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THE NATIONAL UNIVERSITY OF IRELAND, GALWAY

SUMMER EXAMINATIONS 1999

THIRD YEAR ELECTRONIC ENGINEERING EXAMINATION

ELECTRONIC DEVICES AND CIRCUITS

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Duration of Examination : **3 hours**

Instructions — Answer **FIVE** questions.
All questions carry equal marks.

1. An asymmetrical junction silicon diode has an extrinsic concentration of 10^{17} cm^{-3} on the N side and 10^{16} cm^{-3} on the P side. Under thermal equilibrium conditions at 27°C, calculate

   a) the built-in potential across the space charge layer (6 marks)
   b) the maximum electric field intensity inside the space charge layer (6 marks)
   c) the distances the space charge layer extends into the P and N regions. (8 marks)

   Boltzmann's constant, $k = 8.614\times10^{-5}$ eV/°K
   Intrinsic carrier concentration (at 27°C) = 1.4×10^{10} cm^{-3}
   $\epsilon = 11.8\epsilon_o$
   $\epsilon_o = 8.854\times10^{-14}$ F/cm
   $q = 1.6\times10^{-19}$ C

2. a) The resistivity of pure germanium at a particular temperature is 52 ohm-cm. If it is doped with 10^{14} atoms/cm^3 of a trivalent impurity, estimate the new value of resistivity. Assume mobilities μ_n=3800cm^2/Vsec, μ_p=1800cm^2/Vsec and electronic charge $q=1.6\times10^{-19}$C (9 marks)

   b) Compare the DC behaviour of the following BJT-based transistor circuits (fig 2). Sketch the I_{ds}/V_{ds} characteristic and Q point of each device and indicate the mode of operation of each device. (11 marks)

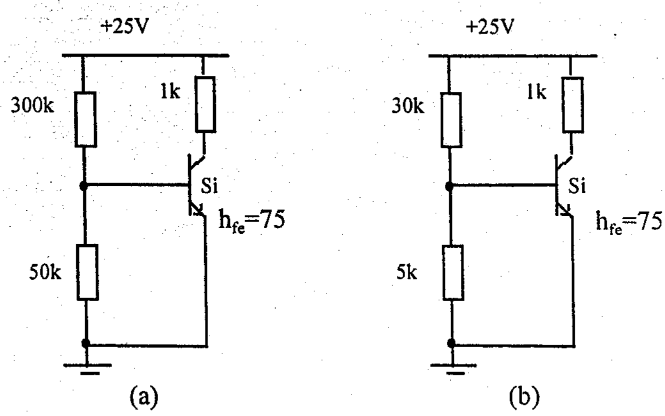
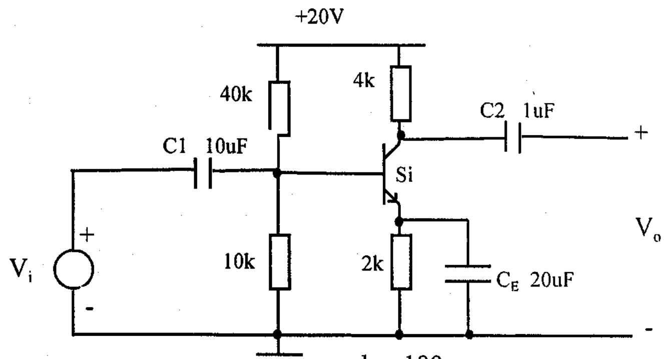


Figure 2 Common Emitter Amplifier DC bias circuits

3. The circuit of figure 3 shows a typical common emitter amplifier.



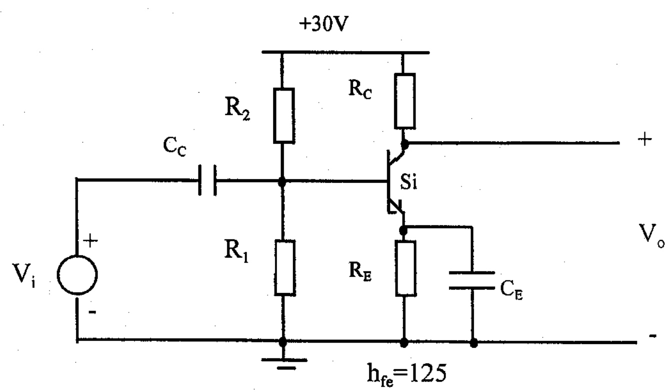
$h_{fe}=100$

Figure 3 Common Emitter Amplifier

a) Calculate the d.c. operating point of the amplifier (6 marks)
b) Draw the small signal model of the amplifier circuit (3 marks)
c) Calculate the amplifier input and output impedances (2 marks)
d) Calculate the amplifier mid-band gain (4 marks)
e) Calculate the lower cut-off frequency of the amplifier (5 marks)

4. A BJT-based amplifier circuit is illustrated in figure 4.

a) Design resistor component values to provide midband gain $A_v = 520$ assuming $I_C = 3$mA. Assume also that $R_1 = 2.4$kOhm. (10 marks)



$h_{fe}=125$

Figure 4 Common Emitter Amplifier

b) Design, using a zener diode a 10 volt regulated power supply to handle load currents of 0 - 500 mA. The input voltage available is an unregulated supply which can vary over the range of 30 - 45 volts. You should allow at least 25 mA zener current under worst-case conditions to ensure that the zener is operating in its active region. (6 marks)

c) Calculate the maximum power dissipated in the zener and select a suitable power rating for this device. What are the main disadvantages of this simple zener regulator? (4 marks)

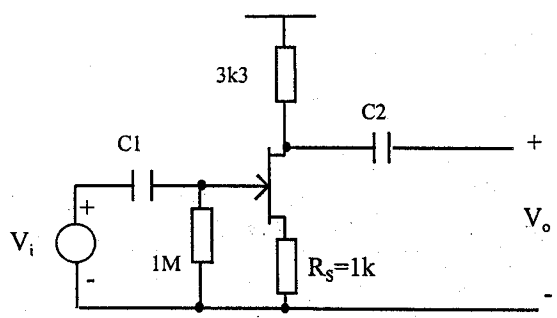
5. a) Illustrate n-channel JFET device operation modes using cross sectional diagrams and I_{ds}-V_{ds} characteristics (4 marks)

b) Explain the role of the resistor in the source path of the FET amplifier circuit (figure 5) (3 marks)

c) Calculate the d.c. operating point of the FET amplifier (6 marks)

d) Sketch the small signal model for the amplifier circuit (3 marks)

e) Calculate the amplifier mid-band gain (4 marks)



I_{DSS}=8mA
V_{DS_p}=6V

$$I_{DSP} = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(cut-off)}}\right)^2$$

Figure 5 JFET Amplifier

6. Figure 6 shows a temperature sensing circuit using a silicon sensor R_t. The sensor resistor has the following characteristics :

R_t = 825Ω at 0°C
R_t = 1.8kΩ at 100°C

a) Calculate the value of R_x which gives V_o = 0V at 0°C (8 marks)

b) Calculate the value of V_o at 100°C (7 marks)

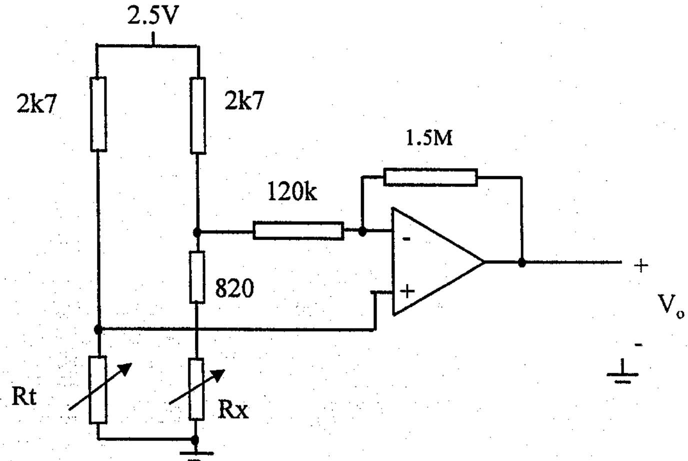


Figure 6 Temperature sensor

c) Sketch a 'super diode' precision rectifier circuit and explain its operation and application. (5 marks)

7. a) Draw the circuit for a Schmitt trigger. Explain its operation and derive the input switching voltage values. (5 marks)

b) Draw the circuit diagram of a differential amplifier and explain its principle of operation (include a current source in the emitters' circuit). (4 marks)

c) Draw the small signal equivalent circuit model for a single ended differential amplifier and derive the expression for the small signal differential gain (6 marks)

d) Explain the following as they apply to operational amplifiers and illustrate (with waveform diagrams), the effect of each on the op-amp output signal. (5 marks)

(i) Input Offset Voltage
(ii) Slew rate
(iii) CMRR