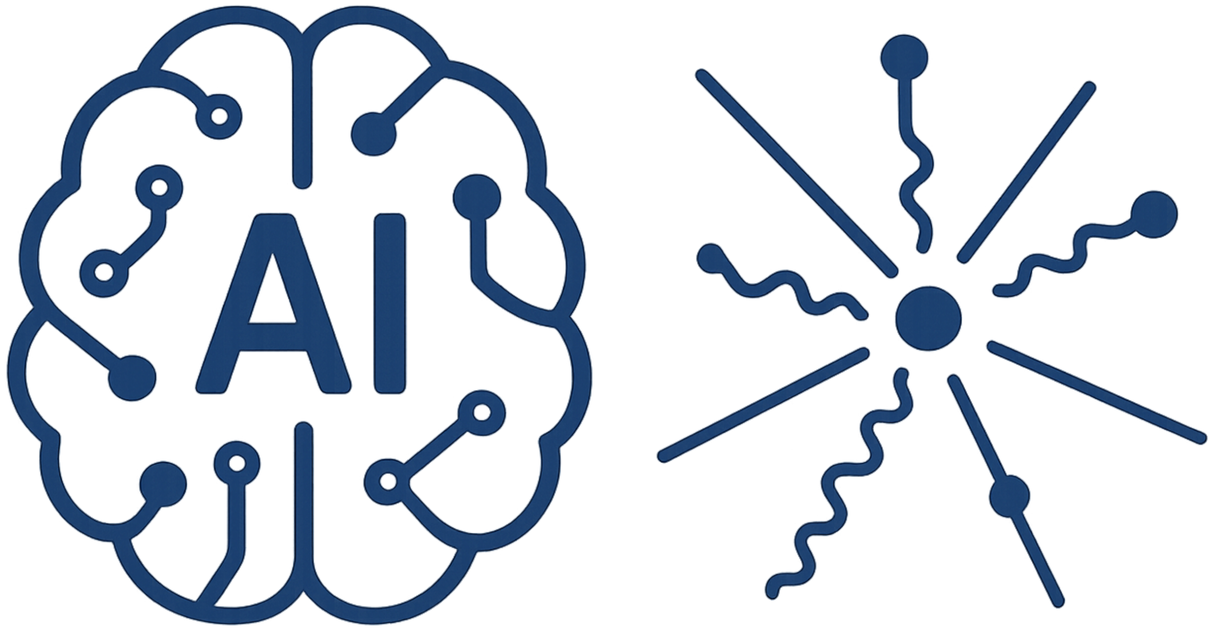
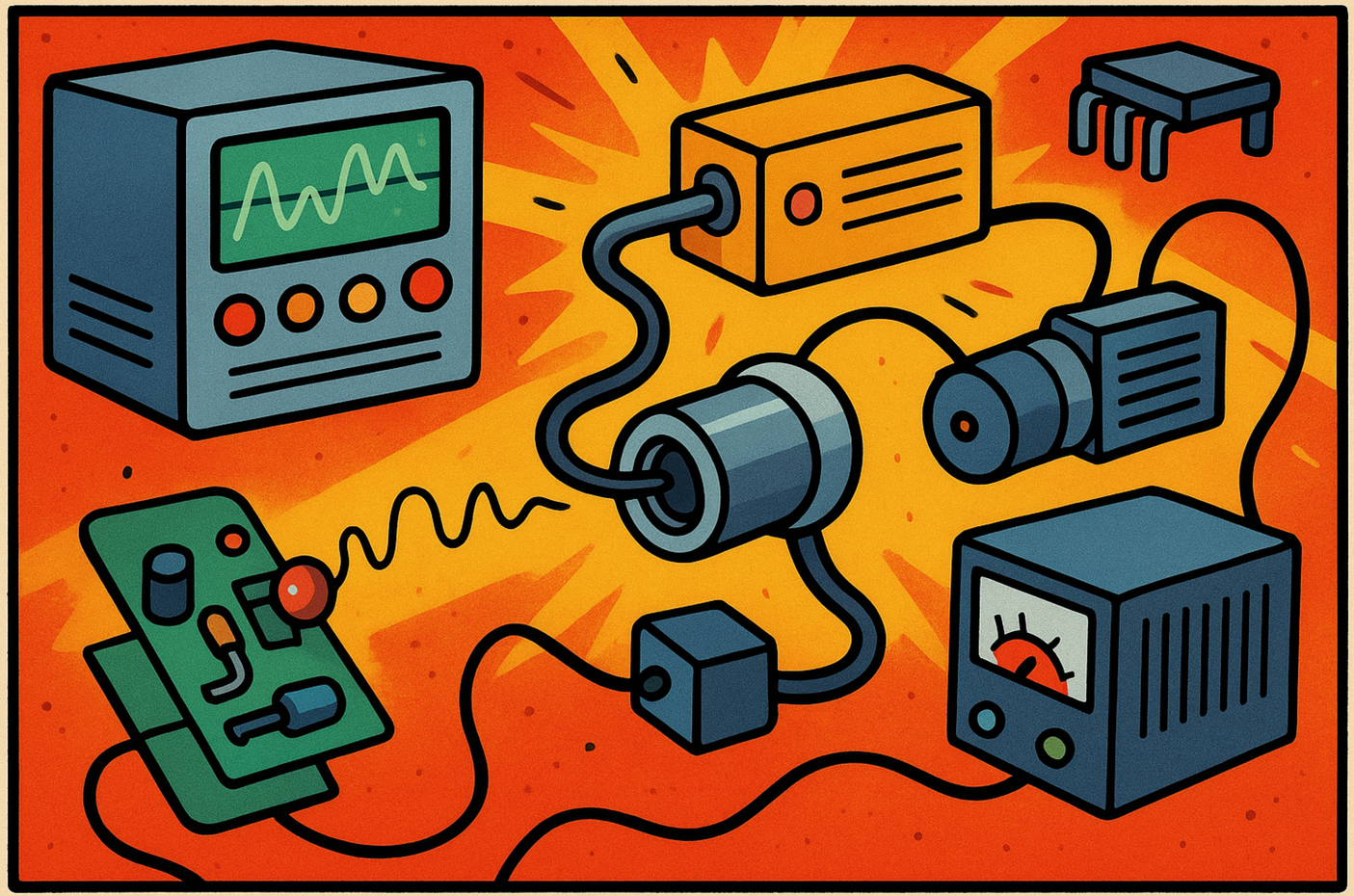
Introduction to

AI-Driven HEP

S. A. Fard - School of Physics (IPM)



AI-Driven HEP 5



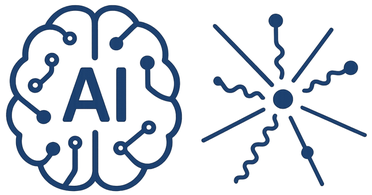
Session 5

Electronic

Grupen, Claus, and Boris Shwartz. Particle detectors. Cambridge university press, 2008.

Ade, Peter AR, Matthew J. Griffin, and Carole E. Tucker. Physical principles of astronomical instrumentation. CRC Press, 2021.

Karttunen, Hannu, et al., eds. Fundamental astronomy. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007.



Measurement of a physical parameter

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i. Photoconductive detector : produces a current proportional to the photon rate incident on the detector

ii. Photovoltaic detector : produces a voltage proportional to the photon rate

iii. Radio antenna : produces a current proportional to the amplitude of the incident electric field

iv. Bolometric detector : produces a change in temperature proportional to the electromagnetic power absorbed by the detector (the temperature change is usually then converted to a change in voltage)

v. Charge Coupled Device (CCD) : produces an amount of charge proportional to the number of photons incident during the exposure.

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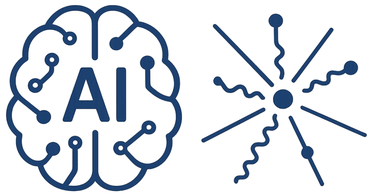
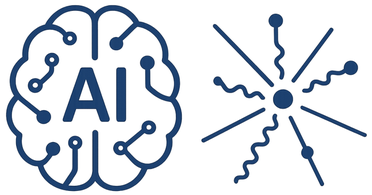
Exercise



Measurement of a physical parameter

Conversion of the input quantity into some easily measurable output quantity



Measurement of a physical parameter

Conversion of the input quantity into some easily measurable output quantity

Photon → voltage or current

The Signal, the Background and the Noise

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The desired output is the Signal

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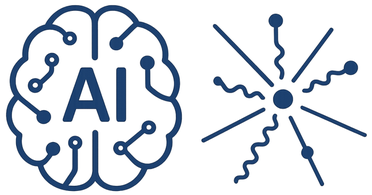
Affect the measurement by introducing uncertainty in the recorded value

Noise

random fluctuation of the signal: cannot be eliminated even in principle



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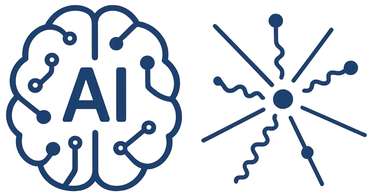
random fluctuation of the background : minimised decreasing background



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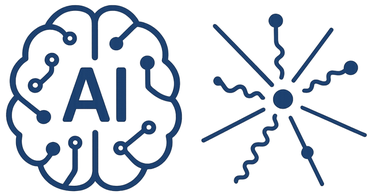
detector : read out

electronic circuits : process the detector signal (e.g. amplifiers)



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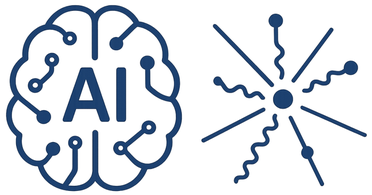

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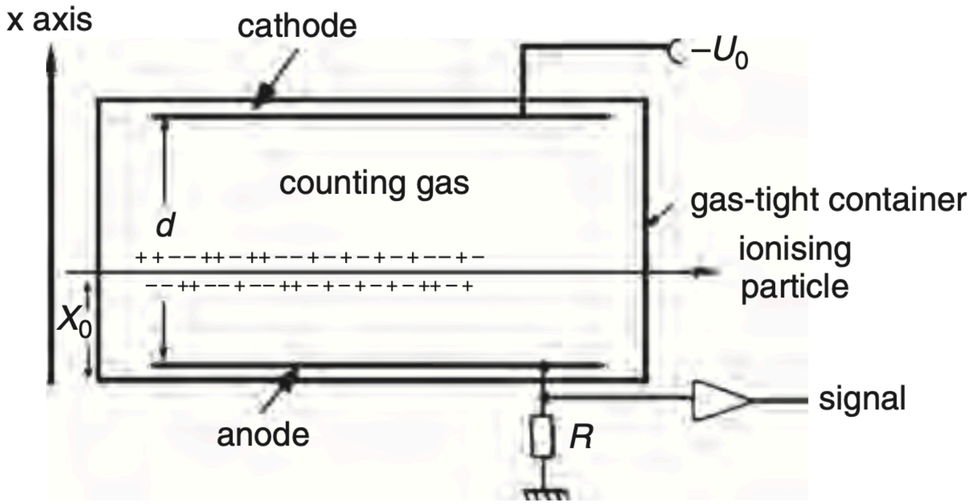
Ionisation Chamber



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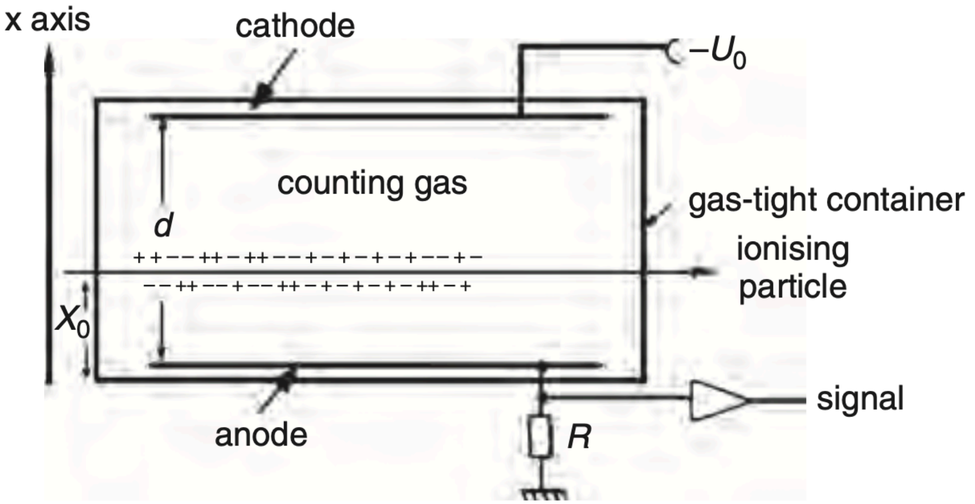
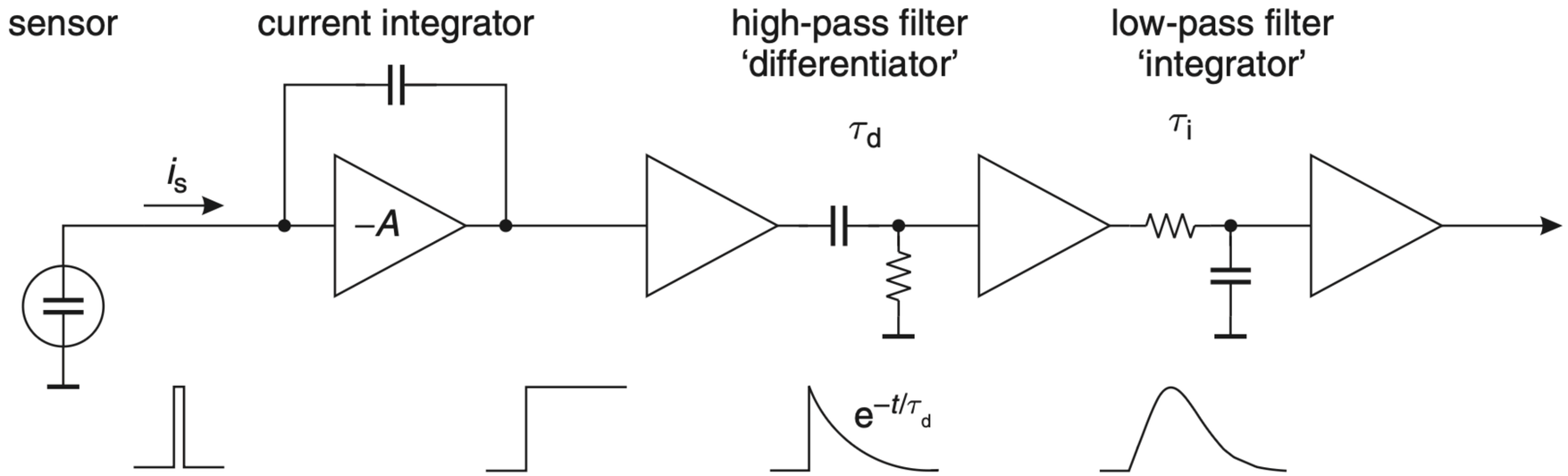
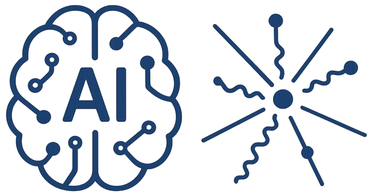
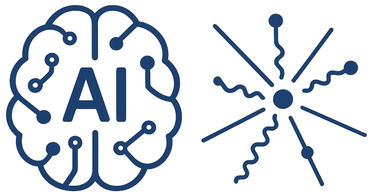






Responsivity

$$S = \frac{\text{Change in output quantity}}{\text{Change in input quantity}}$$



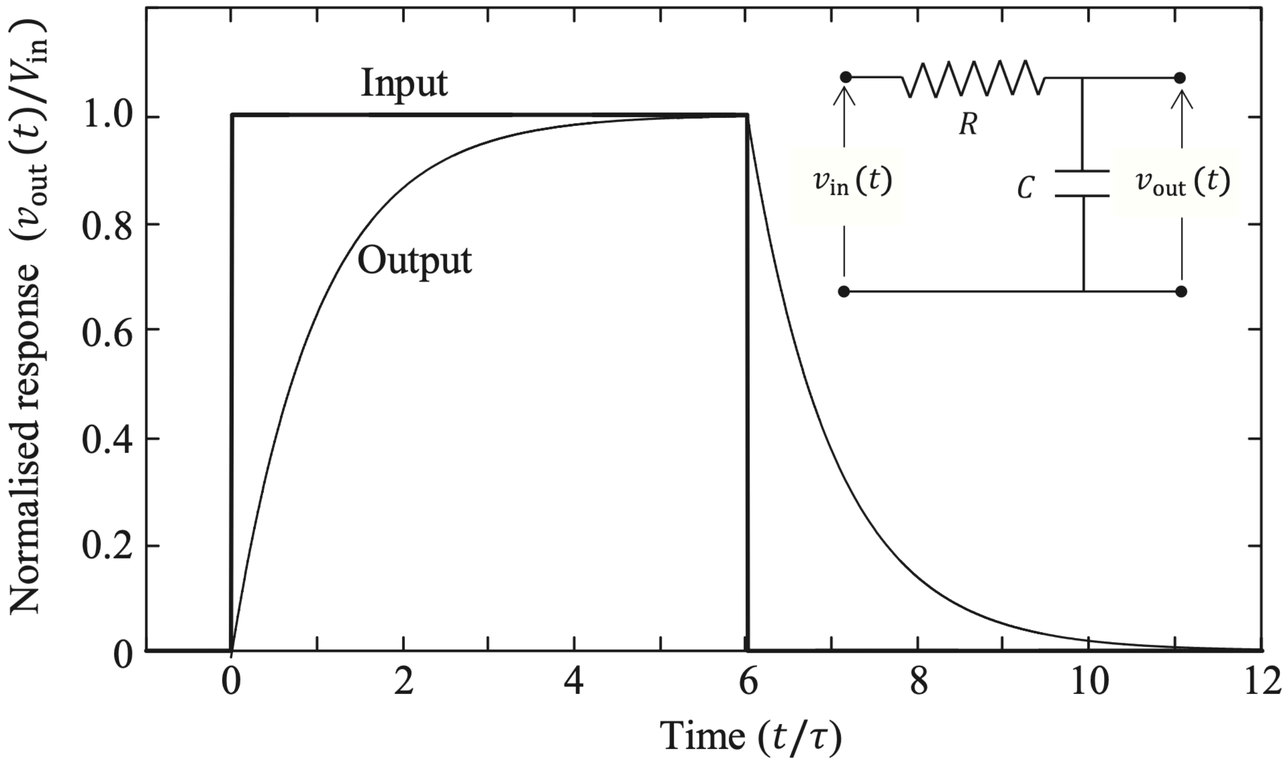
Responsivity

$$S = \frac{\text{Change in output quantity}}{\text{Change in input quantity}}$$

high value of responsivity is a good feature

does not guarantee a sensitive detector

Responsivity



$$v_{out}(t) = V_{in}\left(1 - e^{-t/\tau}\right)$$

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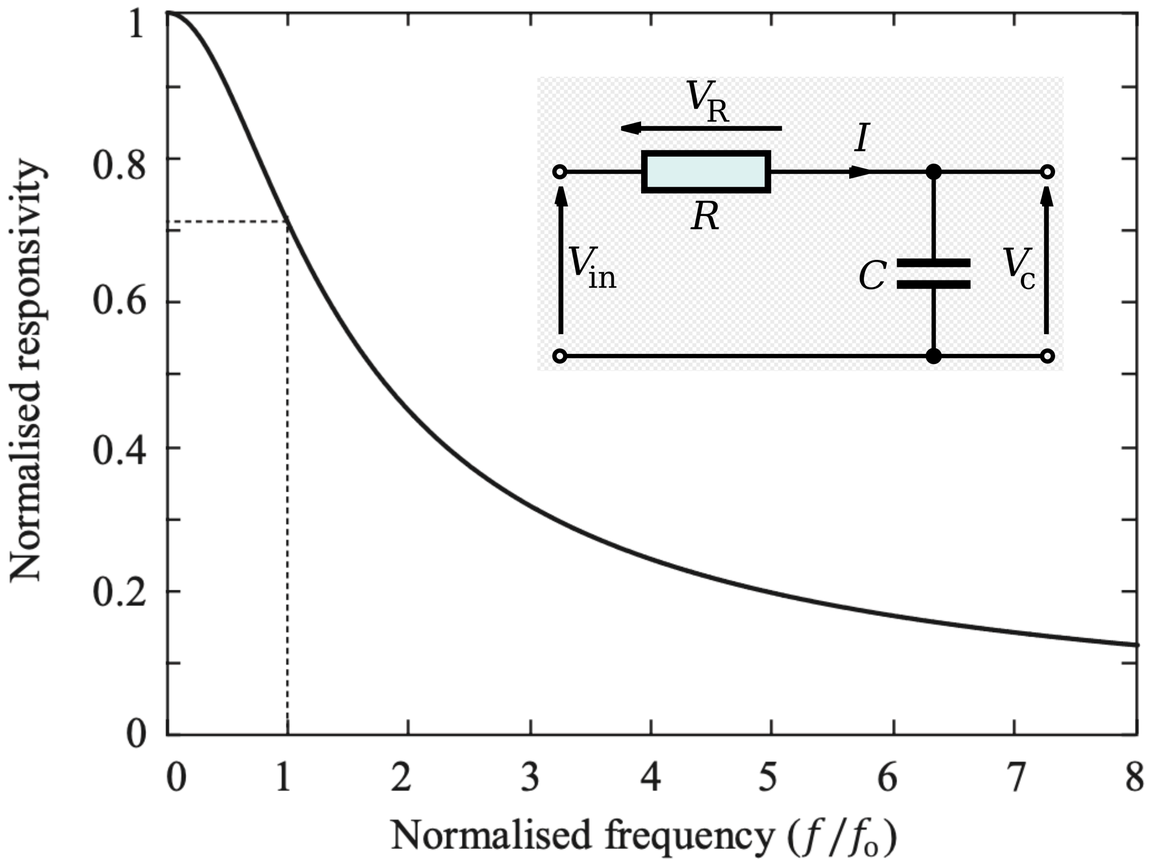
$$\tau = RC$$

Low-Pass and High-pass Filter



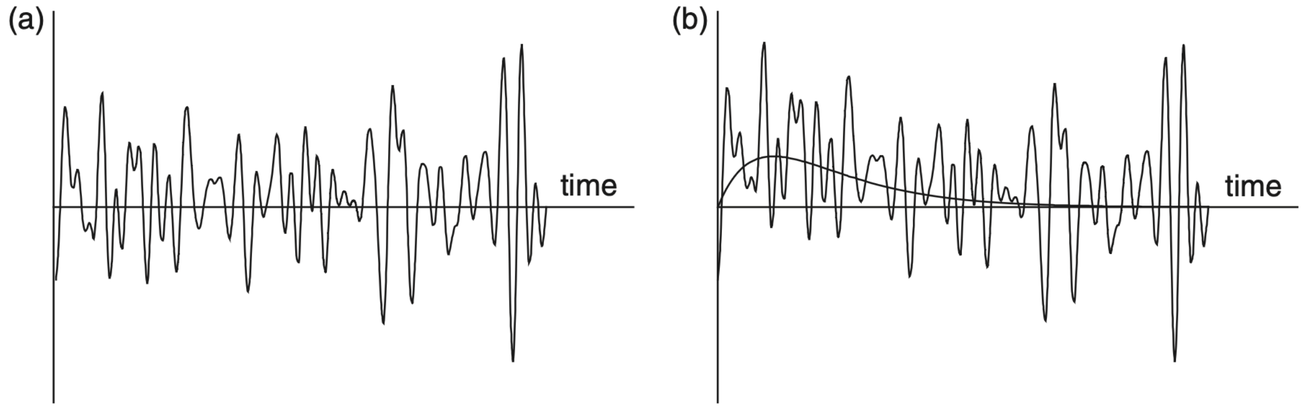
$$V_{out} = \frac{1}{\sqrt{1 + (f/f_0)^2}} V_{in}$$

$$V_{out} = \frac{f/f_0}{\sqrt{1 + (f/f_0)^2}} V_{in}$$

$$f_o = \frac{1}{2\pi\tau}$$

Signal to Noise

$$\mathrm{SNR} = 1$$



$f(t)$ is random variable with mean zero and variance σ^2 which is called noise power

$$R_{ff}(\tau) = \langle f(t) f(t+\tau) \rangle = \sigma^2 \delta(\tau)$$

Signal to Noise

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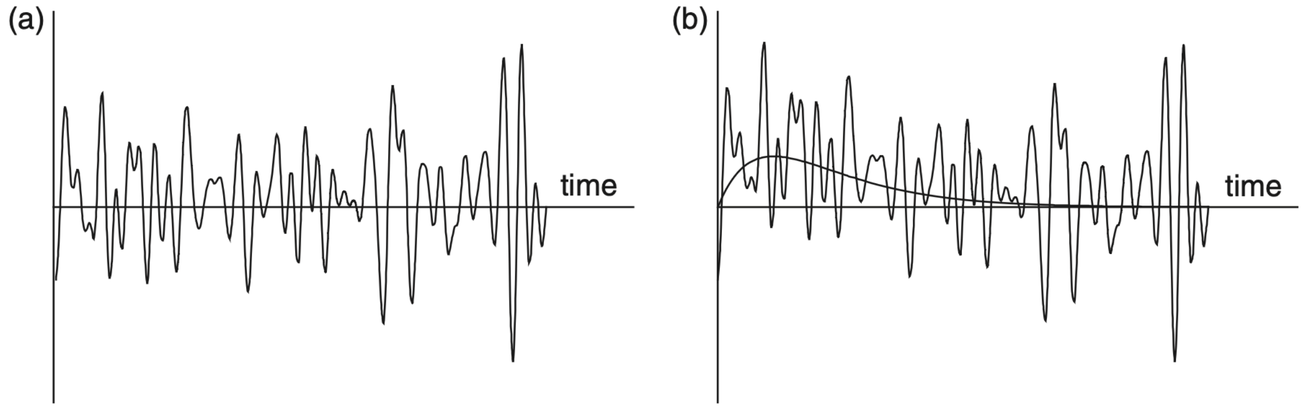

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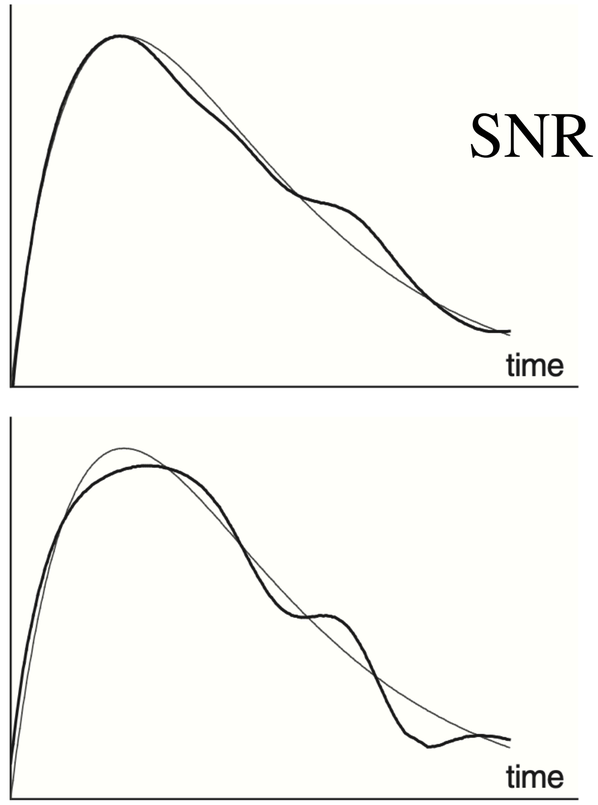
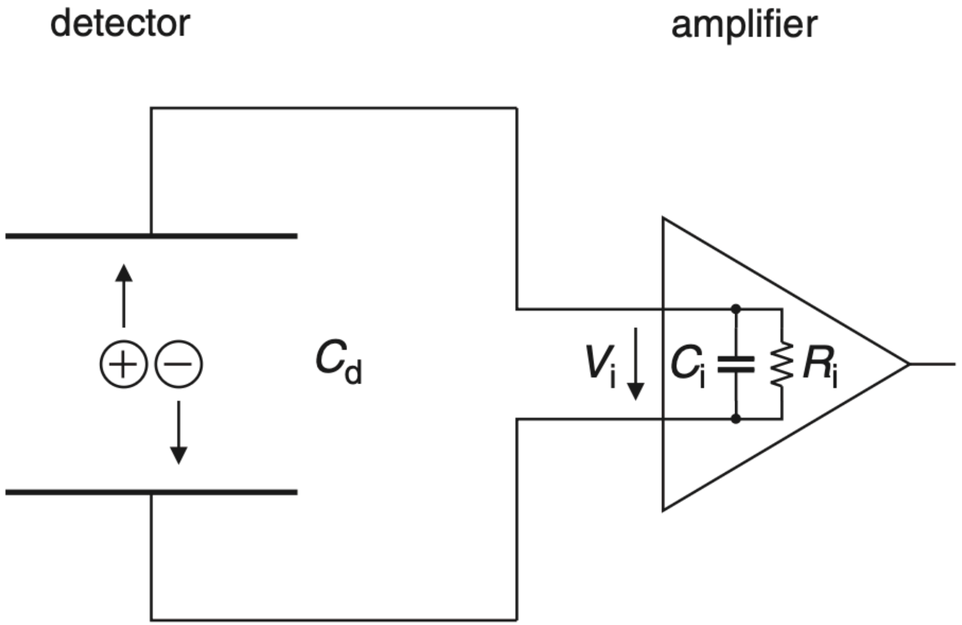
$$\mathrm{SNR} = 20$$



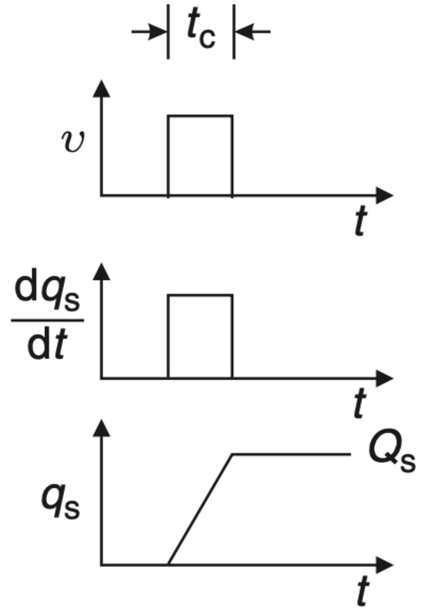
Signal integration-differentiation



velocity of charge carriers

rate of induced charge on sensor electrodes

signal charge



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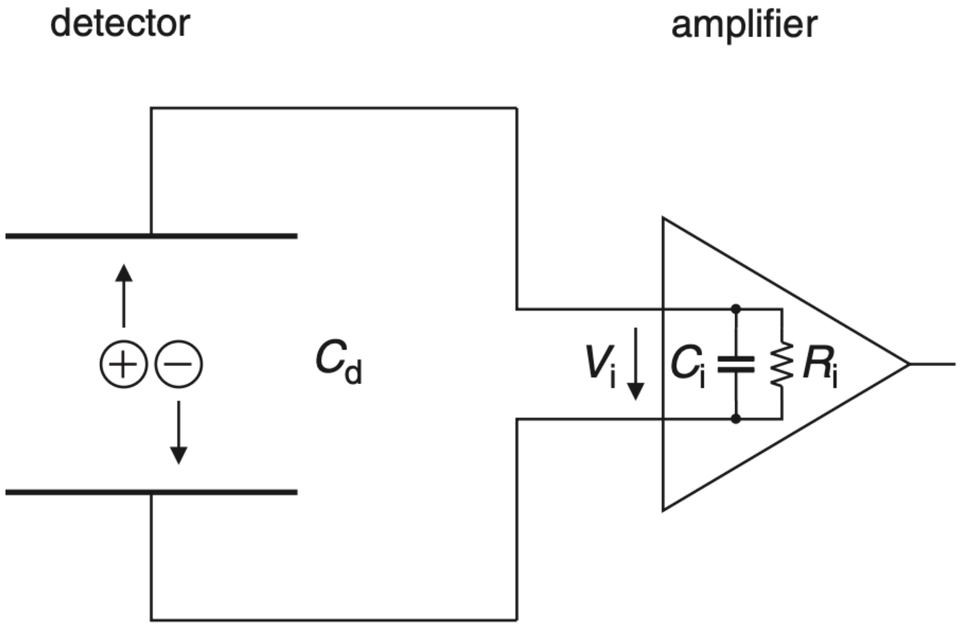

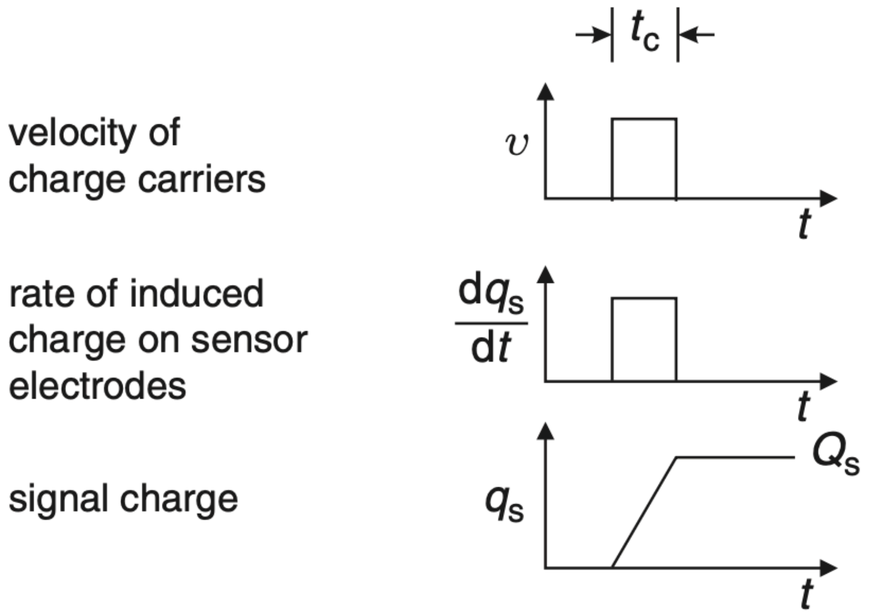

Slow frequency

$$V_C \approx \frac{1}{RC}\int_0^t V_{\text{in}}\,dt$$

Fast frequency

$$V_R \approx RC\frac{dV_{in}}{dt}$$