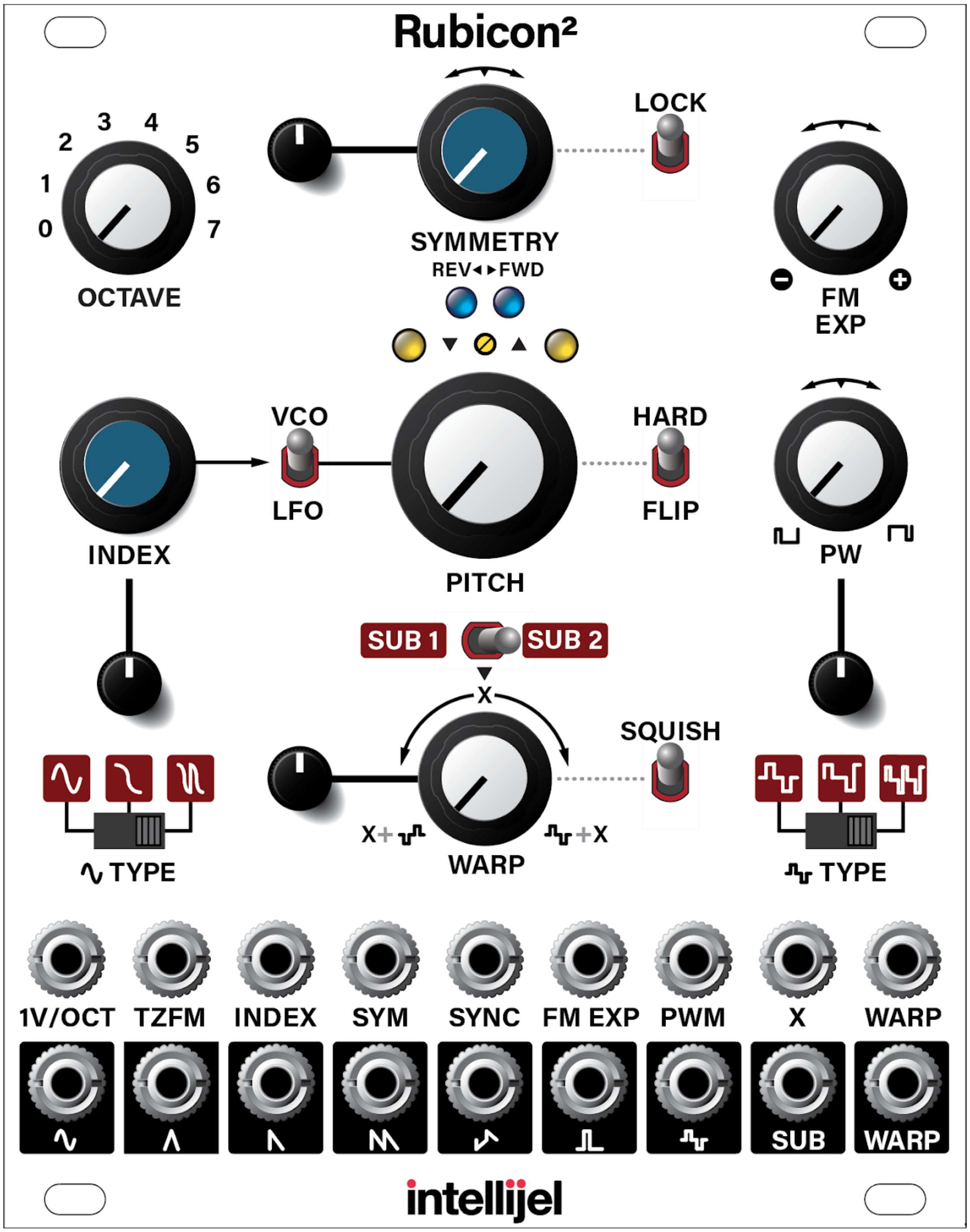
Rubicon²

Thru-Zero Discrete Triangle Core VCO



Manual Revision: 2018.09.13

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Compliance

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by Intellijel Designs, Inc. could void the user's authority to operate the equipment.

Any digital equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.

This device meets the requirements of the following standards and directives:

EMC: 2014/30/EU
EN55032:2015 ; EN55103-2:2009 (EN55024) ; EN61000-3-2 ; EN61000-3-3

Low Voltage: 2014/35/EU
EN 60065:2002+A1:2006+A11:2008+A2:2010+A12:2011

RoHS2: 2011/65/EU

WEEE: 2012/19/EU

Installation

Intellijel Eurorack modules are designed to be used with a Eurorack-compatible case and power supply. We recommend you use Intellijel cases and power supplies.

Before installing a new module in your case, you must ensure your power supply has a free power header and sufficient available capacity to power the module:

- Sum up the specified +12V current draw for all modules, including the new one. Do the same for the -12 V and +5V current draw. The current draw will be specified in the manufacturer's technical specifications for each module.
- Compare each of the sums to specifications for your case's power supply.
- Only proceed with installation if none of the values exceeds the power supply's specifications. Otherwise you must remove modules to free up capacity or upgrade your power supply.

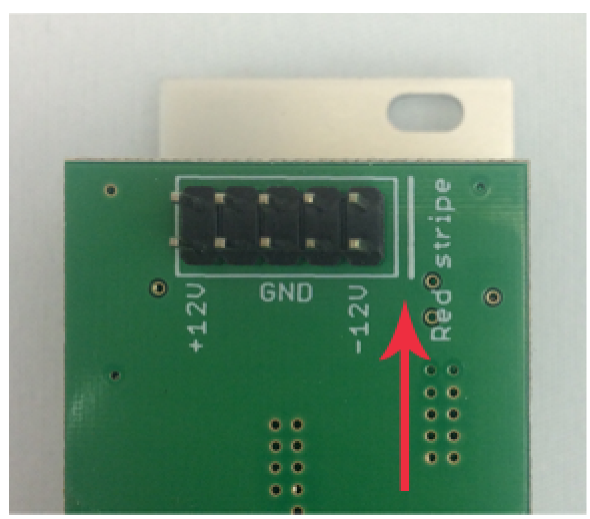
You will also need to ensure your case has enough free space (hp) to fit the new module. To prevent screws or other debris from falling into the case and shorting any electrical contacts, not leave gaps between adjacent modules, and cover all unused areas with blank panels. Similarly, do not use open frames or any other enclosure that exposes the backside of any module or the power distribution board.

You can use a tool like ModularGrid to assist in your planning. Failure to adequately power your modules may result in damage to your modules or power supply. If you are unsure, please contact us before proceeding.

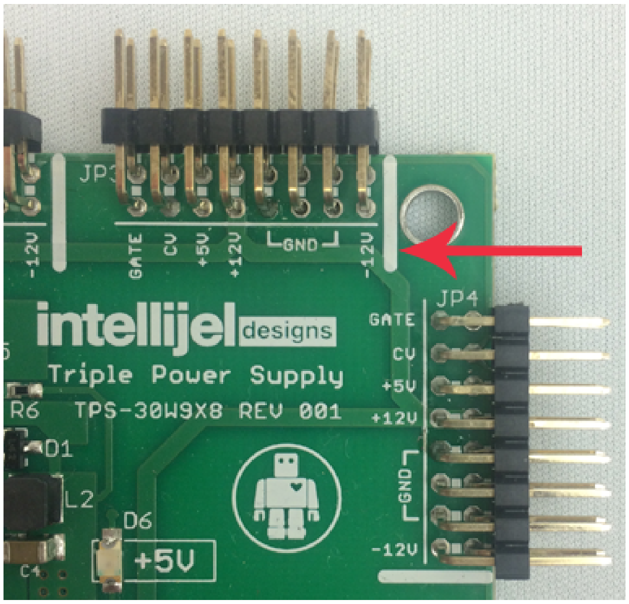
Installing Your Module

When installing or removing a module from your case always turn off the power to the case and disconnect the power cable. Failure to do so may result in serious injury or equipment damage.

Ensure the 10-pin connector on the power cable is connected correctly to the module before proceeding. The red stripe on the cable must line up with the -12V pins on the module's power connector. The pins are indicated with the label -12V, a white stripe next to the connector, the words "red stripe", or some combination of those indicators.



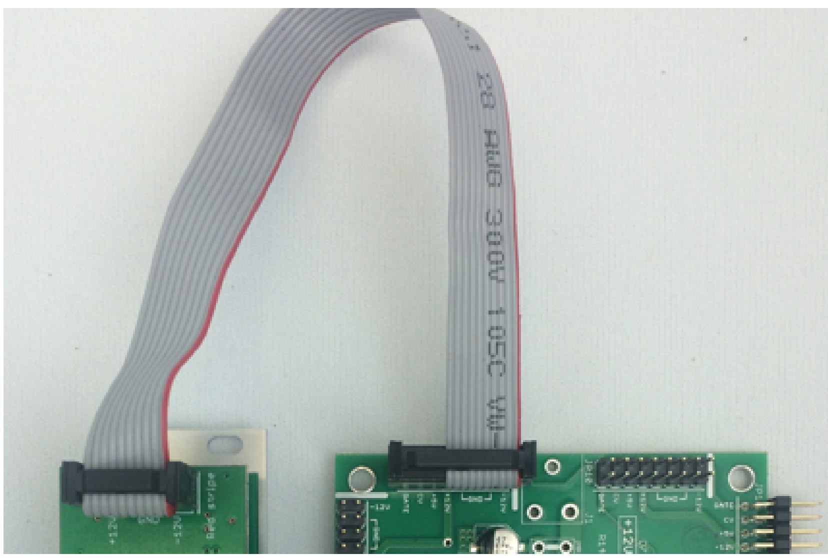
Most modules will come with the cable already connected but it is good to double check the orientation. Be aware that some modules may have headers that serve other purposes so ensure the cable is connected to the right one.



The other end of the cable, with a 16-pin connector, connects to the power bus board of your Eurorack case. Ensure the red stripe on the cable lines up with the -12V pins on the bus board. On Intellijel power supplies the pins are labelled with the label “-12V” and a thick white stripe:

If you are using another manufacturer’s power supply, check their documentation for instructions.

Once connected, the cabling between the module and power supply should resemble the picture below:



Before reconnecting power and turning on your modular system, double check that the ribbon cable is fully seated on both ends and that all the pins are correctly aligned. If the pins are misaligned in any direction or the ribbon is backwards you can cause damage to your module, power supply, or other modules.

After you have confirmed all the connections, you can reconnect the power cable and turn on your modular system. You should immediately check that all your modules have powered on and are functioning correctly. If you notice any anomalies, turn your system off right away and check your cabling again for mistakes.

Overview

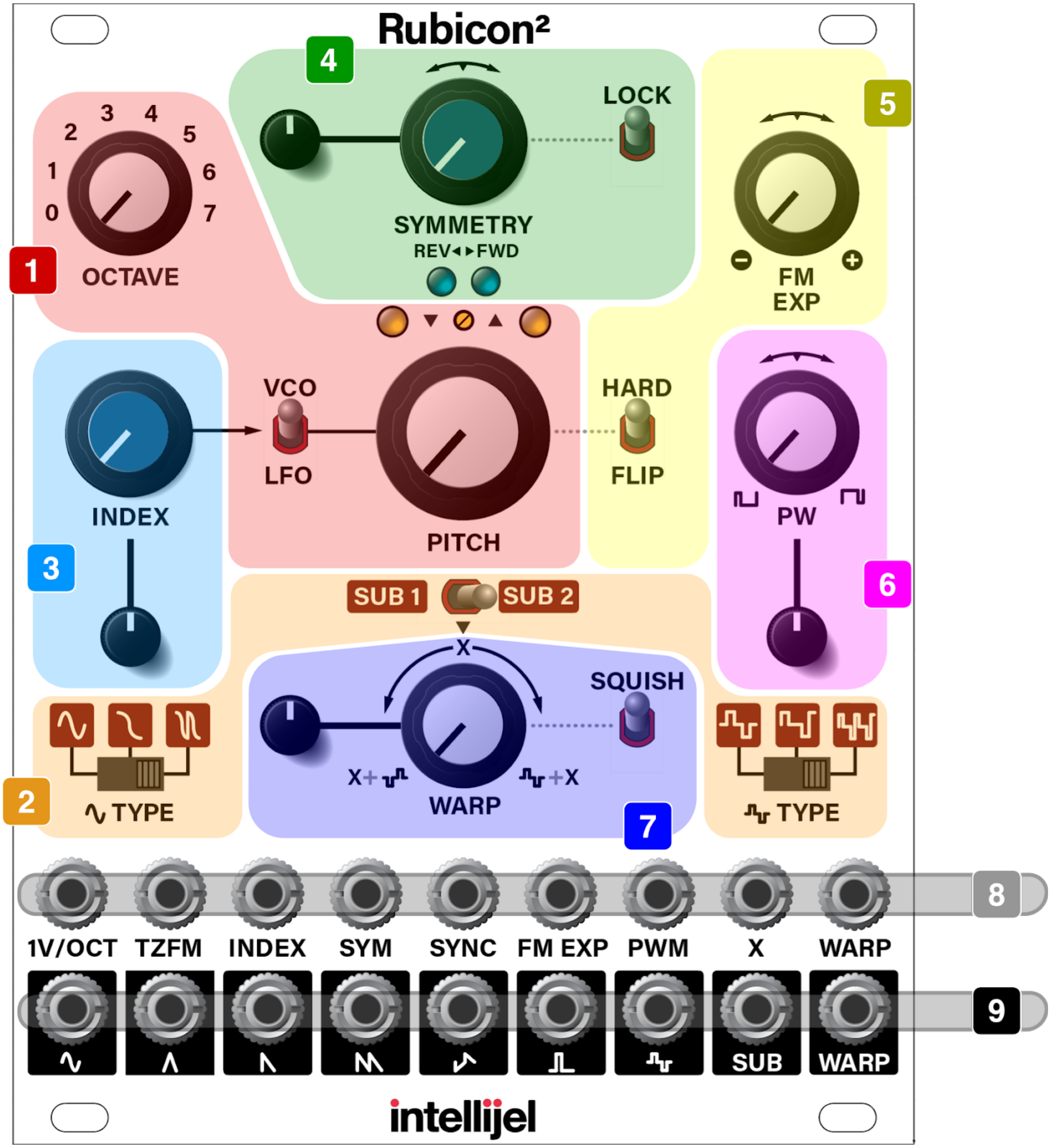
Rubicon^2 is the second generation of the classic Rubicon triangle core analog VCO, designed in collaboration with David G. Dixon.

It features nine simultaneously available waveshape outputs; two sub-oscillators; three variations of a sine wave; a new Tri-State pulse circuit; exponential Frequency Modulation (FM); linear FM; hard and soft (flip) sync; pulse width modulation; CV control of FM index; a new foldable Warp circuit; and the ability to perform perfectly-symmetrical Thru-zero FM with absolutely no change in pitch or tracking accuracy.

This is not a ‘set it and forget it’ oscillator. It’s an oscillator that demands to be tweaked, modulated and explored. It’s an oscillator that’s proudly analog and eschews all shortcuts. As such, it’s an oscillator that rewards its owner with sounds as boundless as their creative limits allow.

For these reasons, we strongly encourage you to do the unthinkable and actually ***read*** this manual. It’s divided into two major sections: A detailed exploration of its numerous knobs, switches and jacks; and a reference section that explores in detail some of the concepts and methodologies behind the Rubicon^2. The more you understand the Rubicon^2, the more you’ll unlock its multifaceted capabilities, and the more you’ll be tempted to explore its depths.

Front Panel


Rubicon²
4
LOCK
SYMMETRY
REV◂▸FWD
5
FM
EXP
1
OCTAVE
0
1
2
3
4
5
6
7
VCO
LFO
PITCH
HARD
FLIP
INDEX
3
PW
6
SUB 1
SUB 2
X
SQUISH
TYPE
2
X+
+X
WARP
7
TYPE
8
1V/OCT
TZFM
INDEX
SYM
SYNC
FM EXP
PWM
X
WARP
9
SUB
WARP
intellijel

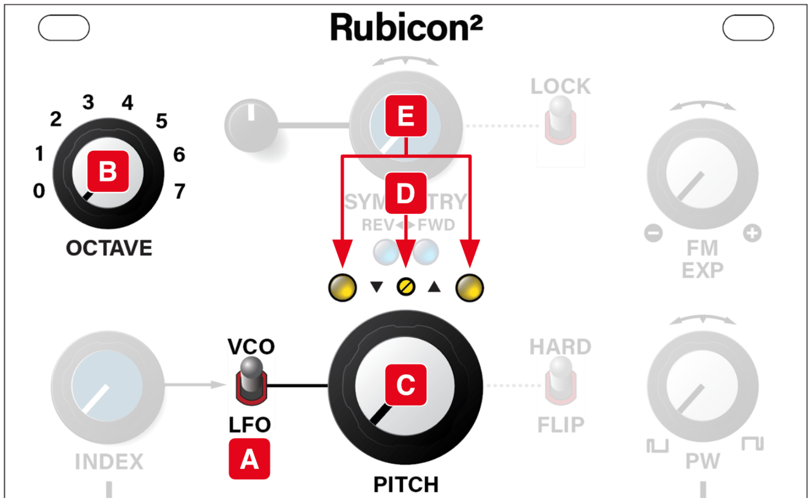
Panel Overview

Rubicon^2 is a deep and flexible analog oscillator, with numerous controls and jacks working in tandem to alter the pitch, waveform and harmonic spectrum in many unique ways. To understand all its features and how they affect the sound, it might be easiest to divide the various controls into sub-sections, and discuss them accordingly.

As you can see from the previous illustration, we have subdivided Rubicon^2's front panel into nine different sections, which are:

1. **Pitch Controls** - Included in these controls are a VCO/LFO switch for switching between audio and LFO rates; an Octave Select switch; a PITCH knob (for fine tuning); an OFFSET trimpot (for adjusting the oscillator's base frequency), and a pair of waveform polarity LEDs.
2. **Wave Type Switches** - These three switches modify waveforms in one way or another. The SINE TYPE switch on the left changes the shape and octave of the sine wave; the SUB switch in the middle selects whether the sub oscillator operates one or two octaves below the main VCO; and the PULSE TYPE switch on the right changes the trigger point and octave of both the pulse and tri-state pulse waves.
3. **FM Index Controls** - This knob and its corresponding attenuator alter the FM INDEX (i.e the depth of Frequency Modulation) for the TZFM input.
4. **Symmetry Controls** - These controls set the direction and magnitude of the waveform through the linear FM circuit.
5. **Misc Controls** - This section offers more timbral manipulation in the form of two additional circuits: one for exponential FM and another for oscillator sync.
6. **Pulse Width Modulation Controls** - This knob and its corresponding attenuverter alter the width of any pulse waves generated by the Rubicon^2.
7. **Warp Controls** - Controls the amount and direction by which the sub oscillator (or any other signal plugged into the **X IN** jack) is warped by the tri-state pulse. An additional **SQUISH** circuit limits and folds the output waveform — the sonic characteristics of which are set with a rear-panel trimpot.
8. **Input Jacks** - This row of input jacks is for connecting audio sources and/or control voltages into the Rubicon^2.
9. **Output Jacks** - This row of output jacks allows you to access all the various waveform types generated by the Rubicon^2.

Pitch Controls



A. **VCO/LFO switch -** This switch changes whether the Rubicon² operates as a low frequency oscillator (**LFO**) or as an audio oscillator (**VCO**). In **VCO** mode the oscillator runs at audio rates with frequencies between 8 Hz and 20 kHz (depending on the position of the **OCTAVE** knob, **SYMMETRY**, and CV inputs). In **LFO** mode, the Rubicon² oscillates at 1/100 the frequency of VCO mode, allowing for cycles as slow as 12+ seconds.

B. **OCTAVE knob** - This eight-position knob sets the coarse tuning of the oscillator. Each position shifts the tuning by one octave. Use the corresponding **PITCH knob** to make fine tuning adjustments within the selected octave.

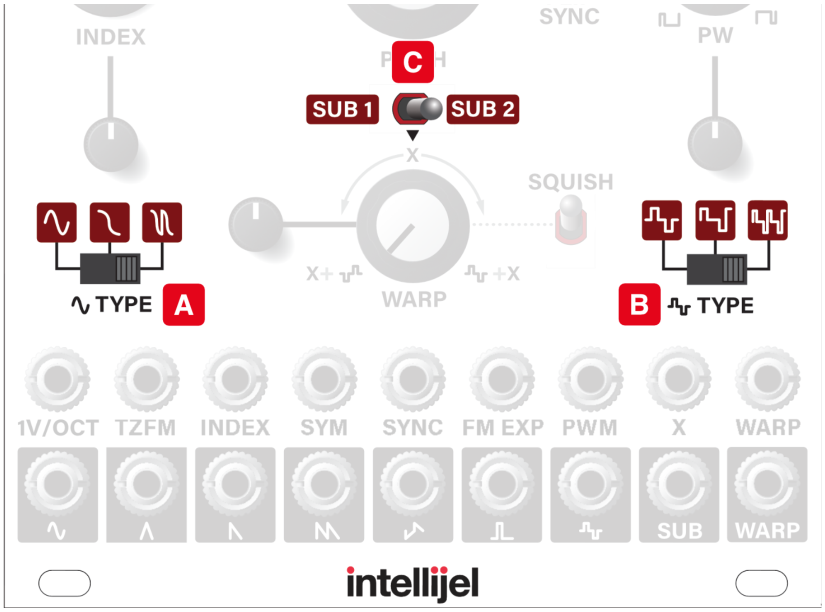
C. **PITCH knob** - Allows finer frequency adjustment over a range of +/- six semitones.

D. **PITCH OFFSET trimpot -** Adjusts the oscillator's base frequency, which in turn defines the actual frequency range produced by each **OCTAVE knob** setting and by the **PITCH knob**.

   For example, if you want the Rubicon² to produce a C note when the pitch knob is at noon, simply set the **PITCH knob** to noon, patch the sine wave output into a tuner, and adjust the trim pot slightly until the tuner reads "C." Or maybe you're the type who thinks in "A", and you want the oscillator to output an A note when the **PITCH knob** is at noon. Small tweaks of this trimpot will allow this.

E. **WAVEFORM POLARITY LEDS** - These two LEDs show the polarity of the triangle core waveform. They're particularly useful when Rubicon² operates as an LFO, since they provide a visual indication of the rate.

Wave Type Switches



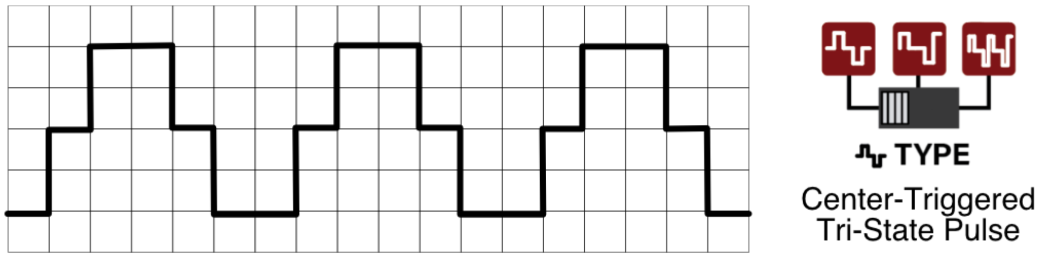
A. **SINE TYPE switch** - Sets the shape of the waveform appearing at the SINE OUT jack. If set to the left, the output is a pure SINE wave. If set to the middle, the output is a SIGMOID. If set to the right, the output is a DOUBLE SIGMOID, which has the effect of doubling the base frequency at the SINE OUT jack.

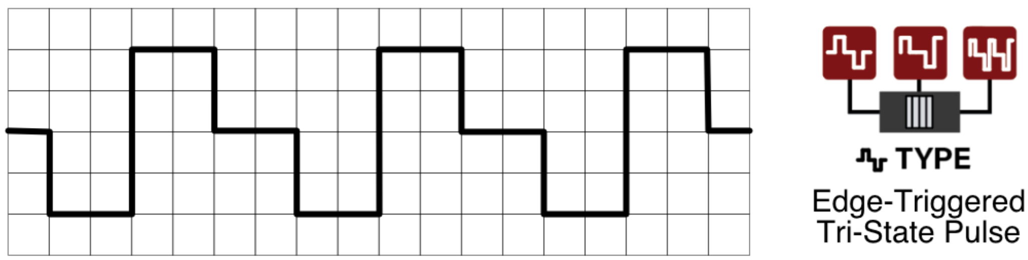
   TECH NOTE: The output of Rubicon^2's sine shaper circuit is what actually appears at the SINE OUT jack. With this switch in the left position, Rubicon^2 feeds a triangle wave into that circuit, resulting in a sine wave. With the switch in either the middle or right positions, Rubicon^2 feeds a sawtooth wave into that circuit, resulting in a sigmoid wave. Sigmoids sound similar to sawtooth waves, only "warmer," and are great for creating metallic sounds.

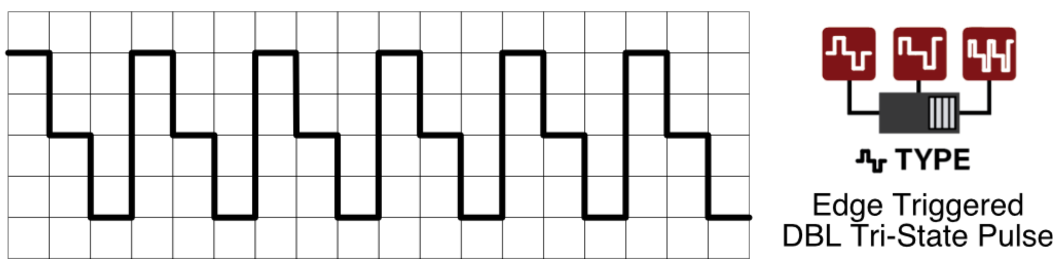
B. **PULSE TYPE switch** - This switch sets whether Rubicon^2 pulse waves are edge-triggered or center-triggered. Specifically, with the switch in the left position, the PULSE and TRI STATE PULSE waves are center-triggered. With the switch in the middle position, these pulse waves are edge-triggered. With the switch to the right, the pulse waves are edge-triggered, but at double the frequency. Note that PULSE TYPE does not affect the SUB oscillator (which is always a square wave), but it does affect the WARP waveform, since the TRI STATE PULSE is a component of the WARP circuit.

   Center-triggering results when you send a triangle wave to the pulse comparator, and edge-triggered pulses result from sending a sawtooth wave to the pulse comparator. The two waveforms are essentially the same, but have different phase relationships, so they sound different when blended or synchronized with other waveforms. In general, edge pulses are better for syncing, but center pulses are perhaps more sonically 'pleasing.' Ultimately, let your ears be the judge.

The following illustration is indicative of how the **PULSE TYPE** switch affects a narrow TRI STATE PULSE.

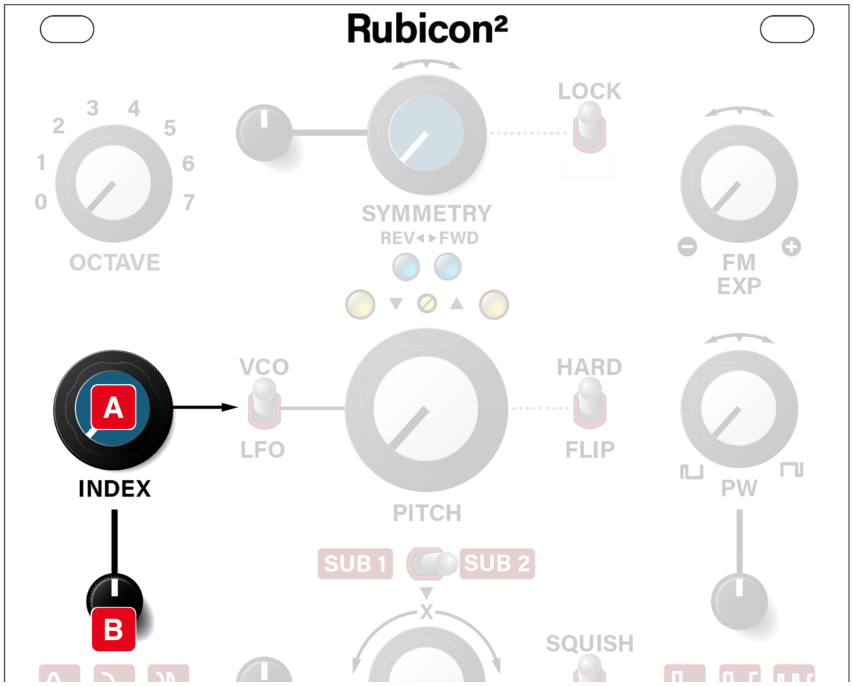






C. **SUB TYPE** - Selects the frequency of the Rubicon² SUB Oscillator. **SUB 1** produces a square wave one octave below the primary oscillator's frequency. **SUB 2** produces a square wave two octaves below the primary oscillator.

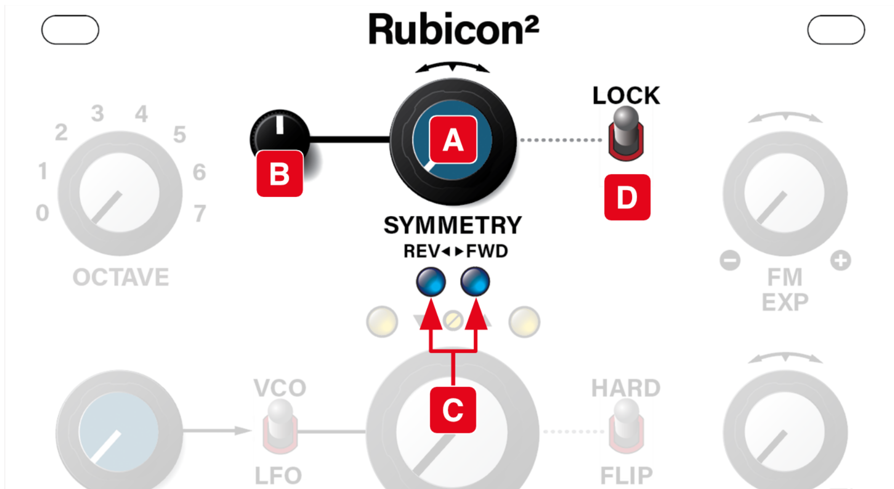
FM Index Controls



A. INDEX knob - Sets the base FM INDEX level, which is the amount that a signal patched into the **TZFM input** will modulate the VCO frequency. At the clockwise position, frequency modulation is at its maximum. At the counterclockwise position, no frequency modulation occurs.

B. INDEX attenuator - You can modulate the INDEX value with a control signal patched into Rubicon²'s **INDEX input**. The **INDEX attenuator** adjusts the extent to which that control signal is added to the value set with the INDEX knob.

Symmetry Controls



A. SYMMETRY knob

Symmetry sets the bias of the oscillator — the center point around which a signal patched into the **TZFM input** varies the output pitch of the oscillator. Basically, when **SYMMETRY** is set to either extreme (fully clockwise or fully counterclockwise), Linear FM is achieved. With **SYMMETRY** at the 12:00 (noon) position, fully symmetrical TZFM is achieved. Intermediate **SYMMETRY** settings result in asymmetrical TZFM (where pitch changes are greater in one direction than another).

Perhaps the best way to understand the sonic differences between Linear FM and Thru Zero FM is to listen. Patch an external LFO into the **TZFM input** and turn up the Rubicon² **INDEX** knob. Set the **SYMMETRY** knob fully clockwise and listen to the Rubicon² **TRIANGLE WAVE** output. The sound you hear is Linear FM. Turn on the **LOCK** switch (which sets Rubicon² to a perfectly symmetrical and pitch-corrected state) and listen to the same Triangle Wave output — the sound you now hear is TZFM. Switch the LOCK switch on/off while varying the frequency of the signal sent to the TZFM input and make note of the timbral differences.

TZFM and symmetry can be somewhat complicated topics to grasp, so anyone who wishes to have a better understanding of the different types of FM, plus TZFM and how SYMMETRY affects it, should read Understanding FM, later in this manual.

*NOTE: Changing the **SYMMETRY** knob changes the base frequency of the oscillator, which also decreases the oscillator's v/oct tracking accuracy (since changing the base frequency alters the performance of the oscillator's high frequency compensation). However, you can still achieve perfectly symmetrical TZFM with accurate v/oct tracking by using the **LOCK** switch, described later.*

B. **SYM attenuator** - You can modulate the SYMMETRY value with a control signal patched into the Rubicon² **SYM input**. The **SYM attenuator** adjusts the extent to which that control signal is added to the value set with the **SYMMETRY knob**.

*NOTE: External CV control of **SYMMETRY** is possible even with the **LOCK** switch turned on (up position).*

C. **REV/FWD LEDs** - These lights indicate whether the oscillator is running in the standard “forward” direction, or if it’s running in reverse. Every time the oscillator switches direction, it’s performing thru-zero FM.

D. **LOCK switch** - This switch enables the Rubicon² to function as a perfectly symmetrical Thru-Zero FM oscillator without significantly changing the oscillator’s output pitch or its v/oct tracking accuracy.

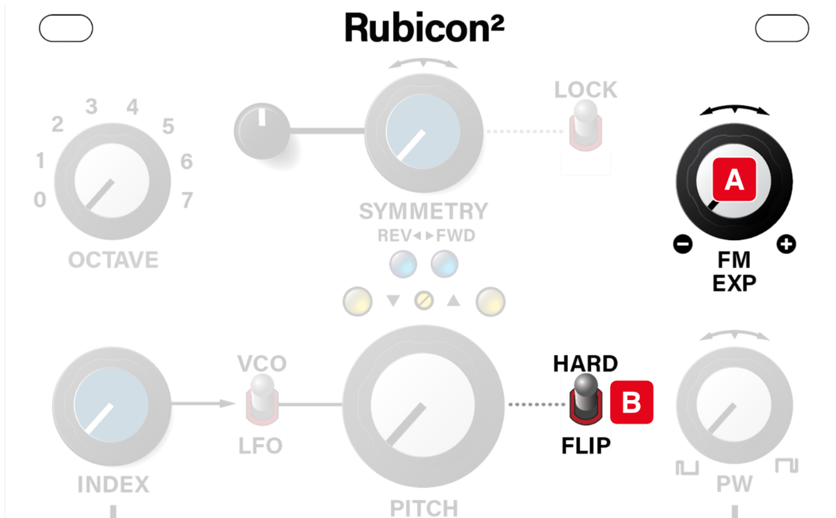
When you switch on **LOCK** (up position), the Rubicon² ignores the position of the **SYMMETRY** knob, internally setting it to a balanced position while simultaneously adding compensation voltage to bring the oscillator back to its original base frequency.

Using the **LOCK** switch, you can directly compare the sound of Linear FM and TZFM without having to re-tune your oscillator or suffer v/oct tracking issues. Specifically, with the **SYMMETRY** knob fully clockwise and the **LOCK** turned off (switch is down), then Rubicon² produces standard Linear FM. If you then turn on **LOCK** (switch is up), it produces Thru-Zero FM (TZFM) at the same frequency as Linear FM.

*NOTE 1: When **LOCK** is on, turning the **SYMMETRY** knob has no effect, however CV control of SYMMETRY is still possible.*

*NOTE 2: At higher frequencies, engaging the **LOCK** switch can have a minor effect on the output pitch. For this reason, you should keep the LOCK switch turned off if you’re not frequency modulating the Rubicon² via its TZFM input.*

Miscellaneous Controls



1. **EXP FM attenuverter -** Sets the attenuation and polarity of the modulator signal patched into the **FM EXP** input.

   With the knob at noon, no exponential FM occurs. When set clockwise from the noon position, Rubicon^2's oscillator *increases* in pitch when it receives positive voltages at the **FM EXP** input. When set counterclockwise from the noon position, the oscillator *decreases* in pitch when a positive voltage appears at the **FM EXP** input. In practical terms, this has no appreciable sonic affect when sending an audio rate oscillation to the **FM EXP** input. However, the difference will be evident if you're feeding the **FX EXP** input with either a slow LFO or a unipolar signal (like an envelope).

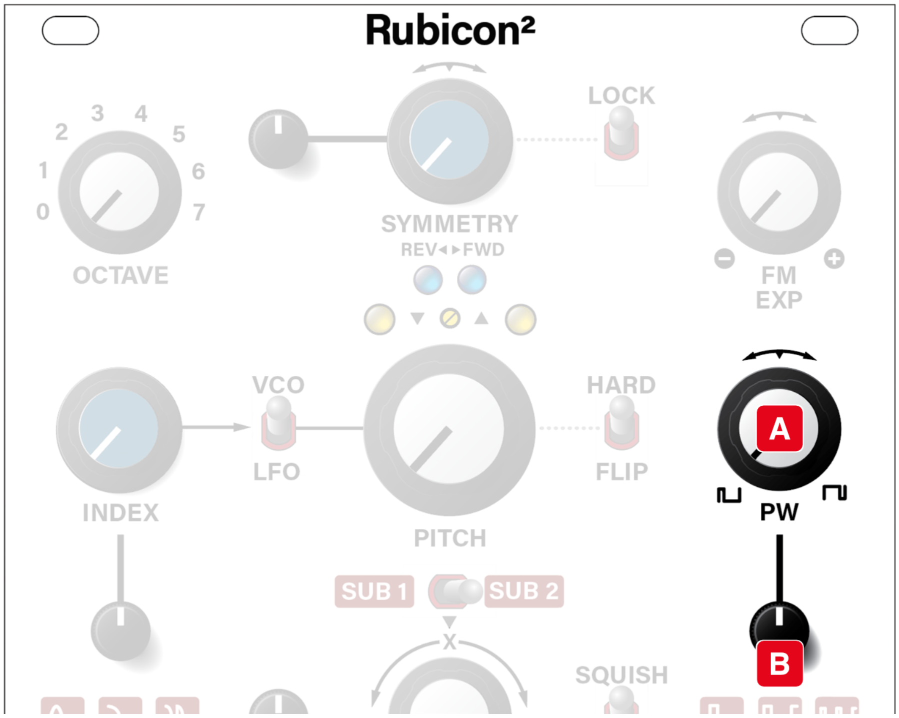
2. **HARD/FLIP Sync Mode Switch**

   The setting of this switch determines how the Rubicon^2 syncs to a signal patched into its **SYNC input**:

   > **HARD -** This is the traditional VCO hard sync method, which resets the Rubicon^2 waveforms when the **SYNC IN** signal crosses zero.
   >
   > **FLIP** – This is a form of soft sync common with triangle core oscillators, which offers a different timbre than HARD sync. Instead of the Rubicon^2 waveform resetting when the **SYNC IN** signal crosses zero, it reverses the direction of its triangle core wave. Waveforms with sharp edges (like square or sawtooth) work best with **FLIP** sync.

   For more information about oscillator sync, see Understanding Sync later in this manual.

Pulse Width Controls

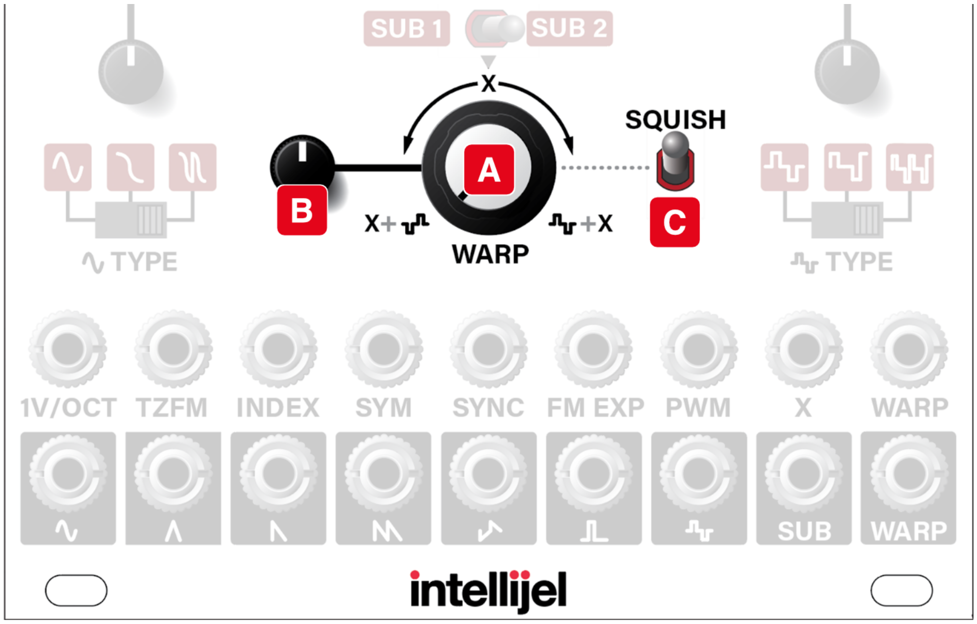


A. **PW knob** - Sets the width of the **PULSE**, **TRI STATE PULSE** and, by consequence, the **WARP** waveforms. At the noon position, both the PULSE and TRI STATE PULSE waveforms are square.

NOTE: Rubicon² supports the entire range of possible pulse widths, meaning it can have a pulse width as narrow as 0% at one extreme, and as wide as 100% at the other. At such extremes, the wave is essentially a DC source, meaning you will no longer hear it. Some oscillators limit these extremes to prevent the pulse wave from ever going silent, but Rubicon² was created for sound designers. And sound designers often employ PW modulation to exploit these extreme widths, allowing the modulation to rhythmically gate the pulse output.

B. **PW attenuator** - You can modulate the PW value with a control signal patched into the Rubicon² **PWM input**. The **PW attenuator** adjusts the extent to which that control signal is added to the value set with the **PW knob**.

WARP Controls



A. **WARP knob** - Controls the amount and direction by which a signal plugged into the **X IN** jack is warped by the Tri State Pulse. If no signal is plugged into the **X IN** jack, then the Sub Oscillator feeds into the Warp circuit by default. The output of the warped signal appears at the **WARP OUT** jack.

   NOTE: The WARP circuit is described in detail in the "Understanding Warp" section, later in this manual.

   Turning the **WARP** knob clockwise adds the Tri State Pulse to **X**.

   Turning the **WARP** knob counterclockwise adds an inverted Tri State Pulse to **X**.

   At noon (straight up), **X** is unwarped by the Tri State Pulse and appears unaffected at the **WARP OUT** jack.

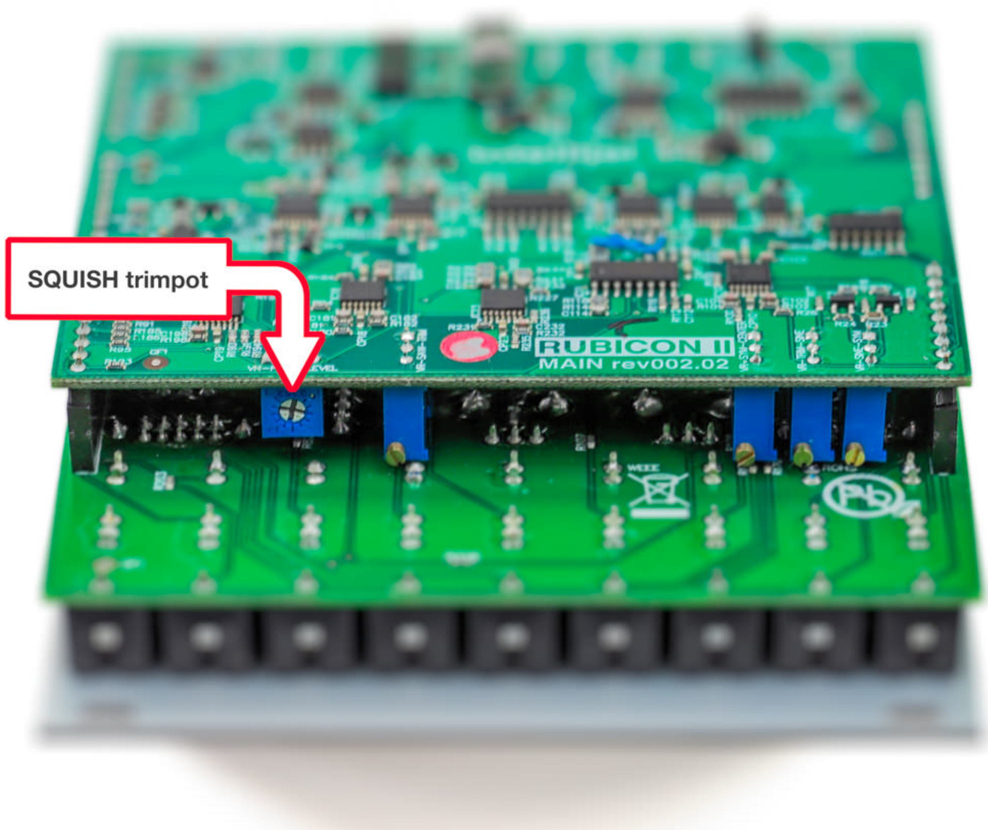
   TIP: Since the WARP circuit uses the Tri State Pulse, be sure to experiment with different PULSE TYPE settings, and definitely tweak and/or modulate the PULSE WIDTH — both of which will provide a wealth of new and interesting WARP waveforms. Similarly, try self-patching various Rubicon² waveforms into the X input. The sonic variation is nearly infinite.

B. **WARP attenuator** - You can modulate the WARP amount with a control signal patched into the Rubicon² **WARP input**. The **WARP attenuator** adjusts the extent to which that control signal is added to the value set with the **WARP knob**.

C. **SQUISH switch** - Engages the Squish circuit, which limits the **WARP OUT** voltage to 10V p-p, making it match the volume of the other Rubicon² waveshape outputs. The sonic characteristic of the Squish circuit is variable from “smooth” to “aggressive,” and can be adjusted to your own personal taste using a trimpot on the back of the Rubicon.

Because the Warp circuit works by summing two different waveforms together, it’s very likely that an unsquished WARP output will be “hotter” than the 10V p-p output of Rubicon^2’s other waveform jacks. Sometimes this might be just what you want, and you can always compensate by attenuating the WARP OUT with an external module, but the Squish circuit gives you an internal and harmonically rich solution.

When the **SQUISH switch** is in the up position, the Squish circuit is engaged, and the WARP circuit’s peak-to-peak output voltage is reduced to typical 10V p-p levels. You can alter the sonic characteristic of the Squish circuit by using the trimpot on the back of the Rubicon.



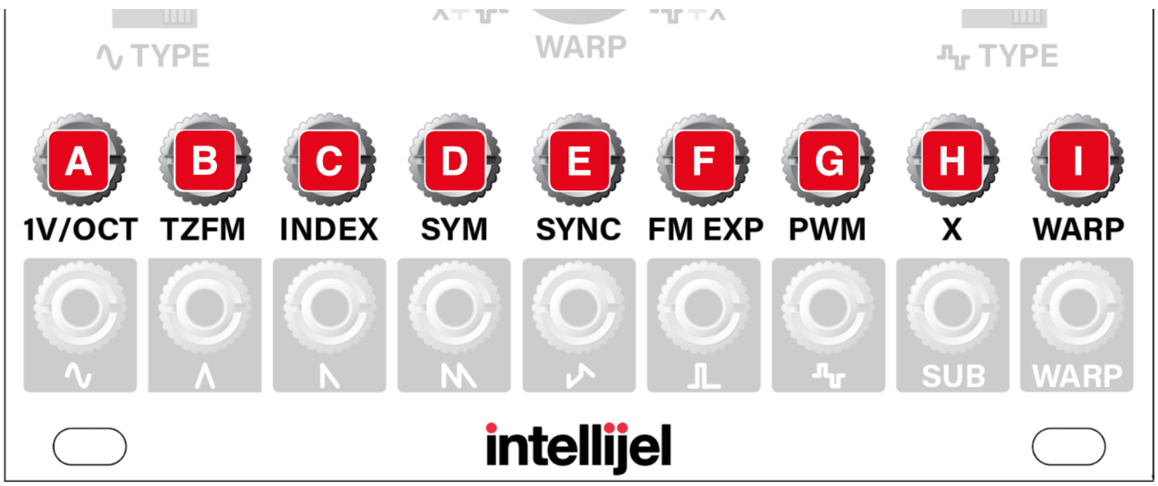
Turning this trimpot counterclockwise creates a “smoother” squish — inducing fewer folds into the compressed waveform, which results in fewer sonic artifacts. Turning this pot clockwise introduces more aggressive wavefolding and a harmonically richer sound than the unsquished WARP output. Rubicon^2 ships from the factory with this trimpot in the mid position.

Should you find the Squish circuit too sonically aggressive for your needs, simply turn the trimpot a bit further counterclockwise — when set fully counterclockwise there is very little sonic change between a squished and an unsquished waveform (other than output level).

Should you find the Squish circuit too tame, turn the trimpot a bit further clockwise. The more you turn it, the more wavefolding you introduce into the output signal.

It's up to you how you want SQUISH to sound. In general, you might prefer counterclockwise settings if you plan to feed the WARP OUT into an external wavefolder module, since that module can be used to dial in more aggressive folding. If you're not using an external wavefolder module, you might prefer to rotate the Trim pot clockwise to introduce some wavefolding characteristics into the Rubicon²'s squished WARP OUT signal.

Inputs



A. **1V/OCT IN** - Controls the frequency of the VCO. Every 1V increase doubles the frequency of the VCO.

B. **TZFM IN** - FM input for either Linear or Thru-Zero FM. The amount of frequency modulation is controlled by a VCA built in to the INDEX circuitry, which is controlled by both the **INDEX knob** and the **INDEX IN** jack and its corresponding attenuator.

C. **INDEX IN** - CV input to control the FM INDEX (which is the amount that a signal patched into the **TZFM input** will modulate the VCO frequency). The extent to which this input modulates the INDEX amount is governed by the associated **INDEX attenuator** mini knob.

D. **SYM IN** - CV input to modulate the SYMMETRY setting for Thru-Zero FM. The extent to which this input modulates the SYMMETRY amount is governed by the associated mini SYM attenuator.

E. **SYNC IN** - Rubicon^2's waveform will either hard or soft (flip) synchronize to the waveform present at this input, depending on the position of the **HARD/FLIP Sync Mode switch**.

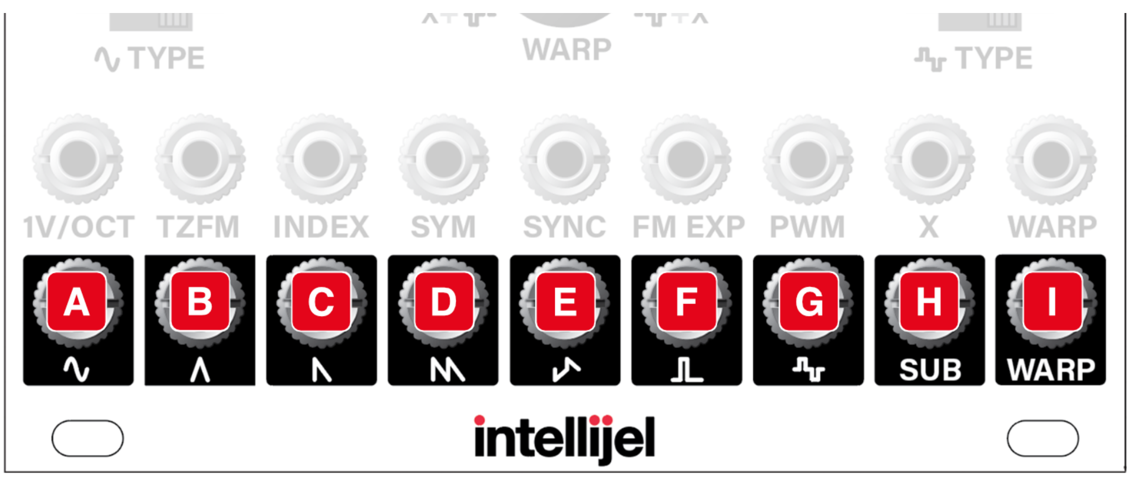
F. **FM EXP IN** - FM input for traditional exponential FM. The extent to which this input modulates the frequency (either positively or negatively) is set by the **FM EXP** attenuverter.

G. **PWM IN** - CV input for modulating the width of the Rubicon^2 pulse wave. The extent to which this input modulates the pulse width is governed by the associated **PW attenuator** mini knob. Note that **PWM** also affects the width of the **Tri State Pulse** and the **WARP** waveforms.

H. **X IN** - Waveform input for the WARP circuit. Any waveform appearing at the **X IN** jack is warped by the Tri State Pulse by an amount and direction determined by the WARP KNOB. If no signal is plugged into the **X IN** jack, then the Sub Oscillator feeds into the Warp circuit by default.

I. **WARP IN** - CV input for modulating the amount (and direction) by which **X IN** is warped by the Tri State Pulse. The **WARP attenuator** adjusts the extent to which that control signal is added to the value set with the **WARP knob**.

Outputs



A. **SINE OUT** - Outputs either a Sine wave, Sigmoid wave, or Double Sigmoid wave depending on the position of the SINE TYPE switch.

B. **TRIANGLE OUT** - Outputs a Triangle wave.

C. **SAWTOOTH OUT** - Outputs a Sawtooth wave.

D. **DOUBLE SAWTOOTH OUT** - Outputs a Double Sawtooth wave, which is double the frequency of a standard sawtooth.

E. **ZIG ZAG OUT** - Outputs a Zig Zag wave.

F. **PULSE OUT** - Outputs a Pulse wave of the type selected by the PULSE TYPE switch, and with a width set by the PW knob (and/or PWM CV input).

NOTE: Rubicon supports the entire range of possible pulse widths, meaning it can have a pulse width as narrow as 0% at one extreme, and as wide as 100% at the other. At such extremes, the wave is essentially a DC source, meaning you will no longer hear it. Some oscillators limit these extremes to prevent the pulse wave from ever going silent, but Rubicon² was created for sound designers. And sound designers often employ PW modulation to exploit these extreme widths, allowing PWM to rhythmically gate the pulse output. So if you ever patch a cable into the PULSE OUT jack and wonder why you don't hear anything, check to make sure the PW knob isn't set to either extreme.

G. **TRI STATE PULSE OUT** - Outputs a Tri State Pulse of the type selected by the **PULSE TYPE** switch, and with a width set by the PW knob (and/or PWM CV input).

See Understanding the Tri State Pulse to learn more about Tri State Pulses.

H. **SUB OUT** - Outputs a square wave that's pitched either 1- or 2-octaves below the primary oscillator. When the **SUB TYPE** switch is set to **SUB 1**, the sub oscillator operates one octave below the primary oscillator. When the **SUB TYPE** switch is set to **SUB 2**, the sub oscillator operates two octaves below the primary oscillator.

I. **WARP OUT** - Outputs the WARP waveform, which results from adding (or subtracting) a Tri State Pulse to any waveform present at the Rubicon² **X IN** jack. If no waveform is patched into the **X IN** jack, then the WARP waveform uses the Sub Oscillator for X. For more information about the Rubicon² WARP circuitry, see the **WARP Controls** and **Understanding Warp** discussions elsewhere in this manual.

Rubicon^2 School

Rubicon^2 is a fully featured and advanced analog oscillator. As such, it might employ concepts or features with which you're not overly familiar. Although this section of the manual isn't designed to supplant a proper university, technical bookstore or Google search, it might help you get a better understanding of what's happening behind the Rubicon^2's front panel.

Understanding FM

Frequency modulation is a classic synthesis technique in which you modulate the frequency of one waveform (the carrier) with a second waveform (the modulator).

It's easiest to understand FM if you first think about what happens when you use a Low Frequency Oscillator (LFO) as a modulator: For example, assume your carrier oscillator is tuned to middle-C, and that you connect an LFO into its FM input. The result, obviously, is vibrato: the carrier oscillator slowly rises and falls in pitch at a rate set by the LFO.

So what happens if you speed up the modulating waveform to audio rates? The pitch rises and falls so quickly that the ear no longer perceives the modulation as vibrato. Instead, it hears new frequencies (called sidebands), which are mixed in both above and below the carrier frequency, resulting in a harmonically complex waveform of fixed pitch. Changing the ratio between the modulating and carrier frequencies alters the quantity, spacing and amplitude of these sidebands. When the modulator and carrier are pitched at simple evenly-divisible multiples of one another (for example, the modulator is 2x or 1/4x the frequency of the carrier), then the sidebands generally fall on and accentuate the harmonics. When the pitch ratio between modulator and carrier are no longer evenly divisible (for example, the modulator is 1.618 times the carrier frequency), then inharmonic sounds are produced.

It's not just the difference between the modulator and carrier frequencies that shape your sound. The waveforms you use for both modulator and carrier also impact the harmonic structure, as does the amplitude difference between the waveforms (which is called *FM Index*).

Exponential vs. Linear FM

In general, there are two distinct types of FM, both of which are supported by the Rubicon²:

- **EXPONENTIAL FM** is the type found in many vintage analog mono synths of the 1970's. When you change the frequency of the modulator, you change the perceived fundamental pitch that emerges from the carrier oscillator. Furthermore, because the harmonic ratio of modulator-to-fundamental changes from note-to-note, neither the resulting pitch nor the timbre track chromatically. This makes Exponential FM ideal for clangorous, atonal sound effects. It's a great source for experimental sounds, particularly when the modulating pitch is, itself, modulated.
- **LINEAR FM** is the type more commonly associated with digital synths in the 1980's, although the linear FM circuitry in the Rubicon² is purely analog. When you change the frequency of the modulator, you alter a note's timbre without affecting its perceived pitch. Furthermore, because the harmonic ratio of modulator to fundamental remains consistent from note-to-note, both the resulting pitch and timbre track chromatically. This makes Linear FM more "musical" than exponential FM, and it's ideal for creating harmonically complex waveforms that track across a range of notes.

Thru-Zero FM (TZFM)

When you frequency-modulate an oscillator, you cause its pitch to go up and down. In a typical (non TZFM) linear FM circuit, the oscillator is biased such that, no matter how great the modulation, the output pitch never dips below 0 Hz. Makes sense, right? After all, who ever heard of a negative pitch?

A TZFM oscillator is one that allows the FM input to modulate pitch into negative territory (i.e. "Through Zero"). It does this by reversing the direction of the oscillator whenever it's asked to produce negative frequencies. This insures that the oscillator will continue to produce sound even when modulated into negative frequencies.

TZFM oscillators can produce "deeper" and "richer" timbres than standard, positive-only FM'd oscillators. Though common in digital oscillators, achieving thru-zero FM is much more complicated (and rare) in analog oscillators.

TZFM Symmetry

Symmetry sets the bias of the oscillator — the center point around which the incoming FM waveform varies the output pitch of the oscillator. Changing the symmetry changes the relative point around which frequency modulation occurs.

With the Rubicon² SYMMETRY knob set to its maximum (fully clockwise) position, the oscillator is biased such that no amount of FM will ask the oscillator to dip into negative pitch. Similarly, with symmetry set to its minimum (fully counterclockwise) value, the oscillator is biased such that no amount of FM will ask the oscillator to produce a positive pitch. Basically, a fully negative symmetry results in an output with the same pitch and sonic characteristics as a fully positive symmetry — the only difference is that the oscillator runs ‘backward,’ meaning its phase is reversed. Neither of these extreme settings require the oscillator to go “through zero,” meaning they produce Linear FM.

Setting SYMMETRY to any value other than fully clockwise or fully counterclockwise results in thru-zero FM.

With the Rubicon^2 SYMMETRY knob set to the noon (12 o’clock) position, the oscillator is biased such that its center, unmodulated frequency is 0 Hz — which is why you hear no sound when the symmetry is at noon and no FM is applied. In this position any FM is as likely to drive the oscillator into positive frequencies as it is into negative frequencies — crossing zero at every oscillation.

At intermediate SYMMETRY values (between the noon and fully CW/CCW settings), there is more frequency change in one direction than the other, essentially changing the symmetry of pitch increases vs decreases in response to an FM signal.

Obviously, radically different timbres can be achieved by changing the symmetry — thereby controlling how often (and by how much) the oscillator passes through zero.

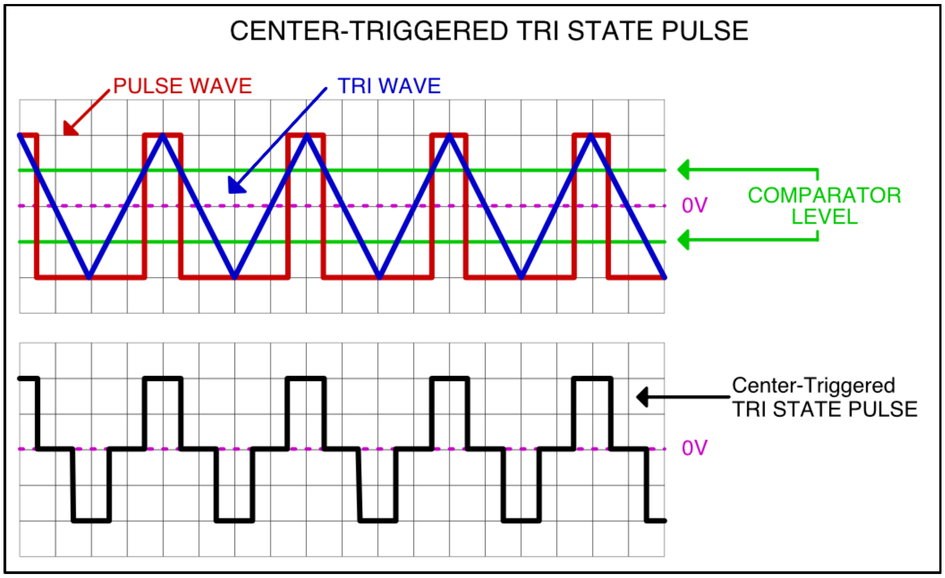
Why Does Pitch/Tracking change with the Symmetry setting?

Eurorack uses the 1V/oct standard, which means that each 1V (linear) change results in a 1 octave (exponential) change in pitch. So a 3x change in voltage would result in an 8x change in frequency (ex. If you play an “A” at 220Hz, the “A” three octaves higher would be 1760Hz — an 8x increase). In order to convert these linear voltage changes into exponential pitch changes, analog oscillators use the rather unimaginatively named “exponential converter” circuit. In general, these circuits track accurately over only about a 3 octave range, after which they drift. In order for the Rubicon^2 to achieve its 8 octave tracking range, additional error correction circuitry is employed, which bases its corrections on the Rubicon^2’s natural oscillation frequency (which is around 16kHz). However, when you change the oscillator’s symmetry, you also change its “natural” oscillation frequency. This means there is now a disconnect between what the tracking compensation circuit *thinks* is the natural oscillating frequency, and what it has become — resulting in a need to retune the oscillator. But what if you want to employ TZFM and not have to retune the oscillator? That’s the purpose of the Rubicon^2 **Symmetry LOCK** switch, which sets TZFM to operate at full symmetry while simultaneously adding compensation voltage to bring the oscillator back to its original base frequency.

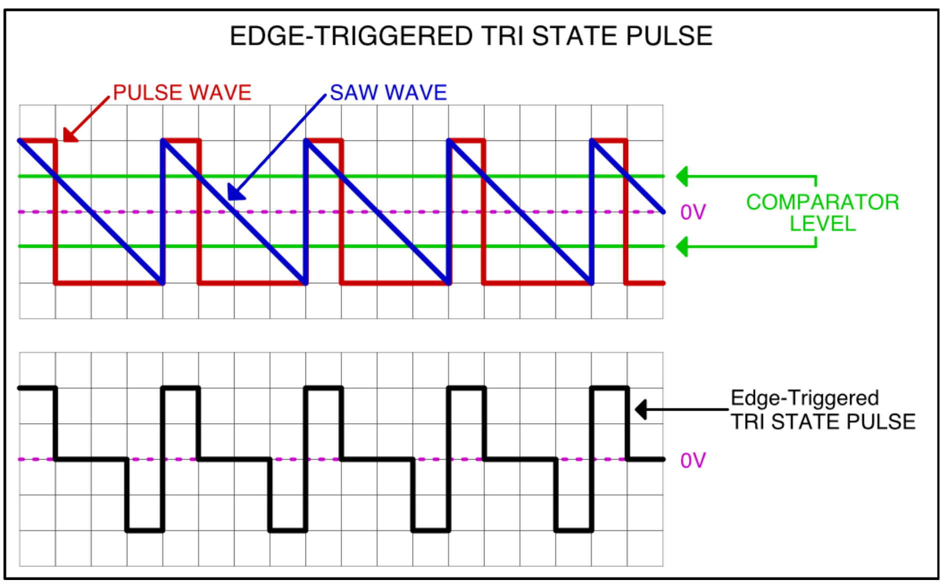
Understanding the Tri State Pulse

Tri State Pulses differ from standard pulse waves in that they switch between three different voltage levels, rather than two. The Tri State Pulse is derived by running two waveforms through a comparator circuit.

If the Rubicon² **PULSE TYPE** switch is set to the left (center triggered) position, then the Tri State Pulse results from a comparison of the PULSE and TRI waves.



If the Rubicon² **PULSE TYPE** switch is set to either the middle or right (edge triggered), then the Tri State Pulse results from a comparison of a PULSE wave and a SAW wave.

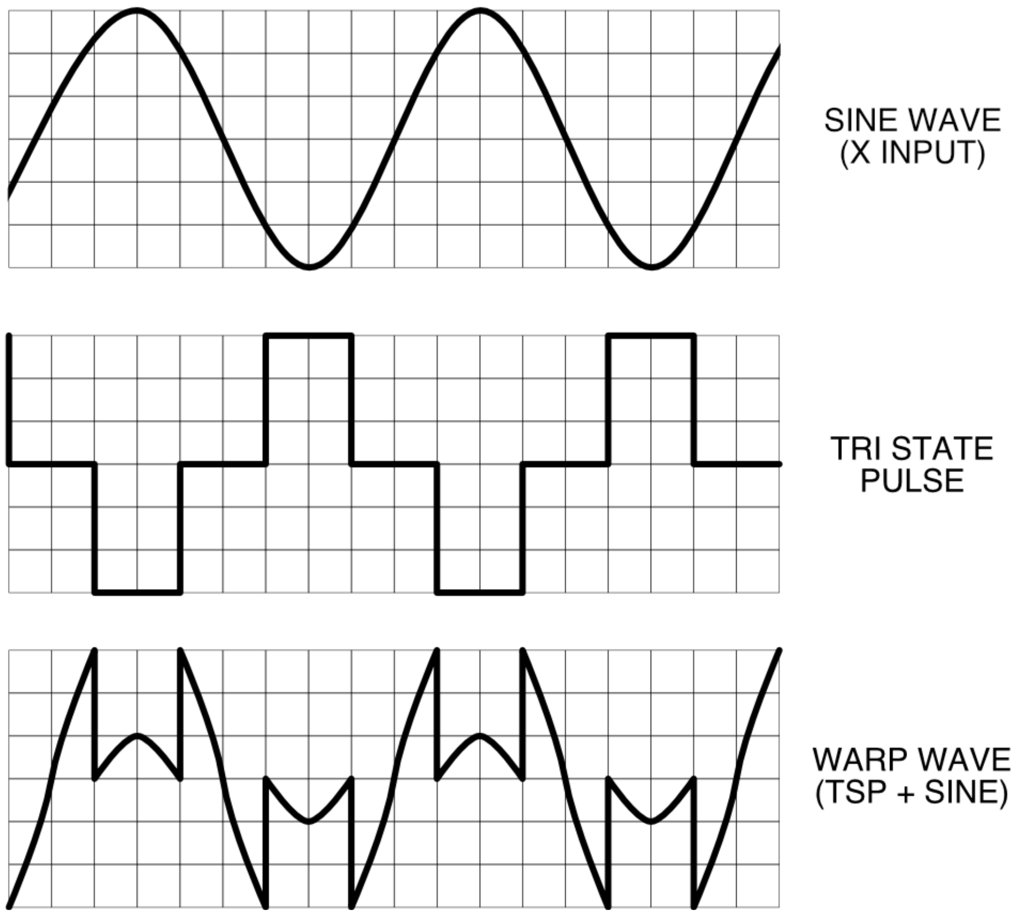


Understanding Warp

The WARP circuit creates new waveforms by combining a Tri State Pulse with another waveform patched into the Rubicon² **X IN** Jack. If nothing is plugged into the **X IN** jack, then the

Sub Oscillator feeds into the Warp circuit by default. The output of the warped signal appears at the **WARP OUT** jack.

Because the Warp circuit adds a Tri State Pulse to the **X** waveform (if the Warp knob is turned clockwise), or subtracts a Tri State Pulse from the **X** waveform (if the Warp knob is turned counterclockwise), it has the effect of “chopping up” the **X** waveform. Self-patching Rubicon^2 waveshapes into the **X IN** jack results in some particularly interesting Warp shapes. Try a sine wave!



Tremendous sonic variation is possible by varying numerous parameters that directly affect the Warp output, such as the PULSE TYPE switch, the PULSE WIDTH and the WARP value. Modulating both the WARP and PULSE WIDTH provides sounds similar to scanning through wavetables.

Because the Warp circuit works by summing two different waveforms together, it’s possible for the WARP output to be “hotter” than the 10V p-p output of the other Rubicon^2 waveform outputs. Sometimes this might be just what you want. Or, if needed, you can attenuate the WARP OUT waveform using an external module. However, if you wish to limit the WARP OUT’s peak-to-peak voltage within the Rubicon^2, you can use its Squish circuit to do so.

When the Rubicon² **SQUISH switch** is in the up position, the Squish circuit is engaged, and the WARP circuit's peak-to-peak output voltage is wavefolded and reduced to typical 10V p-p levels. You can alter the sonic characteristic of the Squish circuit by using the trimpot on the back of the Rubicon. For specific and detailed information about the **SQUISH** circuitry, see **Warp Controls**, earlier in the manual.

Understanding Sync

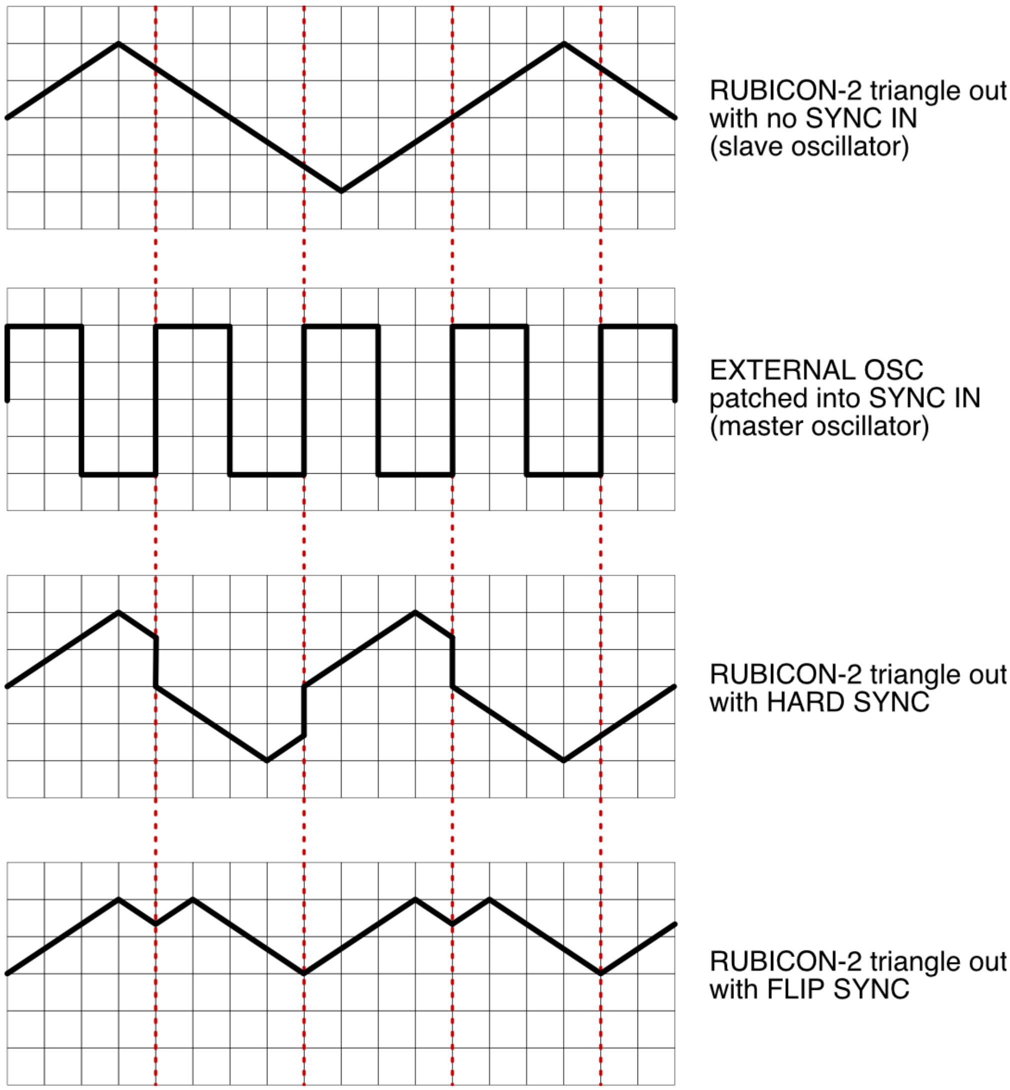
Sync is a situation in which the periodicity of one oscillator (the master) governs that of another (the slave). In other words, when two oscillators are synchronized, the pitch of the master oscillator forces the slave oscillator to cycle at some whole number multiplier of that pitch.

Different timbres are produced when the slave oscillator runs at a different pitch than the master oscillator. In order to synchronize to the master oscillator, the slave oscillator must restart its wavecycle every time the master oscillator reaches some pre-determined point in its cycle. This causes abrupt changes to the slave oscillator's waveform, which results in a harmonically rich sound. Further harmonic complexity is achieved by modulating the pitch of the slave oscillator, which causes its harmonic structure to constantly change since each cycle resets at a different location. This alters the slave oscillator's harmonic complexity over time, while it continues to slave to some multiple of the master oscillator's pitch.

There are various ways to define precisely when and how the slave oscillator should reset itself, and as you might expect, each results in a different timbre. Rubicon² supports two such synchronization options when employed as the slave oscillator.

- HARD SYNC - This is the traditional VCO sync method. It resets the Rubicon² each time the external master oscillator (patched into the SYNC IN jack) crosses zero in the positive direction.
- FLIP SYNC – This is a form of soft sync common with triangle core oscillators and provides a different sync timbre than HARD sync. Instead of the Rubicon² waveform resetting when the SYNC IN waveform crosses zero, it reverses the direction of its triangle core wave. Waveforms with sharp edges (like square or sawtooth) work best with FLIP sync.

The following illustration shows an example of how the two types of sync can affect the output waveform:



Technical Specifications

Width	20 hp
Maximum Depth	38 mm
Current Draw	142 mA @ +12V 150 mA @ -12V