IEC 103

Assignment - 4

Diodes and their Applications

1. A diode test circuit consists of a 9V battery, a 1mA meter movement, and a resistor connected in series to two test probes, one positive (red) and the other negative (black). The circuit is calibrated so that a current of 1mA flows with the probes shorted. When a circuit consisting of an ideal diode and a 3 kΩ resistor connected in parallel is probed, two test circuit current readings are found depending on the ends of the diode to which the red and black probes are connected. What are the two readings you would expect? For the larger one, to which end of the diode is the red probe connected?

2. For the circuits shown in figure 1, find the values of labeled voltages and currents.

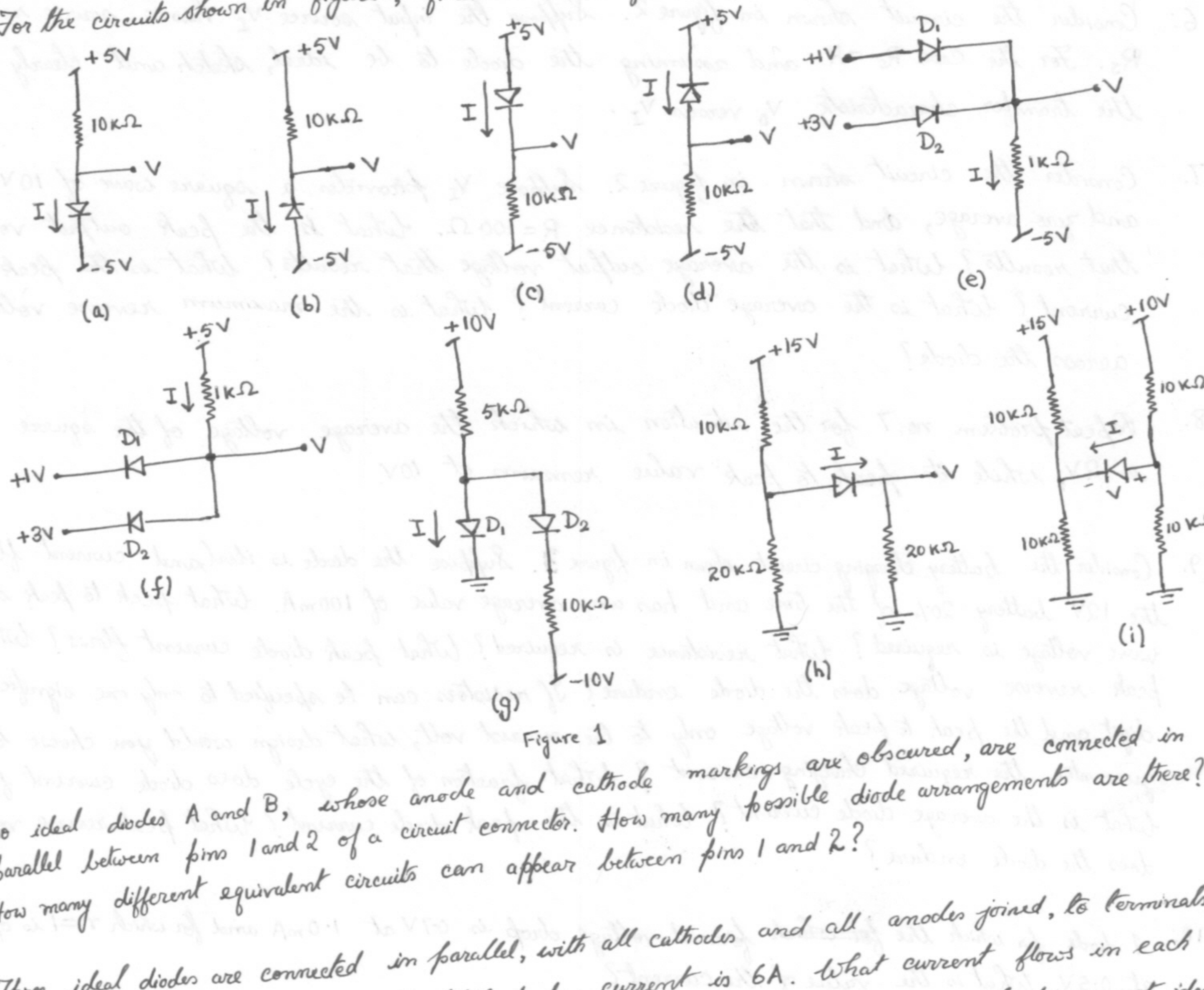

Figure 1

3. Two ideal diodes A and B, whose anode and cathode markings are obscured, are connected in parallel between pins 1 and 2 of a circuit connector. How many possible diode arrangements are there? How many different equivalent circuits can appear between pins 1 and 2?

4. Three ideal diodes are connected in parallel, with all cathodes and all anodes joined, to terminals x and y in a circuit in which total diode current is 6A. What current flows in each diode? What is the voltage drop across each diode? If the diode connecting leads are not ideal, but have a resistance of 10 mΩ, what is the voltage between terminals x and y? If through an error in manufacturing, the leads on one of the diodes is twice the length of each of the others, what current flows in each diode? If two of the diodes have 10 mΩ leads, what voltage results between terminals x and y?

5. Consider the rectifier circuit of figure 2. Let the input sine wave have 120 V rms value and assume the diode to be ideal. Select a suitable value for R so that the peak diode current does not exceed 0·1 A. What is the greatest reverse voltage that will appear across the diode?

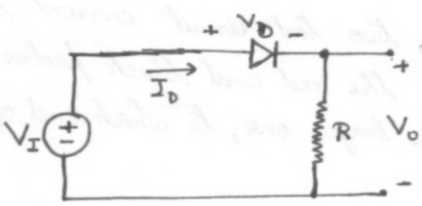

Figure 2.

6. Consider the circuit shown in figure 2. Suppose the input source V_I has a source resistance R_S. For the case $R_S = R$ and assuming the diode to be ideal, sketch and clearly label the transfer characteristic V_o versus V_I.

7. Consider the circuit shown in figure 2. Suppose V_I provides a square wave of 10 V_{p-p} and zero average, and that the resistance $R = 100\,\Omega$. What is the peak output voltage that results? What is the average output voltage that results? What is the peak diode current? What is the average diode current? What is the maximum reverse voltage across the diode?

8. Repeat problem no. 7 for the situation in which the average voltage of the square wave is 2V, while its peak to peak value remains at 10V.

9. Consider the battery charging circuit shown in figure 3. Suppose the diode is ideal and current flows to the 12V battery 20% of the time and has an average value of 100mA. What peak to peak sine wave voltage is required? What resistance is required? What peak diode current flows? What peak reverse voltage does the diode endure? If resistors can be specified to only one significant digit and the peak to peak voltage only to the nearest volt, what design would you choose to guarantee the required charging current? What fraction of the cycle does diode current flow? What is the average diode current? What is the peak diode current? What peak reverse voltage does the diode endure?

10. A diode for which the ~~for which~~ forward voltage drop is 0·7V at 1·0mA and for which $n=1$ is operated at 0·5V. What is the value of the current?

11. A particular diode, for which $n=1$, is found to conduct 3mA with a junction voltage of 0·7V. What is its saturation current I_S? What current will flow in this diode if the junction voltage is raised to 0·71V and 0·8V? What current will flow in this diode if the junction voltage is lowered to 0·69V and 0·6V? What change in junction voltage will increase the diode current by a factor of 10?

12. Consider the circuit shown in figure 3. The circuit utilizes three identical diodes having $n=1$ and $I_S = 10^{-14}$A. Find the value of current I required to obtain an output voltage $V_o = 2$ V. If a current of 1mA is drawn away from the output terminal by a load, what is the change in output voltage?

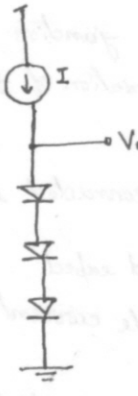

Figure 3.

13. Consider the circuit in figure 4. Both diodes are identical, conducting 10mA at 0.7V and 100 mA at 0.8V. Find the value of R, for which V= 50mV.

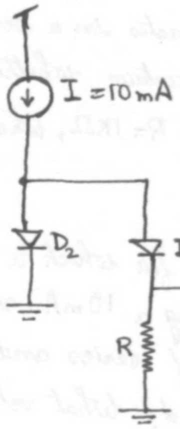

Figure 4.

14. Consider the circuit shown in figure 5. The circuit uses identical diodes for which $I_D = 1$mA and $V_D = 0.7$V with $n=1$. At 20°C, voltage V is measured by a very high resistance meter to be 0.1V. By what factor does the reverse leakage current of these diodes exceed I_S? Estimate the value of V when the temperature is raised by 50°C.

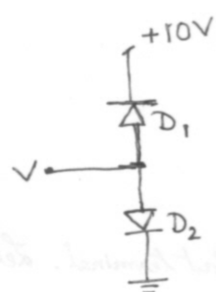

Figure 5

15. When a 10-A current is applied to a particular diode it is found that the junction voltage immediately becomes 700mV. However, as the power being dissipated in the diode raises its temperature, it is found that the voltage decreases and eventually reaches 600mV. What is the apparent rise in junction temperature? What is the power dissipated in the diode in its final state? What is the temperature rise per Watt of power dissipation?

16. A designer of an instrument that must operate over a large supply voltage range, noting that a diode's junction voltage drop is relatively independent of junction current, considers the use of a large diode to establish a small relatively constant voltage. A power diode, for which the nominal current at 0·8V is 10A, is available. Furthermore, he has reason to believe that $n=2$. For his available current source, which varies from 0·5 to 1·5 mA, what junction voltage might he expect? What additional voltage change might he expect for a temperature variation of $\pm 20°C$.

17. A 1 mA diode (i.e. one that has $V_D = 0·7V$ at $I_D = 1mA$) is connected in series with a 200Ω resistor to a 1V supply.
(a) Provide a rough estimate of the diode current you would expect.
(b) If the diode is characterized by $n=2$, estimate the diode current more closely using iterative analysis.

18. Assuming the availability of diodes for which $V_D = 0·7V$ at $I_D = 1mA$ and $n=1$, design a circuit that utilizes four diodes connected in series, in series with a resistor R connected to a 15-V power supply. The voltage across the string of diodes is to be 3·0V.

19. A diode modeled by the 0·1 V/decade approximation operates in a series circuit with R and V. A designer considering using a constant voltage model is uncertain whether to use 0·7V or 0·5V for V_D. For what value of V is the difference only 1%? For V = 2V and R = 1KΩ, what two currents would result from the use of the two values of V_D?

20. A designer has a relatively large number of diodes for which a current of 20mA flows at 0·7V and the 0·1V/decade approximation is relatively good. Using a 10mA current source, she wishes to create a reference voltage of 1·25V. Suggest a combination of series and parallel diodes that will do the job as well as possible. How many diodes are needed? What voltage is actually achieved?

21. Repeat problem no. 2 assuming a drop of 0·7V in the diode model.

22. Consider the circuit in figure 6.

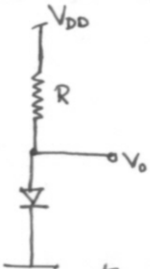

Figure 6

Suppose a load current I_L is drawn from the output terminal. Let V_o be the output voltage. If the value of I_L is sufficiently small so that the corresponding change in regulator output voltage ΔV_o is small enough to justify using diode small signal model, show that $\frac{\Delta V_o}{I_L} = -(r_d \| R)$, where r_d is the diode resistance. If the load R is selected such that at no load, the voltage across the diode is 0·7V and the diode current is I_D show that $\frac{\Delta V_o}{I_L} = -\frac{\eta V_T}{I_D} \cdot \frac{V^+ - 0·7}{V^+ - 0·7 + \eta V_T}$. Select the lowest possible value of I_D that results in a load regulation $\leq 5mV/mA$. Assume $n=2$. If V^+ is nominally 10V, what value of R is required? Generalize the expression for $\frac{\Delta V_o}{I_L}$ for the case m diodes connected in series and R adjusted to obtain $V_o = 0·7m$ volts at no load.

23. A voltage regulator consisting of two diodes in series fed with a constant current source is used as a replacement for a single carbon zinc cell of nominal voltage 1·5V. The regulator current varies from 2 to 7mA. Constant current supplies of 5, 10 and 15mA are available. Which would you choose and why? What change in output voltage would result when the load current varies over its full range? Assume that the diodes have $n=2$.

24. A designer requires a shunt regulator of approximately 20V. Two kinds of zener diodes are available: 6·8V devices with r_z of 10Ω and 5·1V devices with r_z of 30Ω. For the two major choices possible, find the load regulation. In this calculation, neglect the effect of regulator resistance R.

25. Design a 7·5V zener regulator circuit using a 7·5V zener diode specified at 12mA. The diode has an incremental resistance $r_z = 30\Omega$ and a knee current of 0·5mA. The regulator operates from a 10V supply and has a 1·2kΩ load. What is the value of R you have chosen? What is the regulator output when the supply is 10% or 10% low. What is the output voltage when both the supply is 10% high and the load is removed? What is the smallest possible load resistor that can be used while the diode operates at a current no lower than the knee current while the supply is 10% low?

26. It is required to use a peak rectifier to design a dc power supply that provides an average dc output voltage of 15V on which a maximum of ±1V ripple is allowed. The rectifier feeds a load of 150Ω. The rectifier is fed from the line voltage (120V rms, 60Hz) through a transformer. The diodes available have 0·7V drop when conducting. If the designer opts for the half wave circuit:

(a) Specify the r.m.s. voltage that must appear across the transformer secondary.
(b) Find the required value of the filter capacitor.
(c) Find the maximum reverse voltage that will appear across the diode, and specify the PIV rating of the diode.
(d) Calculate the average current through the diode during conduction.
(e) Calculate the peak diode current.

27. Repeat problem no. 26 for the case in which the designer opts for a full wave circuit utilizing a centre tapped transformer.

28. Repeat problem no. 26 for the case in which the designer opts for a full wave bridge rectifier circuit.

29. Consider a half wave peak rectifier fed with a voltage V_s having a triangular waveform with 20V peak to peak amplitude, zero average and 1 KHz frequency. Assume that the diode has a 0.7V drop when conducting. Let the load resistance $R = 100\,\Omega$ and the filter capacitor $C = 100\,\mu F$. Find the average dc output voltage, the time interval during which the conducts, the average diode current during conduction and the maximum diode current.

30. Sketch and label the transfer characteristic of the circuit in figure 7 for $-20V \leq V_I \leq +20V$. Assume that the diodes can be represented by a piecewise linear model with $V_{DO} = 0.65V$ and $r_D = 20\,\Omega$. Assuming that the specified zener voltage (8.2V) is measured at a current of 10mA and that $r_z = 20\,\Omega$, represent the zener by a piecewise linear model.

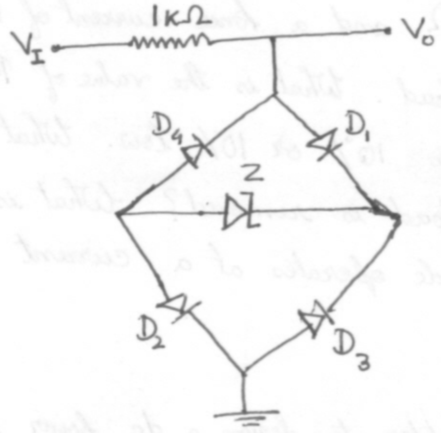

Figure 7

31. A clamped capacitor using an ideal diode with cathode grounded is supplied with a sine wave of 10 Vrms. What is the average dc value of the resulting output?