OPPORTUNITY FOR UNDERGRADUATE RESEARCH

FINAL REPORT

ELECTRIC FENCING SYSTEM

Under the guidance of **Prof. Dinkar Prasad**

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OBJECTIVE

The aim of this OUR Project was to design and fabricate an electric fencing circuit for generating non-lethal high voltage repetitive pulses(~1KV) of short durations (a few microseconds). This circuit should consume low power and be driven from a standard 12 Volt DC (battery) supply. The average current drawn from the battery must be very low.

ABSTRACT

There has always been a requirement for Energy-Efficient and Cost-Effective solutions for daily life problems and devices. One such requirement is electric fencing. In such a device, there is a need for generating high voltage electric pulses with low energy content such that it is capable of giving electric shock but is non-lethal. This kind of voltage is connected to the wire fencing which is erected around the protected area. The fencing itself stands on an insulated structure so that the voltage pulses don't get shorted to the earth potential. This kind of electric fencing is often used to keep animals like elephants inside a confined zone. When animals touch the fencing wire they get electric shock and learn to remain away from it. Hence designing a system that draws very less power and still provides high voltage shocks becomes crucial. Hence the problem is large consumption of electrical energy and also the set-up costs. In my project I have tackled the problem by building an electrical circuit which supplies high

voltage(1000 V) repetitive pulses every 35 milliseconds and this circuit can be powered from a standard 12 Volt DC Battery.

INTRODUCTION

The purpose of this project is to design and fabricate a low power and low-cost electric fencing circuit. The applications of this will be creating non-lethal electrical fencing to contain large and wild animals inside a zone. This can also be used to create boundaries outside prisons to prevent prisoners from escaping. This fencing will be non-lethal for humans or animals but should still be a very strong deterrent for any type of intruders. In a country like India where there is such a high population of farmers, such a low-cost device which can be used to keep animals away from the farms is of a high importance. The current alternatives are much more expensive than what we propose.

This task will be done by generating repetitive high voltage pulses(~1KV) repeating every 35 milliseconds. These Voltage Pulses are of approximately 70 microseconds duration. Such a circuit should consume less electric power and can be operated with the help of a 12 Volt rechargeable battery.

The proposed circuit generates such pulses with the help of a simple electronic switching circuit and coupled inductors. The electronic circuit consists of an n-channel power MOSFET used as a switch. The input control signal of this MOSFET is given by a NE555 timer used as an astable vibrator. Also, for driving the MOSFET with a 555 timer, a Gate Driver circuit is used in between the two, to amplify the current in order to make sure the switching takes place quickly and properly.

CIRCUIT DESIGN AND SIMULATION

In these difficult times of Covid-19 Pandemic, it was not possible for me to complete this project at our University's laboratories. I was only able to solder the 555 astable multivibrator sub circuit and prepare the EE type laminated iron core transformer with 5 primary and 100 secondary turns. Hence, I had no option but to resort to Circuit Simulation tools to be able to properly design, calibrate and simulate this circuit and be able to take readings and see output waveforms at various stages of the circuit. The tool I used is LTspice.

This is a high-performance SPICE simulation software, schematic capture and waveform viewer with enhancements and models for easing the simulation of electrical circuits. This tool allows the user to view waveforms for most switching regulators in just a few minutes.

This tool is primarily used for designing and simulating low voltage analog circuits hence, I was unable to use a few parts which were supposed to be used. For example, a spark plug was supposed to be used but it was unavailable on this simulation tool.

The circuit consists of an NE555 timer, an NPN transistor-based Gate driver, a power MOSFET, 2 Coupled inductors, Zener diodes and Fast Recovery Diodes, resistors, capacitors and finally a 12-volt DC battery. I will now discuss about each and every stage of the circuit in detail and show the waveform outputs.

The design is such that the flow of current is decided by the state of the MOSFET. When it switches on, the current flows through its Drain and Source, but when the switch is off the current passes through the diode towards the RC stage charging the capacitor. The diode is present to prevent the backflow of current. Every time the MOSFET is switched ON or OFF, the polarity of the transformer also changes.

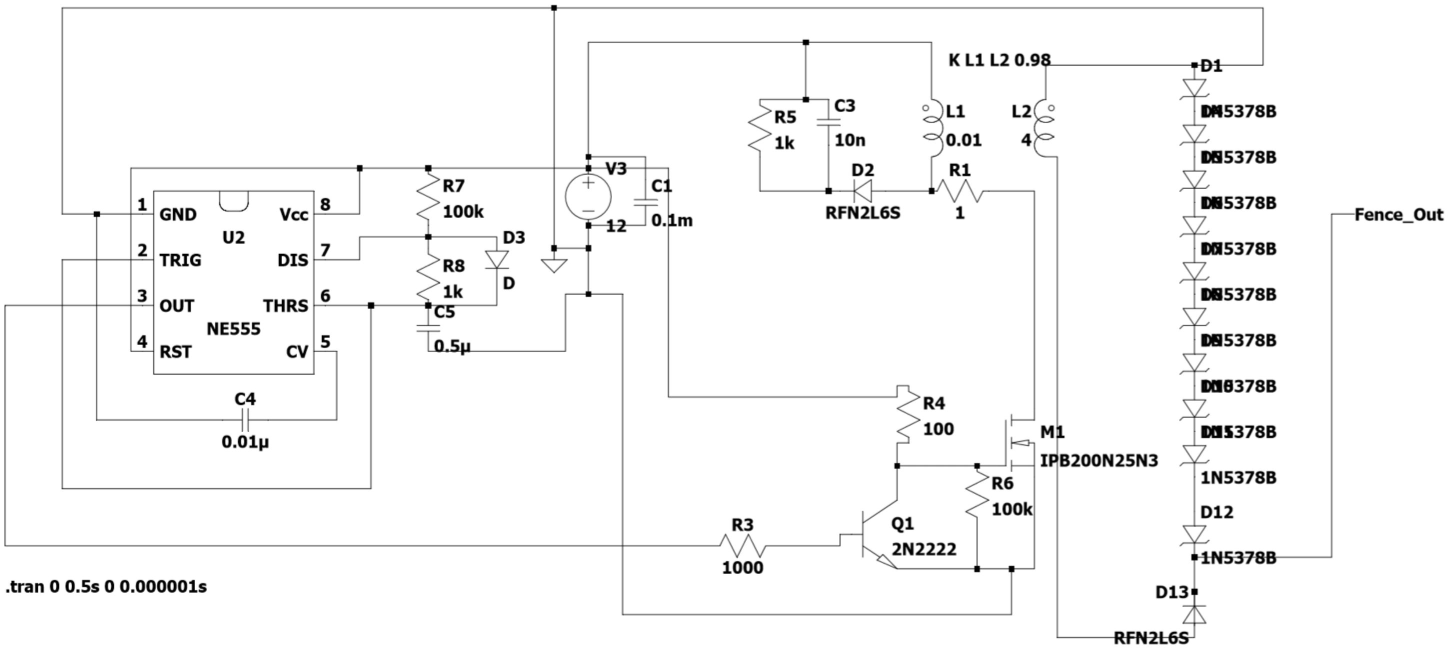

Figure 1 - Circuit Schematic

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The transformer needs to have a turns ratio of 5:100, but since transformers are not available on LTspice, I have taken 2 inductors and coupled them with a coupling factor of 0.98. We know that

$$L_s/L_p = (N_s / N_p)^2$$

Hence, we get the ratios of the 2 inductors equal to 20^2 i.e. 400.

Therefore, we take Inductance of primary inductor equal to 0.01 Henry and that of secondary inductor equal to 4 Henry.

555 Timer

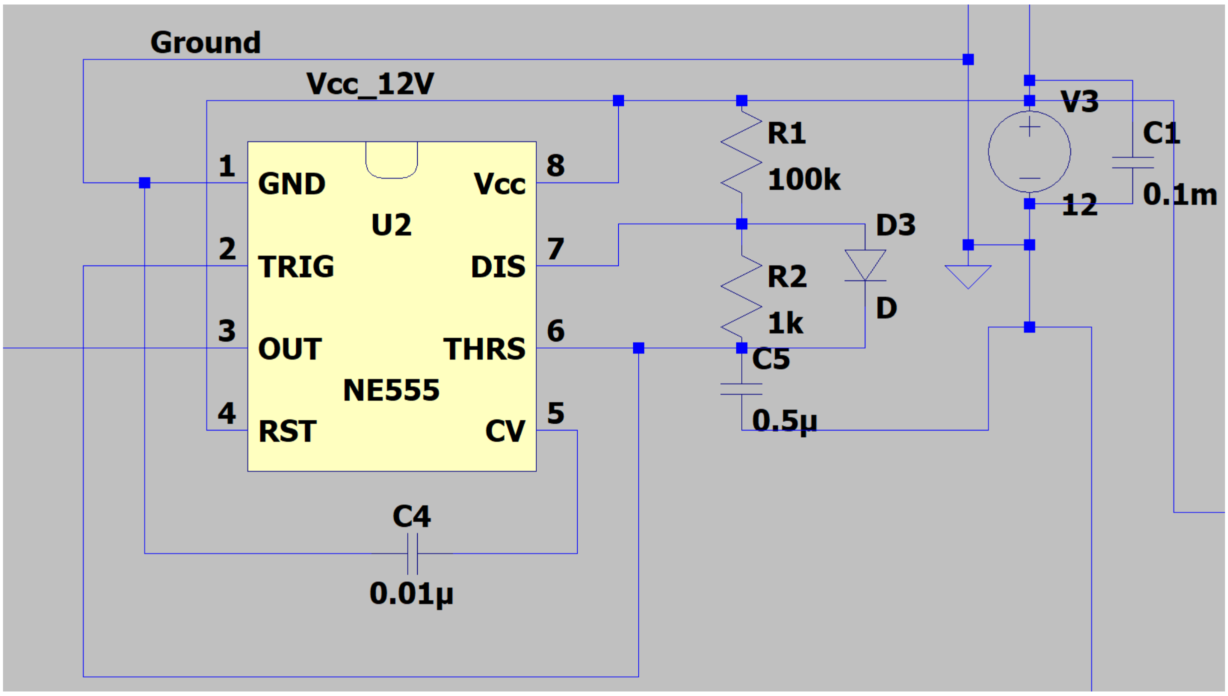


Figure 2 - NE555 Timer Connections

The 555 Timer Integrated Chip is used for a variety of timer, pulse generation and oscillation applications. It can be used in multiple modes but for my use, it is used as an Astable Multivibrator Mode, also known as free running mode, in which the output remains HIGH/ON for a particular time T_{on} and remains off for a time T_{off}. Thus, the total time period of this will be equal to $T_{on} + T_{off}$. These time periods are decided based on the requirement of the circuit and can be set by using appropriate values of resistors (R1 and R2) and capacitor(C). If we want $T_{on} < T_{off}$, we have to use a diode across R2 so that the times are as follows -

$T_{on} = 0.693 * R1 * C$

$T_{off} = 0.693 * R2 * C$

Total time period $T = 0.693 * (R1 + R2) * C$

For our circuit, T~35 milliseconds

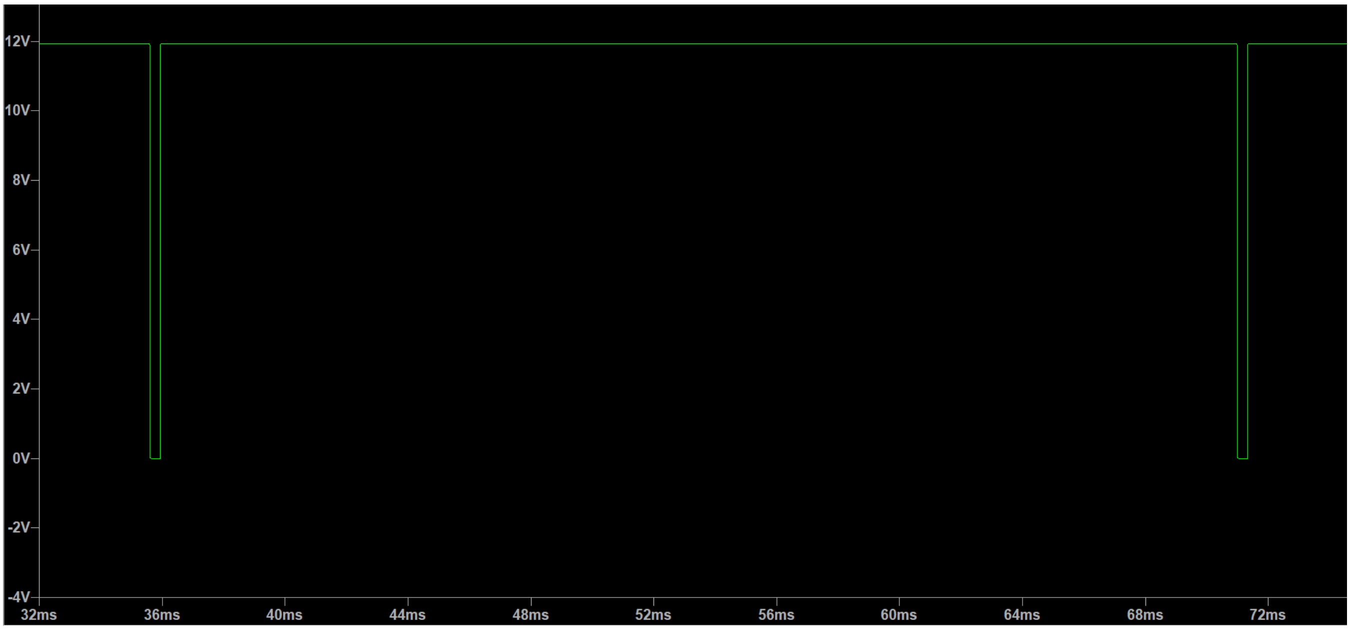


Figure 3-The square wave generated at output that is pin 3 of the 555 timer

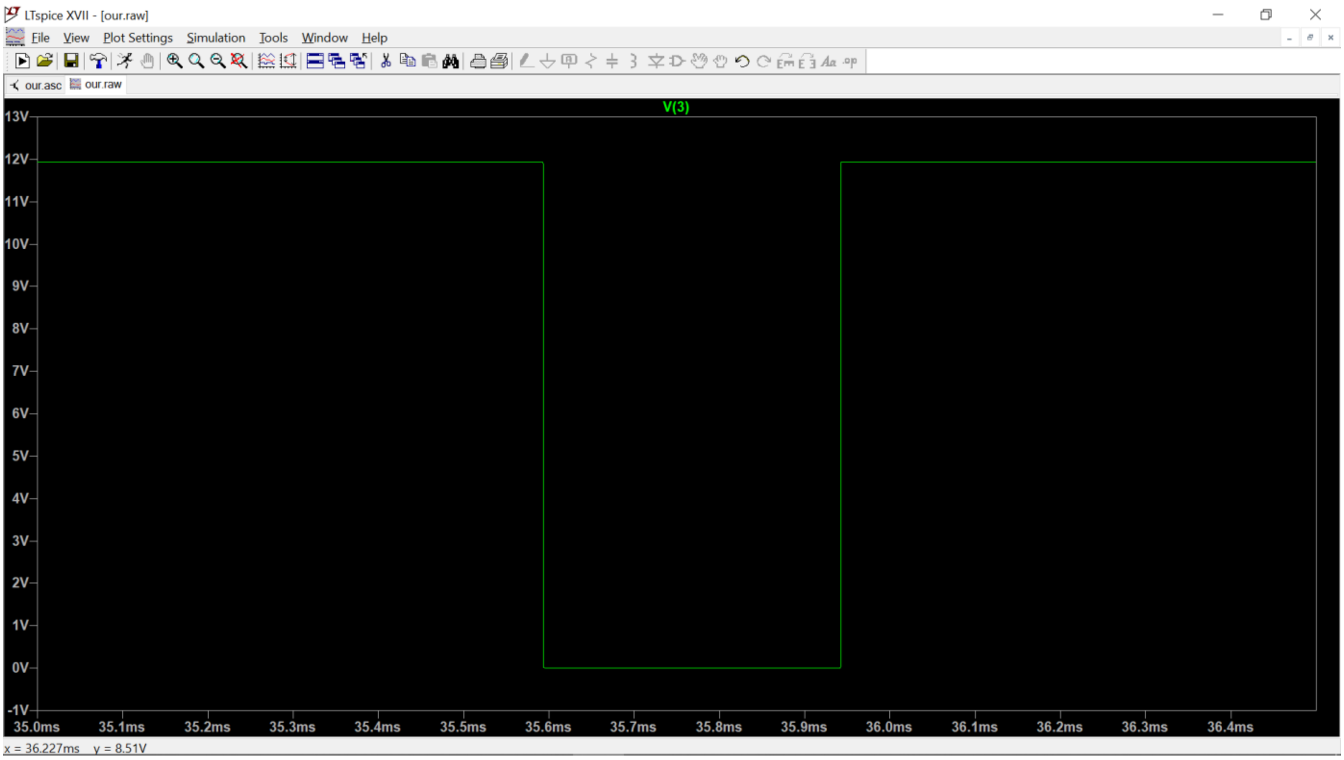


Figure 4-Zooming in at one pulse

NPN Gate Driver

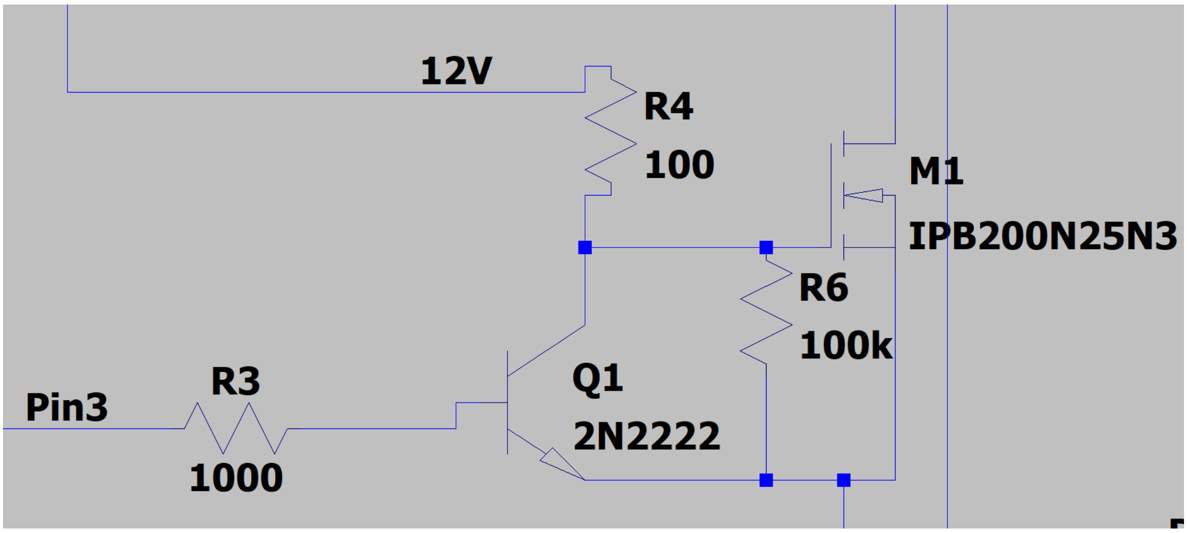


Figure 5 - Gate Driver

The output from NE555 has to act as input for the MOSFET, hence we need to amplify the current. This type of arrangement also acts as isolation between 2 stages of a circuit and can protect the NE555 Timer from any unnecessary load due to later stages. This can be done easily using an NPN transistor with the OUTPUT pin from 555 timer connected to its base via a resistor (for current limiting), the collector is connected to 12 Volt Supply via a 100-ohm resistor and also this collector is connected to the Gate of the MOSFET. When the 555 Timer output is high, the transistor will allow current to flow from its collector to its emitter essentially making the Gate Voltage 0. When the 555 Timer output is low, no current passes through the collector to the emitter, hence all the current from 12 V battery passes through the 100-ohm resistor to the gate of the MOSFET.

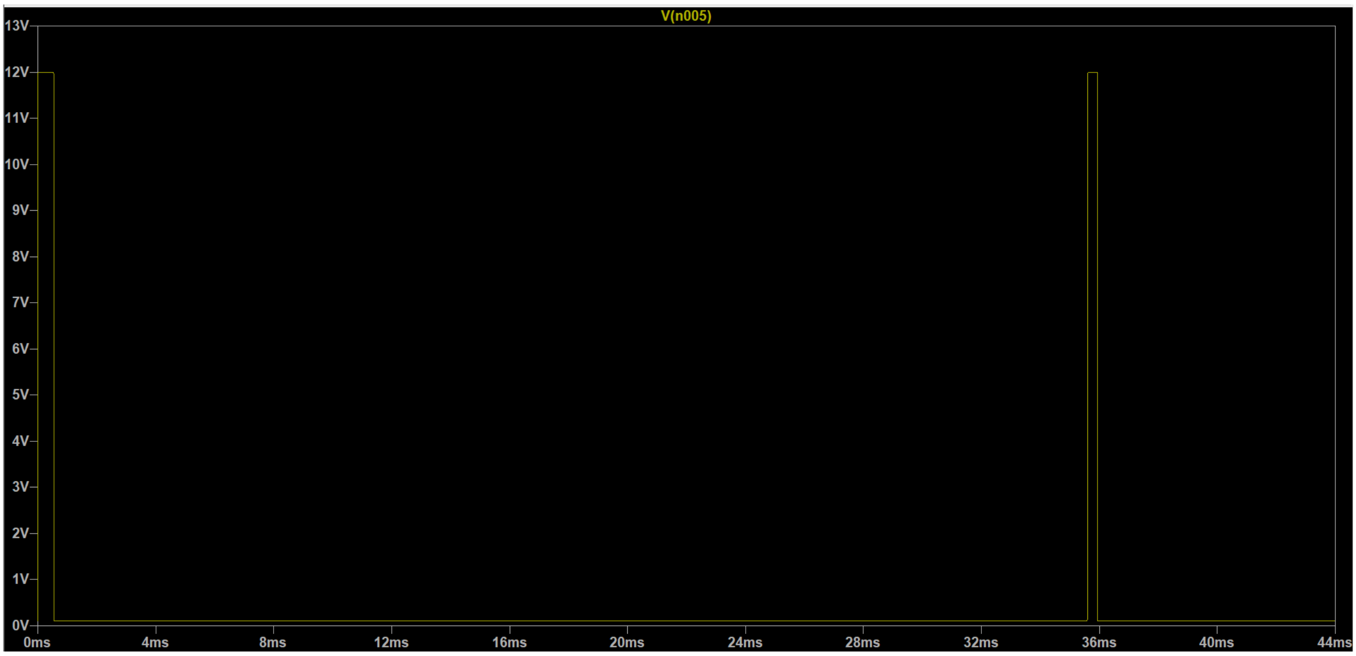
Without this gate driver the input current was approximately 11mA but after this NPN transistor stage, the input current to the MOSFET is now 12 Volt divided by 100-ohms resistor=120mA. Hence the current is amplified, keeping the Voltage same. One key observation here is that this gate driver stage inverts the signal, hence we initially had to invert the output of the 555 Timer by exchanging the R1 and R2 so as to switch the MOSFET properly.

MOSFET STAGE

Metal-Oxide-Semiconductor Field-Effect-Transistor is a Field-Effect-Transistor, with isolated gate, is a 3-terminal device, where the voltage at the Gate determines the conductivity of the device. This ability of the MOSFET to change conductivity by applying voltage at the gate can be used for amplifying or switching electrical signals. Due to its capabilities, this is by far the most common transistor used in digital circuits because thousands of these can be included on a microprocessor or a chip.

If the voltage across the Gate and Source is higher than the Threshold Voltage of that particular MOSFET, the current can flow through its Drain to its Source with a resistance of R_{ds} (=0.02 for this N channel MOSFET).

Following is the input voltage to the MOSFET i.e. between Gate and Source-



Since our Transformer turns ratio is 1:20 and the voltage output at secondary side is 1000 volts, a voltage of 1000/20=50 Volts will be induced on the primary side, hence we expect a voltage of 12+50=62 volts at the Drain of the MOSFET.

Figure 6 - MOSFET input at Gate

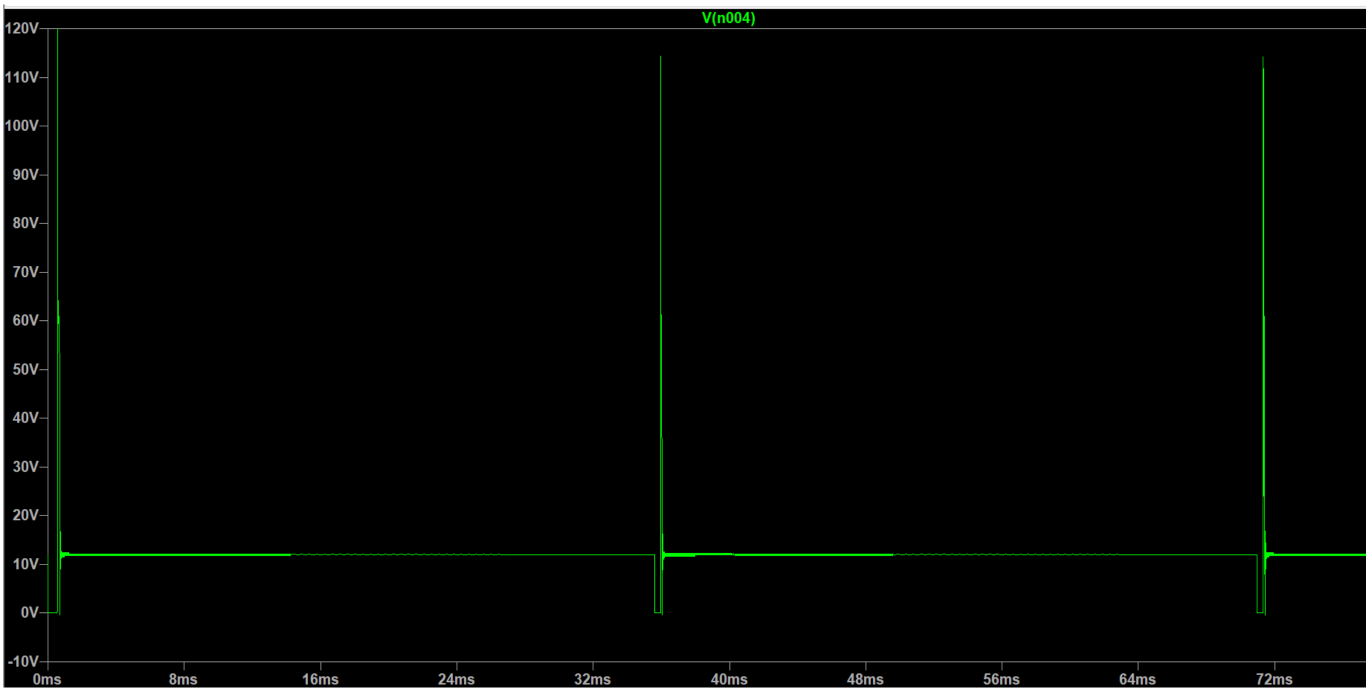


Figure 7 - Pulses after every 35 seconds at Drain of MOSFET

As expected from theory, we see repetitive pulses of approximately 62 volts after every 35 milliseconds at the drain of the MOSFET, with a high voltage noise for a brief period at the starting of the pulse.

Hence the MOSFET here is being used a switch, for a time period, it allows the passage of current through it towards the ground and the rest of the time when it is OFF, all the current passes through the Resistor-Capacitor combination, all this being controlled via the NE555 Timer and the NPN Gate Driver.

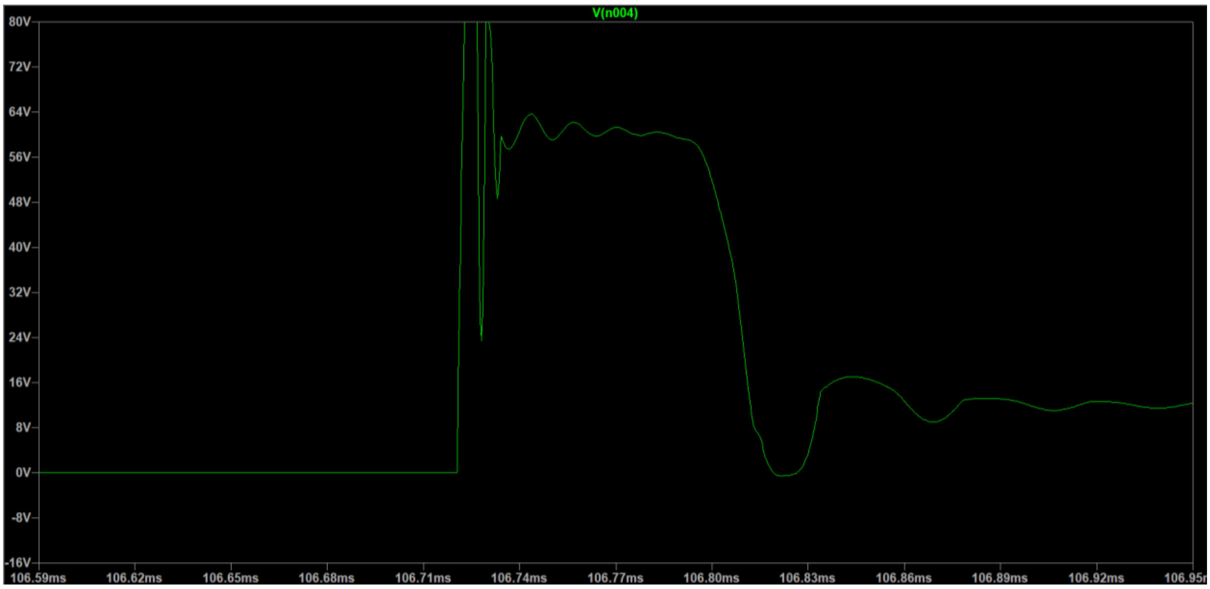


Figure 8 - Voltage Spikes at Drain of MOSFET

SECONDARY SIDE OF TRANSFORMER

Appropriate connections of ground have been made and in order to properly control the voltage at the secondary side of the transformer, Zener diodes need to be placed as voltage regulators. Since a Zener diode with a large Breakdown Voltage was not present, I have used 10 Zener Diodes with Breakdown Voltage equal to 100 Volts so that constant 1000 Volts sparks/pulses are generated at the secondary side, after regular time intervals of 35 milliseconds.

A diode is needed at the secondary side to prevent the flow of current in the backward direction as this can cause damage to the primary side by inducing very high current and voltage at the primary side. The coupling factor between the 2 inductors can be set to any value and instead of choosing perfect coupling, a slightly more realistic 98% coupling factor has been selected.

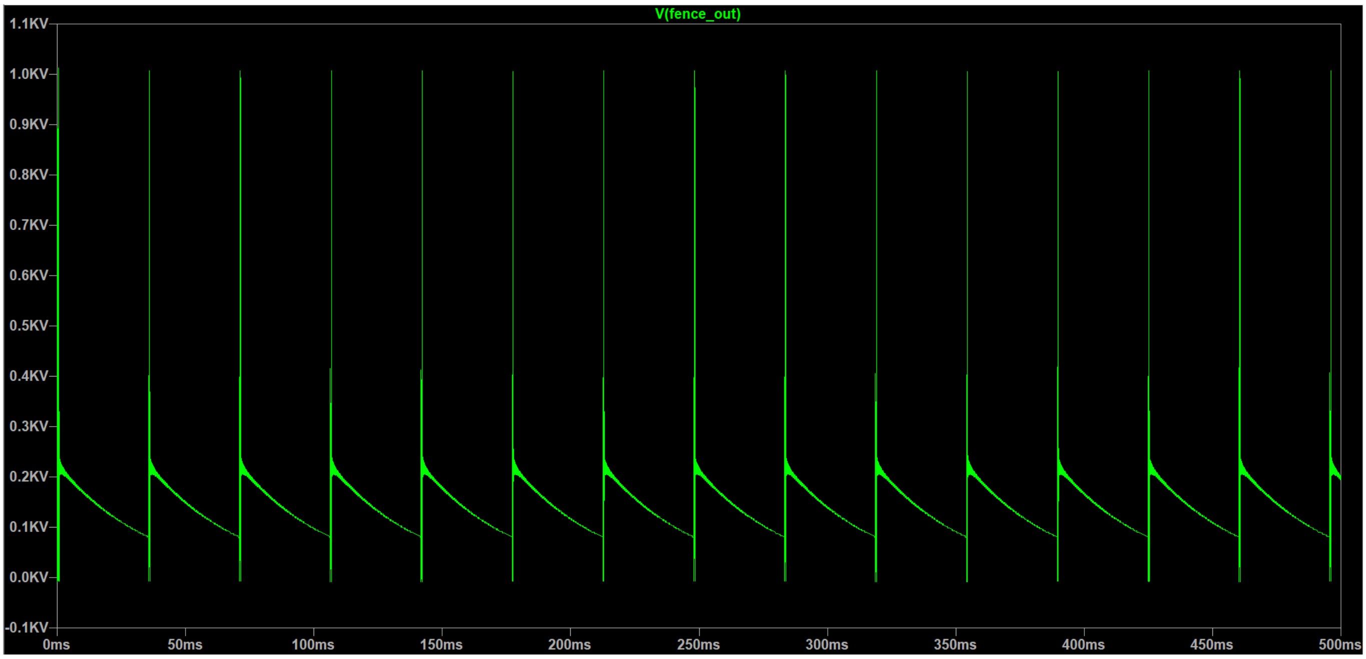


Figure 9 - Output at Secondary Side

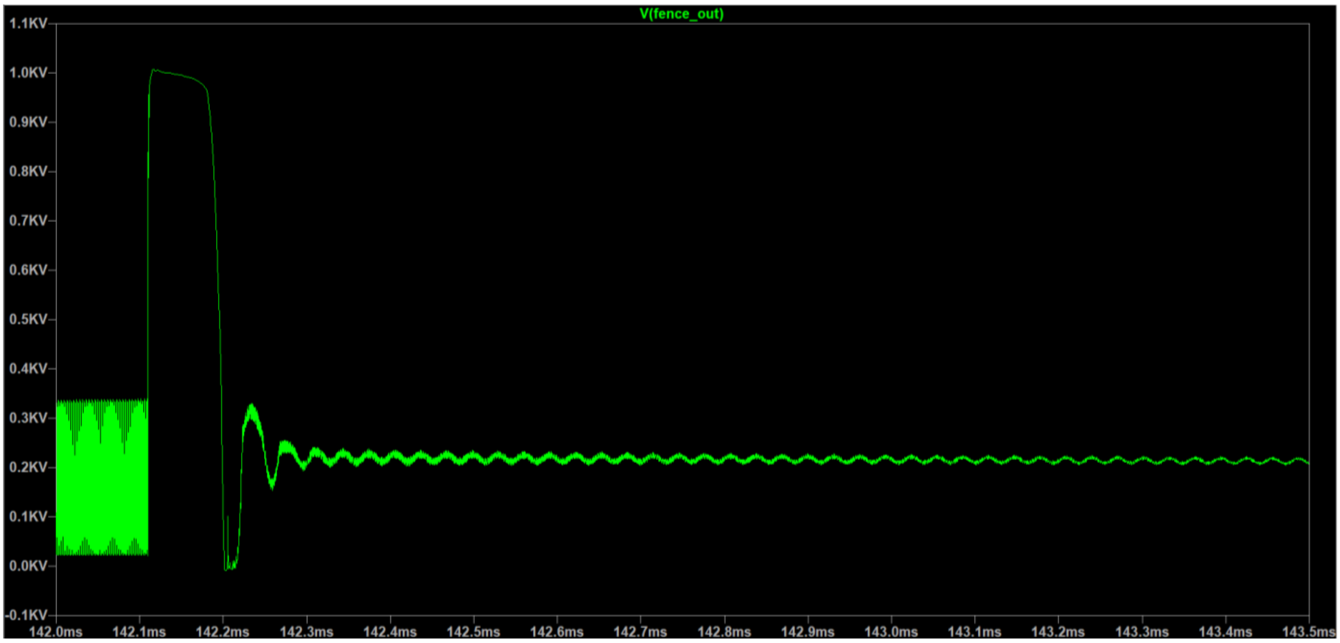


Figure 10 - Zoomed in Output Pulse

CURRENT FROM BATTERY

The current drawn by the battery is used to power 3 components, first is the NE555 Timer, then the NPN Gate Driver and lastly the main circuit where it provides current to inductors, resistors and capacitors. If this current drawn from the battery is measured as a function of time, following results are obtained –(direction of current flow is assumed to be reverse, hence the negative values)

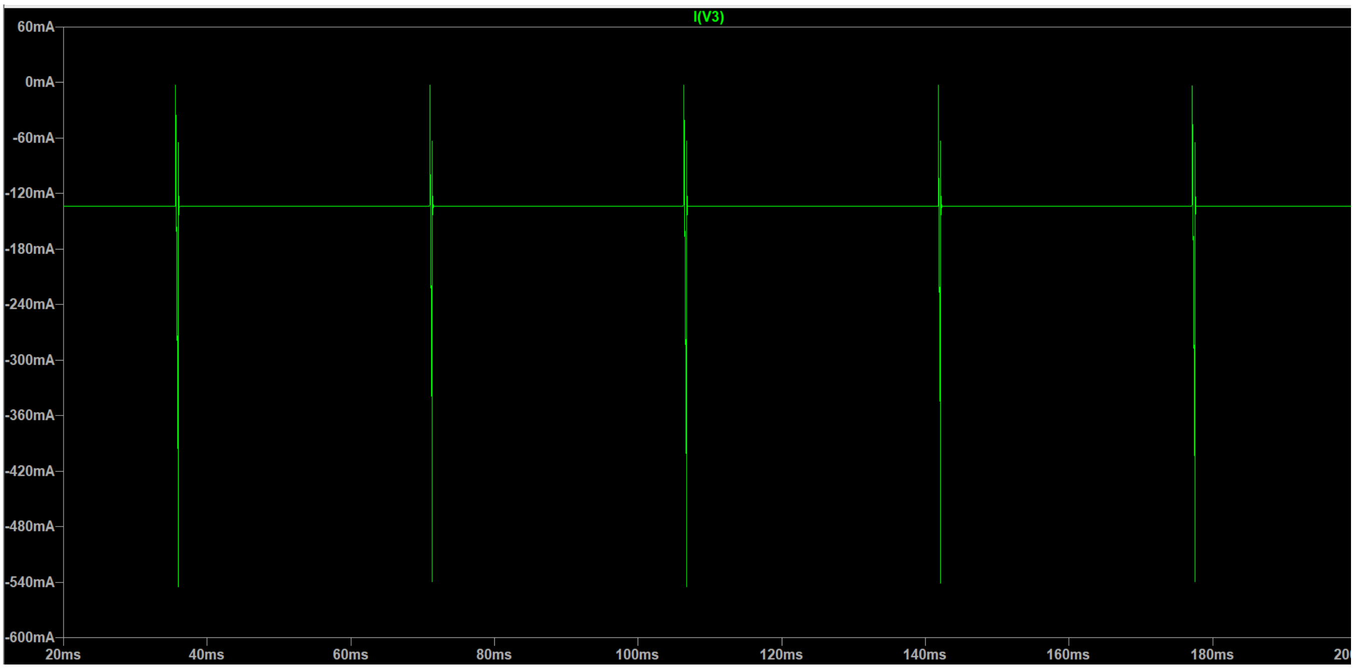


Figure 11 - Current drawn from the battery

As it is clearly evident from the above waveform that very less current(~0.4A) is drawn from the battery, that too after time intervals and not continuously. Hence the time averaged current drawn from the battery is not so significant and hence the total power required by this circuit is also very less.

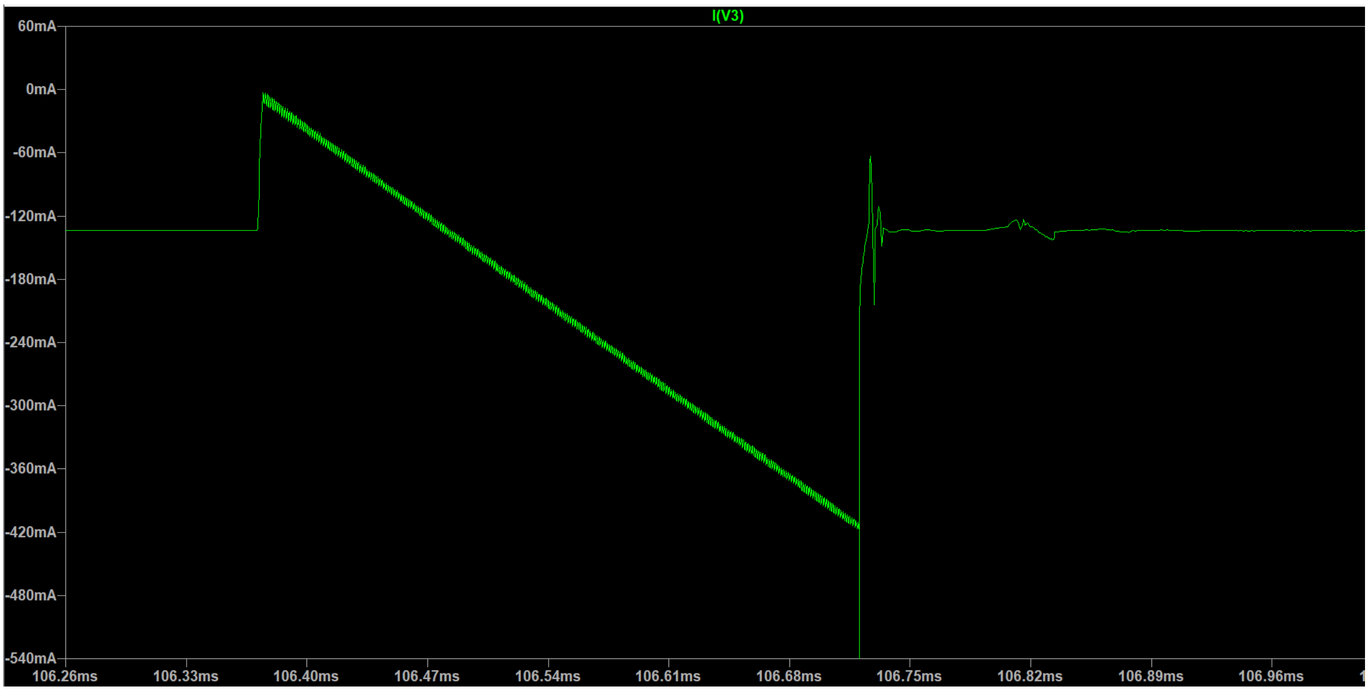


Figure 12 - Current Drawn from Battery

ACKNOWLEDGEMENT

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I owe gratitude to my Faculty Mentor, Prof. Dinkar Prasad who suggested the problem statement, guided me and told me how to go about the problem in stages, till the very end of the project by providing me with all necessary information and solutions for my problems, all along. I sincerely thank him for devoting his precious time on this project.

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Sanskar Tewatia

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