CONSTRUCTION AND PERFORMANCE TEST FOR ASSESSMENT OF SURFACE ROUGHNESS USING LVDT: A CONVENIENT AND INEXPENSIVE WAY OF MEASURING SURFACE IRREGULARITIES

A Project

By

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In partial fulfillment of the requirement for award of the degree

Of

Bachelor of Science in Mechanical Engineering

May, 2025

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DECLARATION

We do hereby solemnly declare that, the work presented here in this project report has been carried out by us and has not been previously submitted to any University Organization for award of any degree or certificate

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ABSTRACT

The assessment of surface roughness is critical in evaluating the quality and performance of machined components. This study presents a convenient and inexpensive method for measuring surface irregularities using a Linear Variable Differential Transformer (LVDT). The LVDT, known for its high sensitivity and precision, effectively detects minute surface deviations by converting mechanical displacement into an electrical signal. The system is designed to provide real-time data acquisition with minimal setup, making it suitable for workshop and laboratory environments. Unlike conventional surface profilometers, the LVDT-based approach offers a low-cost alternative without compromising measurement accuracy. Experimental results demonstrate consistent and reliable readings across various surface finishes, highlighting its potential for widespread application in quality control and production monitoring. This method enables industries, especially small-scale manufacturers, to perform efficient surface analysis and maintain product standards without the need for sophisticated or expensive equipment.

The LVDT sensor successfully detected micro-level surface irregularities through core displacement.Arduino Nano accurately processed the analog LVDT signal and translated it into readable surface roughness values.The 16×2 I2C LCD provided real-time and stable output display with minimal lag.The system showed consistent performance across different surface textures (smooth, semi-rough, rough).Low-cost and compact design proved ideal for academic, lab, and small workshop environments.Overall, the system provides a practical and efficient alternative for basic surface roughness evaluation.

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CHAPTER 1

INTRODUCTION

1.1 Overview

A Linear Variable Differential Transducer (LVDT) is a displacement based transducer. It is a passive transducer used to measure displacement. LVDT is the most preferred displacement measurement transducer used in industries because of its simple design and proven reliability. The major challenge faced in LVDT is linearity in limited stroke range. The performance of the LVDT is subjective to the transducer geometry, the influence of physical parameters on linearity and sensitivity [5] Patranabis, D. (2003).

As LVDT works on the principle of mutual induction between the primary and two secondary windings, the relation between the input and output of the LVDT is derived using the concept of mutually coupled circuits. The output of the LVDT is voltage across the secondary windings, which are connected in series opposition. The flux linkage between the primary and secondary windings changes with the core position [6] Rangan, C. S., Sarma, G. R., & Mani, V. S. V. (1983).

The output measure is based on the variation in mutual inductance between the primary winding and each of two secondary windings when the core moves due to subjected displacement. The displacement to be measured is proportional to the position of the core which is extracted from the output voltage.

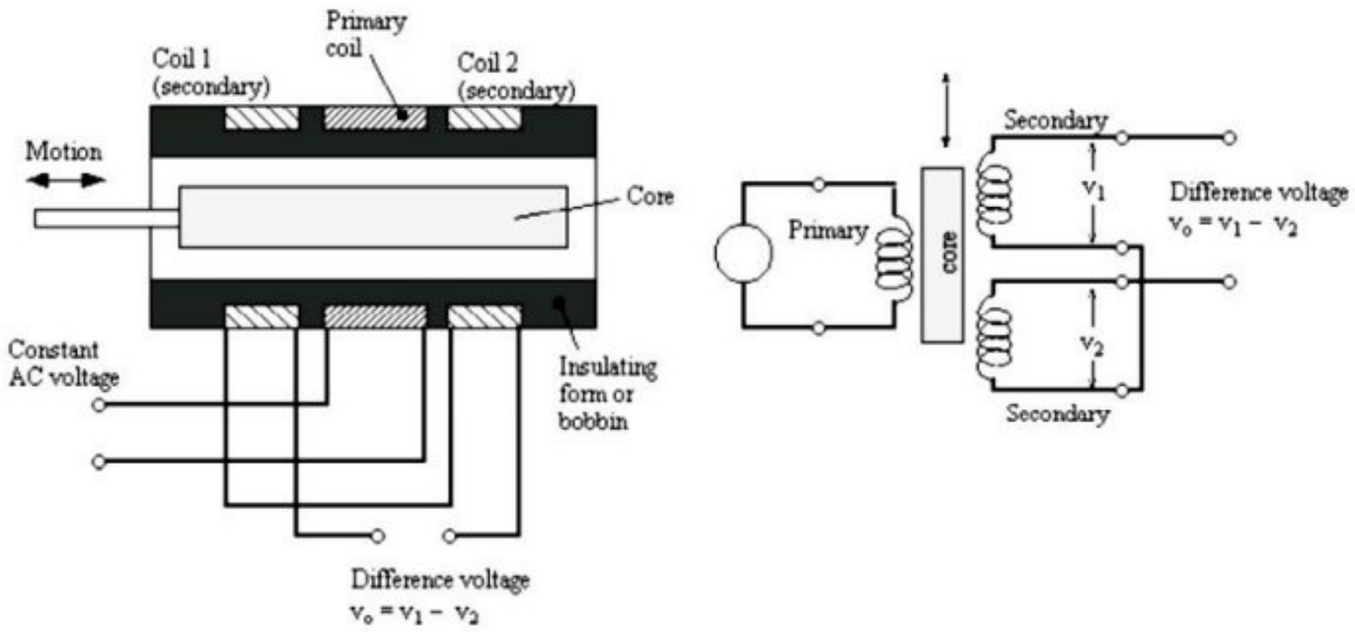


Figure 1.1: Construction of LVDT and Circuit Diagram

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Recent development in manufacturing industries has been increasing a demand of highly more precise, accurate, robust and comparatively less bulky sensor measurement systems to be developed. There various parameter measurements required for a product to be of finished and fine quality; Thickness is one of its kinds. Thickness measurement is very important for the industries whose end product is in sheets which include sheets of polymer, metal, plastic, paper, glass and most important wood. The areas where this kind of thickness measurement is crucial are in automobiles, building materials, electronic devices and paper industries [7] Mohamed, A. M., & Khalil, A. S. G. (2011).

There are various conventional method of measuring the thickness of sheets such as ultrasonic, radiation, laser, optical, magnetic, inductive. F.Tojo et al. developed optical and magnetic sensing system for measurement of thickness of polymer sheet. Nadir et al presented a laser technology for thickness measurement of metallic plates. Wei li et al presented an eddy current method for thickness measurement of metallic plates. K.Suresh et al investigated a resonance method for non-magnetic and conducting sheets thickness measurement.

LVDT is basically an inductive transducer most widely used for measurement of displacement. Due to the characteristic of LVDT, It is used as secondary transducer for industrial application such as pressure, flow, acceleration, force, seismic shock and deformation measurement. This paper presents LVDT based approach for Thickness measurement application using ZigBee and LabVIEW interface for display. The system features the use of wireless communication protocol i.e. ZigBee; System can be used in remote areas where bulky system gets difficult to installation. The motivation of this work is to provide an alternative with low cost, rugged, accurate, less bulky, easy to configure. So this system can be used to measure thickness of glass, plastic, rubber and wooden sheets in industry. [8] F. Tojo, T. Yamaguchi, & K. Uematsu (2001).

1.2 Problem Statement

Accurate surface roughness measurement is vital in manufacturing to ensure product quality and performance. Traditional measurement methods, such as stylus profilometers and optical systems, often involve high costs, complexity, and are susceptible to environmental factors like temperature and humidity . These limitations hinder their widespread adoption, especially in resource-constrained settings. Leveraging the LVDT's

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high sensitivity and non-contact measurement capabilities offers a promising alternative. By integrating an LVDT with microcontroller-based systems, it's possible to develop a cost-effective, efficient, and reliable solution for real-time surface roughness assessment, addressing the limitations of conventional methods and enhancing quality control in various industrial applications .

1.3 Objectives

The objectives of this project are

i. To study and construct about Assessment of surface roughness Using LVDT: A convenient and Inexpensive way of measuring surface irregulaties.
ii. To ensure accurate and real-time detection of surface irregularities.
iii. To reduce dependence on expensive and complex surface profilometers.
iv. To display surface roughness values using a simple output interface like an LCD.

1.4 Methodology

Our used methodology for the project

v. Creating an idea for the design and construction of Assessment of surface roughness Using LVDT: A convenient and Inexpensiveway of measuring surface irregulaties. And designing a block diagram & circuit diagram to know which components we need to construct it.
vi. Collecting all the components and programming the micro-controller to control our desired system.
vii. Setting up all the components in a PCB board & soldering. Then assembling all the blocks in a board and finally running the system to check if it actually works or not.

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1.5 Work Flow Diagram

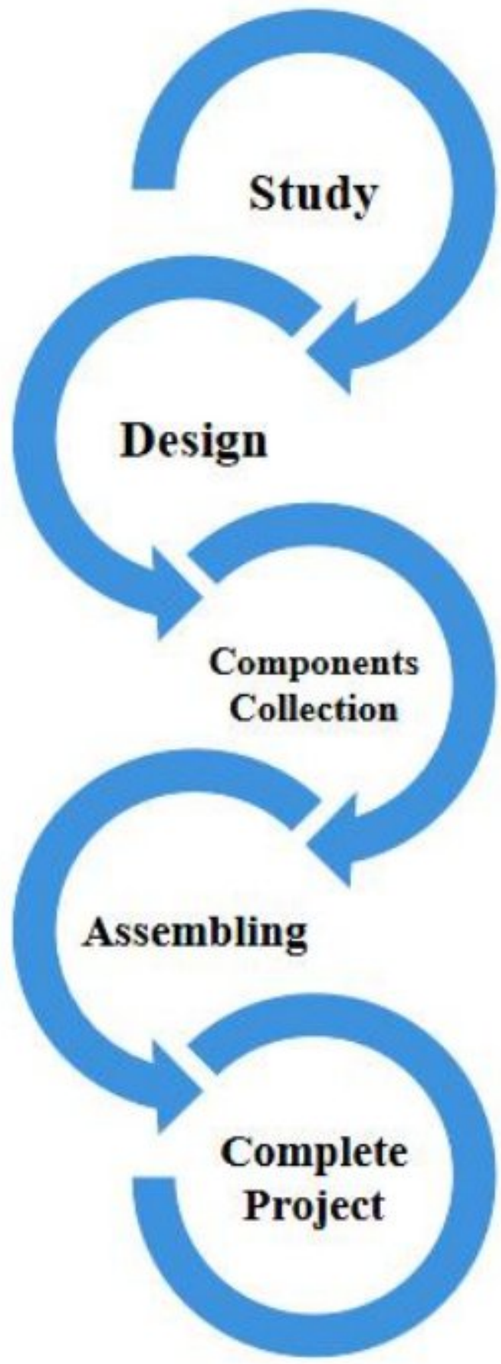


Figure 1.2: Working Flow Diagram

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section topics related to **Accessment of surface roughness Using LVDT: A convenient and Inexpensive way of measuring surface irregulation** are included. These provide a sampling of problems appropriate for the application of Electromagnetic Braking System. The references are summarized below [10].

2.2 Literature Review

Studied displacement values obtained from the PIV method precisely match the LVDT data; hence, load-displacement curves can be easily drawn for steel and RC beams subjected to flexural loading by means of the PIV technique. In this study, the impact of camera resolution on the midspan displacement of steel and RC beam specimens was investigated using two different types of digital cameras [i. e., a Nikon D80 with a resolution of 10.0 megapixels (3,87232,592 pixels) and a Canon 5D Mark II with a resolution of 21.0 megapixels (5,616 33,744 pixels)]. The results show that camera resolution has no significant effect on the accuracy of midspan displacements obtained from PIV analyses [1] Ardalan Hosseini et. al.

Studied the surface settlements of the models during centrifuge tests were monitored with the help of Linear Variable Differential Transformers (LVDTs) wherein centrifuge model test on geogrid soil wall constructed with marginal backfill as backfill and reinforced with weaker reinforcement layers uniformly was found to experience excessive deformations very rapidly. The maximum crest settlement is 0.065 times and maximum normalized face movement is 0.033 times the height of the geogrid reinforced soil wall [2] S. Balakrishnan et. Al.

Studied the analysis of available displacement mea-surement technique using an LVDT shows that only part of the full range of the input scale is used in practice wherein the

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measurement system needs to be recalibrated whenever the LVDT is replaced by another one having different number of pri-mary/secondary windings, dimensions of the coil, and on changing the excitation frequency or ambient temperature [3] Santhosh K. V. et. Al.

Studied the lateral displacements of geotextile reinforced soil and surface settlement of slope using LVDT's wherein he determined the failure mechanism of soil surface using strain and settlement data [2] B. V. S. Vishwanandham et. Al.

Studied that the maximum mid-span deflection increased significantly with the increase of explosive charge weight. However, with the increase of steel tube thickness, the maximum mid-span deflection decreased. As for the effect of cross sectional geometry, the confinement effect benefits circular CFST specimens more under axial loading rather than under lateral loading [4] Hongwei Wang et. al.

2.3 Summary

This project, inspired by the reviewed literature, focuses on using LVDT for accurate surface roughness and displacement measurement. Through continuous teamwork and dedication, we successfully developed a reliable and cost-effective system for monitoring structural behavior and surface irregularities.

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CHAPTER 3

SYSTEM ARCHITECTURE

3.1 Introduction

The project objectives, methods,background evaluation, and other details were all clarified in the preceding chapter. The block diagram, circuit diagram, Working principle, and final project instrument cost analysis will all be covered in this chapter.

3.2 Block Diagram

Here is the block diagram of the **Accessment of surface roughness Using LVDT: A convenient and Inexpensive way of measuring surface irregulation** with all the essential components. All of the components are shown in below as a block in this diagram.Here we use Arduino Nano Micro-controller of our project. Other equipment's are attached with this micro-controller and work together for perform as our desire outcome.

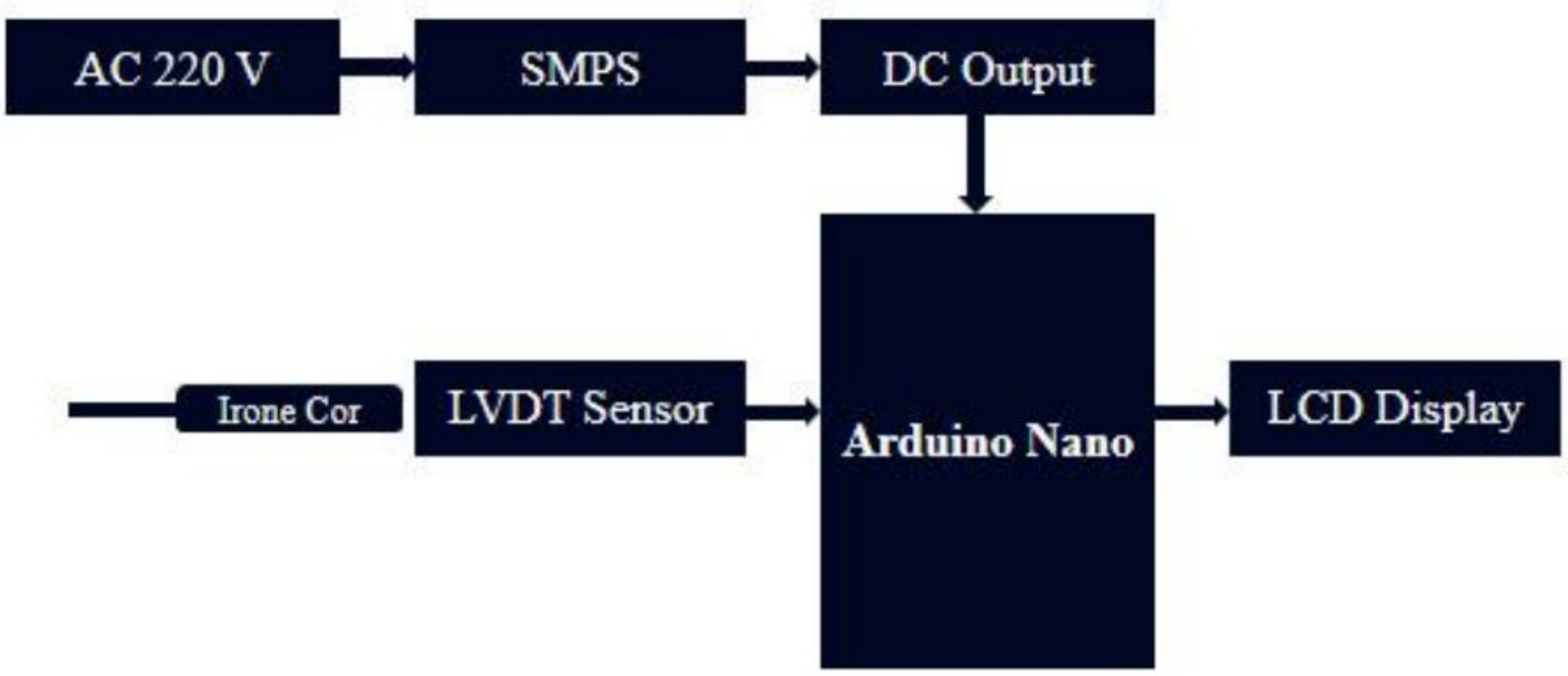


Figure 3.1: Block Diagram of Our Project

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3.3 Circuit Diagram

In this part we show our project circuit design and connect out instrument through standard wire.

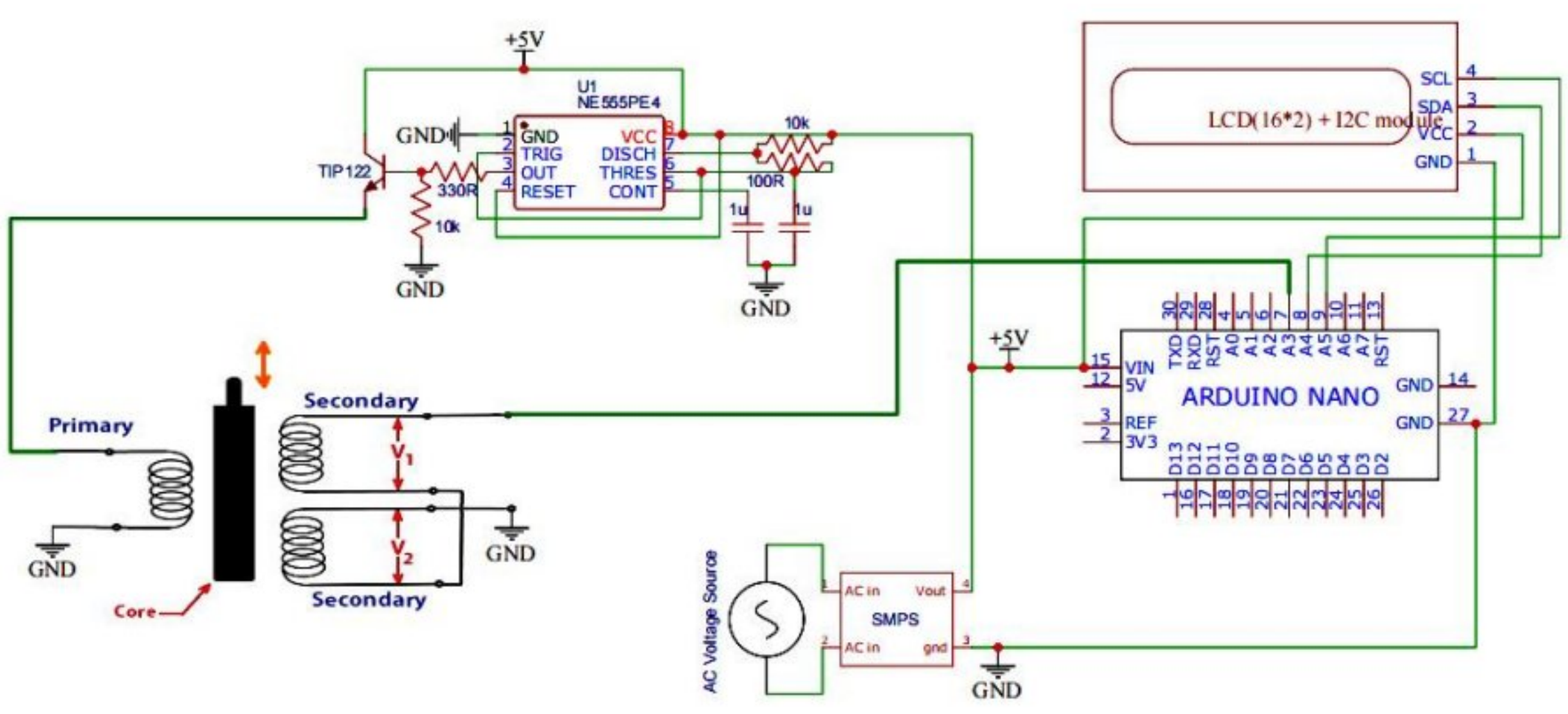


Figure 3.2: Circuit Diagram of Our Project

3.4 Working Principle

This project utilizes an LVDT (Linear Variable Differential Transformer) sensor to measure surface roughness in a precise and cost-effective manner. The LVDT consists of one primary and two secondary coils, with a movable ferromagnetic core. When powered by an AC source, the LVDT produces a voltage output that varies with the position of the core, which moves in response to surface irregularities. An SMPS (Switched Mode Power Supply) converts the AC mains to a stable 5V DC to power the entire system. The analog output from the LVDT is conditioned and fed into an Arduino Nano, which processes the signal and calculates the corresponding displacement. This displacement correlates to the surface's roughness. The Arduino then sends the roughness data to a 16×2 LCD display via I2C communication for real-time monitoring. The system offers an efficient, user-friendly solution for assessing surface quality without the need for expensive industrial equipment.

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CHAPTER 4

HARDWARE & SOFTWARE ANALYSIS

4.1 Introduction

In this section, we will discuss elaborately about "**Accessment of surface roughness Using LVDT: A convenient and Inexpensive way of measuring surface irregulation**" and the component description, features, working procedure of our all equipment.The system hardware fabricates composed of power unit, source unit, power store unite, and many more related components.

4.2 Hardware & Software

Hardware

- SMPS
- Arduino Nano
- LVDT Sensor
- LCD display
- Oscillator Circuit

Software

- Arduino IDE
- Easy EDA

4.3 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy.

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A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight [12] Books.



Figure 4.1: SMPS

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

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The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level. [13] Books.

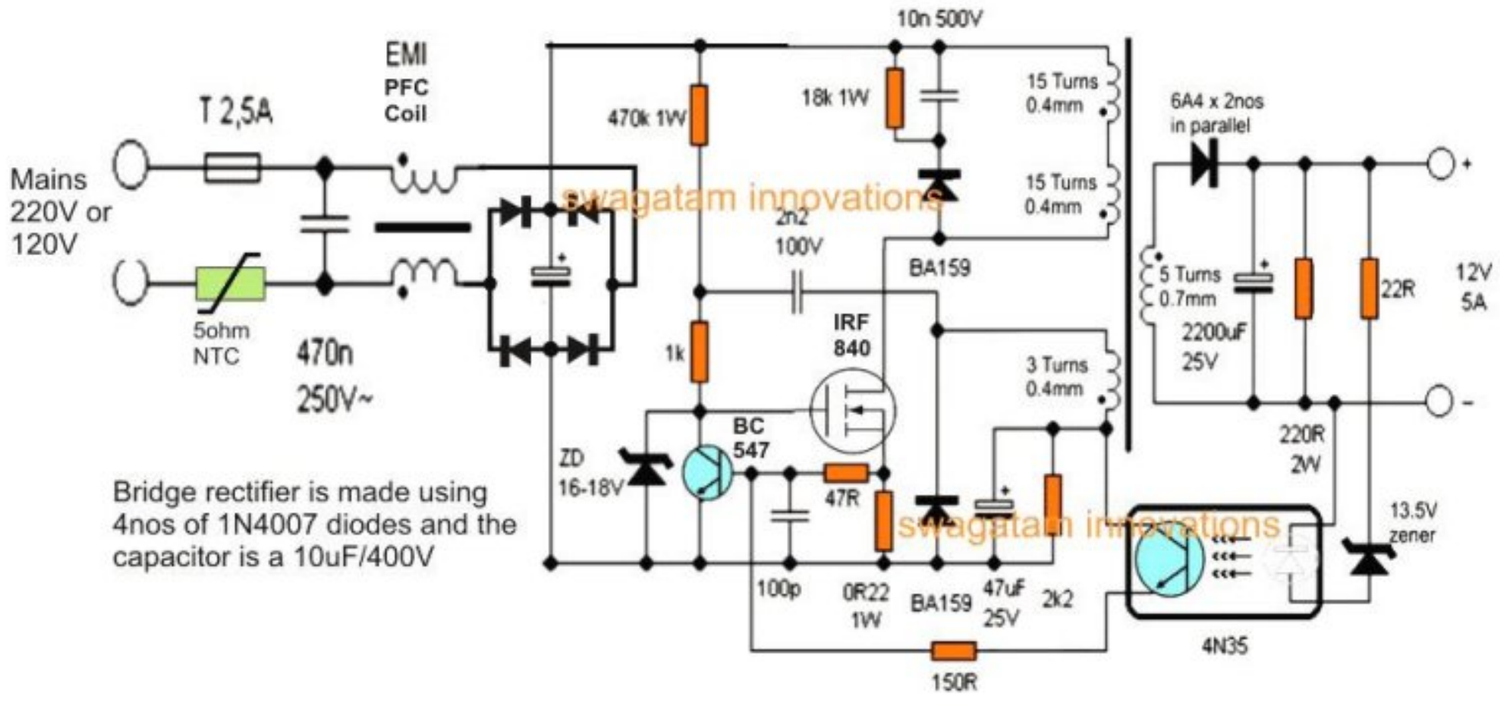


Figure 4.2: SMPS Circuit

Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned. The continuous switching of the capacitor maintains the voltage at the required level [14] M. Rashid.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) pre-regulator followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electrotechnical Commission (IEC) style input connector. As for output connectors and pin outs, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer [15] M. Rashid.

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There are different circuit configurations known as topologies, each having unique characteristics, advantages and modes of operation, which determines how the input power is transferred to the output. Most of the commonly used topologies such as flyback, push-pull, half bridge and full bridge, consist of a transformer to provide isolation, voltage scaling, and multiple output voltages. The non-isolated configurations do not have a transformer and the power conversion is provided by the inductive energy transfer.

Advantages of switched-mode power supplies

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density
- Disadvantages:
- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency. Linear voltage IC regulators have been the basis of power supply designs for many years as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator circuits made from discrete components such a zener diode and a resistor, or transistors and even op-amps.The most popular linear and fixed output voltage regulator types are by far the 78… positive output voltage series, and the 79… negative output voltage series.

These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronic circuits.There is a wide range of these three-terminal fixed voltage regulators available each with its own built-in voltage regulation and current limiting circuits. This allows us

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to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available as well providing an output voltage which is continually variable from just above zero to a few volts below its maximum voltage output [16] Horowitz and Hill.

Switch Mode Power Supply

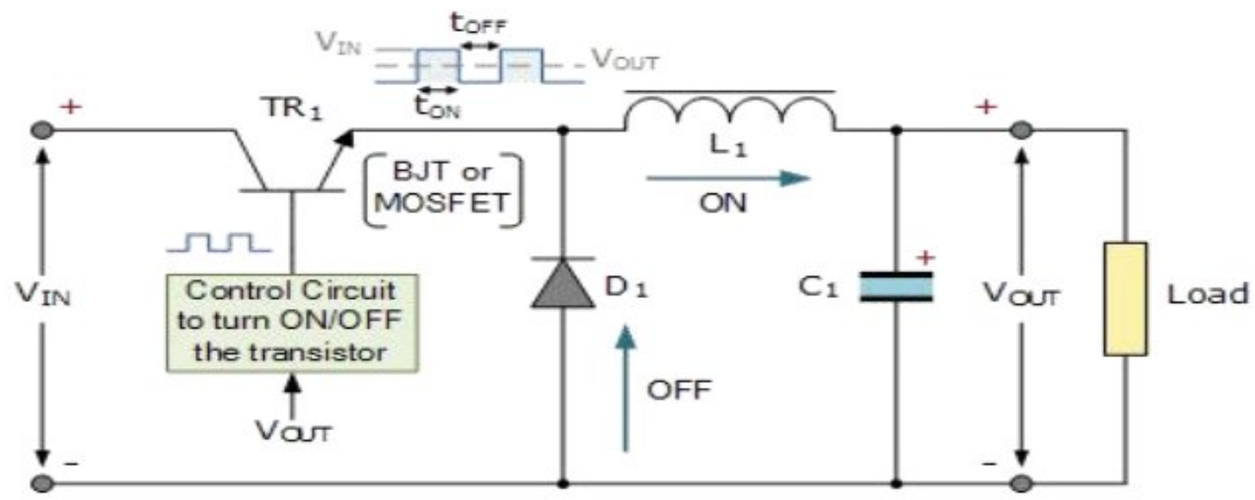


Figure 4.3: SMPS Circuit Connection

Most d.c. power supplies comprise of a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, a filter circuit to remove any ripple content from the rectified d.c. producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabiliser circuit, either linear or switching to ensure the correct regulation of the power supplies output voltage under varying load conditions. Then a typical d.c. power supply would look something like this

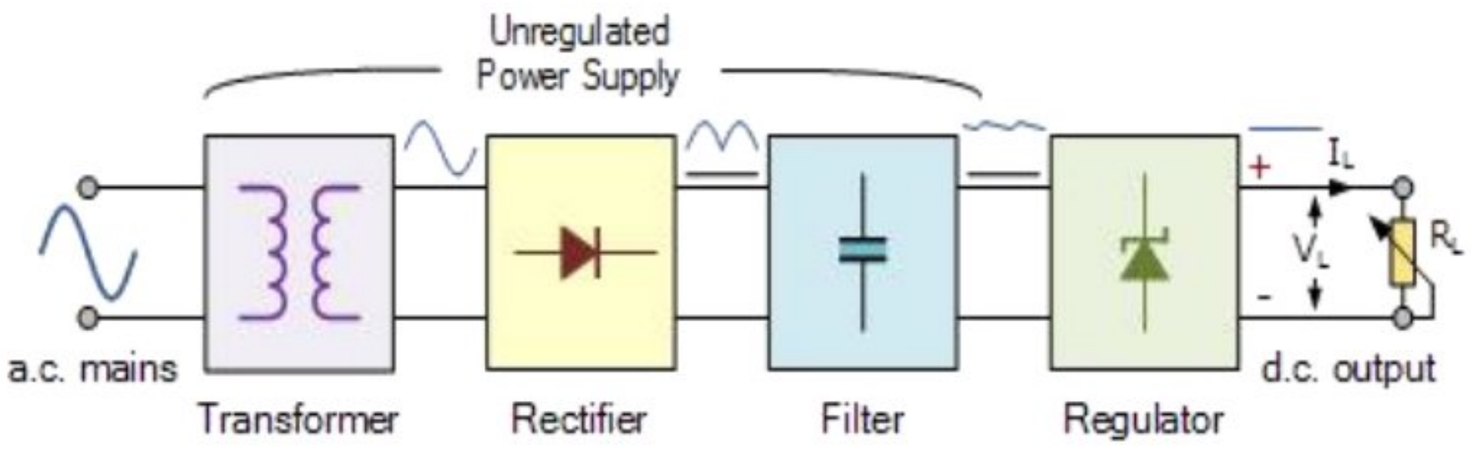


Figure 4.4: DC Power supply way

These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that

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the power supply circuit only needs an input capacitor, output capacitor and some feedback resistors to set the output voltage.

4.4 Arduino Nano

Arduino is open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling Lights, motors, and other actuators.



Figure 4.5: Arduino Nano

The micro-controller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, Maxims'). Arduino Nano is a surface mount breadboard embedded version with integrated USB. It is a small, complete, and breadboard friendly component. It has everything that Decimal/ Duemilanove has (electrically) with more analog input pins and onboard +5V AREF jumper. Physically, it is missing power jack. The Nano can automatically sense and switch to the higher potential source of power [17] Simon Monk.

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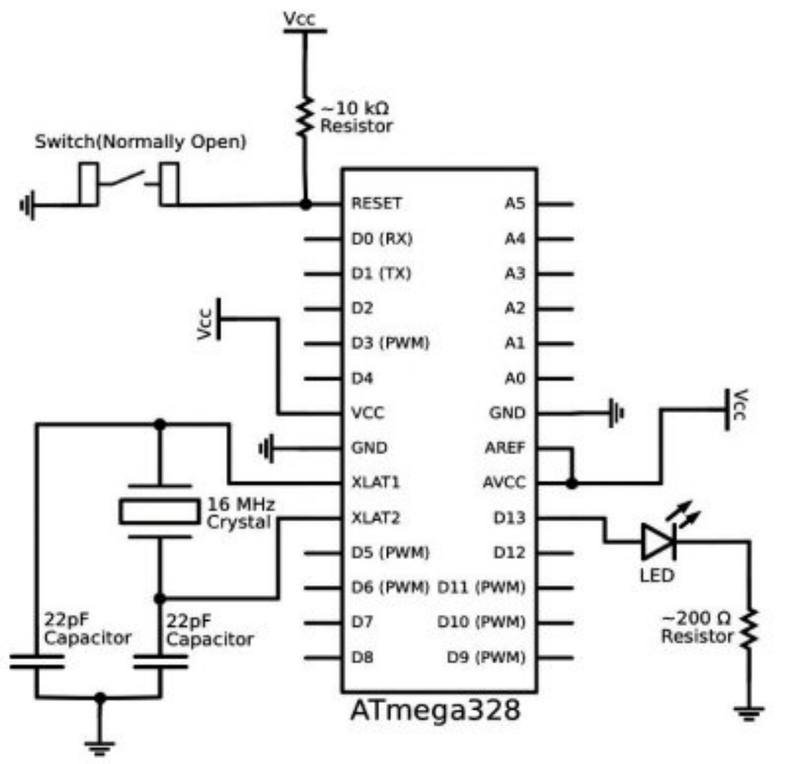


Figure 4.6: Arduino Nano Schematic Diagram

Nano's got the breadboard-ability of the Boarding and the Minibus with smaller footprint than either, so users have more breadboard space. It's got a pin layout that works well with the Mini or the Basic Stamp (TX, RX, ATN, and GND on one top, power and ground on the other). This new version 3.0 comes with ATMEGA328 which offer more programming and data memory space. It has two layers. That make it easier to hack and more affordable. One of the best features of Arduino Nano is, it's easy to use, compact and also small [18] Massimo Banzi & Michael Shiloh.

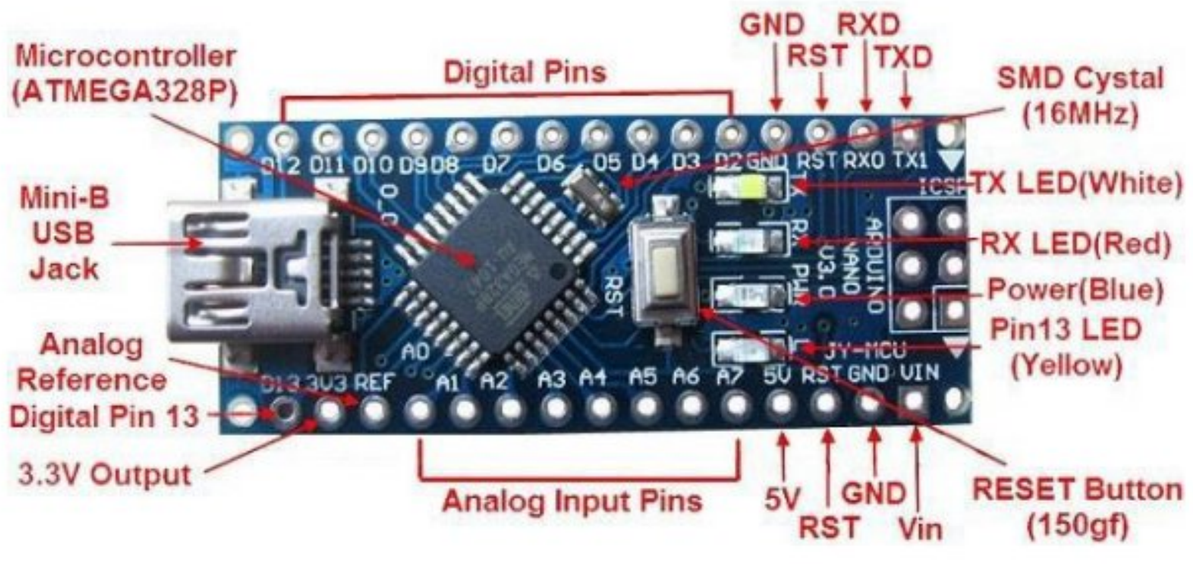


Figure 4.7: How Arduino Nano looks like

Specifications

- Micro-controller: Atmel ATmega328
- Operating Voltage (logic level): 5 V
- Input Voltage (recommended): 7-12 V
- Input Voltage (limits): 6-20 V

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- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 8
- DC Current per I/O Pin: 40 mA
- Flash Memory: 32 KB (of which 2KB used by boot loader)
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock Speed: 16 MHz
- Dimensions: 0.70” x 1.70”

Features

- Automatic reset during program download
- Power OK blue LED
- Green (TX), red (RX) and orange (L) LED
- Auto sensing/switching power input
- Small mini-B USB for programming and serial monitor
- ICSP header for direct program download
- Manual reset switch

Micro-controller IC ATmega328p



Figure 4.8: Micro-controller IC AT mega 328p

The high-performance Microchip Pico Power 8-bit AVR RISC-based micro-controller combines 32KB ISP flash memory with read-while-write capabilities, 1024B EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three

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flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, a 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. By executing powerful instructions in a single clock cycle, the device achieves throughput's approaching 1 MIPS per MHz, balancing power consumption and processing speed [19] Michael Margolis, Arduino Cookbook, O'Reilly Media.

4.5 LVDT Sensor

A Linear Variable Differential Transformer (LVDT) is an electrical transducer or sensor used for the measurement of physical quantities like displacement, force, pressure, acceleration, etc.It works on the principle of mutual inductance, that generates an electrical signal proportional to the physical quantity applied which is to be measured [20] Sawhney A. K.



Figure 4.9: LVDT Sensor

Measurement of Displacement Using LVDT

The measurement of linear displacement ranging from a fraction of mm to cm can be done by using LVDT. The displacement to be measured is applied to the movable core due to which a differential voltage will be produced at the output of the LVDT. The below shows the measurement of displacement using a linear variable differential transformer. [21] E.O. Doebelin & D.N. Manik

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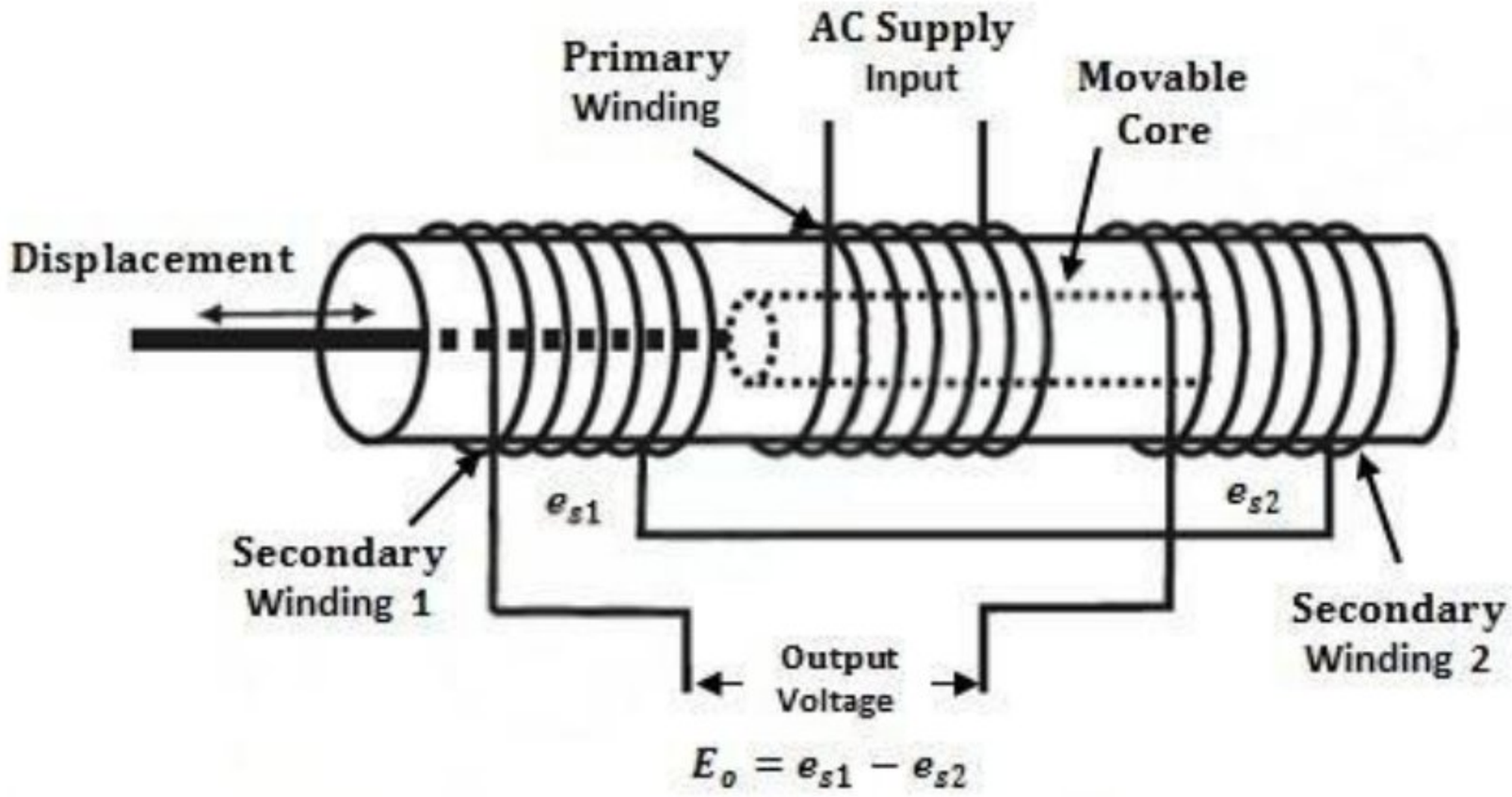


Figure 4.10: Measurement of Linear Displacement using LVDT

Working

Let the emf induced in the two secondary windings are e_{s1} and e_{s2} respectively. In order to obtain a single differential output voltage, the two secondaries are connected in series opposition.

Under the normal condition, when there is no displacement is applied to the movable core. An equal amount of voltages will be induced in the two secondary windings. Since the secondaries are connected in series opposition the net output voltage will be zero.

Now when there is an upward movement in the core due to a displacement applied. The magnetic flux linkage with the secondary winding 1 will be more. This causes more voltage to induce in the secondary winding 1, and thus a differential output voltage with a positive value will be obtained.

Similarly, if the core moves downward, more voltage will be induced in the secondary winding 2. Now there will be a differential output voltage with a negative value. Hence the output voltage obtained is due to the displacement of the core. The measure of output voltage gives the displacement applied when calibrated.

LVDT Accelerometer (Measurement of Acceleration)

The LVDT accelerometer consists of one primary winding and two secondary windings having an equal number of turns. Between the primary and two secondary windings, a

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core is placed which acts as a sensing mass. This core is connected to the housing of the accelerometer by means of two flexible reeds.

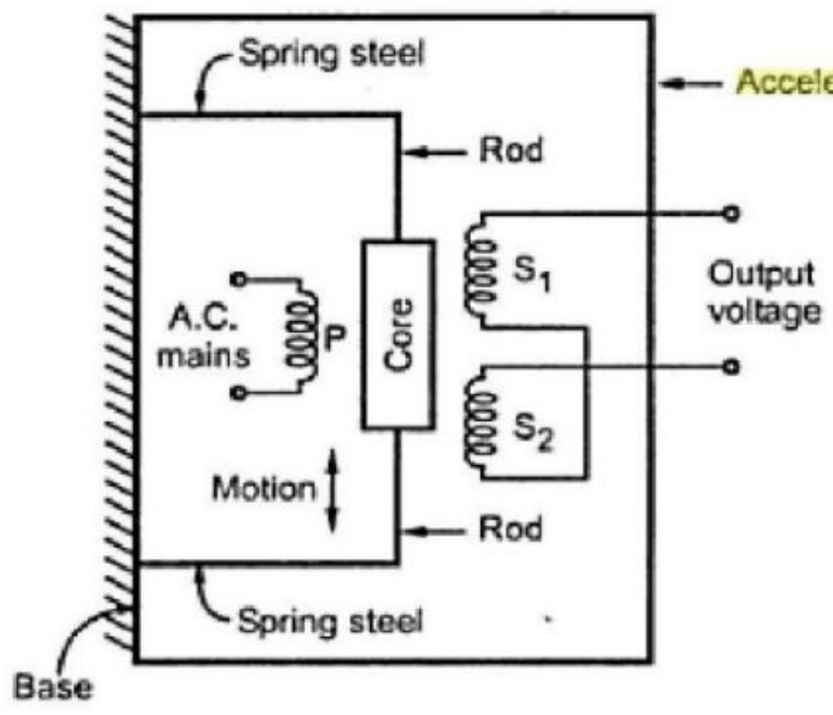


Figure 4.11: LVDT Accelerometer

When the acceleration to be measured is applied, vibrational displacement of core takes place due to which differential output voltage will be produced (at the output of LVDT). This output voltage gives the measure of acceleration.

Working of LVDT Accelerometer

The accelerometer is attached to the object whose acceleration is to be measured. In the presence of acceleration, the vibrational displacement of the core occurs. Depending on acceleration the core moves up and down with respect to two secondaries.

Therefore, an differential output voltage will be generated at the output terminals. The magnitude of induced voltage (i.e., the differential output voltage of two secondaries) is proportional to the displacement of core and hence, gives the amplitude of vibration (i.e., acceleration) [22] R. S. Khandpur.

Measurement of Pressure Using LVDT

An LVDT consists of one primary winding to which an ac supply voltage is given and two secondary windings. The two secondary windings are connected in series of opposite connections so that a differential output voltage can be obtained.

Between the primary and two secondary windings, a core is placed Depending on the position of the core, more or less output will be generated in the two secondary windings.

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Now connect pressure sensing elements such as bellow or bourdon tube, to the core of LVDT such that the output displacement resulting from this transducer by the applied pressure will be transmitted to the core of LVDT as shown below [23] R.K. Jain.

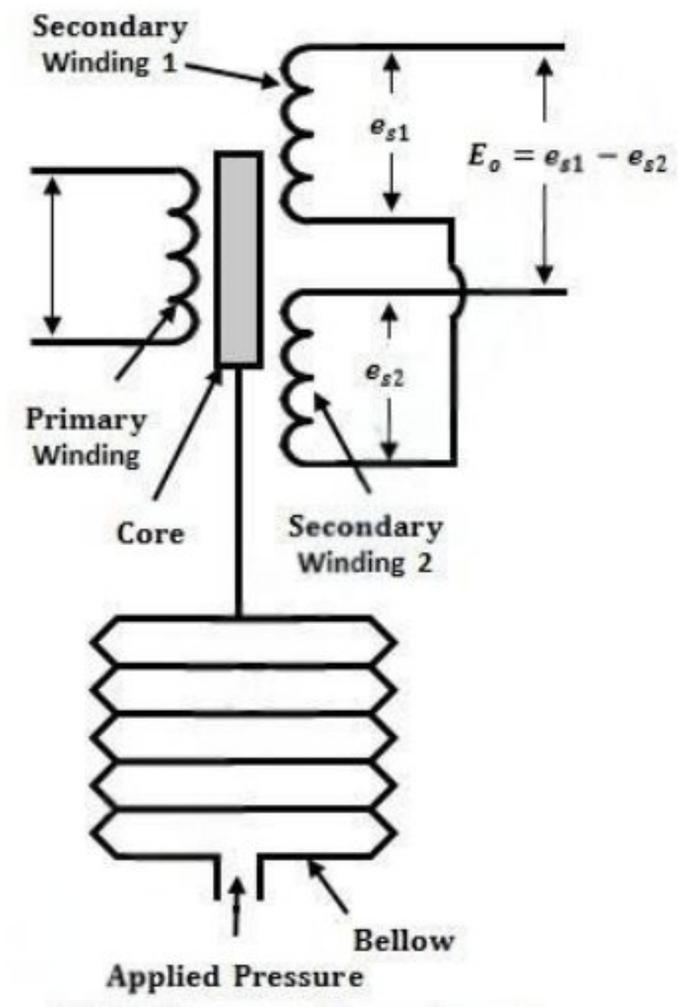


Figure 4.12: LVDT Pressure Transducer

Working

When the core is placed between the primary and two secondaries in such a way that, it is symmetrically to two secondary windings, then the magnitude of the voltage induced in two secondaries are equal due to their series opposition connection. Therefore, the net output voltage is zero and this position is known as the null position.

When the pressure to be measured is applied to the bellow, the bellow deflects (expands upwards) and this movement is given to the rod of the core of LVDT. With this, the core will be lifted up and more voltage will be induced in the upper part of the secondary winding.

Therefore, a positive voltage is generated at the output (i.e., $E_o = e_{s1} - e_{s2}$). In other words, when the core moved upwards from the null position a positive amount of voltage is generated at the output. This positive output will indicate applied pressure.

Now when the pressure is decreased the bellow contracts (comes downwards) and the core comes down from the null position causing more voltage to induce in secondary winding 2,

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which is denoted by e_{s2}, and the net output voltage is negative which indicates the decrease in pressure.

4.6 LCD Display

The LCD (liquid crystal display) screen is an electronic display module and looks for various applications. A 16x2 LCD display is a very basic module and it is very commonly used in various devices and circuits. These modules are preferred over seven sections and many other segments.



Figure 4.13: 16*2 LCD Display

The reasons for having LCD are economic; Easily programmable, special and even custom characters (different in seven sections), there are no restrictions on displaying animations. A 16x2 LCD means it can display 16 characters per line and contains 2 lines. Each character on this LCD is displayed in a 5x7 pixel matrix.

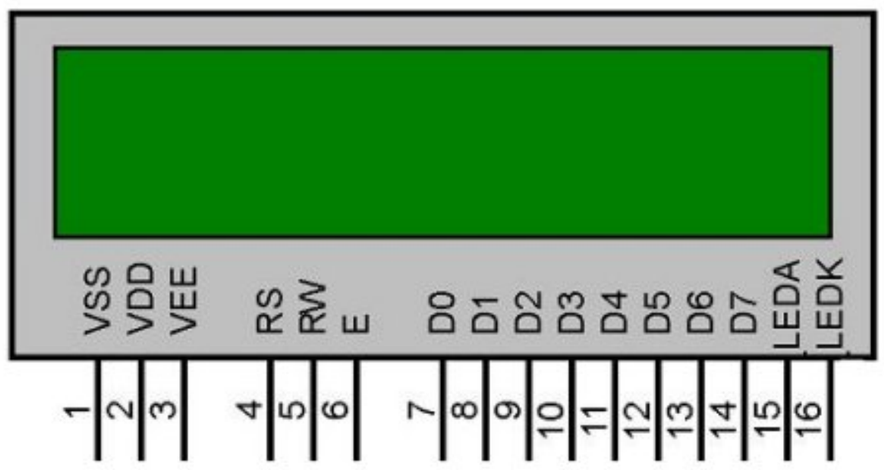


Figure 4.14: Pin out of 16*2 LCD Display

This LCD contains two articles called Command and Data. The command register stores the command instructions on the LCD. The command is a command given to the LCD to perform a predefined task such as starting it, clearing its screen, locating the cursor, controlling the display, etc. [24] Mazidi, M.A., Naimi, S.

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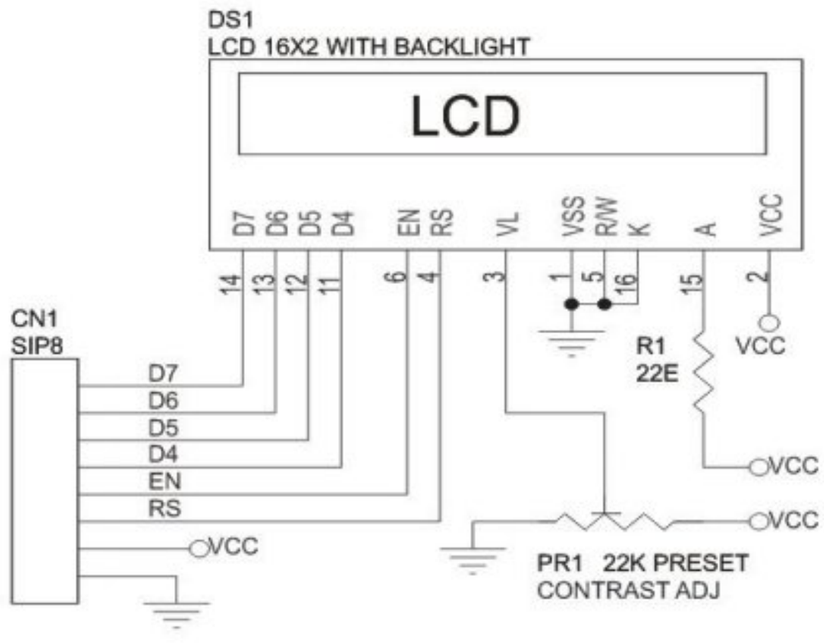


Figure 4.15: 16*2 LCD Display interfacing with Arduino

Feature

The features of this LCD mainly include the following.

- The operating voltage of this LCD is 4.7V-5.3V
- It includes two rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight
- Every character can be built with a 5×8 pixel box
- The alphanumeric LCDs alphabets & numbers
- Is display can work on two modes like 4-bit & 8-bit
- These are obtainable in Blue & Green Backlight
- It displays a few custom generated characters

4.7 Oscillator Circuit

An oscillator circuit is an electronic circuit designed to generate a continuous, repetitive signal—usually a sine wave, square wave, or other periodic waveform—without requiring an external input signal. It works by converting direct current (DC) from a power supply into an alternating current (AC) signal.

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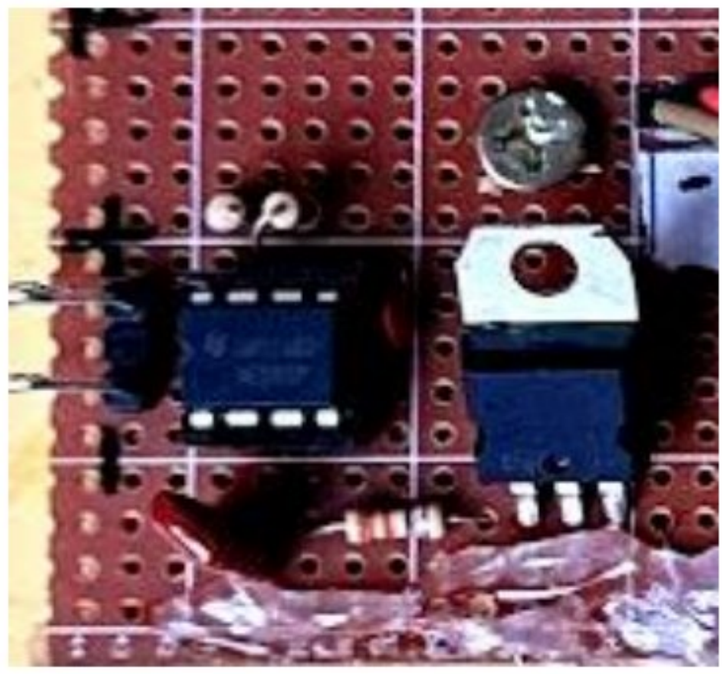


Figure 4.16: Oscillator Circuit

An oscillator circuit is an electronic configuration that generates a continuous, periodic waveform without any input signal. It converts DC power into an AC signal, commonly in the form of sine, square, or triangular waves. Oscillators are fundamental in systems like radios, clocks, computers, and signal generators. The circuit typically includes an amplifier and a feedback network, where part of the output is returned to the input to sustain oscillations. Frequency-determining components such as resistors (R), capacitors (C), and inductors (L) control the oscillation rate. Based on the components used, oscillators are classified into types like RC, LC, crystal, and relaxation oscillators. For instance, an RC oscillator uses resistors and capacitors for low-frequency signals, while a crystal oscillator offers high frequency stability. Oscillator circuits are essential for creating clock pulses in digital electronics, generating carrier waves in communication, and timing functions in microcontrollers. Their simplicity and reliability make them vital in countless electronic applications [25] Sedra, A. S., & Smith.

4.8 Arduino Software IDE

The digital microcontroller unit named as Arduino UNO can be programmed with the Arduino software IDE. There is no any requirement for installing other software rather than Arduino. Firstly, Select "Arduino UNO from the Tools, Board menu (according to the microcontroller on our board). The IC used named as ATmega328 on the Arduino UNO comes pre burned with a boot loader that allows us to upload new code to it without the use of an external hardware programmer [26] Monk, S.

Communication is using the original STK500 protocol (reference, C header files). We can

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also bypass the boot loader and programs the microcontroller through the ICSP (In Circuit Serial Programming) header. The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available. The ATmega16U2/8U2 is loaded with a DFU boot loader, which can be activated by:

On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.The Arduino UNO is one of the latest digital microcontroller units and has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL at (5V) with serial communication, which is available on digital pins 0 -(RX) for receive the data and pin no.1 (TX) for transmit the data. An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an .in file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board.

The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial Communication on pins 0 and 1). A Software Serial library allows for serial communication on any of the Uno digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus. Arduino programs are written in C or C++ and the program code written for Arduino is called sketch. The Arduino IDE uses the GNU tool chain and AVR Lab to compile programs, and for uploading the programs it uses argued. As the Arduino platform uses Atmel microcontrollers, Atmel's development environment, AVR Studio or the newer Atmel Studio, may also be used to develop software for the Arduino.

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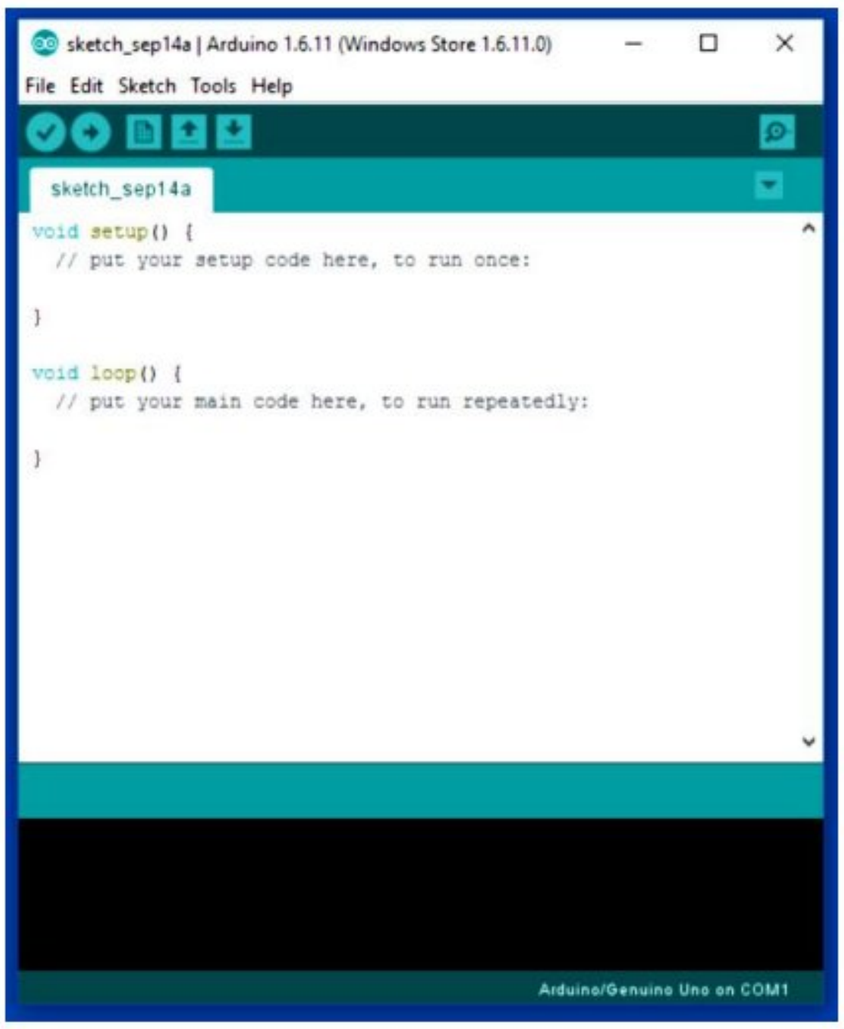


Figure 4.17: Arduino Software Interface IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them [27] Ban zi, M., & Shiloh, M.

Writing Sketches

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension .ino. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom righthand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

Sketchbook

The Arduino Software (IDE) uses the concept of a sketchbook: a standard place to store your programs (or sketches). The sketches in your sketchbook can be opened from the File > Sketchbook menu or from the Open button on the toolbar. The first time you run

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the Arduino software, it will automatically create a directory for your sketchbook. You can view or change the location of the sketchbook location from with the Preferences dialog. Beginning with version 1.0, files are saved with a .ino file extension. Previous versions use the .pde extension. You may still open .pde named files in version 1.0 and later, the software will automatically rename the extension to .ino.

Tabs, Multiple Files, and Compilation

Allows you to manage sketches with more than one file (each of which appears in its own tab). These can be normal Arduino code files (no visible extension), C files (.c extension), C++ files (.cpp), or header files (.h).

Uploading

Before uploading your sketch, you need to select the correct items from the Tools > Board and Tools > Port menus. The boards are described below. On the Mac, the serial port is probably something like /dev/tty.usbmodem241 (for an Uno or Mega2560 or Leonardo) or /dev/tty.usbserial-1B1 (for a Duemilanove or earlier USB board), or /dev/tty.USA19QW1b1P1.1 (for a serial board connected with a Keyspan USB-to-Serial adapter). On Windows, it's probably COM1 or COM2 (for a serial board) or COM4, COM5, COM7, or higher (for a USB board) - to find out, you look for USB serial device in the ports section of the Windows Device Manager. On Linux, it should be /dev/ttyACMx , /dev/ttyUSBx or similar. Once you've selected the correct serial port and board, press the upload button in the toolbar or select the Upload item from the Sketch menu. Current Arduino boards will reset automatically and begin the upload. With older boards (pre-Diecimila) that lack auto-reset, you'll need to press the reset button on the board just before starting the upload. On most boards, you'll see the RX and TX LEDs blink as the sketch is uploaded. The Arduino Software (IDE) will display a message when the upload is complete, or show an error.

When you upload a sketch, you're using the Arduino boot loader, a small program that has been loaded on to the microcontroller on your board. It allows you to upload code without using any additional hardware. The boot loader is active for a few seconds when the board resets; then it starts whichever sketch was most recently uploaded to the microcontroller. The bootloader will blink the on-board (pin 13) LED when it starts (i.e. when the board resets).

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Libraries

Libraries provide extra functionality for use in sketches, e.g. working with hardware or manipulating data. To use a library in a sketch, select it from the Sketch > Import Library menu. This will insert one or more #include statements at the top of the sketch and compile the library with your sketch. Because libraries are uploaded to the board with your sketch, they increase the amount of space it takes up. If a sketch no longer needs a library, simply delete its #include statements from the top of your code.

There is a list of libraries in the reference. Some libraries are included with the Arduino software. Others can be downloaded from a variety of sources or through the Library Manager. Starting with version 1.0.5 of the IDE, you do can import a library from a zip file and use it in an open sketch. See these instructions for installing a third-party library.

Third-Party Hardware

Support for third-party hardware can be added to the hardware directory of your sketchbook directory. Platforms installed there may include board definitions (which appear in the board menu), core libraries, bootloaders, and programmer definitions. To install, create the hardware directory, then unzip the third-party platform into its own sub-directory. (Don't use "arduino" as the sub-directory name or you'll override the built-in Arduino platform.) To uninstall, simply delete its directory.

For details on creating packages for third-party hardware, see the Arduino IDE 1.5 3rd party Hardware specification.

Serial Monitor

This displays serial sent from the Arduino or Genuino board over USB or serial connector. To send data to the board, enter text and click on the "send" button or press enter. Choose the baud rate from the drop-down menu that matches the rate passed to Serial.begin in your sketch. Note that on Windows, Mac or Linux the board will reset (it will rerun your sketch) when you connect with the serial monitor. Please note that the Serial Monitor does not process control characters; if your sketch needs a complete management of the serial communication with control characters, you can use an external terminal program and connect it to the COM port assigned to your Arduino board.

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4.9 Easy EDA

Easy EDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share-publicly and privately-and discuss schematics, simulations and printed circuit boards. Other features include the creation of a bill of materials, Gerber files and pick and place files and documentary outputs in PDF, PNG and SVG formats. Easy EDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.

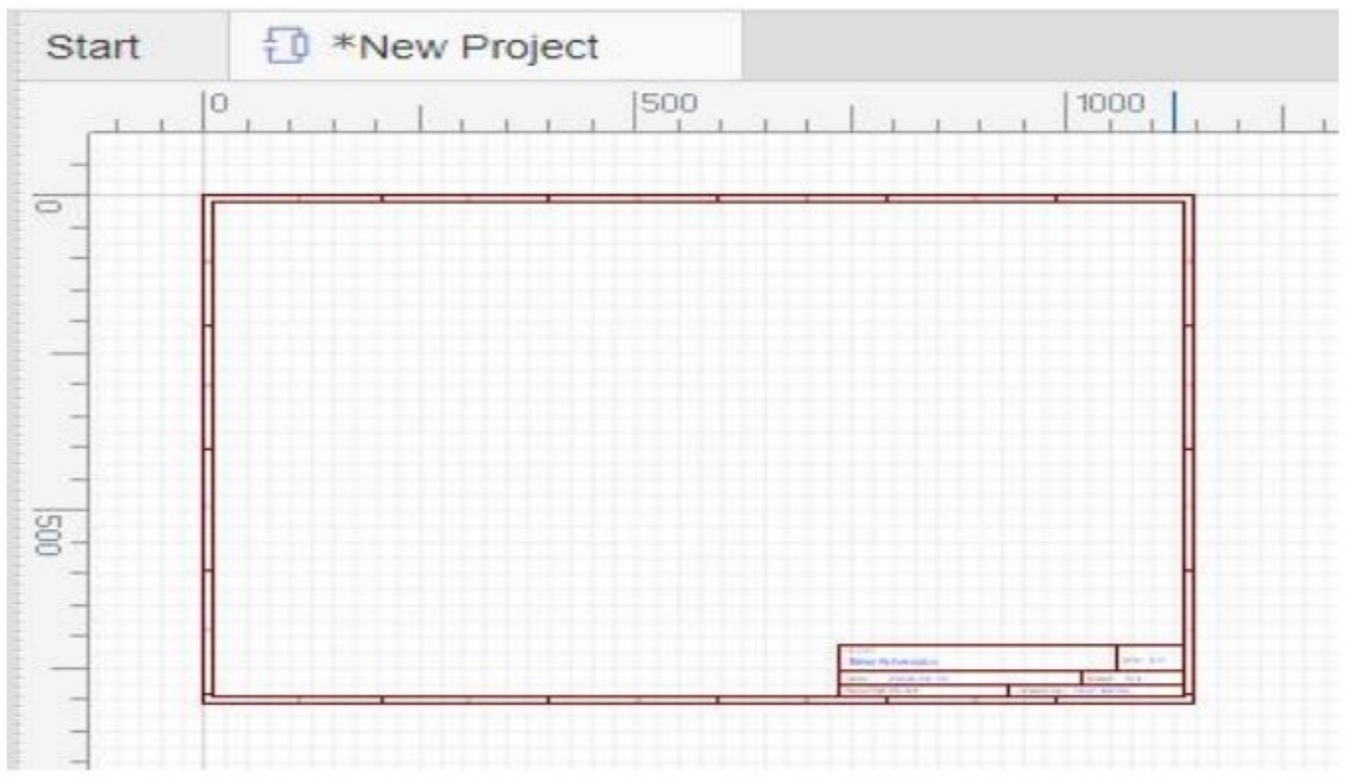


Figure 4.18: Easy EDA Software Interface

Subscription-free membership is offered for public plus a limited number of private projects. The number of private projects can be increased by contributing high quality public projects, schematic symbols, and PCB footprints and/or by paying a monthly subscription.Registered users can download Gerber files from the tool free of charge; but for a fee, Easy EDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third party tools.

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CHAPTER 5

RESULT & DISCUSSION

5.1 Project Output

After finally completing this project, we ran it & we observed the output of this project. We can see that it is working well as expected. After making our project we observe it very careful. It works as we desire. Our project give output perfectly and all equipment are work perfectly. We check how much it works and we get perfect output from this project.

- Finally, we have completed our project successfully & check our project its run accurately according to our objective.
- At first, we start our system.
- The LVDT sensor successfully detected micro-level surface irregularities through core displacement.
- Arduino Nano accurately processed the analog LVDT signal and translated it into readable surface roughness values.
- The 16×2 I2C LCD provided real-time and stable output display with minimal lag.
- The system showed consistent performance across different surface textures (smooth, semi-rough, rough).
- Compared to commercial profilometers, this setup offered good accuracy within acceptable tolerance (for educational and low-cost industrial use).
- Low-cost and compact design proved ideal for academic, lab, and small workshop environments.
- Overall, the system provides a practical and efficient alternative for basic surface roughness evaluation.

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Data Table

Table : LVDT Sensor Displacement vs Voltage

Displacement (mm)	Voltage (V)
0	0.00
10	0.33
20	0.67
30	1.00
40	1.33
50	1.67
60	2.00
70	2.33
80	2.67
90	3.00
100	3.33
110	3.67
120	4.00
130	4.33
140	4.67
150	5.00

Graph

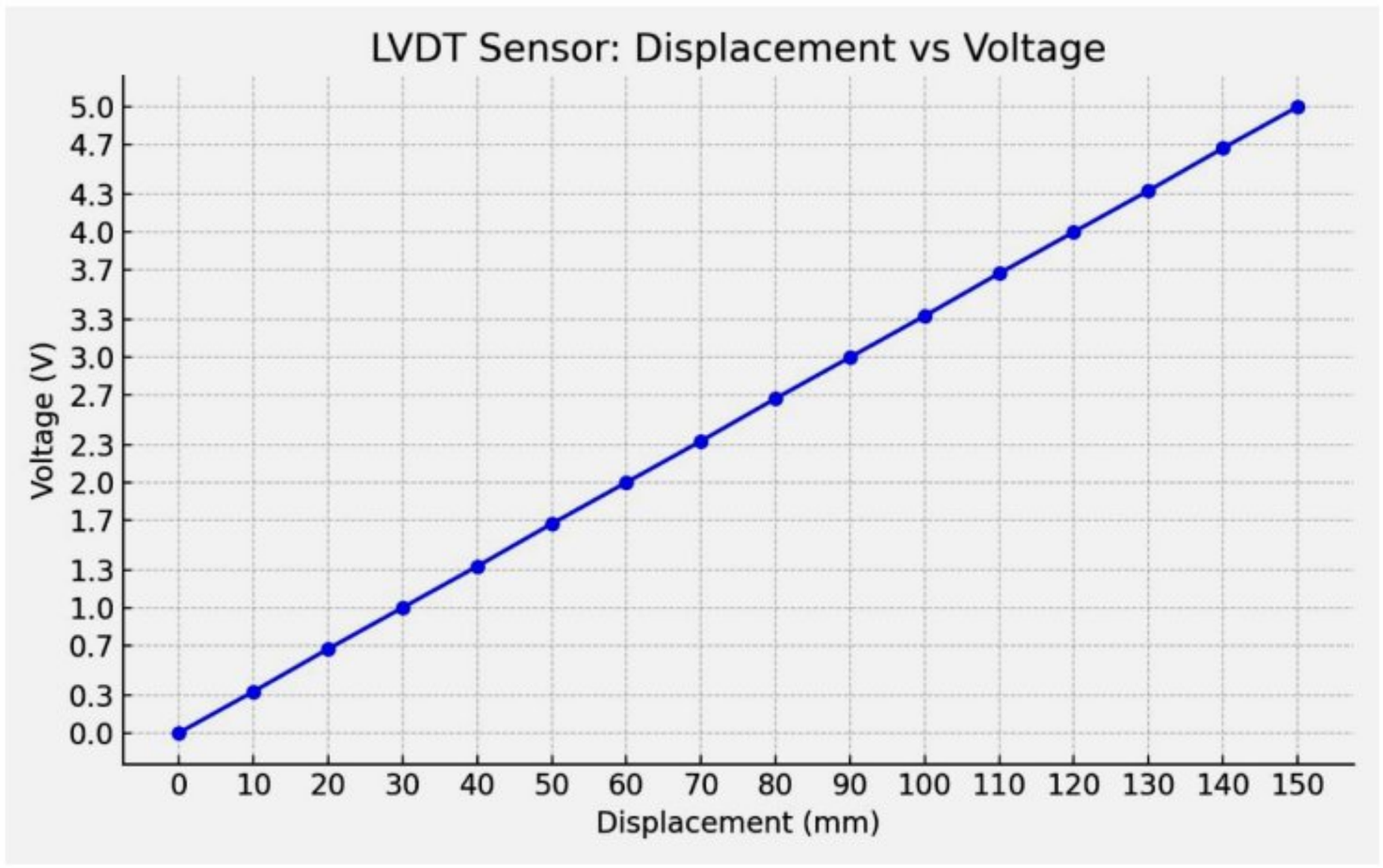


Figure 5.1: LVDT Sensor Displacement vs Voltage

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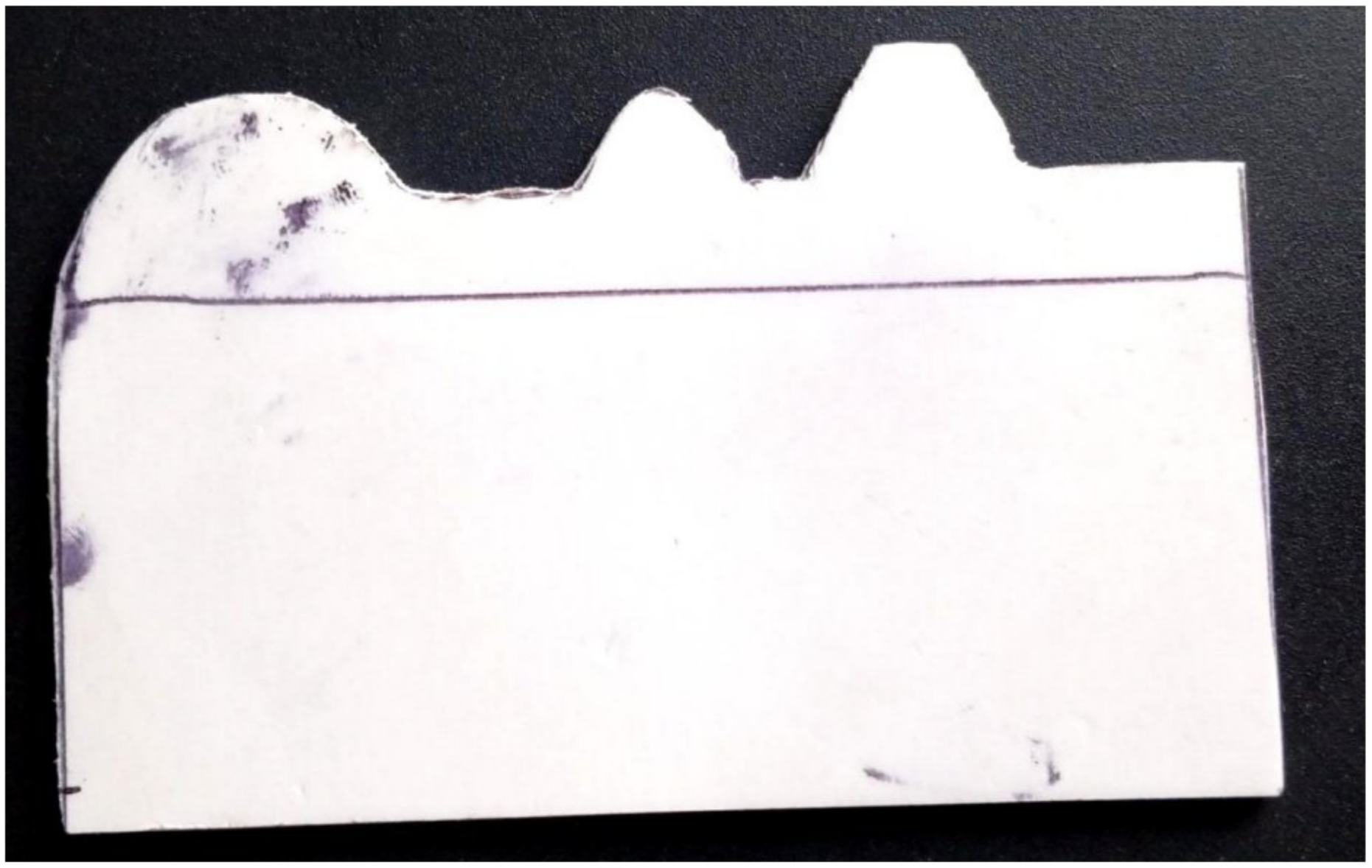


Figure 5.2: Calibration Profile Card for LVDT Measurement [1]

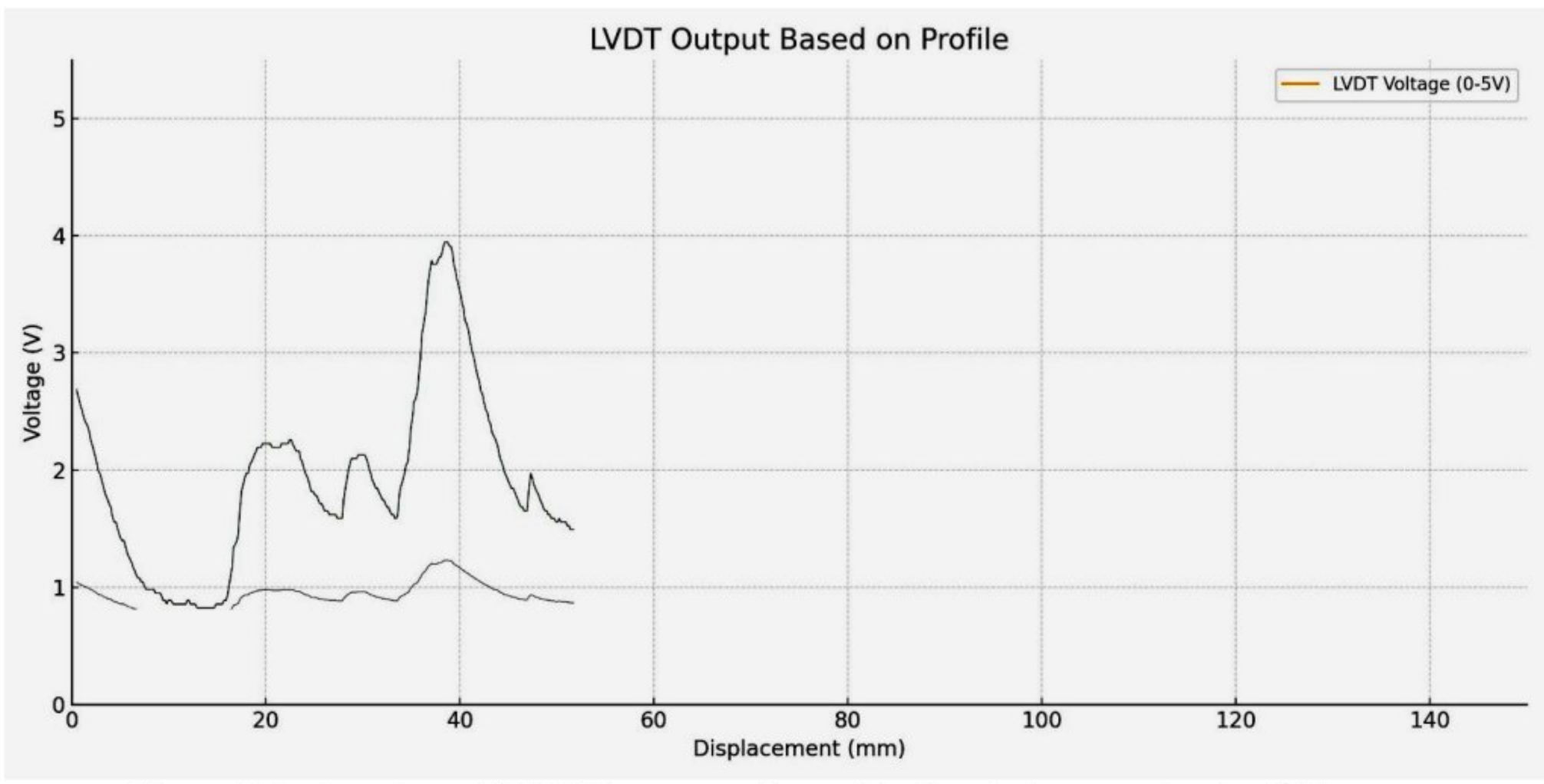


Figure 5.3: Function of LVDT sensor and graphical real-time monitoring [1]

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Figure 5.4: Calibration Profile Card for LVDT Measurement [2]

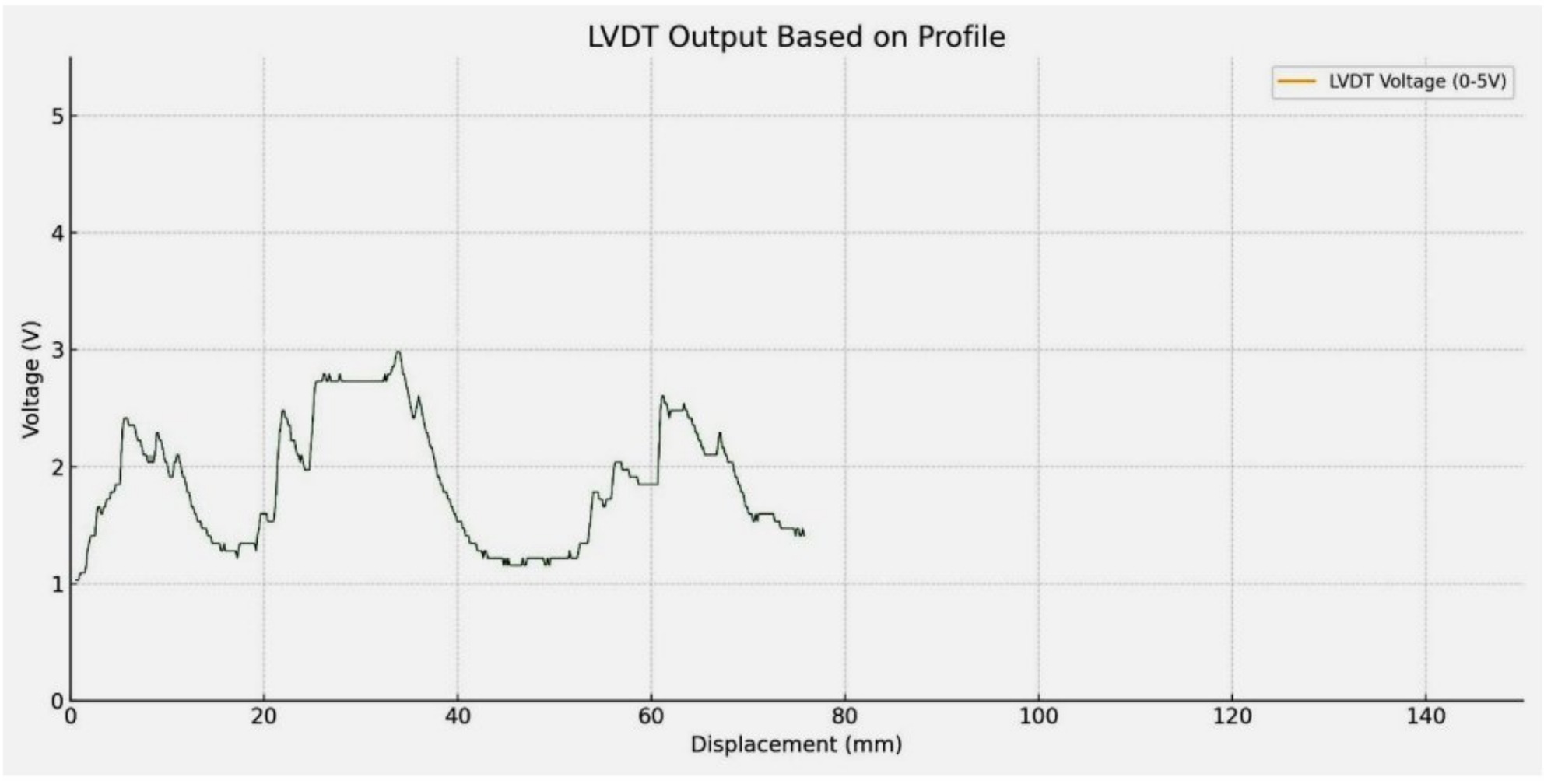


Figure 5.5: Function of LVDT sensor and graphical real-time monitoring [2]

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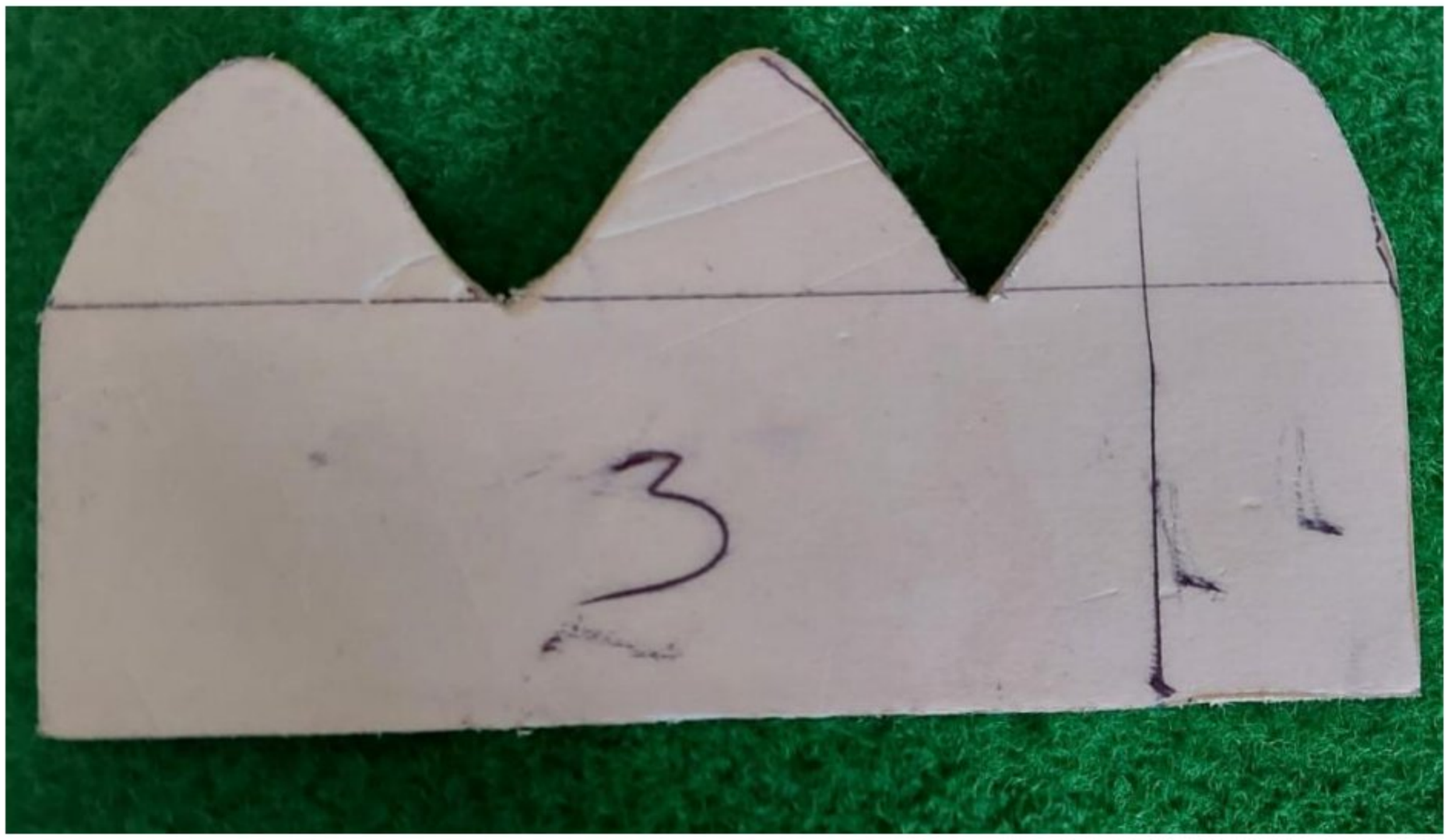


Figure 5.6: Calibration Profile Card for LVDT Measurement [3]

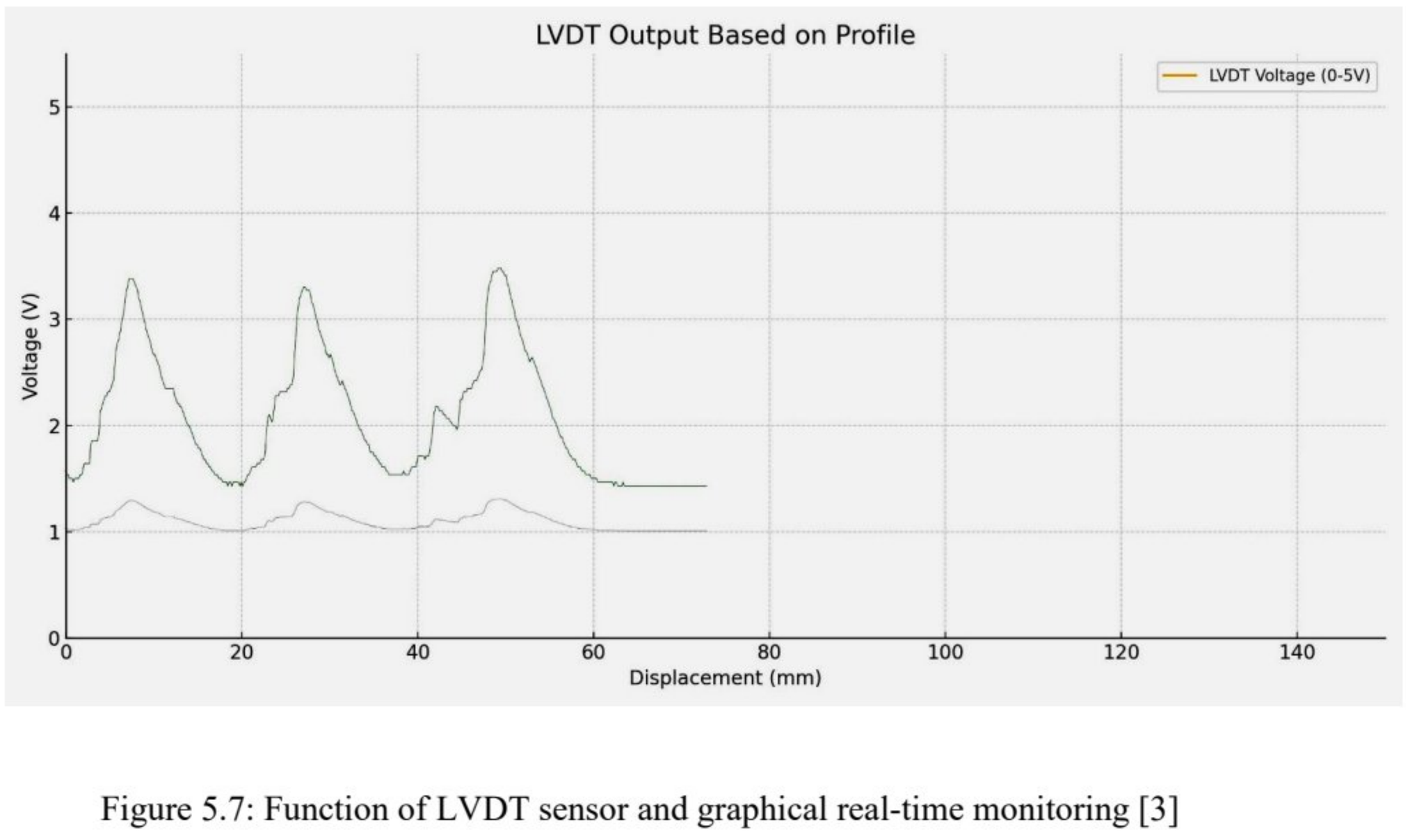


Figure 5.7: Function of LVDT sensor and graphical real-time monitoring [3]

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5.2 Final Project View

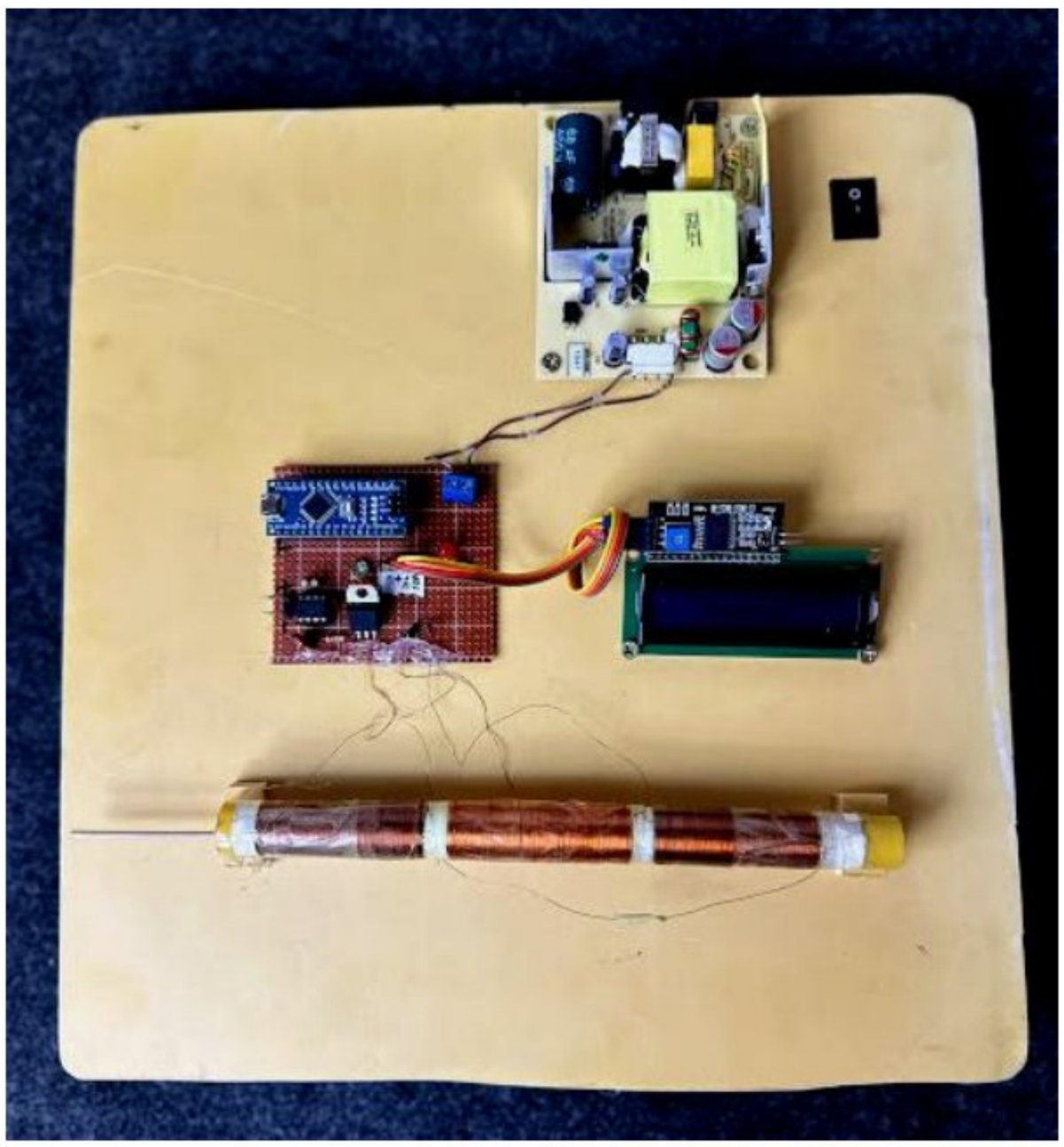


Figure 5.8: Complete Project prototype (Top View)

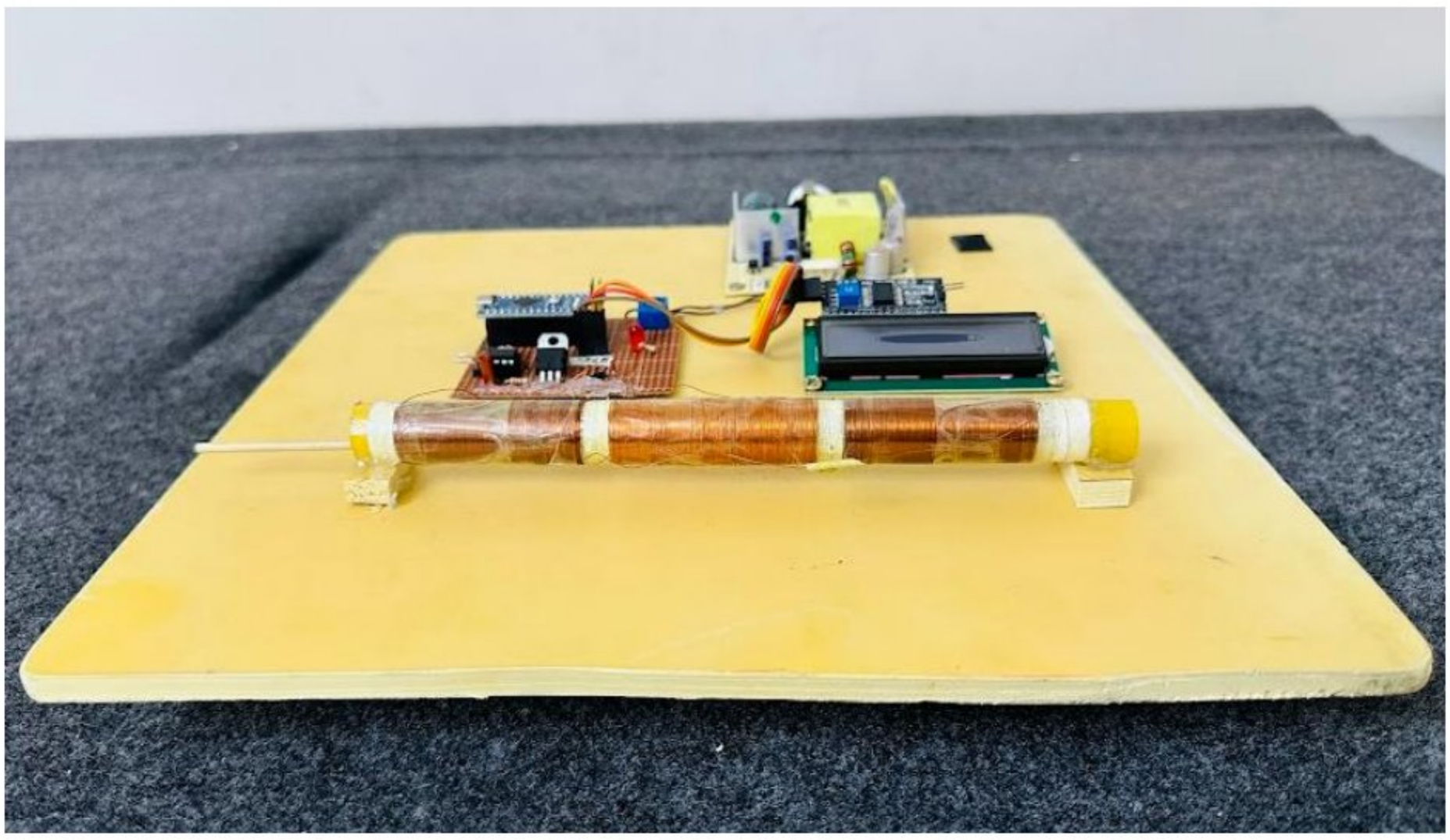


Figure 5.9: Complete Project prototype (Front View)

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5.3 Advantages

There are certainly many advantages of our project and some of the major ones have been given below

- Real-time monitoring
- Easy to use
- Low-cost
- Accurate measurement
- Ideal for labs and workshops
- Simple construction
- Non-destructive testing
- Enhanced signal processing techniques.
- Convenient method for evaluating surface irregularities.
- Inexpensive alternative to advanced surface profilers.

5.4 Application

The application areas for this project in this modern and practical world are huge and some of these are given below

- Surface roughness testing
- Machined part inspection
- Quality control
- Small-scale industry use
- Automotive industry
- Corrosion detection
- Educational demonstration

5.5 Limitations

Through the project has many advantages it has also some limitation, they are given below:

- This project can now be only used for small scale purposes
- No energy backup.
- Sensitive to Vibrations, which can affect measurement precision.
- Only Suitable for Small Surface Areas not ideal for large or complex geometries.
- Dependent on Core Alignment improper core positioning affects output accuracy.

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5.6 Discussion

While working on our project, we did face some difficulties as it is a very complex system but the end results, we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involves improvement in system design and wiring, adding features for more efficient.

The LVDT-based surface roughness measurement system developed in this project provides an affordable and effective alternative to conventional surface profilometers. By using an Arduino Nano for signal processing and a 16×2 LCD for real-time display, the system simplifies surface analysis for small-scale industries and academic purposes. The integration of SMPS ensures stable power supply, while the LVDT offers precise displacement detection based on surface irregularities. Although the system may not match the precision of industrial-grade tools, it delivers reliable results for general inspection tasks. Periodic calibration and environmental control can enhance its accuracy and make it more robust for wider applications.

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CHAPTER 6

CONCLUSION & RECOMANDATION

6.1 Conclusion

This project successfully demonstrates a low-cost, reliable, and efficient method for measuring surface roughness using a Linear Variable Differential Transformer (LVDT) sensor integrated with an Arduino Nano microcontroller. The LVDT accurately detects minute displacements caused by surface irregularities, and the Arduino processes these signals to display real-time surface roughness values on a 16×2 LCD. The inclusion of an SMPS ensures a stable power supply, enhancing the overall performance and reliability of the system.The design is simple, compact, and user-friendly, making it especially suitable for academic environments, workshops, and small-scale industries that cannot afford expensive surface profilometers. Although the system has limitations in terms of precision and measurement range, it provides sufficiently accurate results for basic quality control and educational purposes. Furthermore, it can be easily customized or upgraded for more advanced applications by integrating data logging, wireless communication, or enhanced signal processing techniques.In summary, this project offers a practical and economical approach to surface roughness evaluation. It proves that essential industrial measurements can be conducted effectively using low-cost components and embedded systems, promoting innovation and accessibility in both learning and production environments.

6.2 Future Scope

As we have already discussed about the limitations of this system so definitely there's room for improvement and thus we have Some future scope of work available to us for this system. Some of these are listed below:

- In future development this project can be develop by more efcient .
- In future, I will try it to apply in real field.
- In Future we will add extra power system.
- In future develop Control on IoT System

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REFERENCES

[1] Displacement and Strain Field Measurement in Steel and RC Beams Using Particle Image Velocimetry, Ardalan Hosseini1, Davood Mostofinejad, and Masoud Hajialilue-Bonab.

[2] Performance evaluation of geogrid reinforced soil walls with marginal backfills through centrifuge model tests. Balakrishnan, S. and Viswanadham, B. V. S. 2016, Geotextiles and Geomembranes, Vol. 44, pp. 95-108.

[3] A Smart Displacement Measuring Technique Using Linear Variable Displacement Transducer. Santhosh, K. V. and Roy, B. K. 2012, Procedia Technology, Vol. 4, pp. 854-861. 2nd International Conference on Computer, Communication, Control and Information Technology (C3IT-2012) on February 25-26, 2012.

[4] An Intelligent, multi-transducer signal conditioning design for manufacturing applications. Sillitoe, I., Button, M. and Owhonda, E. 2017, Robotics and Computer-Integrated Manufacturing, Vol. 47, pp. 61-69. SI: FAIM 2015.

[5] Patranabis, D. (2003).
Sensors and Transducers. PHI Learning. Provides in-depth coverage of passive and active transducers, particularly LVDT, its operating characteristics, and applications in industrial setups.

[6] Rangan, C. S., Sarma, G. R., & Mani, V. S. V. (1983).
Instrumentation Devices and Systems. Tata McGraw-Hill. Offers a clear explanation of how the secondary windings are connected in series opposition and how displacement affects the induced voltage.

[7] Mohamed, A. M., & Khalil, A. S. G. (2011).
Non-contact thickness measurement techniques for industrial applications. Measurement, 44(9), 1639–1645. Discusses the need for precise, accurate, and non-invasive thickness measurement methods in modern industries, particularly for sheet materials.

[8] F. Tojo, T. Yamaguchi, & K. Uematsu (2001).
Development of a Non-Contact Measuring System for Polymer Sheet Thickness Using Optical and Magnetic Sensors. Polymer Testing, 20(7), 803–812. Describes an integrated optical and magnetic sensor system developed for accurate thickness measurement of polymer sheets.

[9] S. Mishra, A. Kumar, & P. Sahu (2014).
Design of Wireless Sensor Network System Using ZigBee for Industrial Monitoring.
International Journal of Engineering Research & Technology (IJERT), 3(3), 254–258. Describes the use of ZigBee for wireless sensor networks in industrial monitoring applications.

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[10] Theodore Wildi, Electrical Machines, Drives and Power Systems, Pearson, 2006. Comprehensive coverage of Electromagnetic braking principles and applications.

[11] J.S.R. Jangra, "Surface Roughness Measurement Using LVDT Sensor," International Journal of Engineering Research & Technology (IJERT), Vol. 5, Issue 3, 2016. Experimental study on surface roughness measurement using LVDT sensor.

[12] Books:
"Switching Power Supply Design" by Abraham Pressman, Keith Billings, and Taylor Morey (McGraw-Hill Education) "Power Electronics: Converters, Applications, and Design" by Ned Mohan, Tore M. Undeland, and William P. Robbins (Wiley).

[13] Books:
Switching Power Supply Design by Abraham Pressman, Keith Billings, and Taylor Morey (McGraw-Hill, 3rd Edition) — A classic text with detailed descriptions of inverter operation and feedback control. Power Electronics: Converters, Applications and Design by Ned Mohan, Tore M. Undeland, and William P. Robbins (Wiley) — Comprehensive explanations of SMPS design and control.,

[14] M. Rashid, Power Electronics Handbook, Academic Press, 2010.
Comprehensive explanation of SMPS operation including switching regulators and voltage regulation.

[15] M. Rashid, Power Electronics Handbook, Academic Press, 2010.
Covers AC input filtering, rectification, PFC circuits, and DC-DC converters in detail.

[16] Horowitz and Hill, The Art of Electronics, Cambridge University Press, 3rd Edition, 2015. Explains practical usage of linear regulators, zener diodes, and op-amp alternatives in power supply design.

[17] Simon Monk, Programming Arduino: Getting Started with Sketches, McGraw-Hill Education, 2011. Explains Arduino's programming language (based on Wiring) and its development environment (based on Processing).

[18] Massimo Banzi & Michael Shiloh, Getting Started with Arduino, 3rd Edition, Maker Media, 2014. Covers all Arduino boards, including Nano, and highlights features such as form factor, usability, and breadboard integration.

[19] Michael Margolis, Arduino Cookbook, O'Reilly Media, 2nd Edition, 2011.
Discusses how ATmega328P features (e.g., ADC, timers, UART) are utilized in Arduino programming.

[20] Sawhney, A. K., A Course in Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai & Co., 2015.
Detailed explanation of LVDT as a displacement sensor and its role as a transducer in control systems.

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[21] E.O. Doebelin & D.N. Manik, Measurement Systems: Application and Design, 6th Edition, McGraw-Hill Education, 2011. Covers theory, sensitivity, and linear range of LVDTs for displacement measurement in industrial systems.

[22] R. S. Khandpur, Handbook of Analytical Instruments, Tata McGraw-Hill, 2006. Discusses LVDT-based sensors used in industrial applications, including acceleration and vibration monitoring..

[23] R.K. Jain, Mechanical and Industrial Measurements, Khanna Publishers, 2008. Discusses how mechanical displacement generated by pressure elements (bellows, diaphragms, Bourdon tubes) can be converted into electrical signals using LVDTs

[24] Mazidi, M.A., Naimi, S., & Naimi, S., AVR Microcontroller and Embedded Systems: Using Assembly and C, Pearson Education, 2010.Explains LCD interfacing with microcontrollers, including command and data handling in 16x2 LCD modules.

[25] Sedra, A. S., & Smith, K. C., Microelectronic Circuits, 7th Edition, Oxford University Press, 2014. Comprehensive explanation of oscillator circuits, feedback principles, types (RC, LC, crystal), and frequency determination.

[26] Monk, S., Programming Arduino: Getting Started with Sketches, 2nd Edition, McGraw-Hill, 2016. Explains the Arduino IDE workflow, board selection, and programming using the onboard bootloader.

[27] Ban zi, M., & Shiloh, M., Getting Started with Arduino, 3rd Edition, Maker Media, 2014. Explains bootloader, programming methods, and serial communication in detail.

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APPENDIX

Micro-Controller Programming Code:

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// Initialize LCD address (usually 0x27 or 0x3F — change if needed)
LiquidCrystal_I2C lcd(0x27, 16, 2);

const int sensor_pin = A3;
int sensor_value;
int measured_value;  // this will be your scaled vernier value

// Define max measurable length (like your vernier scale length)
const int max_scale_mm = 150.0;

void setup() {
  Serial.begin(9600);
  pinMode(sensor_pin, INPUT);
  lcd.init();
  lcd.backlight();
}

void loop() {
  sensor_value = analogRead(sensor_pin);

// Map sensor_value (0-1023) to (0.00 - 150.00 mm)
measured_value = (sensor_value / 1023.0) * max_scale_mm;

// Print both raw & scaled values to Serial Monitor
Serial.print("Raw ADC: ");
Serial.print(sensor_value);
Serial.print("\tScaled mm: ");
Serial.println(measured_value, 2);  // 2 decimal places

// Display on LCD
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("varnier:");
lcd.print(measured_value);
  lcd.print("mm");

// lcd.setCursor(0, 1);
//  lcd.print("s-Value:");
//  lcd.print(sensor_value         );
  delay(100);
}
```


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