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 Jan 30, Feb 6/13):
Knoll, Ch 16, I- VI, VIII
Ch 17, I-IV
Chapter 4, I-V, Statistics

Next: Interactions of photons/particles with matter,

ANSEL Experiment Photon spectroscopy

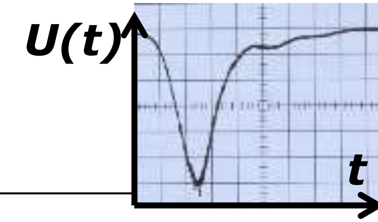
WS: Igor exercises

WS: Intro DDC-8 DAQ

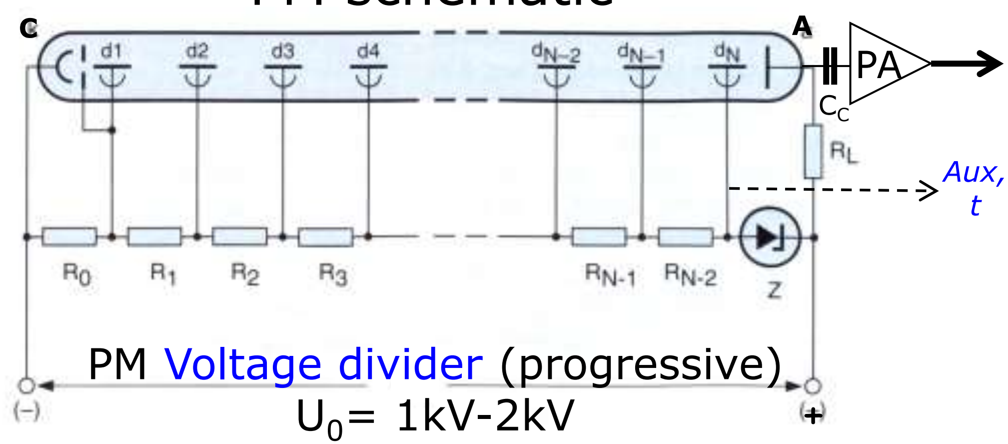
PM Operation

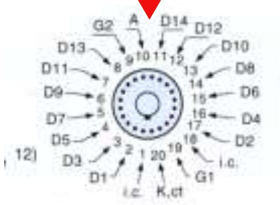
Fast PM: pulse rise time ~2ns, gain: $3{\cdot}10^7$

Philips XP2041
5″ dia cathode
14 dynodes
+ focusing electrodes



PM schematic

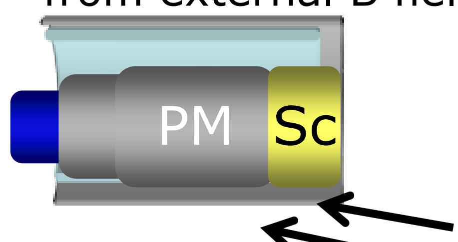




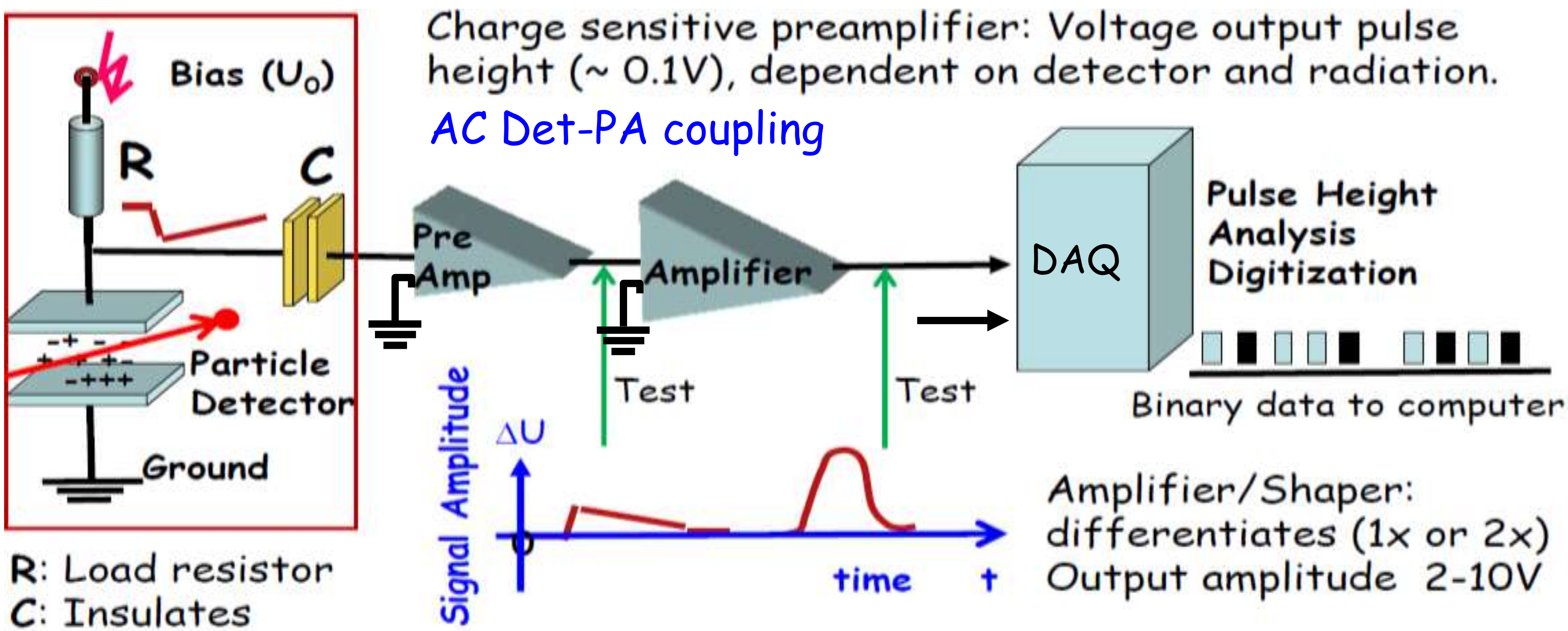
FE1120

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

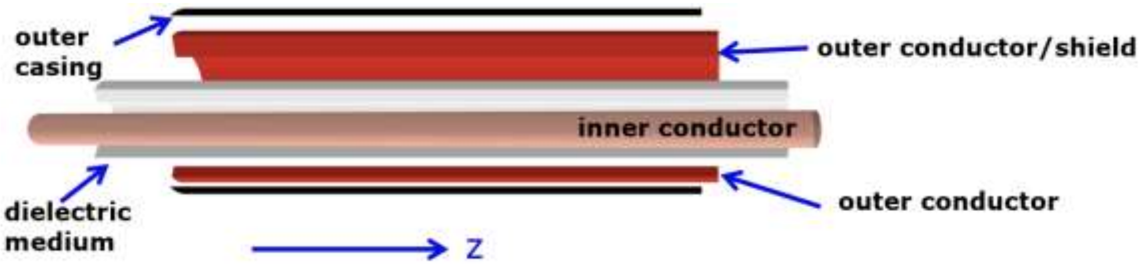
Photomultiplier socket with voltage divider and preamplifier (ORTEC)

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**)

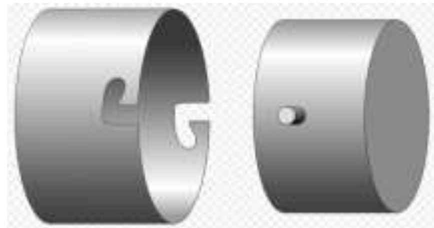
LEMO RG174 coaxial cable (LEMO)

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
Bayonet **N**eill-**C**oncelman

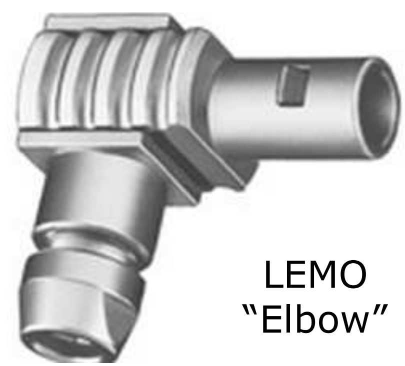
"I"
"Barrel"



Bayonet mount
locking mechanism

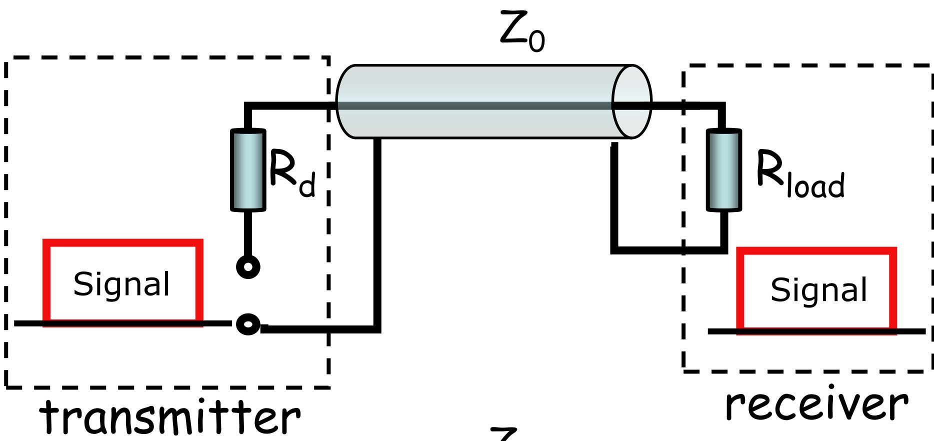
LEMO
Léon **Mo**uttet
Push-pull connectors

"TEE"
Splitter



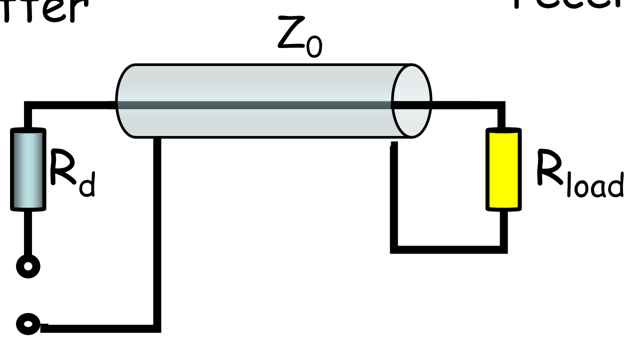
LEMO
"Elbow"

Cable Impedance Matching

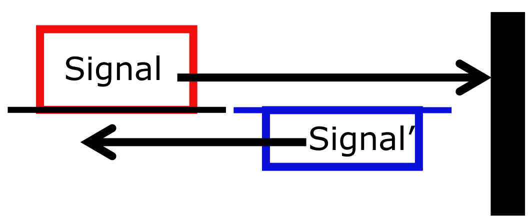


Coax cable has complex impedance Z for signal transmission, $ReZ=Z_0$

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



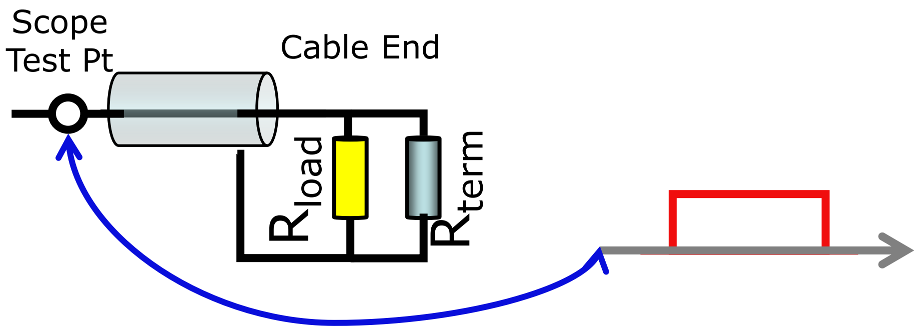
For mismatch, $R_{load} \neq Z_0$, reflections at end, traveling back, superimpose on original signal after travel time to end and back.



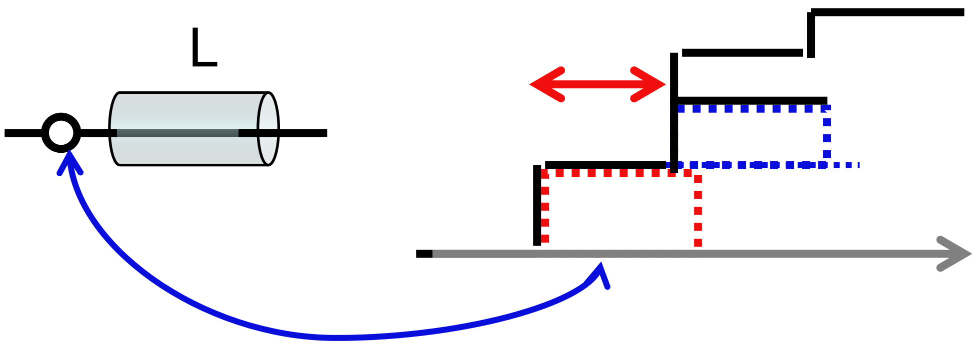
$$\frac{U_{refl}}{U_{in}} = \frac{R_{load} - Z_0}{R_{load} + Z_0}$$

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

Cable Reflections

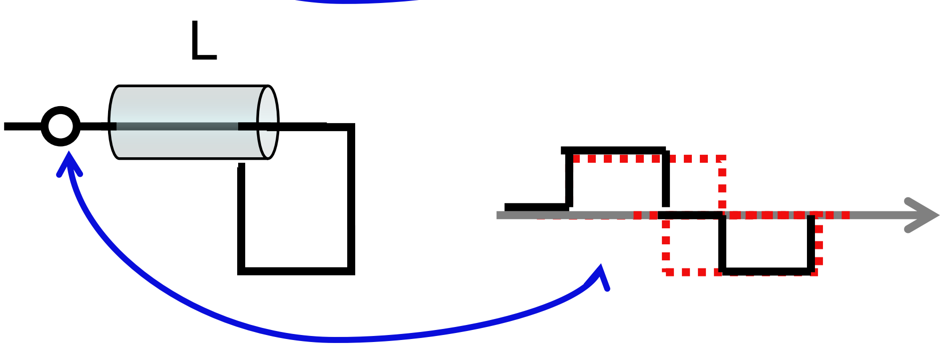


Receiver input impedance $R_{load} \neq Z_0$, → use additional Ohmic termination in parallel



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

$T_{cable} = 2L/c$



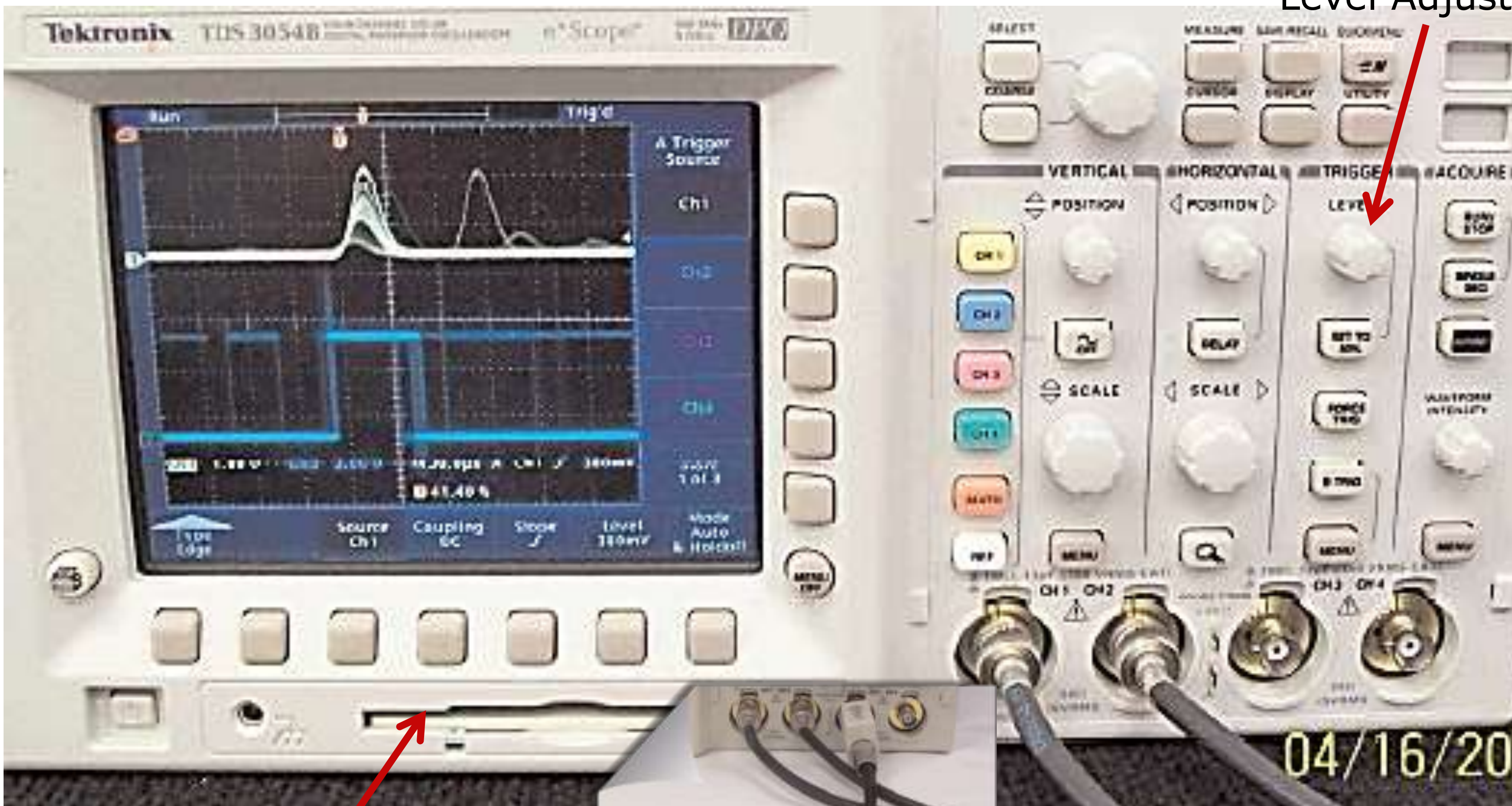
Short: $R_{load}=0$, Input and reflection opposite polarity, superposition = bipolar

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

Digital Sampling Oscilloscope

Check scope input impedance, typical A/C 50Ω

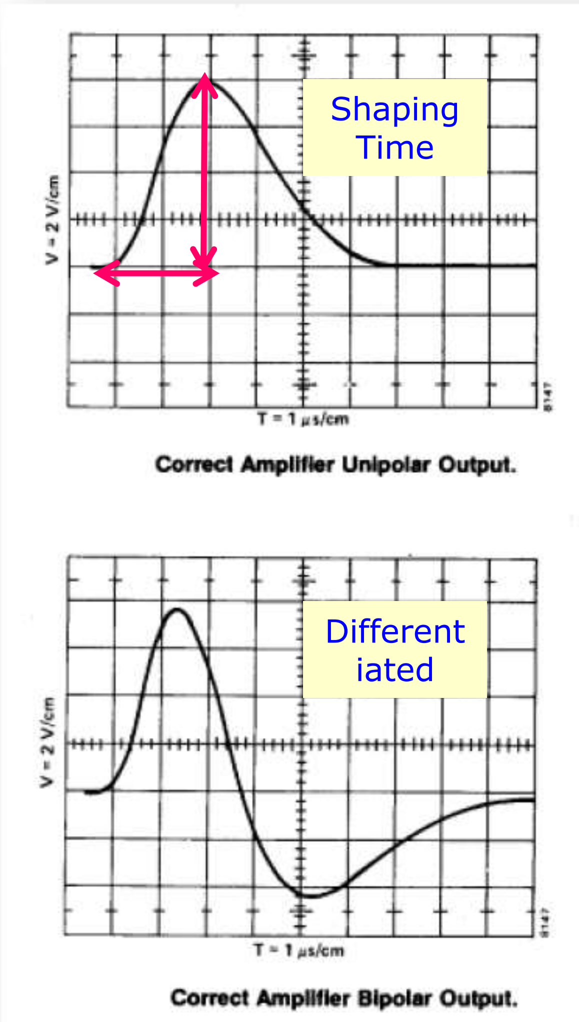
Signal Trigger Level Adjust



Output media for screen shots (USB/Disc)

10x probe (high Ohm)

Main/Spectroscopy Amplifiers



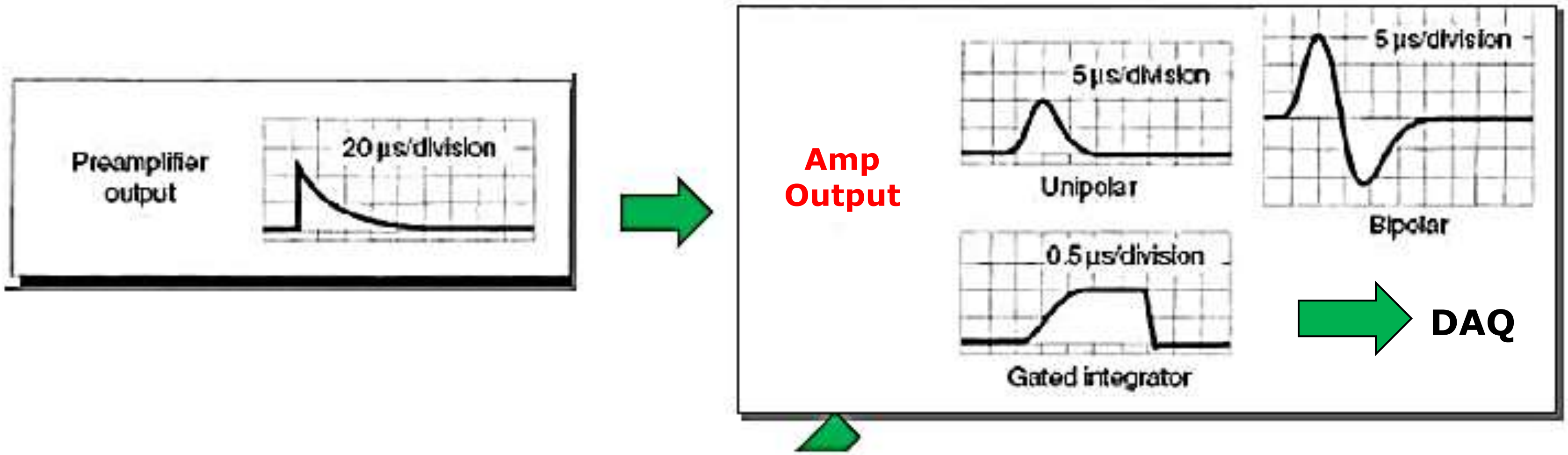
Tasks: Generate signal with amplitude **proportional** to collected detector charge. Needs absolute calibration of pulse amplitude.

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

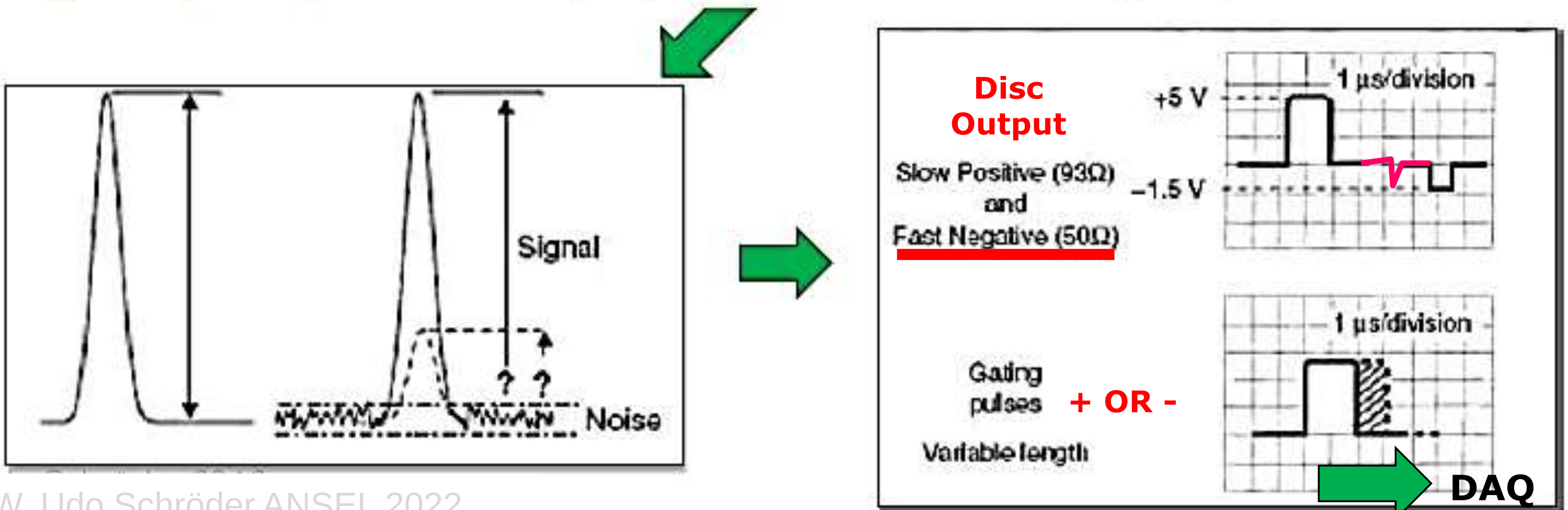
← **Preamp Power**

Spectroscopy with Analog/Digital Electronics

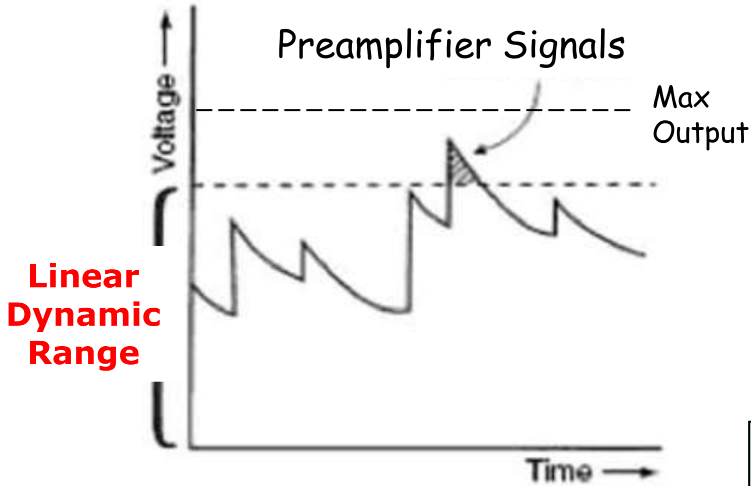
Analog (slow) circuit → proportional image detector output signal



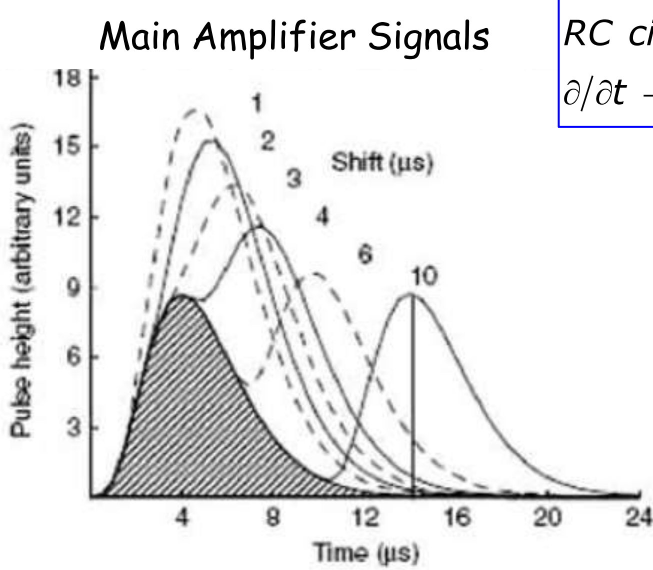
Digital (fast) circuit → yes/no information on signal presence



Spectral Distortions: Pile-Up



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



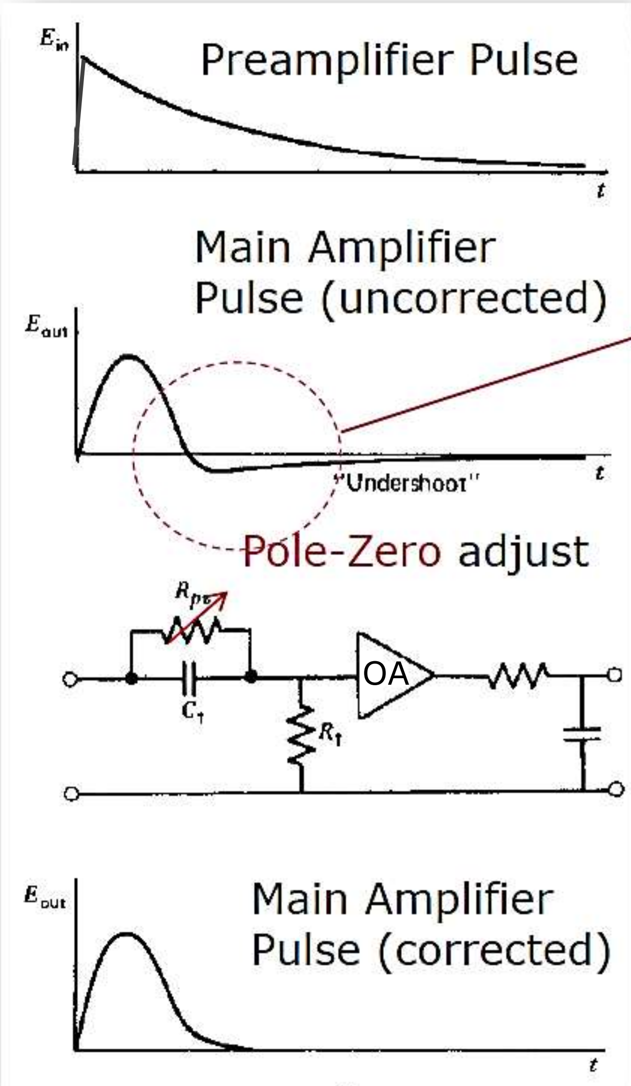
High count rate (relative to pulse length/decay time) can lead to pile up
→ from small non-linearities to serious distortions, line shapes "ghost lines"

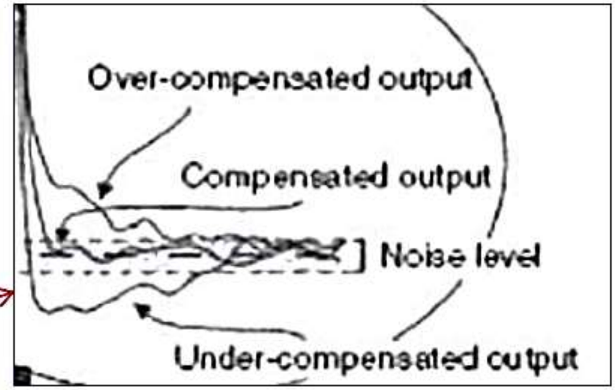
Check signals on very different time and amplitude scales! Danger to miss features.

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

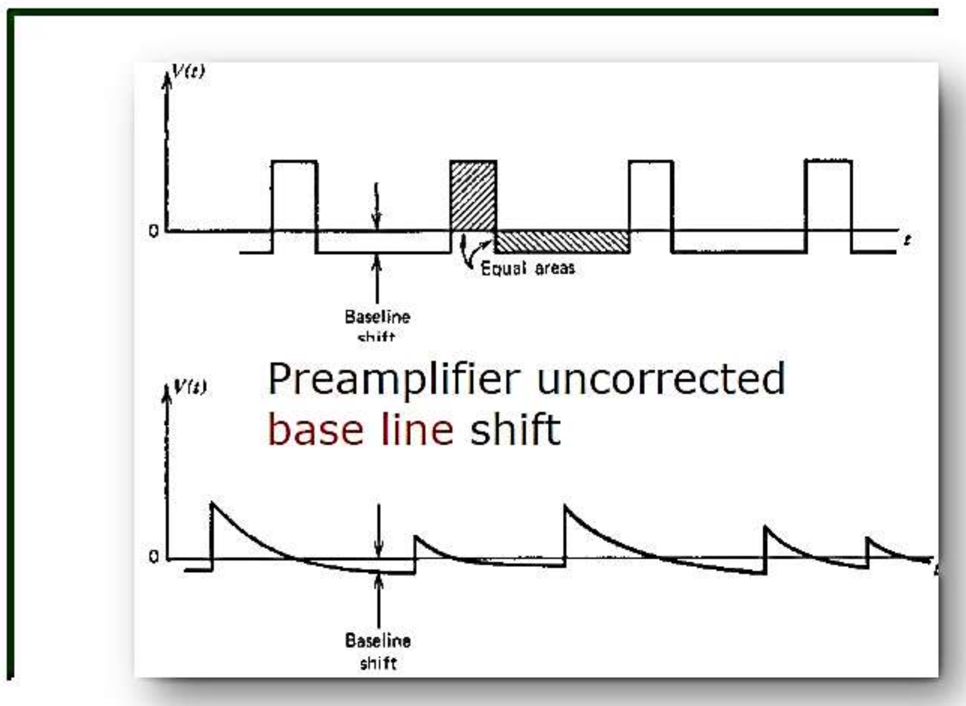
Avoid by reducing signal rate or width (pulse decay time)

Spectral Distortions: Pole-Zero & Base-Line Shift





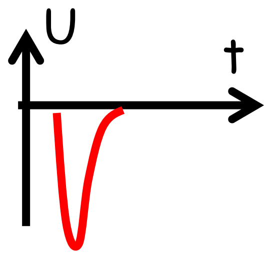
Blow-up of pulse under/over shoot

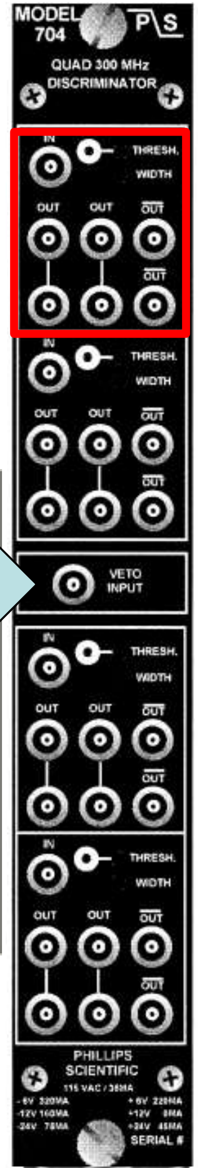


Logic Chain Elements: Fast NIM Modules

Fast LE Discriminator

Pre/Amp





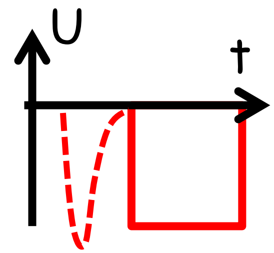
Veto

Input: fast, narrow NIM signal

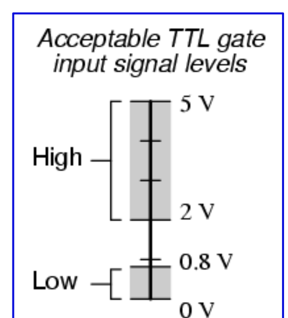
NIM = current based logic, with negative "true"
I = -16 mA
@ 50 Ω → - 0.8 V

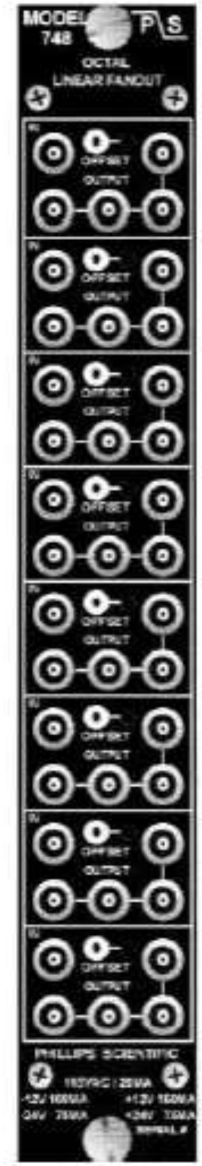
Check on 50 Ω termination

Gate & Delay Generator



Output: Long NIM/TTL "gate" signal

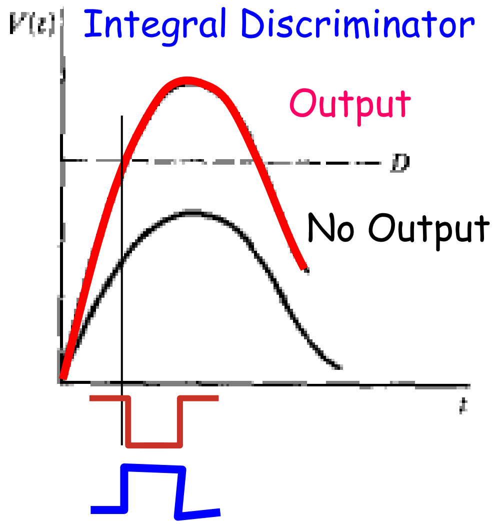


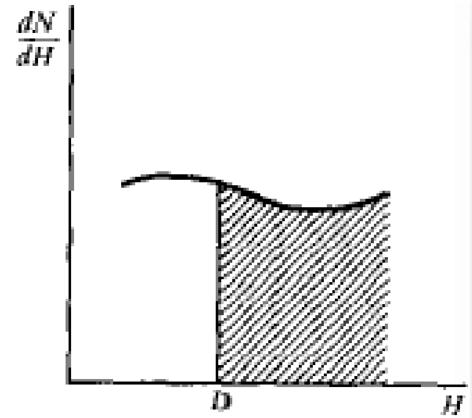


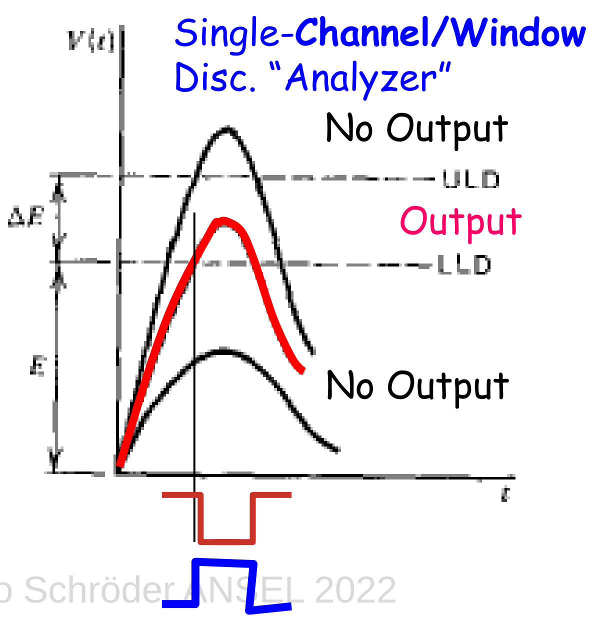
Fan In/ Fan Out Module

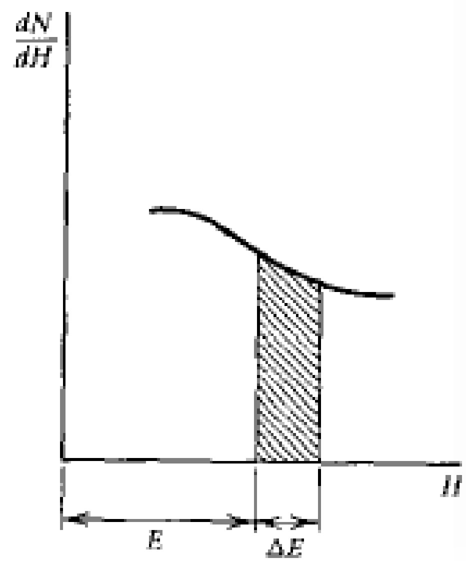
Leading-Edge Discriminator: "Single Channel" TSCA

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



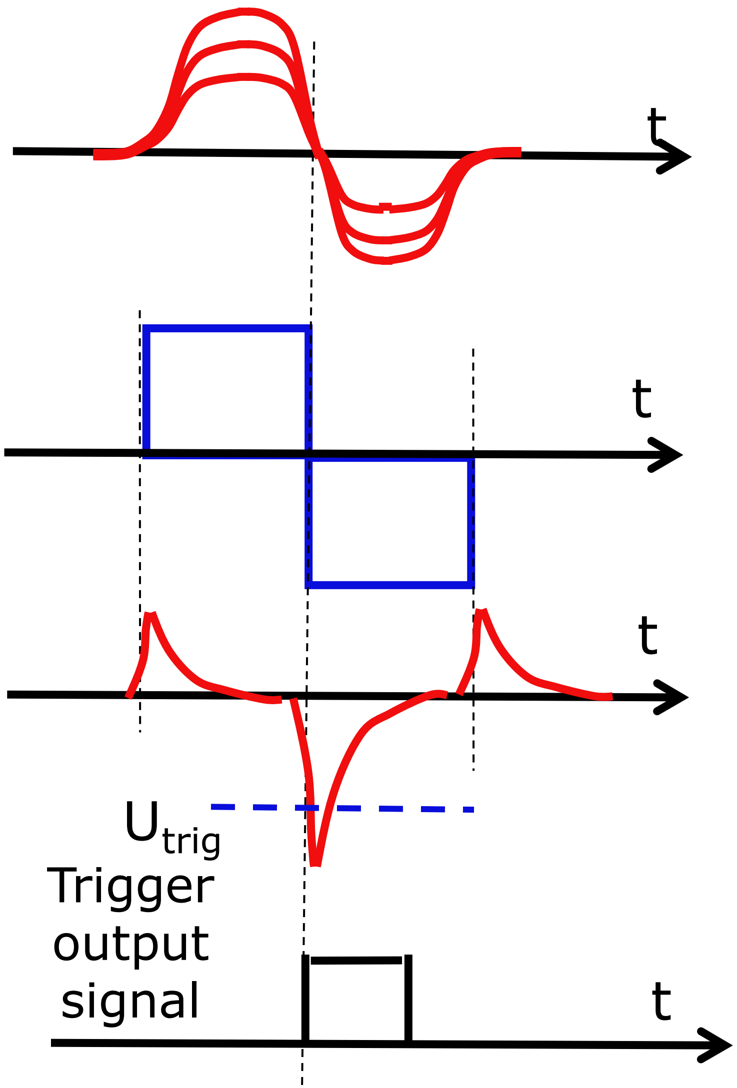






Discriminator: "Single Channel" TSCA

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)

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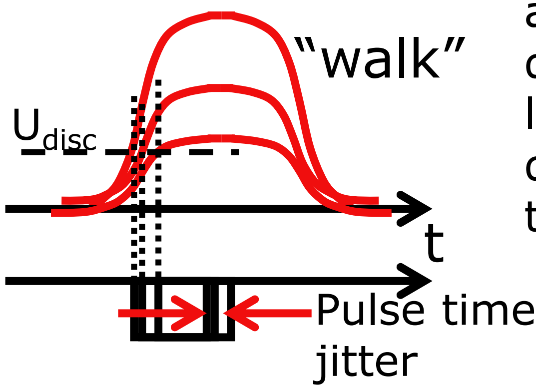
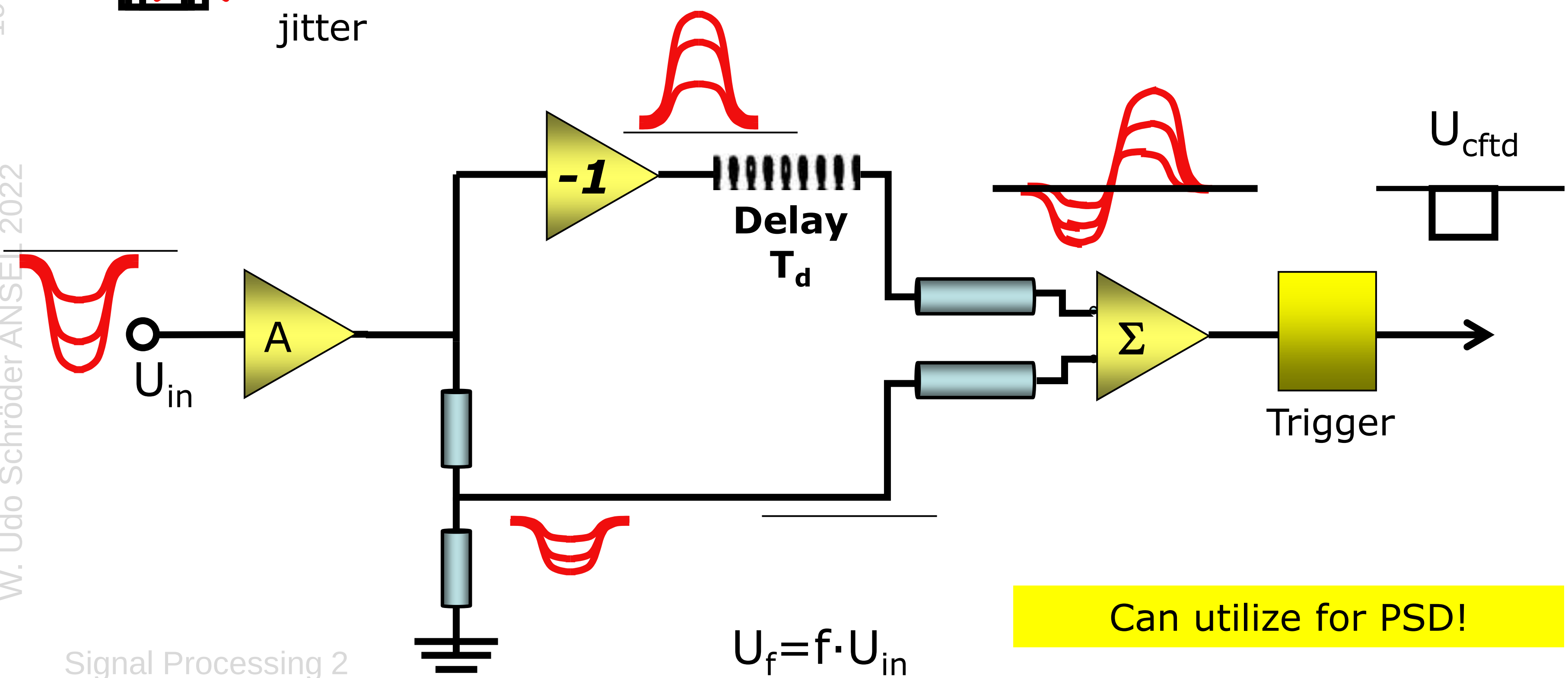
Constant-Fraction Discriminator



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



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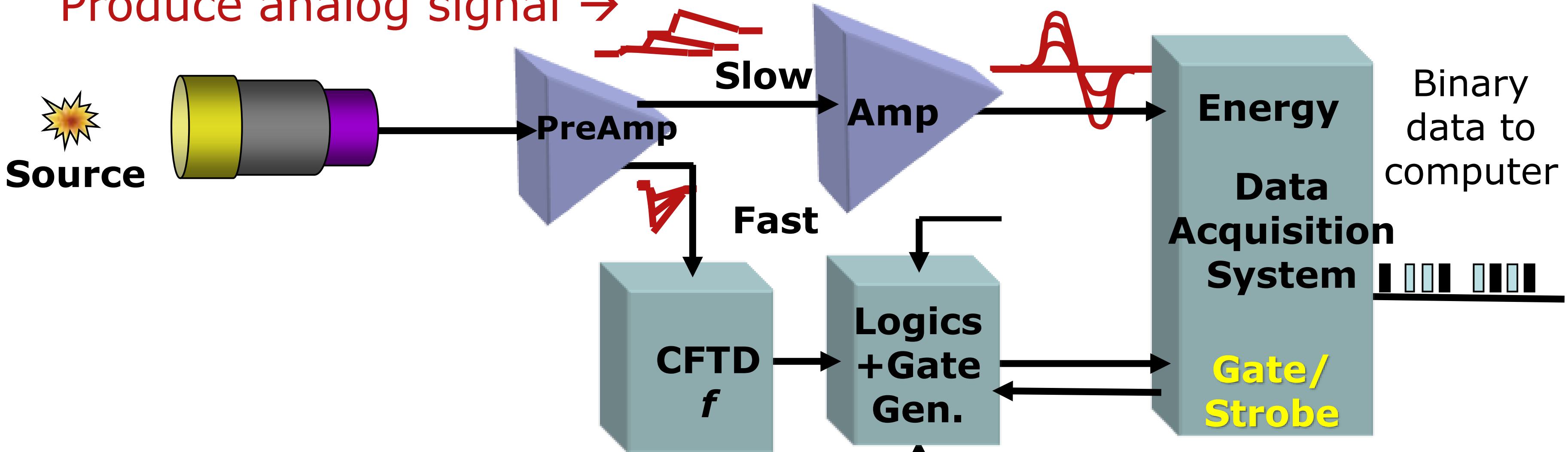
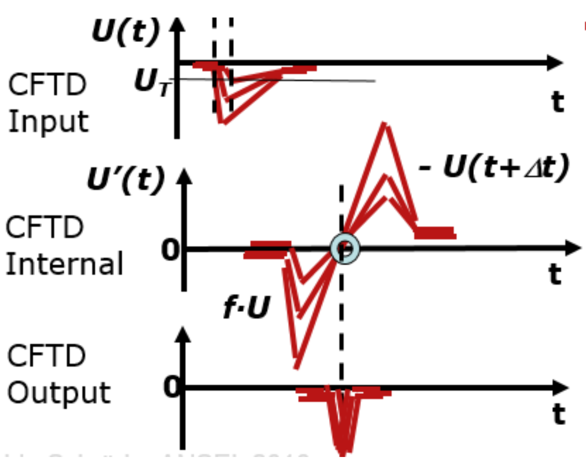
Fast-Slow Signal Processing

Produce analog signal →



Produce logic condition signal →



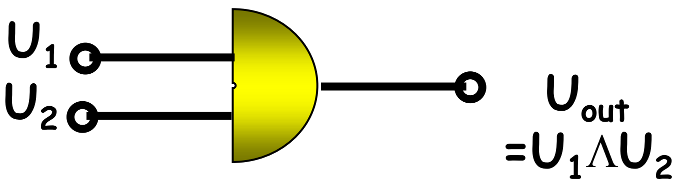
Constant-Fraction Timing Disc.:
Corrects for "***walk***" $t(U)$

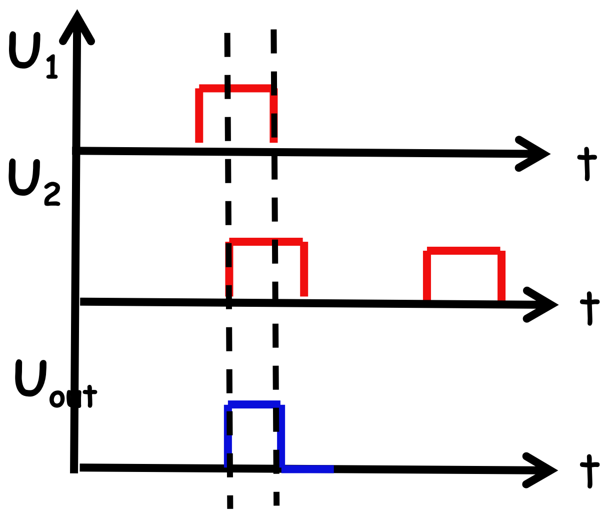
$U'(t) = f \cdot U(t) - U(t+\Delta t)$

→t (U′=0) independent of *U*
t(U′=0)-t(U=U$_T$) *measures* t_R *rise time* (here fraction f = 0.5)

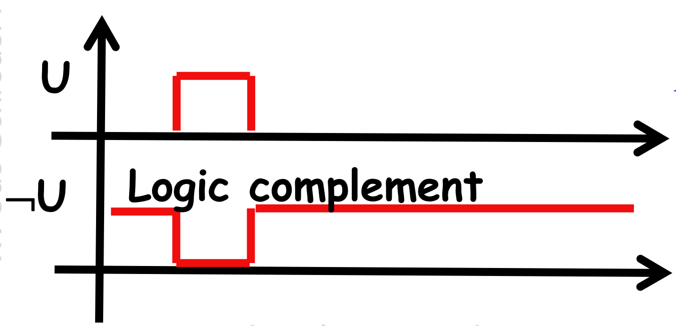
Fast Digital Logic Modules

AND Overlap Coincidence



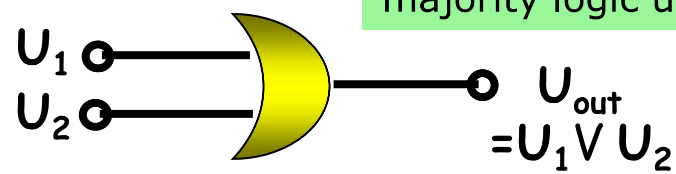


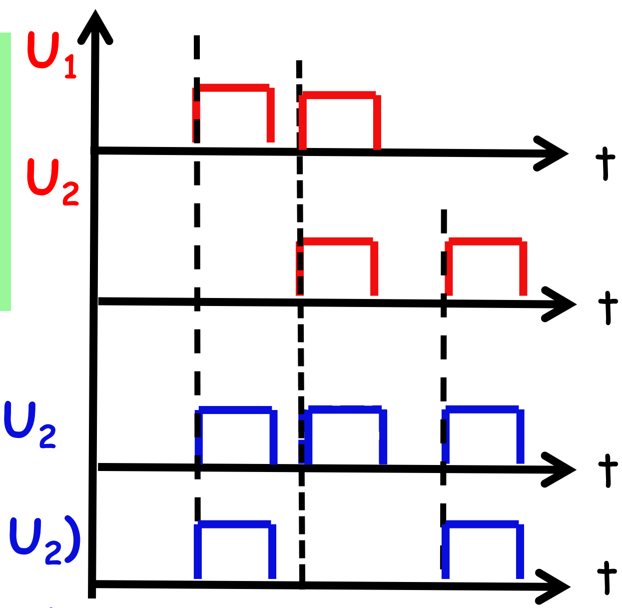
For fast timing: use fast negative logic



OR (inclusive)

Quad 4-fold majority logic unit

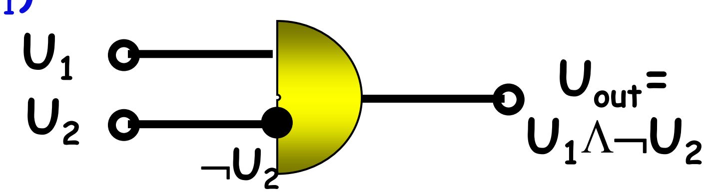




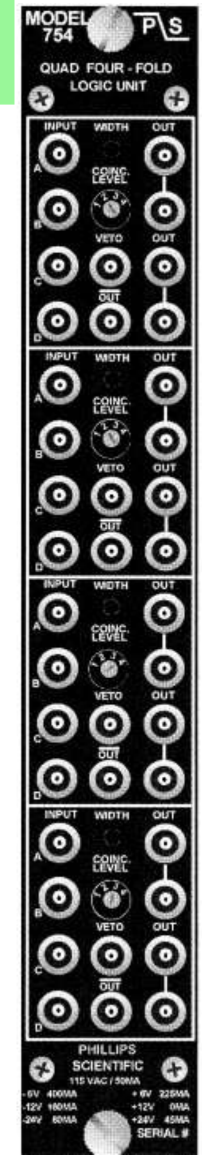
inc $U_1 \vee U_2$

ex $(U_1 \vee U_2)$

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



Anti-Coincidence



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End Electronics II