**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**
**Department of Electrical Engineering and Computer Science**

**6.002 - Electronic Circuits**
**Spring 2007**

**Homework #8**
**Handout S07-040**

**Issued 4/5/2007 - Due 4/13/2007**

Helpful Readings for this Homework: Chapter 10 of A&L

**Exercise 8.1:** Chapter 10, Exercise 10.16 (p. 572)

**Exercise 8.2:** Chapter 10, Exercise 10.24 (p. 575), assuming RC time constants are small.

**Problem 8.1:**

Lem E. Tweakit, a junior in course VI, wants to control his dorm-room lights from his personal computer. He proposes to use a data line from the parallel port on the computer to control the lights, because it is easy to write a program that controls the signal on the parallel port. A TTL parallel port is guaranteed to put out a HIGH signal of greater than $V_{OH}$ = 2.4 Volts and it is guaranteed to put out a LOW signal of less than $V_{OL}$ = 0.4 Volts. However, the lights are 110 Volts at 60 Hz AC, so of course, he cannot directly control the lights from the parallel port. Lem wants to use a relay to work the lights, but the only relay that Lem has in his junkbox requires 100 mA to reliably close the switch. Unfortunately, his parallel port cannot supply anywhere near that much current. He decides to use a MOSFET stage to control the relay, so that it can control the lights. Lem's idea is shown in Figure 1. When Lem's computer puts out a HIGH, current flows through the relay coil and the light switch turns on; when the computer puts out a LOW, the current is stopped and the light switch turns off.

<u>Note:</u> A relay is an electromagnetically-controlled switch. It has a coil of wire that becomes a magnet when current is passed through it. The magnet is used to move an iron armature which actuates a switch. Of course, the coil of wire has inductance and resistance.

The MOSFET that Lem uses has an ON resistance of about $R_{ON}$ = 5 Ohms. It has a threshold voltage of about $V_T$ = 1.5 Volts. The coil of the relay has an inductance of about 1 Henry and a resistance of about 40 Ohms. For all practical purposes, the computer's output voltage changes instantaneously.

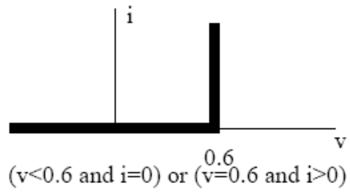
(A) Assume that the computer output has been LOW for a long time; it then goes HIGH. Draw a graph of the current in the relay coil as a function of time. At what time does the relay close and the light go on?

(B) Assume that the computer output has been HIGH for a long time; it then goes to LOW. What happens to the voltage $v_{DS}$ from the drain to the source of the MOSFET? (Hint: Consider what happens to the current in the relay coil at the time of the transition. What does that tell you about the voltage across the relay coil at the time of transition?) Do you expect smoke? Your answer to this part should be only a few short sentences!

(C) Suppose Lem puts a diode across the relay coil as in Figure 2 and the circuit schematic of Figure 3 below. Draw a graph of the current in the relay coil as a function of time, starting when the computer output drops from HIGH to LOW.

Problem continued overleaf…

Note: A diode is a two-terminal device that can be modeled, for this problem, with the characteristic:



(v<0.6 and i=0) or (v=0.6 and i>0)

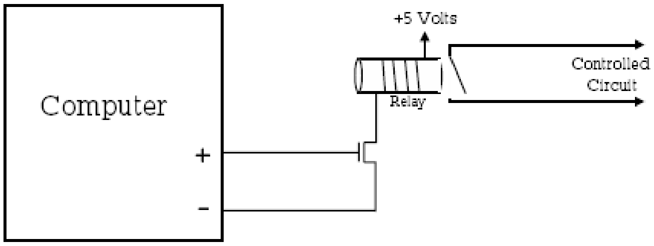


Figure 1

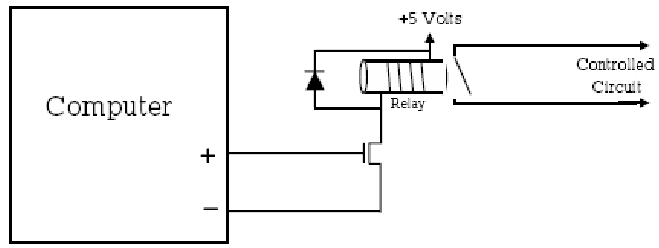


Figure 2

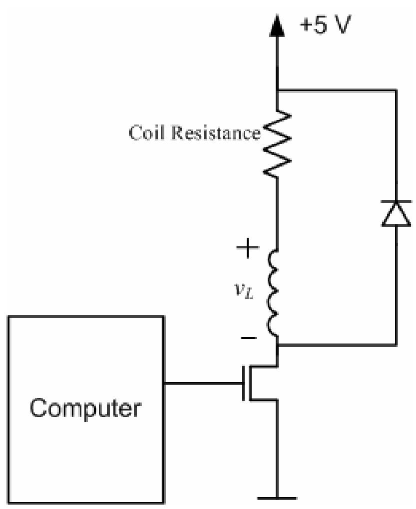


Figure 3.

(D) For the circuit with the diode installed, draw a graph of the voltage across the relay coil inductor and a graph of the voltage $v_{DS}$ across the MOSFET for the same time period. How does the diode solve the problem raised in part B?

**Problem 8.2:** Chapter 10, Problem 10.4 (p.578). Your answer may also depend on $R_L$ (as well as $V_S$, $V_L$, $R_{ON}$, $C_{GS}$, wire length, *l*, and wire parameters).

**Problem 8.3:** Chapter 10, Problem 10.29, parts a, c, and e (p. 591-592). Hint: Try an intuitive approach to the graphs in parts (a) and (c), instead of solving differential equations.