ANALOG CIRCUITS : PROBLEM SET 5

Problem 1

(CURRENT SOURCE) The following configuration acts like a constant current source for varying loads R_L. Within what range can R_L vary ?

Suppose that R_L varies from 1K to 5K. v_{CE} must be greater than or equal to 1 volt, always. Also I_o = 2mA; I_oR_e = 5V, V_{BE} = 0.65V . Find R_1, R_2, R_e and V_{ee} assuming current in the resistors on the base side to be 1 mA.

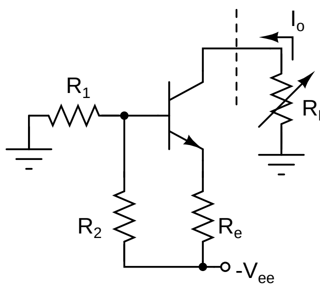

Figure 1: Problem 1

0.1 ANSWERS 1:

$$\begin{aligned} V_{ee} &= 16V \\ R_1 &= 10.35K \\ R_2 &= 5.65K \\ R_e &= 2.5K \end{aligned}$$

Problem 2

v_o should just begin to distort at both the ends. Calculate V_{cc} and V_{ee}. Take V_{BE} = 0.65 V nominally. v_s = $6 \sin \omega t$ V.

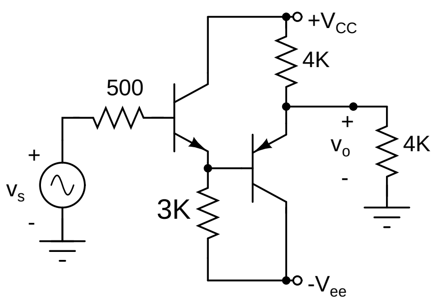

Figure 2: Problem 2

0.2 ANSWERS :

$$\begin{aligned} V_{CC} &= 12V \\ V_{ee} &= 6.65V \end{aligned}$$

Note: The circuit is directly coupled and level shifting is brought about by use of a pnp transistor.

Problem 3

(RESISTANCE OF CURRENT SOURCES). Consider the following current sources used in integrated circuits. All unmarked transistors have size (W/L). The device marked 0.25 in part (c) has a size of 0.25 (W/L). All unmarked transistors have a $V_{SG} - |V_{TP}| = \Delta V$, and an output resistance of r_o. For each of the current sources, determine the incremental output impedance and the highest voltage that can be supported before one of the devices in the current source goes out of the active region.

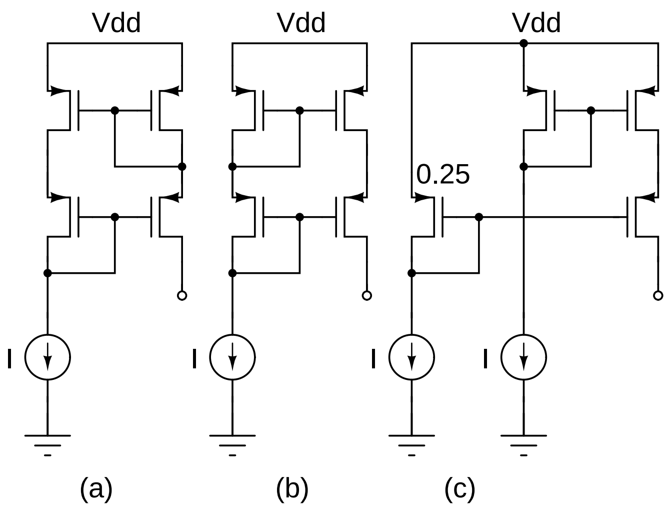

Figure 3: Problem 3

Problem 4

All transistors are identical and the Q-currents in all three are the same. V_{EB} or V_{BE} = 0.65 V, nominally. For T_3, V_{ECQ} = 7 V and I_{CQ} = 2 mA.

Find R_1, R_2, R_3 and V_{CC}.

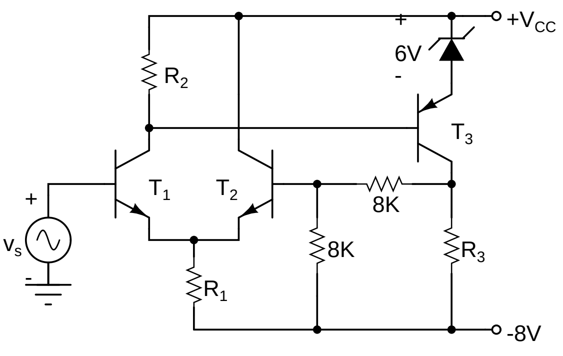

Figure 4: Problem 4

0.3 ANSWERS :

$$
\begin{aligned}
R_1 &= 1.8375K\Omega \\
R_2 &= 3.325K\Omega \\
R_3 &= 16K\Omega \\
V_{CC} &= 21V
\end{aligned}
$$

Problem 5

Take V_{BE} or V_{EB} = 0.65 V, nominally. Assume ideal DC functioning with 0 DC offset at the output. Take V_T = 25 mV, β = 200. Find all dc Q-level voltages and currents.Calculate k, R_{ia}, R_{oa}.

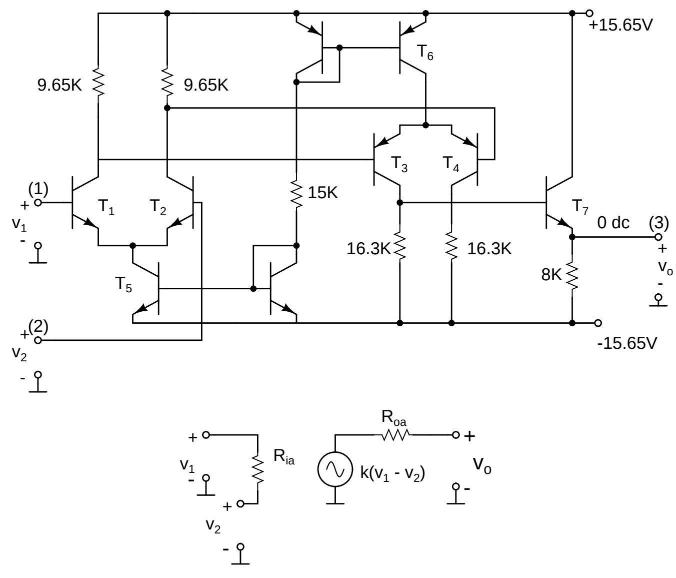

Figure 5: Problem 5

0.4 ANSWERS:

k = 42166.18; R_{ia} = 10.05K; R_{oa} = 92.79Ω.

$$
\begin{aligned}
T_1 \quad T_2 \quad V_{CEQ} &= 6.65V; 1mA \\
T_3 \quad T_4 \quad V_{CEQ} &= 6V; 1mA \\
T_5 \quad\quad V_{CEQ} &= 15V \\
T_6 \quad\quad V_{CEQ} &= 9V \\
T_7 \quad\quad V_{CEQ} &= 15.65V; 1.956mA
\end{aligned}
$$

Problem 6

V_{BE} or V_{EB} = 0.65V, nominally. Take R = 100Ω, V_T = 25mV, h_{fe} = 299. Current sources C_1 and C_4 are ideal while C_2 and C_3 have an incremental resistance of R_C which is 337.5K.

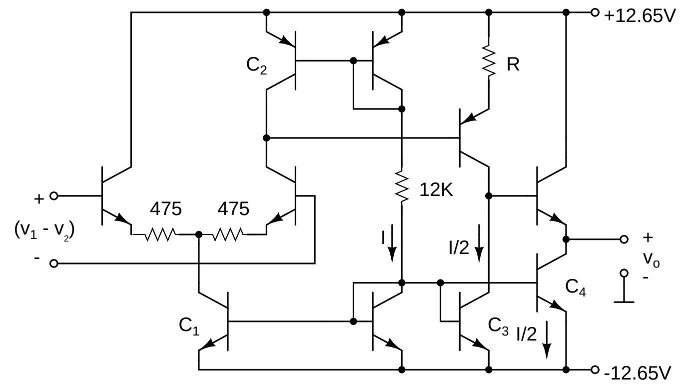

Figure 6: Problem 6

Calculate k, R_{ia}, R_{oa} for small signals.

0.5 ANSWERS:

k = -90518.5125; R_{ia} = 300KΩ; R_{oa} = 1.15KΩ.

Problem 7

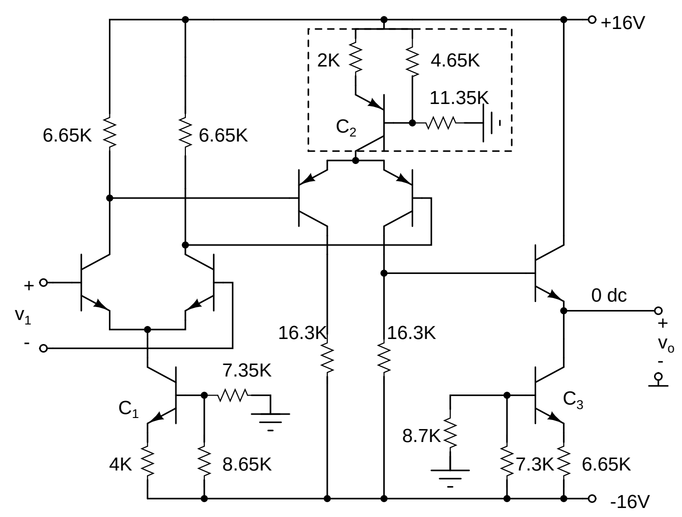

Figure 7: Problem 7

Current source C_3 is ideal while C_1 and C_2 have an incremental resistance of 200K.V_T = 25mV, β = 265. Find R_C, R_{ia}, R_{oa}, k and the CMRR. Find also the allowed swings of v_o.

0.6 ANSWERS :

$$\begin{aligned} R_C &= 16.65K \\ R_{ia} &= 13.3K \\ R_{oa} &= 87.59\Omega \\ k &= 43956.6 \\ CMRR &= 128 * 10^6 \end{aligned}$$

-8.7 $< v_o <$ 8.7

Problem 8

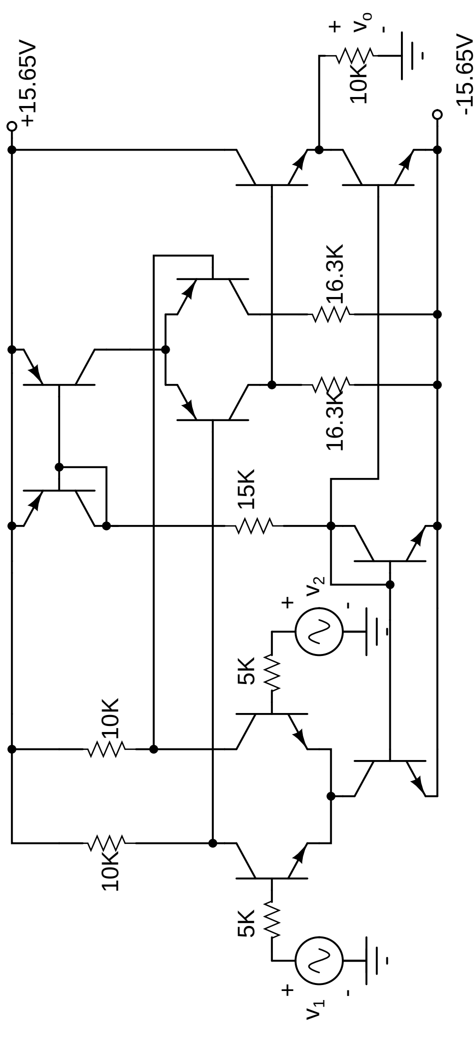

Figure 8: Problem 8

v_1 and v_2 are very small signals. v_o = k(v_1 - v_2). Determine k in sign and magnitude. V_T = 25mV, β = 99. As usual, neglect base currents for operating point calculations.

0.7 ANSWERS :

k = +4538.1284

Problem 9

Take V_{BE} = 0.65V, nominally. For the input signal shown both transistors should be swung to their limits of their active regions during the signal cycle. Find V_{CC}, R_e and the ratio R_x/R_y. Assume $R_x \| R_y$ in the order of R_e.

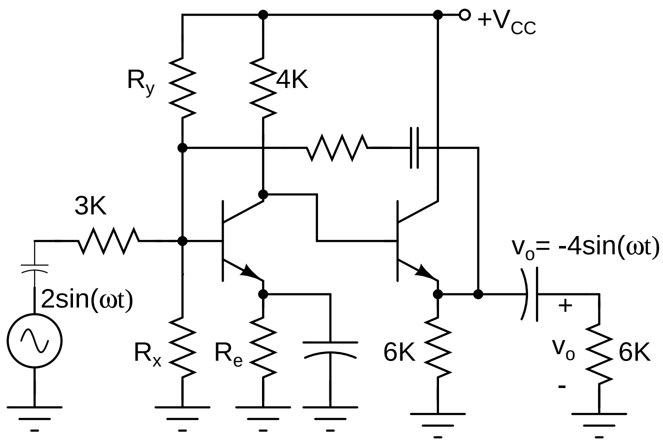

Figure 9: Problem 9

0.8 ANSWERS :

V_{CC} = 16.65V; R_e = 8K; R_x/R_y = 1.08125

Problem 10

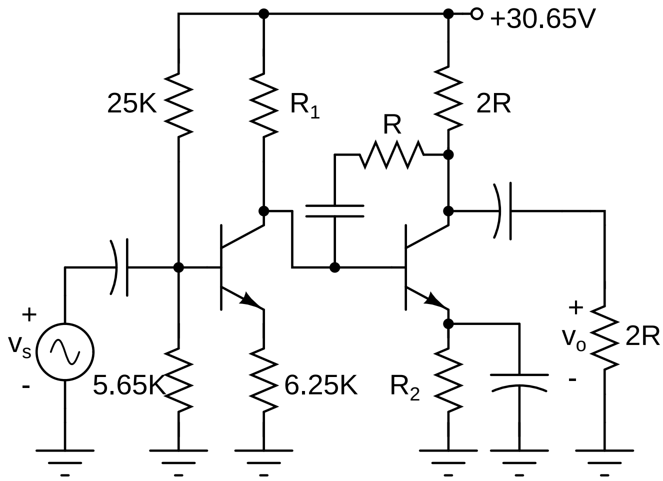

Figure 10:

Take V_{BE} = 0.65V, nominally. V_{smax} is such that both transistors are swung to limits of their active regions during the signal cycle. Find R_1, R_2, R, V_{smax} and V_{omax}.

0.9 ANSWERS :

$$\begin{aligned} R_1 &= 25K \\ R_2 &= 6.25K \\ R &= 5K \\ V_{smax} &= 5V \\ V_{omax} &= 4V \end{aligned}$$

Problem 11

All capacitors are very large valued. Take V_{BE} = 0.65V, nominally. v_c is given to be a small signal, v_m is **not** a small signal. V_T = 50 mV, assume α to be 1. Find $v_o(t)$, the total output voltage including the DC component. Also find the limits within which $v_m(t)$ should lie so that all transistors are always in their active regions. To find these limits assume $v_c/V_T \ll 1$.

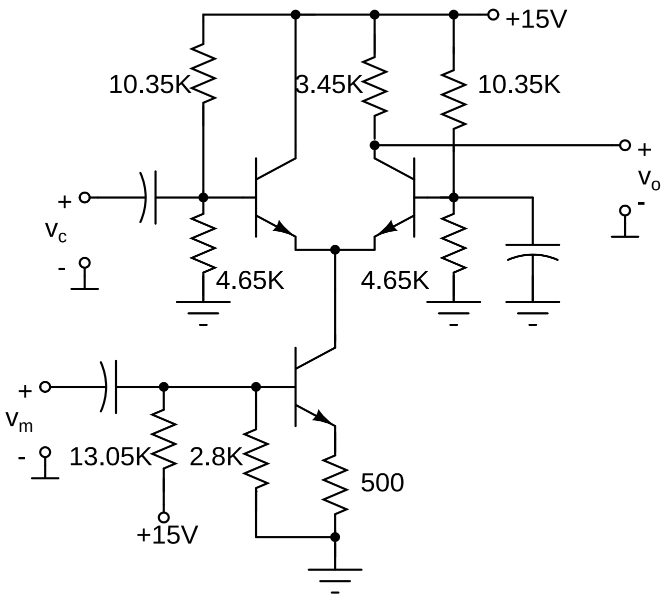

Figure 11: Problem 11