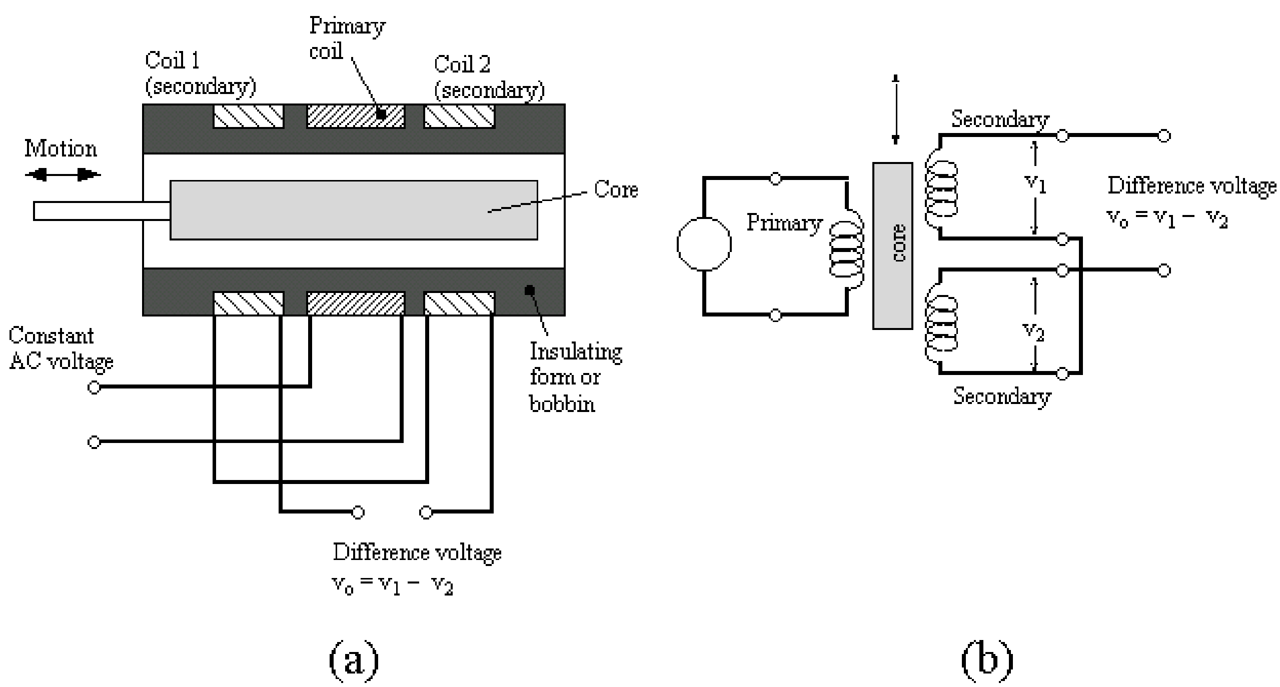
1.INTRODUCTION

"LVDT"

LVDT is most widely used inductive transducer for translating the linear motion into electrical signal. Magnetic coupling between primary and secondary coils is established by using a soft and movable iron core. In normal LVDT both the secondary coils are connected in series opposition. However, the output voltage is zero. As the core moves up or down, the induced voltage in one secondary coil increases while that of the other decreases. Here the magnitude of the output voltage is in AC nature.



COSTRUCTION OF LVDT

2. BACKGROUND

Since the 1930s, linear variable differential transformers (LVDTs) have found widespread application in industry for the measurement of displacement. Early development was driven by the needs of the chemical industry to remotely measure process variables, and during World War II development accelerated rapidly as the LVDT found use in aircraft and weapon systems. Today, the LVDT has evolved into a highly accurate and reliable form of displacement transducer, and is widely used in many branches of industry and science.

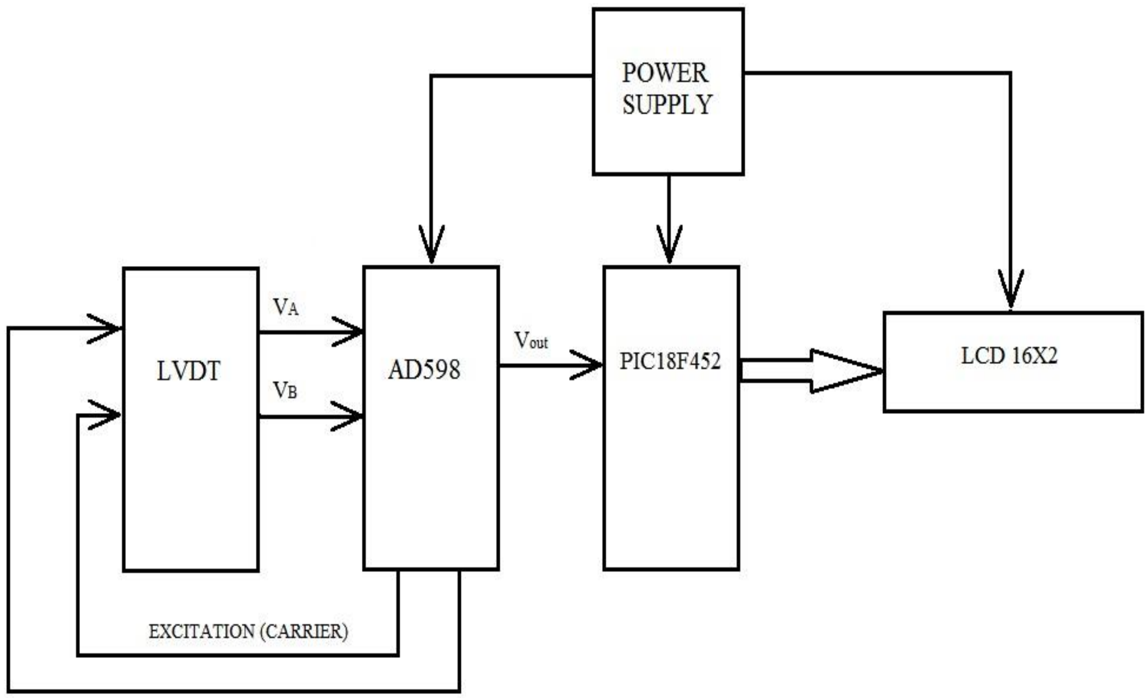
Since the LVDT is basically a transformer, it requires an alternating signal to excite the primary coil and some form of electronic circuit to condition the return signal in order to extract displacement information. Almost all such circuits in use today are designed with analog components for both functions. While these are usually robust and cheap to produce, their design can be challenging if accurate measurements are required. This is because both the construction of the transducer and the presence of spurious phase shift in the return signal path contribute to non-linear measurement error, which can be difficult to eliminate using analog techniques.

Existing Systems

One possible alternative to LVDTs is a magnetostrictive sensor. Magnetostrictive technology might provide several possible advantages to LVDT technology in power generation applications. First, because magnetostrictive sensors are resistant to shock, vibration and other harsh environments, they could meet utility reliability and durability requirements.

The DC-operated LVDT maintains all the desirable characteristics of the AC-operated LVDT, but has the simplicity of DC operation. It is comprised of an AC-operated LVDT and a carrier generator/signal conditioning module.

3. BLOCK DIAGRAM



BLOCK DIAGRAM DESCRIPTION

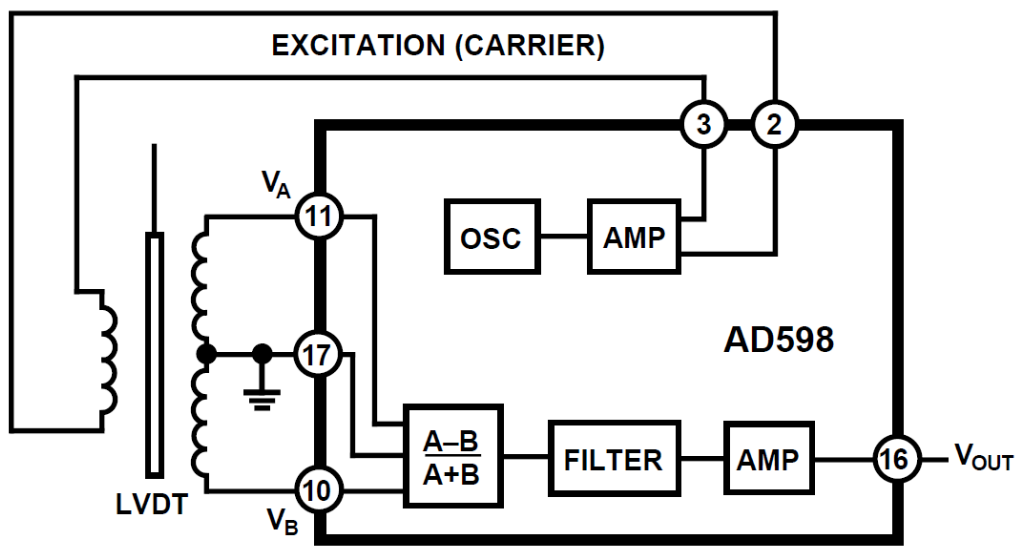
3.1. LVDT

- This LVDT can measure distance precisely from -10 mm to 10 mm.
- For measurement of displacement micro meter screw gauge is provided.
- Primary Coil of LVDT is energized by the voltage provided by IC AD 598.
- The output from the LVDT secondaries consists of a pair of sine waves whose amplitude difference, (VA–VB), is proportional to core position.
- This output of LVDT secondaries is again given back to the IC AD598 then the IC gives proportional constant DC output Voltage.

3.2. AD598

The AD598 is a complete, monolithic Linear Variable Differential Transformer (LVDT) signal conditioning subsystem. It is used in conjunction with LVDTs to convert transducer mechanical position to a unipolar or bipolar dc voltage with a high degree of accuracy and repeatability. All circuit functions are included on the chip. With the addition of a few external passive components to set frequency and gain, the AD598 converts the raw LVDT secondary output to a scaled dc signal.

The AD598 energizes the LVDT primary, senses the LVDT secondary output voltages and produces a dc output voltage proportional to core position. The AD598 consists of a sine wave oscillator and power amplifier to drive the primary, a decoder which determines the ratio of the difference between the LVDT secondary voltages divided by their sum, a filter and an output amplifier. The oscillator comprises a multi vibrator which produces a triwave output. The triwave drives a sine shaper, which produces a low distortion sine wave whose frequency is determined by a single capacitor. Output frequency can range from 20 Hz to 20 kHz and amplitude from 2 V rms to 24 V rms.



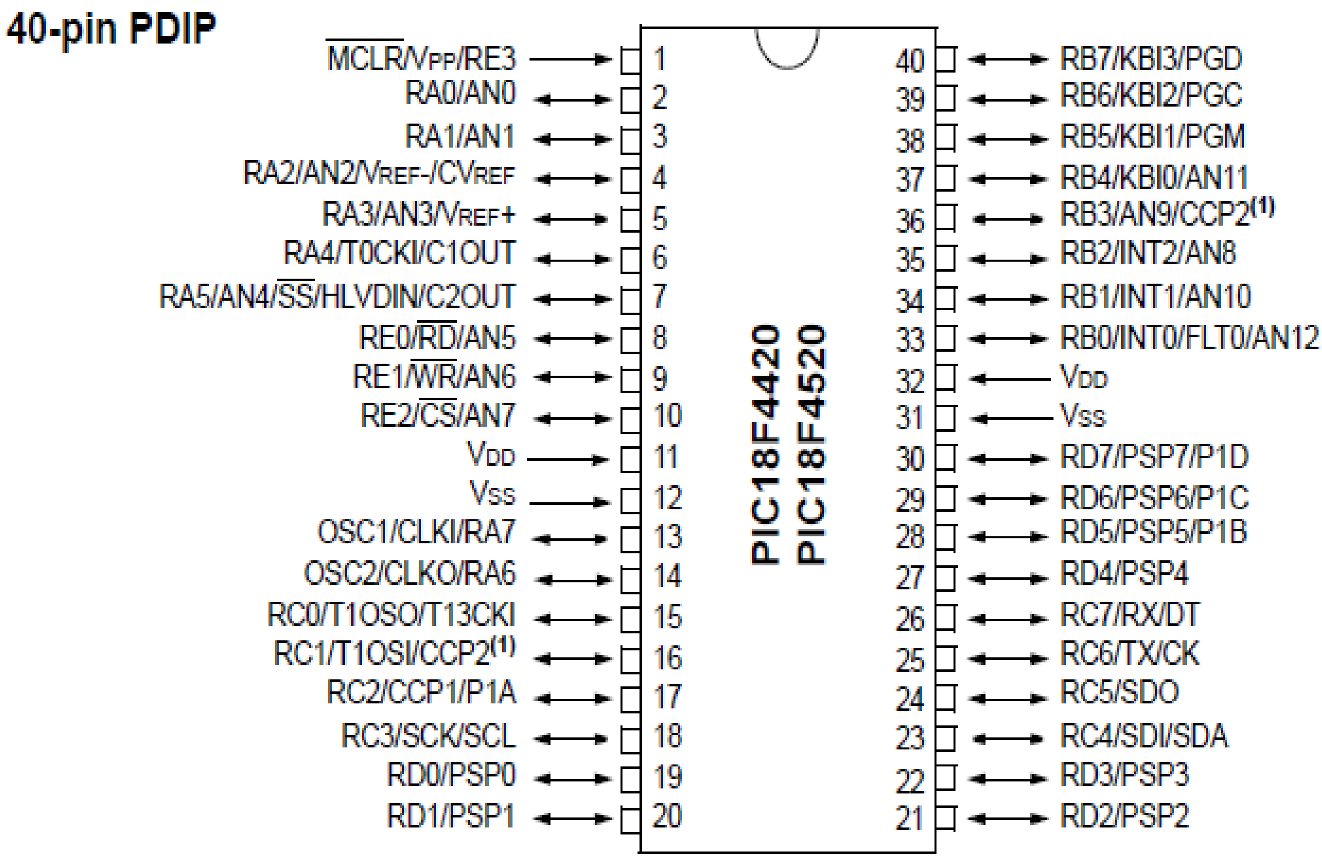
INTERNAL CIRCUIT OF AD598

3.3. Microcontroller PIC18F4520

This family offers the advantages of all PIC18 microcontrollers namely, high computational performance at an economical price – with the addition of high endurance, Enhanced Flash program memory. On top of these features, the PIC18F2420/2520/4420/4520 family introduces design enhancements that make these microcontrollers a logical choice for many high performance, power sensitive applications.

The core features of the microcontroller are as follows:

- High performance RISC CPU
- 10 bit ADC
- Operating speed: DC - 40 MHz clock input DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory, Up to 368 x 8 bytes of Data Memory (RAM, Up to 256 x 8 bytes of EEPROM Data Memory.
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Programmable code protection
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Single 5V In-Circuit Serial Programming capability
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption



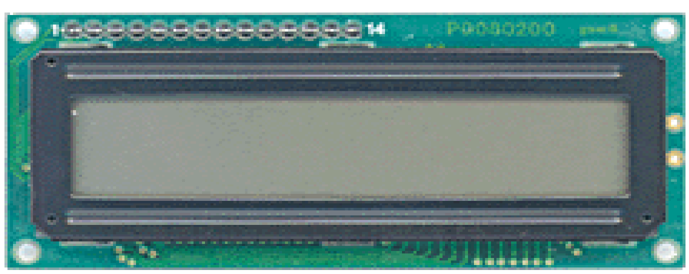
PIN DIAGRAM OF PIC1854520

3.4. DC Power Supply

For microcontroller, as well as the AD598, a regulated DC power supply is required. We have to provide +5V to the microcontroller, while +15&-15V to the AD598. The input to the power supply block is AC mains i.e. 230Vrms, 50Hz, 1-phase. The input AC mains are given to a step down transformer which gives the output voltage as 36Vrms and 1A. The signal obtained is AC in nature, hence it is given to a bridge rectifier circuit to rectify. This signal is further given to a filter capacitor in order to reduce the ripple in the signal. This signal is then given to IC 7815 and IC7915. This regulator IC provides DC voltage (+15V and -15V). The current provided by the power supply unit is around 1A. This voltage and current is used for driving AD598. We have used the Bridge IC instead of Rectifier Diodes it saves space as well as provides stability to supply. We have used BRIDGE IC A10W.

3.5. LCD

Alpha numeric modules display characters, numerals, symbols and some limited graphics. For design that has been presented, we have selected a 16*2 alphanumeric LCD. This alphanumeric LCD has low current drain; it does not require high supply voltage. Thus looking at advantages and availability we have chosen 16*2 alphanumeric LCD.



LCD

4. ELECTRONIC AND HARDWARE DESIGN ASPECT

4.1.POWER SUPPLY DESIGN

The PCB for the power supply unit is a board with the input as AC mains i.e. 230Vrms, 50Hz, 1-phase and the output as +15V and -15V DC. It is a single sided PCB with dimensions 10cm x 6cm. The width of each of the track in the PCB is 1mm. the clearance constraint set is 0.5mm.

A step down transformer is used to step down the voltage from 230Vac to 36Vac. This voltage is further more stepped down to and converted to+15V and -15V DC using a circuit comprising of a bridge rectifier IC, filter capacitor and the 7815 and 7915 regulator IC.

4.1.1 REGULATOR IC

The required output voltage is +15V and -15V. Hence we use regulator IC 7815 and IC7915 which has the following specifications:

- Output Current up to 1A
- Output Voltage of +15V and -15V
- Thermal Overload Protection
- Short Circuit Protection
- Input voltage range: 17.5 V to 30 V

A capacitor valued 2200uF is put at the input side of the regulator IC, in order to improve the transient response and to reduce the ripples in the voltage being applied as the input; a capacitor valued 10uF is put at the output side of the regulator IC, this is done in order to reduce the effect of noise when the distance between load and IC is greater than 6 inches.

4.1.2 DESIGN OF FILTER CAPACITOR

Filters are used in order to reduce the ripple content of the voltage. This is used so that output voltage has minimum amount of ripple content present in it.

Voltage at input of capacitor,

$$V_{IN} = V_O + V_D + V_{SAFETY}$$

$$=15 + 2 + 2 = 19V$$

$$WVDC = 2 \times V_{IN} = 38V$$

Assume ripple voltage, $V_R = 2V$

$$E_{MAX} = V_{IN} + V_R/2 = 20V$$

$$E_{MIN} = V_{IN} - V_R/2 = 18V$$

$$\theta = \sin^{-1}(E_{MIN}/E_{MAX}) = 64.15$$

$$90^\circ \equiv 5ms$$

$$64.15 \equiv 3.56ms$$

$$T1 = time(90^\circ) + time(\theta^\circ) = 8.56ms$$

Value of capacitor, $C = I_L \times T1/V_R = 2140uF$

The value of capacitor used is 2200uF and WVDC as 25V.

For this project we are going to use bridge rectifier IC of Fairchild Conductors A10W.

4.1.3.DESIGN OF THE STEP DOWN TRANSFORMER

To convert the input 230V to 16V and also to electrically isolate the circuit from mains, we have to require the step down transformer.

Voltage at output of the transformer,

$$V_O = Vo_{REG} + V_{DROP(IC)} + V_{DROP(RECTIFIER)}$$

$$= 32 + 2 + 2$$

$$= 36$$

$$\text{Turns ratio} = V_{IN} / V_O$$

$$= 230 / 36$$

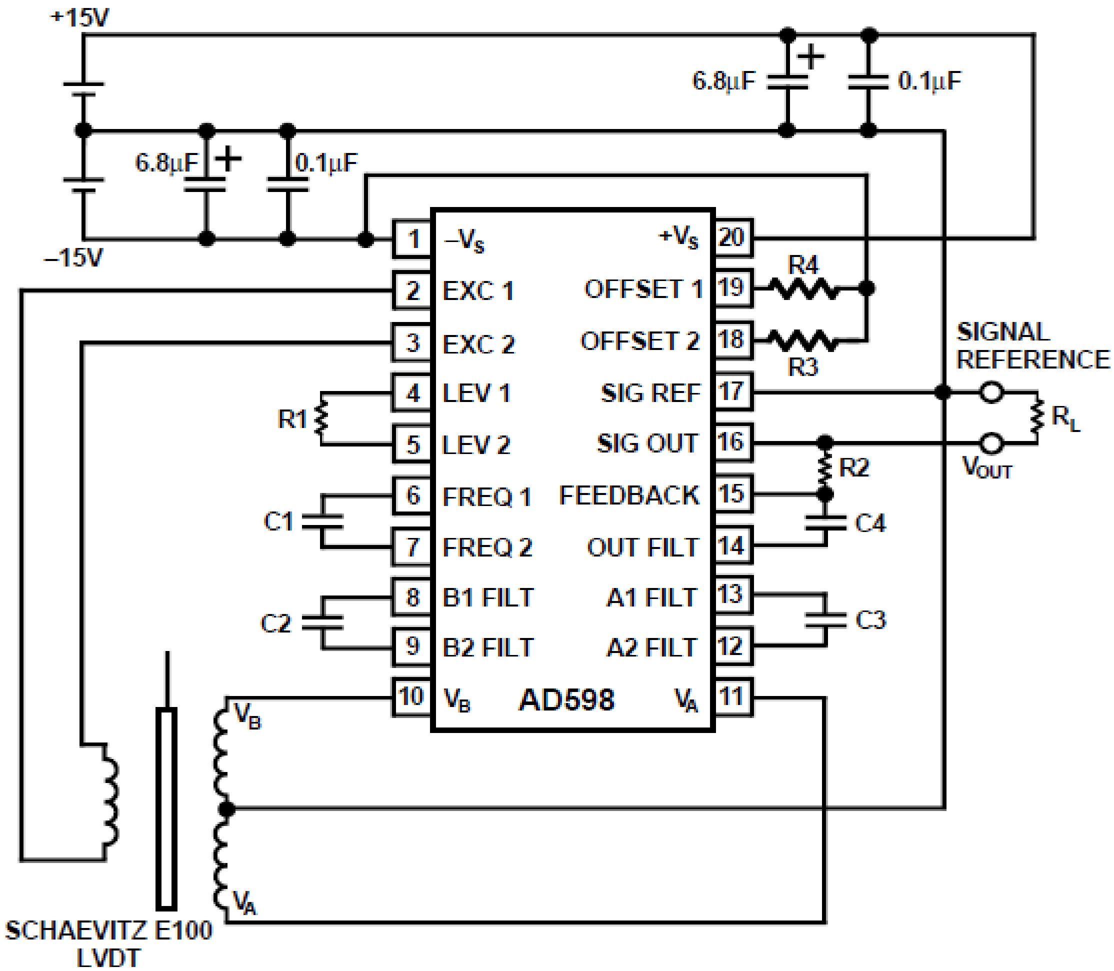
$$=6.38:1$$

$$=7:1$$

4.2 LVDT Signal Conditioning

The AD598 contains a low distortion sine wave oscillator to drive the LVDT primary. The LVDT secondary output consists of two sine waves that drive the AD598 directly. The AD598 operates upon the two signals, dividing their difference by their sum, producing a scaled unipolar or bipolar dc output, following circuit arrangement was used:

Frequency range: 20Hz to 20 KHz for AD598



INTERFACING DIAGRAM OF AD598 WITH LVDT

4.2.1 Selection of components for AD598:

- For mechanical BW. Assume f-SUBSYSTEM = 250 Hz.
- Select minimum LVDT excitation frequency, approximately 10 X f-SUBSYSTEM. Excitation frequency = 2.5 kHz.
- Determine VA+VB = 4.55V rms.

VTR = VPRI/VSEC
For VSEC = 0.85 V rms , VPRI = 3 V rms.
VTR = 3.5

- The AD598 signal input, VSEC, should be in the range of 1 V rms to 3.5 V rms for maximum AD598 linearity and minimum noise susceptibility. Select VSEC = 2 V rms. Therefore,

LVDT excitation voltage VEXC should be:
VEXC = VSEC × VTR = 2 × 3.5 = 7 V rms

As we Vexc is 7Vrms, so R1=4 *k* ohm

- Select the value of the amplitude determining component R1 as shown by the curve.

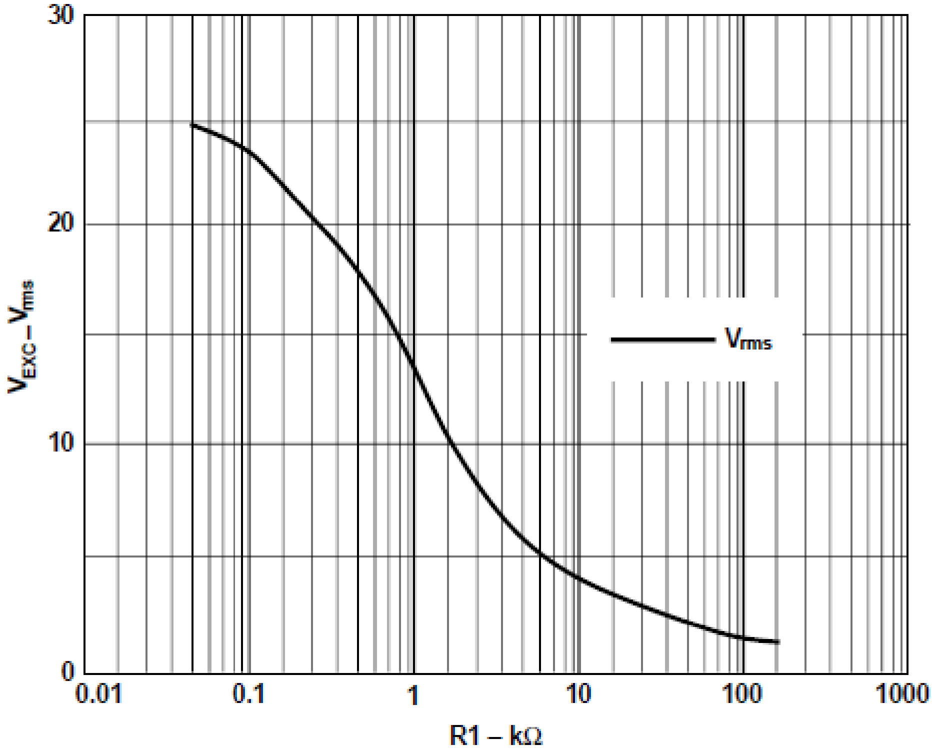


Figure 8. Excitation Voltage V_{EXC} vs. R1

- Select excitation frequency determining component C1.

  C1 = 35 uF Hz/f EXCITATION

  C1 = 35 uF Hz/2.5KHz

  C1=15nf

- C2, C3 and C4 are a function of the desired bandwidth of the AD598 position measurement Subsystem. They should be nominally equal values.

  C2 = C3 = C4 = 10–4 Farad Hz/f SUBSYSTEM (Hz)

  If the desired system bandwidth is 250 Hz, then

  C2 = C3 = C4 = 10–4 Farad Hz/250 Hz = 0.4 uF

  In order to Compute R2, which sets the AD598 gain or full scale output range, several pieces of information are needed:

  LVDT sensitivity(S) Full-scale core displacement(d), Ratio of manufacturer recommended primary drive level, $R2 = \frac{VOUT \times (VA + VB)}{(S \times VPRI \times 500\ \mu A \times d)}$

  For VOUT = 20 V full-scale range (+-10 V) and d = 0.7874 inch full-scale displacement (+-0.393 inch),

- R3 and R4 for voltage offset adjustment. For no offset adjustment R3 and R4 should be open. Set VOS = 500mV

  Since a positive offset is desired, let R4 be open circuit. solving for R3

  $$R3 = \frac{1.2 \times R2}{VOS} - 5kohm = 76.2kohm$$

4.3.POWER BUDGET

COMPONENTS	Current	Voltage	POWER(Watt)
PIC18F4520	300 mA	5 V	1.5 W
LCD	1.2 mA	5 V	0.006 W
AD598	12 mA	30 V	0.360 W
TOTAL POWER			**1.866 W**

Power required = 1.866 W

4.4.MICROCONTROLLER BOARD

PIC SELECTION

Parameter	PIC16F688	PIC16F877	PIC18F4520
Pin Count	14	28/40	28/40/44
Operating vtg	2V – 5.5V	2V – 5.5V	2V – 5.5V
Operating freq	0 to 20MHz	0 to 20MHz	0 to 40MHz
Inbuilt ADC	8	8	13
ADC bits	10	10	10
No of timers(8/16)	1/1	3/0	1/3
Prog Memory	4K	8K	32K
Data memory	256(SRAM),256(EEPROM)	368(SRAM),256(EEPROM)	1536(SRAM),256(EEPROM)

From this comparison we are selecting the PIC 18F4520 as our microcontroller as it is satisfying our project requirements such as high pin count, data memory.

RESET CIRCUIT

We are connecting a circuit to the MCLR (pin1) of the microcontroller (18f4520).The resistor value is taken from the datasheet i.e. of 1Kohm. The PIC has an active low reset, thus when push button is pressed, the path for ground connection gets completed and a low signal is given to the microcontroller.

CRYSTAL CIRCUIT

Here we are connecting two capacitors which are basically of values 15pF each. In other words to give a pure square wave to the microcontroller. Basic rule for placing the crystal on the board is that it should be as close as possible to avoid any interference in the clock.

The microcontroller board gets 5Vdc input from the power supply board or battery. The reset pin on the microcontroller is an active low pin; hence the microcontroller will be in reset state if connected to ground. Hence it is connected to Vcc through a 1k resistor. A reset switch is connected to the MCLR pin. When the reset switch is pushed, the MCLR pin gets connected to ground and thus gets reset.

5. SOFTWARE ASPECTS

a) **PROTEUS:** This software is used for simulations of circuits. This gives us ability to simulate controller based circuits by downloading hex files to it

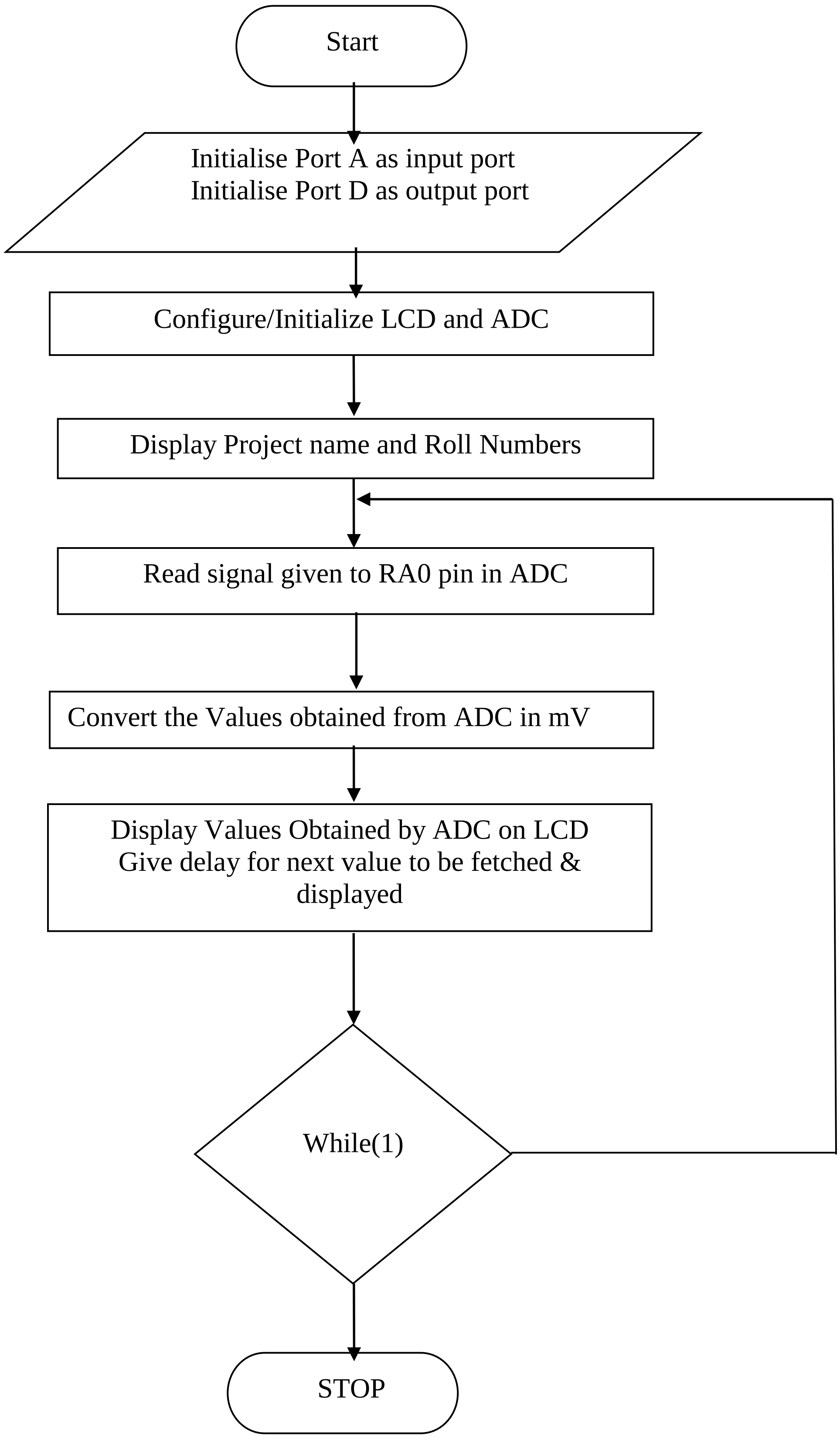
b) **ALTIUM 10:** Altium software is used for designing of PCB. First of all we have to make schematic and then we have to place components logically on PCB Board To make the tracks.

c) **MIKRO C:** For programming of Microcontroller we used 'MIKRO C' Software it has inbuilt function of various commands that are commonly used.

5.1 ALGORITHM

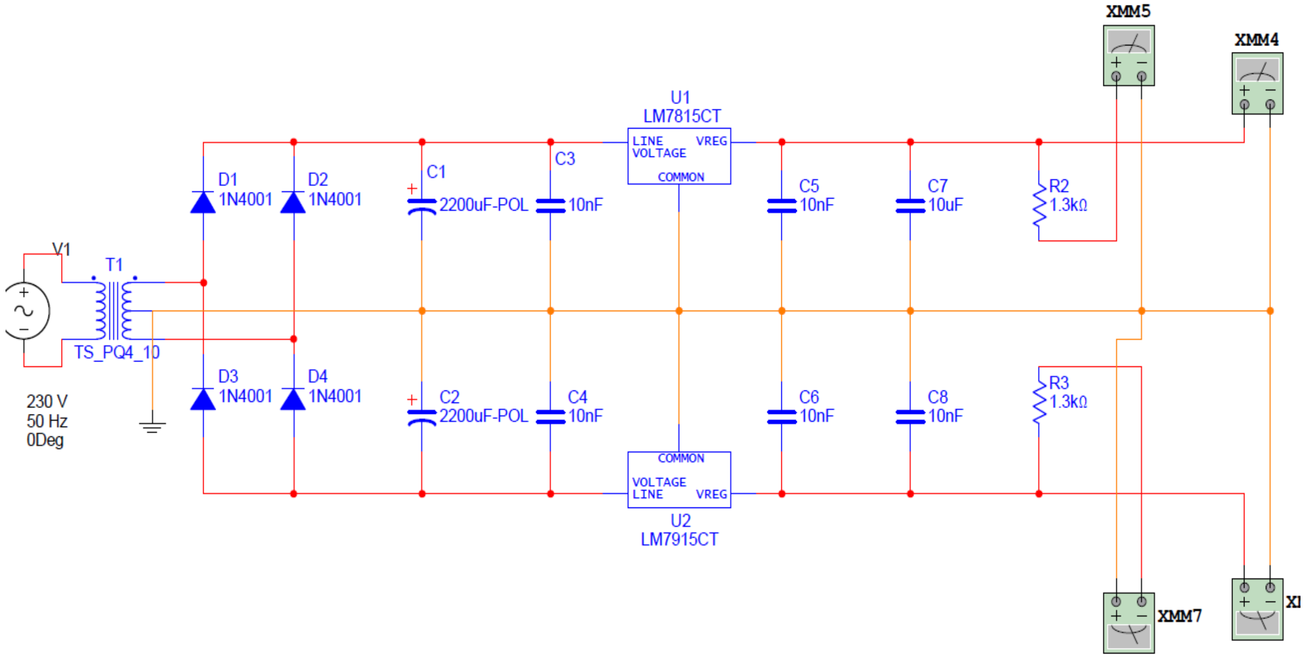
1) **START.**
2) **Initialize the PORT A as input.**
3) **Initialize the PORT D as output.**
4) **Initialize the LCD.**
5) **Initialize the ADC.**
6) **Display "Project Name-LVDT" string.**
7) **Display "3119, 3122, 3123" string**
   Display "DISPLACEMENT".
8) **Read RA0. (Get 10 bit value form ADC)**
9) **Convert the values of ADC into mV.**
10) **Display the values obtained from ADC on LCD.**
11) **Again go to step 8 and execute this loop for infinite times.**
12) **STOP.**

5.2 FLOWCHART

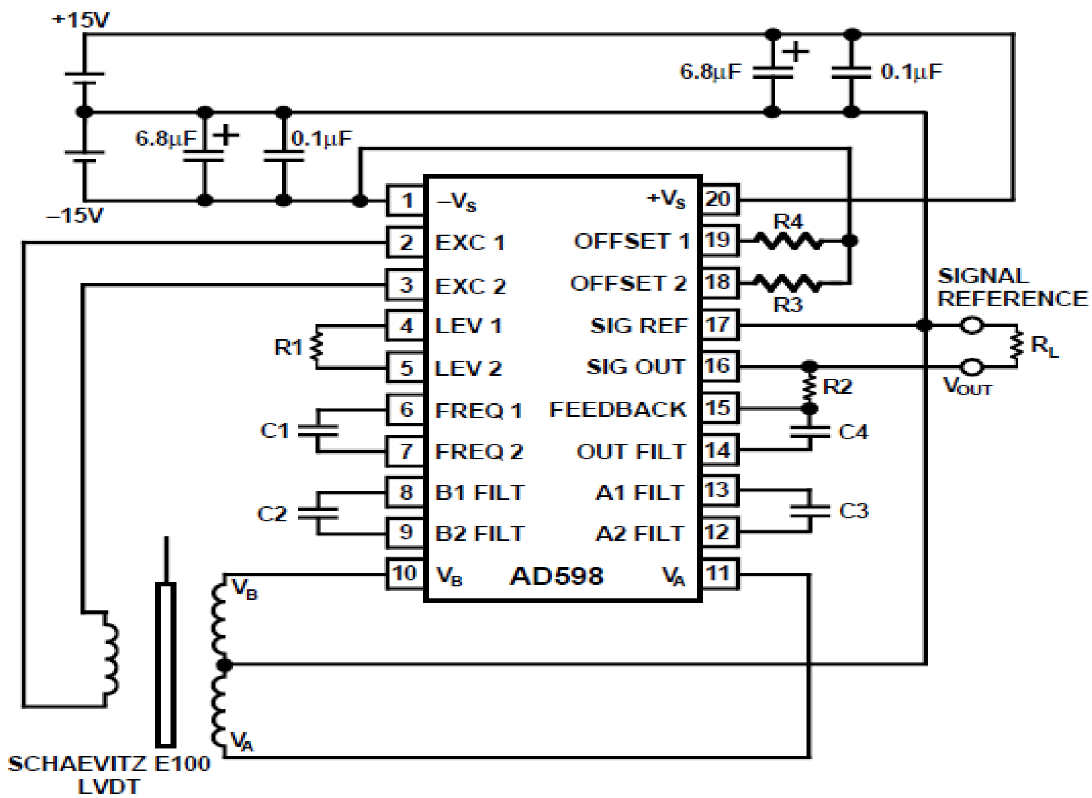


6.Circuit design

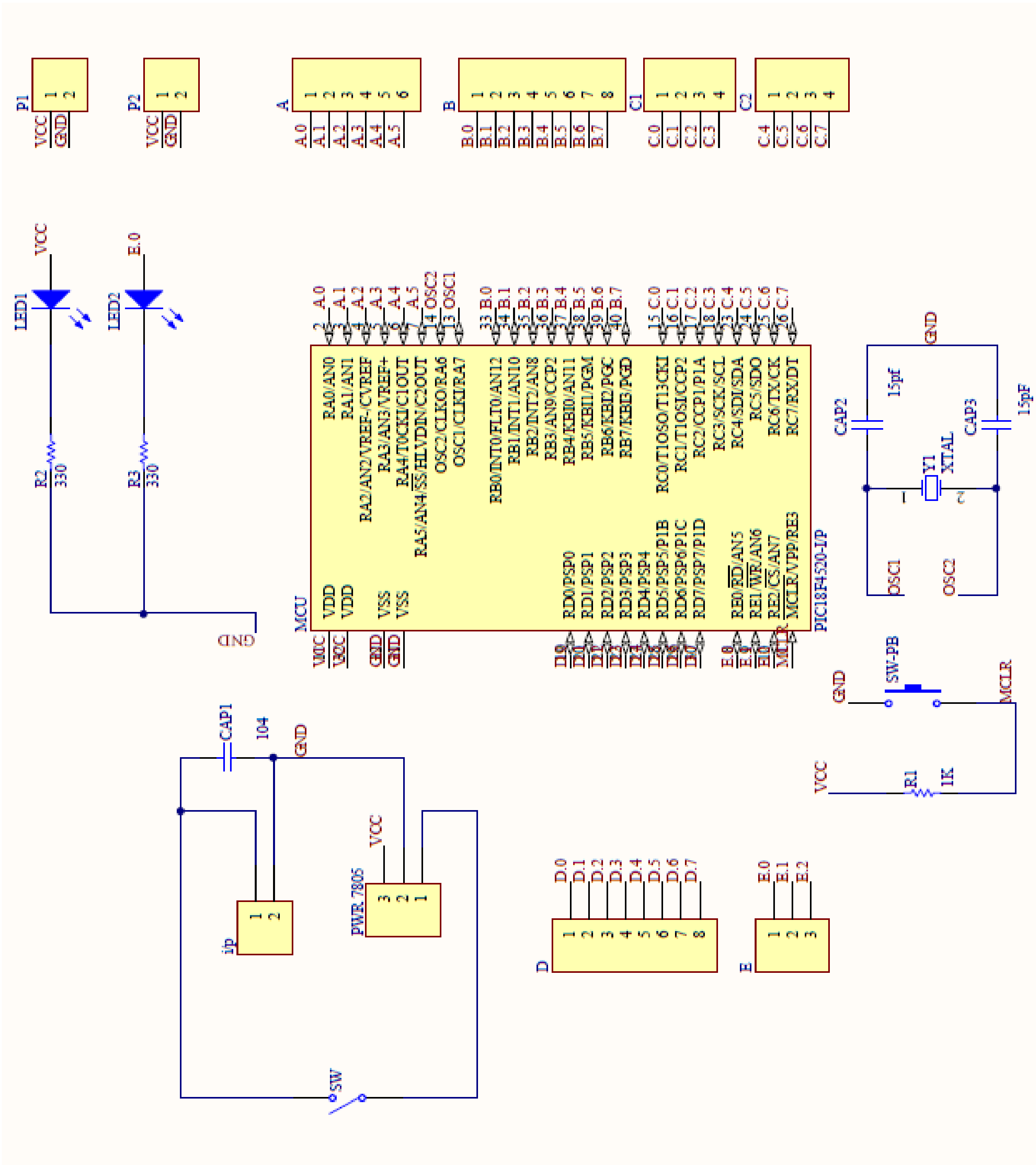
Power supply



Ad598

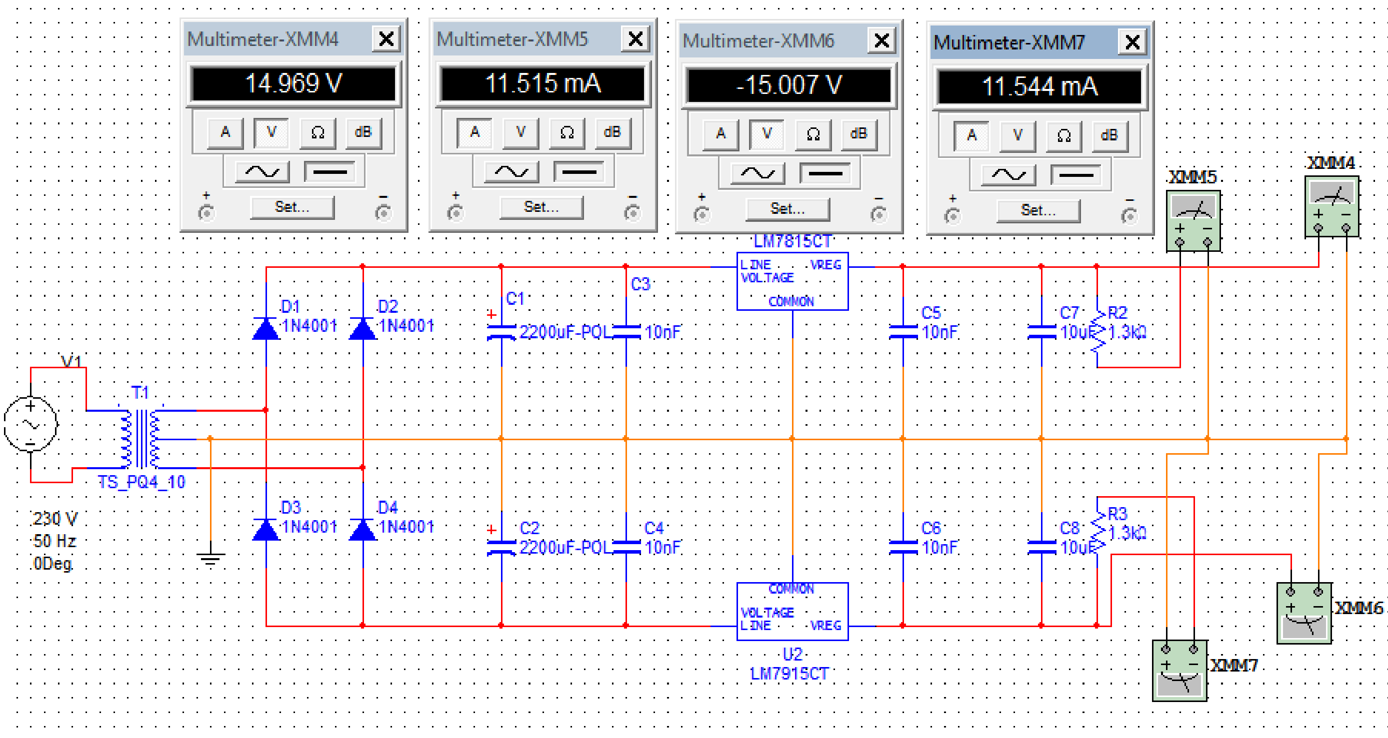


PIC 18F4520

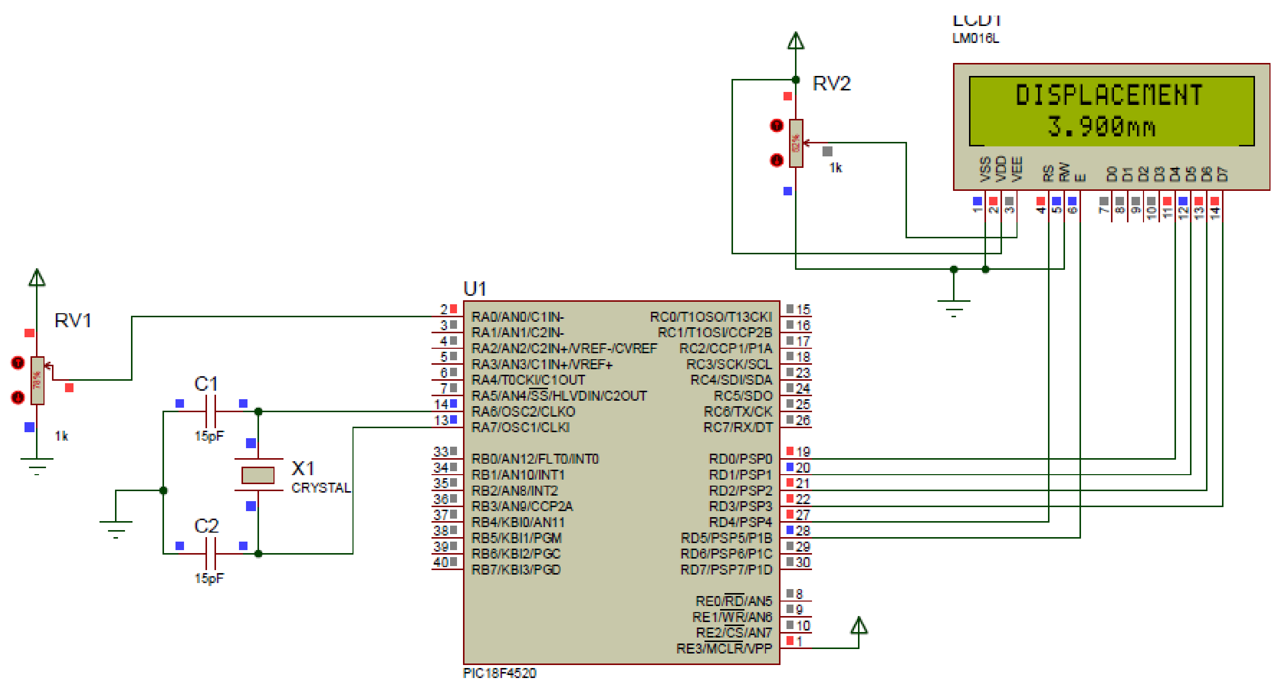

P1
P2
A
B
C1
C2
LED1
LED2
R2
330
R3
330
MCU
PIC18F4520-I/P
CAP1
104
CAP2
15pf
CAP3
15pF
Y1
XTAL
SW-PB
MCLR
R1
1K
i/p
PWR 7805
SW
D
E
VCC
GND
RA0/AN0
RA1/AN1
RA2/AN2/VREF-/CVREF
RA3/AN3/VREF+
RA4/T0CKI/C1OUT
RA5/AN4/SS/HLVDIN/C2OUT
OSC2/CLKO/RA6
OSC1/CLKI/RA7
RB0/INT0/FLT0/AN12
RB1/INT1/AN10
RB2/INT2/AN8
RB3/AN9/CCP2
RB4/KBI0/AN11
RB5/KBI1/PGM
RB6/KBI2/PGC
RB7/KBI3/PGD
RC0/T1OSO/T13CKI
RC1/T1OSI/CCP2
RC2/CCP1/P1A
RC3/SCK/SCL
RC4/SDI/SDA
RC5/SDO
RC6/TX/CK
RC7/RX/DT
RD0/PSP0
RD1/PSP1
RD2/PSP2
RD3/PSP3
RD4/PSP4
RD5/PSP5/P1B
RD6/PSP6/P1C
RD7/PSP7/P1D
RE0/RD/AN5
RE1/WR/AN6
RE2/CS/AN7
MCLR/VPP/RE3
VDD
VSS
OSC1
OSC2

7. SIMULATION RESULT

Power supply



Microcontroller PIC18F4520



8.PCB Design & layouts

The most important requirement of this project was to build a PCB with minimum weight and size. A proper PCB with a drilled board. Proper PCB removes a lot of material from board, and the weight is reduced. Designing method is as followed by using **ALTIUM PCB Designing** Software.

1. Decide proper Circuit Diagram of Both Microcontroller and Power Supply Circuit
2. Actual Placement of components on ALTIUM.
3. Connecting Tracks with proper Width using Proper rules and angles
4. Create Proper Print required for PCB Designing
5. Design PCB using Proper Solutions.
6. Verifying Proper Track widths and Placing of Components at proper Places
7. Verification of Proper Supply and Circuit.

Three PCBs are designed in this project. The PIC18F4520 PCB, the AD598 signal conditioning PCB, and power supply PCB. All PCBs are constructed on simple PCB, and interconnection of PCB's was done by using single stranded wires.

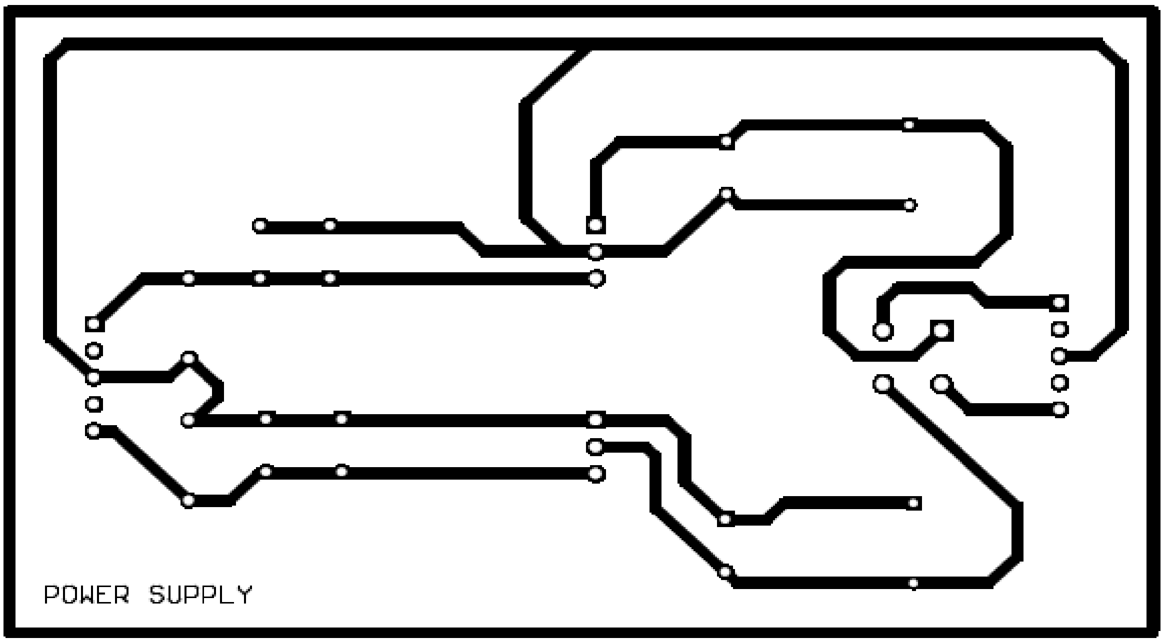
PCB Dimensions

Sr. No	**PCB NAME**	**Length**	**Breadth**	**Clearance**	**Track Width**
1)	POWER SUPPLY	100	60	0.5 mm	1 mm
2)	AD 598 PCB	85	80	0.5 mm	1 mm
3)	PIC 18F4520	95	91	0.5 mm	0.8mm Vcc=1 mm

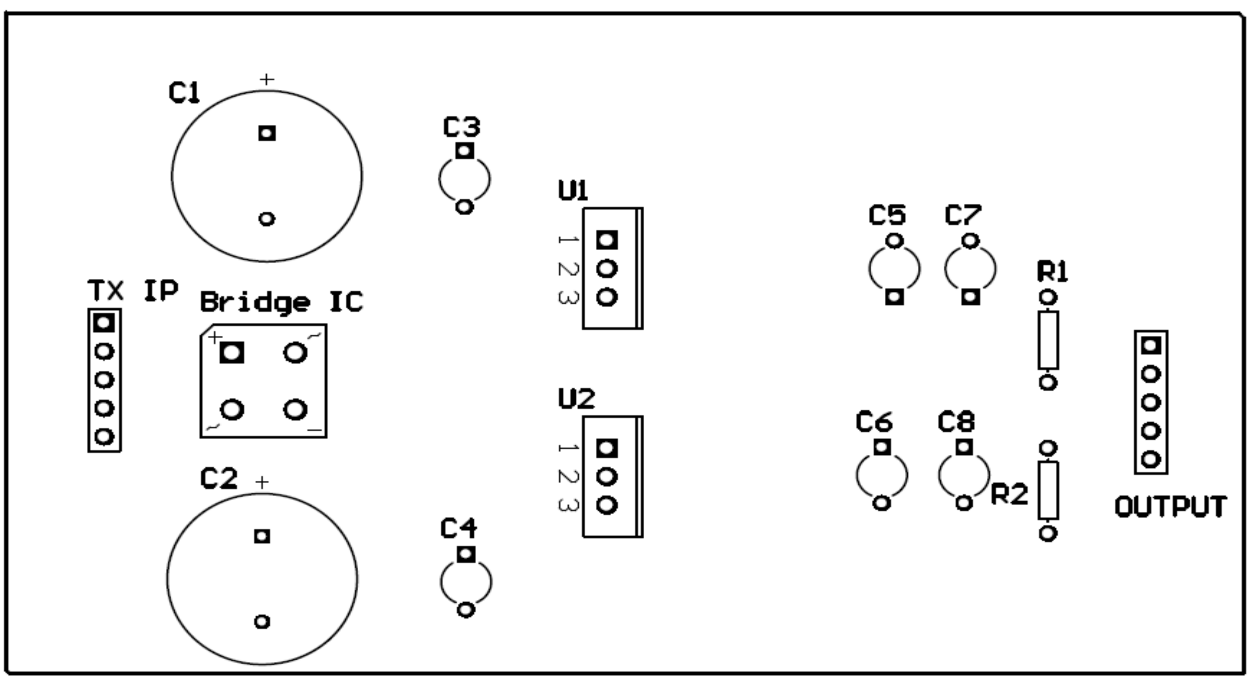
8.1 PCB LAYOUTS

Power Supply PCB

Bottom layer :

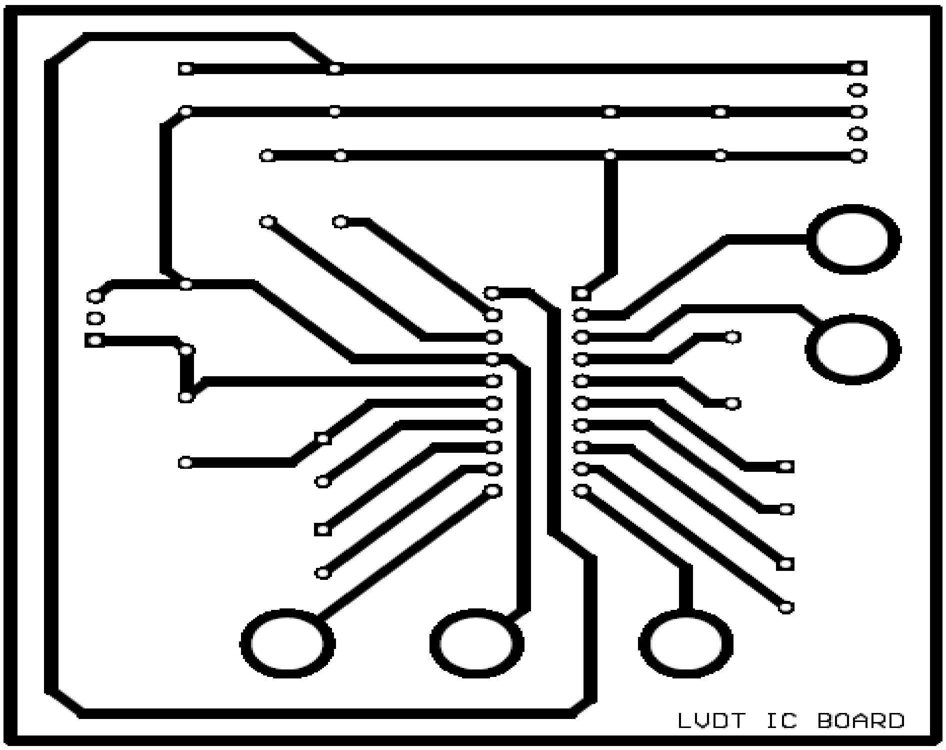


Top OVERLAY:

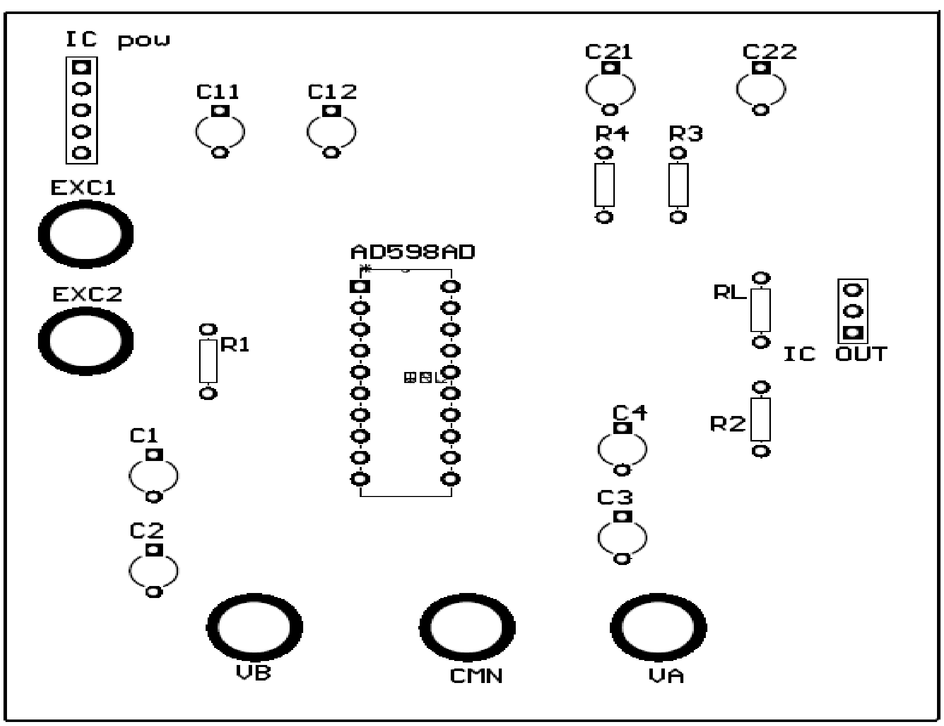


AD598

Bottom layer:

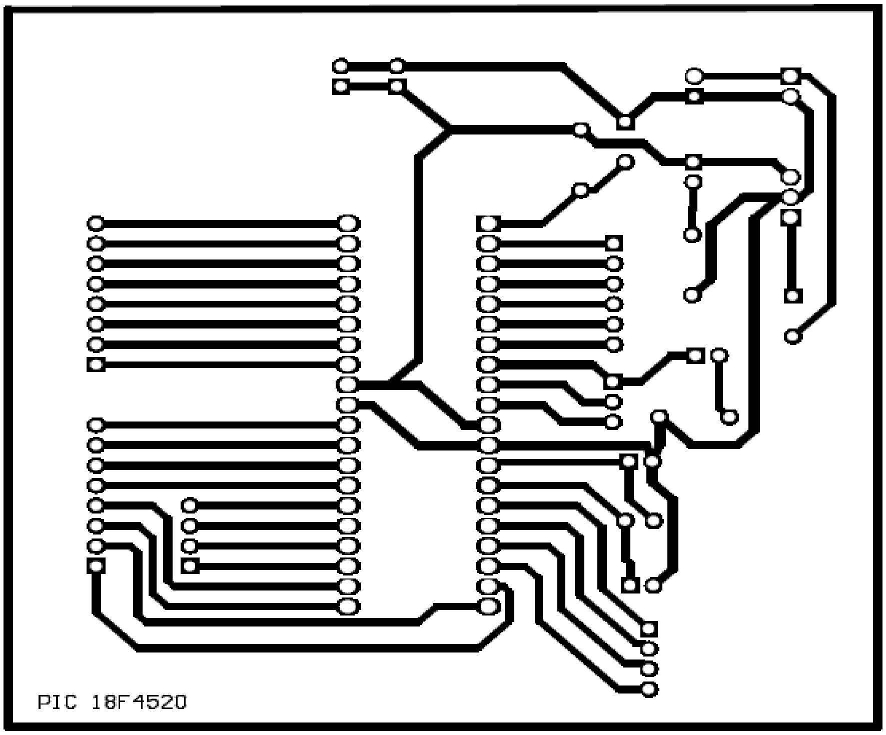


Top OVERLAY:

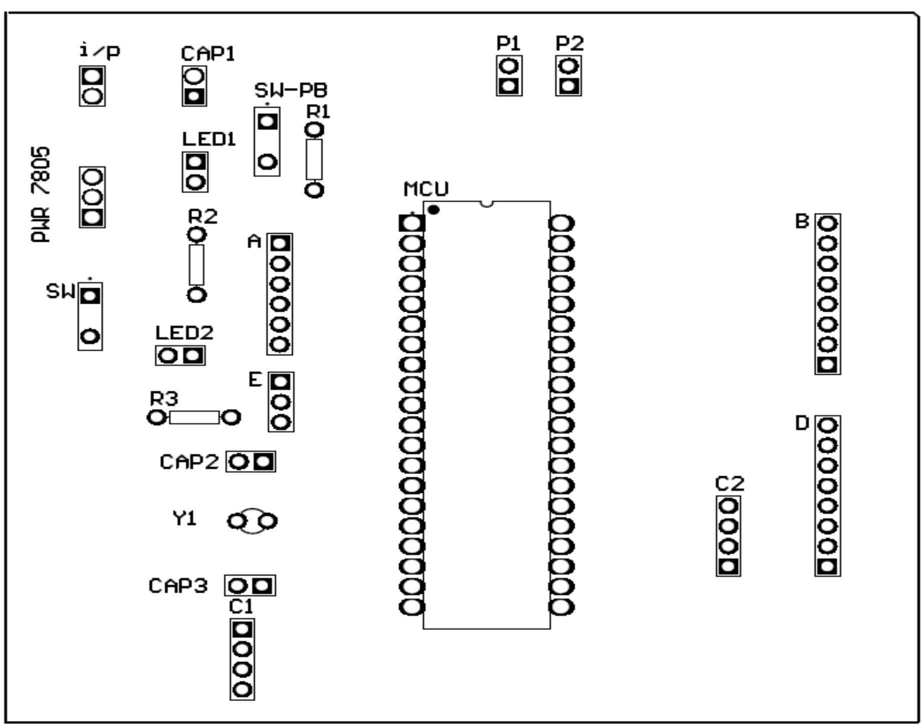


PIC18F4520

Bottom layer:



TOP OVERLAY:



9. TESTING OF MODULES

Continuity of the tracks of PCBs was checked both before and after soldering the components. The components were soldered only after ensuring correctness of the PCB tracks. Then all supply/biasing voltages were checked.

Sr. No.	TEST POINT	VOLTAGE
1.	$\overline{\text{MCLR}}$	+5V
2.	Pin 11,32 of PIC18f452 & Pin 2 of LCD	+5V
3.	Pin 12,31 of PIC18f452 & Pin 1,5,7,8,9,10 of LCD	0V
4.	Input to 7805	15V
5.	Transformer primary winding	≅ 230V A.C.
6.	Transformer secondary winding (18- 0 -18 V)	≅ 36V A.C.
7.	Power supply output	$\pm$ 15V D.C.
8.	Input to AD598	$\pm$ 15V D.C.
9.	Output of AD598	$\pm$ 10V D.C.
10.	Frequency between pin no 6 &7 of AD598	2.5 KHz

10.CABINATE DESIGN AND ASSEMBLY

The cabinet is an acrylic enclosure of dimensions 26*16 cm while the height being 8 cm. The acrylic sheet that we selected is a 3 mm thick sheet. The enclosure formation required cutting, drilling and using adhesives the box is made. The cabinet design requires utmost importance to be given for the spacing and the where to place each component. Apart from this it also requires dimensional analysis of each component.

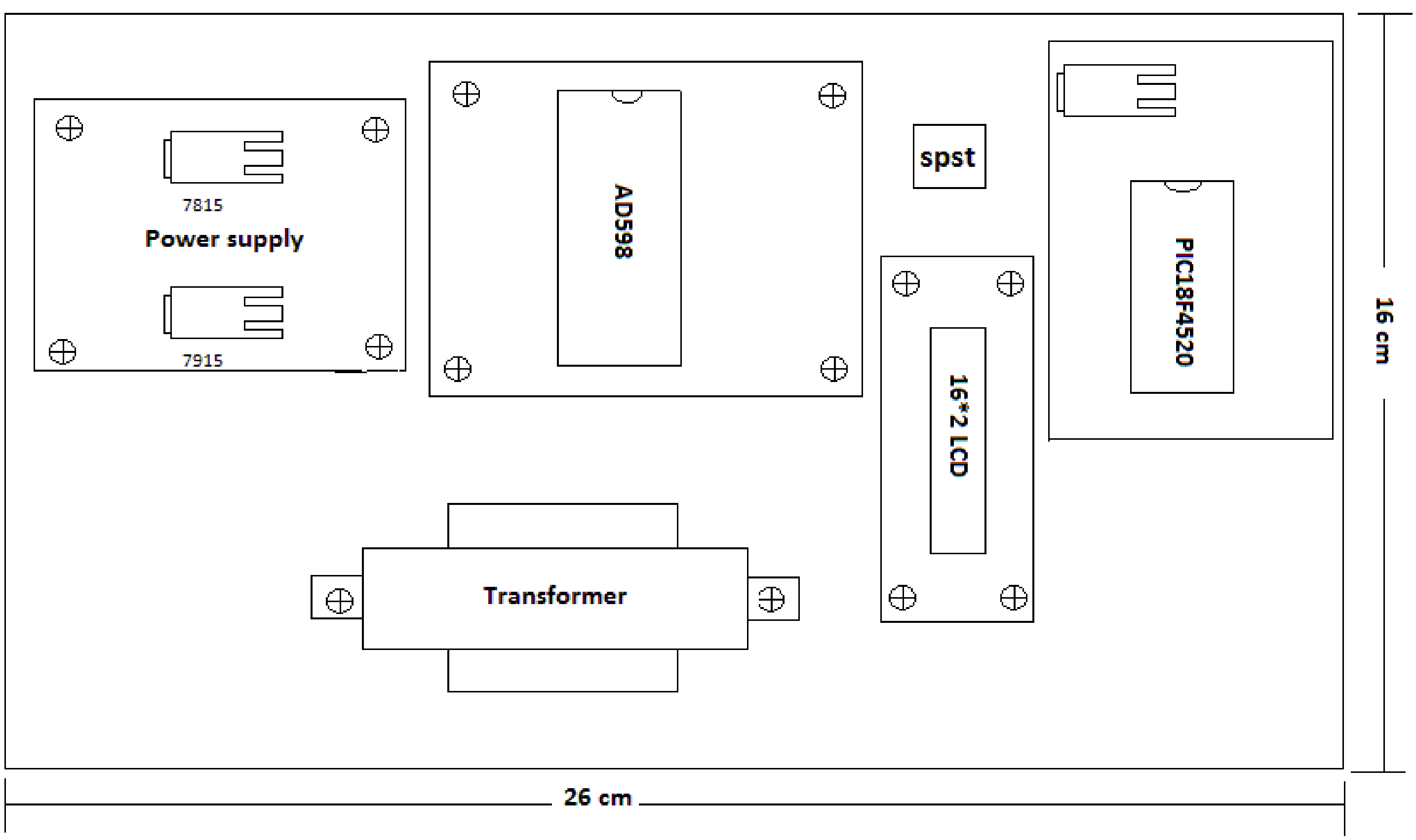
Our Cabinet design specifications are as follows:

Length: 26 cm

Width: 16 cm

Height: 8 cm

Thickness of the acrylic sheet: 3mm



11.BILL OF MATERIALS

SR.NO	COMPONENTS	SPECIFICATIONS	QUANTITY	COST
1	**RESISTOR**			
	10 KΩ pot		1	1/-
	1 KΩ		1	1/-
	330 Ω		2	1/-
	4.2 KΩ		2	1/-
	76.2 KΩ		1	1/-
	63.5 KΩ		1	1/-
2	**CAPACITORS**			
	2200uF	POLAR 25V	2	40/-
	10nF	Ceramic	4	4/-
	10uF	POLAR	2	4/-
	0.1uF	Ceramic	2	2/-
	6.8uF	POLAR	2	2/-
	0.4uF	Mylar Cap	3	3/-
	15nF	Box type	1	1/-
	15pF	Ceramic	2	2/-
3	IC 7805	Vin= 7-20V Vo= 5V Io= 5mA – 1A	1	10/-
4	IC 7815	Vin= 17.5 – 30 V Vo= 15V Io= 5mA – 1A	1	10/-
5	IC 7915	Vin= -18 to -30 V Vo= -15V Io= 5mA – 1A	1	10/-
6	AD598	DC Output Proportional to Position 20 Hz to 20 kHz Frequency Range Linearity: 0.05% of FS max Output Voltage: 611 V min	1	3800/-
7	PIC18F4520	Enhanced Flash Microcontroller with 10-Bit A/D, 32K Flash, 40-Pin PDIP	1	220/-

8	Battery	9V General Purpose Battery	1	15/-
9	Transformer	Step Down Centre tap 18-0-18 V, 1A	1	140/
10	Diode bridge	IC A10W	1	15/-
11	LED	Red Colour	2	2/-
12	SW-PB	Push Button	1	4/-
13	On/off switch	SPST	1	5/-
14	Crystal (XTAL)	10 MHz	1	12/-
15	PCB fabrication	PIC PCB: 95mm x 91mm Power Supply:100mm x 60mm AD 598 PCB:80mm x 85mm	3	400/-
16	ZIF socket	(40pin+20pin)	2	90/-
17	LCD	16X2 alphanumeric LCD	1	150/-
18	Enclosure	Acrylic Sheet Casing	1	500/-
19	LVDT	-10 to 10 mm displacement	1	8000/-
Total				13512/-

12.REFERENCES

1) PIC Microcontroller and Embedded System (Mazidi)
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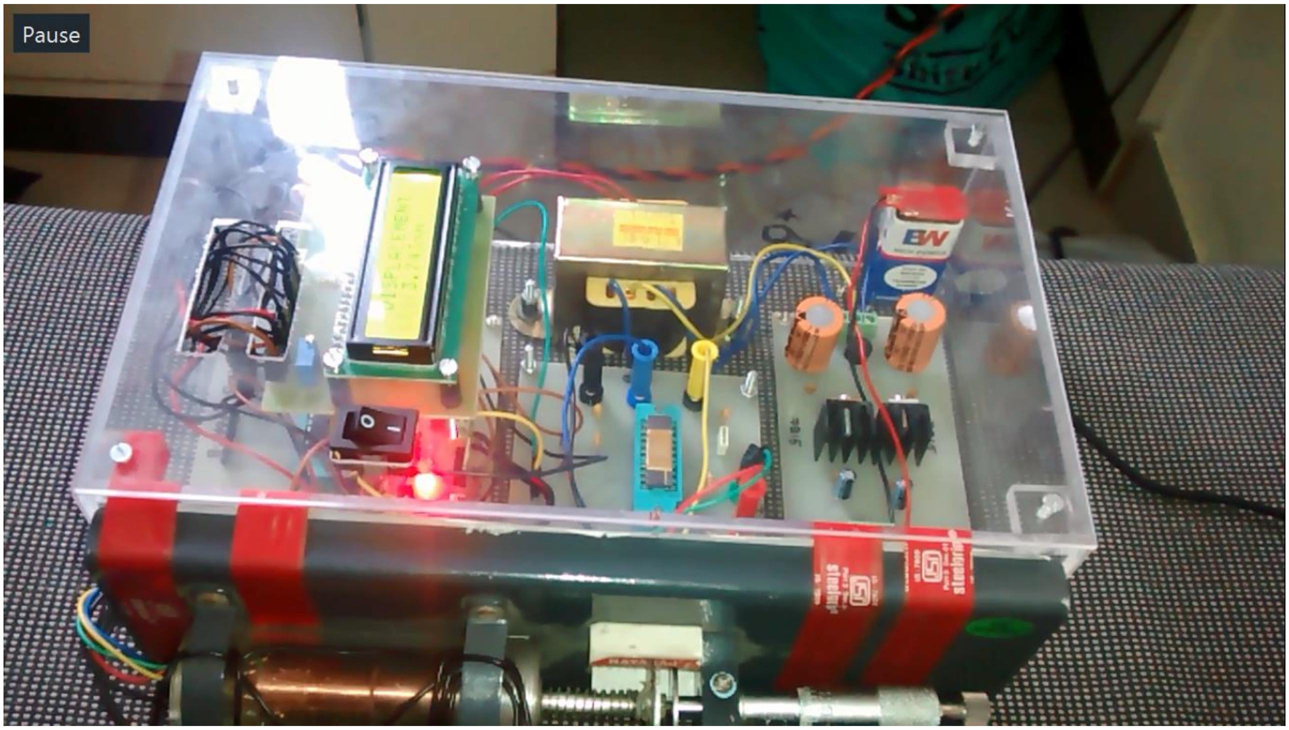
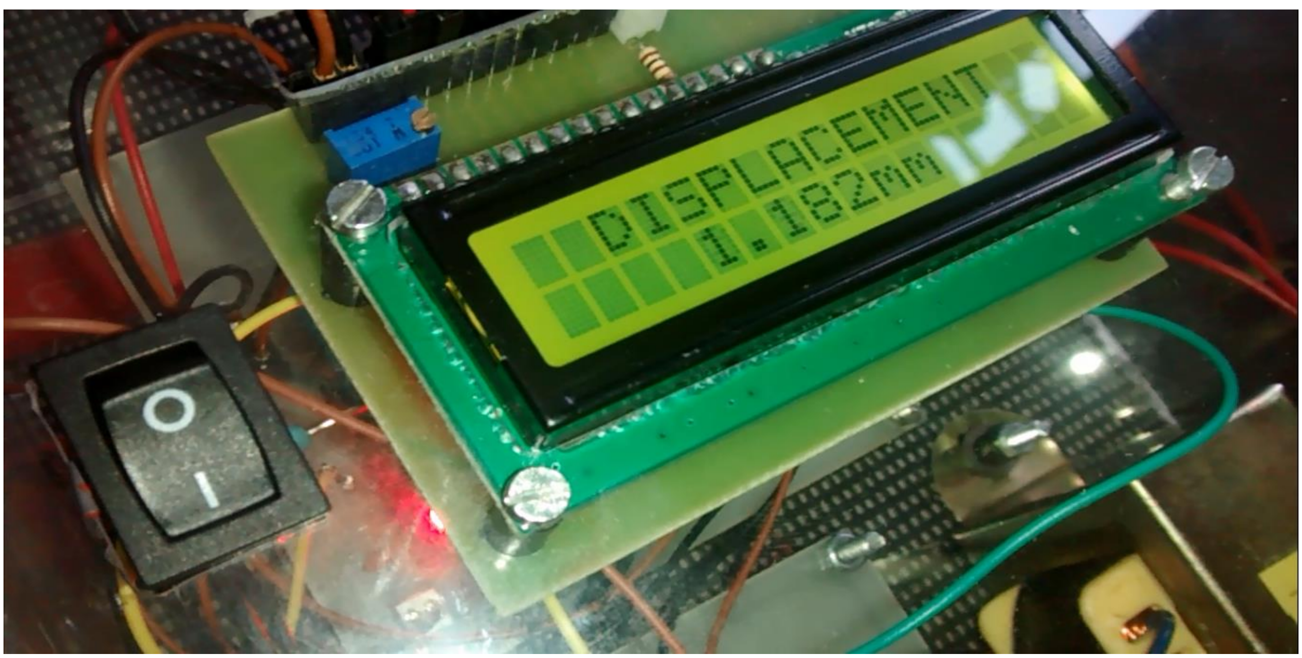
13. PROJECT PHOTO

CABINET

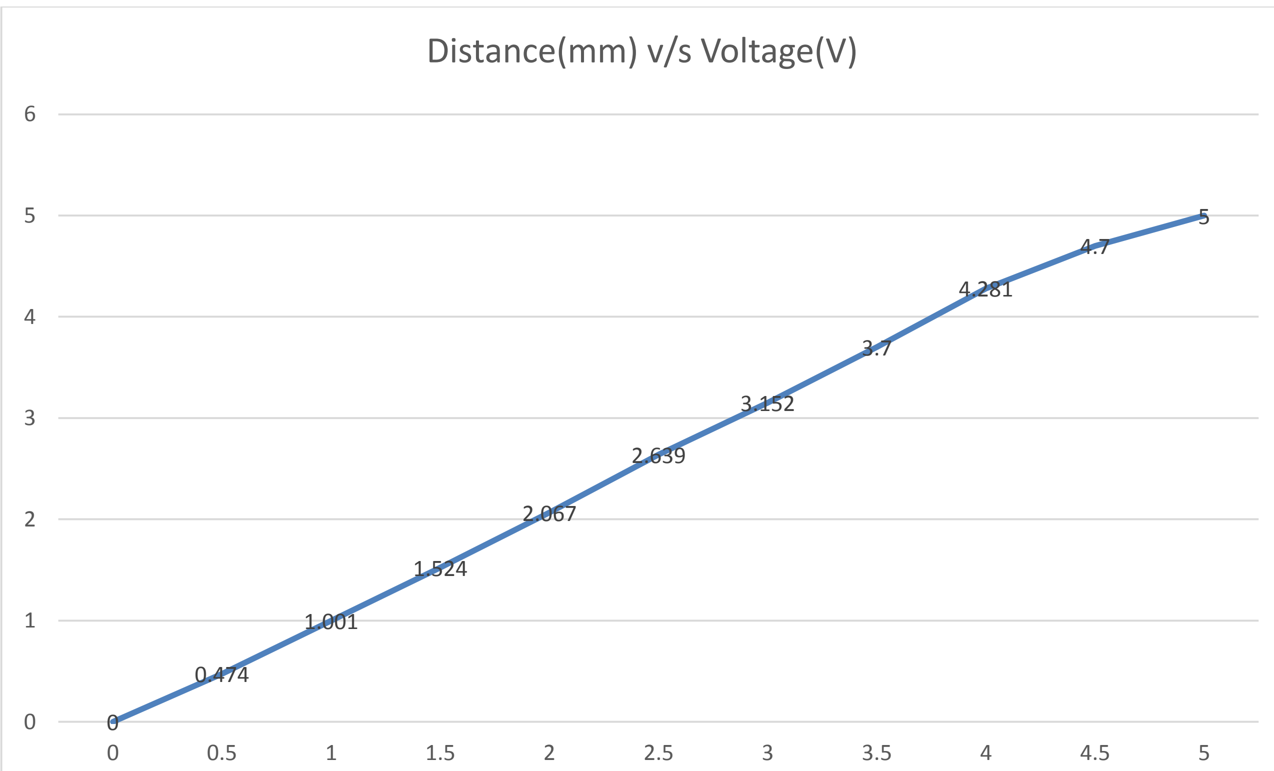


LCD



LVDT

LINEARITY OF LVDT



13. CONCLUSION

Through this project development we not only learnt the ensemble procedures of making a project but also imbibed various design aspects namely soldering, debugging and testing. At the end of the project we have also got an analytic view so as to implement our project at various facets of our life and also to see the shortcomings of the project. We have also learnt to have an outlook to view the project as a "product" and its development in the mere future.