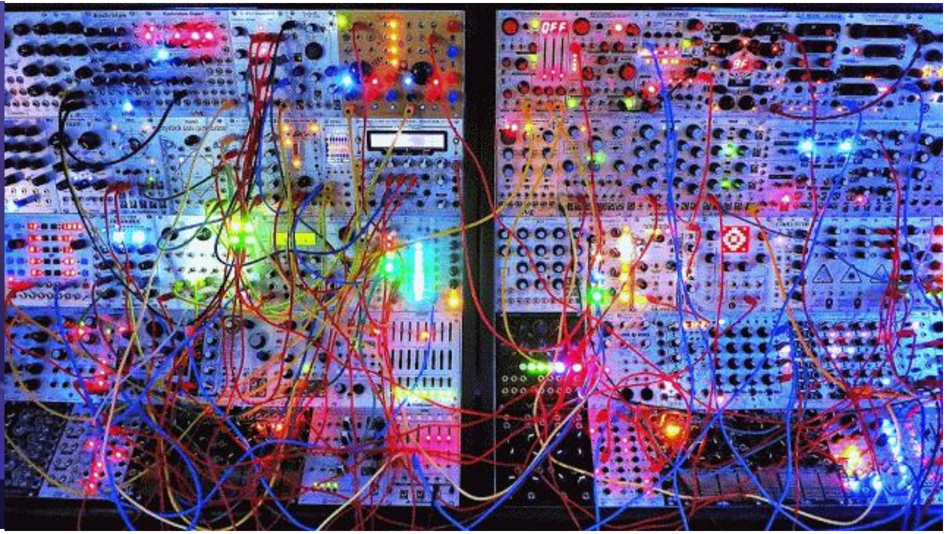
MUSC 4820/5820 Digital Music Techniques 001

Week 2: Signal Fundamentals 2



College of Arts & Media
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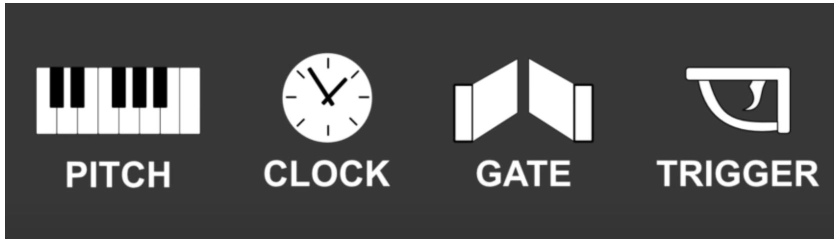
Fundamental Concept: Voltage Control

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



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.

Generating Voltage – a keyboard, sequencer, knob, gate, trigger, modulators that raise and lower voltages in realtime (input and control)

CV Modifiers – CVAs, Attenuators, Attenuverters, Inverters, Offsets, Adders, Multiples, Minimum/Maximum, Rectifiers, Utility mixers and CVP (Control Voltage Processors), switches, triggers, clock dividers, quantizers, lag generator (smoothing rapid changing in control voltages), comparators (watch the output voltage and change behaviors of the patch after a certain threshold has been crossed), slope detectors

Audio Connections between Analog and 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.

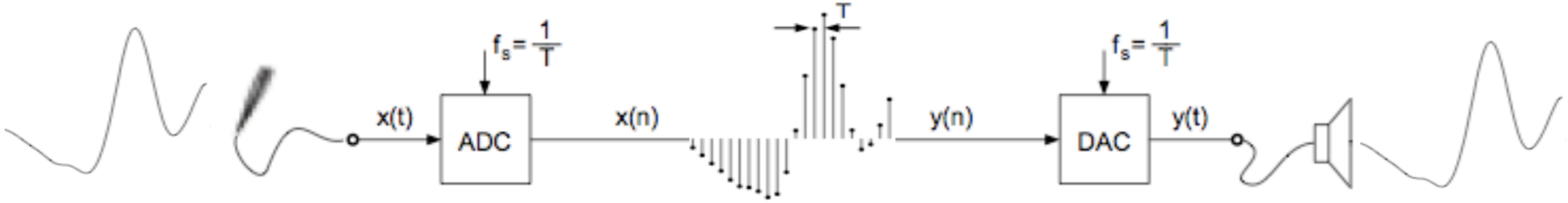
DACs

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.

- In digital audio, the waveform is converted to the digital domain, where it is processed and stored before being converted back to analog. Sounds are stored and replayed precisely, but we have no access to control data (the parameters that generated that sound)



Audio Connections between Analog and Digital World

Typical audio Voltage Ranges:

Format	Voltage References	Wires (Cables)
Eurorack	+-5 V or higher	3.5mm
Pro Level	+-1.78 V (+4 dBu)	Balanced XLR or TRS ¼”
Buchla 200	+-1.75 V (~ pro level)	Tini-Jax
Buchla 100, 200e	+-1.41 V	Tini-Jax
Moog 921	+-0.75 V	¼”
Moog 901	+-0.5 V (~line level)	¼”
Line Level	+-0.45 V (-10 dBV)	Unbalanced phono, 3.5mm or ¼”

- There are two types of line level: +4dBu "Pro" Line Level (balanced) or -10 dBV "Consumer" line level.
- The Pro level (balanced) of the audio signal in a professional studio is +4 dBu or about 1.23 volts (0 dBu=.775 volts).
- When the console output meters read "0" on a VU meter, the level of the signal is +4 dBu (Pro level).
- Inexpensive "semi-pro" gear uses unbalanced Line level, which is -10 dBV or 0.316 volts (0dBV=1 volt).
- This lower "line level" is about 12 dB lower than professional line level.
- Line level’s inter-connecting wiring is four times more likely to have unacceptable hum or noise.
- The professional level is higher and therefore less-sensitive to the introduction of noise.
- dBv is the same as dBu, with 0 dBv = 0.775 volts. For 4 dBv = 20 log (E1 / 0.775) => E1 = 1.23 volts.
- dBV has a voltage reference of 0 dBV = 1 volt. For 4 dBV = 20 log (E1 / 1) => E1 = 1.6 volts. Calculation method

- In real world, we need to take these level differences into account to avoid distorted or sounds “compressed” audio output when fed through our external mixer or DAW.
- For the **input level knob (top of the signal flow)** of your mixer, look for its maximum level specification, and if it’s over +22 dBu (good headroom), you should be ok. If there’s a “Pad”, use it o reduced the input level.
- Then, adjust the channel volume (**mixer’s slider – bottom of the signal flow**) as needed to avoid unwanted clipping
- If the signal is still too hot, use an attenuator module before sending signals to your mixer.
- Also watch out for your effect send levels on the mixer as they likely need to be set lower than usual.

Audio Connections between Analog and Digital World

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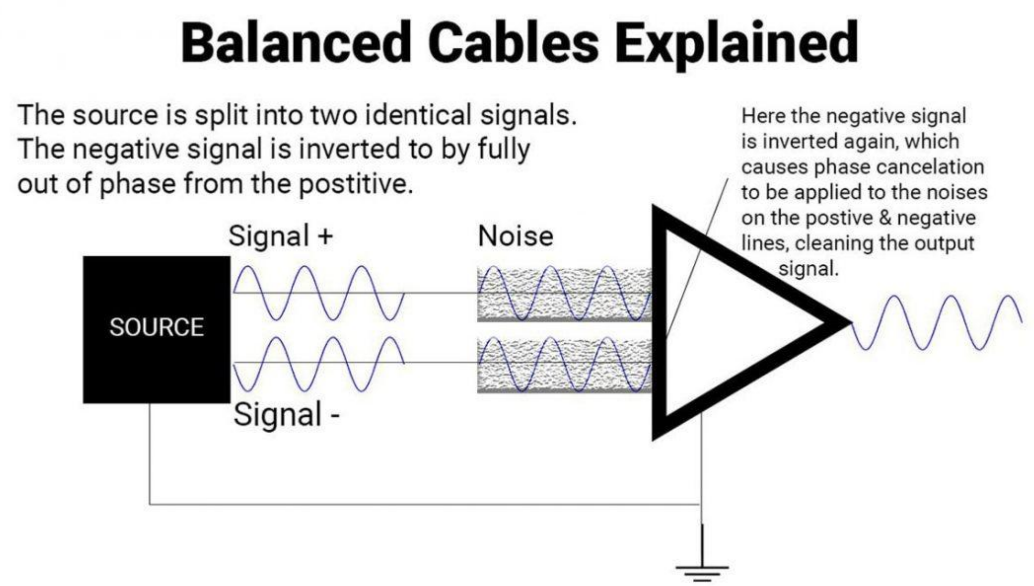
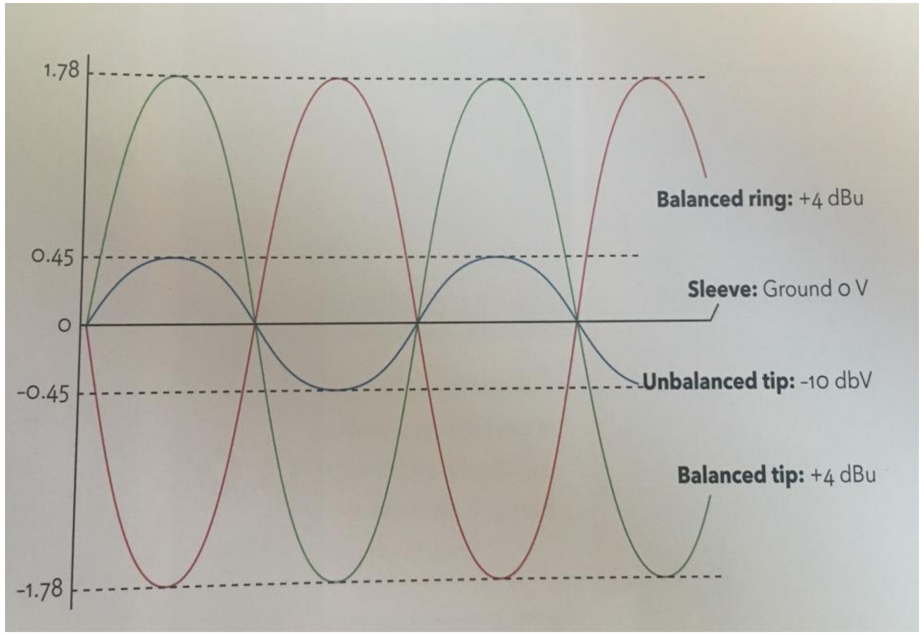
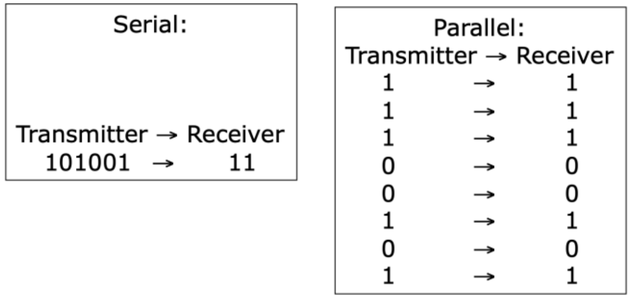




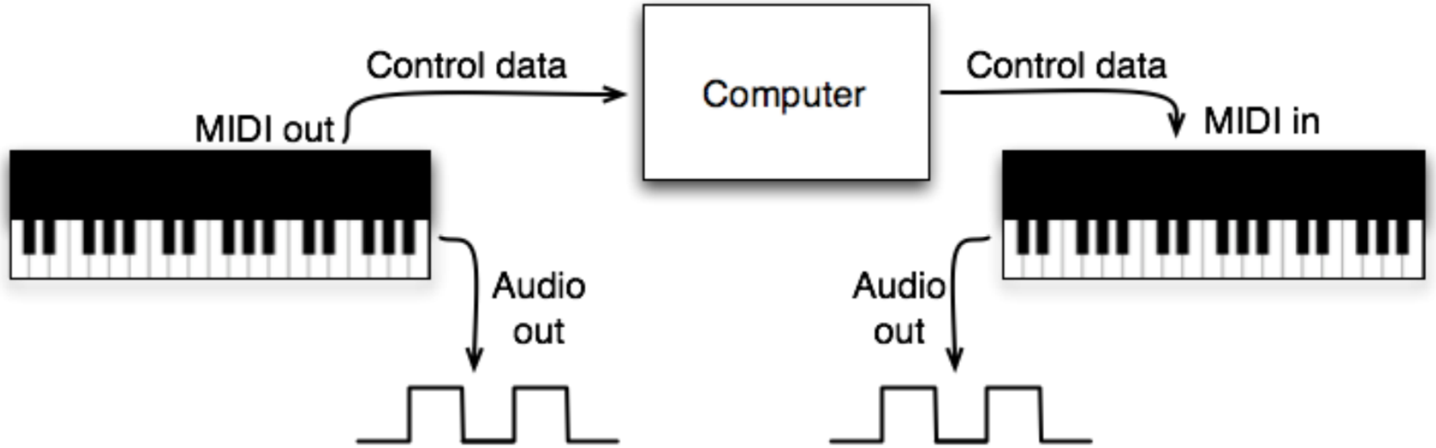
Musical Instrument Digital Interface (MIDI)

- MIDI is a communication protocol for remote/synchronized control mechanism and for storing information
- It’s a standard established in 1983
- It’s extensible, many uses beside MIDI notes
- Max 1.5 kHz bandwidth
- Uni-directional serial interface and asynchronous communication
- These often used one port for timing and another for note triggering and pitch info (as a DC control voltage)
- Max cable length 15 m, USB and wireless MIDI connections also work
- Long cables and slow wifi connection cause unwanted signal distortion and latency
- MIDI/computer Interface: External MIDI/USB devices such as are widely used for multi-port interfaces, which are able to handle a number of MIDI streams (each controlling up to 16 channels) and distribute separately. They also allow the synchronized handling of several devices (video recorder, automated mixer, effects, samplers, etc)
- Message scheme based on keyboard’s model



Musical Instrument Digital Interface (MIDI)

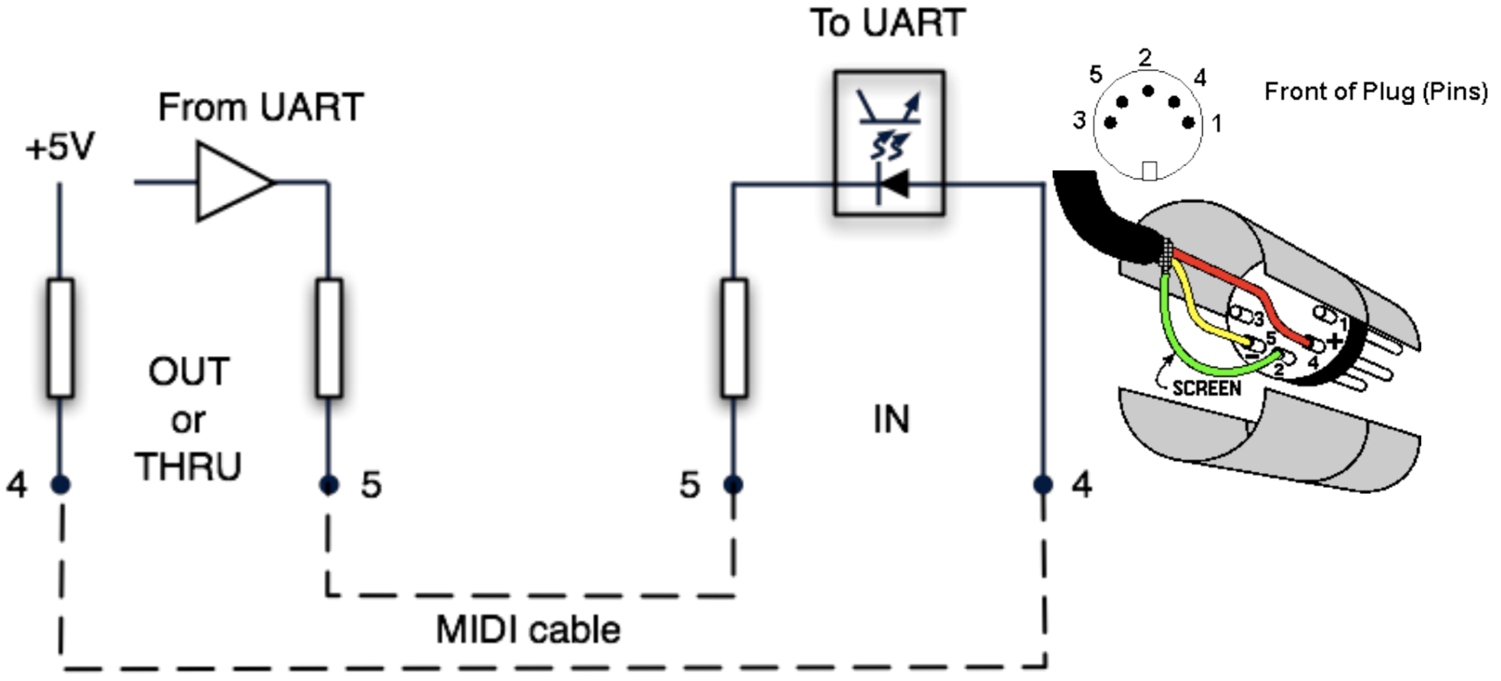
- In MIDI, processing and storage also occurs in the digital domain, but the information being processed is not the audio signal but the control data used to generate it.
- An electronic instrument is needed to reproduce the sound, which means that unless we use the exact same synthesis engine, MIDI-generated sounds are never the same.



- Because it comprises control data only, MIDI uses significantly less memory space than digital audio

Musical Instrument Digital Interface (MIDI)

- There are 3 kinds of MIDI ports: IN, THRU, and OUT. The IN port accepts input to a device, the THRU port passes an amplified copy of the input signal along, and the OUT port is used to transmit the device's output.
- The hardware uses cables terminated in 180-degree 5-pin DIN connectors, of which only three pins are used (5, 4 and 2). (Pin 2 is connected to earth in OUT and THRU only)

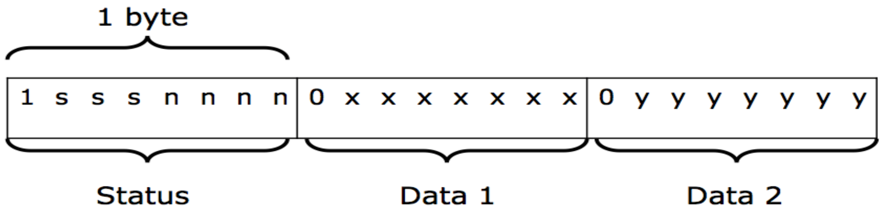


* **UART** stands for "Universal Asynchronous Receiver/Transmitter". It is a piece of digital hardware that transports bytes between digital devices, commonly found as a peripheral on computer and microcontroller systems. It is the device that underlies a serial port, and it is also used by **MIDI**.

Musical Instrument Digital Interface (MIDI)
MIDI Transmission Standard

- A maximum transmission rate of 31250 bits per second (3125 bytes per second), which means no more than 651 notes can be transmitted /second.
- 16 channels limits due to bandwidth
- If first bit =1, the following byte is a “status” byte

  If first bit = 0, the following byte is a “data” byte



- The status byte determines the length of most messages, which are usually 1,2,or 3 bytes in length
- System exclusive messages are of variable length and have a start and ending status byte.
- MIDI uses hexadecimal system: Hexadecimal numbers are a base-16 representation of numbers and are useful for humans when dealing with binary numbers.

  Every 4 binary digits are represented by 1 hexadecimal digit

number base equivalences

dec	hex	bin	dec	hex	bin
0	0	0	8	8	1000
1	1	1	9	9	1001
2	2	10	10	A	1010
3	3	11	11	B	1011
4	4	100	12	C	1100
5	5	101	13	D	1101
6	6	110	14	E	1110
7	7	111	15	F	1111

MIDI Transmission Standard

T23 – MIDI-Code

Status Bytes	Data Bytes	Command type
1000nnnnb (=8mh)	pitch number [0–127], force of attack* [0–127]	Note Off
1001nnnnb (=9mh)	pitch number [0–127], force of attack* [0=off, else 1–127]	Note On
1010nnnnb (=Amh)	pitch number [0–127], force of attack* [0–127]	After-touch
1011nnnnb (=Bmh)	control nummer [0–121: e.g. 7=Volume,....], control value [0–127]	Control Change
1100nnnnb (=Cmh)	program number [0–127] (only 1 data byte!)	Program Change
1101nnnnb (=Dmh)	pressure value [0–127] (only 1 data byte!)	Channel Pressure
1110nnnnb (=Emh)	lower byte [0–127], upper byte [0–127]	Pitch Wheel
11110nnnb (=Fmh)	brand dependent	System Exclusive

* ‘velocity’ for technocrats

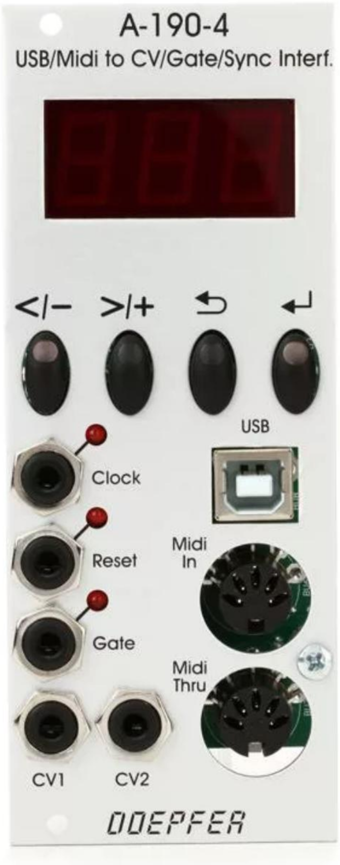
MIDI commands

0x80	Note Off
0x90	Note On
0xA0	Aftertouch
0xB0	Continuous controller
0xC0	Patch change
0xD0	Channel Pressure
0xE0	Pitch bend
0xF0	(non-musical commands)

MIDI Connection Modules

MIDI to control voltage and gates

MIDI TRS DIN Cable (3.5mm)



Deoper A-190-4 MIDI to CV gate converter

Entering the module's displayed IP into your browser's address bar, this also works for OSC configure-tions

- There is no standard for what voltage an oscillator module needs to receive in order to play a certain note
- Look for a wide voltage range (-3V to +7V) and octaves-shifted function for reference note (2 oct)

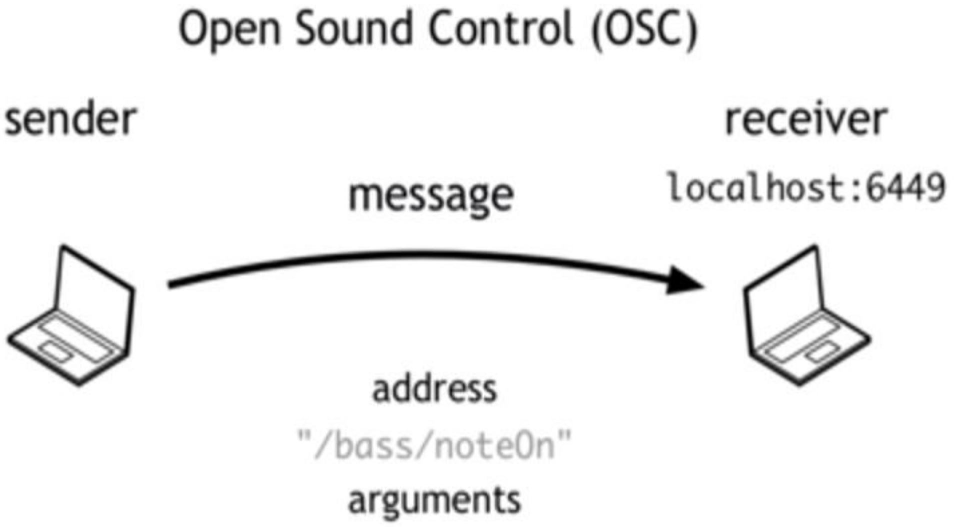
Open Sound Control (OSC)

- Communication protocol
- Flexible (wireless)
- Big community not only in music but also in visual arts
- Same network! IP
- Different address

Different OSC objects,

Different control

- Synchronous events!!



The Building Blocks of Modular Synth

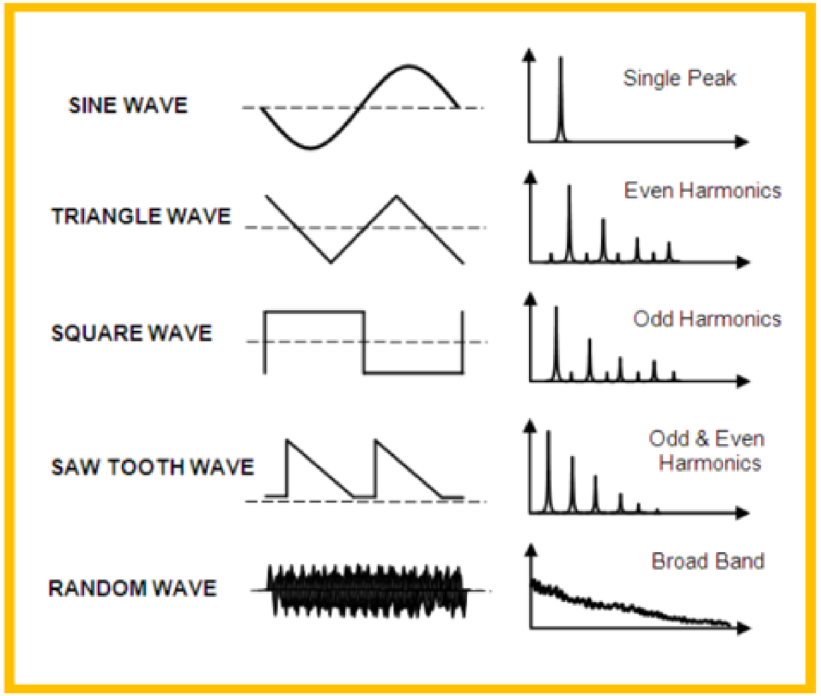
Audio Sources: A raw lump of sonic clay

- **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.



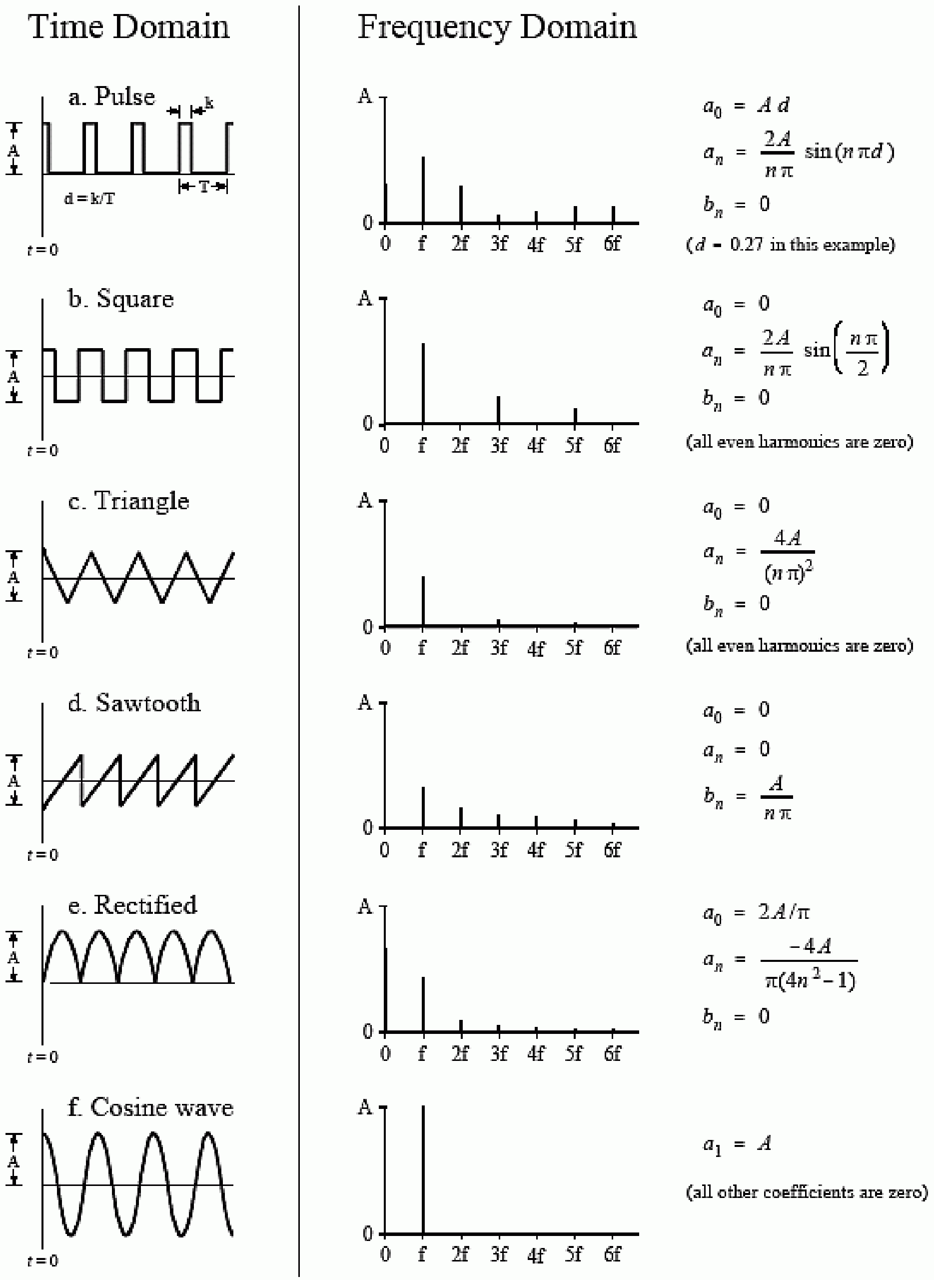
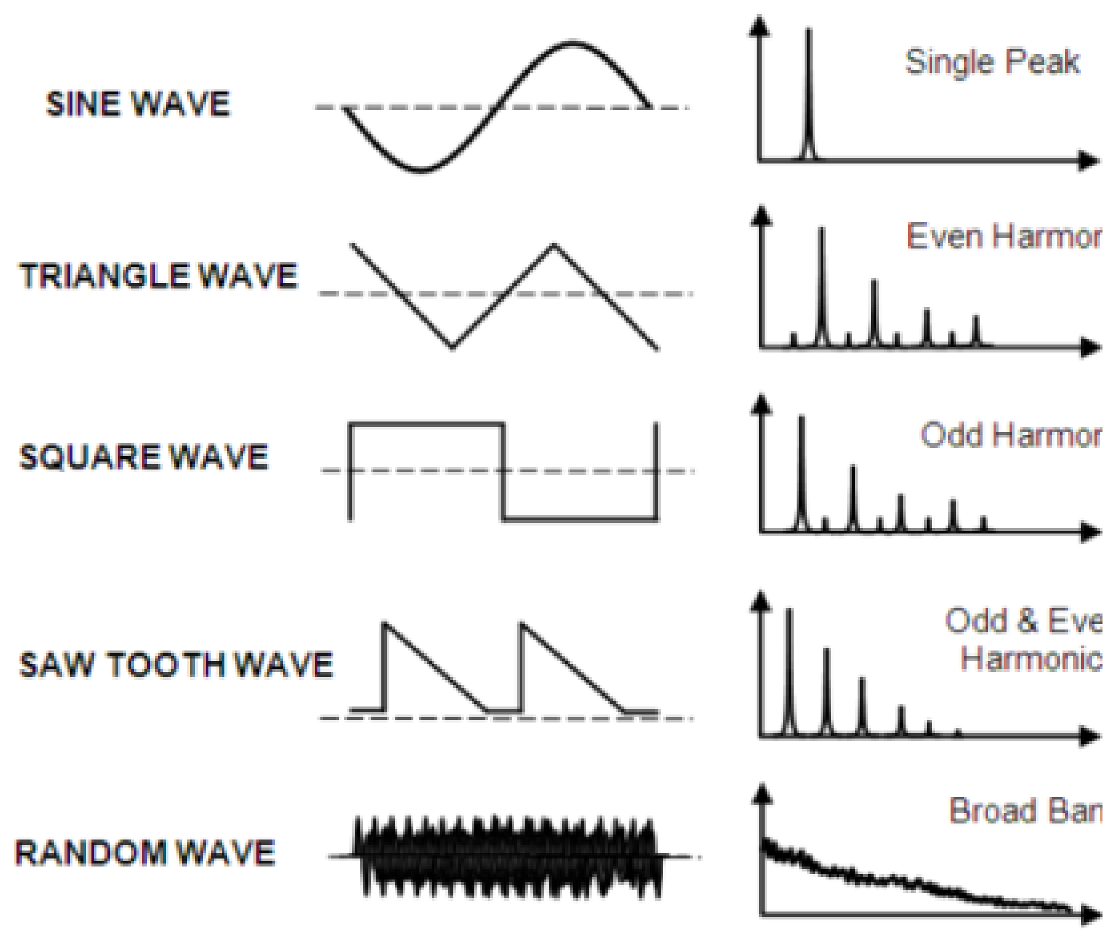


FIGURE 13-10
Examples of the Fourier series. Six common time domain waveforms are shown, along with the equations to calculate their "a" and "b" coefficients.

The Building Blocks of Modular Synth

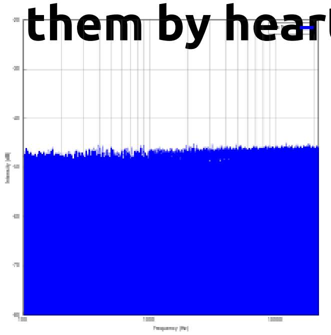
- **Audio Sources**:
  - Sine wave (the purest and simplest tone in the world): The sine wave has energy at only one frequency.
  - Sawtooth wave (most full, brass & string, etc.): The sawtooth wave has energy at all harmonics of the fundamental frequency, and the relative amplitude of each harmonic is proportional to the inverse of the harmonic number, e.g., 1/1, 1/2, 1/3, 1/4, etc.
  - Square wave (half full, hallower): The square wave has energy only at the odd harmonics of the fundamental frequency, and the relative amplitude of each harmonic is proportional to the inverse of the harmonic number, e.g., 1/1, 1/3, 1/5, 1/7, etc.
  - Triangle wave (bass): The triangle wave has energy only at the odd harmonics of the fundamental frequency, and the relative amplitude of each harmonic is proportional to the inverse of the square of the harmonic number, e.g., 1/1, 1/9, 1/25, 1/49, etc.
-



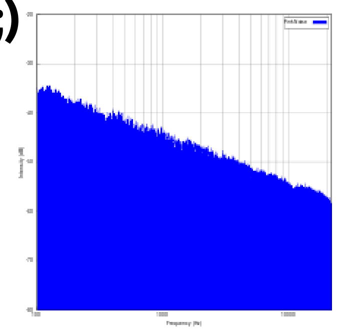
The Building Blocks of Modular Synth

Audio Sources: A raw lump of sonic clay

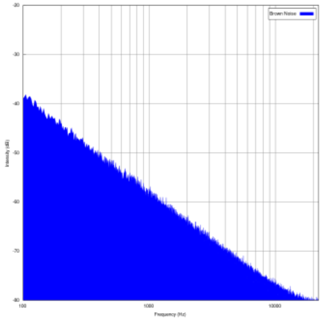
- **Advanced Tone Generators**: digital oscillators can store a desired waveshape in memory as a series of numeric values. These values are read out in rapid succession and converted into a stream of changing voltage levels. The speed determines the resulting pitch. More voltage –> faster stream –> higher 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 ;)**



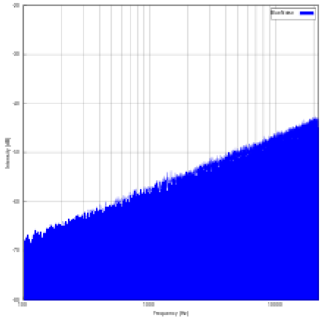
Fall spectrum
White



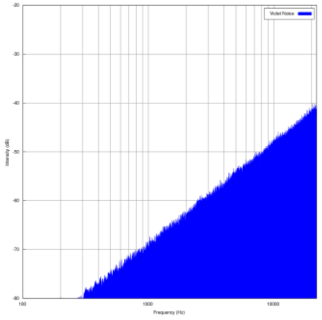
-3 dB/oct
Pink



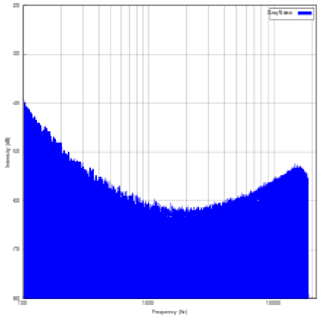
-6 dB/oct
Brown



+3 dB/oct
Blue



+6 dB/oct
Velvet/purple

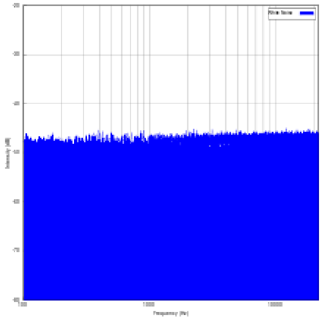


a psychoacoustic equal loudness curve
Grey

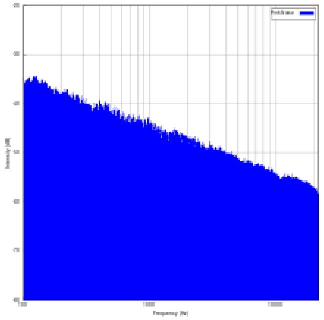
The Building Blocks of Modular Synth

Audio Modifiers: Sculpturing sound

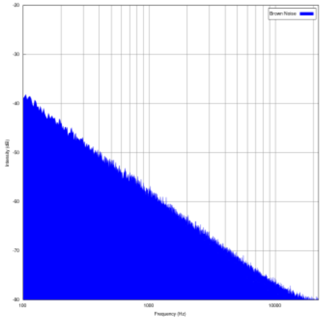
- **Filters**: digital oscillators can store a desired waveshape in memory as a series of numeric values. These values are read out in rapid succession and converted into a stream of changing voltage levels. The speed determines the resulting pitch. More voltage –> faster stream –> higher pitch
- **Wave 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 ;)**



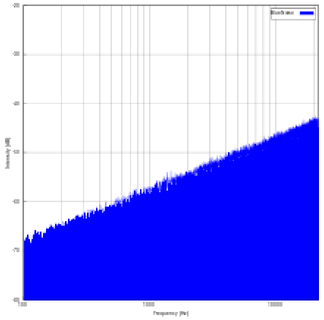
Fall spectrum
White



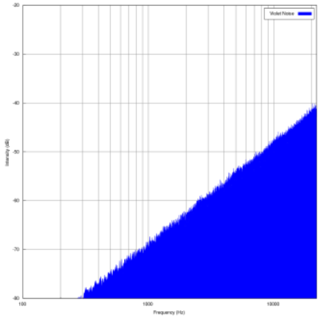
-3 dB/oct
Pink



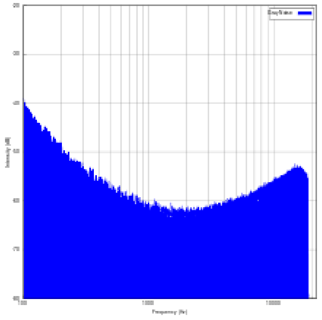
-6 dB/oct
Brown



+3 dB/oct
Blue



+6 dB/oct
Velvet/purple



a psychoacoustic equal loudness curve
Grey

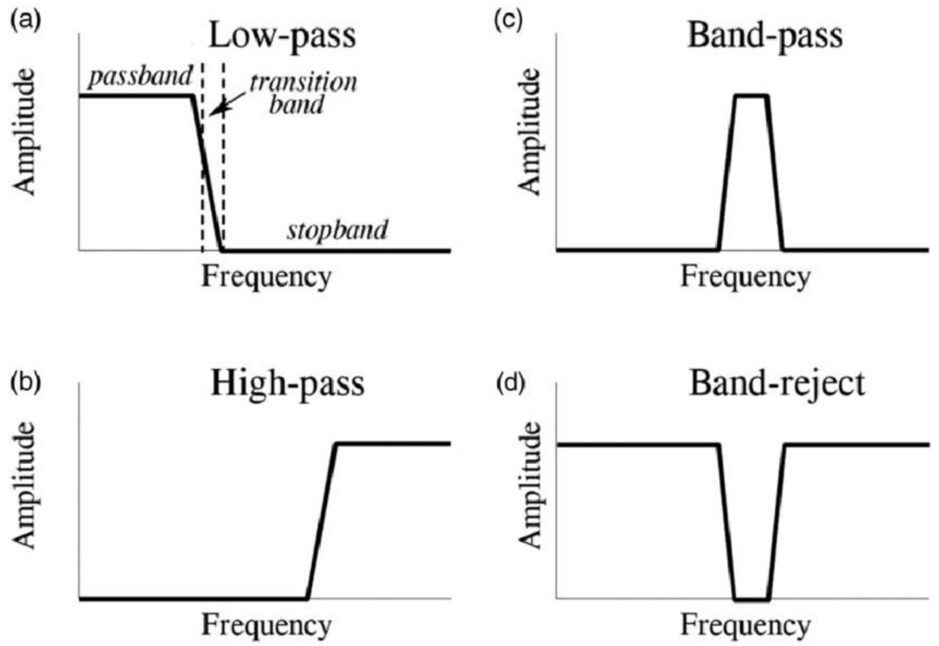
The Building Blocks of Modular Synth

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.”

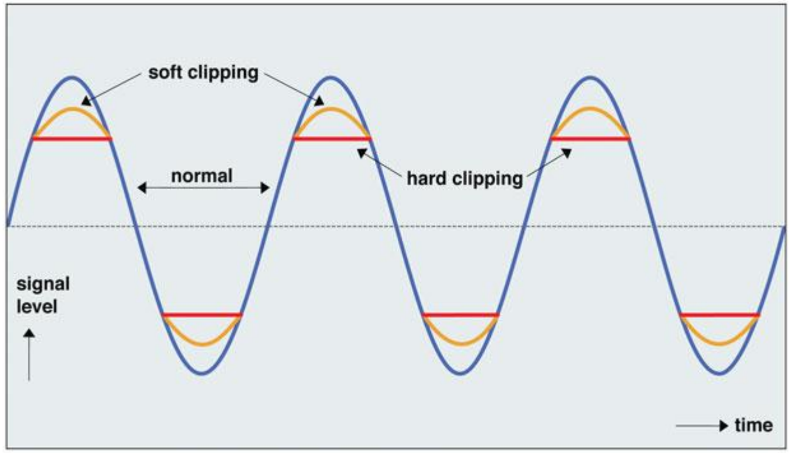


The Building Blocks of Modular Synth

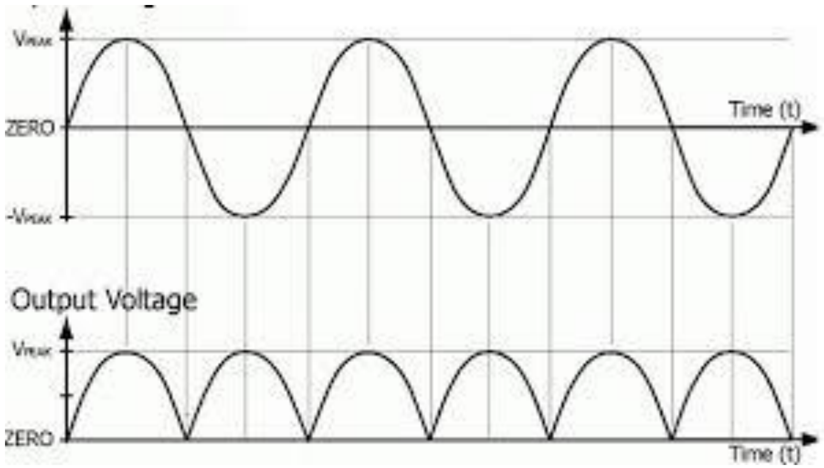
Modulation Sources: Sculpturing sound

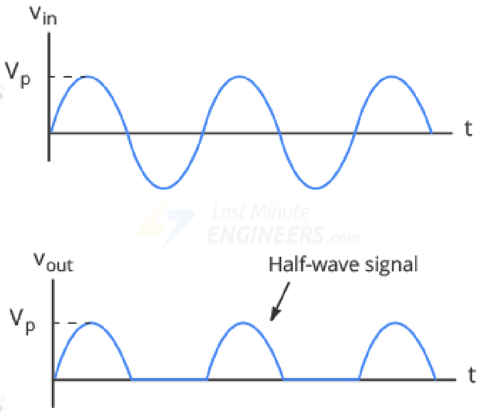
- **Wave shapers**: Directly change the waveforms and then you can fine-tune the sound to make it musical.

1. Clipping, distortions, or saturation circuits.

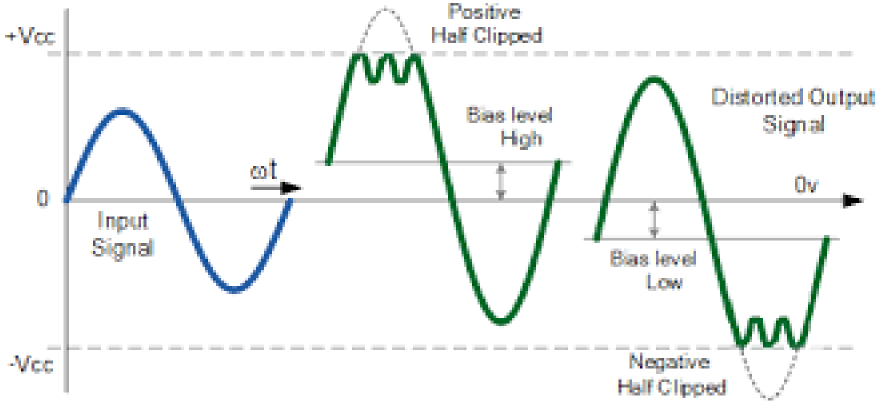


2. Full-wave and half-wave rectifiers





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)