Short-introduction to Signal processing

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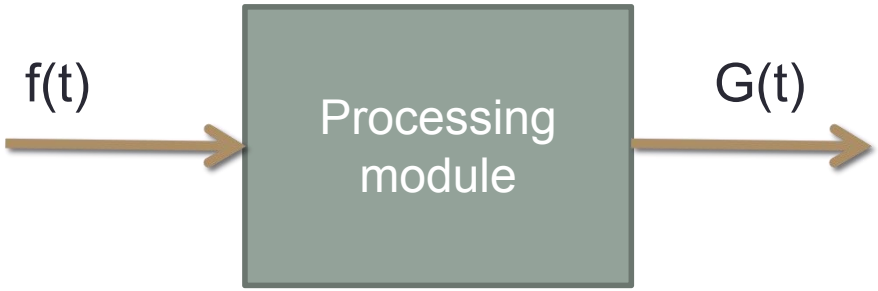
Introduction

- Signal Processing is a way to convert signal from detector into useful signals
- Signal processing includes signal formation due to a particle passage within a detector, signal amplification, signal shaping (filtering) and readout.
- Two types of information can be extracted from a signal
  - Amplitude: energy, type of particle,..
  - Arrival time: localization,..

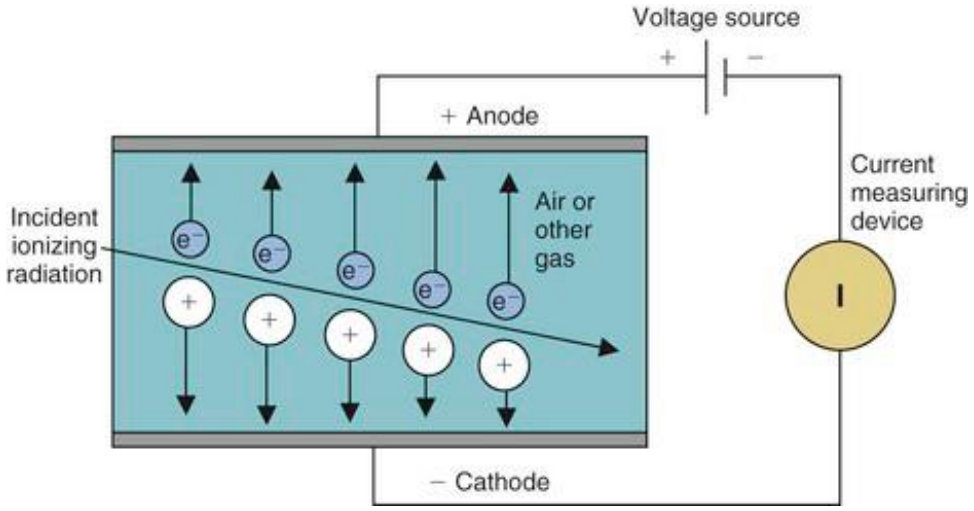
Introduction

- Different pulse processing techniques are typically employed, depending on whether the arrival time or the amplitude of the detected event must be measured.



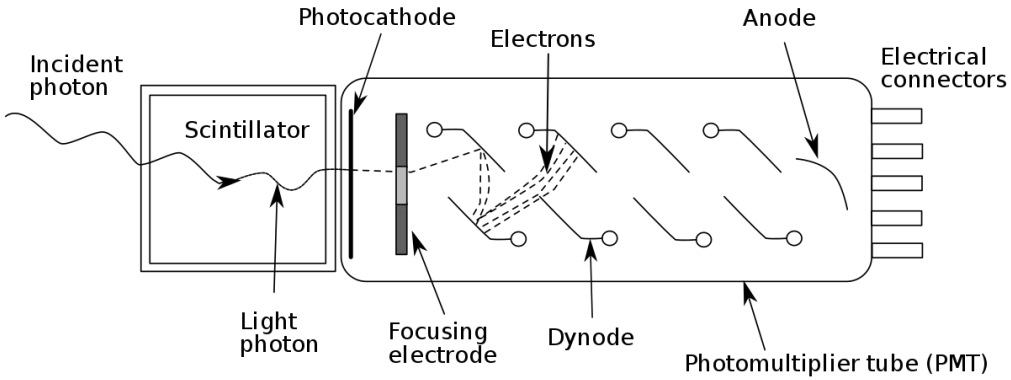
Detector

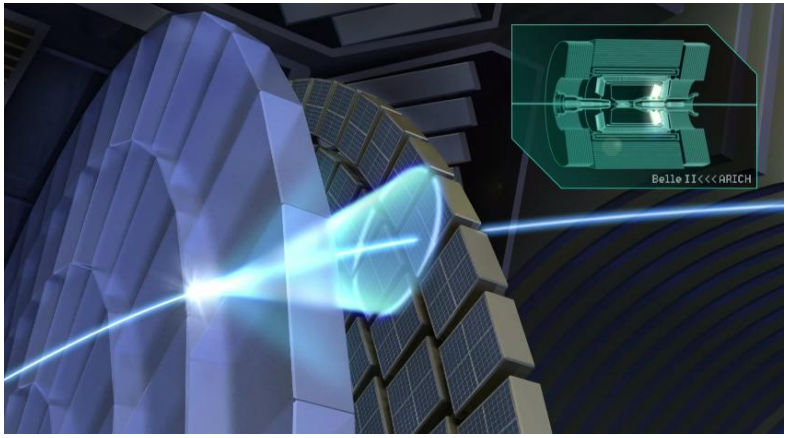
- We detect a particle based on its interaction with the detector material.
- Charged particle interact with detector via ionization/ excitation.
- Neutral need other process to transfer their energy into charged particle.



Detector

- The gas and semiconductor detector: ions/electrons/holes produced by ionization will be collected and produced signal.
- The Scintillator/Cerenkov detector: the interaction will produce light. we need PMT/photo diode to convert light into electric signal.





Cerenkov light are detected by Hybrid Avalanche Photo Detector

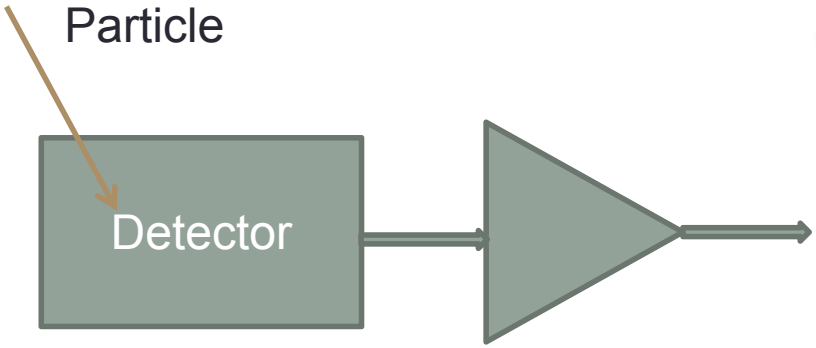
Pre-Amplifier

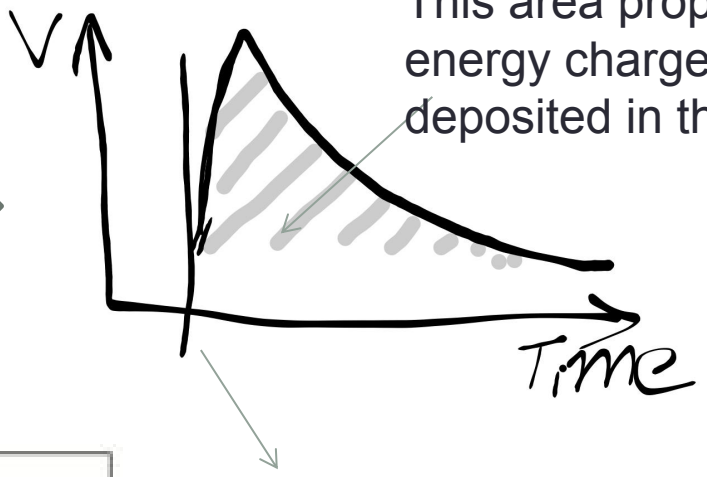
- Amount of charged produced by particle in the detector is very small, the signal is unable to digitize or even count=>need to amplify
- The primary function of a amplifier is to extract the signal from the detector and pre-amplifier without significantly degrading the intrinsic signal-to-noise ratio.

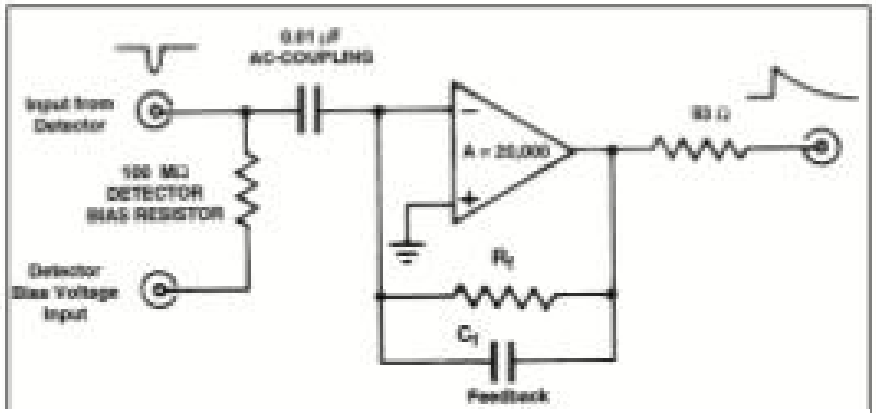
=> Located as close as possible to the detector.

=> The input circuits are designed to match the characteristics of the detector.

Pre-Amplifier







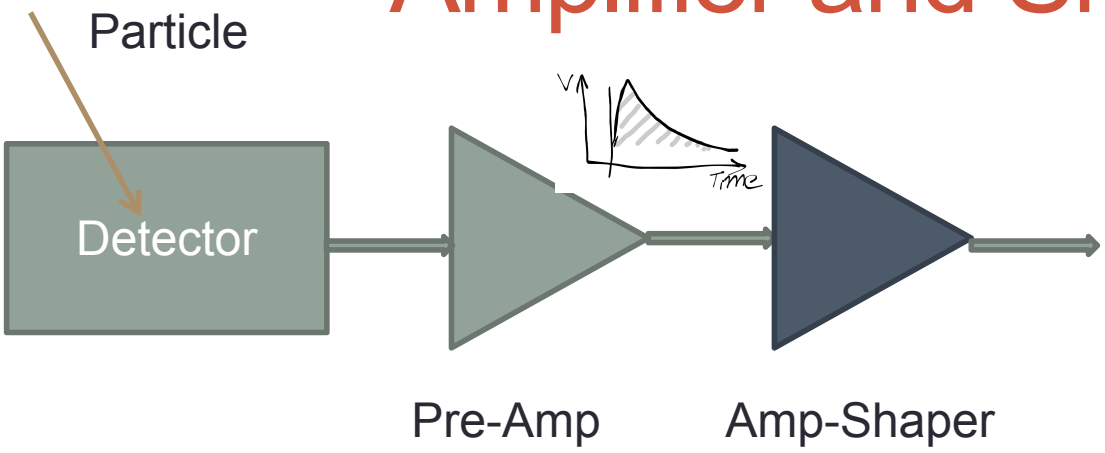
Example of a charged sensitive pre-amp

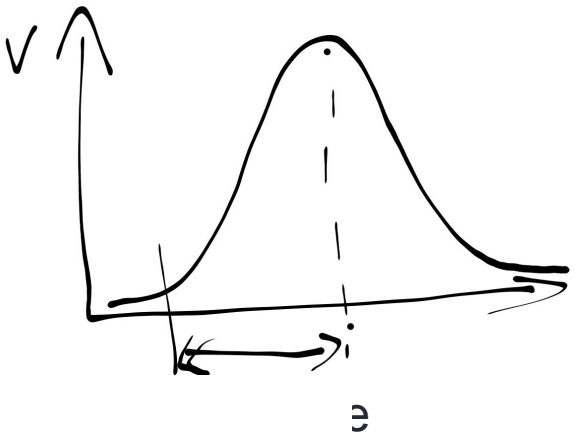
- Depend on purpose and the status of pulse (amplitude, shape) after the pre-amplifier. This signal will be sent to other module for further processes.

Amplifier and Shaper

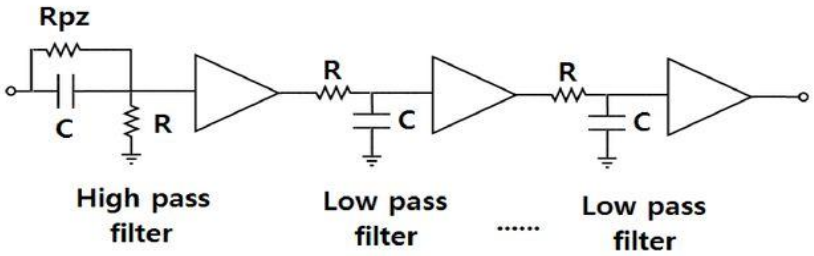
- Ouput pulse from pre-amp is still not approprioate for further process such as amplidude measurement. It will be amplified and shaped before send to next modules such as ADC, Discriminator,...
- The output shape from Amp-shaper is designed to match with the requirement of ADC input. The common shape is Gaussian.
- Typically,amplifier and shaper are implimented together in a single module.

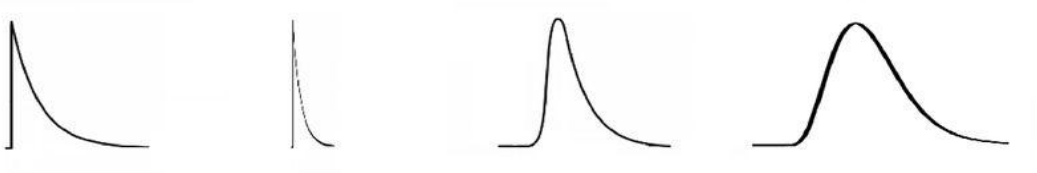
Amplifier and Shaper





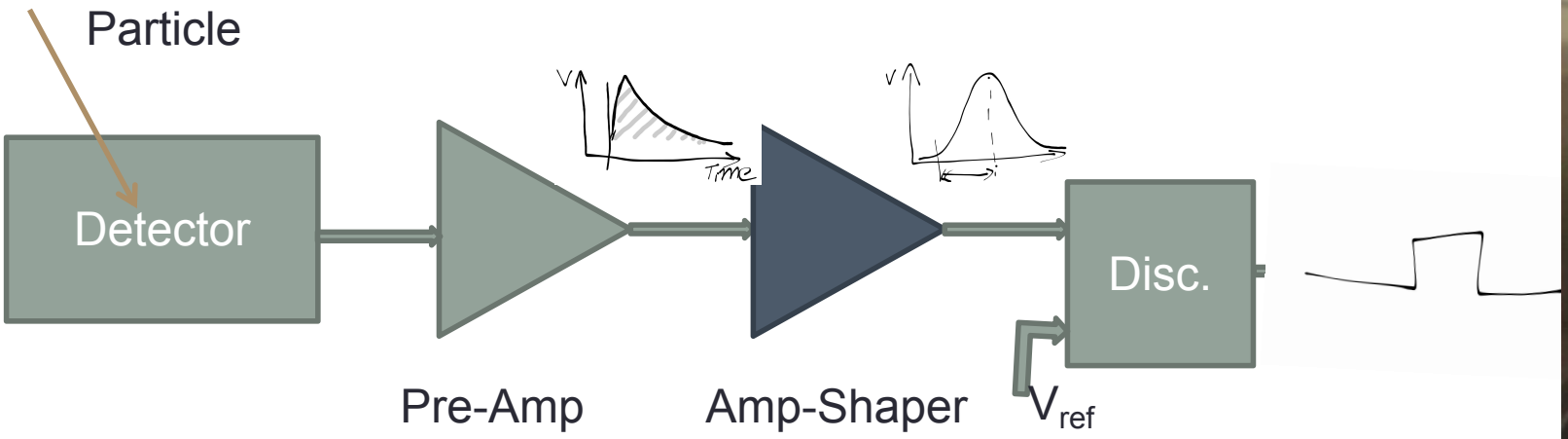
Shaping Amplifier

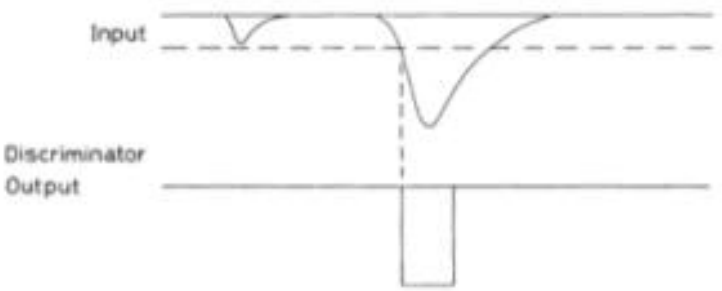




Discriminator

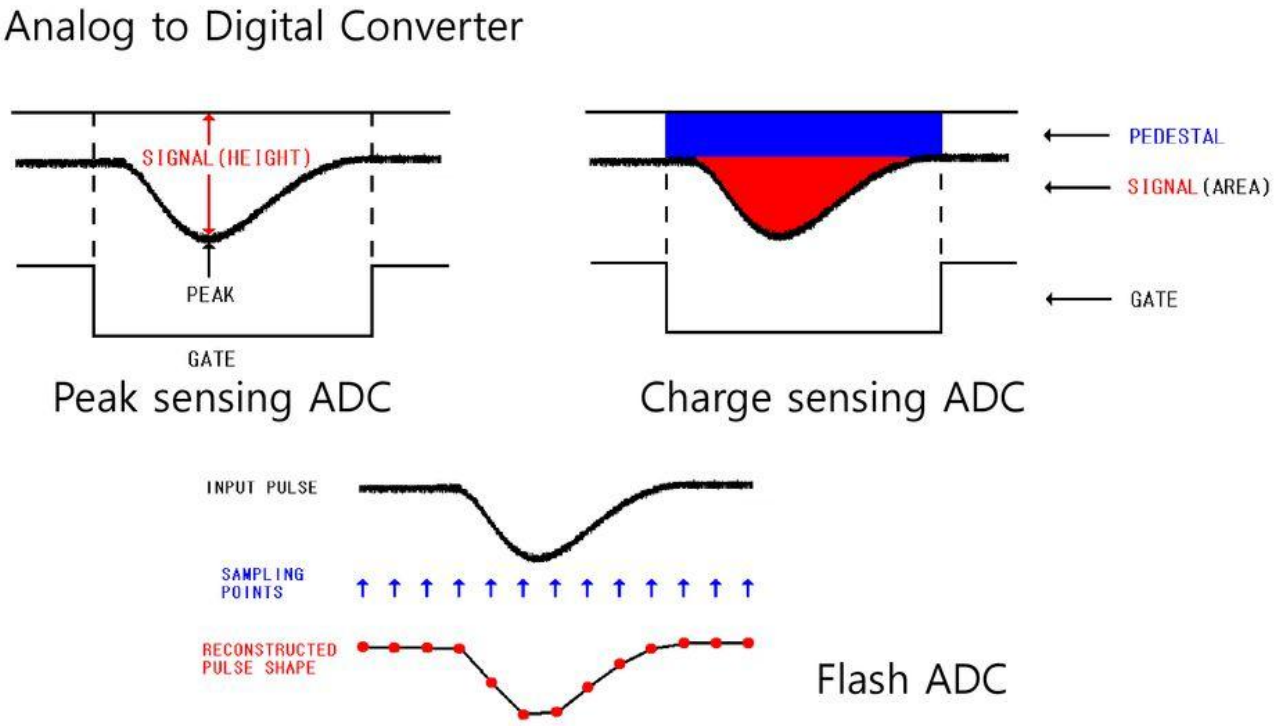
- Produced a logic signal when a signal exceed the threshold.
- Output signal is typically used for trigger or timing measurement, or counting,...





ADC - Analog to Digital Converter

An analog-to-digital converter (ADC) measures the maximum amplitude (or the integrated value) of an analog input pulse and converts that value to a digital number.



Example: ADC wilkinson

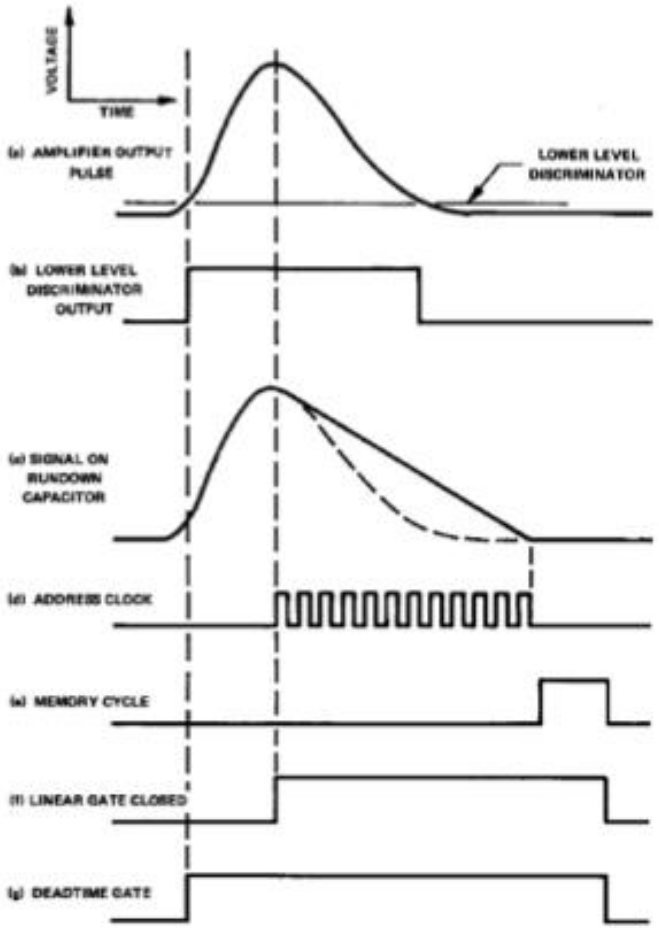


Fig. 1. Signals in the Wilkinson ADC During the Pulse Measurement Process.

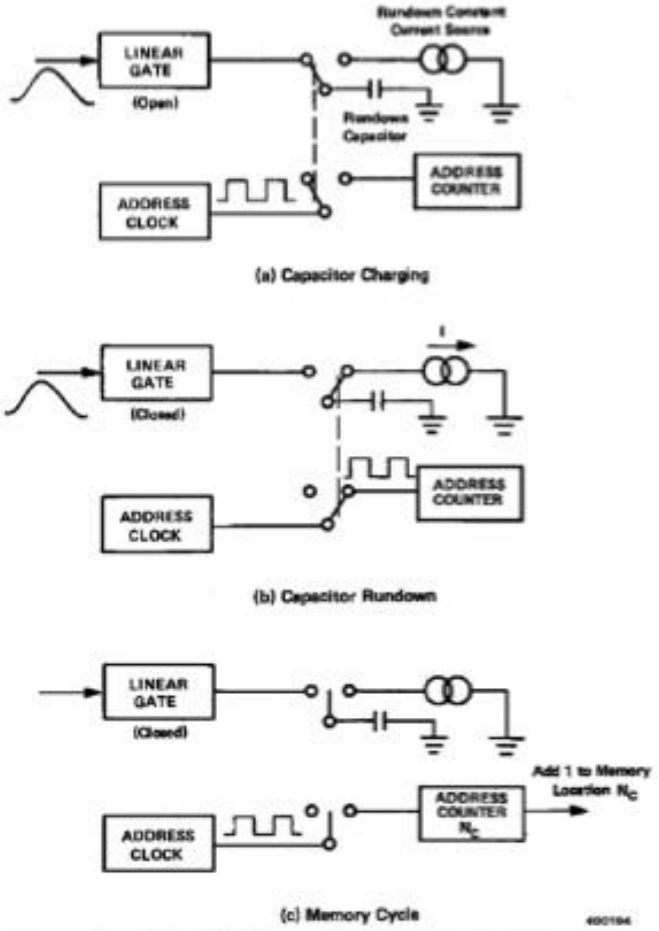


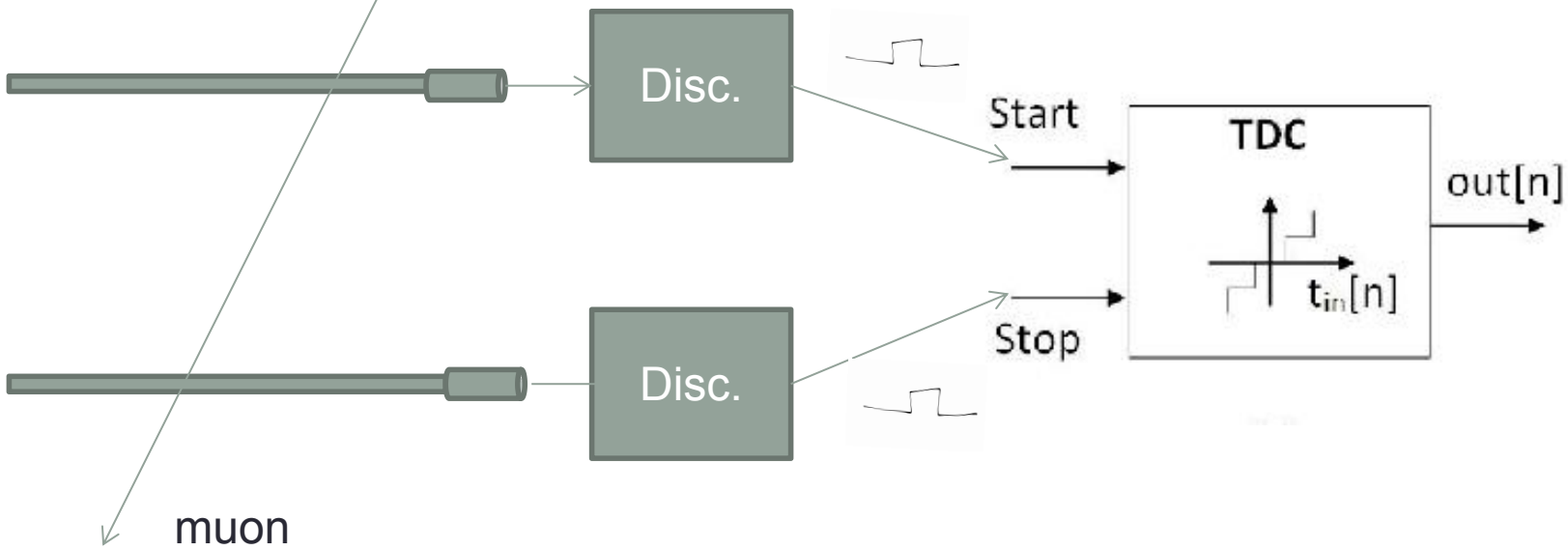
Fig. 2. Operation of the Wilkinson ADC During the Three Stages of Pulse Amplitude Measurement. (a) Charging of the rundown capacitor, (b) Capacitor rundown, and (c) The memory cycle.

Time to Digital Converter (TDC)

- TDC measures the elapsed time between a start and a stop signals

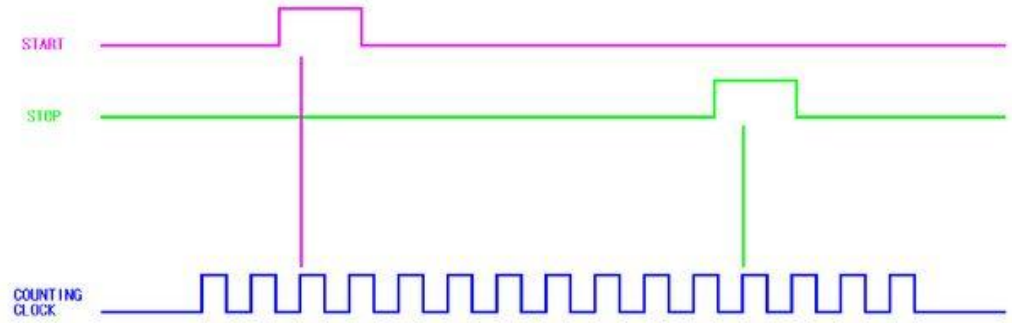
=>Ouput is a TDC count ~time information.

- Start and stop signals are logic signals, such as the output from discriminator, trigger signal.



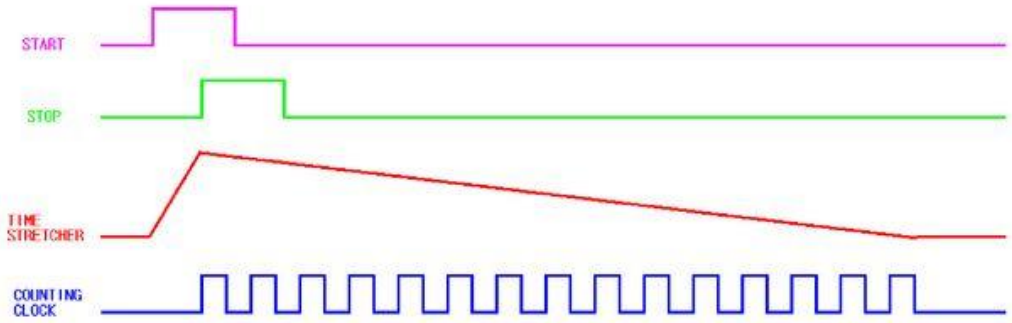
TDC

Time to Digital Converter



Direct counting

Resolution ~ 1 ns

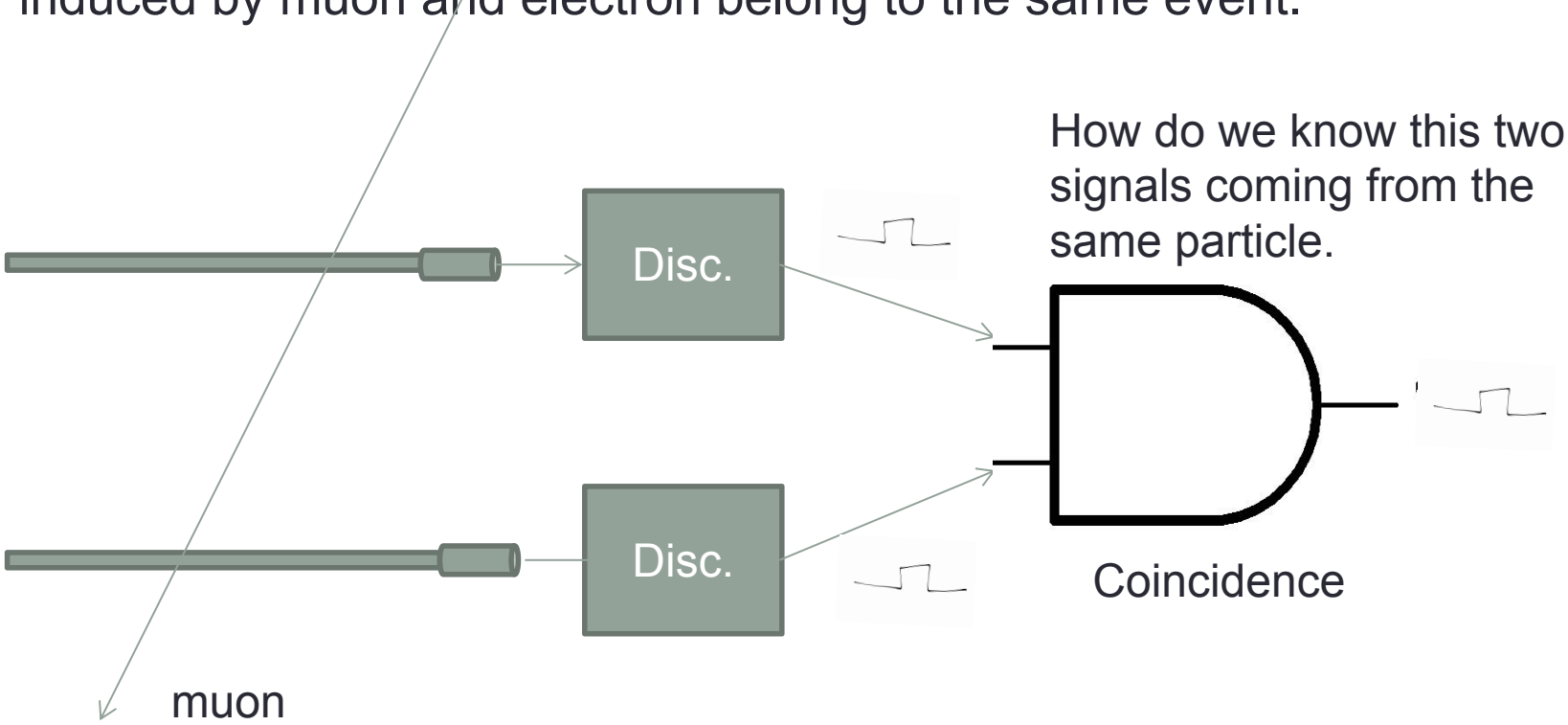


Time stretching

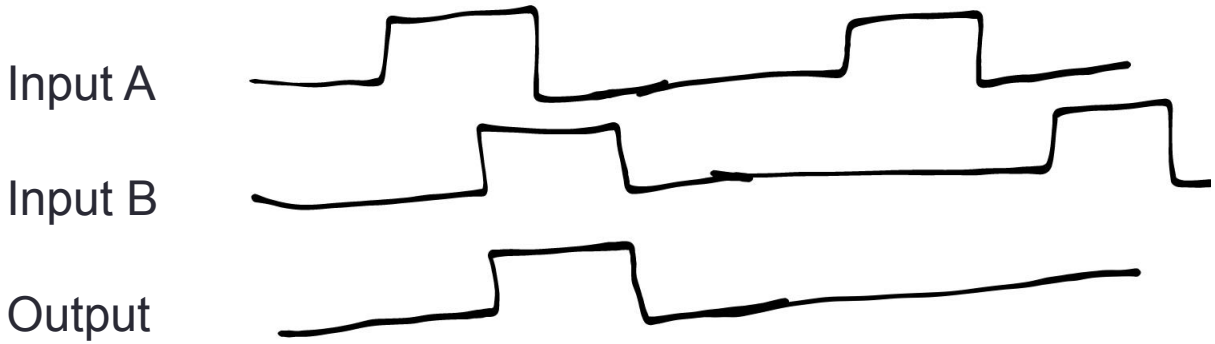
Resolution ~ 10 ps

Coincidence

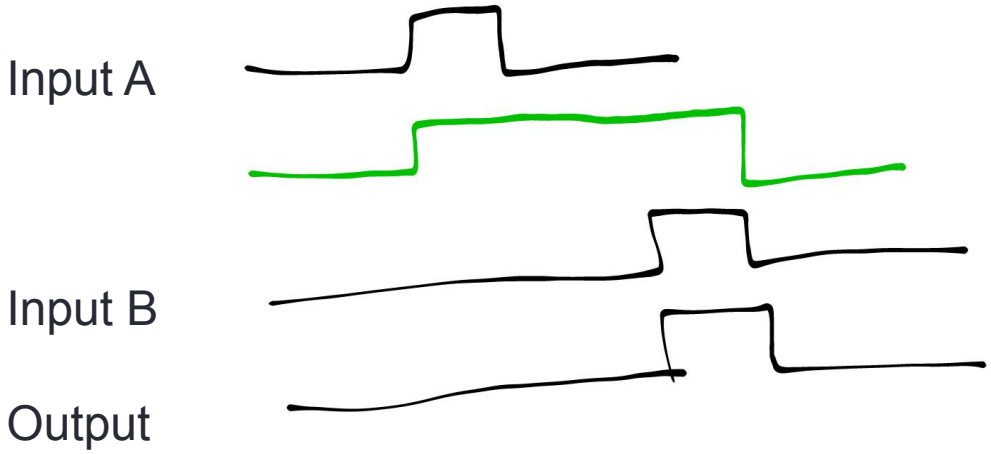
- To identify events which happen simultaneously.
- In muon life time measurement, we have two make sure the signal induced by muon and electron belong to the same event.



Coincidence



What is simultaneously/same time?--> Coicidence window



Counter and timer

- For counting experiment, a counter is used to count number of event at the final step.
- Counter accept logic pulse, e.g the pulse output from discriminator, coincidence modules.

Example: Amplifier-Shaper-Discriminator of Belle II CDC

- Charged particle pass through the detector

→Ionize gas → produce electron → drift to anode →electronic signal

- The timing is important to measure drift time

  → Drift distance → position

- Amplitude of the signal is proportional to dE/dx

→ type of particle

Example: Amplifier-Sharpe-Discriminator of Belle II CDC

We need to measure both timing and amplitude.

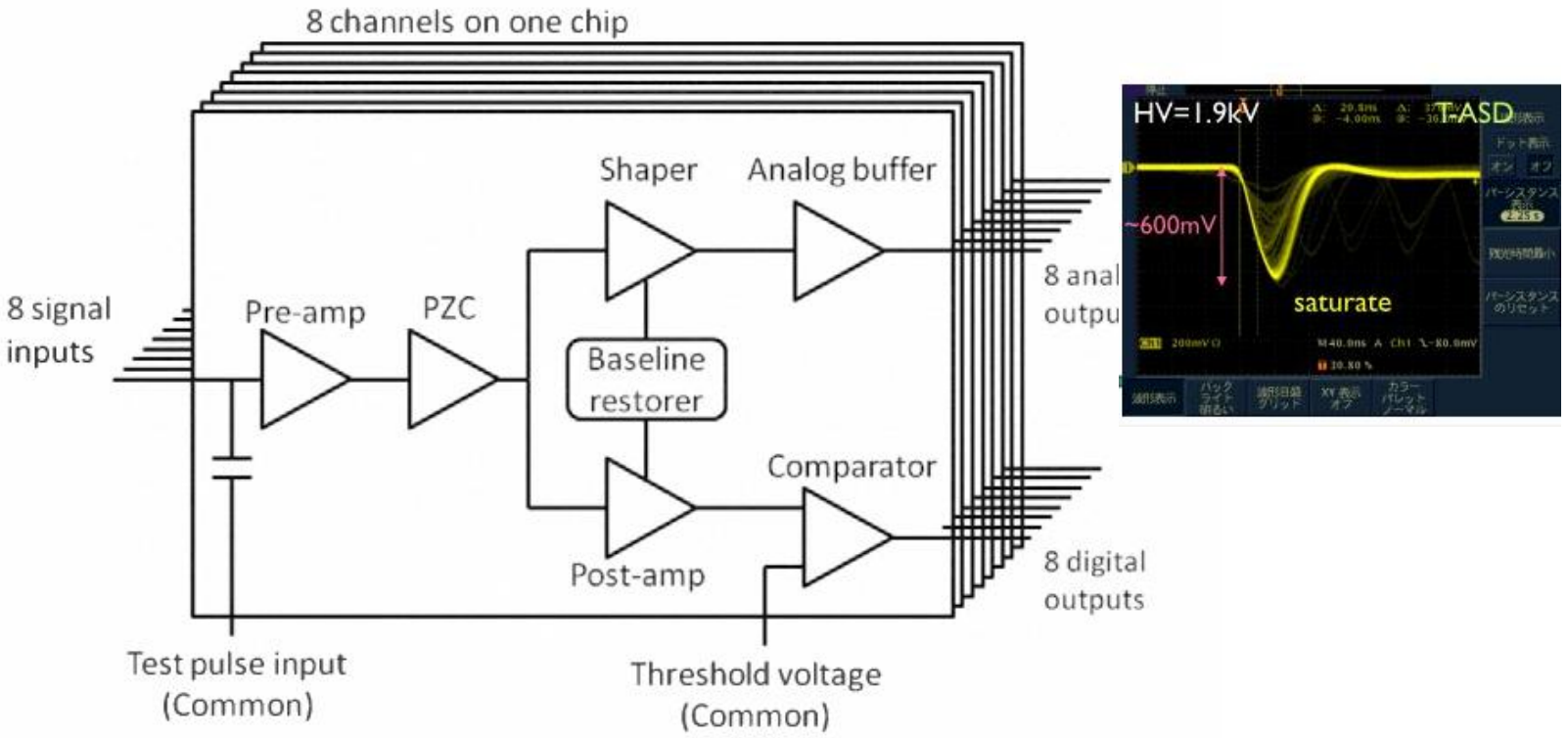
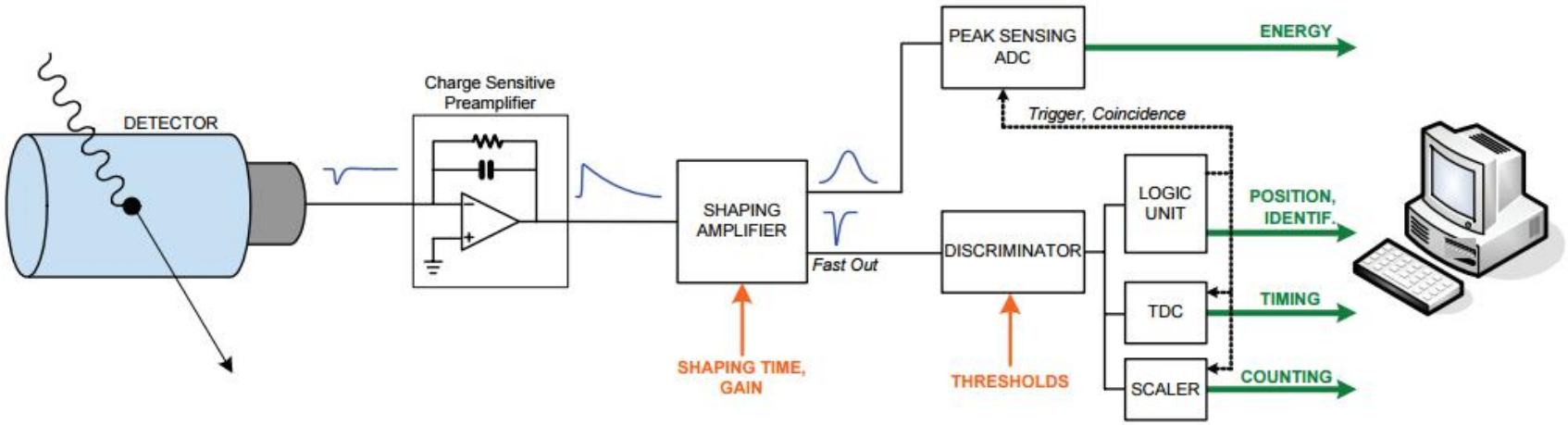
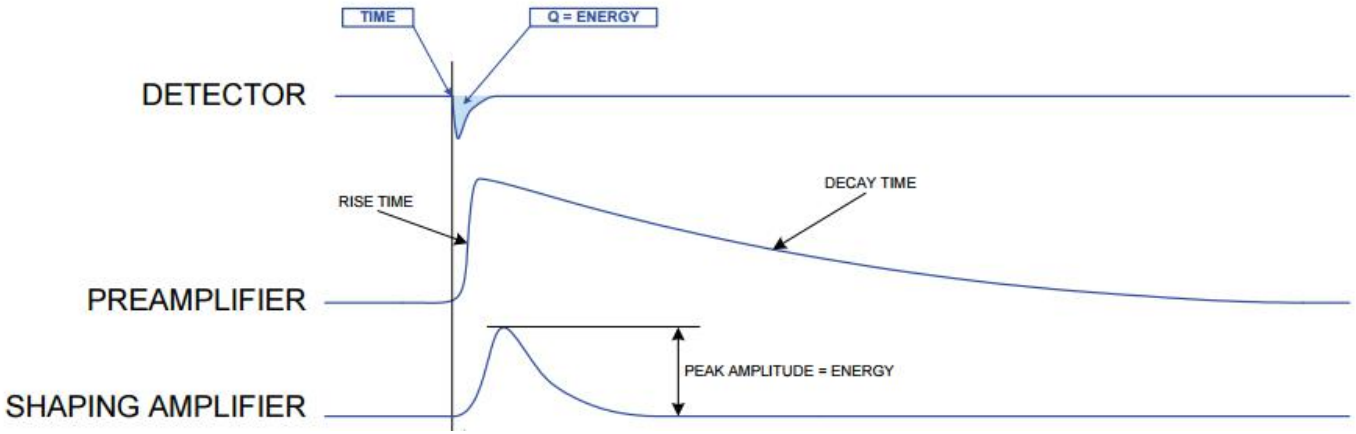


Fig. 4. Block diagram of the frontend ASD.

Example: scintillation detector





How to measure ampliture of 1photon, 2photon,... automatically/precisely?