



Universidad
Carlos III de Madrid
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Sesión 25

Aplicaciones del Amplificador Operacional

Componentes y Circuitos Electrónicos

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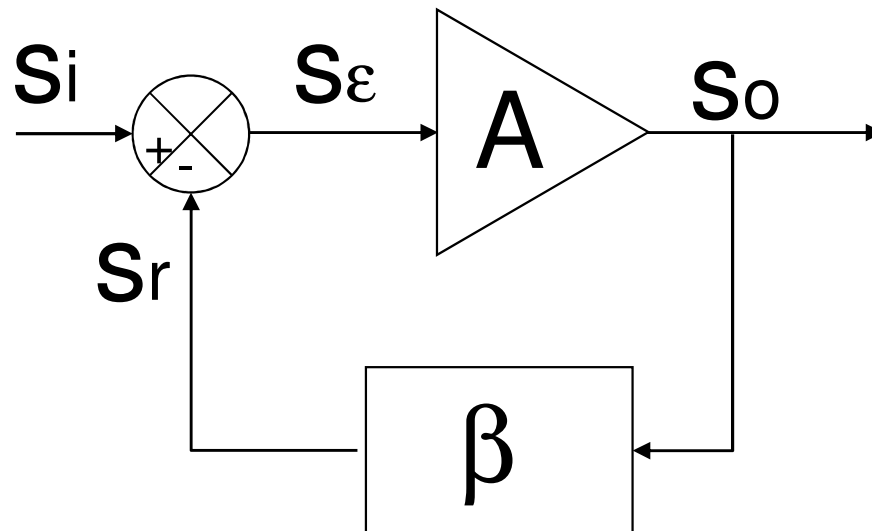
Aplicaciones del amplificador operacional

OBJETIVOS

- Analizar circuitos de aplicación lineales con amplificadores operacionales
- Revisar el análisis al considerar parámetros básicos de un amplificador operacional real
- Distinguir circuitos de aplicación no lineales con amplificadores operacionales y entender su principio de funcionamiento

Introducción: Realimentación negativa

AMPLIFICADOR IDEAL REALIMENTADO

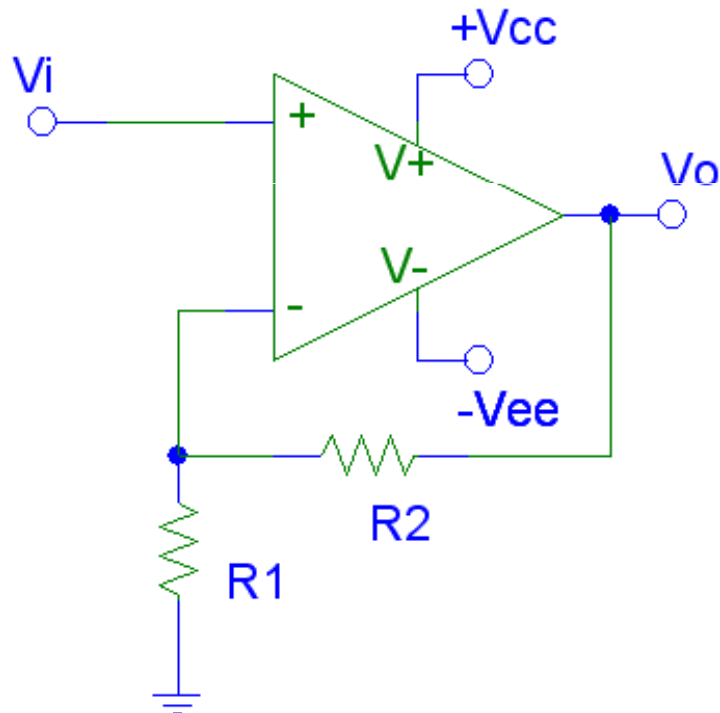


$$S_o = G \cdot S_i$$

$$G = \frac{S_o}{S_i} = \frac{A}{1 + A\beta}$$

$$\begin{array}{l} A\beta \gg 1 \\ [A \rightarrow \infty] \end{array} \Rightarrow \begin{array}{l} G \approx \frac{1}{\beta} \\ S_\epsilon \rightarrow 0 \end{array} \Rightarrow S_o \approx \frac{1}{\beta} \cdot S_i$$

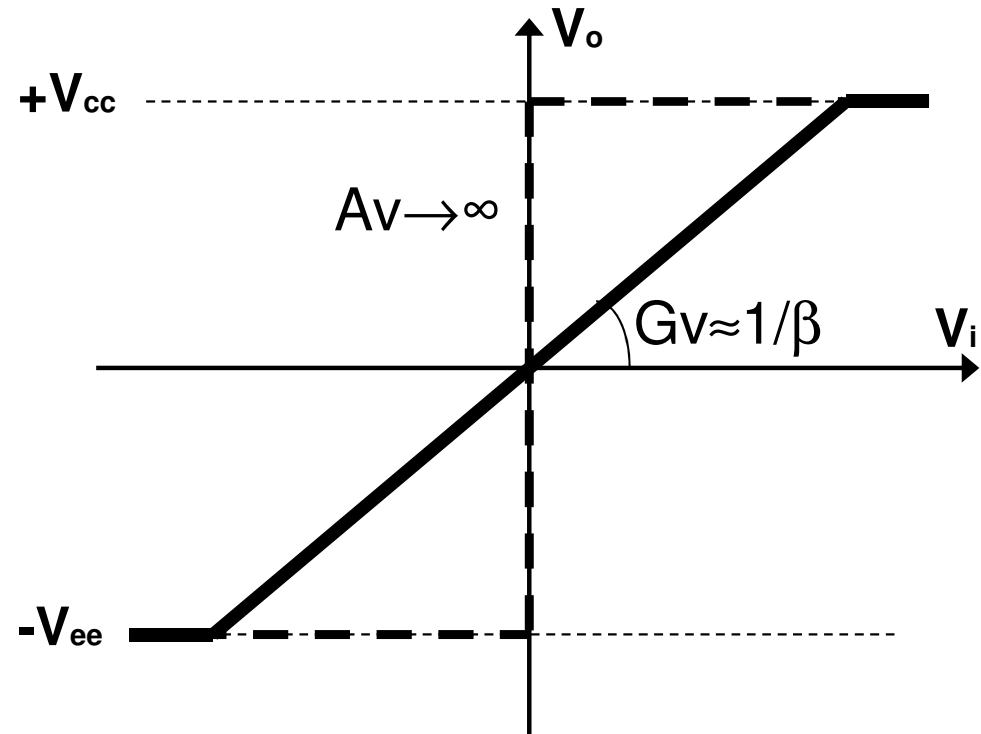
Aplicación lineal AO-IDEAL



Comportamiento Lineal

$$V_o = A_v \cdot V_{id}$$

Realimentación negativa



Cortocircuito virtual

$$V_{id} = 0$$

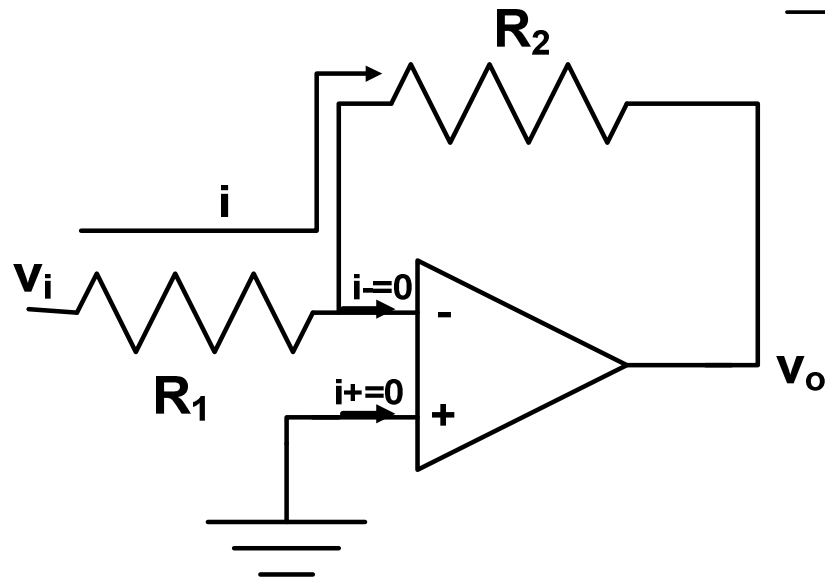
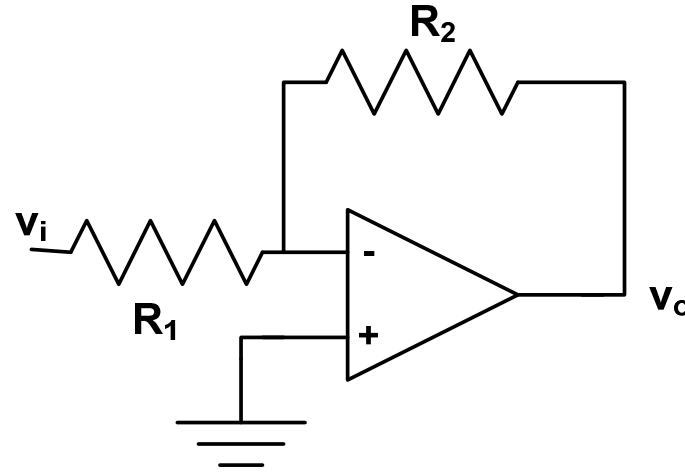
$$V_+ = V_-$$

Aplicaciones lineales del amplificador operacional

ÍNDICE

- Amplificador inversor
- Amplificador no inversor
- Seguidor de tensión
- Sumador inversor
- Amplificador diferencial
- Conversor tensión-corriente
- Conversor corriente-tensión
- Filtro paso bajo / Integrador

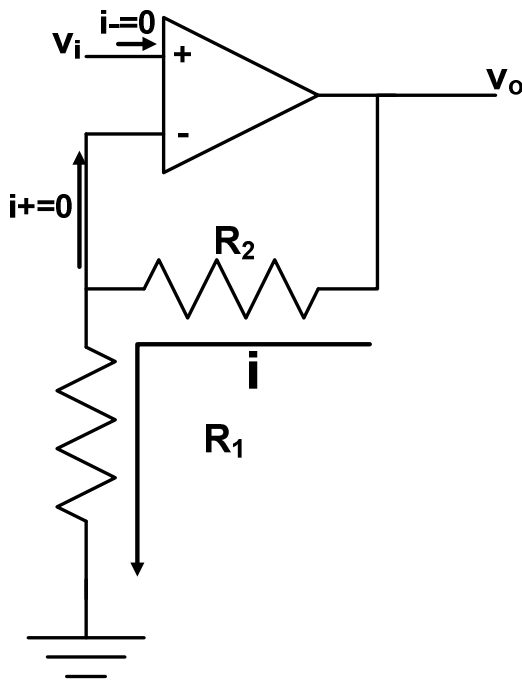
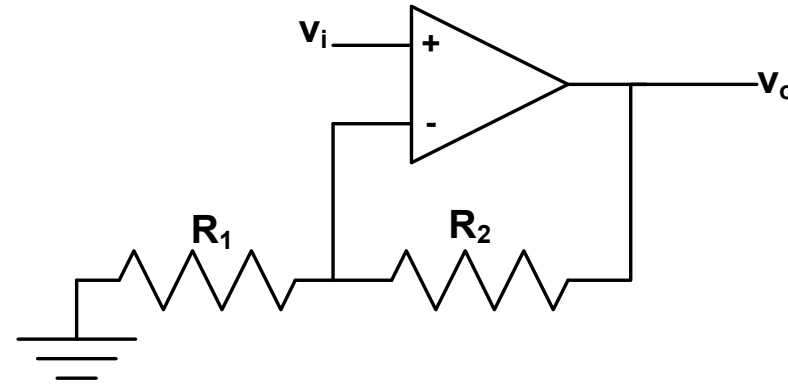
Amplificador inversor



- Cortocircuito virtual: $v_+ = v_-$
- $i(R_1) = i(R_2) = i$

$$\frac{v_i}{R_1} = \frac{-v_o}{R_2} \Rightarrow \frac{v_o}{v_i} = -\frac{R_2}{R_1}$$

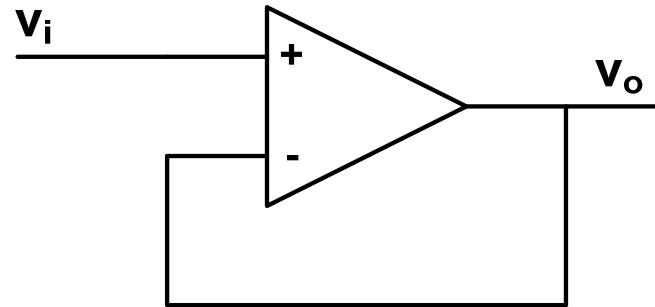
Amplificador no inversor



- Cortocircuito virtual: $v_+ = v_-$
- $i(R_1) = i(R_2) = i$

$$v_i = R_1 \cdot i = R_1 \cdot \frac{v_o}{R_1 + R_2} \Rightarrow \frac{v_o}{v_i} = 1 + \frac{R_2}{R_1}$$

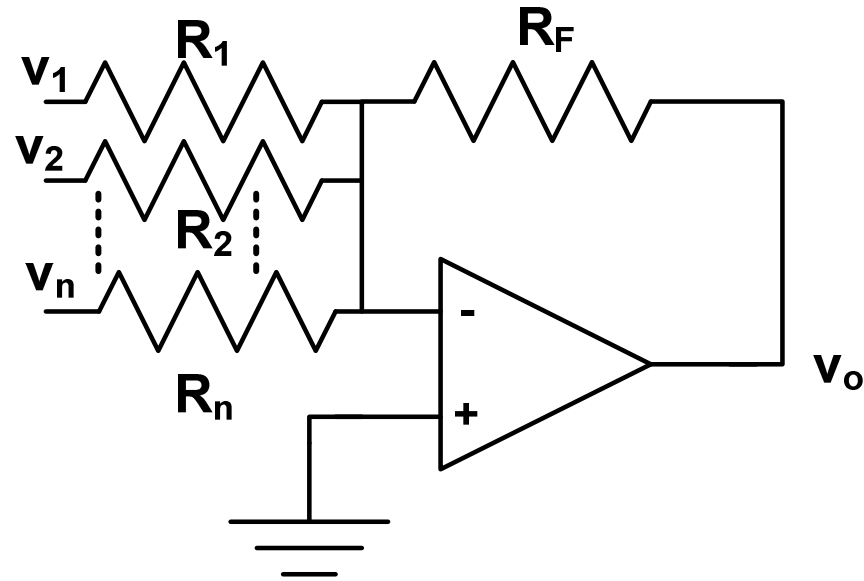
Seguidor de tensión



- Cortocircuito virtual: $v_+ = v_-$ $v_o = v_i \Rightarrow \frac{v_o}{v_i} = 1$

$$\left. \begin{array}{l} R_i \rightarrow \infty \\ R_o \rightarrow 0 \end{array} \right\} \Rightarrow \text{ADAPTADOR DE IMPEDANCIAS}$$

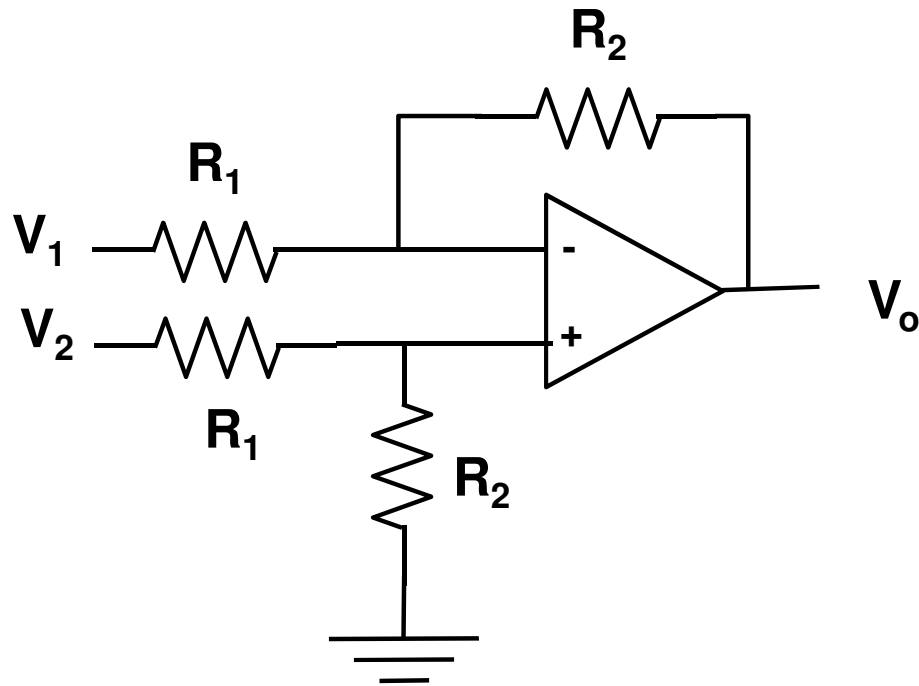
Sumador inversor



- Cortocircuito virtual: $v_+ = v_- = 0$
- $i(R_F) = i(R_1) + i(R_2) \dots + i(R_n)$

$$\frac{-v_o}{R_F} = \frac{v_1}{R_1} + \frac{v_2}{R_2} \dots + \frac{v_n}{R_n} \Rightarrow v_o = - \left(\frac{R_F}{R_1} v_1 + \frac{R_F}{R_2} v_2 \dots + \frac{R_F}{R_n} v_n \right)$$

Amplificador diferencial



- Superposición

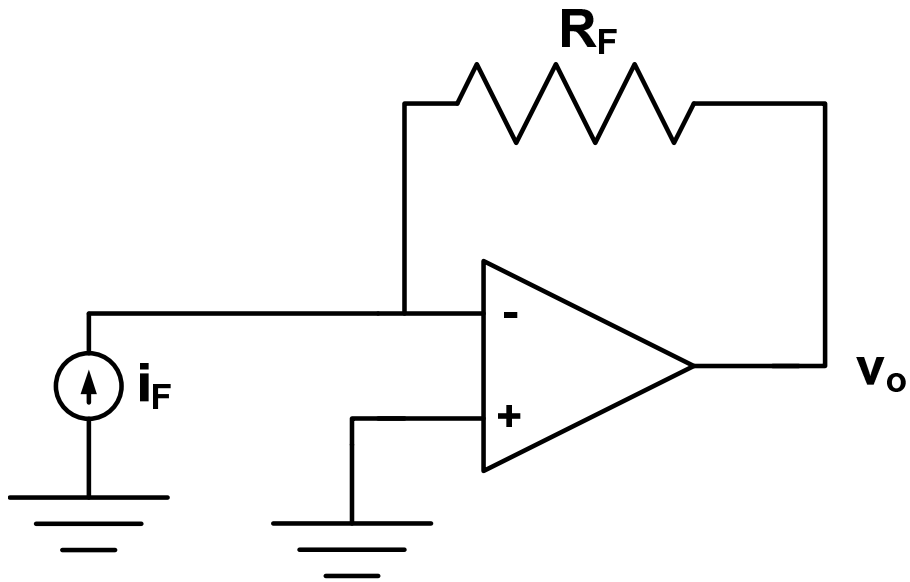
$$v_o = v_o|_{v_1} + v_o|_{v_2}$$

$$v_o|_{v_1} = -\frac{R_2}{R_1} v_1$$

$$v_o|_{v_2} = \left(1 + \frac{R_2}{R_1}\right) \cdot \frac{R_2}{R_1 + R_2} \cdot v_2 = \frac{R_2}{R_1} \cdot v_2$$

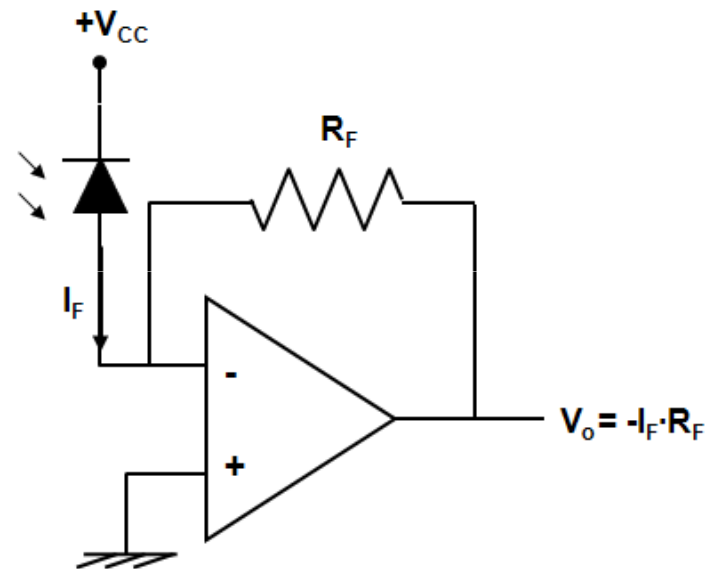
$$v_o = \frac{R_2}{R_1} (v_2 - v_1)$$

Conversor corriente-tensión

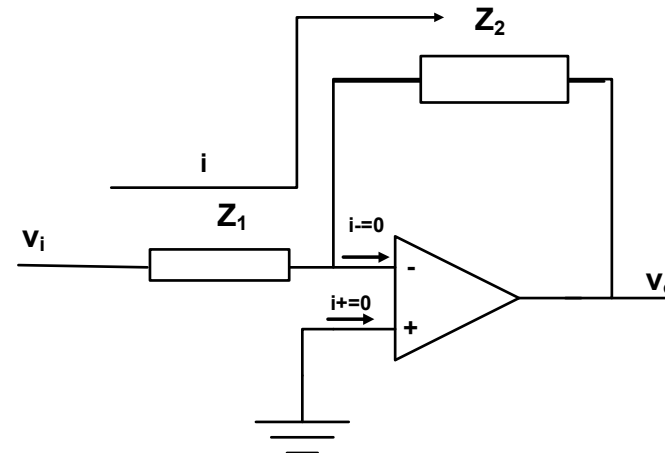
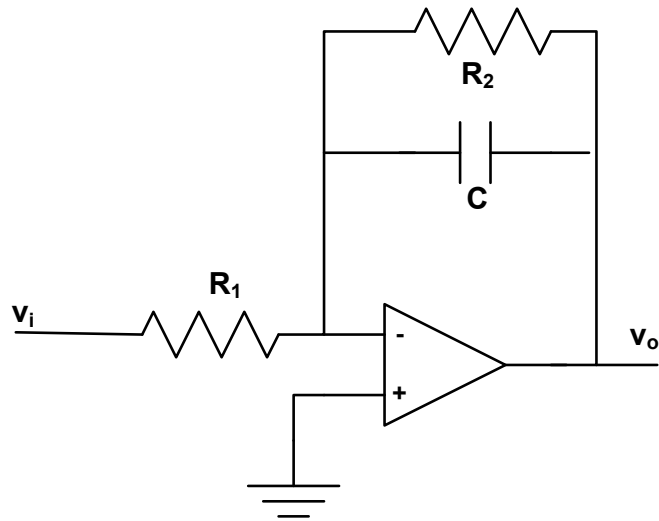


$$v_o = -R_F \cdot i_F$$

Circuito acondicionamiento fotodiodo



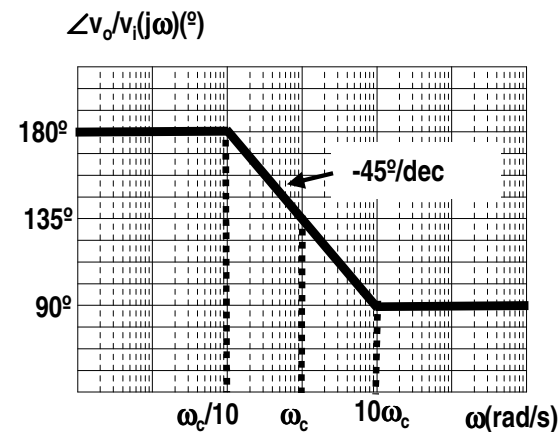
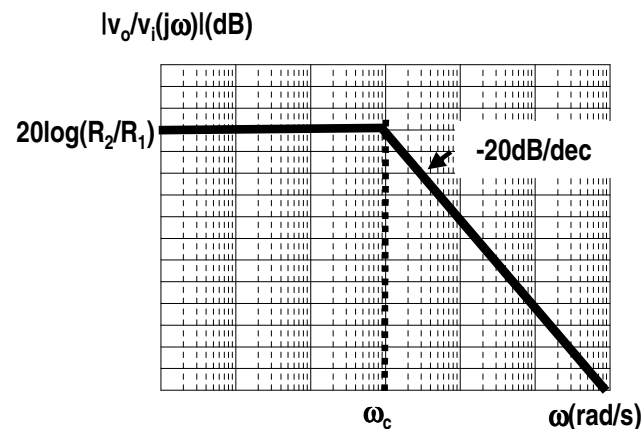
Filtro paso bajo/integrador



- Cortocircuito virtual: $v_+ = v_-$
- $i(Z_1) = i(Z_2) = i$

$$\frac{v_o}{v_i}(j\omega) = -\frac{Z_2}{Z_1} = -\frac{R_2}{R_1 + j\omega R_2 C} = -\frac{R_2}{R_1} \frac{1}{1 + j\omega R_2 C}$$

Polo: $\omega_c = \frac{1}{R_2 C}$



Aplicaciones NO lineales del amplificador operacional

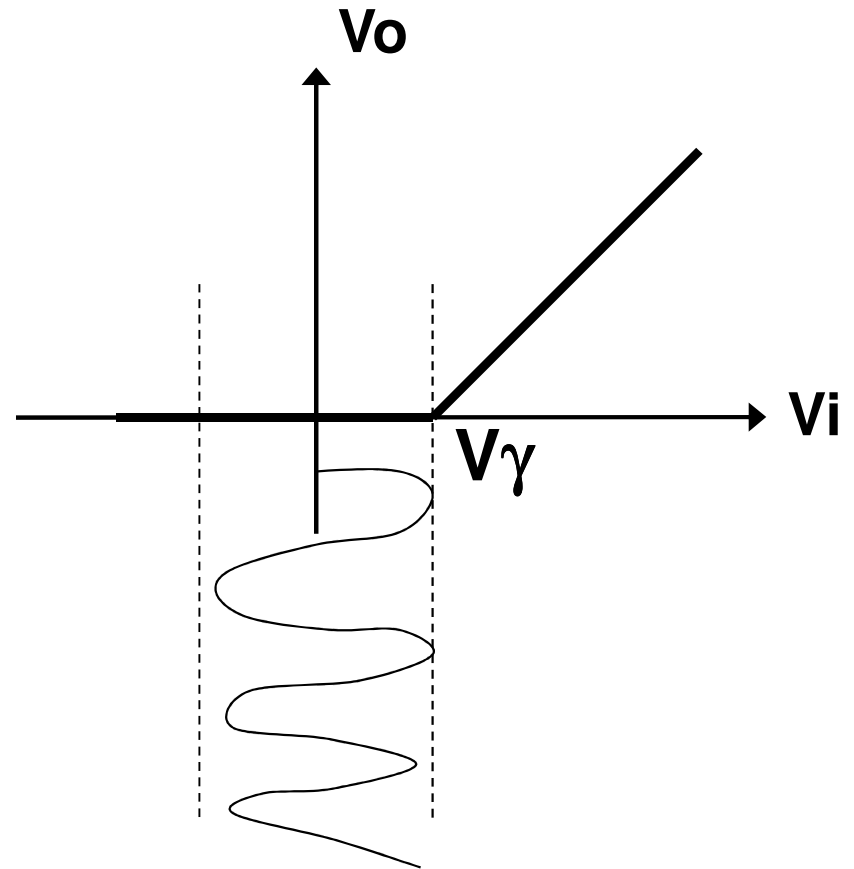
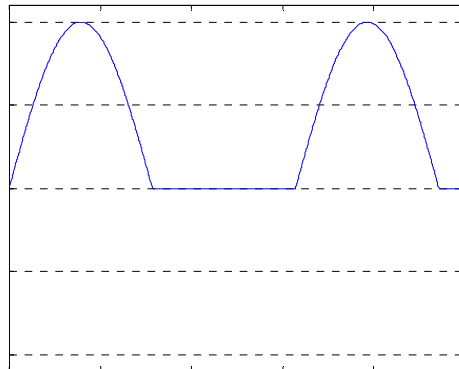
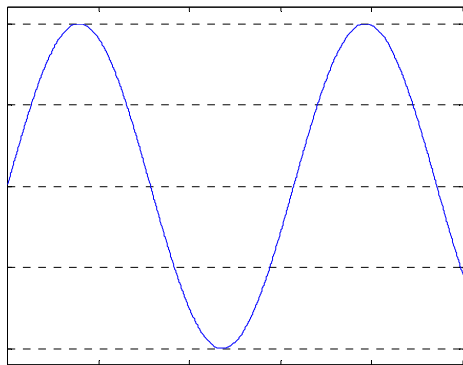
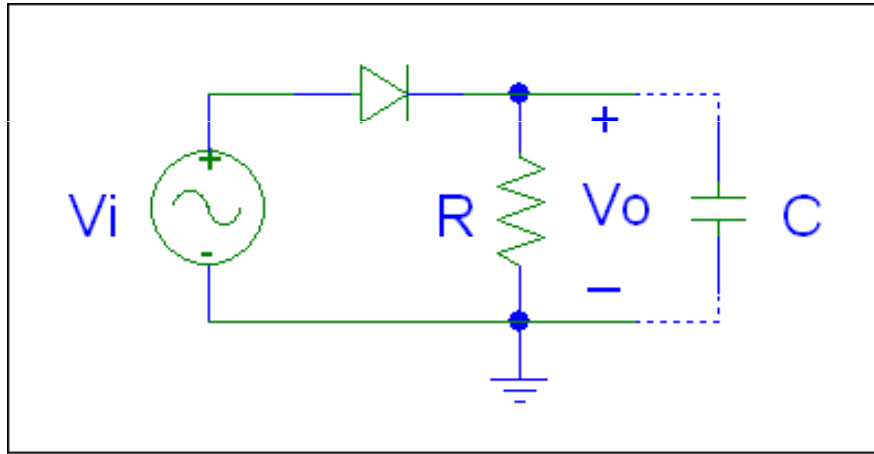
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- Circuitos con diodos
Limitadores y rectificadores de precisión
- Circuitos comparadores
- Comparador con histéresis
- Oscilador de relajación

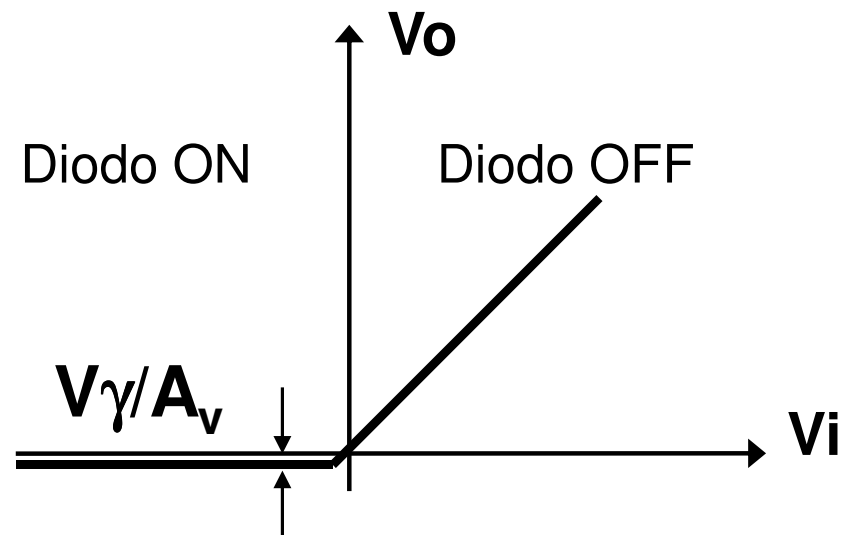
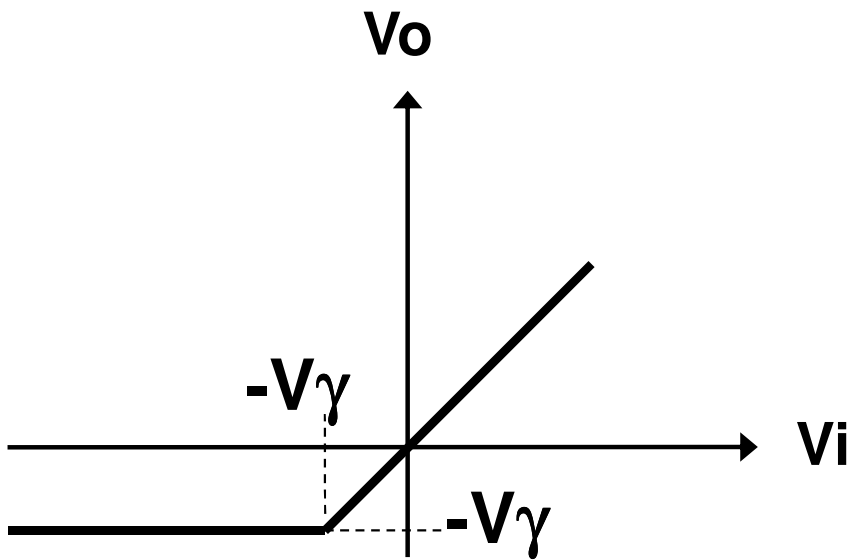
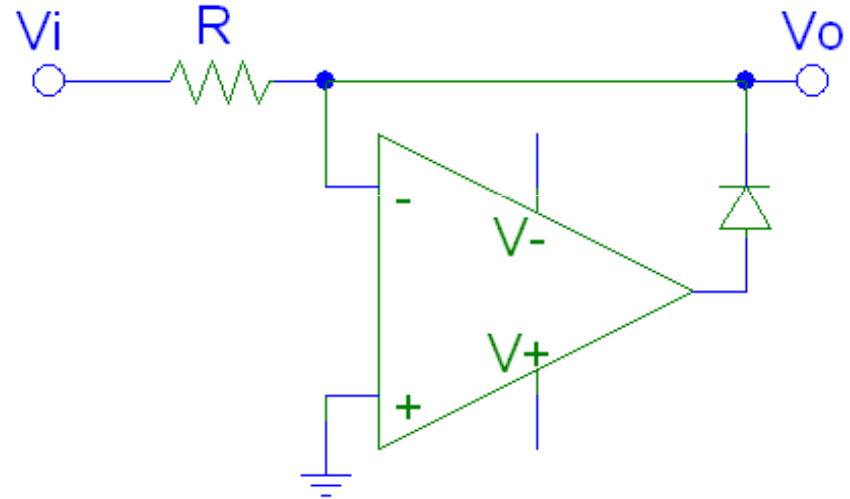
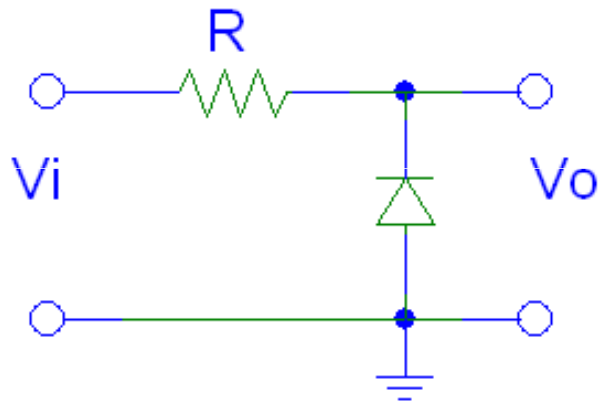
Aplicaciones No Lineales del Amplificador Operacional

Circuitos con diodos
Limitadores y rectificadores
de precisión

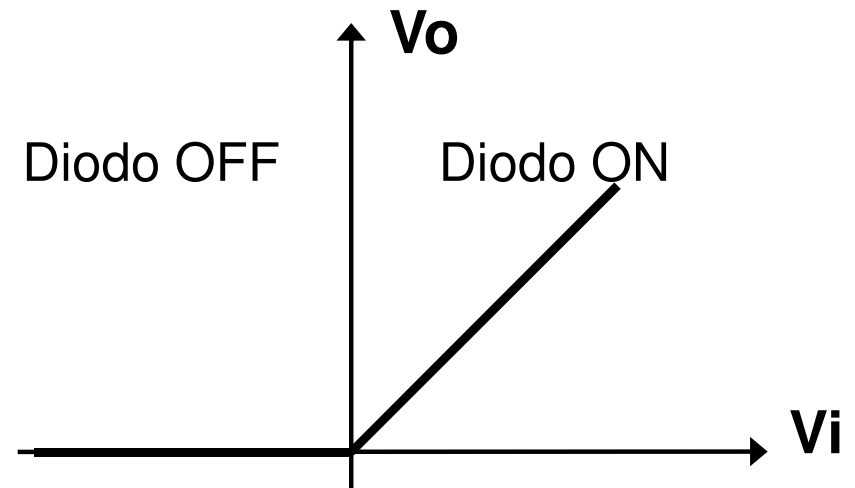
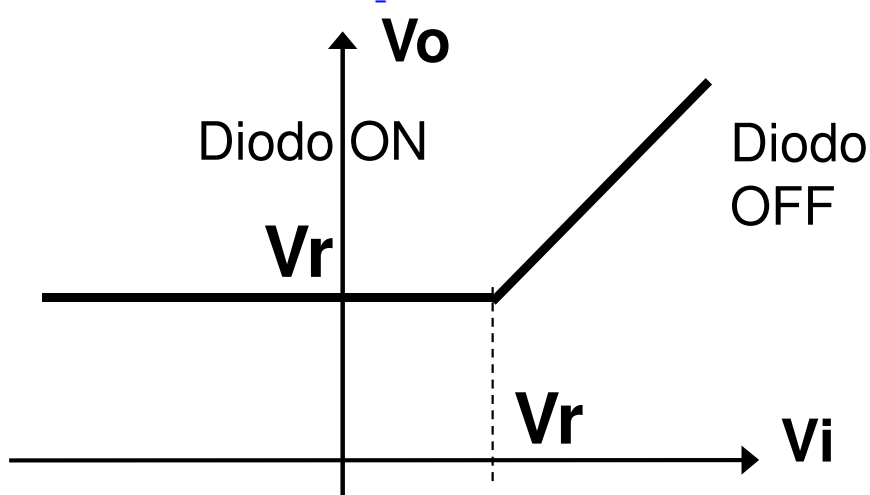
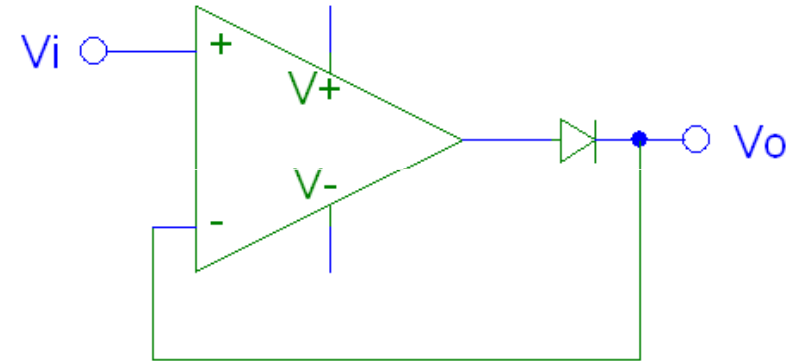
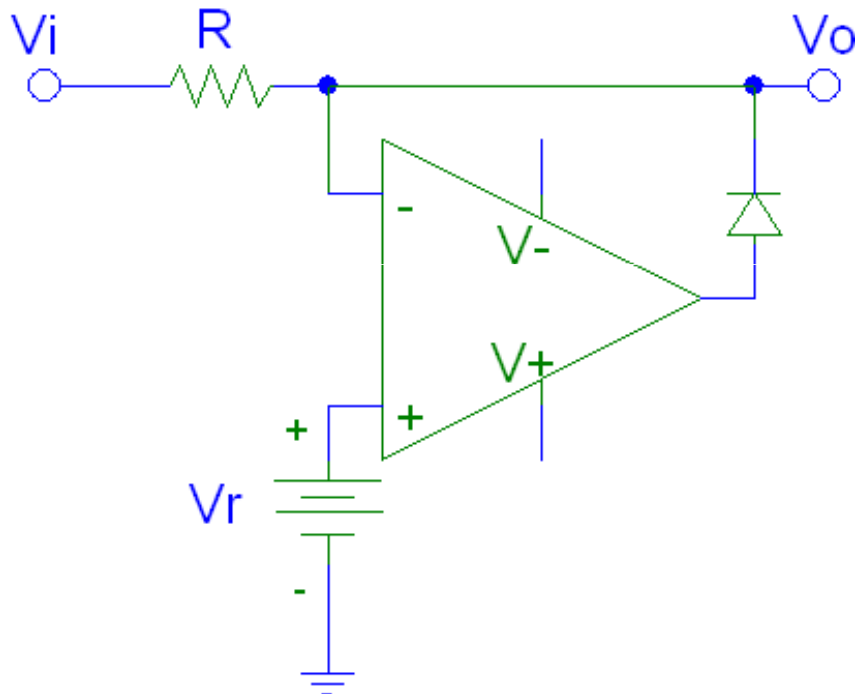
Problema a resolver con rectificadores de precisión



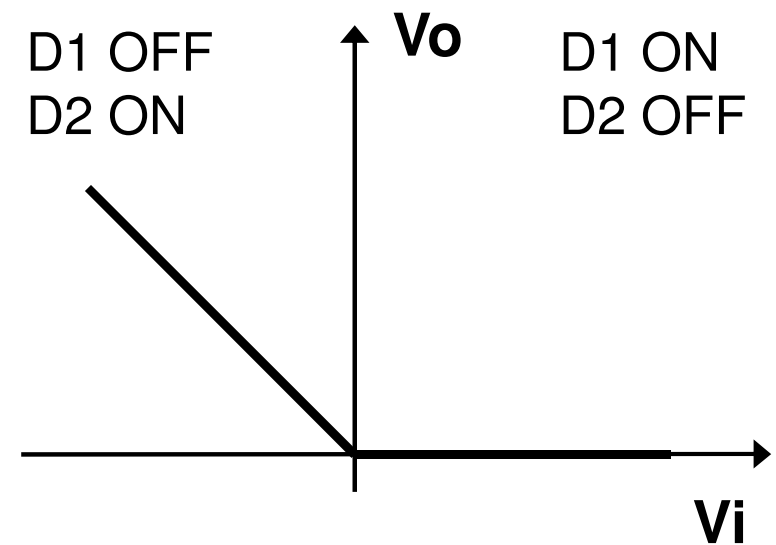
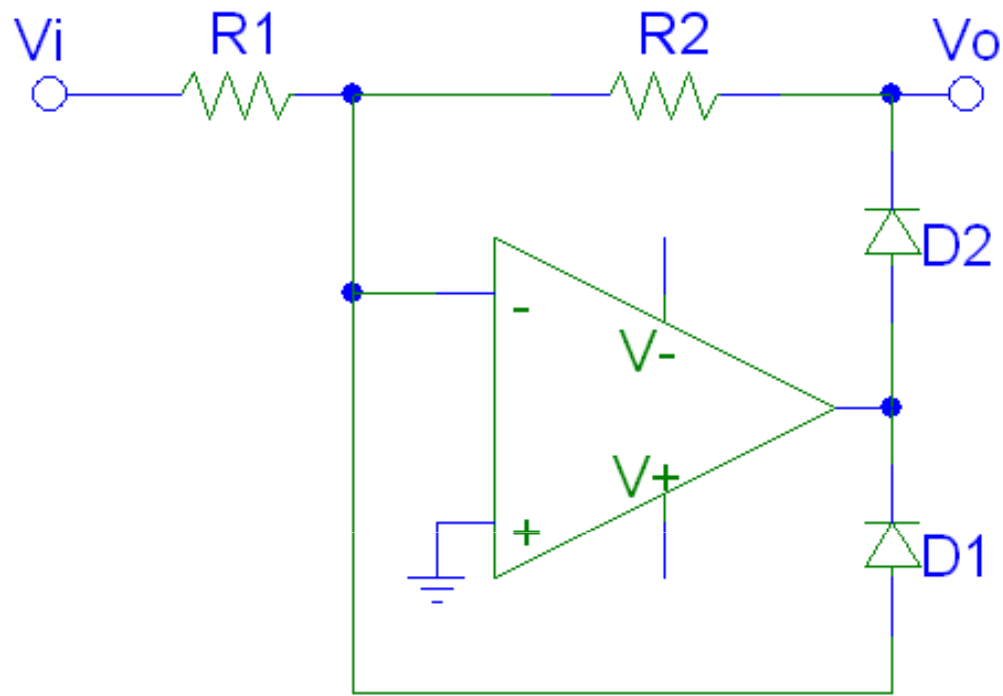
Limitador básico (por analogía)



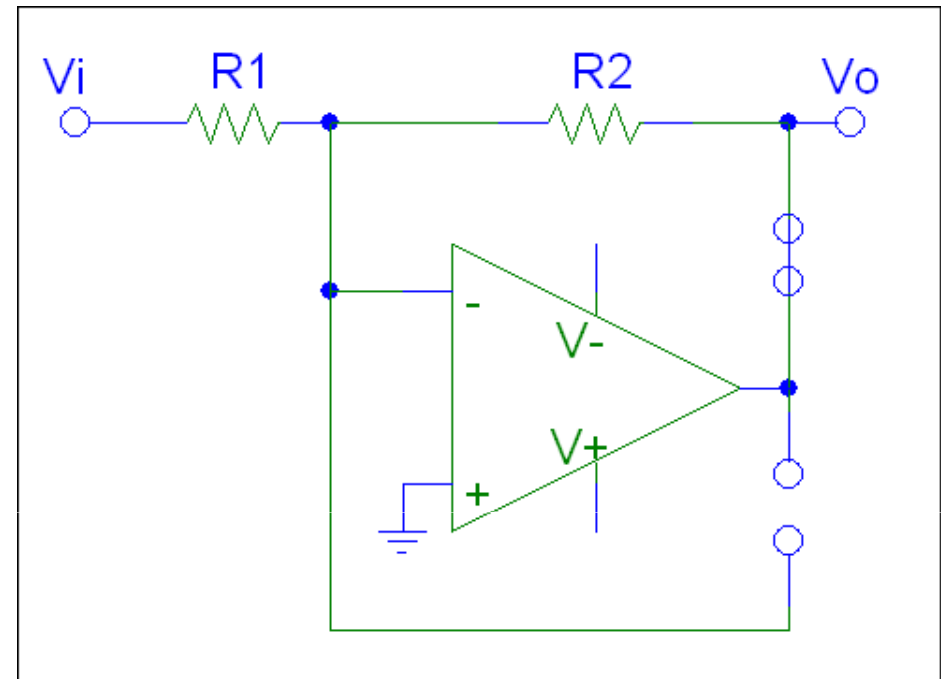
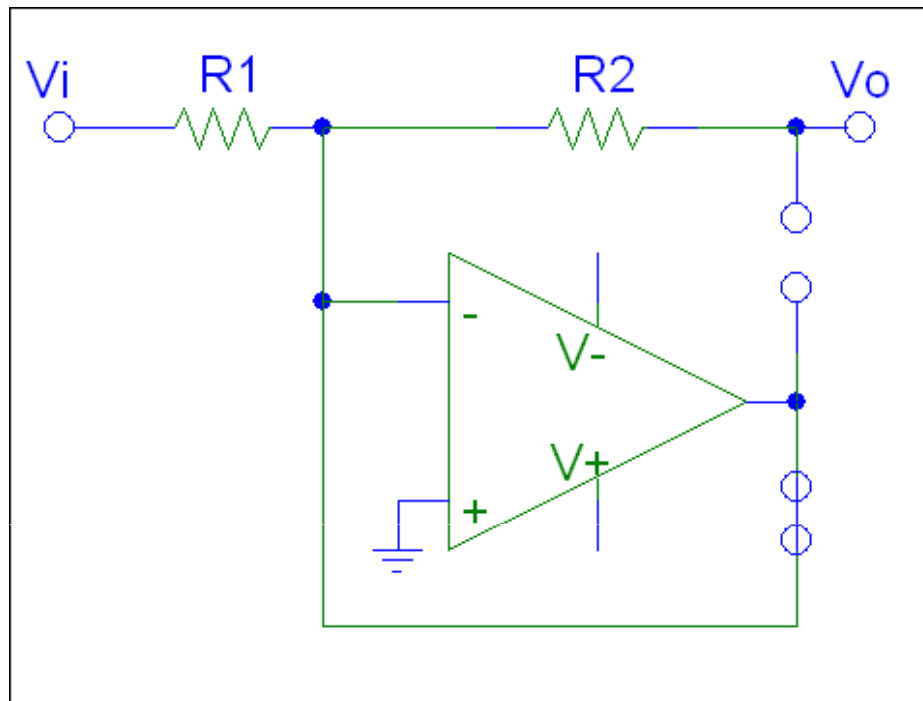
Otros limitadores



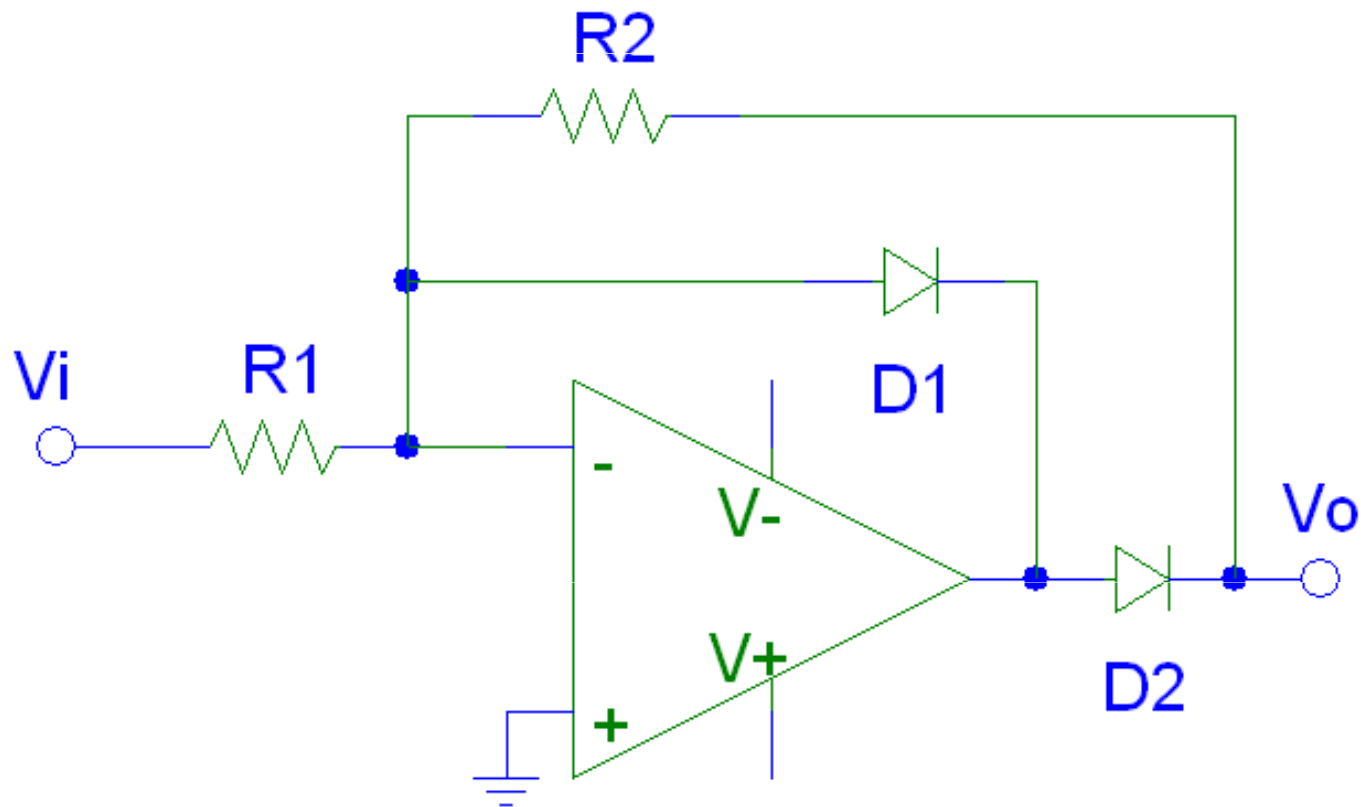
Rectificador de media onda



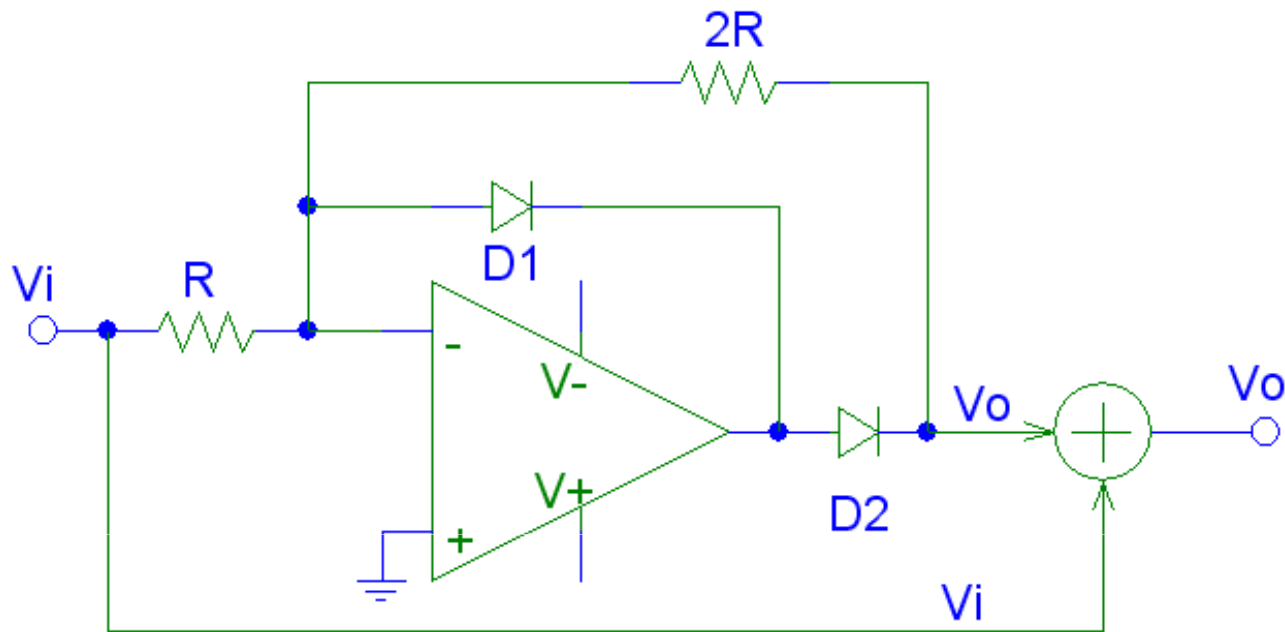
Análisis típico



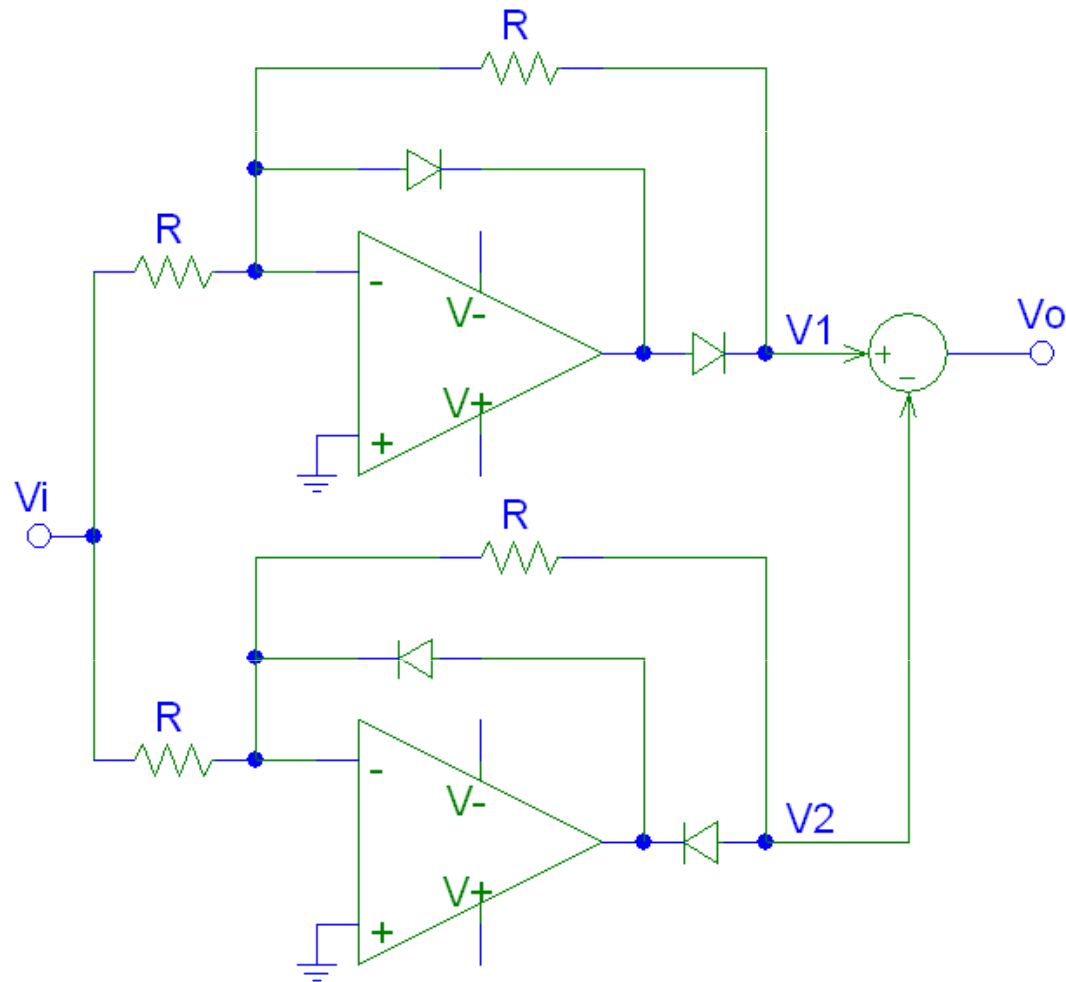
Rectificador de media onda



Rectificador de onda completa



Rectificador de onda completa

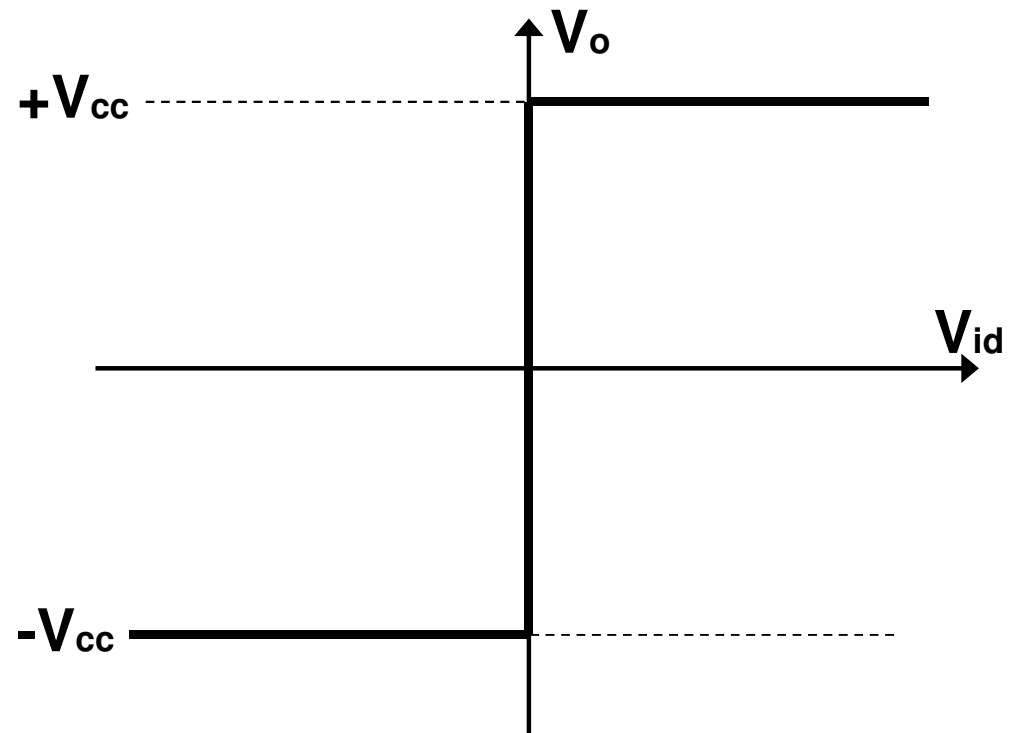
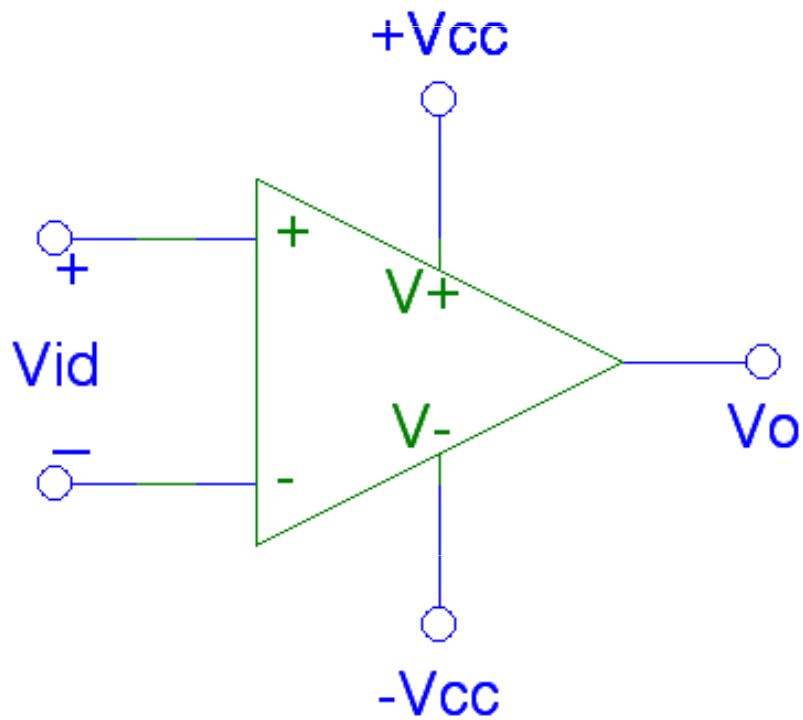


Aplicaciones No Lineales del Amplificador Operacional

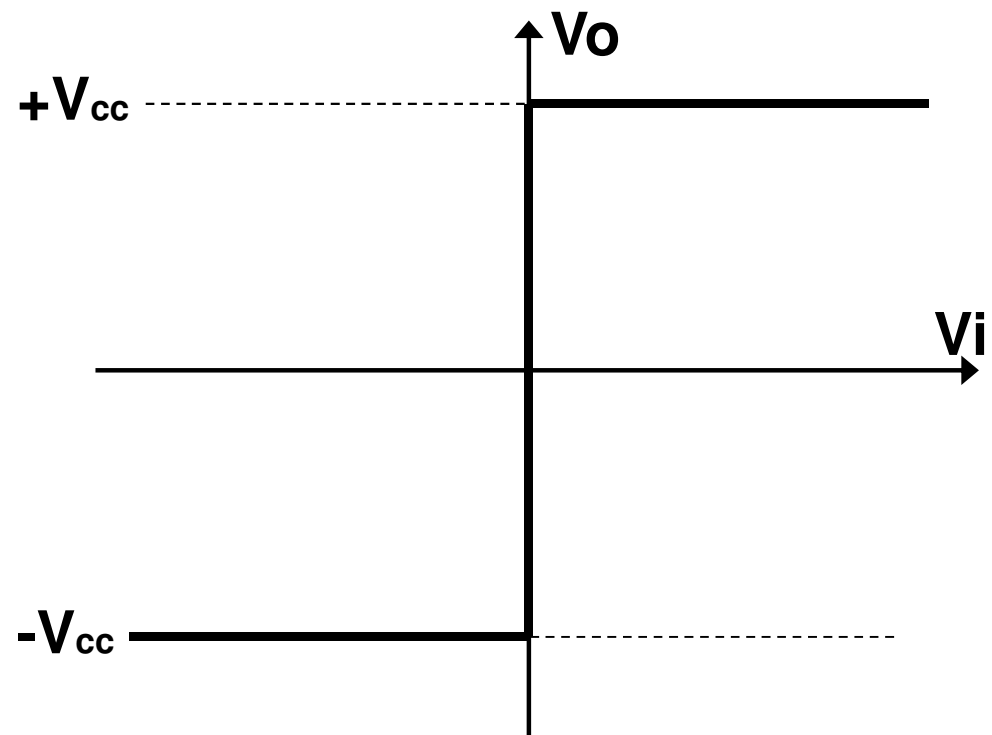
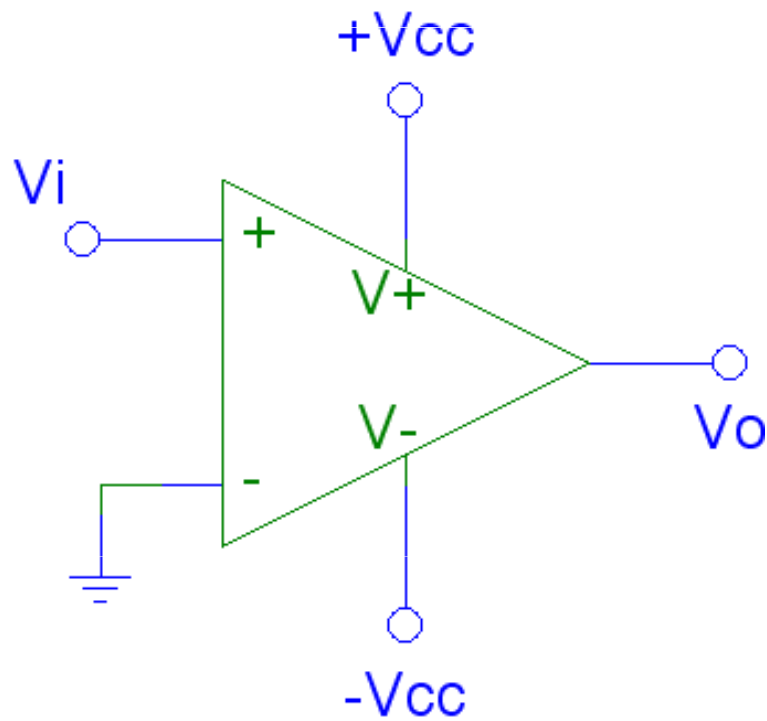
Comparador con histéresis

Oscilador de relajación

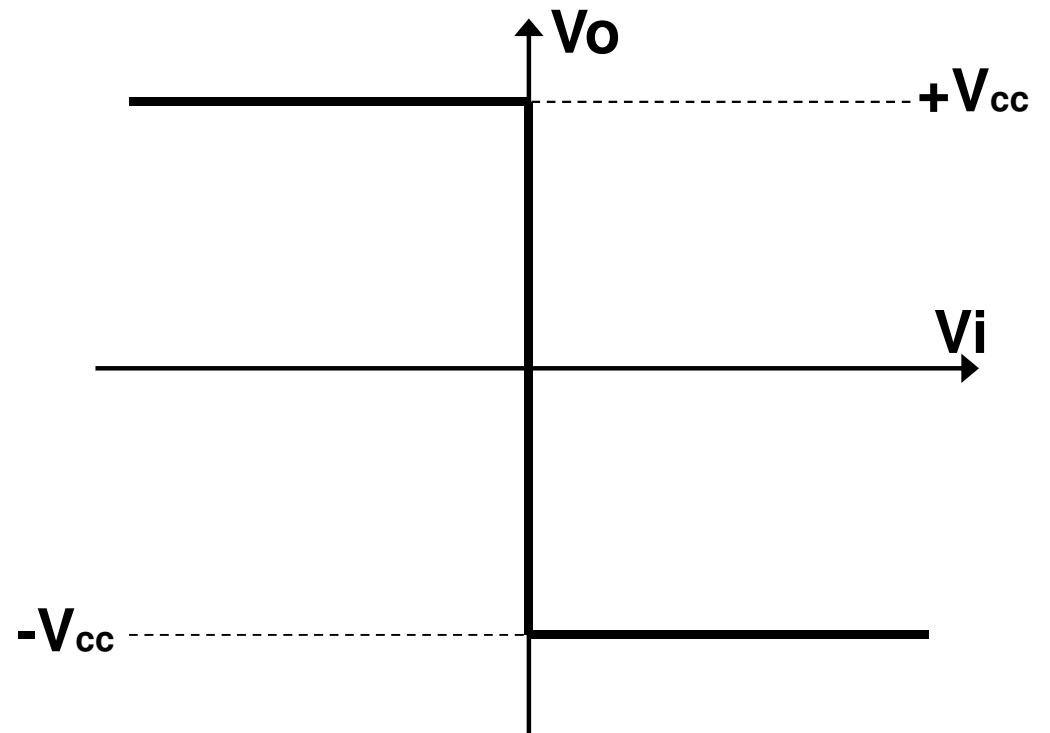
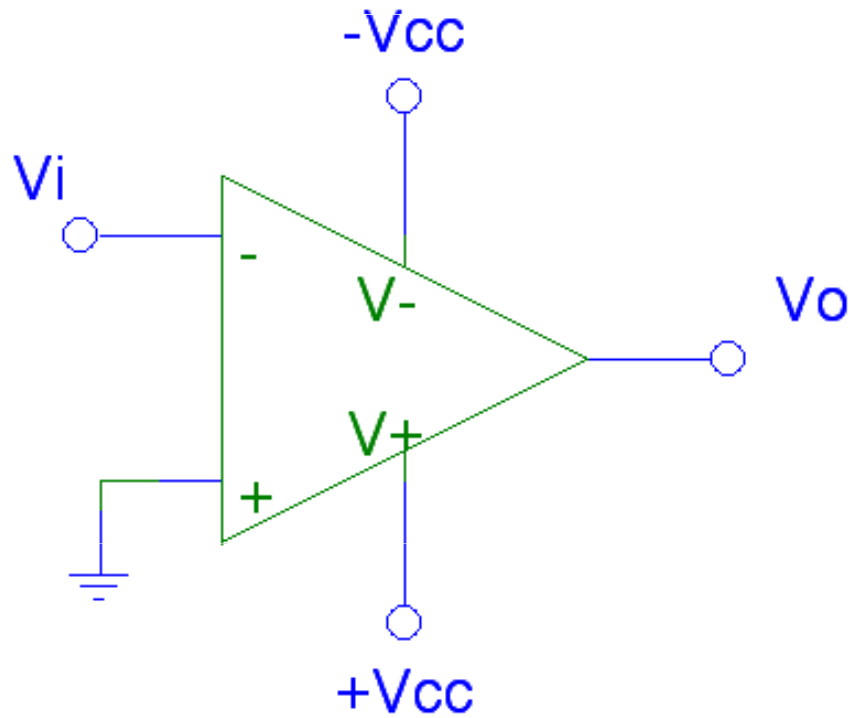
A.O. como comparador



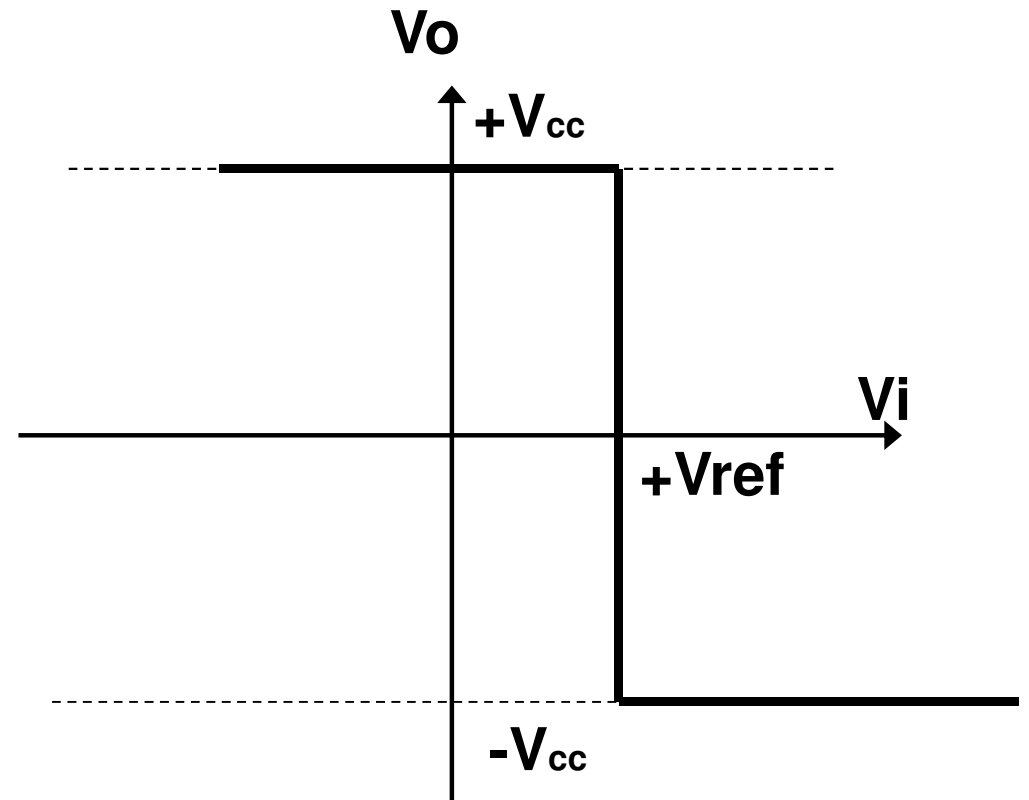
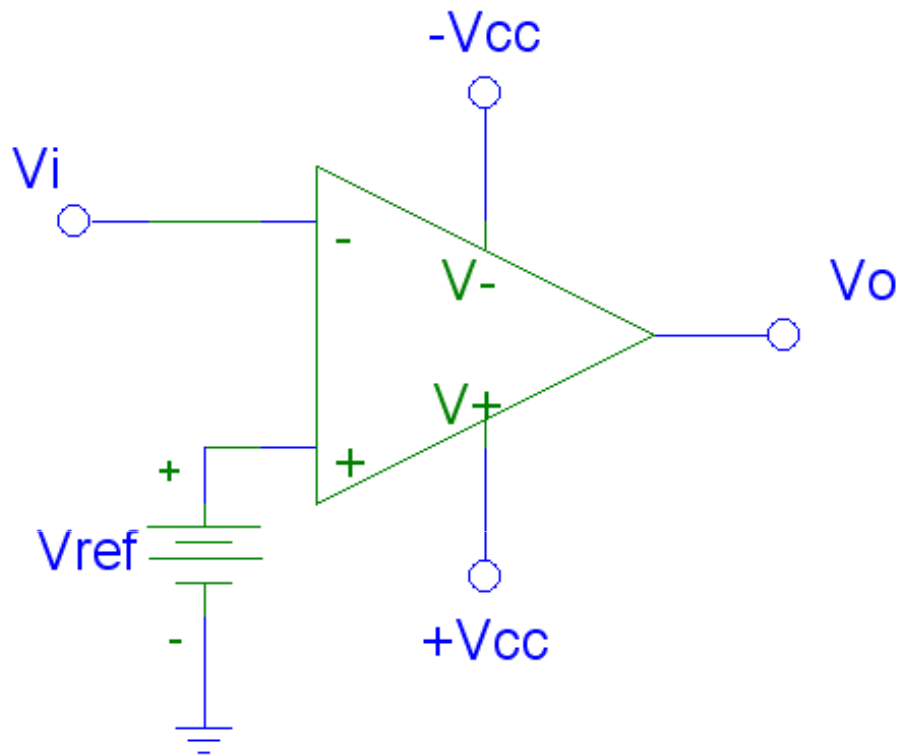
Comparador no inversor



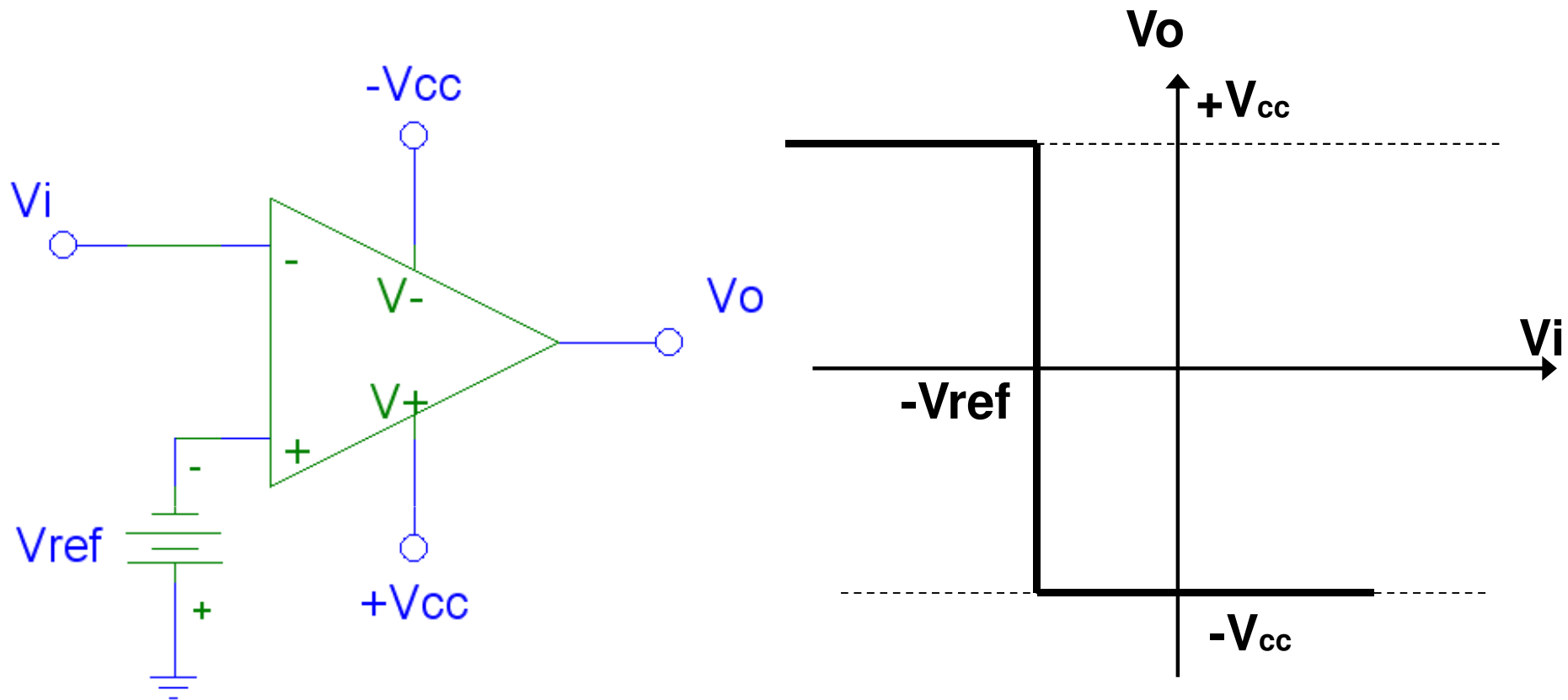
Comparador inversor



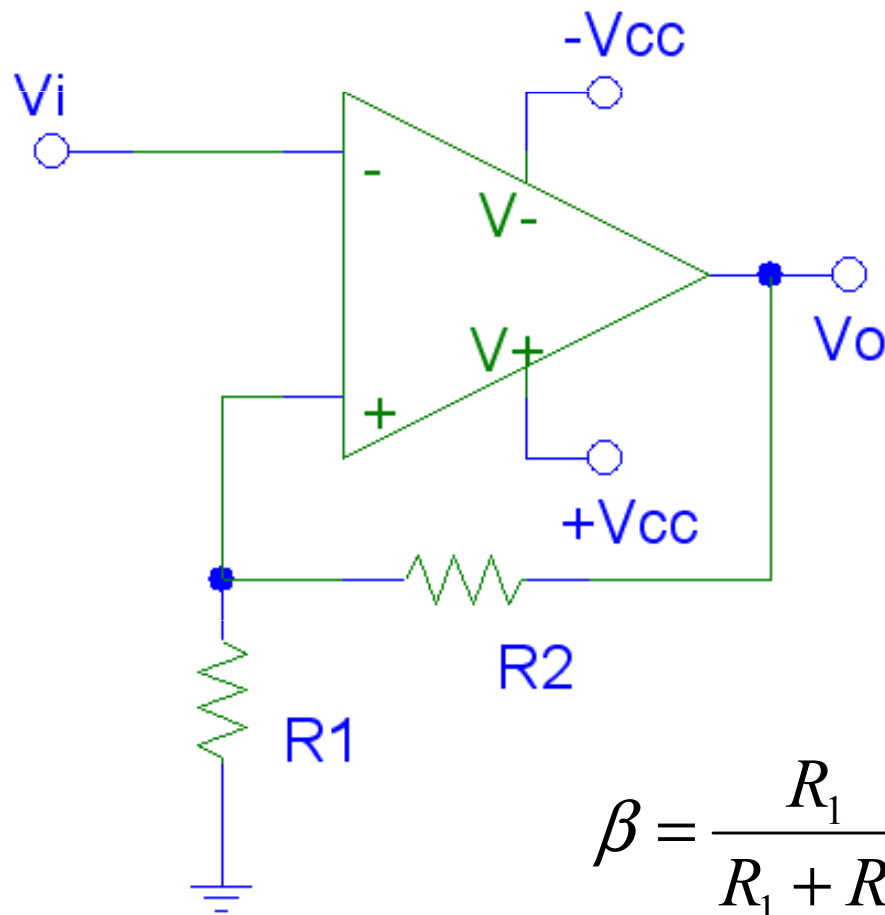
Comparador con una referencia



Ídem referencia negativa

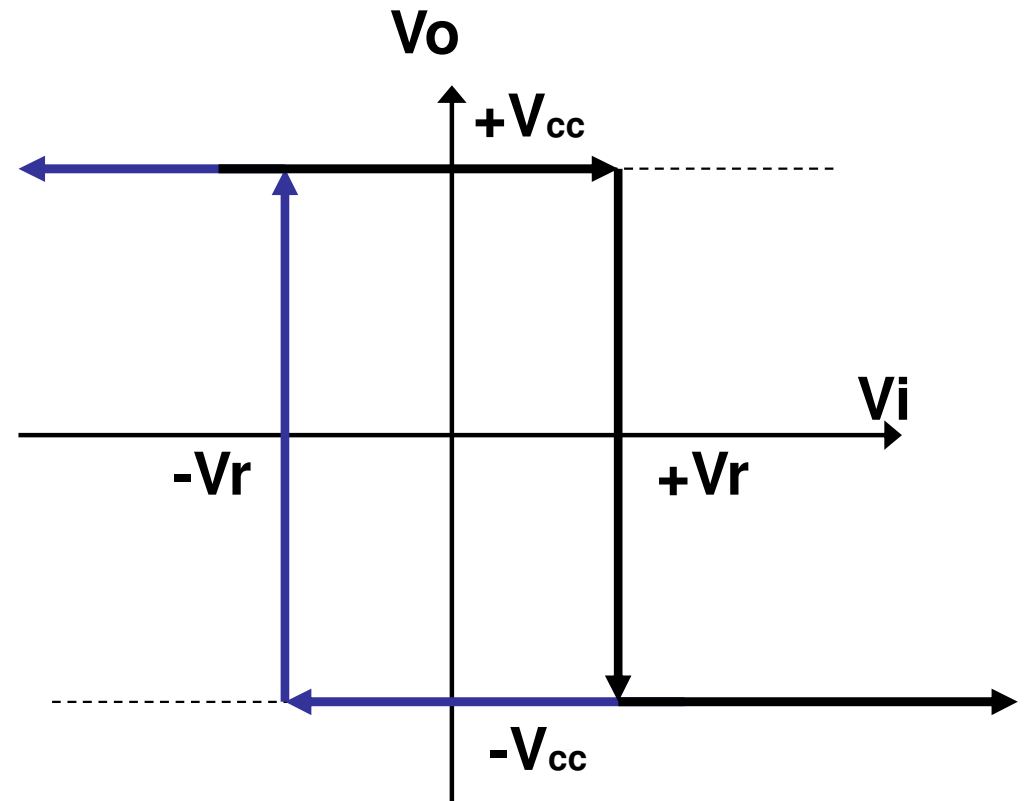


Comparador con Histéresis

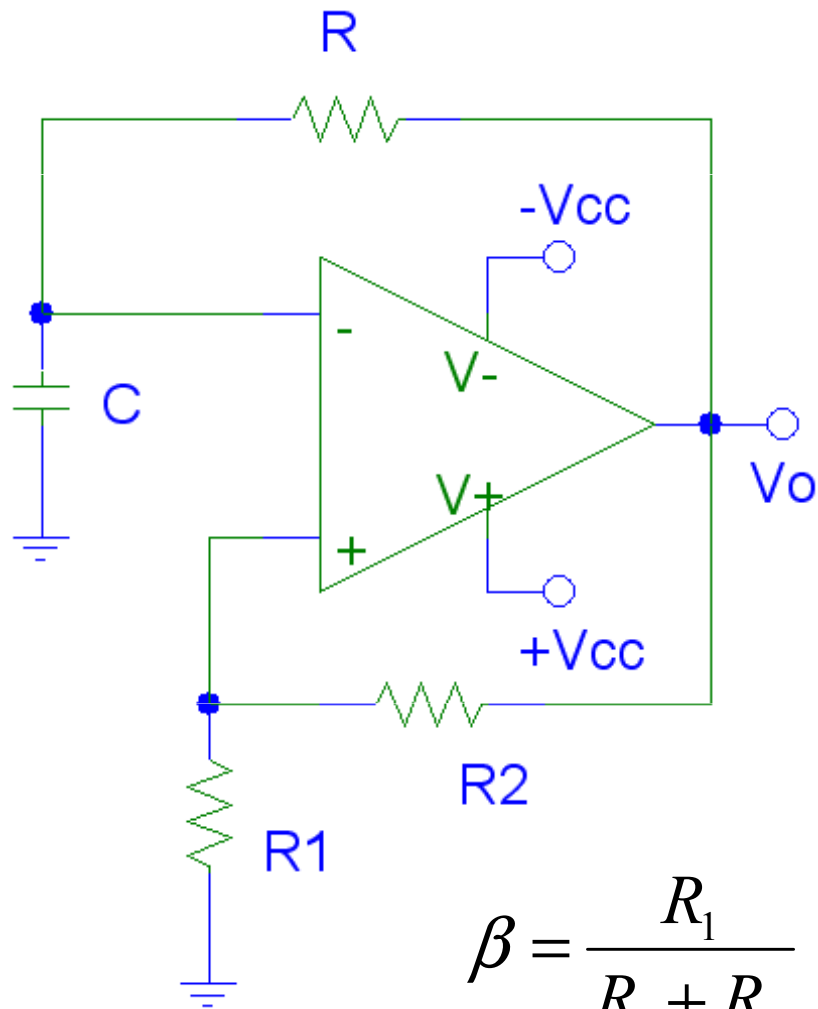


$$\beta = \frac{R_1}{R_1 + R_2}$$

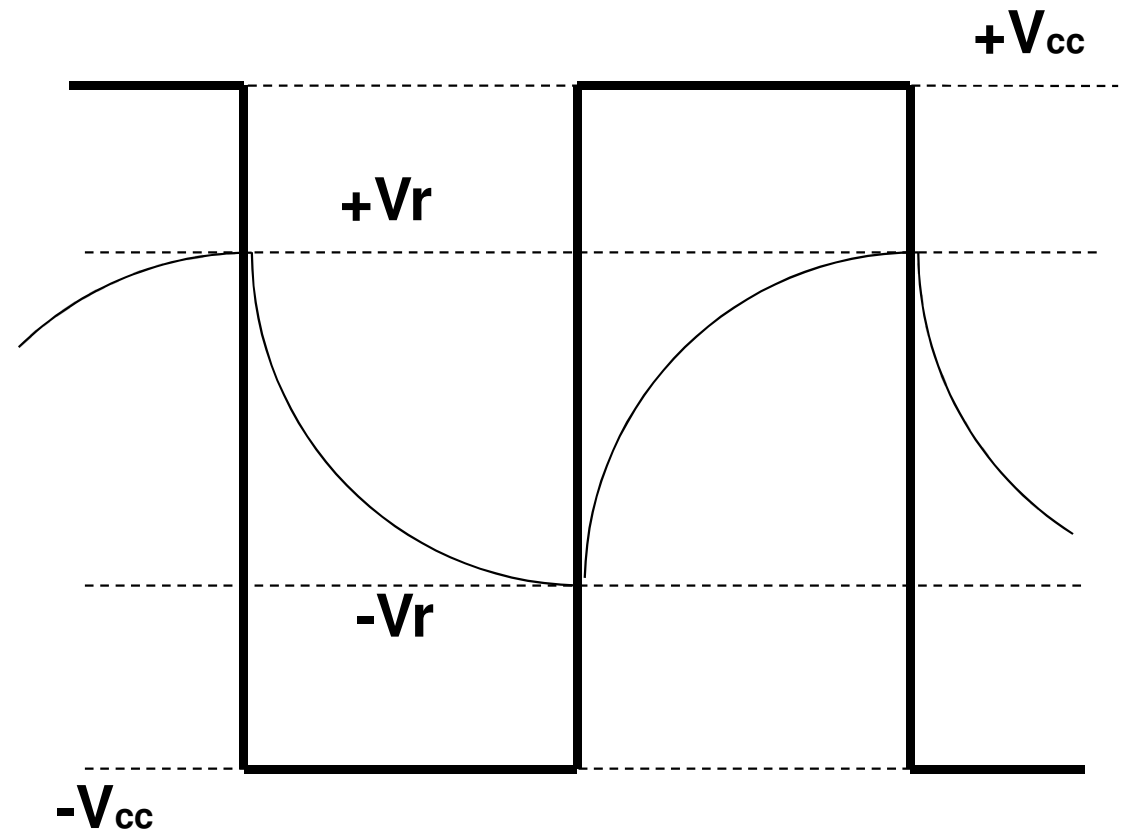
$$V_r = \beta \cdot V_{CC}$$



Oscilador de relajación

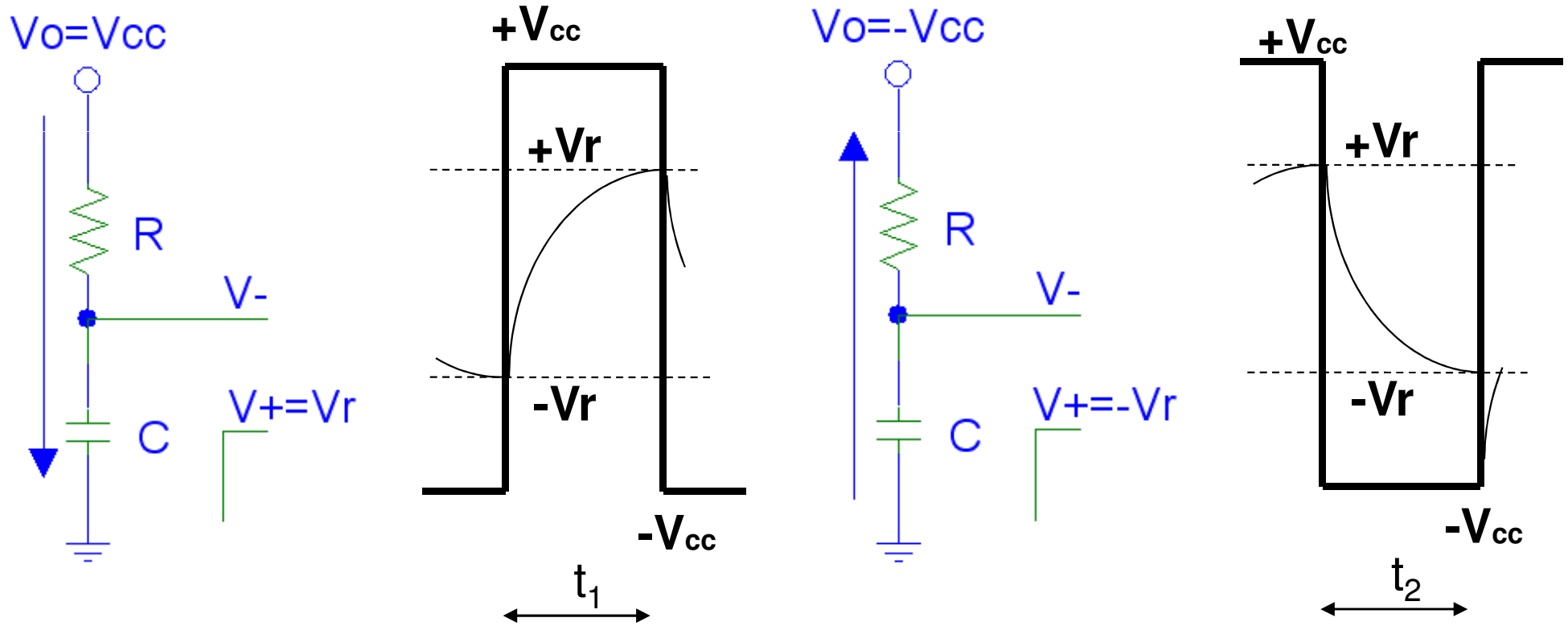


$$\beta = \frac{R_1}{R_1 + R_2}$$



$$V_r = \beta \cdot V_{cc}$$

Temporización (Frecuencia de Oscilación)

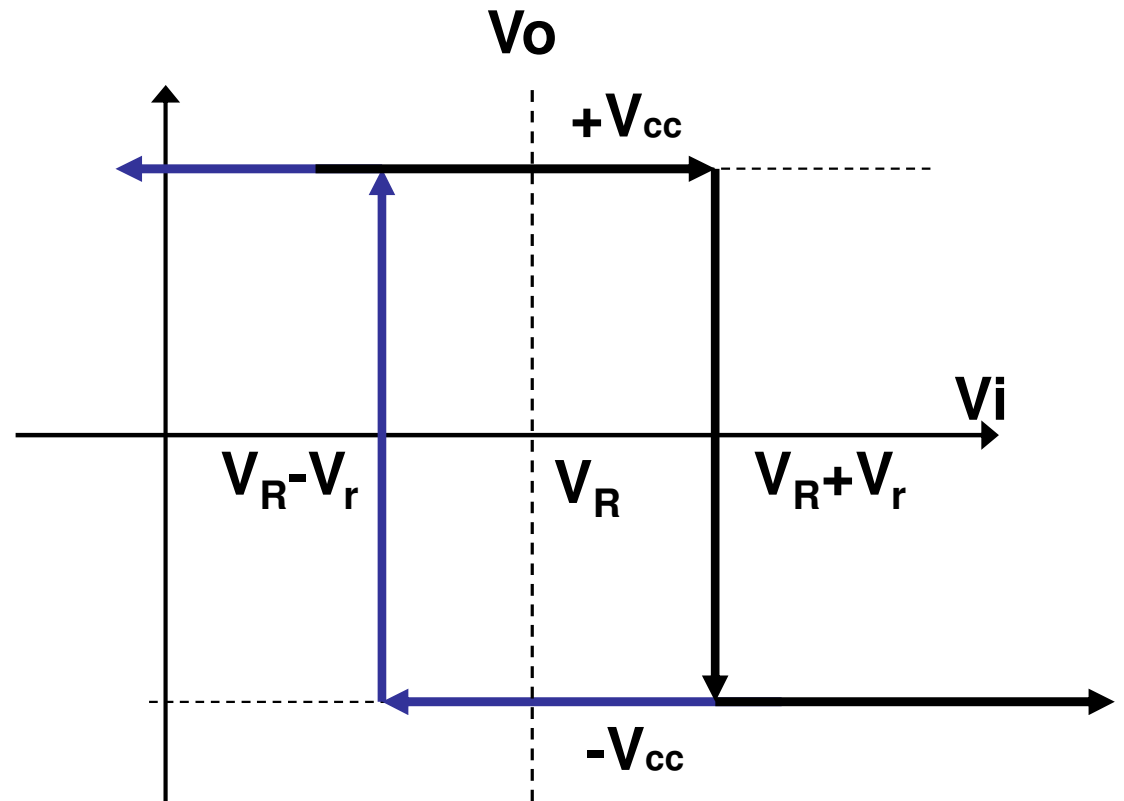
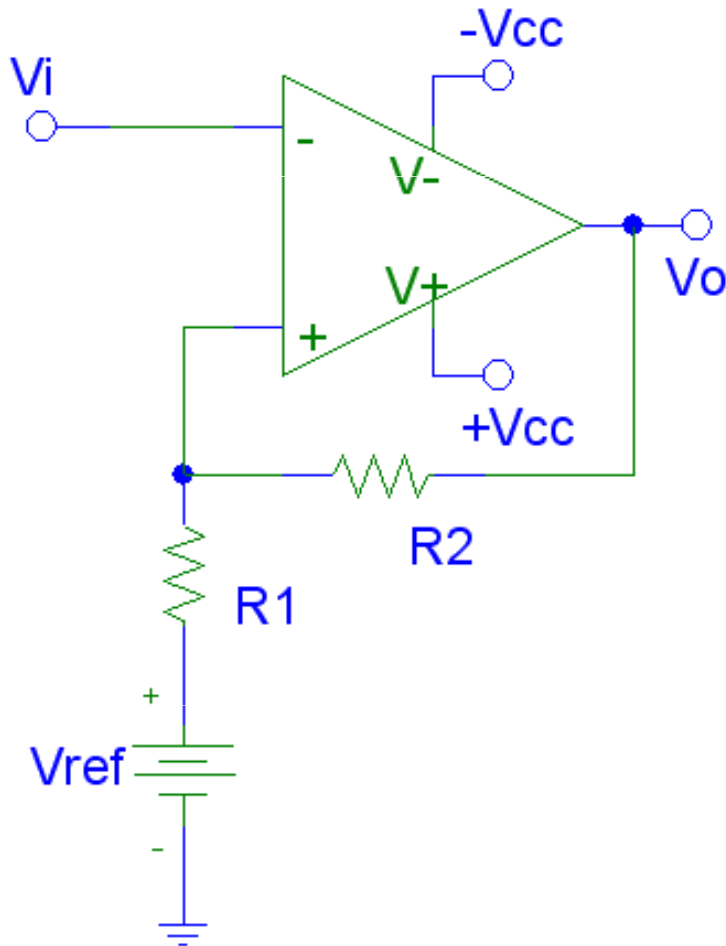


$$t_1 = t_2 = RC \ln \left(1 + \frac{2R_1}{R_2} \right)$$

$$T = 2t_2 = 2RC \ln 3 \approx 2,2RC$$

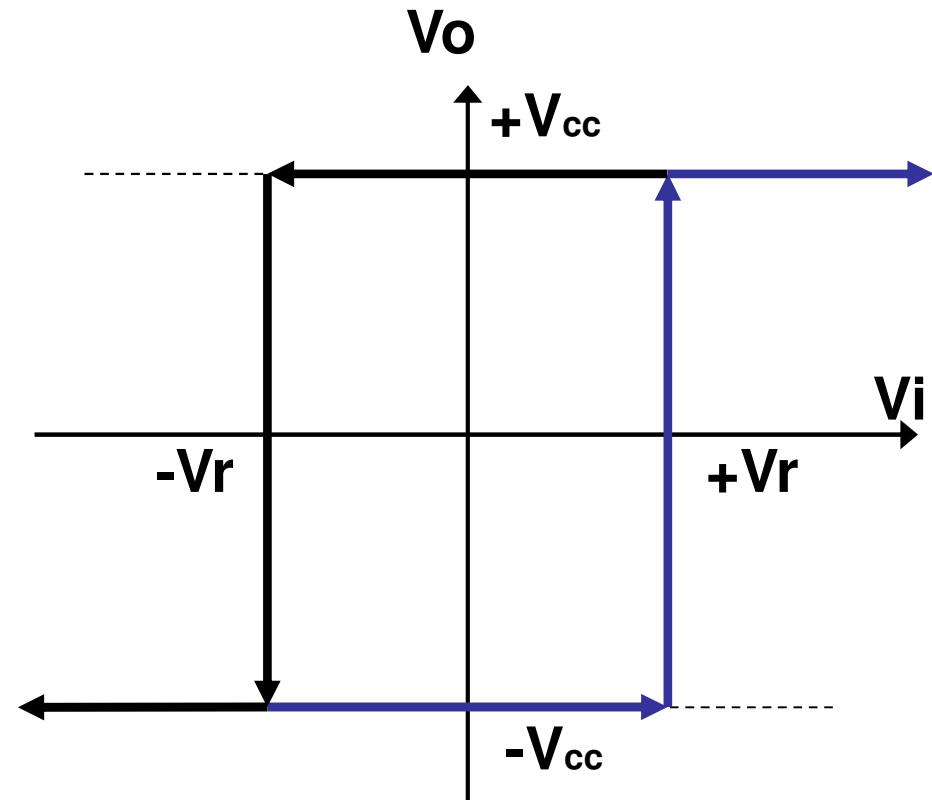
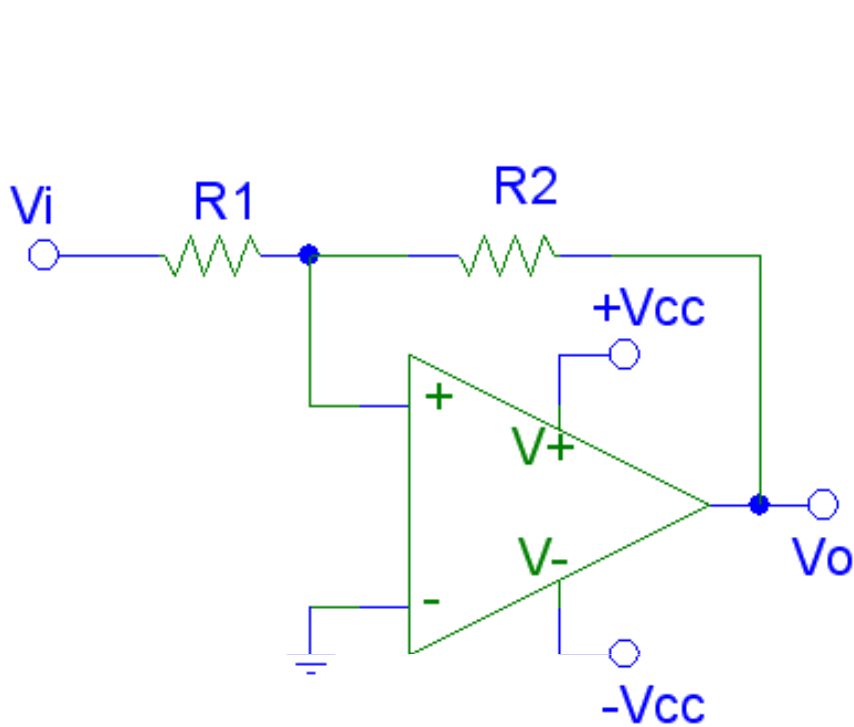
$$\text{si } R_1 = R_2$$

Histéresis con Umbral V_R



$$V_R = \frac{R_2}{R_1 + R_2} V_{ref} \quad V_r = \frac{R_1}{R_1 + R_2} V_{cc}$$

Comparador con histéresis NO inversor



$$\beta = \frac{R_1}{R_2}$$

$$V_r = \beta \cdot V_{CC}$$

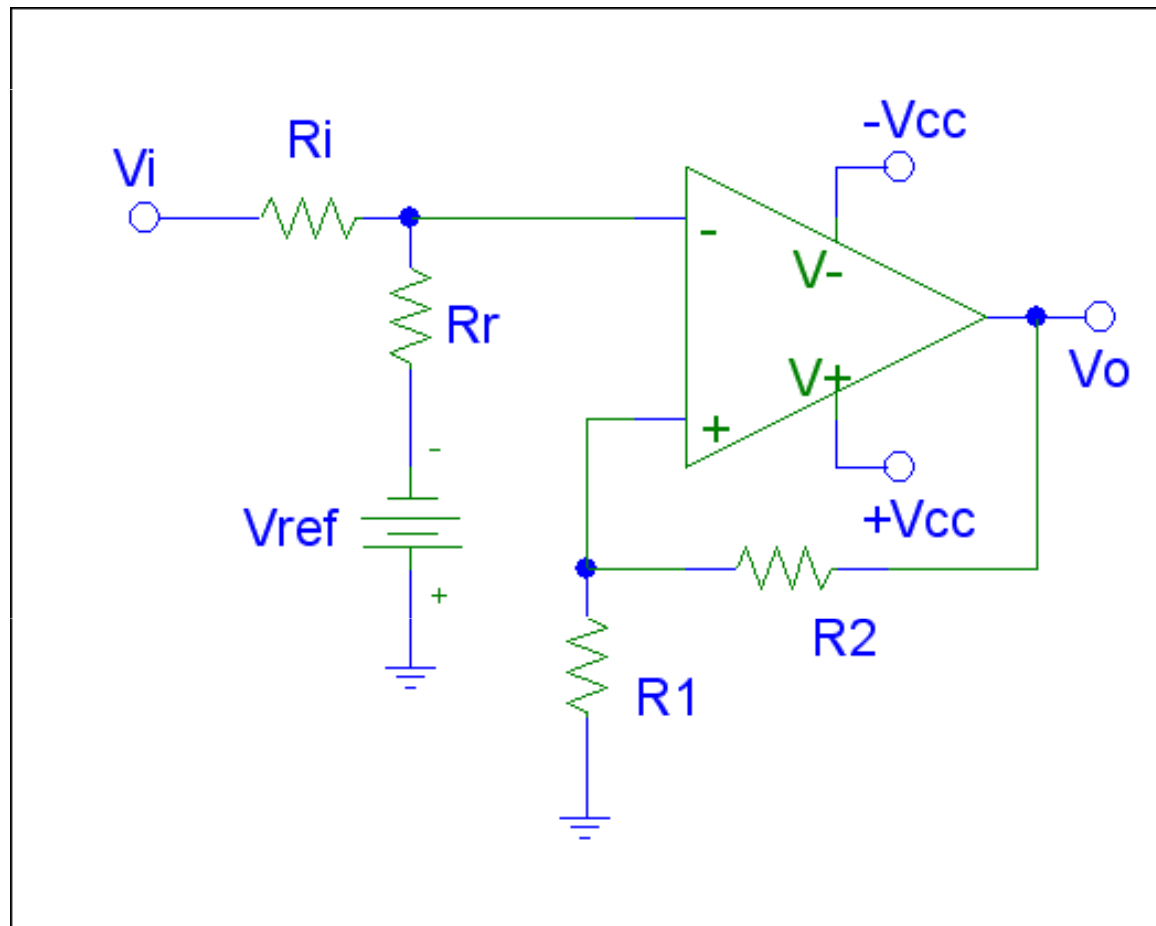
Aplicaciones No Lineales del Amplificador Operacional

Otros circuitos Comparadores

Generador de onda triangular

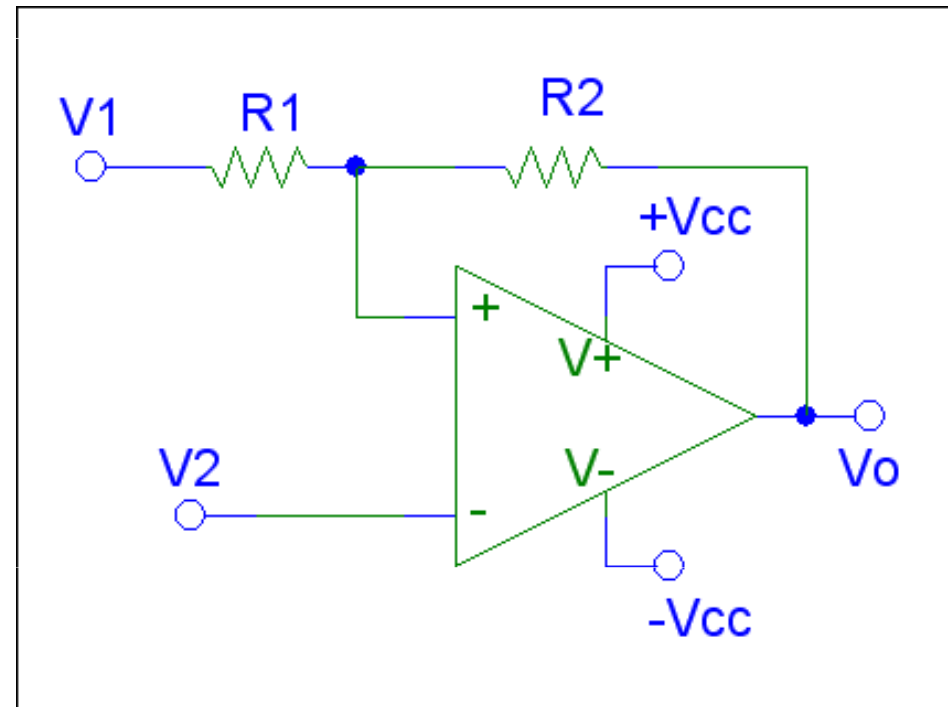
Otros circuitos comparadores

Histéresis con umbral V_R (II)

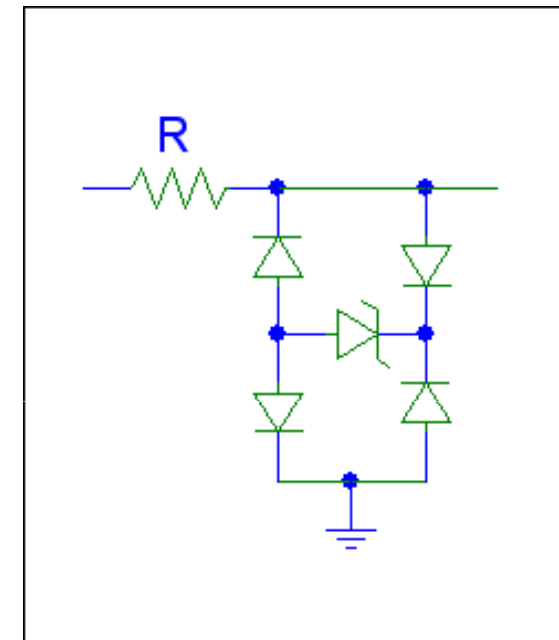
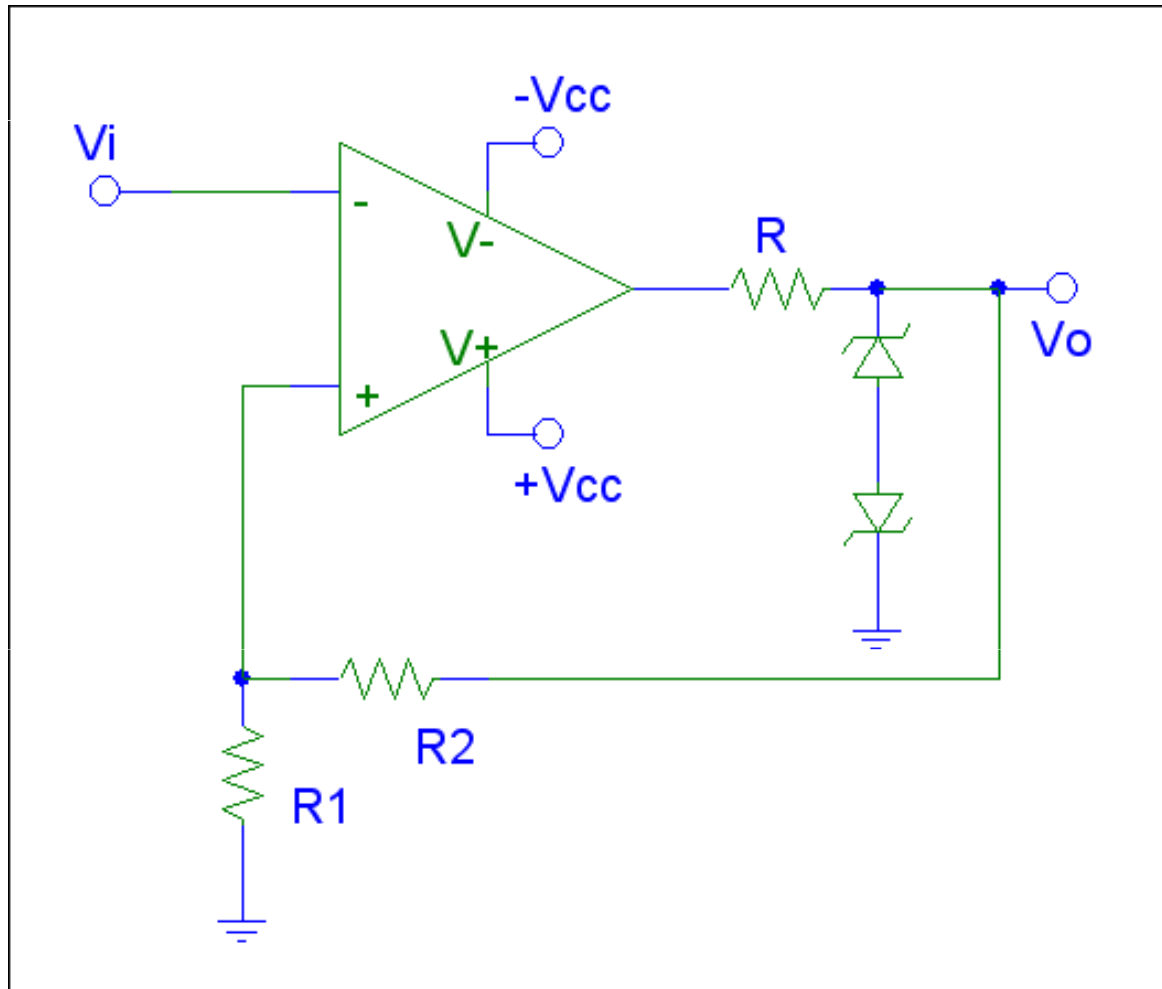


Otros circuitos comparadores

Comparador con histéresis generalizado

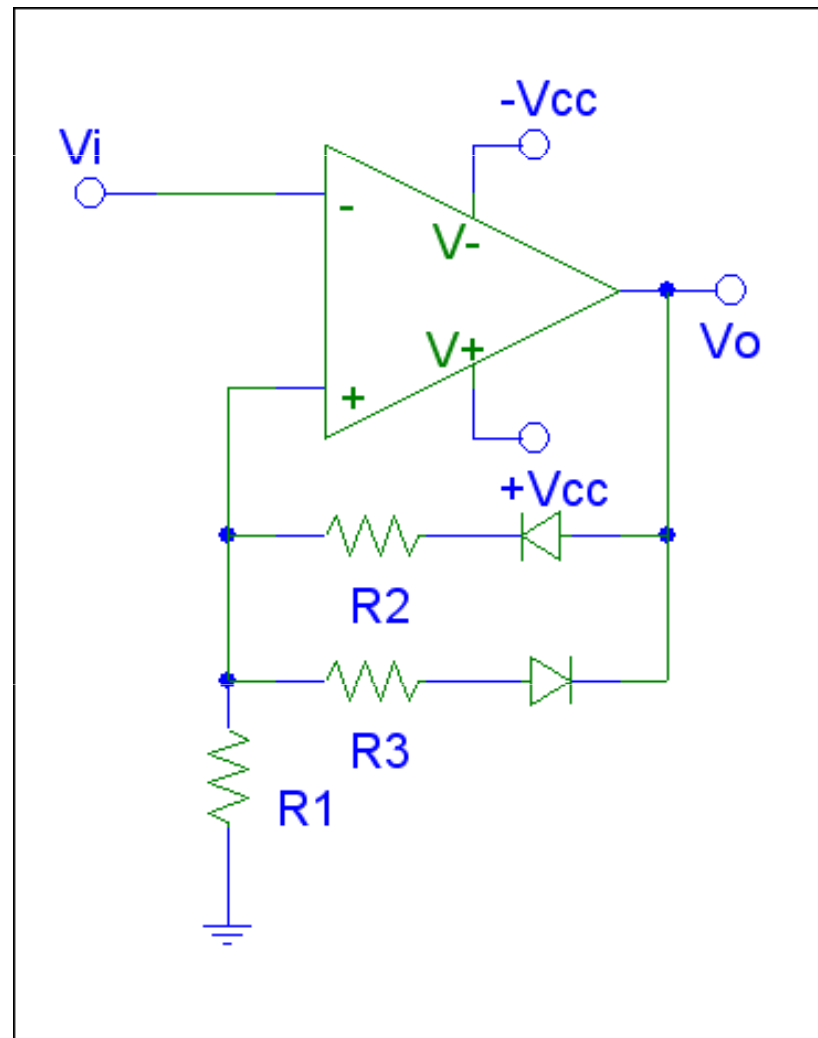


Otros circuitos comparadores (Limitación del rango de salida)



Otros circuitos comparadores

Histéresis asimétrica



Generación de pulsos

