

Instrument for Cutting and Coagulation in Laproscopic Surgery

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Electrosurgery instrument is a popular instrument used for various types of laproscopic operation. This is a general purpose, easy to use, high power and low current instrument where cutting is done by using the heat generated in an electric arc. The RF range for electrosurgery is from 100 KHz to 500 KHz. Here the frequency is generated by an IC chip, which generates the desired waveform from a dc input. Special type of ferrite core transformer is used for replicating the ac waveform and stepping up the voltage in the secondary to as high as 1200 volt. This paper describes a design of an electrosurgical instrument for cutting and coagulation during laproscopic surgery.

Keywords : Electrosurgery; laproscopic; RF range

INTRODUCTION

High frequency currents, apart from their usefulness for therapeutic applications can also be used in the operating rooms for surgical purposes involving cutting and coagulation. The frequency of current used in the surgical unit is of the range 100 KHz - 500 kHz (Radio-frequency range). This is quite high in comparison with that of the mains supply. It has been observed that when a dc voltage or a voltage at low frequency is applied to human body, the electrolysis of cells, particularly nerve cells, takes place. The human body perceives this as an electric shock. Hence, it is necessary to avoid the intense muscle activity and the electrocution hazard which occurs if lower frequencies are applied. People die of shock when the voltage level exceeds 200 volt. But at a frequency of radio wave range above 100 kHz this process of electrolysis of cell does not take place. The only effect left is $I^2 R t$ heating where I is the current, R the resistance in the path and t is the time during which the voltage is applied. This heating property of electrical current is used for cauterizing and coagulation of tissues. Animal cells contain substantial amounts of glucose. Under moderate heating the glucose forms kind of glue and seals the tips of cut blood vessels and that is how it helps in stopping bleeding. Biological tissue contains more or less high concentration of electrolytes, making it sufficiently conductive to be treated electro-surgically. The thermal effect of RF (Radio - frequency) current is used for separating (cutting) and coagulating tissue (homostasis). When high frequency current flows through the pointed end of the probe into tissue, there is a high concentration of current at this point. The tissue is heated to such an extent that the cells immediately under the electrodes are torn apart by the boiling of the cell fluid. The neutral electrode establishes a large area contact with the patient's body and the RF current is, therefore, dispersed so that very little heat is developed at this electrode. If the voltage is high enough, the current flow is maintained by the commencement of arcing between the electrode and the tissue. Arcing commences at voltage value of around 200 Vp. If a voltage above 500 Vp is used, the result is substantial formation of slough due to energy released in the arc. Power

output is automatically adjusted for cutting and coagulation, depending on the preselection of certain arc intensity.

TYPES OF RF SURGERY

RF Surgery is basically of two types:

Monopolar Operation Technique

Here the electric current flows from the small face active electrode to a large face passive or neutral electrode, with the body of the patient always forming part of a closed circuit. Tissue separation or coagulation takes place at the active electrode.

Bipolar Operation Technique

Here the current flows between two paired electrodes, the face of which are either the same or of different sizes depending on the application. Only a small part of the tissue is included in the circuit between the electrodes during the application.

SYSTEM DESCRIPTION

The above technique is implemented by using an electronic circuit controlled by an Intel 89C51 microcontroller based motherboard. A circuit is developed to produce a signal of around 500kHz (in the radio frequency range). This signal is divided by a D Flip Flop to obtain a signal of 250kHz and exactly 50% duty cycle. The signal is then amplified and applied to the end of the coil of a center-tapped transformer. The inverted part of the same signal is applied to the other end of the transformer coil. The center tap of the coil is connected to a 5A 60V dc power source. The secondary coil of the transformer generates an ac voltage of around 500V, which is utilized for various modes of operation. Variable output power is generated by switching on and off the input signal. Another 100Hz pulse is generated for the ON/OFF of the MOSFET. Hence, at the output of the coil different wattages were achieved which is explained in detail later. The duration of actual operation time is few seconds at a stretch. Varistors were connected across the coil to suppress mains borne transients and voltage spikes, which are produced when inductive loads are switched on. As the working frequency is in the radio frequency range, ferrite core was selected as it reproduces the ac waveform accurately (without distortion) in the secondary side. A coil turn ratio of 1:9 is used for the ferrite core. The core used is of toroidal type, chosen deliberately to reduce energy losses. Care

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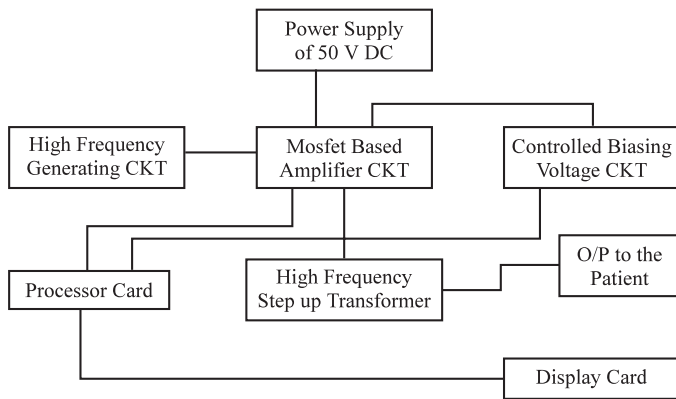


Figure 1 Block diagram of the using intel 89C51

has been taken for electromagnetic shielding. The layout of the cabinet was selected accordingly. Both the power cards consisting of transformer which are comparatively heavy were placed in the bottom and the microprocessor cards were placed on the top with aluminium plate shielding. Shielded wires are used to carry the high frequency currents.

EXPERIMENTAL RESULTS

- Pure Cutting-voltage level 500V
- The maximum power for pure cutting 300W

Blending (Cutting and Coagulation)

- Blend 1-voltage level 600V
- Blend 2-voltage level 700V-800V
- Blend 3-voltage level 1000V

In the Bipolar coagulation the voltage at the tip of the probe was 1000 V but the maximum power generated was 100 W. Block diagram of the circuit is as shown in Figure 1.

TEST RESULTS

The test was carried out on different medium soap, meat before giving a human trial. The cut experience under different wattage was clear and whitish in color. At higher wattage along with the arc smog is seen. At still higher wattage the tissues become stiff.

HIGH FREQUENCY PULSE GENERATING CIRCUIT

The circuit is used to generate a fixed duty cycle high-frequency pulse is depicted in Figure 2.

By varying resistor R and C the time period of the generated pulse can be changed

where

$$V = e^{-t1/RC}$$

$t1$ is the ON time period and V is the maximum voltage applied.

$$t2 = e - t1/R \times C$$

In this case frequency is 500 KHz and $C = 78$ pf. The total time period

$$T = t1 + t2,$$

here $T = 2 t1$, hence $R = 18.5K$.

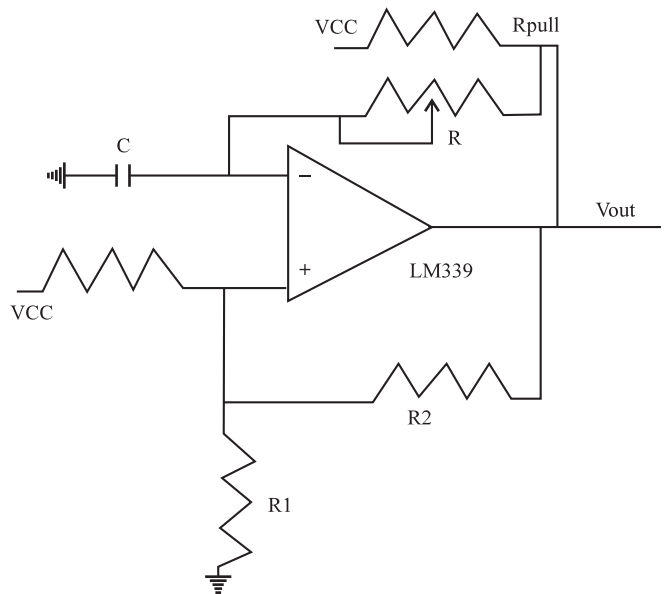


Figure 2 Circuit diagram to generate fixed duty cycle high-frequency pulse

If the circuit is designed with the value of $R = 18.5K$, and $C = 78$ pf, the output pulse is of frequency 500KHz. This basic frequency is halved with the help of the Flip Flop. The output power is controlled by a 10Hz signal of variable duty cycle generated from microcontroller by using its two internal 16 bit timers $T1$ and $T2$. The timer $T1$ corresponds to a signal of 100Hz frequency. The total pulse width of the timer $T1$ is equivalent to 300 watts for the 'Cut' mode and 120 watts for bipolar mode. In hex code the timer $T1$ was loaded 3FED H for 300 watts. Timer $T2$ represents the actual power required by the user — the fraction of the full power available. Now suppose a user wants 100 W power in the 'Cut' mode. Then in timer $T2$ the value of BFF9 H is loaded. Both the timers are switched on together and at that point of time the status of port-2 pin-0 is switched on to high as long as the timer $T2$ is ON.

The moment $T2$ expires the port-2 pin-0 is switched to low. It is again switched to high when $T1$ expires and both $T1$ and $T2$ are restarted. This way port-2 pin-0 produces a signal of variable duty cycle whose on time is proportional to the fraction of peak power. This signal is ANDed with 250 KHz basic radio frequency signal and then fed to the base of the MOSFET. During the off time of the timer signal, all the output transistors are off. This is how the output power is controlled on a time division scale. For the display of power the range is from 0 to 300 W. This full scale is covered in 600 ticks. A 6MHz clock is used for the system. In Intel 8751 the basic clock cycle is divided by 12 to generate the instruction cycle. Hence frequency of the instruction cycle timer is $6 \times 10^6 / 12 = 500KHz$. Therefore the timer is incremented by 1 at every $1/500,000 = 2\mu s$. To generate a frequency of 100 Hz (time period 10 msd from the timer it is required to load OFFFFF (Hex) $- 2 \times 10 \times 10^{-3} / 2 \times 10^{-6}$ (Decimal) = OFFFF (Hex) — 10000 (Decimal) = OFFFF (Hex) - 2710 (Hex) = OD8EF (Hex). This base frequency is generated using $t1$ timer. Supposing that one wants to operate at 150 W, that is 50% of the peak power, the

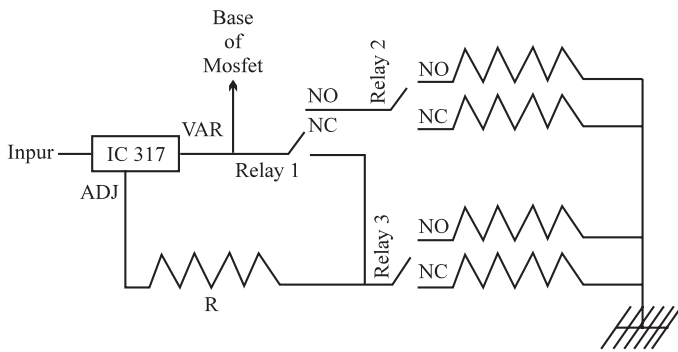


Figure 3 Connection of the regulator IC 317

timer $T2$ will be loaded with a value of FFFF (Hex) — $(FFFF - D8FF) / 2 = EC77$ (Hex).

Coil Features

Inductance of the primary coil is $21.19 \mu\text{H}$. The frequency is 250 kHz. The total power developed across the primary winding is 300 W. The voltage across the primary winding is restricted to 100 V - 120 V. The drain voltage of the MOSFET is changed for different modes. As per the gate current required to switch on the MOSFET, the drain resistor of the previous stage is chosen. The total amplification is developed using two stages of MOSFET.

For different modes of operation different voltage levels are required at the output of the circuit which reaches the operating probe if the instrument. To achieve this the biasing voltage to the gate of the final stage of the MOSFET is varied using different resistors with the power supply regulator IC LM317. Depending on the mode (Cut, Blend etc.) chosen by the user some relays are switched on and off. The relays are placed in the form of a binary

tree. After sensing the user's choice of mode (through the keypad), a sequence of bits is generated from the microcontroller. These bits are applied to the relay coils through buffers. The selected set of relays connects the path of the regulator IC 317 to the appropriate resistors to generate the required biasing voltage to the gate of the MOSFETS.

The circuit showing the connection of the regulator IC 317 is provided in Figure 3.

CONCLUSION

The secondary of the coil has very high voltage across it in the range of 1000 volts. The peak power delivered from it is 300 W. The inductance of the coil is 2.1 mH. Since the secondary of the coil is isolated from the primary no dc voltage or low frequency with high voltage is allowed to affect the patient. In case of any failure in the circuitry the secondary of the coil will either have no voltage or have a very low voltage in it so that the patient never gets electrocuted.

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