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DEVELOPMENT OF PULSED POWER DC SUPPLY FOR MICRO EDM

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Abstract: *Micro holes are useful in reducing the size of pilot hole in wire cut EDM. Micro EDM is useful in creating MEMS components, for producing micro holes, machining very hard materials, and in many other applications. Since the features to be machined are small and require high accuracy, the current level is low and must be precisely controlled.*

In conventional EDM, the current levels are high as well as the voltage required. Mainstream EDMs use voltage levels of about 150V and currents of up to 50A. As a result of higher currents, the electrode gets locally melted and there is welding of the workpiece and electrode. There are also the problems of stray arcing. Moreover, uncontrolled discharge cannot be allowed in micro machining. Thus, a different power supply is required for micro EDM. This paper discusses the step-by-step deSvelopment of a suitable power supply to fulfill these requirements.

Pulsed DC power supply is a critical component for achieving the required parameters of accuracy, finish and size of micro holes via EDM process.

Key words: *Micro EDM, power supply, gap control, relaxation circuit,*

1. INTRODUCTION

The principle of EDM is the removal of material by erosion through the creation of sparks between workpiece and tool. The effectiveness of the EDM process is largely determined by the type of power supply used. The power supply is used to convert the alternating current input into a pulsed unidirectional direct current required to produce the spark.

2. TYPES OF POWER SUPPLIES

The pulsed power supply is produced by the following methods (Springborn, 1967):

a)Rotary Impulse Generator
b)Relaxation Generator
c)Pulse Generator
d)Hybrid Generator

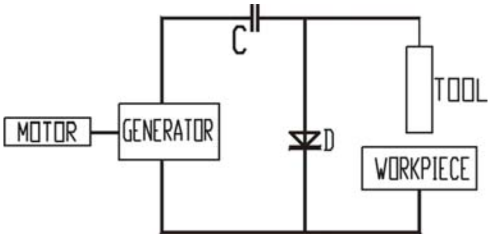

Fig. 1 Rotary Impulse Generator

The first power supply used was the rotary impulse generator (fig 1), in which the voltage waveform is generated based on the DC generator principle, which creates sinusoidal wave pattern similar to rectification. There is no way to control the waveform and so this type of supply is seldom used.

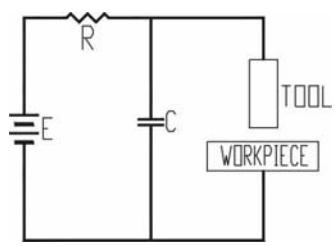

Fig. 2 Relaxation Generator

The relaxation generator (fig 2) is based on the charging and discharging of capacitor connected to the supply. A saw tooth wave is generated. The capacitor is allowed to charge and then is brought in to contact with the workpiece and discharges, creating the spark.

In pulse generator, solid-state devices are used instead of capacitor and resistance. In place of capacitor, solid state switching devices, like transistors, are used. They are toggled between off state and saturation state to generate rectangular pulses which swing between zero and supply voltage. These circuits are used to increase production efficiency as compared to relaxation circuits.

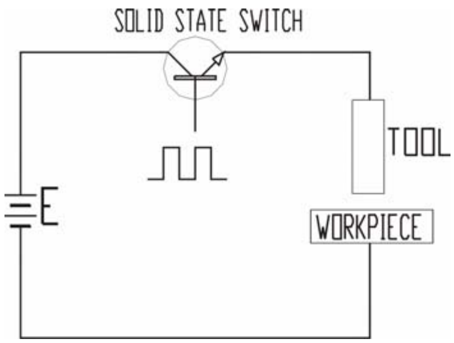

Fig. 3 Pulse Generator

3. POWER SUPPLY FOR MICRO EDM

In conventional EDMs, which are concerned with the machining of macroscopic parts whose size is greater than 1 mm, the power to be supplied is large. Typically, the voltages and currents associated with such EDMs are of the order of 300V and 60A.

When machining large parts, sparks of large magnitude are required, and when voltages and currents of the above magnitude are provided, very often there is uncontrolled discharge between the workpiece and tool. Due to the large surface area between work and tool, such uncontrolled discharges do not cause harm, but instead increase the process of machining.

In micro EDM, such uncontrolled discharges cannot be tolerated. As a result, there must be a tight control on the voltages and currents associated. In typical micro EDMs, the voltages do not exceed 40V and the currents allowed are of the order of milli amperes (mA).

4. DEVELOPMENT OF POWER SUPPLY

4.1 Initial Development

The development of a working and feasible power supply for a micro EDM has come about through a progression of steps, which will be described below.

Since the voltage associated with micro EDM is small, the voltages to be use were decided upon. Using bridge rectifiers and RC filters, different voltages can be used, for example supply voltages can be from as low as 12V DC to as high as 60V DC.

The first design involved the use of a single pole dual throw switch to separate the charging and discharge side. As seen in the circuit (fig 4), the switch toggles between charging position to charge the capacitor and discharge position. When charged, it is manually switched to discharge side and when the tool nears the workpiece there is a discharge, which causes erosion.

There was a problem of mechanical switching and there was no scope for control of the voltages involved. Since the voltages could not be controlled, the tool would frequently get welded to the workpiece due to the process of local melting of work and tool.

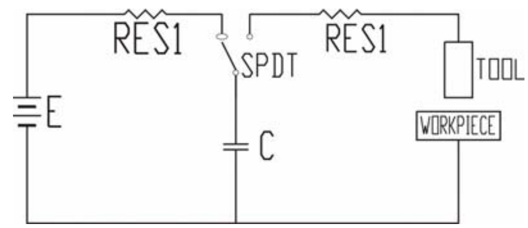

Fig. 4 Relaxation Circuit using SPDT

A circuit was designed which involved the use of the 555 timer circuit in astable mode to generate the high frequency clock required to control the switching of the transistors. It was found that inspite of generation of rectangular pulses with magnitude equal to supply voltage, no discharge was observed to occur. It was concluded that the voltages built up were not sufficient to break down the gap between the workpiece and tool and also the sudden decrease in current from maximum value at time t=0 to zero was not sufficient enough. Another problem could be the selection of the transistors.

4.2 Final Design

In order to tackle the problem of controlling the voltage to which the capacitor charges to and the level up to which it discharges, it was decided to make use of operational amplifiers (opamps) working as comparators to set the voltages.

Using comparators to set the voltages has been done before, but our implementation differs. In the design given by Langlois (Langlois, 1997) for a conventional EDM, he used comparators to set the charging and discharging level voltages in the following way. The voltage across the capacitor is divided using the voltage divider circuit and is fed as an input to the comparators. The output of the comparators is given to the counter which controls the movement of stepper motor, either clockwise or counterclockwise.

Another design has been presented in the paper by Ananian (Ananian, 2002), in which comparators are used as inputs to the required booster ICs to power the high power EDM.

Precise gap control is very necessary to maintain the spark gap between tool and workpiece to ensure that the tool does not touch the workpiece. In case of the tool touching the surface, there may be arcing which can ruin the surface finish and also the wire (electrode) may break and bend which is undesirable.

In comparison with the above two circuits, our design involves much lower power components and deals with spark creation with much lower intensities than that in conventional EDMs.

Our design involves the following main parts:

1.Charging-discharging circuit
2.Control circuit
3.Stepper motor driver

4.2.1 Charging-discharging circuit

Considering the limitations of a transistor as a switching device and maximum current that it can conduct, an alternative was needed. MOSFET (Metal Oxide Semiconductor Field Effect Transistor) was found to be a suitable alternative. MOSFETs have the advantage of high input impedance and absence of thermal runaway and second breakdown as compared to bipolar junction transistors (Horowitz & Hill, 1989).

As a result, MOSFETs are widely used in power applications because of its fast switching times and high current capacity.

N-channel MOSFETs were used to cause the switching between the charging and discharging sides of the circuit. A bank of capacitors is provided to enable charging up to desired level of intensity, as given by the formula

$$Q = 0.5*C*V^2 \qquad (1)$$

Where Q represents the charge stored by capacitor in Coulomb, C is capacitance in Farad, and V is voltage in Volts.

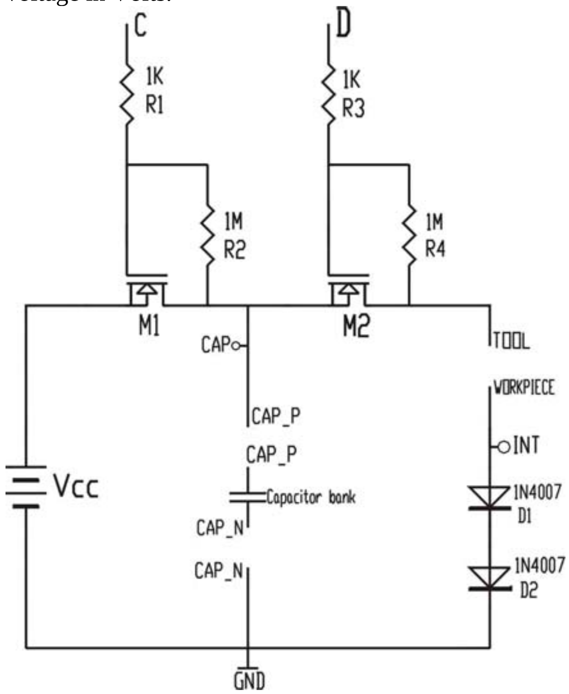

Fig. 5 Charging Discharging circuit

Higher value of capacitance means more storage of charge and hence greater intensity of discharge. The equation also indicates that the charge stored is more affected by change in voltage since charge is proportional to the square of the voltage supplied.

When voltage appears at the gate of the MOSFET, it acts as a closed switch and closes the circuit, thus allowing either charging to occur or discharge to take place.

The discharge side provides connection for the workpiece and tool. The workpiece is made ground but its potential is maintained at a voltage above ground by two diodes. These diodes are used in the controlling part of the circuit.

4.2.2 Control Circuit

The control circuit's function is to set the voltage at which the capacitor is to charge to and the voltage to which it is to discharge up to. In order to do this, comparators are used.

In order to set the voltages, operational amplifiers (opamps) are used as comparators. The characteristics of the opamp is used to make the output swing between the supply voltages when the voltage across the capacitor exceeds the voltage set for charging and also when the voltage across the capacitor decreases below the set discharge voltage.

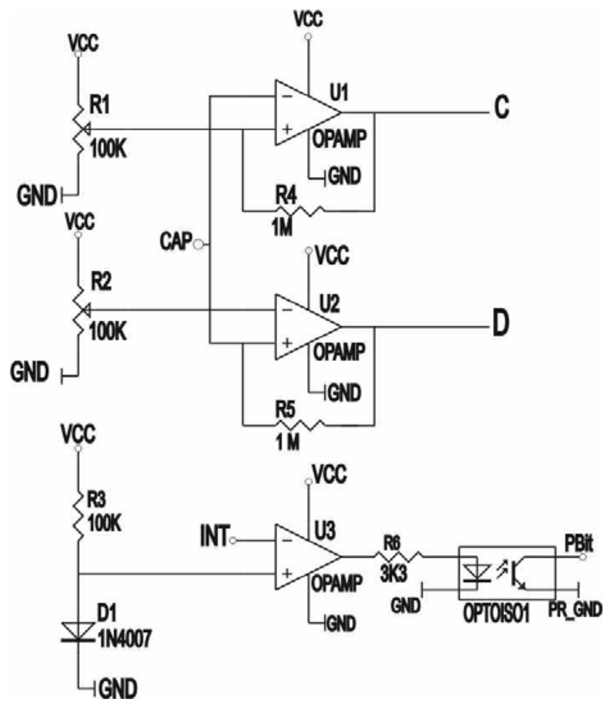

Fig. 6 Controlling Circuit

The sequencing of the signals is crucial to the proper control of the circuit. At no time can both the charge and discharge lines be conducting, i.e. 'on'.

In order to sense the occurrence of discharge, use is made of the diodes provided in series with the workpiece and ground. When discharge occurs, due to flow of current, there is voltage drop across the diodes which get compared with the voltage across the one diode connected at input to comparator. As a result, there is switching between the supply voltages and this is used to identify the spark and cause the motor to stop or reverse its direction momentarily before starting downwards again.

An important feature of the circuit is the isolation between the two grounds, namely the ground of the microcontroller and the ground of the control and charging-discharging circuit. This is achieved by using an optoisolator between the output of comparator and input to the microcontroller. This minimizes the effect of ground plane mismatches since the supply voltages are different.

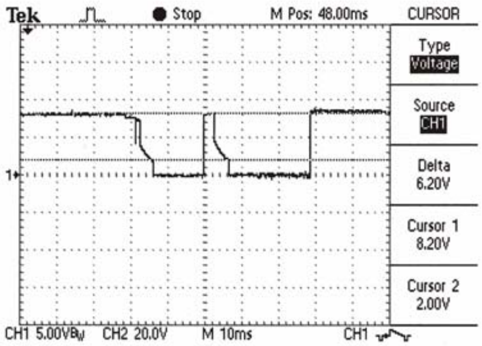

Fig 7 Voltage Waveform (Experimental) voltage levels

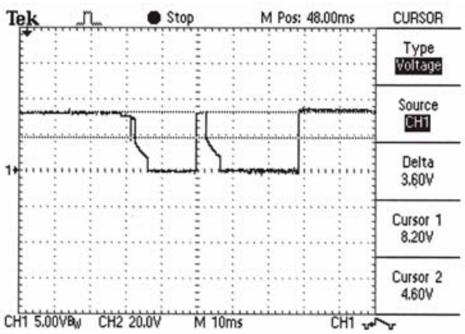

Fig 8 Voltage Waveform (Experimental) discharge

The above waveforms show the occurrence of discharge and have been obtained experimentally from the circuits designed above. Fig 7 shows the setting of charging and discharging voltages of 8.2 and 2 V respectively, and fig 8 shows that at the time of discharge, the voltage suddenly decreases from 8.2 to 4.6 V, a decrease of 3.6 V. This represents the spark between work and tool, and the decreasing waveform thereafter indicates the presence of a low resistance path created by the ionized column existing between work and tool during time of discharge.

Precise gap control is essential for proper discharge to occur. If the tool touches the surface of workpiece, then arcing will occur and surface finish will be affected (Krar & Gill, 1990). The above circuit provides an easy way for maintaining the spark gap. This is because when the spark occurs the electrode is moved up and then again down. When the material gets eroded from the surface, the electrode automatically advances by that much amount when going in the downward direction towards the workpiece. Thus, indirectly, it is possible to have some control on the spark gap being maintained between the workpiece and electrode.

5. FUTURE DEVELOPMENTS

The circuit presented above meets the requirements of the EDM process and machining occurs consistently, leading to creation of hole. But this process is slightly slow as there is addition of time due to motor driving upwards by a few steps (around 3 to 5). This leads to longer machining times.

In order to increase the speed of machining, different methods have been proposed. An oscillator can be made use of to increase the time of charging and discharging of the capacitor to enable much higher machining rates (Langlois, 1997).

When spark occurs, i.e. when both electrodes are near enough and short circuit conditions exist, current increases at the same time after the voltage pulse. By using an ultra high speed comparator, these two states can be distinguished, and hence the gap can be controlled (Hara & Nishioki, 2001).

Ultrasonic vibrations of the tool electrode have been found to improve the overall efficiency of the process. The high frequency pumping action of the electrode accelerates the dielectric circulation and results in saving of about 80% in machining time (Dorf & Kusiak, 1994).

In order to provide higher supply voltages, the supply to the charging-discharging circuit and supply to the controlling circuit can be made different and a voltage divider circuit can be used at the capacitor voltage input to the comparator in order to decrease the voltage to a level tolerated by the comparators, as given in the datasheet of the IC.

6. CONCLUSION

In order to perform micro hole machining using spark erosion, we have proposed an alternative and effective power supply to generate the required controlled discharges. We have also proposed an indirect method for controlling the spark gap between the work and electrode.

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