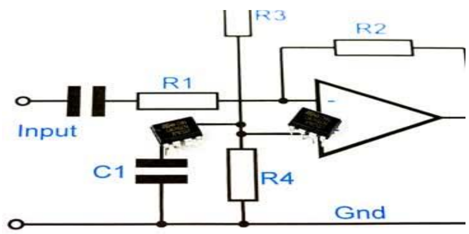
OPERATIONAL AMPLIFIERS AND ITS APPLICATION

Operational amplifiers are particularly versatile circuit blocks. They find applications in a host of different circuits where their attributes of high gain, high input impedance low output impedance and a differential input enable them to provide a high performance circuit with a minimum of components.

By using negative, and sometimes positive feedback around the op amp chip they can be used in many applications and circuits to provide a variety of different functions from amplifiers and filters to oscillators, integrators and many other functions.

There are many op amp circuits that cover most of the main analogue functions that are needed. As a result of this, operational amplifiers have become the workhorse of the analogue electronics designer.



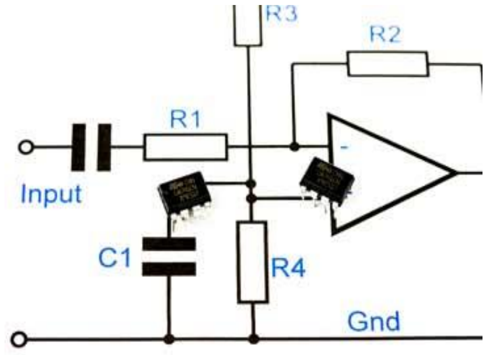
.Inverting amplifier

It is often necessary to know the input impedance of a circuit, and in this case of the inverting amplifier. A circuit with a low input impedance may load the output of the previous circuit and may give rise to effects such as changing the frequency response if the coupling capacitors are not large.

It is very simple to determine the input impedance of an inverting operational amplifier circuit. It is simply the value of the input resistor R1.

It is easy to reason why the input impedance to the amplifier circuit is equal to R1.
The non-inverting input is connected to ground and therefore this is properly at ground potential.

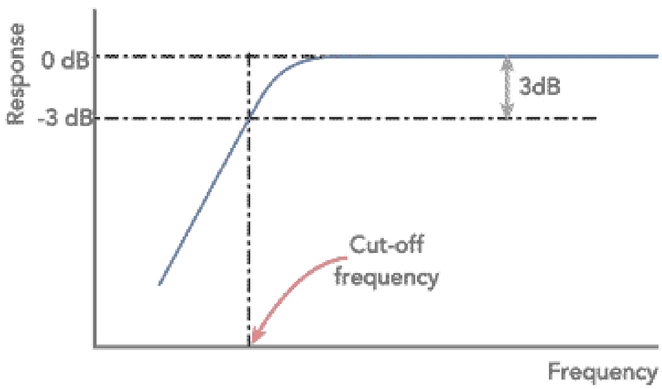
The gain of the operational amplifier is very high, this means that for outputs within the rail voltage, which it is for an analogue amplifier, the voltage difference between the inverting and non-inverting inputs must be very small. As the non-inverting input is at ground, the inverting input must be virtually at ground. It is for this reason that the circuit is sometimes referred to as a virtual earth amplifier.



Op amp inverting amplifier with op amp chips

What is a high pass filter

As the name implies, a high pass filter is a filter that passes the higher frequencies and rejects those at lower frequencies.



High pass filter response curve

The shape of the curve is of importance. One of the most important features is the cut-off frequency. This is normally taken as the point where the response has fallen by 3dB.

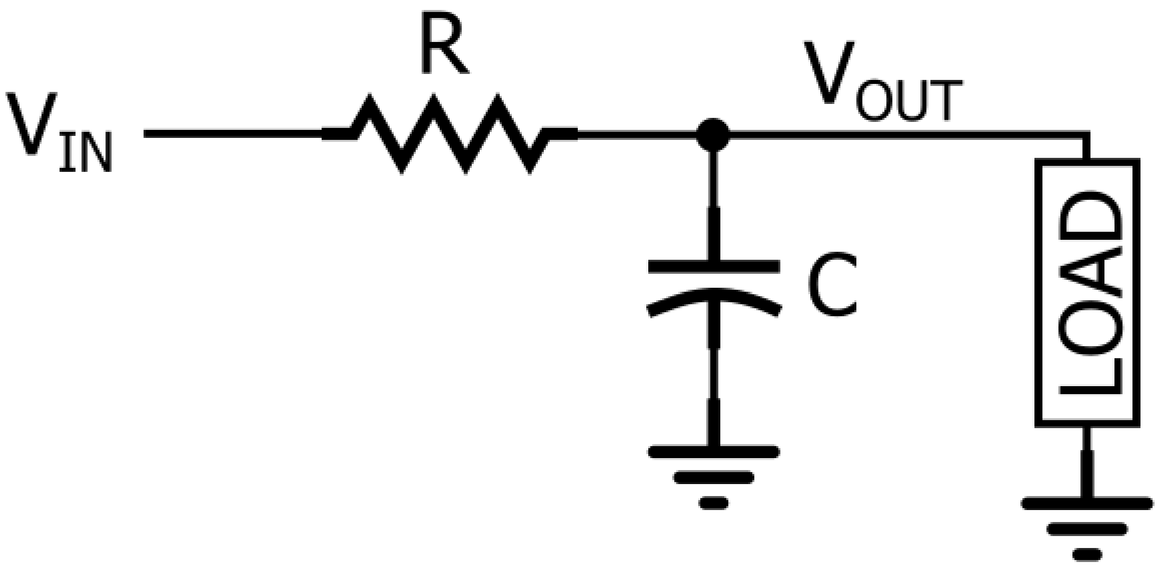
Another important feature is the final slope of the roll off. This is generally governed by the number of 'poles' in the filter. Normally there is one pole for each capacitor or inductor in a filter.

When plotted on a logarithmic scale the ultimate roll-off becomes a straight line, with the response falling at the ultimate roll off rate. This is 6dB per pole within the filter.

The advantage of using an op amp circuit for the high pas filter, is that a multiple pole circuit can be made using just capacitors and resistors, rather than inductors that might otherwise be needed.

LOW PASS FILTER

To create a passive low-pass filter, we need to combine a resistive element with a reactive element. In other words, we need a circuit that consists of a resistor and either a capacitor or an inductor. In theory, the resistor-inductor (RL) low-pass topology is equivalent, in terms of filtering ability, to the resistor-capacitor (RC) low-pass topology. In practice, though, the resistor-capacitor version is much more common, and consequently the rest of this article will focus on the RC low-pass filter.

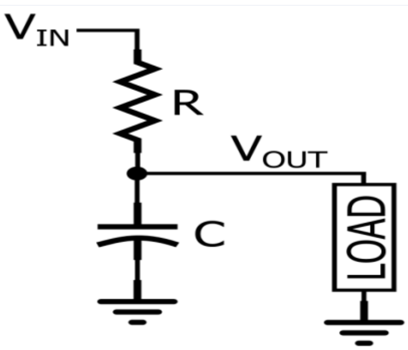


The RC low-pass filter.

As you can see in the diagram, an RC low-pass response is created by placing a resistor in series with the signal path and a capacitor in parallel with the load. In the diagram, the load is a single component, but in a real circuit it might be something much more complicated, such as an analog-to-digital converter, an amplifier, or the input stage of the oscilloscope that you are using to measure the response of the filter.

We can intuitively analyze the filtering action of the RC low-pass topology if we recognize that the resistor and the capacitor form a frequency-dependent voltage divider.

The RC low-pass filter redrawn so that it looks like a voltage divider.



When the frequency of the input signal is low, the impedance of the capacitor is high relative to the impedance of the resistor; thus, most of the input voltage is dropped across the capacitor (and across the load, which is in parallel with the capacitor). When the input frequency is high, the impedance of the capacitor is low relative to the impedance of the resistor, which means that more voltage is dropped across the resistor and less is transferred to the load. Thus, low frequencies are passed and high frequencies are blocked.

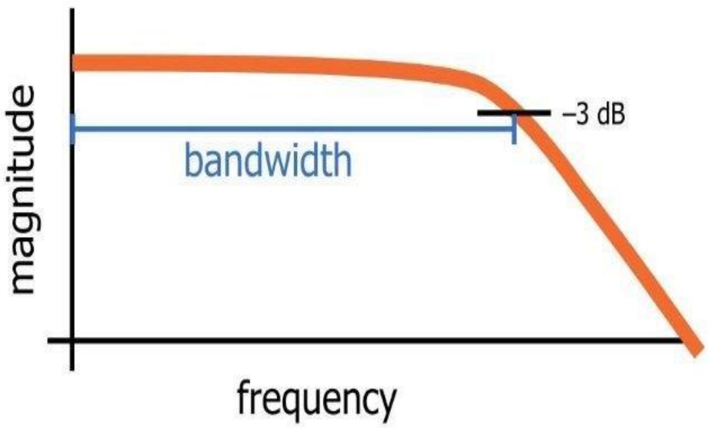
This qualitative explanation of RC low-pass functionality is an important first step, but it isn't very helpful when we need to actually design a circuit, because the terms "high frequency" and "low frequency" are extremely vague. Engineers need to create circuits that pass and block specific frequencies. For example, in the audio system described above, we want to preserve a 5 kHz signal and suppress a 500 kHz signal. This means that we need a filter that transitions from passing to blocking somewhere between 5 kHz and 500 kHz.

The Cutoff Frequency

The range of frequencies for which a filter does not cause significant attenuation is called the **passband**, and the range of frequencies for which the filter does cause significant attenuation is called the **stopband**. Analog filters, such as the RC low-pass filter, always transition gradually from passband to stopband. This means that it is impossible to identify one frequency at which the filter stops passing signals and starts blocking signals. However, engineers need a way to conveniently and concisely summarize the frequency response of a filter, and this is where the concept of **cutoff frequency** comes into play.

When you look at a plot of an RC filter's frequency response, you will notice that the term "cutoff frequency" is not very accurate. The image of a signal's spectrum being "cut" into two halves, one of which is retained and one of which is discarded, does not apply, because attenuation increases gradually as frequencies move from below the cutoff to above the cutoff.

The cutoff frequency of an RC low-pass filter is actually the frequency at which the amplitude of the input signal is reduced by 3 dB (this value was chosen because a 3 dB reduction in amplitude corresponds to a 50% reduction in power). Thus, the cutoff frequency is also called the **–3 dB frequency**, and in fact this name is more accurate and more informative. The term **bandwidth** refers to the width of a filter's passband, and in the case of a low-pass filter, the bandwidth is equal to the –3 dB frequency (as shown in the diagram below).



This diagram conveys the generic characteristics of the frequency response of an RC low-pass filter. The bandwidth is equal to the –3 dB frequency.

$$f_C = \frac{1}{2\pi RC}$$