ALL PRAISE TO ALLAH THE MERCIFUL, THE CREATER, THE SUSTAINER

ELECTRONIC RELAYS IN THE PROTECTION OF POWER SYSTEMS.

BY

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A THESIS

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CERTIFICATE

This is to certify that this thesis work was done by me and it has not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

The objective of this work is to develop an electronic relay which will work as an electromagnetic device for the protection of power systems. A static time-lag over current relay has been designed. In this relay there is a provision for adjusting the time of tripping and also the megnitude of the fault current at which the relay will operate. Seperate switches/knobs will indicate the current and time settings. The static relay which has been designed and constructed will have a very fast operation. It is designed to operate with in about a one cycle of 50 cycles per second wave. This timing could be made faster, but, for the mechanical response of the tripping device there is limitation of making the relay faster.

Results showing the time to operation of the relay with varying fault current magnitudes have been presented. The different sections of the complete protective relay have been constructed and placed on separate boards which are connected in series with the other portions of the circuit, by flexible plug and jack joints, so that the various modular boards can be removed, repaired and/ or replaced as desired.

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CHAPTER - 1
INTRODUCTION

1.1. What a Static Relay Is.

Electronic or static relay is a relay in which the comparison or measurement of the electrical quantities is done by stationary network which gives a tripping signal when the threshold condition is passed. In simple language static relay is one, which has no moving parts except in the slave device. The static relay includes devices the output circuit of which may be electronic, semi-conductor or even electromagnetic. But the output device does not perform relay measurements, it is essentially a tripping device.

1.2. Reasons for Static Relay Development.

As a result of great expension of Electrical transmission and distribution systems during the last thirty years and with the advent of much larger power stations and more extensively interconnected systems, the duty imposed upon protection gear has become more and more severe. Since relays now have to perform much more complicated functions many types tend to become very complex mechanically and hence costly and difficult to test and to maintain.

The basis of the so-called static relaying is the use of circuits and components to achieve a variety of functions and operating characteristics which for protection purposes have traditionlly been obtained using electromechanical devices. Reliability, which is always important, has been determin by short-circuit levels. Circuit ratings and complexity of interconnection have increased & therefore shorter relay operating time have become more essential to preserve dynamic stability as the character and loading of systems approach design limits. The satisfaction of these requirements has left little potential for their improvements in the conventional electromechanical relays. Until fifteen years ago, relay design was dominated by the electromechanical element. Such an element of whatever basic characteristics, e.g. square law induction element has a dynamic behaviour special to that element and design freedom is consequently restricted by factors such as the conflicting requirements of sensitivity and mechanical robustness. Experience shows that these more exacting requirements can readily be met using static relays.

1.3. Historical Buckground of Static Relay.

References to the design and application of electronic relays for power system protection can be found in the literature from the year 1928 onwards. In that year Fitzerald(1) published a scheme for pilot wire protection. Wideroe(2) in 1934 brought out a series of circuits for the common types of protection relays while Loving in 1949 published refinements of these. Macpherson, Warrinton and McConnell[3] updated the developments upto 1948 and these were extended in later years by Barnes, Kennedy, Honey, Reedman, Dlouhy, Cahen and chevallier[11]. In all these schemes either thyratrons or thermionic tubes have been employed.

The research effort upto the year 1956 was predominantly towards circuits employing thermionic tubes, thyratrons etc; since till then solid state devices like transistors, were just in their infancy. None of these circuit reached the commercial stage and the research effort rapidly tapered off. However, there were certain disadvantages in thermionic tube circuit in relaying and the main ones were the following:

(a) Provision of special power supplies for valve heaters - this imposes constant drain on the power supplies.

(b) Provision of appriciable voltages for valve anodes and electrode bias.

(c) Incorrect operation under transient conditions.

In view of these disadvantages, attention has been diverted to the development of static relays using solid state components. There is at present no interest in relays using electronic valves and they are of historical importance only.

The first wholly static relay was developed by M.E. Bivens in 1930 in the laboratories of the General Electric Company, U.S.A., but was not offered for sale because the comparator used a hot-cathode thyratron which at that time was not sufficiently consistant in operation .

The first wholly static relay offered for sale was the electronic mho relay produced in 1948 by the General Electric Company, U.S.A.[3] In this relay a vacuum tube was used as the comparator and a thyratron used only as a tripping device. Unfortunately, no business resulted because at the time power system engineers did not have sufficient confidence in the electronic components.

In the period 1959-1969 the major manfacturing companies have developed static equivalents of all the princ[illegible]al types of relays, but so far there had been a very conservative attitude towards them by the major power companies.

In 1959 Allis - Chalmers, U.S.A., brought out an inverse time current relay[4]; since hem many other manufacturers have developed similar relays but the induction dise type of inverse time-current relay still dominates the market. Somewhat more success has been achieved with static definite time-current relays, specially in the industrial field. A number of differenti current relays hav[illegible] appered for the protection of generators[5] and buses[6]. In 1961 an American company brought out a transistorized version of their electronic distance relay[7] and this was followed by others in England, Switzerland[8] and the U.S.A.

The performance of the more recent static relays has been so much superior to that of the electromagnetic type that the power companies have been forced to accept them. Thus they may be the thin edge of the wedge of general acceptance of static relays .

1.4. Selection of Static Over current relay-design.

Current magnitude is widely used as a means of detecting faults on distribution systems but seldom on transmission systems. This is because the load current tends to be fixed at about 500A irrespective of the system voltage (because about 0.6 in . dia. is an optimum size of conductor for mechanical reasons) whereas, for a given source impedance the fault current must decrease as the voltage rating increases so that, on a high voltage transmission line, the minimum fault current may be less than maximum load current.

Fault current level detectors are called overcurrent relays and in their electromagnetic term, are very simple reliable devices since they consist simply of an electromagnet and a contact carrying armature. In their static form they are somewhat more complicated.Our aim hare is to design and study a static over current relay in simple form.

CHAPTER - 2

RELAYS FOR THE PROTECTION OF POWER SYSTEMS

2.1 Basic Ideas of Relay Protection

An **electric** power system should ensure the availability of electrical energy without interruption to every load connected to the system. When the electric power supply is extended to remote villages the power system would consist of several thousand kilometers of distribution lines. The high voltage transmission lines carrying bulk power could extand over several hundred kilometers. Since all these lines are generally overhead lines and are exposed, there are many chances of their breakdown due to storms, falling of external objects on the lines, damage of the insulators, etc. These can result not only in mechanical damage but also in an electrical fault. One of the sources of trouble to continuous supply in the shunt fault or short circuit, which produces a sudden and sometimes violent change in system operations.

Protective relays or relaying systems detect abnormal conditions like faults in electrical circuits and operate automatic switchgear to isolate faulty equipment from the system as quickly as possible. This limits the damage at the fault location and prevents the effects of the fault spreading into the system. It is the function of the protective relays in association with the switchgear to avert the consequences of the faults. The switchgear must be capable of interrupting both normal currents as well as fault current . The protective relay on the other hand must be able to recogize an abnormal condition in the power system and take suitable steps to ensure its removal with the least possible disturbance to normal operation .

It should be noted that a protective relay does not **prevent** the appearence of faults. It can take action only after the fault has occurred. It would be most desirable if protection could anticipate and prevent faults, but this is adviously impossible **except** where the orginal cause of a fault **creates** some effect which can operate a protective relay. However there are some devices which can anticipate and present major faults, e.g. Buchholz relay, a gas operated device which is capable of detecting the gas accumulation produced by an ancipient fault in a transformer. It is necessary for the protective engineer to provide relays whose business it is to determine what breakers are to operate to clear the trouble when it occurs. Relays then are the " Silent Sentinel" that guard , each in its own observation territory, the service to the community and protect life, propebty and service.

2.2 Nature and Causes of Faults

The nature of a fault simply implies any abnormal condition which causes a reduction in the basic insulation strength between phase conductors, or between phase conductors and earth, or any earthed screens surrounding the conductors. Actually the reduction of the insulation is not considered as a fault until it produces some effect on the system, that is until it results either in a excess current or in the reduction of the **impedance** between conductors or between **conductors** and earth to a value below that of the lowest load **impedance** normal to the circuit.

In a power system consisting of generators, switchgear, transformers, transmission and distribution circuits, it is inevitable that sooner or later in such a large network some failure will occur somewhere in the system. The probability of the failure or occurrence of abnormal condition is more on the power lines, simply because of their greater length and exposure to the atmosphere.

Before proceeding to the examination of the several causes of failures, it would be well to classify them according to the causes of their incidence. These are mentioned below:

(a) Breakdown may occur at normal voltage on account of (i) the deterioration of insulation and (ii) the damage due to unpredictable causes such as the perching of birds, accidental short circuiting by snakes, kite strings, tree branches, etc.

(b) Breakdown may occur because of abnormal voltages, though the insulation is otherwise healthy to withstand normal voltage. This may happen because of either (i) switching surges or (ii) surges caused by lightning.

The present day practice is to provide a high insulation level of the order of 3 to 5 times the normal value of the voltage. But still the pollution on an insulator strimg which is commonly caused by deposited soot or cement dust in industrial areas and by salt deposited by wind-borne sea-spray in coastal areas cause the insulation strength to decrease. This will initially lower the insulation resistance, and causes a small leakage current to be diverted thus hastening the deterioration. Even if the installation is enclosed, such as in sheathed and armoured cables as well as in metal-clad switchgear, deterioration of the insulation occurs because of **ageing**. Void formation in the insulating compound of underground cables due to the unequal expensions and contrations caused by the rise and fall of temperatures is another cause of insulation failure.

The line and apparatus insulation may be subjected to transient overvoltages because of the switching operations. The voltage which rises at a rapid rate, may achieve a peak value which approaches three times phase to nutral voltage. It is for this purpose that a higher insulation level is provided initially. If the insulation levels have been correctly chosen and they have not been impaired in the manner described under (a) above, the system will withstand these routine over-voltages. But if the insulation has developed some form of weakness, it is at the time of switching that failure may be expected.

Lightning produces a very high voltage surge in the power system of the order of millions of volts and thus it is not feasible to provide an insulation which can withstand this abnormality. These surges travel with the velocity of light in the power circuits, the limiting factors are the surge impedance and the line resistance.

2.3 Consequences of Faults

The most serious result of a major uncleared fault is fire which may not only destroy the equipment of its origine but may spread in the system and cause totalfailure. The most common type of fault which is also the most dangerous one is the short circuit which may have any of the following consequences :

(1) A great reduction of the line voltage over a major part of the power system. This will lead to the breakdown of the electrical supply to the consumer and may produce wastage in production.

(2) Damage caused to the elements of the system by the eletric arc which almost always accompanies a short circuit.

(3) Damage to other aperatus in the system due to overheating and due to abnormal mechanical forces setup.

(4) Disturbances to the stability of the electrical system and this may even lead to a complete shutdown of the power system.

(5) A marked reduction in the voltage which may sometimes be so great that relays having voltage coils tend to fail.

(6) Considerable reduction in the voltage in healthy feeders connected to the system **having** fault. This may cause either an abnormally high current being drawn by the motors or the operation of no-voltage coils of the motors. In the later case considerable loss of industrial production may result as the motors will have to be restarted.

2.4. Primary and Backup Protection

The system is divided into protection zones, each having its protective relays for determining the existence of fault in that zone and having circuits breakers for disconnecting that zone from the system.

The relays operate usually from currents and voltages derived from current and potential transformers or potential devices. A station battery usually provides the circuit breaker trip current. Successful clearing depends on the condition of the battery, the continuity of the wiring and tripcoil, and the proper mechanical and electrical operation of the circuit breaker as well as the closing of the relay trip contacts.

In the event of failure of one of these elements, so that the fault in a given zone is not cleared by the main or the primary protection scheme, some form of backup protection is ordinarily provided to do the next best thing.

There are 3 kinds of backup relays:

(a) those which trip the same breaker if the main relay fails (Relay Backup).

(b) those which open the next nearest breakers on the same bus in case one the local breakers fails to open (Breaker Back-up), or in the case there is a failure of the local secondary current of potential supplies, or the a.c. wiring.

(c) those which operate from a neighbouring station so as to backup both relays and breakers and their supplies (Remote Backup) in case of the failure of any local supply including the battery, or in the case a circuit breaker or relay fail to function.

The relays themselves must be connected to trip only the breakers next to the protected unit, the zone of protection of each relay must overlap the zones of **Adjacent** relays to insure that these are no dead spots. This can be achieved by the proper location of each current transformer.

2.5. Economic Considerations

We are quite familier in the day to day life that there is an economic limit to the amount that can be spent on different types of insurances in order to safeguard life and property. Similarly in the power system there is an economic limit to the amount that can be spent on the protection of system. Usually this is a very complex affair since the probability of failure or fault is a function of component, location, time, etc. All these factors can lead to different alternatives for the same problem, and a choice has to be made keeping in view the economic justifiability. The cost of protection is linked with cost of the plant to be protected and increases with the cost of the plant. Usually the protective gear should not cost more than 5% of the total cost. However, when the apparatus to be protected is of paramount importance like the generator or the main transmission line, economic considerations are often subordinated to reliability.

2.6. How Relays Locate Faults.

Protective relays shuld be applied such that only the local area of the fault is removed or isolated from the rest of the system. This means that relays must be able to " Locate " faults and trip only the breakers on circuits directly connected to the faulted equipment. Realys are said to be"selective"when by proper application and setting, a minimum number of circuit breakers are tripped to remove the fault from the system.

It can be seen that in order to apply and set protective relays on a power system, a knowledge of the system performance during faults is necessary. Relays must differentiate between permissible operating conditions and abnormal or fault conditions. Most faults provide **several** characteristics, by which they can be located. The more common of these charecteristics are:

(1) Increased currents in one or more phases (in the order of 2 to 20 times normal load current) and flowing toward the fault.

(2) Reduced voltage of one or more phases. The voltage will be lowest of the fault.

(3) Fault power always flow towards the fault.

(4) Temperature rise in electrical equipment.

Protective relays employ these and other characteristics singly or together to locate and isolate faults. An examples, fault current may energize overcurrent relays which operate either instantaneously or after a time delay. In the later case, the large the current the faster the operation so the relay nearest the fault operates to clear the fault. The time allowance may be only on fraction of a second and seldom more than two seconds. The simultaneous measurement of the increased current and reduced voltage indicates the ohmic distance to the fault so that the relay nearest the fault can operate first.

A responding to the direction of power flow can indicate the direction of the fault. If these relays at each end of a line section can compare the direction of the fault power flow either by carrier or pilot wires, then the faulted section can be quickly isolated. Other relays balance the current flowing in each parallel line so that when the current in one line increases, this faulted line is tripped.

In any piece of electrical equipment, the current flowing into the equipment equals that flowing out and any difference between incoming and outgoing currents, other than the losses in the equipment itself, indicates a fault in the equipment. Hence if the input and output currents are compared and their difference introduced into a relay, an ideal method of obtaining selectivity results.

CHAPTER - 3

RELAY DESIGN AND CONSTRUCTION.

3.1. Factors Affecting Design and Construction

(a) The characteristics of the relay must be such that it always operates for the type of fault which it is intended to protect against, and not for any other conditions.

(b) The relays must have arrangement for adjustment to permit it to operate selectively with other relays.

(c) It should meet the specifications of the country where it is to be used.

(d) A relay must be immune from transient effects, e.g. drop in voltage, peak currents, d.c. signals and hermonics.

(e) The construction should be simple and accessible, so as to facilitate maintenance.

(f) The wiring and terminal arrangement should facilitate testing and the tracing of faults.

(g) The construction should facilitate the making of minor modifications to meet unusual conditions of temperature, humidity, corrosive atmospheres, mechanical shock etc.

3.2. Functional Characteristics of Protective Relaying.

3.2.1. SENSITIVITY, SELECTIVITY, AND SPEED.

"Sensitivity", "Selectivity", and "Speed" are terms commonly used to describe the functional characteristics of any protective relaying equipment. All of them are implied in the considerations of primary and backup relaying. Any relaying equipment must be sufficiently "sensitive" so that it will operate reliably, when required, under the actual condition that produces the least operating tendency. It must be able to "selact" between those conditions for which prompt operation is required and those for which no operation, or time-delay operation, is required. And its must operate at the required "speed". How well any protective-relaying equipment fulfills each of these requirements must be known for each application.

The ultimate goal of protective-relaying is to disconnect a faulty system element as quickly as possible. Sensitivity and selectivity are essential to assure that the proper circuit breakers will be tripped. The benifits to be gained from speed will be considered later.

3.2.2. RELIABILITY

"Reliabilty" is a qualitative term. Quantitatively it can be expressed as a probability of failure. Failure is not confined to protective gear but may also be due to breaker defects. Therefore every component and circuit involved in fault clearance must be regared as a potential source of failure. Failure can be reduced to a small calculated risk by inherently reliable designs backed by regular and thorough maintenance. Quality of personnel must not be overlooked when considering reliability, for mistakes by personnel are among the most likely causes of failure. Some features of design and manufacture which make relay inherently reliable are high contact pressures, dust free enclosures, well braced joints and impregnated coils. (Electromagnetic relays). Precautions in manufacture and assembly reduce liability of failure. Components should be **treated** to prevent contamination. Acid fluxes and acid producing insulation should be avoided. On assembly direct handling of components should also be avoided as far as possible. Actual field test should be made periodically. These field tests provide an excellent means for cheaking the over-all operation of all equipment involved.

3.3. Choice of the Type of Relay or Comparator

In broad terms protection relays are in two catagories of construction, (a) those which are wholly electromagnetic or electrothermal, in which the comparison is done by the relay itself by balancing two forces or magnetic fluxes and (b) using a static comperator, in which the comparison is done

Table for Evaluation of Comperator Units

Quality	Moving Armeture Electromagnet				Static Comperators with **slave** Relay			
	Attracted Armeture	Induction Disc	Induction Cup	Thermal	Electronic	Transitors	Rectifier Bridge	Magnetic Amplifier
Low Cost	5	7	4	8	1	2	3	6
Accuracy	2	3	5	1	8	7	6	4
Speed	5	2	4	1	8	7	6	3
Output Quality	1	4	3	2	7	6	8	5
Sensitivity	4	2	3	1	8	7	6	5
Stability	1	4	2	3	6	7	8	5
Robustness	5	4	6	3	1	7	2	8
Simplicity	8	6	5	7	2	1	4	3
Experience	6	8	7	5	2	1	4	3
Total	37	40	39	31	43	45	47	42

in a static circuit by comparing two or more currents or voltages and feeding the resultant output into a slave devices which takes the required action.

The table[9] compares eight types of relay constructions, four electromagnetic and four static. The number in the table represent order of marit among them in comparison rather than degree, since the degree would depend very much upon the actual design. The highest number 8, represents the best performance. Reliability is not listed because it is covered under stability, simplicity, robustness, etc. Stability includes overtravel and transient overreach. Experience is confined to their use in protective relays. In the column headed "Quality" the fourth term "output quality" refers to the steadiness of the torque or force in the case of electromagnetic relays and to the smoothness and range limitation of the output voltage and current in the case of static relays.

3.4. Static Relay Operating Principle

The static overcurrent relay consists of a rectifier unit which **converts** to a.c. signals to d.c. levels, followed by overload level detector, timing circuit, level detector and a trip. Fig. 3.1. represents the block schematic of a time-current relay.

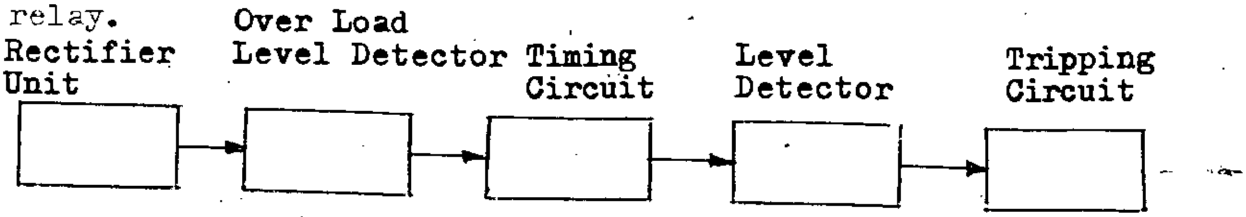


Fig.3.1. Block diagram of a time-current relay

The current from the CT is redued to 1/1000 th by an auxillary CT, the auxillary CT has taps on the primary for selecting the desired pickup and current range and its rectified output is supplied to an overload level detector and an RC timing circuit. When the voltage on the timing capacitor has reached the value for triggering the level detector, tripping occurs.

3.5. Advantage of Static Relays

The main advantages offered by semiconductor relays are low burden and superior performance, viz :

(a) Fast response, long life and high resistence to shock and vibration.

(b) Quick reset, a high resetting value and the absence of over shoot are easy to obtain in static relays because of the absence of mechanical **inertia** and thermal storage.

(c) With the absence of bearing friction and contact troubles (corrosion, bouncing and wear), better characteristics can be obtained and there is **less** necessary for maintenance.

(d) Very frequent operation causes no delerioration.

(e) The case of providing amplification enables greater sensitivity to be obtained.

(f) The low energy levels in the measurement circuits permit miniaturization of equipment and minimize CT inaccuracy.

(g) Low burden on CTs and PTs, **since** the operating power is from an anxillary d.c. supply.

(h) A variety of charecteristics can be obtained with static relays. Thereby selectivity, stability and adequateness can be achieved.

(i) Static relays resisted by power line carrier can be used for remote backup and network monitoring.

(j) Static relays are compact. Furtermore, with use of integrated circuits, complex protection schemes can be installed on a single panel.

(k) Complex protection **schemes** employ logic circuits. "Logic" means the process of reasoning, induction or deduction. Suppose, several **conditions** are imposed on a protection system such that for certain conditions, **the** relay should operate, and for some other conditions, the relay should remain stable ; in such cases, logic gates can be adopted.

On the other hand, static relays have a number of limitations which must be compensated for:

(a) Variation of characteristics with temperature and **age** Temperature error can be eleminated by appropriate use of **thermistors.** Ageing can be minimized by pre-soaking for a number of hours in a relatively high temperature.

(b) Vulnerability to voltage spikes and high ambient temperatures .

Protection against voltage spikes can be provided by filters and shielding. Silicon transistors can be used where high temperatures are involved.

(c) Dependance upon the reliability of a large number of small components and their electrical connections.

Modern methods of soldering, wire-wrapping, etc. and the selection of superior components can ensure a high degree of reliability.

(d) The lack of life-test data due to rapid replacement by new designs.

The manufacturers of transistors say that the experience gained with one transistor is embodied in its successor.

(e) Low short-time overload capacity compared with electromagnatic relays.

Overload must be avoided by circuit design.

(f) Anxiliary voltage requirement.

This disadvantage is not any importance as anxiliary voltage can be obtained from station battery supply.

(g) To introduce the relays in the power system, enough expertise should be available with the manufacturer and electricity boards as regards operation, maintenanc of static relays.

The relays can be introduced only when their reliability in assured, the maintenance personnel are trained and power systems are fully prepered for adoptation.

3.6. Reliability of Static Relays

Reliability of protective relaying is very important. Electromagnetic relays have high reliability, due to (1) precision of manufacture, (2) few reliable components in their construction (3) experience gained in designing, manufacturing, tesing, and maintenance. Static relays are in infant stage and have to prove their reliability. As the static relays have several discrete components such as resistors, capacitors, semi-conductors in their construction, reliability depends on reliability of these components and reliability of the total assembly. It is, therefor necessary to choose the components with great care. Each component should be type tested. Care should be taken in connections, soldering, etc. The ambient conditions, voltage spikes should also be considered. " The use of integrated circuits increases reliability of static relays". Integrated circuits are much more reliable than the equivalent discrete component circuits. Reliability of components is improved by strict quality control, presoaking the components to improve temperature-response. Pre-soaking of a relay means, operating the relay under service conditions for certain time with current and voltage connected to it. With this method, bad components and poor joints can be detected.

CHAPTER - 4

STATIC RELAY COMPONENTS AND THEIR CHARACTERISTICS

Electronic Devices operate either as switches or as control devices, controlling an output current or voltage in response to an input signal. Either the switching or control can be very rapid and can be accomplished with very little input energy. Since the controlled energy may be large, the concept of power gain or amplification is important. In some cases a small energizing signal may graw regenerate into a very large output signal from power supplied by a d.c. or a.c. power effective in performing various functions. Some of the commonly used components in static relays are discussed briefly in the sections that follow.

4.1. Semiconductor Diodes

If a piece of p-type metal is fused to a piece of N-type metal so that the crystal lattice is continuous, the junction has a rectifying charcteristic (Fig. 4.1); it also has a non-linear resistance as shown in Fig. 4.2. Its resistance falls rapidly with increasing temperature (Fig.4.3) or the incidence of light.

If a source of e.m.f. is connected to the p-n junction the polarily shown if fig. 4.1, then the "spare" holes in the P-type region are drawn easily to the negative pole and the electrons are drawn from the N-type to the battery positive If the barrery potential is reversed then the holes are repelled

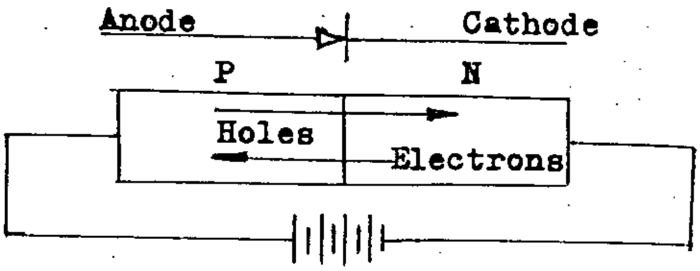


Fig. 4.1, P-N Junction diode

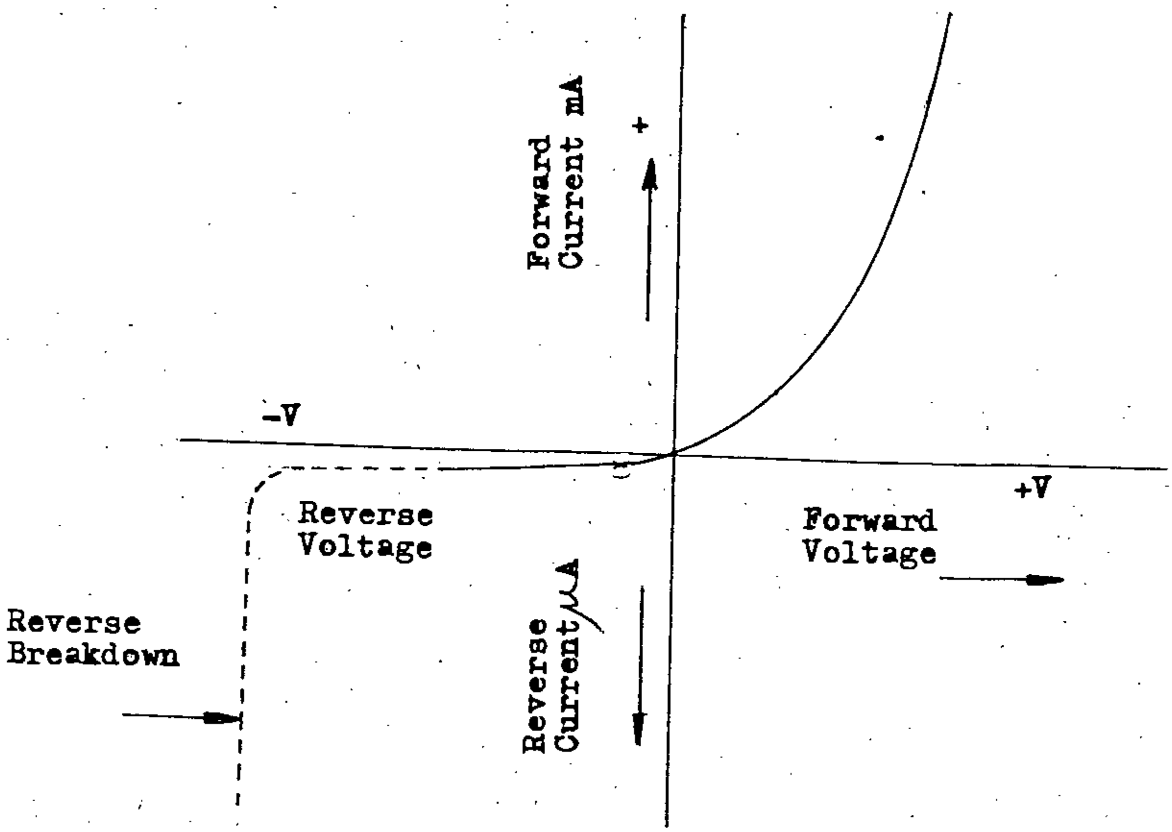


Fig. 4.2. Rectification effect of P-N Junction diode

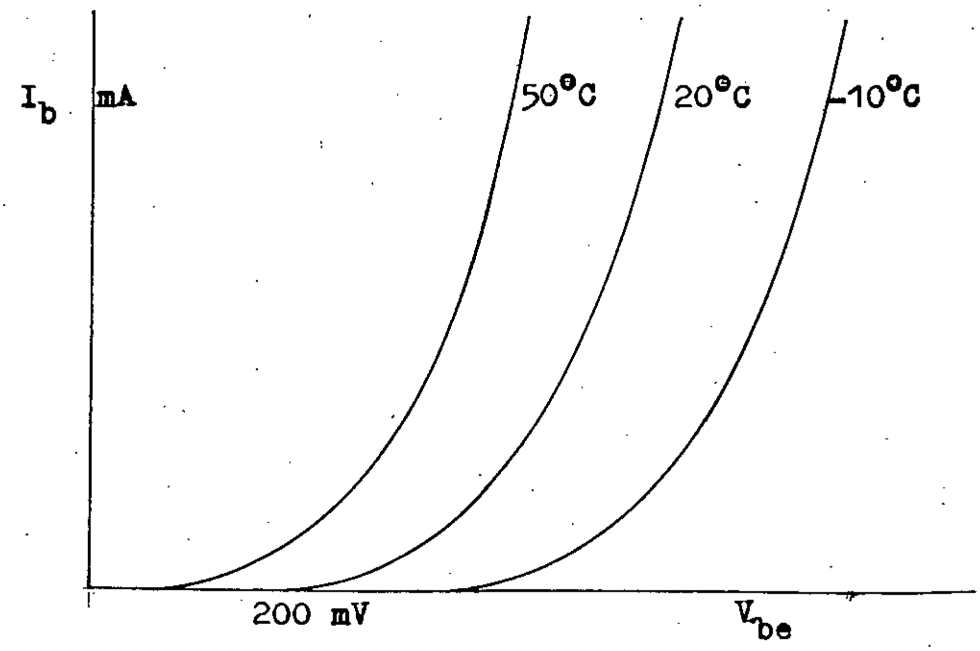


Fig. 4.3. Effect of temperatue on P-N junction diode.

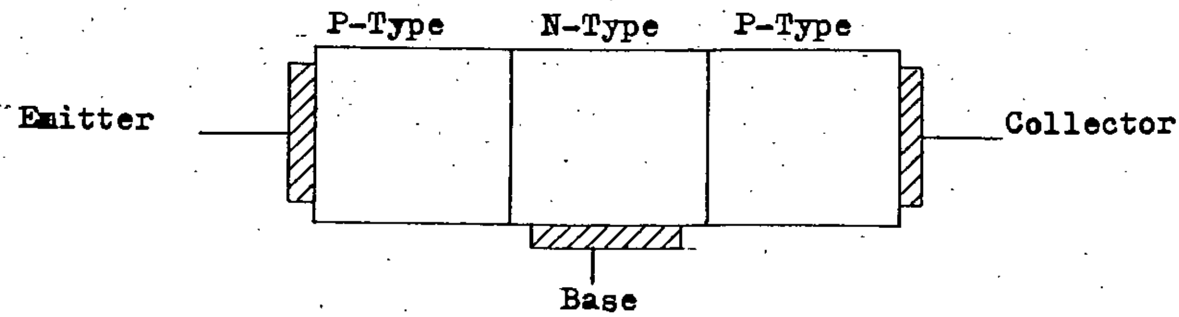


Fig. 4.4. P-N-P transistor.

from the positive pole and likewise the electrons from the negative pole. Consequently, little current flows until such time as the electric stress is so high that a process similar to an electric discharge occurs. Hence, a current characteristic for forward and reverse polority is as shown in Fig.4.2. and has definite rectifying properties.

If a double junction be made as in Fig.4.4. a transister is formed which has even more remarkable characteristics. A thyristor which have three p-n junctions. Which is a special type of transistor is discussed in article 4.5.

4.2. Zener Diode(Voltage Regulating Diode).

Zener diode is used for voltage stabilization. Zener diodes have been developed in range of from a few volts to several hundred volts and for power handling ability of over 100 watts. Some reverse biased junction diodes exhibit breakdown at a very low reverse voltage(about 5 volts) due to spontaneous pairs within the junction region from inner electron shells. Zener diode can operate in reverse breakdown mode continuously without damage. Under reverse breakdown condition, for a wide range of current the voltage across the zener diode remains constant. This property is used in voltage regulation circuits.

4.3. Junction Transistor(Bipolar Transistor)

Transistors are used in amplifiers, level detectors, switching circuits.

A junction transistor has two junctions and can be either PNP or NPN transistor as shown in Fig.4.5. In PNP transistor a N-type layer is sanwiched between two P-type layers. In NPN transistor a P-type layer is sandwiched between two N-type

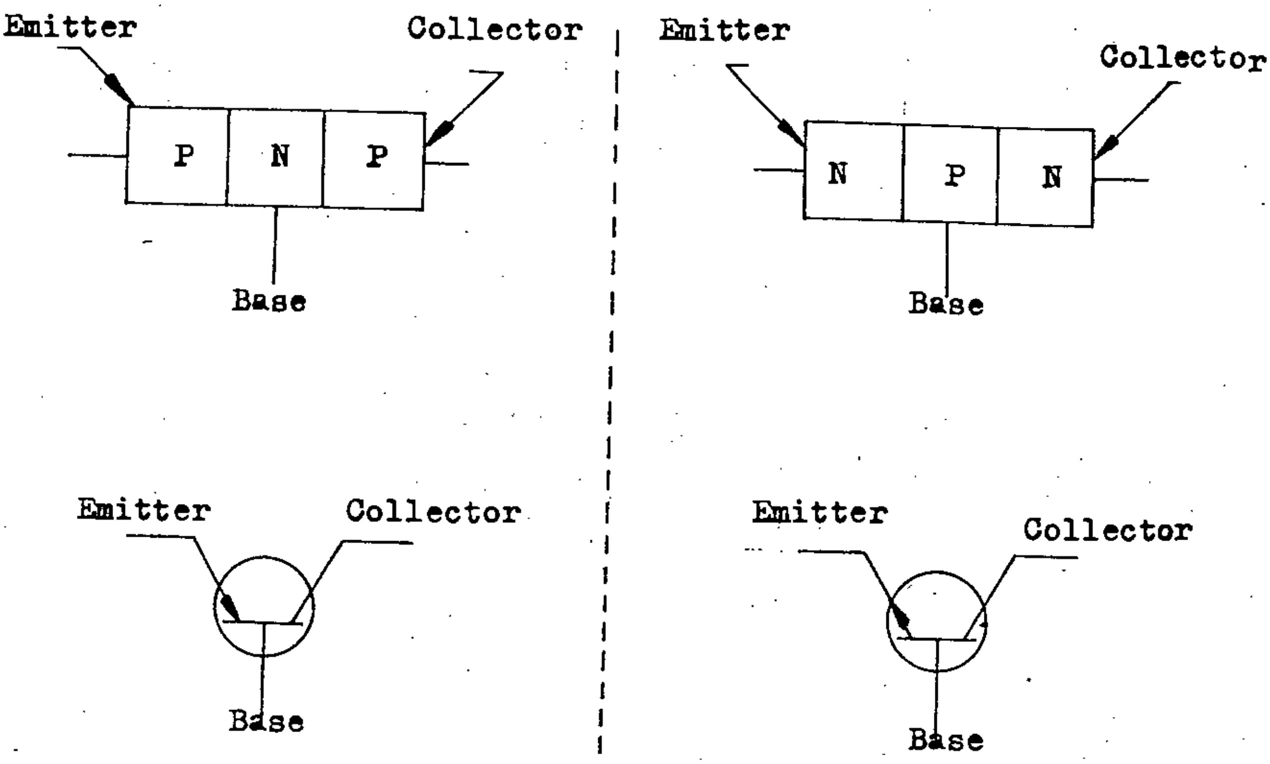


Fig. 4.5. Transistors.

layers . In both the layers, the central layer should be **thin** for successful operation. The central layer is known as Base (corresponds to grid of a triode). One of the remaining two layers is called Emitter (Corresponds to cathode of the triode) and the other layer is known as collector (corresponds to the anode of the triode). For efficient operation the emitter must have much higher conductivity than the base. The arraw in the symbol represents the conventional direction of current. For correct operation, emitter-base junctio should be reversed biased. Correct biasing is indicated in Fig.4.

The two transistors obey kirchhoff's **law ;**

$I_E = I_B + I_C$, **Fig. 4.6**

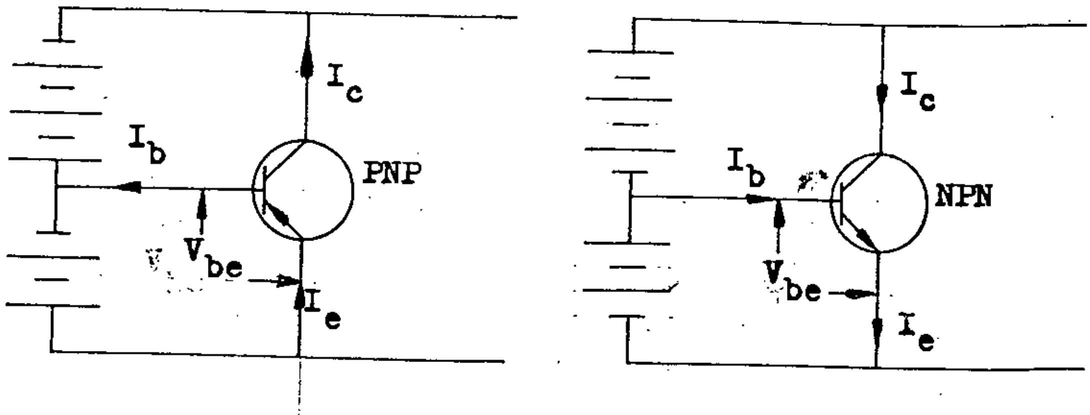


Fig. 4.6. Biasing polarities and current flow

If forward bias V_{BE} is changed, the emitter current changes changing base current and hence collector current. Thus the through current is controlled by voltage or current or current input and the ratio between these currents is such that amplification can be achieved.

Switching transistors are used in static relays.

(1) In PNP transistor, the emitter has an arrow mark towards the base.

PNP transistor is turned on when base is given a positive pulse with respect to collector.

(2) In NPN transistor, the emitter has an arrow mark pointing outwords.

NPN transistor is turned on when base is given a negative pulse with respect to collector.

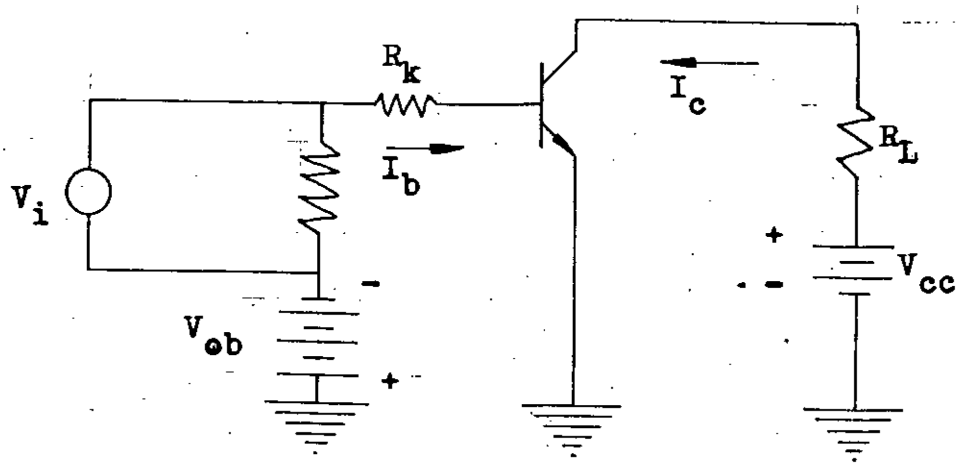


Fig. 4.7. Basic Transistor switching circuit.

Bipolar transistors may be operated in 3 different modes called common base, common emitter and common collector. Common base is used for r.f. applications, common emitter is used for various general purpose amplifiers and common collector for matching purposes.

Alloy junction transistors have wide range of applications including general purpose amplifiers, oscillators. There cut-off frequency is low, being in 10 - 20 MHz range. Alloy deffused transistors have cut-off frequency upto 300 MHz and are used in i.f. and r.f. amplifiers, mixtures, oscillators, for switching line it.

4.3.1. OPERATION OF TRANSISTORS AS AN AMPLIFIER

The amplifier amplifies the input signal. The output of the amplifier is more than the input.

The performance of a transistor can be described by its static characteristics when connected in three different way, viz :

(a) grounded - emitter (Fig. 4.8)

(b) grounded - collector (Fig. 4.9)

(c) grounded - base (Fig. 4.10)

The most useful characteristics is the curve of collector current versus collector voltage. This is plolled for various values of lb for the grounded-emitter circuit (fig. 4.11) or Ie for the grounded-base circuit (fig.4.12)

The fact that current amplifieation is linear, whereas the voltage amplification depends upon the load impedance, means that transistor amplifiers are linear only as current amplifiers, i.e. the input must be a current source or the source impedance must be high compared with the transistor input impedance if a voltage source is used.

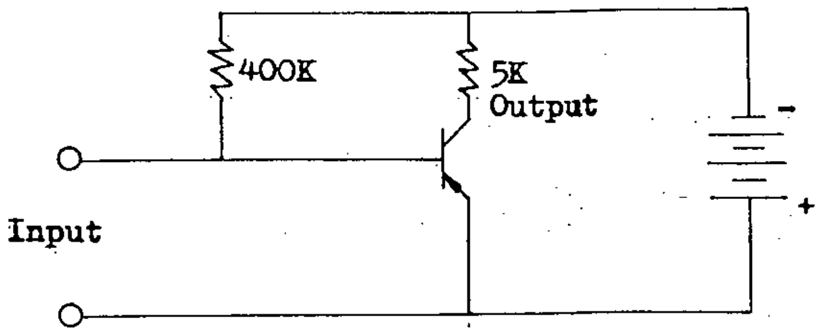


Fig.4.8. grounded Emitter ckt.

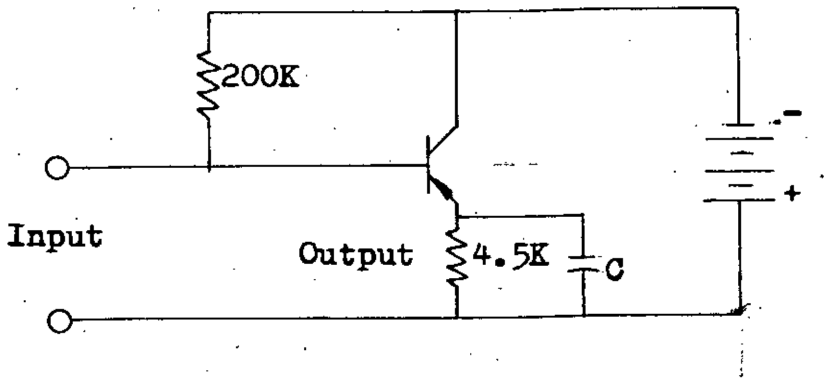


Fig.4.9 grounded-collector Circuit.

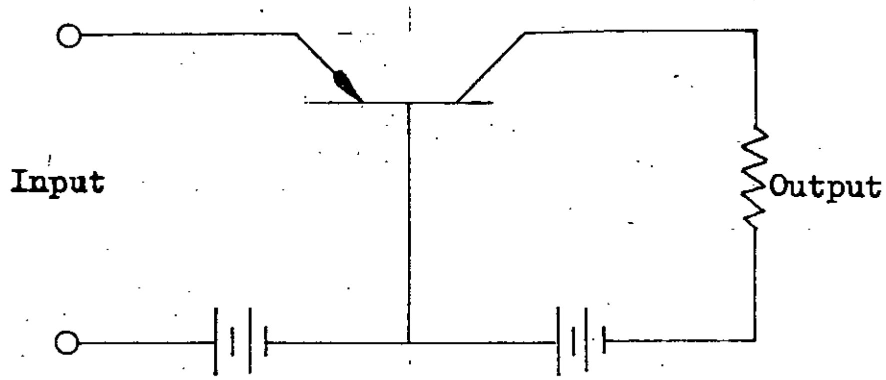


Fig.4.10. grounded-base ckt.

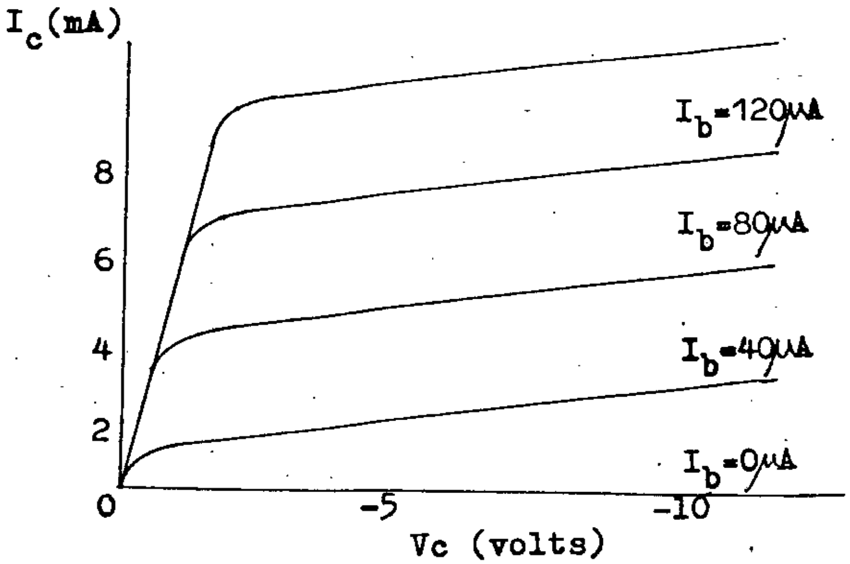


Fig.4.11 Collector current versus collector voltages in the grounded emitter circuit.

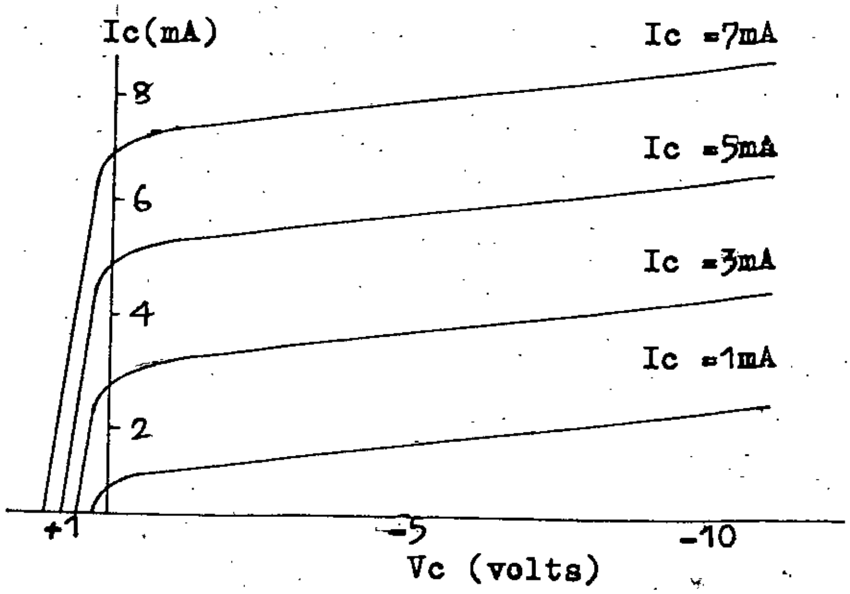


Fig.4.12 Collector current versus collector voltage in the grounded base circuit.

Table

Comparison of Transistor Connections

grounded Electrode	Emitter	Base	Collector
Input Electrode	Base	Emitter	Base
Current Gain	High	None	High
Voltage Gain	High	High	None
Power Gain	High	Medium	Low
Input Impedance	Medium	Low	High
Output Impedance	Medium	High	Low
Phase Shift	180°	0°	0°

4.3.1.1. GROUNDED-EMITTER AMPLIFIER

Fig. 4.8. shows a p-n-p amplifying circuit in which the base bias is obtained without a seperate battery by means of a leakage resistence connected to the collector end of the battery ; for a.c. the base must be biased in the forward direction well above the toe voltage. This circuits is called the grounded (or common) emitter circuit ; it gives high current and power gains and is the circuits most commonly used for amplification, specially in circuits where the input impedance Z_{be} as in the case where output of a comparator is to be amplified. It presents a low input impedance Z_{be} and a fairly high output impedance, it causes 180° phase shift.

The current gain ($\beta = \frac{ie}{ib}$) is not much affected by the load impedance but the power gain increass with the load upto an optimum value where the load impedance **matches** the output impedance of the transistor ; the voltage gain is high because the input voltage is only the base-emitter drop ; this also contributes to the power gain.

The collector resistance for a given value of i_b is $V_c = \frac{Vc}{Ic}$ when Ib = O, the lakage current Ico/ (1-α) flows in the collector and increases slightly with increasing voltage.

4.3.1.2. GROUNDED-COLLECTOR AMPLIFIER.

Fig.4.9. shows the grounded (or common) collector circuit. When the transistor becomes conductive the current through the output impedance reduces the voltage between the emitter and the base, providing a limiting action like negative feedback; this stabilies the d.c. working point but does not affect the a.c. amplification if a small capacitor is connected across the output, as shown in Fig. 4.9. It has about the same current gain as the grounded-emitter circuit but the voltage gain is negligible because the drop across the output is also the input circuit, hence the power gain is small.

The input impedence is high and the output impedance is low ; hence this circuit can be used as a matching stage to match the high output impedance of one grounded-emitter amplifier stage to the low input impedance of another. It has no phase shift.

4.3.1.3. GROUNDED-BASE AMPLIFIER

Fig.4.10. shows a grounded (or common) base amplifier. This has a very low input impedance and a high output impedance. If given no current amplification with d.c.; the amplification is small with a.c. and depends upon the position of the i_c/i_e transfer curve ; hence it is no good for R-C amplifiers but can be used for power amplification with transformer coupling. It has no phase reversal and is temperature stable.

The static characteristics is as shown in Fig. 4.12 The collector resistence $r_c = V_c/I_c$ is generally greater than 1 megohm.

4.3.2. D.C. AMPLIFIERS

These are amplifiers which have zero frequency as the lower band limit to retain the initial displacements, d.c. components and low frequency transient offsets that may accompany the a.c. and time-varying signals. It is not possible to use reactive coupling elements to seperate signals and bias quantities. Any drift in the quiescent operating values can not be distinguished from singals which are to be amplified. Direct-coupled amplifiers, therfore, have special problems in long time stability. The main reasons for the drift (a slow variation of the output voltage and current of the amplifier when the input signal is maintained at a constant level) are (i) variation of emitter to base voltage, (ii) variation in the gain of the transistor, and (iii) variation in the power supply voltage . Temperature variation is one of the main causes of these variation. There are numerous compensation techniques for the temperature . The principal feature of interest in direct coupled amplifiers is their ability to amplify signals ranging from d.c. to a frequency of many megahetz.

4.4. The Field-Effect Transistor (FET)

The field-effect transistor(FET) is a unipolar device as compared to bipolar transistor. It consists of a bar of semiconductor material whose resistance is modulated by varying either the cross-sectional area of the bar or the density of current carriers in it, or both, by some electrical means. Two structures are use. One is an all-junction device in which the controlled modulation involves only the cross-section of the conducting channel. This is usually called junction FET. The other structure, called an insulated-gate FET(IGFET) or metal-oxide silicon FET (MOSFET) involves modulation of both the channel cross-section and the density of current carrier in it.

Junction FET is illustrated in cross-section in Fig. 4.13. An N-type bar of germanium is flanked by two regions of P-type germanium. The conduction current to be modulated is carried between the end of N-type bar.

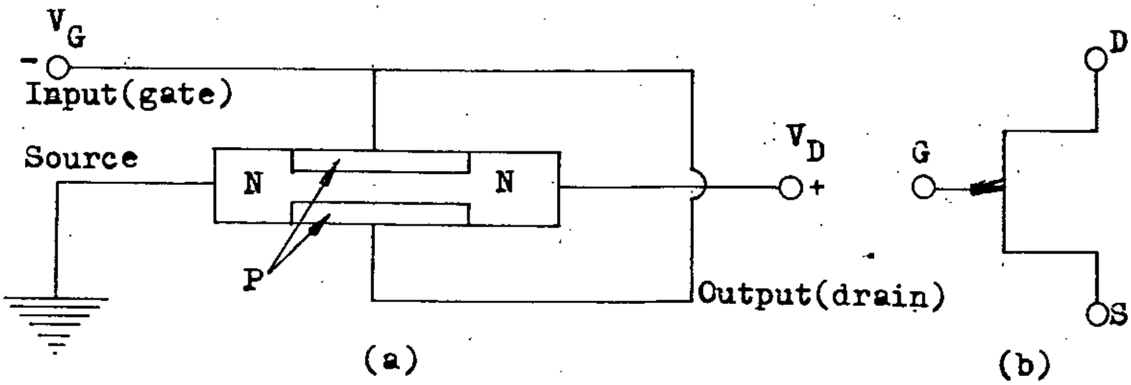


Fig. 4.13. (a) A cross-sectional view of junction inN-channel FET device; (b) Symbolic representation.

The cross-sectional area available for conduction between the two P-type regions is a function of the magnitude of the reverse bias between the two P-type regions and the n-type bar. The input impedance of this device is quite high, and the output impedance is **moderately** high. This type of device shows less internal feedback between the input and output than the **conventional** transistor. Typical characteristics curves of junction FET are shown in Fig.4.14. It has characteristics similar to pentode tube. A few voltage

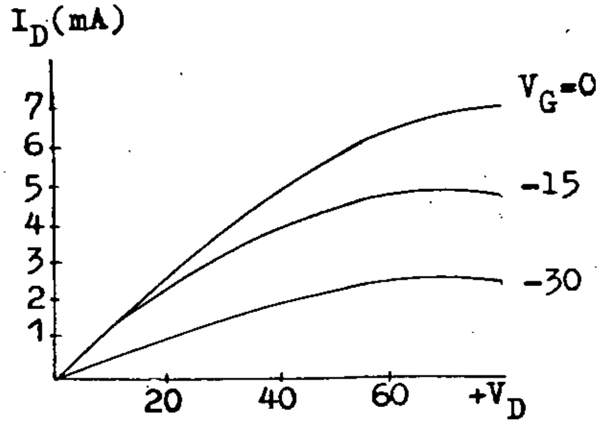


Fig. 4.14. Typical junction FET characteristics.

negative bias on the gate blocks the current between drain and source by vertue of the field effect.

4.4.1. THE FET AS A SWITCH

At low frequencies the FET has no offset voltage. There is no threshold required of the signal being switched. In an ordinary bipolar transistor the signal being switched must exceed the voltage of the knee in the forward diode characteristic of the collector before there is apprciable signal through the switch in the on state. Here the channel, when opened by the gate, is a linear resistance requiring no such threshold. At a high frequency of switching there is a current due to the rapid charging and discharging of the gate capacitance through the channel, creating an IR drop in the channel which acts like an offset voltage.

4.5. Thristor (SCR)

The structure of thyristor consists of four alternate P-and N-type layers. In the thyristor (also called a silicon controlled rectifier - SCR) connections are made available to the inner layers. It acts like two transistors in tandem, one pnp and another npn. Fig.4.15. shows the circuit symbol for the SCR.

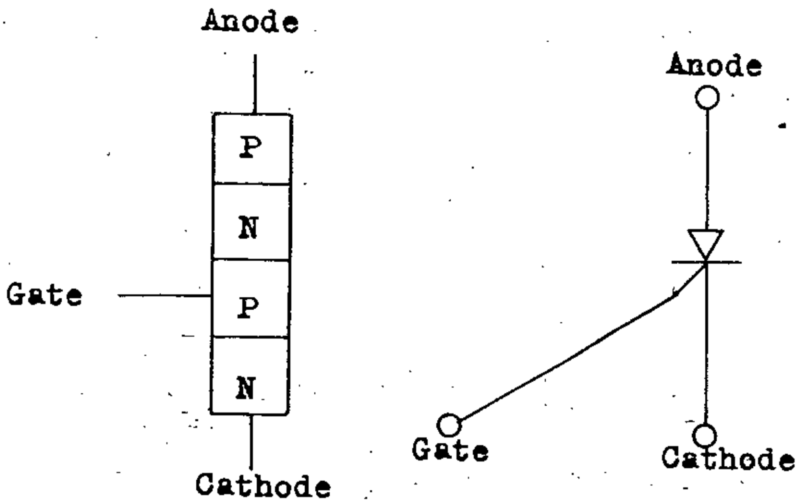


Fig. 4.15. Circuit symbol for SCR.

The usefulness of the gate terminal rests on the fact the current introduced into the gate may be used to control the anode to cathode breakover voltage. In fig. 4.16. the volt-ampere characteristics of an SCR is shown for various gate currents. It can be observed that the firing voltage is a function of the gate current, decreasing with increasing gate current and increasing when the gate current

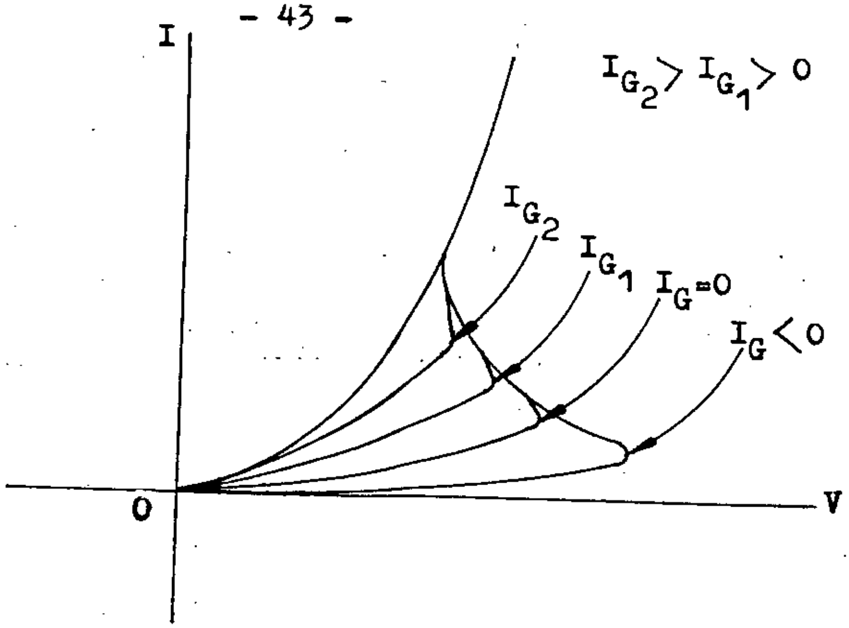


Fig.4.16. Volt-ampere characteristics of an SCR.

is negative andconsequently a direction to reverse-bias the cathode junction. The current after breakdown may well be large by a factor of 1000 than the current before breakdown. When the gate current is very large, breakdown may occur at so low a voltage that the characteristic thus the appearance of a simple pn diode.

Suppose that a supply voltage is applied through a load resitor between anode and chathode of a SCR. Consider that the bias is such that the applied voltage is less than breakover voltage. Then the rectifier will remain off and may be turned on by the application of the gate by a triggering current or voltage adequate to lower the breakdver voltage to less than the applied voltage. The rectifier having been turned on, it latches and it is found to be impractical to stop the conduction by reverse-biasing the gate. For Example, it may well be that the reverse gate current for turn off is nearly equal to the anode current.

Because of its high speed a thyristor is easily triggered by a small voltage signal (5v, 0.1 mA). To prevent wrong operation it is customary to design the circuit so that the tripping signal will not trigger the thyristor unless it lasts for at least 2 msec. This prevents operation on interference spikes since they are momentary in nature (in order of μsec.)

Thyristors can be used in severl applications such as controlled rectifiers, motor control circuits, temperature control devices, a.c./ d.c. switch circuits, inverters, etc.

4.6. Unijunction Transistor (UJT)

It is a three terminal device with only one pn-junction. It is made up of N-type silicon wafer having two base controls and a P-type alloy junction which acts as emitter electrode. In normal operation the lower ohmic contact (base B_1) is grounded. If the emitter junction is left open circuited, the voltage between B_1 and B_2 sets up a current propertional to the conductance of the wafer. The base B_2 is made positive with respect to B_1 by voltage V_{BB} and fraction of this voltage appears between the emitter E and B_1. Under the conditions of no current in the emitter, the UJT between B_1 and B_2 has characteristics of an ordinary resistance called the interbase resistence R_{BB}. At 25°c this resistance lies between 4 to 10kohm. and increases linearly with temperature upto about 140°C. The normal biasing conditions for the UJT and its symbol are indicated in Fig.4.17. If V_E applied is less than V_{BB}, the emitter will be reversed biased and only leakage current will flow. If V_E is greater than V_{BB} the junction becomes forward biased and large emitter current flows with a low forward voltage drop between emitter B_1.

The characteristics show that there is a large negative resitance region for fast switching action. The use of UJT is in generating trigger input of SCR_s. For such an application, the basic circuit of Fig.4.18. is used. The capacitor C_1 charge through R_1 until V_E reaches the

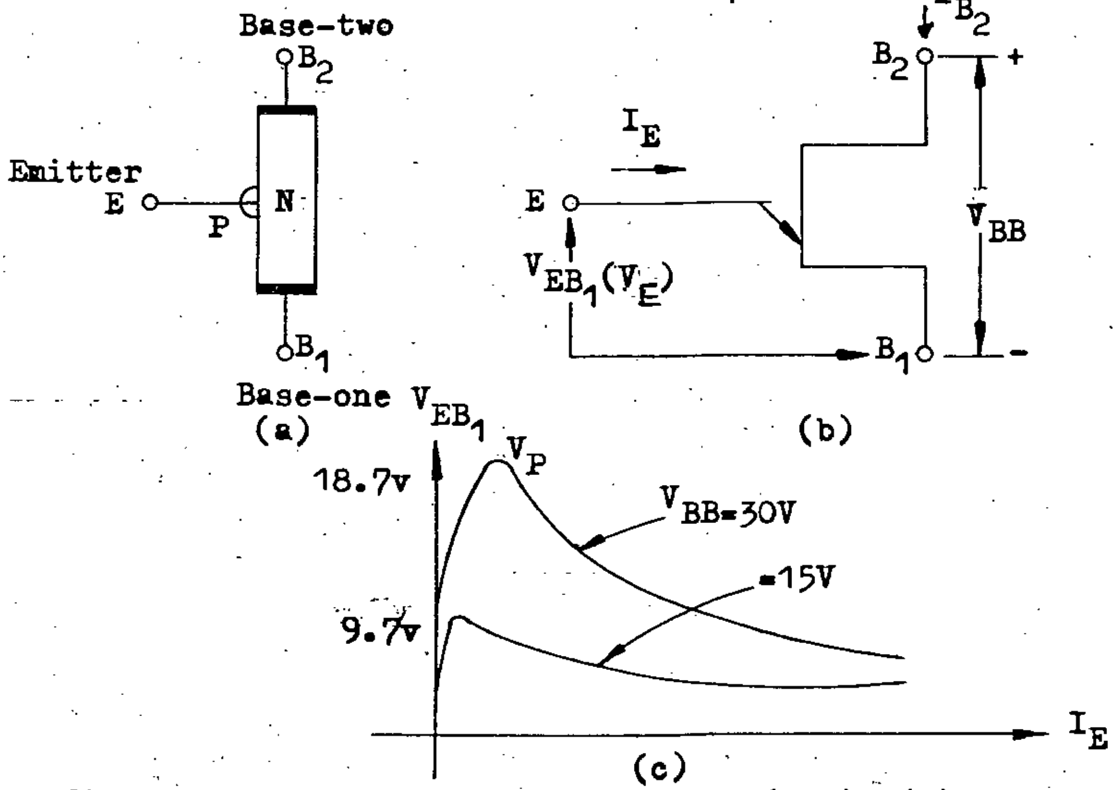


Fig.4.17. The unijunction transistor (UJT). (a) the constraction, (b) the symbol for the device (c) the V-I characteristics at the emitter terminal.

peak point voltage V_p, when the UJT triggers and discharges C_1 through R_{B_1}. When V_E reaches a low value, perpaps 2v, the capacitor can no longer supply the necessary emitter-base current, and UJT turnes off. Base resitor R_{B_1} provides an output voltage pulse during the very short high-current

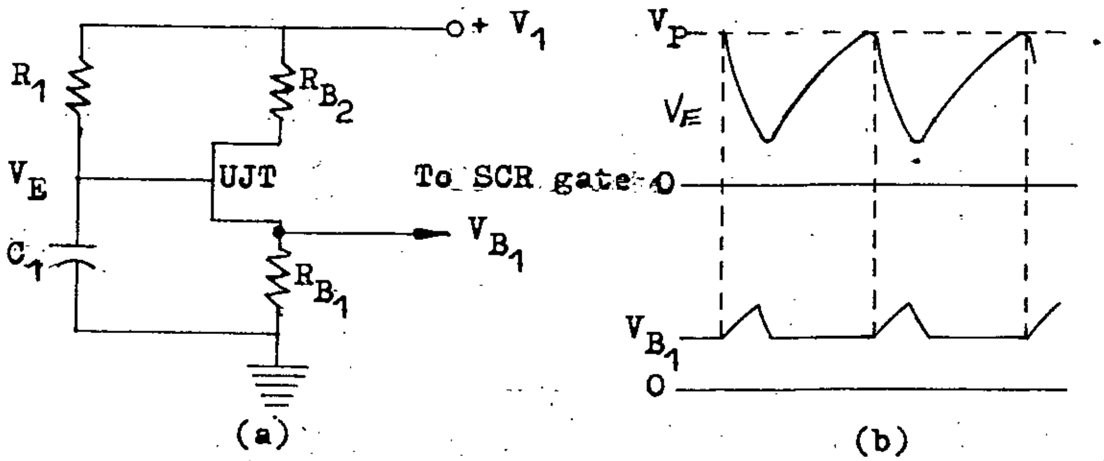


Fig.4.18. Triggering SCR with UJT.

transiton through the negative resistence region as shown in Fig.4.18b. This pulse is coupled to the gate of an associated SCR and provides precise triggering.

4.7. Triac

The output element of a static relay can be a "Triac". Triac is a further development of SCR. Thyristor (SCR) conducts only in one direction (D.C) when a positionpulse is applied to its gate; and conducts until the D.C. supply is interrupted. Triac is bi-directional device and passes current in either direction (A.C.) when triggered by either positive or negative gate signal. Once turned on, the triac conducts till the load current falls to Zero. In D. C. circuit load current should be switched off by an auxiliary switch. In A.C. circuit load current reaches zero twice in a cycle.

With signal continuously present on the gate, the triac automatically turns on and off at the beginning and end of each half cycle. Thus the period of conduction is almost a complete cycle.

Since SCR and Triac cuts-off at current zero, there is no problem of switching over-voltages and radio-interference.

4.8. Thermistors

Thermistors are used for temperature measuruments, temperature compension circuits. The type include negative-temperature co-efficient thermistors and position temperature co-efficient thermistor. The resistance of an n.t.c. thermistor decreases with the increase in temperature.

4.9. Static Relays with Integrated Circuits

The hybrid IC's have resitance, capacitance, semi-conducting, and insulating materials on a passive or a eutral base such as glass or ceramic by process of diffusion,pinting /doping. These are not truely monolithic IC's, but a step towards IC's.

Truely monolithic IC has abaisc electronic circuit (with its passive elements such as resistors, capacitors and active elements such as diodes, and transistors) in a single piece of silicon wafer (chip). The entire circuit is formed in a single manufacturing process.

A single silicon wafer of about 25 mm diameter can accommodate about ten to hundred IC's made simultaneously, the number depending upon the complexity and size of the individual circuits. The individual IC's are then seperated. To give an idea, a complete IC comprising about 12 transistors and associated resistors can be accommodated on a 1.3 mm^2. The IC package containing this circuit and terminals will be about 15 mm^2.

Such a circuit is known as Integrated Circuit (IC). Integrated circuits for common functions are manufactured on large scale as per international standards. Standard IC's are commercially available. Integrated circuits can be broadly divided in two categories.

- Analogue
- Bigital

Analogue IC's operate on continuous signal and linear range. They are used mainly in operational amplifiers, oscillators, regulators, etc. They find application in carrier current protection, and various static relay functional circuits. Digital IC's are principally used as switching units which perform on/off functions. These IC's do not require precise components like analogue IC's. Hence Digital IC's are easier and cheaper to manufacture and are preferred in wide range of applications such as binary logic circuits, switching gates etc.

The digital systems are based on pulse and pulse chain inputs. They are used inlogic circuits. Logic circuits are being increasingly used in protective relaying.

Monolithic techniques are used to make ICs(Integrated Circuits). A monolithic circuits is contained within a single crystal. The advantages of integrated circuits compared with discrete circuits(circuits where various seperate components are connected to form the circuit) includes:

(a) Higher total reliability as number of soldered points is reduced.

(b) Smaller dimensions

(c) Generally lower price

(d) High stability due to uniform temperature in the monolithic circuit.

(e) Design is simplified.

4.10. Logic Circuits

The concept of static relaying can be better understood by considering the "logic" operations performed by the divices rather than the actual happenings that occar during their operation. This makes complex static relay operation also simple, because the interest then is only on "what" happens rather than "how" its happens, and the "logic" part of the operation is independent of divices used to realize the events dictated by the logic.

Basically, all relays are "bistable dévices",ie. they have two stable states ; either they operate or they do not operate. Consequently Boolean algebra can be applied to study and analized protection schemes consisting of a number of relays. Using these techniques simplified block schemes can be drawn according to the logical functions performed by the various units.

In a d.c. or level-logic, system a bit is implemented as one of two voltage levels. The more positive voltage is the 1 level and the other is the 0 level, the system is said to employ d.c. negative logic system is one which degignates the more negative voltage state of the bit as the 1 level and the more positive as the 0 level positive logic is usually followed.

CHAPTER - 5

CIRCUITS COMMONLY USED TO STATIC RELAYS AND THEIR PRINCIPLE OF OPERATION.

5.1. Auxiliary Voltage Supply for Static Relays.

The static relays require auxiliary d.c. supply ; which is generally obtained from station battery system. The station battery system is also used for other purposes such as tripping, control, etc. Most static relays require various auxiliary d.c. voltage between 24v to 240v d.c. The voltage stabilizers are used in the circuits of relays. The disadvantages of using station battery system for auxiliary d.c. voltage supply to static relays are the followings:

- Voltage transients are introduced by opening of inductive circuits connected to the same battery supply (trip circuit for example). These voltage surges can damage the static relays. Hence special precantions are taken to design the static relays to absorb such transients.
- The battery voltage is generally high, e.g. 250v, this causes higher power losses in volt-ratio boxes used in static relays to get the reduced voltage.

To avoid these difficulties, the d.c. to d.c. converter is used. The station battery voltage is converted to a.c., then transformed and then rectified.

The d.c./a.c. converters are self contained units. The voltages are converted generally from 220v d.c. to about 50v d.c. The converters are of enough ratings to supply the requirements of several relays.

In some cases, nickel-cadmium battery supplies are used for supplying static relays. These batteries are tricle charged from rectified a.c. source obtained from main potential transformers.

In some static relays normal a.c. voltage is stepped down in the built-in auxiliary transformers in the relays, then rectified, established and smoothed.

We have used these for the auxiliary voltage supply for the static relays.

5.2. Rectification

An electric device which has a high resistance to current in one direction and a low resistance to current in opposite direction posseses the ability to convert an alternating current into a current which contains a d.c. component in addition to a.c. component. Such a device is called rectifier and the process done by the device is called rectification. For a sinusoidal input wave form (where average value is zero) this devices is capable of converting it into the unidirectional wave form with a non-zero average component.

For the process of rectification, the rectifying devices available are (a) semiconductor diodes (b) Vacuum diodes, and (c) Gas filled diodes, the important rectifiers for power purposes fall into these general greups depending on their inherant characteristics. The vacuum diode to use as a rectifier, posseses an infinite resistance on the inverse cycle, as the tube will not conduct when the plate is negative with respect to the cathode. On the forward or conducting portion of the cycle the vacuum diode is characterised by an almost constant and low value of resistance. The gas or vapour rectifiers also posseses an infinite resistance in the inverse cycle but they are charactersed by substantially constant tube drop during conduction. Owing to the differences, the resulting operation in a circuit in slightly different.

In our thesis work semoconductor junction diodes are used for rectification. The volt-ampere characteristics of an ideal semi-conductor diode (P-N junction diode) is shown is Fig. 4.2. The curve shows that at negative voltage i.e. when the voltage is applied in the reverse direction the diode is reversed biased and the reverse current I soon reaches its saturation value I_s. Also when the diode is forward biased, there is rapid increase in forward current.

According to rectified wave shape, two types of rectifier circuit arrangements are possible, they are

(1) Circuit for half-wave rectification

(2) Circuit for full-wave rectification.

The simplest single phase rectifier circuit is a half-wave circuit. A variety of other rectifier circuits exists which find wide-spread use. Among these are bridge rectifier circuits. The bridge circuit finds extensive use both as a power rectifier and as the rectifying system in rectifier type a.c. meter.

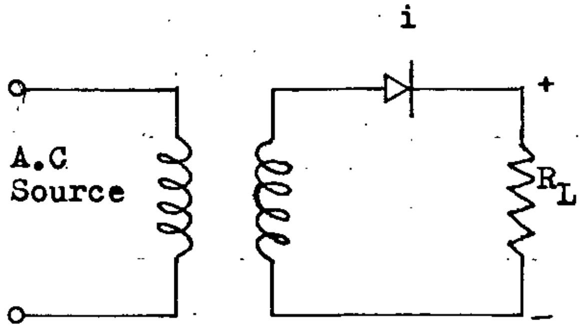


Fig. 5.1. Half-wave rectifier circuit.

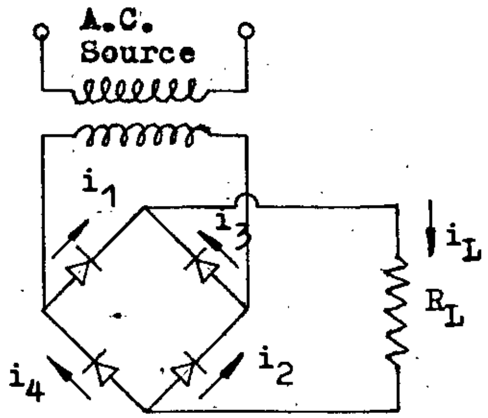


Fig. 5.2. Full-wave rectifier circuit.

For practical purpose, specially in our thesis work, the full wave bridge circuit as shown in Fig. 5.2 is used. The half wave rectifier circuit (Fig.5.1) is not used for it has certain drawbacks: (1) execessive ripple in the output voltage produced by the a.c. component (2) inddequate utilisation of transformer which is used to obtain a.c. voltage of the magnitude corresponds to the required rectified voltage level. The diodes are connected in such a way that during one half of the cycle, current passes through one pair of diodes and during the other half cycle, it passes through the other pair of diodes in the direction as shown in Fig.5.2. The load current i_L flows in the same direction.

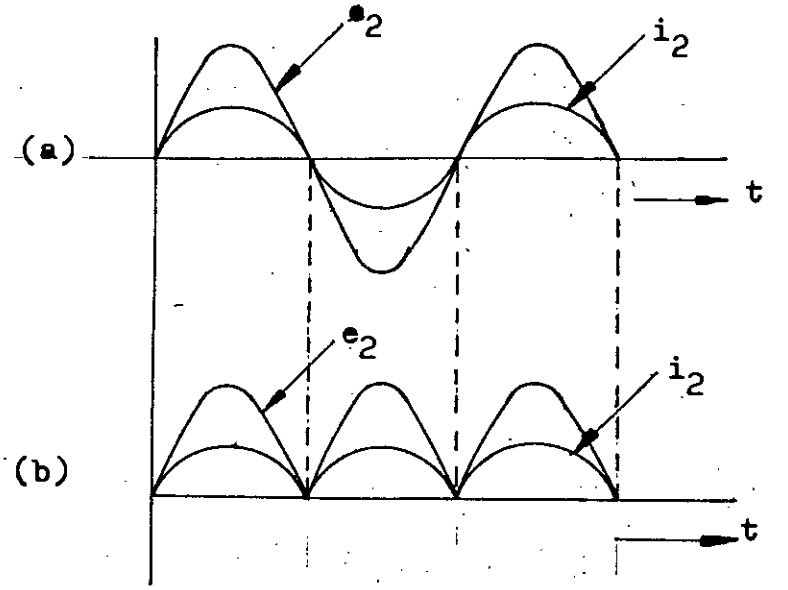


Fig. 5.3.(a) Voltage and current in secoundary winding

(b) Voltage and current in load.

Let the transformer voltage, $e_2 = 2E_2 \text{Sin} wt$

therefore, average rectified voltage,

$$E_L = \frac{1}{T}\int_0^T E_2 \text{Sin } wt \; d(wt)$$

$$\text{i.e. } E_{L_{r.m.s.}} = \frac{E_2}{\pi}\int_0^{\pi} \text{Sin}(wt) \; d(wt) = \frac{2E_2}{\pi}$$

$$\text{or, } E_{L_{max}} = \frac{2\sqrt{2}}{\pi} E_2 = 0.9E_2$$

Average rectified current, $I_L = \dfrac{E_L}{R_L}$ and the average current through the diode for symmetrical circuit is $I = \dfrac{I_L}{2}$.

In the bridge circuit the inverse voltage is determined by phase voltage. Since, the diode in a given half-cycle is connected directly to the secondary winding of the transformer via the other working diodes, its voltage drop can be neglected.

Therefore, Eomax

$$E_{o\ max} = \sqrt{2}\ E_2$$

5.3. Smoothing circuits

The rectification circuits described earlier prove an unidirectional output that may be regarded as a direct component on which is superimposed some alternating higher harmonic component called ripples. The ripples are commonly determined by the greatest defference between the intantaneous voltage values and average value of the output voltage or by the ratio of the most pronounced harmonic component to the average value of the voltage or current. These are undesirable and in many cases detract from the performance of a circuit.

Various circuits are used to smooth the unidirectional output. Rigorous analysis of the action of such a smoothing circuits is Tedius, but an approximate analysis is possible by assuming (a) the supply circuit flows for a small fraction of the cycle, (b) the time of discharge is very much less than the time constant R_LC of the load resitor and the smoothing capacitor.

The explicit expression of current in a half-wave rectifier circuit is given by the Fourier's series:

$$i_L = I_m\left[\frac{1}{\pi} + \frac{1}{2}\sin wt - \frac{2}{\pi}\sum_{K=2,4,6,\ldots} \frac{\cos kwt}{(k+1)(k-1)}\right] \qquad (1)$$

The corresponding Fourier series representation of the output of the full-wave rectifier may be derived from eqn. (1). By recalling that the full-wave circuit comprises two half-wave circuits which are so arranged that one circuit is operating during the interval when the other is not operating. Therefore, the currents are functionally related by

$$i_1(\alpha) = i_2(\alpha + \pi)$$

Therefore, total load current is

$$i_L = Im\left[\frac{2}{\pi} - \frac{4}{\pi}\sum_{k=2,4,6,\ldots}\frac{\cos kwt}{(k+1)(k-1)}\right] \quad \ldots\ldots\ldots\ldots (2)$$

where, $Im = \frac{Em}{r_p + R_L}$, Em = Max. value of transformer potential measured.

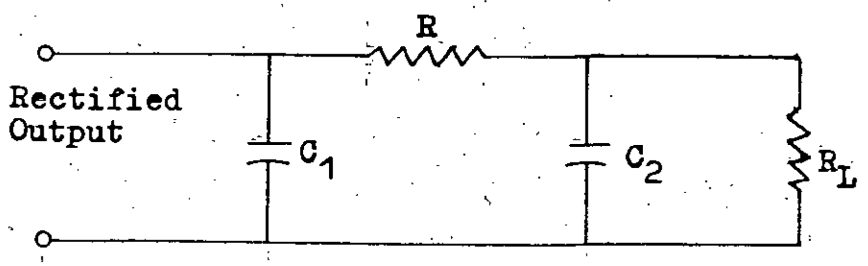


Fig. 5.4. R-C Filter circuit.

A comparison of equation (1) and (2) indicates that the fundamental anguler frequency term has been eleminated in the full-wave circuit, the lowest hermonic term in the output being 2w, a second hermonic term. In order to by pass these hermonic components we used a π- section R-C filter as shown in Fig. 5.4.

The capacitor voltage Vc_1 and the rectified output voltage is shown in Fig. 5.5. Discharge of the capacitor begins when voltage Vc_1 and the rectified output voltage becomes equal. During the discharge period, capacitor current flows through the load resistence R_L. By putting an ammeter in series arm of the π- section filter circuit it has been observed that the current flowing through this new ammeter is the same as load current which is a part of

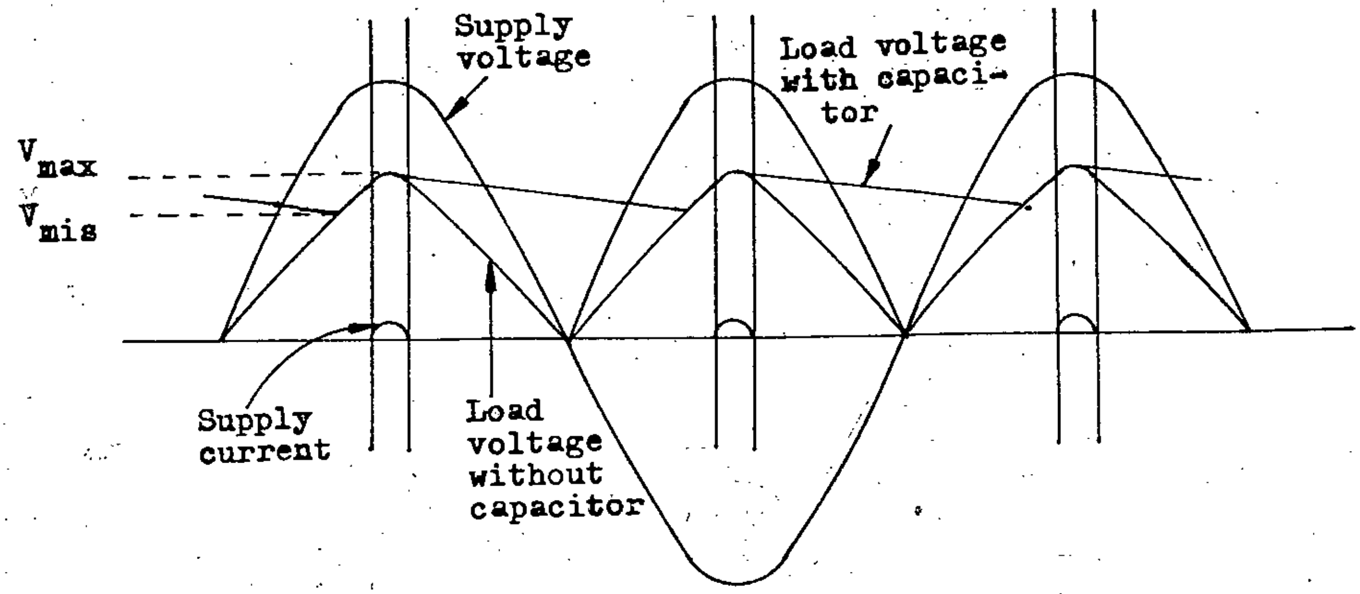


Fig.5.5. Wave forms for full-wave rectification with simple capacitor smoothing.

the observation in design and actually it should be. The function of C_2 is to by pass the a.c. components and for d.c. it is open circuited, so that the same current flows through the load.

The operation of the inductor filter depends in the fundamental property of an inductor to oppose any change of current. As a result, any sudden change that might occur in a circuit without an inductor are smoothed out by the presence of an inductor in the circuit. The inductor offers a high series impedence for the hermonic terms and the capacitor offers a low shunt impedance to them. The resulting current through the load is smoothed out much more efficiently than with either L or C alone in the circuit. The circuit used is an in Fig. 5.6. for the rectificati- and smoothing.

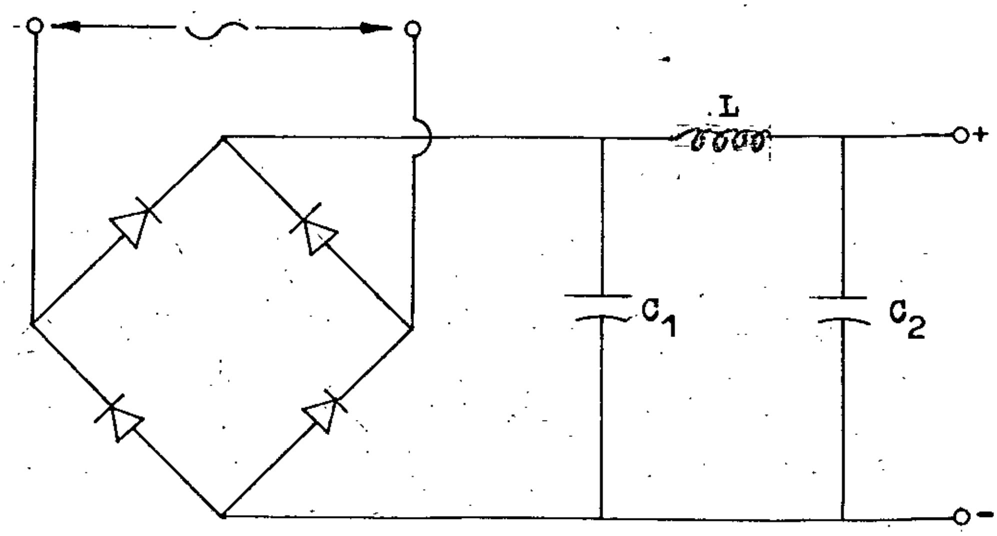


Fig. 5.6. Smoothing circuit for d.c. supply.

5.4. Voltage Stabilization by Zener Diode.

Zener diode is used for voltage stabilization Fig. 5.7. illustrates the method of stabilizing the output voltage of a rectifier bridge by mean of Zener diode, Zener diode is connected for reverse current flow. An improved stabilization is obtained by cascade connection of zener diode, Fig. 5.8.

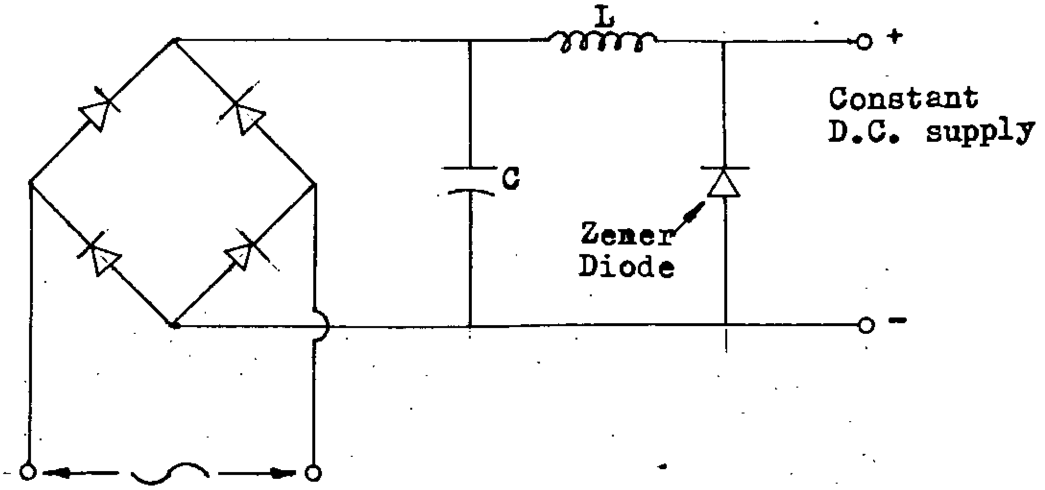


Fig. 5.7. voltage stabilization by zener diode.

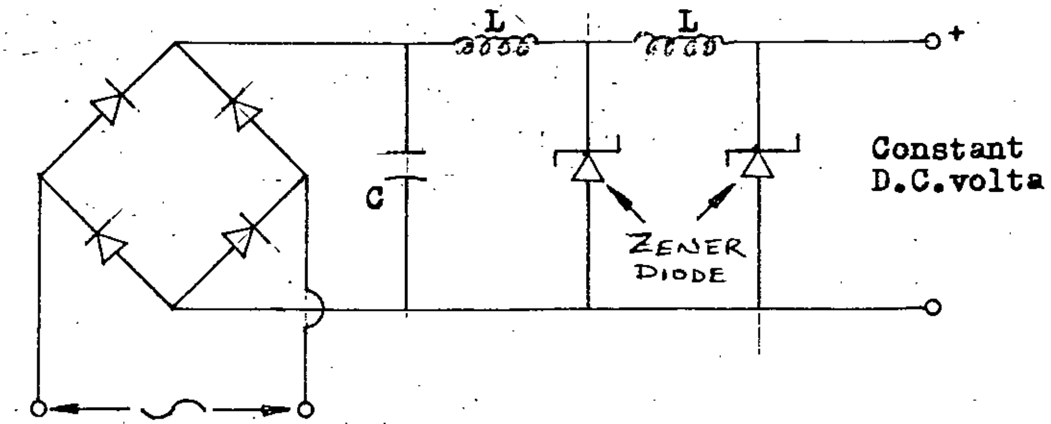


Fig. 5.8. Use of zener diodes in cascade.

The voltage across the zener diode remains constant over a wide range of current. The bias of the circuits in the static relay should be held constant. Zener diode is used for this purpose.

5.5. Time Delay Circuits

A variety of time delay circuits are available such as delay lines, resonant circuits, RC circuits, timer circuts employing transistors, thermistors, etc.

For very short delays (μS) a delay line is generally used (Fig. 5.9). For medium delays (mS) a resonant circuit is common (Fig.5.10). For longer delays (seconds) R-C circuits can be used (Fig. 5.11). Because of the small magnitudes of the currents in transistors circuits, a delay of minutes can be obtained with a few microforads. With tantalum capacitors of a few hundred microforads, delays of several hours are practical. Such R-C circuits are used in time-current relays and industrial timers.

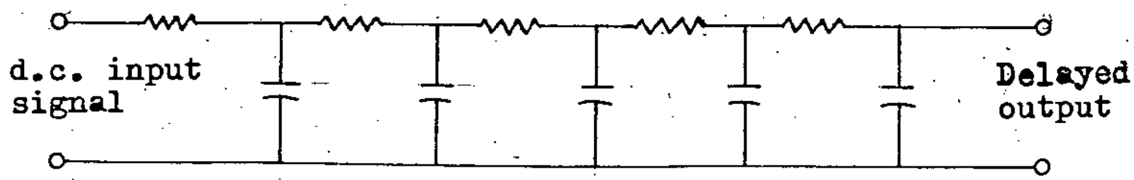


Fig. 5.9. Equivalent circuit of a delay line.

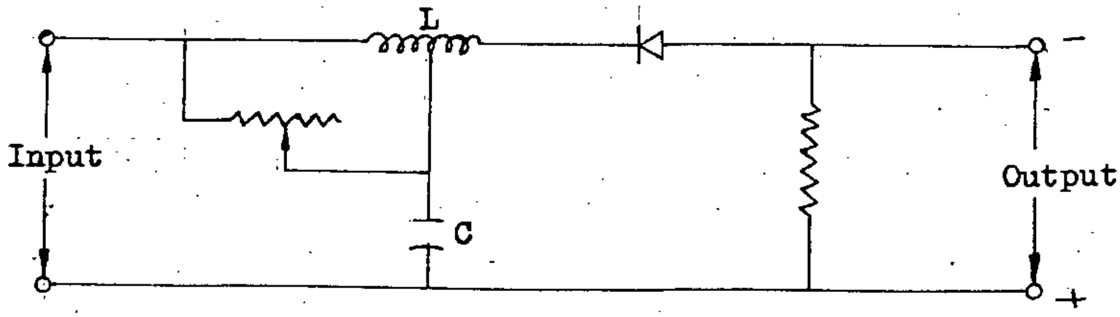


Fig. 5.10. Basic millisecond time-delay circuit.

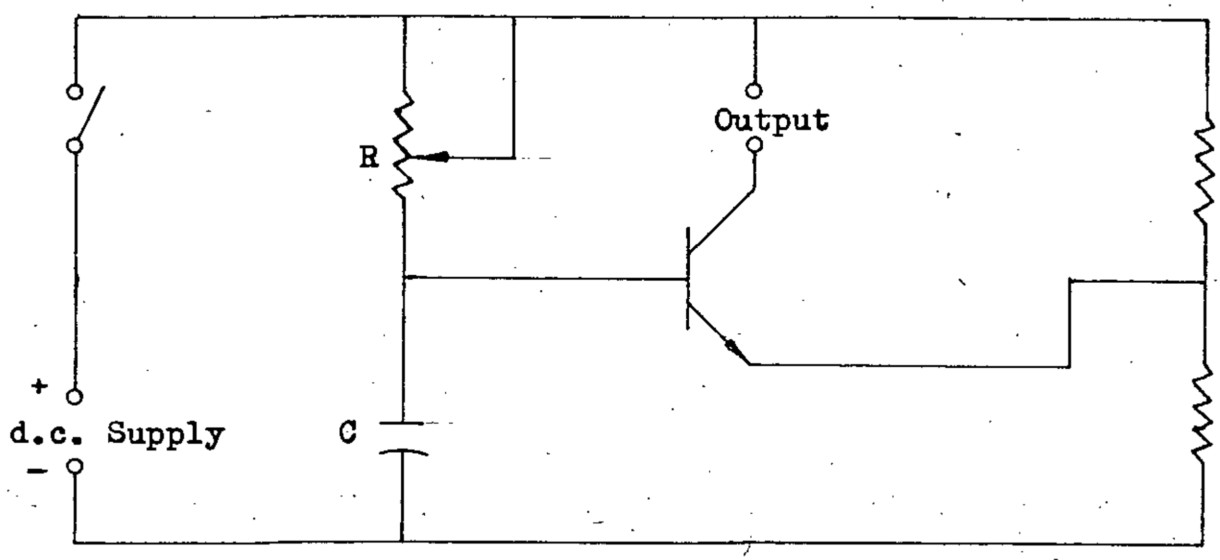


Fig. 5.11. Basic long-line delay circuit.

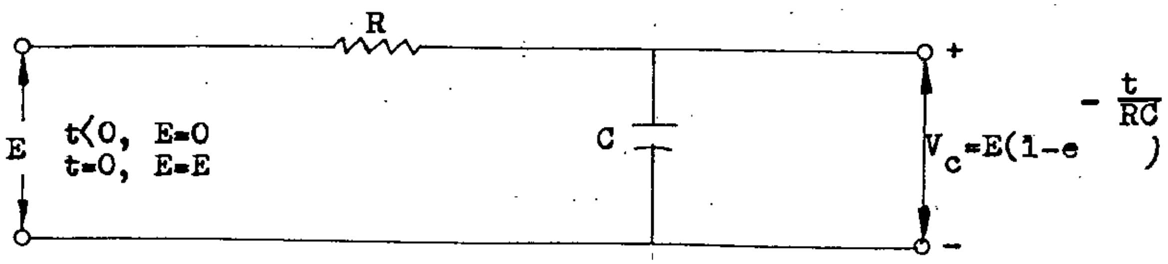
Considering a simple time delay circuit as in Fig.5.12. When d.c. e.m.f. (E) is applied to a capacitor, the voltage across the capacitor (Vc) does not increase instentaneously. Initially it is zero. The voltage increases exponentially, given by

$$Vc = E \left(1 - e^{-\frac{t}{Rc}}\right)$$

where, E = d.c. e.m.f.

Vc= Voltage across capacitor.

Rc= τ = time constant of RC circuit.



At $t = 0$, when e.m.f. is applied,

$$Vc = E(1 - e^{-0}) = 0$$

At $t = \Upsilon$ = time constant

$$Vc = E(1 - e^{-1}) = 0.632E$$

The charging time from $t = o$, at $Vc = o$ to $t = Tc$ at $Vc = Vt$ is given by,

$$Tc = RC \log_e \left[\frac{E}{E - Vt} \right]$$

Hence time delay given by the time delay circuit is given by the above expression. By varying the values of R,C the charging time of the capacitor can be varied without difficulties (Fig.5.13). The basic R,C circuit can also arranged in several series parallel combinations to charge equivalent value of R and Υ.

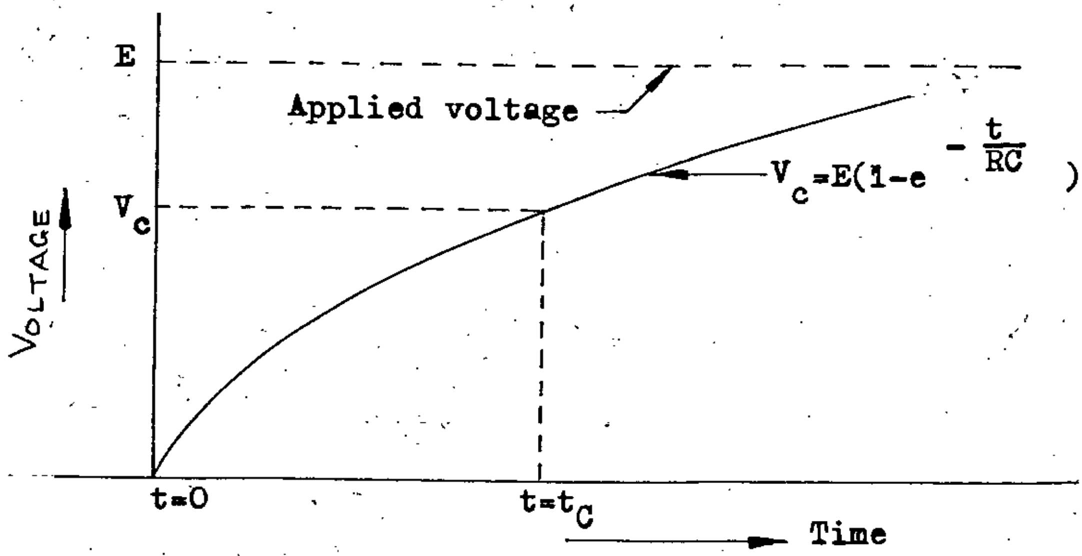


Fig. 5.13 Characteristics of time circuit.

5.5.1. Instantaneous Characteristics.

By omitting the time delay circuit or the capacitor, the relay can be made instantaneous for there is no moving parts in the static relay, By adjustment of the time-delay circuit, the operating time of the order of 1 cycle or 0.02 seconds can be achieved in static relays.

5.6. Level Detector.

A level detector is a functional circuit in a protective relay which dtermines the level of its inputs with reference to apredetermined setting or output. When the input I exceeds the level L, the output O of the level detector exceeds and the output stage of the relay gets a triggering signal via an amplifier as shown in Fig. 5.14.

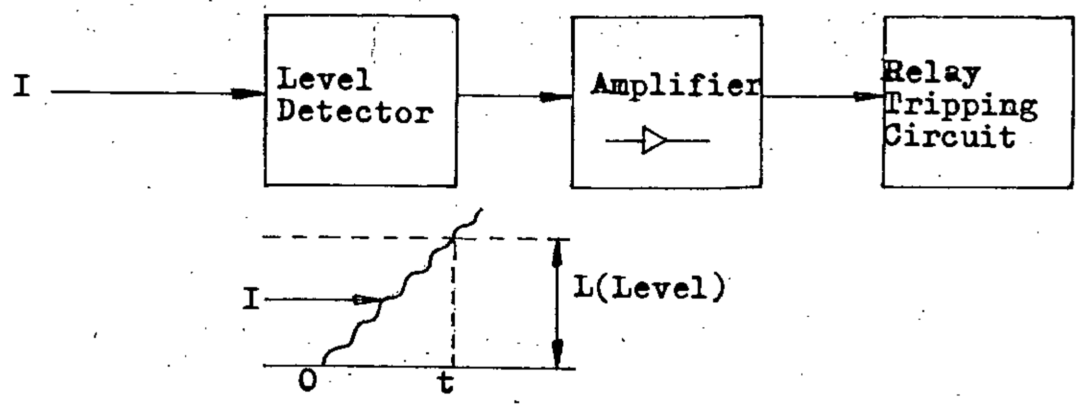


Fig.5.14.Explain level detector (when input I exceeds level L, the output O increases).

When input I is below a certain level, the output is negligibly small.

The input level through the level detector goes to the output-level as in the Fig. 5.14. If the input current is considered as the input voltage in the level detector and it is changes to the output voltage previously determined if it passes through the level detector. So the level detector may be considered an amplifier.

5.7. Amplifier

The pulse in the input of the amplifier to trip the relay circuit is a direct current pulse, because rectifier is connected before the level detector. The very low cutoff frequency or zero frequency required for such an amplifier may eliminate capacitive or transformer coupling from practical consideration and leave only direct coupling as a feasible solution. There are four types of direct coupled amplifiers as (1) Darlington connections, (2) npn -pnp arrangements, (3) differential amplifiers, and (4) the cascode configuration

5.7.1 Darlington Connection.

One method of direct coupling bipolar transistors, known as Darlington connection as in Fig. 5.15. In this arrangement the emitter current of T_1 is the base current of

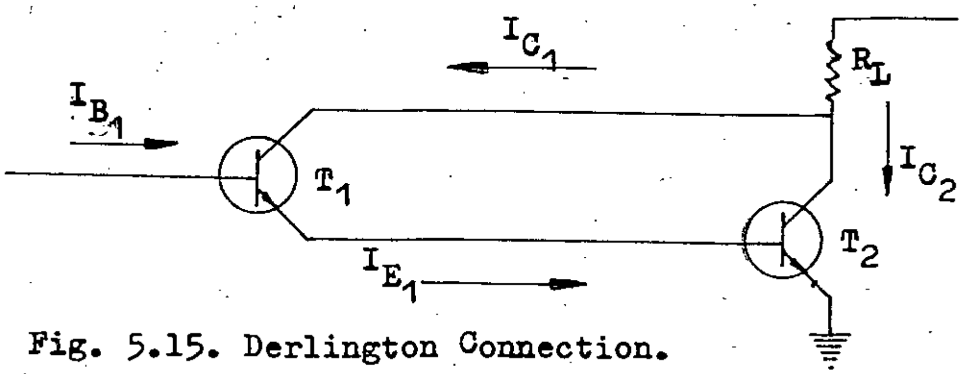


Fig. 5.15. Derlington Connection.

T_2. If R_L is small, $i_{E_1} = (\beta_1 + 1)\, i_{B_1}$ and $i_{C_2} = \beta_2 i_{B_2}$. Then the ratio $i_{c_2} / i_{B_1} = (\beta_1 + 1)\beta_2$. The current i_{C_1}, adds to i_{C_2} in the load resistence, but if β_2 is large, i_{C_1} is negligible and the total amplification factor is approximately the product $\beta_1\beta_2$. Three transistors are sometimes used in the Darlington connection to produce a current gain approximately equal to $\beta_1\beta_2\beta_3$.

5.7.2. npn - pnp Combinations.

A d.c. amplifier can be constructed by alternating npn and pnp types as shown in Fig. 5.16. This amplifier is diode stabilized and the input voltage is assume to provide forward bias for the transistors. It is abserved that the collector current of transistor T_1 is the base current of transisot T_2. Therefore input impedance of transistor T_1 is much lower and the voltage gain much higher for this amplifier as compared with the Darlington amplifier.

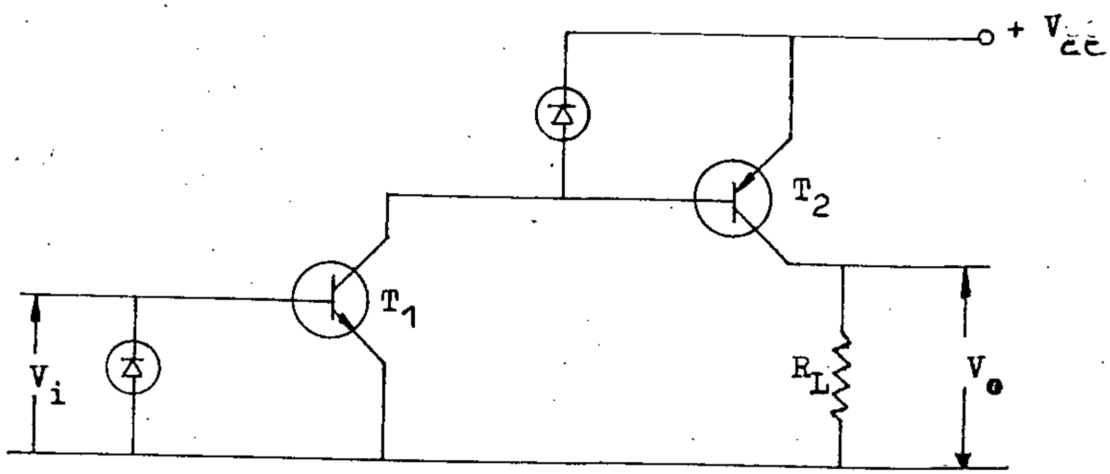


Fig. 5.16. An npn -pnp d.c. amplifier.

5.7.3. Differential Amplifiers

The function of the differential amplifier is to amplify the difference between two signals. In ideal differential amplifier the output signal Vo is given by

$$Vo = A_D (V_1 - V_2) = A_D V_d$$

where, A_D is the gain of the defferential amplifier. In general the output depends not only upon the defference signal V_d of the two signals, but also upon the average level, called common mode signal, Vc, where,

$$Vd = V_1 - V_2 \quad \text{and } Vc = \frac{1}{2} (V_1 + V_2)$$

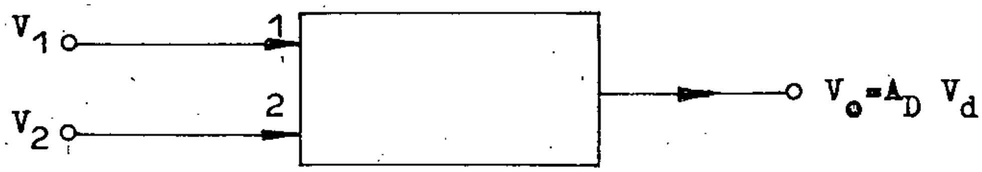


Fig.5.17. Differential Amplifier shown as block diagram.

The output of the Fig. 5.17. can be expressed as a linear combination of the two input voltages.

$$Vo = A_1 V_1 + A_2 V_2$$

$$\text{where, } V_1 = Vc + \frac{1}{2} Vd$$

$$V_2 = Vc - \frac{1}{2} Vd$$

$$\therefore \quad Vo = \frac{1}{2} (A_1 - A_2) Vd + (A_1 + A_2) Vc$$

$$= Ad\ Vd + Ac\ Vc$$

The voltage gain for the differential signal is Ad and that for the common mode signal is Ac. A quantity called the common mode rijection ratio which serves as a figure of marit for a differential amplifier is ρ = Ad/Ac

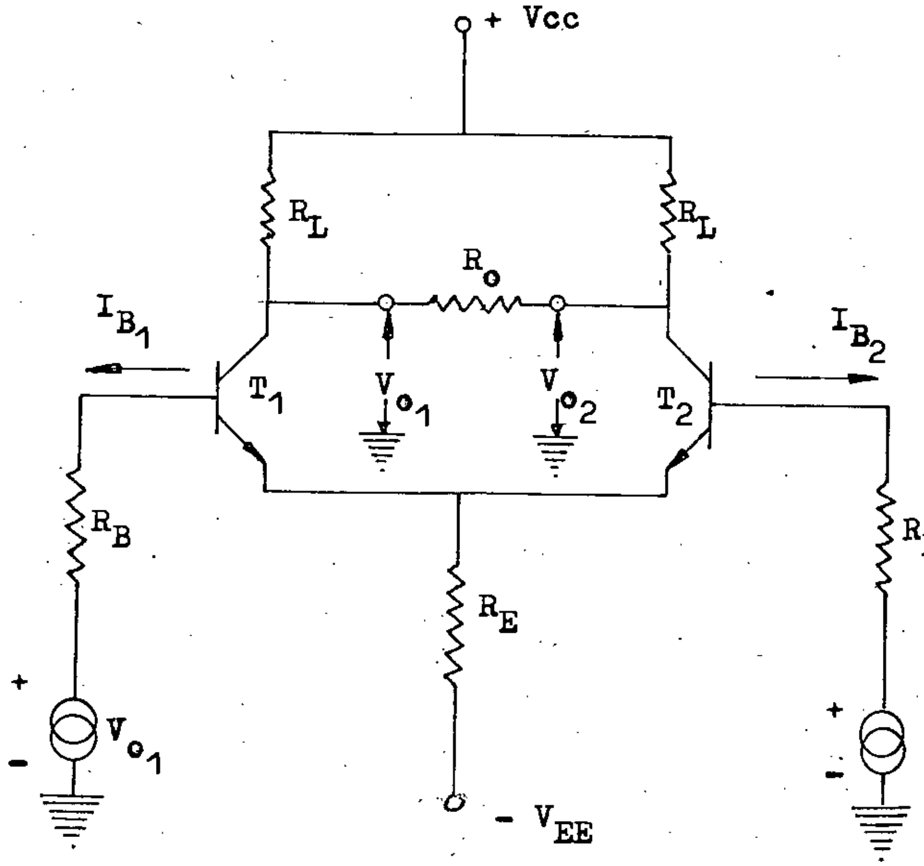


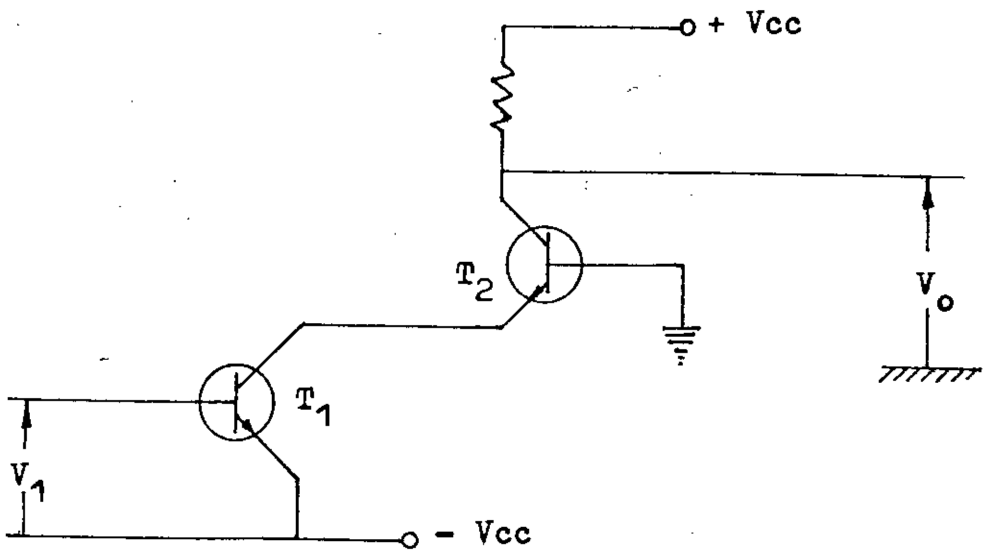
Fig. 5.18. Differential Amplifier.

If the input voltage $V_{i1} = V_{i2}$ and opposite in phase, the collector current of T_1 might increase in which case an identical increase will occur in the current of T_2 . The result will be a differcnce voltage $Vo_1 - Vo_2$. If the input signals are amplified and in phase, output voltage will be equal.

Common mode signal being caused by hum pick up or other interference causes the transistor circuits to raise the voltage drop across R_E raises . This represents negative feedback and reduces the gain for the common mode signal. Differential mode signals are not affected by the emitter resistance since the current through the transistor raises while that the other transistor falls by an equal amount ; the current in R_E remains constant for differential signals. It is usually desired that the difference mode signal be amplified and the common mode signal is suppressed, so a high value of R_E is desirable.

5.7.4. The Cascode Amplifier

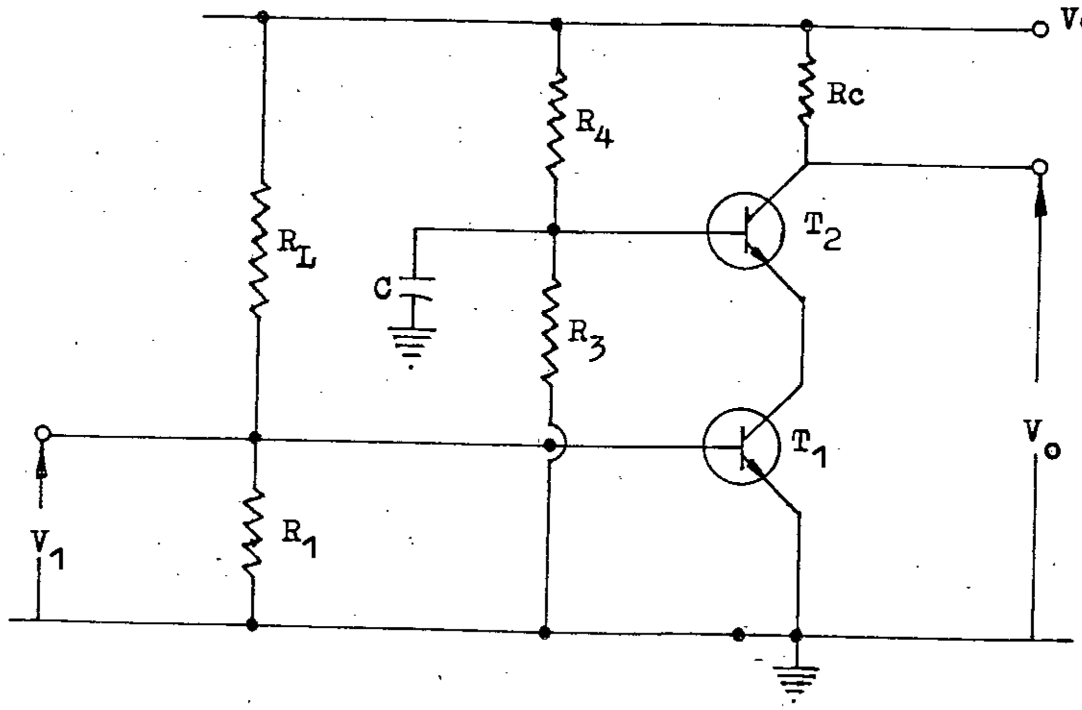
An amplifier configuration somewhat related to the unbalanced differential amplifier. This confignration is known as " cascode " amplifier. Usually, operation from a single power supply is desirable so the confignration shown in Fig. 5.19(b) is used. In this form Fig. 5.19(b), the resitors R_3 and R_4 maintain the base of transistcr T_2 at a d.c. potential above OV. The capacitor C is normally connected from the base of transistor T_2 to ground to remove any signals which may be capacitively coupled into this base circuit.



(a)

Fig. 5.19. A cascode amplifier , (a) two power supply confignratio-

(b) One power supply confignration.



(b)

Electrically, the cascode amplifier is essentially an unbalanced differential amplifier with the common-collector stage replaced by a common-emitter stage. Of course the load on the common-emitter stage is very low(the input impedance of the emitter of T_2) so the voltage gain of this stage is very low.

We have considered the differential amplifier of the unbalanced type. Because it is for the relay or comperator to function for a signal higher than a particular value. That is it is to differentiate the values. Again it is of good thermal stability. The circuit is used as in Fig. 5.20. where the V_2 is removed and the base of T_2 is grounded for the one directional flow of current. That is $V_2 = 0$ and $V_1 - V_2 = V_1$

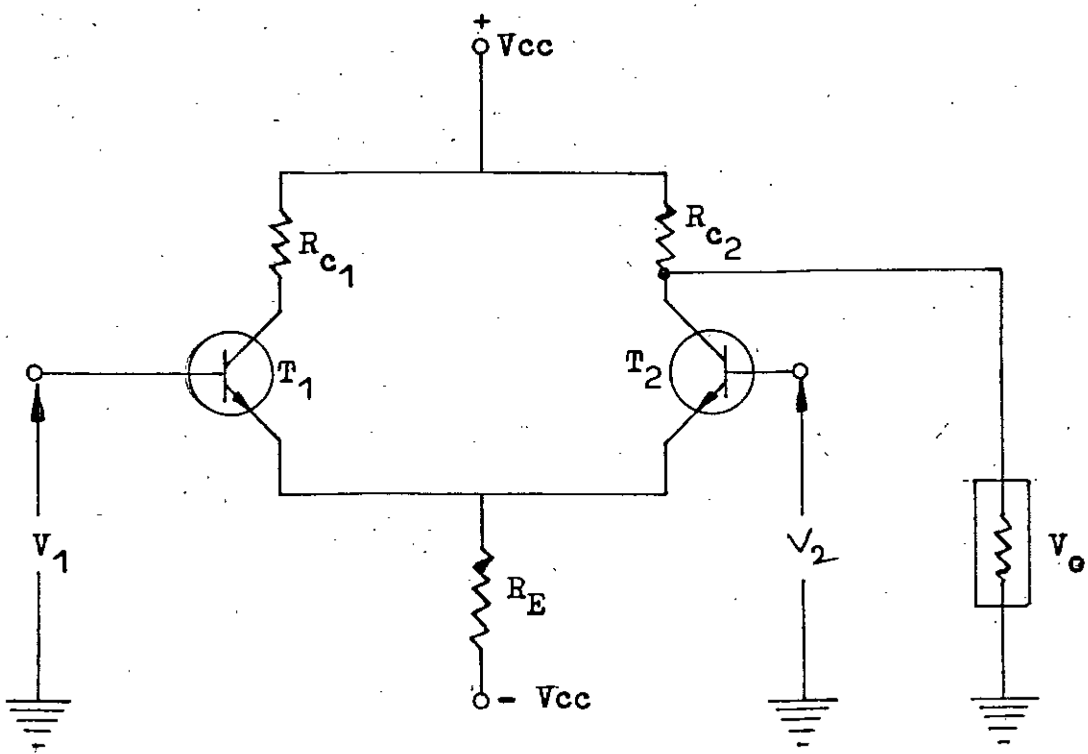


Fig. 5.20. Differential Unbalanced amplifier.

This amplifier (Fig. 5.20) in used both for the power amplifier to operate the relay and for the level detector in our static relay.

5.8. Basic Principle of Static Overcurrent Relays.

The functional blocks in a single actuating quantity over current relay which we considerd in our work is shown in Fig. 5.21.

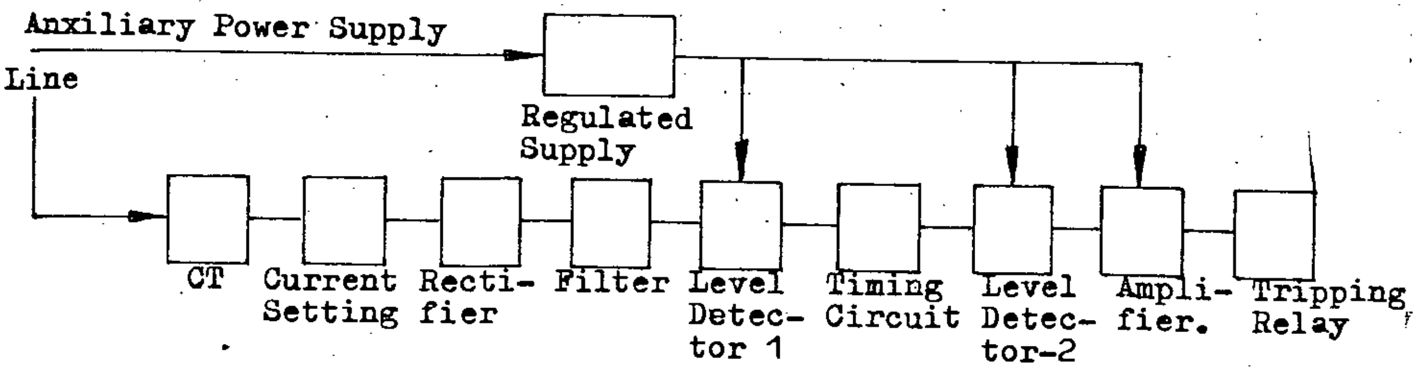


Fig. 5.21. Block diagram of static-Time-long Overcurrent Relay.

The current ratio of CT is selected by unsidering the probable primary current in CT by the line to be protected. It is different for different location of protection scheme.

The current setting is to achieve suitable limitation for the static relay. Because semiconductor material can not withstand for higher current ratings. It is suitable for maximum 1 ampere. This is done by tapping the secoundary of CT to a low resistance resistor with high current ratings.

The current rectified in fullwave rectifier and is smoothened in smoothing circuit comprising resistors or inductors and capcitors. The smoothing circuit eleminates the ripple in the output wave-form of the rectifier. The output of rectifier is propertional to the r.m.s. value of input a.c. waveform.

The output of rectifier is supplied to level detector.

In time-overcurrent relay, the rectifier output is supplied to level detector - 1 and a timing circuit is added in between the level detector-1 and level detector -2.

The output of level detector is amplified in amplifier. The output of amplifier is given to output stage of static relay. The amplifier amplifies the signals from the level detector.

The output of static overcurrent relay is considered attracted armeture type electromagnet.

The auxiliary d.c. supply is necessary for level detectors, amplifiers. It is from an auxiliary a.c. supply and then regulated it to the voltage desired by the level detectors and the amplifier.

CHAPTER - 6

DESIGN AND CONSTRUCTIONAL FEATURES OF THE DIFFERENT BLOCKS OR MODELS USED IN THE STATIC TIME-LAG OVERCURRENT RELAY.

6.1. Current Transformer (CT).

The CT is selected of the specification as

05/3KV, 5VA, 50 HZ.

Primary: 15, 50, 100, 150, 200, 300, 400, 600, 800 A.

Secondary : 5 A. with different types of connections shown in the connection diagrams in Fig. 6.1.

6.2. Current Setting

The secondary of the CT should be alway closed. For the semiconductor materials in the electronic relay small amounts of current (maximum 1 ampere) is required. For the defferent setting of current from the secondary of CT, a voltage connection is taken across a resistor. The resistor that have its ratings: 1.0 ohm. 15A.

4 connections are considered: full, $\frac{3}{4}$ of full, $\frac{1}{2}$ the total and $\frac{1}{4}$ of the full.

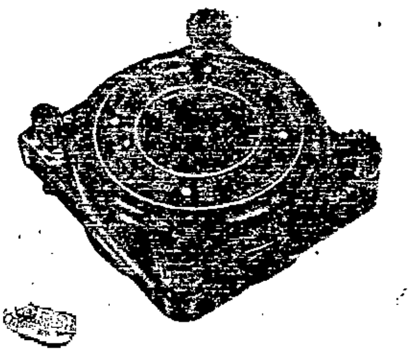
CT secondary current is 5A amp.

voltage in full across the resistor = 5 X 1.0

= 5.0 V.

Connection diagram of CT.

Current Ratio	Primary Connection	Secondary Connection	Fig.
15/5	$K-L_1$	k-l	a
50/5	$K-L_2$	k-l	b
100/5	6 turns inside	k-l	c
150/5	4 "	k-l	d
200/5	3 "	k-l	e
300/5	2 "	k-l	f
400/5	2 "	$k-L_1$ (l-K shorted)	g
600/5	1 "	k-l	h
800/5	1 "	$k-L_1$ (l-K shorted)	i



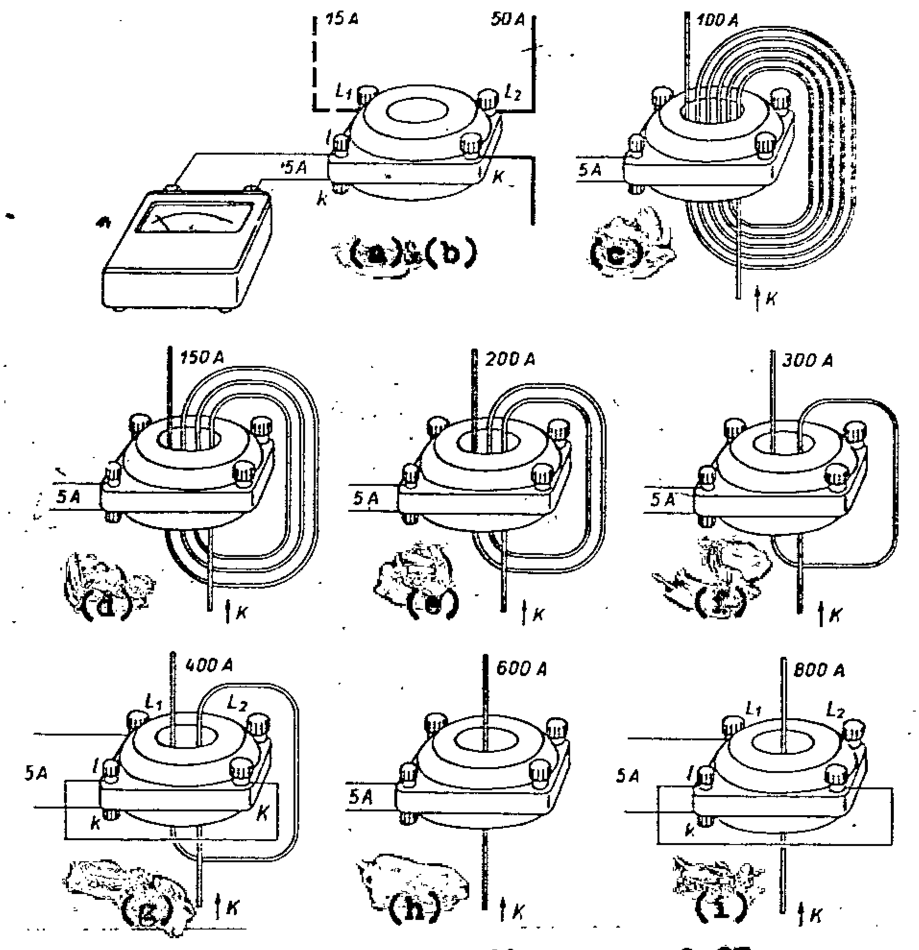


Fig. 6.1. Connection diagrams of CT.

6.3. Rectifier.

Rectified d.c. value is approximately equal to a.c. (r.m.s) value.

$\therefore$ Maximum output d.c. voltage = 5.0 V

So diodes of the Fig. 5.2 for rectification is selected in much higher, specification so that it can withstand in all operating conditions.

6.4. Smoothing Circuit.

As in Fig. 5.6., considering the values as $C_1 = C_2 = 10 \mu f$ of voltage 160 V.

L = 0.65 h one available in the market. Which can withstnad the specified values.

If the load resistance R_2 = 10 kohm

$$\therefore \text{ripple factor}, ^{(10)} r_{\pi} = 0.176 \frac{Xc_1 \; Xc_2}{X_L R_L}$$

$$= 0.176 \frac{\frac{1}{(314 \times 10 \times 10^{-6})^2}}{314 \times 0.65 \times 10 \times 10^3}$$

$$= 0.0086$$

Which may be taken as in consideration.

6.5. Voltage Stabilization Circuit:

The circuit is shown in Fig. 5.7. The value of condenser C is selected as 10 μf as in the filter circuit. Here four 10μf condensers are connected in series - paralleled to make the equivalent as 10μf and each shunted by 120kΩ resistor to equatize voltage applied to the individual condenser.

The Zener diodes are of the ratings 30V and 5V makes 35V in one stabilizing supply and two 12V and one 20V makes 44V in another stabilizing supply is considered. For the regulation of 35V voltage in the regulated supply one zener is not available. So they are connected in series in there reversed bias to operate in there breakdown voltage and to stabilize at that voltage.

The circuit diagram of this stabilizer is in Fig.6.2.

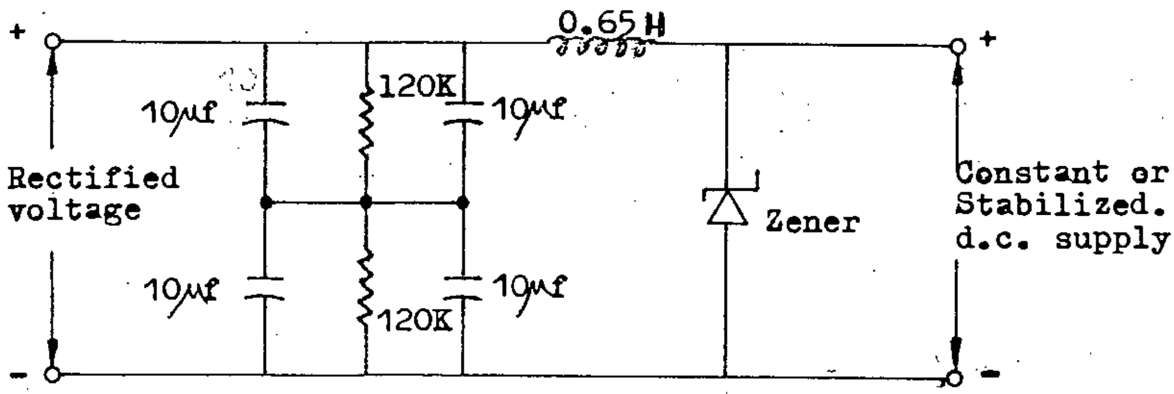


Fig. 6.2. Voltage Stabilizing Circuit.

The positive terminal of the bias supplied by the stabilizing circuit is considered 44V for some voltage is absorved by the condenser in the timer to make the resultant bias as 35V

6.7. Timing Circuit.

The time delay circuit is considered as the circuit in Fig. 5.12.

Where,

Vc = input voltage of the level detector -2, which is fixed value. For we are designing for the tripping value, V_t .

E = Amplified output voltage of the level detector -1 Which is also considered fixed for a particular value. It could be changed. But if it changed the time voltage characteristic curve will change

For designing we have considered E as high as possible and Vc as minimum to have easy handing of the timeing ckt.

For the designed relay,

E = 5V, 7V, 7.6V. are for different current settings

Vc= 0.8 volts.

C = 1760 μf fixed and

R varied to get different time-lag.

6.8. Amplifier and Level Detector.

The level detector is the same as an amplifier. For the level detector -2, the output current or voltage is the input current or voltage of the amplifier. That is level detector -2 may be said for the use of amplifying very weak signal for the tripping of the trip circuit. If the output current and voltage in the timer is a value sufficient to trip the trip circuit after amplifying by the amplifier, there is no needs of the level detector -2. In the level detector -1, the output is the selected value E, the input of the timing circuit.

6.8.1. Amplifier Designing.

6.8.1.1. Choice of Transistor:

Our amplifier is to amplify the signal to trip the tripping circuit of the relay. So it is obvious that the output of the amplifier is the input of the tripping relay and the transistor withstand for the values of tripping circuit.

The tripping circuit has the specification of -

Tripping current = 2.0 mA

Tripping voltage = 15V

This is done by an electromagnet and it is magnetised by the amper - turn passes through the coil of it. So the tripping may occur with less voltage in the terminal but should have the fixed tripping current in the terminal.

The input signal may be higher then the tripping value and the relay must have to withstand in those values also. So it is better to have the safe side to select the transistor of higher ratings.

Specifications of the selected transistor:

Transistor No. : 2N3055

Type : Si - NPN.

V_{cBmax} = 100V

V_{cEmax} = 60V

V_{EBmax} = 7V

I_{cmax} = 15V

T_{jmax} = 200°C

P_{TOT} = 115W

H_{FE} = 20/70, H_{FEbias} = 4A.

where,

Max.collector to base voltage = V_{CBmax}

" collector to emitter voltage = V_{CEmax}

" emitter to base voltage = V_{EBmax}

" collector current = I_{Cmax}

" junction temperature = T_{Jmax}

Total withstanding power = P_{TOT}

d.c. forward current transfer ratio, $\frac{I_C}{I_B} = H_{FE}$

= d.c. current gain.

6.8.1.2. Choice of Circuit:

The circuit selected is the differential amplifier of the unbalanced type. As in Fig. 6.3.

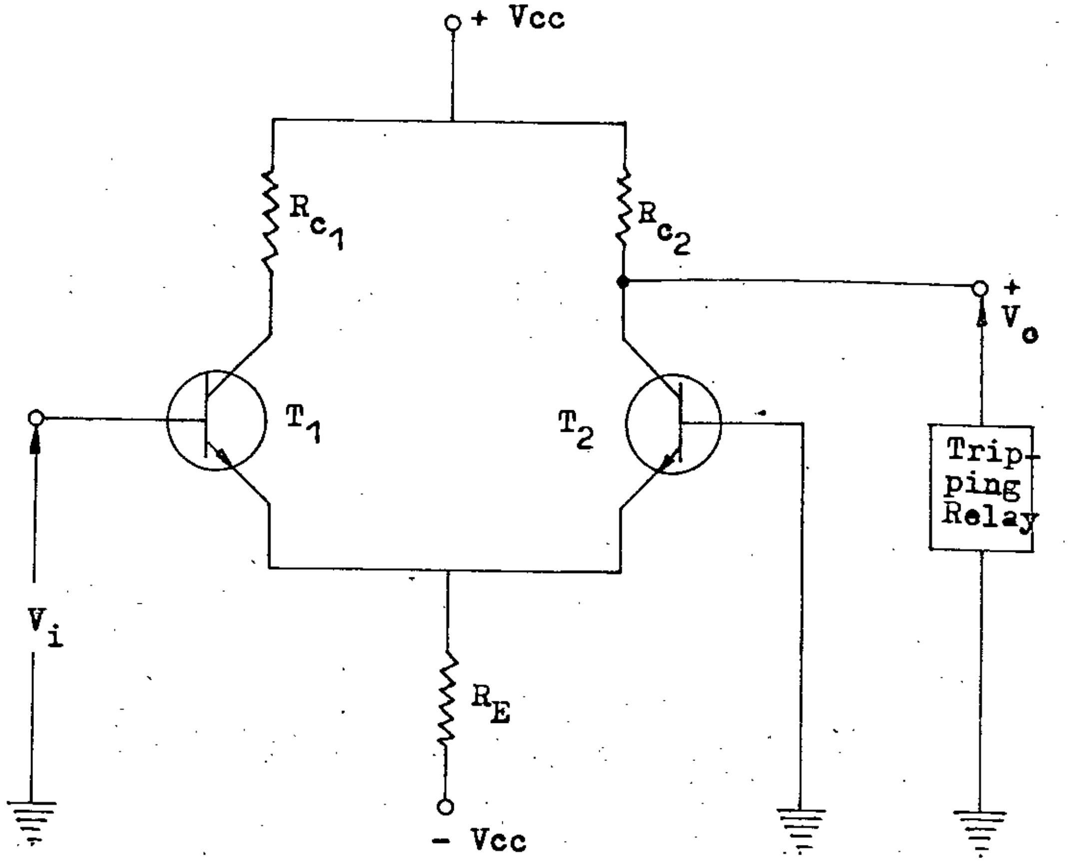


Fig.6.3. Level detector or amplifier circuit.

To have the transistor to run in its active region (i.e. between the saturated and breakdown zone). the transistor should be bias approximately with half the maximum voltage of collector to base. This will give a good quiescent point of operation.

Here we have selected the biasing voltage as 35V by trial and error. It is the minimum value to get the tripping in the tripping circuit.

6.8.1.3. Calculation of the Parameters:

The parameters of the amplifier was found by trial and erro method. R_c should match the output impedance for maximizing amplification. It is selected that $Rc_1 = Rc_2 = 5K\Omega$

Again, when R_E has a small value, high magnitude of current flows through it. So it becomes hotted. R_E is selected as $4K\Omega$

6.9. The Tripping Circuits and the Trip Indicator.

For the tripping circuits an attrected armeture type device is considered. It has the value for tripping is

$V = 15$ v

$I = 2$ mA.

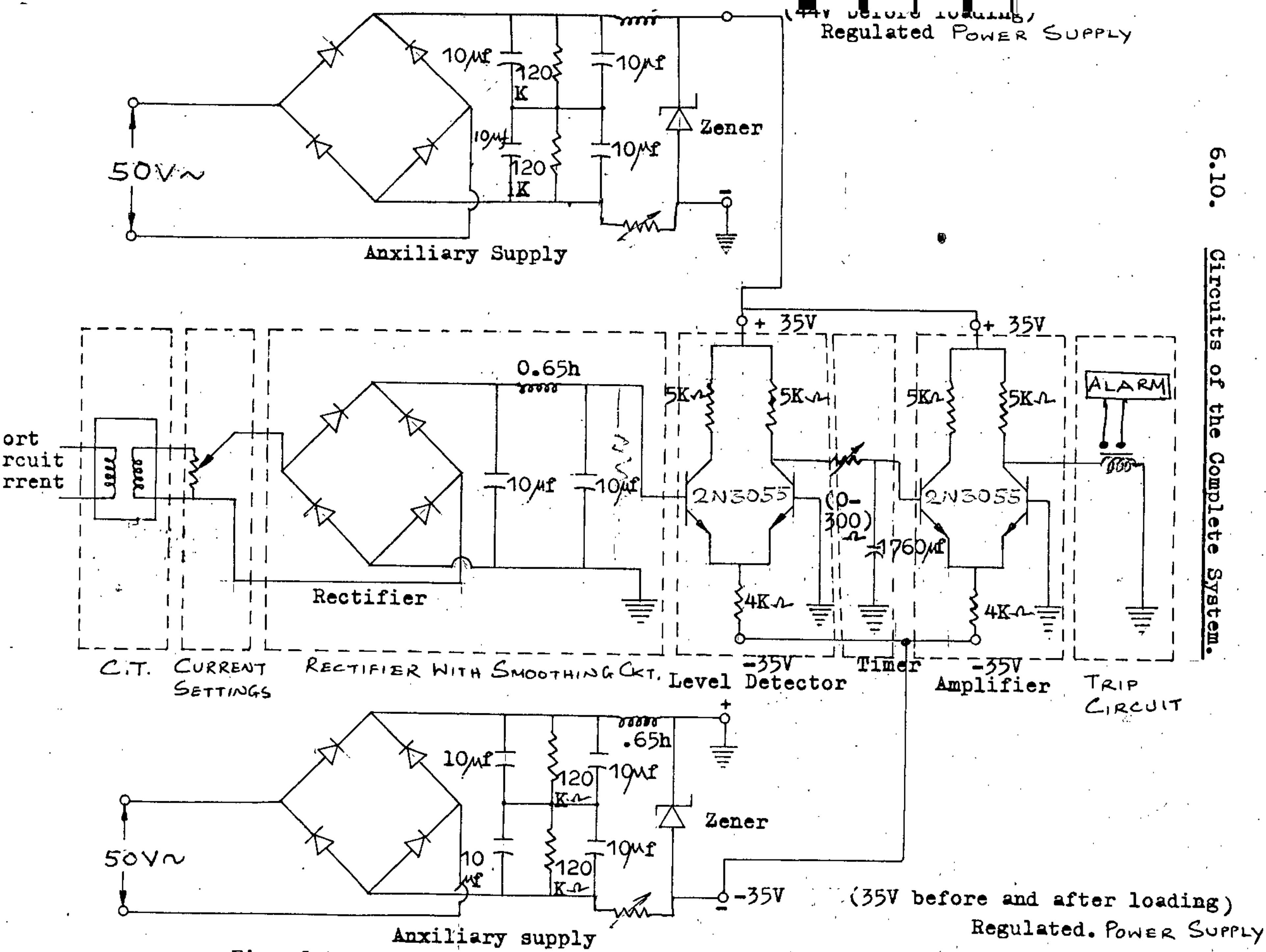


Fig. 6.4. The Complete Static Relay Circuit Diagram that design

CHAPTER - 7

TESTING AND RESULTS

7.1. For Level Detector Without Load.

V_{in} in volts	V_{out} in volts	Av
0	0	
0.1	31.5	315
0.16	33.8	211.25
0.22	34	154.54
0.31	34	109.68

7.2. For Amplifier With Relay Trip Circuit as the Load

V_{in} in volts	I_{in}	V_{out} in volts	I_{out} in mA	Av	A_I	
0.0	50 A	2.6	0.4		8.0	Not Tripped
0.07	100 A	9.2	1.2	131.42	12.0	" "
0.12	170 A	11.0	1.4	91.67	8.23	" "
0.15	250 A	11.5	1.5	76.67	6.0	" "
0.8	1.2 mA	15.0	2.0	18.75	1.67	Tripped
0.95	1.4 mA	16.0	2.4	16.84	1.71	"

So the input voltage and current at tripping is 0.8 V and 1.2 mA respectively which should be the current and voltage of level detector -2 at tripping.

Form the data it is seen that in the amplifier without giving a signal the output voltage is 2.6 volts. This voltage is actually from the leakage input voltage in the input. Since our level detector - 2 has the same circuit confignation. So at the time of tripping it should have 0.8 volts in its output. But it is less than 2.6 volts. That is 0.8 volts can be achieved without input signal in the level detector - 2. That is the input of the level.detector - 2 to achieves the output voltage of 0.8 volts is undetectable. So there is no need of level detector - 2 as will seen in Fig. 6.4.

So if the 0.8 volts and 1.2 mA. is the voltage and current respectively of the output of the time-lag circuit, the relay will trip.

7.3. For Fixing the Maximum Output Voltage (E) of the Level Detector.

We know,

$$V_c = E\left(1 - e^{-\frac{t}{RC}}\right)$$

$T = 1 \text{ cycle} = \frac{1}{50} = .02 \text{ sec}$

$C = 1760 \mu f$

For R = 100 ohm

$$V_c = E\left(1 - e^{-\frac{.02}{100 \times 1760 \times 10^{-6}}}\right) = 0.1E \text{ or } E = 10\, V_c$$

For, R = 200 ohm, $V_c = .055E$, or $E = 18.1\, V_c$

At tripping we have Av = 18.75

For finding Emax, R = 100 ohm circuit may be chosen.

For level detector with all the circuits connected in different current setting at tripping.

Current setting	In timer R in ohm	In Level Detector V_{in} in volts	I_{in} in mA	V_{out} in volts	I_{out} in mA	In timer circuit, V_c in volt
$I = \frac{1}{4} I_T$	100	0.05	0.9	4.9	2.2	4.7
	200	0.08	0.9	5.7	2.2	4.8
	300	0.08	0.9	6.0	3.4	4.6
$I = \frac{1}{2} I_T$	100	1.4	2.0	7.0	4.1	6.6
	200	1.4	2.6	7.4	4.0	6.4
	300	1.2	2.6	7.4	4.0	6.4
$I = \frac{3}{4} I_T$	100	2.8	2.4	7.0	4.1	6.6
	200	2.4	2.4	7.6	4.1	6.2
	300	2.4	2.4	8.0	4.0	6.5
$I = I_T$	100	3.8	3.0	7.6	4.0	7.0
	200	4.4	3.0	7.9	4.0	6.2
	300	4.3	3.0	8.1	4.0	6.4

V_{out} of level detector or E at the timer is selected at different current settings as

at $I = \frac{1}{4} I_T$ is 5.0 volts. $I = \frac{3}{4} I_T$ is 7.0 volts

$I = \frac{1}{2} I_T$ is 7.0 volts. $I = I_T$ is 7.6 volts.

7.4. Tripping Time for the Time-Lag Circuit

For the time-lag circuit the tripping time for defferent current settings and at different R of the tripping circuit.

Here, $C = 1760 \mu f$ (fixed)

$V_t = 0.8$ volts the tripping voltage in the input of the amplifier.

So, from the experimental data,

Current Settings	R in ohms	E in volts	$T = RC \log_e\left(\frac{E}{E - V_t}\right)$
	100	4.9	0.027
$I = \frac{1}{4} I_T$	200	5.7	0.053
	300	6.0	0.075
	100	7.0	0.021
$I = \frac{1}{2} I_T$	200	7.4	0.04
	300	7.4	0.06
	100	7.0	0.021
$I = \frac{3}{4} I_T$	200	7.6	0.039
	300	8.0	0.055
	100	7.6	0.019
$I = I_T$	200	7.9	0.037
	300	8.1	0.055

Time characteristics of the time-lag circuit is also determined from the storage - oscelloscope is shown .

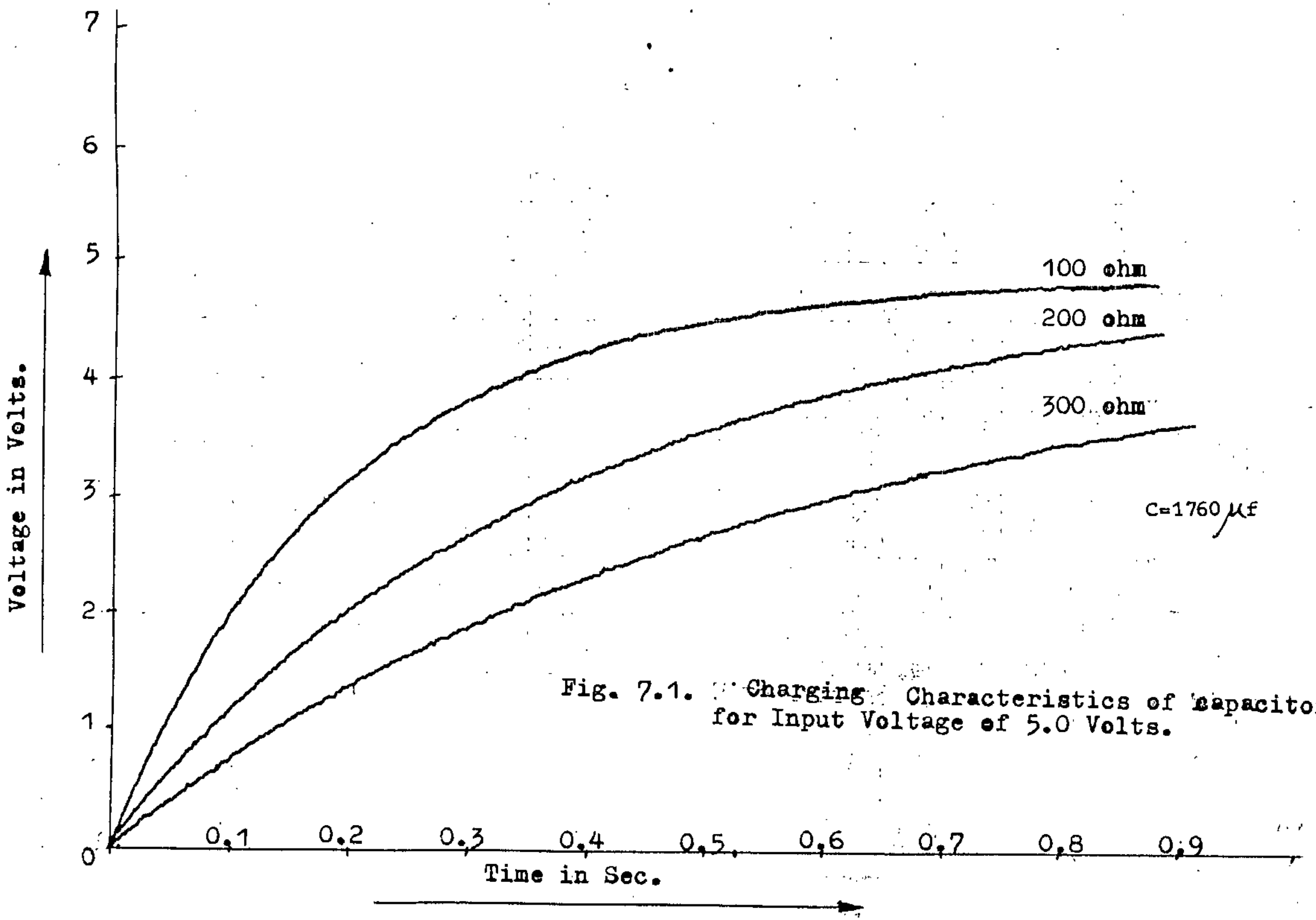


Fig. 7.1. Charging Characteristics of capacitor in Timer for Input Voltage of 5.0 Volts.

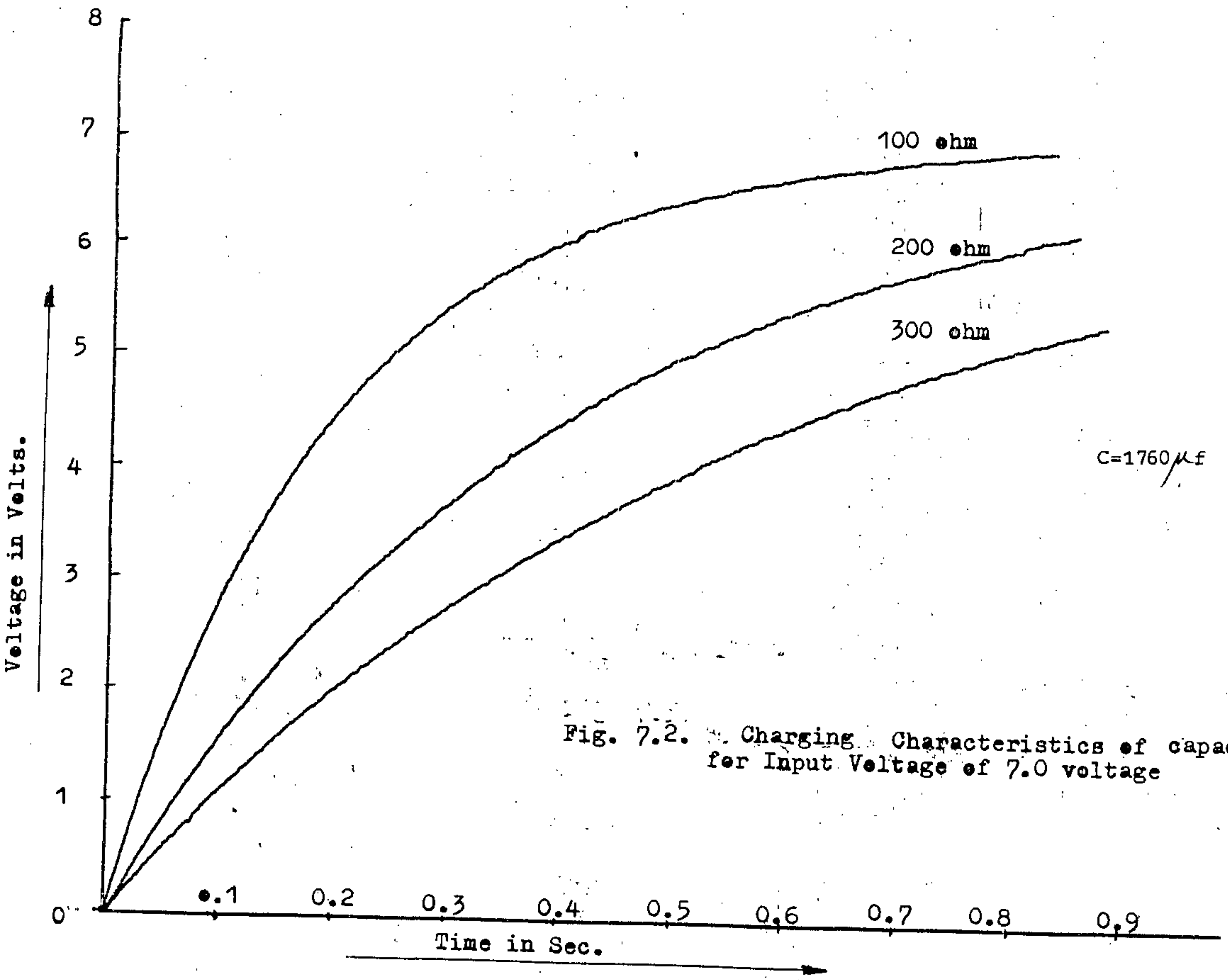


Fig. 7.2. Charging Characteristics ef capacitor in Timer fer Input Veltage ef 7.0 voltage

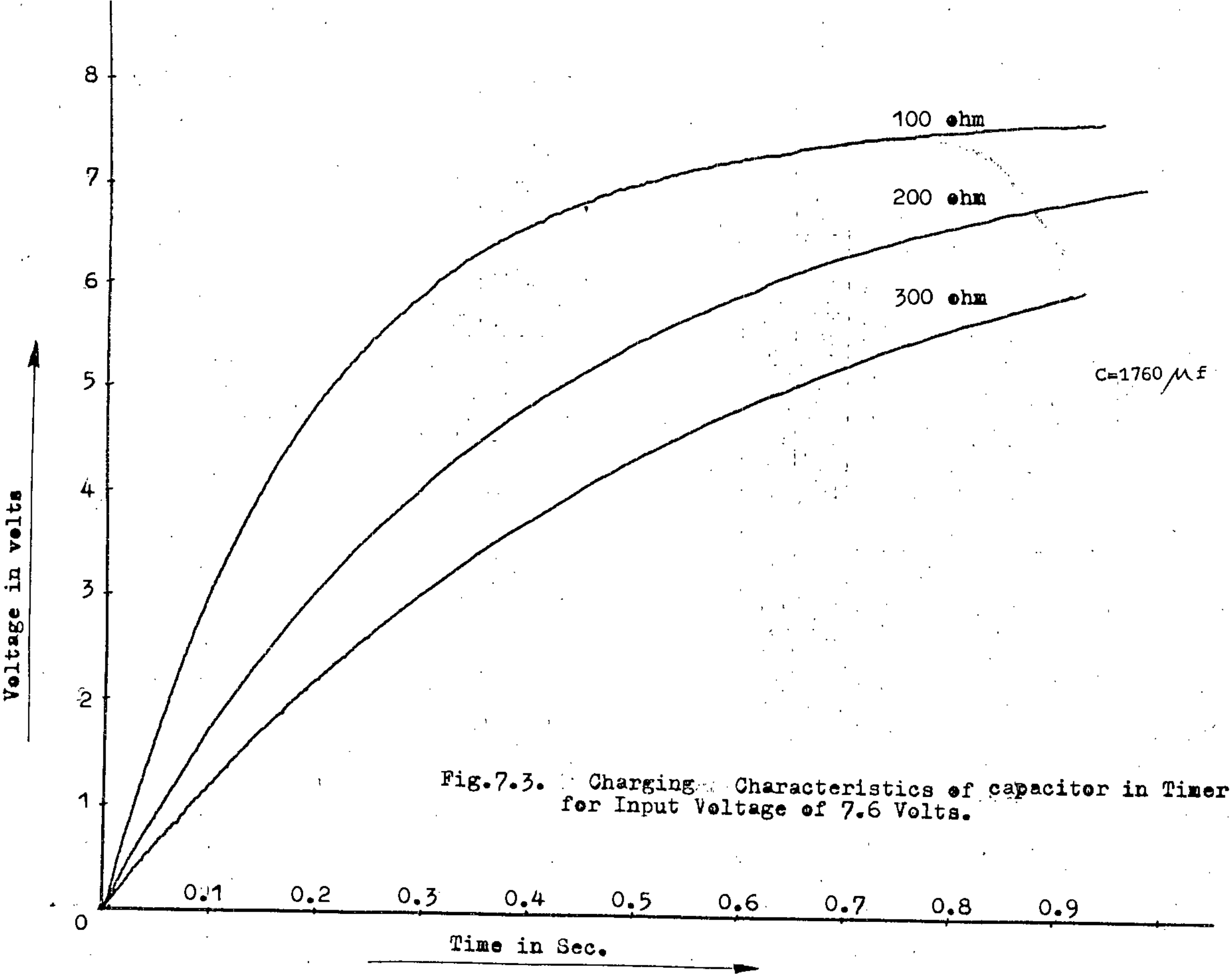


Fig.7.3. Charging Characteristics of capacitor in Timer for Input Voltage of 7.6 Volts.

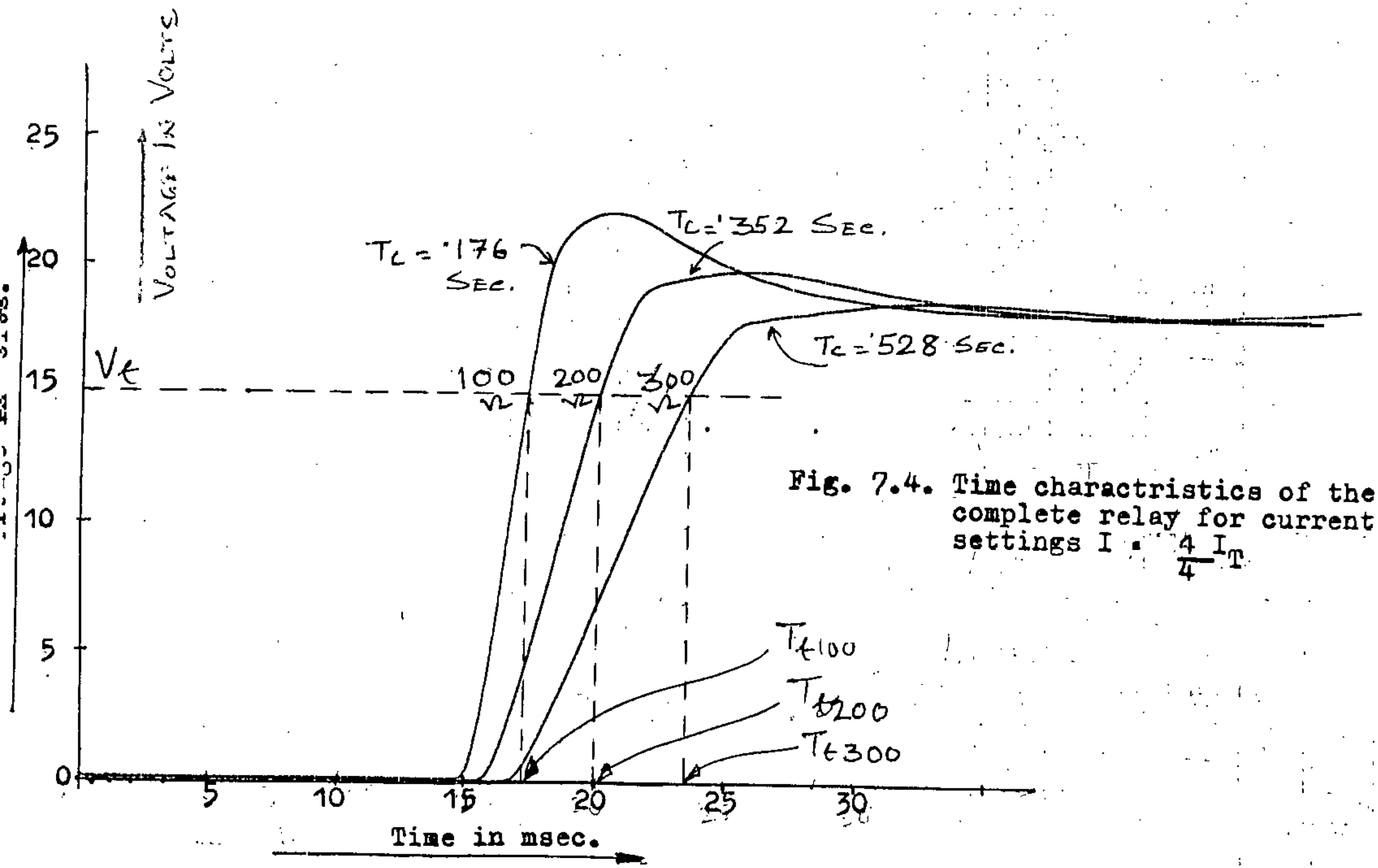


Fig. 7.4. Time charactristics of the complete relay for current settings $I = \frac{4}{4} I_T$

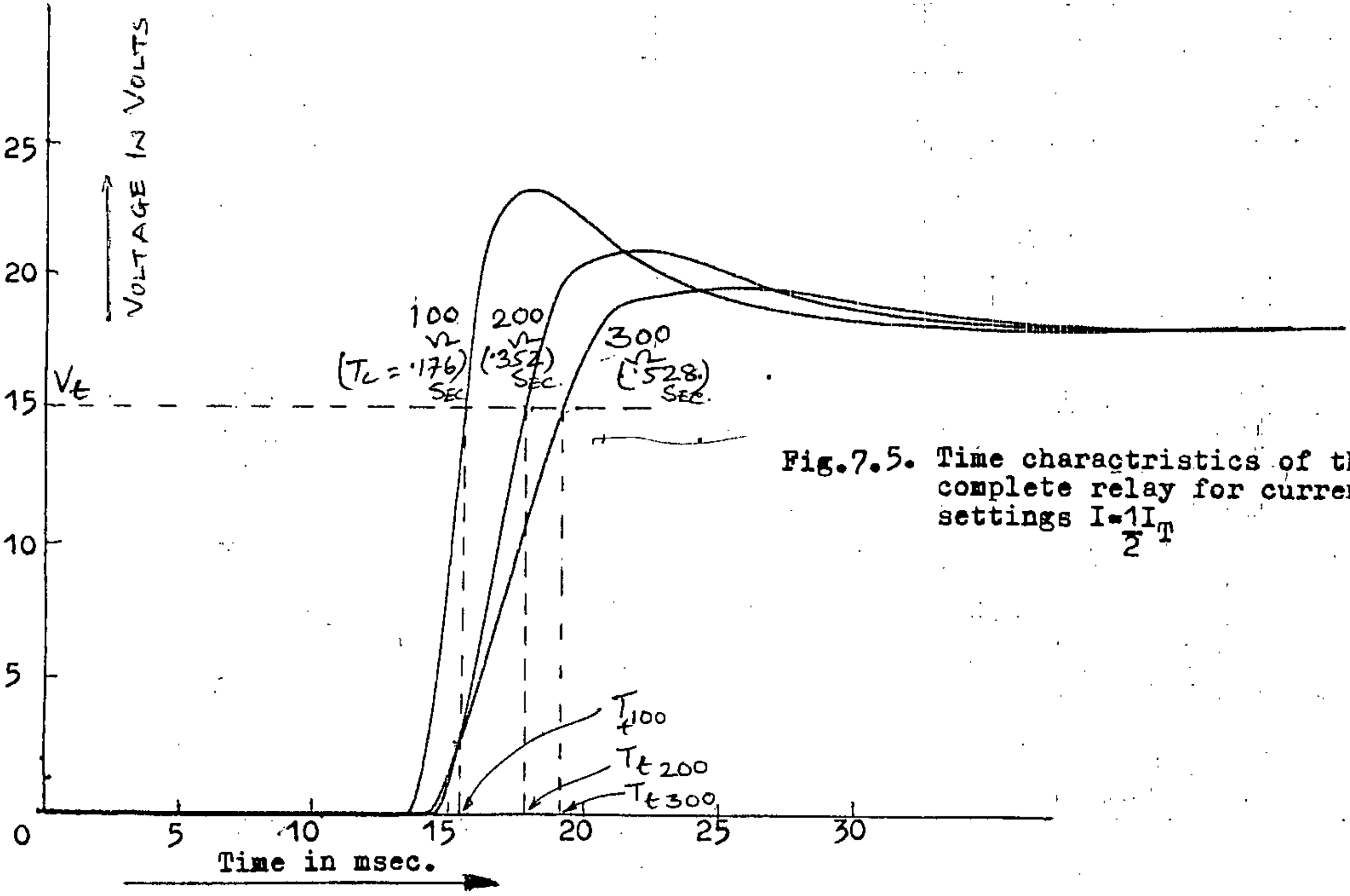


Fig.7.5. Time charactristics of the complete relay for current settings $I = \frac{1}{2} I_T$

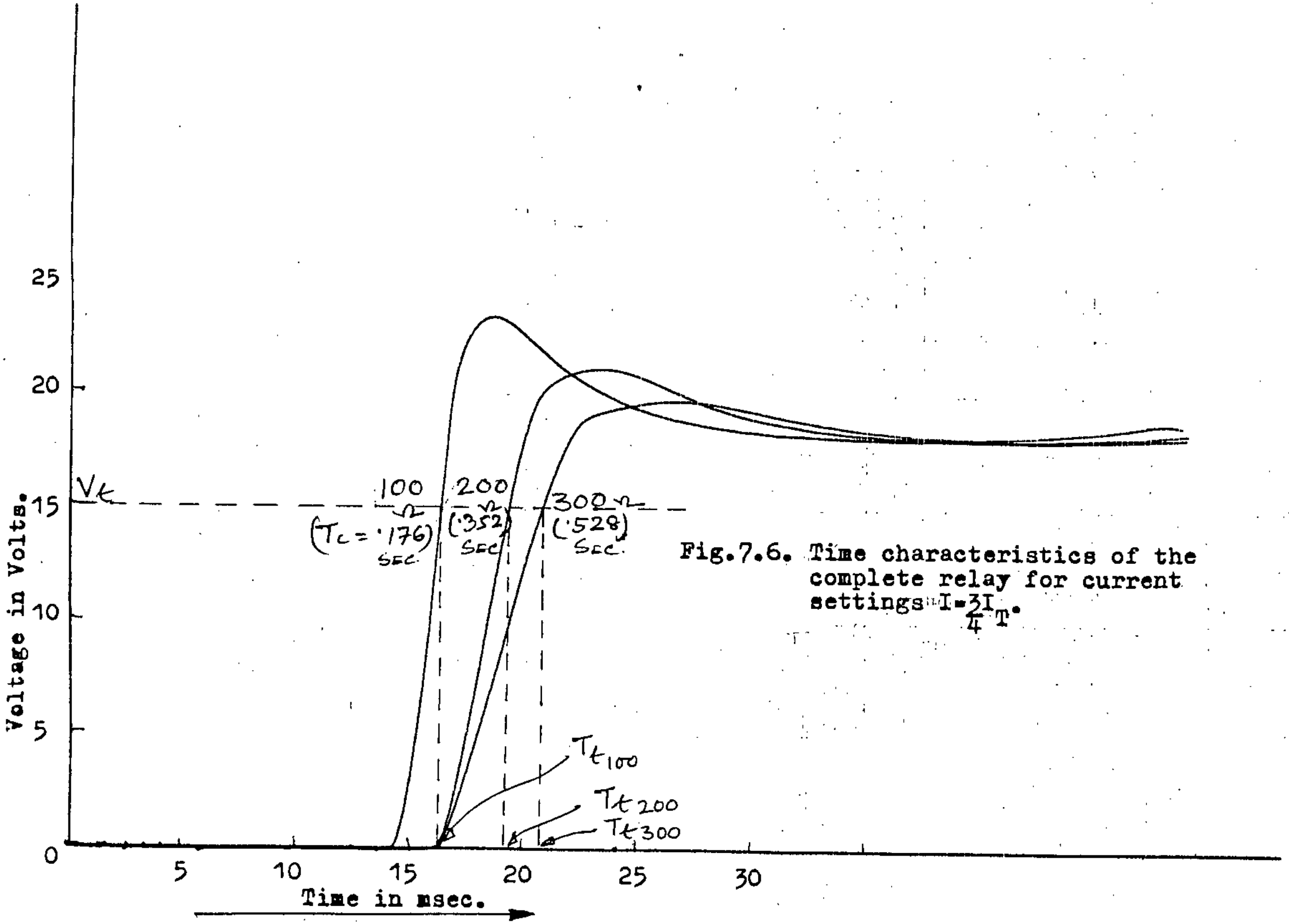


Fig.7.6. Time characteristics of the complete relay for current settings $I = \frac{3}{4} I_T$.

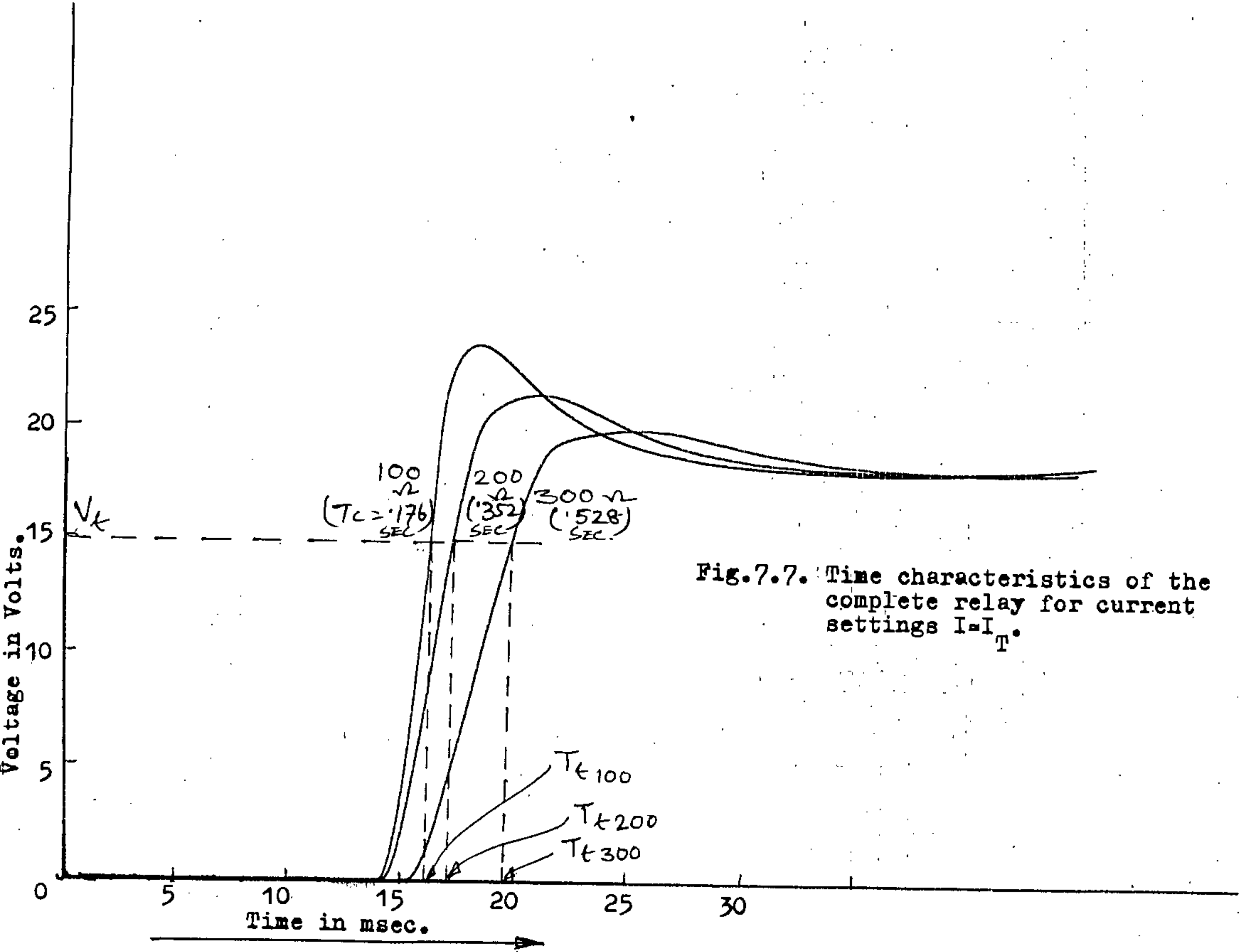


Fig.7.7. Time characteristics of the complete relay for current settings $I = I_T$.

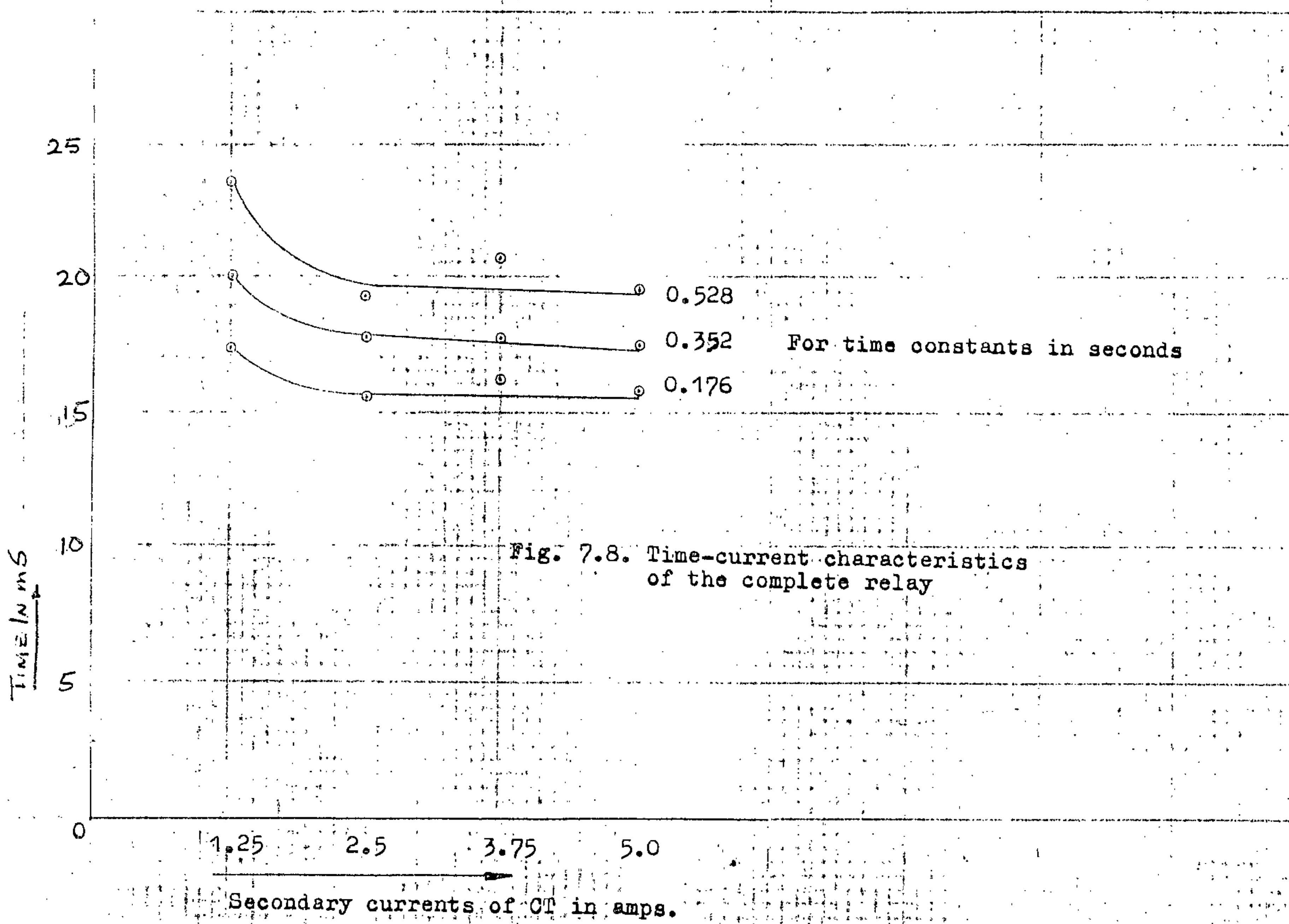


Fig. 7.8. Time-current characteristics of the complete relay

in Fig. 7.1, Fig. 7.2 and Fig. 7.3. for different current settings. Overall, time characteristic of the complete system is also shown for different settings. in Fig. 7.4, Fig. 7.5, Fig. 7.6. and Fig. 7.7.

7.5. Discussion of the Results.

(1) It is seen that the amplifier or level detector has an amplifying factor higher in the lower signal values. That is its operating range is at lower signal values.

(2) If the signal current is increased by the current settings, the input voltage and hence the output voltage increases. It is to be expected.

(3) Increasing current by the current settings the time of tripping decreases for different values of R in the time - lag circuit.

(4) Also it is seen that if R is increased, the tripping time increases.

(5) Generally the current ratio in a current transformer is defined with its secondary short circuited. For a small rasistance in the secondary ($\simeq$ 1 ohm) it is expected that very little effect in the transformation ratio will take place. However the exact amount of error due to the resistance used in the secondary circuit can be determined by careful investigation.

(6) The initial nonresponse time of about 15 mS is probably due to the charging time elapsed in the large capacitances (10 μF, each) used for filtering action in the output of the rectifier used between the CT and the level detector. The exact time delaying action due to these capacitors require further investigation and can be taken up in future work for the improvement of the circuits used.

(7) In the time-current characteristics of the relay it is seen that for a time constant of timer circuit a very inverse characteristic is obtained as seen in Fig. 7.8.

CHAPTER - 8

CONCLUSION AND SUGGESTIONS FOR FURTHER STUDIES

(1) Static relay developed is faster than the electromagnetic relay and has an operating time of about 1 cycle of a 50 cycles/sec signal.

(2) The different sections such as Current Settings, Rectifier, Filter, Level Detector, Amplifier, Tripping and Alerm Device has been developed in module form. It is expected that for repair and maintenance of the relay, the separate moduler sections will prove to be convenient.

(3) Changing the descrete component to integrated circuit. The measuring part of the static relay will be compact. The size of the complete relaying system will be influenced by the size of the transformer, output devices, indicating devices etc.

(4) Using the integrated circuit increases reliability and price.

(5) The design was seriously restricted by the availebity of components in the local market or in the Laboratory. The Performance is expected to be much better and the relay can be made faster if the design components are obtained as desired.

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