APPENDIX A

HARDWARE DETAILS

A.1 COMPONENTS

Different components were used to implement the hardware. They are listed below:

1. PIC Microcontroller 16F84A.
2. Voltage Regulators
   a. 7812 voltage regulator
   b. 7805 voltage regulator
3. IC IR2110 for the amplification of the pulses given by PIC16F84A

A.2 POWER SUPPLY CIRCUIT

![Figure A.1 Power circuit]

Figure A.1 Power circuit
A step-down transformer (230/15) V was used to give the input supply to the power circuit.

The 15V AC input was rectified into 15V pulsating DC with the help of a full bridge rectifier circuit.

The ripples in the pulsating DC were removed, and pure DC was obtained by using a capacitor filter.

The positive terminal of the capacitor was connected to the input pin of the 7812 regulator for voltage regulation.

An output voltage of 12V obtained from the output pin of 7812 was fed as the supply to the pulse amplifier.

An output voltage of 5V obtained from the output pin of 7805 was fed as the supply to the micro controller.

From the same output pin of the 7805, a LED was connected in series with the resistor, to indicate that the power is ON.

A.3 PIC MICROCONTROLLER

Hardware was implemented in this project using the PIC - Microcontroller “PIC 16F84A”. The advantages of the PIC - microcontroller are that, the instruction set of this controller is smaller than that of the usual microcontroller. Unlike Conventional processors, that are generally complex, the instruction set computer (CISC) type, PIC microcontroller is a RISC processor.

The advantages of the RISC processor against the CISC processor are:

1. RISC instructions are simpler, and consequently they operate fast.
2. A RISC processor takes a single cycle for each instruction, while the CISC processor requires multiple clocks per instruction (typically, at least three cycles of throughput execution time for the simplest instruction, and 12 to 24 clock cycles for more complex instructions), which makes decoding a tough task.

3. The control unit in a CISC is always implemented by a micro-code, which is much slower than that of the hardware implemented in RISC.

The idea of using the PIC microcontroller is

1. To employ frequently used instructions as the instruction set, while using a few instructions to achieve a function similar to the one performed in a CISC by a much more complex instruction.

2. The RISC itself has a large number of general purpose registers, and they largely reduced the frequency of the most time-consuming memory access.

3. In terms of the clock rate, the RISC with its much simpler circuits will have a higher clock rate, that again increases the performance of a processor.

The processing power provided by an RISC processor is more than three times that of a CISC processor in a particular field of application.

A.3.1 Features of PIC16F84A

- Have to learn only 35 single word instructions.
- All instructions are of a single-cycle, except for programme branches that are of two-cycles
- Operating speed: DC - 20 MHz clock input DC - 200 ns instruction cycle
- 1024 words of program memory
- 68 bytes of Data RAM
- 64 bytes of Data EEPROM
- 14-bit wide instruction words
- 8-bit wide data bytes
- 15 Special Function Hardware registers
- Hardware stack that is eight-level deep
- Direct, indirect and relative addressing modes
- Four interrupt sources:
  - External RB0/INT pin
  - TMR0 timer overflow
  - PORTB<7:4> interrupt-on-change
  - Data EEPROM write complete
Figure A.2 Block Diagram of PIC16F84A

Figure A.3 Pin Diagram of PIC16F84A
The PIC16F84A belongs to the mid-range family of PIC microcontroller devices. A block diagram of the device is shown in Figure A.2.

The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is of the same width as each device instruction. The data memory (RAM) contains 68 bytes. Data EEPROM has 64 bytes.

There are also 13 I/O pins that are user-configured on a pin-to-pin basis. Some pins are multiplexed with other device functions. These functions include:

- External interrupt
- Change in PORTB interrupts
- Timer0 clock input

### A.3.2 Memory Organization

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 at the same oscillator cycle.

Data memory can be further broken down into the general purpose RAM and the Special Function Registers (SFRs). The operations of the SFRs that control the “core” are described here. The SFRs used to control the peripheral modules have been described in the section discussing each individual peripheral module.

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.

A.3.3 Data EEPROM Memory

The EEPROM data memory is readable and writable during normal operation (full VDD range). This memory is not directly mapped in the register file space. Instead it is indirectly addressed through Special Function Registers. There are four SFRs used to read and write this memory. These registers are:

- EECON1
- EECON2 (not a physically implemented register)
- EEDATA
- EEADR

EEDATA holds the 8-bit data for read/write, and EEADR holds the address of the EEPROM location being accessed. PIC16F84A devices have 64 bytes of data EEPROM with an address range of 0h to 3Fh.

The EEPROM data memory allows bytes to read and write. A byte write automatically erases the location and writes the new data (erase before write). The EEPROM data memory is rated for high erase/write cycles. The write time is controlled by an on-chip timer. The write time will vary with voltage and temperature, as well as from chip to chip. Please refer to AC specifications for exact limits.

When the device is code protected, the CPU may continue to read and write the data EEPROM memory. The device programmer can no longer access this memory.
When the device code is protected, the CPU may continue to read and write the data EEPROM memory. The device programmer can no longer access this memory.

A.3.4 I/O Ports

Some pins for these I/O ports are multiplexed with alternate functions for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

A.3.5 Timer0 Module

The Timer0 module timer/counter has the following features:

- 8-bit timer/counter
- Readable and writable
- Internal or external clock select
- Edge select for external clock
- 8-bit software programmable pre-scaler
- Interrupt-on-overflow from FFh to 00h

A.3.6 Special Features of the PIC16F84A

What sets a microcontroller apart from other processors are the special circuits to deal with the needs of real time applications. The PIC16F84A has a host of such features intended to maximize the system reliability, minimize cost through the elimination of external components, provide power saving operating modes, and offer code protection. These features are:

- OSC Selection
The PIC16F84A has a watchdog timer, which can be shut-off only through configuration bits. It runs off its own RC oscillator for added reliability. There are two timers that offer necessary delays on power-up. One is the Oscillator Start-up Timer (OST), intended to keep the chip in RESET until the crystal oscillator is stable.

The other is the Power-up Timer (PWRT), which provides a fixed delay of 72 ms (nominal) on power-up only. This design keeps the device in RESET while the power supply stabilizes. With these two timers on-chip, most applications need no external RESET circuitry. The SLEEP mode offers a very low current power-down mode. The user can wake-up from SLEEP through the external RESET, the Watchdog Timer Time-out or through an interrupt. Several oscillator options are provided to allow the part to fit the application. The RC oscillator option saves system cost while the LP crystal option saves power. A set of configuration bits is used to select from the various options.
A.3.7 Oscillator Types

The PIC16F84A can be operated in four different oscillator modes. The user can program two configuration bits (FOSC1 and FOSC0) to select any one of these four modes:

- LP Low Power Crystal
- XT Crystal/Resonator
- HS High Speed Crystal/Resonator
- RC Resistor/Capacitor

Reset

The PIC16F84A differentiates between various kinds of RESET:

- Power-on Reset (POR)
- MCLR during normal operation
- MCLR during SLEEP
- WDT Reset (during normal operation)
- WDT Wake-up (during SLEEP)

A.3.8 Power on Reset (POR)

A Power-on Reset pulse is generated on-chip when a VDD rise is detected (in the range of 1.2V - 1.7V). To take advantage of the POR, just tie the MCLR pin directly (or through a resistor) to the VDD. This will eliminate the external RC components usually needed to create Power-on Reset. A minimum rise time for the VDD must be met for this to operate properly.
When the device starts normal operation (exits the RESET condition), to ensure operation, the device operating parameters (voltage, frequency, temperature, etc.) must be met. If these conditions are not met, the device will be held in RESET until the operating conditions are met.

A.3.9 Power-up Timer (PWRT)

The Power-up Timer (PWRT) provides a fixed 72 ms nominal time-out (TPWRT) from POR. The Power-up Timer operates on an internal RC oscillator. The chip is kept in RESET as long as the PWRT is active. The PWRT delay allows the VDD to rise to an acceptable level.

A configuration bit, PWRTE, can enable/disable the PWRT. The operation of the PWRTE bit is for a particular device. The power-up time delay TPWRT will vary from chip to chip due to the VDD, temperature, and process variation.

A.3.10 Interrupts

The PIC16F84A has 4 sources of interrupt:

- External interrupt RB0/INT pin
- TMR0 overflow interrupt
- PORTB change interrupts (pins RB7:RB4)
- Data EEPROM write complete interrupt

The interrupt control register (INTCON) records the individual interrupt requests in flag bits. It also contains individual and global interrupt enable bits. The global interrupt enable bit, GIE (INTCON<7>), enables (if set) all the unmasked interrupts, or disables (if cleared) all the interrupts. Individual interrupts can be disabled through their corresponding enable bits
in the INTCON register. The bit GIE is cleared on RESET. The “return from interrupt” instruction, RETFIE, exits the interrupt routine as well as sets the GIE bit, which re-enables interrupts. The RB0/INT pin interrupt, the RB port change interrupt, and the TMR0 overflow interrupt flags, are contained in the INTCON register.

When an interrupt is responded to, the GIE bit is cleared to disable any further interrupt, the return address is pushed onto the stack, and the PC is loaded with 0004h. In external interrupt events, such as the RB0/INT pin or PORTB change interrupt event, the interrupt latency will be of three to four instruction cycles. The exact latency depends on when the interrupt event occurs. The latency is the same for both one and two cycle instructions. Once in the Interrupt Service Routine, the source(s) of the interrupt can be determined by polling the interrupt flag bits. The interrupt flag bit(s) must be cleared in software before re-enabling the interrupts to avoid infinite interrupt requests.

A.4 OPTOCOUPLEERS

There are many situations where the signals and data need to be transferred from one subsystem to another within a piece of the electronics equipment, or from one piece of equipment to another, without making a direct electrical connection. Often this is because, the source and destination are (or may be at times) at very different voltage levels, like a microprocessor which operates from 5V DC but is being used to control a TRIAC which is switching 240V AC. In such situations, to protect the microprocessor from over voltage damage, the link between the two must be an isolated one.
Relays, can of course, provide this kind of isolation, but even small relays tend to be fairly bulky, compared with ICs and many of today’s other miniature circuit components. Because they are electro-mechanical, relays are also not reliable, and only capable of relatively low speed operation. Where small size, higher speed and greater reliability are important, a much better alternative is to use an optocoupler. These use a beam of light to transmit signals or data across an electrical barrier, and achieve excellent isolation.

Optocouplers typically come in a small 6-pin or 8-pin IC package, but are essentially a combination of two distinct devices: an optical transmitter, typically a gallium arsenide LED (light-emitting diode), and an optical receiver, such as a phototransistor or light-triggered diac. The two are separated by a transparent barrier which blocks any electrical current flow between them, but does allow the passage of light. The basic idea is shown in Figure A.1, along with the usual circuit symbol for an optocoupler.

The most important parameter for most optocouplers is their transfer efficiency, usually measured in terms of the current transfer ratio or CTR. This is simply the ratio between a current change in the output transistor, and the current change in the input LED which produced it. Typical values of CTR range from 10% to 50% for devices with an output
phototransistor, and up to 2000% or so for those with a Darlington transistor pair in the output. Note, however that in most devices, the CTR tends to vary with the absolute current level. Typically, it peaks at the LED current level of about 10mA, and falls at both higher and lower current levels. Other optocoupler parameters include the output transistor’s maximum collector-emitter voltage rating VCE (max), which limits the supply voltage in the output circuit; the input LED maximum current rating IF (max), which is used to calculate the minimum value for its series resistor; and the bandwidth of the Optocouplers, which determines the highest signal frequency that can be transferred mainly by an internal device construction, and the performance of the output Phototransistor.

A.5 IR 2110 – HIGH AND LOW SIDE DRIVER:

- Some of the features of IR 2110 are:
- Floating channel designed for bootstrap operation
- Gate drive supply range from 10 to 20V
- Under voltage lockout for both channels
- 3.3V logic compatible
- Separate logic supply range from 3.3V power ground ± 5V power ground ± 5V offset
- CMOS Schmitt-triggered inputs with pull down
- Cycle by cycle edge-triggered shutdown logic
- Matched propagation delay for both channels
- Outputs in phase with inputs

The IR2110 is a high voltage, high speed power MOSFET driver with independent high and low side referenced output channels. It is fully
operational to +500V or +600V, and tolerant to negative transient voltage 
dv/dt immune. Logic inputs are compatible with the standard CMOS or 
LSTTL output, down to 3.3V logic. The output drivers feature a high pulse 
current buffer stage, designed for minimum driver cross-conduction.

Propagation delays are matched to simplify use in high frequency 
applications. The floating channel can be used to drive an N-channel power 
MOSFET or IGBT in the high side configuration, which operates up to 500 or 
600 volts.

Figure A.5 Pin Diagram OF IR2110/DIP14
A.6 LEAD DEFINITIONS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>Logic Supply</td>
</tr>
<tr>
<td>HIN</td>
<td>Logic input for high side gate drive output (HO), in phase</td>
</tr>
<tr>
<td>SD</td>
<td>Logic input for shut down</td>
</tr>
<tr>
<td>LIN</td>
<td>Logic input for low side gate driver output (LO), in phase</td>
</tr>
<tr>
<td>VSS</td>
<td>Logic ground</td>
</tr>
<tr>
<td>VB</td>
<td>High side floating supply</td>
</tr>
<tr>
<td>HO</td>
<td>High side gate drive output</td>
</tr>
<tr>
<td>VCC</td>
<td>Low side supply</td>
</tr>
<tr>
<td>LO</td>
<td>Low side gate drive output</td>
</tr>
<tr>
<td>COM</td>
<td>Low side return</td>
</tr>
</tbody>
</table>

A.7 APPLICATIONS

1) Power supply regulator

2) Digital logic inputs

3) Microprocessor inputs
Figure A.6 Wiring Diagram of PIC16F84A
Figure A.7 Wiring Diagram of PIC16F84
APPENDIX B

MOSFET

B.1 FEATURES OF POWER MOSFETS

The Power MOSFET has lower switching losses, but its on-resistance and conduction losses are more.

MOSFET is a voltage-controlled device.

MOSFET has a positive temperature co-efficient for resistance. This makes the parallel operation of MOSFET easy. If a MOSFET shares increased current initially, it heats up faster, its resistance rises, and the increased resistance causes this current to shift to other devices in parallel.

In a MOSFET, a secondary break down does not occur, because it has a positive temperature co-efficient.

Power MOSFETS in higher voltage ratings have more conduction losses.

B.2 IRF 840- POWER MOSFET

1) Dynamic dv/dt Rating

2) Repetitive Avalanche Rated

3) Fast switching
4) Ease of paralleling

5) Simple Drive requirements

B.3 DESCRIPTION

The IRF-840 provides fast switching, ruggedized device design, low on-resistance and is cost effective.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220, contribute to its wide acceptance throughout the industry.
Figure B.1 Data Sheet of CD4071BC
Figure B.2 Data Sheet of FR301 thru FR307
Figure B.3 Data Sheet of NPN Transistor 2N2222; 2N2222A

NPN switching transistors 2N2222; 2N2222A

FEATURES
- High current (max. 800 mA)
- Low voltage (max. 40 V).

APPLICATIONS
- Linear amplification and switching.

DESCRIPTION
NPN switching transistor in a TO-18 metal package.
PNP complement: 2N2937A.

QUICK REFERENCE DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{ceo}$</td>
<td>collector-base voltage</td>
<td>open emitter</td>
<td>60</td>
<td>75</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>2N2222</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2N2222A</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$V_{ceo}$</td>
<td>collector-emitter voltage</td>
<td>open base</td>
<td>30</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>2N2222</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2N2222A</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$I_c$</td>
<td>collector current (DC)</td>
<td>$T_{amb} \leq 25$ °C</td>
<td>600</td>
<td>–</td>
<td>mA</td>
</tr>
<tr>
<td>$P_{tot}$</td>
<td>total power dissipation</td>
<td>$I_c = 10$ mA; $V_{CE} = 10$ V</td>
<td>500</td>
<td>–</td>
<td>mW</td>
</tr>
<tr>
<td>$h_{fe}$</td>
<td>DC current gain</td>
<td>–</td>
<td>75</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2N2222</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2N2222A</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$f_{t}$</td>
<td>transition frequency</td>
<td>$I_c = 20$ mA; $V_{CE} = 20$ V; $f = 100$ MHz</td>
<td>250</td>
<td>–</td>
<td>MHz</td>
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<td></td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2N2222A</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$t_{tr}$</td>
<td>turn-on time</td>
<td>$I_{Coff} = 150$ mA; $I_{CEO} = 15$ mA; $I_{CEO} = –15$ mA</td>
<td>250</td>
<td>–</td>
<td>ms</td>
</tr>
</tbody>
</table>

Fig.1 Simplified outline (TO-18) and symbol.
Figure B.4 Data Sheet of IRF540, IRF540S

FEATURES
- 'Trench' technology
- Low on-state resistance
- Fast switching
- Low thermal resistance

GENERAL DESCRIPTION
N-channel enhancement mode field effect power transistor in a plastic envelope using 'trench' technology.

Applications:
- d.c. to d.c. converters
- switched mode power supplies
- T.V. and computer monitor power supplies

The IRF540 is supplied in the SOT78 (TO220AB) conventional leaded package.
The IRF6400S is supplied in the SOT404 (D²PAK) surface mounting package.

PINNING

<table>
<thead>
<tr>
<th>PIN</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>gate</td>
</tr>
<tr>
<td>2</td>
<td>drain</td>
</tr>
<tr>
<td>3</td>
<td>source</td>
</tr>
<tr>
<td>tab</td>
<td>drain</td>
</tr>
</tbody>
</table>

LIMITING VALUES
Limiting values in accordance with the Absolute Maximum System (IEC 134)

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vgs(s)</td>
<td>Drain-source voltage</td>
<td>$T_J = 25,^\circ\text{C}$ to $175,^\circ\text{C}$</td>
<td>100</td>
<td>100</td>
<td>V</td>
</tr>
<tr>
<td>Vdss</td>
<td>Drain-gate voltage</td>
<td>$T_J = 25,^\circ\text{C}$ to $175,^\circ\text{C}$; $R_{DS(on)} = 20 , \Omega$</td>
<td>100</td>
<td>100</td>
<td>V</td>
</tr>
<tr>
<td>Vgs(s)</td>
<td>Gate-source voltage</td>
<td>$T_J = 25,^\circ\text{C}$</td>
<td>-10</td>
<td>10</td>
<td>V</td>
</tr>
<tr>
<td>I_D</td>
<td>Continuous drain current</td>
<td>$T_J = 25,^\circ\text{C}$</td>
<td>20</td>
<td>20</td>
<td>A</td>
</tr>
<tr>
<td>I_Dm</td>
<td>Pulsed drain current</td>
<td>$T_J = 25,^\circ\text{C}$</td>
<td>16</td>
<td>16</td>
<td>A</td>
</tr>
<tr>
<td>P_D</td>
<td>Total power dissipation</td>
<td>$T_{J(max)} = 150,^\circ\text{C}$</td>
<td>100</td>
<td>100</td>
<td>W</td>
</tr>
<tr>
<td>T_J</td>
<td>Operating junction and storage temperature</td>
<td>$-55 \text{ to } 175,^\circ\text{C}$</td>
<td>100</td>
<td>100</td>
<td>W</td>
</tr>
</tbody>
</table>

$R_{DS(on)} \leq 77 \, \Omega$
**Single Supply Quad Operational Amplifiers**

The LM324 series are low-cost quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single-supply applications. The quad amplifiers can operate at supply voltages as low as 1.0 V or as high as 32 V with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

- Short-Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 1.0 V to 32 V (LM224, LM324, LM324A)
- Low Input Bias Currents: 100 nA Maximum (LM224A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the inputs increase ruggedness without affecting device operation

<table>
<thead>
<tr>
<th>MAXIMUM RATINGS</th>
<th>( T_A = -25^\circ C ) to (+85^\circ C ) unless otherwise noted.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating</strong></td>
<td><strong>Symbol</strong></td>
</tr>
<tr>
<td>Power Supply Voltages</td>
<td>( V_{CC} )</td>
</tr>
<tr>
<td>Single Supply</td>
<td>( V_{CC} )</td>
</tr>
<tr>
<td>Split Supplies</td>
<td>( V_{CC} )</td>
</tr>
<tr>
<td>Input Differential Voltage Range (Note 1)</td>
<td>(</td>
</tr>
<tr>
<td>Input Common Mode Voltage Range</td>
<td>(</td>
</tr>
<tr>
<td>Output Short Circuit Duration</td>
<td></td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>( T_J )</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>( T_{STG} )</td>
</tr>
<tr>
<td>Operating Ambient Temperature Range</td>
<td>( T_A )</td>
</tr>
<tr>
<td>LM324, LM324A</td>
<td>0 to 70</td>
</tr>
<tr>
<td>LM224, LM2002</td>
<td>-40 to +85</td>
</tr>
<tr>
<td>LM2002V, NCV2962</td>
<td>-40 to +125</td>
</tr>
</tbody>
</table>


Figure B.5 Data Sheet of LM324
C.1 MCT2 OR MCT2E OPTOCOUPLER

C.1.1 Introduction

There are many situations where signals and data need to be transferred from one subsystem to another, within an electronics equipment, or from one piece of equipment to another, without making a direct ohmic electrical connection. Often this is because the source and the destination are (or may be at times) at very different voltage levels, like a microprocessor, which operates on a 5V DC, but is used to control a MOSFET that switches at a higher voltage. In such situations the link between the two must be isolated to protect the microprocessor from over voltage damage.

Opto couplers typically come in a small 6-pin or 8-pin IC package, but are essentially a combination of two distinct devices: an optical transmitter, typically a gallium arsenide LED (light-emitting diode) and an optical receiver, such as a phototransistor or light-triggered diac. The two are separated by a transparent barrier which blocks any electrical current flow between the two, but allows the passage of light. The basic idea is shown in Figure C.1 along with the usual circuit symbol of an optocoupler. Usually, electrical connections to the LED section are brought to pins on one side of the package, and those for the phototransistor or diac to the other, to physically separate them as much as possible. This usually allows
optocouplers to withstand voltages anywhere between 500V and 7500V between the input and output. Optocouplers are essentially digital or switching devices, so they are the best for transferring either on-off control signals or digital data. Analog signals can be transferred by means of frequency or pulse-width modulation.

![Figure C.1 Construction and Circuit Diagram](image)

### C.1.2 Description

The MCT2/ MCTE family is an Industry Standard Single Channel Phototransistor. Each opto-coupler consists of galium arsenide infrared LED, and a silicon NPN phototransistor. These couplers are Underwriters Laboratories (UL), and comply with a 5300 VRMS isolation test voltage. This isolation performance is accomplished through the Vishay double molding isolation manufacturing process. Compliance with DIN EN 60747-5-2 (VDE0884) DIN EN 60747-5-5 pending partial discharge isolation specification is available for these families, by ordering option 1.

These isolation processes and the Vishay ISO9001 quality programme result in the highest isolation performance available for a commercial plastic phototransistor opto coupler. The devices are available in lead formed configuration suitable for surface mounting, and are also available either on tape and reel, or in standard tube shipping containers.
Figure C.2 Pin Diagram of MCT2/ MCT2E

Specifications

- Gallium Arsenide Diode Infrared Source Optically Coupled to a Silicon NPN Phototransistor
- High Direct-Current Transfer Ratio
- Base Lead Provided for Conventional Transistor Biasing
- High-Voltage Electrical Isolation . . .
- 1.5-kV or 3.55-kV Rating
- Plastic Dual-In-Line Package
- High-Speed Switching:
  - $t_i = 5 \mu s$, $t_f = 5 \mu s$ (typical)
- Designed to be Interchangeable with General Instruments MCT2 and MCT2E

C.2 OPERATIONAL AMPLIFIER - LM324

An operational amplifier ("op-amp") is a DC-coupled high-gain electronic voltage amplifier with a differential input, and usually, a single-ended output. An op-amp produces an output voltage that is typically
hundreds of thousands times higher than the voltage difference between its input terminals.

The LM324 series are low–cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types for single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V, with quiescent currents about one–fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, eliminating thereby the external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Figure C.3 Pin Connection of MC1741

C.3 TRANSISTOR

In electronics, a transistor is a semiconductor device commonly used to amplify or switch electronic signals. A transistor is made of a solid piece of a semiconductor material, with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the
transistor's terminals changes the current flowing through another pair of terminals. Because the controlled (output) power can be much higher than the controlling (input) power, the transistor provides the amplification of a signal. The transistor is the fundamental building block of modern electronic devices, and is used in a radio, telephone, computer, or other electronic systems. Some transistors are packaged individually, but most are found in integrated circuits.

C.4 TRANSISTOR AS AN AMPLIFIER

The common emitter amplifier mentioned above is designed, so that a small change of voltage in (Vin) changes the small current through the base of the transistor, and the current amplification of a transistor combined with the properties of the circuit mean, that small swings in Vin produce big changes in Vout. It is important that the operating parameters of the transistor are so chosen and the circuit designed, that the transistor operates as far as possible within a linear portion of the graph, as that shown between A and B; otherwise, the output signal will get distorted. Various configurations of a single transistor amplifier are possible, with some providing current gain, some voltage gain, and some both.

C.4.1 General Description

In our project we used transistors in the driver circuit. The transistor was used to amplify the signal pulse coming from the microcontroller circuit. We used two main types of transistors that are present in the driver circuit of the Darlington pair circuit.

- CK100
- 2N222
C.4.2 Darlington Pair Circuit

In electronics, the Darlington transistor (often called a Darlington pair) is a compound structure consisting of two bipolar transistors (either integrated or separated devices) connected in such a way, that the current amplified by the first transistor is amplified further by the second one. This configuration gives a much higher current gain (written $\beta$, $h_{fe}$, or $h_{FE}$) than each transistor taken separately and, in the case of integrated devices, can take less space than two individual transistors because they can use a shared collector. Integrated Darlington pairs come packaged in transistor-like integrated circuit packages.

The Darlington configuration was invented by Bell Laboratories’ engineer, Sidney Darlington in 1953. He patented the idea of having two or three transistors on a single chip (and sharing a single collector), but not that of an arbitrary number. A similar configuration, but with transistors of the opposite type (NPN and PNP) is the Sziklai pair, sometimes called the "complementary Darlington".

C.4.3 Transistor-2N2222

![Transistor-2N2222 Diagram](image)

Figure C.4 Simplified Outline and Symbol

The 2N2222, often referred to as the 'quad two' transistor, is a small, common NPN BJT transistor used for general purpose low-power amplifying or switching applications. It has been designed for low to medium current, low power, medium voltage, and can operate at moderately high
speeds. It was originally made with TO-18 metal can as shown in the picture, but is more commonly available now in the cheaper TO-92 packaging, where it is known as the PN2222 or P2N2222.

C.4.4 Flip Flop- CD 4013

In electronics, a flip-flop or latch is a circuit that has two stable states and can be used to store state information. The circuit can be made to change state by signals applied to one or more control inputs, and will have one or two outputs. It is the basic storage element in sequential logic. Flip-flops and latches are the fundamental building blocks of digital electronics systems used in computers, communications, and many other types of systems.

C.4.5 Connection Diagram

In a conventional flip-flop, exactly one of the two complementary outputs is high. This can be generalized to a memory element with N outputs, exactly one of which is high (alternatively, where exactly one of N is low). The output is, therefore, always a one-hot representation.

Figure C.5 Dual-In Line Package
FEATURES

- Wide supply voltage range 4.0V to 15V
- High noise immunity \(0.45 \text{ V}_{\text{dd}}\) (typical)
- Low power TTL compatibility

C.5 IRF 540 POWER MOSFET

C.5.1 Power Mosfet Basics

The MOSFET, or Metal-Oxide-Semiconductor, Field-Effect Transistor is by far the most common field effect transistor in both digital and analog circuits. The MOSFET is composed of a channel of n-type or p-type semiconductor material, and is accordingly called an NMOSFET or a PMOSFET.

![MOSFET Symbol](image)

Figure C.6 Symbol of MOSFET

The gate terminal is a layer of polysilicon (polycrystalline silicon) or aluminum placed over the channel, but separated from the channel by a thin layer of insulating silicon dioxide.

C.5.2 Features of Power Mosfets

- The power MOSFET has lower switching losses, but its on-resistance and conduction losses are more.
• MOSFET is a voltage-controlled device.

• MOSFET has a positive temperature co-efficient for resistance. This makes the parallel operation of a MOSFET easy. If a MOSFET shares increased current initially, it heats up faster, its resistance rises, and this increased resistance makes this current shift to other devices in parallel.

• In a MOSFET, a secondary break down does not occur, because it has a positive temperature co-efficient.

• Power MOSFETs in higher voltage ratings have more conduction losses.

• The state of the art MOSFETs are available with ratings of up to 500V, 140A.

C.6 COMPARATORS

The comparator used for a high speed zero crossing detectors, a PWM converter or the conventional ADC is critical. Low propagation delay and extremely fast operation are not only desirable, they are essential.

A comparator may be the most underrated and underutilized monolithic linear component. This is unfortunate because comparators are one of the most flexible and universally applicable components available. In large measure, the lack of recognition is due to the IC op-amp, whose versatility allows it to dominate the analog design world. Comparators are frequently perceived as devices, that crudely express analog signals in the digital form - a 1-bit A/D converter.
Comparators are underrated as building blocks, and they have two qualities, low input offset and speed. For the application at hand (a zero crossing detector), both these factors will determine the final accuracy of the circuit. The XOR has been demonstrated to give a precise and repeatable pulse, but its accuracy depends on the exact time it 'sees' the transition of the AC waveform across zero. This task belongs to the comparator.

In Figure C.8 we see a typical comparator used for this application. The output is a square wave. This will create a single pulse for each square wave transition, and this equates to the zero crossings of the input signal.

It is assumed for this application that the input waveform is referenced to zero volts, and so, swings equally above and below zero.

C.7 PI CONTROLLER

A proportional–integral controller (PI controller) is a generic control loop feedback mechanism widely used in industrial control systems

- In feedback control systems a controller may be introduced to modify the error signal and achieve better control action.
• This controller will modify the transient response and the steady state error of the system. This increases the loop gain resulting in
  o Steady state tracking accuracy
  o Disturbance signal rejection
  o Relative stability

• A PI controller calculates an "error" value as the difference between a measured process variable and a desired set point.

• The controller attempts to minimize the error by adjusting the process control inputs.
APPENDIX D

HARDWARE BLOCK DIAGRAM

Figure D.1 Overall Block Diagram of buck-boost converter fed PMBLDC Drive

Figure D.2 Control Board
Figure D.3 Control Circuit using MCT 2E
Figure D.4 Control Circuit using Op-Amp