Modular Synthesizers Using VCV Rack
FOR ABSOLUTE BEGINNERS

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About me…

- I am not a musician, but I like the noise synthesizers make
- Wanted to play with modular synths on the cheap, so designed the LushOne system
- Now you can do it even cheaper thanks to software emulation
- “Absolute beginners” format. Try not to assume:
  - electronics, music theory, physics of sound, “synth culture” etc. etc.
  - BUT, this is a big ask, so stop me and ask if I go off track!

What we're going to do

- Install the VCV Rack Software
- Introduce the basic concepts and get your first sounds
- Experiment with ways of modifying the sounds and introduce the key concepts of a modular synth
- Create an instrument you can play
- Explore more complicated ideas (based on time/interest)
- Try a jam session (!!)

What is a modular synth?

- Making sounds using analogue electronics
  - continuous signals, not digital
  - it’s an analogue computer for sound
- Break the process down in to separate modules that can be wired together in different combinations
  - let the musician decide how to connect them
  - Explore what is possible, wild ideas
- Like Lego
- Very flexible, very fun

This is just some ideas

- As with Lego, there is no right way to use the bricks
- Explore, explore, explore
- Ask, ask, ask
- Play, play, play
- Modulars have a great serendipity
- If you are comfortable working on your own and/or have some background in the basics feel free to use the slides to jump ahead

A brief history

First modular synths

Birth of sampling
(Fairlight CMI)

Switched on Bach (Wendy Carlos)

Doepfer invent
Eurorack standard for modular synths

oasis

Prog Rock
(Rick Wakeman: Yes,
Keith Emerson: ELP)

Digital Winter

Guitar Band Winter

Revival

1960s | 1970s | 1980s | 1990s | 2000s | 2010s

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The bad

- Cost (yay emulation)
- Size
- (Lack of) Reliability
- Complexity
- Learning curve
  - A lot of terminology, much tied up with the long history
  - A lot of theory if you want to go deep

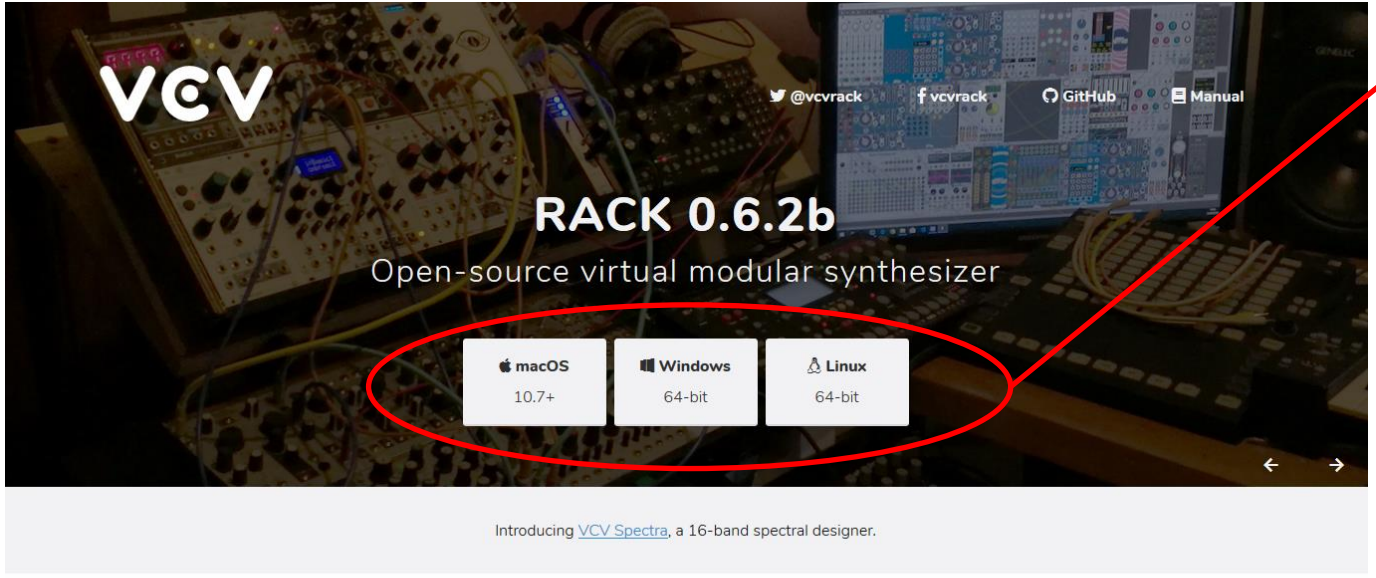
The ugly

Good or bad, depending on your point of view

- Will sound “electronic” as opposed to natural
- Never the same sound twice, especially on real hardware
- Polyphony is hard
- All consuming, for some people

Time for action

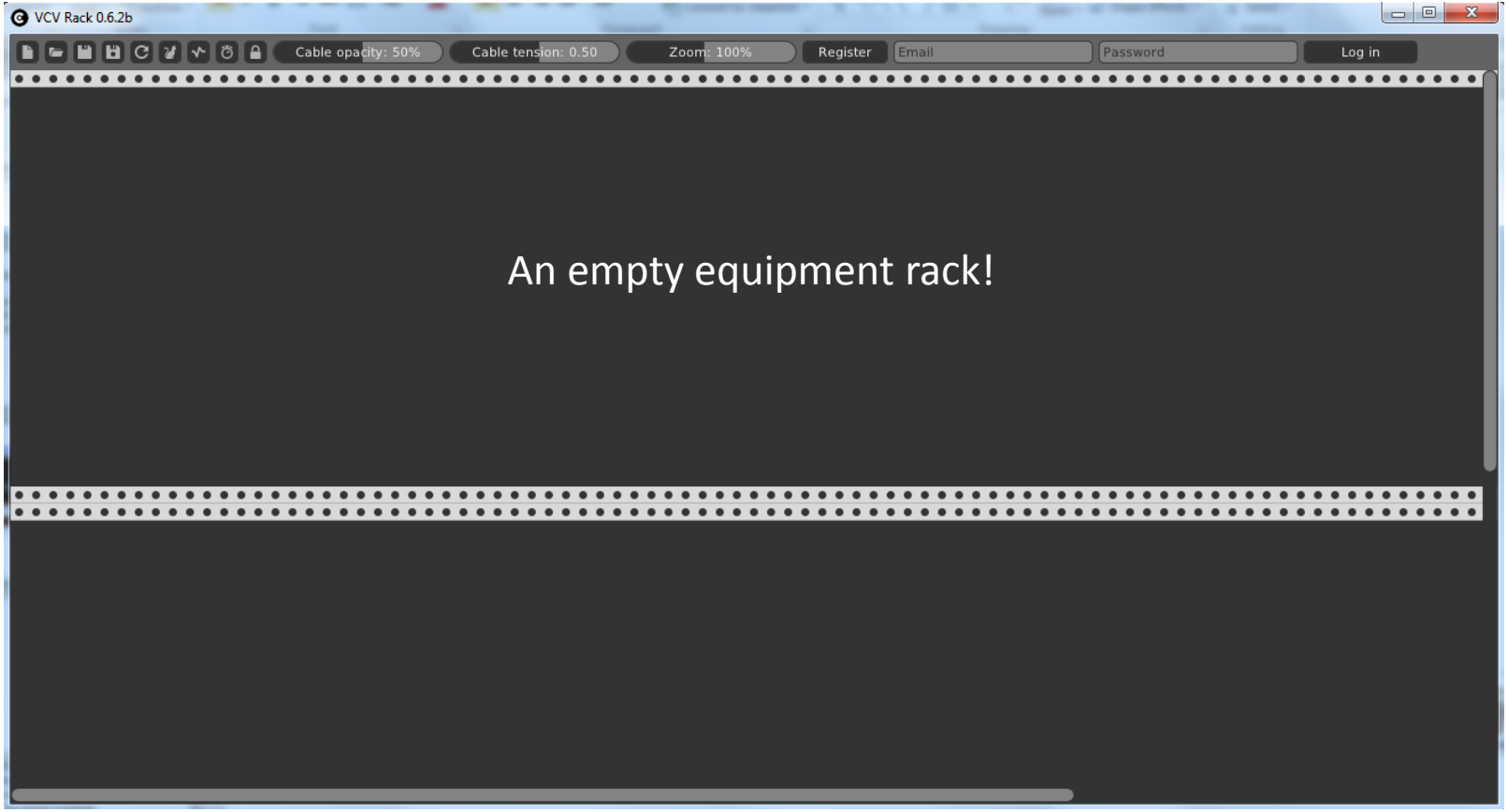
- Go to https://vcvrack.com/



Download and install

Register
(You'll need this later)

Run!



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Make a noise

- VCV comes pre-loaded with the most common and useful module types
- You can also add further modules from an extensive library
  - Both popular and exotic
  - Many free, some paid
- Need just two modules, from the standard set, to make a noise:
  - An *Audio* output to connect to the computer's sound output
  - A oscillator (*VCO1*) to generate an audio signal

Wot VCO1?!

Voltage Controlled Oscillator (Number 1)

- We use electrical signals to represent sounds and control effects in the modular synthesizer
- An oscillator generates a repeating signal that corresponds to a sound
  - Think about physical things oscillating
- An electrical signal that is used to control a module is called a *Control Voltage* (CV)

Place the first modules

- Right click in empty space to get a menu of available modules
- Choose Fundamental->VCO1 to place a VCO1 in the rack
- Choose Core->Audio to place an audio output
- Drag the modules to get them side by side

Indicator Light

Control Switch

Control Knobs
- Click and drag vertically to turn
- Right click to reset

Signal Inputs

Information Display/ Menu

Signal Outputs

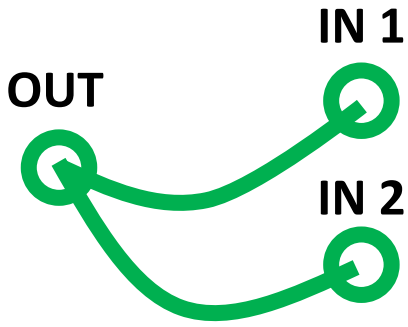
Patching

- Connect an output to an input by dragging a *patch-lead* between them
- Connect VCO1 “SIN” out to Audio Input 1

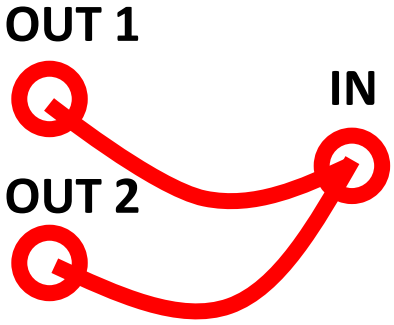
Coloured light:
red = negative voltage,
green = positive voltage,
yellow = going positive and negative,
black = zero voltage

Patching Rules

- Patch lead must go between an output and an input
- Each input can only be connected to one output
- Each output can be connected to multiple inputs



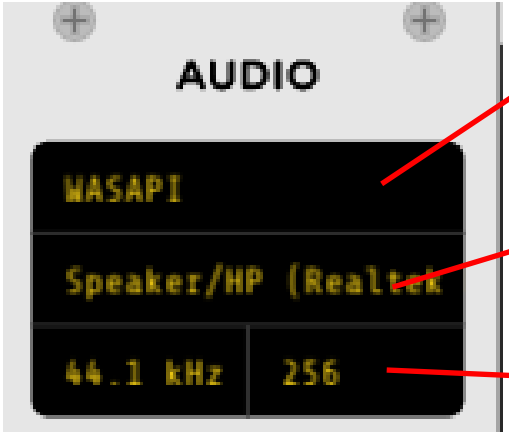
OK



NOT OK

Configure the audio

- Yukky bit – complexity of PC audio meets simulation of analogue electronics



1) Click to choose an audio interface (system software block to output audio). For Windows, “WASAPI” seems the best option

2) Click to choose an output device

3) Set the audio encoding parameters. If the sound stutters increase the block size until the stutter stops (256 in this example)

If all goes well, you should hear a continuous tone from the left speaker. Some trial-and-error may be required.

Change the frequency

- Use these controls to change the frequency of the oscillator
- Frequency is measured in Hertz (Hz) – the number of times the signal does a complete oscillation in 1 second
- Useful frequencies for sounds are about 20Hz – 20kHz
- **Frequency corresponds to the pitch of a note**

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Add a new module

1) Add a module from Fundamental->VCA2

2) Connect the patch leads as shown

3) One output can connect to multiple inputs – either drag from the input to the output or Ctrl-drag from the output.
We use this to send the output to left and right speakers.

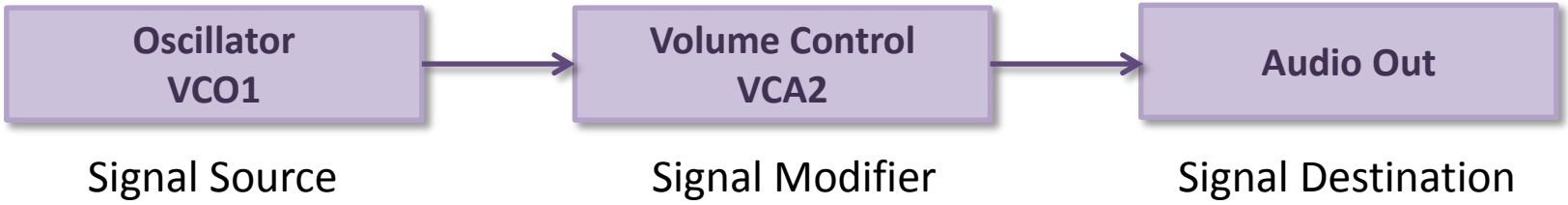
4) Adjust here to change the volume

Wot VCA2?!

Voltage Controlled Amplifier (Number 2)

- In this context, an amplifier can change the level of a signal while keeping the same proportionate shape (and sound)
- This module contains two identical VCAs which operate independently
- If you like, try swapping to using the bottom VCA of the pair

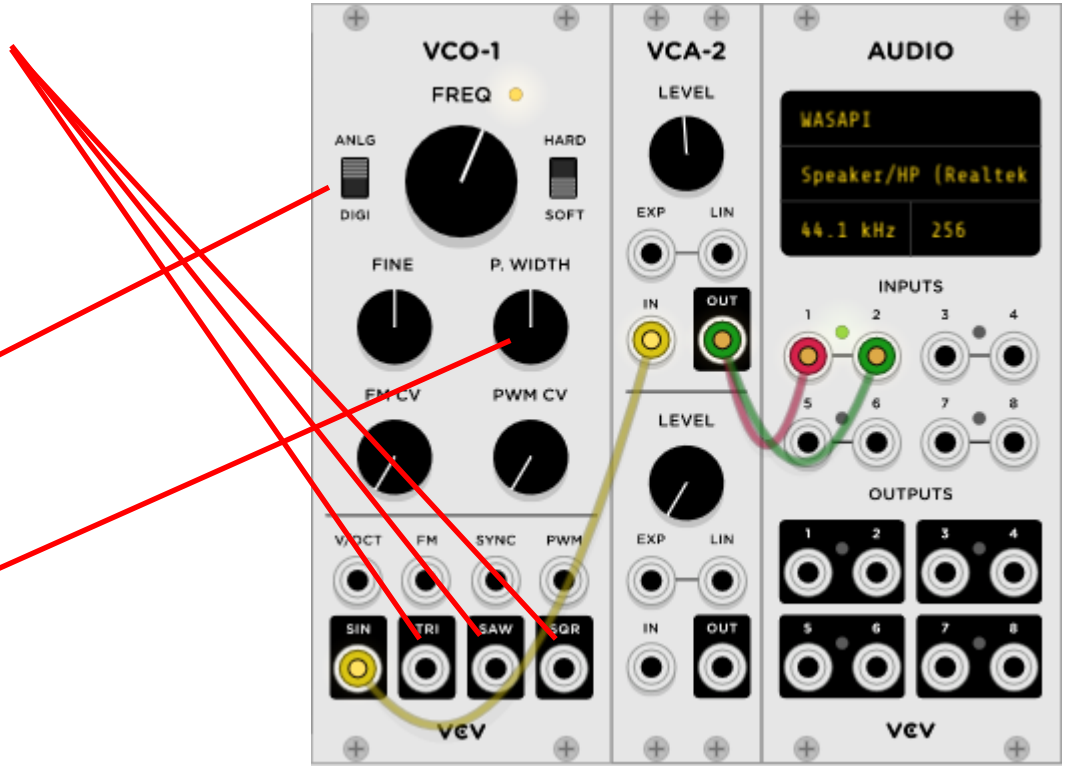
Chaining signals through modules



- A core concept in modular synthesizers to chain a signal through modules
- Each module in the chain can add a different modification to the signal
- You can add as many links in the chain as you wan to achieve the sound you like
- You can also split and combine signals to create chains that follow multiple paths

Try the other oscillator outputs

- Move the patch lead to the other outputs
- How would you describe the sound of the four outputs?
- How does this switch change the sounds?
- How does this control knob change the sound, and which output(s) does it apply to?



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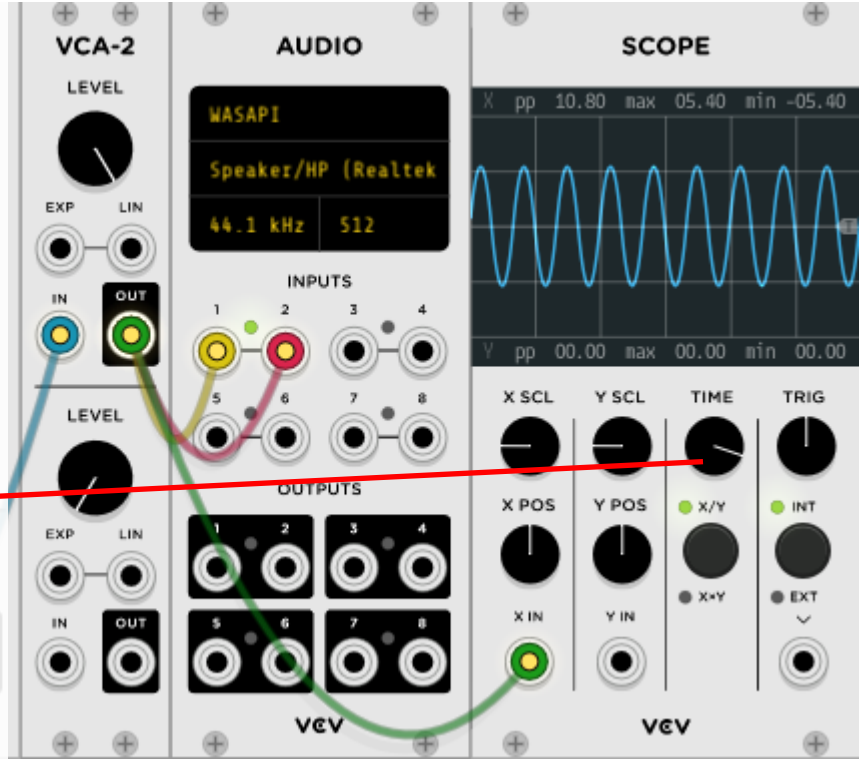
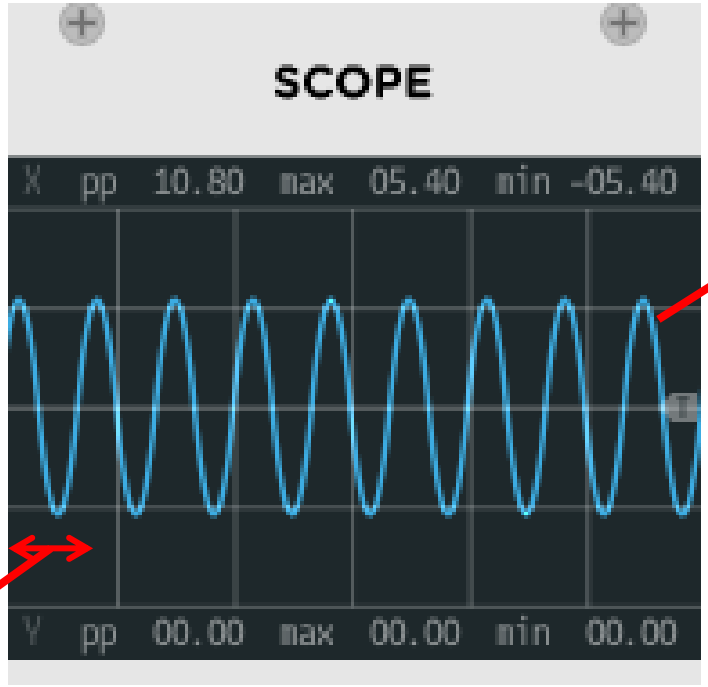
Add a scope

- Add a Oscilloscope from Fundamental->Scope
- Patch the VCA-2 Output to the *X IN* on the scope
- The scope shows the *waveform* of the electrical signal on the X IN
- Adjust the TIME knob for the best view
- Looking at the different VCO-1 outputs on the scope, what do you think the names mean?



Waveform shapes and sounds (roughly)



Waveform amplitude is the loudness of the corresponding sound (Control on the VCA)

Waveform shape is the tonal quality of the corresponding sound (roughly: the more angular, the harsher the sound)

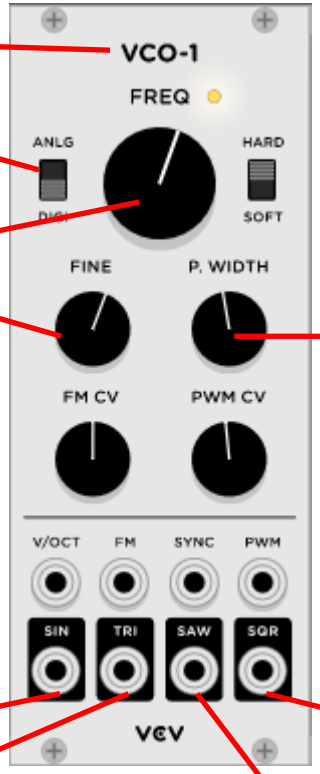
Waveform frequency is the pitch of the corresponding sound

Recap – what we know about the oscillator

Voltage Controlled Oscillator

Analogue or Digital waveform

Frequency (Pitch) Control



Pulse Width for the Square Wave

Sine Wave

Triangle Wave

Sawtooth Wave

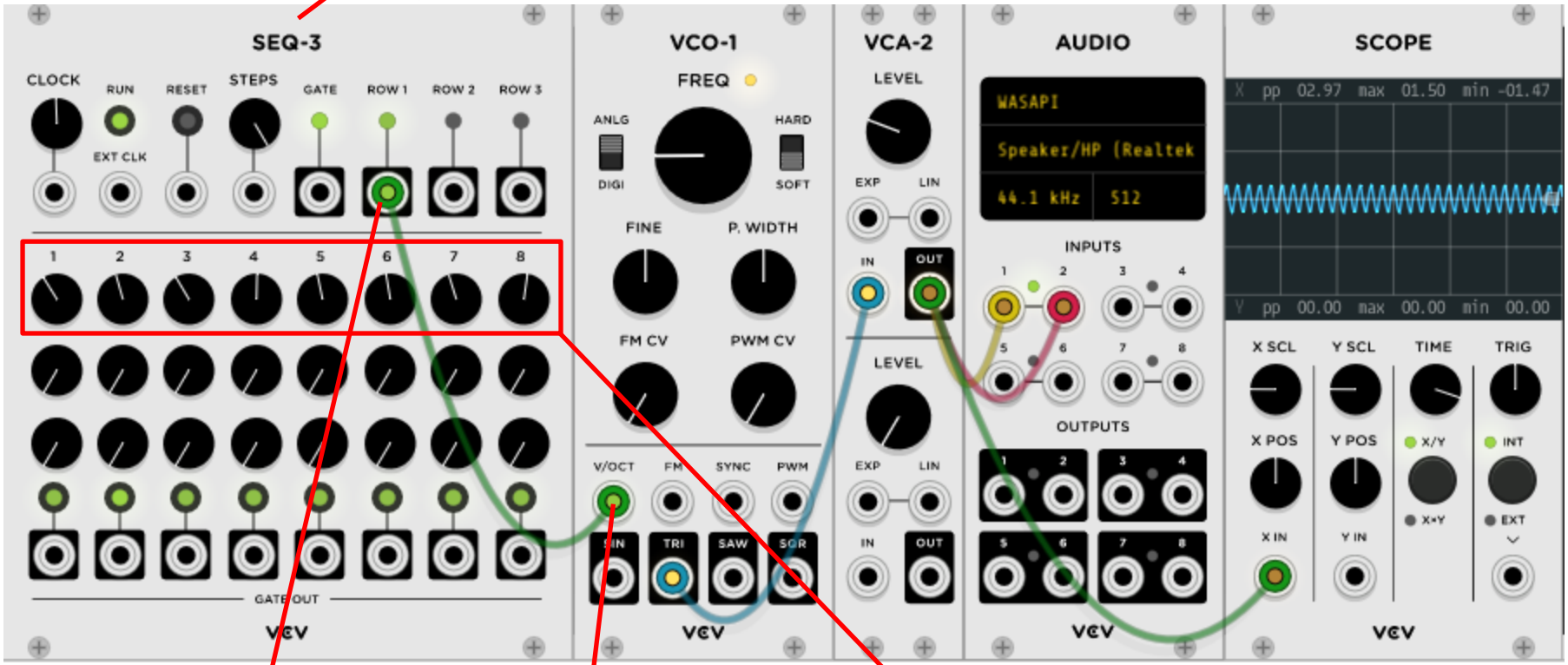
Square Wave

What if…

- …instead of changing behaviours by turning knobs we could have an electrical signal that did the same job?
- Then we could use these signals to automate behaviours in the synthesizer!
- We call this type of signal a *control voltage (CV)* which is another core concept in modular synthesizers
- All the inputs on the VCO-1 and VCA-2 are for control voltages

Use a CV to control the pitch of the oscillator

Sequencer from Fundamental -> SEQ-3



Output from Row 1

CV Input to VCO-1

Change these to play an 8 step sequence

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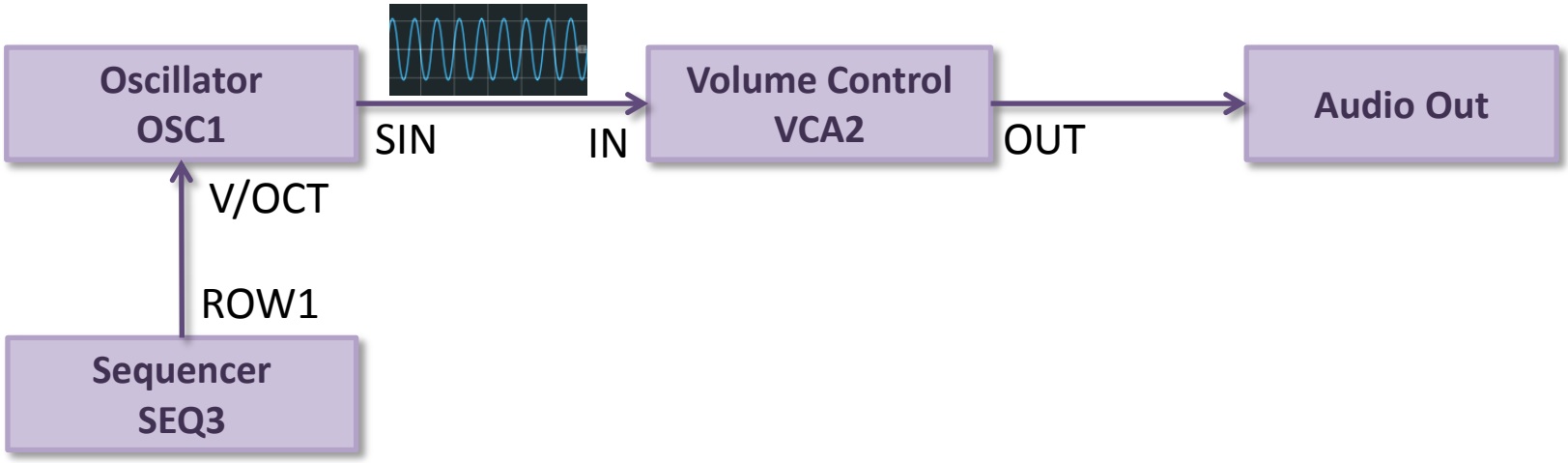
Wot V/OCT?

1 Volt = 1 Octave change in pitch

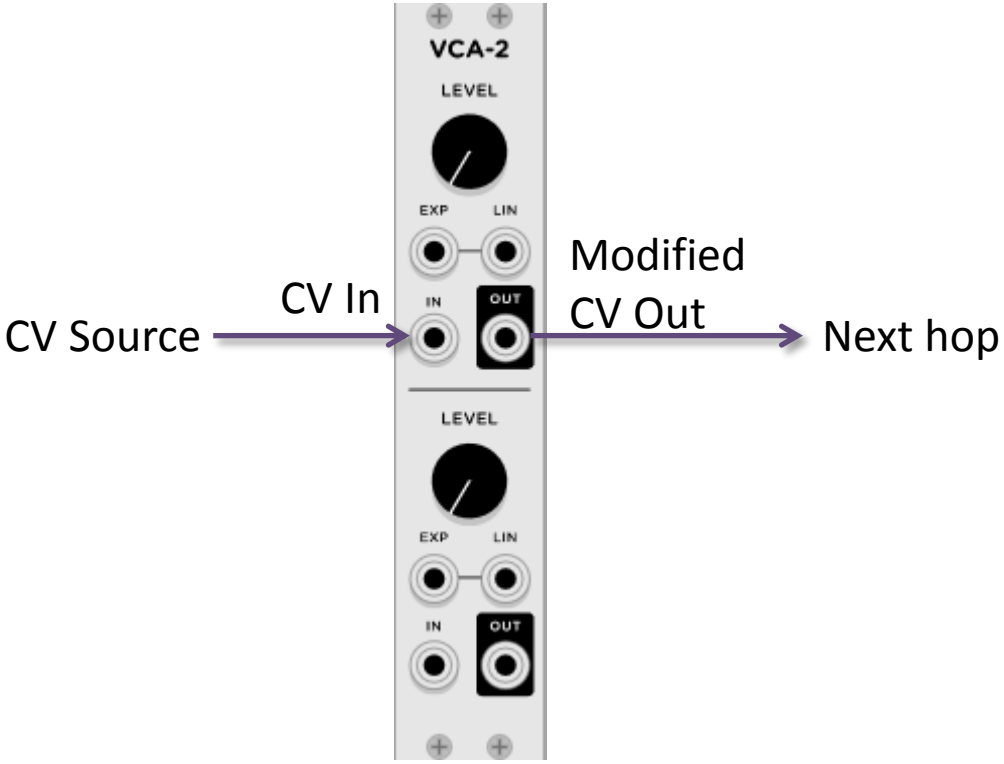
- The V/OCT CV input to the oscillator will change the pitch by 1 octave for each volt at that input
  - Equivalent to halving or doubling the frequency
  - To move one semitone use $1/12^{th}$ of a volt
- +ve voltages go up, -ve voltages go down
- Change is relative to the frequency set with the manual knobs
- For the VCO-1 the starting position of the frequency knobs sets 0V to middle C
  - Right-click knobs to set them back to their initial values

A schematic view (AKA block diagram)



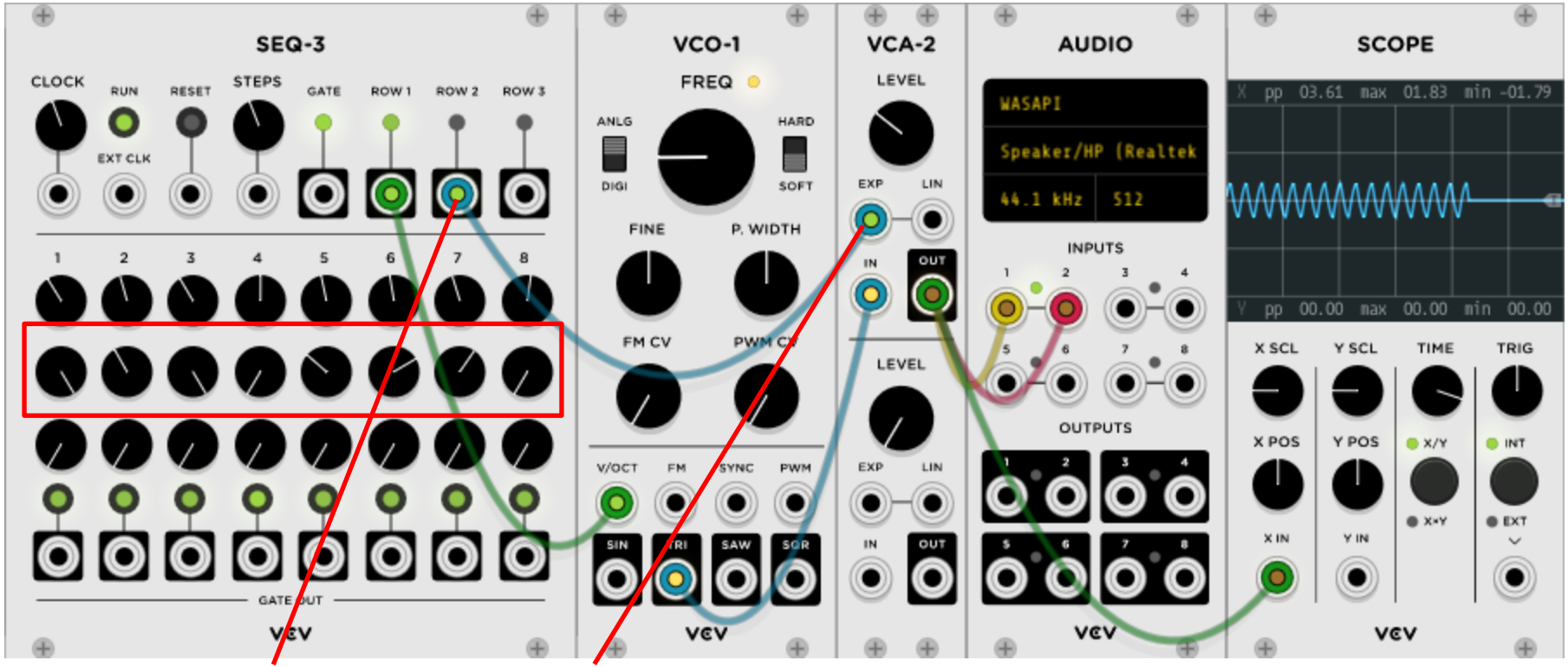
- For some people it's easier to visualize a more abstract view of the system
- Show the modules, inputs, outputs and signal paths
- Could also show the waveforms expected on the key connections

Chaining CVs



- We can even chain CV signals through modules
  - e.g. through a VCA to change the intensity of a CV
- You can see this gets very powerful (and complicated)

CV in to the VCA to change volume



Output from Row 2

EXPonential CV input to VCS-2

Replace the sequencer with a keyboard input

Core -> MIDI-1

Choose input system (e.g. “Computer Keyboard”)

Choose device (e.g. “QWERTY Keyboard”)

CV is V/OCT for the *pitch* of the last note

GATE is positive when a note is played

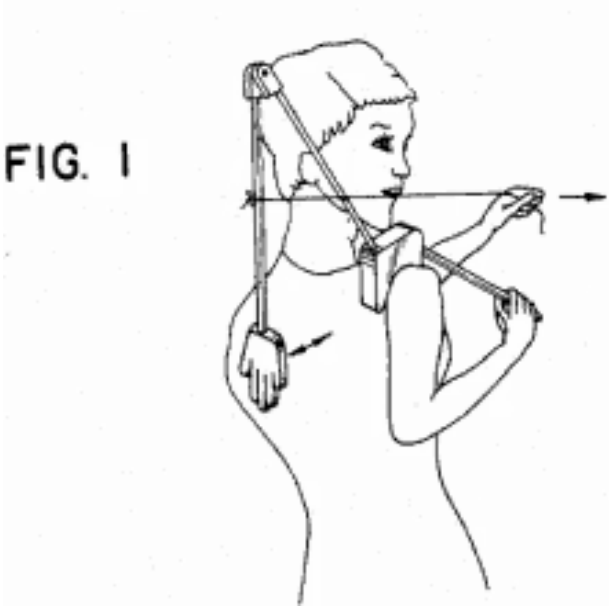
Pause for a moment

Where are we?

- Sounds start with an oscillator (*VCO*) that can produce different waveforms with different sonic qualities
- We can chain the oscillator output signal through other modules (e.g. *VCA*) to further modify its sound
- We can use *Control Voltages (CVs)* to automatically control parameters in modules
- We've seen how to generate CVs from a sequencer module and from a keyboard input
- *Pitch* (1V/Octave) and GATE (note playing or not) are important CVs for conventional instrument behaviour

These are the core concepts for a modular synthesizer, so now we can get in to creating richer and more exciting sounds.

Give Yourselves a Pat on the Back



Other uses for a CV in our configuration

Add *frequency modulation (FM)* to the output, which is a small change in frequency controlled by a CV. Creates vibratos, slurs and zaps.

Use a smooth analogue CV to vary the volume of a sound. Creates “natural” decay of notes and vibrato effects.

Add *Pulse Width Modulation (PWM)* to the oscillator square wave controlled by the CV. Creates “phasing” type sounds.

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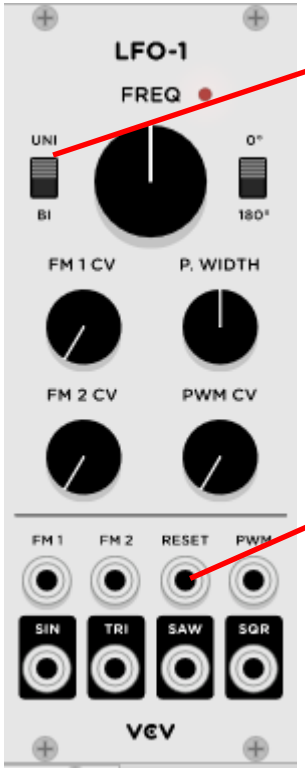
How to generate CVs

- Already seen:
  - Sequencer
  - Input device (could also be mod wheel, pads, key velocity etc. etc.)
- Two other important modules
  - *Low Frequency Oscillator (LFO)*
    - Should really be called a VCLFO, but I guess synth geeks like TLAs
  - An Envelope Generator, commonly *Attack-Decay-Sustain-Release (ADSR)* module

Low Frequency Oscillator (LFO)

- VCV Rack provides an LFO on Fundamentals->LFO 1
- Essential functions are the same as the oscillator we already know, except it operates at lower frequencies
- Use it for vibrato or other repeating effects
- LFO SQR (square wave) outputs can also be used as “Clocks” to deliver regular pulses to modules that need pulse-inputs



Switches output between only positive (UNI) and positive and negative (BI) voltage ranges

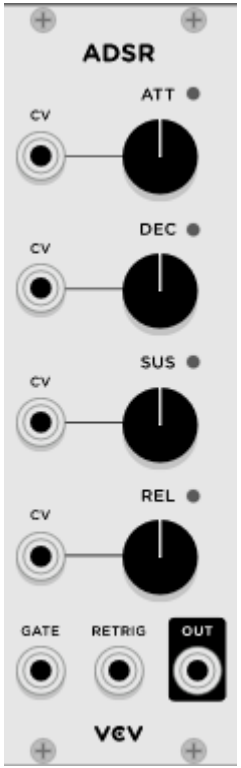
Resets oscillator to the starting position (0 Volts).

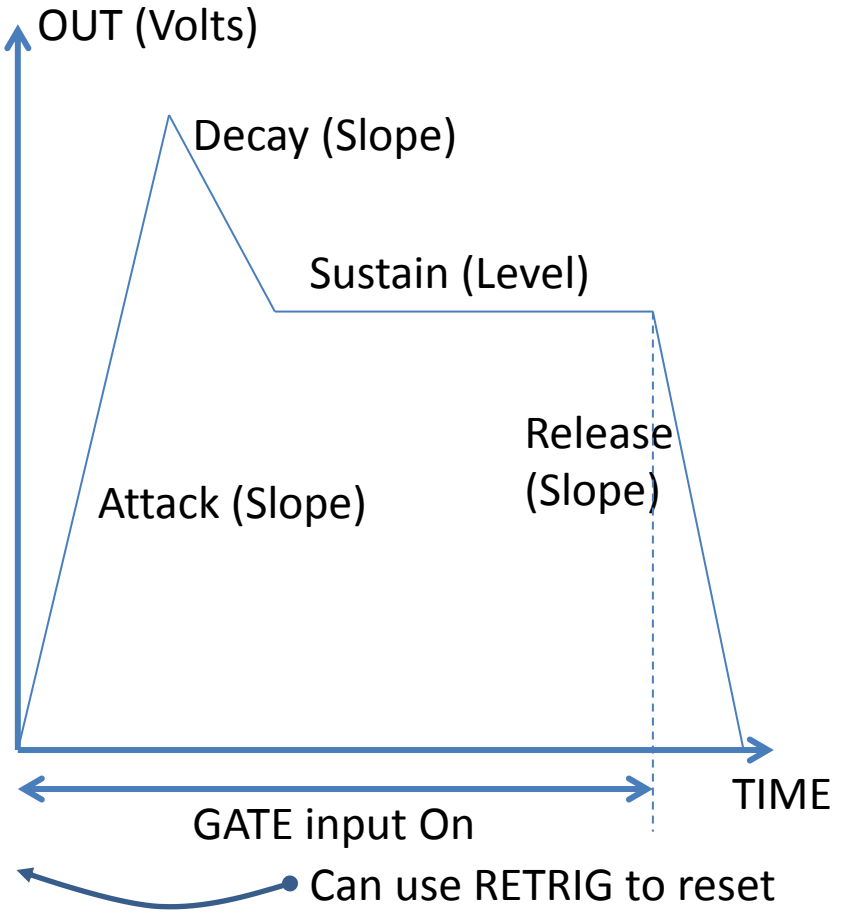
ADSR

Simian Mobile Disco

VCV Rack ADSR

- Fundamental -> ADSR
- ADSR is an engineer's model of how the loudness of a musical note changes as it is played
- Value of the ADSR parameters can be set by control knobs and CVs
- Normally connect the *GATE* input to a *GATE* output from a sequencer or keyboard





Combinations

3 CV Inputs (VCO FM, VCO PWM, VCA EXP)

4 CV sources (LFO, ADSR, Sequencer, User input)

= 12 Combinations

Input to Source	VCO FM	VCO PWM	VCA EXP
LFO	**Vibrato** (Frequency)	Weird Phasing	**Vibrato**
ADSR	Slides and zaps	Phasing	**Natural Notes or Spooky fades**
Sequencer	??	??	??
User Input	Pitch bends	Phasing	Expressive volume

More combinations

- But also:
  - Manual adjustments of parameters
  - Some CV sources, like the LFO, can be controlled by other CVs
  - One CV output can be linked to several inputs
  - Multiple CV sources can be used (e.g. several LFOs with different parameters)

- So, many, many possibilities
- Try adding LFO(s) and ADSR(s) and experiment with the CVs
- If you get suck, there is an example file: LFO_ADSR.vcv

Utility modules

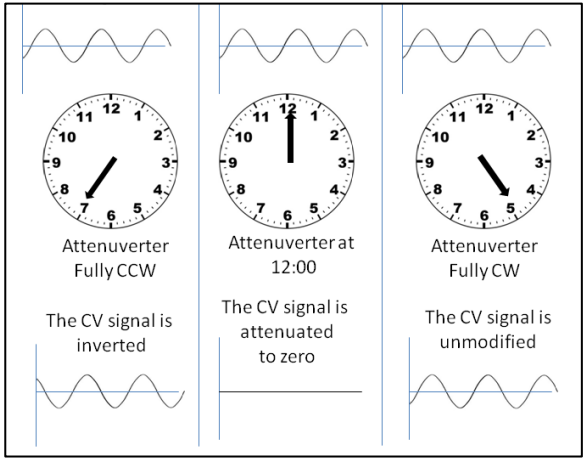
- Utility modules are useful “glue” to help join together more advanced combinations
- Two common utilities for CVs:
  - *Attenuverter* – controls the level and polarity of a CV
    (Word is a combination of attenuate and invert)
  - *Mixer* – add several inputs together to get one output (normally with a gain-control on each input)

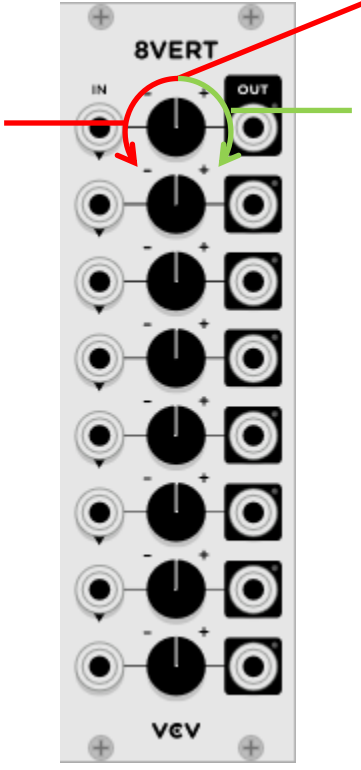
    Fixes the problem of not being able to connect more than one signal to an input

Attenuverter

- VCV Rack contains an 8 x attenuverter module on Fundamental->8vert

Turn this way to increase inverted output





Zero position

Turn this way to increase positive output

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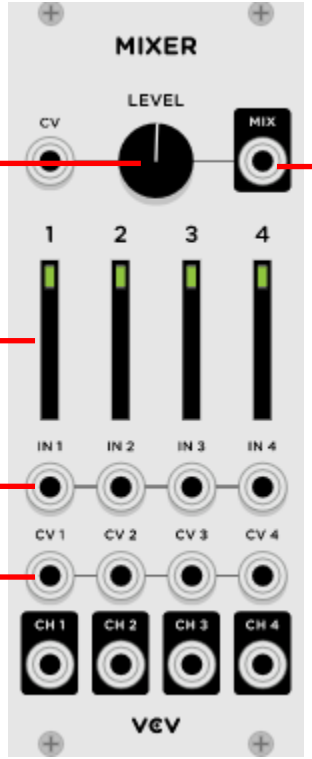
Mixer

- Fundamental -> Mixer



Overall level control

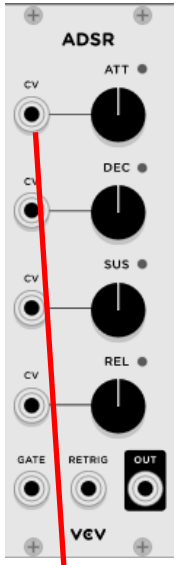
Mix level control for each input

4 inputs

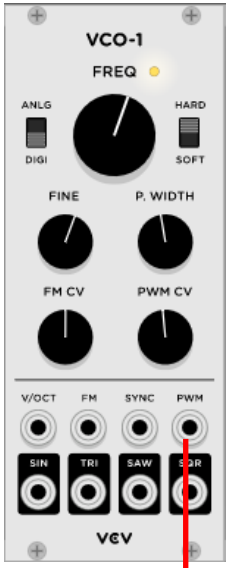
CVs to control the mix levels

Mix output is sum of IN 1 to IN 4, weighed by the levels

Consistently inconsistent CV inputs



CV is added to the manually set parameter



CV is added to the manually set parameter, with built-in sensitivity control

CV is added to the manually set parameter, with built-in attenuverter

Using utility modules

- Load the example utility.vcv
- Change the rising pitch at the start of each note to a falling pitch
  - HINT: Use an attenuverter to change a rising voltage to a falling voltage
- Make the note pitch vibrate as well as rise and fall
  - HINT: Mixer
- Extra: add another VCO and mix the two VCOs together. Try different wave shapes and detuning one oscillator

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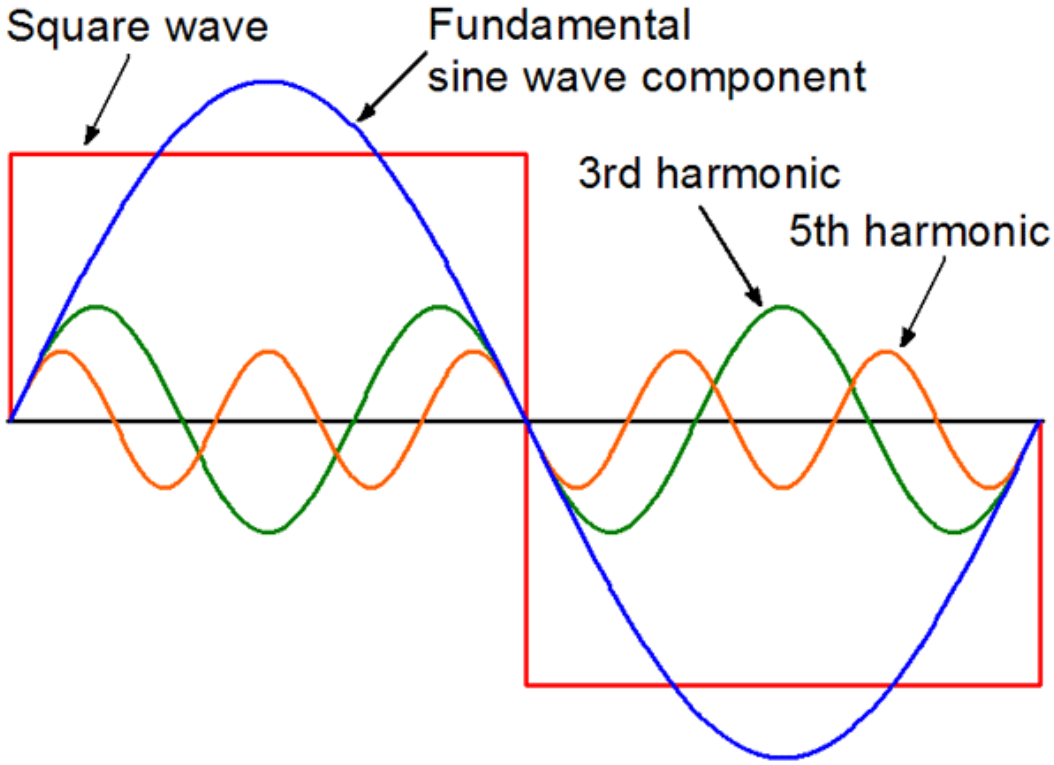
Harmonics



Filters

VCF - Voltage Controlled Filter

- Include a VCF in the audio signal chain to filter the sound present
- Normally based on selecting a particular range of frequencies from the input
- Often add other colour like resonance and distortion effects
- People got a bit nuts about filters
  - Have been described as “the heart” of a synthesiser
- Footnote: The approach of starting with a rich waveform and then applying a filter is called *subtractive synthesis*

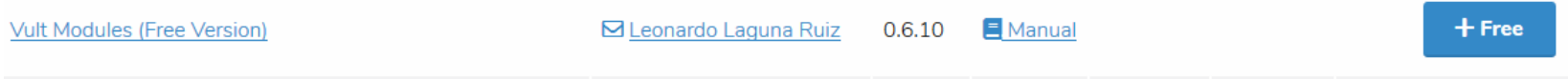
VCV Rack Filters

- VCV Rack has Fundamental -> VCO
- Bad news:
  - It’s a terribly boring filter
- Good news:
  - VCV Rack is richly supported with 3rd party plug-ins, including better filters

Add the Vult plugin

- We're going to use the *Unstabile* filter from the *Vult* plugin
- Login to VCV Rack, then click the *Manage Plugins* button

- This will open a web page listing plugins available
- Scroll down and click the button on *Vult Modules (Free Version)*



- Go back to VCV Rack and click *Update Plugins* to download the new modules
- Restart VCV Rack

Unstabile

- Add the filter from Vult-Free -> Unstabile

Cutoff frequency for the filter

Add resonance through the filter

Controls the signal level. Under-driving and over-driving can give interesting distortions

Low Pass Out

Band Pass Out

Signal In

Cutoff CV in and CV attenuverter

Resonance CV in and attenuverter

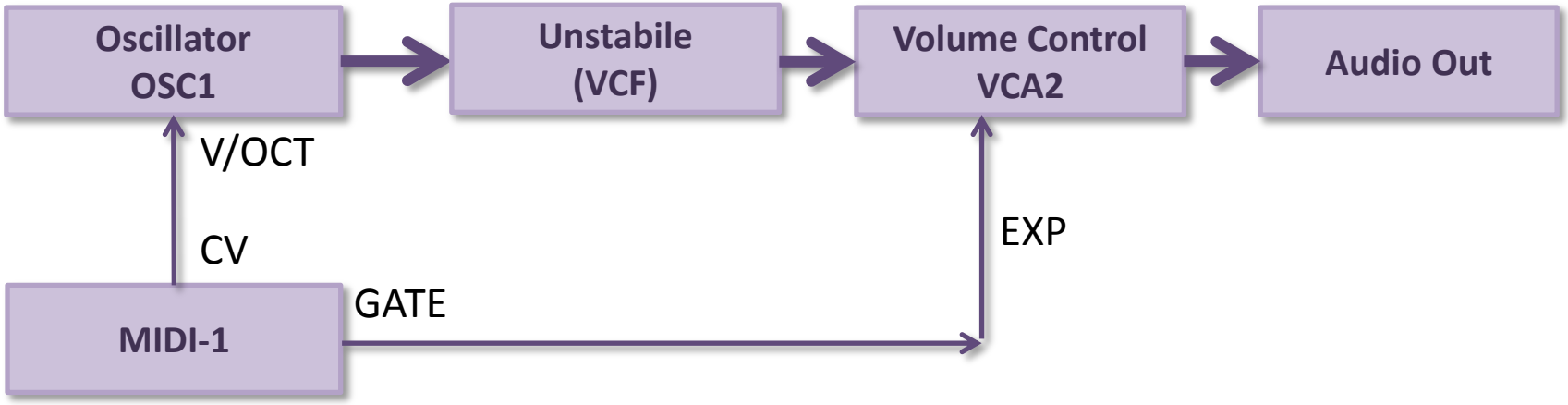
Drive CV in and attenuverter

Semblance out and control – variable between LP and HP

High Pass Out

Chaining the filter in the audio signal

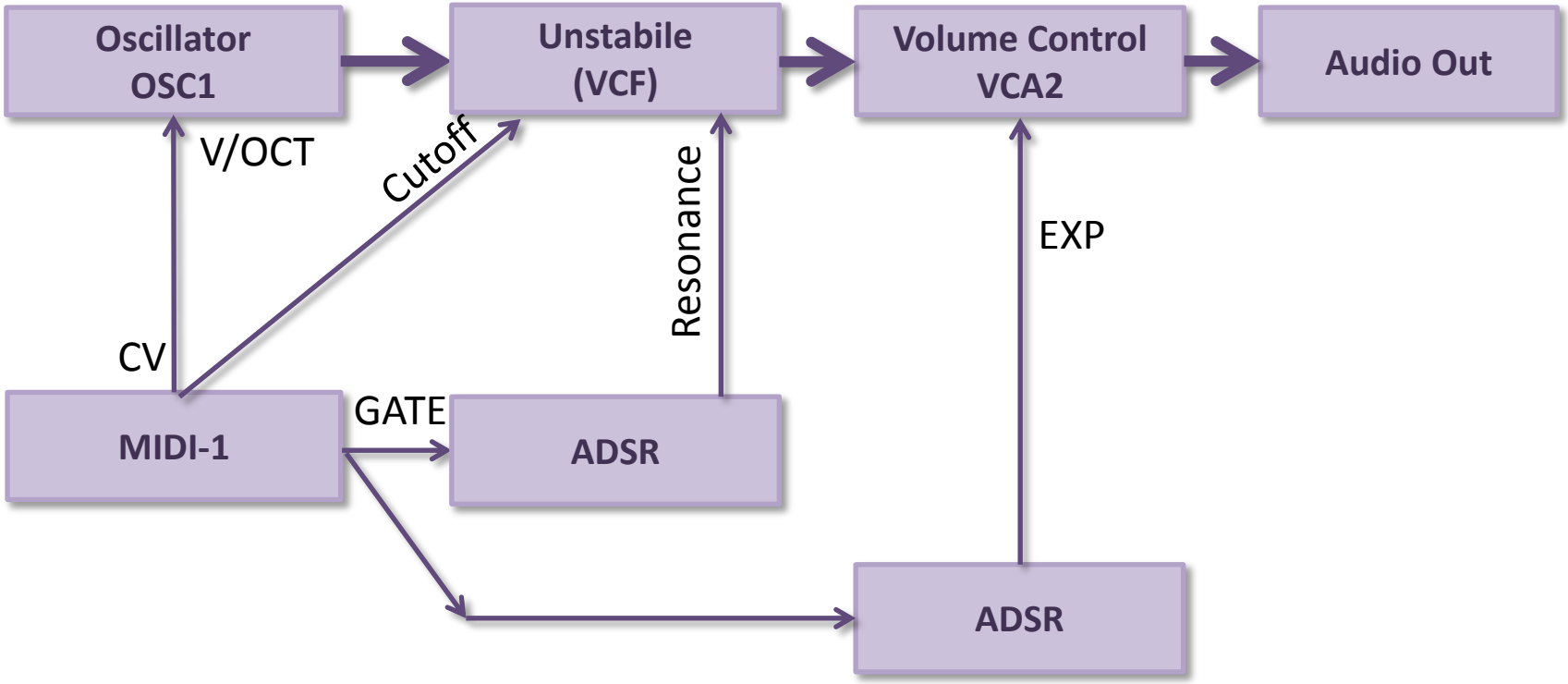
Basic Chain



Uses for filter CVs

- Cutoff tracking
  - Because the filter works on the sounds harmonics to have similar sounds for different pitch notes the cutoff should vary depending on the pith of the note
  - Normally achieved by linking the cutoff CV to the CV controlling the source oscillator pitch
- Peaking the resonance or the drive at the start of the note creates interesting effects
  - e.g. using an ADSR

More Advanced Chain



subtractive.vcv

Some (fun) challenges

- Make:
  - A flute
  - A trombone
  - A piano (v. difficult!)
  - A space zapper
  - R2D2
  - Bagpipes
  - A church organ

More to explore

- Delay effects
- Sample and Hold
- Ring modulators, wave folders and the West Coast Synth concepts
- Randomness
- Generative sequences
  (try Stellare Turing Machine module – needs manual install)
- Polyphony
  (try Gratix plugin)
- Drums and percussion
- Macro Modules
  (try Audible Instruments plugin)

The EMF Chord