The Zero Point Oscillator is not your typical analog VCO or even your standard Thru-Zero FM VCO for that matter.

The core of the ZPO was developed through countless hours of experimentation involving Through-Zero modulation techniques. Through-Zero FM is a form of frequency modulation that produces much deeper FM tones than a typical VCO can accomplish due to the electronic manifestation of the concept of 'time reversals.'

The ZPO utilizes a novel technique for producing TZFM tones and deeper modulation effects for a wider palate of harmonic variation and greater usability in a musical context.

The fusion of FM and AM:

The ZPO's modulation section is a hybrid involving both FM (frequency modulation) and AM (amplitude modulation). Coupling these two techniques substantially expands the performance and tonal shaping possibilities, beyond traditional TZFM. The results are more stable and balanced across the modulation bandwidth and both FM and AM can function together or independently, and anywhere in between.

It's all about the ZERO POINT:

ZERO POINT is a central modulation control of the ZPO. While serving a single function, the effects will vary depending on the use of the ZPO's modulation inputs.

Without any modulation applied to the ZPO, ZERO POINT essentially behaves as a specialized TZ amplifier, producing a full-scale positive output in the fully CW position and a full-scale inverted output while in the fully CCW position.

Therefore, ZERO POINT must be either fully CW or CCW for normally expected operation, when the FM and/or ZERO-P modulation inputs are not being utilized.

If ZP is adjusted away from either of those two extremes, the wave shape and amplitude of the outputs will change. This effect is secondary to the ZERO POINT functional purpose when TZ-MOD or ZERO-P CV is not utilized but may be useful in some circumstances. Before moving on to the major purpose of the ZERO POINT control, we will discuss these effects on the various waveforms now so they can be fully understood.

As stated, when the FM or ZERO-P mod inputs are not in use, ZERO POINT control should be set fully CW or CCW, for normally expected full scale output.

The effects on each waveform output when ZP is varied away from the extremes during basic operation is described below:

TRI – Amplitude reduction and tonal distortion as control or CV is swept Through Zero into inverted state. Center position = silence

SINE – Amplitude reduction and tonal distortion as control or CV is swept Through Zero into inverted state. Center position = silence

SAW - Amplitude reduction and tonal distortion as control or CV is swept Through Zero into inverted state. Center position = half amplitude square wave

Pulse - Fast PWM as control or CV is swept Through Zero into inverted state. Center position = silence
Ripsaw – Amplitude reduction and tonal distortion as control or CV is swept Through Zero into inverted state. Center position = half amplitude square wave

Upsaw –Amplitude reduction as control or CV is swept Through Zero into inverted state. Center position = silence

Even - Amplitude reduction as control or CV is swept Through Zero into inverted state. Center position = silence

Therefore, it can be understood that during basic operation, ZERO POINT works as a TZ amplitude control with additional effects, depending on the waveform output chosen. Which brings us to the next section, TZAM.

TZAM aka Ring Modulation:

The CV input for ZERO POINT, labeled ZERO-P can be used on its own to produce Ring modulation effects for all waveform outputs.
When a modulation source is applied to the ZERO-P input, The ZERO POINT Control may now be used to balance the modulation signal.
If the modulation source is bipolar, from a VCO or LFO for instance, ZERO POINT can be set to center position as a resting position, i.e. the zero point is equivalent to 0V.
Moving ZERO POINT away from center position in either direction will offset the modulation until the +/- extremes of the control, where the modulation will have very little effect on the output (assuming +/-5V modulation signal)
When using an audio rate modulation source, the output will be ring modulated and any variation of the ZERO POINT will affect the depth of modulation and therefore shape and tone of the resultant output.
When using slower modulation sources, i.e. below 5-10 Hz, the wave-shaping and amplitude effects described above for each waveform become more apparent, producing unique tremolo/vibrato sounds that may be useful, but are not primary to the ZERO POINT's purpose.
You will notice that the depth of modulation is more extreme than the mod source (non-linear) when used in this manner.

FM + AM: how ZPO simulates Time-Reversals:

While traditional TZFM techniques involve both a rectified doubling of the modulation frequency, and a theoretically instantaneous reversal of the direction of oscillation, the technique has never been perfected in the analog domain. The ZPO does not claim perfection but rather exhibits a marked improvement in stability and modulation range, is glitch free, and offers a very useful additional feature set for expanding the tonal possibilities through coupled AM and FM techniques.

Rather than reversing the direction of the current that feeds the oscillator core, the ZPO takes advantage of the highly non-linear TZAM ability of the Zero-Point control to flip the polarity of the waveform at a very high speed. Notably fast enough to produce a continuous transfer from one direction to the other. There is a balance between the harmonic generation due to this time-reversal effect and the additional harmonic content from very high-speed AM. The balance is dependent on the ratio of the modulator frequency and ZPO core frequency. The various waveforms exhibit differing behavior as can be extrapolated from the Zero-Point vs. Waveform table, above. Generally, when the modulation frequency is much slower than the carrier, TZAM harmonic generation will be more apparent. As the Modulation frequency nears the carrier, the effect becomes more balanced and as the modulation frequency goes higher than the carrier, overall harmonic generation becomes much more extreme- this is great for producing very convincing bell and other clangorous tones, for instance.

THRU-ZERO MOD switch:

The four position THRU-ZERO MOD switch selects which FM inputs will behave as TZ-MOD inputs. This can be LINEAR, EXPONENTIAL, ALL or OFF. If any of the FM inputs *are not* selected as TZ-MOD inputs, they will function as normal FM inputs – like you would have on any standard VCO.
The four modes are described below in more detail:
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EXP – TZ modulation will only be applied to the Exponential FM input, Linear behaves as normal FM.
LIN – TZ modulation will only be applied to the Linear FM input, Exponential behaves as normal FM
ALL- both Linear and Exponential FM inputs apply TZ modulation.
OFF – both the Linear and Exponential FM inputs behave as typical VCO FM inputs.

When the TZ-MOD switch is in the active, **LIN**, **EXP** or **ALL** position, the applied modulation is routed to both the rectifier into the VCO FM core and the Zero Point TZ Amplifier.

The Zero Point control will then offset the balance of polarity reversal, producing an auditory change in the tonal balance of the TZ modulated waveform:

TZ-MOD will be fully balanced when Zero Point Control is centered (ie Zero Point = 0 Volts) and will be offset as the ZP control position is altered. As with the TZAM functionality described previously (see TZAM aka Ring Modulation), the TZ Amplitude modulation will decrease in intensity as the control approaches the +/- extremes.

The effect is dependent upon choice of modulation waveform, output waveform and depth (attenuation) of modulation, but overall, like a combination of Phase Modulation and PWM and is essentially a built in *Dynamic Depth Control.*

Dynamic Depth of TZ-MOD on the ZPO:

Dynamic depth implies that the modulation source amount be varied over time. This is desired on TZ VCOs because it produces a more natural FM effect when synthesizing metallic and bell-type sounds, for instance, and more expressive modulation in general.

Traditional TZ VCO's would include a CV Input VCA for the FM input, so that an envelope can be applied to modulate the FM depth.

Since the ZPO's TZ-MOD technique utilizes a TZ VCA, this function is already built into the ZPO's Zero Point Control and can be modulated with an Envelope or VCO/LFO via the ZERO-P (Zero Point CV) input.

For example: Set TZ MOD switch to the FM Input you are using. Patch an external VCO into that Input. Patch an external Envelope into the ZERO-P input. Set Zero Point Control to the (-) position. The envelope will dynamically modulate the FM depth – move the Zero Point control to various positions to offset the envelope and hear the effect this can have on the FM depth. Now experiment with different modulation sources, mod rates and offsets to realize the varied effects and animations that are possible, when using this feature for dynamic depth modulation.

Complex TZ-MOD and other FM modes of operation:

By completing the above example, you may realize that the ZERO-P CV input is also a way to arbitrarily flip the output waveform polarity. This can be a way to apply more complex modulation in TZ-MOD mode, for instance – by patching in a secondary modulation signal into ZERO-P, that will sum with the main FM mod source, creating more complex modulation effects.

LFO rate signals will result in a phase-mod or soft PWM effect and accentuate the balance of harmonics heard in the output – depending on the types of waveforms you are modulating with and applying to.

Audio rate signals will produce additional sidebands in the resultant output which depend upon the relation of the frequency between the main modulation source and additional mod source going into the ZERO-P input. Therefore, the two modulation sources can be tuned separately from one another producing extended harmonic or enharmonic sideband frequencies.

Hybrid FM:

The ZERO-P CV input can also be used when not in TZ-MOD mode for a FM input to produce a hybrid modulation, coupling standard FM with TZ Amplitude modulation for a softer TZ/FM hybrid effect.

For instance, when the TZ_MOD Switch is *not* selected for the FM input you are using, the applied modulation signal will *not* be rectified and will *not* be applied the TZ Amplifier.

FM will be applied as it typically would for any standard VCO. However, if the ZERO-P input is modulated either from the same modulation source or an additional mod source, the output waveform can still be polarity flipped arbitrarily, producing a hybrid of typical FM and TZAM.

Even More Extreme Modulation:

It should now become clearer that more complex combinations of FM types and AM/TZAM can be realized through the four TZ-MOD modes, FM inputs and ZERO-P input and Control. Some of the possibilities are highlighted below:

LINEAR TZ-MOD + standard EXP FM

EXP TZ-MOD + standard LINEAR FM

LINEAR TZ-MOD + EXP TZ-MOD

All the above with additional arbitrary ZERO POINT modulation.

Attenuation:

Attenuators, i.e. Level/Depth controls are provided on the ZPO for the LIN FM and EXP FM inputs and the PWM input. In the case of the FM attenuators, it is critical that they are not always set to the maximum position. While it is totally fine and may be desired if they are, you will be missing an infinite amount of possibilities if this is always the case. The level of FM applied will have a dramatic effect on the sounds you are producing so experiment with them, so you don't miss out!

Due to space restrictions, attenuators are not provided for the ZERO-P CV input or WAVE A/B and MORPH CV inputs (described below). While these CV inputs were designed to work well without the added attenuators, we suggest using external attenuators when needed for greater control of these modulation destinations.

WAVE SHAPING

Three wave-shaping outputs are provided and described below:

WAVE A and WAVE B:

In addition to the 8 direct waveform outputs on the ZPO, two more variable wave-shape outputs are provided on either side of the module. These outputs with associated Control and CV inputs are independent but identical feature-wise.

The controls smoothly fade from Pulse to Saw to Triangle to inverted Sine. Therefore, various hybrid waveforms can be achieved by setting the WAVE controls in between the standard wave settings on the WAVE controls.

For instance, setting the WAVE control somewhere in between PULSE and SAW will produce a mix of the two waveforms. Since pulse is affected by the PWM a Super Saw type sound can be synthesized by applying PWM at varying depths of modulation.

We can extend this idea to mixing SAW with TRI and TRI with SINE.

The two WAVE outputs can be used separately or together in pseudo stereo operation.

For more complex wave-shaping and mixing see the MORPH parameter, described on the following page.

Why Inverted SINE?
Through development of the ZPO and in use, we found that the crossover from TRI to SINE on the WAVE A/B outputs was a bit underwhelming in itself and when creating even more complex wave-shapes using the MORPH control (described below).
Simply stated, Inverted SINE produces more interesting subtractive wave-shapes and vibrato/tremolo effects when mixed with the other waveforms.

MORPH:

MORPH is the focal point of the wave-shaping functions of the ZPO and works in conjunction with the WAVE A/B controls.

Morph offers a finer and wider control over waveform mixing and allows any of the waveforms selected by WAVE A/B to be morphed together in various degrees.

This will have a major effect on harmonic content as a wide variety of atypical wave shapes can be created.

As mentioned, the Inverted SINE allows for even more wave-shaping possibilities since the inversion will subtract various levels of the fundamental from whichever wave shape it is being mixed with via MORPH.

Modulating WAVE, A/B and MORPH:

The CV inputs for WAVE A/B and MORPH allow dynamic automated control over the wave-shaping parameters. While slower modulation applied to these inputs produce more subtle interpolation effects, audio rate modulation can also be utilized for an even greater degree of animated and non-standard wave shaping.
When combined with the FM and AM functionality, the ZPO can create a truly staggering variety of tones, all within a single VCO. We recommend pairing the ZPO with a stable VCO/LFO or even a second ZPO for a truly unique complex oscillator experience.

Direct Waveform outputs:

Although we touched on the direct wave outputs a bit in the ZERO POINT section, they will be described in a bit more detail, below.

Standard Waves:

TRIANGLE (TRI)
SAW
SINE
PULSE

Pulse features 3 types of PWM, a manual Pulse-Width control, PWM CV input and attenuator.

EDGE PWM is the most widely known and used in VCOs. The PW duty cycle (time above 0V) will be modulated from less than 10% to more than 90%. We call it 'EDGE" type because the falling edge of the pulse is decreasing/increasing.

CENTER PWM is also used on some VCO's. The duty cycle modulates from less than 10% at both extremes of the PWM control to 50% in the center. We call it 'CENTER' type because both the rising and falling edges of the Pulse move toward or away from the center of the pulse wave.

HYBRID PWM is a special mix of EDGE and CENTER type PWM, creating a multi-state pulse.

Non-standard Waves and Sub-Oscillator:

UPSAW – Octave up version of the standard SAW output.
RIPSAW – A multi tooth SAW and Sub-Oscillator hybrid waveform
EVEN – specialty waveform containing only even ordered harmonic partials.

SUB- Sub Octave Square Wave. Can be one or two octaves below the fundamental frequency.

SUB is not affected by ZERO POINT and therefore any TZAM effects. It can however be affected by any of the possible FM modes.

SYNC:

The ZPO features a unique triangle core sync circuit. It is somewhat sensitive to the waveform shape used to sync the ZPO and the wave output used from the ZPO, itself – which

may become more apparent when other modulation destinations are used in tandem. The Sync sound is harder than typical triangle-core VCO sync and can exhibit some interesting and charming quirks. Try syncing from a Modulation VCO while performing TZ-MOD simultaneously for interesting complex waveform generation.

VCO/LFO/LOCK Switch:

The ZPO has 3 oscillator modes:

VCO – Pitch control covers 10 octaves; TUNE covers one octave. PITCH+TUNE Range: 11Hz-21kHz

LFO - Pitch control covers 10 octaves; TUNE covers one octave. PITCH+TUNE Range: 11mHz-21Hz

LOCK – Pitch control lockout for ease of use with external sequencers/keyboards. TUNE control remains in use and covers a range of one octave.
The LOCK frequency is adjustable via the LOCK TUNE trimmer, accessible through the front panel. There are no standards when it comes to CV control of pitch, hence the LOCK TUNE is provided for the user to either leave as is or set to a convenient base frequency to use with other equipment. Lock Tune range is from 270mHz to 225Hz, with the intention that anywhere from C0 (16.35Hz) to C2(65.41Hz) would be chosen as an appropriate base frequency for sequencers and keyboards.