MASSACHVSETTS INSTITVTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.002 – Electronic Circuits
Fall 2001

Problem Set 4

Issued: 27 September 2001 Due: 5 October 2001

Notice: The material on this problem set is the last material to be tested on Quiz 1, which will be in the evening of Wednesday, 10 October 2001. The quiz will be held in Walker Memorial Gymnasium (50-340), where you must appear by 7:30 PM. You will have 2 hours to work the quiz.

Reading:

- A&L Chapter 8 for Thu. 27 Sept. and Fri. 28 Sept.
- A&L Chapter 5 for Tue. 2 Oct. and Wed. 3 Oct.
- A&L Chapter 6 for Thu. 4 Oct. and Fri. 5 Oct.

Problems:

1. The circuit of Figure 1 below is a simple kind of amplifier. The MOSFET has a threshold

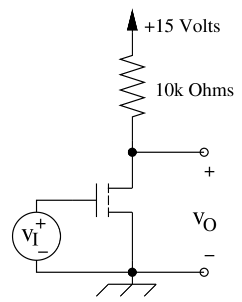

Figure 1: A simple amplifier.

voltage of $V_T = 1.0$ volt and a $K = .0002$ amp/volt^2.

(a) On a piece of graph paper, sketch the output characteristics for the MOSFET: Graph i_D vs. v_{DS}, for values of $v_{GS} = 1, 2, 3, 4, 5$ volts.

(b) On the same graph, sketch the load-line for this circuit.

(c) If $v_I = 0$ the MOSFET is cutoff. If we increase v_I the MOSFET becomes saturated. Further increase in v_I causes it to enter the linear region, and eventually the output voltage v_O goes to zero. What are the critical values of v_I, and the corresponding values of v_O where the MOSFET passes from cutoff into saturation and from saturation into linear?

(d) On another sheet of graph paper, sketch the transfer characteristic of this amplifier: Show v_O vs. v_I.

2. Consider the circuit of Figure 2 below. As before, the MOSFET has a threshold voltage of

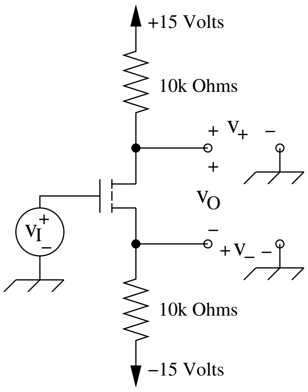

Figure 2: Circuit for Problem 2.

$V_T = 1.0$ volt and a $K = .0002$ amp/volt^2.

(a) How is the load line for this circuit related to the load line for the circuit of Problem 1 above?

(b) If v_I is held at zero volts (so that the gate is at ground potential) what is the current flowing through the MOSFET from the drain to the source?

(c) As v_I is varied between -1 volt and $+1$ volt how does v_O vary? How do v_+ and v_- vary?

(d) Make an incremental model of the MOSFET appropriate to a zero bias voltage on its gate in this circuit. Find the Thevenin equivalent for this circuit as seen from the port whose voltage is labeled v_O.

3. During the first half of the last century, the vacuum tube was the workhorse for designers of electronic circuits. The situation changed abruptly during the 1950's with the development of the transistor, for which Shockley, Bardeen and Brittain received the 1956 Nobel Prize. In spite the remarkable progress made by solid-state devices, e.g., the Bipolar Junction Transistor and MOSFETs, the vacuum tube still finds use today, particularly in high-power applications such as radio and television transmitters. In this problem, we will investigate the behavior of a simple amplifier using a venerable vacuum tube triode, the 6DJ8.

In operation, electrons are boiled off the cathode by thermionic emission and flow to the plate, constituting a current between cathode and plate. The electron stream is controlled by a grid located near the cathode, so that the net cathode-plate current is determined by both the grid to cathode voltage, v_{GK}, as well as the plate to cathode voltage, v_{PK}. Analysis of the physics shows that the relationship takes the form:

$$i_{PK} = K(v_{GK} + \frac{v_{PK}}{\mu})^{3/2}$$

where K and μ are constants. Normally $v_{GK} < 0$ and in this case there is negligible grid current.

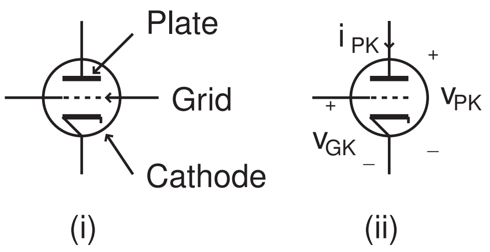

Figure 3: Definition of triode electrodes (i) and voltages and current (ii).

(a) The attached figure shows i_{PK} vs. v_{PK} for the 6DJ8 triode, with v_{GK} as a parameter. Choose one of these curves, for example the one with $v_{GK} = -3V$, and determine K and μ by requiring the above expression to hold at two values of the current i_{PK}, for example $20mA$ and $40mA$. Test your result by comparing the predicted current for a few values of v_{GK} and v_{PK} with that given by the curves.

(b) Consider the 6DJ8 triode amplifier shown in Figure 4-3b(i). Draw the load line showing the locus of possible operating points permitted by the plate circuit on the i_{PK} vs. v_{PK} characteristics and specify the grid bias voltage to obtain an operating point at $i_{PK} = 20mA$.

(c) An incremental model for the amplifier in Figure 4-3b(i) is proposed in Figure 4-3b(ii). Determine R_p, A and R_L at the operating point found in part b) and the gain of the amplifier.

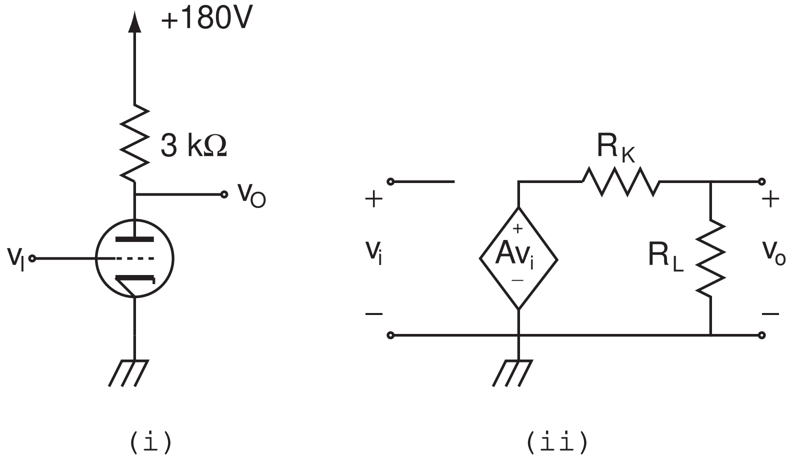

Figure 4: A simple vacuum tube amplifier (i) and its incremental model (ii).