DESIGN OF THREE PHASE INVERTER FOR SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

PROJECT REPORT

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CERTIFICATE

This is to certify that the Project report entitled

DESIGN OF THREE PHASE INVERTER FOR SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

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in partial fulfillment of the requirements for the award of degree of Bachelor of Engineering in the Electrical and Electronics Engineering branch of the Bharathiar University, Coimbatore-641006 during the academic year 2001-2002.

18/8/02

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ACKNOWLEDGEMENT

It is with a deep sense of gratitude that we thank our project guide **Ms.Lavanya**, B.E., Lecturer ,Department of Electrical and Electronics Engineering, for her guidance and invaluable suggestions. The keen and constant interest evinced by her throughout the course of this project has been instrumental in the success of the project.

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Last but not least , we thank the teaching and non teaching staff of our Department for their kind co-operation

SYNOPSIS

Today there is a trend towards tremendous growth and phenomenal modernization of electric system throughout the world. As a general requirement, a practical electric vehicle must satisfy performance requirements in order to merge with traffic, start on a steep grade, pull out of a path hole, climb hills, and pass. Hence, speed control of the drive system plays an important role.

There are many ways to control the speed of three phase ac induction motor. To establish the vehicle tractive effort-speed requirements, three phase inverter is designed. Power MOSFET's play a vital role in the design of inverters, which require high dc voltage.

The speed of ac IM is controlled effectively with a pulse width modulated (PWM) transistor inverter based controller. The inverter design for speed control, finds its application mainly in railways, where three phase supplies are not readily available. The available high voltage dc is inverted to 3 phase ac and thus, the speed of 3 phase ac IM is controlled efficiently. Therefore, this method is economically viable. Thus, an attempt has been made in this direction to design and develop a three phase .inverter for speed control of ac Induction Motor.

CONTENTS

INTRODUCTION

Presently, the DC motor and the DC controller combination is the dominant Electric vehicle drive system configuration, with few vehicles using AC system. However recent studies comparing various Electric vehicle propulsion system approaches, have concluded that the most prominent drive system for near term Electric vehicle use is AC induction motor with a pulse width modulated transistor inverter based controller. The impetus behind the ac drive system is the cost, maintenance, size, reliability and efficiency.

The size, cost and complexity of the controller for this motor represent the technical challenge to the potential and desirable advantages of ac induction motor. Much of the controller complexity exists in signal level controls, where advantages in microelectronic technology will play a significant part in reducing the cost & parts count.

The evolution and downward price trend in high power transistors will allow inverter to be economically feasible and reliable. The use of microcontroller reduces the number of hardware units and hence the complexity of the whole circuit.

PURPOSE OF THIS PROJECT

The main purpose of this development project was to design, fabricate, test, evaluate & test analyze an engineering model ac motor controller for a variable speed traction ac polyphase induction motor.

2.1 PROJECT OVERVIEW

This project was to design a three phase inverter for the speed control of three phase induction motor. During the first stage of operation the input voltage of 230 volts ac is first stepped down to 9 volts ac by a step down transformer. This stepped down 9 volt ac is fed to Rectifier circuit where this 9v ac is converted to 9 volt unregulated dc. Then the 9 volt dc is given to the microcontroller board.

At the input side of a microcontroller board a 7805 regulator IC is used which is used for converting the 9 volt unregulated dc input to a 5 volt regulated dc output. This 5 volt is used to provide supply to microcontroller IC 89c51. A crystal is also used to provide necessary oscillations for the 89c51 IC. This 89c51 IC consists of 4 ports, but we are using only 2 ports for its operation. Port 1 is used as an output port and port 3 is used as input port.

At the input port of the microcontroller board a switching circuit is used which is used for controlling the speed of three phase induction motor. At the output port an indicator board is used with which the switching operation and the variations in the speed can be verified by connecting LED's.

An inverter circuit is also provided at the output port of the 89c51 microcontroller. This inverter board is used to provide three outputs which are of 0 phase shift and three other output's which are phase shifted by 180 degrees. The output of the inverter board is given to the driver circuit which is used to drive the gate of the mosfet.

The second stage consists of another transformer which is used to step down the 230 volts ac supply to 12 volt ac .This 12 volt ac is then converted to 12 volt Dc by means of a rectifier circuit with IC 7812.The output of 12 volt regulated board is then given to the relay coil of the power rectifier circuit. This power rectifier circuit is used to convert the 230volt ac to 320 volt DC which is in turn given to the source and drain of the MOSFET's used in the power circuit. Thus to drive the power circuit 320 volt DC is given as input . Since the gating signals of the MOSFET are phase shifted by 120 degrees the three phase induction motor that is connected to the output of the power circuit is driven and its speed can be effectively controlled.

2.2 SYSTEM BLOCK DIAGRAM

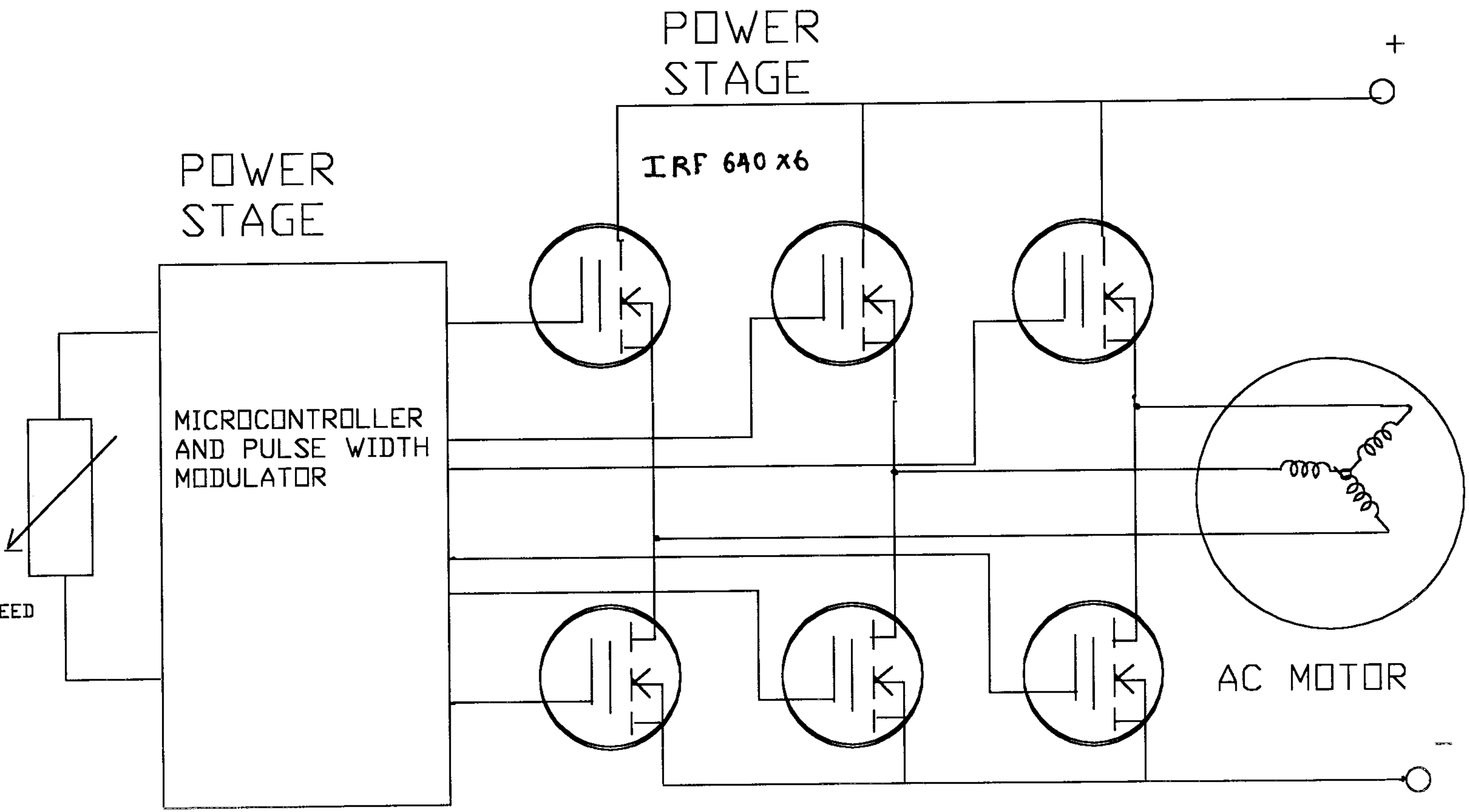
The overall schematic block diagram of single to three phase converter is shown in the fig. Here the speed of the motor is controlled by means of pulse width modulation technique. In this the three phase induction motor is connected to the centre of the star circuit.

The rectifier converts the 240v mains supply to a direct voltage of about 320v. The motor is linked to the converter by six power transistors that are connected to the output of the digital sections of converter. These transistors and the logic circuit controlling them ensure that the current flowing through windings of the motor are sinusoidal and that the three voltages have the correct phase relationships.

The inductor of the motor winding acts as an integrator that converts pulses of varying widths into a sinusoidal signal. The converter ensures that phase shift between the three generated voltages is 120 degrees.

A Microcontroller and pulse width modulator block is used for the accurate switching on and off the Mosfets so that the pulses that are given to the windings of 3 phase induction motor are phase shifted by 120 degree.

SYSTEM BLOCK DIAGRAM



2.3 TRANFORMER DESIGN

TRANSFORMER 1

GENERAL DATA

Turns/Volt	: 7.8328 turns
Safety Margin	: 3
Cross section	: .6585 sq in
Total Area	: 0.9585 sq in

PRIMARY COIL

Input Voltage	: 200 volts
Number of Turns	: 1566.569
Gauge	: 36 SWG
Diameter in	
Inches	: 0.007 in
Millimeters	: 0.1778 mm
Current	: 0.075 amps

SECONDARY COIL

Tapping number : 1

Voltage	: 13.5 Volts
Current	: 1 amps
Number of Turns	: 105.7434
Gauge	: 23 SWG
Diameter in	
Inches	: 0.024 in
Millimeters	: 0.6096 mm

DESIGN OF TRANSFORMER 1

Step 1 :

Output watts = VI = 13.5X1= 13.5 Watts

Step 2 :

Area A=((13.5)^(1/2))/ 5.58 = 0.65846 sq inches

Step 3 :

It is of 90% effecient

Output= 13.5 Watts

Input = (13.5X100)/90 = 15 watts

Step 4 :

At 200v ,1 degree will take 15/200 = 0.075 amps

Step 5 :

Area A= 0.65486 sq inches

Number of Turns N= ((1X10^8)/(4.44X50X60X1X10^3))

N=7.5 turns/volt

Step 6 :

Number of turns for primary= 200X7.5 = 1500 turns

Number of turns in Secondary = 1X7.5 = 7.5 turns

Step 7 :

Half of the primary current = 0.04 amps

Therefore valur of SWG is 36 or 37

Half the value of secondary current = 0.5 amps

SWG for the secondary side= 23

Step 8:

Accepted value of Area = 0.75 inches

N=((1X10^8)/(4.44X50X6000X0.75)) = 10.01 turns/volt

Step 9 :

The Number of turns in the primary =200X1.01= 2002 turns

The Number of turns in the secondary = 9X10.01= 90.09 turns

TRANSFORMER 2

GENERAL DATA

Turns/ Volt	: 10.069 turns
Safety Margin	: 0.28
Cross section	: 0.4656 sq inches
Total area	:0.7456 sq inches

PRIMARY COIL :

Input Voltage	: 200 volts
Number of Turns	: 2013.8027
Gauge	: 40 SWG
Diameter in Inches	: 0.0048 inches
Millimeters	: 0.1219 mm
Current	: 0.0375 amps

SECONDARY COIL :

Tapping Number	: 1
Voltage	: 9 volts
Current	: 0.75 amps
Number of Turns	: 90.6211
Gauge	: 40 SWG
Diameter in	
Inches	: 0.022 inches
Millimeters	: 0.5588 mm

DESIGN DETAILS FOR TRANSFORMER 2

Primary Voltage : 200 volts

Required Secondary : 9V/0.75 A

Step 1 :

Output Voltage = VI=9X0.75 = 6.75 Watts

Step 2 :

Cross sectional area of the core A=w^(1/2)/5.58

A=(6.75)^(1/2)/5.58=0.4656 sq inches

Step 3:

Assuming the transformer to be 90% efficient

Input watts = (6.75*100)/90 = 7.5 watts

Step 4:

At the working voltage of 200 volts primary current = 0.0375 A

Step 5:

To find the number of turns

Taking flux density as 60000 lines per square inch and Area of Cross section as 0.75

N=((1X10^8)/(4.44X50X60X1X10^3*0.75))

N=10.01 turns/volt.

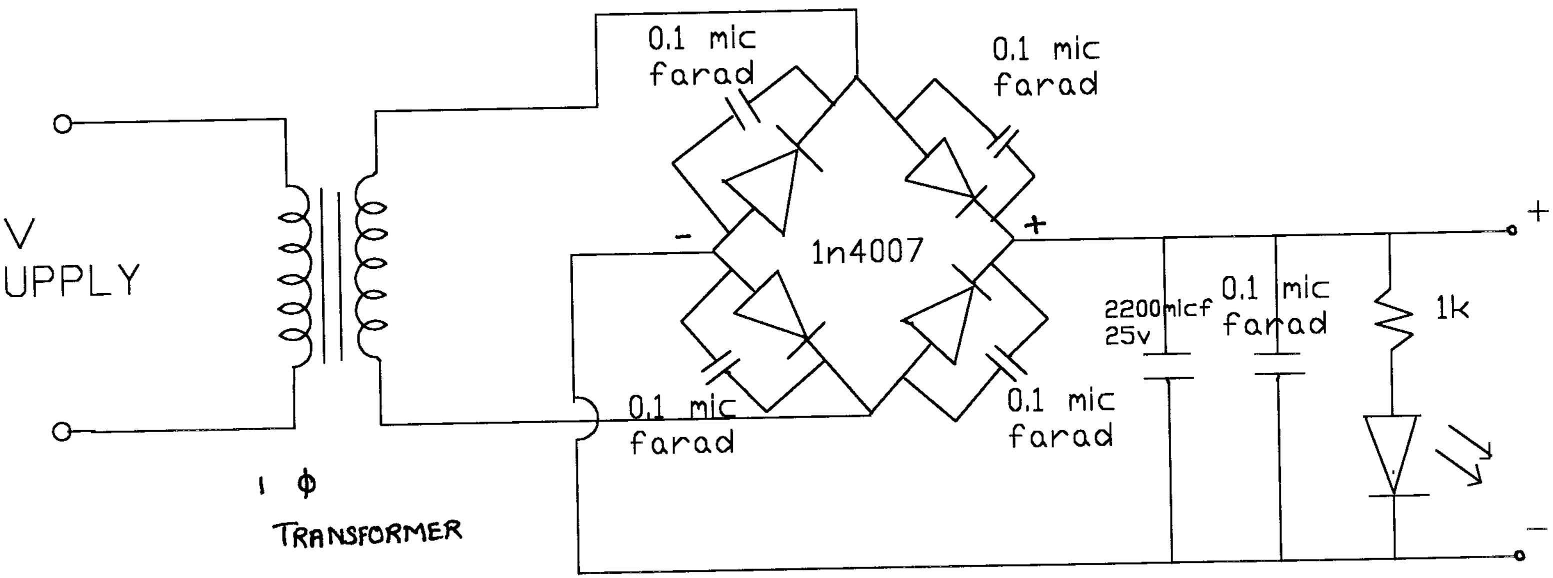
Step 6:

To find the number of turns in the windings

Number of turns in primary = 200*10.01 = 2002 turns

Number of turns in the secondary= 9*10.01=90 turns.

5V UNREGULATED POWER SUPPLY



2.4 SOURCE CIRCUIT

The source circuit for the 5v Unregulated power supply is shown in the fig.

At the input side of the source circuit is the transformer designed for a secondary output of 9v. This 9v is fed to a bridge rectifier which converts this 9v ac to a dc output by means of rectifying action.

The main operation of this bridge rectifier can be explained as follows. During the positive half cycle of the AC input diodes D2 & D4 conducts, thereby a positive wave is obtained at the output. During the negative half cycle of the AC input, diodes D1 & D3 conducts. Because of this again a positive going wave is produced at the output of the bridge rectifier.

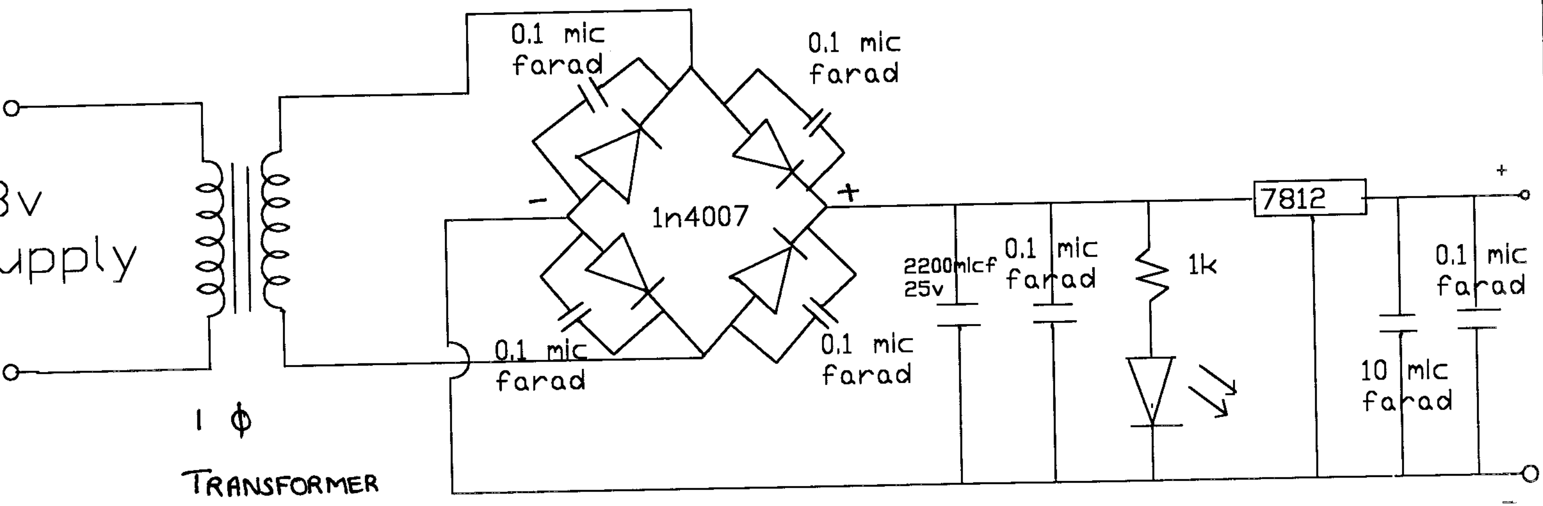
The output got by this method is not a pure DC wave but a DC wave with high ripples is obtained. These ripples have to be eliminated from the output DC wave. To eliminate the ripple contents 2 capacitors, one of value 2200 microfarad and the other 0.1microfarad is used. These capacitors act as filters and the ripple content at the output is eliminated. The output of 5v got by this method can be indicated by the glow of LED connected at the output part of the circuit.

2.5 12 VOLT POWER SUPPLY CIRCUIT

Here the transformers designed for the output of 13.5v is being used. Here also the output DC which is got from input AC by connecting it with bridge rectifier is made devoid of any ripples by passing through two capacitors that are connected in parallel.

To always get a constant output of 12v, a regulator IC 7812 is used. In the IC 7812,the number 78 indicates that the IC is used for positive voltage regulation and 12 indicates that it regulates the output at a constant value of 12v. This DC output of 12v, which is with ripples, is filtered by means of two capacitors of values 10microfarad and 0.1microfarad connected in parallel, together acting as a filtering unit. Thus an output of Regulated 12v DC is got from this unit.

12v regulated power supply

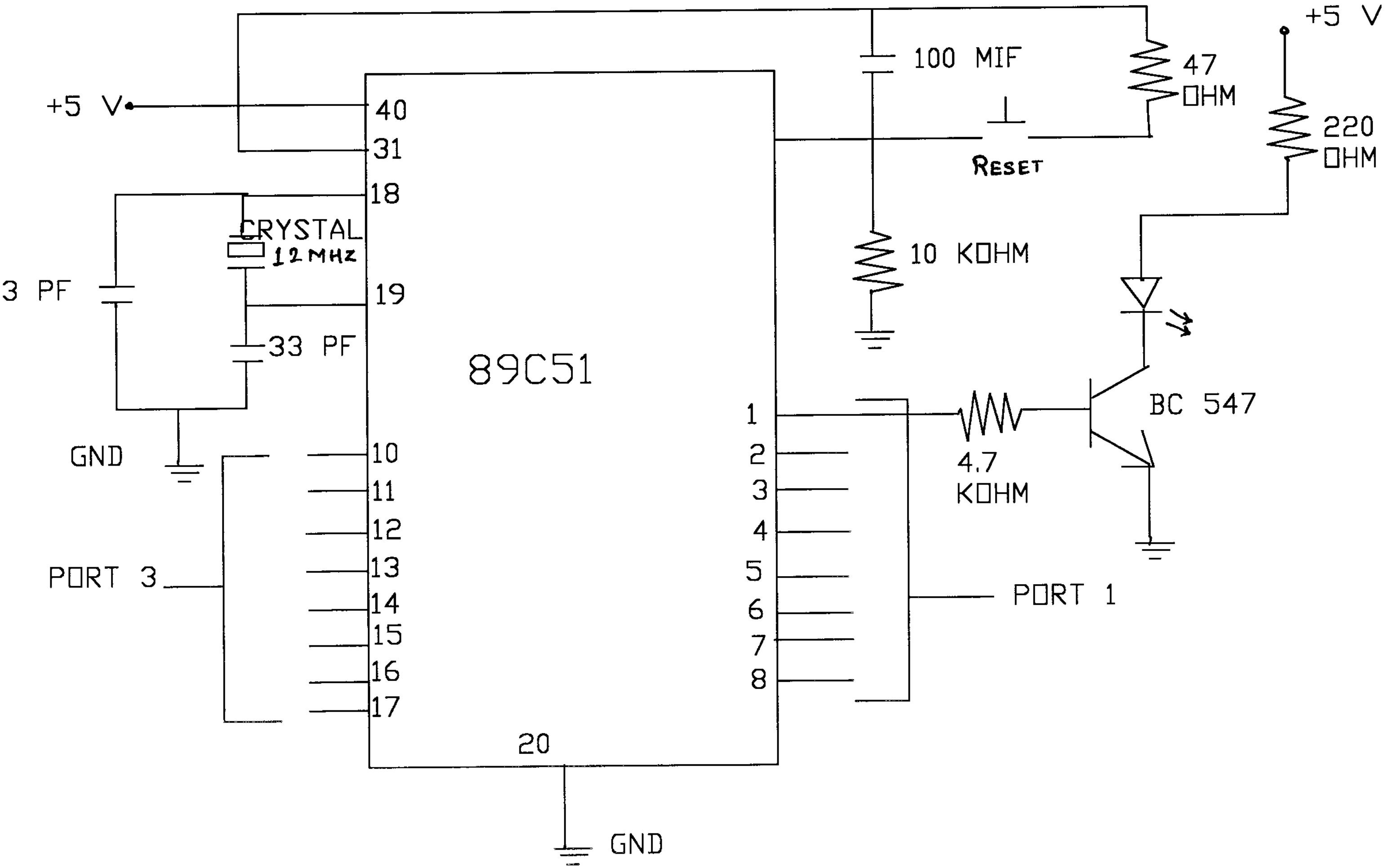


2.6 MICROCONTROLLER BOARD CIRCUIT

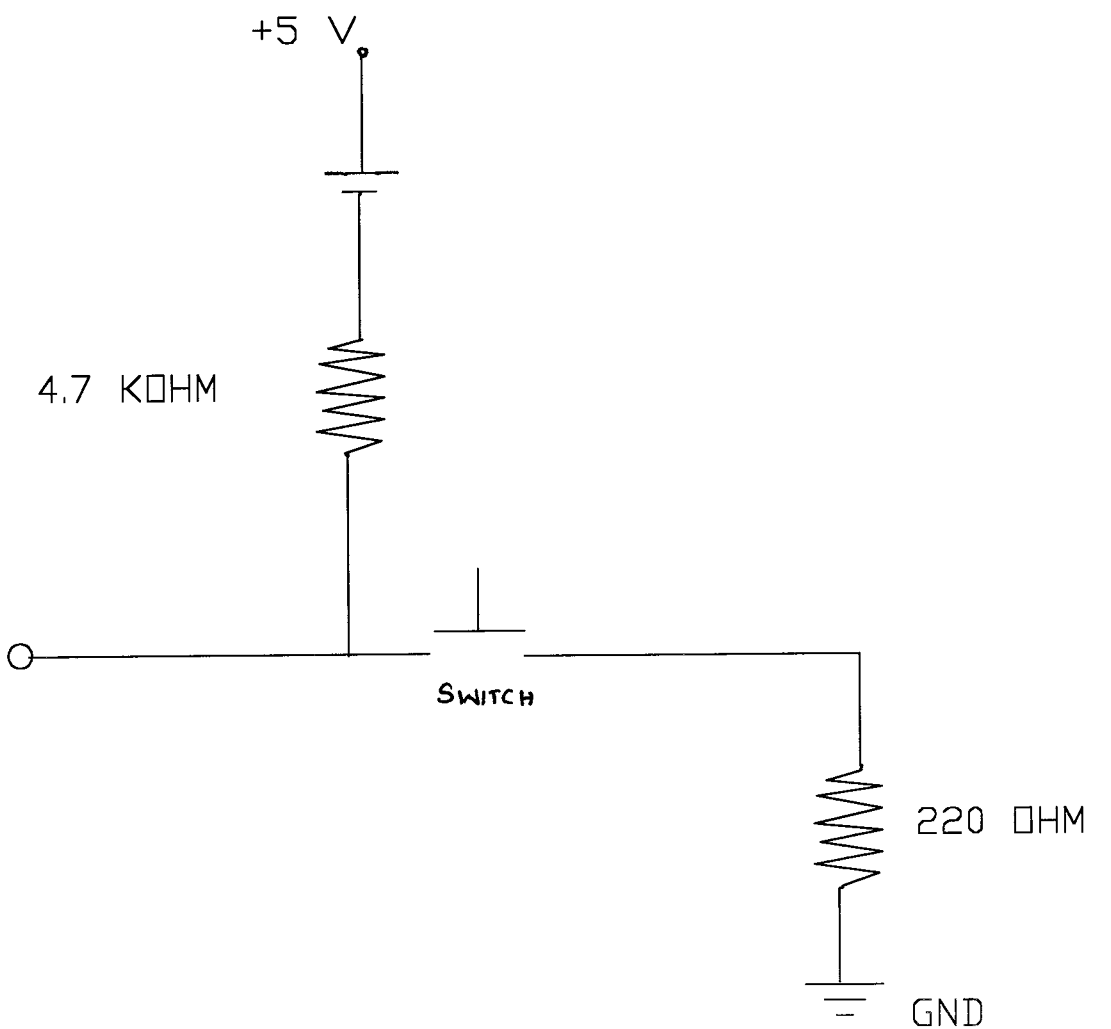
The unregulated 9 volt Dc is given to the input of the microcontroller board circuit. Here the 9 volt Dc input is converted into an 5 volt regulated Dc by means of 7805 voltage regulator. This 5 volt regulated Dc is used to giv3 supply to the 89c51 IC used in the microcontroller section. The 89c51 microcontroller consists of 4 ports out of which only 2 ports Namely port 1 and port 3 are used. Port 1 is used as an output port while the port 3 is used as an input port.

The switching circuit which is connected to the port 3 is used to change the speed of the three phase induction motor and the indicator circuit which is connected to the port 1 is used to verify the variations in the speed for corresponding pressing of switches.

MICROCONTROLLER CIRCUIT BOARD



INDICATOR CIRCUIT

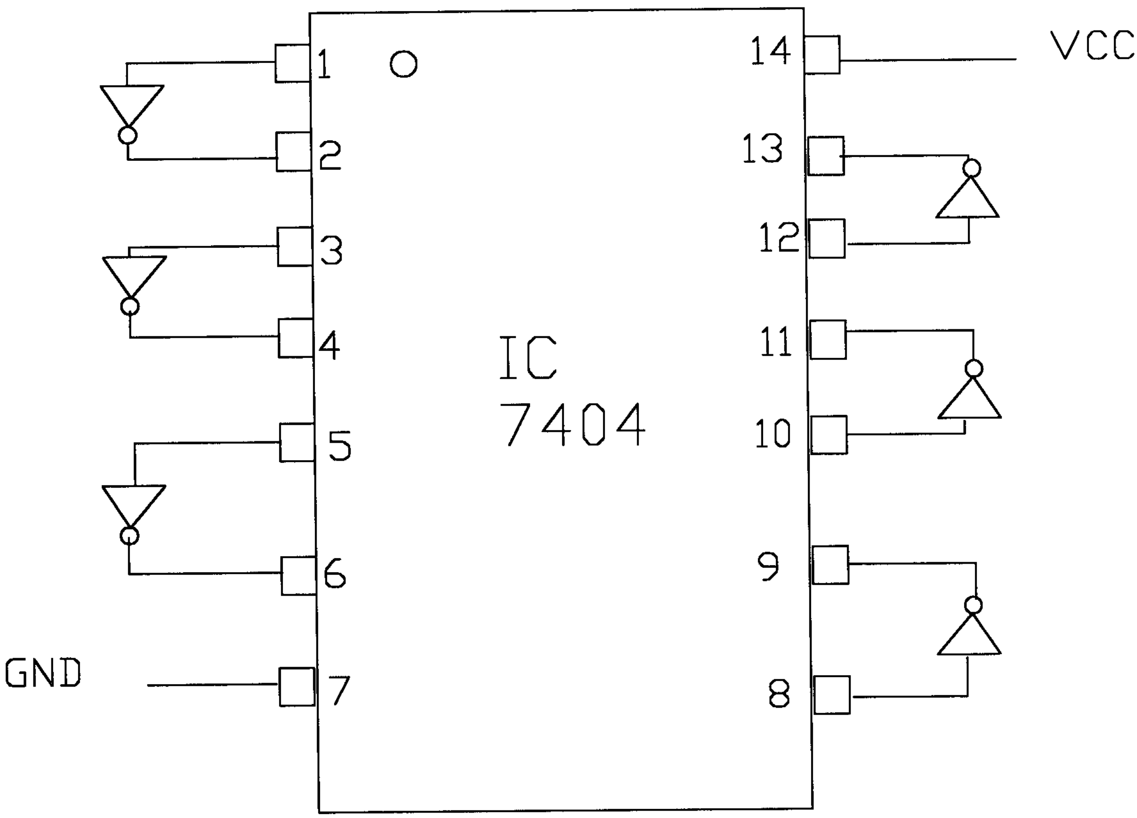


2.7 INVERTER CIRCUIT

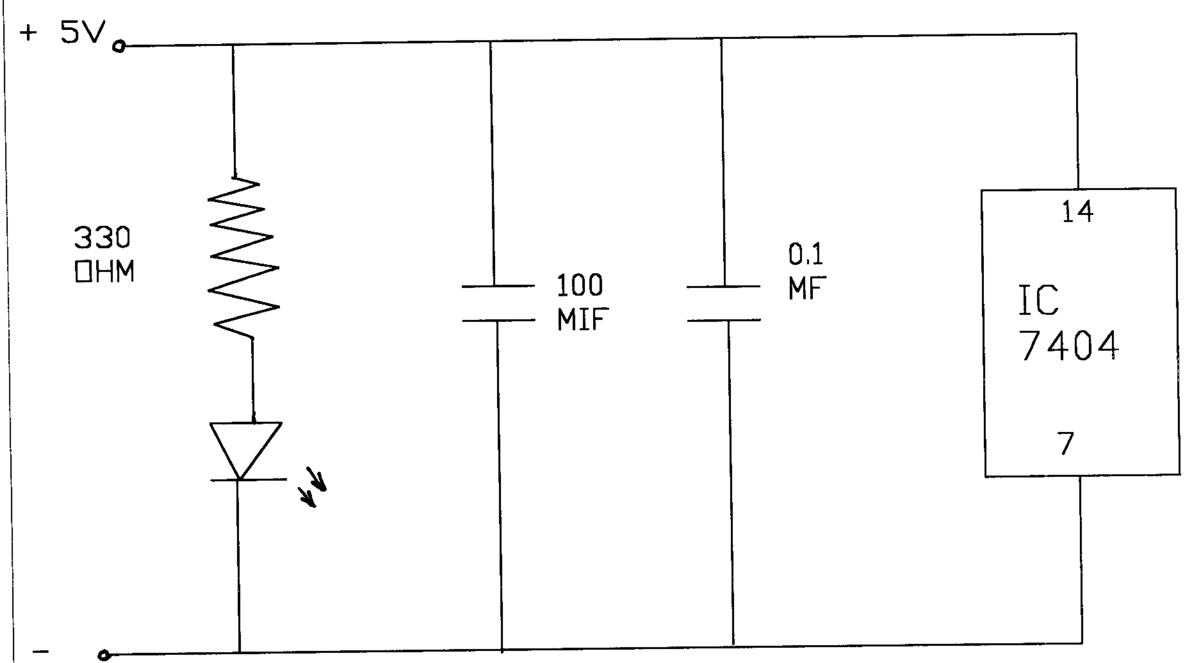
The inverter circuit is used to invert the gating signals that are given to one of the two pairs of MOSFET's. This inverting operation is accomplished by means of 7404 IC which consists of six not gates. Out of these six NOT gates three NOT gates are being used for providing the inverse gating signals. The three inputs for this inverting circuit is taken from the 3 pins in the output port (port1) of the microcontroller. These three signals are inverted and the six output signals from the 7404 IC are given as input to the driver circuit which drives the gate of the MOSFET used in power circuit.

Thus between a pair of MOSFET's the gating signals are made to be out of phase by 180 degrees by the use of Inverter circuit

PIN CONFIGURATION OF IC 7404



INVERTER CIRCUIT

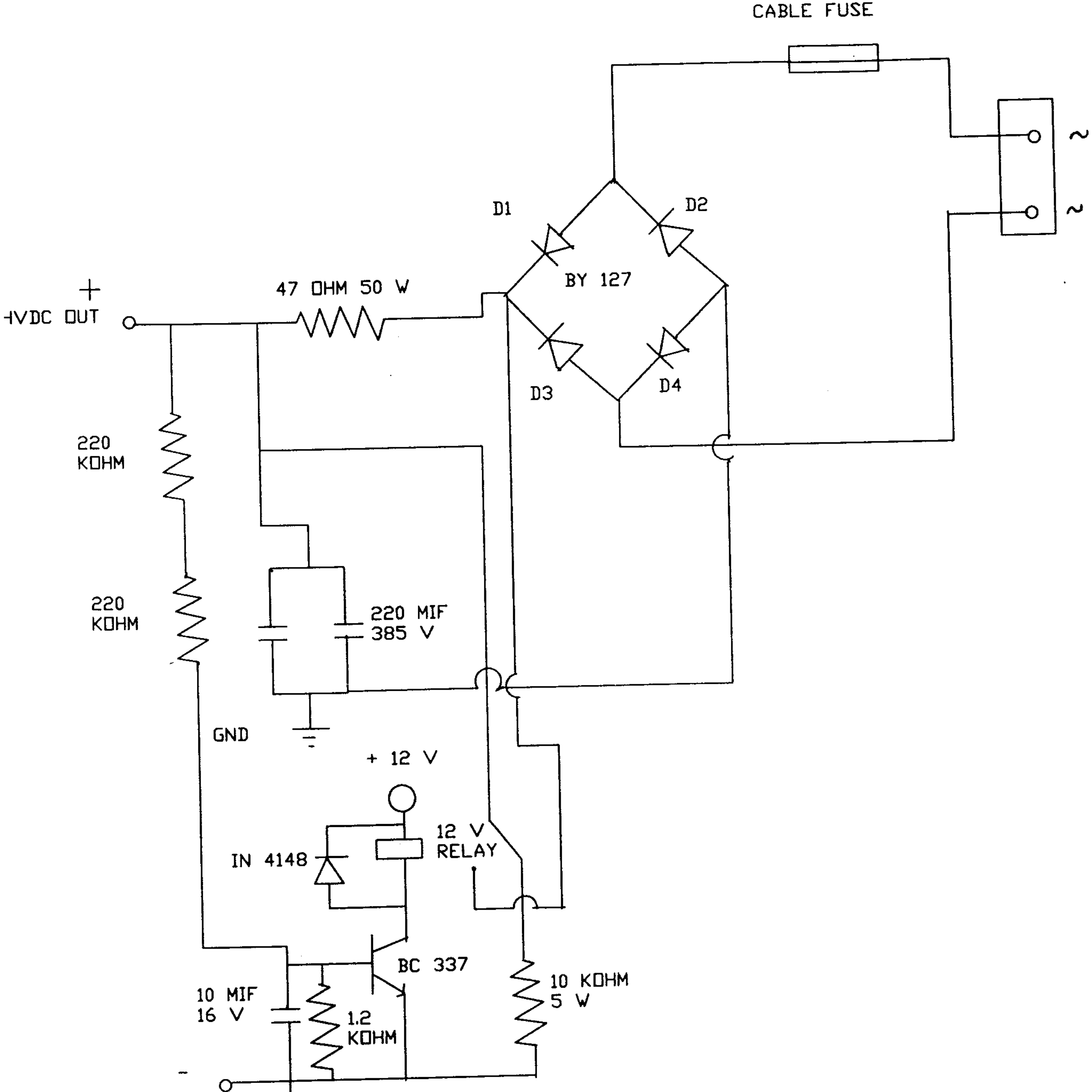


2.8 POWER RECTIFIER CIRCUIT

The power rectifier circuit is used to provide a high value of DC voltage (320 volts) as input to the power MOSFET circuit. An AC voltage of 230 volts is given as input to the power rectifier circuit. The bridge rectifier which is connected to the input side converts the ac input to the high value Dc . A relay is used in the circuit for providing a time delay. This relay requires a 12 volt dc for activating it. The 12 volt is got from the 12 volt regulated power supply board.

The working of this power rectifier circuit can be explained as follows. Normally when no supply is given to the relay the relay is under off condition. During this time the capacitors discharges. When the relay is energized by giving a supply of 12 volt dc then the relay connection changes and the capacitor starts charging. The transistor BC 337 connected to the relay starts conducting and the current flows and the rectified dc high voltage of 320 volts is got at the output of the rectifier circuit. The main advantage of using this relay in addition to providing the required time delay is the current drop in the 47 ohm resistor can be avoided and a high value of current is got at the output of the driver circuit.

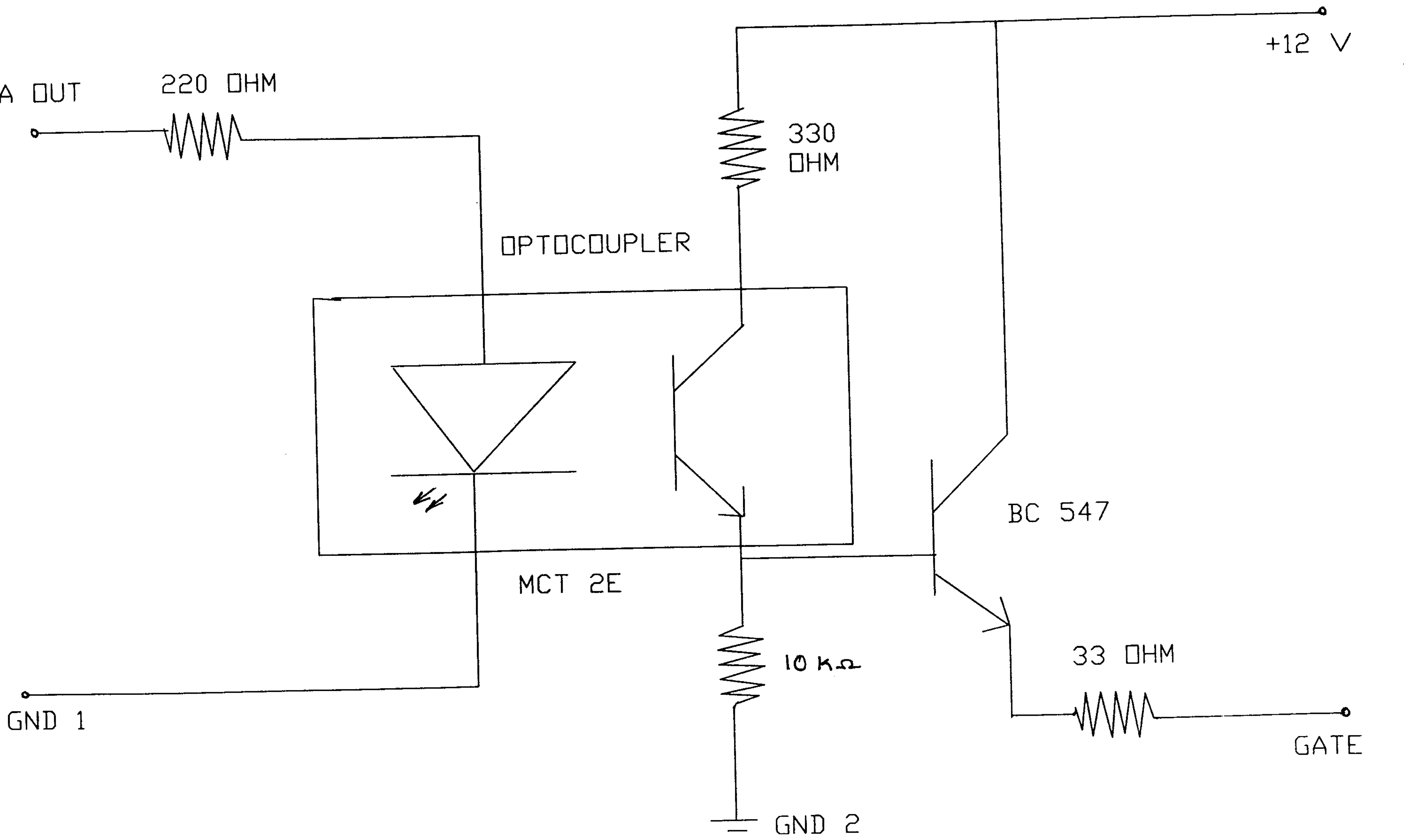
HIGH VOLTAGE RECTIFIER CIRCUIT



2.9 DRIVER CIRCUIT

The Driver circuit is designed to drive the gate signals for the MOSFET's used in the power circuit. The six inputs for the driver circuit is given from the inverter circuit in which three of the six inputs are inverted or phase shifted by 180 degrees. In the the Driver circuit the Optocoupler (IC MCT 2E) and the transistor BC 547 are used. Six such devices are used to drive the gates for the six MOSFEET's. The Transistor BC 547 is used in the driver circuit because of its low leakage current. The main function of transistor BC 547 is to increase the current gain. The six gating signals to the MOSFET's are provided with a phase difference of 120 degrees.

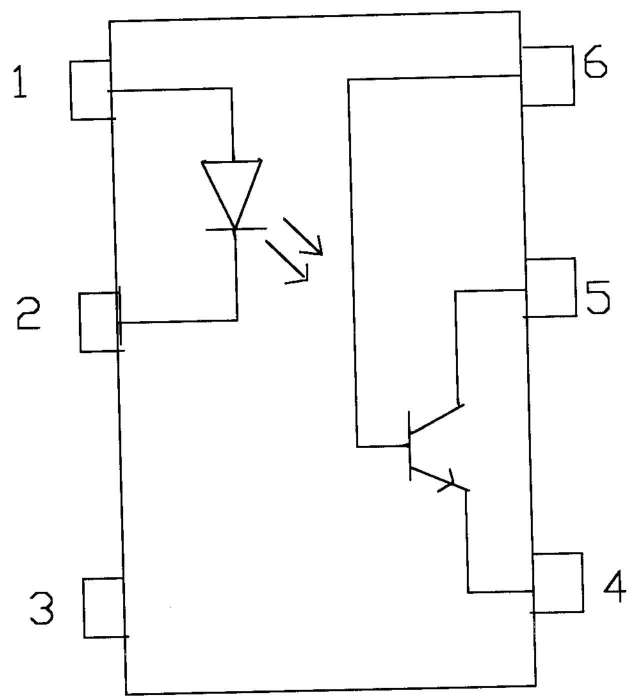
DRIVER CIRCUIT



OPTOCOUPLER IC

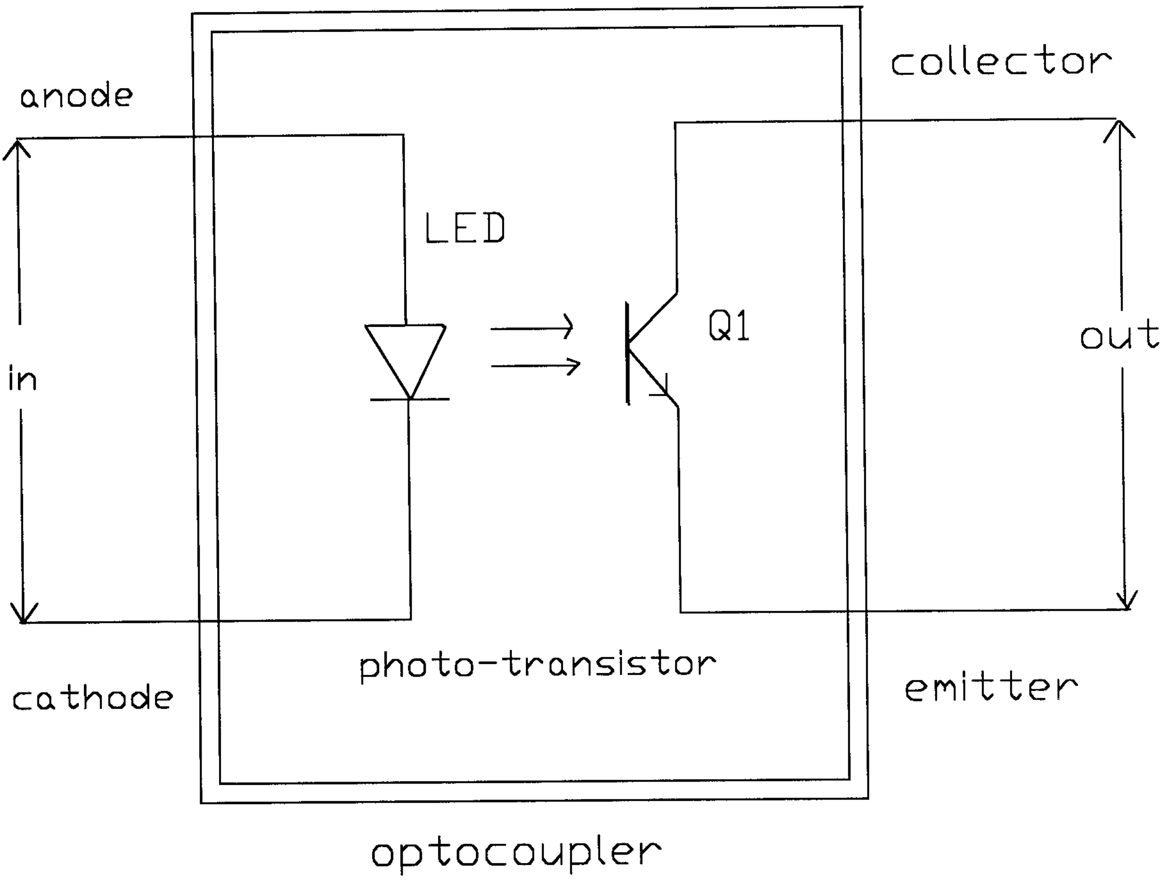
An LED is a Light Emitting device and a phototransistor is a light-sensitive device. Consequently , if the two devices are mounted close together in a single light excluding package so that the LED light can fall on the phototransistor face ,it will be found that the conduction current of phototransistor can be controlled by controlling the conduction current of LED, even though the two devices are physically seperated. Such a package is termed as optocoupler ,since the input(LED) and the output(the phototransistor) devices are optically coupled.

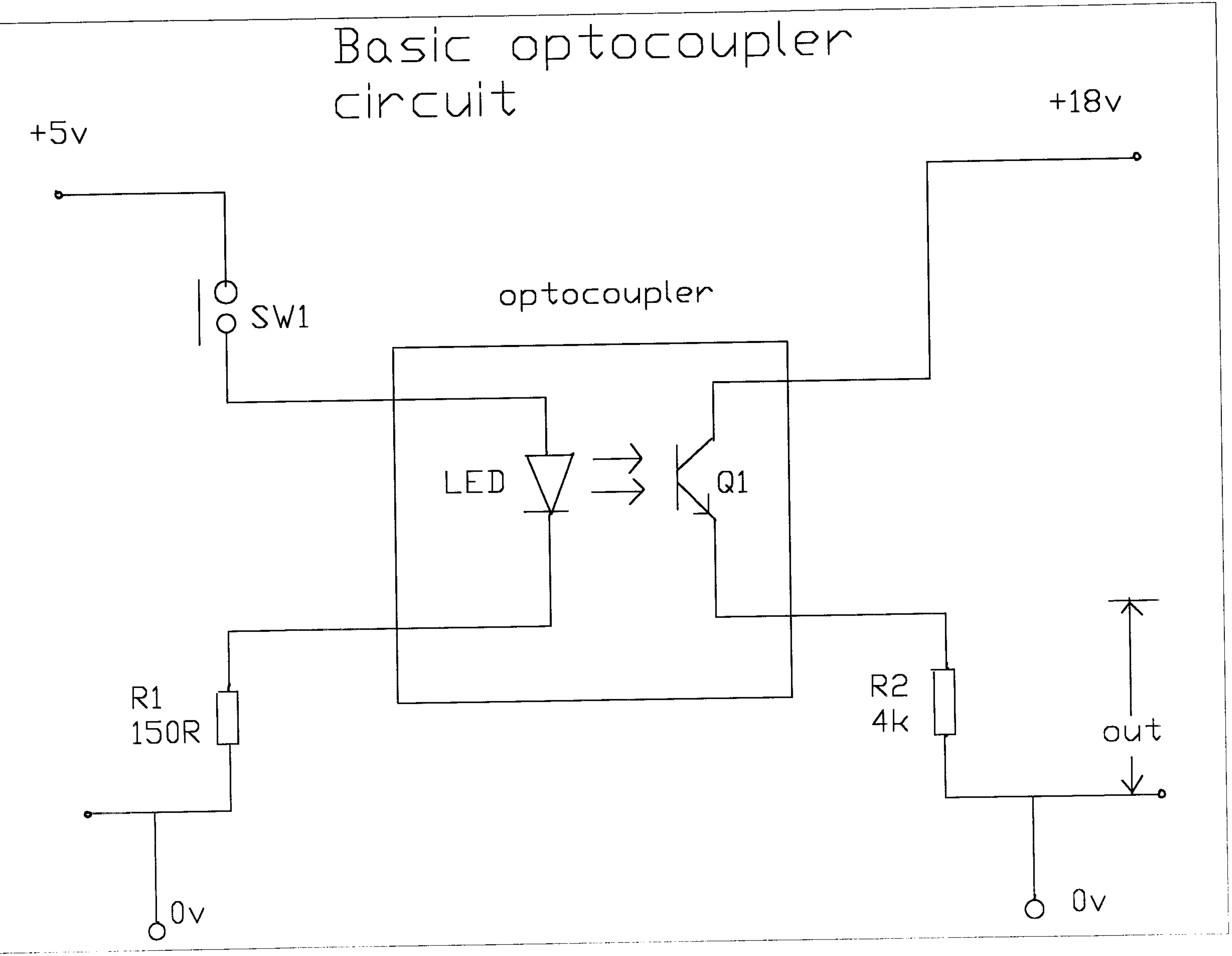
Typical simple ioslating optocoupler



top view

Basic optocoupler device




Basic optocoupler
circuit
+5v
+18v
SW1
optocoupler
LED
Q1
R1
150R
R2
4k
out
0v
0v

2.10 POWER CIRCUIT

The circuit diagram for the power circuit is shown in fig. This circuit is the main inverter circuit which consists of 3 pairs of MOSFET's of brand IRF640. The gating signal to the gate of the six Mosfets are given from by means of driver circuit.

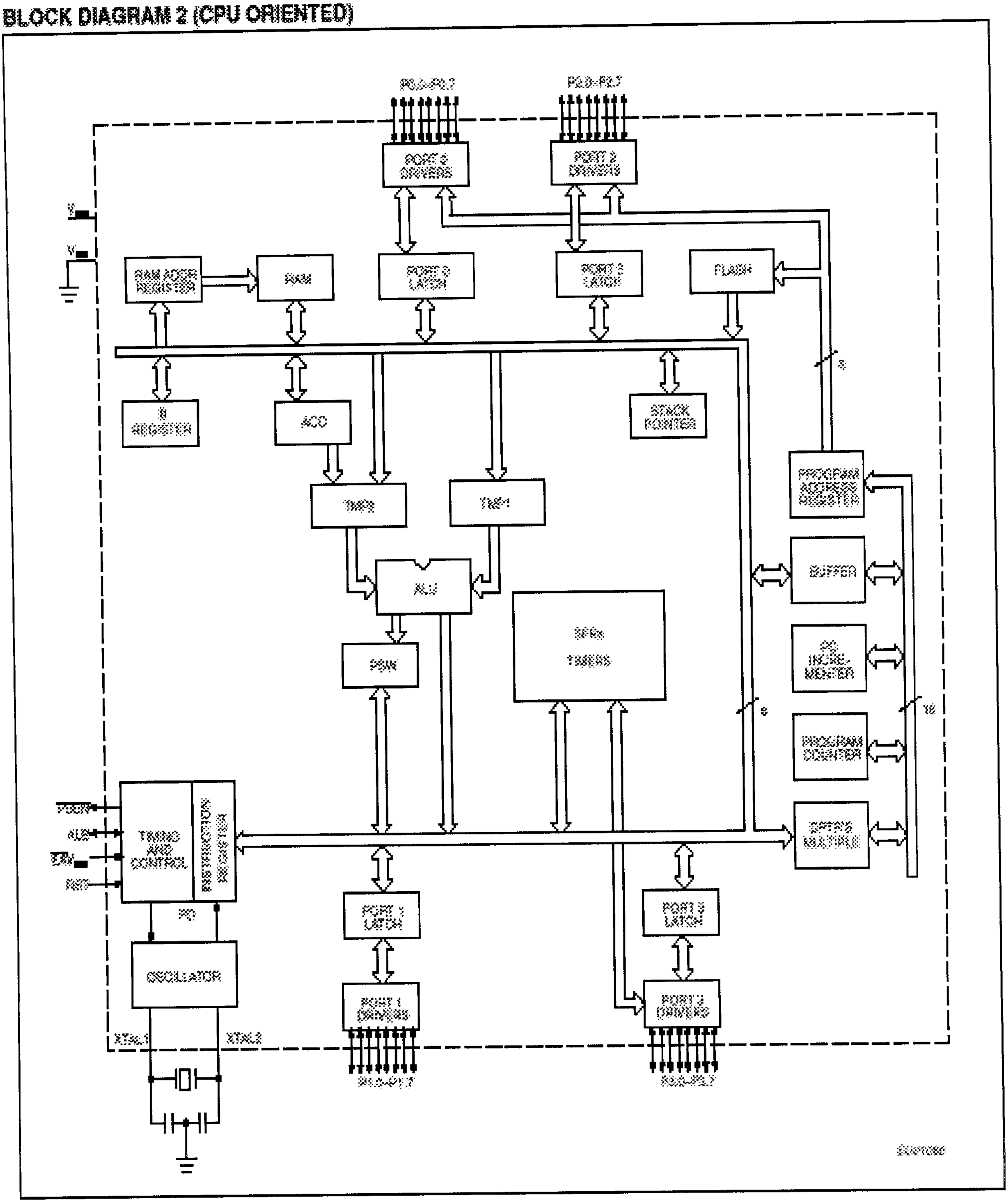
The inverter consists of three pairs of transistors that are arranged in star configuration. The three motor phases are connected cyclically at 120 degree intervals and the switching signals are given from the Mosfet circuit to the motor, with a phase difference of exactly 120degree so that a rotating field is induced in the motor and the motor starts rotating at a particular direction.

3.1 ARCHITECTURE OF 89C51 MICROCONTROLLER

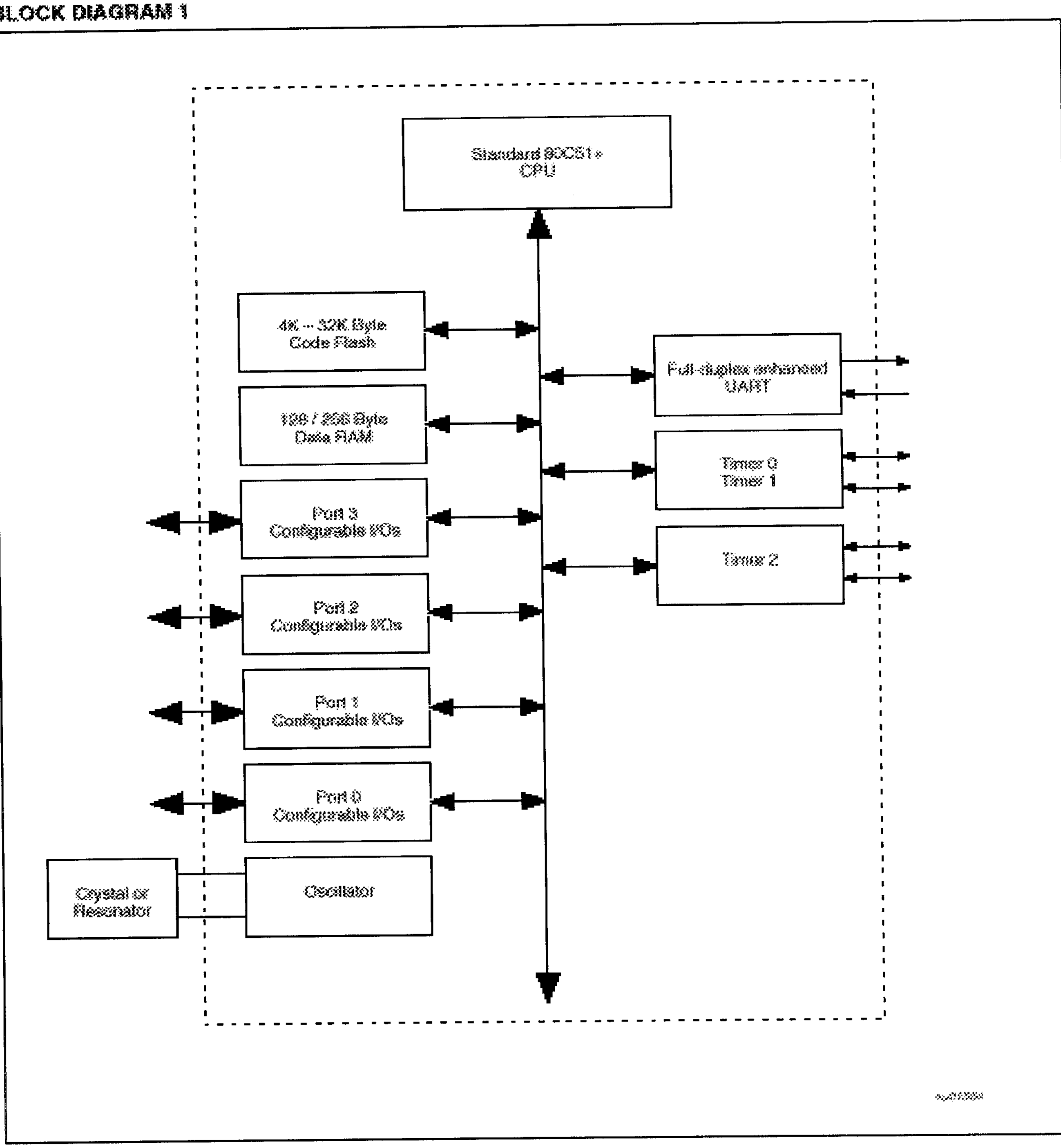
89c51 is a generic part in the family of 8051 Microcontrollers. These 89c51 microcontrollers are available in N-Channel Metal Oxide Silicon and Complementary Metal Oxide Silicon.

The Programming model of 89c51 is shown as a collection of 8 and 16 bit registers and 8 bit memory locations. These registers and memory location can be made to operate using the software instructions that are incorporated as part of the design. The program instructions have to do with the control of registers and the digital data paths that are physically contained inside the 89c51 as well as the memory locations that are located outside the 89c51.Most of the registers have a specific function. Each register with the exception of the program counter , has an internal 1 byte address assigned to it. Some registers are both byte and bit addressable. The entire byte of data at such register addresses can be read or altered, or individually bits may be read or altered.

BLOCK DIAGRAM 2 (CPU ORIENTED)

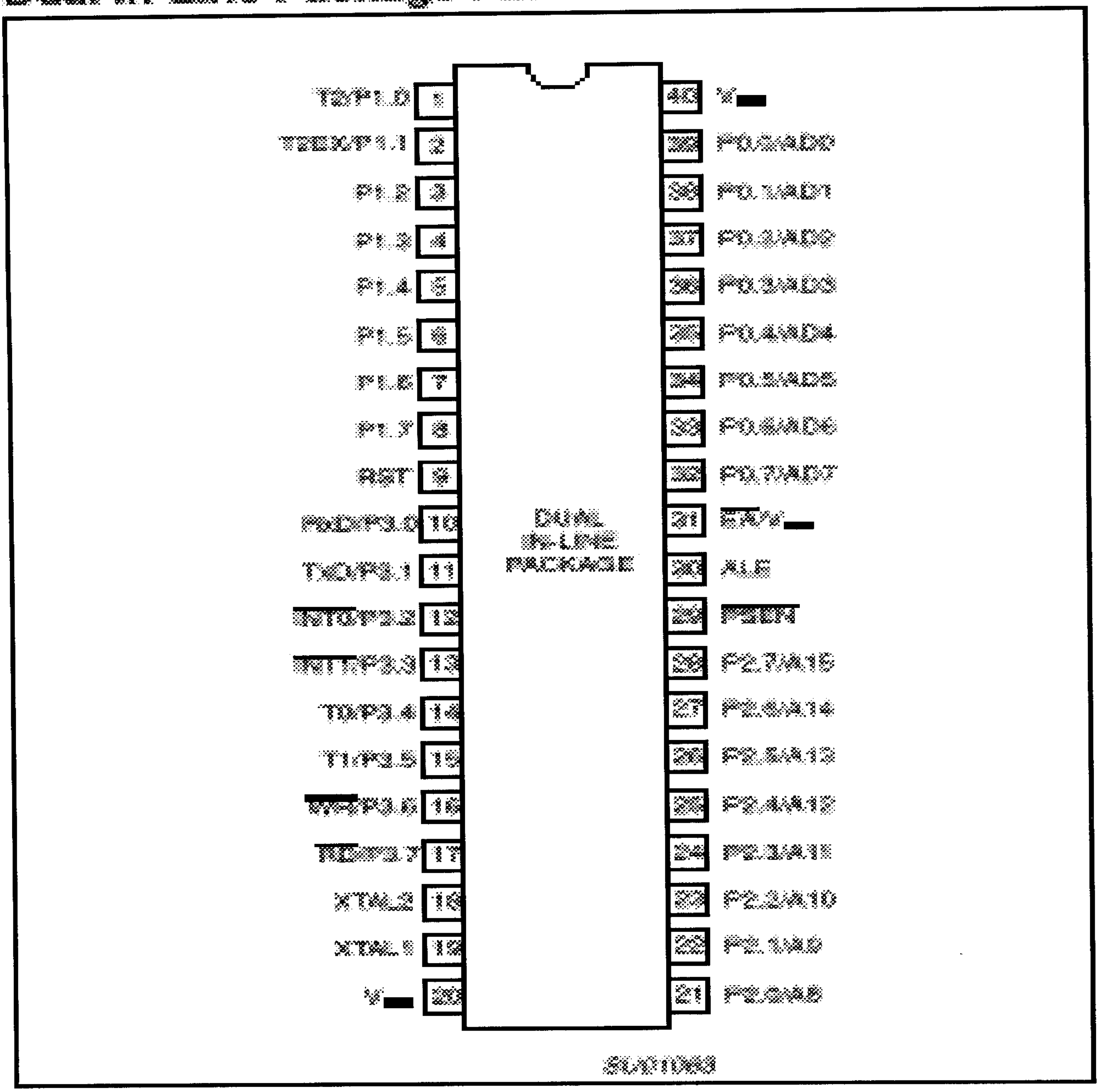


BLOCK DIAGRAM 1

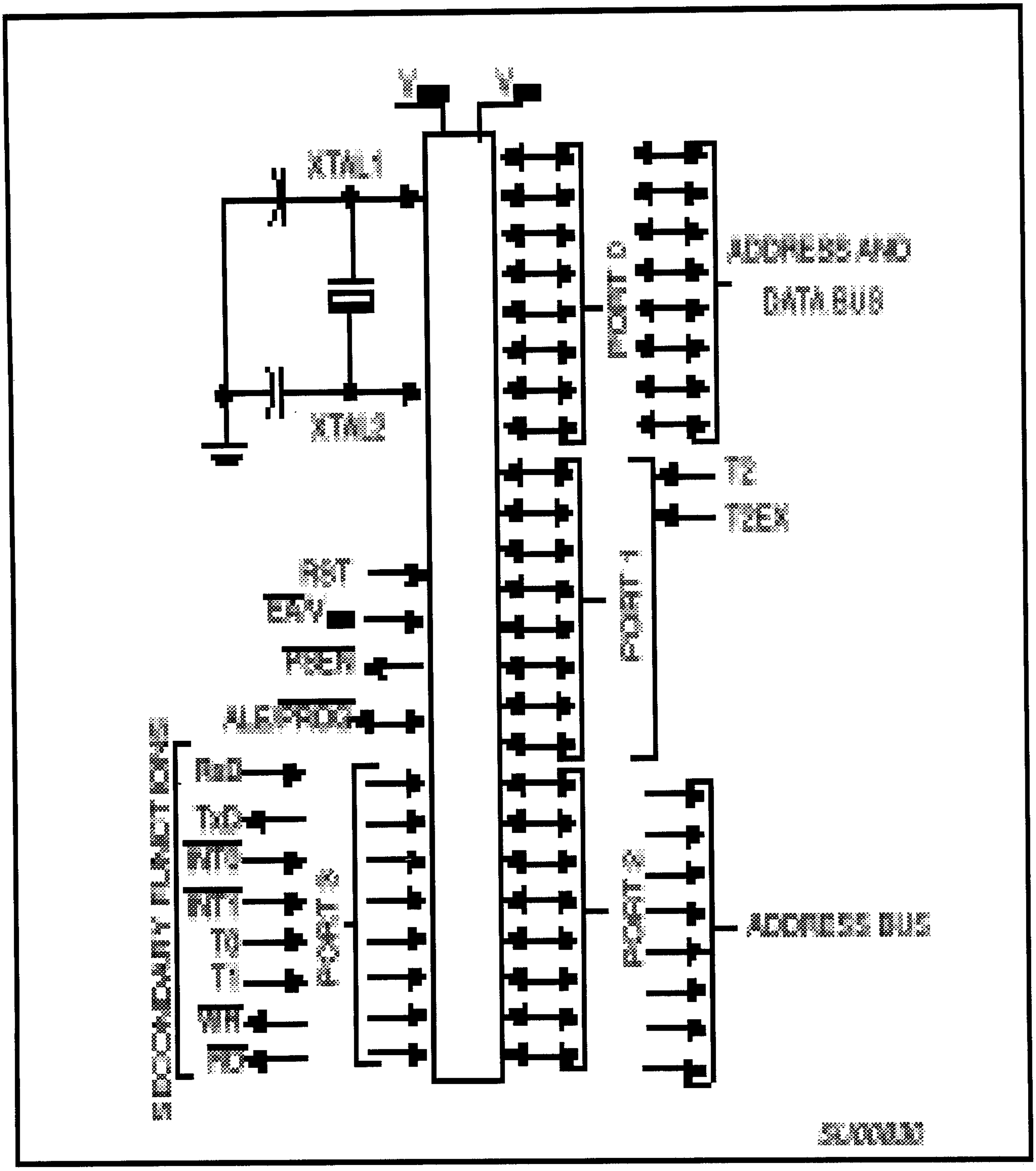


PIN CONFIGURATIONS

Dual In-Line Package Pin Functions



LOGIC SYMBOL



3.2 FEATURES OF 89C51

- It is the 80c51 central processing unit
- On chip FLASH program memory
- Speed up to 33 MHZ
- Fully static operation
- RAM expandable externally to 64 kbytes
- 4 interrupt priority levels
- 6 Interrupt sources
- four 8-bit I/O ports
- Full duplex enhanced UART
- Framing error detection
- Automatic address recognition
- Three 16 bit timers/counters
- Power control modes used are
- Clocked can be stopped and resumed

- Programmable clock out
- Asynchronous port reset
- Low EMI
- Wake up from power down by external interrupt

SOFTWARE PROGRAM

```
        org 0000h

        mov p1,#00h

        mov p3,#0ffh

        clr a

        mov a,#01h


l       setb p1.4

        acall delay

        clr p1.4

        acall delay

        setb p1.4


        mov p1,#05h         ;3 phase sequence

        jb 0b0h,n
```

```
            lcall speedup
n           jb 0b1h,m
            lcall speedown


m           setb p1.4
            acall delay
            clr p1.4
            acall delay
            setb p1.4


            mov p1,#04h
            jb 0b0h,n1
            lcall speedup
n1          jb 0b1h,m1
            lcall speeddown
```

```
m1      setb p1.4
        acall delay
        clr p1.4
        acall delay
        setb p1.4


        mov p1,#06h
        jb 0b0h,n2
        lcall speedup
n2      jb 0b1h,m2
        lcall speeddown


m2      setb p1.4
        acall delay
        clr p1.4
```

```
                acall delay
                setb p1.4

                mov p1,#02h
                jb 0b0h,n3
                lcall speedup
n3              jb 0b1h,m3
                lcall speeddown

m3              setb p1.4
                acall delay
                clr p1.4
                acall delay
                setb p1.4
```

```
        mov p1,#03h
        jb 0b0h,n4
        lcall speedup
n4      jb 0b1h,m4
        lcall speeddown

m4      setb p1.4
        acall delay
        clr p1.4
        acall delay
        setb p1.4

        mov p1,#01h
        jb 0b0h,n5
        lcall speedup
```

```
n5          jb 0b1h,m5
            lcall speeddown

m5          ljmp l
speedup     cjne a,#0ah,up
            ret
up          inc a
            ret

speeddown   cjne a,#01h,down
            ret
down        dec a
            ret
```

CONCLUSION

The feasibility of a three phase ac transistorized inverter for ac induction motor (an electric vehicle) propulsion system application was demonstrated. This type of system has potential cost and maintenance advantages over dc chopper based system. The ac motor has a simple yet rugged construction without commutators & brushes, requires no routine maintenance, is amenable to mass production, is capable of high speeds which reduces its size and can be totally enclosed. The inverter utilizes the advances in high power MOSFET's to obviate the need for costly power level communication circuits that would be needed for a thyristor approach. The inverter is consequently allowed to operate at higher switching frequencies to improve current waveform delivered to motor and thereby to increase the motor efficiency and hence finds application in many areas like Textile industry and railways

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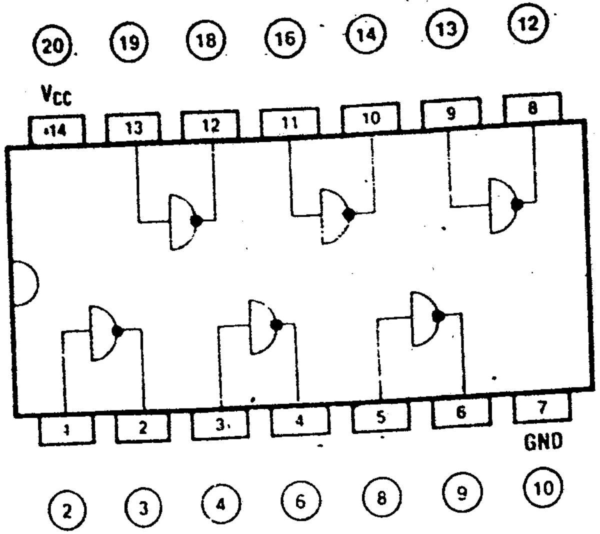
8. www.semiconductors.philips.com/pip/p89c51ubpn.htm

APPENDIX

Inverters
Convertisseurs
Invertitori
Inversores

iehe Section 1
e see section 1
ue voir section 1
logica vedi sez 1
iad. ver sección 1



Typ · Type · Tipo −40…85°C § −25…85°C	−55…125°C	Hersteller Production Fabricants Produttori Fabricantes	Bild Sec. 3 Pins-Art-Nr.	I_S &I_R mA	t_{PD} E·Q ns_{typ}		t_{PD} E·Q ns_{max}		Bemerk. Note f_T §f_Z &f_E MHz
	CD54AC04E	Rca	14-dil-1	& 4μ			6.5	6.5	
CD74AC04E		Rca	14-dil-1	& 4μ			5.9	5.9	
	CD54AC04H	Rca	chip	& 4μ			6.5	6.5	
	CD54AC04M	Rca	14-smd-1	& 4μ			6.5	6.5	
CD74AC04M		Rca	14-smd-1	& 4μ			5.9	5.9	
HD74AC04		Hit	14-dil	& 4μ			7	8.5	
	54AC04D	Fch.Nsc	14-dil-4	& 8μ	3.5	4	7.5	8.5	
74AC04D		Fch.Nsc	14-dil-4	& 4μ	3.5	4	7	7.5	
	54AC04F	Fch.Nsc	14-flat-1	& 8μ	3.5	4	7.5	8.5	
	54AC04L	Fch.Nsc	20-chip-2	& 8μ	3.5	4	7.5	8.5	
74AC04P		Fch.Nsc	14-dil-1	& 4μ	3.5	4	7	7.5	
74AC04S		Fch.Nsc	14-smd-1	& 4μ	3.5	4	7	7.5	
	CD54ACT04E	Rca	14-dil-1	& 4μ			9.3	9.3	
CD74ACT04E		Rca	14-dil-1	& 4μ			8.5	8.5	

0…70°C §0…75°C	−40…85°C §−25…85°C	−55…125°C	Fabricants Produttori Fabricantes	Pins-Art-Nr.	mA	typ				MHz
		CD54ACT04H	Rca	chip	&(4μ			9.3	9.3	
		CD54ACT04M	Rca	14-smd-1	&(4μ			9.3	9.3	
	CD74ACT04M		Rca	14-smd-1	&(4μ			8.5	8.5	
C										
	MM74C04J	MM54C04J	Nsc	14-dil-4		50	50	90	90	
	MM74C04N		Nsc	14-dil-1		50	50	90	90	
		MM54C04W	Nsc	14-flat-1		50	50	90	90	
HC										
BU74HC04			Toy	14-dil	&(2μ			24	24	
	CD74HC04E		Rca	14-dil-1	&(2μ	6	6	21	21	
		CD54HC04F	Rca	14-dil-4	&(2μ	6	6	26	26	
		CD54HC04H	Rca	chip	&(2μ	6	6	26	26	
	CD74HC04M		Rca	14-smd-1	&(2μ	6	6	21	21	
HD74HC04			Hit	14-dil	&(2μ			24	24	
JRC74HC04			Njr	14-dil	&(2μ			24	24	
LC74HC04			Say	14-dil	&(2μ			24	24	
LR74HC04			Sha	14-dil	&(2μ			24	24	
M74HC04			Mit	14-dil	&(2μ			24	24	
MB74HC04			Fu	14-dil	&(2μ			24	24	
		MC74HC04D	Mot	14-smd-1	&(2μ	9	9	16	16	
		MC54HC04J	Mot	14-dil-4	&(2μ	9	9	16	16	
		MC74HC04N	Mot	14-dil-1	&(2μ	9	9	16	16	
		MC74HC04AD	Mot	14-smd-1	&1μ			22	22	
		MC54HC04AJ	Mot	14-dil-4	&1μ			22	22	
		MC74HC04AN	Mot	14-dil-1	&1μ			22	22	
	MM74HC04J	MM54HC04J	Nsc	14-dil-4	&(2μ	9	9	16	16	
	MM74HC04N		Nsc	14-dil-1	&(2μ	9	9	16	16	
	MN74HC04		Mat	14-dil-1	&(2μ			24	24	
	MN74HC04S		Mat	14-smd-1	&(2μ			24	24	
MSM74HC04			Oki	14-dil	&(2μ			24	24	
	PC74HC04P		Phi.Val	14-dil-1	&(2μ	9	9	21	21	
	PC74HC04T		Phi.Val	14-smd-1	&(2μ	9	9	21	21	
SN74HC04D			Tix	14-smd-1	&(2μ	9	9	24	24	
		SN54HC04FH	Tix	20-chip-3	&(2μ	9	9	29	29	
	SN74HC04FH		Tix	20-chip-3	&(2μ	9	9	24	24	
		SN54HC04FK	Tix	20-chip-2	&(2μ	9	9	29	29	
	SN74HC04FN		Tix	20-chip-1	&(2μ	9	9	24	24	
		SN54HC04J	Tix	14-dil-4	&(2μ	9	9	29	29	
	SN74HC04J		Tix	14-dil-4	&(2μ	9	9	24	24	
	SN74HC04N		Tix	14-dil-1	&(2μ	9	9	24	24	
T74HC04			Sgs	14-dil	&(2μ			24	24	
TD74HC04			Tos	14-dil	&(2μ			24	24	
μPB74HC04			Nec	14-dil	&(2μ			24	24	
HCT										
	CD74HCT04E		Rca	14-dil-1	&(2μ	7	7	24	24	
		CD54HCT04F	Rca	14-dil-4	&(2μ	7	7	29	29	

-40...85°C §-25...85°C	-55...125°C	Production Fabricants Produttori Fabricantes	Sec. 3 Pins-Art-Nr.	I_S &I_R mA	t_{PD} E·Q ns_{typ} ↓	t_{PD} E·Q ns_{typ} ↑	t_{PD} E·Q ns_{max} ↓	t_{PD} E·Q ns_{max} ↑	Note f_T §f_Z &f_E MHz
4HCT04M	CD54HCT04H	Rca	chip	&(2µ	7	7	29	29	
		Rca	14-smd-1	&(2µ	7	7	24	24	
		Sha	14-dil	&(2µ			24	24	
		Mit	14-dil	&(2µ			24	24	
		Fui	14-dil	&(2µ			24	24	
	MC54HCT04J	Mot	14-dil-4						
	MC74HCT04N	Mot	14-dil-1						
	MC74HCT04AD	Mot	14-smd-1	&1µ			26	22	
	MC54HCT04AJ	Mot	14-dil-4	&1µ			26	22	
	MC74HCT04AN	Mot	14-dil-1	&1µ			26	22	
HCT04J	MM54HCT04J	Nsc	14-dil-4	&(2µ	14	14	20	20	
HCT04N		Nsc	14-dil-1	&(2µ	14	14	20	20	
HCT04		Mat	14-dil-1	&(2µ			24	24	
HCT04S		Mat	14-smd-1	&(2µ			24	24	
		Oki	14-dil	&(2µ			24	24	
CT04P		Phi,Val	14-dil-1	&(2µ	10	10	24	24	
CT04T		Phi,Val	14-smd-1	&(2µ	10	10	24	24	
		Tix	14-smd-1	&(2µ	14	14	25	25	
	SN54HCT04FK	Tix	20-chip-2	&(2µ	14	14	30	30	
	SN54HCT04J	Tix	14-dil-4	&(2µ	14	14	30	30	
		Tix	14-dil-1	&(2µ	14	14	25	25	
		Sgs	14-dil	&(2µ			24	24	
		Tos	14-dil	&(2µ			24	24	
		Nec	14-dil	&(2µ			24	24	
		Toy	14-dil						
		Njr	14-dil						
		Say	14-dil						
		Mit	-14-dil						
		Fui	14-dil						
	MC74HCU04AD	Mot	14-smd-1	&(2µ	8	8	14	14	
	MC54HCU04J	Mot	14-dil-4	&(2µ	8	8	14	14	
	MC74HCU04N	Mot	14-dil-1	&(2µ	8	8	14	14	
U04J	MM54HCU04J	Nsc	14-dil-4	&(2µ	8.4	8.4	14	14	
U04N		Nsc	14-dil-1	&(2µ	8.4	8.4	14	14	
J04		Mat	14-dil-1						
U04S		Mat	14-smd-1						
		Oki	14-dil						
04P		Val	14-dil-1	&(2µ	8	8	14	14	
04T		Val	14-smd-1	&(2µ	8	8	14	14	
		Tix	14-smd-1	&(2µ	8	8	20	20	
	SN54HCU04FK	Tix	20-chip-2	&(2µ	8	8	24	24	
	SN54HCU04J	Tix	14-dil-4	&(2µ	8	8	24	24	
		Tix	14-dil-1	&(2µ	8	8	20	20	
		Sgs	14-dil						
		Tos	14-dil						
		Nec	14-dil						

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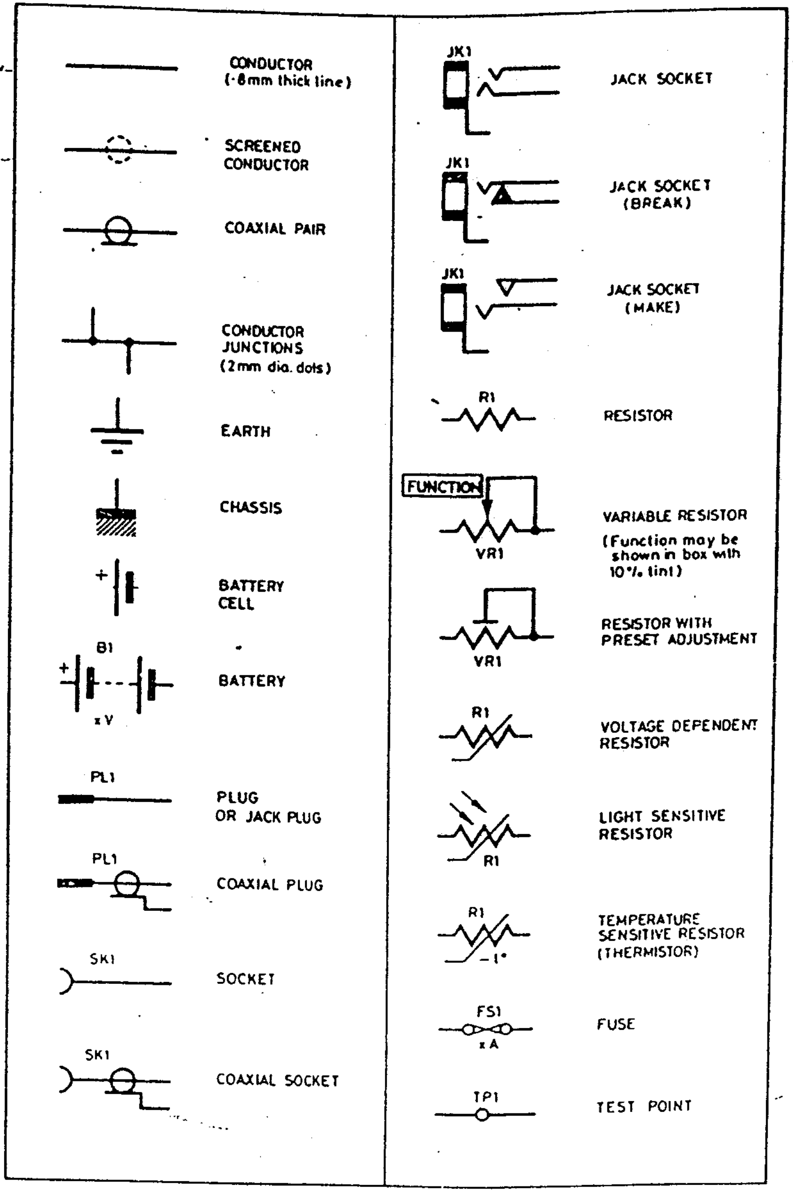
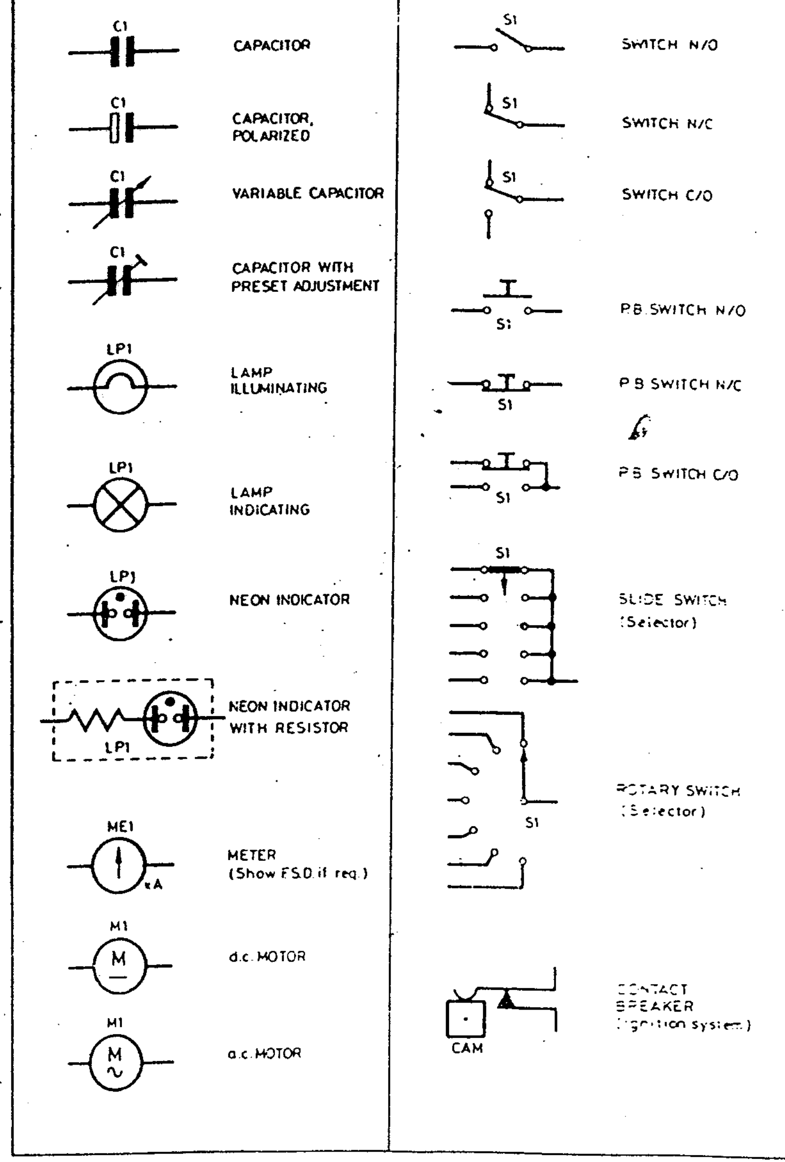
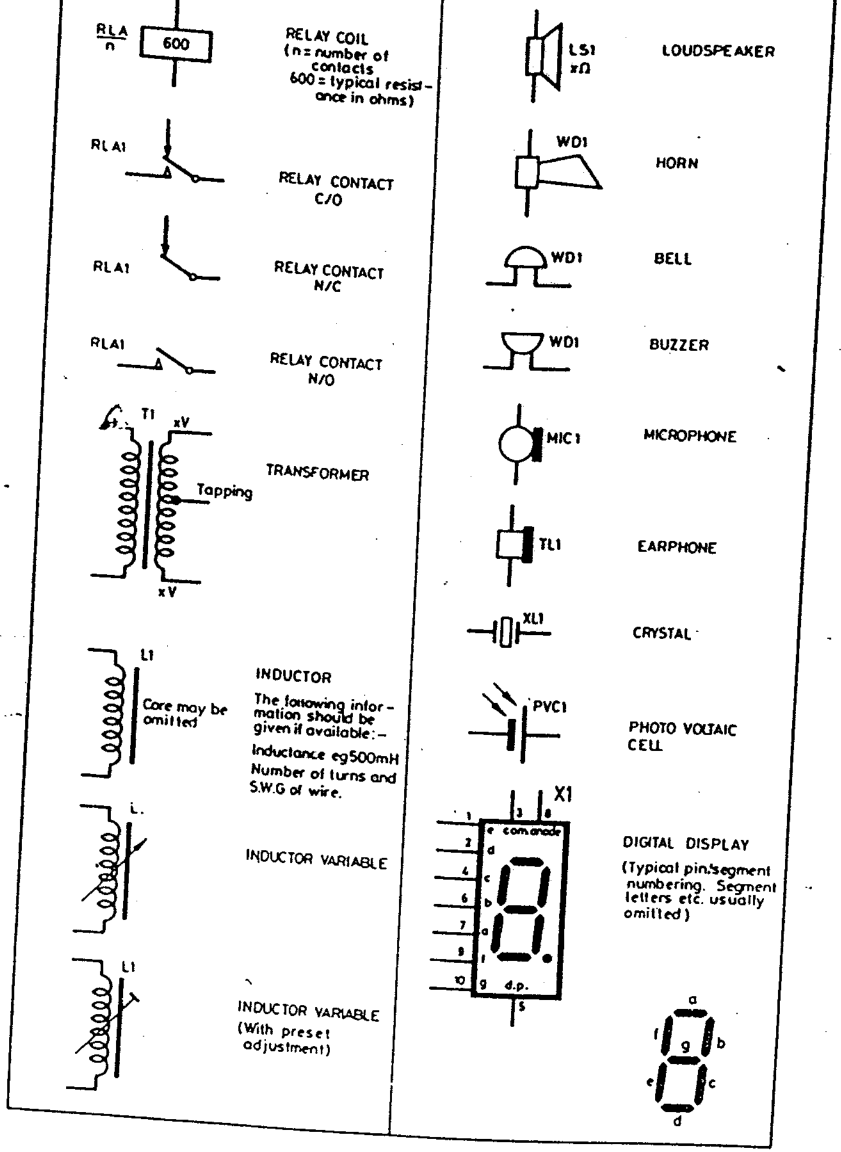
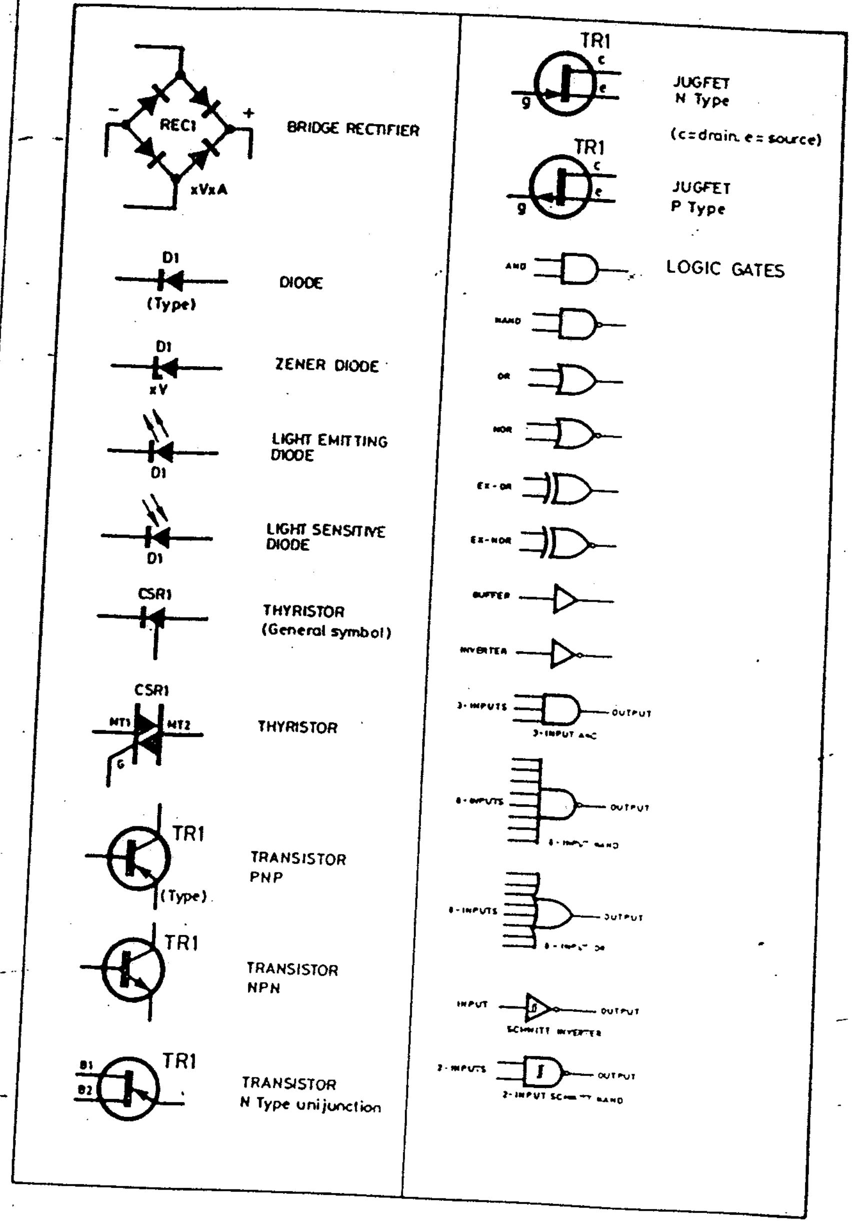
• Typ - Type - Tipo 0...70°C §0...75°C	-40...85°C §-25...85°C	-55...125°C	Hersteller Production Fabricants Produttori Fabricantes	Bild Sec. 3 Pins-Art-Nr.	I_S &I_R mA	t_{PD} E·Q ns_{typ}	t_{PD} E·Q ns_{max}	Bemerk. Note f_T §f_Z &f_E MHz


CONDUCTOR (·8mm thick line)
SCREENED CONDUCTOR
COAXIAL PAIR
CONDUCTOR JUNCTIONS (2mm dia. dots)
EARTH
CHASSIS
BATTERY CELL
B1
xV
BATTERY
PL1
PLUG OR JACK PLUG
PL1
COAXIAL PLUG
SK1
SOCKET
SK1
COAXIAL SOCKET
JK1
JACK SOCKET
JK1
JACK SOCKET (BREAK)
JK1
JACK SOCKET (MAKE)
R1
RESISTOR
FUNCTION
VR1
VARIABLE RESISTOR (Function may be shown in box with 10% tint)
VR1
RESISTOR WITH PRESET ADJUSTMENT
R1
VOLTAGE DEPENDENT RESISTOR
R1
LIGHT SENSITIVE RESISTOR
R1
TEMPERATURE SENSITIVE RESISTOR (THERMISTOR)
FS1
xA
FUSE
TP1
TEST POINT


C1
CAPACITOR
C1
CAPACITOR, POLARIZED
C1
VARIABLE CAPACITOR
C1
CAPACITOR WITH PRESET ADJUSTMENT
LP1
LAMP ILLUMINATING
LP1
LAMP INDICATING
LP1
NEON INDICATOR
LP1
NEON INDICATOR WITH RESISTOR
ME1
xA
METER (Show F.S.D. if req.)
M1
d.c. MOTOR
M1
a.c. MOTOR
S1
SWITCH N/O
S1
SWITCH N/C
S1
SWITCH C/O
S1
P.B. SWITCH N/O
S1
P.B. SWITCH N/C
S1
P.B. SWITCH C/O
S1
SLIDE SWITCH (Selector)
S1
ROTARY SWITCH (Selector)
CAM
CONTACT BREAKER (Ignition system)


RELAY COIL
(n = number of contacts 600 = typical resistance in ohms)
RELAY CONTACT C/O
RELAY CONTACT N/C
RELAY CONTACT N/O
TRANSFORMER
Tapping
INDUCTOR
The following information should be given if available:– Inductance eg500mH Number of turns and S.W.G of wire.
Core may be omitted
INDUCTOR VARIABLE
INDUCTOR VARIABLE (With preset adjustment)
LOUDSPEAKER
HORN
BELL
BUZZER
MICROPHONE
EARPHONE
CRYSTAL
PHOTO VOLTAIC CELL
DIGITAL DISPLAY
(Typical pin/segment numbering. Segment letters etc. usually omitted)
com.anode
d.p.


BRIDGE RECTIFIER
DIODE
ZENER DIODE
LIGHT EMITTING DIODE
LIGHT SENSITIVE DIODE
THYRISTOR (General symbol)
THYRISTOR
TRANSISTOR PNP
TRANSISTOR NPN
TRANSISTOR N Type unijunction
JUGFET N Type
(c=drain. e=source)
JUGFET P Type
LOGIC GATES