Curriculum Topic :
Time-Domain Transmission Lines

TDT9 : Nonlinear Loads on Transmission Lines

Module Outline:	
Prerequisite Skills	Competencies
Supplemental Reading and Resources	Assessments
Laboratory Activities	Power Point Slides and Notes

Prerequisite Skills

Prerequisites / Requirements:
TDT7 Short Pulses on Transmission Lines

Competencies

Competency TDT.9: **Calculate the steady-state and reflection behavior of transmission lines with non-linear loading.**

Competency Builders:
TDT.9.1 Qualitatively understand basic attributes and behaviors of non-linear circuit theory.
TDT.9.2 Calculate the reflection and transmission of a DC pulse at a transmission line junction terminated with a non-linear circuit element.

Supplemental Reading and Resources

Supplemental Reading Materials:

A.F. Peterson and G.D. Durgin. *Transient Signals on Transmission Lines: An Introduction to the Non-Ideal Effects and Signal Integrity Issues in Electrical Systems*. Morgan & Claypool Publishers, 2009. Chapter 7.

Assessments

The following questions and exercises may serve as either pre-assessment or post-assessment tests to evaluate student knowledge.

Question: TDT9.1 *Competency:* TDT.9.1

A third-order circuit with a sinusoidal source and a nonlinear device can, under some conditions, experience ______.

Answer:

chaos

Question: TDT9.2 *Competency:* TDT.9.1

True/False: a transmission line connected to linear sources and lumped circuit elements is capable of producing spectral content at frequencies other than those excited by the source(s).

Answer:

false

Question: TDT9.3 *Competency:* TDT.9.1

What is the behavior called when the number of stable point(s) in a nonlinear circuit output doubles as a parameter in the circuit is swept across a range of values?

Answer:

this is a bifurcation

Question: TDT9.4 *Competency:* TDT.9.1

At the terminal of a transmission line with a non-linear load, the reflection coefficient is a function of ______.

Answer:

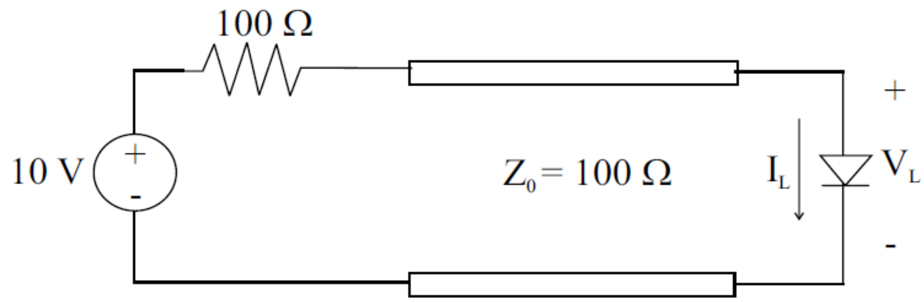
Forward traveling voltage/current

Question: TDT9.5 *Competency:* TDT.9.2

Below is a transmission line that drives a simple diode with the following V-I characteristic:

$$V_L = V_0 \ln\left(\frac{I_L}{I_0} + 1\right)$$

where $V_0 = 0.1$ V and $I_0 = 1$ mA.



(a) Find the steady state load voltage and current. (3 points)

(b) Calculate the steady-state reflected voltage on the line. (2 points)

(c) Now reverse the diode at the end of the line and find the new steady state load voltage and current. (3 points)

(d) Calculate the steady-state reflected voltage on the line. (2 points)

Answer:

(a) We use this basic iterative equation to calculate the solution for this problem:

$$I_L^{\text{new}} = \frac{2}{Z_0}V^+ - \frac{1}{Z_0}f\left(I_L^{\text{old}}\right)$$

where

$$V_L = f(I_L) = V_0 \ln\left(\frac{I_L}{I_0} + 1\right)$$

and $V_0 = 0.1$ V and $I_0 = 1$ mA. Fortunately, this equation converges very rapidly for a diode characteristic. The answers are $V_L = 0.46$ V and $I_L = 95$ mA.

(b) Steady-state forward and reflected voltages:

$$V^+ = \frac{V_L + I_L Z_0}{2} = 4.98 \text{ V}$$

$$V^- = \frac{V_L - I_L Z_0}{2} = -4.52 \text{ V}$$

(c) If the device is flipped in the circuit, we have to modify the characteristic as follows:

$$V_L = f(I_L) = -V_0 \ln\left(\frac{-I_L}{I_0} + 1\right)$$

We'll use the alternative iterative equation for this example, since the other one does not converge nicely:

$$V_L^{\text{new}} = 2V^+ - Z_0 f^{-1}\left(V_L^{\text{old}}\right)$$

The answers are $V_L = 9.90$ V and $I_L = 1$ mA.

(d) Steady-state forward and reflected voltages:

$$V^+ = \frac{V_L + I_L Z_0}{2} = 5.00 \text{ V}$$

$$V^- = \frac{V_L - I_L Z_0}{2} = 4.90 \text{ V}$$