The Educational DIY Synth Thing

External Passive Circuit Projects

Introduction
This carries on from the previous chapters and assumes that one has a working Synth Thing and has worked through all of the starter projects.

There are five sections in this chapter covering the following:

- Basic Principles and Connections
- Accessories and Indicators
- Sensor Voltage Controllers
- Simple Passive Filters

In each case once general amplification and power are required as used previously.

Core Components Required
The following basic additional components are required to perform all the experiments in this chapter:

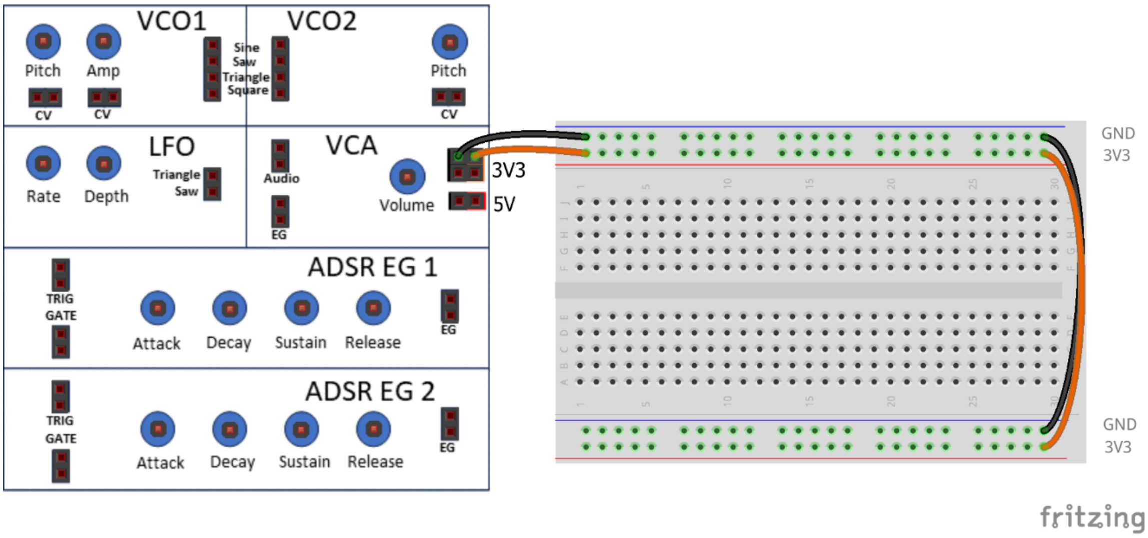
- Solderless breadboard – ideally a "half+" type.
- Optional: Oscilloscope, adaptors and probes (see previous chapter on oscilloscope use).
- 2x 1KΩ, 1x 10KΩ Resistors
- 100KΩ rotary potentiometer.
- 10KΩ or 100KΩ linear (fader/slider) potentiometer.
- Two-way "thumb" joystick.
- 100nF Capacitor.
- 4.7mH Inductor.
- Red and green LEDs.
- Light-dependant resistor (LDR).
- Force sensitive resistor (FSR).

Basic Principles and Connections

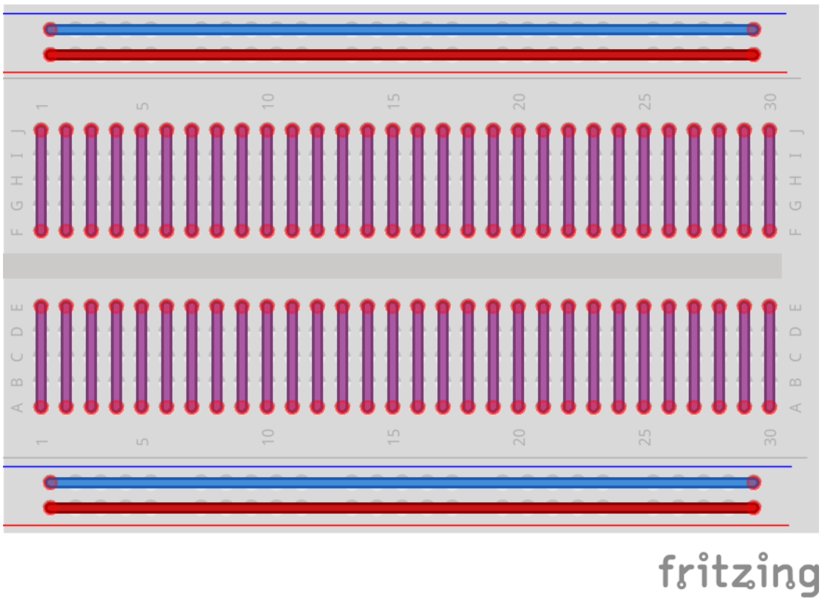
This shows how to connect a solderless breadboard ready to start some experiments.

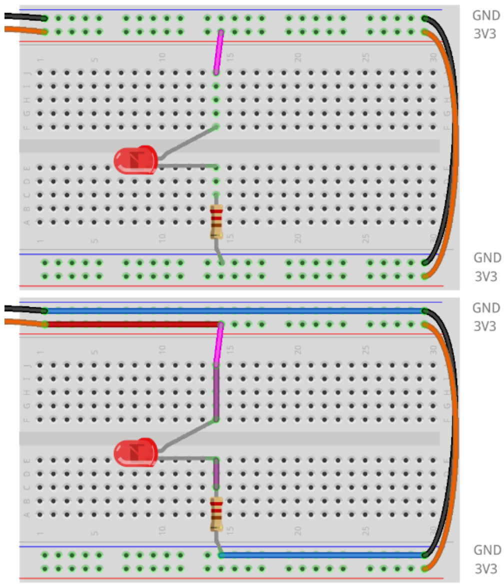
The power should ideally be kept within the 0-3V3 range, so it is recommended that, unless it is stated otherwise, the solderless breadboard is connected to GND and 3V3 as shown below.

It is also recommended that the blue row is used to signify GND and the red row is used for 3V3.



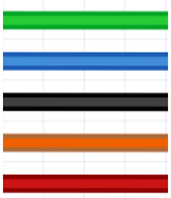
The holes in a solderless breadboard are internally connected as show below, making joining circuits relatively straightforward. Anything plugged into one of the holes in a row or column is automatically connected to anything plugged into any of the other holes in the same row or column.





The top (right) diagram shows how an LED could be wired to 3V3 and GND. The bottom (right) diagram shows the path of the completed circuit through the solderless breadboard.

Summary of the colours used in these project diagrams:

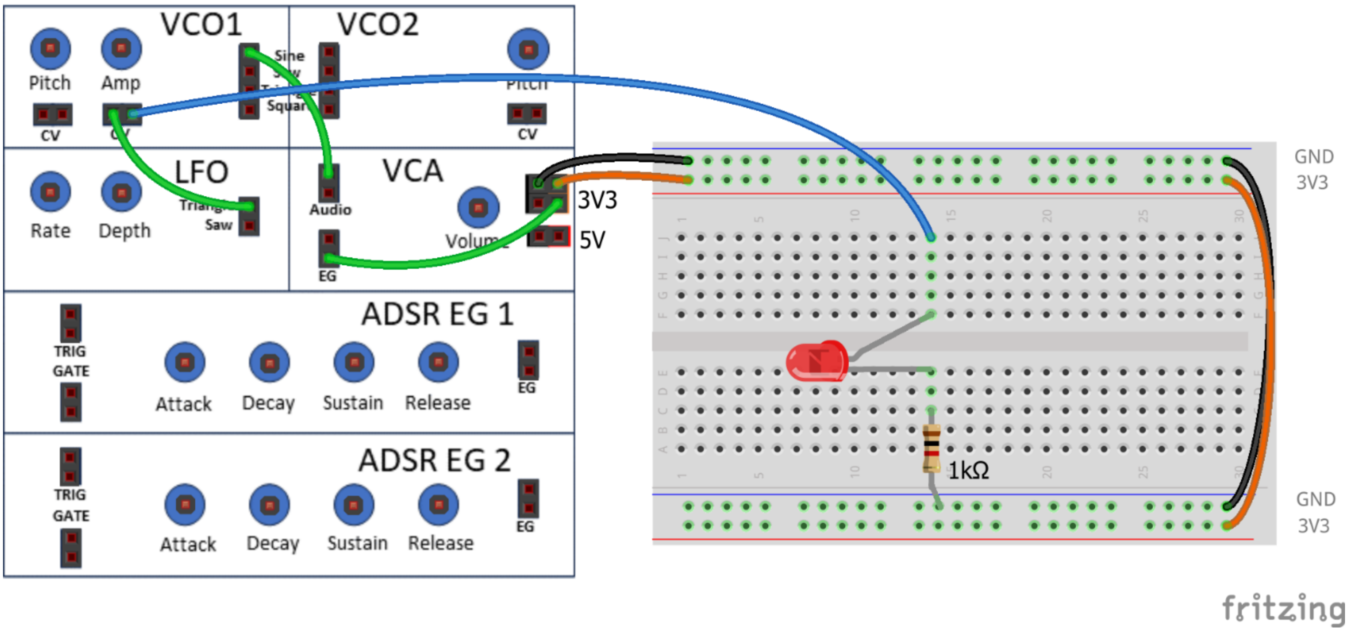


- Green – internal connections between patch points on the Synth Thing.
- Blue – external connections between the Synth Thing and the breadboard.
- Black – GND connections.
- Orange – 3V3 connections.
- Red – 5V connections.
- Other Colours – other connections on the breadboard as required.

Accessories and Indicators

1. LED Indicator

This project shows how an LED can be used as an indicator for various functions of the Synth Thing.



An LED (light emitting diode) will light up when the voltage level is greater than a minimum level (called the "forward voltage" of the LED). This means that it can be used as an indicator for any varying signal, providing that signal has at least part of it greater than the LED's minimum level.

The circuit above shows an LED connected to the LFO output and to GND via a 1KΩ resistor.

Set the Synth Thing controls as follows:

- VCO1 Amp fully anti-clockwise ("off").
- VCO1 Pitch half-way.
- LFO Depth half-way.
- LFO Rate fully anti-clockwise ("slow").

If the LED isn't slowly flashing try turning up the LFO Depth.

Now experiment with the following and see how it affects the LED:

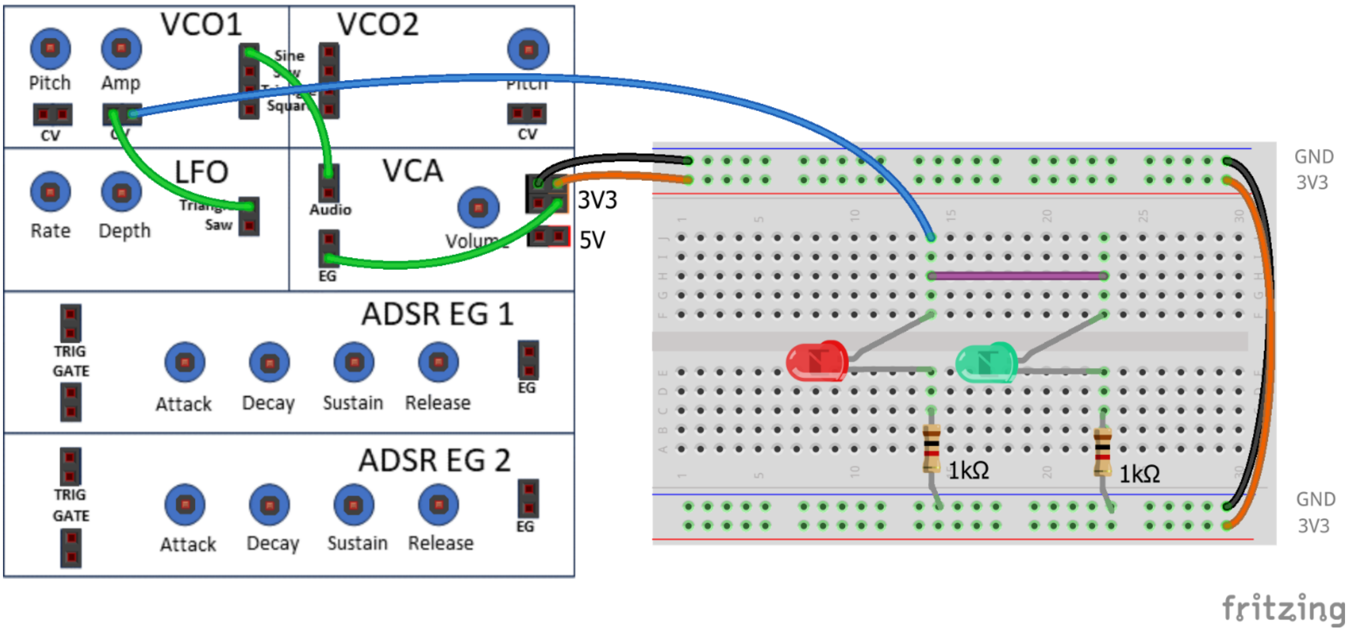
- LFO Rate.
- LFO Depth.
- LFO waveform.

Notice how at a low Rate, with the triangle waveform, it is possible to see the LED come on dimly and get brighter and then dim again.

Also notice how beyond a certain speed it is hard to tell that the LED is flashing at all. Our eye's "persistence of vision" makes it look like the LED is on all the time, but it will still be flashing at the same rate as the LFO.

2. Dual LED Indicator

Different LEDs have different voltages at which they turn on. This project uses that property to make a simple two-level indicator using red and green LEDs.



Repeat the previous experiment, setting the initial controls as follows:

- VCO1 Amp fully anti-clockwise ("off").
- VCO1 Pitch half-way.
- LFO Depth fully anti-clockwise ("off").
- LFO Rate almost fully anti-clockwise ("slow").

Now slowly increase the LFO Depth until the LEDs come on.

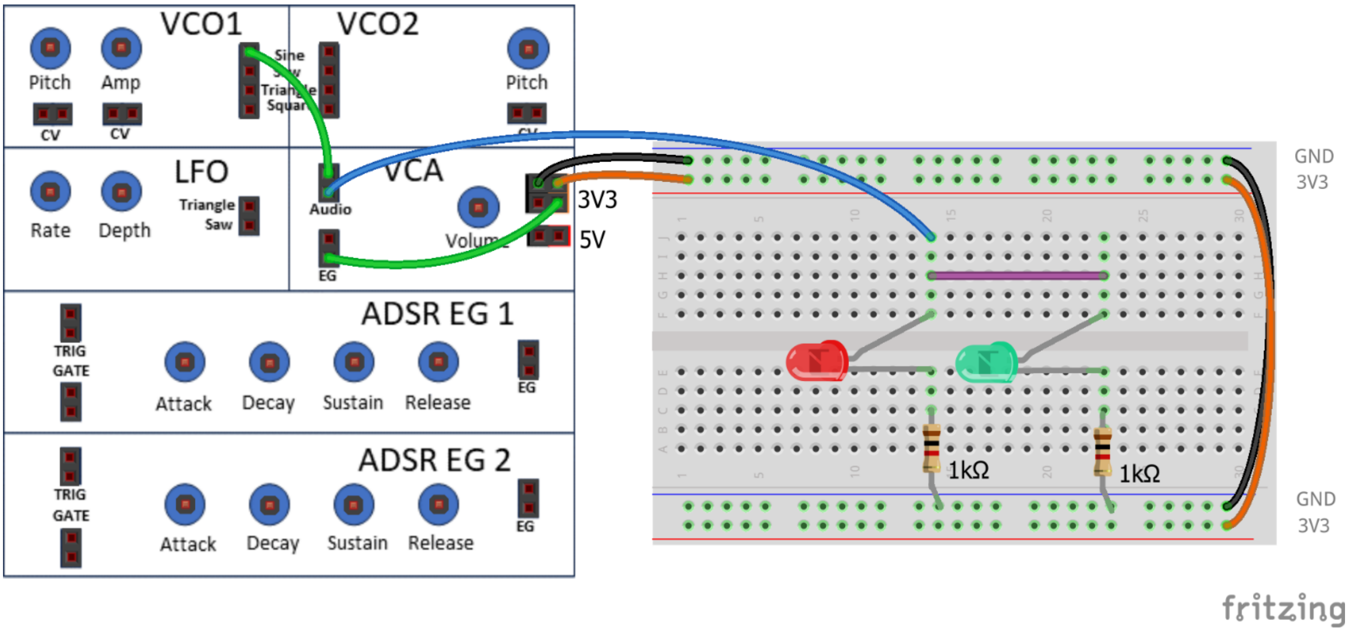
Experiment with the following:

- Can you work out which LED comes on first and which goes off first?
- Can you find a Depth where just one of the LEDs comes on?
- If you have an oscilloscope connected, then measure the voltage at which each LED comes on.

The forward voltage of a red LED is around 2V and green is around 3V, although both will depend on the exact make and model of LED being used. This means that the red LED should always come on and go off at a lower voltage compared to the green LED.

3. Audio Level Meter

If you have a wider range of colours, then it should be possible to arrange them in voltage order and create a simple "vue meter" or audio level indicator type effect. This experiments looks at that.



This experiment is a repeat of the previous experiment but this time using the audio output of the VCO directly. Ideally this would work on the final audio output of the Synth Thing but that requires connecting into the main audio line out.

Set the controls as follows:

- VCA Volume fully clockwise.
- VCO1 Amp fully anticlockwise.
- VCO1 Pitch half-way.

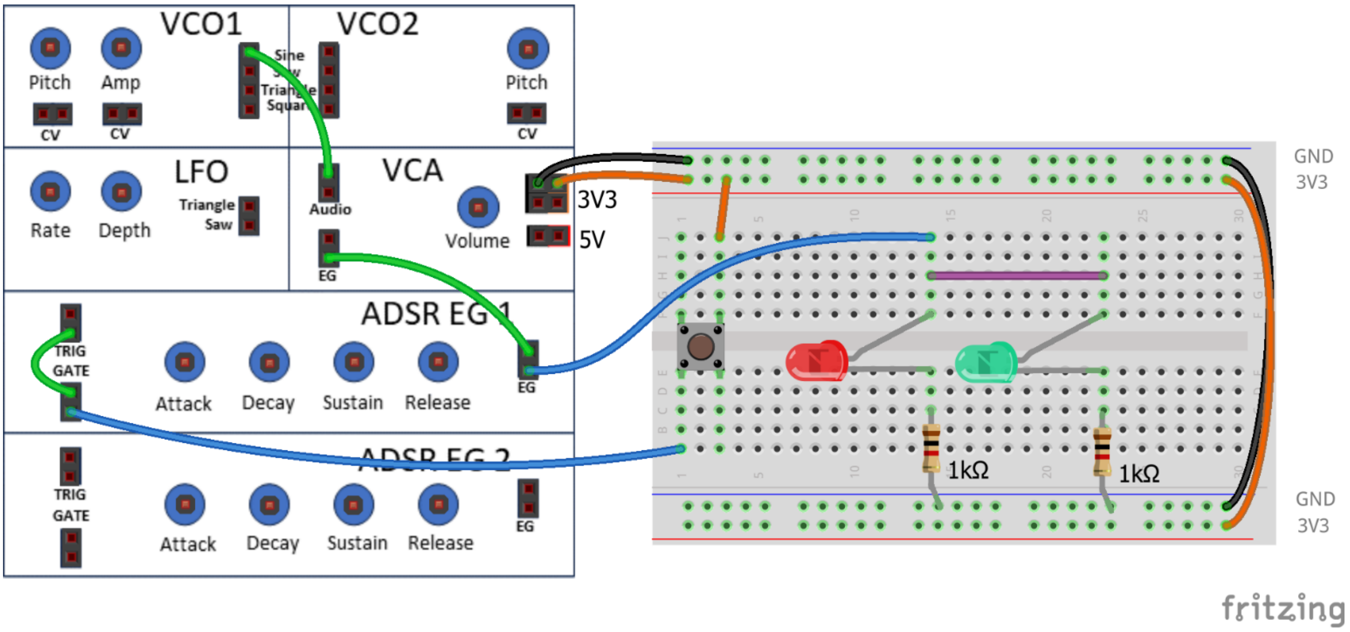
Slowing increase VCO1 Amp until one LED lights up. Increase it further until both LEDs light up.

See how the following affect the final level and consequently which LEDs light up:

- VCO1 Pitch.
- VCO1 Waveform.

4. Audio Level Meter with EG

This adds in the envelope generator to give a bit more shape to the sound being created.



Set the Synth Thing controls as follows:

- VCO1 Amp and VCA Volume fully clockwise.
- VCO1 Pitch half-way.
- ADSR EG1 as follows:
  - Attack – almost fully anticlockwise.
  - Decay – almost fully anticlockwise.
  - Sustain – fully clockwise.
  - Release – half-way.

Now trigger the envelope by pressing the button. Both LEDs should come on.

Experiment with the following:

- ADSR EG1 Sustain setting.

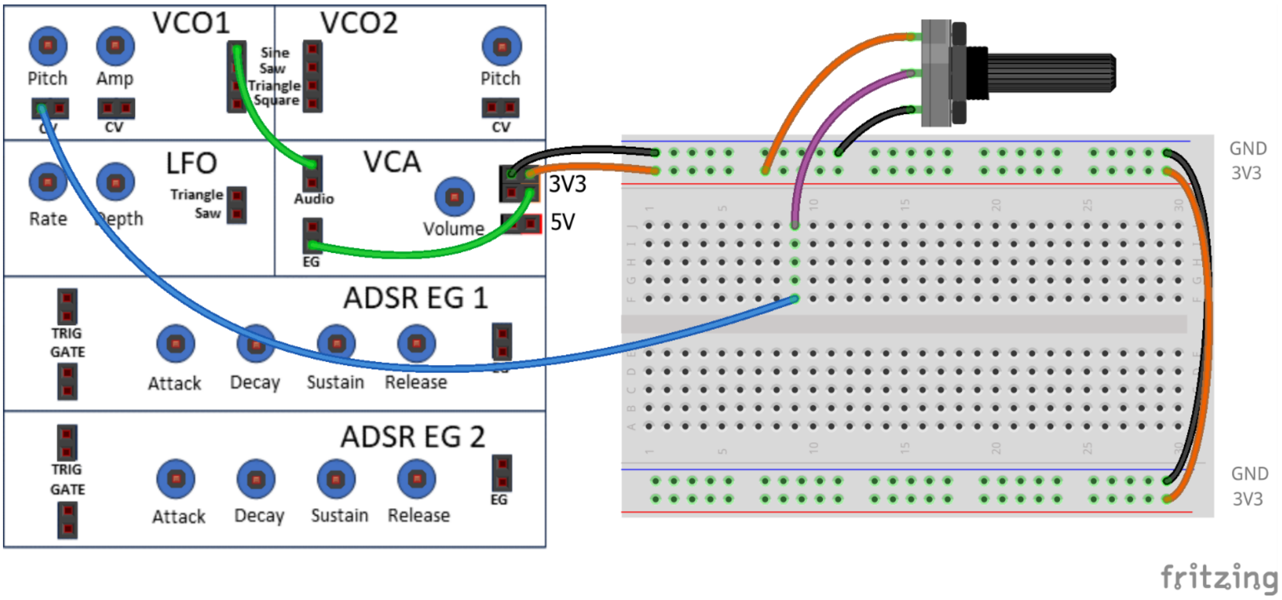
Can you find a sustain level that leaves only one LED on when the button is held on?

Note: this is showing the EG levels directly, not the audio output that it generates – to do that requires tapping into the audio line out of the Synth Thing.

Sensor Voltage Controllers

1. Potentiometer Control

This is a recap on an earlier experiment, reminding us how to wire in a potentiometer to the Synth Thing.



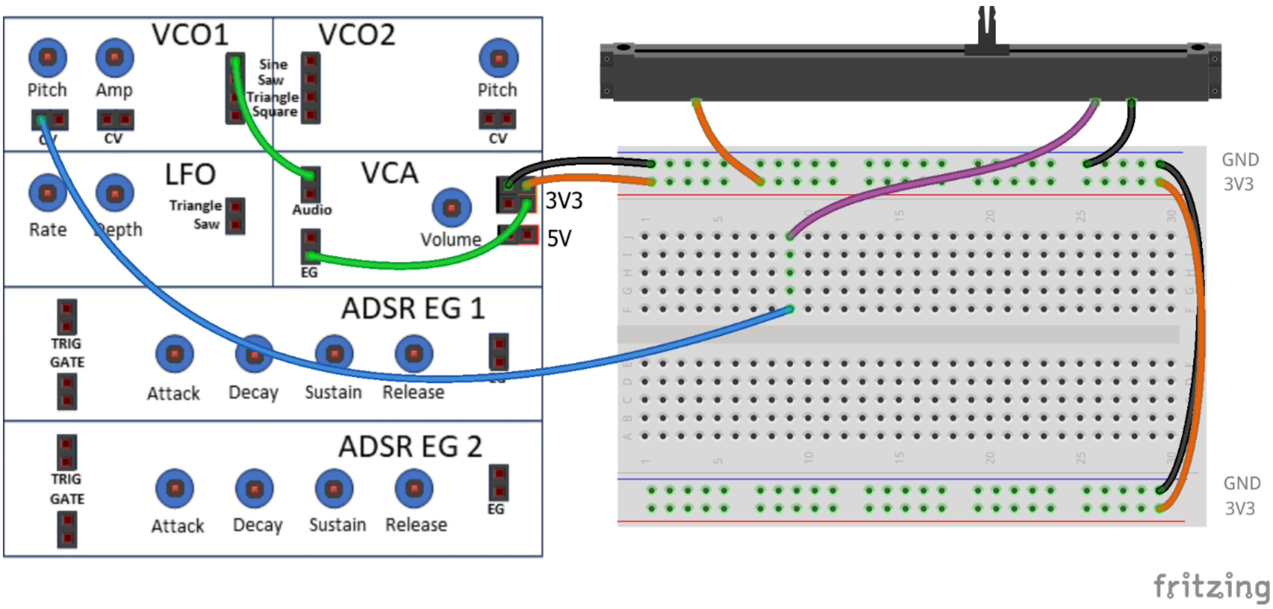
The potentiometer is connected between 3V3 and GND with the centre connector (the "wiper") used as a control voltage for the Synth Thing. In this case it is acting as a second potentiometer for controlling VCO1 Pitch.

Adjust both the external potentiometer and VCO1 Pitch and notice how the two settings are "adding" to each other.

This core idea is used as the basis for some further experiments as follows.

2. Linear Potentiometer Control

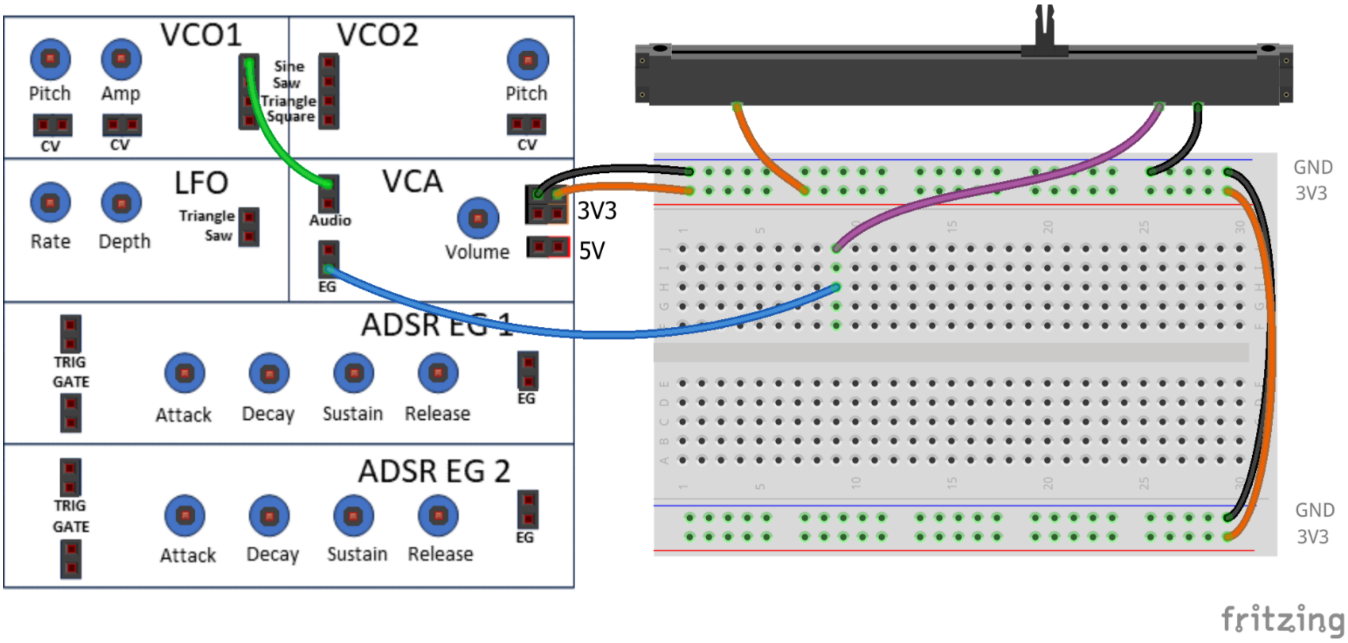
This is a repeat of the previous experiment but with a slider (or fader) style linear potentiometer.



This might work quite well controlling the Amp of VCO1, providing a fader-style volume control. Alternatively it could be used in place of the constant 3V3 level to the EG of the VCA.

3. Linear Potentiometer Volume Fader

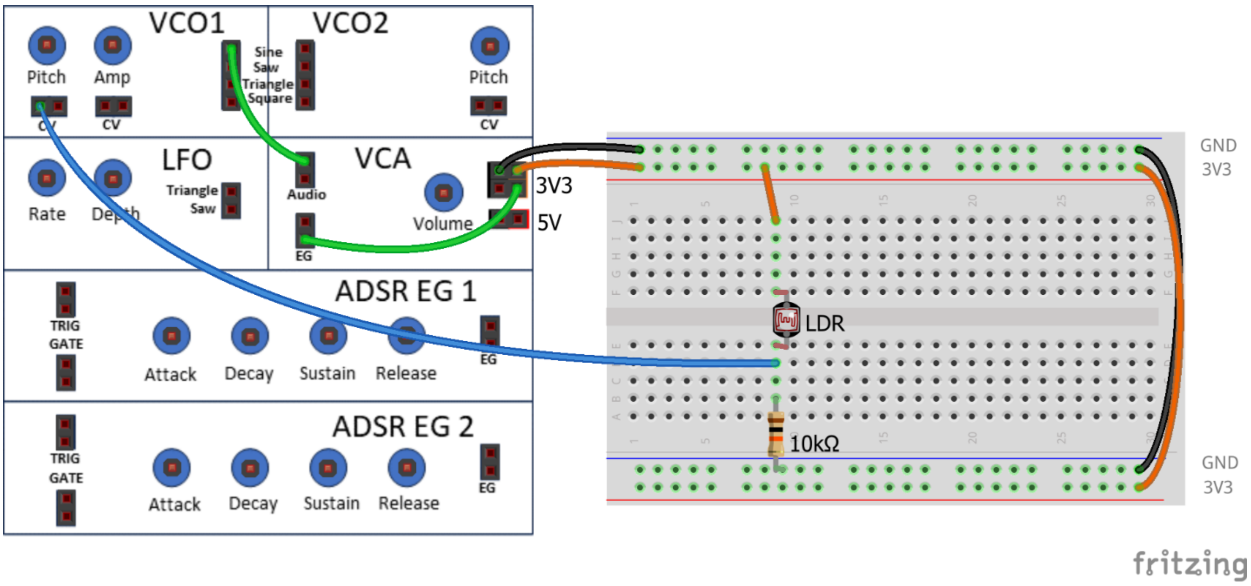
This is a repeat of the previous experiment but with the slider (or fader) style linear potentiometer controlling the VCA.



The constant 3V3 into the VCA has been replaced with the output of the potentiometer. This allows it to be used as a "master fader" control for the Synth.

4. Light Dependent Resistor Control

In this experiment the previous potentiometer is replaced with a light dependant resistor (LDR).

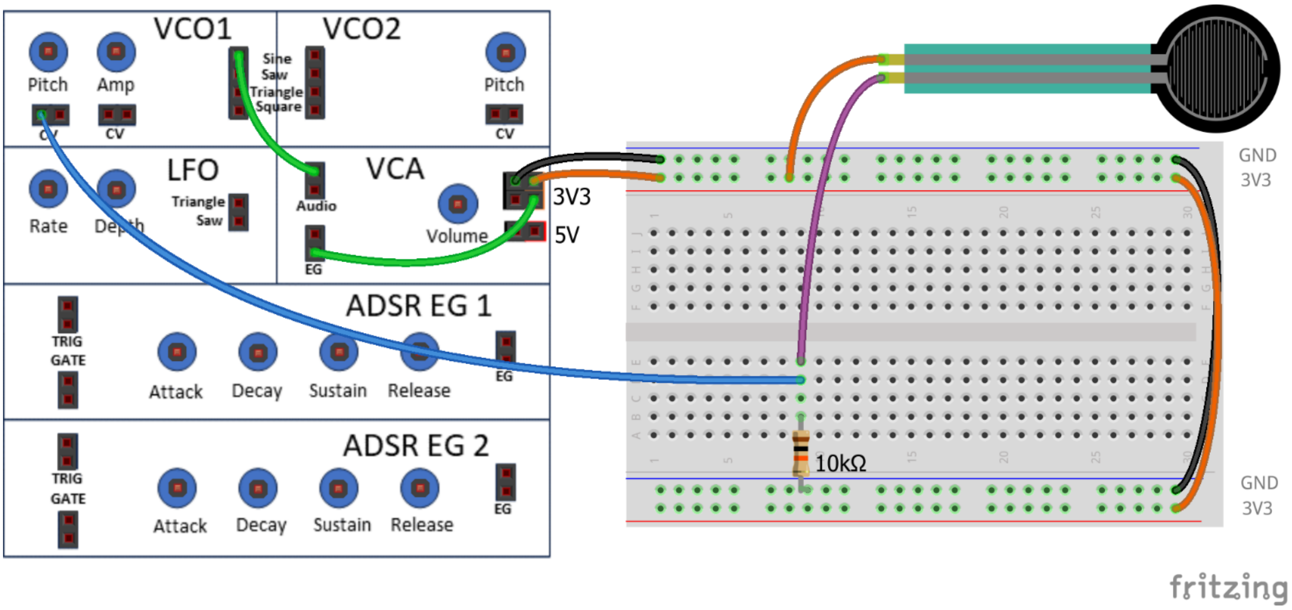


In this circuit the LDR and 10KΩ resistor are doing the same job as the potentiometer – they are creating a control voltage in the range 0V to 3.3V, but the value now depends on how much light the LDR receives.

Set VCO1 Pitch half-way and experiment with covering and part-covering the LDR. This can emulate a hands-free instrument called a Theremin. Using your hand slowly moving it towards the LDR until the LDR is covered and note how the VCO1 pitch changes.

5. Force Sensitive Resistor Control

This follows on from the previous experiment and shows how a force sensitive resistor can control the Synth Thing.

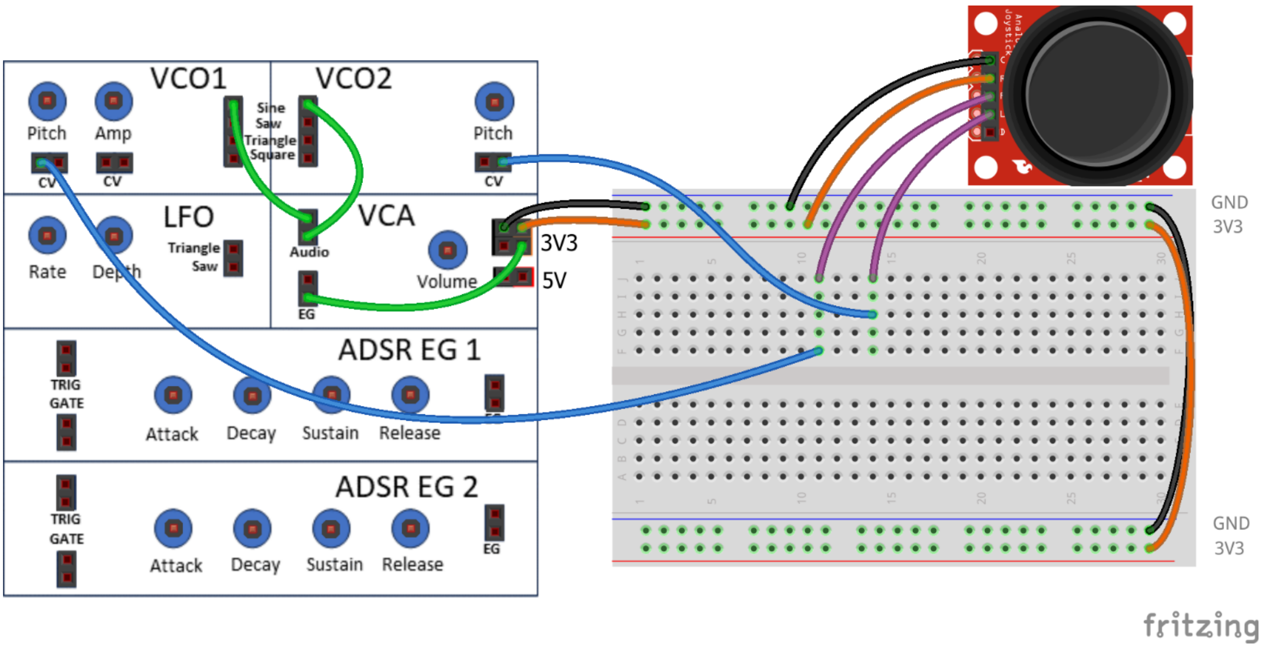


Once again, the FSR is doing the same job as the potentiometer and as shown is connected to VCO1 Pitch CV. Note that these come in various shapes – the circuit above shows a circular one, but rectangular/linear FSRs are quite common too and work in the same way.

See what happens to the pitch as pressure is applied to the FSR.

5. "Thumb" Joystick Control

A gaming "thumb" joystick is often just two potentiometers controlling the X and Y directions, making them fairly easy to use with the Synth Thing as shown below.



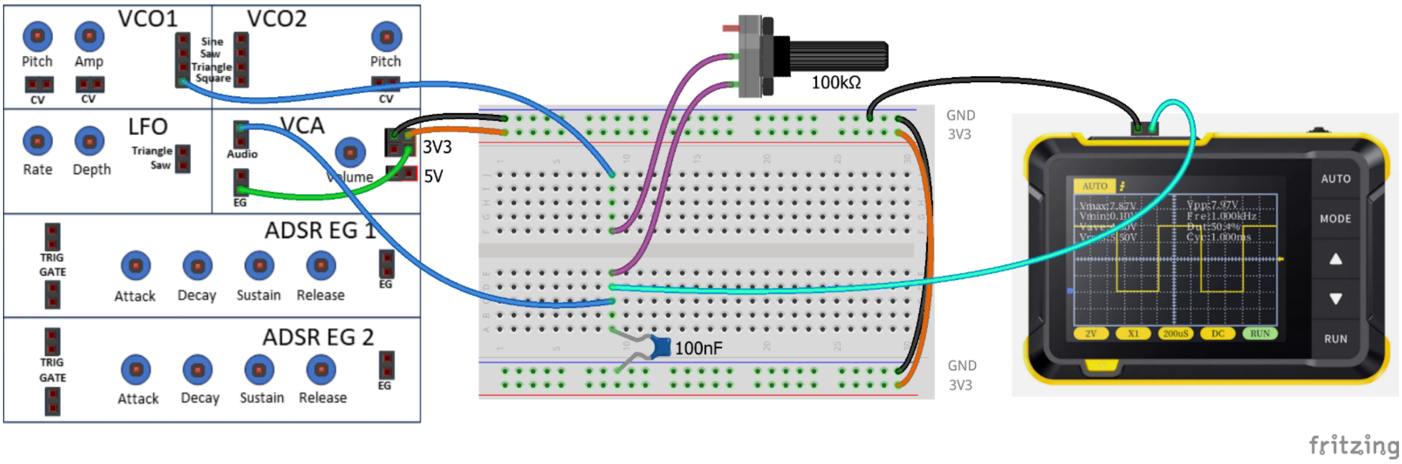
The wiring can often be different for these modules, so check that GND is connected to GND (black) and VCC/+5V/VIN is connected to 3V3 (ignore the +5V – we only need a top voltage to match the Synth Thing's 3V3). Then there should be two signal connections one for "X" and one for "Y". These can be connected as CV sources. In the circuit above they are controlling the Pitch CVs for VCO1 and VCO2.

The last connector might be for a switch, which is not used in this case, but could be used to trigger one of the ADSR Envelope Generators.

Simple Passive Filters

1. Adjustable Low-pass Filter

A single resistor and capacitor can be used to construct a low-pass filter – one that only lets lower frequencies through.



A filter is defined by its “cut-off frequency” that is, the specific frequency when much of the signal is reduced (attenuated). This can be calculated using a specific formula that relates to the values of the resistor and capacitor used. There are several online filter calculators to help work it out.

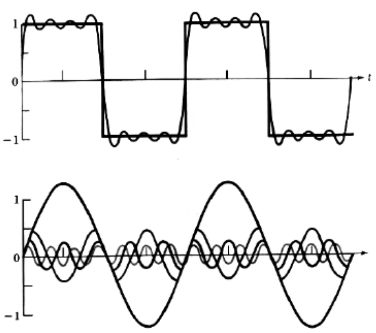
In the above circuit, the capacitor is fixed at 100nF (or 0.1uF) and the resistor is a potentiometer set up as a “variable resistor” with the range 0Ω to 100KΩ. Putting these values into an online calculator gives a cut-off frequency of between infinite (no resistance) and around 16Hz (100K). Any part of the signal with a frequency higher than this will be seriously reduced.

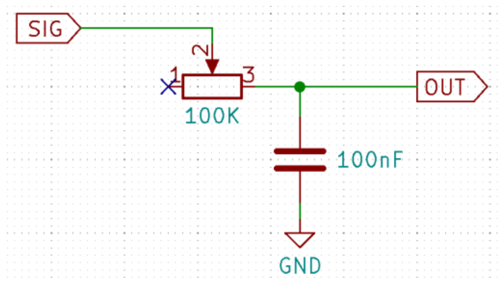
Complex waveforms, such as saw or square wave, are made up of many harmonics set at various multiples of the main (or fundamental) frequency of a pitch. This low-pass filter can be used to reduce the number of harmonics until almost a pure sine wave is the result.

Set the Synth Thing as follows:

- VCO1 Amp and VCA Amp fully clockwise.
- VCO1 Pitch half-way.
- Use the VCO1 square wave output.
- Turn the external potentiometer either fully clockwise or fully anti-clockwise until a square wave can be seen on the oscilloscope.
- Gradually turn the external potentiometer and note what happens to the resulting waveform – both by listening and by looking at the oscilloscope.
- Repeat the experiment with the saw, triangle and sine waves in that order.

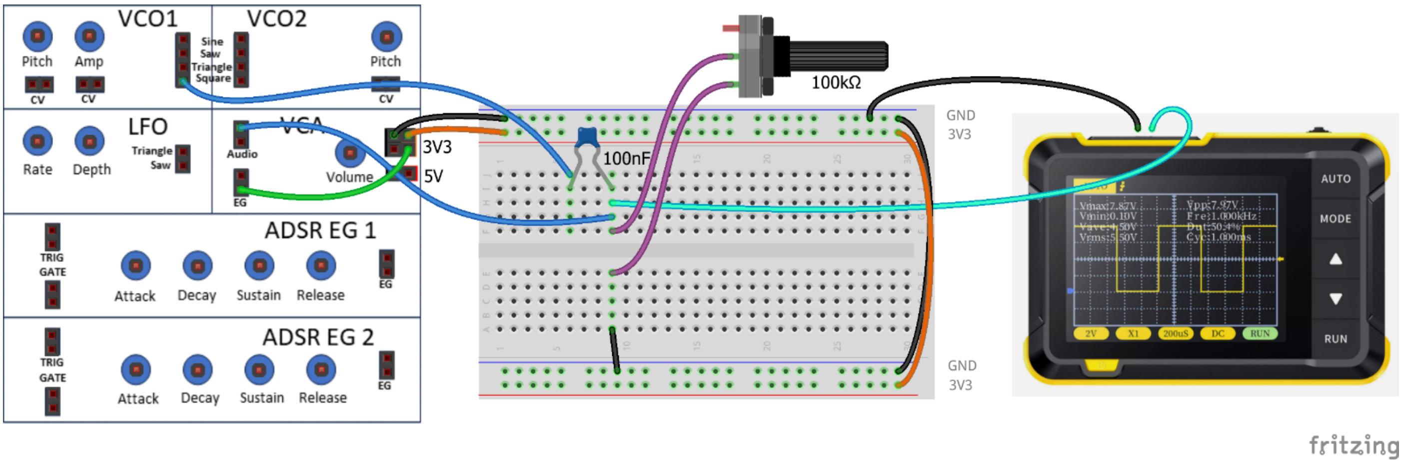
Notice how the more the filter is applied, the closer to a sine wave the result becomes as the higher harmonics get filtered out.





2. Adjustable High-pass Filter

A high-pass filter does the opposite – it only lets the higher frequencies through. A simple filter can be built just by swapping the capacitor and resistor as follows



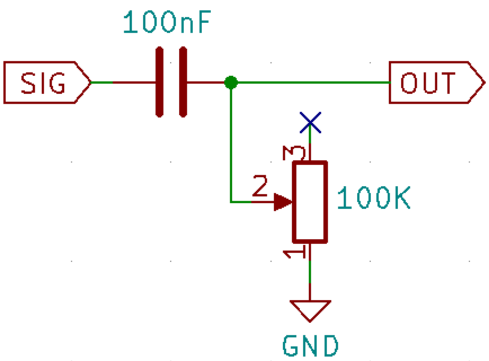
Once again there are online calculators to help work out the values, but for simplicity we're using the same two components as before, but now swapped around, which gives the same cutoff frequencies as before, but this time anything below that frequency is reduced.

Repeat the previous experiment:

- VCO1 Amp and VCA Amp fully clockwise.
- VCO1 Pitch half-way.
- Use the VCO1 square wave output.
- Turn the external potentiometer either fully clockwise or fully anti-clockwise until a square wave can be seen on the oscilloscope.
- Gradually turn the external potentiometer and note what happens to the resulting waveform – both by listening and by looking at the oscilloscope.
- Repeat the experiment with the saw, triangle and sine waves in that order.

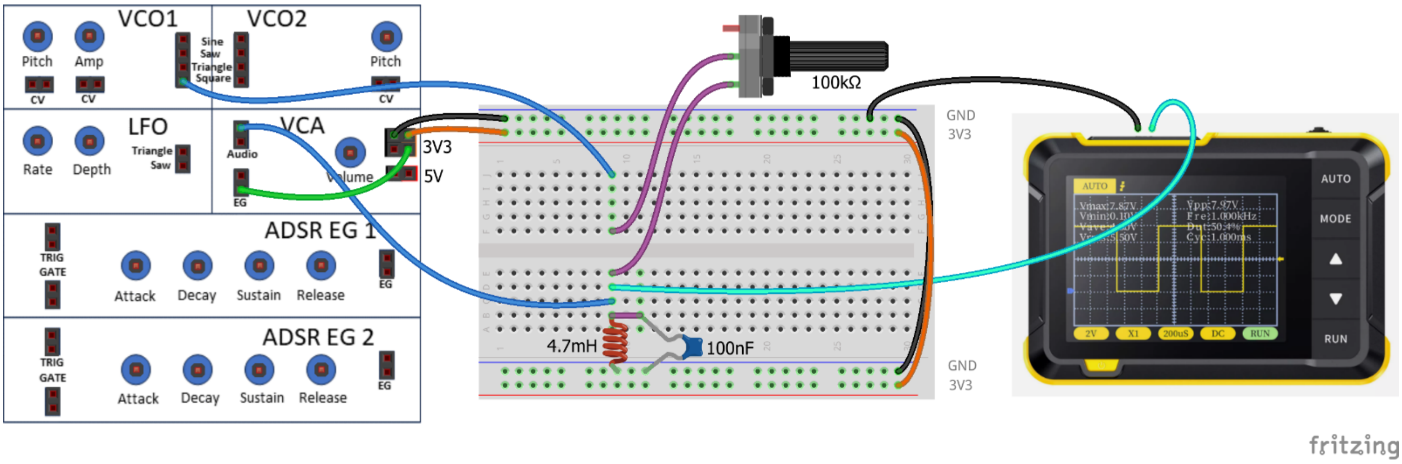
The effect isn't quite as clearly explained as for a LPF, but it should be clear how the lower frequencies are being stopped. Notice how there is a point where the basic frequency is such that nothing gets past the filter.

Ultimately, filters are quite complex in their theory of operation once we are beyond the basics. A practical, working filter would typically be an active circuit using OpAmps and other powered devices rather than simple passive components.



3. Low-pass Filter with Resonance

Using combinations of resistors, inductors and capacitors it is possible to demonstrate simple resonance in a filter circuit, but adding dynamically controlled resonance, as is desirable in an analog synth requires an active filter.



The set up for the Synth Thing is the same as for the previous two experiments:

- VCO1 Amp and VCA Amp fully clockwise.
- VCO1 Pitch half-way.
- Use the VCO1 square wave output.
- Turn the external potentiometer either fully clockwise or fully anti-clockwise until the waveform can be seen on the oscilloscope.
- Gradually turn the external potentiometer and note what happens to the resulting waveform – both by listening and by looking at the oscilloscope.
- Repeat the experiment with the saw, triangle and sine waves in that order.

An even clearer effect can be seen if the potentiometer is removed from the circuit and replaced with a wire link, but there is now even less control.

More finer control could be had with a lower value potentiometer, for example 10KΩ or even 1KΩ.

Ideally a larger inductor value would be used for use with audio frequencies – perhaps even in the 100mH+ range – but these tend to be quite large. But a value of 4.7mH is enough to see an effect compared to the unfiltered waveform.