MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

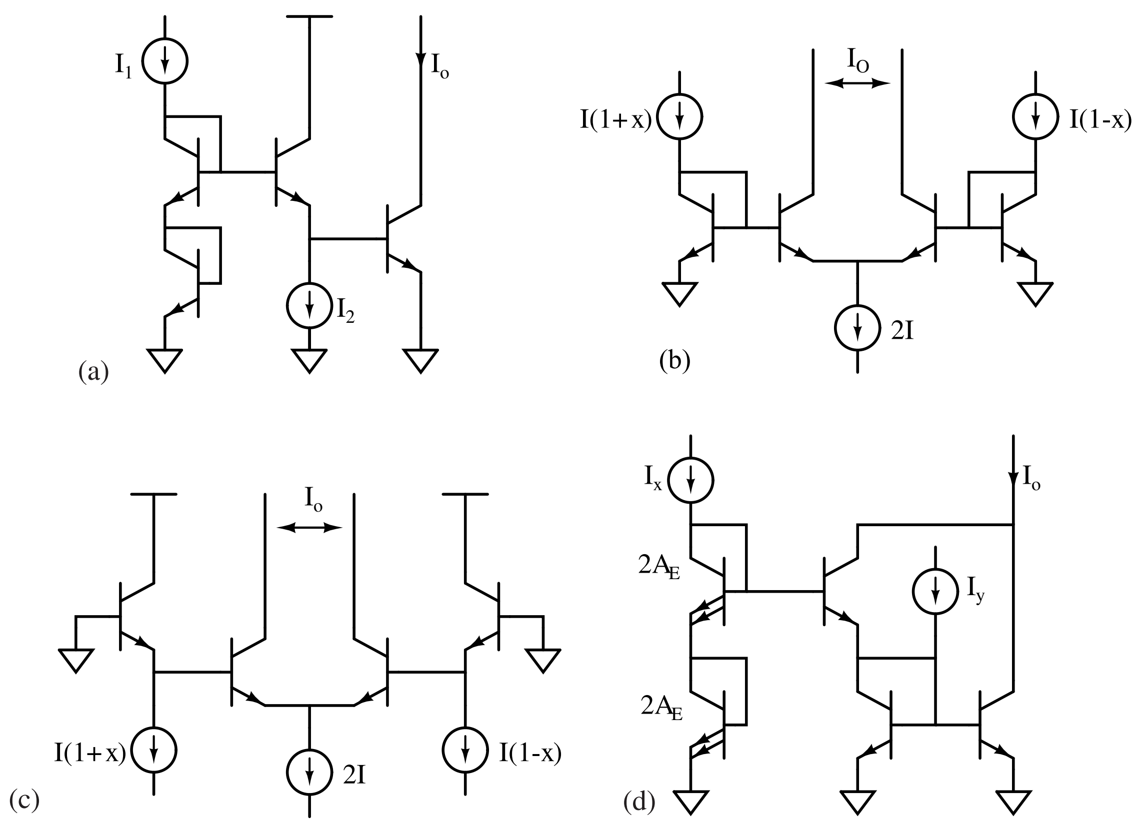
6.301 Solid State Circuits

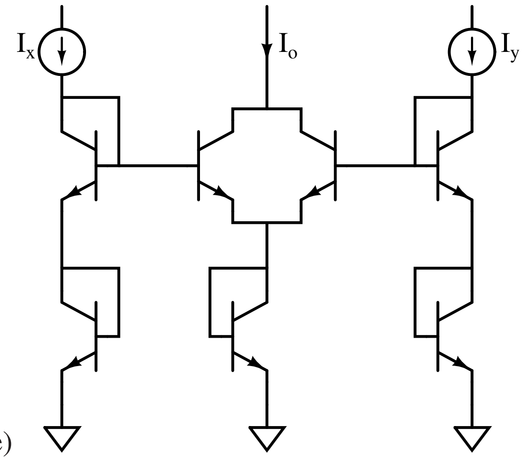
Fall 2013
Problem Set 8

Issued : Nov 19, 2013
Due : Nov 26, 2013

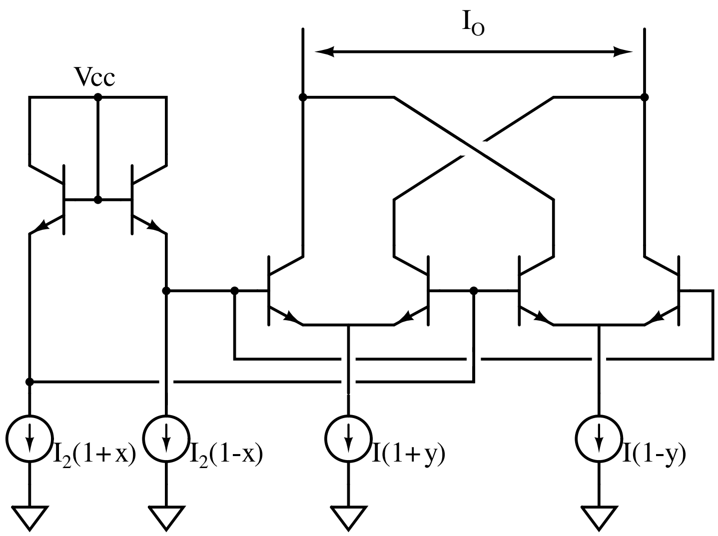
Problem 1: Translinear Jungle Gym

For each of the following circuits use the Gilbert Principle to determine I_o as a function of the other circuit variables. All of these circuits simplify to simple expressions.
A differential output is denoted by an I_o superimposed on an arrow, and double emitter arrows with $2A_E$ indicate that transistor has double the emitter area of the other transistors, thus its I_S is twice as large.
Finally, use the method of open circuit time constants to estimate the $-3dB$ frequency for the circuit in part (a) only.





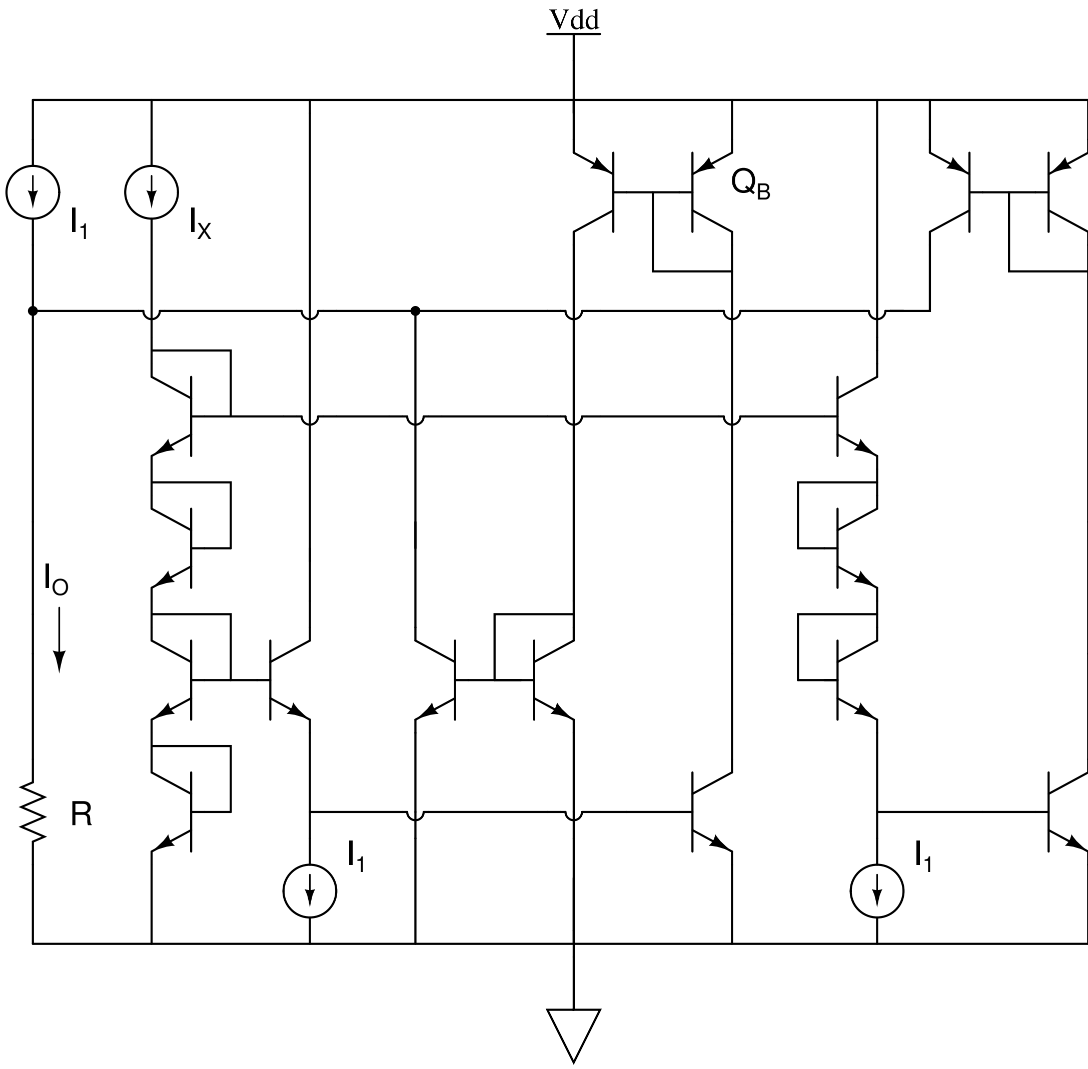
(e)



(f)

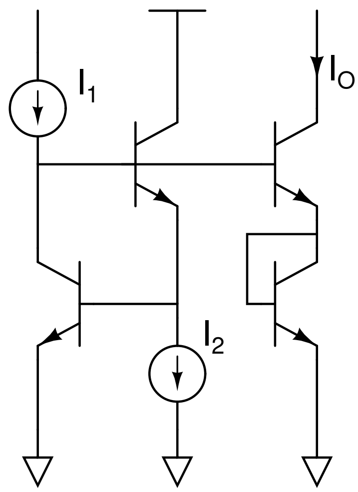
Problem 2: Translinear Approximator

Find $I_o = f(I_x)$, assuming well-matched transistors, negligible base currents, and $I_1 = 1A$. Also assume Q_A and Q_B have emitter areas $24A_E$ and $2A_E$, respectively, while all other transistors have emitter area A_E.
What famous function does I_o approximate for small I_x?



Problem 3: Base Current Error

In the following circuit, assume $I_2 = 1mA$ and $\beta = 100$.

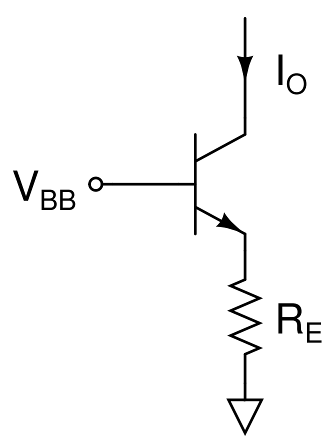


(a) Express I_o in terms of I_1 and I_2.

(b) Assume we can tolerate a maximum I_o error due to β of 50%. For what range of I_1 is this circuit valid?

Problem 4: Temperature Dependence and Compensation

When we design a circuit, we prefer that it operate over a wide range of temperature. Below is a voltage-biased current source with a temperature dependence heavily based on R_E and V_{be}. In the following circuit, assume that $\frac{1}{R}\frac{dR}{dT} = 600ppm/°C$ and $\frac{dV_{be}}{dT} = -2mV/°C$.



(a) Find $\frac{dI_o}{dT}$.

(b) Find the value of R_E in terms of I_o that minimizes $\frac{dI_o}{dT}$.

Problem 5: Your Own Personal Bandgap

Referencing the simplified schematic of the LM109 5V Bandgap Reference from lecture, design a modified verion that produces an output voltage of 7.5V.

Explain the operation of your reference.