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1(25%) The circuit shown in Fig. 1 implements one form of a difference amplifier. Assuming that R_1=5kΩ, R_2=20kΩ, R_3=4kΩ, R_4=50kΩ, and all three op amps are ideal, determine the output v_O in terms of the inputs v_{I1} and v_{I2}, then determine the differential input resistance R_{id} between v_{I1} and v_{I2}.

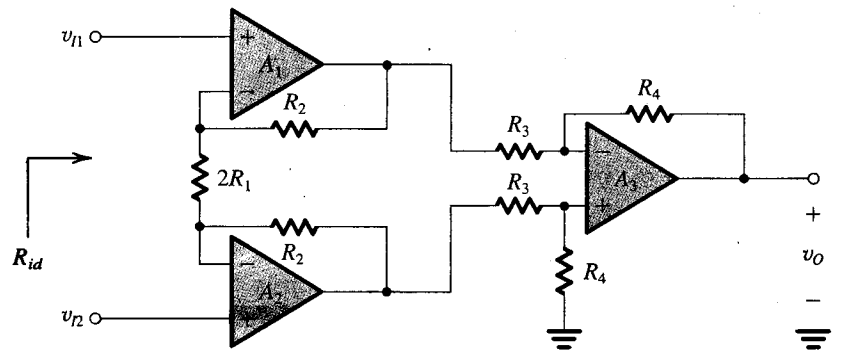


Fig. 1

2(25%) Please depict the circuit symbol of a diode, with a forward current i through it and the voltage drop v across it. It is known that the relationship between i and v can be expressed as $i=I_S\exp(v/nv_T)$. Depict its i-v characteristics for i>0. It is further known that a particular diode displays a forward voltage of 0.704V at a forward current of 1mA, and have a 0.096V/decade current change characteristics. Determine its voltage drop at a forward current of 0.751mA.

3(25%) For the common-emitter amplifier shown in Fig. 3, let V_{CC} = 9V, R_S = 10 kΩ, R_L = 2 kΩ, R_1 = 27 kΩ, R_2 = 15 kΩ, R_E = 1.2 kΩ, and R_C = 2.2 kΩ. The transistor has β = 100 and V_A = 100 V.

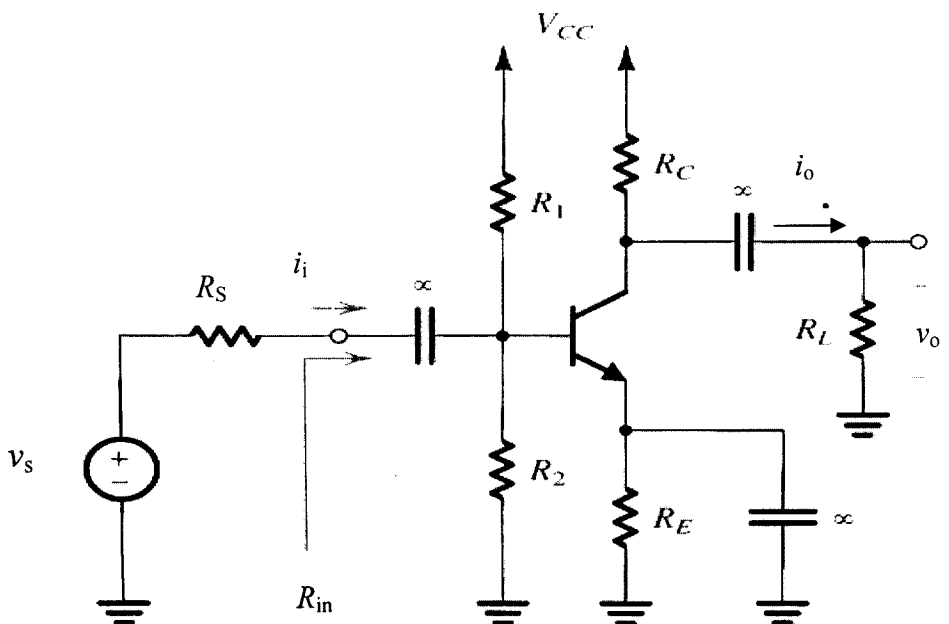
(a) Calculate the dc emitter current I_E.

(b) Replace the transistor with its hybrid-π model, and draw the small-signal equivalent circuit of Fig. 3.

(c) Find the input resistance R_{in}.

(d) Determine the voltage gain v_o/v_s.

(e) Find the current gain i_o/i_i.



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4(25%) Using two transistors Q_1 and Q_2 having equal lengths but widths related by $W_2/W_1 = 5$, design the circuit of Fig. 4(b) to obtain $I = 0.5$ mA. Let $V_{DD} = V_{SS} = 5$ V, $\mu_n C_{ox}(W/L)_1 = 0.8$ mA/V^2, $V_t = 1$ V, and $\lambda = 0$.

(a) Find the required value for R.

(b) What is the voltage at the gates of Q_1 and Q_2?

(c) What is the lowest voltage allowed at the drain of Q_2 while Q_2 remains in the saturation region?

(d) If the circuits of Fig. 4 are implemented in integrated circuit (*IC*) form, which transistor(s) (Q, Q_1, or Q_2) will suffer from the body effect? Why?

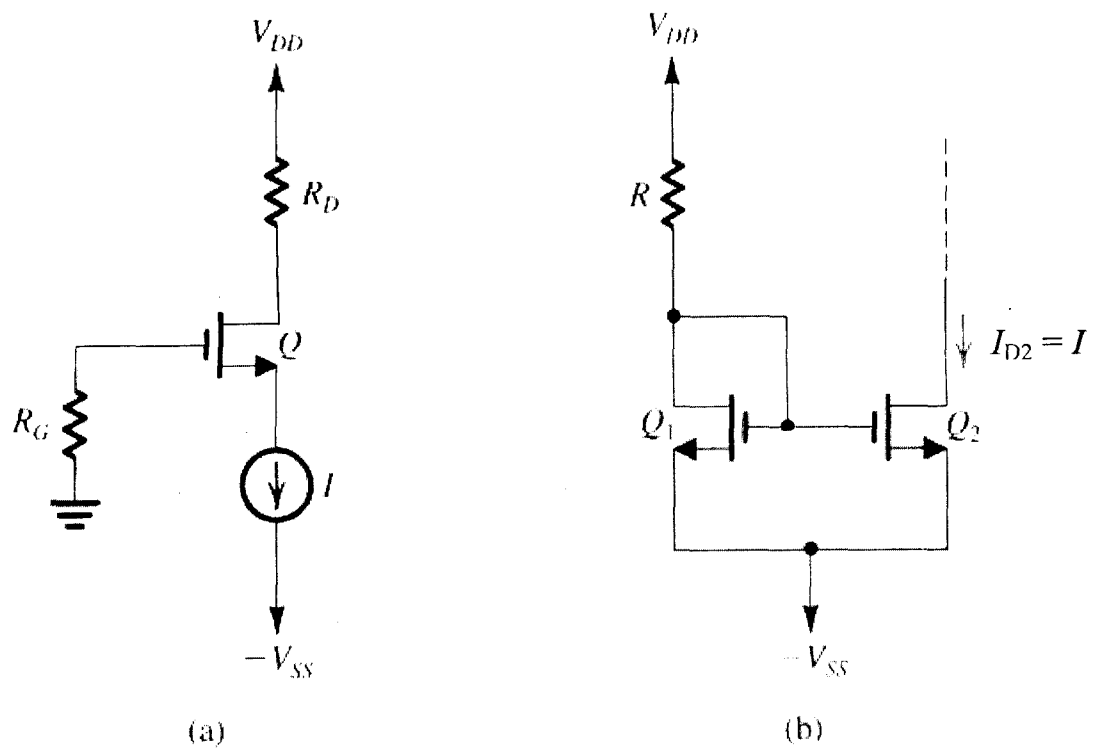

Figure 4 (a) Biasing the MOSFET using a constant-current source I.
(b) Implementation of the constant-current source I using a current mirror.