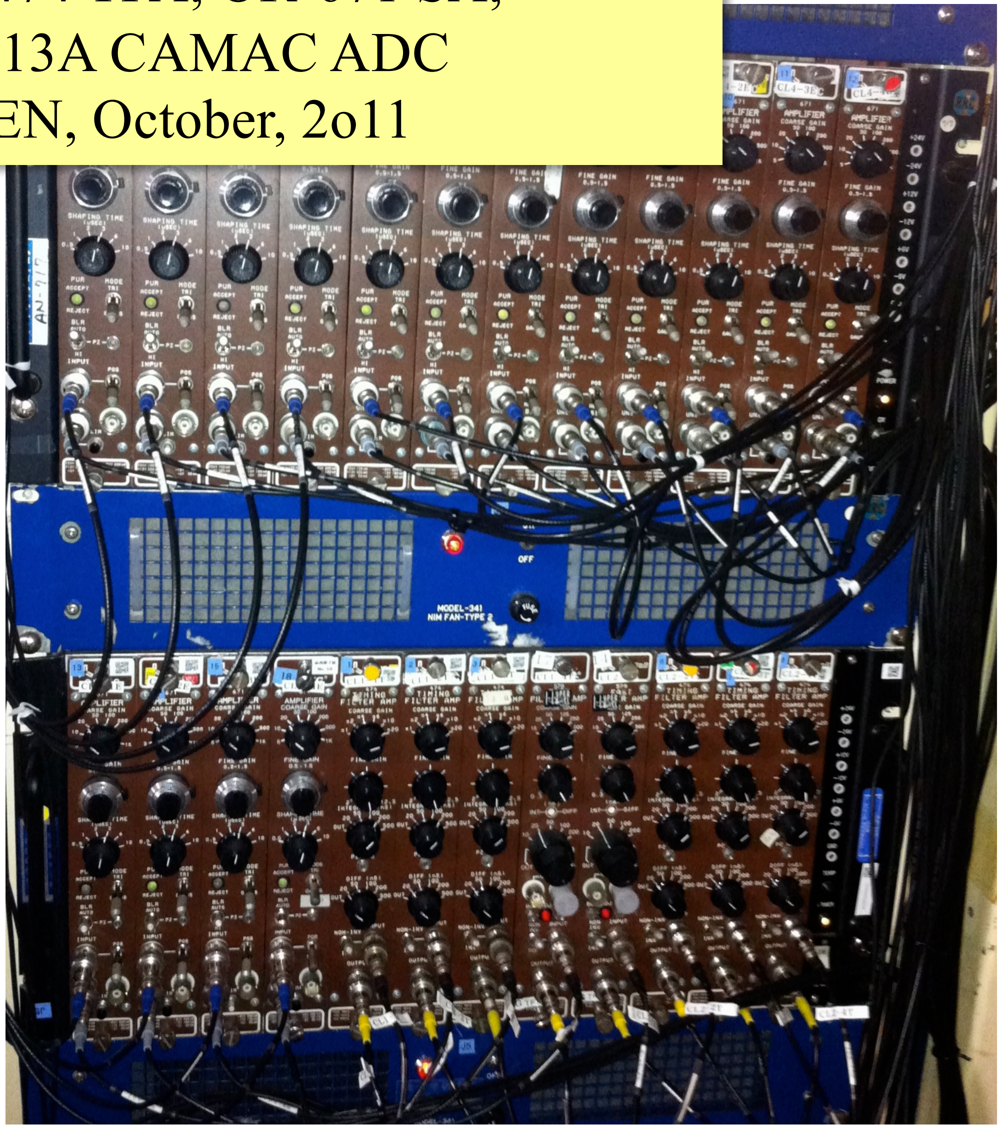
# Week 11: Chap. 16b Pulse Shaping

Pulse Processing (passive)

Pulse Shaping (active)
-- Op Amps
-- CR/RC network
-- Bipolar pulses
--- Shaping network
--- Pole Zero network
--- Baseline Restorer
-- Delay-line clipping

Pulse Processing & Noise

Big RIPS Commercial Electronics
for four clover detectors
OR-474 TFA, OR-671 SA,
AD413A CAMAC ADC
RIKEN, October, 2o11



# Ch. 16b Pulse Processing: Active Pulse Shaping

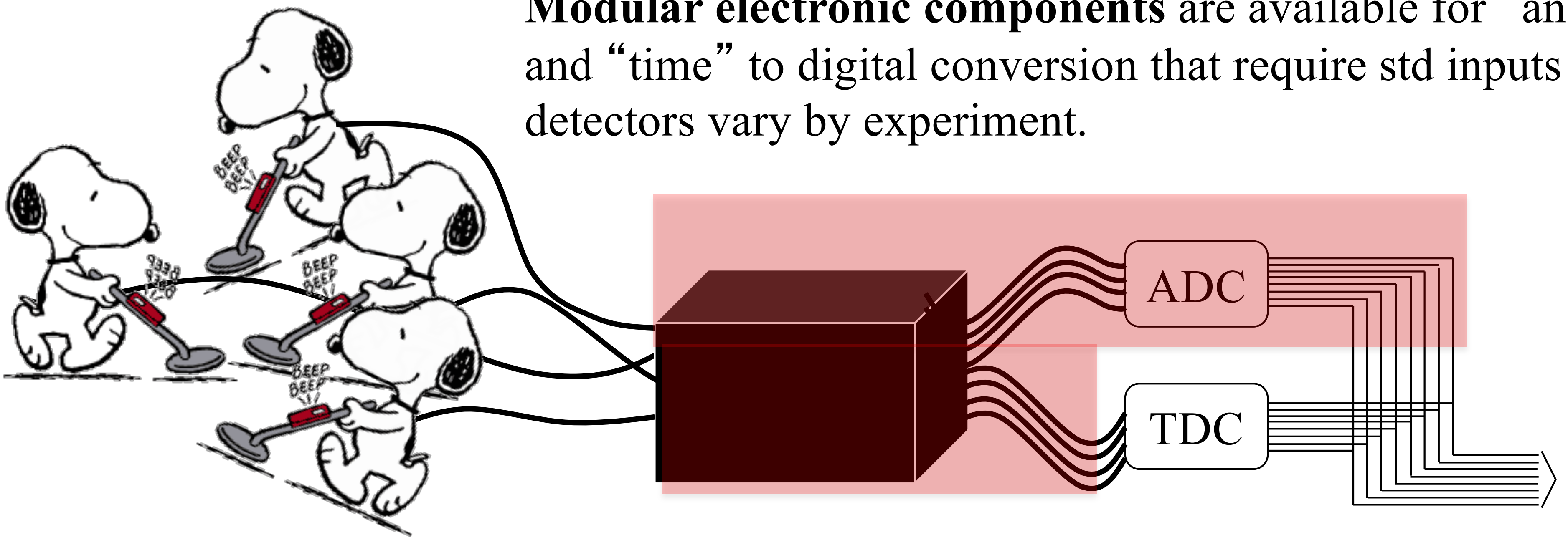
Why shape signals anyway (via analog or digital processing)?

The goal is to measure the charge created in the detector by the primary radiation and the time relationships of signals. We generally need to apply a linear amplification to transmit the signal and to make a decision if we want to process the event.

Pulses from detectors are generally small and either:

- Step functions, sharp rise with long pedestal or tail
- Very fast (sharp in time, ns)
- Time differences are best measured with logic pulses.

**Modular electronic components** are available for "analog" and "time" to digital conversion that require std inputs but detectors vary by experiment.

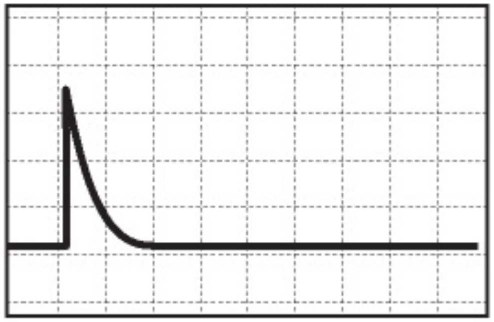


**Digital electronic components** digitize a waveform and apply shaping "filters" to the digital data.

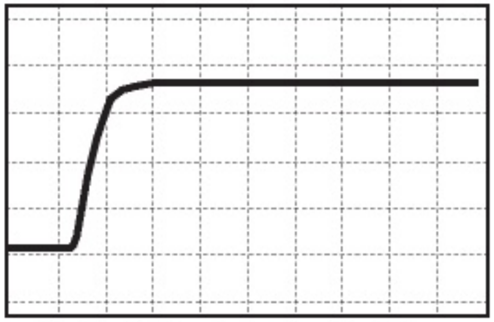
# Pulse Shapes, for example

A recent experiment to study beta decay of exotic nuclei had:

a series of silicon PIN detectors to detect the implantation and then beta decay
→ Output signals from preamp on the PIN detectors have a characteristic rise time of ~10 ns with a decay time of a ~hundred ns.

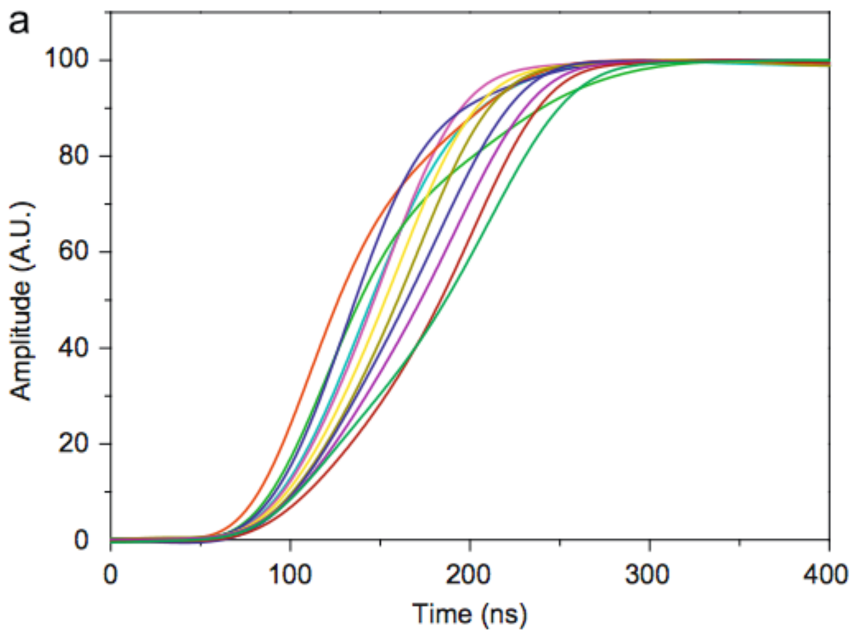


$i_d(t)$: detector current pulse: 10ns/div



$V_{out}(t)$: CSP output pulse: 10ns/div

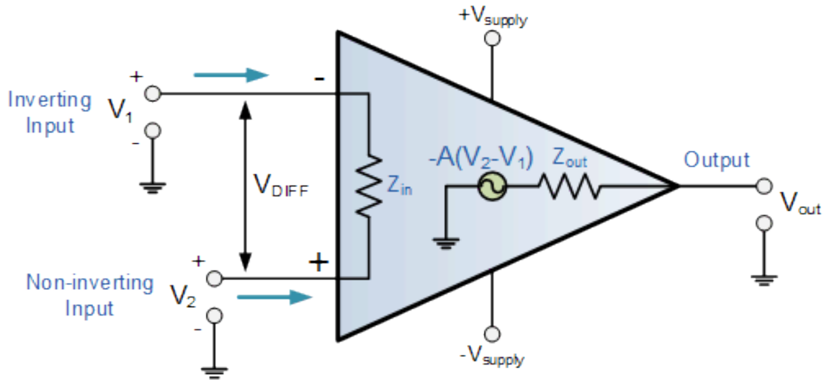
http://physicsopenlab.org/2017/04/28/si-pin-photodiode-β-detector/



Crespi, et al. NIM A 620 (2010) 299

Plus a set of high purity germanium detectors to observe coincident gamma-rays
→ Output signals from the germanium has a characteristic rise time of a few 100 ns and a much longer fall time

# Pulse Processing: Op Amps



An ‘ideal’ or perfect Operational Amplifier is a device with special characteristics such as:

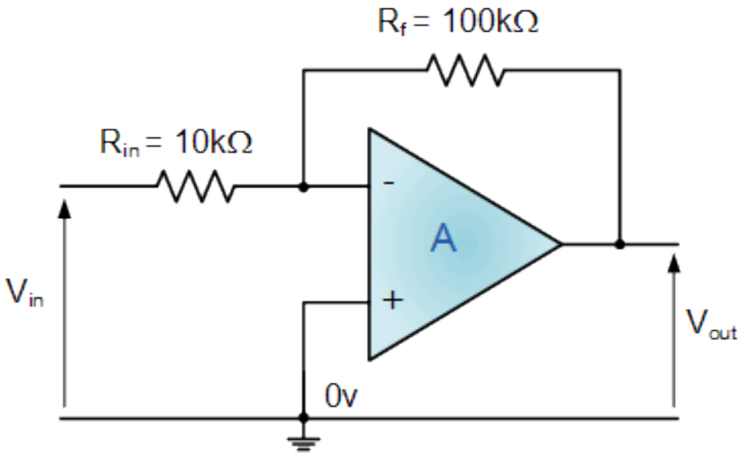
- infinite open-loop gain $A_o$
- infinite input resistance $R_{in}$
- zero output resistance $R_{out}$
- infinite bandwidth (0 to ∞ Hz)
- zero offset (the output = 0 when the input =0)

In reality: $A_0$~100k, $R_{in}$ ~ MΩ, Rout~20Ω

Inverting Voltage Amplifier:

Gain = $V_{out}/V_{in}$ = - $R_f/R_{in}$

This example has G = -10x

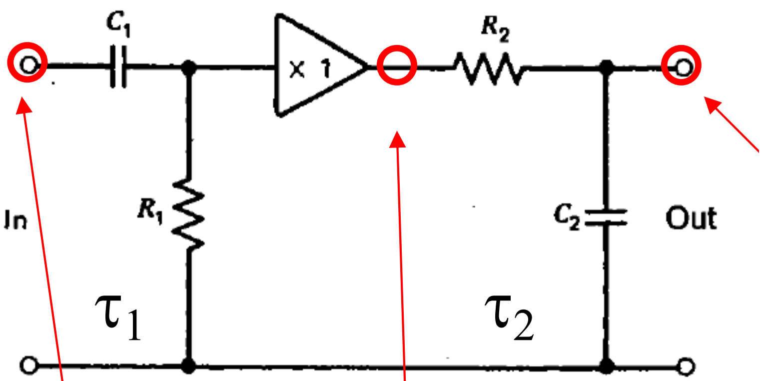


http://www.electronics-tutorials.ws/opamp/opamp_1.html

# Pulse Processing: CR-RC shaper

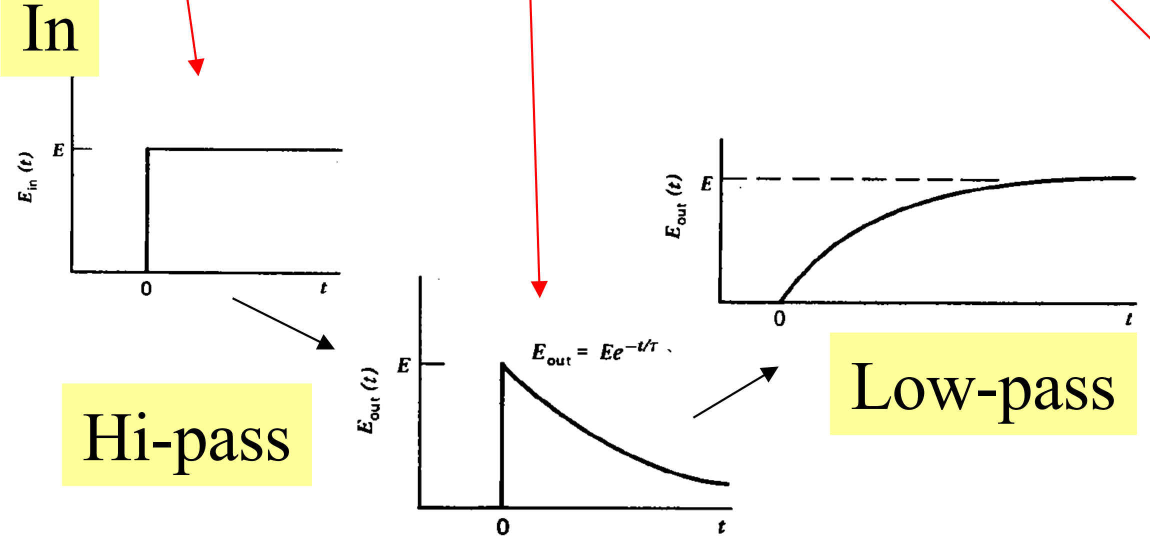
MICHIGAN STATE UNIVERSITY

Fig. 16.11 Knoll, 3rd Ed., 17.4 4th Ed.



The detector output is a “step function” and we would like to convert this into a short “pulse.”

Recall the effect of a poor quality cable on a step function signal: integration.



Cf. Problem 16.11
In Knoll, 3rd Ed.
17.4 in 4th Ed.

$$V_{out} = V_{in}\left(\frac{\tau_1}{\tau_1 - \tau_2}\right)\left(e^{-t/\tau_1} - e^{-t/\tau_2}\right)$$

$$V_{out} = V_{in}\left(\frac{t}{\tau}\right)e^{-t/\tau} \quad \text{for } \tau_{\text{int}} = \tau_{\text{dif}} = \tau$$

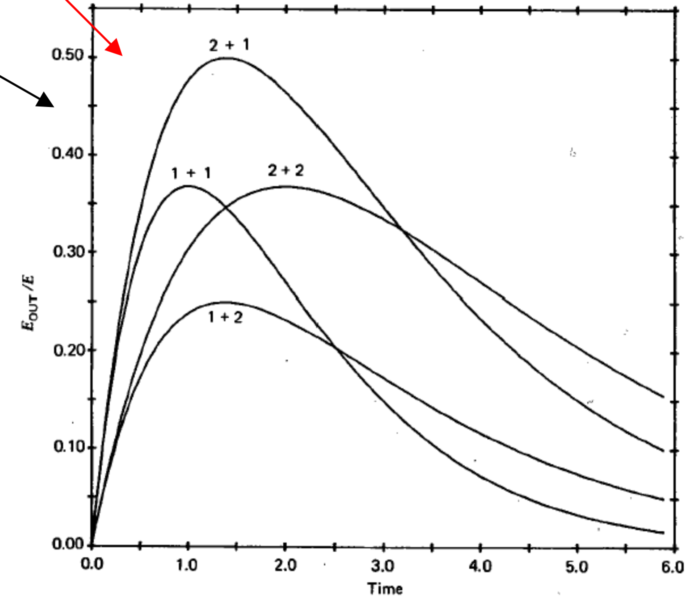
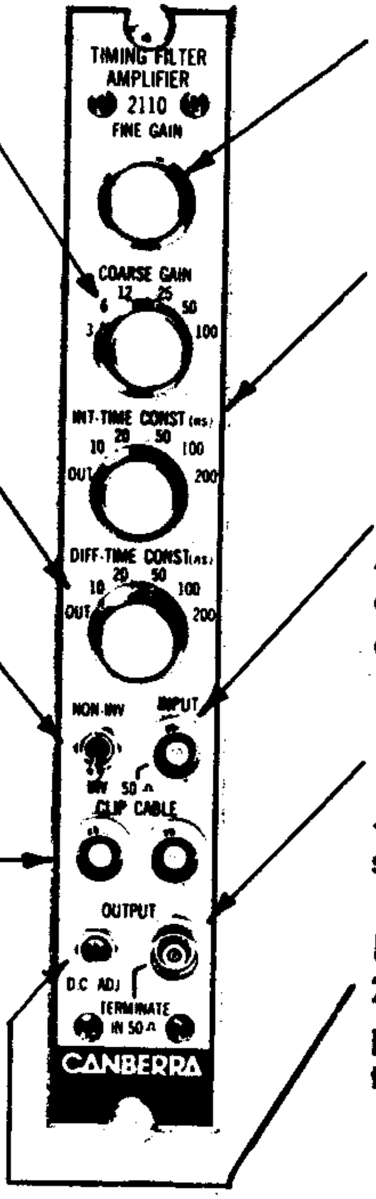


Fig. 16.12 Knoll, 3rd Ed.

17.5 4th Ed.

# Pulse Processing: timing-filter amp

Canberra-2110 “Timing Filter Amplifier”



**COARSE GAIN**
Six position rotary switch to select gain factors of 3, 6, 12, 25, 50 or 100

**DIFF-TIME CONST**
Six position rotary switch to select RC differentiation time constant (DC coupled, 10, 20, 50, 100 or 200 nanoseconds)

**INV-NON INV**
Toggle switch to select inverting or non-inverting output polarity.

**CLIP CABLE**
Provision to use external cable for fastest clipping of pulse width. A 50 ohm terminator is used on left connector when cable clipping is not employed.

**FINE GAIN**
Single turn potentiometer to adjust gain factor from x0.45 to x1.0.

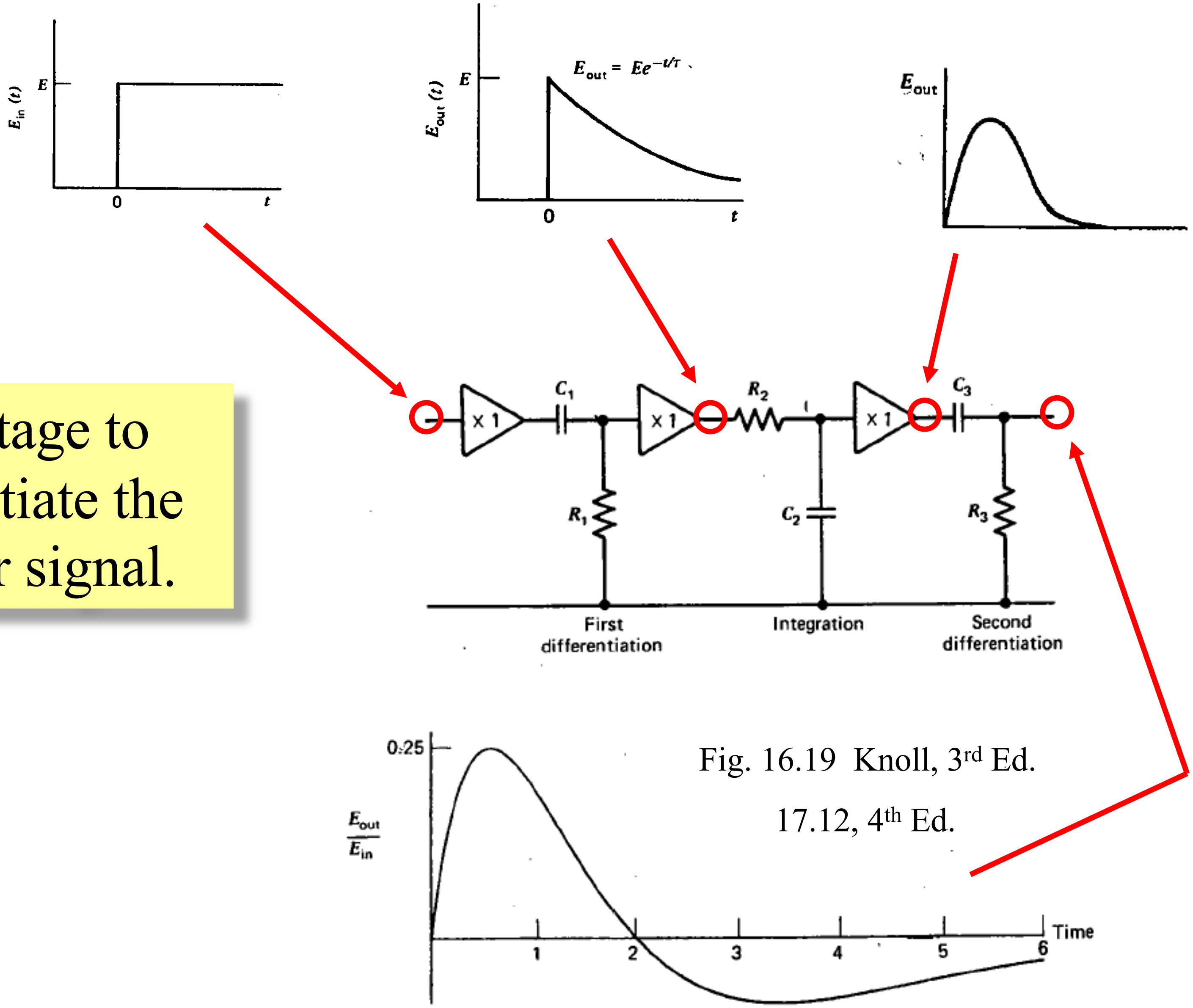
**INT-TIME CONST**
Six position rotary switch to select RC integration time constant (none, 10, 20, 50, 100 or 200 nanoseconds).

**INPUT**
Accepts positive or negative detector signal pulses; Zin = 50 ohms, direct coupled.

**OUTPUT**
Provides current output to external 50 ohm load; swing range ±5V, short circuit protected.

**DC ADJ**
22 turn screwdriver adjustment potentiometer to trim output base line to 0 VDC.

# Pulse Processing: Making Bipolar Pulses

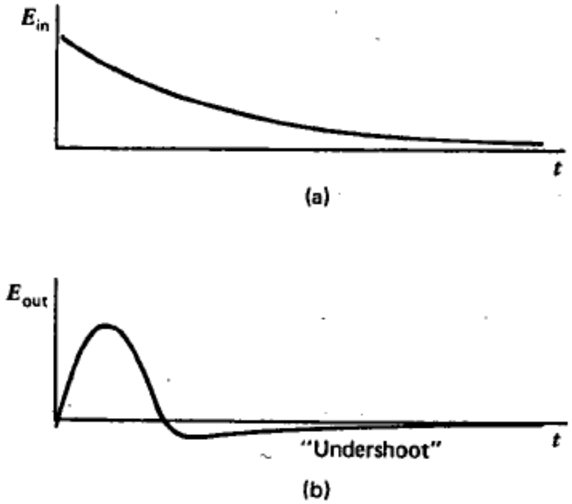


Add a stage to differentiate the unipolar signal.

Fig. 16.19 Knoll, 3rd Ed.

17.12, 4th Ed.

# Pulse Processing: Pole Zero



Common problem is that the input signal is not the step function signal that the shaping amplifier is expecting ...

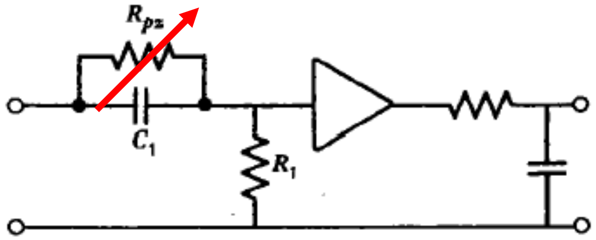
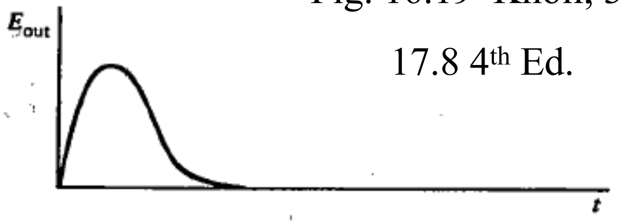


Fig. 16.19 Knoll, 3rd Ed.

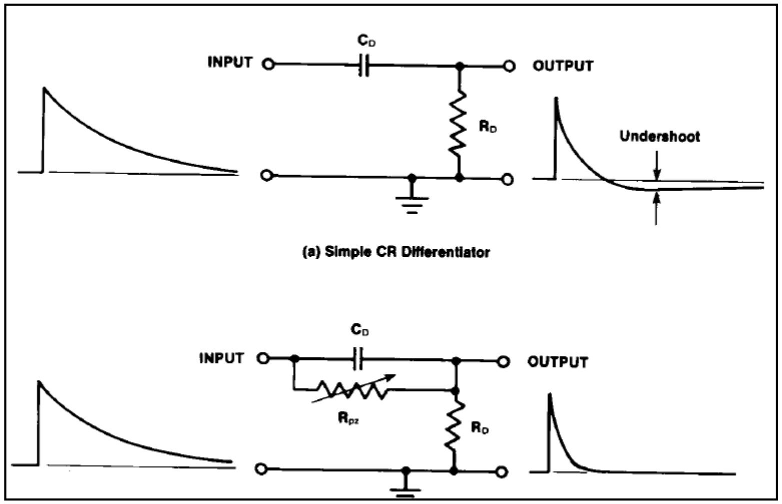
17.8 4th Ed.



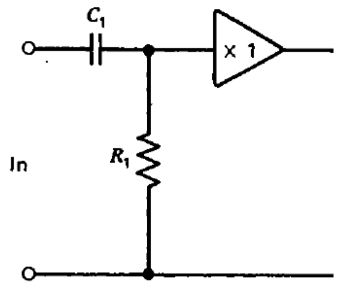
$$\frac{V_{undershoot}}{V_{dif}} \approx \frac{\tau_{dif}}{\tau_{in}}$$

E.g., Silicon preamplifier:
~50 µs → 2% when τ = 1 µs

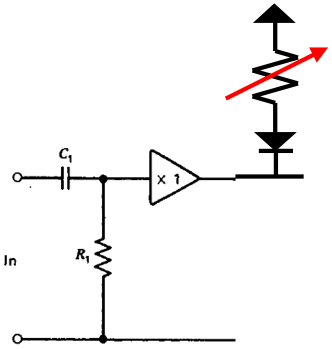
Organic Scintillator & Phototube:
~ 1 µs → 100% when τ = 1 µs



# Pulse Processing: Baseline restoration



Charge injected onto $C_1$ must be cancelled (drained off) by current through $R_1$ (amp has $Z \sim \infty$)



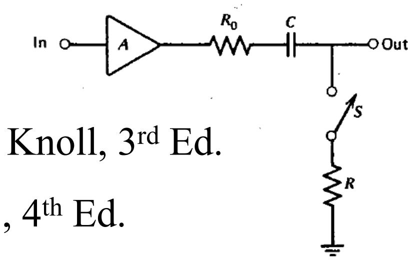
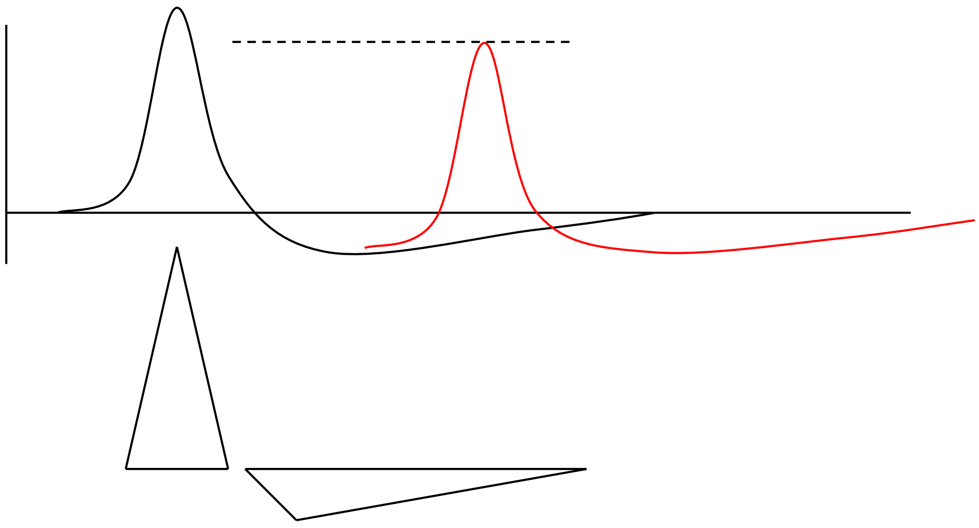
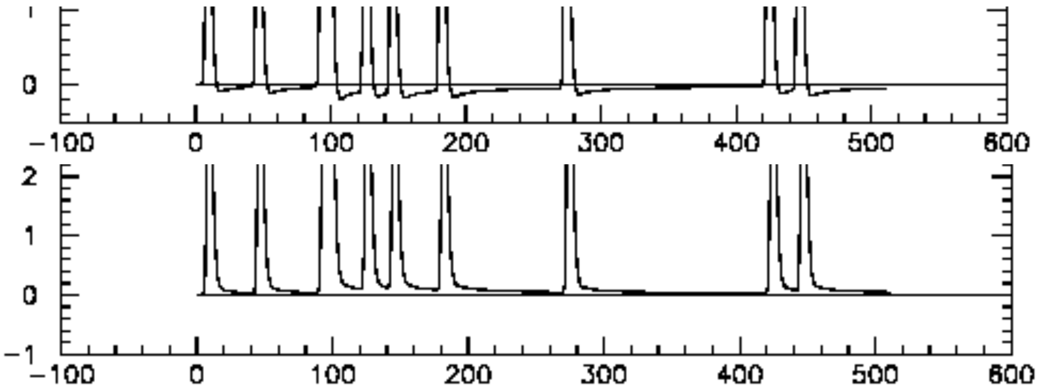


Fig. 16.18 Knoll, 3rd Ed.

17.11, 4th Ed.

A different problem with a similar symptom ... Baseline shift





# Pulse Processing: Delay-line Clipping

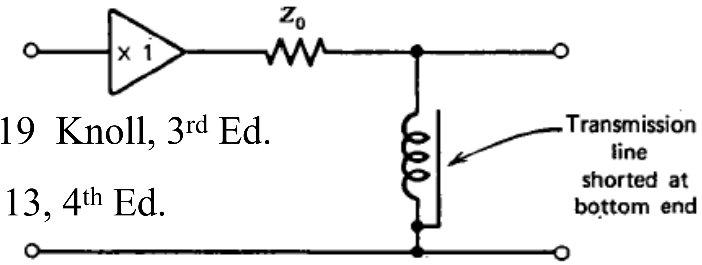
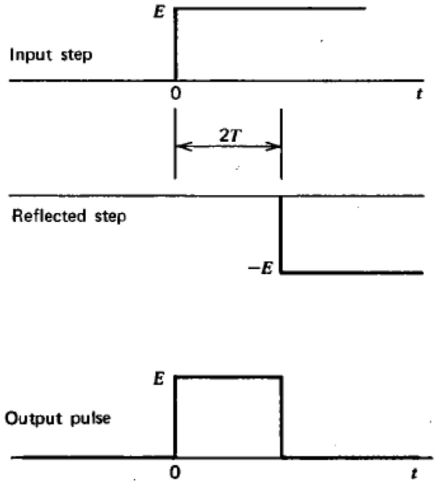


Fig. 16.19 Knoll, 3rd Ed.

17.13, 4th Ed.



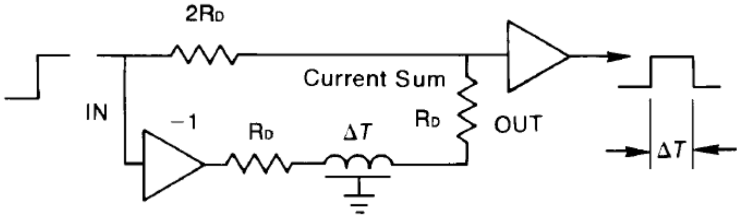


Fig. 14.10a Leo, 2nd Ed.

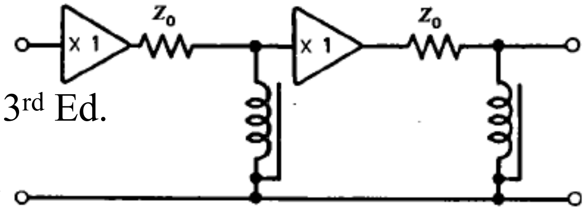
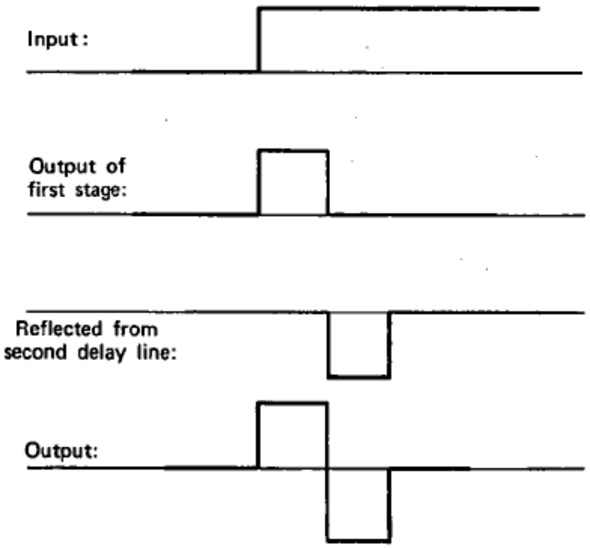


Fig. 16.22 Knoll, 3rd Ed.

17.15, 4th Ed.



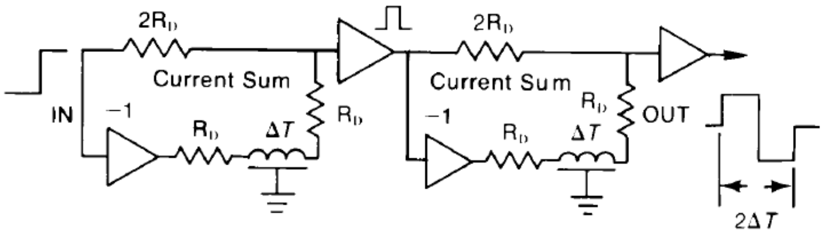
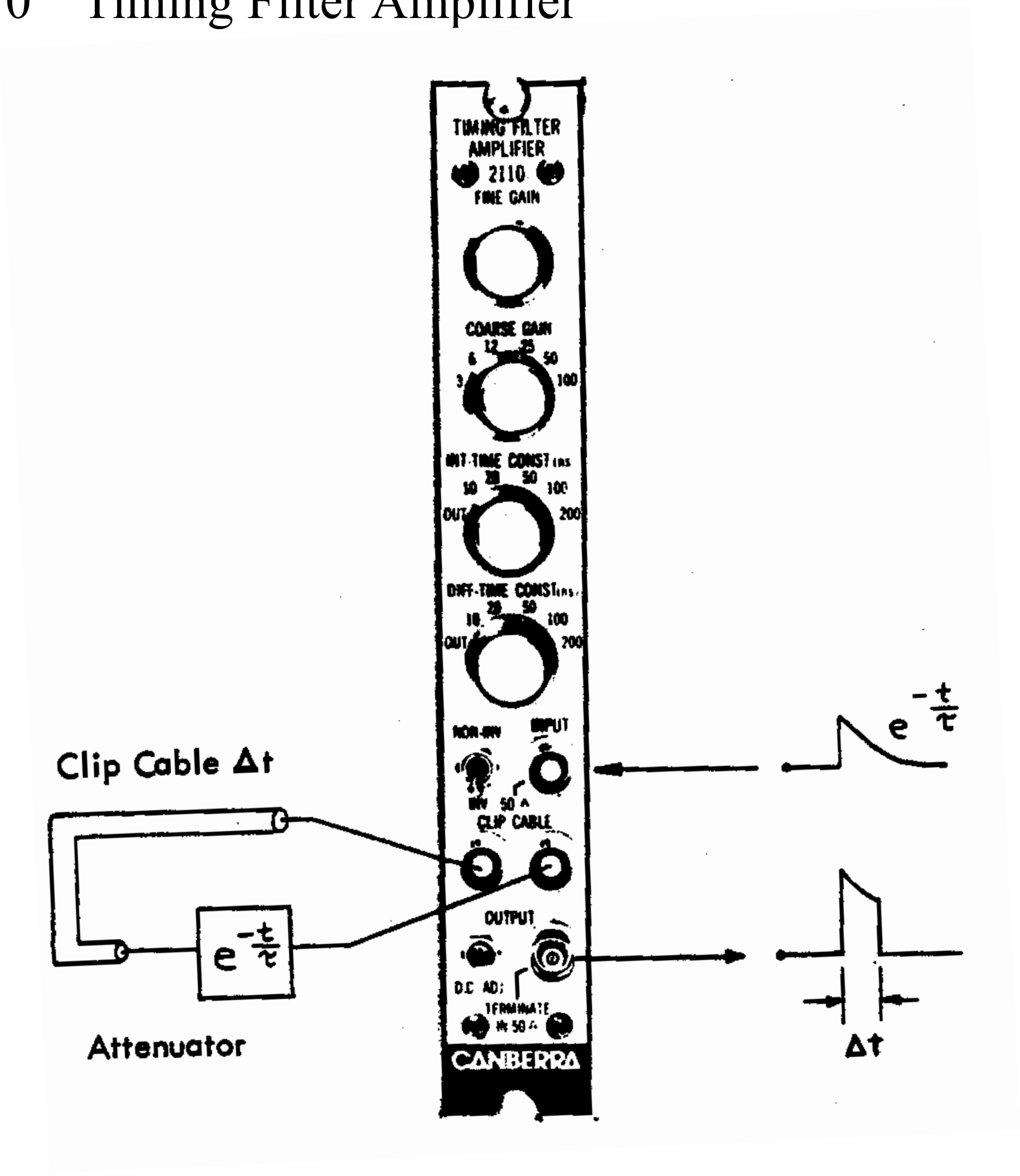


Fig. 14.10b Leo, 2nd Ed.

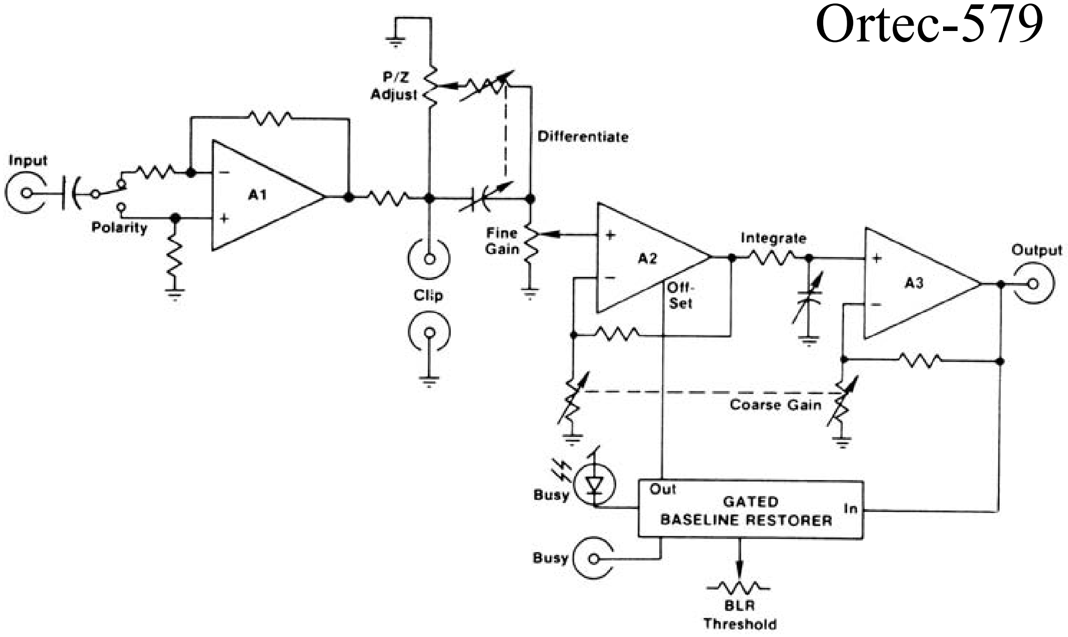
# Pulse Processing: timing-filter amp

Canberra-2110 “Timing Filter Amplifier”



# Pulse Processing: timing-filter amp

Ortec-579 “Fast Filter Amplifier”



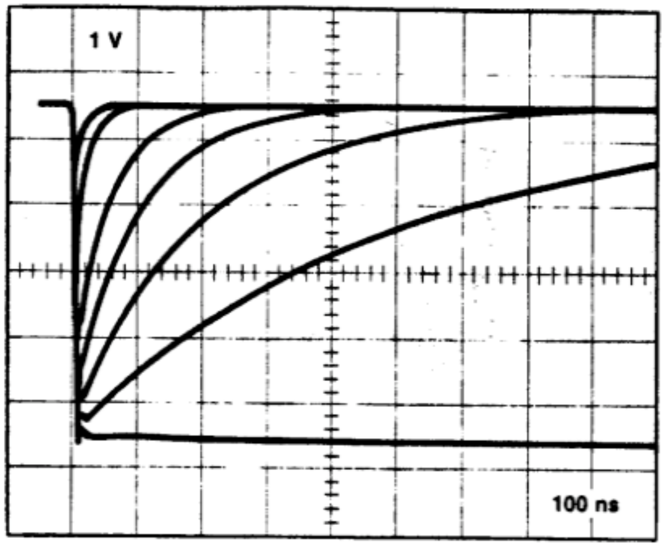


Fig. 1.9. 579 Output Signals for $\tau_I$ = Out and $\tau_D$ = Out, 10, 20, 50, 100, 200, and 500 ns.

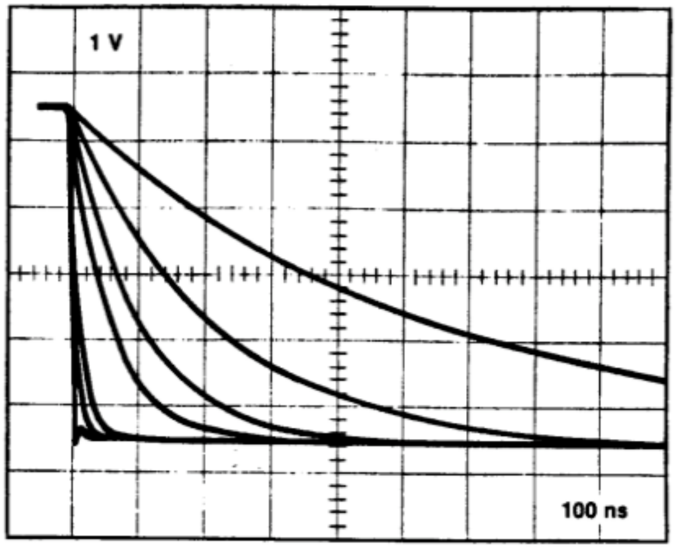
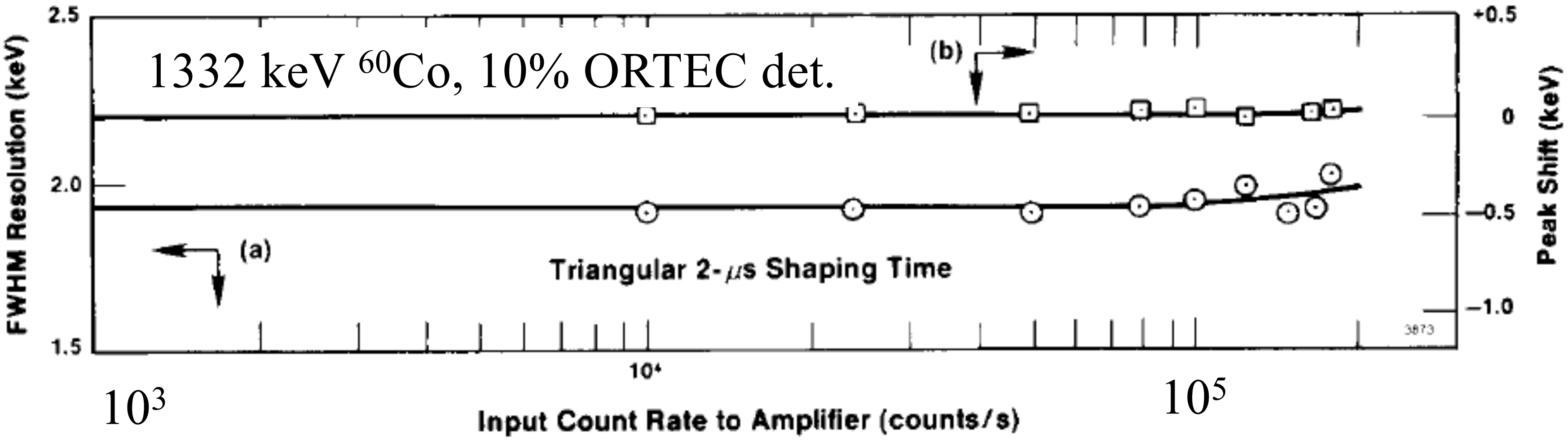


Fig. 1.8. 579 Output Signals for $\tau_D$ = Out and $\tau_I$ = Out, 10, 20, 50, 100, 200, and 500 ns.

# Pulse Processing: Question



The figure shown above is used by ORTEC to advertise the quality of the baseline restorer in a particular linear amplifier. The figure shows the peak shift (upper curve, right scale) and the resolution (lower curve, left scale) for the $^{60}$Co line as a function of counting rate. Compare the indicated shaping time of the amplifier to the mean time between pulses arriving at the input at $10^5$ counts/s.