# Al-Mustaqbal University.
College of Engineering and Technical Technologies.
Biomedical Engineering Department.

***Subject:*** Biomedical Instrumentation Design.

***Class (code):*** 4th (MU0114103).

***Lecture:*** *4.*

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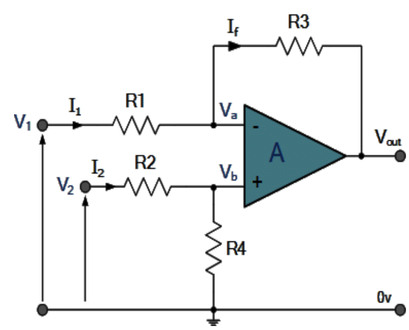
## *The Differential Amplifier*

› Amplifies the voltage difference present on its inverting and non-inverting inputs, so it's function is a **Subtractor**.

› When R1 = R2 and R3 = R4 the transfer function for the differential amplifier is:

$$V_{OUT} = \frac{R_3}{R_1}\left(V_2 - V_1\right)$$




› If R1 = R2 = R3 = R4, then the circuit will become a **Unity Gain Differential Amplifier** and the transfer function for the differential amplifier will be

$$V_{out} = V_2 - V_1.$$

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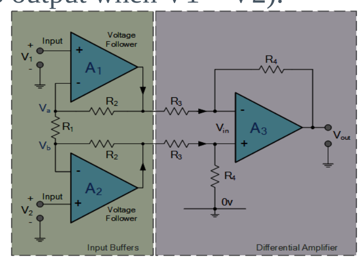
# *Instrumentation Amplifier*

› Instrumentation Amplifiers (in-amps) are very high gain differential amplifiers which have a high input impedance and a single ended output.

› In-amps are mainly used to amplify very small differential signals from strain gauges, thermocouples or current sensing devices in motor control systems.

› In-amp have an internal feedback resistor that is effectively isolated from its input terminals as the input signal is applied across two differential inputs, V1 and V2. In-amp has a very good common mode rejection ratio, CMRR (zero output when V1 = V2).

› A typical example of a three op-amp instrumentation amplifier with a high input impedance (Zin) is given:

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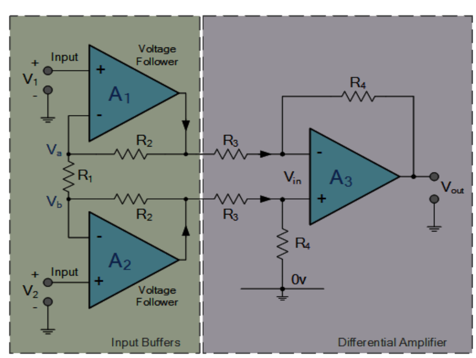
# *Instrumentation Amplifier*

› The amplıfıers A1 and A2 form a differential input stage acting as buffer amplifiers with a gain of $1 + 2R_2/R_1$ for differential input signals and unity gain for common-mode input signals.

› Since amplifiers $A_1$ and $A_2$ are closed loop negative feedback amplifiers, we can expect the voltage at Va to be equal to the input voltage $V_1$. Likewise, the voltage at Vb to be equal to the value at $V_2$.

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# *Instrumentation Amplifier*

›Since the input voltage at the outputs of amplifiers $A_1$ and $A_2$ appears differentially across the three-resistor network, the *differential gain of the circuit can be varied by just changing the value of $R_1$*.

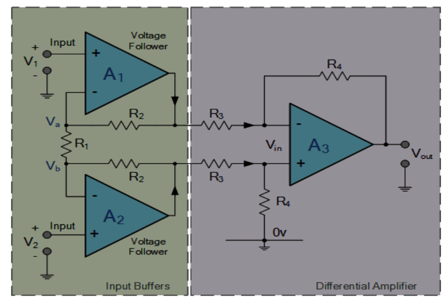
›The voltage output from the differential op-amp $A_3$, acting as a subtractor, is simply the difference between its two inputs (V2 – V1) and which is amplified by the gain of $A_3$.

›The gain of $A_3$ may be unity, (assuming that $R_3 = R_4$).

›The general expression for overall voltage gain

of the instrumentation amplifier circuit

$$V_{OUT} = \left(V_2 - V_1\right)\left[1 + \frac{2R_2}{R_1}\right]\left(\frac{R_4}{R_3}\right)$$

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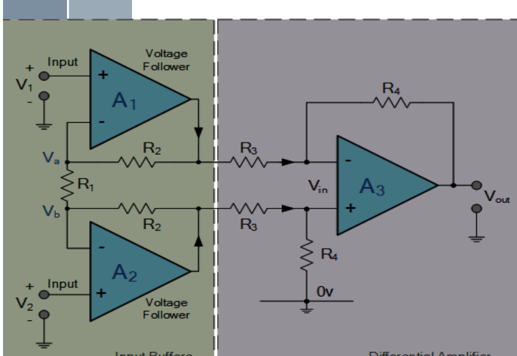


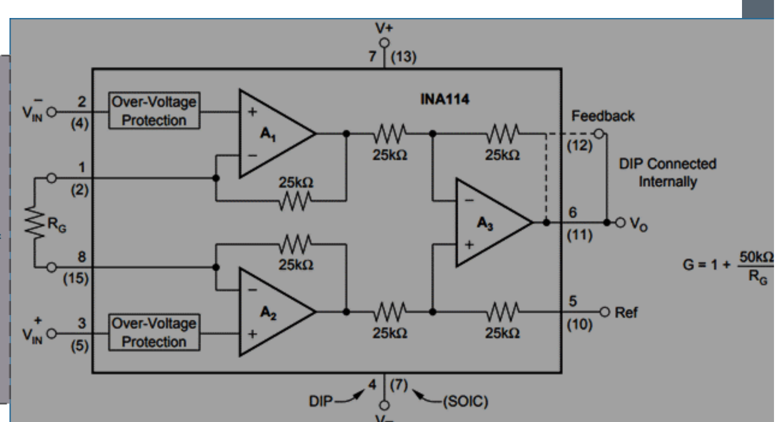


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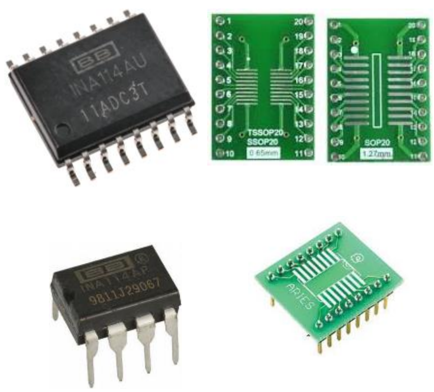
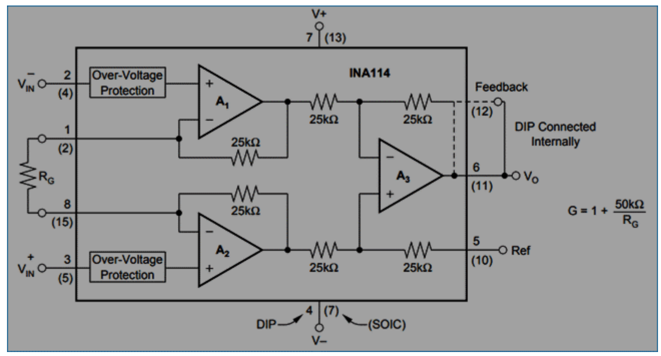
## Instrumentation Amplifier

- Instrumentation amplifier like INA114 IC
- A small outline integrated circuit (SOIC) is a surface-mounted integrated circuit (IC) package which occupies an area about 30–50% less than an equivalent dual in-line package (DIP)



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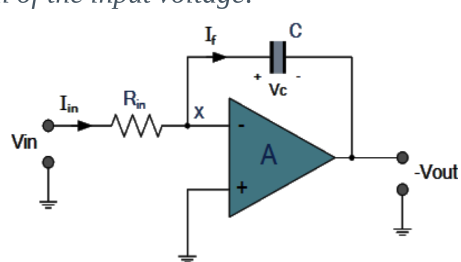
## Integrating Amplifier

- In the integrator op-amp, the feedback element of an inverting amplifier is a capacitor C with a reactance X, thus, an RC Network will be connected across the operational amplifiers feedback path.
- This op-amp performs the mathematical operation of **Integration**, where the output to respond to changes in the input voltage over time as the op-amp integrator produces an *output voltage which is proportional to the integral of the input voltage*.

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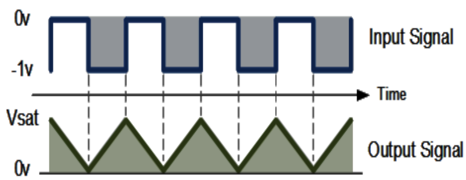
# *Integrating Amplifier*

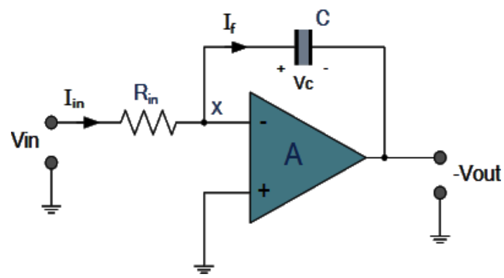
› The potential voltage, Vc developed across the capacitor slowly increases causing the charging current to decrease as the impedance of the capacitor increases.

› This results in the ratio of Xc/Rin increasing producing a linearly increasing ramp output voltage that continues to increase until the capacitor is fully charged and the capacitor acts as an open circuit ((XC/RIN) is now infinite resulting in infinite gain).

› The output of the amplifier goes into saturation as shown below.

$$V_{out} = -\frac{1}{j\omega RC} V_{in}$$

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# *Differentiator amp.*

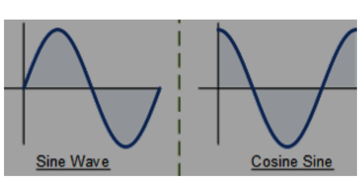
› The input signal to the differentiator is applied to the capacitor.

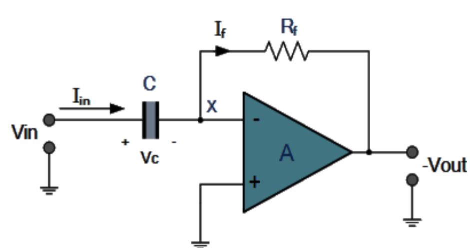
› The capacitor blocks any DC content so there is no current flow to the amplifier summing point, X resulting in zero output voltage.

› At low frequencies the reactance of the capacitor is "High" resulting in a low gain (R*f*/Xc) and low output voltage from the op-amp. At higher frequencies the reactance of the capacitor is much lower resulting in a higher gain and higher output voltage from the differentiator amplifier.

› The ideal voltage output for the op-amp differentiator is given as

$$V_{OUT} = -R_F C \frac{dV_{IN}}{dt}$$

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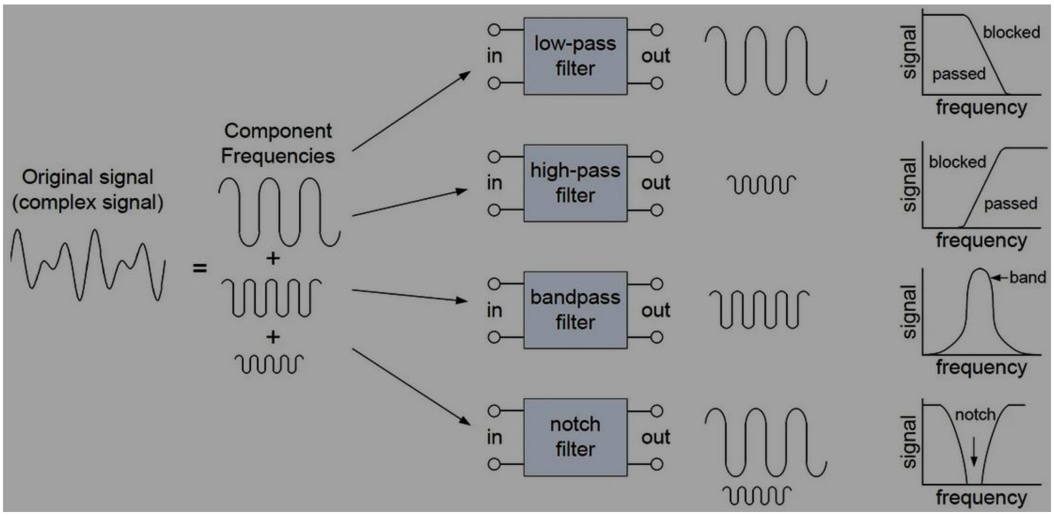
# *Active Filters*

› The Active Filters contain active components such as operational amplifiers, transistors or FET's within their circuit design. They draw their power from an external power source and use it to boost or amplify the output signal.

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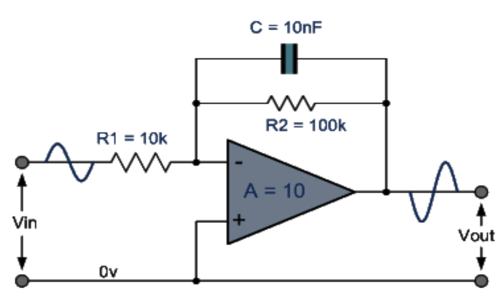
# *Low Pass Active Filters*

› A capacitor has been connected to its feedback circuit in parallel with R2, and this parallel combination of C and R2 sets the -3dB point as before but allows the amplifiers gain to roll off indefinitely beyond the corner frequency.

› At low frequencies, the capacitor's reactance is much higher than R2, so the dc gain is set by the standard inverting formula of: -R2/R1.

› As the frequency increases the capacitors reactance decreases reducing the impedance of the parallel combination of Xc||R2, until eventually at a high enough frequency, Xc reduces to zero.

$$fc = \frac{1}{2\pi C R_2} \ \text{Hertz}$$

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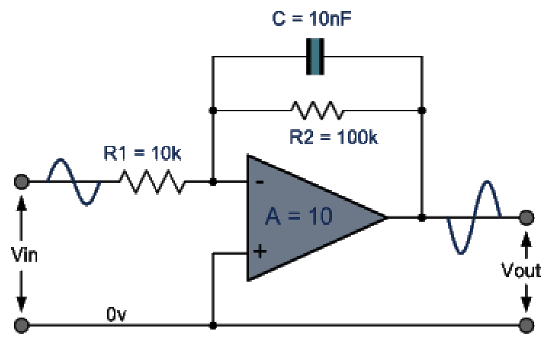
# Low Pass Active Filters

› The advantage of this configuration of LPF is that the circuits input impedance is now just R1 and the output signal is inverted.

› With the corner frequency determining components in the feedback circuit, the RC set-point is unaffected by variations in source impedance and the dc gain can be adjusted independently of the corner frequency.

$$fc = \frac{1}{2\pi C R_2} \; Hertz$$

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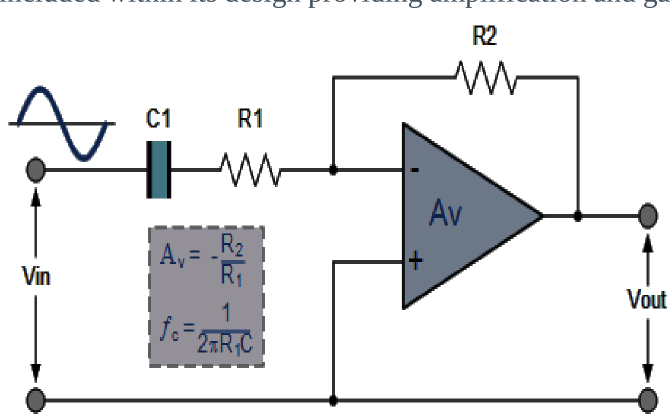
# High Pass Active Filters

› The basic operation of an Active High Pass Filter (HPF) is the same as for its equivalent RC passive high pass filter circuit, except the circuit has an operational amplifier or included within its design providing amplification and gain control

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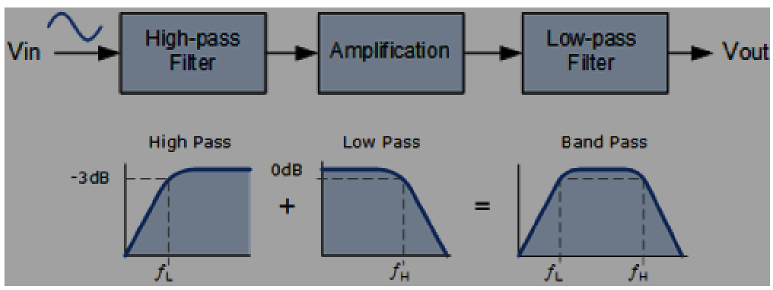
# Active Band Pass Filters

› The Active Band Pass Filter is a frequency-selective filter circuit used in electronic systems to separate a signal at one particular frequency or a range of signals that lie within a certain "band" of frequencies from signals at all other frequencies.

› This band or range of frequencies is set between two cut-off or corner frequency points labeled the "lower frequency" ($f$L) and the "higher frequency" ($f$H) while attenuating any signals outside of these two points.

› Simple Active Band Pass Filter can be easily made by cascading together a single Low Pass Filter with a single High Pass Filter as shown:

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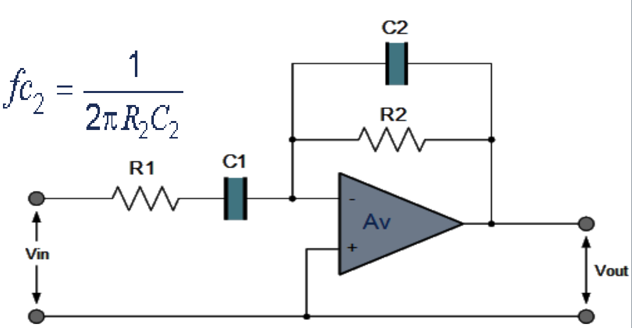
# Active Band Pass Filters

› The cut-off or corner frequency of the low pass filter (LPF) is higher than the cut-off frequency of the high pass filter (HPF).

› The difference between the frequencies at the -3dB point will determine the "bandwidth" of the bandpass filter while attenuating any signals outside of these points.

› One way of making a very simple Active Band Pass Filter is to connect the basic passive high and low pass filters we look at previously to an amplifying op-amp circuit as shown:

$$\text{Voltage Gain} = -\frac{R_2}{R_1}, \quad fc_1 = \frac{1}{2\pi R_1 C_1}, \quad fc_2 = \frac{1}{2\pi R_2 C_2}$$

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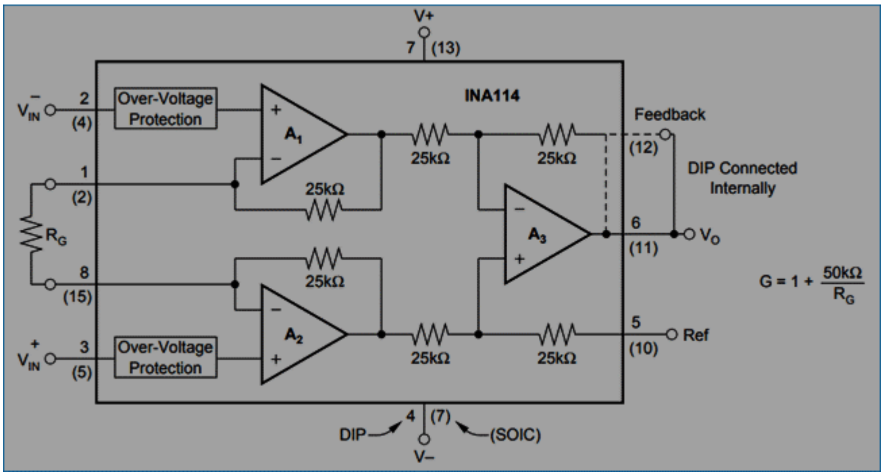
# *Question*

- Calculate $V_o$ for the In-amp. INA114 IC when Vin-=20µV , Vin+=50µV, Consider RG for the following cases:

I: RG=470kΩ, II:RG=50kΩ, III: RG=20kΩ . Comment on your results.

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