BASIC SYNTHESIS/AUDIO TERMS

Fourier Theory

Any wave can be expressed/viewed/understood as a **sum** of a series of **sine waves**.

As such, any wave can also be **created** by summing together a series of **sine waves**.

Fundamental

The lowest frequency of a periodic waveform.

Harmonics/Partials

Harmonics are waves whose frequency is an **integer/whole-number** multiple of the frequency of some reference wave, i.e. the **fundamental**.

Some Basic Waveforms

- **Sine Wave**

  A smooth 'rolling' oscillation.

  Obviously it consists of only 1 **sine wave** so has the most simple spectrum possible.

  Listen

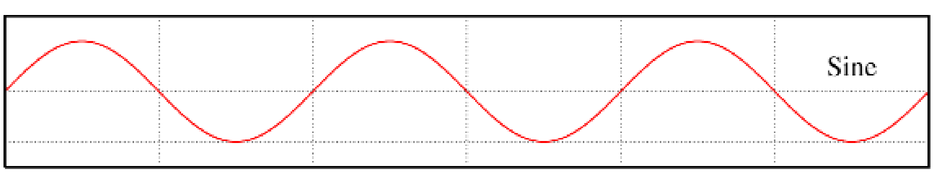

FIGURE 1. Sine Wave [1].

- **Sawtooth/Ramp Wave**

  Resembles the **teeth of a saw**. A straight slope from minimum to maximum is followed by an 'immediate' drop to minimum

Consists of **sine waves** at the **fundamental** frequency, and **every harmonic** of this frequency at gradually decreasing levels, thus has much more **high frequency** content than a **sine wave** - resulting in a 'buzzing' sound.

Listen

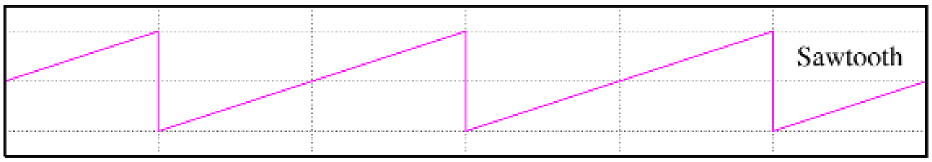

FIGURE 2. Sawtooth Wave [1].

- **Square/Rectangular Wave**

  Alternates between maximum and minimum values, **half** of the cycle is spent at maximum and the other **half** is spent at minimum.

  Consists of only **odd harmonics** (i.e. every **sine wave** which makes up the spectrum is an **odd** number multiple of the **fundamental**) at gradually decreasing levels.

  Also has much more **high frequency** content than a **sine wave**. Somewhat more of a 'hollow' timbre than a **sawtooth**, due to only having **odd** harmonics. Similar to the timbre of a clarinet.

  Listen

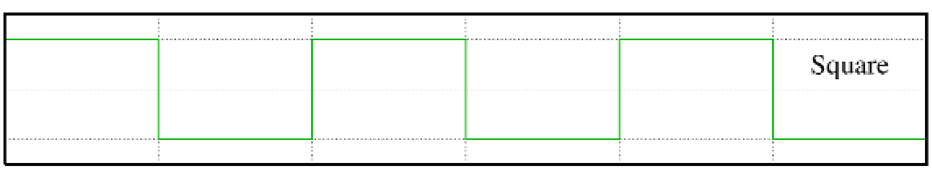

FIGURE 3. Square Wave [1].

- **Triangle Wave**

  Resembles a **triangle**. A straight slope from minimum to maximum is followed by an straight slope back to the minimum.

  Like a **square wave**, a **triangle wave** consists of all **odd** harmonics. However, each harmonic is at a much lower amplitude than in a **square wave**, resulting in a 'warmer,' less

buzzy, timbre. Somewhere between the timbres of a **sine wave** and a **square wave**.
Listen

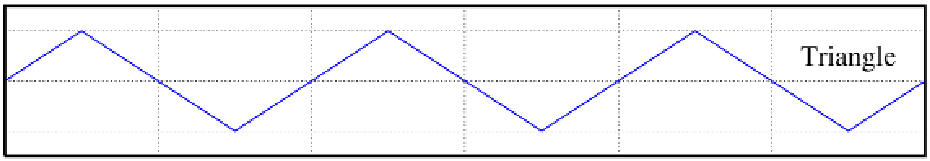

FIGURE 4. Triangle Wave [1].

- **Pulse Wave/Train**

  A **pulse train** is similar to a **square wave**, except the division of time between maximum and minimum values is not necessarily equal. (Note: The *ES E* synthesiser in *Logic Pro X* uses a **pulse train/wave**).

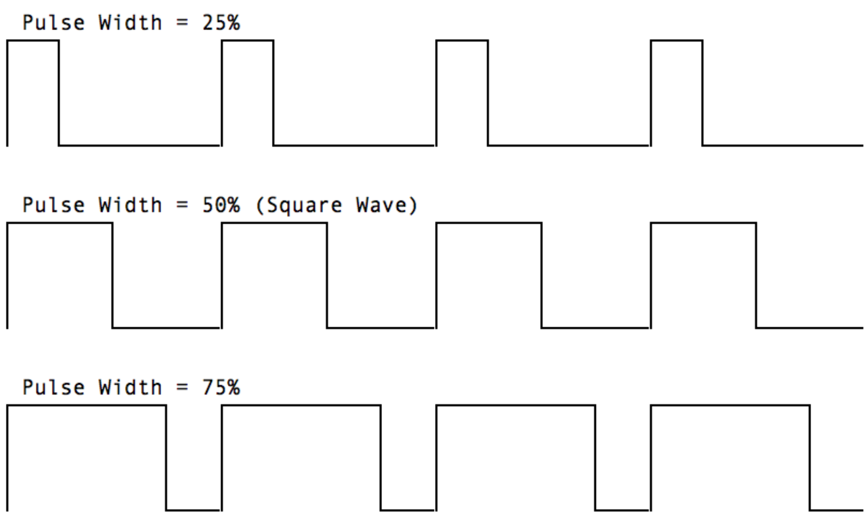

FIGURE 5. Pulse Train/Wave.

Types of Noise

- **White Noise**

  White noise consists of every possible frequency. At each moment in time every frequency has a random amplitude, and there is **no pattern** in the amplitudes between successive moments - i.e. at any moment in time every frequency is just as likely to be at maximum amplitude, minimum amplitude, or any amplitude in between.

  Listen

- **Pink Noise**

  Like **white noise**, **pink noise** contains every possible frequency. However, unlike **white noise**, in **pink noise** the maximum amplitude decreases as the frequency increases - i.e. lower frequencies are more prominent than higher frequencies.

  Listen

- **Brown Noise**

  Again, contains all frequencies, but has an **even greater decrease** in maximum amplitude as frequency increases than **pink noise**.

  Listen

Some Common Synthesis Techniques

- **Additive Synthesis** - In Additive Synthesis, sounds are created by **combining** (i.e. adding) together a number of **different** sine waves, each with a different frequency and amplitude. As more and more sine tones are combined the sound gets more complex.

- **Subtractive Synthesis** - In Additive Synthesis, we typically begin with **white noise**, or some other signal with a **rich spectrum** of frequencies, and then use filters to **remove** frequencies we do not want.

- **Amplitude Modulation (AM) synthesis** - In AM synthesis, one oscillator (the **modulator**) is used to change the **amplitude** of another (the **carrier**). If the frequency of the modulator is less than the lower limit for human hearing (i.e. < 20Hz) this sounds like **tremolo** - i.e. smooth variations in **amplitude**. Once the frequency of the modulator goes above the lower limit for human hearing we get AM synthesis - this is also how *Ring Modulators* work.

- **Frequency Modulation (FM) synthesis** - In FM synthesis, one oscillator (the **modulator**) is used to change the **frequency** of another (the **carrier**). If the frequency of the modulator is less than the lower limit for human hearing (i.e. < 20Hz) this sounds like **vibrato** - i.e. smooth variations in **pitch**. Once the frequency of the modulator goes above the lower limit for human hearing we get FM synthesis.

- **Granular Synthesis** - In Granular Synthesis complex sounds are created by combining numerous **grains** (tiny portions, less than 100ms) of sound. This can be achieved by first dividing a sound into grains and rearranging/redistributing them, or by creating one grain (for example 100ms of a sine wave) and having multiple instances of that one sound play at different pitches, different positions, different lengths etc. This technique usually results in "clouds" of sound...

Filtering/Equalization (EQ)

Audio filters **amplify** (increase the loudness), **pass** (neither increase nor decrease), or **attenuate** (decrease the loudness) specific frequency ranges of incoming audio.

The difference between EQ and Filtering is essentially a matter of terminology. Both can, and often are, used interchangeably, but usually **equalisation** involves "**modest** cuts or boosts of amplitude across the frequency spectrum"[1], while **filtering** usually involves more extreme alteration of the spectrum.

Filter Cutoff Frequency

The frequency at which the incoming audio begins to be **attenuated**.

Filter Resonance/Q

The extent to which the filter **amplifies** the **cutoff** frequency, and the frequencies surrounding it, i.e. the extent to which the filter **resonates** with the **cutoff** frequency.

Bandwidth

The range of frequencies within a specific range/band - i.e. the bandwidth between the notes A3 (220Hz) and A4 (440Hz) is 220Hz, but the bandwidth between A4 and A5(880Hz) is 440Hz.

[1] http://www.soundonsound.com/sos/jan05/articles/qa0105-4.htm

Some Common Filter Types

- **Low Pass** - all frequencies **higher** than the **cutoff** frequency are **attenuated** i.e. it allows **lower** frequencies to **pass**, but **attenuates higher** frequencies.

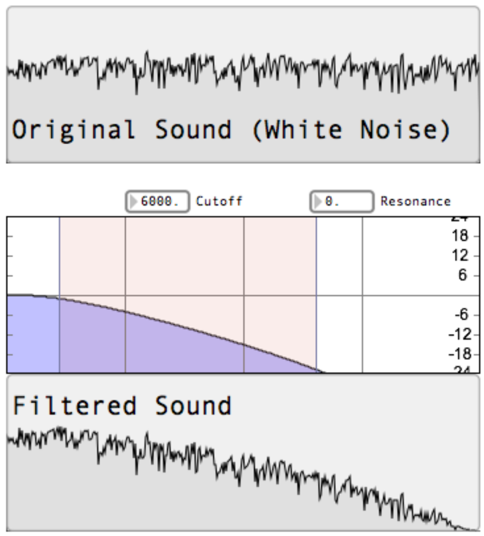

FIGURE 6. Low Pass Filter with low Resonance.

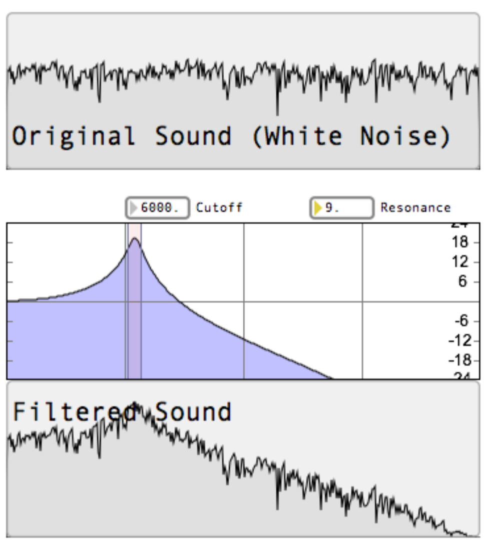

FIGURE 7. Low Pass Filter with high Resonance.

- **High Pass** - all frequencies **lower** than the **cutoff** frequency are **attenuated** i.e. it allows **higher** frequencies to **pass**, but **attenuates lower** frequencies.

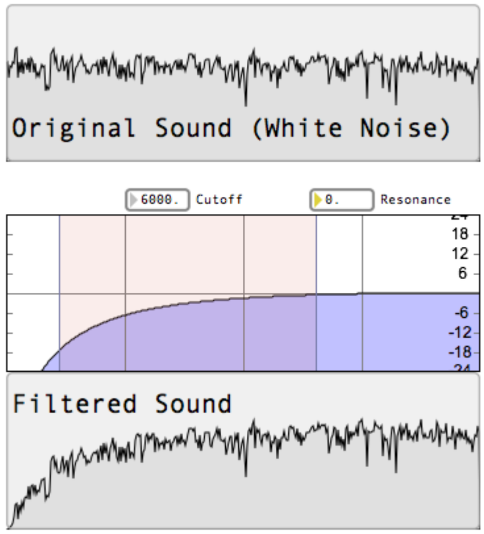

Figure 8. High Pass Filter with low Resonance.

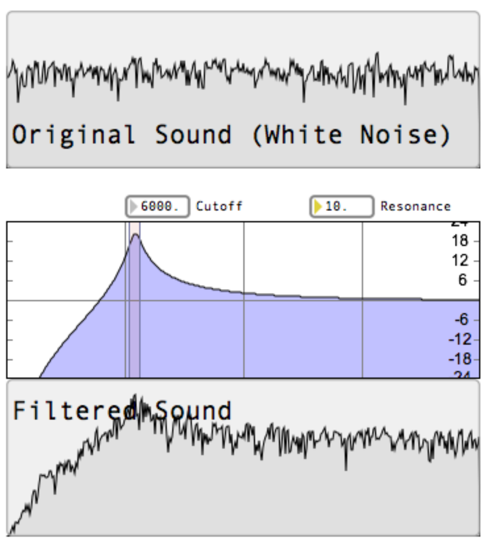

Figure 9. High Pass Filter with high Resonance.

- **Band Pass** - frequencies **surrounding** the **cutoff** frequency are **passed** or **amplified** i.e. it allows a **band**/range of frequencies, with **cutoff** frequency at the **band's** centre point, to **pass**, but **attenuates all other** frequencies.

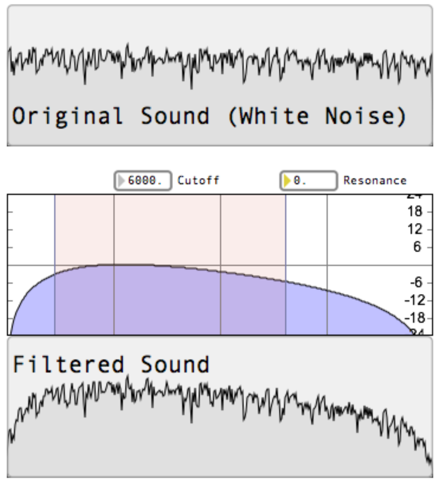

FIGURE 10. Band Pass Filter with low Resonance.

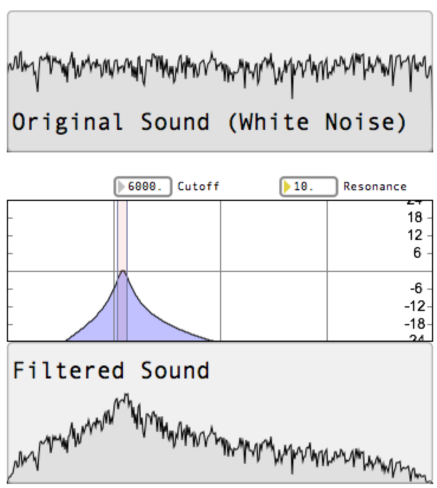

FIGURE 11. Band Pass Filter with high Resonance.

Note: The **resonance/Q** value sets the **bandwidth**, i.e. the higher the **resonance**, the narrower the **band** of frequencies **passed**, and vice versa.
Alternatively a **band pass** filter may be created by combining a **low pass** and **high pass** filter.

- **Band Stop** - the opposite of **band pass**

  i.e. it **attenuates** a **band**/range of frequencies, with **cutoff** frequency at the **band's** centre point.

  Note: The **resonance/Q** value sets the **bandwidth**, i.e. the higher the **resonance**, the narrower the **band** of frequencies **attenuated**, and vice versa.

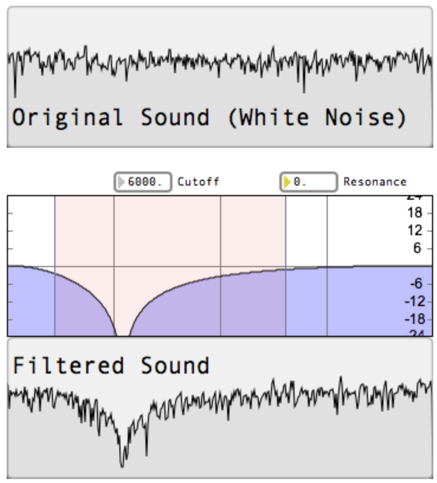

FIGURE 12. Band Stop Filter with low Resonance.

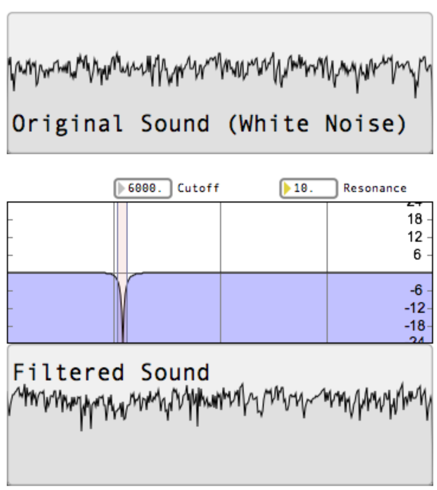

FIGURE 13. Band Pass Filter with high Resonance.

- **Peak Notch** - Allows us to either **amplify** or **attenuate** a **band** of frequencies.

  Note: The **resonance/Q** value sets the **bandwidth**, i.e. the higher the **resonance**, the narrower the **band** of frequencies **attenuated/amplified**, and vice versa.

  We have already seen **peak notch** filters when working with the *Channel EQ* in *Logic Pro*.

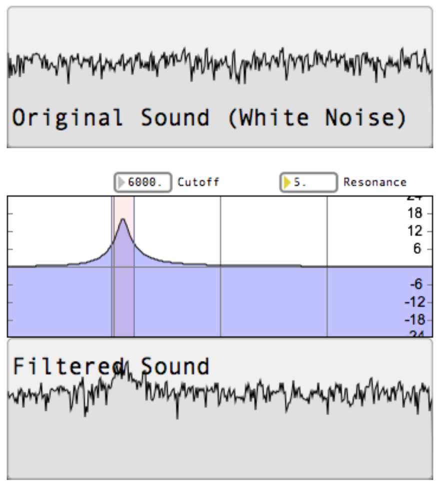

FIGURE 14. Peak Notch Filter with low Resonance.

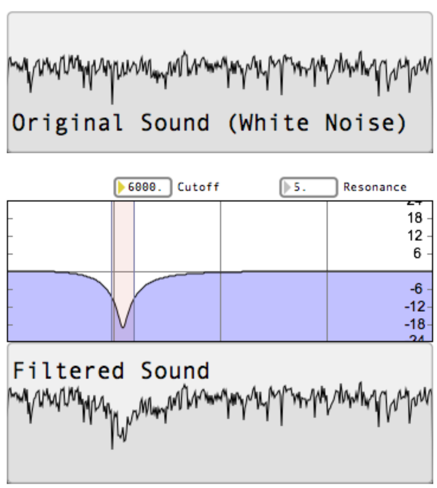

FIGURE 15. Peak Notch Filter with high Resonance.

Low Frequency Oscillators (LFO)

An **LFO** is a wave whose frequency is **below 20Hz**, thus producing a slow oscillation (sine), sweep (triangle/sawtooth), or rhythmic pulse (square/pulse).

We use **LFO**'s to **modulate** other variables such as filter cutoff, filter resonance, amplitude, FM, etc. thus creating **continuous** timbral changes.

Other Resources

General Equalisation Article

Equalization v Filter

Want something even more detailed on filters...

An (admittedly old) article on *Logic Pro*'s built in synthesisers

References

[1] Jeremy Krug. Basic Waveforms. http://public.wsu.edu/~jkrug/MUS364/audio/Waveforms.htm, Accessed October 25, 2015.