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EEECS100/42, Fall 2009 **T. K. Gustafson**

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S.I.D. :

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Due : Dec 9

Problem Set No. 6

Based upon Chapters 3-5 of Hambley, Diode (10.4-10.7) ,and Transistor (13.5,13.7) and digital concepts (Chapt 7). Ignore Chapt 15 on transformers. The essentials are the pair of coupled equations of problem 4. MOS Transistors - 12.4 for small signal (see also 13.7) and 12.7 for CMOS. Three problems are basically review.

Problem Number 1) Sequential Logic Design
a) Hambley 7.88
b) Hambley 7.81

Problem Number 2) Counter Design
Hambley 7.87 (Should have told us that for a 1 D_4 is to be lit, for a 2 D_1 and D_7 ; 3, D_1, D_4 and D_7; 4, D_1, D_2, D_6 and D_7; for 5, those of 4 and D_4; and for 6, all but D_4).

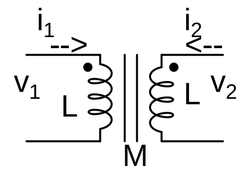
Problem No 3) Small Signal Analysis
Consider Hambley Problem 12.20 from Problem Set 5. In that problem we used $V_{GS} = 3 + V \cdot sin(2000\pi t)$ where $V = 1.$. Now let us choose $V = .1$ and $\omega = 2 \cdot 10^8\pi$ (much smaller amplitude and a much higher frequency). If we pick $C = 1\mu$ F then the capacitor is essentially shorted at this frequency (but open at d. c.)

a) Calculate $v_{ds} - V_{ds} = \Delta v_{ds}$ analytically by using a Taylor expansion around the d.c. operating voltage V_{ds} established by the 20 Volt battery alone.
b) Verify your result using LTSpice (or other simulator).
c) Draw an effective "small-signal equivalent " circuit for this CMOS amplifier. (This is an equivalent circuit that neglects the d.c voltages and currents around which the circuit operates at frequency ω)
d) What are the input and output resistances at the signal frequency (small signal resistances)?

Problem No 4) Coupled Circuits- (Sinusoidal Analysis)

A useful element in circuits is the so-called transformer. It is simply two coils in proximity so that the voltage and current in one influences the voltage and current in the second (and vice versa). It is a neat (and standard) way to couple two (or more) circuits and to transform voltages from one value to another (with conservation of power of course). If the two circuits are resonant the coupling can be enhanced at the resonant frequency (hence resonant energy transfer!).

The governing equations are a simple generalization of the inductor:



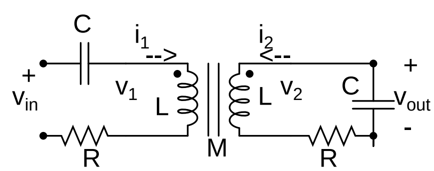
$$v_1 = Lpi_1 + Mpi_2$$

$$v_2 = Lpi_2 + Mpi_1$$

where$p = \frac{d}{dt}$, v_1 and v_2 have there + reference at the dot end of the coils and i flows into the dotted ends. Then M is positive.

We now consider such a transformer in the following circuit:

a) For $v_{in}(t) = V_1 cos(\omega t)$ obtain the value for $V(_out)$ across the capacitor as a function of



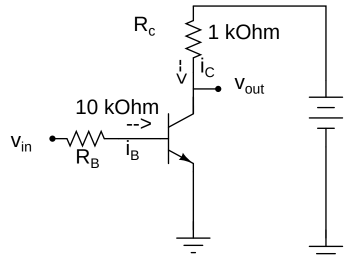
ω if $v_{out}(t) = ReV(_out)exp(j\omega t)$ (note $V(_out)$ is complex)

b) Putting in values, L = 1 μH, $M = .01\mu H$, $C = 1pF$ and $R = 10\Omega$ plot V_{out} versus ω (phase and amplitude). (Use LTSpice or other simulator if you wish). A frequency range of .5 MHz to .3 GHz is plenty

c) Obtain the separation between the two resonant peaks for M=.001, .01, and .1 μH ?

Problem No 5) Resistor-Transistor inverter

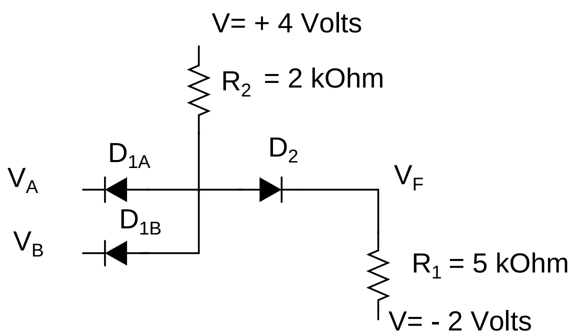
For the ideal bipolar circuit shown below and $\beta_F = 50$, $V_{BE_{on}} = V_{BE_{Sat}} = .7$, and $V_{CE_{Sat}} = .2$.



a) Plot V_{out} versus
V_{in} over the range $V_{in} = 0$ to 5 V.
b) Now connect the input of this gate (gate 1) with the output of an identical gate (gate 2). Also connect the output of gate 2 with the input of gate 1. Predict the three simultaneous solutions for V_{out} and V_{in} of gate 1.
c) Using LTSpice can you show that only two of the solutions are stable?

Problem No 6) Diodes (Review)

For the diode gate below



a) Take $V_A = 5V$. Use $V_{D_{on}} = .7$V . Plot V_F versus V_B.
b) What type of gate is this for positive logic?

Problem No 7) Simple CMOS gates as switches

Hambley Problem 12.59