Test Rack Oscillator from Dome Music Technologies

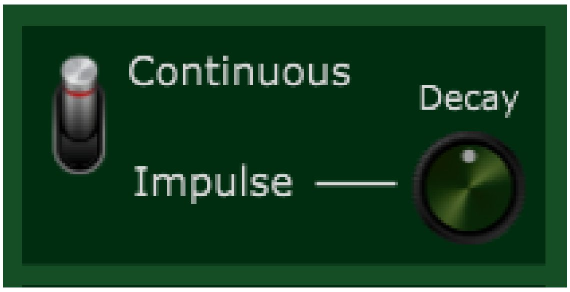
Introduction

The Test Rack Oscillator module from Dome Music Technologies is a voltage-controlled oscillator (VCO) based on an analogue computer model of a harmonic oscillator. Its main features are:

- Sine and cosine phase-quadrature outputs.
- True through-zero negative frequency generation and linear FM.
- Linear and V/Oct FM inputs.
- Internal oversampling up to x16 times base rate (768 kHz).
- "Impulse" mode with variable damping factor for 'pinging' resonators.

For those who are interested in the technical details, the principles of operation are described later in the document. For now, we'll have an overview of what all the knobs, switches and sockets do.

Mode Switch and Decay Knob



The module operates in two modes:

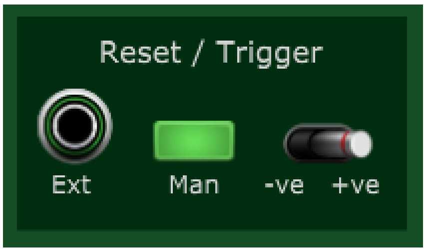
"Continuous Mode" outputs a steady sinusoidal wave which swings between +/- 5V.

"Impulse Mode" introduces a damping factor, which causes the sine wave to decay in amplitude after it has been triggered (via the **Ext** trigger input or the **Man** button – see below).

The **Decay** knob is only active in Impulse Mode. It controls the damping factor of the oscillator, and hence the decay time of the oscillations. At the 7 o'clock position, the damping factor is 100%, which leads to very short decay times. At the 12 o'clock position, the damping factor is 10%, which leads to medium-length decay times. At the 5 o'clock position, the damping factor is reduced to 0% (effectively 'infinite decay'), and it operates in a similar manner to Continuous Mode.

Note that decay time is dependent on a lot of different factors, such as base frequency, oversampling factor, linear FM depth, etc. This means that even with a damping factor greater than 0%, the DSP calculations can still overflow, leading to the oscillations clipping at +/- 5V and sounding continuously. In this situation, simply back off the Decay setting until it stops making a continuous sound.

Reset / Trigger Section



The Reset / Trigger panel allows you to reset the oscillator outputs to their initial state (0V for Sine, +/-5V for Cosine).

An input voltage at the **Ext** socket will reset the outputs whenever it rises from 0V or less to above 0V ('positive edge'). This can be used to 'ping' the oscillator in "Impulse Mode" or provide hard-sync reset in "Continuous Mode". The Velocity input affects the amplitude of the initial Cosine output value when a reset pulse is received on the Ext socket.

The **Man** button will reset the outputs when it is pressed. The Velocity input has no effect on the initial Cosine output when the Man button is pressed; it will always be either +5V or -5V, depending on the position of the polarity switch.

The **Polarity Switch** affects the polarity of the initial Cosine value, and hence the direction of the Sine output (upwards from 0V when the switch is in the +ve position, downwards from zero in the -ve position).

Figure 1- +ve Impulse Trigger Response

Figure 2- -ve Impulse Trigger Response

The Frequency and Modulation Panel

The **Freq** knob determines the base frequency of the oscillator. The default knob position (12 o'clock) is 65.406 Hz, equivalent to the musical pitch C2. At the 7 o'clock position, the frequency is 0 Hz, and the output voltages will be stationary DC values. At the 5 o'clock position, the frequency is 1046.50 Hz, equivalent to the musical pitch C6.

The **Frequency Polarity** switch allows you to select between positive frequencies (Cosine output leads Sine output) and negative frequencies (Sine output leads Cosine output).

Figure 3 - Positive Frequency Plots, Cosine leads Sine, anticlockwise rotation.

Figure 4 - Negative Frequency Plots, Sine leads Cosine, clockwise rotation.

The **Hrm** knob allows you to multiply the base frequency by an integer harmonic number from 1 (7 o'clock) to 16 (5 o'clock). It can also be used as an octave ('footage') selector switch, as found on most standard VCOs. With the Freq knob at its default position:

Harmonic 1	= 65.41 Hz	= C2	= 16'
Harmonic 2	= 130.81 Hz	= C3	= 8'
Harmonic 4	= 261.63 Hz	= C4	= 4'
Harmonic 8	= 523.25 Hz	= C5	= 2'
Harmonic 16	= 1046.50 Hz	= C6	= 1'

The resultant frequency (base frequency multiplied by harmonic number) is displayed in the Frequency Display panel:

Note that the frequency display is not affected by any of the frequency-modification inputs (1V / Oct, Exp FM, Lin FM).

The **Ovr** knob controls the internal oversampling rate of the DSP calculations. Voltage Modular operates on a constant sampling rate of 48 kHz. The Ovr knob allows you to select an internal calculation frequency of up to x16 times the 48 kHz base rate (768 kHz). This becomes important for improving pitch tracking and reducing clipping distortion at higher pitches.

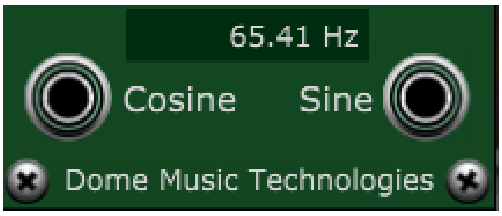
The **1V / Oct** input socket allows you to control the output frequency using a 1V / Oct signal, such as the keyboard pitch. There is no attenuator on this input.

The **Velocity Input** allows you to change the initial value of the Cosine output when a trigger pulse is received at the **Ext** socket on the Reset / Trigger Panel. The **Velocity Knob** controls the depth of velocity sensitivity, from completely flat at the 7 o'clock position (full volume at all times) through to full depth at the 5 o'clock position (0V velocity input = silent, +5V = full volume).

The **Exp FM** input socket allows you to modulate the output frequency using a 1V / Oct signal, such as an LFO. The attenuator is bipolar. At the 7 o'clock position, +1V at the input will lower the pitch by one octave. At the 12 o'clock position, the voltage at the input will have no effect. At the 5 o'clock position, +1V at the input will raise the pitch by one octave.

The **Lin FM** input socket allows you to modulate the output frequency using a linear V / Hz signal, such as another sine-wave oscillator. The attenuator is bipolar. At the 7 o'clock position, +1V at the input will lower the frequency by 100Hz. At the 12 o'clock position, the voltage at the input will have no effect. At the 5 o'clock position, +1V at the input will raise the frequency by 100Hz. Note that if the linear FM input takes the frequency below 0Hz, 'negative frequencies' are generated at the Sine and Cosine outputs.

Phase Quadrature Outputs and Base Frequency Display



The base frequency display shows the unmodified / unmodulated frequency at which the oscillator is currently running. The displayed frequency value is not affected by any of the modulation inputs (1V/Oct, Exp FM or Lin FM).

The Test Rack Oscillator has two outputs, which are phase shifted by 90 degrees.

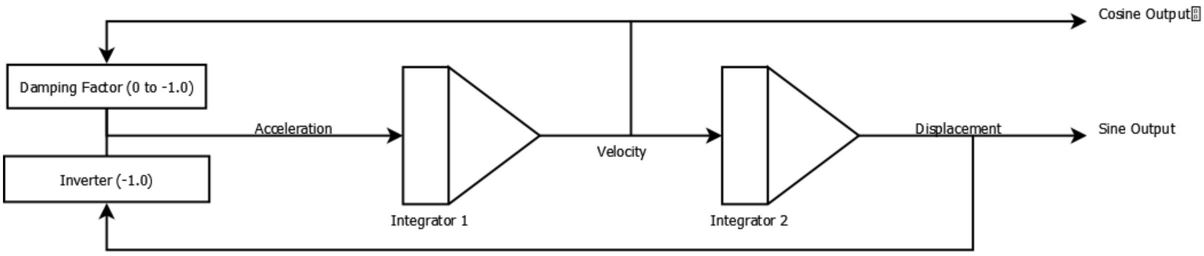
- For positive frequencies, the Cosine output leads the Sine output.
- For negative frequencies, the Sine Output leads the Cosine output.

To get all four phases, you can feed the outputs through four channels of the ACE Constants & Multipliers module with gain values of +1.0, +1.0, -1.0 & -1.0:

Note that in Impulse Mode, the Sine output will reset to zero volts, whereas the Cosine output rises sharply to +5V. This means you will get a ‘click’ on the Cosine output when reset by the Man Trigger button, or externally via the Ext Trigger socket.

Principles of Operation

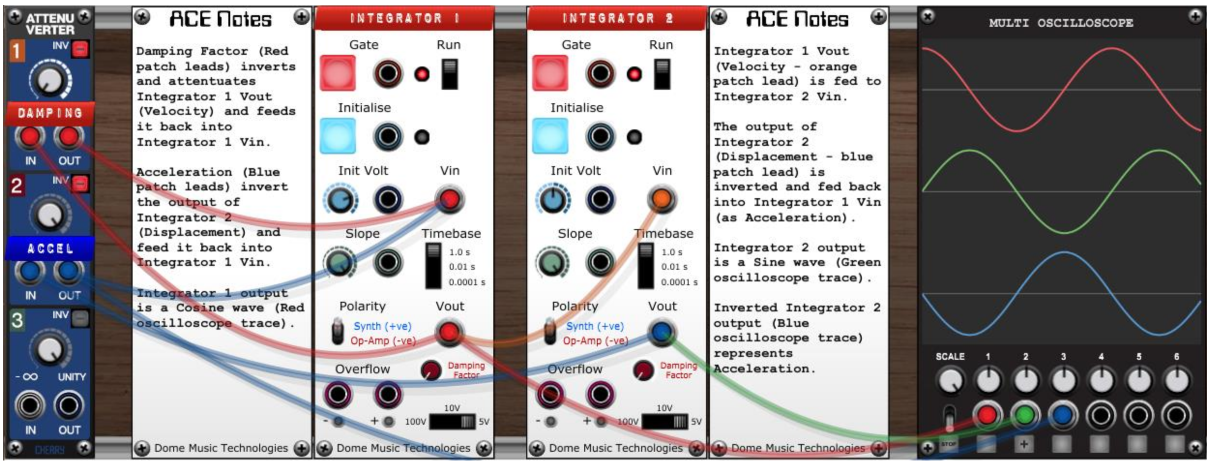
The Test Rack Oscillator is based on the physics of a spring or pendulum. It uses two cascaded integrator modules with a feedback loop to create continuous oscillations:



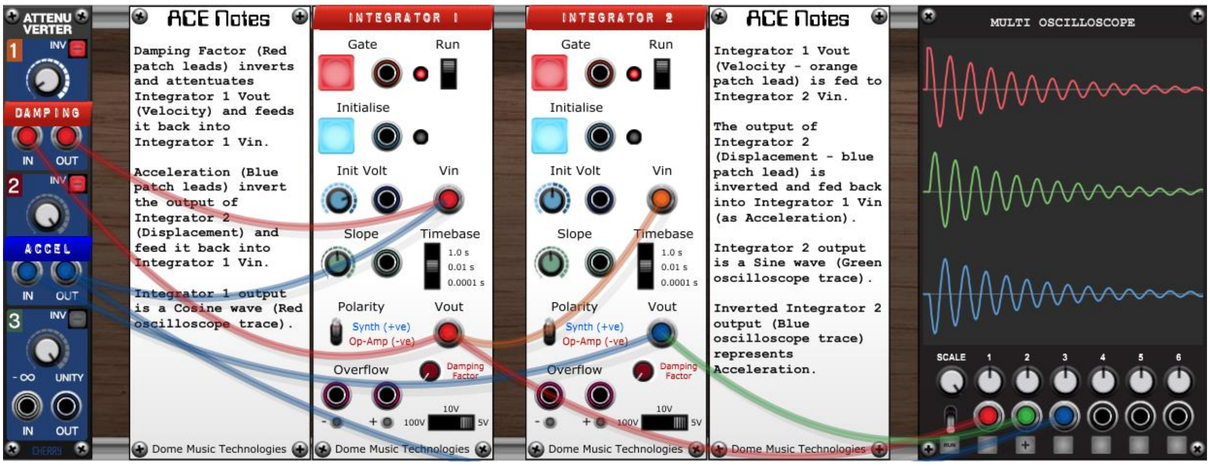
It's easiest to imagine the input to Integrator 1 as being the Acceleration value. The output of Integrator 1 is given an initial value of +5V upon reset. The output of Integrator 1 can be thought of as Velocity, and it is fed into the input of Integrator 2. The inverted 'Velocity' output of Integrator 1 is also fed back to the 'Acceleration' input of Integrator 1 via the "Damping Factor" attenuator. A Damping Factor makes the oscillations die away after being reset

The output of Integrator 2 is given an initial value of 0V upon reset. The output of Integrator 2 can be thought of as Displacement (or position), and it is inverted and fed into the input of Integrator 1. This means that as the displacement moves away from 0V, it starts to slow down the velocity of movement in that direction.

Here is what the acceleration, velocity and displacement values look like when the above circuit is implemented in the Dome Music Technologies Audio Computing Engine:



Simple Harmonic Oscillator with Velocity (Red), Displacement (Green) and Acceleration (Blue) traces.



Damped Harmonic Oscillator

Hints and Tips

Oversampling Factor

Although the patches and schematics shown here look like analogue computer circuits, it is important to remember that Voltage Modular is a discrete-time system which can only approximate the continuous-time operation of genuine integrator circuits. For low frequency applications, such as LFOs, the difference is minimal. However, as oscillation frequencies rise into the audio range, the limitations of a finite delta between audio samples become more apparent. The tendency is for calculations to overshoot their peak values, which then get clipped to values of +/-5V. This can lead to distorted waveshapes and inaccuracies in both tuning and pitch tracking. To mitigate these effects, increase the oversampling factor (**Ovr** knob) until they become inaudible again. The oversampling process isn't particularly CPU intensive, so don't be afraid to increase it all the way up to x16.

Through-Zero Linear Frequency Modulation

When using the Linear FM input (**Lin FM**), it is possible to make the oscillator come to a complete halt (0Hz), and even 'run in reverse' (generating 'negative frequencies').

Damping Factor Also Works in a Negative Direction!

If the Linear FM input takes the oscillator beyond 0Hz into negative frequencies, **everything** starts running in reverse! This means that the damping factor in 'Impulse' mode will cause any existing oscillations to *increase* in amplitude, until they go into clipping at +/- 5V.