Quadrant

A partly echoing, partly arpeggiating, possibly warped synth
for the ArduTouch / SEC-T 0x10sion Music Synthesizer Bagde.

How to use:

-------- Presets --------

There are lots of way cool presets!

A list of all Presets can be seen on page 8 of this document.

Load preset sounds by *Double-Tapping* the Right Button and then pressing any bottom-row touch-key.

Note: A list of all types of Button presses this synth uses, including "*Double-Tapping*" can be seen on page 8 of this document.

Once you choose a preset, play notes on the keyboard and twiddle the knobs while playing and see what beautiful and also warped sounds and music you can create!

If you want to have more control over lots of cool and warped sounds available with the Quadrant synth, the following pages will explain how.

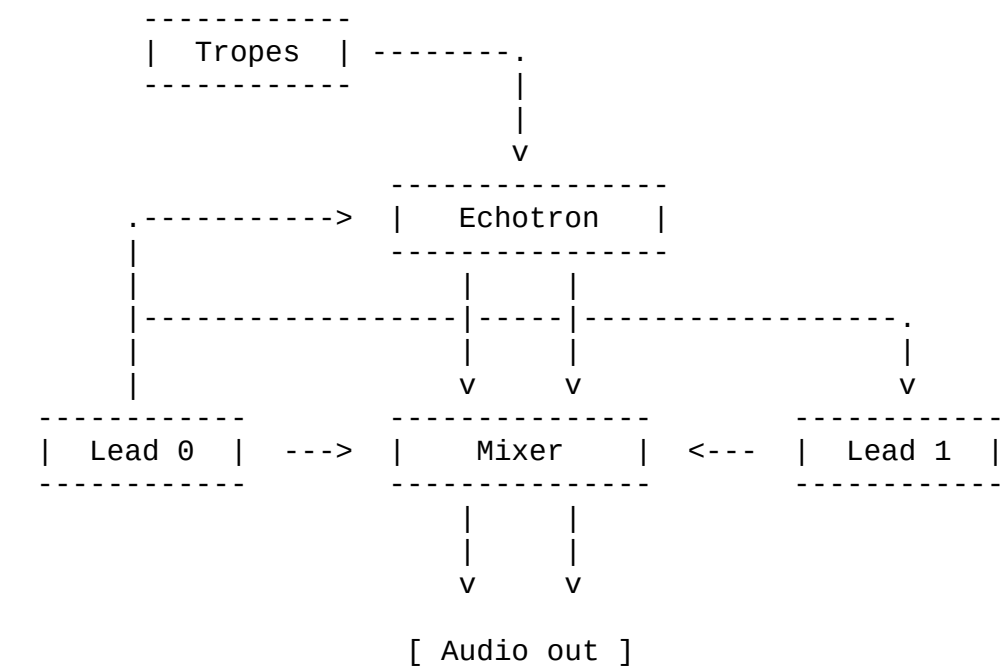
-------- A Note on the User Interface --------

You will be annoyed at the User Interface for this synth. Sorry about that. The reason that it is so annoying is that there are so few Input/Output pins available on the microcontroller. There were only enough I/O pins for 2 LED indicators, 2 Buttons, and 4 Pots.

I had to come up with a way to control all of the functionality of the Quadrant synth with only the above inputs and outputs. The result is not ideal. Yet, with some practice, you will find that your Quadrant synth is quite usable as a really nice performing musical instrument.

FYI: I chose this microcontroller to be the same as the one used in an Arduino Uno: ATmega328. This was so that the project would be easy to use for beginners, easy to learn for beginners, easy to hack, and also as inexpensive as possible.

==== Audio/Control Flow Diagram for the Quadrant Synth ====

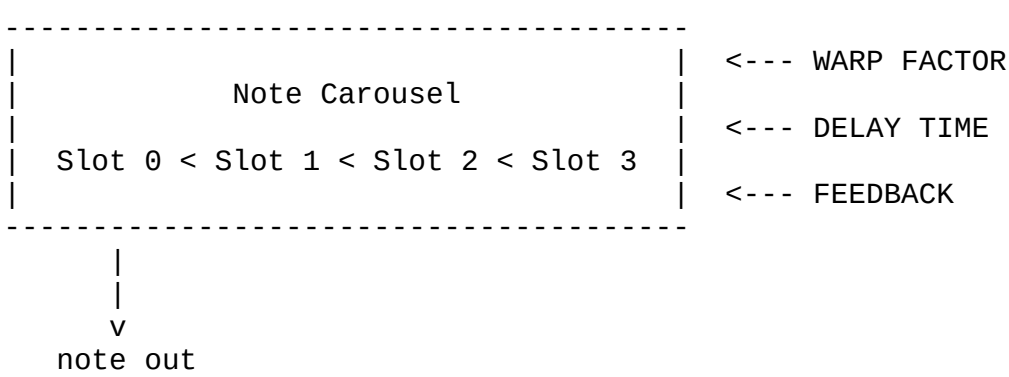


Lead 0 is duplicated in the opposite audio channel by Lead 1 (which may be transposed and/or detuned from Lead 0). The note information for Lead 0 is also fed into the Echotron. At the same time, a "trope" (an arpeggiation pattern) can be applied to the echoed note. The output from the Echotron is internally panned in stereo and then fed into a mixer along with the audio output from Lead 0 and Lead 1.

==== The Echotron Unit ====

The Echotron is a stereo synthesizer in its own right.

At the heart of the Echotron is a carousel of "slots", each of which holds an instance of an echoing note:



The carousel is constantly "revolving", outputting the note held in the current slot (the left-most slot in the above diagram), then shifting the slots.

The speed at which the carousel revolves is controlled by the DELAY TIME.

Each time a note echoes its volume will decrease by an amount controlled by the FEEDBACK setting. If FEEDBACK is set to its highest value (255) then the note will echo forever, or until all the slots in the carousel have been used up, and a new incoming note "overwrites" it.

Each time a note echoes its pitch can be raised or lowered by the current WARP FACTOR.

The number of slots in the carousel is configurable and can be set interactively via the Parameter Menu (see below) to between 1 and 4.

----- Tropes ------

The above description of the note carousel is a simplification. In fact, each slot can contain not just a note, but also a pointer to a "trope" (an arpeggiation pattern) in ROM. Each time the carousel revolves it will play the next note in the arpeggiation pattern for that slot.

----- Note HOLD ------

You can instruct the Echotron to HOLD the next note played (see the Parameter Menu below). When a note is on HOLD it will not decrease in volume as it echoes, and it will not be overwritten by incoming notes when the carousel is full. This is a very useful feature for setting up a constant bass pulse and jamming over it. Better yet, if a trope is active when you hold the note, then you can set up a whole bass line or texture to be played over. And you can hold more than one note :)

----- SAMPLE & HOLD ------

You can globally freeze whatever sound loop the Echotron is producing by enabling SAMPLE & HOLD (toggled via the Parameter Menu, see below). Then you can jam over it freely.

----- ISO-TEMPO -------

This feature allows the Echotron to maintain a constant tempo, regardless of the number of notes in the carousel. So if there are 4 notes currently echoing in the carousel and ISO-TEMPO is on, then the delay time will be 1/4 of what it would be if there were only 1 note in the carousel. The "Telepromt" and "Frara Jaqua" presets use ISO-TEMPO. You can toggle ISO_TEMPO via the Parameter Menu (see below). (NOTE: The "Frara Jaqua" preset is not available on the Synth Badge.)

----- ENVELOPE ------

A master envelope dynamically controls the amplitude of the notes produced by the Echotron. This envelope is a traditional ADSR (Attack/Decay/Sustain/Release) but with a twist: a *Sustain Time* parameter is added. When the envelope for an echoing note reaches the sustain stage it will automatically release after the amount of time specified by the sustain time parameter. The various stages of the master envelope can be controlled via the Pots (see below).

----- PULSE WIDTH ------

The notes produced by the Echotron use square wave oscillators. The PULSE WIDTH of these oscillators can be modified via a Pot (see below). The pulse width controls the ratio between the positive and negative edges of the square wave and can radically alter the timbre of the tones.

----- AUTO-WAH ------

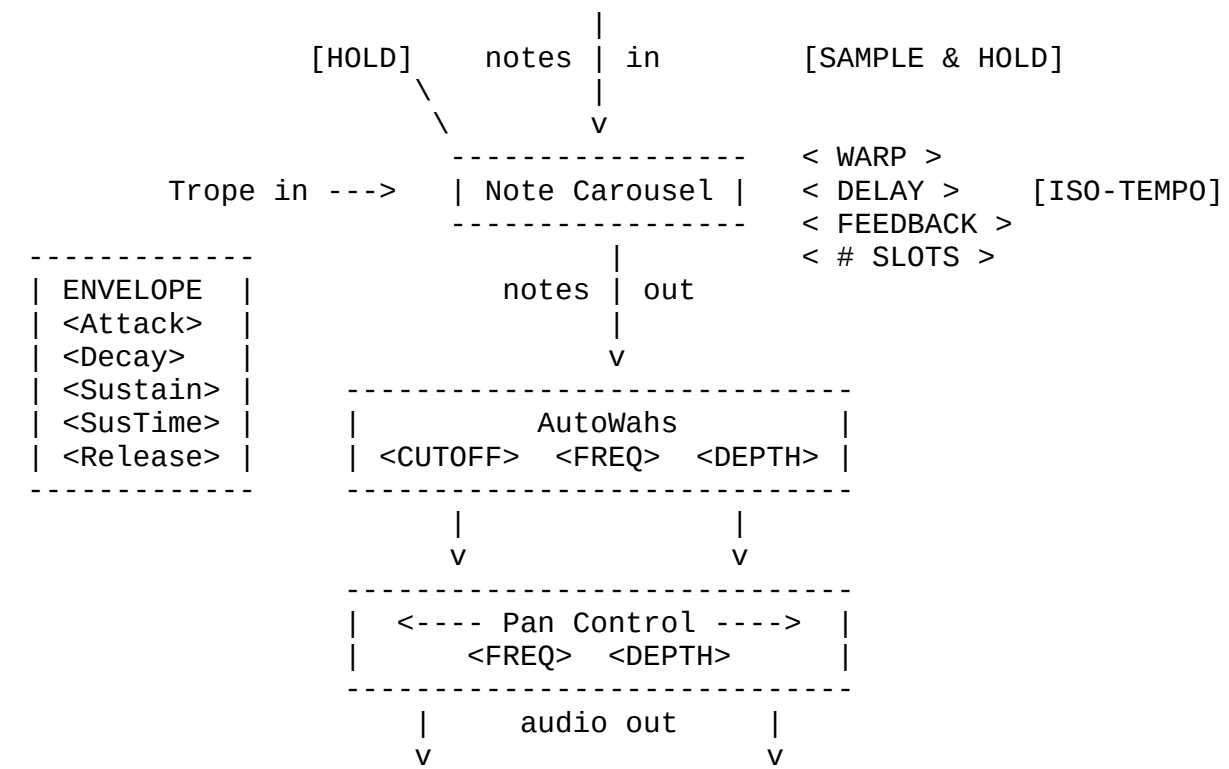
The Echotron has a pair of internal autowahs (oscillating low-pass filters) which are applied to the note output before it is panned. Three parameters control the autowah behaviour: CUTOFF frequency, oscillation FREQ, and oscillation DEPTH. All of these can be modified via the Pots (see below).

----- PAN CONTROL ------

A PAN control dynamically rotates the note output in the stereo field. The DEPTH and FREQ of the panning can be controlled via the Pots (see below).

==== Overview Diagram of the Echotron ====

Now that we have covered each component, here is an overall view:



==== PLAYING THE KEYBOARD ====

The Quadrant keyboard is a mono-touch instrument: you can play one note at a time.

To raise the keyboard by an octave, *Tap* the Right Button once.
To lower the keyboard by an octave, *Tap* the Left Button once.

==== USING THE POTS TO CONTROL PARAMETERS ====

The four Pots can be used to control 18 different parameters. You can choose four parameters to control with the Left and Right Buttons.

By *Pressing* (not *Tapping*) the Left and Right Buttons you can change which four parameters the Pots control. Each time a Button is *Pressed*, its associated LED (Red LED for Left Button, Blue LED for Right Button) will change state (from OFF to ON to BLINKING, back to OFF etc.)

Below is a chart showing which four parameters the Pots control when the LEDs are in a given state:

Red LED	Blue LED	Top POT	Bottom POT	Adjust A POT	Adjust B POT
OFF	OFF	echo WARP	echo DELAY time	autowah FREQ	autowah DEPTH
ON	OFF	echo FEEDBACK	lead/echo BALANCE	autowah CUTOFF	echo PULSE WIDTH
BLINK	OFF	panning FREQ	panning DEPTH	lead 1 DETUNE**	lead 1 TRANSPOSE***
OFF	ON	autowah FREQ	autowah DEPTH	envelope ATTACK*	envelope DECAY*
ON	ON	autowah CUTOFF	echo PULSE WIDTH	envelope SUSTAIN*	envelope RELEASE*
BLINK	ON	lead 1 DETUNE**	lead 1 TRANSPOSE***	echo SUSTIME	lead PORTAMENTO
OFF	BLINK	envelope ATTACK*	envelope DECAY*	--	--
ON	BLINK	envelope SUSTAIN*	envelope RELEASE*	--	--
BLINK	BLINK	echo SUSTIME	lead PORTAMENTO	(weirdness)	--

* these Pots can be configured via the Parameter Menu (see next section) to control:
1) only the LEAD voices
2) only the ECHO voices
3) both the LEAD and ECHO voices

** detunes lead1 from lead 0

*** transposes lead1 from lead0 (range is from -2 to +2 octaves)

==== USING THE PARAMETER MENU ====

You can control additional parameters by using the Parameter Menu.

To access the Parameter Menu *Double-Tap* the Left Button. The LEDs will now start blinking on and off in alternation: this tells you that the Parameter Menu is active. When the Parameter Menu is active the keys will no longer play notes but each key will select and modify a particular parameter as described below. Depending on the parameter, the Pot positions may also be relevant, as described below. The Parameter Menu is active until you press a key on the touch-keyboard: then the parameter associated with that key is modified, and the Parameter Menu is automatically exited (restoring the prior user interface state).

You can exit the Parameter Menu without modifying any parameters by *Double-Tapping* the Left Button a second time.

The list below describes what actions are taken when a key is pressed:

Key	Action
C	toggle Sample-and-Hold on/off
C#	turn Sample-and-Hold off, and unhold all held notes
D	hold next note played
D#	[reserved]
E	toggle lead voices on/off
F	set # of slots in carousel based on Top Pot position *
F#	toggle isoTempo or/off
G	select trope based on Bottom Pot position **
G#	[reserved]
A	ADSR Pots control envelopes of both lead and echo voices ***
A#	ADSR Pots control envelopes of lead voices only ***
B	ADSR Pots control envelopes of echo voices only ***

* turn Top Pot 0 to desired position (all the way left = 1, all the way right = 4) then press F

** turn Bottom Pot to desired position (all the way left = "no trope") then press G

*** A, A#, and B are not available on the SEC-T Synth Badge

==== GUIDE TO QUADRANT'S PRESETS ====

The default patch is active when powered on, and after *Tapping* the Reset Button.

Load presets by *Double-Tapping* the Right Button and then pressing any bottom-row touch-key.

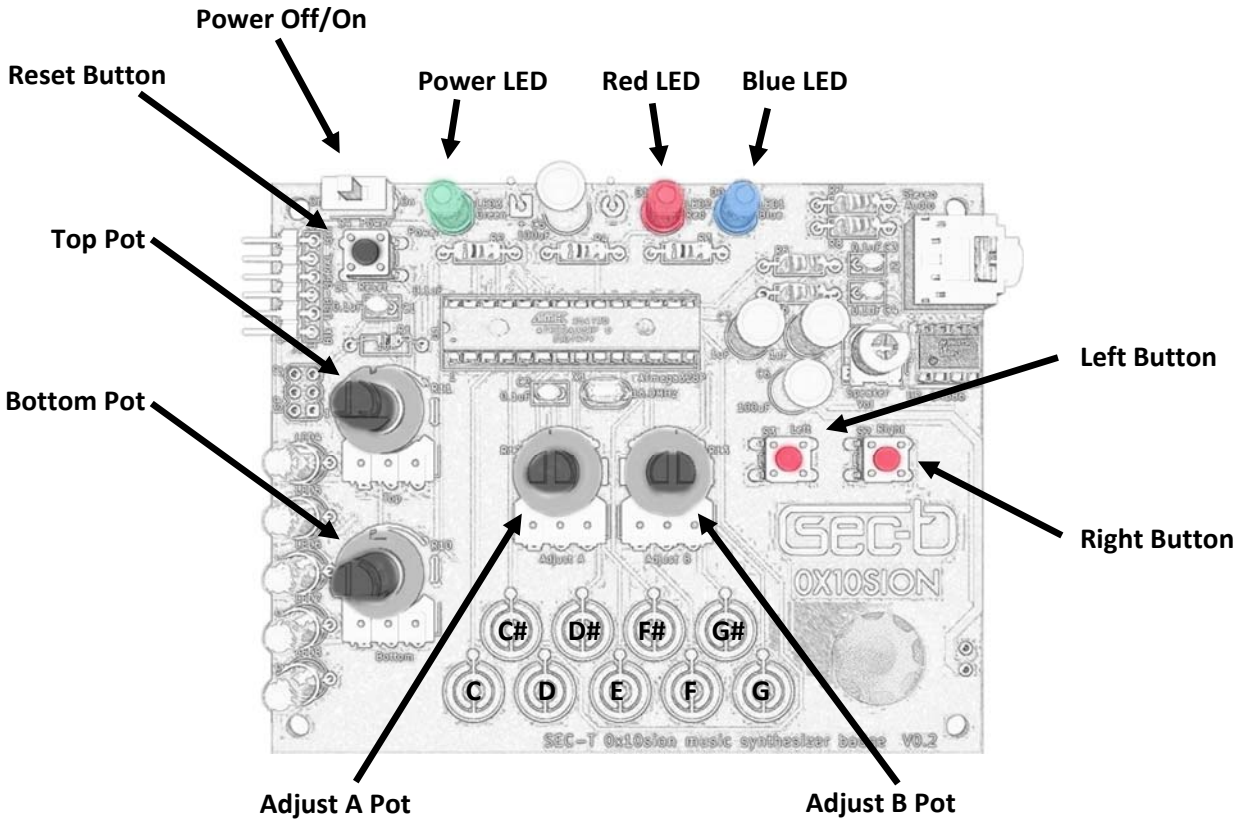
The presets are as follows:

Key	Name	Performance Notes
C	Scaffold	lead voices off (and should stay off)
D	Farsy	
E	Teleprompt	lead voices off (turn them on once 2 slots are playing)
F	Glacial	play very slowly
G	Blur	
A	ToneJack	*
B	FraraJaqua	lead voices off (turn them on once 4 slots are playing) *

* ToneJack and FraraJaqua are not available on the SEC-T Synth Badge

Types of Button presses:

Tap:	quickly tap a Button
Press:	long-press a Button
Double-Tap:	quickly double-tap a Button



About Quadrant's Tuning

When you start playing notes on the keyboard you will probably notice that the 'C' key plays an 'F'. And if you have a really good ear you may also notice that the interval between C# and G# is not exactly a 5th.

Why is this?

To explain the 2nd observation first, Quadrant uses Harmonic Tuning (also known as Just Temperament or "Helmholtz's scale") instead of the usual Equal Temperament (which is the system default).

Harmonic Tuning is actually more "natural" than Equal Temperament (which was created as a compromise so that keyboard instruments could play in all keys). In Harmonic Tuning the relative frequencies of all notes compared to the tonic ('C' in our case) are rational numbers:

Unison	1/1
Minor Second	25/24
Major Second	9/8
Minor Third	6/5
Major Third	5/4
Fourth	4/3
Diminish 5th	45/32
Fifth	3/2
Minor Sixth	8/5
Major Sixth	5/3
Minor Seventh	9/5
Major Seventh	15/8
Octave	2/1

The Echotron uses *quantum square wave oscillators* which can only be set to frequencies which have integral wavelengths. The frequencies produced by these oscillators conform more closely to a scale in Harmonic Tuning than one in Equal Temperament.

But why does the 'C' key play an 'F'?

The short answer is that on the ArduTouch, whose audio rate is ~15.6 kHz, 'F' (in octave 1) has a period of 360 samples. 360 is a number favored by the ancients because it is divisible by a large number of integers: 1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, etc. It so happens that by using a tonic frequency whose period is 360, we are able to use quantum oscillators to closely approximate the Harmonic Tuning scale over several octaves. Low 'F', so to speak, is the natural tonic frequency of the ArduTouch.*

Since Quadrant's tuning is only an approximation to an 'F' Harmonic tuning, certain musical scales (such as E Major, F# Major on the ArduTouch keyboard) will sound a bit sour. C Major / D Minor work best.

* Actually, on the ArduTouch a waveform with a period of 360 samples generates a tone with a frequency of 43.578 Hz. In the equal temperament scale, 'F' in octave 1 has a frequency of 43.654 Hz.