<u>Curriculum Topic</u> :
Time-Domain Transmission Lines

<u>TDT3</u> : DC Signals on Resistively Loaded Transmission Lines

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

Prerequisite Skills

Prerequisites / Requirements:
TDT2 Transmission Line Equations

Competencies

Competency TDT.3: **Analyze an Uncharged Transmission Line Excited by a switched DC Pulse**

Competency Builders:
TDT.3.1 Calculate the transit time of a transmission line from physical attributes
TDT.3.2 Calculate the reflection coefficient of a transmission line junction
TDT.3.3 Sketch a waveform at a specific moment in time on a transmission line as a function of position
TDT.3.4 Sketch a waveform on a specific location on a transmission line as a function of time
TDT.3.5 Construct an equivalent circuit diagram for analyzing time-domain transmission lines
TDT.3.6 Interpret a bounce diagram for a switched DC load on a transmission line

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 3.

Assessments

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

Question: TDT3.1 *Competency:* TDT.3.1

A transmission line has a length of 5cm and a velocity of 5×10^7 m/s. How long after a DC pulse is excited on a transmission line will it take to see the effects of reflections at the source end of the line?

Answer:

Two transit times or 2 ns.

Question: TDT3.2 *Competency:* TDT.3.2

A 50-Ω transmission line is terminated with a variable resistor. To what value should we set the resistor if we desire load reflection coefficients of a) ½, b) – ½, c) + ¼, d) 0?

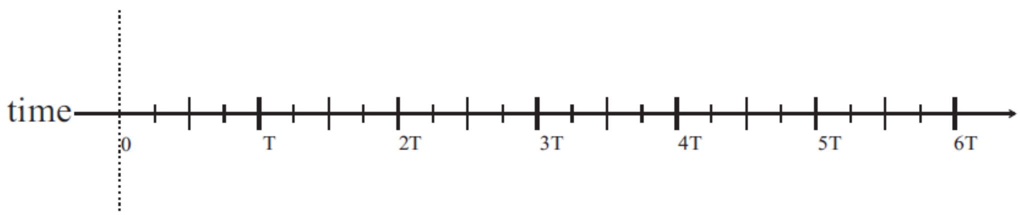
Answer:

The load resistance should be set to a) 150 Ω, b) 16.7 Ω, c) 83.3 Ω, d) 50 Ω.

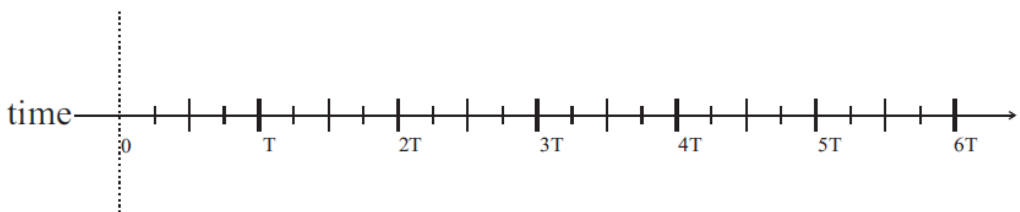
Question: TDT3.3 *Competency:* TDT.3.3,4

Reflection Sketches: There is an uncharged transmission line with transit time T, length D, and reflection coefficients $\Gamma_G = -\frac{1}{2}$ and $\Gamma_L = \frac{1}{2}$. At $t = 0$ a DC source is connected to the line and 16 Volts DC begins to travel down the line. Please sketch and label the amplitudes of the time-domain waveforms that would be measured at the locations listed below.

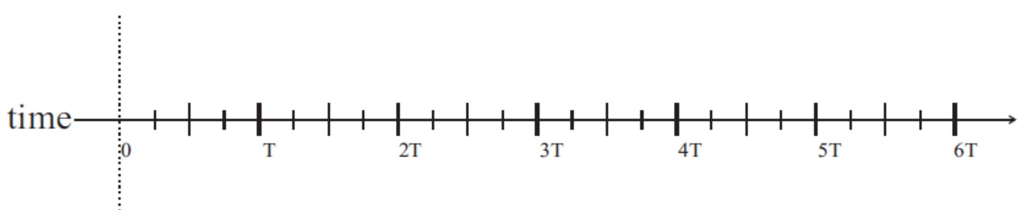
a. The voltage observed at the load side of the transmission line:



b. The voltage observed at the source side of the transmission line:

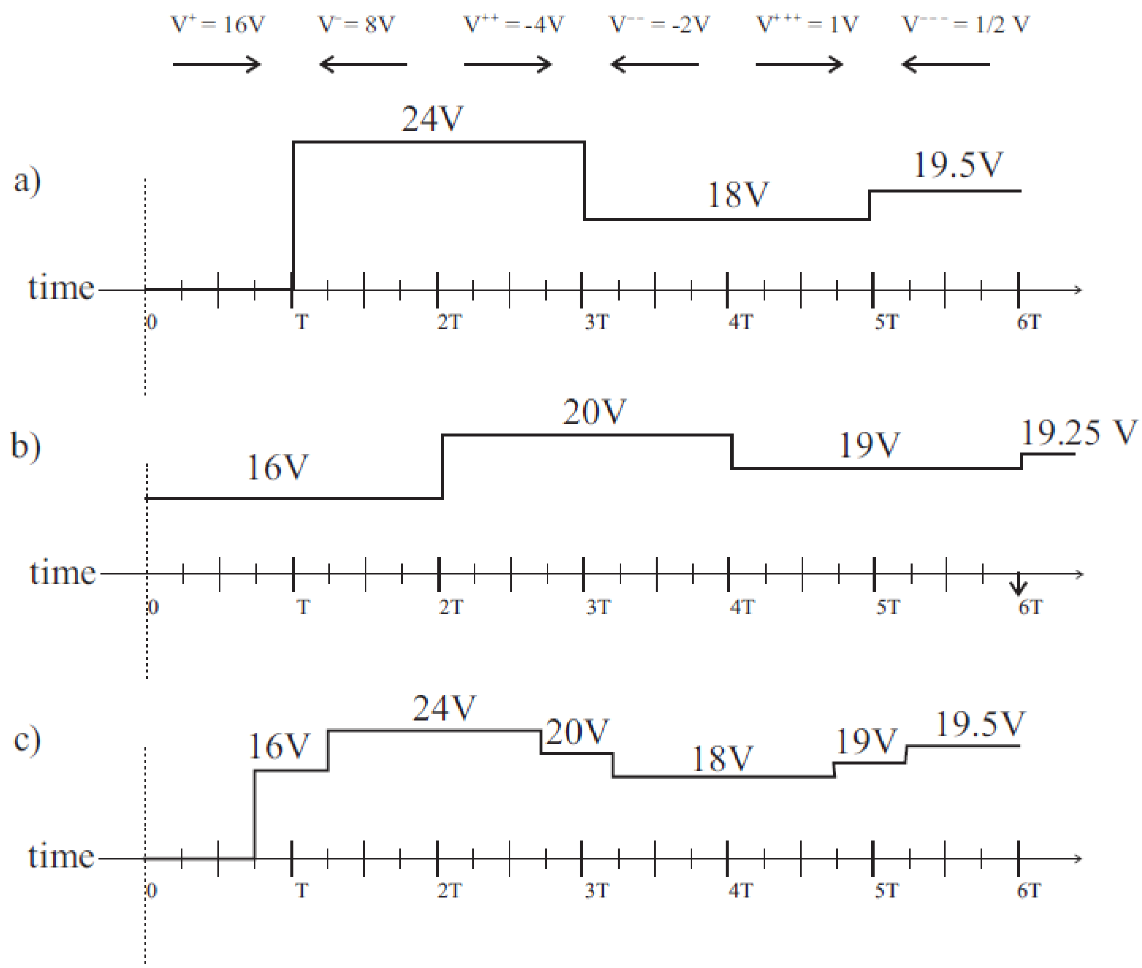


c. The voltage observed exactly **three-quarters** ($z = \frac{3D}{4}$) down the transmission line:



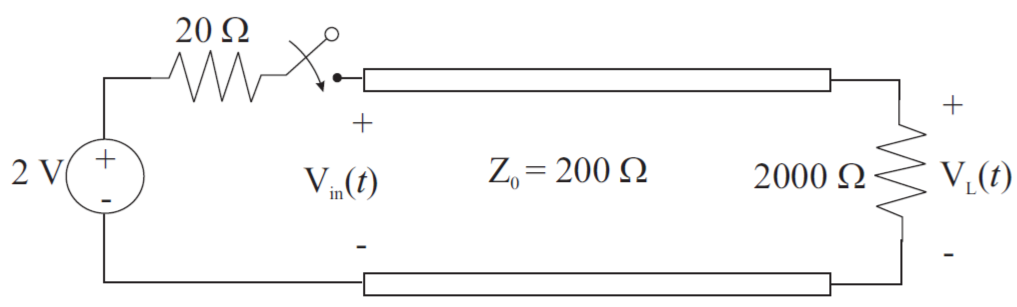
Answer:

Reflection Sketches:



Question: TDT3.4 *Competency:* TDT.3.4

Below is a transmission line arrangement that is completely discharged at $t \leq 0$.



The switch is thrown at $t = 0$. Sketch or plot the load voltage as a function of time, $V_L(t)$, over the interval [0,10T], clearly labeling all voltage levels.

Answer:

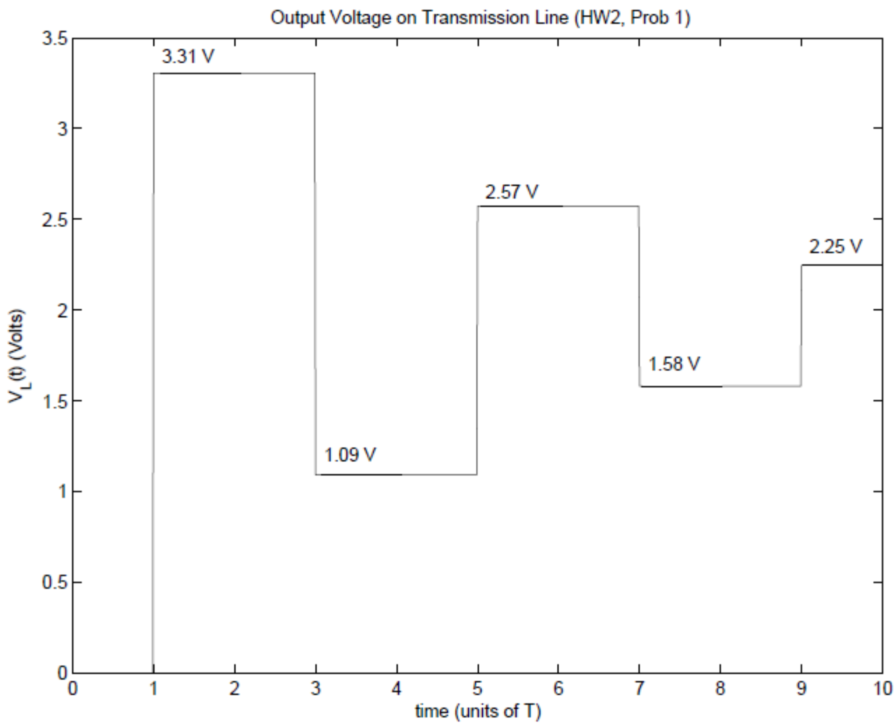
. The reflection coefficients for this transmission line are $\Gamma_G = -0.818$ and $\Gamma_L = 0.818$. Since the source is 2V DC, switched on at $t = 0$, the initial input voltage to the transmission line may be calculated using the voltage divider equation:

$$V_{in} = V_S \frac{Z_0}{R_G + Z_0} = 1.82 \text{ Volts}$$

Now we can use our general form equation for the output of a transmission line as a function of time:

$$V_L(t) = (1 + \Gamma_L) \sum_{n=0}^{\infty} (\Gamma_G \Gamma_L)^n \underbrace{V_{in} \mathrm{u}\left(t - [2n+1]T\right)}_{f(t)}$$

where u(·) is the unit step function. You don't have to write out this expression – a simple graph constructed of step-by-step reflections suffices. However, this equation is useful if you want to produce a computer plot like the one below:

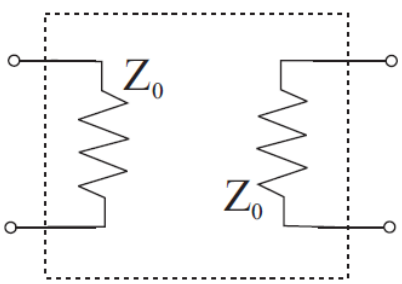


For those interested, the Matlab program used to construct this graph is listed below:

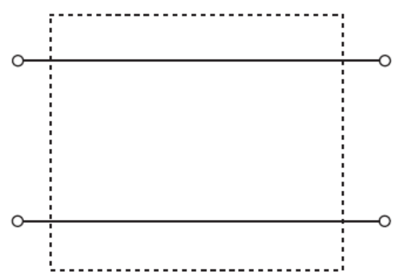
```
% Solution to Problem 1
function VL = problem1

t = 0:.01:10;                   % time axis
GS = (20-200)/(20+200);         % source-side reflection coefficient
GL = (2000-200)/(2000+200);     % load-side reflection coefficient
Vin = 200/(200+20)*2;           % initial input voltage
VL = zeros(size(t));            % initialize array for load-side voltage

for n = 0:5,                    % loop through 5 reflections
    VL = VL + (1+GL)*(GS^n)*(GL^n)*Vin * ustep(t-(2*n+1));
end;

plot(t,VL);
xlabel('time (units of T)');
ylabel('V_L(t) (Volts)');
title('Output Voltage on Transmission Line (HW2, Prob 1)');

% Voltage Labels
text(1.1,3.4,'3.30 V'); text(3.1,1.2,'1.09 V');
text(5.1,2.65,'2.57 V'); text(7.1,1.7,'1.58 V');
text(9.1,2.35,'2.25 V');
print problem1.ps;              % save output
return;

function x=ustep( t )           % unit step function
  x = (t>=0);
end;
```

Question: TDT3.5 *Competency:* TDT.3.5

When are the following two equivalent circuit diagrams useful for analyzing transmission lines?



and



Answer:

The left circuit model is valid for a completely discharged transmission line. The right circuit model is valid for a lossless transmission line that has reached a steady DC state.