EE 105: Voltage Supply Design

Abstract

This lab relates to the design and simulation of a simple constant voltage supply. The purpose of the circuit is to deliver a relatively constant voltage to a load resistance.

1 Lab

1. Figure 1 shows a low-pass filter with input v_i and output v_o. The resistor has value $R = 1000$ Ohms. The capacitor has value $C = 100\mu$ Farads. The transfer function from input to output is

$$\frac{V_o(s)}{V_i(s)} = H(s) = \frac{sL + R}{L^2Cs^3 + RLCs^2 + 2Ls + R}.$$

   Find the value of L so that the magnitude of the transfer function at $\omega = 2\pi 60$ is approximately 0.1 (i.e., $|H(j2\pi 60)| = 0.1$).

   Although you could do this analytically, I recommend that you use MATLAB. For example, construct a vector of L values. For each value of L, compute the magnitude of $H(j2\pi 60)$, using 'polyval'. Plot the transfer function magnitude versus L and read the appropriate value from the plot.

2. Figure 2 shows a circuit for implementation of a DC voltage supply. The input u is the household AC wall outlet that is modeled as voltage source $u(t) = 120\sin(2\pi 60t)$. The circuit involves a transformer with a turns ratio of $N = 10$ and a diode. The diode current and voltage are related by the nonlinear function in Table 1.

   Note that the voltage to current function in Table 1 is algebraic. There is no integration or differentiation. Because this effort-flow relationship is algebraic, the diode is an R-element, with a nonlinear function.

   (a) Construct and simplify the bond graph for the circuit.

   (b) From the bond graph, define a (nonlinear) state space model. The output vector is $\mathbf{y} = [v_o, v_i, v_d, i_d]^\top$.

```
function [i_d]=diode(v_d)
A = 0.0007;
if v_d > 0.7
    Rd = 0.01;
    i_d = A + (v_d - 0.7)/Rd;
else
    Rd = 1000;
    i_d = A + (v_d - 0.7)/Rd;
end.
```

Table 1: Piecewise affine diode model.

   (c) Implement a simulation for the state space system in SIMULINK. You could implement the state space model in an m-file, then use the MATLAB function block and an integrator.[1] For simulation parameters, set the maximum step size to 0.001 seconds and the duration of the simulation to 0.8 sec.

   (d) Simulate the system. Plot each element of the output vector versus time. Discuss each graph. Your discussion should compare the various elements of the output vector. Use appropriate graph scaling to make the discussion clear.

   (e) Consider the circuit as having two subsystems connected together at the terminals connected by the black circles shown in Fig. 2.

      i. What is the purpose of the left portion?
      ii. What is the purpose of the right portion?
      iii. What is the purpose of the diode, the transformer, the inductors, and the capacitors?

   (f) Simulate the system for various values of the resistance (i.e., $R = 100, 200, \ldots, 1000$). Plot the percentage variation[2] in output voltage versus resistance. Explain the shape of the graph?

[1] The TA will describe this at the start of the lab.

[2] For a given value of R, after the system has reached a steady-state oscillation, how much does the output voltage change (i.e., ripple around its average value). The TA will describe this at the start of the lab.

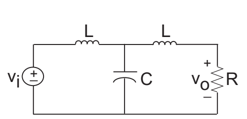

Figure 1: Filter for voltage supply.

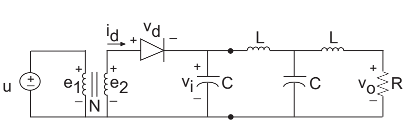

Figure 2: Voltage supply circuit.