

Problem Set 1 Solutions

6.101 Analog Electronics Lab

Spring 2007

Problem 1 (a) (10pts)

$$\begin{aligned} I &= I_s(e^{V_D/V_T} - 1) \\ 150\mu A &= 10^{-11}(e^{V_D/V_T} - 1) \approx 10^{-11}e^{V_D/V_T} \\ V_D &= V_T \ln\left(\frac{150\mu A}{10^{-11}}\right) = 0.026 \ln\left(\frac{150\mu A}{10^{-11}}\right) = 0.430V \end{aligned}$$

(b) (10pts)

$$V_D = V_T \ln\left(\frac{150\mu A}{10^{-13}}\right) = 0.026 \ln\left(\frac{150\mu A}{10^{-13}}\right) = 0.549V$$

Problem 2 (a) (10pts)

$$\begin{aligned} \frac{I_{D_1}}{I_{D_2}} &= 10 = \exp\left(\frac{V_{D_2} - V_{D_1}}{V_T}\right) \\ \Delta V_D &= V_T \ln(10) = 59.9mV \approx 60mV \end{aligned}$$

(b) (10pts)

$$\Delta V_D = V_T \ln(100) = 119.7mV \approx 120mV$$

Problem 3 (20pts)

Minimum Diode Current for $V_{PS}(min)$: $I_D(min) = 2mA$, $V_D = 0.7V$

$$I_2 = \frac{0.7}{R_2}, \quad I_1 = \frac{5 - 0.7}{R_1} = \frac{4.3}{R_1}$$

We have:

$$I_1 = I_2 + I_D$$

so:

$$(1) \frac{4.3}{R_1} = \frac{0.7}{R_2} + 2$$

Maximum diode current for $V_{PS}(max)$:

$$P = I_D V_D \quad 10 = I_D(0.7) \Rightarrow I_D = 14.3mA$$

$$(2) \frac{9.3}{R_1} = \frac{0.7}{R_2} + 14.3$$

Using Equation (1):

$$\frac{9.3}{R_1} = \frac{4.3}{R_1} - 2 + 14.3 \Rightarrow R_1 = 0.41K\Omega$$

Then $R_2 = 82.5\Omega$. Standard values are $R_1 = 0.43K\Omega$ and $R_2 = 82\Omega$.

Problem 4 $V_I = 6.3V$, $R_i = 15\Omega$, $V_Z = 4.8V$, $5mA < I_Z < 100mA$

(a) (10pts)

$$I_I = \frac{6.3 - 4.8}{15} = 100mA$$

$$I_L = I_I - I_Z = 100mA - I_Z$$

$$0mA < I_L < 95mA \Rightarrow 50.5(\approx 51)\Omega < R_L < \text{open circuit}$$

(b) (10pts) Need a half watt rating for both R_L and the zener:

$$P_Z = I_Z V_Z = (100mA)(4.8V) = 480mW$$

$$P_L = I_L V_o = (95mA)(4.8V) = 456mW$$

Problem 5 (10pts) An open circuit voltage of 9V tells us the internal voltage of the battery. When a resistor is placed across the terminals of the battery and 8.7V is measured, we can solve for the internal resistance of the battery.

$$I_{\text{battery}} = \frac{8.7V}{510\Omega} = 17.1mA$$

$$R_{\text{internal}} = \frac{V_{\text{source}} - V_{\text{measured}}}{I_{\text{battery}}} = \frac{9V - 8.7V}{17.1mA} = 17.58\Omega$$

Problem 6 (10pts) This problem was intended to address a very specific problem far too many people do not understand about oscilloscopes. The ground lead is connected to Earth Ground! That is zero potential and anything else relative to earth ground (function generators, some multimeters, many power supplies, etc.) will see the ground lead of the scope probe as a short to ground.

In the transistor circuit, connecting the ground lead of the oscilloscope probe to one side of the differentially driven speaker will short it to ground. This puts a very strong (low resistance) 15Volts across the FET, and when connected as shown (the FET is turned on very similar to a switch) a LOT of current will flow through it. This is very similar to a short circuit and the high amount of current will likely blow the FET time and time again.

Optional (+5pts): To measure a differential voltage, two oscilloscope probes can be used and the scope can take the difference between their voltages. The ground lead, however, is connected to earth ground, not to anything seen in the schematic for this circuit. A more expensive approach is to use a differential scope probe that has two floating inputs.