

The Educational DIY Synth Thing



Introduction to the Synth Thing

This Synth Thing has been designed to provide an “all-in-one” box that can be used to explore the core principles of subtractive analog synthesis. It is designed to be relatively easily linked up to solderless breadboards to allow further experimentation with new circuits.

There are many educational analog synthesizers available, but the key aims of this project are as follows:

- Open Source.
- Can be “DIY” built relatively cheaply in terms of components¹.
- Lo-Fi but good enough to explore the concepts.
- Has real knobs and pluggable wires.
- The wires are “real signals” that can be monitored with an oscilloscope.
- Low voltage.
- MIDI IN compatible.
- Expandable.

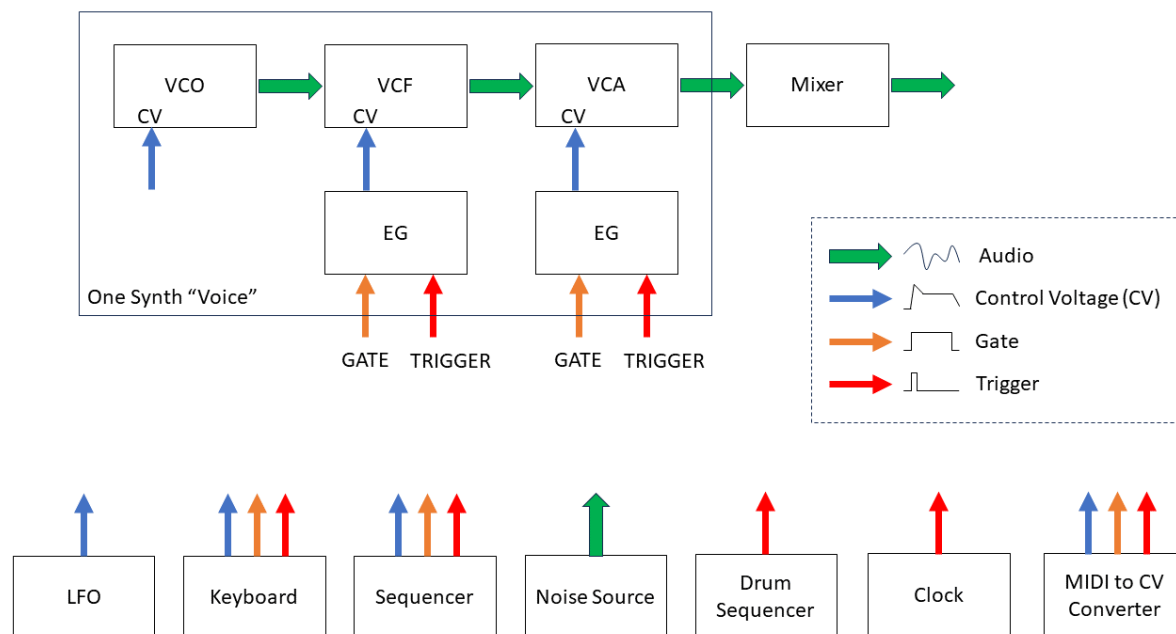
Further details of the design and build process can be found here:

<https://diyelectromusic.com/2024/05/07/educational-diy-synth-thing/>

¹ The prototypes were built for a cost of around £50 for a single unit, but four units can probably be built for around £100 due to minimum buys and bulk discounts on components. The real cost of course is the time required to build and 3D print each unit.

Introduction to Analog Synthesis

The Synth Thing is based on a common architecture for an analog synthesizer for **subtractive synthesis** as follows:



The bottom row of boxes shows some common sources of the different types of signals in an analog synthesizer.

There are many tutorials available online for the core principles of analog synthesis, but the key concepts relevant to the Synth Thing are:

Control Voltages (CV) – most components in an analog synth can be controlled by voltages – be that from a potentiometer (knob), a music keyboard, other synthesizer, sequencer, or whatever. These can be constant (e.g. representing the pitch of a single note), slowly varying (e.g. a vibrato effect), with a specific shape (e.g. defining an envelope or shape for a sound), or quickly changing (e.g. as a modulating signal).

Some modules create control voltages e.g. a low-frequency oscillator (**LFO**) or envelope generator (**EG**) and many receive them e.g. a voltage controlled oscillator (**VCO**), filter (**VCF**) or amplifier (**VCA**).

Gates and Triggers – control voltages represent continuously varying control whereas gates and triggers define start and stop end points for sounds – e.g. starts of notes and ends of notes.

An **audio path** shows how an audio signal passes from one module to another to eventually be mixed into a final audible signal.

A audio path would typically define a single playable note – a **monophonic** ("one sound") synthesizer.

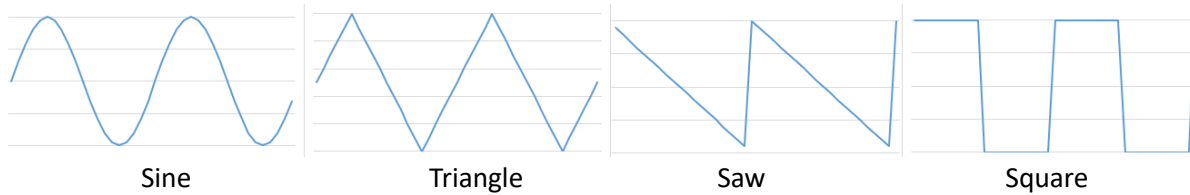
To play several notes at the same time, e.g. in a chord, requires a **polyphonic** synthesizer and several parallel audio paths. Or at least parallel oscillators that then share the same audio path once mixed together.

In an analog synthesizer almost any signal could be made into a control voltage, trigger or gate, even audio signals, using suitable electronics.

Typically an analog synthesizer will consist of combinations of oscillators, filters, amplifiers, mixers, sound sources, controllers and a variety of other more specialised modules to create a typically unique type of complex sound.

There are several common **waveforms** that can be generated by an **oscillator** in an analog synthesizer.

Here are some of the common ones:

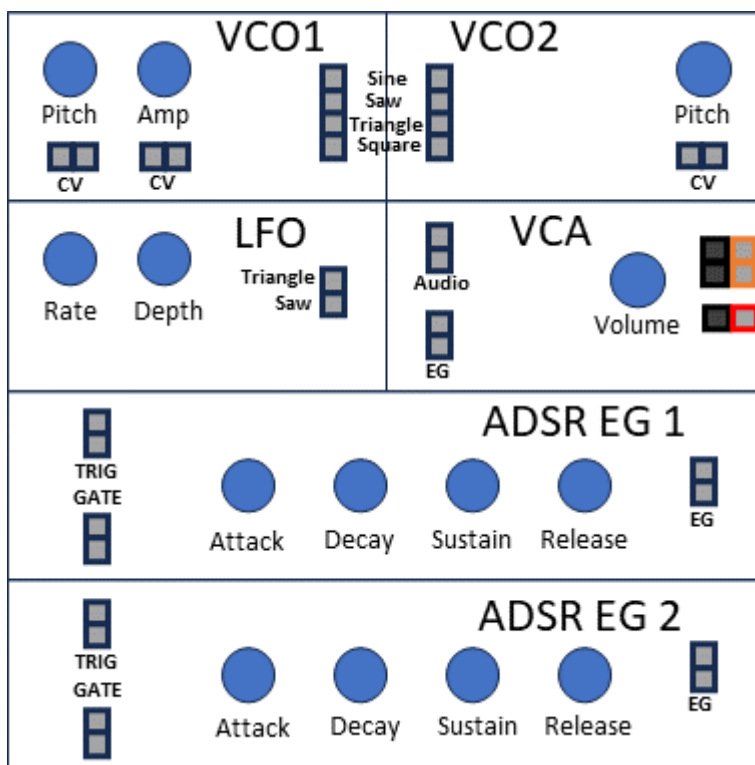


It should be noted that all the waveforms are in physical reality combinations of sine waves built up from the harmonics of a fundamental (base) frequency. In fact, in **additive synthesis** this is exactly how complex waveforms are generated – by adding together sine waves of different frequencies.

The Synth Thing is designed for **subtractive synthesis**. It starts with a complex waveform and will eventually use filters to “subtract” elements of the waveform to create interesting sounds.

The Synth Thing

The Synth Thing provides two voltage-controlled oscillators (VCO1 and VCO2), a low-frequency oscillator (LFO), a voltage-controlled amplifier (VCA) and two four-stage (ADSR) envelope generators (EG1 and EG2) as shown below.



There are no built-in filter stages.

All inputs, and the two EG outputs, have two pin headers. Generally this isn't for mixing signals, it is to make it easy to monitor input signals using an oscilloscope or to duplicate inputs to other modules. The one exception is the input to the VCA which can act as a simple passive mixer for both VCOs if required.

Both oscillators produce sine, saw, triangle and square wave outputs at the same time.

There are 3V3 and 5V power headers for linking out to solderless breadboards and other circuits.

IMPORTANT: If either of the 3V3 or 5V signals are connected directly to the GND signals then that will short out the Synth Thing and **could damage some of the components**.

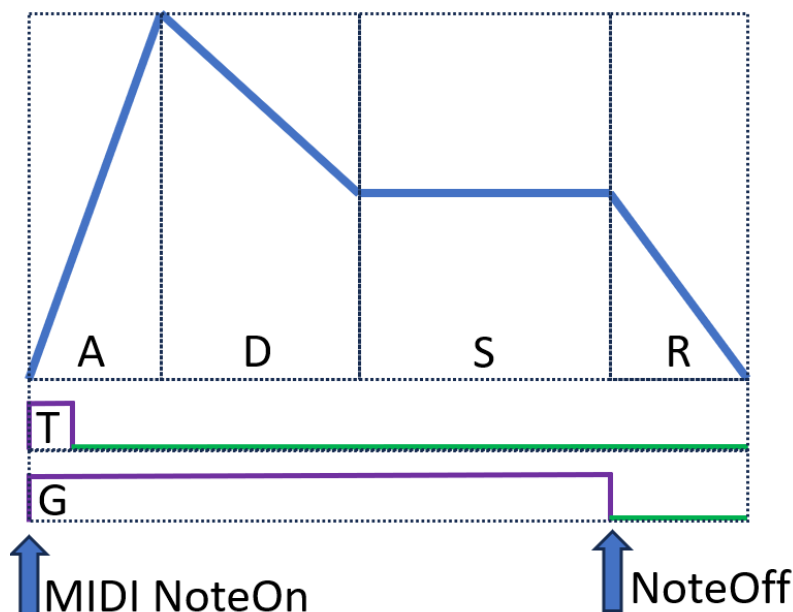
Basic Signal Properties

- Control voltages (CV) are in the range 0 to 3.3V.
- Gates and Triggers will be either 0V (off) or 3.3V (on).
- Audio signals are in the range 0 to 3.3V, centred on 1.7V (i.e. they are DC biased).
- The VCO CVs will accept varying control voltage signals up to around 500Hz, so are fine when used with a low-frequency oscillator, but are not fast enough for frequency modulation between oscillators.
- All CV, gate and trigger signals have a degree of protection so can accept (but will cut off) signals up to 5V. They will probably cope with higher (e.g. “Eurorack” signal levels), but this is not recommended.
- A pitch CV of 0V is internally mapped onto frequency 65.406Hz which is equivalent to MIDI note C2.
- Pitch CVs use the 1V/oct system, so there is a coverage of just over 3 octaves via CV input.

MIDI Support

The Synth Thing will respond to (monophonic) MIDI Note On and Note Off messages.

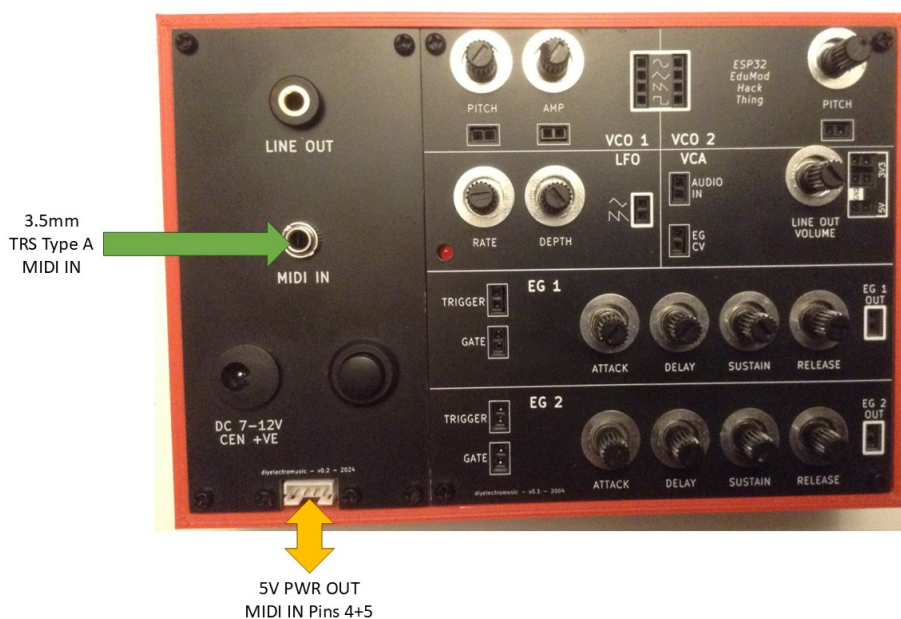
A trigger is generated on reception of a Note On message and the gate will be set HIGH. It will remain HIGH until the corresponding Note Off message is received. The pitch is determined by the note value in the Note On message.



Whilst the control voltages are internally mapped so that 0V corresponds to MIDI note C2, when driven over MIDI the Synth Thing will actually respond to any MIDI note from 0 through to 127 (G9) although practically any produced notes are limited by the performance of the hardware to around B8 due to the sample rates used.

MIDI will also set both VCOs to the same pitch, but the control knobs can be used to add to the pitch to detune them further.

When using the additional connections panel there are two options for MIDI: either use a TRS ("Type A" wiring) MIDI jack or the custom JST header connection:



Note: It is important that only one MIDI connection is plugged in at any one time.

Details of how to use the custom JST header can be found here:

<https://diyelectromusic.com/2024/07/14/educational-diy-synth-thing-part-7/>