Example Problem Set

$IIP_3, P_{1dB}$ calculation

1. We will be analyzing the nonlinear behavior of the cascaded, tuned amplifier shown above. The key to analyzing a relatively complex circuit such as this is to ignore any components that do not affect your signal path and then attack it one stage at a time. Redraw the schematic, replacing as many components as you can with ideal components (as far as the signal is concerned, which devices can you treat as current sources/sinks, as infinite impedances, and as short circuits?). What small signal components can you ignore (i.e. is $r_o \gg Z_L$?).

One additional hint: most of the small signal properties of an emitter degenerated transistor can be found by adjusting by a factor of $(1 + g_m R_E)$, that is, $g'_m = \frac{g_m}{1 + g_m R_E}$, $r'_\pi = r_\pi \times (1 + g_m R_E)$, $C'_\pi = \frac{C_\pi}{1 + g_m R_E}$, but $C'_\mu = C_\mu$

(a) Find the small signal voltage gain, as a function of frequency. At what frequency is gain maximized? Confirm with a SPICE simulation.

(b) What is the 3rd-order power series that best characterizes $I_d = f(V_{in})$ for the first differential pair? Remember that a BJT differential pair has the relationship: $I_d = I_{EE} \times \tanh(\frac{V_{in}}{2V_T})$.

(c) What is the 3rd-order power series that best characterizes $I_d = f(V_{mid})$ for the second differential pair?

(d) What is the IIP3 of the cascaded amplifier? Assume that the two tones used to generate IM3 products are 1 GHz±1 MHz. Does the narrow-band nature of the amplifier prevent you from using the cascaded approximation? Note that the two tones and their IM3 products all fall in-band.

(e) What is the input-referred 1 dB compression point of the cascaded amplifier for a 1 GHz signal? What is the HD3 of the cascaded amplifier for $V_{in} = 3$ mV with a frequency of 1 GHz? Can you use the cascaded approximation? Confirm with SPICE.
VCC = 2.5, $R_E = 60\Omega$, $R_L = 160\Omega$, $R_{bias} = 10k\Omega$, $C_{coup} = 100pF$, $C_L = 6.1pF$, $L = 4nH$, $Q_{yd} = 4$

IS = 1fA  BF = 100  VAF = 50V  ISE = 300fA  NE = 2
BR = 10  NR = 1  VAR = 100V  ISC = 200fA  NC = 1
RB = 0  RE = 0  RC = 0  CJE = 120fF  VJE = 0.6V
MJE = 0.27  TF = 6.4ps  CJC = 60fF  VJC = 0.3V