E416 – Spring 2007-set 1

Suggested problems – Current mirrors and switched currents

1. Calculate the frequency dependence of the input impedance of a source degenerated common source amplifier. Use this result to calculate the frequency dependence of the small signal input impedance of the Wilson current mirror. It may help to do the analysis as feedback problem rather than a circuit problem. Please remember the current input is meant to be driven by a vanishing admittance current source!

2. Calculate the DC current gain error for matched BJT transistors for the simple current mirror. Include the Early Effect. Use this result to infer the small signal current gain error of the MOS simple current at a finite frequency, if you know the f_T of the process. Remember the finite frequency current gain of a MOS transistor is imaginary, i.e. incurs a 90 degree phase lag.

3. Calculate symbolically the small signal power gain of a simple BJT mirror at a finite frequency.

4. Calculate the harmonic distortion of a class A FET simple current mirror if the AC signal amplitude is equal to the bias, and if the AC signal amplitude is half the bias, both at a finite frequency. Note that in strong inversion the gate-source capacitance is essentially constant, so that the circuit IS NOT linear-time invariant!

5. Calculate symbolically and plot the I-V characteristic of a diode connected (gate-drain connected together) FET, for:
    a. A long gate FET: $I_{DS} = K_L \frac{W}{2L}\left(V_{GS} - V_T\right)^2 \left(1 - \lambda V_{DS}\right)$
    b. A short gate FET: $I_{DS} = K_S \frac{W}{1.5L}\left(V_{GS} - V_{T0} - \alpha V_{DS}\right)^{1.5}$
    c. In weak inversion: $I_{DS} = M \frac{W}{L} e^{q\left(V_{GS} - V_T\right)/nkT} \left(1 - e^{qV_{DS}/kT}\right)$

   For the purposes of this exercise you may assume $K_L = 10\mu A/V^2$, $K_S = 10\mu A/V^{1.5}$, $M = 100nA$, $V_T = 0.3V$, $\lambda = .01$ and $\alpha = .05$. What is the gm of each case? What are the typical impedance levels encountered?

6. Observe that a second generation switched current memory cell is equivalent to a simple current mirror driven by the signal masked by the switching waveform. Use the results form Q3 above, the Convolution theorem and Power conservation to estimate the gain error as a function of switching and signal frequency, provided the signal frequency satisfies the Nyquist criterion.