

University of California Berkeley
Department of Electrical Engineering and Computer Sciences
EECS 100, Professor Leon Chua

LABORATORY 4 v2

STRAIN GAGE

In this laboratory we design our first electronic device, an electronic weight scale! The key component is a strain gage, a resistor that changes its value in response to mechanical stress. We will also use an instrumentation amplifier to gain up the signal.

Figure 1 shows a strain gage with two electrical leads on the right side. The serpentine structure consists of a resistive material (e.g. a metal) mounted on top of an insulator. Increasing the length of the resistor (e.g. by adding additional serpentes) increases its value. Question: what happens if we pull on the resistor to make it longer? Well, its value increases. In this laboratory we use this effect by gluing a strain gage on one side of a flexible beam. When the beam is bent, one side gets longer while the other gets shorter. The glue transfers this effect to the strain gage, which in turn changes its resistance value as a function of beam bending. Applications include airplane wings where strain gages are used to determine the degree of wing deformation during flight from the change of resistance. Strain gages are invaluable for evaluating not only airplane frames, but also automobiles, bridges, and buildings.

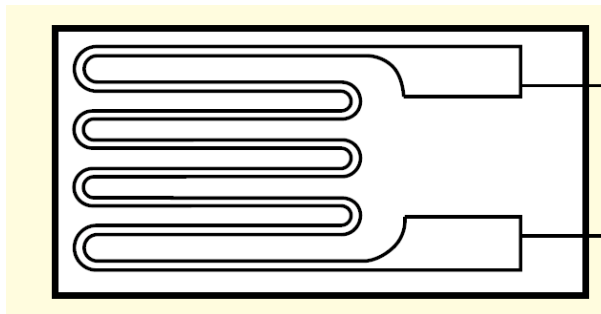


Figure 1 Resistive strain gage with electrical leads on the right side

In the laboratory we will be using a strain gage that is glued to an aluminum band. The end that is closer to the gage is clamped to the table. Adding weights to the other end bends the aluminum band. As a consequence, one side of the band gets slightly longer while the other one gets shorter. The weight scales you see along highways that are used to check the load of trucks use the same principle.

In the lab we will first characterize the resistance change and then gradually develop improved versions of the weight scale circuit to produce an amplified output voltage that is proportional to the applied weight.

LAB REPORT

Lab Session:

Name 1:

SID:

Name 2:

SID:

1. Strain Gage

Clamp the strain gage to the lab bench and use the Ohm-meter to determine the resistance R_o of the unloaded gage. Load the gage with an increasing number of weights, re-measure the resistance R_N (for N weights) and calculate the relative change of resistance, Δr . Do not permanently deform the gage.

Note ppm is "parts per million" and is used for unitless fractions that are much smaller than 1%. Just like to get % you multiply the fraction by 100, for ppm, you multiply by one million.

R_o : _____ Ω _____ of 1 M

Number of weights N	R_N [Ω]	$\Delta r = \frac{R_N - R_o}{R_o}$ [ppm]
0		
1		
2		
3		
4		
5		
6		
7		
8		

_____ of 5 M

2. Half Bridge Circuit

Using a voltage divider, we can easily convert the output into a voltage. Form a divider consisting of the strain gage and a constant 120Ω resistor and put $V_{DD}=5V$ across the bridge.

- Draw a half bridge (voltage divider) circuit showing the variable resistance strain gauge as one of the elements

___ of 2 **P**

- Derive an expression for Δv (where the output at 0 strain is V_0 and the output with strain is) as a function of Δr (as defined in part 1), R_0 and V_{DD} . Derivation should be shown in prelab

Expression for Δv _____

___ of 5 **P**

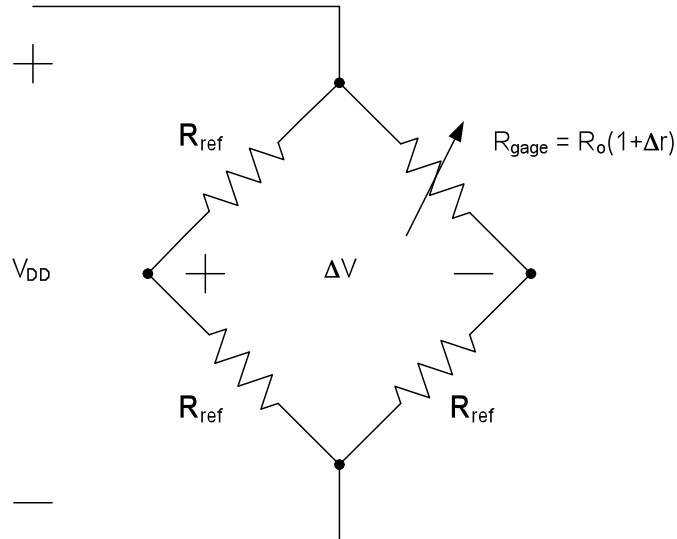
- Build the circuit on your breadboard
- Measure the voltage V_R across the 120Ω resistor
- Fill in the table below:

Number of weights	V_R [V]	$\Delta v = \frac{V_R - V_{DD}}{V_{DD}}$ [ppm]
0		
1		
2		
8		

___ of 4 **M**

3. Full Bridge Circuit

The circuit from part 2 has a major problem: the output voltage is non-zero when the gage is not loaded. This problem is easily overcome with a second voltage divider that produces the reference voltage for an unloaded gage. The output is the voltage difference ΔV between the two dividers.



- a) Derive an expression for ΔV as a function of Δr , R_o , R_{ref} , and V_{DD} . Show derivation in prelab.

Expression for ΔV :

____ of 5 P

- b) In practice ΔV is still not exactly zero, even if the gage is not loaded. Give two reasons why.

Reason 1:

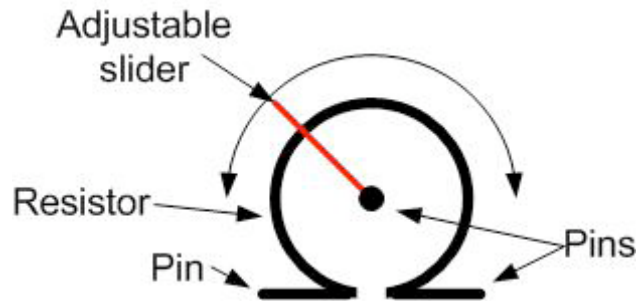
____ of 5 P

Reason 2:

____ of 5 P

- c) In order to reduce this error a manually adjustable resistor can be placed in the circuit to adjust the

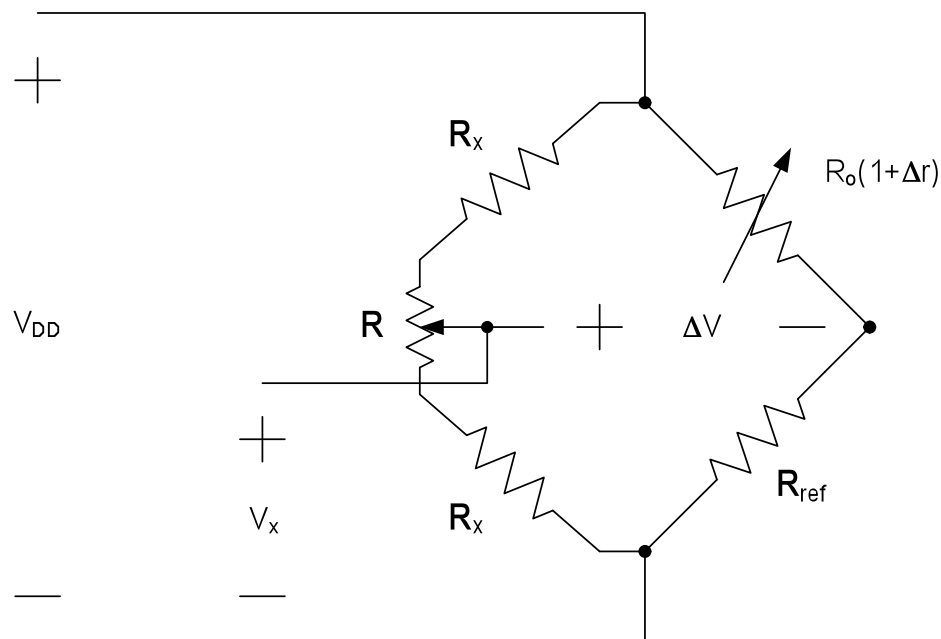
reference voltage. This adjustable resistor is called a potentiometer. See the figure below for an example of how potentiometers are made. The resistance between the two main pins is fixed, but the adjustable slider can be turned to change the resistance between the slider and the other pins.



The circuit below adds a potentiometer to manually adjust the zero point. Calculate the value of R/R_x needed to result in a 5% adjustment range, e.g. by turning the slider of the potentiometer to the extreme positions $V_x = V_{DD}/2 \pm 5\%V_{DD}$. Thus, at the lowest setting of the potentiometer V_x should read $.45*V_{DD}$. At the highest setting, V_x should read $.55*V_{DD}$.

Expression for R/R_x :

____ of 5 P



- d) A simpler circuit would connect the potentiometer directly to the supply, omitting the resistors R_x . Describe briefly the advantage of having R_x .

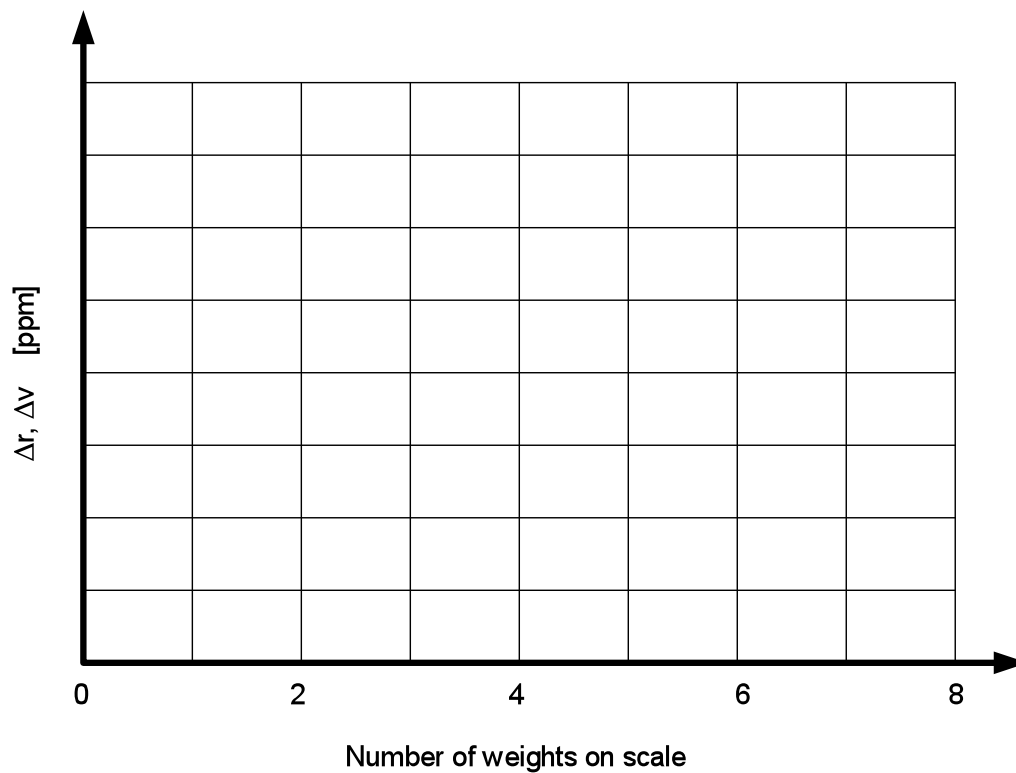
____ of 5 P

- e) Build the circuit from part (c) using $R_{\text{ref}}=120\Omega$, $R_x=1\text{k}\Omega$ and $R=100\Omega$. Adjust the potentiometer such that $\Delta V=0\text{V}$ when the gage is not loaded. Then take measurements of ΔV to fill in the table below:

Number of weights	ΔV [mV]	$\Delta v = \frac{\Delta V}{V_{DD}}$ [ppm]
0		
1		
2		
8		

___ of 4 **M**

- f) Summarize your measurement results for Δr and Δv from parts 1-3 in a graph.



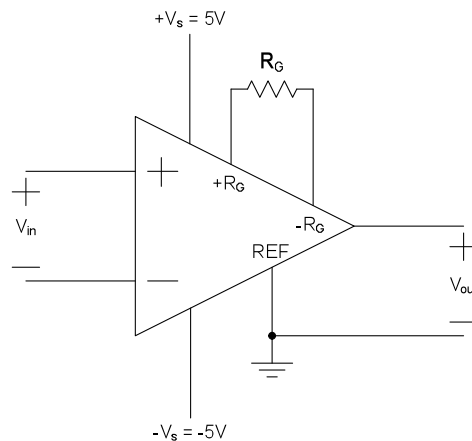
___ of 8 **M**

4. Instrumentation Amplifier

In this part we add an instrumentation amplifier to amplify the gage output. Instrumentation amplifiers will be analyzed in the homework. The connections are shown in the circuit below. Resistor R_G sets the gain $G = V_{out}/V_{in}$ according to the formula

$$R_G = \frac{100k\Omega}{G - 1}$$

You find this equation in the datasheet of the AD623 instrumentation amplifier.

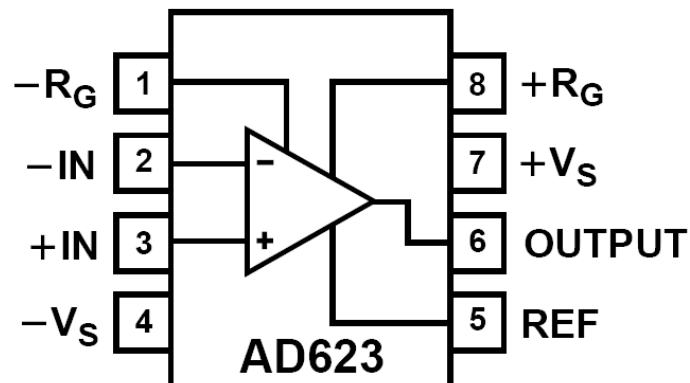


- a) What is the correct value of R_G for $G=100$?

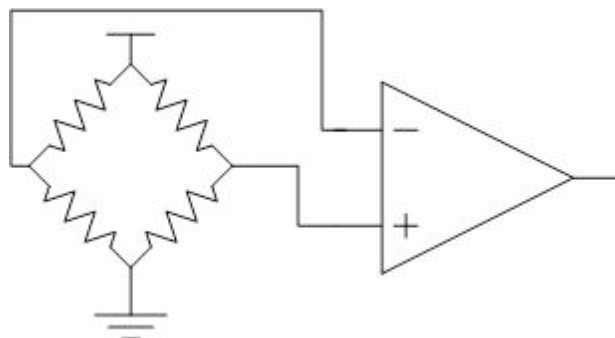
R_G :

____ of 5 P

- b) Add the instrumentation amplifier to the strain gage circuit. Use $R_G=1k\Omega$. The connection diagram of the AD623 is as follows (the datasheet has more information):

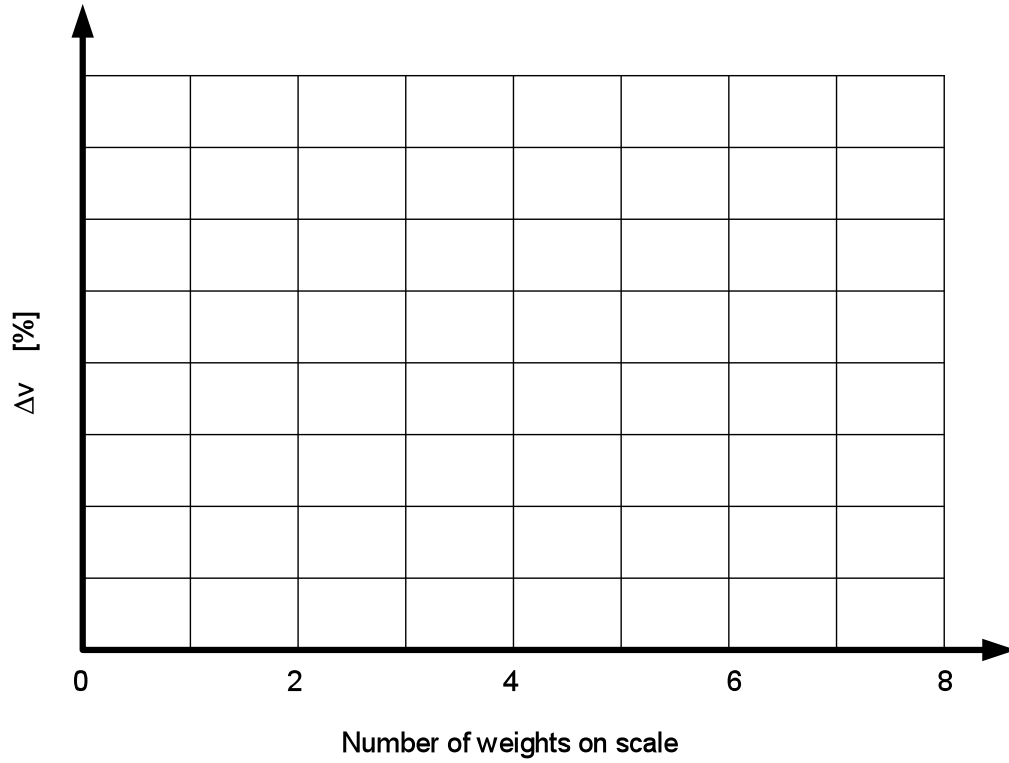


Hookup the output of your full bridge circuit to your amplifier circuit



Measure the amplifier output voltage as a function of the number of weights.

Number of weights	V_{out} [mV]	$\Delta v = \frac{V_{\text{out}}}{V_{DD}}$ [%]
0		
1		
2		
3		
4		
5		
6		
7		
8		



____ of 20 **M**

SUGGESTIONS AND FEEDBACK

Time for completing prelab:

Time for completing lab:

Please explain difficulties you had and suggestions for improving this laboratory. Be specific, e.g. refer to paragraphs or figures in the write-up. Explain what experiments should be added, modified (how?), or dropped.

PRELAB SUMMARY

Lab Session:

Name 1:

SID:

2. **Half Bridge Circuit**

Draw a half bridge (voltage divider) circuit showing the variable resistance strain gauge as one of the elements

___ of 2 **P**

Derive an expression for Δv (where the output at 0 strain is V_0 and the output with strain is) as a function of Δr (as defined in part 1), R_0 and V_{DD} . Derivation should be shown in prelab

Expression for Δv

___ of 5 **P**

3. **Full Bridge Circuit**

Derive an expression for ΔV as a function of Δr , R_o , R_{ref} , and V_{DD} .

Expression for ΔV : _____ **___ of 5 P**

In practice ΔV is still not exactly zero, even if the gage is not loaded. Give two reasons why.

Reason 1: _____ **___ of 5 P**

Reason 2: _____ **___ of 5 P**

Calculate the value of R/R_x needed to result in a 5% adjustment range, e.g. by turning the slider of the potentiometer to the extreme positions $V_x = V_{DD}/2 \pm 5\%$.

Expression for R/R_x : _____ **___ of 5 P**

A simpler circuit would connect the potentiometer directly to the supply, omitting the resistors R_x . Describe briefly the advantage of having R_x .

_____ **___ of 5 P**

4. Instrumentation Amplifier

What is the correct value of R_G for $G=100$?

R_G : _____ **___ of 5 P**