1. INTRODUCTION

1.1 THEORY

The basic theory behind the project is simple. Figure 1.1 shows a single coil winding with a conductive projectile passing through it. As current is discharged through the winding, a magnetic field is created. This field passes through the projectile and the change in the flux induces a current to flow within the projectile. Finally, a force in the launch direction is produced by the field and the induced current.

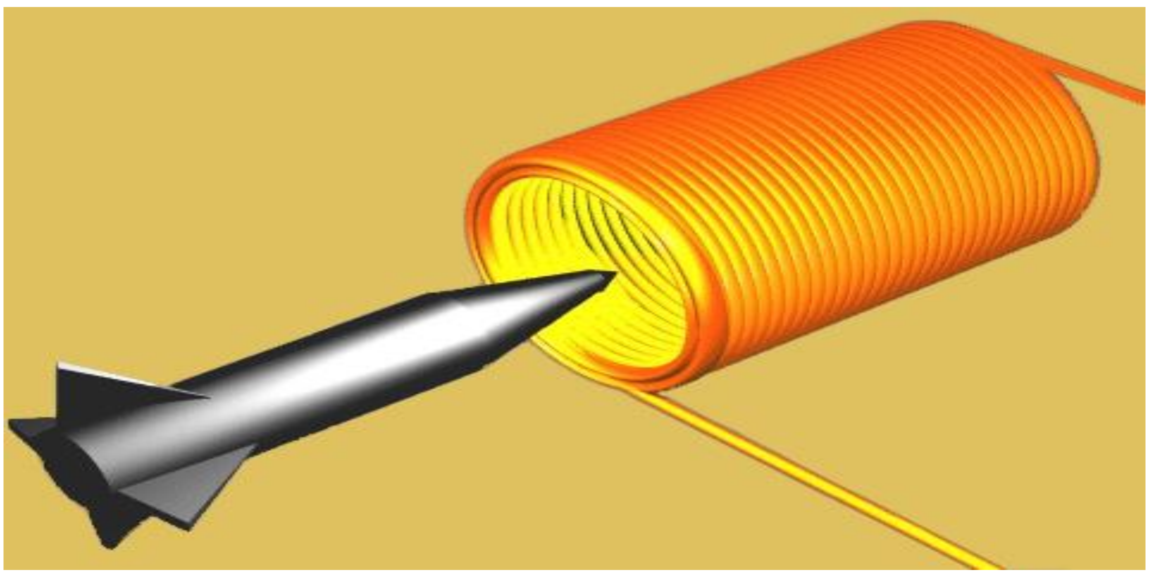

Fig. 1.1 Linear Induction Motor Theory Overview

Our Linear Induction Motor uses this principle to eject an iron cylinder of 10 mm diameter at speeds of 40 to 50km/hr. A novelty of our system is that the projectile is further accelerated at two extra stages after the initial propulsion. The system we used employs three separate capacitor banks that are charged to a certain voltage to provide the current discharge. The three banks are connected to three different coils that are wrapped consecutively around the barrel. In order to discharge the latter capacitor bank stages at optimal timings, we also used optical sensors and a microcontroller, the details of which will be provided later.

1.2 SCOPE

The aims of the project were:

- To design and build a working prototype with a multistage coil.
- To perform testing and analysis to optimize the machine's performance.
- To improve the prototype by adding more coils and varying the timings to achieve the best performance.

The testing was performed on a small scale low-voltage test rig, where between one and three stator coils were used to accelerate a solid metal rotor along a tube. Power to energize the coils was stored in capacitors, and the timing of the pulses was controlled by a microcontroller using a closed-loop optical feedback system.

1.3 OBJECTIVES

The project goal is to safely demonstrate a coil gun which launches a projectile at 40 to 50km/hr. We also want to display the launch speed on a monitor.

Features:

- Isolation of all high voltage components
- Capacitor bank for storing charge
- Sensing capabilities in launch barrel
- 3 Relay’s for each of the three capacitor to allow current to flow to coils
- Microcontroller to determine the optimal timing to launch projectile
- Launch button to enable triggering
- Projectile speed display

1.4 WHY WE USE 89S52?

We are living in the embedded world. You are surrounded with many embedded products and your daily life depends on the proper functioning of these gad jets. Television, radio, cd player of your living room, washing machine or microwave oven in your kitchen, card readers, access controllers, palm devices of your work space enable to do many of your tasks very effectively.

In recent days, you are showered with variety of information about these embedded controllers in many places. All kinds of magazines and journals regularly dish out details about latest technologies, new devices; fast applications which make you believe that your basic survival is controlled by these embedded products. Now you can agree to the fact that these embedded products have successfully invaded into our world. You must be wondering about these embedded controllers or systems. What is this embedded system?

These days designers have many choices in microprocessors\microcontrollers. Especially, in 8 bit and 32 bit, the available variety really may overwhelm even an experience designer. Selecting a right microprocessor may turn out as a most difficult first step and it is getting complicated as new series continue as new devices continue to pop up very often.

In the 8 bit segment, the most popular and used architecture is Intel's 8031.market acceptance angle of this particular family has driven many semiconductor manufactures to develop something based on this particular architecture. Even after 25 years of existence, semiconductor manufactures still come out with some kind of device using this 8031 core.

Points for selection of 89s52:

- We need two interrupts signal
- All required functions are available in chip
- Cheaper compare to other controller
- Three-level Program Memory Lock
- 256 x 8-bit Internal RAM
- Easily homemade programmer kit.
- Eight Interrupt Sources

1.5 RATING

In this project we will design the working model of LIM to achieve following parameters.

- Operating voltage & current: +48 volt DC
- Operating current: 0.8 A
- Max. Speed: 40 to 50km/hr.

1.6 LITERATURE REVIEW

The first prototype linear motor was built by Charles Wheatstone in the 1840s, however it is unknown if the prototype was ever tested. Over the next hundred years, various patents were granted for linear motors to power devices such as railways and textile. The first useful application of a linear motor was during WW2 as an aircraft catapult and shortly afterward the first full-size working prototype of a linear motor powered transport system was built More recently, linear motors are being used for small scale industrial applications due to their simplicity of construction, reliability and low cost.

Linear Motors

The most common use of the linear motor is transport. They are ideal for trains, because the thrust produced is independent of the wheel's adhesion to the track, which allows for higher velocities. In addition, a perpendicular force is produced which can levitate the car above the track, eliminating friction. Both LIMs and linear synchronous motors (LSMs) are used in transport applications, and efficiency is high due to the long moving coil reducing end-effect.

LIMs come in two types. Attraction motors have a travelling magnetic field in front of the rotor pulling it along, whereas repulsion motors have the magnetic field travelling behind the rotor pushing it along. Simple single-stage repulsion accelerators have been studied (Sade din, 1991), built and tested, and achieved the highest acceleration ever achieved; a 2 gram ring to 5km/s over a 1cm length. The disadvantage of repulsion accelerators is that the rotor needs to be the same shape as the stator coils, typically a disc or torus, which makes them less practical and may be why there has not been more development of the technology. Studies have been performed of coil-based coaxial LIMs and launchers on varying scales.

In terms of rotor design, Andrews & Devine, 1991, concluded that wound multi-turn rotors perform better than solid metal rotors, however their drawbacks include susceptibility to being damaged by large acceleration and magnetic forces, and increased cost. Almost all more recent experiments have all been done with a solid metal rotor, demonstrating that the practicality of a solid metal rotor outweighs the advantages of a wound rotor in most cases. In another study, simulations showed that current density was high in the solid rotor and heat was generated, but it didn’t affect the machine’s performance.

EM Weapons

The most recent research in linear motor technology is the development of electromagnetic weapons, using linear motors to accelerate projectiles to speeds much higher than is attainable with conventional chemically-propelled weapons. This gives a much longer range, and cost & weight are saved as need for propellant or an explosive warhead is negated as the weapon inflicts damage by kinetic energy alone. The necessary technology has been in existence for the last sixty years, however has only recently been made practically possible by developments in energy storage and switching technology.

The simplest type of electromagnetic launcher is the ‘railgun’ which uses a pulse of current through two conductive rails along which the projectile is forced by magnetic repulsion. The main limiting factor is extreme physical wear on the rails due to the massive currents and forces involved. (Wong, 2013)

More complex is the ‘coilgun’ which is a large scale open-ended coaxial LIM, with coils pulsed in turn. This technology is more recent and less developed as it requires a more complex control system, and so velocities attained are not currently as high. An advantage of a coilgun over a railgun is the fact that the projectile does not contact the rails and can be made to levitate inside the tube, eliminating major wear and required maintenance. In addition, coilguns have lower noise, use less overall power, and are easier to scale down. For these reasons it seems to be widely expected that coilgun technology will replace railguns as enabling technology is advanced, both in large scale naval applications and small-scale battlefields. Coilgun technology is further behind railgun development, but it is advancing nonetheless, for example a recent study has been done devising a method for muzzle velocity calculation, and last year a 15-stage coil gun was built that could launch 5kg 120mm diameter projectiles at 220m/s, yielding 121kJ kinetic energy.

Current and energy requirements for large scale electromagnetic weapons are enormous, in the order of millions of Amps per shot, and so at present large ships are the only vehicles capable of supplying the necessary current to operate them. As such, the US Navy has invested a lot of funding in the technology over the last two decades which is rapidly advancing as a result. The current record is a test performed in 2010, by the US ONR, of a 32MJ railgun which launched a 10.4kg slug at 2500m/s.

2. BLOCK & CIRCUIT DIAGRAM

2.1 BLOCK DIAGRAMS

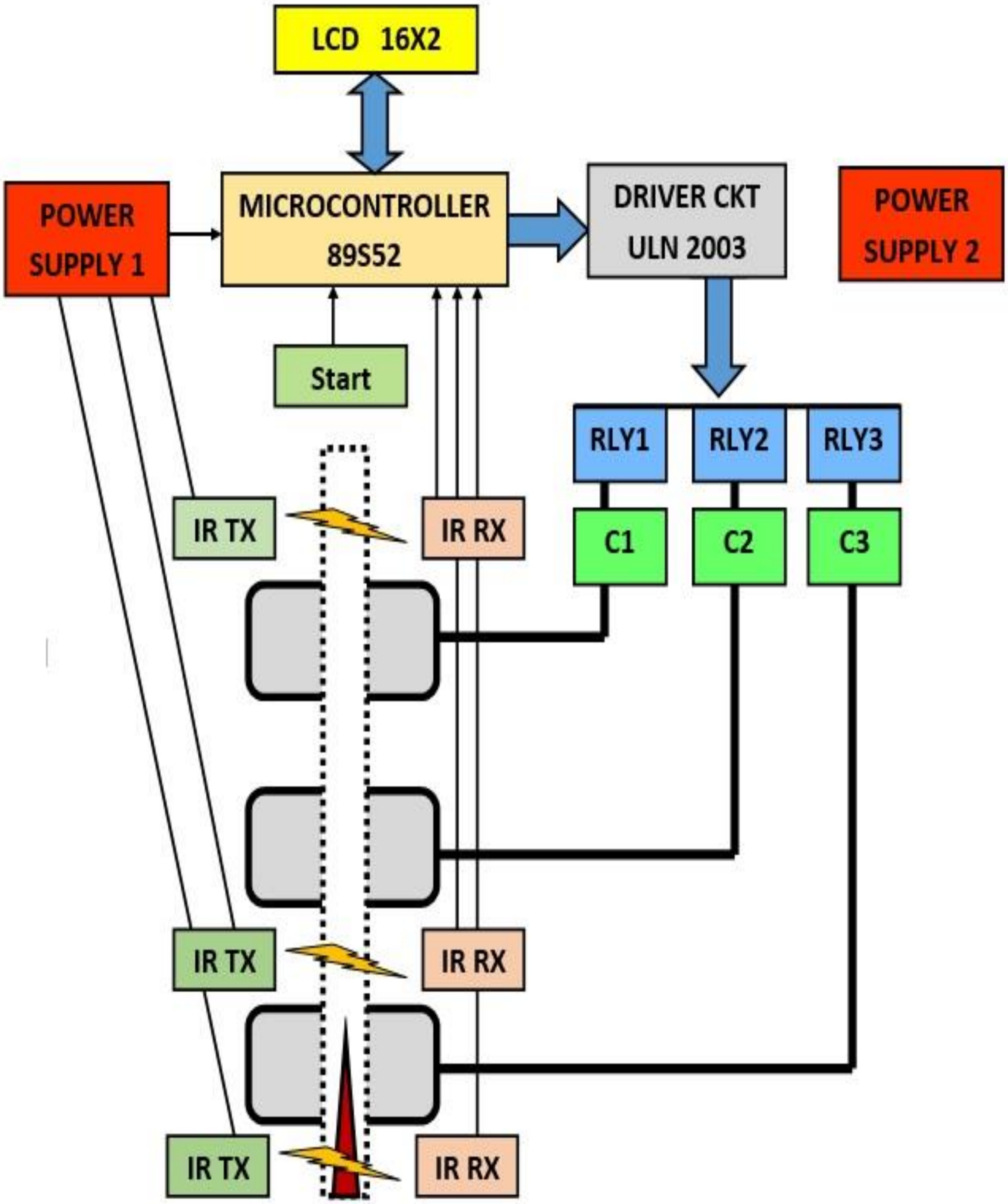

Fig. 2.1 Block Diagram of Linear Induction Motor

2.1.1 BLOCK DESCRIPTION

Power Supply

For low voltage we used Regulated power supply. The low voltage power supply is used to power the sensor I/O circuits, microcontroller and display.

The high voltage power supply receives signals from the trigger circuit which control to discharge to the three sets of coil windings. Each coils will be controlled by a relays.

Sensor Circuit

The sensor circuit is the primary interface between the photodiodes and microcontroller. Using a series of potentiometers and op-amps the circuit takes the analog signal from the photodiodes and translates them to clear, stable digital inputs for the microcontroller.

Microcontroller

Once the microcontroller receives the input signal, it calculates the optimal timing to trigger the consecutive coils. The microcontroller completes these calculations by measuring the speed of the projectile between the first two sensors. After extracting the necessary information from the input signal, the microcontroller will relay the signal to trigger circuit.

In our project we used 89s52 microcontroller

- 89s52 is low power, high performance CMOS 8bit microcontroller with 8kbytes of In System Programmable flash memory.
- It is highly flexible and cost effective.
- It works on +5v.
- It is used for controlling and programming.

Driver Circuit

The driver circuit receives the signal from the microcontroller to trigger the relays. The circuit will allow electrical isolation between the high voltage power supplies and the microcontroller and amplify the output signal from the microcontroller to trigger the relays.

Coil Gun Windings

The Coil Gun windings are three sets of coils connected to each set of high voltage supply. The current will be discharged through the first coil when the launch is triggered. The supply will controlled to discharge current to the second and third coils by the microcontroller.

Monitor Display

A monitor will be used to display the launch speed which is calculated by the microcontroller. LCD is connected with 89s52 microcontroller. We are using 16x2 LCD.

2.2 CIRCUIT DIAGRAM

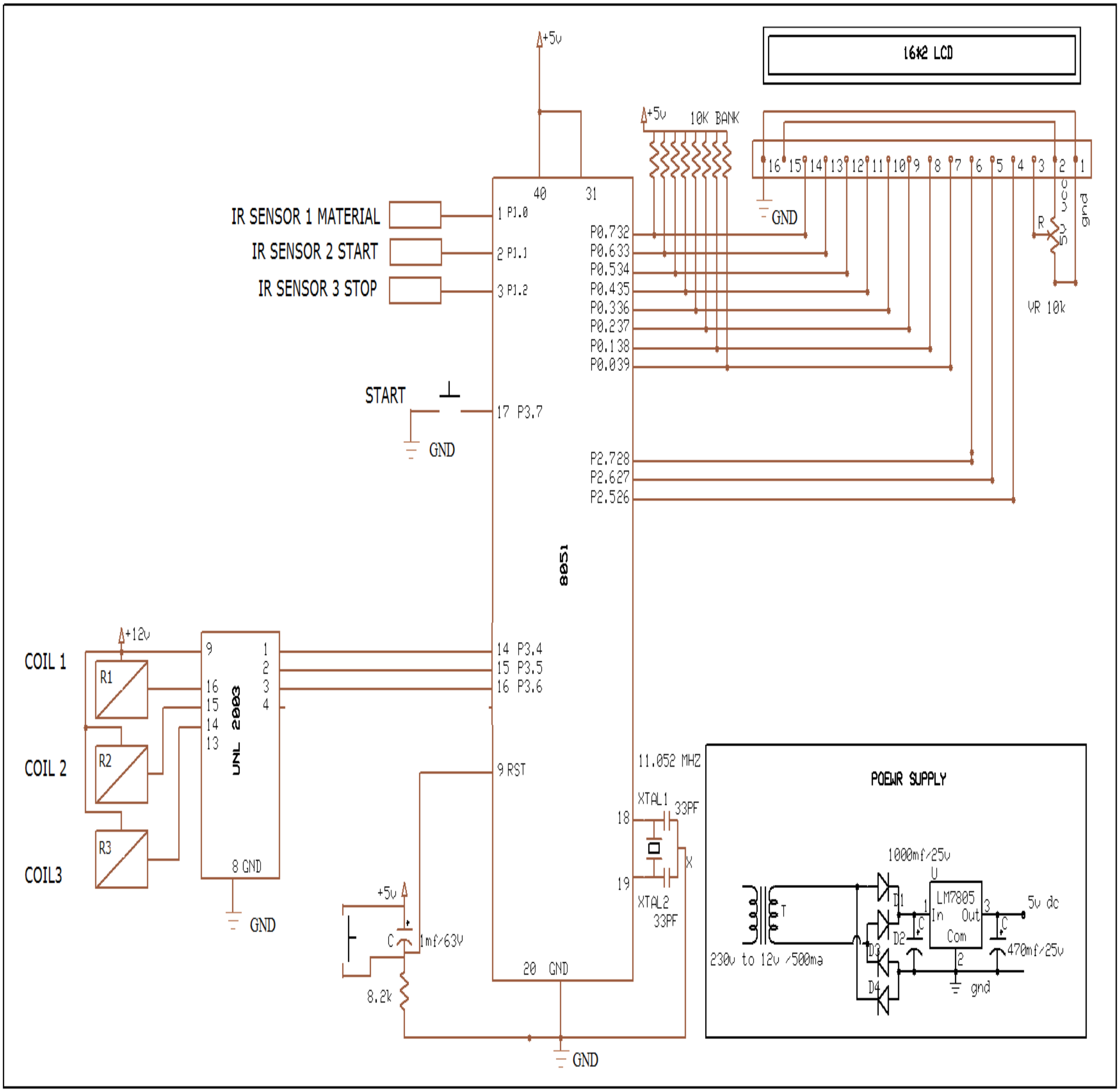

Fig. 2.2 LIM Circuit Diagram

Fig. 2.3 Hardware

2.2.1 Circuit Working

Heart of this circuit is microcontroller 89s52 and remaining all parts of circuit is directly connected with the microcontroller control according to the programmed is write inside the chip. Based on that logical programmed it will control all connected components.

The basic need of microcontroller is +5v dc for its reset circuit and clock oscillation circuit. +5v dc supply provide to microcontroller through power supply circuit. The function of power supply circuit is main 230v ac converted to +12v dc and +5v dc. Power supply brief description explain latter in next chapter.

In this system driver IC ULN 2003 is connected to Port number P3.4 to P3.5 in microcontroller. The output of this IC is than given to three relays. Relays are used for triggering each coil based on microcontroller timing calculation. The sensor circuit output are connected to Port numbers P1.0 to P1.2. LCD data control pin are connected to Port number P0.0 to P0.7 and LCD control signal are connected to P3.7 Port.

Rotor (projectile) is placed in material sensor in tube, so microcontroller is detect the whether the rotor is available or not in tube. If available then microcontroller is ready for trigger. If not then it show Empty status in display. Now, press the push button switch. Based on programming microcontroller calculate the time for each coils to trigger sequentially. After calculating time it produce signal to drive IC 2003. IC then operate the relays sequentially. During the triggering of first relay the rotor moved from sensor position 1 to sensor 2 position. When rotor reach at second sensor. It produce the output signal and give it to microcontroller. When the relay are triggered the supply is given to coil. Current is discharge through the coil winding and it create magnetic field. Finally, a force in launch direction is produced by field.

After launching of rotor the microcontroller give signal to display the value of speed. This is done due to time taken by rotor between two sensor START & STOP sensor. Generally, the speed measured in km/hr. if the rotor are not placed inside the tube then display reading show EMPTY. The solid iron projectiles perform very well in this system and that projectile length is not very important to launch performance.

2.3 PHYSICAL COMPONENT DIAGRAM

There are seven main components in our project design:

- High Voltage Power Supply
- Low Voltage Power Supply
- Trigger Circuit
- Sensor Circuit
- Microcontroller
- Capacitor
- Coil

The working of our project is best described in two separate phases. The first phase consists of all of the mechanisms leading to the discharge of the first capacitor and the initial propelling of the projectile towards the second coil winding. The second phase consists of all the mechanisms controlling the discharge of the second and third capacitor leading to the eventual ejection of the projectile from the barrel.

Phase 1

The high voltage power supply (HV power supply) is used to charge the capacitor banks through the use of the charge controller as shown in fig 1.4.1. Hence, the source of the force which propels the projectile originates from the HV power supply.

The charge controller consists of three individual switches which can be pressed to charge each capacitor bank. The launch button is also a part of the charge controller and when it is activated, the first capacitor bank discharges which initiates the projectile's movement towards the second coil winding. This concludes the first phase.

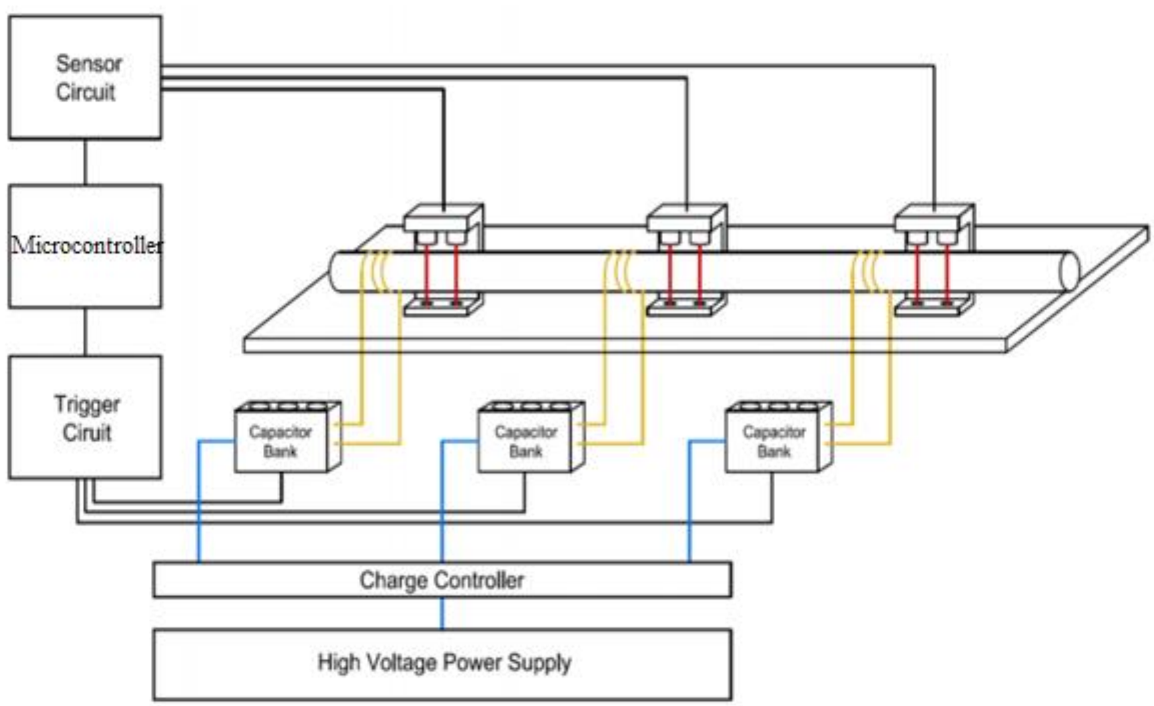

Fig. 2.4 Physical Component Diagram

Phase 2

The low voltage power supply (LV power supply) is used to power the sensor circuit, microcontroller, and display. We have lasers continuously shining on photodiodes after each coil winding. The first set of optical sensors provides a drop in voltage when the projectile, passing through the barrel, comes in between the laser and photodiode. The voltage drop signal is sent to the microcontroller.

The microcontroller uses the information given by the sensor circuit to calculate the speed of the projectile. This is done by using the difference in the times logged for the voltage drop from a set of two optical sensors and the known distance between the sensors. The microcontroller then uses the speed to calculate the optimal discharge time for the next capacitor bank. The detailed explanations of these calculations are given in the design section. Finally, the microcontroller sends a signal to the trigger circuit to activate driver uln 2003 which after trigger the relay. This entire phase 2 process is repeated once more for the second set of sensors and third capacitor bank after which the projectile is ejected from the barrel.

2.3.1 Power Supply

2.3.1.1 Regulated Power Supply

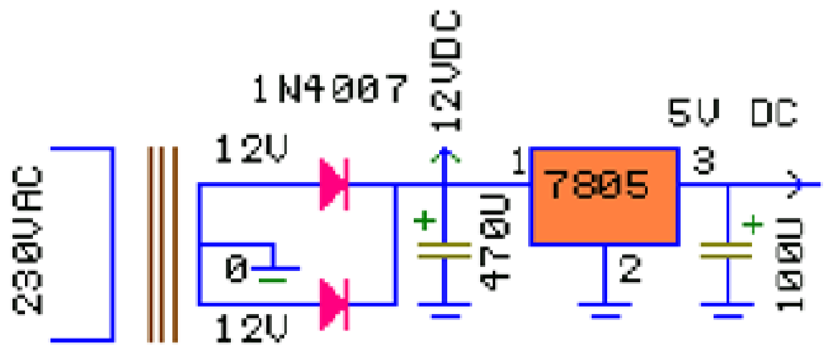

Fig. 2.5 Circuit Diagram of Regulated Power Supply

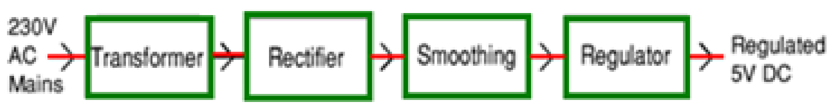

Fig. 2.6 Block Diagram of Regulated Power Supply

Every circuit requires power for its operation. Here we require +5V D.C. to operate Microcontroller, Relays, and certain ICs.

The supply voltage of 230V A.C. is step downed to 12V by using the step-down Transformers. As the circuit requires only the D.C. supply the in fed A.C. is converted to D.C. by using the rectifying unit.

The rectifying unit consists of full wave rectifiers comprising diodes for rectification Purpose. Any of the ripples coming out of the rectifying unit is bye passed by connecting the Capacitor in parallel.

As the microcontroller circuit requires only +5V D.C. supply, the outputs is further diminished by the regulator (IC7805) for accurate +5V to the microcontroller circuit. The capacitor (100uf) is connected in parallel for suppressing the ripples.

2.3.1.2 High Voltage Power Supply

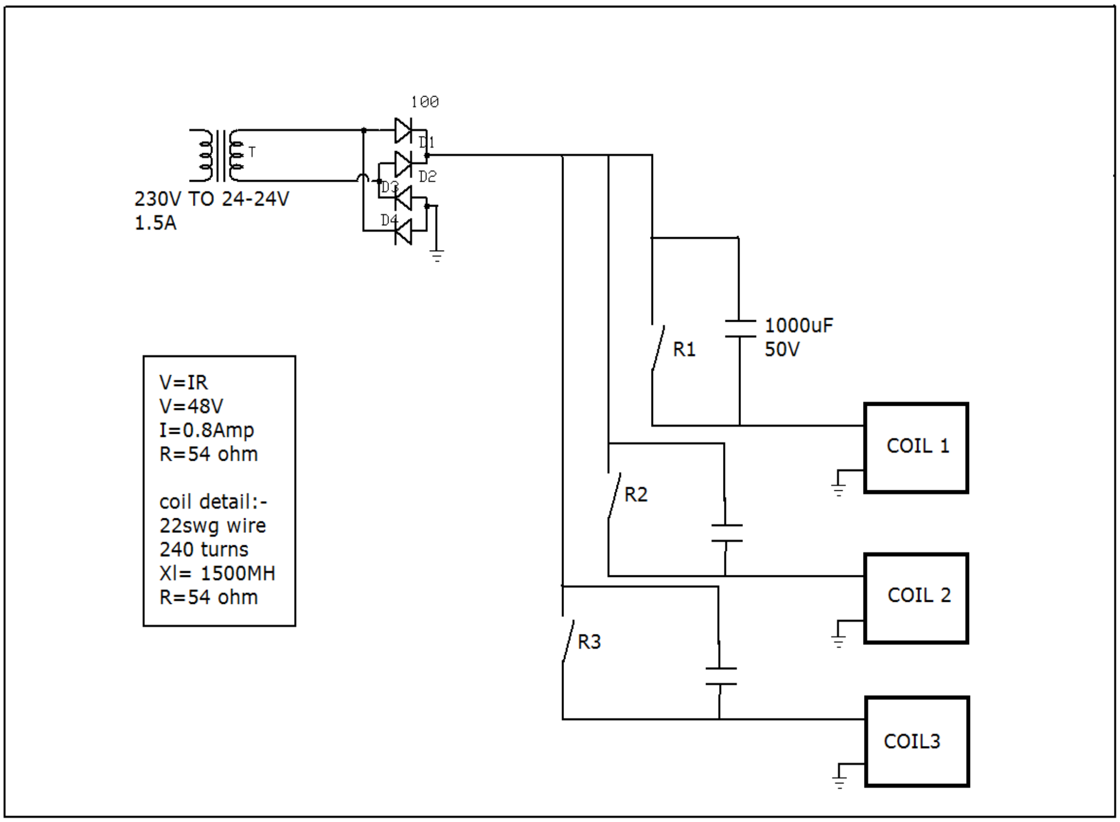

Fig. 2.7 HV Power Supply

The high voltage power supply consists of the capacitor and the high voltage DC power supply. The capacitors store charge to provide the power for the projectile launch. The capacitors will be in an enclosure as to prevent them from being exposed. The high voltage power supply receives signals from the trigger circuit which control the capacitors to discharge to the three sets of coil windings. Each capacitor will be controlled by a relay.

2.3.2 Sensor Circuit

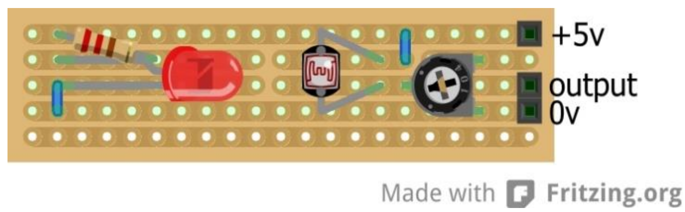

Fig. 2.8 Light Gate Circuit

The sensor circuit module included infrared LED, photodiodes, and potentiometers. When the phototransistor receives the infrared light, it conducts electricity so the current travels through it straight to earth. When the phototransistor is not receiving IR, it resists the current, which instead flows to the base of the transistor and switches on the LED. This interruption will result in a voltage change of approximately 100mV

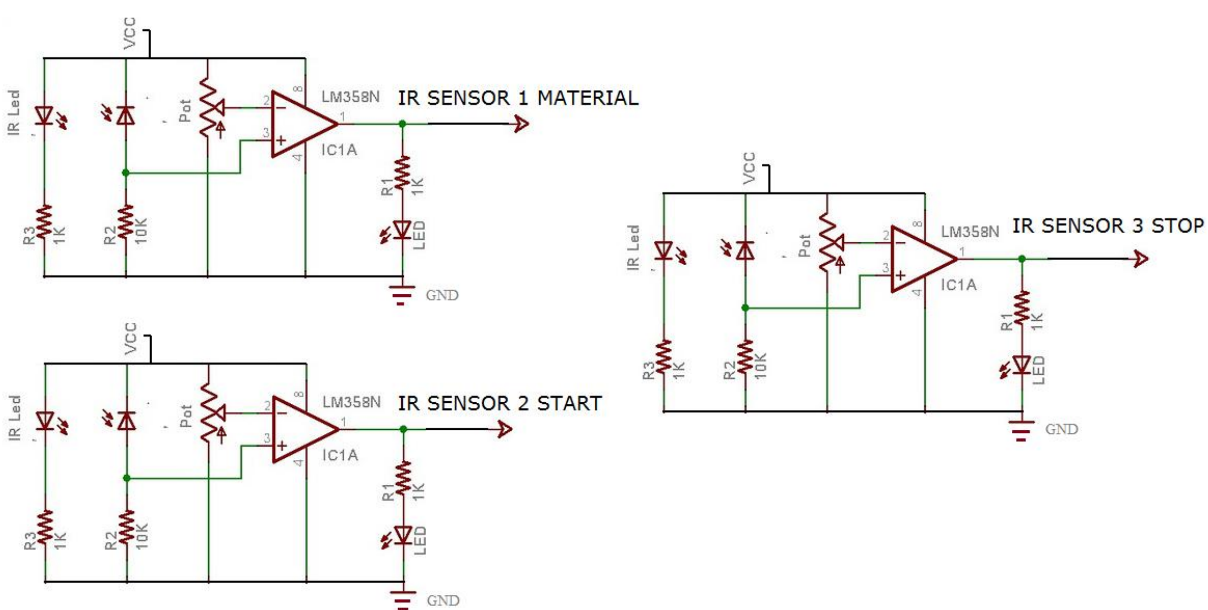

Fig. 2.9 Sensor Circuits

If the IR LED emissions become incident on the photodiode, the photodiode's resistance comes down to a finite value. The drop across the 10K series resistor is what we use as the input, which is compared with the threshold. The point to be noted here is that more the incident radiation on the photodiode, less will be the drop across it, and hence more will be the drop across the series resistor. If the voltage developed across the resistor is greater than the threshold set by us, the output of the IC will be high, else it will be low. Hence, if our reflected radiation is never strong enough to be greater than the threshold and we have a constant low as output, we can reduce the threshold voltage by turning the "minus shaped" slit in the variable resistance towards its terminal where we connected Gnd. In case our threshold is very low and the output is always high in spite of no radiation or if it is just too sensitive, then you can increase the threshold by turning the slit the other way. When the emissions are absorbed by a black surface, the resistance of the photodiode becomes very high due to no incidence of IR emissions on it, and the output remains low. LED is use to indicate the output and it give signal to microcontroller.

Features:

- Active Low on object detection
- 3 pin easy interface connector
- Indicator LED
- Very accurate

Applications:

- Line Follower sensor
- Obstacle Avoidance Robot
- Edge avoiding robot
- Anti-falling robot
- Light/Fire sensing

2.3.3 Microcontroller

In this section microcontroller basic circuit like clock generator circuit, reset circuit and also interface circuit attached with this like sensor circuit, LCD circuit and drive circuit. All circuit operating voltage is 5vdc.

PORT PIN CONFIGURATION OF MICROCONTROLLER (89S52) WITH THIS SYSTEM IS AS FOLLOWS.

PORT	PORT PINS	DEVICE ATTACHED/FUNCTION
PORT 0	P0.0 TO PO.7	LCD DATA CONTROL
PORT 1	P1.0 TO P1.3	IR SENSOR 1, 2 & 3
PORT 2	P2.7 P2.6 P2.5	LCD CONTROL SIGNAL
PORT 3	P3.4 TO P3.6 P3.7	DRIVER UNL 2003 TRIGGER BUTTON

Table 2.1 Port Pin Configuration of 89s52

2.3.4 Coil

2.3.4.1 Coil Triggering

Each coil of wire will require a short, powerful pulse of high current to attract the rotor. Each coil will need to be triggered as the rotor approaches it. To do this, a closed-loop system can be used whereby light gates are positioned between the coils, and the passage of the rotor through each light gate sends a signal back to the microprocessor, which triggers the next coil. As the rotor will be moving at high speed, the switching speed must be as fast as possible to increase precision and accuracy.

For switching high currents, the main two options are mechanical switches (relays) and semiconductors. Standard electromechanical relays can handle high current, but their main drawback is the switching time. Since it takes time for the coil in the relay to energize and for the armature to contact, this causes a delay which would be a hindrance and possible source of error in this application.

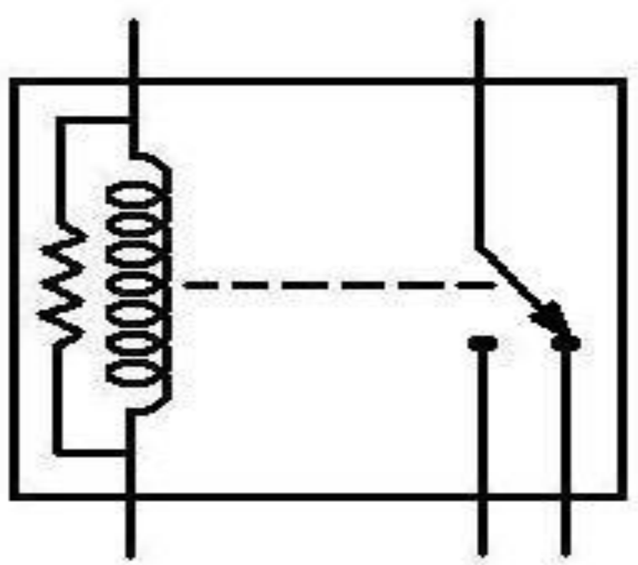

Fig. 2.10 Electromechanical Relay Symbol

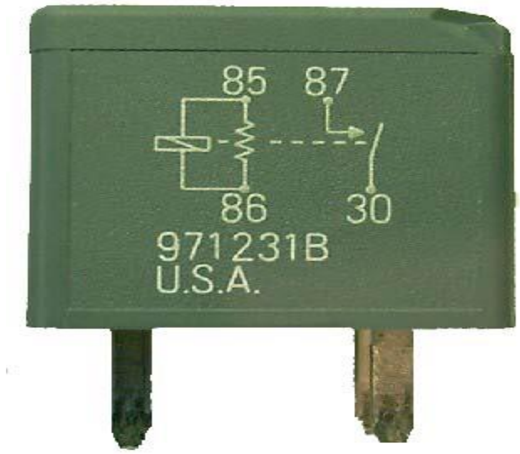

Fig. 2.11 Electromechanical Relay

Solid state relays use semiconductors in place of mechanical parts, and they have an almost instantaneous switching time. Nevertheless, they have a higher voltage drop across them than mechanical relays. Solid state relays can handle high current, however they still have a switching time of around 10ms, which is an improvement on the electromechanical relay but still not ideal.

2.3.4.2 Coil Design Calculation

A crucial factor that affects the performance of the machine is the duration of the pulse through the coil. Too short, and it will not have sufficient time for the magnetic field to accelerate the rotor. Too long, and the magnetic field will hinder the rotor's progress as it leaves the coil. Ideally, the pulse should begin as the rotor approaches the coil, and end as the rotor is at the midpoint of the coil. The timing of the start of each pulse will be controlled by the feedback system.

Coil Design Calculations

	A	B	C	D	E	F	G	H
1								
2		**Parameter**				**Unit**		
3	**Inductor**							
4		Number of turns	N	=	80	Turns		
5		Inside radius	r1	=	0.007	Metres		
6		Outside radius	r2	=	0.013	Metres		
7		Coil length	l	=	0.02	Metres		
8		**Inductance**	**L**	**=**	**35.14**	**Micro Henries (uH)**		
9								
10	**Capacitor**							
11		Capacitance	C	=	1000	MicroFarads		
12		Voltage	V	=	50	Volts		
13		**Stored Energy**	**E**	**=**	**1.25**	**Joules**		
14								
15		**Pulse Duration**	**T**	**=**	**1.177**	**Milliseconds**		
16								
17								
18								
19	**Formulae Used**							
20		Capacitor Stored energy		=	1/2CV^2			
21		Inductance of a multi layer air-cored inductor		=	(31.6 x (N^2) x (r1^2)) / ((6 x r1) + (9l) + 10(r2-r1))			http://www.circuits.dk /calculator_multi_layer_aircore.htm
22		Time Constant for an LC circuit		=	2 x pi x SQRT(LC)			
23								

Fig. 2.12 Coil Design Calculation

The actual pulse time will vary from the predicted pulse time due to factors such as equivalent series resistance and coil reluctance. Once a coil has been paired with a capacitor, the actual time constant can be measured using an oscilloscope or similar.

Fig. 2.13 Coil View

The coil’s physical dimensions are dictated by the space available:

- Coil length must fit into the transformer core.
- Inside diameter must fit snugly on the firing tube.
- Outside diameter should be large (to maximize turns/inch), but small enough to fit within the transformer core.
- Note that inductance (L) is proportional to N^2 (square of turns), so plan on building a coil larger than needed and then remove turns during tuning.

3. 89S52 MICROCONTROLLER

3.1 INTRODUCTION

This module is the "brain" of our project. It will log the times when the projectile has passed through the sensors and calculate the speed of the projectile. Using the speed and the known distance between the sensors and the next coil, it will wait for a certain period of time before triggering the coils for the next stage.

The microcontroller will receive a signal from the sensor circuit and log the time for when the input signal voltage drops from HIGH to LOW. For each set of photodiode-laser pairs, the microcontroller will take the difference of the logged times. The microcontroller can then calculate the speed of the projectile using the difference between the logged times and the known distance between the photodiodes in each set. With the speed and the known distance between the sensors and the next coil, it can estimate when to fire the next stage coil.

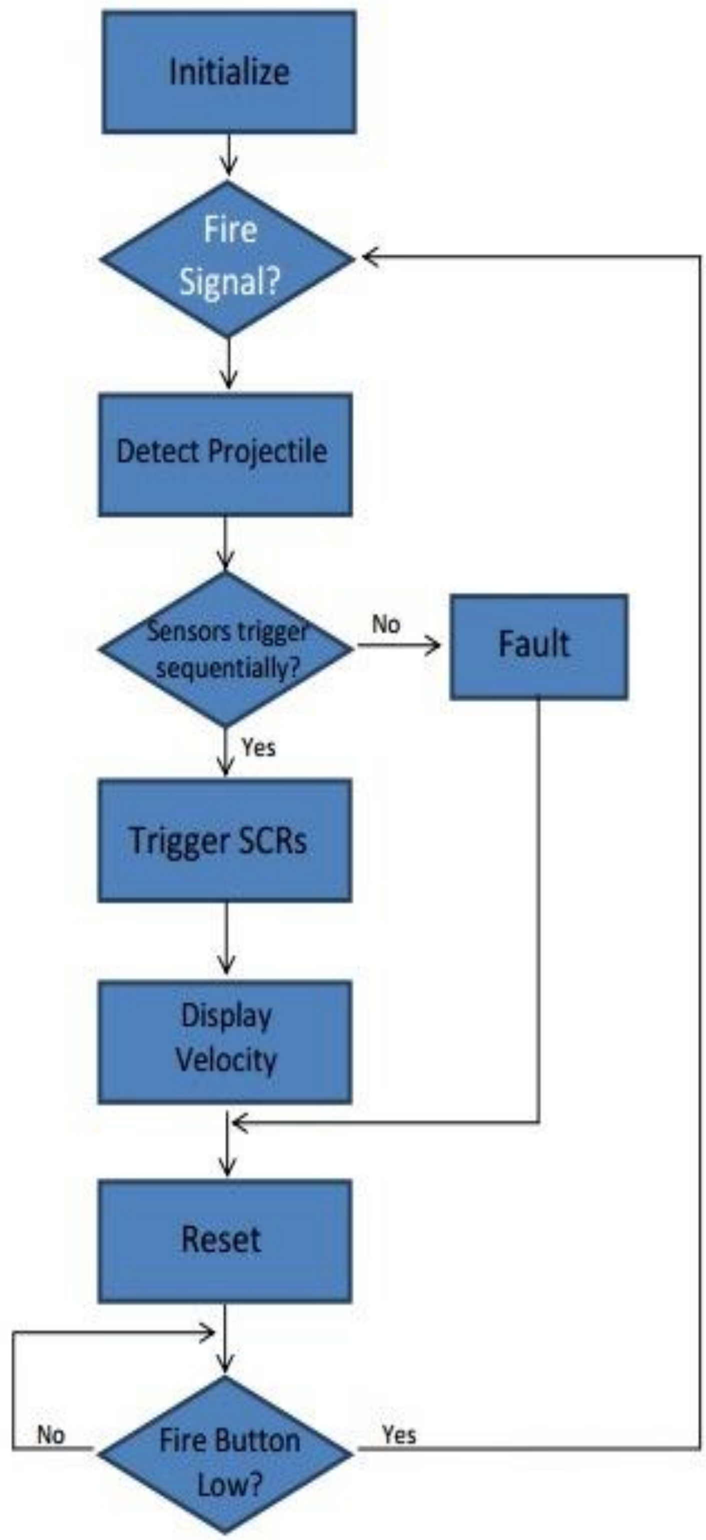

Fig. 3.1 Microcontroller Flow Chart

3.2 DESCRIPTION

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8Kbytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the industry- standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

Fig. 3.2 AT89S52 Microcontroller

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

3.3 BLOCK DIAGRAM

The 89S52 has 4 different ports, each one having 8 Input/output lines providing a total of 32 I/O lines. Those ports can be used to output DATA and orders do other devices, or to read the state of a sensor, or a switch. Most of the ports of the 89S52 have 'dual function' meaning that they can be used for two different functions.

The first one is to perform input/output operations and the second one is used to implement special features of the microcontroller like counting external pulses, interrupting the execution of the program according to external events, performing serial data transfer or connecting the chip to a computer to update the software. Each port has 8 pins, and will be treated from the software point of view as an 8-bit variable called 'register', each bit being connected to a different Input/output pin.

There are two different memory types: **RAM** and **EEPROM**. Shortly, RAM is used to store variable during program execution, while the EEPROM memory is used to store the program itself, that's why it is often referred to as the 'program memory'. It is clear that the CPU (Central Processing Unit) is the heart of the micro controllers. It is the CPU that will Read the program from the FLASH memory and execute it by interacting with the different peripherals

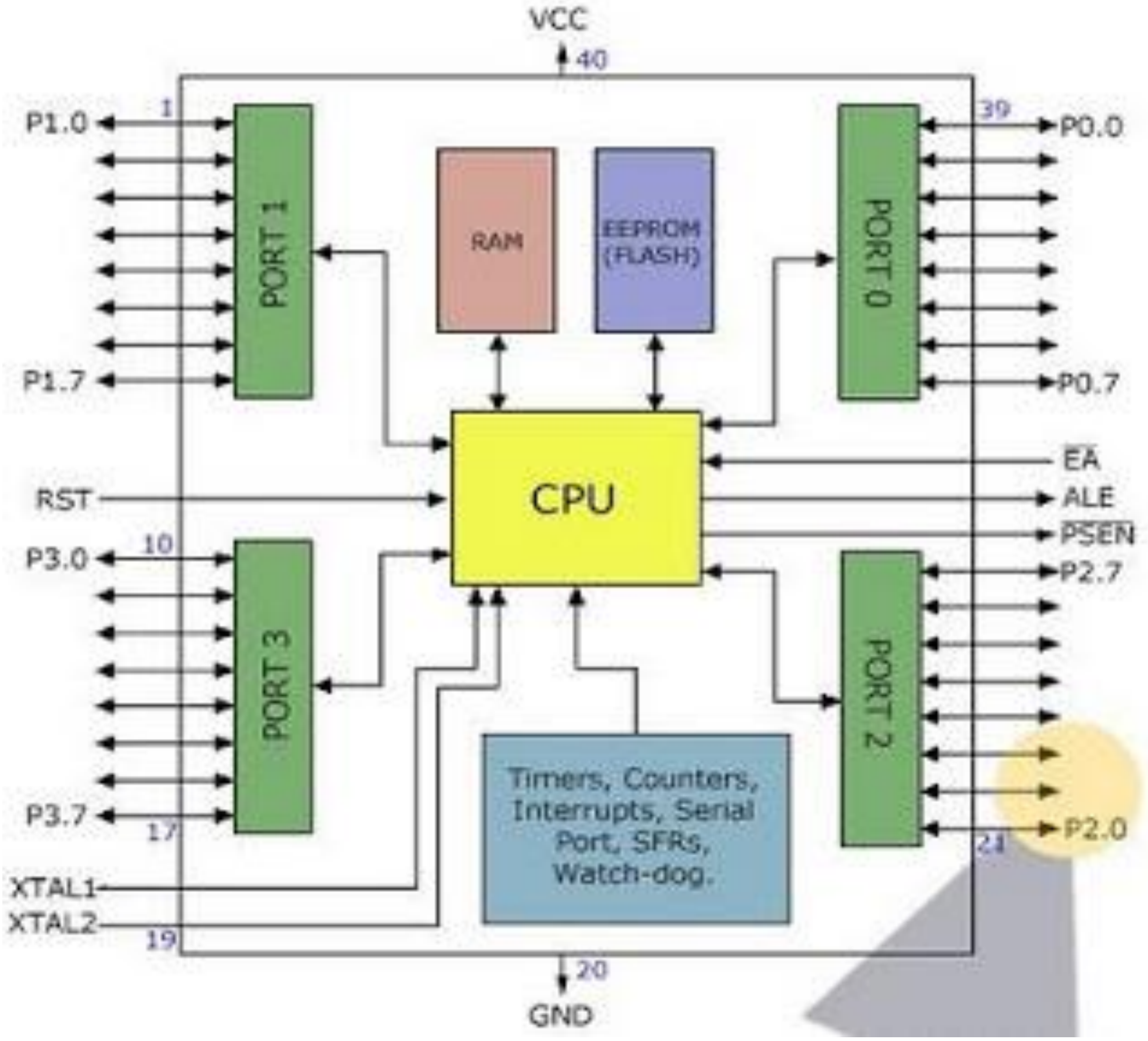

Fig. 3.3 Block Diagram of 89S52

Diagram below shows the pin configuration of the 89S52, where the function of each pin is written next to it, and, if it exists, the dual function is written between brackets. Note that the pins that have dual functions can still be used normally as an input/output pin. Unless the program uses their dual functions, all the 32 I/O pins of the microcontroller are configured as input/output pins.

3.4 PIN CONFIGURATION

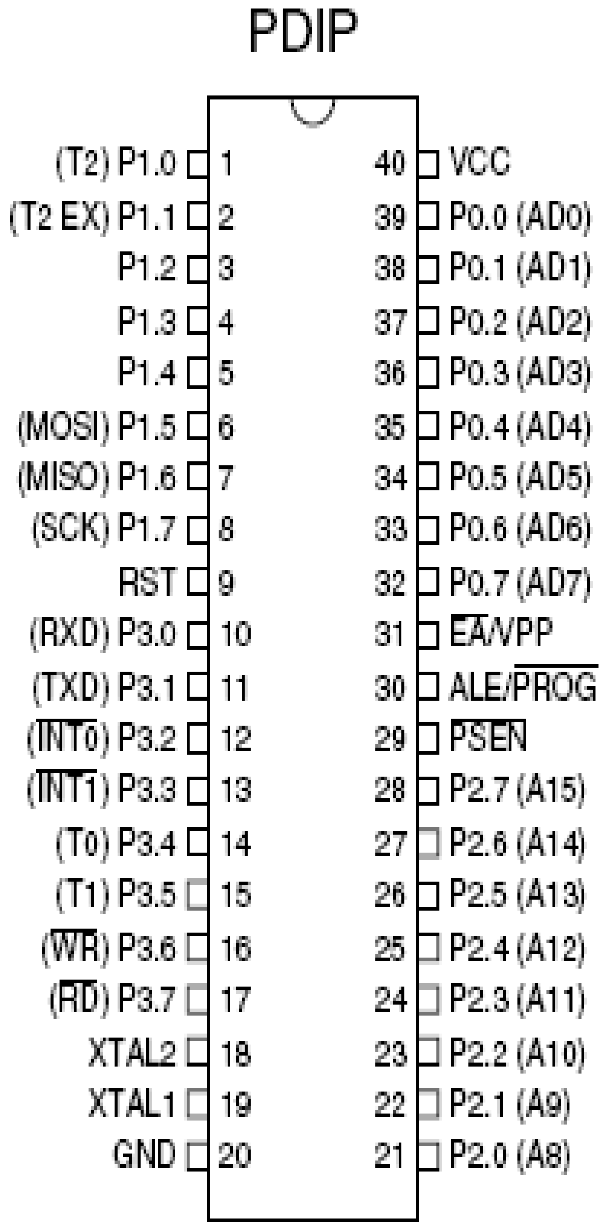

Fig. 3.4 Pin Configuration

Pin Description:

VCC: Supply voltage.

GND: Ground.

Port 0:

Port 0 is an 8-bit open drain bidirectional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high impedance inputs.

Port 0 can also be configured to be the multiplexed low order address/data bus during accesses to external program and data memory. In this mode, P0 has internal pull ups. Port 0 also receives the code bytes during Flash programming and outputs the code bytes during program verification. External pull ups are required during program verification.

Port 1:

Port 1 is an 8-bit bidirectional I/O port with internal pull ups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins, they are pulled high by the internal pull ups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (IIL) because of the internal pull ups. In addition, P1.0 and P1.1 can be configured to be the timer/counter 2 external count input (P1.0/T2) and the timer/counter 2 trigger input (P1.1/T2EX), respectively, as shown in the following table. Port 1 also receives the low-order address bytes during Flash programming and verification.

Port Pin	Alternate Functions
P1.0	T2 (external count input to Timer/Counter 2), clock-out
P1.1	T2EX (Timer/Counter 2 capture/reload trigger and direction control)
P1.5	MOSI (used for In-System Programming)
P1.6	MISO (used for In-System Programming)
P1.7	SCK (used for In-System Programming)

Table 3.1 Port 1 Pins

Port 2:

Port 2 is an 8-bit bidirectional I/O port with internal pull ups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins, they are pulled high by the internal pull ups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (IIL) because of the internal pull ups.

Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that use 16-bit addresses (MOVX @ DPTR). In this application, Port 2 uses strong internal pull-ups when emitting 1s. During accesses to external data that use 8-bit addresses (MOVX @ RI), Port 2 emits the contents of the P2 Special Function Register. Port 2 also receives the high-order address bits and some control signals during Flash programming and verification.

Port 3

Port 3 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (IIL) because of the pull-ups.

Port 3 also serves the functions of various special features of the AT89S52, as shown in the following table. Port 3 also receives some control signals for Flash programming and verification.

3.5 BASIC MICROCONTROLLER CIRCUITS

The basic microcontroller circuit means the circuit that requires for the operation of microcontroller. It mainly includes two circuits.

- Crystal circuit
- Reset circuit

3.5.1 Crystal Circuit

The crystal circuit includes the crystal oscillator and two ceramic capacitors to make resonance. The circuit is shown in below figure.

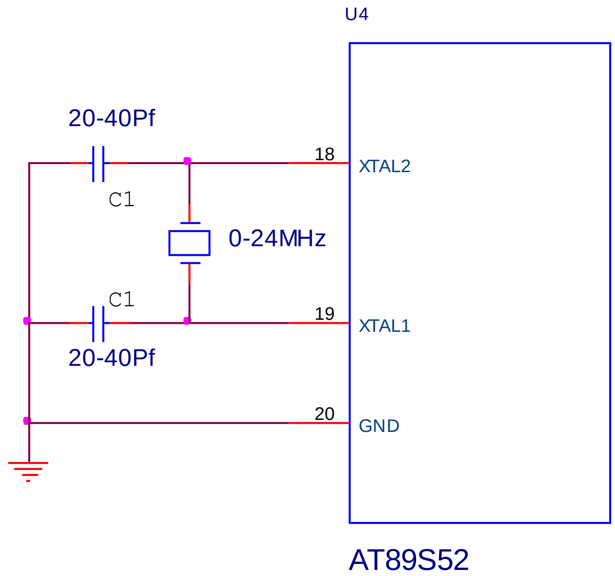

Fig. 3.5 Crystal Circuit

The crystal circuit provides the clock pulses to microcontroller which acts as a reference pulses for its operation. The value of crystal may vary from 0-24MHz as shown in figure. Similarly the value of ceramic capacitor may vary from 20-40Pf.

3.5.2 Reset Circuit

Pin no-9 of microcontroller is the RESET pin. A high pulse on this pin causes the microcontroller to be reseted. The below figure shows the circuit diagram of RESET circuit.

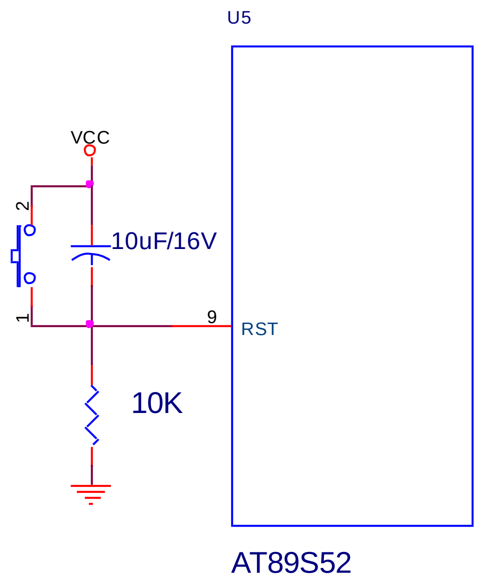

Fig. 3.6 Reset Circuit

When the switch is pressed, the reset pin of microcontroller (pin no-9) gets a high pulse. Hence all the register contents are flushed out and microcontroller starts its execution from memory location 0000H. The capacitor of 10uF is provided for power-on reset. Initially when capacitor is fully discharged, it acts as a short circuit. Hence reset pin gets high pulse and system is reseted. Hence power-on reset is achieved.

Features:

- Compatible with MCS-51® Products
- 8K Bytes of In-System Programmable (ISP) Flash Memory
- Endurance: 1000 Write/Erase Cycles
- 4.0V to 5.5V Operating Range
- Fully Static Operation: 0 Hz to 33 MHz
- Three-level Program Memory Lock
- 256 x 8-bit Internal RAM
- 32 Programmable I/O Line
- Three 16-bit Timer/Counters
- Eight Interrupt Sources
- Full Duplex UART Serial Channel
- Low-power Idle and Power-down Modes

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	$\overline{\text{INT1}}$ (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.6	$\overline{\text{WR}}$ (external data memory write strobe)
P3.7	$\overline{\text{RD}}$ (external data memory read strobe)

Table 3.2 Port 3 Pins

RESET:

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device. This pin drives High for 96 oscillator periods after the Watchdog times out. The DISRTO bit in SFR AUXR (address 8EH) can be used to disable this feature. In the default state of bit DISRTO, the RESET HIGH out feature is enabled.

ALE/PROG:

Address Latch Enable (ALE) is an output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input (PROG) during Flash programming. In normal operation, ALE is emitted at a constant rate of 1/6 the oscillator frequency and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external data memory. If desired, ALE operation can be disabled by setting bit 0 of SFR location 8EH. With the bit set, ALE is active only during a MOVX or MOVC instruction. Otherwise, the pin is weakly pulled high. Setting the ALE-disable bit has no effect if the microcontroller is in external execution mode.

PSEN:

Program Store Enable (PSEN) is the read strobe to external program memory. When the AT89S52 is executing code from external program memory, PSEN is activated twice each machine cycle, except that two PSEN activations are skipped during each access to external data memory.

EA/VPP:

External Access Enable. EA must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed, EA will be internally latched on reset. EA should be strapped to VCC for internal program executions. This pin also receives the 12-volt programming enable voltage (VPP) during Flash programming.

XTAL1:

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2:

Output from the inverting oscillator amplifier.

4. COMPONENTS DESCRIPTIONS

4.1 7805 -VOLTAGE REGULATORS

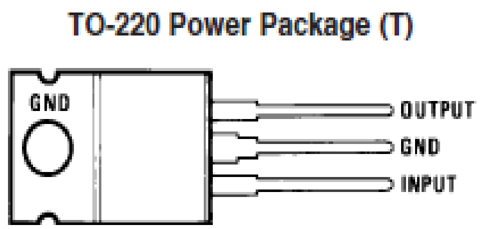

Fig. 4.1 7805-Voltage Regulator

General Description:

- The LM140/LM340A/LM340/LM78XXC monolithic 3-terminal positive voltage regulators employ internal current-limiting, thermal shutdown and safe-area compensation, making them essentially indestructible.
- If adequate heat sinking is provided, they can deliver over 1.0A output current.
- They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single-point regulation.
- In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.
- The 5V, 12V, and 15V regulator options are available in the steel TO-3 power package.

Features

- Complete specifications at 1A load
- Output voltage tolerances of ±2% at Tj = 25°C and ±4% over the temperature range (LM340A)
- Internal thermal overload protection
- Internal short-circuit current limit

4.2 RESISTORS

In resistors, current is directly proportional to applied voltage. A resistor is an electrical component with a known specified value of a resistance. It is probably the most common component in all kinds of electronic equipment ranging from a small radio to a colour television receiver. As its name suggests, a resistor resists or opposes the flow of current through it. Resistance is necessary for any circuit to do useful work. In fact without resistance, every circuit would be a short circuit.

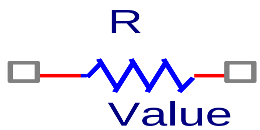

Fig. 4.2 Resistor Symbol

Sometimes, in electronics circuit, it becomes necessary to adjust the value of currents and voltages. For example, to change the volume of sound in transistor radio and television to adjust the brightness and contrast of television picture etc. This adjustment can be made with the help of variable registers. The variable resistor may be carbon composition or wire wound resistors.

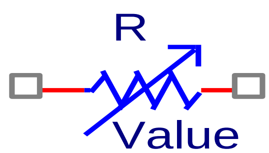

Fig. 4.3 Variable Resistor

4.3 CAPACITORS

The property of capacitor is to store electricity may be called its capacitance.

There are several important factors in choosing an energy storage capacitor for a project.

Fig. 4.4 Capacitor

Voltage

The PE (potential energy) depends greatly on voltage. Note that PE is proportional to voltage-squared, so it is a great advantage to use higher voltages.

$$PE = \frac{1}{2}CV^2$$

Each coil of wire will be energized with a pulse of current from its own capacitor. As the circuit is effectively a capacitor and an 'inductor' connected in series, it is essentially an LC circuit, and so it can be analysed using some of the formulae used on LC circuits.

The natural frequency of an LC circuit is given by

$$\omega_o = \frac{1}{\sqrt{LC}}$$

The above formula returns the result in radians per second. Dividing by pi gives the frequency in Hz:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

The time period of an oscillator is one over the frequency, which gives

$$\tau = 2\pi\sqrt{LC}$$

The above formula shows that the time period of the circuit increases with both capacitance and inductance. The pulse of energy needs to energize the coil for a very short duration. A pulse of energy that lasts for too long will continue to act on the rotor after it has left the coil, and it thus will slow it down, reducing the efficiency of the device.

The capacitor used will be relatively large, so to keep the pulse of energy short the inductance will need to be low. Once the coil/capacitor circuit has been designed, the discharge can be measured using an oscilloscope or similar, and the coil positioning can then be determined to achieve maximum efficiency.

Other factors that come into play when designing the coil and selecting the capacitor include:

Coil internal diameter. This depends on the diameter of the tube used to guide the rotor.

Capacitor voltage - Energy stored in a capacitor increases exponentially with the voltage ($1/2CV^2$) so higher voltages can store much more energy.

Safety - In order to keep the experiment as safe as possible, the capacitors chosen should not be capable of delivering a harmful dose of energy upon human contact. They will be fitted with bleeder resistors which will discharge the stored energy if it isn't used, so the capacitors can be safely handled.

In conclusion, the coil and capacitor need to be chosen using the formula = $2\pi\sqrt{LC}$

4.4 16X2 LCD

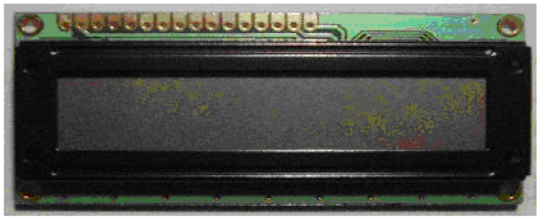

Fig. 4.5 Liquid Crystal Display

A liquid crystal display (LCD) is a thin, flat electronic visual display that uses the light modulating properties of liquid crystals (LCs). LCs do not emit light directly. LCDs therefore need a light source and are classified as "passive" displays. Some types can use ambient light such as sunlight or room lighting. There are many types of LCDs that are designed for both special and general uses. They can be optimized for static text, detailed still images, or dynamic, fast-changing, video content.

They are used in a wide range of applications including: computer monitors, television, instrument panels, aircraft cockpit displays, signage, etc. They are common in consumer devices such as video players, gaming devices, clocks, watches, calculators, and telephones. LCDs have displaced cathode ray tube (CRT) displays in most applications. They are usually more compact, lightweight, portable, and lower cost. They are available in a wider range of screen sizes than CRT and other flat panel displays.

pin	symbol	Description
1	GND	Ground Connection
2	VCC	5v Dc Supply For Electronics
3	V0	Contrast adjustment
4	RS	Register select: low = instruction, high = data
5	R/W	Low For Writing Data To LCD
6	EN	Enable (active high)for transferring data
7	D0	Data-bus bit 0 (low for 4 bit interface)

8	D1	Data-bus bit 1 (low for 4 bit interface)
9	D2	Data-bus bit 2 (low for 4 bit interface)
10	D3	Data-bus bit 3 (low for 4 bit interface)
11	D4	Data-bus bit 4
12	D5	Data-bus bit 5
13	D6	Data-bus bit 6
14	D7	Data-bus bit 7
15	LED+	Positive backlight supply
16	LED-	Connect To Ground

Table 4.1 List of Electrical Connections

LCD PINS DESCRIPTIONS

LCD used has 16 pins. Functions of each pin are given in below

1. **V_{CC}, V_{SS} and V_{EE}**

While Vcc and Vss provides +5volts and ground respectively. Vee is used for controlling LCD contrast.

2. **RS, Register Select**

There are two very important registers inside the LCD. RS pin is used for their selection as follow.

If **RS = 0** the instruction command code register is selected allowing user to send a command such as a clear display cursor at home, etc.

If **RS =1** the data register is selected allowing use to send data to be displaying on the LCD.

3. **R/W, Read Write**

R/W input allows the user to write information to the LCD or read information from it.

R/W =1 when reading.

R/W =0 when writing.

4. **E, Enable**

LCD to latch information presented to its data pins uses the enable pin. When data is supplied to data pins a high to low pulse must be supplied to these pins in order for the LCD to latch in the data present at the data pins. This pulse must be of 450 ns wide.

5. **D0 - D7**

The 8 bit data pins are used to send information to LCD or read the content of LCD internal registers to display letters and numbers we send ASCII code for the numbers A-Z, a-z and 0-9 to these pins while making RS=1.

LCDs are more energy efficient, and offer safer disposal, than CRTs. Its low electrical power consumption enables it to be used in battery-powered electronic equipment. It is an electronically-modulated optical device made up of any number of pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector to produce images in color or monochrome.

4.5 DRIVER ULN 2003

Fig. 4.6 ULN2003

Description:

The ULN2003 is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diode for switching inductive loads. The collector-current rating of a single Darlington pair is 500mA. The Darlington pairs may be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED gas discharge), line drivers, and logic buffers. The ULN2003 has a 2.7kW series base resistor for each Darlington pair for operation directly with TTL or 5V CMOS devices.

Features:

- 500mA rated collector current(Single output)
- High-voltage outputs: 50V
- Inputs compatible with various types of logic.
- Relay driver application

4.6 IR LED

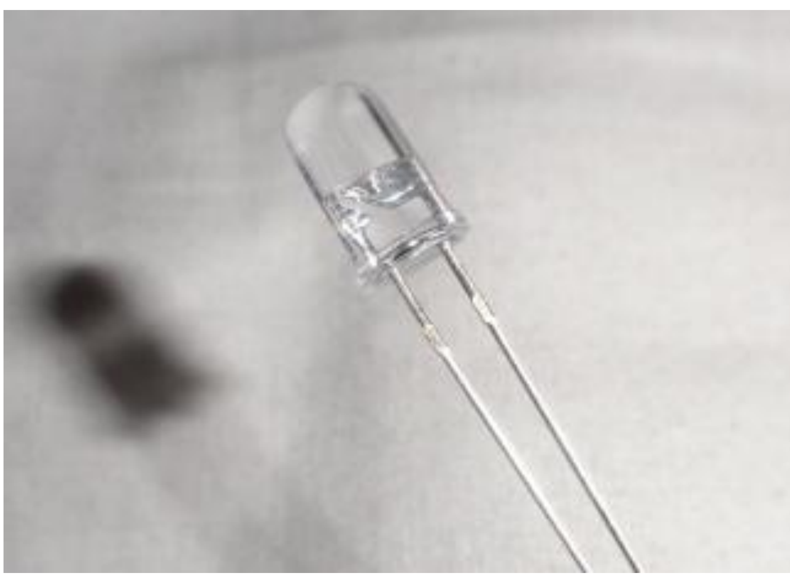

Fig. 4.7 IR LED

Description:

IR LED is used in this circuit to transmit infrared light.

An Infrared light-emitting diode (IR LED) is a type of electronic device that emits infrared light not visible to the naked eye.

The wavelength and colour of the light produced depend on the material used in the diode. Infrared LEDs use material that produces light in the infrared part of the spectrum, that is, just below what the human eye can see. Different infrared LEDs may produce.

Since the human eye cannot see the infrared radiations, it is not possible for a person to identify whether the IR LED is working or not, unlike a common LED. To overcome this problem, the camera on a cell phone can be used. The camera can show us the IR rays being emanated from the IR LED in a circuit.

Features:

- High reliability
- High radiant intensity
- Peak wavelength P=940mm
- Low forward voltage
- 2.54 lead spacing

4.7 PHOTO DIODE

Fig. 4.8 Photo Diode

Description:

Here Photo diode is used to capture reflected light of IR LED.

A semiconductor diode that, when exposed to light, generates a potential difference or changes its electrical resistance. A Photo diode is a reverse biased silicon or germanium pn junction in which reverse current increases when the junction is exposed to light. When no light is incident on the pn junction of photo diode, the reverse current is extremely small. This is called DARK CURRENT.

When light is incident on the pn junction of the photo diode there is a transfer of energy from the incident light (photons) to the atoms in the junction .this will create more free electrons (and more holes) these additional free electrons will increase the reverse current. This electrical energy can be recorded as voltage drop fluctuations by using a series resistor in the outer circuit and taking voltage readings across it.

4.8 LM 358N

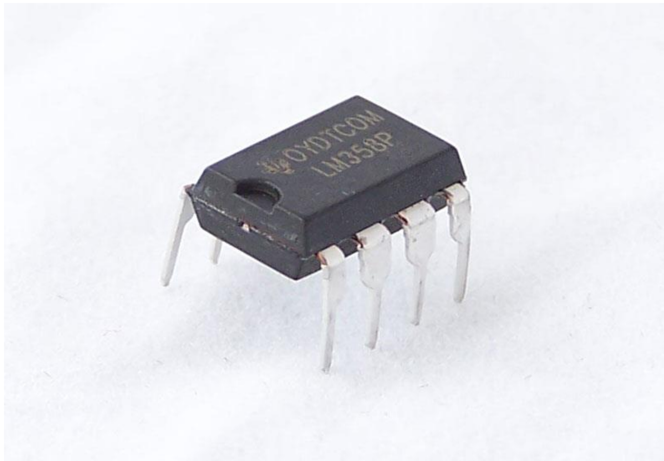

Fig. 4.9 LM 358N

Description:

The LM-358 IC consists of two independent operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages.

Here Op-amp is used as comparator.

Pin configuration of LM-358 is giving as follows-

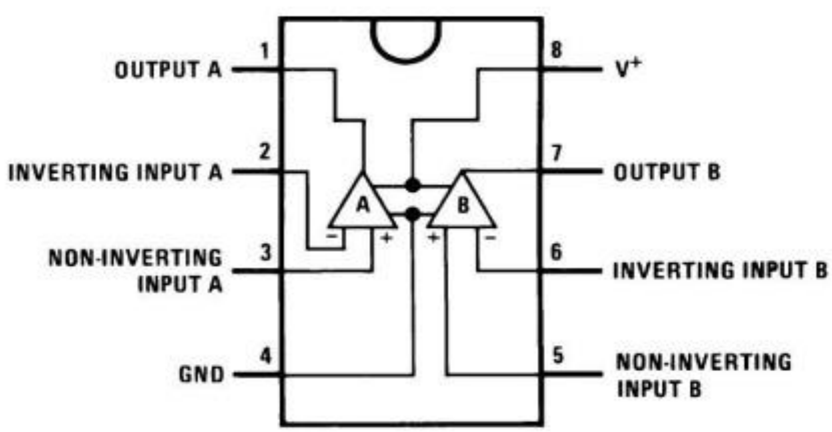

Fig. 4.10 Pin Configuration of LM-358

4.9 TRANSFORMER

Transformers are devices which step down a relatively higher AC input Voltage into a lower AC output voltage. To find the input and output terminals of a transformer is very tricky. Refer to the following illustration or the internet to understand where what is I/O Terminals of a Transformer

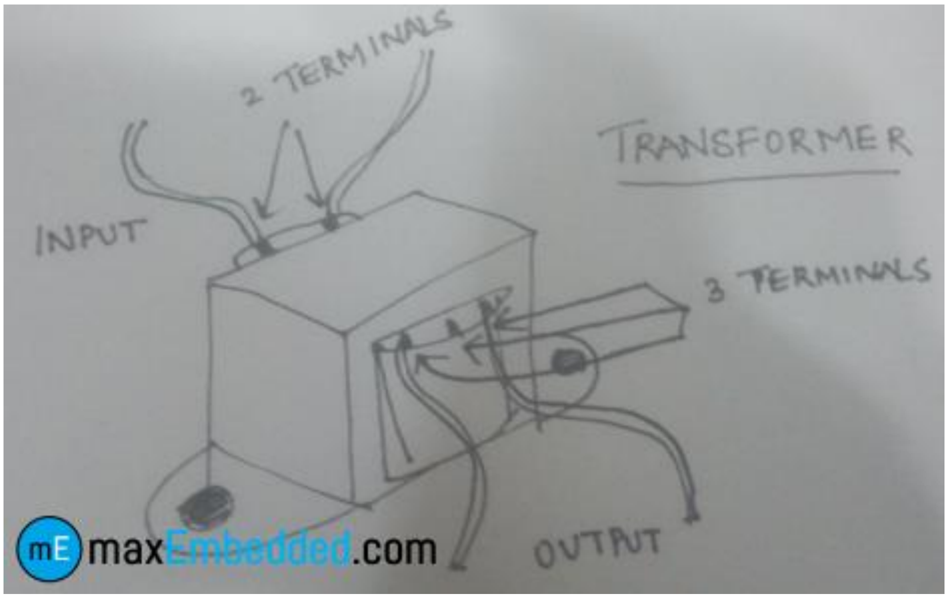

Fig. 4.11 Transformer

Basically, there are two sides in a transformer where the coil winding inside the transformer ends. Both ends have two wires each (unless you are using a centre-tapped transformer for full wave rectification). On the transformer, one side will have three terminals and the other will have two. The one with the three terminals is the stepped down output of the transformer, and the one with the two terminals is where the input voltage is to be provided.

5. PROGRAMMING

5.1 MICROCONTROLLER PROGRAMMING

```
;P0 FOR LCD DATA
;P2.5 2.6 2.7 LCD DATA
;P1.0 RELAY 1
;P1.1 RALAY 2
;P1.2 RELAY 3
;P1.7 SWITCH
;P3.2 START MEASURING IR
;P3.3 STOP MESURING IR
;P1.4 BASIC IR SNSOR

  .ORG 0000H
      LJMP MAIN
 .ORG 0003H   ; INT 0
    SETB TR0
    SETB 01H
    RETI

 .ORG 0013H   ; INT 1
   CLR TR0
   CLR 01H
   RETI
 .ORG 000BH ;TIMER
    ACALL DLPY
    RETI
```

```
   .ORG 0060H

MAIN: MOV SP,#70H
      CLR P1.0
      CLR P1.1
      CLR P1.2
      SETB P1.7
      MOV TMOD,#0000001B
      MOV R5,#00H
      MOV IE,#10000111B
      SETB TCON.2
      SETB TCON.0
      SETB TCON.1
      SETB TCON.3
      MOV TH0,#00H
      MOV TL0,#00H
      MOV 60H,#50D
      CLR 00H
     ACALL M_DISP
     ACALL DELAY_2
     ACALL LCD_SETUP

AGAIN:  JB P1.7,HP1
        ACALL DELAY_1
       JB P1.4,HP2
       ACALL LCD_SETUP
       MOV TH0,#00H
       MOV TL0,#00H
       MOV 60H,#50D
       CLR 00H
```

```
         SETB 01H
         ACALL ON
         SETB P1.0
         CLR P1.1
         CLR P1.2
         ACALL DELAY_1
         CLR P1.0
         ACALL DELAY
         SETB P1.1
         CLR P1.0
         CLR P1.2
         ACALL DELAY_1
         CLR P1.1
         ACALL DELAY
         SETB P1.2
         CLR P1.0
         CLR P1.1
         ACALL DELAY_1
         CLR P1.2
         ACALL DELAY
         CLR P1.2
         CLR P1.0
         CLR P1.1
         ACALL OFF
         ACALL DELAY_1

HP5:     JNB P1.7,AGAIN
         JB 01H,HP5
         MOV A,60H
         CJNE A,#50D,HP4
```

```
        SJMP HP3

HP4:  JB 00H,HP3
        MOV A,60H
        ACALL CONV1
        ACALL DISPLAY_1
        SJMP HP1

HP3:  ACALL OUTRNG
        SJMP HP1

HP2:  ACALL Empty

HP1:  ACALL DELAY_1
        SJMP AGAIN

DLPY:        MOV TH0,#00H
             MOV TL0,#00H
             MOV A,60H
             CJNE A,#00H,LPPS1
             MOV 60H,#00H
             SETB 00H

LPPS1:        DEC 60H
              RET

CONV1:   MOV R2,#00H
           MOV R3,#00H
           MOV R4,#00H
           MOV  B,#10     ;divide by 10
```

```
        DIV  AB
        MOV  R2,B     ;save low digit
        MOV  B,#10    ;divide by 10 once more
        DIV  AB
        ORL  A,#30H   ;make it ASCII
        MOV  R4,A     ;save MSD
        MOV  A,B
        ORL  A,#30H   ;make 2nd digit an ASCII
        MOV  R3,A     ;save it
        MOV  A,R2
        ORL  A,#30H   ;make 3rd digit an ASCII
        MOV  R2,A     ;save the ASCII
        RET

DISPLAY_1:  MOV    A,#0C9H      ;LINE 1 POSITION 10
            ACALL  COMMAND      ;issue command
            MOV A,R4
            ACALL DATA_DISPLAY
            MOV A,R3
            ACALL DATA_DISPLAY
            MOV A,R2
            ACALL DATA_DISPLAY
            RET

OUTRNG:  MOV A,#0C9H
         ACALL COMMAND
         MOV A,#'L'
         ACALL DATA_DISPLAY
         MOV A,#'O'
         ACALL DATA_DISPLAY
```

```
        MOV A,#'W'
        ACALL DATA_DISPLAY
        RET

ON:   MOV A,#89H
      ACALL COMMAND
      MOV A,#'S'
      ACALL DATA_DISPLAY
      MOV A,#'t'
      ACALL DATA_DISPLAY
      MOV A,#'a'
      ACALL DATA_DISPLAY
      MOV A,#'r'
      ACALL DATA_DISPLAY
      MOV A,#'t'
      ACALL DATA_DISPLAY
      RET

OFF:   MOV A,#89H
       ACALL COMMAND
       MOV A,#'S'
       ACALL DATA_DISPLAY
      MOV A,#'t'
      ACALL DATA_DISPLAY
      MOV A,#'o'
      ACALL DATA_DISPLAY
      MOV A,#'p'
      ACALL DATA_DISPLAY
      MOV A,#' '
      ACALL DATA_DISPLAY
```

```
        RET

Empty:  MOV A,#89H
        ACALL COMMAND
        MOV A,#'E'
        ACALL DATA_DISPLAY
        MOV A,#'m'
        ACALL DATA_DISPLAY
        MOV A,#'p'
        ACALL DATA_DISPLAY
        MOV A,#'t'
        ACALL DATA_DISPLAY
        MOV A,#'y'
        ACALL DATA_DISPLAY
        RET

LCD_SETUP: MOV A,#38H   ;init. LCD 2 lines,5x7 matrix
           ACALL   COMMAND      ;issue command
           MOV     A,#0CH       ;LCD on, cursor off
           ACALL   COMMAND      ;issue command
           MOV     A,#01H       ;clear LCD command
           ACALL   COMMAND      ;issue command
           MOV     A,#06H       ;shift cursor right
           ACALL   COMMAND      ;issue command
           MOV     R0,#80H      ;cursor: line 1, pos. 0
           MOV     DPTR,#L13B       ;data from l1 to dptR
           ACALL FLASH
           MOV     R0,#0C0H
           MOV     DPTR,#L14B       ;data from l1 to dptR
           ACALL FLASH
```

```
        RET

M_DISP:   MOV    A,#38H   ;init. LCD 2 lines,5x7 matrix
          ACALL  COMMAND      ;issue command
          MOV    A,#0CH       ;LCD on, cursor off
          ACALL  COMMAND      ;issue command
          MOV    A,#01H       ;clear LCD command
          ACALL  COMMAND      ;issue command
          MOV    A,#06H       ;shift cursor right
          ACALL  COMMAND      ;issue command
          MOV    R0,#80H      ;cursor: line 1, pos. 0
          MOV    DPTR,#L13A         ;data from l1 to dptR
          ACALL FLASH
          MOV    R0,#0C0H
          MOV    DPTR,#L14A         ;data from l1 to dptR
          ACALL FLASH
          RET

FLASH:   MOV A,R0            ;PUT LINE ADDRESS FROM R0 IN TO ACC
         ACALL  COMMAND      ;command subroutine
LOOP:     CLR A
          MOVC A,@A+DPTR
          JZ OUT
          ACALL DATA_DISPLAY
          INC DPTR
          SJMP LOOP
OUT:   RET
    COMMAND: ACALL   READY       ;is LCD ready?
    MOV    P0,A        ;issue command code
    CLR    P2.5        ;RS=0 for command
```

```
        CLR     P2.6         ;R/W=0 to write to LCD
        SETB    P2.7         ;E=1 for H-to-L pulse
        CLR     P2.7         ;E=0 ,latch in
        RET

DATA_DISPLAY:   ACALL   READY        ;is LCD ready?
                MOV     P0,A         ;issue data
                SETB    P2.5         ;RS=1 for data
                CLR     P2.6         ;R/W=0 to write to LCD
                SETB    P2.7         ;E=1 for H-to-L pulse
                CLR     P2.7         ;E=0, latch in
                RET

READY:   SETB    P0.7           ;make P1.7 input port
         CLR     P2.5        ;RS=0 access command reg
         SETB    P2.6        ;R/W=1 read command reg

BACK1:    CLR     P2.7       ;E=1 for H-to-L pulse
          SETB    P2.7       ;E=0 H-to-L pulse
          JB      P0.7,BACK1       ;stay until busy flag=0
          RET

DELAY_2:  MOV 23H,#10H
C111:    MOV 21H,#0FFH
B111:    MOV 22H,#0FFH
A111:    DJNZ 22H,A111
         DJNZ 21H,B111
         DJNZ 23H,C111
         RET
```

```
DELAY_1:  MOV 13H,#01H
C11:      MOV 14H,#09FH
B11:      MOV 15H,#0FFH
A11:      DJNZ 15H,A11
          DJNZ 14H,B11
          DJNZ 13H,C11
          RET

DELAY: MOV 10H,#01H
C1:       MOV 11H,#3FH
B1:       MOV 12H,#0FFH
A1:       DJNZ 12H,A1
          DJNZ 11H,B1
          DJNZ 10H,C1
          RET

L13A:   .DB "Liner Induction ",0
L14A:   .DB "     system     ",0
L13B:   .DB "Status:-        ",0
L14B:   .DB " Speed:-     Kmh",0

.END
```

6. COMPONENTS LIST

SR NO.	COMPONENT	PRICE
1	Microcontroller 89s52 (1 pc)	180
2	Transformer: 12-0-12V 1 Amp (1 pc)	85
3	Transformer:24-0-24 1.5V Amp (1 pc)	120
4	40 pin IC socket (1 pc)	28
5	18 pin IC socket (1 pc)	20
6	8 pin IC socket (3 pc)	36
7	Diode IN4007 (8 pc)	24
8	IC 7805 Regulated (1 pc)	15
9	Capacitor 104 0.1pf (1 pc)	02
10	Capacitor 470mf 25v (2 pc)	18
11	Capacitor 1000uf 50v (1pc)	10
12	Capacitor 33pf (2 pc)	16
13	Crystal 11.0592 MHz (1 pc)	28
14	Photo Diode (3 pc)	60
15	IR LED (3 pc)	36
16	LED (6 pc)	12
17	Relay 250V (3 pc)	75
18	LCD 16X2 (1pc)	250
19	Resistor 10K pot (4 pc)	20
20	Resistor 10K (3 pc)	06
21	Resistor 1K (6 pc)	12
22	Resistor bank 10k 9 pin (1 pc)	18
23	Push to on switch (2 pc)	06
24	LM395 (3 pc)	45
25	ULN 2003 (1 pc)	14
26	Glass Tube L 22 cm/ Diameter 0.8mm (1 pc)	70
27	General purpose PCB (1 pc)	15
28	Stator Coil 22 swg wire 240 turns	390
29	Wire	50
30	Projectile L 64mm Diameter 6mm	45
31	Solder wire (1 pc)	60
32	Ply wood	90
33	Connectors	30

Table 6.1 Component List

7. APPLICATIONS

Some of the applications of LIM are as follows:

- Sliding doors
- Metallic belt conveyers
- Travelling cranes
- Electromagnetic pumps
- Catapults to accelerate warplanes
- Robotic systems
- Linear accelerators
- Aircraft carrier catapults
- Maglev trains
- Rollercoaster launches
- Futuristic weapons
- Automotive crash test rigs

8. CONCLUSIONS

In conclusion, the project was successful given that we were able to most of our requirements. We consistently achieved projectile speeds of 40 – 50 km/hr.

We successfully built a coil gun and tested its performance with a wide variety of projectiles. Furthermore, conclusive results were reached for a number of different classes of projectiles. It was found that solid iron projectiles perform very well in a coil gun and that projectile length is not very important to launch performance. Furthermore, permanent magnets perform well in a coil gun but not substantially different from their iron counterparts. Additionally, steel projectiles can perform well, but not as well as iron slugs. However, steel is a harder and stronger material and may be more useful than iron in real-world applications.

9. FUTURE EXPANSION

- The efficiency of the motor can be improved by many factors. These include coil dimensions, coil pulse timing and rotor properties.
- For high speed, SCR or Thyristor is best choice for triggering of coil. The switching time of an SCR is in the order of microseconds, which is a great improvement and will result in increased accuracy and precision when switching the coils.
- The future research in linear motor technology is the development of electromagnetic weapons, using linear motors to accelerate projectiles to speeds much higher than is attainable with conventional chemically-propelled weapons. This gives a much longer range, and cost & weight are saved as need for propellant or an explosive warhead is negated as the weapon inflicts damage by kinetic energy alone.
- This motor will use in the future on an enormous scale to launch payloads into orbit at a fraction of the cost of an existing rocket.

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