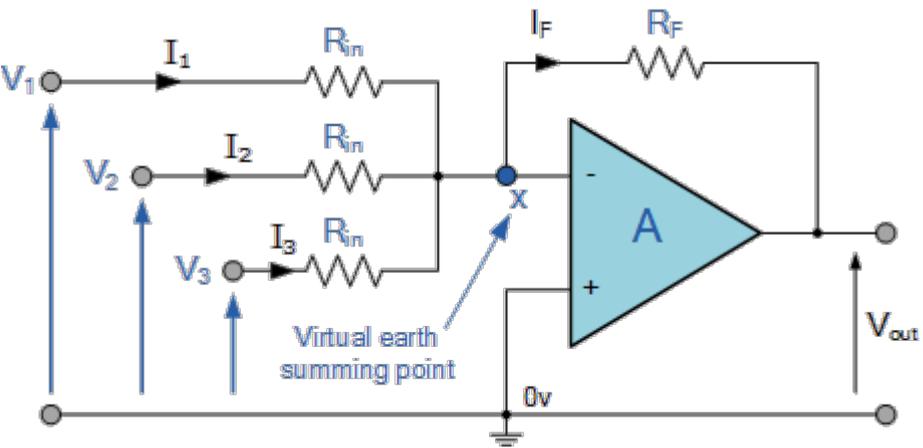# The Summing Amplifier

The **Summing Amplifier** is another type of operational amplifier circuit configuration that is used to combine the voltages present on two or more inputs into a single output voltage.

We saw previously in the inverting operational amplifier that the inverting amplifier has a single input voltage, (Vin) applied to the inverting input terminal. If we add more input resistors to the input, each equal in value to the original input resistor, (Rin) we end up with another operational amplifier circuit called a **Summing Amplifier**, "*summing inverter*" or even a "*voltage adder*" circuit as shown below.

Summing Amplifier Circuit

In this simple summing amplifier circuit, the output voltage, (Vout) now becomes proportional to the sum of the input voltages, V_1, V_2, V_3, etc. Then we can modify the original equation for the inverting amplifier to take account of these new inputs thus:

$$I_F = I_1 + I_2 + I_3 = -\left[\frac{V1}{Rin} + \frac{V2}{Rin} + \frac{V3}{Rin}\right]$$

$$\text{Inverting Equation: } Vout = -\frac{Rf}{Rin} \times Vin$$

$$\text{then, } -Vout = \left[\frac{R_F}{Rin}V1 + \frac{R_F}{Rin}V2 + \frac{R_F}{Rin}V3\right]$$

However, if all the input impedances, (R_{IN}) are equal in value, we can simplify the above equation to give an output voltage of:

Summing Amplifier Equation

$$-Vout = \frac{R_F}{R_{IN}}\left(V1 + V2 + V3....\text{etc}\right)$$

We now have an operational amplifier circuit that will amplify each individual input voltage and produce an output voltage signal that is proportional to the algebraic "SUM" of the three individual input voltages V_1, V_2 and V_3. We can also add more inputs if required as each individual input "sees" their respective resistance, Rin as the only input impedance.

This is because the input signals are effectively isolated from each other by the "virtual earth" node at the inverting input of the op-amp. A direct voltage addition can also be obtained when all the resistances are of equal value and Rf is equal to Rin.

Note that when the summing point is connected to the inverting input of the op-amp the circuit will produce the negative sum of any number of input voltages. Likewise, when the summing point is connected to the non-inverting input of the op-amp, it will produce the positive sum of the input voltages.

A **Scaling Summing Amplifier** can be made if the individual input resistors are "NOT" equal. Then the equation would have to be modified to:

$$-V_{OUT} = V_1\left(\frac{R_f}{R_1}\right) + V_2\left(\frac{R_f}{R_2}\right) + V_3\left(\frac{R_f}{R_3}\right) .... \text{etc}$$

To make the math's a little easier, we can rearrange the above formula to make the feedback resistor Rf the subject of the equation giving the output voltage as:

$$-V_{OUT} = R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right) .... \text{etc}$$

This allows the output voltage to be easily calculated if more input resistors are connected to the amplifiers inverting input terminal. The input impedance of each individual channel is the value of their respective input resistors, ie, R_1, R_2, R_3 ... etc.

Sometimes we need a summing circuit to just add together two or more voltage signals without any amplification. By putting all of the resistances of the circuit above to the same value R, the op-amp will have a voltage gain of unity and an output voltage equal to the direct sum of all the input voltages as shown:


$$V_{out} = -(V_1 + V_2 + V_3)$$
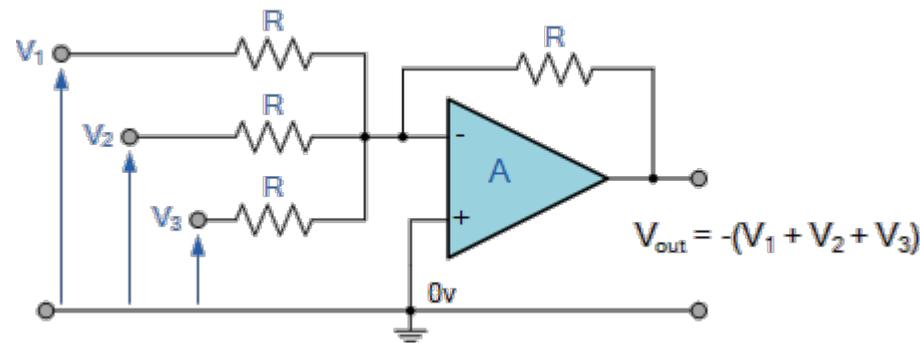
The **Summing Amplifier** is a very flexible circuit indeed, enabling us to effectively "Add" or "Sum" (hence its name) together several individual input signals. If the inputs resistors, R_1, R_2, R_3 etc, are all equal a "unity gain inverting adder" will be made. However, if the input resistors are of different values a "scaling summing amplifier" is produced which will output a weighted sum of the input signals.

Summing Amplifier Example No1

Find the output voltage of the following *Summing Amplifier* circuit.

Summing Amplifier
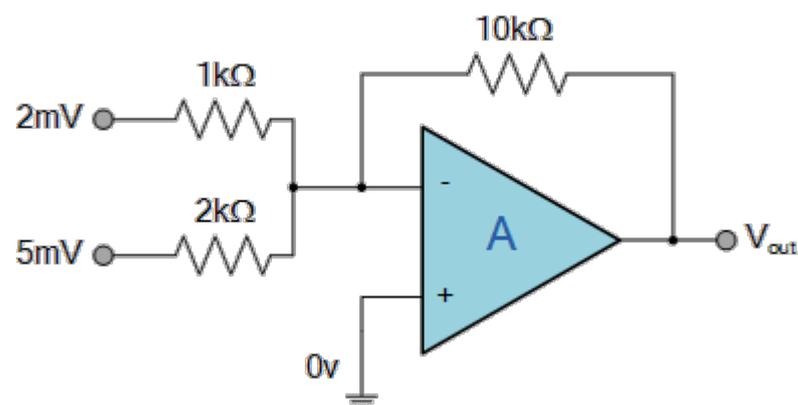
Using the previously found formula for the gain of the circuit:

$$\text{Gain}\,(Av) = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

We can now substitute the values of the resistors in the circuit as follows:

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

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

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

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

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

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
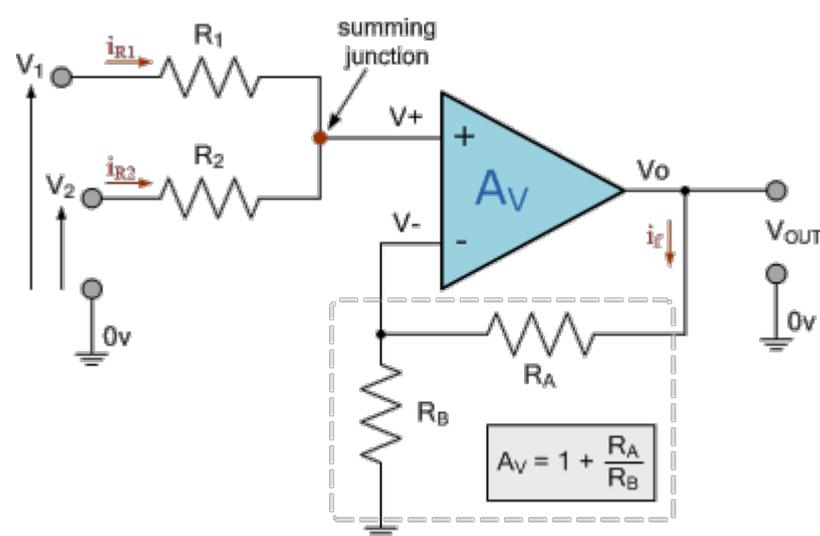
So what's the advantage of the non-inverting configuration compared to the inverting summing amplifier configuration. Besides the most obvious fact that the op-amps output voltage V_{OUT} is in phase with its input, and the output voltage is the weighted sum of all its inputs which themselves are determined 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.

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

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

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

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

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

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

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

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

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

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

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

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.

For example, measuring temperature, you could add a negative offset voltage to make the output voltage or display read "0" at the freezing point or produce an audio mixer for adding or mixing together individual waveforms (sounds) from different source channels (vocals, instruments, etc) before sending them combined to an audio amplifier.

Audio Mixer Circuit
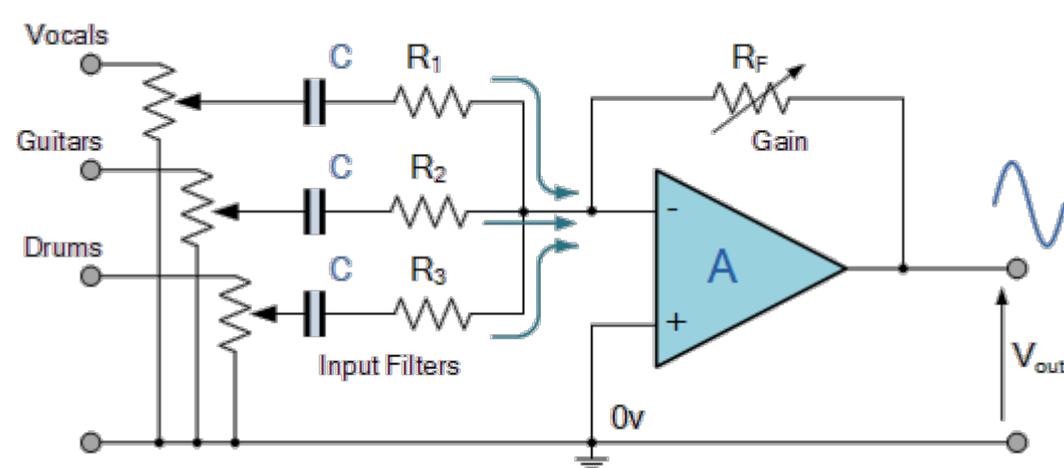
Another useful application of a **Summing Amplifier** is as a weighted sum digital-to-analogue converter, (DAC). If the input resistors, R_{IN} of the summing amplifier double in value for each input, for example, 1kΩ, 2kΩ, 4kΩ, 8kΩ, 16kΩ, etc, then a digital logical voltage, either a logic level "0" or a logic level "1" on these inputs will produce an output which is the weighted sum of the digital inputs. Consider the circuit below.

Digital to Analogue Converter
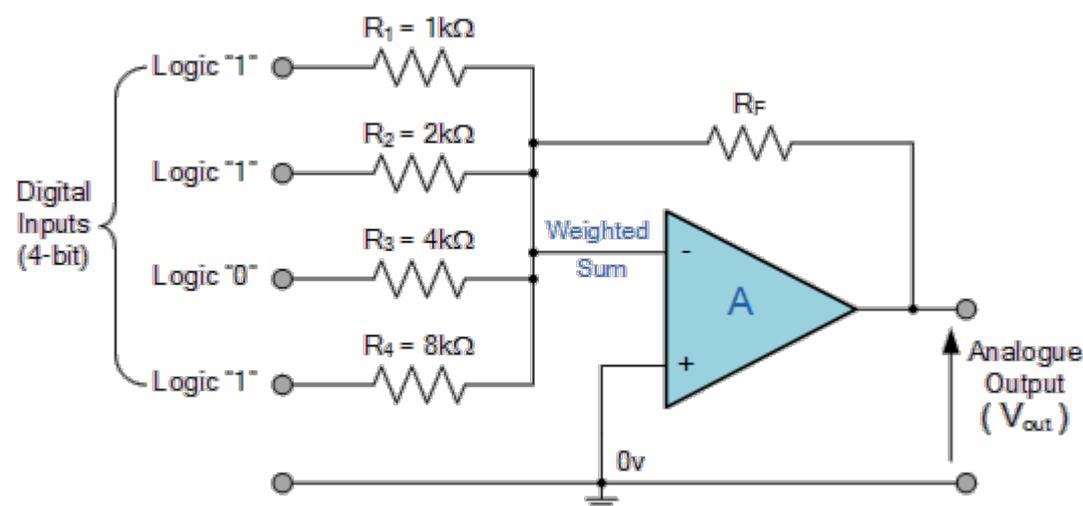
Of course this is a simple example. In this DAC summing amplifier circuit, the number of individual bits that make up the input data word, and in this example 4-bits, will ultimately determine the output step voltage as a percentage of the full-scale analogue output voltage.

Also, the accuracy of this full-scale analogue output depends on voltage levels of the input bits being consistently 0V for "0" and consistently 5V for "1" as well as the accuracy of the resistance values used for the input resistors, R_{IN}.

Fortunately to overcome these errors, at least on our part, commercially available Digital-to Analogue and Analogue-to Digital devices are readily available with highly accurate resistor ladder networks already built-in.

In the next tutorial about operational amplifiers, we will examine the effect of the output voltage, Vout when a signal voltage is connected to the inverting input and the non-inverting input at the same time to produce another common type of operational amplifier circuit called

a Differential Amplifier which can be used to "subtract" the voltages present on its inputs.

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- *Stephen K Nyarko*

  If five input is giving and all is have the same value of Rf how well we go about it

  Posted on [June 28th 2024 | 10:37 am](#)
  [Reply](#)
- *nkululeko zulu*

  How is summing amplify used in an adc?

  Posted on [April 16th 2024 | 6:42 am](#)
  [Reply](#)
  - *Wayne Storr*

    Please read our tutorial about the [Analogue to Digital Converter](#)

Posted on [April 16th 2024 | 7:30 am](#)
[Reply](#)

- *Muluken*

  Giv examples

  Posted on [October 16th 2023 | 1:42 pm](#)
  [Reply](#)
- *Panashe Musaingana*

  Uses of summing amplifier

  Posted on [August 22nd 2023 | 3:03 pm](#)
  [Reply](#)
- *Nayanajith Sandeepa*

  Good

  Posted on [August 12th 2023 | 12:02 pm](#)
  [Reply](#)
- *MIKE KALANDITSE*

  Very good notes.

  Posted on [August 03rd 2023 | 7:31 pm](#)
  [Reply](#)
- *Raj Kapoor Jaiswal*

  Cse student

  Posted on [February 24th 2023 | 9:47 pm](#)
  [Reply](#)
- *Torcher*

  Why do I even need opamp here? I already have sum of the inputs at the node X.

  Posted on [December 29th 2022 | 2:44 pm](#)
  [Reply](#)
  - *Wayne Storr*

    The inverting op-amp provides isolation between the individual inputs and output due to its virtual ground at node "X", otherwise you just have resistors in parallel and no summing.

    Posted on [December 30th 2022 | 9:03 am](#)
    [Reply](#)
- *john*

  This excellent website truly has all of the information I needed about this subject

  Posted on [November 30th 2022 | 12:43 pm](#)
  [Reply](#)
- *Gianfranco*

  The equation for the non-inverting voltage adder are wrong.

  When stating:

  VIn = V+

You are neglecting the fact that there's a voltage divider between Vout and V-. Indeed,

Vin = V+ – V-

And V- is different from 0 because there's a resistor connecting it to ground.
As a proof, try to load the circuit on any simulator. You will quickly notice that by simply setting the Rf = Ri, the output voltage is NOT the sum of the input voltages.

Posted on July 29th 2022 | 3:59 pm
Reply

- *Abdul Rashid Salim*

Excellent explanation

Posted on July 25th 2022 | 6:08 am
Reply

- *Max*

Sorry but I don't understand why the summing amplifier is considered as summing? The output voltage is 45mV not (2+5)mV?

Posted on June 27th 2022 | 3:11 am
Reply
    - More

- *Che junior6*

Good

Posted on May 11th 2022 | 4:53 pm
Reply

- *ATTILI HAREESH SAI*

Magnitude comparator

Posted on January 23rd 2022 | 11:40 am
Reply

- *Nchimunya Banda*

Very Helpful

Posted on December 08th 2021 | 11:17 am
Reply

- *Ngo Fynegace*

I have gone through few topics of the tutorial and find it extremely interesting. I will continue with the subsequent topics in due time. Indeed my day is made and I am very happy.
I will revert back as soon as possible.
God bless you all.
Ngo Fyneface

Posted on November 07th 2021 | 10:33 am
Reply

- *bikila*

good tutorial, thanks

Posted on April 16th 2021 | 1:08 pm
Reply

- *Nitesh kumar ram*

  thank you dear sir

  Posted on
  Reply
- *OSEI- WUSU PHILIP*

  can you help me with this questions
  2.A. An amplifier is represented by the frequency response curve in Figure 2.
  i.Determine the band with
  ii.The operating frequency

  75%

  300Hz 2MHz
  Figure 2

  B.Find the output voltage of the Summing Amplifier circuit shown in Figure 3.

  Posted on
  Reply
- *mohmmed Alothman*

  Explain with draw how to use the summing amplifier as a DC shifter to shift an ECG signal with
  variable gain (from 0.1 to 2.5). Then discuss the most five important parameters of the selected
  operational amplifier which has been chosen. (

  Posted on
  Reply