Automatic Voltage Controlled AC Supply with Overload Protection

PROJECT REPORT

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submitted by

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This is to certify that the following **ELECTRICAL AND ELECTRONICS ENGINEERING** branch students of **KUMARAGURU COLLEGE OF TECHNOLOGY, COIMBATORE** have successfully completed and tested the project titled **"AUTOMATIC VOLTAGE CONTROLLED AC SUPPLY WITH OVERLOAD PROTECTION"** in our concern.

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In the period of December'95 to April'96.

For **CONTROLS & DRIVES COIMBATORE (P) LTD.**

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DEDICATED TO OUR BELOVED PARENTS

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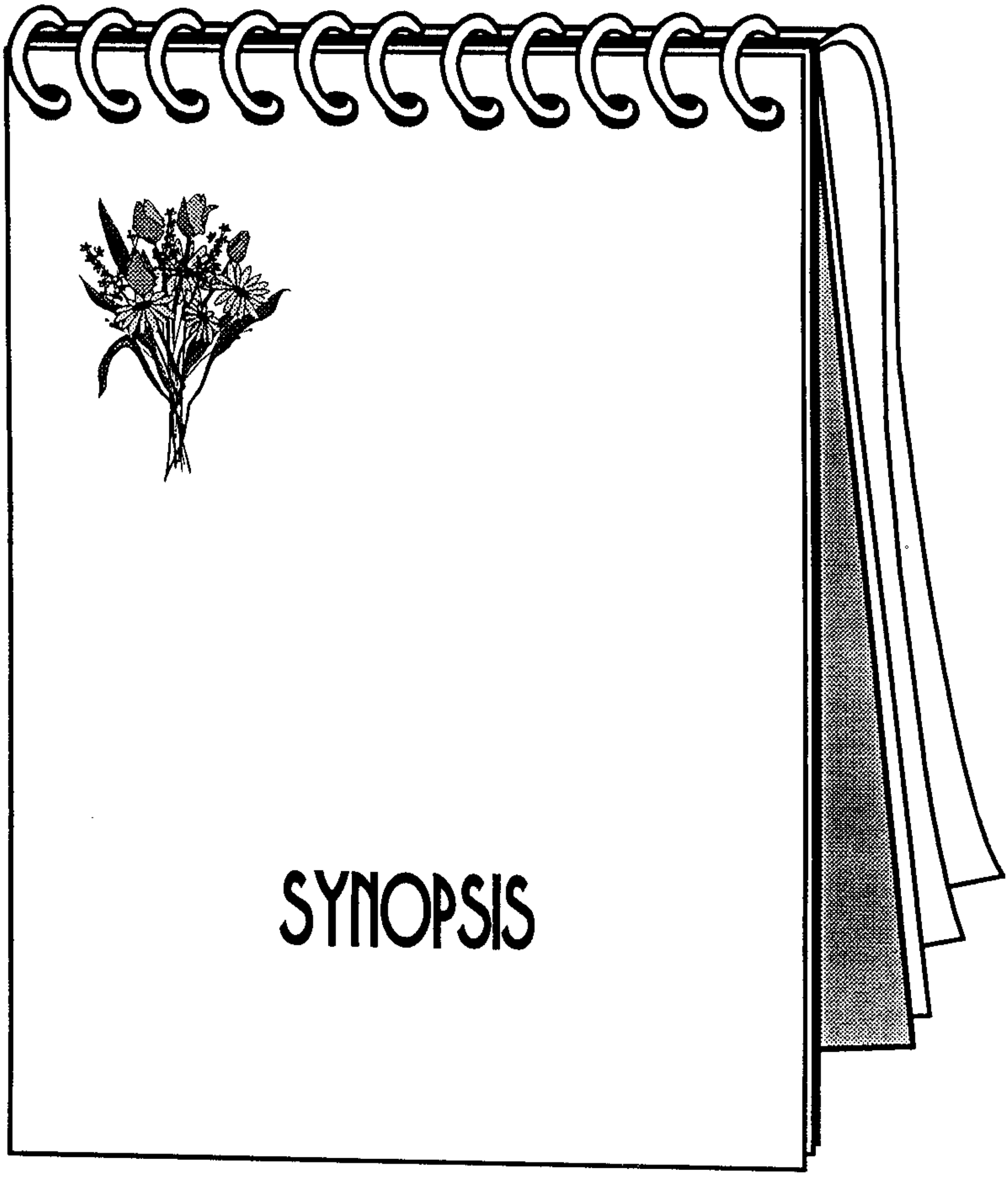
SYNOPSIS

SYNOPSIS

The machines of the modern era required power supplies within a specified range of voltage. And the immediate requirement of the consumer is a single unit with controlled output voltage for all the electrical appliances used in house with automatic 3 phase to 1 phase change over and overload protection.

Our project, titled "**Automatic Voltage Controlled A.C. supply with Over - Load Protection**", is a sure step towards satisfying the market requirement.

This project basically deals with the design, fabrication and testing of automatic voltage controlled A.C. supply and P.C. based design of transformers. The toroidal transformer used ensures higher efficiency than the other core transformers.

Consequently the shape and size of the unit has been designed so that it is wall mountable. Necessary indications have also been provided to indicate the state of the unit.

The design particulars, fabrication details, mode of relay mechanism and the testing procedure have been extensively dealt within this report.

CONTENTS

CONTENTS

CHAPTER 1

INTRODUCTION

INTRODUCTION

1.1. NEED FOR VOLTAGE STABILIZER WITH OVER LOAD PROTECTION

According to specifications of each electrical equipment, the power supply voltage should not rise or drop by more than 5% of the normal voltage. But we find voltage fluctuations from the 230v main supply voltage to as low as 140v or as high as 280v occasionally.

When the supply voltage is other than 200v - 250v the efficiency and life span of the electrical equipment are reduced and some of the equipments will not function properly. With enormous increase in loads connected to a distribution transformer, the electricity supplier now finds it exceedingly difficult to maintain the voltage within the stipulated values. This has made it necessary the use of an automatic voltage stabilizer for almost every equipment. Even domestic appliances like refrigerators and television sets need a stabilizer before connecting it to the power supply, not to speak of computers and other expensive equipments.

Instead of using a stabilizer for each and every appliance a single unit can be installed for all the equipments.

The load on the power supply unit should not exceed the rating and hence to control the over load protection should be done.

1.2. PRINCIPLE OF VOLTAGE STABILIZER

Fig 1.1. shows the block diagram of voltage controlled a.c. supply connected to the mains. When there is a change in input voltage from 140v to 280v, the output voltage of 200v to 250v.

The stabilizer's size increases generally with its KVA rating.

1.3. TYPES OF VOLTAGE STABILIZERS

The various types of voltage stabilizers are

a Ferro resonant type stabilizers.
b Servo type stabilzers.
c Relay type stabilizers.

1.3.1. FERRO RESONANT TYPE STABILIZER

This type of stabilizer uses two transformers and one of them is of saturating core. The principle at ferro resonance in a saturating core was used to keep the output voltage constant even though the input voltage had variations over and below the rated nominal voltage. But the output voltage waveform in such a stabilizer is distorted due to the saturation effects and some equipments face this problem. But ferroresonant type being a static, with no moving parts is reliable and has a long life.

1.3.2. SERVO STABILIZERS

Conventional stabilzers employ a toroidal and a servomotor driven by a current which senses the voltage. The toroidal auto transformer has a toroidal core. It has a contact arm housing a carbon brush, which makes a sliding contact with the coil wound over the toroid, just as in potentiometer. The toroidal core is circular.

Enamelled copper wire which is wound around the toroid uniformly, is exposed at the top side where the contact is made by the carbon brush of the moving assembly. The output voltage is varied automatically on varying the position of this contact. For this purpose, a servo motor fitted with gears is coupled to the contact arm.

The sensing circuit senses the voltage difference between the output and the nominal voltage. It drives the servomotor after suitable power amplification in clock wise or anticlock wise direction. As the motor moves the contact on the winding of the auto transformer, it reduces the voltage difference. The voltage difference becomes zero when the output voltage reaches the nominal value and hence there is no error signal now.

A servo stabilizer has the following disadvantages. It tends to 'hunt' if the input voltage fluctuates too often. Also it acts slowly and cannot adjust to sudden shoots or drops of main voltage. Actually the servo motor takes atleast a second to make a movement for say a 20v input change. But if the voltage fluctuates suddenly from say 180v to 260v, as is common when a heavy power load is switched off on the distribution line it will take more than one second and during this time, the equipment will be subjected to this sudden over voltage of 260v. Infact, it is these sudden fluctuations that really spoil the equipment.

1.3.3. RELAY TYPE STABILIZER

Relay type automatic stabilizers carter for small variations in input voltage.

The relay contact change over is done by a sensing circuit. This circuit compares a fraction of the rectified input voltage with a fixed reference voltage depending on the value being over or below the reference, it causes the relay to operate in the extra boost, boost, normal and buck positions.

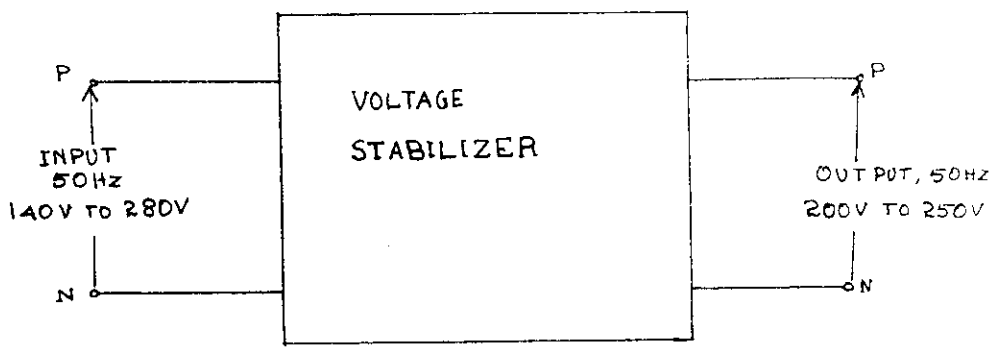

Fig 1.1 GENERAL VOLTAGE STABILIZER

CHAPTER 2

BLOCK DIAGRAM AND OPERATION OF THE UNIT

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2.1. INTRODUCTION

The block diagram shows the essential components of the unit. It comprises of the following components:

1 On line phase selector
2 Two pole two way switch
3 Toroidal transformer
4 Relay section
5 Over load protection relay
6 Control card
7 Indicators, etc.

The operation of the whole unit is illustrated with the help of the block diagram. The unit is designed to control the line voltage which is selected by the on-line phase selector within the range of 200v to 250v against the line voltage changes of 140v to 280v.

For the designing convenience the entire line voltage range to be controlled is divided into four ranges. The operating modes and the corresponding voltage ranges are shown in table 2.1.

The control circuitry senses the line voltage and selects the correct mode by energising and de-energising the appropriate relays. The unit is in the OFF state when the line voltage is less than 140v and greater than 280v and the appropriate indications will be activated.

Since the unit is designed to draw 5 KVA as the maximum power it is provided with over load protection circuitry. It senses the output power when it is over loaded and the corresponding indications are activated.

In case of any fault in the unit the user is allowed to utilise the electrical power from the main line directly by changing manually the position of the bypass switch.

2.2. ON LINE PHASE SELECTOR

Nowadays the houses are provided with 3 phase supply. The on-line phase selector is used to select one of the three phases in which the supply is available and gives a single phase output.

The connection diagram for obtaining the on-line phase selector using two contactors are shown in fig 2.2. The coil of contactor 1 is connected across the Y phase and neutral, and coil of contactor 2 is connected across the B phase and neutral.

When B phase is alive, contactor 2 closes contacts 4-4' and selects B phase. When B phase is not alive contactor2 closes contacts 3-3'. When phase is alive contactor1 closes contacts 2-2' and selects Y phase . When Y phase is not alive contactor1 closes the contact 1-1' and selects R phase.

The contactor used here is an electromagnetic attraction type shown in fig 2.4. The contactor has an electro magnet energised by coil. This coil is energised by the operating quantity. A plunger is subjected to the action of magnetic field produced by the operating quantity.

2.3. RELAY SECTION

The relays are used to select the appropriate tappings of the toroidal transformer. The relay coils are energised and de-energised by the voltage control card. The relays used in this unit are double change over electromagnetic relay shown in fig 2.3.

The relay comprises of an electromagnet energised by a coil whose energising voltage is 12v d.c. and a spring controlled movable contactor.

The three relay connections for proper selection of the toroidal transformer tappings are given in fig 2.5.

The tapping selection, energising and de-energising configuration of relays are shown in table 2.2.

TABLE 2.1. OPERATING MODES

SERIAL NO.	MODE OF OPERATION	LINE VOLTAGE RANGE
1	EXTRA BOOST	140 v - 180 v
2	BOOST	180 v - 220 v
3	NORMAL	220 v - 250 v
4	BUCK	250 v - 280 v

TABLE 2.2. RELAY CONFIGURATION

TAPPING SELECTED	RELAY ENERGISING CONFIGURATION		
	A	B	C
EXTRA BOOST	1	0	0
BOOST	1	1	0
NORMAL	1	1	1
BUCK	1	0	1
CUT - OFF	0	0	0

1 - INDICATES THE CORRESPONDING RELAY IS ENERGISED.
0 - INDICATES THE CORRESPONDING RELAY IS DEENERGISED.

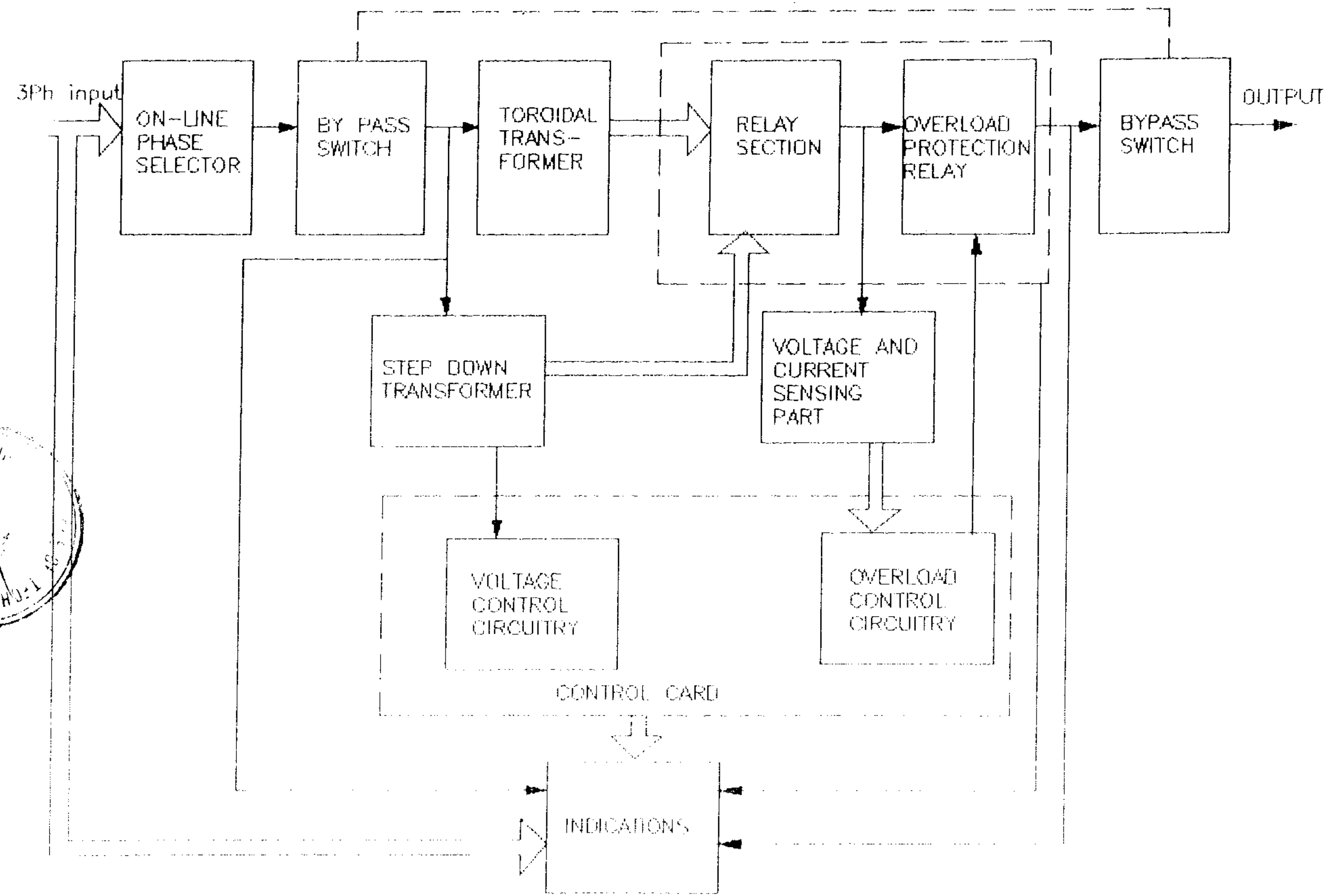


Fig 2.1 BLOCK DIAGRAM OF AUTOMATIC VOLTAGE CONTROLLED A.C.SUPPLY WITH OVERLOAD PROTECTION

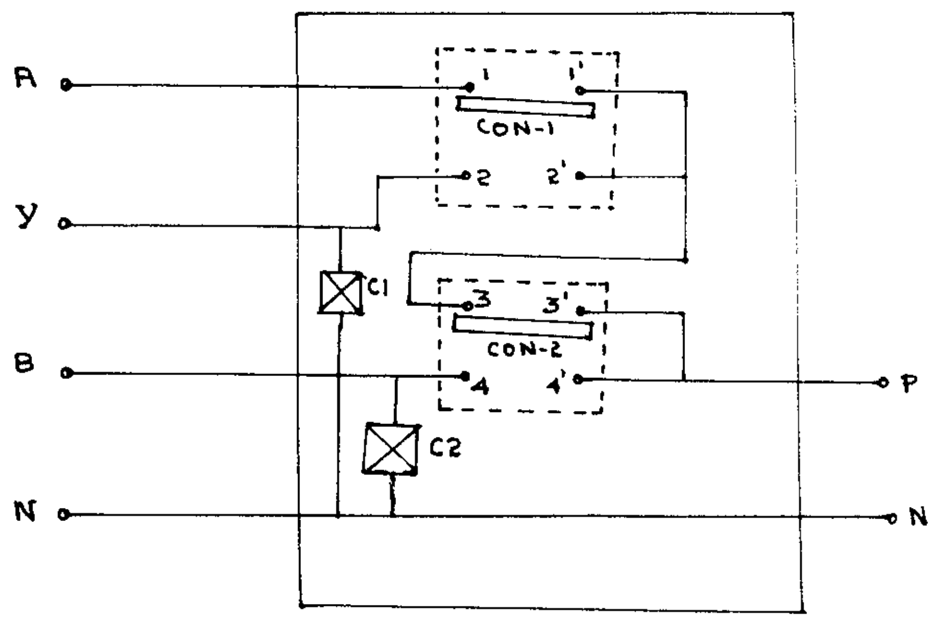


Fig 2.2 ON-LINE PHASE SELECTOR

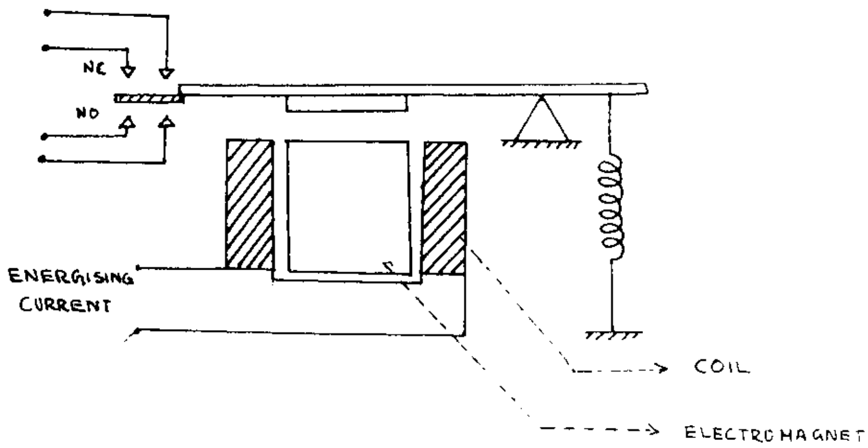


Fig 2.3 RELAY

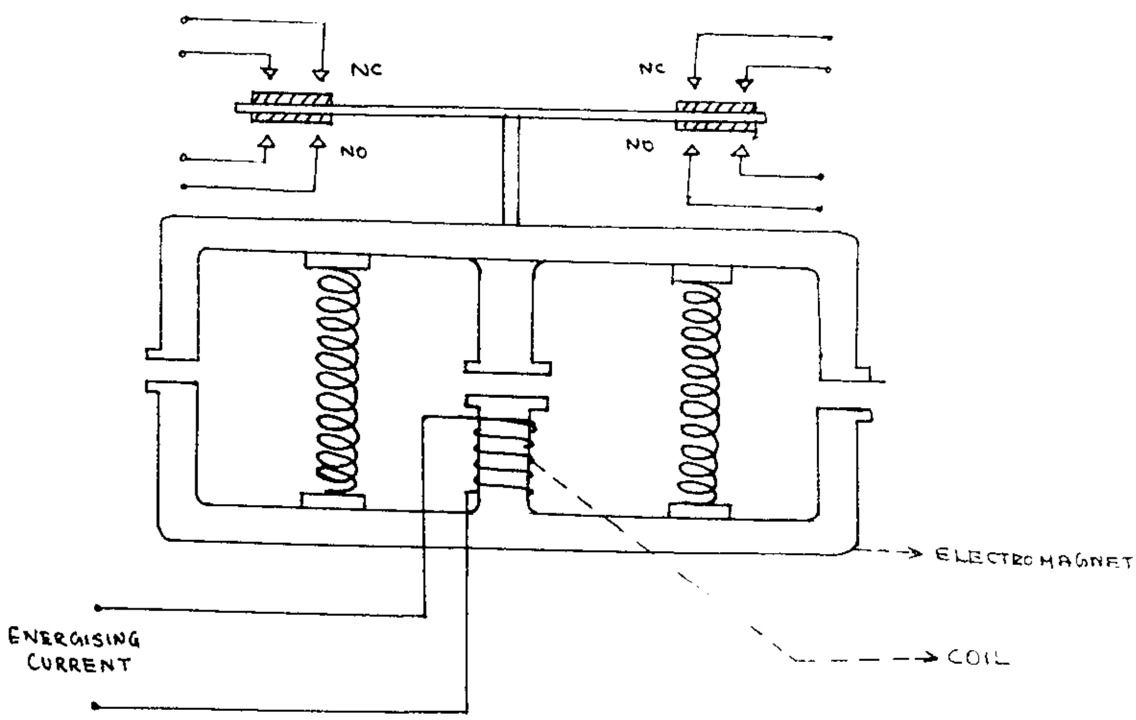


Fig 2.4 CONTACTOR

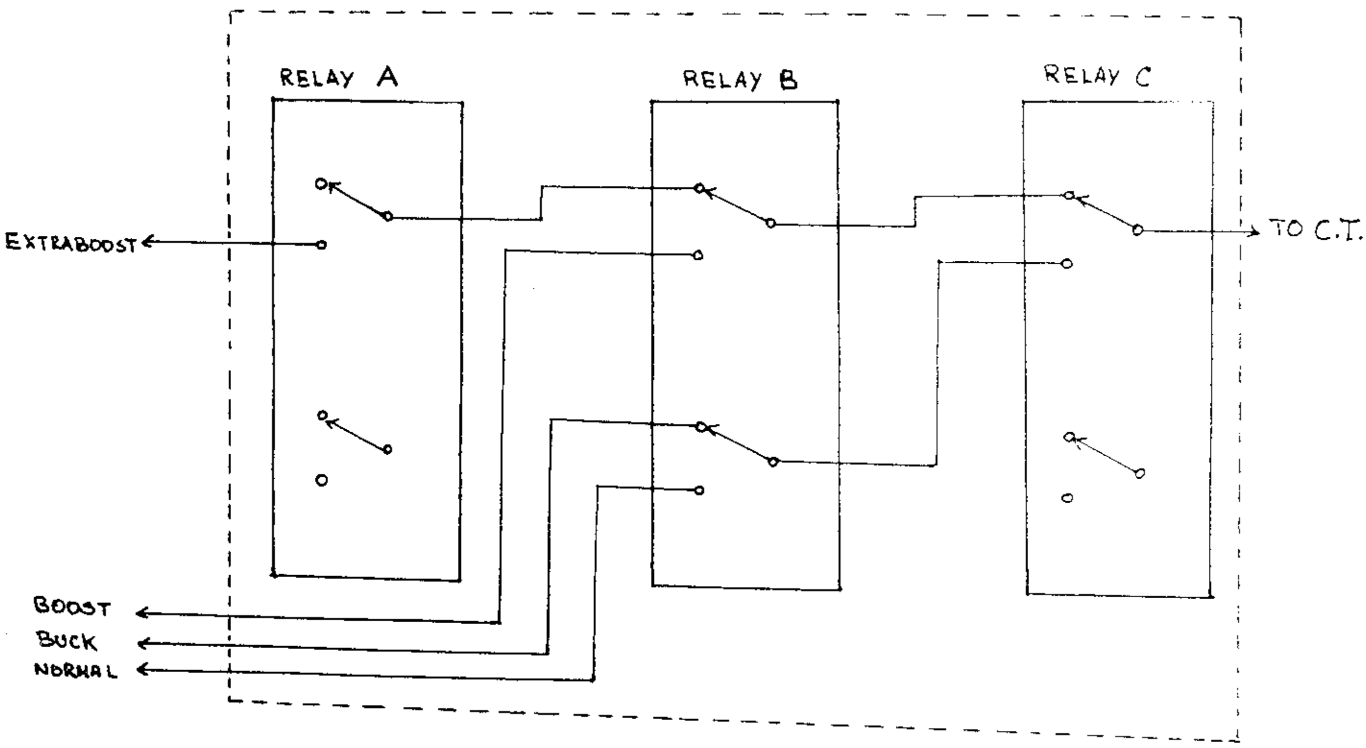


Fig 2.5 RELAY SECTION

CHAPTER 3

VOLTAGE CONTROL CARD

VOLTAGE CONTROL CARD

3.1. OPERATION OF VOLTAGE CONTROL CIRCUITRY

The circuit diagram of voltage control card is shown in fig 3.1. The function of the voltage control card is to maintain the voltage within its range of 200 volts to 250 volts by selecting the appropriate tapping on the toroidal transformer through the relays according to the input voltage.

The input voltage is stepped down using a transformer which has two secondaries and is given to the voltage control card. These two a.c. voltages are rectified using two bridge rectifiers and filtered using capacitor filters in order to get a smooth d.c. voltage. The output of bridge2 is used for energising the relay coil and output of bridge1 is used for generation of reference and sensing voltage. A zener regulator is used to obtain a constant reference voltage of 3.3v from the variable d.c. voltage.

The ground of bridge2 is raised to the level of reference voltage with respect to the ground of bridge1. Therefore the switching transistor goes to ON state, when the bridge voltage is greater than ground2 voltage by 1.2volts (i.e., V_B is 4.5v respect to ground1)

The variable sensing voltage is given to five potential dividers. The output voltage of bridge2 is given to the 3 set of PNP-NPN direct-coupled transistor amplifiers which act as switches.

The 3 relay coils are connected between the collector of PNP transistors Q3, Q5, Q7 and ground2. The diodes D7, D9 and D11 connected across the relay coils are functioning as free wheeling diodes. The movable terminals of the five potential dividers are connected to the base of five NPN transistors (switching transistors) Q2, Q4, Q6, Q8 and Q9 and their movable terminals are positioned in such a point that the specified transistor will be biased according to the input line voltage. The transistor Q1 is used to drive the low voltage indicator. When the input line voltage is below 140v no transistor will be biased and the L.V. indication LED will get the proper voltage and it glows.

When the input line voltage crosses 140v the transistor Q1 and Q2 will get proper bias voltage and will go to ON state, causing the L.V. indication LED not to glow and the transistor Q2 provides the base bias voltage for transistor Q3. The transistor Q3 will go to ON state and the relay A will be energised. When the input line voltage becomes 180v the transistor Q4 will get necessary bias voltage which brings the transistor Q5 into ON state and the relay B will be energised. When the input line voltage becomes 220v the transistor Q6 will get the necessary bias voltage which drives Q7 into ONstate and the relay C will be energised.

When the input line voltage becomes 250 volts the transistor Q8 will get the correct bias voltage which drives the transistors Q4 and Q5 into OFF state by making the base voltage of transistor Q4 as zero and relay B will be de-energised.

When the input line voltage becomes 280 volts the transistor Q9 will get the correct bias voltage and it brings the transistor Q6, Q7, Q2 and Q3 into OFF state by making the base voltage of transistor Q2 and Q6 to zero. The relays A and C will be de-energised and the H.V. indicating LED will get the necessary voltage and will glow.

3.2. TRANSISTOR ACTING AS A SWITCH

3.2.1. SWITCHING DESIGN CONSIDERATION

The basic concept in switching circuit is that of a discrete change in state of voltge change, a current change or both. It is used to transfer energy as in relay drivers.

Two static states are considered in transistor circuitry, the ON state is marked by a very low collector current and the OFF state is marked by a relatively high collector voltage and a very small collector current. The selection of components and supply voltages which allow this change of state will be called the "d.c." design procedure.

A transistor cannot change the states in zero time. The time interval between initiation and completion of the switching action is a measure of switching speed. In this relay type stabilizer, the switching time of transistor is negligible when compared to the change over time of electromagnetic relays. One of the first step in switching circuit design is the selection of circuit values to ensure turn-on and turn-off in the circuit.

A worst case design may be accomplished by assuming that all transistor and component tolerances go to their worst case at one time.

The transistor maximum and minimum parameter values are obtained from the data sheet. The resistor and power supply maximum and minimum values are determined from the relationships,

$$\overline{X} = \text{Xnominal} (1 + \Delta)$$

and $$\underline{X} = \text{Xnominal} (1 - \Delta)$$

where Δ is tolerance of X expressed as a decimal fraction. The temperature effects on resistors are ignored, assuming that the temperature change is compensated by a uniform drift of all resistors in the same direction. Temperature effects on transistor however must be considered.

The turn ON worst case occurs at low temperature and turn OFF worst case occurs at high temperature. The worst case design procedure yields the most reliable individual circuit.

A special case of statistical design technique is satisfactory for many applications, nominal values of resistance and supply voltage are used with worst case values of transistor, current gain and leakage currents. The yield of usable circuits is usually very high for this type of design.

In a switching circuit, the average power dissipated in the transistor is much less than the peak dissipation. Consequently, relatively large currents and voltages can be handled without exceeding the rated dissipation of the transistor however the voltages should be limited to a safe value below the breakdown voltage and the current should stay within the maximum ambient temperature.

The expression 3.1 is the average power dissipated in a transistor switch.

$$P(\text{average dissipation}) = \frac{V_{CE(sat)} I_P T_{ON}}{T} + \frac{V_P I_{CO} T_{OFF}}{T} + \frac{I_P V_P T_{SW}}{3T} \qquad (3.1)$$

ON OFF SWITCHING

The equation illustrates the fast switching and low saturation voltage for efficient switching.

3.2.2. LOAD LINE ANALYSIS

An important consideration in achieving maximum reliability in a high-load switch is the transistor's load-line. A method of observing load line is shown in fig 3.2.

The vertical plates of an oscilloscope are connected across a small resistor inserted in the collector circuit. It should be non-inductive, and its resistance should be much smaller than any other impedance in series with the transistor. The horizontal plate, are connected to the collector and emitter terminals. The resulting trace shows the current and voltage that the transistor is handling as it functions in the circuit. The peak power dissipated by the transistor during switching can be determined by taking the peak product of the currents and voltages which occur simultaneously.

A load line for a single ended switch with an inductive load is shown in fig 3.5. The voltage induced in the inductance at turn-off adds, to the supply voltage spike. This voltage could exceed the applicable collector to emitter voltage spike and collector to emitter voltage break-down of transistor BV_{CEX}.

Another equally important possibility is that the transistor would experience a secondary voltage breakdown because of the large current and voltage appearing simultaneously during turn OFF. That is the maximum allowable collector to emitter voltage is determined by the load line as well as by rated BV_{CEX}. From the voltage consideration alone, the maximum collector-emitter voltage could safely approach BV_{CEX}. But loading consideration (i.e., simultaneously current and voltage variations) often reveals that the maximum voltage must be restricted to some what less than BV_{CEX}, especially for inductive load. Limiting the maximum collector to emitter voltage to BV_{CEX} rating (rather than to BV_{CEX}) often affords a safety factor for resistive and slightly inductive loads. However even this may not be conservative enough for a high-level switching circuit with an inductive load line similar to than shown in fig 3.7.

In every instant it is advisable to switch the transistor operating point through due region of high dissipation as rapidly as possible. The most common method of protecting the transistor from the energy stored in the inductance of an inductively loaded single-ended switch is shown in fig 3.6.

The diode limits the voltage across the transistor during turn-OFF of the supply voltage.

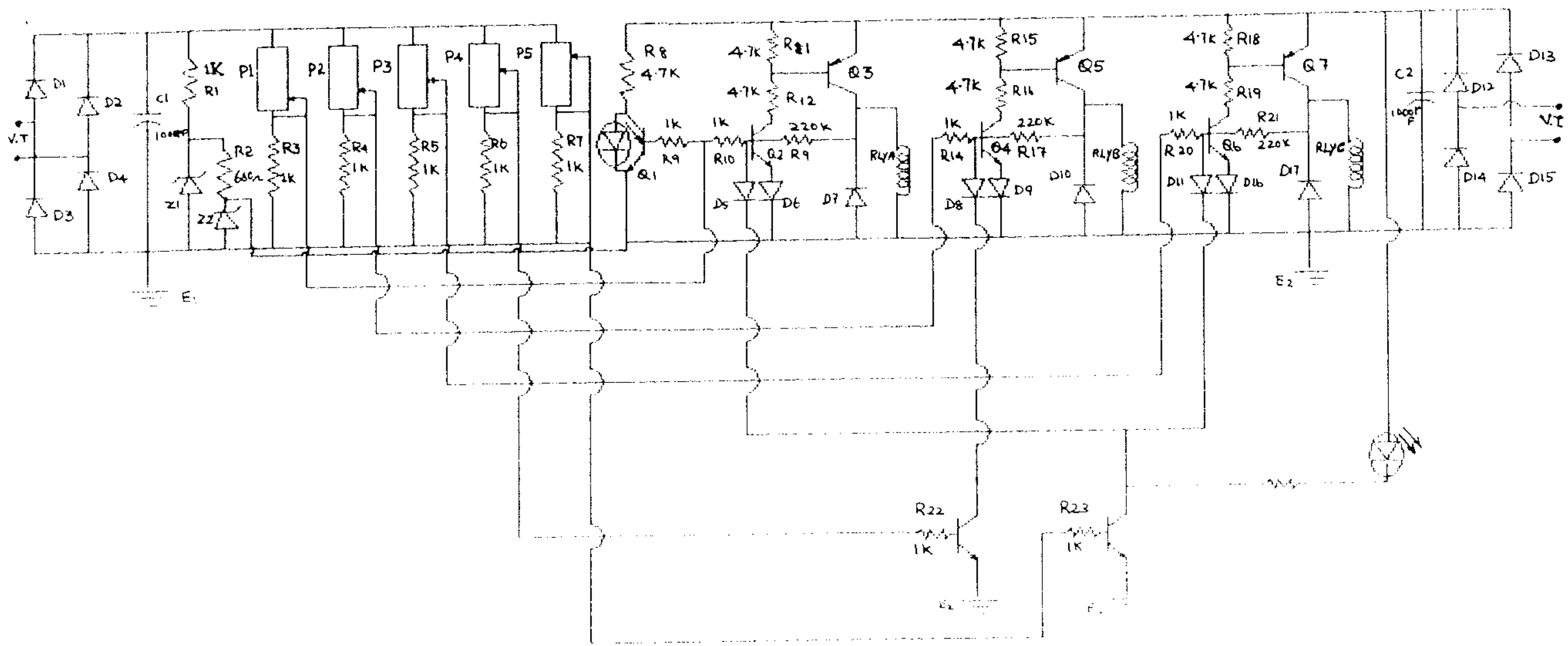


Fig 3·1 Voltage Control Card

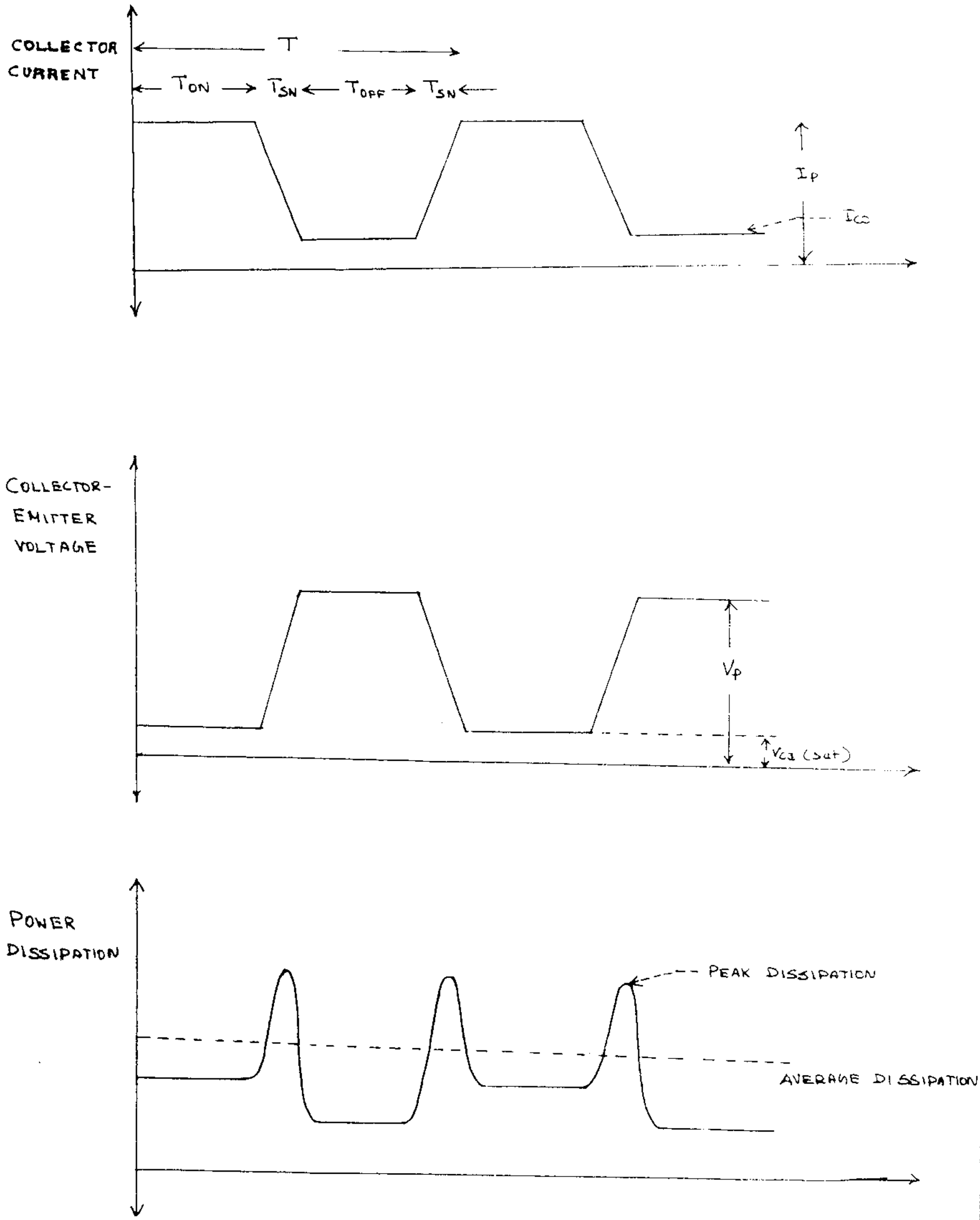


Fig 3·2 IDEALISED CURRENT AND VOLTAGE WAVE FORMS OF SWITCHING TRANSISTOR.

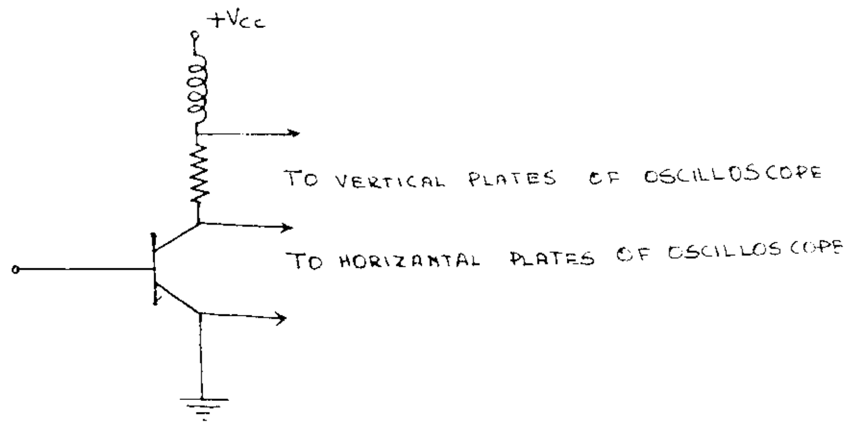


Fig 3.3 CIRCUIT DIAGRAM FOR OBTAINING LOAD LINE OF A TRANSISTOR

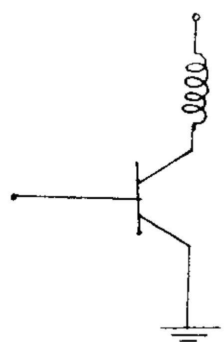


Fig 3.4 TRANSISTOR WITH INDUCTIVE LOAD

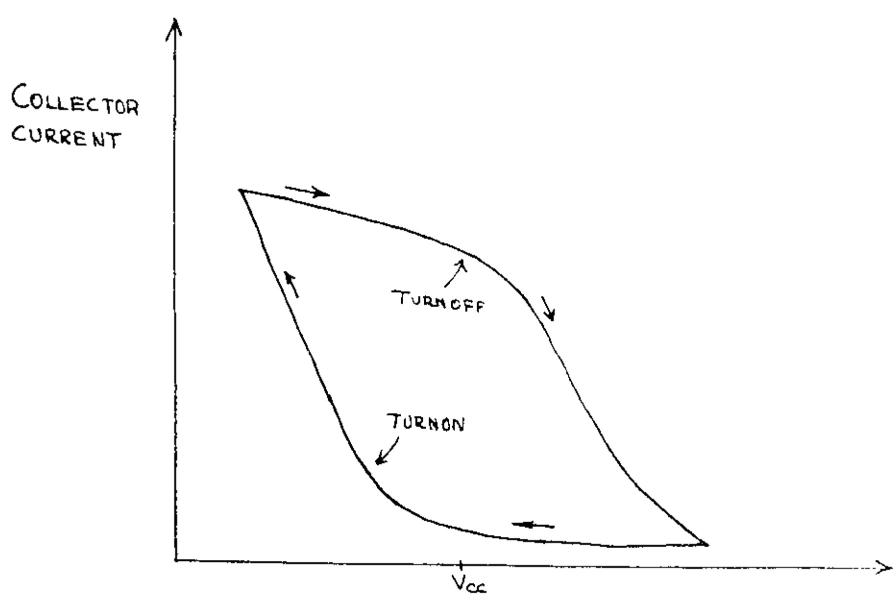


Fig 3.5 LOAD-LINE OF A TRA SISTOR WITH INDUCTIVE LOAD

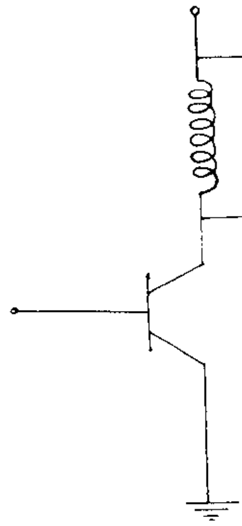


Fig 3·6 TRANSISTOR WITH INDUCTIVE LOAD HAVING FREE WHEELING DIODE

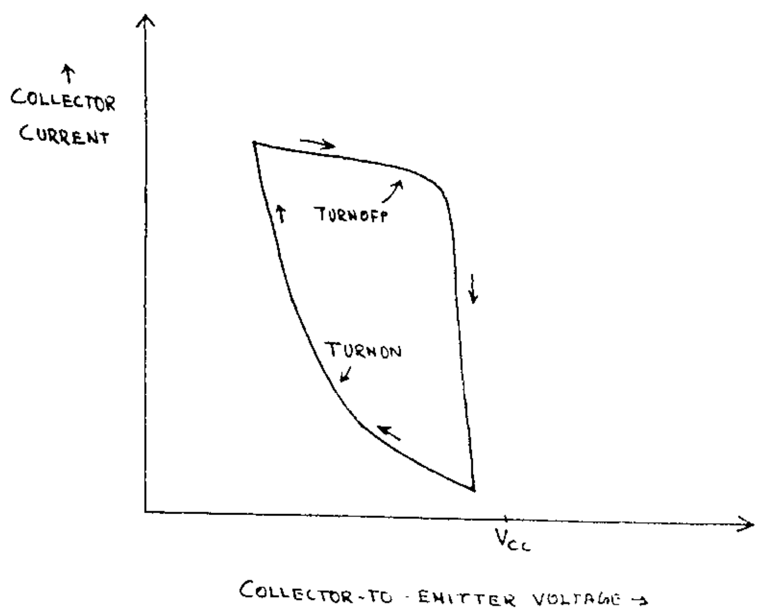


Fig 3·7 LOAD-LINE OF A TRANSISTOR WITH INDUCTIVE LOAD HAVING FREE WHEELING DIODE.

CHAPTER 4

OVERLOAD PROTECTION CARD

OVER LOAD PROTECTION CARD

4.1. OPERATION OF THE OVER LOAD PROTECTION CIRCUITRY

The function of the over load protection card is to monitor the output voltage and current. When the output exceeds 5 KVA. The over load protection card should actuate the over load protection relay and the over load indications.

The sensing circuitry senses the output voltage and current, of the unit using voltage and current transformers and provides two voltage signals V_{OV} and V_{OI} to the power supply section of the over load protection card. The voltages V_{OV} and V_{OI} are proportional to output voltage and current respectively.

The power supply section of the over load protection card is shown in fig 4.1. The signal voltage V_{OI} from the current transformer is rectified by bridge rectifiers and filtered using capacitor filter. The voltage V_2 across the terminating resistor of the bridge rectifier varies proportional to the output current of the unit.

The voltage signal V_{OV} from the voltage transformer is rectified using a half wave rectifier and filtered using a capacitor filter. The +12 volt and -12 volt d.c. supply for IC's and LED are obtained using three zener regulators in the output of the three rectifiers.

The reference voltage for KVA setting is obtained by using a 7812 IC regulator. One of the rectifier output is given to a potential divider and the movable terminal of the potential divider gives a voltage V_1 which varies in proportion to the output voltage of the unit. The KVA setting section is shown in fig. 4.2.

The voltage signals V_1 and V_2 are given to the inverting input of two logarithmic amplifiers. The logarithmic amplifiers gives the output voltages proportional to the logarithmic value of V_1 and V_2 (i.e.) Log-Amp2 gives the output voltage V_1' proportional to the logarithmic value of output voltage of the unit and Log-amp3 gives the output voltage V_2' proportional to the logarithm of output current of the unit. But these two output voltages V_1' and V_2' are temperature dependent. The constant voltage V_{REF} is given to the inverting terminal of Log-Amp1 and its output V_{REF}' is used for temperature compensation, in order to eliminate the temperature dependencies of V_1' and V_2'.

The inverting input of two differential amplifiers DA1 and DA2 are fed with V_1' and V_2' respectively and their non-inverting input is fed with temperature compensation voltage V_{REF}'.

The differential amplifiers DA1 and DA2 gives temperature independent output voltages V_{O1} and V_{O2} where V_{O1} is proportional to the logarithmic value of output voltage of the unit and V_{O2} is proportional to the logarithmic value of output current of the unit.

(i.e.) $V_{O1} \propto \text{Log } V$

and $V_{O2} \propto \text{Log } I$

Both the voltage V_{O1} and V_{O2} are given to an adder which gives an output voltage V_O which is the sum of the two input voltages V_{O1} and V_{O2}.

(i.e.) $V_O \propto (\text{Log } V + \text{Log } I)$

$V_O \propto \text{Log } (VI)$

Therefore the output voltage of the adder is proportional to the logarithmic value of V I product (i.e., KVA) and is given to the non-inverting input of a comparator. The inverting input of comparator is fed with the voltage V_{REF}.

The voltage $V_{P\ REF}$ is set such that, as long as the output KVA of the unit is less than 5 KVA V_O is less than $V_{P\ REF}$ and hence the comparator output is -12 volts. As soon as the output KVA of the unit exceeds 5 KVA V_O becomes higher than $V_{P\ REF}$ and comparator output goes to +12 volts which provides bias voltage to a switching transistor. The transistor goes to ON state and activates the over load protection relay and over load indication.

Once the comparator output goes high the diode in the feed-back path of the comparator gets forward biased and this provides +12 volts to the non-inverting input of comparator.

Therefore the feed-back diode and the capacitor C7 in the non-inverting terminal of the comparator holds the comparator output of +12 volts until it is reset manually.

4.2. THE IDEAL OP-AMP

An ideal operational amplifier exhibits the following characteristics:

a Infinite voltage gain A.

b Infinite input resistance Ri , so that almost any signal source can drive it and there is no loading of the preceding stage .

c Zero output resistance Ro, so that output can drive an infinite number of other devices .

d Zero output voltage when the input is zero.

e Infinite bandwidth so that any frequency signal from zero to infinity Hz can be amplified without attenuation .

f Infinite common mode rejection ratio so that the output common mode noise voltage is zero .

g Infinite slew rate so that output voltage changes occur simultaneously with input voltage changes.

Fig 4.3. shows the equivalent circuit of an operational amplifier. This circuit includes important values from the data sheets A, Ri and Ro. Here Avid is an equivalent resistance looking back into the output terminal of an operational amplifier.

4.3. LOGARITHMIC AMPLIFIER

The fundamental log-amp circuit is shown in fig 4.4. Where a grounded base transistor is placed in the feed back path. Since the collector is held at virtual ground and the base is also grounded, so the transistor current relationship becomes that of a diode and is given by,

$$I_E = I_S \left(e^{(qV_E/KT)} - 1 \right) \quad (4.1)$$

Since $I_C = I_E$ for a grounded base transistor

$$I_C = I_S \left(e^{(qV_E/KT)} - 1 \right) \quad (4.2)$$

I_S = emitter saturation current = 10^{-13}
K = Boltzmann constant
T = absolute temperature (in K)

Therefore,

$$\frac{I_C}{I_S} = \left(e^{(qV_E/KT)} - 1 \right) \quad (4.3)$$

or $$e^{(qV_E/KT)} = \frac{I_C}{I_S} + 1 \quad (4.4)$$

$$= \frac{I_C}{I_S} \qquad [\text{as } I_S = 10^{-13}\text{ A}, I_E >> I_S] \quad (4.5)$$

Taking natural log on both sides, we get

$$V_E = \frac{KT}{q} \ln\left[\frac{I_C}{I_S}\right]$$

Also from the diagram $I_C = \frac{Vi}{R_1}$

$$V_E = -V_O$$

$$V_O = \frac{-KT}{q} \ln\left[\frac{Vi}{R_1 I_S}\right] = \frac{-KT}{q} \ln\left[\frac{Vi}{V_{REF}}\right] \qquad (4.6)$$

where $V_{REF} = R_1 * I_S$

The output voltage is thus proportional to the logarithmic value of input voltage. Although the circuit gives natural log.

The circuit however has one problem. The emitter saturation current I_S varies from transistor to transistor and with temperature. Thus a stable reference voltage V_{REF} cannot be obtained. This is eliminated by the circuit given in fig. 4.5. In circuit 4.5 the transistor in feed back path is replaced by a diode because the function of transistor at that place is to give diode current relationship.

The input is applied to one log-amp, while a reference voltage is applied to another log-amp. The two transistors are integrated close together in the same silicon wafer. This provides a close match of saturation currents and ensures good thermal tracking.

Assume

$$I_{S1} = I_{S2} = I_S \qquad [$$

and then $V_1 = \frac{-KT}{q R_1} \ln \left[\frac{V_1}{I_s}\right]$

and $V_2 = \frac{-KT}{q} \ln \left[\frac{V_{REF}}{R_1 I_S}\right]$

$$V_O = V_2 - V_1 = \frac{KT}{q} \ln \left[\frac{V1}{V_{REF}}\right] \quad (4.7)$$

This reference voltage is now set with a single external voltage source. Its dependence on device and temperature has been removed.

4.4. DIFFERENTIAL AMPLIFIER

A circuit that amplifies the difference between two signals is called a differential amplifier. A typical circuit is shown in fig 4.6.

Since the differential voltage of the input terminals of the op-amp is zero, nodes 'a' and 'b' are at the same potential designated as V_3. The nodal equation at 'a' is

$$\frac{V_3 - V_2}{R_1} + \frac{V_3 - V_O}{R_2} = 0 \quad (4.8)$$

and at ‘b’ is

$$\frac{V_3 - V_1}{R_1} + \frac{V_3}{R_2} = 0 \quad (4.9)$$

Rearranging and subtracting equation (4.9) from equation (4.8), we get,

$$V_O = \frac{R_2}{R_1}(V_1 - V_2) \qquad (4.10)$$

4.5. NON - INVERTING SUMMING AMPLIFIER

The non-inverting summing amplifier shown in fig.4.7. Let the voltage at the (-) input terminal be Va. The voltage at (+) input terminal will also be Va. The nodal equation at node 'a' is given by

$$\frac{V_1 - Va}{R_1} + \frac{V_2 - Va}{R_2} = 0$$

From which we have

$$Va = \frac{(V_1/R_1) + (V_2/R_2)}{(1/R_1) + (1/R_2)}$$

The op-amp and two resistors Rf and R constitute a non- inverting amplifier with

$$V_O = 1 + \frac{R_f}{R} \; \frac{(V_1/R_1) + (V_2/R_2)}{(1/R_1) + (1/R_2)}$$

which is a non- inverted weighted sum of inputs.

Let $R_1 = R_2 = R = R_f / 2$

which gives $V_O = V_1 + V_2$

4.6 COMPARATOR

A comparator, as its name implies, compares a signal voltage on one input of an op-amp with a known voltage called the reference voltage on the other input. In its simplest form, it is nothing more than an open loop op-amp with two analog inputs and a digital output. The output may be (+) or (-) saturation voltage, depending on which input is larger.

Fig 4.8 shows an op-amp used as a comparator. A fixed reference voltage V_{REF} is applied to the (-) input and the other time varying signal voltage Vcn is applied to the (+) input. Because of this arrangement, the comparator is called the non-inverting comparator. When Vcn is less than V_{REF} the output voltage V_O is at -Vsat(= $-V_{EE}$) because the voltage at the (-) input is higher than that at the (+) input. On the other hand when Vcn is greater than ref the (+) input becomes positive with respect to the (-) input and Vo goes to +Vsat (= + Vcc). Thus Vo changes from one saturation level to another whenever Vcn crosses V_{REF} .

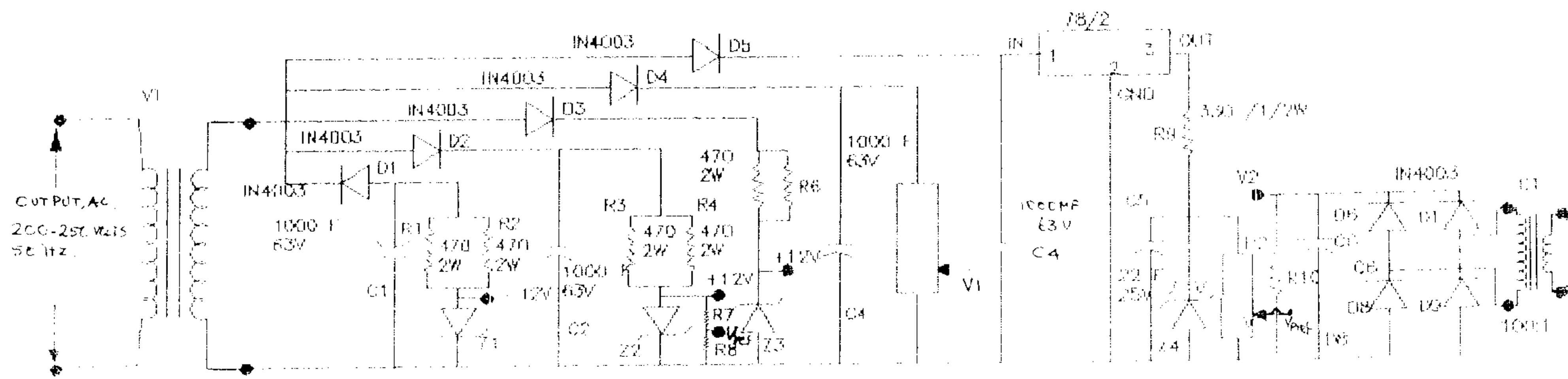


Fig 4.1 I/P Card Power Supply Section

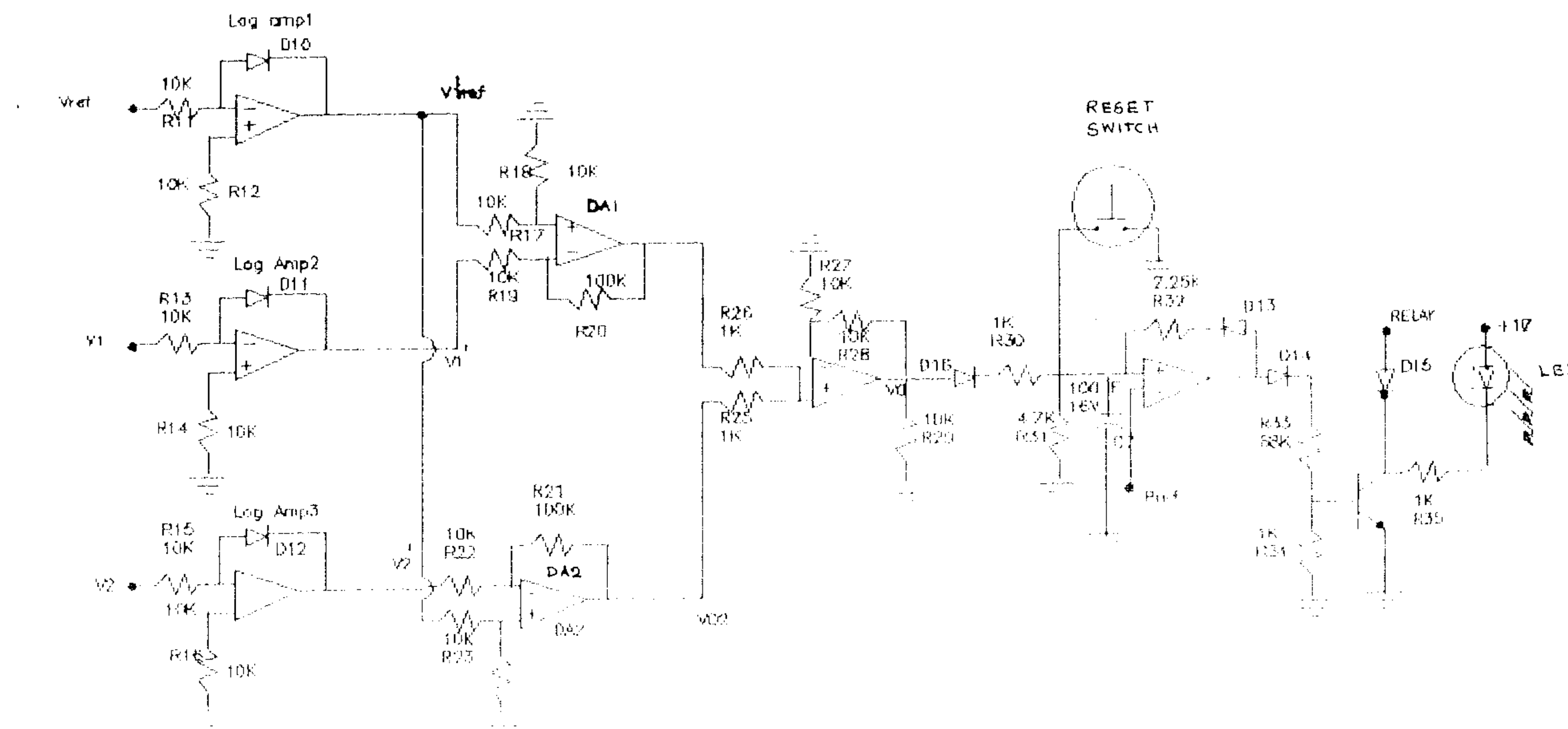


FIG 4.2 OHP Card - Logarithmic & KVA Setting section

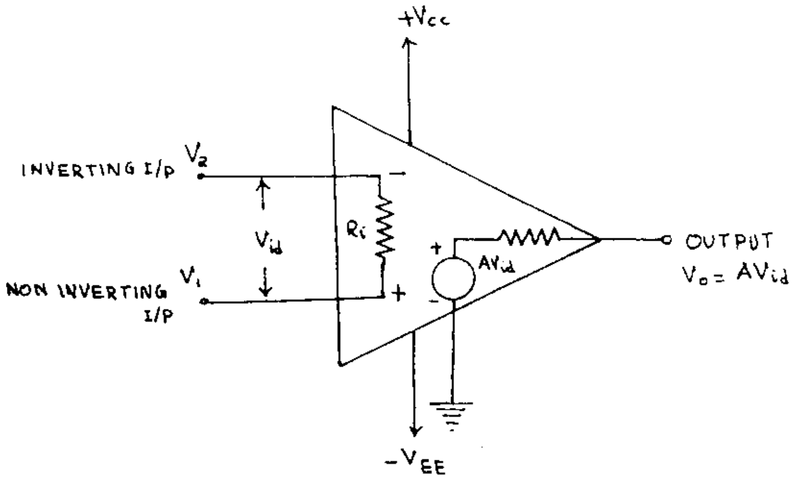


Fig 4.3 THE IDEAL OP-AMP.

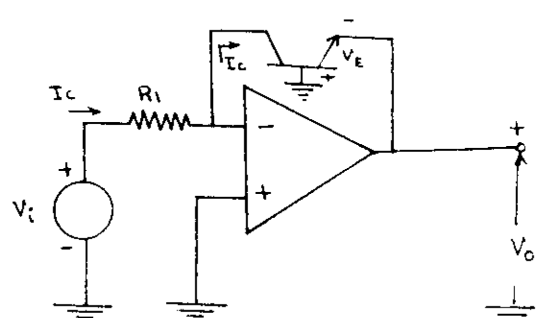


Fig 4.4 LOG-AMP.

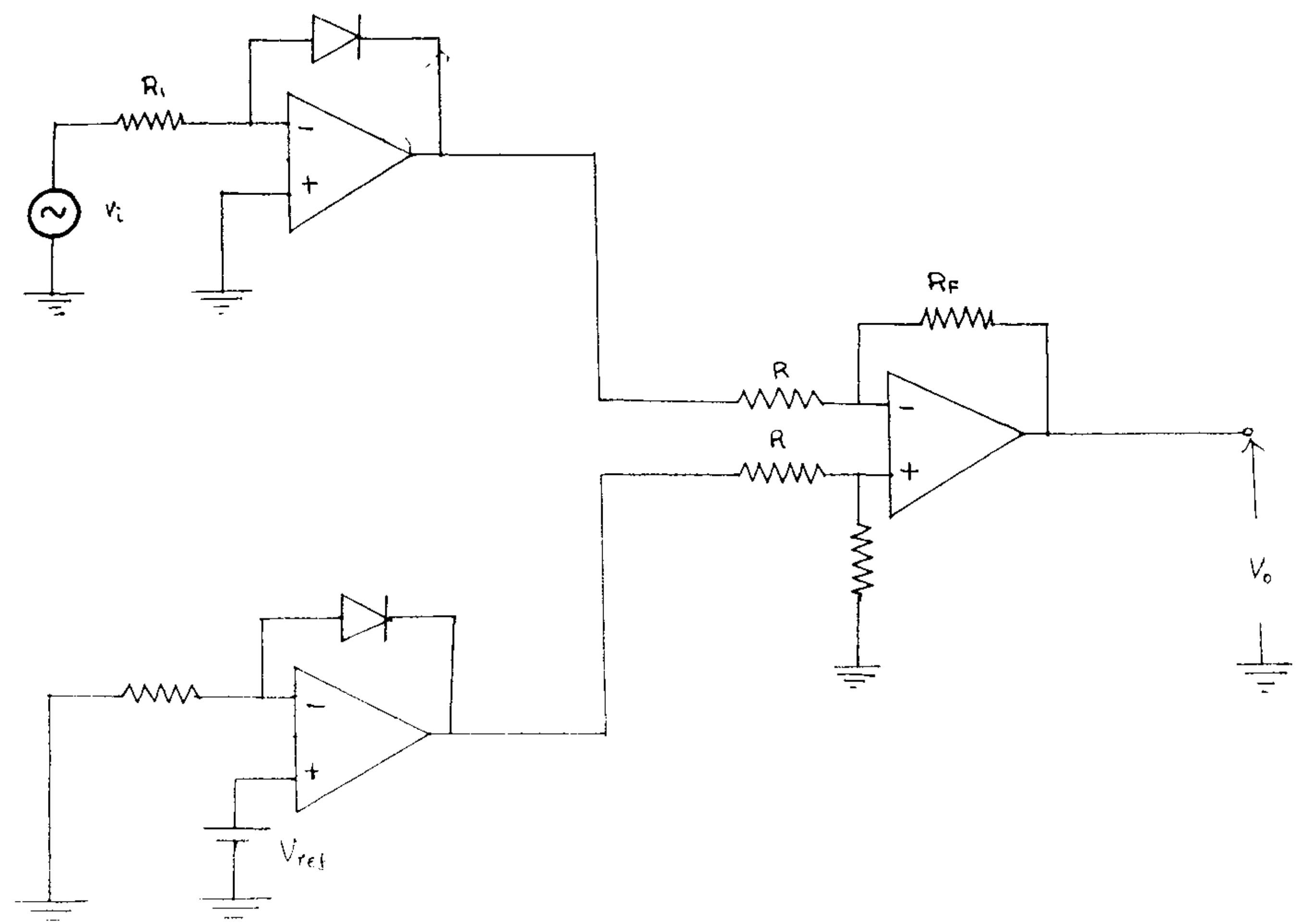


Fig 4·5 LOGRITHMIC AMPLIFIER WITH TEMPERATURE COMPENSATION

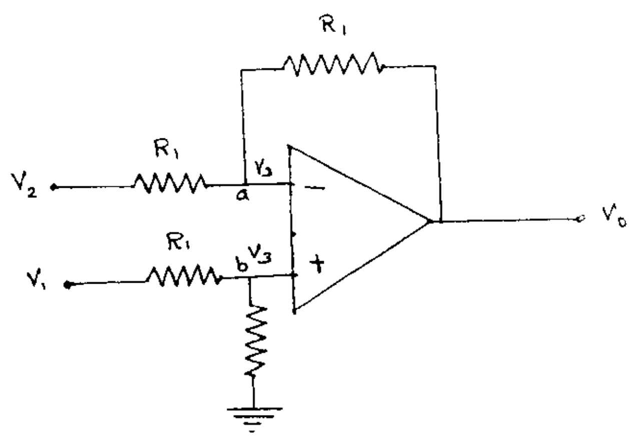


Fig 4·6 DIFFERENTIAL AMPLIFIER

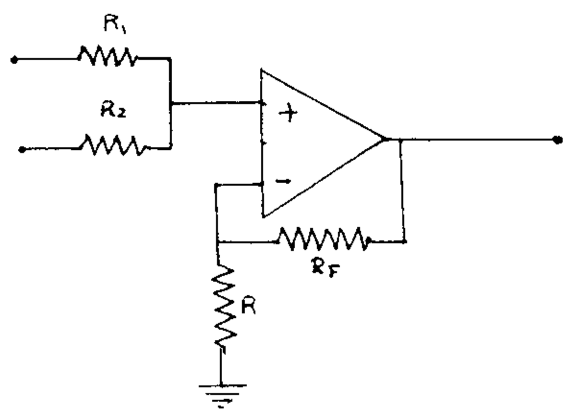


Fig 4·7 SUMMING AMPLIFIER

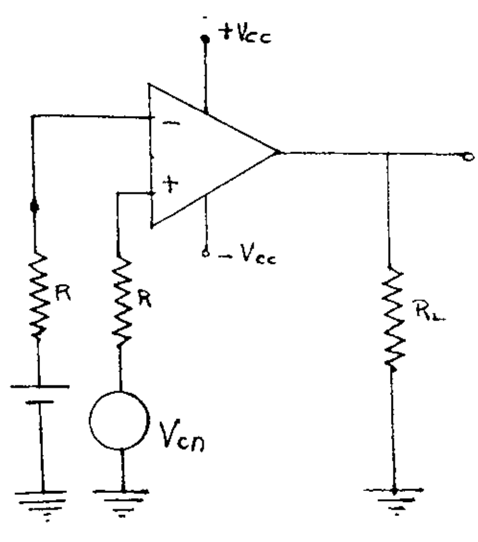


Fig 4·8 COMPARATOR

CHAPTER 5

VOLTAGE REGULATORS

VOLTAGE REGULATORS

5.1. 7812 REGULATOR

The function of a voltage regulator in this voltage unit is to provide a stable d.c. voltage for getting a constant voltage Vpref or KVA setting. A voltage regulator should be capable of providing substantial output current.

Here series regulator is being used. Series regulators use a power transistor connected in series between the unregulated d.c input and the load. The output voltage is controlled by the continuos voltage drop taking place across the series pass transistor.

The voltage regulator is an electronic circuit that provide a stable d.c. voltage independent of variations. The series voltage regulator consists of the following 4 parts :

1 Reference voltage circuit.
2 Error amplifier.
3 Series pass transistor.
4 Feed back network.

It can be seen from the fig 5.1. that the power transistor Q1 is in series with unregulated output voltage V_O. So it must absorb the difference between these 2 voltages whenever any fluctuation in output voltage V_O occurs. The transistor Q8 which is also connected as an emitter follower provides sufficient current gain to drive the load. The output voltage is sampled by the R_1-R_2 divider feedback to the negative input terminal of the op-amp error amplifier. This sampled voltage is compared with the reference voltage V_{REF} (usually obtained by the zener diode). The output V_O' of the error amplifier drives the series transistor Q1. If the output voltage increases the sampled voltage βVo also increases.

where $\beta = \frac{R_2}{(R_1+R_2)}$

This in turn reduces the output voltage V_O' of the differential amplifier due to the 150° phase difference provided by the op-amp. V_O' is applied to the base of Q1, which is used as an emitter follower. So Vo follows V_O', i.e., V_O also reduces. Hence the increase in Vo is nullified. The above circuit is incorporated on a monolithic silicon chip by which it gives low cost, high reliability, reduction in size and excellent performance .

5.2. ZENER VOLTAGE REGULATOR

The zener diode serves as a reference voltage source capable of delivering considerable current. Unlike a battery, its life is infinitely long, although it must be supplied with a continuos current for many of its applications. The main use of the zener regulator in this unit is to provide constant +12 volts and -12 volts supply for IC's and to provide reference voltage.

The zener breakdown takes place in very thin junctions, when both sides of the junction are very heavily doped and consequently the depletion layer is narrow. In very thin depletion layer width, the electric field becomes as high as 10^7 v/m with only small applied reverse bias in the transition region are steeply tilted as shown in fig 5.2. It becomes possible for some electrons to jump across the barrier from the valence band in P-material to some of the unfilled conductive levels in N-material. This process is known as tunnelling through the barrier and is purely a quantum mechanical effect attributed to the wavelike properties of the electrons. This is also sometimes known as the internal field emission or Zener breakdown. The zener breakdown level is quite stable and choice of material conductivity permits design of diode units with varying break down levels. Such units known as zener diodes are used to accurately regulate d.c. voltage sources. The break down phenomenon is reversible and not damaging to the junction, provided the power loss is limited and operating temperature is maintained within the safe limits. The volt-ampere characteristics of typical zener diode is shown in fig. 5.3.

In these diodes when the break down voltage is reached, the current increases rapidly with additional voltage. As a result a diode in break down maintains an almost constant voltage across itself over wide current range. Thus zener diodes are ideally suited for voltage regulation and can be easily tailored to specific voltages by changing the doping levels.

A typical voltage regulator circuit showing the use of zener diode is indicated in fig. 5.4. The attendent input voltage V_S output voltage characteristics is shown in fig. 5.5.

The output voltage V_O follows the input voltage Vi, with a slope dependent on the load resistor R_L, until V_B is reached. Thereafter, V_O remains constant as long as $(Vi\, R_L/(R_L+R_1)) > V_B$.

Zener diodes are rated in terms of maximum current $I_{Z\,MAX}$ and ordinarily the operating current, I_Z is maintained at about 20% of the maximum rating. Thus the value of resistor R_1 may be found as

$$R_1 = \frac{(Vi - V_O)}{I_L + 0.2\, I_{Z\,MAX}}$$

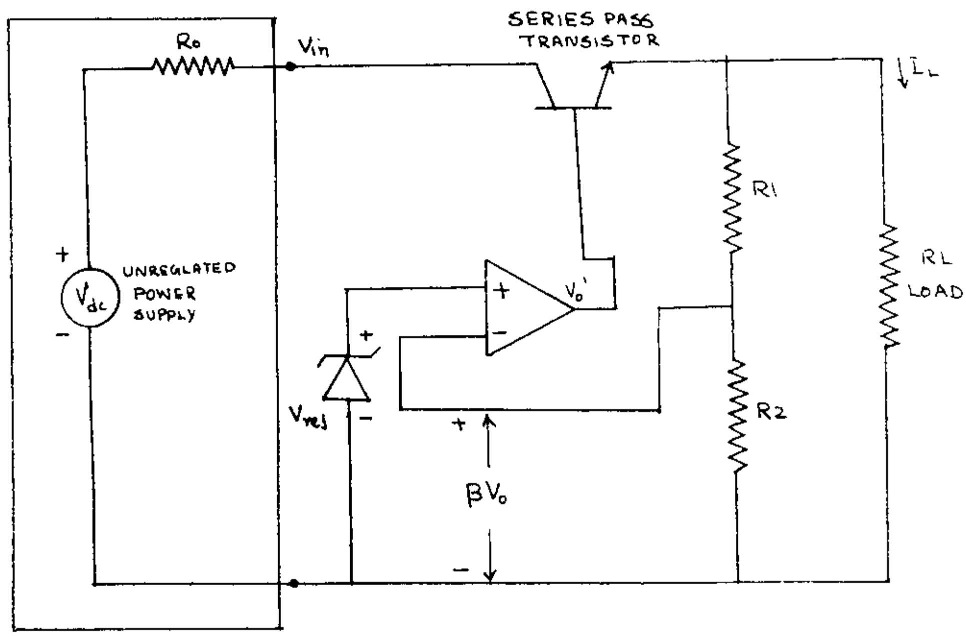


Fig 5.1 7812 VOLTAGE REGULATOR

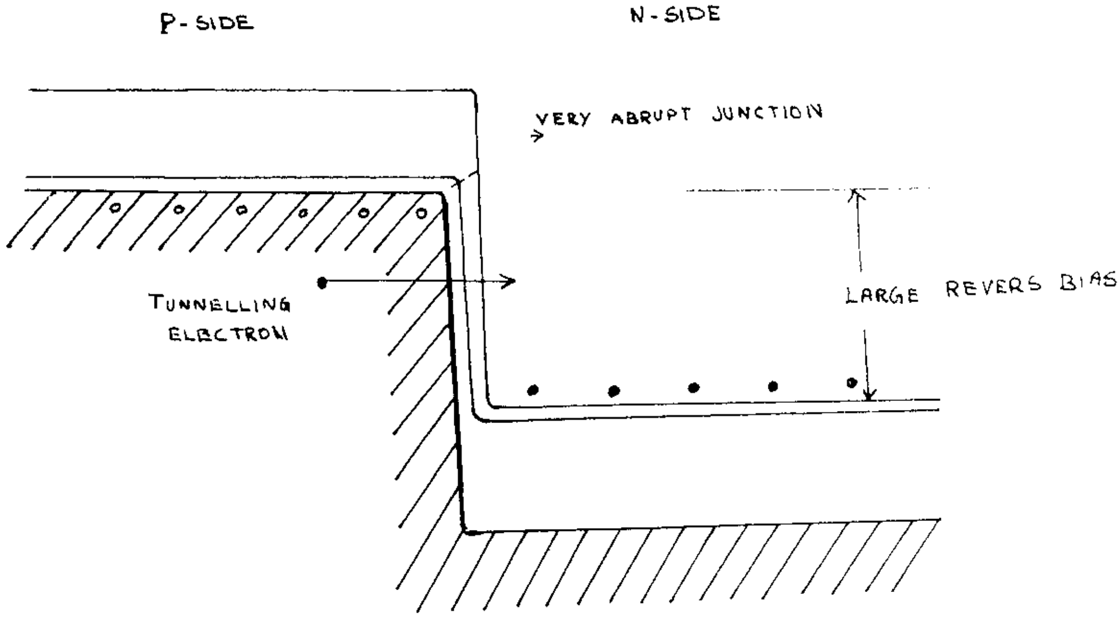


Fig 5.2 ENERGY BAND DIAGRAM OF A ZENER DIODE

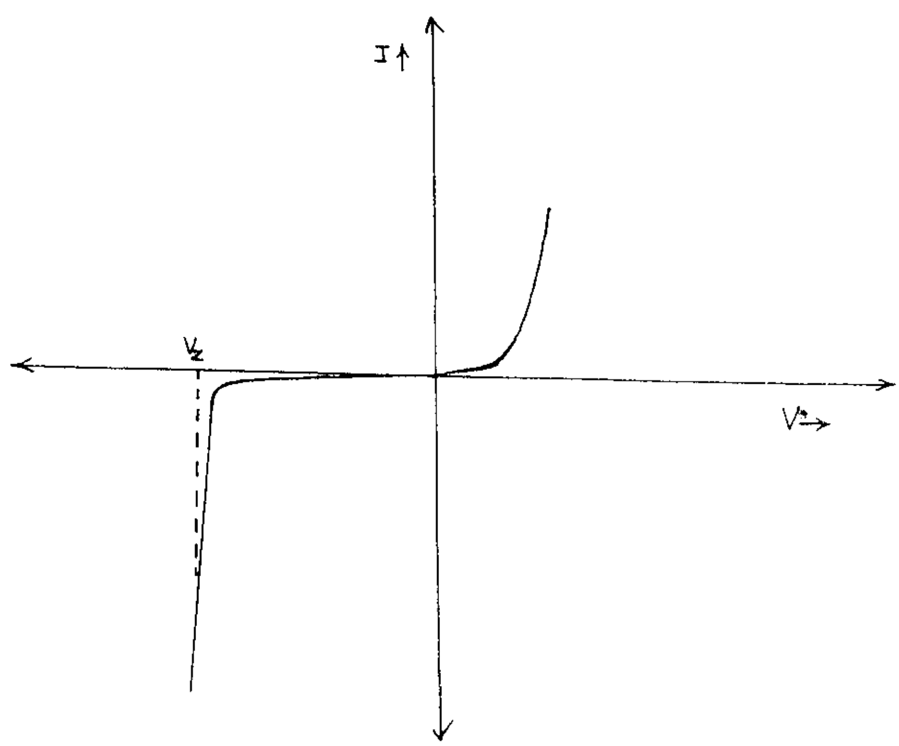


Fig 5.3 VOLT-AMPERE CHARACTERISTICS OF A ZENER DIODE

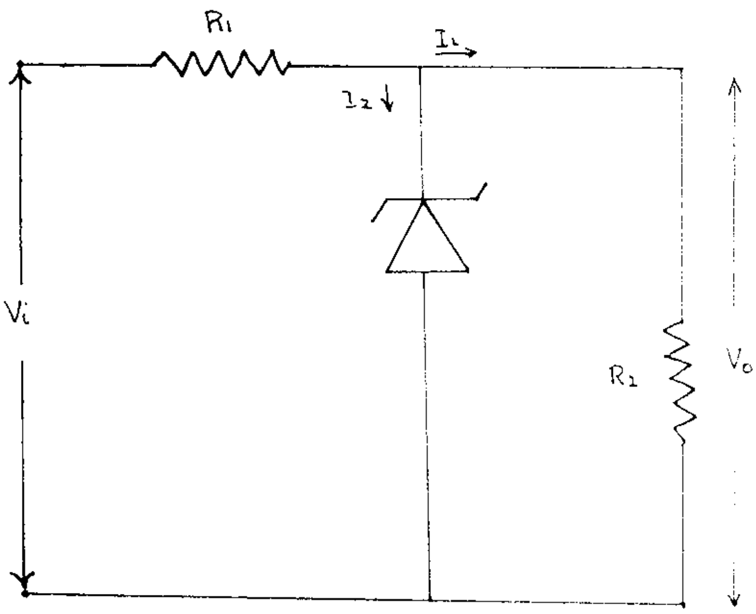


Fig 5.4 ZENER VOLTAGE REGULATOR

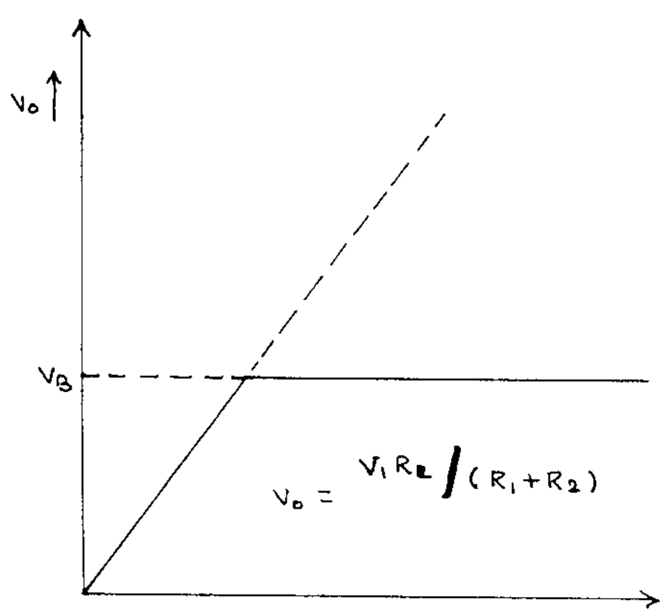


Fig 5.5 INPUT-OUTPUT VOLTAGE CHARACTERISTICS OF A ZENER REGULATOR

CHAPTER 6

TOROIDAL TRANSFORMER DESIGN

TOROIDAL TRANSFORMER

6.1. GENERAL DESCRIPTION

A doughnut is a torus (or) toroidal - shaped object with a permeability about the same as that of air. It probably has low electrical resistivity, no hysterisis loss, a complete linear B - H curve, and an infinitely high saturation point.

The toroid core is wound from metal tape. This permits the easiest direction of magnetisation to be utilized, giving toroids the same advantage over stampings possessed by cut core. Then there is the shape, the magnetic field of toroid is contained almost entirely within the toroid. Leakage inductance and stray capacitance are very small. Note only that, when the toroid is placed in an interfering forces tend to act equally all around the toroid, resulting in the cancellation of interfering voltages in the coils.

Big plus for the toroid is that it is not cut there is no gap in the magnetic circuit and therefore there is very little depreciation of the line magnetic qualities of the alloys used.

These cores are constructed with insulated metal tape wound on to a mandrel under closely controlled tension, then annealed and treated to develop fully the required magnetic characteristics. Unlike other types of core, the characteristics of toroid never dependent on the way the user assembles the cores .

They are assembled and treated at the factory for optimum results.

The finished core is then permanently encased in plastic or aluminium to protect it from the strains of winding and other external forces.

A damping medium fills the space between the core and the case to further protect it from shock and vibration.

6.1.1. WINDINGS ON TAPE WOUND CORE

There are also advantages in toroidal windings. The word "toroidal" is used here to describe the special shape of the toroidal core rather than just any old winding on a toroidal core, because not all windings on toroidal cores are toroidal in shape.

A prime advantage of the toroidal winding is that it has very small external field. The field is concentrated mainly inside the toroid.

A second important feature is that leakage inductance is minimized since it is difficult for the flux lines to escape from the core without linking the windings.

And third, the effects of external fields, from whatever direction tend to cancel in the windings in a manner similar to that in the astatic winding.

6.1.2. LAYERS AND TURNS PER LAYER

Unlike the standard coil every layer is a different length; therefore for a given winding every layer has a different number of turns. The length of first layer is the length of the inside circumference and the number of turns on it is determined by this length times the turns per inch figure for the wire gauge being used. The winding length available for the second layer is less than the first.

Number of layers,

$$n = \frac{a + 3 - (a + 3) - 12N_T}{6}$$

where,

'a' is the number of turns in first layer
'n' is the number of layers,
'N_T' is the total number of turns.

6.1.3. LENGTH OF WIRES

In toroids, as in other formats, the length of wire is needed inorder to determine resistance, voltage drop, and power loss. It is also needed for obvious reason of knowing how long the wire is, a matter of some importance when winding toroids. If the winding is being done manually, the wire may be rewound on to a small spool, or if it isn't too long, simply retained in a hank but handled very carefully.

If a core is not of the plastic encased type, it will be necessary to protect the winding by wrapping tape around the metal core. Remember to take account of this addition when making calculations on build and winding space.

6.2. DESIGN OF TOROIDAL TRANSFORMER FOR 5 KVA

6.2.1. PRIMARY

Maximum voltage given to primary	=	280 volts
Minimum voltage given to secondary	=	140 volts
Maximum capacity	=	5 KVA

Current flowing from C to A,

$$= \frac{5 * 1000}{140 * 0.95} = 37.594 \text{ Amps}$$

Efficiency = 95%

when input is 140 volts, then the current flowing from A to F $= \frac{5*1000}{200}$

$= 25$ amps

Difference in current = 37.594 - 25
= 12.594 Amps

$$\text{Turns per volt} = \frac{10^8}{28.64 * f * Ai * Bm}$$

where,

Ai is the cross-sectional are of core = 2" * 1.575" = 3.15"

Bmax is the maximum flux density in lines per sq. inch.

For CRNO Type core,

Bmax = 14000 line/sq.inch

Frequency of supply, f = 50 Hz

$$\text{Turns per volt} = \frac{10^8}{28.54 * 50 * 3.15 * 14000 * 0.95}$$

= 1.667 turns / volt

Maximum number of turns required for primary = 280 * 1.667 = 467 turns

The turns required for boost mode at 180 volts $= 467 * \frac{200}{180} = 519$ volts

The turns required for extra boost mode at 140 volts $= 467 * \frac{200}{140} = 667$ turns

The turns required for normal mode at 220 volts $= 467 * \frac{205}{220} = 435$ turns

The turns required for buck mode at 250 volts $= 467 * \frac{205}{250} = 383$ turns

6.2.2. GAUGE SELECTION

As per standard, we have chosen 400 circular mils per Amp.

For 25 Amps,
= 25 * 400 = 10000 circular mils.

From the table, the gauge selected for 25 Amps winding is 12 SWG.

For 12.594 Amps,
= 12.594 * 400 = 5037.6 circular mils.

From the table, the gauge selected for 12.594 Amps winding is 15 SWG.
From the table,
12 SWG wire has 2.64 mm diameter.
15 SWG wire has 1.83 mm diameter.

6.2.3. LAYER CALCULATION

Circumference of the core $= 3.14 * D$

$= 3.145 * 100 = 314.5$ mm

Number of turns in the First layer $= \frac{\text{Circumference}}{\text{dia of conductor}} = \frac{314.5}{2.65} = 119$ turns

Number of turns in the second layer $= \dfrac{3.14(100 - 2 * 2.65)}{2.65}$

$= 113$ turns

Number of turns in the third layer $= \dfrac{3.14 * (100 - 4 * 2.65)}{1.83}$

$= 153$ turns

Number of turns in the Fourth layer $= \dfrac{3.14(100 - 4 * 2.65 - 2 * 1.83)}{1.83}$

$= 147$ turns

Number of turns in the fifth layer $= 135$ turns

6.2.4. LENGTH OF THE CONDUCTOR

Length of conductor in th first layer $= 180 * 119 = 21420$ mm

$= 21.42$ m

Length of conductor in the second layer $= (180 + 8 * 2.65) * 113$

$= 201.2 * 113$

$= 22.735$ m

Total length of 2.65 mm conductor is $= 21.42 + 22.735$m

$= 44.155$ m

Length of the third layer of 1.83 mm conductor $= (201.2 + 8 * 2.65)\ 153$

$= 222.4 * 153$

$= 34.027$ m

Length of the fourth layer of 1.83 mm conductor $= (222.4 + 8 * 1.83)\ 147$

$= 234.04 * 147$

$= 34.84$ m

Length of the fifth layer of 1.83 mm conductor $= (237.64 + 8 * 1.83)\ 135$

$= 251.6 * 135$

$= 33.976$ m

Total length of 1.83 mm conductor = 102.848 metres

From table,
Weight of 12 SWG conductor = 48.72 gm/m

Total weight of 12 SWG conductor of length 44.155m $= \frac{48.72 * 44.155}{1000}$

$= 2.15$ kgs

weight of 15 SWG conductor = 23.35 gm/m

Total weight of 15 SWG conductor of length 102.845 m $= \frac{102.845 * 23.35}{1000}$

$= 2.4$ kgs

6.3. COMPUTER AIDED DESIGN

6.3.1. ALGORITHM

1 Get the input of voltage in primary, KVA and toroidal dimensions.

2 Get the input voltage of boost, buck and normal conditions.

3 Calculate the number of turns in primary and secondary (i.e. boost, buck, extra boost and normal).

4 Calculate the circular turns and the gauge corresponding to it is found from table.

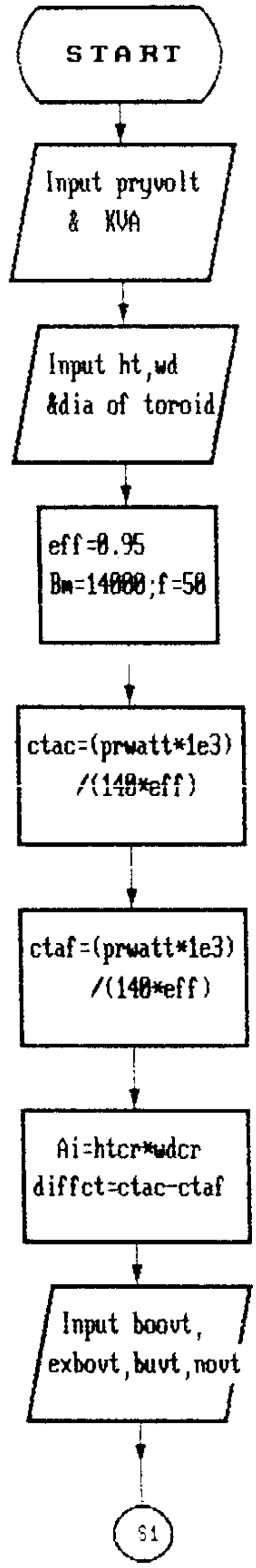
5 Calculate the number of layers and the total length of each gauge.

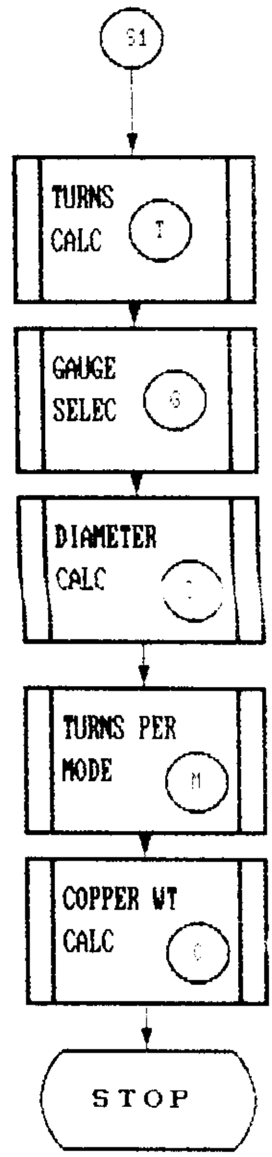
6 Calculate weight of the wire.

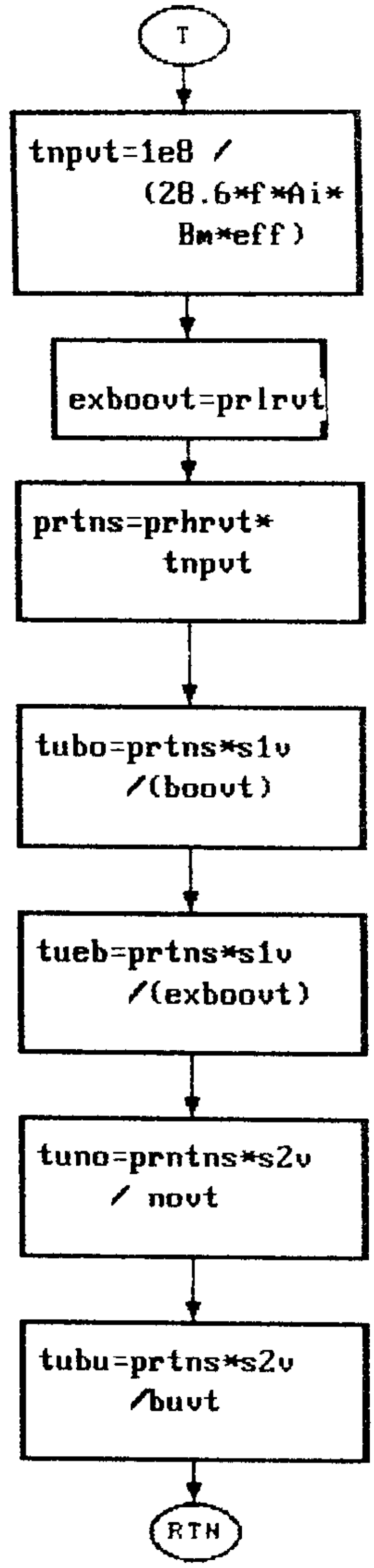
7 The required calculated output details are displayed on the VDU.

The implementation of the above algorithms has been done using C language.

6.3.2. FLOW CHART




61
TURNS
CALC
T
GAUGE
SELEC
G
DIAMETER
CALC
TURNS PER
MODE
M
COPPER WT
CALC
STOP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tnpvt=1e8 / (28.6*f*Ai* Bm*eff)
exboovt=prlrvt
prtns=prhrvt* tnpvt
tubo=prtns*s1v /(boovt)
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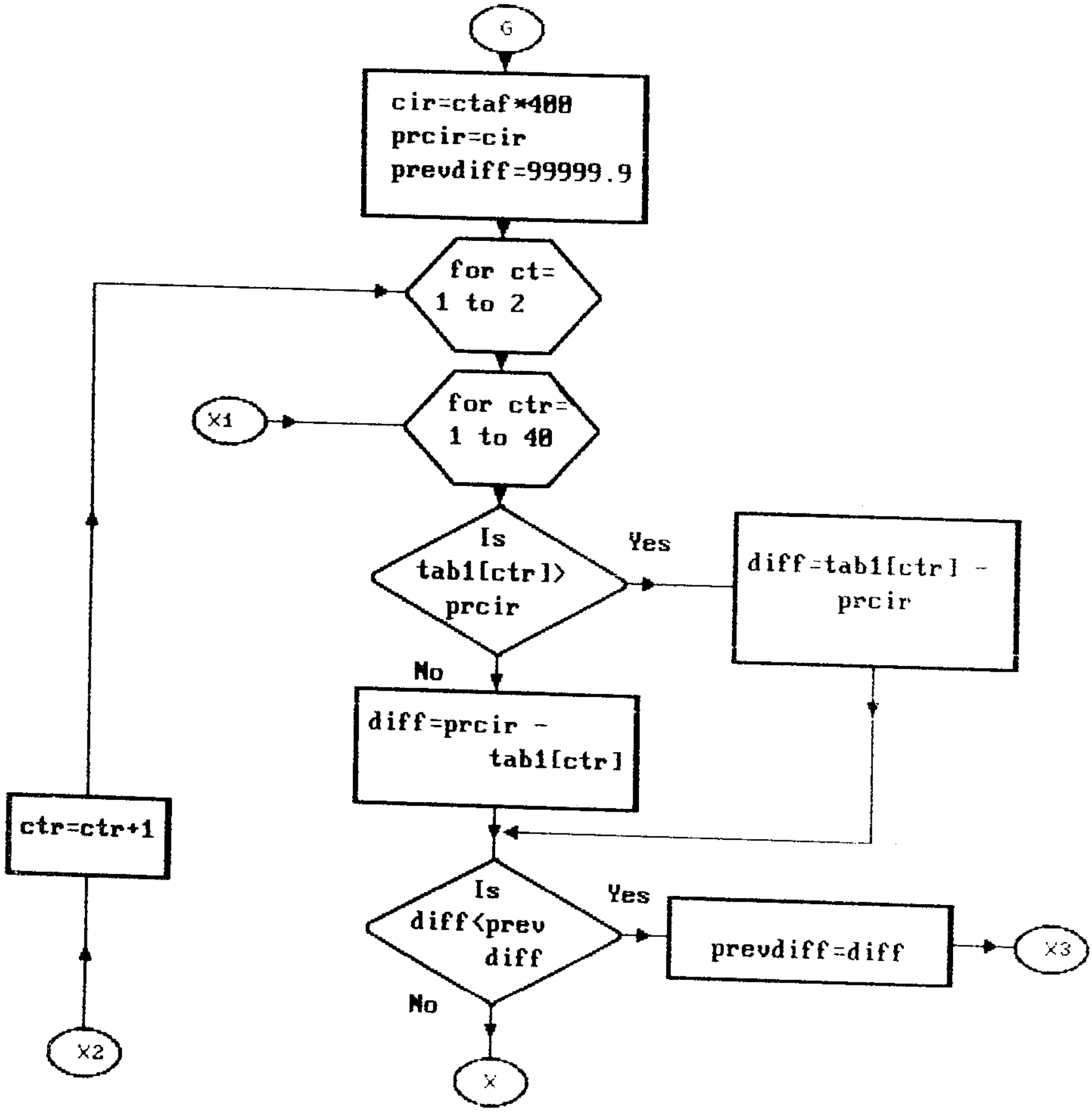
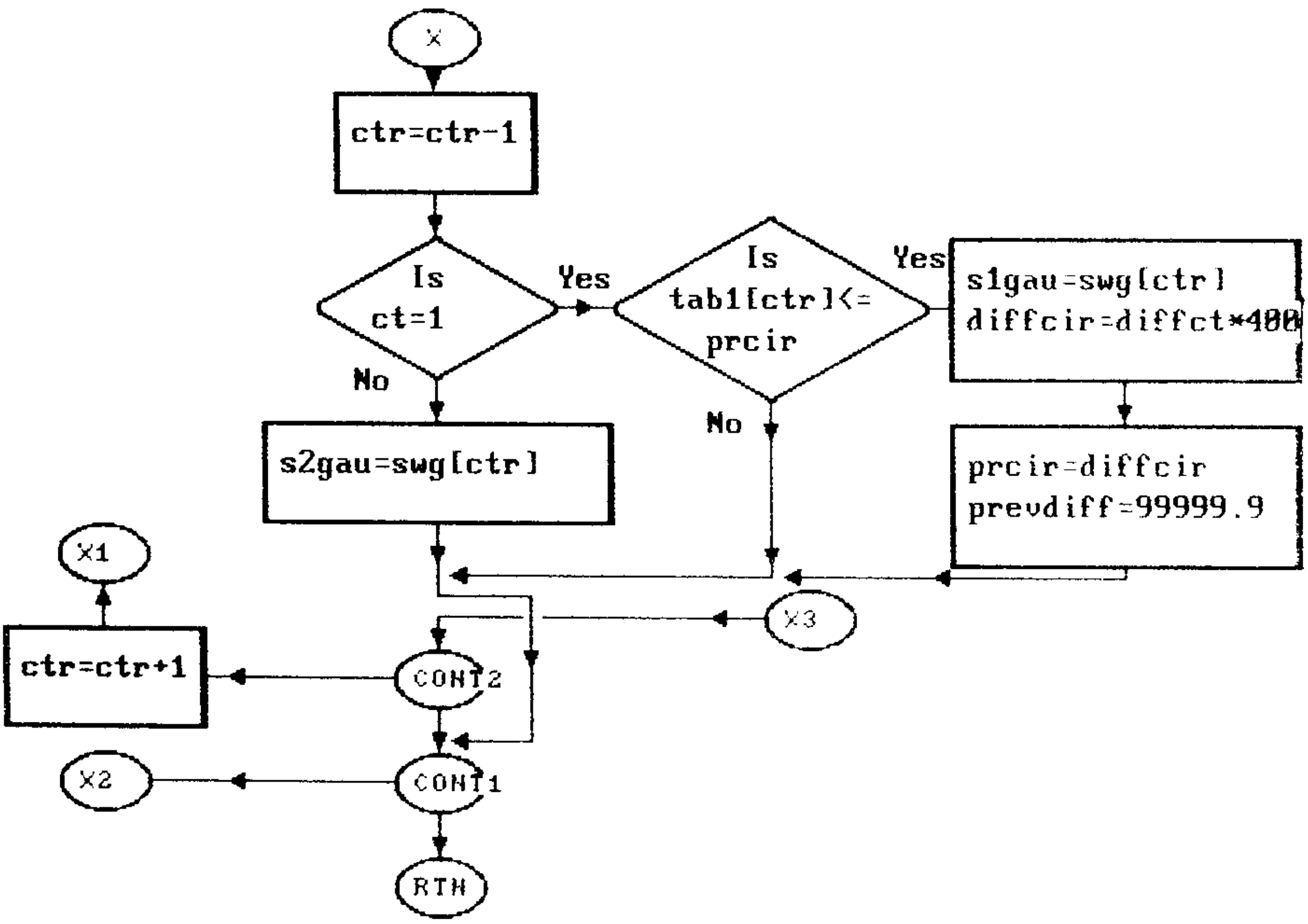
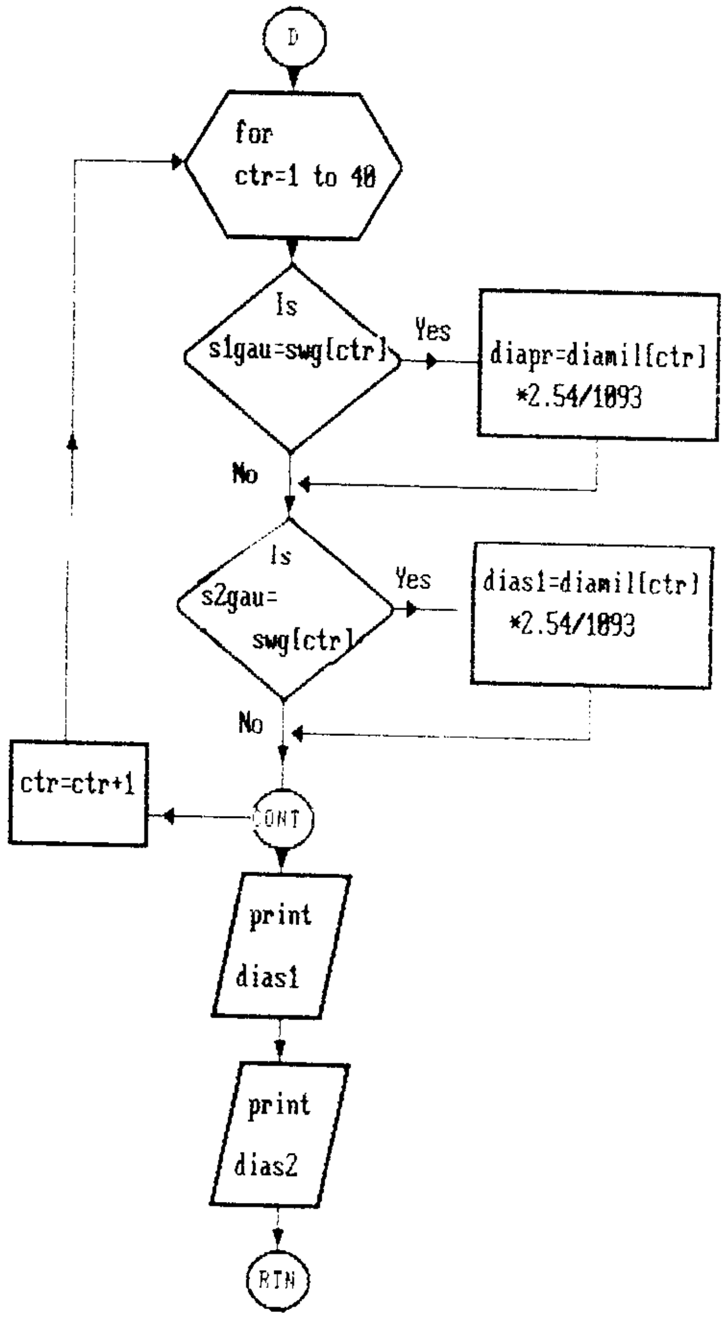
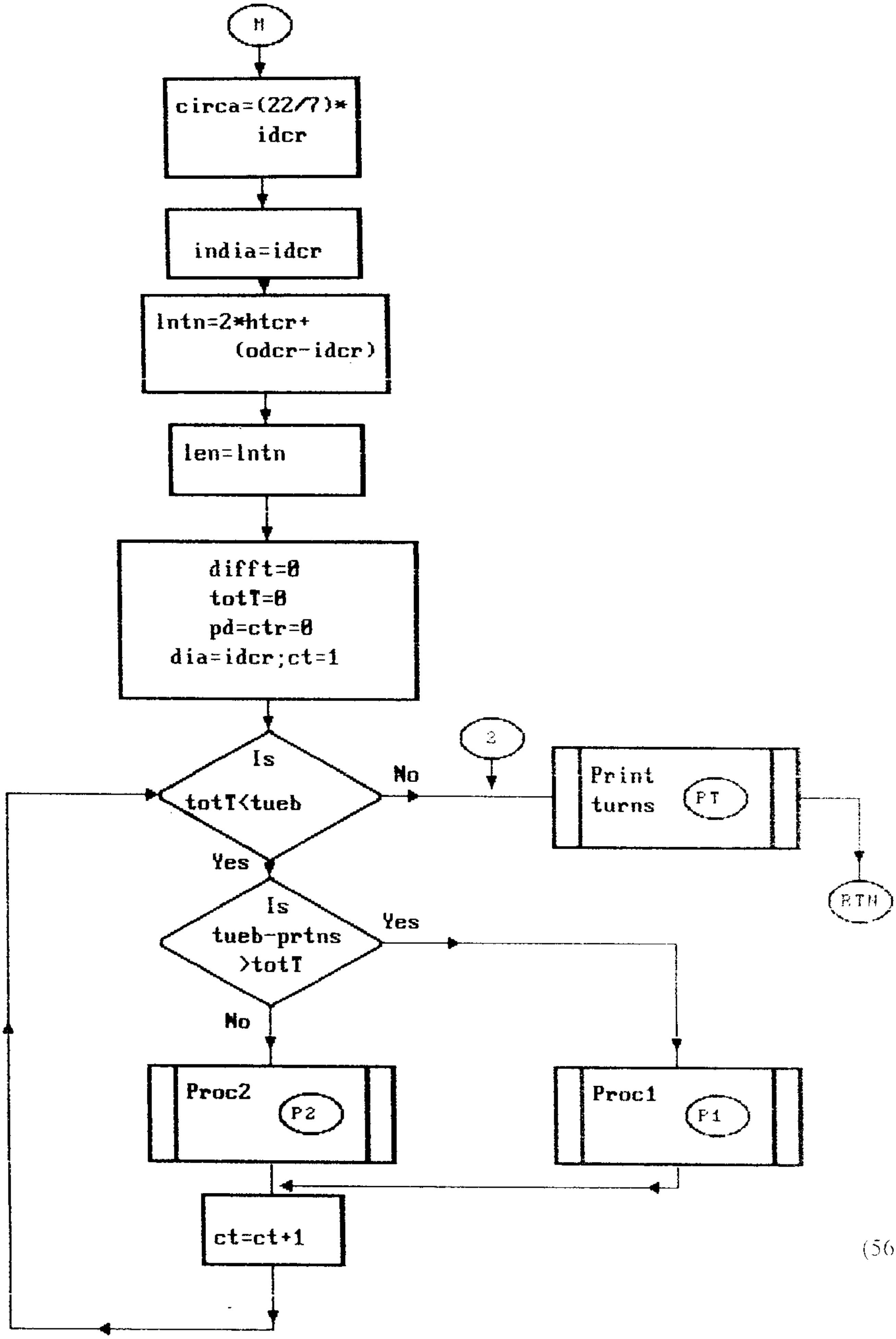
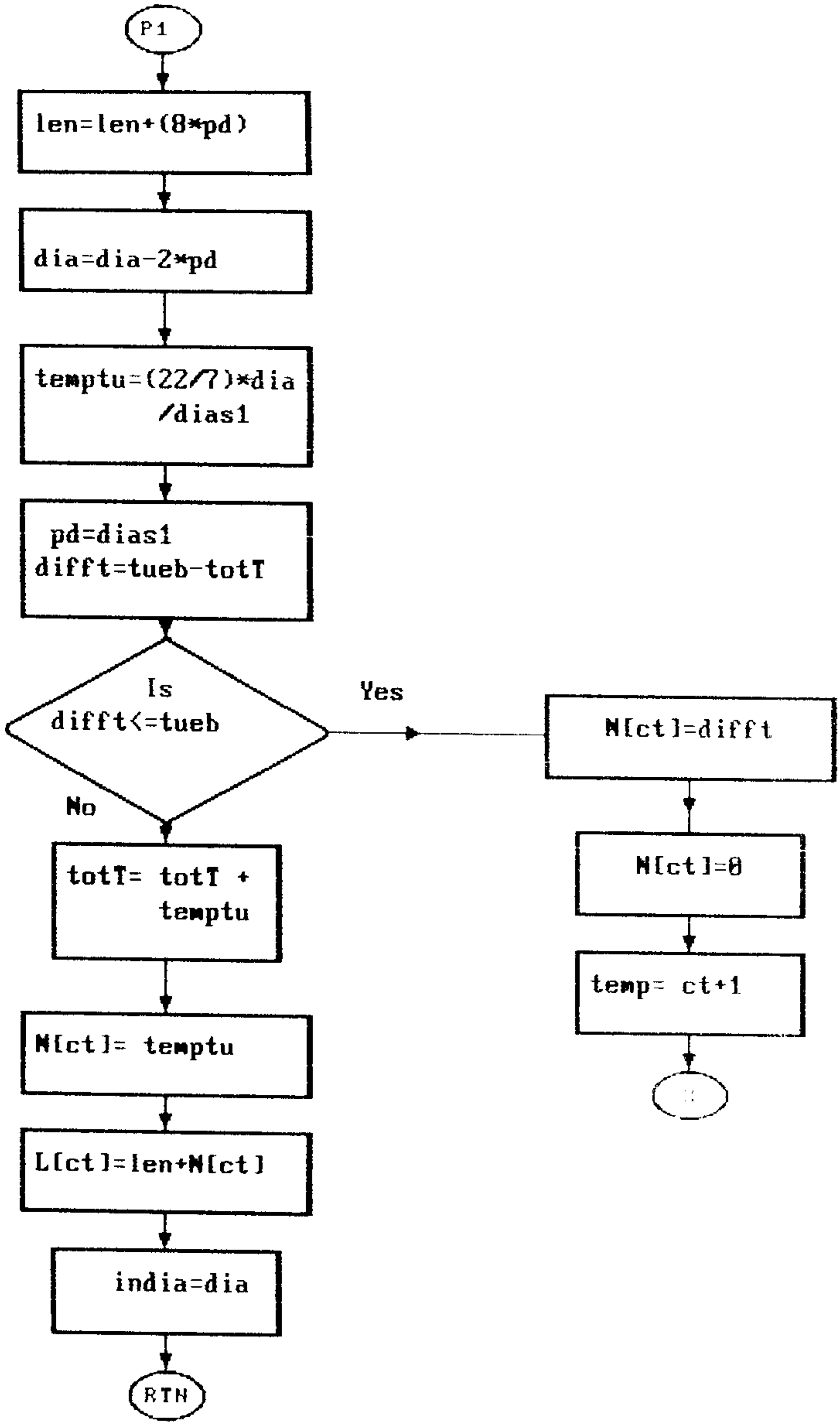
RTN

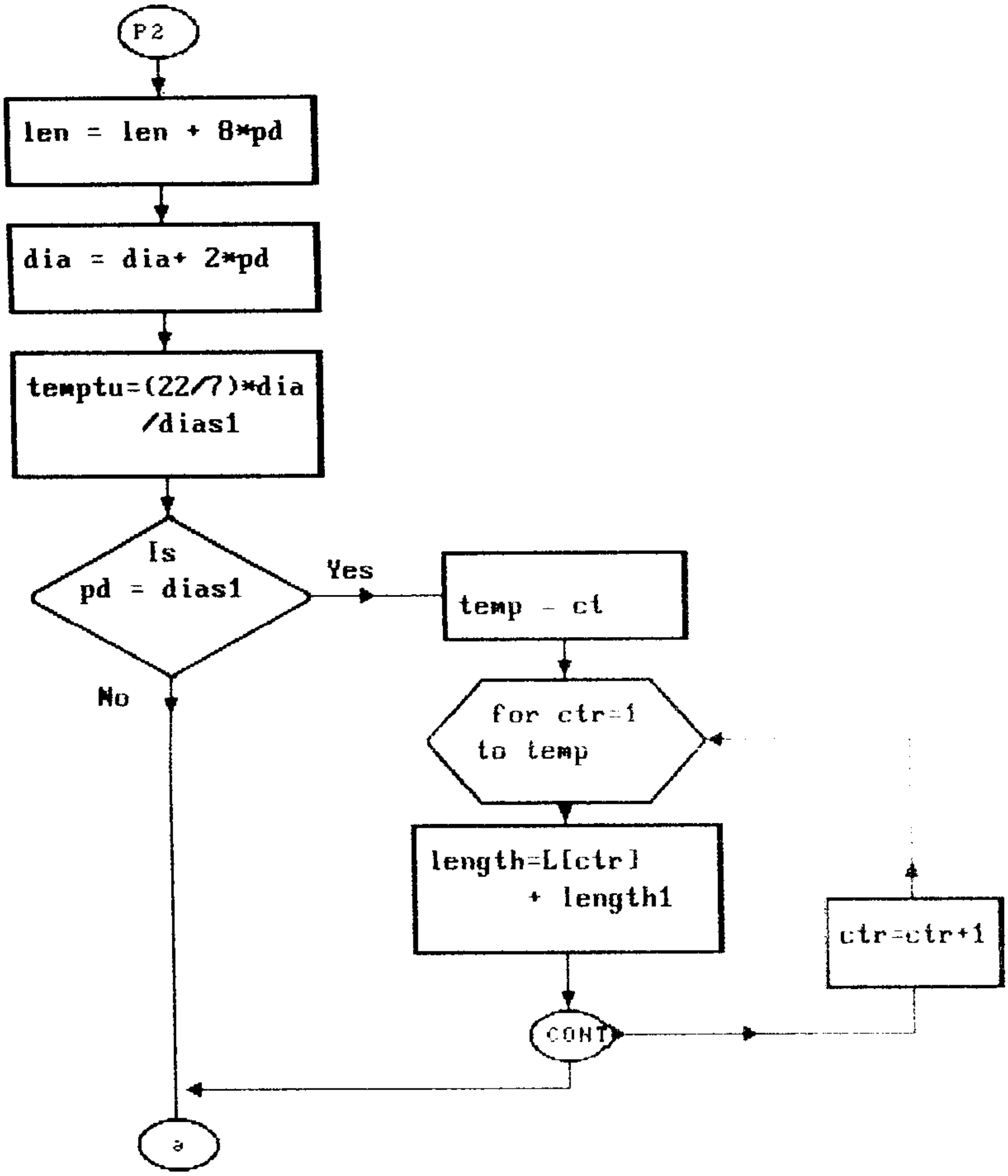

G
cir=ctaf*400
prcir=cir
prevdiff=99999.9
for ct=
1 to 2
X1
for ctr=
1 to 40
Is
tab1[ctr]>
prcir
Yes
diff=tab1[ctr] -
prcir
No
diff=prcir -
tab1[ctr]
ctr=ctr+1
Is
diff<prev
diff
Yes
prevdiff=diff
X3
No
X2
X

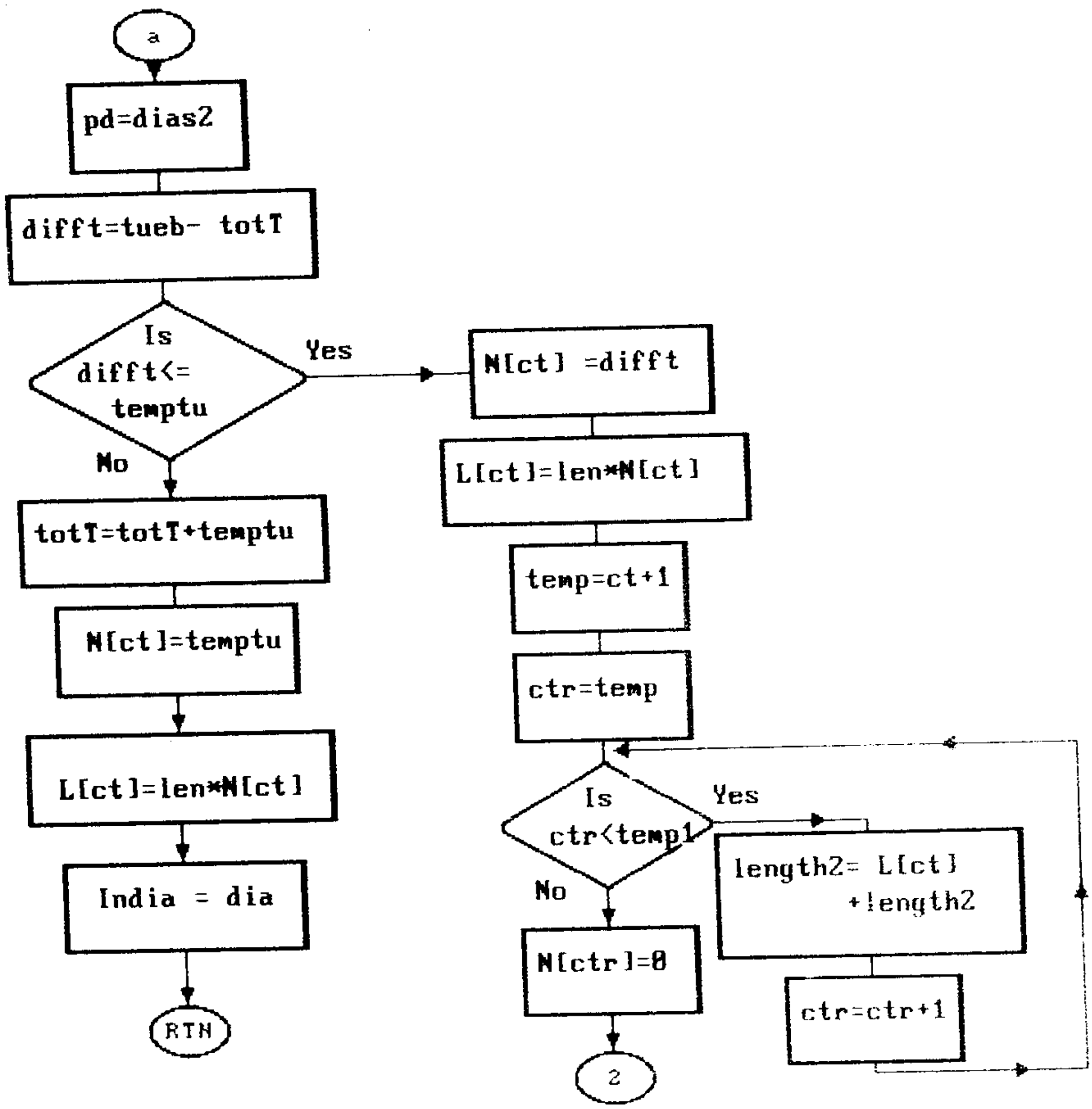

X
ctr=ctr-1
Is
ct=1
Yes
No
Is
tab1[ctr]<=
prcir
Yes
No
s1gau=swg[ctr]
diffcir=diffct*400
s2gau=swg[ctr]
prcir=diffcir
prevdiff=99999.9
X1
ctr=ctr+1
X3
CONT2
X2
CONT1
RTN

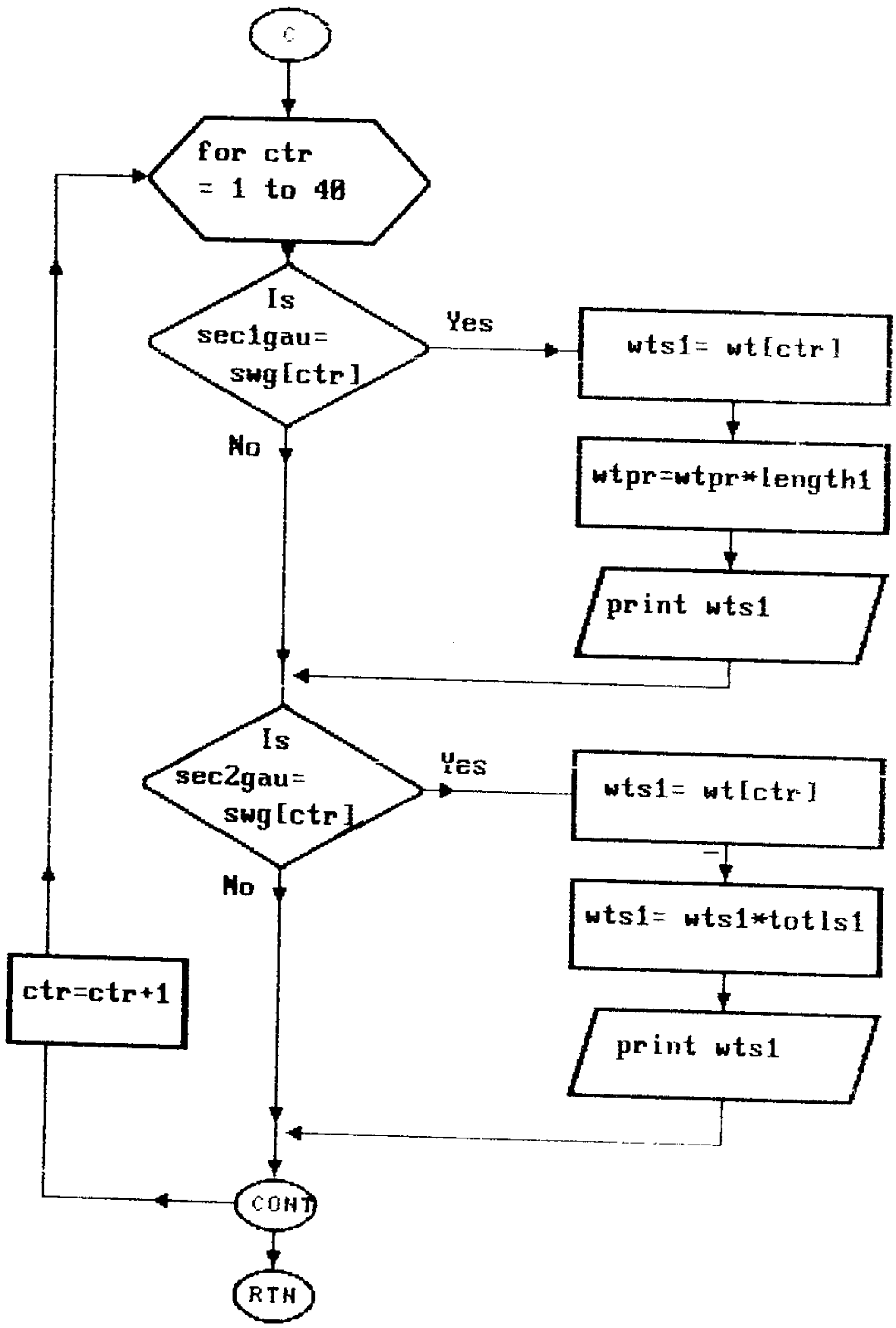

D
for
ctr=1 to 40
Is
s1gau=swg[ctr]
Yes
diapr=diamil[ctr]
*2.54/1093
No
Is
s2gau=
swg[ctr]
Yes
dias1=diamil[ctr]
*2.54/1093
No
ctr=ctr+1
CONT
print
dias1
print
dias2
RTN


M
circa=(22/7)*
idcr
india=idcr
lntn=2*htcr+
(odcr-idcr)
len=lntn
difft=0
totT=0
pd=ctr=0
dia=idcr;ct=1
Is
totT<tueb
No
2
Print
turns
PT
RTN
Yes
Is
tueb-prtns
>totT
Yes
No
Proc2
P2
Proc1
P1
ct=ct+1


P1
len=len+(8*pd)
dia=dia-2*pd
temptu=(22/7)*dia
/dias1
pd=dias1
difft=tueb-totT
Is
difft<=tueb
Yes
No
N[ct]=difft
N[ct]=0
temp= ct+1
totT= totT +
temptu
N[ct]= temptu
L[ct]=len+N[ct]
india=dia
RTN


P2
len = len + 8*pd
dia = dia+ 2*pd
temptu=(22/7)*dia
/dias1
Is
pd = dias1
Yes
No
temp - ct
for ctr=1
to temp
length=L[ctr]
+ length1
ctr=ctr+1
CONT
a


a
pd=dias2
difft=tueb- totT
Is difft<= temptu
Yes
No
N[ct] =difft
L[ct]=len*N[ct]
temp=ct+1
ctr=temp
totT=totT+temptu
N[ct]=temptu
L[ct]=len*N[ct]
India = dia
RTN
Is ctr<temp1
Yes
No
length2= L[ct] +length2
ctr=ctr+1
N[ctr]=0
2


C
for ctr = 1 to 40
Is sec1gau= swg[ctr]
Yes
No
wts1= wt[ctr]
wtpr=wtpr*length1
print wts1
Is sec2gau= swg[ctr]
Yes
No
wts1= wt[ctr]
wts1= wts1*totls1
print wts1
ctr=ctr+1
CONT
RTN

6.3.3. PROGRAM

```
# include <stdio.h>
# include <string.h>
# include <conio.h>
# include <math.h>
# include <stdlib.h>
# include <a.h>

int ctr,ctr1,ct,dummbo;

float Ai,afvt,Bm,boovt,buvt,cir,ctac,ctaf,circa,
      diff,diffcir,diffct,dias1,dias2,difft,dia,eff,exboovt,f,htcr,
     india,idcr,intn,length1,length2,lntn,len,novt,
      odcr,prtns,prhrvt=0,prlrvt,prwatt,prcir,prgau, prevdiff,pd,
     s1v=200,s2v=205,s1gau,s2gau,
      tubo,tuno,tueb,tubu,tnpvt,totT,temptu,temp,temp1,
     wdcr,wtpr,wts2,wt1,wts1,wts2,wt2;
float N[10],L[10];

char cho,choice,dumm;

main()
{
clrscr();

printf("\nEnter the max voltage to primary:");
scanf("%f",&prhrvt);
printf("\nEnter the min voltage to primary:");
scanf("%f",&prlrvt);
printf("\nEnter the max capacity (in KVA):");
scanf("%f",&prwatt);
```

```
printf("\nEnter ht of toroidal core:");
scanf("%f",&htcr);
printf("\nEnter wd of toroidal core:");
scanf("%f",&wdcr);
printf("\nEnter inner diameter of toroidal core:");
scanf("%f",&idcr);
printf("\nEnter outer diameter of toroidal core:");
scanf("%f",&odcr);
prhrvt=280;prlrvt=140;prwatt=5;htcr=1.575;wdcr=2;idcr=100;odcr=200;
eff=0.95;
ctac=(prwatt*1e3)/(140*eff);
ctaf=(prwatt*1e3)/s1v;
diffct=ctac-ctaf;
Ai=htcr*wdcr;
Bm=14000;
f=50;
/*****************************************************/
/************* CALCULATION OF NO. OF TURNS *******/

tnpvt=1e8/(28.637*f*Ai*Bm*eff);

clrscr();

printf("\nEnter the voltage at boost mode :");
scanf("%f",&boovt);
printf("\nEnter the voltage at normal mode :");
scanf("%f",&novt);
printf("\nEnter the voltage at buck mode :");
scanf("%f",&buvt);
exboovt=prlrvt;
prtns=prhrvt*tnpvt;
tubo=(prtns*s1v)/boovt;
tueb=prtns*s1v/exboovt;
```

```
tuno=prtns*s2v/novt;
tubu=prtns*s2v/buvt;

printf("\nNO. of turns in the primary :%f",prtns);
printf("\nNo. of turns for boost mode :%f",tubo);
printf("\nNo. of turns for extra boost mode :%f",tueb);
printf("\nNo. of turns for normal mode :%f",tuno);
printf("\nNo. of turns for buck mode :%f",tubu);

/*****************************************************/
/**************** GAUGE SELECTION *****************/

/* A standard of 400 circular mils per amp*/
cir=ctaf*400;
prcir=cir;

prevdiff=99999.9;
for(ct=1;ct<=2;ct++)
{
for(ctr=1;ctr<=40;ctr++)
{
        if(tab1[ctr]>prcir)
          diff=tab1[ctr]-prcir;
        else
          diff=prcir-tab1[ctr];
        if (diff< prevdiff)
         prevdiff=diff;
        else
         {
        ctr=ctr-1;
        if (ct==1)
        {
        if (tab1[ctr]<= prcir)
```

```
{
s1gau=swg[ctr];
diffcir=diffct*400;/* circular mils of in which difference */
prcir=diffcir;
prevdiff=9999999.9;
}
}
else
{
s2gau=swg[ctr];
}
break;
}

}; /*end of second for loop*/
}; /*end of first for loop*/
/* DIAMETER CALCULATION */
ctr=1;
while(ctr<40)
{
if(s1gau==swg[ctr])
{
cho=getch();
dias1=diamil[ctr]/1093;   /*  diameter of pry wdg in inches   */
printf("Diameter of %f =%f(in mils)in %d",s1gau,diamil[ctr],ctr);
}
if(s2gau==swg[ctr])
{
dias2=diamil[ctr]/1093;   /* diameter of sec2 wdg in inches   */
printf("Iam diamil of %f =%f(in mils) in %d",s2gau,diamil[ctr],ctr);
cho=getch();
}
ctr++;
```

```
}
dias1=dias1*2.54*10;
dias2=dias2*2.54*10;

/**************************************************/

circa=(22.0/7.0)*idcr;
india=idcr;
htcr=40;
lntn=2*htcr+(odcr-idcr);
len=lntn;
difft=0;
totT=0;
pd=ctr=0;
dia=idcr;
for(ct=1;totT<tueb;ct++)
 {
   if((tueb-prtns)>totT)
    {
        len=len+8*pd;
        dia=dia-2*pd;
        temptu=((22.0/7.0)*dia)/dias1;
        pd=dias1;
        difft=(tueb-totT);
        if(difft<=temptu)
         {
         N[ct]=difft;
         temp=ct+1;

         N[ct+1]=0;
         break;
         }
        else
```

```
{
totT=totT+temptu;
N[ct]=temptu;
L[ct]=len*N[ct];
printf("\nN[ct]=%f",N[ct]);
}
india=dia;

}
else
{
len=len+8*pd;
dia=dia-(2*pd);
temptu=(22.0/7.0)*dia/dias2;
if( pd==dias1)
{
temp=ct;
for (ctr=1;ctr<temp;ctr++)
{
length1=L[ctr]+length1;
};
};
pd=dias2;
difft=tueb-totT;
if(difft<=temptu)
{
N[ct]=difft;
L[ct]=len*N[ct];
temp1=ct+1;
for (ctr=temp;ctr<temp1+1;ctr++)
{
length2=L[ctr]+length2;
}
```

```
  N[ct+1]=0;
  break;
 }
 else
 {
  totT=totT+temptu;
  N[ct]=temptu;
  L[ct]=len*N[ct];
 }
 india=dia;
 }

 };
/*******************************************************/
  for(ct=1;N[ct]>0;ct++)
  {
  printf("\n the no. of turns in %d is %fand length is
%f",ct,N[ct],L[ct]);
  };

  printf("\n\n\nLENGTH OF COPPER \n");
  printf("\n length of %f SWG copper : %f",s1gau,length1/1000);
  printf("\n length of %f SWG copper : %f",s2gau,length2/1000);

/**************** WEIGHT OF COPPER ****************/

ctr=1;
while(ctr<40)
{
if(s1gau==swg[ctr])
wts1=wt[ctr];   /*  wt of sec1 wdg in gm/m  */
if(s2gau==swg[ctr])
wts2=wt[ctr];   /*  wt of sec2 wdg in gm/m  */
```

```
ctr++;
}
printf("\n wt of %f swg from table=%f",s1gau,wts1);
printf("\n wt of %f swg from table=%f",s2gau,wts2);
wt1=length1*wts1/1e6; /* wt 1st type of wire */
wt2=length2*wts2/1e6; /* wt 2nd type of wire */
printf("\n\nWEIGHT  OF  COPPER \n");
printf("\n wt of %f SWG copper : %f",s1gau,wt1);
printf("\n wt of %f SWG copper : %f",s2gau,wt2);

}
```

CHAPTER 7

VOLTAGE AND CURRENT TRANSFORMERS

VOLTAGE AND CURRENT TRANSFORMERS

7.1. GENERAL DESCRIPTION

7.1.1.VOLTAGE TRANSFORMERS

A simple elements of a transformer consists of two coils having mutual inductance and laminated steel core. The two coils are insulated from each other and the steel core.

In all types of transformers, the core is constructed with sheet steel laminations to provide a continuos magnetic path with a minimum air gap included. The steel used is of high silicon content sometimes heat treated to produce a high permeability and low hysterisis loss at the usual operating fluxes. The eddy current loss is minimised by laminating the core, the laminations being insulated from each other by a light coat of core plate varnish or by an oxide layer on the surface. Constructionally, the transformers are of two general types:

1 Shell type
2 Core type

In order to avoid the high reluctance at the joints where the laminations are bolted against each other, the alternate layer are stacked differently to eliminate these joints.

7.1.2. CURRENT TRANSFORMER

It is difficult to construct ammeters and the current coils of wattmeters, energy (kwh) meters and relays to carry alternating currents greater than about 100 A. Furthermore, if the voltage of the system exceeds 500v, it is dangerous to connect such instruments directly to the high voltage. These difficulties are over come by using current transformers.

The secondary circuit of a current transformer must on no account be opened while the primary winding is carrying a current, Since all the primary-ampere turns would then be available to produce flux. The core loss due to the high flux density would cause excessive heating on the core and windings, and a dangerously high might be induced in the secondary winding.

Hence if it is desired to remove the ammeter from the secondary circuit, the secondary winding must first be short circuited, this will not be accompanied by an excessive secondary current, since the latter is proportional to the primary current and since the primary winding is in series with the load, the primary current is determined by the value of the load and not by the secondary current.

7.2. DESIGN OF SMALL TRANSFORMERS

7.2.1. CORE SELECTION

As the first step to the design of a transformer, the primary and secondary voltage ratings and the secondary current rating must be clearly stated. Then decide the core material to be used. (i.e.) Ordinary steel stamping (or) cold rolled gain oriented (CRGO) stampings. CRGO has a higher allowable flux density and low losses.

The optimum cross-sectional area of the core is approximately given by:

$$Ai = \sqrt{\frac{W}{5.58}} \quad \text{(in inches)}$$

Primary winding calculations:

primary voltage = 280v

Secondary :

watttage of Ist secondary = $20 * 500 * (10^{-3})$

= 10 watts

wattage of II nd secondary = $15 * 200 * (10^{-3})$

= 3 watts

total watts = 13 watts

Cross-sectional area of core $= \sqrt{\frac{W}{5.58}} = \sqrt{\frac{13}{5.58}}$

= 0.646 sq inches

Assume the allowance of 0.25 sq inches

So Ai = 0.9 sq inch

$$\text{Input power} = \frac{\text{Output}}{\text{efficiency}}$$

Assuming the efficiency of 90 %

$$\text{Input power} = \frac{13}{0.9} = 14.4 \text{ watts}$$

$$\text{primary current} = \frac{14.4}{140} = 0.103 \text{ amps}$$

Maximum flux density = 1.1 wb/m^2

Volts per turn

$$= 4.44 * f * B_m * Ai$$
$$= 4.44 * 50 * 1.1 * 0.9 * (2.54 * 10^{-3})^2$$
$$= 0.142 \text{ volts / turn}$$

Calculation of

$$\text{number of turns in primary} = \frac{V}{E_t} = \frac{280}{0.142} = 1975 \text{ turns}$$

I st Secondary :

$$\frac{20}{0.142} = 141 \text{ turns}$$

II nd Secondary :

$$\frac{15}{0.142} = 106 \text{ turns}$$

7.2.2. GAUGE SELECTION

From Table

1 Amp = 400 circular mils in primary

In primary

0.103 * 400 = 41.2 circular mils

Gauge = 37 SWG

In Ist Secondary
$500 * 10^{-3} * 400 = 200$ circular mils

Gauge = 29 SWG (0.013")

In II nd Secondary
$200 * 10^{-3} * 400 = 80$ circular mils

Gauge = 34 SWG (0.009")

7.2.3.LAYER CALCULATION

CORE NO. = TYPE 15

In Primary

$$\text{Turns per layer} = \frac{1.50''}{0.0068} = 220 \text{ turns}$$

$$\text{No of layers} = \frac{1975}{220} = 8.97 = 9 \text{ layers}$$

$$\text{Height of the winding} = \frac{9}{220} = 0.041''$$

In Secondary

In Ist secondary

$$\text{Turns per layer} = \frac{1.5''}{0.013} = 115 \text{ turns}$$

Another 26 turns will come in second layer.

In IInd secondary

$$\text{Turns per layer} = \frac{1.5''}{0.009} = 167 \text{ turns}$$

7.2.4. TOTAL LENGTH OF CONDUCTORS

Total length of primary winding = 1.5" * 4 * 2.54 * 1975
= 301 metres.

Total length of Ist secondary = 1.5" * 4 * 2.54 * 141
= 22 metres

Total length of IInd Secondary = 1.5" * 4 * 2.54 * 106
= 16.15 metres

7.2.5.WEIGHT OF COPPER

weight of 37 SWG Copper = 0.2083 * 301
= 62.69 gms

weight of 29 SWG Copper = 0.8344 * 22

$= 18.35$ gms

weight of 34 swg Copper $= 0.3813 * 16.16$
$= 6.16$ gms

7.3. DESIGN OF CURRENT TRANSFORMERS

Secondary current = 0.25 A
Primary current = 25 A
Secondary voltage = 2.5v

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$$V_1 = \frac{V_2 * I_2}{I_1}$$

$$= \frac{2.5 * 0.25}{25}$$

$$= 0.025 \text{ v}$$

1 amp = 400 circular mils
primary circular mils = 25 * 400 = 10000 circular mils
therefore from table gauge selected is 12 swg (0.09322")
secondary circular mils = 0.25 * 400 = 100 circular mils
therefore from table gauge slected is 34 swg (0.009")
Turns per layer in primary = 1

Turns per layer in secornary $= \frac{1.5''}{0.009} = 166$ turns

Total length of primary $= 1.5'' * 4 * 2.54 * N_1$
$= 1.5'' * 4 * 2.54 * 1/100$
$= 0.1524$ metres

Total length of secondary = 1.5" * 4 * 2.54 * N_2

= 1.5" * 4 * 2.54 * 100/100

= 15.24 metres

Weight of copper:

In primary = 48.72 * 0.1524

= 7.42 gms

In secondary = 0.3813 * 15.24

= 5.81 gms

7.4. COMPUTER AIDED DESIGN

7.4.1 ALGORITHM

1 Get the choice for voltage or current transformer

2 If it is voltage transformer,

   2.1. Get the primary voltage, frequency, secondary voltage and current.

   2.2. Get the choice for the second secondary.

   2.3. Calculate the total wattage and core area.

   2.4. Calculate the allowance based on the total wattage.

   2.5. Calculate the input power, primary current and volt per turn.

   2.6. Calculate of number of turns.

   2.7. Based on the circular mils, select the gauge.

   2.8. Calculate the turns per layer and number of layers in primary and secondary.

   2.9. Calculate the total length and weight of copper for the windings.

3. If it is a current transformer,

   3.1. Get the input regarding primary current, secondary current and secondary voltage.

   3.2. Calculate the primary circular mils and secondary circular mils.

3.3. Calculate the gauge of primary and secondary windings.

3.4. Calculate the layers in secondary and the number of turns in a layer.

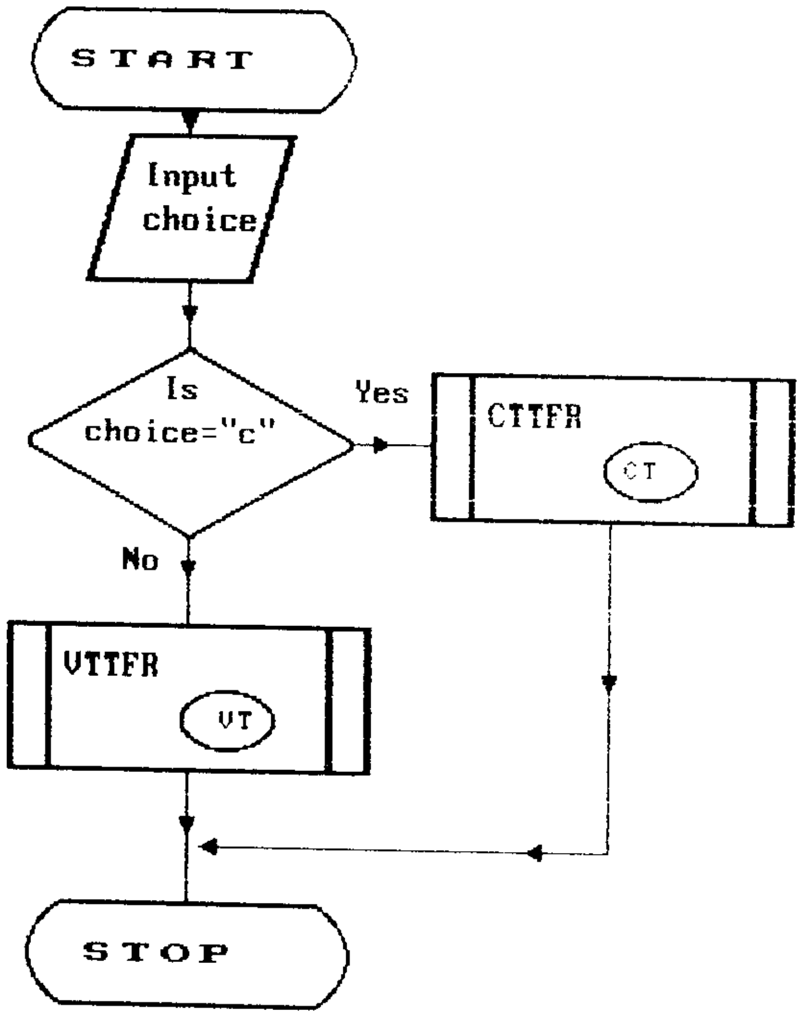
3.5. Calculate the total length for both the windings.

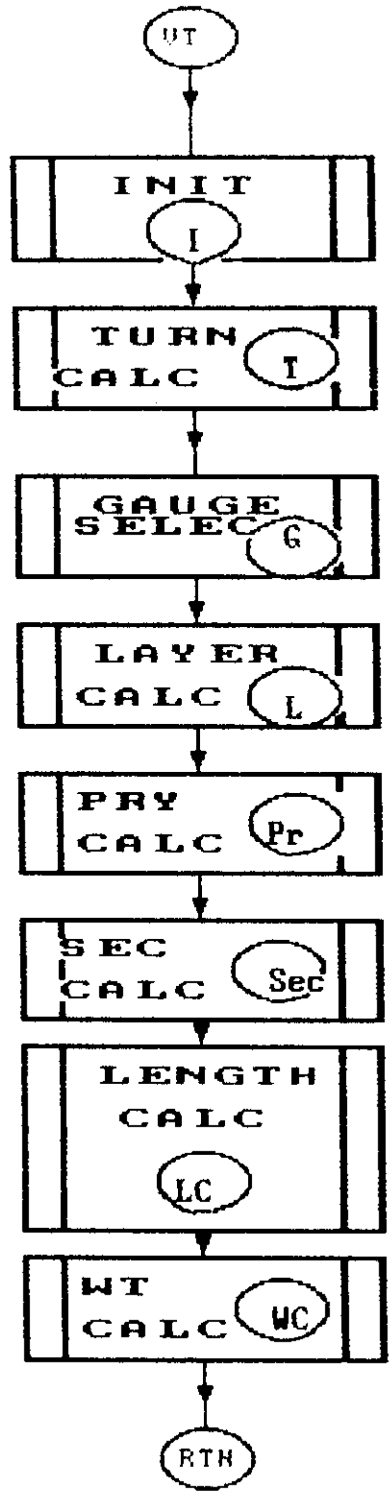
3.6. Calculate the weight of the copper wires from the table and the total weight of each winding is obtained.

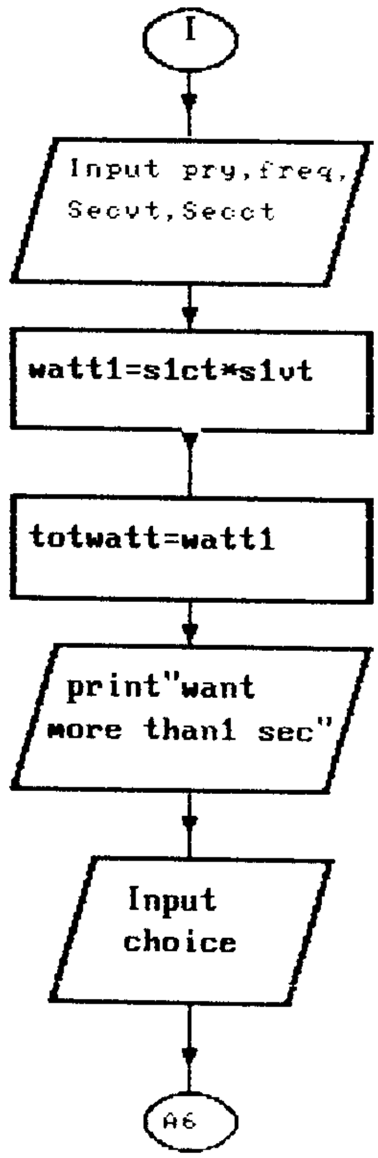
4. The required outputs are displayed on the Visual display unit.

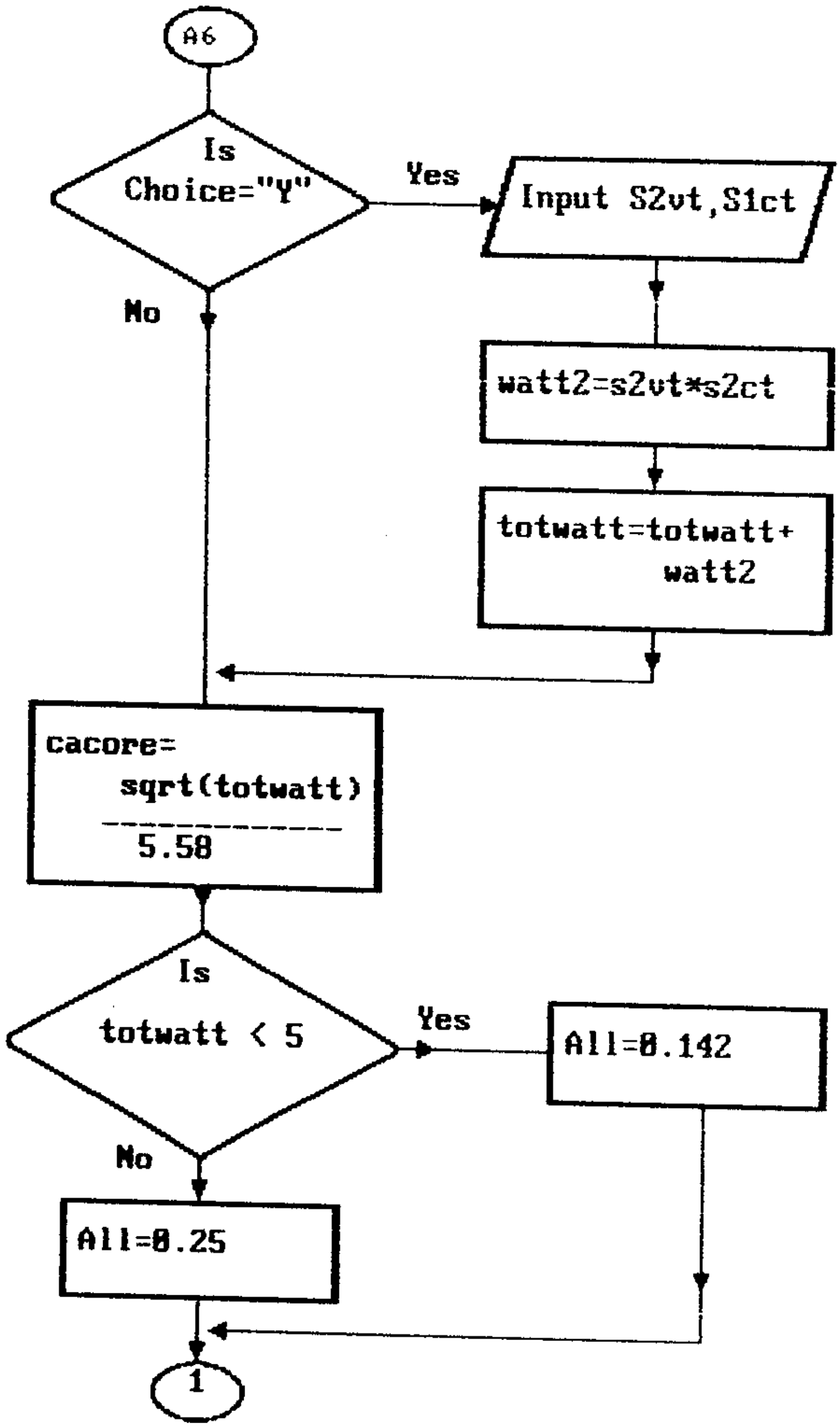
The implementation of the above algorithm has been done using C language.

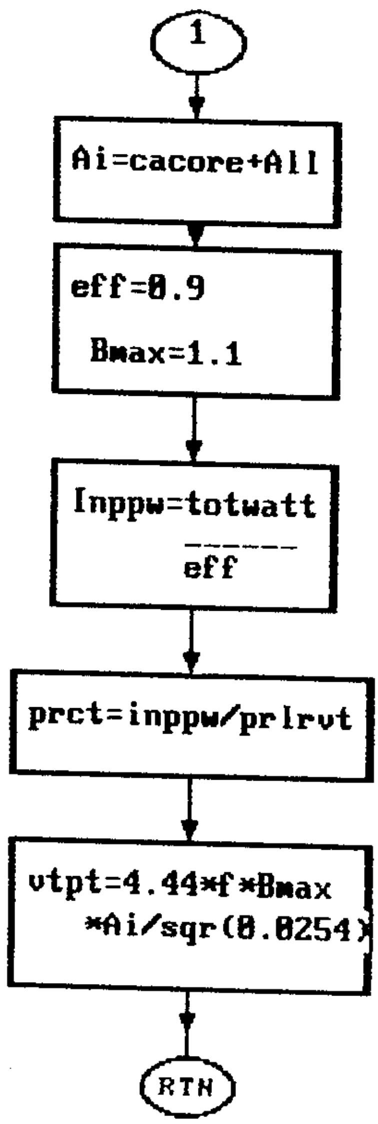
7.4.2. FLOW CHART

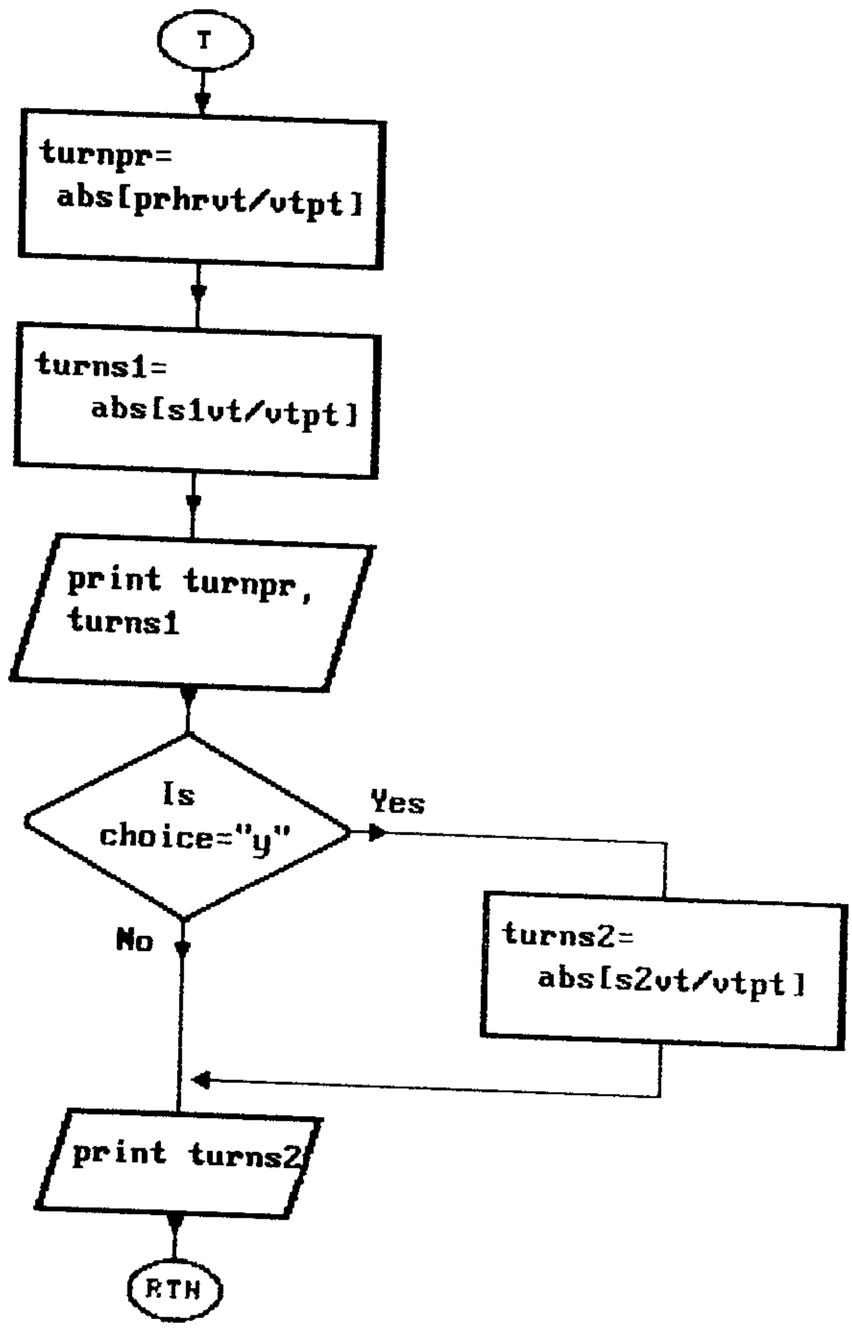


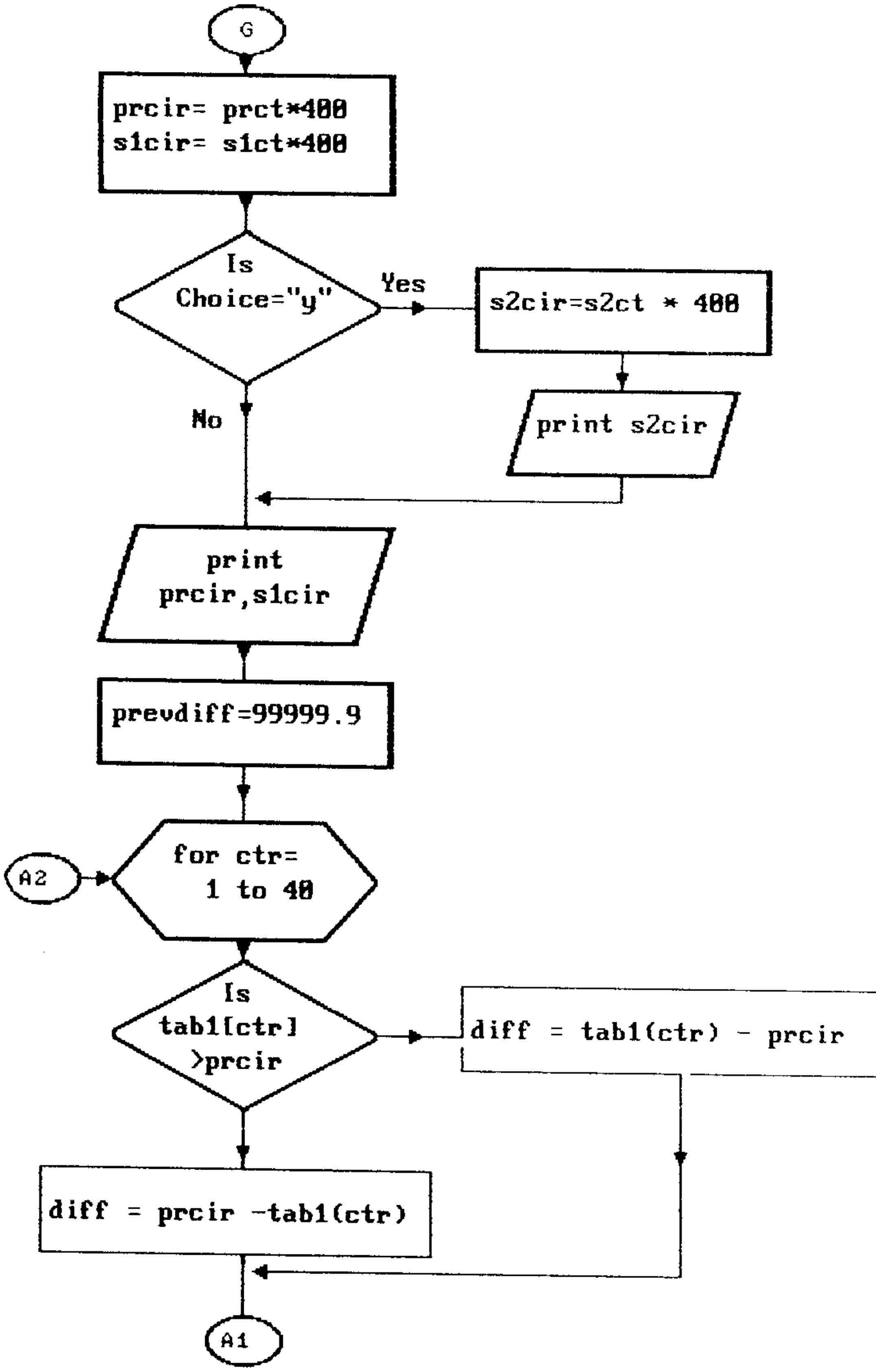

WT
INIT
I
TURN
CALC
T
GAUGE
SELEC
G
LAYER
CALC
L
PRY
CALC
Pr
SEC
CALC
Sec
LENGTH
CALC
LC
WT
CALC
WC
RTN

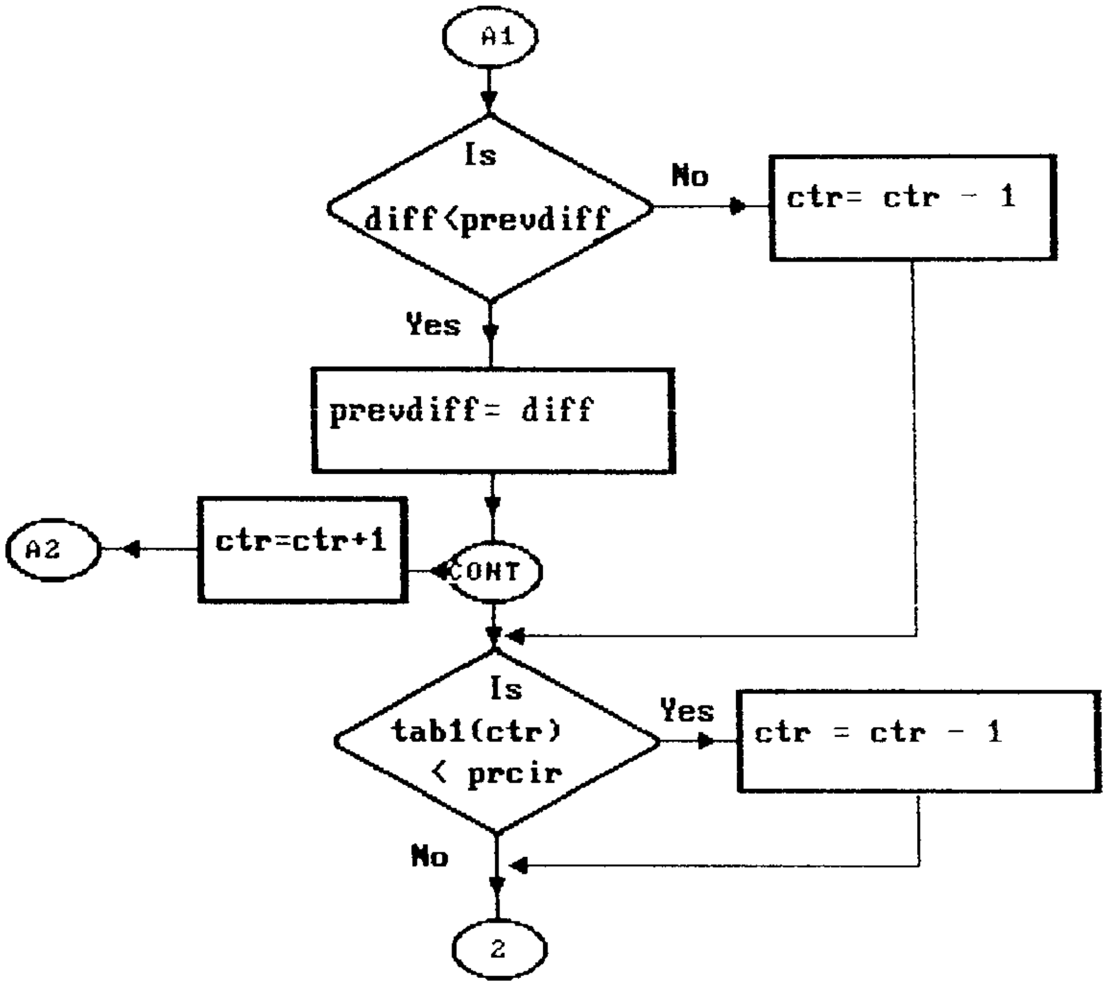

I
Input pry,freq,
Secvt,Secct
watt1=s1ct*s1vt
totwatt=watt1
print"want
more than1 sec"
Input
choice
A6

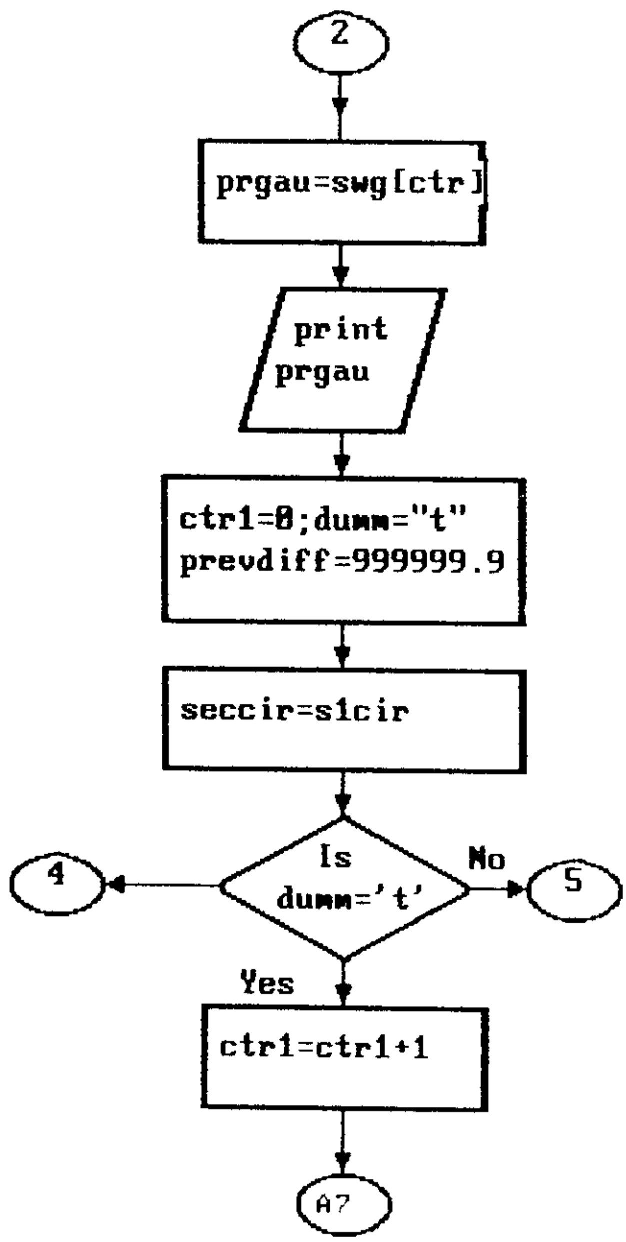

A6
Is
Choice="Y"
Yes
No
Input S2vt,S1ct
watt2=s2vt*s2ct
totwatt=totwatt+
watt2
cacore=
sqrt(totwatt)
5.58
Is
totwatt < 5
Yes
No
All=0.142
All=0.25
1

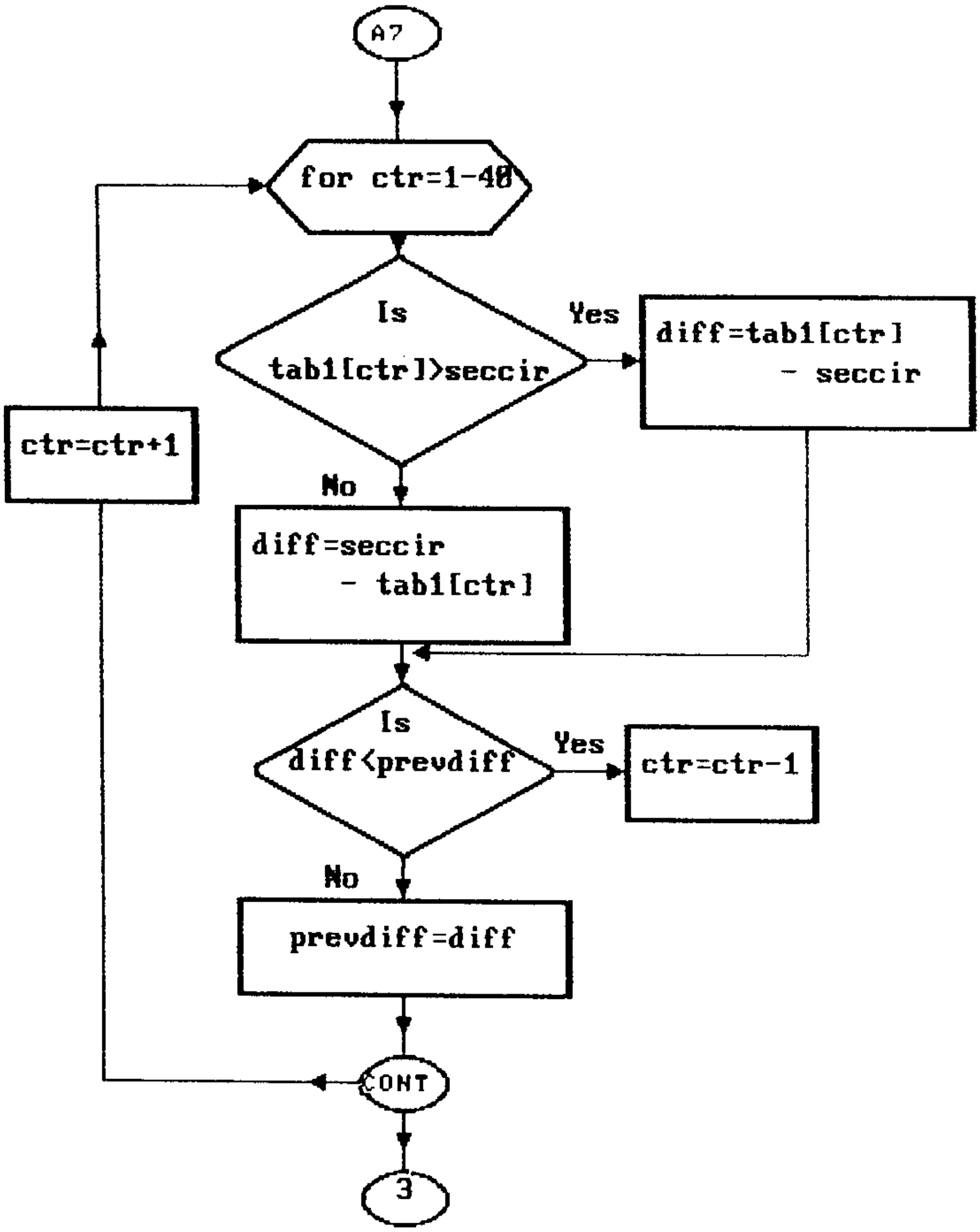

1
Ai=cacore+All
eff=0.9
Bmax=1.1
Inppw=totwatt
eff
prct=inppw/prlrvt
vtpt=4.44*f*Bmax
*Ai/sqr(0.0254)
RTN

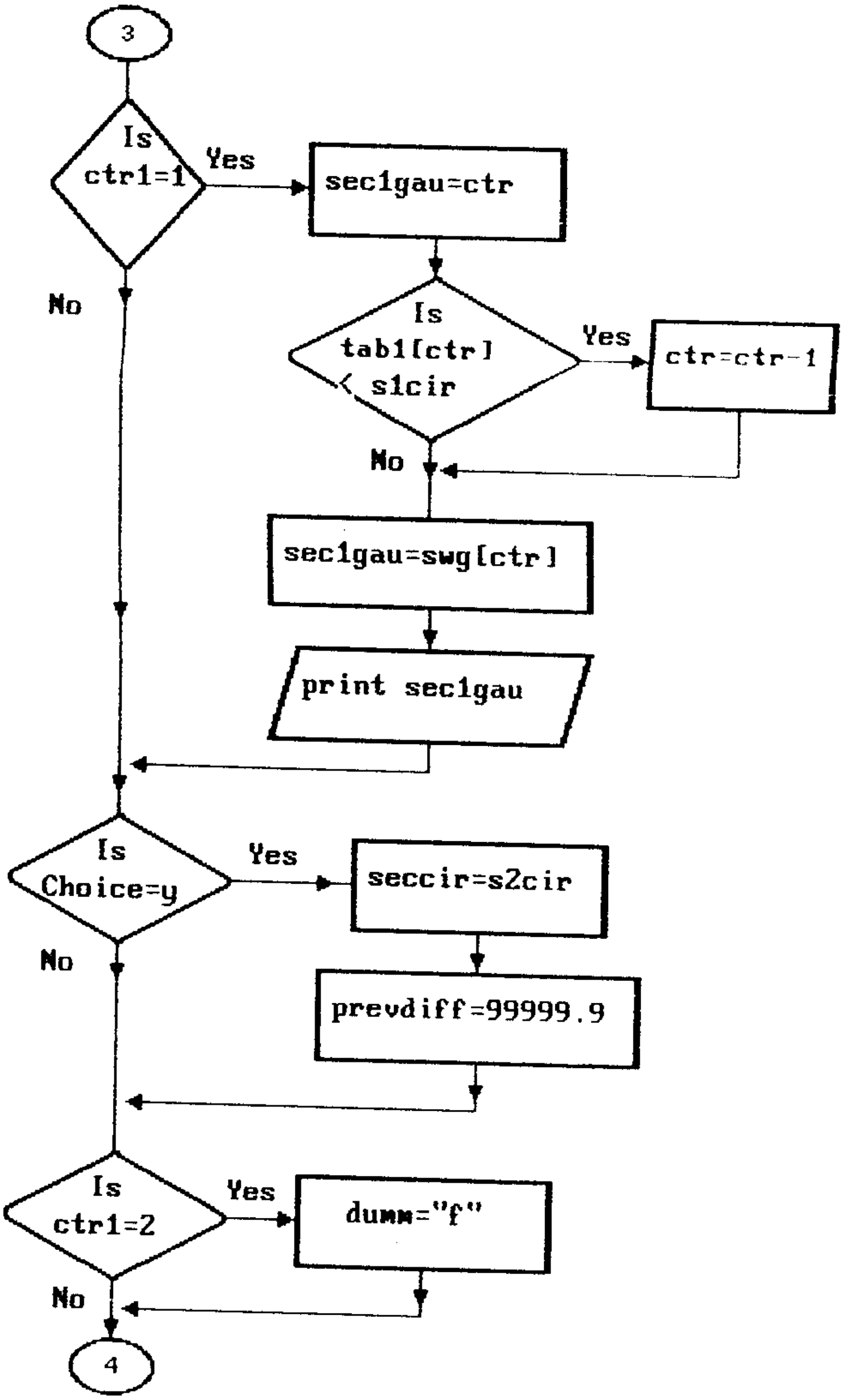

T
turnpr=
abs[prhrvt/vtpt]
turns1=
abs[s1vt/vtpt]
print turnpr,
turns1
Is
choice="y"
Yes
turns2=
abs[s2vt/vtpt]
No
print turns2
RTN

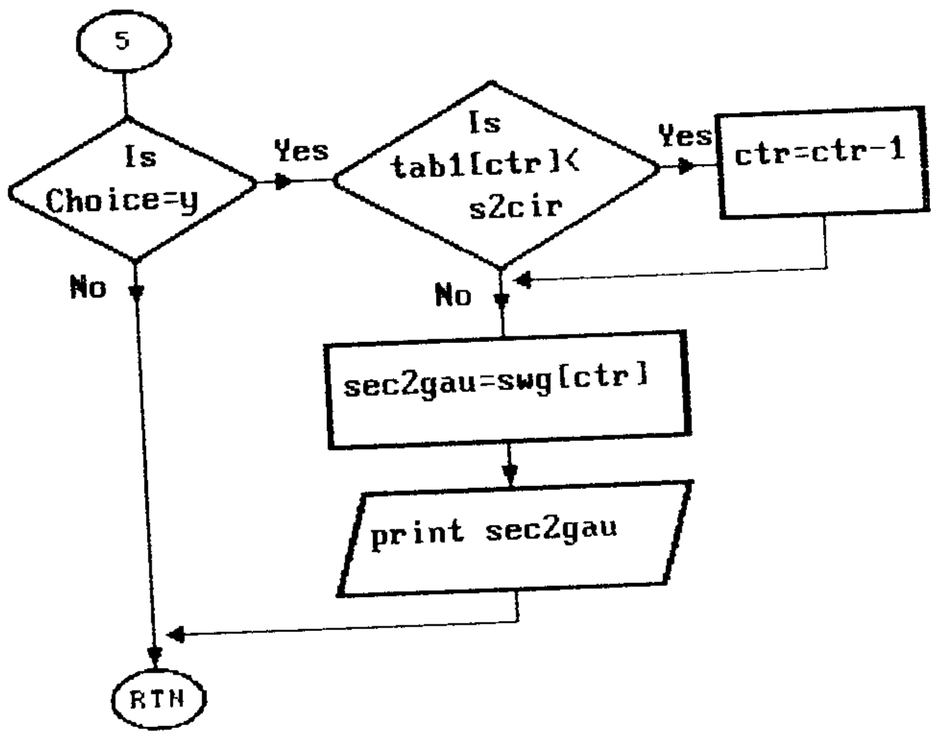

G
prcir= prct*400
s1cir= s1ct*400
Is
Choice="y"
Yes
s2cir=s2ct * 400
print s2cir
No
print
prcir,s1cir
prevdiff=99999.9
A2
for ctr=
1 to 40
Is
tab1[ctr]
>prcir
diff = tab1(ctr) - prcir
diff = prcir -tab1(ctr)
A1

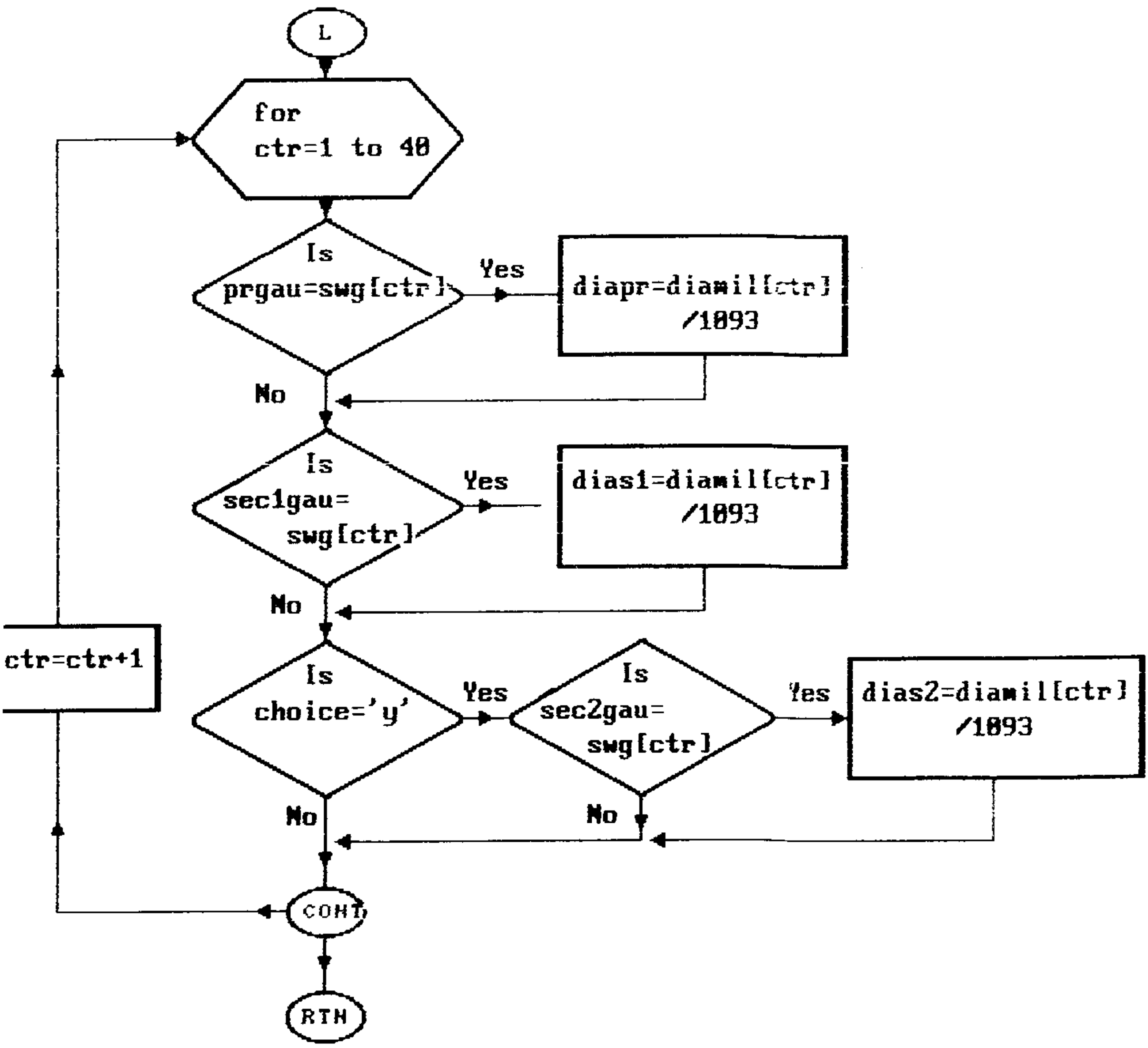

A1
Is
diff<prevdiff
No
ctr= ctr - 1
Yes
prevdiff= diff
A2
ctr=ctr+1
CONT
Is
tab1(ctr)
< prcir
Yes
ctr = ctr - 1
No
2

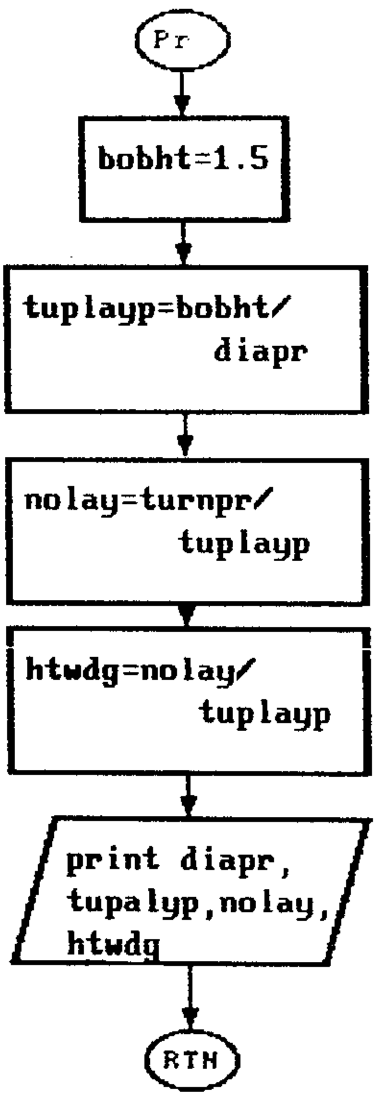

2
prgau=swg[ctr]
print
prgau
ctr1=0;dumm="t"
prevdiff=999999.9
seccir=s1cir
Is
dumm='t'
No
5
4
Yes
ctr1=ctr1+1
A7

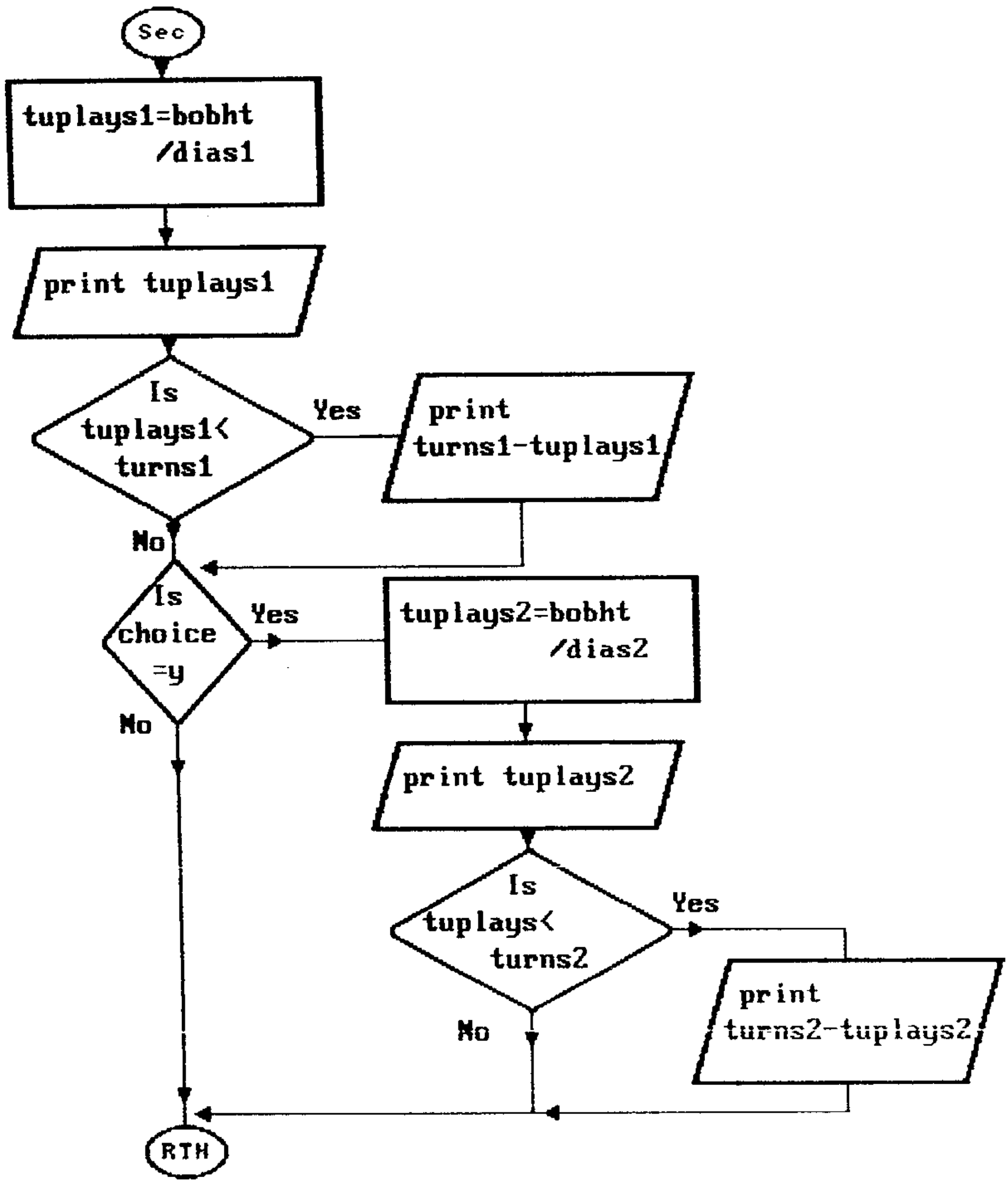

A7
for ctr=1-40
Is
tab1[ctr]>seccir
Yes
diff=tab1[ctr]
- seccir
ctr=ctr+1
No
diff=seccir
- tab1[ctr]
Is
diff<prevdiff
Yes
ctr=ctr-1
No
prevdiff=diff
CONT
3

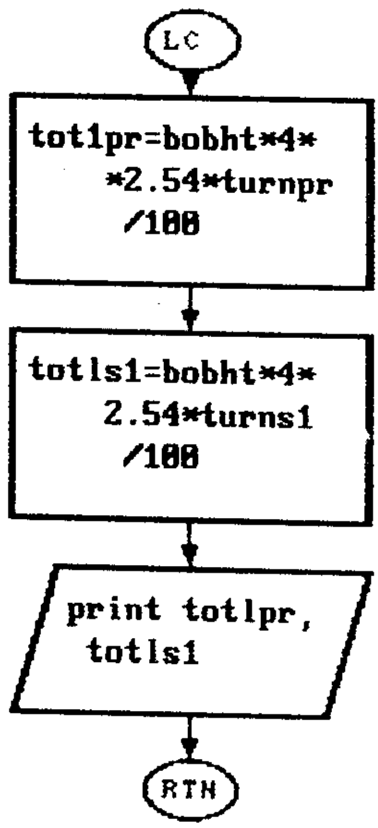

3
Is ctr1=1
Yes
No
sec1gau=ctr
Is tab1[ctr] < s1cir
Yes
ctr=ctr-1
No
sec1gau=swg[ctr]
print sec1gau
Is Choice=y
Yes
seccir=s2cir
prevdiff=99999.9
No
Is ctr1=2
Yes
dumm="f"
No
4

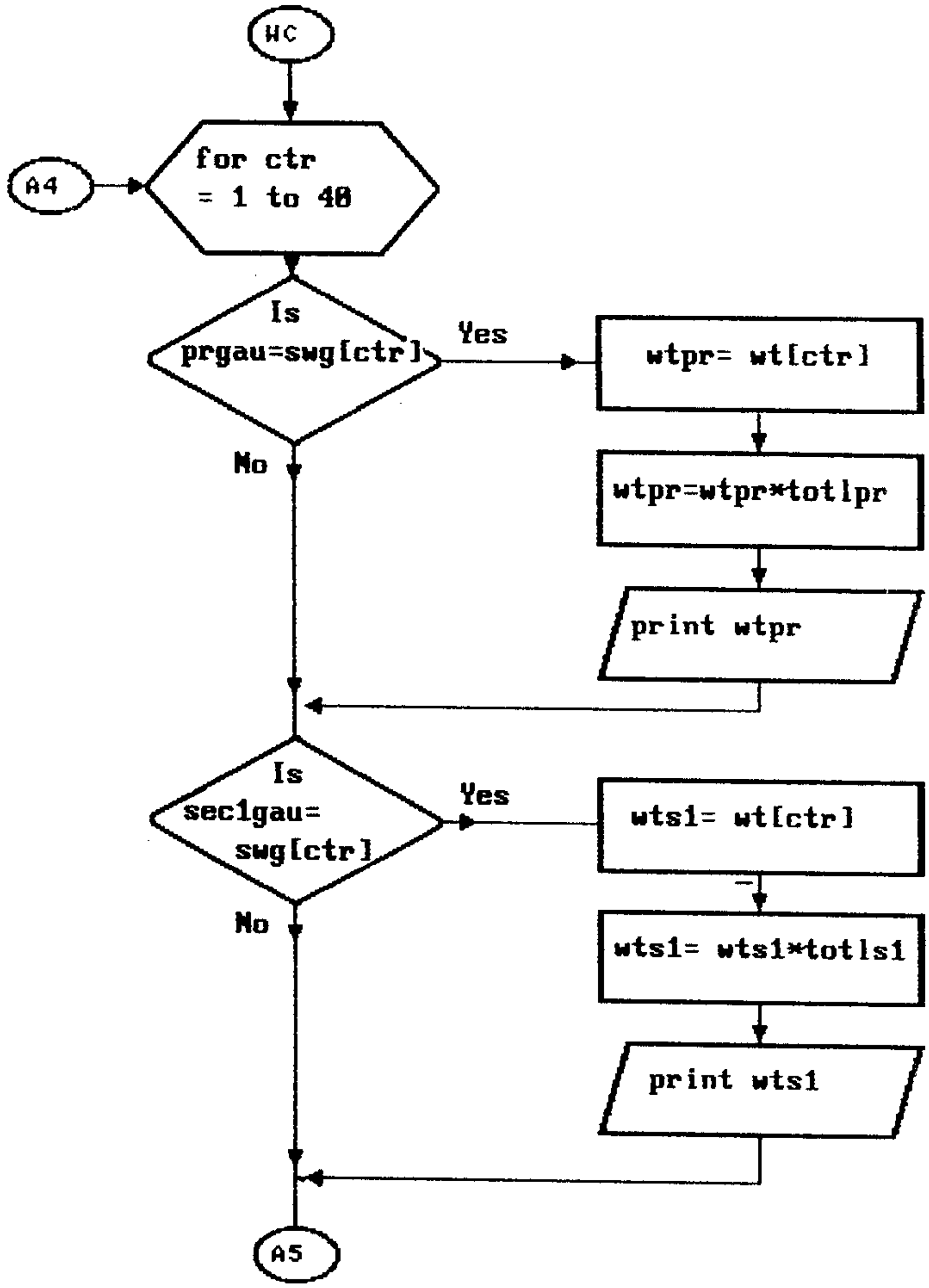

5
Is
Choice=y
Yes
Is
tab1[ctr]<
s2cir
Yes
ctr=ctr-1
No
No
sec2gau=swg[ctr]
print sec2gau
RTN

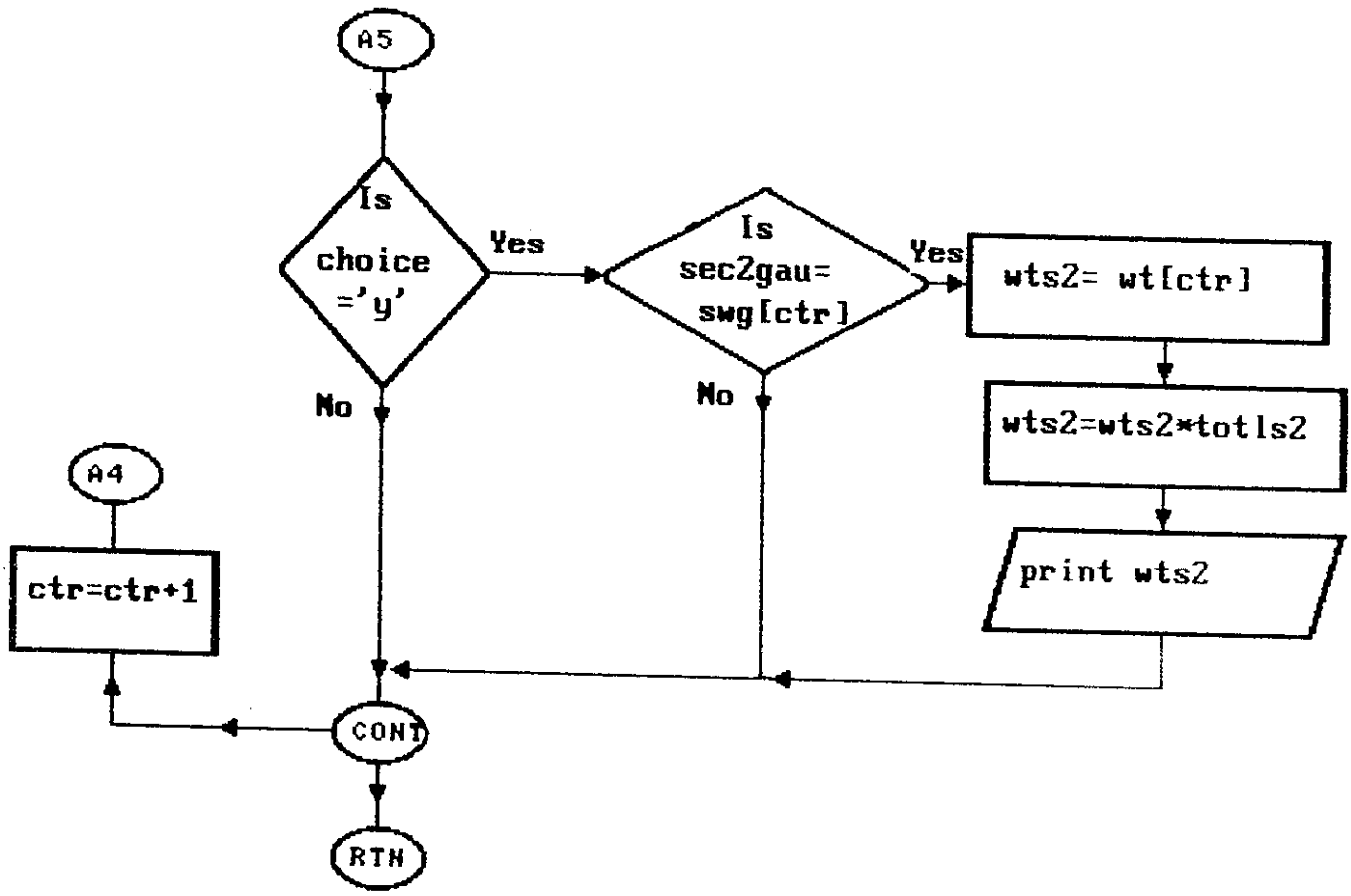

L
for
ctr=1 to 40
Is
prgau=swg[ctr]
Yes
diapr=diamil[ctr]
/1093
No
Is
sec1gau=
swg[ctr]
Yes
dias1=diamil[ctr]
/1093
No
ctr=ctr+1
Is
choice='y'
Yes
Is
sec2gau=
swg[ctr]
Yes
dias2=diamil[ctr]
/1093
No
No
CONT
RTN

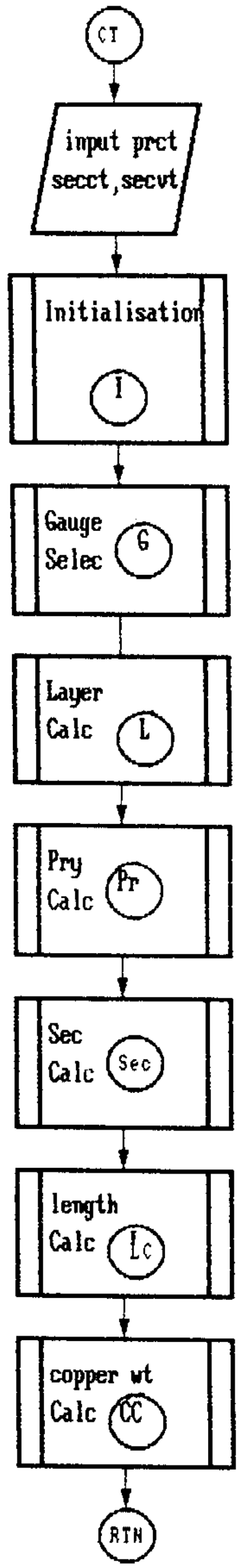

Pr
bobht=1.5
tuplayp=bobht/diapr
nolay=turnpr/tuplayp
htwdg=nolay/tuplayp
print diapr,
tupalyp,nolay,
htwdg
RTN

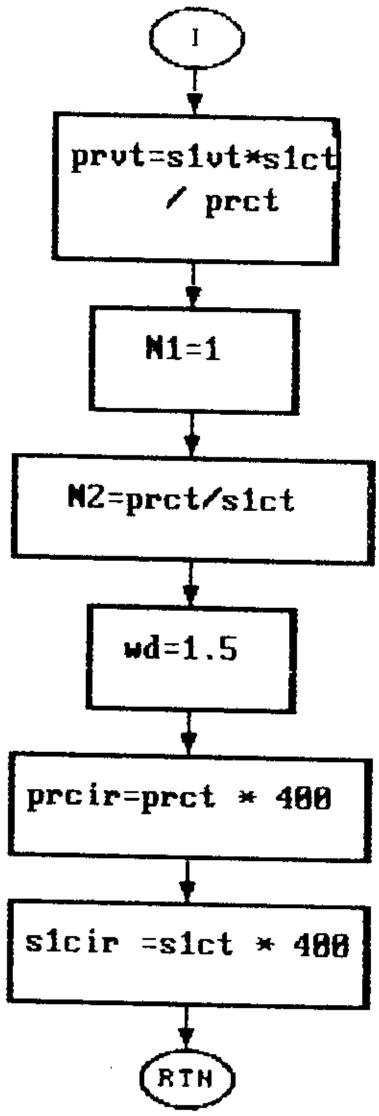

Sec
tuplays1=bobht
/dias1
print tuplays1
Is
tuplays1<
turns1
Yes
print
turns1-tuplays1
No
Is
choice
=y
Yes
tuplays2=bobht
/dias2
No
print tuplays2
Is
tuplays<
turns2
Yes
print
turns2-tuplays2
No
RTN

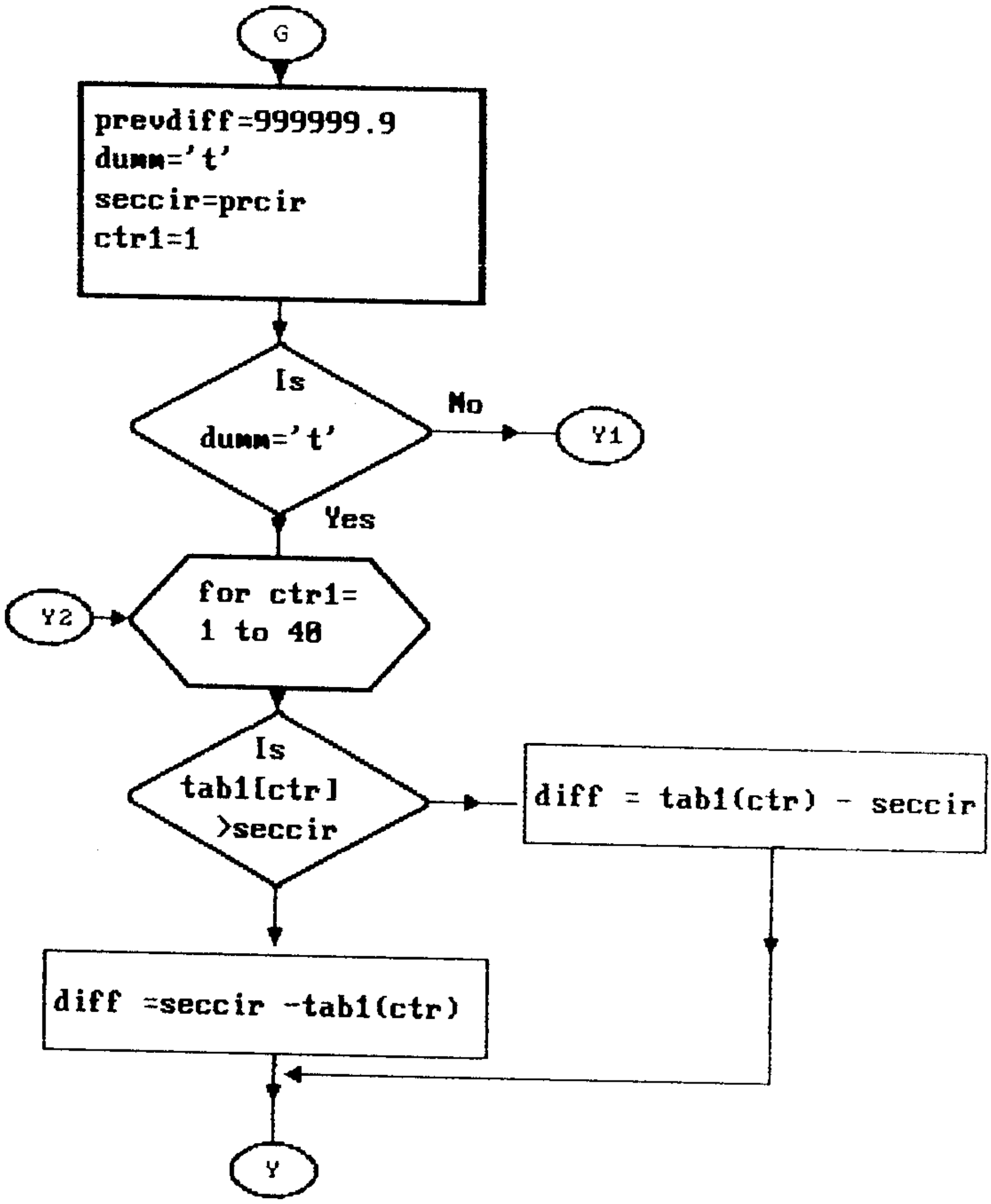

LC
totlpr=bobht*4*
*2.54*turnpr
/100
totls1=bobht*4*
2.54*turns1
/100
print totlpr,
totls1
RTN

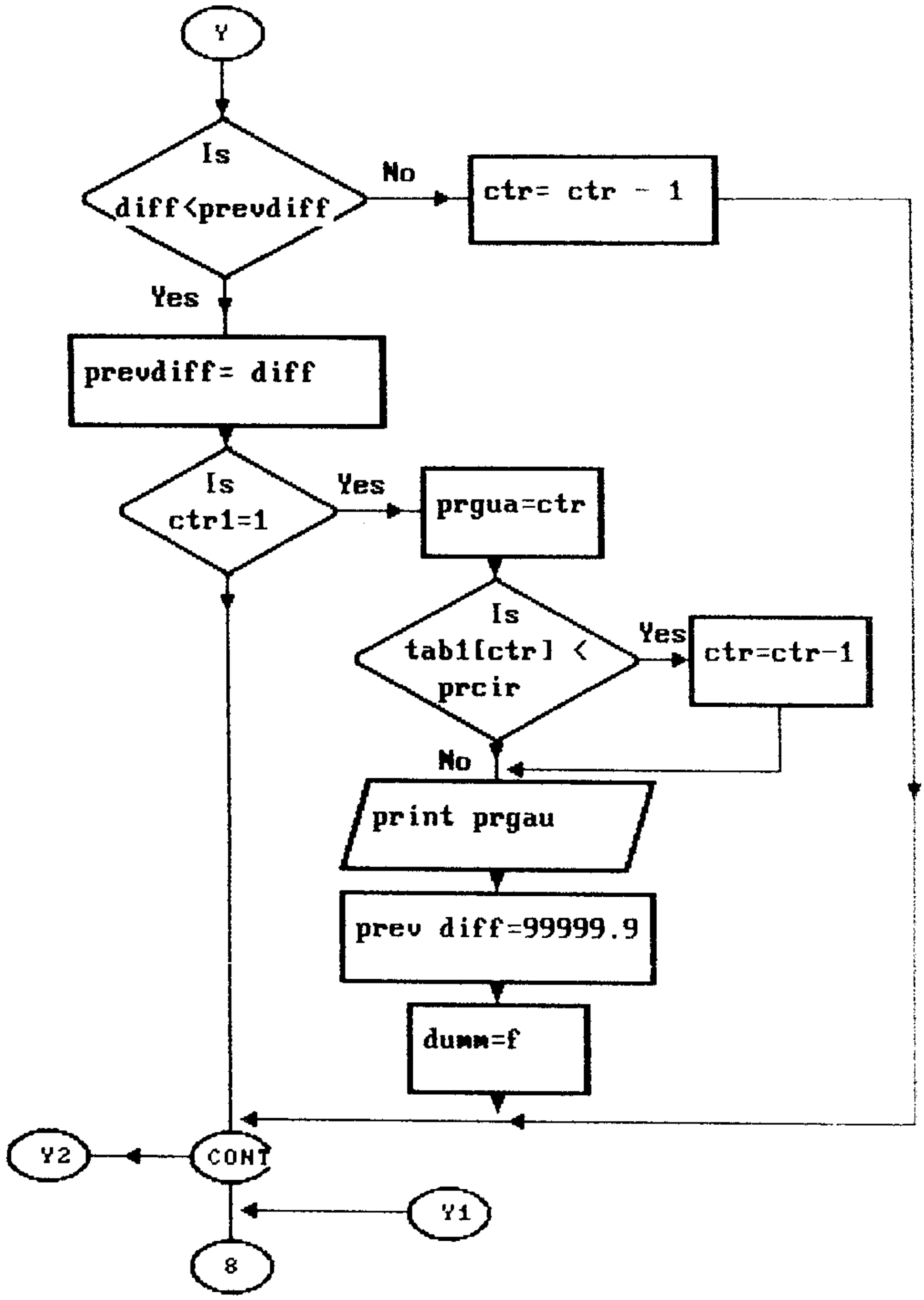

WC
A4
for ctr
= 1 to 40
Is
prgau=swg[ctr]
Yes
wtpr= wt[ctr]
wtpr=wtpr*totlpr
print wtpr
No
Is
sec1gau=
swg[ctr]
Yes
wts1= wt[ctr]
wts1= wts1*totls1
print wts1
No
A5


A5
Is
choice
='y'
Yes
Is
sec2gau=
swg[ctr]
Yes
wts2= wt[ctr]
wts2=wts2*totls2
print wts2
No
No
A4
ctr=ctr+1
CONT
RTN

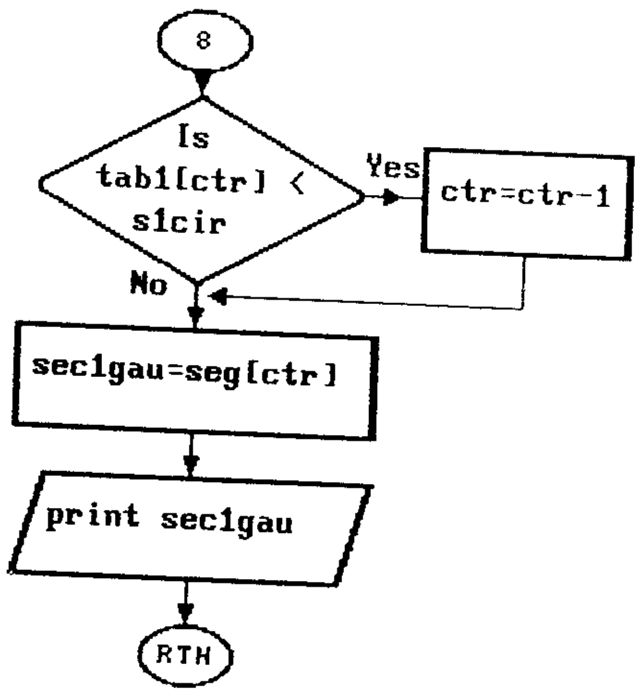

CT
input prct
secct,secvt
Initialisation
I
Gauge
Selec
G
Layer
Calc
L
Pry
Calc
Pr
Sec
Calc
Sec
length
Calc
Lc
copper wt
Calc
CC
RTN

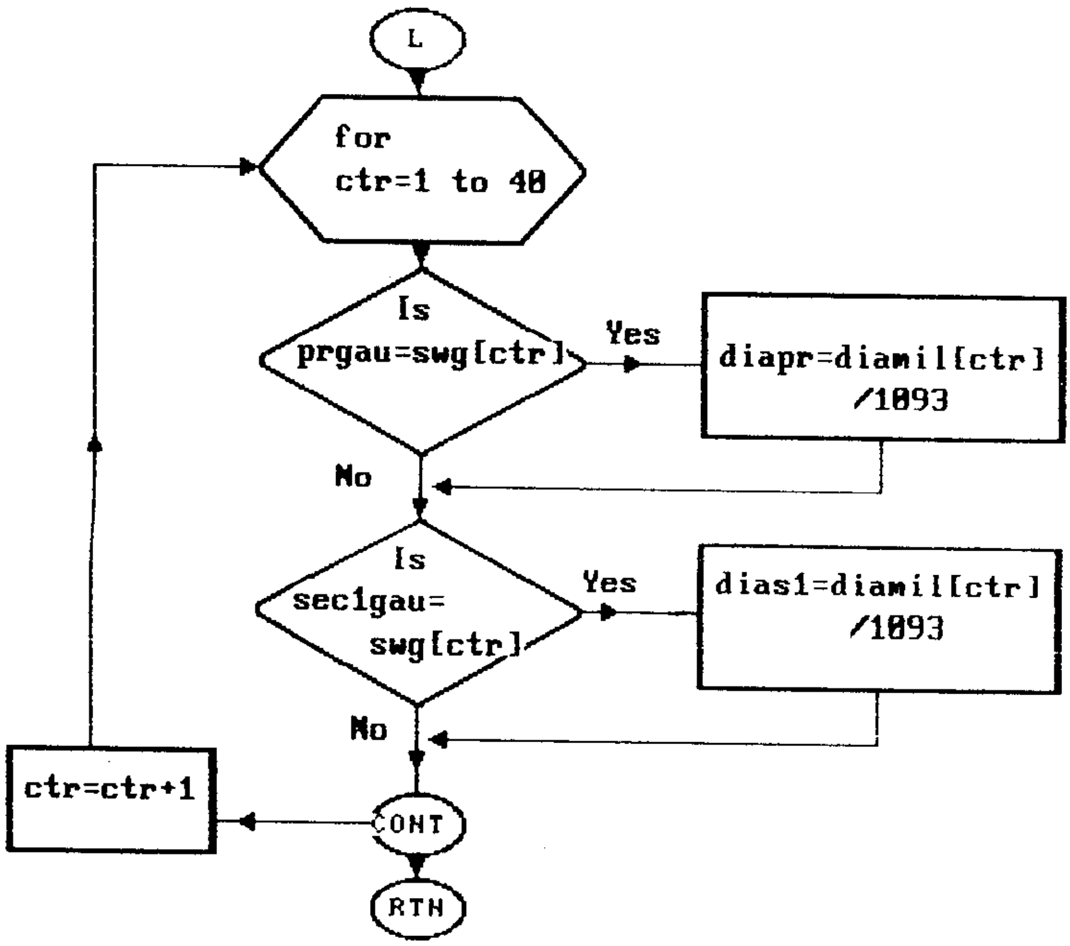

I
prvt=s1vt*s1ct / prct
N1=1
N2=prct/s1ct
wd=1.5
prcir=prct * 400
s1cir =s1ct * 400
RTN

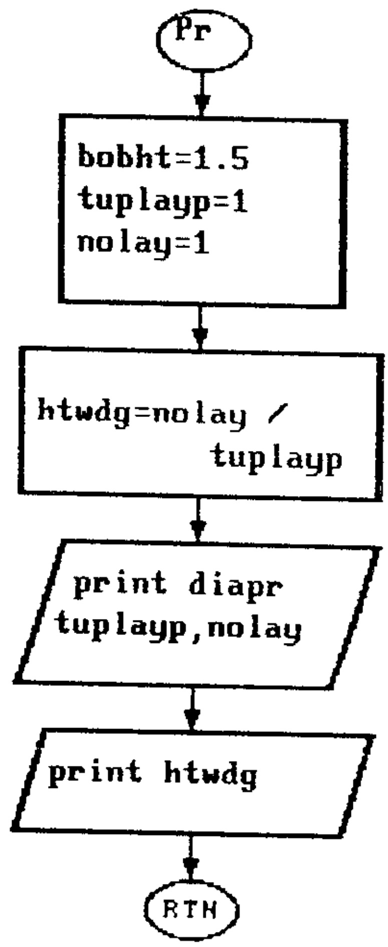

G
prevdiff=999999.9
dumm='t'
seccir=prcir
ctr1=1
Is
dumm='t'
No
Y1
Yes
Y2
for ctr1=
1 to 40
Is
tab1[ctr]
>seccir
diff = tab1(ctr) - seccir
diff =seccir -tab1(ctr)
Y

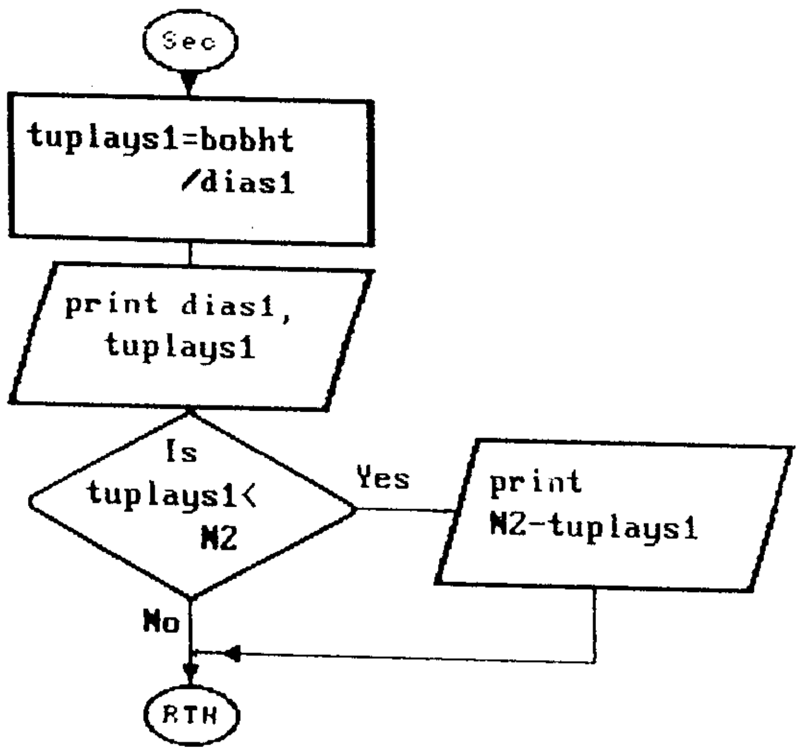


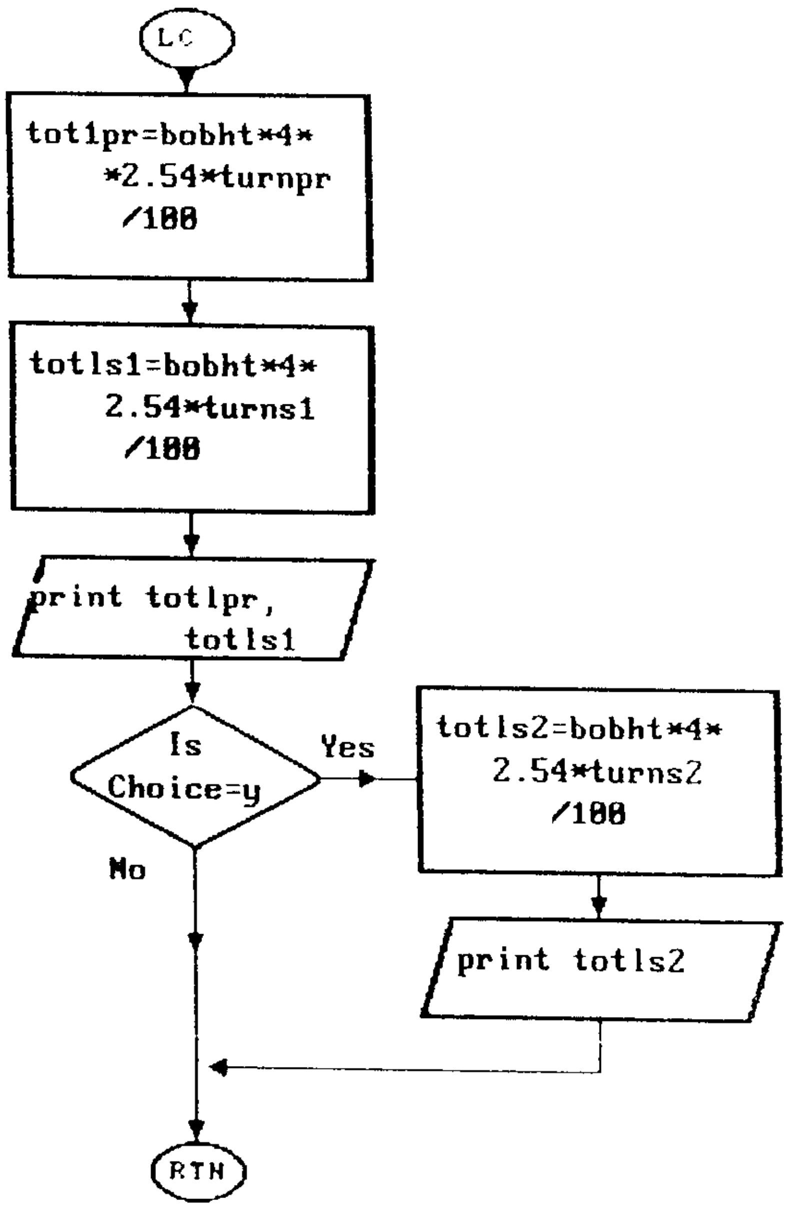
Y
Is
diff<prevdiff
No
ctr= ctr - 1
Yes
prevdiff= diff
Is
ctr1=1
Yes
prgua=ctr
Is
tab1[ctr] <
prcir
Yes
ctr=ctr-1
No
print prgau
prev diff=99999.9
dumm=f
Y2
CONT
Y1
8

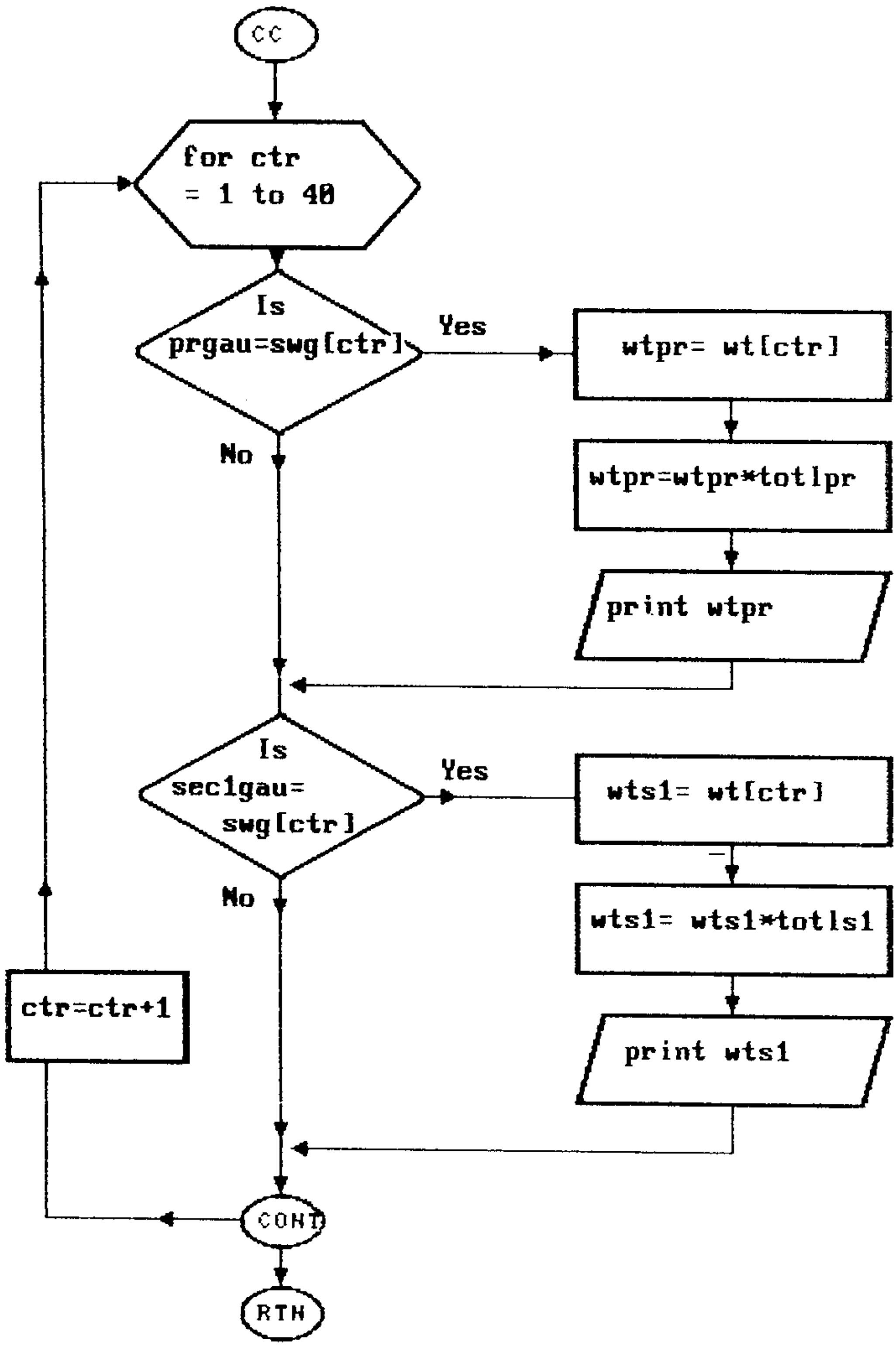

8
Is
tab1[ctr] <
s1cir
Yes
ctr=ctr-1
No
sec1gau=seg[ctr]
print sec1gau
RTN


L
for
ctr=1 to 40
Is
prgau=swg[ctr]
Yes
diapr=diamil[ctr]
/1093
No
Is
sec1gau=
swg[ctr]
Yes
dias1=diamil[ctr]
/1093
No
ctr=ctr+1
CONT
RTN


Pr
bobht=1.5
tuplayp=1
nolay=1
htwdg=nolay /
tuplayp
print diapr
tuplayp,nolay
print htwdg
RTN


Sec
tuplays1=bobht
/dias1
print dias1,
tuplays1
Is
tuplays1<
N2
Yes
print
N2-tuplays1
No
RTN


LC
tot1pr=bobht*4*
*2.54*turnpr
/100
totls1=bobht*4*
2.54*turns1
/100
print totlpr,
totls1
Is
Choice=y
Yes
No
totls2=bobht*4*
2.54*turns2
/100
print totls2
RTN



CC
for ctr
= 1 to 40
Is
prgau=swg[ctr]
Yes
wtpr= wt[ctr]
wtpr=wtpr*totlpr
print wtpr
No
Is
sec1gau=
swg[ctr]
Yes
wts1= wt[ctr]
wts1= wts1*totls1
print wts1
No
ctr=ctr+1
CONT
RTN

7.4.3. PROGRAM

```
# include<stdio.h>
# include<stdlib.h>
 int choice;
 main()
 {
 clrscr();
 gotoxy(10,10);
 printf("1. Voltage Transformer \n\n");
 printf("2. Current Transformer \n\n\n");
 printf("Enter the choice...");
  scanf("%d",&choice);
 if (choice==1)
 {
system(" cttfr.exe");
 }
 else
 {
system("pow.exe");
 }
 }
```

```
/*****************************************************/
/********* DESIGN OF POWER TRANSFORMER **********/
/*****************************************************/

# include <stdio.h>
# include <string.h>
# include <conio.h>
# include <math.h>
# include <stdlib.h>
# include <ana.h>

int ctr,ctr1,dummbo;

float
prlrvt,prhrvt=0.0,prct,s1vt,s1ct,watt1,totwatt,watt2,s2vt,s2ct,cacore,
inppw,eff,Bmax,vtpt,f,Ai,turnpr,turns1,turns2,prcir,s1cir,s2cir,
prevdiff=999999.9,diff,prgau,sec1gau,sec2gau,diapr,dias1,dias2,bobht,tuplayp,
nolay,tuplays1,tuplays2,htwdg,totlpr,totls1,totls2,wtpr,wts1,wts2,seccir,All;

char cho,choice,dumm;

main()
{
clrscr();

/*****************************************************/
/***************** INPUTS OBTAINED *****************/
/*****************************************************/

printf("Enter the primary lower lt voltage:");
scanf("%f",&prlrvt);
printf("\nEnter the primary higher lt voltage:");
scanf("%f",&prhrvt);
```

```
printf("\nEnter the frequency ;");
scanf("%f",&f);
printf("\nEnter the secondary voltage :");
scanf("%f",&s1vt);
printf("\nEnter the secondary current :");
scanf("%f",&s1ct);
watt1=s1ct*s1vt;   /* wattage of the first secondary */
totwatt=watt1;
printf("\n\nDo you want more than one secondary");
choice=getche();

if(choice == 'y')
{

printf("\nEnter the second secondary voltage :");
scanf("%f",&s2vt);
printf("\nEnter the second secondary current :");
scanf("%f",&s2ct);
watt2=s2vt*s2ct;    /**** wattage of the second secondary ****/
totwatt=totwatt+watt2;

}

/*******************************************************/
/****************** INITIALISATION ********************/
/*******************************************************/

cacore=sqrt(totwatt)/5.58;/*cross-sec area of core in sq inch */
if(totwatt<5)
All=0.142;  /* All is allowance which is assumed as 0.142  sq inch
*/
else
All=0.25;/* Allowance is assumed as 0.25 sq inch  */
```

```
Ai=cacore+All; /* Ai is core area */
eff=0.9;/* Assuming efficiency as 0.9 */
inppw=totwatt/eff;  /****  input power  in watts ****/
prct=inppw/prlrvt;  /**** primary current in amps ****/
Bmax=1.1; /**** maximum flux density ****/
vtpt=4.44*f*Bmax*Ai*pow(0.0254,2); /**** voltage per turn ****/

/*****************************************************/
/******** CALCULATION OF NUMBER OF TURNS **********/
/*****************************************************/

printf("\n turnpr=%f",turnpr);
printf("\n vtpt=%f",vtpt);
printf("\n prhrvt=%f",prhrvt);

turnpr=(float)abs(prhrvt/vtpt)+1;/* maximum no of turns in primary */
turns1=(float)abs(s1vt/vtpt)+1; /* no of secondary 1 turns */
if (choice=='y')
turns2=(float)abs(s2vt/vtpt)+1;/* no of secondary 2 turns */
printf("\nthe pr turns=%f",turnpr);
printf("\nthe sec1 turns=%f",turns1);
printf("\nthe sec2 turns=%f",turns2);

/*****************************************************/
/****************** GAUGE SELECTION *****************/
/*****************************************************/

/* calculating for 400 circular mils */
prcir=(float)abs(prct*400.0);/****  primary circular mils ****/
s1cir=(float)abs(s1ct*400.0);/****  secondary 1 circular mils ****/

if (choice=='y')
s2cir=(float)abs(s2ct*400.0);/*  secondary2 in circular mils */
```

```
printf("\n prcir=%f",prcir);
printf("\n s1cir=%f  s2cir=%f",s1cir,s2cir);
printf("\n Press any key to continue...\n ");
cho=getch();
clrscr();

/*****************************************************/
/************* PRIMARY GAUGE SELECTION *************/
/*****************************************************/

prevdiff=99999.9;/* previous difference is assigned highvalues */

/**** Selection of gauge of primary for the    ****/
/**** nearest primary circular mil calculated ****/

for(ctr=1;ctr<=40;ctr++)
{
     if(tab1[ctr]>prcir)
     {
       diff=tab1[ctr]-prcir;
     }
     else
     {
       diff=prcir-tab1[ctr];
     }
     if (diff< prevdiff)
     {
       prevdiff=diff;
     }
     else
     {
       ctr=ctr-1;
```

```
        break;
      }
  }
if (tab1[ctr]< prcir)
        ctr--;
prgau=swg[ctr];  /**** primary gauge ****/

printf("\nthe primary gauge is %f",prgau);


/*****************************************************/
/************ SECONDARY GAUGE SELECTION ***********/
/*****************************************************/

ctr1=0;
prevdiff=99999.0;
dumm='t';
seccir=s1cir;

/**** Selection of gauge of secondary for the    ****/
/**** nearest secondary circular mil calculated ****/

while(dumm=='t')
{
   ctr1++;
   for(ctr=1;ctr<=40;ctr++)
   {
      if(tab1[ctr]>seccir)
      {
        diff=tab1[ctr]-seccir;
      }
      else
      {
```

```
    diff=seccir-tab1[ctr];
   }
   if (diff< prevdiff)
   {
    prevdiff=diff;
   }
   else
   {
    ctr=ctr-1;
    break;
   }
}
if(ctr1==1)
{
 sec1gau=ctr;
 if (tab1[ctr]< s1cir)
  ctr--;
 sec1gau=swg[ctr];
 printf("\nthe secondary1 gauge is %f",sec1gau);
}
else
{
 sec2gau=ctr;
}

 if(choice=='y')
 {
  seccir=s2cir;
  prevdiff=99999.9;
 }
 if (ctr1==2)
 {
  dumm='f';
```

```
    }

  };

 if (choice=='y')
 {
  if (tab1[ctr]< s2cir)
   ctr—;
   sec2gau=swg[ctr];
   printf("the seconadary2 gauge is %f",sec2gau);
 };

/*******************************************************/
/***************** LAYER CALCULATION ****************/
/*******************************************************/


  ctr=1;
  while(ctr<40)
  {
     if(prgau==swg[ctr])
     {
        diapr=diamil[ctr]/1093; /*   diameter of pry wdg in inches   */
        printf("\n**** Diameter of gauge %f =%f (in
 inches)",prgau,diapr);
     }
     if(sec1gau==swg[ctr])
     {
        dias1=diamil[ctr]/1093; /* diameter of sec1 wdg in inches */
        printf("\n**** Diameter of gauge %f =%f (in
 inches)",sec1gau,dias1);
     }
     if (choice=='y')
     {
```

```
        if(sec2gau==swg[ctr])
        {
        dias2=diamil[ctr]/1093; /* diameter of sec2 wdg in inches   */
        printf("\n**** Diameter of gauge %f =%f (in
inches)",sec2gau,dias2);
        break;
        }
    }
ctr++;
}

/******************************************************/
/*********** PRIMARY WINDING CALCULATION **********/
/******************************************************/

bobht=1.5;/**** bobbin ht is 1.5" ****/

tuplayp=bobht/diapr; /**** turns per layer ****/
nolay=turnpr/tuplayp;/**** no. of layers ****/
htwdg=nolay/tuplayp;/**** height of the winding ****/
clrscr();
printf("\n PRIMARY WINDING DETAILS");
printf("\n *********************\n\n\n");

printf("\n Diameter of primary:%f",diapr);
printf("\n The turns per layer in primary :%f",tuplayp);
printf("\n The no. of layer:%f",nolay);
printf("\n Height of the winding :%f",htwdg);
```

```
printf("\n Press any key to continue...\n ");
cho=getch();

/*******************************************************/
/******** SECONDARY WINDING CALCULATION **********/
/*******************************************************/

tuplays1=bobht/dias1;/**** turns per layer in sec1 ****/
clrscr();
printf("\n SECONDARY WINDING DETAILS");
printf("\n ***********************\n\n\n");
printf("\n Diameter of sec1:%f",dias1);
printf("\n Turns per layer in secondary1 is:%f",tuplays1);
if(tuplays1<turns1)
printf("\n another %f will come in next layer",(turns1-tuplays1));
if (choice=='y')
{
  tuplays2=bobht/dias2;/**** turns per layer in sec2 ****/
  printf("\n Turns per layer in secondary2 is:%f",tuplays2);
  if(tuplays2<turns2)
   printf("\n another %f will come in next layer",(turns2-tuplays2));
}
printf("\n Press any key to continue... ");
cho=getch();

/*******************************************************/
/*********** TOTAL LENGTH CALCULATION ************/
/*******************************************************/

clrscr();
totlpr=bobht*4*2.54*turnpr/100;/**** total length of primary wdg
in metres ****/
totls1=bobht*4*2.54*turns1/100;/**** total length of sec1 wdg in
```

```
metres ****/
if (choice=='y')
totls2=bobht*4*2.54*turns2/100;/*8 total length of sec2 wdg in
metres*/
printf("\n\n\n\n TOTAL LENGTH CALCULATION ");
printf("************************\n");
printf("\n total length of primary winding   : %f",totlpr);
printf("\n total length of secondary1 winding: %f",totls1);
if (choice=='y')
  printf("\n total length of secondary2 winding: %f",totls2);
printf("\n Press any key to continue... ");
cho=getch();

/*****************************************************/
/******** CALCULATION OF WEIGHT OF COPPER *******/
/*****************************************************/


ctr=1;
while(ctr<40)
{
  if(prgau==swg[ctr])
   wtpr=wt[ctr];          /****   wt of pry wdg in gm/m    ****/
  if(sec1gau==swg[ctr])
   wts1=wt[ctr];   /****   wt of sec1 wdg in gm/m   ****/
  if (choice=='y')
  {
  if(sec2gau==swg[ctr])
  wts2=wt[ctr];   /****   wt of sec2 wdg in gm/m   ****/
  break;
  }
 ctr++;
 }
 wtpr=wtpr*totlpr; /**** wt of primary copper ****/
```

```
wts1=wts1*totls1; /**** wt of secondary1 copper ****/
if (choice=='y')
wts2=wts2*totls2; /**** wt of secondary2 copper ****/
clrscr();
printf("\n\n\nWEIGHT OF COPPER ");
printf("\n****************\n\n\n");
printf("\n wt of %f SWG copper : %f",prgau,wtpr);
printf("\n wt of %f SWG copper : %f",sec1gau,wts1);
if (choice=='y')
printf("\n wt of %f SWG copper : %f",sec2gau,wts2);
printf("\n Press any key to continue...\n ");
cho=getch();
clrscr();

printf("End");

}
```

```
/*******************************************************/
/********** DESIGN OF CURRENT TRANSFORMER *********/
/*******************************************************/

# include <stdio.h>
# include <string.h>
# include <conio.h>
# include <math.h>
# include <stdlib.h>
# include <a.h>

int ctr,ctr1;

float bobht,N1,N2,prvt=0.0,prct,s1vt,s1ct,f=50,prcir,s1cir,
prevdiff=999999.9,diff,prgau,sec1gau,diapr,dias1,bobht,tuplayp,
nolay,tuplays1,htwdg,totlpr=0.0,totls1=0.0,wtpr,wts1,wd,seccir;

char cho,dumm;

main()
{
clrscr();

printf("Enter the primary current:");
scanf("%f",&prct);
printf("\nEnter the secondary current :");
scanf("%f",&s1ct);
printf("\n Enter the secondary voltage :");
scanf("%f",s1vt);

prvt=s1vt*s1ct/prct; /* primary voltage */
```

```
/*******************************************************/
/**** SINCE IT IS CURRENT TRANSFORMER ASSUME ****/
/******* THE NO. OF TURNS IN THE PRIMARY IS 1 *******/
/*******************************************************/

printf(" \nThe primary turn is assumed to be 1");
N1=1; /* No. of turns in the primary */
N2=prct/s1ct; /*No. of turns in the secondary */
printf("\nThe number of secondary turns is : %f",N2);
/**** assume type of core used is TYPE 15 ***/
/**** Therefore the width corresponding to the above is 1.5" ***/
wd=1.5;

/*******************************************************/
/**************** GAUGE SELECTION ******************/
/*******************************************************/

/* calculating for 400 circular mils */
prcir=(float)abs(prct*400.0); /* primary circular mils */
s1cir=(float)abs(s1ct*400.0); /* secondary circular mils */

cho=getch();
clrscr();

prevdiff=99999.9; /* previous difference */
dumm='t';
seccir=prcir;
ctr1=1;

while(dumm=='t')
{

for(ctr=1;ctr<=40;ctr++)
```

```
{
if(tab1[ctr]>seccir)
        {
        diff=tab1[ctr]-seccir;
        }
else
        {
         diff=seccir-tab1[ctr];
        }
 if (diff< prevdiff)
   {
   prevdiff=diff;
   }
 else
   {
   ctr=ctr-1;
   break;
   }
  }
  if(ctr1==1)
  {
   prgau=ctr;
    if (tab1[ctr]< prcir)
     {
     ctr--;
     }
     prgau=swg[ctr];
     printf("\nthe primary gauge is %f",prgau);
     prevdiff=999999.9;
     ctr1++;
     seccir=s1cir;

   }
```

```
else
{
 sec1gau=ctr;
 prevdiff=999999.9;
 dumm='f';
 }
}
if (tab1[ctr]< s1cir)
 ctr—;
 sec1gau=swg[ctr];
 printf("\n the seconadary gauge is %f",sec1gau);

/**********************************************************/
/***************** LAYER CALCULATION ****************/
/**********************************************************/

for(ctr=1;ctr<40;ctr++)
{
if(prgau==swg[ctr])
{
diapr=diamil[ctr]/1093;   /*  diameter of pry wdg in inches    */
printf("\n******** Diameter of %f (primary)=%f ( in
inches)",prgau,diapr);
}
if(sec1gau==swg[ctr])
{
dias1=diamil[ctr]/1093;   /* diameter of sec1 wdg in inches   */
printf("\n******** Diameter of %f (secondary)=%f ( in
inches)",sec1gau,dias1);
break;
}
}
```

```
/*******************************************************/
/******************** IN PRIMARY *********************/

bobht=1.5;/* bobbin ht is 1.5" */
tuplayp=nolay=1;
 /* tuplayp turns per layer in primary */
 /* no. of layers in primary */
htwdg=nolay/tuplayp;/* height of the winding */
printf("\n Diameter of primary:%f",diapr);
printf("\n The turns per layer in primary :%f",tuplayp);
printf("\n The no. of layer:%f",nolay);
printf("\n Height of the winding :%f",htwdg);
printf("\n Press any key to continue...\n ");
cho=getch();
clrscr();

/*******************************************************/
/****************** IN SECONDARY *******************/

tuplays1=bobht/dias1;/* turns per layer in sec1 */
printf("\n Diameter of sec1:%f",dias1);
printf("\n Turns per layer in secondary1 is:%f",tuplays1);
if(tuplays1<N2)
printf("\n another %f will come in next layer",(N2-tuplays1));

/*******************************************************/
/****************** TOTAL LENGTH ******************/
/*******************************************************/

totlpr=bobht*4*2.54*N1/100;/* total length of primary wdg in
metres */
totls1=bobht*4*2.54*N2/100;/* total length of sec1 wdg in metres
*/
```

```
printf("\n\n TOTAL LENGTH\n");
printf("\n total length of primary winding   : %f",totlpr);
printf("\n total length of secondary1 winding: %f",totls1);

/*******************************************************/
/**************** WEIGHT OF COPPER *****************/
/*******************************************************/

ctr=1;
while(ctr<40)
{

if(prgau==swg[ctr])
wtpr=wt[ctr];              /*   wt of pry wdg in gm/m    */
if(sec1gau==swg[ctr])
{
wts1=wt[ctr];   /*   wt of sec1 wdg in gm/m   */
break;
}
ctr++;
}
cho=getch();

printf("\n wtpr %f totlpr %f",wtpr,totlpr);
wtpr=wtpr*totlpr; /* wt of primary copper */
wts1=wts1*totls1; /* wt of secondary1 copper */
printf("\n wt of %f SWG copper : %f",prgau,wtpr);
printf("\n wt of %f SWG copper : %f",sec1gau,wts1);
printf("\n Press any key to continue...\n ");
cho=getch();
clrscr();

}
```

```
float
tabl[41]={0,83698,66370,52640,41740,33100,26250,20820,16510,13090,
       10000,8234,6530,5030,4107,3257,2583,1624,1288,1022,
       810.1,642.4,509.5,404.0,320.4,254.1,201.5,159.8,126.7,100.5,
       80.7,63.21,50.13,39.75,31.52,25.00,19.83,15.72,11.67,9,88};
float
diamil[41]={0,289.3,257.6,229.4,284.3,181.9,162.0,144.3,128.5,114.4,
       113.6031,98.74,88.81,78.71,64.83,57.87,50.082,40.30,
       35.89,31.96,28.46,25.35,22.57,28.18,17.98,15.94,14.2,
       12.64,11.26,10.03,8.928,7.958,7.888,6.385,5.615,5.000,4.453,
       4.372,3.531,3.14};
float
wt[41]={0,405.4,236.1,242.4,282.4,139.53,115.32,93.43,73.79,68.63,48.72,
       38.13,28.83,23.35,18.451,14.126,18.379,7.287,5.838,4.613,
       3.531,2.595,2.180,1.8018,1.4595,1.2116,0.8334,0.6928,
       0.6063,0.4583,0.3813,0.2602,0.2083,0.16217,0.12180,
       0.10379,0.08721,0.07207,0.05338,0.04613};

float
swg[41]={0,1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,
       25,26,27,29,30,31,33,34,36,37,38,39,40,41,42,43,44};
```

7.5 TEST RESULTS

The voltage response of the automatic voltage controlled a.c.supply for each 10v of interval at no-load and full-load are tabulated as follows :

(i) NO-LOAD

Input voltage (volts)	Output voltage (volts)
0 - 140	0
141	200
150	208
160	215
170	230
180	240
190	250
191	200
200	209
210	219
220	231
221	200
230	205
240	212
250	220
252	200
260	204
270	221
280	220
281	0

(ii) Full load

Input Voltage (volts)	Output voltage (volts)
0-140	0
150	195
160	210
170	220
180	230
190	240
200	205
210	215
215	220

7.6. ADVANTAGES

1. Wide range.
2. Over-load protection.
3. There is no moving parts.
4. Adaptable for both single phase and three phase.
5. Protection for both very low(<140v) and very high voltage(>280v).
6. Wall mountable.
7. High efficiency.
8. Less Temperature rise.
9. Audible and visible indications for abnormal condition.
10. High sensitivity.
11. Less cost.

7.7. COST ESTIMATION

Sl. No.	COMPONENT	QUANTITY	AMOUNT(Rs.)
1.	Toroidal transformer core	1	600.00
2.	Copper wire for toroidal transformer		1000.00
3.	Small transformer	2	100.00
4.	Current transformer	1	30.00
5.	Contactors	2	600.00
6.	2 pole 2 way switch	1	150.00
7.	Relay	4	350.00
8.	Cabinet	1	300.00
9.	Buzzer	1	20.00
10.	LED	8	10.00
11.	Control Card	2	700.00
12.	Other Components		240.00

TOTAL AMOUNT **4100.00**

CHAPTER 8

CONCLUSION

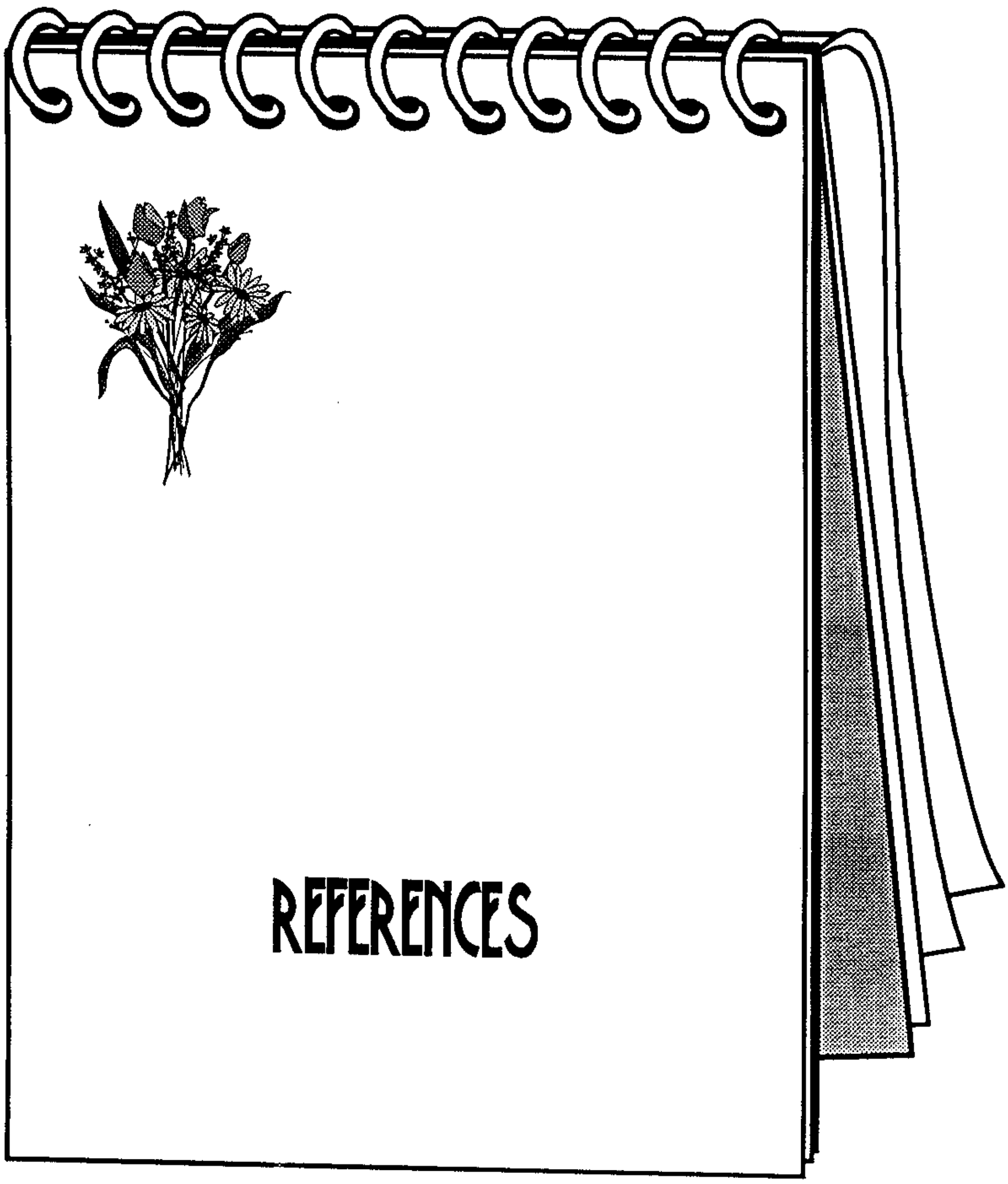
CONCLUSION

The project "Automatic Voltage Controlled A.C. Supply with Over-Load Protection" has been designed, fabricated and tested successfully. In addition to the voltage stabilization, the unit has over-load protection and on-line phase selection.

The main feature of this project over the existing models in the market is that both the output voltage and current of the unit are sensed and the tripping is done based on the volt-ampere product. This ensures the full utilization of power and avoids the over loading of the unit.

Further the output voltage can be maintained within a very narrow range by increasing the number of tappings on the toroidal transformer.

The performance and switching time of relay section can be very much improved by replacing the mechanical relays by static relays and the whole operation of the unit can be controlled by a single microcontroller IC chip.



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REFERENCES

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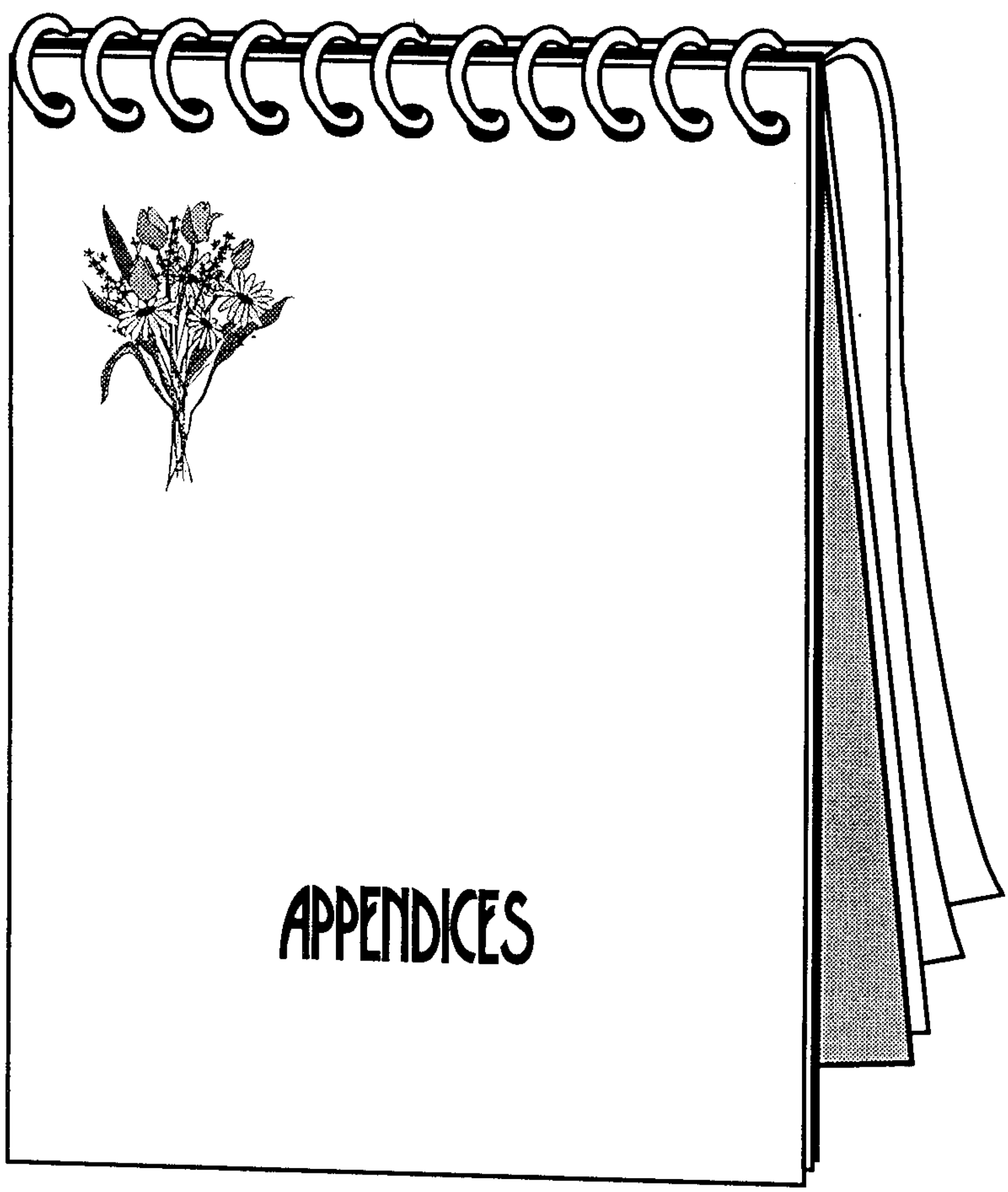

APPENDICES

A. PIN DETAILS OF IC'S

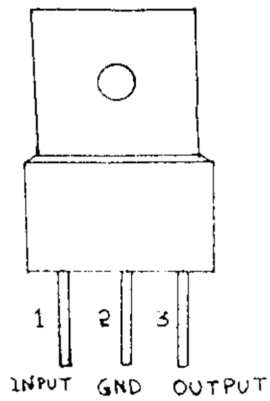


Fig A·1 IC 7812

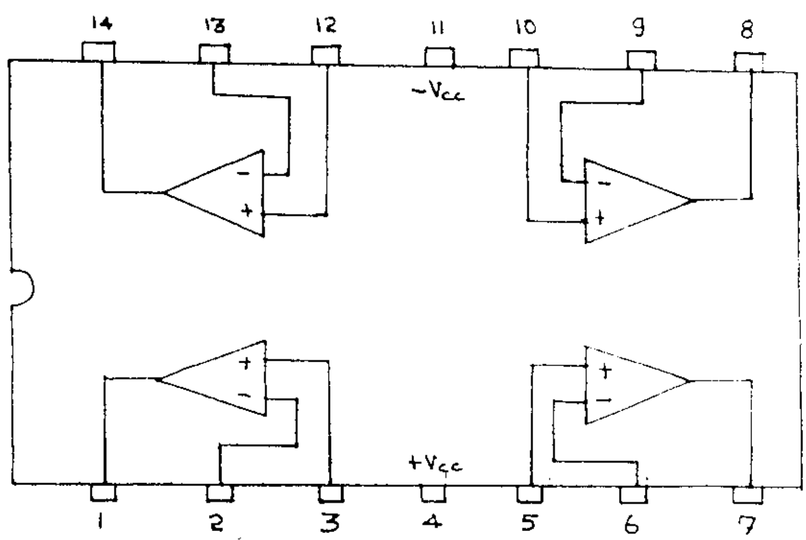


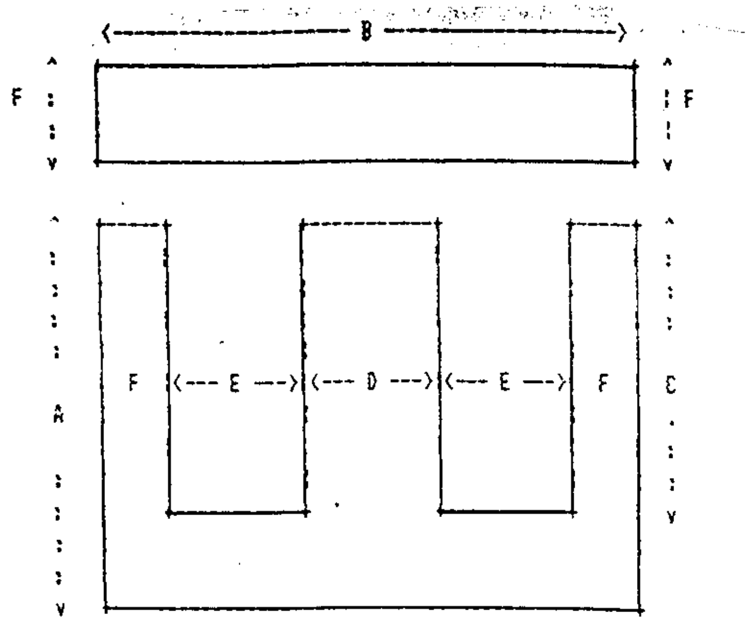
Fig A-2 IC LF 347

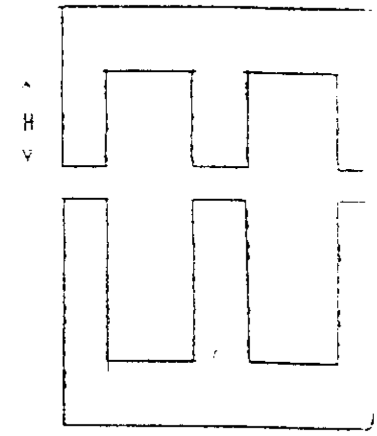
B. TRANSFORMER DATA DETAILS

GAUGE SWG	CURRENT CARRING CAPACITY AT 700 CIR MILS PER AMP	NOMINAL DIAMETER IN mm	CALCULATED AREA IN mm 2	NOMINAL WEIGHT gm/m	STANDARD RESISTANCE (OF) HARD DRAWN WIRE AT 20 DEGREE C OHMS/km	AT 70 DESREE C OHMS/km	SIZE SWG
1	119.6	7.62	45.6	405.4	0.3375	0.4218	1
2	94.8	7.01	38.6	343.2	0.4579	0.5723	2
3	94.8	6.4	32.18	286.1	0.5495	0.6868	3
4	75.2	5.89	27.27	242.4	0.6489	0.8111	4
5	59.6	5.38	22.77	202.4	0.7770	0.9713	5
6		4.88	18.68	166.06	0.9478	1.18475	6
7	47.3	4.47	15.70	139.53	1.129	1.4112	7
8	37.5	4.06	12.97	115.32	1.366	1.7075	8
9	29.7	3.66	10.51	93.43	1.686	2.1075	9
10	23.6	3.25	8.302	73.79	2.136	2.67	10
11	18.7	2.95	6.818	60.63	2.601	3.2512	11
12	14.8	2.64	5.49	48.72	3.237	4.0462	12
13	11.8	2.34	4.289	38.13	4.137	5.1712	13
14	9.33	2.03	3.243	28.83	5.471	6.8387	14
15	7.4	1.83	2.627	23.35	6.756	8.445	15
16	5.87	1.63	2.076	18.451	8.552	10.690	16
17	4.65	1.42	1.589	14.126	11.46	13.970	17
18	3.69	1.22	1.1630	10.379	15.21	19.0125	18
19	2.32	1.02	0.8107	7.207	21.91	27.3975	19
20	1.84	0.911	0.617	5.038	27.04	33.8	20
21	1.46	0.813	0.5189	4.613	34.22	42.775	21
22	1.16	0.711	0.3973	3.531	44.7	55.875	22
23	0.918	0.610	0.2919	2.595	60.85	76.062	23
24	0.728	0.559	0.2452	2.180	72.42	90.525	24
25	0.577	0.508	0.2027	1.8018	87.43	109.28	25
26	0.458	0.457	0.16417	1.4595	108.2	135.25	26
27	0.363	0.417	0.13628	1.2116	130.4	163.00	27
28		0.376	0.11099	0.9865	160.1	200.1	28
29	0.288	0.345	0.09372	0.8334	189.5	236.3	29
30	0.288	0.315	0.07791	0.6928	227.9	284.8	30
31	0.191	0.295	0.06818	0.6063	260.4	325.5	31
32		0.274	0.05918	0.5252	300.8	376.0	32
33	0.144	0.254	0.05067	0.4503	350.6	438.25	33

GAUGE SWG	CURRENT CARRING CAPACITY AT 700 CIR MILS PER AMP	NOMINAL DIAMETER IN mm	CALCULATED AREA IN mm 2	NOMINAL WEIGHT gm/m	STANDARD RESISTANCE (OF) HARD DRAWN WIRE AT 20 DEGREE C OHMS/km	AT 70 DEGREE C OHMS/km	SIZE SWG
34	0.114	0.234	0.04289	0.3813	414.3	517.8	34
35	--	0.213	0.03575	0.3178	496.8	621.00	35
36	0.098	0.193	0.02927	0.2602	607.0	758.75	36
37	0.72	0.173	0.02343	0.2083	758.2	947.75	37
38	0.057	0.152	0.01824	0.16217	973.9	1217.3	38
39	0.045	0.132	0.01378	0.12180	1297	1621.2	39
40	0.036	0.122	0.01168	0.10379	1522	1902.5	40
41	0.028	0.112	0.009010	0.08721	1811	2263.7	41
42	0.022	0.102	0.008107	0.07207	2192	2740.0	42
43	0.018	0.091	0.006567	0.05338	2706	3383.0	43
44	0.014	0.081	0.005189	0.04613	3424	4280.0	44
45		0.071	0.003973	0.03531	4473	5591.2	45
46		0.061	0.002919	0.02595	6087	7608.7	46
47		0.051	0.002027	0.01802	8766	10957.5	47
48		0.041	0.001297	0.01153	13696	17120.0	48
49		0.0012	0.0007297	0.006487	24350 24050	30437.5	49
50		0.025	0.0005067	0.004505	35063	43828.0	50

NEAREST BRITISH SWG NO.	DIA IN MILS	CIRCULAR MIL AREA	ENAMEL TURNS PER INCH X	1/X	FEETS PER POUND BARE	FEETS PER POUND DCC	OHMS PER 1,000 FT 25 DEGREE C	CURRENT CARRYING CAPACITY AT 700 CIR MILS PER AMP	NEAREST BRITISH SWG NO.
1	289.3	83690	-	-	3.947	-	0.1264	119.6	1
3	257.6	66370	-	-	4.977	-	0.1593	94.8	3
4	229.4	52640	-	-	6.276	-	0.2009	75.2	4
5	204.3	41740	-	-	7.914	-	0.2533	59.6	5
7	181.9	33100	-	-	9.980	-	0.3195	47.3	7
8	162.0	26250	-		12.58	-	0.4028	37.5	8
9	144.3	20820	-	-	15.87	-	0.5080	29.7	9
10	128.5	16510	7.6	0.131	20.01	19.6	0.6405	23.6	10
11	114.4	13090	8.6	0.116	25.23	24.6	0.8077	18.7	11
12	101.9	10380	9.6	0.104	31.82	30.9	1.018	14.8	12
13	90.74	8234	10.7	0.094	40.12	38.8	1.284	11.8	13
14	80.81	6530	12.0	0.084	50.59	48.9	1.619	9.33	14
15	71.96	5178	13.5	0.074	63.80	61.5	2.042	7.40	15
16	64.08	4107	15.0	0.067	80.44	77.3	2.575	5.87	16
17	57.07	3257	16.8	0.06	101.4	97.3	3.247	4.65	17
18	50.802	2583	18.9	0.053	127.9	119	4.094	3.69	18
18.5	45.26	2048	21.2	0.048	161.3	150	5.163	2.93	18.5
19	40.30	1624	23.6	0.043	203.4	188	6.510	2.32	19
20	35.89	1288	26.4	0.038	256.5	237	8.210	1.84	20
21	31.96	1022	29.4	0.034	323.4	298	10.35	1.46	21
22	28.46	810.1	33.1	0.031	407.8	370	13.05	1.16	22
23	25.35	642.4	37.0	0.027	514.2	461	16.46	0.918	23
24	22.57	509.5	41.3	0.025	648.4	584	20.76	0.728	24
25	20.10	404.0	46.3	0.022	817.7	745	26.17	0.577	25
26	17.90	320.4	51.7	0.02	1031	903	33.00	0.458	26
27	15.94	254.1	58.0	0.018	1300	1118	41.62	0.363	27
29	14.2	201.5	64.9	0.016	1639	1422	52.48	0.288	29
30	12.64	159.8	72.7	0.014	2067	1759	66.17	0.230	30
31	11.26	126.7	81.6	0.013	2617	2207	83.44	0.181	31
33	10.03	100.5	90.5	0.011	3287	2534	105.2	0.144	33
34	8.928	79.7	101	9.9E-3	4145	2768	132.7	0.144 (0.114)	34
36	7.950	63.21	113	8.85E-3	5227	3137	167.3	0.090	36
37	7.080	50.13	127	8.00E-3	6591	4697	211.0	0.072	37
38	6.305	39.75	143	6.99E-3	8310	6168	266.0	0.057	38
38-39	5.615	31.52	158	6.32E-3	10480	6737	335.0	0.045	38-39
39-40	5.000	25.00	175	5.71E-3	13210	7877	423.0	0.036	39-40
41	4.453	19.83	198	5.05E-3	16660	9387	513.4	0.028	41
42	3.965	15.72	224	4.46E-3	21010	10666	672.6	0.022	42
43	3.531	12.47	248	4.03E-3	26500	11907	848.1	0.018	43
44	3.145	9.88	282	3.55E-3	33410	14222	1069	0.014	44





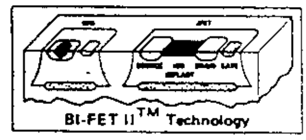
TYPE 32 ONLY

SL. NO.	CORE TYPE NO.	A	B	C	D	E	F	CORE WT. PER INCH STACK Kg.
1	32	0.5"	1.0"	0.375" 3/8"	0.25" 1/4"	0.25" 1/4"	F=0.125" G=0.25" H=0.125"	0.057
2	74	1-3/8" (1.375")	2-1/16" (2.0625")	1-1/16" (1.0625")	11/~~32~~16" 0.6875 ~~(0.34375")~~	11/32" (0.34375")	11/32 ~~0.362~~ (0.34375)	0.368
3	15	2"	3"	1-1/2"	1"	1/2"	1/2"	0.788
4	33	56mm	84mm	42mm	26mm	14mm	14mm	For 28mm stack 1.058
5	7	3.9375" 3-15/16" (=4")	6"	2.9375" 2-15/16" (=3")	2"	1"	1"	3.11
6	8	~~3-1/2"~~ 5-3/4	7-1/4"	4-3/4"	2"	1-5/8" 1.625"	1"	4.388

LF347

National Semiconductor

Operational Amplifiers/Buffers



LF347 Wide Bandwidth Quad JFET Input Operational Amplifier

General Description

The LF347 is a low cost, high speed quad JFET input operational amplifier with an internally trimmed input offset voltage (BI-FET II™ technology). The device requires a low supply current and yet maintains a large gain bandwidth product and a fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF347 is pin compatible with the standard LM348. This feature allows designers to immediately upgrade the overall performance of existing LM348 and LM324 designs.

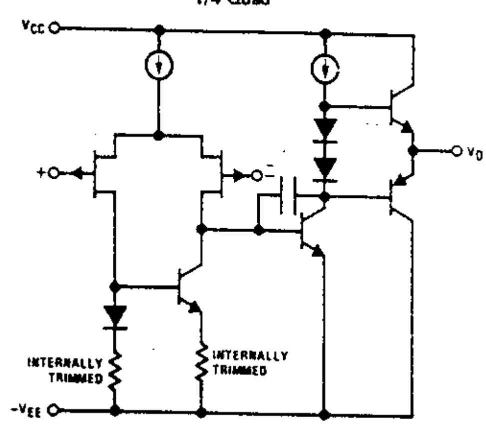
The LF347 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The device has low noise and offset voltage drift.

Features

- Internally trimmed offset voltage — 2 mV
- Low input bias current — 50 pA
- Low input noise voltage — $16\ nV/\sqrt{Hz}$
- Low input noise current — $0.01\ pA/\sqrt{Hz}$
- Wide gain bandwidth — 4 MHz
- High slew rate — 13 V/µs
- Low supply current — 7.2 mA
- High input impedance — $10^{12}\Omega$
- Low total harmonic distortion $A_V = 10$, $R_L = 10k$, $V_O = 20$ Vp-p, BW = 20 Hz–20 kHz — <0.02%
- Low 1/f noise corner — 50 Hz
- Fast settling time to 0.01% — 2 µs

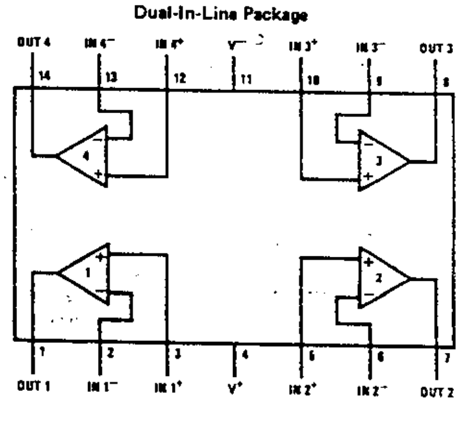
Simplified Schematic

1/4 Quad



Connection Diagram

Dual-In-Line Package



Order Number LF347N, LF347AN or LF347BN
See NS Package N14A

Order Number LF347J, LF347AJ or LF347BJ
See NS Package J14A

LF347

...ute Maximum Ratings

Voltage	±18V
Dissipation (Note 1)	500 mW
...ing Temperature Range	0°C to +70°C
...AX)	115°C
...ential Input Voltage	±30V
Voltage Range (Note 2)	±15V
Short Circuit Duration (Note 3)	Continuous
Temperature Range	−65°C to +150°C
...mperature (Soldering, 10 seconds)	300°C

...C Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF347A MIN	LF347A TYP	LF347A MAX	LF347B MIN	LF347B TYP	LF347B MAX	LF347 MIN	LF347 TYP	LF347 MAX	UNITS
...OS	Input Offset Voltage	$R_S = 10\ k\Omega$, $T_A = 25°C$		1	2		3	5		5	10	mV
		Over Temperature			4			7			13	mV
...OS/ΔT	Average TC of Input Offset Voltage	$R_S = 10\ k\Omega$		10			10			10		μV/°C
	Input Offset Current	$T_j = 25°C$, (Notes 4, 5)		25	100		25	100		25	100	pA
		$T_j \leq 70°C$			2			4			4	nA
	Input Bias Current	$T_j = 25°C$, (Notes 4, 5)		50	200		50	200		50	200	pA
		$T_j \leq 70°C$			4			8			8	nA
	Input Resistance	$T_j = 25°C$		10^{12}			10^{12}			10^{12}		Ω
	Large Signal Voltage Gain	$V_S = \pm15V$, $T_A = 25°C$, $V_O = \pm10V$, $R_L = 2\ k\Omega$	50	100		50	100		25	100		V/mV
		Over Temperature	25			25			15			V/mV
	Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$	±12	±13.5		±12	±13.5		±12	±13.5		V
	Input Common-Mode Voltage Range	$V_S = \pm15V$	±11	+15		±11	+15		±11	+15		V
				−12			−12			−12		V
	Common-Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	80	100		80	100		70	100		dB
	Supply Voltage Rejection Ratio	(Note 6)	80	100		80	100		70	100		dB
	Supply Current			7.2	11		7.2	11		7.2	11	mA

...C Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF347A MIN	LF347A TYP	LF347A MAX	LF347B MIN	LF347B TYP	LF347B MAX	LF347 MIN	LF347 TYP	LF347 MAX	UNITS
	Amplifier to Amplifier Coupling	$T_A = 25°C$, f = 1 Hz–20 kHz (Input Referred)		−120			−120			−120		dB
	Slew Rate	$V_S = \pm15V$, $T_A = 25°C$		13			13			13		V/μs
	Gain-Bandwidth Product	$V_S = \pm15V$, $T_A = 25°C$		4			4			4		MHz
	Equivalent Input Noise Voltage	$T_A = 25°C$, $R_S = 100\Omega$, f = 1000 Hz		16			16			16		$nV/\sqrt{Hz}$
	Equivalent Input Noise Current	$T_j = 25°C$, f = 1000 Hz		0.01			0.01			0.01		$pA/\sqrt{Hz}$

...1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 125°C/W junction to ambient or ...W junction to case.

...2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

...3: P_D max rating cannot be exceeded.

...4: These specifications apply for $V_S = \pm15V$ and $0°C \leq T_A \leq +70°C$. V_{OS}, I_B and I_{OS} are measured at $V_{CM} = 0$.

...5: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_j. ...to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction ...erature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \Theta_{jA} P_D$ where Θ_{jA} is the thermal resis... from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

...6: Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with com... practice.

Application Hints (Continued)

state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output; however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

The amplifiers will operate with a common-mode input voltage equal to the positive supply; however, the gain bandwidth and slew rate may be decreased in this condition. When the negative common-mode voltage swings to within 3V of the negative supply, an increase in input offset voltage may occur.

Each amplifier is individually biased by a zener reference which allows normal circuit operation on ±4V power supplies. Supply voltages less than these may result in lower gain bandwidth and slew rate.

The LF347 will drive a 2 kΩ load resistance to ±10V over the full temperature range of 0°C to +70°C. If the amplifier is forced to drive heavier load currents, however, an increase in input offset voltage may occur on the negative voltage swing and finally reach an active current limit on both positive and negative swings.

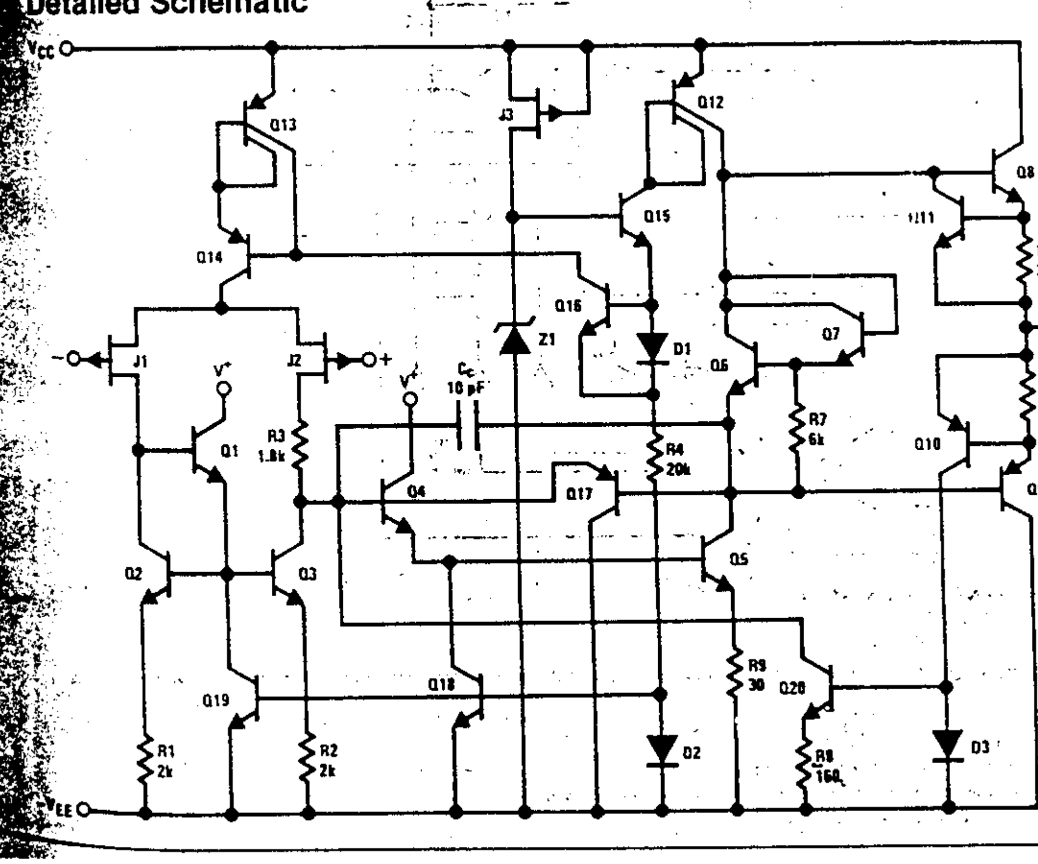
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Because these amplifiers are JFET rather than MOSFET input op amps they do not require special handling.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pick-up" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

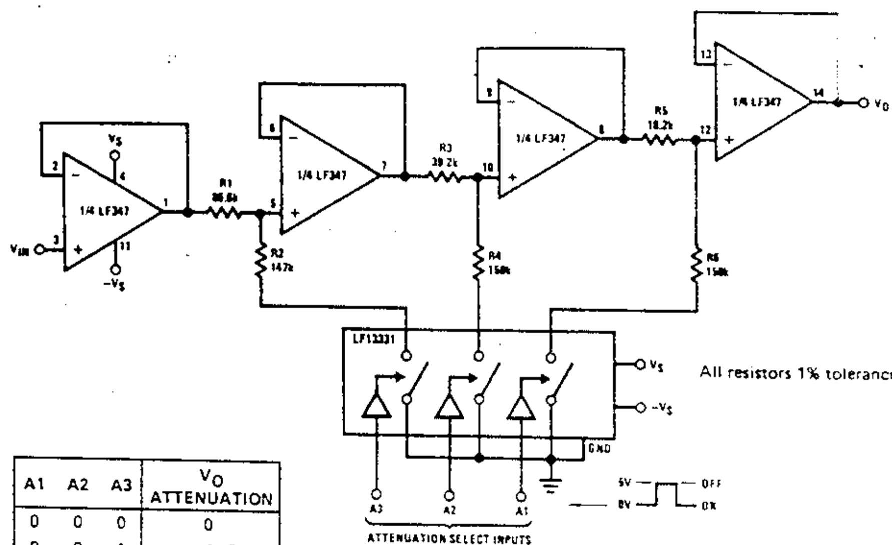
A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately 6 times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

Detailed Schematic



Typical Applications

Digitally Selectable Precision Attenuator

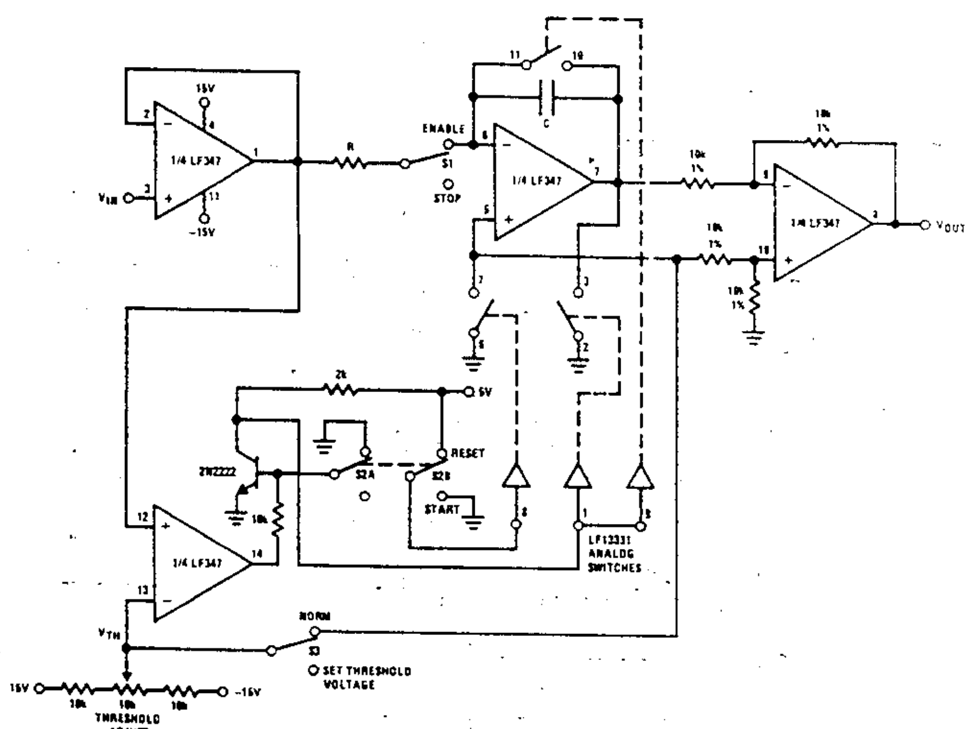


All resistors 1% tolerance

A1	A2	A3	V_O ATTENUATION
0	0	0	0
0	0	1	−1 dB
0	1	0	−2 dB
0	1	1	−3 dB
1	0	0	−4 dB
1	0	1	−5 dB
1	1	0	−6 dB
1	1	1	−7 dB

- Accuracy of better than 0.4% with standard 1% value resistors
- No offset adjustment necessary
- Expandable to any number of stages
- Very high input impedance

Long Time Integrator with Reset, Hold and Starting Threshold Adjustment



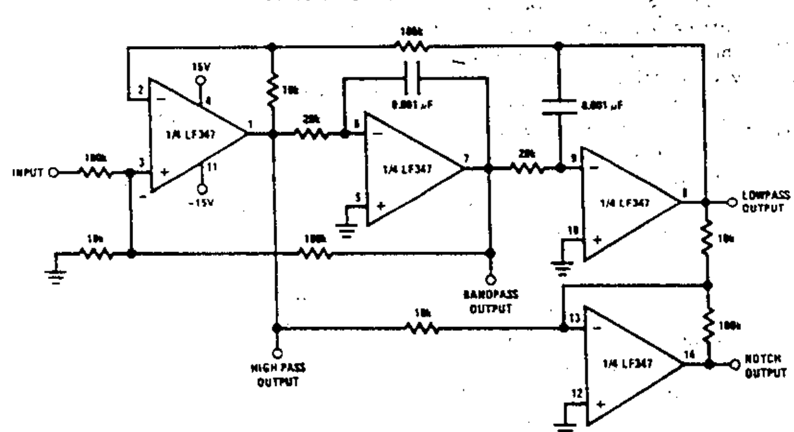
- V_{OUT} starts from zero and is equal to the integral of the input voltage with respect to the threshold voltage:

$$V_{OUT} = \frac{1}{RC}\int_0^t (V_{IN} - V_{TH})dt$$

- Output starts when $V_{IN} \geq V_{TH}$
- Switch S1 permits stopping and holding any output value
- Switch S2 resets system to zero

Typical Applications (Continued)

Universal State Variable Filter



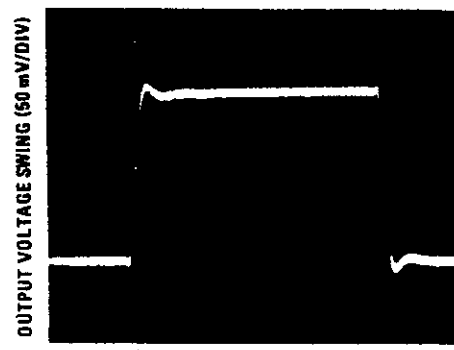
For circuit shown:
f_o = 3 kHz, f_{NOTCH} = 9.5 kHz
Q = 3.4
Passband gain:
Highpass – 0.1
Bandpass – 1
Lowpass – 1
Notch – 10

- $f_o \times Q \leq 200$ kHz
- 10V peak sinusoidal output swing without slew limiting to 200 kHz
- See LM348 data sheet for design equations

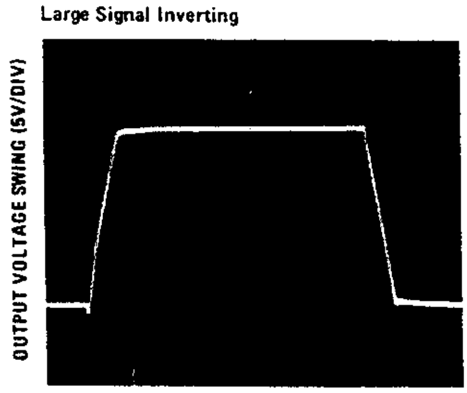
Pulse Response

Small Signal Inverting

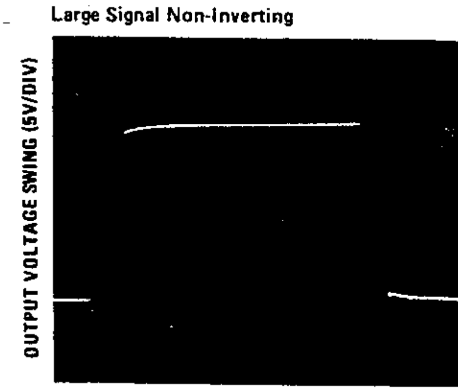
Small Signal Non-Inverting



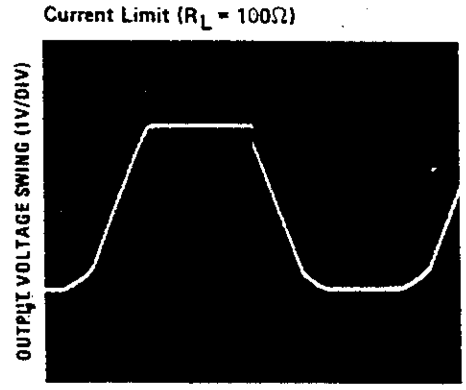
Large Signal Inverting



Large Signal Non-Inverting



Current Limit (R_L = 100Ω)



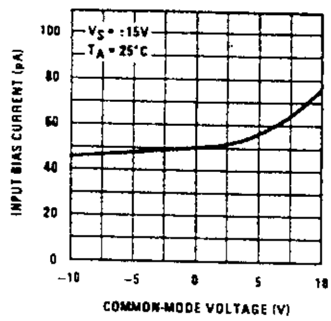
Application Hints

The LF347 is an op amp with an internally trimmed input offset voltage and JFET input devices (BI-FET II™). These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore, large differential input voltages can easily be accommodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will ca large currents to flow which can result in a destro unit.

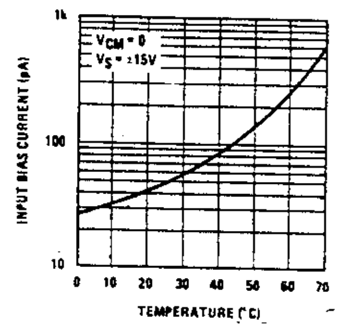
Exceeding the negative common-mode limit on eit input will cause a reversal of the phase to the out and force the amplifier output to the correspond high or low state. Exceeding the negative common-m limit on both inputs will force the amplifier output t

Typical Performance Characteristics

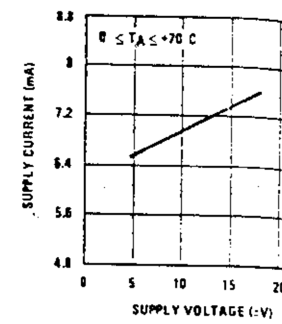
Input Bias Current



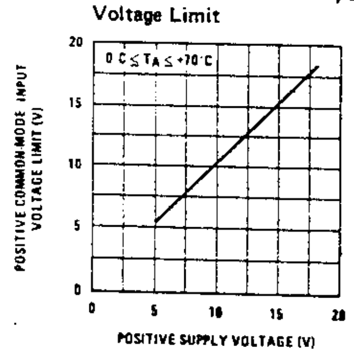
Input Bias Current



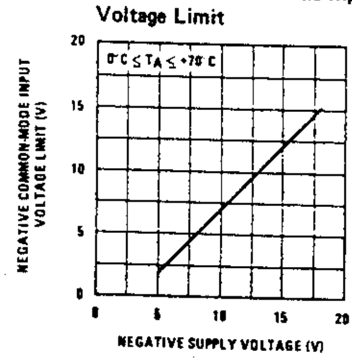
Supply Current



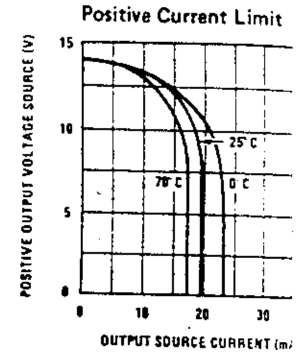
Positive Common-Mode Input Voltage Limit



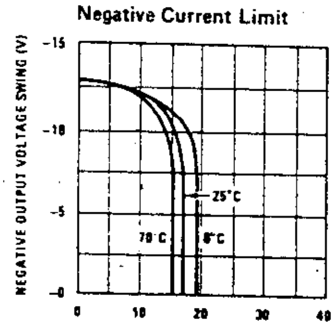
Negative Common-Mode Input Voltage Limit



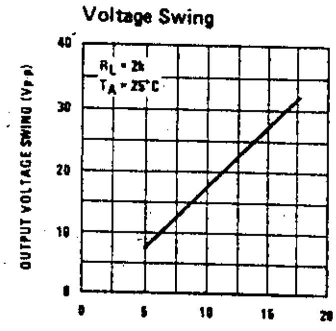
Positive Current Limit



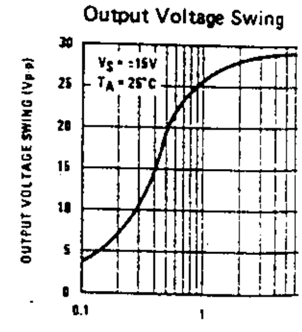
Negative Current Limit



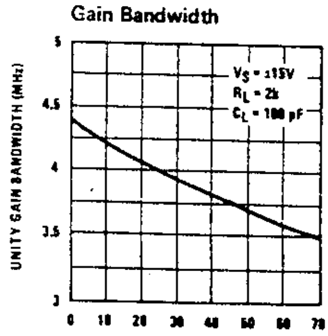
Voltage Swing



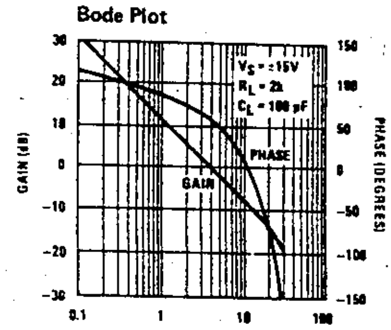
Output Voltage Swing



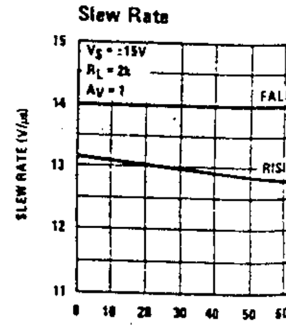
Gain Bandwidth



Bode Plot

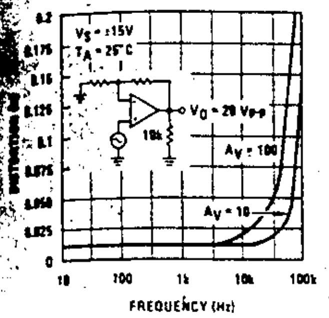


Slew Rate

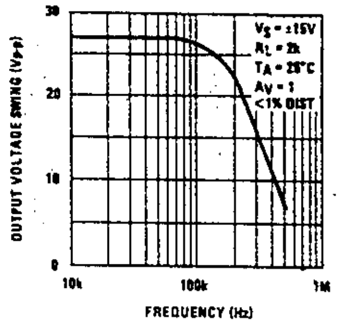


Typical Performance Characteristics (Continued)

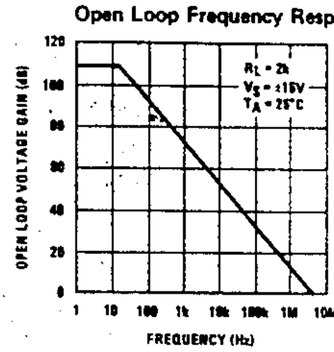
Distortion vs Frequency



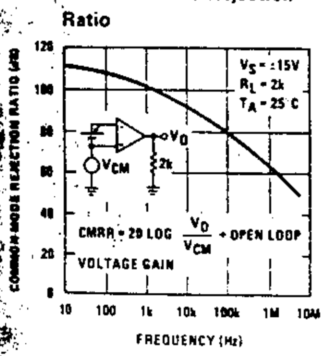
Undistorted Output Voltage Swing



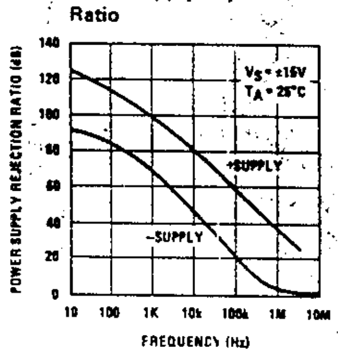
Open Loop Frequency Response



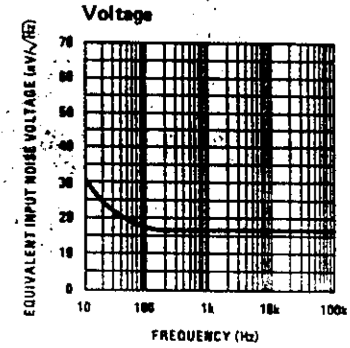
Common-Mode Rejection Ratio



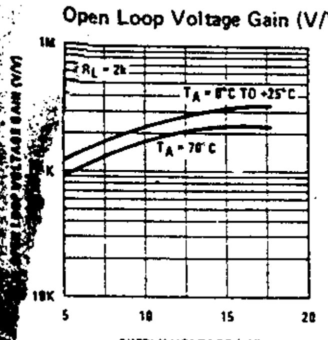
Power Supply Rejection Ratio



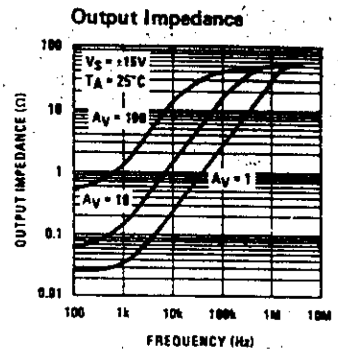
Equivalent Input Noise Voltage



Open Loop Voltage Gain (V/V)



Output Impedance



Inverter Settling Time