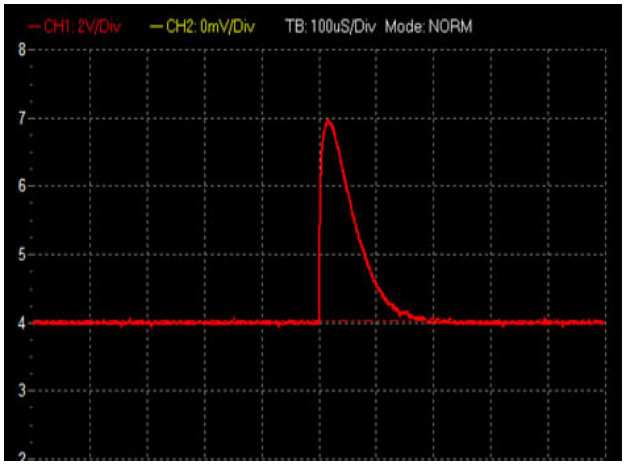
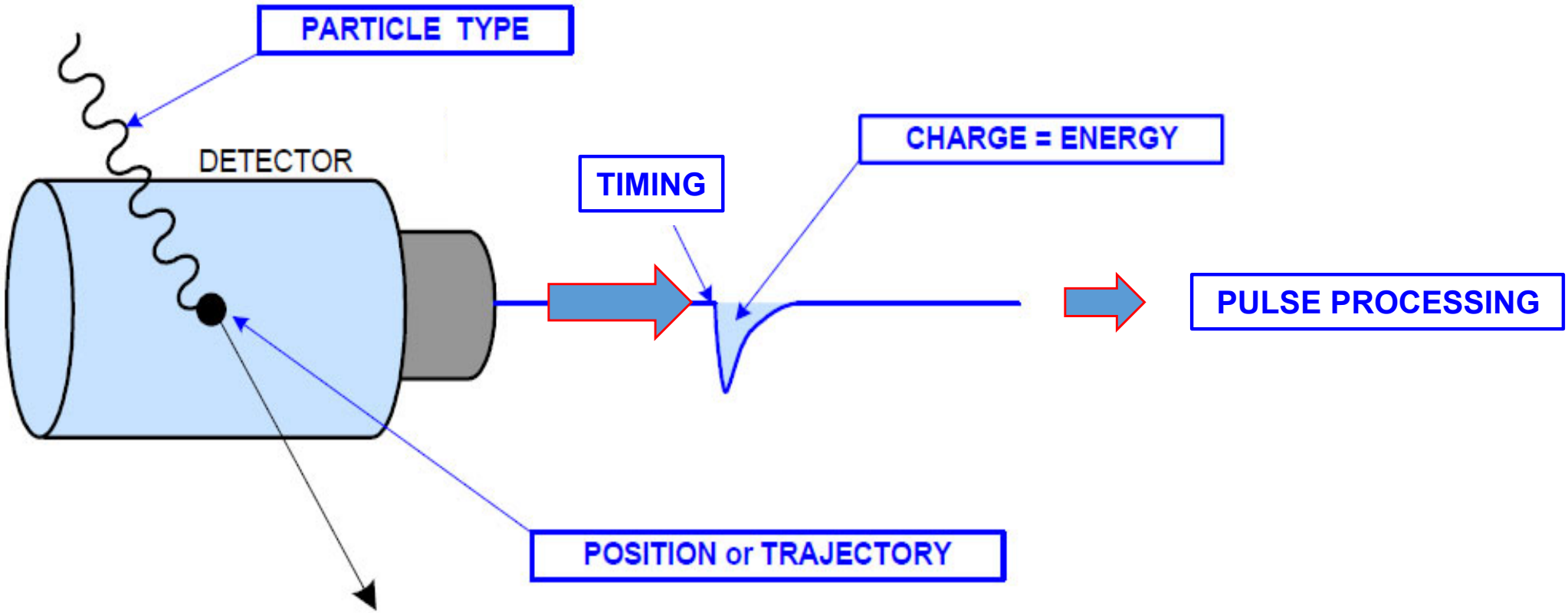
ELECTRONICS - 2



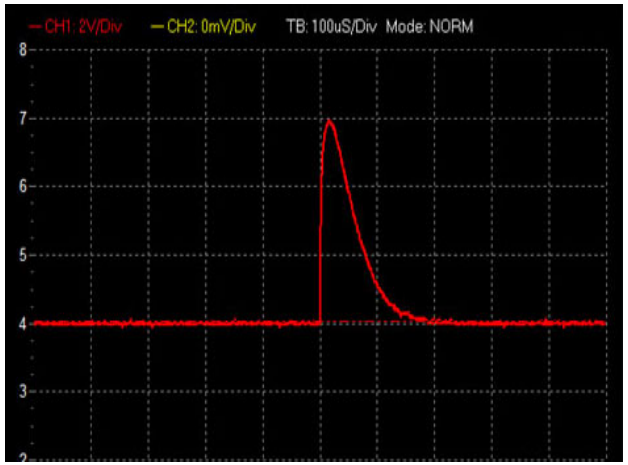
General scheme



Pulse: main actor

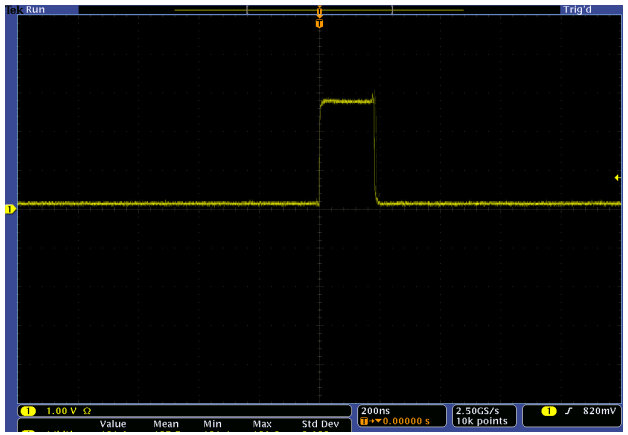
PULSES:

Linear:
(analog)

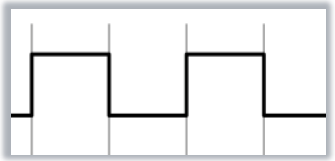


- Collection of output current by circuit; rise and fall generated by interaction of ionizing radiation with detector;
- the analysis of the amplitude of the pulse is the end result of a typical application;
- signal amplitude is proportional to the parameter of interest (e.g. the **energy**);

Logic:
(digital)



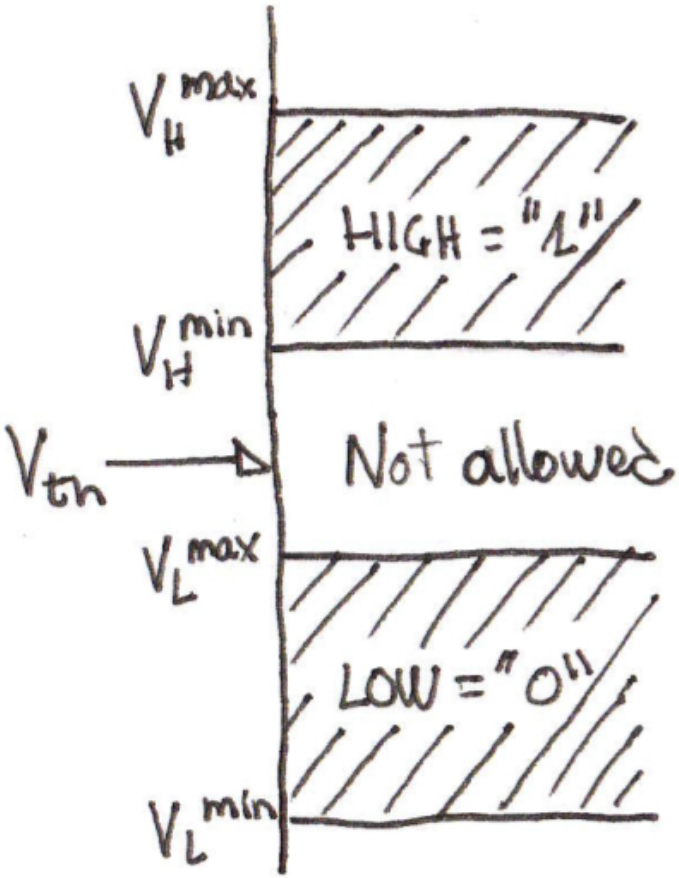
- have a fixed shape and amplitude;
- convey information by their presence, absence, or relation to time (**counts, timing**).



Final goal: counts, energy, timing

Standard digital pulses

- Digital signals encode information in a discrete number of states usually two



- $V_L^{min} < LOW < V_L^{max}$
- $V_H^{min} < HIGH < V_H^{max}$
- The values in the range $[V_L^{max}, V_H^{min}]$ are undefined.
- V_{th} is the typical logic threshold between '0' and '1'.

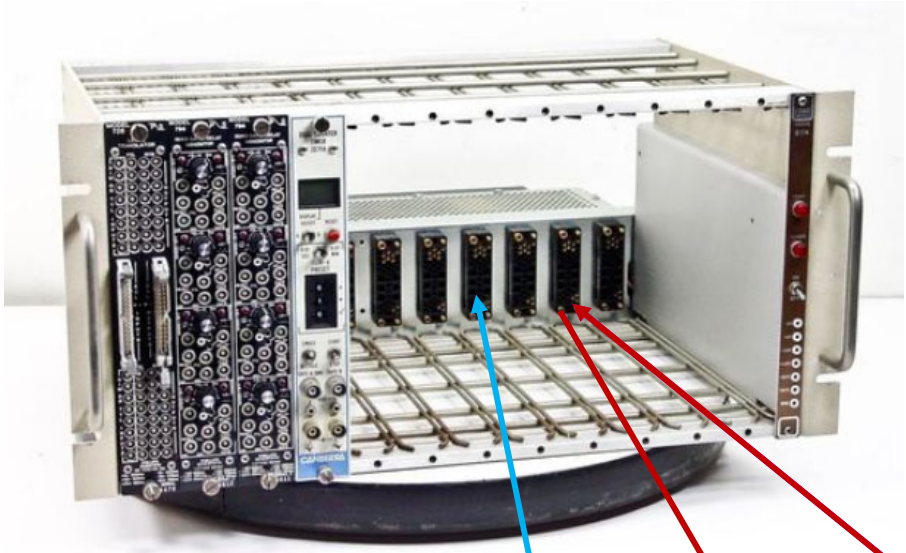
Standard digital pulses

		V_{cc}	V_L^{min}	V_L^{typ}	V_L^{max}	V_{th}	V_H^{min}	V_H^{typ}	V_H^{max}
TTL	inp	+5V	-0.4V		+0.8V	+1.2 V	+2.0V		+5.4V
	out		+0.0V	+0.2V	+0.4V		+2.4V	+3.3V	+5.0V
CMOS	inp	+5V	-0.2V		+1.5V	+2.5 V	+3.3V		+5.4V
	out		+0.0V	+0.2V	+0.4V		+4.6V	+4.9V	+5.0V
ECL	inp	-5.2V	-5.0V		-1.5V	-1.3V	-1.1V		-0.0V
	out		-1.9V	-1.8V	-1.6V		-1.0V	-0.9V	-0.8V
NIM	inp	$\pm 12V$	-2.0V		+1.5V		+3.0V		+12.0V
(slow)	out	$\pm 24V$	-2.0V	+0.0V	+1.0V		+4.0V	+6.0V	+12.0V
NIM	inp	$\pm 12V$	-4.0mA		+20mA		-12mA		-36mA
(fast)	out	$\pm 24V$	-1.0mA	+0.0mA	+1mA		-14mA		-18mA

- NIM: Mechanical and electrical standard for nuclear instrumentation. Levels defined in terms of currents. Logic 1 = 16 mA
- TTL: Widely electrical standard. Levels defined only in terms of voltage
- ECL: Differential electrical standard

Pulse-processing instruments: NIM

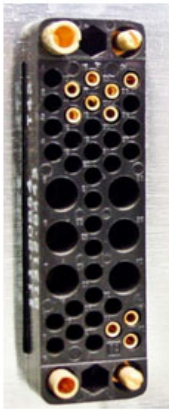
NIM = Nuclear Instruments Module

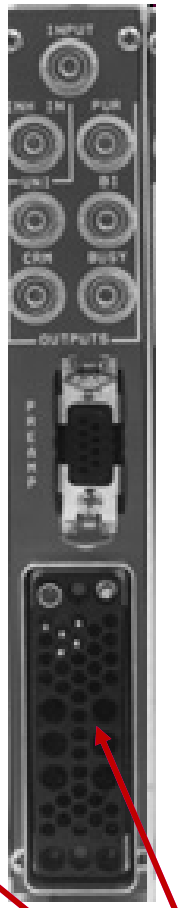


EG&G ORTEC

EG&G ORTEC 4001C BIN Chassis

12 slots





Electrical parameters :

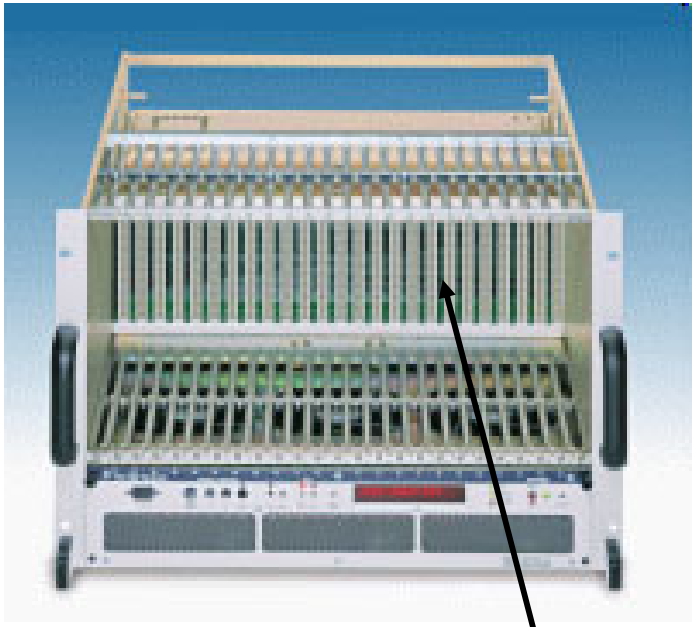
+/- 24 V, +/- 12 V, +/- 6 V, +/- 3 V (sometimes)

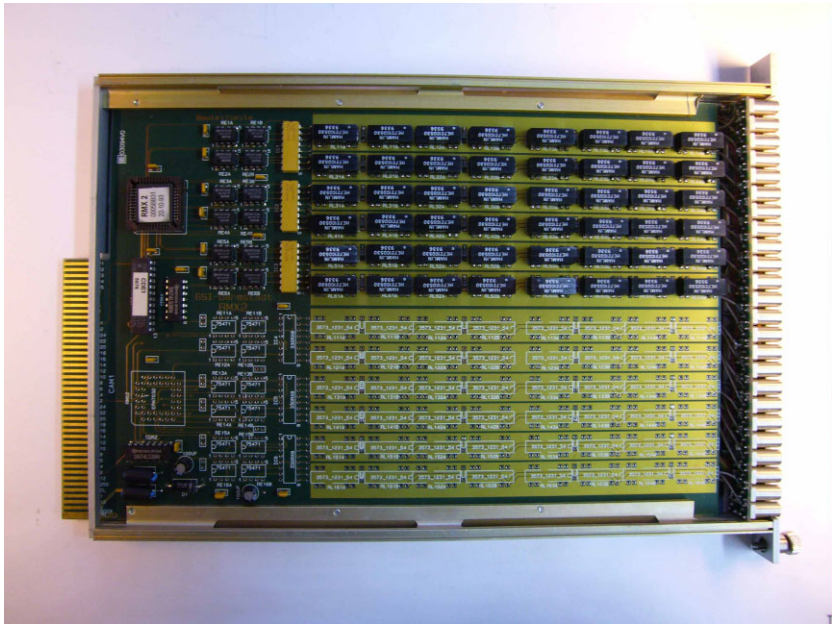
connector

Pulse-processing instruments: CAMAC

CAMAC = **C**omputer **A**utomated **M**easurement and **C**ontrol

Main difference with NIM – computer interface





Controller serves as interface between the modules in the bin

Back plane contains power bus as well as data bus

Slots 24 & 25 reserved for the controller

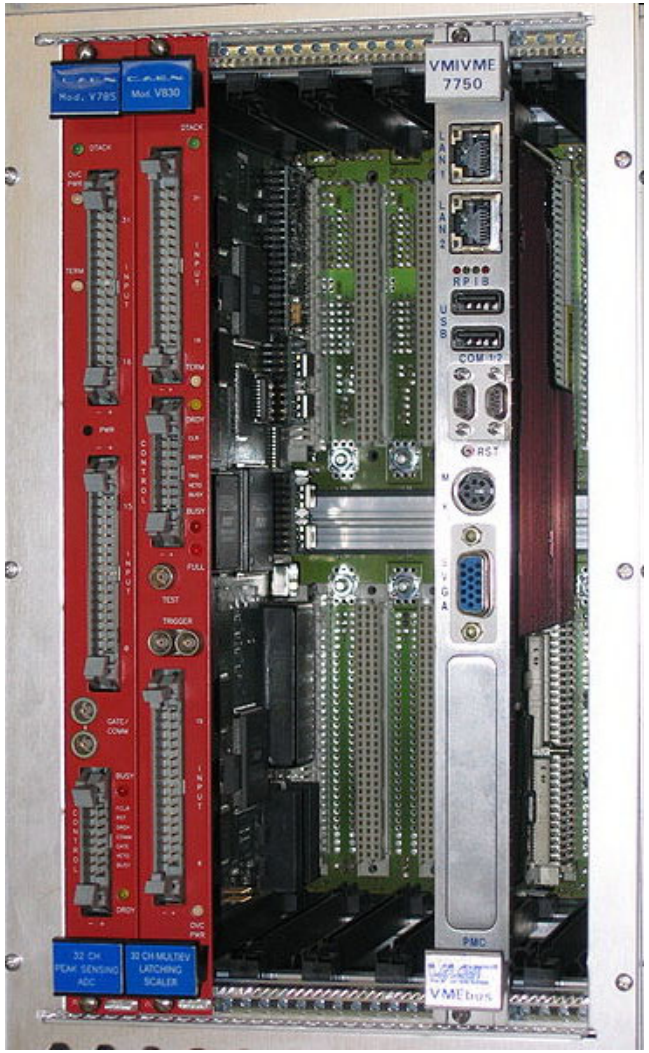
Pulse-processing instruments: examples of CAMAC modules

LeCroy 2280 ADC System Processor CAMAC Module

LeCroy CAMAC Modules

Pulse-processing instruments: VME

VME = **V**ersa **M**odule **E**urocard (**E**uropa)



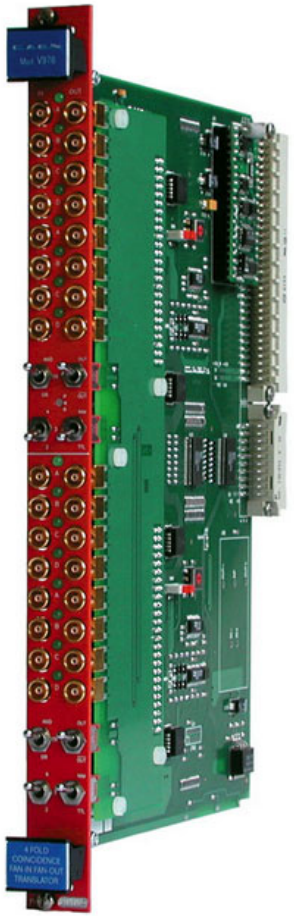
Developed in 1981 by Motorola

Much more compact, high speed bus

Fiber optic communication possible

Pulse-processing instruments: example of VME-board

VME – **V**ersa **M**odule **E**urocard (**E**uropa)



V976

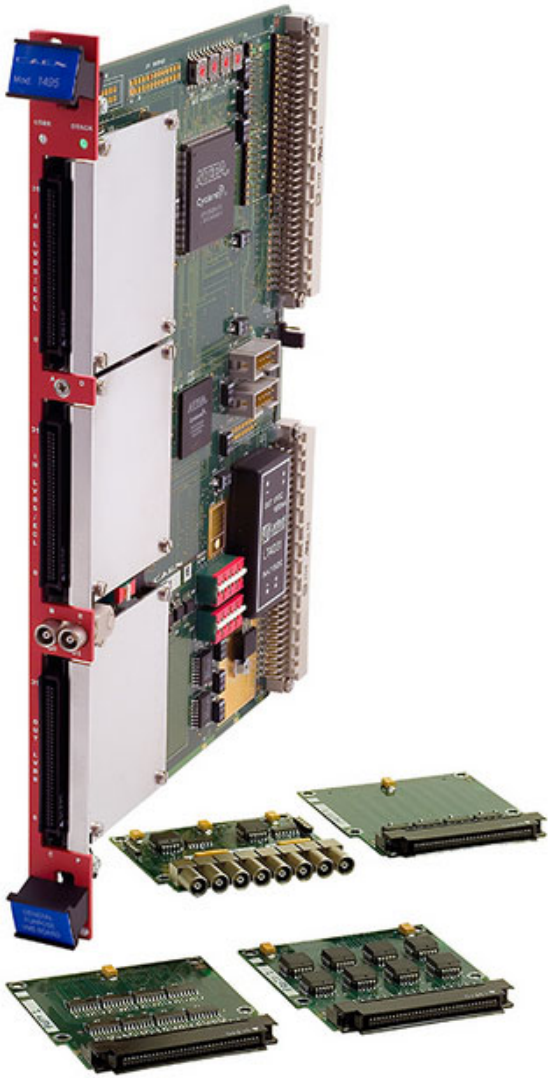
Quad 4 Fold AND/OR/MAJ, NIM-TTL TTL-NIM Translator, Fan-In Fan-Out

- Four independent sections with four channels each
- TTL and NIM inputs automatically detected
- NIM/TTL selectable output level
- AND, OR, Majority function with selectable number of inputs
- Logic Fan In / Fan Out
- Selectable direct or negated output

CAEN
Tools for Discovery

Pulse-processing instruments: example of VME-board

VME – **V**ersa **M**odule **E**urocard (**E**uropa)



V1495

General Purpose VME Board

- User customisable FPGA Unit (with preloaded demo code)
- LVDS/ECL/PECL inputs (differential)
- 64 inputs, expandable to 162 (with 32 outputs)
- 32 outputs, expandable to 130 (with 64 inputs)
- 405 MHz maximum frequency supported by clock tree for registered logic
- I/O delay smaller than 15 ns (in Buffer Mode)
- Programmable 3-color LED
- Libraries (C and LabView) and Software tools for Windows and Linux

CAEN
Tools for Discovery

Pulse-processing units

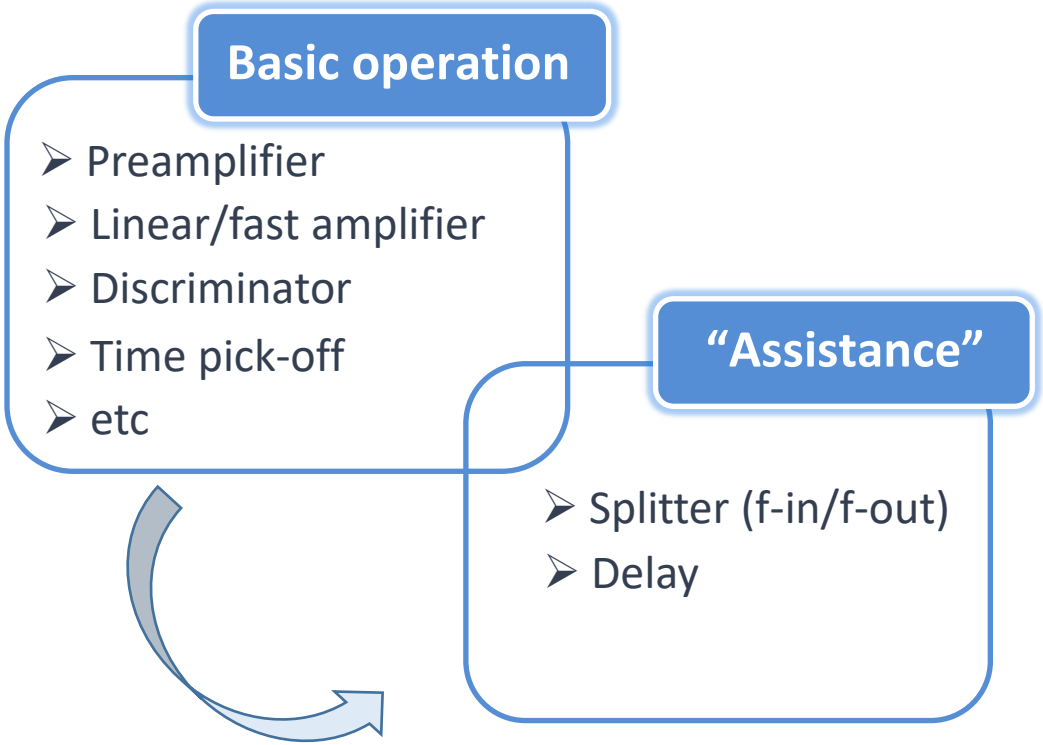
properties and intro to modules

Pulse-processing units: “crude” role classification

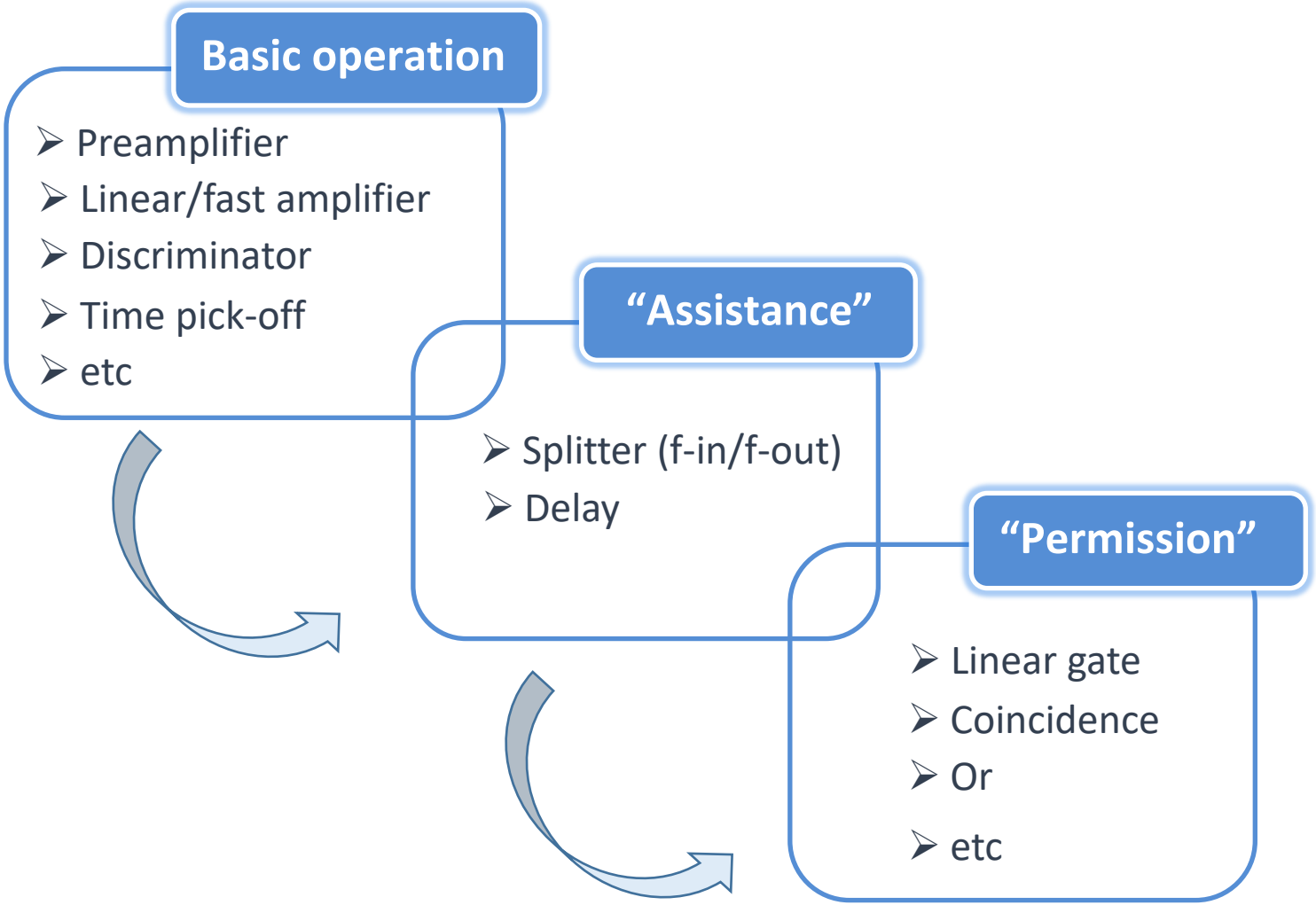
Basic operation

- Preamplifier
- Linear/fast amplifier
- Discriminator
- Time pick-off
- etc

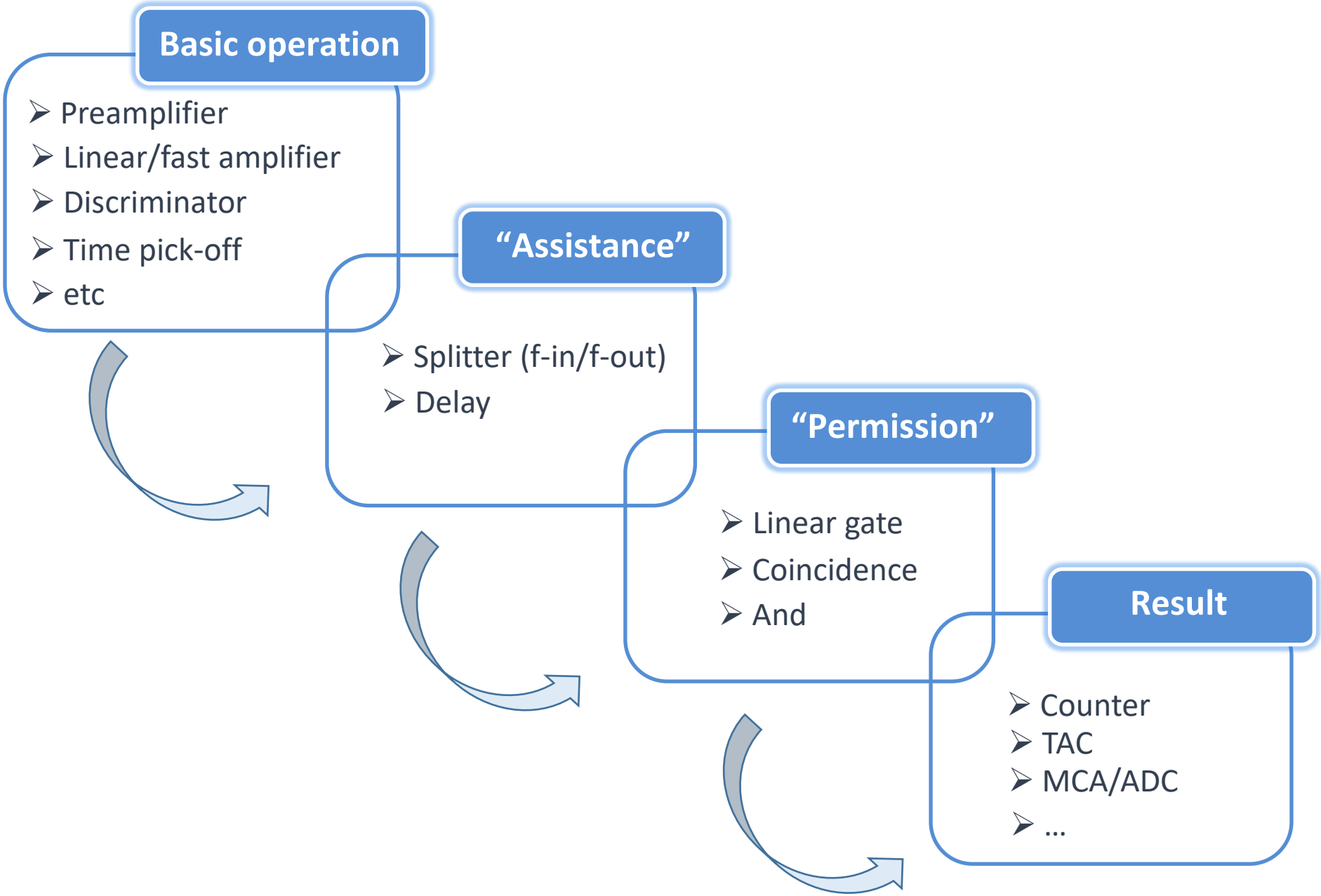
Pulse-processing units: “rude” role classification



Pulse-processing units: “rude” role classification



Pulse-processing units: “rude” role classification

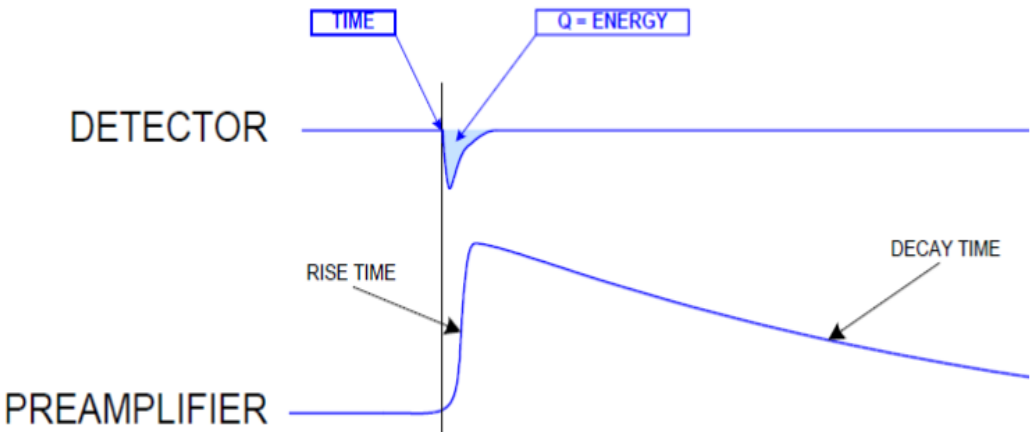


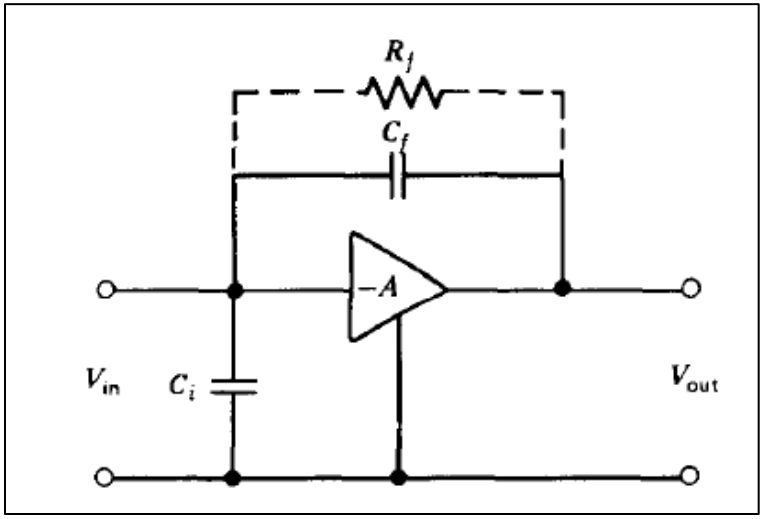
Pulse-processing units: “crude” role classification

Basic operation

- Preamplifier
- Linear/fast amplifier
- Discriminator
- Time pick-off
- etc

Preamplifier





Input: linear charge pulse from detector

Output: linear tail pulse with amplitude proportional to input

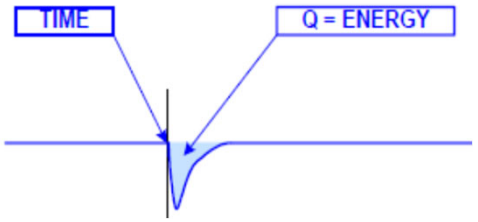
Rise time : as short as possible (consistent with charge collection time)

Decay time : long(~50-100µs)

Output amplitude: $V_{out} = \frac{Q}{C} \approx$ 10s-100s mV

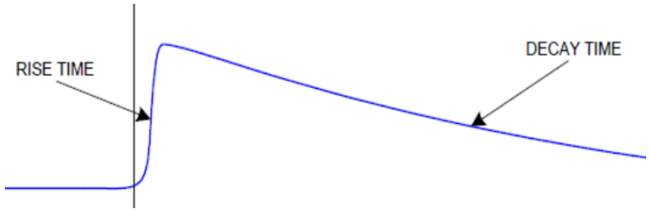
Basic operation

charge pulse from detector



PREAMP

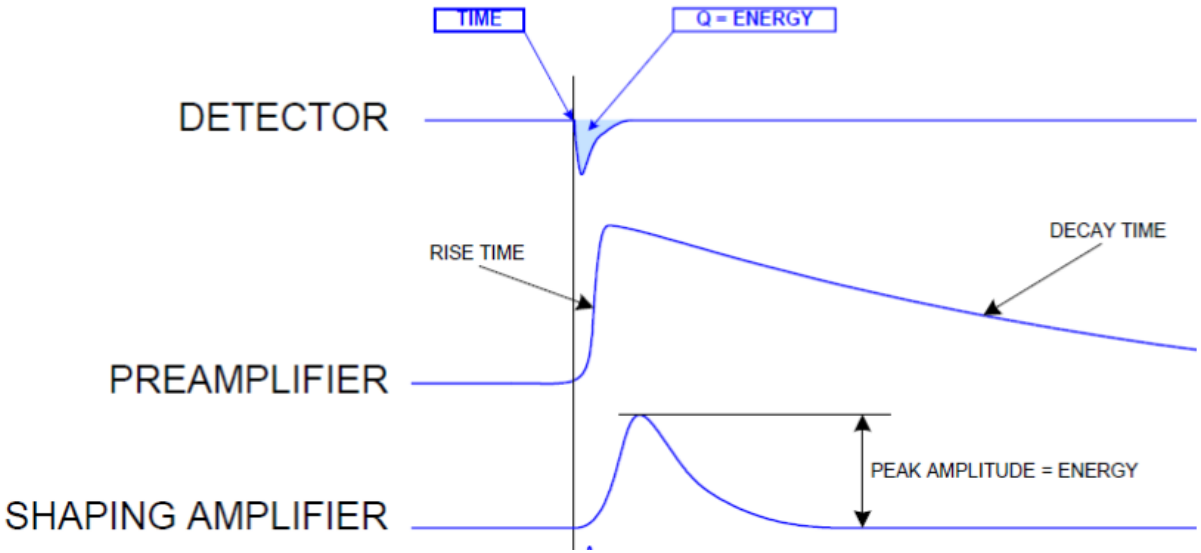
tail linear pulse



Model 2003BT
Silicon Detector Preamplifier

CANBERRA

Linear (shaping) amplifier



Input: linear tail pulse from preamplifier

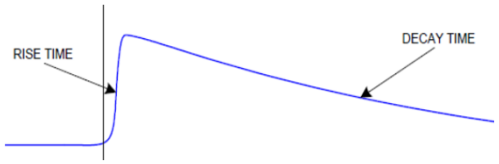
Output: amplified and shaped linear pulse

Shaping time : ~0.5-10µs

Output amplitude: $V_{out} \approx$ 0-10 V

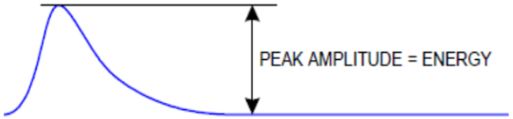
Basic operation

Tail linear pulse



Shaping amplifier

Shaped linear pulse

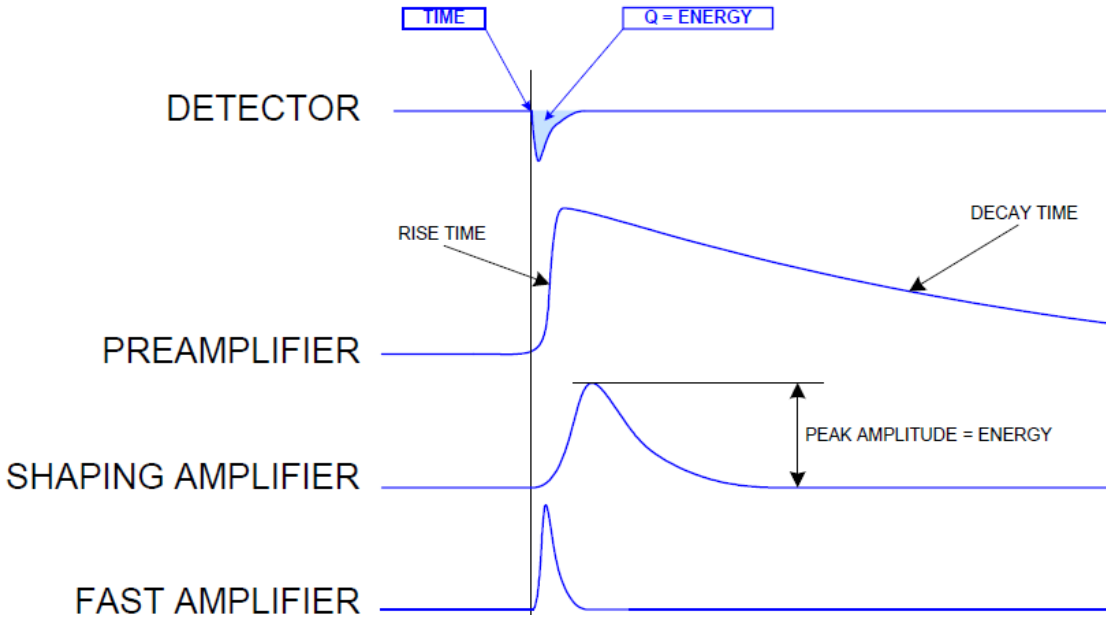


572A Amplifier

- General-purpose amplifier for energy spectroscopy with all types of detectors
- Built-in pile-up rejector and gated BLR with automatic thresholds for excellent performance at high counting rates
- Unipolar and bipolar outputs
- Active filter networks with wide range of time constants
- Wide gain range

ORTEC | AMETEK

Fast amplifier



Input: linear tail pulse from preamplifier

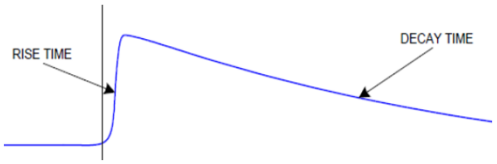
Output: fast (short length) linear pulse

Timing: few ns

Output amplitude: $V_{out} \approx$ few V

Basic operation

Tail linear pulse



Fast amplifier

Fast linear pulse

9309-4 Quad Fast Amplifier

- Rise Time <1.5-ns (for unipolar ≤±25 mV inputs).
- DC Coupled to allow high counting rates.
- 0 to 10 Adjustable Gain to provide flexible gain requirements.
- Two Outputs for each Amplifier allows simultaneous counting and timing.

ORTEC | AMETEK

Discriminator

- **Integral disciminator**

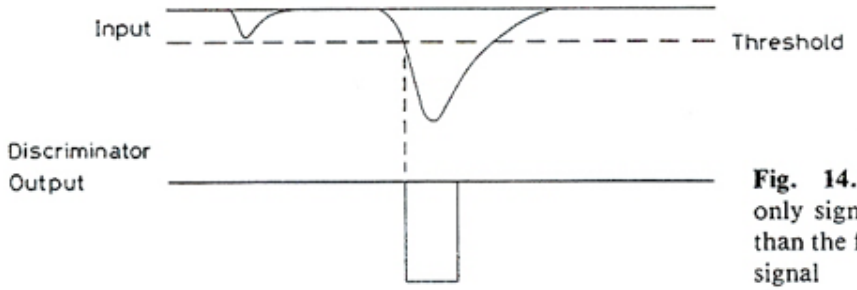


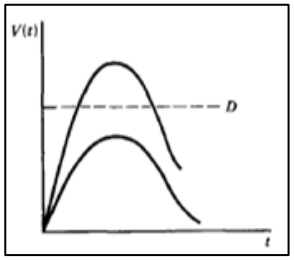
Fig. 14.14. Discriminator operation: only signals whose amplitude is greater than the fixed threshold trigger an output signal

Input: shaped linear pulse

Output: logic pulse if input amplitude exceeds discrimination level D

Discriminator

❖ Integral disciminator



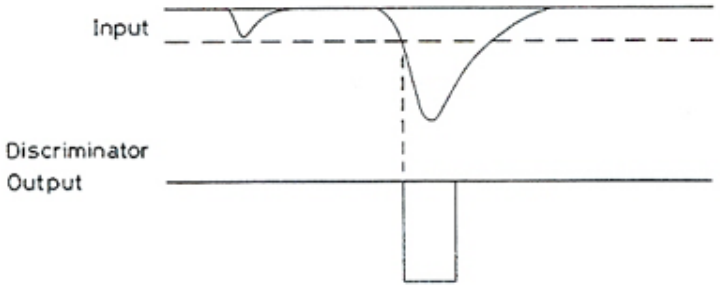
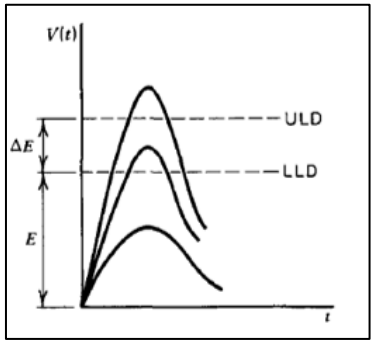


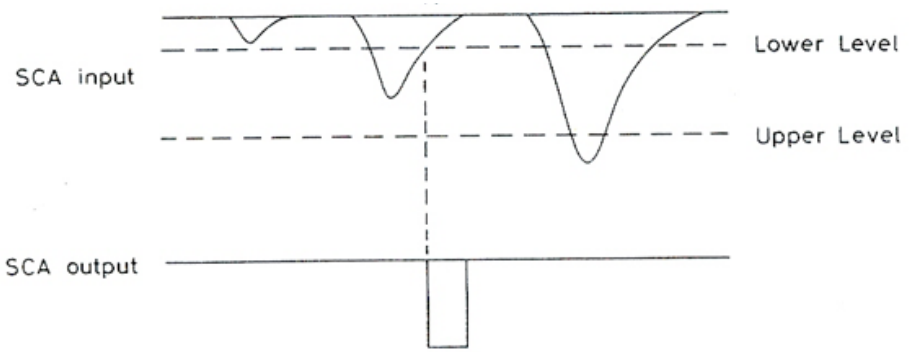
Fig. 14.14. Discriminator operation: only signals whose amplitude is greater than the fixed threshold trigger an output signal

Input: shaped linear pulse

Output: logic pulse if input amplitude exceeds discrimination level

❖ Differential discriminator (Single Channel analyzer)





Input: shaped linear pulse

Output: logic pulse if input amplitude lies within acceptance window

SCA: Single channel Analyzer

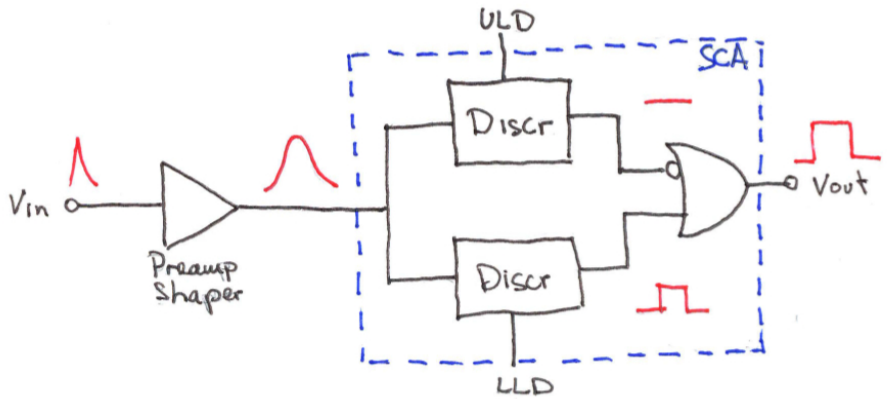
- In a large number of applications we are interested in counting the number of interesting events

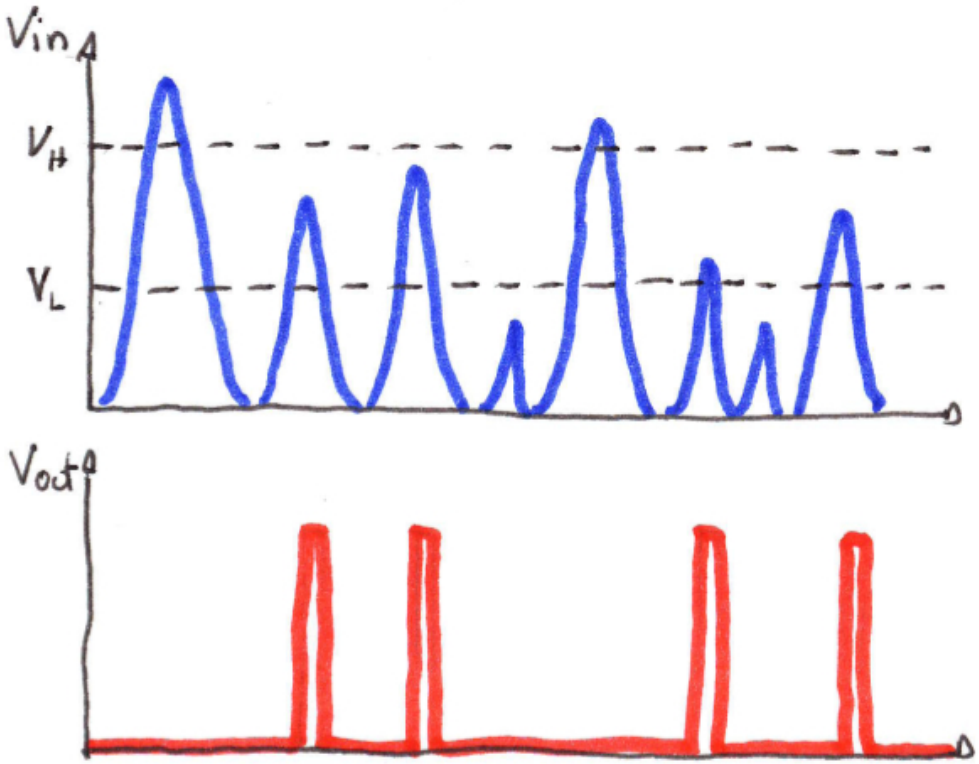
  Interesting : pulses generated by radiation passage
  pulses lying in an energy band

- Rest of pulses should be "cleaned-up"

- This step is necessary in almost all readout chain to eliminate
  - unavoidable existence of noise
  - spurious pulses

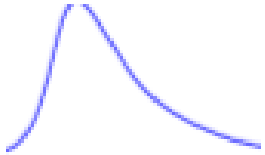
SCA: Technical Implementation





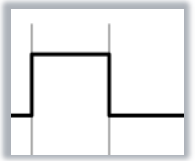
Basic operation

Shaped linear pulse



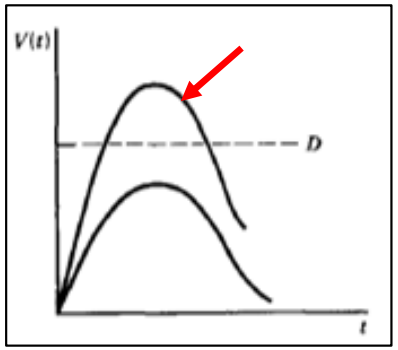
Discriminator
(integral / differential, SCA)

Logic pulse



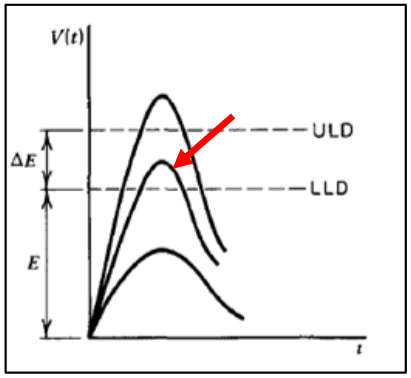
e.g. Tennelec TC 405
Integral Discriminator

Logic pulse at output for every input pulse with amplitude above threshold level D



e.g. ORTEC 850 Quad
Single Channel Analyzer
(Differential Discriminator)

Logic pulse at output for every input pulse with amplitude between the upper threshold level ULD and the lower threshold LLD



Timing Information

- Timing refers to the determination of the time arrival of a pulse
- Timing information is used to:
  - Control the time evolution of a process
  - Measurement of coincident events (trigger, cleaning, ...)
  - Time of flight techniques (particle id, trigger, ...)

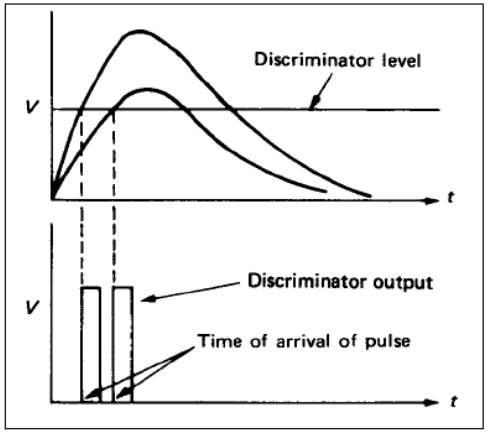
- Many methods developed but all of them based in measure the time on a certain point of the signal development
  - Leading-Edge Timing Method
  - Zero-Crossing Timing Method
  - Constant Fraction Timing Method

Time pick-off (trigger)

- **Leading edge timing**

Records the time when the pulse crosses a fixed discrimination level for amplitude.

Used for pulses with similar shape and amplitude.



Leading-Edge Timing Method

- Time determination with the help of a discriminator
  - Time measured with the output signal of the discriminator
  - Usually used the leading edge.
  - Trailing edge can be affected of stray capacitances, etc...

- Heavily affected by walk and jitter
  - Walk time: Time difference induced by different rise-time slope from different pulses
  - Jitter: electronic noise

  Walk time can be sometimes corrected with Time-Over-Threshold

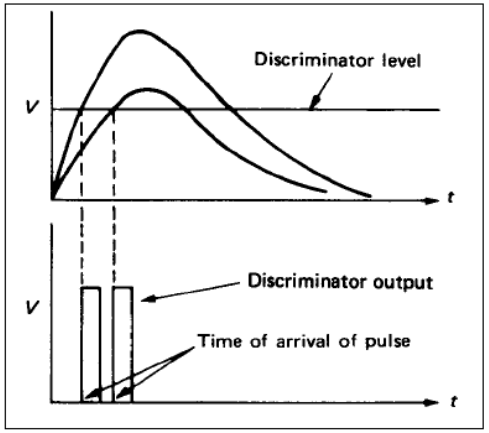
- Threshold level is critical
  - Low thresholds may allow to pass a fraction of random noise
  - Large thresholds may reduce the number of valid thresholds

Time pick-off (trigger)

Leading edge timing

Records the time when the pulse crosses a fixed discrimination level for amplitude.

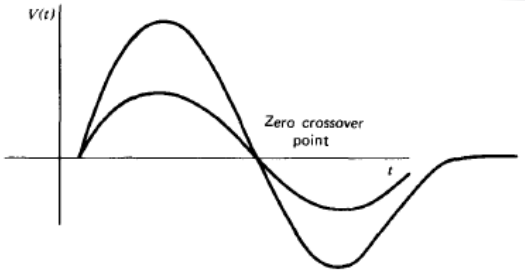
Used for pulses with similar **shape and amplitude**.



Zero Cross-over timing

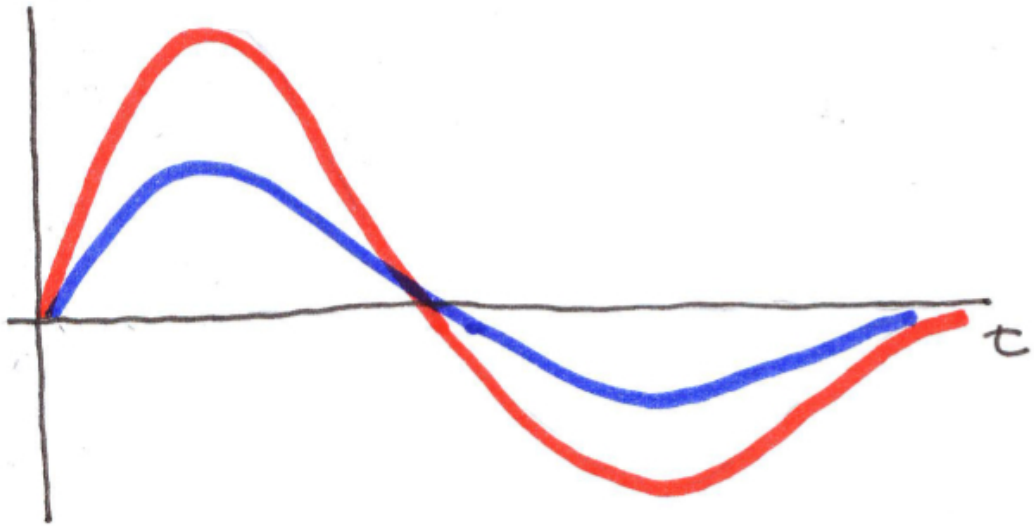
Records the time at which the waveform crosses from the positive to the negative side (requires bipolar shape).

Used for pulses with large variation in **amplitude**.



Zero-crossing method

- Effects due to jitter and walk time ca be avoided using the time from the zero crossing of a bipolar pulse
  - Based on the fact that the zero-crossing point is "independent" of pulse height
  - Jitter is reduced but not eliminated
  - Small walk dependence depending on risetime
- Needed to generate a bipolar pulse: problems with high rates

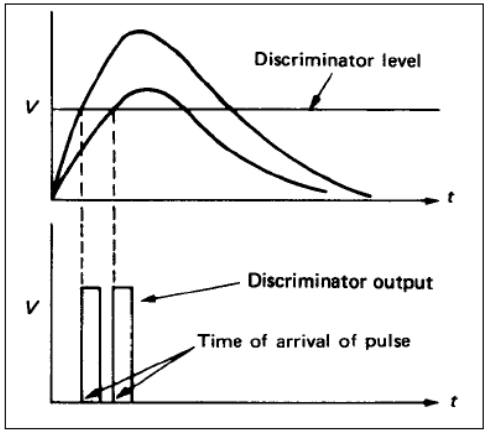


Time pick-off (trigger)

Leading edge timing

Records the time when the pulse crosses a fixed discrimination level for amplitude.

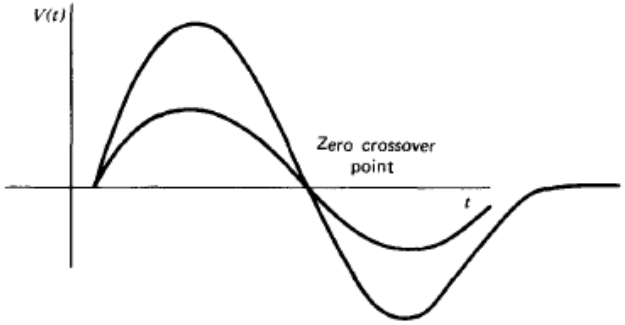
Used for pulses with similar **shape and amplitude**.



Zero Cross-over timing

Records the time at which the waveform crosses from the positive to the negative side (requires bipolar shape).

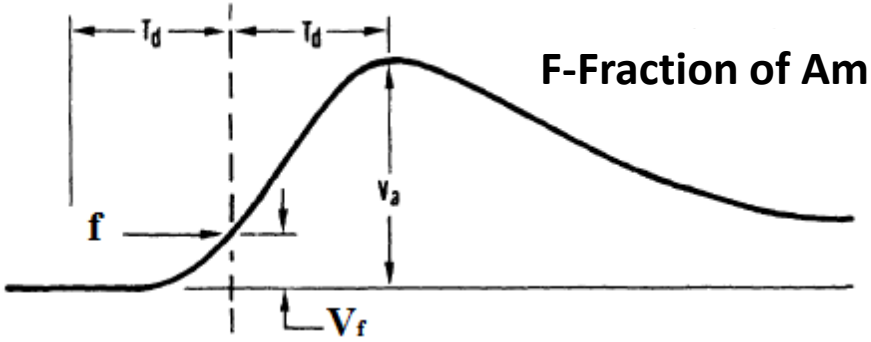
Used for pulses with large variation in **amplitude**.



Constant fraction timing

Records the time after which the leading edge of the pulse has reached a *constant fraction* of the peak pulse amplitude.

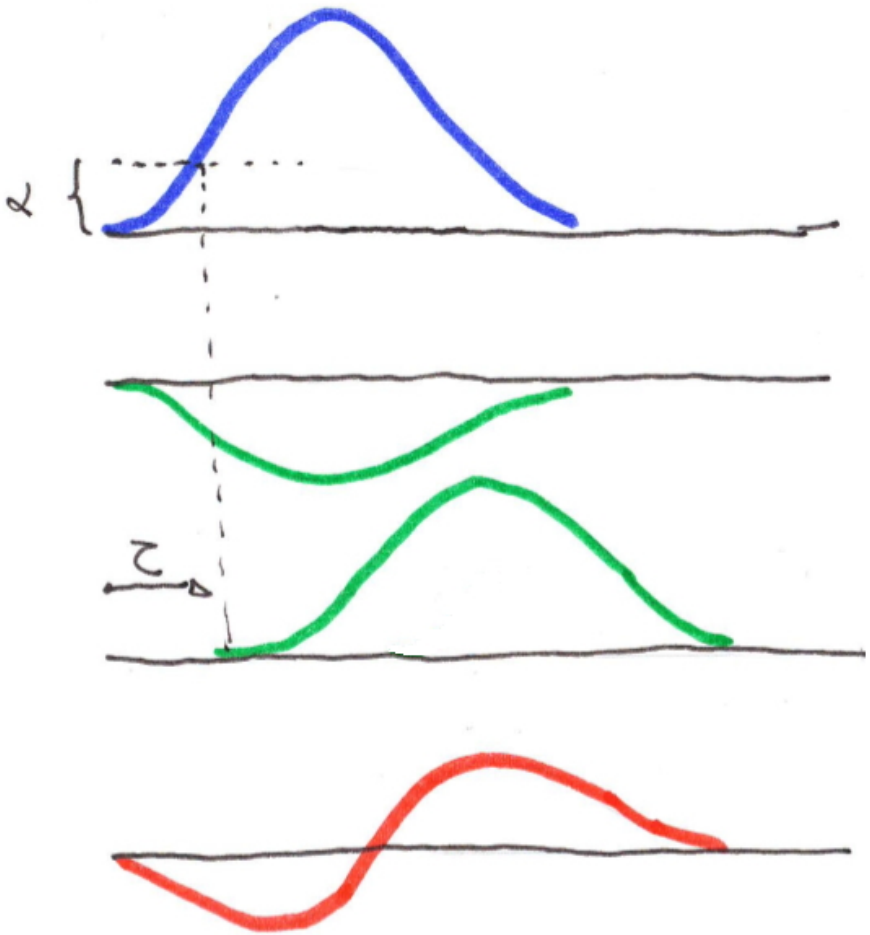
Used for pulses with similar **shape**, independent of the amplitude.



Constant-Fraction Method

- Most efficient and versatile timing method
- Timing signal is generated at a constant fraction (k) of its pulse height $\rightarrow$ walk time free
- Technique based on empirical test showing that there is an optimal threshold for timing. Depends on each signal
  1. Input signal is split in two
  2. One signal is inverted and attenuated by the fraction k
  3. The other signal is delayed by the time τ it takes to arrive to this fraction
  4. Both signals are summed and the zero-crossing point of the resulting signal is used
- This technique uses zero-crossing, but unlike this, a bipolar pulse is not required.
- Timing method needed when high time resolutions are required ($< 100ps$)

Constant-Fraction Method



$$f(t) = V(t-\tau) - \alpha V(t) = 0$$

$$V(t-\tau) = \alpha V(t)$$

$$V(t-\tau) = 2V_{-0.5}$$

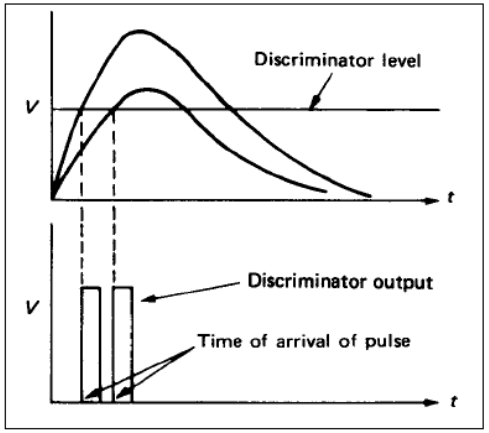
$$\alpha = \frac{V(t-\tau)}{V_{max}}$$

Time pick-off (trigger)

Leading edge timing

Records the time that the pulse crosses a fixed discrimination level for amplitude.

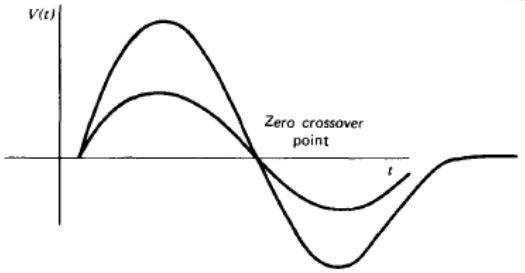
Used for pulses with similar shape and amplitude.



Zero Cross-over timing

Records the time at which the waveform crosses from the positive to the negative side (requires bipolar shape).

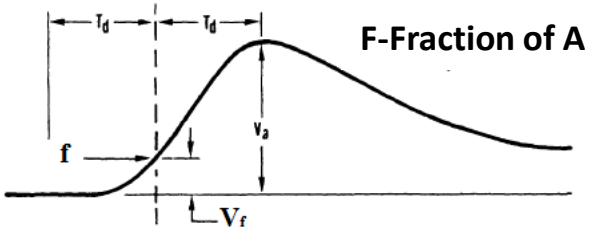
Used for pulses with large variation in amplitude.



Constant fraction timing

Records the time after the leading edge of the pulse has reached a *constant fraction* of the peak pulse amplitude.

Used for pulses with similar shape, independent of the amplitude.

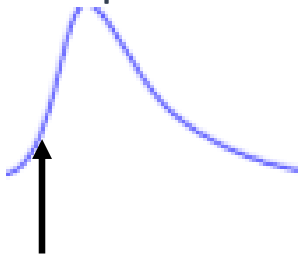


Input: fast linear or shaped linear pulse

Output: logic pulse synchronized with some feature of input pulse

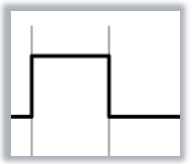
Basic operation

Fast (shaped) linear pulse



Time pick-off
(pulse appearance time)

Logic pulse



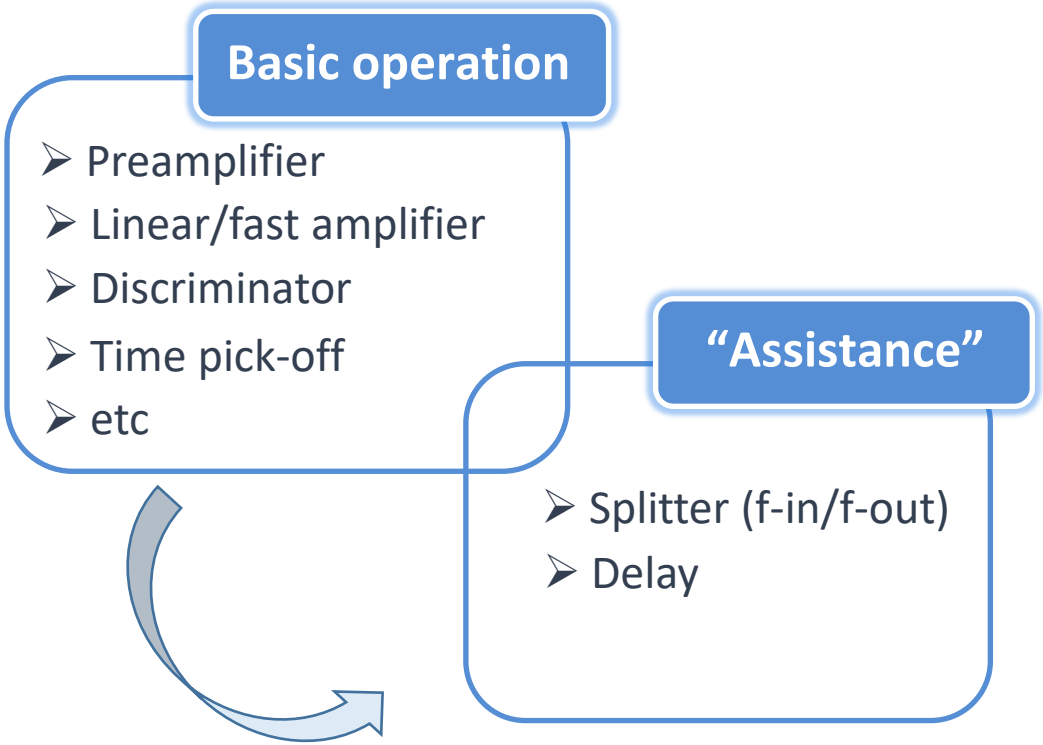
Features

- Four CF discriminators in a single-width NIM
- 200 MHz count rate capability
- 1000:1 dynamic range
- Typical walk <±30 ps for 100:1 dynamic range
- Selectable fraction or leading edge operation
- Output indicator LEDs
- Gated operation

Model 454 200 MHz Quad
Constant Fraction Discriminator

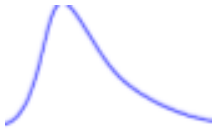
CANBERRA

Pulse-processing units: “rude” role classification



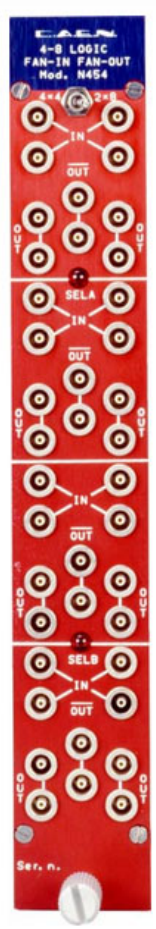
“Assisting”

Shaped linear pulse



Two identical pulses

Fan-in/ Fan-out



N454

4-8 Logic FAN-IN/FAN-OUT

- 4 independent sections with 4 inputs each
- OR output with fan out of four per section
- Possibility of cascading channels to form dual 8-fold fan-in/ fan-out
- Input/output delay less than 7 ns
- 100 MHz max. input frequency

CAEN
Tools for Discovery

“Assisting”

DELAY

Signal ~66% of light speed (5ns/m)

Input: linear pulse (fast or shaped)

Output: identical pulse after fixed time delay

“Assisting”

To test electronics and monitor dead time :

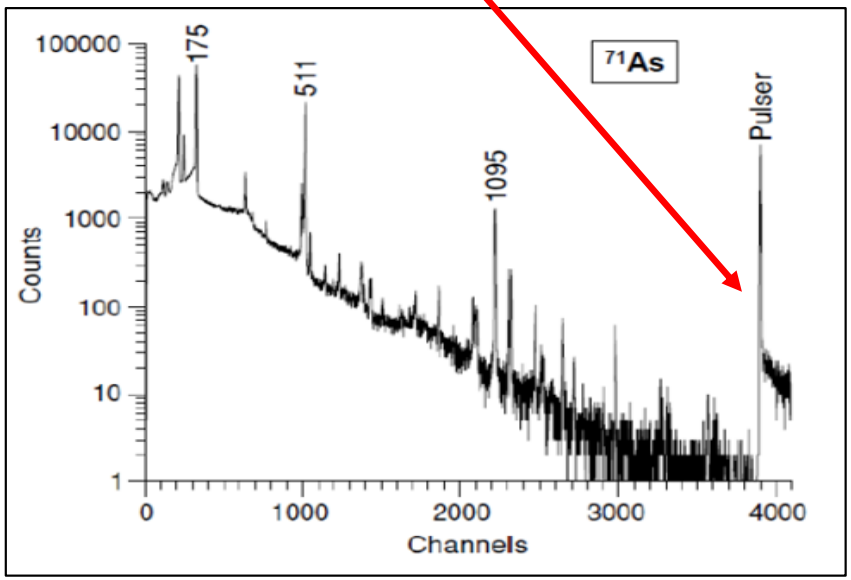
Pulse generator

Exponential linear pulse
(you set frequency and amplitude)

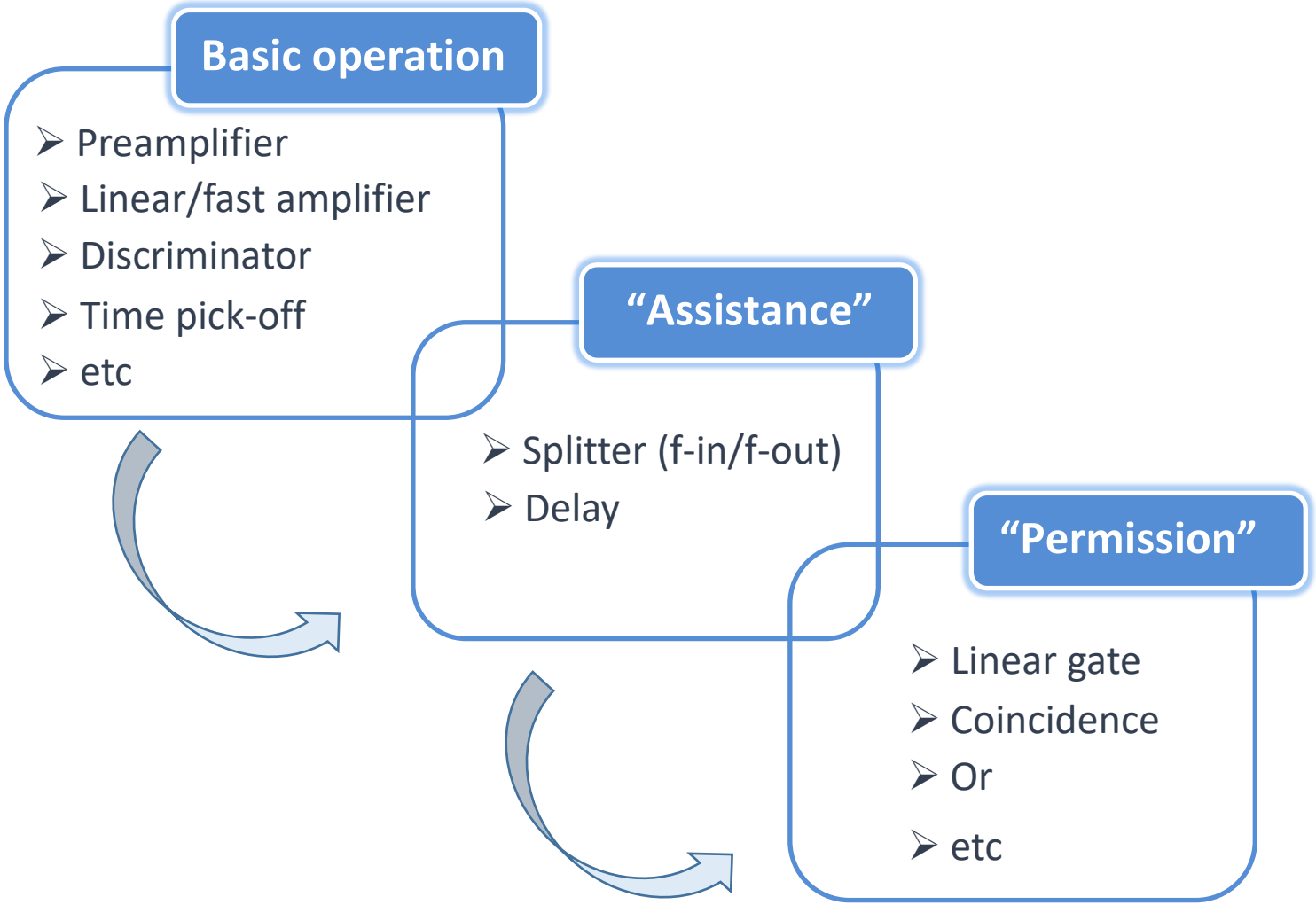
419 Precision Pulse Generator

- Simulates detector output signals
- Precision dial may be calibrated to read directly in terms of equivalent energy deposition in semiconductor radiation detectors
- Exponential pulse shape with 5- to 250-ns rise time and 200- or 400-µs decay time constant
- Line frequency or 70-Hz pulse rate
- Positive or negative polarity
- Direct 0 to 1-V output (0 to 10 V with external reference voltage)
- Attenuated output with 2000:1 attenuation range
- Internal or external reference voltage

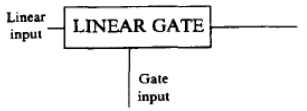
ORTEC | AMETEK



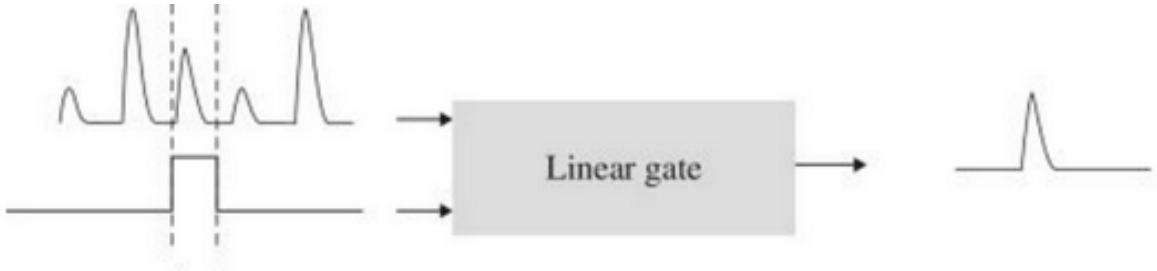
Pulse-processing units: “rude” role classification



“Permission” units: linear gate



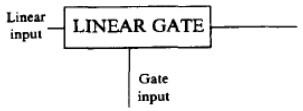
❖ Linear gate **permits** a signal when it is accompanied with a logic pulse



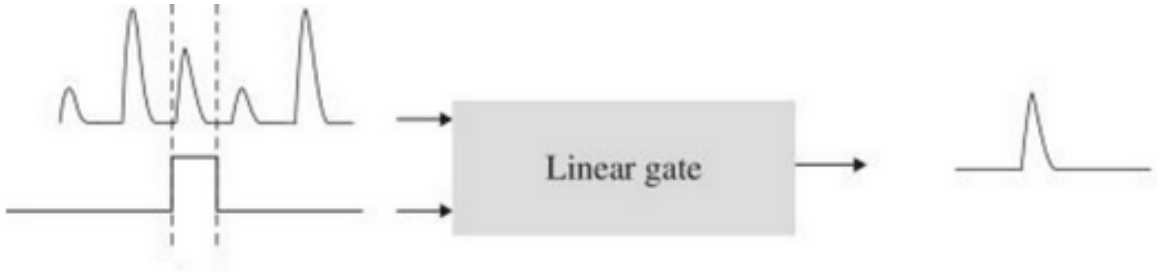
Input: 1) shaped linear pulse and 2) gate pulse (logic)

Output: linear pulse identical to input if gate (logic) pulse is supplied in time overlap

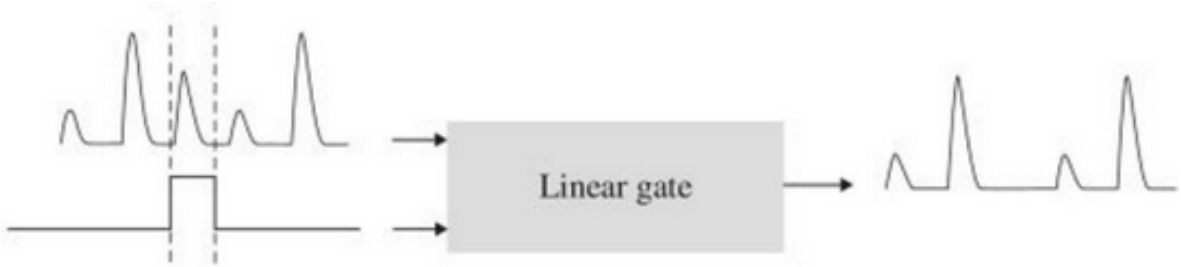
“Permission” unites: linear gate



❖ Linear gate **permits** a signal when its accompanied with a logic pulse



❖ Linear gate **blocks** a signal when its accompanied with a logic pulse

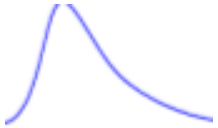


Input: 1) shaped linear pulse 2)gate pulse

Output: linear pulse identical to input if gate (logic)pulse is supplied in time overlap

“Permission”

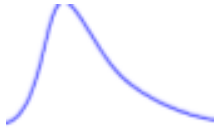
Shaped linear pulse



Linear Gate

Permission logic pulse

Identical pulse



426 Linear Gate

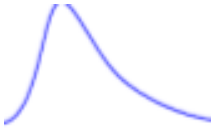
- For passing and blocking analog signals in the range from +0.2 to +10 V
- Ungated or gated with coincidence or anticoincidence gating
- External or internal control of gate pulse width

The ORTEC Model 426 Linear Gate provides a variable gate duration with width controlled by a single-turn front-panel-mounted potentiometer.

ORTEC | AMETEK

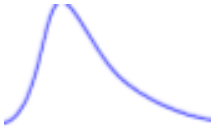
“Permission-Assisting”

Shaped linear pulse



Gate-and-Delay Generator

Shaped linear pulse



Permission logic pulse

416A Gate and Delay Generator

- Provides adjustment of the delay, width, polarity, and amplitude of gating pulses
- Positive or negative polarity input pulse
- Time delay from 0.1 to 110 µs
- Output pulse width from 0.4 to 4 µs
- Excellent time delay stability

ORTEC | AMETEK

“Permission” units: coincidences

- Coincidence

(anticoincidence)

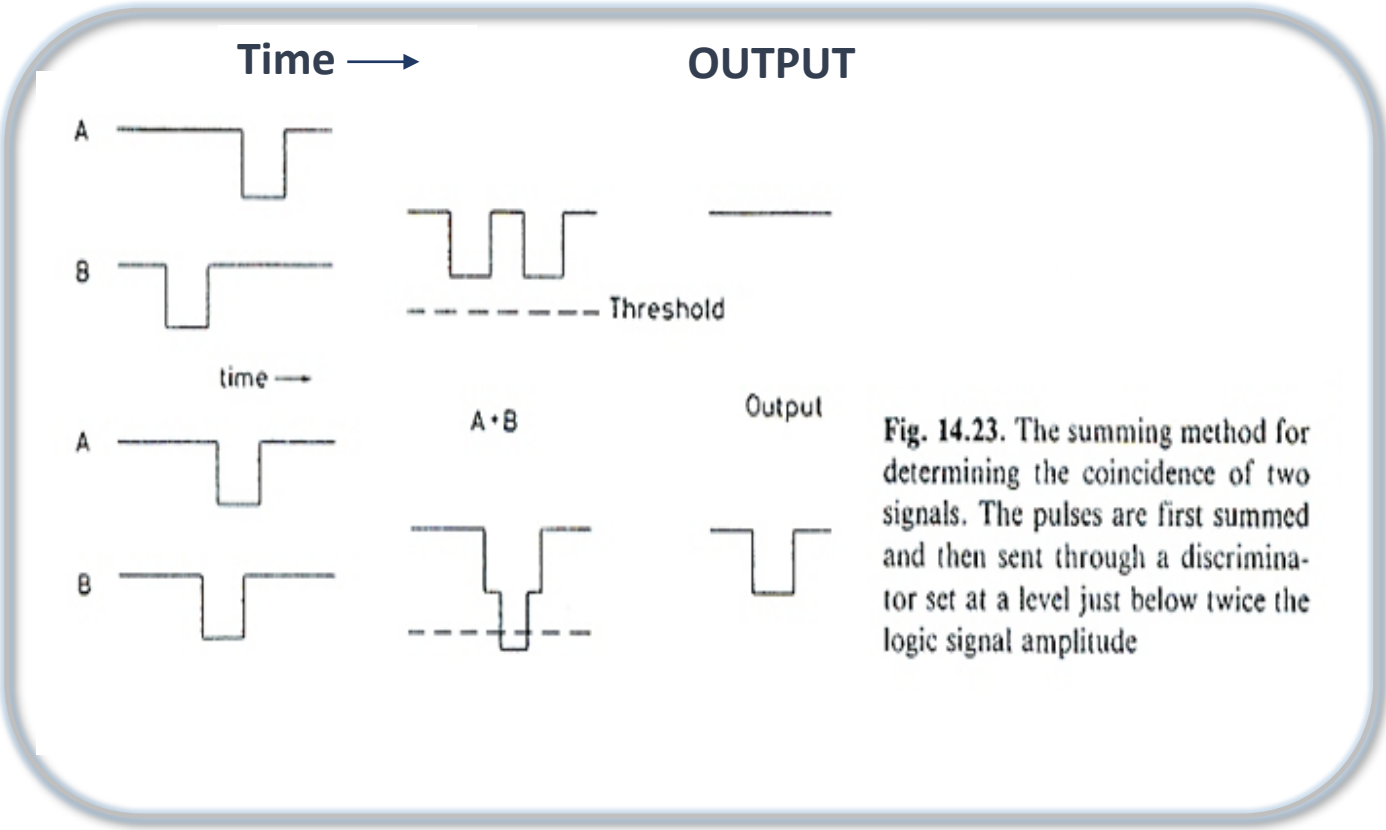


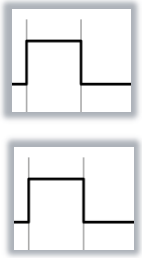
Fig. 14.23. The summing method for determining the coincidence of two signals. The pulses are first summed and then sent through a discriminator set at a level just below twice the logic signal amplitude

Input: logic pulses (for timing!) at two or more inputs

Output: logic pulse if pulses appear at all inputs at time interval τ (resolving time)

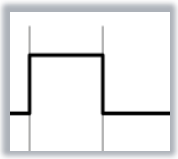
“Permission”

2 Logic pulses



Coincidence (anti)

Logic pulse



N455

Quad Coincidence Logic Unit

- 4 identical independent sections
- Two inputs per section
- 130 MHz Max input frequency
- 6 ns double pulse resolution
- 10 ns I/O delay
- Switch selectable AND/OR logical function
- Adjustable output FWHM (4 to 650 ns)
- Overlap output
- Common Veto

CAEN *Tools for Discovery*