# ZEROSCILLATOR OPERATION MANUAL

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## == Introduction ==

Congratulations on your clever purchase of the most advanced analog VCO ever. The Zeroscillator is a general-purpose electronic music VCO designed for FM synthesis technique.  Operation of the Zeroscillator is a little more complicated than traditional VCOs, but not difficult to master.  Within a few minutes, you will be making sounds that up until now, were the sole property of digital synthesizers.

Lets dive right in and make some noise.

## == Quick Start ==

To make a "classic" FM sound, you will need a few more modules in addition to the Zeroscillator.  They are: a VCO, a VCA, one or two envelope generators, and a 1/octave keyboard with gate signal.  We assume you own these things already as they are part and parcel of every analog system.

Set up the patch as shown in figure 1.  If you have only one envelope generator available, then use its output for both connections.

Be sure you have both the BIAS and RANGE switches set to high (you can fool with these later).  Use the TUNING knob to set pitch.

With the FM INDEX knob fully counterclockwise, you should be able to play the keyboard and hear a flutey sine wave sound being shaped by envelope generator #2 controlling the VCA.

Now comes the fun.  Slowly turn up the FM INDEX control as you play.  You will hear the effect of envelope generator #1 controlling the depth of FM and radically affecting the sound.  By tuning the VCO and Zeroscillator to different pitches, zillions of timbres are available.  A consistent timbre up and down the keyboard is attained when the oscillators track equally.

Useful timbres are found by holding down a key for a sustained sound.  Then tune the VCO and Zeroscillator for a sound with little or no beating.  You will find many tuning combinations where this occurs.  Adjust envelopes to suit.

Use envelope generator #1 and the FM INDEX control as you would an envelope and VCF in a subtractive synthesis patch.  They are analogous.  When the FM index is increased, more sidebands (harmonic and inharmonic overtones) are generated and the sound gets brighter.

You could just play with this patch forever, and if you never did anything else, the Zeroscillator will have fulfilled its purpose.  We suggest you park yourself here a while to get the feel of your new vehicle.  This patch is basically the "Minimoog" or standard of FM.

**== Zeroscillator Accuracy ==**
A conventional VCO relies on the sum of its exponential inputs to determine pitch over a very wide range.  Its linear component is fixed internally at an optimum value to accomplish this.

The frequency at which the Zeroscillator (from now on "ZO") runs is determined by 3 factors:
1. The TUNING knob (exponential) plus voltages from exponential inputs.
2. The LINEAR BIAS switch plus voltages from linear inputs.
3. The RANGE switch.

The sum of all exponential inputs and the sum of all linear inputs (including BIAS) are *multiplied* together to determine the ZOs pitch.  Any time you multiply, wildly varying results are possible.  This is partly what gives the ZO its personality.

Just like an engine of a certain size requires the correct mix of fuel and air to run at a certain RPM, the ZO requires proper control settings to run optimally.  (If you are not interested in musical accuracy, you can do anything you want.)  Carrying this analogy one step further, we can think of the exponential and linear voltages as fuel and air, and the RANGE switch as the engines size.

There are several combinations of voltages and controls which will result in the same operating frequency, so here are the guidelines for proper operation:
1. Always use the *lowest* position of the RANGE switch that gives you what you want.

2. Try to use the HIGH position on the BIAS control.  This position allows up to 1350% FM.  The LOW position allows greater than 6,000%, but is less accurate.  To enhance accuracy further (at the expense of modulation range), you can apply a DC voltage to the LINEAR FM input to bias the oscillator up even higher.

3. Try to operate the TUNING control in the middle of its range.  Too low reduces pitch accuracy and too high may run you out of room when playing the high end of your keyboard.
4. The RANGE switch gives you several octaves of free ride that do not affect accuracy.

You will understand why these guidelines are necessary by the following example.

Both these settings result in the same pitch:
A. 1 volt of linear bias and 3 volts exponential input.
B. 0.015 volts of linear bias and 9 volts exponential input.
Setting B. is undesirable because even the finest analog components built by Martian superscience would have a hard time maintaining musical accuracy with a tiny 15mV input. Once again, if youre just making noises, this is irrelevant.

**== Zeroscillator FM in depth (Ooh, a pun!) ==**
The right side of the module contains the exponential inputs. They are conventional in every way and react just like similar inputs on every other VCO, so I'll stop talking about them right now except to say that they will not take the ZO through zero (so don't try).

The left side of the module carries the new and exciting linear modulation inputs. A good understanding of these is essential to getting the most from your ZO.

The linear modulation section contains three channels which are mixed (summed).

1. LINEAR FM INPUT or LIN FM (depending on format). This input with its attenuator is DC coupled directly to the ZO core.

2. The 4-quadrant, dynamic depth VCA channel with two modulation inputs (DYN1 & DYN2) and the VCA control voltage (marked FM INDEX). On most models, DYN1 is DC coupled and DYN2 is AC coupled.

3. BIAS switch. Since the ZO comes to a halt when no linear voltage is present, the BIAS switch is provided as a convenience. Think of it as the idle screw on your carburetor. The upper position provides about 1volt of bias and the lower about 1/5volt. The middle position is zero volts, and unless you provide some non-zero linear input, the oscillator will not run. Some of the waveform outputs may even hiss or squeal with indecision.

All linear inputs and the VCA control input are bipolar, accepting positive and negative voltages. When the sum of all the linear inputs approaches and then crosses through zero, the oscillator slows to a stop and reverses direction. Do not confuse this action with an inversion of sign or phase, which is totally different. The ZO actually travels the opposite direction in time. You know, the Stanley Steamer automobile was put into reverse by changing the direction of the steam and driving the engine backward. Same here.

The AC coupled input is provided to create symmetrical (about 0V) waves out of asymmetrical ones. For example, a 0 to 5V sawtooth, when used as a modulator with DC coupling, will pull the ZO radically sharp every time it is gated through. Patching via the AC input will automatically place half the sawtooth above and half below zero so the modulation will be symmetrical and the note stable.

The non-banana versions are provided with a normal (dotted line on panel) from the AC coupled input to the direct input.  Many FM patches require background FM when the envelope is at zero.  By dialing in a little direct FM, this is accomplished.  Patching to the direct LIN FM input breaks the normal. Bananaheads just patch this themselves.

The linear modulation section is provided with a MOD OUT jack which presents the sum of all linear inputs (including VCA action).  You can patch this signal into the direct LIN FM input on more ZOs to present matching modulation signals (thus freeing up inputs and conserving patchcords).  You may even want to audition this jack in self-modulation or other complicated cross-mod patches.

How much linear modulation is possible?
A conventional VCO is capable of 100% linear modulation.  If its running at 1KHz, you can take it up much higher, but you can only take it down to zero.  (Most VCOs restrict the range of the linear modulation input, so you can't even realize 100%).  At 1KHz, it can move downward a maximum of -1KHz.  At 90Hz, it can only move -90Hz  always 100% maximum.  This is not the case with the ZO.  No matter what the operating frequency, you can modulate several thousand percent because the ZO can go through zero and into negative frequencies.  Just what negative frequencies are is beyond the scope of this instruction sheet, but if your'e interested, the Cyndustries website has several links to some good explanations.

Here's the nut--
The range of modulation that is possible has to do with the bias level and the highest voltage available in the module.  Op-amps saturate at about 13.5 volts on a 15 volt supply (10.5 on a 12V supply).  So, if you are using HIGH bias on the switch (1 volt), then you can modulate 13.5 / 1 = 1,350%.  If you are using LOW bias, then you can modulate 13.5 / 0.2 = 6,750%!!!  As you can see, the modulation range is the ratio between your idle setting and red-line (Will this car analogy never stop??!).  At zero bias the modulation range is infinite, but that makes my brain hurt so I promise never to mention it again.

**== Zeroscillator Waveforms ==**
The ZO uses a triangle core.  All other waveforms are derived from that. Because the oscillator can run forward and backward, the waveforms that emerge from the various outputs may bear little or no resemblance to their label when heavy FM is being used.  Also, since a reversal may occur at any time, outputs such as the sawtooth may experience multiple flybacks in quick succession, resulting in noises you may not have anticipated.  Depending on the pulse-width setting, the pulse output may seem like it is vanishing and reappearing when certain FM settings are used.  This is because the core can actually hang out near one extreme undergoing multiple reversals before it finally crosses the trigger point to make the pulse output change states.  If thats too

technical for you, just realize that abnormal behavior is sometimes the norm with the Zeroscillator.

Most of the time, the SINE output will be found the most useful and expresses FM qualities the best. If you are going to post-process with a filter or if you want "edge", you might want to try the buzzier waveforms.

**== Morphable Quadrature Outputs ==**
The top of the module hosts the 4 quadrature outputs and their morph controls. When waveforms are in quadrature, they are separated by 90 degrees of phase. More technically, if one is sine, the other is cosine. The four phases are 0, 90, 180, and 270 degrees -- or, sine, cosine, -sine and -cosine. The 180 output is the inversion of the 0 output, and the 270 output is the inversion of the 90 output. These inversions are provided for completeness and convenience.

These outputs are capable of a true morph from triangle through sine to nearly square. The knob sets the initial waveform, and it is summed with the external MORPH A & B inputs. The complete morph takes 5V to achieve. If you are viewing the wave on a scope, you will notice that the amplitude shrinks as it moves towards a squarewave. This was done because a square wave contains twice the energy as a triangle wave and sounds much louder. The amplitude is controlled so that only the timbre shift is perceived without a volume boost.

The MORPHASE switch controls the relative directional behavior of the two morph channels.

Left position:
The MORPH A input and control drive *both* morph channels in phase.

Center position:
MORPH A and MORPH B channels operate separately and independently.

Right position:
The MORPH A input and control drive *both* morph channels in *opposite* phase.

**== Synch and Time Reversal ==**
A signal at the SYNCH input causes the triangle core to reverse direction *if* the triangle wave (in the core) is beyond the synch threshold (as set by the VARI-SYNCH control). In other words: A low VARI-SYNCH setting will result in infrequent reversals and a high setting will result in guaranteed reversals. This is soft through hard sync.

The TIME REVERSAL input acts in a similar way except that a signal here *always* results in a reversal.

The two inputs use separate circuitry and may be used separately or together with different synch sources. The SYNCH and TIME REVERSAL inputs have Schmitt-type comparators set at +1V, so any waveform that crosses above +1V creates a valid sync or time-reversal pulse.

Try adding a modulating voltage to the TIME REVERSAL Input, "TRM" or Time Reversal Modulation can result in some surprising vocal like tones!

**== LEDs ==**
The red(+) and green(-) LEDs on either side of the TUNING control provide a visual indication of linear modulation. The red(+) LED lights when positive frequencies are being generated, and the green(-) LED corresponds with negative frequencies. With nothing patched in, setting the BIAS switch to LOW will result in a dim glow of the red(+) LED. Changing to HIGH BIAS causes that LED to glow a little brighter. External linear modulation sources which drive the ZO to its limit, will take the LEDs up to full brightness.

**== THROUGH-ZERO Switch ==**
This switch allows you to switch the through-zero capability of the Zeroscillator off and on, changing it from a typical VCO into a Zeroscillator. In the upper THROUGH-ZERO position, the ZO can pass into negative frequencyland. The TYPICAL setting causes the ZO to *stop oscillating* when the linear sources reach zero and below. This setting produces interesting rhythmic gating patterns when the modulation source drives the linear inputs positive and negative.
The TYPICAL setting also disables the green(-) LED.

**== Conclusion ==**
I have told you virtually all I know about the operation of the Zeroscillator (Its pretty new to me too!). You might want to read up on FM synthesis if you want to go about your task in a purposeful way. However, the beauty of analog modular is that discovery is just a knob-twist away and there are no rules. I'm sure you will impress us all with what you do with your new through-zero FM VCO. Have a great time!

Mark Barton

**Zeroscillator Specifications**

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All waveform outputs on all formats are symmetrical bipolar 10Vpp.

Sync & Time Reversal input levels are +1V with small hysteresis.

All inputs without attentuators are 100K input Z.

All inputs with attenuators are 50K minimum input Z.

All inputs are DC coupled except single AC coupled dynamic FM input with HP cutoff frequency at 0.2Hz.

All outputs are 1K.

Output frequency range is one-cycle-takes-a-long-time to well over 120KHz.

Morph input CV = 0V -> 5V

PWM input full range (control at center) = -5V -> +5V

(Power Consumption = 150mA Positive / 100mA Negative)

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