

# The Educational DIY Synth Thing

Projects – v0.1 – Nov 2024  
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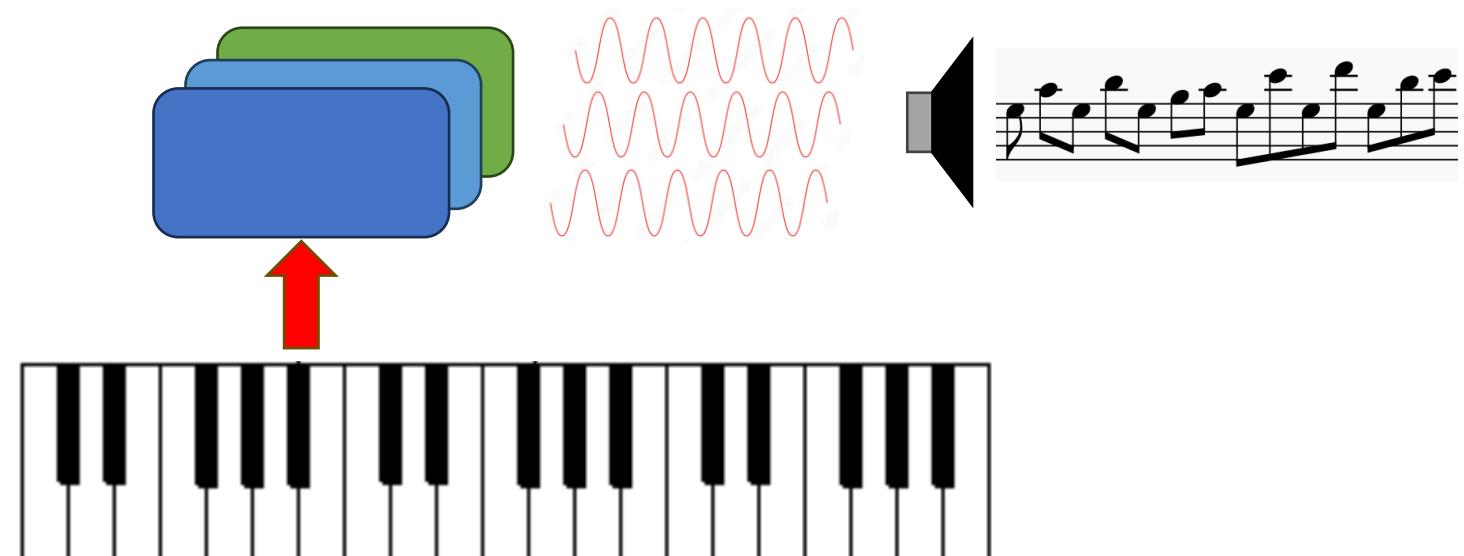
<https://diyelectromusic.com/2024/05/07/educational-diy-synth-thing/>



# Ch 1 - Introduction

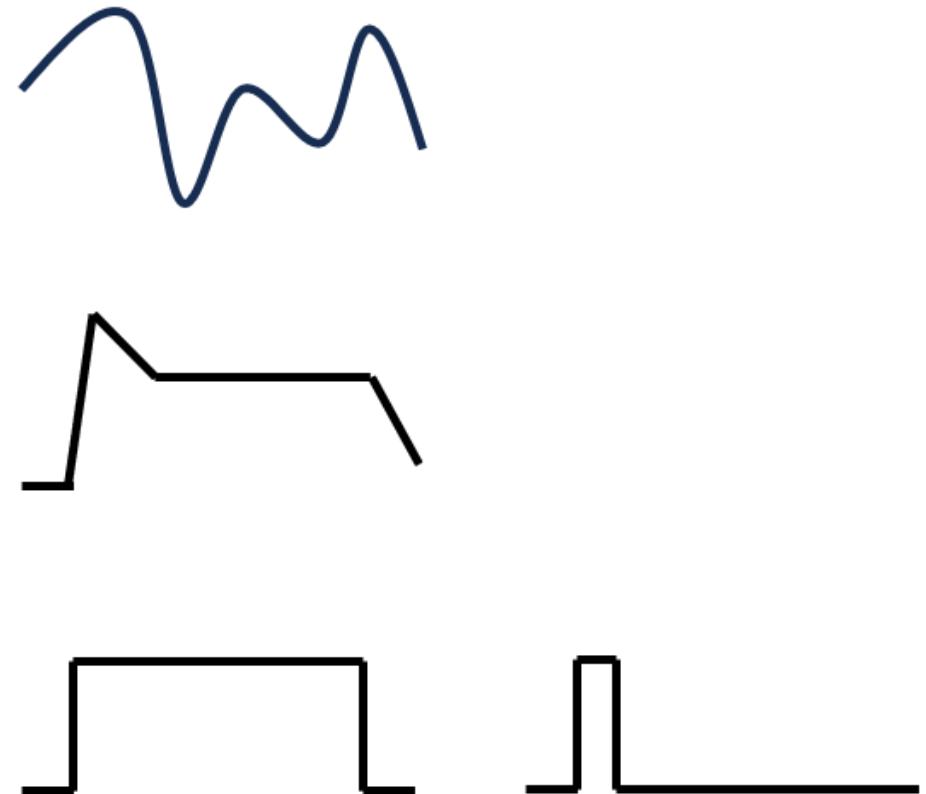
# Introduction to Analog Synthesis

- Key Principles:
  - Audio Signals
  - Voltage Control
  - Gate and Trigger Signals
- Other Principles:
  - Envelopes
  - Modules
  - Monophonic
  - Polyphonic

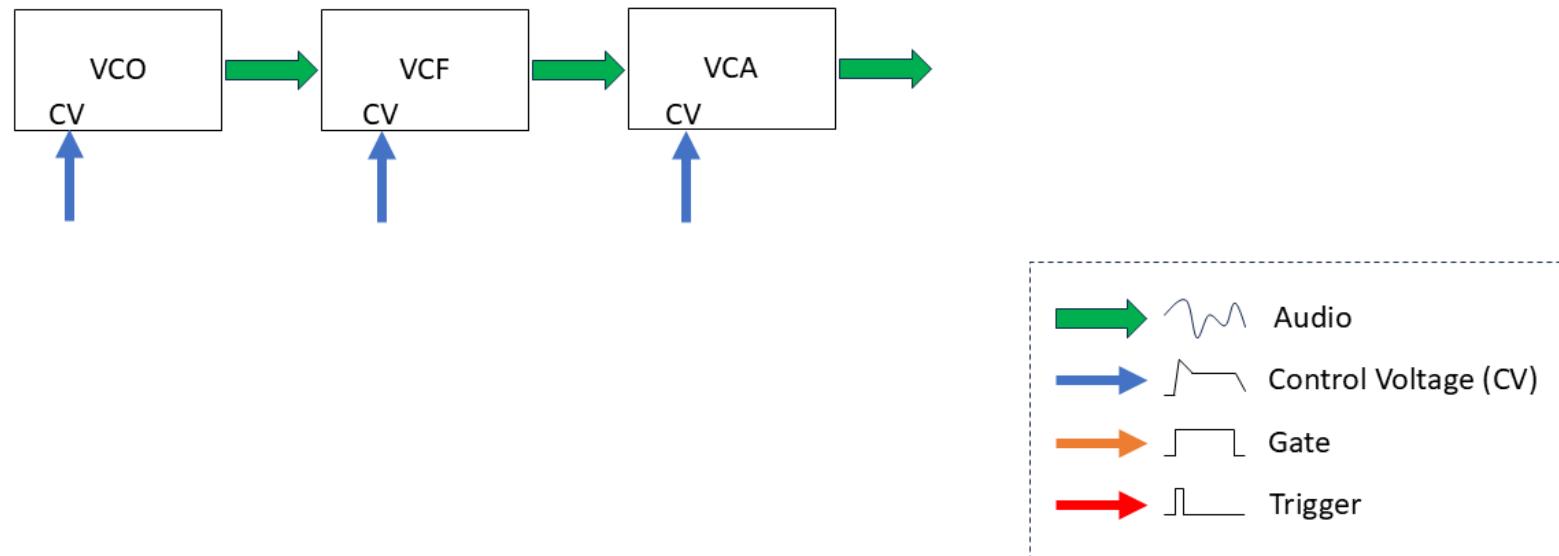


# Key Principles

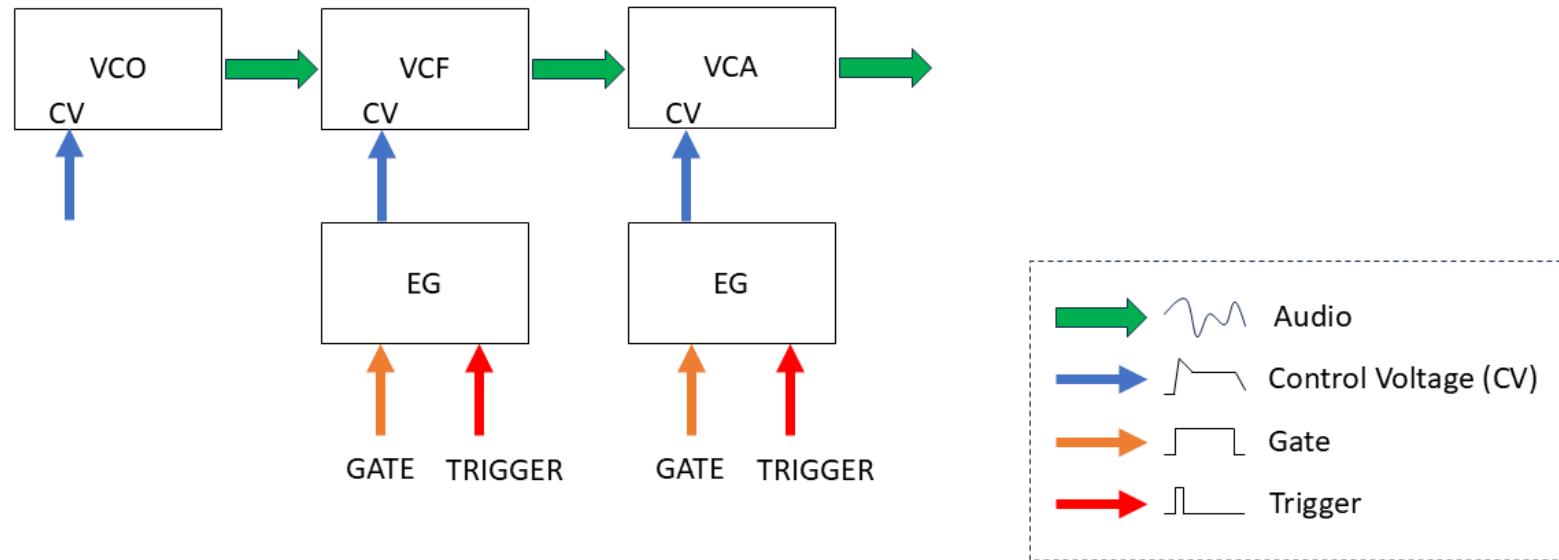
- Audio Signals
  - Produce the sounds.
- Control Voltages
  - Everything is controlled by voltage levels.
  - Can be constant or changing.
  - Can be continuous or with a start and end.
- Gates and Triggers
  - Start and stop sounds.



# Basic Structure of an Analog Synthesizer

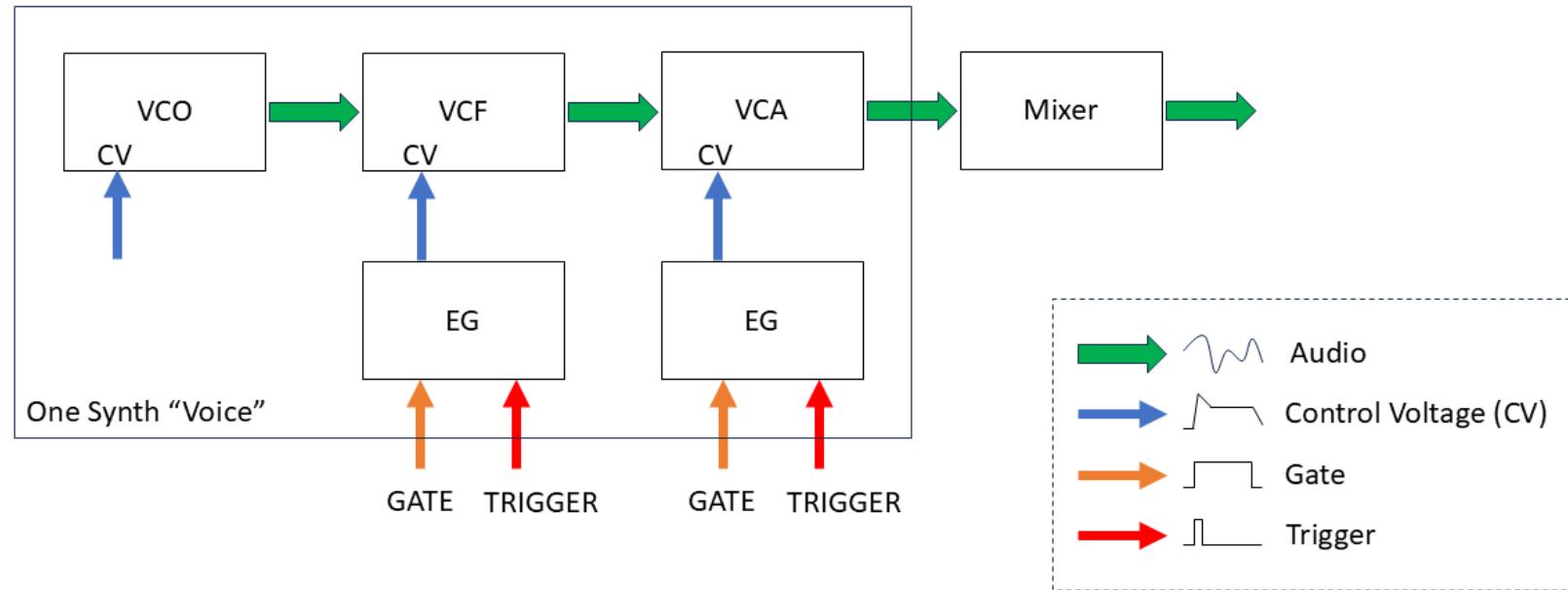


# Basic Structure of an Analog Synthesizer



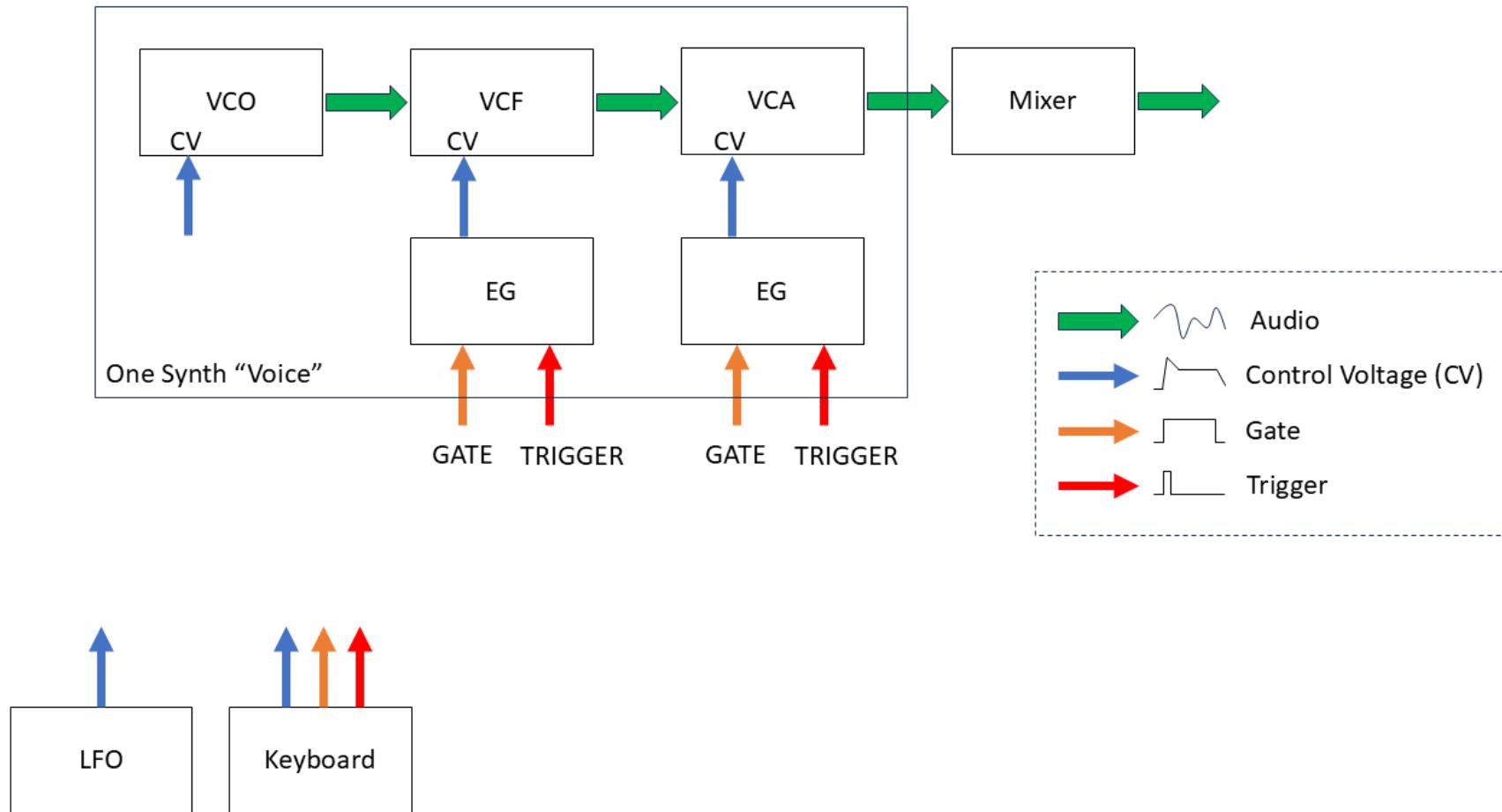
One Voice = Monophonic

# Basic Structure of an Analog Synthesizer

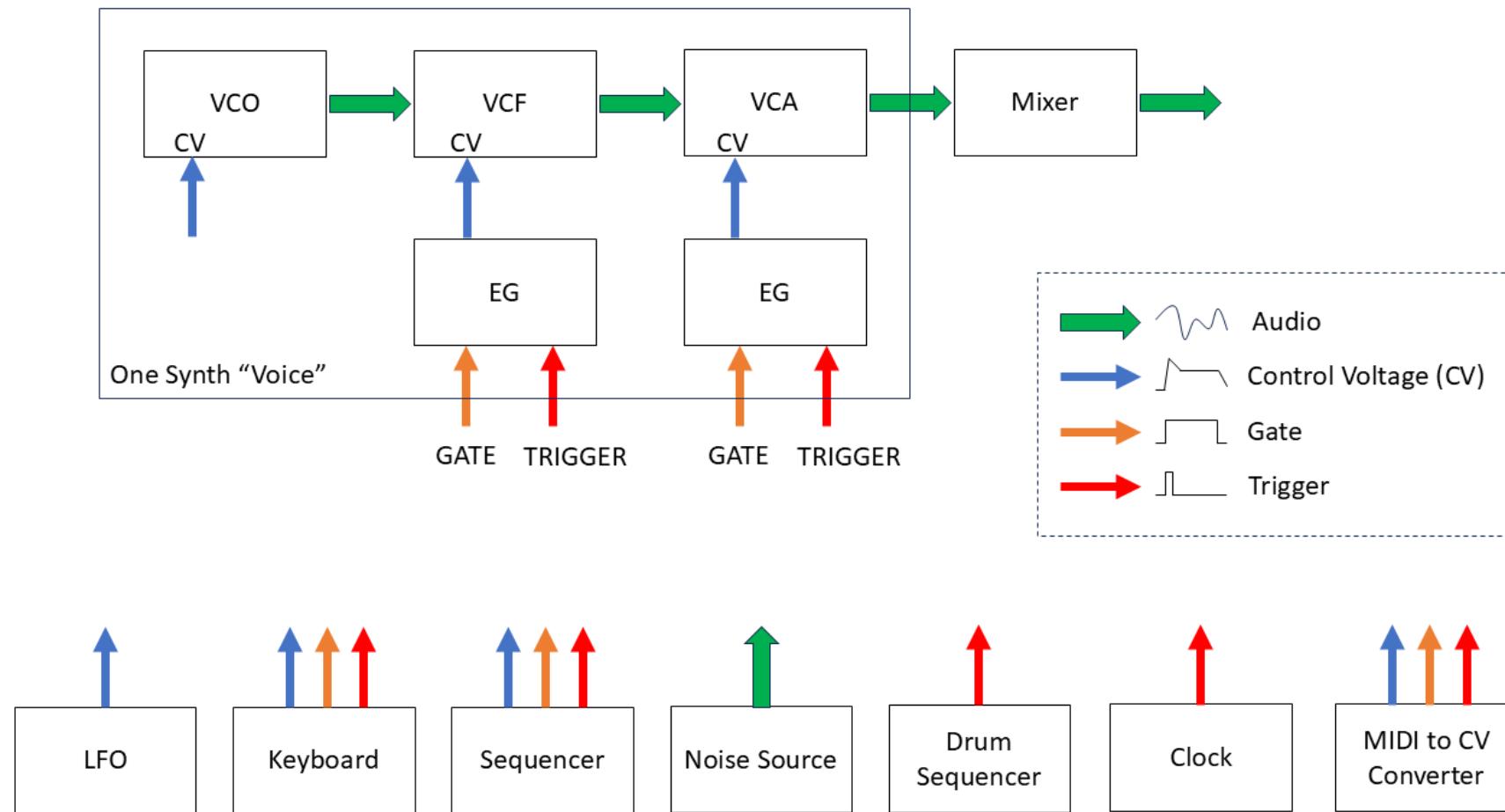


Many Voices = Polyphonic

# Basic Structure of an Analog Synthesizer



# Basic Structure of an Analog Synthesizer



# Waveforms



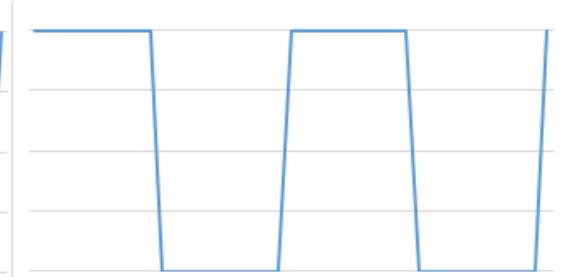
Sine



Triangle

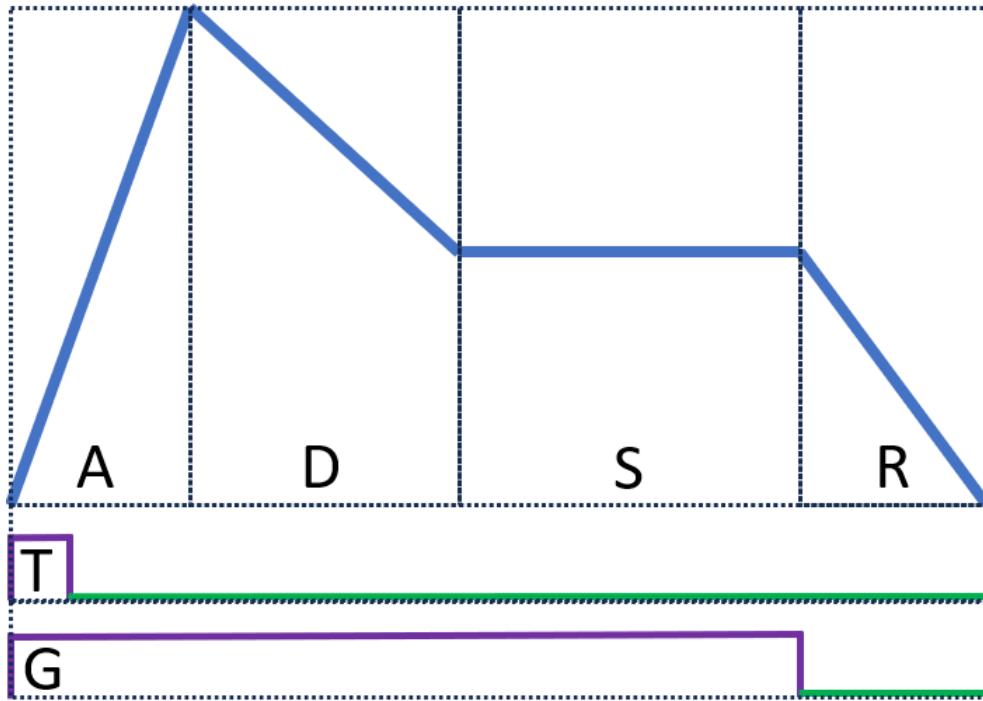


Saw



Square

# Envelopes



- Attack (A)
- Decay (D)
- Sustain (S)
- Release (R)

< Trigger

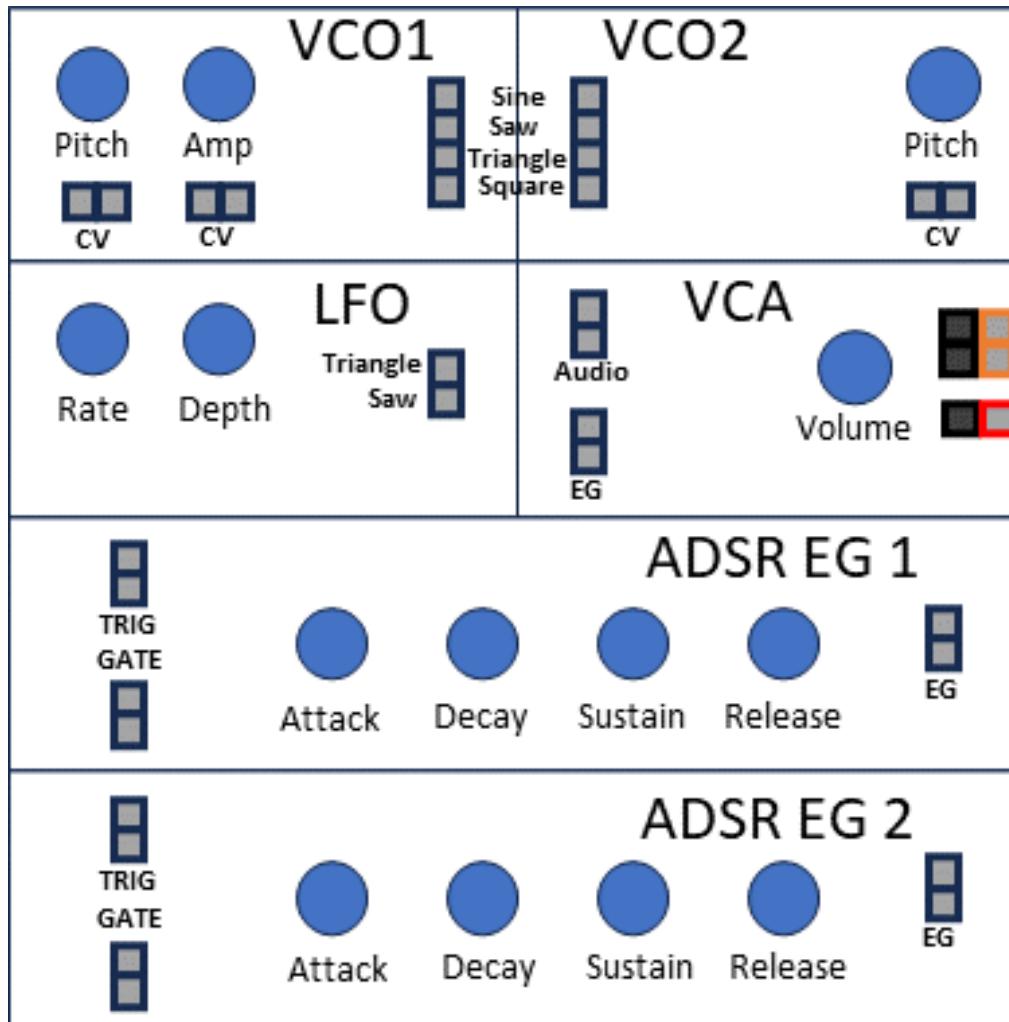
< Gate

# Key Points of Analog, Modular Synths

- (Pretty much) Everything can be voltage controlled.
- (Pretty much) Any signal can be a control voltage!

The Synth Thing

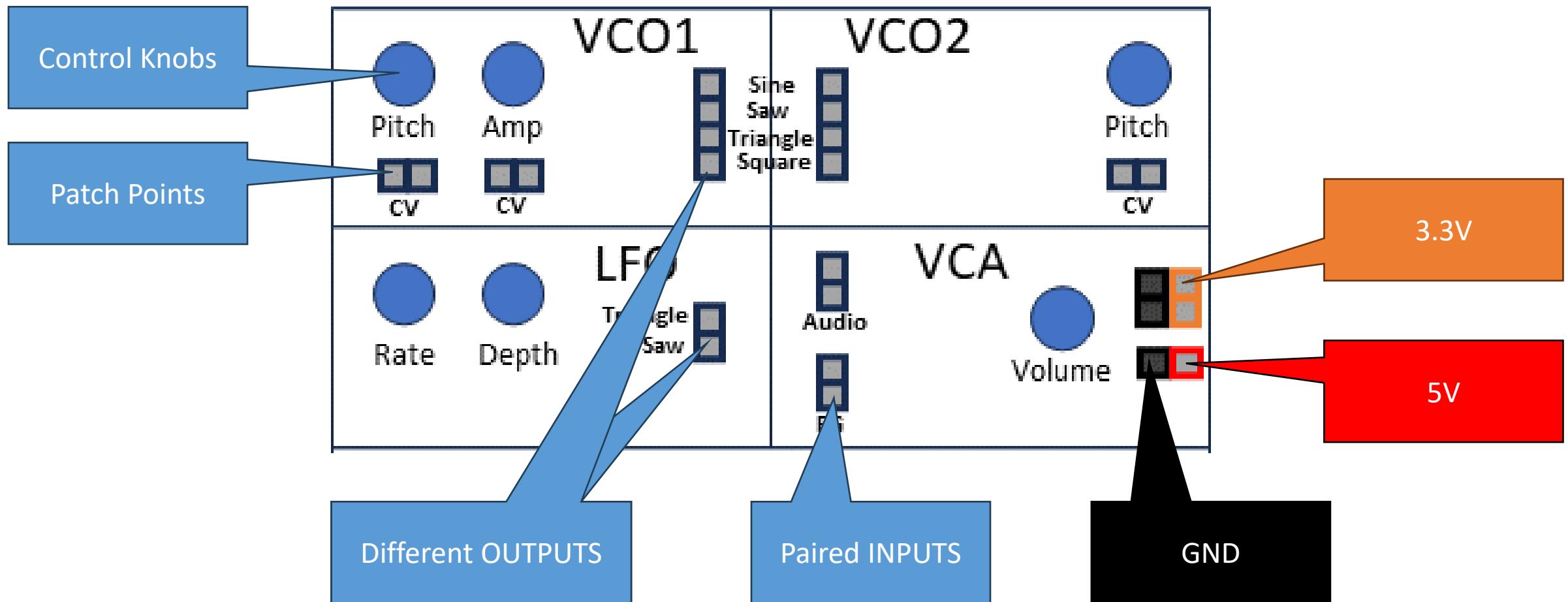
# The Synth Thing



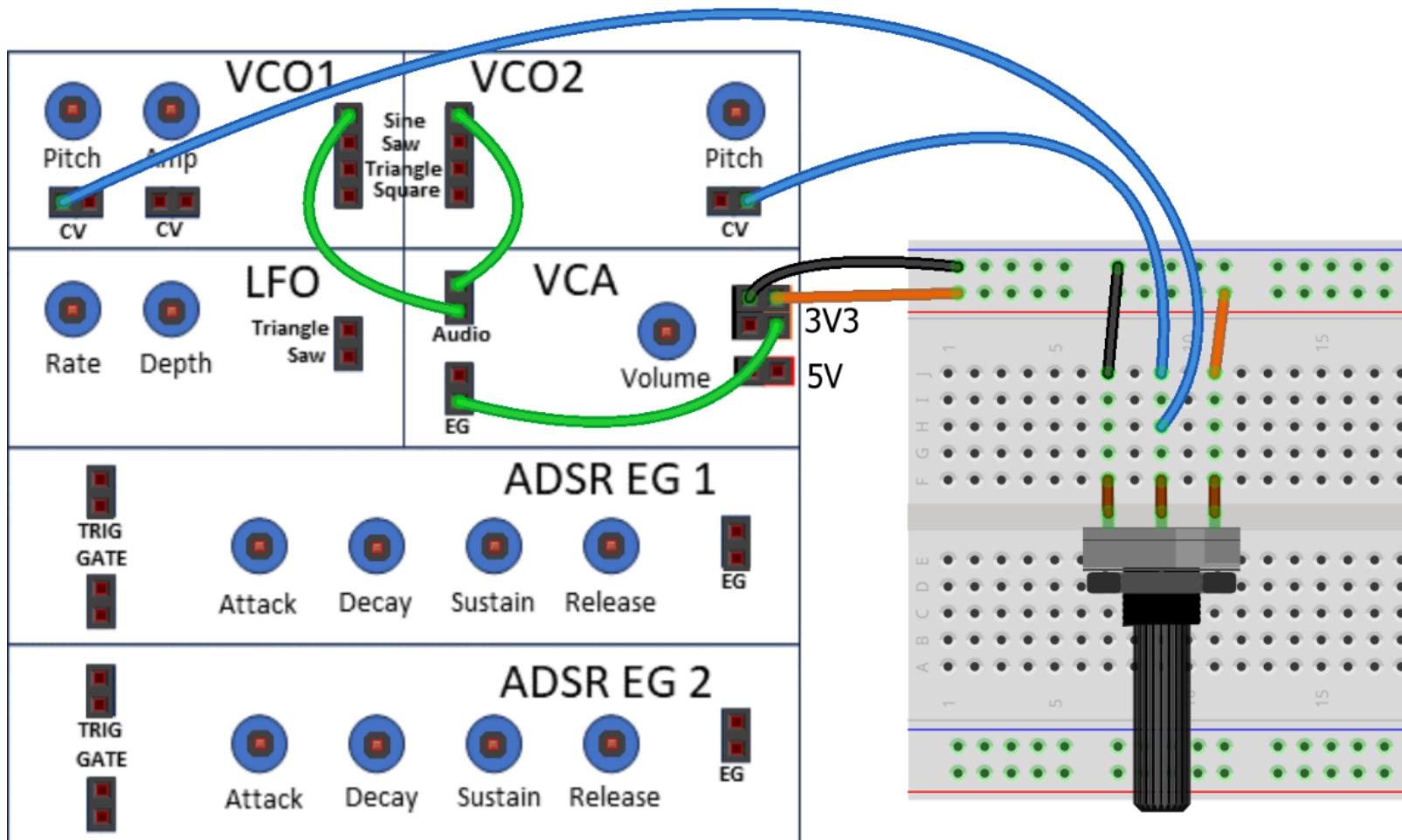
## Modules:

- 2x Voltage Controlled Oscillators.
  - 4x VCO waveforms.
- 1x Low-Frequency Oscillator.
  - 2x LFO waveforms.
- 1x Voltage-Controlled Amplifier.
  - Audio output.
- 2x Envelope Generators.
  - ADSR.
- *Every patch point is a real signal!*

# Patch Points: control, audio, power

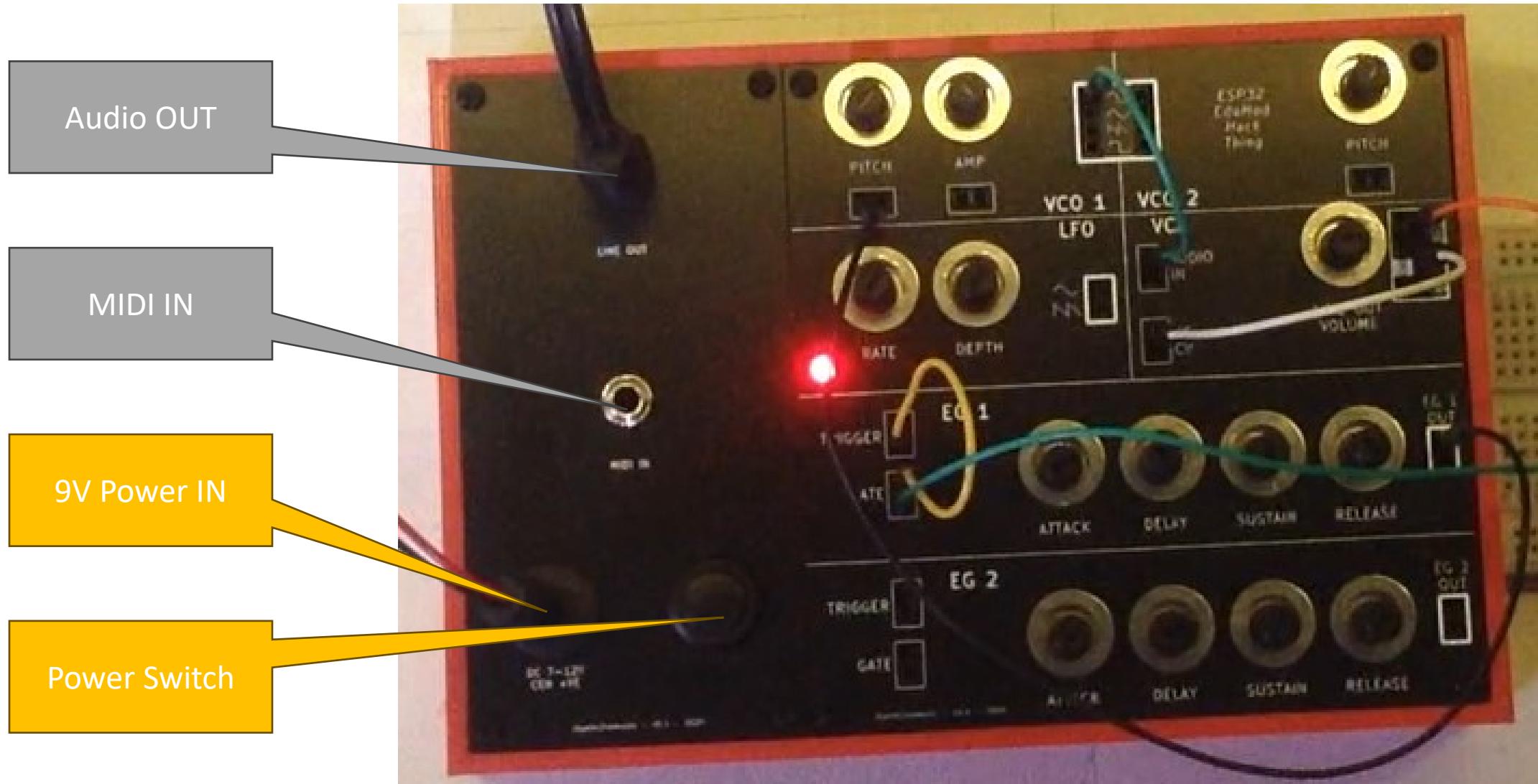


# Patch Diagrams



- Green: Internal Links
- Blue: External Links
- Black: GND
- Orange: 3.3V
- Red: 5V

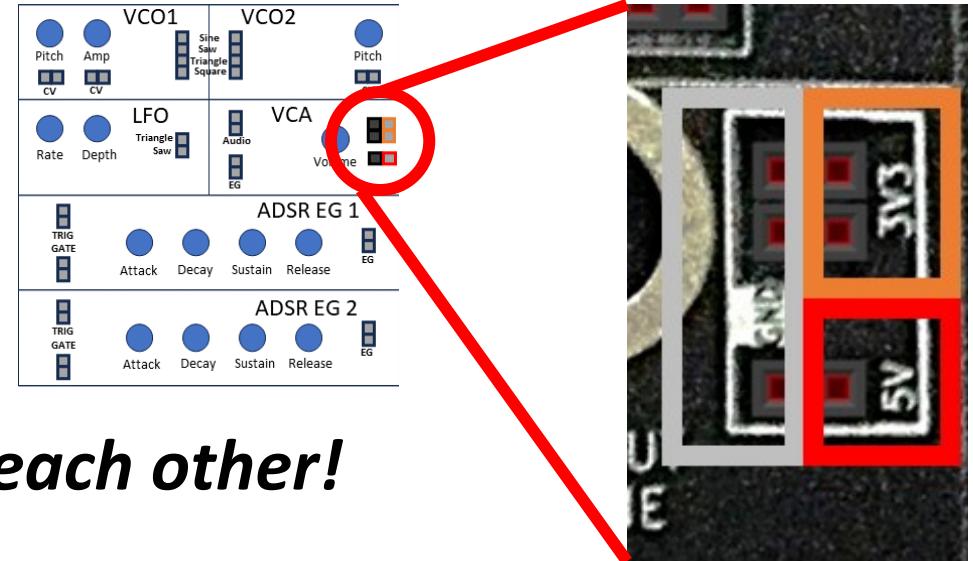
# Extra Connections



# Basic Dos and Don'ts

## *Don'ts:*

- ***DO NOT CONNECT 3V3 or 5V or GND to each other!***



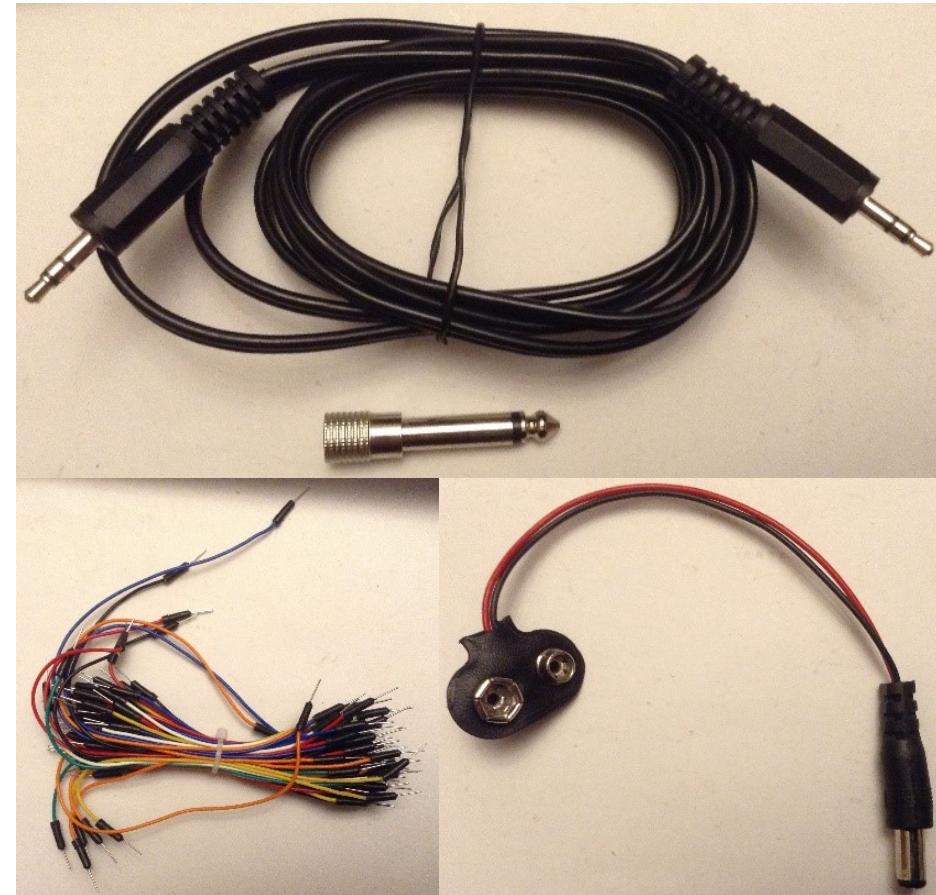
## *Dos:*

- Experiment with the different signals!
- Link to a solderless breadboard to make new circuits.
- Look at signals with an oscilloscope.
- Use MIDI.



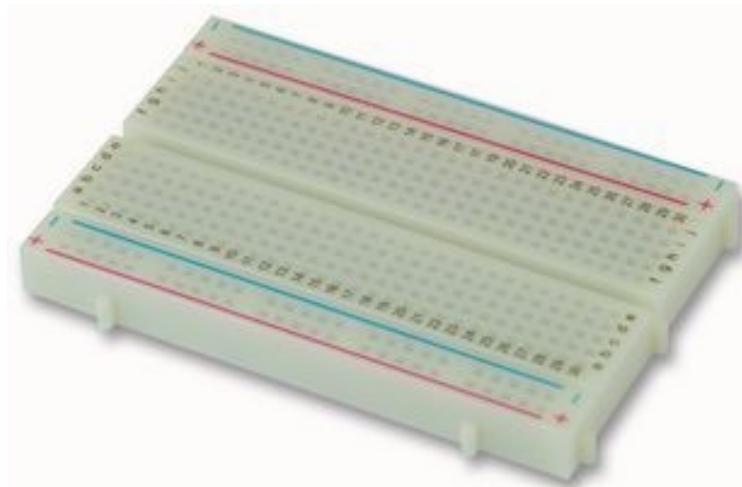
# Ch 2 - Starter Projects

# Getting Started

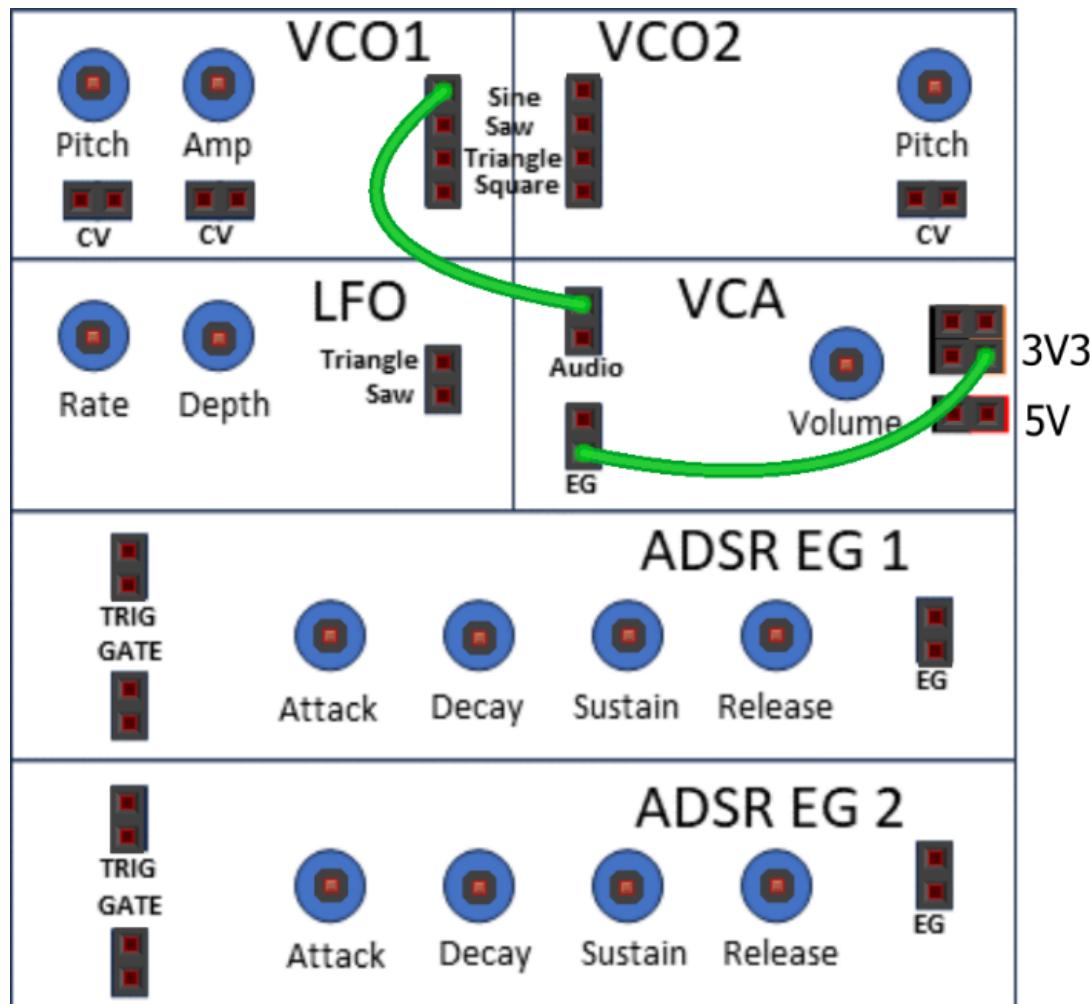


# Other Equipment

- Optional: Oscilloscope
- Solderless breadboard
- Potentiometer (10K to 100K)
- Button
- (Cheap/Old) Amplification

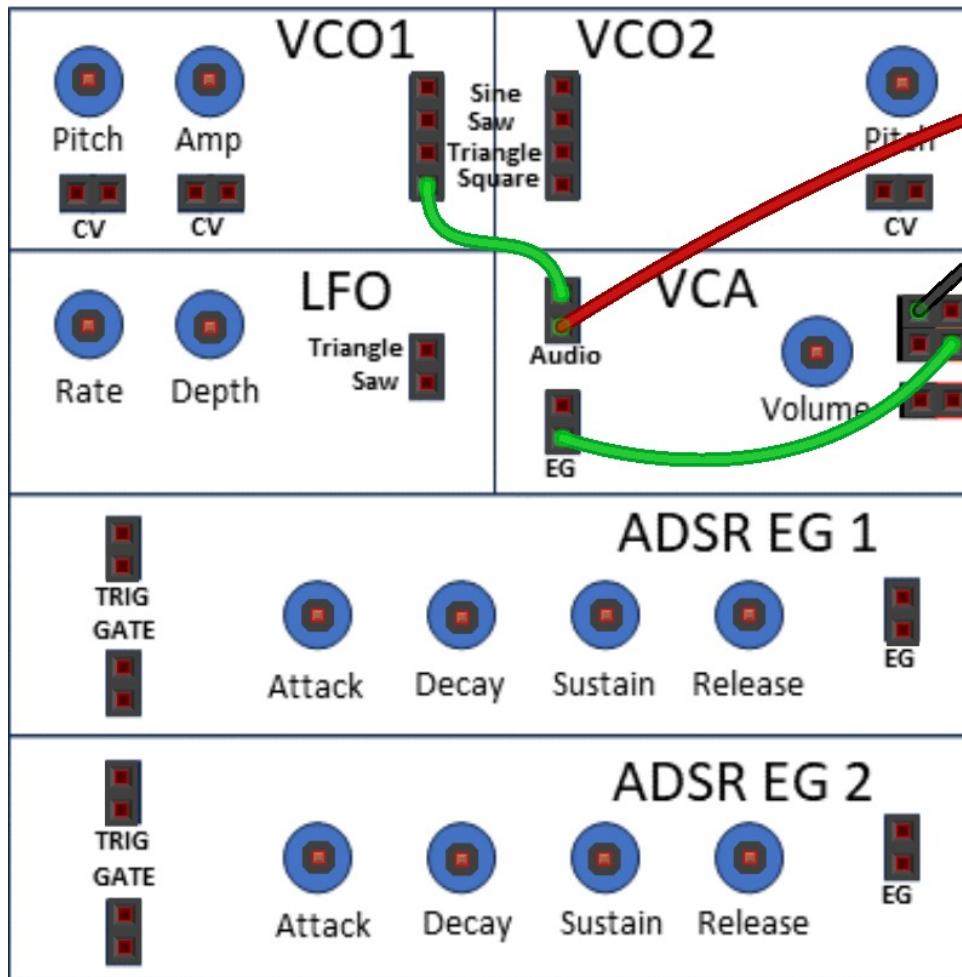


# 1. Basic Oscillator (VCO) Output



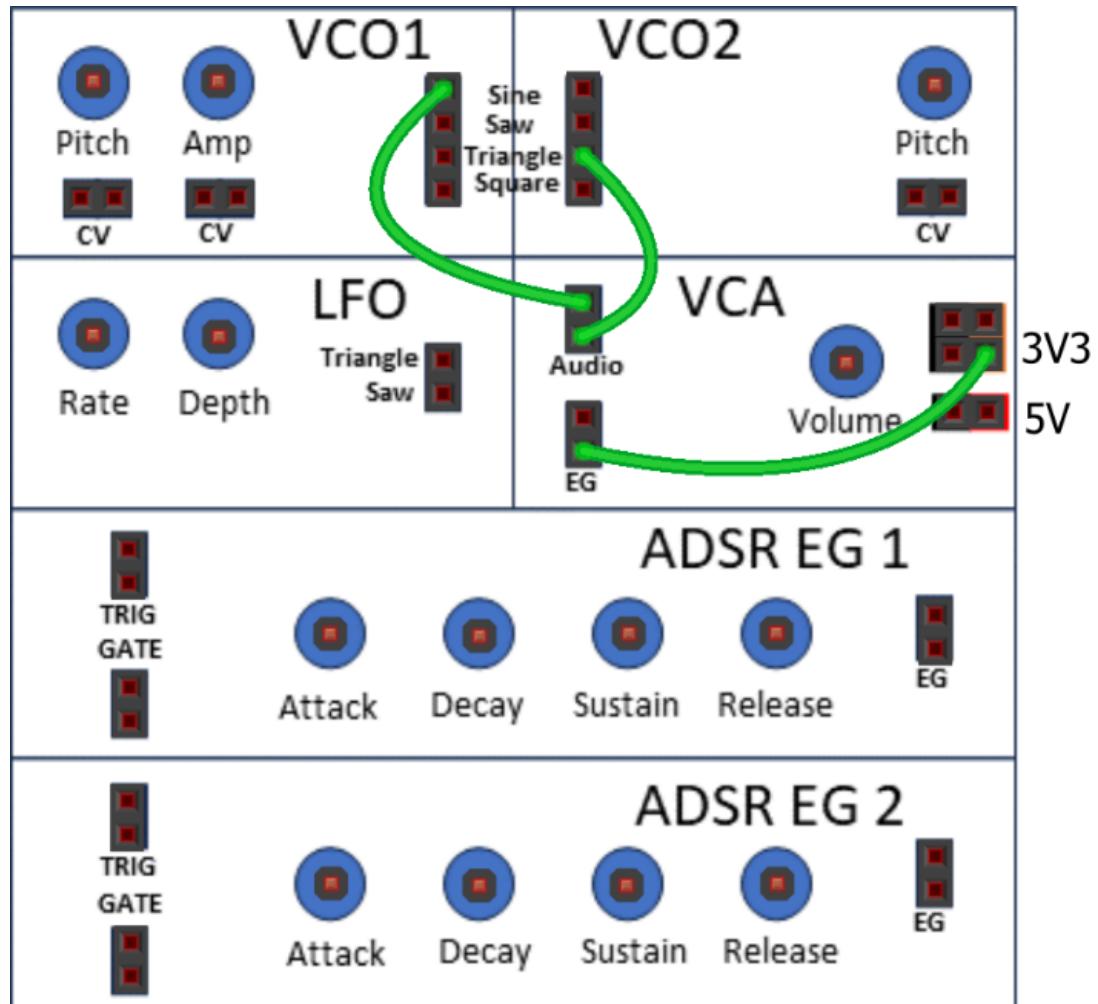
- VCA EG fixed at 3V3.
- Turn up VCA Volume.
- Experiment with:
  - VCO1 Amp.
  - VCO1 Pitch.
- What are the highest and lowest frequencies?

## 2. VCO Waveform on an Oscilloscope



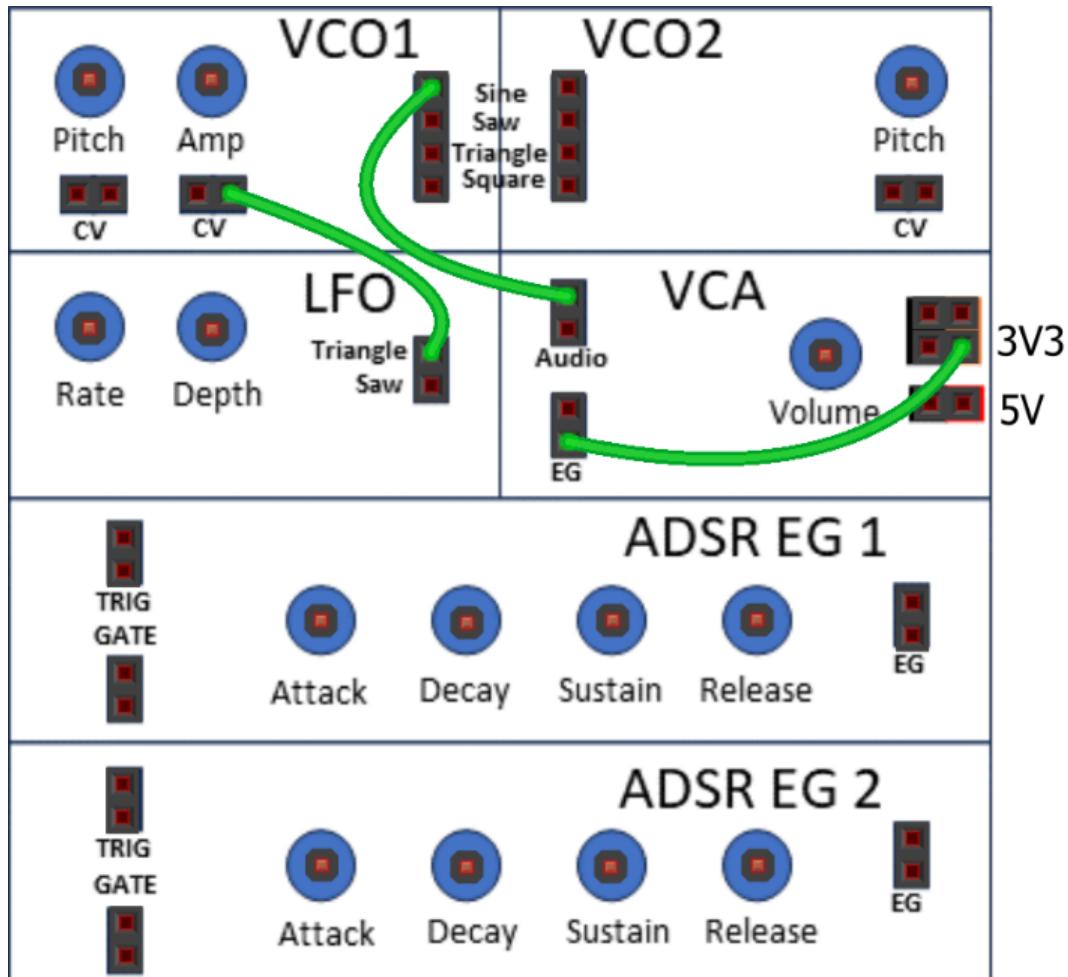
- **Note: Needs a GND connection.**
- Try all four VCO1 waveforms.
- Change the VCO1 Amp and Pitch.
- Measure highest and lowest frequencies.

# Dual Oscillator Output



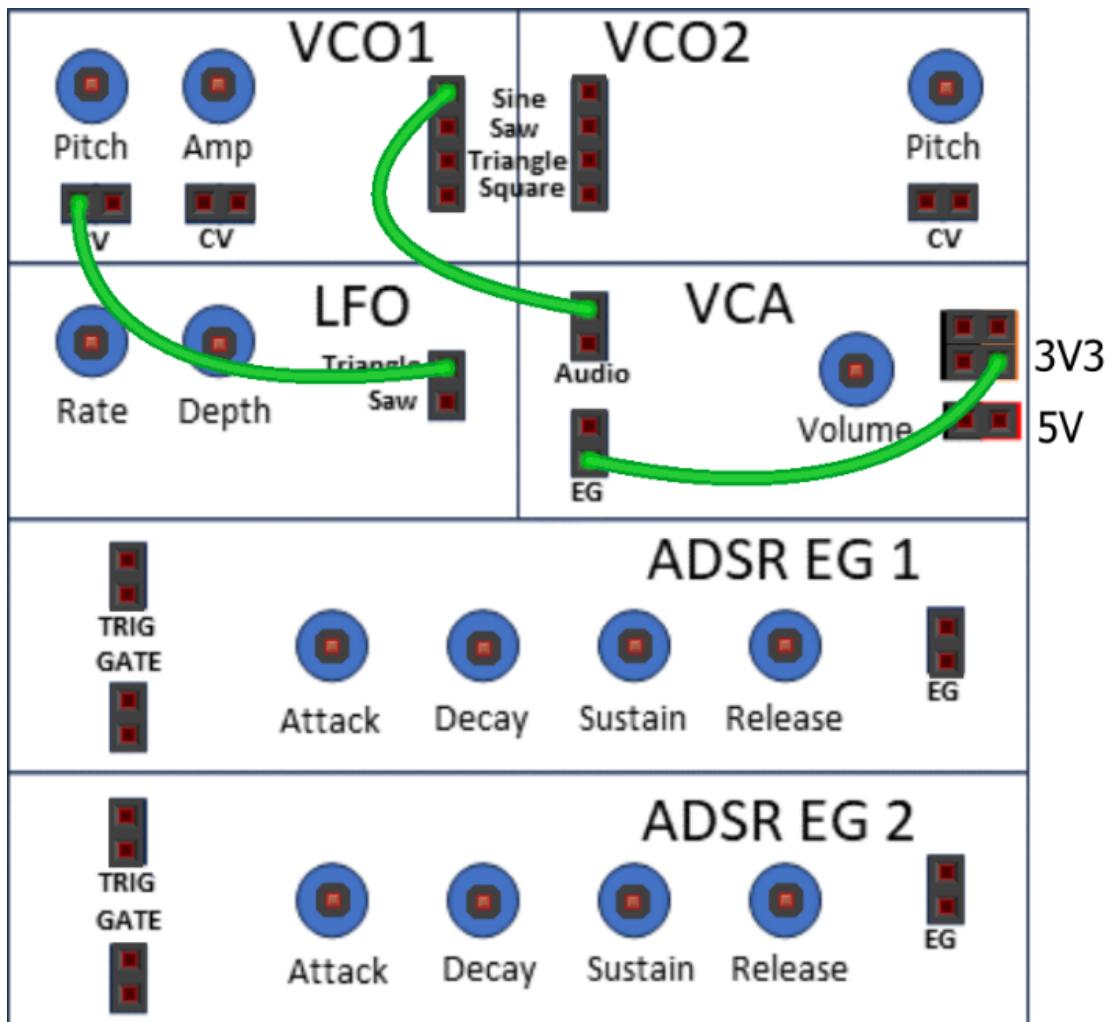
- Change:
  - VCO1 and VCO2 Pitch.
  - VCO1 Amp.
  - VCO1 and VCO2 Waveforms.
- Experiments:
  - Tune to same pitch.
  - Detune one slightly.
  - Tune to 1 octave apart.
  - Tune to 2 octaves.
  - Find other intervals.

# 4. LFO Amplitude Modulation



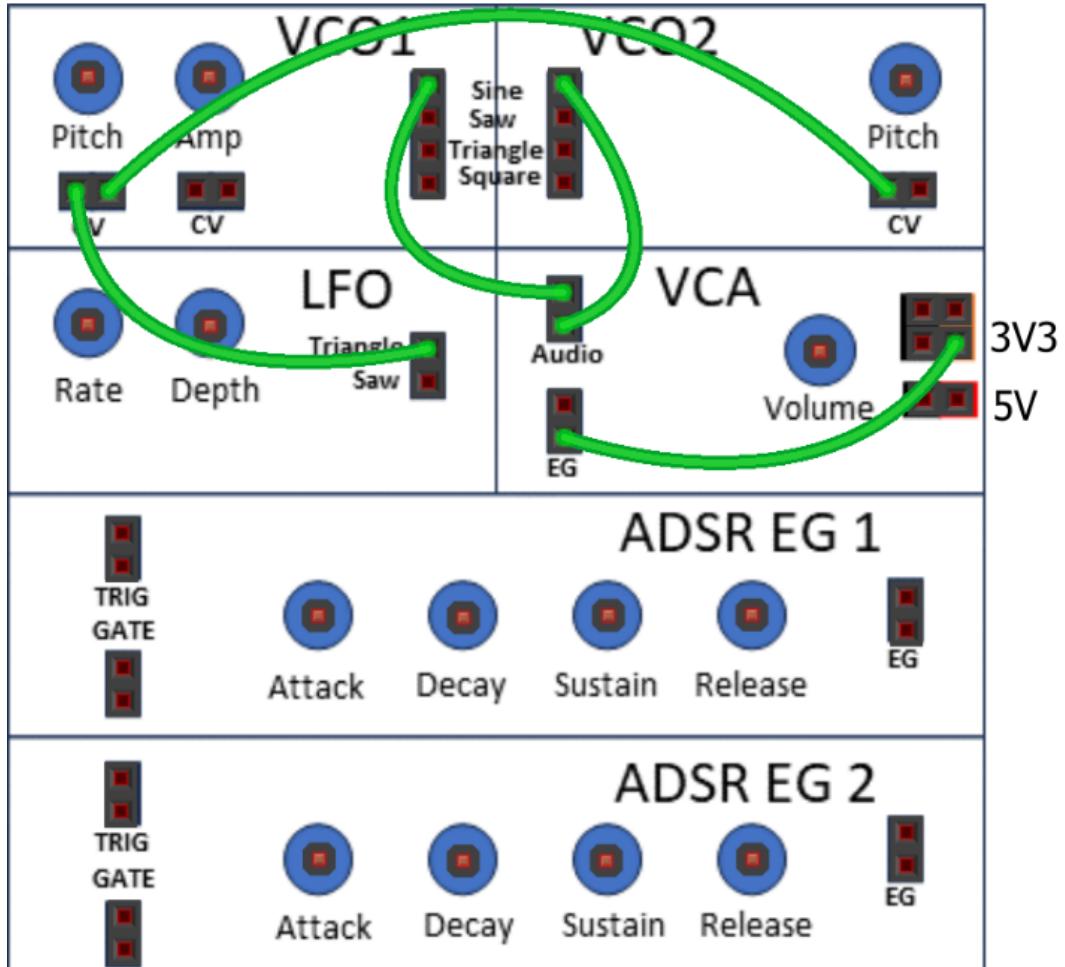
- VCO1 Amp must be turned down.
- Try LFO Rate and Depth.
- Try both LFO waveforms.

# 5. LFO Pitch Modulation



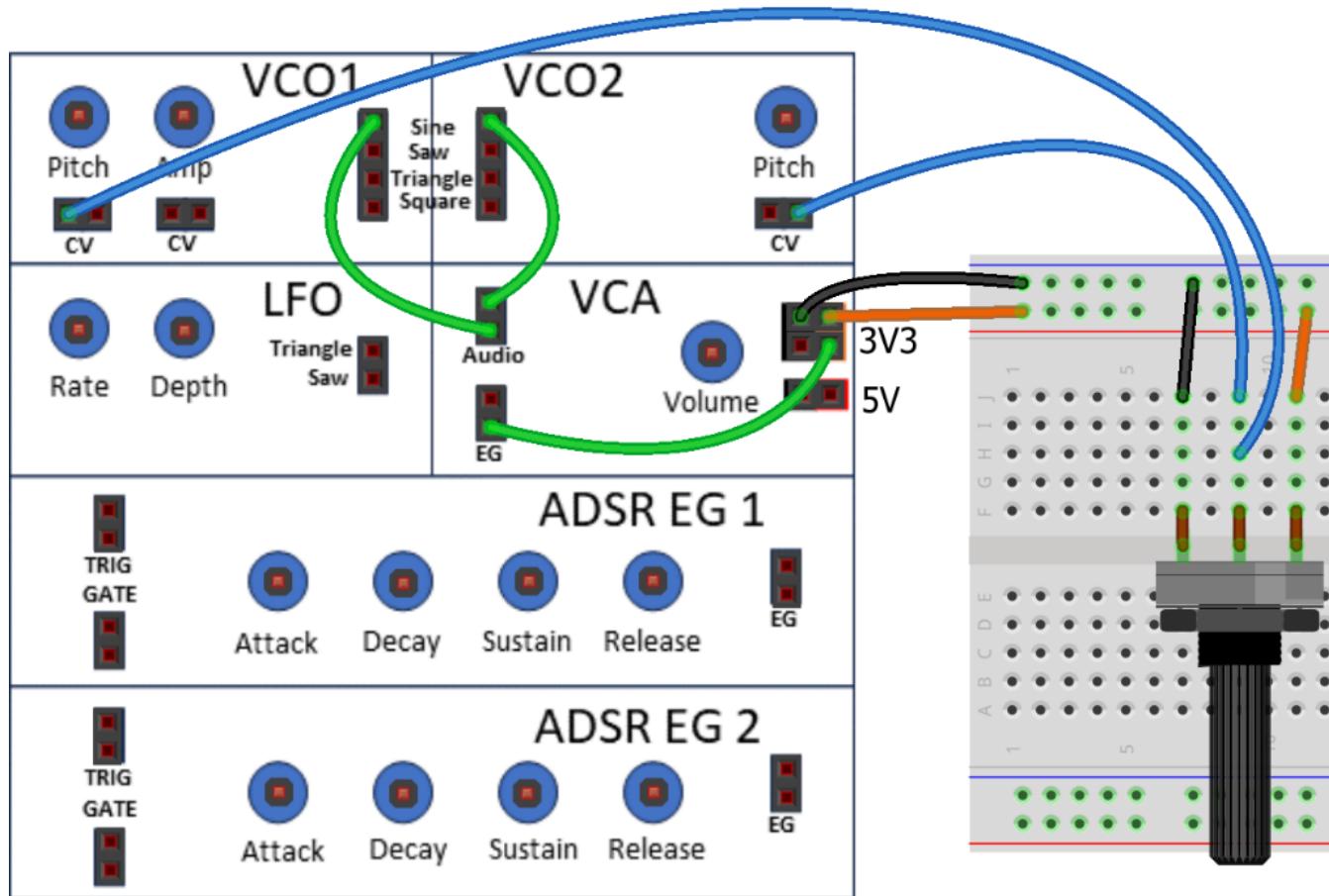
- Turn VCO1 Amp up.
- Try LFO Rate and Depth.
- Try both LFO waveforms.
- Combine Pitch and Amp modulation using both LFO waveforms at the same time.

## 6. Dual VCO+LFO Pitch Modulation



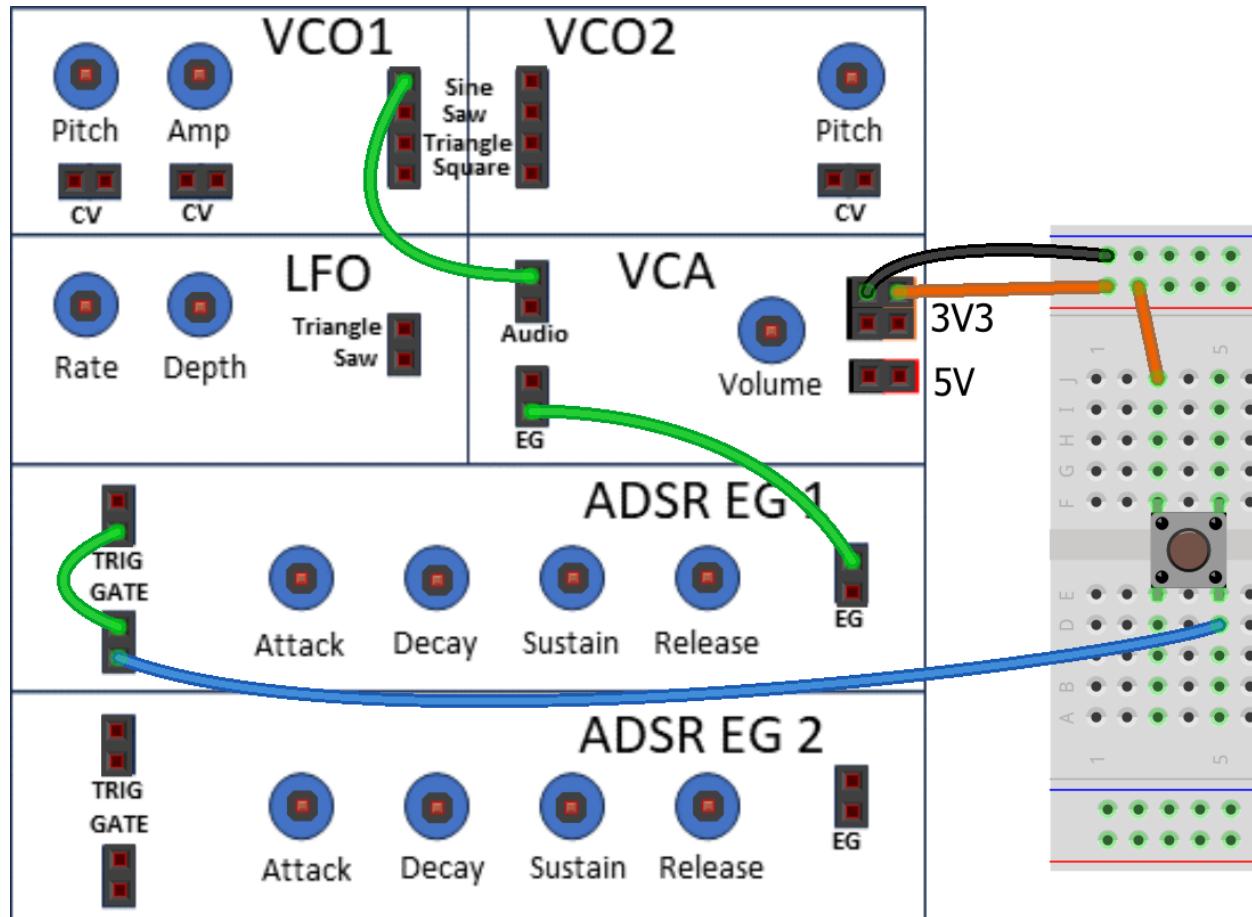
- Links VCO1 and VCO2 CVs.
- Turn LFO off and tune VCOs to 1 octave.
- Try LFO Rate and Depth.
- Try LFO waveforms.
- Connect one LFO waveform to VCO1 and one to VCO2.

# 7. External Dual VCO Pitch Control



- 3V3 and GND to breadboard.
- Potentiometer to VCO1 and VCO2 CVs.
- Detune one VCO.
- Try:
  - Tune to one octave or different intervals.
  - Different waveforms.
  - Add LFO to amplitude modulate VCO1.

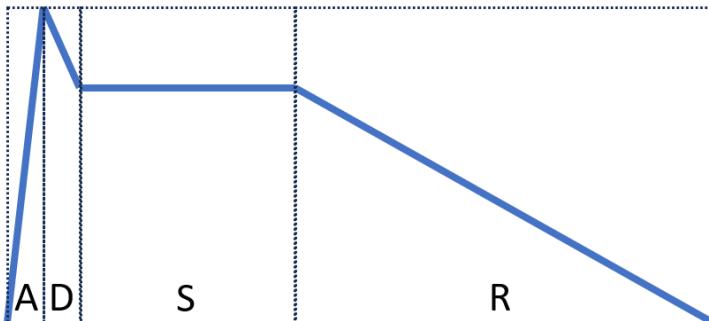
# 8. ADSR Envelope Generator



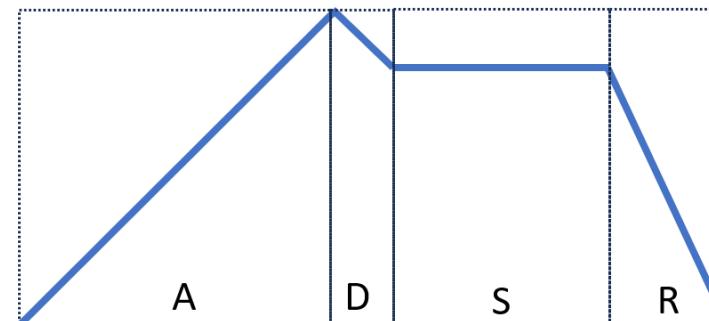
- 3V3 and GND to breadboard.
- ADSR EG1 EG to VCA.
- EG1 TRIG and GATE linked.
- Start with:
  - A: almost full anti-clockwise.
  - D: almost full anti-clockwise.
  - S: fully clockwise.
  - R: in the middle.
- Try different A, D, S, R settings.

# 9. ADSR Envelope Generator – Part 2

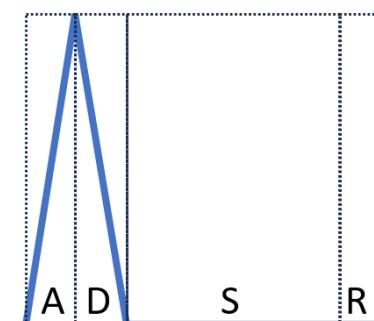
- Attempt to create the following envelopes:



Short attack.  
Short decay.  
High sustain.  
Long release.

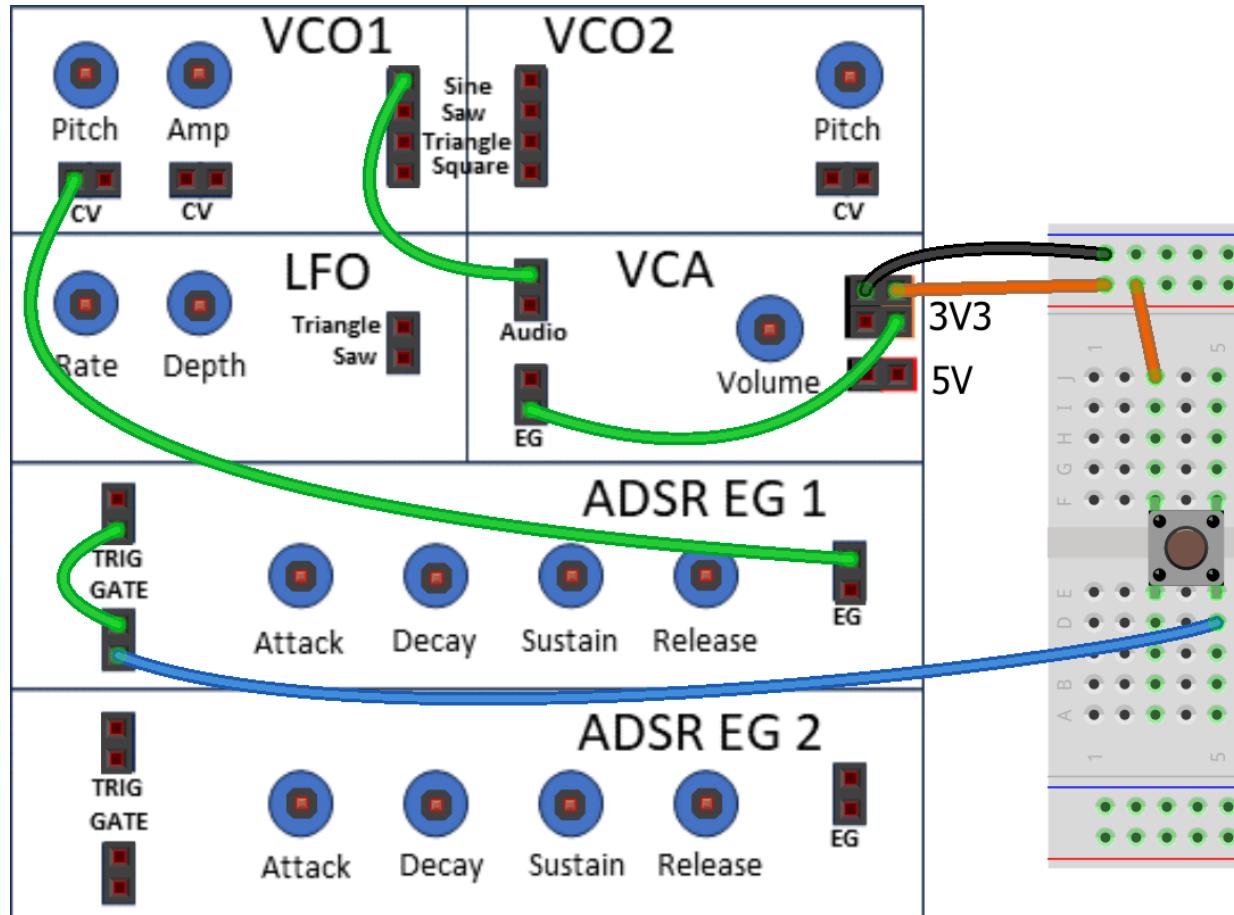


Long attack.  
Short Decay.  
High sustain.  
Short release.



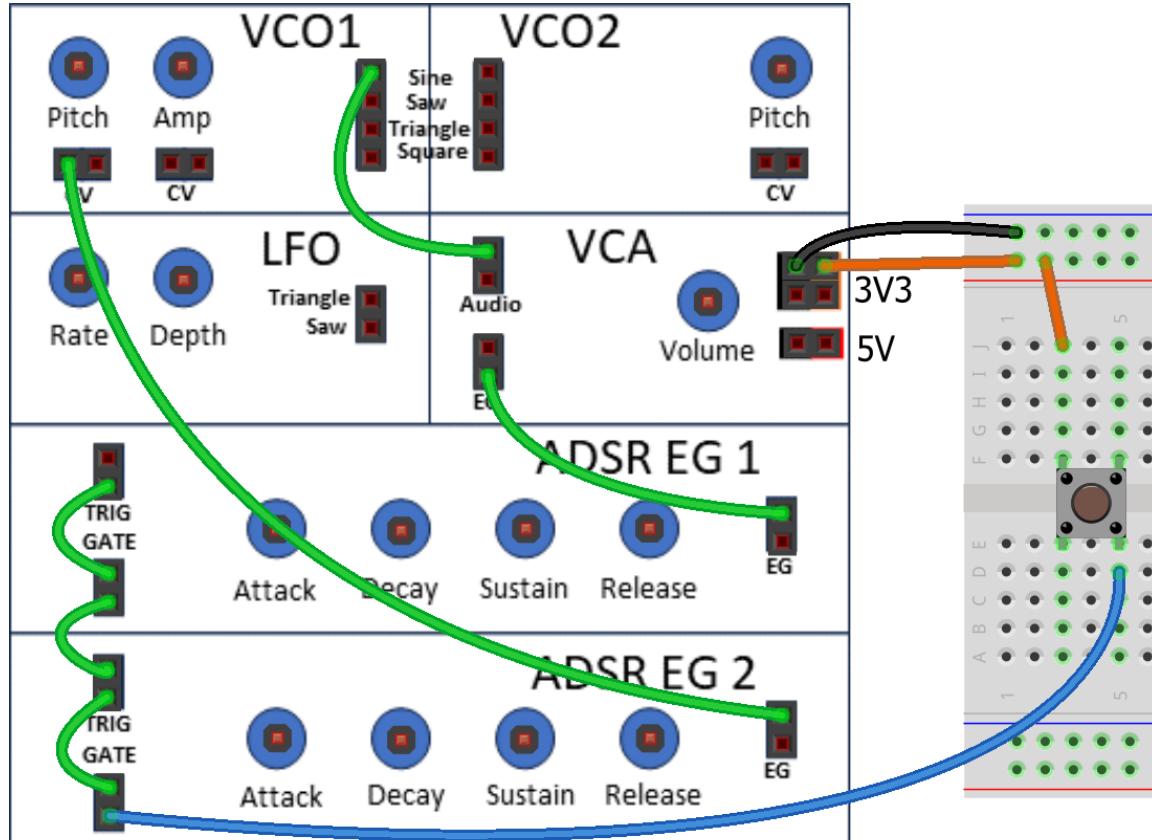
Short attack.  
Short decay.  
No sustain.  
No release.

# 10. ADSR Envelope Generator for Pitch



- VCA EG to 3V3 again.
- EG1 to VCO1 Pitch.
- Try different A, D, R timings.
- Try different S level.

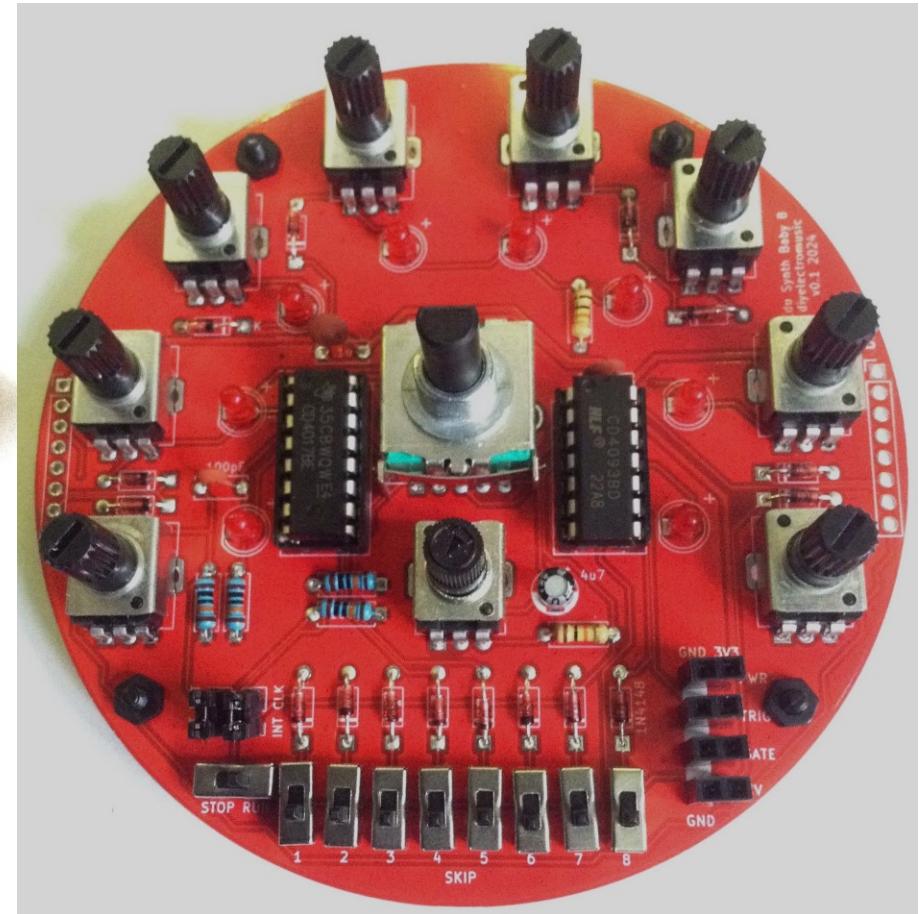
# 11. ADSR Envelope Generator for Amplitude and Pitch



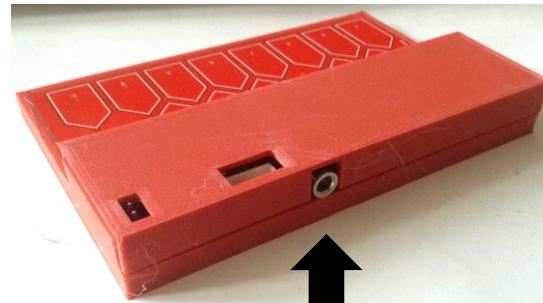
- EG1 back to controlling VCA.
- EG2 now controlling VCO Pitch.
- Try different A, D, S, R settings for both amplitude and pitch.

# Ch 3 - Add-on Projects

# Keyboard and Sequencer

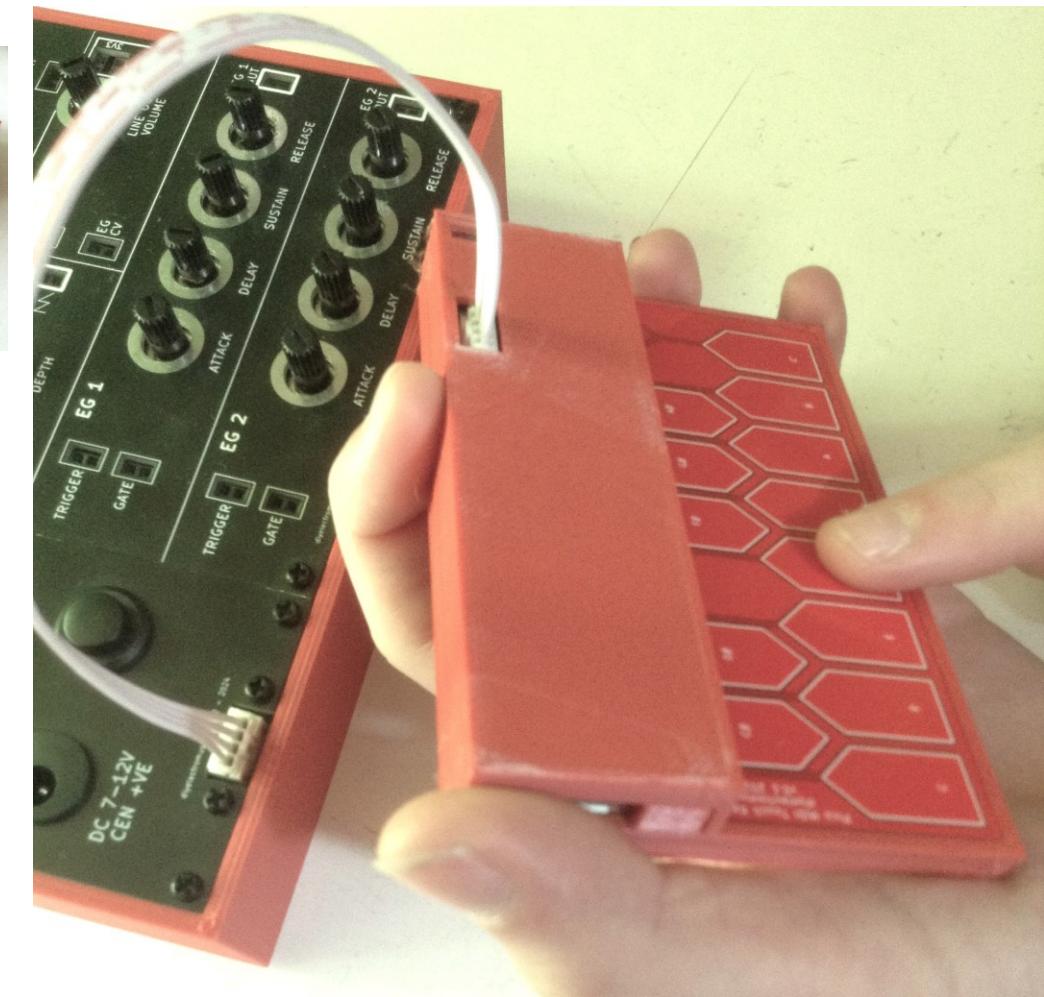


# Adding a Touch Keyboard

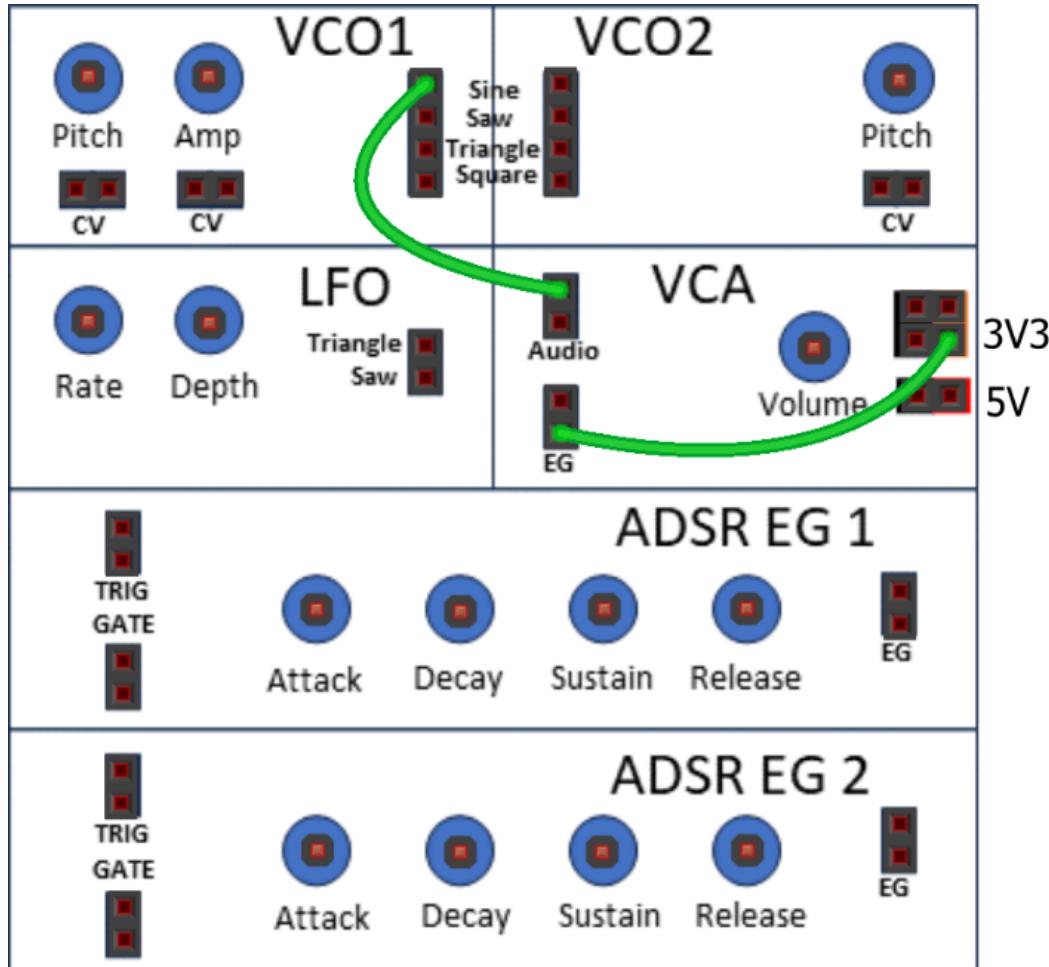


GND Point.

Touch when in use  
for better accuracy  
and reliability...

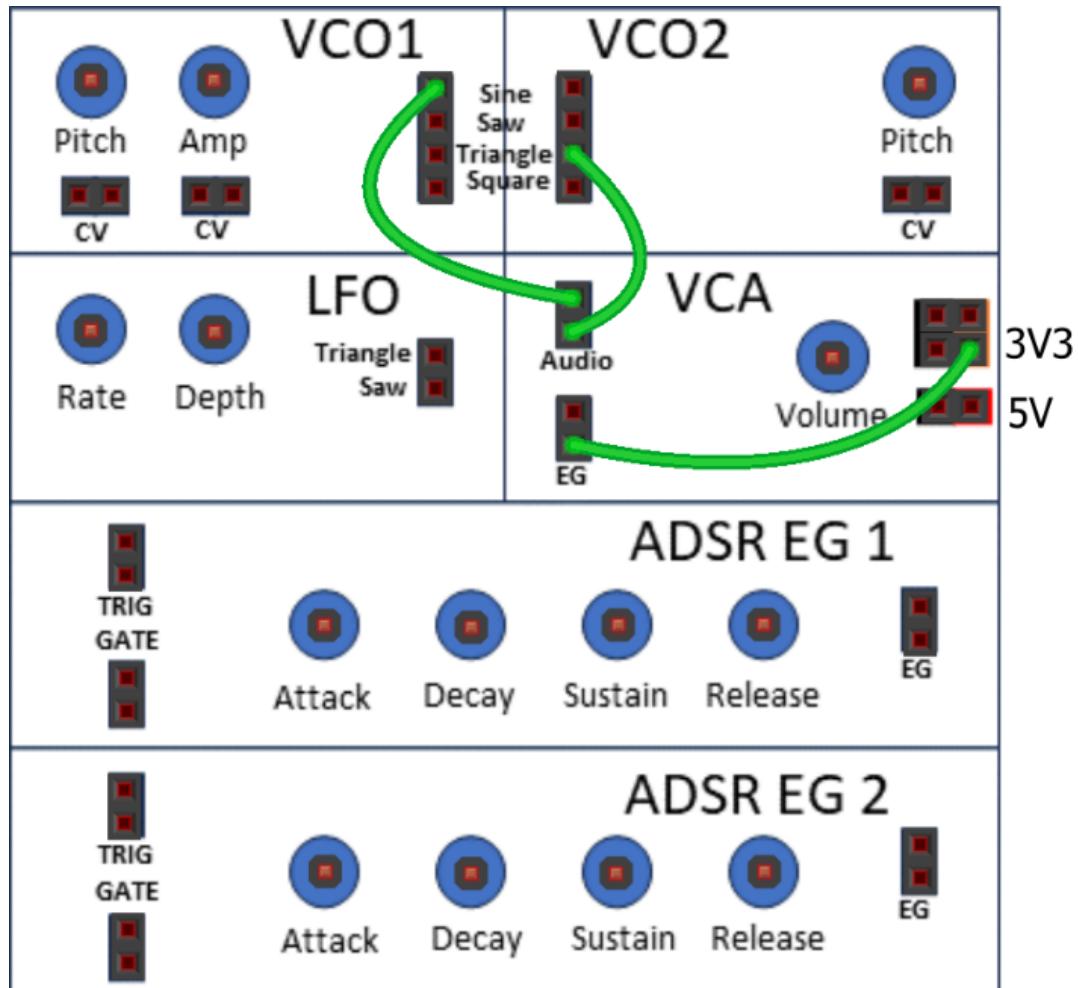


# 1. Basic Oscillator (VCO) Circuit



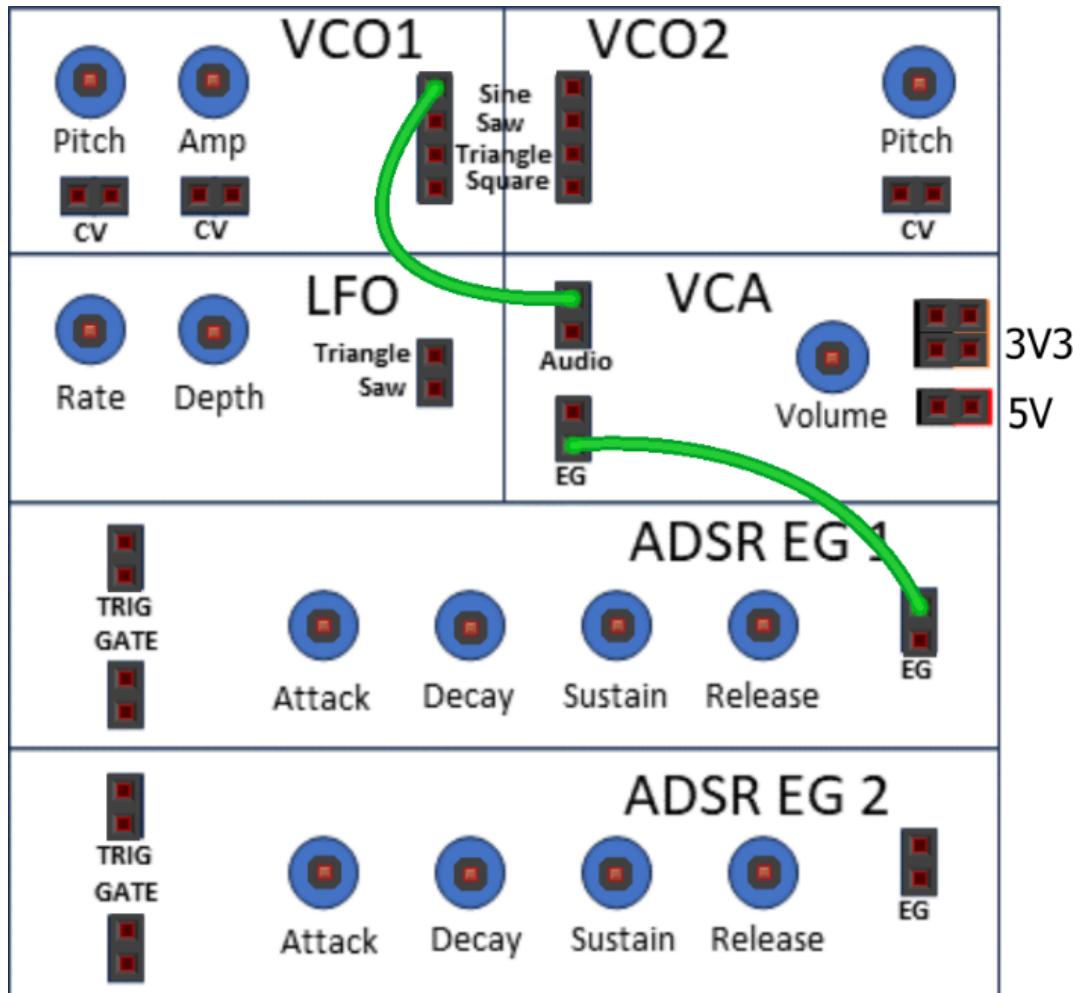
- VCA EG Fixed at 3V3.
- Turn up VCA Volume.
- Turn down VCO1 Pitch.
- Play some notes.
- Experiment with:
  - VCO1 Amp.
  - VCO1 Pitch.

## 2. Dual Oscillator Circuit



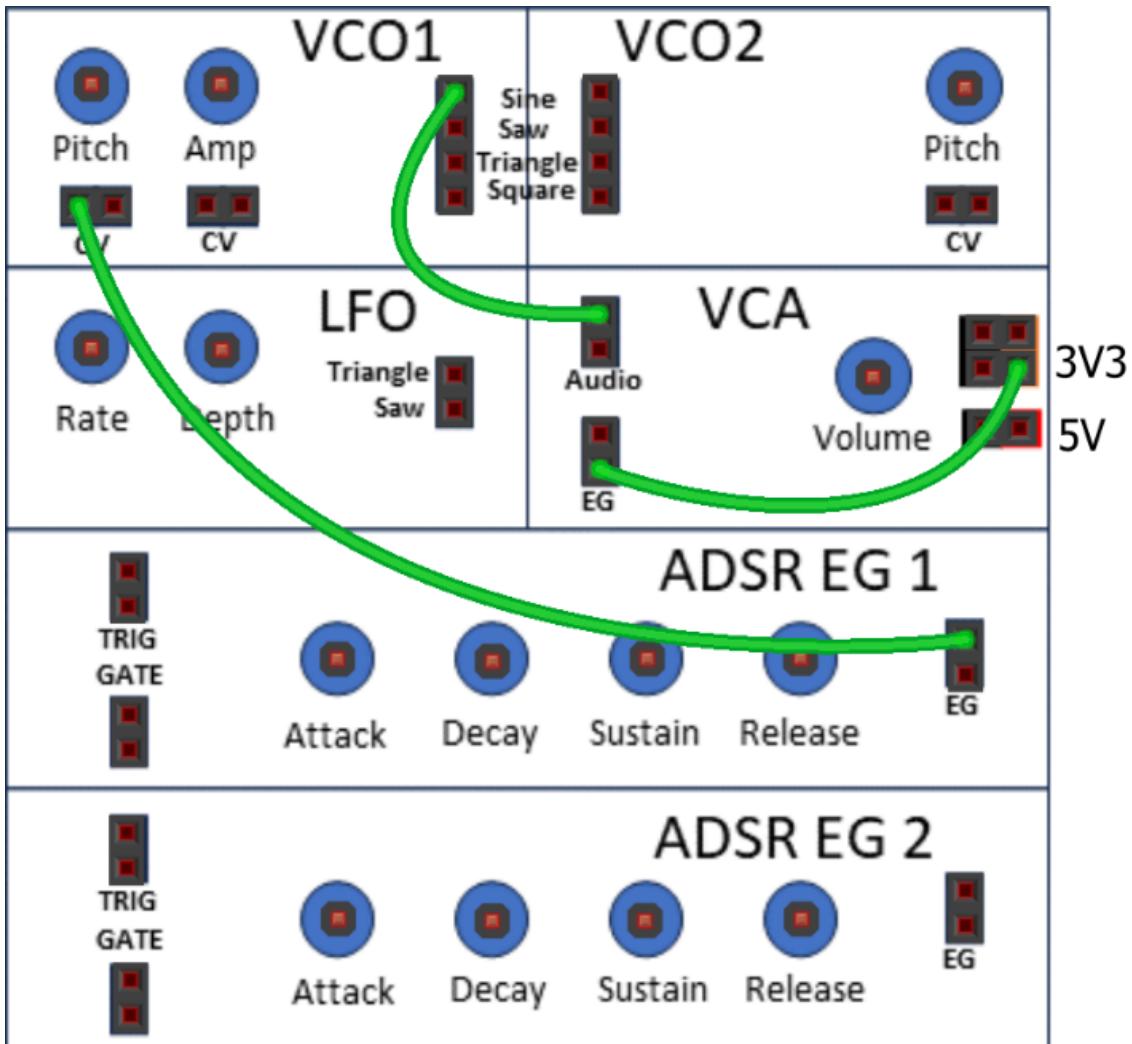
- Turn down VCO1 and VCO2 Pitch.
- Turn up VCO1 Amp and VCA Volume.
- Play some notes.
- Experiment with:
  - Changing VCO2 Pitch to detune.
  - Different Waveforms.
  - Changing VCO1 and VCO2 Pitch.

### 3. ADSR Envelope Generator



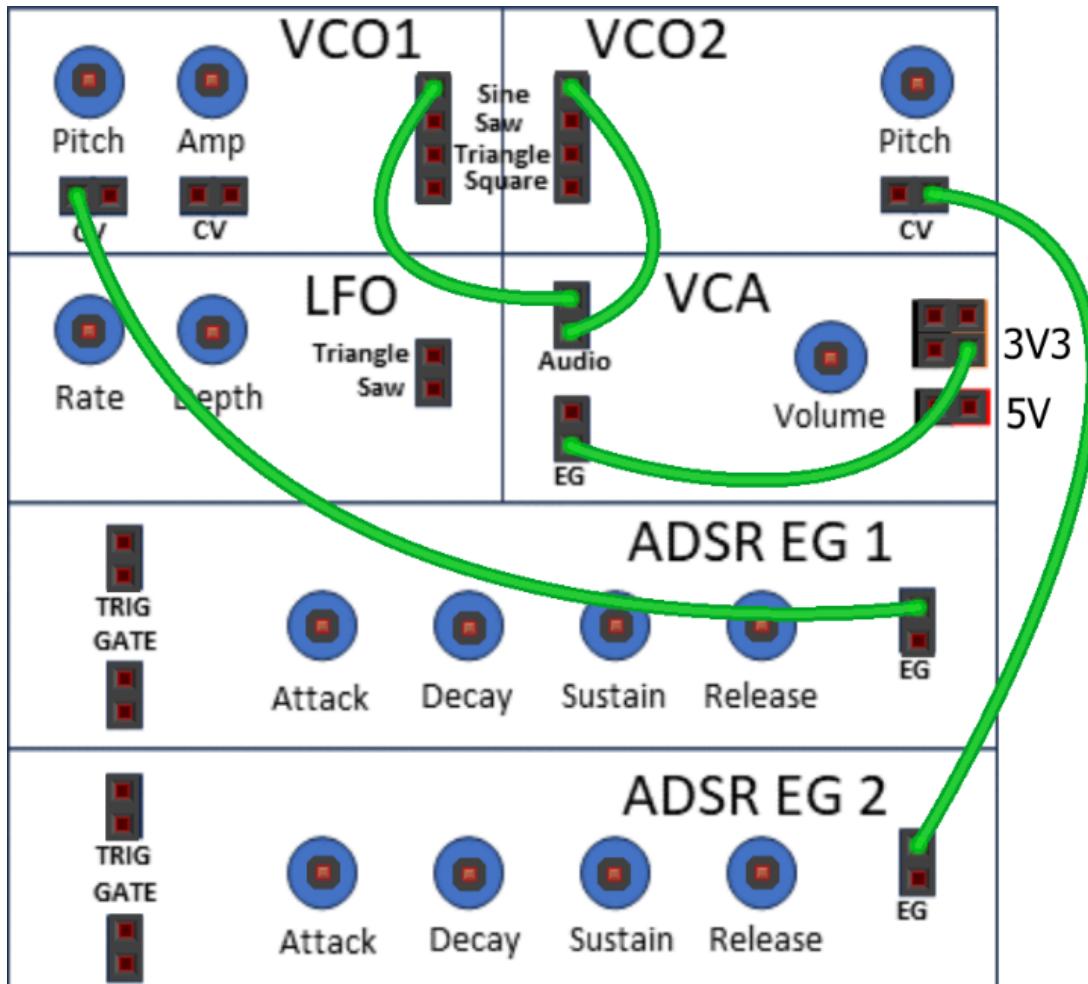
- VCA is now connected to EG1.
- Start with:
  - VCO1 Pitch right down.
  - VCO1 Amp and VCA Volume right up.
  - A: almost full anti-clockwise.
  - D: almost full anti-clockwise.
  - S: fully clockwise.
  - R: in the middle.
- Play some notes.
- Experiment with different ADSR settings.

## 4. ADSR Generator for Pitch



- VCA is back to constant 3V3 CV.
- Start with:
  - VCO1 Pitch turned right down.
  - Fairly low Sustain.
  - VCO1 Amp and VCA Volume turned up.
- Play some notes.
- Experiment with:
  - Different ADSR settings.
  - VCO1 Pitch control.

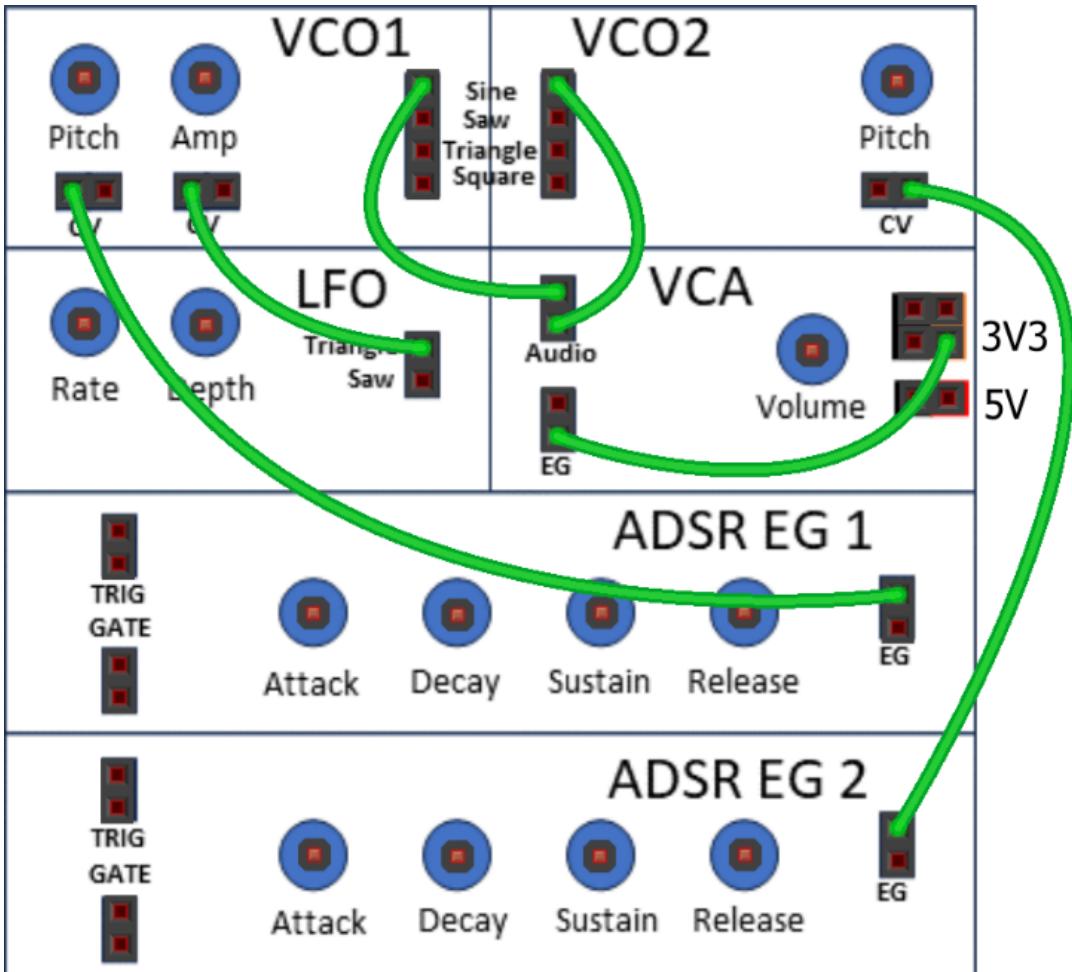
# 5. ADSR Envelope Generator – Dual Pitch



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- Start with:
  - Both Pitch controls turned right down.
  - Low Sustain (S) level on each EG.
- Play some notes.
- Experiment with:
  - Both sets of ADSR Settings.
  - Detuning VCO2.
  - Setting VCOs an octave apart.
  - Different waveforms.

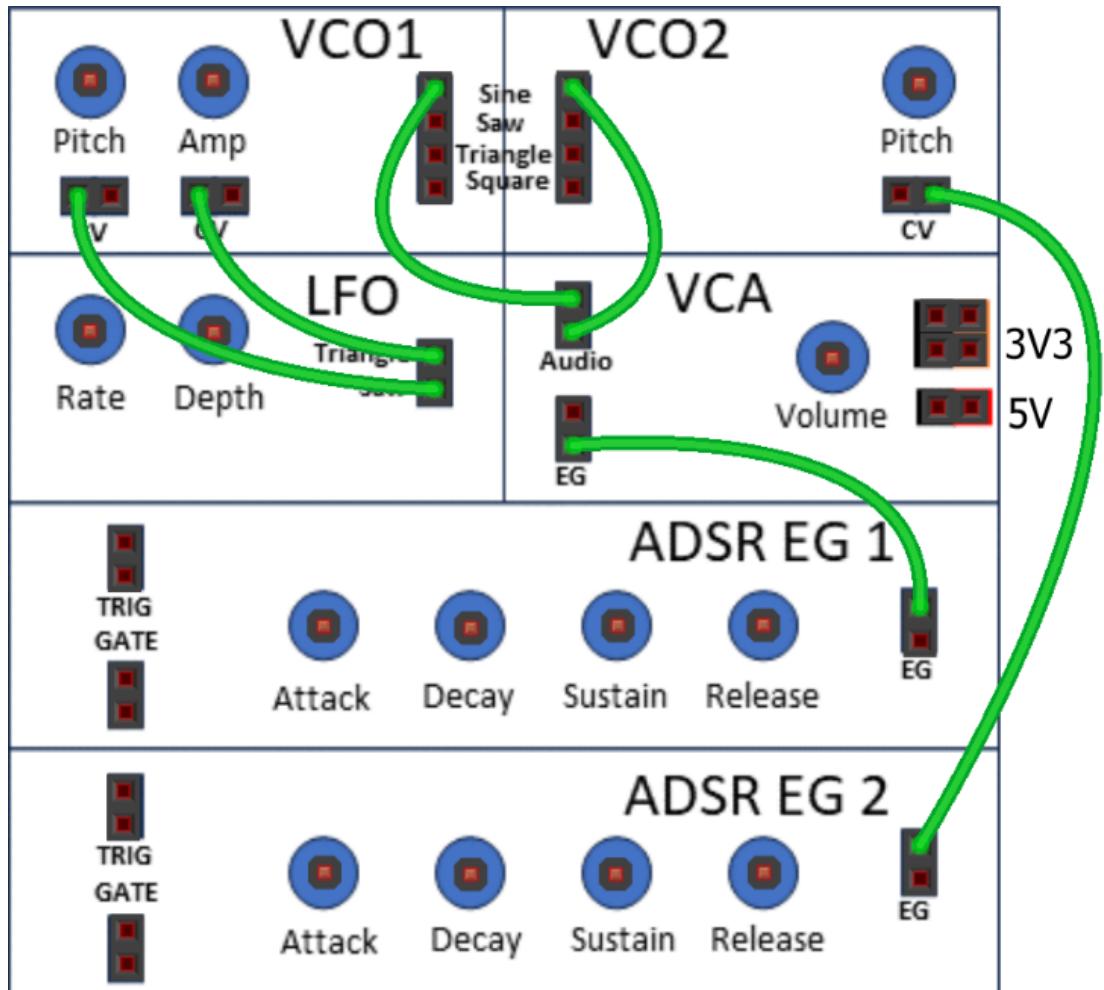
# 6. Include the LFO



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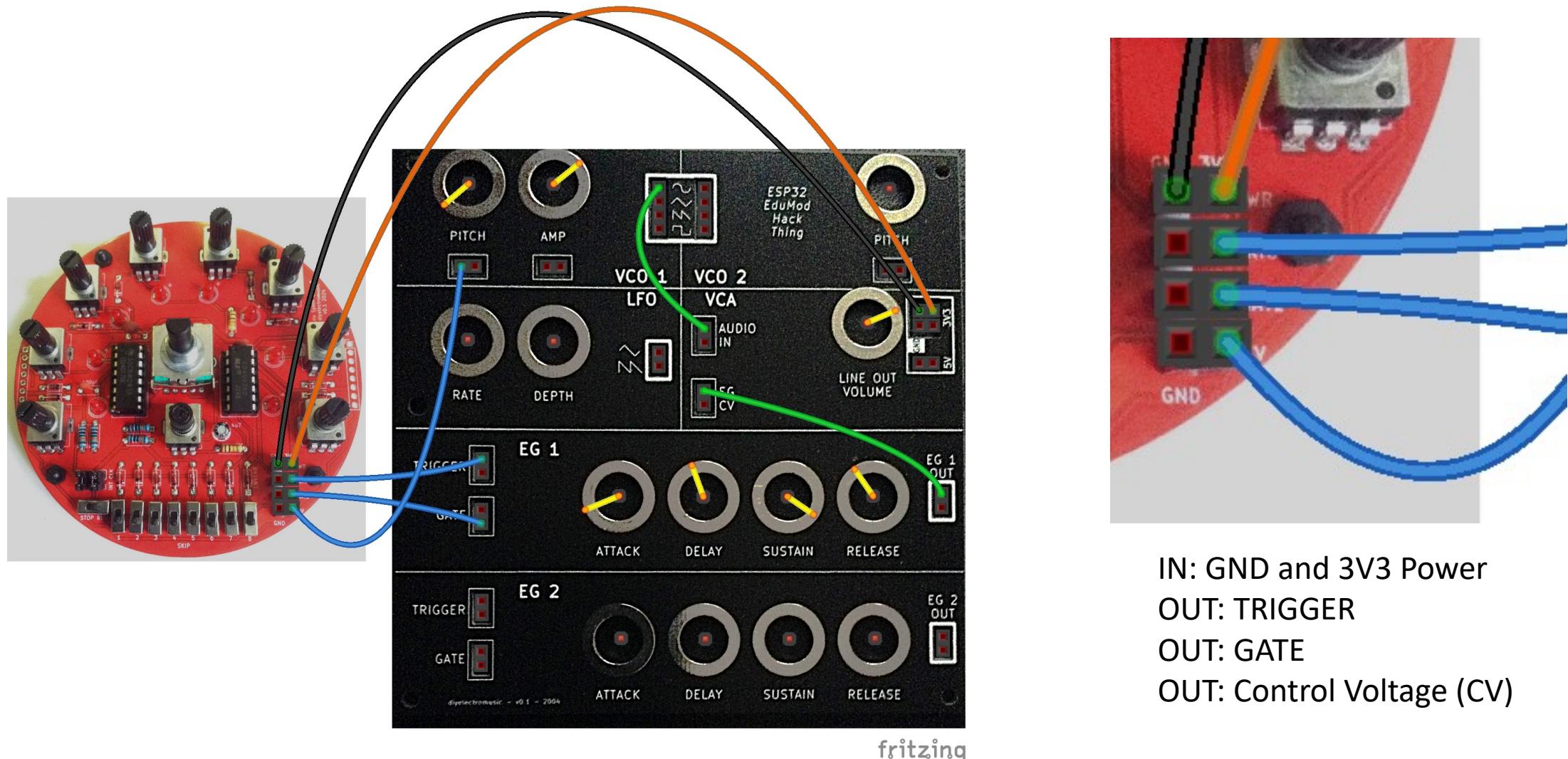
- Start with:
  - Both VCO Pitch turned down.
  - VCO1 Amp turned down.
  - VCA Volume turned up.
  - Sustain (S) pretty low or even disconnect EGs to start with.
- Experiment with:
  - LFO Rate and Depth.
  - LFO Waveforms.
  - ADSR for both EGs.
  - VCO Pitch controls.
  - VCO Waveforms.

# 7. Final Keyboard Patch

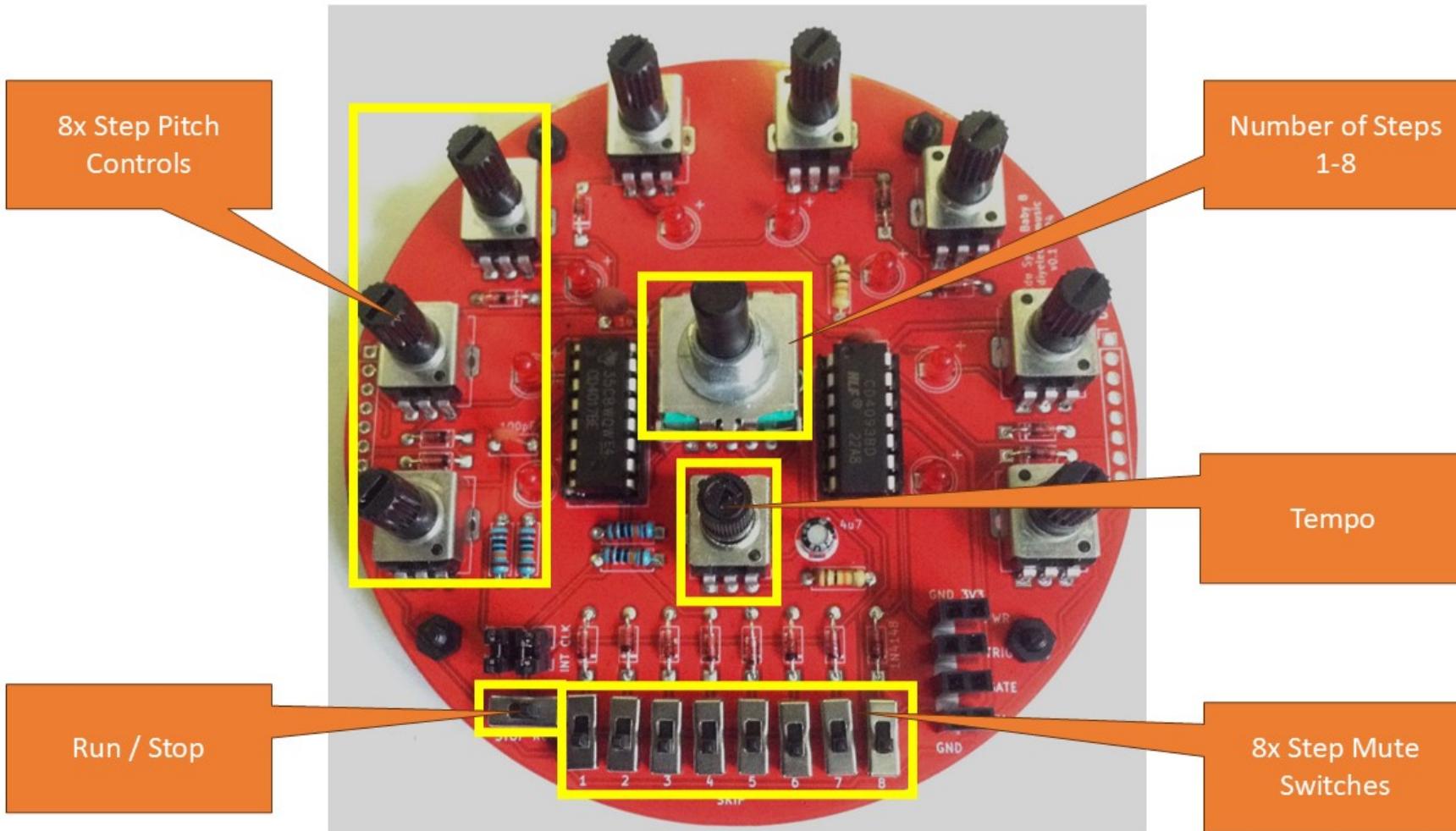


- Complete keyboard patch:
  - EG1 controls VCA.
  - LFO controls both Pitch and Amp for VCO1.
  - EG2 controls VCO2.
- Experiment with:
  - Rate and Depth of LFO.
  - Different links between LFO and VCO1.
  - VCO waveforms.
  - EG1 ADSR.
  - EG2 ADSR.

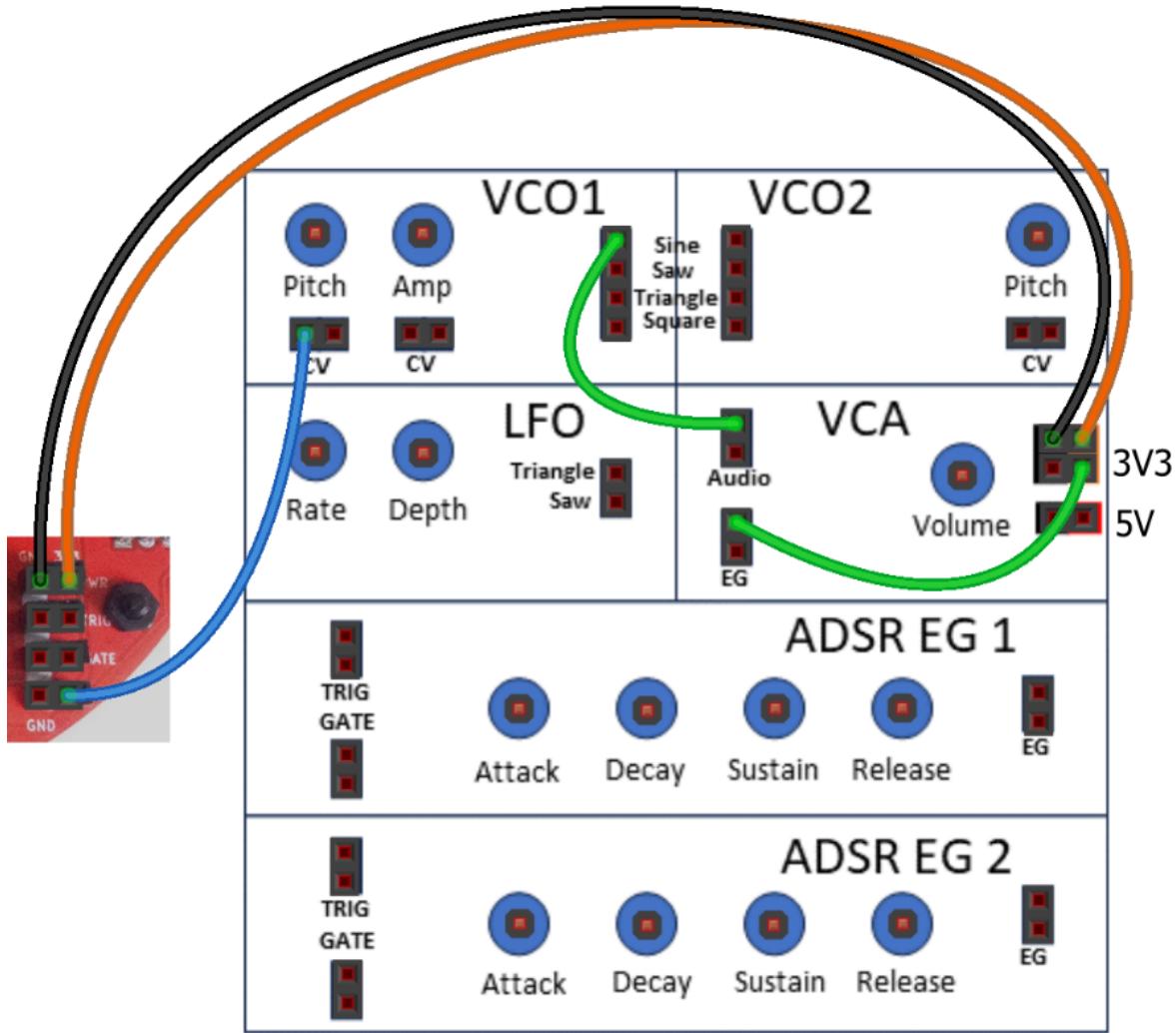
# Adding a Baby-8 Sequencer



# Basic Controls

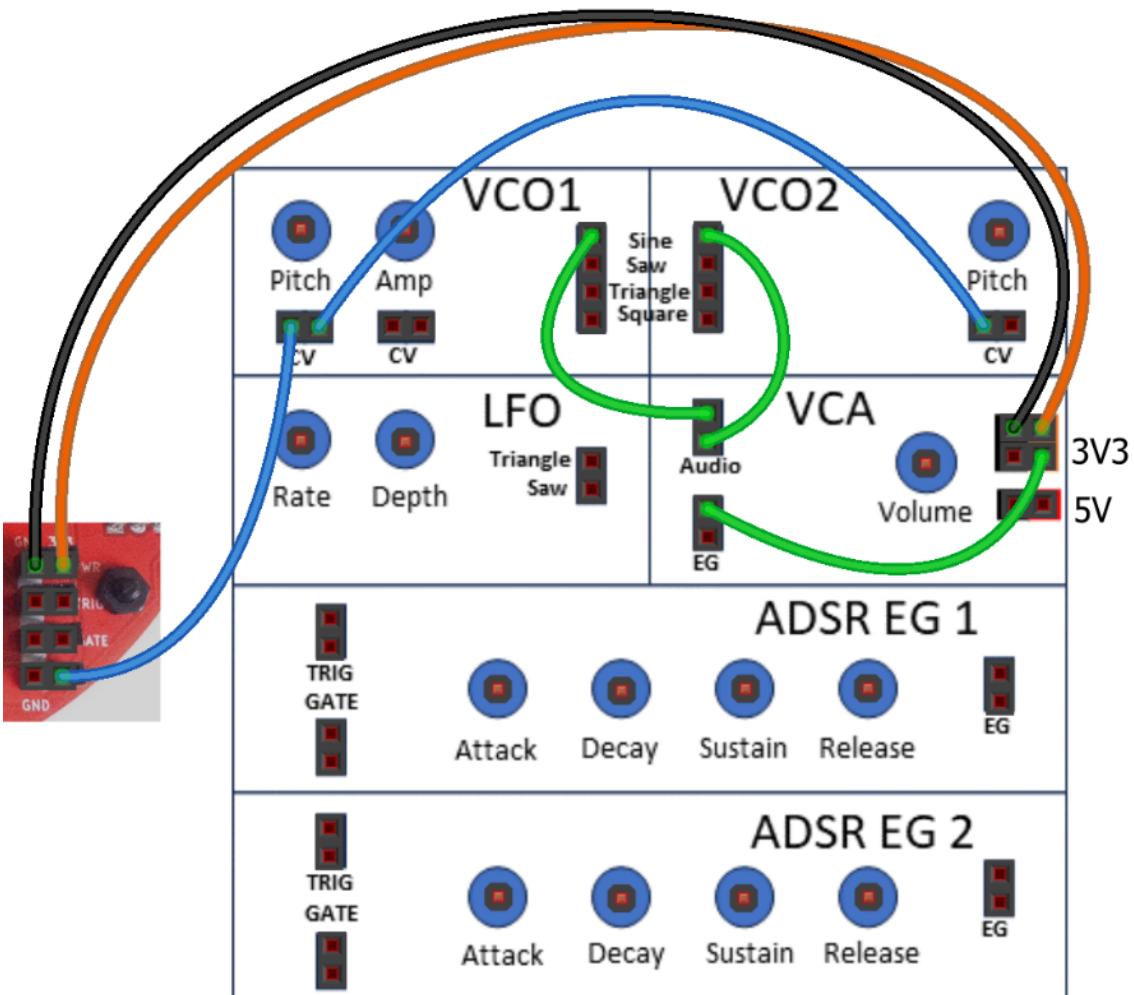


# 1. Simple Pitch Sequence



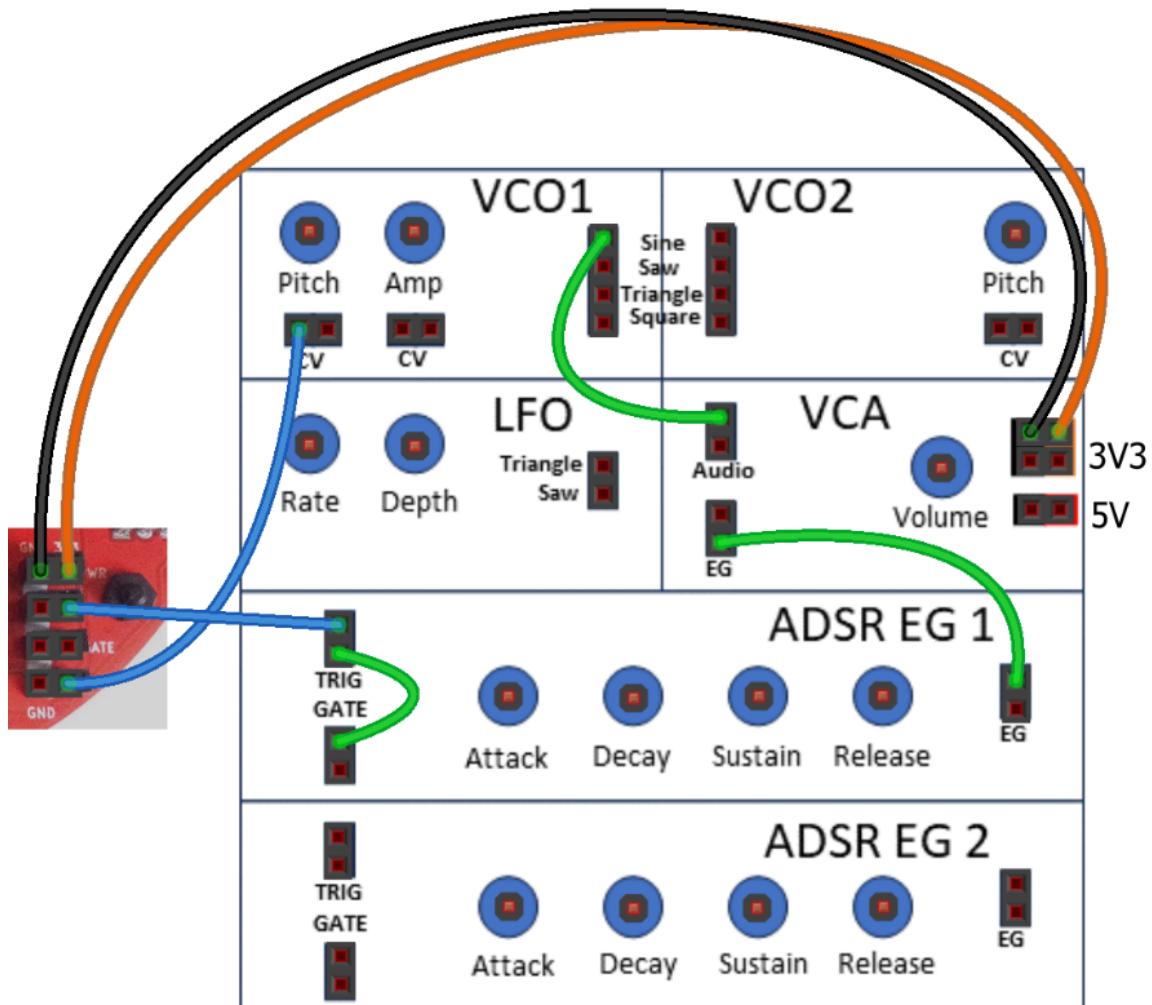
- VCA EG Fixed at 3V3.
- Start with:
  - Turn down VCO1 Pitch.
  - Turn up VCO1 Amp and VCA Volume.
  - Baby 8 Steps fully clockwise (8 steps).
  - Baby 8 Run/Stop -> Run (to the right).
- Experiment with:
  - All 8 Baby 8 step Pitch controls.
  - Baby 8 Tempo.
  - Baby 8 Number of Steps.
  - Baby 8 Run/Stop.

## 2. Dual Pitch Sequence



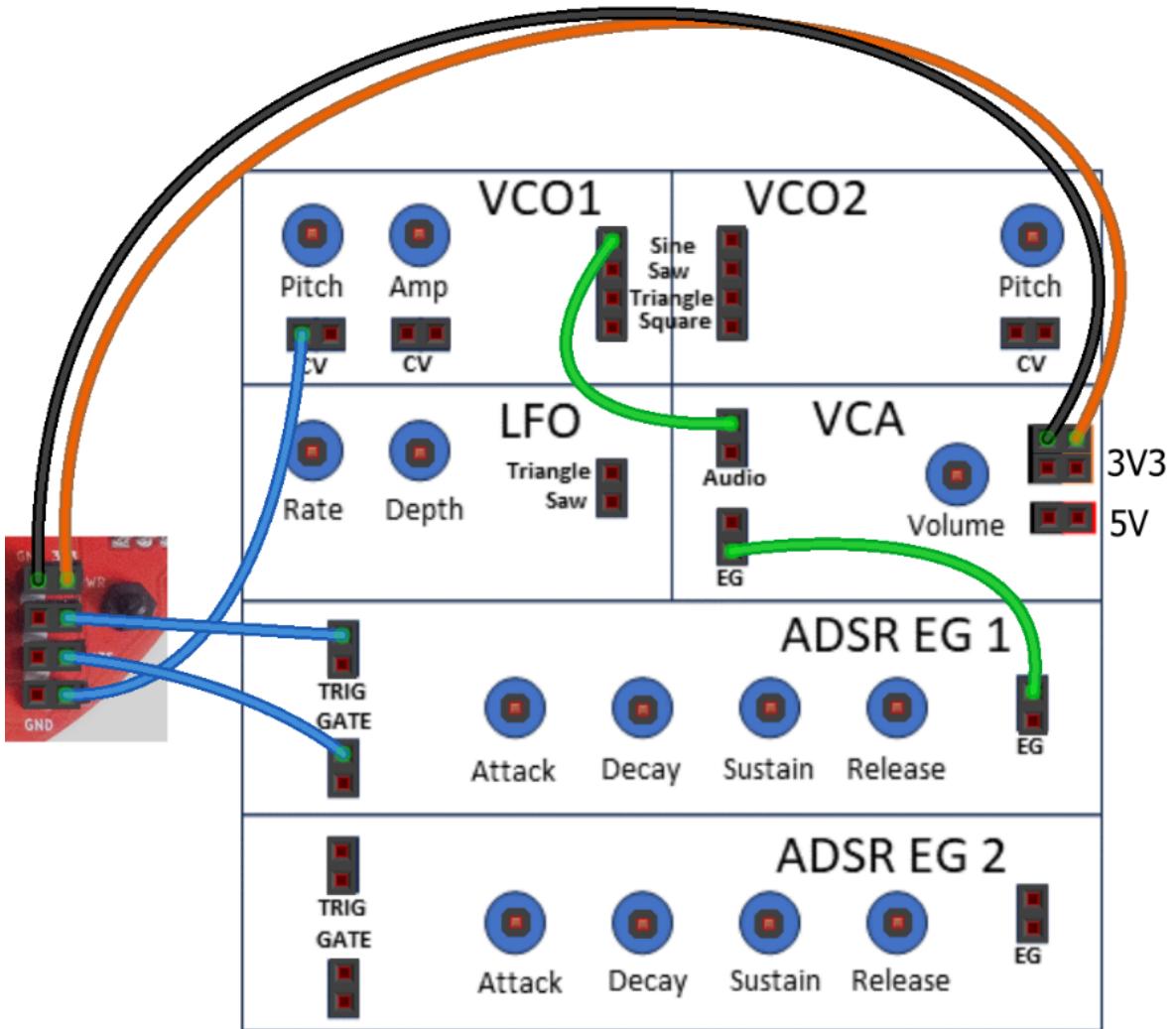
- Both VCOs connected.
- Start with:
  - VCO Pitch controls turned right down.
  - VCO1 Amp and VCA Volume right up.
  - Baby 8 steps fully clockwise (8 steps).
  - Baby 8 Run/Stop -> Run (to the right).
- Experiment with:
  - Detune VCO2.
  - Different Waveforms.
  - Different Pitch controls.
  - Adjust the sequence.

### 3. Baby 8 Trigger



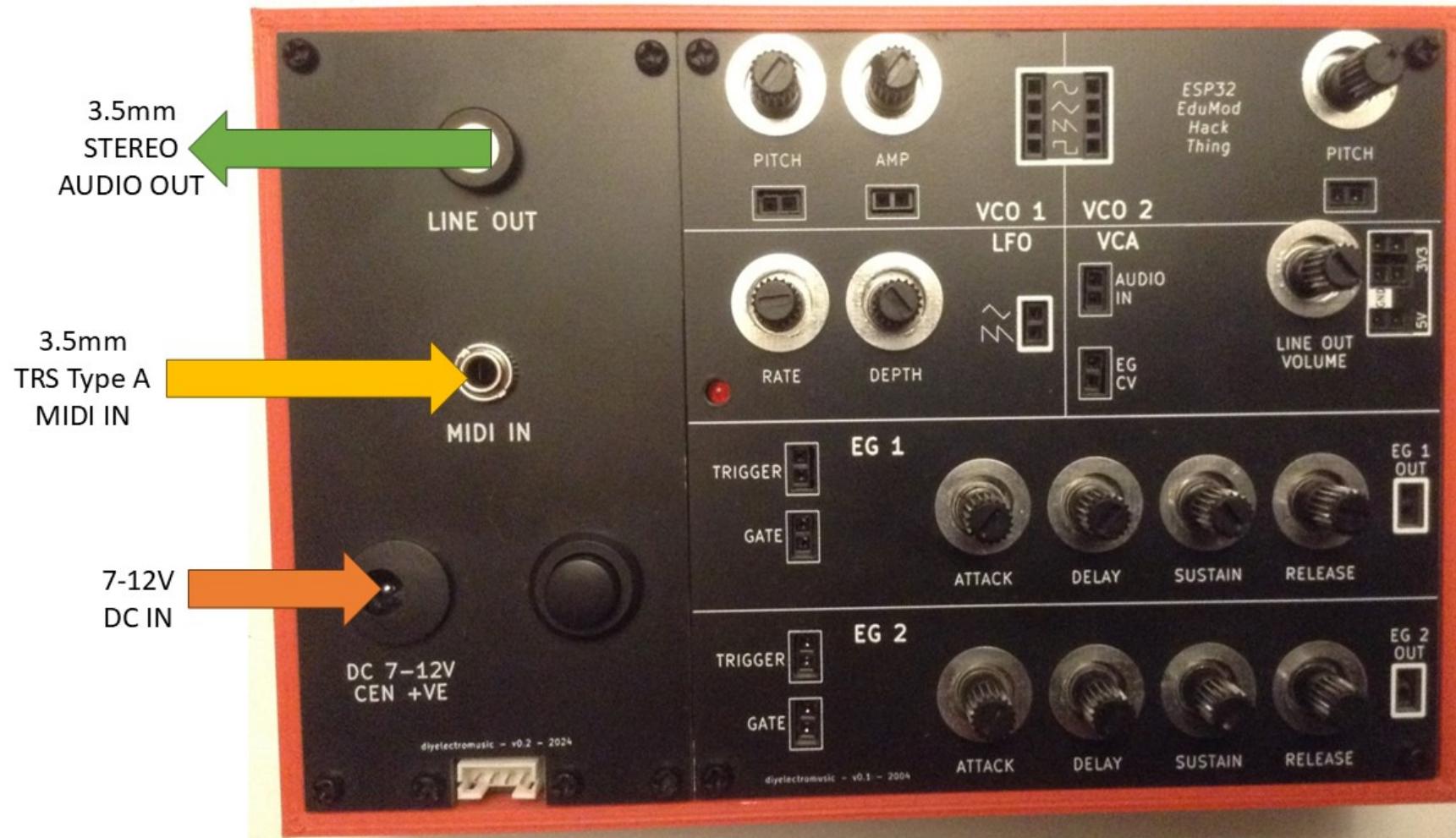
- More useful Baby 8 EG Option
- Start with:
  - VCO1 Pitch right down.
  - VCO1 Amp and VCA Volume right up.
  - A: almost full anti-clockwise.
  - D: almost full anti-clockwise.
  - S: fully clockwise.
  - R: in the middle.
  - Baby 8 slow Tempo (anti-clockwise).
- Experiment with:
  - Adjust ADSR settings.
  - Baby 8 mute switches.
  - Baby 8 Tempo.

## 4. Baby 8 Trigger and Gate

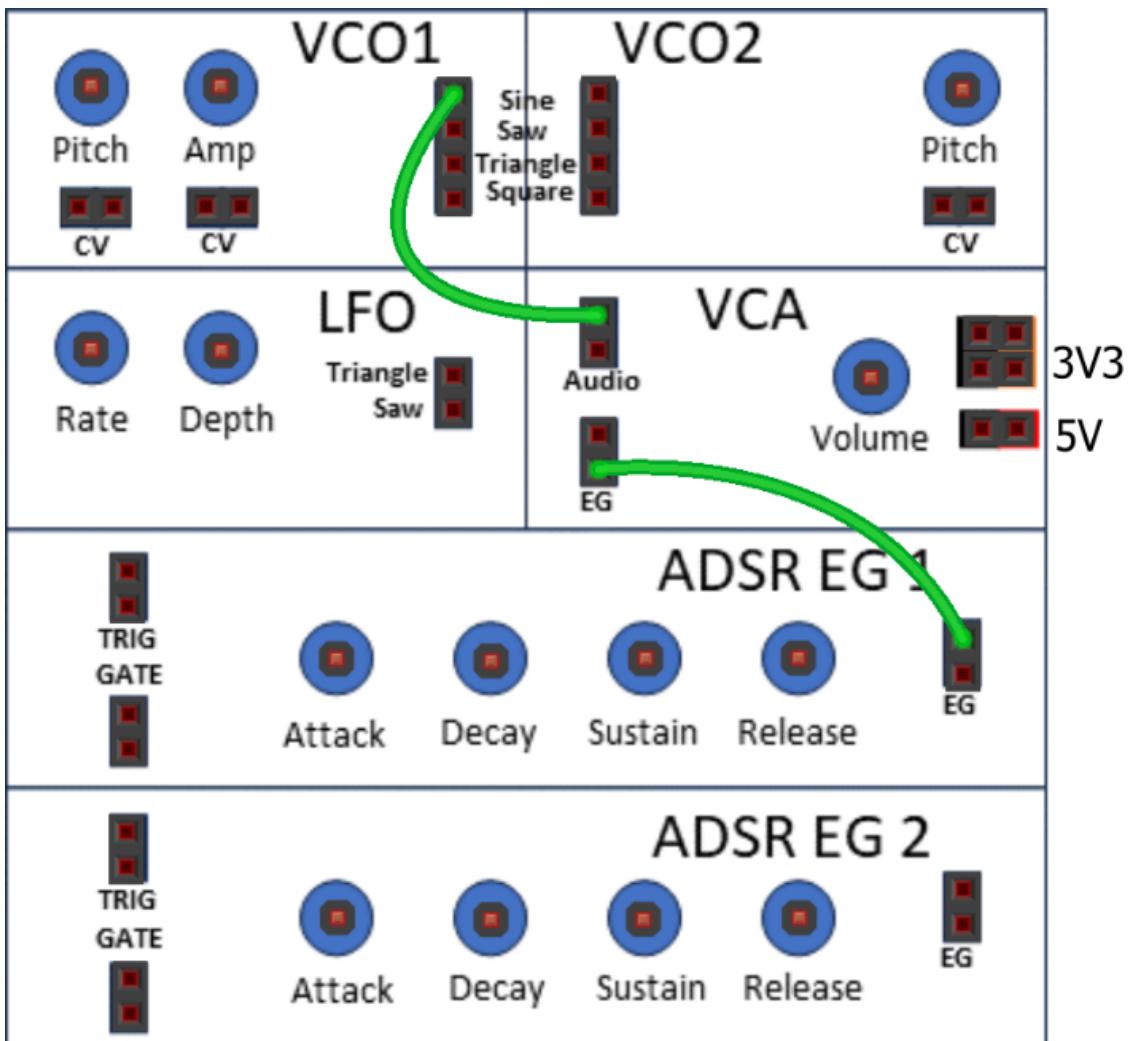


- The less useful (more complex) option!
- Start – as previous experiment.
- Try muting steps 2, 4, 6 and 8.
- Experiment with ADSR settings.

# MIDI



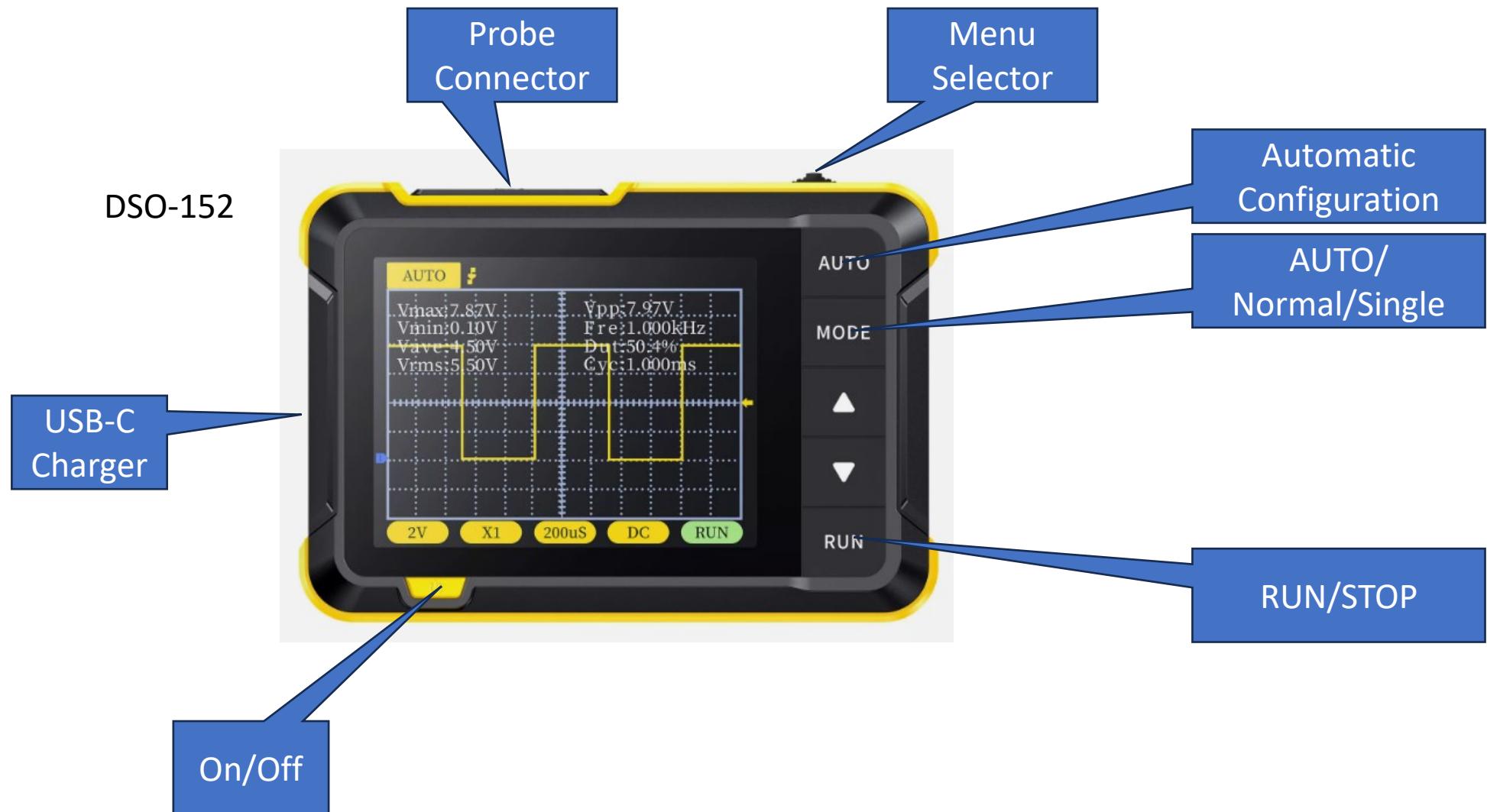
# Basic MIDI Patch



- MIDI Channel 1. Mapped to:
  - Both VCO Pitch CVs.
  - Both EG TRIG and GATE.
- Start with:
  - VCO1 Pitch turned right down.
  - VCO1 Amp and VCA Volume turned right up.
  - EG1: Short A, Short D, High S, Medium R.
- Experiment with:
  - Pitch range available through MIDI.
  - Adding second VCO.
  - ADSR settings.
  - Adding LFO.
  - Adding second EG2.

# Ch 4 – Oscilloscope Use

# Oscilloscope Controls - Operation



# Oscilloscope Controls - Display

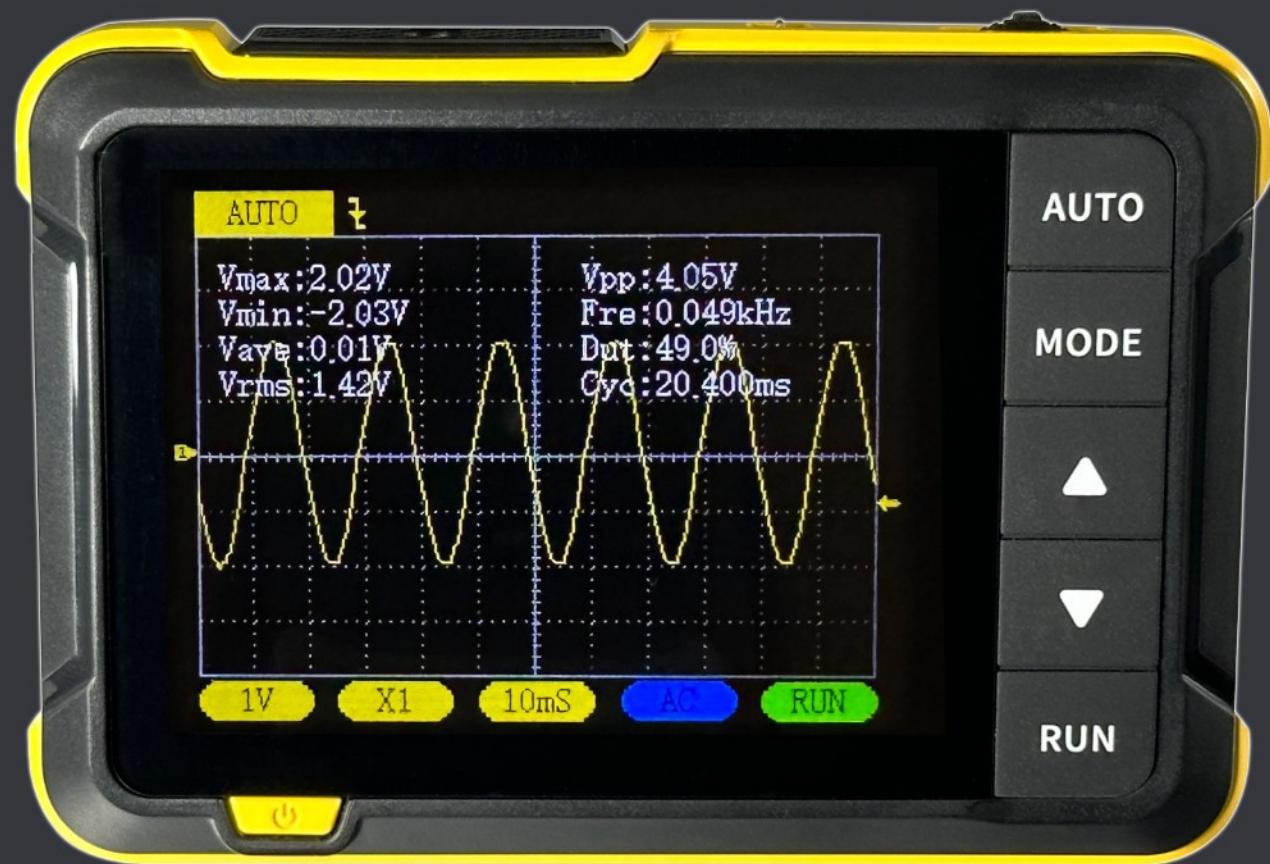
DSO-152



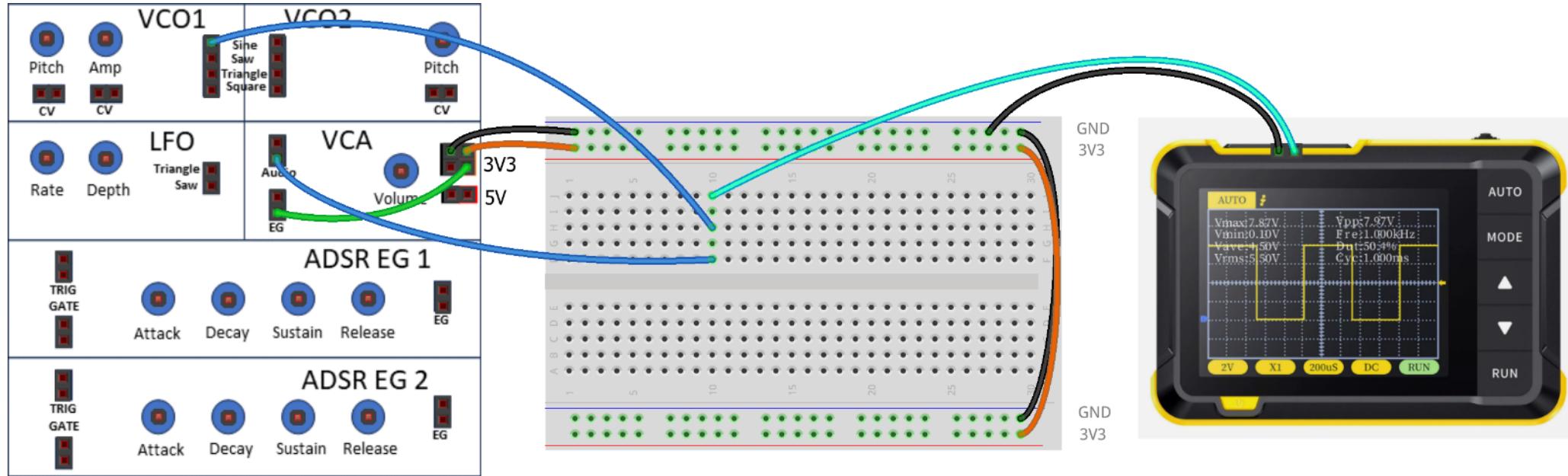
## KEY FUNCTION

BUTTON	OPERATION	FUNCTION
	Short press	Control parameters function selection
	Short press	Exit auto calibration (Auto calibration page)
	Long press	Enter the automatic calibration page
	Short press	Control parameters function selection
AUTO	Short press	Automatic adjustment (frequency below 45Hz cannot be calibrated correctly)
MODE	Short press	AUTO/Single/Normal switching
	Long press	Rising edge/falling edge switching

BUTTON	OPERATION	FUNCTION
	Short press	Parameter addition adjustment
	Short press	Parameter subtraction adjustment
RUN	Short press	Run/pause waveforms (other pages) Enter auto calibration (Auto calibration page)
	Long press	Show/close detailed parameters
	Short press	On
	Long press	OFF



# 1. Oscilloscope and Breadboard



## Setup:

- VCO1 Amp and VCA Amp turned fully clockwise.
- VCO1 Pitch half-way.
- Press “AUTO” on the oscilloscope.

## Experiment:

- Try all four waveform outputs.
- Switch back to Sine.

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## 2. Oscilloscope Detailed Parameters



### Setup

- Same circuit as before
- Push and hold “RUN” for detailed parameters.

### Experiment

- Change VCO1 Pitch – watch Freq value
- Change VCO1 Amp – watch Vmax and Vpp values.

### 3. Oscilloscope Horizontal Scale

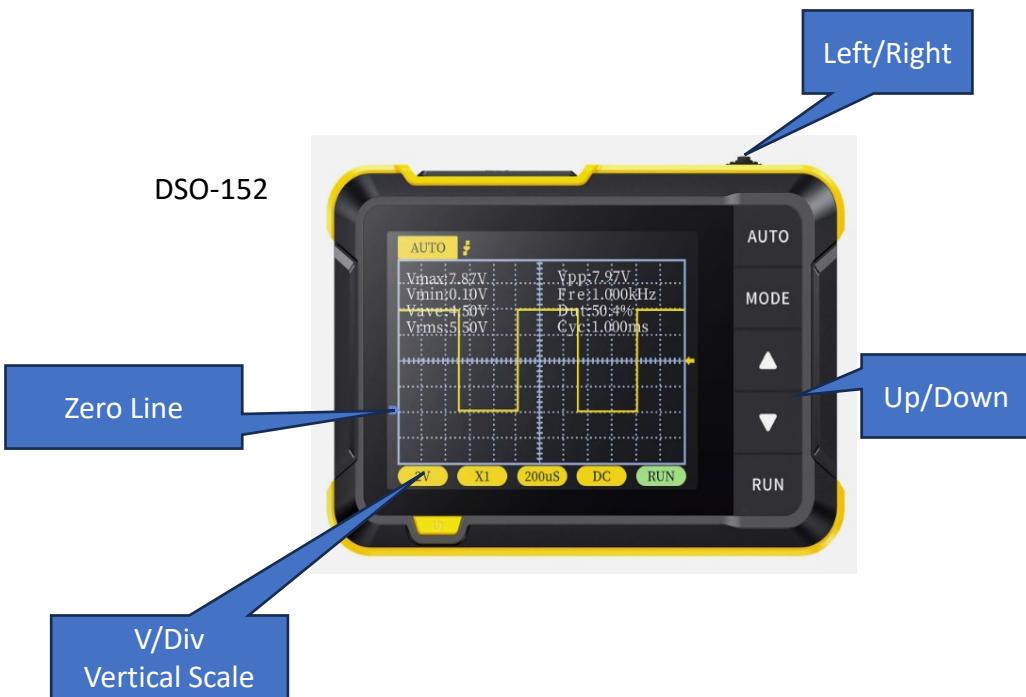
DSO-152



Use same circuit as before.

- Try to set the pitch to close to 440Hz.
- Use the left/right and up/down buttons to select 2mS as the timebase.
- Observe how each wave pattern is close to being a single box wide.
- Experiment with different timebase settings and see how the display changes.

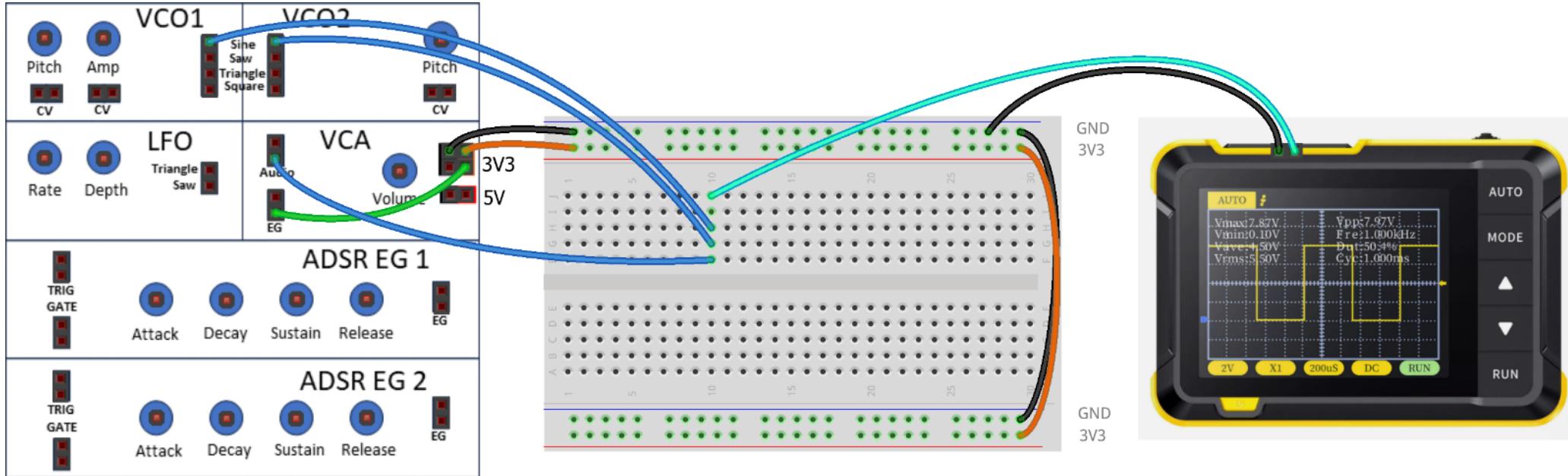
# 4. Oscilloscope Vertical Scale



Use same circuit as before.

- VCO1 Amp fully clockwise.
- Use the left/right and up/down buttons to select 1V.
- Observe how the waveform should now span around two and a half boxes on the display.
- Adjust V/Div to 500mV – it is now possible the top of the wave is off the top of the display!
- Use the left/right and up/down buttons to select the “zero line” and move it downwards.
- Experiment with the VCO1 Amp control to change the level.

# 5. Dual Oscillators and Oscilloscope



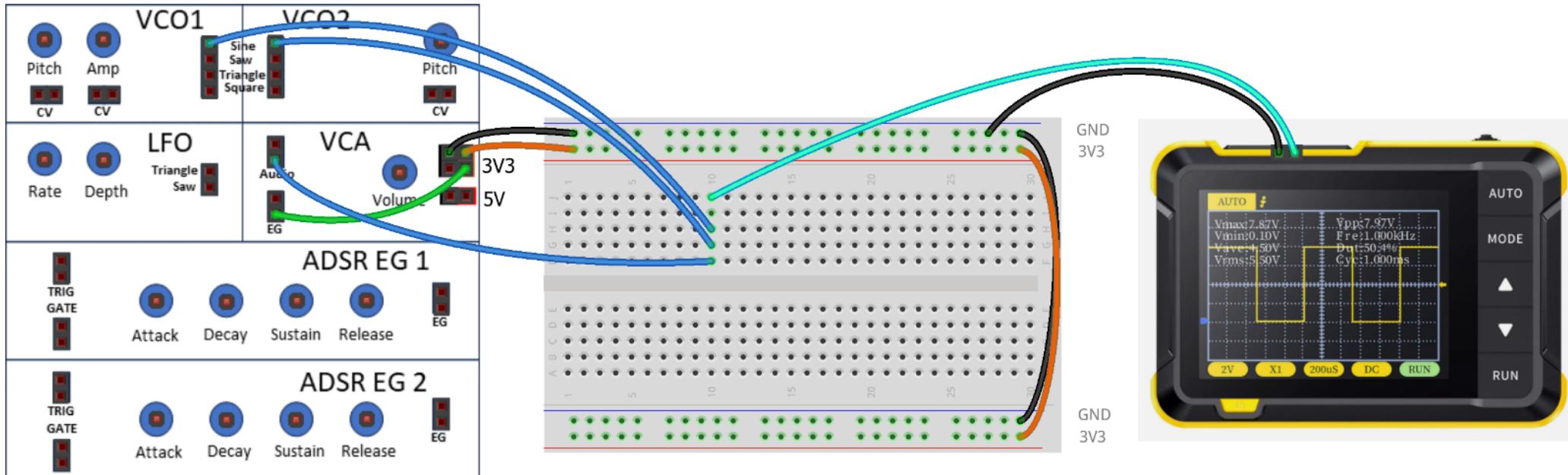
## Setup:

- VCA Amp turned fully clockwise.
- VCO1 Amp fully anticlockwise (off).
- VCO1 and VCO2 Pitch half-way.
- Use both Sine outputs.

## Experiment:

- Slowly increase VCO1 Amp.
- Tune both VCOs to same Pitch.
- Watch how the waveform slowly changes.

# 6. Dual Oscillators – Complex Waveforms



Using same circuit as previously

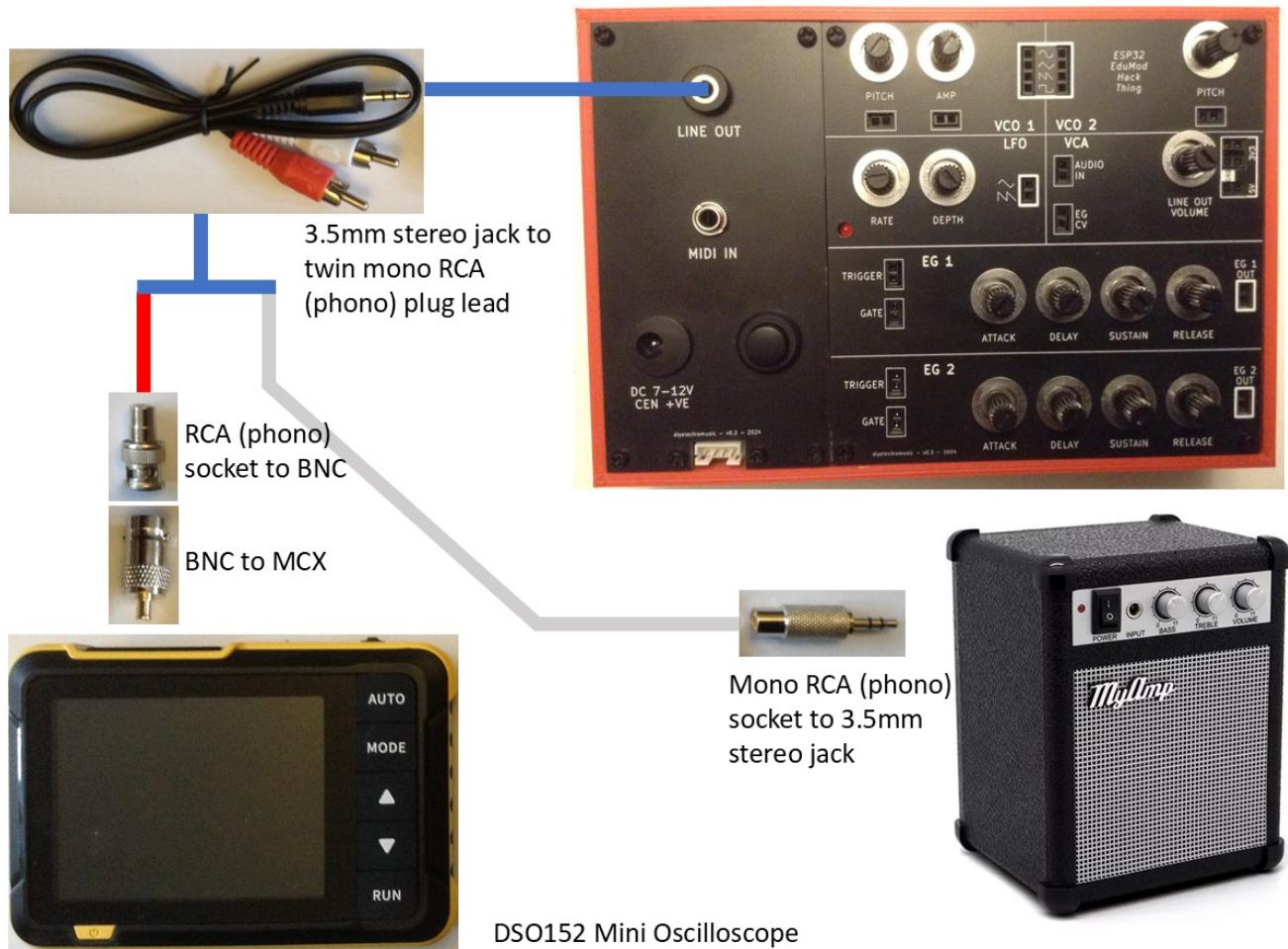
- Adjust VCO2 to be just below VCO1
- Set VCO2 to be almost the same as VCO1
- Set VCO2 to be just above VCO1.

Further Experiments

- Tune VCO1 and VCO2 to be one octave apart.
- Experiment with different intervals.
- Experiment with different waveforms.

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# 7. Oscilloscope and Audio Output



The oscilloscope can be patched into the Audio output (line out) path from the Synth Thing to an amp as shown here.

This is using a jack-to-phono “splitter” cable and various adaptors.

The oscilloscope can now be used to capture the final output of the Synth Thing – including the use of envelopes or any external circuitry – which will be useful later!