# Intro to Signal Processing cont'd.

# Today's Agenda

## Electronics tasks for ANSEL experiments (continued)

- ❑ Radiation → PM Sc. detector → electronic signal
- ❑ Electronic modules, cables
- ❑ Signal distortions
- ❑ Spectrum calibration
- ❑ More complex electronics setups

Reading Assignments
(Weeks Feb 12, 19, 26):
Knoll, Ch 4 Radiation Detectors,
Ch 8 Pulse Processing
Ch 17 Linear and Logic Pulse
Functions

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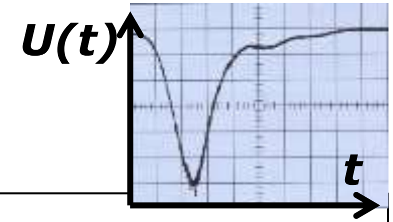
Next: Interactions of particles with matter,

ANSEL Experiments spectroscopy with solid state detectors

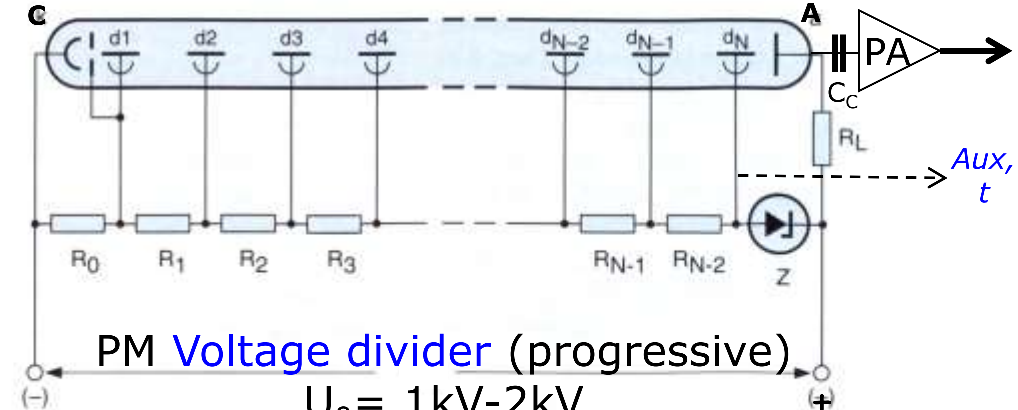
# PM Operation

Fast PM: pulse rise time ~2ns, gain: $3 \cdot 10^7$



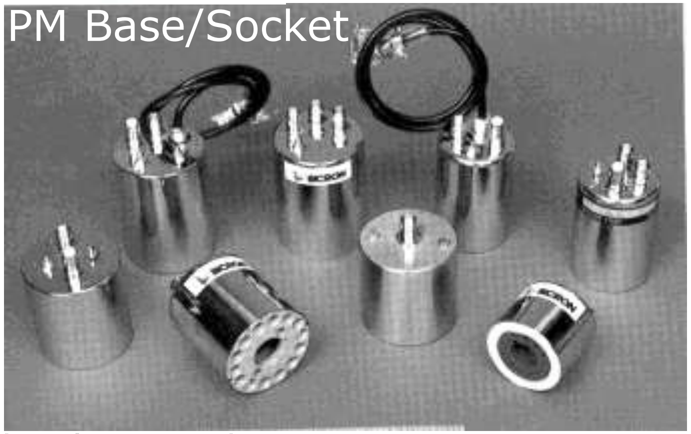


Philips XP2041
5″ dia cathode
14 dynodes
+ focusing electrodes



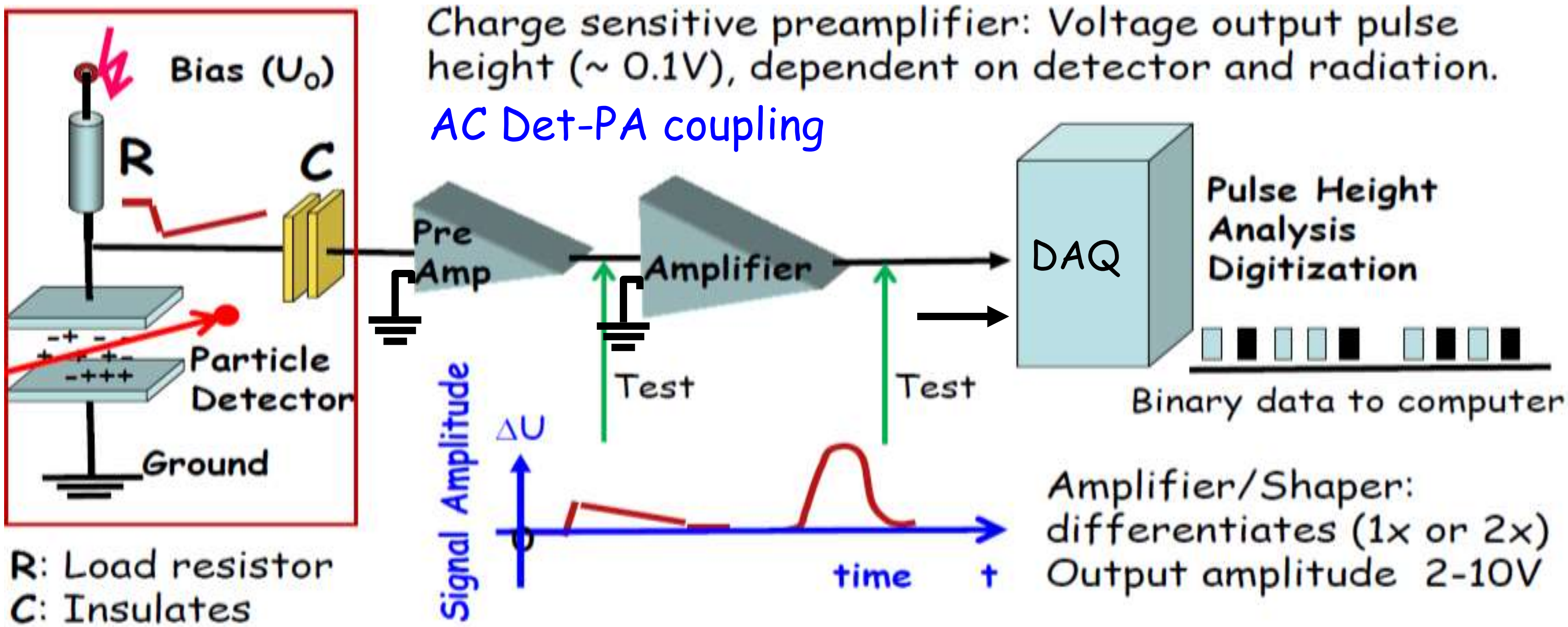


Socket FE1120 pin connections




mu-metal shield tube provides protection from external B field.

# Basic Radiation Detection/Counting System




**R**: Load resistor
**C**: Insulates electronics from HV bias.
Pulse height 20-100 mV

Preamplifier:
1) Integrates all radiation produced $e^-$ within rise time
   Energy information contained in rising part.
2) Makes tail pulses, $\tau_f \sim R \cdot C$ .

Main amplifier:
1) Amplifies signal
2) Reduces noise from detector, PA
3) Shapes output signal

# Pre-Amplifiers

Photomultiplier socket with voltage divider and preamplifier (ORTEC)

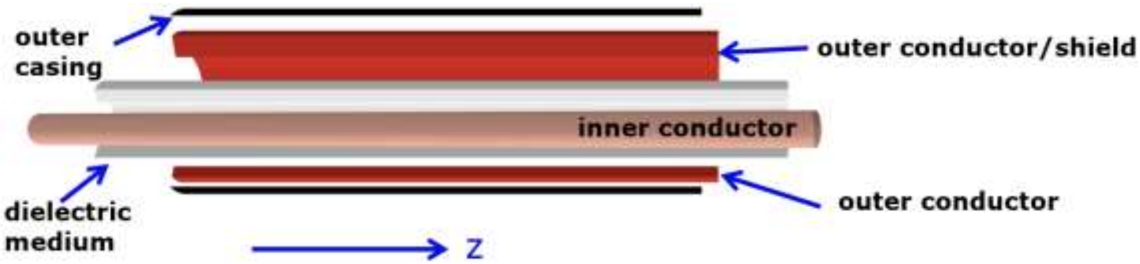
Preamplifier for solid-state detectors (ORTEC)



Functions: Provide operating power (DC bias) to detector, decouple time-dependent signal, produce, amplify and transfer response proportionally as voltage or current pulse for further signal processing.

Also: Test input for external signals (linearity).

# RF Coax Signal Cables/Wave Guides




Coaxial cables/transmission lines ←→ traveling waves in cavity resonators

Coaxial cable carries AC voltage differential between coaxial inner and outer conductors. Specific resistivity, capacity, inductivity per unit length.
→ complex impedance ***Z***.

## RG59/U coaxial cable (BNC)

Stiffer than RG58
75 Ohm impedance
Dual shielded cable:
copper braid (60%) over foil
22 AWG copper covered steel center conductor

## Amphenol **RG58** coaxial cable (BNC)

Impedance 50 Ohm
Black PVC cable, tinned copper center conductor & braid
for high Velocity of Propagation: 66% (**5ns/m**)

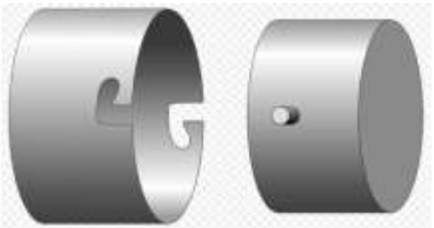
## LEMO RG174 coaxial cable (LEMO)

| | |
|---|---|
| Impedance | 50 ohms |
| Inner Conductor Diameter | 0.48 mm |
| Dielectric Diameter | 1.52 mm |
| Shield Diameter | 2.23 mm |
| Capacitance | 100.0 pF/meter (30.5 pF/foot) |
| Minimum Operating Temperature | -40 C (-40.0 F) |
| Maximum Operating Temperature | 75 C (167.0 F) |
| Jacket Diameter | 2.79 mm |
| Jacket Material | PVC |
| Velocity Ratio | 66% |
| Core | stranded |

# Connectors for Coax Signal Cables

**BNC**
**B**ayonet **N**eill-**C**oncelman

"I"
"Barrel"



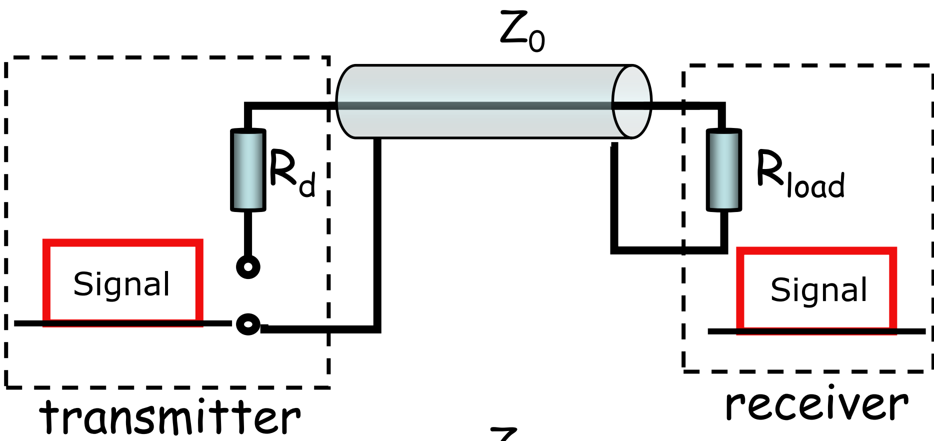
Bayonet mount
locking mechanism

**LEMO**
**Lé**on **Mo**uttet
Push-pull connectors

"TEE"
Splitter

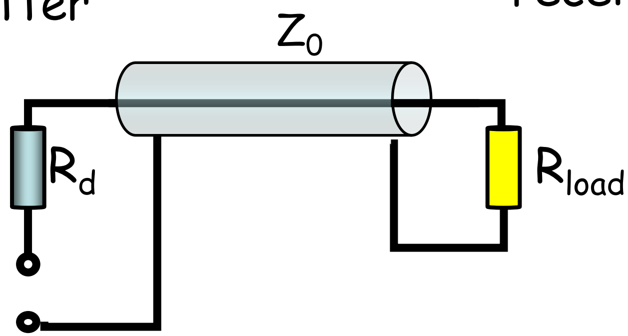
LEMO
"Elbow"

# Cable Impedance Matching

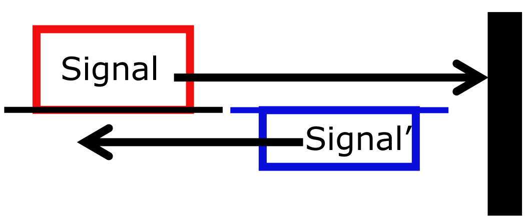



Coax cable has complex impedance Z for signal transmission, $ReZ=Z_0$

For impedance matching, $R_{load} = Z_0$, cable "looks" infinitely long: no obstacle, no reflections from end. $Z_0 \approx 50\ \Omega$ here



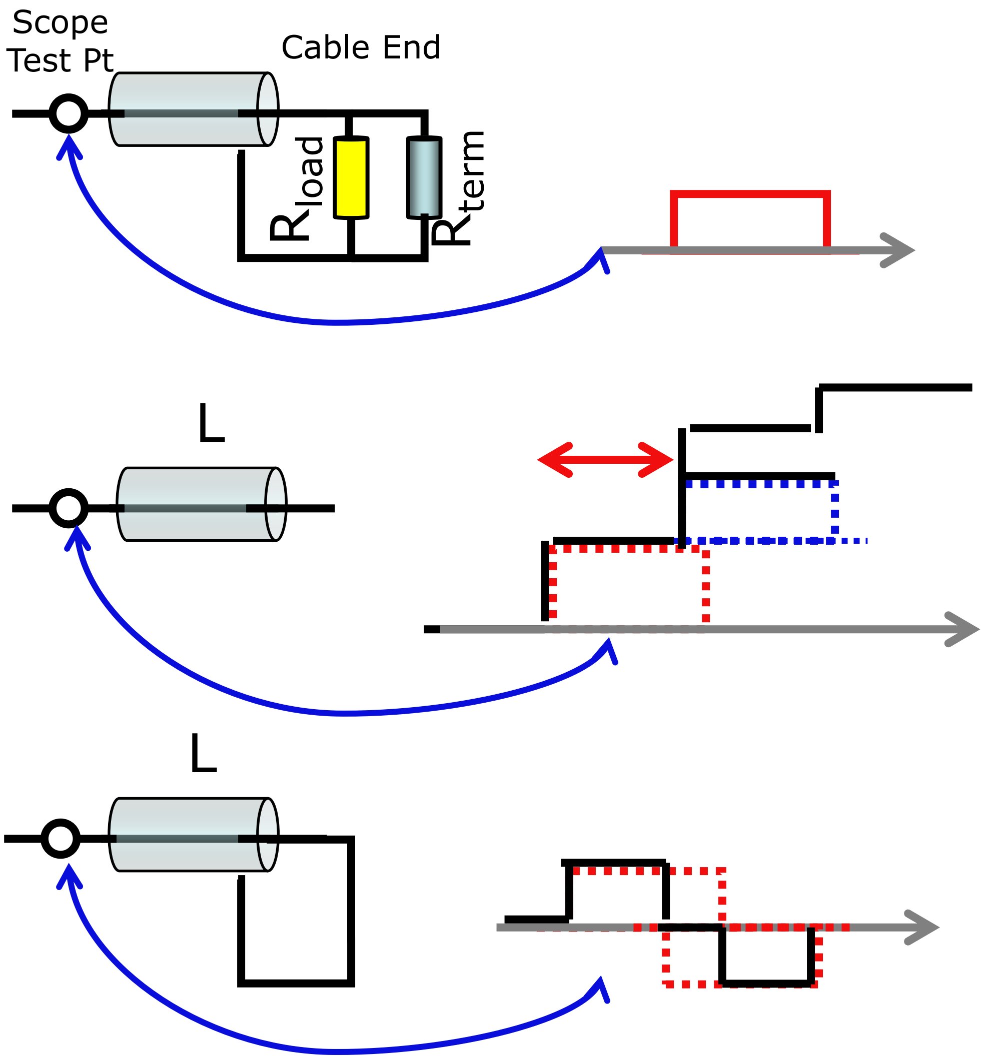

For mismatch, $R_{load} \neq Z_0$, reflections at end, traveling back, superimpose on original signal after travel time to end and back.




$$\frac{U_{refl}}{U_{in}} = \frac{R_{load} - Z_0}{R_{load} + Z_0}$$

Q: What is polarity of reflected signal for $R_{load} = 0$ (short) or $\infty$ (open circuit) ?

# Cable Reflections




Receiver input impedance $R_{load} \neq Z_0$,
→ use additional Ohmic termination in parallel

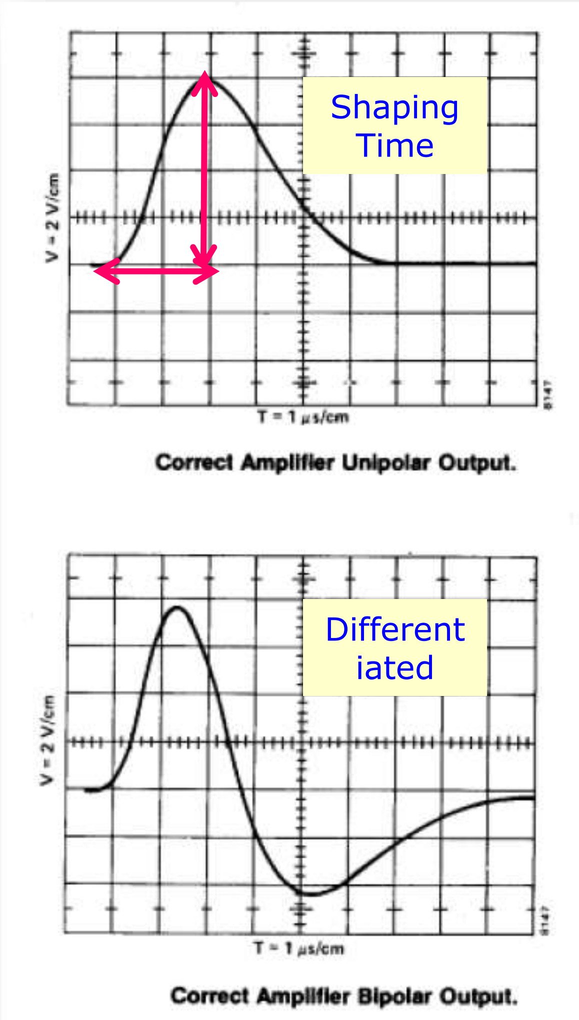
Open end: $R_{load} = \infty$
Input and reflection equal polarity, overlap for $t > 2T_{cable}$

$T_{cable} = 2L/c$

Short: $R_{load}=0$, Input and reflection opposite polarity, superposition = bipolar

Multiple (n) reflections attenuated by $R^{-n}$

# Main/Spectroscopy Amplifiers







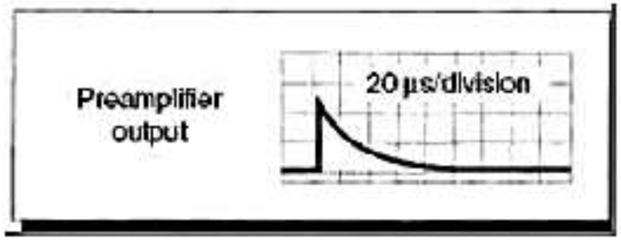
**Tasks:** Generate signal with amplitude **proportional** to collected detector charge. Needs absolute calibration of pulse amplitude.

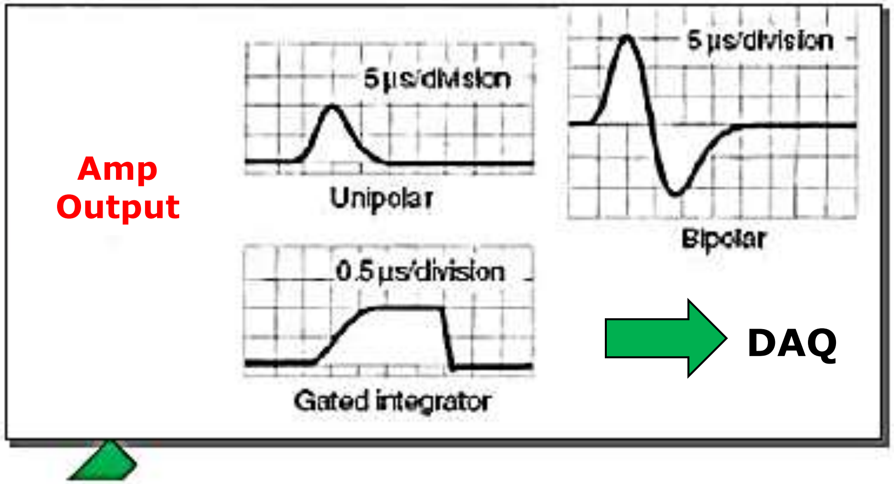
Amplifier shaping time affects amplitude (peak height), resolution, and time at max.

← **Preamp Power**

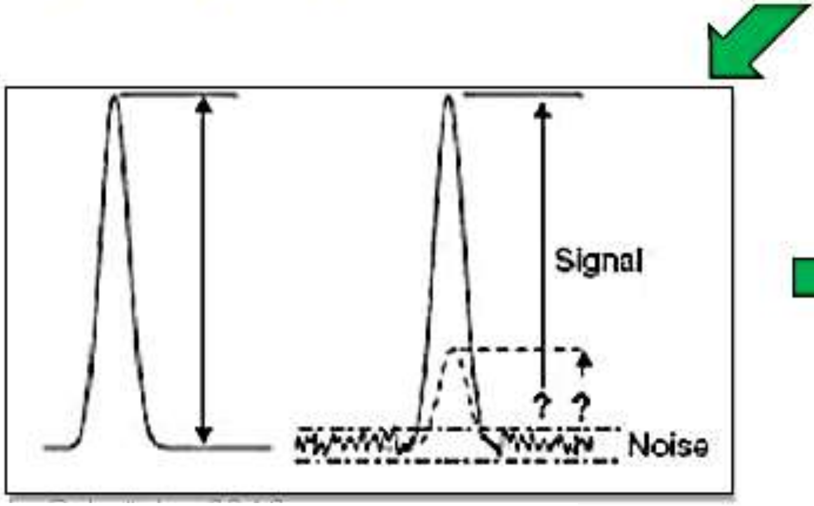
# Spectroscopy with Analog/Digital Electronics

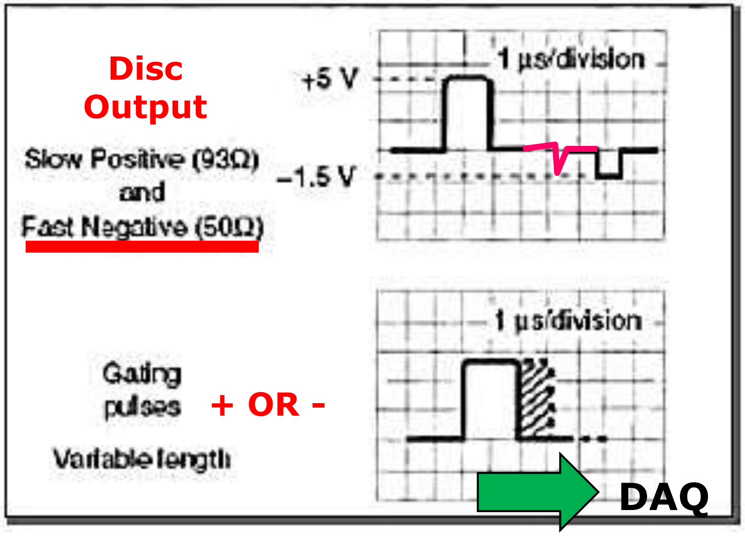
**Analog (slow) circuit** → proportional image detector output signal



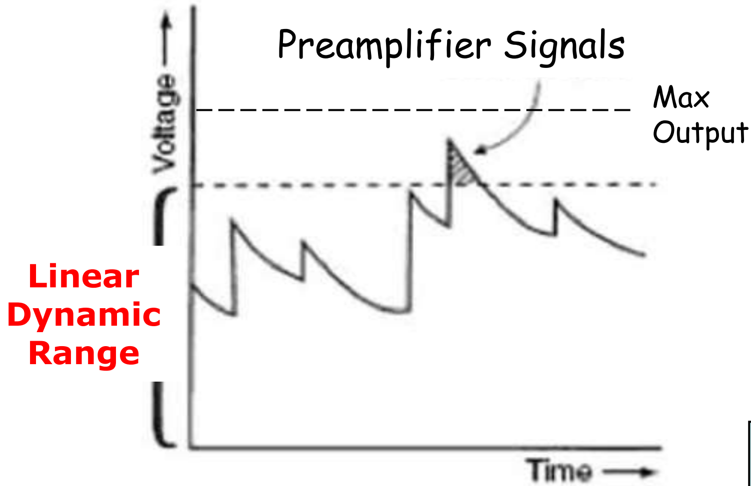




**Digital (fast) circuit** → yes/no information on signal presence

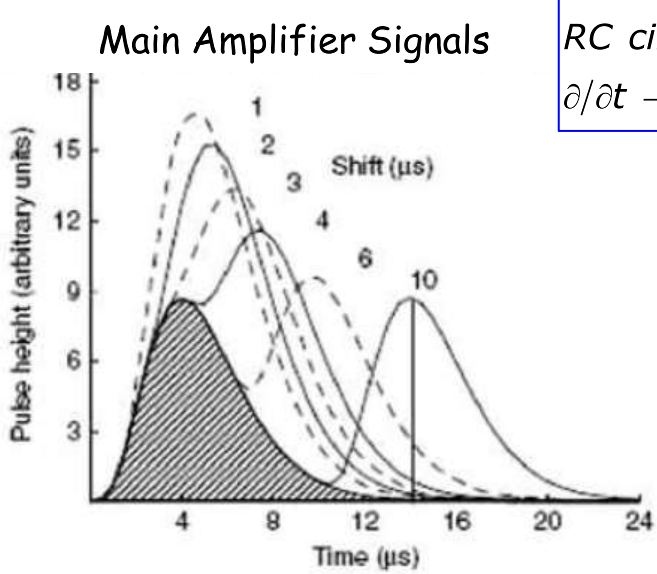


# Spectral Distortions: Pile-Up




*Main Amp*
*RC circuits*
$\partial/\partial t \rightarrow \int dt$



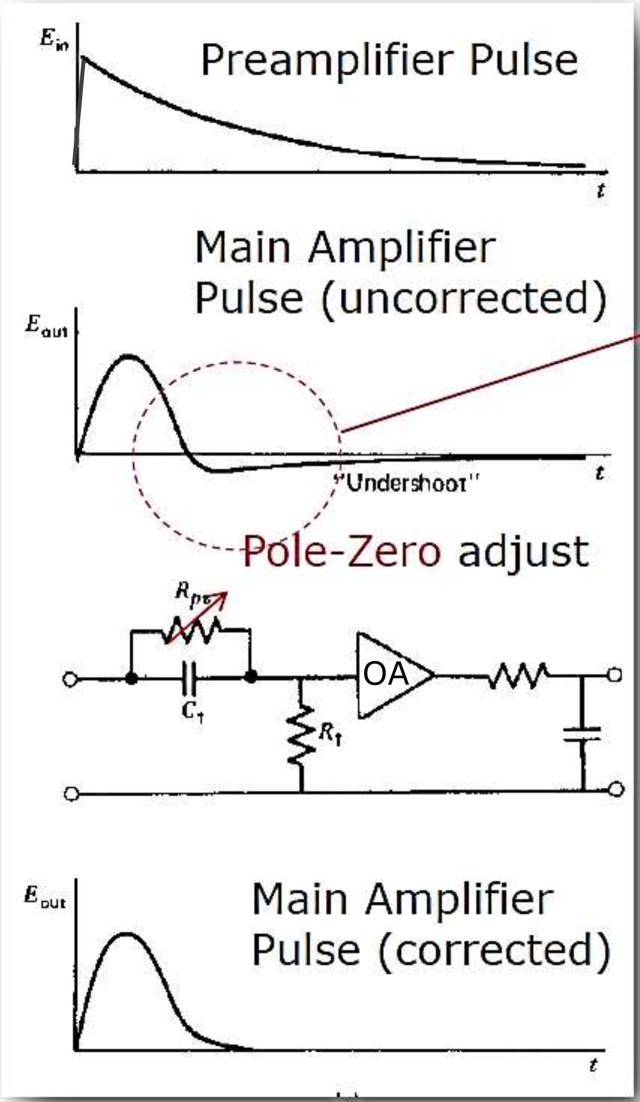

High count rate (relative to pulse length/decay time) can lead to pile up
→ from small non-linearities to serious distortions, line shapes "ghost lines"

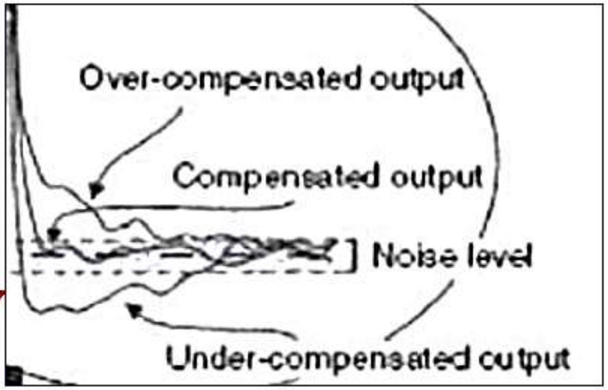
Check signals on very different time and amplitude scales!
Danger to miss features.

Artificial test of the pile-up effect. Successive signals add on to each other, creating an effectively non-zero base line.

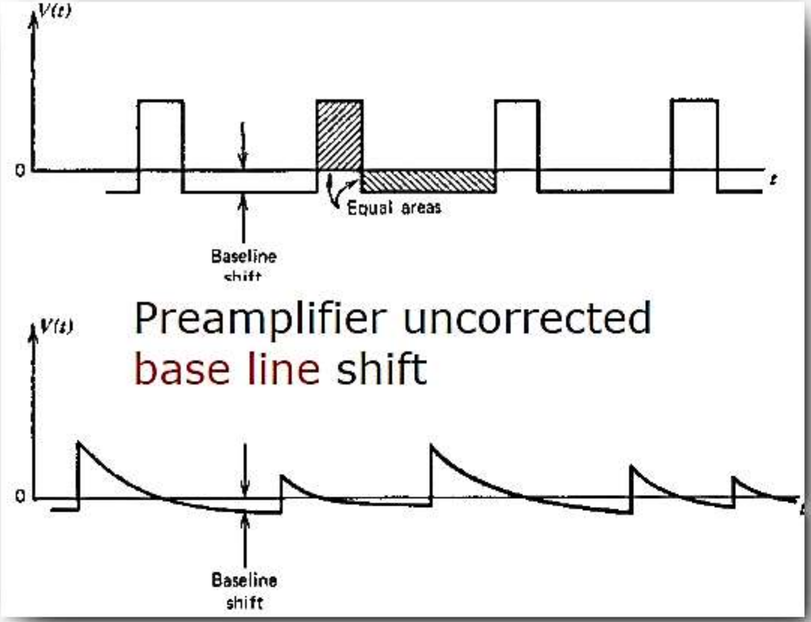
Avoid by reducing signal rate or width (pulse decay time)

# Spectral Distortions: Pole-Zero & Base-Line Shift



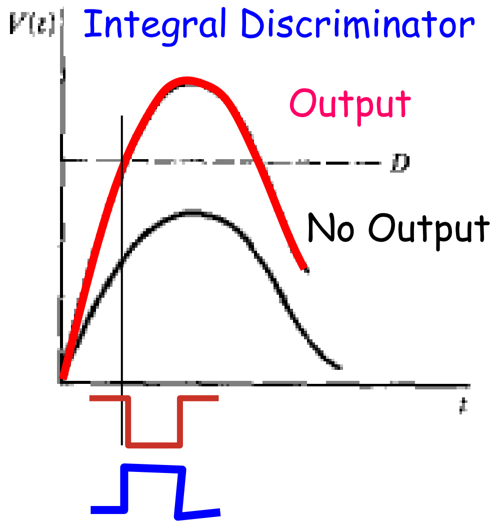



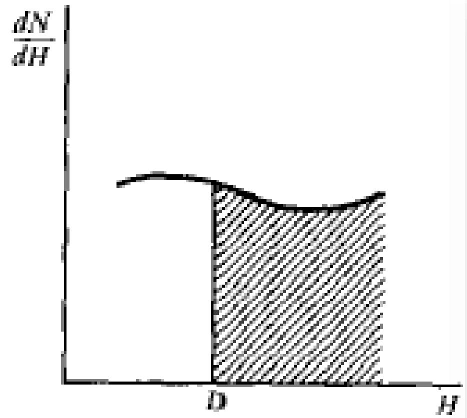

Blow-up of pulse under/over shoot

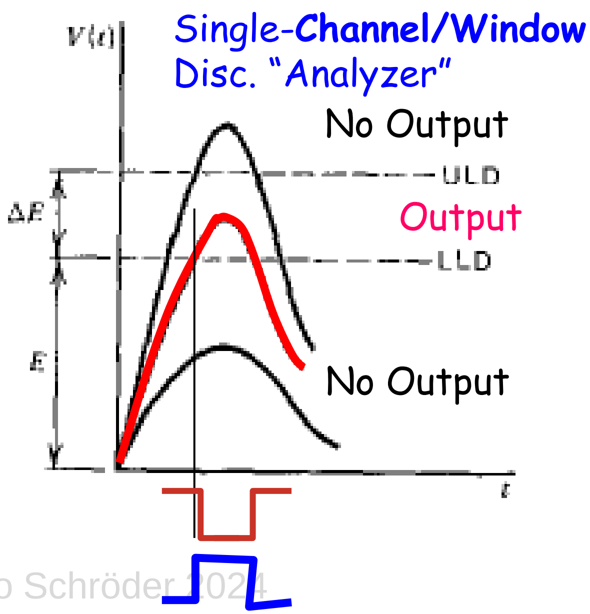


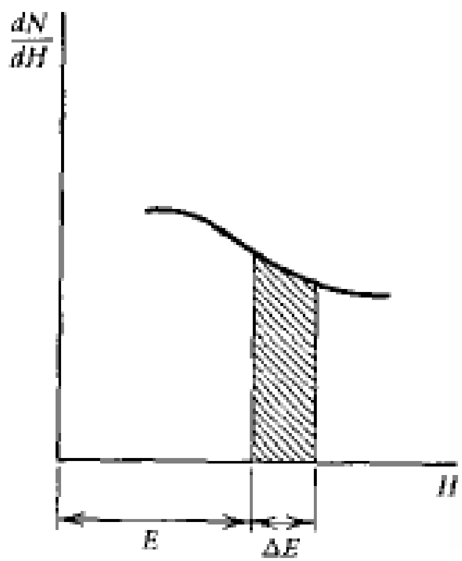
# Leading-Edge Discriminator: "Single Channel" TSCA

**Tasks: Indicate presence of event, define time-zero $t_0$**



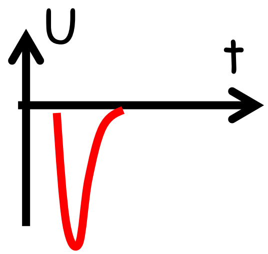



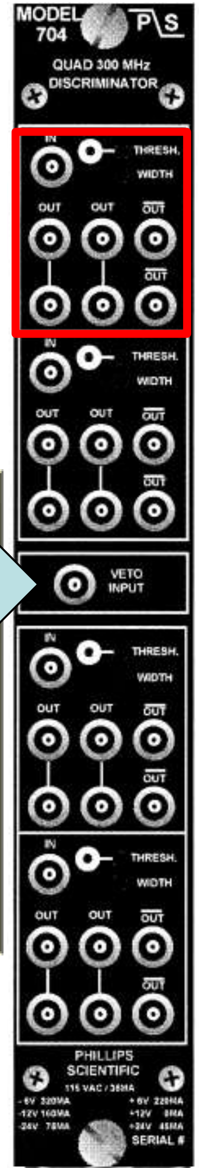




# Logic Chain Elements: Fast NIM Modules

Fast LE Discriminator

Pre/Amp




Veto

Input: fast, narrow NIM signal

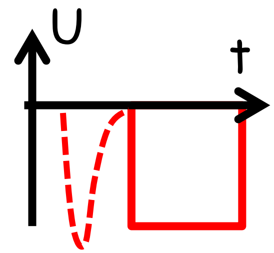
**NIM =** current based logic, with negative "true"

$I$ = -16 mA

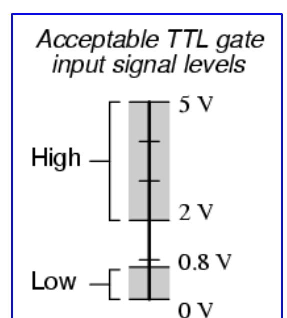
@ 50 Ω → - 0.8 V

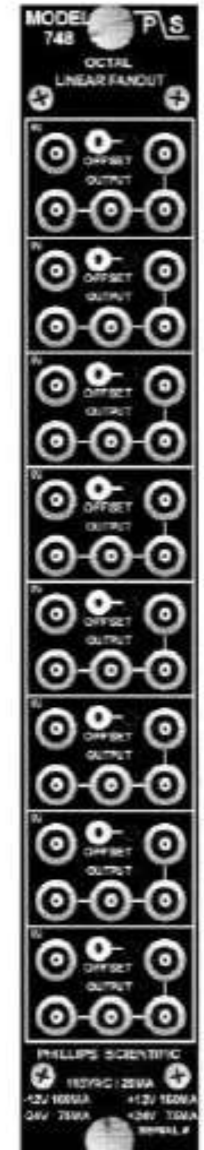
Check on 50 Ω termination


Gate & Delay Generator




Output: Long NIM/TTL "gate" signal

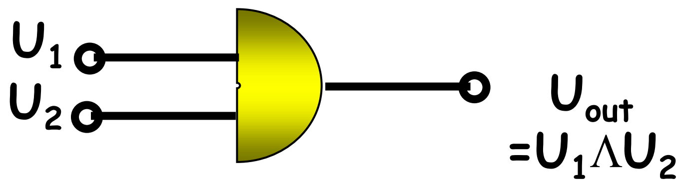


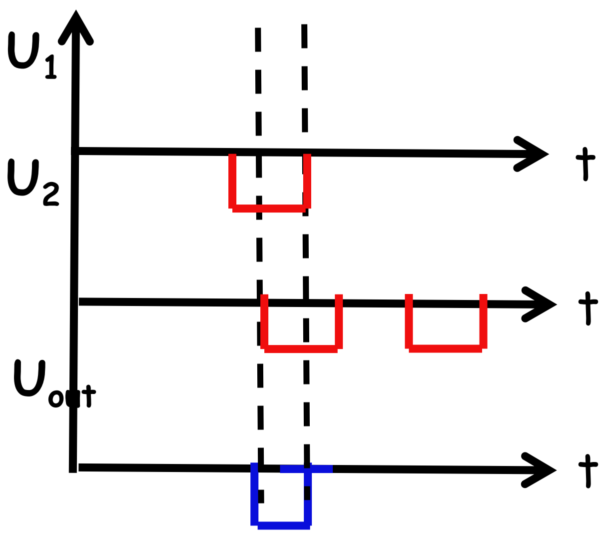




Fan In/ Fan Out Module

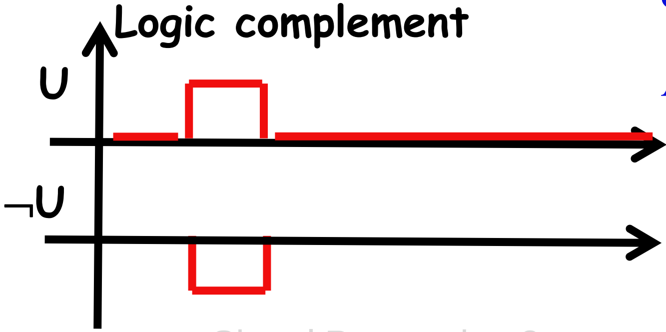
# Fast Digital Logic Modules

AND Overlap Coincidence



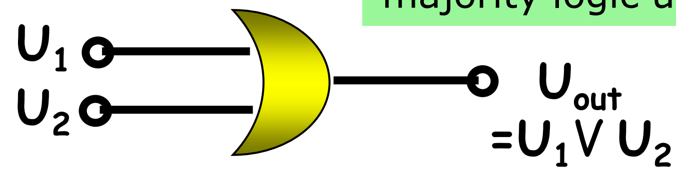




Logic complement

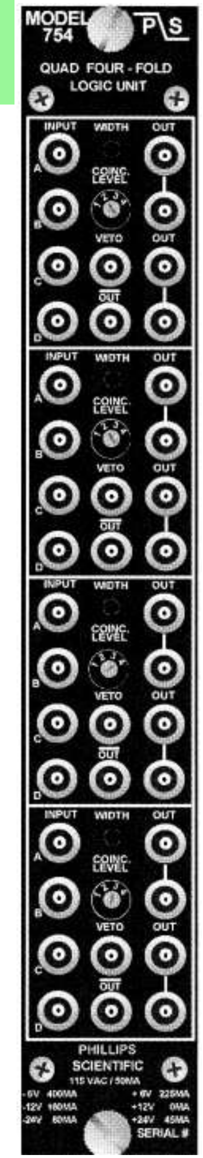


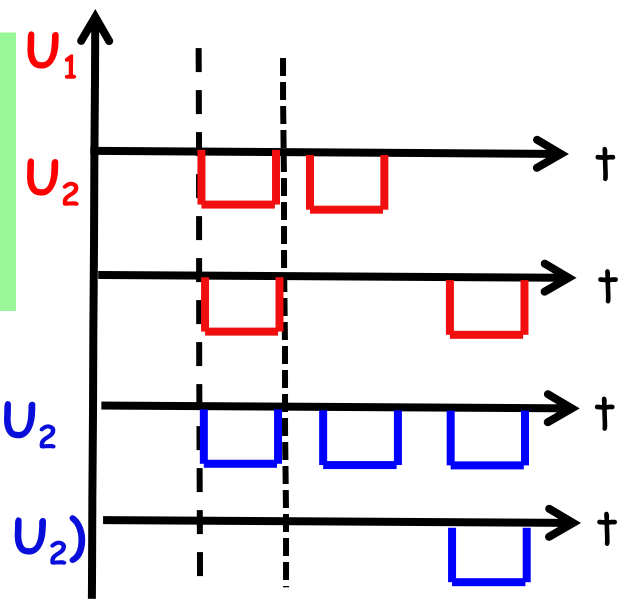

For fast timing: use fast negative logic

OR (inclusive)




Quad 4-fold majority logic unit

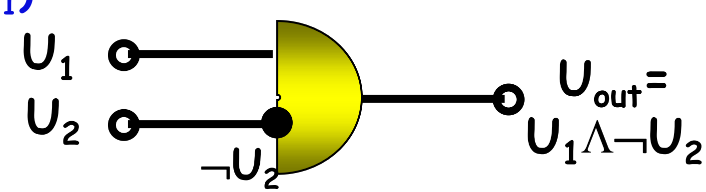



inc $U_1 \vee U_2$

ex $(U_1 \vee U_2)$

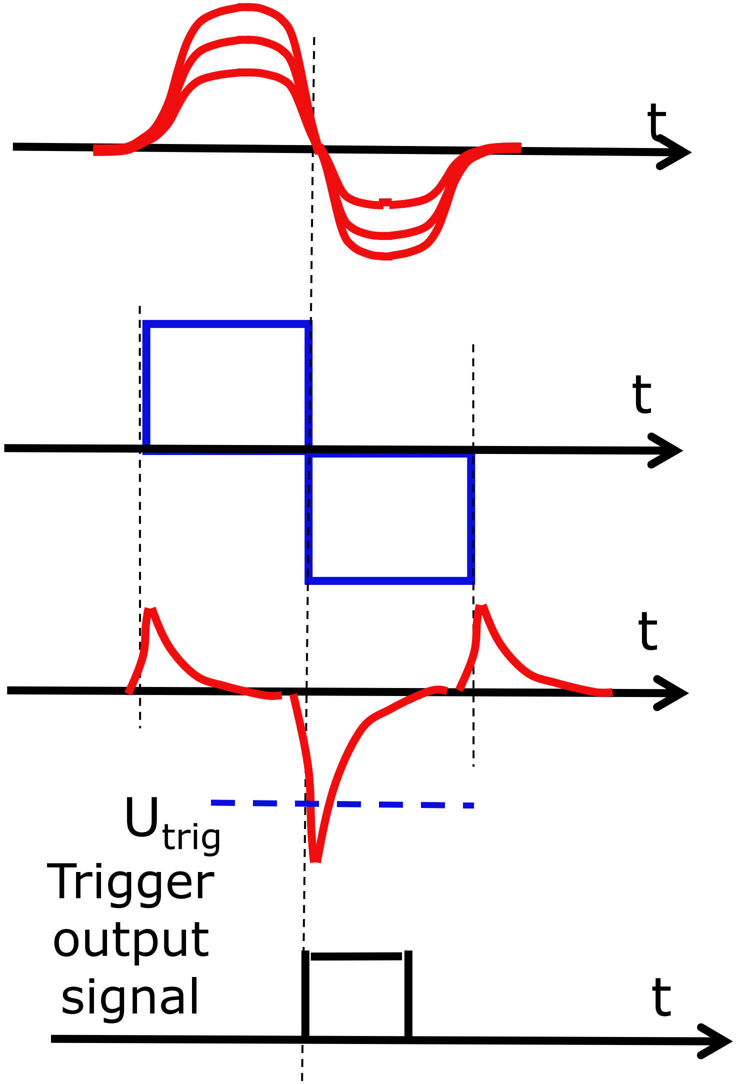
$\wedge\neg (U_2 \wedge U_1)$




Anti-Coincidence

# End Electronics II

# Zero-Crossing Timing




Alternative to "Leading Edge" Disc

Produce fast, bipolar linear pulse.
Possible: different gains for positive and negative parts → zero crossing at different time (fraction of time to maximum)

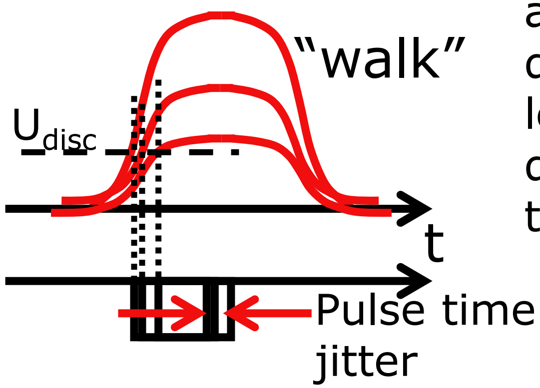
Produce "saturated" uniform pulse

Differentiate saturated pulse, use triplet pulse as input for trigger (negative pulse polarity).

Trigger output appears at zero crossing

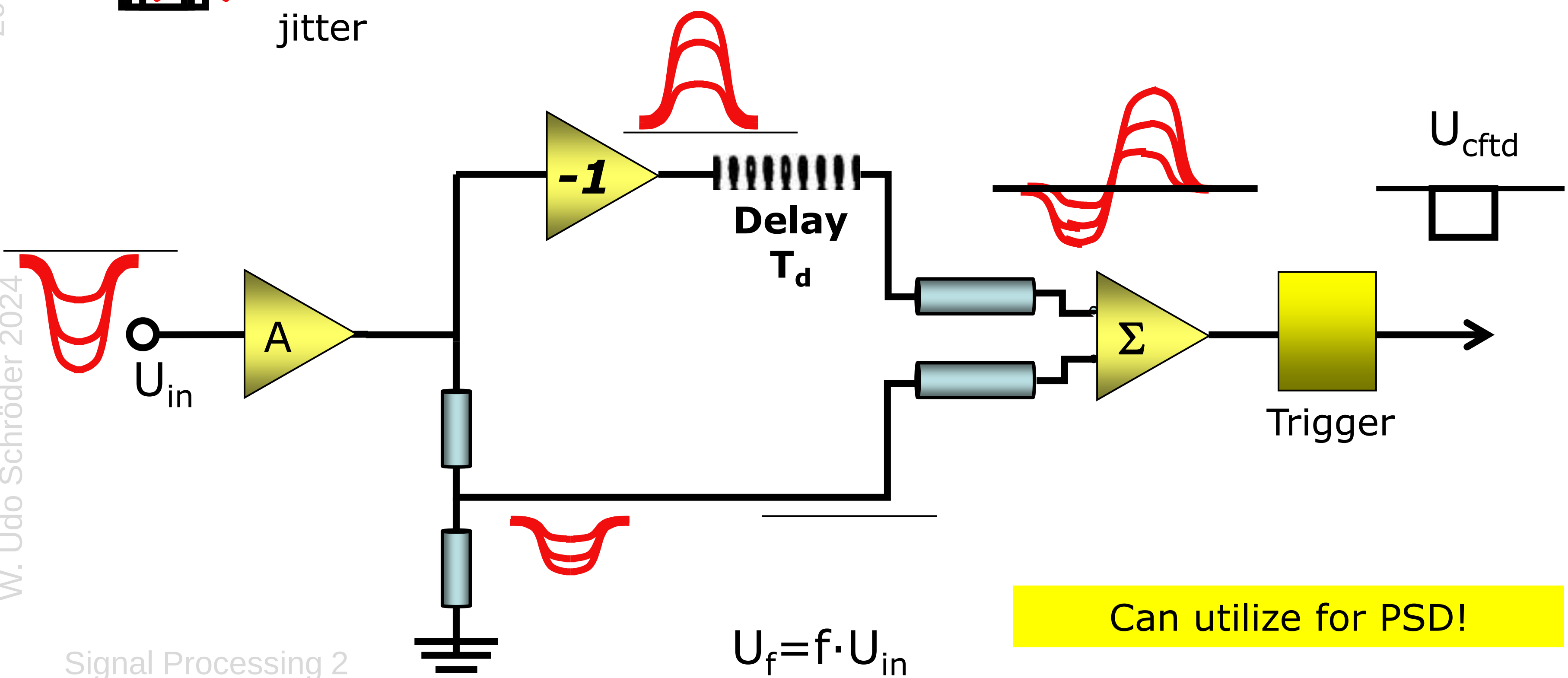
(Internal delays neglected)

# Constant-Fraction Discriminator



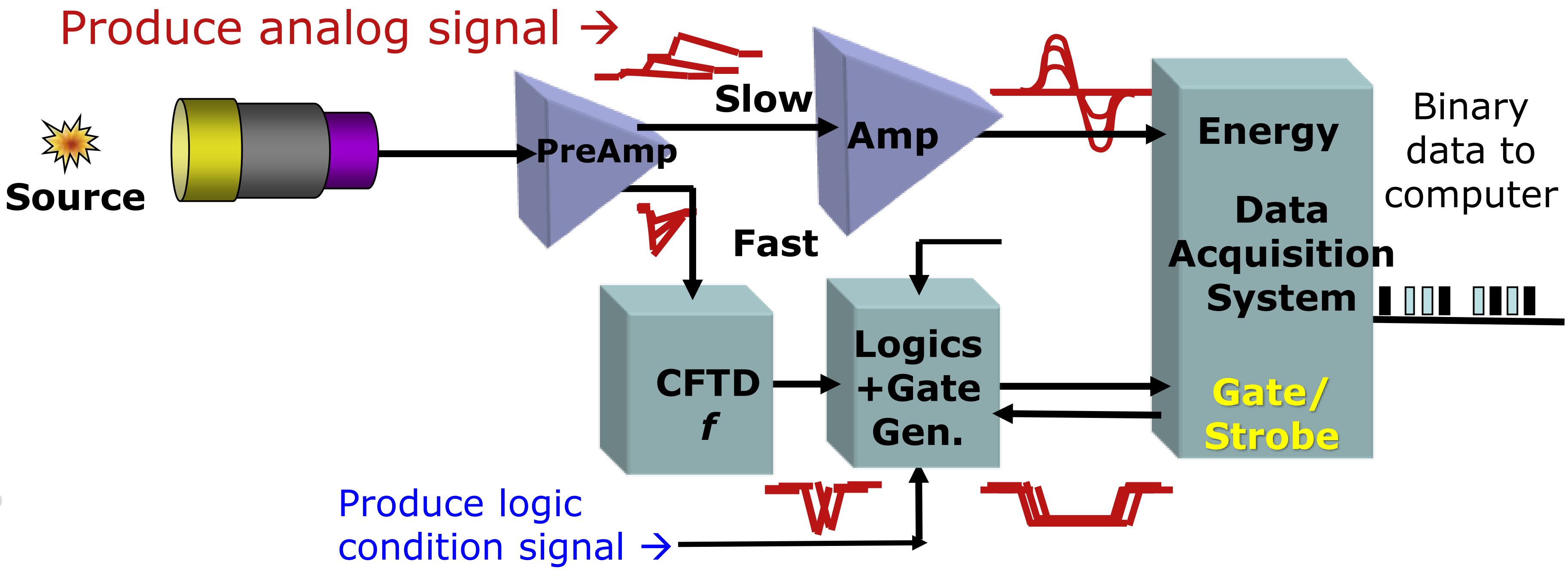

amplitude dependent leading edge discr. output timing

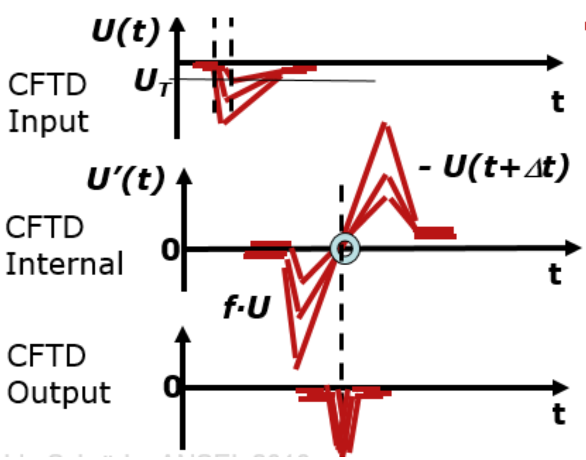
Zero crossing timing always at same physical time, independent of pulse amplitude for fixed pulse shape: no “walk” with energy




Can utilize for PSD!

# Fast-Slow Signal Processing




Constant-Fraction Timing Disc.:
Corrects for "***walk***" **$t(U)$**

$$U'(t) = f \cdot U(t) - U(t+\Delta t)$$

**→t (U′=0) independent of *U***
***$t(U'=0)-t(U=U_T)$*** *measures* **$t_R$** *rise time* (here fraction *f* = 0.5)

# Discriminator: “Single Channel” TSCA


For triggering the ANSEL DDC-8 DAQ units, use the **negative** TSCA output signal (“NIM-0 In”)