

Finite Length Transmission Lines

Real-world T-Lines have finite length.

Even short T-Lines will exhibit a z_0 for sufficiently fast edges or frequencies.

When the wavefront propagates down a line:

- behind the edge : $v^+(t, z) = I^+(t, z) z_0$ $I^+(t, z) = \frac{1}{z_0} v^+(t, z)$
- At the edge : $v^+(t, z) = I^+(t, z) z_0$ $I^+(t, z) = \frac{1}{z_0} v^+(t, z)$
- in front of the edge: zero zero

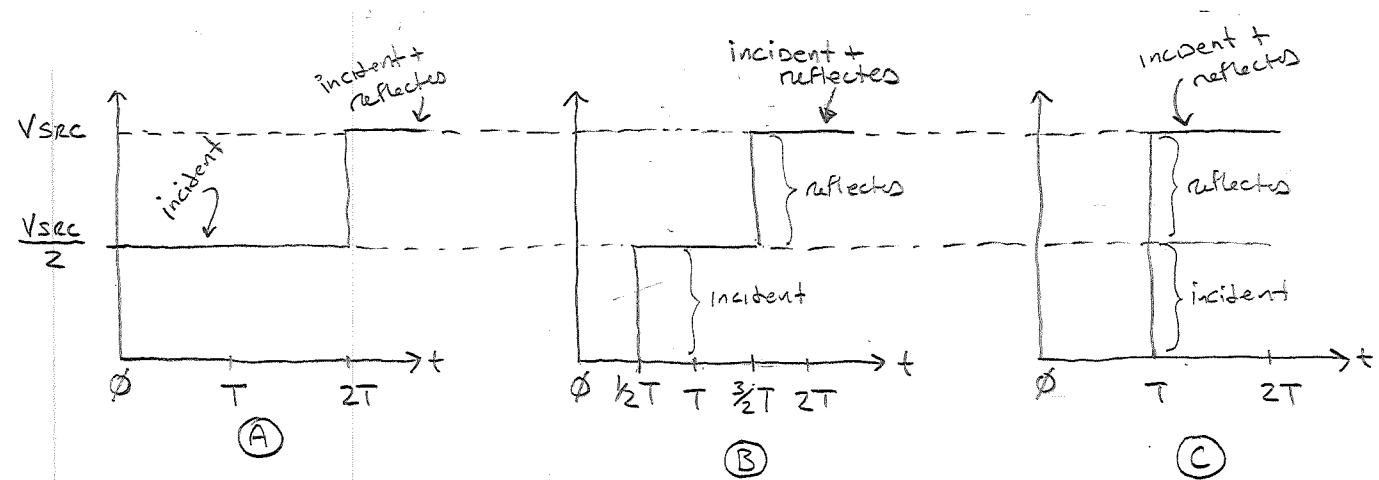
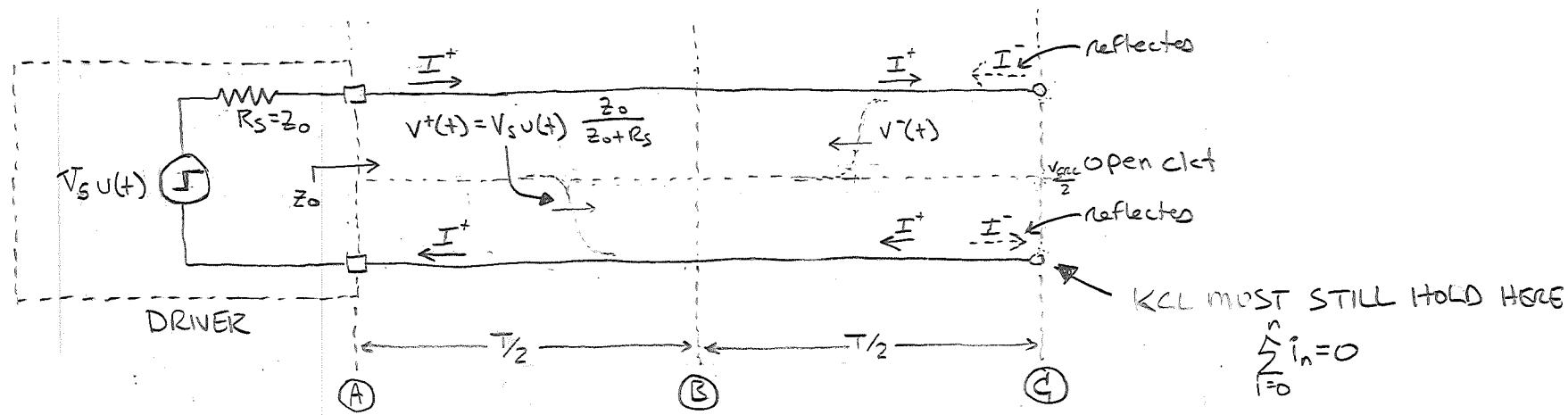
At the "end" of the T-Line what happens depends upon the load present

- load can be an open-circuit
 - load can be a short-circuit
 - load can be modeled as resistor = z_0
- } 3 important scenarios

As usual, KCL + KVL must be obeyed at all points on the T-Line as well as the boundaries for all time (all $t + z$).

We will later expand our analysis to reactive elements and non-linear elements.

Finite Length T-Lines - Open Circuit Case

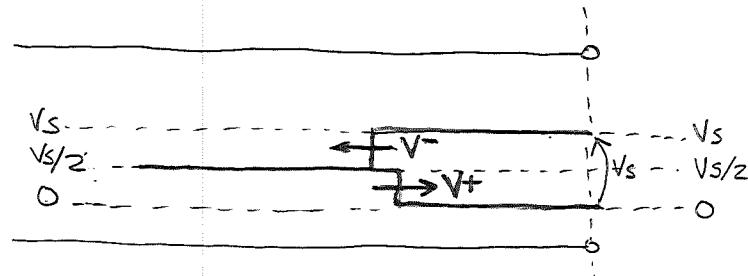


Why $\frac{V_{sec}}{2} \geq R_{src} + Z_0$?
form a voltage divider.

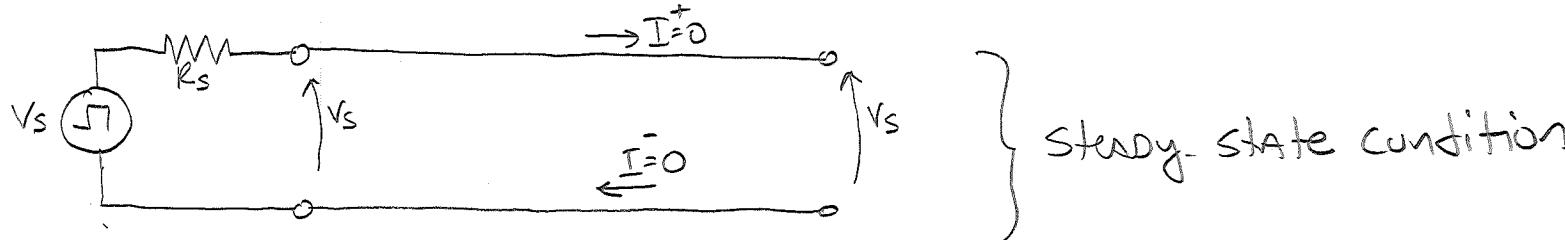
At (B) we only see the
incident wave until
the reflection returns

At (C) the waveform
apparently doubles!

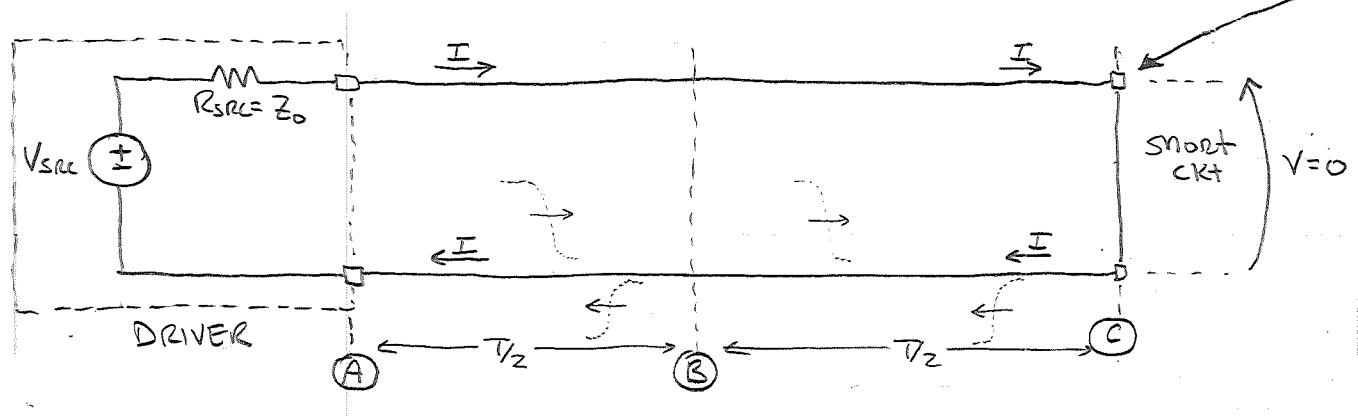
Finite Length Lines - Open Circuit Case



- When the wavefront reaches the open circuit, the only way an equal and opposite current can flow back down the line (to preserve KCL) is for the voltage to increase to twice its incident magnitude.
- Beginning at the open circuit the two waveforms superimpose creating a " V_s -size" voltage. Then a $V_s/2$ -sized wavefront returns to the left.
- Behind the returning wavefront the voltage is V_s and no current is flowing.
- Upon reaching the driver again, no potential difference between driver & T-Line exist, causing all currents to stop.
- After the reflection has returned...

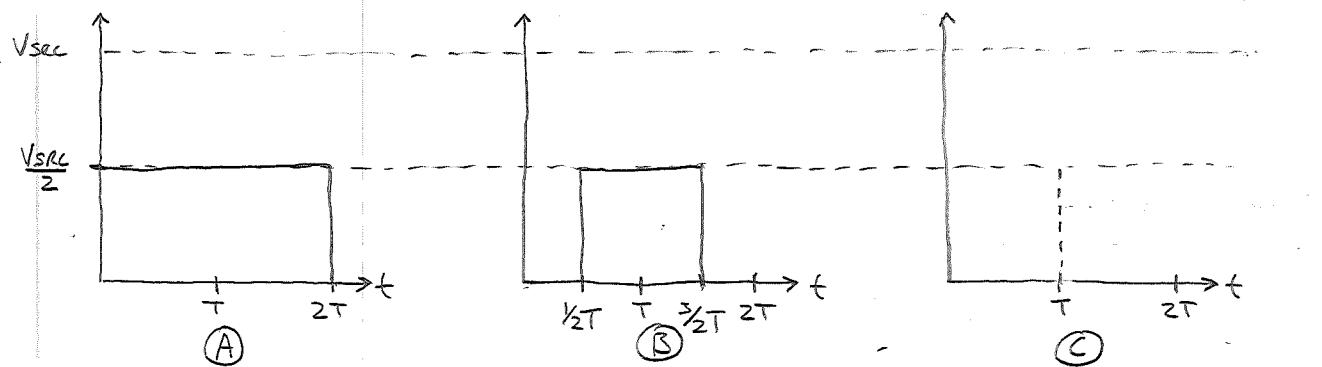


Finite Length Lines - Short Circuit Case

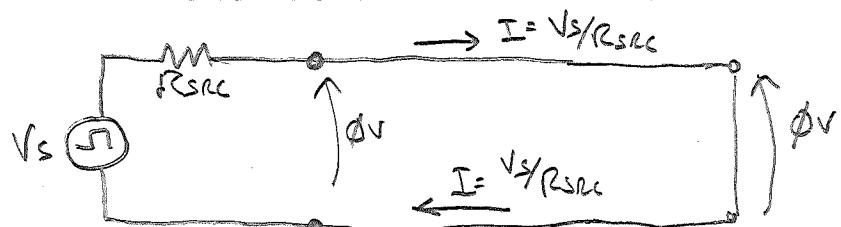


No voltage can appear here

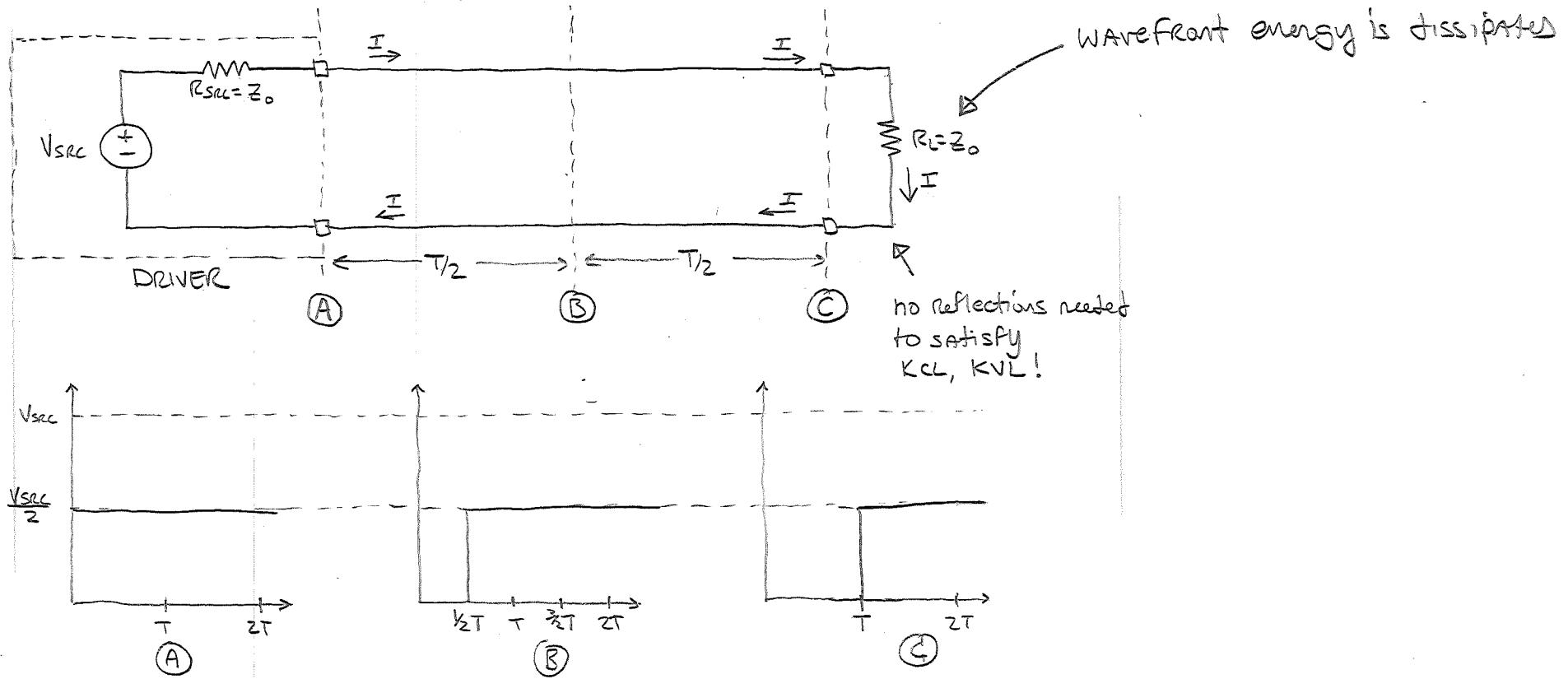
To maintain zero volts
At the shorted end, a
equal but opposite
polarity wave must be
generated.



- The superposition of forward + reverse waves cancel each other beginning at the endpoint.
- The negative reflected wave negates the incident wave voltage back to the source.
- After the reflection has returned to the source, all points on the T-Line have zero volts and the current $I = V_s / R_{src}$.



Finite Length Lines - Terminated in Z_0 case



This is not a typical termination scenario (double terminated) but is used sometimes.

In the open + shorted lines, the lossless T-line could not dissipate any energy. only the resistor R_S could. Here, both $R_S + R_L$ dissipate the energy of the edge.

Double-terminated Application:

