Laboratory Report

Experiment 1: Calibration and Characterization of Sensors

Programme: Mechatronics Engineering
Mechatronics Control and Automation Lab (MCTA 3104)
Section 2
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Objectives

- To get acquainted with a common analog sensor.
- To demonstrate the process of integrating a sensor to a system.
- To familiarize the students to the calibration process of the sensor.
- To acquaint the students with the characteristics of the sensor.
- To design and implement operational amplifiers in instrumentation applications.

Introduction

An operational amplifier or (Op-amp) for short, is a device that possesses linear characteristics. It is good at signal processing as it is used to amplify voltage signals. It is a basic differential amplifier consisting of three terminals. Of these three terminals, two are used for input and one for output. The first terminal at the input is known as the inverting terminal and is represented by a minus sign. The second terminal at the input represents the non-inverting terminal and is represented by a plus sign. It is capable of performing basic arithmetic operations such as addition, subtraction, multiplication, and division. It is fundamentally a device used with external feedback components such as resistors and capacitors between its output and input terminals. These components will determine the resulting function of the amplifier.

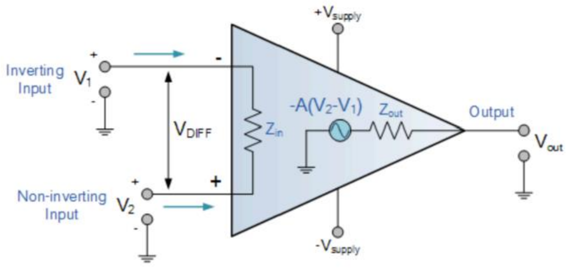


Figure 1: Operational amplifier (Op-amp).

Hysteresis is the phenomenon of when the value of a property lags behind the changes in the effect causing it. To illustrate, when using a manual weighting scale to weigh something heavy and then removing the heavy object, the scales' pointer will be lower in position compared to when it was never used before. So, this difference in value is called Hysteresis loss.

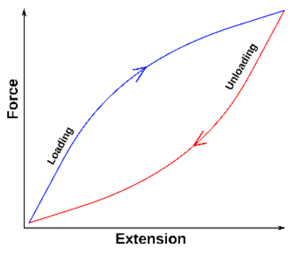


Figure 2: Hysteresis curve.

One of the applications of the Op-amp is a voltage follower as seen in Fig.2. It produces an output signal that equals the input signal in amplitude. A voltage follower is used for problematic impedence relationships. If a high output impedance circuit transfers a signal to a low input impedance circuit, the voltage follower when placed between those two circuits will make sure to deliver the full voltage to the load.

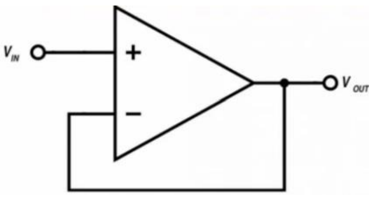


Figure 3: Voltage follower.

The consistency of measurements across the whole measurement range is indicated by linearity. Although it can be a deceptive indicator when used alone, it is generally a good indicator of a sensor's performance quality. Simply put, linearity indicates how closely an instrument measurement matches reality. Moreover, the sensitivity of an instrument is the smallest change in an input signal that can cause the measuring device to respond.

In this report, we will go over the Hysteresis curve gotten from our results and the linearity range and sensitivity measured, as well as discuss the reason behind using a voltage follower in out circuit.

Equipment

- Oscilloscope
- Function generator
- Digital multimeter
- FSR
- ±15V DC power supply
- 741 Op-amp
- 20 kΩ resistor
- 30 kΩ resistor
- 50 kΩ resistor
- Jumper wires

Setup

- Connect resistor to GND and P3 on op-amp.
- Connect FSR to +5V and P3 on op-amp.
- Connect +15V to P7 on op-amp.
- Connect -15V to P4 on op-amp.
- Connect P2 to P6 on op-amp.
- Connect multimeter to GND and P6 on op-amp.

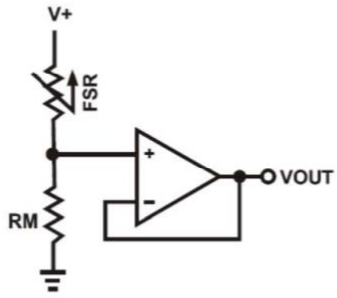


Figure 4: Circuit for experiment.

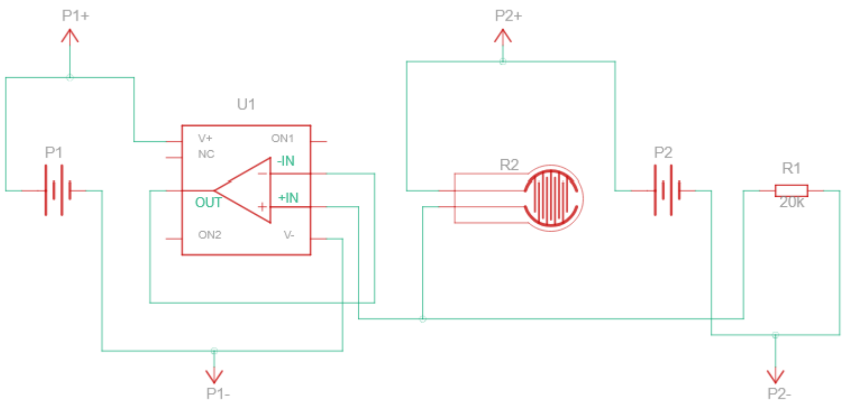


Figure 5: circuit diagram of experiment setup.

Experimental Procedure

1. Construct the circuit.
2. Get three values for the RM resistor.
3. Connect multimeter to Vout and ground to measure the voltage.
4. Connect a force sensing resistor (FSR) to the circuit in place of the second resistor.
5. Place weights on the FSR and actively record the voltage shown on the multimeter.
6. Remove the weights placed in reverse and record the voltage again.

Results

Mass (g)	RM = 20kΩ, V_{out}(V)	RM = 30kΩ, V_{out} (V)	RM = 50kΩ, V_{out} (V)
0	1.065	0.854	0.966
10	0.67	0.755	0.633
30	0.201	0.307	0.34
50	0.001	0.211	0.264
100	0.001	0.015	0.24
50	0.002	0.176	0.357
30	0.07	0.336	0.361
10	0.382	0.567	0.661
0	0.785	0.867	1.025

Discussions

1) Force Vs Vout.

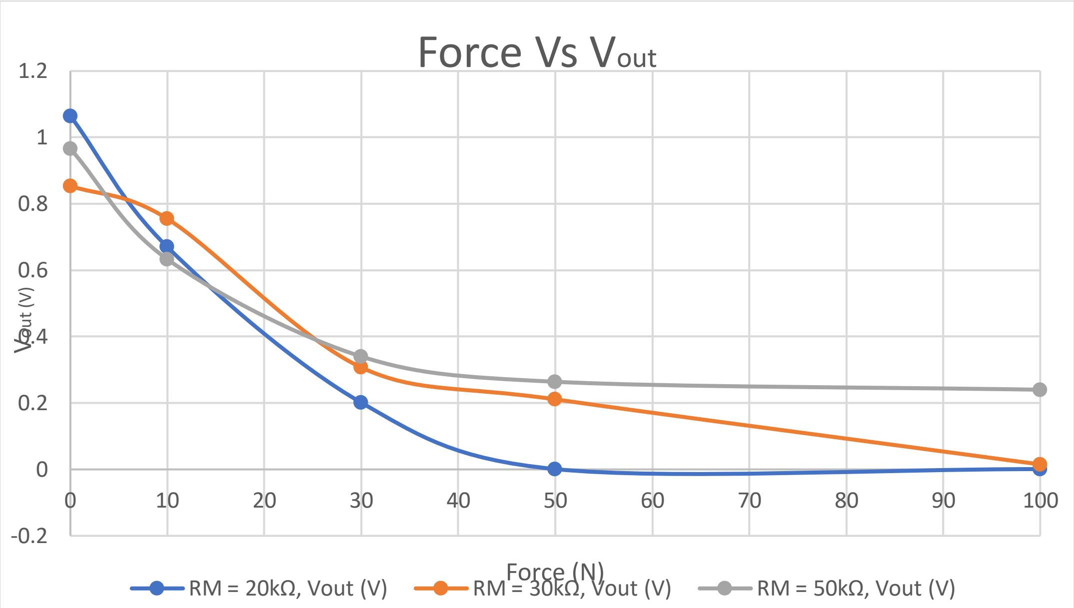


Figure 6: Force vs Vout curves for all three resistors.

As the force applied on the FSR increases the output voltage decreases. The curves generally start above 0.8 V and as they progress to the end they drop in value and stop at voltages below 0.3 V.

2) Plot Hysteresis curve and discuss.

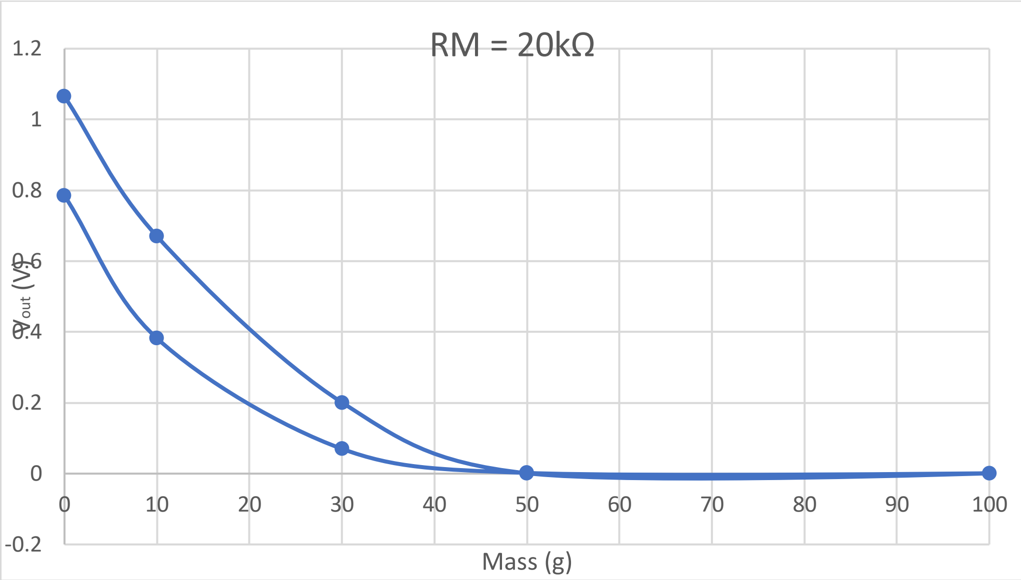


Figure 7: Hysteresis curve for circuit with 20kΩ resistance.

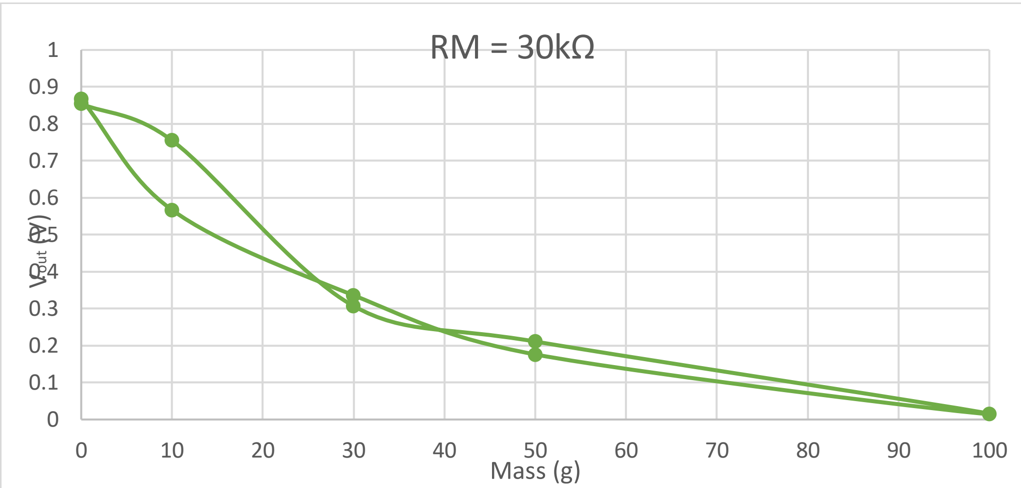


Figure 8: Hysteresis curve for circuit with 30kΩ resistance.

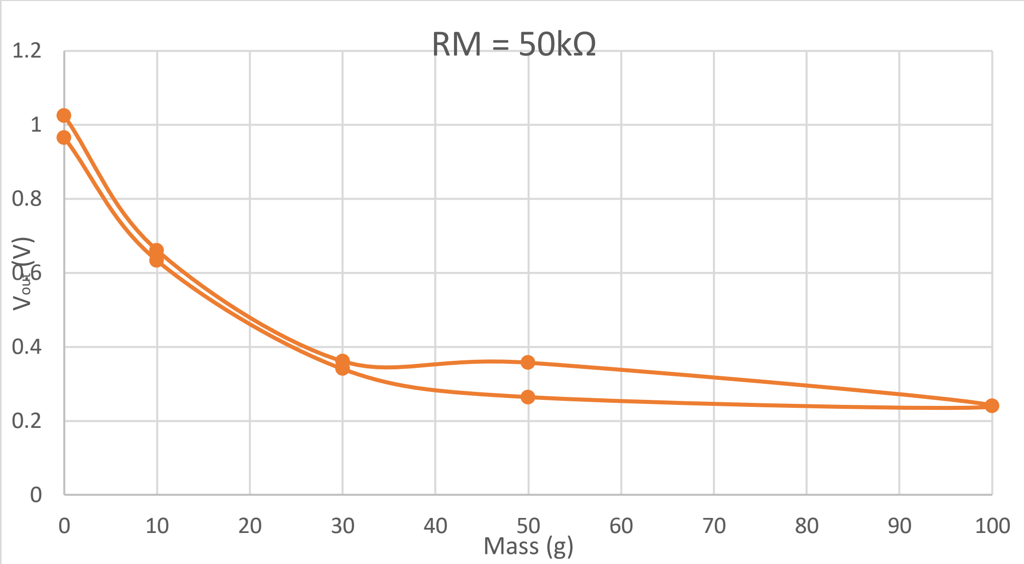


Figure 9: Hysteresis curve for circuit with 50kΩ resistance.

3) Find out the linearity range and discuss.

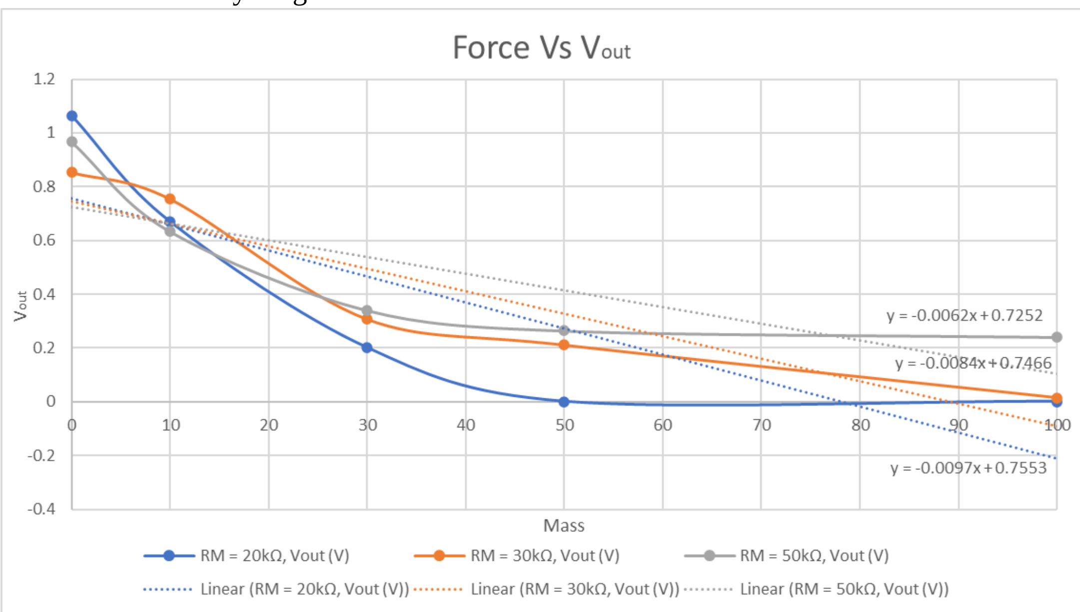


Figure 10: Linearity range and equation for the graphs.

For graph of resistance value of 20 kΩ, the equation is $V_{out} = -0.0097x + 0.7553$. The slope C=-0.0097 indicates that the output voltage decreases as the applied force increases.

As for graph of resistance value of 30 kΩ, $V_{out} = -0.0084x + 0.7466$ is the equation. And again, the output voltage decreases as the applied force, however, the drop in voltage is less than the circuit with a resistance of 20 kΩ.

Finally for the graph with resistance value of 50 kΩ, the equation is $V_{out} = -0.0062x + 0.7252$. This equation lets us know that the drop in output voltage as the force applied increases is the least among the three resistances.

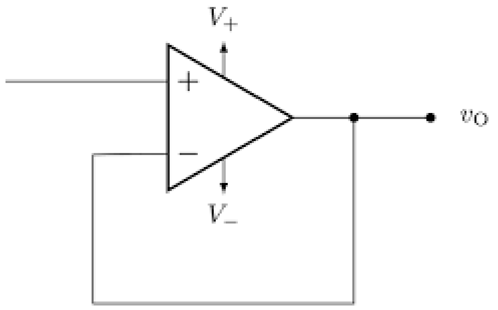
Based on the behaviour of the graphs, the system is decreasing linearly.

4) Find out the sensitivity and discuss.

The sensitivity of a sensor refers to the smallest change in force that the sensor can detect. In this experiment, the data show that as resistance in the circuit increases, the voltage drops due to applied force decreases. This indicates the system's sensitivity varies depending on the resistor used, with higher resistance providing lower sensitivity. For instance, a 20kΩ resistor showed a larger voltage response per unit of force compared to the 50kΩ resistor, making it more sensitive to small force changes.

5) What is the purpose of using voltage follower in this circuit? Explain with elaborate discussion and sketch.

The voltage follower is used in this circuit to maintain a stable output without loading the sensor. A voltage follower has a high input impedance and a low output impedance, allowing it to buffer the signal from the force-sensing resistor (FSR). This ensures that any connected devices or measurement tools do not alter the FSR's output voltage. It provides the same voltage as the input, but the buffering allows for a stable and accurate reading across devices without affecting the FSR's performance.



The op-amp in a voltage follower configuration has negative feedback applied to its inverting input. This feedback loop forces the op-amp to adjust its output voltage to match the input voltage. The high open-loop gain of the op-amp ensures that the voltage difference between the inverting and non-inverting inputs is nearly zero. The source's output impedance and the load's input impedance form a voltage divider, and consequently, voltage transfer depends on the ratio of input impedance to output impedance. Effective voltage transfer requires a source circuit with low output impedance and a load circuit with high input impedance. Voltage followers are indispensable tools in sensor calibration and characterization. Their ability to buffer signals, isolate circuits, and provide impedance matching makes them essential for accurate and reliable sensor measurements.

Conclusion

The experiment successfully demonstrated the calibration and characterization of an analog sensor (FSR) using various resistors. The results confirmed the relationship between force and output voltage: as force increased, the output voltage decreased linearly. The use of different resistors showcased variations in sensitivity and linearity, with lower resistances yielding a steeper response to force. Additionally, the voltage follower effectively buffered the sensor's output, ensuring accurate measurements. Overall, the experiment highlighted key aspects of sensor integration, calibration, and the role of circuit components like the operational amplifier and voltage follower in instrumentation applications.

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Appendices

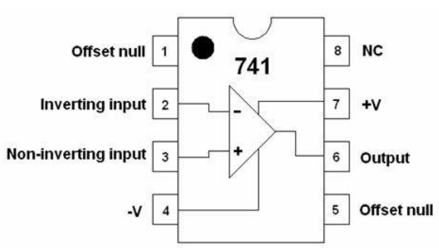
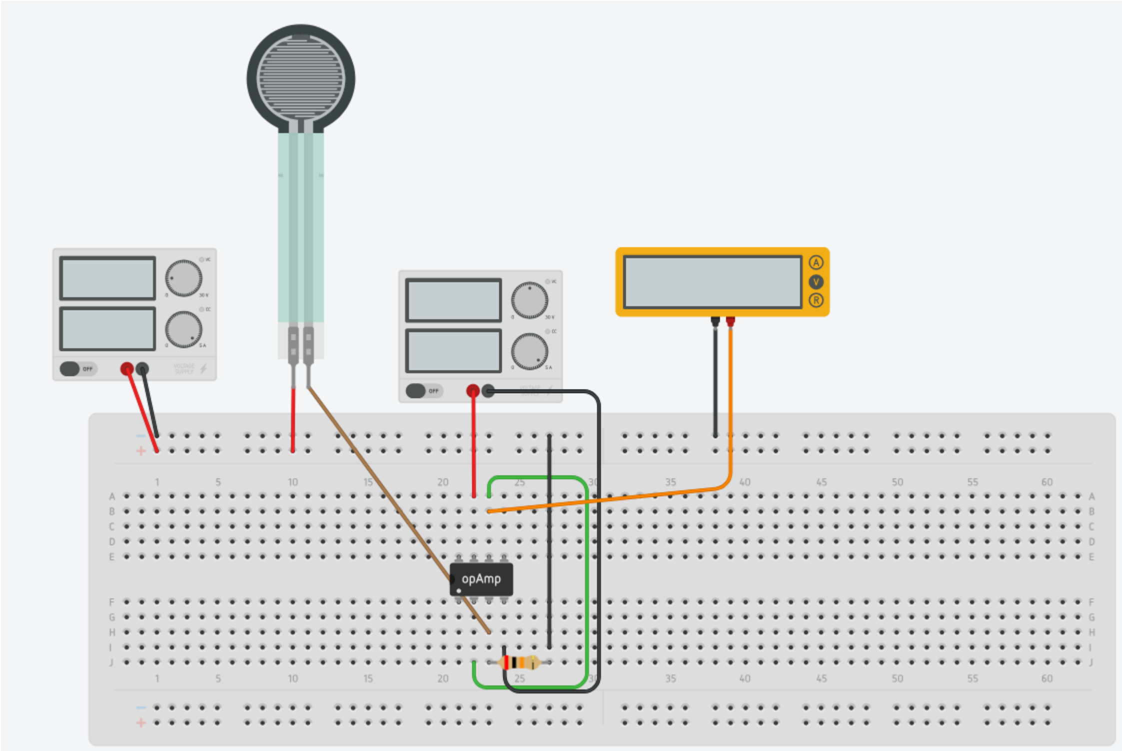
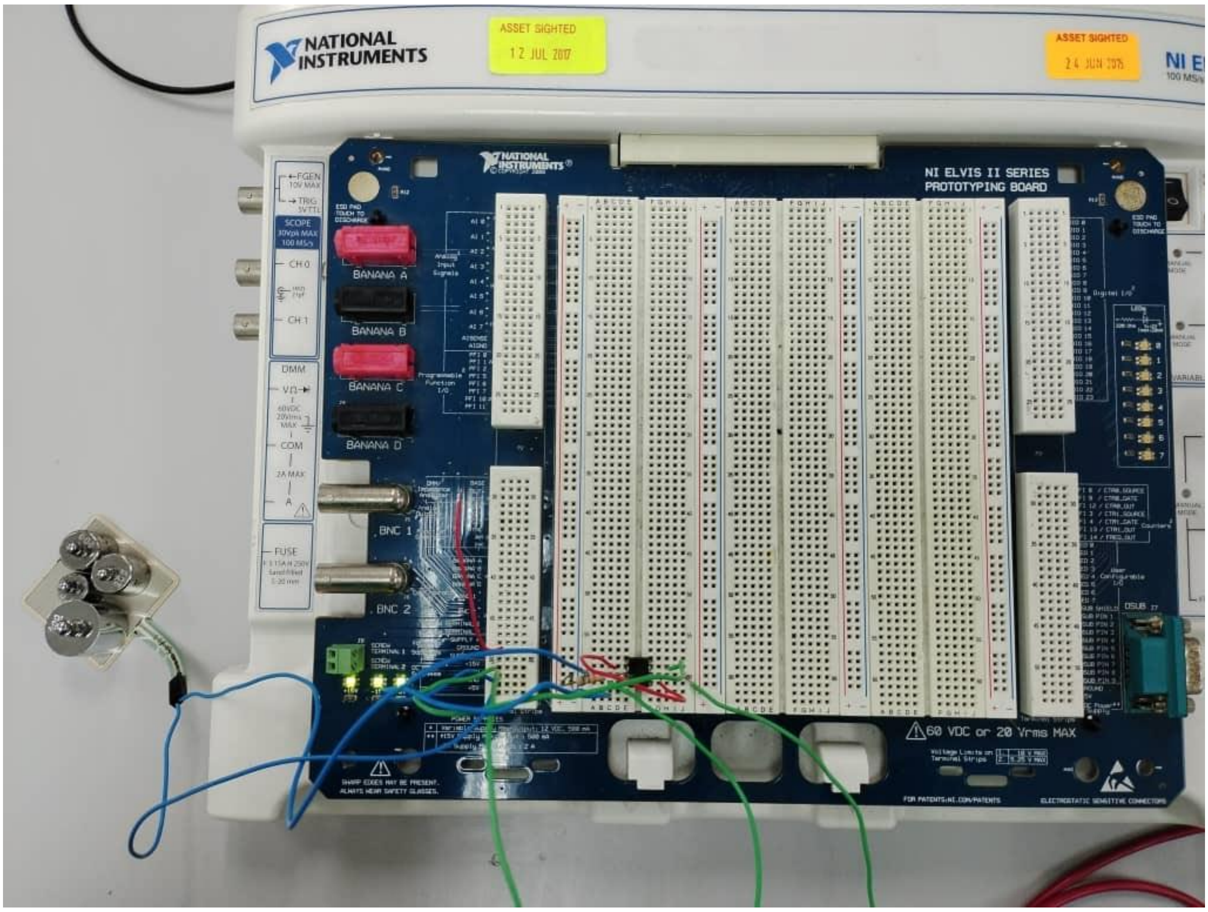


Figure 11: OP-AMP 741 pin configuration..


opAmp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