430L

By

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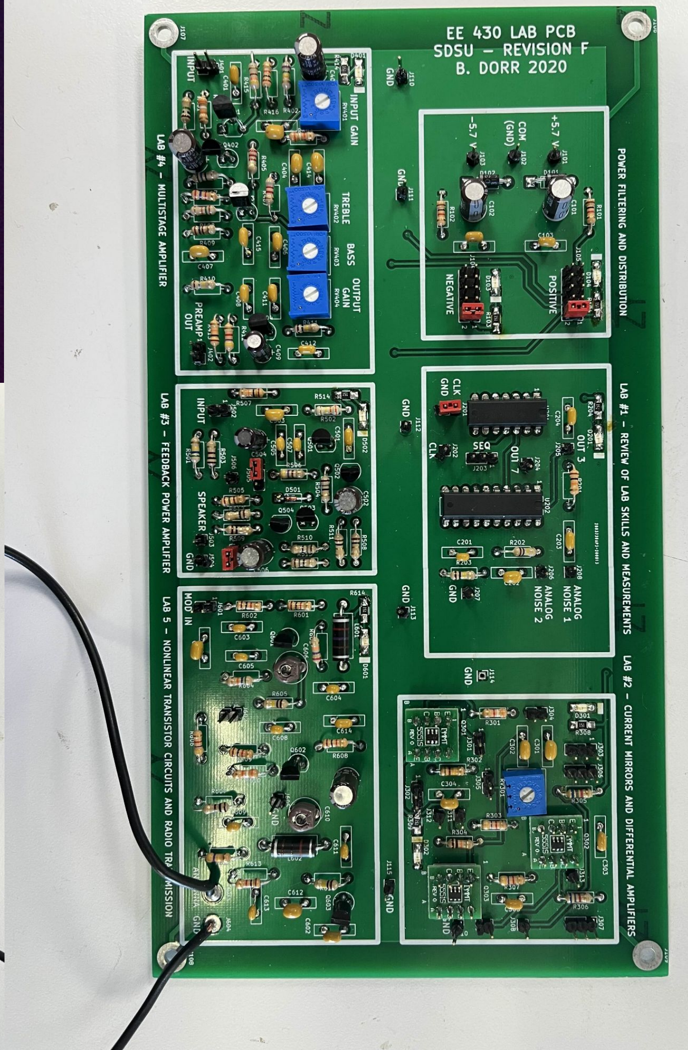


Semester Overview

August-September

Lab 0: Filtering and Distribution

Lab 1: Review of Lab Skills and Measurements

October

Lab 2: Current Mirrors and Differential Amplifiers

Lab 3: Feedback Power Amplifier

November

Lab 3: Feedback Power Amplifier

Lab 4: Multi-Stage Amplifier

December

Lab 5: NonLinear Transistor Circuits and Radio Transmitter

This Presentation

Lab 2

- Current mirror and differential amplifier
- We calculated the resistance , current and beta value for this circuit with Q301
- Rc refers to R301
- Rb refers to R302

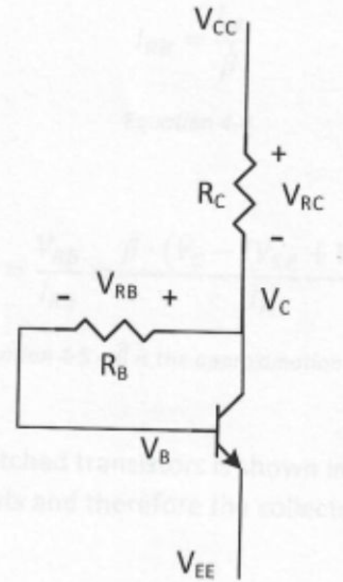
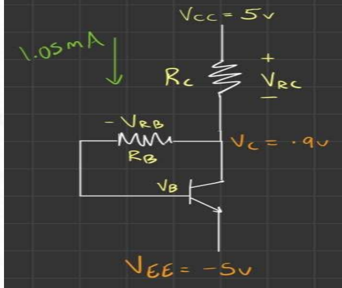


Figure 4-1 - Beta measurement using feedback resistor biasing

Circuit 1



$$\frac{5-.09}{1.05\times10^{-3}} = \frac{4.1}{1.03\times10^{-3}} \Rightarrow \boxed{R_C = 3.9k\Omega}$$

$$V_B = V_{EE} + .65\,v$$
$$V_B = -4.35\,V$$
$$R_B = \frac{.9 - {-4.35}}{10.5\times10^{-6}}$$
$$\boxed{R_B = 500k\Omega}$$

$$I_{RB} = \frac{I_E}{\hat{\beta}} = \frac{1.05mA}{100} = 10.5\mu A$$

$\hat{\beta}$ = ideal 100 beta that is wrong

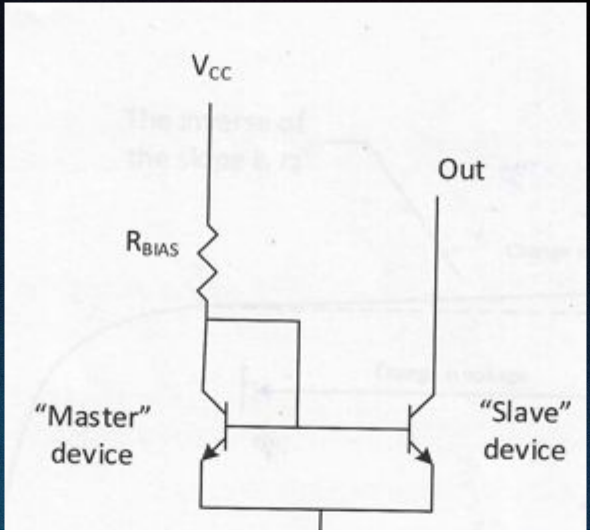
$$V_{RB} = 1.6577\,V$$
$$V_{RC} = 2.0425\,V$$

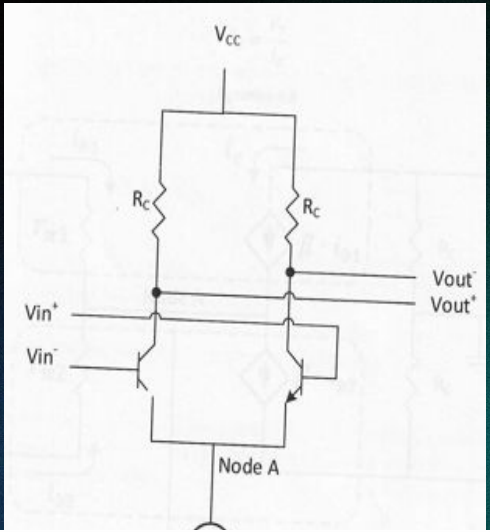
$$\beta = \frac{I_C}{I_B} \simeq \frac{I_E}{I_B} = \frac{V_{RC}/R_C}{V_{RB}/R_B} = \frac{V_{RC}}{V_{RB}} \cdot \frac{R_B}{R_C}$$

$$\beta = \left(\frac{2.0425}{1.6577}\right)\left(\frac{500k}{3.9k}\right) = 157.965$$

$$\boxed{\beta = 158}$$

- Master Device: generates the reference current
- Slave Device: replicates the reference current and outputs it
- Differential amplifier: amplifies the difference between 2 input voltages while rejecting the common voltage between them





$$A_o = 2 \cdot \frac{V_{out}^{+}}{V_{in}^{+}} = 2 \cdot \frac{0.8^{V}}{13^{mV}} = 123$$

$$A_{cm} = \frac{V_{cm\ out}}{V_{cm\ in}} = 2 \cdot \frac{20^{mV}}{0.166^{V}} = 0.241$$

$$CMRR = 20 \log_{10}\left(\frac{123.077}{0.241}\right) = 53.1\ dB$$

- As the potentiometer is turned voltage increases but current remains moderately similar
- Our transistor had a limit of 3.7 volts so we didn't hit the rated 4.5

volts	resistance	current
0.5v	1.4kΩ	0.35mA
1V	2.7kΩ	0.37mA
1.5V	4.1kΩ	0.36mA
2v	5.4kΩ	0.37mA
2.5V	6.8kΩ	0.36mA
3V	8.1kΩ	0.37mA
3.5V	9.4 kΩ	0.37mA
3.7V	9.9kΩ	0.37mA
4.5V cannot go higher than 3.7V	n/a	n/a

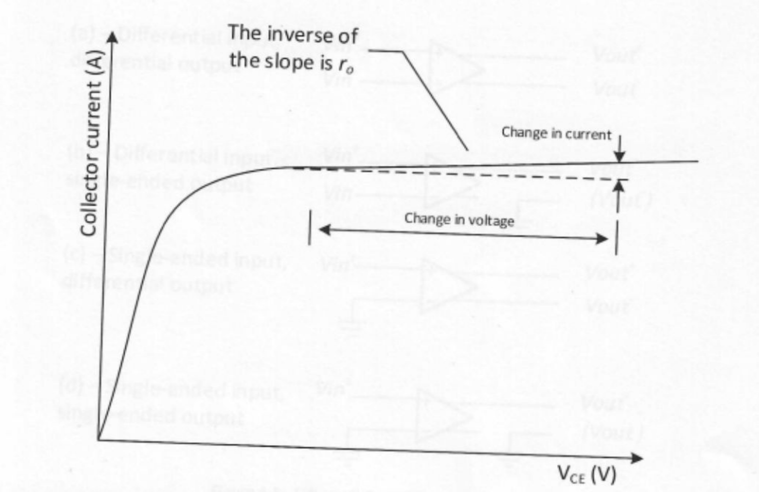


Figure 4-3 - r_O is the slope of the collector current vs V_{CE} when the transistor is in the active region.

Difficulties

- Soldering was very annoying
- Our transistor blew and needed to be replaced
- Scoping the BJTs were annoying

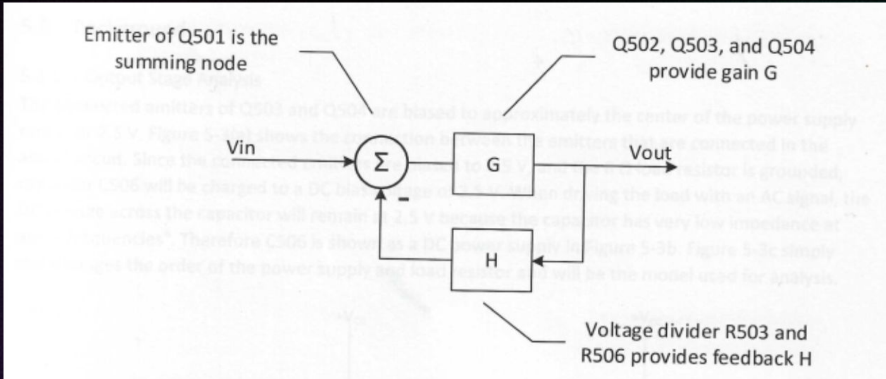
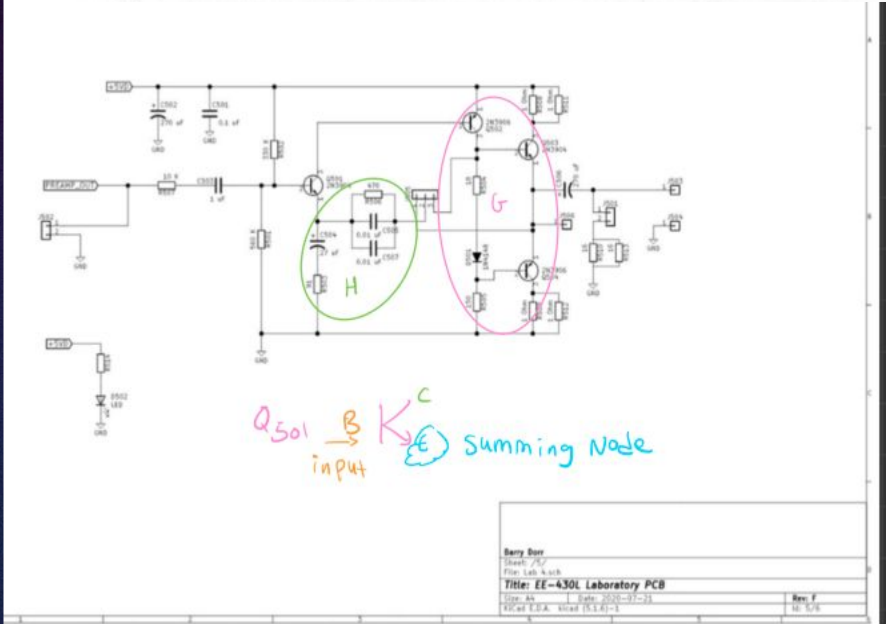


Figure 5-2 - Feedback amplifier viewed as a control system. Gain is computed for positive output signal excursions. The gain for negative excursions is identical.



- The amplifier can be viewed as a negative feedback control system
- The G component encompasses Q502, Q503, and Q504
- The H component focuses on the voltage divider
- The emitter of Q501 is the summing junction

- An 8 ohm load is connected to for basic operation of the amplifier

transistor	V_E (theory)	V_E (meas)	%error V_E	V_B (theory)	V_B (meas)	%error V_B	V_C (theory)	V_C (meas)	%error V_C
Q501	2.5V	2.447V	2.12%	3.15V	2.974V	5.59%	4.35V	4.1V	5.75%
Q502	5V	4.902V	1.96%	4.35V	4.1V	5.75%	3V	2.785V	7.16%
Q503	2.5V	2.426V	2.96%	3V	2.798V	6.73%	5V	4.902V	1.96%
Q504	2.5V	2.42V	3.2%	2V	1.84V	8%	0V	0V	0%

$R_e = R_{503} \parallel R_{506}$

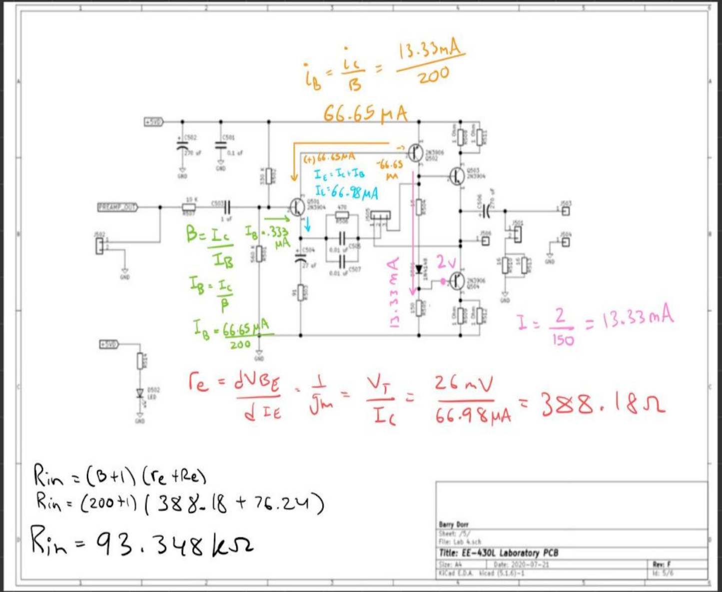
$R_e = 91 \parallel 470$

$$R_e = \frac{(91)(470)}{91+470}$$

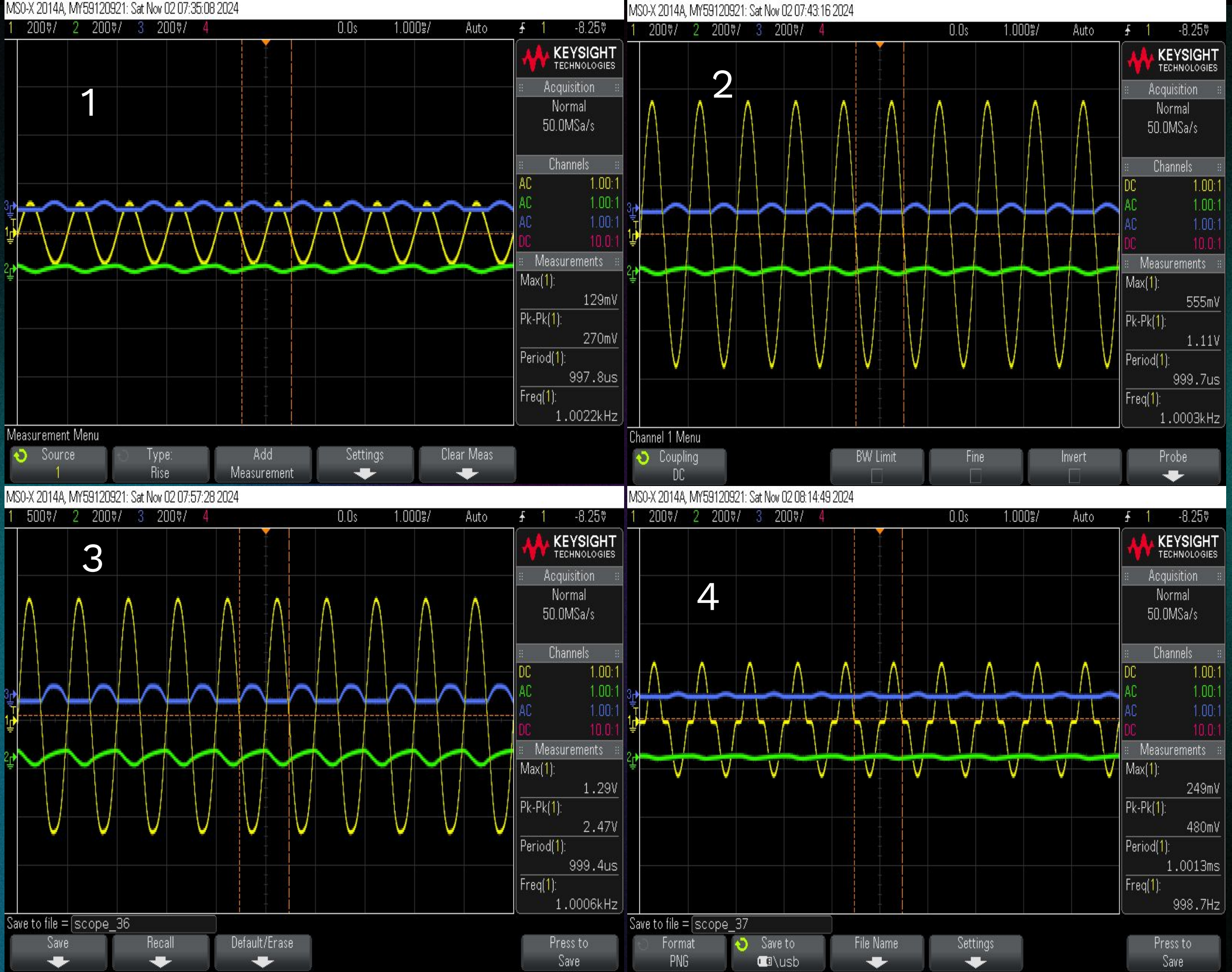
$R_e = 76.24\ \Omega$

Pg 46

Q501 $\beta = 200$



- Image 1 shows the input signal at yellow from J502, the collector at Q502 in blue, and the collector for Q503 in green
- Image 2 shows output signal of J506in yellow, the collector of Q504 in blue, and collector of Q503 in green
- Image 3 shows the output of J503 before distortion at the 2.5 Volt peak, a 1 kHz sine wave in yellow, the collector of Q504 in blue, and the collector of Q503 in green
- Image 4 shows the output of J506, where the shorting clip was moved to produce feedback in the collector of Q502, creating a min, max, and deadzone of the transistor, the collector of Q504 in blue , and the collector of Q503 in green



Difficulties

- In this lab we learned alternative ways of taking transistor measurements
- We learned to measure components on the same node of these transistors to measure their values

Lab 4: Multi-Stage Amplifier

This lab consists of 4 main sections

- The input stage
- The tone stage
- Emitter follower stage
- The gain stage

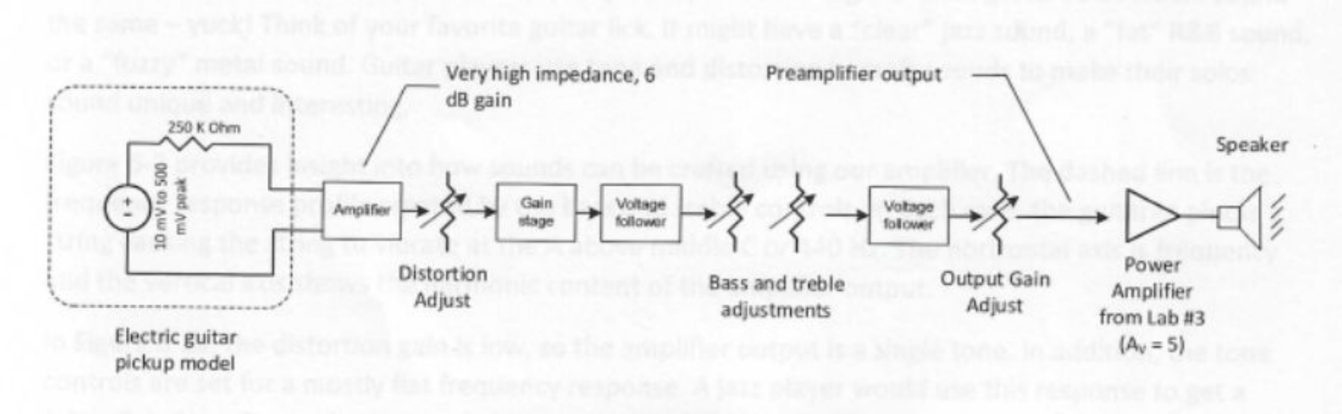
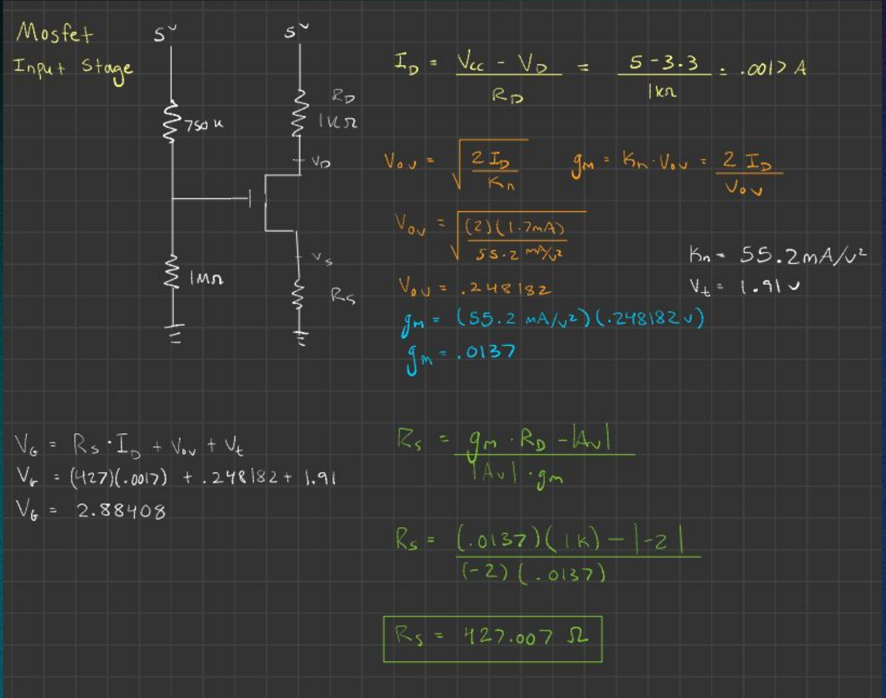


Figure 6-1 - Multistage Amplifier - Block Diagram

Mosfet Input Stage

- Must have high impedance to prevent drawing current from the signal source
- The 2 bias resistors reduce the input impedance to 429 kΩ



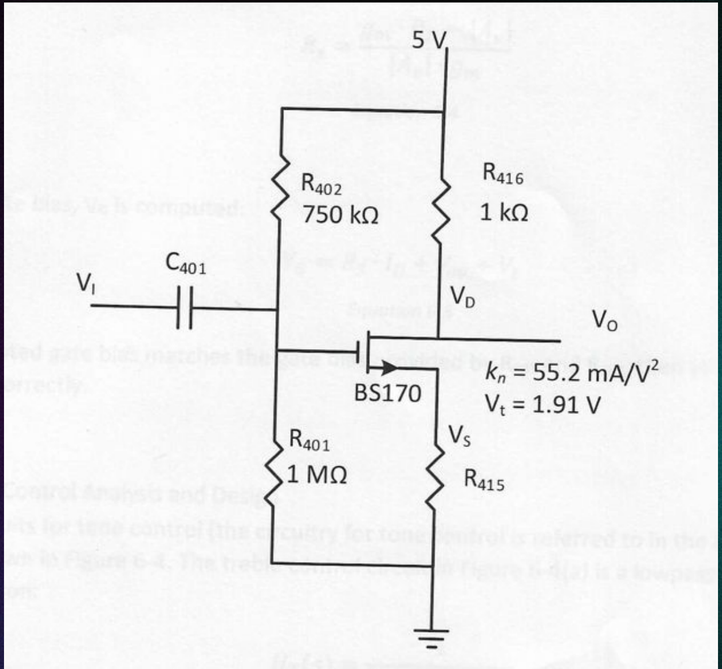


Figure 6-3 - MOSFET Input Stage

Tone Stack Stage

- At high frequencies CT and CB act as a short circuit (1 ⁄ 2πfc)
- Treble control from the high pass controlled by RT
- Bass control from the low pass controlled by RB

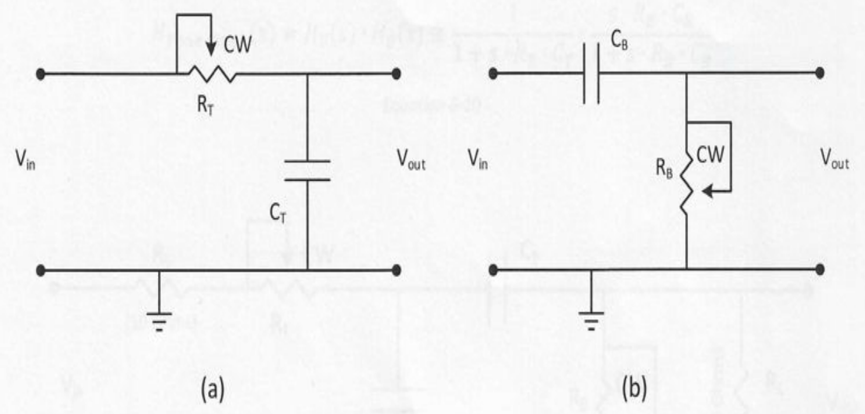
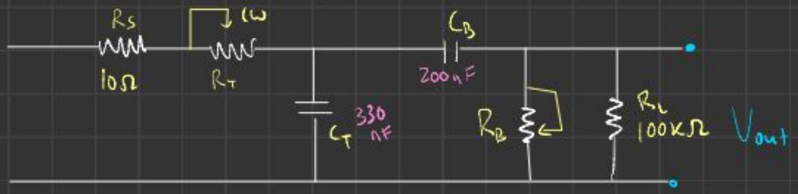


Figure 6-4 – Building blocks for Treble and Bass Tone Controls, (a) treble control, (b) bass control

Tone Stack



$$H_T(s) = \frac{1}{1 + s \cdot R_c \cdot C_T} \qquad f_{3db} = \frac{1}{2\pi R_T \cdot C_T}$$ lowpass 3db

$$H_B(s) = \frac{s R_B C_B}{1 + s R_B C_B} \qquad f_{3db} = \frac{1}{2\pi R_B \cdot C_B}$$ High pass 3db

$$482 = \frac{1}{(2\pi)(R_T)(330\times10^{-9})}$$

$$964\times10^{-6} R_T = 1$$

$$R_T = \frac{1}{964\times10^{-6}}$$

$$\boxed{R_T = 1037.34\ \Omega}$$

$$88 = \frac{1}{(2\pi)(R_B)(200\times10^{-9})}$$

$$88 = \frac{1}{1.25663706\times10^{-6} R_B}$$

$$1.10584061 R_B = 1$$

$$R_B = \frac{1}{1.10584061}$$

$$\boxed{R_B = 9042.895\ \Omega}$$

Emitter Follower

- Provides a voltage swing to the load
- Handles impedance matching for input and output
- Prevents distortion

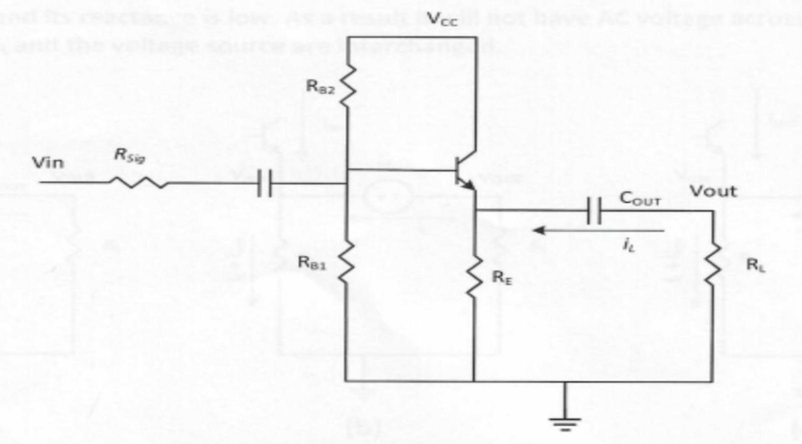


Figure 6-7 - Emitter Follower Circuit

$r_e = \frac{V_T}{I_E} = \frac{25\times10^{-3}}{100\times10^{-6}} = 250\Omega$

$r_{out} = r_e + \frac{R_{sig} \parallel R_{B_1} \parallel R_{B2}}{\beta}$

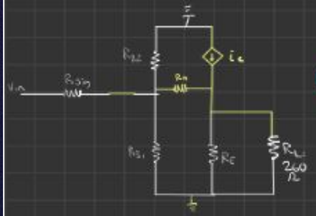
$R_{in} = (\beta+1)(r_e + R_e \parallel R_L)$

$\beta = 200$ $R_L = 260\ \Omega$

$V_T = 25\ mV$ $V_E = 2.5V$

$V_{BE} = .65V$ $i_{min} = 100\ \mu A$

$r_{out} = 15\Omega$ $V_{opk} = 1.5\ V_{pk}$



$R_E \parallel R_L$

$160 \parallel 260$

99.05

$V_{min} = \frac{V_{cc}}{2} - V_{opk}$

$\frac{V_{min}}{R_E} \geq \frac{V_{opk}}{R_L} + I_{min}$

$R_E < \frac{\frac{V_{cc}}{2} - V_{opk}}{\frac{V_{opk}}{R_L} + I_{min}}$

$R_E < \frac{\frac{5}{2} - 1.5}{\frac{1.5}{260} + 100\mu}$

$R_E < 170.38\Omega$

$R_E = 160\Omega$

Gain Stage

- Determines how much voltage gain is used in the circuit

- Av of 20 is expected in an ideal case but for our circuit it is 22.4

$C_{405} = ?$ from $20Hz$, & 29.5Ω

$$C_{405} = \frac{1}{2\pi \cdot f \cdot R} = \frac{1}{2\pi \cdot 20Hz \cdot 29.5\Omega} =$$

$$= 2.697 \cdot 10^{-4} \approx 270\mu F$$

$R_E = R_{417} \| R_{406}$, $g_m = \frac{i_c}{V_T}$, $R_L = 1.5k\Omega$, $V_c = 3.5V$, $R_{405} = 2.2k\Omega$

$$I_C = \frac{V_{CC} - V_C}{R_{405}} = \frac{5 - 3.5}{2.2k\Omega} = 0.682mA$$

$$g_m = \frac{0.682mA}{25mV} = 27mS$$

$$|A_v| = \frac{g_m \cdot R_L}{1 + g_m R_E} = 22.4 V/V \Rightarrow 1 + g_m R_E = \frac{g_m R_L}{A_v} \Rightarrow g_m R_E = \frac{g_m R_L}{A_v} - 1$$

$$R_E = \frac{g_m R_L}{A_v g_m} - \frac{1}{g_m} = \frac{g_m R_L - A_v}{A_v g_m} = \frac{27mS \cdot 1.5k - 22.4}{22.4 \cdot 27mS} = 30\Omega = R_{417}$$

$$V_B = V_{CC} \cdot \frac{R_{404}}{R_{403} + R_{404}} = 5 \cdot \frac{1}{2} = 2.5V \Rightarrow V_E = V_B - V_{BE} = 2.5 - 0.65 = 1.85$$

$$I_E = \frac{V_E}{R_{406}} \Rightarrow R_{406} = \frac{V_E}{I_E} = \frac{1.85}{0.682mA} = 2.71k\Omega$$

Difficulties

- When connecting lab 3 and lab 4, we got unusual clipping and noise
- We believed that the mosfet was the cause of the issue
- Replacing the mosfet made the signal less noisy but still led us to this abnormal signal
- Fixing 2 broken traces