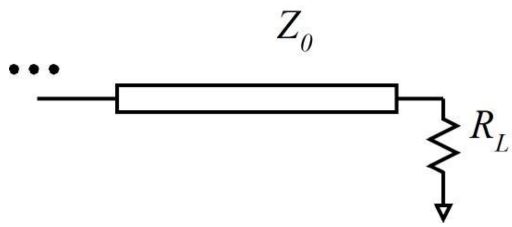
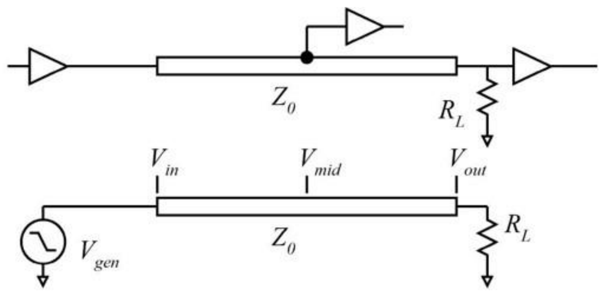
ECE 145a /218A first problem set
(basics of transmission lines and lumped elements)

Problem 1: A transmission line has 50 Ohms characteristic impedance and a load impedance of (a) 25 Ohms (b) 100 Ohms (c) 50 Ohms. Compute in each case the voltage reflection coefficient.



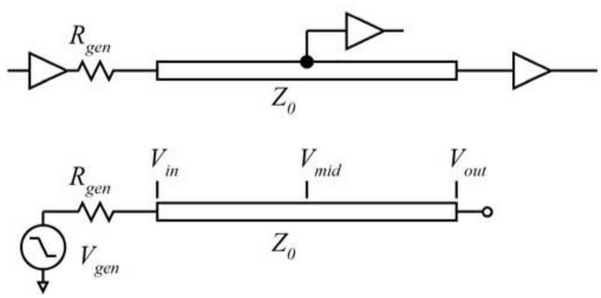
Problem 2: : lattice diagrams:

(a) A logic gate with low (zero ohms) output impedance drives a 50 Ohm transmission line of 1 m length and $2*10^8$ m/s propagation velocity. The equivalent circuit is in the lower image. The load impedance is 50 Ohms and Vgen is a 1V step-function occurring at time = zero..



Draw clean plots of Vin, Vmid, and Vout as a function of time

(b) a logic gate with 50 Ohms output impedance drives a 50 Ohm transmission line of 1 m length and $2*10^8$ m/s propagation velocity. The equivalent circuit is in the lower image. The load impedance is infinity Ohms (an open circuit) and Vgen is a 1V step-function occurring at time = zero..

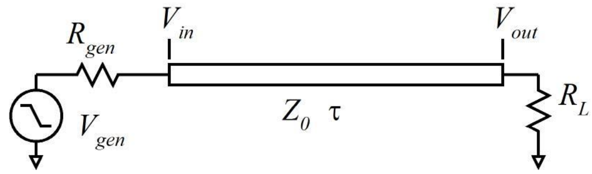


Draw clean plots of Vin, Vmid, and Vout as a function of time

c) Comment of on the relative utility of the 2 schemes for distributing logic signals using a transmission-line bus

Problem 3:

lumped-distributed relationships



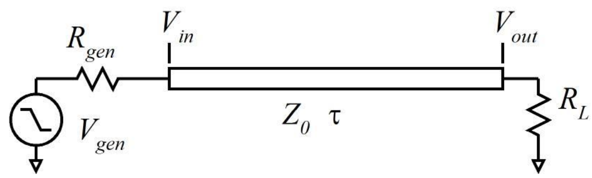
Z_o = 50 Ohms, $\tau = l / v$ = 100 ps, and V_{gen} is a 1 V step-function.

a) R_L =250 Ω, R_{gen} =250 Ω: Compute and plot $V_{in}(t)$ using lattice diagram methods

b) R_L =10 Ω, R_{gen} =10 Ω. Compute and plot $V_{in}(t)$ using lattice diagram methods

c) R_L =10 Ω s, R_{gen} =250 Ω. Compute and plot $V_{in}(t)$ using lattice diagram methods

Problem 4: lumped-distributed relationships



Z_o = 50 Ohms, $\tau = l / v$ = 100 ps, and V_{gen} is a 1 V step-function.

In each of the cases (a,b,c) below, replace the transmission-line with a T or Pi equivalent circuit, compute and compute and plot $V_{in}(t)$ using basic circuit analysis. Hint: it is easiest to use a T equivalent for (a), a Pi equivalent for (b), and a Pi equivalent for (c). To make the analysis simpler, in cases (a) and (b) first compute L/R and RC time constants, and ignore either L or C if the associated time constant is more than 5:1 less than the dominant time constant. In case (c) , the Pi equivalent has two capacitors, but one has a much shorter time constant $(C/2)R_L$ than the other $(C/2)R_{gen}$; therefore ignore the capacitor $(C/2)$ connected between the output and ground.

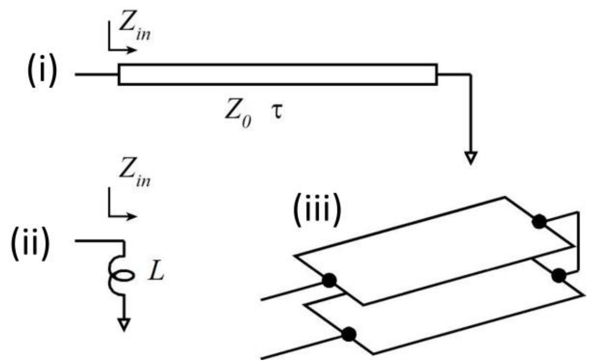
a) R_L =250 Ω, R_{gen} =250 Ω:

b) R_L =10 Ω, R_{gen} =10 Ω.

c) R_L =10 Ω s, R_{gen} =250 Ω.

Problem 5: lumped-distributed relationships

A transmission line (iii) has length l = 10 cm and propagation velocity and v equal to the speed of light in Teflon (look up its dielectric constant). Z_o = 50 Ohms.



a) The plate vertical separation is 1 mm. Using approximate microstrip-line formulas, compute the *width* of the conductor.

b) Using the relationship $L = Z_o\tau = Z_o l / v$, compute (ii) the line inductance. Compute the impedance $Z_{in} = j\omega L$ from DC to a frequency of $f_{high} = v / l$

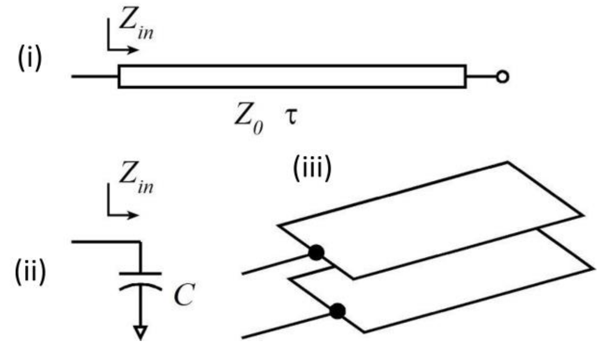
c) The transmission-line is short-circuited (i). Using the relationships $Z_{load} = 0\Omega$,
$\Gamma_{load} = \left(\left(Z_L / Z_o\right) - 1\right) / \left(\left(Z_L / Z_o\right) + 1\right)$,
$\Gamma_{in} = \Gamma_L \exp(-j2\beta l) = \Gamma_L \exp(-j2\omega\tau) = \Gamma_L \exp(-j4\pi l / \lambda)$
and $Z_{in} = Z_0\left(\left(1 + \Gamma_{in}\right) / \left(1 - \Gamma_{in}\right)\right)$
….derive an algebraic expression for Z_{in}.

d) Using the Smith chart, compute Z_{in} at the following frequencies:
$f = 0, v/8l,\ 2v/8l,\ 3v/8l,\ 4v/8l,\ 5v/8l,\ 6v/8l,\ 7v/8l,$

e) Using *cartesian* axes (straight lines, not a Smith chart), make a plot of the imaginary part of Z_{in}, plotting the answers from parts (b), (c), and (d). Comment on the similarities and differences between the three curves

Problem 6: lumped-distributed relationships

A transmission line (iii) has length l = 10 cm and propagation velocity, and v equal to the speed of light in Teflon (look up its dielectric constant). Z_o = 50 Ohms.



a) Using the relationship $C = \tau / Z_o = l / vZ_o$, compute (ii) the line capacitance. Compute the impedance $Z_{in} = 1/ j\omega C$ from DC to a frequency of $f_{high} = v / l$

b) The transmission-line is short-circuited (i). Using the relationships $Z_{load} = \infty\ \Omega$,
$\Gamma_{load} = \left(\left(Z_L / Z_o\right) - 1\right) \big/ \left(\left(Z_L / Z_o\right) + 1\right)$,
$\Gamma_{in} = \Gamma_L \exp(-j2\beta l) = \Gamma_L \exp(-j2\omega\tau) = \Gamma_L \exp(-j4\pi l / \lambda)$
and $Z_{in} = Z_0 \left(\left(1 + \Gamma_{in}\right) \big/ \left(1 - \Gamma_{in}\right)\right)$
….derive an algebraic expression for Z_{in}.

c) Using the Smith chart, compute Z_{in} at the following frequencies:
$f = 0, v/8l,\ 2v/8l, 3v/8l, 4v/8l, 5v/8l, 6v/8l, 7v/8l,$

e) Using *cartesian* axes (straight lines, not a Smith chart), make a plot of the imaginary part of Z_{in}, plotting the answers from parts (a), (b), and (c). Comment on the similarities and differences between the three curves