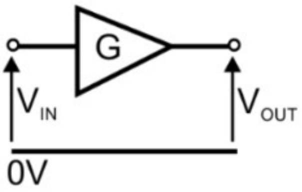
AS-05 Operational Amplifiers

Revision sheet

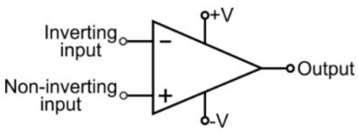
1 Introduction To Amplifiers

Amplifiers take an analogue signal as an input, multiply it by the *gain* then output the value.



Voltage gain (G) can be calculated using the following equation.
$G = \frac{V_{OUT}}{V_{IN}}$
There are two broad categories of amplifer - non inverting which just amplifies the signal and inverting which amplifies the signal and inverts it.

2 Op Amp



Op-Amps have two inputs, inverting and non inverting. They require dual rail supply (positive and negative), these are usually not shown in circuit diagrams however. It amplifies the difference between the two input voltages.

2.1 Feedback

This is where you feed some of the output back into the input. There are two types.

2.1.1 Positive Feedback

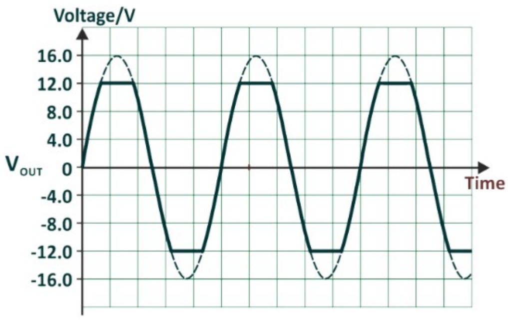
A portion of the output signal is fed back into the amplifer input. This causes the output signal to grow uncontrollably, which is bad.

2.1.2 Negative Feedback

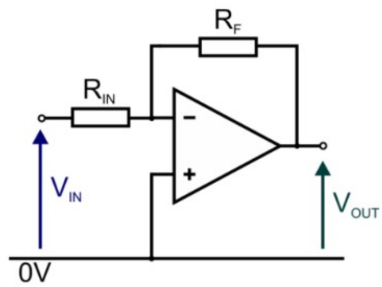
This is where a portion of the output signal is subtracted from the input. It can be used to set the gain and reduce the distortion of the amp. The gain of the amplifier depends only on the feedback fraction.

2.2 Saturation

Op-Amps have a value at which they saturate. They cannot produce voltages above this point. When this happens, they distort the signal, in the method of clipping distortion.



3 Inverting Amplifier



$G = \frac{-R_F}{R_{IN}}$

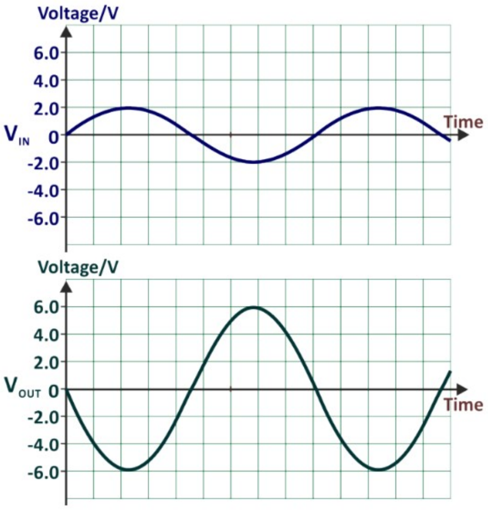
3.1 Input Impedance

The input impedance of an inverting amplifier is R_{IN}.

3.2 Example

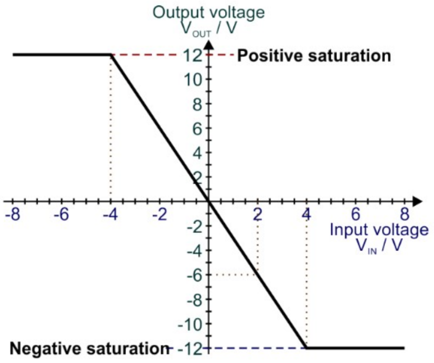
In this example, the top graph shows the input voltage which has peak value of 2V. This

2V is multiplied by the gain of -3 to produce ±6V. The waveform is inverted whilst the time period and frequency remain unchanged.

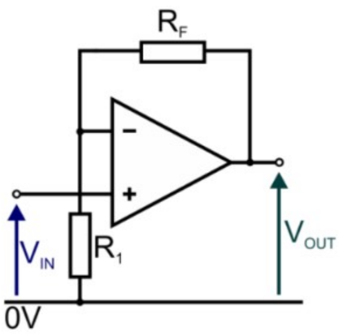


3.3 Saturation

The op-amp saturates at ±12V. This can be seen on the following graph.



4 Non-Inverting Amplifier



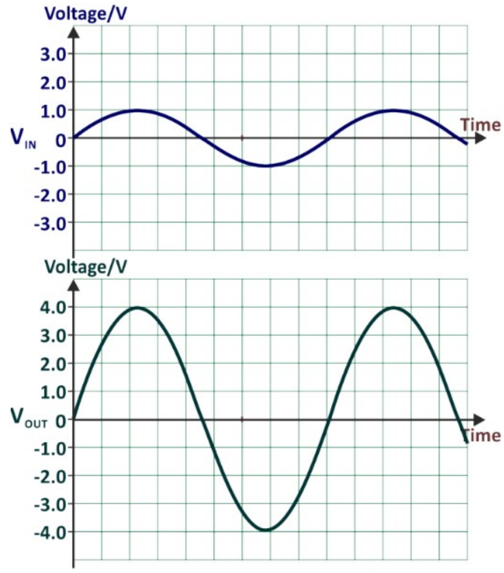
$$G = 1 + \frac{R_F}{R_{IN}}$$

4.1 Input Impedance

The input impedance of a non-inverting amplifier is the input impedance of the op-amp it is built from.

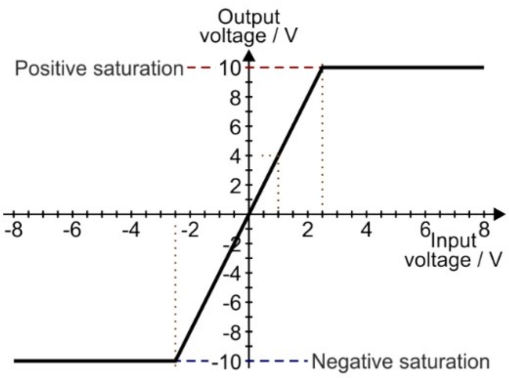
4.2 Example

In this example, the top graph shows the input voltage which has a peak value of 1V. This 1V is multiplied by the gain of 4 to produce ±4V. The waveform, time period and frequency are unchanged.



4.3 Saturation

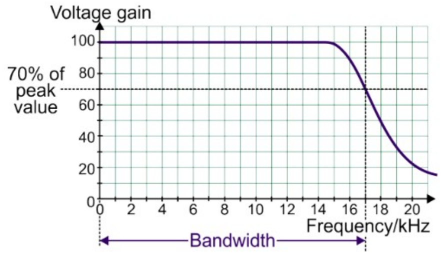
The op-amp saturates at ±10V. This can be seen on the graph below.



5 Real World Op-Amps

5.1 Bandwidth

Bandwidth is the range of frequencies that the amplifier can re-produce. It is shown on a graph called a frequency response graph.



Bandwidth is the point at which the gain drops to $\frac{1}{\sqrt{2}}$ (70%) of its peak value.

5.2 GBP

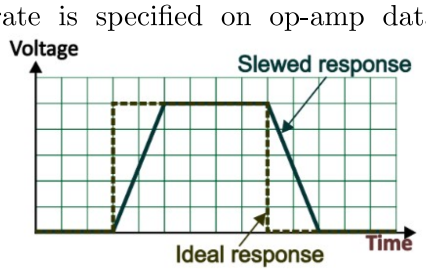
Gain Bandwidth Product (GBP) is a property of the op-amp. It can be calculated using the following formula
$GBP = gain \times bandwidth$
It has the units Hz and will usually be in the MHz.

5.3 CMRR

Common Mode Rejection Ratio (CMRR) is the ratio of the common-mode gain to differential-mode gain. Ideal op-amps should have infinite CMRR. Real op-amps have some CMRR, the higher it is the better it is.

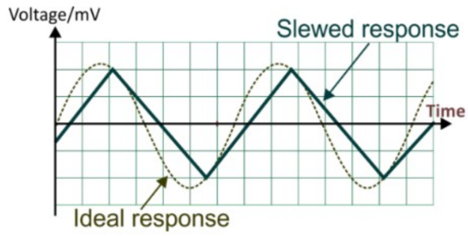
5.4 Slew Rate

Slew Rate specifies how quickly the output voltage can change in response to a change in input voltage. The higher the slew rate, the better as this means it takes a shorter time to change. Slew rate is specified on op-amp data sheets.



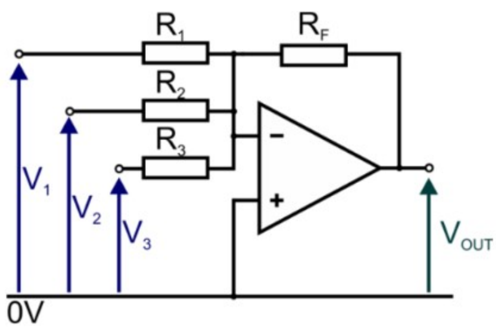
Slew-Rate can be calculated by using the following formula.
$$Slew\ Rate = \frac{\Delta V}{\Delta t}$$

5.5 Sine Waves

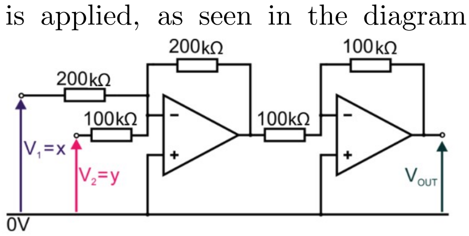


When a sine wave gets distorted enough, it can become a triangular wave. To overcome this, we have to choose an op-amp with a high enough slew-rate to cope with our highest frequency signal. The following equation can be used to calculate the slew rate required for a distortion free output.
$Slew\ Rate = 2\pi f V_p$

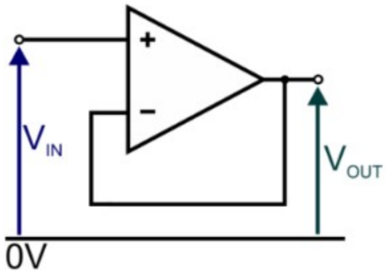
6 Summing Amplifier



The Virtual Ground Summing Amplifier is used in digital to analogue counters and sound mixers. The value of V_{OUT} can be calculated using the following equation:
$$V_{OUT} = -R_F \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \dots \right)$$
The equation can be expanded or shrunk to fit as many inputs as required. As this makes use of an inverting amplifier design, the output is inverted. This can be reversed by adding another standard inverting amplifer to the output, with R_F and R_1 equal, so that no gain is applied, as seen in the diagram below.



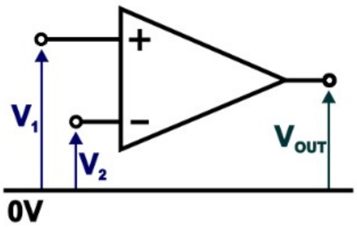
7 Voltage Follower



This can be used as an impedance buffer. It can reduce the resistance so that a subsystem connected after the buffer gets the right resistance and current.

8 Comparator

This compares the input and outputs a value depending on which is bigger.



If $V_+ > V_- \therefore V_{OUT} = +V_{sat}$
If $V_- > V_+ \therefore V_{OUT} = -V_{sat}$
We can set V_- to a fixed value then the comparator will tell us if V_+ is bigger or smaller. A photodiode could be used as part of the sensor subsystem.