of 10 uA.

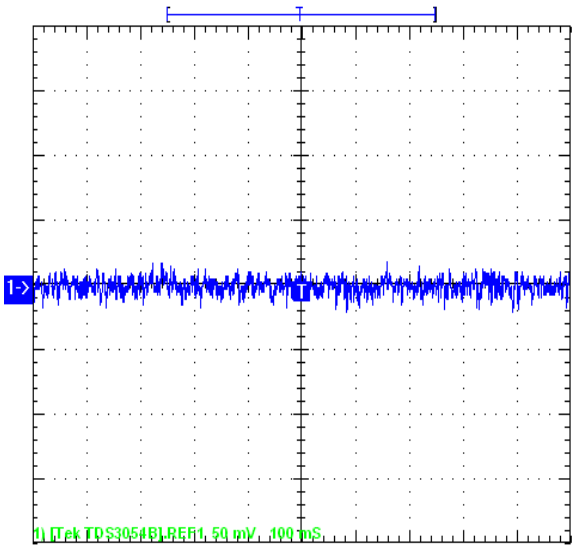

Figure -5. Noise in the output voltage of HV Module (Auto-transformer based). The measurements are carried out using the Tektronix Oscilloscope (DSO 3054B) with probe of input impedance 10MΩ.

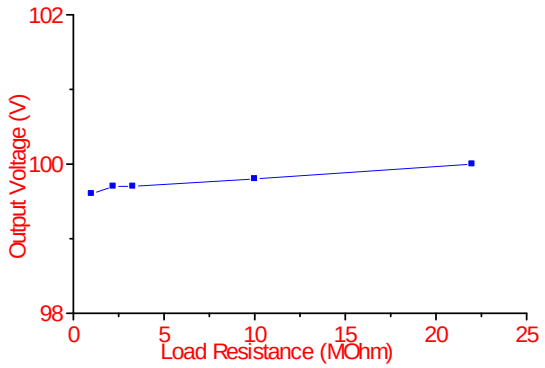

Figure 6. Variation of output voltage with change in load resistance. Voltage is measured with a high voltage probe of R_{in} 600 MΩ and 6-1/2 digit DMM

The change in output voltage with varying input supply has been measured to see the line regulation and it is found that the output voltage varies from 97.4V to 100.5V for an input supply variation from 3V to 6V. The results are plotted in figure-7.

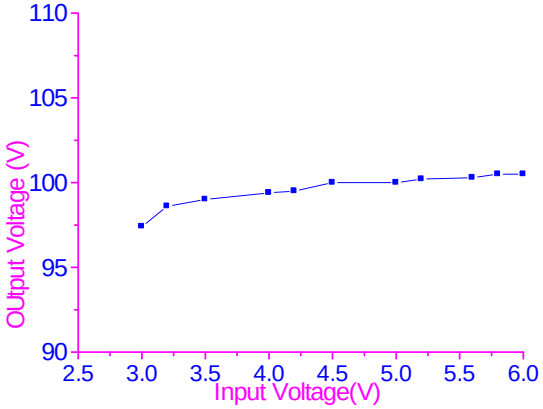

Figure 7. Variation of Output voltage with change in input supply voltage. Voltage is measured with a high voltage probe of R_{in} 600 MΩ and 6-1/2 digit DMM

4. CONCLUSION

The HV module developed has low noise and good line and load regulation. The compactness and noise performance can the improved if SMD components are used instead of through-hole leaded components.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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