

Transient-Domain Analysis of Transmission Line Circuits

(Part 3)

Dr. José Ernesto Rayas-Sánchez

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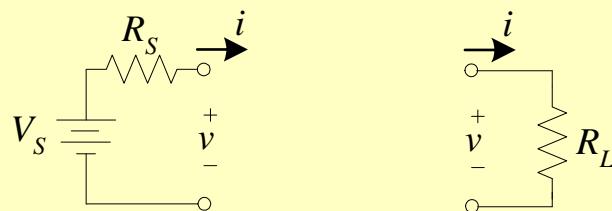
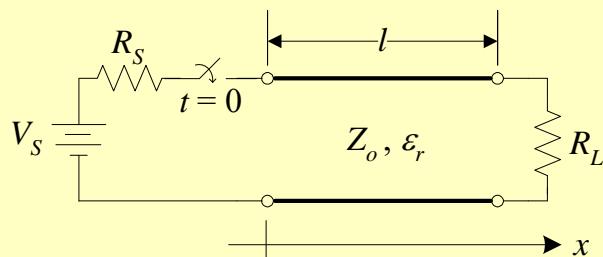
Outline

- Basic concepts on Bergeron diagrams
- Bergeron diagrams for TLs with linear terminations
- Alternative notation for Bergeron diagrams
- Examples using the alternative notation
- Bergeron diagrams for TLs with nonlinear loads
- Bergeron diagrams for TLs with non ideal drivers
- Bergeron diagrams with fully nonlinear terminations

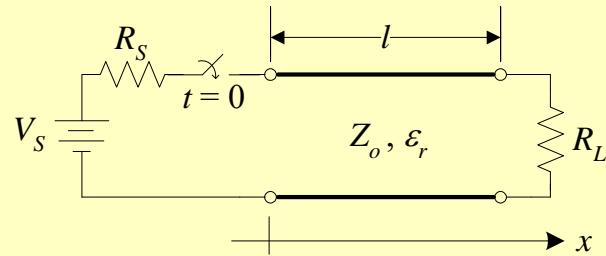
Bergeron Diagrams

- It is a technique for calculating transient waveforms on transmission line circuits
- As in the lattice diagrams, it is restricted to lossless transmission lines
- It allows to easily calculate the transient voltages and currents at the input of the line and at the load (intermediate points can not be directly calculated)
- It can be applied to TLs with nonlinear sources and loads (as oppose to lattice diagrams)
- It is based on the $i-v$ characteristics of the driver, the transmission line and the load

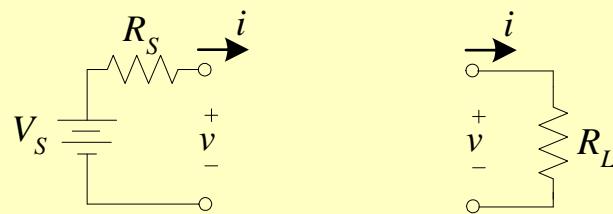
Bergeron Diag. for a TL with Resistive Term.



Bergeron Diag. for a TL with Resistive Term.



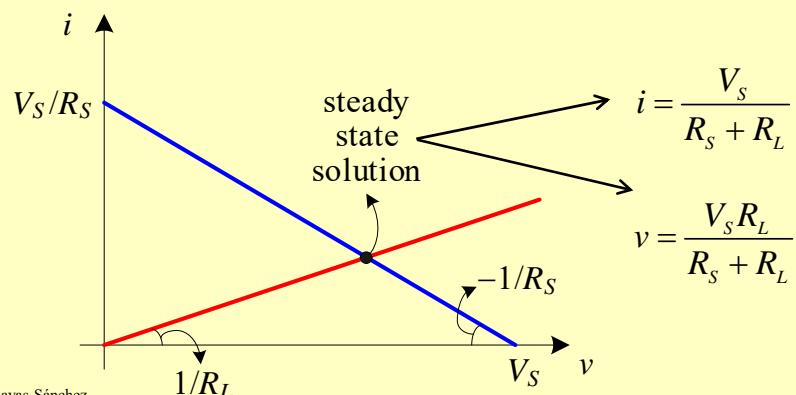
at steady-state...



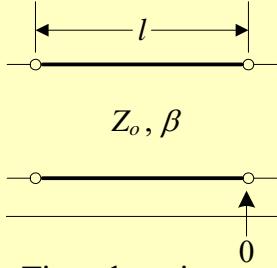
$i-v$ Characteristics of the Source and Load

The source $i-v$ characteristic is a blue line with slope $-1/R_S$ and intercept V_s/R_S on the vertical axis. The load $i-v$ characteristic is a red line with slope $1/R_L$ and intercept 0 on the vertical axis.

$$i = \frac{V_s - v}{R_s} \quad i = \frac{v}{R_L}$$



i-v Characteristics of a Lossless TL



Frequency domain:

$$V(z) = V_o^+ e^{-j\beta z} + V_o^- e^{+j\beta z}$$

$$I(z) = I_o^+ e^{-j\beta z} + I_o^- e^{+j\beta z}$$

$$I(z) = \frac{1}{Z_o} (V_o^+ e^{-j\beta z} - V_o^- e^{+j\beta z})$$

Time domain:

$$v(z, t) = |V_o^+| \cos(\omega t - \beta z + \phi^+) + |V_o^-| \cos(\omega t + \beta z + \phi^-)$$

$$v(z, t) = v^+(z, t) + v^-(z, t) \quad i(z, t) = i^+(z, t) + i^-(z, t)$$

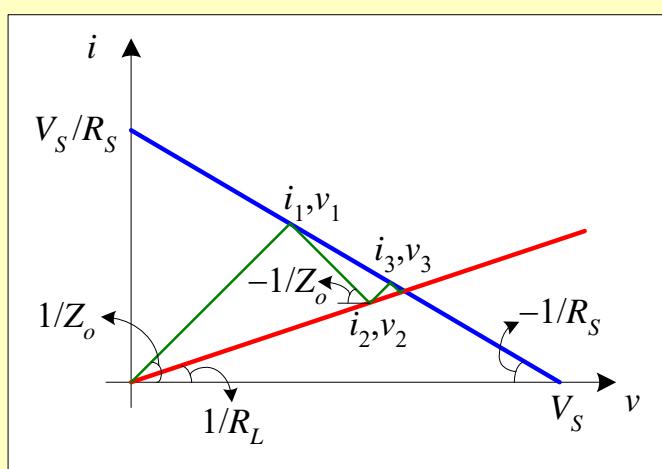
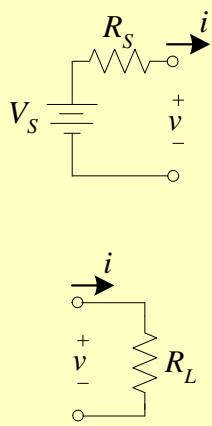
$$i(z, t) = \frac{1}{Z_o} (v^+(z, t) - v^-(z, t))$$

$$i^+(z, t) = \frac{v^+(z, t)}{Z_o} \quad i^-(z, t) = \frac{-v^-(z, t)}{Z_o}$$

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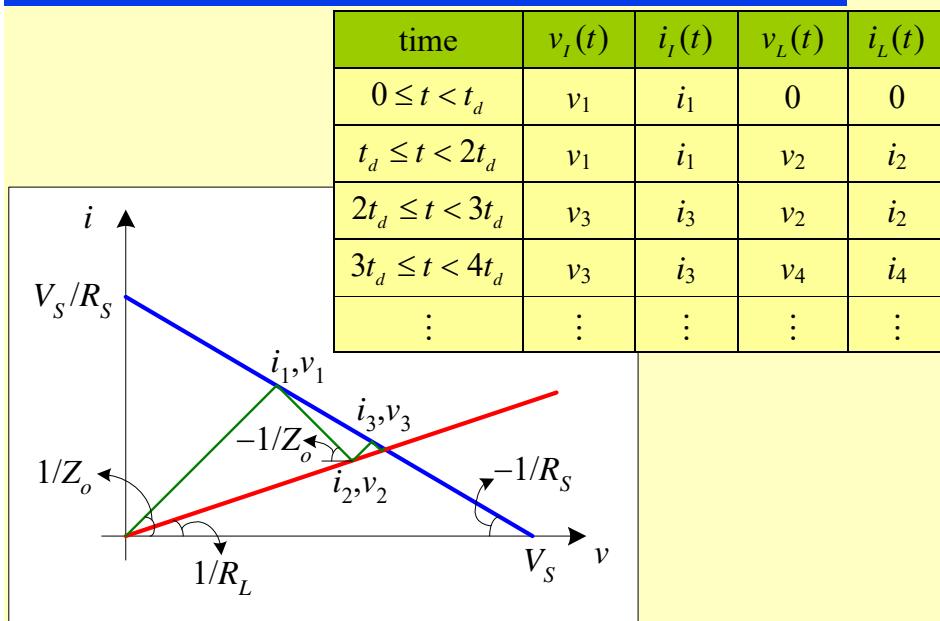
Bergeron Diag. for a TL with Resistive Term.



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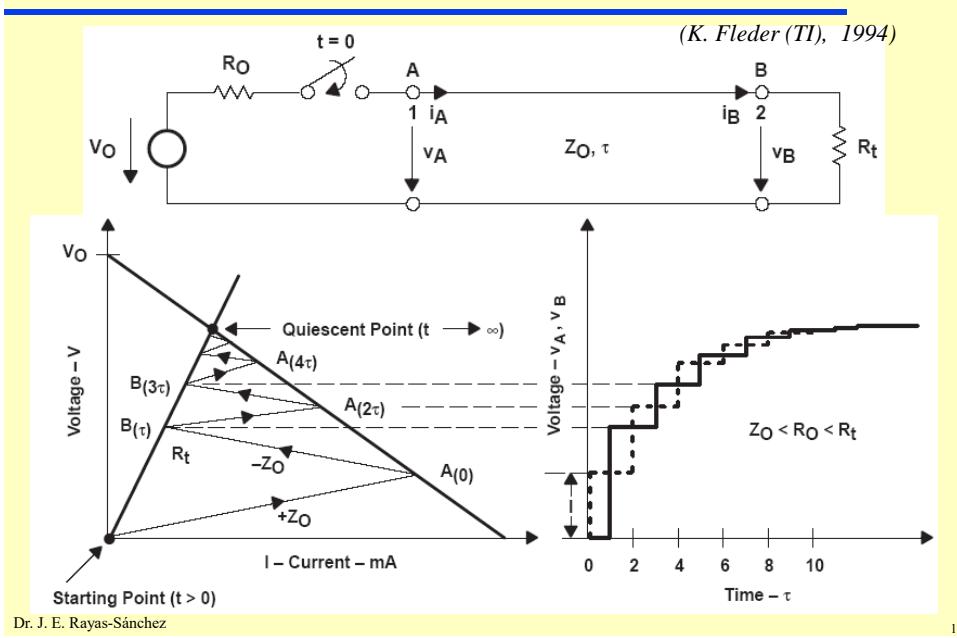
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Bergeron Diag. for a TL with Resistive Term.



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Alternative Notation for Bergeron Diagrams

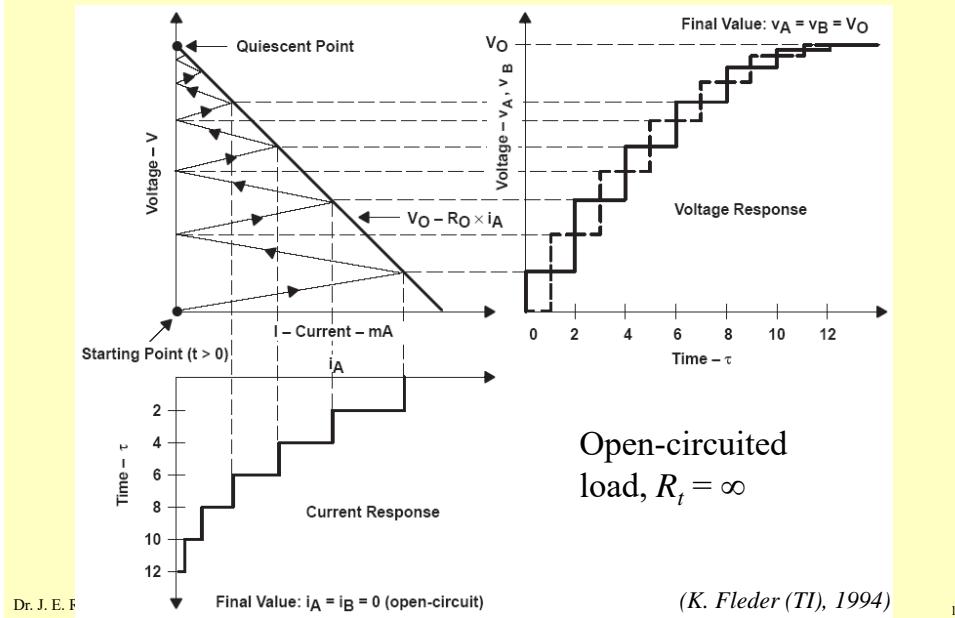


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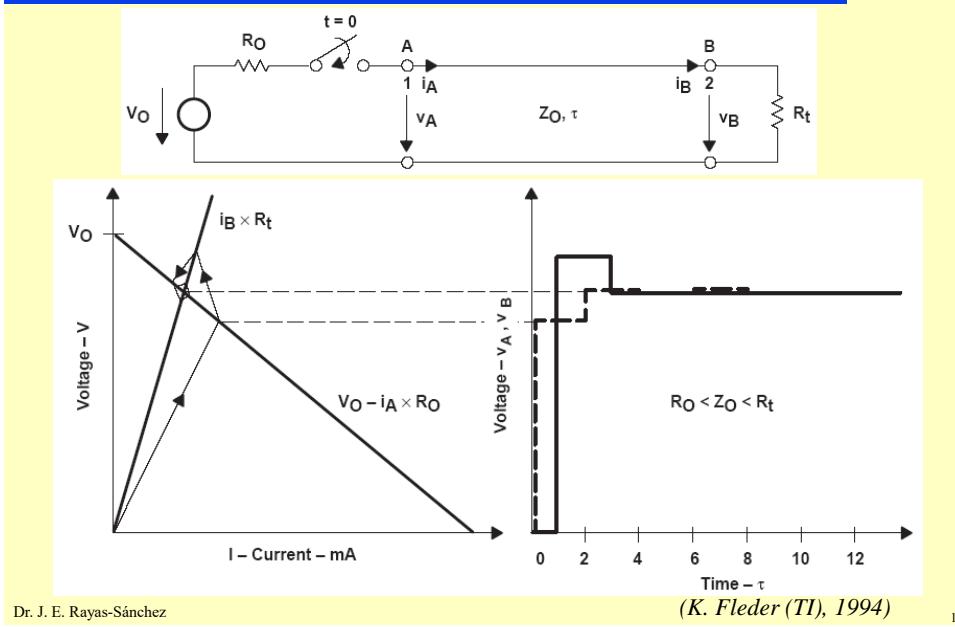
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Alternative Notation - Example 2



Alternative Notation - Example 3

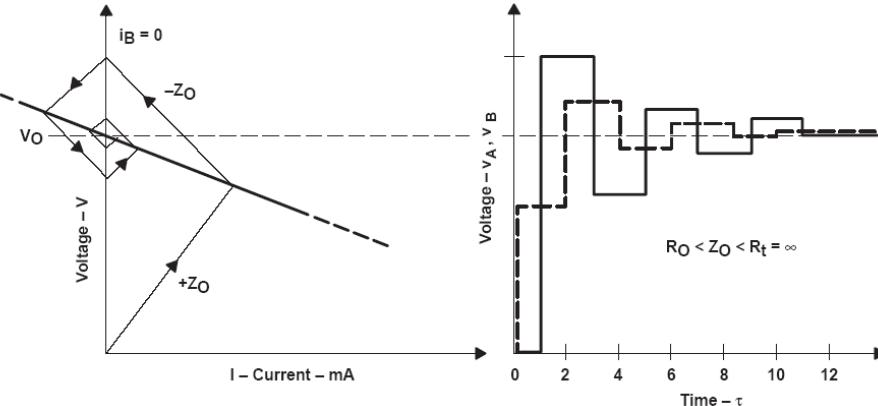
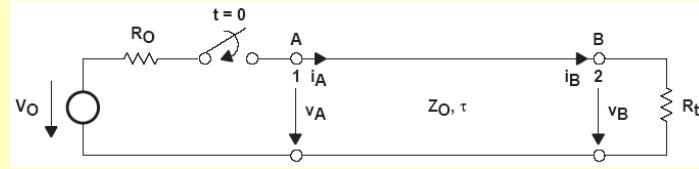


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Alternative Notation - Example 4

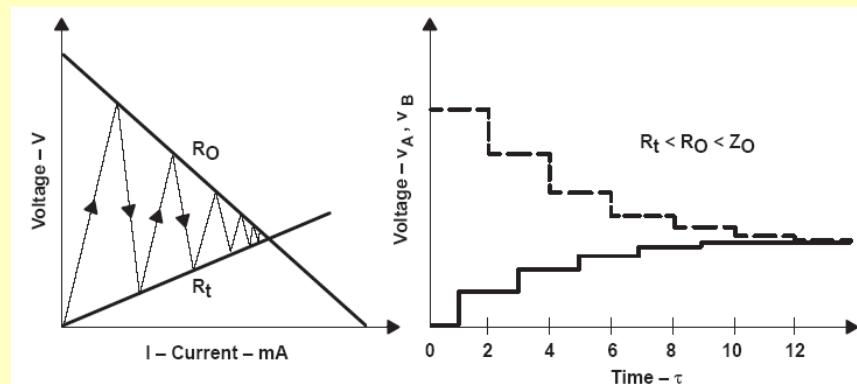
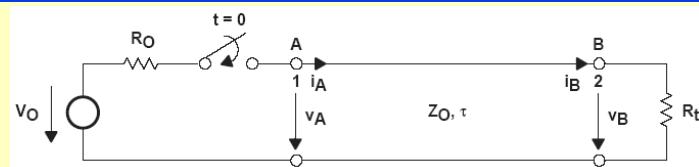


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(K. Fleder (TI), 1994)

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Alternative Notation - Example 5



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(K. Fleder (TI), 1994)

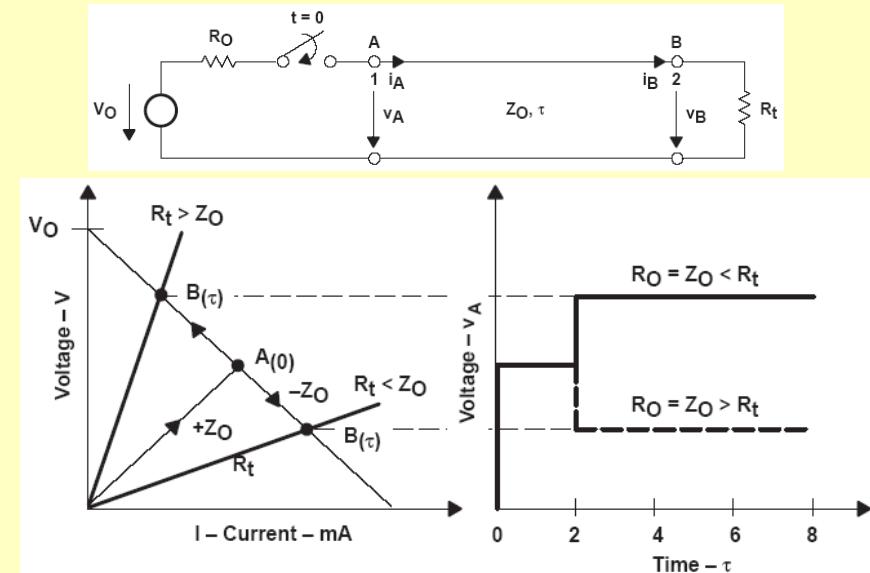
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Alternative Notation - Ex. 6 (Source Matched)

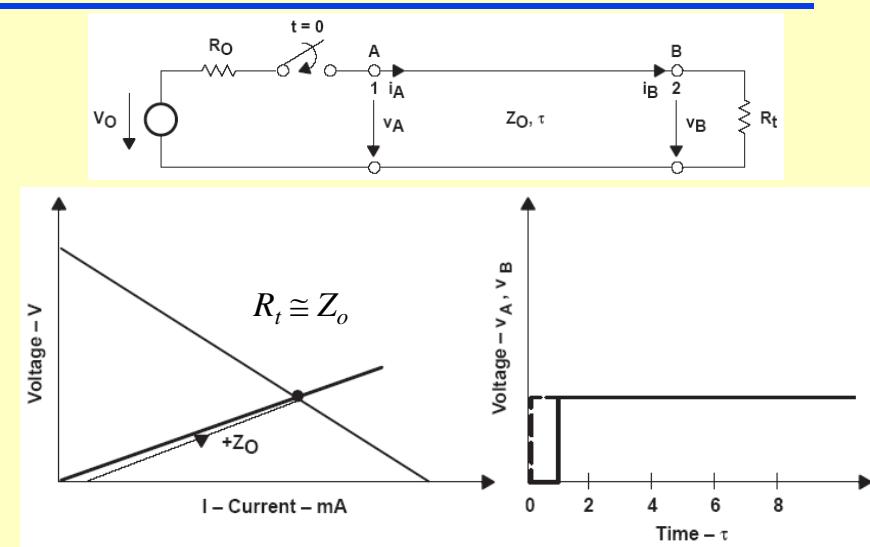


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(K. Fleder (TI), 1994)

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Alternative Notation - Ex. 6 (Load Matched)

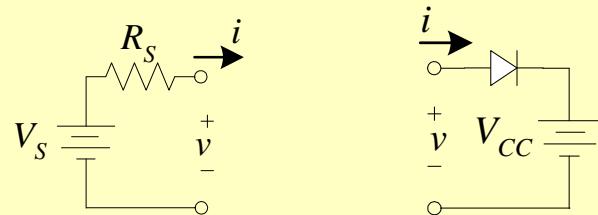
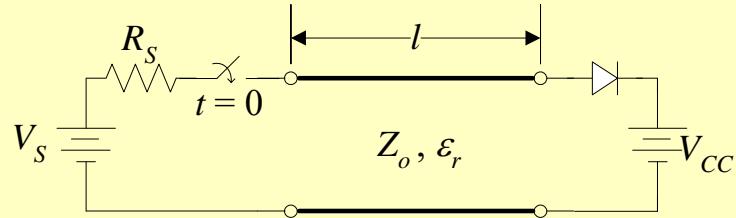


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(K. Fleder (TI), 1994)

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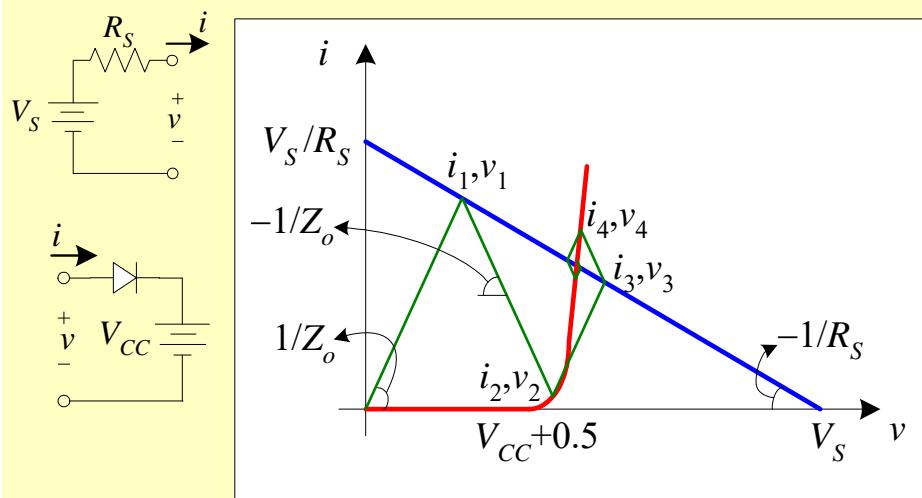
Bergeron Diag. for a TL with Diode Termination



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Bergeron Diag. for a TL with Diode Termination



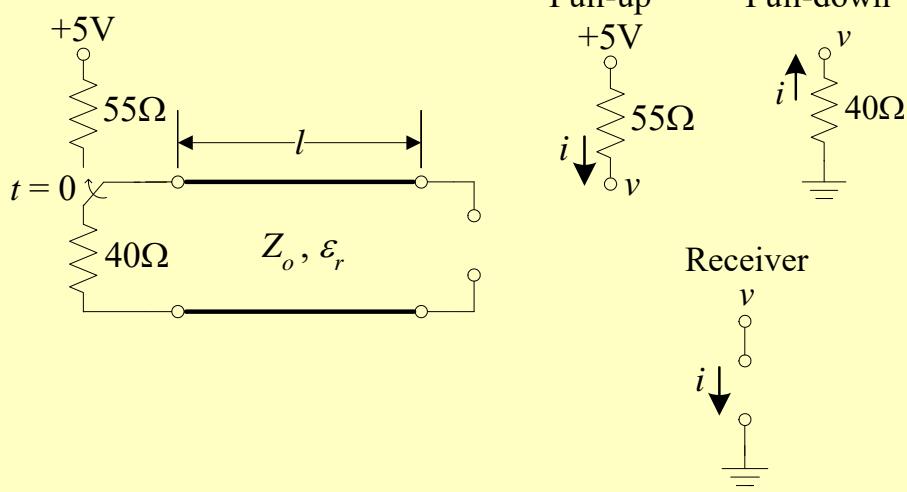
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Bergeron Diag. for a TL with Non-ideal Driver

Low to High Transition:

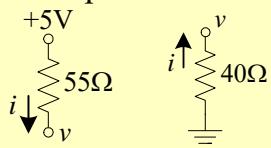


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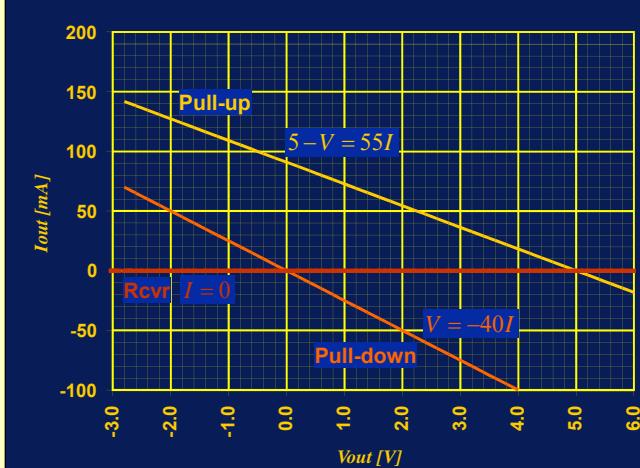
Bergeron Diag. for a TL with Non-ideal Driver

Pull-up Pull-down



(H. Heck, 2002)

Receiver

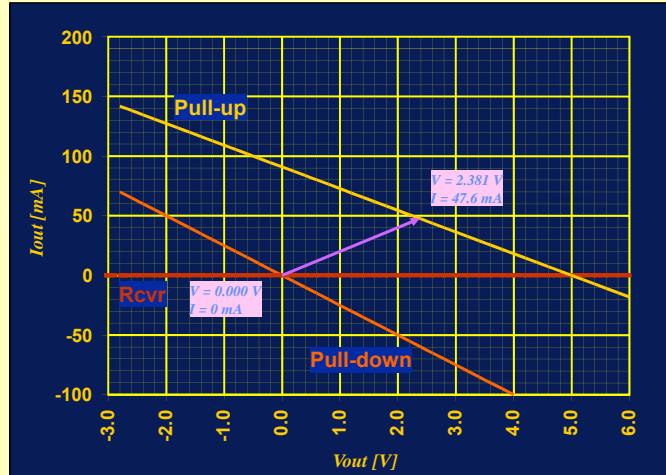


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Bergeron Diag. for a TL with Non-ideal Driver

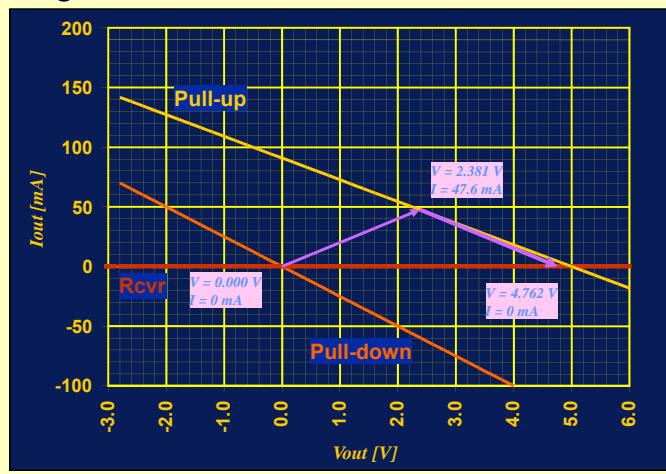
Low to High Transition:



(H. Heck, 2002)

Bergeron Diag. for a TL with Non-ideal Driver

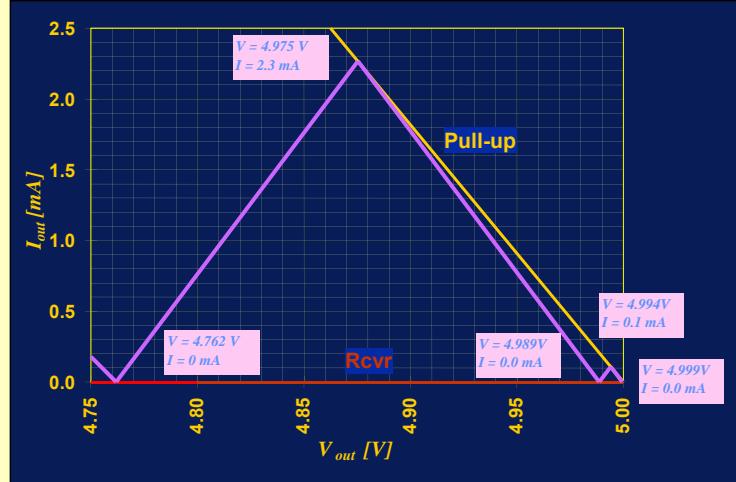
Low to High Transition:



(H. Heck, 2002)

Bergeron Diag. for a TL with Non-ideal Driver

Low to High Transition:



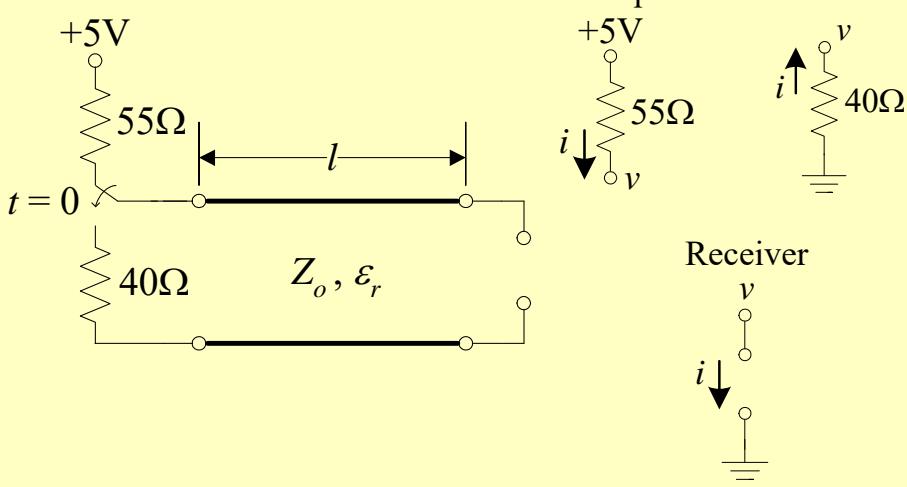
(H. Heck, 2002)

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Bergeron Diag. for a TL with Non-ideal Driver

High to Low Transition:

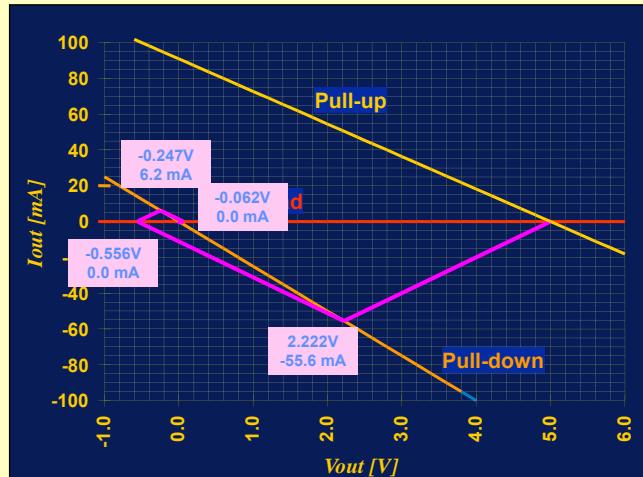


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Bergeron Diag. for a TL with Non-ideal Driver

High to Low Transition:



(H. Heck, 2002)

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Bergeron Diag. for TLs with Non-linear Devices

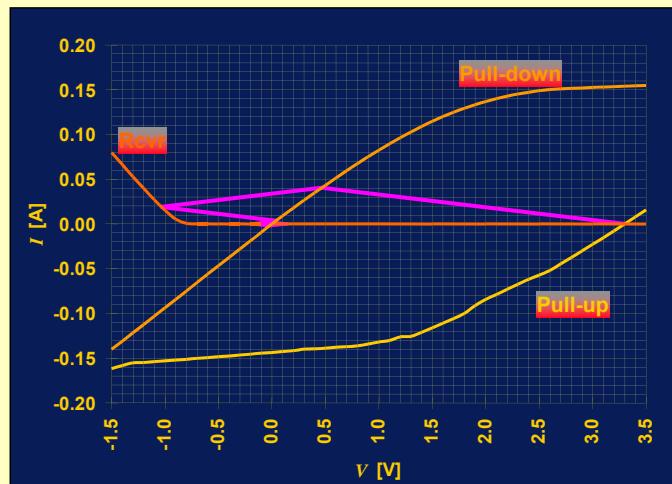


(H. Heck, 2002)

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Bergeron Diag. for TLs with Non-linear Devices

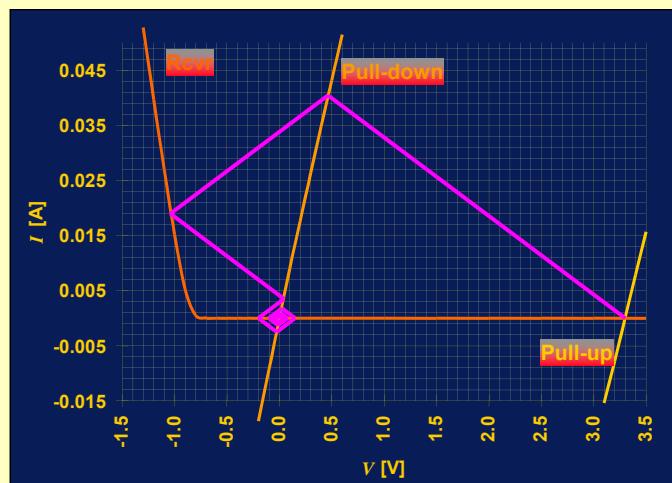


(H. Heck, 2002)

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Bergeron Diag. for TLs with Non-linear Devices

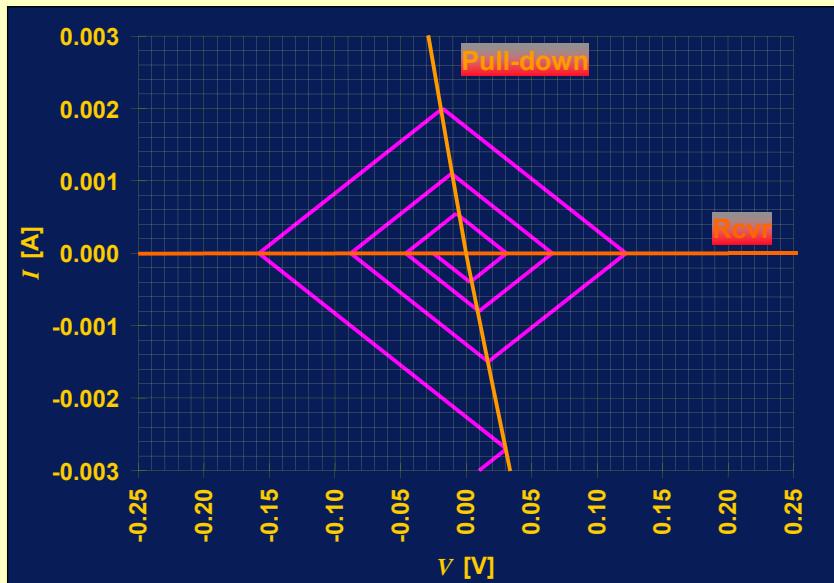


(H. Heck, 2002)

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Bergeron Diag. for TLs with Non-linear Devices



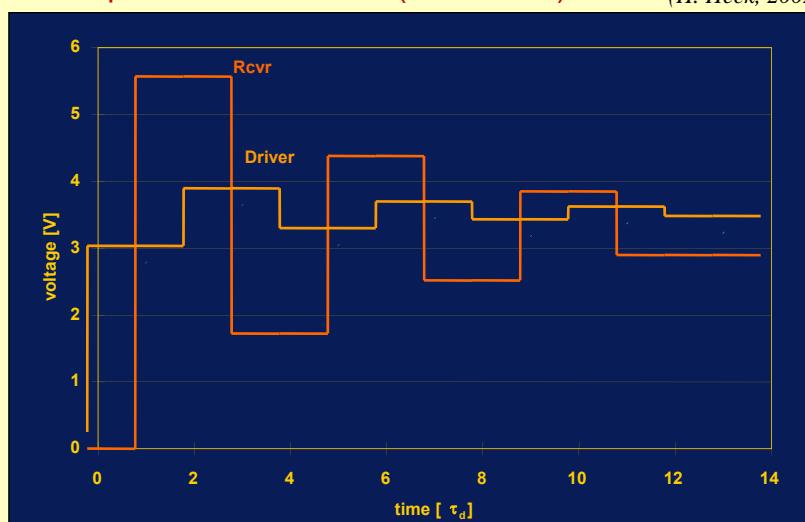
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Bergeron Diag. for TLs with Non-linear Devices

Example: PowerPC 604E (other case)

(H. Heck, 2002)



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