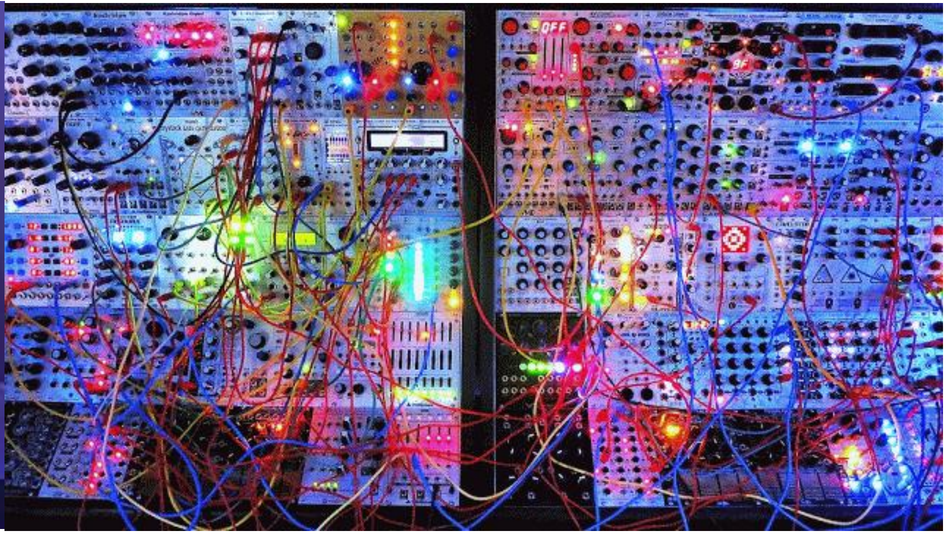
MUSC 4820/5820 Digital Music Techniques 001

Week 1: Signal Fundamentals 1

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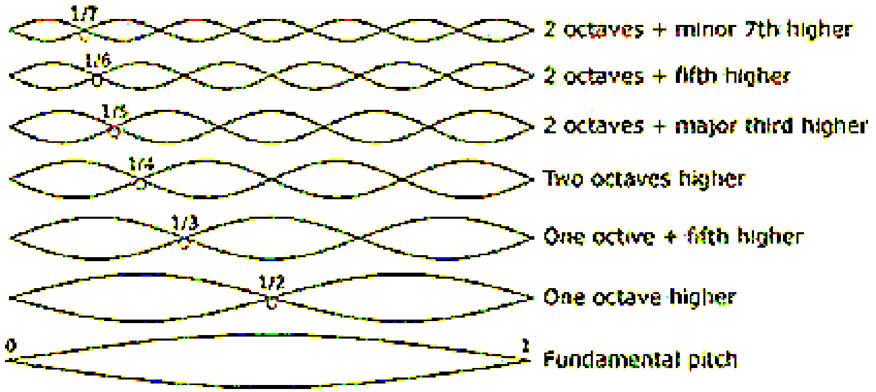
Fundamental Concept: Harmonics and Sound

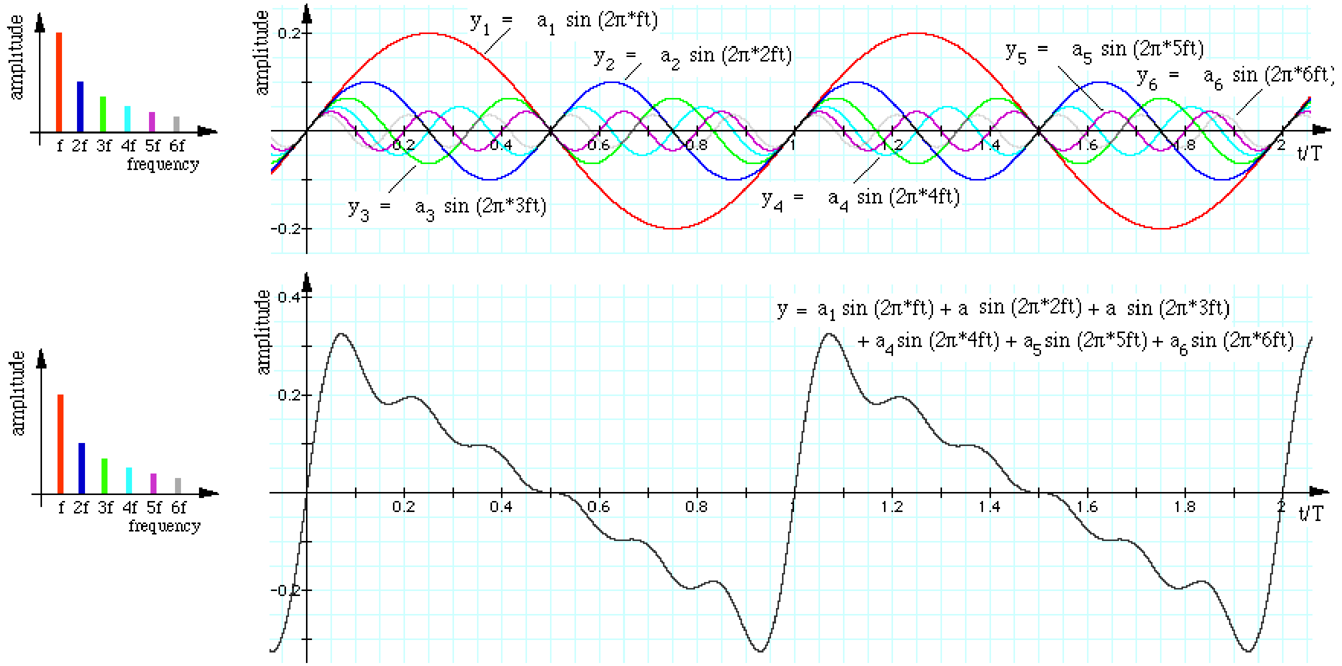
Try while maintain the same pitch and loudness, say the vowels “AEIOU” How do they sound like? And Why?

Harmonics: small components of sound – sometimes called “overtones” or “(harmonic) partials” – that are blended together in varying amounts of harmonics to create unique “waveshapes” (patterns of vibration) -> sounds. Changing the harmonic mix is the core of synthesizing sounds.

Partials and Overtones:



Fundamental frequency, coloring, & timbre



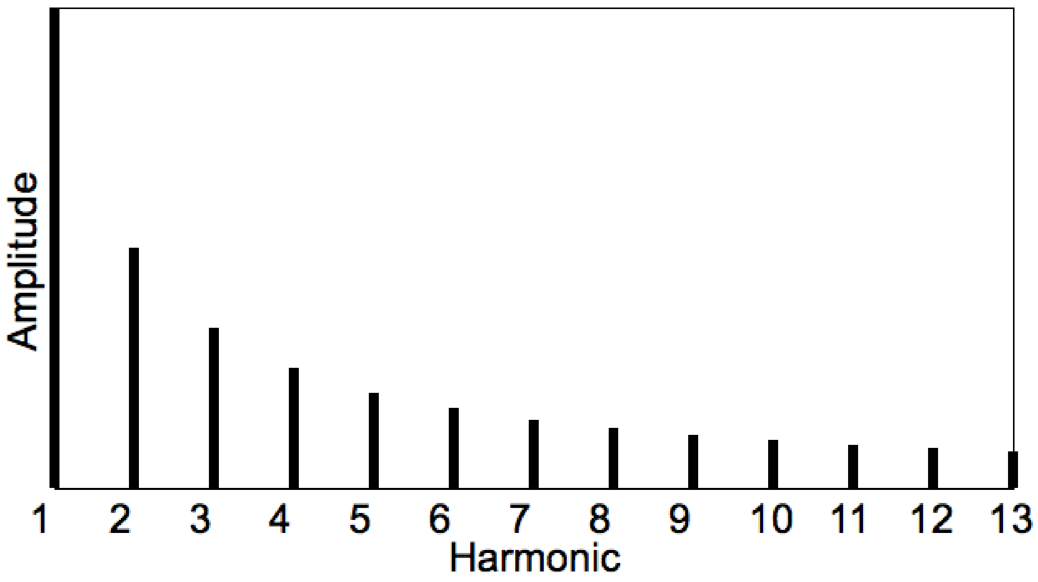
An example of a harmonic spectrum: the sawtooth wave (see patch)

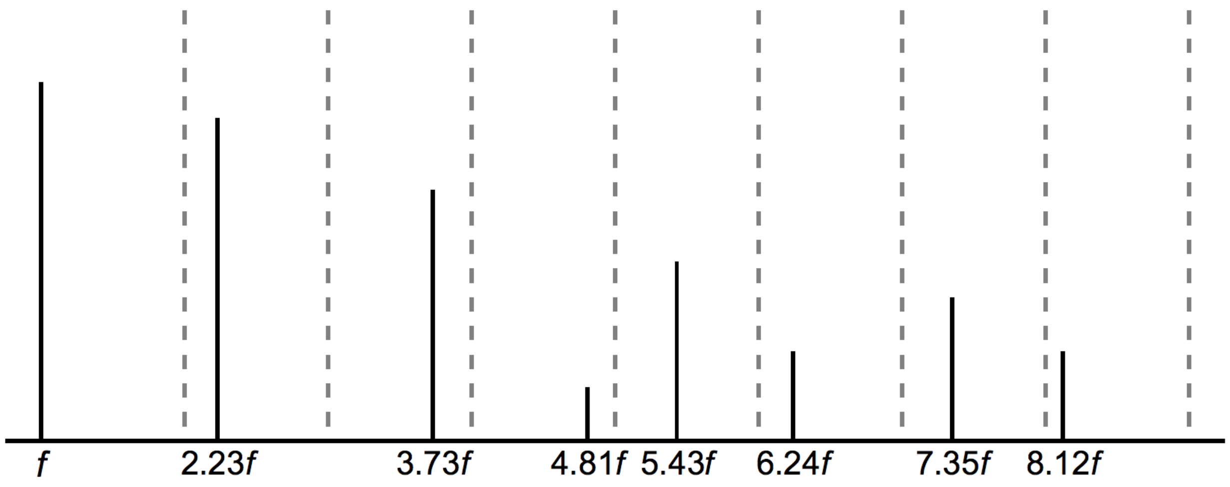
Fundamental Concept: Harmonics and Sound

Try while maintain the same pitch and loudness, say the vowels “AEIOU” How do they sound like? And Why?

Note: Not all overtones are intergers, and in the messy, real-world overtones are not as well behaved and that’s where things get really exciting :D !!!!

Cymbals and drumheads have overtones spaced at 1.594x, 2.136x, 2.296x, 2.653x, and other “inharmonic” multiples of the fundamental frequency. Even the partials of the lowest, thickest piano strings are not space by perfect integers,





Fundamental Concept: Harmonics and Sound

Try while maintain the same pitch and loudness, say the vowels “AEIOU” How do they sound like? And Why?

Subharmonic (Undertone series): Harmonics are added below the fundamental frequency, usually with the same integer spacing as normal harmonics. You can explore subharmonic synthesis using the Doepfer A-113 subharmonic generator module, or the Moog sub-harmonicon semi-modular synth.

- Subharmonic synthesis is used extensively in dance clubs in certain genres of music such as disco and house.
- They are often implemented to enhance the lower frequencies, in an attempt to gain a "heavier" or more vibrant sound.
- Various harmonics can be amplified or modulated, although it is most common to boost the fundamental frequency’s lower octave.
- The kick drum can benefit greatly from this type of processing.
- A subharmonic synthesizer (or "synth" as it is known in the industry) creates a bigger presence and can give the music that much sought-after "punch".

Tibetan Throat Singing is a natural application of subharmonics!!!

See Patch

Fundamental Concept: Voltage Control

How do you tell a synthesizer module what you want it to do? How do modules know what others are doing?

Pitch Voltages – Voltage used to define pitch: Sending 1 volt to a Voltage Controlled Oscillator's (VCO) pitch control input instructs it to play a sounds at a particular pitch, such as middle C; sending it 2 volts will usually tell it to play one active higher; sending a lower voltage will have it play lower.

Control Voltage – Similarly, sending a particular voltage to the frequency or "cutoff" input on a voltage-controlled filter (VCF) will tell it at what "corner" frequency it should start altering the sounds going through it. For another example, the same voltage tell a voltage-controlled amplifier (VCA) how much to boost or attenuate the sound. Raising the voltage will change which frequencies get through the VCF and makes the sound going through the VCA louder; reducing the voltage to zero tells a VCA to mute the sound.
(Patch samples)

Digital (microcontroller based) Eurorack modular synthesizer – Most signals outside of the module are analog, so these signals need to be translated into the digital domain when entering the module, and back into the analog domain when exiting the module.

VCV Rack – the pure digital representation of modular synthesizer signals (physical modeling)

Fundamental Concept: Voltage Control

What technologies exist to translate from the analog to the digital world?

ADCs
An analog to digital converter (ADC) is used to bring analog signals into the digital domain. Most microcontrollers include ADCs as part of their feature set. ADCs can also be added in the form of external chips that communicate with the microcontroller over a serial line giving potentially higher resolution and signal quality.

DACs
A digital to analog converter (DAC) is used to take the digital signal and turn it back into an analog signal. Many microcontrollers have built in DACs, but many use a technique called Pulse Width Modulation (PWM) to simulate analog output using only digital I/O. True DACs can also be added in the form of an external chip that can communicate with the microcontroller over a serial line providing much improved signal quality.

Digital I/O
All microcontrollers have digital I/O; these are pins that can be configured to read or write a digital signal. These pins are used for the digital signals associated with Eurorack modules. They can also be configured to produce PWM, a pseudo- analog signal mentioned above. More digital i/o can also be added in the form of an external chip that can communicate with the microcontroller over a serial line.

Fundamental Concept: Voltage Control

What parameters determine the quality of the signal created by ADCs and DACs?

Assuming that the external circuitry is well designed, and the ADCs and DACs are stable and of high quality, two parameters determine the quality of the converted signal:

Sample rate

This is how many samples can be converted in a second and still have processor cycles left over for other processing.

Bit depth

This is how much information will be included in the conversion. The converter produces a digital number, and the more bits in that number, the better quality the signal:

8 bits allows for values of 0 to 255

10 bits provides values from 0 to 1023

16 bits provides 65536 states, from o to 65,535

Different types of signal require different sample rates and bit depth, determined by the amount of information in the analog signal. Typical audio (at CD rates) runs at a sample rate of 44,000 times a second, and a bit depth of 16. On the other hand, 1 volt per octave pitch control voltage signals require much less resolution; in almost all cases sampling at 1000 times a second with a bit depth of 12 would be enough that no listener could hear the difference.

The Building Blocks of Modular Synth

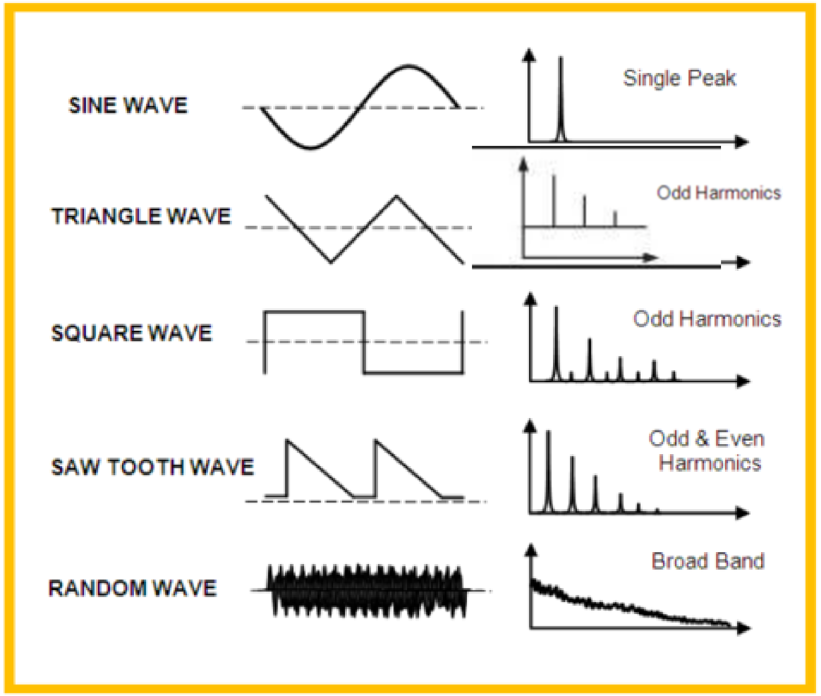
Audio Sources: VCOs - A raw lump of sonic clay

- **Oscillator**: output a voltage that fluctuates between positive and negative values at a speed in the audible range (20hz-20khz). This vibration causes our eardrums to vibrate in a similar way, which our brain interprets as sound.

The classic oscillator waveforms:

1. Sine wave (the purest and simplest tone in the world)
2. Triangle wave (bass)
3. Square wave (half full, hallow
4. Sawtooth wave (most full, bra & string, etc.
5. Paulse wave (A variation on a square, but the % of positive negative portion can be vario so it sounds buzzy or reedy)

- All of them can be used as a control signal, audio shaper, c modulation parameters.



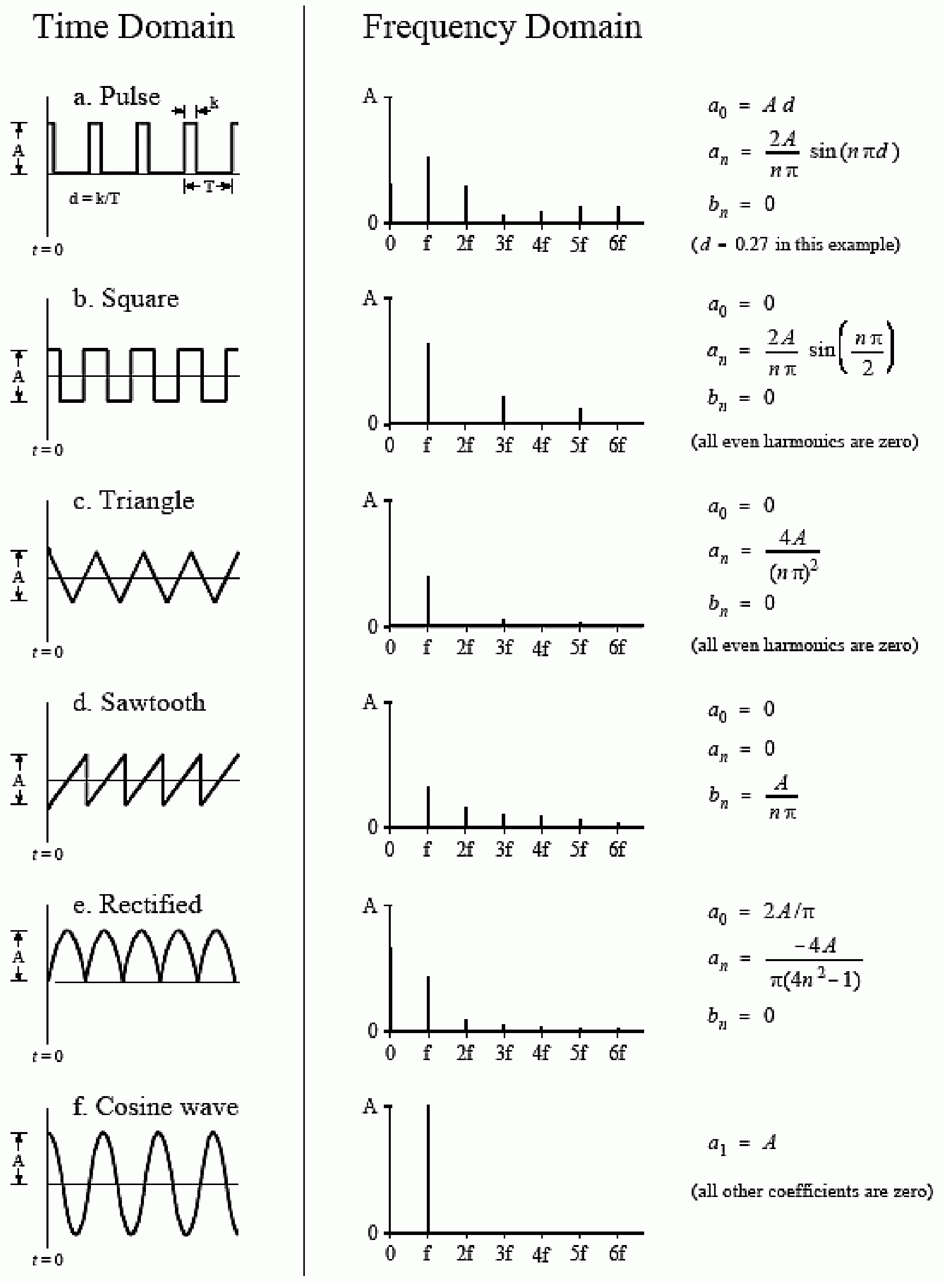
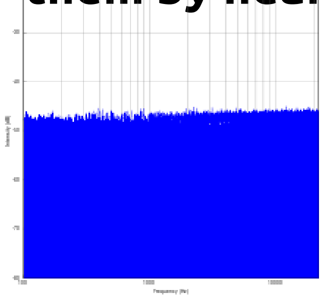


FIGURE 13-10
Examples of the Fourier series. Six common time domain waveforms are shown, along with the equations to calculate their "a" and "b" coefficients.

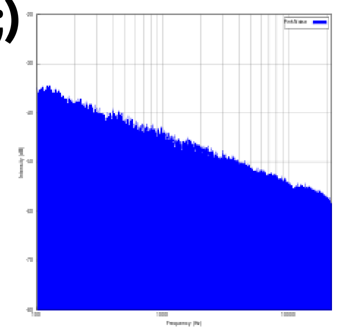
The Building Blocks of Modular Synth

Audio Sources: A raw lump of sonic clay

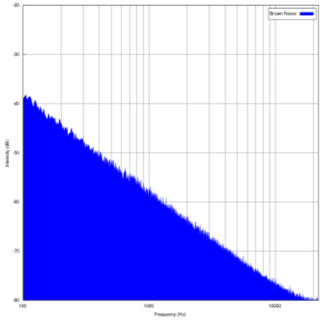
- **Advanced Tone Generators**: digital oscillators can store a desired waveshape in memory as a series of numeric values. These values are read out in rapid succession and converted into a stream of changing voltage levels. The speed determines the resulting pitch. More voltage –> faster stream –> higher pitch
- **Banks of Waveforms (Digital wavetables):** they can switch or crossfade between each others under front panel or voltage control, allowing the resulting timbre to evolve over time. They can also be pre-recorded analog sounds that are ripe for further manipulation (Sampling).
- **Waveforms from Computer Models:** random generators, digital oscillators create their waveforms on the fly.
- **Digital Noise Generators:** [the colors of noise]
- **Listen to them, love them, & remember them - as an audio geek you should be able to identify them by heart ;)**



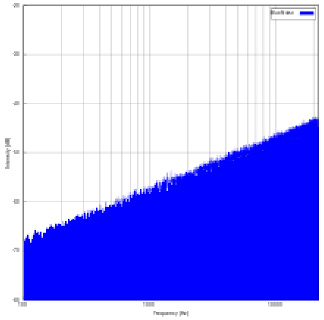
Fall spectrum
White



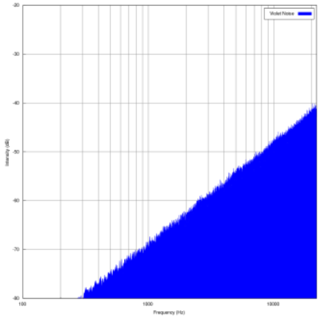
-3 dB/oct
Pink



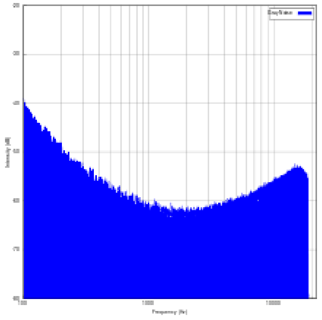
-6 dB/oct
Brown



+3 dB/oct
Blue



+6 dB/oct
Velvet/purple

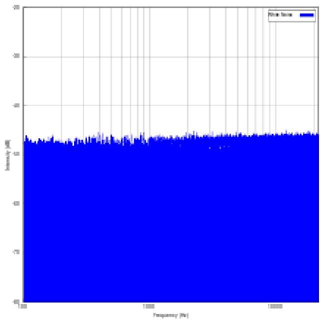


a psychoacoustic equal loudness curve
Grey

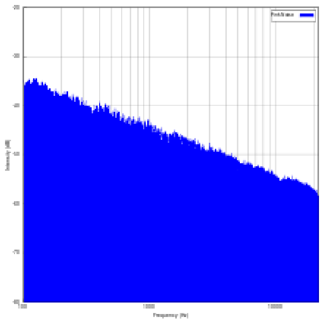
The Building Blocks of Modular Synth

Audio Modifiers: Sculpturing sound

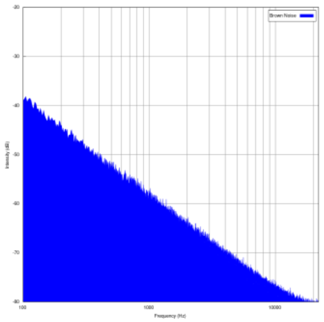
- **Filters (VCF)**: digital oscillators can store a desired waveshape in memory as a series of numeric values. These values are read out in rapid succession and converted into a stream of changing voltage levels. The speed determines the resulting pitch. More voltage –> faster stream –> higher pitch
- **Wave shapers**: they can switch or crossfade between each others under front panel or voltage control, allowing the resulting timbre to evolve over time. They can also be pre-recorded analog sounds that are ripe for further manipulation (Sampling).
- **Loudness Control:** random generators, digital oscillators create their waveforms on the fly.
- **Digital Noise Generators: the colors of noise**
- **Listen to them, love them, & remember them - as an audio geek you should be able to identify them by heart ;)**



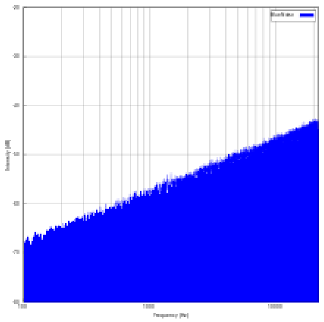
Fall spectrum
White



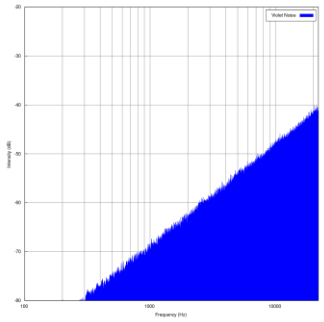
-3 dB/oct
Pink



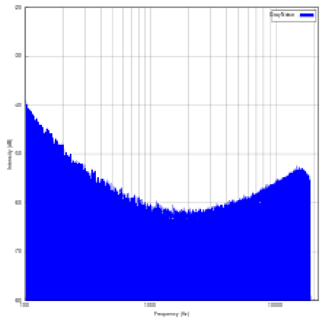
-6 dB/oct
Brown



+3 dB/oct
Blue



+6 dB/oct
Velvet/purple



a psychoacoustic equal loudness curve
Grey

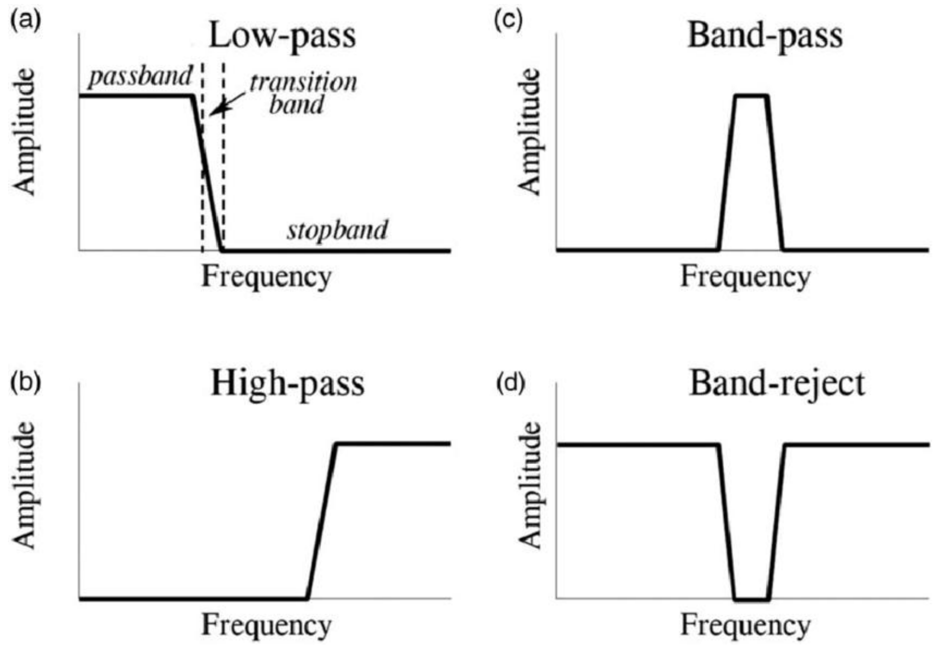
The Building Blocks of Modular Synth

Modulation Sources: Sculpturing sound

- **Filters**: These modlues weakens or removes some of the sonic harmonics. In modular synth, they are called Voltage Controlled filter, aka. “VCF”.

Note:

1. Different filters may use different circuit designs which resulting in different tonal shifts every though they have the same specifications.
2. Many filters create internal feedback loop, often referred to as ”resonance” of “Q.” This feedback reinforces or strengthened harmonics around the cutoff frequency. This is also known as “self-oscillation.”

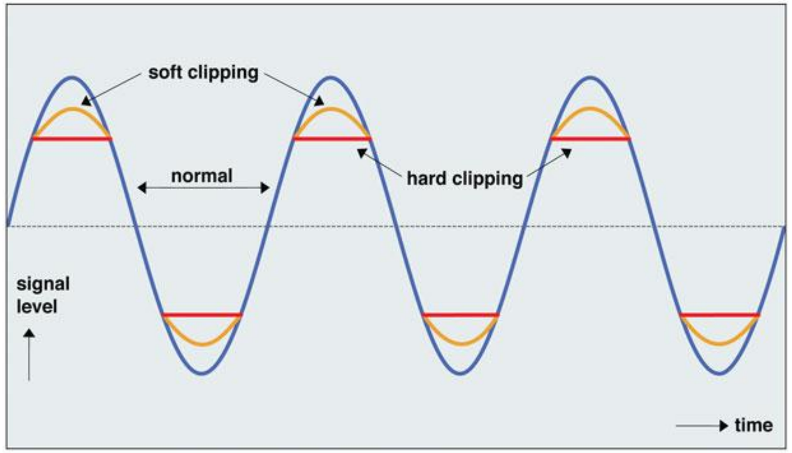


The Building Blocks of Modular Synth

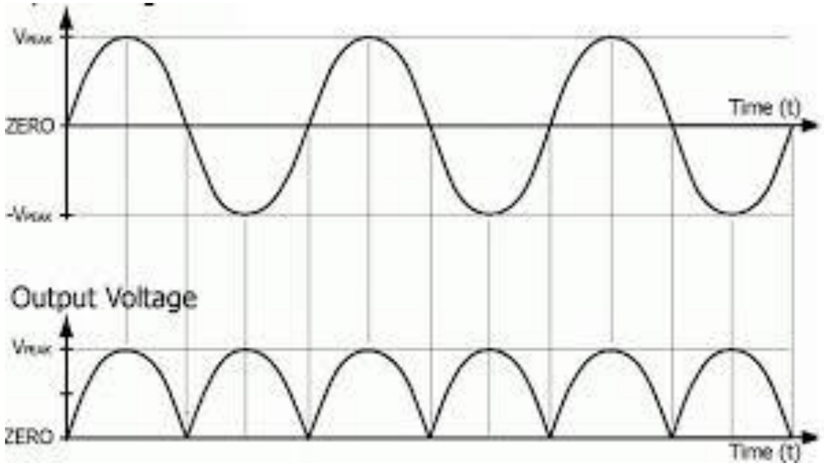
Modulation Sources: Sculpturing sound

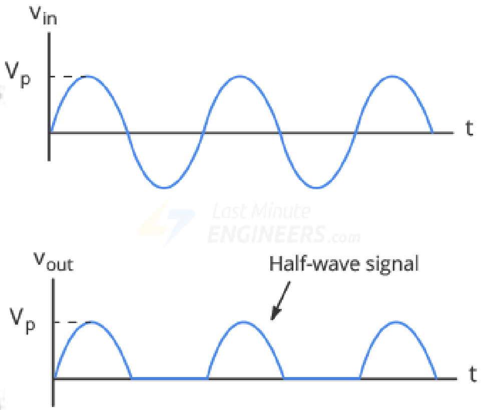
- **Wave shapers**: Directly change the waveforms and then you can fine-tune the sound to make it musical.

1. **Clipping, distortions, or saturation circuits.**

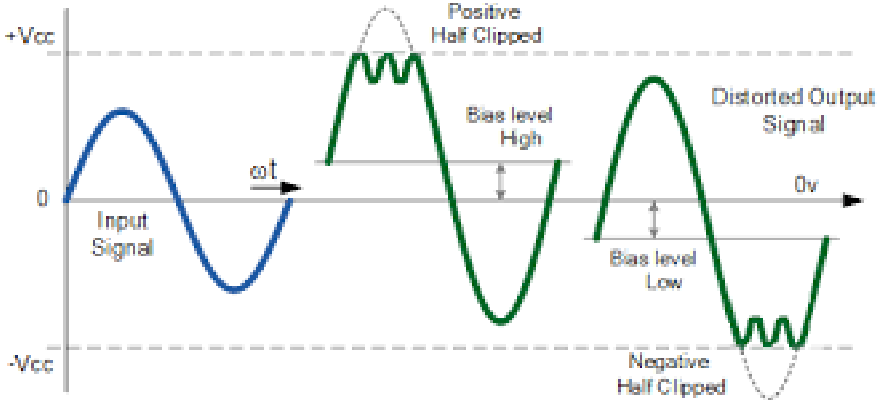


2. **Full-wave and half-wave rectifiers**





3. **Wavefolders**



4. **Waveshapers**

The Building Blocks of Modular Synth

Loudness Control: “Loudness envelopes” determine how it changes volume during the life of a note. This usually is performed by a VCA (Voltage -Controlled Amplifier)

Gates, triggers, and clocks (quantizers): The time perspective of sounds

Modulation sources: Sound transformation and mutation

- Envelopes
- Low frequency oscillators
- Audio-rate modulation

Performance Controllers: the human control or random control by the computer

- Modules can be run all of the time automatically without intervention, or you can control the operation in an expressive way.
- Random sources (triggers, gates, and random voltage)