Bandwidth

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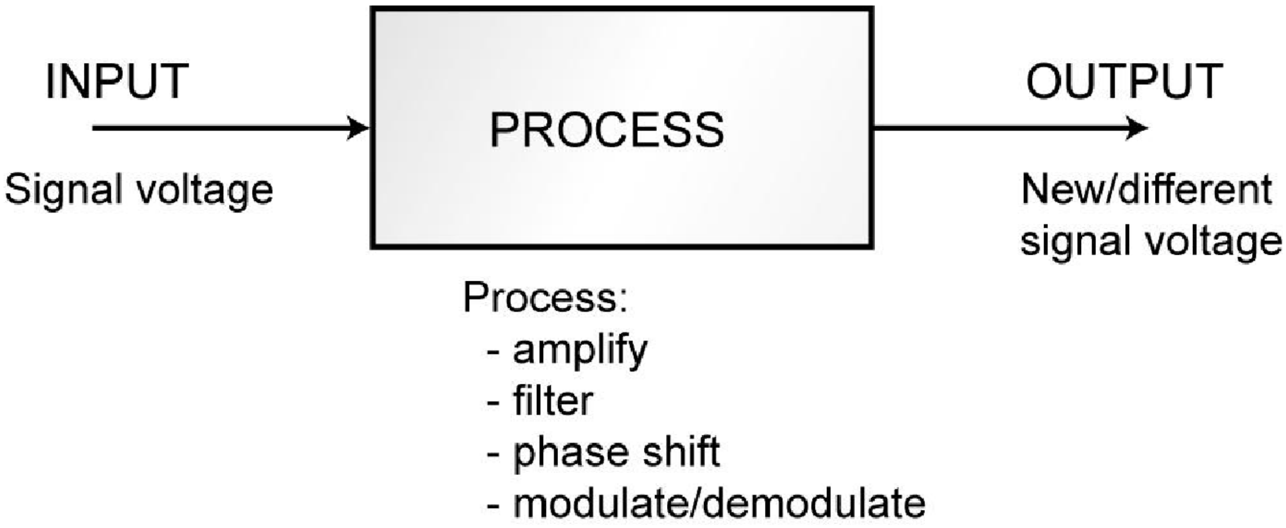
Bandwidth is the specific range of frequencies over which the circuit operates. That range is called the frequency response of the circuit. It passes some frequencies and rejects others.

When analyzing an electronic circuit, you must know both the bandwidth and the frequency content of the input signal.

If the two are compatible, the circuit will pass all of the components of the signal including most of the harmonics it contains.

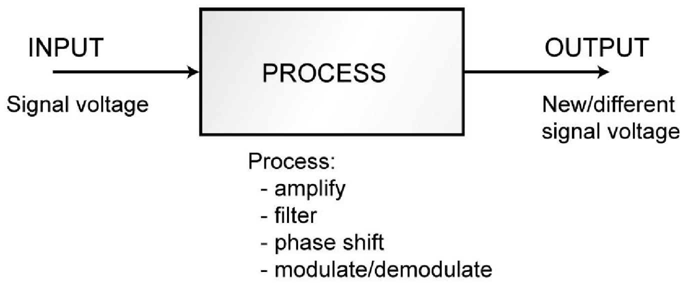
The bandwidth of a circuit must be wide enough to pass most of the harmonics.

The Concept of Bandwidth



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

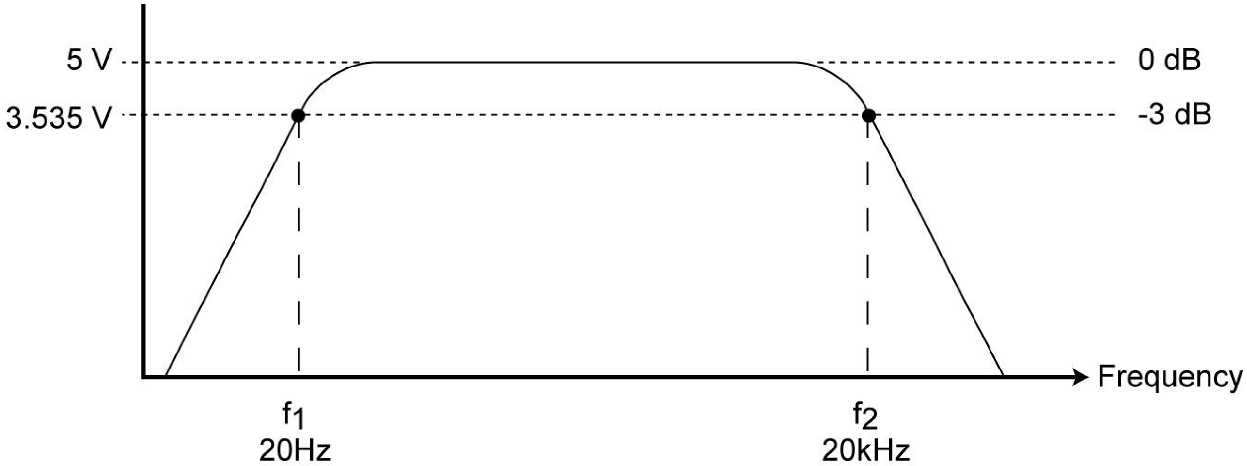
The Concept of Bandwidth



All electronic circuits use the input-process-output model. The signal voltage is applied to the input and the circuit processes the signal is some way. For example, an amplifier processes the signal by multiplying it by some gain factor or a filter performs some frequency selective operation on the signal.

Whatever the process, all circuits have a finite bandwidth (BW). Bandwidth is the specific range of frequencies over which the circuit operates. That range is called the frequency response of the circuit. It passes some frequencies and rejects others.

Frequency Response



$$BW = f_2 - f_1$$
$$= 20000 - 20 = 19980 \text{ Hz}$$

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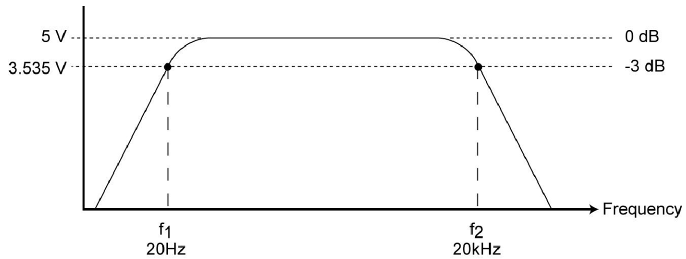
Frequency Response



BW = f_2 - f_1
= 20000 - 20 = 19980 Hz

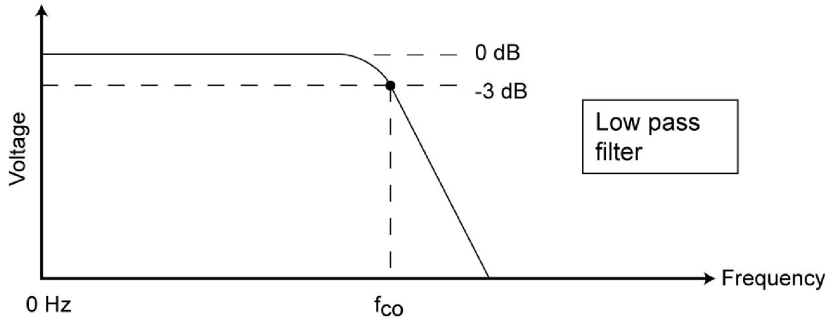
The frequency response of an audio amplifier passes audio frequency signals between the upper and lower limits of human hearing (from about 20 Hz to 20 kHz.) The bandwidth of this circuit is the difference between the two cut-off frequencies f_1 and f_2. The cut-off frequencies are those frequencies where the gain of the amplifier drops 3 dB from the flat maximum output voltage. The -3 dB points have a voltage that is 0.707 of the maximum output voltage. If the voltage is 5 volts at the mid-range, the voltage at the f_1 and f_2 frequencies is 5 x 0.707 = 3.535 volts.

The bandwidth is the difference between the upper and lower cut-off frequencies or: BW = f_1 - f_2

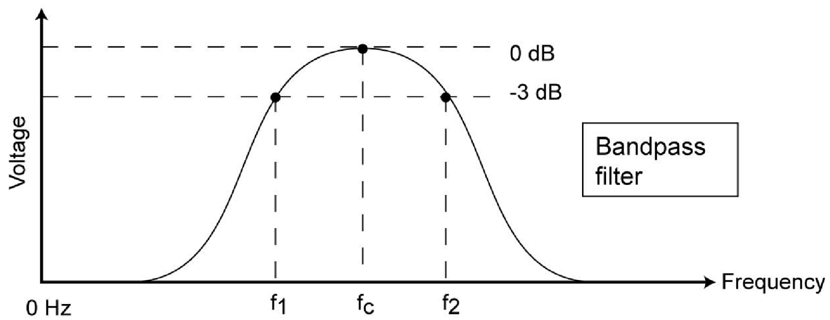
With the frequencies shown, the bandwidth is:

BW = 20,000 – 20 = 19,980 Hz

Filter Bandwidth



$BW = f_{co} - 0\ Hz = f_{co}$



$BW = f_2 - f_1$

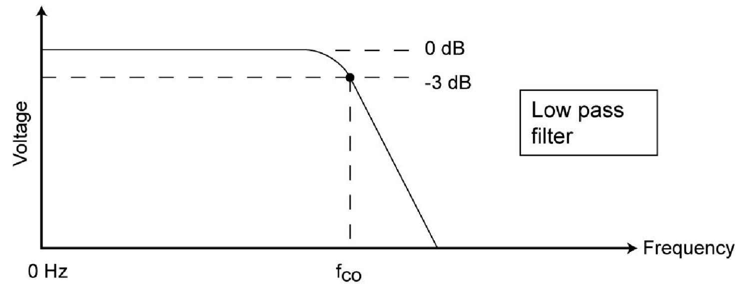
A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

Filter Bandwidth

All filters have a bandwidth. The figures show low pass and band pass filter frequency response curves.

Low pass filters have a lower cut-off frequency of 0 Hz since they pass DC. The bandwidth is the value of the upper cut-off frequency f_{co}.

In a band pass filter, the bandwidth is the difference between the upper (f_2) and lower (f_1) cut-off frequencies.



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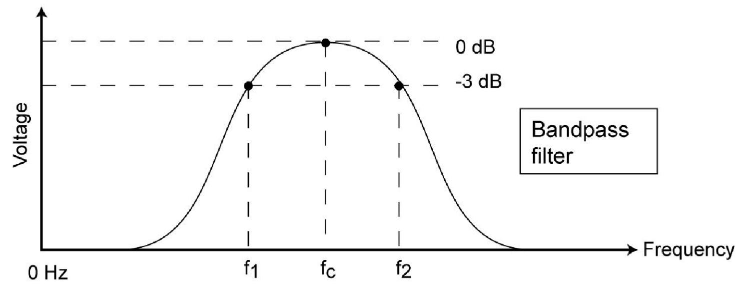


$BW = f_2 - f_1$

The Consequence of Bandwidth

When analyzing an electronic circuit, you must know both the bandwidth and the frequency content of the input signal.

If the two are compatible, the circuit will pass all of the components of the signal including most of the harmonics it contains.

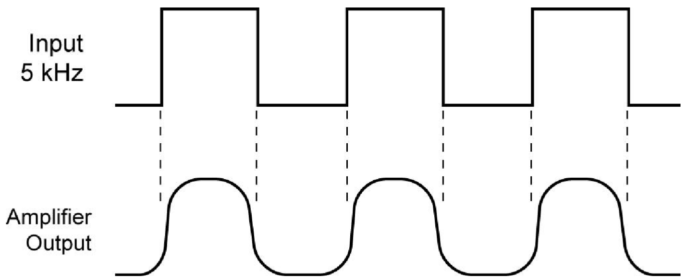
If the circuit has a limited bandwidth, it will act as a filter. Some of the parts of the signal, typically the upper level harmonics, will not be passed. As a result, the output signal will be a distorted version of the input.

The Consequence of Bandwidth Example

If a 5 kHz square wave is applied to the input of an audio amplifier, the output will contain the 5 kHz fundamental sine wave and the 15 kHz third harmonic.

The 5th and higher level harmonics will be either greatly attenuated or filtered out. The amplifier output will be a severely distorted square wave with rounded corners and longer rise and fall times.

The bandwidth of the circuit must be wide enough to pass most of the harmonics.



Predicting Bandwidth

The bandwidth of an amplifier, filter, or other circuit can be determined by applying a signal generator to the input and changing the frequency in increments. The output voltage is then measured and plotted over a wide range of frequencies. This results in a frequency response curve.

Another popular approach is to pass a fast square wave through the amplifier or filter and then measure the rise time (t_r) of the output signal.

The bandwidth then is approximately:

$$BW = 0.35/\ t_r$$

BW is in MHz and t_r is in microseconds.

Calculating Bandwidth

A low pass filter with a square wave input produces an output pulse with a rise time for 750 nS.

The bandwidth is:

$$BW = .35/t_r = .35/750 \times 10^{-9} = 467 \text{ kHz}$$

The faster the rise time, the wider the bandwidth. The fast rise time is the result of passing many of the higher harmonics.

The greater the bandwidth, the greater the number of higher harmonics that add together to produce a steep rise time.

Test your knowledge

Fourier Theory Knowledge Probe 4

Bandwidth

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Then choose **Knowledge Probe 4**.