Física Experimental VI – 4300314

1º Semestre de 2017

Instituto de Física
Universidade de São Paulo

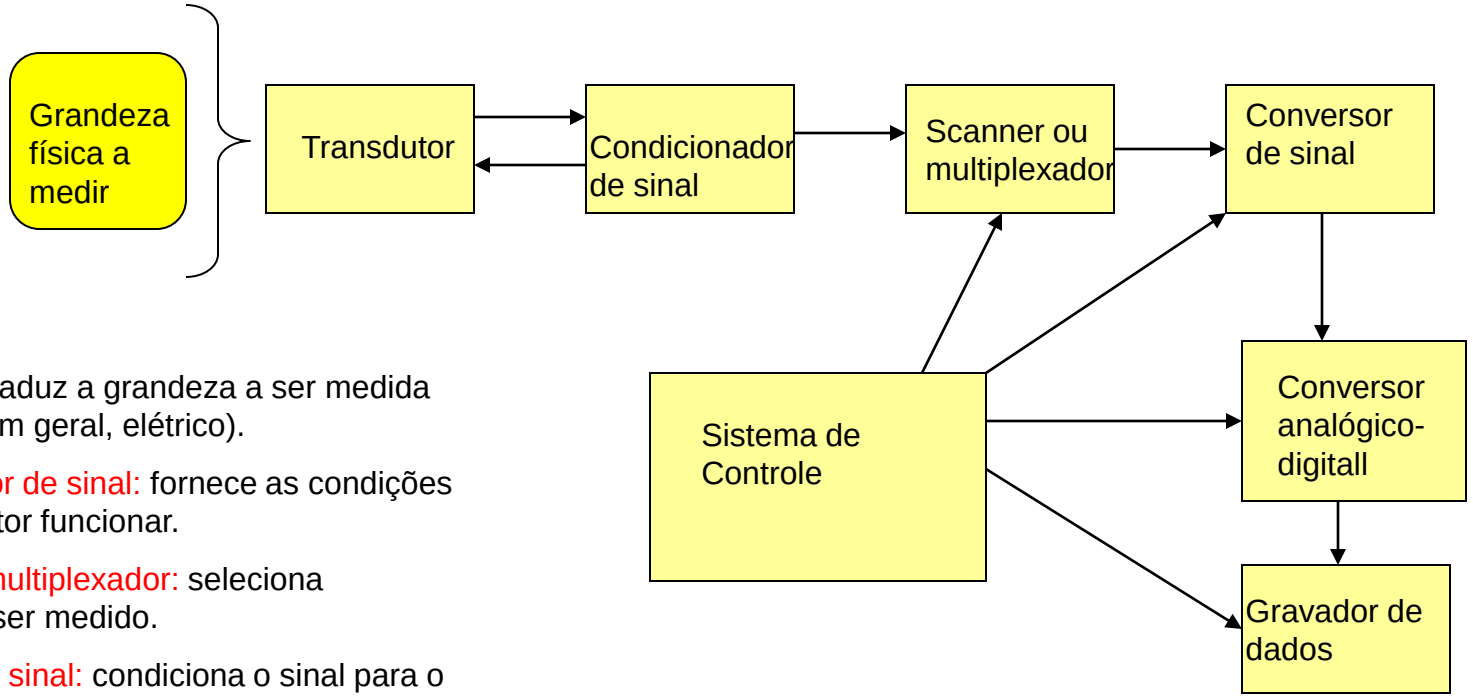
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Fone: 3091.6886

05 de abril

Sinais, medidas, ruídos, . . .

Sistema genérico de aquisição de dados experimentais

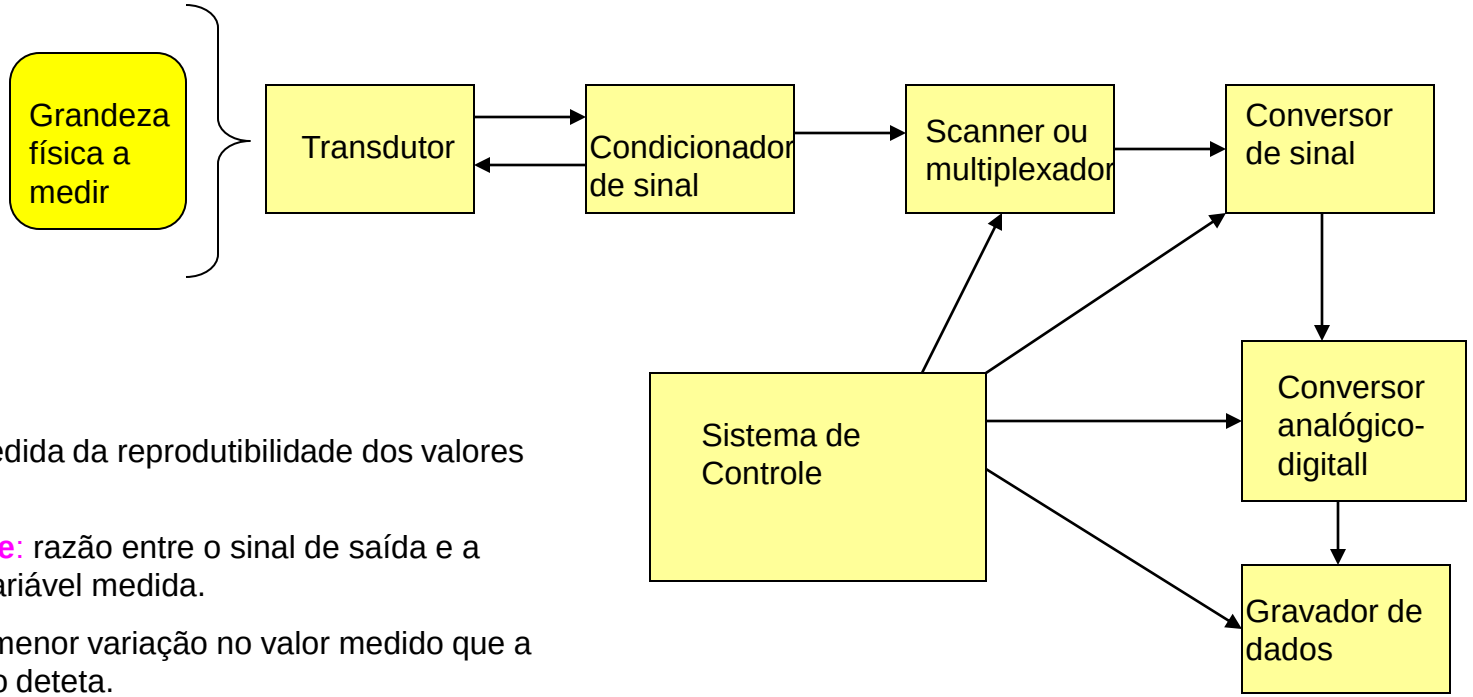


- Transdutor: traduz a grandeza a ser medida em um sinal (em geral, elétrico).
- Condicionador de sinal: fornece as condições para o transdutor funcionar.
- Scanner ou multiplexador: seleciona instrumento a ser medido.
- Conversor de sinal: condiciona o sinal para o ADC.
- Gravador de dados: armazena as informações.
- Sistema de contrôle: Gerencia todas as atividades.

Digital ou Analógico ?

Sinais, medidas, ruídos, . . .

Sistema genérico de aquisição de dados experimentais



- **Precisão**: medida da reprodutibilidade dos valores medidos.

- **Sensibilidade**: razão entre o sinal de saída e a mudança da variável medida.

- **Resolução**: menor variação no valor medido que a instrumentação deteta.

- **Acurácia**: proximidade com que a instrumentação se aproxima do valor verdadeiro.

- **Erro**: diferença entre o valor verdadeiro e o valor medido.

Sinais, medidas, ruídos, . . .

Transdutores (+ condicionador de sinal)

- Tipo
- Condições físicas e ambientais de trabalho
- Compatibilidade com outros equipamentos.

TABLE 11-1 TYPES OF TRANSDUCERS

Electrical parameter and class of transducer	Principle of operation and nature of device	Typical application
	Passive Transducers (Externally Powered)	
Resistance		
Potentiometric device	Positioning of the slider by an external force varies the resistance in a potentiometer or a bridge circuit.	Pressure, displacement
Resistance strain gage	Resistance of a wire or semiconductor is changed by elongation or compression due to externally applied stress.	Force, torque, displacement
Pirani gage or hot-wire meter	Resistance of a heating element is varied by convection cooling of a stream of gas.	Gas flow, gas pressure
Resistance thermometer	Resistance of pure metal wire with a large positive temperature coefficient of resistance varies with temperature.	Temperature, radiant heat
Thermistor	Resistance of certain metal oxides with negative temperature coefficient of resistance varies with temperature.	Temperature
Resistance hygrometer	Resistance of a conductive strip changes with moisture content.	Relative humidity
Photoconductive cell	Resistance of the cell as a circuit element varies with incident light.	Photosensitive relay

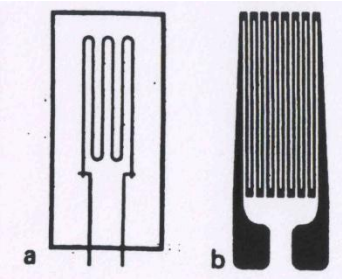
TABLE 11-1 TYPES OF TRANSDUCERS (*continued*)

Electrical parameter and class of transducer	Principle of operation and nature of device	Typical application
Capacitance		
Variable capacitance pressure gage	Distance between two parallel plates is varied by an externally applied force.	Displacement, pressure
Capacitor microphone	Sound pressure varies the capacitance between a fixed plate and a movable diaphragm.	Speech, music, noise
Dielectric gage	Variation in capacitance by changes in the dielectric.	Liquid level, thickness
Inductance		
Magnetic circuit transducer	Self inductance or mutual inductance of ac-excited coil is varied by changes in the magnetic circuit.	Pressure, displacement
Reluctance pickup	Reluctance of the magnetic circuit is varied by changing the position of the iron core of a coil.	Pressure, displacement, vibration, position
Differential transformer	The differential voltage of two secondary windings of a transformer is varied by positioning the magnetic core through an externally applied force.	Pressure, force, displacement, position
Eddy current gage	Inductance of a coil is varied by the proximity of an eddy current plate.	Displacement, thickness
Magnetostriction gage	Magnetic properties are varied by pressure and stress.	Force, pressure, sound
Voltage and current		
Hall effect pickup	A potential difference is generated across a semiconductor plate (germanium) when magnetic flux interacts with an applied current.	Magnetic flux, current
Ionization chamber	Electron flow induced by ionization of gas due to radioactive radiation.	Particle counting, radiation
Photoemissive cell	Electron emission due to incident radiation on photoemissive surface.	Light and radiation
Photomultiplier tube	Secondary electron emission due to incident radiation on photosensitive cathode.	Light and radiation, photosensitive relays
	Self-Generating Transducers (No External Power)	
Thermocouple and thermopile	An emf is generated across the junction of two dissimilar metals or semiconductors when that junction is heated.	Temperature, heat flow, radiation
Moving-coil generator	Motion of a coil in a magnetic field generates a voltage.	Velocity, vibration
Piezoelectric pickup	An emf is generated when an external force is applied to certain crystalline materials, such as quartz.	Sound, vibration, acceleration, pressure changes
Photovoltaic cell	A voltage is generated in a semiconductor junction device when radiant energy stimulates the cell.	Light meter, solar cell

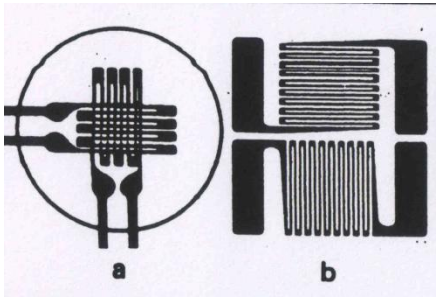
Sinais, medidas, ruídos, . . .

Transdutores (+ condicionador de sinal)

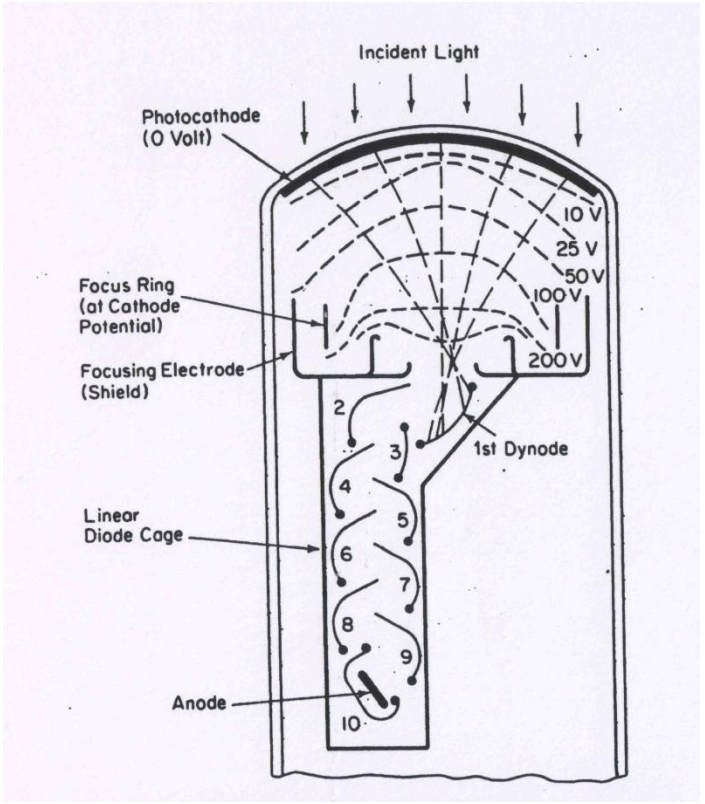
- Tipo
- Condições físicas e ambientais de trabalho
- Compatibilidade com outros equipamentos.



Sensor de deformação (Strain gauge)

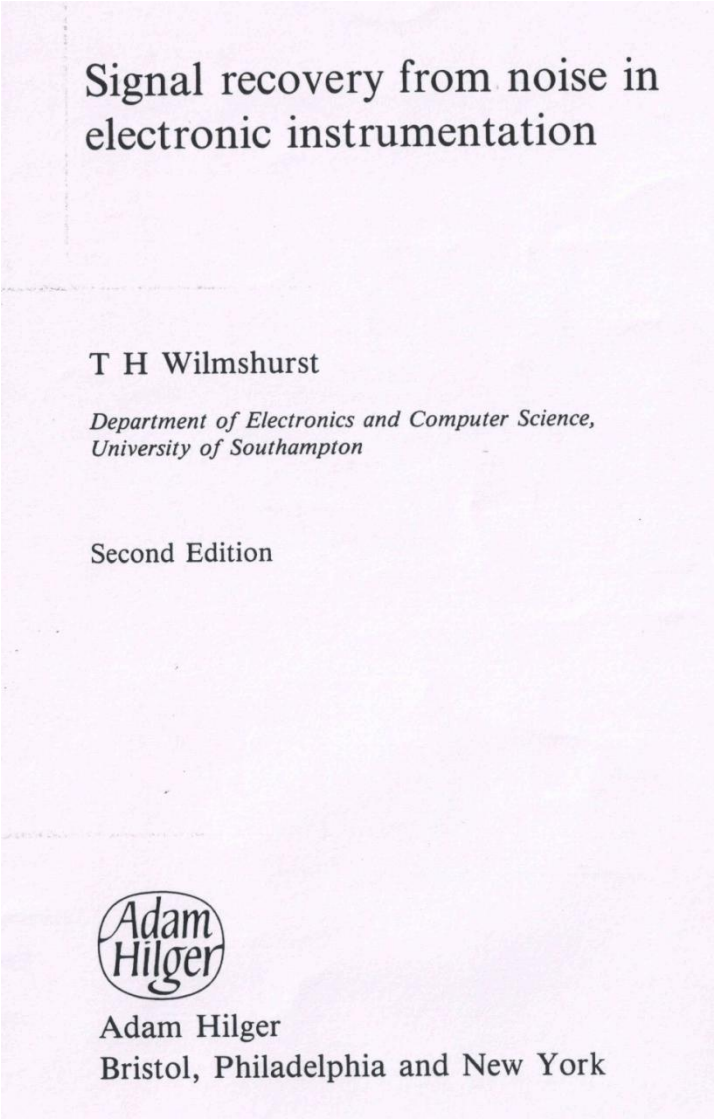


Fotomultiplicadora



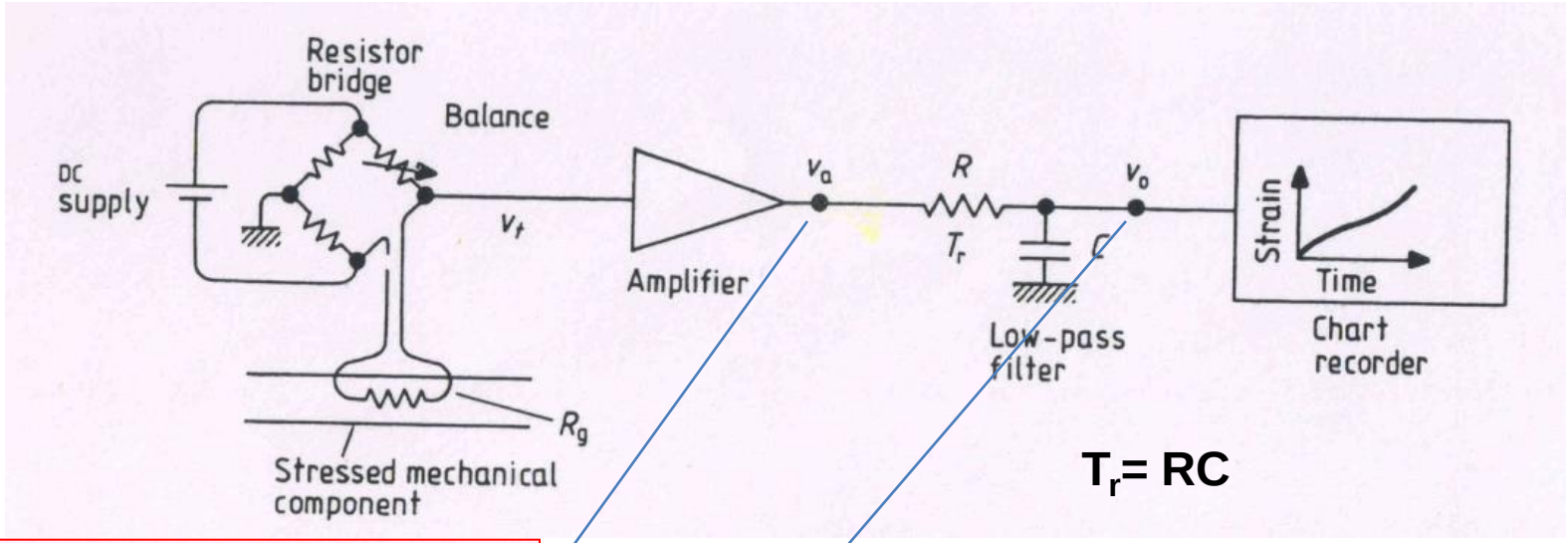
Sinais, medidas, ruídos, . . .

Extração do sinal, frente ao ruído:

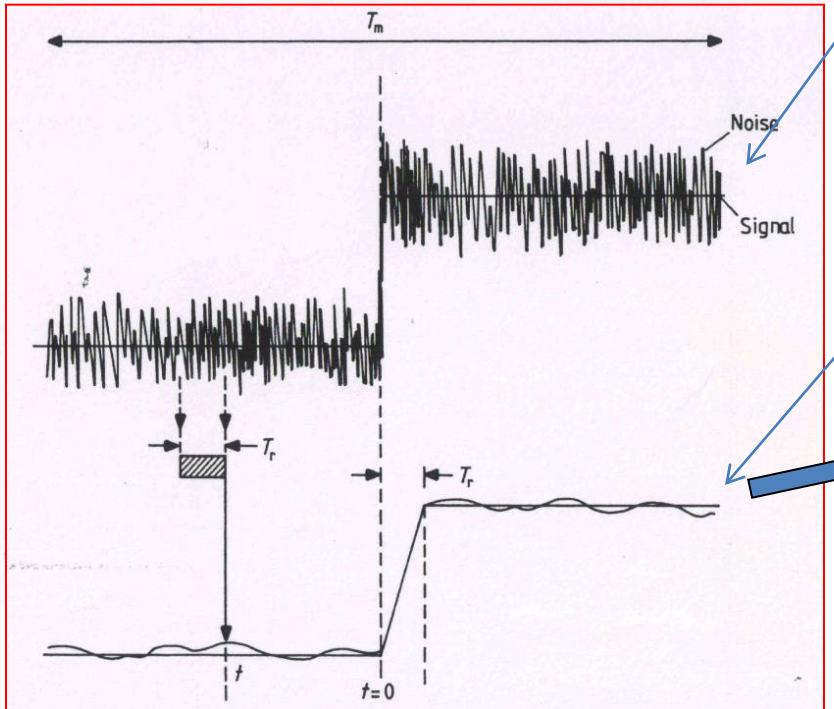


Sinais, medidas, ruídos, . . .

Extração do sinal, frente ao ruído:



$T_r = RC$



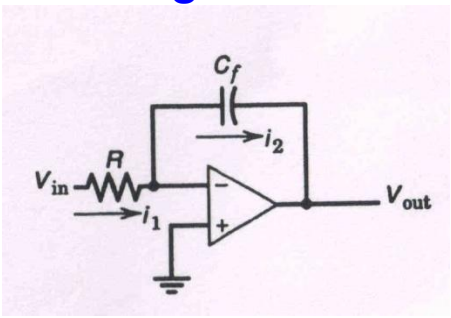
Ruído branco (aleatório) e filtro passa-baixas:

Ruído branco:

$$\tilde{v}_n \propto T_r^{-1/2}$$

Filtros

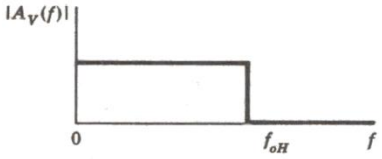
integrador



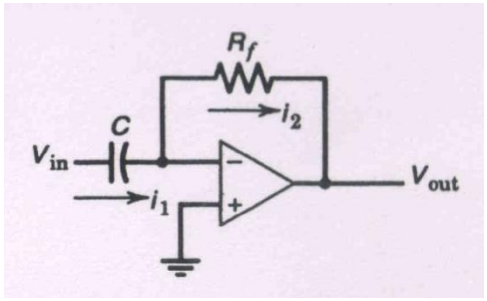
Para sinal senoidal:

$$V_{out} \propto \frac{V_{in}}{\omega R C_f}$$

Filtro passa-baixas



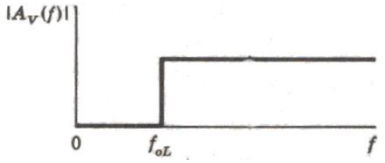
diferenciador



Para sinal senoidal:

$$V_{out} \propto \omega R C_f V_{in}$$

Filtro passa-altas



Combinação de filtros

Filtro passa-banda

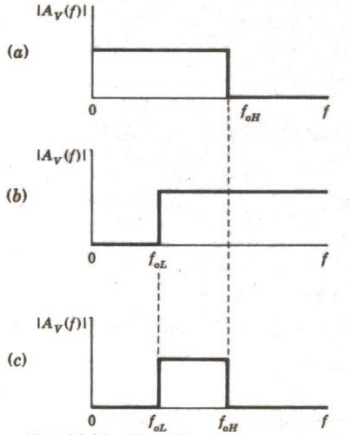


Fig. 16-15 Ideal filter characteristics. (a) Low-pass, (b) high-pass, and (c) bandpass.

Filtro rejeita-banda

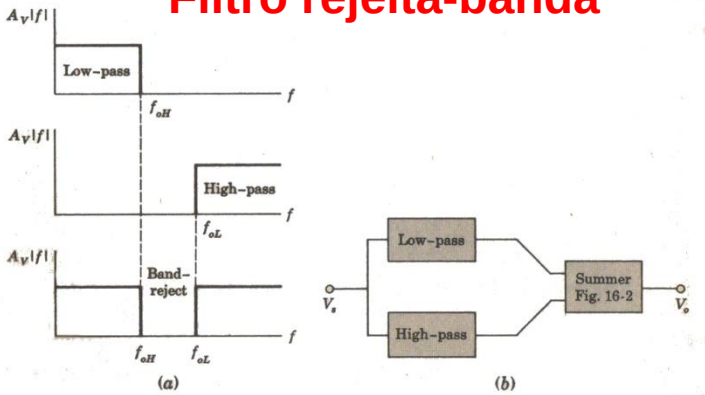


Fig. 16-20 (a) Ideal band-reject-filter frequency response. (b) Parallel combination of low-pass and high-pass filters results in a band-reject filter.

Sinais, medidas, ruídos, . . .

Outras perturbações:

Deriva (drift) e **Deslocamento** (offset)

Fontes de **deslocamento**: transdutor e amplificador

(ponte desbalanceada e correntes de fuga no amplificador) que podem ser corrigidas.

Fonte principal de **deriva**: lentas mudanças na temperatura

Deriva é proporcional ao tempo de medida (T_m)

Para **Deriva** (drift)

Média de Múltiplas Medidas

(fazer cada experimento rapidamente e repetir várias vezes.

Deteção Síncrona (phase-sensitive detection)

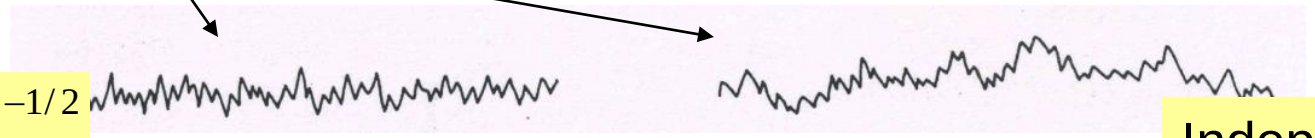
(técnica AC a ser estudada mais tarde)

Ruído 1/f

Ruído branco tem um espectro que independe da frequência.

Ruído 1/f é inversamente proporcional à frequência

(α 1/f)



$$\tilde{v}_n \propto T_r^{-1/2}$$

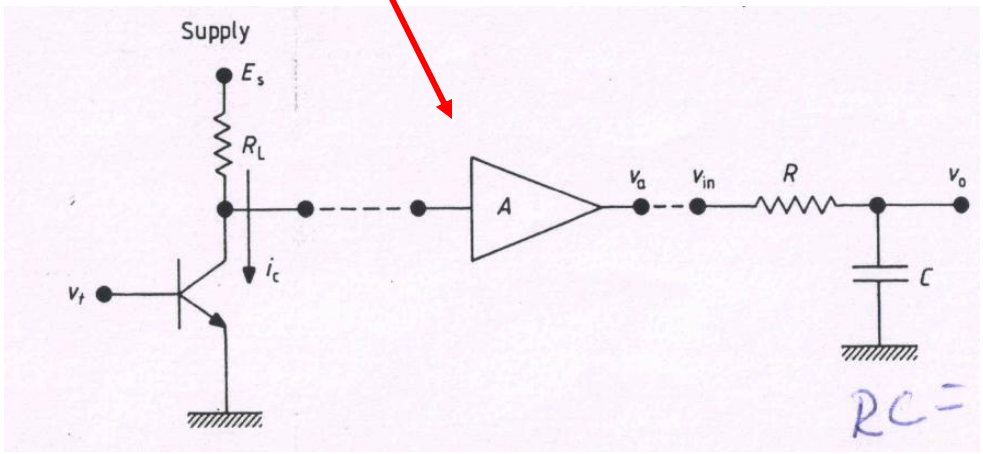
Independe de T_r

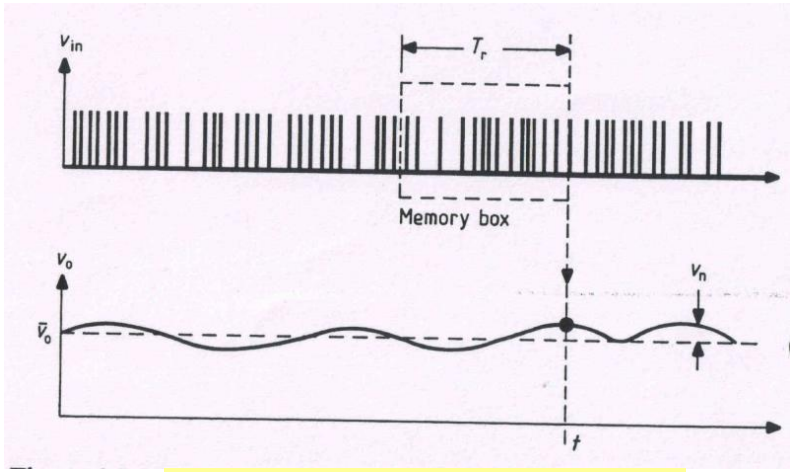
Sinais, medidas, ruídos, . . .

Ruído branco

Ruído térmico, devido às correntes elétricas nas resistências.

Ruído impulsivo (shot noise), devido ao caráter discreto dos portadores de carga



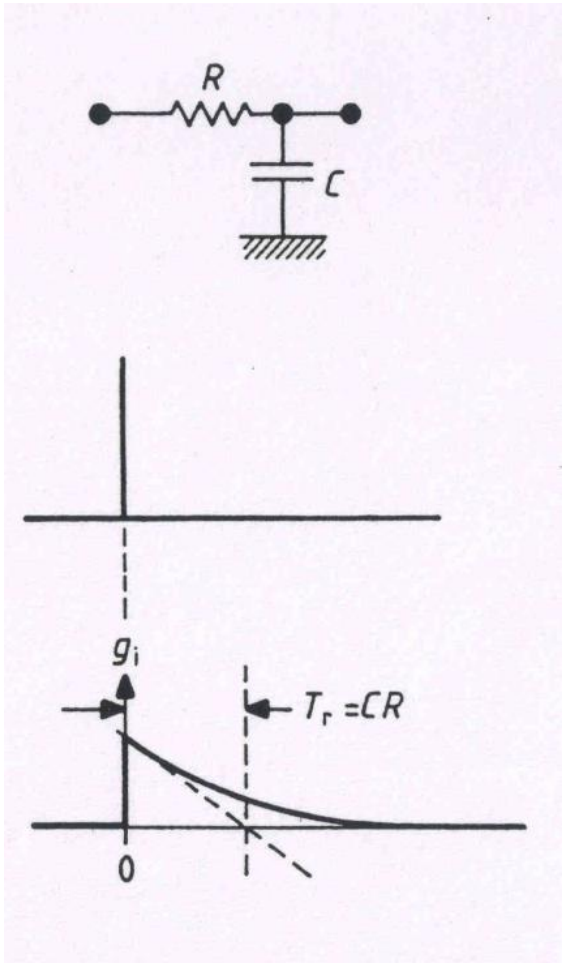


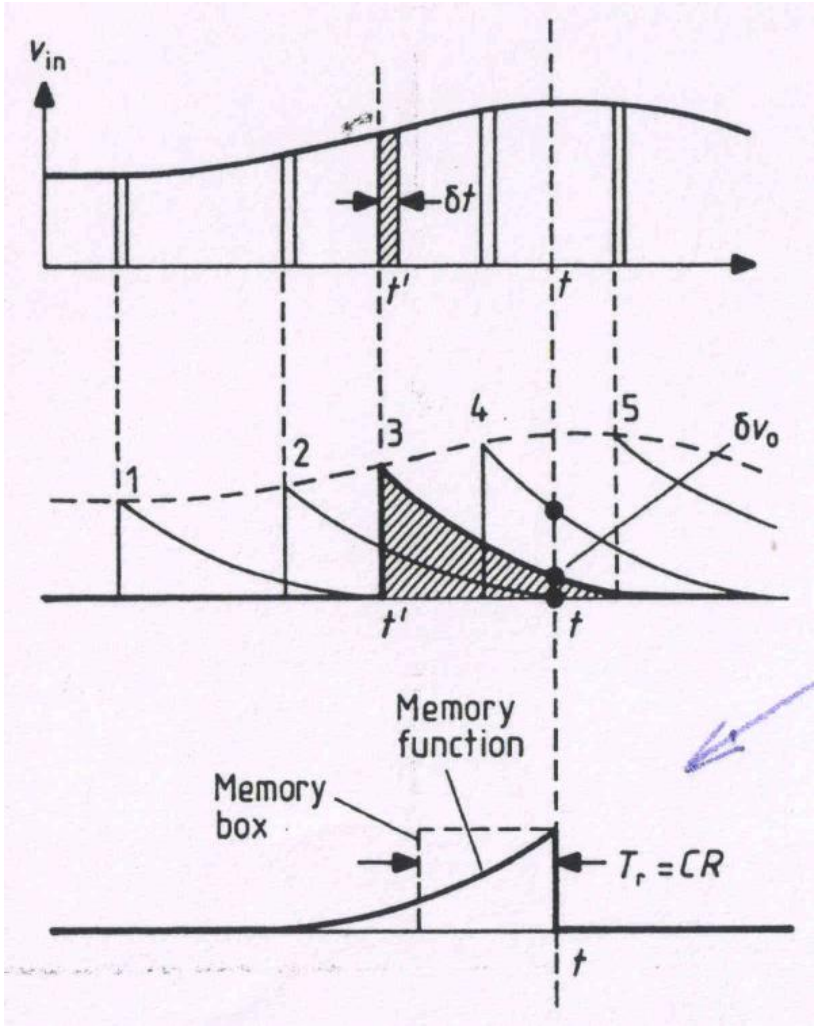
$$v_0 = T_r^{-1} \int_{t-T_r}^{t} v_{in}(t')dt'$$

$$\tilde{v}_n \propto T_r^{-1/2}$$

Sinais, medidas, ruídos, . . .

Resposta do Filtro RC (g_i)



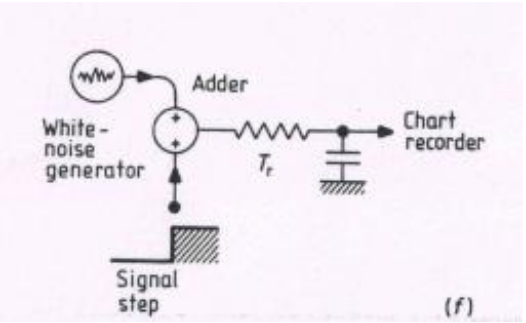


$$v_0(t) = \int_{-\infty}^{t} v_{in}(t')g_i(t-t')dt'$$

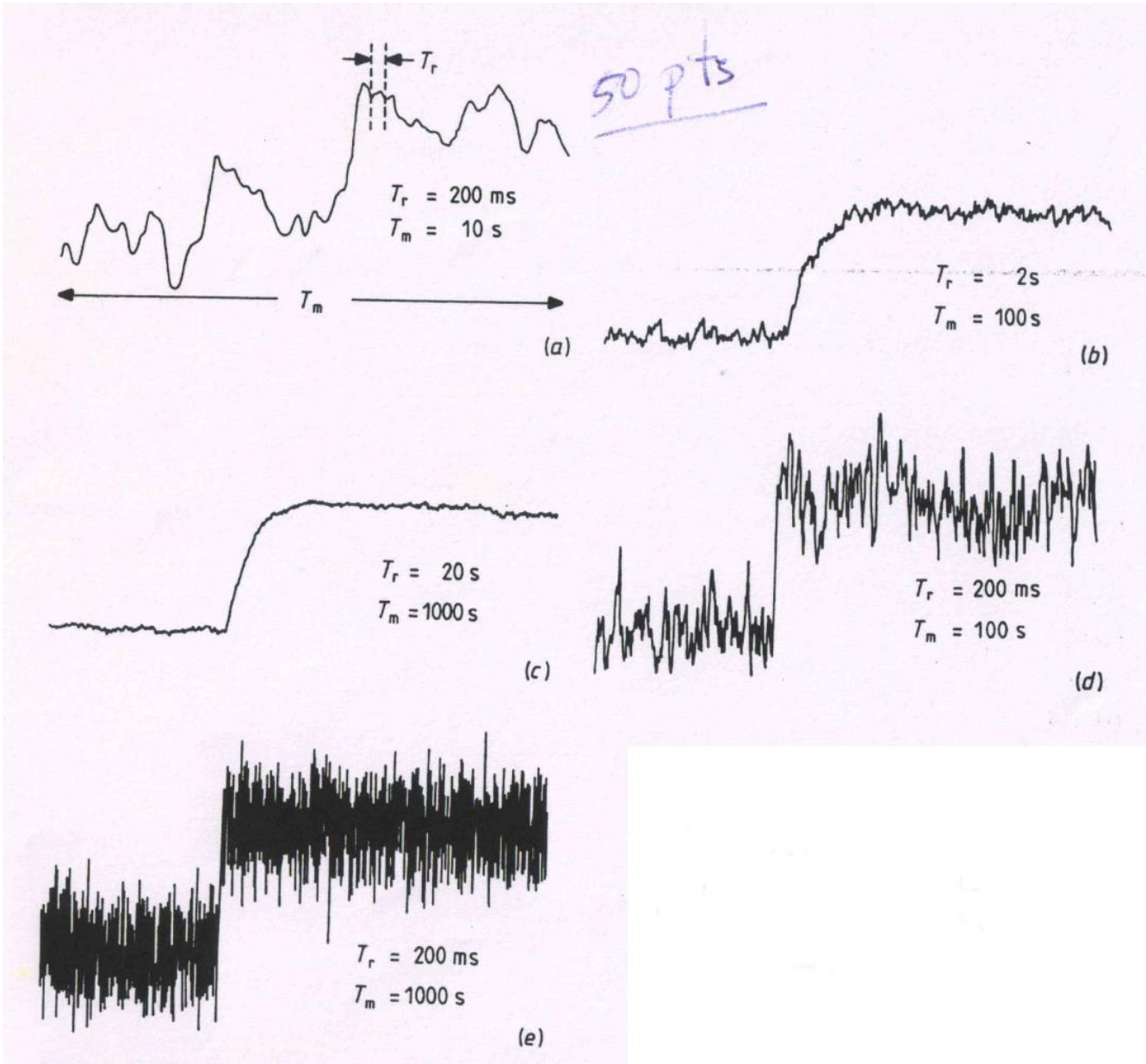
$$\tilde{v}_n \propto T_r^{-1/2}$$

Sinais, medidas, ruídos, . . .

Efeito de T_r e T_m (um exemplo experimental)

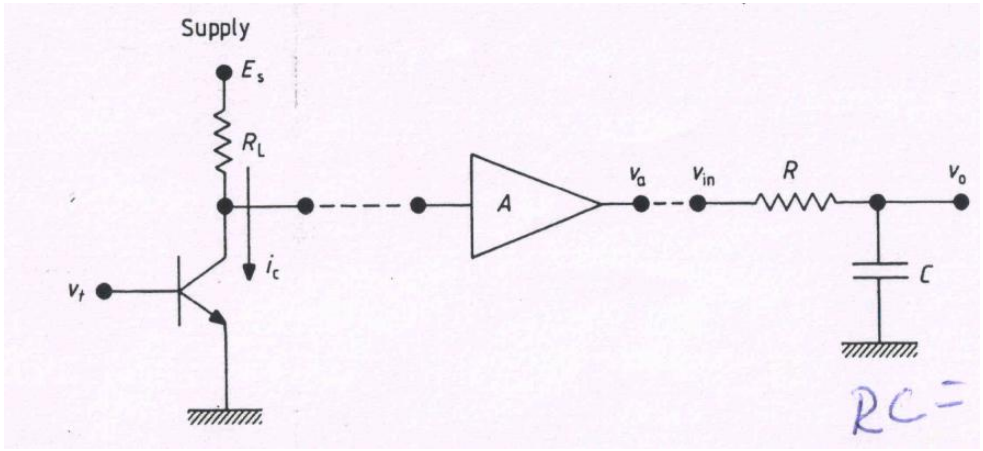


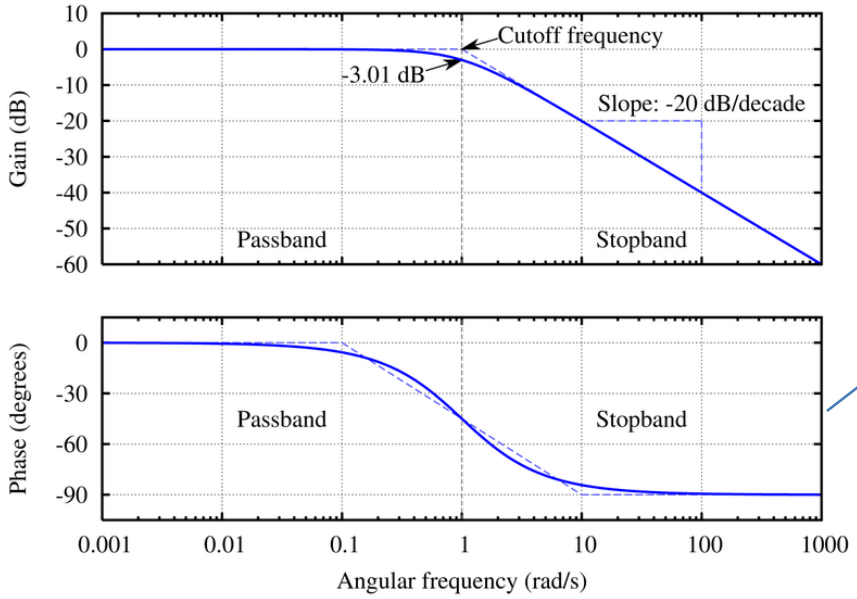
$$\tilde{v}_n \propto T_r^{-1/2}$$



Sinais, medidas, ruídos, . . .

Filtro de primeira ordem





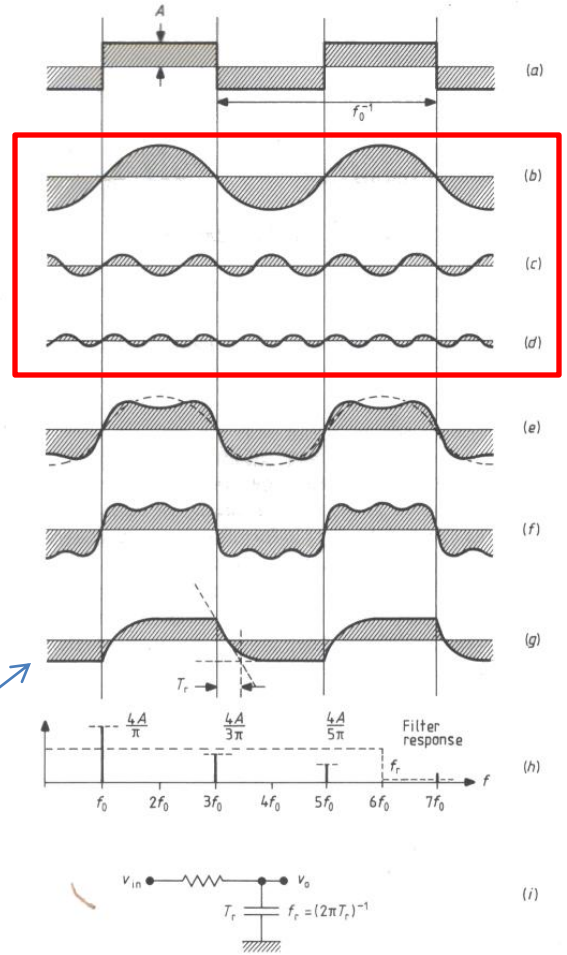
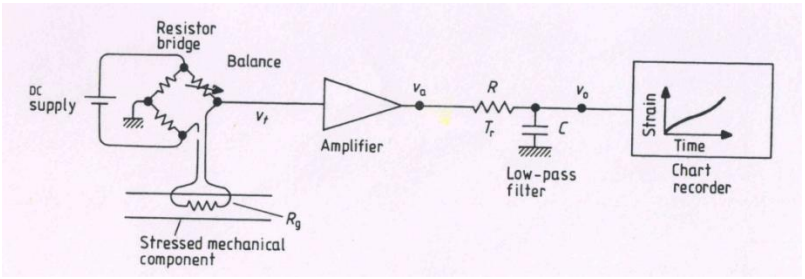
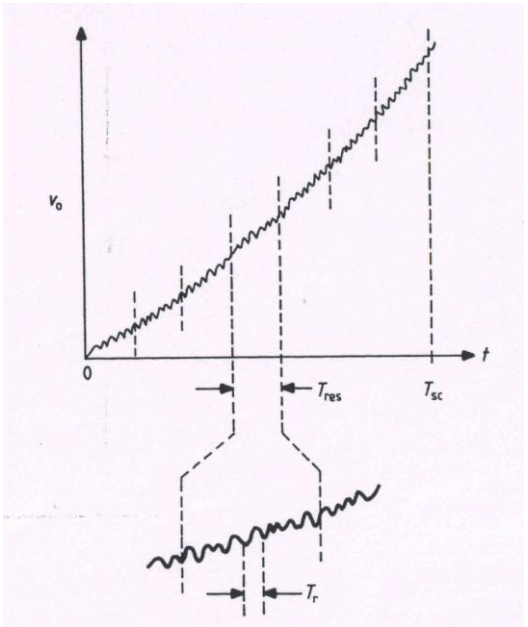


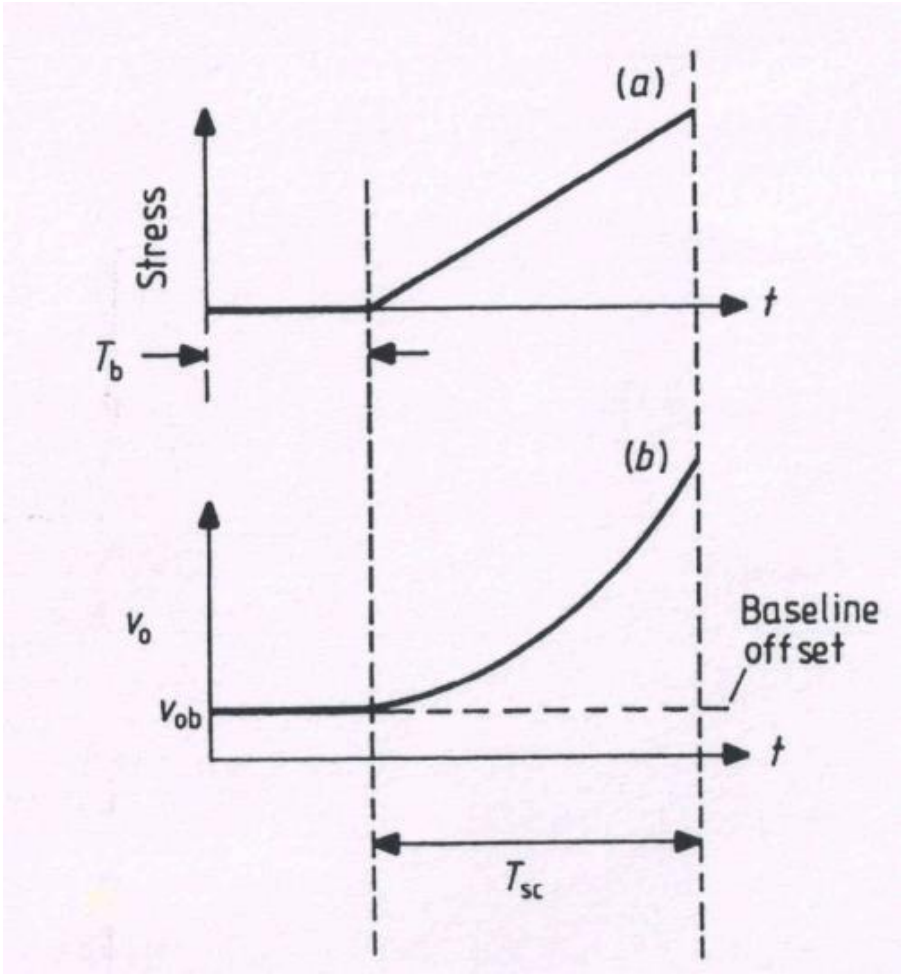
Figure 4.1 Fourier analysis of a square wave (*a*) into sine wave components: (*b*) fundamental of frequency f_0, (*c*) and (*d*) third and fifth harmonics, respectively, with frequencies $3f_0$ and $5f_0$, (*e*) fundamental + third harmonic, (*f*) with fifth harmonic added. (*g*) Square wave when filtered by low-pass filter (*i*). (*h*) Spectrum for square wave, showing frequency response of low-pass filter giving the output waveform in (*f*).

Sinais, medidas, ruídos, . . .

Medida da deformação em função da tensão mecânica aplicada







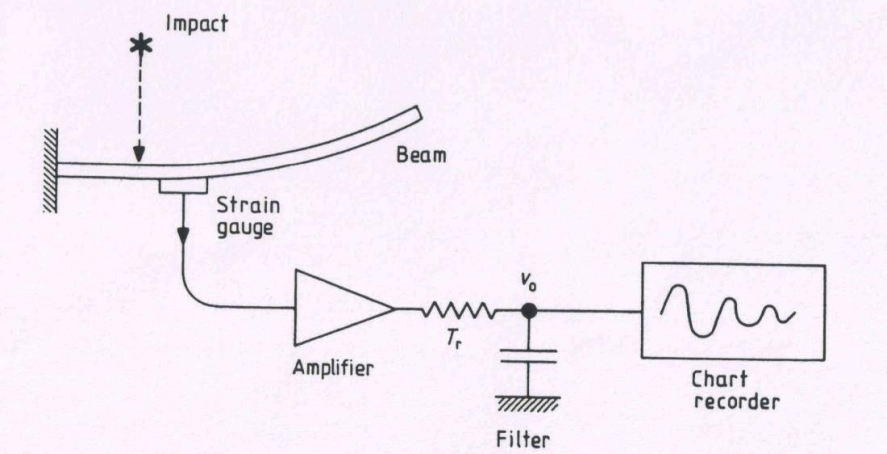
$T_b >> T_{res}$

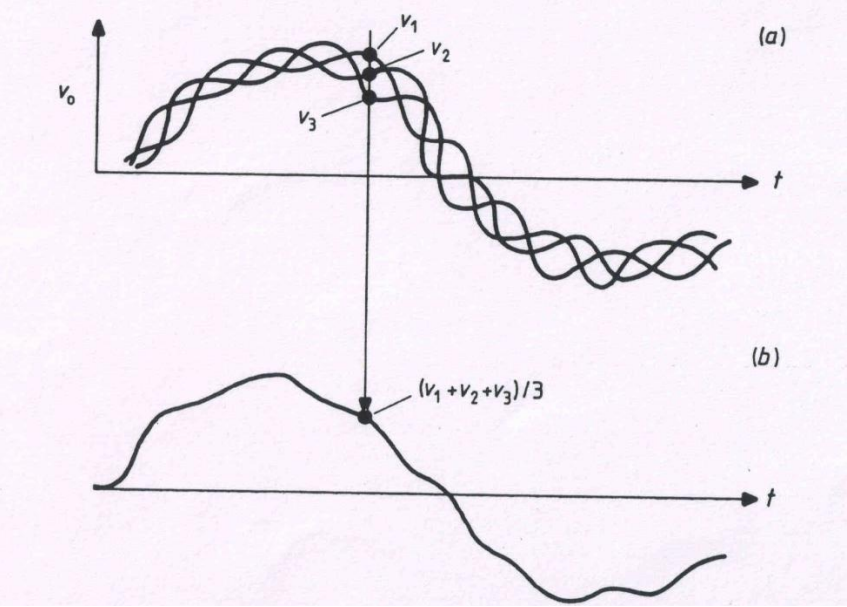
Subtração da linha de base

Tensão nula durante T_b para definir a linha de base e posteriormente subtraí-la.

Sinais, medidas, ruídos, . . .

Média de Múltiplas Medidas





$$\tilde{v}_1 = kT_r^{-1/2}$$

Se não for possível alongar o experimento e aumentar a constante de tempo T_r

Necessário sincronizar o instante inicial de cada repetição.

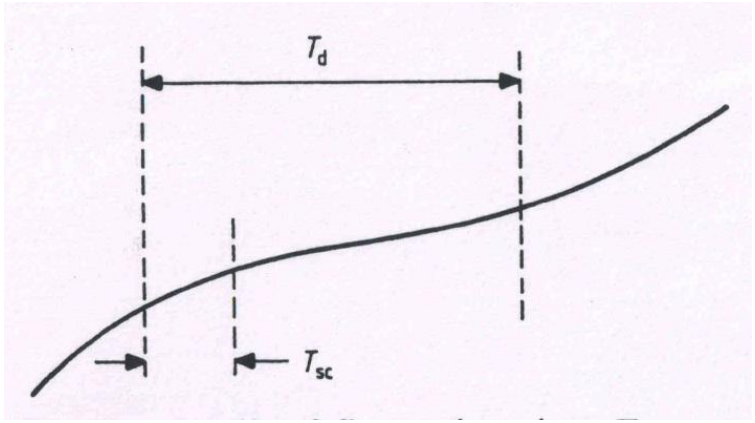
Média de cada instante sobre as várias repetições das medidas.

$$\tilde{v}_n = k(nT_r)^{-1/2} \qquad \tilde{v}_n \propto n^{-1/2}$$

Sinais, medidas, ruídos, . . .

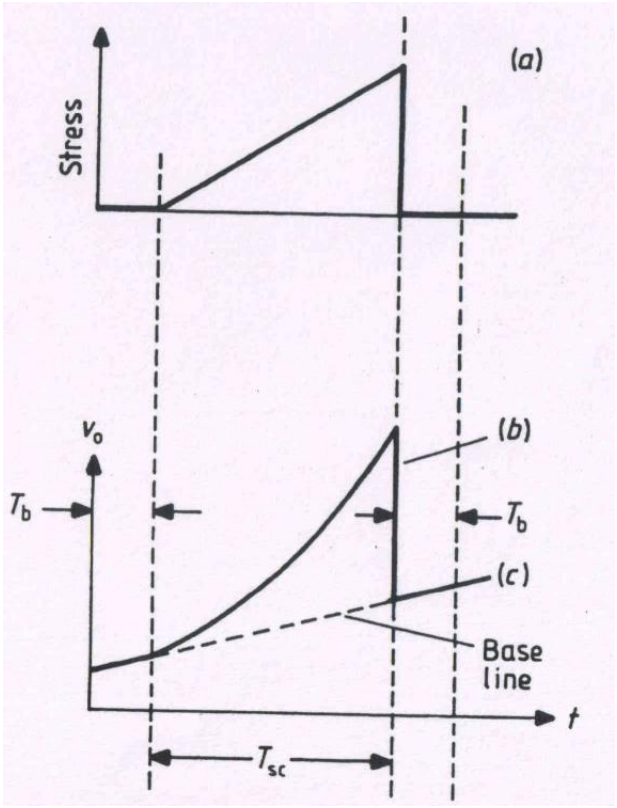
Média de Múltiplas Medidas – Deriva

(devido a lentas variações de temperatura, influenciando o ajuste de zero (offset))



Em geral, o período da deriva >> tempo de varredura de uma medida.

Portanto, pode se supor que a deriva é aproxidamente constante.

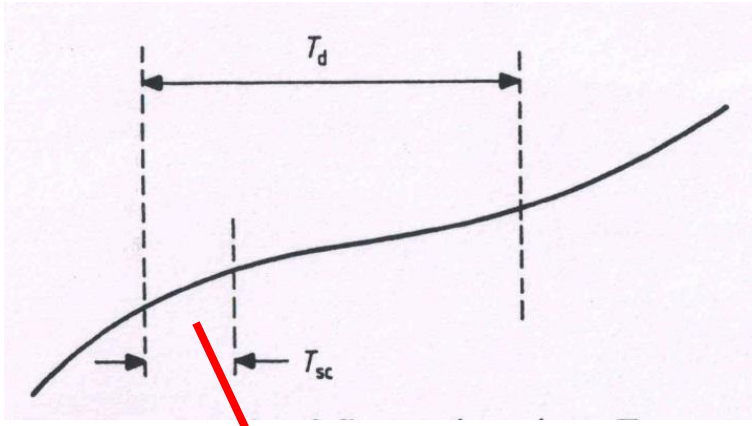


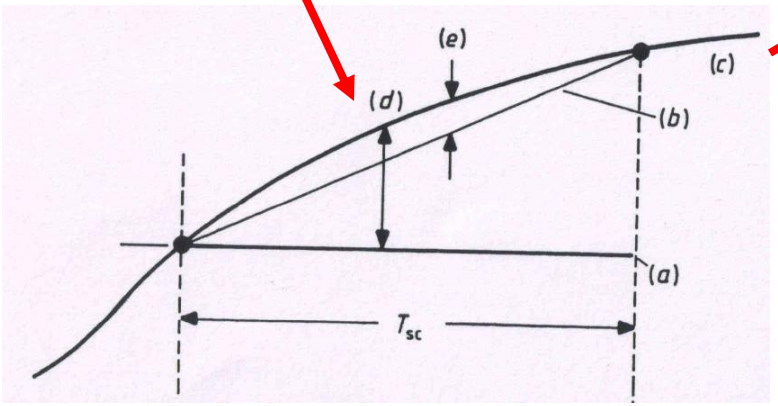
Subtração da linha de base

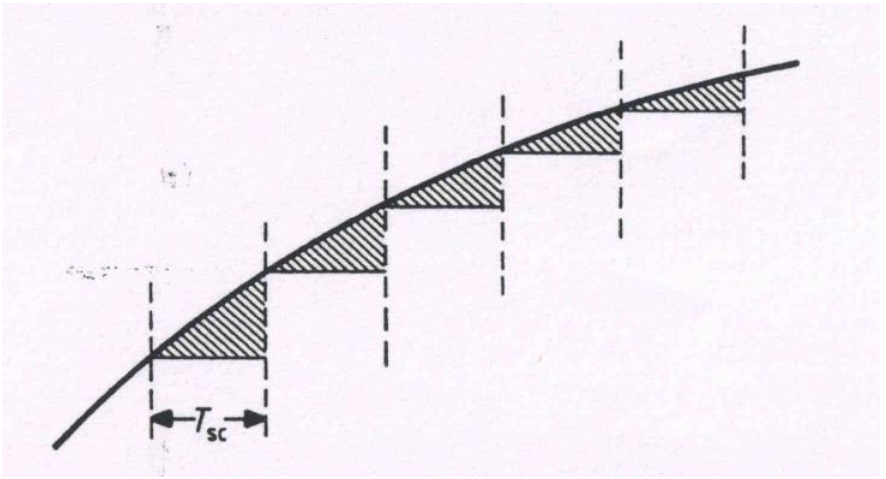
Tensão nula durante T_b para definir a linha de base e subtraí-la.

Sinais, medidas, ruídos, . . .

Média de Múltiplas Medidas – Deriva





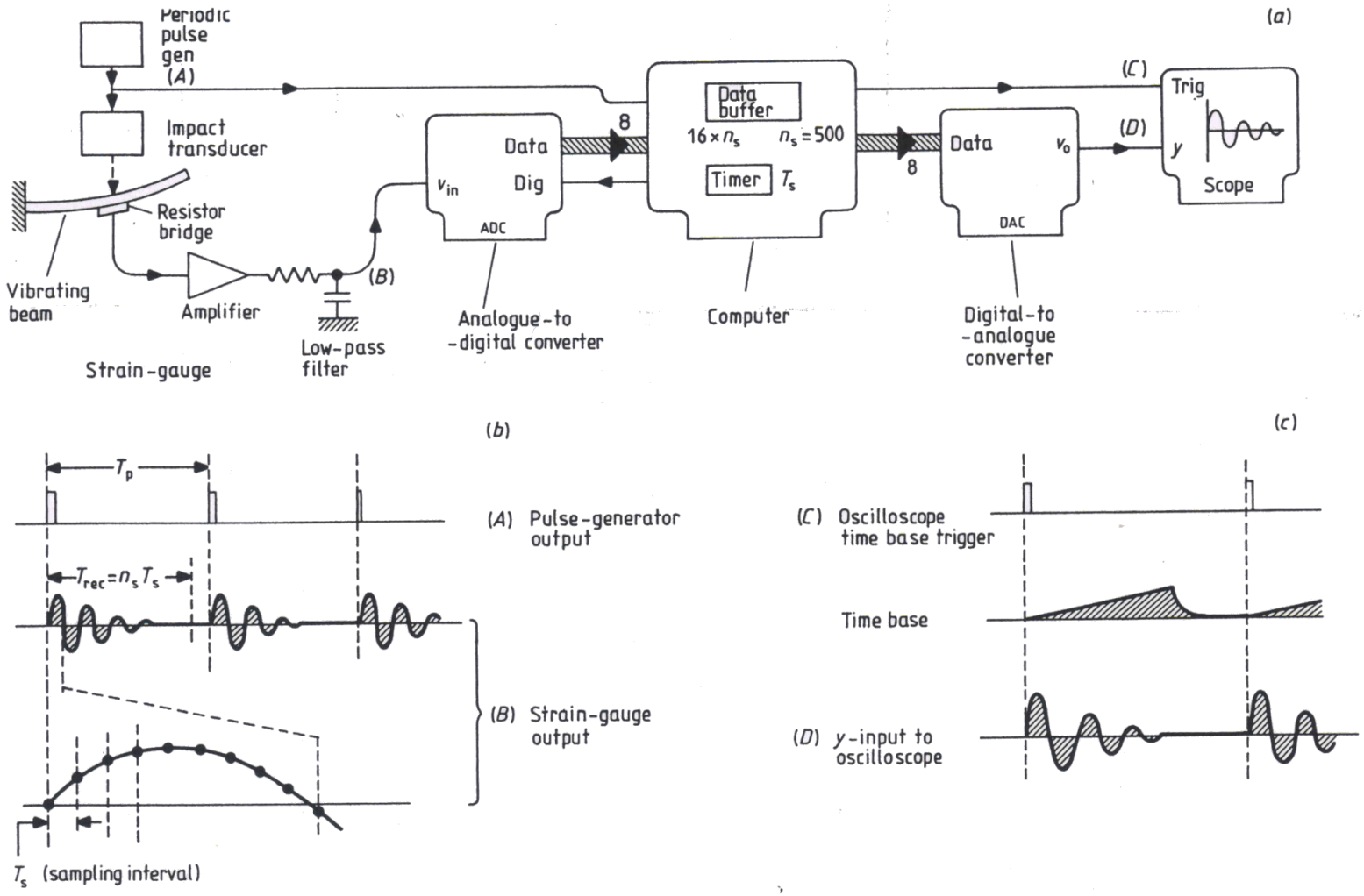


Reduzindo T_{sc}, reduz-se a deriva.

Para manter o mesmo nível de ruído, repete-se n vezes a varredura.

Sinais, medidas, ruídos, . . .

Média de Múltiplas Medidas

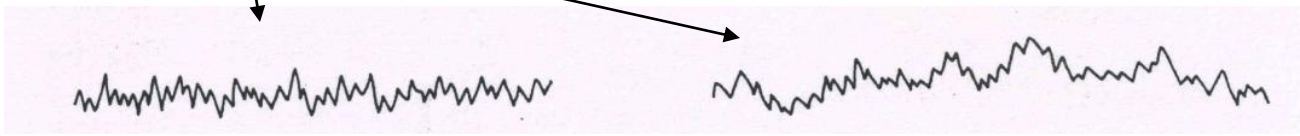


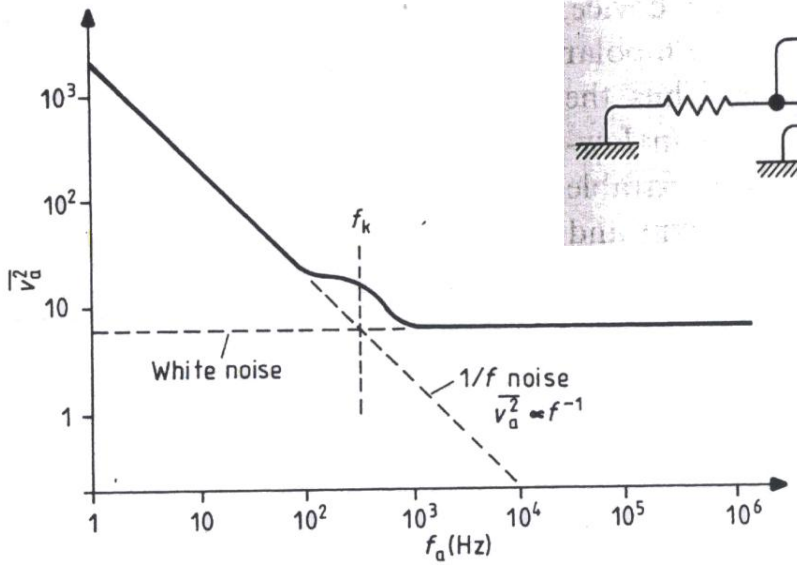
Sinais, medidas, ruídos, . . .

Ruído 1/f

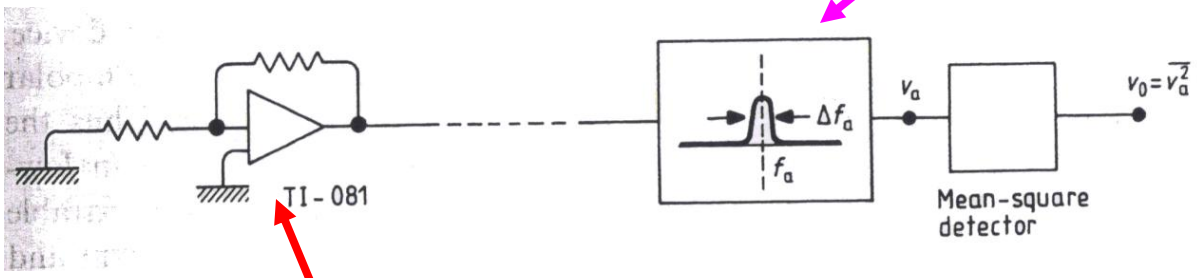
Ruído branco tem um espectro que independe da frequência.

Ruído 1/f é inversamente proporcional à frequência





Filtro espectral



Ruído 1/f vem de defeitos superficiais.

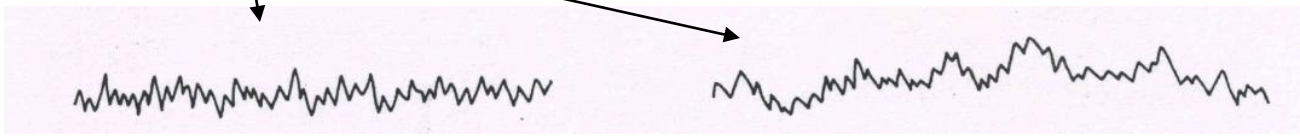
Dispositivos semicondutores frequentemente dependem de interfaces e superfícies.

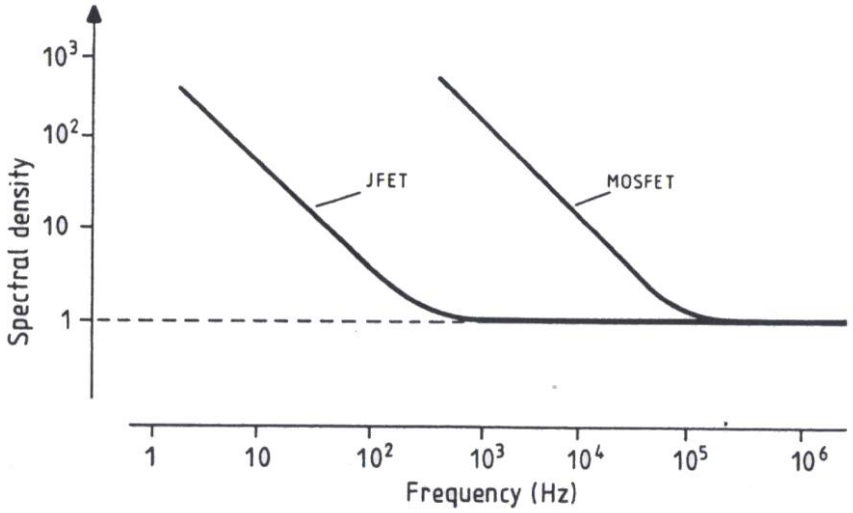
Sinais, medidas, ruídos, . . .

Ruído 1/f

Ruído branco tem um espectro que independe da frequência.

Ruído 1/f é inversamente proporcional à frequência





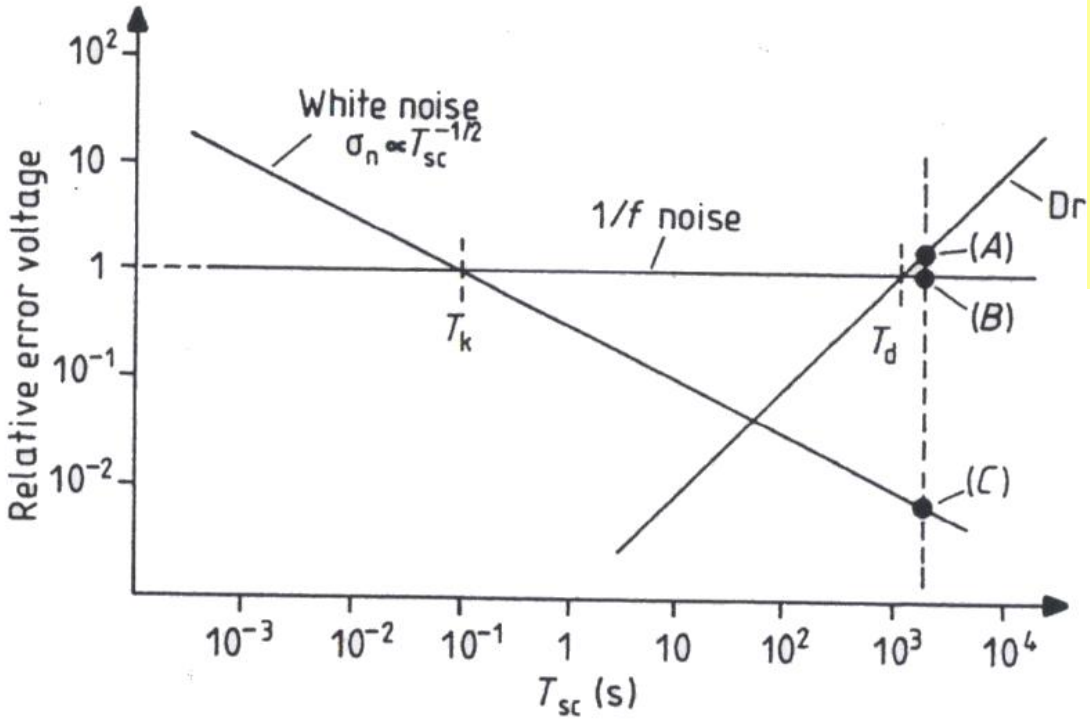
Ruído 1/f vem de defeitos superficiais.

Dispositivos menores apresentam mais ruído 1/f.

Ruído 1/f independe de T_r

Sinais, medidas, ruídos, . . .

Ruído 1/f + ruído branco + deriva



Deriva aumenta com o tempo de medida (T_{sc}).

Ruído 1/f independe do tempo de medida (T_{sc}).

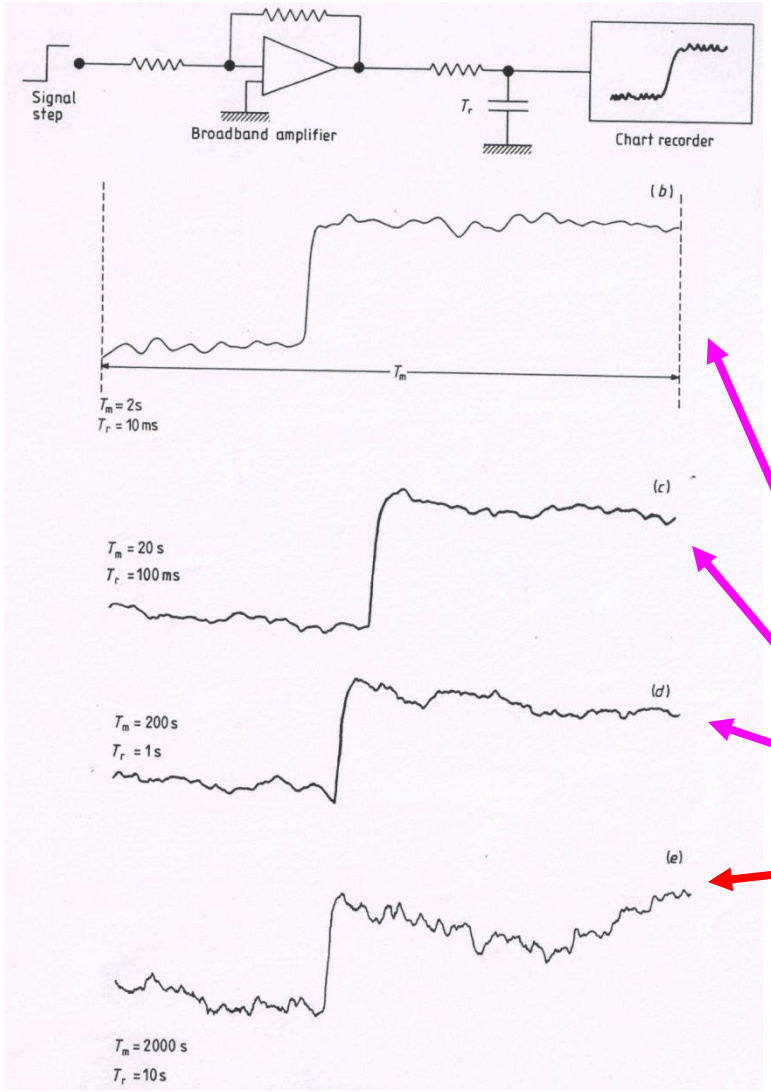
$$\tilde{v}_n \propto T_{sc}^{-1/2}$$

Deriva e ruído branco podem ser minimizados por Média de Múltiplas Medidas.

Ruído 1/f também pode ser minimizado por Média de Múltiplas Medidas.

Sinais, medidas, ruídos, . . .

Ruído 1/f + ruído branco + deriva



Ruído 1/f é preponderante

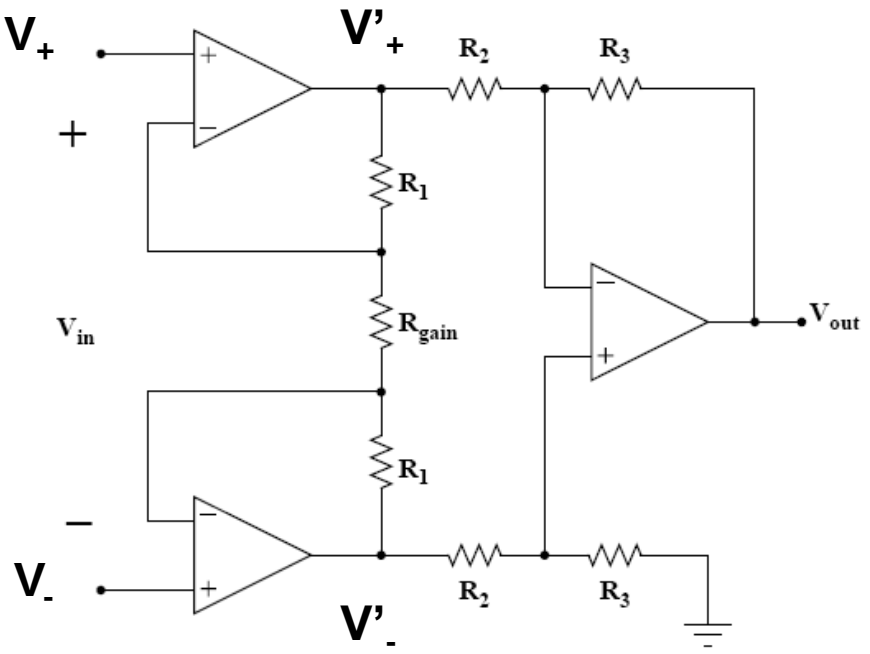
Deriva

Wikipedia:

An instrumentation (or instrumentational) amplifier is a type of differential amplifier that has been outfitted with input buffers, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment.

Additional characteristics include very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, and very high input impedances. Instrumentation amplifiers are used where great accuracy and stability of the circuit both short- and long-term are required.

Entrada diferencial

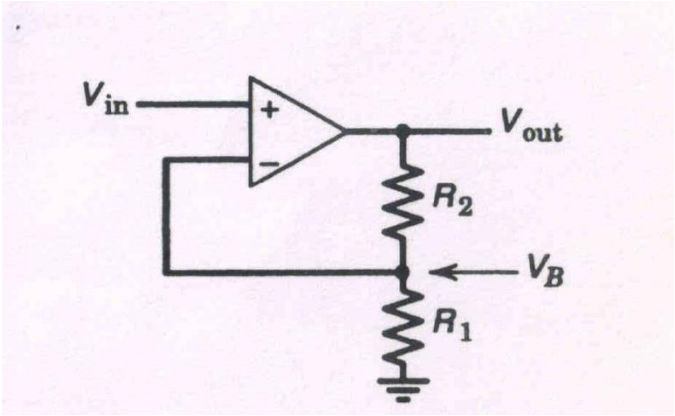


$$\left.\begin{aligned} V_+ - V_- &= R_g \cdot I_g \\ V_+^{'} - V_-^{'} &= (R_g + 2R_1) \cdot I_g \end{aligned}\right\} \quad \left.\begin{aligned} V_+^{'} - V_-^{'} &= \left(\frac{R_g + 2R_1}{R_g}\right) \cdot (V_+ - V_-) \\ V_{out} &= \frac{R_3}{R_2}(V_+^{'} - V_-^{'}) \end{aligned}\right\} \quad \frac{V_{out}}{V_+ - V_-} = \left(1 + \frac{2R_1}{R_g}\right) \cdot \frac{R_3}{R_2}$$

Alguns usos de Amplificadores Operacionais

Idealmente: (A= ∞ , i_i= 0)

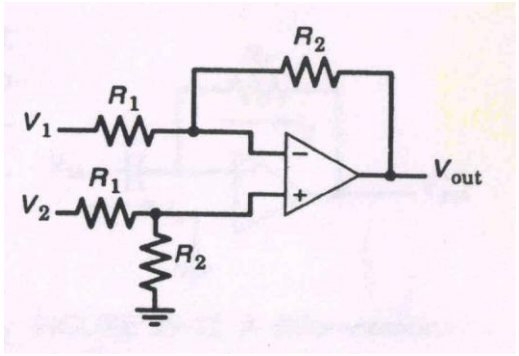
Amplificador não inversor



$$e' = -(V_+ - V_-) \sim 0$$
$$V_{in} = V_B$$
$$V_B = V_{out}\left(1+\frac{R_2}{R_1}\right)$$

$$V_{out} = \left(1+\frac{R_2}{R_1}\right)\cdot V_{in}$$

Amplificador de diferença



$$V_+ = V_2\frac{R_2}{R_1+R_2} = V_-$$

$$\frac{V_1 - V_+}{R_1} = \frac{V_+ - V_{out}}{R_2}$$

$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

Entrada diferencial

$$\frac{V_{out}}{V_+ - V_-} = \left(1 + \frac{2R_1}{R_g}\right) \cdot \frac{R_3}{R_2}$$

