Homework Solution Set 4
EECE2412: Electronics – Spring 2013
Due Thursday, 14 March 2013

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Problem 4.25

Assuming that current is constant at 2 mA we have

$$V_{BET2} = V_{BET1} + (2\ \text{mV})(T_2 - T_1)$$
$$= -0.7 + 0.002(180 - 30)$$
$$= -0.4\ \text{V}$$

At 180° we have $V_T = kT/q = \frac{1.38 \times 10^{-23}(273 + 180)}{1.60 \times 10^{-19}} = 39.1\ \text{mV}$.

Now we compute the value of I_s for a temperature of 180°.

$$I_s = \frac{I_C}{\exp(V_{BE}/V_T - 1)} = \frac{2 \times 10^{-3}}{\exp(0.4/0.0391 - 1)} = 71.6\ \text{nA}$$

Finally we compute V_{BE} for a current of 0.1 mA at 180°C.

$$V_{BE} = V_T \ln(I_C/I_s + 1) = 0.0391 \ln[10^{-4}/(71.6 \times 10^{-9} + 1)]$$
$$= 0.283\ \text{V}$$

Problem 4.34

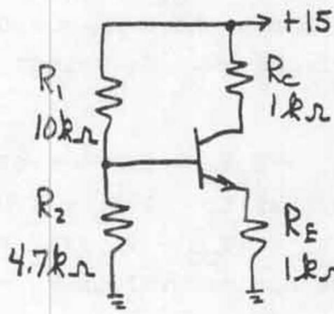
Circuit	β	Region	I (mA)	V (V)
(a)	100	active	2.38	5.25
(a)	300	saturation	4.45	9.80
(b)	100	cutoff	0	10
(b)	300	cutoff	0	10
(c)	100	active	4.26	-10.74
(c)	300	active	4.29	-10.71
(d)	100	Q_1 active Q_2 active	10	10
(d)	300	Q_1 active Q_2 saturation	14.8	14.8

Problem 4.45

Dc circuit:

$\beta = 100$

$V_{BEQ} = 0.7$ V



$V_B = V_{CC}R_2/(R_1 + R_2) = 4.80$ V $\quad R_B = R_1 || R_2 = 3.20$ kΩ

$I_{BQ} = \dfrac{V_B - V_{BEQ}}{R_B + (\beta + 1)R_E} = 0.0393$ mA $\quad I_{CQ} = \beta I_B = 3.93$ mA

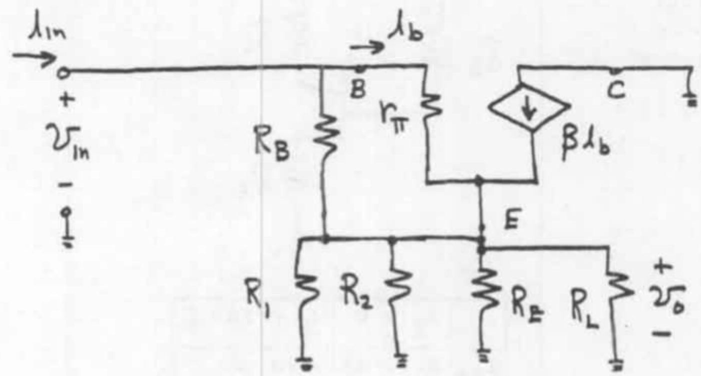
$r_\pi = \beta V_T / I_{CQ} = 662\ \Omega \quad R'_L = R_L || R_C = 500\ \Omega$

$A_v = -\beta R'_L / r_\pi = -75.5 \quad A_{vo} = -\beta R_L / r_\pi = -151$

$Z_{in} = R_1 || R_2 || r_\pi = 548\ \Omega \quad A_i = A_v Z_{in} / R_L = -41.4$

$G = A_v A_i = 3124 \quad Z_o = R_C = 1$ kΩ

Problem 4.56



Let $R_L' = R_1 || R_2 || R_E || R_L$

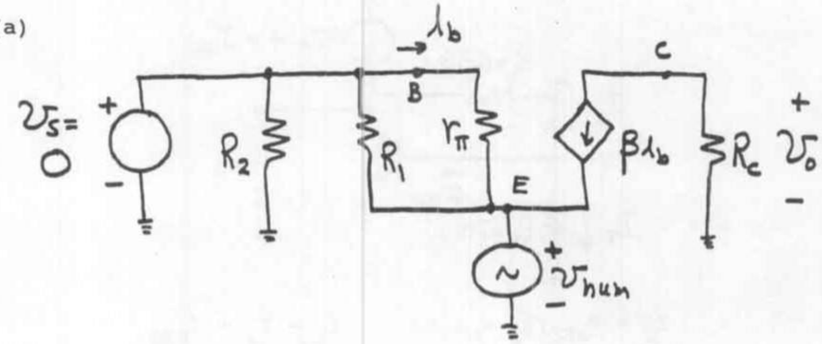
$$v_o = R_L'\left(i_b + \beta i_b + \frac{r_\pi i_b}{R_B}\right) \qquad v_{in} = r_\pi i_b + v_o$$

$$A_v = \frac{v_o}{v_{in}} = \frac{R_L'\left(1 + \beta + \frac{r_\pi}{R_B}\right)}{r_\pi + R_L'\left(1 + \beta + \frac{r_\pi}{R_B}\right)}$$

$$i_{in} = \frac{v_{in} - v_o}{R_B || r_\pi} = \frac{v_{in} - A_v v_{in}}{R_B || r_\pi} \qquad z_{in} = \frac{v_{in}}{i_{in}} = \frac{R_B || r_\pi}{1 - A_v}$$

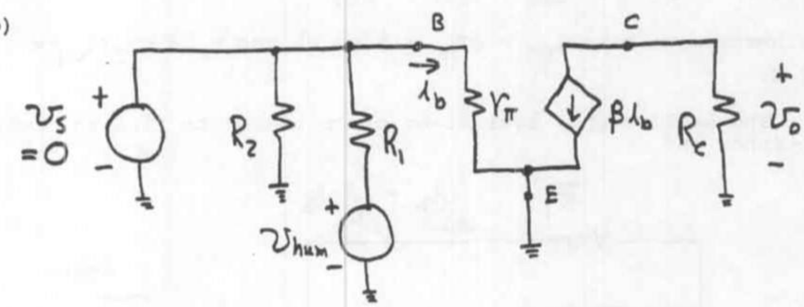
Problem 4.59

(a)



$$A_{hum} = \frac{v_o}{v_{hum}} = \frac{-\beta i_b R_C}{-r_\pi i_b} = \frac{\beta R_C}{r_\pi}$$

(b)



Because $v_s = 0$ we have $i_b = 0$ and $v_o = 0$. Thus $A_{hum} = 0$.

Because of lower sensitivity to power-supply hum, the circuit of Figure P4.59b is preferable to that of Figure P4.59a. In other words, the emitter bypass capacitor should be connected from emitter to ground.

6 Audio Amplifier Design

The purpose of this assignment was to get you to apply the various principals you have learned throughout your undergraduate career to create an audio amplifier.

6.1 Initial Analysis

6.1.1 Number of Stages

There are three stages in this amplifier circuit. Please refer to Figure 1 to see each stage.

6.1.2 Types of Stages

Stage 1 and 2 are common emitters and the stage 3 is in a push–pull configuration. The third stage is utilized to deliver a lot of power to the speaker relatively efficiently. The common emitter amplifiers are known as "Class–A" amplifiers and the push–pull is known as a "Class AB" amp.

6.1.3 Voltage at Q1's base

≈ 0.7 V

6.2 Desired Input and Output Impedance

To obtain the maximum power transfer with minimum distortion, we must match impedances into and out of the circuit. Therefore, the input should be ≈ 300 Ohms and the output impedance should be ≈ 8 Ohms.

6.3 Purpose of D_1 and D_2

They serve to bias the circuit. This accounts for the drop across base–to–emitter for both Q_3 and Q_4.

6.4 Purpose of C_1

Both C_1 and C_3 serve as decoupling capacitors. The remove the DC component of the previous stage so it does not contribute to the DC bias of the

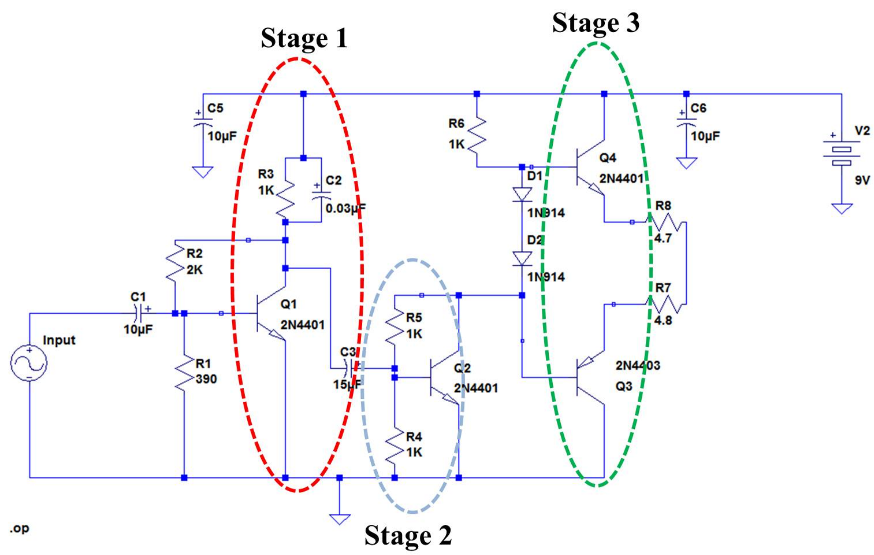


Figure 1: Amplifier Stages

current stage. It is important to note that C_2 does not do this. **note:** → I erroneously referred to C_5 and C_6 as decoupling capacitors in the homework. ←

6.4.1 Purpose of C_5 and C_6

The capacitors reduce the effect of power supply noise. On a schematic, we assume a 0 Ohm connection between points. However, in a real implementation of a circuit, this is not true. This means a connection between two points might experience a voltage drop across the connection if there is a there is a sudden influx of current. These capacitors help "smooth out" the effects of this resistivity.

6.5 DC analysis

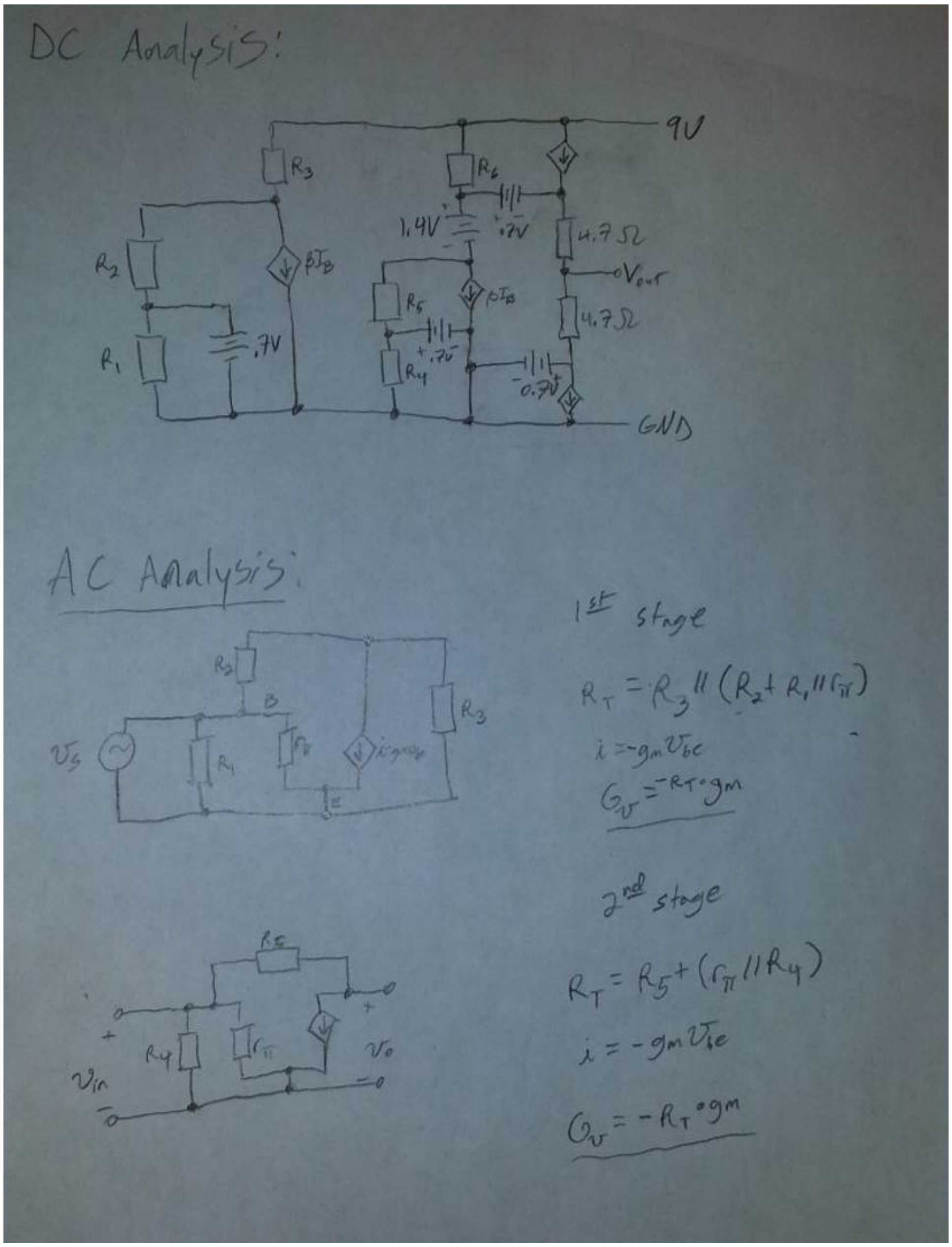
Design Limitations (in order of importance

1. $v_{be} = 0.7V = \frac{R_2}{R_1+R_2} v_{out}$
2. $R_{in} = 300\Omega = \frac{R_2 R_1}{R_1+R_2}$
3. $v_{out} = 4.5V$ (allow for maximum voltage

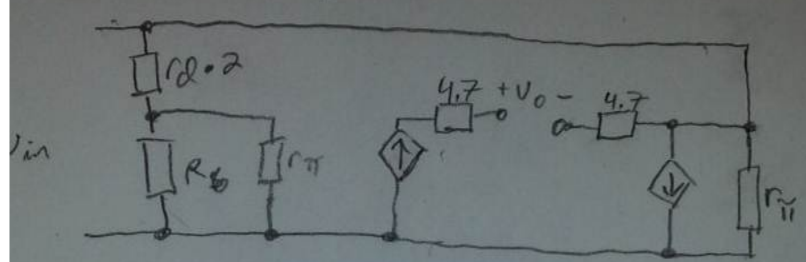
I chose the following easy-to-obtain resistors

$R_1 = 390\Omega$

$R_2 = 2k\Omega$


DC Analysis:
9V
R3
R6
R2
R1
βIB
.7V
1.4V
4.7Ω
Vout
R5
R4
0.7V
GND
AC Analysis:
R2
R1
R3
B
E
vs
1st stage
RT = R3 // (R2 + R1 // rπ)
i = -gm vbe
Gv = -RT·gm
2nd stage
R5
R4
rπ
vin
vo
RT = R5 + (rπ // R4)
i = -gm vbe
Gv = -RT·gm

3rd stage



$$R_T = [2 \cdot r_d + (R_6 \,||\, r_\pi)] \,||\, r_{\pi_2}$$

with no load,

$$v_{out} = -g_m v_{be} \cdot r_\pi$$

Assume an $8\,\Omega$ load

$$v_{out} \simeq g_m v_{be} (2 \cdot 4.7 + 8)$$

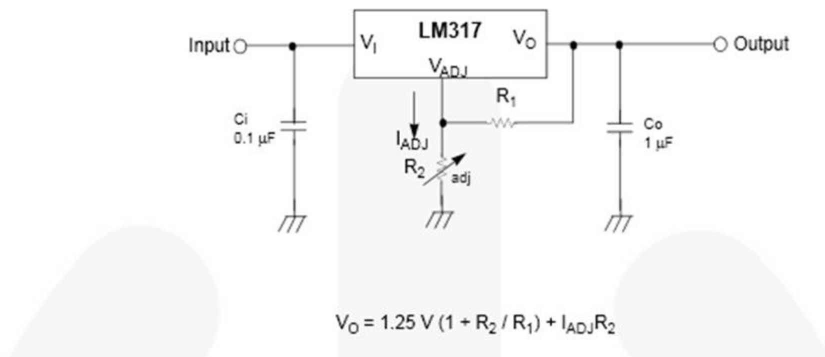


Figure 2: Example implementation from Fairchild spec sheet.

7 Extra Credit

One example implementation of the LM317 is shown in Figure 2 (As described in the Fairchild spec sheet). Note, this chip is produced by many different manufacturers and some included a diode between the output and input of the chip to protect against reverse biasing the chip. It is important to note that this is only required in a situation where multiple voltages are used in a circuit. If this is the case, it still may not be advisable to use the diode for battery–powered electronics.