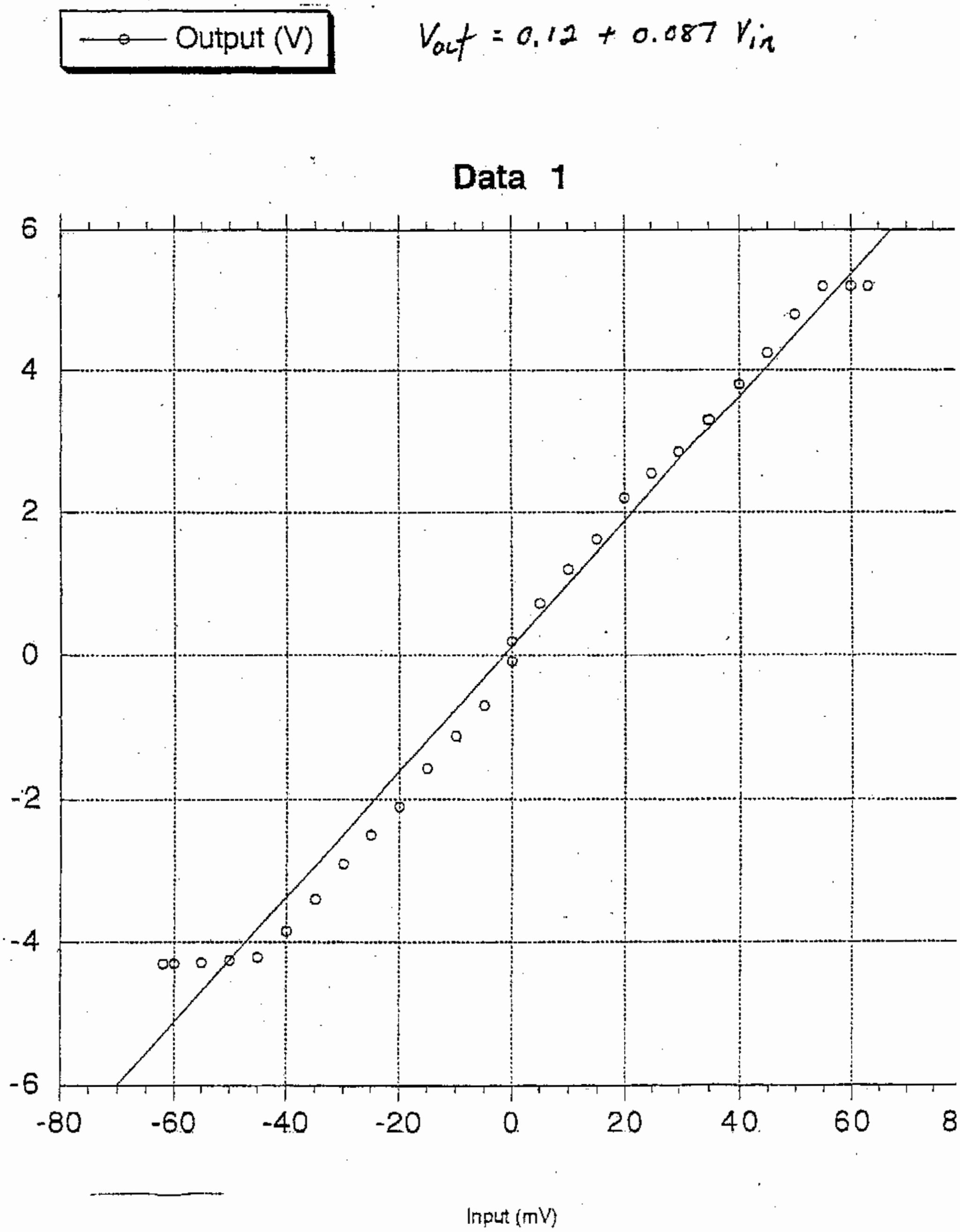
# Experiment Amp Solutions



| | Input (mV) | Output (V) | C |
|---|---|---|---|
| 0 | -62 | -4.30 | |
| 1 | -60 | -4.30 | |
| 2 | -55 | -4.28 | |
| 3 | -50 | -4.25 | |
| 4 | -45 | -4.21 | |
| 5 | -40 | -3.85 | |
| 6 | -35 | -3.40 | |
| 7 | -30 | -2.90 | |
| 8 | -25 | -2.50 | |
| 9 | -20 | -2.10 | |
| 10 | -15 | -1.58 | |
| 11 | -10 | -1.12 | |
| 12 | -5.0 | -0.700 | |
| 13 | 0.0 | -0.0800 | |
| 14 | 0.0 | 0.200 | |
| 15 | 5.0 | 0.730 | |
| 16 | 10 | 1.20 | |
| 17 | 15 | 1.62 | |
| 18 | 20 | 2.20 | |
| 19 | 25 | 2.55 | |
| 20 | 30 | 2.85 | |
| 21 | 35 | 3.30 | |
| 22 | 40 | 3.80 | |
| 23 | 45 | 4.25 | |
| 24 | 50 | 4.80 | |
| 25 | 55 | 5.20 | |
| 26 | 60 | 5.20 | |
| 27 | 63 | 5.20 | |

Problem 1: Here is my data for Output vs input for my amplifier. When I switched leads to measure negative input voltages, there was an offset of ± .28 volts. Note on the graph this is clear.

$V_{out} = 0.12 + 0.087\, V_{in}$

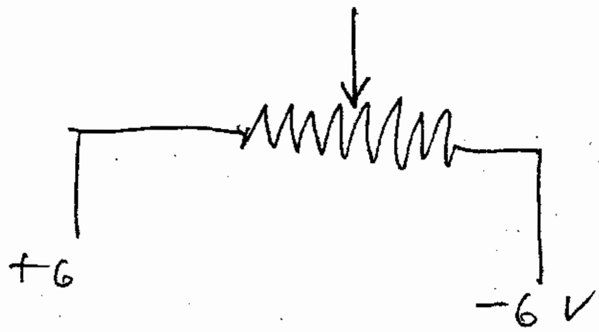



The gain is the slope

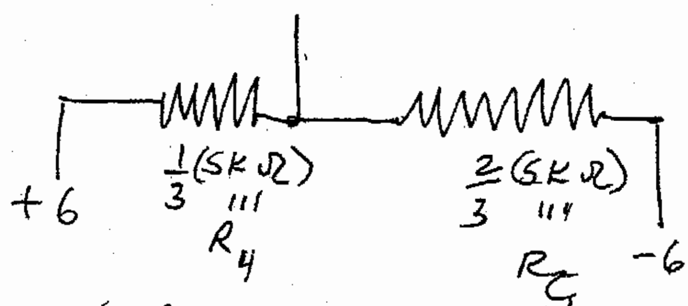
$\dfrac{V_{output}}{V_{input}} = .087\,\dfrac{V}{mV}$

$= 87$

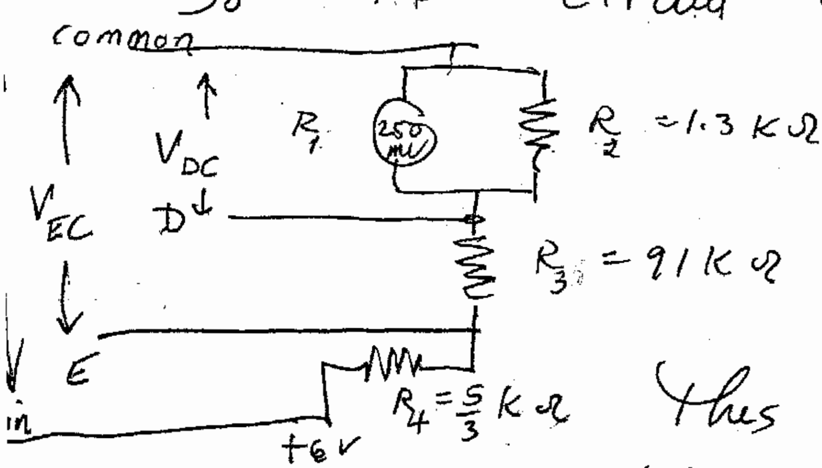
The gain does remain constant until $-40\,mV$ and $+50\,mV$ inputs part b1) when the pot is turned 2/3 of the way in the direction of the +6 V line, we mean that the $5K\Omega$ resistance is divided




into "two" resistors $R_4 = \frac{5}{3} K\Omega$, $R_5 = \frac{10}{3} K\Omega$



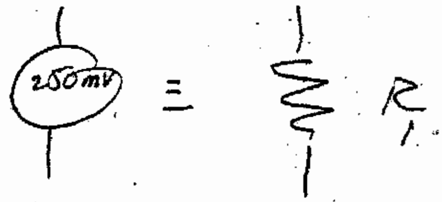

So the circuit diagram looks like




notice we can ignore the connection to the -6 V line.

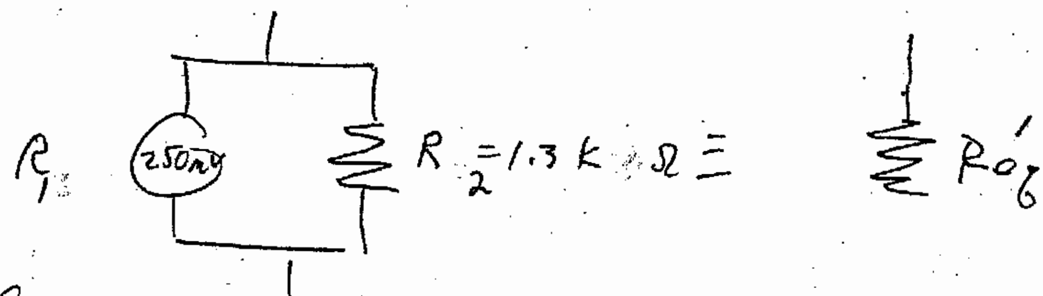
This circuit acts like a voltage divider the 250 mV setting acts like a resister

the



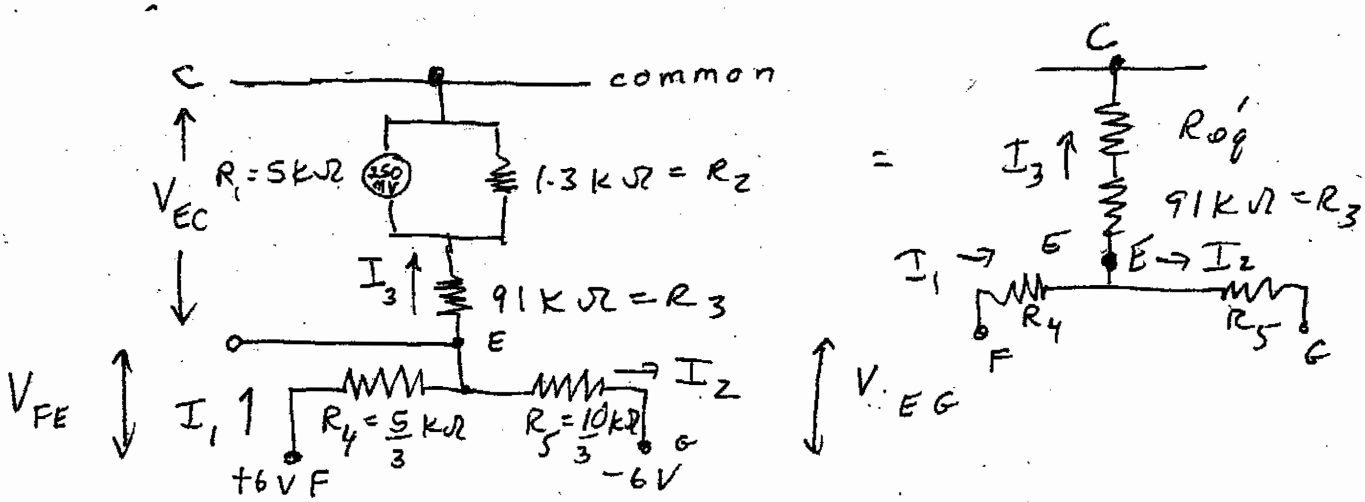
has a resistance $R_1 = \left(\frac{20{,}000\ \Omega}{\max V}\right)\left(250\ mV\right) = 5K\Omega$

So



these two resistors have an equivalent resistance (parallel rule)

$$R_{eq}' = \frac{R_1 R_2}{R_1 + R_2} = \frac{(5K\Omega)(1.3K\Omega)}{5K\Omega + 1.3K\Omega} = 1.03 K\Omega$$



We are trying to determine the voltage $V_{EC}$

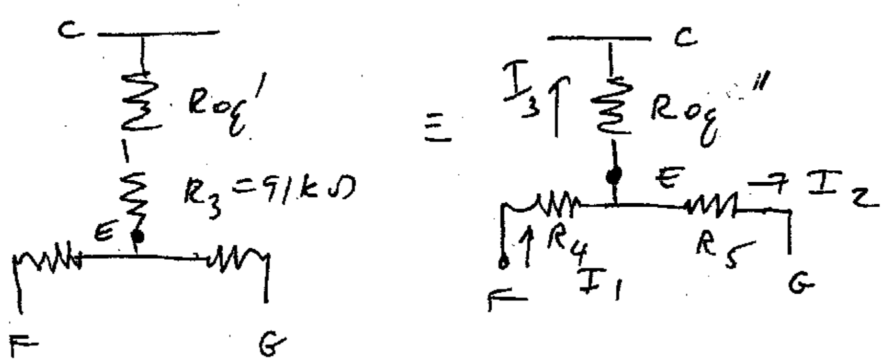
let $V_{FE} = V_F - V_E$ , $V_{EG} = V_E - V_G$ , $V_{EC} = V_E - V_C$

$$I_1 = \frac{V_{FE}}{R_4} \qquad I_2 = \frac{V_{EG}}{R_5}$$

$$V_{FE} + V_{GE} = 12 \text{ volts}$$

$$I_1 = I_2 + I_3$$

$$R_{eq}' = \frac{R_1 R_2}{R_1 + R_2} = \frac{(5k\Omega)(1.3k\Omega)}{(6.3k\Omega)} = 1.03\ k\Omega$$




$$R_{eq}'' = R_{eq}' + R_3 = (1.03\ k\Omega) + 91k\Omega = 92k\Omega$$

$$I_3 = \frac{V_{EC}}{R_{eq}''}$$

$I_1 = I_2 + I_3$ becomes

$$\frac{V_{FE}}{R_4} = \frac{V_{GE}}{R_5} + \frac{V_{EC}}{R_{eq}^2} \qquad (1)$$

Now

$$V_{FE} + V_{EC} = 6 \text{ Volts}$$

$$-V_{EC} + V_{EG} = -(V_E - V_C) + V_E - V_G = V_C - V_G = 6\,V$$

thus

$$V_{FE} = 6\,V - V_{EC} \qquad (2)$$

$$V_{EG} = 6\,V + V_{EC} \qquad (3)$$

Then eq (1) becomes after substituting eq (2) and eq (3)

$$\frac{6V - V_{EC}}{R_4} = \frac{6V + V_{EC}}{R_5} + \frac{V_{EC}}{R_{eq}^2}$$

solving for $V_{EC}$

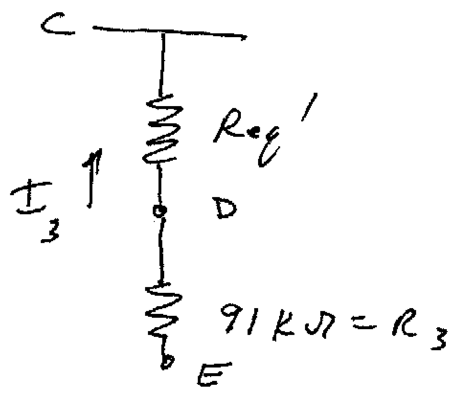
$$6V\left(\frac{1}{R_4} - \frac{1}{R_5}\right) = V_{EC}\left(\frac{1}{R_5} + \frac{1}{R_{eq}^2} + \frac{1}{R_4}\right)$$

$$V_{EC} = \frac{6V\left(\frac{1}{R_4} - \frac{1}{R_5}\right)}{\frac{1}{R_5} + \frac{1}{R_{eq}^2} + \frac{1}{R_4}} = \frac{6V\left(\frac{1}{\frac{5}{3}k\Omega} - \frac{1}{\frac{10}{3}k\Omega}\right)}{\left(\frac{1}{\frac{5}{3}k\Omega} + \frac{1}{92\,k\Omega} + \frac{1}{\frac{10}{3}k\Omega}\right)}$$

$$V_{EC} = 1.98\,V$$

b2) From part b1)

$$V_{EC} = 1.98\ V \quad , \quad I_3 = \frac{V_{EC}}{R_{eq}''} = \frac{1.98V}{92k\Omega} = 21.5mA$$

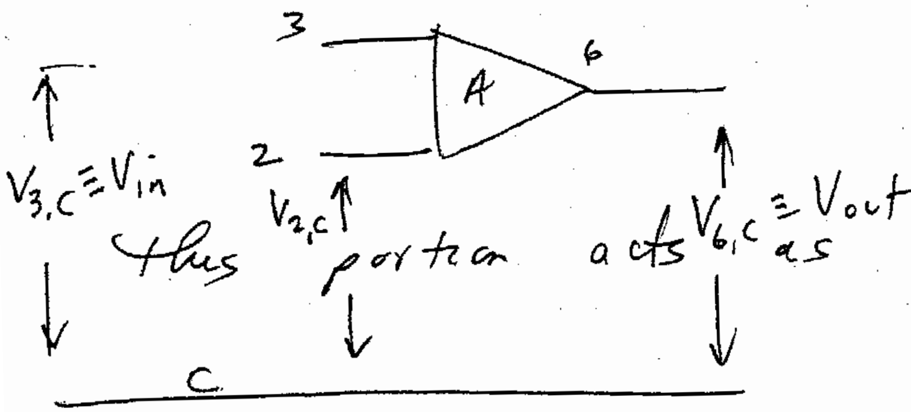



$$V_{DC} = I_3 R_{eq}'$$

$$= V_{EC} \frac{R_{eq}'}{R_{eq}''} = (1.98V)\left(\frac{1.03k\Omega}{92k\Omega}\right) = 22\ mV$$

b3) when I set my pot to 63 mV input, (about 2/3), my output was 5.20 Volts. This is in the range where the amplifier was saturated (see graph

## Problem 2:




this portion acts as an amplifier.

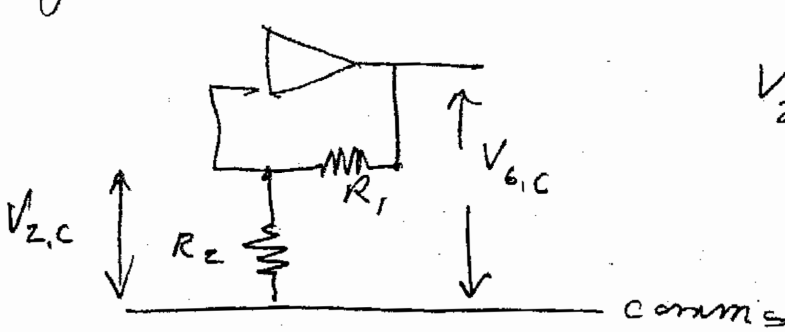
I. the first step is to subtract $V_{2,c}$ from $V_{3,c}$

$$(V_{3,c} - V_{2,c})$$

this voltage is then amplified to get the output voltage

$$A(V_{3,c} - V_{2,c}) = V_{6,c} \equiv V_{out} \qquad (1)$$

II. the voltage $V_{2,c}$ is the result of a voltage divider like the last problem




$$V_{2,c} = V_{6,c}\,\frac{R_2}{R_1 + R_2}$$

The ratio $\beta \equiv \dfrac{R_2}{R_1+R_2} = \dfrac{.1\,K\Omega}{(9.1K\Omega + .1K\Omega)} = \dfrac{1}{92}$

So
$$V_{2,c} = \beta V_{6,c} = \beta V_{out} \qquad (2)$$

III Combining these two results

$$A(V_{3,c} - V_{2,c}) = V_{6,c}$$

note:
$$V_{3,c} \equiv V_{in}$$
$$V_{6,c} = V_{out}$$
$$V_{2,c} = \beta V_{out}$$

So
$$A(V_{in} - \beta V_{out}) = V_{out} \qquad (3)$$

Solve eq (3) for $G = V_{out}/V_{in}$

$$A V_{in} = V_{out} + A\beta V_{out}$$
$$= V_{out}(1 + A\beta)$$

$$\Rightarrow G = \frac{V_{out}}{V_{in}} = \frac{A}{1+A\beta} \qquad (4)$$

Now $A \simeq 10^5$, $\beta \simeq 10^{-2}$ so

$A\beta \simeq 10^3 \gg 1$ thus

$$1 + A\beta \simeq A\beta \qquad (5)$$

Therefore

$$G = \frac{V_{out}}{V_{in}} = \frac{A}{1+A\beta} \simeq \frac{A}{A\beta} \simeq \frac{1}{\beta} = 92$$

The gain $G$ is independent of the amplification $A$ which will vary according to temp and other factors!

In problem 1, $G \simeq 87$ so this is pretty close in agreement to the theoretical prediction. (note: values for resistors are accurate to 5%)