Development of Microcontroller Caliper.

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ABSTRACT

The process by which an electronic quantity is detected and measured remains essentially the same, but the equipment used has undergone great changes in accuracy, range, ease of operation, and reliability. This paper addresses the design, analysis, and construction of a digital caliper. The design analysis is presented by applying the appreciation of the techniques used to convert a direct analogies voltage to a digital display via the analog-to-digital conversion (ADC) techniques. The techniques employed were based on voltage generated from the variable potentiometers and feed into the ADC, which converts analog signal to digital equivalent, while a microcontroller is used to coordinate the system operation, save, and process the digital output of the converter, and to the seven segment display unit which display the measured values. It will measure length, diameter or thickness as an object in centimeter with accuracy of ±0.1 cm, digital display measurement and with little power consumption.

(Keywords: potentiometer, analog to digital converter, ADC, microcontroller, LED)

INTRODUCTION

Modern technology has made immense strides in the development of instrumental means of information acquisition from physical objects and events. The information is encoded in the form of a physical signal and can be output in the form of a number representing a physical signal and can be processed by a variety of information machines. The information can be output in the form of a number representing a physical property, in other word a measure. These powerful modern means of information acquisition and processing constitute the nerves and brain of an immerse variety of modern technical systems, for measurement.

Measurement of voltage using a DC resistance potential divider is achieved by a high-non inductive resistance, across which a small portion of it is attached to a voltmeter. Wheatstone bridge is another means of measuring voltage by comparison process and resistance value may be determined by comparing voltage drops across a known and unknown resistor. Venire caliper and micrometer screw gauge can also be used to measure the length, thickness and diameter of an object.

The above mentioned methods and instruments for measuring voltage and length are good in producing the result with the least uncertain a greater amount of skill, experience, and absolute seriousness of the user. In addition, they are clumsy, require meticulous handling, and the time required to perform the measurement may be quite large.

Therefore, the need for a digital instrument with certain features like the ease of reading the output, quick reading, and simplicity of use is essential. The aim of this paper is to design and construct a digital caliper that satisfies all the above requirements.

Digital instruments are intelligent instruments that can make decisions, based on previous readings, manipulate information, process values, and initiate actions based on the results of these abilities. They have certain feature that makes them very attractive for certain applications. These are, the ease in reading the output, digital coded output, which can be feed directly to a digital computer.

In view of the above mentioned qualities of digital instruments, the aim of this paper was to build a digital caliper that will have almost all of the qualities of a good digital instrument. It measures length, diameter, or thickness of an object in centimeters, with accuracy of ± 0.1cm, with a digital display of the measurement and with little power consumption.

Potentiometer: The function of the potentiometer as a transducer is to transform an input displacement of the slider into a proportional voltage. The basic element is usually a coiled wire or strip of conducting material.

Design Calculations: The circuit consists of a source of EMF, a variable resistor and a resistance wire AB of length L. A sliding contact C may connect anywhere along L and x from A. If no current is taken through the contacts A and C, then the current I is the same through ACB.

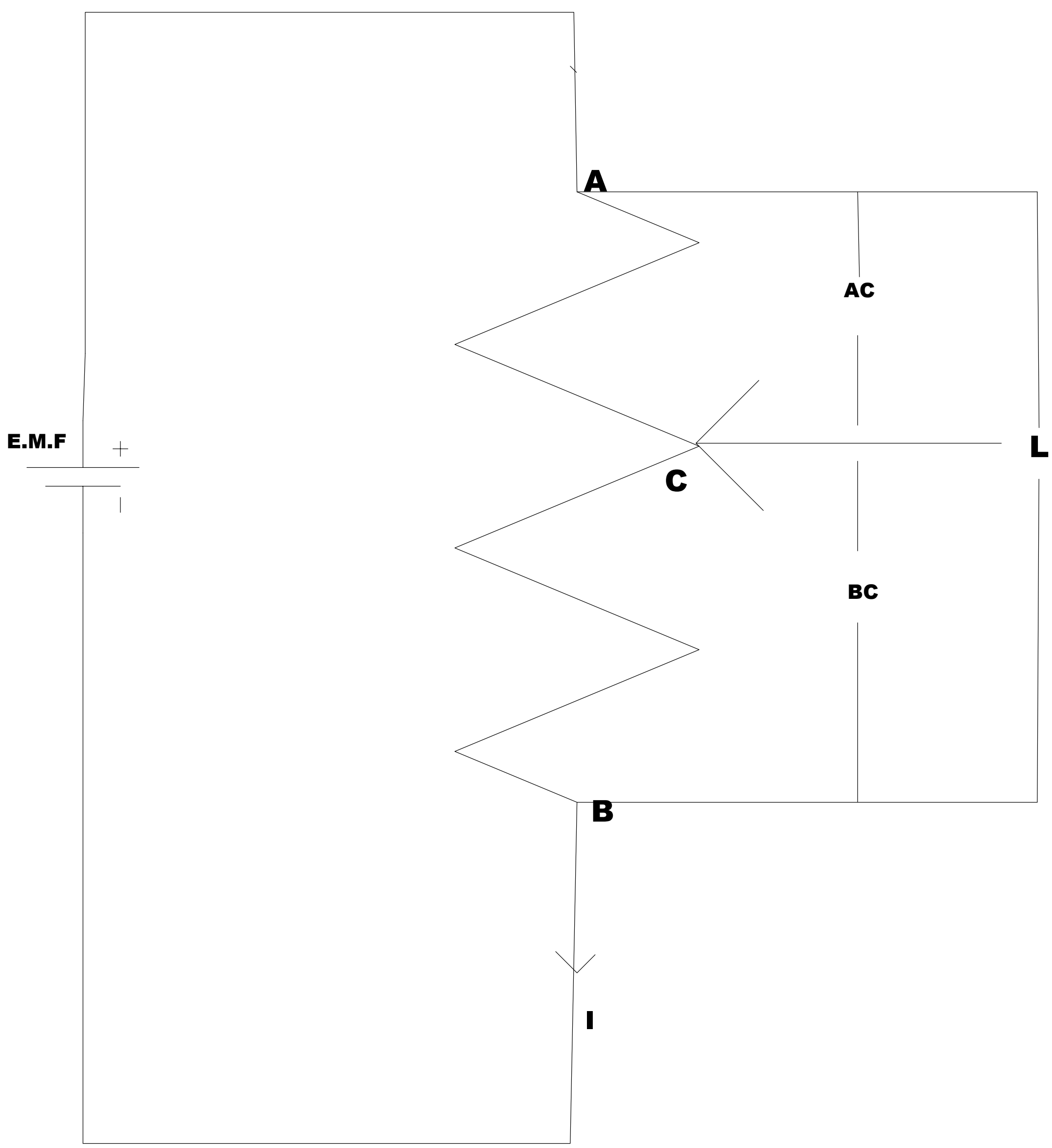

Figure 1: Potentiometer.

$V_{ab}=IR_{ab}$

$V_{ac}=IR_{ac}$

therefore,

$$\frac{Vab}{Vac} = \frac{IRab}{IRac} = \frac{Rab}{Rac}$$

Also, if the resistance of the wire is proportional to its length, then,

R_{ab} = constant x ab

R_{ac} = constant x ac

$$\therefore \frac{Vab}{Vac} = \frac{constant*ab}{constant*ac}$$

$$\frac{Vab}{Vac} = \frac{ab}{ac} = \frac{L}{X}$$

$$X = \frac{Vac}{Vab} * L$$

Thus, if V_{AB} is maintained at a constant value, V_{AC} may be measure and is proportional to this distance x.

If the instrument is to sense a dimension of 0.1am, then the voltage across the length of the wire AB is determined by:

Resolution of the ADC = $V_{ref/2}{}^{8}$ = 5V/256 = 0.01953V

For 0.1cm

If 0.01953V ≡ 0.1cm

IV = 0.1cm/ 0.01953 = 5.12cm

5V = 5.12cm x 5 = 25.6cm

In this paper, it is require designing a caliper of length 8.0cm. Therefore, the voltage across the length (L = 8.0cm) of the wire is given by:

IV = 5.12cm

1cm = IV/5.12 = 0.1953v

;. 8.0cm = 0.1953v x 8.0 = 1.563v

Voltage across the length L = 1.563v

Voltage across variable resistor = 5 - 1.563 = 3.437v.

The resistance of the wire = 9.4km.

The value should be high enough in order to prevent the wire from heated up.

The value of the variable resistor can be calculated by voltage divider theorem:

$$V_R = \frac{R}{9400+R} * 5$$

$$3.437 = \frac{(R*5)}{9400+R}$$

3.437 (9400 + R) = 5R

R = 20.68kΩ

The Analog-to- Digital Converter: To convert the analog voltage equivalent of the sensed length to its equivalent digital value, which can be manipulated by system controller, an interface device capable of translating the quantity from the analog domain to digital is needed. This is realized using an ADC 0804 8-bit analog-to-digital converter. It belongs to the ADC 080X family, which is a Cmos 8-bit, successive approximation ADC that uses a differential potentiometric ladder for conversion. The device is package in 20-pin DIP package. The key features are listed below:

- Compatible with 8080 microprocessor derivates.
- Easy interface to all microprocessors, or operates stand alone.
- Differential analog voltage inputs.
- Logic inputs and outputs meet both CMOS & TTL voltage level specifications.
- On-chip clock generator.
- Resolution of 8-bit.
- Conversion time of 100 microseconds.

The device is capable of operating on a clock frequency up to 1.4MHZ.

The analog voltage from the potentiometer is applied to pin 6 and 7 of the ADC. The binary equivalent is available at pin11 through pin 18 (DB7—DB0). Pin1 & 2 (chip select CS and RS) were connected to ground so that the chip should be always enabled. ADC 0804 includes an internal oscillator which requires an external capacitor and a resistor to operate. 150PF capacitor is connected from pin 4 (clock in) to ground and 10kohms resistor from pin 4 to pin 19(clock R). The device is run at a clock frequency given by RC combination on pin 19 as: F= 1/1.1RC. R= 10Kohms and C=150PF.

The conversion is initiated by pulsing the WR pin low and then high and completed about 100microsecond after, and the INTR pin goes low to indicate end of conversion

The device is configured for system operation as shown in Figure 2.
The device as shown is interfaced with system controller over port 1 and two pits on port 3(P3.0 & P3.1). A reference voltage of 1.563V was set on pin 9 (Vref) to establish the relationship between the input analog voltage and the digital output voltage.

SYSTEM CONTROLLER

Microcontroller is employed in modern electrical system today to co-ordinate the system operation. An AT89S51 microcontroller is used in this project to capture, save and display digital data. The device possessed the following standard features.

- 4KB of in-system programmable flash memory.
- 128 bytes of internal ram.
- 32 programmable input/output lines.
- Two 16-bits timer/counter

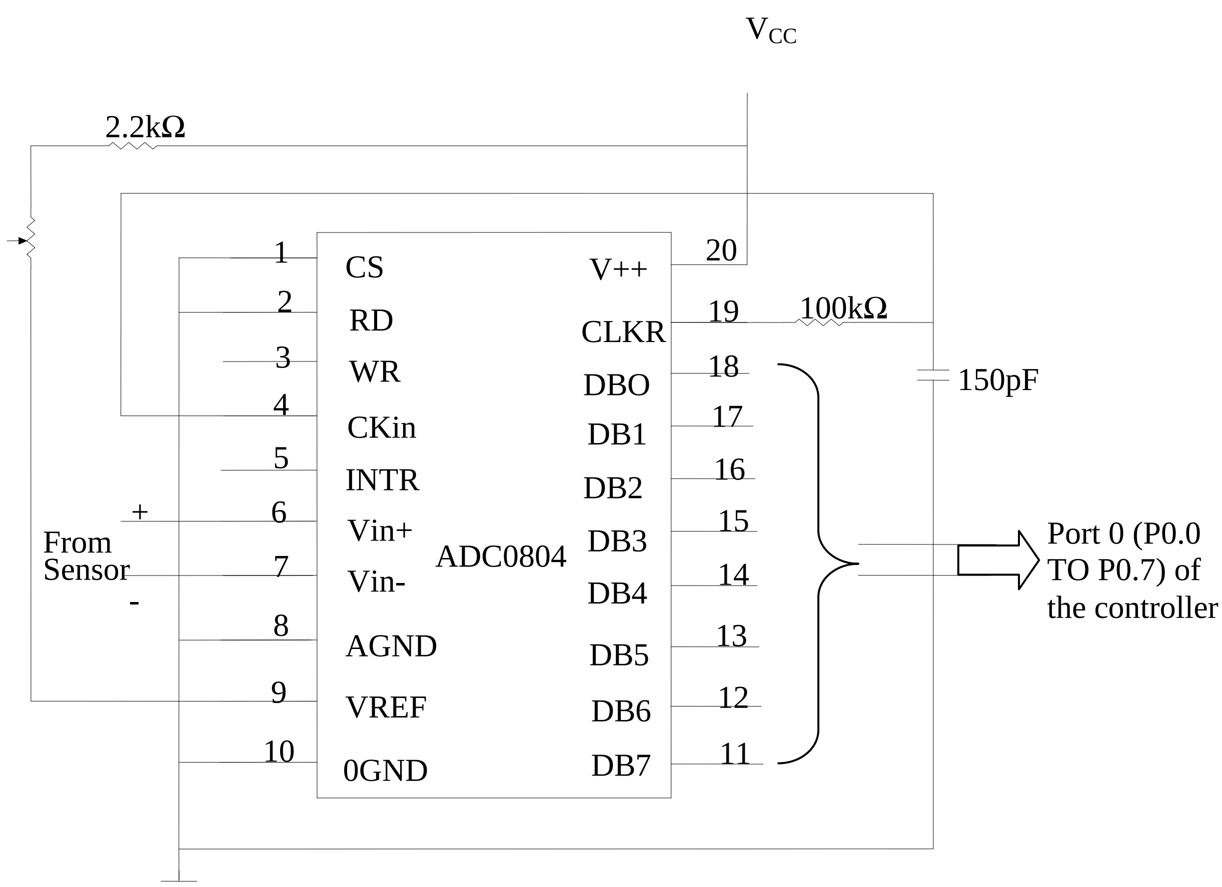

Figure 2: The Interface between ADC and Controller.

The device is a low power, high performance, CMOS 8-bits microcontroller with 4KB of flash programmable and erasable read only memory (PEROM). The on chip flash allows the program memory to be reprogrammed in system or by a conventional non volatile memory programmer.

The device is programmed to control the whole system via software written in assembly language. The 18.432MHZ crystal was connected to the device to provide the required clock pulse for the controller to execute instructions. The circuit connection is shown Figure 3 below.

The device as shown is interfaced with ADC through port 1. P2.0 — P2.3 controlled the four transistors used for display multiplexing. Port 0 interfaced with 4-dgits common-anode seven segment display operating in the multiplexed mode. The order by which each of the four segments displayed is controlled by the four transistors. The device executes the system control software from power on till power off. The system controlled software consists of the following main bodies of the code.

1. Power up system initialization.
2. Conversion via ADC.
3. Processing of digital value.
4. Writing of data to display
5. Loop to 2

The software turns the anode drivers (transistors) on and off at a high speed, giving the illusion of the stationary display. In reality only one digit position is on at a time. The processing of digital equivalent of the ambient temperature is done in the following stages:

- Start conversion.
- Take 2 reading from ADC and find the average.
- Convert the average reading to BCD digits.
- Convert the BCD digits to 7-segment code.
- Refresh the display.

The conversion of the binary ADC value to BCD value is effected using repeated division. The BCD to 7-segment encoding is affected via a look-up table where the 7-segment 8-bit codes were stored. The table is referred via the content of the accumulator. Writing the 7-segment code to port 0 and turning on the anode driver for the corresponding digit position writes the value to the display.

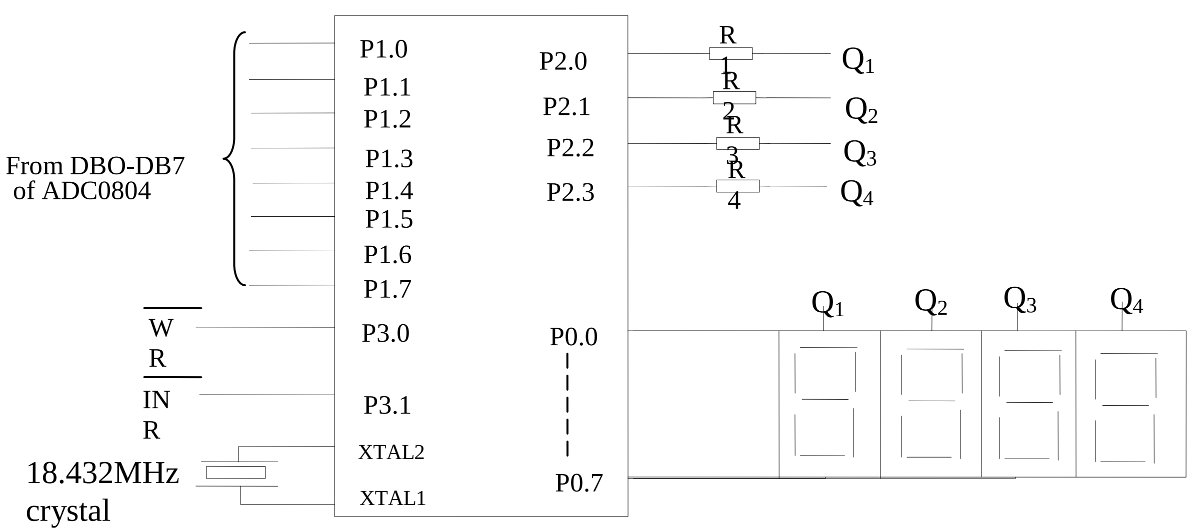

Figure 3: Microcontroller Circuit Connection.

OUTPUT DISPLAY UNIT

The unit basically consists of four-control transistors and four-seven segment display and a multiplexed 4-digit 7 segment display were used. The display is wired with all their common cathodes wired together (i.e., all the ‘a’s, on the 4-digits were interconnected, the ‘b’s, ‘c’s, etc). The segment is interfaced with microcontroller through port 0. The digits were controlled by digits drivers (2SA1015GR PNP transistors). The display requires an I_{LED} of 20mA at V_F of 1.7V. Since no current limiting resistors were used in series with segments, the current through them had to be tightly regulated. The maximum I_C current is programmed using R_B resistors in the base-emitter circuit of each anode driver. The circuit diagram of the unit is shown in fig 4 below.

The transistor used has an HFE (gain) of 200 for any-digits display, the average forward current through each segment is $n*I_L$, for equal brightness. For a 4-digits display, with each LED running with a steady forward current of 20mA, 80mA of pulsed current is therefore required for acceptable brightness.

$I_B = I_C/hfe$
$= 80mA/200$
$= 400\mu A$.

R_B is calculated via the expression;

$$R_B = \frac{V_E - V_{BE} - Voi\ (8951)}{I_B}$$

$V_E = 5V$, $V_{BE} = 0.7V$, $V_{OI}\ (8951) = 0.2V$,
$I_B = 400\mu A$

$$R_B = \frac{5-0.7-0.2}{400\mu A} = 10250\Omega = 10.25K\Omega$$

This value is noticed to produce a dull display. A 1KΩ R_B resistance is used instead and it produced a display with full brightness. A display program involves the under listed sequence of software events.

1. Turn off all digit drivers(Q1—Q4)
2. Write 7-segment code of value to display to common data port.
3. Turn on the associated digital driver.
4. Delay for visibility.
5. Turn off the digit driver.
6. Go to 2.

The above process was done at a high rate, the software time to provide a display refresh of about 250Hz. For a refresh frequency greater than 50Hz, the illusion of persistence is realized and the eyes see a continuously light 4-digit display. In actuality, only one digit position is on at a time.

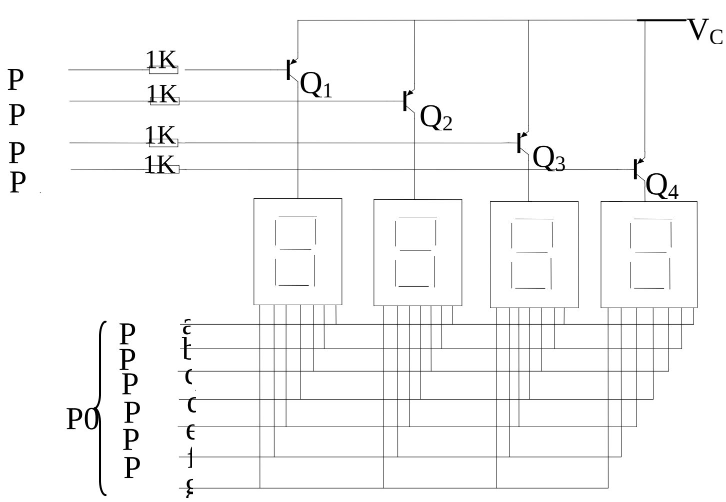

Figure 4: Display Unit.

CONCLUSION

The aims and objectives of this project were to design and construct a device that can measure the length, thickness, and diameter of an object and display it on a visual digital display. The aims and objectives were achieved because the digital caliper constructed was able to measure the length and thickness of wire and display it on a visual digital display. The system worked accordingly to specification and quite satisfactory. The microcontroller caliper is relatively affordable, reliable, and it is easy to operate.

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