ECE6410 | HW02 | Brendon Simonsen

ECE 6410 HW02 | BRENDON SIMONSEN | 2026-01-22

1) SOURCES ON NOISE MINIMIZED BY RATIOMETRIC

1) POWER SUPPLY, SPECIFICALLY VARIATIONS OR DRIFT
2) GAIN ERROR IN EXCITATION VOLTAGE
3) REFERENCE VOLTAGE DRIFT FROM INTERNAL REFERENCE AGING, TEMPERATURE, AND/OR REFERENCE TOLERANCE.

ELIMINATED BY DIFFERENTIAL CIRCUITS

1) COMMON-MODE ELECTROMAGNETIC INTERFERANCE
2) GROUND POTENTIAL DIFFERENCES
3) CABLE PICKUP NOISE

2) a) FOR A BALANCED BRIDGE, THE OTHER RESISTORS SHOULD BE 350 Ω AS WELL

b) $S = \frac{\Delta V_{out}}{\Delta R_{sensor}}$

$\Delta V_{out} = V_A - V_B$

BRIDGE RATIO $k = \frac{R_{sensor}}{R_0}$

$k_i = k_{min} \cdot \left(\frac{k_{max}}{k_{min}}\right)^{\frac{i-1}{N-1}}$

$k_i = 1 \cdot \left(\frac{10}{1}\right)^{i-1/9}$

$R_s = k \cdot R_0$

NEED TO NORMALIZE $\left.\frac{V}{\Omega} \cdot \frac{R_{ref}}{V_{ref}}\right\} \frac{h_0}{V_{in}}$

k	$R_s(\Omega)$	$V_{out}(V)$
1.01	352	-0.014
1.26	441	-0.575
1.58	553	-1.124
2	700	-1.667
2.51	879	-2.152
3.16	1106	-2.596
3.98	1393	-2.992
5.01	1754	-3.336
6.31	2209	3.652
9.99	3499	-4.091

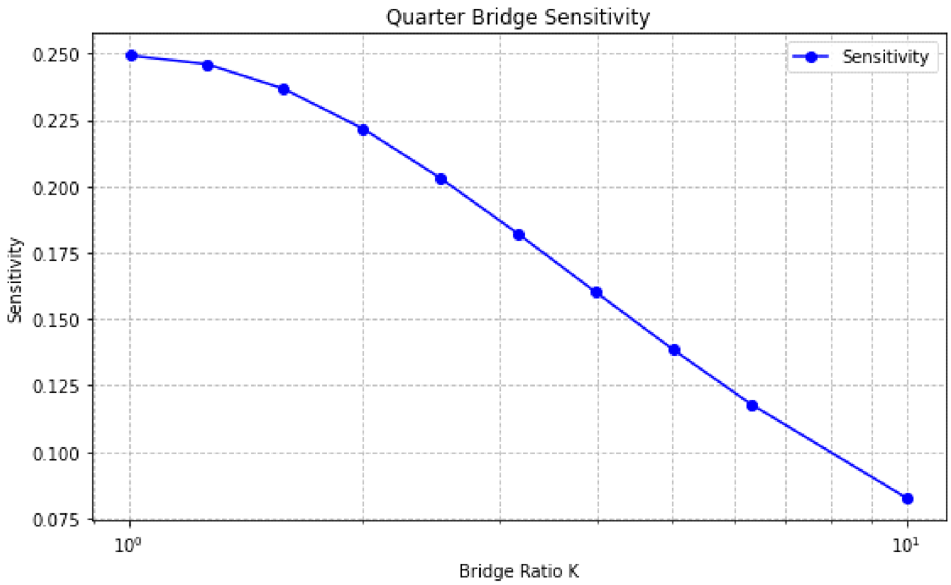
3) USE A HALF BRIDGE, THIS INCLUDES 2 STRAIN GAUGES. ONE GAUGE WILL BE ACTIVE, MEANING IT IS PLACED IN A POSITION TO MEASURE STRAIN. THE SECOND GAUGE WILL BE INACTIVE, MEANING IT WILL EXPERIENCE CHANGES IN TEMPERATURE BUT NOT STRAIN

R_1 - ACTIVE STRAIN GAUGE
R_2 - INACTIVE STRAIN GAUGE
R_3 - MATCHING RESISTOR
R_4 - MATCHING RESISTOR

THE MATCHING RESISTORS SHOULD HAVE THE SAME TEMPERATURE COEFFICIENT OF RESISTANCE (TCR) AS THE STRAIN GAUGES, IF POSSIBLE

AT NO STRAIN BUT CHANGING TEMPERATURE, BOTH GAUGES CHANGE BY THE SAME AMOUNT.

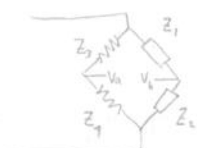
AT STRAIN AND CHANGING TEMPERATURE, ONLY THE ACTIVE GAUGE WILL CHANGE AS A RESULT OF THE STRAIN.



ECE 6140 HW02 | BRENDON SIMONSEN | 2026-01-22

3. b) THE INACTIVE STRAIN GAUGE WILL BE MOUNTED ON A MATERIAL THAT IS THERMALLY CONNECTED TO THE ENVIRONMENT BEING TESTED, BUT IT WON'T EXPERIENCE THE EFFECTS OF STRAIN. THIS WILL ENSURE THE INACTIVE GAUGE IS THERMALLY COUPLED WITH THE ACTIVE GAUGE AS WELL AS MECHANICALLY ISOLATED.

c) $R(\varepsilon, T) = R(1+g\varepsilon)(1+\alpha[T-T_0])$ $[\Omega]$



$Z_1 = R(1+g\varepsilon)(1+\alpha[T-T_0])$ *(ACTIVE)

$Z_2 = R(1+\alpha[T-T_0])$ *(NON ACTIVE)

$Z_3 = R$

$Z_4 = R$

$$\therefore V_0 = V_{ref}\Bigg(\underbrace{\frac{R(1+\alpha[T-T_0])}{R(1+g\varepsilon)(1+\alpha[T-T_0]) + R(1+\alpha[T-T_0])}}_{V_b} - \underbrace{\frac{R}{R+R}}_{V_a}\Bigg)$$

$$\Rightarrow V_{ref}\left(\frac{1+g\varepsilon}{2+g\varepsilon} - \frac{1}{2}\right) = V_{out}$$

WE CAN SEE THAT TEMPERATURE IS NOT IN THE SIMPLIFIED EQUATION. THIS ALGEBRAICALLY PROVES THAT THE OUTPUT (V_{out}) IS NOT AFFECTED BY TEMPERATURE.

d)

°C	V_{out} (V)
20	2.757
-50	2.75
800	401 mV

(WITH STRAIN)(ADJUSTED VALUES)

$120\,\Omega$ @ 20°C
$255\,\Omega$ @ -50°C ? 86.33Ω
$1405\,\Omega$ @ 800°C

(2% STRAIN)
$415\,\Omega$ @ 20°C
$298\,\Omega$ @ -50°C
$1650\,\Omega$ @ 800°C

$\frac{415}{298} = 1.39$ $\quad \frac{120}{x} = 1.39 \Rightarrow x = \frac{120}{1.39} \Rightarrow x = 86.33\,\Omega$

$\frac{1650}{415} = 3.98$ $\quad \frac{1405}{120} = 11.7$

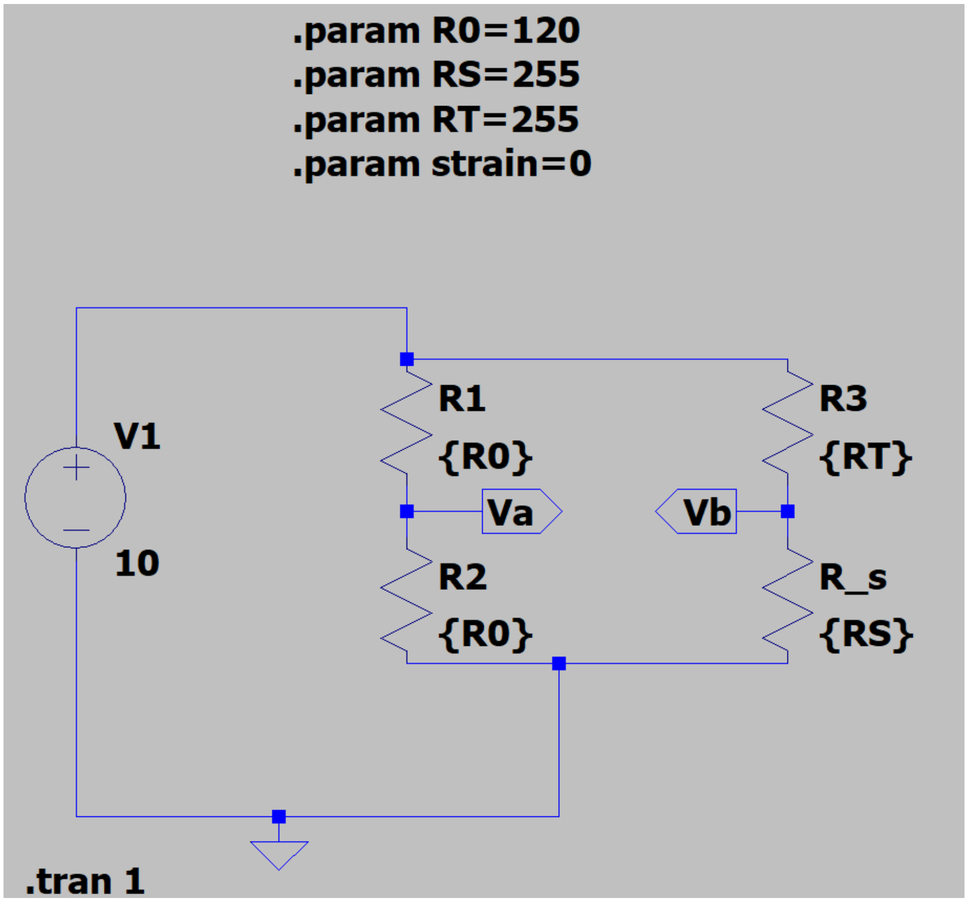
°C	V_{out} (WITH STRAIN)
20	2.75
-50	588 mV
800	401 mV

(WITHOUT STRAIN) $\rightarrow$

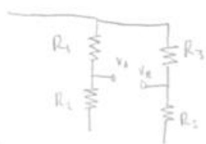
°C	V_{out}
20	0
-50	0
800	0

WHEN THERE IS NO STRAIN, WE CAN SEE THAT $V_{out} = 0$. THIS DEMONSTRATES HOW THE INACTIVE STRAIN GAUGE CAUSES THE CHANGE IN TEMPERATURE TO HAVE NO EFFECT ON THE BALANCING OF THE BRIDGE.

FROM THE PROVIDED VALUES FOR THIS STRAIN GAUGE, IT APPEARS THAT THE RESISTANCE DOES NOT HAVE A LINEAR, OR CLOSE TO LINEAR, RELATION TO CHANGES IN TEMPERATURE. THIS CAN BE OBSERVED BY LOOKING AT THE TABLE ABOVE.


.param R0=120
.param RS=255
.param RT=255
.param strain=0
V1
10
R1
{R0}
Va
R2
{R0}
R3
{RT}
Vb
R_s
{RS}
.tran 1

4.



$R_1 = R_2 = R_3 = 100\Omega$

$R_S = 100\Omega$

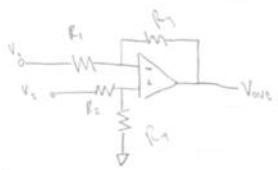
	R_S	V_{out} $(\lvert V_1 - V_2 \rvert)$
	100	0
(+10%)	110	238 mV
(-10%)	90	263 mV

THE WORST CASE SCENARIO IS WHEN R_S HAS -10% VARIATION.
THE TABLE ABOVE SHOWS HOW V_{OUT} CHANGES WITH A +/- 10% VARIATION TO R_S. FOR EASE OF USE, I SELECTED THE RESISTOR VALUES TO BE 100Ω.

5.

a) WITH $10k\Omega$ RESISTORS, WE HAVE A FAIRLY HIGH INPUT IMPEDANCE. IT LOOKS LIKE THE LT1793 WOULD BE THE BETTER OPTION BECAUSE IT APPEARS TO BE DESIGNED FOR HIGH IMPEDANCE. WHEREAS THE LT1363 IS DESIGNED FOR LOW IMPEDANCE

b)



CASE 1: $R1 = R2$, $R3 = R4$ $\quad V_{out} = \frac{R_3}{R_1}(V_2 - V_1)$

CASE 2: $R4 = R3$ $\quad V_{out} = (V_2 - V_1)\left[1 + \frac{2R_2}{R_1}\right]$

$10\,V_{PK\text{-}2\text{-}PK} \Rightarrow V_{OUT} = 5\,V$

RAILS ARE +/- 12V

$V_{in} = 0.5\,V$

CASE 1: $V_{in} = V_1 - V_2 = 0.5\,V$

$GAIN = \frac{10V}{0.5} = 20$ GAIN $\quad R1 = R2 = 1k\Omega$

$R3 = R4 = 20k\Omega$

$GAIN = 20 = \frac{R_3}{R_1} = \frac{R_3}{1k\Omega} \Rightarrow R3 = 20k\Omega$

CASE 2:

$R4 = R3 = 20k\Omega$ $\quad V_{out} = (V_2 - V_1)\left[1 + \frac{2R_2}{R_1}\right]$

$R1 = 1k\Omega$ $\quad GAIN = 20 = 1 + \frac{2R_2}{R_1} \Rightarrow R_2 = \frac{[illegible]}{1k\Omega} \Rightarrow R_2 = 9.5\,k\Omega$

$R2 = 9.5\,k\Omega$

USING 20% SENSITIVITY, $RS = 877\Omega$

5.

ECE 6140 HW02 | BRENDON SIMONSEN | 2026-01-29

CASE1: $V_{out} = \frac{R_3}{R_1}(V_2 - V_1)$ $R1 = R_2 = 10k$ $V_{diff} = 0.215\ V$

$R3 = R4$

$10_V = \frac{R_3}{10k}(0.215) \Rightarrow R_3 = \underline{465.116\,k\Omega}$ GAIN: 46.5

CASE2: $V_{out} = (V_2 - V_1)\left[1 + \frac{2R_2}{R_1}\right] \Rightarrow 10_V = (0.215V)\left[1 + \frac{2R_2}{10k}\right] \Rightarrow R_2 = \underline{227558\,k\Omega}$

$R4 = R3 = 10k$ $R_1 = 10k$ GAIN: 46.5

VOLTAGE ACROSS R_{LOAD} CASE1: ~2.752V ~ 2.755V
CASE2: ~0.675V ~ 0.676V

$V_{in} = 0.215$
$V_{in} = 0.190$

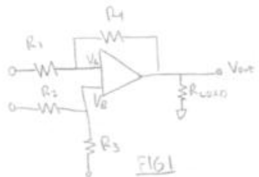


FIG1

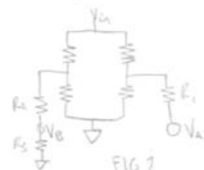
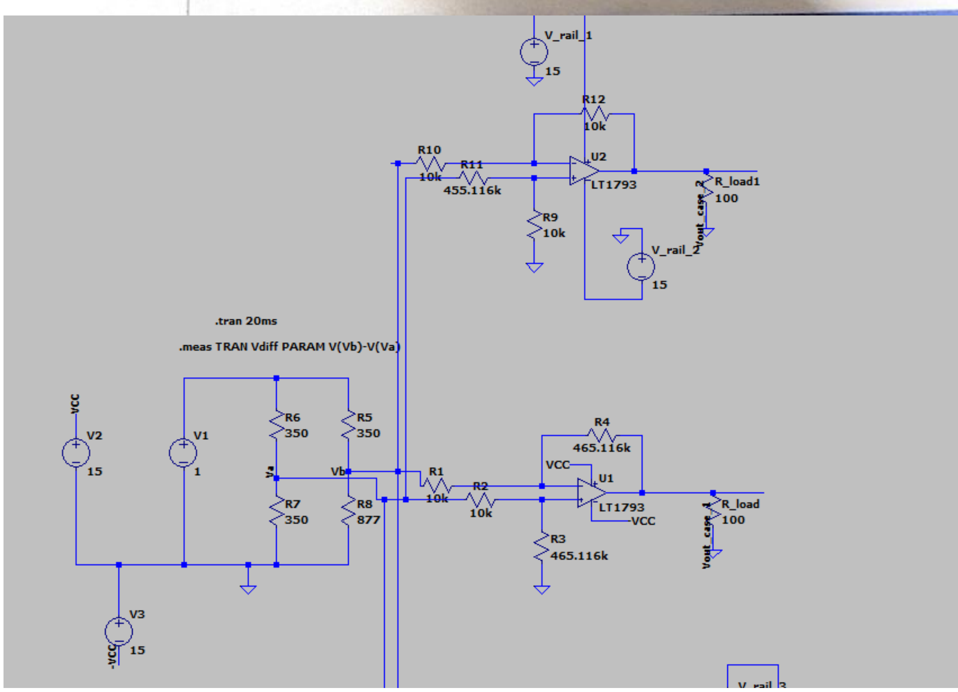
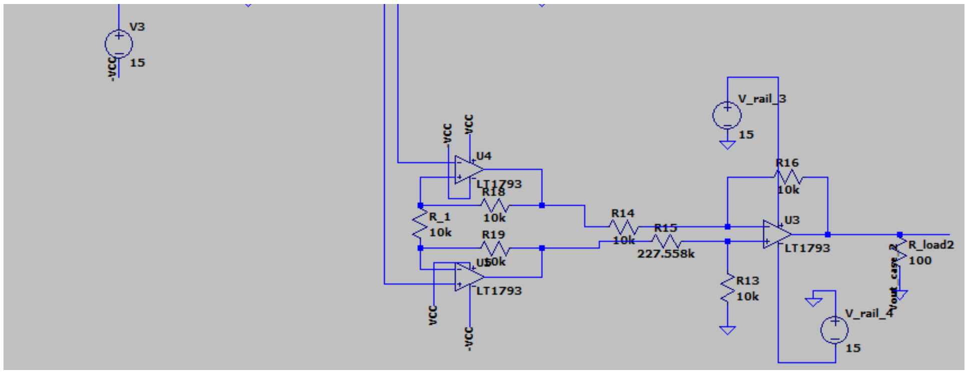


FIG 2

WHEN MEASURING THE VOLTAGE ACROSS R_{LOAD}, IN CASE 1 $V_{out} \approx 2.75V$ AND IN CASE 2 $V_{out} \approx 0.67V$. WHILE THE GAIN IN BOTH CASES IS VERY SIMILAR, THE V_{out} IS QUITE DIFFERENT. AS SHOWN IN FIG 2 ABOVE, WE HAVE AN EQUIVALENT CIRCUIT FOR WHEN THE OP-AMP IS CONNECTED TO THE BRIDGE.

THE VALUE OF V_B IS INFLUENCED BY A VOLTAGE DIVIDER USING R2 AND R3. WHEN WE CHANGE THIS RATIO FROM CASE1 TO CASE2, WE HAVE EFFECTIVELY CHANGED THE VALUE OF V_B, THUS CHANGING THE VOLTAGE COMING OUT OF THE OP-AMP, V_{out}, THAT IS NEEDED TO DRIVE $V_A = V_B$. THIS IS WHY WE SEE DIFFERENT VALUES OF VOLTAGE OVER THE LOAD RESISTOR IN CASES 1 AND 2.





V3
15
-VCC
VCC
VCC
U4
LT1793
R18
10k
R_1
10k
R19
10k
U5
LT1793
VCC
-VCC
R14
10k
R15
227.558k
V_rail_3
15
R16
10k
U3
LT1793
R13
10k
V_rail_4
15
R_load2
100