Chap. 16a – Pulse Processing

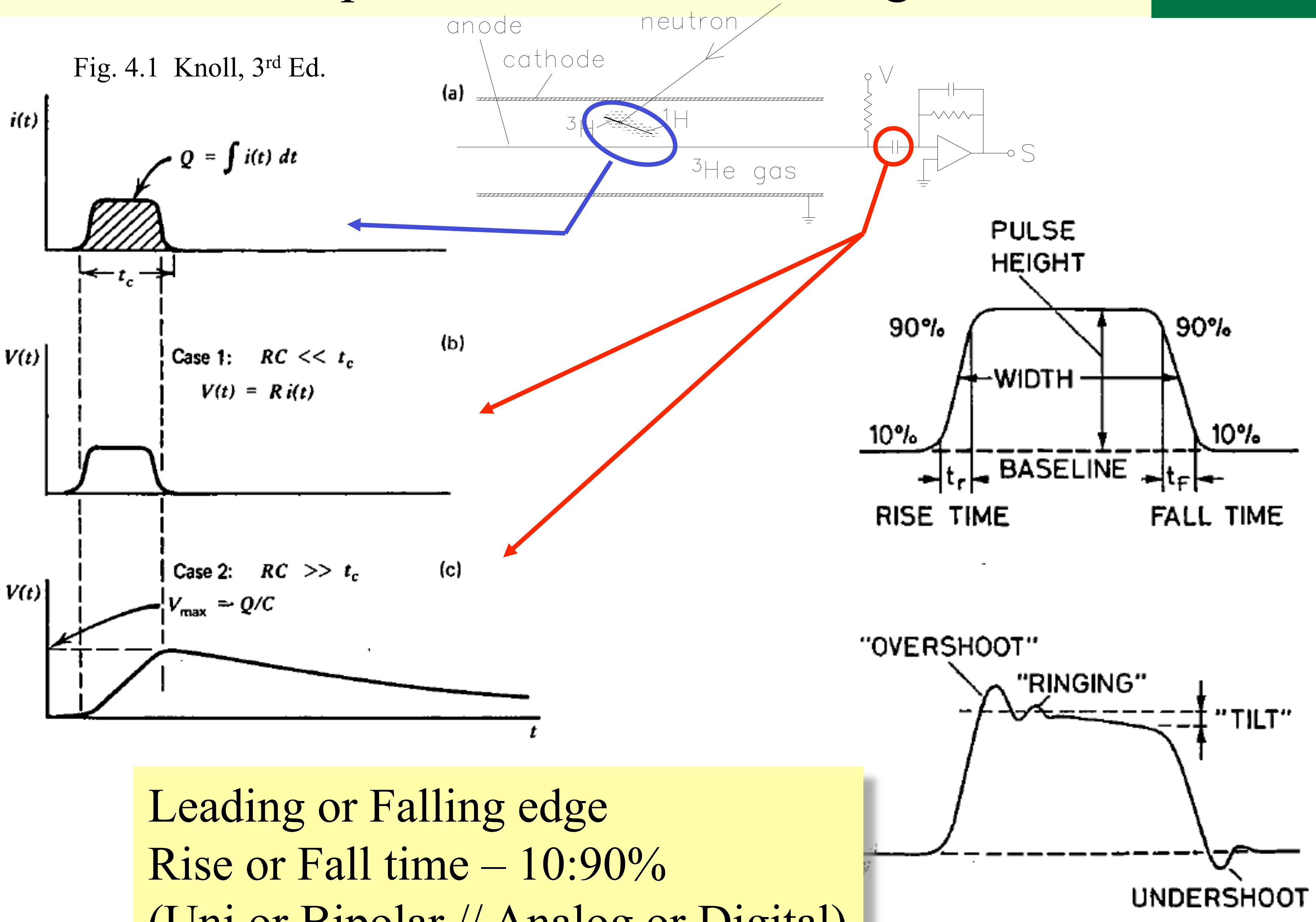


Fig. 4.1 Knoll, 3rd Ed.

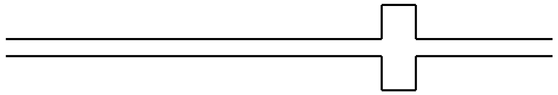
Fig. 11.1 Leo, 2nd Ed.

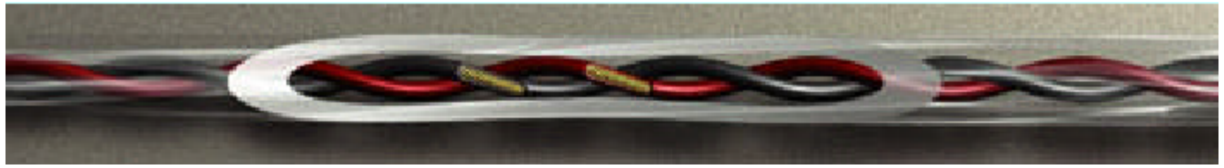
Leading or Falling edge
Rise or Fall time – 10:90%
(Uni or Bipolar // Analog or Digital)

© DJMorrissey, 2oo9

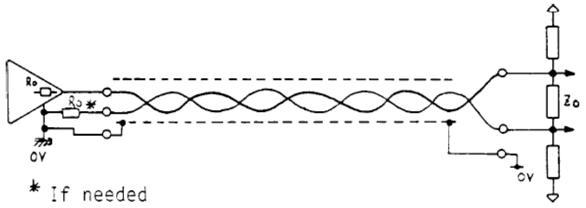
Pulse Processing: cables

Twisted pairs – “differential” signals, logic or analogue

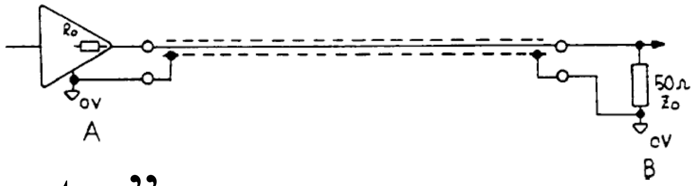




Shielded Twisted Pair Cable True Differential Input

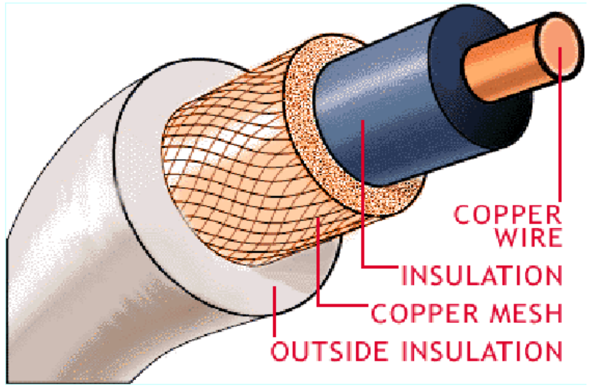


Coaxial Cable - Single-Ended Connection



Coaxial conductor/shield – signal on the “center”

Each configuration has a RG/U name with a characteristic capacitance and inductance per unit length, and an impedance (with a negligible resistance).

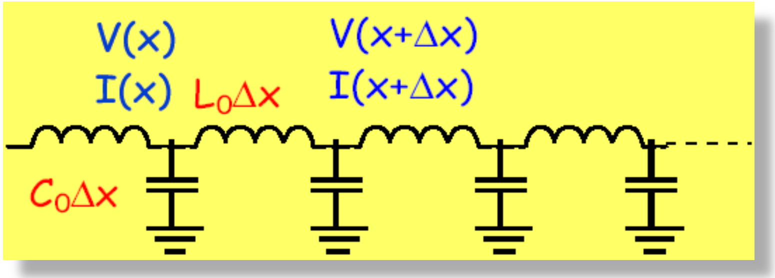


$$\frac{d^2V}{dx^2} = -\omega^2 L_0 C_0 V$$

$$V = Ae^{jkx} + Be^{-jkx} \qquad k^2 = \omega^2 L_0 C_0$$

$$v = \frac{\omega}{k} = \frac{1}{\sqrt{L_0 C_0}}$$

$$Z_0 = \sqrt{\frac{L_0}{C_0}}$$



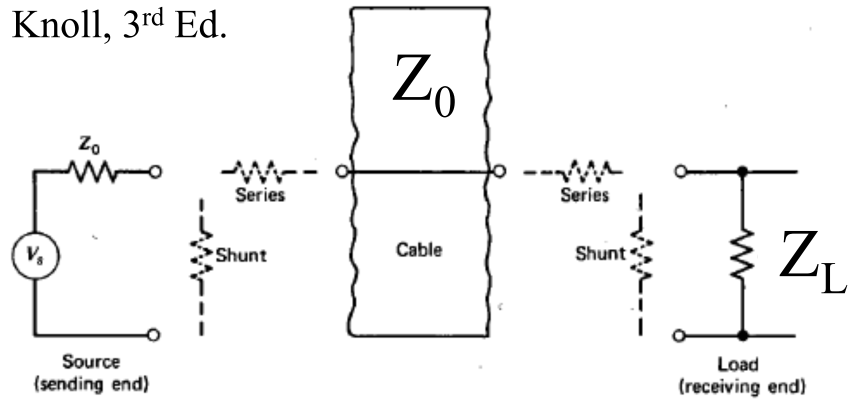
for coax

$$C_0 = 2\pi\varepsilon / \ln(r_2/r_1)$$

$$L_0 = (\mu/2\pi)\ln(r_2/r_1)$$

Pulse Processing: impedance matching

Fig. 16.4 Knoll, 3rd Ed.



$$I_{Inc} + I_{ref\,l} = I_L$$

$$V_{Inc} + V_{ref\,l} = V_L$$

$$V_{ref\,l} = -I_{ref\,l} Z_0$$

$$\rightarrow \quad \frac{V_{ref\,l}}{V_{Inc}} = \frac{Z_L - Z_0}{Z_L + Z_0} \;\&\; \frac{V_L}{V_{Inc}} = \frac{2Z_L}{Z_L + Z_0}$$

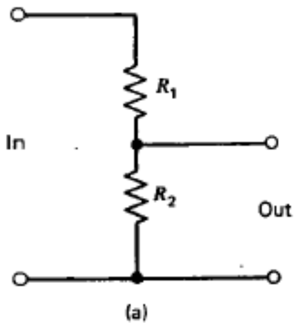
What happens?

- Open circuit .. $Z_L \sim \infty$
- Short circuit .. $Z_L = 0$
- Match circuit .. $Z_L = Z_0$

Match to get maximum transmission to load (S/N), minimize reflections (ringing), maintain signal shape.

Don't Match to minimize transmission .. Weak signals into high impedance loads or low power sources (but must use short cables).

Pulse Processing: simplest manipulations



Voltage divider (recall PMT base)

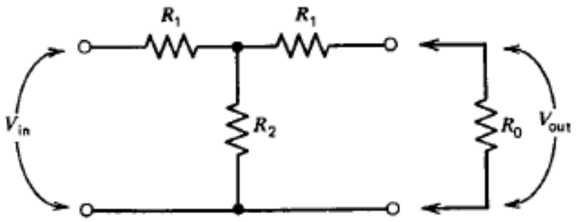


Fig. 16.5 Knoll, 3rd Ed.

Attenuation $\alpha = V_{out}/V_{in}$

$R_1=R_0\ \alpha-1 / \alpha +1$

$R_2=R_0\ 2\ \alpha / \alpha\ 2-1$

Signal Inverter

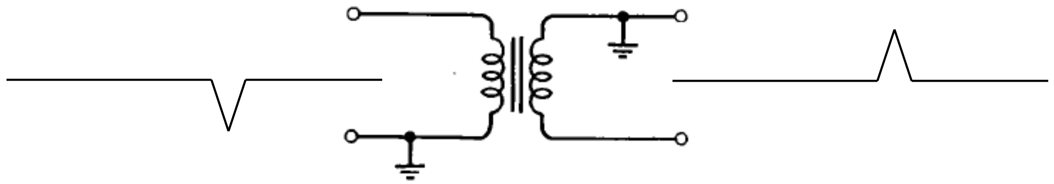


Fig. 16.7 Knoll, 3rd Ed.

Signal splitter: $R=R_0/3$

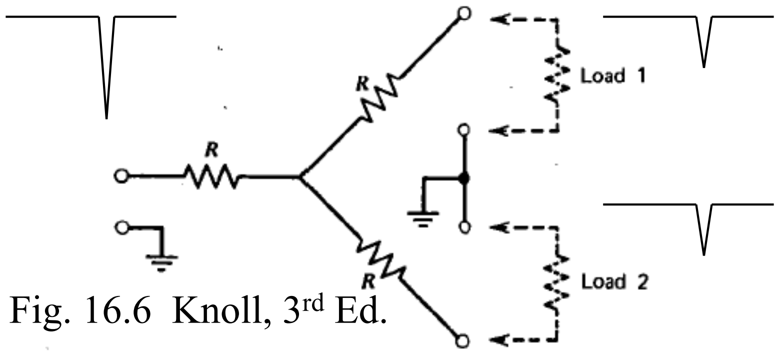
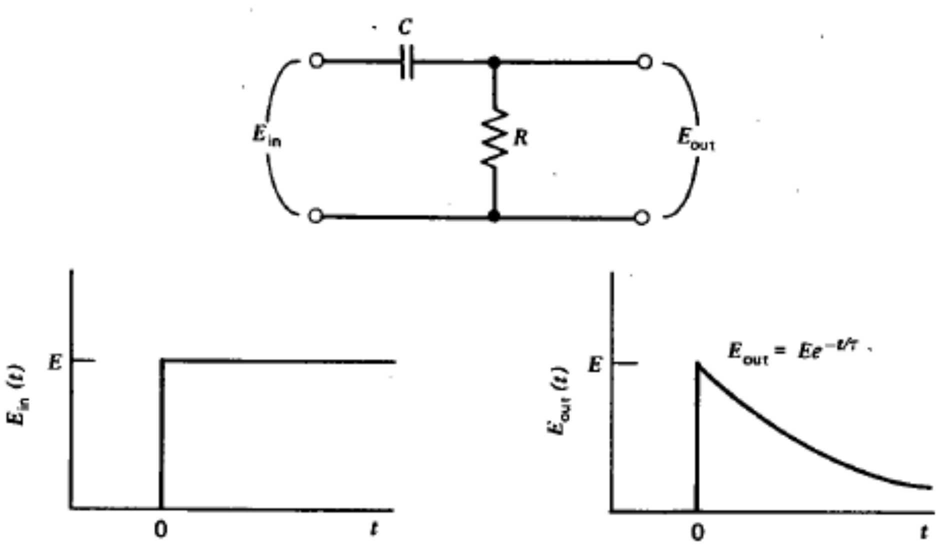


Fig. 16.6 Knoll, 3rd Ed.

All loads must be present, or else see previous discussion about reflections!

Pulse Processing: CR circuit

Fig. 16.9 Knoll, 3rd Ed.



$$V_{in} = \frac{Q}{C} + V_{out}$$

$$\frac{dV_{in}}{dt} = \frac{1}{C}\frac{dQ}{dt} + \frac{dV_{out}}{dt} \qquad (C \textit{ is constant})$$

$$\frac{dV_{in}}{dt} = \frac{V_{out}}{RC} + \frac{dV_{out}}{dt} \qquad dQ/dt = i = V/R$$

$$\tau\frac{dV_{in}}{dt} = V_{out} + \tau\frac{dV_{out}}{dt} \qquad \tau = RC$$

$$V_{out} \approx \tau\frac{dV_{in}}{dt} \quad \text{for small } \tau$$

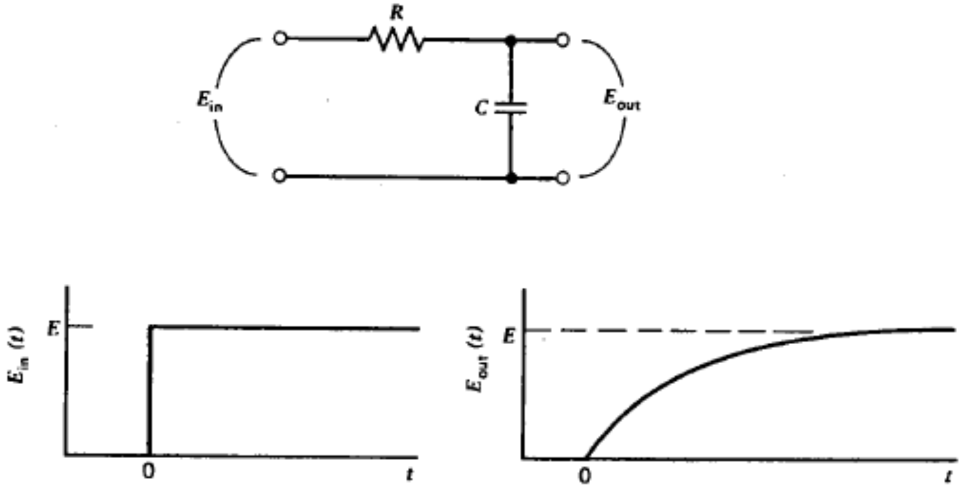
$$\tau\frac{dV_{out}}{dt} \approx \tau\frac{dV_{in}}{dt} \quad \text{for large } \tau$$

$$V_{out} \approx V_{in} \quad \textit{"slow electronics"}$$

The differentiator (when τ is small, “fast” electronics) .. Should remove low frequency components and is called a “high-pass” filter.

Pulse Processing: RC circuit

Fig. 16.10 Knoll, 3rd Ed.



$$V_{in} = iR + V_{out}$$

$$i = \frac{dQ}{dt} = C\frac{dV_{out}}{dt} \quad (on\ capacitor)$$

$$V_{in} = RC\frac{dV_{out}}{dt} + V_{out}$$

$$\frac{V_{in}}{\tau} = \frac{dV_{out}}{dt} + \frac{V_{out}}{\tau}$$

$$\frac{V_{in}}{\tau} \approx \frac{dV_{out}}{dt} \quad \rightarrow \quad \frac{1}{\tau}\int V_{in}dt \approx V_{out}$$

$$V_{out} \approx V_{in} \quad \text{for small RC}$$

The integrator (when τ is large, "slow" electronics)
.. Should remove high frequency components and is called a "low-pass" filter.

Pulse Processing: Cable Consequences

$$v = \frac{\omega}{k} = \frac{1}{\sqrt{L_0 C_0}}$$

$$Z_0 = \sqrt{\frac{L_0}{C_0}} \quad \textit{so that} \quad Z_0 C_0 = \sqrt{L_0 C_0} = \tau$$

However, this is an unusual time constant – note that it has dimensions of (s / length) The τ depends on the length of the cable. Some (poor) examples from Beldin Cables:

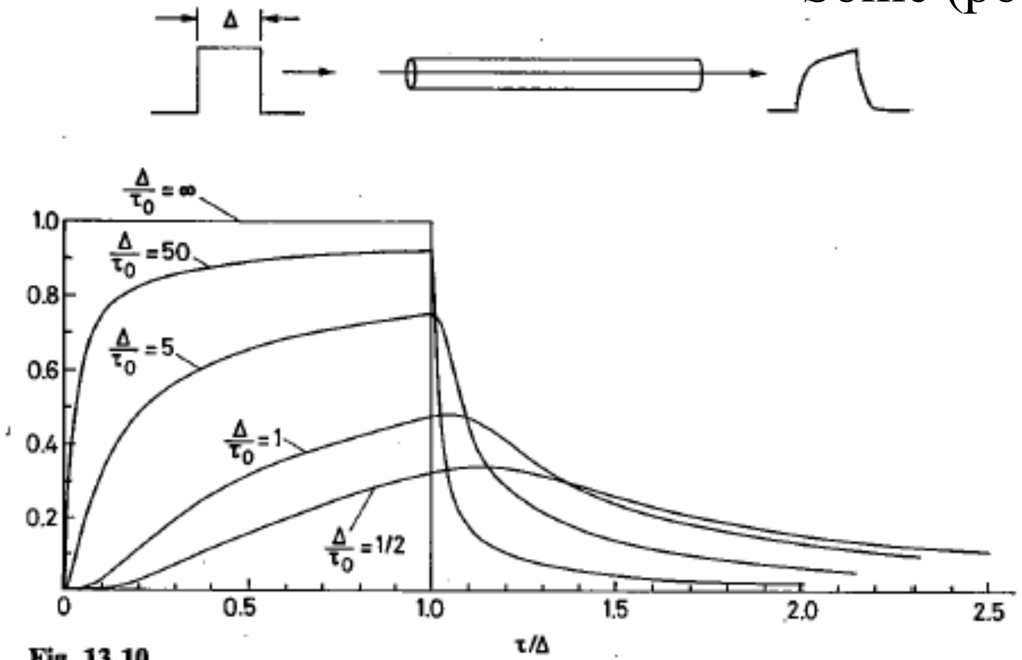
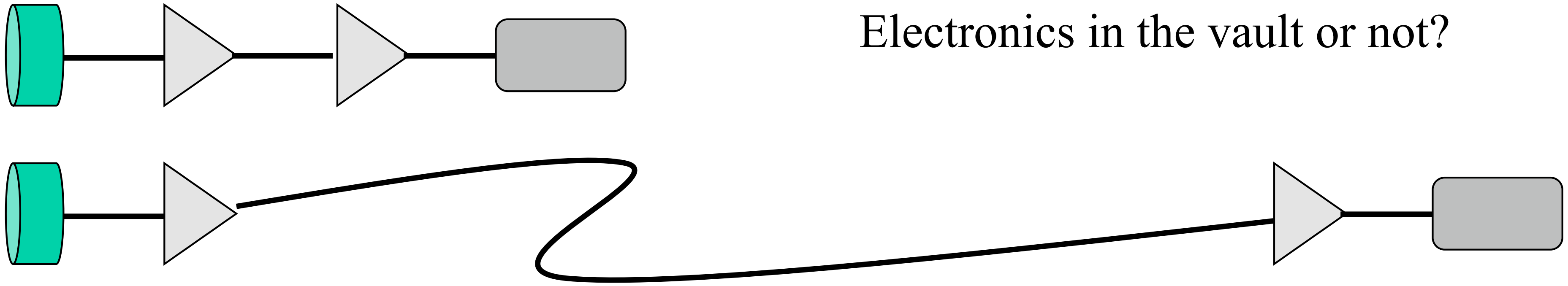


Fig. 13.10

Fig. 13.10 Leo, 2nd Ed.

	58 /U	59 /U	316 /U
Zo	50 Ω	75	50
Co	24.3 pF/ft	16.3	29
Lo	0.064 μH/ft	0.107	0.067
v/c	0.77	0.83	0.695
τ	1.2 ns/ft	1.3 ns/ft	1.4 ns/ft

Pulse Processing: Question

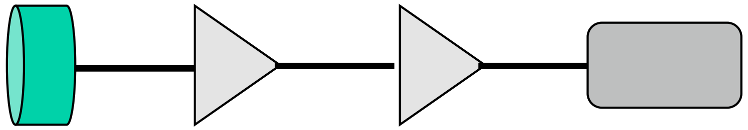


Electronics in the vault or not?

Compare the output of a preamp step-function pulse that passes through a 1m Beldin RG-58/U cable to that that passing through 50 m of the same cable. Use the Fermi function with a=1ns , t_0=10, and t in ns.

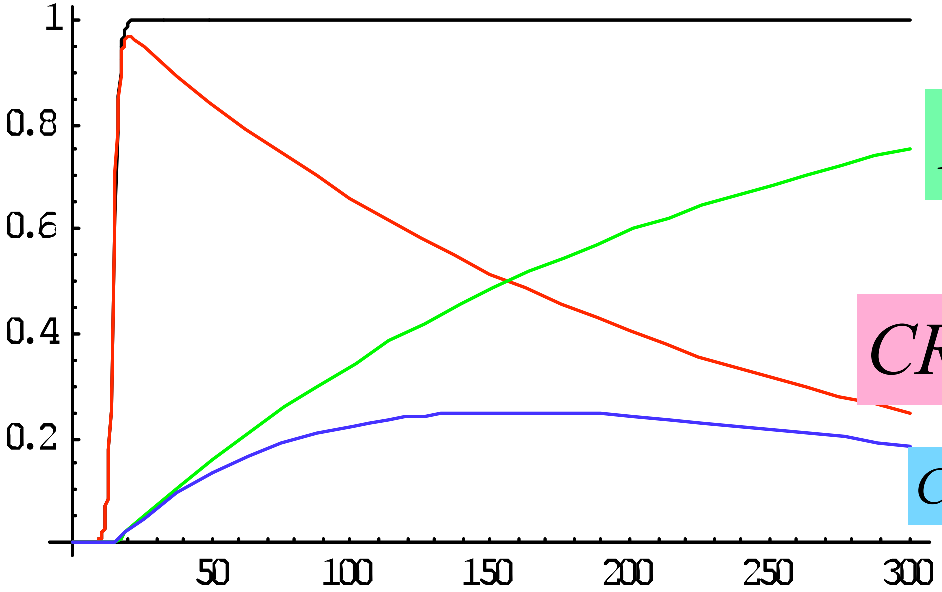
$$f(t) = 1/(1 + e^{-(t-to)/a})$$

Pulse Processing: Answer



Electronics in the vault or not?

Compare the output of a preamp step-function pulse that passes through a 1m Beldin RG-58/U cable to that that passing through 50 m of the same cable. Use the Fermi function with a=1ns , t_0=10, and t in ns.



$$f(t) = 1/(1 + e^{-(t-to)/a})$$

$$RC: \quad 1/(1 + e^{-(t-to)/a})\,[1 - e^{-(t-to)/\tau}]$$

$$CR: \quad 1/(1 + e^{-(t-to)/a})\, e^{-(t-to)/\tau}$$

$$CR\,\&\,RC: \quad 1/(1 + e^{-(t-to)/a})\, e^{-(t-to)/\tau}[1 - e^{-(t-to)/\tau}]$$