PRELAB 7

STAGE1: THE DIFFERENTIAL PAIR

The first stage in this audio amplifier is the differential-pair circuit of Figure P7-2.

a) DC BIAS

Determine values for the resistances R_{1A}, R_{1B}, and R_2 to achieve the following bias voltages and currents (assume $\beta = 100$ for each transistor). HINTS: Apply superposition and symmetry.

- $I_{BIAS} \approx 500\mu A$
- $V_{O1} = V_{O2} \approx 9.3V$

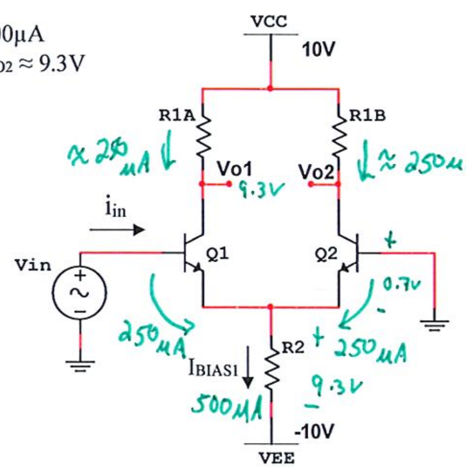

Figure P7-2

b) SMALL SIGNAL ANALYSIS

Now using small-signal analysis find the following:

- Small-signal voltage gains v_{O1}/v_{in} and v_{O2}/v_{in}.
- Differential output gain $(v_{O1}-v_{O2})/v_{in}$.
- Small-signal input resistance *Rin* at the input to the amplifier.

NOTE: In this example, since one of the inputs is tied to ground, the bias current I_{BIAS1} will remain fairly constant. Therefore, it may be set to zero in the small-signal model. Also, since only one single-ended output is required to drive the next stage, one of the collector resistors may be replaced with a short circuit without affecting the performance of this amplifier.

c) SIMULATION

Produce graphs of $v_{O1}(t)$, $v_{O2}(t)$ and for $v_{O1}(t) - v_{O2}(t)$ for an input signal of v_{in} being a 10mVpk 1kHz sine wave signal. NOTE: Expect only a small fluctuation in the output (less than a volt). **Use the 2N3904 NPN BJT model for simulation.**

DC BIAS

$$R_2 = \frac{-0.7V - (-10V)}{500\mu A} = \frac{9.3V}{500\mu A} = 18.6K\Omega \approx 20K\Omega \text{ (KIT)}$$

$$R_{1A} = R_{1B} = \frac{10V - 9.3V}{250\mu A} = \frac{0.7V}{250\mu A} = 2.8K\Omega \approx 3K \text{ (KIT)}$$

SMALL-SIGNAL

$$\frac{V_{o1}}{V_{in}} = -\frac{R_C}{r_e + r_e \| R_E} \approx -\frac{R_C}{2r_e}$$

$$g_m = \frac{I_C(BIAS)}{nV_T} = \frac{250\mu A}{(1)(25mV)} = 10mA/V$$

$$r_e = \left(\frac{\beta}{\beta+1}\right)\left(\frac{1}{g_m}\right) \approx 100\Omega$$

$$\therefore \frac{V_{o1}}{V_{in}} = -\frac{3K}{2(100\Omega)} = -15 V/V$$

$$\frac{V_{o2}}{V_{in}} = +\frac{3K}{2(100\Omega)} = +15 V/V$$

$$\therefore \frac{V_{o1} - V_{o2}}{V_{in}} = -30 V/V$$

STAGE 2: COMMON EMITTER BJT AMPLIFIER WITH ACTIVE LOAD

The output of the differential pair is then connected to a Common Emitter BJT Amplifier comprised of a PNP transistor with an active (current source) load as shown in Figure P7-3. This configuration relies on the high input impedance of the current source to achieve high gain.

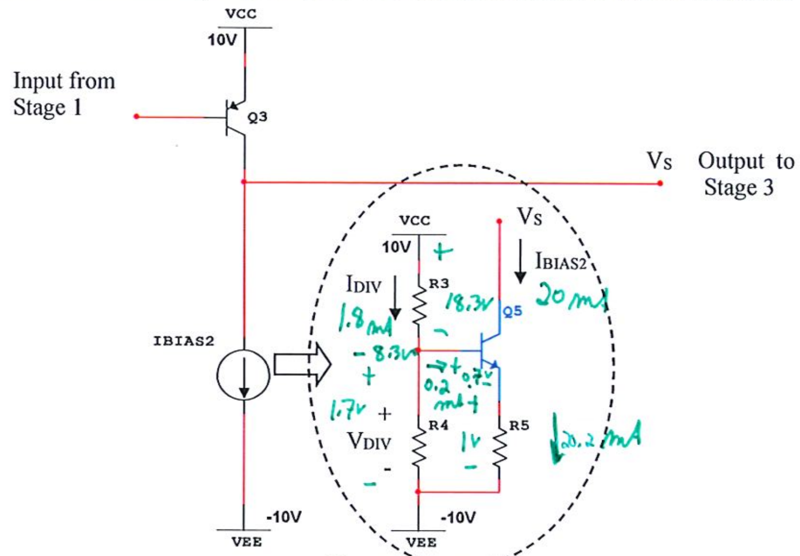

Figure P7-3

a) DC CURRENT SOURCE DESIGN

The actual current source circuit is comprised of a NPN BJT and a voltage divider network (oval insert). Choose values for the resistors R3, R4 and R5 to achieve the following specifications (assuming $\beta = 100$):

- I_{BIAS2} $\approx$ 20mA
- I_{DIV} $\approx$ 1.8mA (with Q5 disconnected)
- V_{DIV} $\approx$ 1.7V across R4

b) SIMULATION

- Using DC ANALYSIS in simulation, verify the values of I_{BIAS2}, I_{DIV} and V_{DIV}.
- Connect the output of the current source to a separate DC supply (Vs) and use DC SWEEP analysis to vary the voltage from -10 to +10 Volts.
- Produce a plot of I_{BIAS2} as a function of Vs. What is the dynamic voltage range of the output? (ie. Over what range of output voltage does the current source work properly?)

$I_C = 20mA$, $I_B = 200\mu A$ } $I_E = 20.2\,mA$

$R_5 = \frac{1V}{20.2mA} = 49.5\Omega \approx 51\Omega$ (KIT)

$R_3 = \frac{10V - (-8.3V)}{1.8mA} = \frac{18.3V}{1.8mA} = 10.17K\Omega \approx 10K\Omega$ (KIT)

$R_4 = \frac{1.7V}{1.8mA - 0.2mA} = 1.06k\Omega \approx 1K$ (KIT)

(OR)

[$R_4 = \frac{1.7V}{1.8mA} = 944\Omega$ w/ Q5 DISCONNECTED]