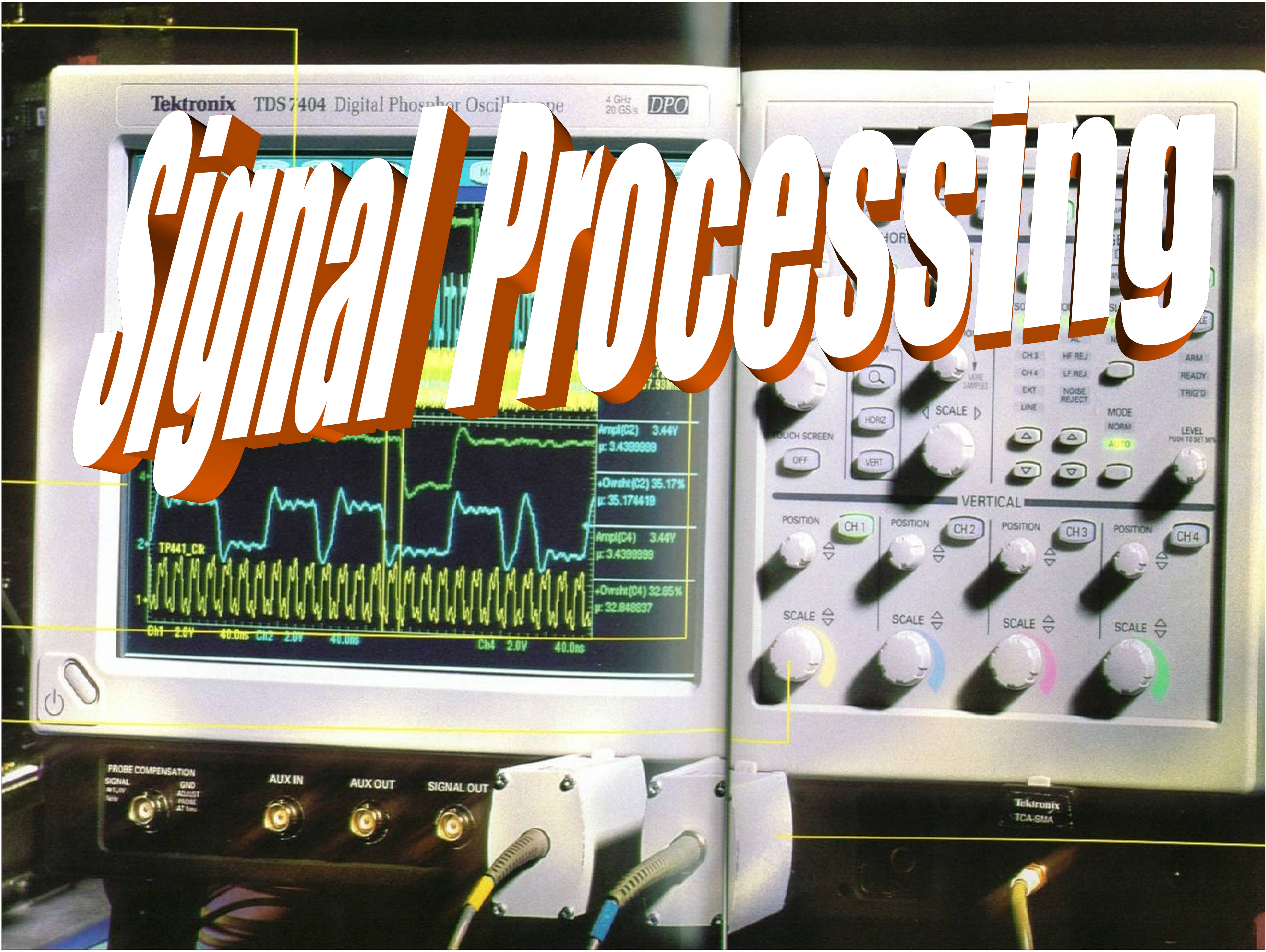
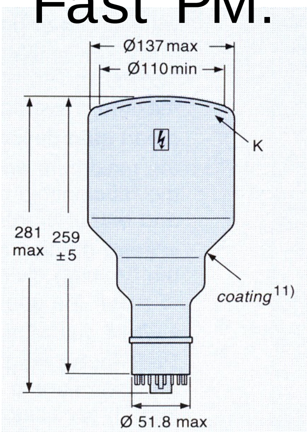
Signal Processing

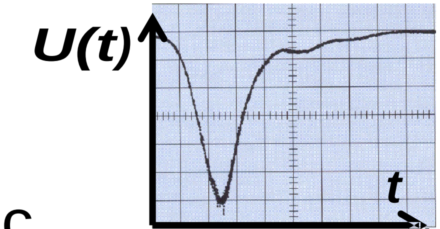


PM Operation

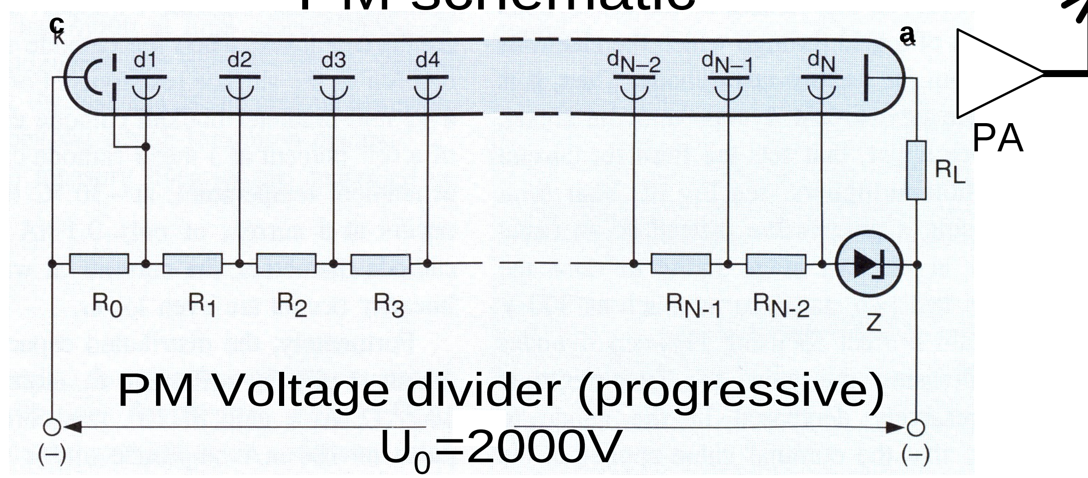
Fast PM: pulse rise time ~ 2ns, gain: $3 \cdot 10^7$



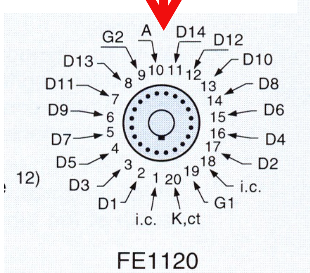
Philips XP2041
5″ dia cathode
14 dynodes
+ focussing
electrodes



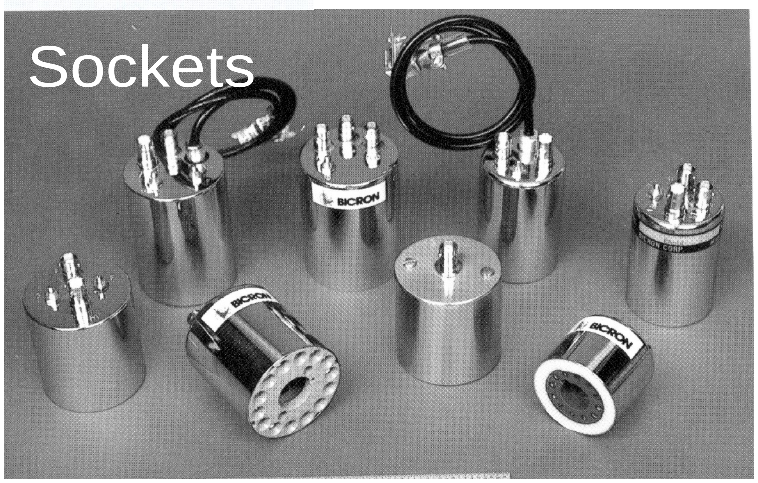
PM schematic



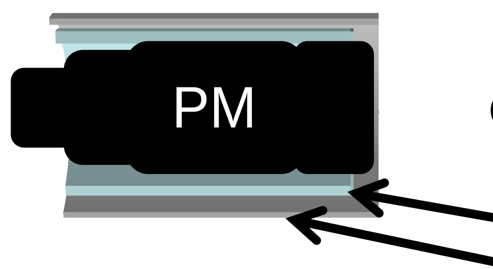
PM Voltage divider (progressive)
U_0=2000V



Socket FE1120
pin connections



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

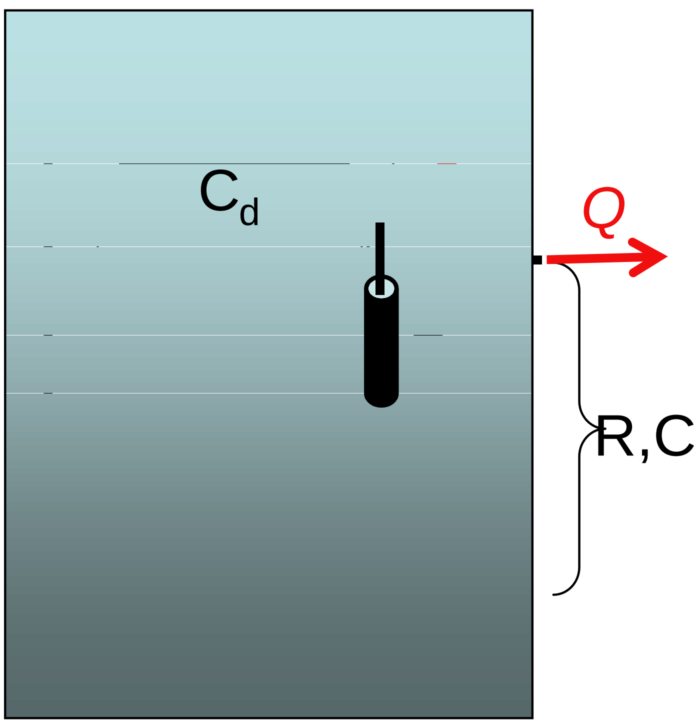


mu metal
soft iron

Pre-Amplifiers

Task: amplify weak detector signals (mV) to ~ 1V, transmit through cable.
Main types: charge-sensitive or voltage-sensitive

Charge sensitive preamps integrate charge $\boldsymbol{Q(t)} \propto \boldsymbol{E_{deposit}}$ from detector directly. Use for semiconductor diodes.
Voltage sensitive preamps amplify $U(t) = Q(t)/C$, $C = const.!$ → *PM, PC*

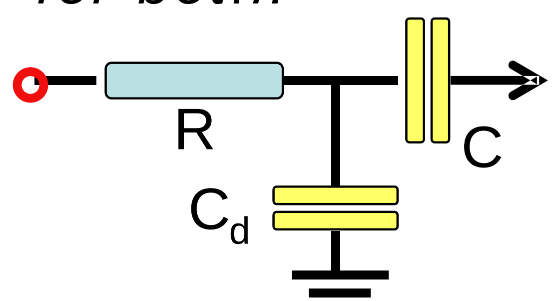


Detector is essentially a capacitor C_d, delivers a time dependent charge $Q(t)$, current $I = dQ/dt$

For E measurement, integrate Q

For t measurement, differentiate Q

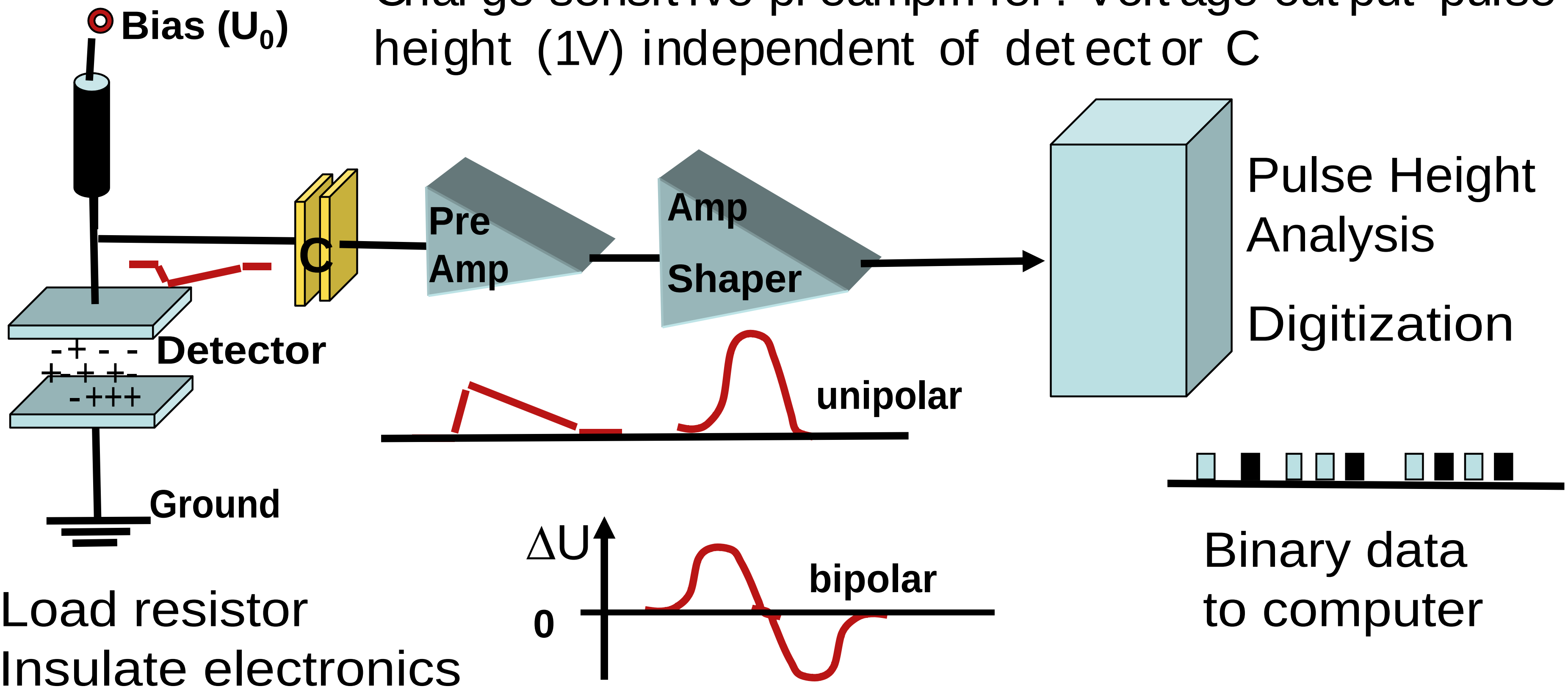
Use operational amplifiers (op-amp) for both.



Replacement circuit for detector and decoupling

Basic Counting System

Charge sensitive preamplifier: Voltage output pulse height (1V) independent of detector C

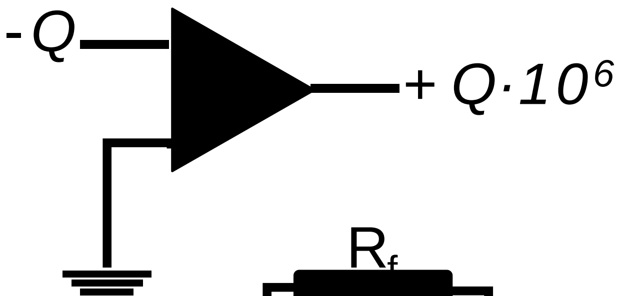


R: Load resistor
C: Insulate electronics from high voltage (bias)
Pulse height 100 mV

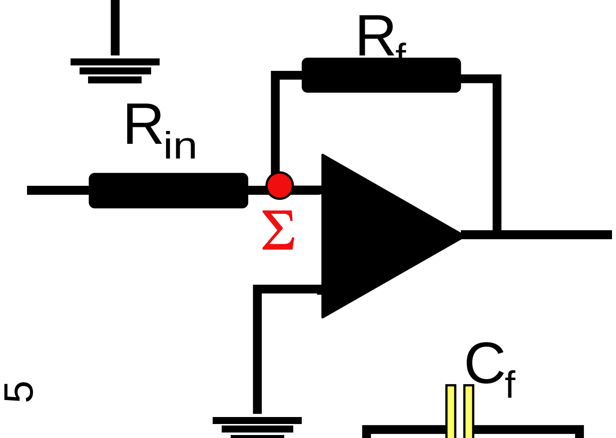
Amplifier/Shaper: differentiates (1x or 2x)

Final amplitude 2-10V

Operational Amplifiers

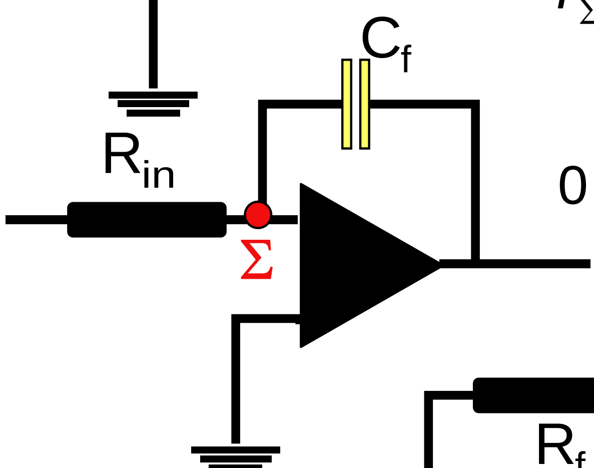


Gain is very high (~ 10^6), inverting.
Properties of amp can be determined by feedback circuit:



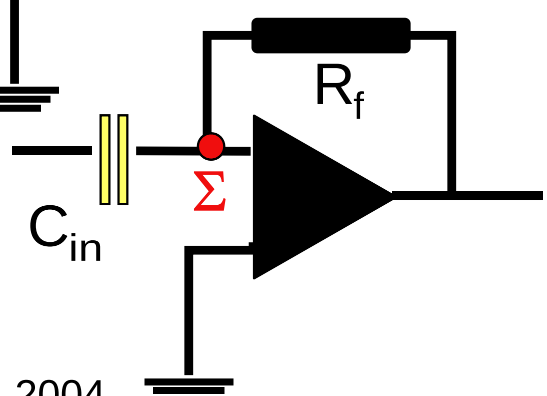
Feeding back the negative of the input signal to the summation point cancels the signal at Σ

$$I_\Sigma = 0 = I_{in} + I_f = \frac{U_{in}}{R_{in}} + \frac{U_{out}}{R_f} \rightarrow \boxed{U_{out} = -\frac{R_f}{R_{in}} \cdot U_{in}}$$



$$0 = I_{in} + I_f = \frac{U_{in}}{R_{in}} + C_f \frac{dU_{out}}{dt} \rightarrow \boxed{U_{out} = -\frac{1}{R_{in}C_f} \cdot \int U_{in} dt}$$

Integrator



$$\boxed{U_{out} = -C_{in} R_f \frac{dU_{in}}{dt}}$$

Differentiator

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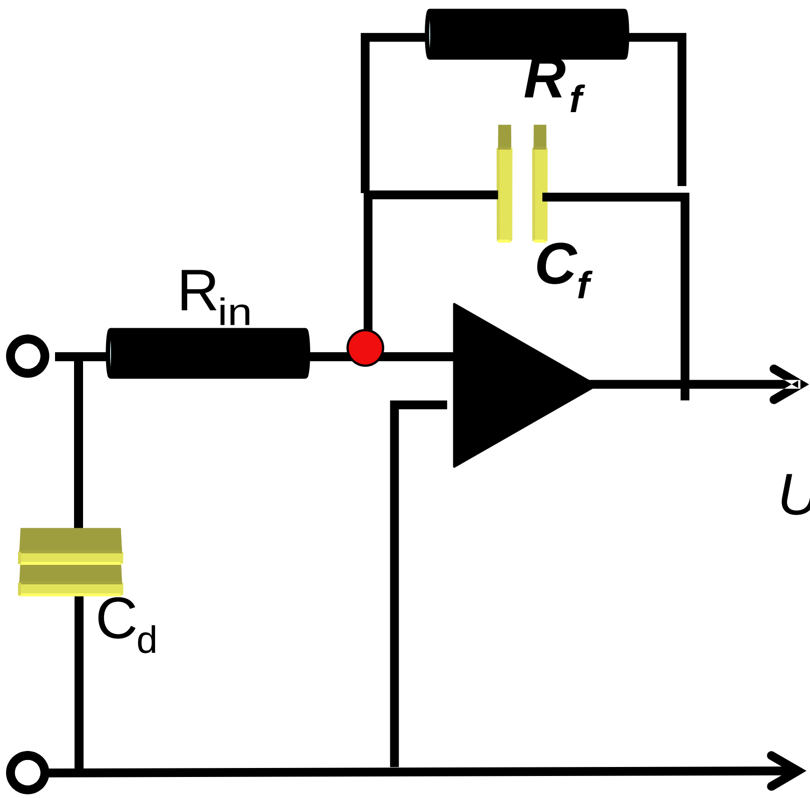
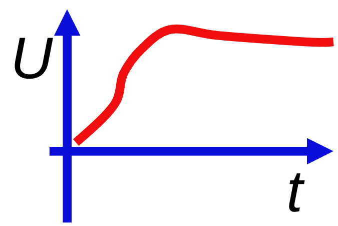
Charge Sensitive Preamp



Inverting, integrating preamp

Pulse decay governed by $t_{dec} \approx 1/R_f C_f$.

Additional amplifier necessary for pulse shaping and gain.



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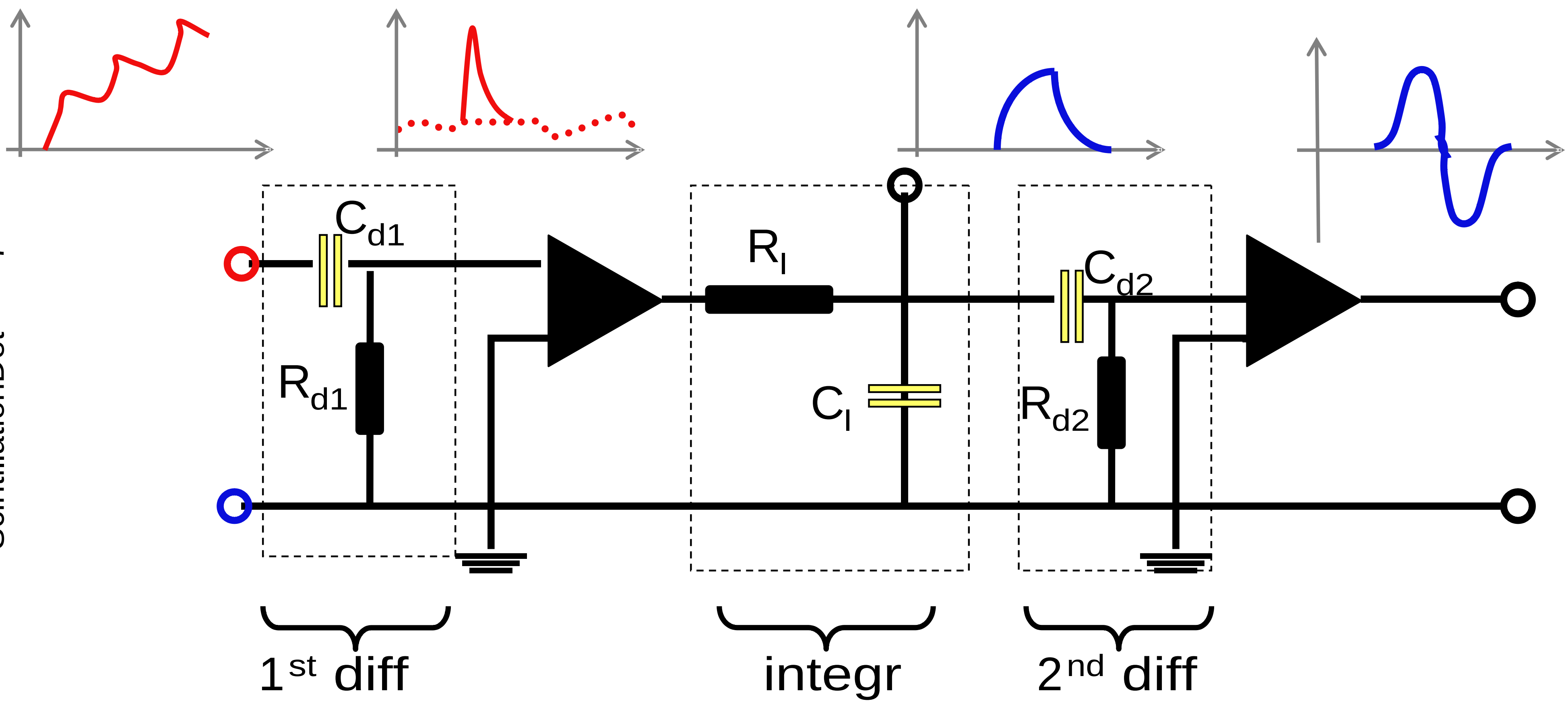
Main/Shaping Amplifiers

Tasks: 1) Linear amplification to pulse heights of U ≈(1-10)V

2) Improvement of signal/noise ratio (integration)

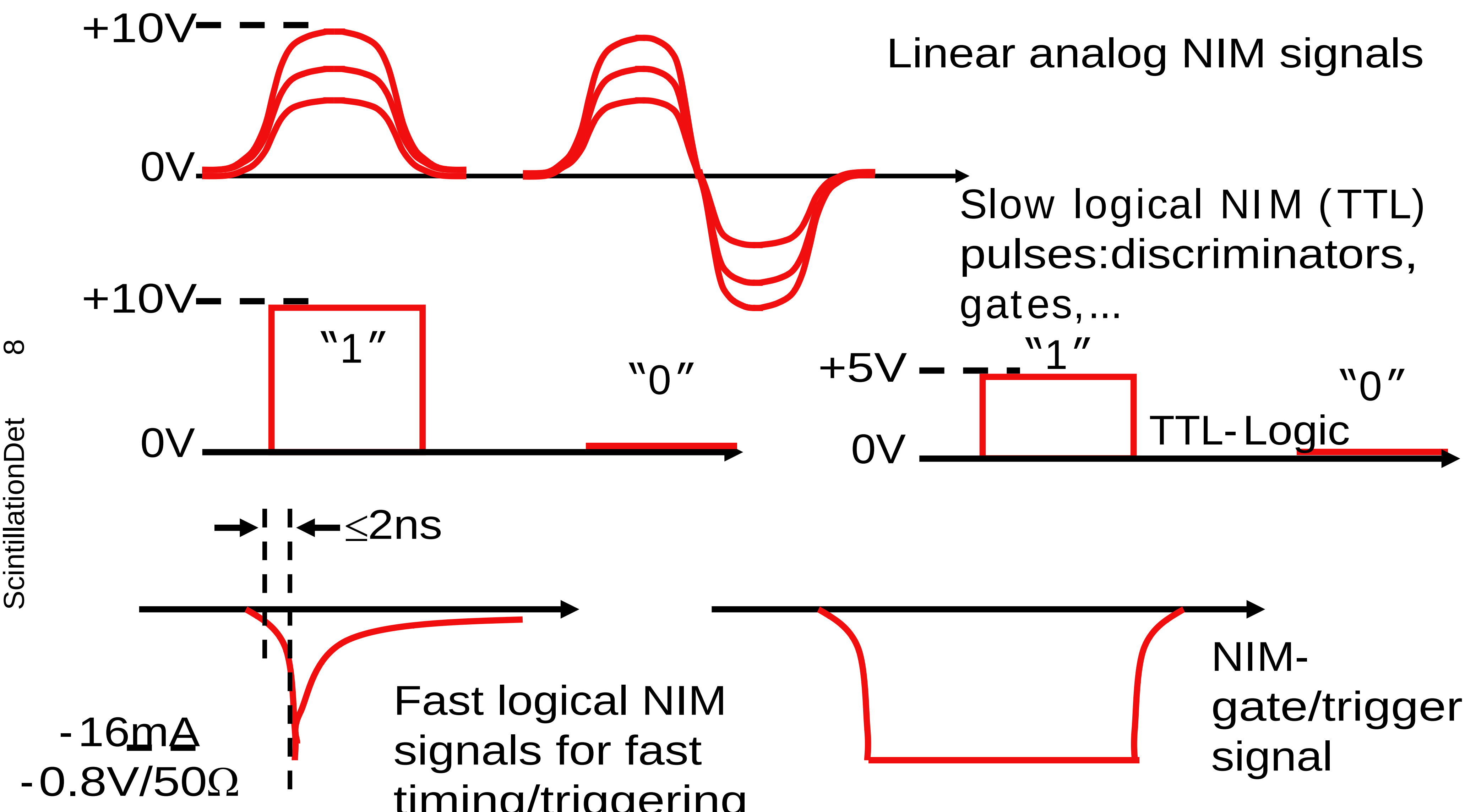
3) Pulse shaping (Gaussian shape is best)



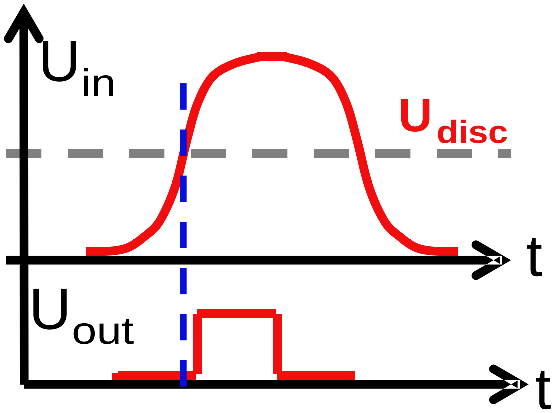
More versatility: RC-circuits → active filters

NIM Signal Standards

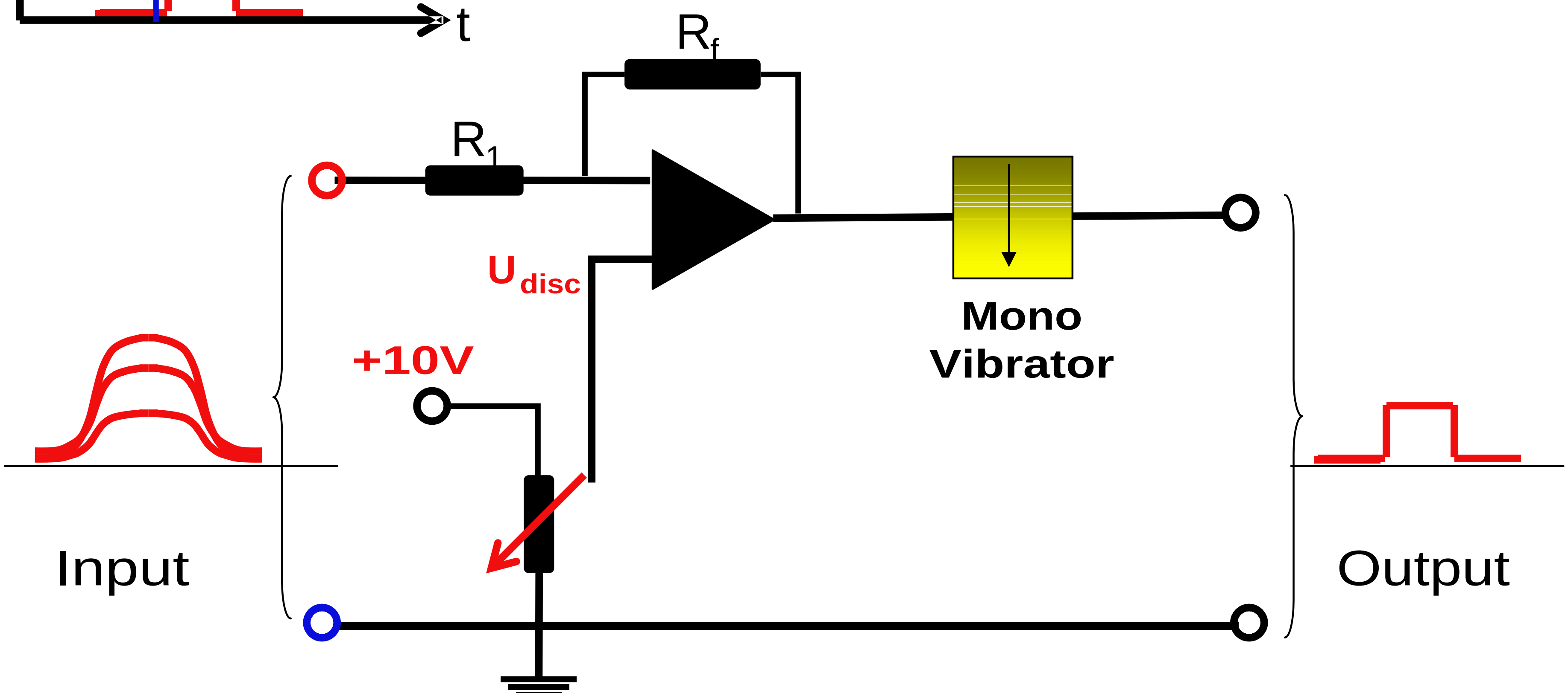
(National Instruments Methods)



Discriminator/Trigger

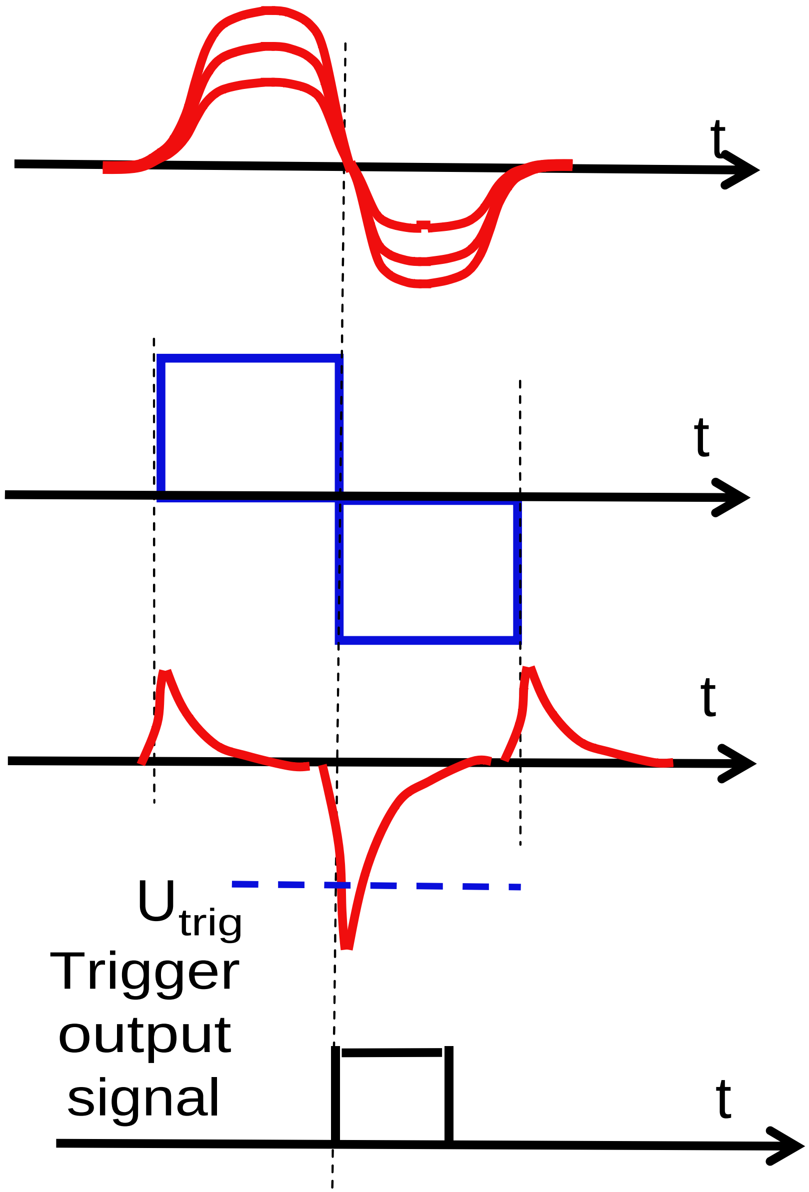


Task: Produce a logical signal, whenever analog signal exceeds threshold U_{disc}. Use for logical decisions (open acquisition,...). Exist for slow and fast pulses.



For fast timing, use negative NIM logic units

Zero-Crossing Triggering



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

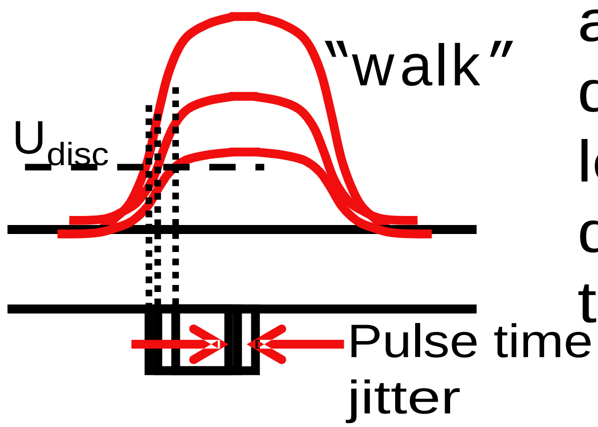
Produce "saturated" uniform pulse

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

Trigger output appears at zero crossing

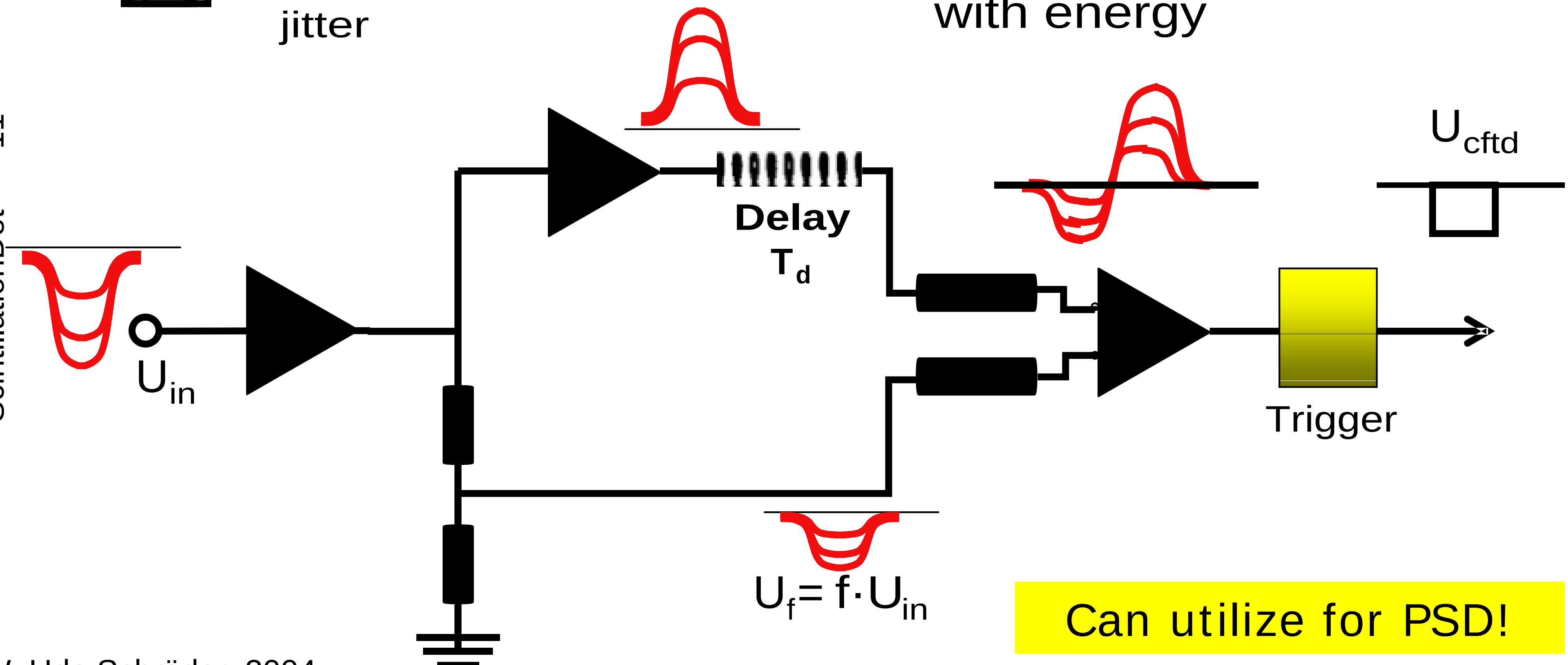
(Internal delays neglected)

Constant-Fraction Discriminator



amplitude dependent leading edge discr. output timing

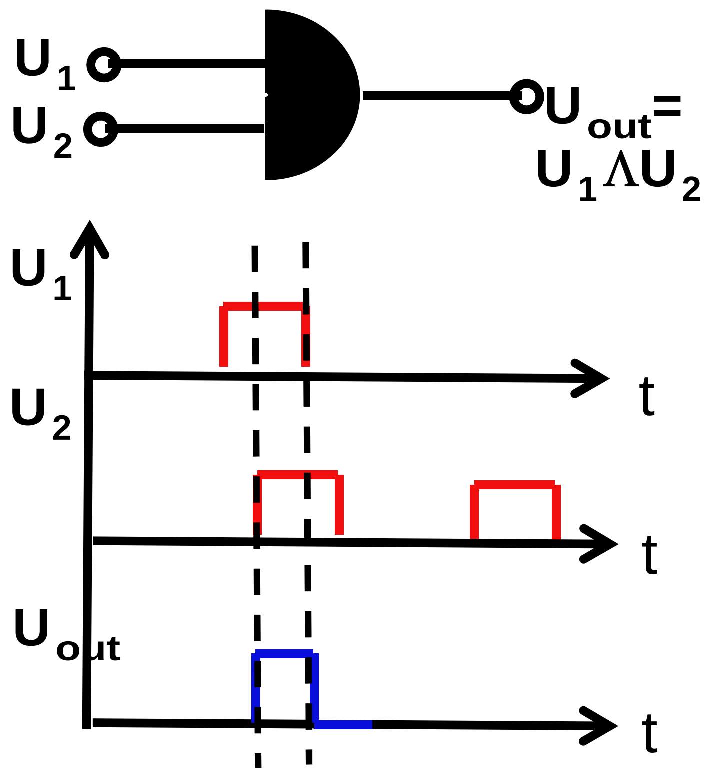
Zero crossing timing always at same physical time, independent of pulse amplitude for fixed pulse shape: no "walk" with energy

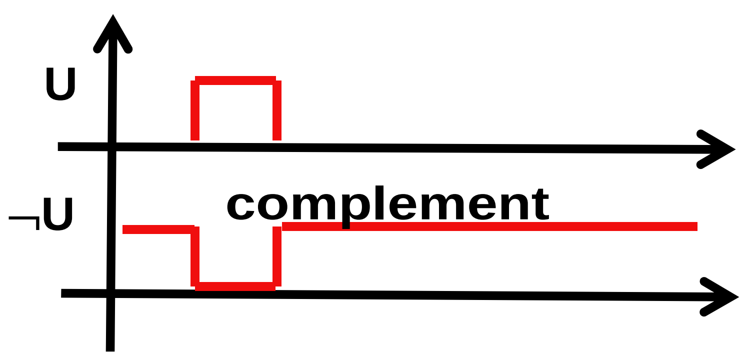


Can utilize for PSD!

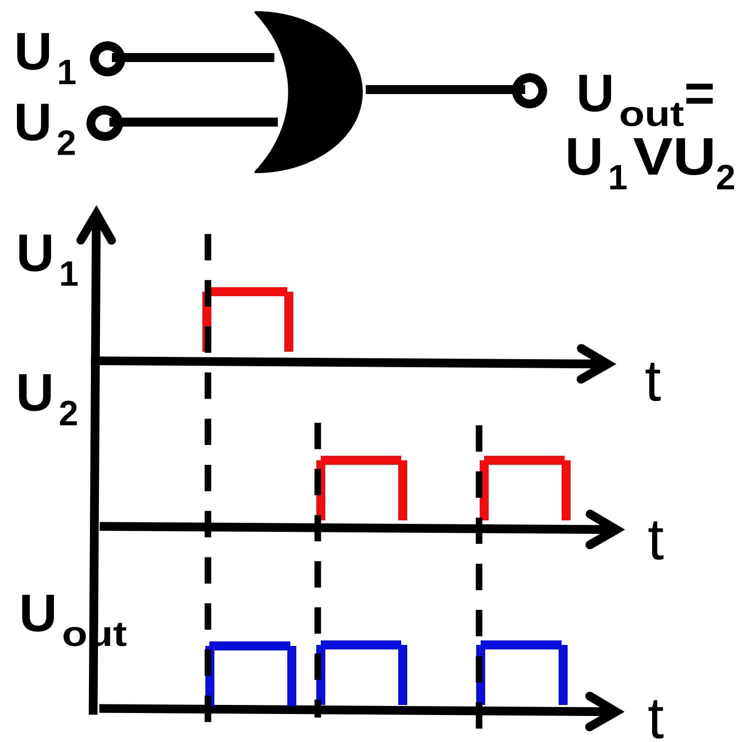
Logic Modules

Overlap Coincidence

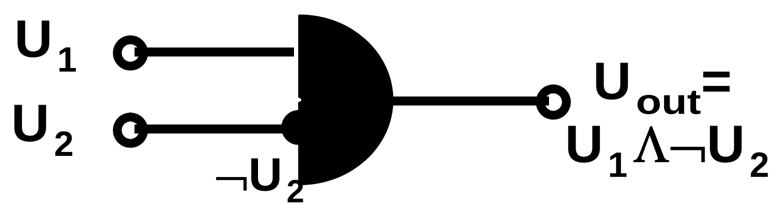




Or (inclusive)



For fast timing: use fast negative logic



Anti-Coincidence

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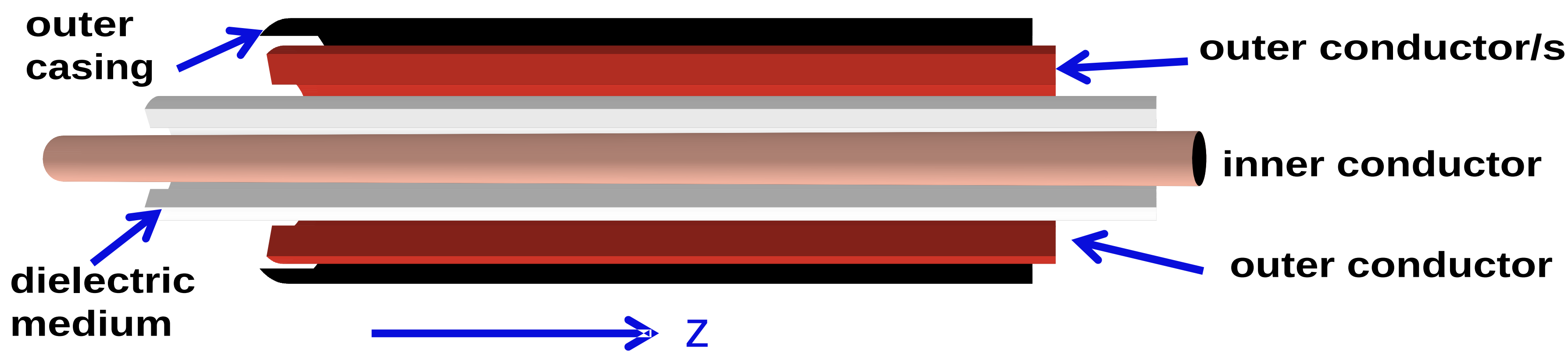
Signal Transmission



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

Wave equation (R=0):

$$\boxed{\frac{\partial^2 U}{\partial z^2} = L \cdot C \cdot \frac{\partial^2 U}{\partial t^2}}$$

L: inductivity/length
C: capacity/length
depend on diameter and dielectric

signal propagation speed (speed of light):

$$c = 1/\sqrt{LC}$$

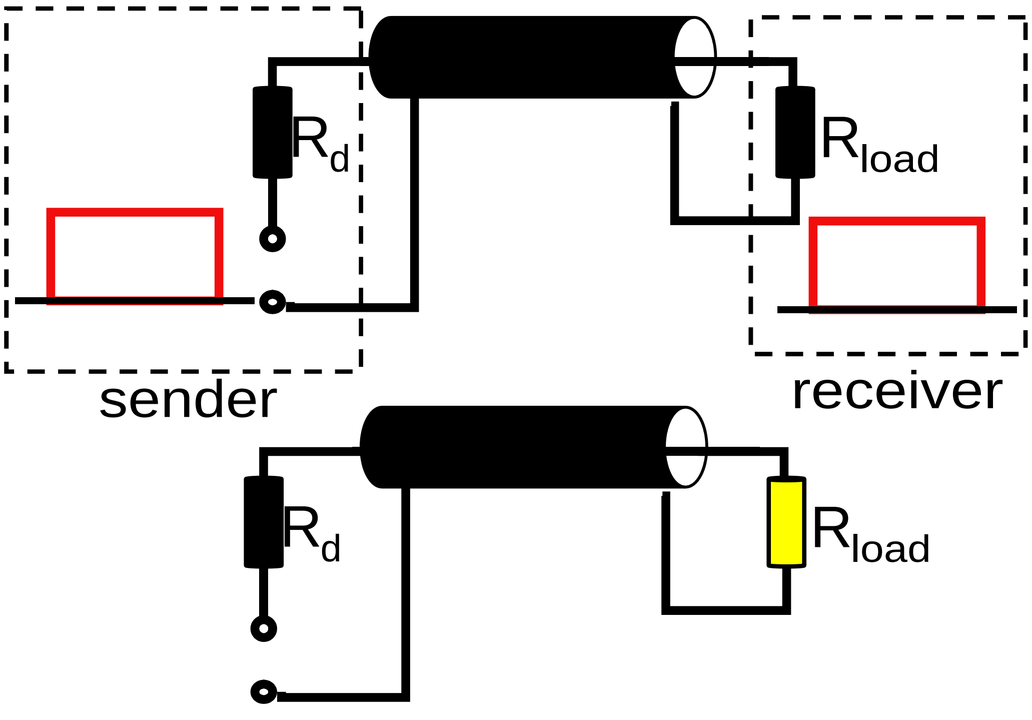
typically c^{-1}=5 ns/m

characteristic resistance Z_0= Ohmic resistance!
For R≠0, $Z_0(\omega)$ complex

$$Z_0 = \sqrt{L/C}$$

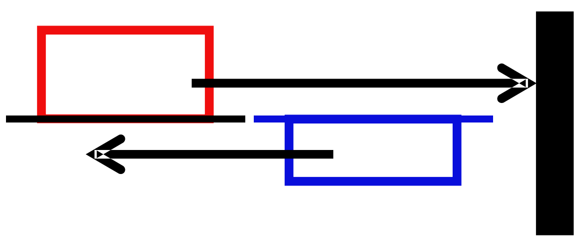
$Z_0 = 50\ \Omega$ or $93\ \Omega$ used for timing, spectroscopy, resp.

Impedance Matching



For impedance matching, $R_{load}=Z_0$, cable looks infinitely long: no reflections from end.

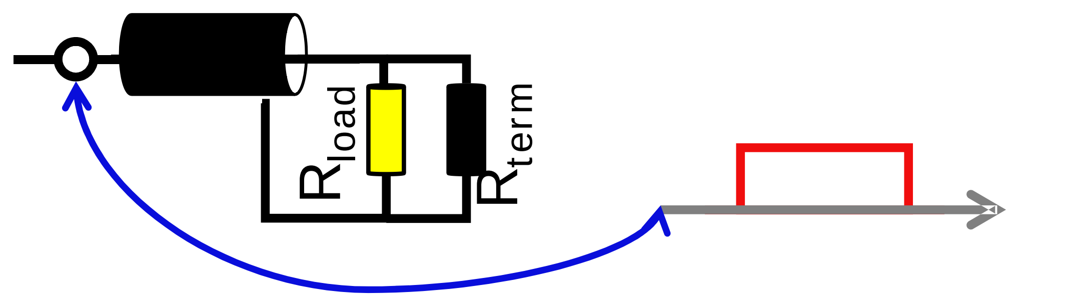
For mismatch, $R_{load} \neq Z_0$, reflection at end, traveling back, superimpose on signal



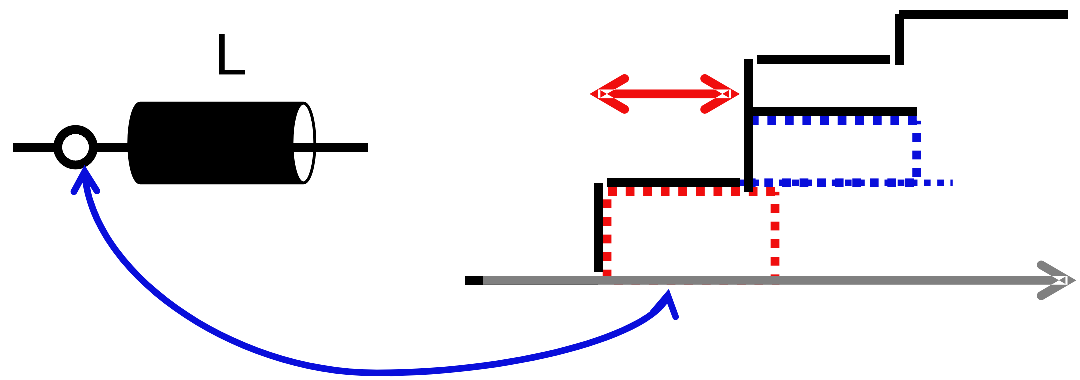
$$\frac{U_{refl}}{U_{in}} = \frac{R_{load} - Z_0}{R_{load} + Z_0}$$

Polarity of reflected signal $R_{load}=0, \infty$

Cable Reflections

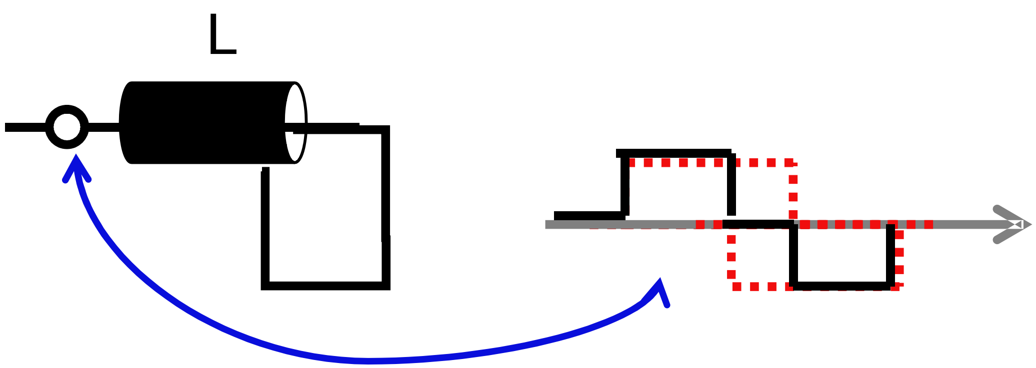


Receiver input impedance $R_{load} \neq Z_0$,
→ use additional Ohmic termination in parallel



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}

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The End