2018

# UNI-COMPRESSIVE STRAIN MEASUREMENT OF ROCK SAMPLES USING PIC MICROCONTROLLER

Final Report of Summer Fellowship Under IAS Fellowship Program

Under the Guidance of

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Submitted by:

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# ***CERTIFICATE***

This is to certify that ***Kumari Renuka*** of B Tech (**Computer Science and Engineering)** of NIIT University, Neemrana have successfully completed the Summer Research Fellowship Program at CSIR-National Geophysical Research Institute, Hyderabad on the project entitled **" Uni-Compressive Strain Measurement of Rock Samples Using Pic Microcontroller”.** The project was carried out from 25$^{th}$ May 2018 to 24$^{th}$ July 2018.

The project on evaluation fulfils the start criteria and the student’s work is her original work.

Mr. Sateesh Chandrapuri
Scientist
Electrical Geophysics
CSIR-NGRI, Hyderabad

# *DECLARATION*

I, ***Kumari Renuka***, student of B Tech (**Computer Science and Engineering)** of NIIT University, Neemrana, have completed my summer internship work entitled "**Uni-Compressive Strain Measurement of Rock Samples Using Pic Microcontroller**" is solely based on the work carried out by me during May 25th, 2018 to July 24th, 2018 under the guidance and supervision ***of Mr. Sateesh Chandrapuri***, Scientist, Electrical Geophysics, CSIR – National Geophysical Research Institute, Hyderabad.


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# *ACKNOWLEDGEMENT*

First and foremost, I would like to thank Indian Academy of Sciences (IAS) for providing me the **IASc-INSA-NASI Summer Research Fellowship 2018**. This gave me a great opportunity to pursue summer research project on "**Uni-Compressive Strain Measurement of Rock Samples Using Pic Microcontroller**" under the guidance of **Mr. Sateesh Chandrapuri** for a period of 59 days from **25th May to 24th July, 2018** at **CSIR-NGRI, Hyderabad**.

I would like to express my profound gratitude and sincere thanks to my guide **Mr. Sateesh Chandrapuri,** Scientist, of Electrical Geophysics Department, **CSIR – National Geophysical Research Institute, Hyderabad,** for his exemplary guidance, monitoring and constant encouragement and for providing me invaluable time and information which added value and quality to the project. Secondly, I would like to thank each of our **fellow teammates** for their equal and invaluable contribution towards the making of this project successful. Without the whole team working dedicatedly for the assigned project, we wouldn't have been able to complete the project at this scale on time.

Next, I would also like to extend my special thanks of gratitude to **The Director** of **CSIR-NGRI** for providing me an opportunity to be the part of **summer trainee** at CSIR-NGRI for Summers 2018. I would also like to thank all the scientist and staff members for their constant support during my stay at CSIR- NGRI, Hyderabad. I would like to appreciate all the research scholars at NGRI for making my sojourn so enjoyable that will remain in my memory for a long time to cherish sincere gratitude.

And lastly, I would like to thank **Professor Prosenjit Gupta**, **Head of Department of Computer Science and Engineering of NIIT University** for the constant support and for the letter of recommendation. I learned a lot through the project during my stay at CSIR-NGRI, Hyderabad. The knowledge acquired during the internship period would definitely help me to frame my career in the future.

Renuka

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# CHAPTER 1

# INTRODUCTION

The uniaxial compressive strength (UCS) is the maximum axial compressive stress that a right-cylindrical sample of material can withstand before failing. It is also known as the unconfined compressive strength of a material because confining stress is set to zero. It is used to measure the strength of rock or soil sample when crushed in one direction without lateral restraint between the two plate which are moving towards each other gradually. Uniaxial compressive strength is one of the most important mechanical properties of rocks which is mainly used for the design of structures and characterization of intact rock materials. It is mainly used to determine the failure strength of an intact rock specimen.

In National Geophysical Research Institute, to determine the UCS the rock mechanics department make use of Universal Testing Machine (UTM) for applying huge amount of pressure. Currently, they are able to measure only the breaking point of the rock samples.

We are trying to make a prototype system for the measurement of the tensile and compressive strength of rock samples by providing an interface between the load cell and PIC microcontroller. We will also be using the temperature and humidity sensor (HDC1080) for monitoring surrounding humidity and temperature around the sample. The data generated by the load cell and the various sensors will be send to the PIC microcontroller through ADC which will then be displayed in LCD, subsequently the data would be transferred to computer through serial communication for storage and further can be used for real-time processing and data analysis.

We have experimented with three rock samples which are basalt rock, coarse granite rock and granite rock with the successful data collection to the computer. Now, we are using the data for the further processing in order to obtain the values of different parameters of rock samples. Hence, the performance of the different parameters will be shown through graphical representation after the successful analysis of the data.

***Keyword-*** universal testing machine (UTM), uniaxial compressive strength (UCS), PIC microcontroller (18F452), temperature and humidity sensor (HDC1080), Analog to Digital convertor (ADC- HX711), Serial communication (RS232), load cell and LCD.

# CHAPTER 2

# COMPONENT DESCRIPTION

## 1) PIC 18F452

This powerful 10 MIPS (100 nanosecond instruction execution) yet easy-to-program (only 77 single word instructions) CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful PIC architecture into a 40- or 44-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX, PIC16CXX and PIC17CXX devices and thus providing a seamless migration path of software code to higher levels of hardware integration.

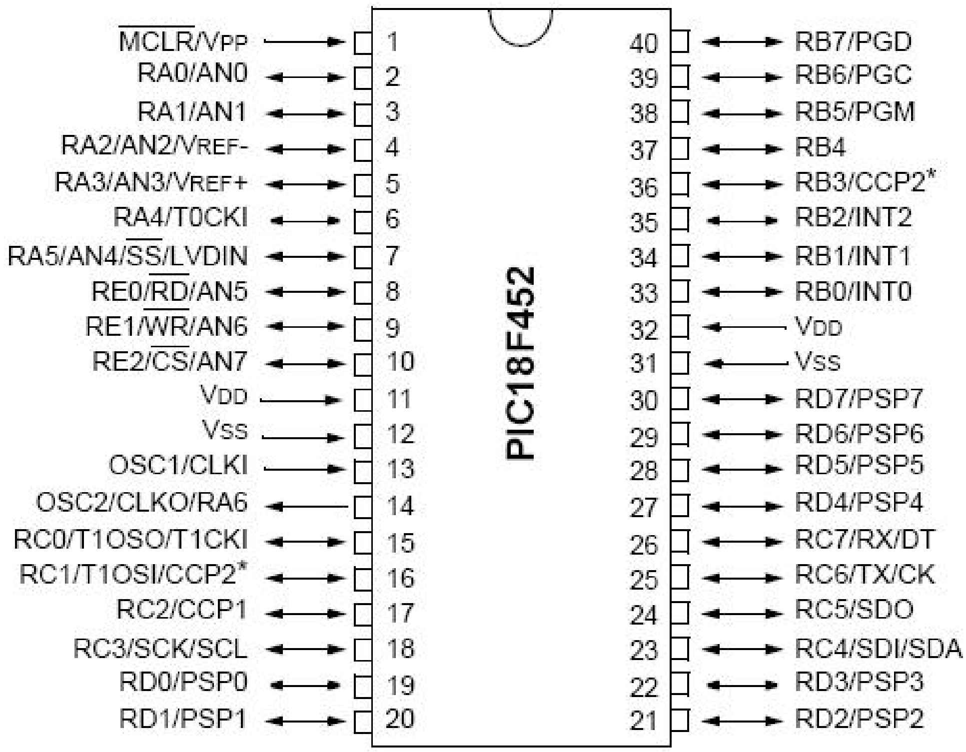



**FIG 1: PIC 18F452 PIN DIAGRAM**

The PIC18F452 features a 'C' compiler friendly development environment, 256 bytes of EEPROM, Self-programming, an ICD, 2 capture/compare/PWM functions, 8 channels of 10-bit Analog-to-Digital (A/D) converter, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI) or the 2-wire Inter-Integrated Circuit ($I^2C$) bus and Addressable Universal Asynchronous Receiver Transmitter (AUSART). All of these features make it ideal for manufacturing equipment, instrumentation and monitoring, data acquisition, power conditioning, environmental monitoring, telecom and consumer audio/video applications.


**FIG 2: PIC 18F452**

## 2) LCD DISPLAY

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical, easily programmable, have no limitation of displaying special and even custom characters (unlike in seven segments), animations and so on.

A **16x2 LCD** means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. The data can have any ASCII value between 0 and 255.

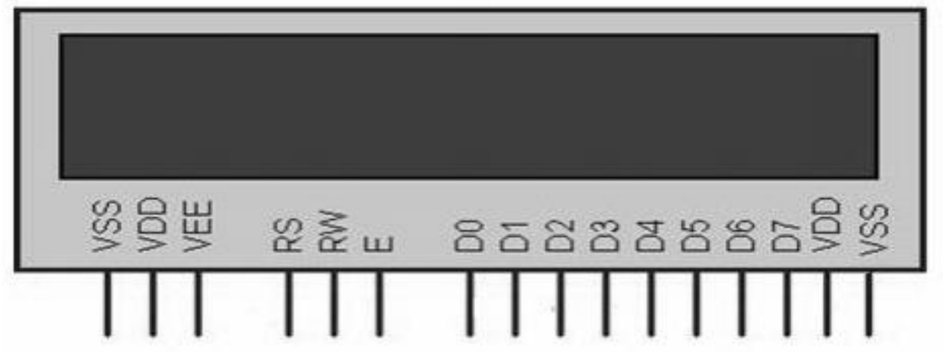



**FIG 3: LCD DISPLAY PIN DIAGRAM**

## 3) VOLATAGE REGULATOR(LM7805)

LM78XX/LM78XXA 3-T March 2008 LM78XX/LM78XXA3-Terminal 1A Positive Voltage Regulator Features General Description Output Current up to 1A The LM78XX series of three terminal positive regulators, 1A P Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24 are available in the TO-220 package and with several Thermal Overload Protection fixed output voltages, making them useful in a wide range of applications. Each type employs internal current Short Circuit Protection limiting, thermal shut down and safe operating area pro- Output Transistor Safe Operating Area Protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output positive current. 7805 is a famous IC which is being widely used in 5V voltage regulator circuits.

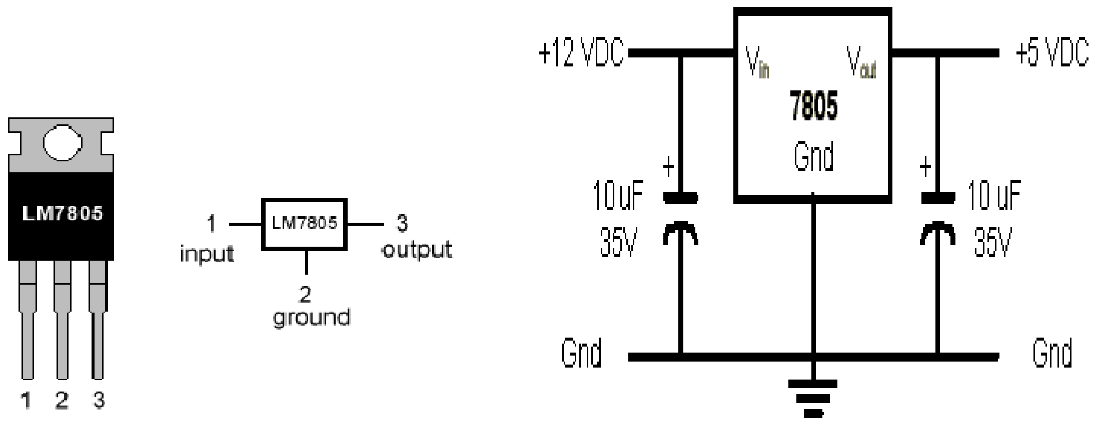



**FIG 4: VOLTAGE REGULATOR CIRCUIT DIAGRAM**

## 4) CRYSTAL OSCILLATOR

A Crystal Oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a precise frequency. This frequency is commonly used to keep track of time, as in quartz wristwatches, to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. Here we are using crystal oscillator of frequency 20MHz to provide the clock input to the PIC Microcontroller.

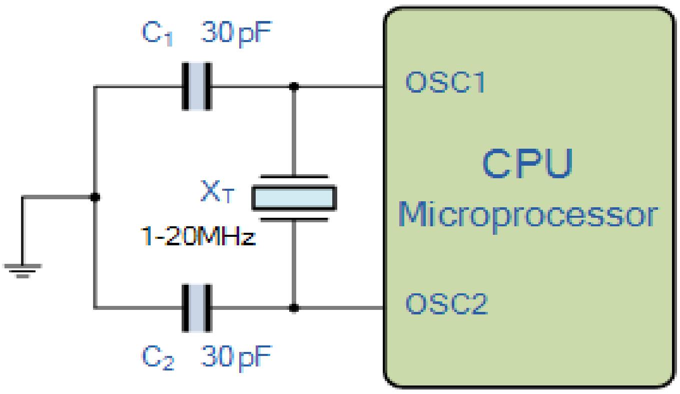




**FIG 5: CRYSTAL OSCILLATOR**

## 5) WHEATSTONE BRIDGE

A Wheatstone bridge is a divided bridge circuit used for the measurement of static or dynamic electrical resistance. The output voltage of the Wheatstone bridge circuit is expressed in millivolts output per volt input. In order to measure strain with a bonded resistance strain gauge, it must be connected to an electric circuit that is capable of measuring the minute changes in resistance corresponding to strain. Strain gauge transducers usually employ four strain gauge elements electrically connected to form a Wheatstone bridge Circuit.

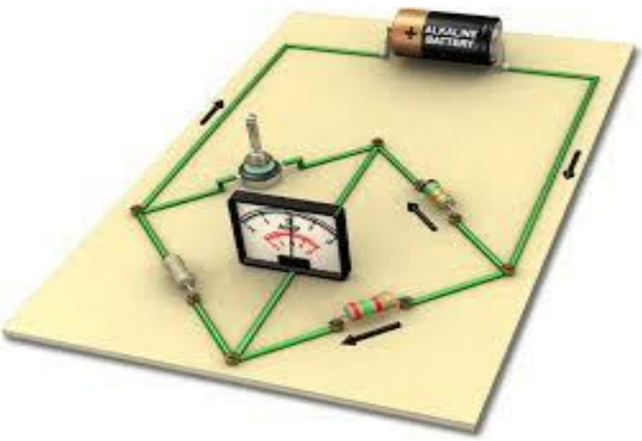



**FIG 6: WHEATSTONE BRIDGE**

## 6) STRAIN GAUGE

A strain gauge is a device that used to measure the strain of an object and convert the load acting on them into electrical signals. Due to application of load, strain changes the electrical resistance of the gauge in proportion to the applied load.

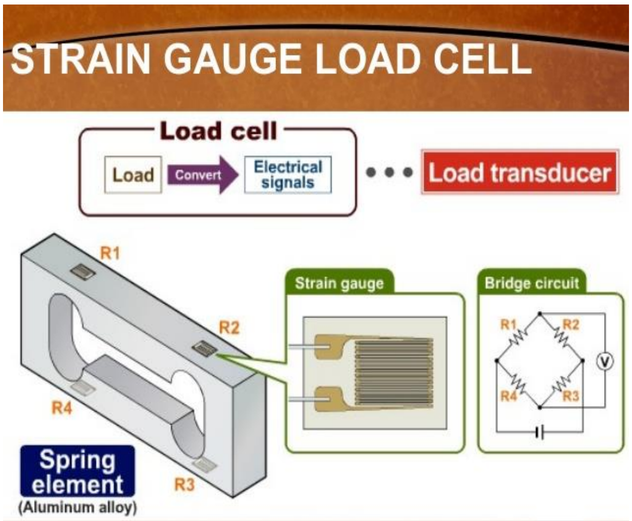



**FIG 7: STRAIN GAUGE**

## 7) LOAD CELL

Load cell is a type of transducer which performs the functionality of converting force into an electrical output which can be measured. It is a device that measures strain and then convert force into electrical energy which serves as measurement for further processing. It is used in industrial scales, load test machines etc.

***Types of load cells-***

- ***Single Load Cell-*** a load cell is located under a platform that is loaded with a weight from above
- ***Bending Beam Load Cell-*** several load cells are positioned under a steel structure and are loaded with a weight from above
- ***Compressive Force Load Cell-*** several high capacity load cells are positioned under a steel structure that is loaded with a weight from above
- ***Tensile Load Cell-*** a weight is suspended from one or more load cells.


**FIG 8: LOAD CELL**

## 8) CAPACITORS

A capacitor, is a passive two-terminal electrical component that stores potential energy in an electric field. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit.


**FIG 9: CAPACITOR**

An electrolytic capacitor (e-cap) is a polarized capacitor whose anode or positive plate is made of a metal that forms an insulating oxide layer through anodization. This oxide layer acts as the dielectric of the capacitor. A solid, liquid, or gel electrolyte covers the surface of this oxide layer, serving as the (cathode) or negative plate of the capacitor. Due to their very thin dielectric oxide layer and enlarged anode surface, electrolytic capacitors have a much higher capacitance-voltage (CV) product per unit volume compared to ceramic capacitors or film capacitors, and so can have large capacitance values. There are three families of electrolytic capacitor: aluminium electrolytic capacitors, tantalum electrolytic capacitors, and niobium electrolytic capacitors.

## 9) RESISTOR

The resistor is a passive electrical component to create resistance in the flow of electric current. In almost all electrical networks and electronic circuits they can be found. The resistance is measured in ohms. An ohm is the resistance that occurs when a current of one ampere passes through a resistor with a one volt drop across its terminals.

Resistors are used for many purposes. A few examples include delimit electric current, voltage division, heat generation, matching and loading circuits, control gain, and fix time constants. They are commercially available with resistance values over a range of more than nine orders of magnitude.  They can be used to as electric brakes to dissipate kinetic energy from trains or be smaller than a square millimetre for electronics.

**FIG 10: RESISTORS**

## 10) POTENTIOMETER

A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat. Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment. Potentiometers operated by a mechanism can be used as position transducers.

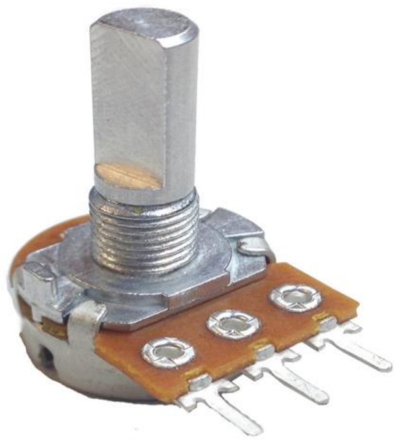
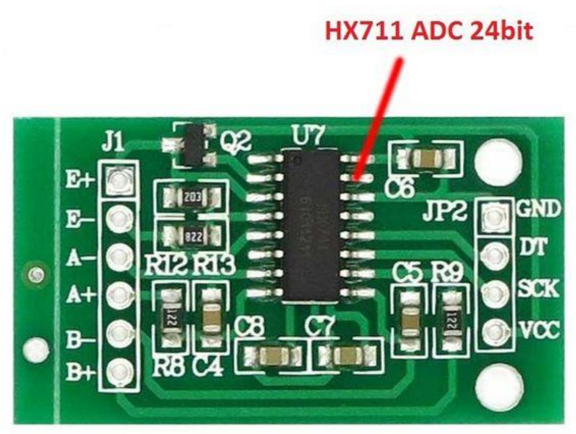


**FIG 11: POTENTIOMETER**

## 11) ADC CONVERTOR(HX711)

The HX711 IC 24-bit ADC allows to easily read the output of the load cells to measure weight. By connecting the amplifier to the microcontroller, we will be able to read the changes in the resistance of the load cell, and with some calibration we will be able to get very accurate weight measurements. This can be handy for creating industrial scale, process control or simple presence detection.




Pin Configuration-

E+ (Excitation VCC)
E- (Excitation GND)
A- (Channel A Signal-)
A+ (Channel A Signal+)
B- (Channel B Signal-)
B+ (Channel B Signal+)
GND (Ground)
DT (Data Output)
SCK (Clock input)
VCC (Power Supply)

**FIG 12: ADC CONVERTOR (HX711)**

## 12) SWITCH

A switch is an electrical component that can "make" or "break" an electrical circuit, interrupting the current or diverting it from one conductor to another. The mechanism of a switch removes or restores the conducting path in a circuit when it is operated. A pull switch is a switch that is actuated by means of a chain or string. A push button is a momentary or non-latching switch which causes a temporary change in the state of an electrical circuit only while the switch is physically actuated. An electric pull switch is attached to a toggle type switch: one pull to switch on and next pull to switch off.


**FIG 13: SWITCH**

## 13) USB SERIAL(RS232)

**RS-232** is a standard communication protocol for linking computer and its peripheral devices to allow serial data exchange. In simple terms RS232 defines the voltage for the path used for data exchange between the devices.

| | |
|---|---|
|   | Pin Configuration-<br><br>3V3 – 3.3 Volt Power Supply<br>TXD – Transmitter<br>RXD – Receiver<br>GND – Ground<br>+5V – VCC, 5 Volt Power Supply |

**FIG 14: USB SERIAL (RS232)**

## 14) TEMPERATURE AND HUMIDITY SENSOR(HDC1080)

HDC1080 is a digital humidity sensor with integrated temperature sensor that provides excellent measurement accuracy at low power. The HDC1080 operates over a wide supply range and is a low cost alternative to competitive solutions in a wide range of common applications. The humidity and temperature sensors are factory calibrated.

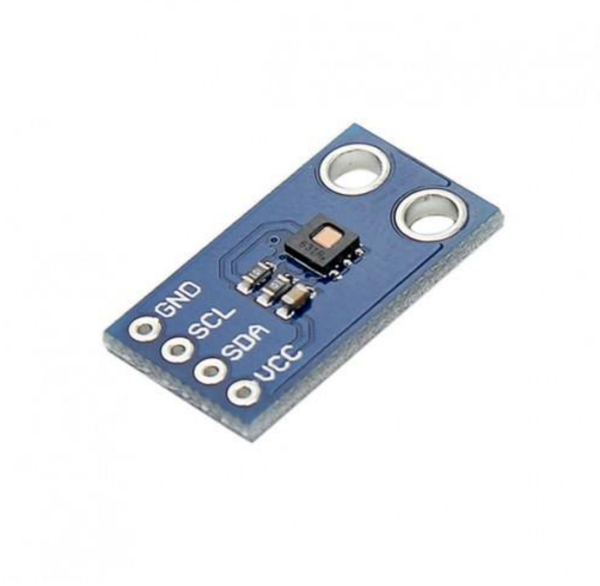



**FIG 15: TEMPERATURE AND HUMIDITY SENSOR (HDC1080)**

***Features of humidity sensors-***

- Digital Humidity Sensor
- PWSON (6-PIN) Package
- 14-bit resolution
- Low power
- Extremely Accurate
- 12C Interface
    - Easy to use
    - Requires pull up resistors

# CHAPTER 3

# PCB BOARD DESIGN

## 3.1 DESIGNING THE LAYOUT

The PCB design was made based on the required circuit using a PCB designing software. The final sketch of the PCB layout is as shown in the figure 16 below

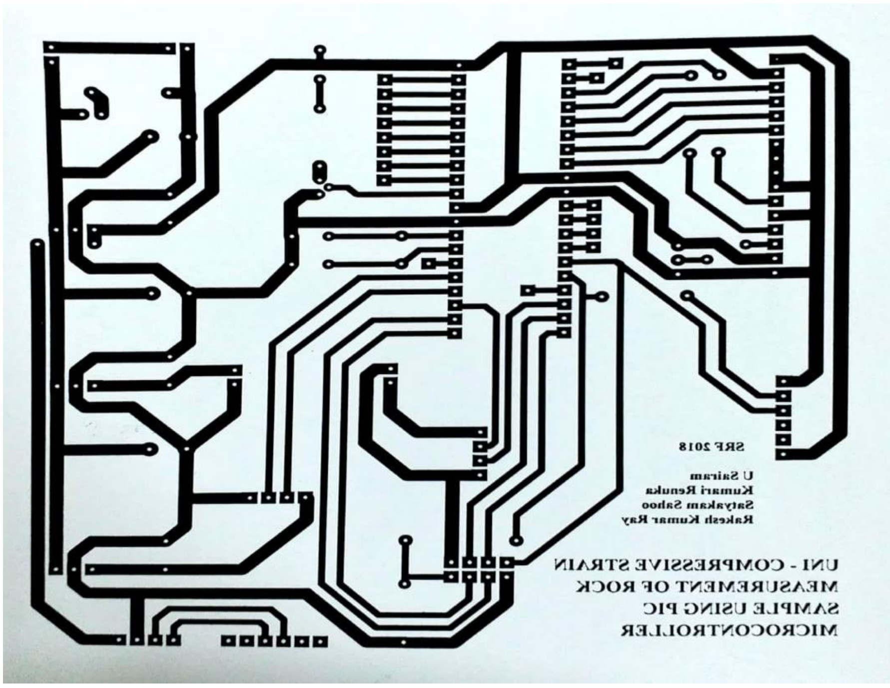



**FIG 16: PCB DESIGN LAYOUT (Photopaper)**

## 3.2 TONER TRANSFER

Once the PCB layout was ready, it was printed on a photo-paper. The printed design was transferred onto the PCB board using toner transfer method using a laminator such as the one shown in the following figure 17:

**FIG 17: LAMINATOR (Toner Transfer)**

## 3.3 PCB ETCHING AND DRILLING

After transferring the layout onto the PCB board, it was dipped in FeCl3 solution at the required temperature for about 2-3 hours as shown in the figure 18. This process resulted in the etching of the layout on the board.

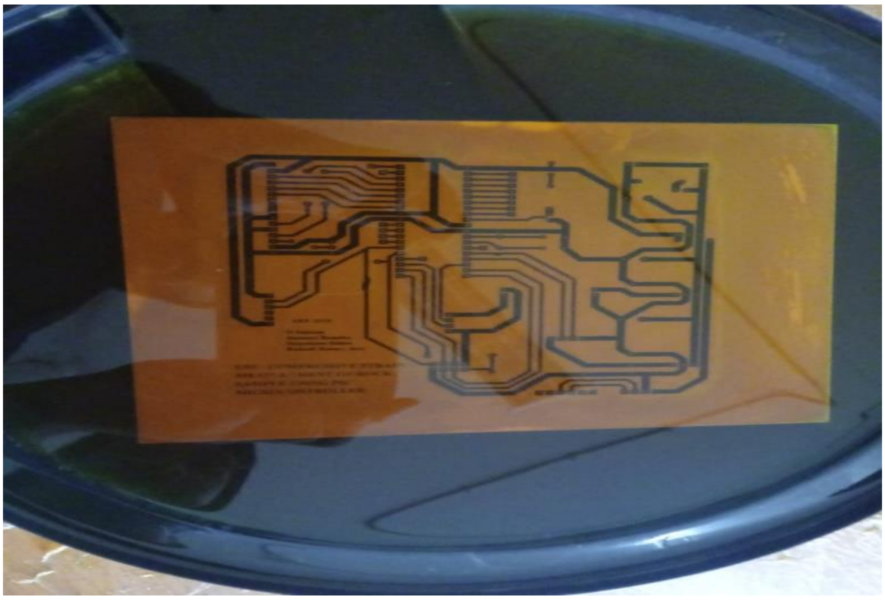


**FIG 18: DURING ETCHING OF PCB**

After removing the board from the solution, it was cleaned using a cleaning agent to remove all the unwanted carbon on it. The result of cleaning was the board as shown in the following figure 19.

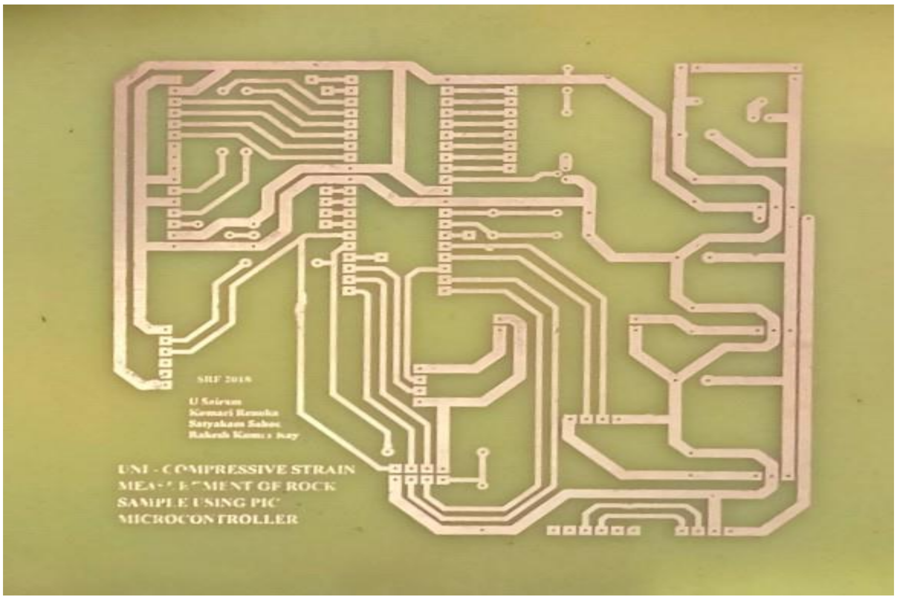



**FIG 19: AFTER ETCHING OF PCB**

After the etching is done, holes were drilled into the board using a drilling machine using 1mm drill bit. During drilling, the board appeared as in the figure 20.


**FIG 20: PCB DRILLING**

## 3.4 FIXING OF COMPONENTS

Once the PCB is ready with the holes, the components were mounted onto it in an orderly manner. The jumpers were mounted first followed by the IC bases. Next, LED's, capacitors and resistors were mounted. Once all the bases and passive components were mounted, the other remaining components were fixed. Figure 17 represents the diagram after fixing of the components. After this we started the testing phases.

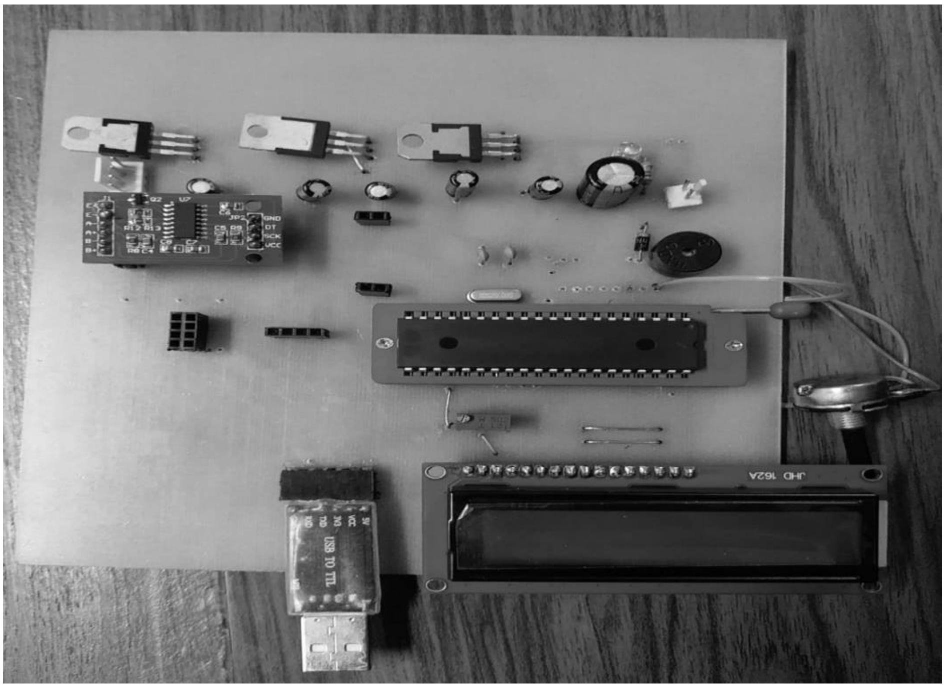


**FIG 21: AFTER FIXING THE COMPONENT**

# CHAPTER 4

# FINAL PROGRAM

*Final Program for Uni-compressive Strain Measurement of Rock Sample Using Pic Microcontroller*

***Description-***

This program will take the Analog Signal from Load cell through HX711 ADC. Interfacing with HX711 CLK in PIN_C2 and DATA in PIN_C1. Data transfer to PC through serial communication for further processing.

```
#include <18F452.h>
#fuses HS,NOWDT,NOPROTECT,NOLVP
#use delay(clock=10000000)
#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8)
#include <LCD_4BIT.c>

int i,j;
int32 q , t ; // Variable Declaration
float v;

void main()
{
   set_tris_D(0x00); // Port setting
   set_tris_C(0x02);

   delay_ms(2000);
   lcd_init ();   // LCD initialization
   delay_ms(2000);
```

```
for(;;)     // Continuous Loop
       {
       delay_us(100);
       t = 0;
       for (j=0;j<20;j++)
             {
                output_high(PIN_C1);  // data =1;
                output_low(PIN_C2);   //clk = 0;
                q = 0x00000000;
                while (input(PIN_C1)); // waiting for data ready

                for (i=0;i<24;i++)
                    {
                         output_high(PIN_C2);   //clk = 1;
                         q = q << 1;
                         delay_cycles( 1 );
                         if (input(PIN_C1)) q++;
                         output_low(PIN_C2);   //clk = 0;
                    }
                for (i=0;i<3;i++)
                    {
                         output_high(PIN_C2);   //clk = 1;
                         q = q ^ 0x00800000;
                         output_low(PIN_C2);   //clk = 0;
                    }
                t = t + q;
             }
      t = t / 20;
     v = t * 5000 / 16777215.0;
```

```
        printf (lcd_data,"%g",v);
        printf ("%g",v);
        delay_ms(500);
        lcd_cmd (0x01);
       }
}
```

LCD_4BIT.c

```
#define LCD_EN 0x20
#define LCD_RS 0x10

void lcd_reset()
{
    output_b(0x5F);
    delay_ms(200);
    output_b(0x03+LCD_EN);
    output_b(0x03);
    delay_ms(100);
    output_b(0x03+LCD_EN);
    output_b(0x03);
    delay_ms(10);
    output_b(0x03+LCD_EN);
    output_b(0x03);
    delay_ms(10);
    output_b(0x02+LCD_EN);
    output_b(0x02);
    delay_ms(100);
}
```

```
void lcd_cmd (int cmd)
{
        output_b(((cmd >> 4) & 0x0F)|LCD_EN);
        output_b(((cmd >> 4) & 0x0F));
        output_b((cmd & 0x0F)|LCD_EN);
        output_b((cmd & 0x0F));
        delay_ms(10);
 }

void lcd_init ()
{
        lcd_reset();        // Call LCD reset
        lcd_cmd(0x28);      // 4-bit mode - 2 line - 5x7 font.
        lcd_cmd(0x28);      // 4-bit mode - 2 line - 5x7 font.
        lcd_cmd(0x28);      // 4-bit mode - 2 line - 5x7 font.
        lcd_cmd(0x0C);      // Display on cursor blink.
        lcd_cmd(0x06);      // Automatic Increment - No Display shift.
        lcd_cmd(0x80);      // Address DDRAM with 0 offset 80h.
 }

void lcd_data (int dat)
{
        output_b((((dat >> 4) & 0x0F)|LCD_EN|LCD_RS));
        output_b((((dat >> 4) & 0x0F)|LCD_RS));
        output_b(((dat & 0x0F)|LCD_EN|LCD_RS));
        output_b(((dat & 0x0F)|LCD_RS));
        delay_ms(10);
}
```

# CHAPTER 5

# OUTPUT AND DATA ANALYSIS

In National Geophysical Research Institute, to determine the UCS the rock mechanics department make use of Universal Testing Machine (UTM) for applying huge amount of pressure. Currently, they are able to measure only the breaking point of the rock samples. We made a prototype system for the measurement of the tensile and compressive strength of rock samples by providing an interface between the load cell and PIC microcontroller. The data generated by the load cell is sent to the PIC microcontroller through ADC which is then displayed on LCD, subsequently the data is transferred to computer through serial communication for storage.

We have experimented with three rock samples which are massive basalt, Vesicular basalt and granite rock. Table 1 gives the results of the experiment conducted. The following steps were followed in order to obtain the results-

We connected our circuit to the Load Cell of Universal Testing Machine (UTM) of the rock mechanics department in order to measure the uni-compressive strain.

**Experiment 1** – First experiment was conducted with granite rock sample with length as 5.944cm and diameter as 2.922. The measured value of Bridge offset was 365.5 μV.

**Experiment 2 –** The second experiment was conducted with massive basalt rock sample with length as 7.482 cm and diameter as 2.988. The measured value of Bridge offset was 365.2 μV.

**Experiment 3 –** The third experiment was conducted with vesicular basalt rock sample with length as 7.362 cm and diameter as 2.990. The measured value of Bridge offset was 359.8 μV.

For all the above experiments the Conversion factor calculated as 22. Each experiment consists of three columns. The first column is the output of the load cell. The second column represent the actual axial load which is shown by the UTM display. The third column represents the calculated value of load is the measured using the designed circuit. From the results, as shown in Table 1 it is cleared that the designed prototype model shows the optimal results with an error for Granite, Massive Basalt and Vesicular Basalt are -0.0109 %, -0.0353% and 0.051141 % respectively. The data is successfully transferred to the computer for further processing and storage purpose.

Experiment Description : Experiment, 10 Ton range UTM
Mode of Experiment : Uni-axial Compressive Test

| | Sample : Granite<br>Length (cm): 5.944<br>Diameter(cm): 2.922<br>Bridge Offsets: 362.5 µV<br>Conversion Factor: 22 | | | Sample : Massive Basalt<br>Length (cm): 7.482<br>Diameter(cm): 2.988<br>Bridge Offsets: 365.2 µV<br>Conversion Factor: 22 | | | Sample : Vesicular Basalt<br>Length (cm): 7.362<br>Diameter(cm): 2.990<br>Bridge Offsets: 359.8 µV<br>Conversion Factor: 22 | | |
|---|---|---|---|---|---|---|---|---|---|
| Sl. No. | Output Load Cell | Axial Load | Calculated Load | Output Load Cell | Axial Load | Calculated Load | Output Load Cell | Axial Load | Calculated Load |
| | ( µV) | (kg) | (kg) | ( µV) | (kg) | (kg) | ( µV) | (kg) | (kg) |
| 1 | 377.4 | 327.3 | 327.8 | 386.4 | 468.4 | 466.4 | 366.4 | 144.4 | 145.2 |
| 2 | 385.3 | 502 | 501.6 | 424 | 1295.2 | 1293.6 | 383.7 | 525.1 | 525.8 |
| 3 | 395.6 | 728.9 | 728.2 | 442.9 | 1711.2 | 1709.4 | 388.8 | 637.4 | 638 |
| 4 | 409.8 | 1039.6 | 1040.6 | 462.5 | 2142.5 | 2140.6 | 392.6 | 721.4 | 721.6 |
| 5 | 423.4 | 1338.6 | 1339.8 | 484.2 | 2619.1 | 2618 | 429.4 | 1529.2 | 1531.2 |
| 6 | 445.2 | 1819 | 1819.4 | 502.4 | 3019.6 | 3018.4 | 474.7 | 2526.6 | 2527.8 |
| 7 | 470.2 | 2369.8 | 2369.4 | 529.1 | 3606.2 | 3605.8 | 495.1 | 2975.6 | 2976.6 |
| 8 | 491.9 | 2846.9 | 2846.8 | 546.1 | 3980.4 | 3979.8 | 524 | 3610.3 | 3612.4 |
| 9 | 509 | 3222.2 | 3223 | 565.7 | 4412.9 | 4411 | 545.2 | 4077.9 | 4078.8 |
| 10 | 531.3 | 3713.6 | 3713.6 | 588.3 | 4909 | 4908.2 | 568.3 | 4585.3 | 4587 |
| 11 | 547.4 | 4067.7 | 4067.8 | 623.6 | 5686 | 5684.8 | 587.8 | 5015.7 | 5016 |
| 12 | 564.3 | 4438.8 | 4439.6 | 638.5 | 6013.6 | 6012.6 | 608.8 | 5476.5 | 5478 |
| 13 | 583.9 | 4871.2 | 4870.8 | 657 | 6421 | 6419.6 | 622.5 | 5778.3 | 5779.4 |
| 14 | 594.7 | 5108.4 | 5108.4 | 681.6 | 6960.9 | 6960.8 | 641 | 6186.4 | 6186.4 |
| 15 | 611.7 | 5482.7 | 5482.4 | 712.6 | 7643.5 | 7642.8 | 649.8 | 6379.6 | 6380 |
| 16 | 622.5 | 5718.7 | 5720 | 732.3 | 8076.3 | 8076.2 | 664.4 | 6700.7 | 6701.2 |
| 17 | 635.5 | 6005 | 6006 | 752 | 8510.5 | 8509.6 | 676.3 | 6962.2 | 6963 |
| 18 | 654.8 | 6429.7 | 6430.6 | 779.9 | 9125.3 | 9123.4 | 691.8 | 7303 | 7304 |
| 19 | 670 | 6765.4 | 6765 | 808.2 | 9746.5 | 9746 | 697.9 | 7436.7 | 7438.2 |
| 20 | 681.2 | 7010.1 | 7011.4 | 823.8 | 10090.9 | 10089.2 | 704.7 | 7585.8 | 7587.8 |
| 21 | 693.4 | 7278.9 | 7279.8 | 848.5 | 10632.9 | 10632.6 | 710.7 | 7718.3 | 7719.8 |
| 22 | 700.7 | 7440.5 | 7440.4 | 869.2 | 11088.7 | 11088 | 721.2 | 7948.7 | 7950.8 |
| 23 | 708.9 | 7620.3 | 7620.8 | 888.8 | 11520 | 11519.2 | 724.5 | 8021.6 | 8023.4 |
| 24 | 725.5 | 7985.1 | 7986 | 922.9 | 12270.9 | 12269.4 | 742.6 | 8421.2 | 8421.6 |
| 25 | 735.5 | 8205.1 | 8206 | 935.8 | 12554.6 | 12553.2 | 756.9 | 8734.6 | 8736.2 |
| 26 | 745.3 | 8422.2 | 8421.6 | 960.1 | 13089.9 | 13087.8 | 770.8 | 9041.2 | 9042 |
| 27 | 765.4 | 8863.8 | 8863.8 | 977.5 | 13472 | 13470.6 | 776.2 | 9160.4 | 9160.8 |
| 28 | | Breaking Point | | 1012.1 | 14233.8 | 14231.8 | | Breaking Point | |
| 29 | | % Error | -0.0109 | 1037.3 | 14787.2 | 14786.2 | | % Error | 0.0511 |
| 30 | | | | 1052.2 | 15114.3 | 15114 | | | |
| 31 | | | | 1107.7 | 16335.9 | 16335 | | | |
| 32 | | | | 1146.4 | 17186.6 | 17186.4 | | | |
| 33 | | | | | Breaking Point | | | | |
| | | | | | % Error | -0.0353 | | | |

**TABLE -1 EXPERIMENT DATA**

# CHAPTER 6

# CONCLUSION

In National Geophysical Research Institute, to determine the Uni-Compressive Strain of the rock samples in Rock Mechanics Department make use of Universal Testing Machine (UTM) for applying huge amount of load. Currently, they are able to measure only the breaking point of the rock samples as well as taking reading from UTM dial gauge. We try to make a prototype system for the measurement of the uni-compressive strain and breaking point of the rock samples by providing an interface between the load cell and PIC microcontroller. The signal generated by the load cell is sent to the PIC microcontroller through ADC which is then displayed on LCD, subsequently the data is transferred to computer through serial communication for processing and storage. We have experimented with three rock samples which are massive basalt, Vesicular basalt and granite rock. We compared the calculated load value with the results obtained by the UTM machine in order to show the accuracy. The designed prototype model shows the optimal results with an error for Granite, Massive Basalt and Vesicular Basalt rock samples are -0.0109 %, -0.0353% and 0.051141 % respectively. The data is successfully transferred to the computer for the storage purpose and hence can be used for real-time processing and data analysis in order to make improvements.

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