Synthesizer_Design.doc
Dropbox:/Arduino_Synthesizer/Synth_Class/...

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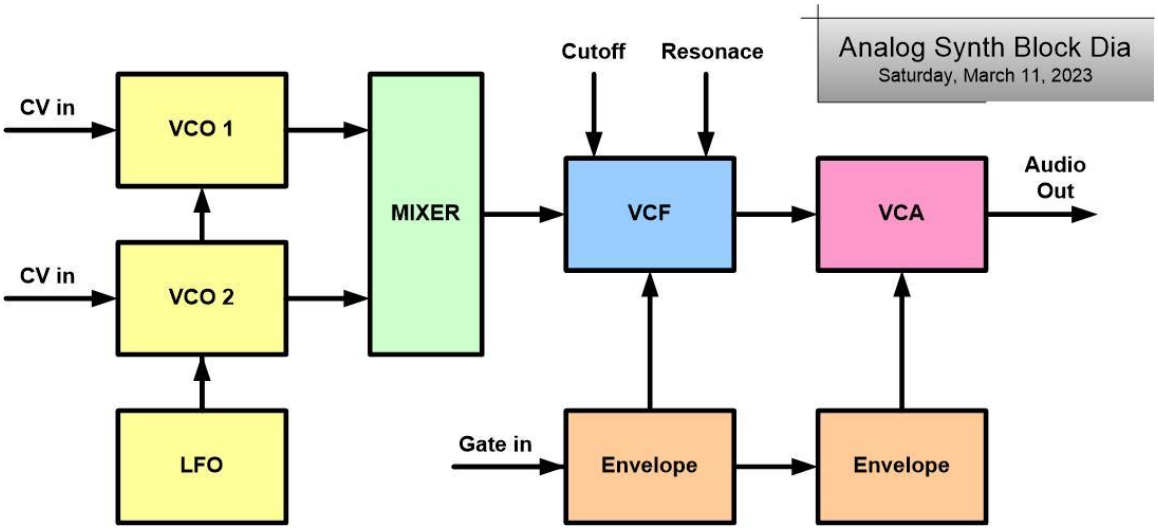
Subject: Design of Analog HW and Software Synthesizers

I have a website for the Synthesizer class (a rich source of information) at:
http://www.hamptonsailer.com/Synth

Getting started with synthesizer music can take one of two paths. One is having the actual hardware synthesizer used to play music on. The other is using software simulation of a synthesizer that runs on a PC. Both have certain advantages and disadvantages. Using a software synth can be lower cost (around $100) to get started, although you will need some kind of MIDI keyboard controller to play notes. The other is a physical hardware synthesizer, which will be more expensive (starting in the $500 range), but offer greater flexibility in how you can patch equipment together. Both methods can run up into the multi thousand dollar range. See Sweetwater.com.

Basic Design of Analog Synthesizer

The Synth keyboard produces a Control Voltage (CV) that is proportional to the pitch of the key struck, and a Gate signal when the note should be active.
Most analog synthesizers have a common layout of the modules that make up the sound. Normal flow starts with the Voltage Controlled Oscillator. There could be several VCOs (sometimes influenced by a Low Frequency Oscillator) the signal of each is mixed together and signal fed to a Voltage Controlled Filter. The VCF gives the tonal quality to the signal. The VCF can be dynamically adjusted during the note event, which is controlled by an Envelope Generator. The note event is marked by a Gate signal, which remains on during the note strike, and fades away as the note terminates. At the end of the signal chain is the Voltage Controlled Amplifier, which starts and then silences the note when finished.

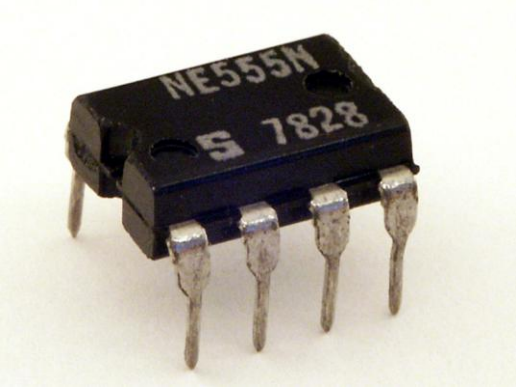


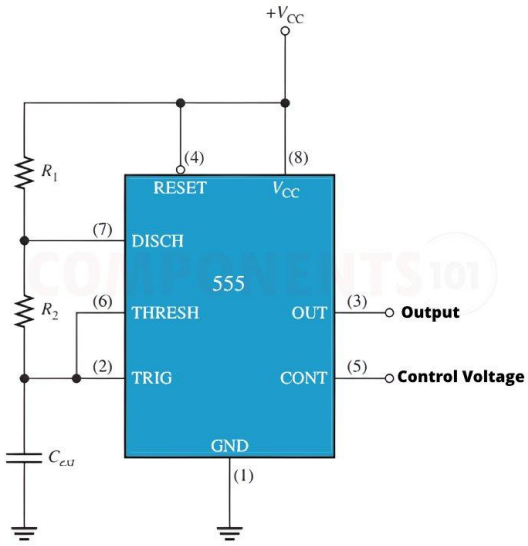
Voltage Controlled Oscillator

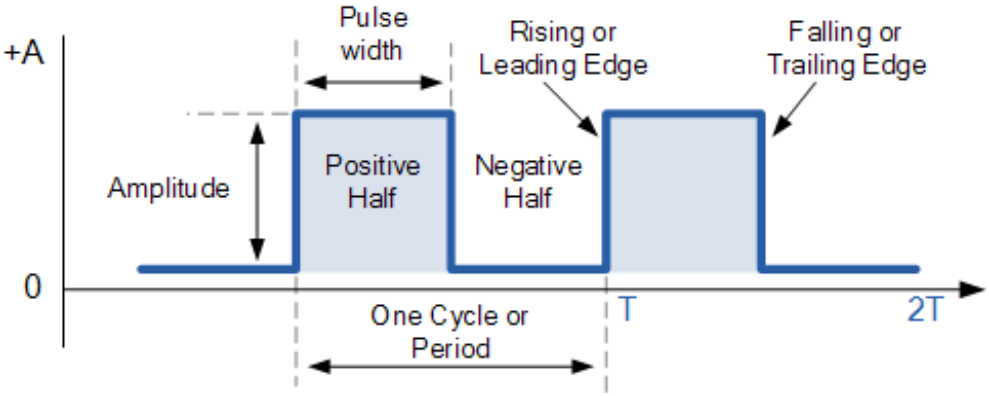
A **voltage-controlled oscillator** (**VCO**) is an electronic oscillator whose oscillation frequency is controlled by a voltage input. The applied input voltage determines the instantaneous oscillation frequency. VCOs are used in synthesizers to generate a waveform whose pitch can be adjusted by a voltage determined by a musical keyboard or other input.

One example of a Voltage Controlled Oscillator is the NE555 Timer which is an integrated circuit uses a ramp signal controlled by a set of voltage comparators, and a Flip-Flop. In astable mode, there is a capacitor that is charged and discharged as state of the control flip-flop register. This produces a regular waveform proportional to the charge/discharge rate of the capacitor. Think of it as a pendulum that is under timing control of a voltage. Another VCO example is the CEM3340 integrated circuit, which has 1Volt/Octave control.
https://electricdruid.net/cem3340-vco-voltage-controlled-oscillator-designs/

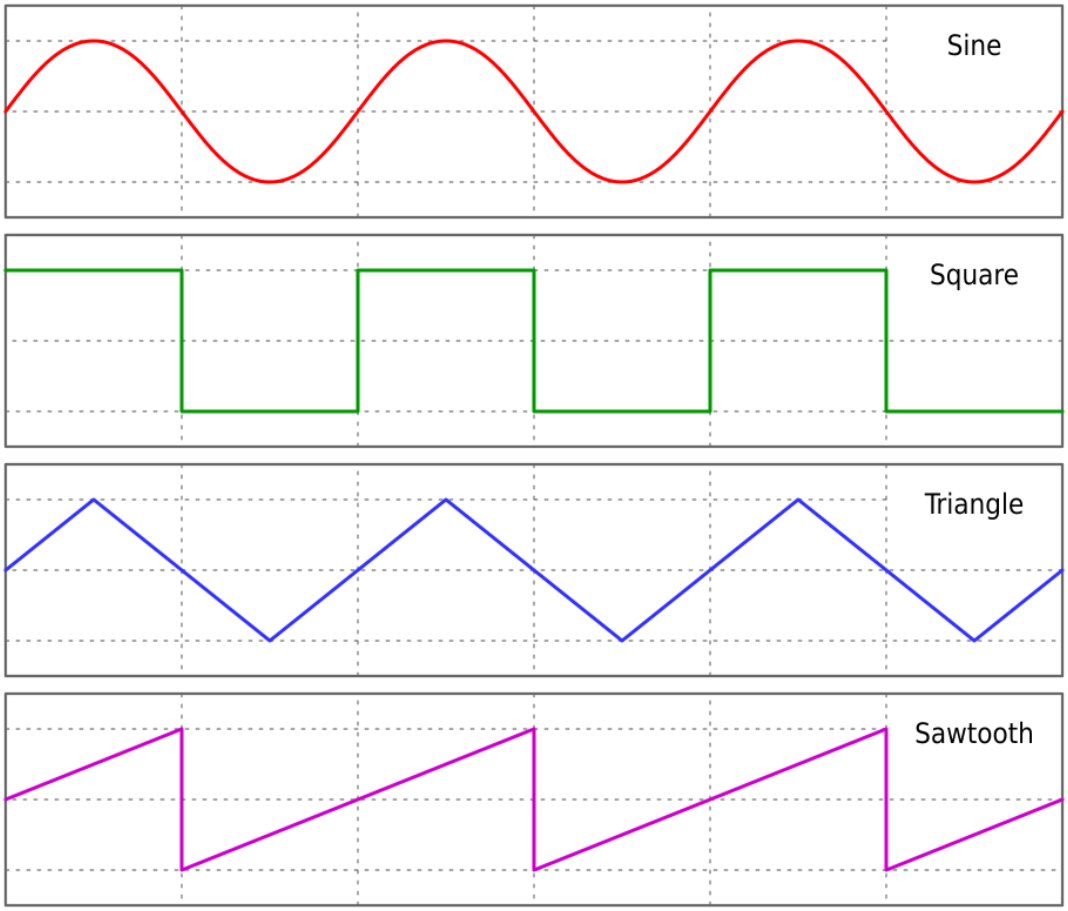
There are many articles about the 555 Timer on the Internet. These devices can be purchased for little money from many online distributors, such as Amazon, eBay, Digikey, Mouser and others. https://en.wikipedia.org/wiki/555_timer_IC
https://www.talkingelectronics.com/projects/50%20-%20555%20Circuits/50-555Circuits.pdf
The periodic nature of a 555 timer is similar to a Pendulum. Pendulum - Wikipedia





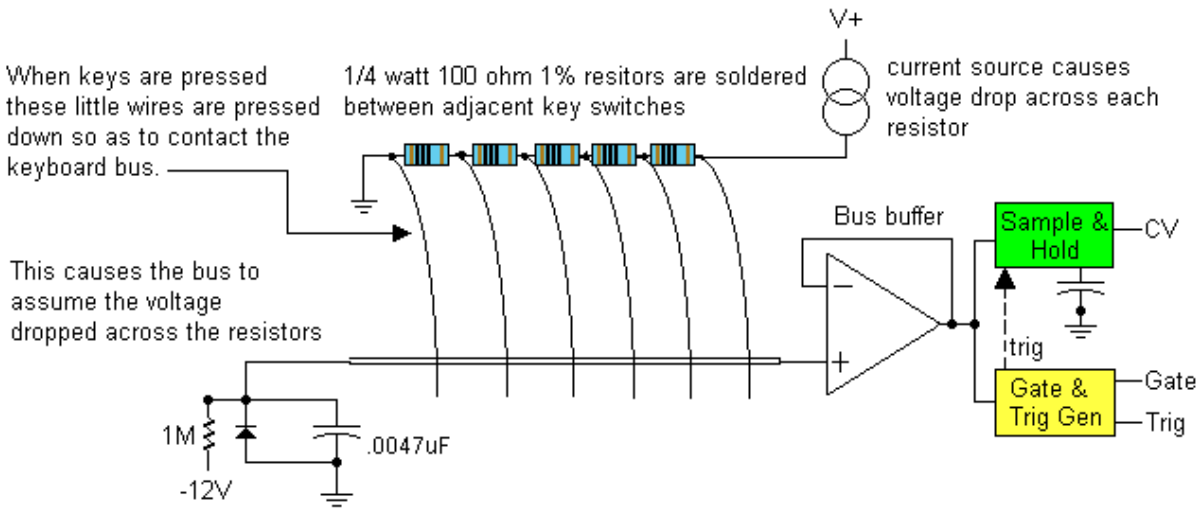


Different types of waveforms can be used in a synthesizer.



These signals are mixed together to produce a more complex waveform. Some of the signals can be used as modifiers to other oscillators, shifting the frequency based on a pattern.

An analog keyboard divides the musical octave into 12 equal voltage steps.

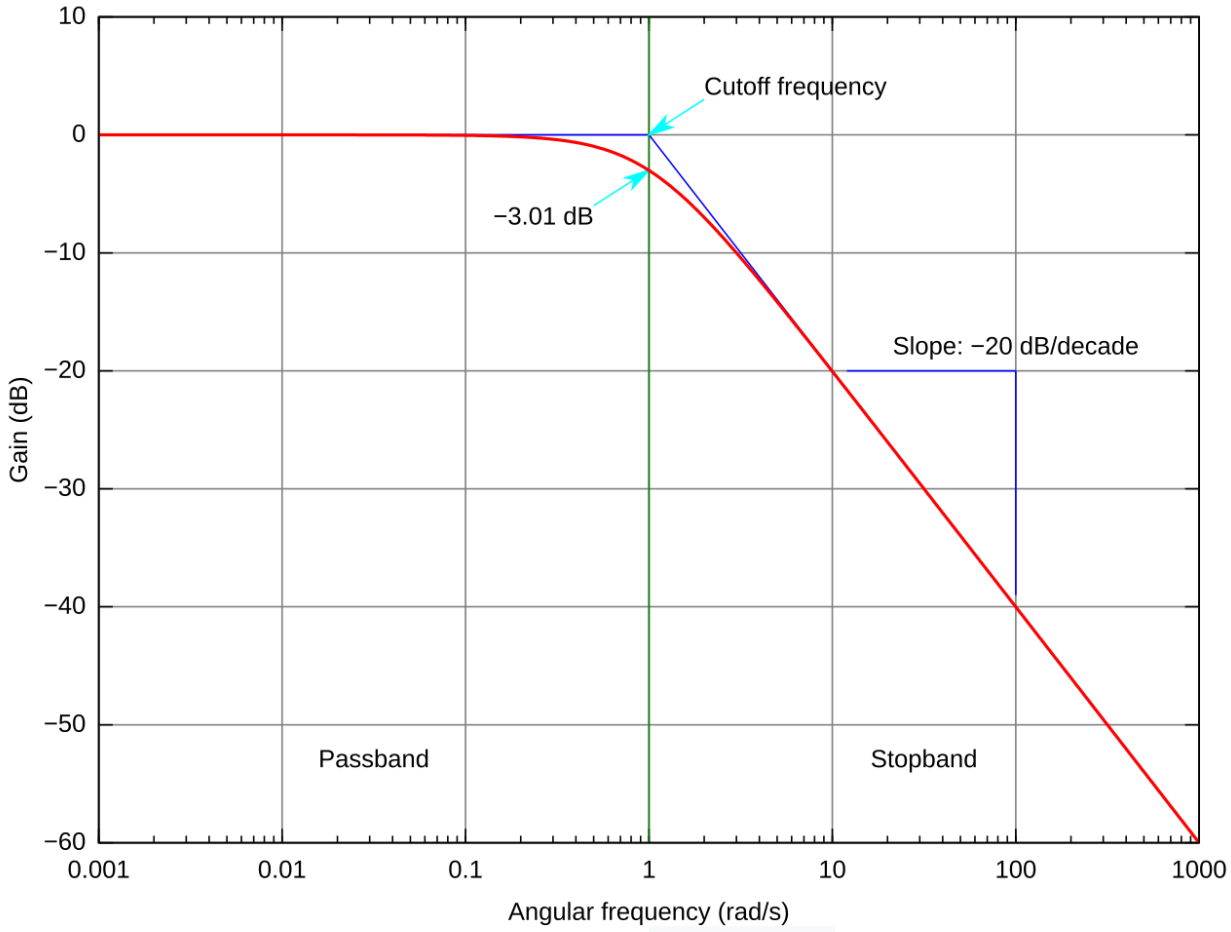


Voltage Controlled Filter

A **voltage-controlled filter** (**VCF**) is an electronic filter whose operating characteristics (primarily cutoff frequency) can be set by an input control voltage.[1] Voltage-controlled filters are widely used in synthesizers. The effect of a low pass filter on a square wave signal gives that characteristic sound we associate with electronic music.

A music synthesizer VCF allows its cutoff frequency, and sometimes its Q factor (resonance at the cutoff frequency), to be continuously varied. The filter outputs often include a lowpass response, and sometimes highpass, bandpass or notch responses.

In modular analog synthesizers, VCFs receive signal input from signal sources, including oscillators and noise, or the output of other processors. By varying the cutoff frequency, the filter passes or attenuates partials of the input signal.



Picture courtesy of Krishnavedala

Envelope Generator

In sound and music, an **envelope** describes how a sound changes over time. For example, a piano key, when struck and held, creates a near-immediate initial sound which gradually decreases in volume to zero. An envelope may relate to elements such as amplitude (volume), frequency (with the use of filters) or pitch. An Analog Synthesizer Keyboard produces a "Gate" signal during the active portion of a key being struck. The Gate is used to trigger the Envelope Generator. Typically a square wave pulse from 0 to 5 Volts. The output of the Envelope Generator is a discrete analog voltage that swings smoothly from 0 to 5 Volts and eventually back again to 0 volts, in proportion to the desired wave shape.

Envelope generators, which allow users to control the different stages of a sound, are common features of synthesizers, samplers, and other electronic musical instruments. The most common envelope generator is controlled with four parameters:

attack: The leading edge, how fast a signal rises

decay: The initial decay of a signal, after the first peak.

sustain: The sustain pedal of a piano allows the tone to persist for a longer period of time.

release: The final decay to silence at the end of a note.