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Generation of Variable Step up DC Voltage Using Marx Generator Circuitry

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Abstract— The Generation of self-supplied variable step up DC voltage proposed is originates from conventional Marx generators. This recently developed Marx generator circuit employs high voltage (HV) Metal Oxide Semiconductor Field Effect Transistor (MOSFET) as switches and series connected diodes as isolated components. Optic coupler are use to isolate and protect the damaging of low voltage deices from HV circuit. Project Results of 10 stages having pulses of 12v, 10ms and 50Hz are accustomed in project. The switching of MOSFET will be done and controlled by matrix keyboard and programmed microcontroller such that, we can get variable step up DC voltage. This topology of the circuit generates pulses with fast rise time and allows easy variable step-up output voltage. In addition, as there is use of microcontroller the circuit is capable to adjust positive or negative pulse Width, dead-time between two pulses.

Index Terms— MOSFET, microcontroller, step up DC voltage, self-supplied, Marx generator, solid-state devices, High voltage pulses.

I. INTRODUCTION

The generator capacitance C is to be first charged and then discharged into the wave shaping circuits. A single capacitor C may be used for voltages up to 200 kV. For producing very high voltages, a bank of capacitor are charged in parallel and then discharged in series. The arrangement for charging the capacitors in parallel and then connecting them in series for discharging was originally proposed by Erwin Otto Marx in 1923 as shown in Fig.1. Usually the charging resistance is chosen to limit the charging current to about 50 to 100 mA, and the generator capacitance C is chosen such that the product CRs is about 10s to 1 min. The gap spacing is chosen such that the breakdown voltage of the gap G is greater than the charging voltage V. Thus, all the capacitances are charged to the voltage V in about 1 minute. When the impulse generator is to be discharged, the gaps G are made to spark over simultaneously by some external means. Thus, all the capacitors C get connected in series and discharge into the load capacitance or the test object. The discharge time constant CR_1/n (for n stages) will be very small (microseconds), compared to charging time constant CRs which will be few seconds.

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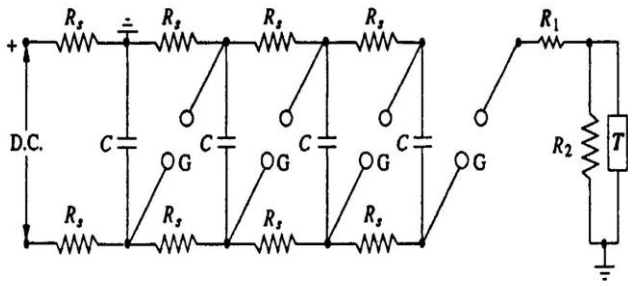

Fig. 1 Conventional Marx Generator

A. Modern Marx Generator

With the development of solid-state electronics, solid-state devices are becoming more and more suitable for pulsed power application. They could provide the pulsed power systems with compactness, reliability, high repetition rate, and long life time. The rising of pulsed power generators using solid-state devices eliminates limitations of conventional components, and promises pulsed power technology to be widely used in commercial applications. However, Solid-state switching devices such as Metal Oxide Semiconductor Field Effect Transistor (MOSFET) available now are only rated up to a few kilo Volts. Previously, it employed spark gaps as switches which are replaced by electronic switches such as (MOSFETs) and resistors as isolator is replaced by diodes. Therefore, Convention Marx generator had drawbacks such as low repetition rate, short life time, and inefficiency are eliminated by modern Marx generator as shown in Fig.2.

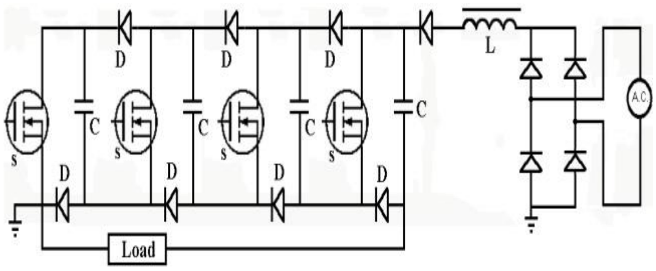

Fig. 2 Contemporary Structure of Marx Generator

II. CONFIGRATION OF MARX GENERATOR

Typically, Marx generator with n stages consists of:-

1. n number switches (MOSFET)
2. n number capacitors
3. 2n numbers of isolators.

The simplified structure of contemporary Marx generator with 4 stages is shown in Fig.2 and it replaces spark gaps and resistive isolators with MOSFETs and diodes respectively.

Marx generator using solid-state devices is proposed to combine the merits of both power semiconductor switches and Marx circuits.

A. Marx Generator Concept

Primary energy source is taken as a step down AC supply. It is step down to suitable voltage and rectified to get constant DC supply for charging of capacitors. Capacitors are charge storage device. The charging of capacitor takes place as they are parallel connected to the rectifier. When capacitor is having appropriate charge stored in it, switches are use to connect all capacitor in series and discharge of capacitor take place and we get n times of rectifier voltage across the load. Due to various practical constraints, the output voltage is somewhat less than **n×V** (**n** is stages). The Fig.3 shows the concept of Marx generator.

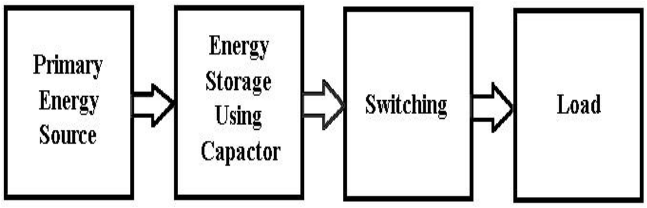

Fig. 3 Marx Generator Concept

B. Operation

Mainly there are 2 modes of Marx generator operation:-

1. Mode 1: charge mode
2. Mode 2: discharge mode.

C. Charge Mode

In this mode, MOSFETs are at off-state. As shown in Fig.10, the secondary winding of transformer has step down voltage of 12 V passes through the rectifier, filter circuit and voltage regulator form constant voltage of 12 V. this constant supply voltage is given to both Marx generator circuitry. Here, charging of capacitor take place via the large inductor L and diodes D. The capacitors C in parallel are charged. The large inductor acts as a current limiter and cause boost of the voltage of capacitors. Fig.4 shows the path of flow of current during charging of **n** no. of capacitor.

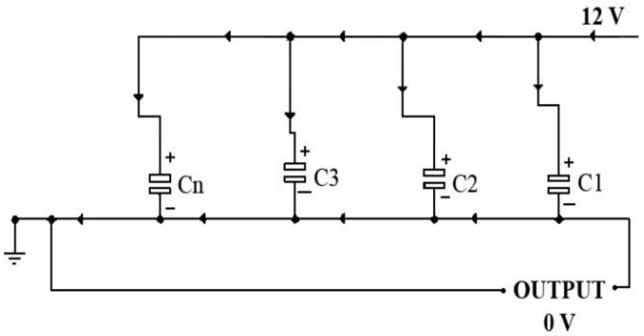

Fig. 4 Charge Mode

D. Discharge Mode

In this mode, MOSFETs turn on simultaneously. Then they are at on-state and, consequently, the capacitors are linked in series. Thus, the load could acquire a negative high voltage which is the sum of the voltage of capacitors. Via MOSFETs, the capacitors discharge their energy to the load. Diodes take place of resistors as the isolator in conventional Marx generator. The Fig.5 shows the path of flow of current during discharge mode. The output voltage during discharge mode across each Marx generator circuitry is **n×V** (**n** is stages).

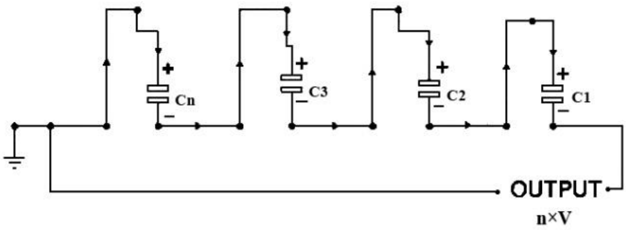

Fig. 5 Discharge Mode

E. MOSFET Gate Drive Optocoupler

An Optocoupler is an electronic component provides electrical isolation between an input source and an output load using just light. The basic design of an Optocoupler consists of an LED that produces infra-red light and a semiconductor photo-sensitive device that is used to detect the emitted infra-red.

There are 2 states of operation of MOSFET gate drive optocoupler:-

1. MOSFET ON
2. MOSFET OFF

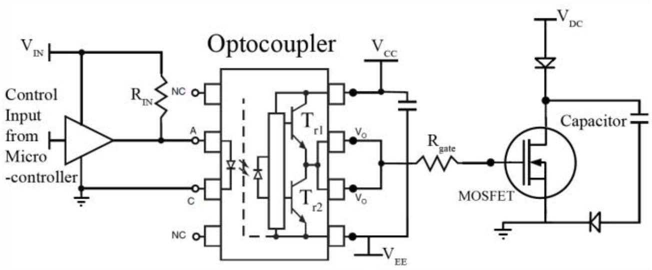

Fig. 6 MOSFET Gate Drive Optocoupler

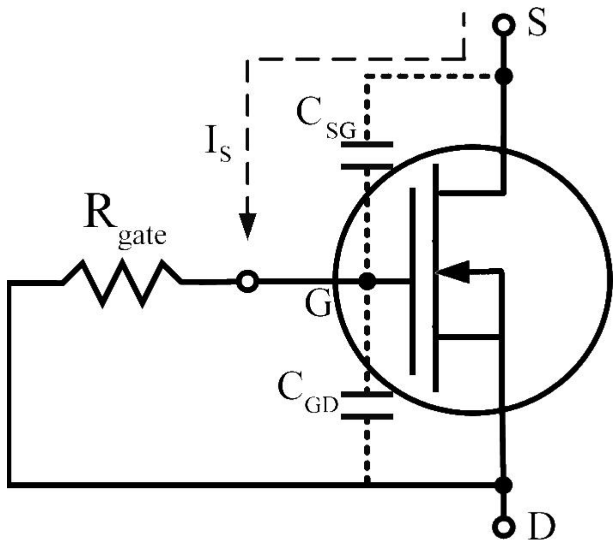

Fig. 7 R_{gate} Effect on MOSFET

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F.MOSFET On

As shown in Fig.6, the control input is given by microcontroller as the control signal is very low in magnitude it is difficult to be detected by the optocoupler. So first it is amplified and then given to the input terminal of optocoupler IC pin. When the control signal given by microcontroller is logically high it will turn ON the LED of optocoupler due to this transistor T_{r1} will be ON and transistor T_{r2} will be OFF. The output of the optocoupler will be high. This high control signal is given to the gate terminal of the MOSFET. When a gate signal is applied, the gate emitter voltage of the MOSFET rises from zero to $V_{GD\ (TH),}$ as shown in Fig.8. This voltage rise is due to the gate resistance (R_{gate}) and the C_{GD}. The turn-on time is a function of the output impedance of the drive circuit and the applied gate voltage. Hence, it is possible to control the turn-on speed of the device by choosing an appropriate value of gate resistance (R_{gate}).

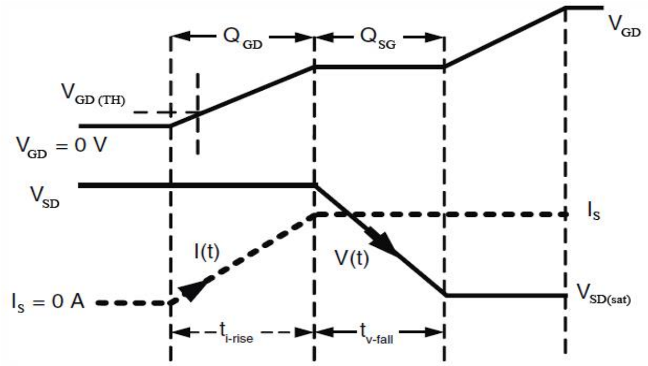

Fig. 8 MOSFET Turn-ON Sequence

G. MOSFET Off

When the control signal given by microcontroller goes from high to low logical the LED of optocoupler will turn off due to this transistor T_{r1} will be OFF and transistor T_{r2} will be ON. So the output of optocoupler will be low. At turn-off, the gate voltage begins to decrease until it reaches the value when the Miller effect occurs during this time the V_{SD} voltage increases changing the output characteristics with constant I_S. The turn off of MOSFET is shown in Fig.9.

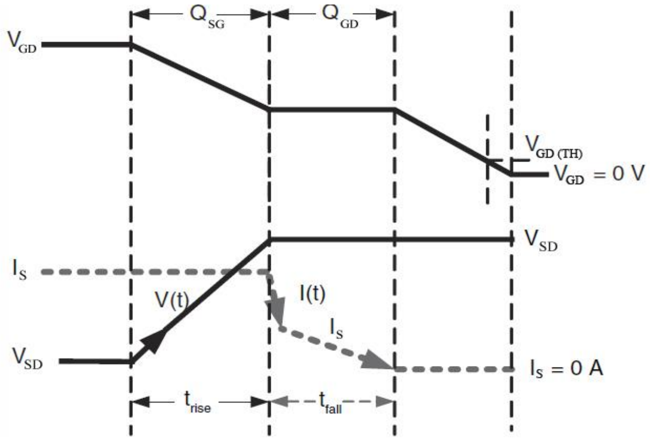

Fig. 9 MOSFET Turn-OFF Sequence

III. MARX GENERATOR CIRCUITRY

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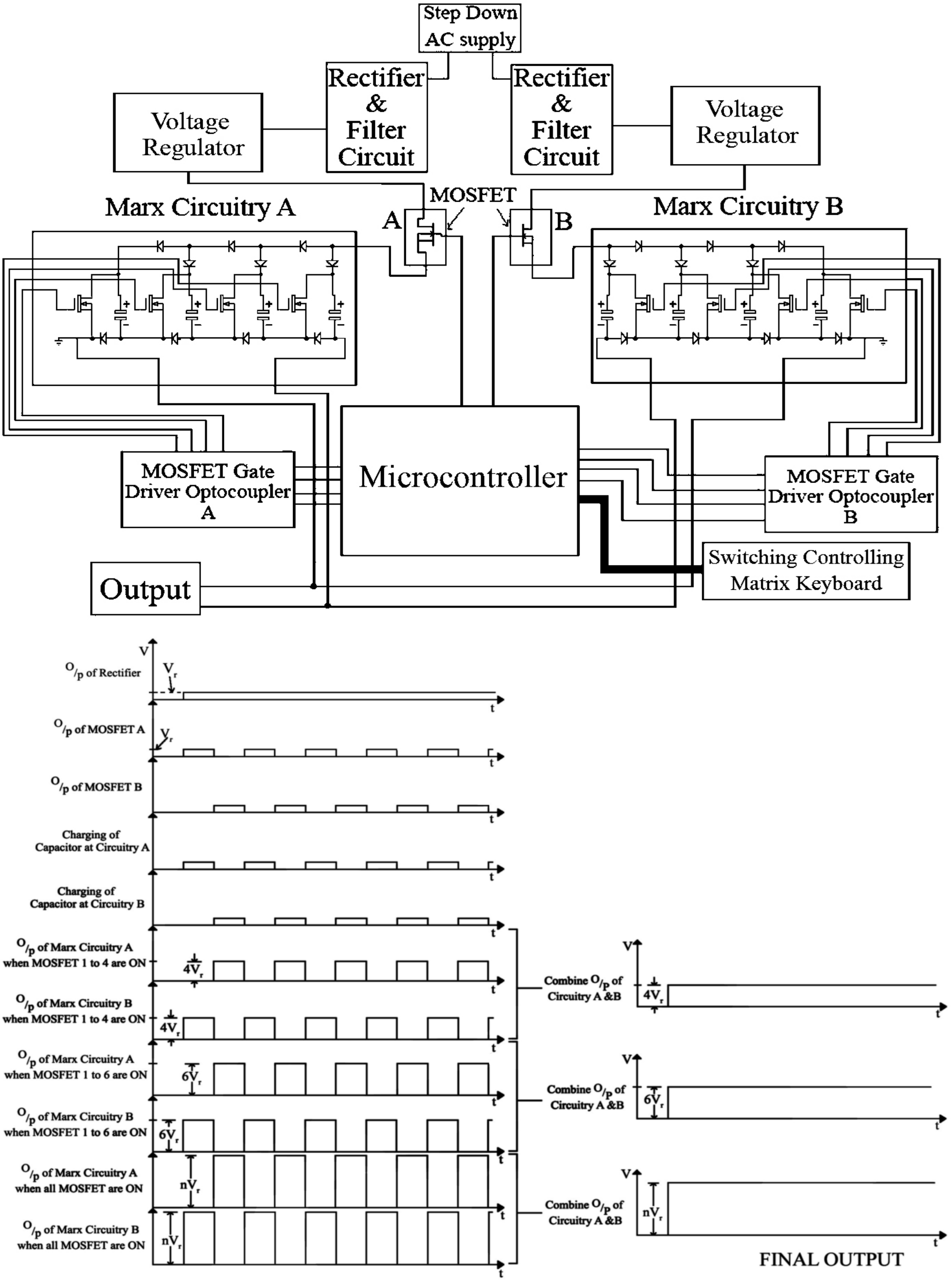

Fig. 10 Simplified Layout of Variable Step-up DC Voltage Using Marx Generator Circuitry

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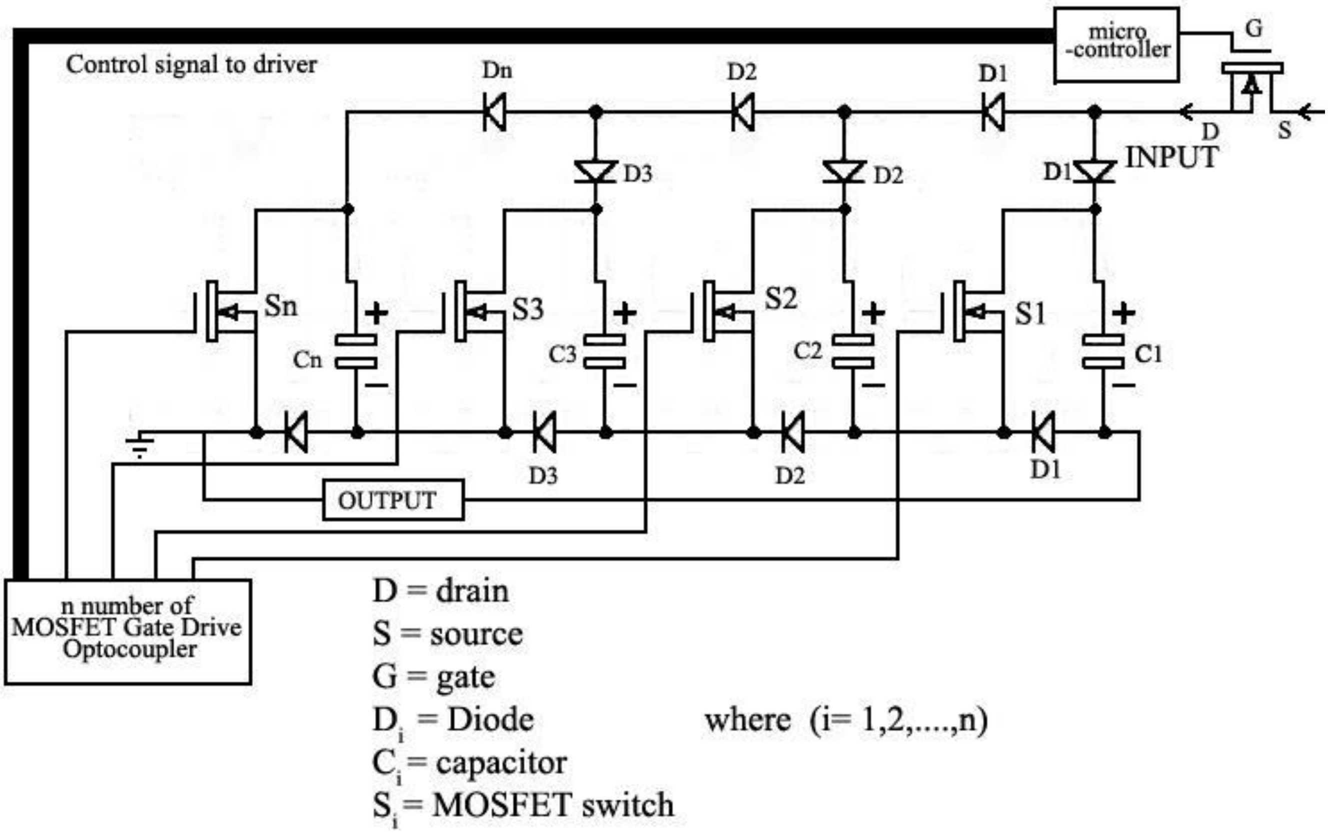

Fig. 11 Single Marx Generator Circuitry

IV. CONCLUSION

In this paper, solid-state devices such as MOSFETs, Diodes and Optocouplers are used in Marx generator to replace of gap switches and resistors. Furthermore, it is reasonable that MOSFET drivers utilize method of self-supplied power and increase the flexibility of convention Marx generator. The experimental results of resistive load indicate that it can easily generate variable step up repetitive high voltage rectangle pulses with low voltage power source. It can be applied for high voltage testing and other applications. As shown in Fig.12, V_r is an input voltage and according to the switching of sets of MOSFET using matrix keyboard and programmed microcontroller we can get $\mathbf{n\times V_r}$ voltage across the Output terminal.

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