Week 11: Chap. 16a Pulse Processing

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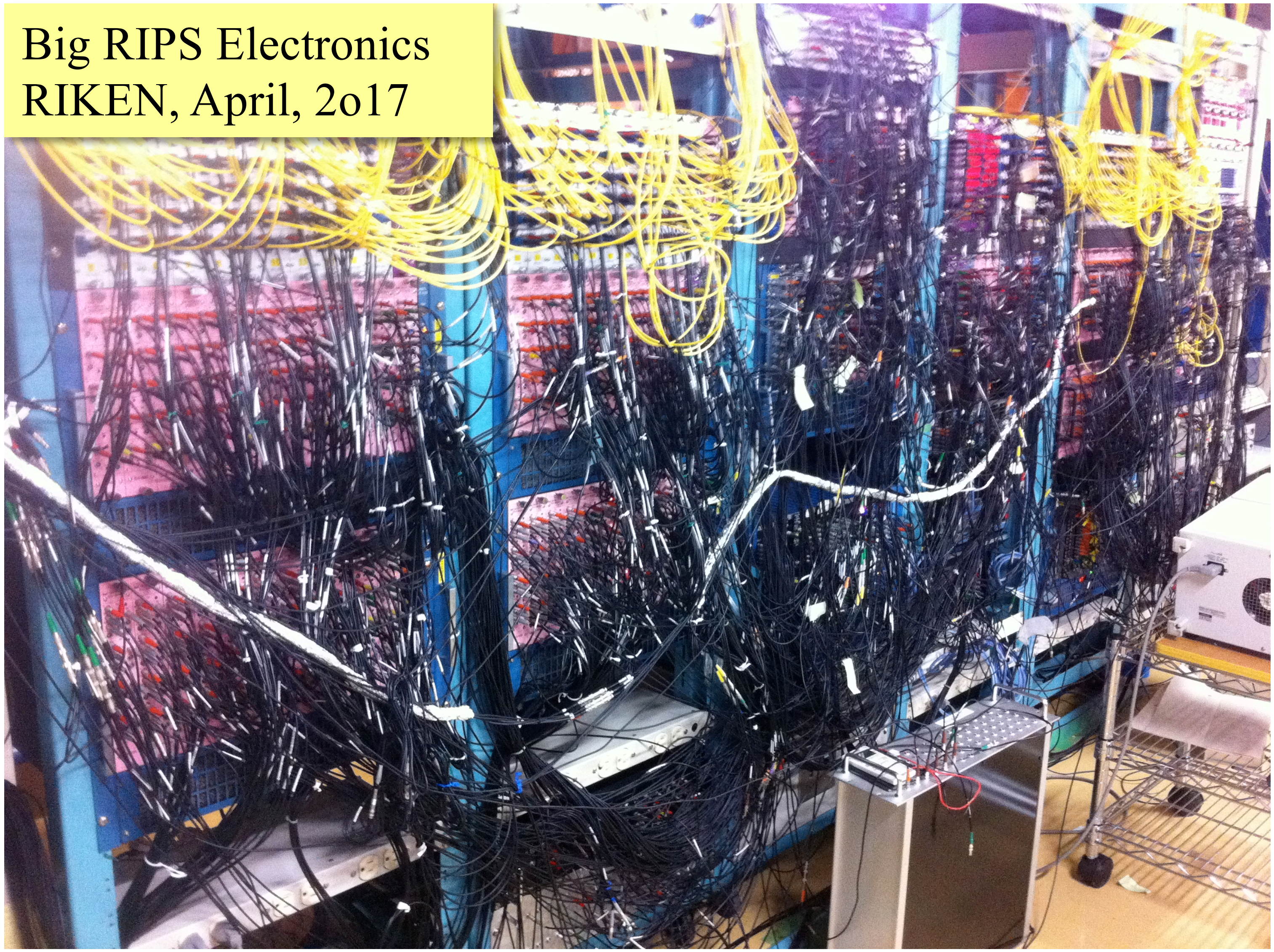
Fast Neutron Detection

Pulse Processing (passive)
-- Signal shape
-- Cable properties
--- connecters
--- impedance
-- CR, RC filters

Pulse Processing (active)

Big RIPS Electronics
RIKEN, April, 2o17



Pulse Processing: overview

Fig. 16.1 Knoll, 4th Ed.

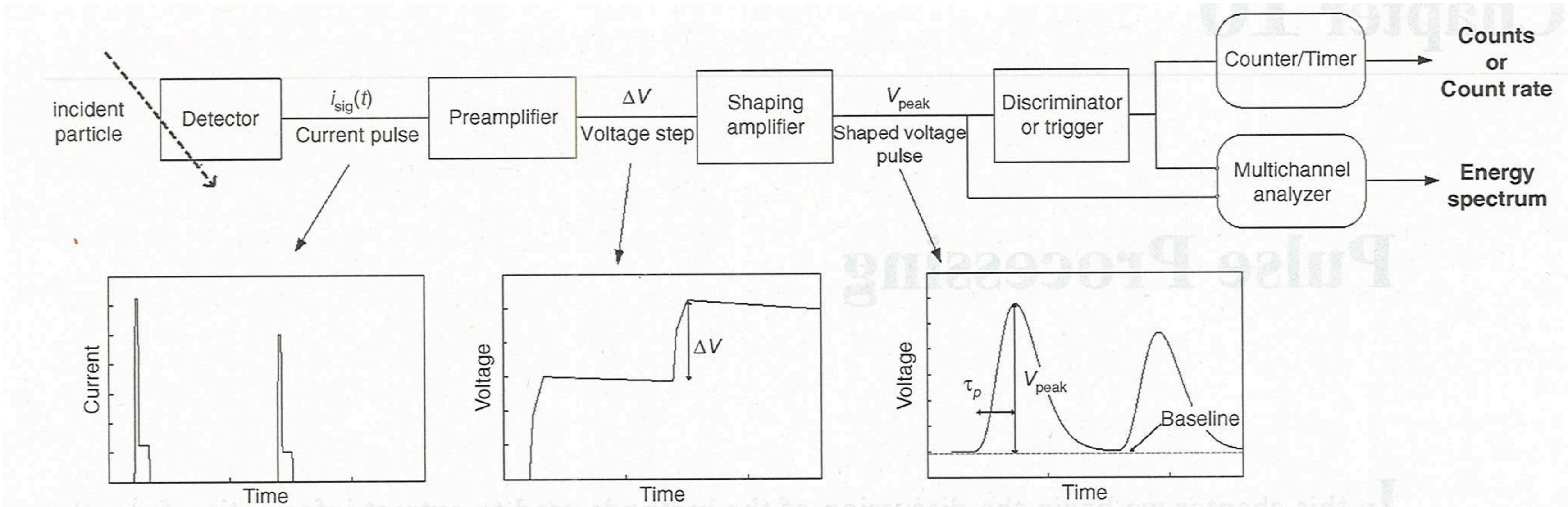
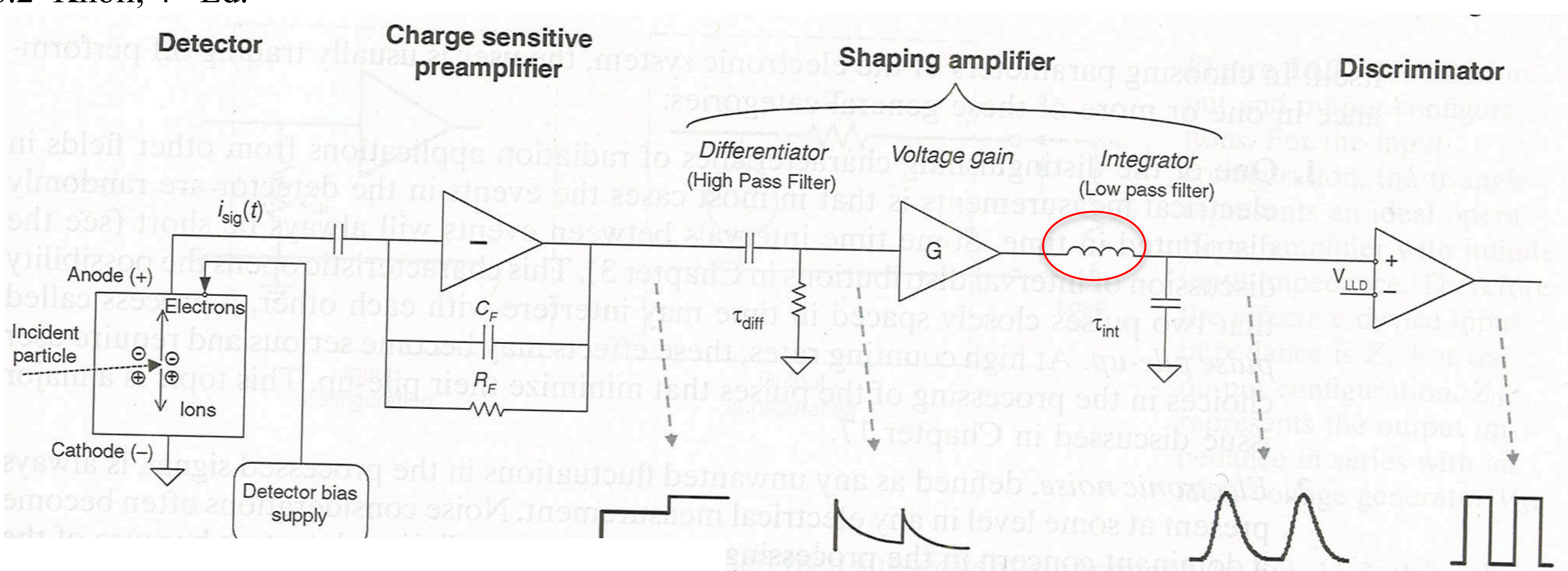
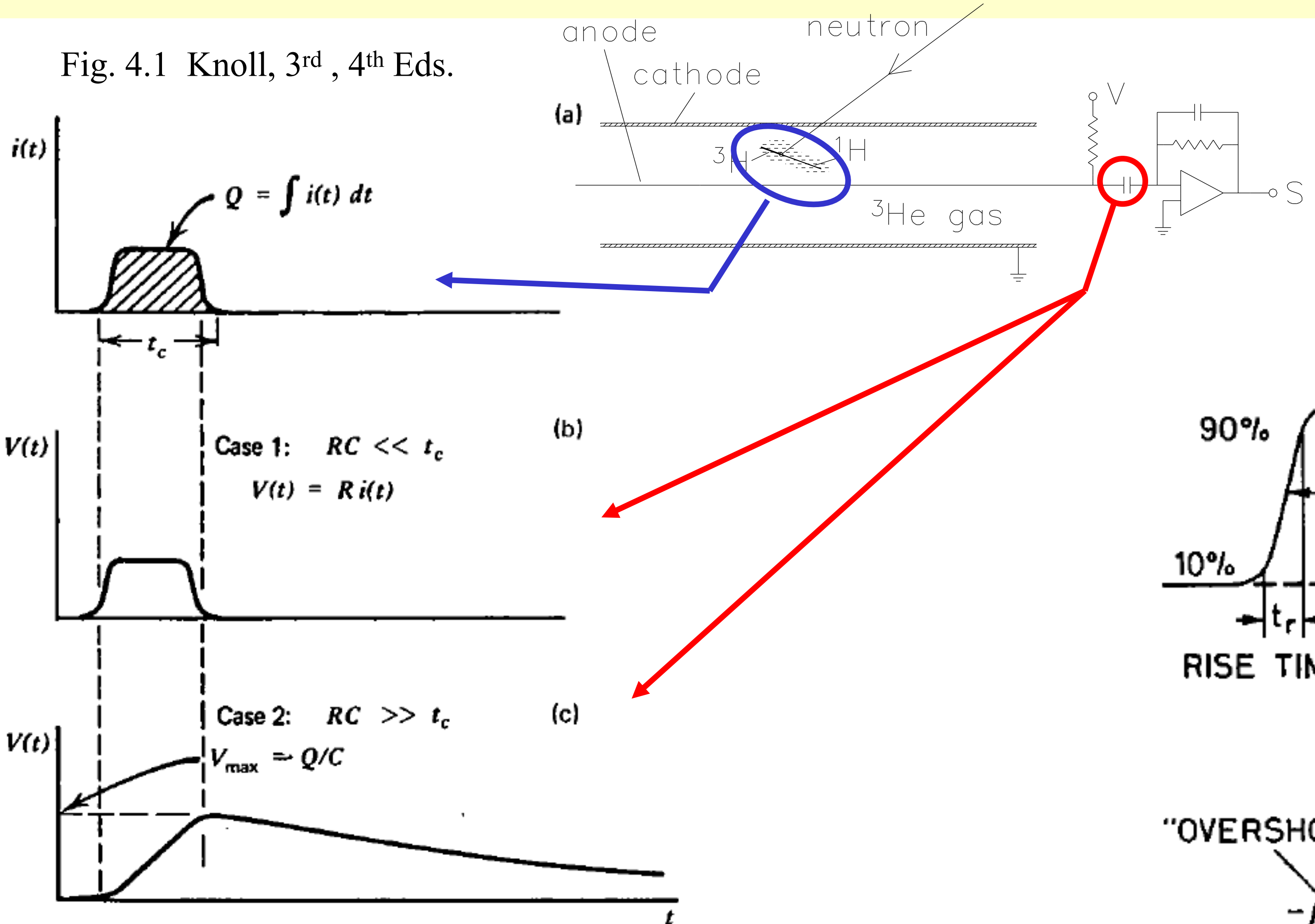


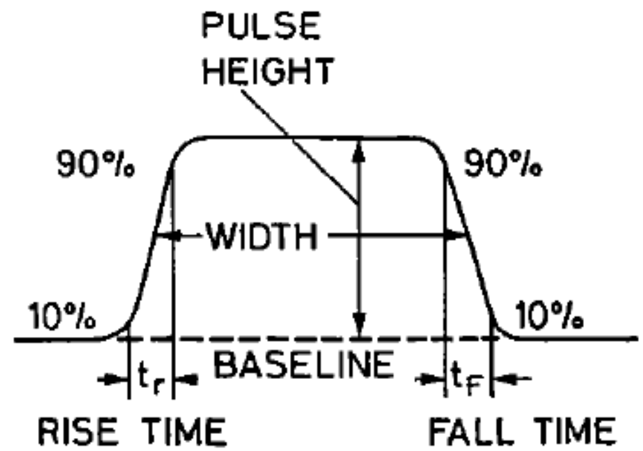
Fig. 16.2 Knoll, 4th Ed.



Chap. 16a – Pulse Processing

Fig. 4.1 Knoll, 3rd, 4th Eds.





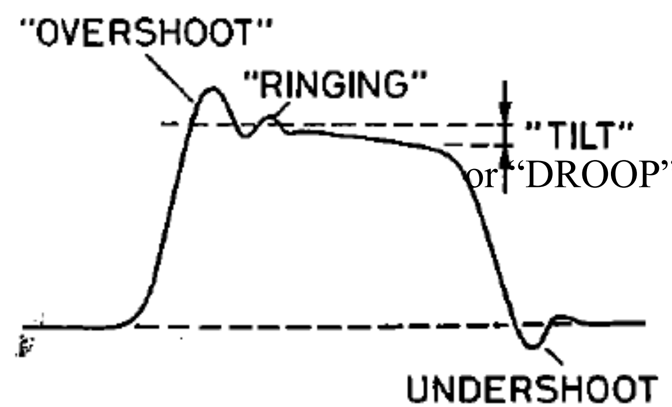


Fig. 11.1 Leo, 2nd Ed.

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

Pulse Processing: cables

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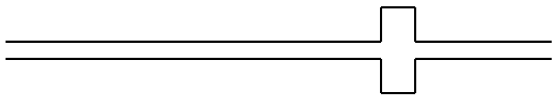
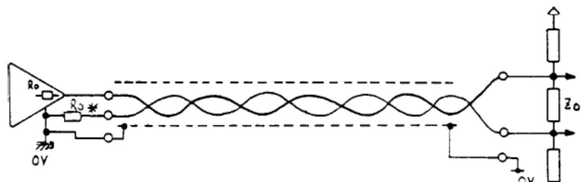
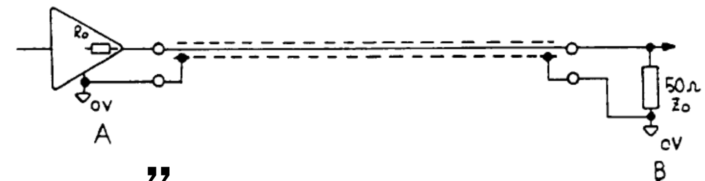
Twisted pairs – "differential" signals, analogue or logic



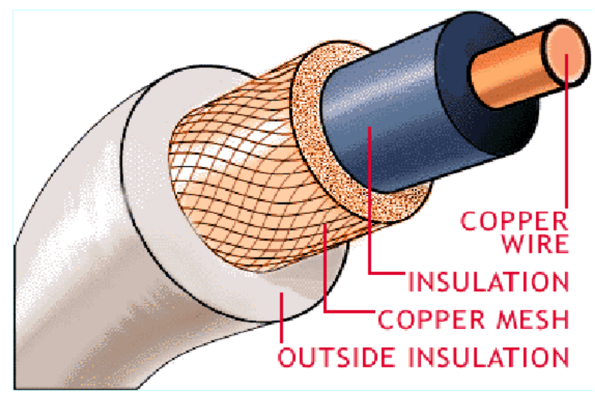
Shielded Twisted Pair Cable True Differential Input



Coaxial Cable - Single-Ended Connection



Coaxial conductor/shield – signal on the "center"



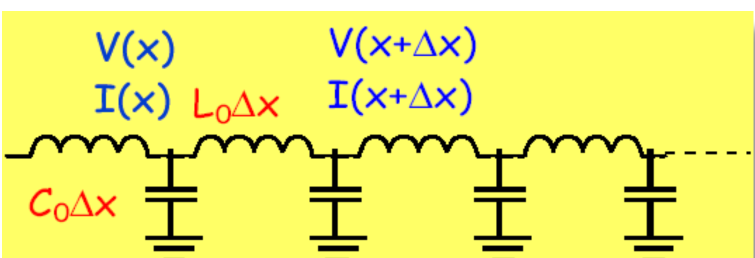
Each configuration has a RG/U name with a characteristic capacitance and inductance per unit length, and an impedance (with a negligible resistance).

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

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

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

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



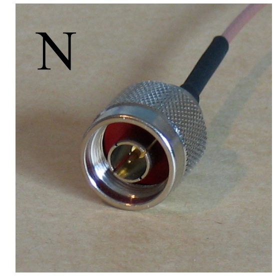
for coax

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

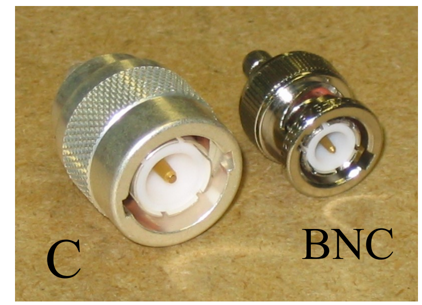
$$L_0 = (\mu/2\pi)\ln(r_2/r_1)$$

Pulse Processing: some connectors


http://www.cdint.com/catalog/model/CC-B
https://www.amphenolrf.com/connectors/bnc.html



"BNC is an acronym for Bayonet Neill-Concelman, after Paul Neill of Bell Labs (inventor of the N connector) and Amphenol engineer Carl Concelman (inventor of the C connector). BNC is often erroneously expanded to "Baby Neill-Concelman", "Baby N connector", "British Naval Connector", "Bayonet Nut Connector", "Bayonet Network Connector", "Barrel Nut Connector", "Bayonet N-type Compact", "Berkeley Nucleonics Corp." …

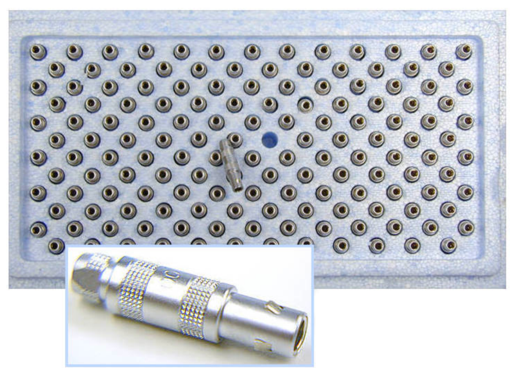


"This connector has a characteristic impedance of 50 ohms, and needs to be mated with 50 ohm coaxial cable in order to prevent signal loss, noise, and/or transmitter damage due to signal reflections at the point of mismatch. 50 ohm coax cable, connectors, and adapters are commonly used in co-ax wifi cables (old school, 802.11 wireless LAN) antennas, ham transceivers, and other radio frequency (RF) analog and digital signaling, microwave, radar, hi-fidelity professional audio, non-destructive testing (NDT), oil and petroleum production, ultrasonic transducers, accelerometers, strain gauges, and some professional video applications."

LEMO documentation

http://www.lemo.com/en/documentation

(**L**é**on** **Mo**uttet)



LEMO to BNC

Pulse Processing: impedance matching

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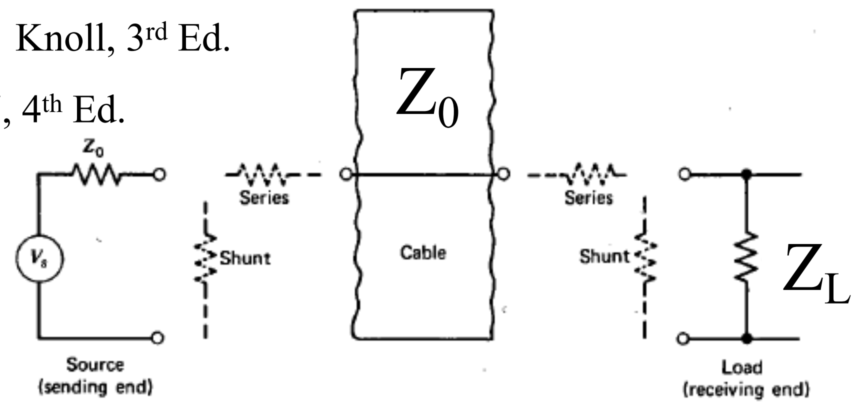
Fig. 16.4 Knoll, 3rd Ed.

16.7, 4th Ed.



$$I_{\text{Inc}} + I_{\text{refl}} = I_L$$

$$V_{\text{Inc}} + V_{\text{refl}} = V_L$$

$$V_{\text{refl}} = -I_{\text{refl}} Z_0$$

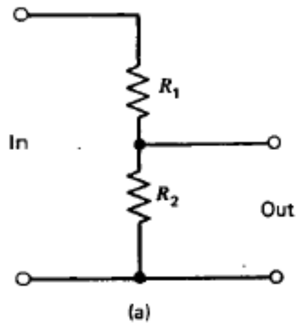
$$\rightarrow \quad \frac{V_{\text{refl}}}{V_{\text{Inc}}} = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad \frac{V_L}{V_{\text{Inc}}} = \frac{2Z_L}{Z_L + Z_0}$$

What happens if: ?

- 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)

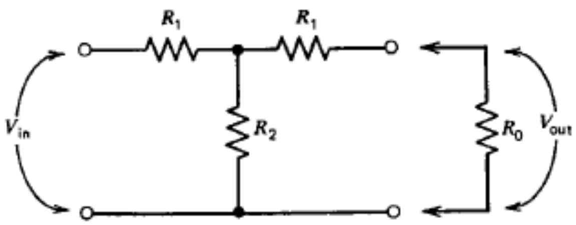


Fig. 16.5 Knoll, 3rd Ed.

16.8, 4th 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

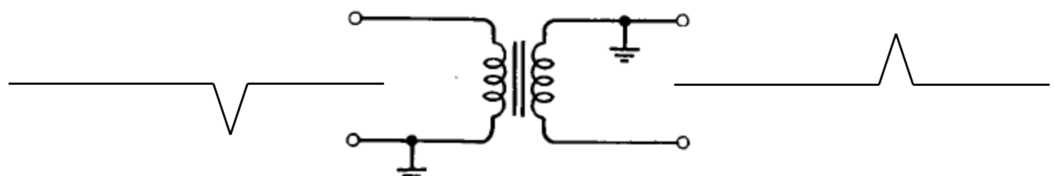


Fig. 16.7 Knoll, 3rd Ed.

16.10 4th Ed.

Signal splitter: $R = R_0/3$

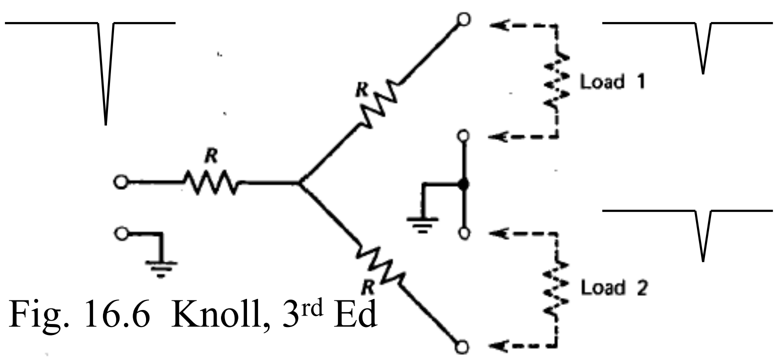


Fig. 16.6 Knoll, 3rd Ed

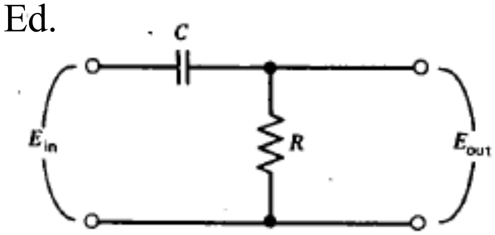
16.9, 4th Ed..

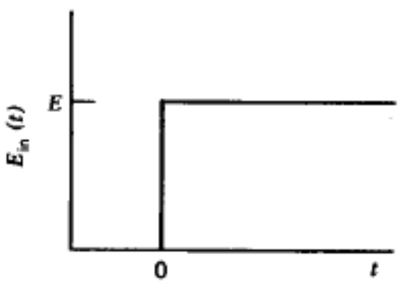
All loads must be present, or else see previous discussion about reflections!

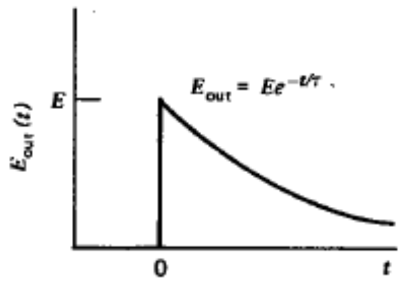
Pulse Processing: CR circuit

Fig. 16.9 Knoll, 3rd Ed.

17.2 4th Ed.







$$V_{in} = \frac{Q}{C} + V_{out} \qquad (C \text{ is constant})$$

$$\frac{dV_{in}}{dt} = \frac{1}{C}\frac{dQ}{dt} + \frac{dV_{out}}{dt} \qquad \frac{dQ}{dt} = i = V/R$$

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

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

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

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

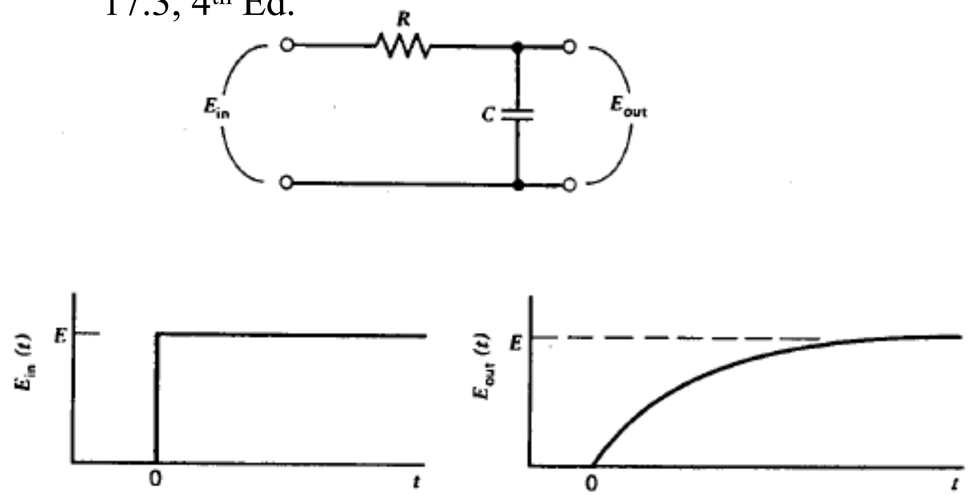
$$V_{out} \approx V_{in}$$

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. 16.9 Knoll, 3rd Ed.

17.3, 4th Ed.



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

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

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

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

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

$V_{out} \approx V_{in}$ 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 Properties

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

$$Z_0 = \sqrt{\frac{L_0}{C_0}} \rightarrow Z_0^2 C_0 = L_0$$

$$v = \frac{\omega}{k} = \frac{1}{\sqrt{Z_0^2 C_0^2}} = \frac{1}{Z_0 C_0}$$

A velocity has dimensions of (length / time)
The time depends on the length of the real cable.
Some example properties from Belden Cables:

	58 /U	59 /U	213/U	316 /U
Zo	50 Ω	75	50	50
Co	24.3 pF/ft	16.3	30.8	29
Lo	0.064 μH/ft	0.107	0.077	0.067
v/c	0.77	0.83	0.66	0.695
τ	1.2 ns/ft (4 ns/m)	1.3 ns/ft	1.5 ns/ft	1.4 ns/ft

Pulse Processing: Cable Consequences

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

$$Z_0 = \sqrt{\frac{L_0}{C_0}} \rightarrow Z_0^2 C_0 = L_0$$

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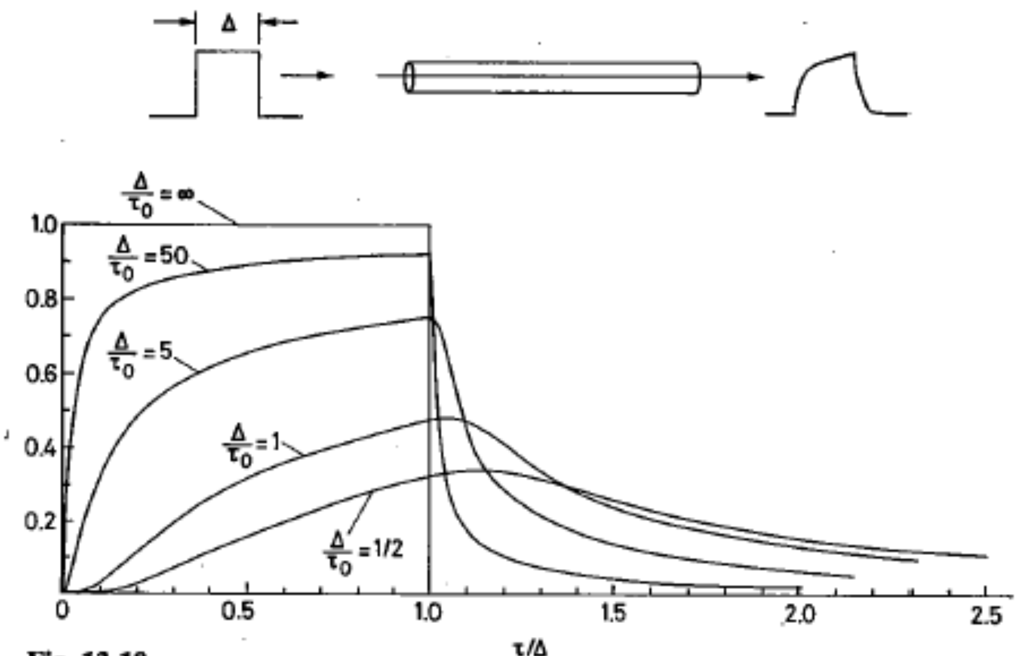
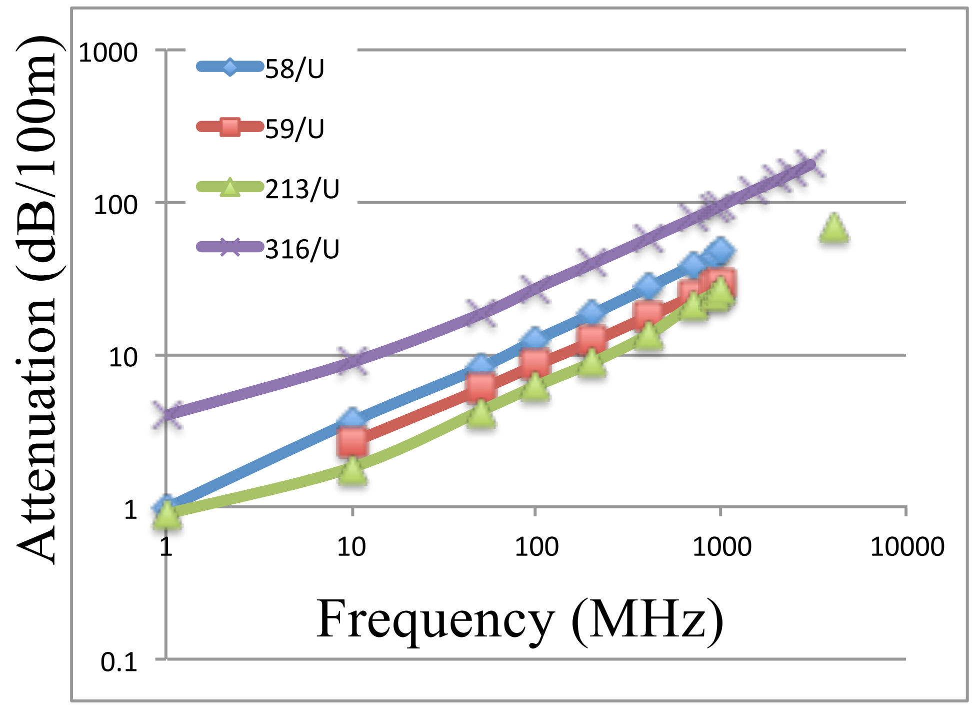
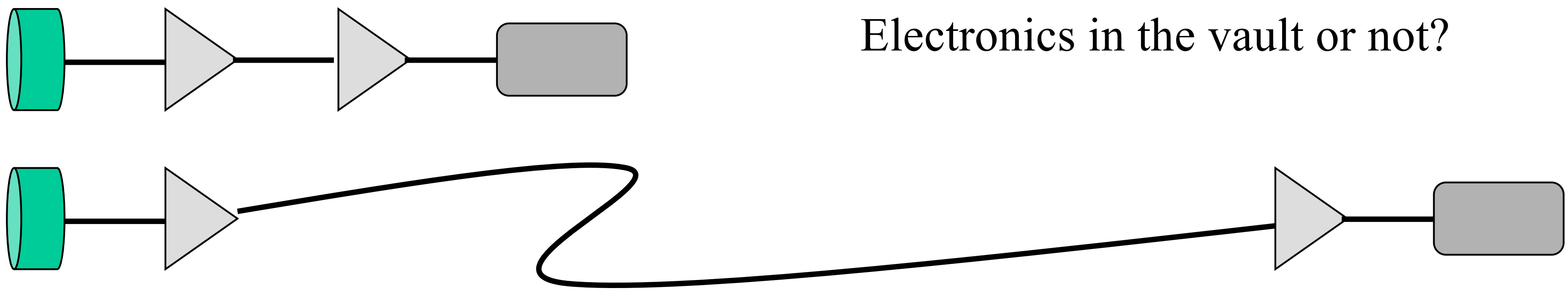


Fig. 13.10 Leo, 2nd Ed.



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 from passing through 50 m of the same cable. Use the Fermi function with a=1 , t_0=10, τ = 4 ns/m, and t in ns.

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

Pulse Processing: Answer

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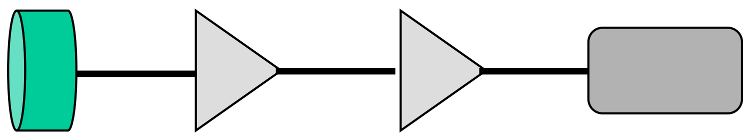

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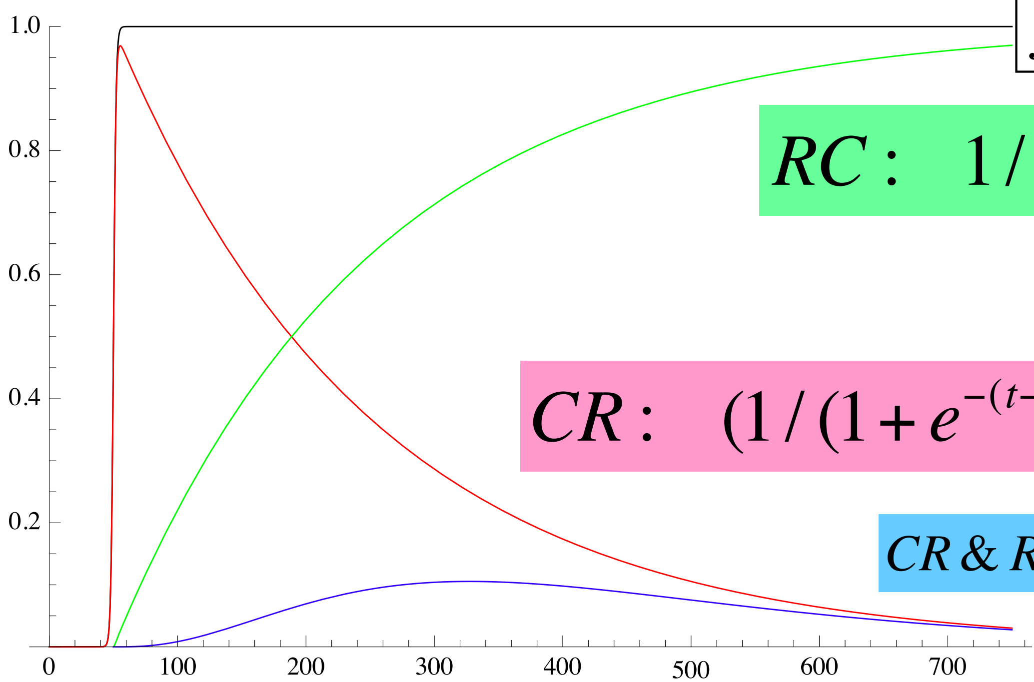

$$f(t) = 1/(1+e^{-(t-to)/a})$$

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

$$CR: \quad (1/(1+e^{-(t-to)/a}))^2 \; e^{-(t-to)/\tau}$$

$$CR \,\&\, RC: \quad (1/(1+e^{-(t-to)/a}))^2 \; e^{-(t-to)/\tau}[1-e^{-(t-to)/\tau}]$$