## Chapter Four

## Operational Amplifiers (OP-Amp



## Chapter Outline: -



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### 4.1 Ideal Op Amp



Golden Rules of Op Amps:

1. The output attempts to do whatever is necessary to make the voltage difference between the inputs zero.
2. The inputs draw no current.

### 4.2 Inverting Amplifier

Current into op amp is zero

$$
\begin{aligned}
& v_{-}=v_{+}=0 \\
& i_{i}=\frac{v_{i}-0}{R_{1}}=\frac{v_{i}}{R_{1}} \\
& i_{i}=\frac{0-v_{0}}{R_{2}}=\frac{-v_{0}}{R_{2}} \\
& \frac{v_{i}}{R_{1}}=\frac{-v_{0}}{R_{2}} \\
& A_{F}=\frac{v_{o}}{v_{i}}=-\frac{R_{2}}{R_{1}}
\end{aligned}
$$

$$
\begin{aligned}
& -v_{\text {out }} \\
& -v_{\text {in }}
\end{aligned}
$$

### 4.3 Non-inverting Amplifier

## Current into op amp is zero

$$
\begin{gathered}
\boldsymbol{v}_{+}=\boldsymbol{v}_{-}=\boldsymbol{v}_{\boldsymbol{i}} \\
v_{i}=v_{+}=v_{-}=\frac{R_{1}}{R_{1}+R_{2}} v_{o} \\
A_{F}=\frac{v_{o}}{v_{i}} \\
A_{F}=\frac{v_{o}}{v_{i}}=1+\frac{R_{2}}{R_{1}}
\end{gathered}
$$

EX. For the inverting Op-Amp in bellow. Find the gain voltage if vi=5v, R1=2 $\Omega$ and $R 2=10 \Omega$
$A_{F}=\frac{v_{o}}{v_{i}}=-\frac{R_{2}}{R_{1}}$

$$
A_{F}=\frac{10}{2}=5
$$



### 4.4 Summing OP-AMP

It is one of the inverting op-amp applications where the inverting input is connected to several voltage sources $\left[V_{1}, V_{2}, \ldots V_{n}\right] ; \mathrm{n}=$ number of inputs, as shown in the Figure above.

$$
\begin{align*}
& I=-I_{F}=I_{1}+I_{2}+\cdots+I_{n}  \tag{1}\\
& I_{F}=\frac{V_{O}}{R_{F}}  \tag{2}\\
& I_{1}=\frac{V_{1}}{R_{1}}  \tag{3}\\
& I_{2}=\frac{V_{2}}{R_{2}}  \tag{4}\\
& I_{n}=\frac{V_{n}}{R_{n}} \tag{5}
\end{align*}
$$



Sub. In equation (1) yields:-
$I=\frac{V_{O}}{R_{F}}=-\left[\frac{V_{1}}{R_{1}}+\frac{V_{2}}{R_{2}}+\cdots+\frac{V_{n}}{R_{n}}\right]$
So, the output voltage
$V_{O}=-\left[\frac{R_{1}}{R_{F}} V_{1}+\frac{R_{2}}{R_{F}} V_{2}+\cdots+\frac{R_{n}}{R_{F}} V_{n}\right]$
EX: Design op-amp summing circuit to solve the following equaions:-

1) $V_{O}=0.2 V_{1}+V_{2}-0.2 V_{3}$
2) $V_{O}=2 V_{1}-0.5 V_{2}-0.4 V_{3}$ (homework)
3) $V_{O}=2.5 V_{1}-0.2 V_{2}$ (homework)

Consider the feedback resistance is equal to $10 \mathrm{~K} \Omega$
SOL.

$$
\begin{aligned}
& \text { بما انة دائرة الجامع هي من تطبيقات المكبر القالب , يجب اعتبار قطبية الفولتيات عكس الإشارة الجبرية } \\
& \text { بالمعادلة عند رسم الدائرة . } \\
& \text { المعادلة الأولى تحتوي على ثلاثة حدود (n=3) }
\end{aligned}
$$

$R_{F}=10 K \Omega$ by using eq (7) we get:-
$V_{O}=-\left[\frac{R_{1}}{R_{F}} V_{1}+\frac{R_{2}}{R_{F}} V_{2}+\cdots+\frac{R_{n}}{R_{F}} V_{n}\right]$

