University Of Balamand
Faculty Of Engineering
ELEN303 Circuits Lab

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ELEN303 – Project

By

Sally Tabbal A2210239

Mario Makhlouta A2220007

Presented to

Dr. Nayla Greige

Circuits Lab

Faculty of Engineering

University of Balamand

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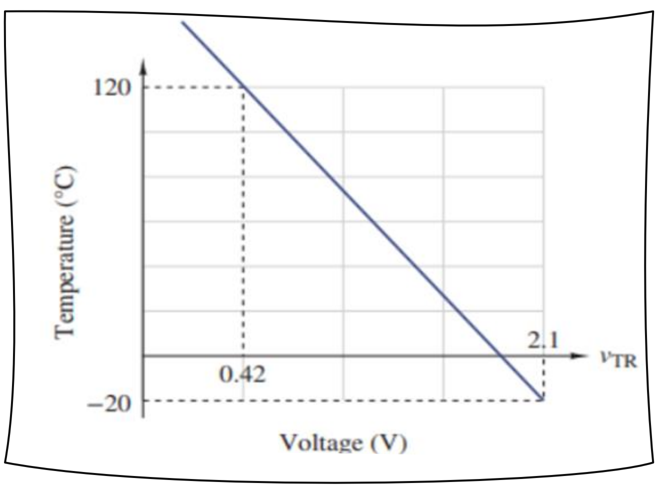
Introduction:

Temperature transducers, also known as temperature sensors, are essential devices used to measure temperature and convert it into electrical signals. In this project, we aim to design an operational amplifier (op-amp) circuit that converts the output of a temperature transducer, covering a temperature range from -20°C to 120°C, into a voltage range of 0V to 3V. This conversion allows for standardized voltage representation of temperature data, facilitating compatibility with electronic systems.

Utilizing op-amp circuits for their precision and versatility, alongside a standard 2-Volt battery for biasing, we seek to demonstrate how temperature sensor outputs can be efficiently converted into usable voltage signals. This report outlines the design process, calculations, and implementation details, providing insights into the practical application of temperature sensing and signal conditioning in various industries.

Objectives:

- Design an OP AMP circuit to convert the transducer output for temperatures ranging from −20 C to 120 C to a ranging of 0 V to 3 V, respectively.
- Use a standard 2-V battery as the reference source for the required bias.
- In the following graph, the corresponding output voltages for temperatures **-20** and **120** are respectively **2.1 V** and **0.42 V.**
- The main purpose is then to provide an OP AMP circuit to convert the output voltages from the range (**0.42 V to 2.1 V)** to the range (**0 V to 3 V)**.



Discussion:

To convert the range (0.42 V to 2.1 V) to the range (0 V to 3 V):

- **First,** we should subtract 0.42 V from the transducer voltage output to obtain the range (0.42 - 0.42 to 2.1 - 0.42) which is (0 to 1.68).

- This step can be done using a **subtractor op-amp**.

- **Second,** we want to multiply the new range (0 to 1.68) by some gain to obtain the range (0 to 3).

  The gain k = $\frac{desired\ output}{desired\ input} = \frac{3-0}{1.68-0} = \frac{3}{1.68} = 1.785714285714286$

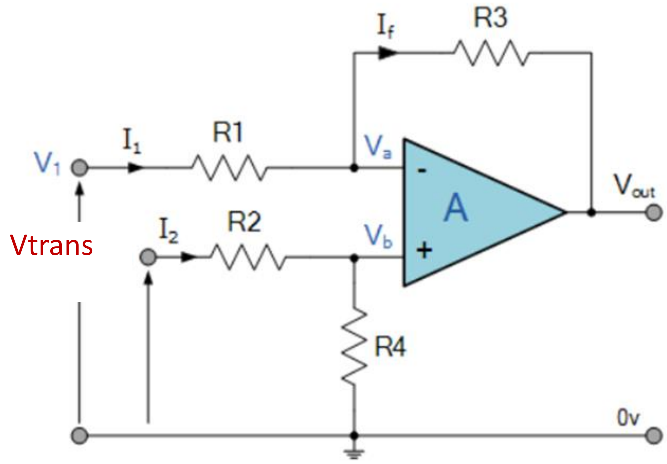
  Then, **Vout = k * Vin.**

- This step can be done using a non-inverting op-amp.

Suppose **Vtrans** is the output voltage of the transducer and **Vfinal** is the final output of the circuit.

Note: We have an equation like: $$\mathbf{Vfinal} = \underbrace{\mathbf{(Vtrans - 0.42)}}_{\boxed{\text{Subtracting}}} \underbrace{\mathbf{* \ k}}_{\boxed{\text{Non-inverting}}}$$

1) Differential op-amp (subtractor):



After applying superposition, we obtain the **general formula for voltage output:**

$$\boldsymbol{Vout} = -V1\left(\frac{R3}{R1}\right) + Vtrans\left(\frac{R4}{R2+R4}\right)\left(\frac{R1+R3}{R1}\right)$$

The desired output voltage is:

$$\boldsymbol{Vout} = Vtrans - 0.42$$

By identification between the 2 formulas:

$$Vtrans\left(\frac{R4}{R2+R4}\right)\left(\frac{R1+R3}{R1}\right) - V1\left(\frac{R3}{R1}\right) = Vtrans - 0.42$$

We could have simply chosen to set the coefficients of Vtrans and V1 to '1' and have all equal resistors R1=R2=R3=R4:

Vtrans – V1 = Vtrans – 0.42 *and simply set V1 = 0.42*

- But in order to use a standard **2-V battery** as the reference source for the required bias, we set V1 = 2V, so the equation becomes:

$$\text{Vtrans}\ \mathbf{\left(\frac{R4}{R2+R4}\right)\left(\frac{R1+R3}{R1}\right)} - 2 * \left(\frac{R3}{R1}\right) = \text{Vtrans}\ \mathbf{*1} - 0.42$$

Now by identification:

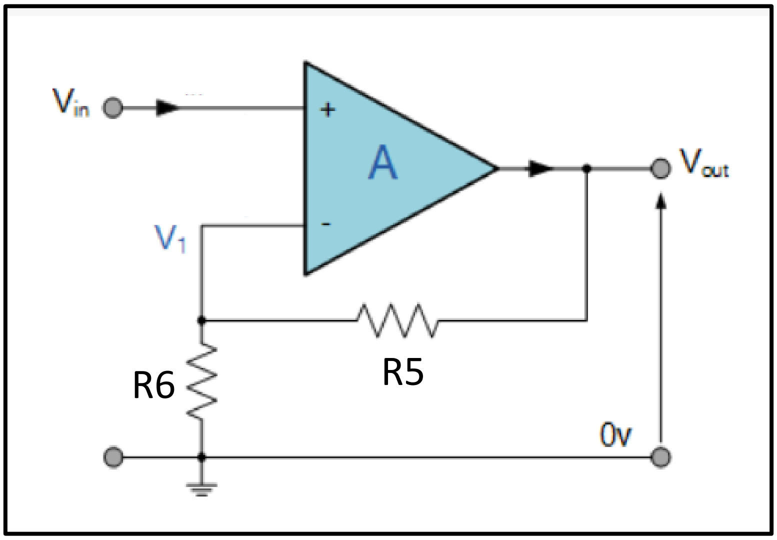
$$\left(\frac{R4}{R2+R4}\right)\left(\frac{R1+R3}{R1}\right) = 1$$

$$2 * \left(\frac{R3}{R1}\right) = 0.42 \rightarrow \mathbf{\left(\frac{R3}{R1}\right) = 0.21}$$

We chose the corresponding resistors that satisfy these equations:

R1 = R4 = 100 kΩ and R2 = R3 = 21 kΩ

2) Non-inverting op-amp:



Now, the Vout of the subtractor op-amp will be the input voltage of the non-inverting op-amp.

As we calculated, **k = 1.785714285714286**

Since the gain for the non-inverting op-amp is given by **k=** $\left(\frac{R6+R5}{R6} \right)$

Then, $\left(1 + \frac{R5}{R6} \right) = 1.785714285714286$

We tried to choose two values of R6 and R5 to satisfy this equation and based on the resistors available in our lab:

R5 = 26 kΩ

R6 = 33 kΩ

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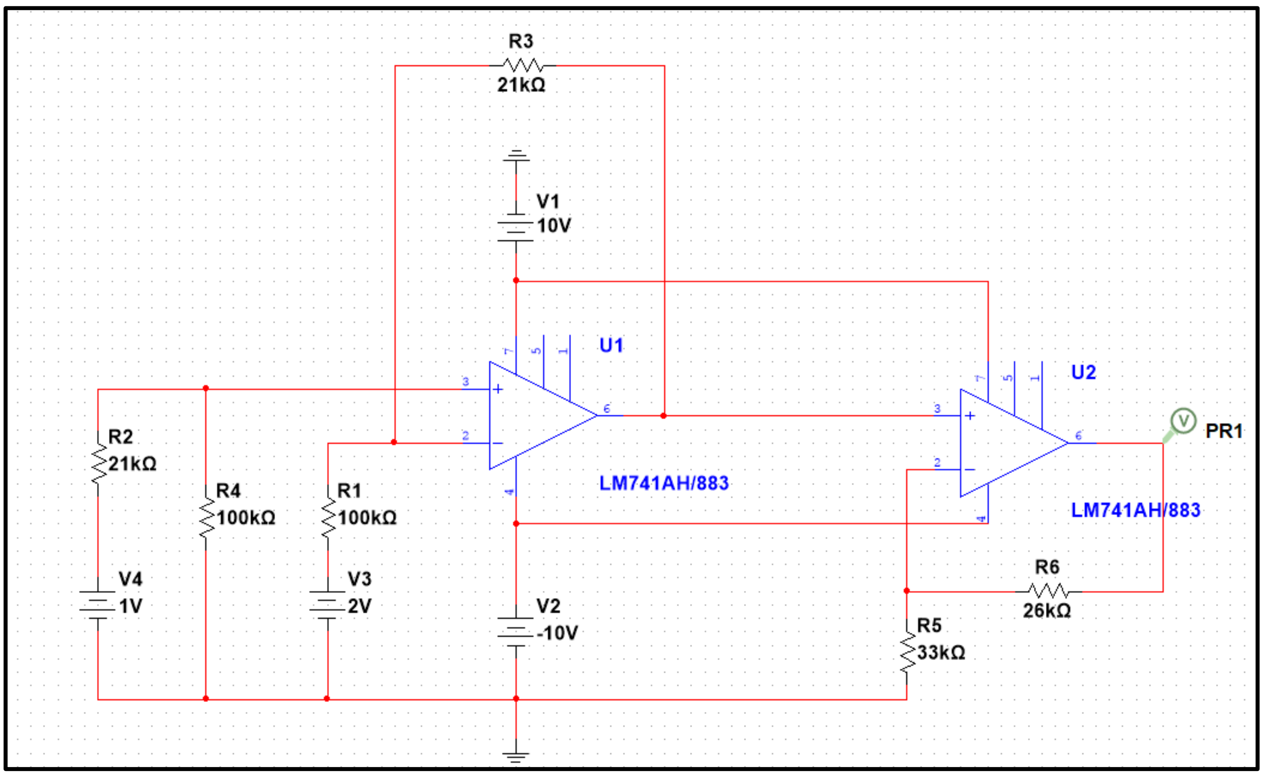
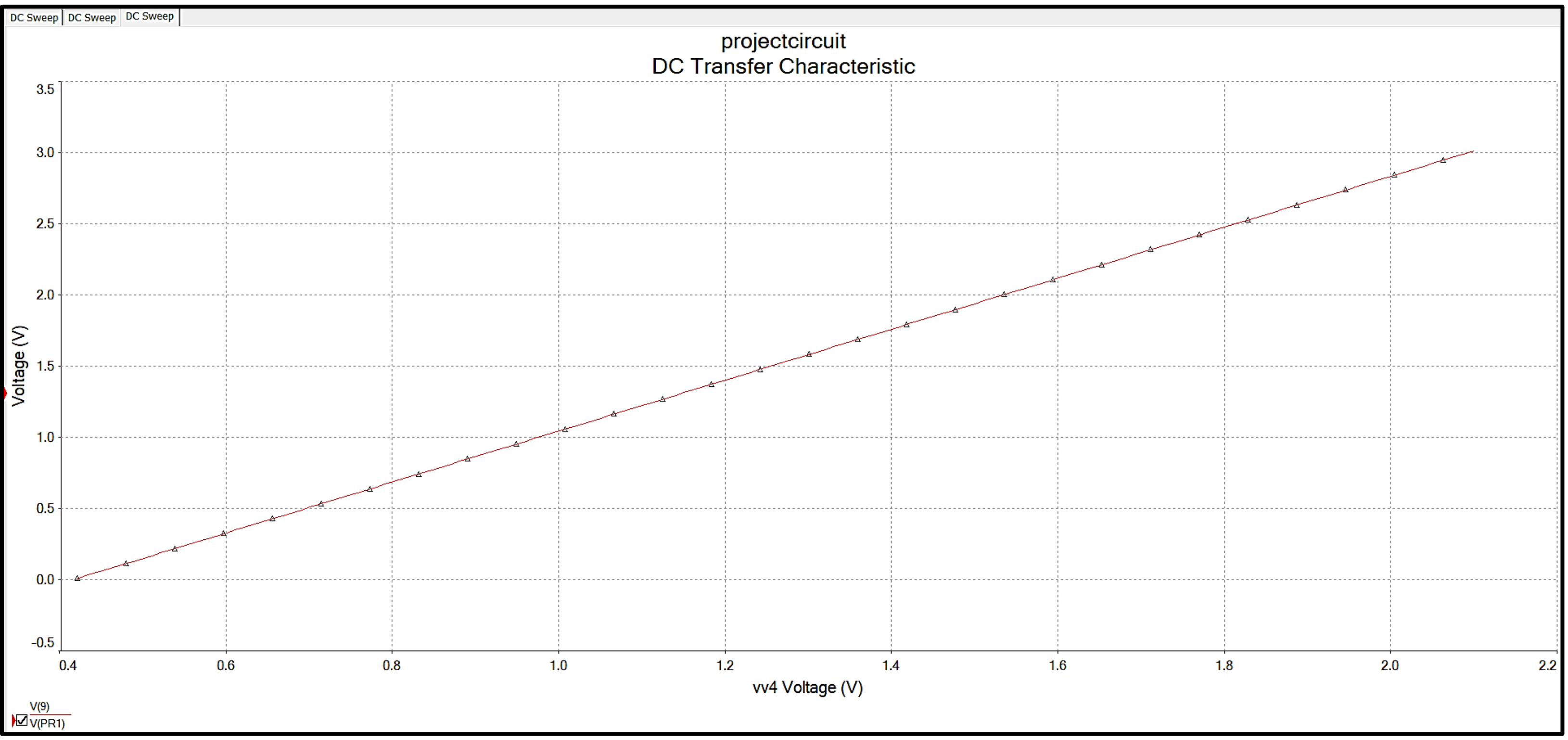
Final circuit design (Multisim):



Final voltage output graph:



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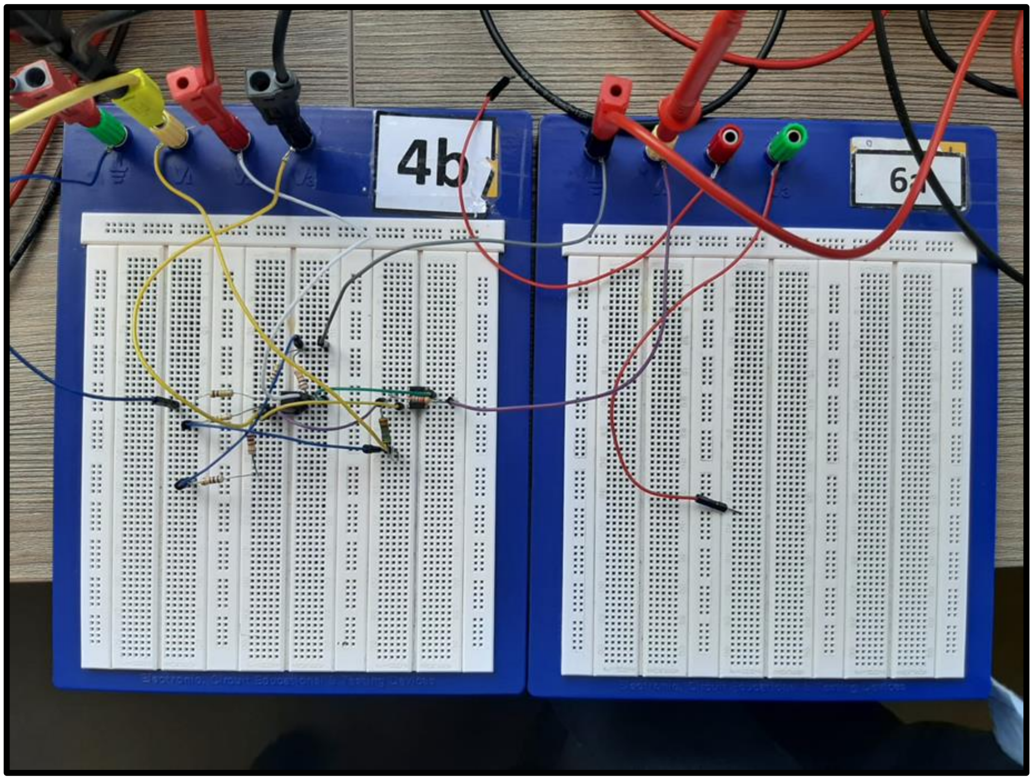
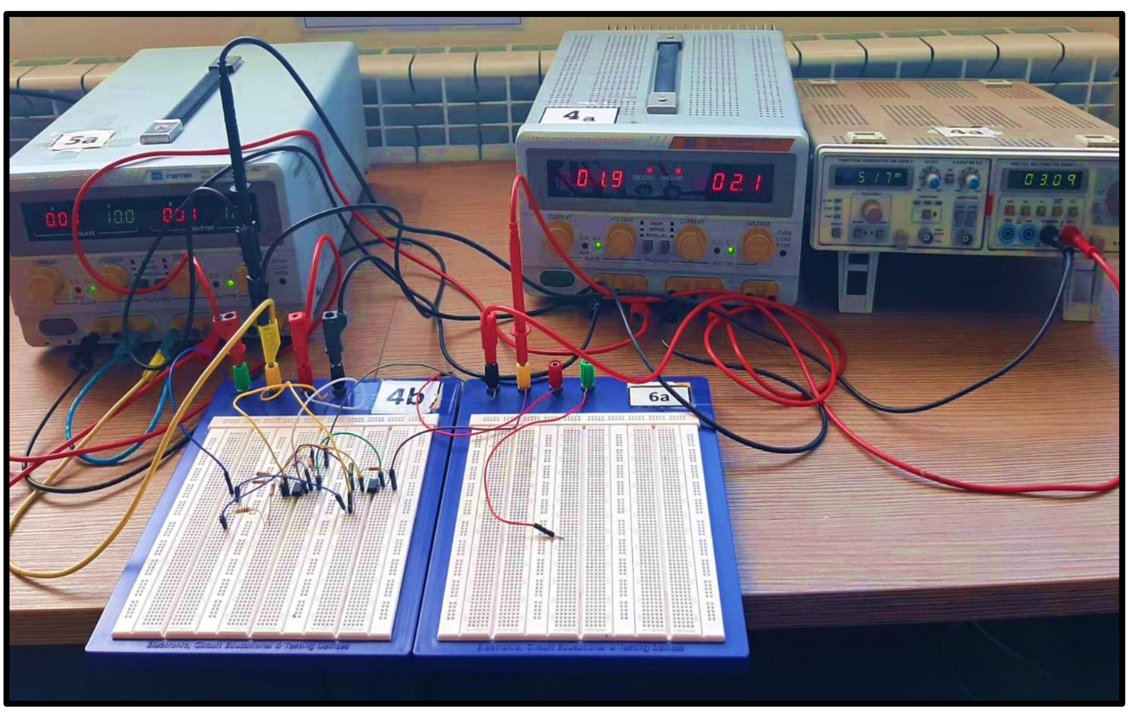
Circuit implementation on board (in Lab):





Results discussion:

- The tools used in the design:

- **Resistors:**
  Two resistors 20 kΩ, two resistors 1 kΩ, two resistors, and 100 kΩ for the subtractor op-amp (each combination of 20 and 1 is in series to obtain the 21 kΩ).
  One resistor 26 kΩ and one resistor 33 kΩ for the non-inverting op-amp.

- **Two power supplies:** One for the +Vcc and -Vcc, and one to provide the fixed voltage input of 2 V and the input voltage similar to Vtrans ranging from 0.42 V to 2.1 V.

- **Two OP-AMPs:** One op-amp playing the role of a subtractor, one op-amp playing the role of non-inverting.

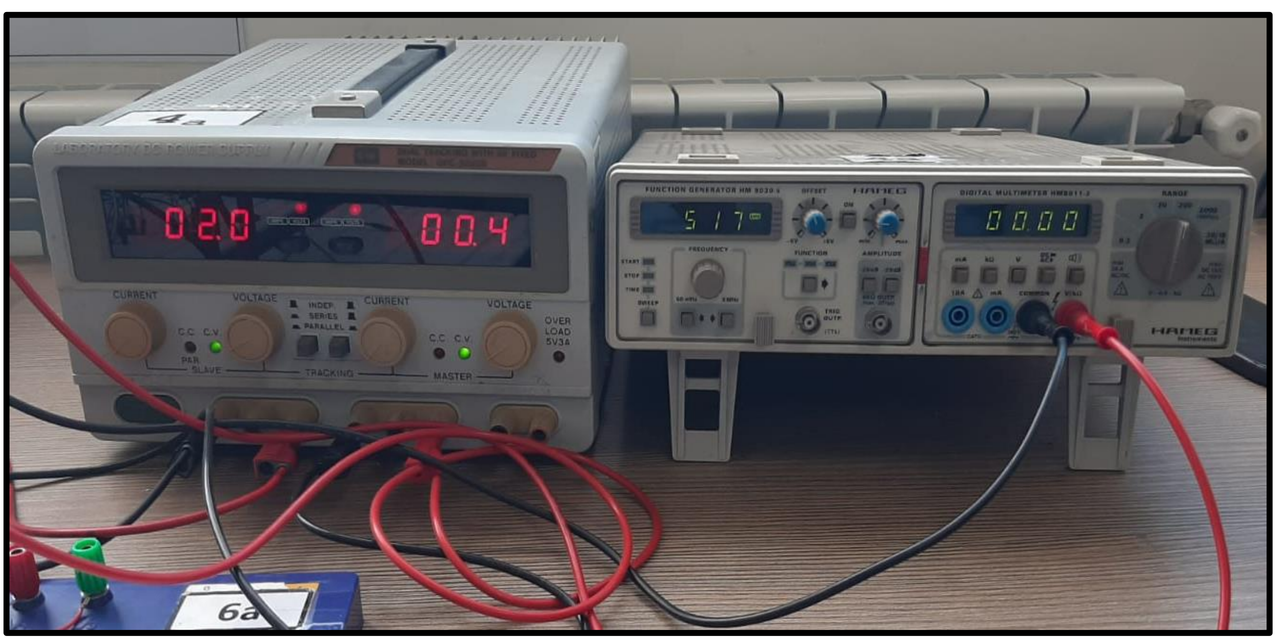
- **Wires**

- **Digital multimeter (DMM):** to measure the final output voltage ranging from 0 V to 3 V.

- Results:

Case 1:

When we tried the input voltage of 0.42 V, we observed the output voltage 0 V as desired, which is compatible with the graph provided from MULTISIM.



Case 2:

When we tried the input voltage of 1 V, we observed the output voltage 1.18 V as desired, which is compatible with the graph provided from MULTISIM.

Case 3:

When we tried the input voltage of 2.1 V, we observed the output voltage 3 V as desired, which is compatible with the graph provided from MULTISIM.

Conclusion:

We observe that for the input voltage values ranging from **0.42 V to 2.1 V (x-axis),** we obtained the desired output voltage range which is from **0 V to 3 V (y-axis).**

In summary, the op-amp circuit successfully converts temperature changes into a usable voltage signal. Multisim simulation verified its functionality. This project highlights op-amp circuits' practical role in sensor interfacing, with potential for further refinement.