NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronics Engineering

An IGBT Inverter Using The Microcontroller PIC16F84

Graduation Project
EE 400

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First of all I would like to thank NEU authority who gave me the opportunity to study the Engineering Faculty on this sweet island.Also my family who supported me to study.

I would like to thank Prof. Dr. Şenol Bektaş and my instructor and project adviser Dr Özgür Özerdem and all other instructors who gave us the ability of doing this project and taught us to be engineer.

ABSTRACT

Energy is used to produce any product. It is the most effective source of production. One of the main energy types is the electrical energy in today's life. Because it has advantages in transmission, distribution and easy use, the electrical energy is the most widely used enery type both in real life and in industrial environments . It can be distributed with a line of a few *cm* of diameter and easily be converted to mechanical energy or heat by the producer, using simple methods.

Converting the electrical energy to mechanical energy is an important step on a production line. Different types of induction motors with different powers are used to get the needed amount of mechanical energy. Controlling the torque and speed of these motors to get the needed mechanical energy, some semiconductor electronic power components has been improved. The power which supplies a motor can be controlled in different ways using these semiconductors.

The power and speed control mechanism of an A.C. motor is so called inverter. It mainly consumes DC power and generates A.C power..Some inverters has the ability of adjusting the frequency, too. It can be designed using different types of electronic components.

This project uses a different approach to design a "3 phase adjustable frequency inverter" to create the A.C power. Simply 6 IGBTs are used to drive the 3 phase A.C. motor and a microcontroller is used to control the frequency and phases of the inverter.

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INTRODUCTION

The design is a project of a 3 phase square wave Igbt inverter with adjustable frequency. A "microcontroller" is programmed to derive 3 square signals, each with 120 degree between, and the reverse of each phase.These 6 outputs trigger the "Igbt drivers" and the igbts drive the motor.

The project can be divided into four main parts.These are regulation part, control part, driving part and power part.

Regulaiton Part

The regulation part supplies the microcontroller and the igbt drivers.It supplies a constant 5V and an adjustable voltage between 3-24V.

Control Part

The control part cosists of a "microcontroller" , a dot matrix display and 2 buttons. The microcontroller is programmed to derive the signals and to drive the "dot matrix display". The dot matrix display indicates the frequency. 2 buttons are used to manage the control of the microcontroller.One is used to let the user change the frequency and the other is used to let the user tum on/off the light of the LCD.

lgbt Driving Part

This part contains 6 igbt driver chips. These chips drive 6 igbts and isolate the power part from the control part to protect the low power side.

Power Part

The power part contains 6 igbts. This part has the ability of driving an inductive A.C. load.

CHAPTER 1

1.1 Overview

This chapter contains explanation for each component used in the project. The properties of each component is explained in a separate part.

1.2 Components:

Resistor	Carbon Composition
Capacitors	Seramic Capacitor (Disc-Monolithic - Non-polarized)
	Aluminum Electrolytic Capacitor (Polarized)
	Tantalium Oxide Capacitor (Non-Polarized)
Potentiometers	Carbon Composition Potentiometer
Switch Button	Simple on/off switch button
Oscillator	Crystal 4.0 Mhz
Voltage Regulators :	LM7805 - LM317
lgbt	IRG4PH40KD
lgbt Driver	Tlp250
Microcontroller	Pic16f84
Display	Dot Matrix Led 1602-01

1.2.1 Resistors

A resistor is a standard component that provides resistance in an electrical or electronic circuit. It is available as either a fixed resistor having a specific value in ohms or as a variable resistor with an adjustable range of specified values. Figure 1.1 shows symbol of a resistor, Figure 1.2 shows a simple resistor.

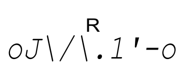


Figure 1.1 Symbol of a Resistor

Figure 1.2 Simple Resistor

Resistors are color coded. To read the color code of a common.Simply 4 band IK ohm resistor with a 5% tolerance, start at the opposite side of the Gold tolerance band and read from left to right. Write down the corresponding number from Table 1.1

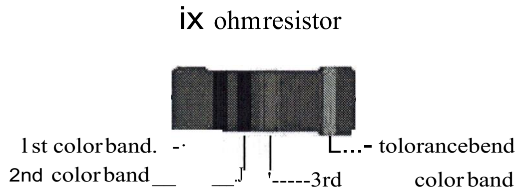


Figure 1.3 A Resistor With Colour Codes

For the 1st color band BROWN. To the right of that number, write the corresponding number for the 2nd band BLACK. Now multiply that number by the corresponding multiplier number of the 3rd band (RED) (100). Your answer will be 1000 or 1K. As shown in figure 1.1.

Table 1.1 can be used to read the colour codes .

Band Color	1st Band #	2nd Band #	*3rd Band #	Multiplier x	Tolerances ± %
Black	0	0	0	1	
Brown	1	1	1	10	± 1%
Red	2	2	2	100	± 2 %
Orange	3	3	3	1000	
Yellow	4	4	4	10,000	
Green	5	5	5	100,000	± 0.5 %
Blue	6	6	6	1,000,000	± 0.25 %
Violet	7	7	7	10,000,000	± 0.10 %
Grey	8	8	8	100,000,000	± 0.05 %
White	9	9	9	1,000,000,000	
Gold				0.1	± 5 %

Table 1.1 Colour Codes

Carbon composition resistors are used in this circuit.

1.2.1.1 Carbon Composition Resistors

Carbon composition resistors are useful in general-purpose applications. A filler and binder are mixed with carbon powder and then formed into a cylinder with leads anchored to its ends.

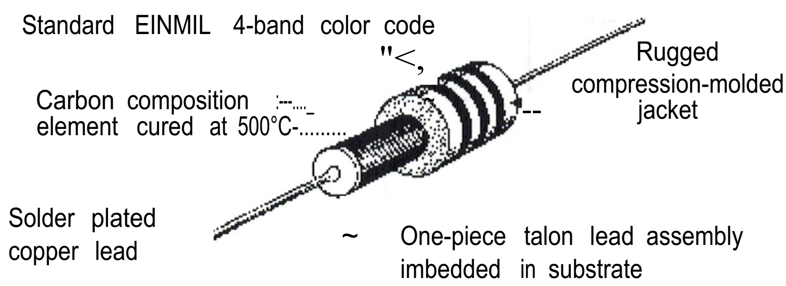


Figure 1.4 Carbon Composition Resistor Construction

Carbon film resistors are manufactured with resistance values and power ratings similar to those of carbon composition types (1 ohm to 22 megohms and 1/8 watt to 2 watts). Tolerances range from ±2% to ±10%, with the TC about one third that of carbon composition (approximately 2500 ppm/°C). Carbon film resistors, however, tend to generate more electrical noise than carbon composition resistors. The epoxy coating provides physical protection and resistance to certain environmental stresses.

Carbon composition resistors are intended for applications where there are no stringent requirements for resistance tolerance, temperature stability, or low noise. They are specified in commercial, industrial, or consumer equipment, and for military and space applications. These resistor types are sometimes used where instantaneous surge currents are present since they are capable of safely handling sudden overloads of current and power for a short time.

RAN"GE AND TOLERANCES
Carbon composition resistors range from 1 ohm to 22 megohms with tolerances of: ±20%, ±10, and ±5%

Base values indicate the first two numbers of the resistance value, e.g.: a 3000 ohm resistor (base value = 30) is only available as a ±5% tolerance type.
(See Figure 9 9)

The base values are established by the Electronics Industry Association (EIA)

POV!ER CAP ABILITY
Power capability is dependent upon the physical size of the resistor and ranges from J{ watt to 2 watts.

TElvIPERATURE COEFFICIENT
The temperature coefficient (TC) of carbon composition resistors is relatively very high, about 6500 ppm/°C, or 0 65% change in resistance per °C change in temperature.

±20%	± 10%	±5%
10	10	10
		11
	·12	12
		13
15	15	15
		16
	18	18
		20
22	22	22
		24
	27	27
		30
33	33	33
		36
		39
		43
47	47	47
		51
	56	56
		62
68	68	68
		75
	82	82
		91

Table 1.2 Tolerance ranges

1.2.2 Capacitors

A capacitor is an electrical storage component that has the capability of accepting an electrical charge (voltage and current) from a voltage source. This charge can be stored for as long as required and then released. The unit of capacitance is the farad, F, named after Michael Faraday. By definition, a one farad capacitor will charge to one volt in one second with a current of one ampere.In its basic form, a capacitor consists of two conducting metal plates with terminals attached to each plate. Sandwiched between the two metal plates is a nonconducting material called the dielectric. By applying a voltage across the metal plates (terminals) of the capacitor, an electric charge is applied across its dielectric where it is stored until discharged. The polarity of the voltage is maintained across the dielectric until the applied voltage is reversed or the capacitor is discharged.

Capacitance is the measure of the storage capability of a capacitor, and its value is dependent upon the area of the metal plates, the distance between them, and the specific dielectric material between the plates. Figure 1.5 shows construction of a simple resistor.

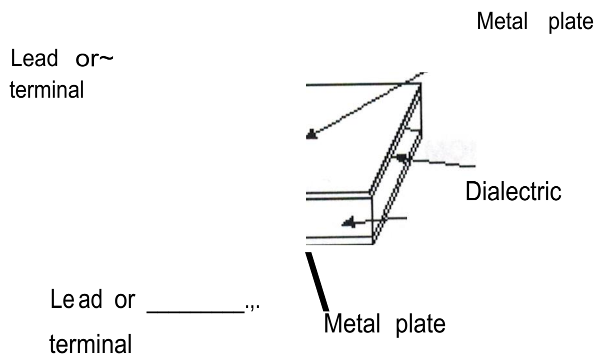


Figure 1.5 Construction of capacitor

1.2.2.1 Capacitor Types

Capacitors are categorized as variable non-polarized, fixed non-polarized, and fixed polarized. Their schematic symbols are shown in Figures 1.6. Many varieties of capacitance characteristics exist within each category such as tolerance, voltage capability, temperature range, the capability to withstand environmental stress, package configurations, and process techniques. Different dielectric materials provide unique electrical characteristics required for each type. Figure 1.6 shows symbols of these capacitor types.

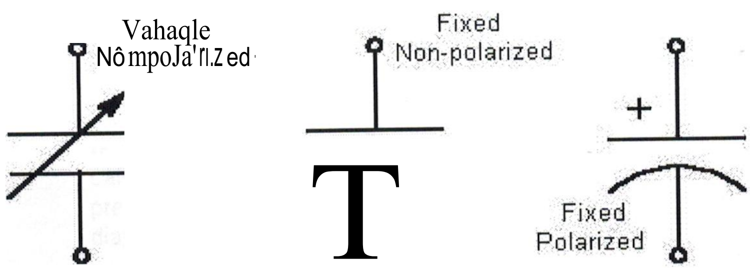


Figure 1.6 Capacitor Symbols

3 different capacitor type are used in this project.

1.Seramic Capacitor (Disc-Monolithic - Non-polarized)

2.Aluminum Electrolytic Capacitor (Polarized)

3.Tantalium Oxide Capacitor (Non-Polarized)

1.2.2.2 Ceramic Capacitors

This type of capacitors are used in high-frequency coupling and filter application circuits, fast timing circuits, and RF tuned circuits. Capacitance values range from lpf to 10 OF with voltage breakdown capability up to 50,000 volts.

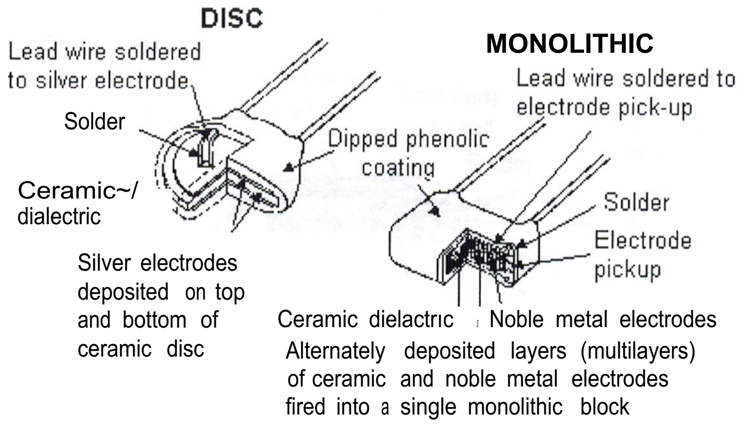


Figure 1.7 Construction of Capacitors

1.2.2.3 Aluminum Oxide

This type of capacitors are used in commercial, industrial, and consumer applications in DC filters, low frequency AC filters, and voltage storing circuits, is used over a limited temperature range (-40°C to +85°C). Capacitance values range from 0.1 OF to 1 farad. Voltage ratings range from 3 to 500 volts. See Figure 1.8.

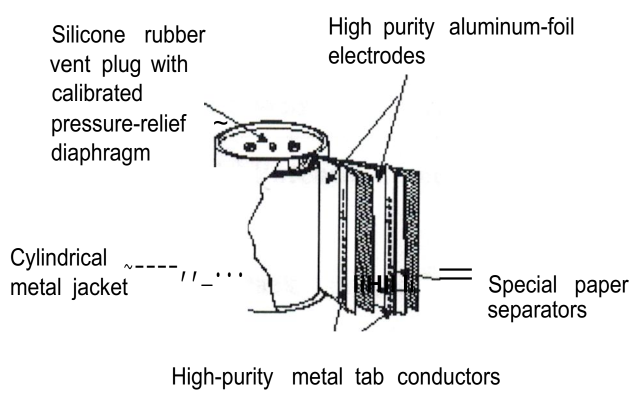


Figure 1.8 Construction of Aluminum Oxide Capacitor

1.2.2.4 Tantalium Oxide Capacitors

Applicable for the same applications as aluminum oxide types. They have approximately the same capacitance and voltage ratings. Tantalum oxide capacitors are specifically intended for military and space applications because of their wide operating and storage temperature range (-55°C to +125°C). In comparison with aluminum oxide capacitor types, they have greater stability and reliability, are physically smaller, but are more expensive.See Figure 1.9 for construction of a tantalium oxide capacitor.

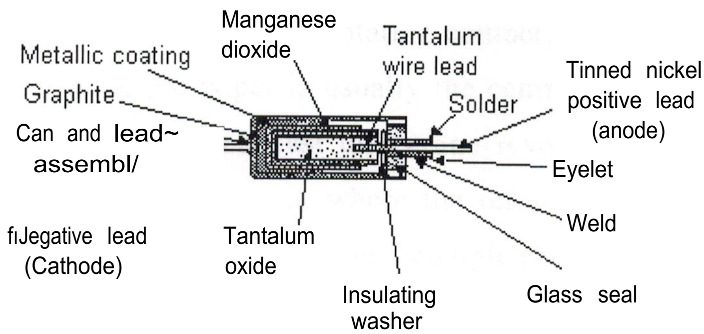


Figure 1.9 Constrution of Aluminum Oxide Capacitor

1.2.3 Potentiometers

A potentiometer has three terminals and is basically a variable potential divider. Figure 1.10 shows symbols of a simple potentiometer.

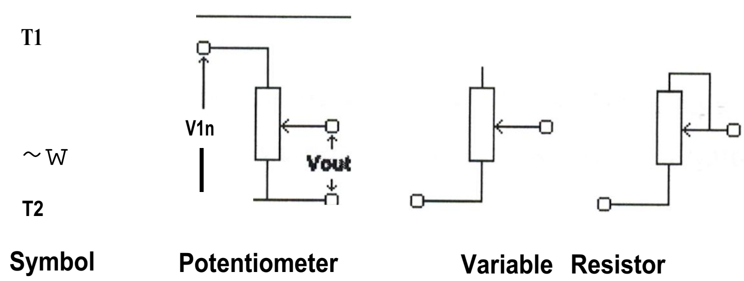


Figure 1.10 Potentiometer Symbols

A potentiometer has a resistive track (normally made of carbon), the ends of which are connected to two of the pins (Tl and T2). The value marked on a potentiomer refers to the resistance of this track. The third pin is the the 'wiper' connection (W); this touches the track at an adjustable point set by the control shaft. The internal construction of a potentiometer is shown in Figure 1.11.

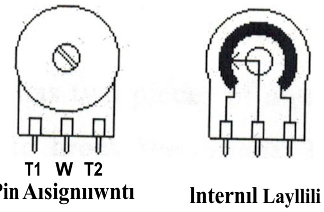


Figure 1.11 Internal construction of Potentiometer

A potentiometer is constructed using a flat graphite annulus as the resistive element, with a sliding contact (wiper) sliding around this annulus. The wiper is connected to an axle and, via another rotating contact, is brought out as the third terminal. On panel pots, the wiper is usually the centre terminal. For single turn pots, this wiper typically travels just under one revolution around the contact. 'Multiturn' potentiometers also exist, where the resistor element may be helical and the wiper may move 10, 20, or more complete revolutions. In addition to graphite, other materials may be used for the resistive element. These may be resistance wire or carbon particles in plastic or a ceramic/metal mixture. One popular form of rotary potentiometer is called a *string pot.* It is a multi-turn potentiometer with an attached reel of resistance wire turning against a spring. It's very convenient for measuring movement and therefore acts as a position transducer. In a linear slider pot, a sliding control is provided instead of a dial control. The word *linear* also describes the geometry of the resistive element which is a rectangular strip, (not an annulus as in a rotary potentiometer). Because of their construction, this type of pot has a greater potential for getting contaminated. Potentiometers can be obtained with either linear or logarithmic laws. The internal construction of a potentiometer is shown in Figure 1.11.

1.2.4 Switch Buttons

A switch is a device for changing the course (or flow) of a circuit. The prototypical model is a mechanical device (for example a railroad switch) which can be disconnected from one course and connected to another. See Figure 1.12 for symbol of a switch

Figure 1.12 Symbol of a Switch

In the simplest case, a switch has two pieces of metal called contacts that touch to make a circuit, and separate to break the circuit. The contact material is chosen for its resistance to corrosion, because most metals form insulating oxides that would prevent the switch from working. Sometimes the contacts are plated with noble metals. They may be designed to wipe against each other to clean off any contamination. Nonmetallic conductors, such as conductive plastic, are sometimes used. The moving part that applies the operating force to the contacts is called the actuator, and may be a toggle or dolly, a rocker, a push-button or any type of mechanical linkage. See Figure 1.13 to for switche buttons used in the circuit.

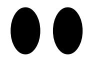


Figure 1.13 A Button

1.2.5 Crystals

A crystal is a solid in which the constituent atoms, molecules, or ions are packed in a regularly ordered, repeating pattern extending in all three spatial dimensions.See Figure 1.14 for symbol of a cyristal.and its equivalent circuit.

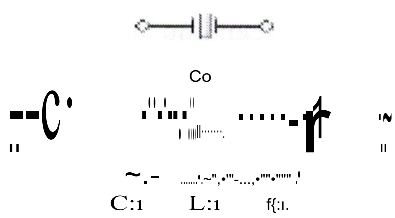


Figure 1.14 Equivalent Circuit of Crystal

Almost any object made of an elastic material could be used like a crystal, with appropriate transducers, since all objects have natural resonant frequencies of vibration. For example, steel is very elastic and has a high speed of sound. It was often used in mechanical filters before quartz. The resonant frequency depends on size, shape, elasticity and the speed of sound in the material. High-frequency crystals are typically cut in the shape of a simple, rectangular plate. Low-frequency crystals, such as those used in digital watches, are typically cut in the shape of a tuning fork. For applications not needing very precise timing, a low-cost ceramic resonator is often used in place of a quartz crystal. See Figure 1.15

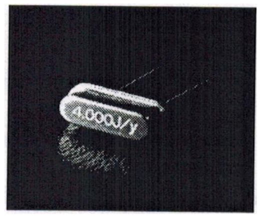


Figure 1.15 A Crystal

When a crystal of quartz is properly cut and mounted, it can be made to bend in an electric field, by applying a voltage to an electrode near or on the crystal. This property is known as piezoelectricity. When the field is removed, the quartz will generate an electric field as it returns to its previous shape, and this can generate a voltage. The result is that a quartz crystal behaves like a circuit composed of an inductor, capacitor and resistor, with a precise resonant frequency. Quartz has the further advantage that its size changes very little with temperature. Therefore, the resonant frequency of the plate, which depends on its size, will not change much, either. This means that a quartz clock, filter or oscillator will remain accurate. For critical applications the quartz oscillator is mounted in a temperature-controlled container, called an crystal oven, and can also be mounted on shock absorbers to prevent perturbation by external mechanical vibrations. Quartz timing crystals are manufactured for frequencies from a few tens of kilohertz to tens of megahertz. More than two billion (2×10^9) crystals are manufactured annually. Most are small devices for wristwatches, clocks, and electronic circuits. However, quartz crystals are also found inside test and measurement equipment, such as counters, signal generators, and oscilloscopes.

1.2.6 Voltage Regulators

A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level.It may use an electromechanical mechanism, or passive or active electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.With the exception of shunt regulators, all voltage regulators operate by comparing the actual output voltage to some internal fixed reference voltage. Any difference is amplified and used to control the regulation element. This forms a negative feedback servo control loop. If the output voltage is too low, the regulation element is commanded to produce a higher voltage. If the output voltage is too high, the regulation element is commanded to produce a lower voltage. In this way, the output voltage is held roughly constant. The control loop must be carefully designed to produce the desired tradeoff between stability and speed of response.

1.2.6.1 Integrated Circuit Regulators

Usually having three legs, converts varying input voltage and produces a constant regulated output voltage. They are available in a variety of outputs. The most common part numbers start with the numbers 78 or 79 and finish with two digits indicating the output voltage. The number 78 represents positive voltage and 79 negative one. The 78XX series of voltage regulators are designed for positive input. And the 79XX series is designed for negative input.

1.2.6.1.1 The LM7805

The LM7805 is a three terminal positive regulator.It This regulator can provide local on card regulation, eliminating the distribution problems associated with single point regulation. The constant voltage allow the LM7805 be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. . It is used to supply a constant 5V to Pie 16F84 and to the LCD. See Figure1. 16-1.17 for block diagram and pin connections of a LM7805.

Features

- Input Voltage of 7-36V
- Output Voltage of 5V
- Output Current up to 1A
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor SOA Protection

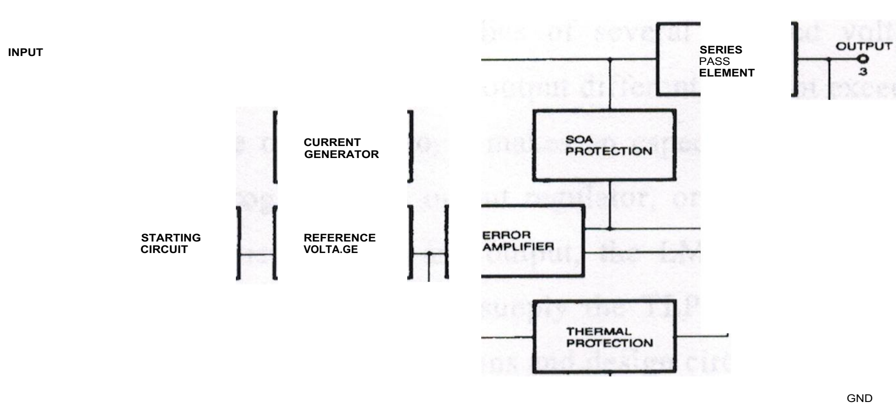


Figure 1.16 Block Diagram of LM7805

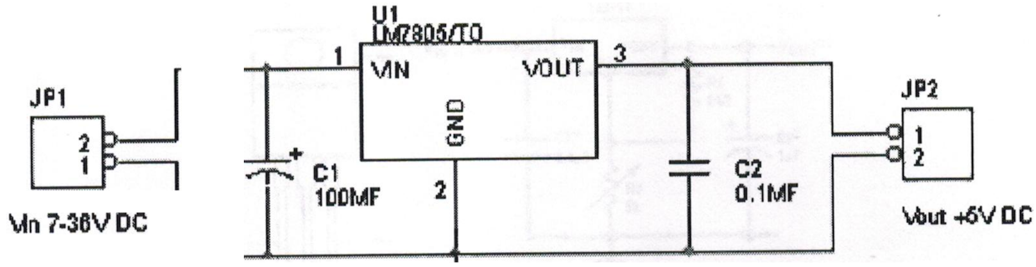
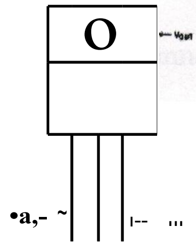


Figure 1.17 Application Circuit for LM7805

1.2.6.1.2 The LM317

The LM317 is adjustable 3-terminal positive voltage regulator. It is capable of supplying in excess of 1.5A over a 1.2V to 37V output range. It is exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM317 is packaged in standard transistor packages which are easily mounted and handled. In addition to higher performance than fixed regulators, the LM317 offers full overload protection available only in IC' s. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected. Normally, no capacitors are needed unless the device is situated more than 6 inches from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection ratios which are difficult to achieve with standard 3 terminal regulators.Besides replacing fixed regulators, the LM317 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded, i.e., avoid short-circuiting the output. Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment pin and output, the LM317 can be used as a precision current regulator. It is used to supply the TLP250 Igbt driver, in the project. See Figures 1.18-1.19 pin connections and design circuit.



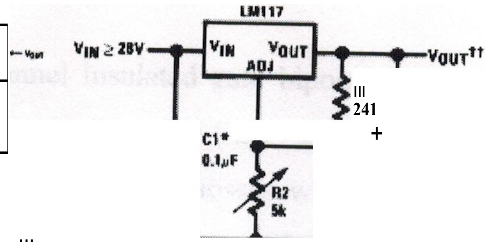


Figure 1.18 Appeariance ofLM317 Figure 1.19 Application Circuit for LM317

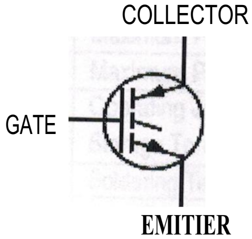
Features

- Guaranteed 1 % output voltage tolerance
- Guaranteed max. 0.0l %/V line regulation
- Guaranteed 1 .5A output current
- Adjustable output down to 1.2V
- Current limit constant with temperature
- P+ Product Enhancement tested
- 80 dB ripple rejection
- Output is short-circuit protected

1.2.7 Igbts (Insulated Gate Bipolar Transistor)

The IGBT is, in fact, a spin-off from power MOSFET technology and the structure of an IGBT closely resembles that of a power MOSFET. The IGBT has high input impedance and fast turn-on speed like a MOSFET. IGBTs exhibit an on-voltage and current density comparable to a bipolar transistor while switching much faster. }GBTs are replacing MOSFETs in high voltage applications where conduction losses must be kept low. With zero current switching or resonant switching techniques, the IGBT can be operated in the hundreds of kilohertz range. Although turn-on speeds are very fast, turn-off of the IGBT is slower than a MOSFET. The IGBT exhibits a current fall time or "tailing." The tailing restricts the devices to operating at moderate frequencies (less than 50 kHz) in traditional "square waveform" PWM, switching applications. Check Figures 1.20-1.21 to see symbol and crossection of an Igbt.

It is used to drive the load in the project.



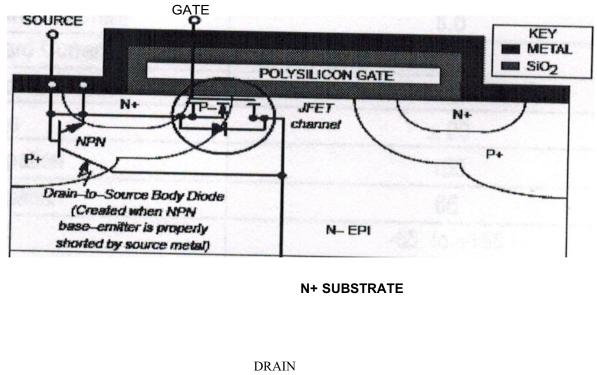


Figure 1.20 Symbol of Igbt **Figure 1.21 Internal Construction of Igbt**

1.2.7.1 Irg4ph40kd

The irg4ph40kd is an "n" channel insulated gate bipolar transistor.It is a high short circuit rating optimized igbt for motor control (tsc =lüµs, VCC = 720V, *TI*= 125°C, VOE = 15V). It Combines low conduction losses with high switching speed. It has tighter parameter distribution and higher efficiency than previous generations. This igbt is co-packaged with HEXFREDTM ultrafast, ultrasoft recovery antiparallel diodes. It is the latest generation Igbt and it offer high power density motor controls possible. HEXFREDTM diodes are optimized for performance with Igbts. In this igbt, minimized recovery characteristics reduce noise, and switching losses. See Figure 1 .22.

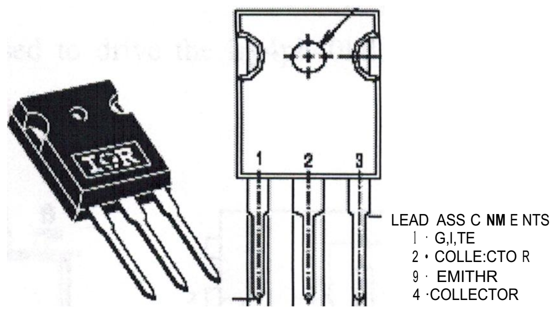


Figure 1.22 A lrg4ph40kd lgbt Pin Connections

Features

· Vess = 1200V

· VCE(on) = 2.74V

· VGE = 15V

·le =15A

Check Table 1 .3 for absolute maximum ratings.

	Parameter	Max.	Units
VcEs	Conecıor-to-Emitter Voltage	1200	V
le @Tc= 25°C	Continuous Collec1or Current	30	A
le@ Tc= 100°C	Continuous Collector Current	1'5	
IcM	Pulsed Collector Current (D	60	
ILM	Clamped Induc1ive Load Curren! @	60	
IF@ Tc= 100°c	Diode Continu,ous Forward Current	8.0	
IFM	Diode Maximum Forward Current	130	
I,	Short Circuit Wıthstand Tıme	10	µs
VGE	Gale-to-Emitter Voltaqe	±20	V
Po @Tc=25°C	Maximum Power Dissipati,on	160	W
Po@ Tc= 100°C	Maximum Power Dissipation	65	
TJ Tste	Operating Junc1i,on and Storage Temperature Range	.55 to +150	°C
	So!derincı Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mountinq Torque, 6-32 orM3 Screw.	10 lbf.i,n (U N•ml	

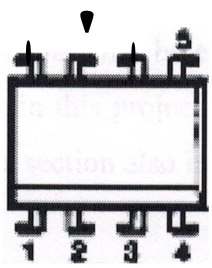
Table 1.3

1.2.8 Photocouplers

A photocoupler is a coupling device in which a light-emitting diode, energized by the input signal, is optically coupled to a photodetector such as a light-sensitive output diode, transistor, or silicon controlled rectifier ar Igbt. It is an optical isolator. It is also known as optocoupler.

1.2.8.1 Tlp250

The Tlp250 is a photocoupler. It consists of a GaAlAs light emitting diode and a integrated photodetector. This unit is 8-lead DIP package. It can drive gate of an Igbt or Power Mosfet. It is used to drive the Irg4ph40kd and protect the Pic16f84A in this project. See Figure 1.23-1.24



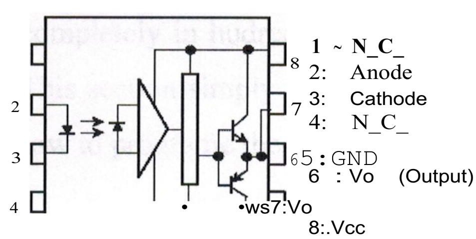


Figure 1.23Top View of TLP250 **Figure 1.24 Pin Connections and Internal Construction of TLP250**

- Input threshold current: IF=5mA(max.)
- Supply current (ICC): 1 lmA(max.)
- Supply voltage (VCC): 10-35V
- Output current (IO): ±1.5A (max.)
- Switching time (tpLH/tpHL): 1.5μs(max.)
- Isolation voltage: 2500Vrms(min.)
- Maximum operating insulation voltage: 630VPK
- Highest permissible over voltage: 4000VPK

Check Table 1.4-1.5 for the truth table and for recommended operating conditions of Tlp250

		Tr1	Tr2
Input LED	On	On	Off
	Off	Off	On

Table 1.4 Truth Table for TLP250

Characteristic	Symbol	Min.	Typ.	Max.		Unit
Il'1)ut current, on (Note 7)	If(ON)	7	8	10		mA
11'1)ut voltage, off	VF(OFF)	0	-	0.8		V
Supply voltage	Vee	15	-	30	20	V
Peak output current	IopttfloPL	-	-	±0.5		A
Operating temperature	Topr	-20	25	70	85	OC

Table 1.5 Recommended Operating Conditions of TLP250

1.2.9 Microcontrollers

It is a microcomputer used for precise process control, in data handling, communication, and manufacturing.. It is first programmed and later used for any application.

Some important features of Piel 6F84 will be discussed in this section. Since the Pie 16F84A itself may not be explained completely in hudreds of pages, there will not be much details in this project about it. This section simply indroduce the Piel 6F84A, its registers.This section also introduces how to programe the Piel 6F84.

1.2.9.1 The Pic16F84A

The PIC16F84A belongs to the mid-range family of the PICmicro® microcontroller devices. The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is the same width as each devce instruction. The data memory (RAM) contains 68 bytes. Data EEPROM is 64 bytes. There are also 13 I/O pins (Port A - Port B)that are user-configured on a pin-to-pin basis. Some pins are multiplexed with other device functions. These functions include:

• External interrupt
• Change on PORTB interrupt
• Timerü clock input

The Mid-Range Architecture includes members of the PIC12 and PIC16 families that feature a 14-bit program word architecture. These families are available with 8- to 64-pin package options. The PIC microcontrollers featuring Microchip's Mid-Range 14-bit program word architecture are available in higher pin-count packages with Flash and

OTP program memory options. The Flash products offer an operating voltage range of 2.0V to 5.5V, small package footprints, interrupt handling, a deeper hardware stack, multiple AID channels and EEPROM data memory. All of these features provide the Mid-Range microcontrollers with an intelligence level not previously available. See the block diagram in Figure 1.25 to see features of Piel 6f84A. See Table 1.6 for pin descriptions.

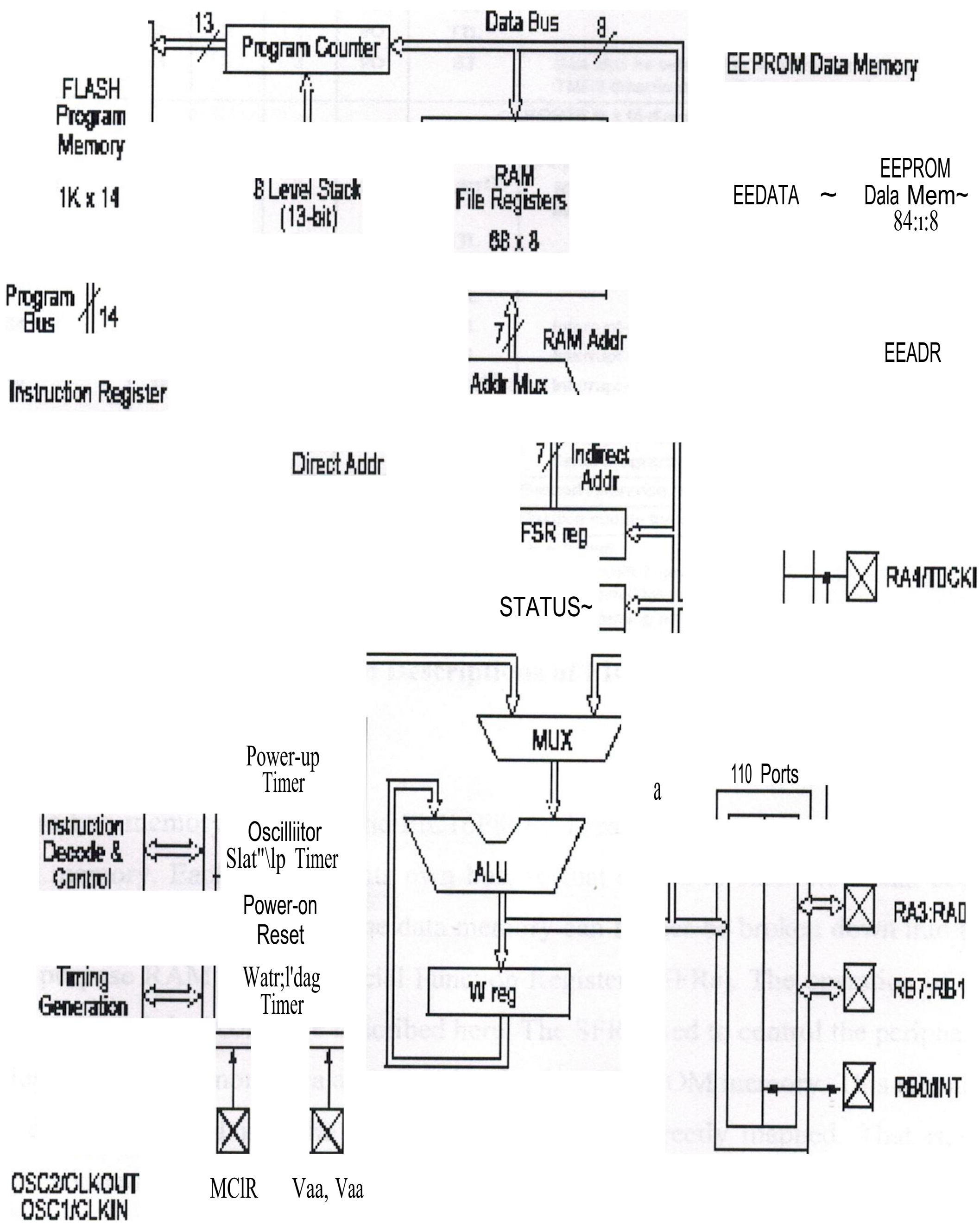


Figure 1.25 Features of PIC16F84A

Pin Name	PDIP No.	SOIC No.	SSOP No.	IIOlP Type	Buffer Type	Description
OSC1fCU<IN	16	16	1a	l	STICMosP}	Oscillator crystal inpYlfextemal clock source input.
OSC2fCl.KOUT	15	15	1Q	O	-	Oscillator crystal oulp,ut. Conrıecls fo crystal or resorıe1oı" tn Crystal Oscillator mode. ln RC moı:le, OSC2 pin oulpu1s CLKOUT; wrıich has 1Jl4 lhe ~uency cf OSC 1 and ı:lenoies ttıe irlS!rucl.ion cycle rate.
MCLR	4	4	4	lfP	ST	MBS1er Clear (Reset) inp,utlprogramming vottage input. This pin is an active-low RESET to the device.
						PORTA is a bi-directional I/O port.
RAO	17	17	19	,l0	TTL	
RA1	18	18	20	LIO	TTL	
RA2	l	l	l	PIO	TTL	
RA3	2	2	2	!/O	TTL	
RA4rTOCKl	3	3	3	f/0	ST	Can also be selected to 0e ltıe clock input: to trıe TMRO lmerfcounter. Output is open draiı type.
						PORTS ls a bi-directional l'/0 port. PORTO can be softııare programmed for internal weak p,ulk.ıp on al inputs.
RBOIINT	il	6	7	rıo	nusT•l›	RBOJfNTcan am be seileciec as an external interrupt pin.
RB1	7	7	a	,l0	TTL	
RB2	a	8	Q	f/0	TTL	
RB3	Q	9	10	LIO	TTL	
RB4	10	10	11	l'/0	TTL	lnterrupt-cırı-ch-ange pin.
RB6	11	11	12	l'/0	TTL	lrıterrupt-cırı-dıange pin.
RBll	12	'12	13	!/O	TTLJST12l	lrıterrupt-on,.dıımge pin. Serial programmiıg clock.
RB7	13	13	14	f/0	TIU ST~	lrıterrupt-on,-change pin. Serial p,rogramming dala.
VSS	!i	5	5,6	P	-	Ground reference for logic and I/O psıs,
VDD	14	14	15,'16	P	-	Positive sı..ıpplyi:ır logic and I/O pm-ıs.

Legend: != iıput O = Ou1put 110 = lnputı<Aılput P = Power
- = Not used TTL = TTL input ST= Schmitt Trigger irıput

Note 1: Trıis tmffer is a Scrımitt Trigger input Wilen config.ured as ttıe external interrupt.
2: This buffer is a Scrımitt Trigger input Wilen used iı Serial Programming mode.
3: Trıis buffer is a Scrımitt Trigger input Wilen -configured in RC oscillator mode and a CMOS iıput olhenıris.e.

Table 1.6 Pin Descriptions of PIC16F84A

1.2.9.1.1 Memory Organisation

There are two memory blocks in the PIC16F84A. These are the program memory and the data memory. Each block has its own bus, so that access to each block can occur during the same oscillator cycle. The data memory can further be broken down into the general purpose RAM and the Special Function Registers (SFRs). The operation of the SFRs that control the "core" are described here. The SFRs used to control the peripheral modules The data memory area also contains the data EEPROM memory. This memory is not directly mapped into the data memory, but is indirectly mapped. That is, an indirect address pointer specifies the address of the data EEPROM memory to read/write. The 64 bytes of data. EEPROM memory have the address range 0h 3Fh.See Figure 1.26.

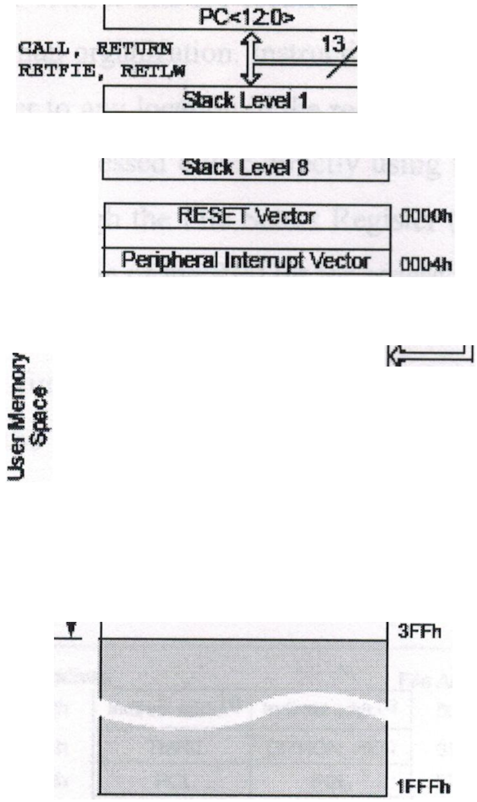


Figure 1.26 Memory Organisation of 16F84A

1.2.9.1.1.1 Program Memory Organization

The PIC16FXX has a 13-bit program counter capable of addressing an 8K x 14 program memory space. For the PIC16F84A, the first IK x 14 (OOOOh-03FFh) are physically implemented (Figure 2-1). Accessing a location above the physically implemented address will cause a wraparound. For example, for locations 20h, 420h, 820h, C20h, 1020h, 1420h, 1820h, and 1C20h, the instruction will be the same. The RESET vector is at 0000h and the interrupt vector is at 0004h.See Figure 1.26

1.2.9.1.1.2 Data Memory Organization

The data memory is partitioned into two areas. The first is the Special Function Registers (SFR) area, while the second is the General Purpose Registers (GPR) area. The SFRs control the operation of the device. Portions of data memory are banked. This is for both the SFR area and the GPR area. The GPR area is banked to allow greater than 116 bytes of general purpose RAM. The banked areas of the SFR are for the registers that control the peripheral functions. Banking requires the use of control bits for bank selection. These control bits are located in the STATUS Register. Figure shows the data memory map organization. Instructions MOVWF and MOVF can move values from the W register to any location in the register file ("F"), and vice-versa. The entire data memory can be accessed either directly using the absolute address of each register file or indirectly through the File Select Register (FSR) (Section 2.5). Indirect addressing uses the present value of the RPO bit for access into the banked areas of data memory. Data memory is partitioned into two banks which contain the general purpose registers and the special function registers. Bank 0 is selected by clearing the RPO bit (STATUS<5>). Setting the RPO bit selects Bank 1. Each Bank extends up to 7Fh (128 bytes). The first twelve locations of each Bank are reserved for the Special Function Registers. The remainder are General Purpose Registers, implemented as static RAM. See Figure 1.27

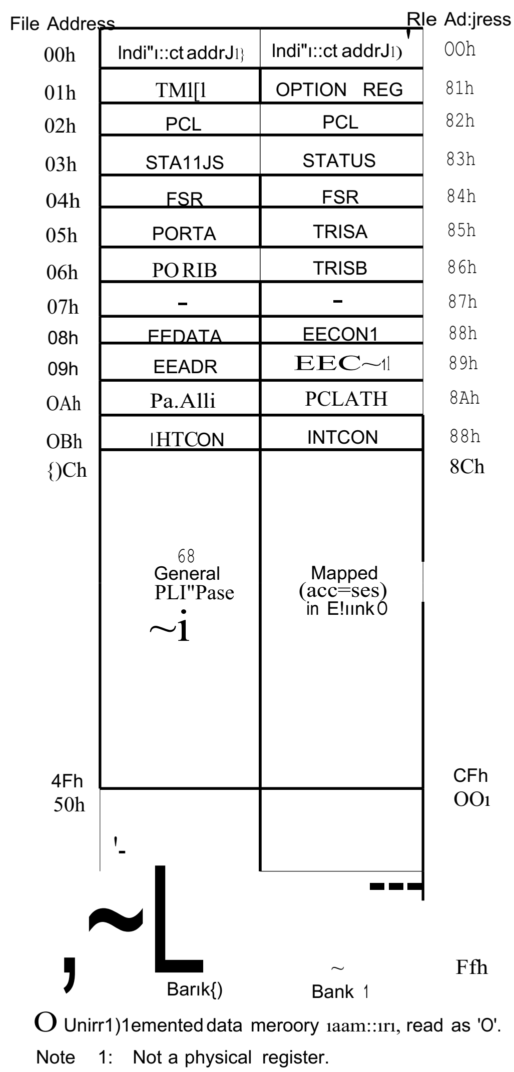


Figure 1.27 Data Memory Organisation of 16F84A

1.2.9.2 Programming 16F84A

The Pie16F84 is microcomputer and it is programmed using a * .hex (hexadecimal) file.The * .hex file is created using Pie Basic program.

"The Pie Basic Pro" program is written by- microchip company that produces the Pie series of microcontrollers. Pie Basic Pro Compiler is "BASIC StampII like" and has some libraries and functions of "Basic program". The following commands are known by Pie Basic Compiler

@
ASM..ENDASM
ADCIN
BRANCH
BRANCHL
BUTION
CALL
CLEAR
CLEARWDT
COUNT
DATA
DTMFOUT
EEPROM
END
FREQOUT
FOR-NEXT
GOSUB
GOTO
HIGH
HSERIN
HPWM
HSEROUT
I2CREAD
I2CWRITE
INPUT
IF-THEN-ELSE
LCDOUT
LCDIN
{LET}
LOOKDOWN
LOOKDOWN2
LOOKUP
LOOKUP2
LOW
NAP
OUTPUT
OWIN
OWOUT
PAUSE
PAUSEUS
POT
PULSIN
PULSOUT
PWM
RANDOM
RCTIME
READ
READCODE
RETURN
REVERSE

SELECT-CASE
SERIN
SERIN2
SE ROUT
SEROUT2
SHIFTIN
SHIFTOUT
SLEEP
SOUND
STOP.
SWAP
TOGGLE
WRITE
WRITECODE
WHILE-WEND

The first step is the writing of a program code in some of enumerated text editors. Every written code must be saved on a single file with the ending .BAS exclusively as ASCII text. An example of one simple BASIC program - BLINK.BAS is shown in Figure 1.28

```
~                                                   Pxogxl!.lh'!  BLI•I.JIA!

' Exaı:ı.ple of  a  pı:ogr:eın. lılleı:e  the  LED  diode  connected  on
' PORT B  pin  7  s\1'1tche s  on  and  ot:C  every  0. 5  seconds

Loop:
        High  PORTE. 7           ' 5-uitch  on  LED·  on  pin  7  ot  poı::t .B
        Pa:ue  SOO               ' 0. 5  s ec  pe.u~e

        Low  PORTB.7             ' SW1 tch  off  LED  on  pirı  ,  ot  po [t  13
        Pa.tite  SOO             ' 0. 5  sec  pause

        Goto  loop               ' Go  back  ee  Loop

                                 ' End  o :c  pio•ı;ıı:: am.
```

Figure 1.28 An Example Written in Basic

When the original BASIC program is finished and saved as a single file with .BAS ending it is necessary to start PIC BASIC compiler. The compiling procedure takes place in two consecutive steps.

Step 1. In the first step compiler will convert BAS file in assembler s code and save it as BLINK.ASM file.

Step 2. In the second step compiler automatically calls assembler, which converts ASM

- type file into an executable HEX code ready for reading into the programming memory of a microcontroller. The transition between first and second step is for a user - programmer an invisible one, as everything happens completely automatically and is thereby wrapped up as an indivisible process. In case of a syntax error of a program code, the compilation will not be successful and HEX file will not be created at all. Errors must be then corrected in original BAS file and repeat the whole compilation process. The best tactics is to write and test small parts of the program, than write one gigantic of 1000 lines or more and only then embark on error finding. As a result of a successful compilation of a PIC BASIC program the following files will be created.

- BLINK.ASM - assembler file
- BLINK.LST - program listing
- BLINK.MAC - file with macros
- BLINK.HEX - executable file which is written into the programming memory

SeeFigure 1.29

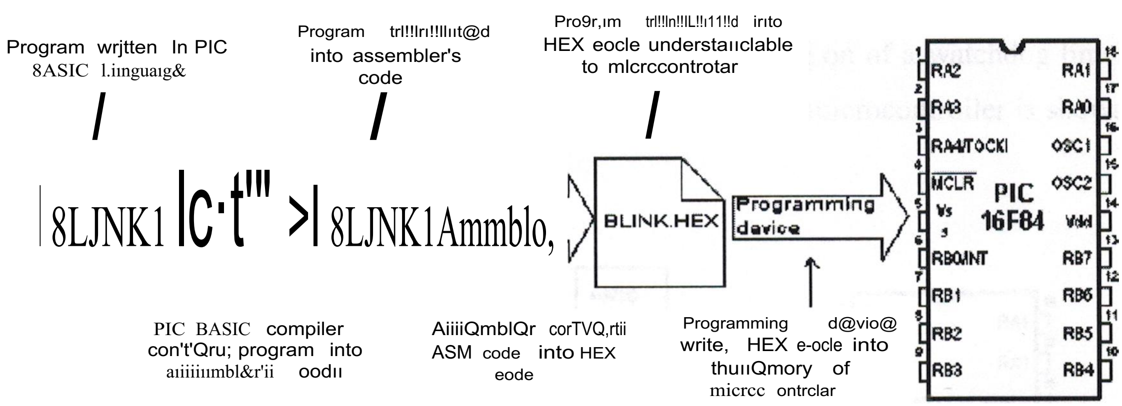


Figure 1.29 File Conversion for Programming a PIC16F84A

File with the HEX ending is in effect the program that is written into the programming memory of a microcontroller. The programming device with accessory software installed on the PC is used for this operation. Programming device is a contrivance in charge of writing physical contents of a HEX file into the internal memory of a microcontroller. The PC software reads HEX file and sends to the programming device the information about an exact location onto which a certain value is to be inscribed in the programming memory. PIC BASIC creates HEX file in a standard 8-bit Merged Intel HEX format accepted by the vast majority of the programming software. In Figure 1.30 contents of a file BLINK.HEX is given.

```
:10 00000028 28A30uzo 0FF30A20 70 31c.A.30 70 31C 9A
:10 00100 02328033 0A.100DF300F200328A101E83 B90
:10 00200 0A000A109FC30031C182SAO0703181528FC
:10 00300 0A0076400.A.10F152820181E28AO1C2228 44
:100040000000022280800831303138312640008 00B1
:100050000 61483160 610B3120130A.300F430022028
:1000 60000 61083160 61083120130A300F43002201C
:06007000282863003928 76
:02-400B00753DFE
:000000011".F
```

Figure 1.30 A Hexadecimal File

Besides reading of a program code into the programming memory, the programming device serves to set the configuration of a microcontroller. Here belongs the type of the oscillator, protection of the memory against reading, switching on of a watchdog timer etc. The connection between PC, programming device and the microcontroller is shown in Figure 1.31.

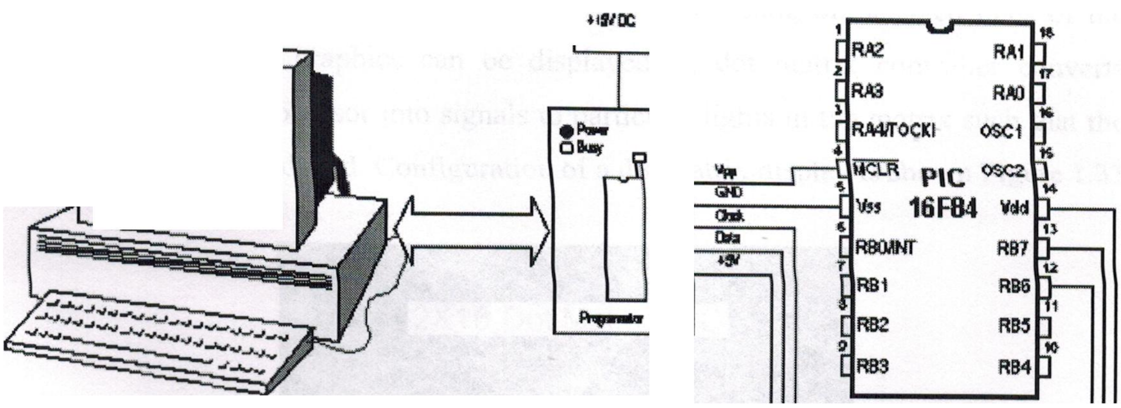


Figure 1.31 Programming a PIC16F84A

1.2.9.3 Running The Program

For correct operating of a microcontroller, i.e. correct running of a program it is necessary to assure the supply of the microcontroller, oscillator and the reset circuit. See Figure 1.32.

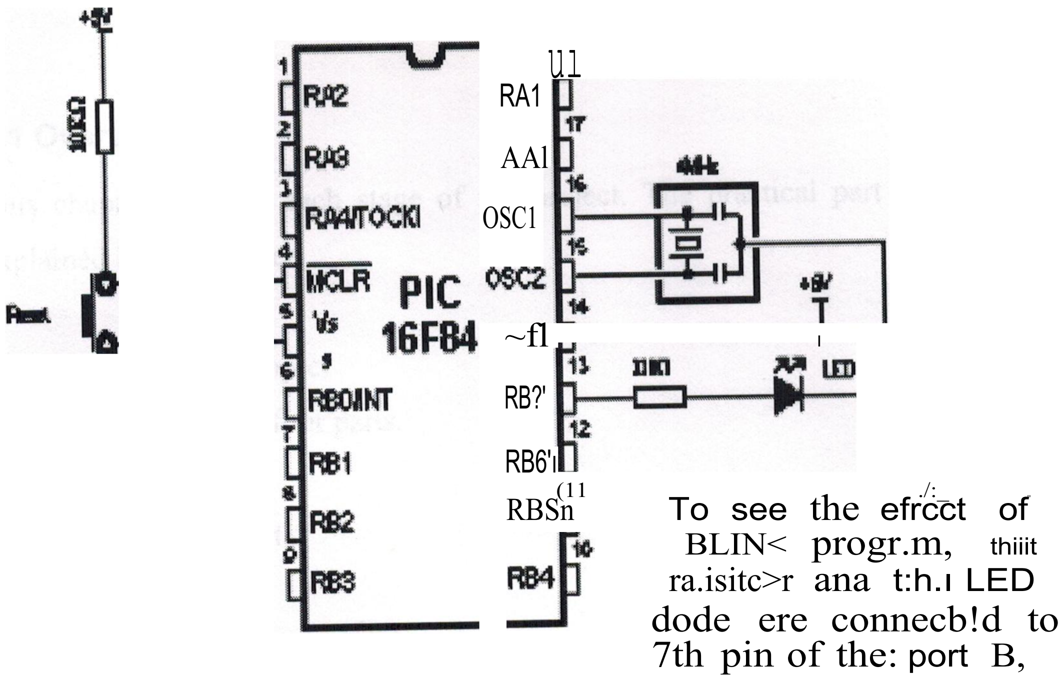


Figure 1.32 Pin Connections and Maintenance of 16F84A

1.2.10 Dotmatrix LCD

A Dot Matrix Display is a display device used to display information on machines and other devices requiring a simple display device of limited resolution. The display consists of a matrix of lights arranged in a rectangular configuration (other shapes are also possible, although not common) such that by switching on selected ones of the lights text or simple graphics can be displayed. A dot matrix controller converts instructions from a processor into signals to particular lights in the matrix such that the required display is produced. Configuration of a dot matrix display is shown Figure 1.33

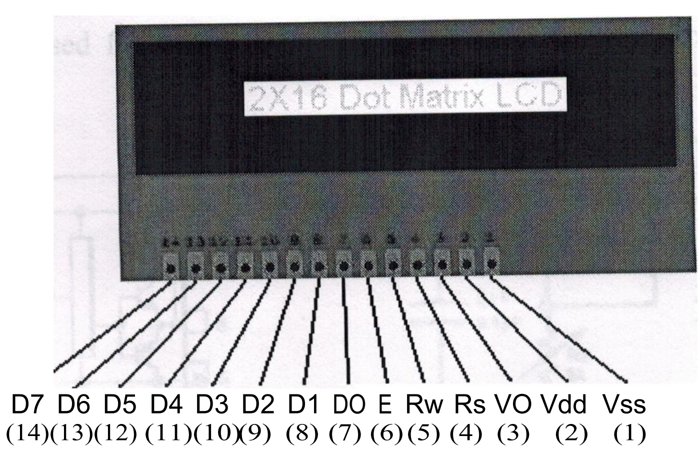
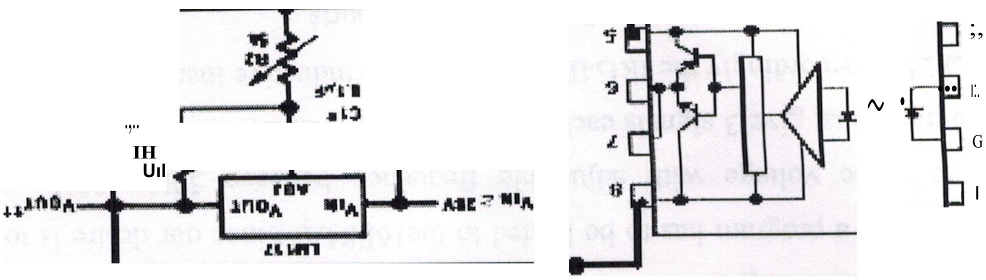


Figure 1.33 A Dot Matrix Display

Figure 2.1 Suppliying a TLP250 with LM317



·;un8y

8U!MOHOJ g-qı U! UMo-qs S! uouoouuoo g-qı -uouaıcdo SSBdAq *10J* pgsn ere s10ıpBdBJ g-qı -punors g-qı pıra uıd rav sn uggMıgq poıooıruoo 'roıcuıotıuoıod uı-qo){ç B ,{q poısnfpB S! gnlBA gzlBllOA g-qı AOS-AO1 ugg,\:\ıgq gzlBllOA B sgnddns n "Ç08LW'1 ::ı-qı S::l!lddns puB (S1::lA!1P ıqzl!) S::)I QÇZd'11 9 sg!1ddns l! puB AZS ,{q poqddns S! n "Ll £W'1 B S! n

J.IUd sıjo**A 0£ 1T'Z'Z**

- Ç08LW'1
- *l* **I**SW'1

-ıred S!lll U! s1oıB1n8::ı1 ::ı8Bl10A OMl ::llB ::ı1::ı-qı

J.IUd uonuın'aal{ I'Z'Z

- µBdl::lMOd
- µBd zlU!A!lQ ıqzlı
- µBd 101ıuo::)
- µBd U0l!B1nzlg1!

-sırad lnOJ JO lS!SUO:) ıooford ::ı-qı

roo]**O.Id aq.ı JO sa'aUJS Z·Z**

·1::ııdB-qJ srqı u~ poumjdxo

s~ ıooford ::ı-qı JO ired TBJ~pmd ::llU -ıooford ::ı-qı JO gzlBıs -q::,B::ı stnajdxo roıdcqo s~qı

Ma!AJaAQ ~'Z

Z aa.ıavao

- gqı 11ufaUBl{'J JO gyqudu'J gq oı rosn gqı oı g;)BJJglU! ue gıu1gug1J oı 1gp10 UI
- ·vt8d9 I gqı JO sμod 9 pggu gM. 'uıoqı jo gs1gAg1 pun soscqd ocrqı gıu1gug'a oı
- ·sμod 9 pggu ggM. a::::r1 gqı ıootruoo oı 1gp10 uj

·ı!ml!'J gqı u'a!sgp sıgı ·puoy gA!PTIPU! gqı pun Q)IütHdtOm gqı ıCy'au!plO'J'JB 'SQÇ'Z::d11 gql oxup Ol 'uroqı jo osroxcr pUB uggM.lgq ggJ'agp QZl 1{'JBg SIBU'a!S £ gA!'a lSTIUl UIB11301d ugnpM. gqı 'ZHOO1-zHQÇ uggM.ıgq A'JmnbgJJ gyquısnfpu 1{1!M. g'auıyoA osnqd ocrqı u gımgug1J oı S! ansop mo g;)U!S ·vt8d9 Igqı ot pgpuoy gq ot suq uıaıfiord u nu JO ıs1!d

Vfi8il91 aqı ~umo.11uo:1)Z'Z:'Z:

·roısısor u puu suoııng

JJOfUO OM.l 'Q;)1 UB Slül!'JBdB'J Z 'IBlSı\.J'J B 'Vt8d91 Old B JO lS!SUO'J ırad 101ıuo'J gqı

I.JUd fO.IJUO:) Z:'Z'Z:

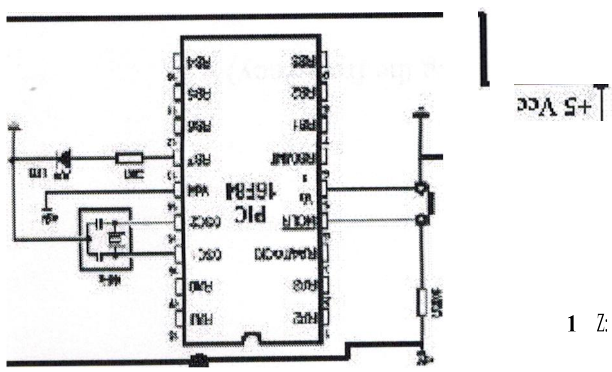
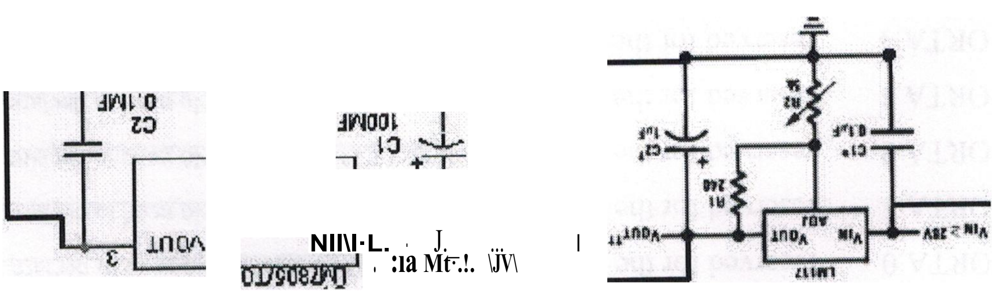


Figure 2.2 Circuit of 5Volts Power Part

1 Z f ·fı S 9 L 8 6 ot :if z:::: fl 'fl st 9I

,(l:;)'l



·Z·Z gm'a!d U! UM.Ol{S S! ırad JgM.od sıjo AÇ gqı 'P'Jl xuınur ıop gqı puu t8d9 I;)Id gqı sgnddns ıı ·AÇ ıuaısuoo u S! g'auıyoA ındıno gqı ·A8Z-A8 uggM.lgq sgpuA ÇQ8LW1 oı g'auıyoA mdut gqı 'L1£W1 ıCq pgnddns S! 1l 'SJOl!'JBdB'J OM.l 1{1!M. Ç08LW1 u S! ıı

I.JUd snoAS Z:TZ'Z:

frequency ,we need at least 1 port. Since 16F84A has totaly 13 ports. We have only one port that can be assigned for the user interface.

The arrangment of the ports is as following (maybe changed) ;

PORTA.O reserved for the LCD (Default for LCD connection.No need to declare inthe prog.)
PORTA.1 reserved for the LCD (Default for LCD connection.No need to declare inthe prog.)
PORTA.2. reserved for the LCD (Default for LCD connection.No need to declare inthe prog.)
PORTA.3 reserved for the LCD (Default for LCD connection.No need to declare inthe prog.)
PORTA.4 reserved for the LCD (Default for LCD connection.No need to declare inthe prog.)
PORTB.3 reserved for the LCD (Default for LCD connection.No need to declare inthe prog.)
PORTB.O 1. phase
PORTB.1 1. phase inverse
PORTB.2 2. phase
PORTB.4 2. phase inverse
PORTB.5 3. phase
PORTB.6 3. phase ınverse
PORTB.7 Assigned for the user interface(changing the frequency)

The pic connections is shown in figure

2.2.2.2 Programming The 16F84A

In order to generate a frequency between 50Hz-100Hz we have to find the time needed between each phase to generate the delay.

To find the the time needed, to make the phase shift and generate the needed signals, the following operations are done;

The time delay for a each phase must be 1/50 = 20 milliseconds. That is for each phase the output will be logic 1 for 1Oms and logic 0 for 10 ms. Since each wave is totaly equal to 360 degree.

For 120degree we need 20/3 = 6.6666ms

and to complete all phases once for 360 degree the total angle we expererience is

Total angle = 120X5 = 600 degree.

and the total time needed to comlete all phases ones is;

Total time needed =6.666X5 =33.333ms

The time needed to increase the value of the frequency 5Hz

1/55=18.1818ms

=> 20ms-18.1818ms=l .8181;:::;l .82ms

A simple command referance of Pie Basic Pro that can help write this program is as follows;

END	Stop execution and enter low power mode.
GOTO	Continue execution at specified label.
HIGH	Make pin output high.
IF..THEN..ELSE..ENDIF	Conditionally execute statements.
INPUT	Make pin an input.
LCDOUT	Display characters on LCD.
{LET}	Assign result of an expression to a variable.
PAUSE	Delay (1mSec resolution).
PAUSEUS	Delay (1 uSec resolution).

The program can be written in a text editor as follows;

```
output PORTB.O          'Make PORTB.O output
output PORTB.1          'Make PORTB.1 output
output PORTB.2          'Make PORTB.2 output
output PORTB.4          'Make PORTB.4 output
output PORTB.5          'Make PORTB.5 output
output PORTB.6          'Make PORTB.6 output
input PORTB. 7          'Make PORTB. 7 input
```

```
freq var word                    'Declare freq as a word
time var word                    'Declare time as a word
m   varword                      'Declare m as a word
let time = 6666                  'Assign 6666 to time(time=6666microsec)
let freq= 50
res: Let time=6666               'Assign 6666 to time(time=6666microsec)
   let freq= 50                  'Assign 50 to freq(frequency=50Hz)
   Lcdout $fe, 1                 'Clear LCD screen
   Lcdout "The freq is 50Hz"     'Display "The freq is 50Hz"
loop : let m=O                   'Give the value 0 to m
loop2: let m=m+1                 'Make the calculation m=m+1

    High  PORTB.O                'Make PORTB.O logic 1
    low   PORTB.1                'Make PORTB.1 logic 0
    PAUSEus time                 'Pause time(micro sec)
    HIGH  PORTB.2                'Make PORTB.2 logic 1
    LOW   PORTB.4                'Make PORTB.4 logic 0
    pauseus time                 'Pause time(micro sec)
    HIGH  PORTB.5                'Make PORTB.5 logic 1
    LOW   PORTB.6                'Make PORTB.6 logic 0
    pauseus time                 'Pause time(micro sec)
    low   PORTB.O                'Make PORTB.O logic 0
    High  PORTB.1                'Make PORTB.1 logic 1
    PAUSEus time                 'Pause time(micro sec)
    LOW   PORTB.2                'Make PORTB.2 logic 0
    HIGH  PORTB.4                'Make PORTB.4 logic 1
    pauseus time                 'Pause time(micro sec)
    LOW   PORTB.5                'Make PORTB.5 logic 0
    HIGH  PORTB.6                'Make PORTB.6 logic 1

if m<250 then loop2              'if m<250 go to loop2


if PORTB. 7 = 0 and freq<lOO then loop
```

```
if PORTB.7 = 0 and freq>=lOO then loop
if PORTB. 7 = 1 and freq<lOO then cond
if PORTB.7 = 1 and freq>=lOO then res


cond: let freq=freq+S              'Make the calculation freq=freq+S
let time=time-182                  'Make the calculation time=time-182
Lcdout $fe, 1                      'Clear screen of the LCD
LCDOUT "The freq is"               'Print "The Freq is "
Lcdout #freq                       'Print "Hz"
LCDOUT "Hz"
goto loop
```

This program will generate 3 phase and inverse of them at 50Hz.When the switch is turned on and PORTB.7 is made high; the time delay will decrease and the frequency will increase. This will stop when PORTB.7 is made low. When the frequency reach lOOHz, the time will reset and the frequeny will change back to 50Hz.See Figure 2.3

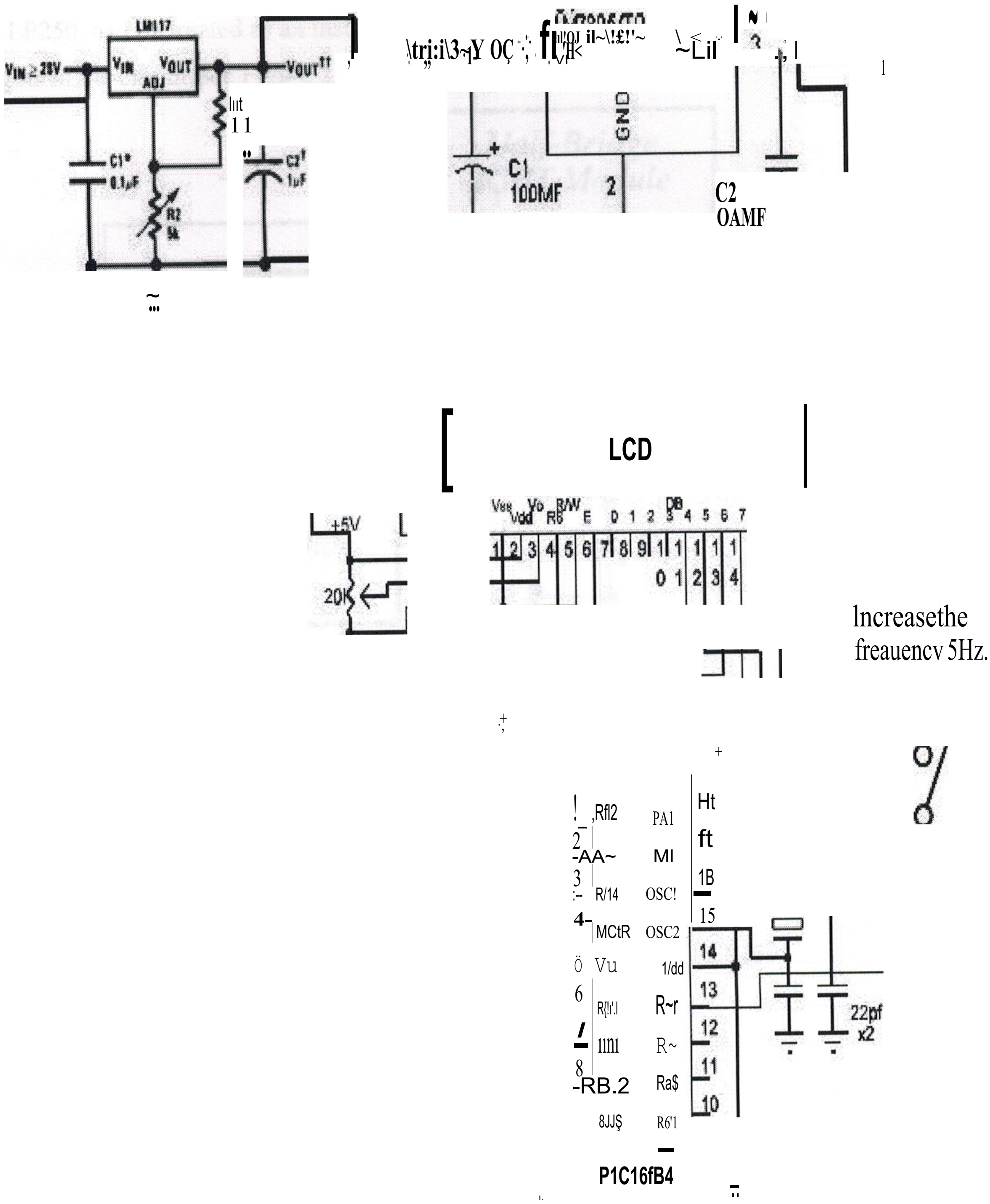


Figure 2.3 Circuit Construction of TLP250 Driving Part With LCD and PIC16F84

2.2.3 Igbt Driving Part

This part contains 6XTLP250 photocoupler.The photo couplar are are connected to phase and inverse phase of the PICl 7F84A. The drive the 6 Igbts depending on the signal coming from the microcontroller. The TLP250 protects the microcontroller.

TLP250 can be treated as an insulation material between the microcontroller and the Igbts in the circuit.See Figure 2.4

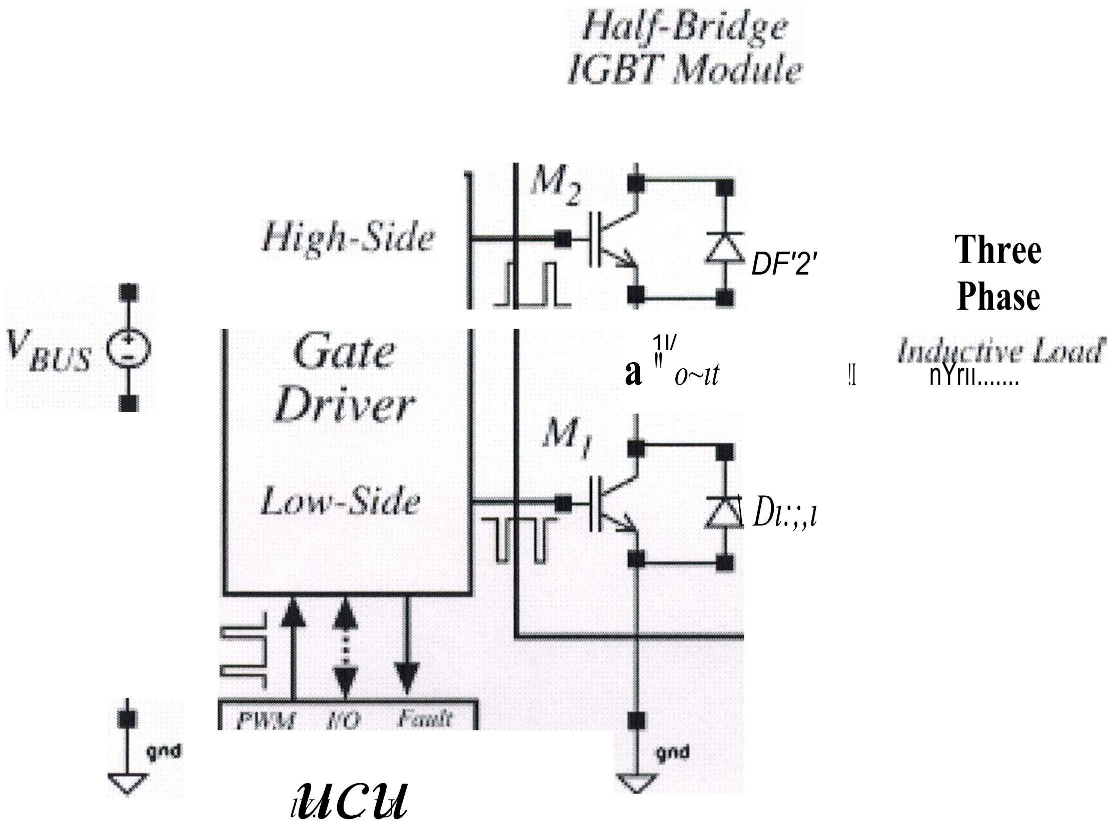


Figure 2.4 Driving The IRG4PH40KD With TLP250