

UNIDAD 5: ACONDICIONAMIENTO DE SEÑALES

- Introducción: Acondicionamiento de señales
 - Transductor y sensor. Características de las señales
 - Circuitos que no sirven para señales de sensores típicos
- Amplificador Operacional (AO)
 - Simbología y terminales
 - AOs comerciales. Encapsulados y circuitos internos
 - Etapas de un AO
 - Modelo de un AO: Real e Ideal
- Montajes lineales
 - Amplificador Inversor
 - Amplificador No Inversor, Seguidor de Tensión
 - Sumador
 - Integrador y diferenciador
 - Amplificador Diferencial (restador)
 - Amplificador de Instrumentación
- Montajes no lineales
 - Comparadores sin histéresis
 - Comparadores con Histéresis

Transductor

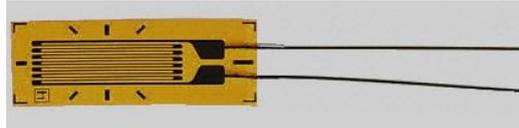
+

Acondicionamiento

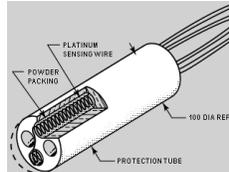
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Sensor

Fuerza-presión

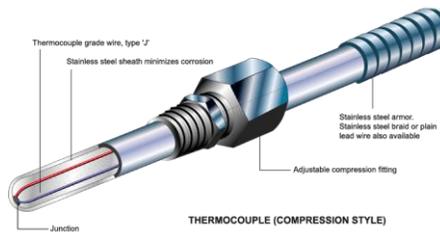


Strain gauge
(120 ohm,
350 ohm)

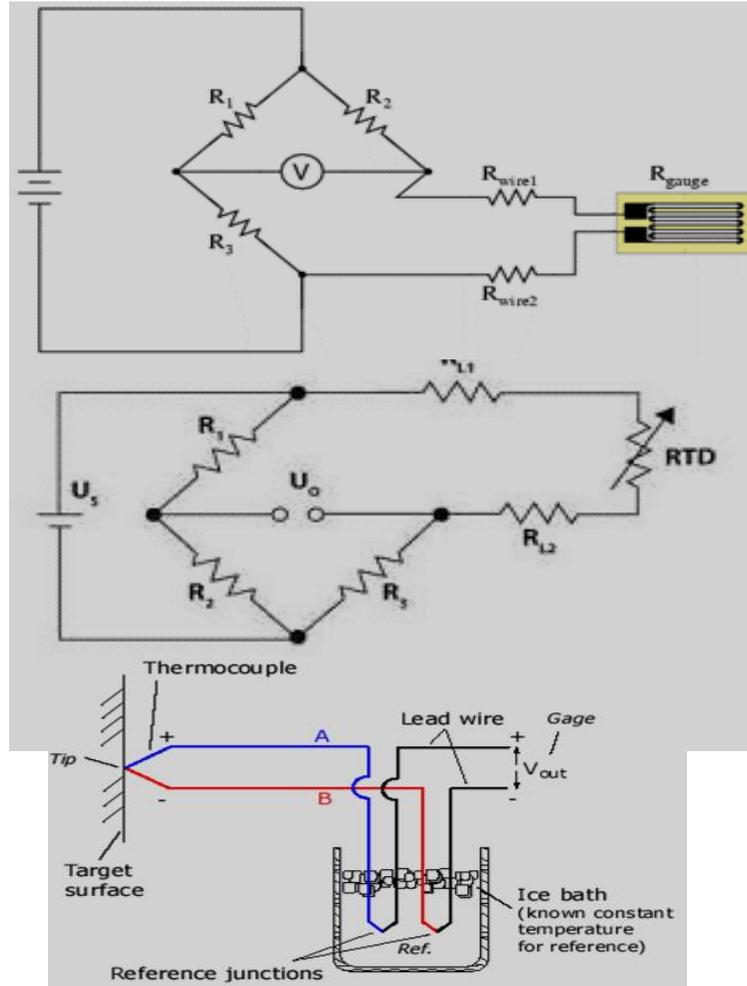


RTD (PT100)

Temperatura



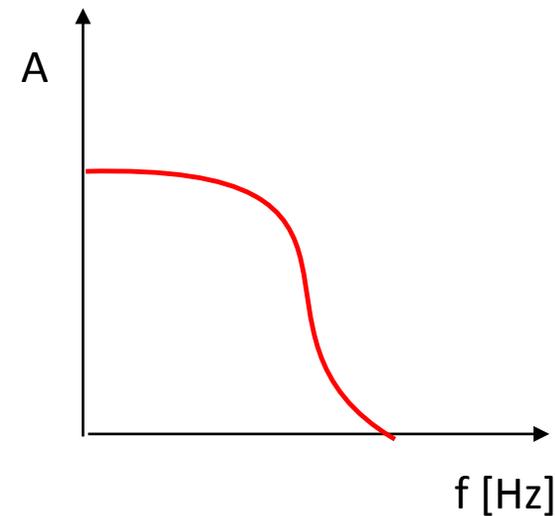
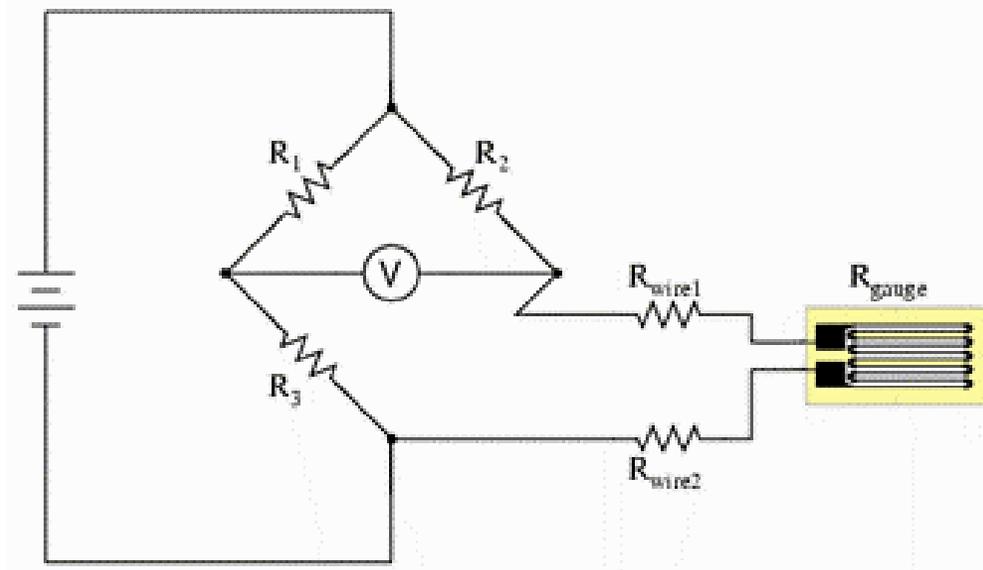
Termocupla



Transductor (Presión, Temp etc)+ acondicionamiento = Sensor (Presión, Temp etc)
 Sensor (Presión, Temp etc) + transmisión (analógica)= Transmisor de Presión, Temp etc)

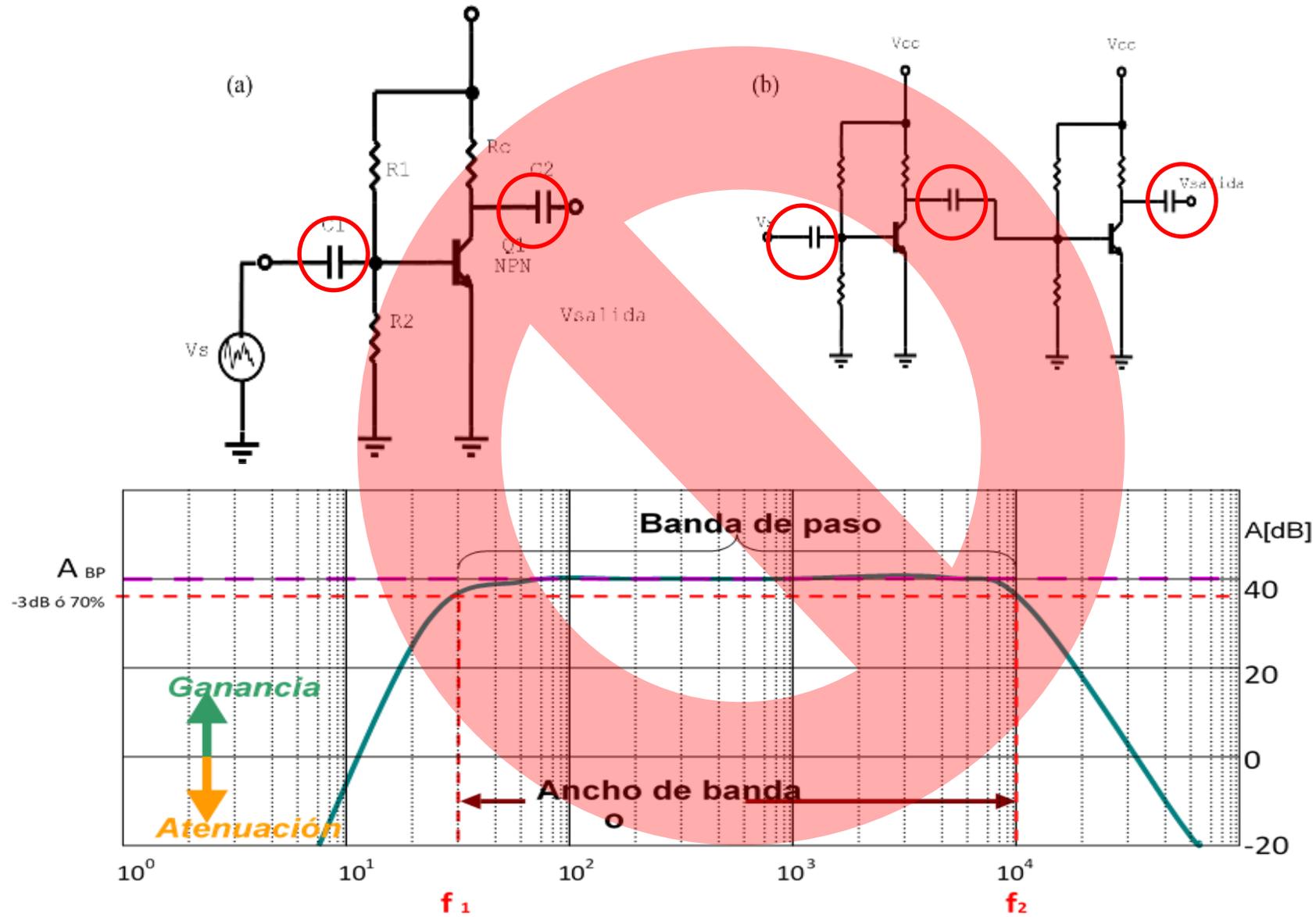
Control de proceso	Sensor	Transductor	
		Acondicionamiento	U1-U5
		Transmisión analógica o digital (ON-OFF)	U7
	Controlador	Entrada analógica o digital	U6
		Muestreo/Digitalización (A/D)	U6
		Procesamiento (algoritmos de control)	U3-U4
		Salida analógica o digital (D/A)	U6
		Comunicación con supervisor u otros controladores	U7-U8
	Actuador	Aislación	U6
		Amplificación de potencia	U2
Actuador primario			
Supervisión	Comunicación	Medio físico, protocolos	U7-U8
	Software	SCADA, otras aplicaciones	U9
	Interfaz H-M		
Otras tareas	Planificación, Gerencia etc		

Características de las señales de sensores

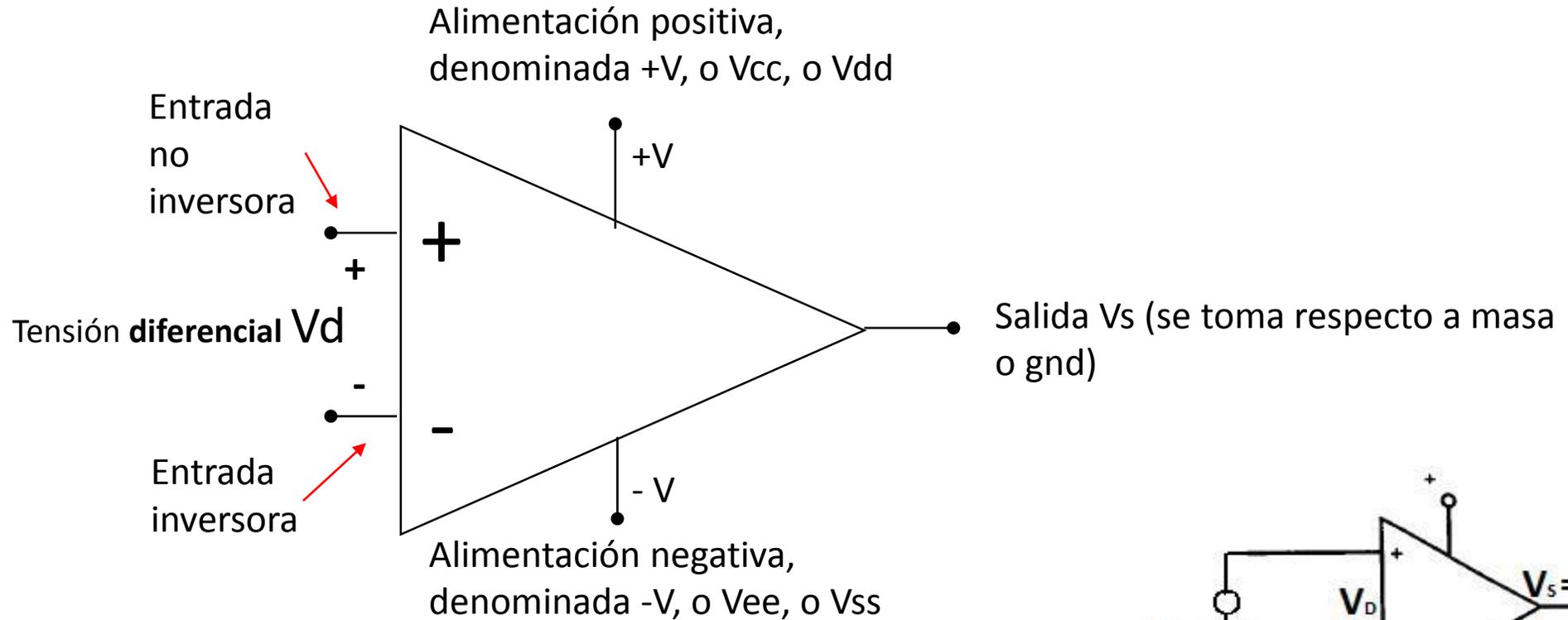


- Muchas variables físicas (P, T) son lentas \rightarrow Las señales son **lentas**
- Muchos transductores entregan señal diferencial (ej Termocuplas) o se colocan en un circuito Puente que entrega **señal diferencial**.

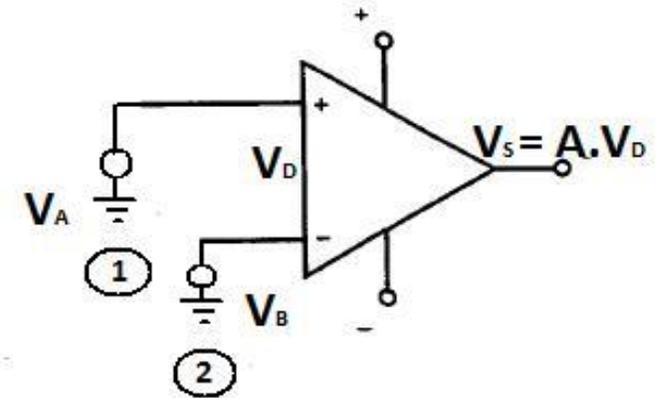
Etapas de amplificación acopladas en CA no sirven para sensores lentos



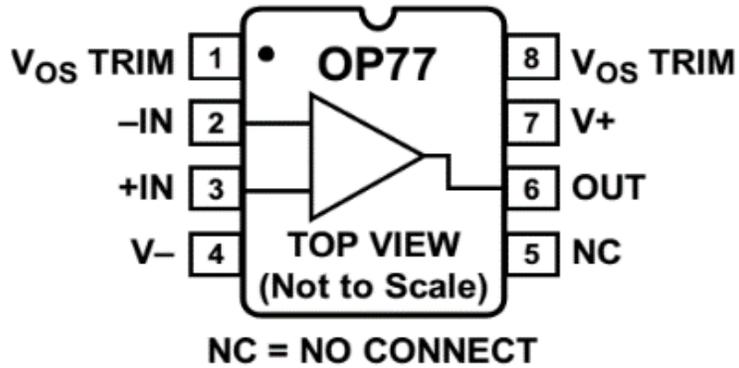
Amplificador Operacional (AO) (o *OPA*, *operational amplifier*)



$$V_S = A \cdot V_D \quad \text{con} \quad V_D = V(+)-V(-)$$



AO comerciales – encapsulados (algunos)

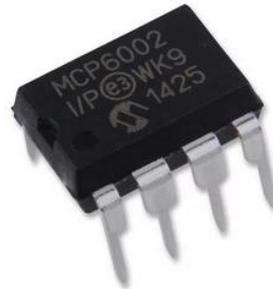
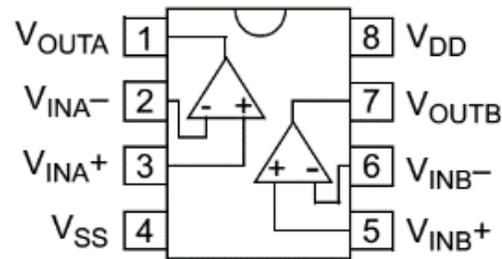


DIP

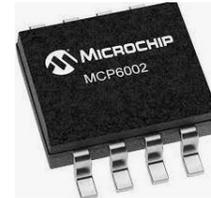


TO-99

MCP6002



DIP

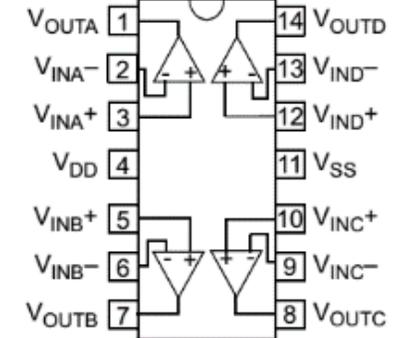


SOIC

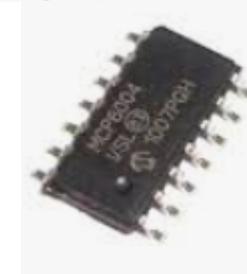


MSOP

MCP6004



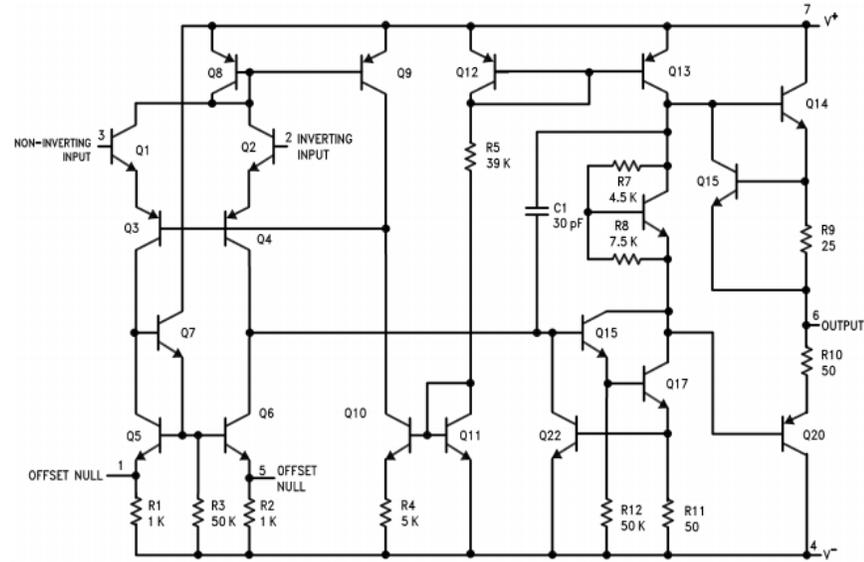
DIP



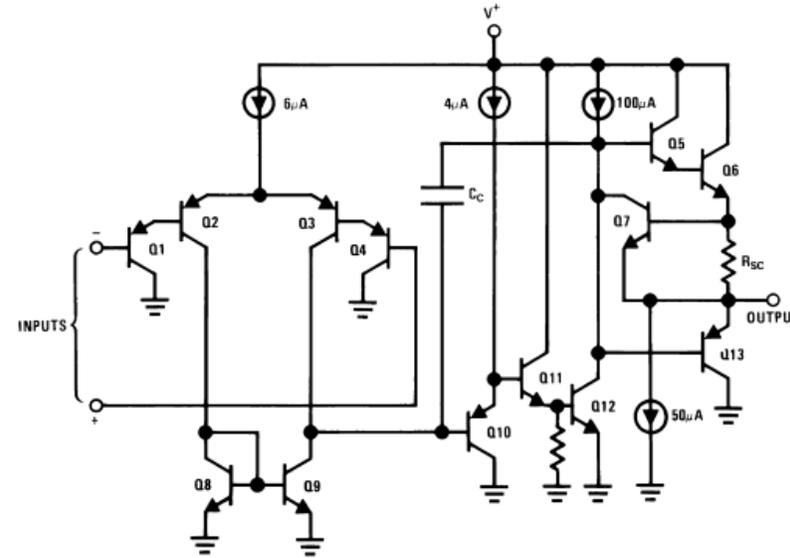
SOIC

Hay cientos de modelos con diferentes características de impedancia, ganancia, velocidad de respuesta/ancho de banda, precisión, rangos de tensiones, corrientes y temperaturas, RRMC.

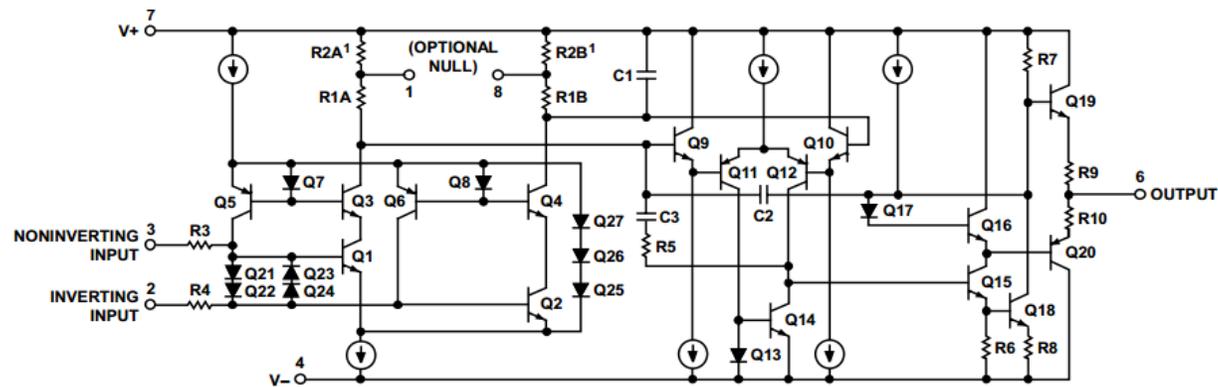
AO comerciales – circuitos internos



LM741



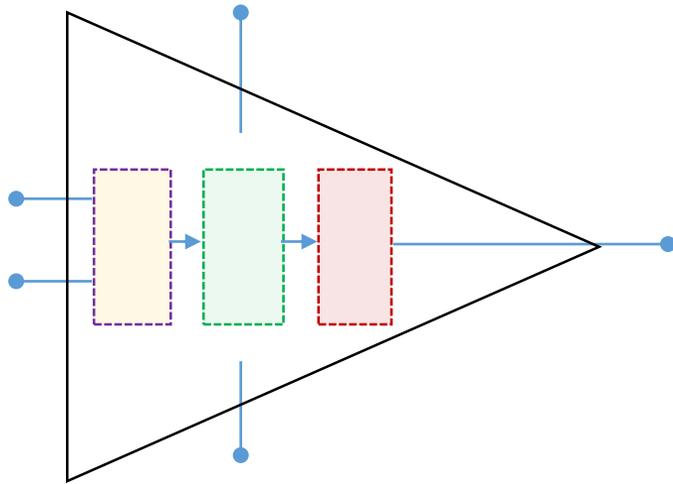
LM124 (1/4)



OP77

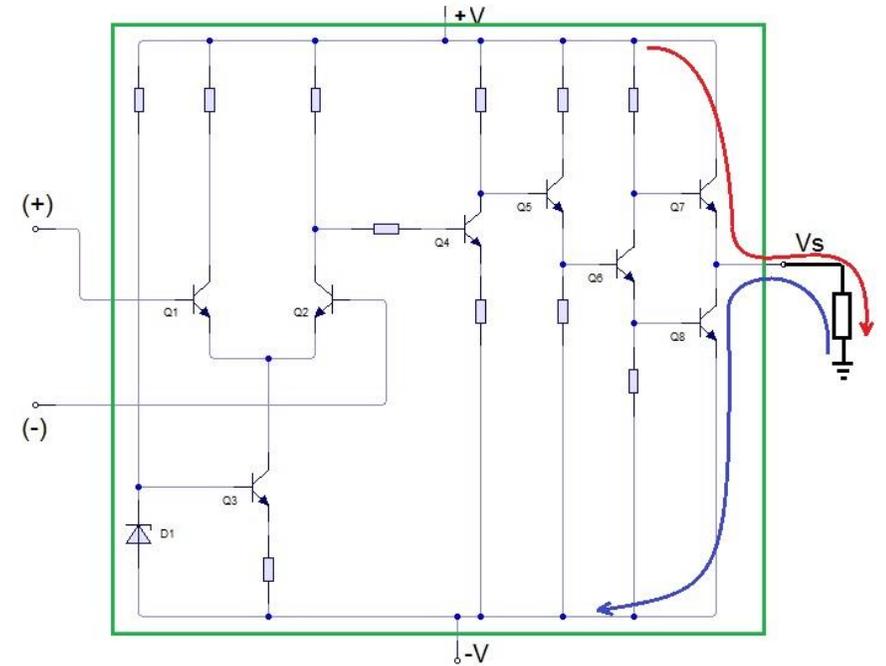
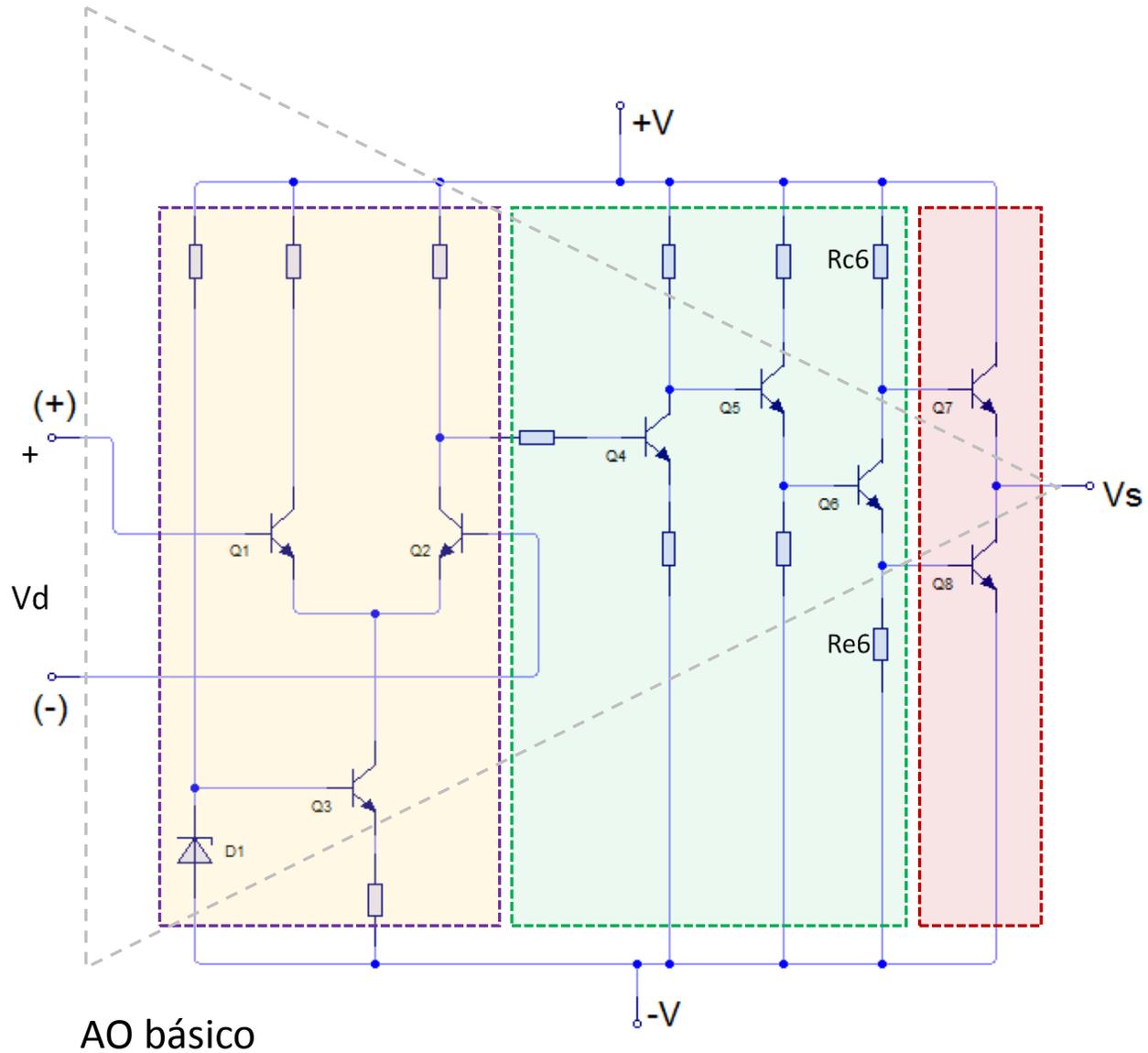
¹R2A AND R2B ARE ELECTRONICALLY ADJUSTED ON CHIP AT FACTORY.

Etapas de un AO



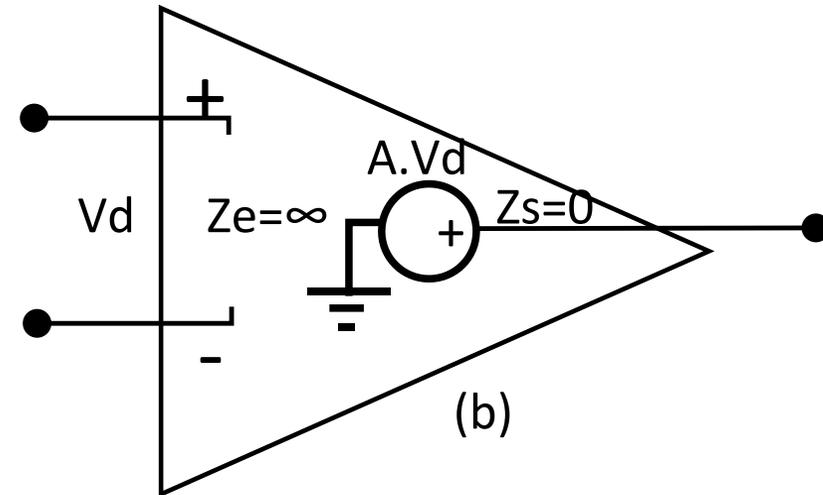
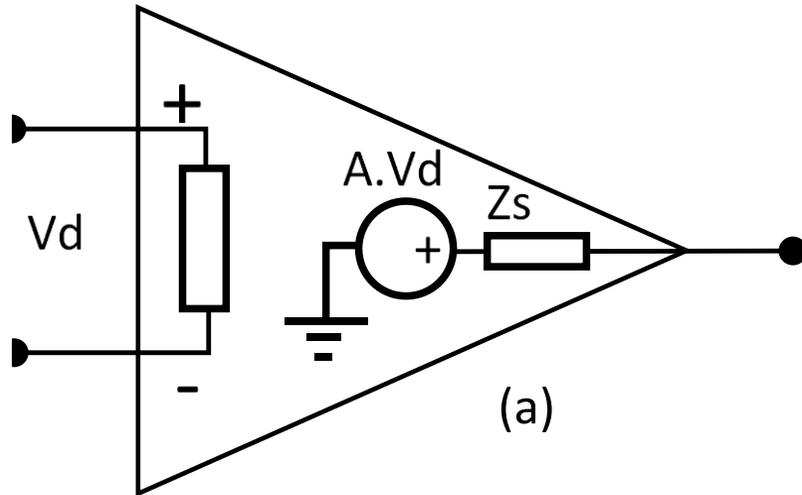
- **Etapa de entrada** conformada por un amplificador diferencial y una fuente de corriente, que presenta elevada impedancia de entrada y rechazo de las señales de modo común.
- **Etapa intermedia** que brinda una elevada ganancia de tensión.
- **Etapa de salida** de tipo complementaria *clase AB* que provee capacidad de corriente y baja impedancia de salida.

Etapas de un AO



Corrientes en la salida **con Vd positivo** y **Vd negativo**

Modelo de un AO ("real" e ideal)



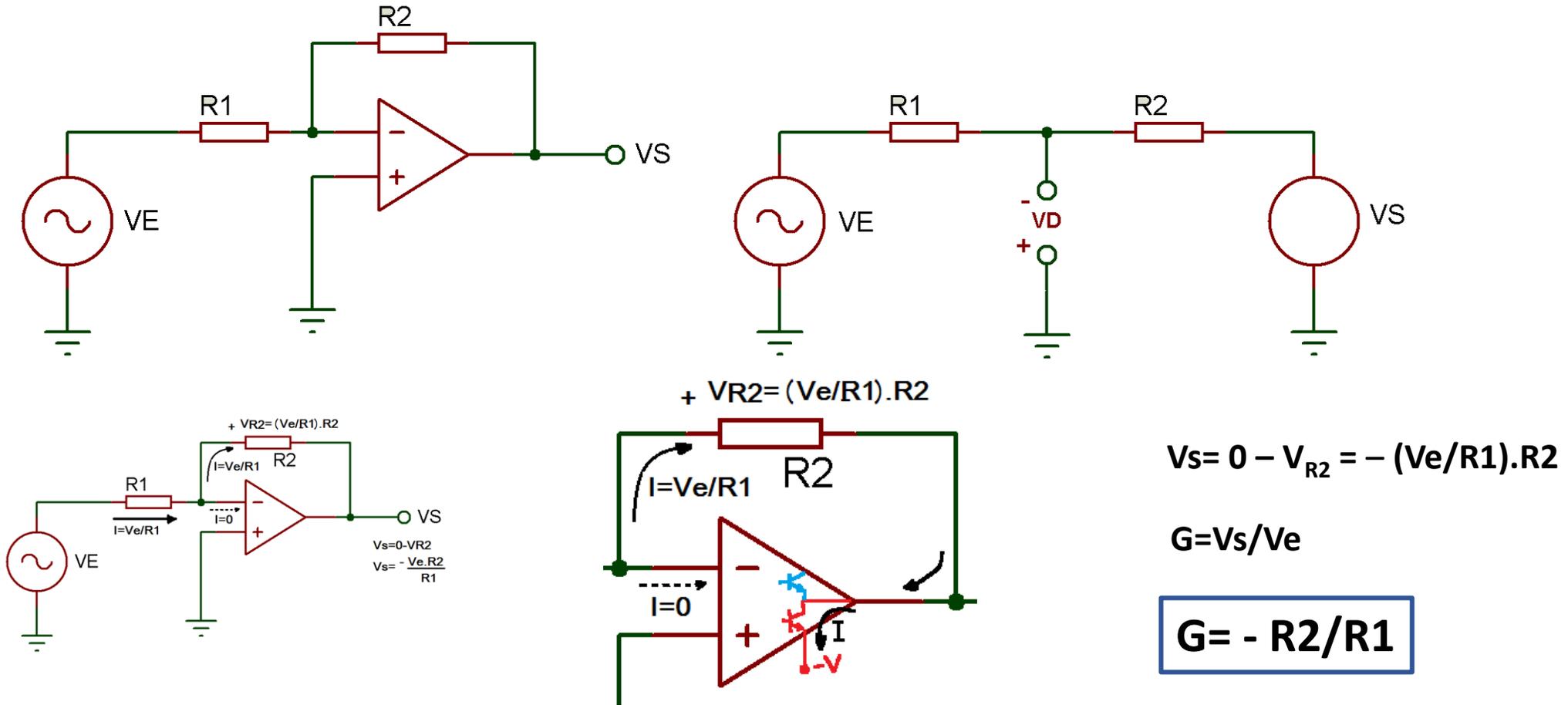
Parámetro	IDEAL	REAL
Imp Entrada	∞	10^6 a $10^{15} \Omega$
Amplificación	∞	10^5 a 10^6 V/V (o 100 a 120 dB)
Imp Salida	0	50 a 75Ω
RRMC	∞	60 a 120 dB

Nota: Decibel

$$V_a/V_b \text{ [dB]} = 20 \log (V_a/V_b)$$

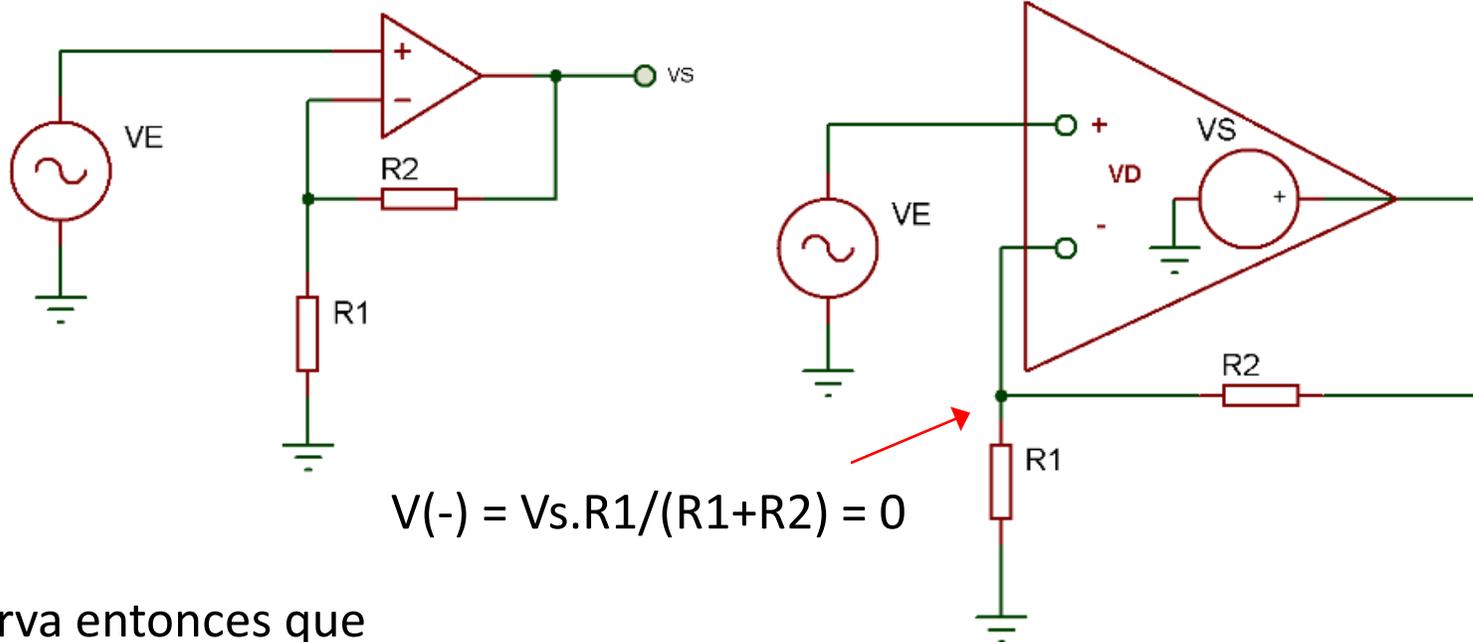
$$P_a/P_b \text{ [dB]} = 10 \log (P_a/P_b)$$

Montajes lineales: Amplificador Inversor



¿Cómo (cuánto) es la impedancia de entrada del Amplificador Inversor?

Montajes lineales: Amplificador No Inversor



$$V(-) = V_s \cdot R_1 / (R_1 + R_2) = 0$$

Se observa entonces que

$$V_e = V(-) = V_s \cdot R_1 / (R_1 + R_2)$$

Es decir, la salida es;

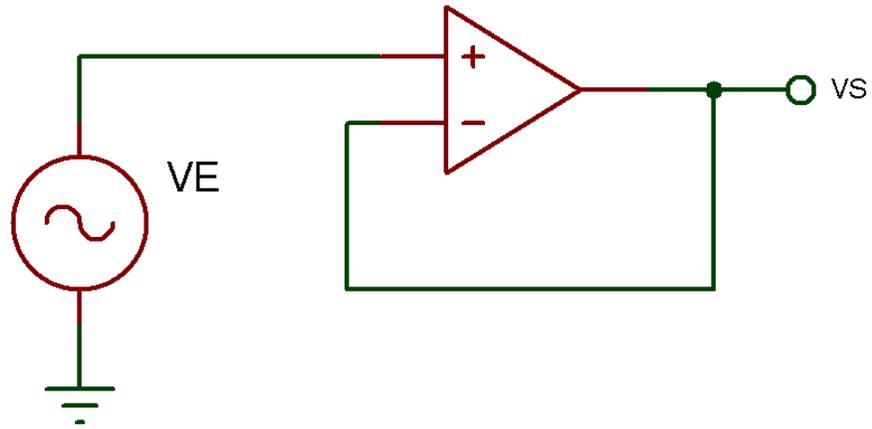
$$V_s = V_e \cdot (R_1 + R_2) / R_1 = V_e \cdot (1 + R_2 / R_1)$$

La ganancia de tensión del amplificador no inversor es

$$\mathbf{G = 1 + R_2 / R_1}$$

¿Cómo (cuánto) es la impedancia de entrada del Amplificador No Inversor?

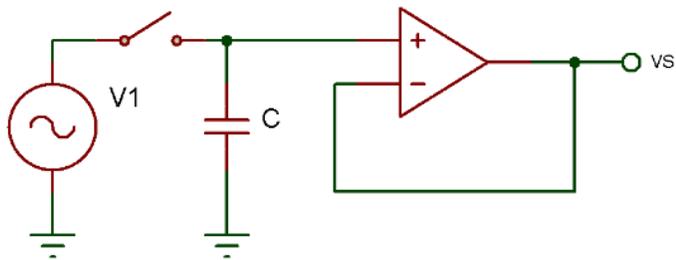
Montajes lineales: Seguidor de Tensión



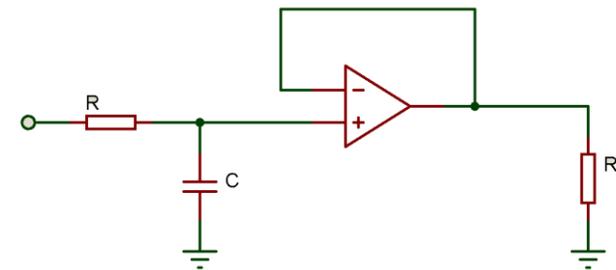
$$V_S = V_E$$

$$G = 1$$

Ejemplos de aplicación

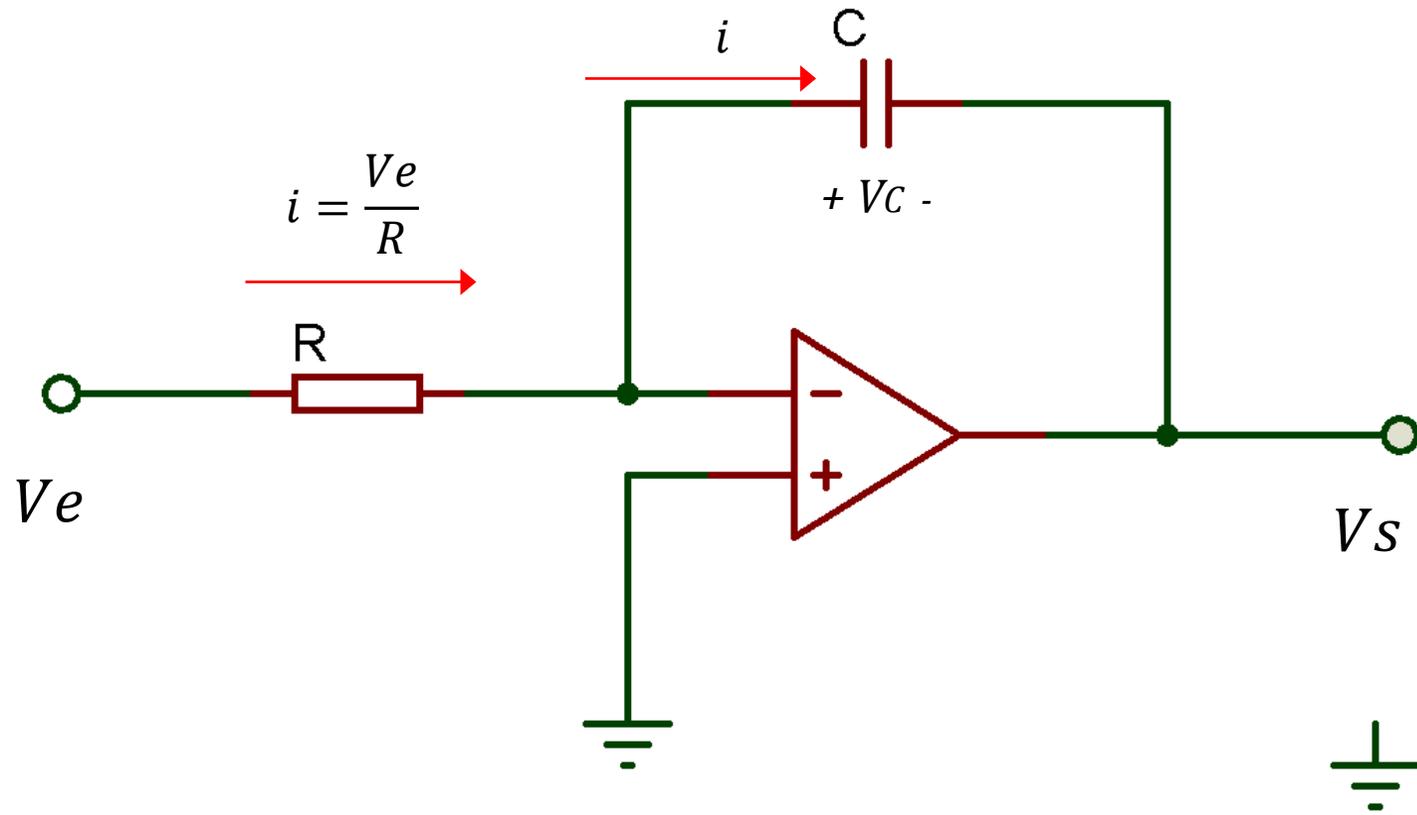


Medir Voltaje de C Cdescargarlo



Separar la carga RL de la etapa de filtrado

Montajes lineales: Integrador



$$V_C = \frac{Q}{C}$$

$$\frac{dV}{dt} = \frac{1}{C} \frac{dQ}{dt} = \frac{1}{C} i$$

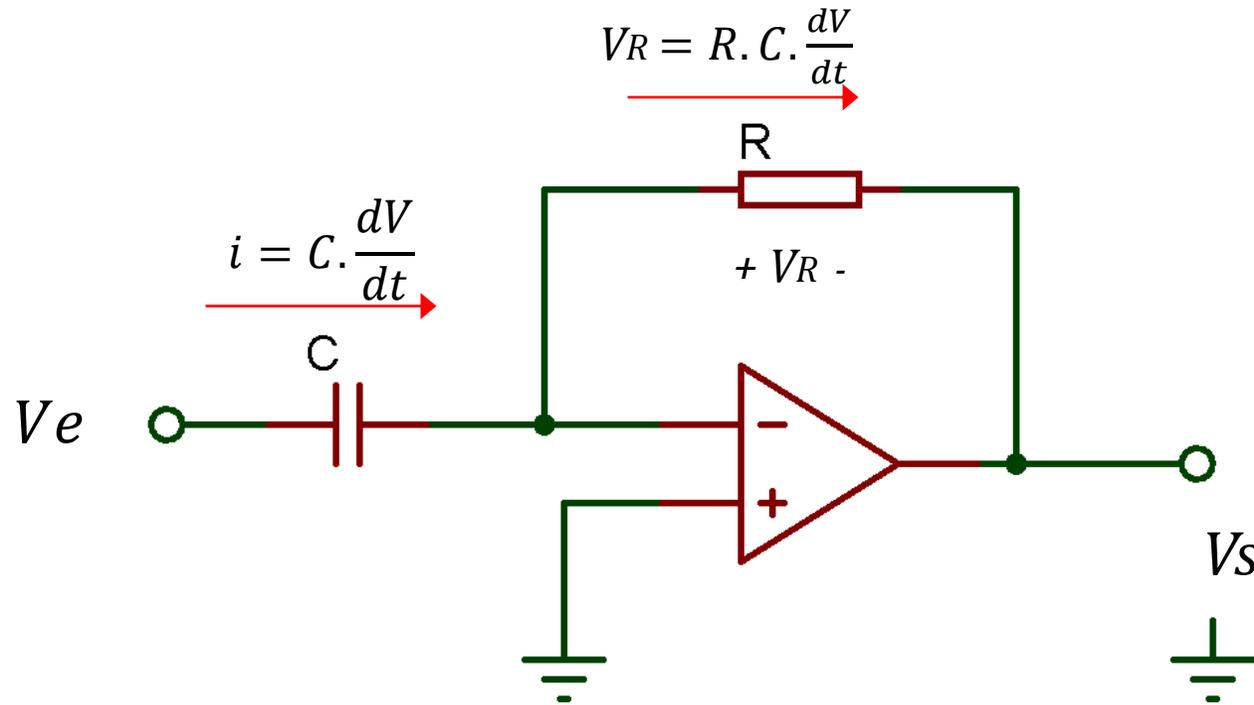
$$V_C = \frac{1}{C} \int i dt =$$

$$i = \frac{V_e}{R}$$

$$V_S = 0 - V_C$$

$$V_S = -\frac{1}{R \cdot C} \int V_e dt$$

Montajes lineales: Derivador o diferenciador



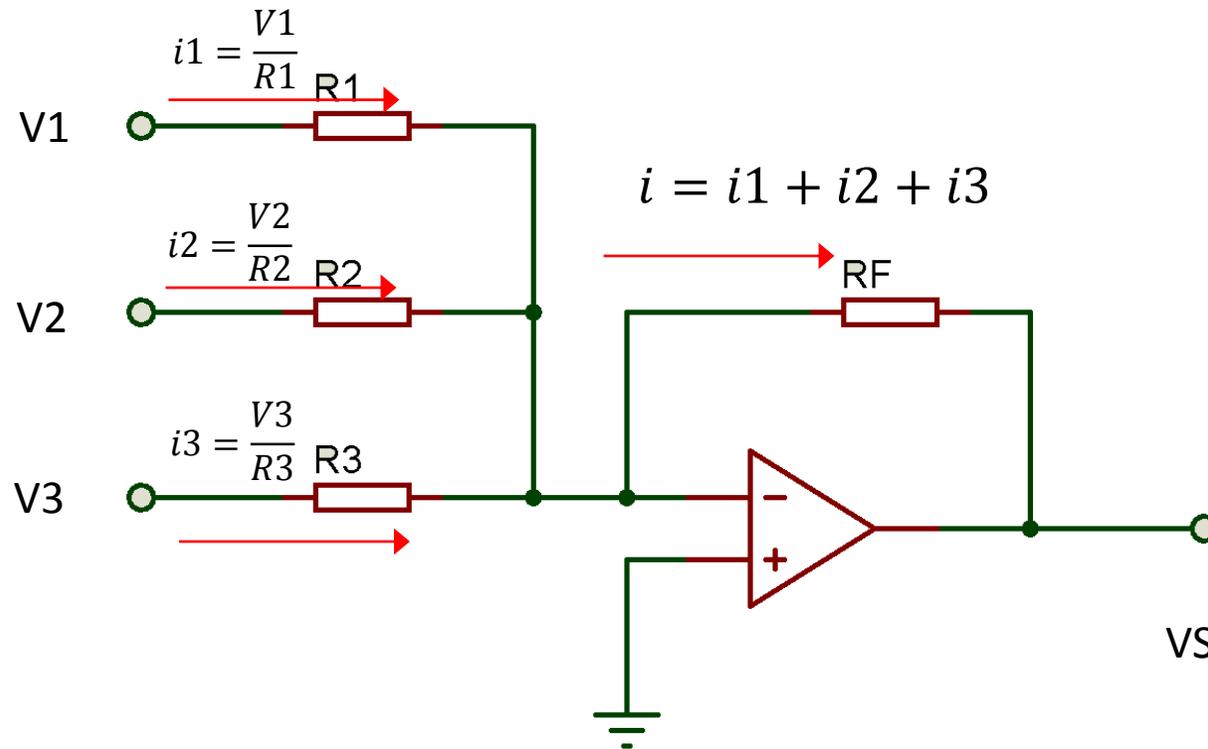
$$V_C = \frac{Q}{C}$$

$$\frac{dV}{dt} = \frac{1}{C} \frac{dQ}{dt} = \frac{1}{C} i \rightarrow i = C \cdot \frac{dV}{dt}$$

$$V_S = 0 - V_R = 0 - i \cdot R$$

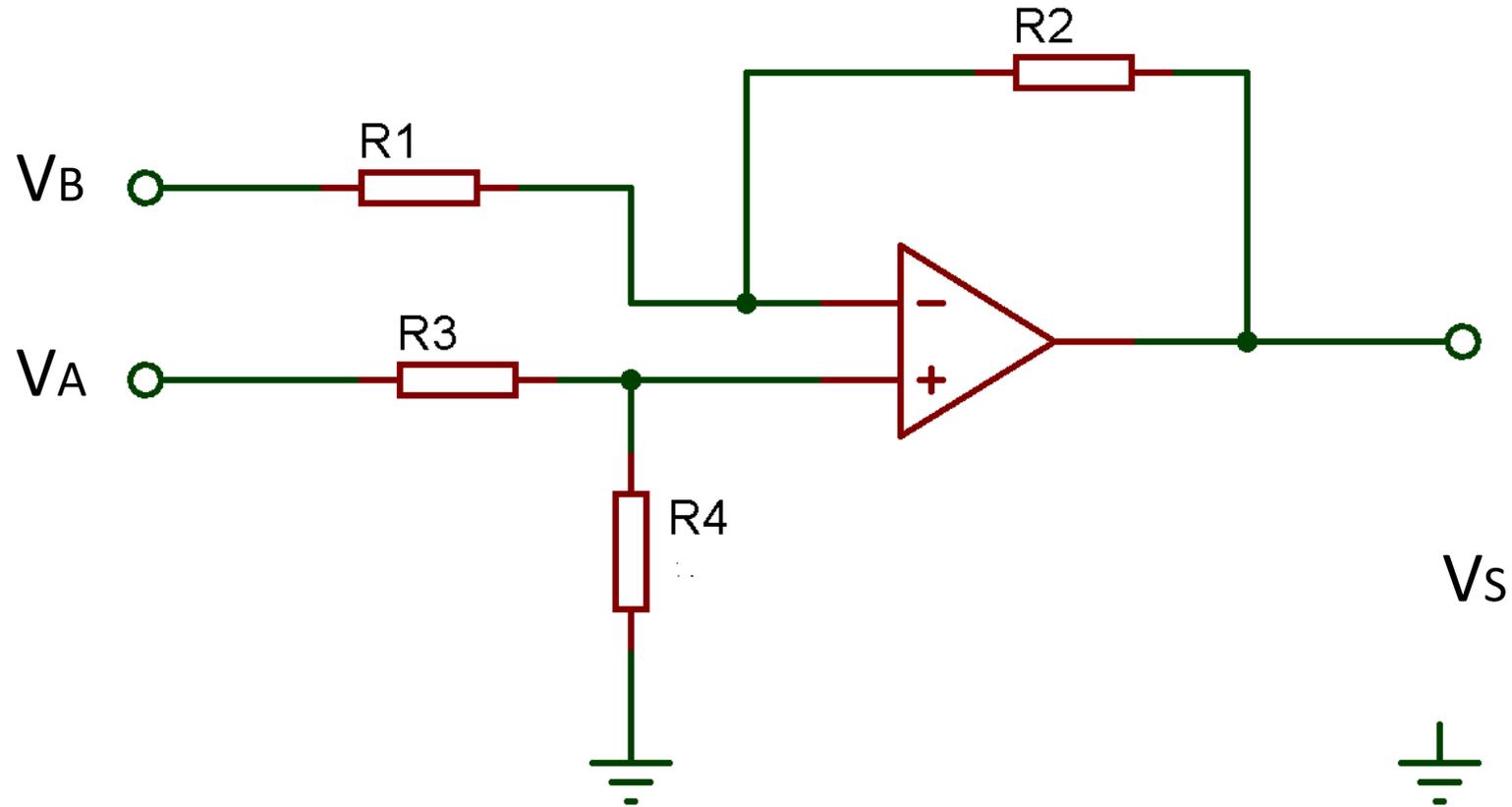
$$V_S = -R \cdot C \cdot \frac{dV}{dt}$$

Montajes lineales: Sumador



$$V_S = - \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right) \cdot R_F$$

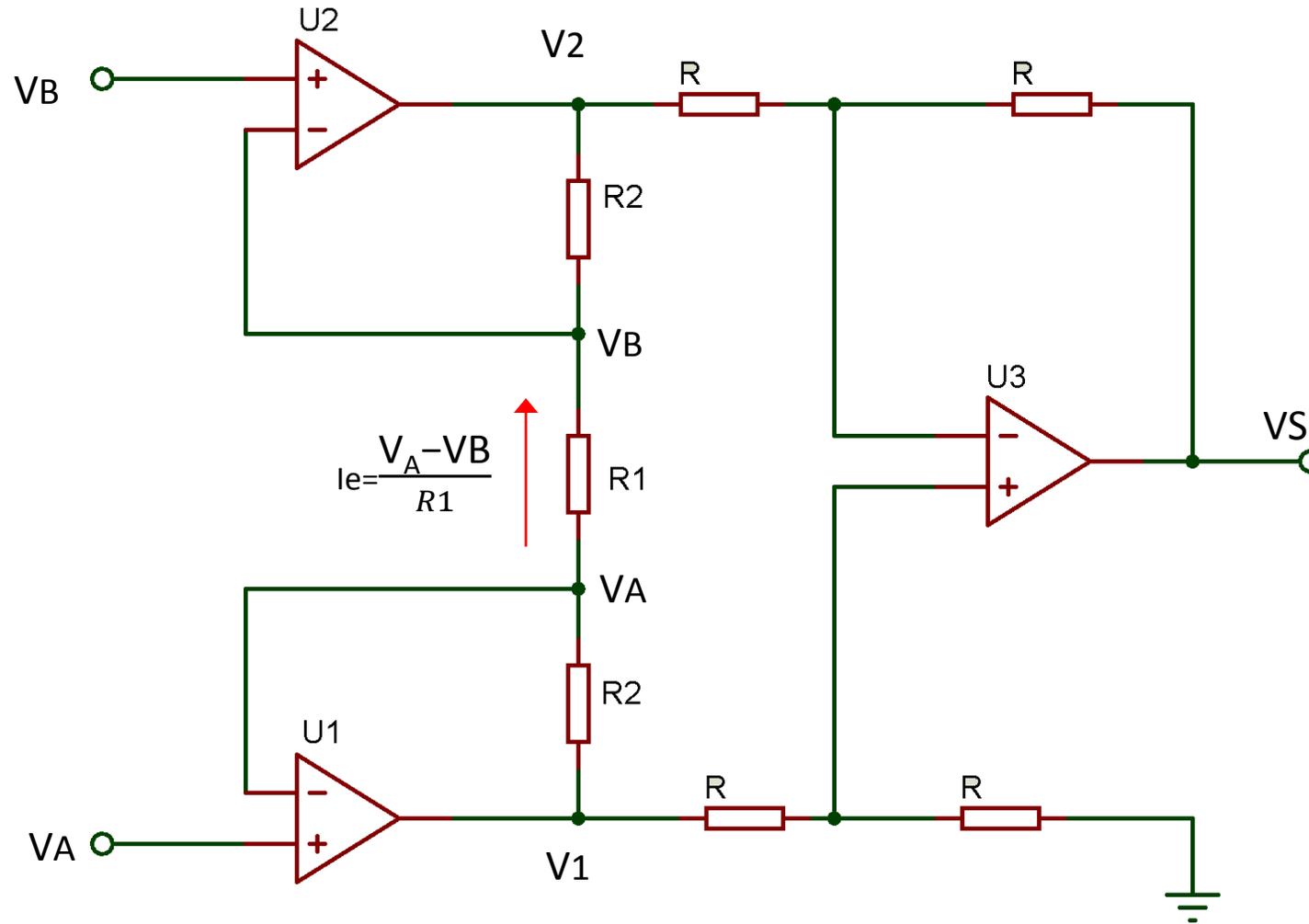
Montajes lineales: Amplificador Diferencial (Restador)



Si $R_3 = R_1$ y $R_4 = R_2 \rightarrow$

$$V_s = \left(\frac{R_2}{R_1} \right) \cdot (V_A - V_B)$$

Montajes lineales: Amplificador de Instrumentación



$$V1 - V2 = I_e \cdot (R2 + R1 + R2) \\ = I_e \cdot (R1 + 2 \cdot R2)$$

$$V_S = G \cdot (V1 - V2),$$

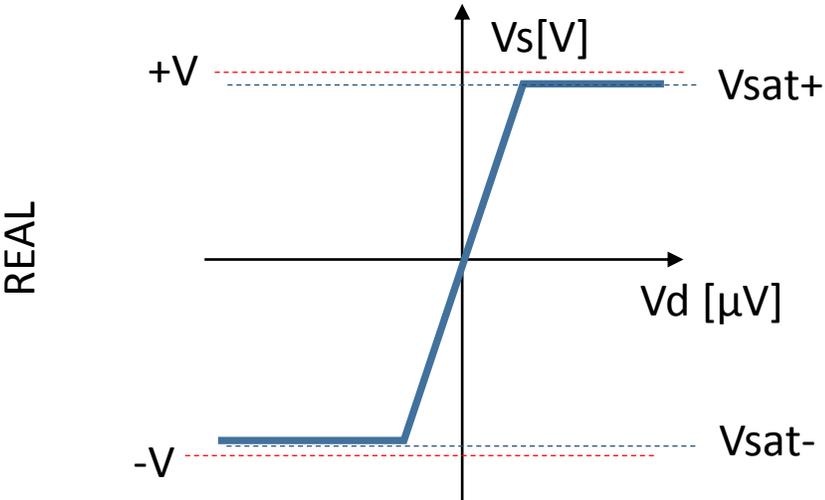
con $G = 1$ es $V_S = (V1 - V2)$

$$V_S = \left(\frac{V_A - V_B}{R1} \right) \cdot (R1 + 2 \cdot R2)$$

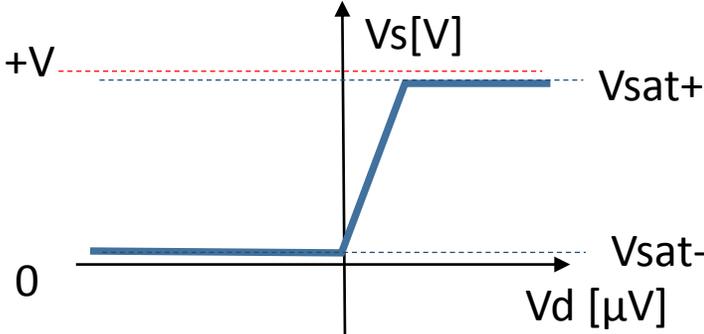
$$V_S = (V_A - V_B) \cdot \left(1 + 2 \cdot \frac{R2}{R1} \right)$$

Amp Operacional a lazo abierto: Función de Transferencia (V_s vs V_d)

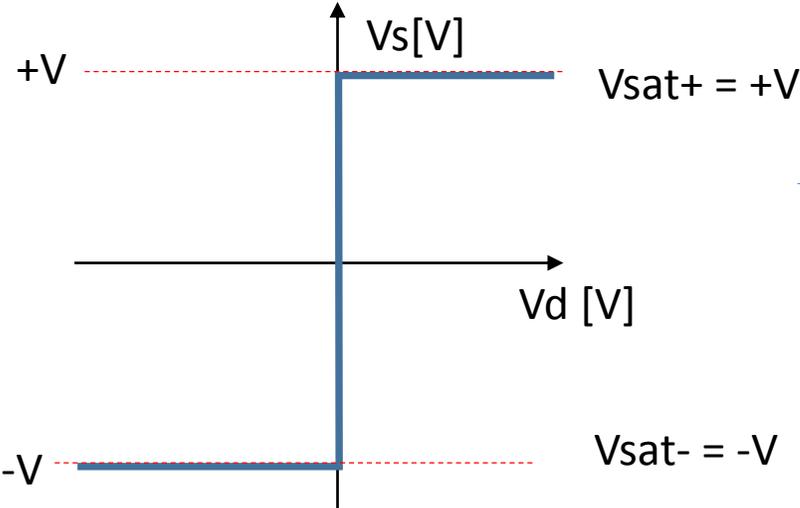
Con $+V$ y $-V$



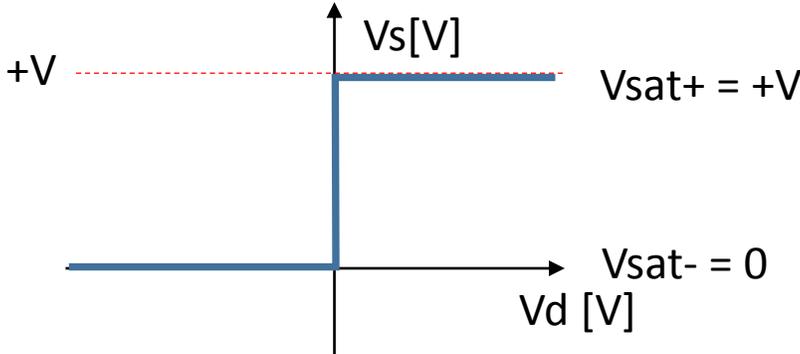
Con $+V$ y 0



APROXIMADO

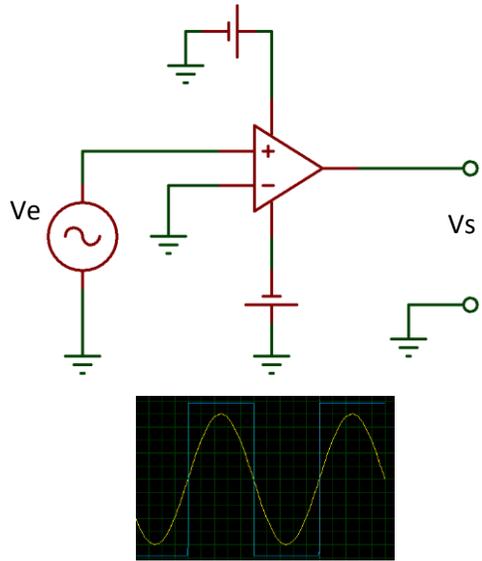


V_d	V_s
< 0	$-V$
> 0	$+V$

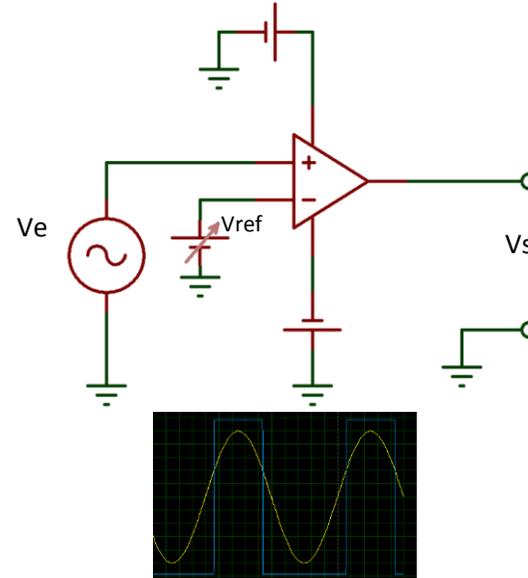
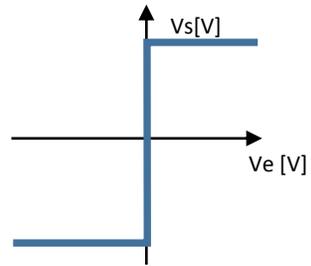


V_d	V_s
< 0	0
> 0	$+V$

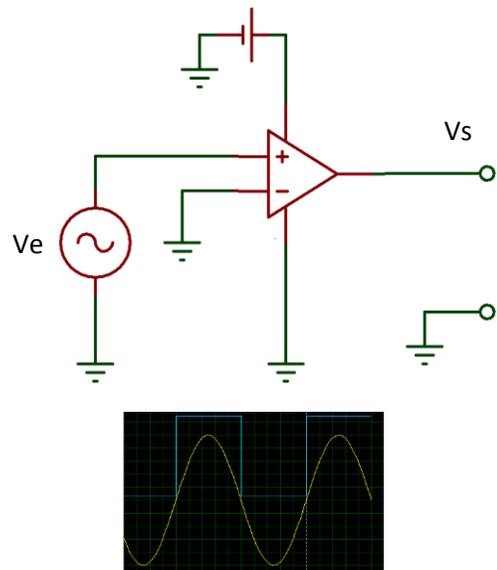
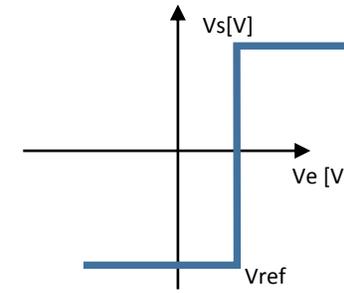
Comparador No inversor sin Histéresis (lazo abierto)



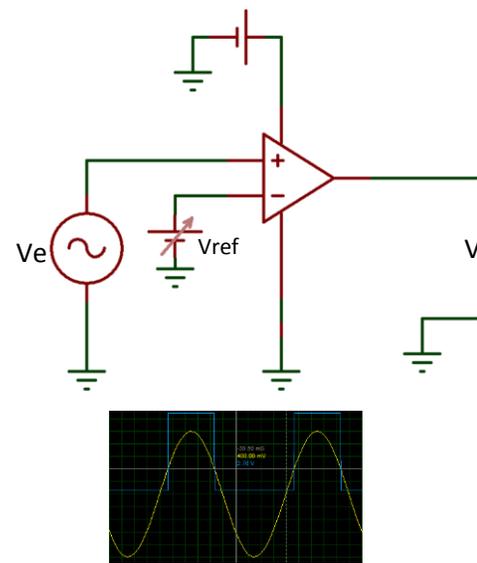
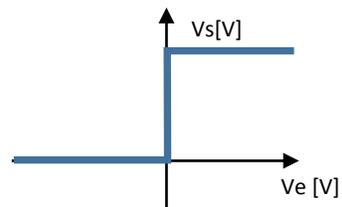
Ve	Vs
<0	-V
>0	+V



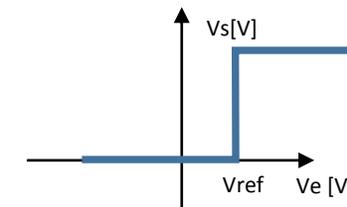
Ve	Vs
<Vref	-V
>Vref	+V



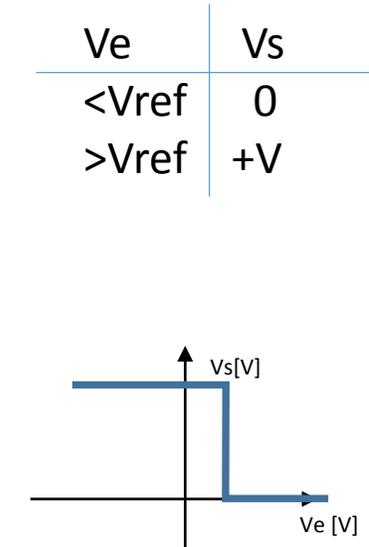
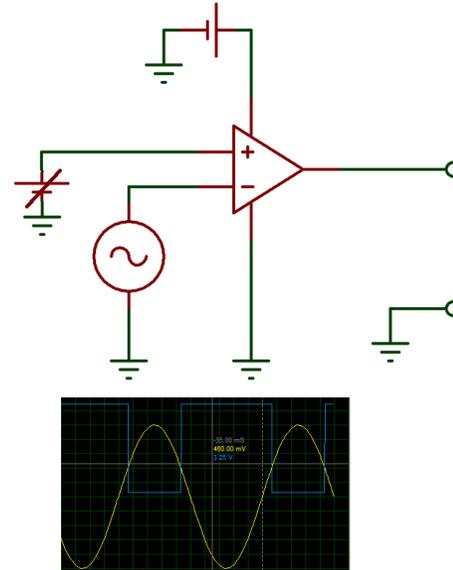
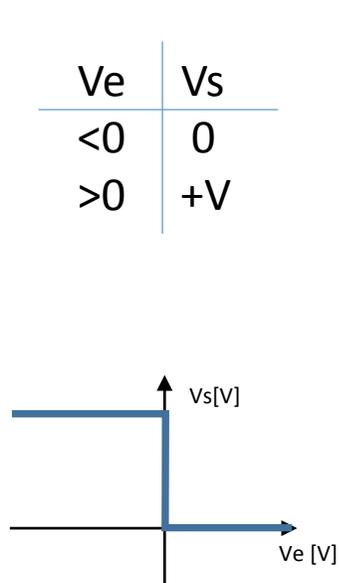
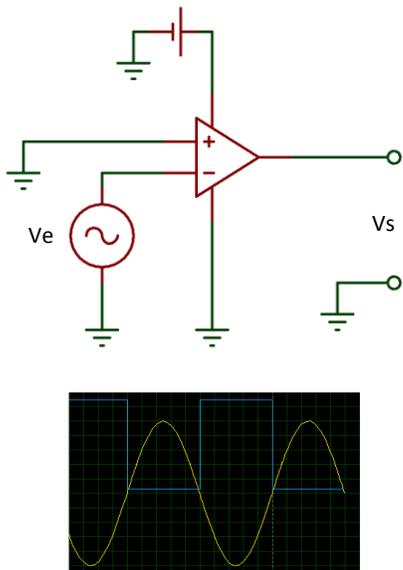
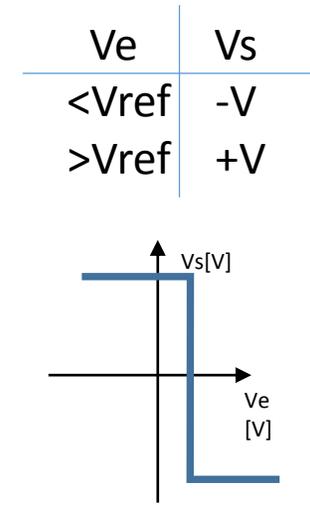
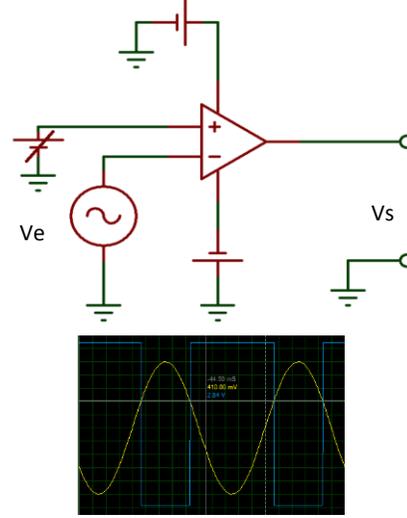
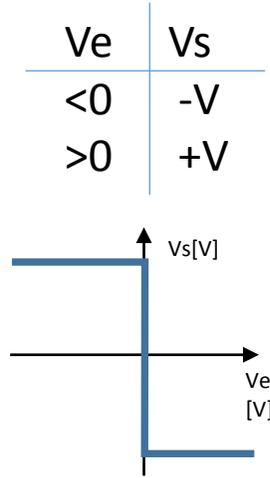
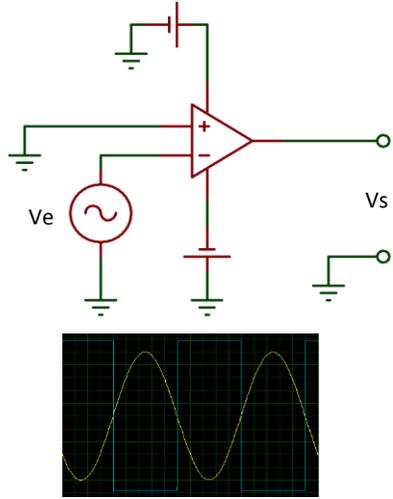
Ve	Vs
<0	0
>0	+V



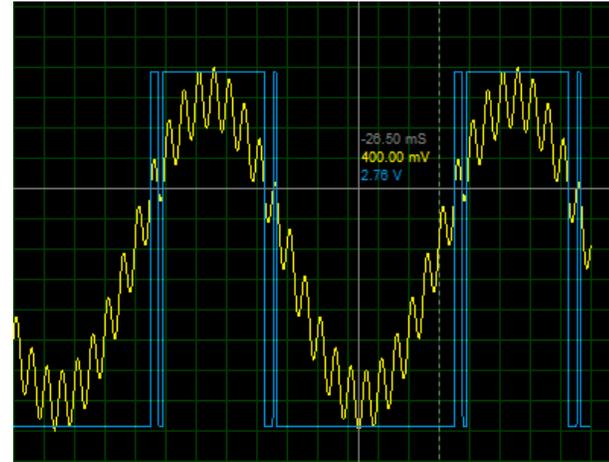
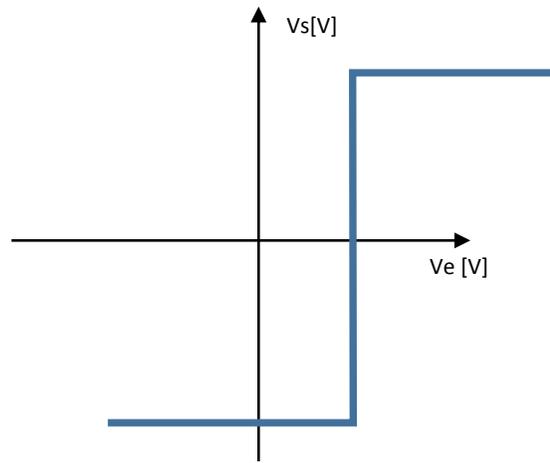
Ve	Vs
<Vref	0
>Vref	+V



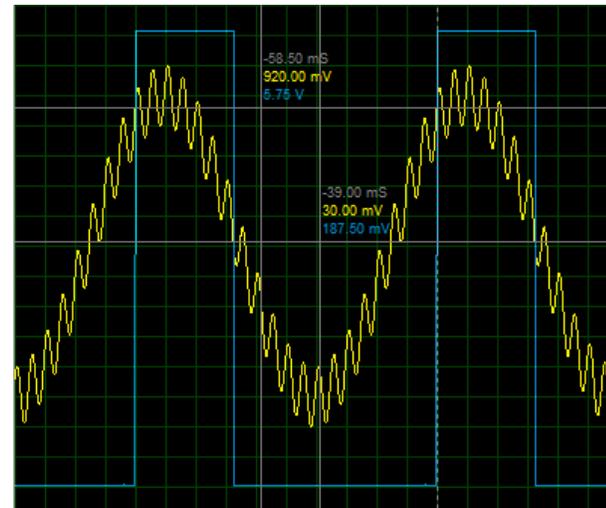
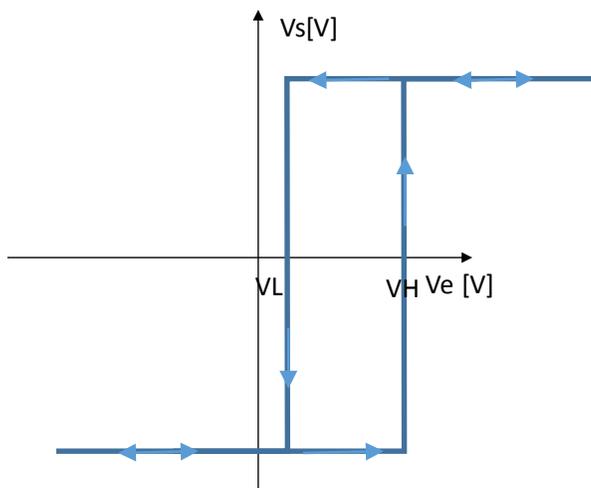
Comparador inversor sin Histéresis (lazo abierto)



Histéresis

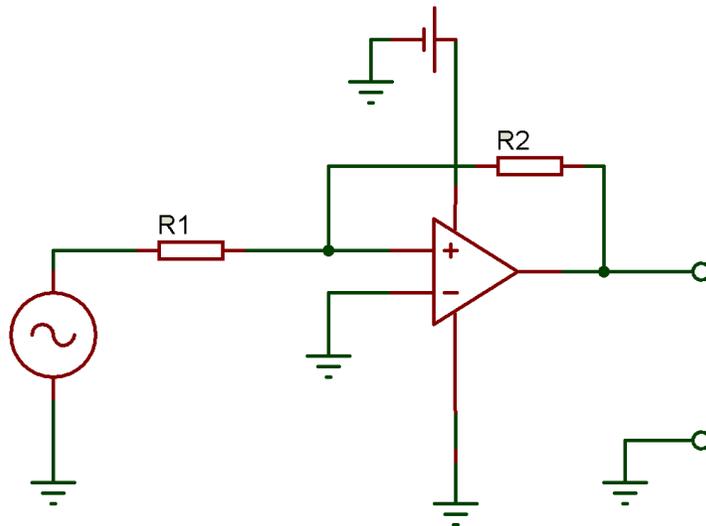
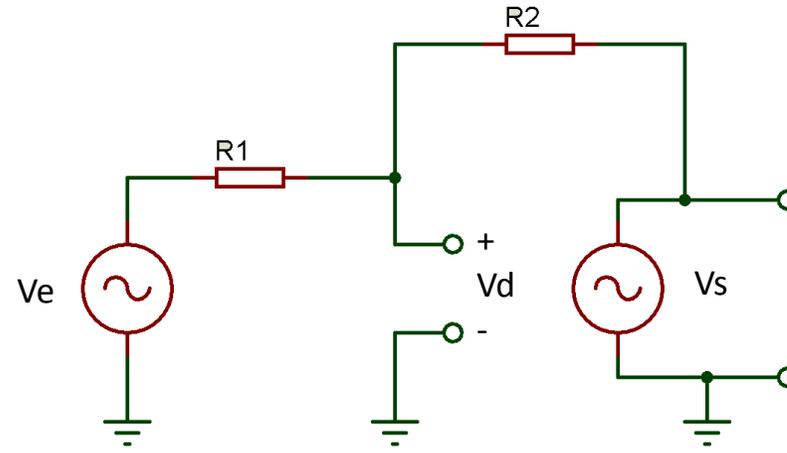
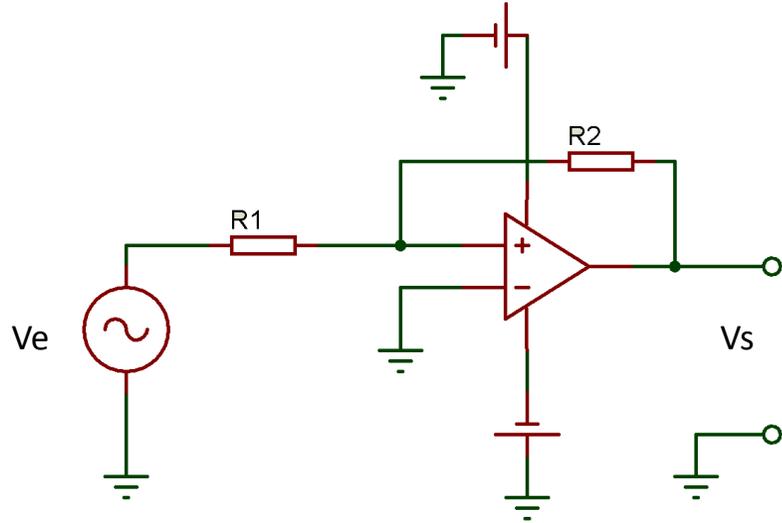


sin histéresis se producen múltiples conmutaciones por ruido



Con la histéresis adecuada se eliminan las múltiples conmutaciones

Comparador No inversor con Histéresis (realimentación positiva)



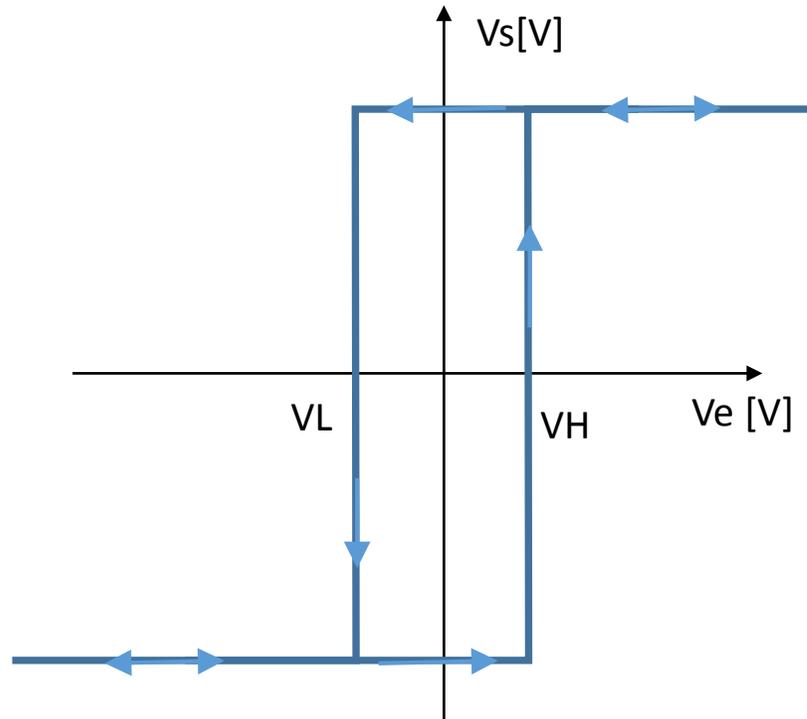
$$V_d = V_e \cdot \left(\frac{R_2}{R_1 + R_2} \right) + V_s \cdot \left(\frac{R_1}{R_1 + R_2} \right)$$

La conmutación ocurre en $V_d = 0$. Despejando

$$V_e = - V_s \cdot \left(\frac{R_1}{R_2} \right)$$

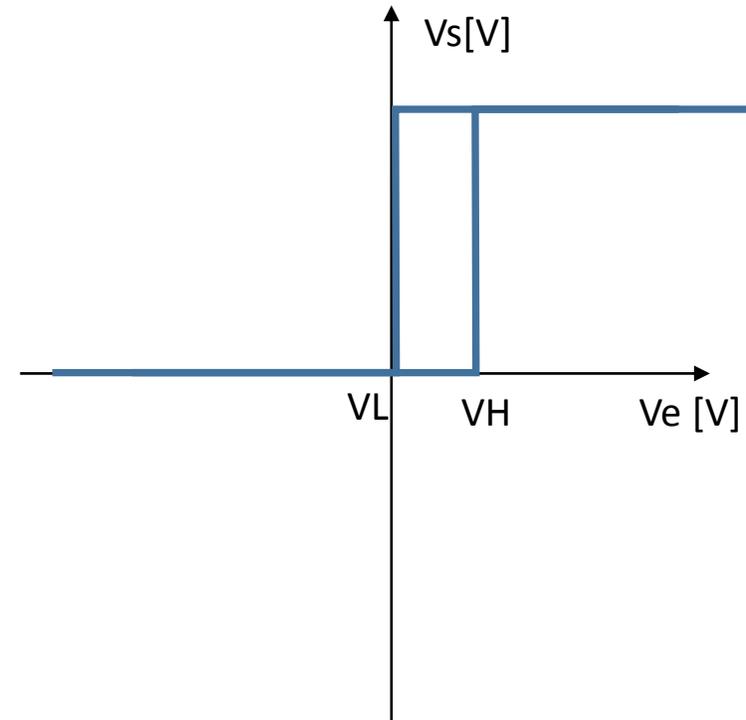
Comparador No inversor con Histéresis (lazo abierto)

Con fuente doble



$$V_H = V \cdot \left(\frac{R_1}{R_2} \right) \quad V_L = -V \cdot \left(\frac{R_1}{R_2} \right)$$

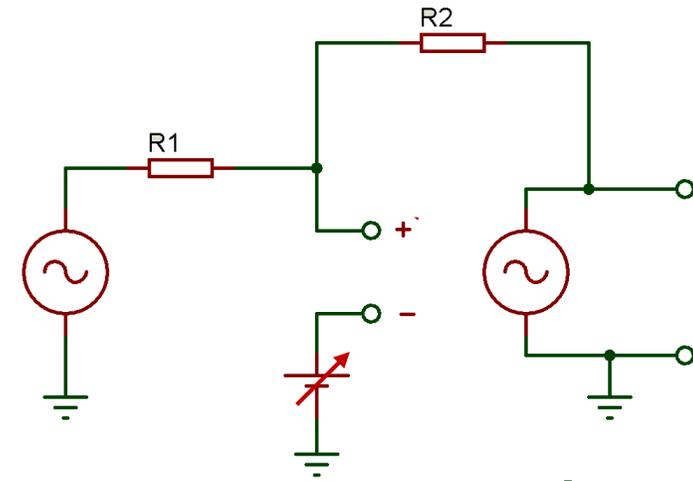
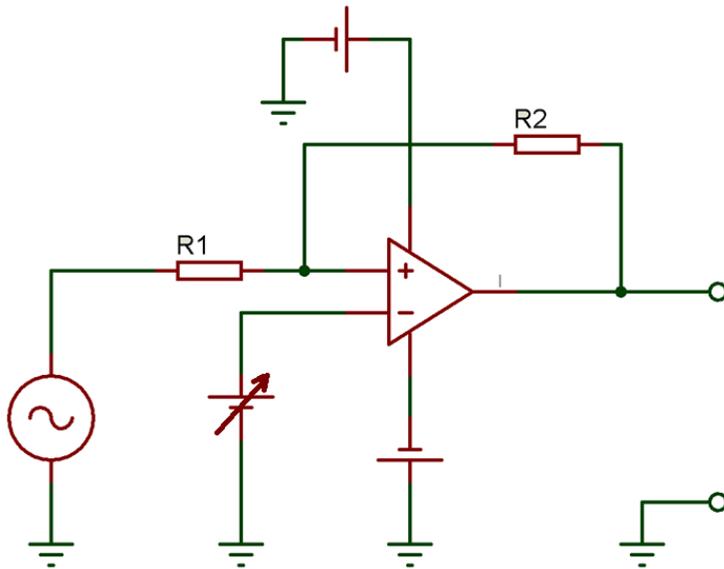
Con fuente única



$$V_H = V \cdot \left(\frac{R_1}{R_2} \right) \quad V_L = 0$$

Comparador No inversor con Histéresis (realimentación positiva)

Idem anterior, pero con Vref en la entrada inversora



$$V_d = V_e \cdot \left(\frac{R_2}{R_1 + R_2} \right) + V_s \cdot \left(\frac{R_1}{R_1 + R_2} \right) - V_{ref}$$

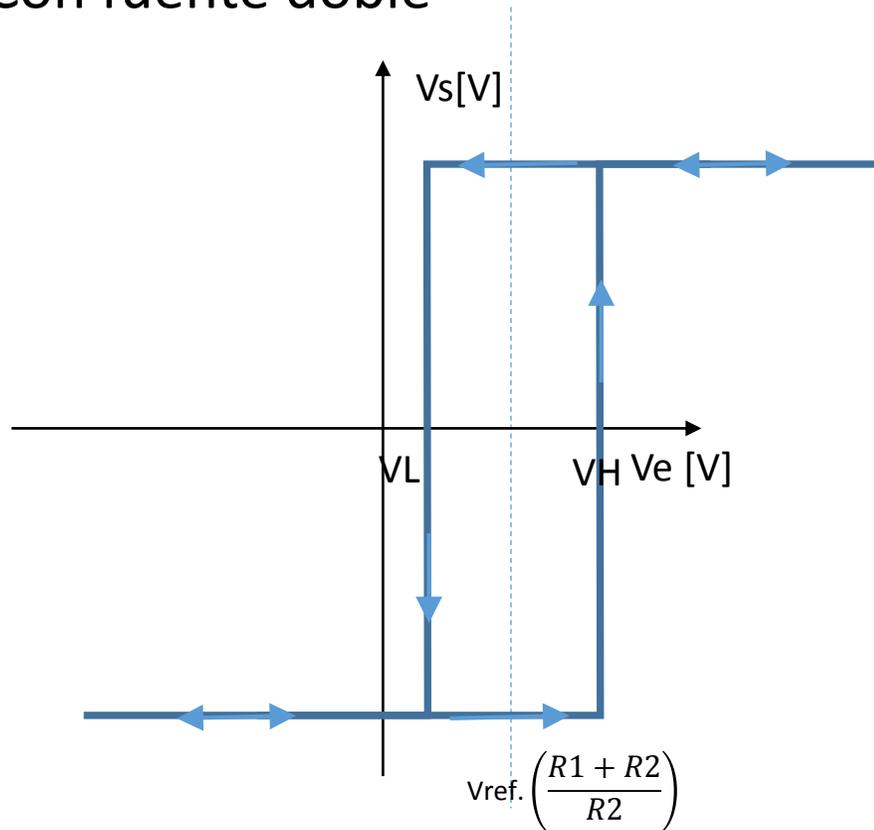
La conmutación ocurre en $V_d = 0$. Despejando

$$V_e = -V_s \cdot \left(\frac{R_1}{R_2} \right) + V_{ref} \cdot \left(\frac{R_1 + R_2}{R_2} \right)$$

La conmutación ocurre en $V_d = 0$. Despejando

Comparador No inversor con Histéresis (realimentación positiva)

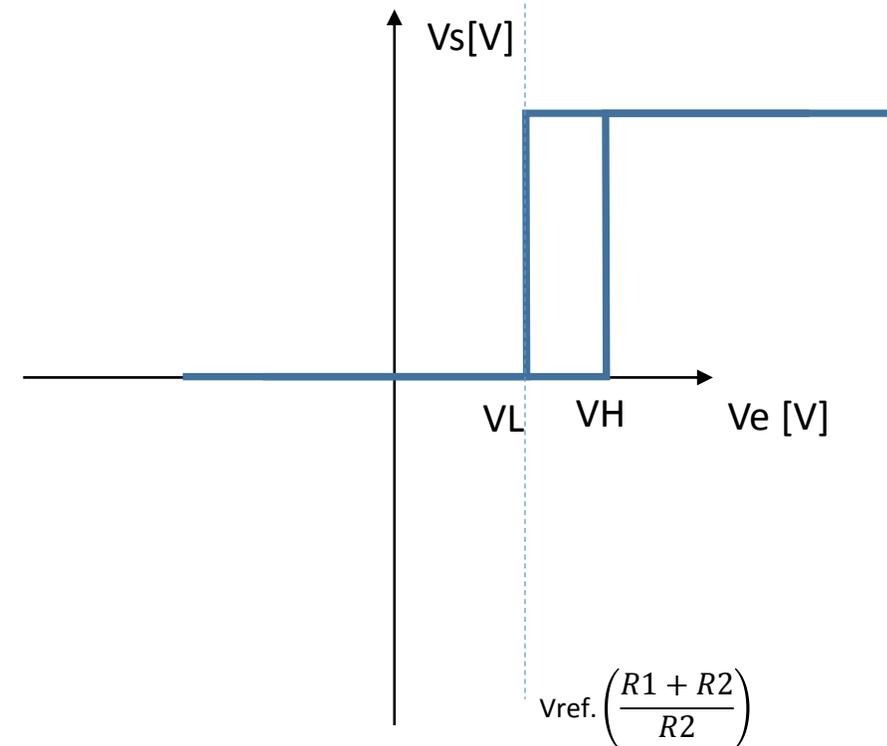
Con fuente doble



$$V_H = v. \left(\frac{R_1}{R_2} \right) + V_{ref.} \left(\frac{R_1 + R_2}{R_2} \right)$$

$$V_L = -v. \left(\frac{R_1}{R_2} \right) + V_{ref.} \left(\frac{R_1 + R_2}{R_2} \right)$$

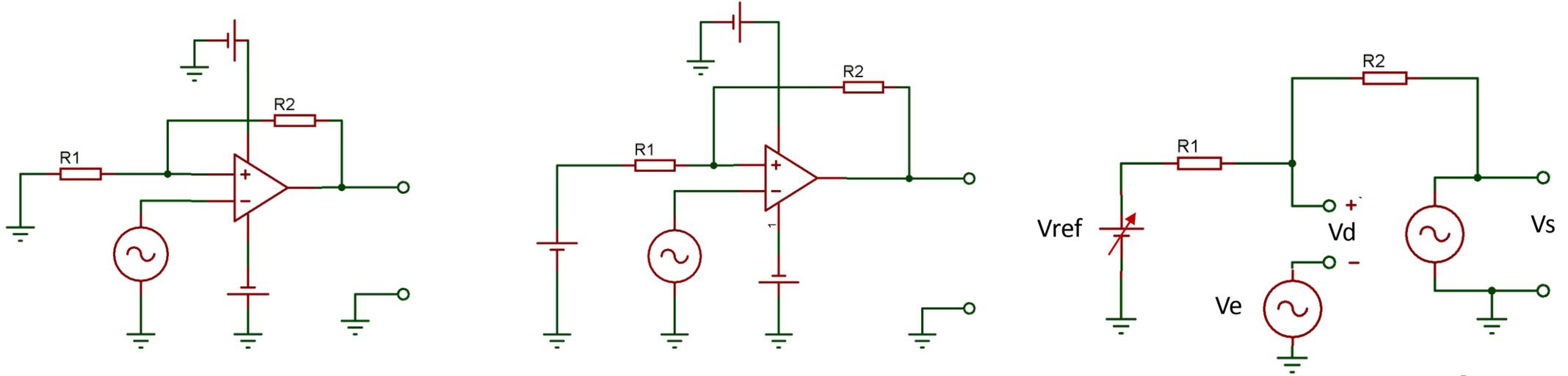
Con fuente única



$$V_H = v. \left(\frac{R_1}{R_2} \right) + V_{ref.} \left(\frac{R_1 + R_2}{R_2} \right)$$

$$V_L = V_{ref.} \left(\frac{R_1 + R_2}{R_2} \right)$$

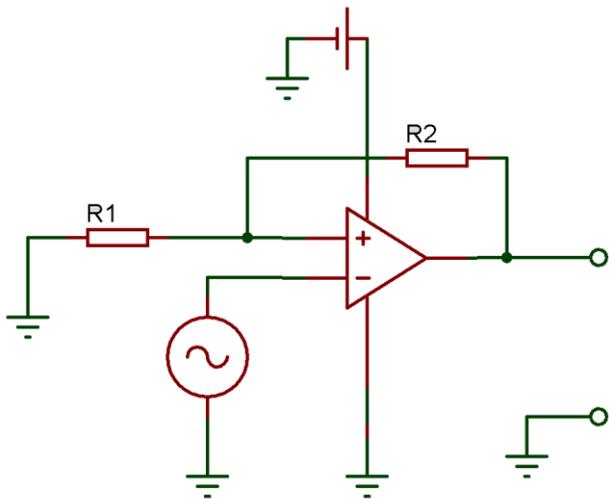
Comparador Inversor con Histéresis (realimentación positiva)



$$V_d = V_{ref} \cdot \left(\frac{R_2}{R_1 + R_2} \right) + V_s \cdot \left(\frac{R_1}{R_1 + R_2} \right) - V_e.$$

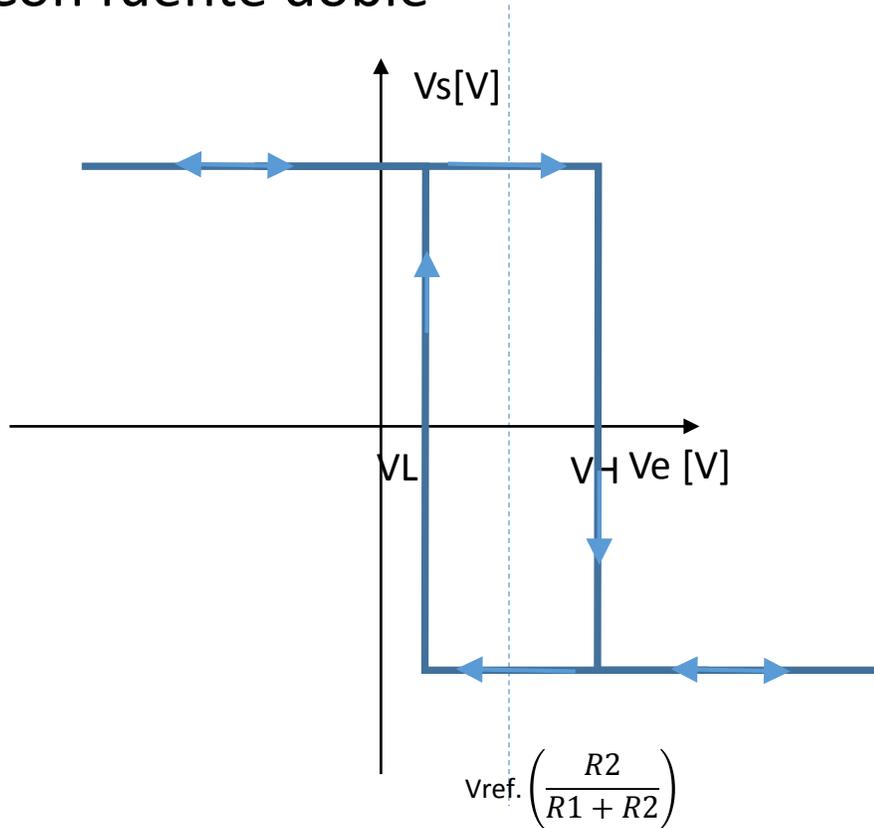
La conmutación ocurre en $V_d = 0$. Despejando

$$V_e = -V_s \cdot \left(\frac{R_1}{R_1 + R_2} \right) + V_{ref} \cdot \left(\frac{R_2}{R_1 + R_2} \right)$$



Comparador Inversor con Histéresis (realimentación positiva)

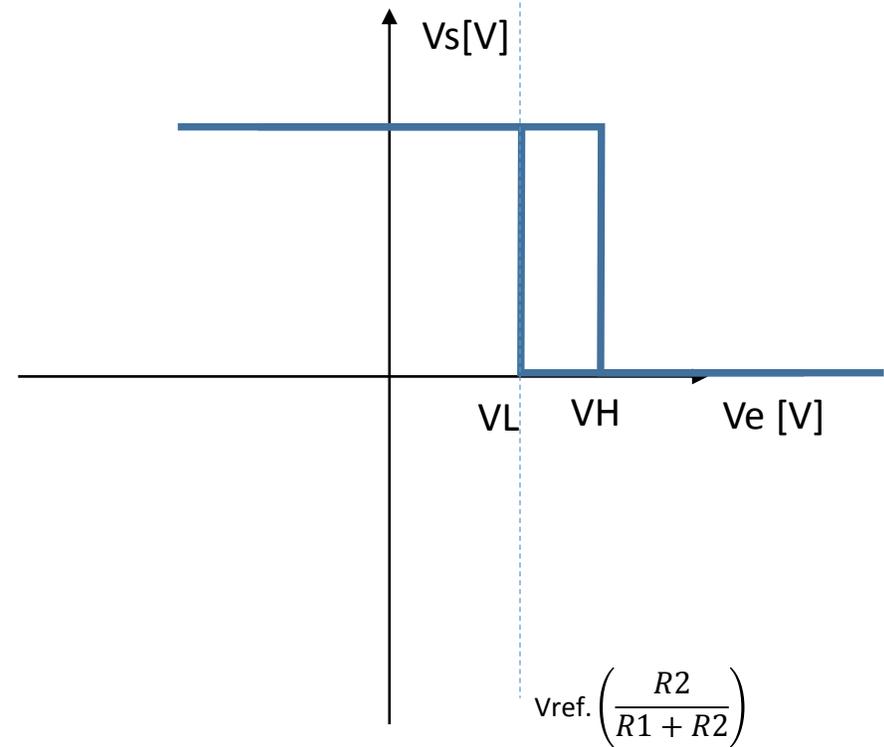
Con fuente doble



$$V_H = v. \left(\frac{R_1}{R_1 + R_2} \right) + V_{ref}. \left(\frac{R_2}{R_1 + R_2} \right)$$

$$V_L = -v. \left(\frac{R_1}{R_1 + R_2} \right) + V_{ref}. \left(\frac{R_2}{R_1 + R_2} \right)$$

Con fuente única



$$V_H = v. \left(\frac{R_1}{R_1 + R_2} \right) + V_{ref}. \left(\frac{R_2}{R_1 + R_2} \right)$$

$$V_L = V_{ref}. \left(\frac{R_2}{R_1 + R_2} \right)$$