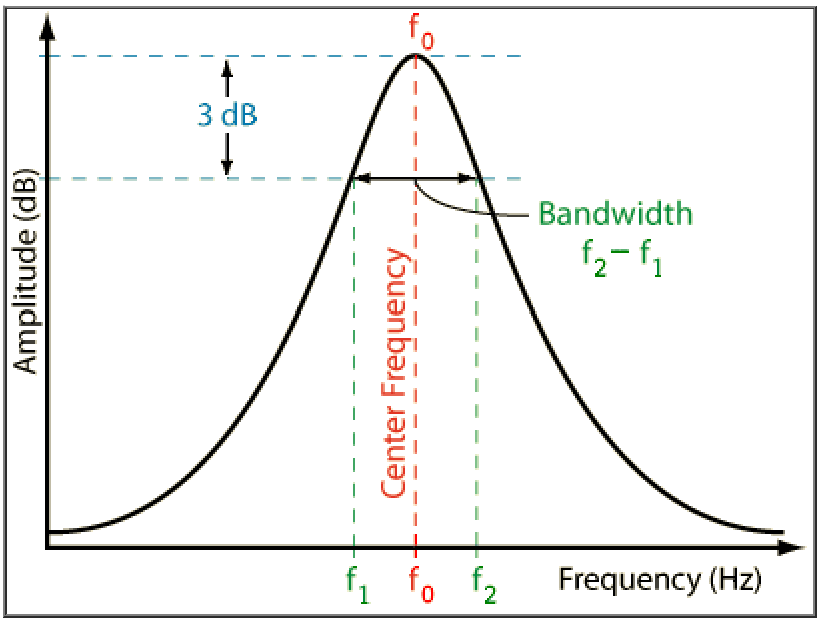
Tontechnik-Rechner - sengpielaudio

Deutsche Version

• Calculation − Equalization − Bandpass − Filter •

Calculating the bandwidth at −3 dB cut-off frequencies f_1 and f_2 when center frequency f_0 and Q factor is given.

The bandwidth BW is between lower and upper cut-off frequency.



3 dB bandwidth $BW = f_2 - f_1 = f_0/Q$ and quality factor is Q factor

EQ filter conversion Q factor to bandwidth in octaves N

Parametric peak equalizer and notch (dip) equalizer

People use 'Q' and 'bandwidth' interchangeably, though they're not.
Defining the bandwidth for a bandpass as the −3 dB points cannot be correct for a boost gain of 3 dB or less.

f_1 and f_2 = corner frequency = cut-off frequency = crossover frequency = half-power frequency = 3 dB frequency = break frequency is all the same.

The center frequency f_0 is the geometric mean of f_1 and f_2

$BW = \Delta f = f_0 / Q$ $\quad Q = f_0 / BW$ $\quad f_0 = BW \times Q = \sqrt{(f_1 \times f_2)}$

$BW = f_2 - f_1$ $\quad f_1 = f_0^2 / f_2 = f_2 - BW$ $\quad f_2 = f_0^2 / f_1 = f_1 + BW$

Center frequency f_0 1000 Hz

Q factor or quality factor Q 1.414

reset ↓ calculate

Lower cutoff frequency f_1 Hz

Upper cutoff frequency f_2 Hz

Formula for the lower cutoff frequency:

$$f_1 = f_0\left(\sqrt{1+\frac{1}{4Q^2}} - \frac{1}{2Q}\right)$$

Formula for the upper cutoff frequency:

$$f_2 = f_0\left(\sqrt{1+\frac{1}{4Q^2}} + \frac{1}{2Q}\right)$$

Formula for the Q factor:

$$Q = \frac{f_0}{f_2 - f_1}$$

Formula for the bandwidth:

$$f_2 - f_1 = \frac{f_0}{Q}$$

A high filter quality means narrow-band filtering (notch), with a large Q factor. This results in steep filter flanks with a small bandwidth.

A low filter quality means broad-band filtering, with a small Q factor. This results in flat filter flanks with a large bandwidth.

Notice:
A low Q factor gives a broad band (wide) bandwidth or a high Q factor gives a narrow band (small) bandwidth.

Q factor as a function of the bandwidth in octaves N (octave bandwidth)

Bandwidth in octaves N	Q factor
3.0 wide	0.404 low
2.5	0.511
2.0	0.667
1.5	0.920
1.0	1.414
2/3	2.145
1/2	2.871
1/3	4.318
1/6	8.651

1/12 small	17.310 high

Conversion: 'bandwidth in octaves' *N* to quality factor *Q*
Interrelationship of 'octave bandwidth' *N* and the quality factor *Q*
Formulas for conversion of bandwidth in octaves to quality factor
Questions on "Parametric filter adjustment"
Conversion table *Q* to *N* and *N* to *Q* for parametric filters
Filter slope or steepness (dB/oct) is not bandwidth
Excel conversion - quality factor *Q* to bandwidth in octaves *N*
Calculating the center frequency from a given bandwidth
Finding the filter center frequency - geometric mean
Conversion RC-pad − R × C to Corner frequency fc and Cutoff frequency to R × C − Time constant t (tau) = R × C

Why is the bandwidth and the cutoff frequency found at the level of "−3 dB"?
Why we always take 3 dB down gain of a filter?
Full width at half maximum (FWHM).
Answer: That is the point where the energy (power) is fallen to the value ½ or 0.5 = 50 percent of the initial power as energy quantity, that is equivalent to (−)3 dB = 10×log(0.5). A (−)3 dB power drop is a decrease of 50 % to the value of 50 %.
There the voltage is fallen to the value of √(½) or 0.7071 = 70.71 percent of the initial voltage as field quantity equivalent to (−)3 dB = 20×log(0.7071). A (−)3 dB voltage drop is a decrease of 29.29 % to the value of 70.71 %.

(−)3 dB implies ½ the electric power and since the power is proportional to the square of voltage, the value will be 0.7071 or 70.71 % of the passband voltage.
√½ = 1/√2 = √0.5 = 0,7071. $P \sim V^2$, that is $0{,}5 \sim 0{,}7071^2$.

Sound engineers and sound designers ("ear people") mostly use the usual (sound) **field quantity.**
That'swhy they say:
The cutoff frequency of a device (microphone, amplifier, loudspeaker) is the frequency at which the output voltage level is decreased to a value of (−)3 dB below the input voltage level (0 dB).
• (−)3 dB corresponds to a factor of √½ = 1/√2 = 0.7071, which is 70.71% of the input voltage.

Acousticians and sound protectors ("noise fighters") seem to like more the (sound) **energy quantity.**
They tell us:
The cutoff frequency of a device (microphone, amplifier, loudspeaker) is the frequency at which the output power level is decreased to a value of (−)3 dB below the input power level (0 dB).
• (−)3 dB corresponds to a factor of ½ = 0.5, which is 50% of the input power (half the value).

Note: Power gain (power amplification) is not common in audio engineering.
Even power amplifiers for loudspeakers don't amplify the power.
They amplify the audio voltage that moves the voice coil.

Sound field quantities Sound pressure, sound or particle velocity, particle displacement or displacement amplitude, (voltage, current, electric resistance). **Inverse Distance Law 1/*r***		**Sound energy quantities** Sound intensity, sound energy density, sound energy, acoustic power. (electrical power). **Inverse Square Law 1/*r*²**

Note: A sound field quantity (sound pressure p, electric voltage V) is not a sound energy quantity (sound intensity I, sound power P_{ak}). $I \sim p^2$ or $P \sim V^2$. Sometimes you can hear the statement: The cutoff frequency is there where the level L is

decreased by (−)3 dB.
Whatever the user wants to tell us so accurately: Level is level or dB is dB.

Bandwidth for Yamaha Parametric Equalizer

For a Yamaha parametric equalizer EQ there is the filter bandwidth of an octave divided in 60/60 (12 semitones).
One half tone step (semitone) is then 5/60 − 01V Digital Mixing Console.
Conversion:
N = "bandwidth in octaves" (semi tone or half tone distance). Q = Q factor

Filter EQ	N	Q	Interval		Filter EQ	N	Q	Interval
5/60	0.083	17.31	Semitone step		95/60	1.583	0.867	
10/60	0.167	8.651	Whole tone		100/60	1.667	0.819	
15/60	0.25	5.764			105/60	1.75	0.776	
20/60	0.333	4.318	1/3 octave		110/60	1.833	0.736	
25/60	0.417	3.45			115/60	1.917	0.7	
30/60	0.5	2.871	1/2 octave		120/60	2	0.667	2 octaves
35/60	0.583	2.456	Fifth		125/60	2.083	0.636	
40/60	0.667	2.145			130/60	2.167	0.607	
45/60	0.75	1.902			135/60	2.25	0.581	
50/60	0.833	1.707			140/60	2.333	0.556	
55/60	0.917	1.548			145/60	2.417	0.532	
60/60	1	1.,414	1 octave		150/60	2.5	0.511	2.5 octaves
65/60	1.083	1.301			155/60	2.583	0.49	
70/60	1.67	1.204			160/60	2.667	0.471	
75/60	1.25	1.119			165/60	2.,75	0.453	
80/60	1.333	1.044			170/60	2.883	0.436	
85/60	1.417	0.979			175/60	2.917	0.419	
90/60	1.5	0.92	1.5 octaves		180/60	3	0.404	3 octaves

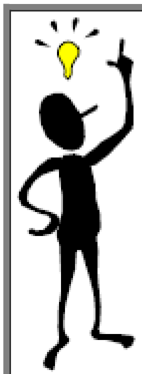
The "BW/60" control replicates the effect of the Behringer Pro DSP1124P - Feedback Destroyer bandwidth setting.
This control sets the bandwidth of the filter between the half-gain points with:

$$\text{BW (Hz)} = f_0 \times (\text{BW} / 60) \times \sqrt{2}$$

For example, at a bandwidth setting of 60/60 a filter centred on 1 kHz with a gain of −6 dB will have a bandwidth of 1,414 Hz between the points where its response crosses −3 dB. This bandwidth remains constant as the filter's gain is adjusted.
Note that the Behringer DSP1100 - 24 band parametric equalizer software package does **NOT** correctly reproduce the way the bandwidth control actually operates, its bandwidths are too small by a factor of √2.
Defining filter bandwidth in this way is not uncommon (the TMREQ filters use a similar definition).
The relationship between Q and BW for the DSP1124P is:

$$Q = 60 / [(\text{BW} / 60) \times \sqrt{2}]$$

So the bandwidth range of 1/60 to 120/60 gives a range from Q = 42.4 to 0.35.



At the cut-off frequency f_c of a drop the **voltage** V is always fallen to the value
$1/\sqrt{2} = 0.7071 \equiv 70.71$ % and the voltage level is damped by
$20 \times \log (1/\sqrt{2}) = (-)3.0103$ dB.

At the cut-off frequency (half-power frequency) the less interesting **power** P
is always fallen to
$1/2 = 0.5 \equiv 50$ % and the power level is damped by
$10 \times \log (1/2) = (-)3.0103$ dB − that is the same dB value.

	This is often confusing. 0.7071 × 0.7071 is 0.5 and $P = V^2/R;\ P \sim V^2$. What do you mean by 3 dB cutoff frequency? Why is it 3 dB, not 1 dB? Answer: The power P is always fallen there to 1/2 = 0.5 = 50 %.

Quality Factor $Q = f_0\,/\,BW$

$BW = f_0/Q$ $Q = f_0/BW$ $f_0 = BW \times Q$

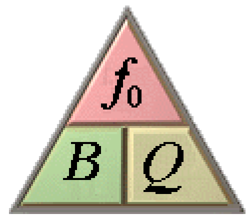
Please enter **two** values, the third value will be calculated.

Center frequency f_0 Hz

Bandwidth BW Hz

Quality Factor Q

reset calculate



Measurement of input impedance and output impedance

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