LOGIC CIRCUIT DESIGN FOR VARIOUS POWER CONVERTERS

BY

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ABSTRACT

This project work presents simple design and construction techniques of logic circuits for controlling various power converters. Power conversion techniques require switching ON and OFF of power semiconductor devices of various converters. Low level electronic circuits which normally consist of integrated circuits and discrete components, generate required gating signals for the power devices to turn them ON and OFF. In this project work effort has been made to use of ICs and discrete components readily available in local market.

Control circuits of various power converter ie, ac-dc, ac-ac, dc-ac are constructed. These control circuits has been used to run practical power converter circuits in the power electronics laboratory. The logic circuits are designed by simple electronic circuit principles. In some cases it is possible to implement the logic circuit in different methods. To illustrate this point logic circuits are designed and constructed in two ways separately for a.c. voltage controller, controlled rectifier and inverter circuits.

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The project report titled, "**Logic Circuit Design for Various Power Converters**", submitted by Md. Nazmul Haque Roll No : 871342P Registration No : 81123 of M.Engineering (EEE) has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Engineering (Electrical & Electronic).

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CHAPTER - 1

Introduction

1.1 Introduction

Power electronics deals with conversion and control of electrical power in various industrial commercial, residential, municipal and aerospace applications. The motivation for using various logic circuits is to switch ON and OFF the converters and elimination of large audio noise, easy maintenance, improvement of reliability and high quality performance of the converters, etc. The history of power electronics started with the invention of mercury-arc rectifiers at the beginning of this century. Gradually other types of gas tubes such as phanotrons thyratrons and ignitrons were introduced in the 1930's. Much of todays converter technology i.e, phase controlled rectifiers, inverters and cycloconverters originated during that time. Then came the area of saturable reactor magnetic amplifiers which essentially appeared during the World War I-I. The real revolution in power electronics started when the thyristors or silicon controlled rectifiers (SCR)s were invented by Bell Laboratories in 1956 and was commercially introduced by general Electric Company in 1958. Modern power electronics uses various semiconductor devices in switching mode for rectification (ac-dc), inversion (dc-ac), cycloconversion (frequency changing), dc-dc conversion and ac power control (at the same frequency).

Conversion techniques require the switching ON and OFF of power semiconductor devices. Low-level electronic circuits which normally consist of integrated circuits and discrete components generate the required gating signals for control of power devices. Now-a-days Integrated circuits and discrete components are being replaced by microprocessors.

An ideal power device should have no switching ON and OFF limitations in terms of turn-on time, turn-off time, current and voltage handling capabilities. Though such devices are not available, the power semiconductor technology is developing fast switching power devices with increasing voltage and current limits. Power switching devices such as power BJTs, power MOSFETs, MOSIGTs, SCRs, TRIACs, GTOs and other semiconductor devices are finding increasing applications in a wide range of products. With the availability of faster switching devices and modern microprocessors in synthesizing the control strategy for gating power devices, the conversion specifications are widening the scope of power electronics.

Device rating has increased tremendously in the last few years. This fact can be seen from ratings of some available devices as shown below [3],

Type	Rating
GTO	2500 V, 1000 A
SCR	3000 V, 1000 A
MOSFET	1000 V, 100 A
FET	1000 V, 50 A

Converter :

A converter may be considered as a switching matrix and may be classified as,

1. AC - DC Converters (controlled rectifier)
2. AC - AC Converters (ac voltage controller)
3. DC - DC Converters (dc choppers and switch mode power supplies)
4. DC - AC Converters (inverters)
5. AC - AC Cycloconverters.

A bulk of power electronics is routinely used in electro- chemical processes such as metal refining, electroplating, anodizing and production of chemical gases. Recently, the high-frequency fluorescent lamp ballast is showing promise for energy saving and dimming. The electronic welding area uses thyristor ac switches for fast and precision control of electrical power. Solid state active power filters are used for harmonic filtering and VAR compensation on utility lines. High voltage dc(HVDC) transmission and asymmetrical frequency inverter-tie systems use thyristor converters at both ends. Photo-voltaic and fuel cell generators produce dc power, which is then converted to ac by solid state inverters. In aircraft power supplies variable speed constant frequency (VSCF) system converts power from the engine alternator to 400-HZ power supply.

Solid state dc and ac circuit breakers have been used in low to medium power capacity. Heating, melting and heat treatment of metals use induction heating method using solid state inverters. Motor drive has the largest applications of power electronics in speed control for both ac and dc drives. As evident from above discussion power electronics has already found an important place in modern technology and is now being used in a great variety of high power products.

Proper application of these converters demands the understanding of working principles of these converters. This project work is aimed at design and construction of required control signals to run properly and adequately some of the commonly used converters.

1.2 Objectives

The design of a power semiconductor converter (ac voltage controller, rectifier, inverters etc.) starts with the design of the power circuit of that converter, including the specification of the required switching devices. During the design of the power circuits the required control signals are set and the design of the control circuit follows.

This project work is concerned with the design and implementation of the control circuits (Logic circuits) for some common power converters. The designed controlled circuits described here in have been successfully used (Logic circuit) for running various converters such as ac voltage controller, rectifiers, inverters and cyclocconverters.

1.3 Thesis outline.

A simple logic circuit for a.c. voltage controller and controlled rectifier is described in chapter 2. In designing this control circuit basic concept of the one shot multivibrator circuit is used. For this purpose we have used dual one shot multivibrator MC 4528 chip. With the help of this chip we can generate the gating signals of a.c. voltage controller and controlled rectifier. Another alternative approach is also described in chapter 2 for design and construction of logic circuit of ac voltage controller and controlled rectifier. In chapter 3 the construction of the logic circuit of a single phase bridge inverter (square wave) is described. This chapter is devoted to silicon controlled rectifier (SCR) inverters,their applications and requirements of the logic circuits. Chapter 4 describes the operation principle of a cycloconverter and a simple logic circuit design for generating gating signals of a single phase cycloconverter. Chapter 5 reviews the entire work presented in the project report and presents relevant conclusions. It also focuses on the future potential for a computer package for the analysis of the whole family of static converters.

CHAPTER - 2

SINGLE PHASE A.C.VOLTAGE CONTROLLER AND CONTROLLED RECTIFIER LOGIC CIRCUITS.

2.1 A.C. Voltage Controllers

2.1.1 Introduction

AC voltage controllers are employed to vary the rms value of alternating voltage applied to a load circuit by introducing thyristors or other type of switching devices between the load and the ac source. Usually ac voltage controllers are phase controlled.

The power circuit, output voltage and the output current waveforms of a fullwave and a halfwave voltage controller supplying a resistive load are shown in Fig 2.1 and Fig 2.2. The output voltage is controlled by varying the conduction time of SCRs.

For power transfer, two types of control are normally used,

1. ON - OFF control and the
2. Phase - angle control.

In ON - OFF control, thyristor switches connect the load to the ac source for a few cycles of input voltage and then disconnect it for another few cycles. In phase control, thyristor switches connect the load to ac source for a portion of each cycle of input voltage.

The ac voltage controllers can be classified into two types, (1) Single phase controllers and (2) polyphase controllers. Each type can again be subdivided into (a) unidirectional or half wave controller and (b) bi-directional or full wave controller. Three phase controllers also have various types depending on the connections of static switches.

Since the input voltage is ac, thyristors are usually line commutated, however, in ON-OFF controlled controllers the switching devices may be forced commutated. Since, phase control thyristors are operated at line or same frequency, relatively inexpensive and slow semiconductor switches are normally used. For applications upto 400 Hz, TRIACs can be used if they are available to meet the voltage and current ratings of a particular application.

Due to line or natural commutation in phase controlled voltage controllers there is no need of extra commutation circuitry and the circuits for ac voltage controllers become are very simple. However, the analysis for the derivations for explicit expressions for the performance parameters of circuits are not simple. Especially, for phase angle controlled converters when they are loaded with RL loads.

The principal of phase control can be explained with reference to Fig 2.1(a). The power flow to the load is controlled by delaying the firing angle of thyristor T_1 and T_2. During the positive half cycle of input voltage, the power flow is controlled by varying the delay angle for thyristor T_1, and thyristor T_2 controls the power flow during the negative half cycle of input voltage. The firing angles are kept 180 degree apart. The gating signals for T_1 and T_2 are shown in Fig 2.1(b).

If $Vs = \sqrt{2}\ Vs\ Sin wt$ is the input voltage and the delay angles of thyristors T_1 and T_2 are $\alpha_1 = \alpha_2 = \alpha$ the rms output voltage of the controller with resistive load can be found as,

$$V_0 = [\ 2/\ 2\pi \int_{\alpha}^{\pi} 2\ V_s^2\ Sin^2\ wt\ d(wt)]^{1/2}$$

$$= [\ 4\ V_s^2/4\pi \int_{\alpha}^{\pi} (\ 1 - Cos\ 2wt\ )\ d(wt)]^{1/2}$$

$$= V_S\ [\ 1/\pi\ (\ \pi - \alpha + Sin\ 2\alpha\ /\ 2\ )]^{1/2}$$

By varying α from 0 to π, V_0 can be varied from V_s to 0.

The gating circuits for thyristors T_1 and T_2 must be isolated. It is possible to have a common cathode for T_1 and T_2 by adding two diodes as shown is Fig 2.1(a). During the positive half cycle thyristor T_1 and diode D_1 conduct together and during the negative half cycle thyristor T_2 and diode D_2 conduct together.

In a single phase half wave controller, only one thyristor is used and hence one gating signal is used to turn ON the SCR during the positive half cycle. The gating signal is 360 degree apart from each other. This type of controller is shown in Fig 2.2.

If $v_s = V_m \mathrm{Sin} wt = \sqrt{2}\, V_s \mathrm{Sin} wt$ is the input voltage and the delay angle of thyristor T_1 is α, the rms output voltage can be found for resistive load as,

$$V_0 = [\ 1/2\pi \{ \int_{\alpha}^{\pi} 2\, V_s^2\ \mathrm{Sin}^2\, wt\ d(wt) + \int_{\pi}^{2\pi} 2\, V_s^2\ \mathrm{Sin}^2\, wt\ d(wt)\}]^{1/2}$$

$$= [\ 2\, V_s^2\ /4\pi \{ \int_{\alpha}^{\pi} (\ 1 - \mathrm{Cos}\ 2wt\ ) + \int_{\pi}^{2\pi} (\ 1 - \mathrm{Cos}\ 2wt)\ \ d(wt)\}]^{1/2}$$

$$= V_S\ [\ \ 1/2\pi\ (\ 2\pi - \alpha + \mathrm{Sin}\ 2\alpha\ /\ 2\ )]^{1/2}$$

If α is varied from 0 to π , V_0 varies from V_s to $V_s/\sqrt{2}$

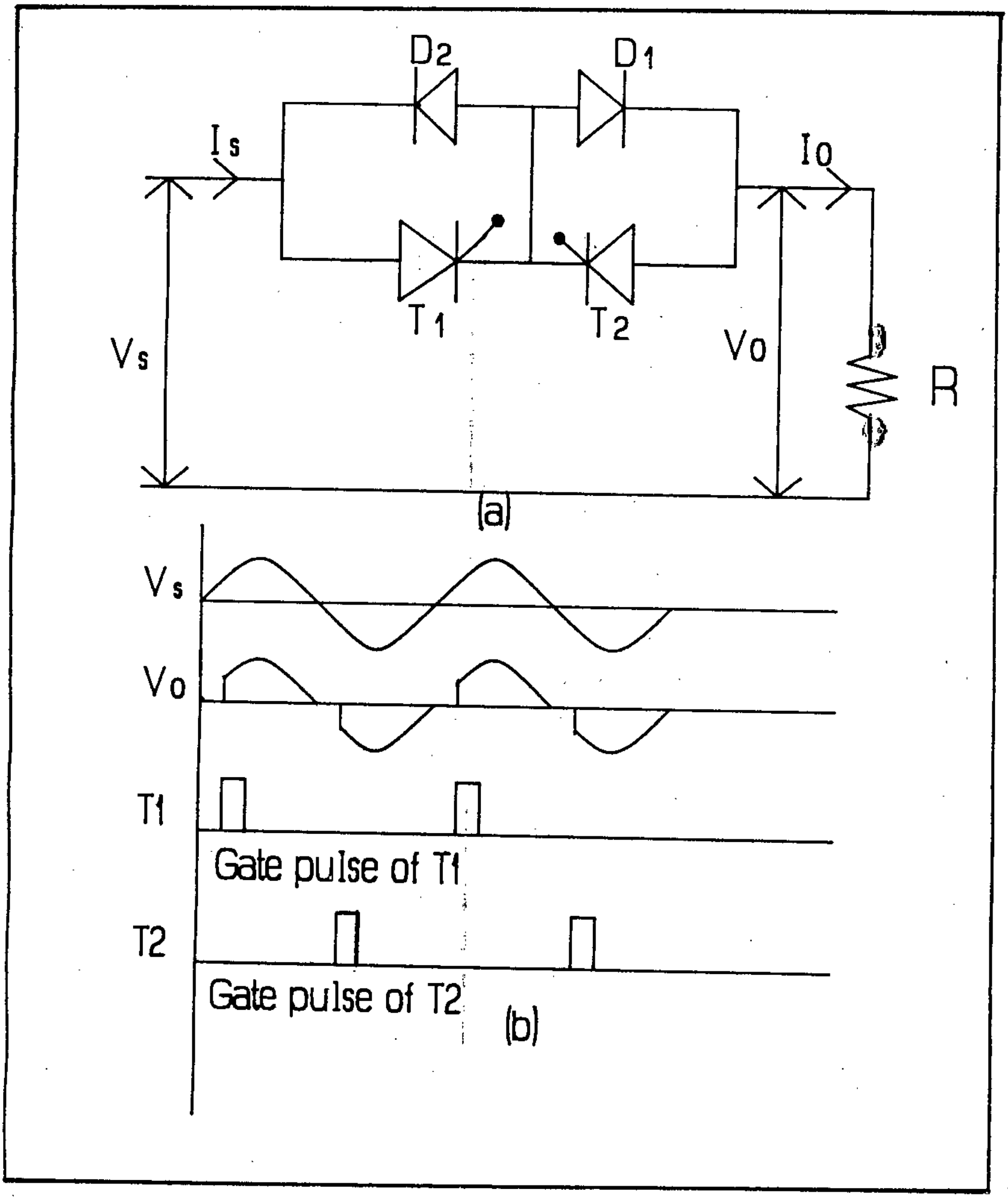


Fig 2.1 Single phase fullwave controller and its various waveforms

a) the voltage controller circuit

b) input voltage and output voltage waveforms for resistive load (gating pulses for SCRs T_1 and T_2 are also shown)

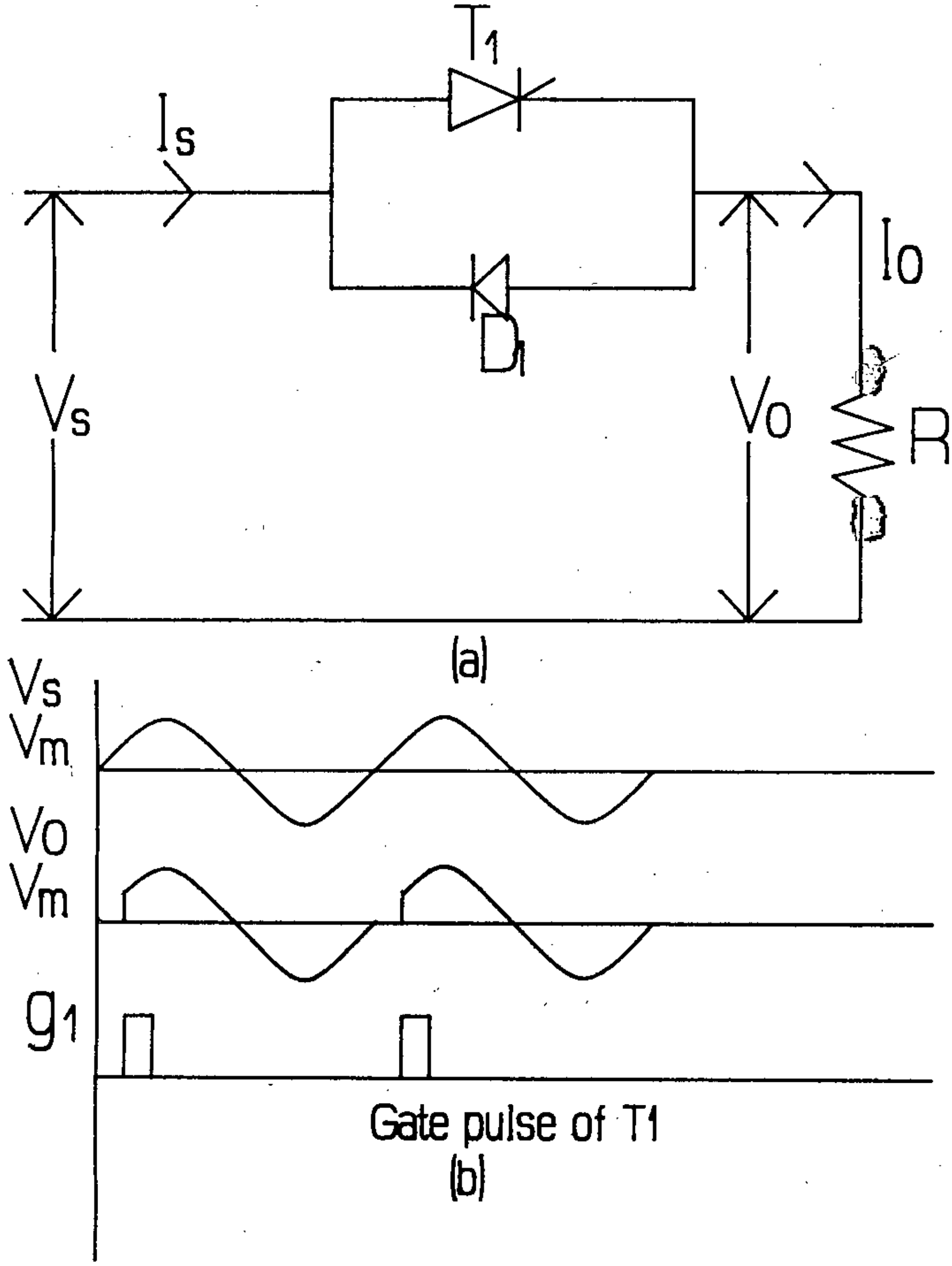


Fig 2.2 Single phase halfwave controller and its various waveforms

a) the voltage controller circuit

b) input voltage and output voltage waveforms for resistive load (gating pulse for SCR T_1 also shown)

The average value of output voltage is

$$V_{dc} = 1/2\pi \left[\int_{\alpha}^{\pi} \sqrt{2}\ V_s\ \text{Sin}wt\ d(wt) + \int_{\pi}^{2\pi} \sqrt{2}\ V\ \text{Sin}wt\ d(wt) \right]$$

$$= \sqrt{2}\ V_s/2\pi\ \ (\text{Cos}\alpha - 1)$$

If α is varied from 0 to π, V_{dc} varied form 0 to $\sqrt{2}\ V_s/\pi$.

Applications of ac voltage controllers include the following,

1. Industrial heating,
2. Induction heating of metals,
3. Lighting controls,
4. Primary transformer control for electro chemical processes,
5. Transformer tap changing and
6. Speed control of induction motor driven pumps and fans etc.

Once the operation of the voltage controller is understood, the logic circuit requiments for generating the control signals of SCRs of a voltage controller can be undertaken as described below. The description includes the timing diagrams of various waveforms and a possible block diagram and the circuit diagram of the practical circuit of the block diagram.

2.1.2 Logic circuit design.

The supply voltage is stepped down and taken as the reference for generating the required gating signals. This ensures that the phase controlled signals are properly synchronized with the supply voltage and random firing of SCRs dose not occur. The sine wave is needed for generating the square wave (B) [Fig 2.3] which is then rectified to get a square wave (C) of positive half cycle only. The inversion of square wave gives the inverted signal (D). The two square waves are used to trigger one shot multivibrators to produce waveforms E and F respectively. The one shot outputs width can be varied by varying the RC constants of the multivibrator. Signals E & F when ANDED with square waves C and D, the required gating signals of voltage controller G_1 and G_2 would result.

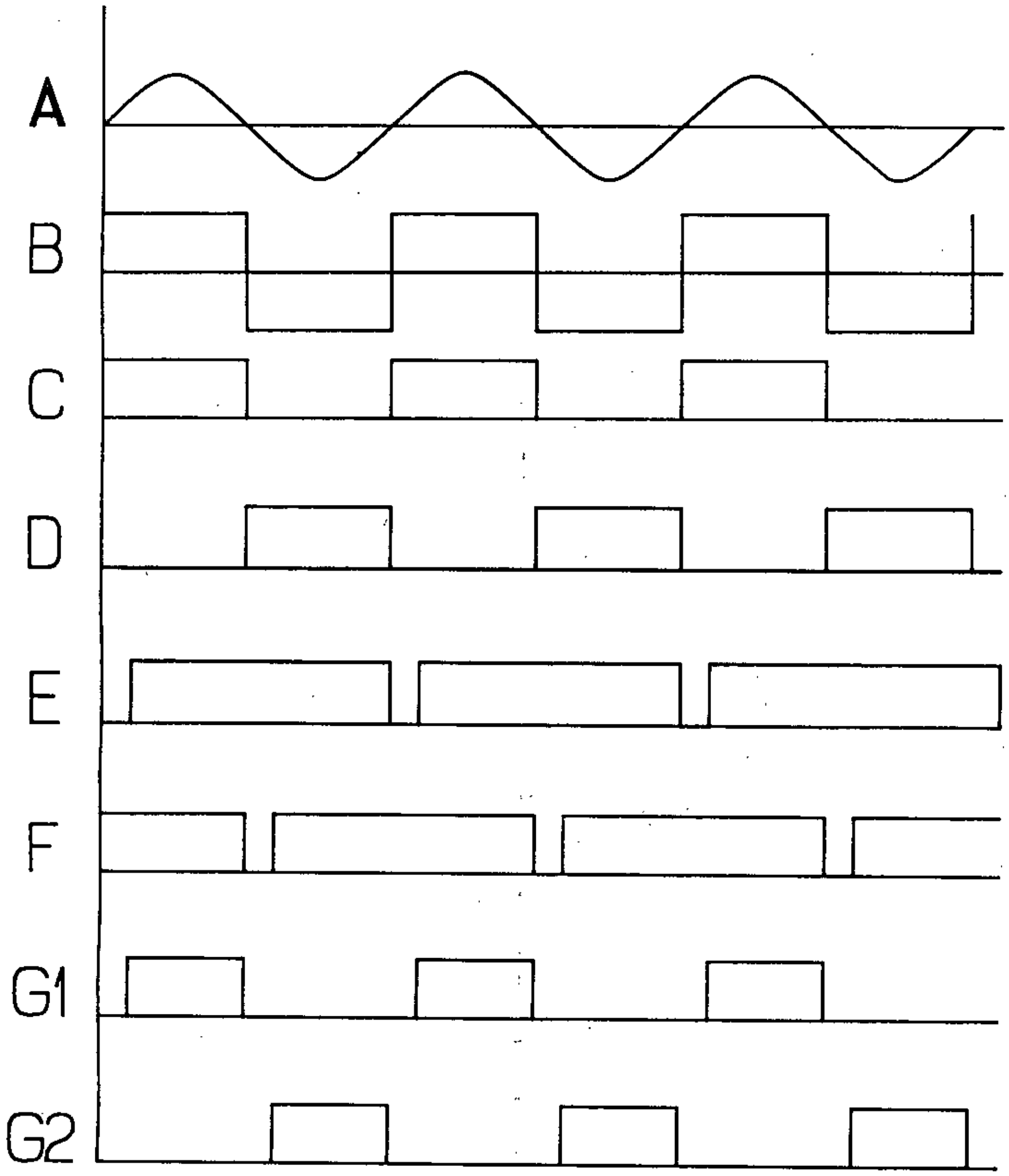


Fig 2.3 Timing diagram of a fullwave single phase ac voltage controller. G_1 and G_2 are the required gating signals of the voltage controller.

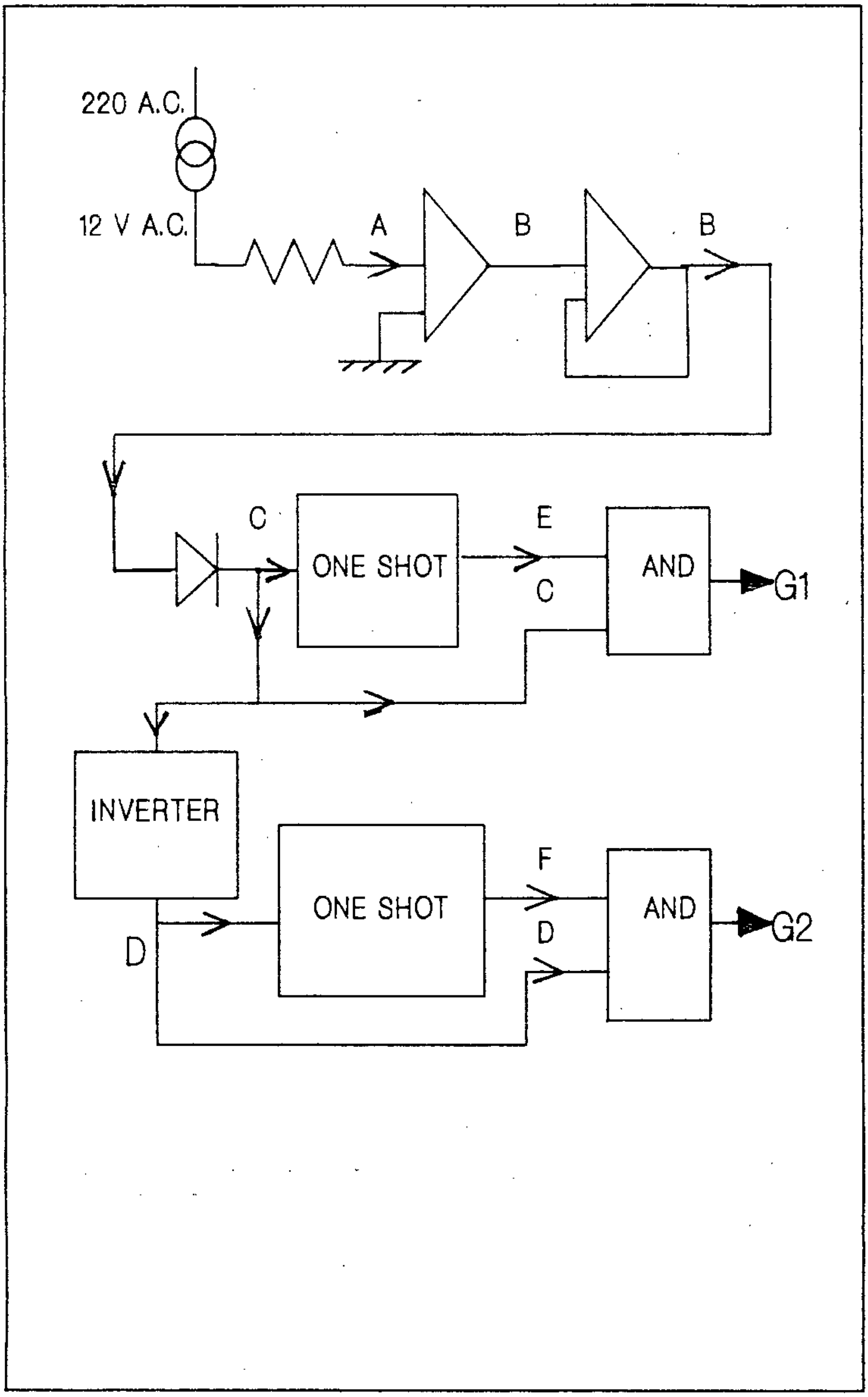


Fig 2.4 Block diagram of the logic circuit of the ac voltage controller.

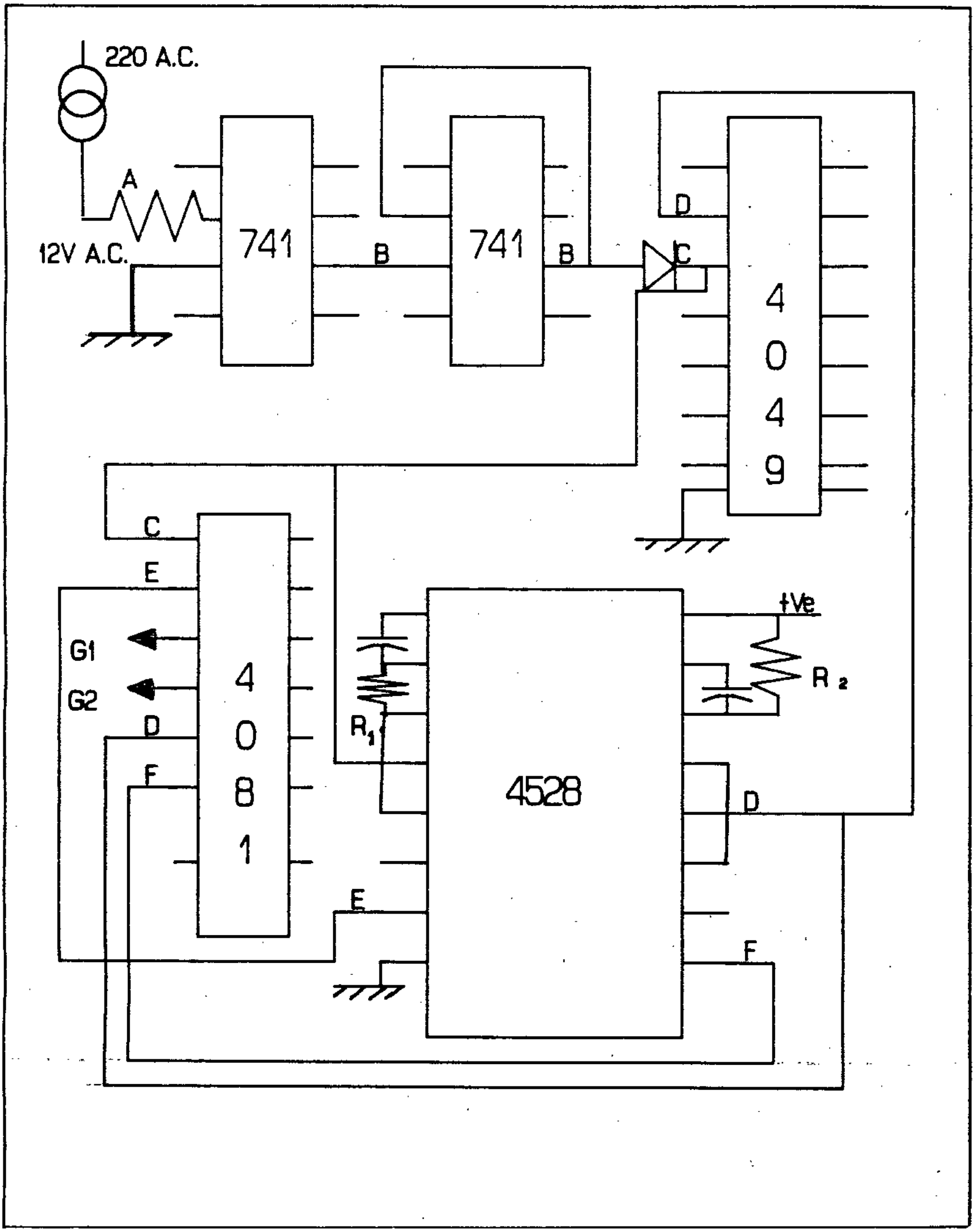


Fig 2.5 Practical circuit of the logic circuit of the ac voltage controller. (Using one shot by variable RC constant)

2.1.3 Description of the practical circuit.

Description of the total circuit (as shown in Fig 2.5 with respect to block diagram is given below.

Low voltage a. c. is produced by using a 220/12 step down transformer from the main source. Then the square wave signal B is produced by using OPAMP (LM 741). Signal C is produced after passing the signal B through a diode. Signal C is inverted by using HEX inverter (MC 4049) and produced signal D. Signal C is used as a input of dual one shot multivibrator (MC 4528) to produce signal E and signal D is used as a input of dual one shot multivibrator to produce signal F. Then signal G_1 is produced by using Quadruple AND (MC 4081) with signals C and E at input pins of AND gates. Signal G_2 is produced by using (MC 4081) with signals D and F at the input of the AND gate.

If the value of resistance R_1 and R_2 of the dual one shot multivibrator is varying simultaneously and equally then the duration of the length of one shot would be changed. So it could be possible to variation of the delay angle of G_1 and G_2.

In half wave a.c. voltage controller only gating signal G_1 is used. But in full wave a.c. voltage controller both G_1 and G_2 are used.

2.1.4 Experimental results.

The circuit diagram of the practical realization of the logic circuit is given in Fig 2.5. The circuit was built and tested for running a voltage controller module available at the power electronics lab. The gating signals of the circuit and the voltage waveforms of the controller with resistive load are shown in Figs 2.6, 2.7 and 2.8.

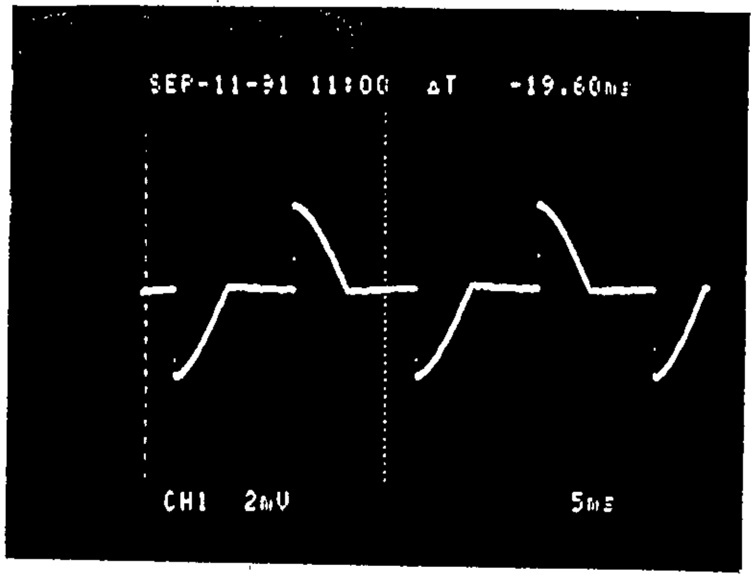


Fig 2.6 Output voltage waveform of a single phase voltage controller ($\alpha = 90^0$)

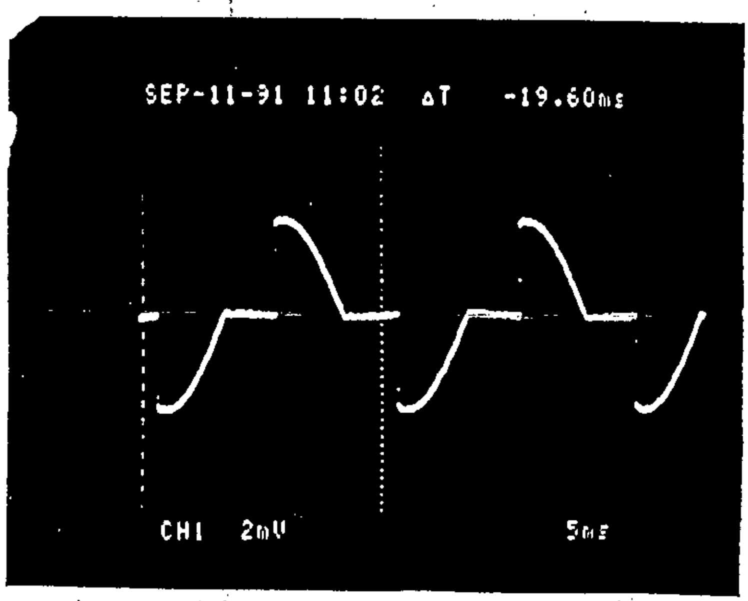


Fig 2.7 Output voltage waveform of a single phase voltage controller ($\alpha = 85^0$)

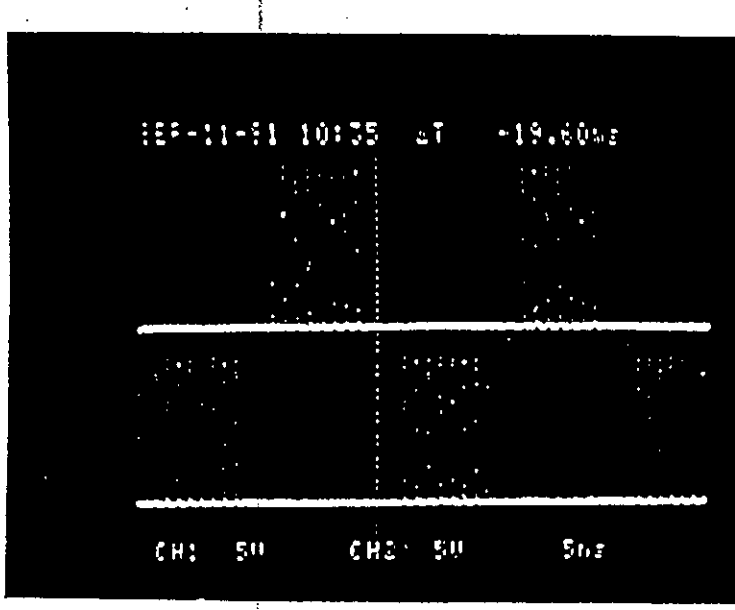


Fig 2.8 Gating pulses for single phase voltage controller.

2.2 Controlled Rectifier

2.2.1 Introduction

The AC-DC converters are commonly known as rectifier. The diode rectifiers provide fixed DC output voltage. Controlled rectifiers are used to vary the average value of the d.c. voltage applied to a load circuit by introducing thyristors or switching devices between the load circuit and a constant voltage ac source. For this purpose the thyristors are usually phase controlled. Some of the uses of controlled rectifier are as follows,

a). DC motor speed control system, widely used in steel mills paper mills and so on,

b). Electro chemical and electrometallergical processes,

c). Magnet power supplies,

d). Converters at the input and of dc transmission lines, and

e). Portable hand tool drives etc.

Like ac voltage controllers controlled rectifiers may be employed in closed loop control systems. In general a single phase ac source is adequate for rectifier ratings of 1 to 2 kw, but for a higher power a three phase ac source is normally used. Once again, the problem of current harmonics in the supply system and load circuit arises. The magnitude of these harmonic must be determined and effort should be made to reduce their bad effects.

The phase controlled converters can be classified into two types,

1. Single phase converter and
2. Three phase converter.

Each type can be subdivided into,

a) Semiconverter

b) Full converter and

c) Dual converter

A semiconverter is a one quadrant converter and it has one polarity of output voltage and current. A full converter is a two quadrant converter and the polarity of these output voltage can be either positive or negative. However, the output current at the full converter has one polarity only. A dual converter can operate in four quadrants and both the output voltage and current can be either positive or negative.

A half wave controlled rectifier with a resistive load as shown in fig 2.9(a). During the positive half cycle of the input voltage,the thyristor anode is positive with respect to its cathode and the thyristor is said to be forward biased. When thyristor T_1 is fired at $wt = \alpha$, it conducts. Input voltage starts to be negative at $wt= \pi$, the thyristor anode is negative with respect to its cathode and thyristor T_1 is said to be reversed biased and it is turned OFF. The time after the input voltage starts to go positive until the thyristor is fired at $wt= \alpha$ is called the delay or firing angle α .

Fig 2.9(b) shows the input voltage, output voltage and gating signals for such a controlled rectifier.

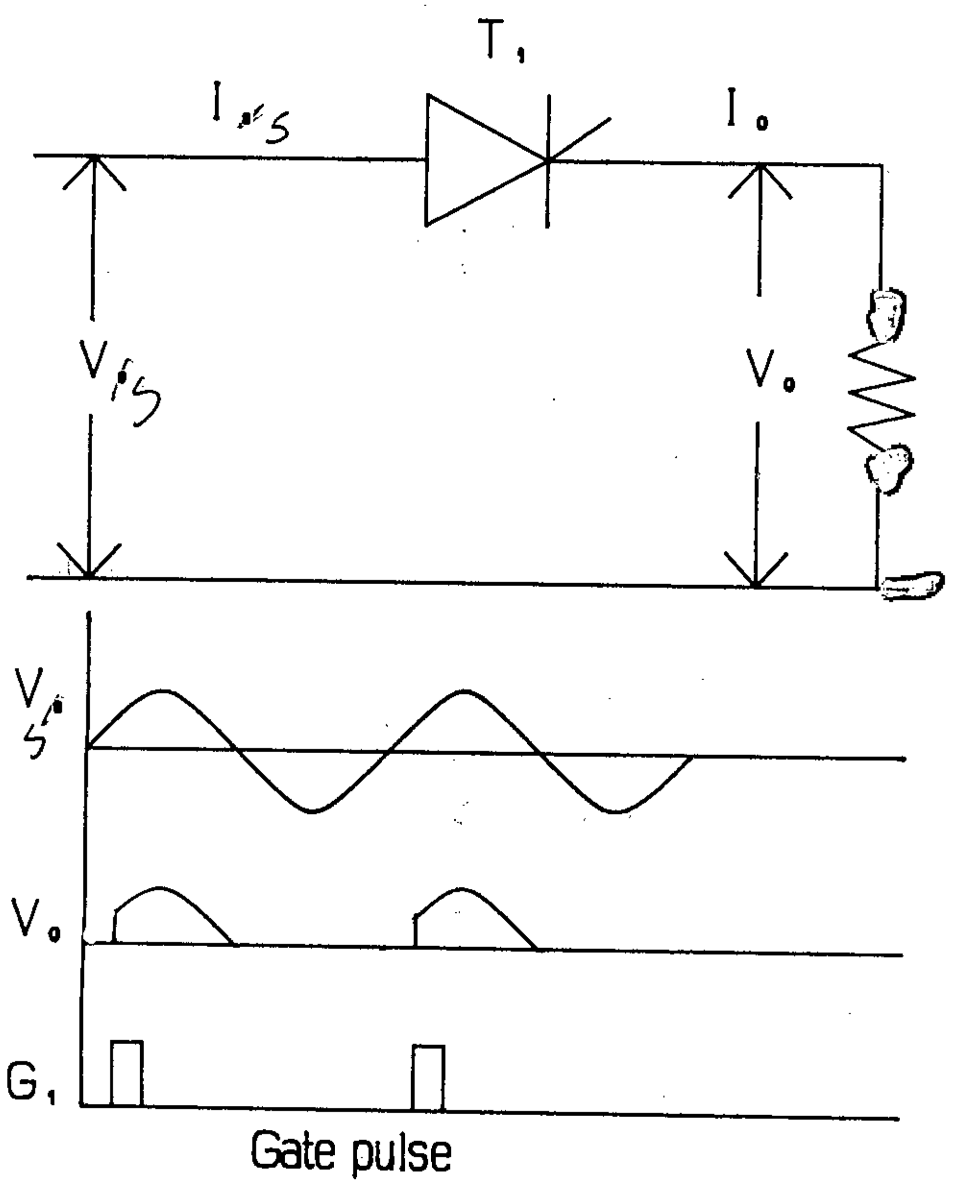


Fig 2.9 A single phase halfwave controlled rectifier with resistive load, the input and output voltage waves for a certain gating pulse.

If $V_s = V_m$ Sinwt is the input voltage the average output voltage can be found by,

$$V_{dc} = 1/2\pi \int_{\alpha}^{\pi} V_m \text{ Sinwt } d(wt)$$

$$= V_m/2\pi \left[- \text{Coswt} \right]_{\alpha}^{\pi}$$

$$= V_m/2\pi \ (1 + \text{Cos}\alpha)$$

and V_{dc} can be varied from V_m/π to 0 by varying α from 0 to π.

If the circuit is full wave controlled rectifier with a resistive load then it may appear as shown in Fig 2.10(a).

During the positive half cycle SCR Q_1 and Q_2 are forward biased and Q_3 and Q_4 are reversed biased. When SCR Q_1 and Q_2 are fired simultaneously by the gating signal G_1 then the positive half cycle of the input voltage is passed through the load R. During the negative half cycle SCR Q_3 and Q_4 and are forward biased and Q_1 and Q_2 are reversed biased. When SCR Q_3 and Q_4 are fired simultaneously by the gating signal G_2 then the negative half cycle of the input voltage is passed through the load R. Fig 2.10 (b) shows typical input voltage ,output voltage and gating signals of such a converter.

If V_m is the peak input voltage ,the average output voltage can be found from

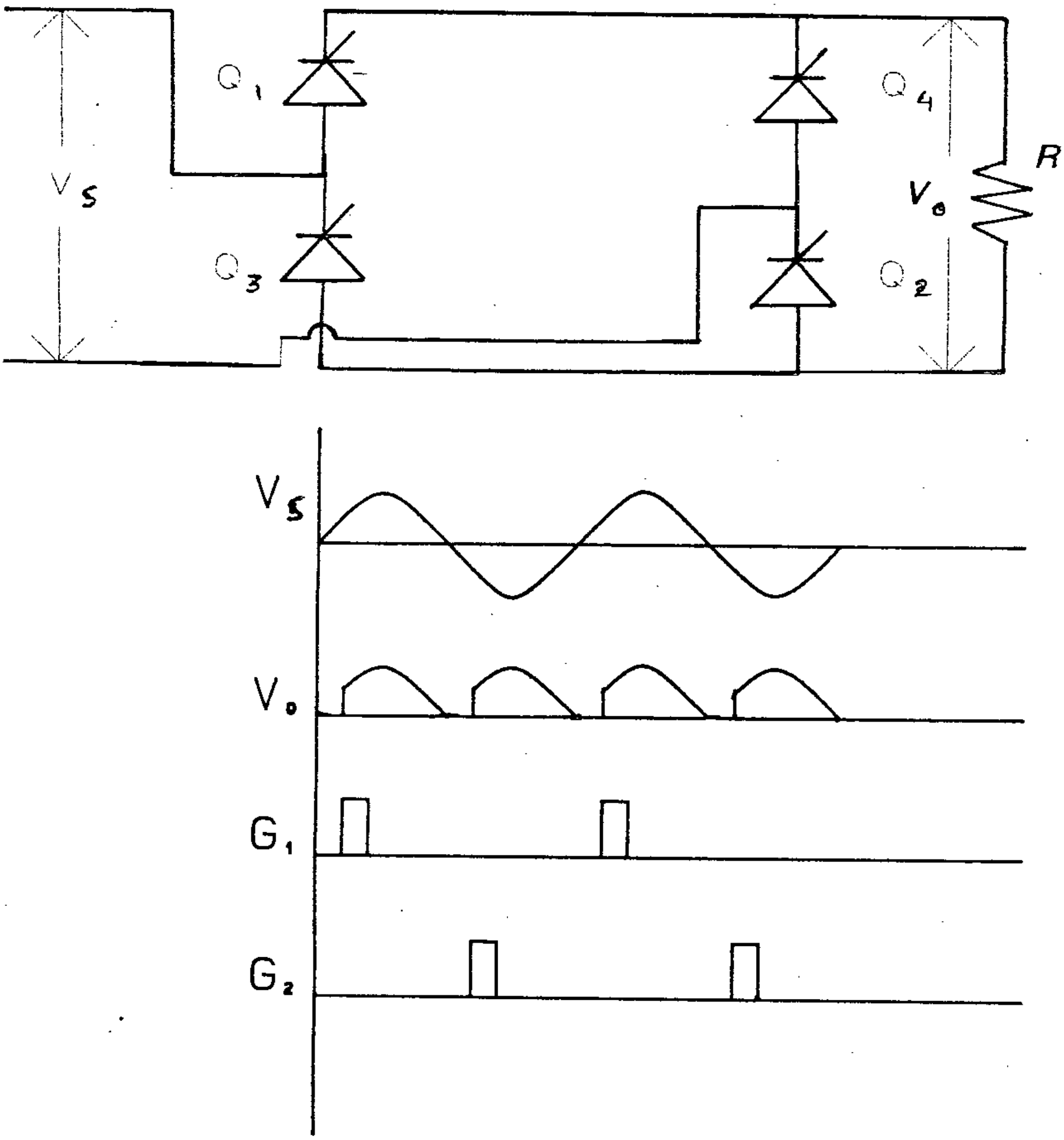


Fig 2.10 A single phase fullwave controlled rectifier with resistive load and the input and output voltage waves for particular gating pulse.

$$V_{dc} = 2/2\pi \int_{\alpha}^{\pi} V_m \ \mathrm{Sin}wt \ d(wt)$$

$$= 2V_m/2\pi \ \left[- \mathrm{Cos}wt \right]_{\alpha}^{\pi}$$

$$= V_m/\pi \ (1 + \mathrm{Cos}\alpha)$$

V_{dc} can be varied from $2V_m/\pi$ to 0 by varying α from 0 to π.

2.2.2 Logic circuit design.

Basically there is no difference between the logic circuit of the a.c. voltage controller and controlled rectifier. Same logic circuit can be used for a.c. voltage controller and controlled rectifier. Only difference is the circuit arrangement of the output or the loading arrangement of the converter.

2.2.3 Experimental results.

The logic circuit which has been built for the voltage controller was also tested to run the ac-dc converter. The waveforms of the output voltage of the converter with resistive load and the associated gating signals are shown in Figs 2.11, 2.12 and 2.13.

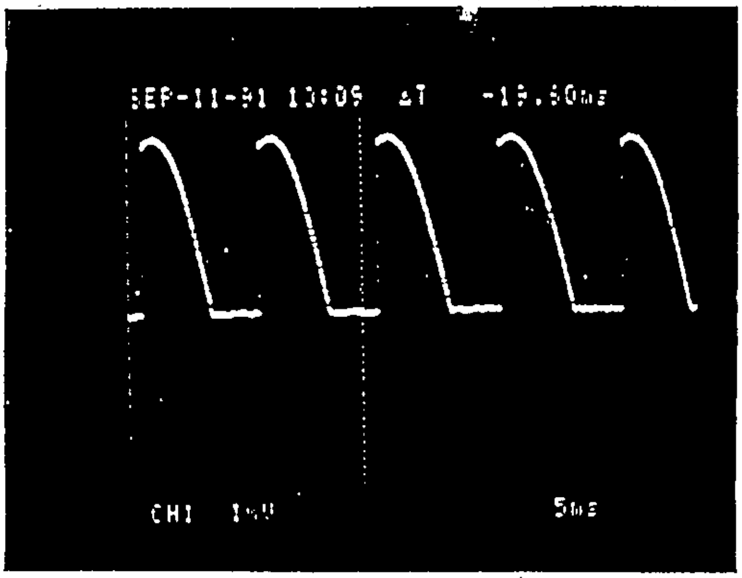


Fig 2.11 Output voltage waveform of a single phase bridge rectifier controller ($\alpha = 85^0$)

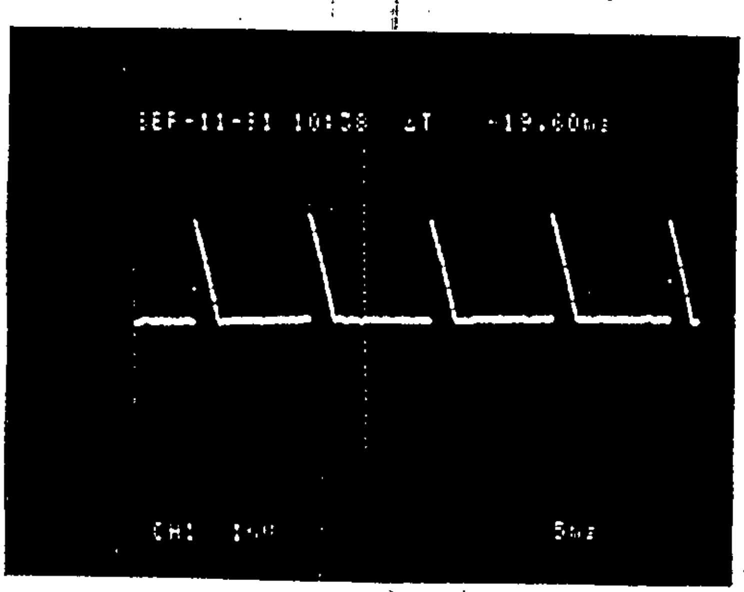


Fig 2.12 Output voltage waveform of a single phase bridge rectifier controller ($\alpha = 135^0$)

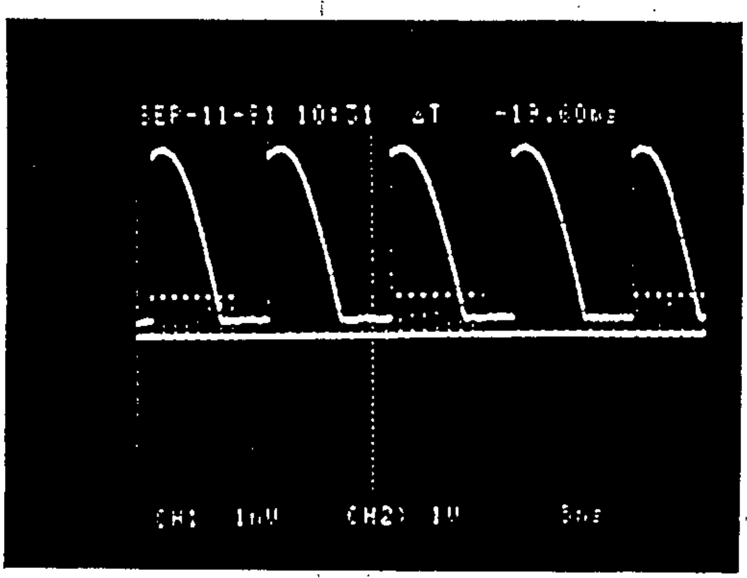


Fig 2.13 Output voltage waveform of a single phase controlled rectifier and the gating pulses for one pair of SCRs.

2.3 An alternative approach.

2.3.1 Introduction.

There are several alternatives by means of which the control signals may be generated. Such an alternative logic circuit for firing ac-ac or ac-dc single phase converter is described in this section. Here we have compared the a.c. signal to a variable d.c. voltage by an OPAMP (LM 741). If we increase the d.c. voltage the delay angle is decreased and if the dc voltage is decreased, the delay angle is increased. This method has the advantage of putting the system in the feedback control of dc motors and other devices.

2.3.2 Logic circuit design.

In earlier sections we have discussed the design and construction of the logic circuit for a voltage controller and a controlled rectifier by using one shot multivibrator circuit. The duration of one shot can be varied by varying the RC constant of the multivibrator. In such a circuit it is very difficult to have smooth variation of the delay duration. To avoid this situation we have designed a logic circuit for the same purpose by using variable dc voltage. Here we have achieved smooth variation of the deley angle.

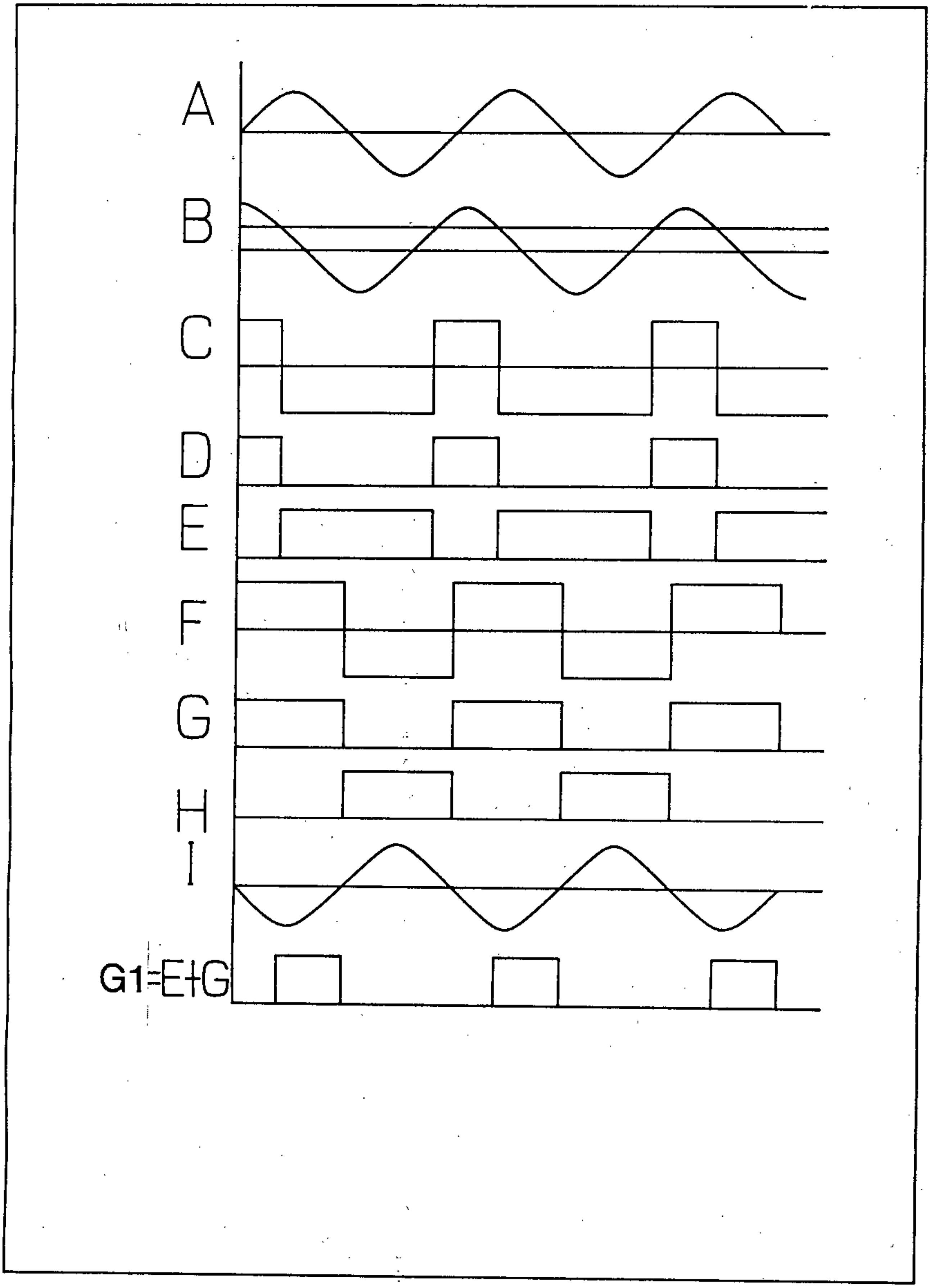


Fig 2.14 Timing diagram of the logic circuit of a single phase ac voltage controller and fullwave controlled rectifier.

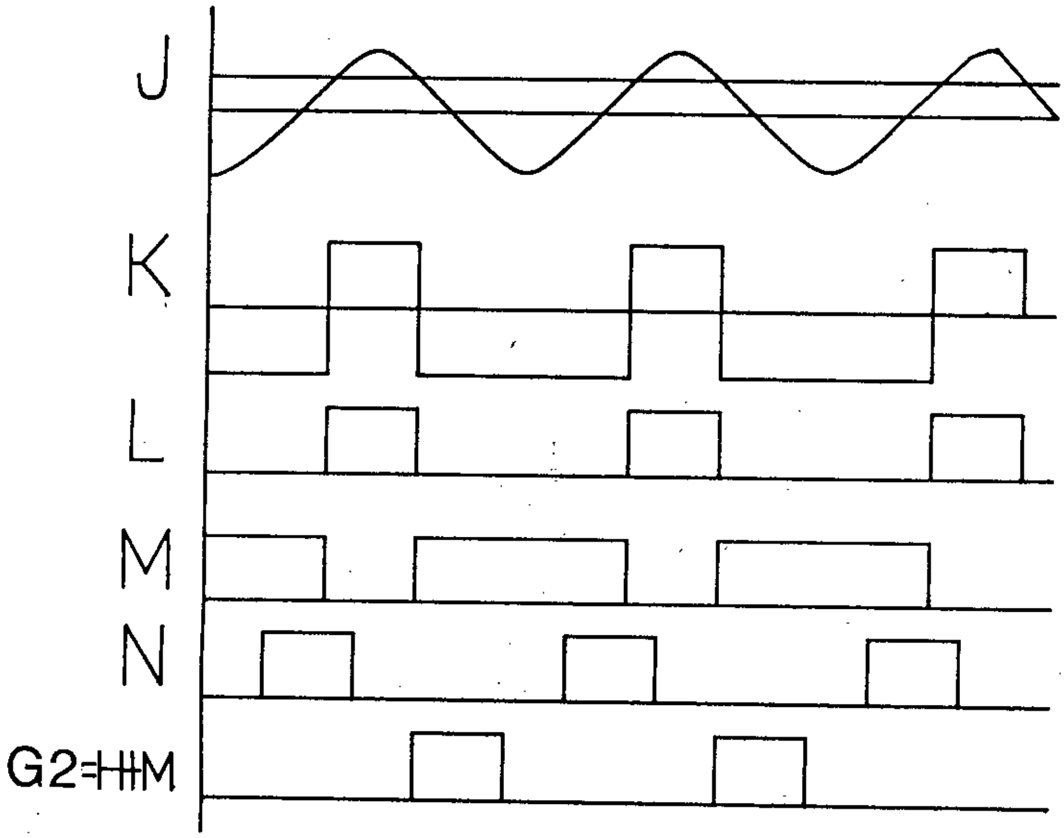


Fig 2.15   Continuation of Fig 2.14

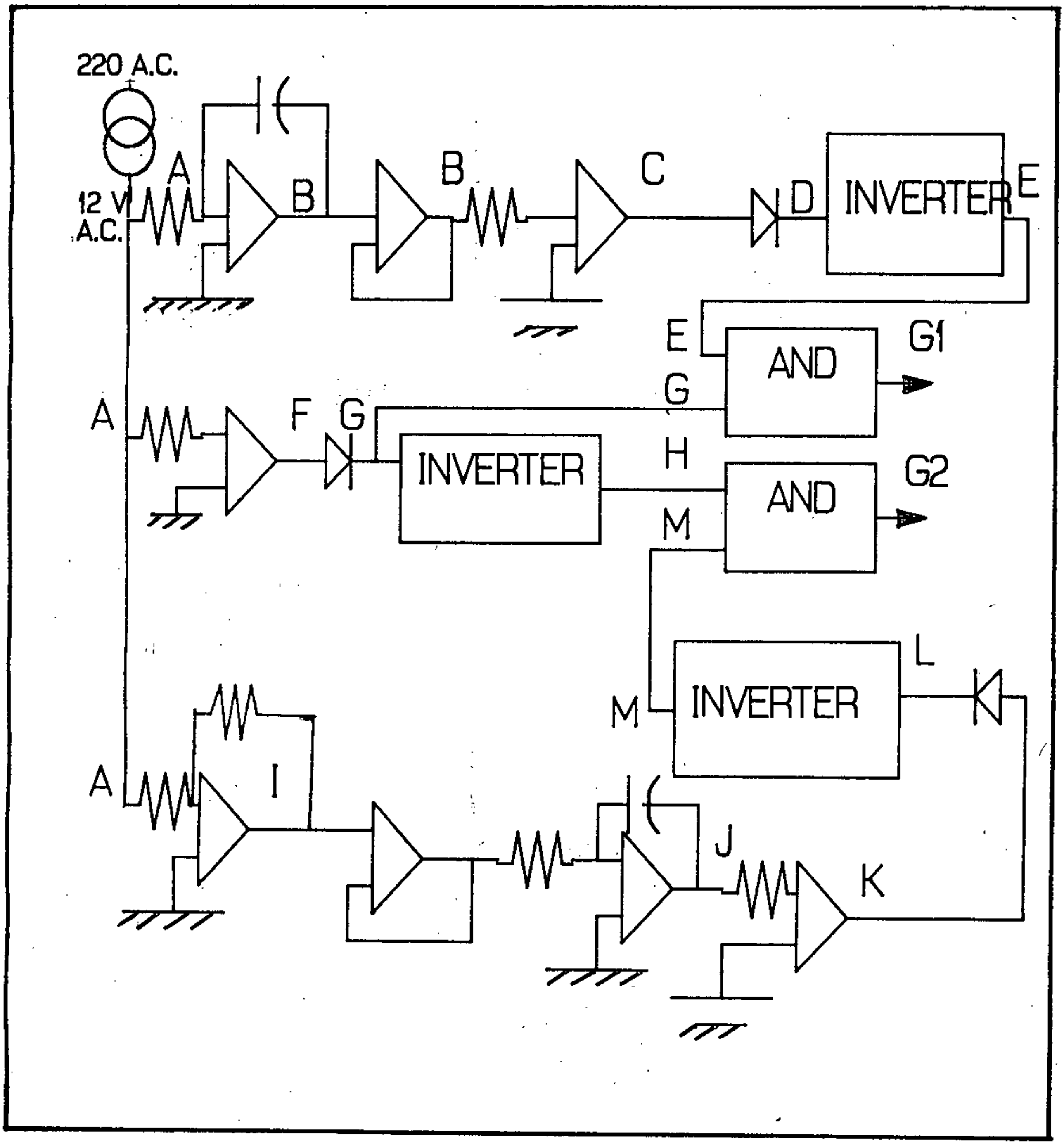


Fig 2.16 Block diagram of the logic circuit for a single phase ac voltage controller and single phase fullwave controlled rectifier.

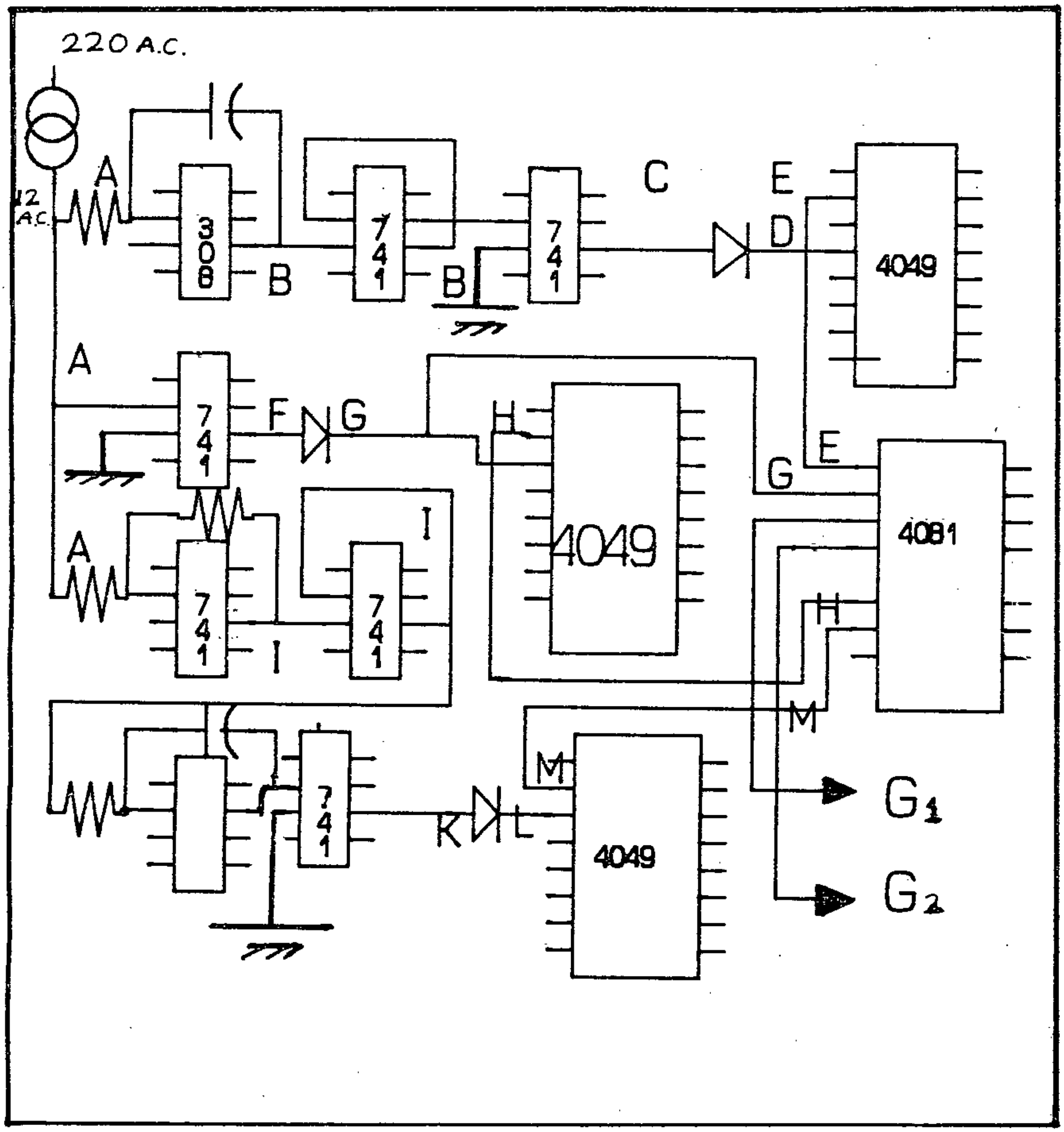


Fig 2.17 Practical circuit of a single phase ac voltage controller and single phase fullwave controlled rectifier.

2.3.3 Description of the practical circuit.

Description of the total circuit as shown in Fig 2.16 with respect to block diagram.

First the low voltage a.c. wave "A" is produced by using a 220/12 v. step down transformer from the main source. By integrating this signal, signal B is produced. Integration is made by OPAMP (LM 741). In this case a capacitor is introduced between the input and the output. Signal B is 90 degree phase shifted from signal A. This phase shifting signal B is compared to a variable D.C. voltage by OPAMP(LM 741) to obtain the square wave signal C. Signal D is produced after passing the signal C through a diode. Signal D is inverted by using HEX inverter (MC 4049) and we get signal E.

The square wave signal F is produced from signal A by using OPAMP(LM 741). Signal G is produced after passing the signal F through a diode. Signal G is inverted by using HEX inverter (MC 4049) and we get signal H.

Signal I is produced from signal A by using OPAMP(LM 741). Signal I is 180 degree phase shifted from signal A. By integrating this signal A, signal J is produced. Integration is made by OPAMP(LM 741). In this case a capacitor is introduced between the input and output. It is 90 degree phase shifted from signal I. This phase shifted signal J is compared to a variable D.C. voltage by OPAMP(LM 741) and a square wave signal K is produced. Signal L is produced after passing the signal K through a diode. Signal L is inverted by using HEX inverter (MC 4049) and we get signal M.

Then signal G_1 is produced by using Quadruple AND (MC 4081) with signals E and G at its input pins and also G_2 is produced by using MC 4081 with signals H and M as inputs.

Variation of D.C. voltage of the OPAMP (LM 741), the delay angle of the gating signals would be varied.

CHAPTER - 3

SINGLE PHASE INVERTER LOGIC CIRCUIT.

3.1 Using one shot multivibrator.

3.1.1 Introduction

Inverters convert dc power to ac power at some desired output voltage and frequency. The output voltage could be fixed or variable at a fixed or at a variable frequency. A variable output voltage can be obtained by varying the input dc voltage. On the other hand if the dc input voltage is fixed and it is not controllable a variable output voltage can be obtained by varying the gain of the inverter. The inverter gain may be defined as the ratio of the ac output voltage to dc input voltage.

The output voltage waveforms of ideal inverters should be sinusoidal. However, the waveforms of practical inverters are nonsinusoidal and contain harmonics. For low and medium power applications, square wave or quasi-square wave voltages may be acceptable but for high power applications sinusoidal waveforms of low distortion are required.

In solid state inverters both transistorized and thyristor circuits are used. Thyristor(SCR) circuit take precedence where high power is involved. However, other criteria being equal there is a general preference for the use of transistors. This is primarily because no extra commutation circuits are necessary in the transistor circuits. SCR circuits perform well where commutation can be successfully implemented and maintained. At present SCRs have greater power handling capability and have wide applications in inverters of high power ratings.

According to the need of applications various controls and modifications are incorporated in the basic inverter circuit. One of the most versatile control techniques is the pulse width modulation (PWM) technique.

An inverter is called a voltage-source inverter (VSI) if the input voltage remains constant or a current-source inverter(CSI) if the input current is maintained constant.

Inverters are used typically in drive systems to provide power for adjustable frequency ac motors, to regenerate energy back to ac line from decelerating dc motors and to pump rotor power back to ac line from wound rotor induction motors. In non drive systems, these are used to supply uninterruptible ac power to computers and to convert energy between ac and dc at the terminal of high voltage dc power transmission line. Inverters are also used for standby power supplies and for induction heating, etc.

This chapter describes the operation of a single phase inverter (Power module) and the design and construct procedure to build a logic circuit which will generate the gating signal for controlling the single phase inverter. The procedure discussed includes the timing diagram, block diagram, practical circuit and power supply circuit.

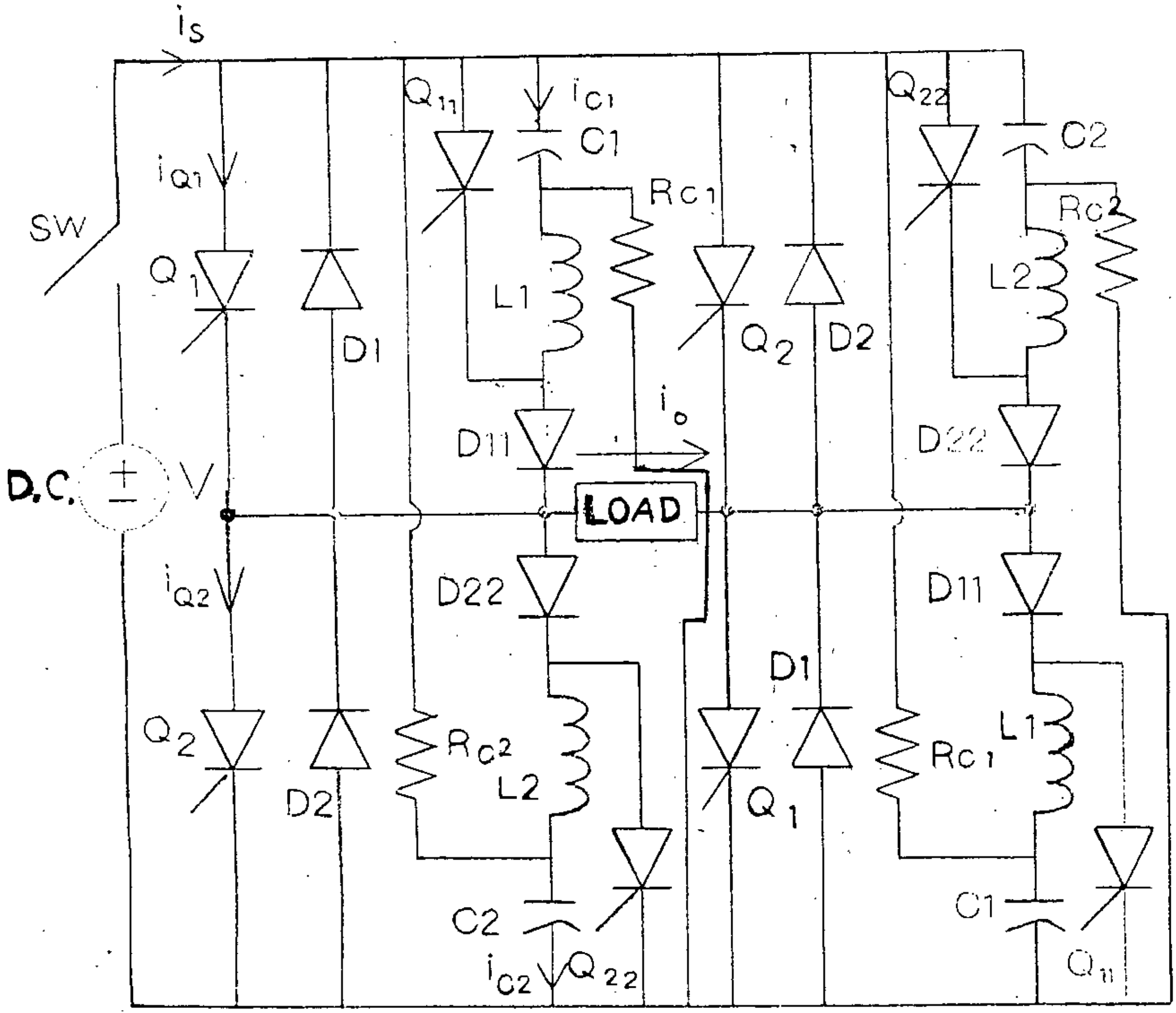


Fig 3.1 Single phase SCR inverter.

Description of the single phase inverter:

The sequence of operation for the entire circuit (as shown in Fig 3.1) is as follows :

1. The inverter is connected to the source by closing the switch SW and all capacitors C_1, C'_1, C_2, C'_2 are charged up to V_C = V volts via R_C resistors.

2. At t = 0, when the capacitor C_1 and C'_1 are fully charged, SCRs Q_1 and Q'_1 are turned ON and load current increases exponentially from zero to I_{max}.

3. At $t = t_{ON}$, SCRs Q_{11} and Q'_{11} are turned ON initiating the commutation cycle and two oscillatory currents flow in the two ringing circuits C_1, L_1, Q_{11} and C'_1, L'_1, Q'_{11}. i_{C1} and i'_{C1} are initially negative. It is assumed that i_0 remains sensibly constant at the value I_{max} throughout the commutation interval. It is also assumed that R_{C1} and R'_{C1} are sufficiently large to permit i_{RC1} and i'_{RC1} to be neglected in the analysis of the commutation circuit but is yet small enough to permit V_c to decay to the value V before the next commutation cycle is initiated.

4. After some time i_{C1} and i'_{C1} reverse in direction and Q_{11} and Q'_{11} turn OFF. Capacitor currents now flow through diodes D_{11} and D'_{11} and since the voltage across the SCRs Q_1 and Q'_1 are zero, the oscillatory elements continue to be short circuited. For this part i_{C1} and i'_{C1} may be considered to flow in a negative direction through Q_1 and we get $i_{Q1} = i_0 - i_{C1}$, and $i'_{Q1} = i_0 - i'_{C1}$. Since i_0 is assumed constant, i_{C1} and i'_{C1} reduces i_{Q1} and i'_{Q1} respectively.

5. When i_{Q1} and i'_{Q1} are reduced to zero by the increasing value of i_{C1} and i'_{C1} diodes D_1 and D'_1 begins to conduct and the forward voltage drop across this diode commutates SCR Q_1.

6. The oscillatory cycle of i_c is completed and i_c becomes zero.

7. i_0 decays exponentially and simultaneously V_C decays through R_c to $V_c = v$.

8. At $t = T/2$, when $i_0 = I_{min}$, Q_2 and Q'_2 are turned ON and the above sequence of operation are repeated.

3.1.2 Logic circuit design.

Requirements of the logic circuit :

From the preceding section it is obvious that to operate the SCRs of a inverter, besides producing the main SCR signals, it is necessary to follow the procedures outlined below,

1. Main gating signals of variable pulse widths are generated.

2. Proper time OFF between main SCRs are necessary.

3. Commutation signals at proper time has to be generated.

4. Since the SCRs are transformer isolated from the logic circuit, high frequency modulation is necessary of the main SCR signals.

5. Amplifiers to convey the signals to the main and the commutation SCRs are necessary.

The signal as outlined above can be generated by digital circuits as shown in the timing diagram below (the main oscillator signal has been used from a function generator).

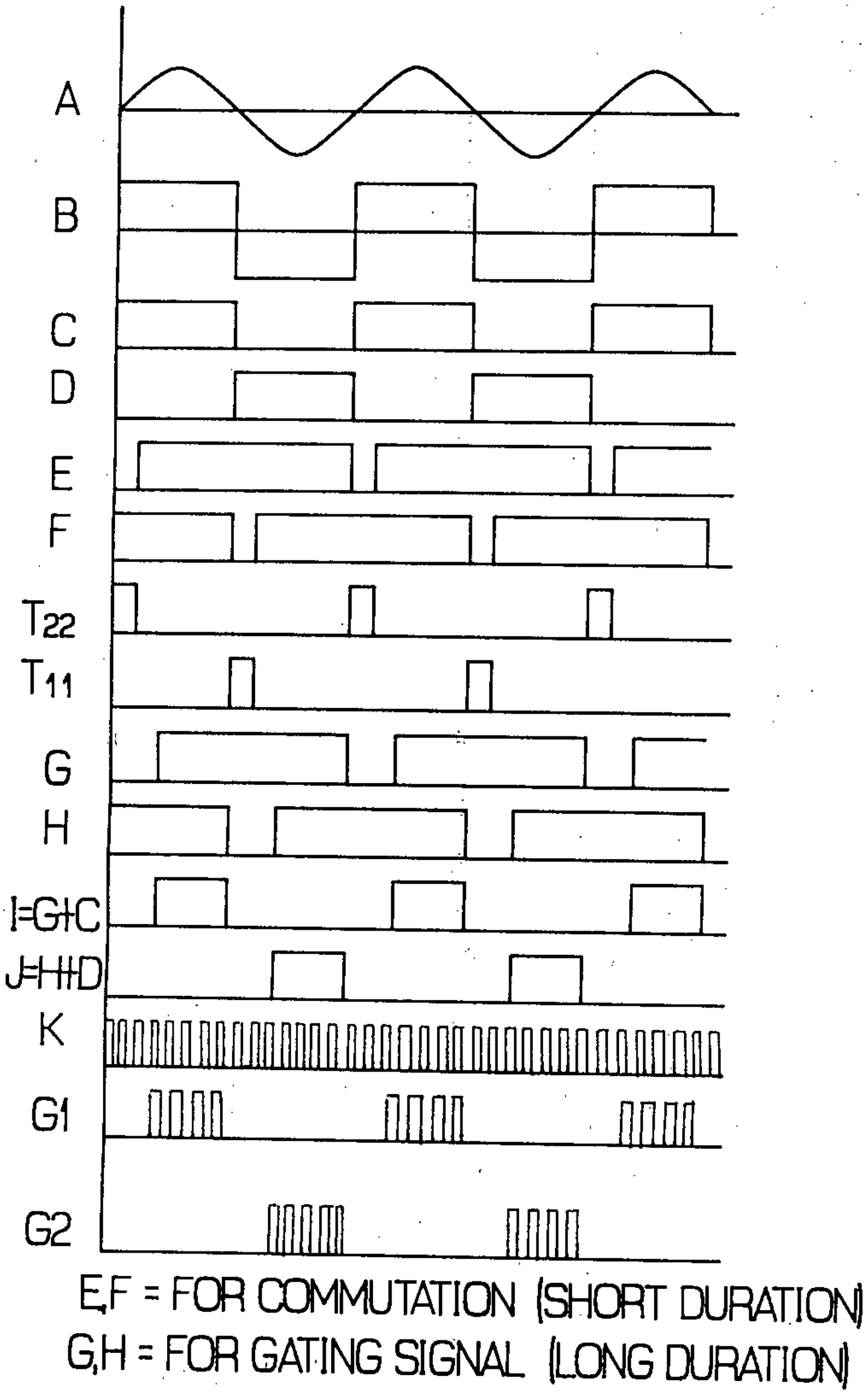


Fig 3.2 Timing diagram of inverter logic circuit (using one shot)

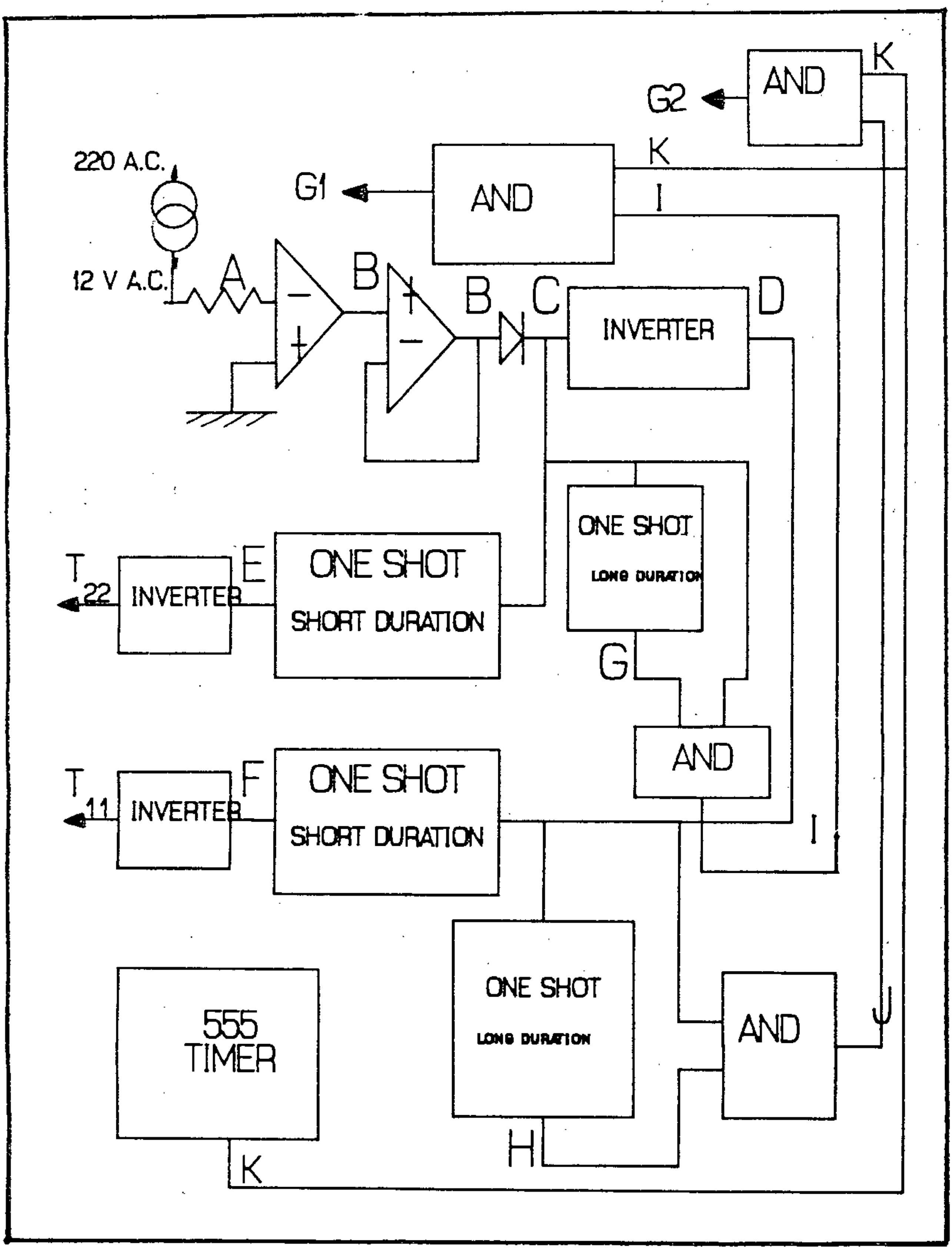


Fig 3.3 Block diagram of inverter logic circuit (using one shot)

(Fixed frequency inverter logic with f = 50 HZ)

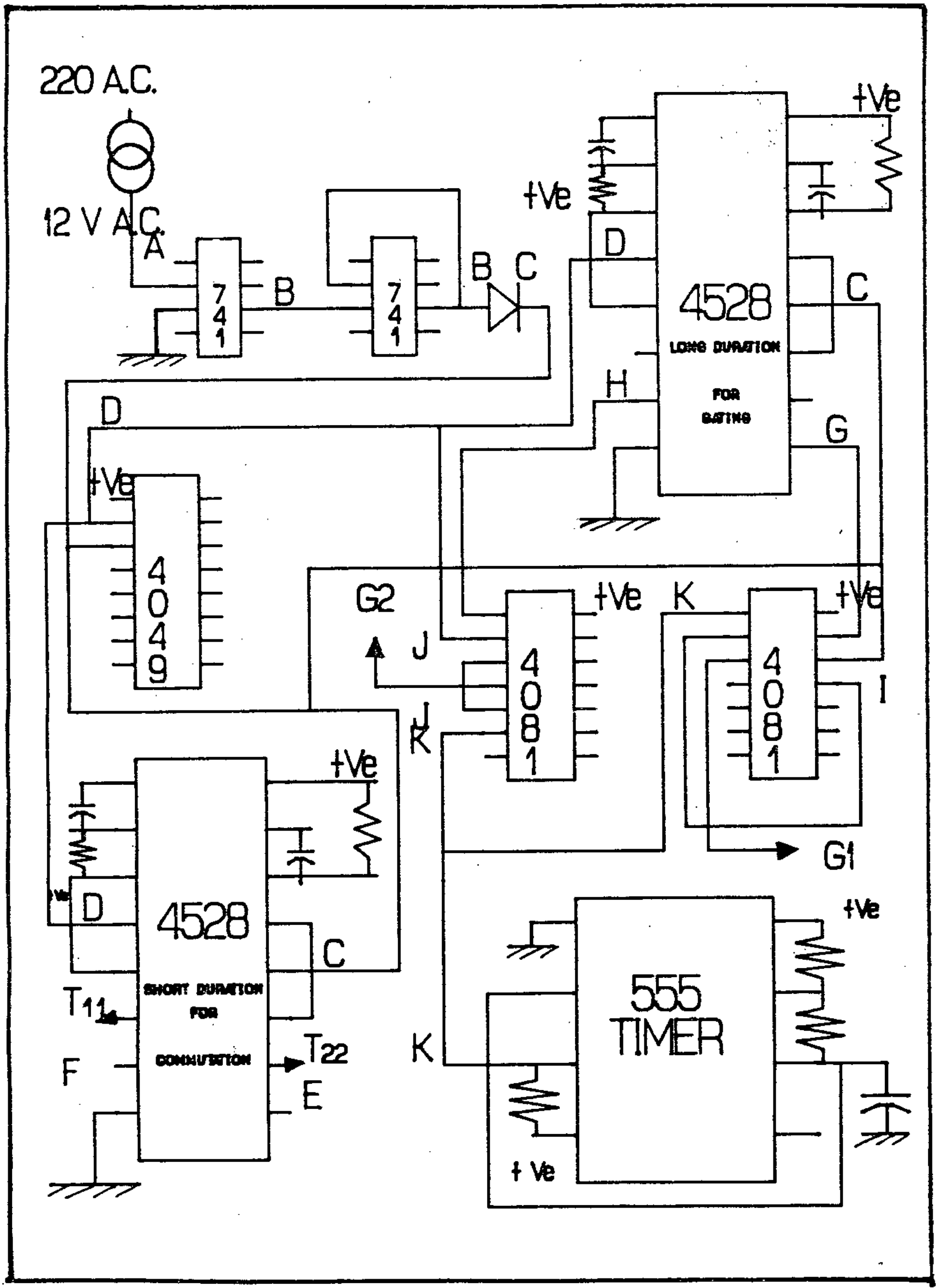


Fig 3.4 Practical circuit of inverter logic circuit (using one shot)

3.1.3 Description of the practical circuit.

Description of the total circuit as shown in Fig 3.4 with respect to block diagram.

A low voltage a.c. signal A from fuction generator is used as reference signal. Then the square wave signal B is produced by using OPAMP (LM 741). Signal C is produced by passing signal B through a diode. Signal C is inverted using HEX inverter (MC 4049) to obtain signal D. Signal C is used as an input of the dual one shot multivibrator (MC 4528) to produce signal E. Signal D is also used as the input of the dual one shot multivibrator to produce signal F. The inverted output of signal E and F from this one shot multivibrator (MC 4528) is the commutation signals T_{11} and T_{22}. The duration of commutation signal is small. T_{11} and T_{22} can be taken from the pin number 6 and 10.

Again signal C and D is used as inputs of dual one shot multivibrator to produce signal G and H. The duration of this one shot is longer than commutation signal. Signal I is produced by using Quadruple AND (MC 4081) with signals G and C at its input pins. Similarly signal J is produced by using MC 4081 with signals H and D as input signals.

Signal K is produced by using (MC 555) timer. Now Quadruple AND(MC 4081) is used with signals I and K at its input pins to produce signal G_1. Similarly signals J and K are used to produce signal G_2. High frequency ANDing was necessary because isolation transformers were used for isolating logic signal from the power side of the converters.

3.2 By using cosine firing angle.

3.2.1 Logic circuit design.

The cosine firing angle scheme described in previous chapters for voltage controllers can also be used for generating logic signals to drive inverters of fixed frequency operation. Such operations may be necessary for UPS and similar systems. The details of such a scheme is described in the following sections.

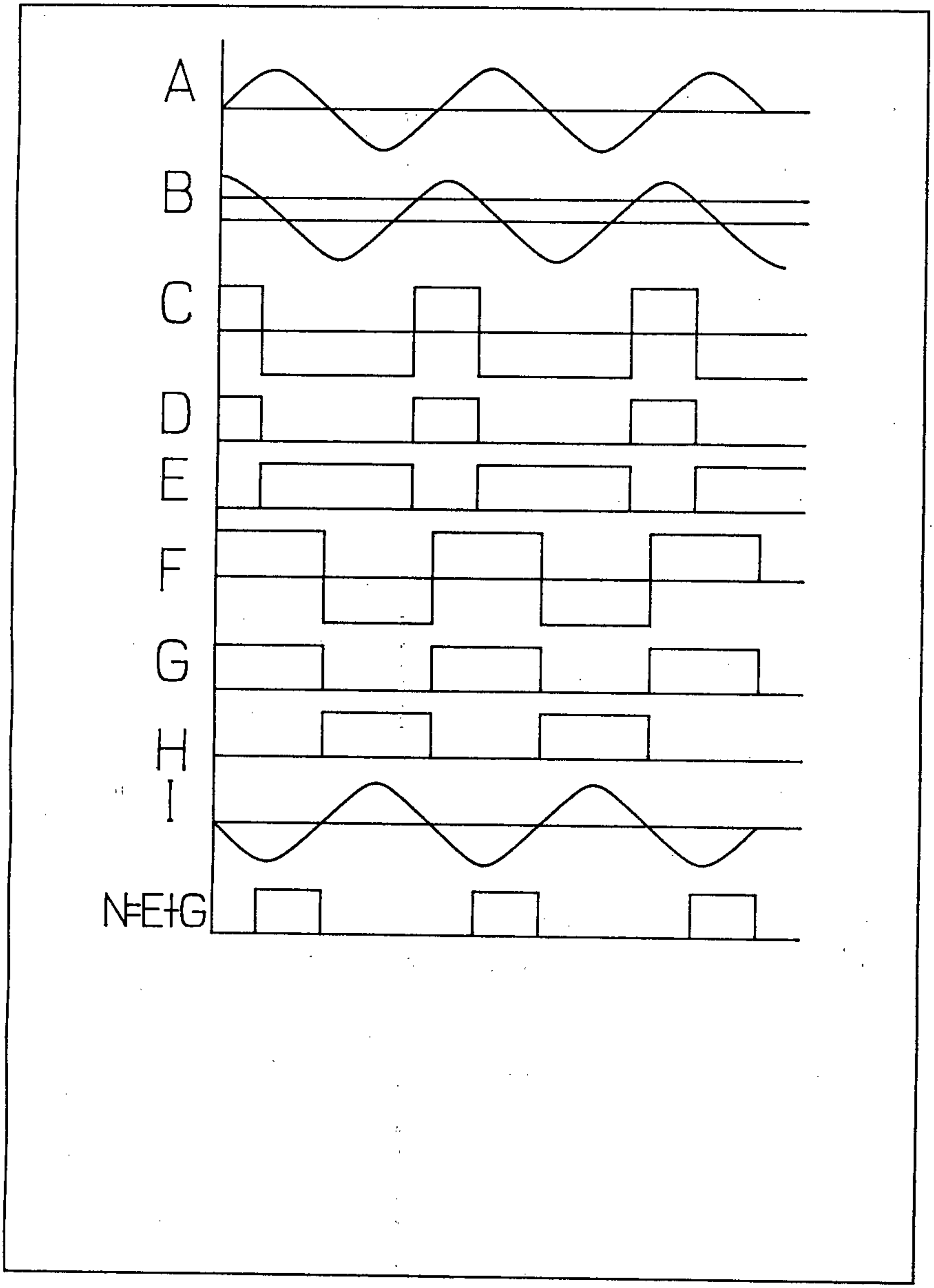


Fig 3.5 Timing diagram of inverter logic circuit (cosine firing angle)

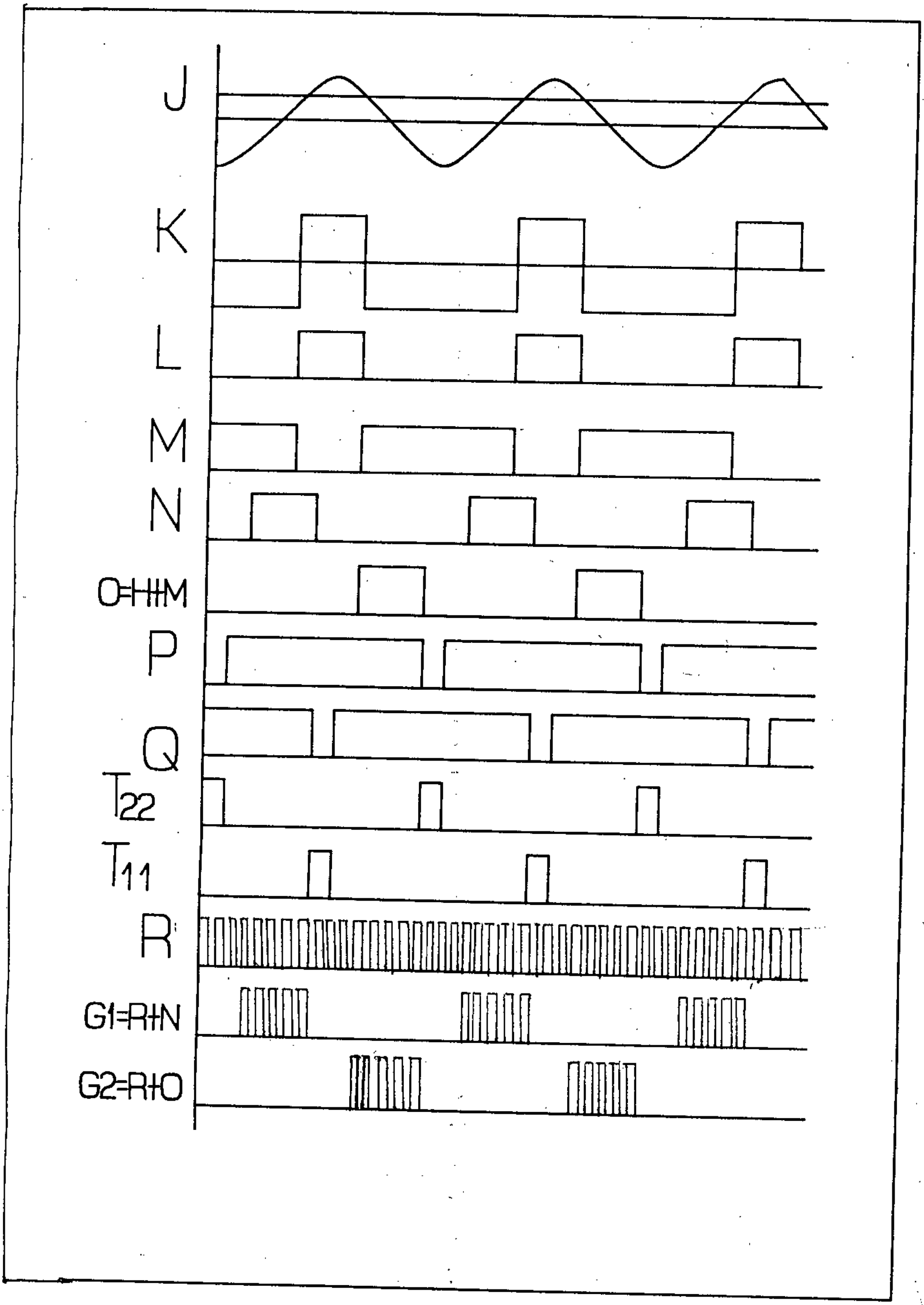


Fig 3.6 Continuation of Fig 3.5

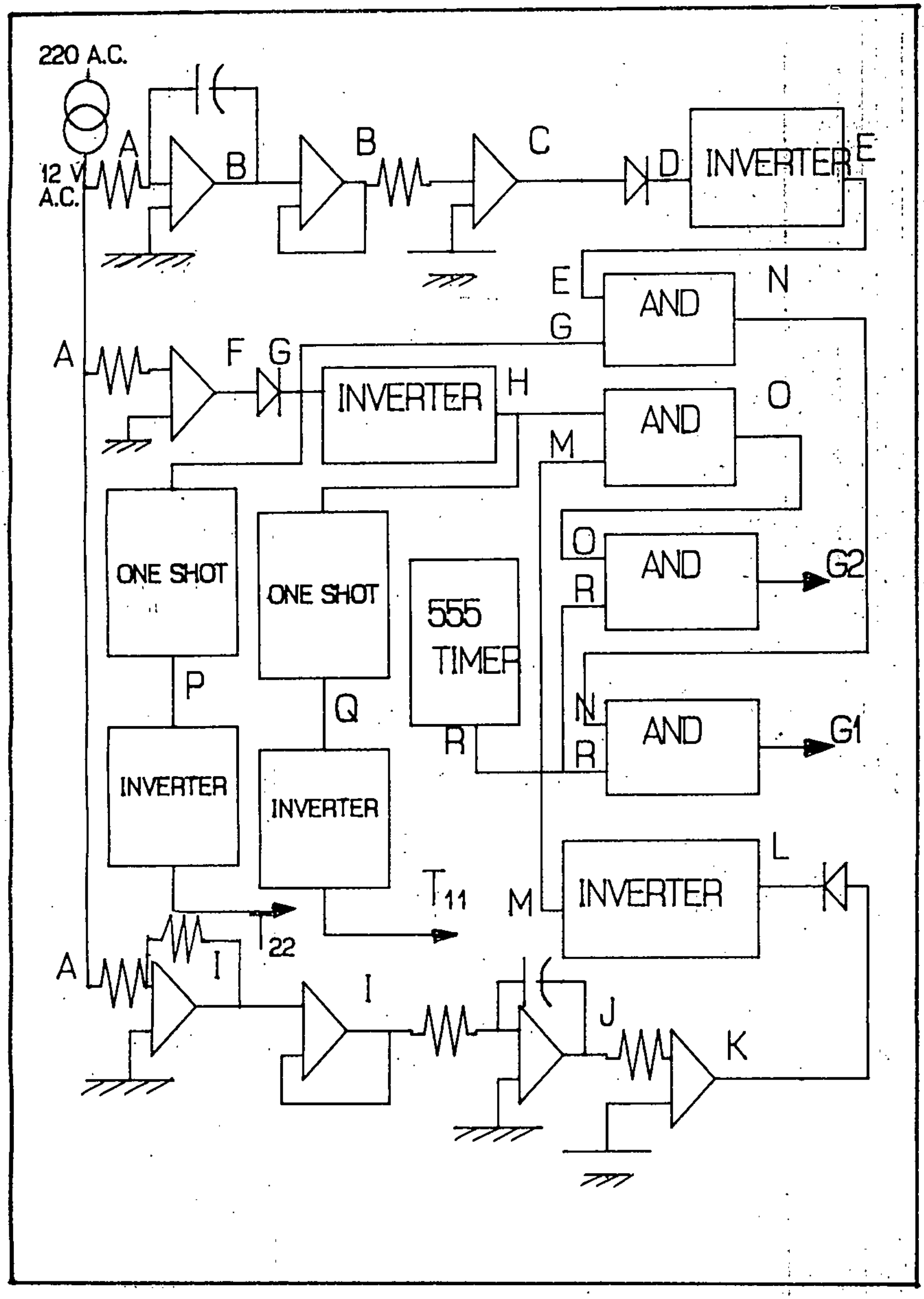


Fig 3.7 Block diagram of inverter logic circuit (cosine firing angle)

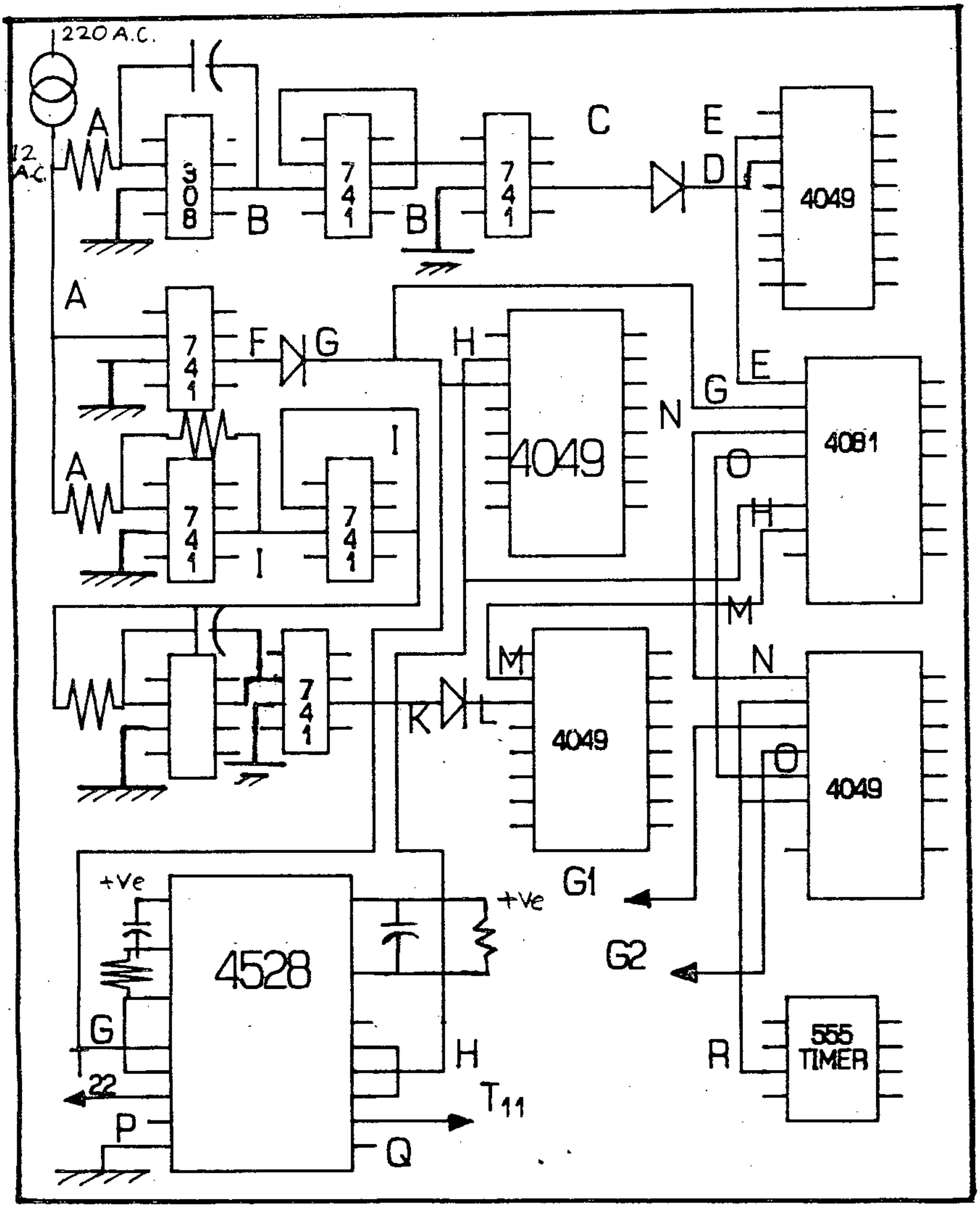


Fig 3.8 Practical circuit of inverter logic circuit (cosine firing angle)

3.2.2 Description of the practical circuit.

Description of the total circuit as shown in Fig 3.8 with respect to block diagram is as follows.

First the low voltage a.c. wave A is produced by using a 220/12 v. step down transformer from the main source. By integrating this signal A, the signal B is produced. Integration is made by OPAMP (LM 741). In this case a capacitor is introduced between the input and output "B" is 90 degree phase shifted from signal A. This phase shifted signal B is compared to a variable D.C. voltage by OPAMP(LM 741), square wave signal C is produced. Signal D is produced by passing the signal C through a diode. Signal D is inverted by using HEX inverter (MC 4049), signal E is produced.

The square wave signal F is produced from signal A by using OPAMP(LM 741). Signal G is produced after passing the signal F through a diode. Signal G is inverted by using HEX inverter (MC 4049) and we get signal H.

Signal I is produced from signal A by using OPAMP(LM 741). Signal I is 180 degree phase shifted from signal A. By integrating this signal I, signal J is produced. Integration is made by OPAMP(LM 741). In this case a capacitor is introduced between the input and the output. It is 90 degree phase shifted from signal I. This phase shifted signal J is compared to a variable D.C. voltage by OPAMP(LM 741), square wave signal K is produced. Signal L is produced after passing the signal K through a diode. Signal L is inverted by using HEX inverter (MC 4049) and we get signal M.

Then signal N is produced by using Quadruple AND (MC 4081) with signals E and G at its input pins and also O is produced by using MC 4081 with signals H and M.

Signal G is used as an input of dual one shot multivibrator (MC 4528) to produce signal P and also signal H is used as input of dual one shot multivibrator to produce signal Q. The inverted output of signal P and Q from this one shot multivibrator (MC 4528) is the commutation signals T_{22} and T_{11}. The duration of the commutation signal is very short. T_{11} and T_{22} can be taken from the pin number 6 and 10.

Signal R is produced by using IC (MC 555) timer circuit. Quadruple AND (MC4081) is used with signals N and R at its input pins to produce signal G_1 and also with signals O and R at its input pins to produce signal G_2.

3.2.3 Experimental results of inverter (pulse width modulated)

The logic circuit which has been built for the inverter was also tested to run the dc-ac converter. The waveforms of the output voltage of the converter with resistive load and the associated gating signals are shown in Figs 3.9, 3.10, 3.11, and 3.12.

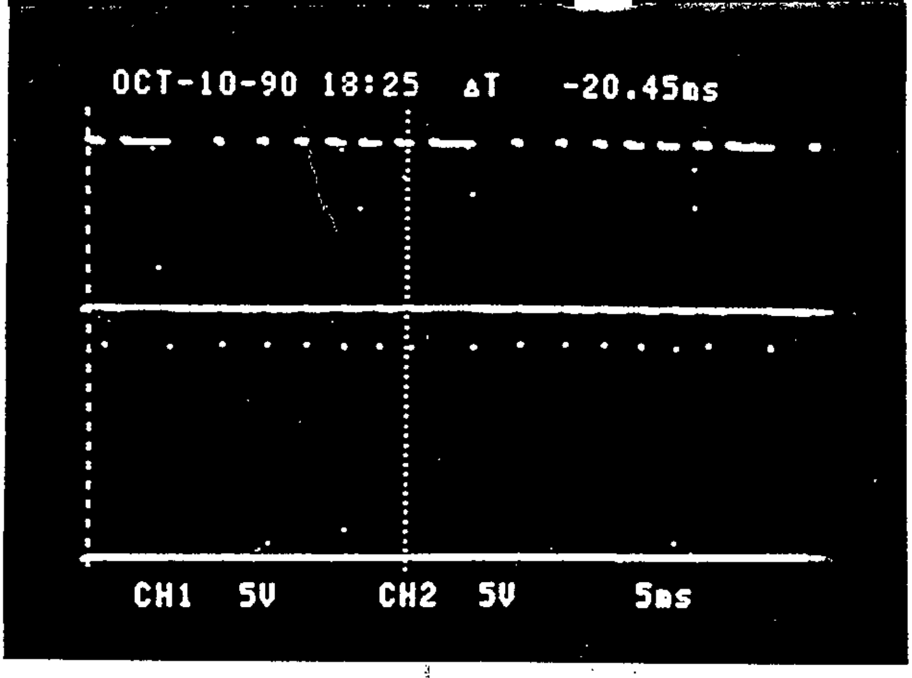


Fig 3.9 Main and corresponding commutation signals of a one pair of SCRs of a single phase pwm inverter.

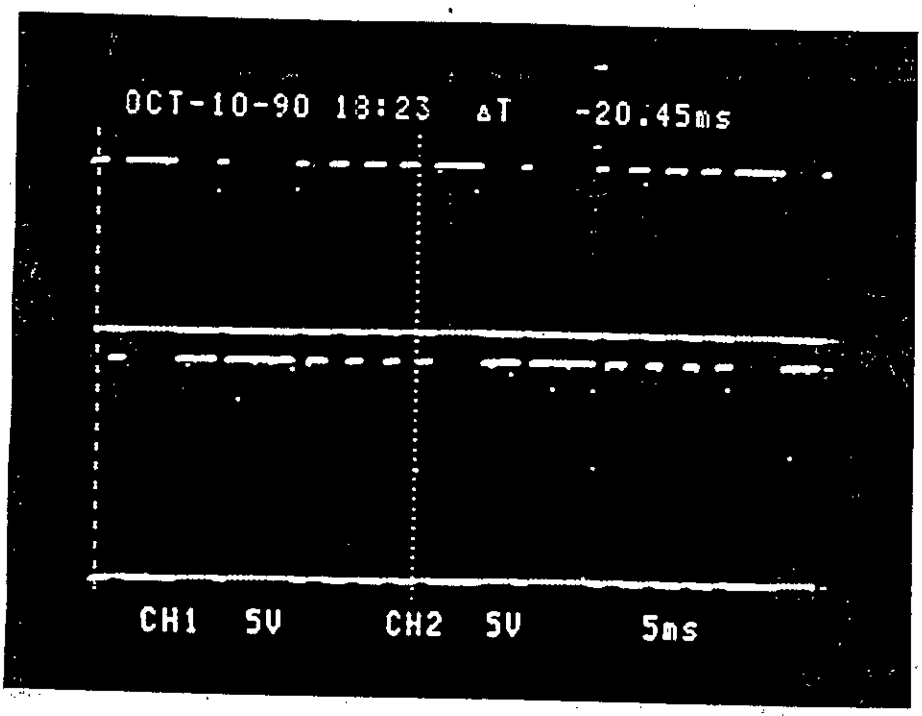


Fig 3.10 The main firing signals of SCRs of a of a single phase pwm inverter.

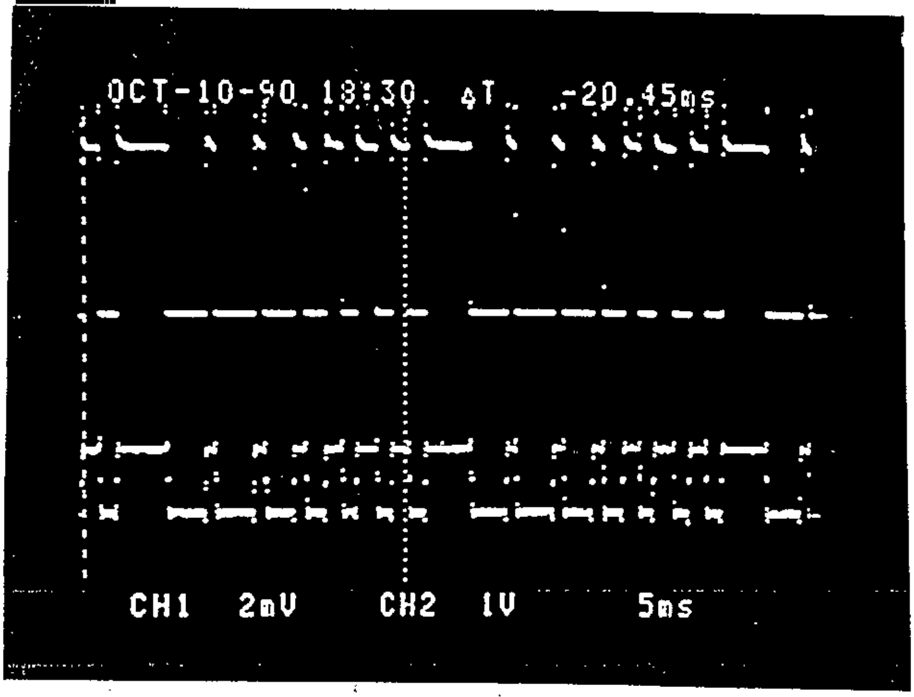


Fig 3.11 The output voltage and input current waveshapes of a single phase pwm inverter.

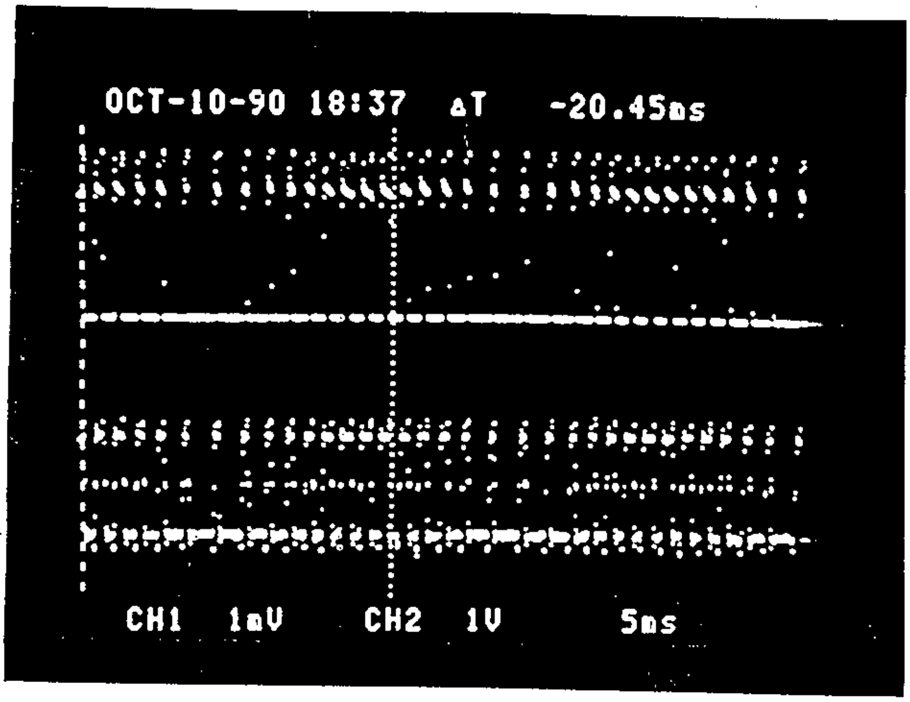


Fig 3.12 The output voltage and input current waveshapes of a single phase pwm inverter for a different frequency of operation.

CHAPTER - 4

SINGLE PHASE CYCLOCONVERTER AND PHASE SHIFT CIRCUIT.

4.1 Introduction

Cycloconverters are converters which convert ac to ac for variable voltage and frequency. Two phase-controlled rectifier connected as dual converters can be operated as direct frequency changers known as cycloconverters. These converters in general have the following features,

a) Due to the elimination of one or more converters needed to provide an intermediate d.c. link ,they are more efficient.

b) In most cases, output voltage control is inherent in the converter.

c) Line or load commutation is normally employed. With the development of fast switching power devices,the force commutation of cycloconverters is possible.

d) Input power factor correction and harmonic reduction are usually necessary.

The principle of operation of single-phase to single phase cycloconverters can be explained with the help of Fig 4.1 [1 (one)]. The two single-phase controller are operated as bridge rectifiers. However,their delay angle are such that the output voltage of one converter is equal and opposite to that of the other converter. If converter P is operated alone, the output voltage is positive and if converter N is operating alone, the output voltage is negative. Fig 4.1(b) shows the waveforms for output voltage and gating signals of

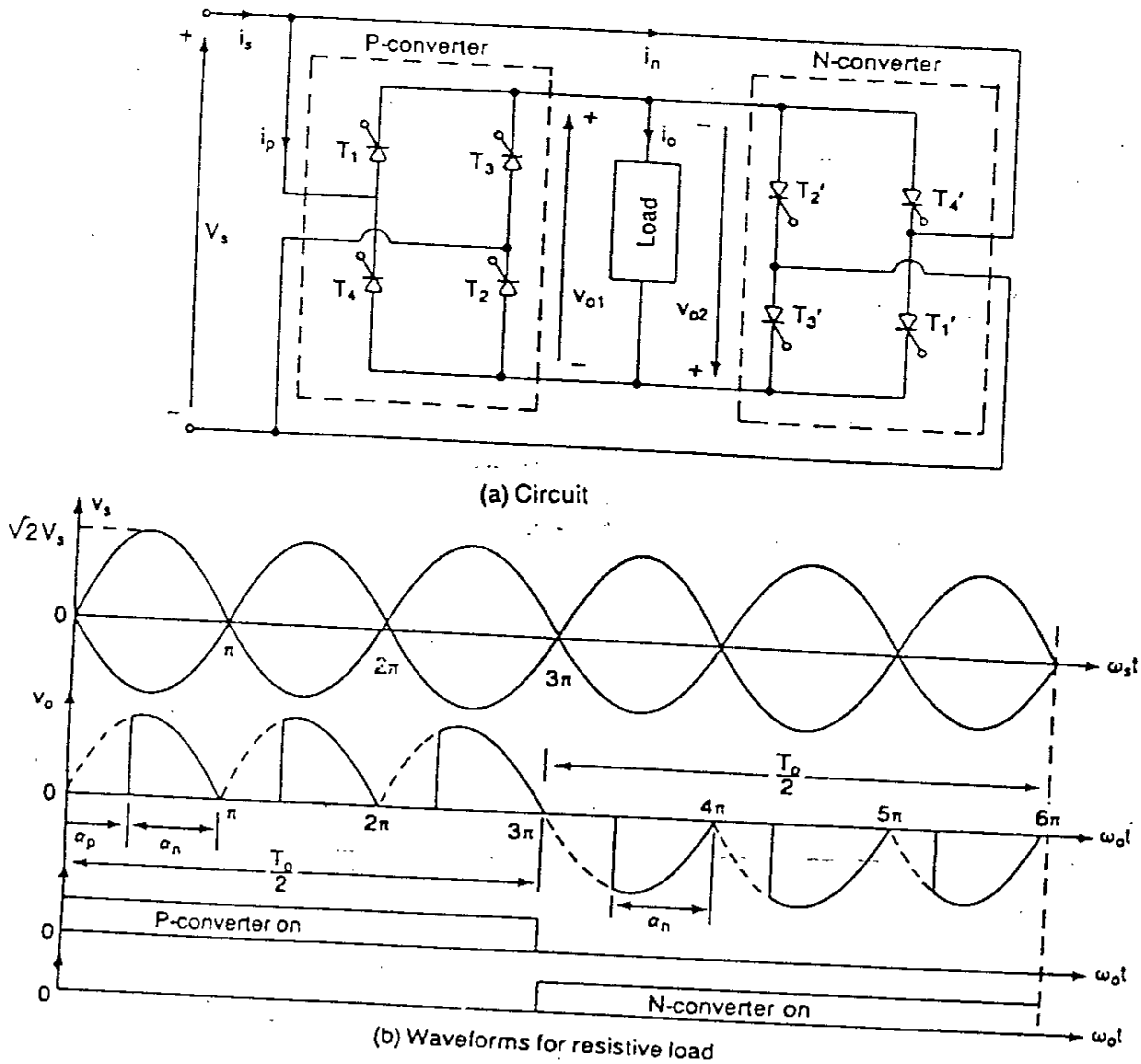


Fig 4.1 Single-phase cycloconverter.

positive and negative converters, with the positive converter ON for time $T_0/2$ and the negative converter ON for the time $T_0/2$. the frequency of the output voltage is $f_0 = 1/T_0$.

If α_p is the delay angle of positive converter,the delay angle of negative converter is $\alpha_n = \pi - \alpha_p$. The average output voltage of the positive converter is equal and opposite that of the negative converter

$$v_{02} = - v_{01}$$

4.2 Logic circuit design.

Logic circuit for phase shift circuit have also designed by the basic principle of the logic circuit of a.c. voltage controller and controlled rectifier. Such operations may be used for starting single phase motor and similar operations.

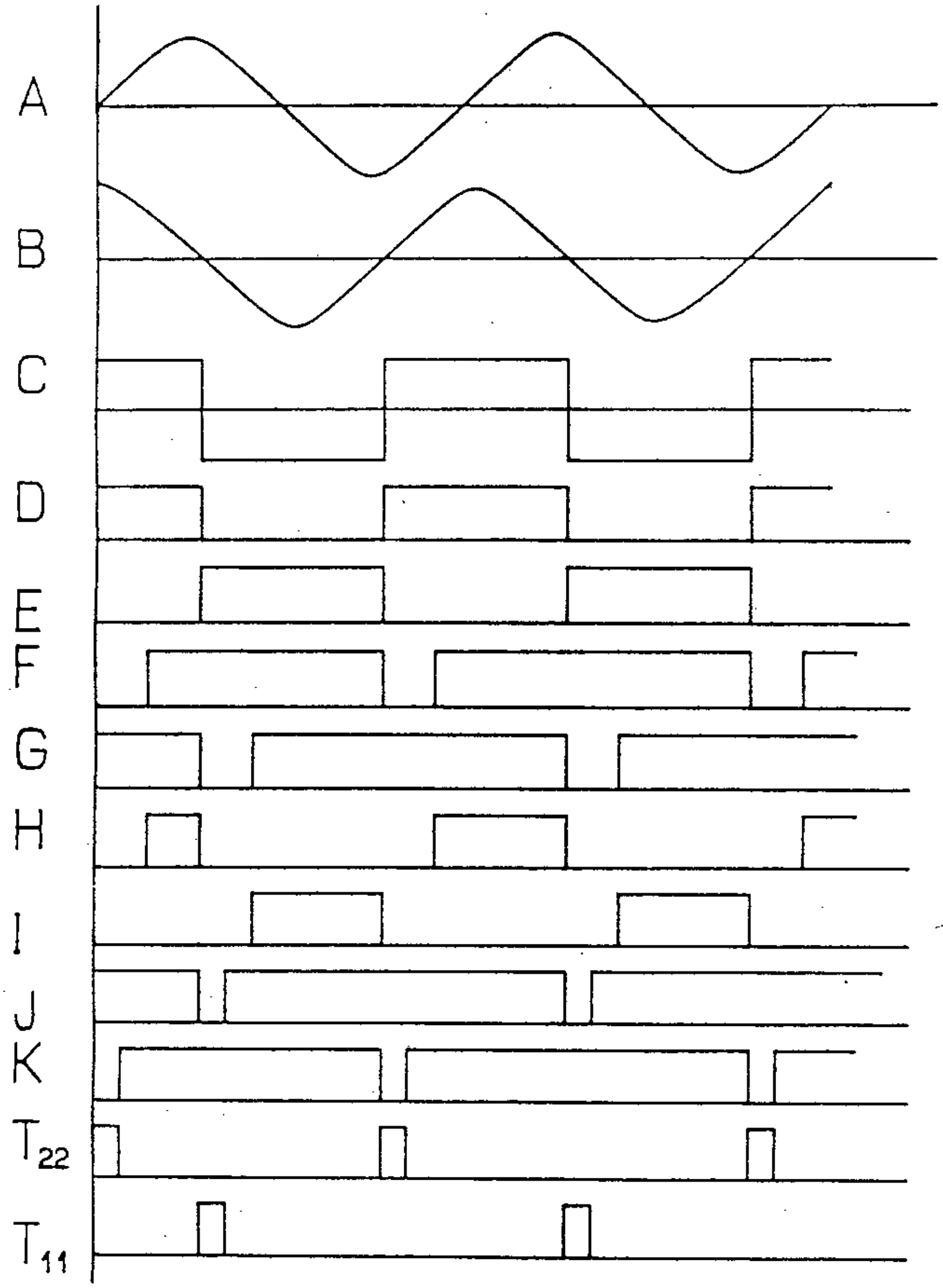


Fig 4.2 Timing diagram of a logic circuit of the **phase** shift circuit.

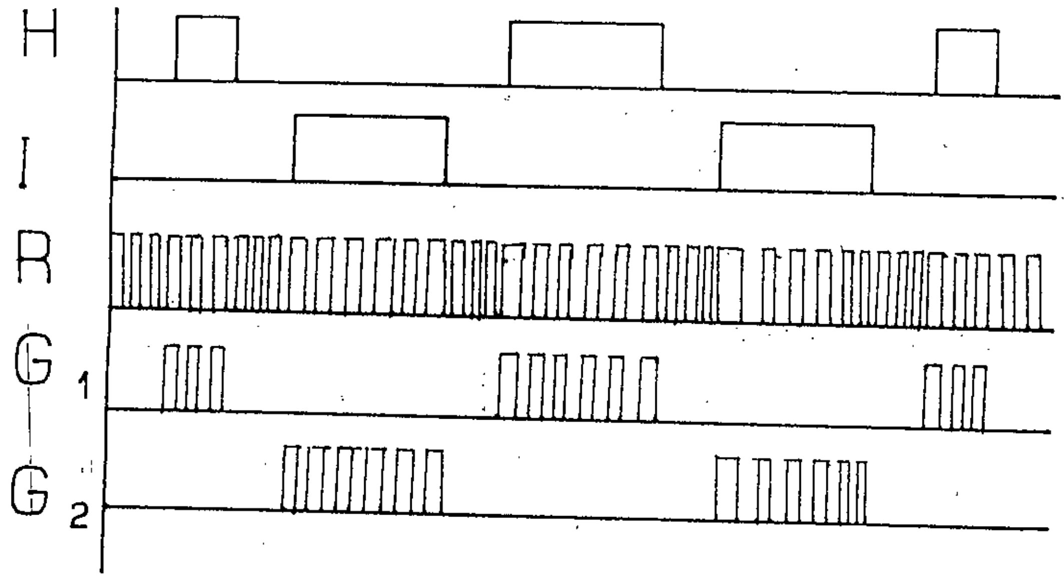


Fig 4.3 Continuation of Fig 4.2.

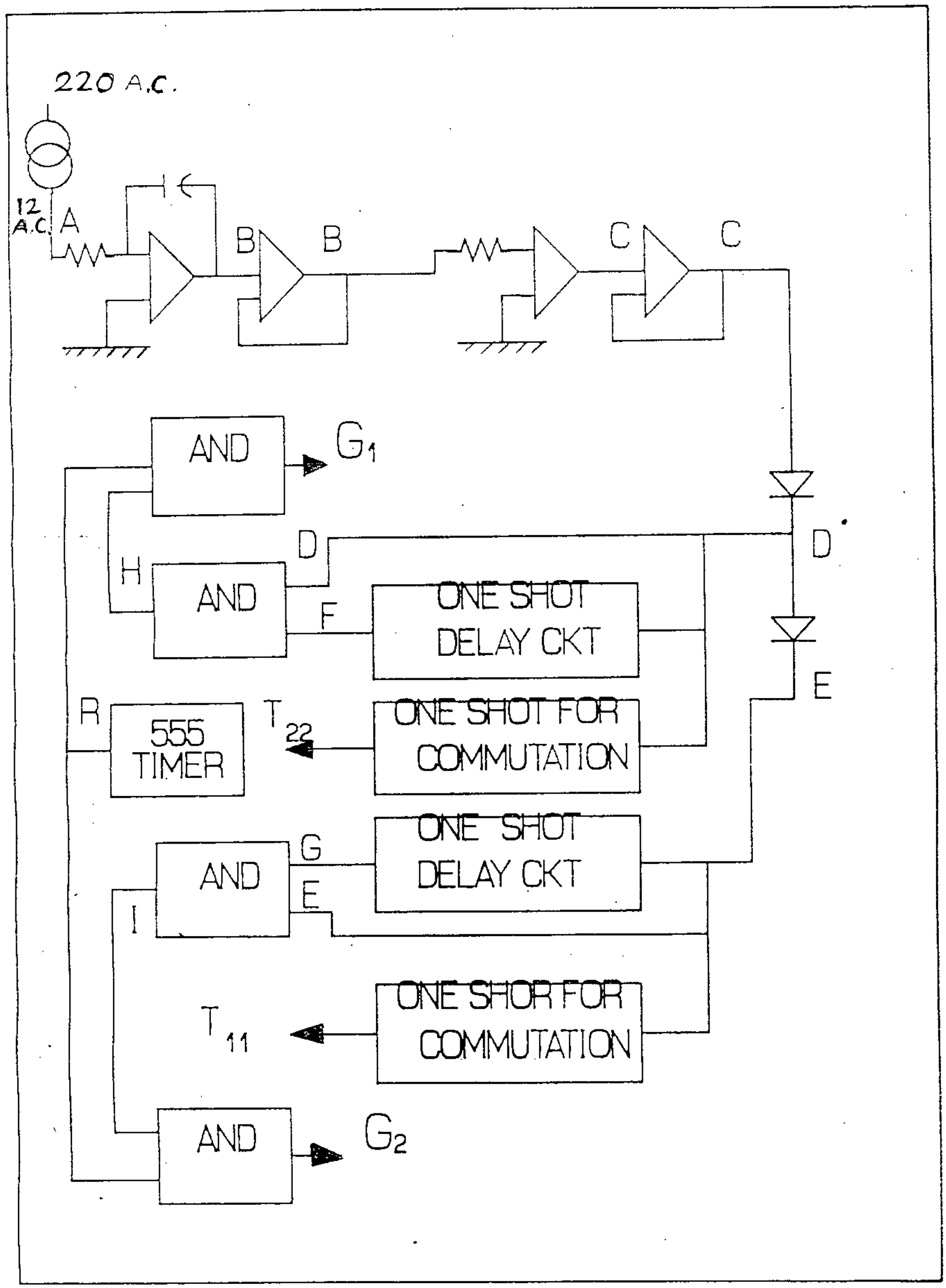


Fig 4.4 Block diagram of the logic circuit of the phase shift circuit.

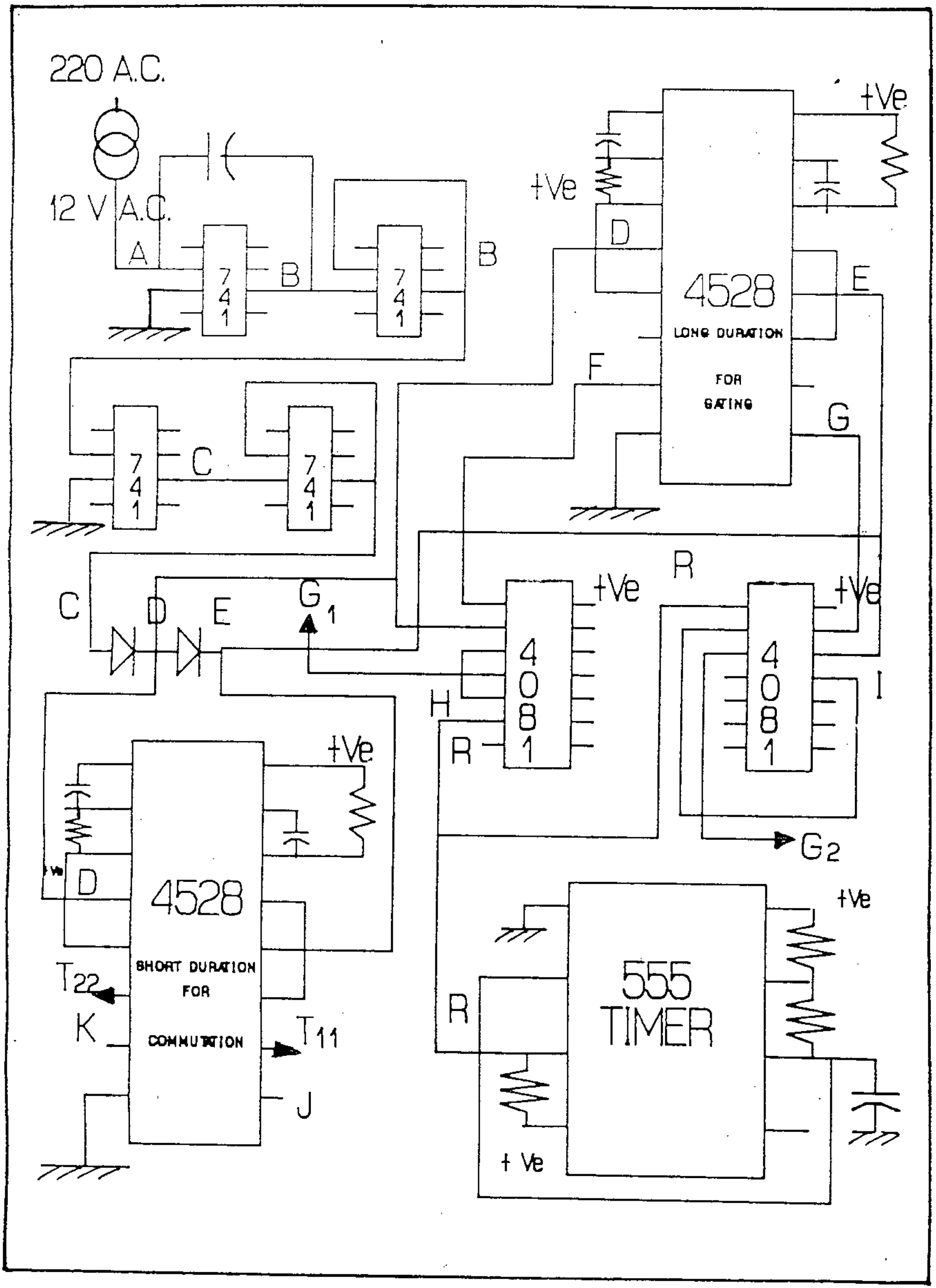


Fig 4.5 Practical circuit of the logic circuit of the phase shift circuit.

4.3 Experimental results of phase shift circuit.

The logic circuit which has been built for the phase shift circuit was also tested to run the ac-ac converter. The waveforms of the output voltage of the converter with resistive load and the associated gating signals are shown in Figs 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, and 4.12.

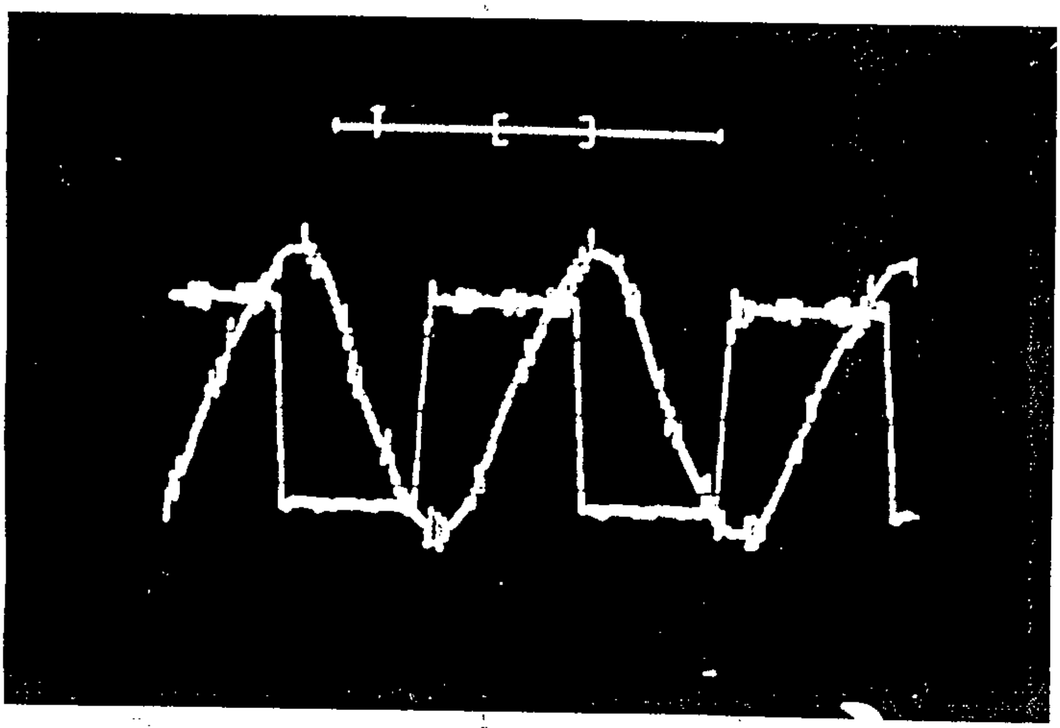


Fig 4.6 Reference sine wave and the phase shifted gating signal of the phase shift circuit.

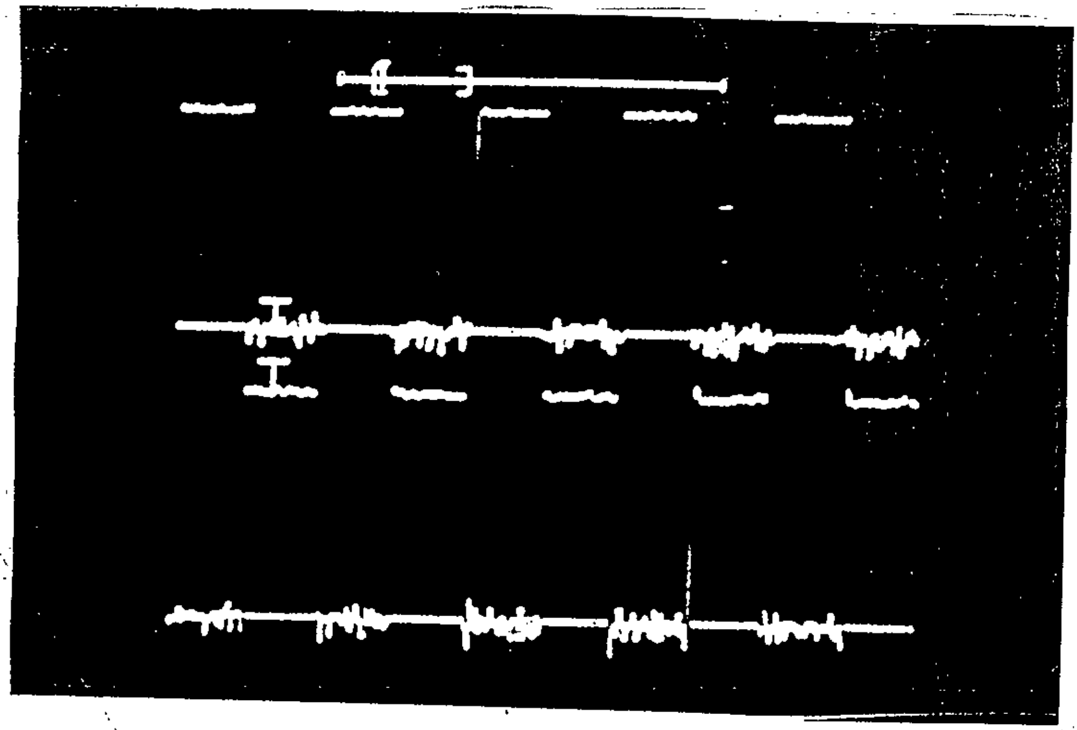


Fig 4.7 The gating signals of the SCRs for phase shift circuit (and also for cycloconverter).

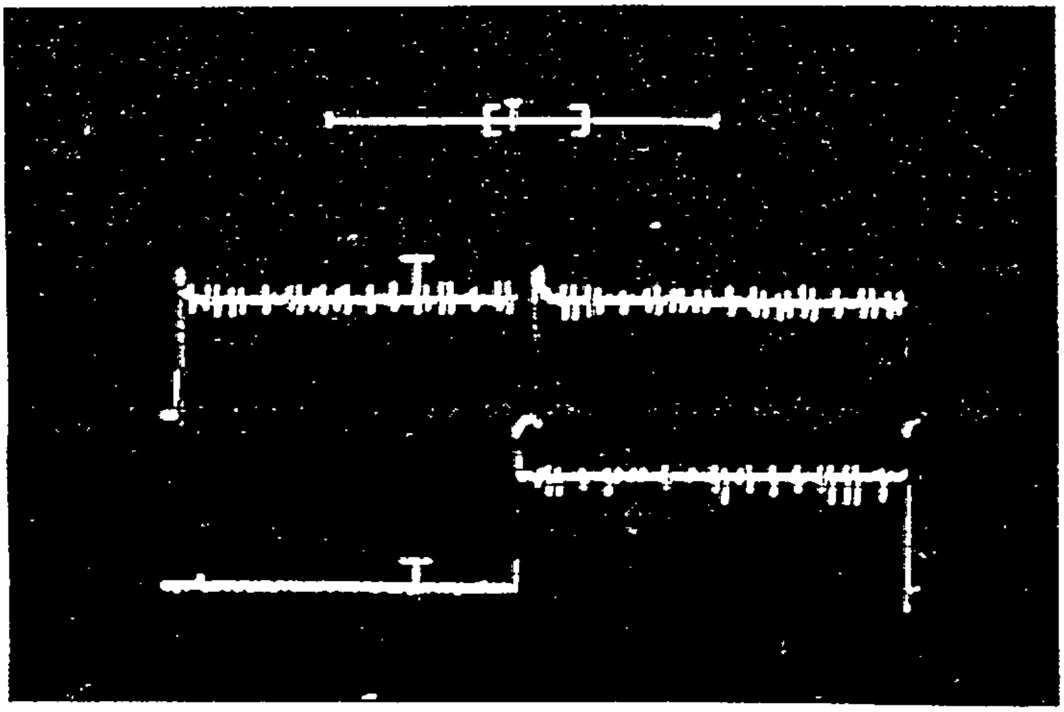


Fig 4.8 The intermediate signals showing the waveforms before AND gating to obtain required delay time for forced commutation.

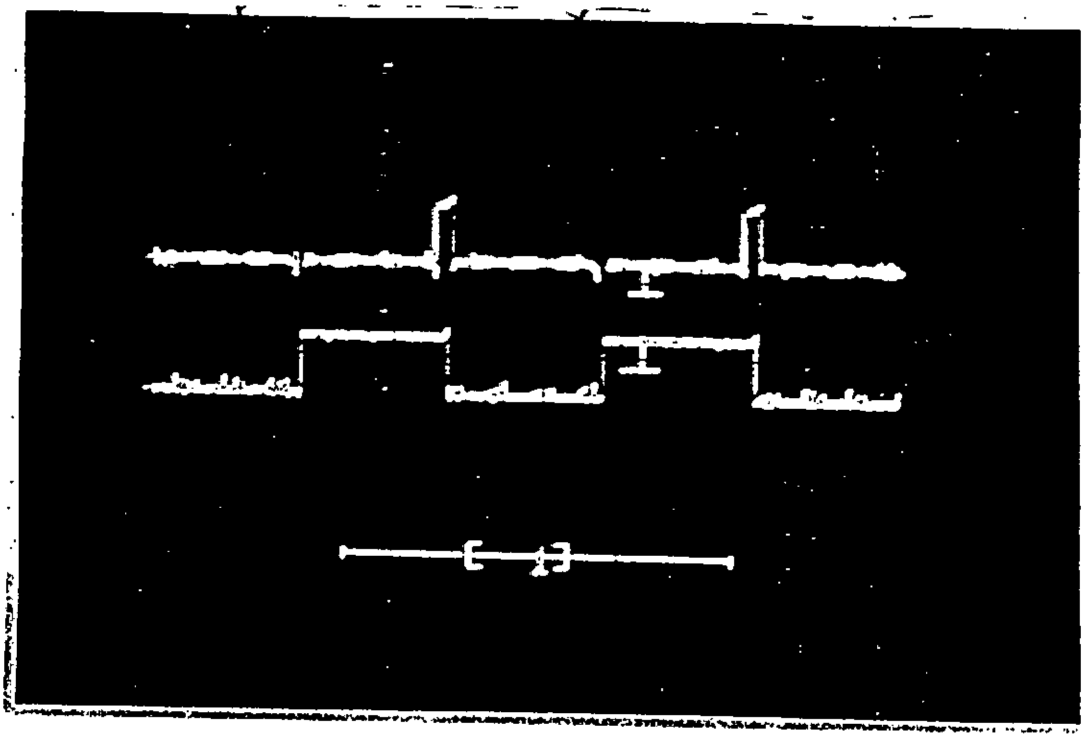


Fig 4.9 One of the main SCR firing signal and corresponding commutation SCR firing signal.

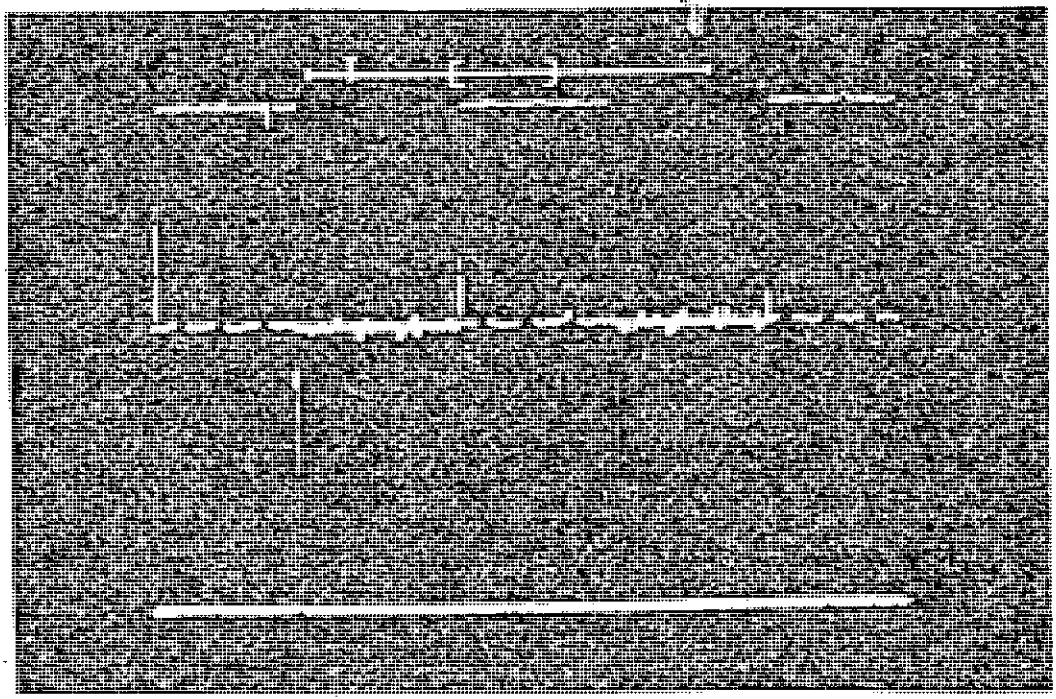


Fig 4.10 One of the main SCR firing signal after high frequency mudulation and the corresponding commutation SCR signal.

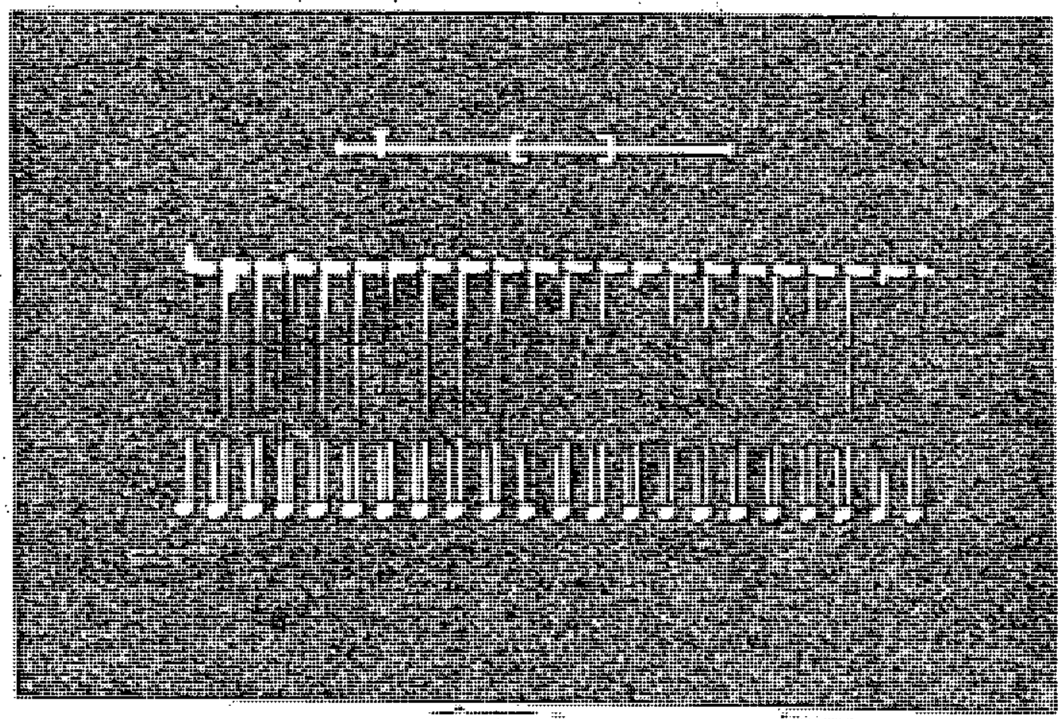


Fig 4.11 Modulated signal before processing for SCR firing.

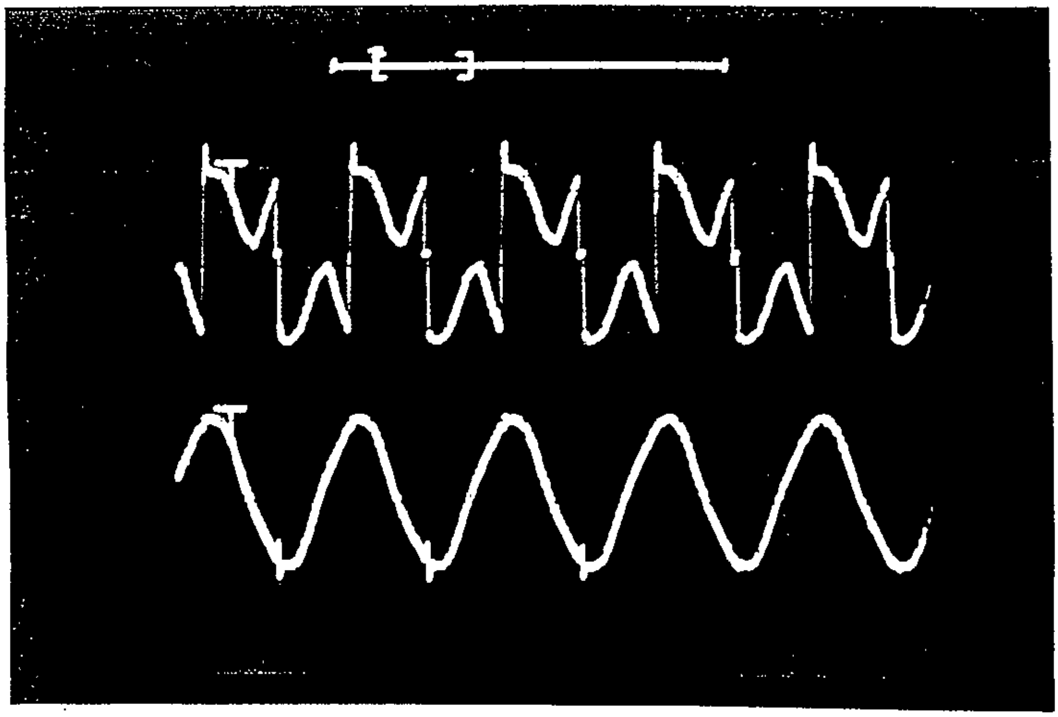


Fig 4.12 Output of the phase shift circuit (above) and the input waveforms.

CHAPTER - 5

CONCLUSION AND RECOMMENDATION.

5.1 Conclusion

The objective of this project were to design various logic circuit for SCR full bridge inverter,controlled rectifier and a.c. voltage controller using ICs and discrete electronic components. The work involved a preliminary study of the various power converter circuits and their working principle. After a brief study of the operation principles of various converters the work for design and construction of a full bridge square wave inverter, a controlled rectifier and an a.c.voltage controller logic circuit were undertaken. Accordingly these logic circuit were designed and built to meet the requirements of firing SCR based full bridge single phase inverter,a.c.voltage controller and controlled rectifier. The work included the following parts:

1. Design of the logic circuits for a single phase full bridge square wave inverter, a controlled rectifier and an a.c.voltage controller.

2. Building the logic circuits for a square wave inverter, a controlled rectifier and an a.c.voltage controller.

3. Testing of the logic circuits to run a single phase square wave full bridge inverter, a controlled rectifier and an a.c.voltage controller.

All the phases of the project were successfully completed with satisfactory results,some of which are recorded in this report. Design and implementation procedures relied mainly on the ICs both analog and digital in kind. Troubleshooting was also a part of this work intermittently.

At present the design and construction of inverters, a.c.voltage controller,controlled rectifier are very limited in our country. Where as the use of inverters, a.c. voltage controllers, controlled rectifier are widely accepted in many industrial applications. This project shows that instead of importing this technology,it is possible to manufacture these devices locally for medium range applications possibly at very low costs. Hence serious effort should be made in manufacturing these converters locally for their subsequent applications.

5.2 Suggestion for future work.

This project report shows that design and construction of the logic controller for various power converters are possible with locally available components and expertise. Further work can be done to enhance the feasibility by undertaking the design and construction of power converters themselves.

APPENDIX

In this project work various logic circuits for different converters were made by the combination of different integrated circuits (ICs) or chips. There are various types of ICs which have been used. These ICs consist of different gates. Such as MC 4049 consists of inverters,MC 4081 consists of AND gates,LM 741 and LM 308 consist of operational amplifiers. To activate these ICs power is necessary to different pins. Here we discuss these different ICs and also power supply requirements of these chips.

MC 4528

This chips is used for one shot output. We can vary the length of one shot by varying the value of resistance or capacitance. For commutation signal we need very small duration of one shot. From the pin number 7 and 9 we get one shot output. We have got inverted output of one shot respectively from pin number 6 and 10.

MC 555

From pin number 3 we have got high frequency output signal.

LM 741 OR LM 308

These chips are operational amplifiers. In these chips pin number 2 is the input pin and pin number 3 is the reference pin. From pin number 6 we have got OPAMP output. If output pin number

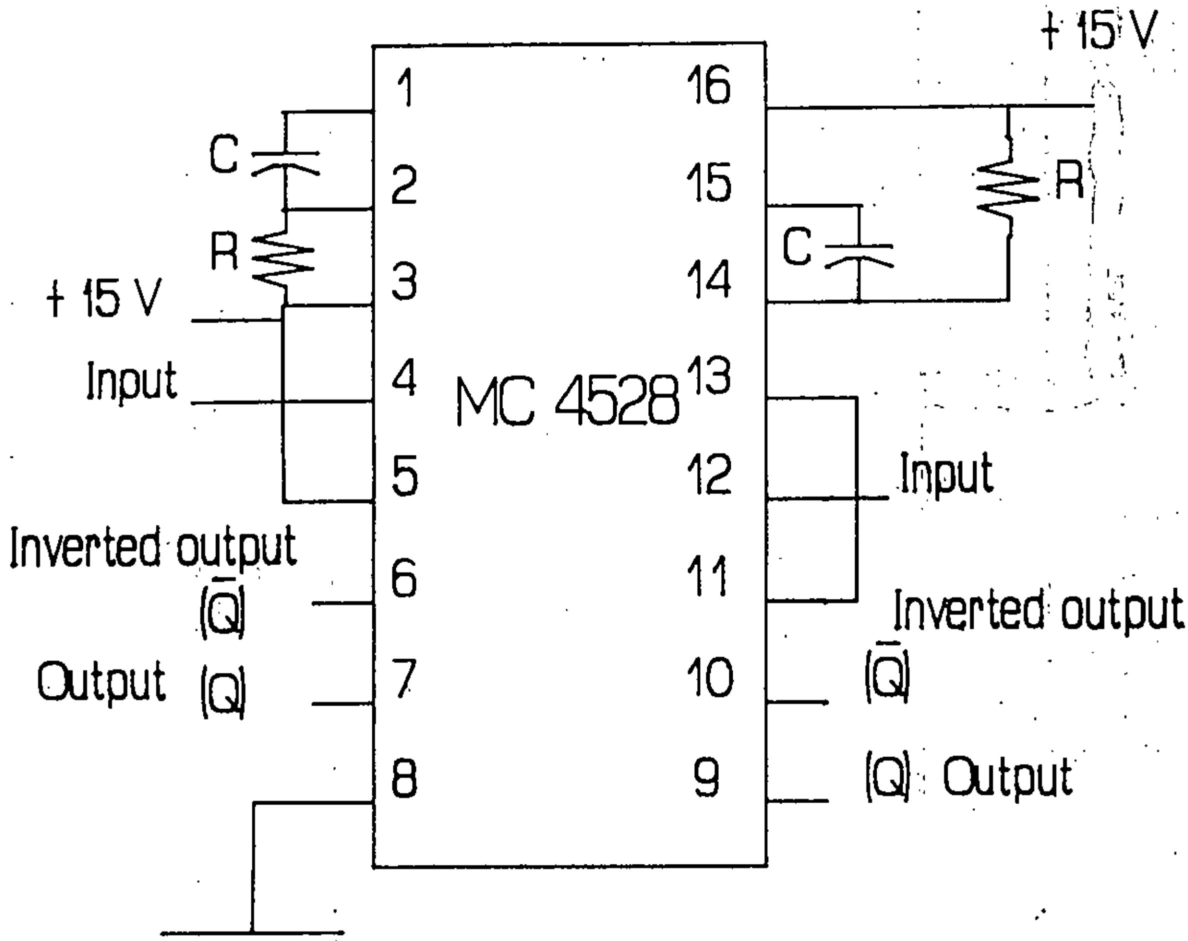
6 and pin number 2 is short circuited and the input pin is 3,then it is simply called the buffer circuit. Here we get the output from pin number 6 same as the input. It prevents the distortion or ripple due to loading of the output to the next stage.

<u>MC4049</u>

Input pin numbers are 3, 5, 7, 9, 11 and 14. Respectively output pin numbers are 2, 4, 6, 10, 12 and 15.

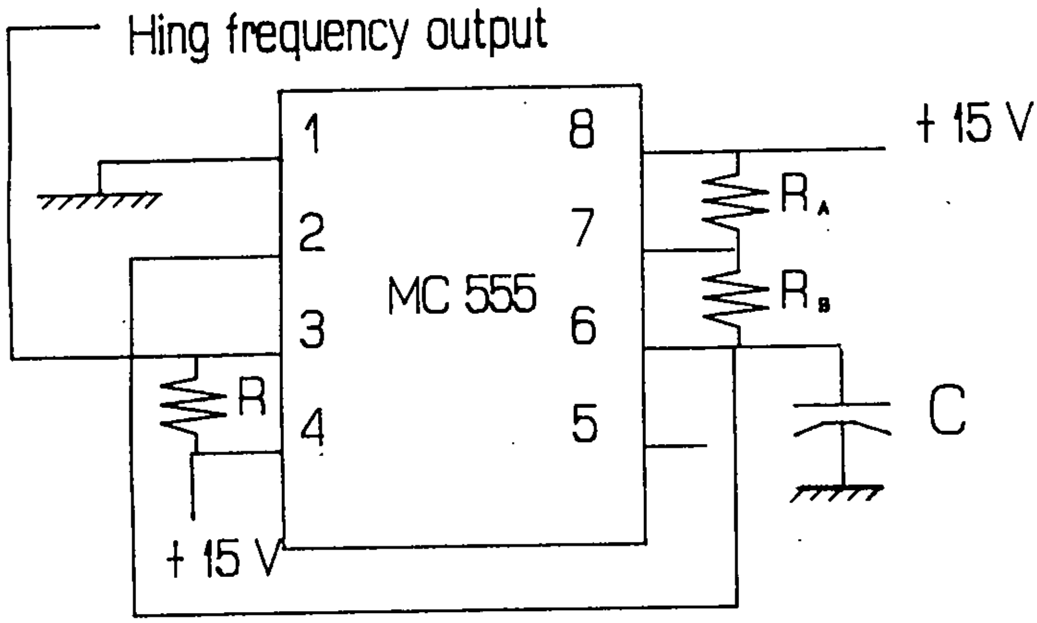
<u>MC4081</u>

Input pin numbers are 1, 2; 5, 6; 8, 9 and 12, 13. Respectively output pin numbers are 3, 4, 10 and 11.

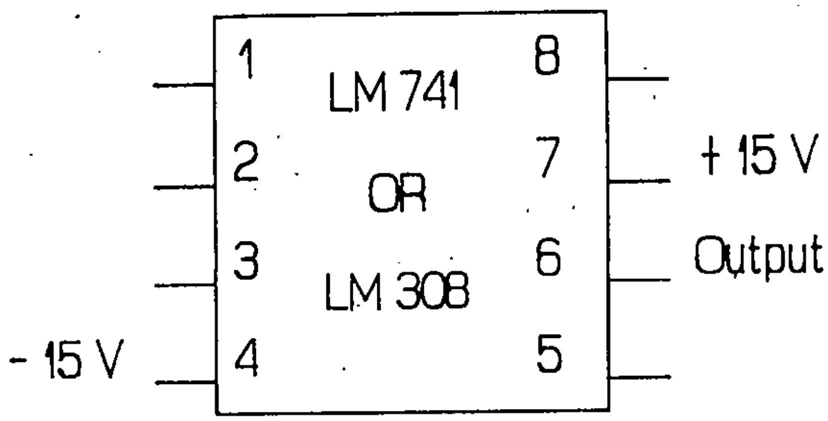


For commutation ckt,R = 100K, C = .01 microfarad
For delay ckt, R = 100K, C = .05 microfarad

Fig 5.1 IC 4528 connection diagram used as one shot multivibrator.



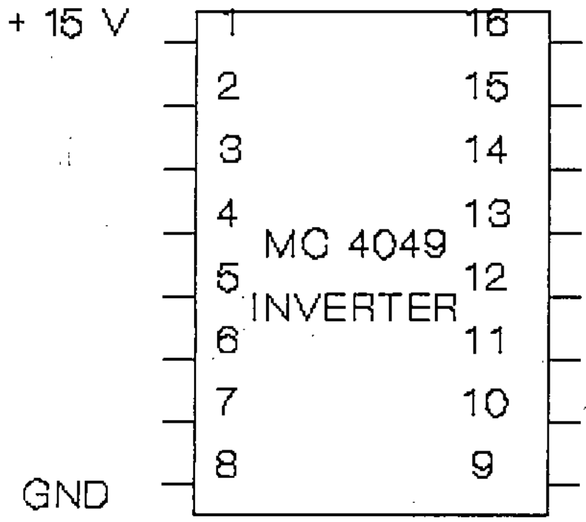
(a)



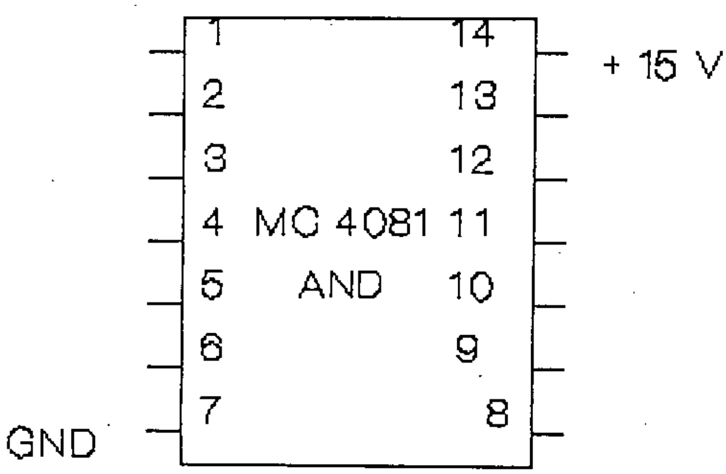
(b)

Fig 5.2 a) IC 555 timer circuit diagram for generating high frequncy (15 KHz).

b) IC 741 OPAMP pin diagram showing supply pins.



(a)



(b)

Fig 5.3 Pin diagram showing the supply pins of ICs 4049 and 4081.

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