
STRAIN GAUGES

By: Pinank Shah

Date : 03/22/2006

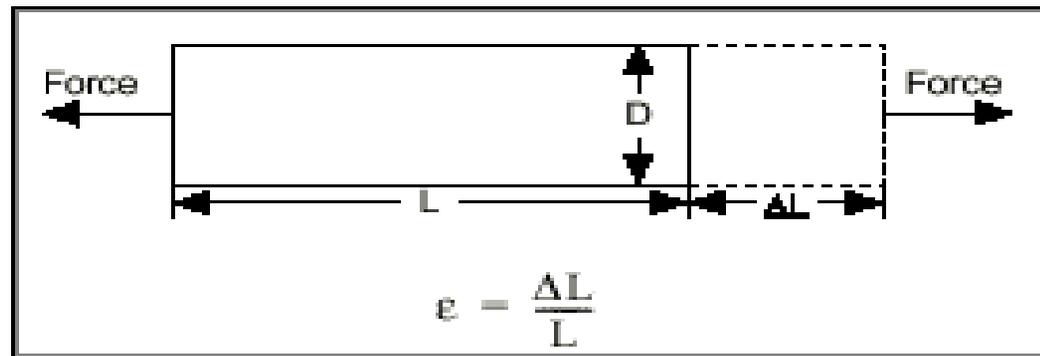
Overview of Topics

- n What is Strain?
- n What is Strain Gauge?
- n Operation of Strain Gauge
- n Grid Patterns
- n Strain Gauge Installation
- n Wheatstone bridge
- n Instrumentation Amplifier
- n Embedded system and Strain Gauge
- n Strain Measurement System
- n Applications of a Strain Gauge

What is Strain ?

- n Strain is the amount of deformation of a body due to an applied force. More specifically, strain (e) is defined as the fractional change in length.

n

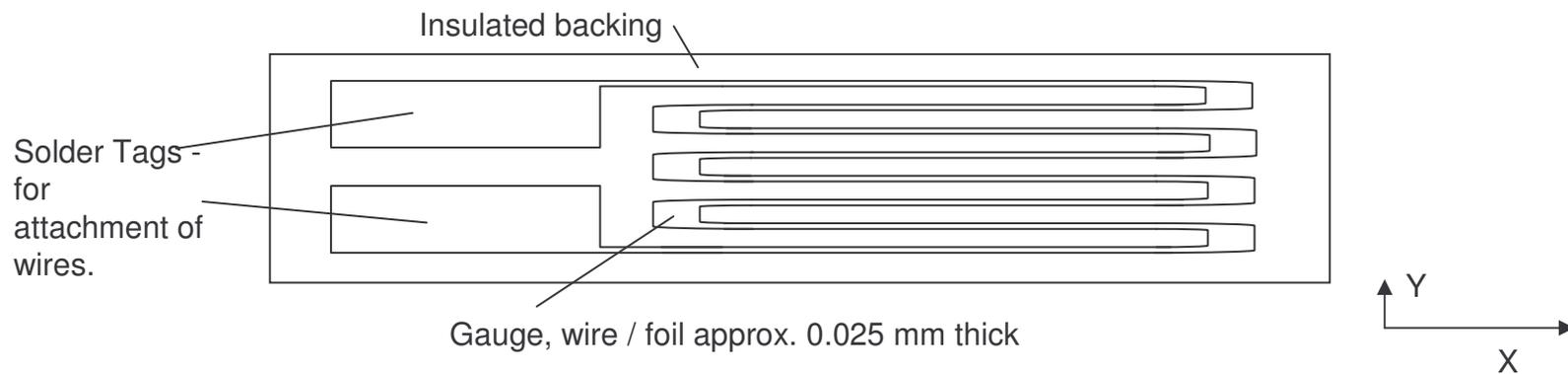


- n Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm.
- n In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain ($\mu\epsilon$), which is $e \times 10^{-6}$.

What is a Strain Gauge ?

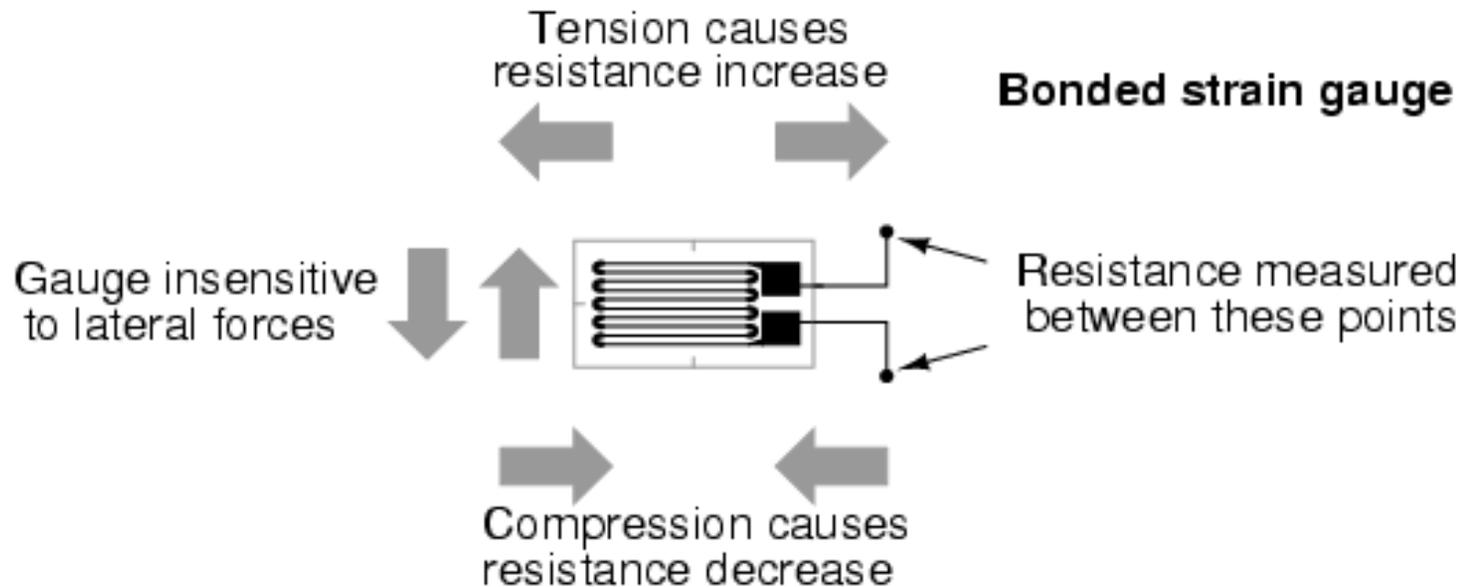
- n Strain Gauge is a device used to measure deformation (**strain**) of an object.
- n Strain gauges have been developed for the accurate measurement of strain
- n Fundamentally, all strain gauges are designed to convert mechanical motion into an electronic signal.

Schematic View Of Strain Gauge



- n The gauge shown here is primarily sensitive to strain in the X direction, as the majority of the wire length is parallel to the X axis.

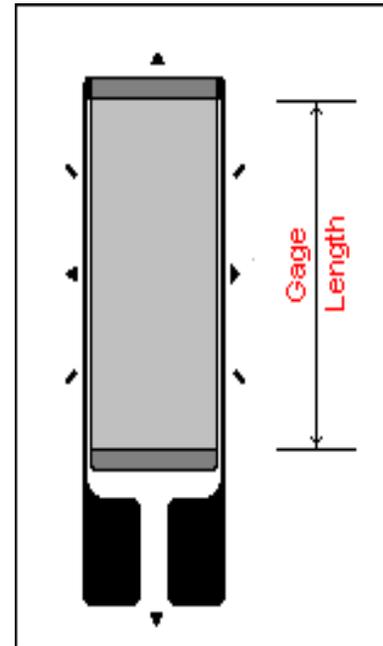
Strain Gauge



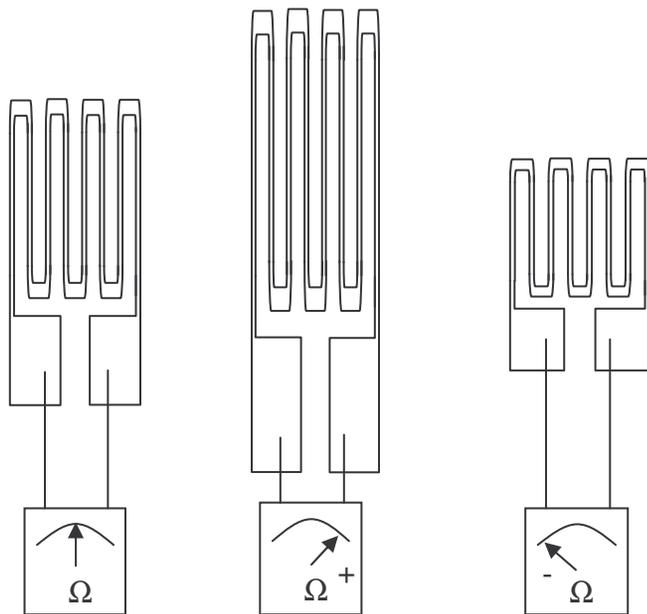
- n The name "bonded gauge" is given to strain gauges that are glued to a larger structure under stress (called the *test specimen*).

Gage Length

- n Gage length is an important consideration in strain gage selection
- n The gage length is the dimension of the active grid as measured inside the grid end loops.
- n The gage length (**GGG**) ranges from 0.008 in (0.2 mm) to 4 in (100 mm).

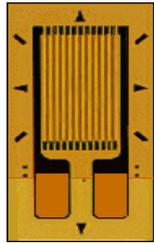


Strain Gauge Operation

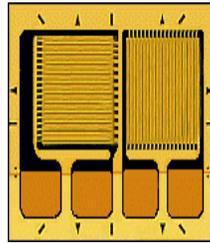


- n This schematic shows how the strain gauge resistance varies with strain (deformation).
- n On applying a force a change in resistance takes place.
- n Tension causes resistance increase.
- n Compression causes resistance decrease.

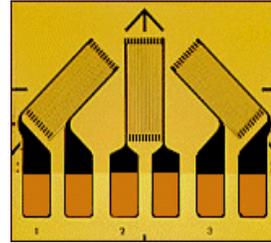
Grid Pattern



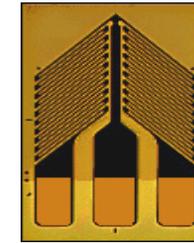
(a)



(b)



(c)



(d)

- n **Uniaxial** Gage with a **single grid** for measuring strain in the grid direction .
- n **Biaxial Rosettes** Gage with **two perpendicular grids** used to determine principal strains when their directions are known.
- n **Three-Element Rosettes** Gage with **three independent grids** in three directions for ascertaining the principal strains and their directions.
- n **Shear Patterns** Gage having **two chevron grids** used in half-bridge circuits for direct indication of shear strains (difference in normal strains) .

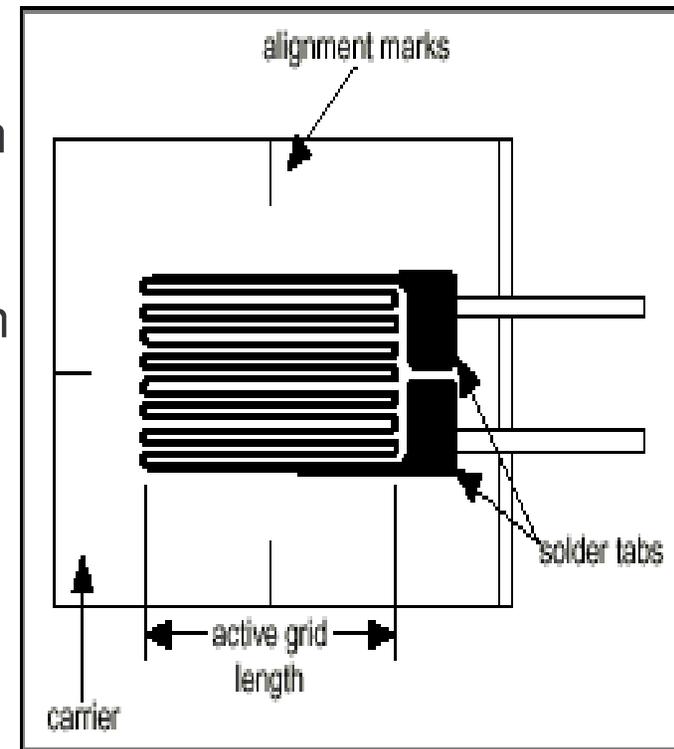
Strain Gauge Installation

- n The Strain Gauge is bonded to the specimen under test, only after the following:
 - q cleaning the surface using a degreaser
 - q cleaning it again with a conditioner solution (mild acid that accelerates the cleaning process)
 - q neutralizing by applying a base (neutralizes any chemical reaction introduced by the Conditioner)
 - q finally bonding it with a super glue.
- n The Strain Gauge has 2 leads which exhibit variation in resistance when strain is applied.

The bonded metallic strain gauge

- n The metallic strain gauge consists of a very fine wire or metallic foil arranged in a grid pattern.
- n The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction.
- n The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen.
- n The strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance.

- n Gauge factor is defined as:
$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\epsilon}$$

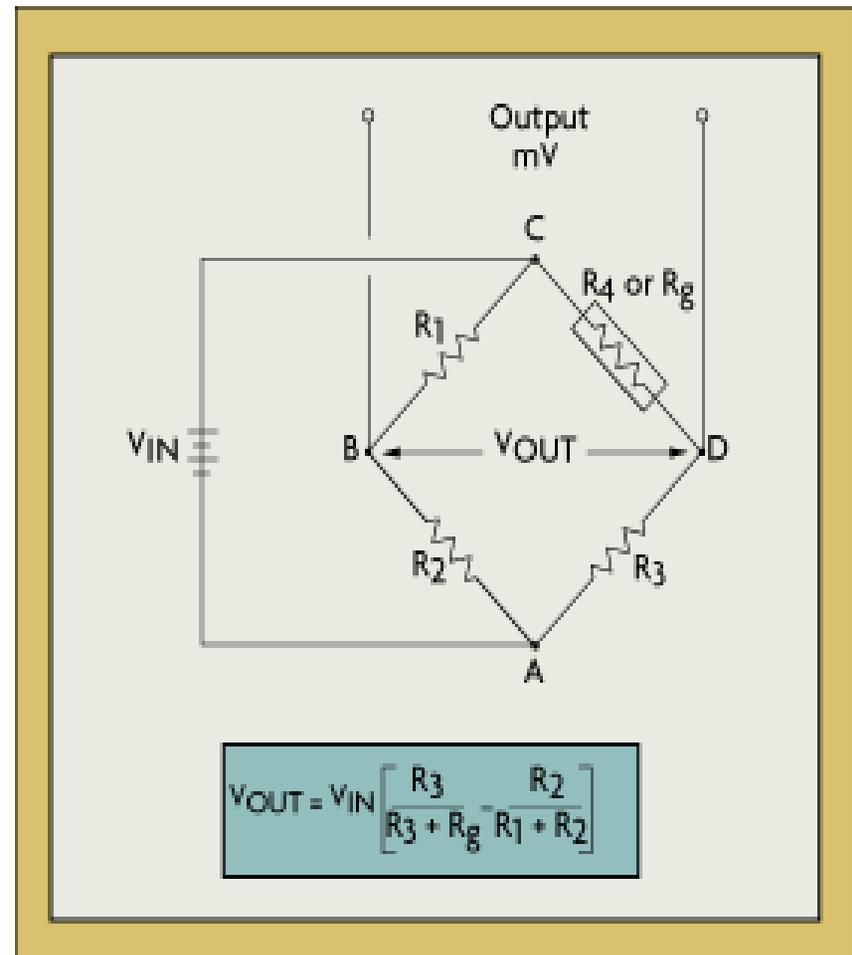


Measuring Circuits

- n 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
- n Strain gauge is connected in a Wheatstone bridge circuit
- n A strain gauge bridge circuit indicates measured strain by the degree of imbalance
- n It provides an accurate measurement of that imbalance

Wheatstone Bridge

- n In Figure, if R_1 , R_2 , R_3 , and Strain gauge are equal, and a voltage, V_{IN} , is applied between points A and C, then the output between points B and D will show no potential difference.
- n However, if R_4 is changed to some value which does not equal R_1 , R_2 , and R_3 , the bridge will become unbalanced and a voltage will exist at the output terminals.
- n The variable strain sensor has resistance R_g , while the other arms are fixed value resistors.



Wheatstone Bridge

- n The sensor, however, can occupy one, two, or four arms of the bridge, depending on the application.
- n The total strain, or output voltage of the circuit (V_{out}) is equivalent to the difference between the voltage drop across R1 and R4, or Rg.
- n It is given by $V_{out} = V_{cd} - V_{cb}$

Wheatstone Bridge Working

- n The bridge is considered balanced when $R1/R2 = Rg/R3$ and, therefore, V_{OUT} equals zero.
- n Any small change in the resistance of the sensing grid will throw the bridge out of balance, making it suitable for the detection of strain.
- n A small change in Rg will result in an output voltage from the bridge.
- n If the gage factor is GF , the strain measurement is related to the change in Rg as follows:

$$\text{Strain} = (\Delta R_g / R_g) / GF$$

Problem - Low Level Output

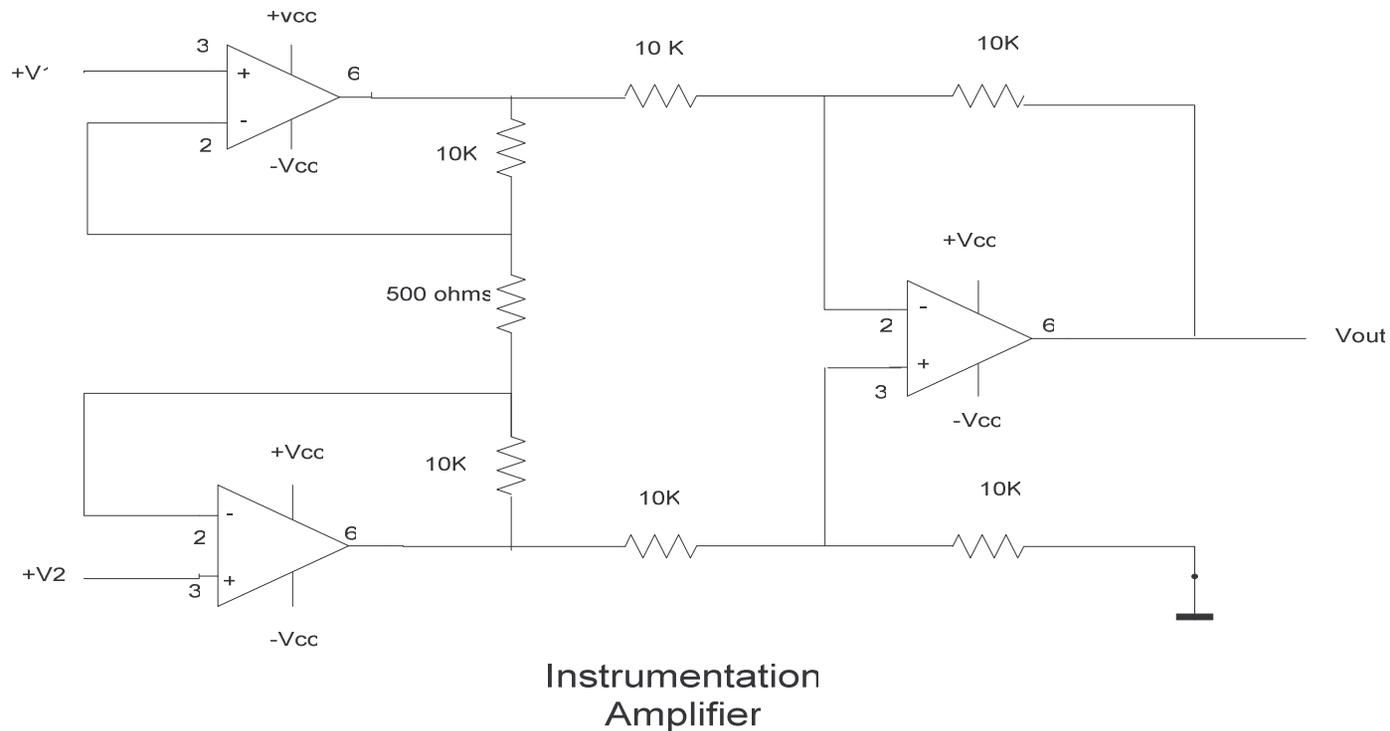
- n The output of a strain gauge circuit is a very low-level voltage signal
- n The low level of the signal makes it particularly susceptible to unwanted noise from other electrical devices.
- n Capacitive coupling caused by the lead wires' running too close to AC power cables or ground currents are potential error sources in strain measurement.
- n Other error sources may include magnetically induced voltages when the lead wires pass through variable magnetic fields, parasitic (unwanted) contact resistances of lead wires, insulation failure, and thermocouple effects at the junction of dissimilar metals.
- n The sum of such interferences can result in significant signal degradation.

Solution

- n **Shielding:** Most electric interference and noise problems can be solved by shielding.
- n A shield around the measurement lead wires will intercept interferences and may also reduce any errors caused by insulation degradation.
- n Shielding also will guard the measurement from capacitive coupling.
- n If the measurement leads are routed near electromagnetic interference sources such as transformers, twisting the leads will minimize signal degradation due to magnetic induction.
- n By twisting the wire, the flux-induced current is inverted and the areas that the flux crosses cancel out.
- n For industrial process applications, twisted and shielded lead wires are used almost without exception.

Instrumentation Amplifier

- n The variation in voltage at the output of the bridge is in the range of millivolts. It needs to be amplified in order to calculate precise value of strain.

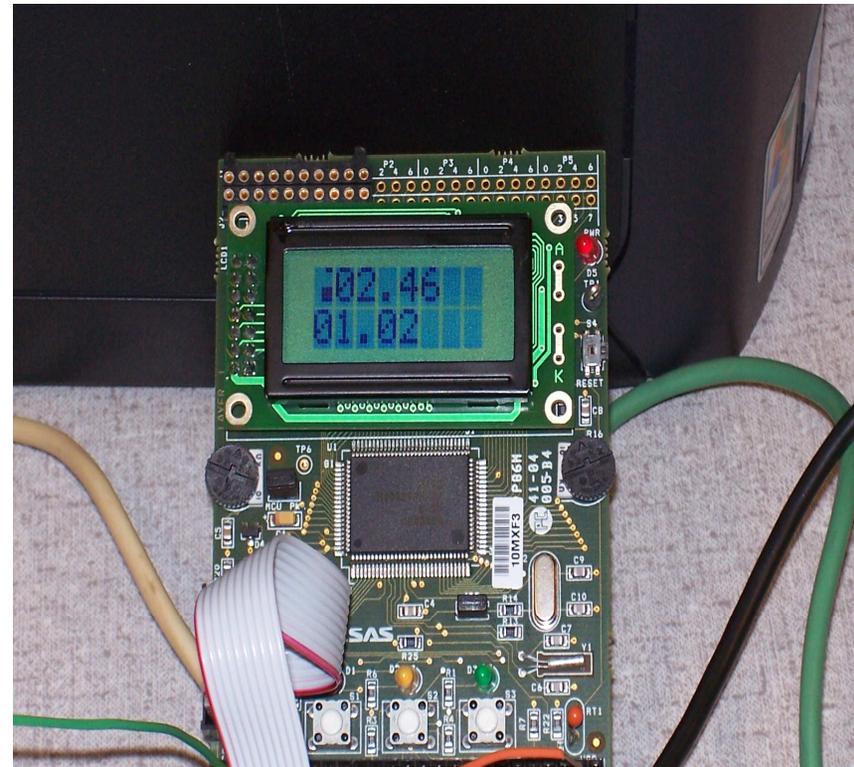


Features of Instrumentation Amplifier

- n Differential inputs helps in accurate voltage transfer
- n High CMRR.
- n Low offset voltage: 50uv max.
- n Variable Gain.
- n The gain of the instrumentation amplifier is given by $A_v = 1 + (2 * R_2) / R_g$ where R_2 is 10 K ohms fixed resistor and R_g is the gain select resistor
- n Three 741 Op-amps are used to build the circuit for instrumentation amplifier.

Instrumentation Amplifier and Microcontroller Integration

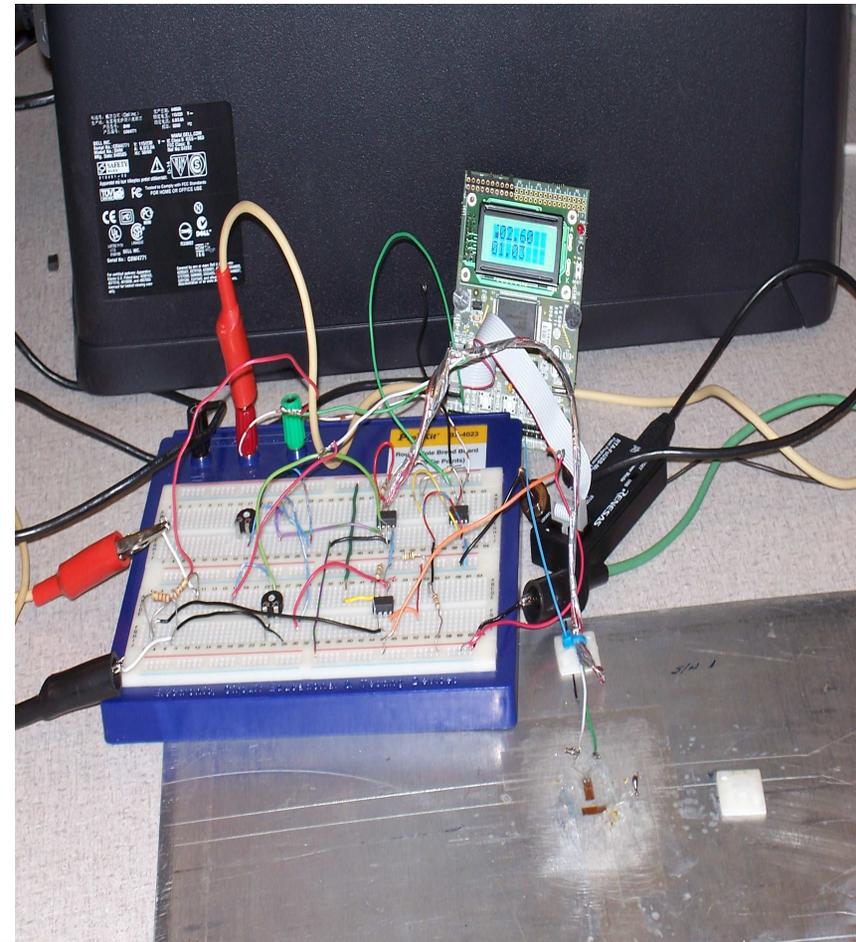
- n The output of the instrumentation amplifier is connected to the M16C/62P microcontroller.
- n The ADC, converts the o/p into digital value and the voltage read in is displayed on the LCD display available on M16CSKP board.
- n A_D converter input port no. 10_3 is used
- n The A_D converter is configured to read in the analog value after every 1 second and is set to convert at a resolution of 10 bits for better precision.



Strain Measurement System

Consists Of:

- ∅ Test Specimen-piece of metal
- ∅ Strain gauge-placement of the Strain Gauge on the specimen is very crucial for precise measurement of the strain
- ∅ Wheatstone bridge
- ∅ Instrumentation Amplifier
- ∅ Microcontroller M16C/62P



Software execution

n The software performs the following calculation on the digital value:-

q The value read in is converted into digital and is available in one of the registers of the microcontroller. The ADC resolution is selected as 10 bit. The step size thus becomes 48.8 mV.

q Multiply it by 48.8 mV to get the actual analog voltage

q Divide the analog voltage by 24(gain of the amplifier).

q $V_o / V_{ex} = (\text{Gauge Factor} * E) / 2$ where E is the strain in micro strain.

q $E = (V_o * 2 / \text{Gauge Factor} * V_{ex})$

q $= V_o / ((1.03) * (4V))$ [Gauge Factor = 2.06] [V_{ex} = 4volts]

q $= V_o / 4.12$ [V_o is the output of the Bridge]

q Divide the value by 4.120

q This gives the value of the strain.

q Value of the strain displayed on the LCD is refreshed every 1 second.

Readings

n **Results:**

n Under no strain condition:

n $V_{out} = 2.20\text{volts}$ (output of the instrumentation amplifier)

n **$E = 0.91$ micro strain.**

n Bend the test specimen both ends downwards (Elongation effect on the Gauge)

n $V_{out} = 2.28\text{volts}$ (output of the instrumentation amplifier)

n **$E = 0.94$ micro strain.**

n Bend the test specimen both ends upwards (Compression effect on the Gauge)

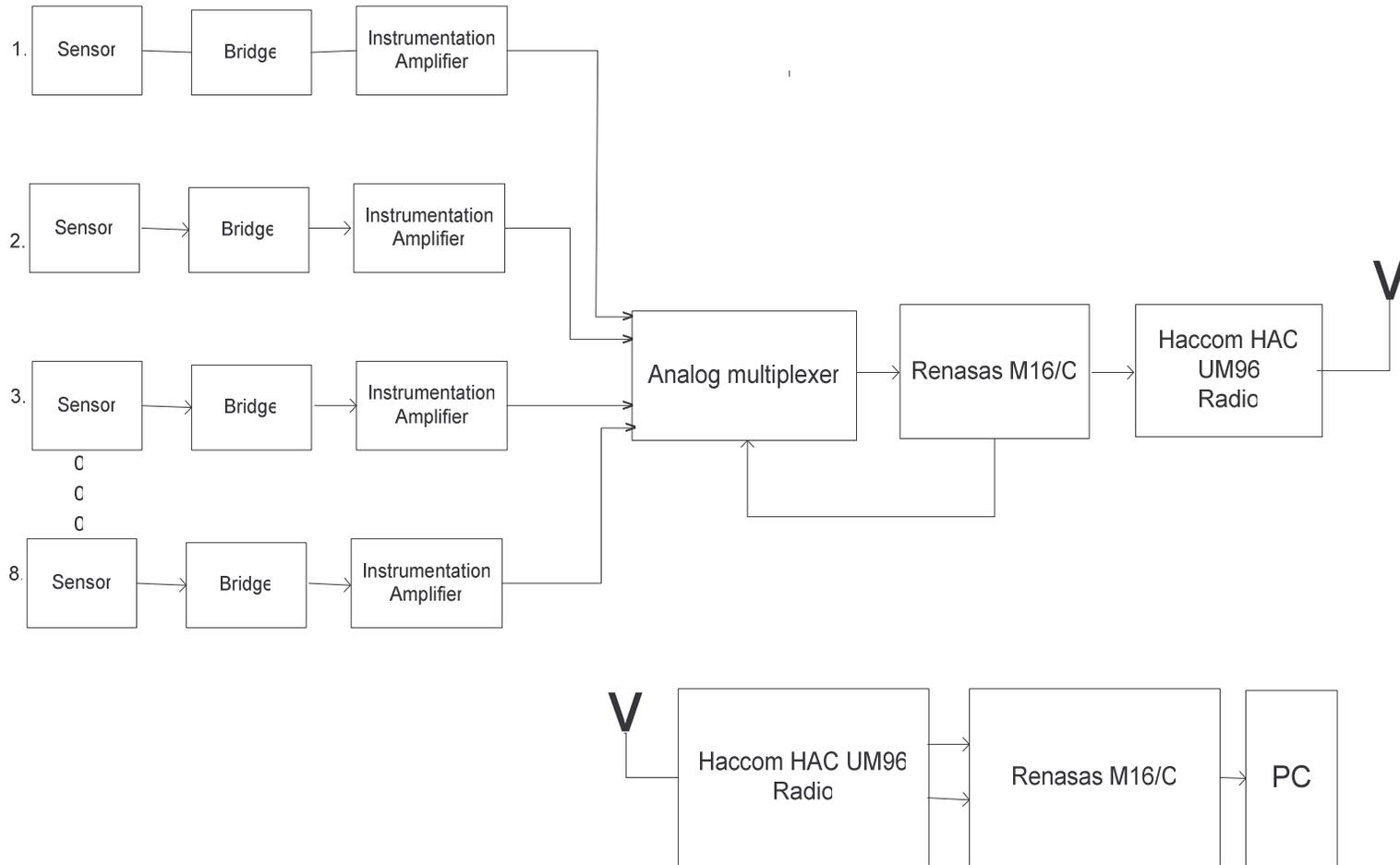
n $V_{out} = 2.16\text{volts}$ (output of the instrumentation amplifier)

n **$E = 0.89$ micro strain.**

Features Of Strain Measurement System

- n This system is very compatible and is cost effective.
- n The microcontroller used has many other features like UART interface which can be utilized to transfer the strain readings to a PC.
- n Upcoming Project:
 - A multi strain measurement system (SMS)
 - Making SMS wireless

Block Diagram Of Strain Gauge Array Measurement System



Ultra Low Power Data Radio Module

- n Ultra low power transmission – 10 mW transmission power
- n High anti-interference and low BER (Bit error Rate)
- n Long transmission distance
- n Multi-channel-the standard radio module configuration provides 8 channels
- n Low power consumption and sleeping function -receiving, current is <math><30\text{mA}</math>, transmitting current is <math><40\text{mA}</math>, and sleep current is <math><20\mu\text{A}</math>.
- n High reliability, small and light

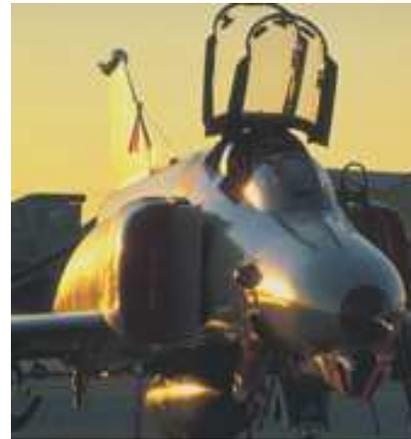


Strain Gauge Array Measurement System

- n The advanced strain measurement system accumulates the data from all the widespread gauges, processes the collected data, enables wireless transmission of collected information to the remote Data Acquisition System.
- n With the combination of low power microprocessors, flexible software operating modes this system is optimized for very low power operation, while permitting high speed data logging and wireless communication capabilities.

Applications of Strain gauge

- n In load cells for weighbridges, scales, vehicles and in medical and educational applications.
- n For monitoring structures such as bridges and buildings.
- n In research and development applications, including automotive, aerospace, medical, process, oil and gas, and power generation.
- n Virtually every other sector of industry.



References

- n <http://zone.ni.com/>
- n <http://www.omega.com/>
- n <http://www.vishay.com/>
- n <http://www.allaboutcircuits.com/>
- n <http://www.strain-gauges.com/>



QUESTIONS.....

