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Indirect Length Measurement between Two Points on a Remote Plane

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ABSTRACT
Length measurement systems in civil applications require high accuracy, ease of measurement and reliability. It will be easy for an indirect length sensing equipment to provide all the above quoted advantages. Here we present such a length measurement system to measure lengths between two points in a plane from a far off distance. This system consists of an ultrasonic distance sensor, potentiometer, servo motor, LASER and an LCD display. Here using the ultrasonic sensor, the distance between the plane containing the points and the instrument is measured. Now the angle made by the instrument between the two points is measured using a potentiometer. With the obtained values, the length between the points will be calculated using the program loaded to the Arduino board. Finally LCD displays the output. This work is practical and feasible according to the economic point of view and accuracy. The desired objective is highly accurate measurement of length between two points in a plane.

Keywords
Indirect length measurement, Ultrasonic distance sensor, Arduino.

1. INTRODUCTION
Various length measurement techniques have been employed so far by us since the evolution. In the past, measurement using tapes which require human involvement was done. It is time consuming, tough and impractical. So many modern length measurement systems have evolved that can overcome these deficiencies. This includes use of interferometers, diffraction methods, using sensors etc. The main objective of this work is to familiarize with both hardware and software of an indirect length measurement system which uses distance sensors, Arduino, servomotor, LASER and potentiometer. Thereby we are stepping into the very vast world of instrumentation technology with this work.

2. METHODOLOGY
The scheme we have adopted to build up a system described above is presented here. As a range detector we have used an ultrasound distance sensor capable of detecting objects up to a length of 4mts. Once the distance of the plane from the instrument is obtained, a LASER is used to point out the spots between whose length are to be measured. A servomotor connected to it aids the movement of the LASER between the points. The distance and the angle thus obtained are given to the Arduino for further calculation. Finally the LCD interfaced with the Arduino gives the output. As an LCD display is fabricated here to display the output, this kind of setup provides a complete user friendly unit.

3. SYSTEM OVERVIEW
At first we find the distance of the plane containing points, to the instrument using the Ultrasonic Distance Sensor. A LASER is attached to the potentiometer and geared DC motor in such a way that the rotation of the motor cause the rotation of LASER pointer along with motor shaft. Once the distance is obtained, we spot the first point with the LASER. Now using the DC Gear Motor system the shaft of the Potentiometer is moved to the next point. The second point is accurately identified with the help of LASER. The Potentiometer output voltage now corresponds to the angle between the points. The obtained values of distance of the plane from the instrument and the angle subtended by the points are fed to the Arduino board for calculation. With the help of Arduino Development Environment, Arduino is programmed so as to obtain the length between the points as the output. The obtained output is fed to the display.

4. CIRCUIT DESCRIPTION
· The circuit basically consists of Arduino board, Ultrasonic sensor and the potentiometer.
· Ultrasonic distance sensor senses the distance between the instrument and the plane.
· Once the distance is obtained, it is fed to the Arduino.
· Now the angle subtended by the two points with the instrument is measured with the help of a rotary potentiometer.
· This value is also fed to Arduino. Arduino calculates the length between the points using the equations:

L_1=D/tan (Θ_1)
L_2=D/tan (180-Θ_2)
Total Length = L_1 + L_2

where, D is the distance measured by Ultrasonic distance Sensor.

D, L_1 and L_2 are in meters and Θ is in radians. See figure 1.

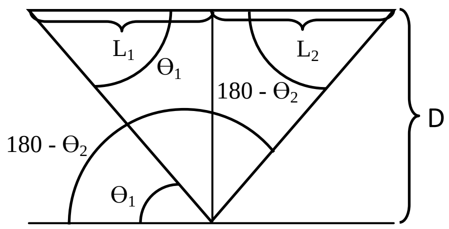

Fig.1

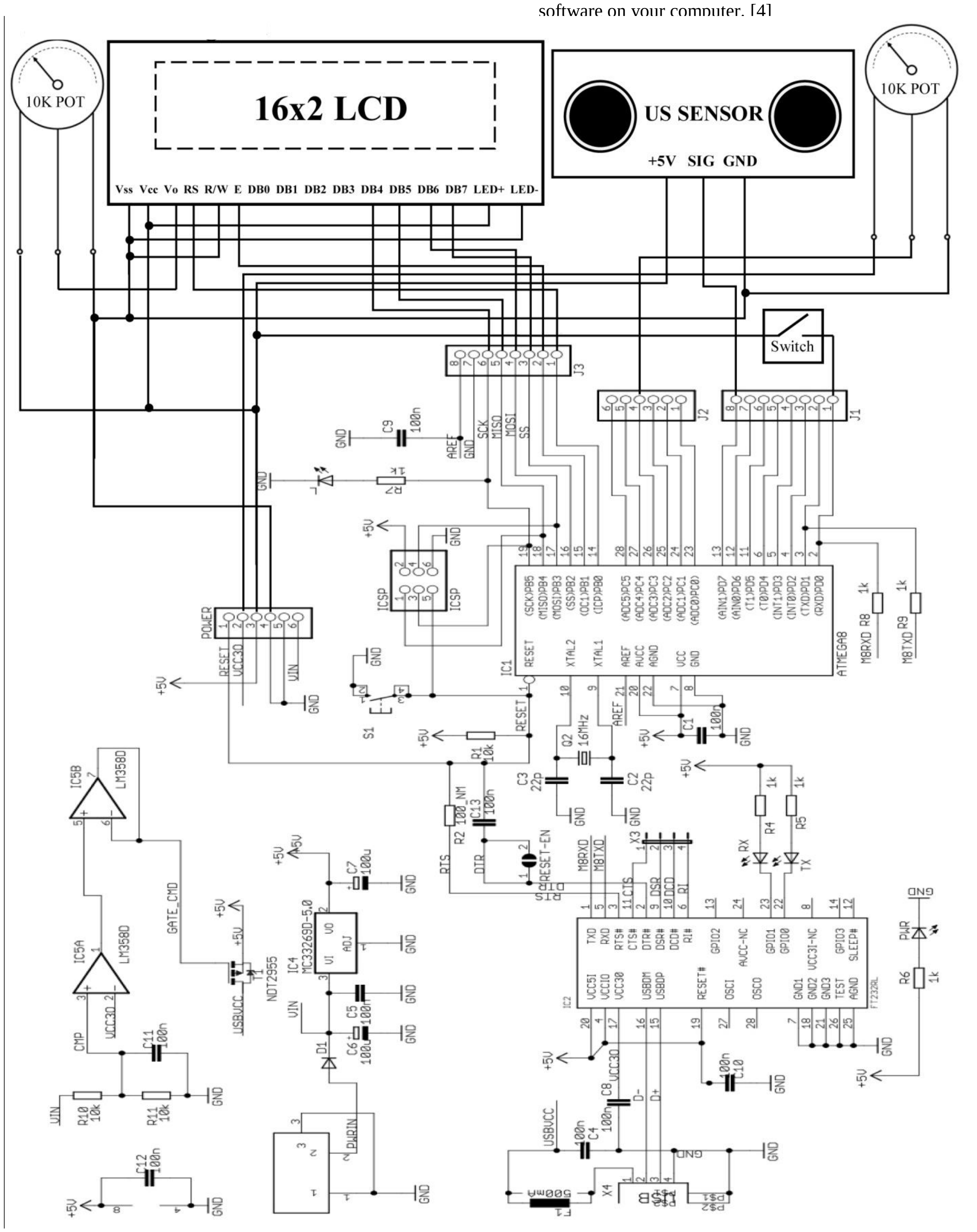

Fig.2. Circuit Diagram

4.1 ARDUINO

Arduino is a physical computing platform based on a simple input/output board and a development environment that implements the 'Processing' language. Arduino can be used to develop stand alone interactive objects or can be connected to software on your computer. [4]

ulti

b. You can program it via USB cable, not a serial port. This feature is useful, because many modern computers don't have serial ports.

c. It is based on the Processing programming IDE, an easy to use development environment used by artists and designers.

Power Supply for Arduino: Arduino processing board may be powered from the USB Port during project developments. However, it is highly recommended that an external power supply be employed. This will allow developing projects beyond the limited current capability of the USB Port. [5]
Power Supply Recommendations: 7 – 12 V DC.

Arduino Software: Software used is called as 'Arduino development environment'. It can be downloaded freely from www.arduino.cc.
Arduino Duemilanove: Here we have used the latest revision of the basic Arduino board called Arduino Duemilanove. The Board is equipped with a USB connecter to allow programming the processor from a host PC. Duemilanove is also equipped with a USB to serial converter to allow compatibility with the host PC and serial communication systems aboard the ATmega 328 processor. It also has several small surface mount LEDs to indicate serial transmission, reception and an extra LED for project use. The header strip at the top of the board provides access for an analog reference signal, PWM signals, digital input output and serial communications. The header strip at the bottom of the board provides analog inputs for analog to digital (ADC) system and power supply terminal. Finally, the external power supply connector is provided at the bottom left corner of the board.[5]

ATmega 328: The host Processor for the Arduino Dueminalove is the Atmel ATmega 328. The “328” is a 28 pin 8bit microcontroller. The architecture is based on the Reduced Instruction Set Computer (RISC) concept which allows the Processor to complete 20 million instructions per second (MIPS) when operating at 20 MHZ. [5]

“328” is equipped with a wide variety of features. The features may be categorized into following systems:
- Memory system
- Port system
- Timer system
- ADC
- Interrupt system
- And the serial communication.

4.1.1. ANALOG TO DIGITAL CONVERSION PROCESS IN ATMEL AT mega 328

The goal of the ADC process is to accurately represent analog signals as digital signals. Before the ADC process, we convert a physical signal into electrical signal with the help of a transducer. The ATmega 328 uses a successive approximation converter to convert an analog sample into a 10 bit digital representation. Successive approximation technique uses a digital to analog converter, a controller, and a comparator to perform the ADC process. Starting from the most significant bit, down to the least significant bit the controller turns on each bit at a time and generates an analog signal. Based on the result of the comparison, the controller changes or leaves the current bit and turns on the next most significant bit. The process continues until decisions are made for all available bits. The advantage of this technique is that the conversion time is uniform for any input, but the disadvantage of the technology is the use of complex hardware for implementation. [5]

The Atmel ATmega 328 ADC system has the following features [5]:
- 10 bit resolution.
- ±2 least significant bit (LSB) absolute accuracy.
- 13 ADC clock cycle conversion time.
- 6 multiplexed single ended input channels.
- Selectable right or left result justification
-0 to Vcc ADC input voltage range.

4.2. ULTRASONIC DISTANCE SENSOR

An Ultrasonic distance sensor measure the length or presence of target objects by sending a pulsed ultrasound wave at the object and then measuring the time for the sound echo to return. Knowing the speed of sound the sensor can determine the length of the object. The ultrasonic distance sensor regularly emits a barely audible click. It does this by briefly supplying a high voltage either to a piezoelectric crystal or to magnetic fields of Ferromagnetic materials. [2] The speed of sound travelling through various media changes appreciably with the media and with temperature and pressure conditions of the media. The sensor must be mounted and aimed to direct the ultrasonic signal toward the material to be sensed to provide the most direct paths of measurement. Measurements can be made for solids or liquids. [1]
Applications:
i) Machine builders
ii) Automation
iii) Process control.
The sensor used here provides very short (2CM) to long range (4M) detection and ranging. The sensor provides precise, stable non contact distance measurements from about 2cm to meters with very high accuracy. Its compact size, higher range and ease of usability make it a handy sensor for distance measurement and mapping.

4.3. H Bridge

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. The device is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications. The H bridge arrangement is usually used to reverse the polarity of the motor but can be also used to apply brakes to the motor. It is built with four switches. The opening and closing of the switches allow a forward and reverse voltage to rotate the motor back and forth. Here we have used L293D IC to aid the control of motor. L293D is a quadruple high current half H driver. The L293D is designed to provide bi-directional drive currents of up to 600-mA at voltages from 4.5V to 36V.

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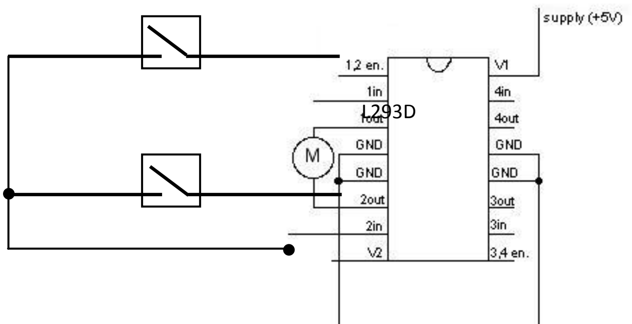

Fig.3. Motor Driving Circuit Diagram

4.4. LASER

The word LASER is an acronym for light amplification by stimulated emission of radiation. The LASER makes use of a process that increase or amplifies light signals after those signals have been generated by other means. These processes include a) stimulated emission, a natural effect that was deduced by considerations relating to thermodynamic equilibrium and b) optical feedback that is usually provided by mirrors. [6]

Properties of LASER:
- LASER light is intense.
- They are narrow and will not spread out like ordinary light beams. i.e. LASER light is coherent.
- LASER produces light of one color only. i.e. LASER light is monochromatic. [7]

Here we use LASER to sharply point out the points between whose length is to be measured.

4.5. DC GEAR MOTOR

A DC Gear motor is basically a regular DC motor with a special gear box attached to the output shaft. DC Gear motor works by gearing down a fast DC Motor to make the motor turn at slower speed and give the motor a higher torque suitable for locomotion. [8]

The power produced by an electric motor can be converted with the help of a series of gears connected to the motor's output shaft. Such a motor is called gear motor. A gear motor can be any type of electric motor, as long as it has a gear box that reduces the output speed of the motor shaft. Each gear motor should have a gear ratio that specifies the ratio of input speed to the output speed of the motor output shaft. [10] We have used a 30RPM DC Motor with Gearbox.

4.6. POTENTIOMETER

Potentiometer is basically a three terminal variable resistance device. [14] It has a sliding contact that forms a voltage divider. It is used to measure an unknown voltage by comparing it with a known voltage. The known voltage may be supplied by a standard cell or any other known voltage. [11] A potentiometer can also be used as a basic analog position transducer for measuring linear and angular displacement. [13] Potentiometers having rotary motion are called rotary potentiometers. If the movement of the slider is in a circular path along a resistance element, rotational information is converted to information in the form of a potential difference. The output of the rotary transducer is proportional to the angular movement. [3]

Other Applications of Potentiometers:
a) Calibration of voltmeters, ammeters, watt meters etc.
b) Measurement of resistance.
c) Measurement of power.

A 10K rotary potentiometer capable of rotating 270 degrees is used here. The potentiometer movement is on logarithmic scale. i.e. the output voltage is a logarithmic function of the mechanical angle of potentiometer.

4.7. LCD DISPLAY

Liquid Crystal Displays (LCDs) are familiar devices in Laptop computers and in Desktop applications as well. An LCD device is a two dimensional electro optical light modulator that is placed in front of a backlight. The light is modulated at each pixel location by applying an electric field to a thin layer of pneumatic liquid crystal placed between crossed polarizers. The luminance of an LCD display is limited only by the intensity of the backlight. [9] The Liquid crystal display has the distinct advantage of having low power consumption than LED. Its other advantages are low cost and good contrast.

The applications of LCDs are display of numeric and alphanumeric characters in segmental and dot matrix displays. [12] A basic 16 character by 2 line display was used here. It has LED back light and works both in 4bit and 8bit modes.

5. RESULT

The results obtained were as expected and can be discussed as follows:

Table.1. Observation

Serial no.	Distance between the instrument and the plane (m)	Actual length between the points (m)	Observed length between the points (m)	Percentage Error (%)
1	0.750	0.300	0.299	+0.330
2	0.750	0.400	0.396	+0.910
3	0.750	0.500	0.495	+0.930
4	0.750	0.600	0.604	-0.800
5	0.750	0.700	0.696	+0.530

Table.2.

Serial no.	Distance between the instrument and the plane (m)	Actual length between the points (m)	Observed length between the points (m)	Percentage Error (%)

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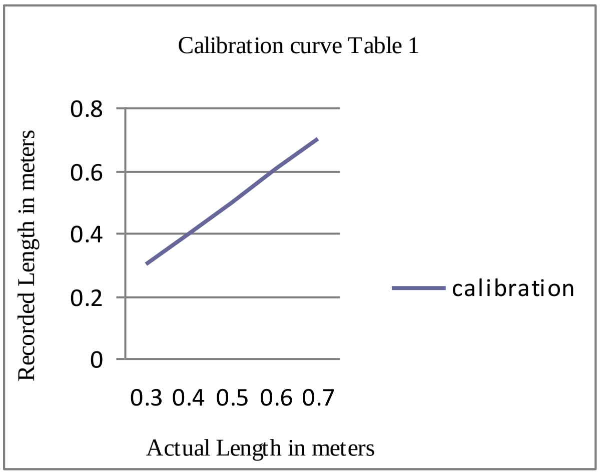
1	1.000	0.300	0.297	+1.000
2	1.000	0.400	0.402	-0.500
3	1.000	0.500	0.504	-0.800
4	1.000	0.600	0.598	+0.333
5	1.000	0.700	0.685	+0.714

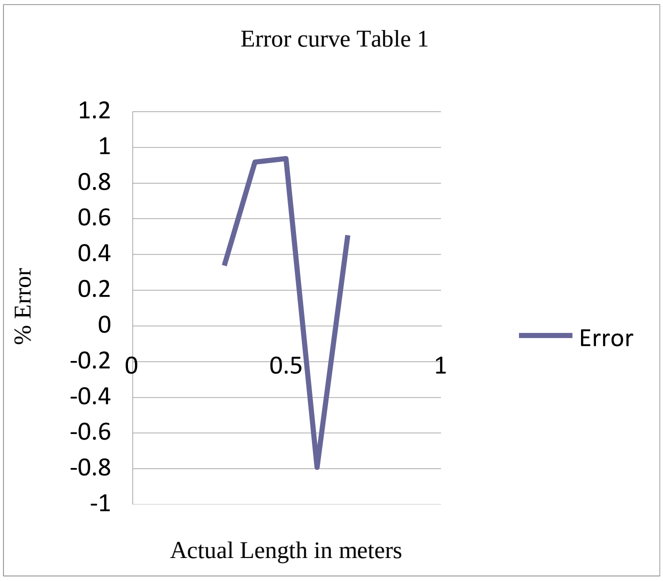
Table.3.

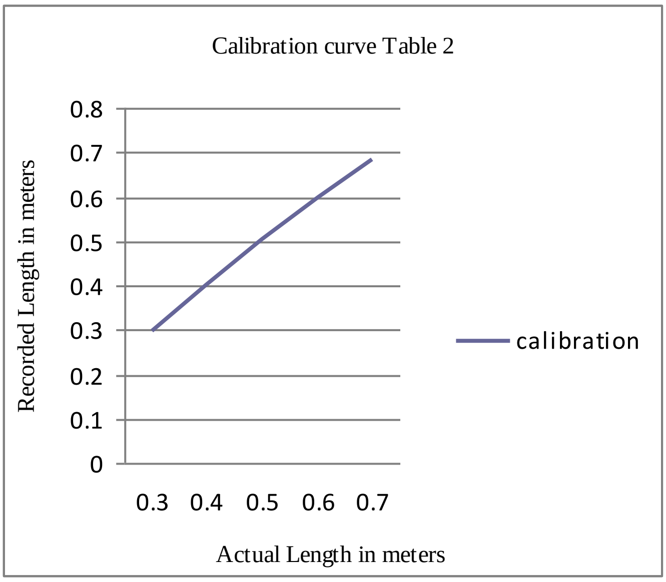
Serial no.	Distance between the instrument and the plane (m)	Actual length between the points (m)	Observed length between the points (m)	Percentage Error (%)
1	1.500	0.300	0.301	-0.333
2	1.500	0.400	0.397	+0.750
3	1.500	0.500	0.503	-0.600
4	1.500	0.600	0.595	+0.833
5	1.500	0.700	0.704	-0.571

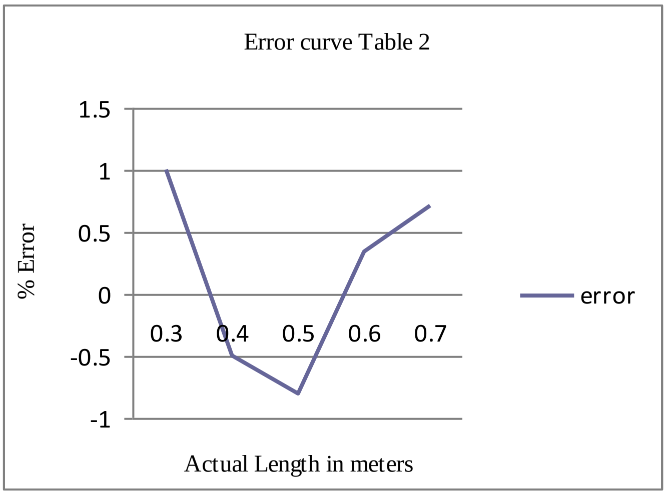
Table.4.

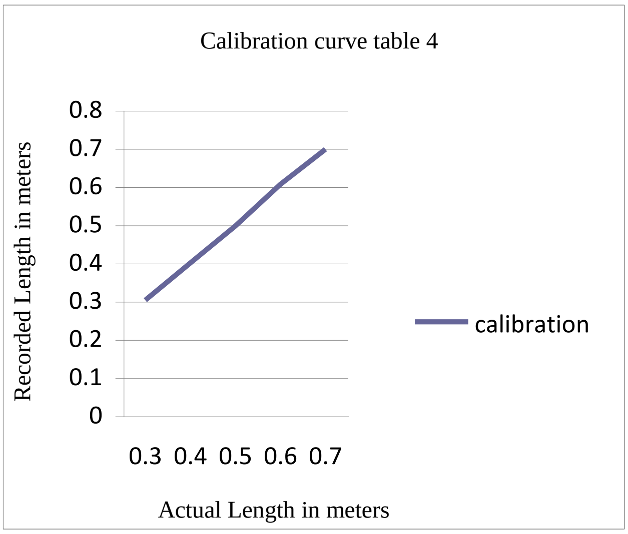
Serial no.	Distance between the instrument and the plane (m)	Actual length between the points (m)	Observed length between the points (m)	Percentage Error (%)
1	2.250	0.300	0.302	-0.666
2	2.250	0.400	0.399	+0.250
3	2.250	0.500	0.496	-0.800
4	2.250	0.600	0.605	-0.833
5	2.250	0.700	0.697	+0.428

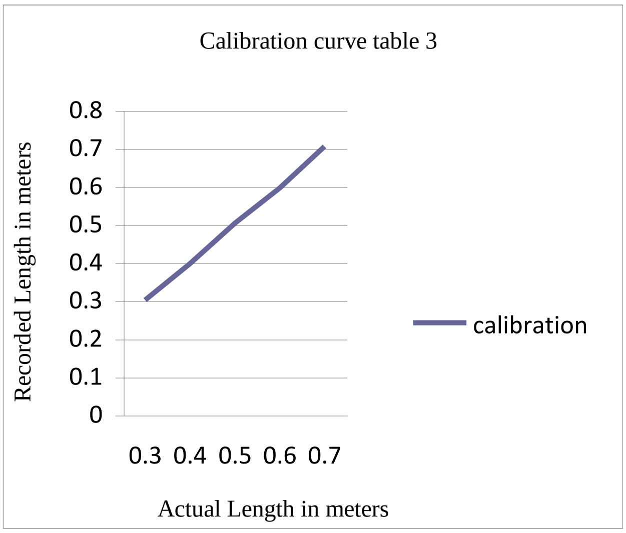


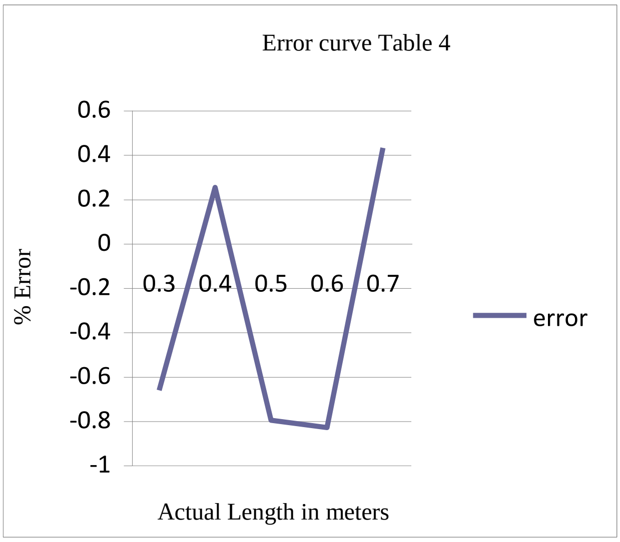


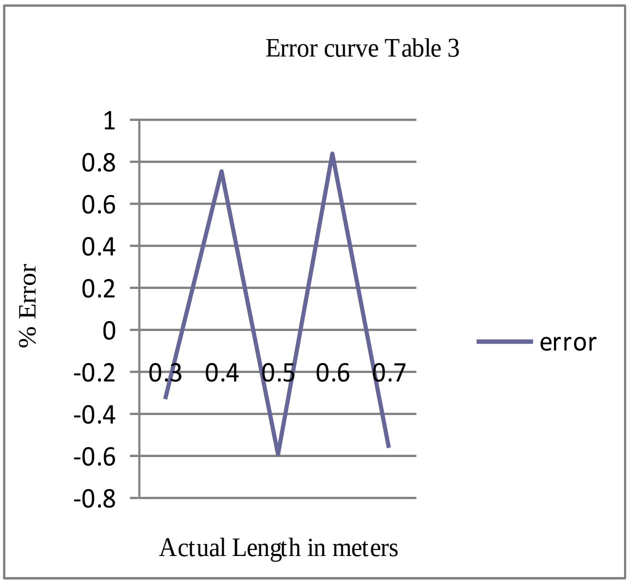












6. CONCLUSION

The indirect length measurement system has been successfully introduced. A microcontroller board based on ATmega 328 was used to perform the software tasks. The time taken to take the reading is considerably reduced with the use of this system. The errors that occur are very minute and the calibration curves are linear. The observations from the error and calibration curves clearly depict the excellence of the system and its capability to measure lengths between any two points from a remote plane with superior precision and accuracy. It is made user friendly so that anybody can operate the system without trouble. So it can be concluded that the indirect length measurement system presented here can effectively replace other systems in terms of accuracy, ease of operation, cost and reliability.

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