$$A_1 = \frac{10k\Omega}{1k\Omega} = -10$$

$$A_2 = \frac{10k\Omega}{2k\Omega} = -5$$

We know that the output voltage is the sum of the two amplified input signals and is calculated as:

$$Vout = \left(A_1 \times V_1\right) + \left(A_2 \times V_2\right)$$

$$Vout = (-10(2mV)) + (-5(5mV)) = -45mV$$

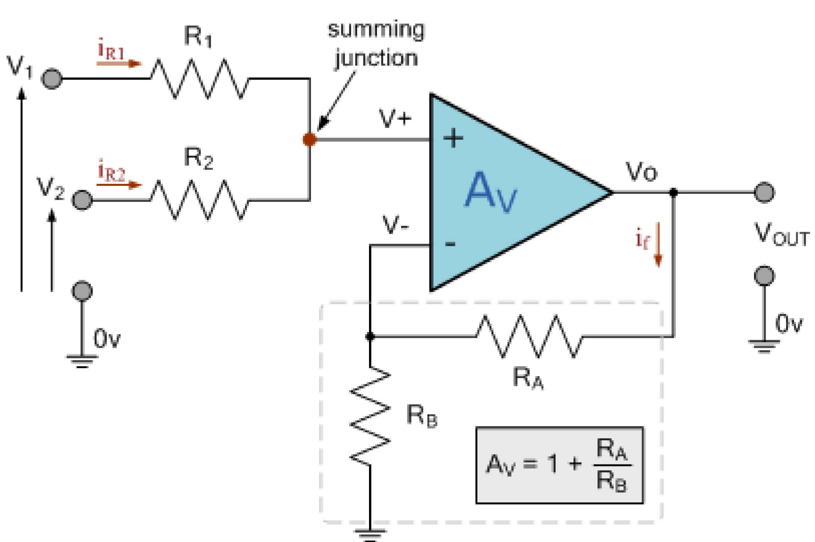
Then the output voltage of the **Summing Amplifier** circuit above is given as **-45 mV** and is negative as its an inverting amplifier.

Non-inverting Summing Amplifier

But as well as constructing inverting summing amplifiers, we can also use the non-inverting input of the operational amplifier to produce a *non-inverting summing amplifier*. We have seen above that an inverting summing amplifier produces the negative sum of its input voltages then it follows that the non-inverting summing amplifier configuration will produce the positive sum of its input voltages.

As its name implies, the non-inverting summing amplifier is based around the configuration of a non-inverting operational amplifier circuit in that the input (either ac or dc) is applied to the non-inverting (+) terminal, while the required negative feedback and gain is achieved by feeding back some portion of the output signal (V_{OUT}) to the inverting (-) terminal as shown.

Non-inverting Summing Amplifier



So what's the advantage of the non-inverting configuration compared to the inverting summing amplifier configuration. Besides the most obvious fact that the op-amps output voltage V_{OUT} is in phase with its input, and the output voltage is the weighted sum of all its inputs which themselves are determined by their resistance ratios, the biggest advantage of the non-inverting summing amplifier is that because there is no virtual earth condition across the input terminals, its input impedance is much higher than that of the standard inverting amplifier configuration.

Also, the input summing part of the circuit is unaffected if the op-amps closed-loop voltage gain is changed. However, there is more maths involed in selecting the weighted gains for each individual input at the summing junction especially if there are more than two inputs each with a different weighting factor. Nevertheless, if all the inputs have the same resistive values, then the maths involved will be a lot less.

If the closed-loop gain of the non-inverting operational amplifier is made equal the number of summing inputs, then the op-amps output voltage will be exactly equal to the sum of all the input voltages. That is for a two input non-inverting summing amplifier, the op-amps gain is equal to 2, for a three input summing amplifier the op-amps gain is 3, and so on. This is because the currents which flow in each input resistor is a function of the voltage at all its inputs. If the input resistances made all equal, ($R_1 = R_2$) then the circulating currents cancel out as they can not flow into the high impedance non-inverting input of the op-amp and the voutput voltage becomes the sum of its inputs.

So for a 2-input non-inverting summing amplifier the currents flowing into the input terminals can be defined as:

$$I_{R1} + I_{R2} = 0 \quad (\text{KCL})$$

$$\frac{V_1 - V+}{R_1} + \frac{V_2 - V+}{R_2} = 0$$

$$\therefore \left(\frac{V_1}{R_1} - \frac{V+}{R_1} \right) + \left(\frac{V_2}{R_2} - \frac{V+}{R_2} \right) = 0$$

If we make the two input resistances equal in value, then $R_1 = R_2 = R$.

$$V+ = \frac{\frac{V_1}{R} + \frac{V_2}{R}}{\frac{1}{R} + \frac{1}{R}} = \frac{\frac{V_1 + V_2}{R}}{\frac{2}{R}}$$

$$\text{Thus} \quad V+ = \frac{V_1 + V_2}{2}$$

The standard equation for the voltage gain of a non-inverting summing amplifier circuit is given as:

$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{V_{OUT}}{V+} = 1+\frac{R_A}{R_B}$$

$$\therefore \quad V_{OUT} = \left[1+\frac{R_A}{R_B}\right]V+$$

$$\text{Thus:} \quad V_{OUT} = \left[1+\frac{R_A}{R_B}\right]\frac{V_1+V_2}{2}$$

The non-inverting amplifiers closed-loop voltage gain A_V is given as: $1 + R_A/R_B$. If we make this closed-loop voltage gain equal to 2 by making $R_A = R_B$, then the output voltage V_O becomes equal to the sum of all the input voltages as shown.

Non-inverting Output Voltage

$$V_{OUT} = \left[1+\frac{R_A}{R_B}\right]\frac{V_1+V_2}{2}$$

$$\text{If } R_A = R_B$$

$$V_{OUT} = [1+1]\frac{V_1+V_2}{2} = \cancel{2}\frac{V_1+V_2}{\cancel{2}}$$

$$\therefore V_{OUT} = V_1 + V_2$$

Thus for a 3-input non-inverting summing amplifier configuration, setting the closed-loop voltage gain to 3 will make V_{OUT} equal to the sum of the three input voltages, V_1, V_2 and V_3. Likewise, for a four input summer, the closed-loop voltage gain would be 4, and 5 for a 5-input summer, and so on. Note also that if the amplifier of the summing circuit is connected as a unity follower with R_A equal to zero and R_B equal to infinity, then with no voltage gain the output voltage V_{OUT} will be exactly equal the average value of all the input voltages. That is $V_{OUT} = (V_1 + V_2)/2$.

Summing Amplifier Applications

So what can we use summing amplifiers for, either inverting or non-inverting. If the input resistances of a summing amplifier are connected to potentiometers the individual input signals can be mixed together by varying amounts.