SURGICAL DIATHERMY - TWIN MODE CONCEPT

P-1356

PROJECT REPORT 1999 - 2000

Submitted by

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Under the guidance of
Asst. Prof. **K. RAMPRAKASH** M.E.,

in partial fulfilment of the requirements
for the award of the Degree of
BACHELOR OF ENGINEERING
In ELECTRONICS AND COMMUNICATION ENGINEERING
of the Bharathiar University, Coimbatore.

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<u>CERTIFICATE</u>

This is to certify that the Project Entitled

"SURGICAL DIATHERMY

-TWIN MODE CONCEPT"

has been submitted by

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in partial fulfillment of the requirements for the Award of Degree of Bachelor of Engineering (Electronics and Communication branch) of Bharathair University, Coimbatore-641046 during the year 1999-2000.

(Guide) **(Head of the Department)**

certified that the candidate was examined by us in the project viva-voce examination held on 16/3/2000 and the university register number is ____________________.

(Internal Examiner) **(External Examiner)**

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TO WHOMSOEVER IT MAY CONCERN

THIS IS TO CERTIFY THAT THE FOLLOWING STUDENTS OF KUMARAGURU COLLEGE OF TECHNOLOGY COIMBATORE

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HAD UNDERTAKEN THEIR FINAL YEAR PROJECT "SURGICAL DIATHERMY" IN THE ACADEMIC YEAR 1999-2000 IN OUR INDUSTRY AND HAVE SUCCESSFULLY COMPLETED IT.

THEIR PERFORMANCE DURING THAT PERIOD WAS FOUND TO BE GOOD.

WE WISH THEM ALL SUCCESS.

GUIDEDE BY

DR.V.L.CHANDRASEKARAN & MR. A.MUTHUCHAMY.

FOR MEDICON INSTRUMENTS

DR.V.L.CHANDRASEKARAN
PROPRIETER.

ACKNOWLEDGEMENT

First and foremost, we thank our Principal ***Dr. K.K. Padmanabhan, B.Sc. (Engg), M.Tech., Ph.D.*** *for providing us with excellent laboratory facilities for doing the project work.*

It is a great pleasure to thank our head of the department ***Prof. M. Ramaswamy, M.E., M.I.S.T.E., M.I.E.E.E., M.I.E., C (Engg)*** *for being the chief motivation behind our project work and for having provided us with laudable advice and material at the time of need.*

We express our gratitude to our guide ***Asst. Prof. K. Ramprakash, M.E.,*** *for having provided us with constructive ideas and efficiently guiding us in the design and implementation of our project work.*

We are highly indebted to ***Dr.V.L.Chandrasekhar & Mr.A.Muthuchamy,MEDICON INSTRUMENTS.,COIMBATORE.*** *for having enthusiastically given us valuable suggestions.*

We are immensely grateful to all the staff members of Electronics and Communication Engineering Department, who helped us directly or indirectly to complete our project work.

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CIRCUIT DESCRIPTION AND DESIGN.

SYNOPSIS

With the advances made in Electronics, it has made inroads into many fields. One important field is medicine, where surgery is a necessity to cure certain types of illness. It involves cutting, removing and stitching of the tissues of the human body when the person is under anesthesia. In surgery, the time involved must be minimized with minimum possible loss of blood. The development of the ***DIATHERMY – TWIN MODE CONCEPT*** *- is an answer to many problems faced by surgeons. This project involves the design, construction and testing of such a unit using solid state devices. It uses high frequency currents for bloodless surgery and coagulation of tissues in the body. Use of such a unit is explained such that the supremacy of this unit with all its safety precaution will be amply clear.*

INTRODUCTION

The history of disease is an old as the history of humanity. The basic forms of diseases, tumors, trauma and congenital abnormalities have existed unchanged. Today's surgeons obviously manage them in a different fashion than did their colleagues of pre-historic time. The field of biomedical engineering is fast developing and there has been a tremendous increase in the use of electronic equipment in the medical field for clinical and research purposes.

A medical instrument performs a specific function on a biological system. The function may be the measurement of the variables, their rate of change, monitoring, diagnosis, surgery, therapy etc.

This project titled ***DIATHERMY-TWIN MODE CONCEPT*** *-is a surgical tool, which finds extensive application in operating theaters.*

DIATHERMY is the use of high frequency current for bloodless surgery and for the coagulation of blood.

The design makes use of a tuned collector LC tank oscillator to generate high frequency RF current. This current is used to perform surgery on human body without much loss of blood. Two main operations performed by this unit are:

1. *Cutting.*
2. *Coagulation.*

The former is achieved by the vaporization of the body fluids and the latter by the denaturisation of the proteins. The cutting mode requires continuous and uninterrupted passage of RF current through the skin and the latter is achieved by the interrupting the continuous RF current by means of pulses generated from a 555 timer operating in the stable mode.

The final power amplification is achieved by means of five bux 48A power transistors connected in parallel configuration. The output voltage is stepped up by means of ferrite core transformer. The power control is achieved at the primary by means of two SCRs connected in anti-parallel configuration.

There have not been many changes in the basic design of electrosurgical experiment except for the availability of solid state versions with the better safety provisions for the patients and their operators.

Though, much more sophisticated and precise surgical equipment's are commercially available the main advantage of this equipment is that is not very complicated and it is cheaper compared to other surgical equipments.

Advantages of high-frequency 1-3 MHz current used in surgical diathermy

- *This high frequency is necessary to avoid the intense muscle activity and the electrocution hazard that occurs if lower frequencies are employed.*
- *The separation of tissues by electric current always takes place immediately in front of the cutting edge and is not caused by it therefore electrocutting does not require any application of force. This permits elegant and effortless surgery.*
- *The electrode virtually melts through the tissue instantaneously and seals capillary and other vessels, thus preventing contamination by bacteria.*
- *Simplified method of coagulation saves valuable time, since bleeding can be arrested immediately by touching the spot briefly with the coagulating electrode.*
- *A high frequency apparatus is regarded as standard equipment in the operating theater and it is kept ready for all surgical interventions even if high frequency surgery is not intended, so that use can be made of its superior method of electrocoagulation.*

An attempt has been made in this project to design and constructs a DIATHERMY UNIT - capable of performing the functions of cutting and coagulation.

CONVENTIONAL SURGERY

Surgery can be viewed as the treatment of diseases through operational procedures. To cut, open a tissue, doctors were making use of knives to gain access into the interior parts of the human body. But the drawbacks associated with this type of surgery are as follows:

- *Problem of bleeding at the site of incision.*
- *Sterilization of the incision to avoid infection.*

HISTORY OF ELECTROSURGERY

The most important advancement in the field of surgery is the use of high frequency current for surgery. It was not until 1890 that the biological effects of high frequency current became a subject of interest to the professor of Arsonval at the College de France in Paris. He found that the muscular contractions increased in vigour upto the point where the impulses attained a frequency of 5000 contractions per second. The production of heat was explained on the basis of increased metabolism rather than as due to ohmic resistance.

In the recent past, Hoeing in 1975 worked out a detailed derivation of the significant parameters affecting the distribution of electro surgical RF power in the tissue. He analyzed how electro surgical RF power is localized in the vicinity of the cutting electrode. It was shown that the combination of fine wire electrodes, high RF voltage and high cutting speeds are necessary for the confinement of tissue destruction in electrosurgery. These parameters are of great value in microsurgery since localization of electrosurgical effects would be accompanied by coagulation and hemostasis. His analysis supported the supposition that evolving steam bubbles in the tissue at the surgical tip continuously rupture the tissue and are responsible for the cutting mechanism.

At present, high power, high frequency semiconductor devices as Bux 48A are available to construct the highly efficient electrosurgical units.

TYPES OF DIATHERMY :

MEDICAL DIATHERMY

Here sufficient heat is generated only to warm the tissues and not to burn them. Frequency used is in the range of 500 Hz to 3000 kHz.

SHORT-WAVE DIATHERMY

This is used for deeply penetrating heat requirement. The Frequency range used is about 27.12 MHz, wavelength of 11m and a relatively high power upto 500W for deep heating. It is used in physiotherapy to relieve pain or to treat infections. It is used to overcome the disadvantages if externally applied sources of heat like hot towels, infra-red lamps and electric treating pads which often produce discomfort and the skin burns long before adequate heat has penetrated to the deeper tissues.

MICROWAVE DIATHERMY

This consists of irradiating the tissues of the patient's body with very short wireless waves having frequency in the microwave region. Typically, the frequency used is 2450 MHz *corresponding to a wavelength of 12.25cm. The microwaves are transmitted from an emitter and are directed towards the portion of the body to be treated. These waves pass through the intervening air space and are absorbed by the surface of the body producing heating effect.*

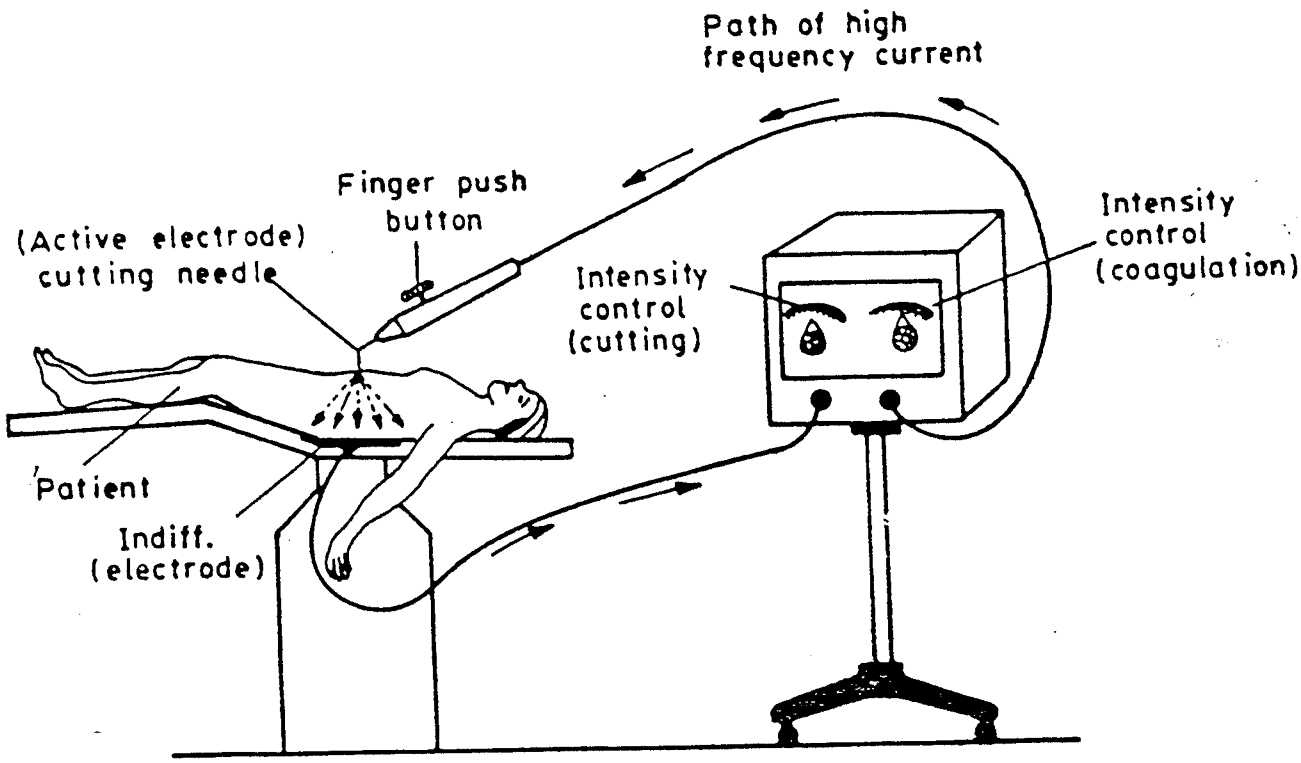
SURGICAL DIATHERMY

It is mainly used to coagulate blood vessels or to dissect tissues to perform surgery with minimum loss of blood. The range of frequency used is from 300 Hz to 300 kHz with operating power ranging from 200 to 500 Watts. The advantage is that the treatment can be controlled precisely. Careful placement of the electrode permits localization of the heat to the region to be treated.

PRINCIPLES OF ELECTROSURGERY

Electrosurgery is defined as a surgical technique that makes use of high frequency RF currents in the range of 1-3 MHz for cutting a tissue into two by means of heating the same. This frequency is quite high in comparison with that of the 60hz mains supply. This high frequency is necessary to avoid the intense muscle activity and the electrocution hazard which, occurs if lower frequencies are employed. The power level required for Electro surgery is below the threshold of neural stimulation provided that the diathermy frequency is in the RF range.

Surgical Diathermy machines depend on the heating effect of electric current. When high frequency current flows through the sharp edge of a wire loop or band loop or the point of a needle into the 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. This is illustrated in the fig (1) below.



BASIC DIATHERMY UNIT

FIG (1)

The indifference electrode established a large area contact with the patient and the RF current is therefore, dispersed so that very little is developed at the electrode. Hemostasis is a method of arresting the flow of blood from incised or transacted blood vessels. The Electrosurgical effect is primarily governed by the following factors:

- *Geometry of the electrode.*
- *Amplitude and the wave shape of the electrosurgical current.*
- *Duration of application.*

MODES OF OPERATION:

The Electro surgical unit can be operated in the following modes:

- *Electrocutting.*
- *Electrocoagulation.*

ELECTROCUTTING:

The leading edge of the active electrode has relatively small surface area. When it reaches the tissue, the current from the electrode enters the tissue at a very high density. The electrode enters the tissue at a very high density. The tissue offers electrical resistance whereby only a limited zone at the edge of the electrode is heated rapidly and intensely by joule heating which causes the tissues to boil and an arc is formed between the tissue and electrode. This type of tissue separation forms the basis of Electro surgical cutting. The tissue is cleanly cut and the effect is as if a very fine knife had been drawn through the tissue.

Undamped continuous sinusoidal currents yield clean electrosugical cut. There is however no control of bleeding accompanying the cutting action when such a continuous wave is used.The process and waveform diagram is illustrated in the fig 2(a), (b), and (c).

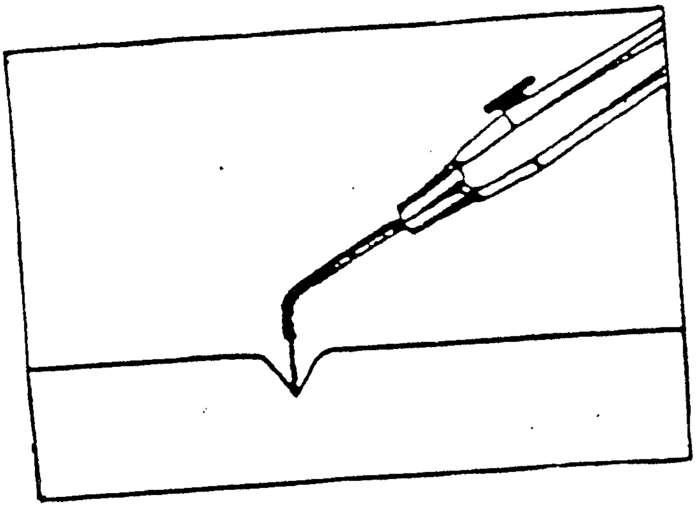
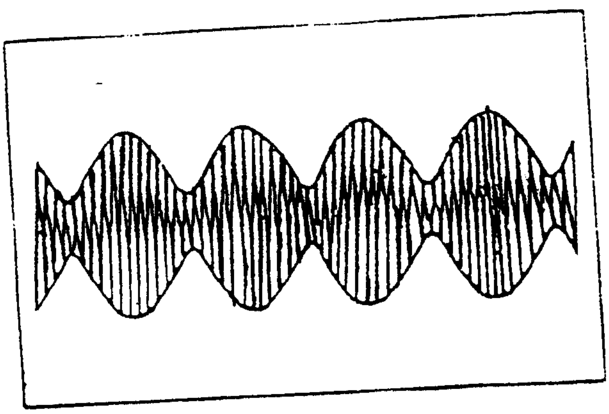
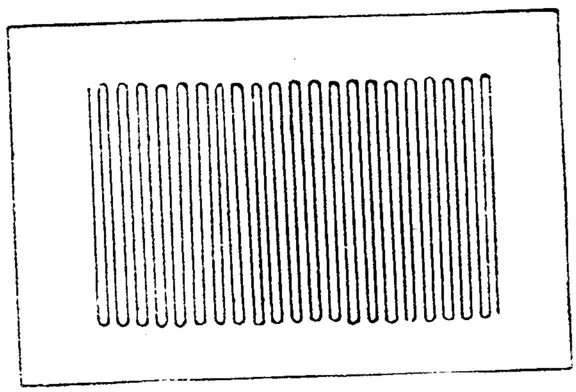


FIG2(a) **CUT MODE**



CUT WAVEFORM GENERATED BY ELECTRON TUBE CIRCUIT

FIG2(b)



CUT WAVEFORM GENERATED BY A SOLID STATE DEVICE

FIG2(c)

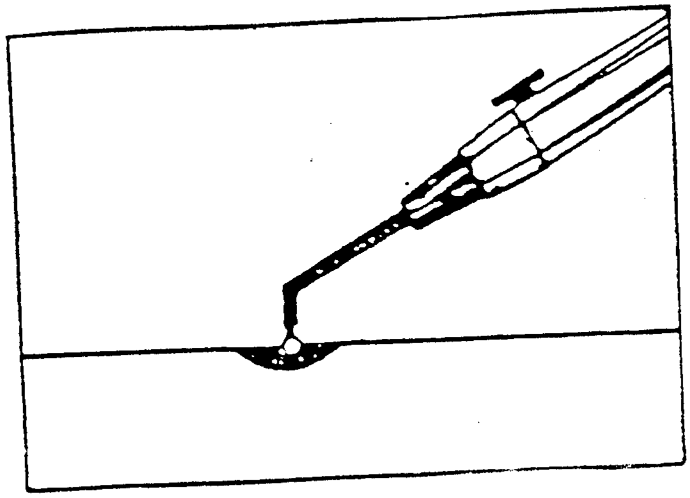
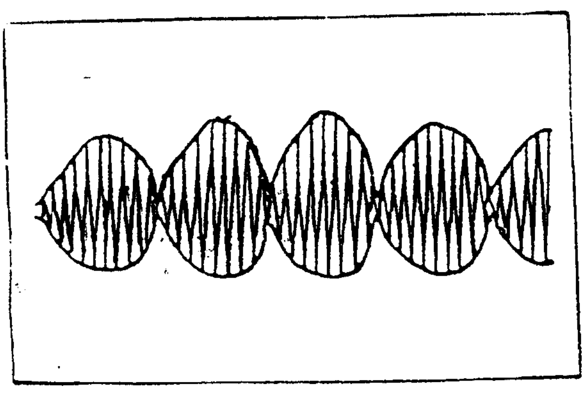


FIG3(a) **COAGULATION**

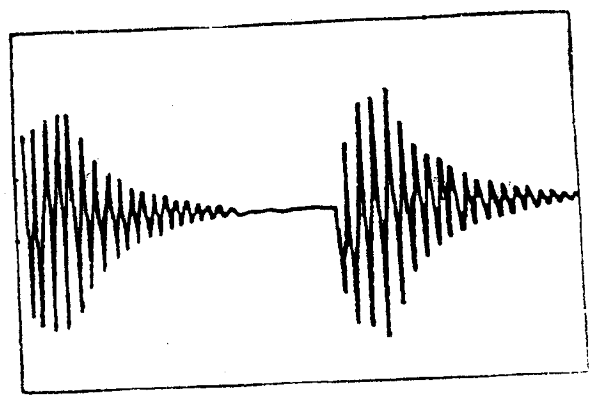


COAGULATION WAVEFORM

GENERATED BY A

SPARK GAP GENERATOR

FIG3(b)



COAGULATION WAVEFORM

GENERATED BY

SOLID STATE DIATHERMY

FIG3(c)

ELECTROCOAGULATION:

Coagulation is used to seal the tissues and to overcome the bleeding accompanying the cutting action. The process and the waveforms are illustrated in the fig 3(a), (b) and (c).

Electrosurgical coagulation of tissue is caused by the high frequency current flowing through the tissue and heating it locally so that it coagulates from inside. The coagulation process is accompanied by a greyish-white discoloration of the tissue at the edge of the electrode. The contrast to thermocauter, better coagulation can be obtained by high frequency currents because it does not produce superficial burning.

Electro-coagulation can be accomplished by the following two techniques. They are

1. *Desiccation.*
2. *Fulguration.*

DESICCATION:

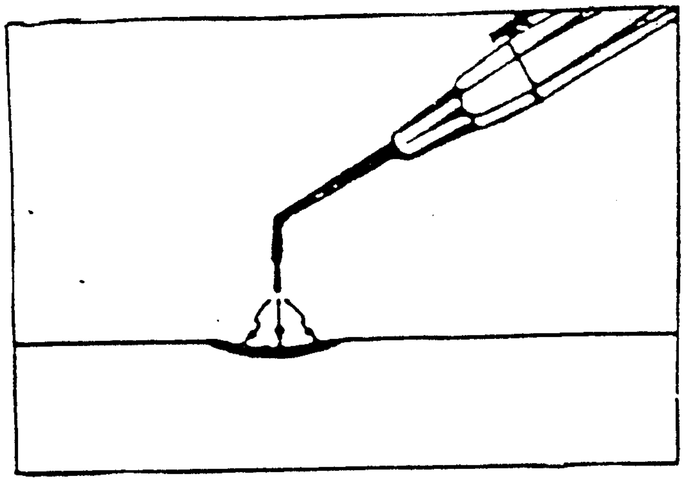
In desiccation, the needle point electrodes are stuck into the tissues and then kept steady. Depending upon the intensity and duration of application of current, a high local increase of heat will be *obtained and effective desiccation will be obtained. The tissue changes due to drying and limited coagulation. The process is explained in the fig (4) below.*

FULGURATION

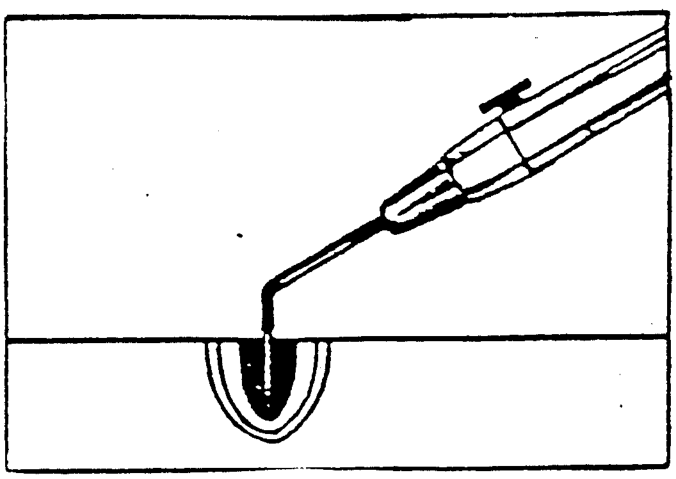
The term ' Fulguration ' refers to superficial tissue destruction without effecting the deep-seated tissues. This is obtained by passing sparks from a needle or ball electrode held near the tissue without touching it, an electrode are will be produced, whose heat dries out the tissue. Fulguration permits fistulas and residual cysts to be cauterized and minor hemorrhages stopped.

Effective fulguration results with a waveform of high crest factor (i.e., ratio of peak voltage to effective rms voltage) and short duty cycle. The high voltage ionizes the air gap between the tissue and the electrode, thus creating a spark. The spark is quickly

quenched and the delivered power spreads superficial coagulation that prevents any excavation that would occur during cutting. This process is illustrated in the fig (5) below.



FIG(4) DESICCATION.



FIG(5) FULGURATION.

The concurrent use of continuous radio-frequency current for cutting and a burst wave radio frequency for coagulation is called Hemostasis mode.

OPERATIONAL PROCEDURES

Our body is made up of cells that are surrounded by cellular fluids. The currents enter the body through an active electrode having a small cross sectional area. The current density is sufficiently high to cause adequate local heat causing a rise in temperature. This causes the cell fluids to boil and they rapidly volatize creating controlled tissue destruction at the point of placement of the active electrode.

Complaints of electric shocks during surgery can always be attributed to muscle contraction of the patient. This is caused by the rectification of the high frequency energy at the junction of the active Electrosurgery. This phenomenon is observed mostly while operating in a site of sensitive nerve tissue. There is, however, no danger to the patient or the operating due to the operator due to this action.

On the other hand anyone in the proximity of the radio frequency carrying cables or electrodes will have some energy induced in his body. If by chance he touches the metal cabinet of the surgical unit or any other conductive surface, current will flow through his body, resulting in a spark at the point of contact. It is advised to avoid contacts with conducting surfaces by those who happen to be near the machine or cables.

ELECTRODE CONFIGURATION

There are three functional types of generator output circuits that are classified based on the arrangement of the active electrodes.

1) BI-TERMINAL MONOPOLAR / DI-TERMINAL UNIPOLAR MODE:

Here the unipolar active electrode is coupled with a disperse return electrode. Since the disperse electrode has a large area, the current display is less resulting in minimal thermal effects. It is illustrated in the fig 6(a) below.

2) BI-TERMINAL BIPOLAR MODE:

Bipolar technique is used in most of the application involving surgical diathermy. The high potential terminal of the diathermy is connected to the cutting electrode that is mounted in an insulated handle. It uses a pair of active electrode generally in the form of special insulated forceps having the active tip electrodes. It is used in intracranial and neuro surgical procedures and in female sterilization. This is illustrated in the fig 6(b) below.

3) MONOPOLAR MONO-TERMINAL MODE:

It has one active electrode and no direct return path electrode. This system relies on stray capacitance between the patient and the ground for the return current. It is illustrated in the figure 6(c) below.

BI-TERMINAL—UNIPOLAR

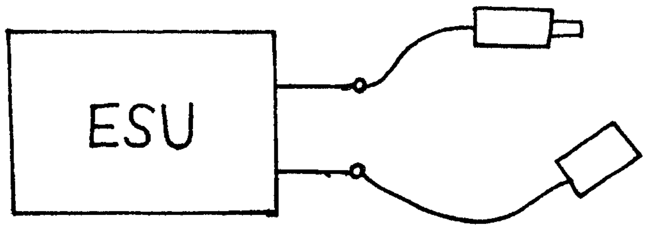


FIG6(a)

BI-TERMINAL—BIPOLAR

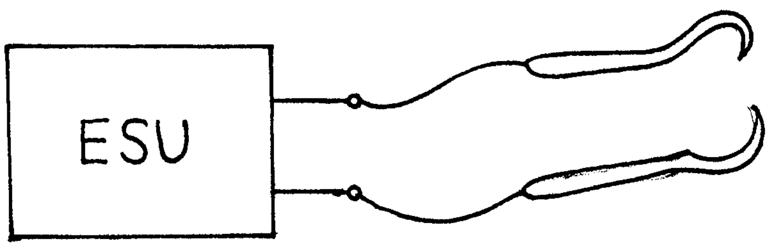


FIG6(b)

MONOTERMINAL—MONOPOLAR

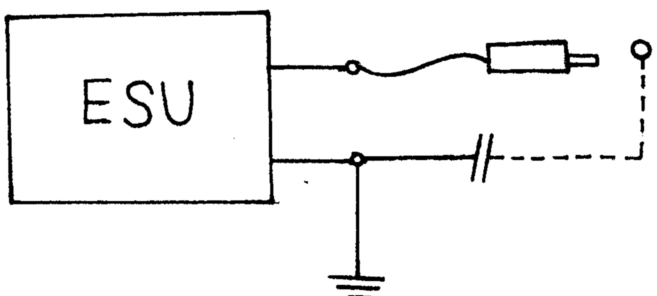


FIG6(c)

SURGICAL ELECTRODES

Special kinds of electrodes are used in diathermy. In surgical diathermy, the high power produced is delivered to the patient using different electrodes for different applications. The surgical electrodes include the following.

- The dispersive electrode.
- The electrode holder.
- The active electrode.

DISPERSIVE ELECTRODE:

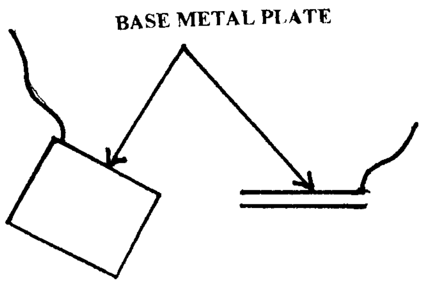
The low potential terminal of the radio frequency output lead is connected to the indifferent or dispersive electrode. It leads the current from the body and disperses it away. Its large area makes the current density and temperature low.

This electrode consists of a lead plate [15 x 20 cm] wrapped in a cloth bag. It is soaked in a saline solution and wrapped into the patient's thigh. An alternate arrangement is to use a flexible non-crumpling stainless steel sheet plate without any covering. Good contact is established with the film of perspiration between the plate *and the patient's body. Quite often, a liberal amount of conductive paste like the ECG paste is applied to the plate. This gives excellent electrical contact and removes the need to keep a wet gauge pad. However, problems may arise if the paste is not cleaned from the plate after use as if may form a hard layer.*

An alternate approach is to use capacitively coupled plates in which no direct contact is made between the metal of the indifferent electrode and the patient's skin. The electrode comprises a large sheet of thin metal sandwiched between the two sheets of neoprene, which formed a capacitor with the patient's body. This capacitor allows an easy path for the passage of high frequency diathermy currents. However, it adds to the problem of introducing burn hazard by providing alternative current paths when other equipment with grounded patient connected is used.

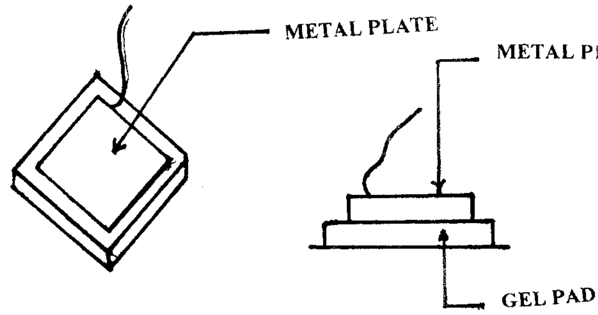
A variety of self-adhesive electrodes are available and are of smaller area than the plate type of electrodes. They are convenient and effects of burns are avoided by their use when the patient has to be moved or turned. It is illustrated in the fig 7(a), (b), (c) and (d) below.

TYPES OF DISPERSIVE ELECTRODES



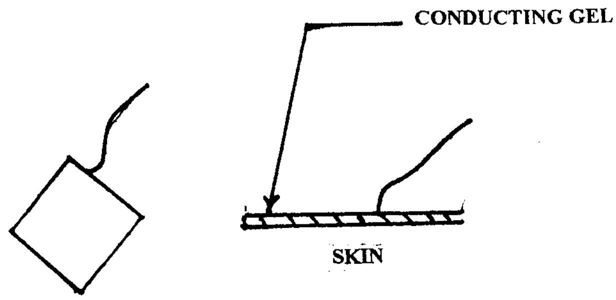
DRY METALPLATE

FIG7(a)



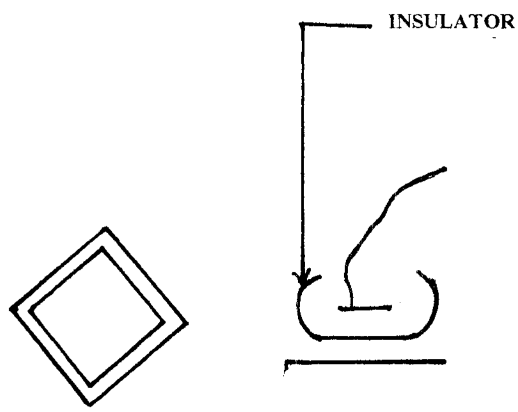
GELLED FOAM PAD

FIG7(b)



METAL PLATE COATED WITH A CONDUCTING GEL

FIG7(c)



CAPACITIVE ELECTRODE

FIG7(d)

The most common reason for the faulty performance of the electrosurgical unit is the improper placement of the indifferent electrode. This electrode must be placed in firm contact with a fleshy portion of the patient and near to the operating site. Poor contact or excessive distance from the operating site causes a considerable loss of energy for the actual surgical procedures.

ELECTRODE HOLDER:

It is a tube like structure made of ceramic or Teflon that contains a metal tube burning throughout the body. Different type of electrodes may be required for different types of operations. The RF power from the generator is connected to an active electrode using a screw. The electrode is inserted into the tube by adjusting the screw. The cable carrying the RF power and the electrode should have perfect contact with the metal tube to prevent any appreciable loss of power at the junctions. The length and weight should be such that it facilitates easy handling. In eletrosurgery, the surgeons must be able to switch the high frequency current ON/OFF by himself. This is done by a fingertip switch on the electrode handle or a foot switch near the leg does this.

ACTIVE ELECTRODES:

The shape of the active electrode is an important factor in deciding the performance of the electrode. They are all made of stainless steel and must be kept bright and greaseless. A small electrode has a high current density and better cutting is accomplished. A large electrode spreads the current over a large area of the tissue.

A flat elongated blade [2-3 mm wide and 1.5 cm long] with relatively sharp edges and tip is commonly used in general surgical procedures. The blade acts both as a cutting instrument when the edges are in the direction of the movement through the tissue and as adessicating electrode when one of the flat sides of the blade is held against the tissue and activated for control of bleeding. Different types of electrodes are used for different application. The active electrodes for coagulation purposes are of the ball type or plate type as shown in the fig8 (a), (b), and (c).

Ball electrode whose end is in the shape of a ball is used for coagulating small bleeding areas. Balls of different diameters

COAGULATION ELECTRODES USED WITH DIATHERMY MACHINES

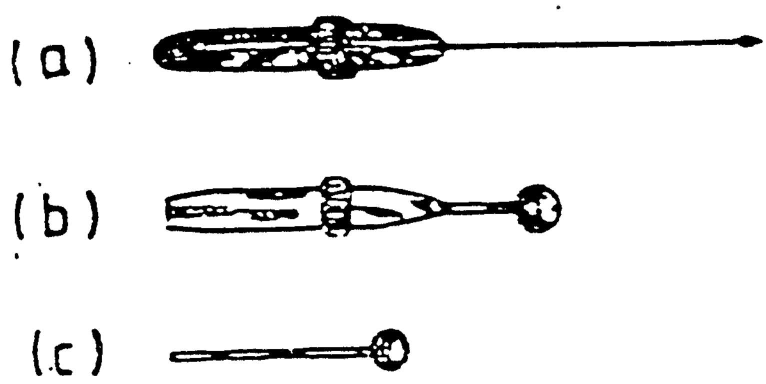


FIG8

a) PLATE TYPE.

b) BALL TYPE.

c) BALL TYPE.

are used for different areas. In vascular areas such as tonsil beds and neuro surgery, it is practical to combine the electro surgery coagulation electrode with the tip of suction catheter. The suction device, insulated except at the tip is used to clear the area of bleeding. Then bleeding area is identified and blood is arrested by application of current by way of a suction tip.

Plate electrode is used for coagulation of larger bleeding surfaces where ball electrodes cannot be used. Scissors' electrodes or forceps are used for sealing bleeding vessels. Both tips can be energized from a single active cable to form a unipolar electrode or each tip must be separately energized. In this mode coagulating currents are applied to the tissue immediately adjacent to the grasping side and other tissues or other portions of the body are uninvolved in the process.

The cutting electrode is available in a variety of shapes as illustrated in the fig 9(a), (b), (c), (d), and (e), the choice depending on the nature of application. Loop electrodes are used in exsecting [for opening up] channels and extirpating growths, etc.,

CUTTING ELECTRODES USED WITH DIATHERMY MACHINES

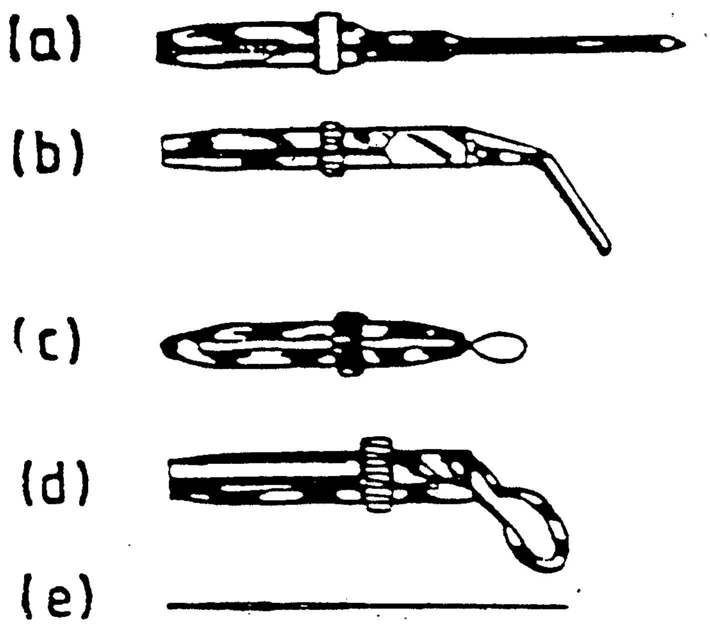


FIG9

a) NEEDLE ELECTRODE.

b) ANGULATED LANCET ELECTRODE.

c) WIRE LOOP ELECTRODE.

d) ANGULATED BAND LOOP ELECTRODE.

e) STRAIGHT LANCET ELECTRODE.

Wire loop electrodes are employed in surgery where a wire is bent in the form of a loop and electrode sections are inserted into the power is applied. For different tumors, different loop diameters are use.

Lancet electrodes are in the form of a double-edged pointed knife, to make a puncture in the desired region. The length of the pointed region varies depending on the punctures to be made. The angulated and the straight lancelet are the two types of lancet electrodes.

The angulated electrode is used to reach even those regions where the ordinary straight lancelet is not able to reach. Specific types of needle electrodes are preferred for epitation and desiccation.

HAZARDS

The risks associated with electro surgery fall into three main categories

- *Burns.*
- *Low frequency shocks.*
- *Explosion.*

BURNS

The predominant hazard associated with electro surgical unit is burns caused by excess current density at a rate at which it is meant to be present.

- *The burn usually occurs at the dispersive electrode because of the failure to achieve adequate contact.*
- *The injury can also occur because unintended current pathway may be created.*
- *The skin temperature attained will be a function of the blood flow, especially when the current density approaches a level that will just produce a burn. With a diathermy plate positioned under a bony area where the main burn determining factor may be the blood flow in the skin covered by the plate. The high electrical resistance and*

the low blood flow in the adipose tissue also contribute to a diathermy burn.

- *Besides the indifferent electrode site, monitoring electrodes are always possible sites of burns. If the current density under an electrode is too great that the heat generated cannot be dissipated fast enough either by convection due to circulation of blood in the underlying tissue or by the thermal heat sink capabilities of the electrode.*
- *The risk of burns also exists in the presence of the moisture i.e., the accumulation of prepping agents, blood or other fluid around the indifferent electrode can lead to small highly conductive areas.*

THE BURNS CAN BE AVOIDED BY

- *Placing the indifferent electrode over an area where there is good flow of blood.*
- *Burns resulting from small conductive areas between the limbs can be prevented by means of a dry cloth between them.*
- *During surgery, the output power of the electro-surgical unit should not be increased if the desired surgical effect is not obtained. Abnormal power settings indicate that something is wrong and the fault must be identified.*

- *It is advisable to carry out the surgical work with the power setting as low as possible.*

LOW FREQUENCY SHOCKS

Another serious hazard associated with the use of the surgical diathermy machine is the possible electrocution of the patient from the faulty mains operated equipment. This happens when the output circuit supports the flow of the low frequency currents. The risk associated with this can be reduced by placing a capacitor in series with one of the output leads, usually the active lead.

EXPLOSIONS

The explosions are mainly caused due to the danger zone developed because of the use of cleaning agents such as ether, alcohol, etc., and by using explosive anesthetic gases or mixture with oxygen. The sparks associated with the use of surgical diathermy can cause a dangerous explosion if proper precautions are not taken. If flammable gases are used it is important that the electro surgical unit be located outside the zone in which the anesthetic is used.

Some diathermy machines are fitted with automatic anti-explosive devices. When the fingertip switch is operated, this device causes a stream of nitrogen to emanate from the electrode handle to form a protective cloud around the cutting and the coagulation electrode before the high frequency generator is switched on.

OUTPUT CIRCUIT CONFIGURATION

The output configuration plays an important role in the radio frequency current circuit. There are three technical approaches.

- Earthed output system.
- Earth referenced System.
- Isolated System.

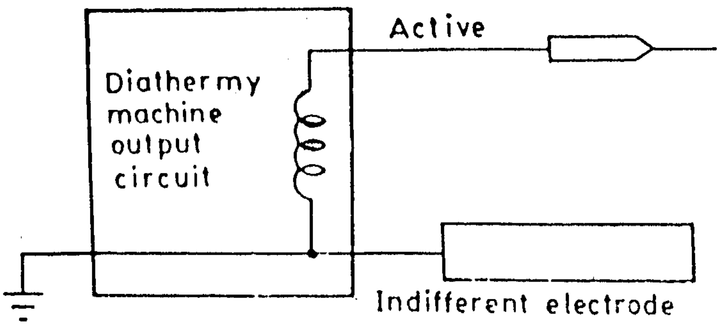
EARTHEDOUTPUTSYSTEM:

In this the indifferent electrode is connected conductively to a protective earth. This is illustrated in fig 10(a).

EARTH REFERENCED SYSTEM:

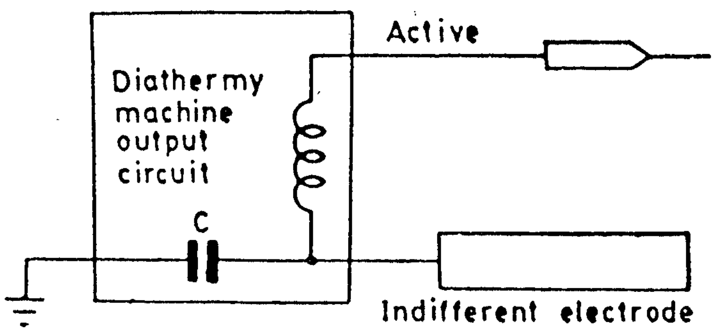
This makes use of a capacitor connected to the indifferent electrode to earth. This permits the RF current to flow through the machine, however effectively blocking the passage of the low frequency currents, namely 50 Hz. This is illustrated in the fig 10(b).

FIG10(a) **EARTHED OUTPUT SYSTEM**



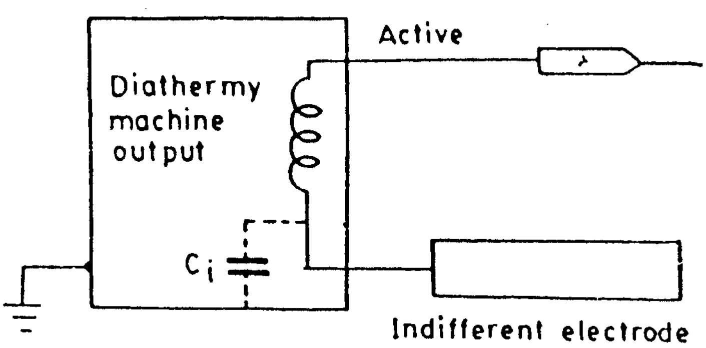
Output circuit configuration in which the indifferent circuit is directly connected to the mains earth.

FIG10(b) **EARTHED REFERENCE SYSTEM**



Use of capacitor in the output circuit. This permits RF currents to flow to earth through the diathermy machine. However, it effectively blocks the passage of low frequency currents (50 Hz).

FIG10(c) **ISOLATED SYSTEM**



RF isolated output circuit configuration. Obviously, there is no direct connection of the indifferent circuit to ground. The RF leakage current is due to stray capacitance within the machine.

ISOLATED SYSTEM:

In the isolated system the dispersive electrode is floating, i.e., there is no intentional connection to the earth. The value of the capacitor is such that it offers a very low impedance to the main frequency.

This is illustrated in the fig 10 (c). Obviously there is no direct connection to the indifferent circuit to ground and the RF leakage current is due to the stray capacitance within the machine.

Of the three types of the electro-surgical output systems namely, Earthed, earth-referenced and isolated only the last two are recommended. For surgical application in which the danger of ventricular fibrillation cannot be excluded electro-surgical units of the isolated output type [type CF] should be used as they offer the best protection against fibrillation.

In other applications, it may be noted that although isolated systems reduce the risk of serious burns, they can greatly increase the risk of small burns and shocks. The voltage of the power *transformer in a surgical diathermy machine is high enough to cause serious injuries. Therefore, when checking voltages, it is advisable to take adequate care. Also, cautions should be taken to avoid damage to the test equipment due to high voltages and currents.*

CIRCUIT DESCRIPTION AND DESIGN

This section includes the design and the implementation of the various functional blocks presented in the block diagram in the fig 11.

This section has been classified under the following head

- Power supply module.
- Control circuit module.
- Oscillation and Power amplifier module.
- Pulse generator module.
- Output circuit module.

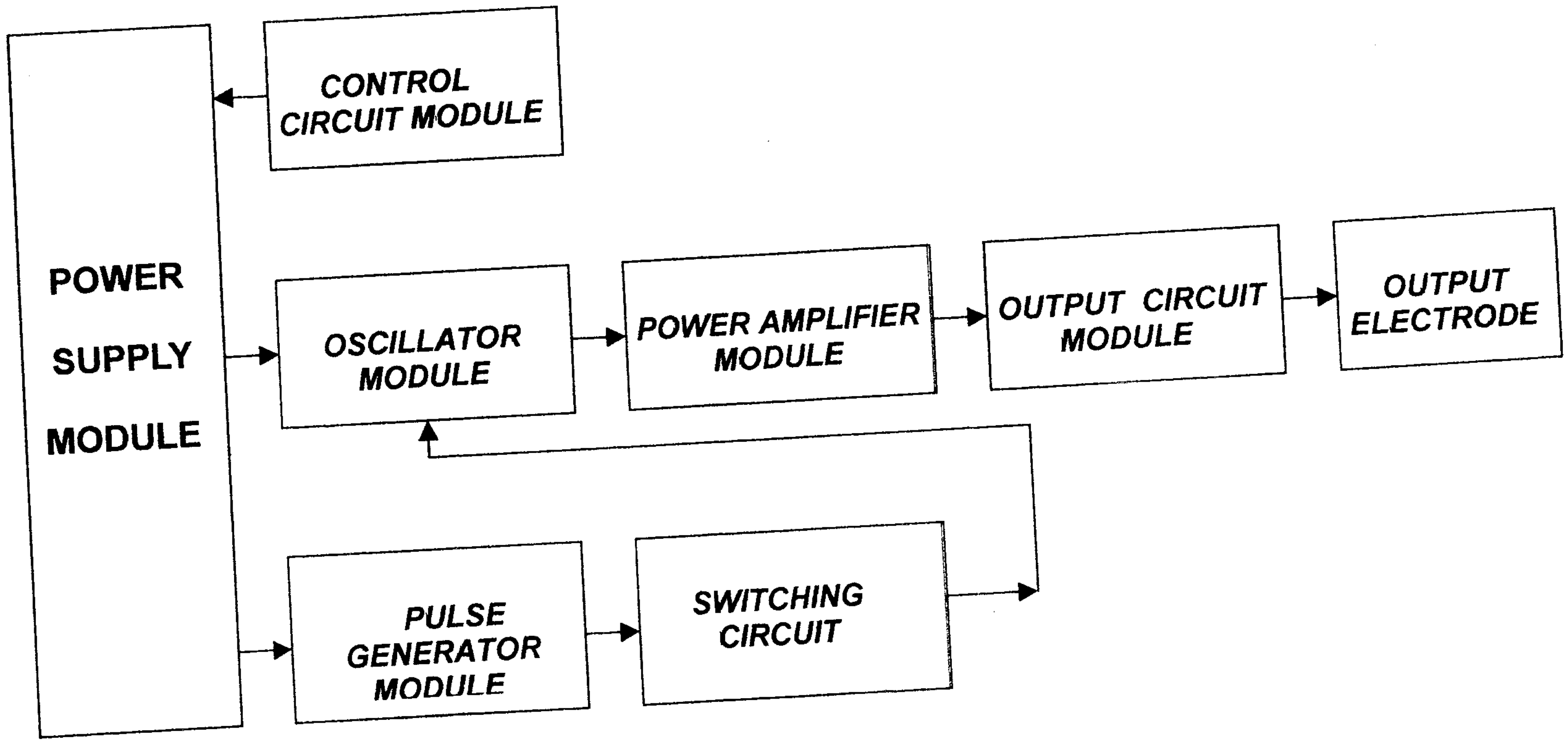
The total circuit diagram is shown in the fig 12.

POWER SUPPLY MODULE:

The power supply is a piece of equipment, which converts the alternating waveform from the power line into an essential constant direct voltage. The power to the unit is supplied from the power supply module, which consists of a transformer with a primary supply of 230V, 50Hz AC from the mains. At the secondary, a 65V tapping has been taken as a supply to the oscillator circuit and the potentiometer. A 11V tapping is given as the supply to the pulse generator. Both the output voltages from the secondary are each first rectified and then filtered by capacitor filters separately.

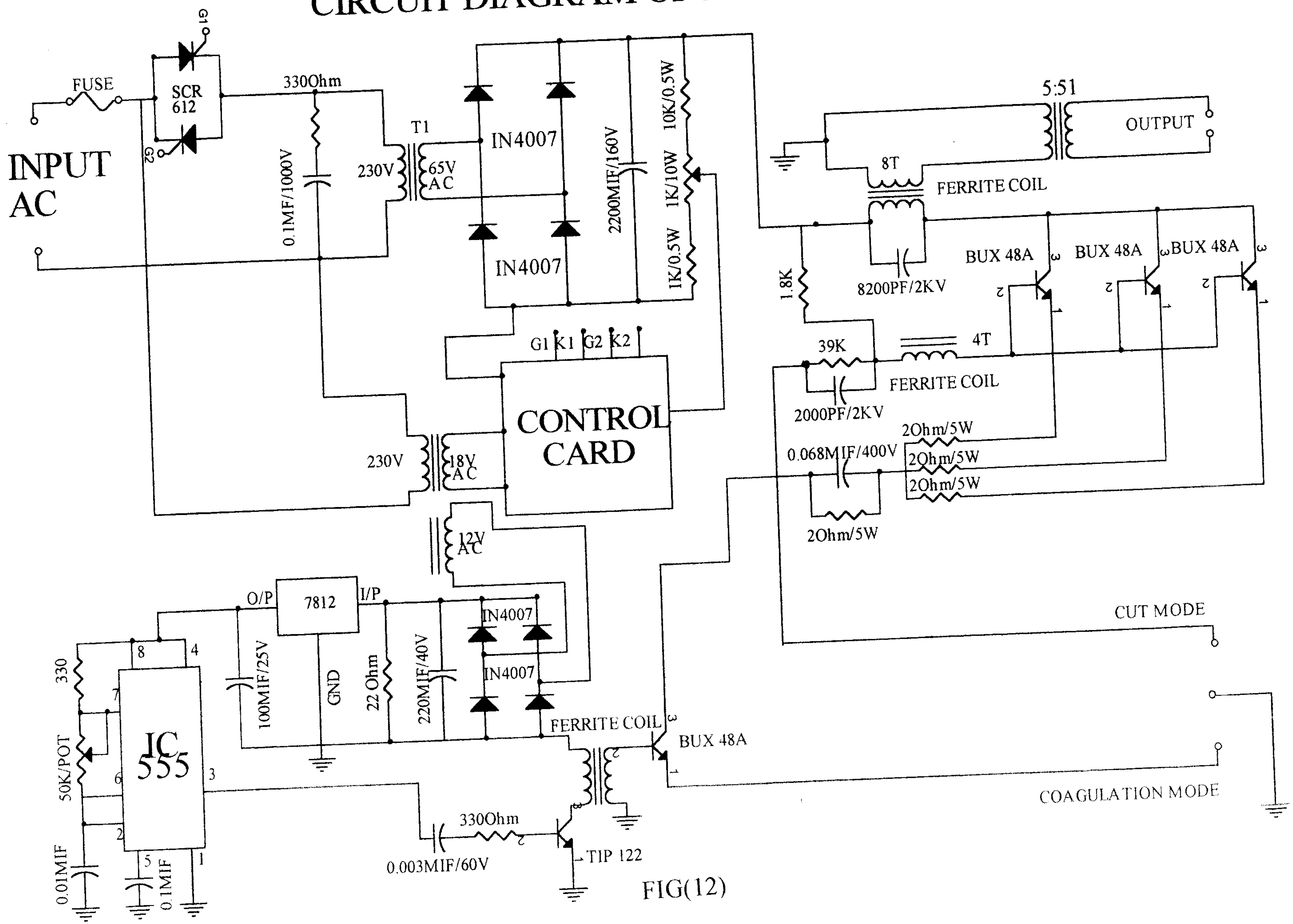
BLOCK DIAGRAM OF A SURGICAL DIATHERMY

- TWIN MODE CONCEPT



FIG(11)

CIRCUIT DIAGRAM OF A DIATHERMY



FIG(12)

The power consumed by the load can be changed by varying the firing angle of the SCR's connected in the anti-parallel configuration. This is achieved by means of phase control of two TYN 612 SCR's

To prevent the false triggering of the SCR's due to the reapplied dv/dt which results in the loss or phase control, a RC snubber circuit is connected in parallel. The RC snubber reduces the effect of switching transients, which is the main cause of exceeding the critical rate of the voltage rise.

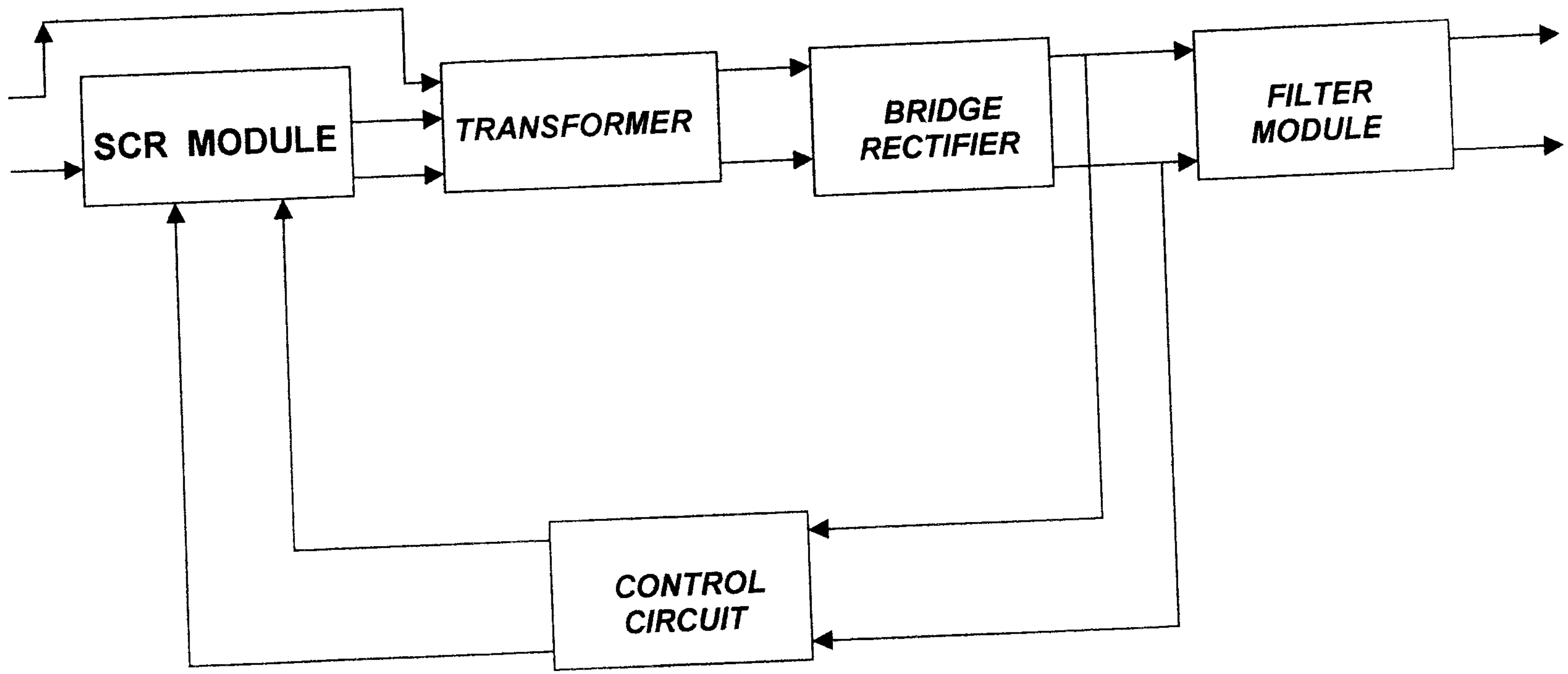
CONTROL CIRCUIT MODULE:

The required phase control to vary the firing angle of the SCR is achieved by this unit. The basic building blocks of the control circuit are shown in the fig 13(a) and fig 13(b). The circuit diagram is shown in the fig 14.

POWER SUPPLY:

A regulated voltage of 18v is applied to this unit from a separate transformer used exclusively for this purpose.

FIG 13(a) BLOCK DIAGRAM OF A CONTROL CARD



BLOCK DIAGRAM OF A CONTROL CARD

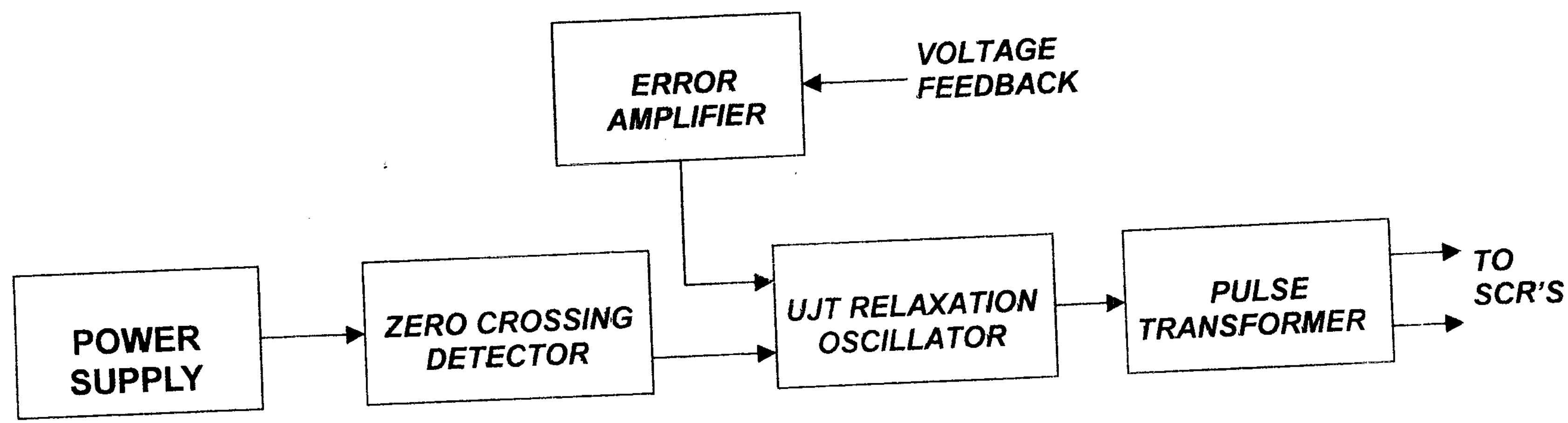
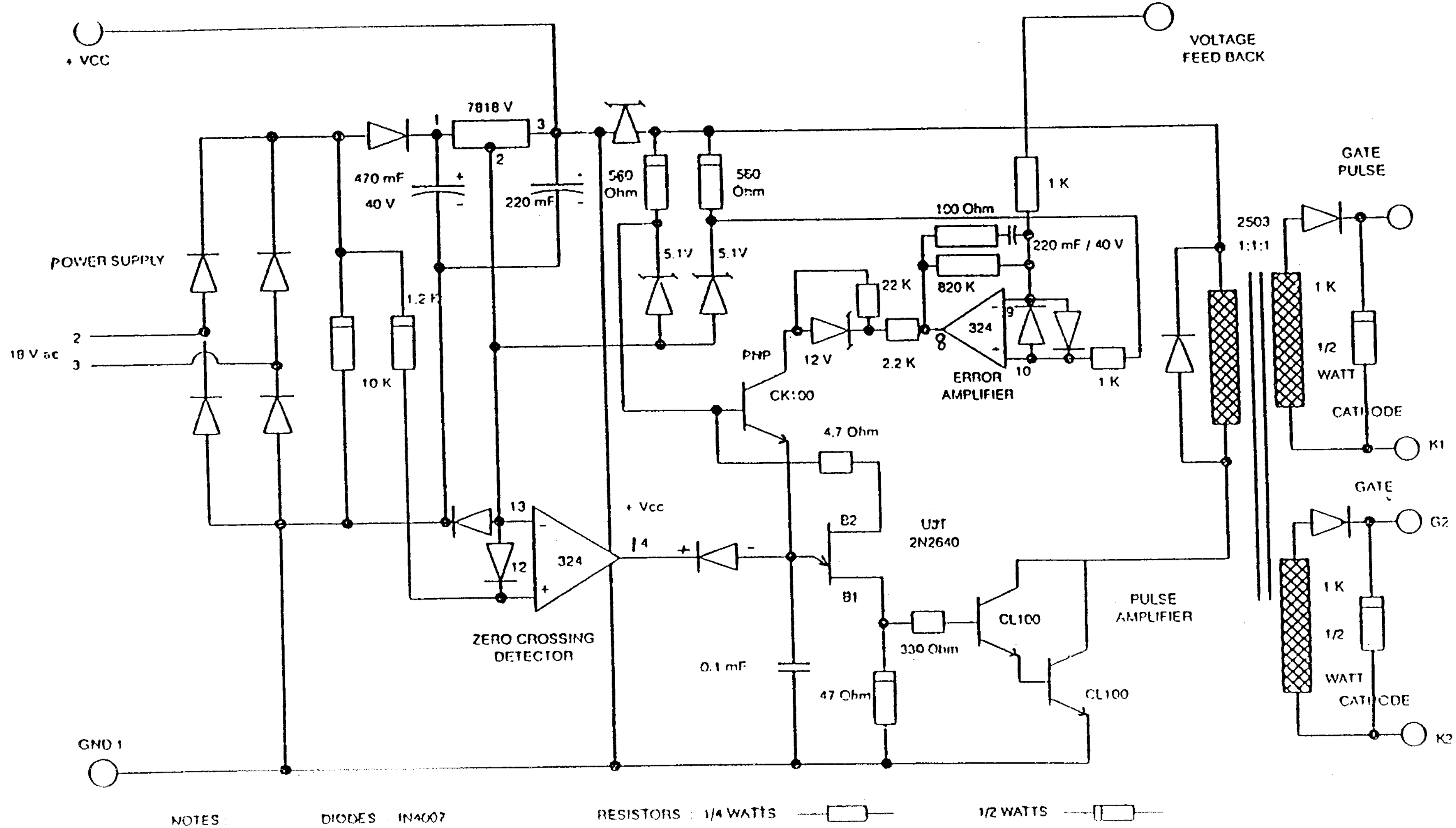


FIG13(b)

CONTROL CARD



FIG(14)

ERROR AMPLIFIER:

The regulated voltage level is set by the operator at the output by varying the resistance of the potentiometer, which is inturn connected to the output of the bridge rectifier. The voltage across the potentiometer is fed back to the error amplifier in the control circuit. The other input of the error amplifier is filed with a constant 5.1v, which is taken from the output of the zener regulator. The output from the error amplifier, which is the difference of the two input voltages, is fed to the emitter of the transistor CK100 through a 12v-zener regulator LM 324A. The error amplifier used here is a low power quadrature operational amplifier and a 10K pot is used in conjunction with this.

UNI-JUNCTION TRANSISTOR:

The uni-junction transistor is one of the oldest and simplest semiconductor devices. As the name implies, the UJT is a three terminal device with a single PN junction. It is primarily a switching device that is different in several ways from other semiconductor devices.

- *It's triggering voltage is approximately a fixed percentage of the power supply voltage.*
- *It exhibits a stable negative resistance region that suggests its use in oscillator and trigger circuits.*
- *The UJT often reduces the number of components to perform a given function to less than half that required if bipolar transistors are used.*
- *The UJT internal resistance in OFF condition is relatively high [5 to10K ohms], hence its idling power is low.*
- *The device has very low triggering current requirements [2 – 10A].*
- *UJT's have high pulse current, capabilities [2A].*
- *Many UJT structures are very inexpensive.*
- *Reasonably high [3 – 5V] peak output voltage are available for triggering thiristors.*
- *UJT's input current is low [1 – 10nA].*
- *Complementary or programmable UJT, are capable of even*
  - *Higher internal OFF resistance < 30 K ohms.*
  - *Lower firing currents [0.1A].*
  - *Lower operating currents [< 1.0mA].*
  - *Higher peak output voltage pulses [upto 10v].*
  - *Comparable prices.*

UJT CONNECTED AS A RELAXATION OSCILLATOR:

The UJT connected as a relaxation oscillator as in fig 15(a) generates a voltage waveform VB1 as shown in fig 15(b). This can be applied as a triggering pulse to an SCR gate to turn on the SCR.

OPERATION OF THE CIRCUIT IS AS FOLLOWS:

When switch, S1 is first closed, applying power to the circuit capacitor CT starts charging exponentially through Rt to the applied voltage Vt. The voltage across Ct is the voltage Ve applied to the emitter of the UJT. When Ct has charged to the peak point voltage Vp of the UJT, the UJT is turned on decreasing greatly the effective resistance RB1 between the emitter and base1. A sharp pulse of current 1E, limited only by R1, flows through the base 1 into the emitter, discharging CT. When voltage across Ct has dropped to approximately 2V, the UJT turns off and the cycle is repeated. The waveforms in the fig illustrates the saw tooth voltage VE, generated by the charging of CT and the output pulse, VB1 developed across R1. AB1 is the pulse, which will be applied to the gate of an SCR to trigger the SCR.

UJT CONNECTED AS A RELAXATION OSCILLATOR

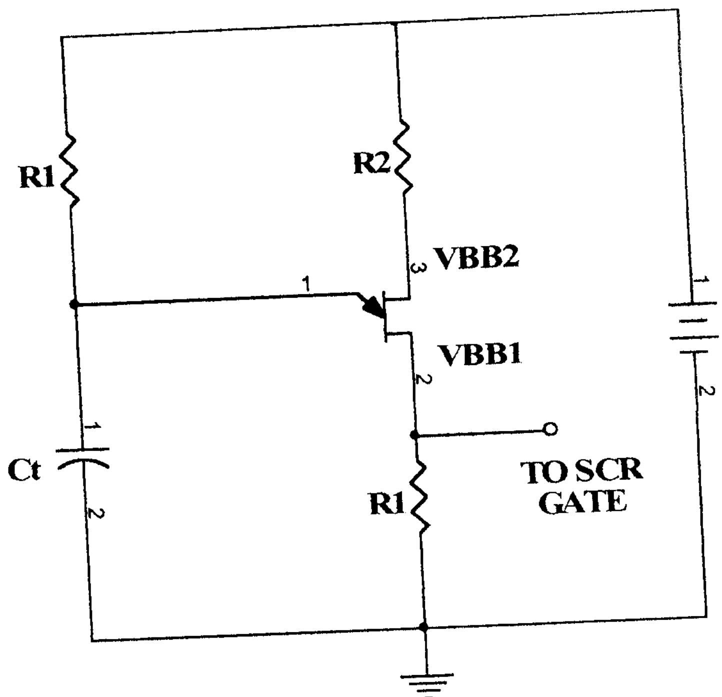


FIG15(a)

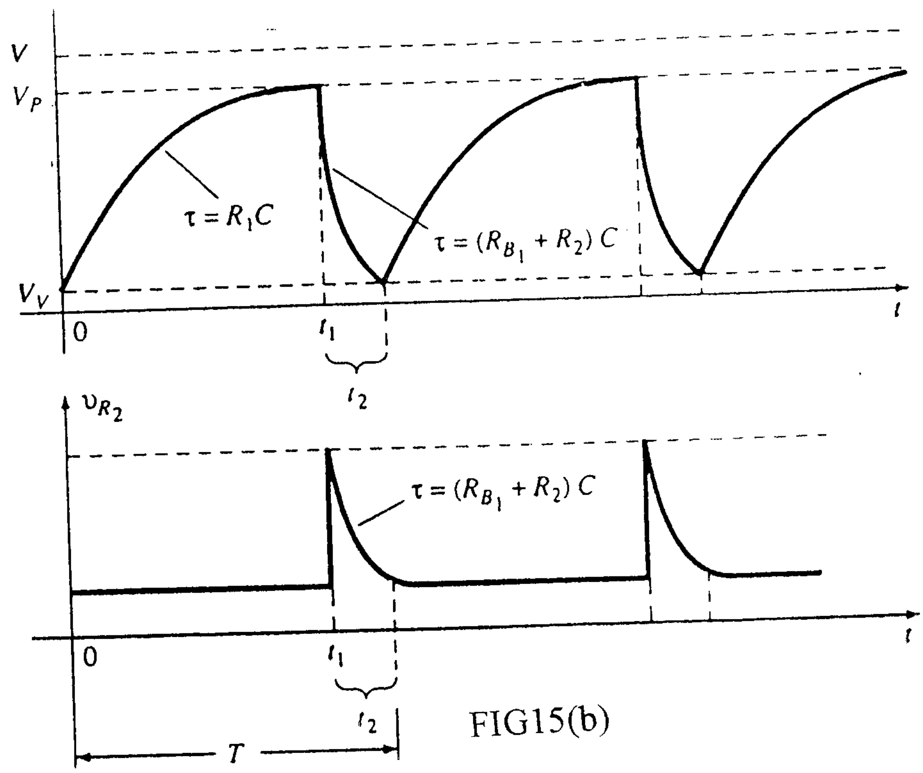


FIG15(b)

The frequency of the relaxation oscillator depends on the time constant CT CR and on the characteristics of the UJT. For values of $R1<100$ chm, the period of oscillation T is given approximately by the equation

$T = 1/f = Rt\ Ct\ Ln\ 1/[1-n].$

The value of Rt is limited to the range 3000 ohm to 3M ohm.

The supply voltage V1 normally used in the range of 10 to 35 V.

SCR TRIGGERED BY THE UJT RELAXATION OSCILLATOR:

According to the difference voltage, which is available at the output of the error amplifier, an amplified signal from the collector of transistor CK 100 drives the UJT into conduction at various instances.

The voltage applied to the emitter of CK100 can be varied such that the timing of the triggering pulse developed by the UJT operated in the relaxation operation mode may be adjusted. As a result, the firing of the SCR is varied at different points on the input cycle obtained from the main and the required power control is achieved at the output.

ZERO CROSSING DETECTOR:

The trip point of a computer is the input voltage where the output switches states. When the Vin is greater than the trip point, the output is high and when the Vin is lower than the trip point, the output is low. If the trip point is set at zero, then the comparator is called zero-crossing detector and spikes are obtained whenever the input signal crosses the zero axis of trip point. The zero crossing detectors are used in this circuit to achieve synchronization.

DARLINGTON PAIR:

The output of the UJT is given to two CL100 transistors connected in the Darlington pair configuration. The emitter current of the first transistor drives the base of the second transistor; the total current gain is B=B1*B2, leading to greater amplification width.

PULSE TRANSFORMER:

The pulse transformer has extensive application. It is used here to effect DC ISOLATION between the source and the load. Pulse transformer is a type of iron core transformer, which behaves as *a reasonable approximation to a perfect transformer when used in connection with fast waveforms.*

In a small pulse transformer, the preservation of the pulse shape is more than the efficiency of operation. The winding resistance may therefore be permitted to be quite large Small wire sizes may be used with a cosequent reduction in capacitances.

The permeability actually achieved in the pulse transformers is very much less than the maximum value indicated by the manufactures, when an abrupt set of current is driven through the transformer winding, the magnetic flux in the core is initially confined largely to the surface [the skin effect] because of the eddy current that flows. The effective cross section of the core is thereby reduced. As time passes, the flux penetrates deeper into core and eventually becomes uniform.

Accordingly, the effective permeability of the core increases with increasing pulse duration. In order to reduce eddy currents for minimizing both losses and the skin effect, it is important that the core be laminated. The output of the Darlington pair amplifier is given to the transformer of the ratio [1:1:1]. The two pairs of pins constituting the secondary are used to supply the pulses to the SCR's gate for firing purposes.

OSCILLATION AND POWER AMPLICATION MODULE:

This module mainly consists of

- *Frequency determining network [FDN].*
- *Positive feedback network.*
- *The amplifier network.*

FDN NETWORK:

The FDN consists of a capacitor [8200 PF] and a coil, which forms the primary winding of a setup transformer.

OSCILLATOR:

A simple block diagram of a feedback amplifier is shown in the fig 16. The input signal Vs is applied to a mixer network, where it is combined with a feedback signal, Vi is then the input voltage to the amplifier. A portion of the amplifier output, Vo I s connected to the feedback network [B], which provides a reduced portion of the output as feedback signal to the input mixer network.

The combination of the L and C forms an oscillatory tank circuit to set the frequency of oscillations, In this unit,

BLOCK DIAGRAM OF FEED BACK AMPLIFIER

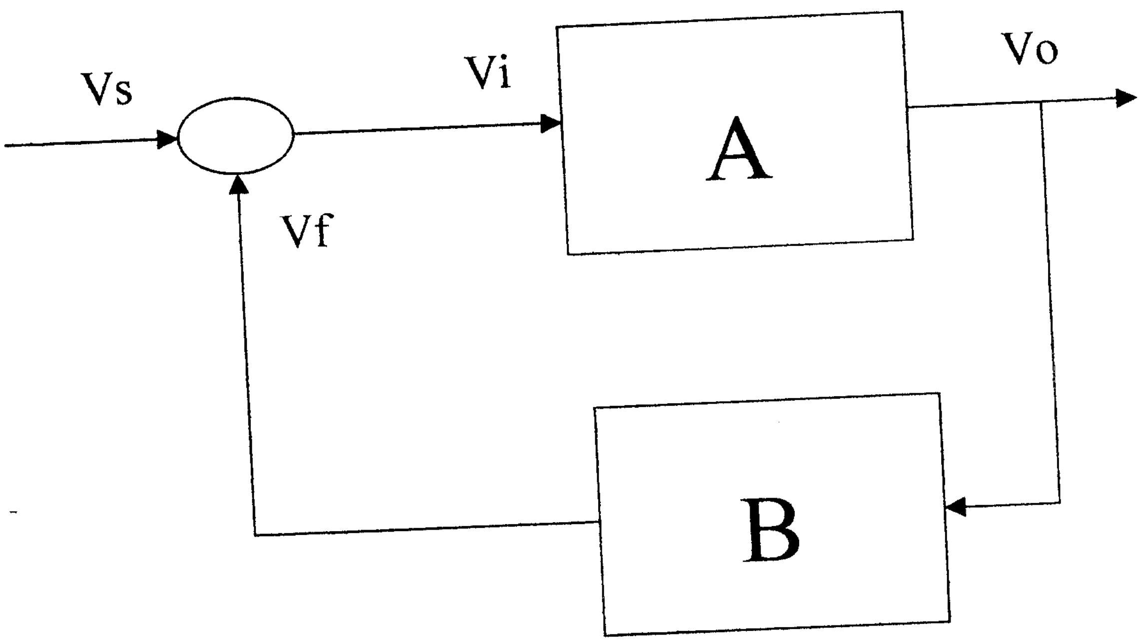


FIG 16

a tuned collector oscillator using a transistor in the common-emitter configuration is used to generate the high frequency oscillatory current.

The choice of the correct oscillator for a given application is based upon the following specification:

- Frequency stability required.
- Output frequency required.
- Allowable waveform distortion.
- Range of frequency tuning, if required.
- Output power needed.

NECESSARY CONDITIONS FOR OSCILLATIONS:

- For self-sustained oscillations in a circuit, the active device must permit power gain at the frequency of oscillation.
- The device must have sufficient gain to overcome circuit losses and establish exactly unity gain around the feedback loop i.e., $AB=1$.
- The phase shift introduced by the active device and the feedback network result exactly zero phase shift around the overall circuit.
- For building up of oscillation at the beginning, there must be more than unity loop gain i.e., $AB>1$

Tuned LC circuits can be made to store energy. The essential parameters of the oscillatory tank circuit are natural frequency of oscillations, selectivity and characteristic impedance. The tank circuit performs the following functions:

- *It determines the frequency of oscillation.*
- *It forms the feedback network.*
- *It determines the stability of the oscillator.*
- *It is a part of the coupling network to the load.*
- *It effected the noise energy output of the oscillator.*
- *It is a Principal factor determining the circuit efficiency.*

Thus the tank acts as a feedback network connected across the active device.

During the circuit operation, the capacitor 0.068 mF by passes 39K ohm and 2-ohm resistor so that they have no effect on the AC operation of the circuit. Thus they provide an AC ground to the transformer secondary L1.This arrangement is also used to couple the start up pulse to the base of the transistors. The start up pulse is obtained from the 65V AC secondary winding of the transformer T1.

BIASING:

The basis for the oscillator is obtained from the R1 C1 [R1=39K, C1=2000pF] parallel combination in series with the base as shown in the fig . If the R1 C1 time constant is large compared with one period, the base capacitor will charge upto the peak base voltage. The voltage across C1 acts as bias and the base is therefore driven slightly positive only for a short interval at the peak value is approximately at ground potential, so it can be said that the base is clamped to ground. The operation of this oscillation is class C.

When the circuit is first energized, the base bias is zero and it operates with a large transconductance Gm. The loop gain is therefore greater than unity and the amplitude of the oscillations start to grow. Clamping takes place and the bias automatically adjusts itself so that its magnitude equals the peak value of the grid voltage.

As the bias becomes negative, the value of Gm decreases and the amplitude stabilizes itself at the value for which the loop gain for the fundamental is reduced to unity. Thus oscillations will be sustained.

The feedback between the collector-emitter circuit and the base emitter circuit is provided by the transformer secondary-winding L1 mutually coupled to L. As far as ac signals are concerned L1 is connected to emitter via the low reactance capacitors.

OPERATION:

When the supply is first switched on, a transient current is developed in the tuned LC circuit as the collector current rises to its quiescent values. This transient current initiates the natural oscillations in the tank circuit. These natural oscillations induce a small emf into L1 by mutual inductance, which causes corresponding variation in the current.

The variation in the base current are amplified B times and appear in the collector circuit. Part of this amplified energy is used to meet the losses in the oscillatory circuit and the balanced radiated out in the form of electromagnetic waves.

As the frequency of oscillation equals the resonant frequency of the tuned circuit i.e., 1/LC, the impedance of the tank circuit is arbitrarily large and purely resistive. The transistors used for amplification produces a voltage drop across the collector to ground which is 180 degree out of phase with the voltage of the base.

The direction of the secondary winding is such that it will introduce an additional phase shift of 180 degree. A total phase shift of 360 degree or 0 degree is produced between the input and output, resulting in positive feedback between the two. Thus the oscillations produced are sustained.

DESIGN STEPS OF THE OSCILLATOR:

The design procedure for the oscillator is usually treated on the linear basis even though self-sustained oscillations indicate non-linear operation.

- *Select a transistor capable of providing sufficient gain and desired power output as the operating frequency based on the data sheet specifications.*
- *Design the DC bias network to establish the bias point and provide the necessary stability.*
- *Design the tank or frequency determining network so that the frequency of operations is according to the desired value by using the formula*

  W= 1/LC

  *F=1/2 * 3.14 * l*C*

- *Make necessary arrangements in the feedback and the bias network to optimize efficiency.*
- *Use a trimming capacitor capacitor to make final adjustments, if necessary, to the oscillator frequency.*

POWER AMPLIFICATION MODULE:

To attain the required current handling capability and requisite output power levels, a set of five Bux 48A power transistors are used in the parallel in the signal but will also provide sufficient amplification for the oscillatory action to take place. The outputs of the BJT's are connected to a parallel resonant circuit and the oscillatory current is taken to the output circuit.

This power amplifier is driven by the oscillator and is supplied with power directly from the power supply. As the Vbe in each of the transistors are not equal, equal current sharing is not possible. To facilitate this resistors are connected in series with the emitter. We have used wire wound resistors for this purpose.

WIRE WOUND RESISTORS

They are made by winding a wire made from metal alloy onto a ceramic former. They are used with either very low values of resistance (as specified) or when the resistor to be of very precise value.

Resistors of this type are usually non-inductively wound which means that the wire forming the resistance is doubled and wound in such a way that adjacent sections of the wire carry charges flowing in opposite directions and these fields will automatically cancelled out.

HEAT SINKS

One way to increase the power rating of a transistor is to get rid of the internal heat faster. This is the purpose of the mass of metal called the heat sink, through which we increase the surface area of the surrounding air. Two types of heat sinks are used in the surgical unit.

In a power tab transistor a metal tab provides a path out of the transistor for heat. This metal tab can be fastened to the chassis of the electronic equipment e.g., SCR because the chassis is a massive heat sink, heat can easily escape from the transistor to the chassis.

The BUX transistor is a large power transistor and if uses the second category of heat sinks. They have the collector connected directly to the case to let heat escape as early as possible. The transistor case is then fastened to the chassis.

To prevent the collector from shorting to the chassis ground, a thin mica washer is used between the transistor case and the chassis. The important idea here is that the transistor has a higher power rating at the ambient temperature. Sometimes, the transistor is fastened to a large heat sink with fins; this is even more efficient in removing heat from the transistor.

The purpose of the heat sink is to lower the case temperature because this will lower the internal junction temperature of the transistor.

CASE TEMPERATURE:

When heat flows out of a transistor, it passes through the case of the transistor and in to the heat sink, which then radiates the heat into the surrounding air. The temperature of the transistor case, Tc, will be slightly higher than the temperature of the heat sink. Ts, which inturn is slightly higher than the ambient temperature.

P = D [Tc.25 degree c]

Where

P – decrease in power rating.

D – derating factor.

Tc – case temperature.

PULSE GENERATOR MODULE:

The purpose of this module is to achieve pulse mode operation of the unit. It mainly comprises of the pulse generator, which is a 555 timer. In this case, it is operating in the astable mode.

MULTIVIBRATOR:

An electronic circuit that generates square waveforms or other sinusoidal waveforms such as rectangular, sawtooth wages is known as multivibrator. A multivibrator is a switching circuit, which depends for operation on positive feedback. It is basically a two-stage amplifier with output of one feedback to the input of the other. The circuit operation in two stages [i.e., ON and OFF] controlled by circuit conditions.

Depending upon the manner in which the two stages interchange their stages, the multivibrators are classifies as.

- Astable [or] free running multivibrator.
- Monostable[or] one short multivibrator.
- Bistable [or] flip-flop multivibrator.

ASTABLE MULTIVIBRATOR is also known as free running multivibrator. The circuit has to quasi-stable [no stable states]. Thus there is oscillation between these two stages and no extended signals are required to produce the change in state. Astable circuits are used generate square waves, for [e.g.] clock generator in digital systems.

TIMER USED IN ASTABLE MODE:

Fig 18(a) shows a 555 timer connected as an astable multivibrator. In this mode of operation, the timing capacitor charges towards Vcc [assuming Vo is high initially] through [Rs +Rb] until voltage across the capacitor reached the threshold level of 2Vcc/3. At this point comparator C1 switches state causing the flip-flop output Q to go high i.e., Q=V1.

FIG18(a) **Astable multivibrator using 555 timer**

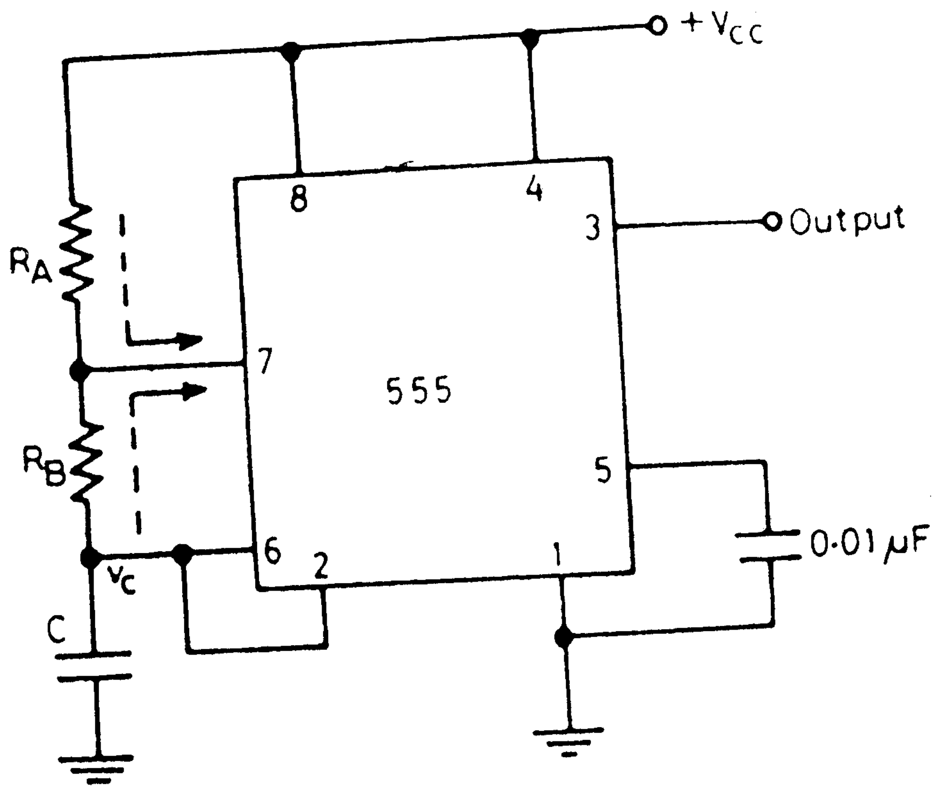
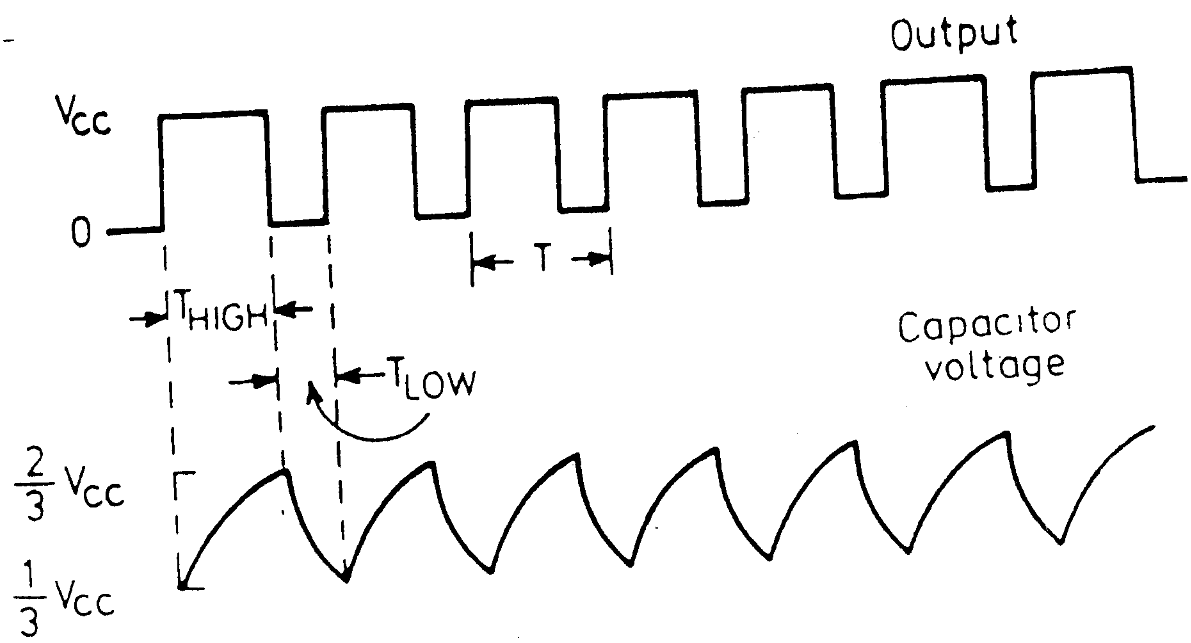


FIG18(b) Timing sequence of astable multivibrator



This turns 'on' the discharge transistor Q1 and the timing capacitor C then discharges through Rb and Q1 [pin 7]. The discharging continues until the capacitors voltage drops t Vcc/3 at which point comparator C2 switches states causing the Flip-flop output Q to go low, i.e., Q = V (1) turning 'off' the discharged transistor Q1. At this point the capacitor starts to charge again, thus completing the cycle.

The output voltage [Vo] and capacitor voltage [Vx] Waveforms are shown in the fig 18(b). As shown in this figure, the capacitor is periodically charged and discharged between 2Vcc/3, At this point comparator C1 switches state causing the flip-flop output Q to go high i.e., Q = V1,respectively let us determine these periods.

During the charging period $0 < t < Tc$, the voltage across the capacitor will be given by

$Vx=2Vcc/3\ [1-exp\ \{-t/[2+Rb]*C\}]+Vcc/3$

At time $t = Tc$, the capacitor voltage Vx reaches the threshold level of 2Vcc/3, so that

$2Vcc/3 = 2Vcc/3[1 - exp\ \{Tc/\{Rs+Rb\}*C\}] + Vcc/3$

Solving for the charging time T c gives,

$Tc = [Ra+Rb]\ C\ In2 = 0.0.693[Ra+Rb]\ C$ ⟶ [1]

During the discharge interval Td, we have that

$Vx=2Vcc/3 \exp[-t/Rb*c]$

At time t=Td, the voltage across the capacitor reaches the trigger level of Vcc/3

So we have that Vx [t=Td]

$Vcc/3=2Vcc/3 \exp[-Td/Rd*c]$

Solving for Td, we obtain

$Td=Rb*C \ln 2=0.693\ Rb*C$ ⟶ [2]

The total period T= Tc+Td and is given as

$T = 0.693[Ra+2Rb]\ C$ ⟶ [3]

And the frequency of oscillation will be

$Fo=1/T\ 1/[0.693[Ra+Rb]*C] = 1.44/[Ra+2Rb]*C]$ ⟶ [4]

Equation [4] indicates that the frequency Fo is independent of the supply voltage.

The % duty cycle of the output pulse waveform is given by

$\%\ Duty\ cycle = [Tc/T]*100 = [Ra+Rb]/[Ra+2Rb]*100$

The duty cycle will always be less than 50 % for this circuit. To achieve 50% duty cycle we should make Ra=0 ohms. However, there is a danger in making Ra=0 ohm, with Ra=0 ohm, Pin

7 is connected directly to positive Vcc When the capacitor discharges through Rb and Q1 an extra current is supplied to Q1 by Vcc through a short terminal between Pin 7 and Vcc which does not requires shorting of Ra This circuit produces output with 50% duty cycle simply by connecting diode D across resistor Rb. Astable multivibrator with 50% duty cycle is also knowns as a square wave oscillator.

The output of the timer is fed to the base of a switching transistor which is used to switch the pulse generated to the main oscillator for the modulation of the high frequency signal thus reducing the power level to that required for pulse mode. BUX 48A is used here for this purpose. Necessary isolation between the pulse generator and the oscillator circuit is achieved by means of a ferrite -core transformer.

DESIGN CONSIDERATION FOR ASTABLE OPERATIONS:

The configuration of the 555 timer with the various resistor values to generate a signal of frequency 50 MHz is shown in fig 19. The resistor values are chosen according to the formula

$F = 1.45/[Ra + 2\ Rb]*C$

Where,

f = 50 MHz.

Ra=2.2K ohm.

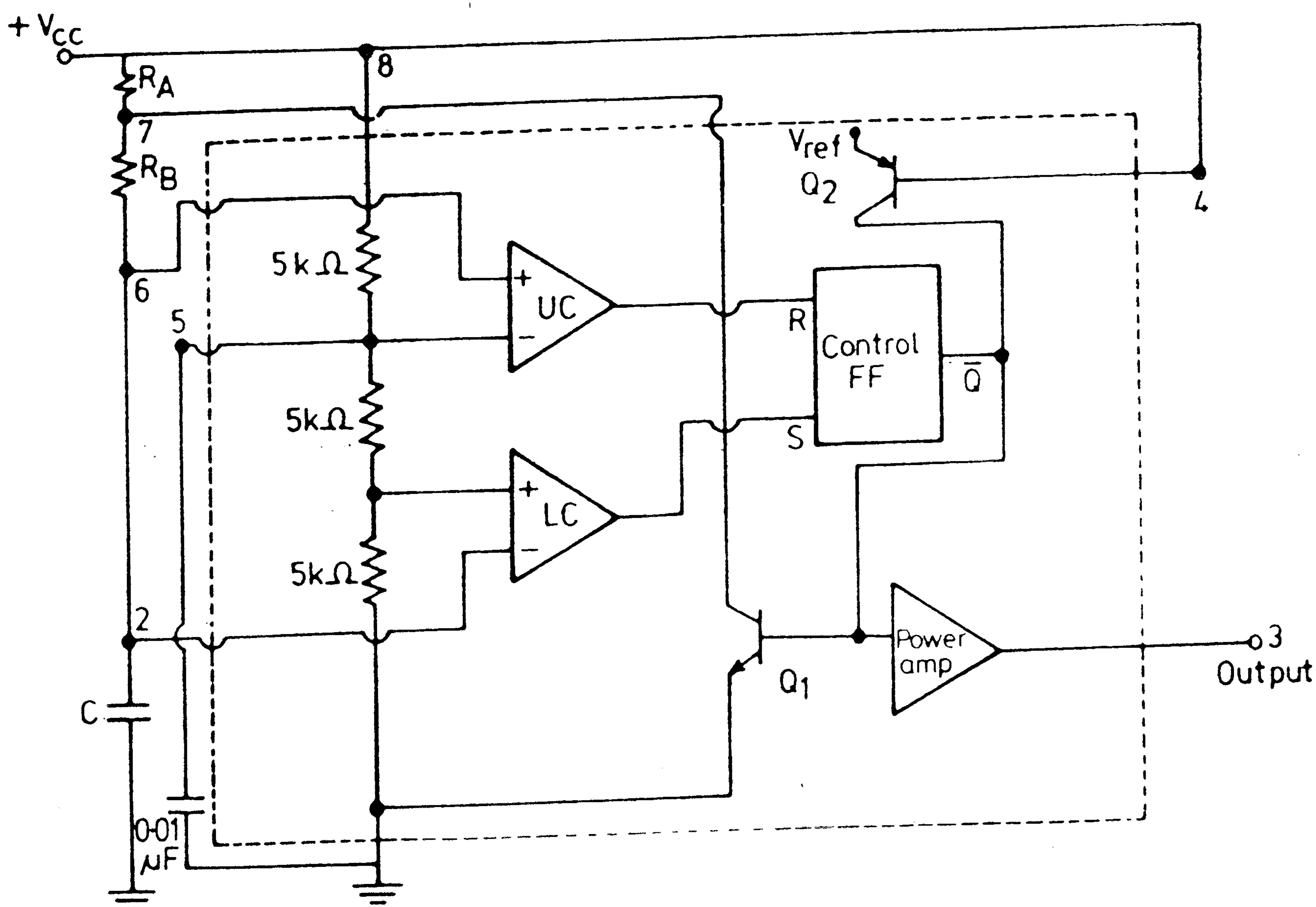
c = 0.01 Micro F.

Pin 5 can be used to vary the timing or frequency as a function of control voltage. Bypass capacitor C1 range between 0.1 and 10 Muf. Disc. Ceramic or tantalum capacitors should be used. The timing capacitor should be silver, mica, polystyrene, tantalum, or mylar for best results. Also the timing capacitor leakage should be much less than the available charging current.

OUTPUT CIRCUIT MODULE

The module consists of a ferrite core transformer, which is used both in the 555-output timer and also the collector output to the electrode. During the past two decades, developments of a wide range of ferrites have given rise to a new technique in the overall improvement of the communication and computer system.

The rapid development and increasing complexity of radio frequency equipment emphasized the need for a ferromagnetic material in which eddy current losses would not be a serious problem



FIG(19) **Functional diagram of astable multivibrator** *at high frequency because of it's high resistively. The reduction of eddy current losses was achieved by laminating the cores.*

Ferrites are hard and brittle, ceramic like material, which cannot be shaped by normal machining techniques. The negligible eddy current in ferrites at high frequency enables the transformers to be replaced by solid state ferrite cores resulting in a considerable amplification in construction. The absence of eddy currents in the ferrite allows the material to be affective in producing a larger concentration of magnetic flux in the ferrite rod.

The use of ferrite rod cores for output transformers has considerable advantages in overall performance with very little increase in power requirements.

In our circuit, the ferrite core transformers are mainly used as cores of high frequency inductors and transformers. Ferrites are usually dense homogenous ceramic structures. Generally, ferrites are expressed by the molecular formula MF e203 [M is an Oxide of a divalent metal]. Mixed ferrites such as manganese zinc ferrites [Mn-Zn] and nickel-zinc ferrites [Ni – Zn] are mainly used as

APPLICATIONS

- *Ophthalmology.*
- *Surgery on prostrate gland.*
- *Urology.*
- *Neurosurgery.*
- *Carcinoma surgery.*

OPHTHALMOLOGY:

Ophthalmologists use them to treat a variety of eye problems including retinal bleeding, the excess growth of blood vessels in the eye caused by diabetes and for " spot welding" i.e., reattaching retinal that have become partly detached from the back surface of the eye, the chroid. To do the same, surgeons have used the photo coagulation effect i.e., heating the tissue to 60 degree centigrade to denature the proteins. Here the target molecules for light absorption are blood [hemoglobin] and pigment epithelium. In ophthalmic surgery liquid electrodes are preferred to metal electrodes as uniform contact with the tissues can be established and maintained permitting careful control of electric current. Certain types of Eglaucoma i.e., increased pressure in the eye can also be treated by this technique.

CONCLUSION:

Surgery has come a long way in the last two or three decades. One of the most recent advances has been the development of robots to perform precise total joint operations. The surgical electro technology is evolving at a steady rate. Thus, the patient can now look to science for a solution to his predicament and also a kinder and simpler treatment.

The benefits to the patients outweigh the potential risks that are involved. This unit is a low cost, low power-working model. The improvements that can be incorporated in this unit for safety and reliability are:

- *The use of optical isolators.*
- *Microprocessor based self-diagnostic procedures.*

It is also possible to generate the electrosurgical unit waveforms with a microprocessor controlled pipeline memory, which directly accesses the analog modulation circuit, but the idea is still in the research stage.

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APPENDIX

CK 100 [PNP] and CL 100 [NPN]

FEATURE :

- High collector-emitter breakdown voltage and current handling capacity upto 1 amp.
- Silicon planar epitaxial PNP and NPN complementary transistors with build in sink.

SPECIFICATIONS :

Collector	Emitter Voltage 1	Vceo 50 V.
Collector	Base Voltage	Vcbo 60 V.
Emitter	Base Voltage	Vebo 5 V.
Collector	Continuous current	Ic 1000 mA.
Total device dissipation Tambient [25 deg C]		Pd1.75 W.
Total device dissipation [25 deg C]		Pd 10W.
Storage junction Temperature TiTbT		–55 deg to 150 deg C.
Collector	Cut-off Current	Icbo 50 nA[max].
Emitter	Cut-Off Current	Iebo 25 nA [max].