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Electronic Systems for Sensor Acquisition

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LAB 01

Analog Temperature Sensor

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1,1 - Exercise : Active Current Bridge

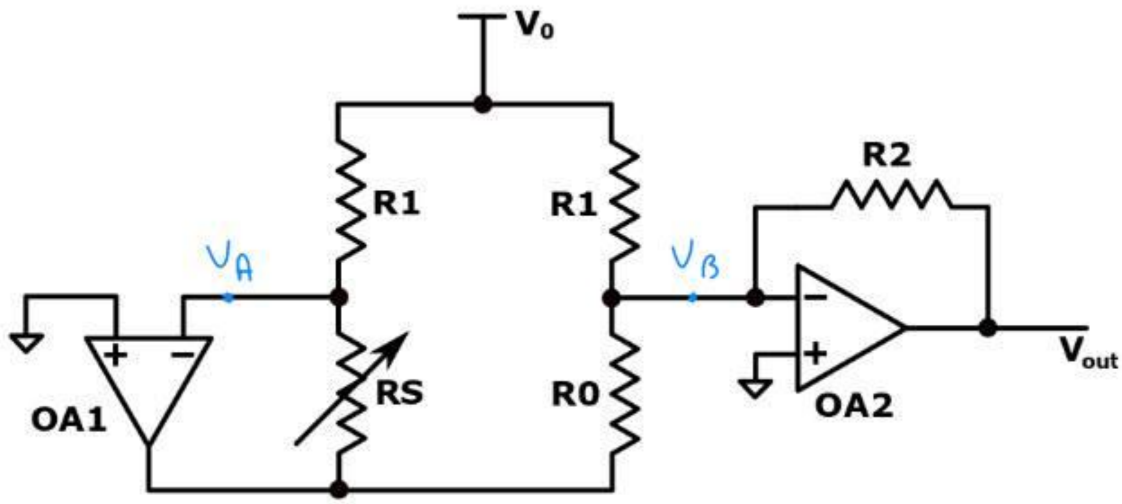


Figure 1 : Active Curret Bridge

The specifications of the circuit are the following:

- Sensor type: Pt 1000 temperature sensor
- Rs = R0 (1 + αt), where R0 = R@Tmin (so that the output voltage is always positive) andthe average value of α = 0,00385 °C-1
- Current flowing through the sensor must be lower than 1mA to avoid self-heating (much less if you can).
- Vo = 10V (obtained from external power supply)
- Temperature range: Tmin = 0 °C, Tmax =100 °C
- Vout@Tmin = 0V
- Vout@Tmax = 10V

From the figure of the specification of the Temperature Sensor PT1000 , We can get the value of the Resistance at Tmin = 0 °C We get that :

- R_0 = 100 ohms
- $R_{s\,,\,MIN}$ = 100 ohms
- $R_{s\,,\,MAX}$ = 138,5 ohms

Node Voltage at Point A (connected to OA1):

The voltage at Point A (let's call it VA) is the result of a voltage divider between R1 and RS:

$$V_A = V_0 \cdot \frac{R_S}{R_1 + R_S}$$

Node Voltage at Point B (connected to OA2):

The voltage at Point B (let's call it VB) is the result of a voltage divider between R1 and R0 :

$$V_B = V_0 \cdot \frac{R_0}{R_1 + R_0}$$

The differential voltage between points A and B is:

$$V_{diff} = V_A - V_B$$

Substituting the values of VA and VB :

$$V_{diff} = V_0 \cdot \frac{R_S}{R_1 + R_S} - V_0 \cdot \frac{R_0}{R_1 + R_0}$$

The differential voltage Vdiff_ is fed into OA2, which is configured as a non-inverting amplifier with a feedback resistor R2 . Then , We get the formula of the Output Voltage :

$$V_{out} = -V_{diff} \times \frac{R_2}{R_1}$$

By substituting the value of V_diff We get the equation of Vout :

$$Vout = -\left\{V0 \, . \frac{Rs}{R1 + Rs} - V0 \, . \frac{R0}{R1 + R0}\right\} . \frac{R2}{R1}$$

Following the calculation of the Resistances in order to get Vout between a minimum value = 0 V and a maximum value = 10 V , And choosing R1 = 120 Kohm . We get that R2 = 620 ohm

At the end , We have the following values of the resistances of the Resistors :

- R0 = 100 ohm , R1 = 120 Kohm , R2 = 620 ohm , $Rs = \begin{matrix} Min = 100 \; ohm \\ Max = 138{,}5 \; ohm \end{matrix}$

1,2 - Exercise : Voltage Reference

Design a simple voltage reference to be used together with your measurement bridge .

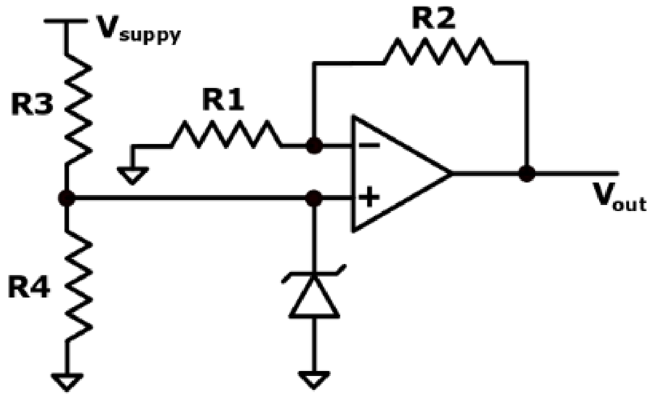


Figure 2 : Simple Votage Reference

The Specification of this Circuit are the followings :

- Vout = 10 V
- Considering that the Zenner Diode present in the laboratory is of Vz = 5 V

Following this consideration We need to force the Voltage that will be limited by the Zener Voltage to be higher than 5V in order for the voltage entering the Operational Amplifier in the positive terminal to be a constant voltage equal to 5V

Voltage Divider (R3 and R4):

- R3 and R4 create a voltage divider from the supply voltage Vsupply .
- The voltage at the non-inverting input of the op-amp (V+)

$$V_+ = V_{supply} \cdot \frac{R_4}{R_3 + R_4}$$

The Voltage generator we can set it as V_supply = 15 V

A possible choice to get V+ bigger than 5 V , We can choice that V+ = 10 V by choissing R3 = 10 Kohm & R4 = 20 Kohm

Considering that We want to get that Vout = 10 V as a DC voltage and not alternating for this reason the presence of the Zener Diode in order to limit the voltage entering the positive terminal of the Operational Amplifier :

$$V_+ \approx V_Z$$

Having an Operational Amplifier is working as non-Inverting Amplifier , We get the equation of Vout :

$$V_{out} = V_+ \cdot \left(1 + \frac{R_2}{R_1}\right)$$

Considering that V+ is set approximately equal to Vz :

$$V_{out} = V_Z \cdot \left(1 + \frac{R_2}{R_1}\right)$$

Following that Vz = 5 V & Vout = 10 V .

Then , Any choice of R1 & R2 is accepted with the only constraint of having R1 and R2 of equal values

Finally , The chosen values of Resistances of the Resistors in order to respect the specifications of this Design Process :

- R1 = 10 Kohm ; R2 = 10 Kohm ; R3 = 10 Kohm ; R4 = 20 Kohm

1.3 – EXERCISE: Analog to Digital Converter

Complete your design by including a simple PWM Analog To Digital Converter as seen during the course. You can use a simple comparator and a sawtooth signal generated by the waveform generator available in the laboratory. The schematic is reported in Figure 3. Remember that this circuit works with positive voltage values.

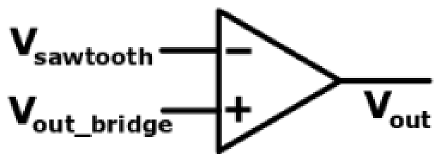


Figure 3 : Comparator

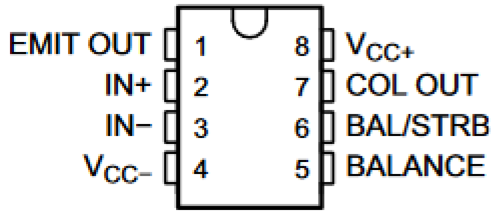
The specifications of the circuit are the following:

- Frequency = 100Hz
- At 100 °C the maximum value of Duty Cycle should be Dmax = 100%.

Sawtooth Waveform Parameters:

- Frequency: The waveform frequency is given as 100 Hz.
- Period: Since frequency f=100 Hz Then We get the period T= 1/f = 0.01s or 10 ms.
- Rise Time and Fall Time: In a sawtooth waveform, the rise time is the duration over which the voltage increases from 0 to the peak, and the fall time is the period of time in which the voltage is zero
- Peak to Peak Voltage: is the voltage between the two extremes of voltage between the maximum and minimum voltage
- Offset: Adjust the offset as needed to align the waveform with the input requirements of the comparator.

Top View



- Voltage from Collector output Vcc- = 40 V
- Operating free-air temperature range = [0,70] Celsius

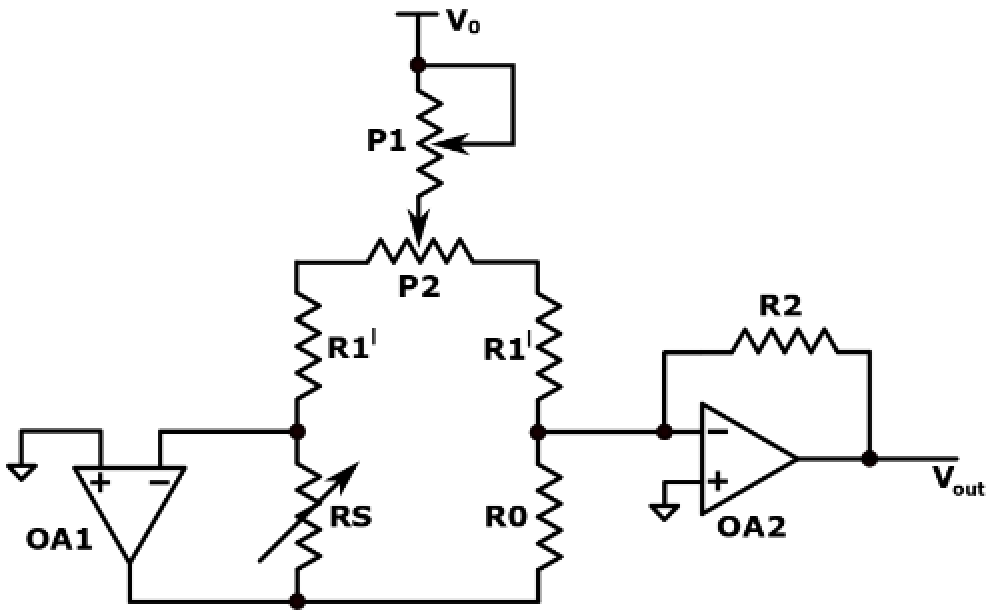
PARAMETER		TEST CONDITIONS		T_A[1]	LM111 LM211 LM211Q			LM311			UNIT
					MIN	TYP[2]	MAX	MIN	TYP[2]	MAX	
V_{IO}	Input offset voltage	See[3]		25°C		0.7	3		2	7.5	mV
				Full range			4			10	
I_{IO}	Input offset current	See[3]		25°C		4	10		6	50	nA
				Full range			20			70	
I_{IB}	Input bias current	$1 V \le V_O \le 14 V$		25°C		75	100		100	250	nA
				Full range			150			300	
$I_{IL(S)}$	Low-level strobe current[4]	$V_{(strobe)} = 0.3 V$, $V_{ID} \le -10 mV$		25°C		−3			−3		mA
V_{ICR}	Common-mode input-voltage range[3]	Lower range		Full range		−14.7	−14.5		−14.7	−14.5	V
		Upper range			13	13.8		13	13.8		
A_{VD}	Large-signal differential-voltage amplification	$5 V \le V_O \le 35 V$, $R_L = 1 k\Omega$		25°C	40	200		40	200		V/mV
I_{OH}	High-level (collector) output leakage current	$I_{(strobe)} = -3 mA$, $V_{ID} = 5 mV$	$V_{OH} = 35 V$	25°C		0.2	10				nA
				Full range			0.5				μA
		$V_{ID} = 5 mV$, $V_{OH} = 35 V$		25°C					0.2	50	nA
V_{OL}	Low-level (collector-to-emitter) output voltage	$I_{OL} = 50 mA$	$V_{ID} = -5 mV$	25°C		0.75	1.5				V
			$V_{ID} = -10 mV$	25°C					0.75	1.5	
		$V_{CC+} = 4.5 V$, $V_{CC-} = 0 V$, $I_{OL} = 8 mA$	$V_{ID} = -6 mV$	Full range		0.23	0.4				
			$V_{ID} = -10 mV$	Full range					0.23	0.4	
I_{CC+}	Supply current from V_{CC+} output low	$V_{ID} = -10 mV$,	No load	25°C		5.1	6		5.1	7.5	mA
I_{CC-}	Supply current from V_{CC-} output high	$V_{ID} = 10 mV$,	No load	25°C		−4.1	−5		−4.1	−5	mA

A possible choice for this design exercise chould be :

- Rise Time = Fall Time = Half the duration of the Period = 5 ms
- Peak – to – Peak Voltage = An appropriate choice is 10 V

Ecercise 1,4 – Error Correction :

For this exercise on **Error Correction using a Bridge Circuit**, you are required to compensate for errors in a bridge configuration. The circuit in Figure 4 aims to address the errors that can arise in sensor systems using discrete components.



Breakdown of the Exercise:

1. **Bridge Circuit Overview**:
   - The bridge consists of resistors R1& R0 , and potentiometers P1 & P2
   - The operational amplifier OA2 is used in a differential configuration to output Vout , which is sensitive to the balance of the bridge.
   - Errors like offset voltage, bias current, sensor mismatches, and component tolerances can affect the accuracy of the bridge output.
2. **Compensation Mechanism**:
   - The potentiometer P1 adjusts the gain of the circuit.
   - P2 compensates for errors that unbalance the bridge.
   - When the potentiometers are centered, the equivalent resistance of R1 becomes:

$$R_1 = R1' + P2/2 + P1$$

- This configuration provides flexibility in tuning the bridge to minimize errors.

3. **Task Requirements**:

- **Selection of Potentiometers**:
    - Choose values for P1 and P2 that result in an equivalent resistance close to the original R1 of the bridge.
    - If matching R1 precisely isn't possible due to limited potentiometer options, consider adjusting R2 as an alternative.

Detailed Design Steps

1. Bridge Balance and Selection of Potentiometer Values

- The bridge is balanced when the voltage at the midpoints of both branches (across OA1) is the same.
- When potentiometers P1 and P2 are centered, the new effective resistance for R1 becomes:

$$R_1 = R1' + P2/2 + P1$$

- Let's assume the following component values to balance the bridge:
    - R1' = 1 Kohm
    - P1 = 500 Kohm
    - P2 = 1 Kohm

In the middle position, the combined resistance R1 would then be:

$$R_1 = 1\,\mathrm{k}\Omega + \frac{1\,\mathrm{k}\Omega}{2} + 500\,\Omega = 2\,\mathrm{k}\Omega$$

By adjusting P1 and P2, you can make small adjustments to R1R_1R1 to balance the bridge if the measured parameter (like resistance RSR_SRS) shifts due to environmental changes.

2. Gain Adjustment Using OA2

- **Choosing R2** : The gain of the second operational amplifier OA2 can be set to amplify the differential voltage from OA1.
- For a moderate gain, let's choose R2=10 Kohm

- The gain can be adjusted based on the desired output voltage range. If needed, add a feedback resistor across OA2 to further control the gain.

3. Compensating for Errors

Errors can arise from:

- **Temperature changes** affecting resistor values.
- **Offset voltages** in the operational amplifiers.
- **Component tolerances** causing mismatches in R0 , R1, or RS.

The potentiometers P1 and P2 allow for fine-tuning to address these mismatches and bring the bridge back into balance, minimizing the differential voltage across the input of OA1 when the bridge is balanced. This effectively compensates for drift or tolerance variations in R0 and RS.

4. Testing and Final Adjustment

- Adjust P1 and P2 experimentally until the output voltage at OA2 is minimized when the bridge is balanced (i.e., when there's no error).
- If the available potentiometer values do not perfectly balance the bridge, you may need to adjust R0 slightly to achieve a close approximation.

Summary of Component Values

- **R1'**: 1 Kohm (fixed resistor)
- **R0**: 1 Kohm
- **P1**: 500 ohm potentiometer for fine adjustments
- **P2**: 1 Kohm potentiometer for further adjustment
- **R2**: 10 Kohm (gain control for OA2)