# Analog Wheatstone bridge-based automatic interface for grounded wide-range resistive sensors

Ayaz Mumtaz Ansari
Jamia Millia Islamia
26/06/2024

Abstract

Presenting an analog Wheatstone bridge-based architecture for a resistive sensor circuit. In this circuit, the change in external stimulus is measured with a highly sensitive change in resistance. The change in resistance is then converted into output voltage, which holds a direct relation with the reciprocal of the sensor resistance. The circuit operates in autonulling mode, meaning the bridge remains balanced automatically for a wide range of sensor resistance.
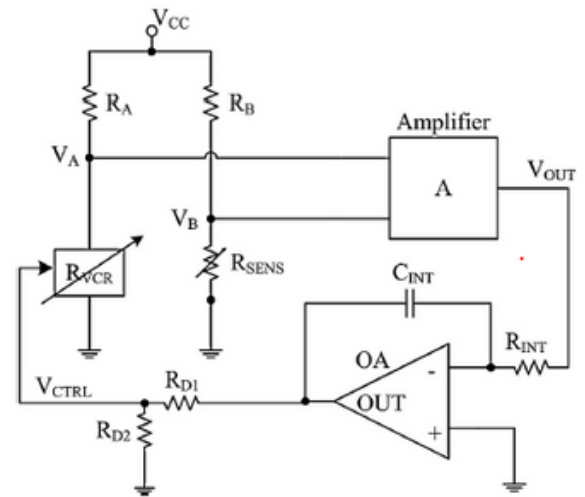
proposed uncalibrated Wheatstone bridge.

Circuit Design

The proposed circuit works properly for the range of resistive sensor 10kohm to 200kohm in the autonulling mode. In the auto nulling mode the change in the sensor resistance is automatically callibrated across the parallel arm of the bridge and the overall bridge remains balanced, outside the auto-nulling region the bridge is unbalanced as the integrator saturates and in this case output of the amplifier (Va-Vb) is the measure of sensor resistance. A **voltage controlled resistance** has been employed using a Analog Multiplier by which we can control the resistance value with the help of integrator output voltage.

- In this Circuit RSens is the sensor resistance and it will vary accoding to external stimulus.
- If the Sensor resistance is in the range of 10kohm to 200kohm . The circuit properly operates in the autonulling mode and the bridge is automatically balanced.
- In the auto-nulling mode the measure of the sensor resistance is given by the ouput of the integerator (Vctrl).
- In the autonulling mode the differential output of amplifier should be ideally zero.
- Outside the autonulling mode , the measure of the sensor resistance is given by the differential output of the INA.
- We will analyse the resistance of the VCR by ohms law formula and verify if the bridge is balanced or not.
- **For the balanced bridge condition to satisfy we must get (Rvcr=Rsens/10) .**
- **(Taking RA/RB=0.1)**

Multisim Schematic-
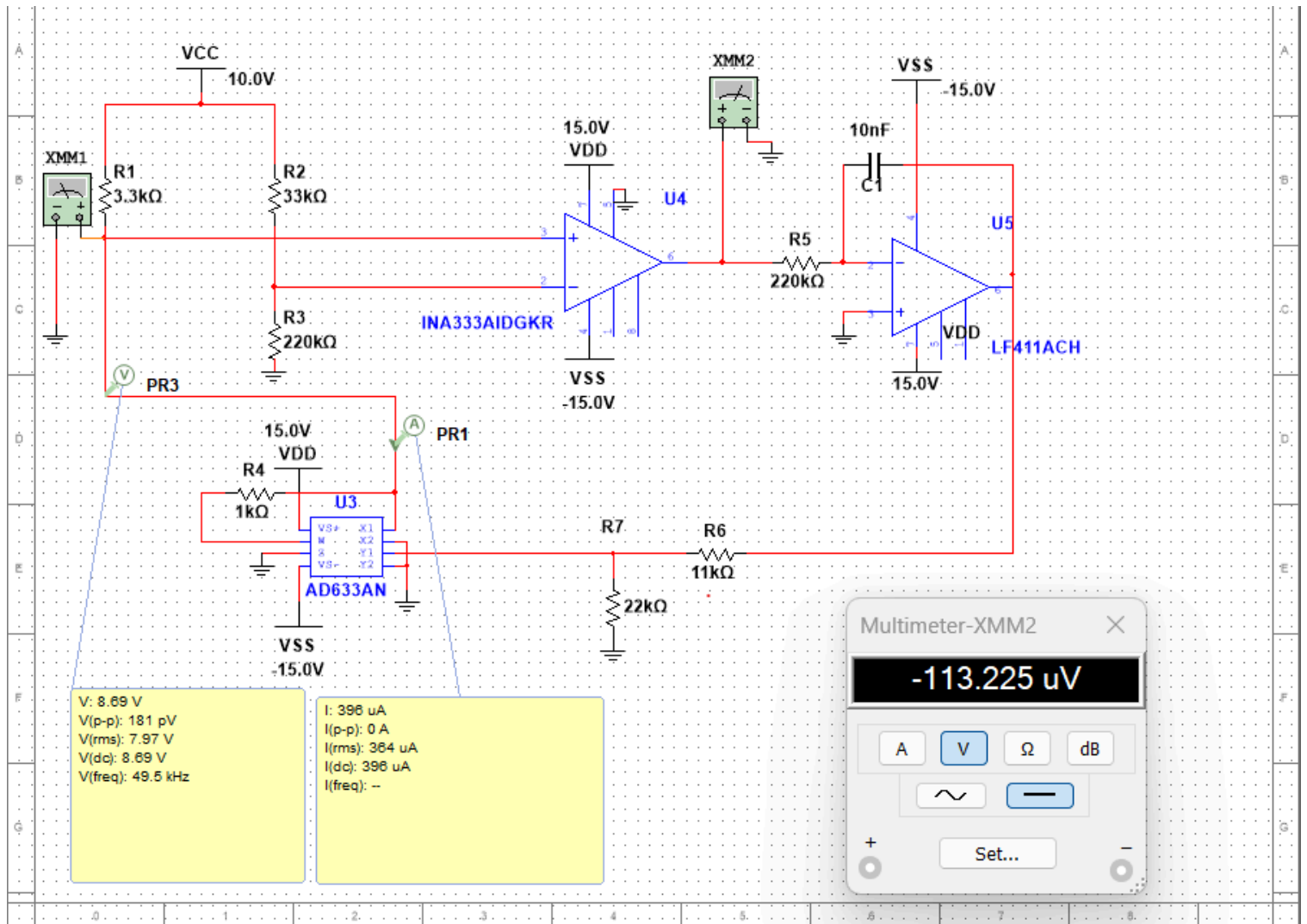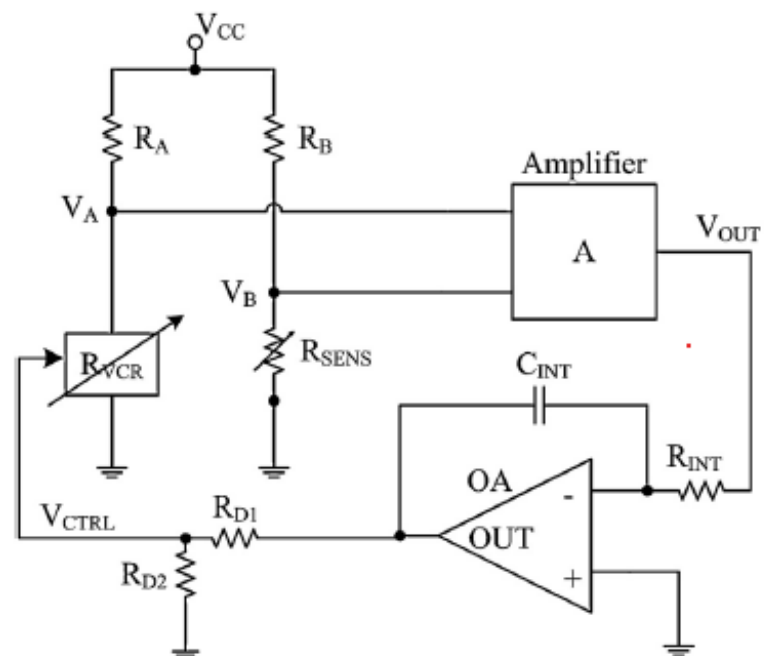

Circuit Simulated in Multisim

Note: Here R3 is the grounded sesnsor resistance.

- **We can see for Rsens= 200kohms , we get Va=8.69 V and I=0.396mA. So we get Rvcr = Va/I=21.944kohm.**
- **Similarly the circuit works for the range of 10kohm to 220kohm**

EESchema Schematic-

- Here i have made **INA using 3 lm-741 op amps.**
- The working of the schematic will be verified similarly as done in multisim simulation that is by calculating Rvcr.
- In the auto nulling mode , the bridge to be balanced the valur of **Rvcr should be Rsens/10**.
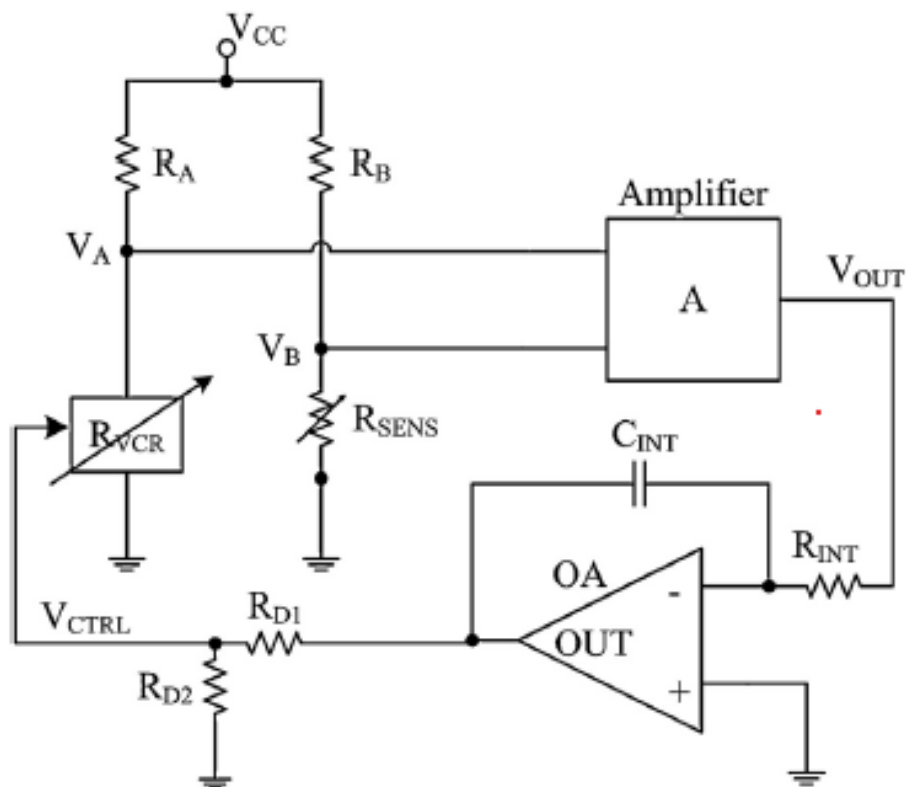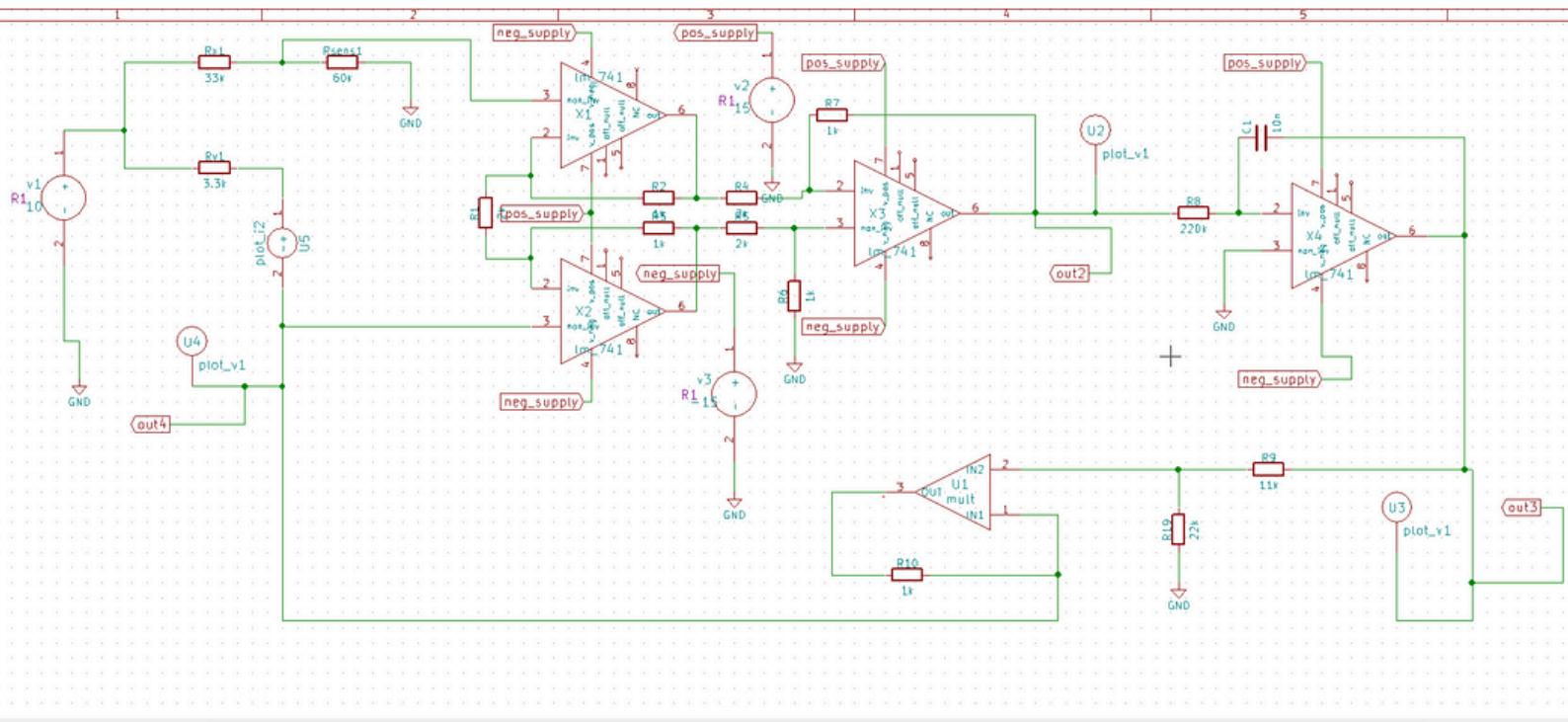
NGspice result-

- Here Rsens = 60k , therefore Rvcr should be 6kohm.
- We Measure Rvcr in simulation by value of U4 (Voltage in branch of VCR) and U5(Current in branch of VCR)

x1.net-_q15-pad2_	-14.3309
x1.net-_q15-pad3_	-14.9645
x1.net-_q18-pad3_	6.48925
net-_r2-pad2_	6.43617
x1.net-_q19-pad3_	6.43617
x2.net-_q1-pad1_	14.4587
out4	6.47515
x2.net-_q1-pad3_	5.95242
net-_r1-pad1_	6.47589
x2.net-_q2-pad3_	5.95281
x2.net-_q3-pad2_	-13.9466
x2.net-_q13-pad1_	5.43364
x2.net-_c1-pad2_	-13.7933

D:\ayaz\newproject\newproject.cir.out

- **Va /U4 =6.47515 volts**

x4.net-_q18-pad3_	12.5354
x4.net-_q19-pad3_	12.5259
net-_r19-pad2_	8.35063
net-_r10-pad1_	5.40716
v_u5#branch	0.00106814
v3#branch	0.00821387
v2#branch	-0.0107561
v1#branch	-0.00117576
a1#branch_1_0	0.00106799

No. of Data Rows : 108
ngspice 1 ->

D:\ayaz\newproject\newproject.cir.out

- **I /U5 =1.06799mA**

- **Hence we get Rvcr=Va/I = 6.063 K ohms which is close to 6kohms and thus the bridge is balanced**

|	
x3.net-_q14-pad2_	-0.116332
x3.net-_q14-pad3_	-0.757231
x3.net-_q15-pad2_	-14.3151
x3.net-_q15-pad3_	-14.9567
x3.net-_q18-pad3_	0.0281473
out2	0.0281473
x3.net-_q19-pad3_	-0.0786426
net-_c1-pad1_	0.000677512
out3	12.5259
x4.net-_q1-pad1_	14.4611
x4.net-_q1-pad3_	-0.518449
x4.net-_q2-pad3_	-0.518089
x4.net-_q3-pad2_	-13.9492

D:\ayaz\newproject\newproject.cir.out

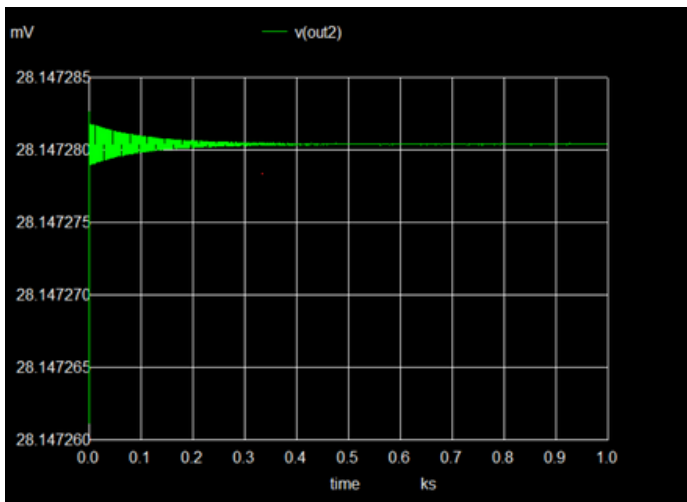**Differential output voltage Va-Vb**
(ideally should be zero in auto-nulling but there is a minute error)

Vctrl (Output of integerator,
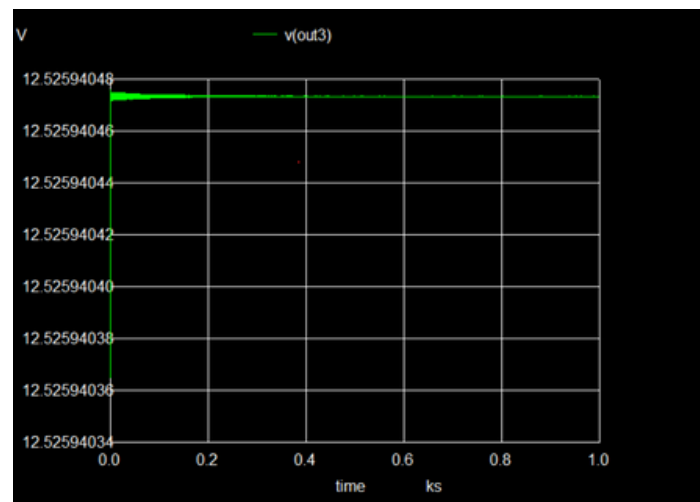**this is the measure of Rsens in auto-nulling mode)**

NGspice Plot-
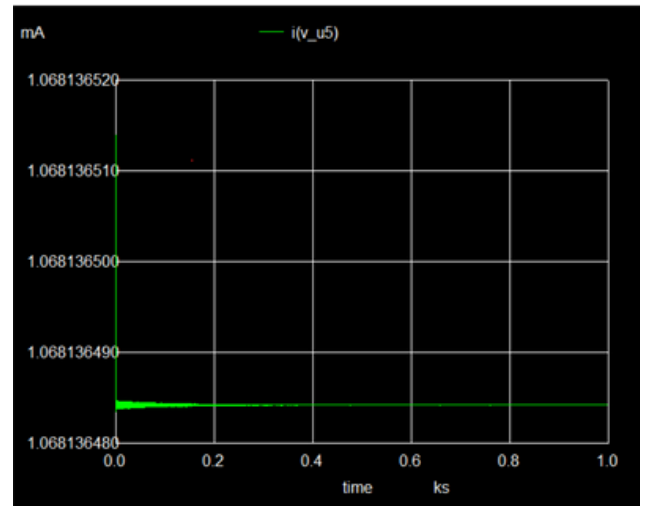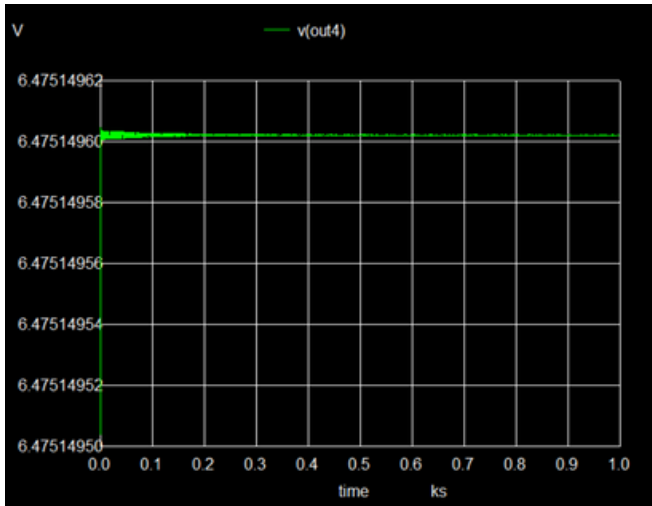
$$Rvcr=Vou4/I= 6.063kohm$$

Va-Vb = Differential Output of the Balanced Bridge

Vctrl = Output of the Integerator

Observation-

- The Circuit Works Properly for a range of 10kohm to 200kohm with max error of _____ in the autonulling mode (Automatic Bridge Balanicing).
- The Simulation have been performed in Multisim and EeSchema both , the result is then verified.

Future Work Scope -

- I am working on the same circuit for AC Excitation.

Reference -

- Analog Wheatstone bridge-based automatic interface for grounded and floating wide-range resistive sensors - DOI: 10.1016/j.snb.2012.12.044