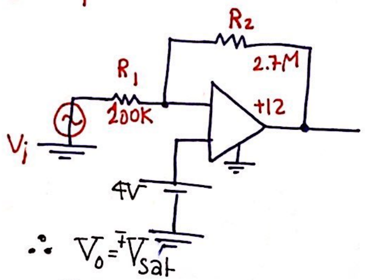
Electronics 236 → L21, Part 1 Opamp Active filters

Example : assume V_i is sine wave
1- find & Sketch $V_o(t)$
2- find & Sketch $V_o = f(V_i)$



$\therefore V_o = \mp V_{sat}$

$\therefore +V_{sat} = 12 - 2 = 10\ V$

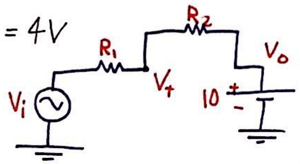
$-V_{sat} = 0 + 2 = 2\ V$

Solution: this is the Schemitic Triggar "Positive feedback"

[1] let $V_o = +V_{sat} = 10$

$V_+ > V_-$; but $V_- = 4V$

Find V_+ ?



Eq. circuit : two-Sourses → Use saperpos.

Kill Vi ⇒ $V_+ = \frac{R_1}{R_1+R_2} \cdot 10 = \frac{0.1}{2.8} \cdot 10 + \frac{R_2}{R_1+R_2} \cdot V_i > V_- = 4$; $\frac{R_2}{R_1+R_2} \to \frac{2.7}{2.8}$

$V_i > \left(4 - \frac{1}{2.8}\right) \cdot \frac{2.8}{2.7} = 3.777$

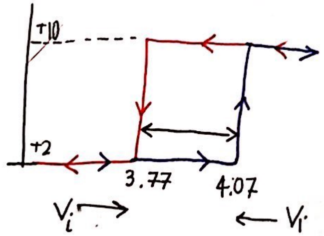
but when $V_i \downarrow < 3.77 \to V_o$ From $+V_{sat}$ to $-V_{sat}$

[2] let $V_o = -V_{sat} = 2$

$V_+ < V_- \Rightarrow V_+ = \frac{R_1}{R_1+R_2} \cdot 2 + \frac{2.7}{2.8} V_i < 4$

$V_i < \left(4 - \frac{0.2}{2.8}\right) \times \frac{2.8}{2.7} = 4.07\ v$

When $V_i < 4.07$, $V_o = -V_{sat}$ & switches ~~from~~ to $+V_{sat}$ if $V_i > 4.07V$

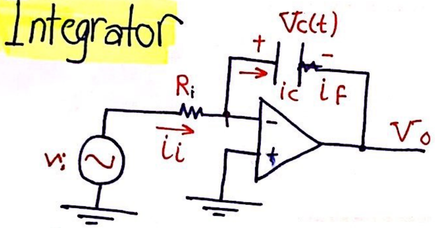


Hysteresis = 4.07 - 3.777
= 0.3 V

Other OP-Amp Applications

- Active filters (To remove loading effect & provide Gain)
- Integrator
- Differentiator

Integrator



$$I_i = I_c = I_f = \frac{V_i}{R_i}$$

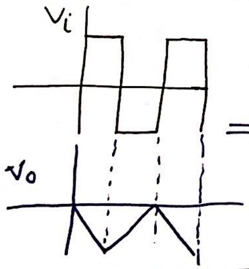
$$I_c = C\frac{dV_c}{dt}$$

$$\therefore V_c(t) = \frac{1}{C}\int_0^T i_f(t)\,dt$$

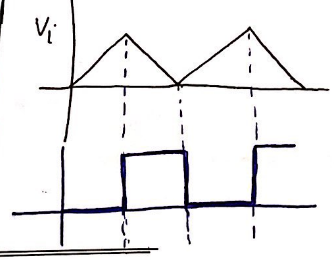
also $V_o = -V_{c(t)}$

$$V_o = \frac{-1}{C}\int_0^T \frac{V_i(t)}{R_i}\,dt = \frac{-1}{RC}\int V_i(t)\,dt$$ "Output is $\int$ of Input"

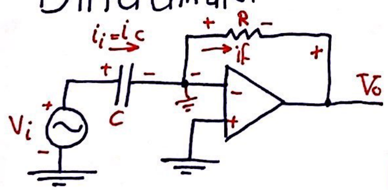
يعني لما احط قيم موجبة بطلع متناقص ولما احط قيم سالبة بطلع متزايد



⇒ Integrator



Differentiator



$$i_c = i_i = i_f$$

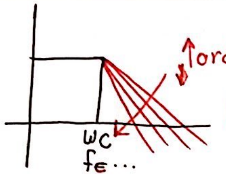
$$i_c = C\frac{dV_c}{dt}$$

$$V_o = -I_f R$$

$$V_o = -RC\frac{dV_c}{dt} \Rightarrow V_o = -RC\frac{dV_i}{dt}$$

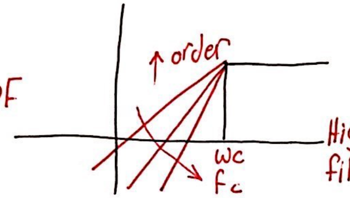
Filters

LPF



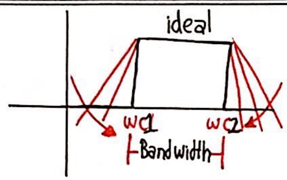
Low Pass filter

HPF

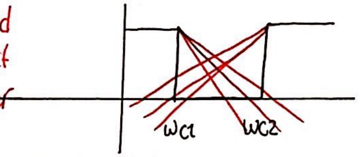


High Pass filter

Band Pass filter



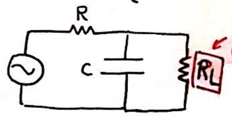
Band reject filter



Filters

Passive : R, L, C

- Gain ≤ 1



تقلل Gain

$$w_c = \frac{1}{RC} \rightarrow$$

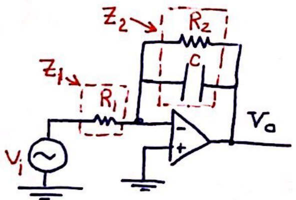
$A_v \downarrow$

$w_c \rightarrow$ changes $\rightarrow w_c = \frac{1}{R_{eq} \cdot C}$

Active : R, C, op-amps

- Gain ← >1, <1

Active low pass filter



$$V_o = -\frac{Z_2}{Z_1} \cdot V_i$$

$$A_v = \frac{V_o}{V_i} = -\frac{Z_2(jw)}{Z_1(jw)}$$

$$\rightarrow \frac{1}{jwC}$$

$$Z_1(jw) = R_1$$

$$Z_2(jw) = R_2 \parallel \frac{1}{jwC}$$

$$A_V = \frac{\dfrac{-R_2 \cdot \frac{1}{jwC}}{R_2 + \frac{1}{jwC}}}{R_1} = \boxed{\frac{-R_2}{R_1}\left[\frac{1}{(1+jwCR_2)}\right]} \ldots (1)$$

Define $w_c = 2\pi f_c = \frac{1}{R_2 C}$ ← Cut-off freq.

$k = \frac{R_2}{R_1}$ (dc gain)

Sub in [1] $A_c = \frac{-K}{1 + \frac{jw}{w_c}}$ ⟹ frequency response
- magnitude $| \; |$
- phase $\angle$

Complex (↑ A_c) → mag $| \; |$; → phase $\angle$

Magnitude plot ← Bodé plot

X-axis $\log f$, $\log \omega$ ← in decade "when move from 10 to 100 It's here as 1→2"

y-axis $20 \log | \; |$ ← In decibels **dB**

$$|A(j\omega)| = \frac{K}{\sqrt{1 + \left(\frac{\omega}{w_c}\right)^2}} \;;$$

$20 \log |A(j\omega)|$ ← Evaluation for different ω's

if $k = 1$ $\quad | \; | = \frac{1}{\sqrt{1 + \left(\frac{w_c}{w_c}\right)^2}} = \frac{1}{\sqrt{2}}$ (عند ال Cutoff)

$20 \log 0.707 = $ **−3 dB**

$k = 10$ $\quad 20 \log \frac{10}{\sqrt{2}} = 20 \log 10 - 20 \log \sqrt{2}$

$20 - 3\text{ dB} = 16.98$

("maximum − 3 dB يعني")

بنلاحظ انو كل ما ضربنا ال w x10
كل ما نقص المقدار ال 20log||
بمقدار 20

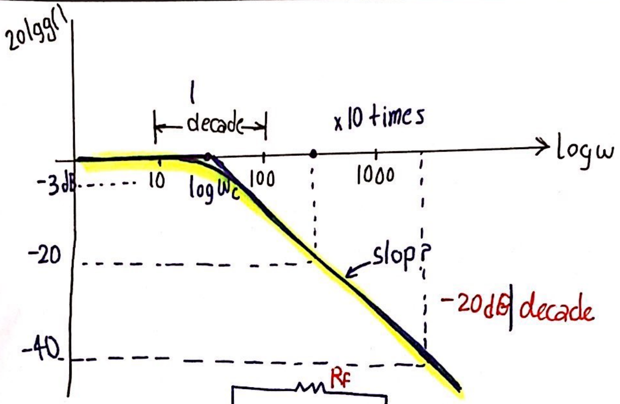
if $\omega = 0.1\, w_c$

$$20 \log \frac{1}{\sqrt{1 + \left(\frac{0.1\, w_c}{w_c}\right)^2}} = 20 \log \frac{1}{\sqrt{1.01}} \cong \textbf{0 dB}$$

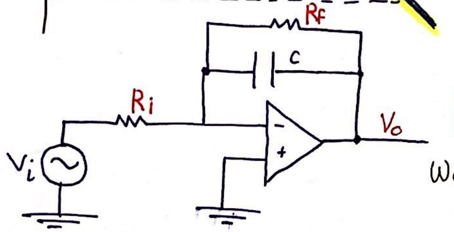
if $w = 10\, w_c$

$$20 \log \frac{1}{\sqrt{1 + (10)^2}} = 20 \log \frac{1}{\sqrt{101}} \cong \textbf{-20 dB}$$

Filter



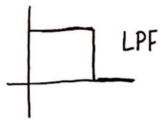
magnitude freq. Response



Filter Type?

$W = 0 \rightarrow C \rightarrow$ open

$V_o = \frac{-R_F}{R_i} \cdot V_i \neq 0$

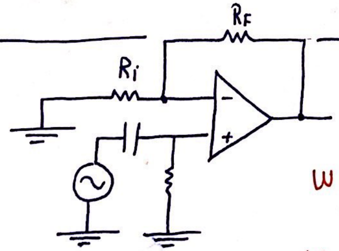


Qualative Analysis

$W = W_c$

$W = \infty \rightarrow C \rightarrow$ Short

$V_o = 0$



$V_o = \left(1 + \frac{R_F}{R_i}\right)$

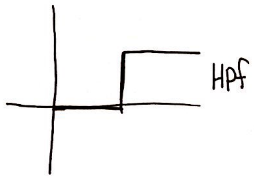
$W = 0 \Rightarrow C \rightarrow$ open

$V_o = 0$

$W = W_c$

$W = \infty \Rightarrow C \rightarrow$ short

$V_o \neq 0$



$R_2 \rightarrow$ effect gain

R_1 & $C \rightarrow$ Cut off freq.