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Regulated High Voltage Power Supply for the Vac-Ion Pump of Vacuum Tube

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Anbstract

This paper describes an approach to the design of a DC Regulated High Voltage power supply units for ion pump for degassing of ion from microwave tubes to maintain proper vacuum inside the tube. This power supply is designed for 3.5KV DC, 100µA & it has a short circuit protection to limit the short circuit current to 2.0 mA. The power supply consists of Voltage regulator, Power MOSFETs & Complimentary square pulse generator circuitry with 50% duty cycle to drive the MOSFETs that is connected with high frequency step up transformer and the output of the secondary is rectified & filtered. Feedback network provides status of power supply failure & output short circuit to shut down the whole microwave tube. Output voltage and current measurement provision were incorporated through serial data communication.

Key Words: High voltage DC supply; SMPS; Vacuum tube; PSIM; Multisim & Labview.

1. Introduction

The design and operation of the Vac ion power supply source for degassing of ion, that is produced inside the microwave tube at the time of operation. This ion disturbs the vacuum inside the microwave tube due to which arcing may be happen inside the vacuum tube & vacuum tube may get damage. The design is based on switch mode power supply(SMPS) over a conventional power supply because switch mode based power supply are, smaller, lighter, lower cost, more efficient & regulated in comparison with conventional high voltage power supply& the size of filter capacitor is reduced. This circuit converts low voltage DC into high frequency, high voltage

AC then converted back into the high voltage DC supply that is used to power up the Vac ion pump for degassing of ion. Power supply have self short circuit protection if overcurrent or short circuit occurs in output & a potential free contact is provided for interlocking of other integrated system. The serial port is provided for the monitoring of output voltage & current via 10 bit A/D converter technique using Ardunio uno board which can be interfaced with PC & labview.

1.1 System description

Figure 1 shows a block diagram of the Regulated high voltage power supply for the Vac ion pump for degassing of ion from inside the vacuum tube. In this development a low voltage input DC is regulated & controlled by the voltage regulator. Output DC supply is given to primary of the center tap high frequency step-up transformer through two power MOSFETs [Giesselmann et al., 2005 ; . Tamuri et al., 2010]. This power MOSFETs is triggered by a complementary trigger signal generated by CD4047 with fixed 50% duty cycle at 10kHz frequency. Two MOSFET based switches are driving the 24 volt input step up transformer at a 10kHz frequency in +ve & -ve cycles, then the step-up transformer will convert 24 V input voltage to approximately 3500 V AC. Then the output of the transformer is rectified by the full-wave bridge rectifier using 15kv,100mA diode and filter it using high voltage capacitor. One potential divider connected to measure the generated output voltage & to limit the short circuit current to 2mA a series resistance bank is placed between filter capacitor and output terminal & one more feedback resistance is placed in the return path to measurement of output current as well as short circuit protection of power supply. A comparator generates a logic signal high, according to the set value of reference voltage & triggers the tripping transistor of DC power supply to switch off the input DC supply of step-up transformer till the fault is cleared.And potential free NO NC feedback contact is provided for switching off the whole integrated system if any fault occurred. A/D converter is used for monitoring the output voltage & current of the supply in computer through serial data communication for this purpose Ardunio uno is used as 10 bit A/D conversion.

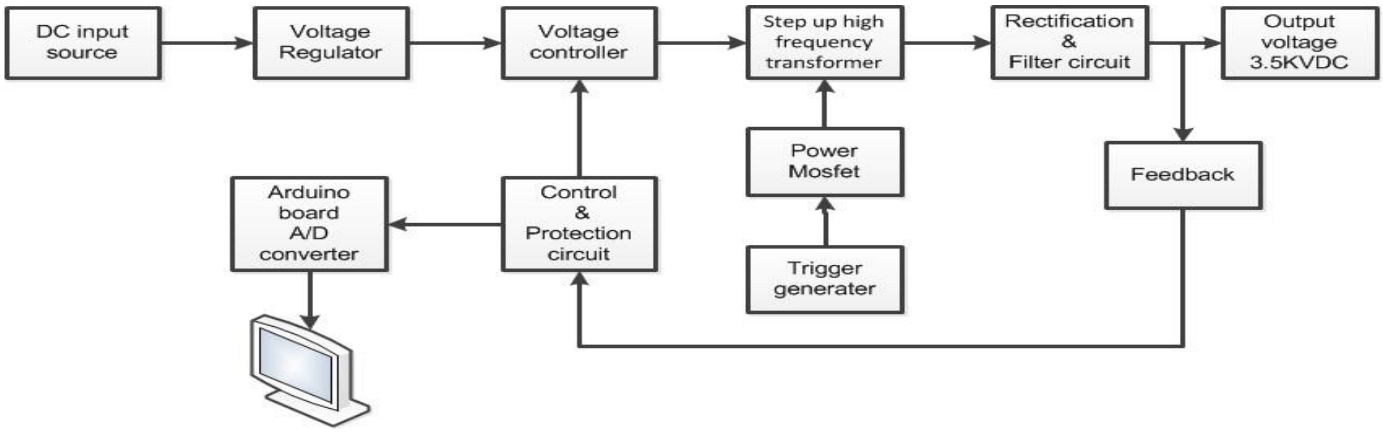

Figure 1. Block diagram of the system

2. Circuit design and selction of components

Switch mode power supply based technology is used for development of 3.5KVDC regulated high voltage. Figure 2(b) & Figure 2(c) show the circuit diagram & schematic diagram for computer interface of the power supply respectively. LM338 is used to produce a regulated 30VDC supply & with the help of power transistor 2N3055 the output voltage can be varied by varying the base voltage of the transistor which is adjusted by voltage regulator IC LM317 is given as.

$$V_b=1.25V\ (1+R_4/R_3)\ +I_{adj}*R_4$$

Set the resistance R_4 in such a way that the output voltage from transistor 2N3055 is 24VDC & which is converted to 3500 VAC, 10 kHz by step up transformer & MOSFETs switch. Two power MOSFETs IRF3205 are used for high speed switching & 10 KHz complementary switching trigger pulse is generated by HFC4047 is given as.

$$F= \frac{1}{4.4RC}$$

For 10 KHz frequency R= 5kΩ pot & C=0.1µF polyester type.

Center tap step up transformer is made on high frequency core & the primary have approximately 25 turns & secondary have 3650 turns, core area 2.25sq.cm, consider flux density is 1066 gauss.

$$Npi = Vpi * \frac{10^8}{4 * f * B * A}$$

$$\frac{Npi}{Nsec} = \frac{Vpi}{Vsec}$$

Where,

Vpi = voltage (volts)

Npi = Primary coil turns

A = Core's cross-sectional area (sq.cm)

F = Frequency (hertz)

B = Flux density (gauss)

The output of step-up transformer is rectified by full wave bridge rectifier circuitry. 2CL2FL 15KV, 100mA diodes are used for rectification & output is filtered by 6KV, 0.25µF paper capacitor. The minimum value of filter capacitor is decided by the given equation.

$$C = \frac{I_{DC}}{(2*f*V_{ripple})}$$

Where,

C = Filter capacitor

I_{DC} = Load current

f = Frequency of the switching pulse

V_{ripple} = Allowable output peak to peak ripple voltage

2.1 Curremt measurement topology

Ardunio uno have inbuilt 10bit ADC and the maximum allowable input analog voltage is 5V

As per design 1µA =10mV

Accuracy of 10 bit ardunio is 5/2^10=4.882mV

The accuracy of current measurement system is 0.4882µA

And in this design Ardunio is capable for measurement of max current is 500µA

Current calibration chart is given in figure 2(a) for measurement of current upto 100µA.

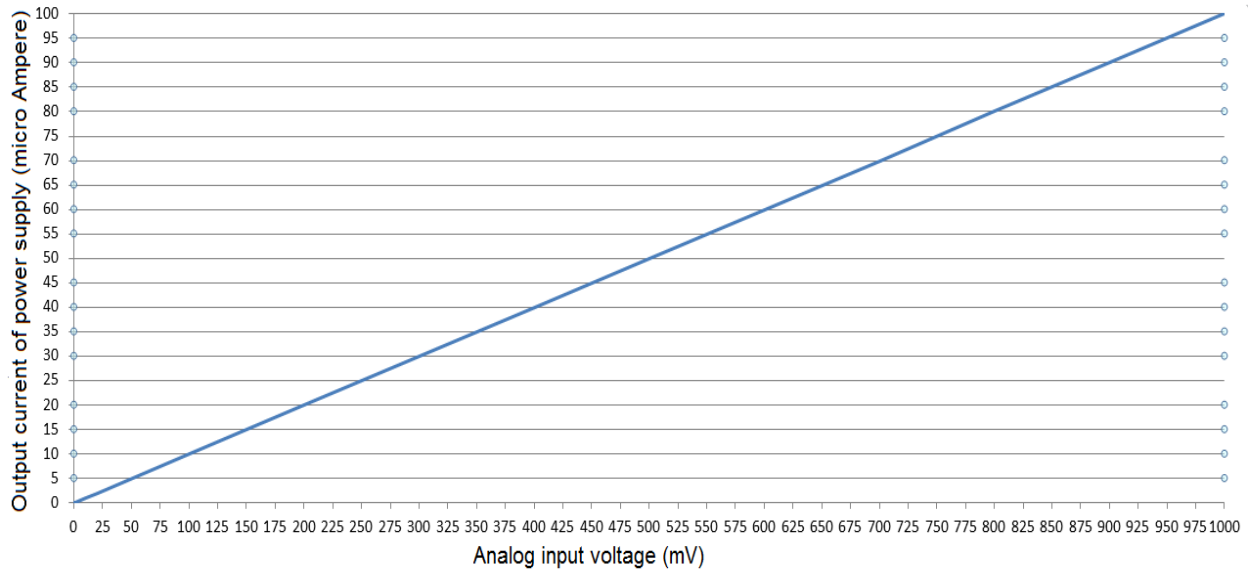

Figure 2(a). Output current & analog input voltage relationship

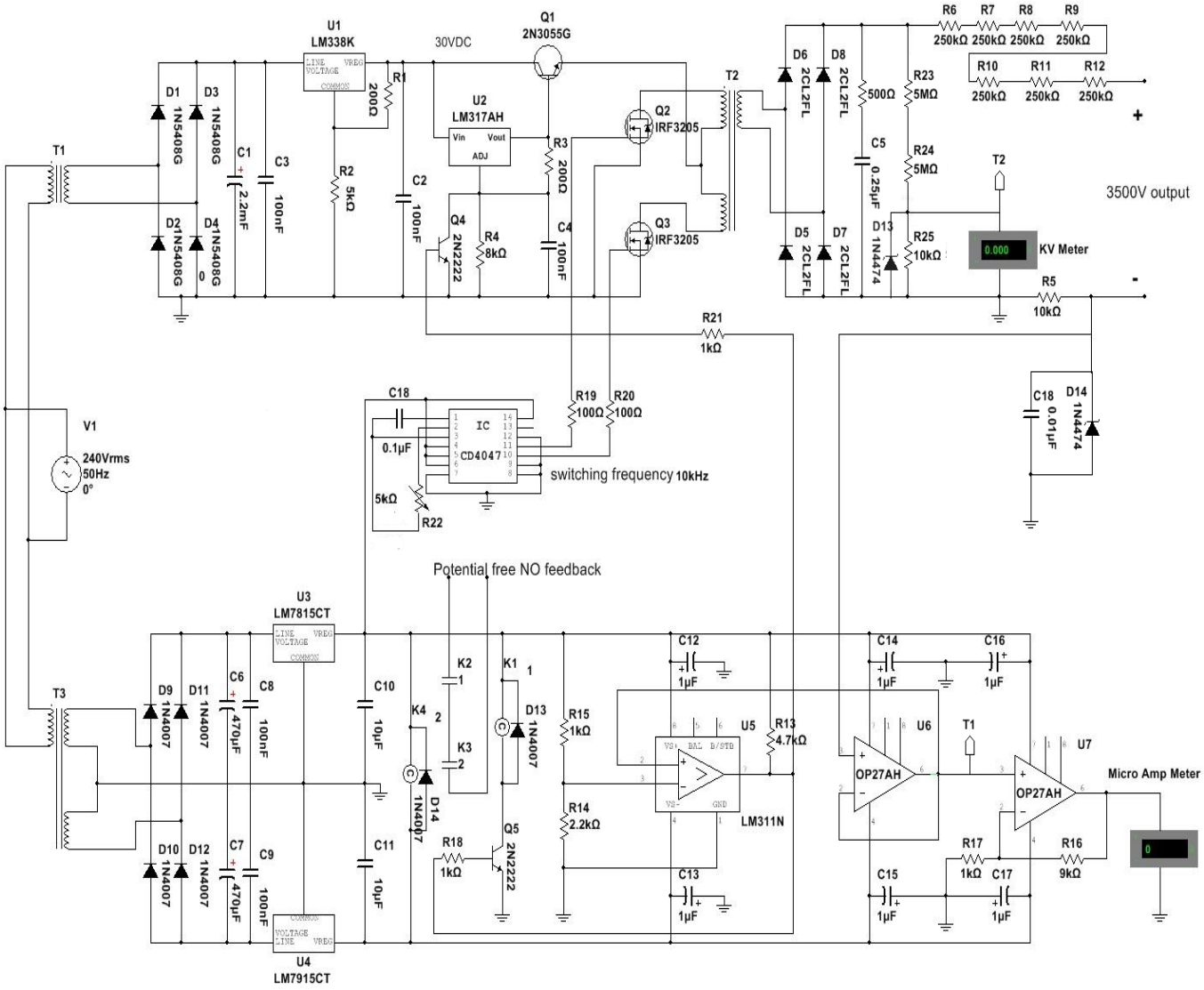

Figure 2(b). Circuit diagram

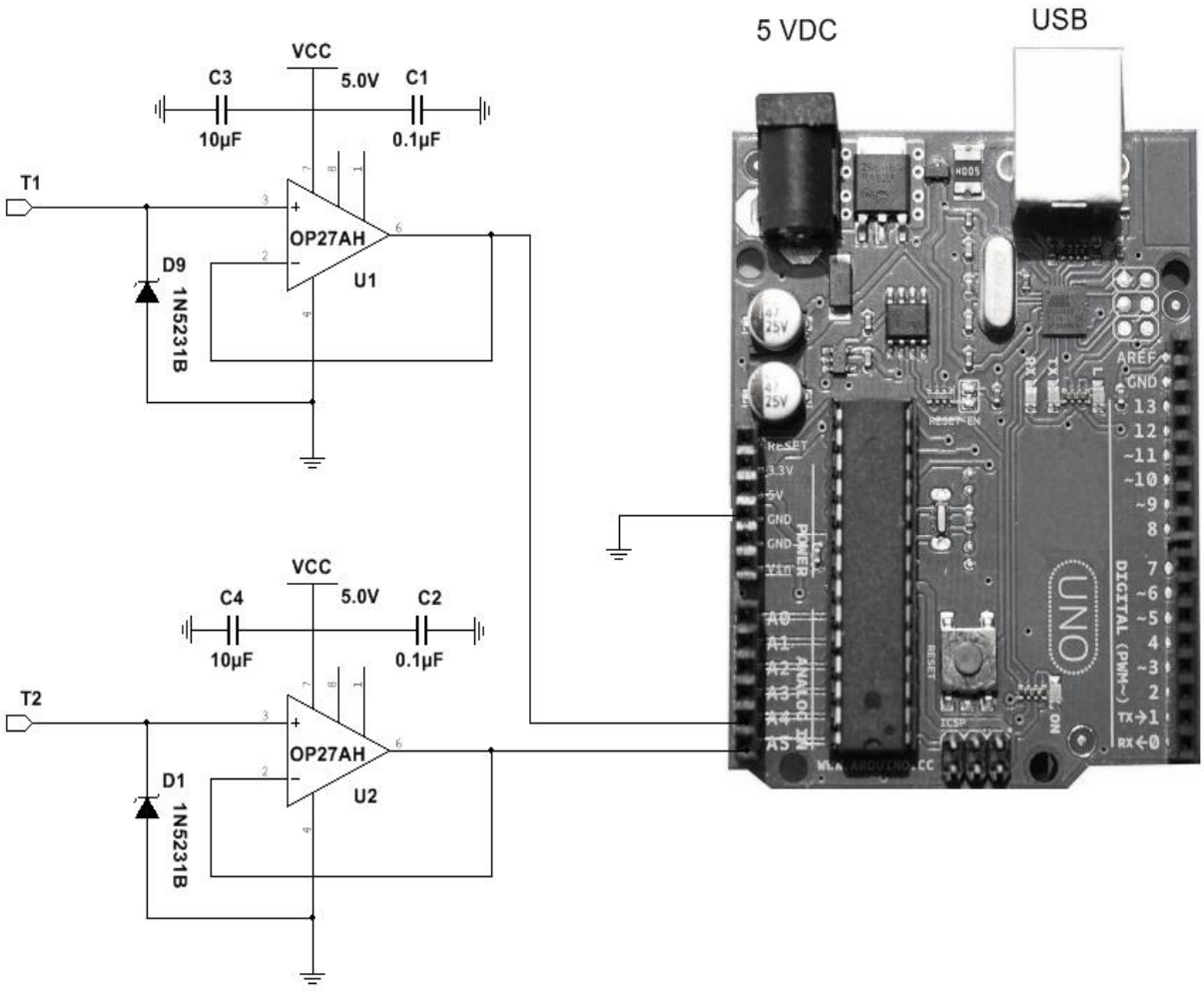

Figure 2(c). Schematic diagram for computer interface

3. Analysis and Result

Complementary input trigger voltage waveform at MOSFETs gate terminal & Output voltage wave form of the power supply are shown in Figure 3(a) & Figure 3(b) respectively. The simulation based measuring result is obtained and detail presented in table 1.

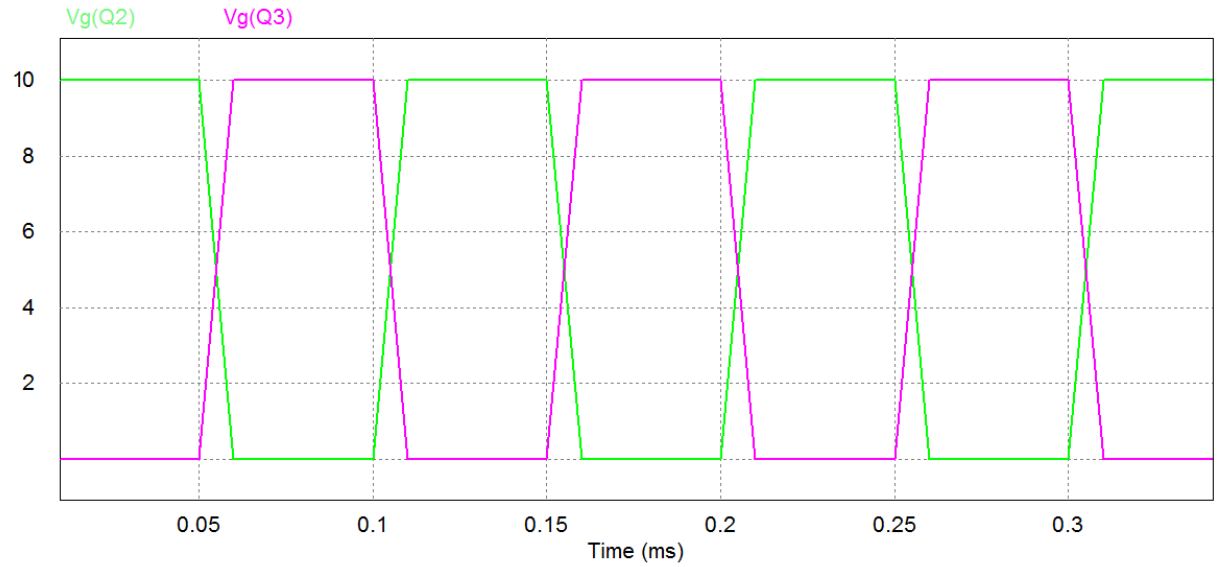

Figure 3(a). Complementary inputs trigger voltage waveform

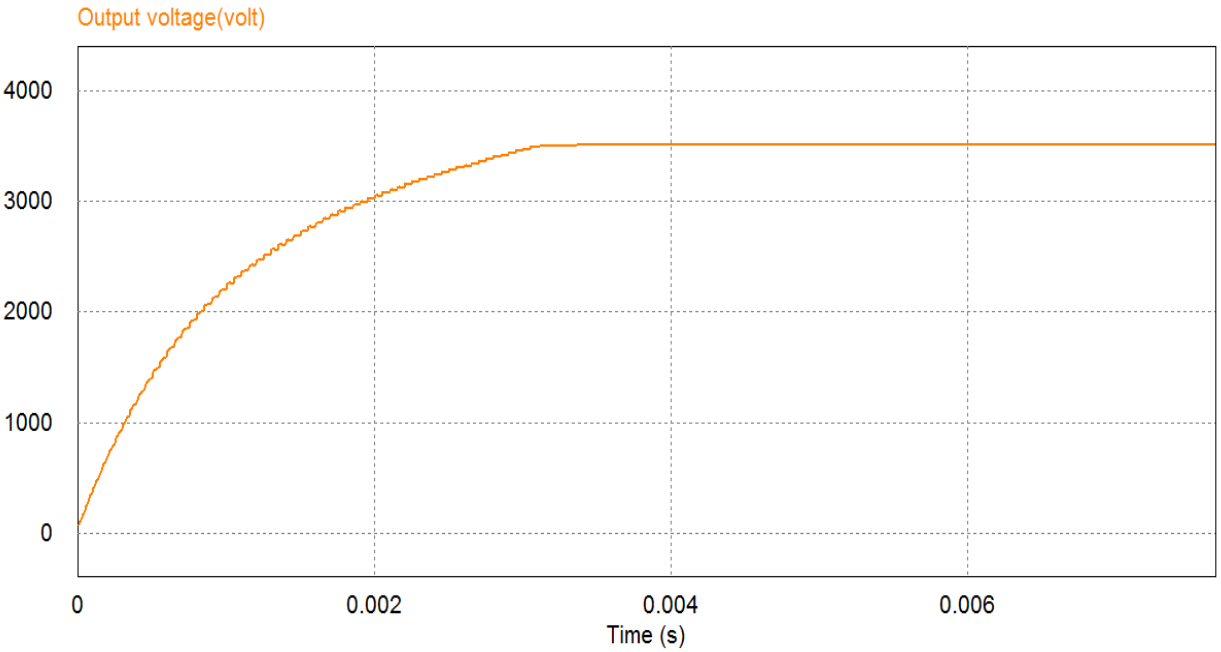

Figure 3(b). Output voltage waveform

Table 1: Parameters of Regulated high voltage power supply

Parameters	**Unit**	**Value**
Switching Frequency	KHz	10
Duty cycle	%	50
Input voltage range	VDC	24 to 30
Trigger	Volt	10
Output voltage	VDC	3500
Shot circuit current	mA	2
Nominal output current	µA	0 to100

4. Conclusion

Thus, the design of high voltage vac ion power supply using SMPS technique is derived. The maximum short circuit current is 2mA with safety protection. This high voltage power supply has been used for degassing of Ion from the microwave tubes & monitoring the output parameter in local meter & remotely in PC with the help of ardunio uno & labview.

By adopting this technique,

i. Failure of power supply unit during fault is protected by establishing feedback loop sensing return current.
ii. Real time monitoring of current and voltage from remote PC.
iii. Overshoot and ripples in output voltage of power supply unit is smoothened by using RC filter network.
iv. Voltage is regulated, maintaining the output constant irrespective of fluctuation in input supply, by incorporation of IC LM388.

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Giesselmann, M. , Palmer, B. , Neuber A.,High voltage impulse generator using HV-IGBTs, *IEEE International Pulse Power Conference* Monterey,CA, June 2005.

Tamuri, A. R. , Bidin N., & Daud Y. M., high voltage power supply for electro-optics applications ,*IJRRAS* **3** (2), May 2010.

The technical information of components and devices are taken from thefollowing sources :

(1) Application note, *Positive adjustable voltage regulator*, Fairchild Semiconductor corporation.

(2) Data sheet of *CD4047BCLow Power Monostable/Astable multivibrator*, Fairchild Semiconductor Corporation.

(3) Data sheet of *LMx11 Quad Differential Comparators*, Texas Instruments.

(4) Data sheet of *Arduino Uno based on ATmega328 Microcontroller*.