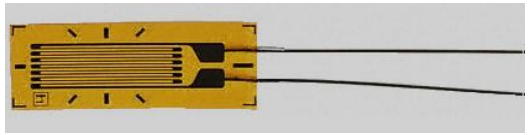
UNIDAD 5: ACONDICIONAMIENTO DE SEÑALES

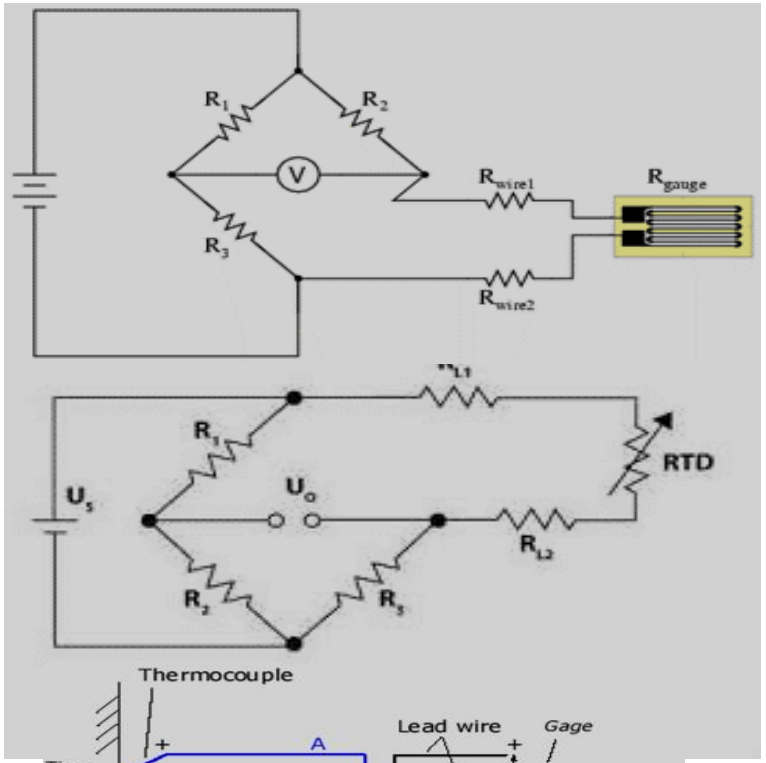
- Introducción: Acondicionamiento de señales
  - Transductor y sensor. Características de las señales
  - Circuitos que no sirven para señales de sensores típicos
- Amplificador Operacional (AO)
  - Simbología y terminales
  - AOs comerciales. Encapsulados y circuitos internos
  - Etapas de un AO
  - 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 → Sensor

Fuerza-presión

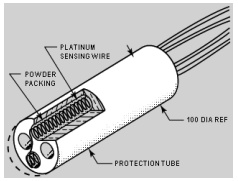


Strain gauge (120 ohm, 350 ohm)



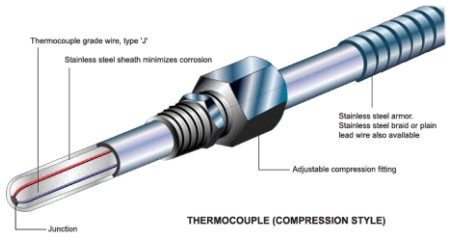


Temperatura



RTD (PT100)



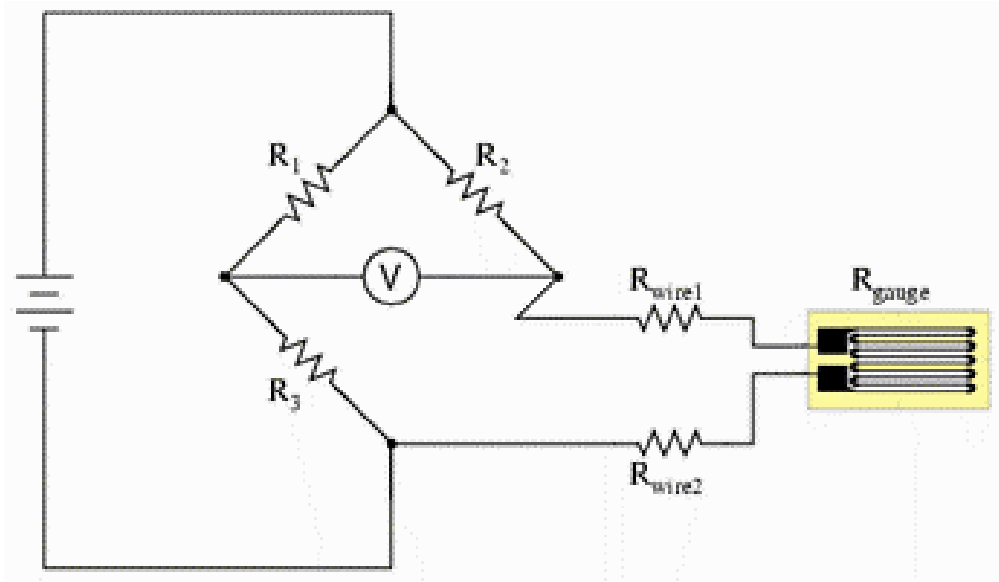


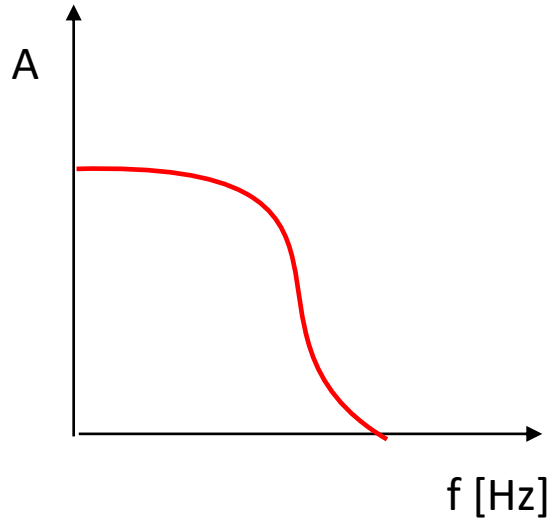
Termocupla

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		

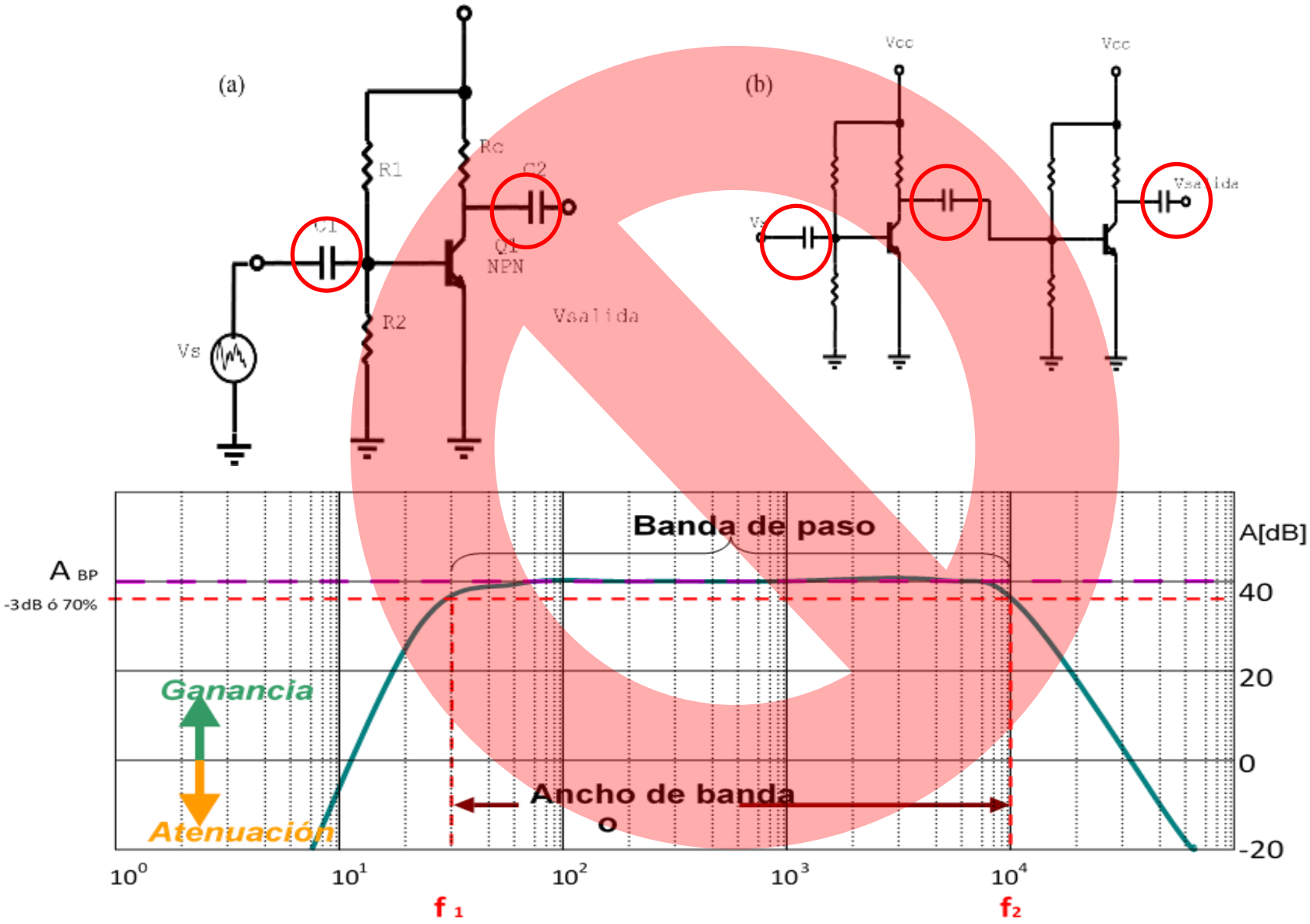
Características de las señales de sensores



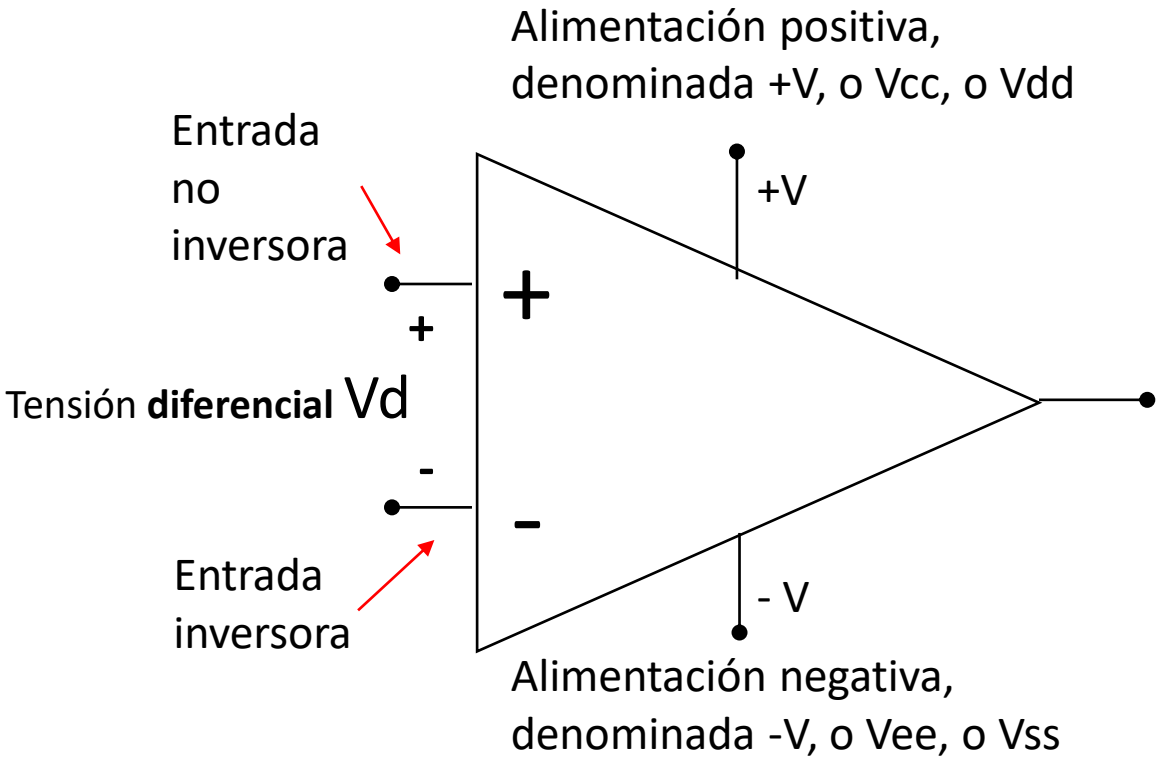


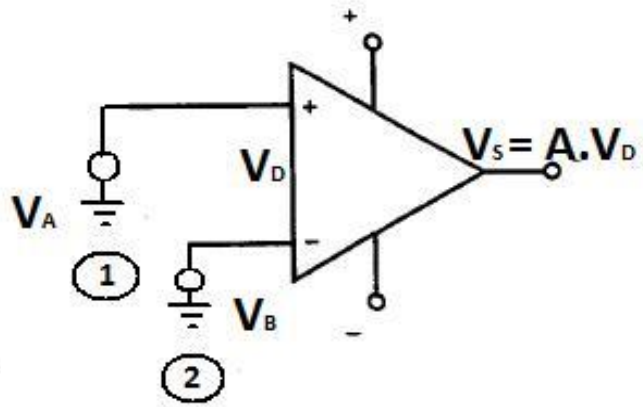
- Muchas variables físicas (P, T) son lentas → Las señales son **lentas**
- Muchos transductores entregan señal diferencial (ej Termocuplas) o se colocan en un circuito Puente que entrega **señal diferencial**.

Etapas de amplificación acopladas en CA no sirven para sensores lentos



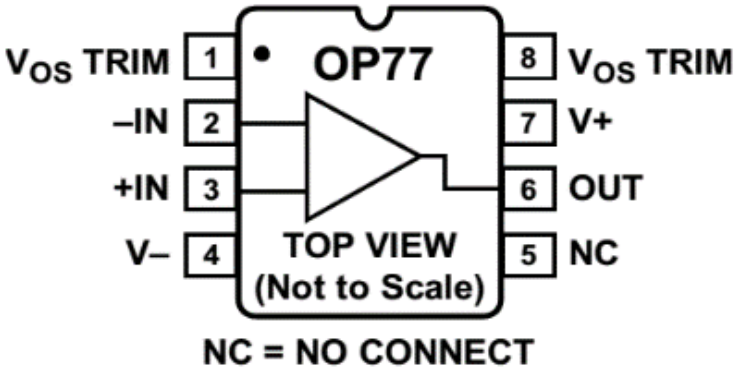
Amplificador Operacional (AO) (o *OPA, operational amplifier*)





$Vs = A.Vd$ con $Vd = V(+) - V(-)$

AO comerciales – encapsulados (algunos)



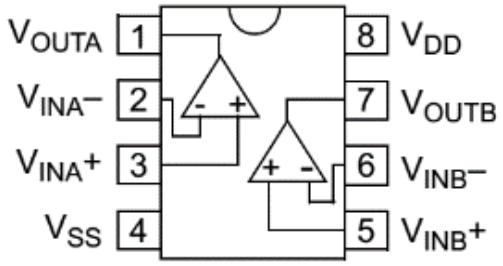


DIP



TO-99

MCP6002





DIP

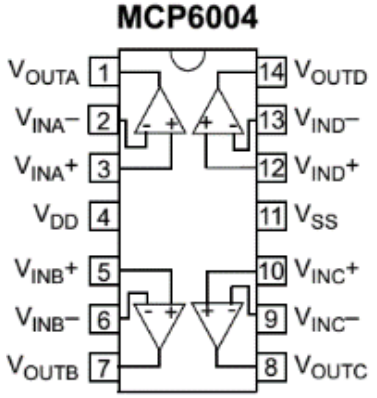


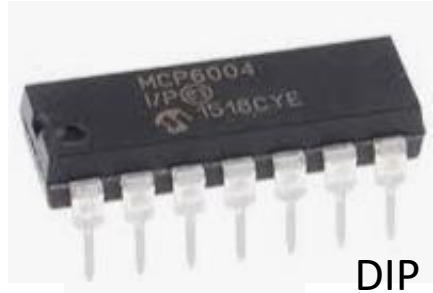
SOIC



MSOP

MCP6004





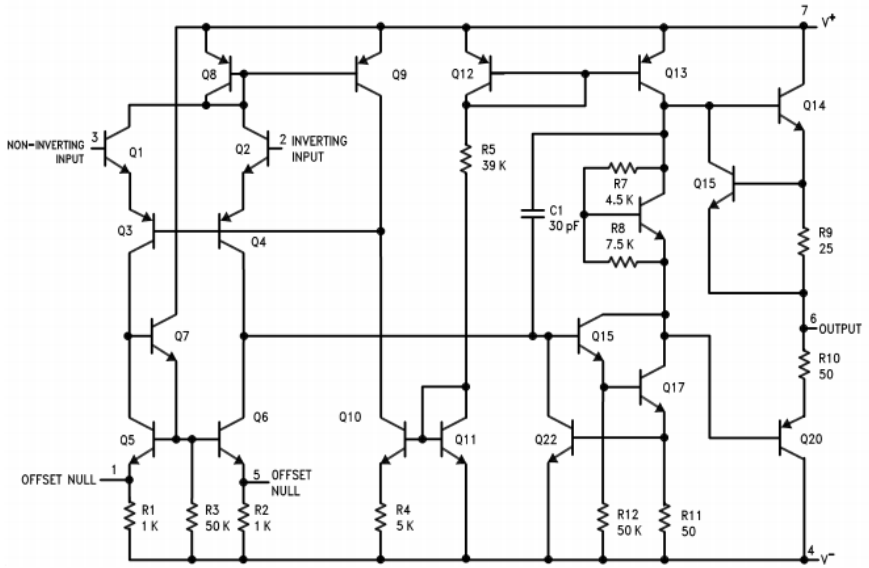
DIP



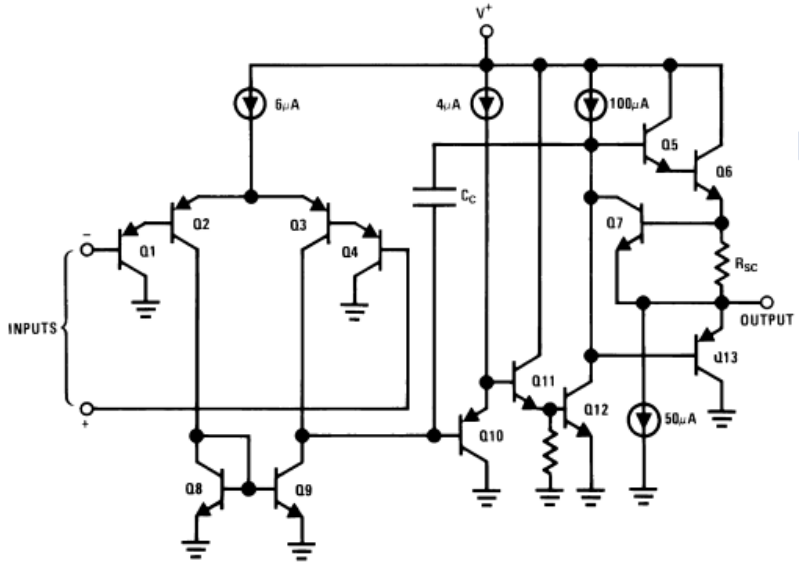
SOIC

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

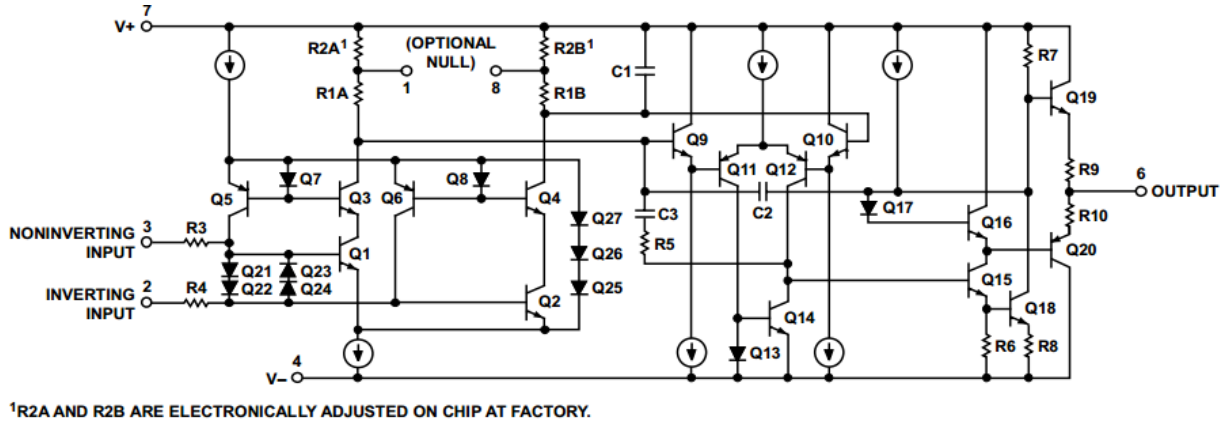
AO comerciales – circuitos internos



LM741



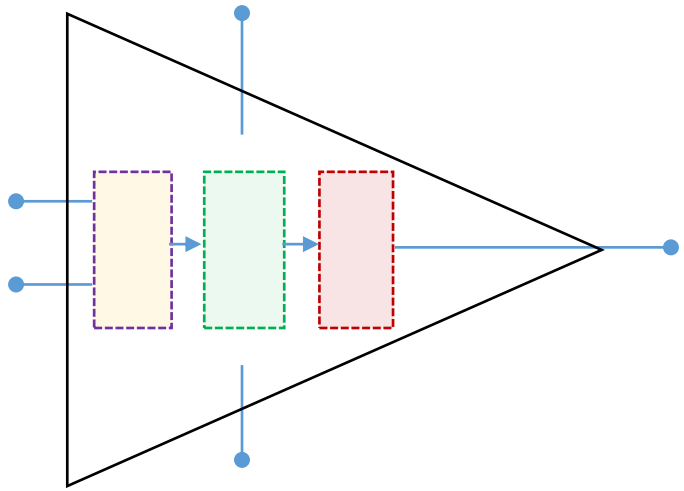
LM124 (1/4)



OP77

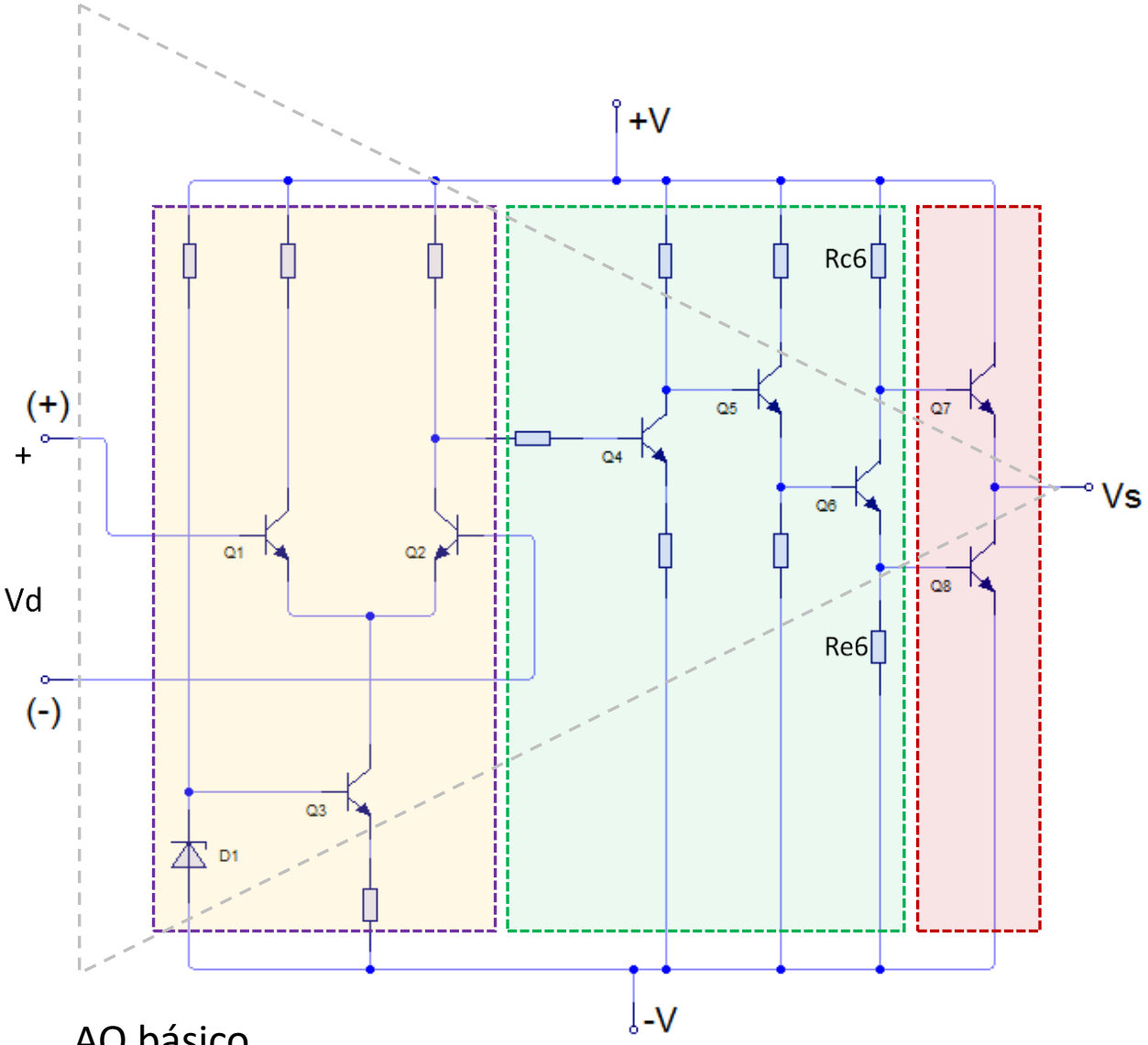
[1]R2A AND R2B ARE ELECTRONICALLY ADJUSTED ON CHIP AT FACTORY.

Etapas de un AO

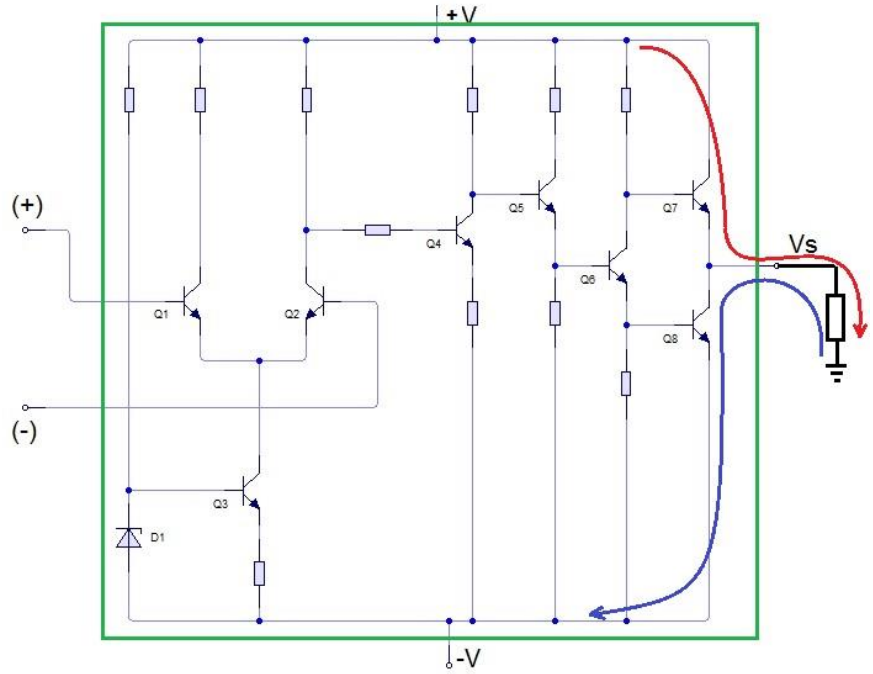


- **Etapa de entrada** conformada por un amplificador diferencial y una fuente de corriente, que presenta elevada impedancia de entrada y rechazo de las señales de modo común.
- **Etapa intermedia** que brinda una elevada ganancia de tensión.
- **Etapa de salida** de tipo complementaria *clase AB* que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

Etapas de un AO

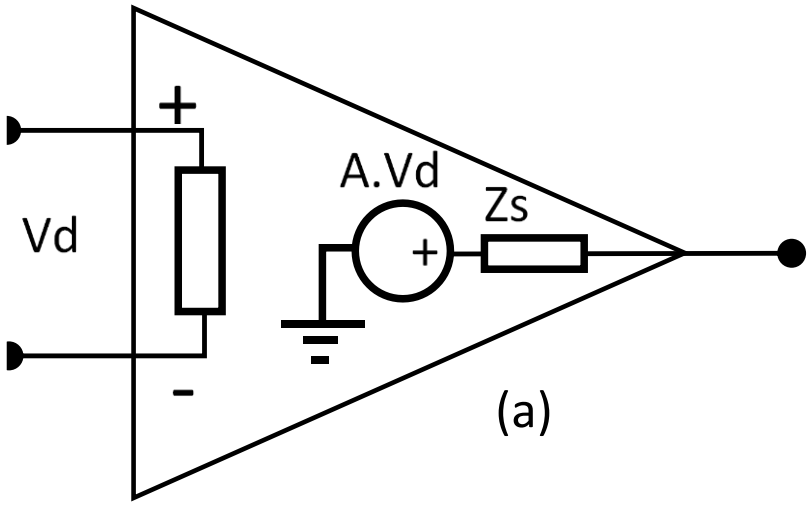


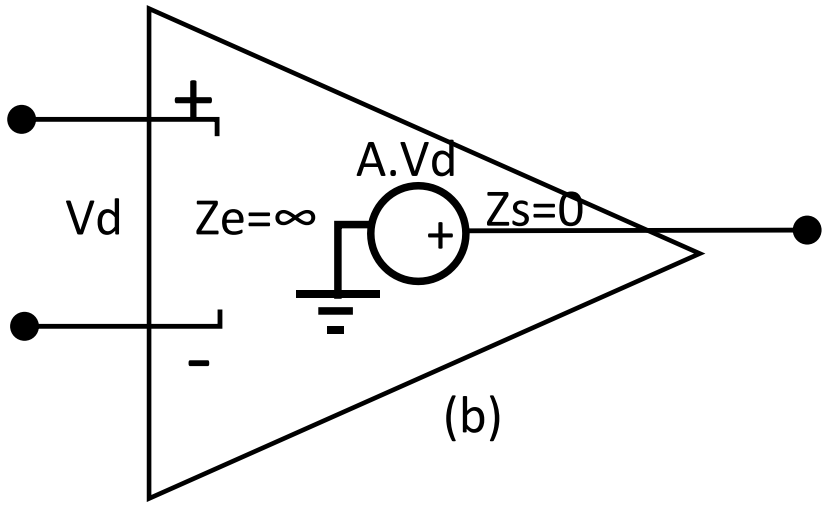
AO básico



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

Modelo de un AO (“real” e ideal)





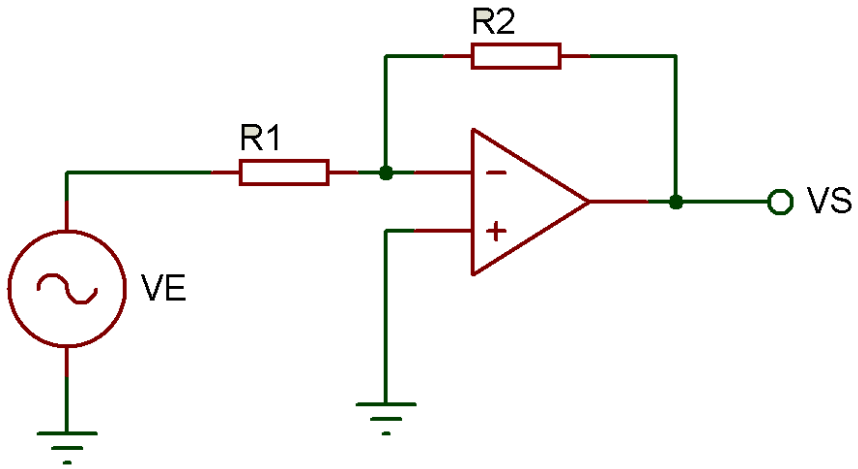
Parámetro	IDEAL	REAL
Imp Entrada	∞	10^6 a 10^{15} Ω
Amplificación	∞	10^5 a 10^6 V/V (o 100 a 120 dB)
Imp Salida	0	50 a 75Ω
RRMC	∞	60 a 120 dB

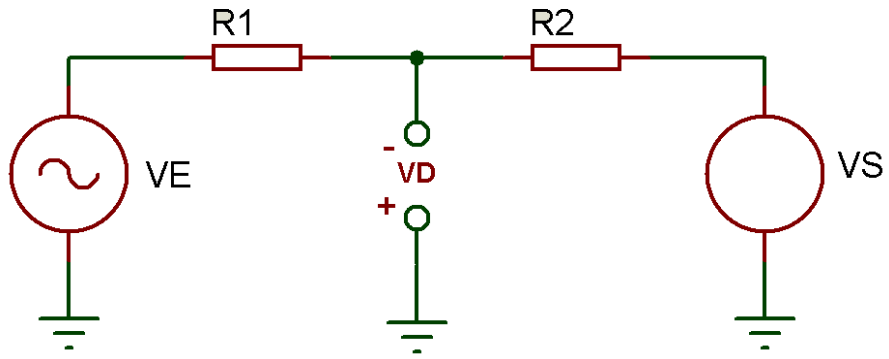
Nota: Decibel

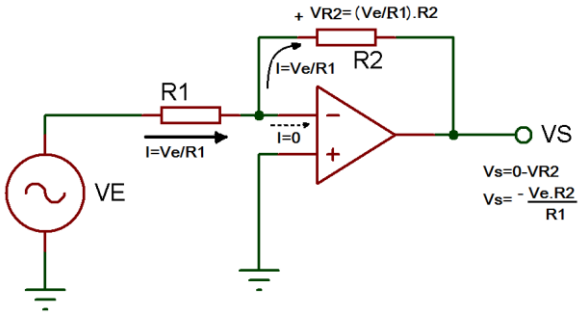
Va/Vb [dB] = 20 log (Va/Vb)

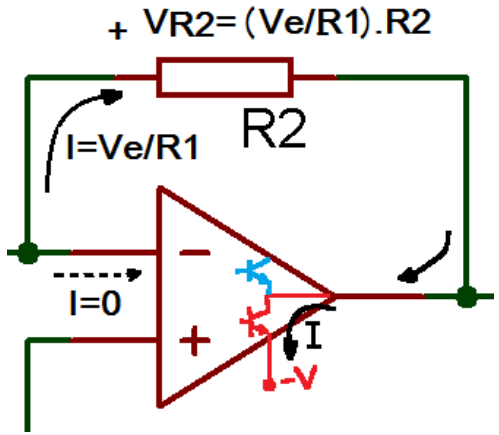
Pa/Pb [dB] = 10 log (Pa/Pb)

Montajes lineales: Amplificador Inversor









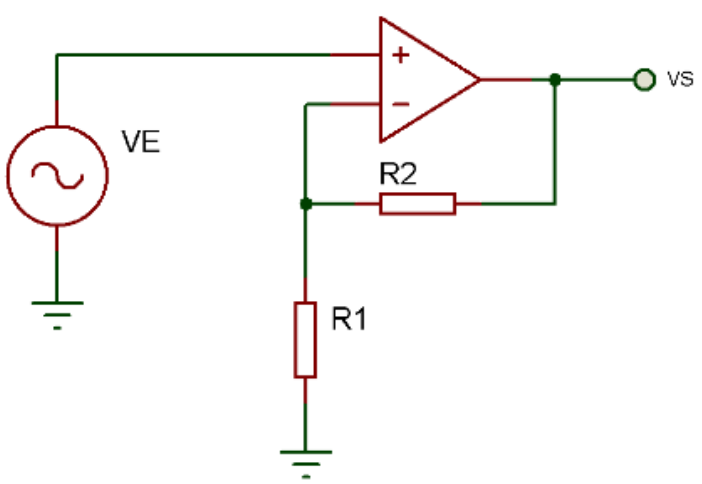
Vs= 0 – V_{R2} = – (Ve/R1).R2

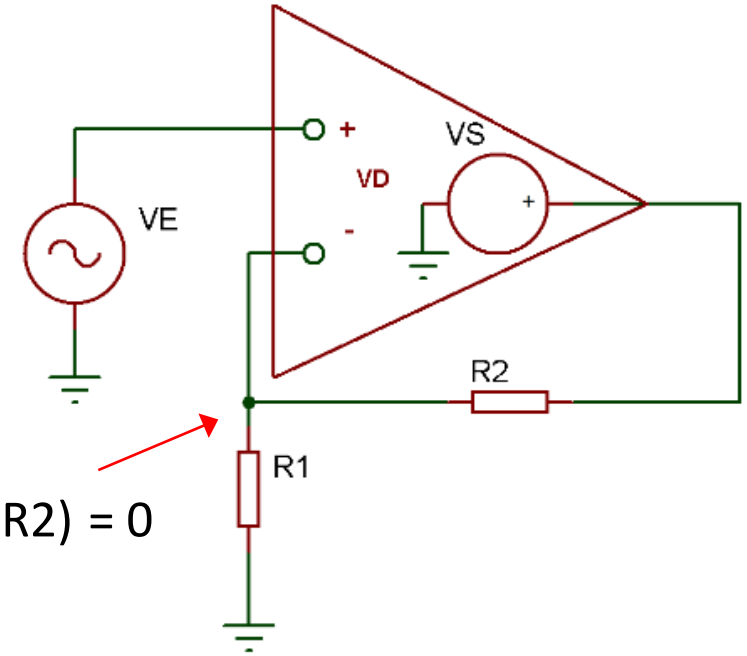
G=Vs/Ve

G= - R2/R1

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

Montajes lineales: Amplificador No Inversor





$V(-) = Vs.R1/(R1+R2) = 0$

Se observa entonces que

$Ve = V(-) = Vs.R1/(R1+R2)$

Es decir, la salida es;

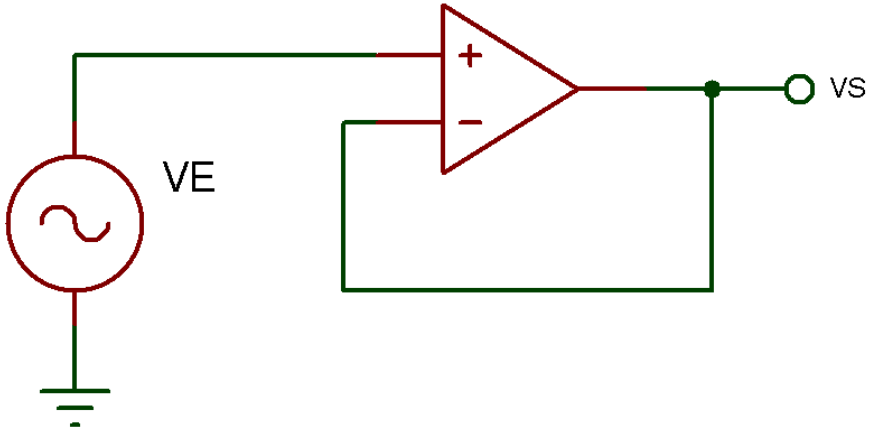
$Vs = Ve \,.\, (R1+R2)/R1 = Ve.\, (1+R2/R1)$

La ganancia de tensión del amplificador no inversor es

$G= 1+ R2/R1$

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

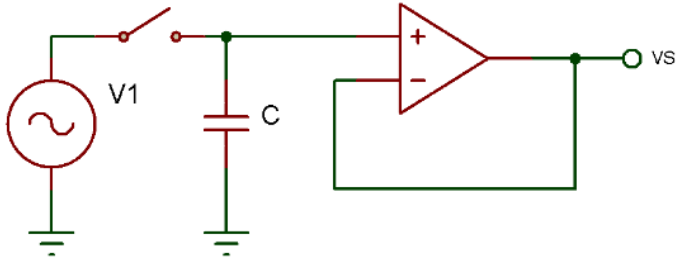
Montajes lineales: Seguidor de Tensión



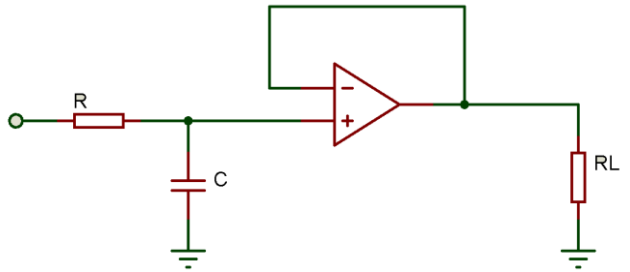
$V_S = V_E$

G= 1

Ejemplos de aplicación

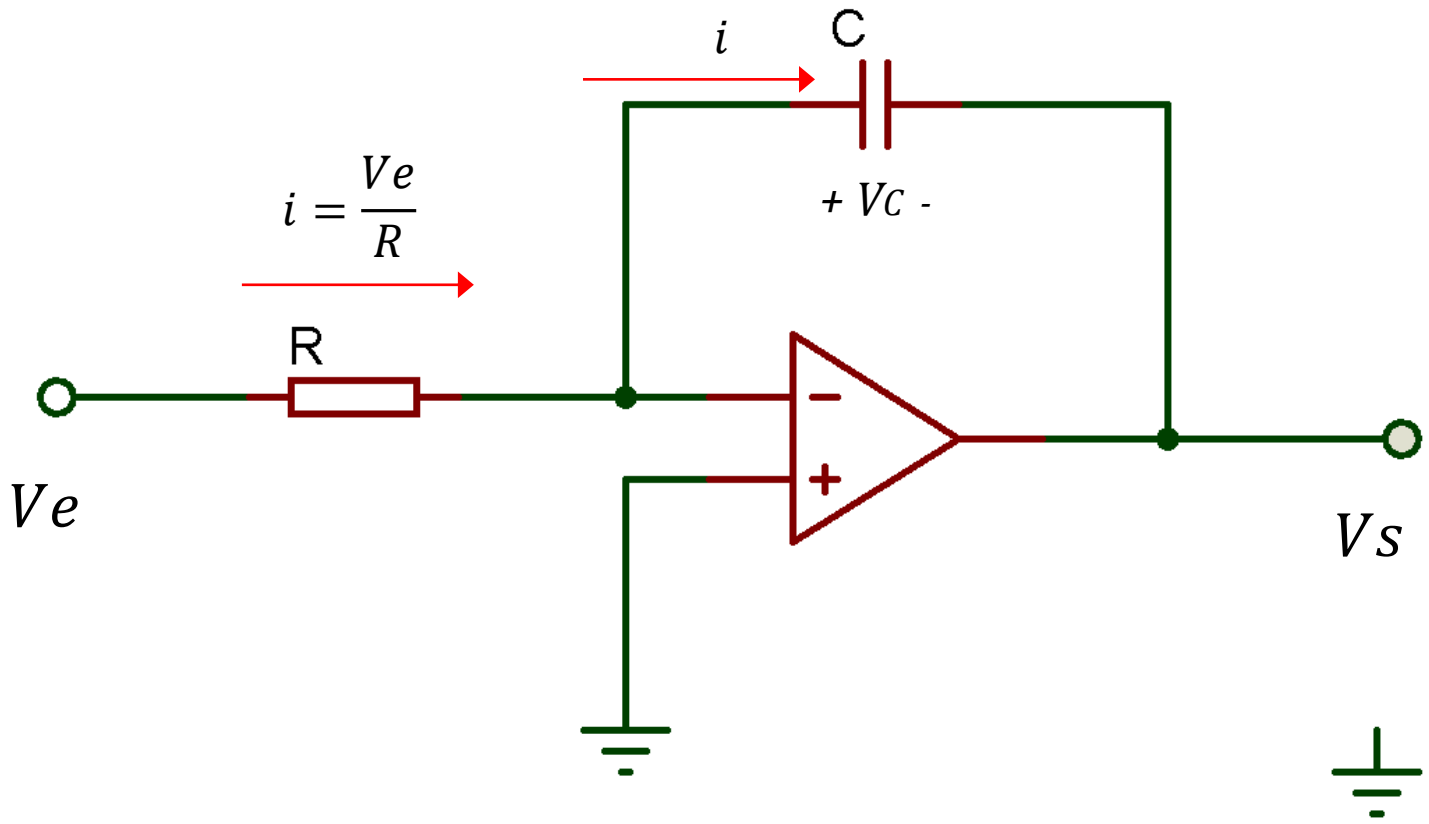


Medir Voltaje de C Cdescargarlo



Separar la carga RL de la etapa de filtrado

Montajes lineales: Integrador



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

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

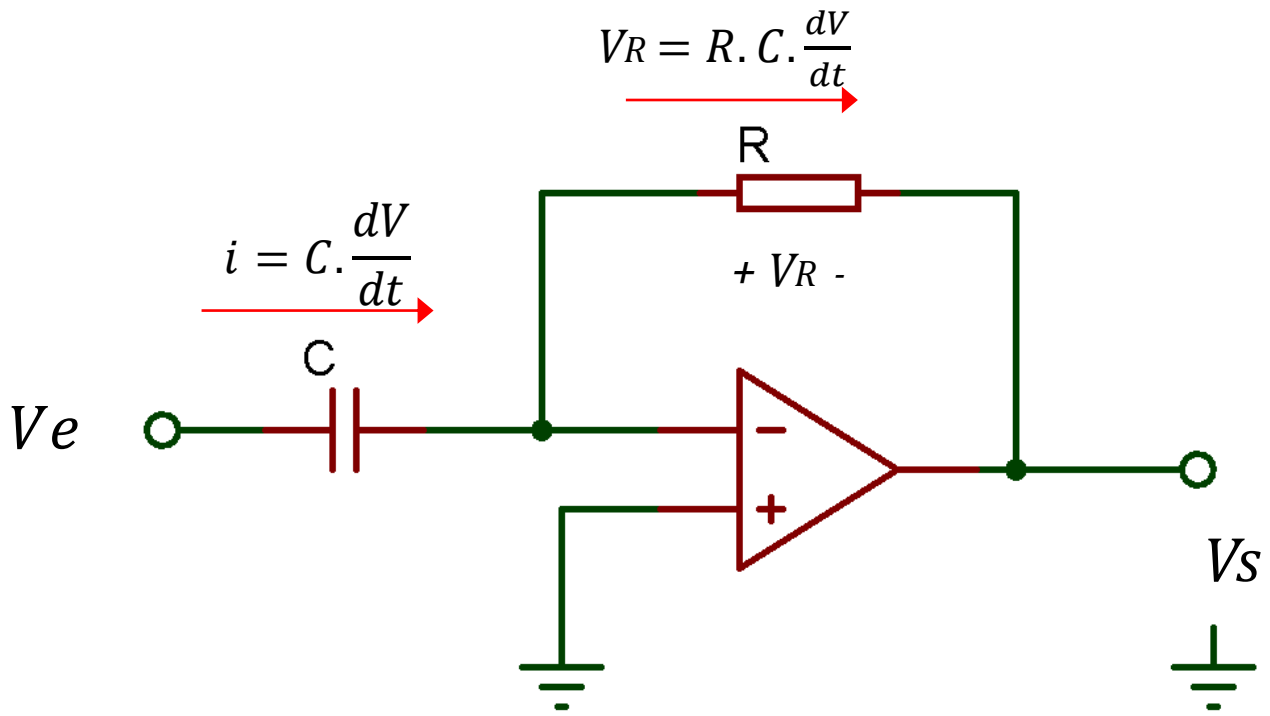
$$Vc = \frac{1}{C}\int i\ dt =$$

Como $i = \frac{Ve}{R}$

$$Vs = 0 - Vc$$

$$\boxed{Vs = -\frac{1}{R.C}\int Ve\ dt}$$

Montajes lineales: Derivador o diferenciador



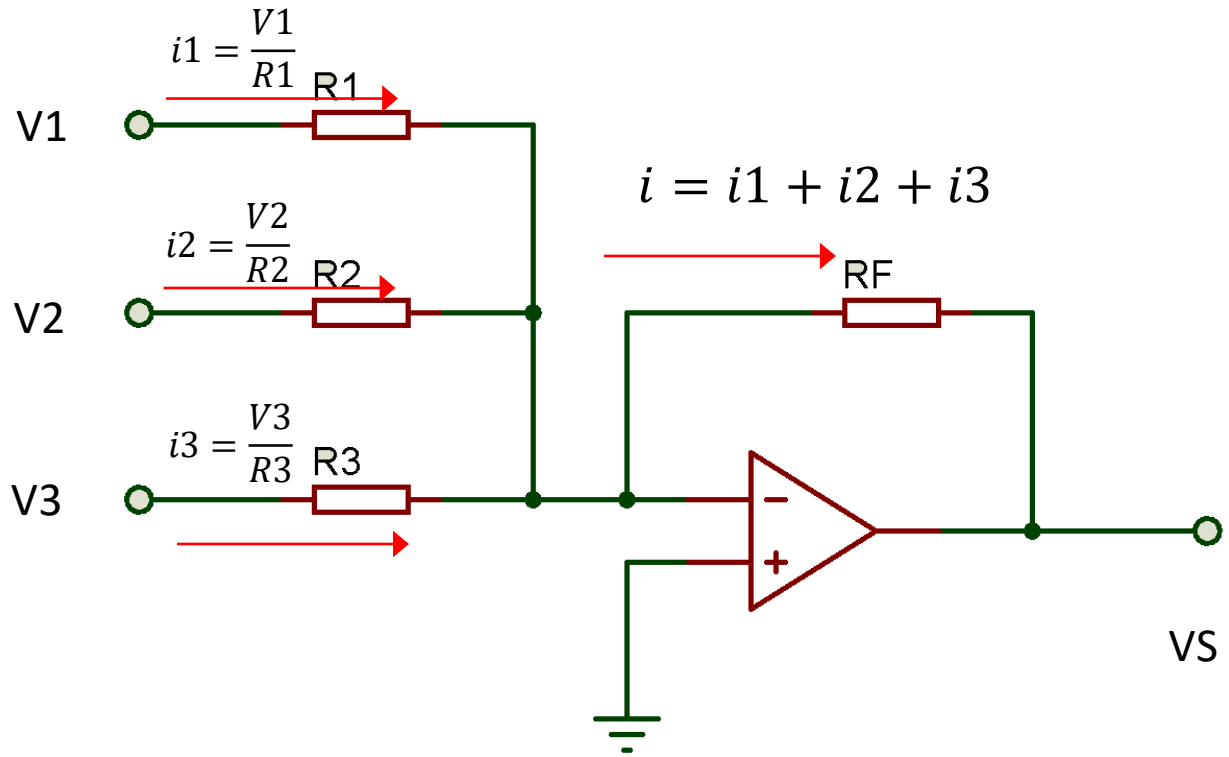
$$Vc = \frac{Q}{C} \qquad con\ Vc = Ve$$

$$\frac{dVe}{dt} = \frac{1}{C}\frac{dQ}{dt} = \frac{1}{C}\ i \rightarrow \quad i = C.\frac{dVe}{dt}$$

$$Vs = 0 - V_R = 0 - i\ .\ R$$

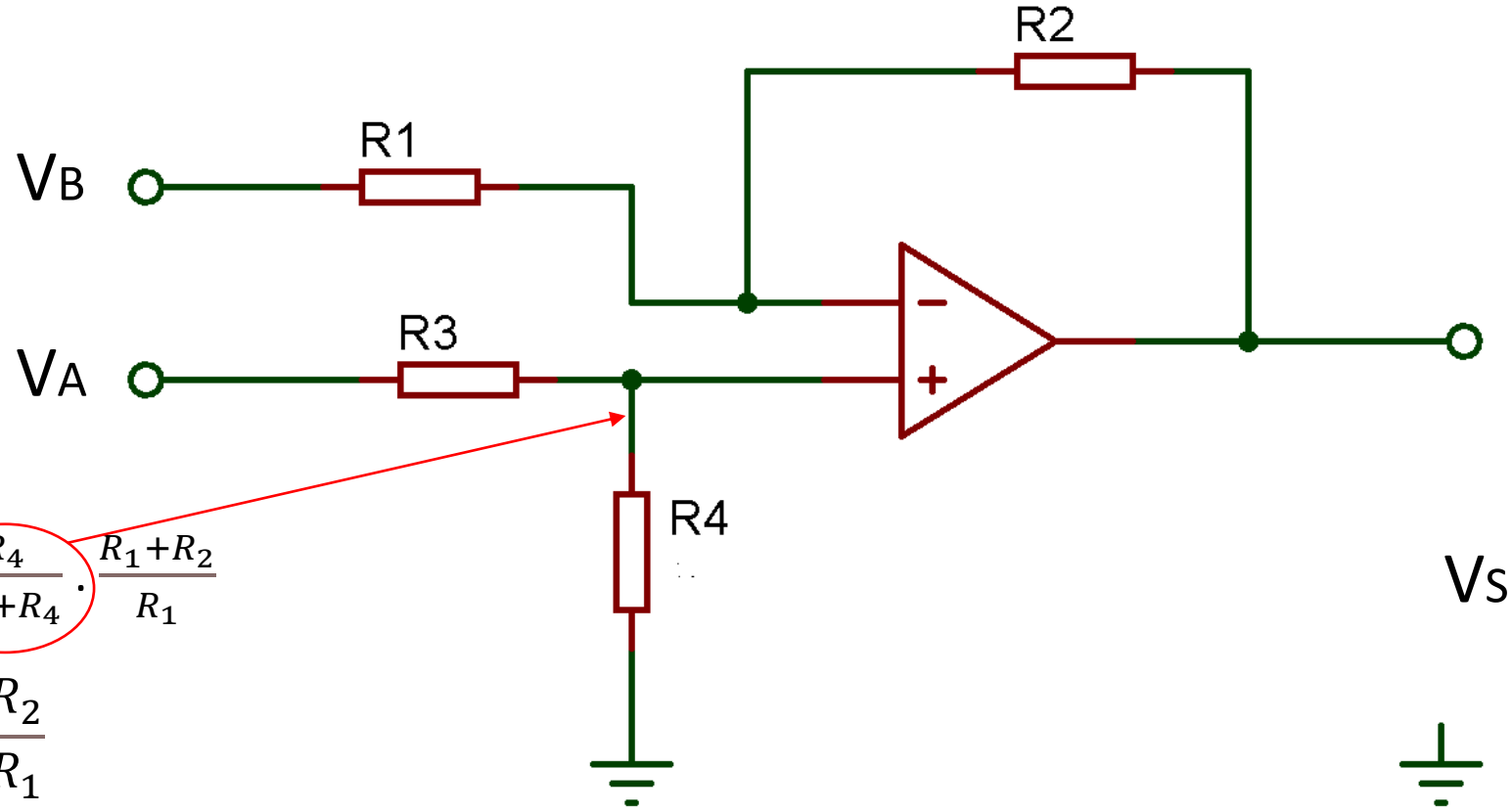
$$\boxed{Vs = -R.C.\frac{dVe}{dt}}$$

Montajes lineales: Sumador



$$Vs = -\left(\frac{V1}{R1} + \frac{V2}{R2} + \frac{V3}{R3}\right) . RF$$

Montajes lineales: Amplificador Diferencial (Restador)

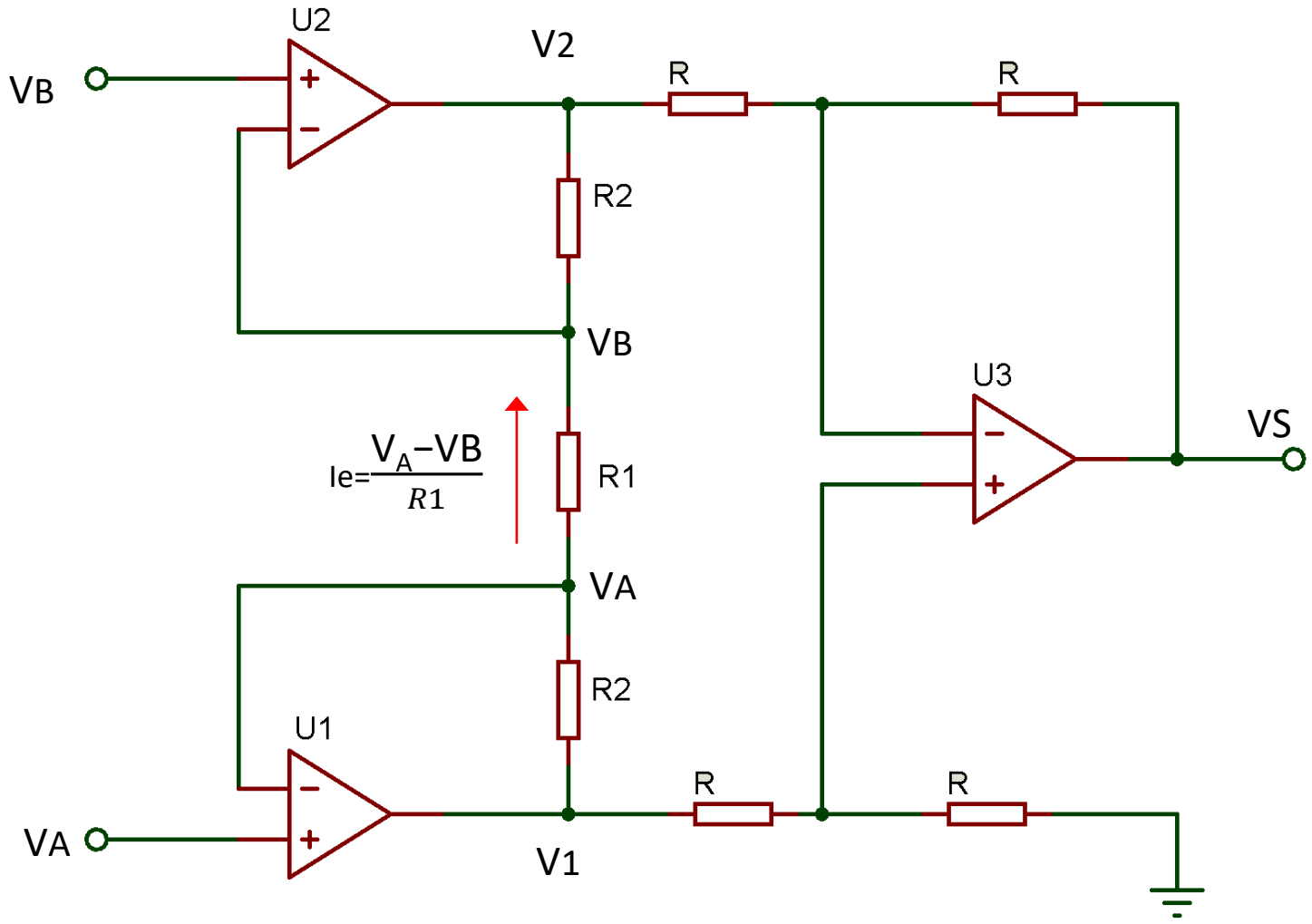


$$\begin{cases} V_S|_{v_A} = v_A \cdot \frac{R_4}{R_3+R_4} \cdot \frac{R_1+R_2}{R_1} \\ V_S\Big|_{v_B} = -v_B \cdot \frac{R_2}{R_1} \end{cases}$$

Si R3 = R1 y R4 = R2 →

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

Montajes lineales: Amplificador de Instrumentación



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

$= Ie \cdot (R1+2.R2)$

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

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

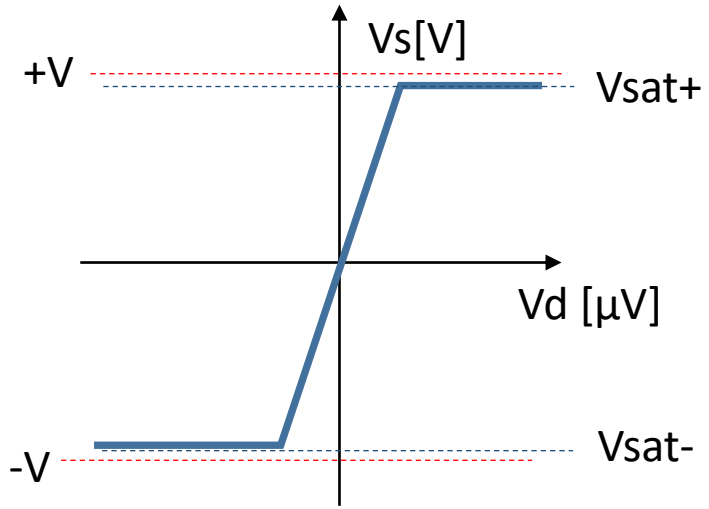
$Vs=(\frac{V_A - VB}{R1}) \cdot (R1+2.R2)$

$$Vs= (V_A - VB) \cdot \left(1+2.\frac{R2}{R1}\right)$$

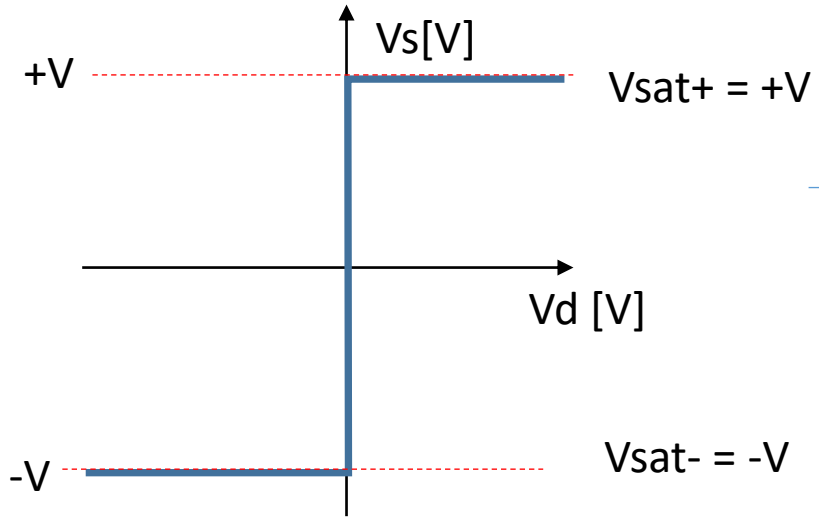
Amp Operacional a lazo abierto: Función de Transferencia (Vs vs Vd)

Con +V y -V

REAL

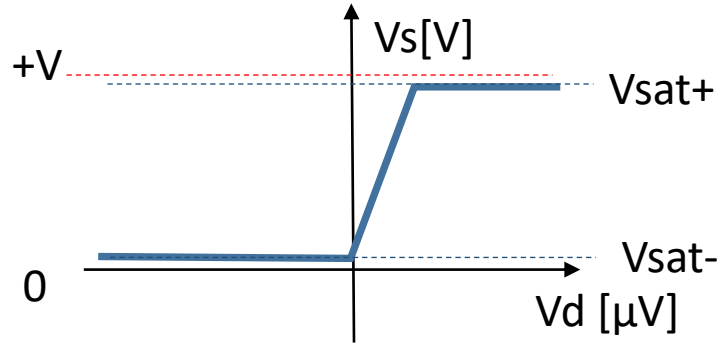


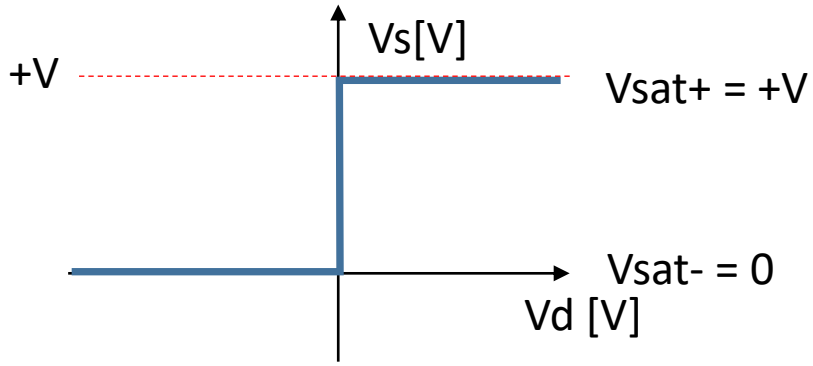
APROXIMADO



Vd	Vs
<0	-V
>0	+V

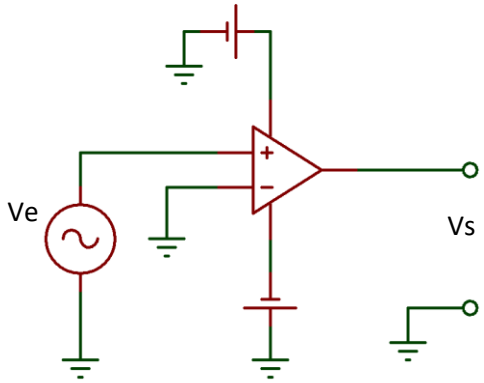
Con +V y 0

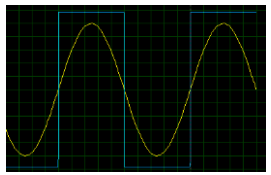




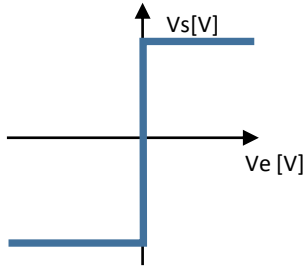
Vd	Vs
<0	0
>0	+V

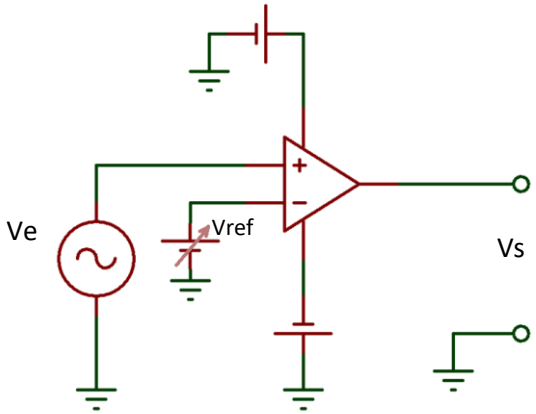
Comparador No inversor sin Histéresis (lazo abierto)

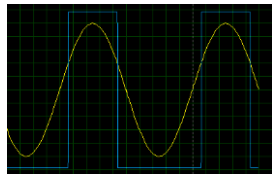




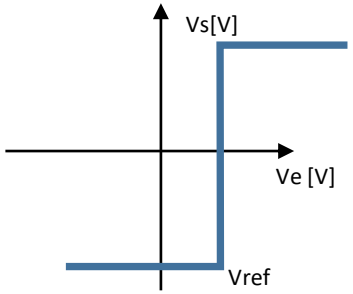
Ve	Vs
<0	-V
>0	+V

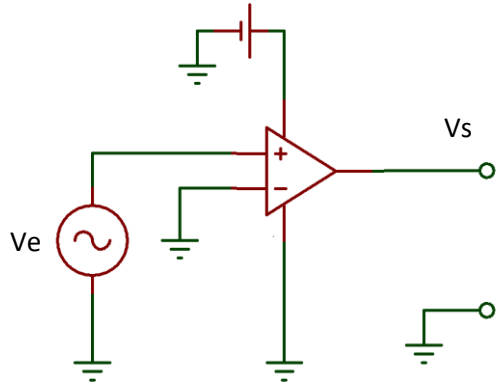


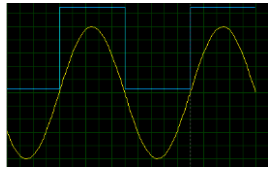




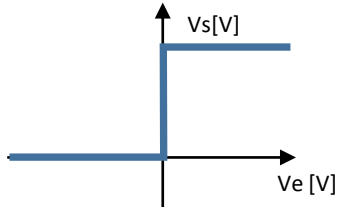
Ve	Vs
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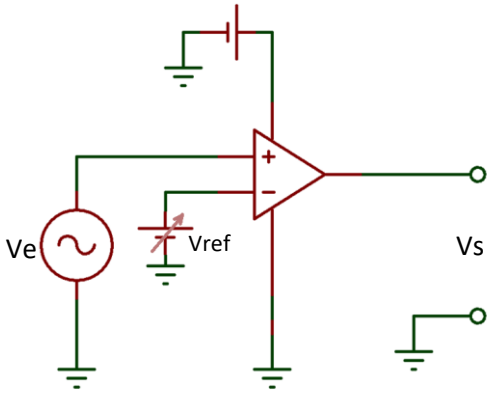


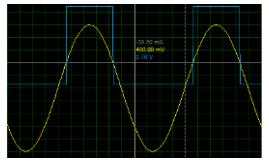




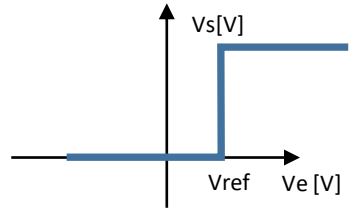
Ve	Vs
<0	0
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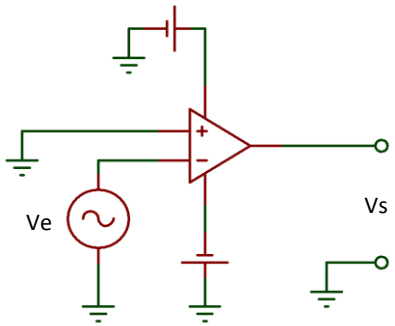


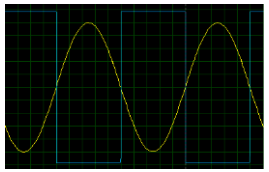


Ve	Vs
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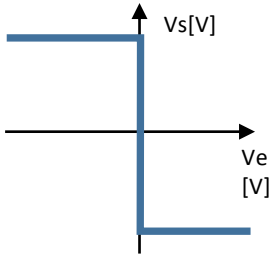


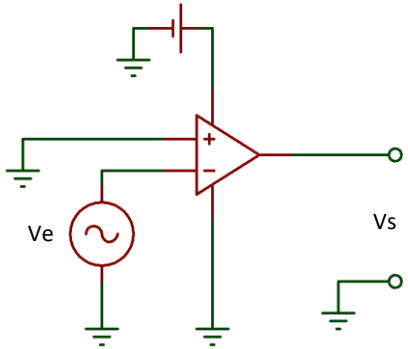
Comparador inversor sin Histéresis (lazo abierto)

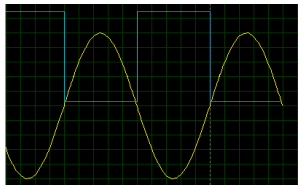




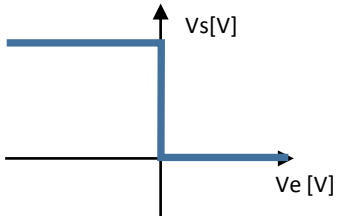
Ve	Vs
<0	+V
>0	-V

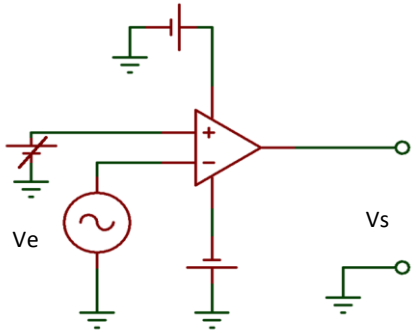


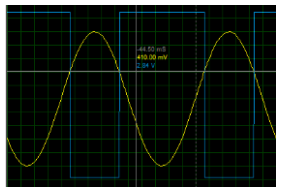




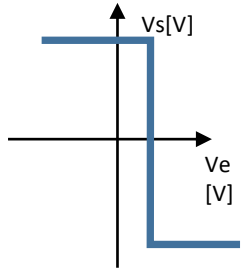
Ve	Vs
<0	+V
>0	0

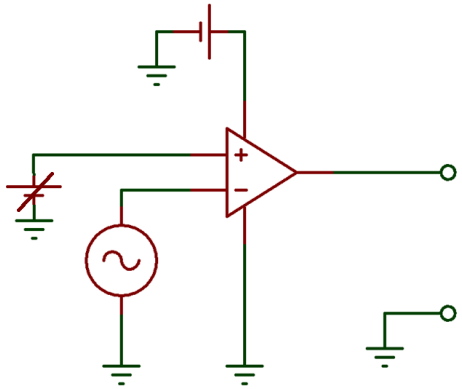


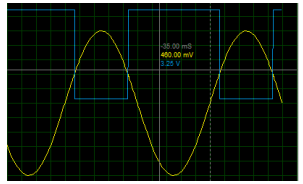




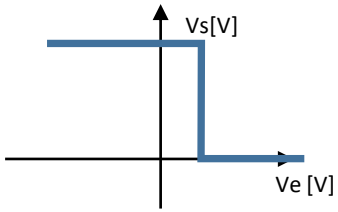
Ve	Vs
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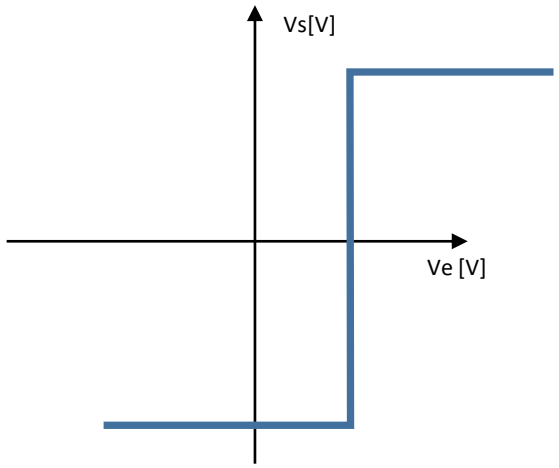


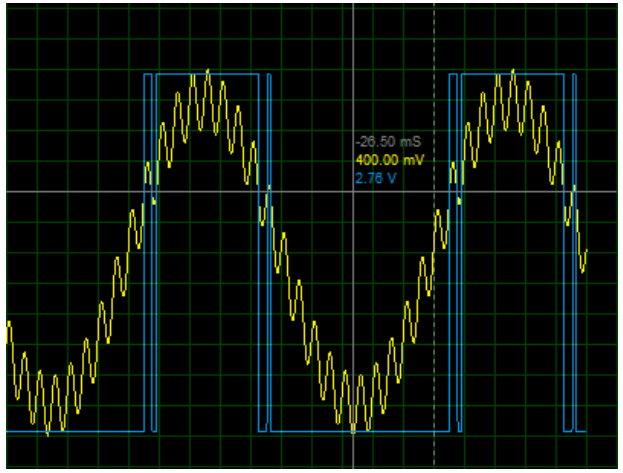


Ve	Vs
<Vref	+V
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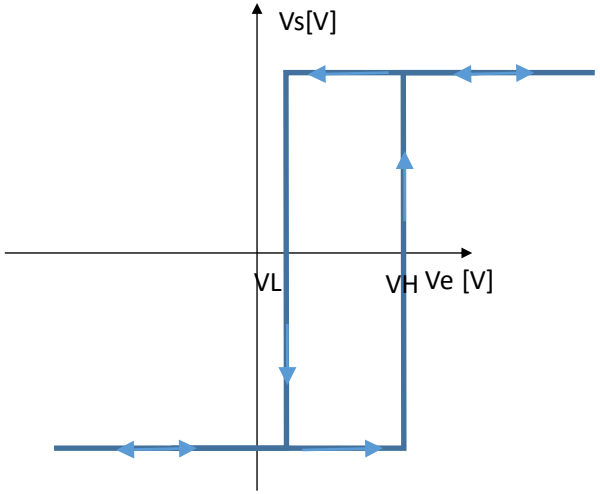


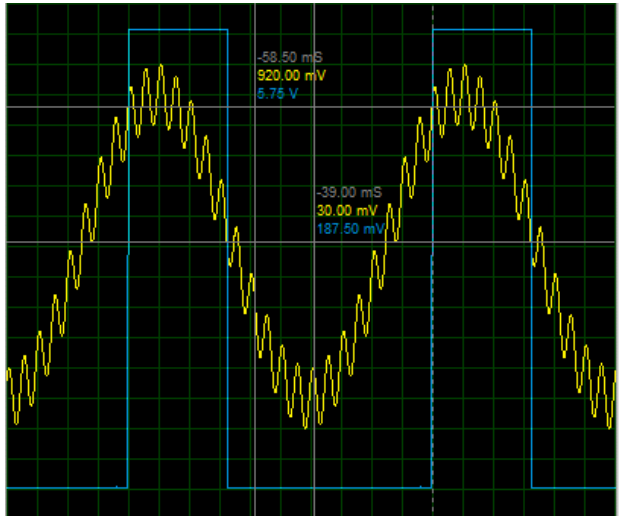
Histéresis





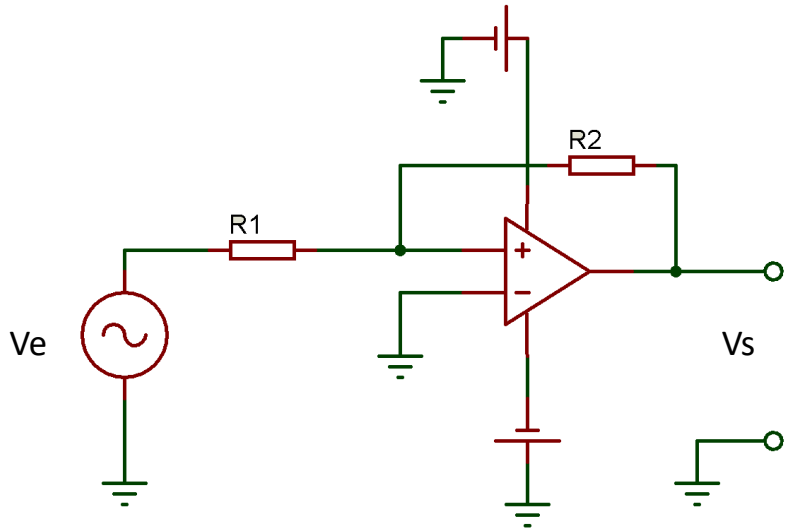
sin histéresis se producen múltiples conmutaciones por ruido

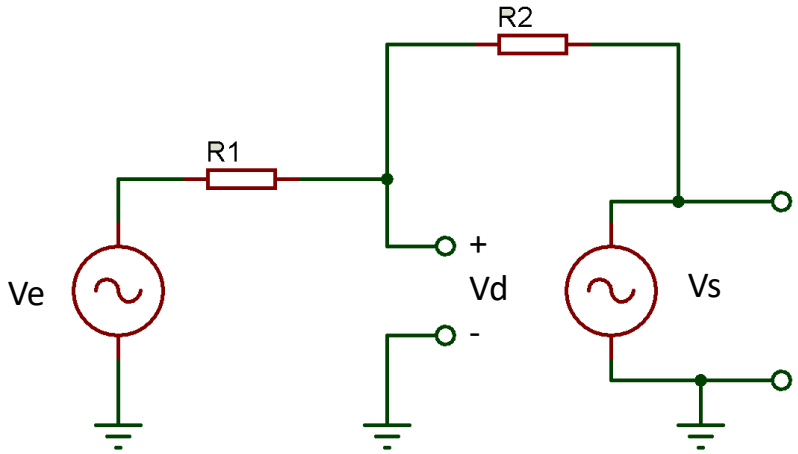


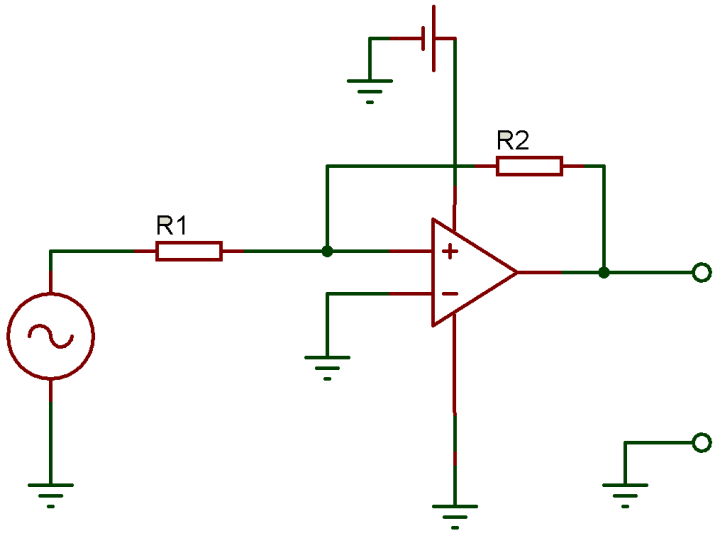


Con la histéresis adecuada se eliminan las múltiples conmutaciones

Comparador No inversor con Histéresis (realimentación positiva)







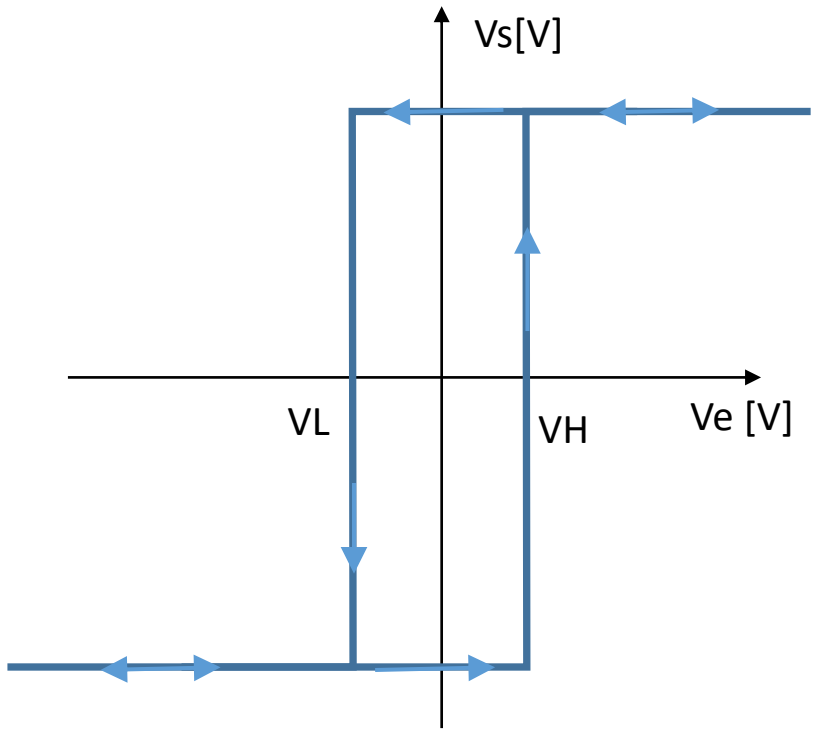
$$Vd = Ve.\left(\frac{R2}{R1+R2}\right) + Vs.\left(\frac{R1}{R1+R2}\right)$$

La conmutación ocurre en Vd=0. Despejando

$$Ve = -Vs.\left(\frac{R1}{R2}\right)$$

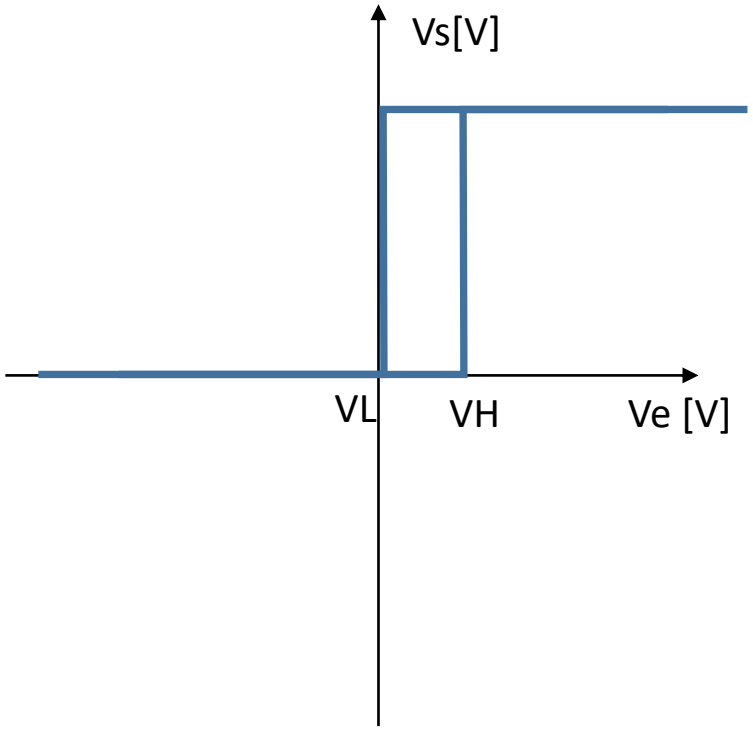
Comparador No inversor con Histéresis (lazo abierto)

Con fuente doble



$$VH = V.\left(\frac{R1}{R2}\right) \qquad VL = -V.\left(\frac{R1}{R2}\right)$$

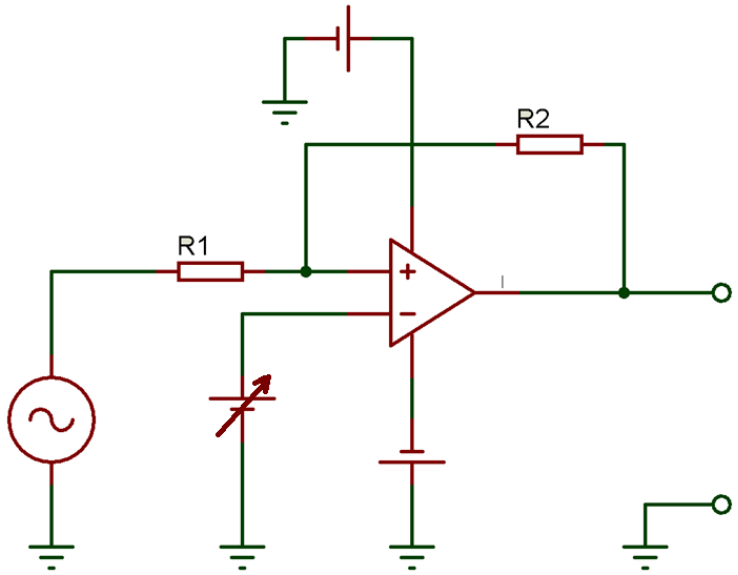
Con fuente única

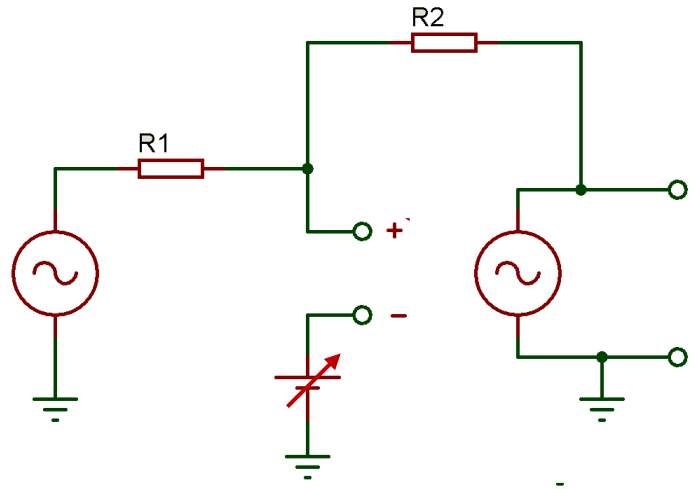


$$VH = V.\left(\frac{R1}{R2}\right) \qquad VL = 0$$

Comparador No inversor con Histéresis (realimentación positiva)

Idem anterior, pero con Vref en la entrada inversora





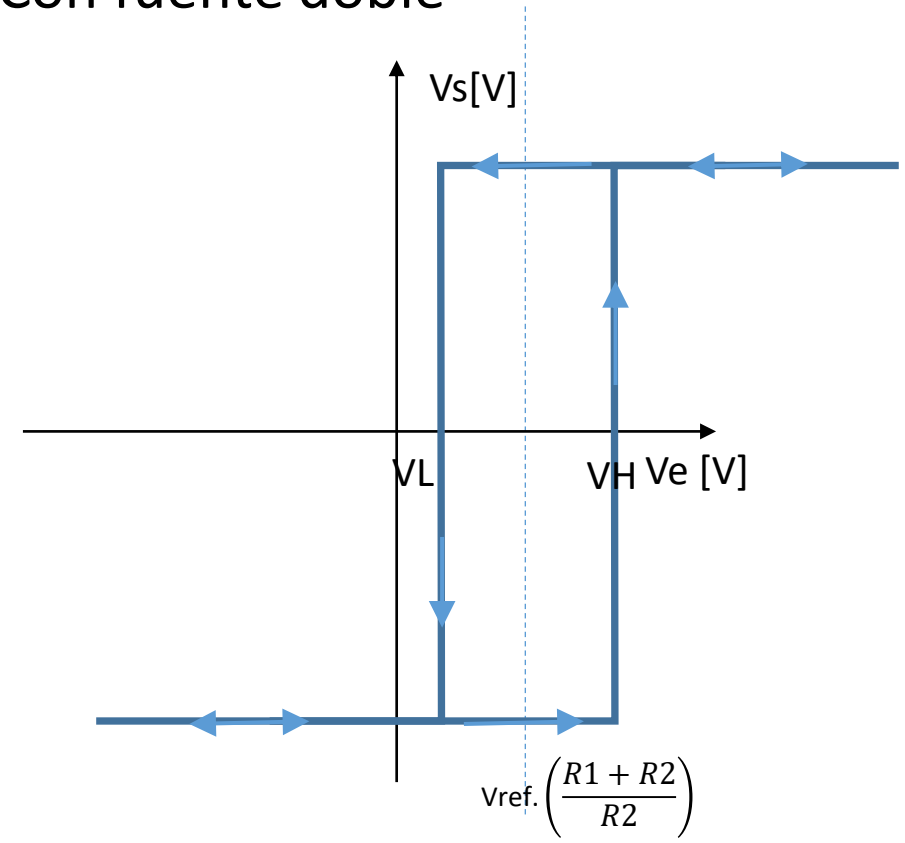
$$Vd = Ve.\left(\frac{R2}{R1+R2}\right) + Vs.\left(\frac{R1}{R1+R2}\right) - Vref.$$

La conmutación ocurre en Vd=0. Despejando

$$Ve = -\mathbf{Vs.}\left(\frac{R1}{R2}\right) + Vref.\left(\frac{R1+R2}{R2}\right)$$

Comparador No inversor con Histéresis (realimentación positiva)

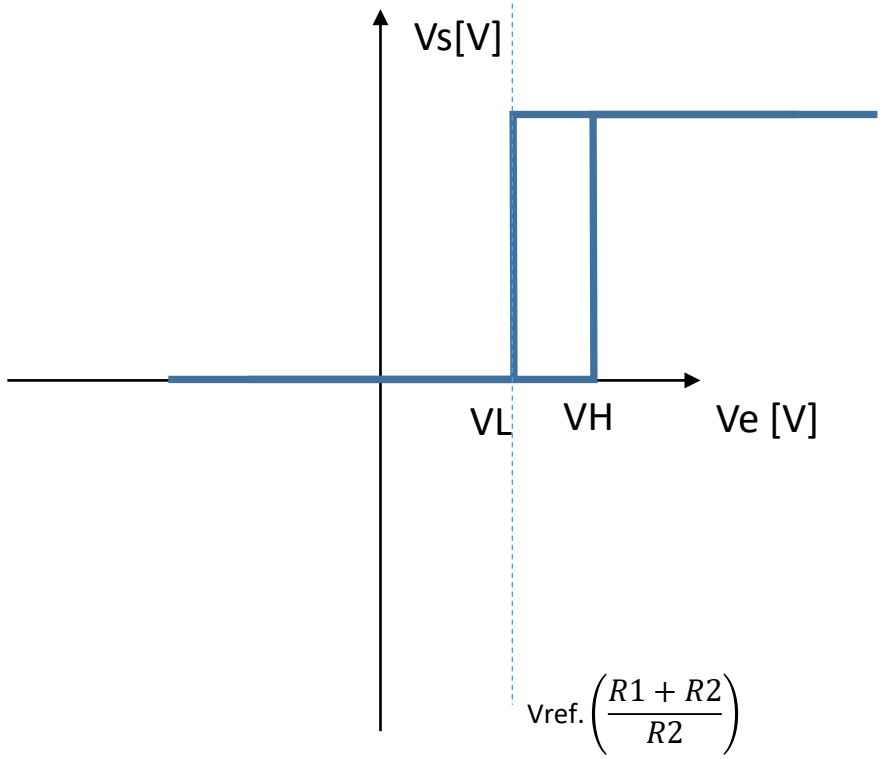
Con fuente doble



$$VH = V.\left(\frac{R1}{R2}\right) + Vref.\left(\frac{R1+R2}{R2}\right)$$

$$VL = -V.\left(\frac{R1}{R2}\right) + Vref.\left(\frac{R1+R2}{R2}\right)$$

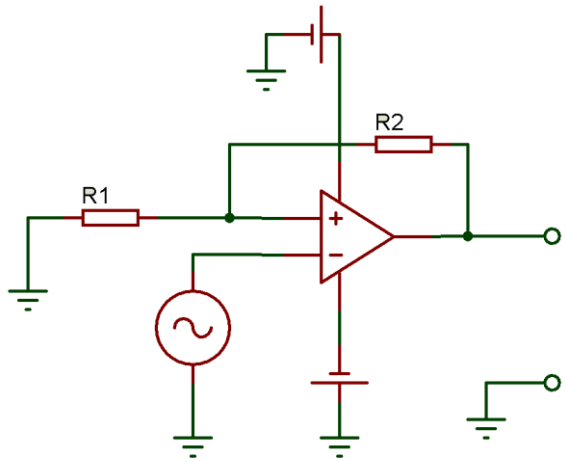
Con fuente única

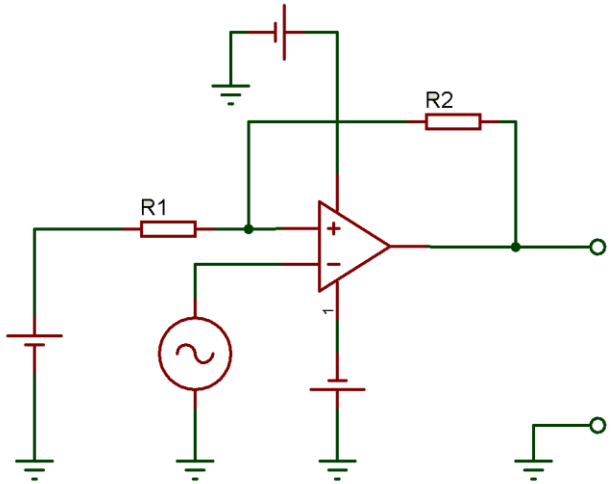


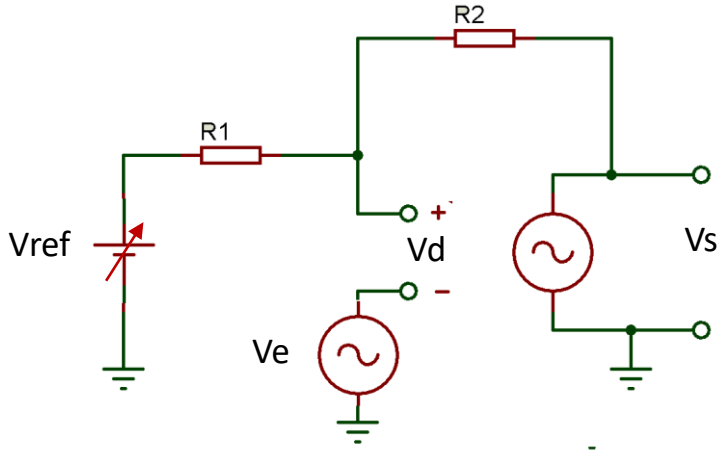
$$VH = V.\left(\frac{R1}{R2}\right) + Vref.\left(\frac{R1+R2}{R2}\right)$$

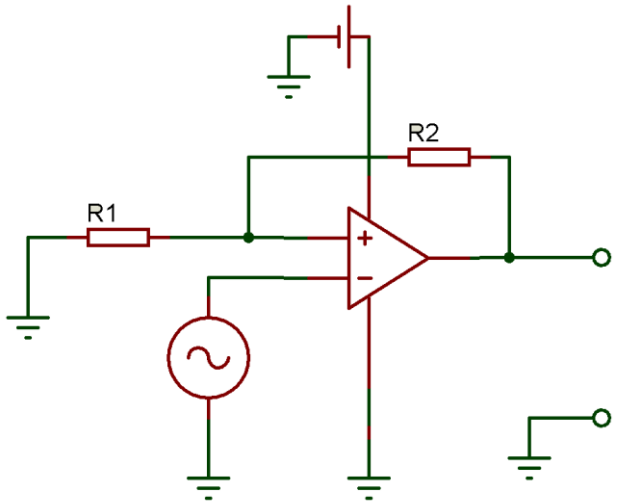
$$VL = Vref.\left(\frac{R1+R2}{R2}\right)$$

Comparador Inversor con Histéresis (realimentación positiva)









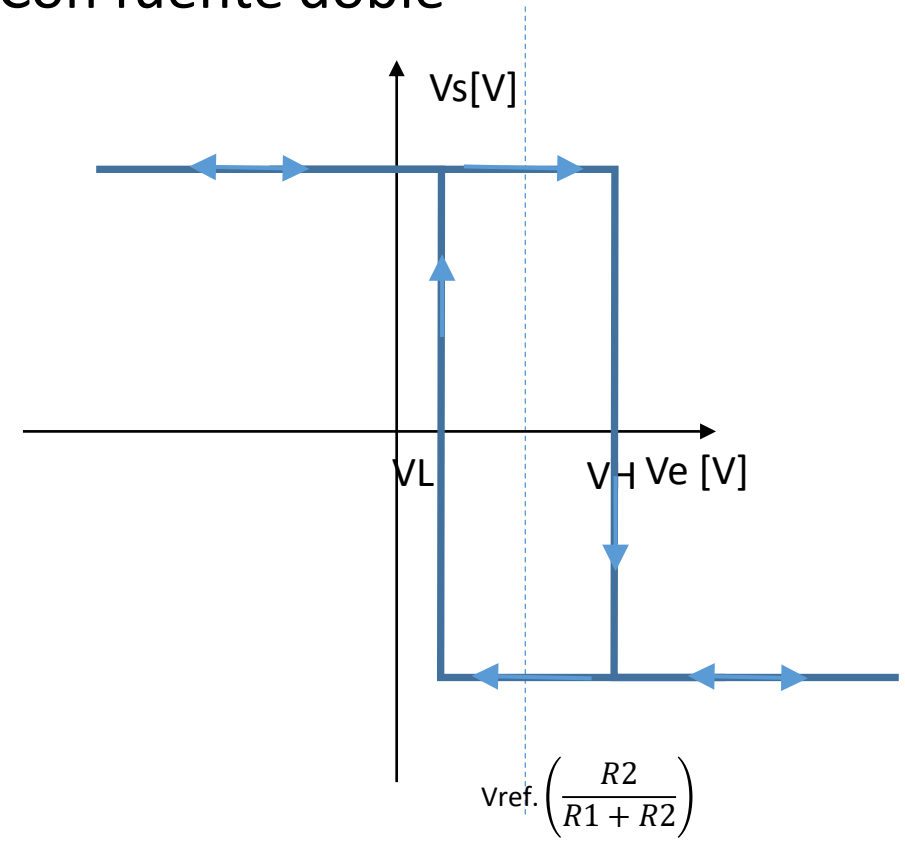
$$Vd = Vref.\left(\frac{R2}{R1+R2}\right) + Vs.\left(\frac{R1}{R1+R2}\right) - Ve.$$

La conmutación ocurre en Vd=0. Despejando

$$Ve = -Vs.\left(\frac{R1}{R1+R2}\right) + Vref.\left(\frac{R2}{R1+R2}\right)$$

Comparador Inversor con Histéresis (realimentación positiva)

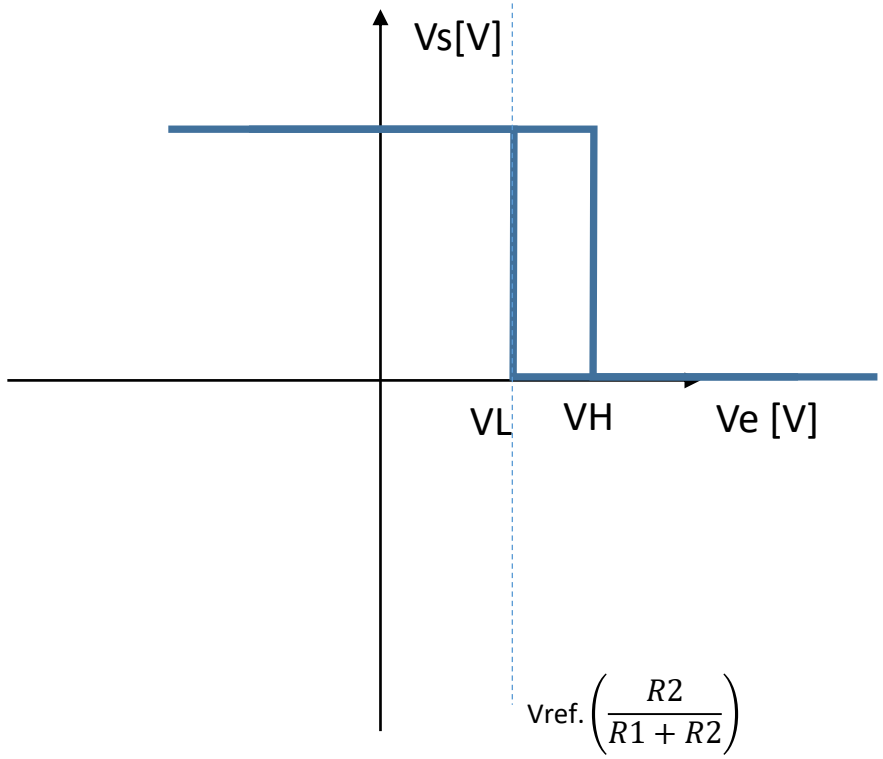
Con fuente doble



$$VH = V.\left(\frac{R1}{R1+R2}\right) + Vref.\left(\frac{R2}{R1+R2}\right)$$

$$VL = -V.\left(\frac{R1}{R1+R2}\right) + Vref.\left(\frac{R2}{R1+R2}\right)$$

Con fuente única



$$VH = V.\left(\frac{R1}{R1+R2}\right) + Vref.\left(\frac{R2}{R1+R2}\right)$$

$$VL = Vref.\left(\frac{R2}{R1+R2}\right)$$