OPERATIONAL AMPLIFIER Basics

- Three terminal device
  - Inverting input to “minus” sign
  - Non-inverting input “plus” sign
  - Output
  - Two power supplies from +/- 8V to +/- 38V

- IDEALIZED OP-AMP
  - Open Loop Gain AOL = infinity
  - Differential voltage $V_d =$ input
    $V(+) - V(-) = 0$
  - Input impedance = infinity Ohm
  - Output impedance = 0 Ohm
  - Bandwidth (BW) = as large as possible
  - Offset Voltage ($V_{i/o}$): zero volt
  - The amplifiers output will be zero when the voltage difference between the inverting and the non-inverting inputs is zero
• Practical Op-Amp
  • Output voltage $V_{out} = V_{in}(+) - V_{in}(-) \times A_{ol} = V_d \times A_{ol}$
  • $V_d =$ different between two inputs
  • The Gain ($A_{ol}$) of 741 Op-Amp closed to 200000
  • The output of Op-Amp is never higher than the power supplies voltage
  • When input applies is too high that force the op-amp into the saturation and the OP-AMP output will be equal to +/- saturation voltages (less than power supplies about 1.4 V)
  • Open loop gain ($A_{ol}$) is defined as the amplifier output amplification without any external feedback signals connected to it and for a typical operational amplifier is a about 100 decibel at DC (zero Hertz)
EXAMPLE 01:

An op-amp has open loop gain \( A_{ol} = 200000 \)
with power supplies \(+15\) V and \(-15\) V

Given \( V_{saturation} = \pm 15 \) V

Complete \( V_d \) and \( V_{out} \) in the following table

<table>
<thead>
<tr>
<th>NO.</th>
<th>input (+)</th>
<th>input (-)</th>
<th>( V_d )</th>
<th>( V_{out} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 microV</td>
<td>40 microV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10 microV</td>
<td>-60 microV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-50 microV</td>
<td>-30 microV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>20 microV</td>
<td>-120 microV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-100 microV</td>
<td>45 microV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>110 microV</td>
<td>45 microV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-25 microV</td>
<td>75 microV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-130 microV</td>
<td>-90 microV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: \( V_d = \text{input(+) - input (-)} \) and \( V_{out} = A_{ol} \times V_d \)
Voltage Gain, \( A \) = \( \frac{V_{out}}{V_{in}} \)

The open-loop frequency response curve shows the gain in decibels (dB) as a function of frequency in Hertz (Hz). The slope is given as -20 dB per decade, and the -3 dB point is indicated. The unity gain is also shown on the graph.

Gain in Decibels or (dB) is given as:

\[
20 \log(A) \text{ or } 20 \log \left( \frac{V_{out}}{V_{in}} \right) \text{ in dB}
\]
Inverting Operational Amplifier

- \( R_f = \) feedback resistor between output and inverting input to produce Closed Loop gain ACL.
- No current flows into the input terminals (high input impedance)
- The differential input is zero (\( V_d = V_1 - V_2 = 0 \) means \( V_1 = V_2 \))
- Closed Loop Gain (\( A_{cl} = - \frac{R_f}{R_{in}} \))
For circuit shown

1. \( V_{\text{in}} = 1 \text{ Vdc} \)
2. \( R_5 = \text{Load resistor} \)
3. Solve for:
   1. Gain \( A_{\text{cl}} = \____ \)
   2. \( V_{\text{out}} = \____ \text{ V} \)
   3. Current \( I \) through \( R_2 = \____ \) milliA
   4. Load current \( I_L = \____ \) milliA
   5. Op-amp current \( I_{o} = \____ \) milliA
For the above circuit. Solve for:

1. Closed loop gain:_________  \hspace{1cm} Vout=_________Vp-p
2. Current I through R1=______ milliAp-p
3. NOTE: the input and output is inverted or 180 degrees out of phase
Non-inverting Operational Amplifier

- Input Vin connect to the Non-inverting input of the Op-Amp
- the closed loop gain is $A_{cl} = 1 + \frac{R_f}{R_2}$ where $R_f$ is feedback resistor
- The input and output is in-phase

**EXAMPLE:**
- For the above circuit, given $R_f=1\,k\Omega$ and $R_2=1.5\,k\Omega$, $V_{in}=-2.5\,V_{DC}$

Solve for:

1. Gain $A_{cl} =$ ____________  \hspace{1cm} V_{out} = ____________ V_{DC}
2. Current through $R_2 =$ ____________ milliA
• **UNITY GAIN AMPLIFIER**
• Another names: Buffer Amplifier, isolation amplifier, Follower
• Gain $A_c=1$ ($V_{out} = V_{in}$)