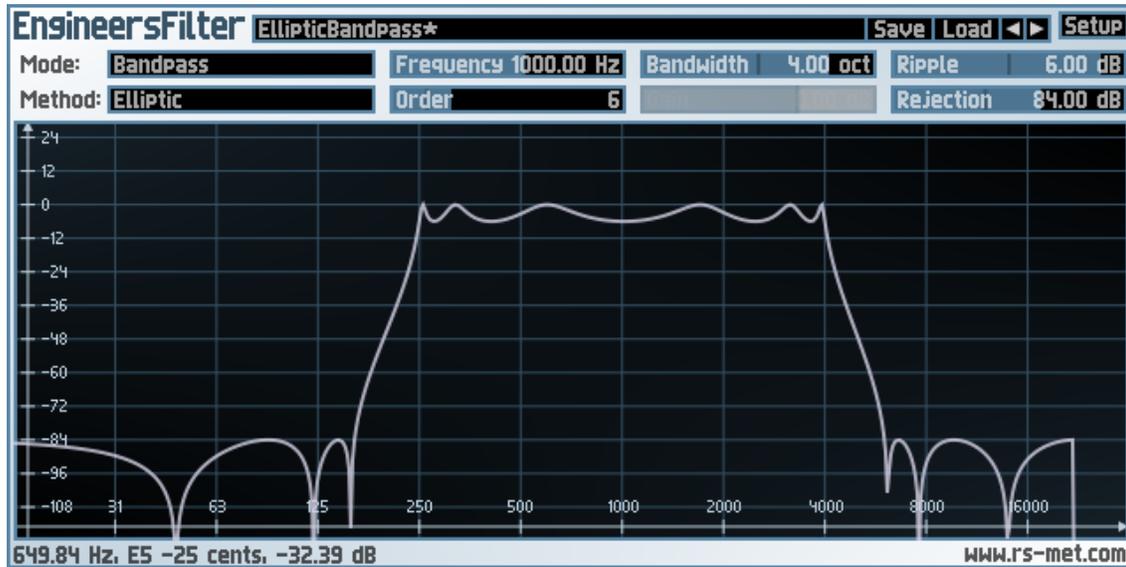# Engineers Filter - User Manual

What is Engineers Filter?

Engineers Filter is a filter plugin that allows for extremely steep filtering. It achieves this by implementing high order IIR filter design methods that are commonly used in science and engineering, namely Butterworth, Chebychev, inverse Chebychev, elliptic (aka Cauer), Bessel and Papoulis filters. Each of these filter design methods can be applied to create lowpass, highpass, bandpass, bandreject, high/low shelving and peak/dip filters of orders up to 20.

Parameters

Mode Selects the type of the desired frequency response. Available modes are: Lowpass, Highpass, Bandpass, Bandreject, High/Low Shelving and Peak/Dip.

Method Selects the design method for the filter, that is, the mathematical method by which the desired frequency response will be approximated. Available choices are: Butterworth, Chebychev, Inverse Chebychev, Elliptic, Bessel and Papoulis.

Frequency The characteristic frequency of the filter. For lowpass and highpass filters, this will be the cutoff frequency, for bandpass-, bandreject-, and peak/dip filters, it is the center frequency and for the shelving filter types, it is the frequency at which the magnitude response goes through its half-gain point on a dB scale. In case of the Butterworth and inverse Chebychev design, the cutoff frequency is defined to be the frequency at which the magnitude response goes through the -3.01 dB point, for Chebychev and elliptic designs, the magnitude response goes through a dB-value which is defined by the ripple parameter - for higher order filters, it goes through this value several times, hence the term "ripple".

Order   Determines the order of the filter. For lowpass-, highpass- and shelving filters, this value here *is* the order, but for the other types (bandpass, bandreject, peak/dip), the actual order will be twice this value.

Bandwidth   Sets the bandwidth in octaves for bandpass-, bandreject- and peak/dip filters (grayed out when not applicable). For bandpass and bandreject filters, it is taken to be the distance between the two cutoff frequencies, for peak/dip filters, it's the distance between the two half-gain points.

Gain   Sets the maximum (or minimum) gain for the shelving and peak/dip filter types (grayed out when not applicable).

Ripple   Sets the ripple inside the passband for Chebychev and elliptic filters (grayed out when not applicable). These two filter design methods achieve a higher steepness than a Butterworth filter of the same order by allowing the magnitude response to ripple inside the passband. The amount of this ripple can be set up here. In case of lowpass, highpass-, bandpass- and bandreject-filters, the ripple is dialed in directly as a value in dB. In case of shelving and peak/dip filters, the ripple is dialed in as percentage of the maximum gain.

Rejection   Sets the stopband rejection for inverse chebychev and elliptic filters (grayed out when not applicable). These two filter design methods achieve a higher steepness than a Butterworth filter of the same order by allowing the magnitude response to ripple inside the stopband. The amount of this ripple can be set up here and is dialed in directly in dB.

Background: Filter Approximation Methods

When we design a filter, we typically first define our goal. In the context of filter design, the goal is to obtain the desired frequency response for the filter. For example, for a lowpass filter we would define our desired magnitude response as one that lets pass all signals below a certain cutoff frequency unchanged and does not let pass anything above that cutoff frequency. This defined idealized goal is typically not practically achievable, so we must resort to a practical solution that - in some sense - approximates our ideal frequency response. This is where the different design methods come in. They all approximate the desired ideal magnitude response in a different way and each of the approximations has its own strengths and weaknesses. The Butterworth method has the strength of having no ripple, neither in the passband nor in the stopband and the magnitude response is as flat as posssible in the passband. The Chebychev design allows for some ripple in the passband to increase the initial slope of the filter at the cutoff frequency. The Inverse Chebychev design, on the other hand, allows for ripple in the stopband, which means that the magnitude response has sidelobes through which unwanted frequencies may leak through. The elliptic design allows for ripple in both regimes - pass- and stopband - and thereby achieves narrowest transition bandwidth between passband and stopband that is possible for a filter of the given order. The Bessel design method approximates a linear phase response and is therefore suitable whenever the waveform shape in the time-domain should be preserved. Finally, the Papoulis design method achieves the maximum possible (negative) slope at the cutoff frequency under the constraint that the magnitude response should be monotonically decreasing. There exist yet other design methods such as Gaussian, Halpern, etc. which are not (yet?) implemented here - each of which with a different approximation objective.