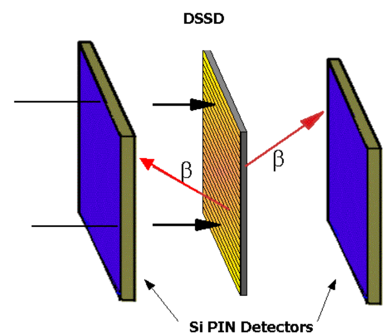
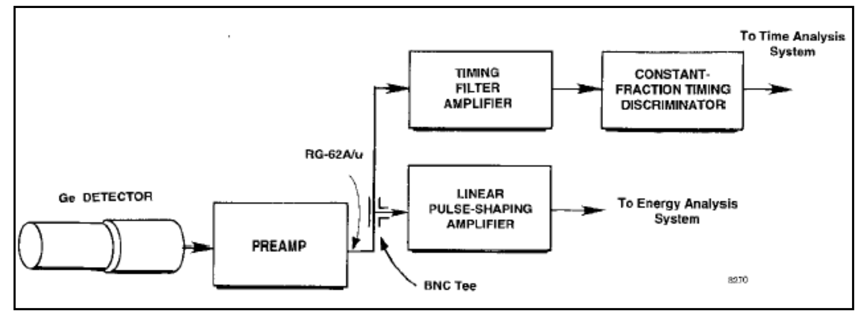
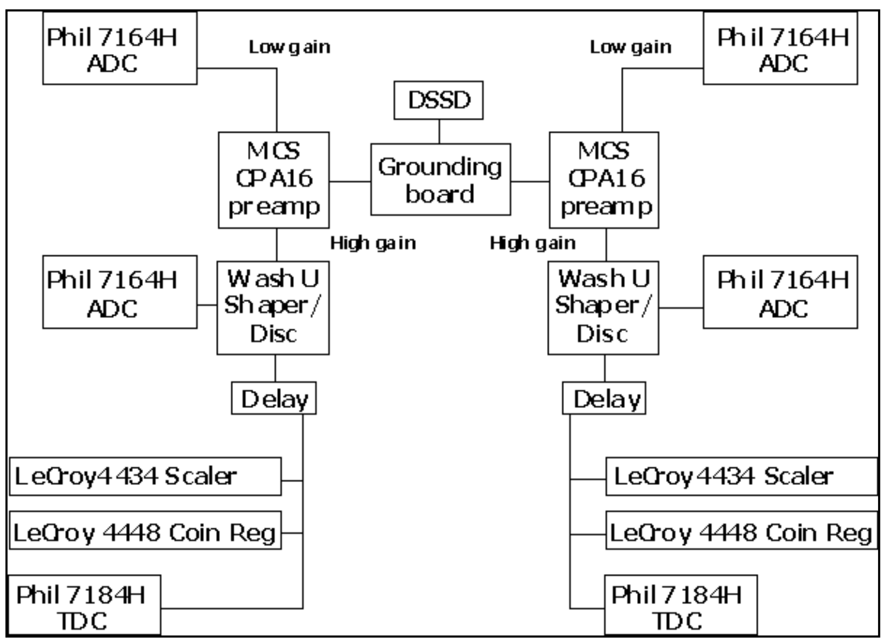
Chap. 17 – Pulse Analysis: Linear Chains





x 8 very high resolution (1/8192)



x 40 x 2 sides, High resolution (1/4096)
x 2 (low/high gains)

http://www.cem.msu.edu/~mantica/equip/betastrip.html

Pulse Analysis: Noise –1–

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Noise in an electronic system is an unwanted signal that obscures the wanted signal.

For our purposes there are two classes of electronic noise:

•External noise: pickup of signals from sources outside the detector/electronics. Very often motors of various types, lights, ground loops. In principle, external noise can be avoided by careful construction, grounding and operation. (more on this in a moment)

•Internal noise: fundamental property of the detector/electronic components – can't be avoided by should be minimized by good design. There are three subclasses of internal noise:

Thermal noise (Johnson noise, series noise): mean value is zero but one expects fluctuations around zero. $\sigma(V) \sim \mathrm{Sqrt}(4\,kT\,R\,\Delta f)$ where Δf is the frequency range of observation (bandwidth) – the variance tends to be small except for highest frequencies (fastest signals) – *a White Noise*
e.g. $\sigma(V) \sim \mathrm{Sqrt}(4{*}0.026{*}1.6\text{e-}19{*}R{*}\Delta f) \rightarrow 30\ \mu V$ at 50 Ω & 1ns at 300 K
Real components with R & C in parallel: $\sigma(V) \sim \mathrm{Sqrt}(kT/C)$

Shot noise (parallel noise): fluctuations in the current due to its quantization in electrons.
$\sigma(V) \sim \mathrm{Sqrt}(2\,q_e\,I_{DC}\,\Delta f)$ where I_{DC} is the (macroscopic) DC current – *a White Noise*

1/f noise: a catch-all for the fact that many sources of fluctuations have a exponential time dependence which transforms into a 1/f power spectrum.

Pulse Analysis: Noise –2–

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Why is the preamp discussed separately from the shaping amplifier?

Internal sources of noise tend to most significant at the input stage where the true signal is smallest. Test to determine if S/N depends on shaping amplifier gain. First stage of amplification should be sufficient that signal >> noise pickup during transmission.

Noise is generally referred to in terms of *Equivalent Noise Charge* which can be directly compared to the number of electrons created in the detector and input into the preamplifier. The ENC can be given in Coulombs or more recently "electrons".

The variances of independent noise sources are to be combined in quadrature, as usual.

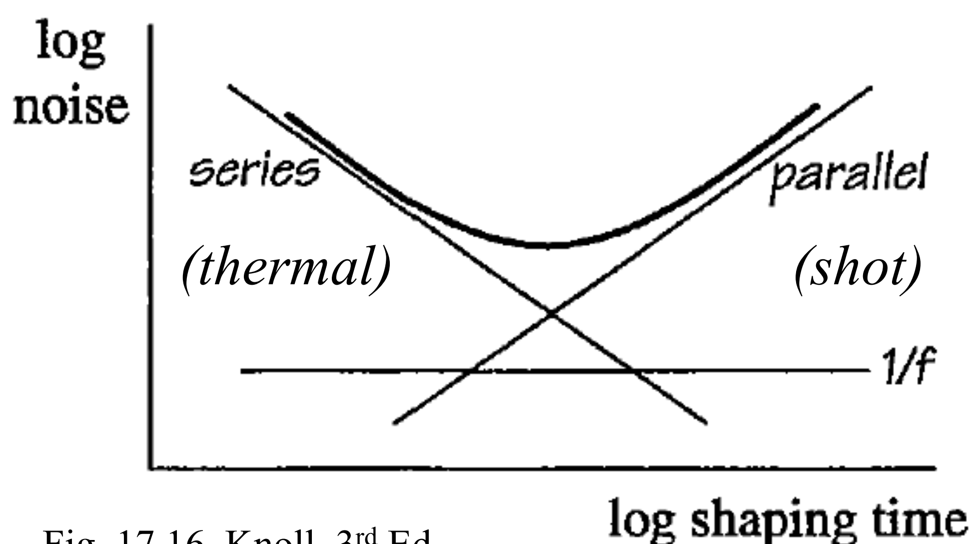


Fig. 17.16 Knoll, 3rd Ed.

Pulse Analysis: Noise –3–

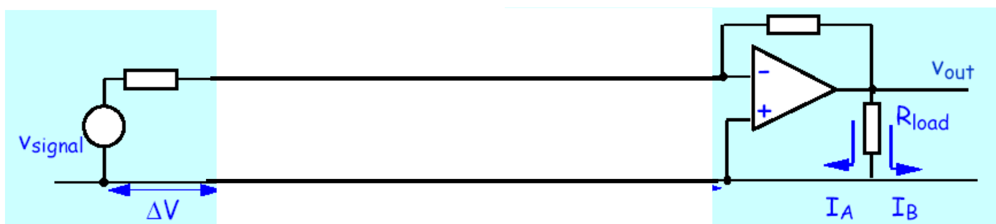
Sources of external noise:

Direct injection of EM energy – lights, fluctuations in power supply voltages (low frequency), High frequencies from switching power supplies (kHz).

Pickup of EM radiation through capacitive coupling – Motors (60 Hz) … TMP's (MHz), RF systems, Computers and Data-buses in CAMAC, VME crates, AC-Welders

Microphonics – mechanical variation of (detector) capacitance

Ground loops – local & long distance



Solutions?

Complete metal enclosure, gaps must be << λ (3cm at 1 MHz, 3μm at 1 GHz)
penetration of EM wave falls exponentially with a coefficient of ~0.1mm at 1 MHz in Al

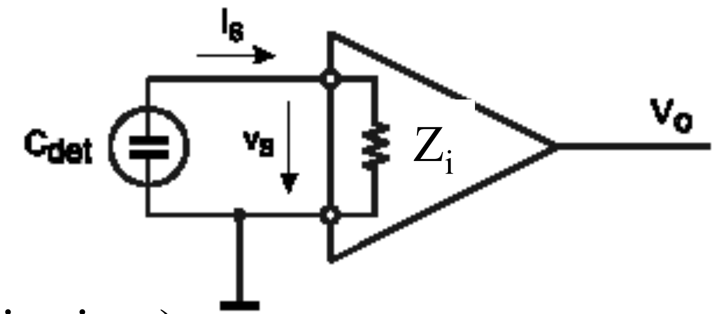
Bypass capacitors from signal line to ground with capacitance: $\omega C >> 1$

Opinion: Ground all components with very low impedance connections
(use differential signals, optical transmission over long distances)

Pulse Analysis: preamplifiers

Operation amplifier – voltage gain, A

$V_{out} = A\, V_{in}$, Impedance Z_i



Simple operational amp – output pulse shape (in time) depends on product of $Z_i\, C_{det}$ as discussed before .. Doesn't work well for radiation detectors, as is, Z_i should be ∞ in ideal device

Voltage sensitive system: $-A$ & $Z_i \sim \infty$

$V_{out} = -A\, V_{in}$ with no feedback

$V_{out} \sim -(R_2 / R_1)\, V_{in}$ when $A >> R_2 / R_1$

(R_1 is an important thermal noise source)

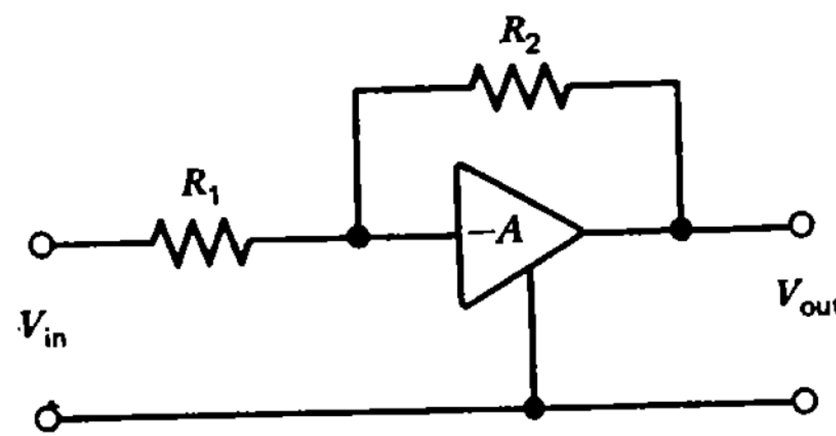


Fig. 17.1 Knoll, 3rd Ed.

Pulse Analysis: charge sensitive preamplifier

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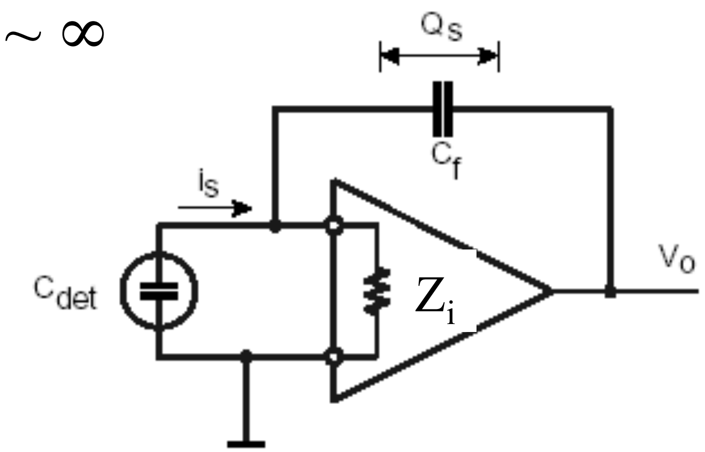
<u>Charge sensitive system</u>: inverting, -A & $Z_i \sim \infty$



$$V_{out} = -A\,V_{in}\ ;\ Q_{out} = Q_{in}\ (Z_i \sim \infty)$$

$$V_{out} = -A\,Q_{in} / [C_i + (A+1)\,C_f]$$

Note that: $V_{out} \sim -Q_{in} / C_f\ e^{-t/R_f C_f}$ with feedback R

Pulser or "test" input

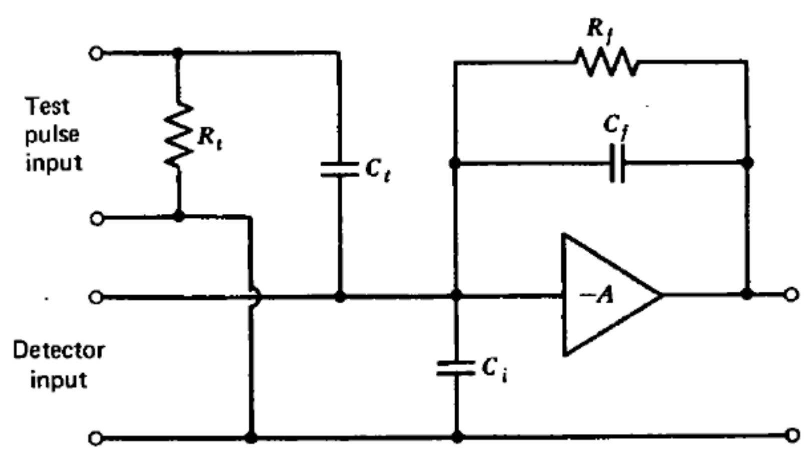


Fig. 17.2 Knoll, 3rd Ed.

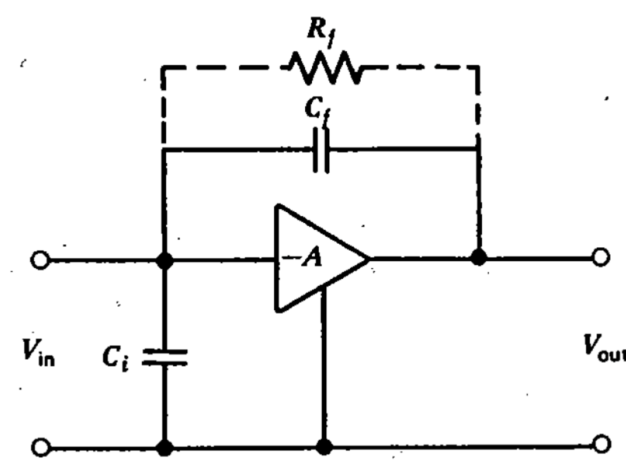
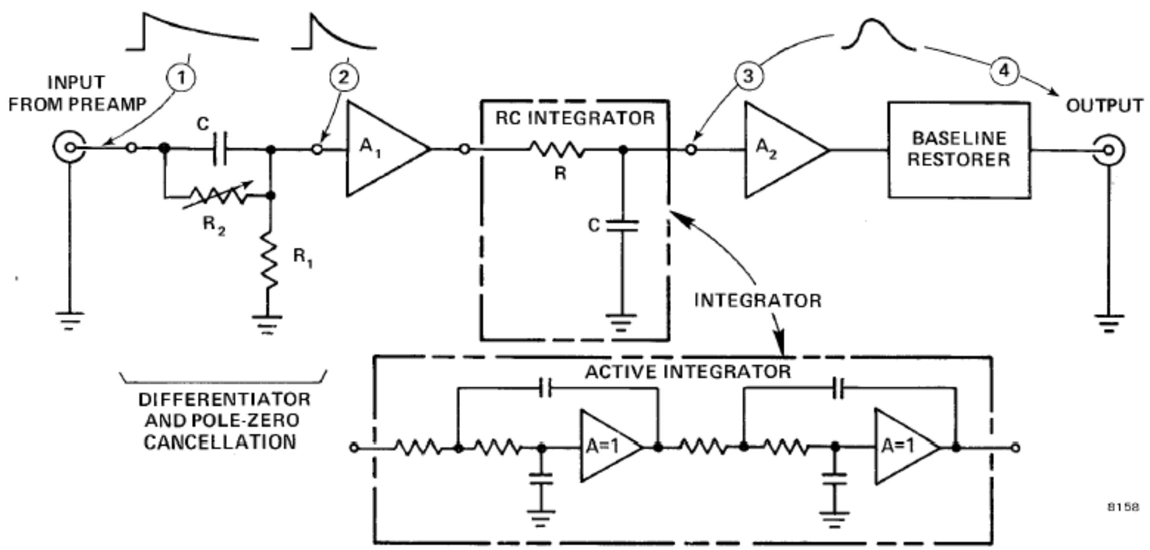


Fig. 17.2 Knoll, 3rd Ed.

Pulse Analysis: CR-(RC)^n shaper



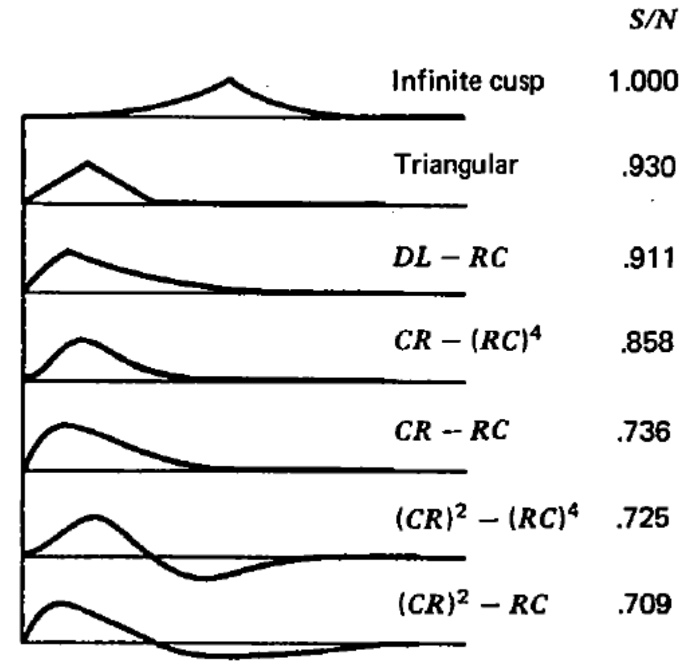


Fig. 17.15 Knoll, 3rd Ed.

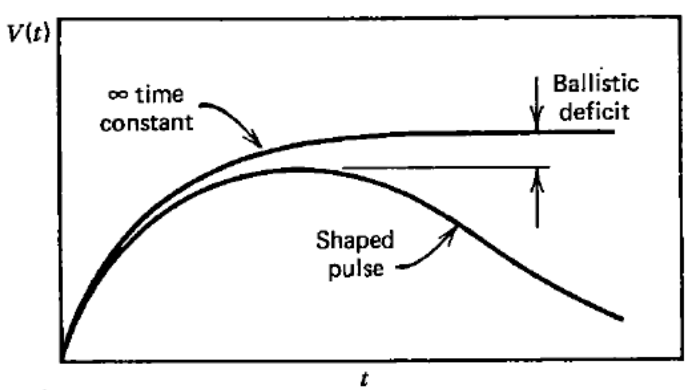


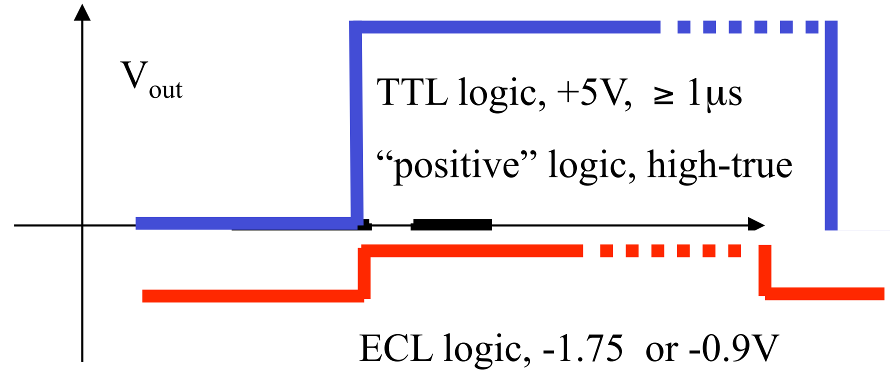
Fig. 17.13 Knoll, 3rd Ed.

One more issue with shaping amps:
Can the shaping time be too short? Yes …

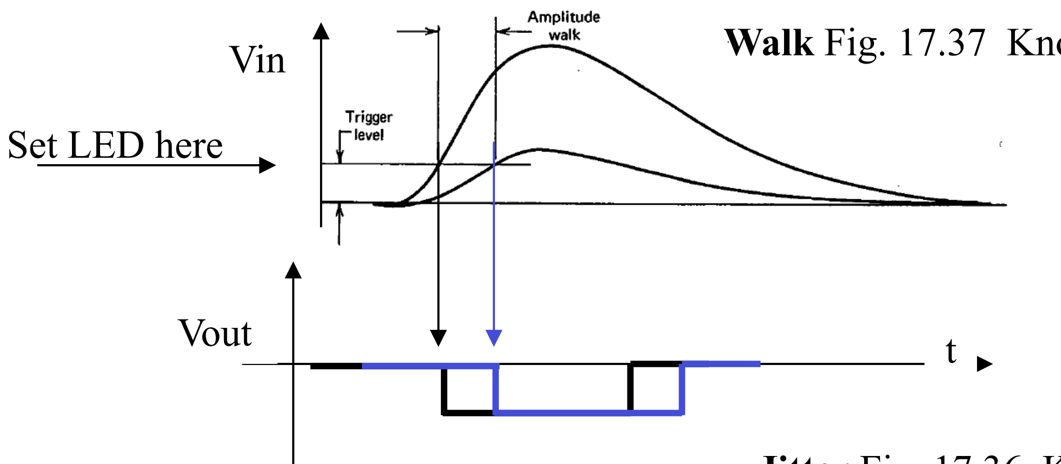
Thus, variations in the rise time will lead to signals with different pulse heights. Most significant for Ge detectors and proportional counters without grids.

Pulse Analysis: Leading Edge Discriminator

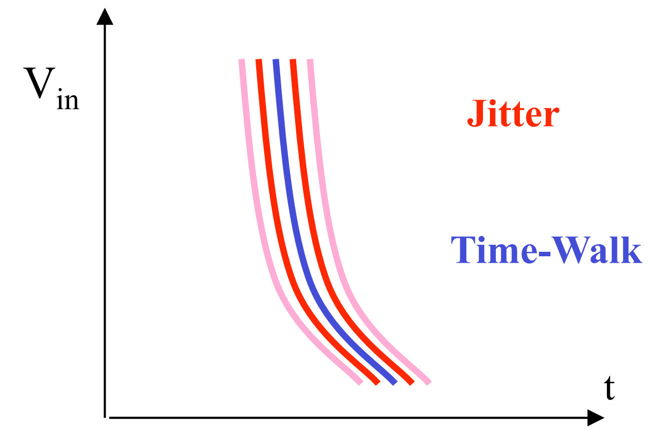
We need a way to generate a logic pulse that maintains a rigid time relationship to the interaction of the radiation in the detector.



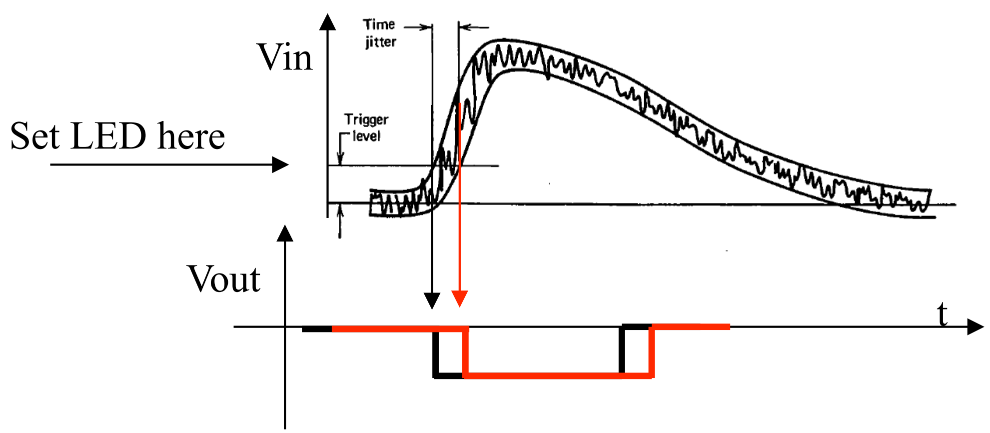
ECL logic, -1.75 or -0.9V
"positive" logic, high-true
Differential Input



Walk Fig. 17.37 Knoll, 3rd Ed



Jitter Fig. 17.36 Knoll, 3rd Ed.



Z/C of bipolar pulse is constant in time but slow

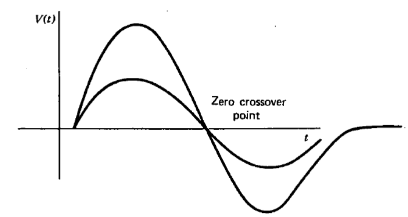


Fig. 17.39 Knoll, 3rd Ed.

Pulse Analysis: Constant Fraction Discriminator

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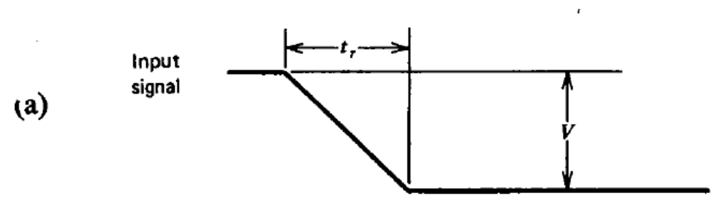
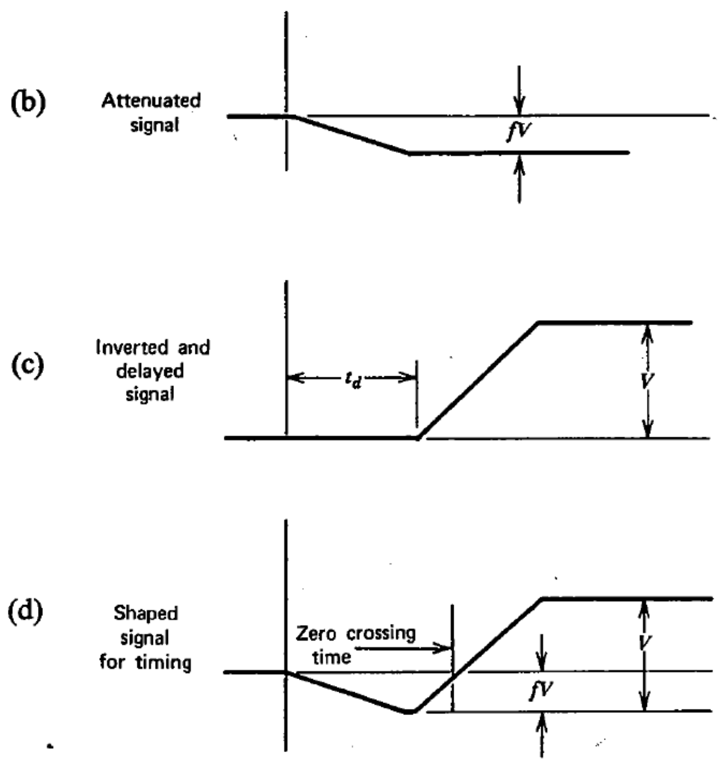


Fig. 17.40 Knoll, 3rd Ed.

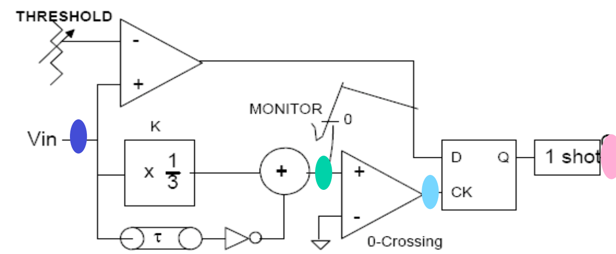


For a linear rise (or fall) slope zero-crossing occurs at $t = t_d / 1\text{-}f$

Thus: set $t_d = f * t_r$

Phillips 715

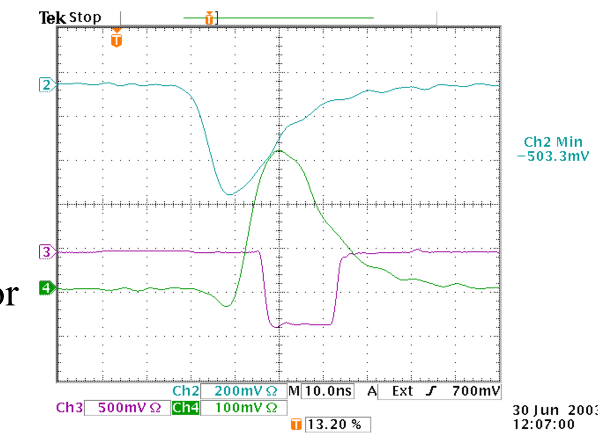
f =1/3



Input

Output

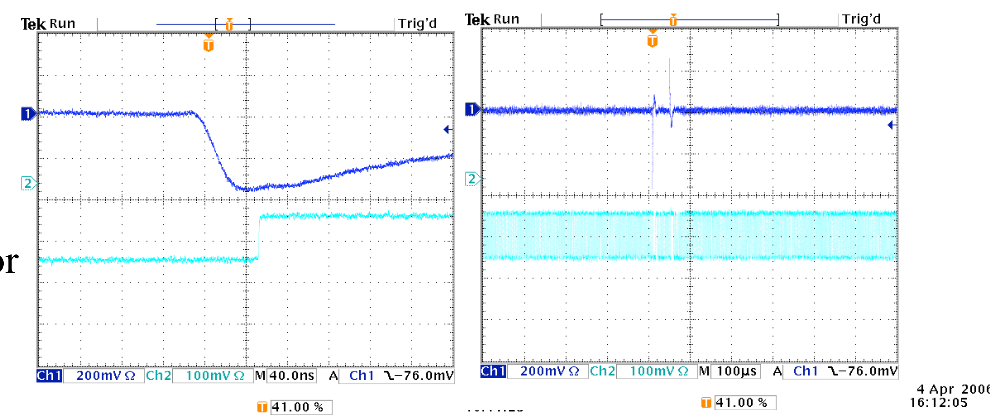
Monitor



Tennelec-455 f=0.2

Input

Monitor



Time width is given by rise-time / (S/N)

Chap. 17 – Pulse Analysis: Question

A silicon detector is attached to surface barrier detector for detecting alpha particles.   What is the maximum *equivalent noise-charge* (ENC) for the preamp if the user wants to resolve the two alpha lines emitted by an ^{241}Am source?