



CS-8 Series

Owners' Manual
Omega-Phi

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PREFACE

First of all, congratulations on the purchase of this 3U euro rack synthesizer module. This manual contains a condensed description of the functionality and addresses users with a certain level of elementary technical knowledge.

The current **Thru-Zero²** $\omega - \frac{\delta\varphi}{\delta t}$ **high performance VCO Omega-Phi** of the CS-8 series is a so-called *thru zero* oscillator to the power of 2. Oscillators of this type are able to process negative control voltages resulting in a reversal of their curve.

With that technical difference, for **thru zero** oscillators are arising very significant properties. In comparison to ordinary oscillators the harmonic relationships will kept constant independently of the modulation depth (index), wherefore true Fm synthesis is possible with this type of oscillators (provided that they bring the required technical qualities with it).

The ultimate feature of the **Omega-Phi**, moreover, is the capability of an additional true **phase-modulation** section. It is connected downstream to the oscillator core and the sound is very similar to the sound aesthetic of the frequency modulation. The downstream architecture provides lots and mighty possibilities of sound synthesis. E.g. it is possible to create PM sounds (Phi section) and having at the same time clean standard waves at the core outputs (Omega section) for other kinds of synthesis. Also modulation cascades are possible, where a first modulator creates FM synthesis and a second one a phase modulation of the FM result. The possibilities are beyond the constraints of this manual.

Moreover, there exists a number of **synchronization** possibilities, interesting intermediate states (between "Thru zero" and "normal"), for each of the both sections (Omega & Phi) a by one octave decimated sub frequency wave and apart from PWM a mighty saw-tooth wave-shaping with 1-2 octaves-up effect and an absolute super round sine-wave.

The frequency range can be selected very quickly and reliable by a 4-pole rotary switch and a toggle switch over seven octaves and can be varied from there continuously by ± 1 octave, as well as ± 100 cents. The finally frequency range reaches from a couple of hundred seconds to umpteen kilohertz.

The oscillator has, thanks of absolute high-tech-components, a very high octave linearity, finest temperature stability and because of its extremely low phase-noise (jitter) an extraordinary pure sound and powerful potential.

Design and implementation meet highest technical standards concerning usability, sound quality, and electromagnetic immunity. The entire design and production work was done in Germany. Have fun!

Made in Germany

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1. WARRANTY

1.1 Limited Warranty

Schippmann electronic musical instruments warrants the mechanical and electronic components of this product for a period of two (2) years from the original date of purchase, according to the warranty regulations described below. If the product exhibits any faults within the specified warranty period that are not excluded from this warranty, *Schippmann electronic musical instruments* shall, at its discretion, either replace or repair the product. This warranty exists in addition to the general terms of business of the manufacturer *Schippmann electronic musical instruments*.

1.2 Terms of Warranty

Schippmann electronic musical instruments reserves the right to execute warranty services only if the product comes with a copy of the dealer's original invoice. Final discretion of warranty coverage lies solely with *Schippmann electronic musical instruments*. Any *Schippmann electronic musical instruments* product deemed eligible for repair or replacement under the terms of this warranty will be repaired or replaced within 30 days after receiving the product at *Schippmann electronic musical instruments*. Damages or defects caused by improper handling or opening of the unit by unauthorized personnel (user included) are not covered by this warranty. Products which do not meet the terms of this warranty will be repaired exclusively at the buyer's expense and returned C.O.D. with an invoice for labour, materials, return shipping, and insurance. Products repaired under warranty will be returned with shipping prepaid by *Schippmann electronic musical instruments*. **Outside Germany, products will be returned at the buyer's expense.**

1.3 Warranty transferability

This warranty is extended to the original purchaser and cannot be transferred. No other person (retail dealer, etc) shall be entitled to give any warranty promise on behalf of *Schippmann electronic musical instruments*.

1.4 Claim for damages

Schippmann electronic musical instruments does not accept claims for damages of any kind, especially consequential loss or damage, direct or indirect of any kind however caused. Liability is limited to the value of this product. The general terms of business drawn up by *Schippmann electronic musical instruments* apply at all times.

Please note: The controls and switches, especially the **Tune** or **Index** controls are programming facilities, **no real-time controllers!** Tweak them carefully since we cannot be held liable for “abused” potentiometers and switches.

2. CE AND FCC COMPLIANCE STATEMENTS

This device has been tested and deemed to comply with the **DIN EN 60065** standards.

This device has been tested and deemed to comply with the requirements, listed in FCC Regulations, part 15. The device complies with **EN 55103-1** and **EN 55103-2** standards.

Because of the entirely analogue construction, this device does not generate radio frequencies and will not interfere with radio frequencies generated by other electronic devices.

3. DISPOSAL

This device has been manufactured to RoHS-standards, in compliance with the requirements of the European parliament and council and is thus free of lead, mercury, and cadmium.

!! Notice: This product is still special waste and is not to be disposed of through regular household waste !!

For disposal, please contact your local dealer or *Schippmann electronic musical instruments*

4. SAFETY INSTRUCTIONS

BEFORE USING THIS PRODUCT FOR THE FIRST TIME, PLEASE READ THE ENTIRE USER MANUAL THOROUGHLY.

- PLEASE AVOID SHARP BENDING OF ANY CORDS AND CABLES.
- CORDS SHOULD NOT BE INSTALLED WITHIN THE REACH OF CHILDREN OR PETS.
- DO NOT TREAD THE ENCLOSURE OF THE PRODUCT, DO NOT PLACE HEAVY OBJECTS ON IT.
- BEFORE REMOVING THE PRODUCT FROM THE RACK, PLEASE DISCONNECT THE POWER PLUG AND ALL OTHER CABLE CONNECTIONS.
- PLEASE DISCONNECT THE POWER PLUG FROM THE OUTLET IN CASE OF A THUNDERSTORM.
- NEVER OPEN THE ENCLOSURE OF THE PRODUCT! NEVER TRY TO MODIFY THE INTERNAL CIRCUITRY! ONLY QUALIFIED SERVICE PERSONNEL IS ALLOWED TO OPEN THE ENCLOSURE.
- DO NOT PLACE OPEN FIRE ON TOP OF THE PRODUCT (CANDLES, ASH TRAYS, HOT THAI CURRIES ETC).
- NEVER EXPOSE THE PRODUCT TO WATER, BEER, OR MOISTURE.
- ADULTS ARE TO MAKE SURE THAT CHILDREN FOLLOW ALL SAFETY INSTRUCTIONS. SAME THING GOES FOR PETS.
- AVOID MECHANICAL STRESS OR IMPACT. DO NOT DROP THE PRODUCT; EVEN IF THERE IS A CONTROL LABELLED "DROP!".
- DO NOT USE THE PRODUCT WITH TOO MANY OTHER ELECTRONIC DEVICES RUNNING FROM ONE SINGLE OUTLET, ESPECIALLY IN CONNECTION WITH EXTENSION CORDS. DO NOT ATTEMPT TO SAVE MONEY ON CHEAP SOLUTIONS. BUY PROPER HIGH-DUTY POWER DISTRIBUTORS AND CORDS!
- NEVER USE EXTENSION CORDS WITH LESS MAXIMUM LOAD THAN THE TOTAL POWER CONSUMPTION OF ALL DEVICES CONNECTED TO A SINGLE POWER OUTLET COMBINED. OVERLOADING EXTENSION CORDS CAN CAUSE FIRE.
- **AVOID MECHANICAL STRESS ON SOCKETS AND KNOBS / SWITCHES.**
- **PROTECT YOUR SPEAKERS AND EARS (!) AGAINST EXCESSIVE AUDIO LEVELS. THE CS-8 PHS-28 UNIT IS CAPABLE OF GENERATING EXTREMELY LOW AS WELL AS EXTREMELY HIGH FREQUENCIES. BOTH**

MIGHT CAUSE SERIOUS DAMAGE TO AUDIO EQUIPMENT AND EAR-DRUMS!

5. MAINTAINANCE/ CLEANING

- BEFORE CLEANING THE PRODUCT, PLEASE DISCONNECT THE POWER PLUG FROM THE OUTLET OR DISCONNECT THE MODULE FROM ITS POWER CONNECTOR BY PULLING THE FLAT RIBBON CABLE.
- USE A DRY OR SLIGHTLY MOIST CLOTH OR COMPRESSED AIR FOR CLEANING. NEVER USE ANY CLEANER OR THINNER (E.G. PAINT THINNER OR ACETON). PRINTS AND PAINTWORK WILL IMMEDIATELY BE DESTROYED!! ALSO AVOID ALCOHOL (ISOPROPYLIC), GAS, SPIRITS (SCOTCH SINGLE MALTS, FOR A START) OR ABRASIVE HOUSEHOLD CLEANERS!

6. GETTING STARTET

6.1 Unpacking

The box should contain the following items:

- 1 x CS-8 Series VCO Omega-Phi 3HE rack-mount module
- 1 x Ribbon cable (20 cm length with two 16 pole IDC-connectors)
- 4 x M3 screws
- 4 x polypropylene washers
- This owners' manual

If the content of the box turns out to be incomplete, please get in touch with your dealer or *Schippmann electronic musical instruments* immediately. In case of damage caused in transit, please get back to the responsible carrier and *Schippmann electronic musical instruments* immediately. We will support you in this case.

6.2 Installation

Place the unit on a clean, dry and sturdy surface, or use a suitable keyboard stand or 19" rack. For 19" rack mounting, a suitable rack (3U Eurorack with +/- 12V power supply rails) is required. The Omega-Phi uses discrete all-analogue

electronics. Thus the oscillator frequency may be temperature-sensitive. We recommend placing the module away from heat sources such as radiators, lamps or other units that produce heat (e.g. power amps or internal power supplies).

7. CONTROLS

7.1 Front panel

Fig. 1 shows the front panel with consecutively numbered controls and jacks.

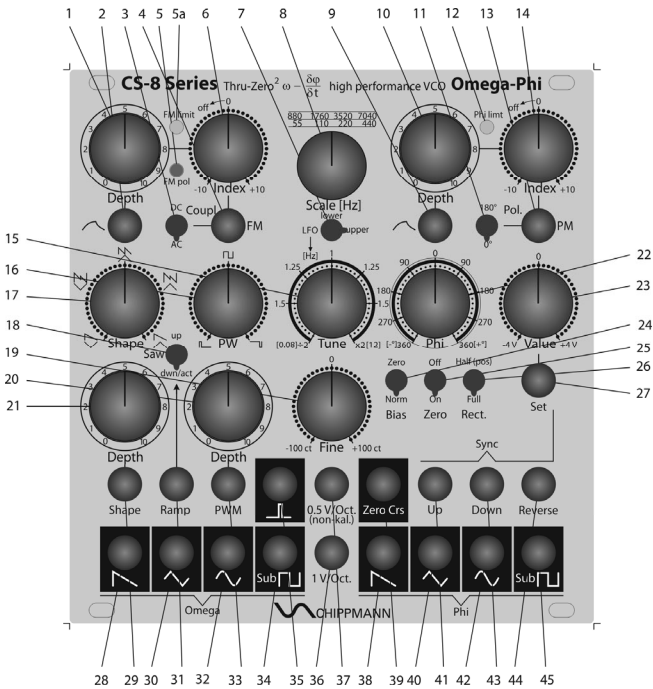


Fig. 1 Omega-Phi front panel

1. **Depth** control – attenuates the modulation signal at *jack 2* between 0 and 1
2. **Modulation input** (envelope symbol) jack – channels the applied signal via *Depth control 1* to the control input of the FM-Index-VCA
3. **Coupling** 2-pos. toggle switch – selects for the FM-modulation signal at *jack 4* the coupling AC (alternating voltage) or DC (direct current)
4. **FM** jack (input) – channels the applied signal to the signal input of the FM-Index-VCA
5. **FM pol** 2-colour-LED – displays the current working range of the core VCO; "green" -> positive frequency range, "red" -> negative frequency range
- 5a. **FM limit** 2-colour-LED – displays the convergency of the maximum frequency modulation index; "green" -> positive voltages, "red" -> negative voltages
6. **Index** control – adjusts the modulation depth of the FM input signal (*jack 4*) at the control input of the FM-Index-VCA
7. **Scale** 3-pos. toggle switch – determines the base frequency (without applied external control voltages) of the VCO
8. **Scale** 4-pole rotary switch – determines the base frequency (without applied external control voltages) of the VCO
9. **Modulation input** (envelope symbol) jack – channels the applied signal via *Depth control 10* to the control input of the PM-Index-VCA
10. **Depth** control – attenuates the modulation signal at *jack 9* between 0 and 1
11. **Polarity** 2-pos. toggle switch – selects the polarity of the PM-modulation input signal at *jack 13* (non-inverted or inverted)
12. **Phi limit** 2-colour-LED – displays the maximum/minimum border of the possible phase-shift; "green" -> positive phase border, "red" -> negative phase border
13. **PM** jack (input) – channels the applied signal to the signal input of the PM-Index-VCA
14. **Index** control – adjusts the modulation depth of the PM input signal (*jack 13*) at the control input of the PM-Index-VCA
15. **Tune** control – detunes the frequency, set by scale, by another ± 1 octave
16. **PW** control – adjusts the duty-cycle of the variable rectangle signal at *jack 35*
17. **Shape** control – displaces the progress of the saw-tooth curve at *jack 28* related to the triangle signal (*jack 30*) at its corner-(reverting)points

18. **Saw** 2-pos. toggle switch – selects rising or falling saw-tooth output and activates *jack 31* (position "dwn/act") at the same time
19. **Fine** control – detunes the frequency, set by scale, by another ± 100 cent
20. **Depth** control – acts on the duty cycle of the pulse output (*jack 35*); attenuates the signal at the PWM input at *jack 33* between 0 and 1
21. **Depth** control – acts on the saw-tooth displacement; attenuates the signal at the Shape input at *jack 29* between 0 and 1
22. **Phi** control – adjusts the phase (Phi) of all Phi-outputs (*jacks 38, 40, 42, 45*) related to the Omega-outputs (*jacks 28, 30, 32, 34, 35*) between $\pm 360^\circ$
23. **Value** control – determines the setting-voltage (± 4 V) of the triangle, when a Sync trigger at *jack 27* occurs
24. **Bias** 2-pos. toggle switch – switches on an internal bias voltage at the linear-FM-input to generate a basic frequency ("norm") or of ("Zero") (oscillator doesn't oscillate anymore without voltage at the FM-input)
25. **Zero** 2-pos. toggle switch – turns on the Thru Zero capability (phase reverse) ("On") or off ("Off")
26. **Rectifier** 2-pos. toggle switch – determines the method of rectifying at the FM-linear input, full-wave ("Full") or half-wave for only positive input voltages ("Half (pos)") - this is a special function due to the applied thru zero architecture
27. **Set** jack (input) – synchronization input sets the triangles output value to the voltage value (adjusted with *Value control 23*) by passing the trigger threshold (+3 V) (hard sync)
28. **Saw (Symbol)** jack (output) – saw-tooth of the VCO core (Omega), 4 - 8 Vpp
29. **Shape** jack (input) – CV-input, attenuated by *control 17*, displaces the saw-tooth curve
30. **Triangle (Symbol)** jack (output) – Triangle output of the VCO core (Omega), 8 Vpp
31. **Ramp** jack (digital-input) – only active in position "dwn/act" of the *switch 18*, 0 V = saw-tooth rising, > +3 V (or floating input) = saw-tooth falling
32. **Sinus (Symbol)** jack (output) – Sine-wave output of the VCO core (Omega), 8 Vpp
33. **PWM** jack (input) – CV-input, attenuated by *control 20*, varies the duty-cycle at *jack 35*
34. **Sub Rectangle (Symbol)** jack (output) – 50%-rectangle output decremented by one octave, 10 Vpp
35. **Pulse (Symbol)** jack (output) – rectangle output with variable duty cycle of the VCO core (Omega), 10 Vpp

36. **1V/Oct.** jack (input) – CV-input for calibrated exponential control of the oscillator frequency (Omega & Phi) with a sensitivity of one octave per Volt
37. **0.5V/Oct. (non-cal.)** jack (input) – CV-input for non-calibrated exponential control of the oscillator frequency (Omega & Phi) with a sensitivity of two octaves per Volt
38. **Saw (Symbol)** jack (output) – saw-tooth of the Phase section (Phi), 8 Vpp
39. **Zero Crs** jack (output) – Output of the zero-cross-detector of the FM-linear input, +5 V -> positive total control voltage, 0 V -> negative total control voltage
40. **Triangle (Symbol)** jack (output) – Triangle output of the phase section (Phi), 8 Vpp
41. **Up** jack (input) – Synchronization input sets the triangles direction to rising up by passing a trigger threshold (+3 V) (soft sync)
42. **Sinus (Symbol)** jack (output) – sine-wave output of the phase section (Phi), 8 Vpp
43. **Down** jack (input) – Synchronization input sets the triangles direction to fall down by passing a trigger threshold (+3 V) (soft sync)
44. **Reverse** jack (input) – Synchronization input sets the triangles direction to its current opposite direction (reverse) by passing a trigger threshold (+3 V) (soft sync)
45. **Sub Rectangle (Symbol)** jack (output) – 50%-rectangle output (Phi section) decremented by one octave, 10 Vpp

7.2 Backside

Fig. 2 shows the back of the module with consecutively numbered elements.

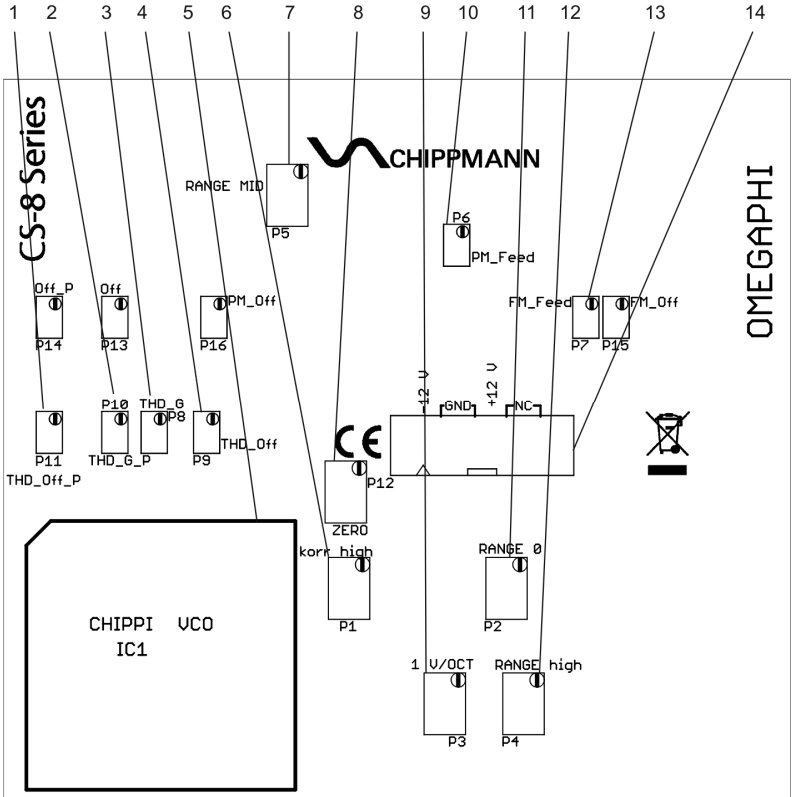


Fig. 2 back side of the module

1. **THD off P** 12-gauge-trimmer **P11** – THD-calibration of sinus' (Phi-Output)
2. **THD G P** 12-gauge-trimmer **P10** – THD- calibration of sinus' (Phi-Output)
3. **THD G** 12-gauge-trimmer **P8** – THD- calibration of sinus' (Omega-Output)
4. **THD off** 12-gauge-trimmer **P9** – THD- calibration of sinus' (Omega-Output)
5. **IC 1** - pinned VCO module
6. **korr high** 25-gauge-trimmer **P1** – calibration of gain error of the e-generator at 7.04 kHz

7. **Range MID** 25-gauge-trimmer **P5** – calibration of the standard A (440 Hz)
8. **ZERO** 25-gauge-trimmer **P12** – calibration to 0 Hz at Bias = Zero & exp. frequency = 20 kHz
9. **1 V/OCT** 25-gauge-trimmer **P3** – calibration of the scale at *jack 36* to 1 Volt/octave
10. **PM Feed** 12-gauge-trimmer **P6** – feed-through calibration of the phase modulation-VCA's
11. **Range 0** 25-gauge-trimmer **P2** – calibration of the lower basic frequency (55 Hz)
12. **Range high** 25-gauge-trimmer **P4** – calibration of the upper frequency (7040 Hz, upper row)
13. **FM Feed** 12-gauge-trimmer **P7** – feed-through calibration of the frequency modulation-VCA
14. **16 Pin power supply-box header**

7.3 Initial operation

The power connector's (14) pin-out in top view (refer to fig. 2) is assigned as follows:

Bottom to top, left to right. Thus pin 1 is located at bottom left, pin 2 above pin 1 etc. Pin 15 is at bottom right, pin 16 at top right.

Pin 1, 2 = -12 V (labeled with a triangle)

Pin 3-8 = GND (regarding ground, 0 V), located outward on all jacks

Pin 9, 10 = +12 V

Pin 11-16 = not connected

To hook up power to the module, connect one of the IDC-connector of the included flat ribbon cable to the box header (refer to fig. 2). Observe guide key for the polarity of the connector in order to avoid pin reversal. The red tag of the cable is to match the triangle-label.

8. MODULE DESCRIPTION

8.1. Layout and functions

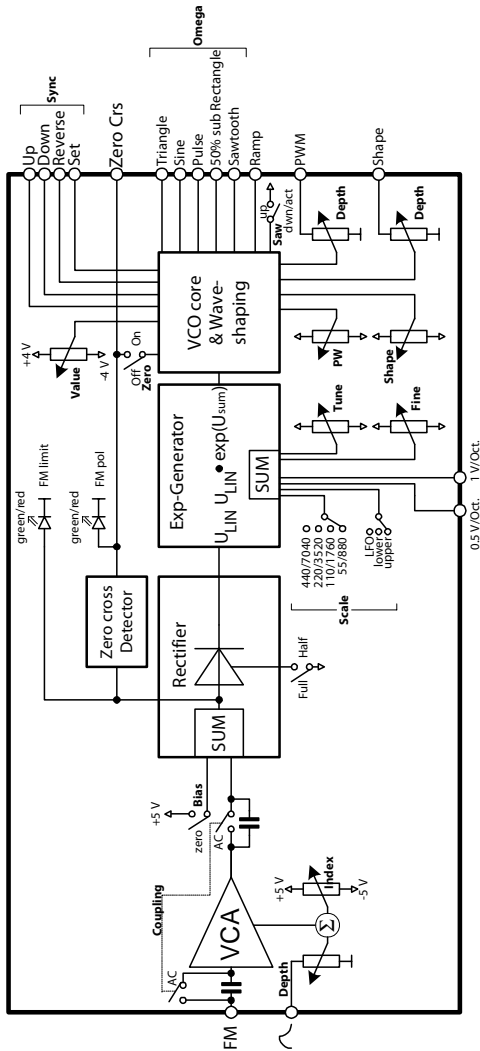


Fig. 3a Structure of the VCO core

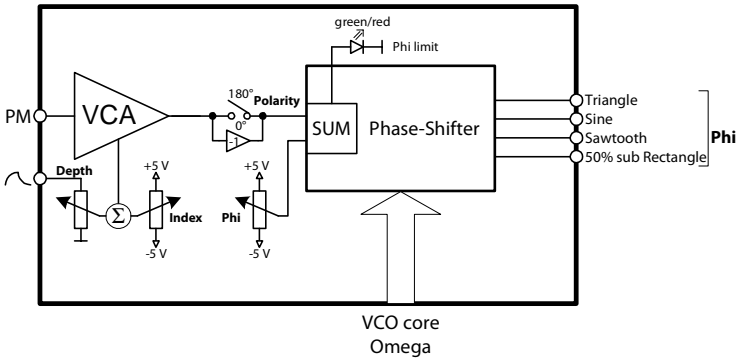


Fig. 3b Structure of the phase-shifting section

Fig. 3a and 3b showing the complete structure of the oscillator. Now, step by step all parts of it will be described in the following chapters.

8.2. The e-function-generator

An e-function-generator (Exp-Generator, Fig. 3a) is mostly part of every music VCO. They have a linear input and the exponential input. The linear one is scaled Hertz/Volt and the exponential one in octaves/Volt or decades/Volt. Generally, for resulting voltage output U_c one obtain the mathematical expression: $U_c = U_{lin} \cdot e^{\alpha \cdot U_{sum}}$, where α is an exponential scaling-factor and U_{sum} the total input voltage at the exponential input (following called e-input) and it is the result of the following parts.

Scale-switches: The 3-position toggle switch (*upper, lower, LFO*) determines the range of the 4-position-rotary switch. In position "lower" the lower row of frequencies of the rotary switch will be output by the VCO core in steps of octaves 55 Hz, 110 Hz, 220 Hz and 440 Hz. In position "upper" it is the upper row, 1760 Hz, 3520 Hz and 7040 Hz. In position "LFO" the oscillators frequency at "55 Hz"-position of the rotary switch and at full CCW (counter clockwise) of the *Tune*-controller is about 0.08 Hz.

Tune: The normal position of this controller is the middle. In the positions "upper" and "lower" it decrements/increments (left/right) the oscillators'

frequency by ± 1 octave (a bit more). In position "LFO" it has a much wider range. In position "55 Hz" the frequency ranges (from left to right) from about 0.08 Hz to 12 Hz, that's a factor of 150 and equals 7.2 octaves. The rotary switch still octaves the frequencies. So, in position "440 Hz" *Tune* ranges from 0.64 Hz to about 100Hz. Fine, so far.

Fine: This controller was intended for finest frequency corrections and definite beats. Normal position is the middle and it detunes the frequency once again by ± 100 cent (a bit more). 100 cent equals a semitone step at the equally-temperate scale.

1 V/Oct-jack: An external voltage at that jack increments (or decrements) the current oscillator frequency with a sensitivity of one octave (x2) per +Volt, resp. ($\div 2$) per -Volt (negative voltages). This input is calibrated.

0.5 V/Oct-jack: An external voltage at that jack increments (or decrements) the current oscillator frequency with a sensitivity of two octaves (x4) per +Volt, resp. ($\div 4$) per -Volt (negative voltages). This input is **not** calibrated, i.e. this scale is tolerant with some percent and different from VCO to VCO.

Each of these influence quantities at the e-input operates by a frequency multiplication not by summing!

8.3. The VCO core and its wave-shapes

The VCO output its frequency as different waveforms, which are sinus, triangle, saw-tooth, variable rectangle and a 50% rectangle with **half** frequency (one octave down). Fig. 4 shows these functions and there phase relations e.g. as voltage versus time.

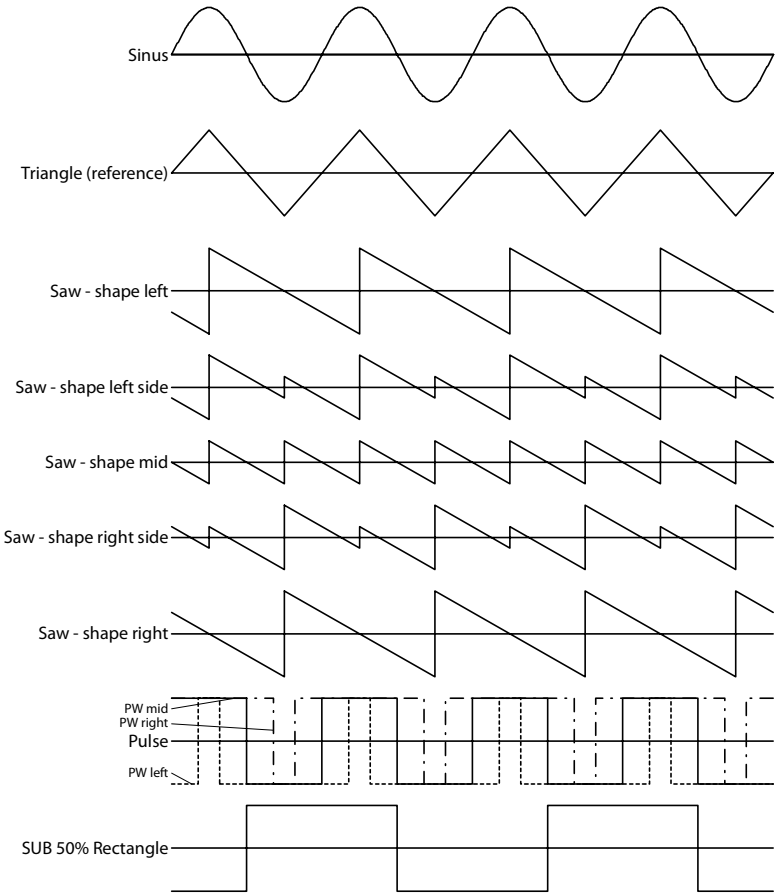


Fig. 4 The waveforms of the VCO core (Omega-outputs)

The triangle is the reference for all other waveforms.

PW/PWM/Depth: The controller *PW* determines as shown in the graph the duty-cycle from 0% (full CCW) to 100% (full clockwise, CW) of the pulse wave.

For *Depth* at full CW a voltage range of 2 V at the *PWM* input jack controls the total range of this parameter.

Shape/Shape/Depth: The *Shape*-controller breaks the saw-tooth wave during passing through at a further point. The graphs illustrate how. In the middle position one obtain a saw-tooth with double frequency and half amplitude (4 $V_{\text{peak-to-peak}}$ instead of 8 V_{pp}). Both in full CCW and full CW position one obtain a full saw-tooth wave displaced by a half triangle wave (180°) (that's not the same as inverting!). The *Depth*-controller in full CW voltage range of 5 V at the *Shape* jack controls totally this parameter.

Ramp-jack/Saw-switch: The *Saw*-switch selects for the saw-tooth output the direction either rising (position "up") or falling (position "dwn/act") for both Omega section and Phi section. In position "dwn/act" the jack *Ramp* is activated. A voltage of $>+3$ V or floating input means "falling" and 0V "rising". Because this function equals a multiplication with ± 1 , one obtain a semi-analogue/semi-digital **ring modulator!**

8.4. The linear frequency modulation FM

In Abb. 3a above the U_{Lin} -input of the e-generator, which finally is fed with the FM voltages, goes to the output of a **Rectifier**. (There may exist different solutions for the realization of a thru zero oscillator, but the realized approach here seemed to be the most elegant one.)

To imagine, generally, how FM works and how a carrier waveform becomes influenced by modulation, some explanations based on graphs will follow. Fig. 5a (top) shows the non-modulated sine wave (carrier) of the oscillator, the next graph below shows the rectifier output (modulator); this curve modulates now the carrier at the U_{Lin} -input of the e-generator. The modulator is a cosine-curve with same frequency as the carrier to obtain more intuitive wave shapes, because the FM-result depends on the phase relationships of carrier and modulator. The modulation amplitude was chosen, that the minimum at the rectifier output becomes exactly zero. So, the modulation index is 1, which means that the magnitude of the modulator is as large as the bias and the middle graph is normalized to the bias.

Bias: With that switch the bias can be switched on (position "Norm") or off (position "Zero"). If it is switched off the oscillator will stop oscillate without

any voltage at the FM input, regardless of the scale setting and any other control voltages at the e-input. So, the position "Norm" is very important for the normal mode. In position "Zero" the oscillator will track with the modulator.

The lower graph shows the modulation result. At that points, where the rectifier output is zero (vertical dotted line), the oscillator stops for this moment, because the oscillators' frequency is zero. Exactly up to here every ordinary oscillator with linear FM-input can process this, too.

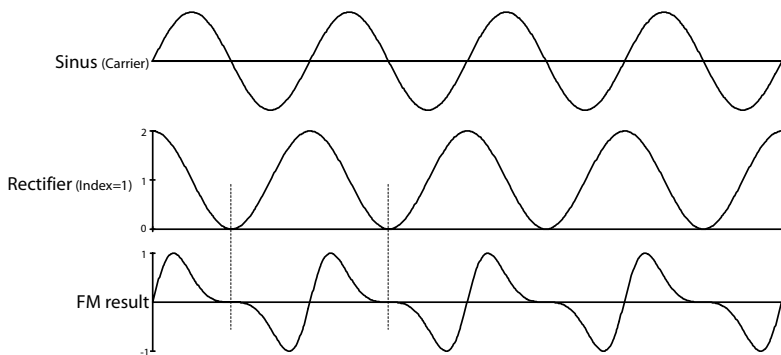


Fig. 5a FM with index=1

Fig. 5b shows under the same preconditions as above for carrier and modulator the results for index =2. I.e., the modulation magnitude is twice as high as the bias. For the wave of the modulator the rectifiers' output would reach the values +3 (normalized graph) and -1. Because the oscillator doesn't "understand" negative voltages at its U_{Lin} -input, the **full-wave-rectifier** reconstruct the values +3 und +1 (upper graph). For a correct processing, the oscillator core receives the sign from the **zero-cross-detector** (s. Fig. 3a). With every change of the sign the oscillator will change its phase direction. This is also true for saw-tooth waves; they fall or rise depending on the detector sign. A negative sign means a reversed phase direction.

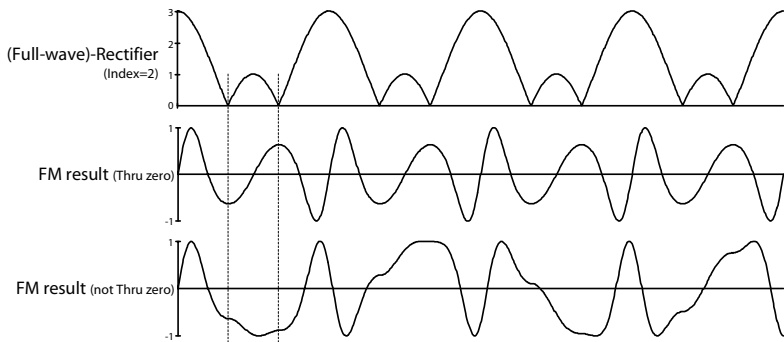


Fig. 5b FM with index=2

The middle graph shows the FM result with thru zero technique, whereas the lower indeed gets the rectifiers output but no more the detector sign information, which means a solely positive interpretation. It is evident that the result is no longer periodic and hence not harmonic. This comes because with the start of the rectifying process an average voltage value is obtained, which shifts the basic oscillator frequency. With a continuously increasing modulation amplitude, single harmonic frequencies will appear again and again. Moreover, one can see that only in thru zero operation an oscillator direction change occurs before reaching the value minimum/maximum. For switching "on" or "off" the thru zero mode there is the

Zero-switch: Thru zero operation in position "on" and not in position "off". I.e., the information of the **zero-cross-detector** for the oscillator core is active or not. The information about the rectifier input sign will be displayed by the

FM pol LED: *Green* for positive voltages at the rectifier input (this is still possible with negative FM-inputs, if the bias is active!) and *red* for negative values.

Zero Crs-jack: Moreover the output of the **zero-cross-detector** is applied at this jack. 0 V for negative, +5 V for positive. This signal is suitable for exotic synchronizations! This output is also active when the Zero-switch is "off".

Fig. 5c shows the case for half-wave rectifying mode.

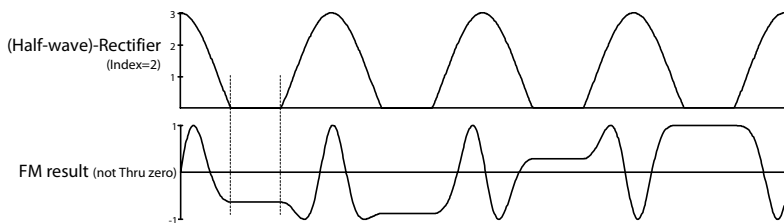


Fig. 5c FM with index=2 and half-wave rectifying

This is the mode of every ordinary oscillator. When the input voltage at the U_{Lin} -input becomes zero or lower, nothing more will happen; the oscillator stops. And it's also evident that the result is not periodic for the same reason as described above.

Rect-switch: This switch determines the mode of the rectifier. In position "Full" it works as shown in Fig. 5b and in position "Half" as in Fig. 5c.

8.4.1. The FM VCA

Fig. 3a above shows, that the rectifier is fed with the bias and a further external modulation input signal. This modulation signal will be applied at the

FM-jack: It channels the input unabated to an VCA-input. These input voltages shouldn't exceed ± 11 V, if linear working of the VCA is wished, best is ± 4 V or 8 Vpp, resp..

Index/Depth-controller: The *Depth*-controller attenuates the modulation signal at *jack 2* (envelope symbol) between 0 and 1. This signal will be added to the value of the *Index*-controller. In case that no signal is applied at *Depth* or it's in full CCW position, initially turning *Index* from the middle position (no effect) to full CW will increase the modulation depth. Turning *Index* from the middle to full CCW, nothing more will happen. At *Depth* positive as negative voltages can be applied, which either increases or decreases the index value. By turning the *Index*-controller to the left, positive modulation voltages at the *Depth*-controller can be cut so.

Hint: With no signal at the FM input jack, the inherent noise of the VCA at high *Index* values can become audible! So, don't forget to turn *Index* to zero.

Coupling-switch: This switch selects the mode of coupling of the VCA-FM-input to the rectifier. In position "AC" (capacitive decoupled) only alternating voltages with frequencies higher than 2 Hz will be processed. This mode of coupling could become very important to avoid a detune of the oscillator by lowest offset voltages of the VCA or by DC voltages as part of the modulation signal. In position "DC" direct current voltages can be processed.

Note: The 50% sub rectangle outputs of the Omega- and Phi section will be in phase after switching on the oscillator. After FM or PM they could oscillate in anti-phase, which is not avoidable. The probability is 50/50.

8.5. The synchronization section

The principle of operation of the different synchronization modes are shown exemplarily for triangle and saw-tooth waves. Any of the overall 4 Sync input jacks needs a minimum positive voltage of +3 Volt to trigger its function. These inputs are equipped with an upper and a lower threshold, so, they are able to process any wave shapes, which could slowly approach the trigger threshold (+3 V). After triggering by exceeding the upper threshold the signal has to fall below the lower threshold (+1 V) before another trigger can occur (hysteresis). To make it easier in the following graphs the syncs appears as unit step functions. The designations "Up", "Down" and "Reverse" are related to the curve direction of the triangle wave. The saw-tooth is derived from the triangle and so it could lead to very different shapes; with these sync-functions it's not possible to reverse the saw-tooth's direction! This is only possible for negative voltages at the FM input in thru zero mode or with the Ramp/Saw-function (s. above).

Sync Up/Down-jacks: Fig. 6a illustrates, that "Up" and "Down" triggers will only change the curve direction, if the trigger occurs at a time when the triangle has currently the inverse direction, otherwise nothing special will happen.

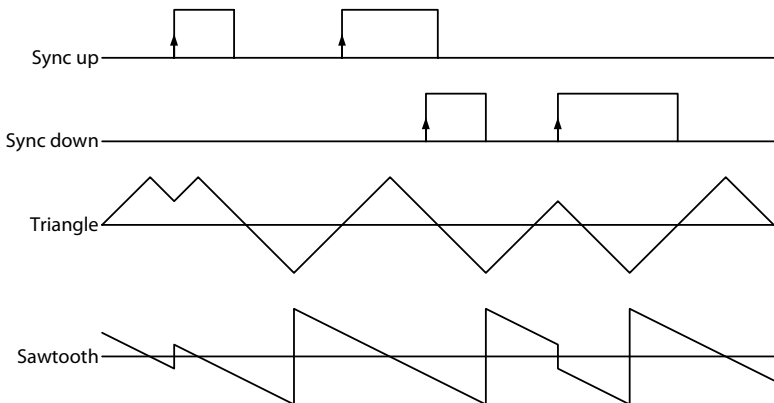


Fig. 6a Synchronization Up and Down

Sync Reverse/Set-jacks: "Reverse" means that with every trigger the current curve direction will be reversed. The "Set"-function is commonly known as hard-sync. A trigger at the *Set*-jack sets the triangle immediately to that value adjusted with the

Value-controller: It can be set to all positive or negative values (± 4 V) the triangle can attain. The currently direction will not be influenced however. The triangle will continue its direction, even when set back just before reaching an extremum. But, combining of "Set" and e.g. "Up" is useful to force the triangle to definite values an slopes, this is the classical hard-sync. Fig. 6b illustrates the Set function for 0 V of the *Value*-controller in combination with "Reverse".

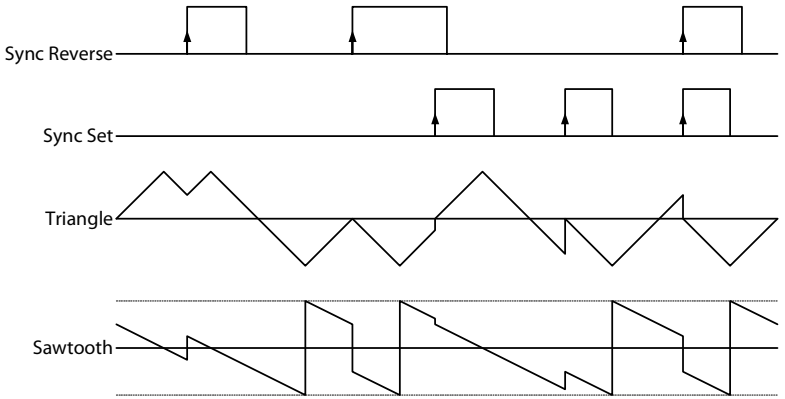


Fig. 6b Synchronization Reverse and Set

8.6. The phase modulation PM

The phase-shifter shown in Fig. 3b above is connected downstream to the oscillator core. Everything what will be processed here will have **NO** reaction to the oscillator core. The sound aesthetic and the spectrums are very similar to FM. However, there are existing clear differences. First of all the similarities and even identities. Considering solely sine-wave functions and a system of two oscillators (carrier and modulator) then theoretically there is nothing which could be done with FM which cannot also be done with PM. So, that what is shown in Fig. 5a above is also possible with PM as shown in Fig. 7a. To obtain the same wave shape, only the phasing between carrier and modulator has to be chosen differently. The modulator now is sine, not cosine. The results for the indices 1 and 6 are shown.

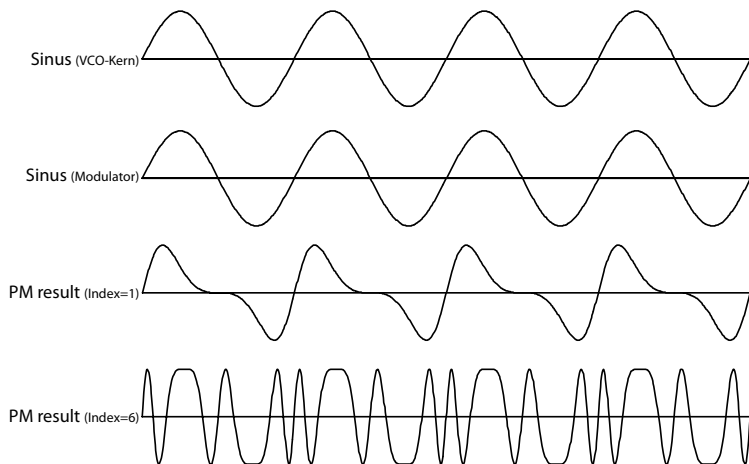


Fig. 7a PM with Index 1 and 6

A limit of the Phase-shifter is its phase shifting range. This is $\pm 360^\circ$ ($\pm 2\pi$ radian measure).

Phi-output jacks: The phase of the Phi-waveforms saw-tooth, triangle and sine can be shifted referred to the VCO core (Omega-outputs) by maximum $\Phi = \pm 360^\circ$ ($\pm 2\pi$ radian measure). Thus, the 50% sub-rectangle with the **half** frequency will be shifted by $\pm 180^\circ$ ($\pm \pi$ radian measure).

Phi-controller: It sets this phasing Φ to a fixed value. The phasing of the waves by itself has no effect of their sound and spectrum. Only **changes** of the phase causes real frequency shifts at the Phase-shifter output.

This fact is one of the big differences to the FM. And this finally means that the modulation index goes proportional to the modulation frequency without any limit. So, the index is **not** a constant as for the FM. Fig. 7b shows the PM result for the as twice higher modulation frequency without doubling the index as it would be necessary for the FM to get the same result.

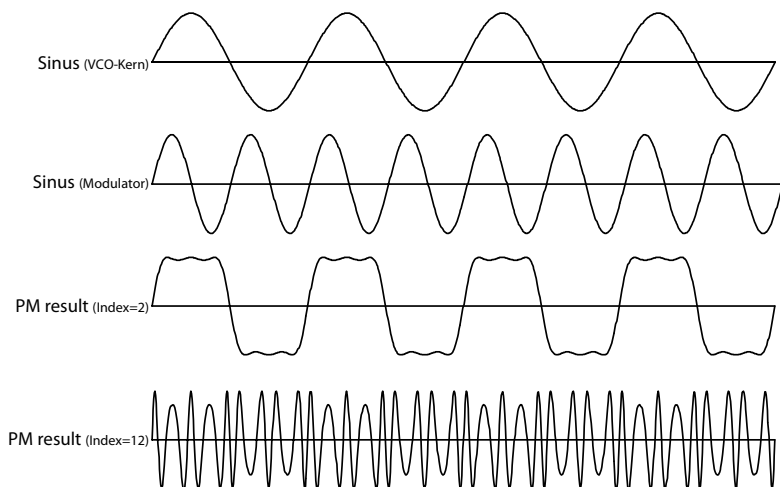


Fig. 7b PM with doubled index by frequency doubling (modulator)

One can say, that the phase modulation is a "harder" modulation than FM, since one cannot generate stepping waves due to modulation. For my hearing this is limited true. On the one hand the modulation index of the PM rises with higher frequencies on the other hand the FM needs for frequency shifts only a constant voltage, whereas a steady phase movement therefore is necessary for the PM. And this is, why the PM sounds more gentle, finally. What is impossible with FM are sudden jumps of curve values; an infinite short and infinite high voltage pulse would be needed to generate a definite jump in a sine carrier. With the PM a step function as the modulator forces the phase to jump.

Because it is the phase **change** which could be heard, with low-frequency saw-tooth waves, e.g., which amplitude is adjusted to shift the phase by exactly 360° or 720° , constant detunes can be generated. E.g. with a rising saw-tooth of 1 Hz, which shifts the phase repetitive by 360° , detunes the output frequency by +1 Hz, with 720° phase shift by +2 Hz. Superposition with the VCO core outputs (Omega) one obtain a fat beat as you would have two detuned oscillators.

8.6.1. The PM VCA

Fig. 3b above shows that the control input of the Phase-shifter is fed by the value of the *Phi*-controller on the one hand and by an output of the PM-VCA on the other hand. The PM-modulation signal will be applied at the

PM-jack (13): It channels the input unabated to the PM-VCA input. These input voltages shouldn't exceed ± 11 V, if linear working of the VCA is wished, best is ± 4 V or 8 Vpp, resp..

Index/Depth- controller: The *Depth*-controller attenuates the modulation signal at *jack 9* (envelope symbol) between 0 and 1. This signal will be added to the value of the *Index*-controller. In case that no signal is applied at *Depth* or it's in full CCW position, initially turning *Index* from the middle position (no effect) to full CW will increase the modulation depth. Turning *Index* from the middle to full CCW, nothing more will happen. At *Depth* positive as negative voltages can be applied, which either increases or decreases the index value. By turning the *Index*-controller to the left, positive modulation voltages at the *Depth*-controller can be cut so.

Hint: With no signal at the PM input jack (13), the inherent noise of the PM-VCA at high *Index* values can become audible! So, don't forget to turn *Index* to zero.

PM limit LED: This LED slowly starts to glow *green* just before reaching the maximum positive phase shift angle of $+360^\circ$ and *red* for reaching the maximum negative angle of -360° . The *Phi* controller value and the *PM* input voltage (*jack 13*) are summed for this indication since both influences the phase.

Polarity-switch: This switch inverts or not the modulation signal at the PM-input, inverting in position "180°", non-inverting in position "0°".

A capacitive decoupling is not necessary, because offsets only leading to a constant phasing, what could be corrected with the *Phi*-controller. But, as mentioned above, the polarity could be of interest and therefore there is the

9. THEORETICAL PRINCIPLES

To understand the mathematics behind these modulating operations, specific knowledge are absolute requirements. So, this chapter turns to experts, but shouldn't be unmentioned for the sake of completeness. However, results are formulated intelligible to all.

9.1. Frequency modulation FM

In general terms the frequency modulation with a sinus function as a carrier could be written as follow

$$FM(t) = A_0 \cdot \sin \left(\int_0^t [\omega_0 + m_{FM} \cdot \omega_0 \cdot M(\tau)] d\tau \right) \quad Eq. 1$$

FM(t) is the modulation result, A_0 its amplitude, ω_0 is the basic angular frequency of the oscillator (that is $2\pi f_0$, with f_0 the oscillator frequency) given by the **bias** (s. above) and the scale. **M(t)** is the modulation signal normalized to ± 1 and m_{FM} initially can be seen as a multiplier ≥ 0 or as an index (modulation depth). Because a sole information about a fix frequency implies a steady curve of the phase, a time depending frequency is to integrate over the time to obtain the phase as a function of time, instead of simply write $\omega_0 \cdot t$. The term in the squared bracket is a time depending frequency and is to integrate over the time. The result, term in the round bracket, describes the *phase* (state of the carrier) as a function of time. Frequency, generally, now means, by how much degrees per second the phase is running forward, stopping or reverting - the result is no longer sinusoidal.

Taking for $M(t)=\sin(\omega_m t + \varphi_F)$ a sinus-function, as chosen in all the examples above, with ω_m as the modulation angular frequency and φ_F as an arbitrary constant phase value, then is

$$FM(t) = A_0 \cdot \sin \left(\int_0^t [\omega_0 + m_{FM} \cdot \omega_0 \cdot \sin(\omega_m \tau + \varphi_F)] d\tau \right) \quad Eq. 2$$

and the integral calculated leads to

$$FM(t) = A_0 \cdot \sin\left(\omega_0 t - m_{FM} \cdot \frac{\omega_0}{\omega_m} \cdot [cos(\omega_m t + \varphi_F) - cos(\varphi_F)]\right) \quad Eq. 3$$

The term in the overall round bracket, now, is the time depending phase of the carrier, resp. FM(t).

9.2. Phase modulation PM

The phase modulation can be written as:

$$PM(t) = A_0 \cdot \sin(\omega_0 t + m_{PM} \cdot \Phi \cdot M(t) + \varphi_C) \quad Eq. 4$$

Because M(t) influences directly the carrier phase and not the frequency, there is no integral. $\Phi (= 2\pi)$ is the half value of the above mentioned phase shifting range (phase space) of the phase-shifter. With $M(t)=\sin(\omega_m t + \varphi_P)$ again as a sinus-function leads to

$$PM(t) = A_0 \cdot \sin\{\omega_0 t + m_{PM} \cdot \Phi \cdot \sin(\omega_m t + \varphi_P) + \varphi_C\} \quad Eq. 5$$

φ_F , φ_P , φ_C can be chosen that PM(t) and FM(t) formal becomes equal. Choosing in our example $\varphi_F = \frac{\pi}{2}$ (90°) and $\varphi_P = \varphi_C = 0$ leads to (Eq.3 and Eq.5)

$$FM(t) = A_0 \cdot \sin\left(\omega_0 t + m_{FM} \cdot \frac{\omega_0}{\omega_m} \cdot \sin(\omega_m t)\right) \quad Eq. 3a$$

$$PM(t) = A_0 \cdot \sin(\omega_0 t + m_{PM} \cdot \Phi \cdot \sin(\omega_m t)) \quad Eq. 5a$$

With $m_{PM} \cdot \Phi = m_{FM} \cdot \frac{\omega_0}{\omega_m}$ Eq. 3a and Eq. 5a becomes identical.

$m_{FM} \cdot \frac{\omega_0}{\omega_m}$ of Eq.3a can be called as the phase modulation index of FM(t), because this term describes by how many degrees the phase of the carrier will be shifted by the modulator. And it is obvious that this index goes reciprocal with the modulator frequency, so, increases to lower frequencies and goes with $\omega_m \rightarrow 0$ to infinite.

Then becomes $\lim_{\omega_m \rightarrow 0} \left(m_{FM} \cdot \frac{\omega_0}{\omega_m} \cdot \sin(\omega_m t)\right) = m_{FM} \cdot \omega_0 \cdot t$, which corresponds to a frequency shift with the index m_{FM} by a constant DC voltage.

The phase space therefore must hold ready the infinity. Vice versa the index of the frequency modulation of the PM can be computed, because shifting the phase causes a change of the frequency, inevitably. Therefore the term in the round bracket of equation 4 (the time depending phase).

$$\phi(t) = \omega_0 t + m_{PM} \cdot \Phi \cdot M(t) + \varphi_C \quad \text{Eq. 6}$$

is to derivate with respect to time (inversion of integration). Let be $\omega_{PM}(t)$ the momentary time depending frequency of PM(t).

$$\omega_{PM}(t) = \frac{d\phi(t)}{dt} = \omega_0 + m_{PM} \cdot \Phi \cdot \frac{dM(t)}{dt} \quad \text{Eq. 7}$$

And with $M(t)=\sin(\omega_m t + \varphi_P)$ we obtain

$$\omega_{PM}(t) = \omega_0 + m_{PM} \cdot \Phi \cdot \omega_m \cdot \cos(\omega_m t + \varphi_P) \quad \text{Eq. 7a}$$

To obtain the momentary time depending frequency of FM(t) only the term of the squared bracket of Eq.1 has to be written down. And with $M(t)=\sin(\omega_m t + \varphi_F)$ we obtain

$$\omega_{FM}(t) = \omega_0 + m_{FM} \cdot \omega_0 \cdot \sin(\omega_m t + \varphi_F) \quad \text{Eq. 8}$$

Replacing the modulator functions sine and cosine by the modulus of their maximum values (± 1) and calculating the difference of $\omega_{FM}(t)$ or $\omega_{PM}(t)$, resp. and ω_0 and normalizing to ω_0 after that, we obtain the frequency modulation indices **FI_{PM}** and **FI_{FM}** , resp..

Summarizing we obtain for the PM and for the FM the indices of frequency modulation and phase modulation, each time.

Phase modulation:

$$PI_{PM} = m_{PM} \cdot \Phi, \quad 0 \leq m_{PM} \leq 1 \quad \text{Eq. 5.1}$$

$$FI_{PM} = \frac{\omega_{PM,max}}{\omega_0} - 1 = m_{PM} \cdot \Phi \cdot \frac{\omega_m}{\omega_0}, \quad 0 \leq m_{PM} \leq 1 \quad \text{Eq. 7.1}$$

Frequency modulation:

$$PI_{FM} = m_{FM} \cdot \frac{\omega_0}{\omega_m}, \quad 0 \leq m_{FM} \leq 44 \quad \text{Eq. 3.1}$$

$$FI_{FM} = \frac{\omega_{FM,max}}{\omega_0} - 1 = m_{FM}, \quad 0 \leq m_{FM} \leq 44 \quad \text{Eq. 8.1}$$

As one can see FI_{PM} rises proportional with the modulation frequency ω_m , whereas FI_{FM} is kept frequency independently constant. Against this PI_{FM} decreases reciprocal, whereas PI_{PM} is kept frequency independently constant.

Interesting is that typical spectral characteristics like frequency effacements are kept constant, as long as the phase modulations index (PI) will be kept constant, independently of the frequency! For the PM this fact is given, naturally according to **Eq. 5.1**, whereas for the FM m_{FM} is to fit to ω_m for each frequency.

It is the phase space, which will be travel through by the modulator, which is responsible for the spectral characteristics. Also, accordingly to my hearing the PM seems to be more gentle and natural than the FM, where always the typical effect of low-pass filtering is audible (integral in **Eq.1**). And exactly this fact again leads to a softer sound esthetic of the FM. With the PM, in contrast to the FM, higher modulation frequencies and also harmonics in the modulation signal win influence (rising FI), which is similar to a high-pass filtering. So, in contrast to this lower modulation frequencies (e.g. slow changes of DC parts) win influence with the FM (very large phase space). Hence, because of the human hearing properties (psychoacoustics) the FM will mainly appear as the more dynamic and stronger modulation synthesis. Fortunately for all of us, this VCO provides both methods of synthesis.

Maths tangible: The half phase space Φ of this oscillator is 2π . To obtain with the PM the same modulation index FI as possible here with the FM accordingly to **Eq.7.1** and **Eq.8.1** the following must come true:

$$m_{PM} \cdot \Phi \cdot \frac{\omega_m}{\omega_0} = m_{PM} \cdot 6,28 \cdot \frac{\omega_m}{\omega_0} \geq m_{FM}.$$

For this oscillator is $m_{PM} = 1$ and $m_{FM} = 44$, maximum. To reach this FI for the PM, we obtain $\frac{\omega_m}{\omega_0} \geq 7$. I.e., the phase modulation frequency has to be at least 7 times (2.8 octaves) higher than the oscillator basic frequency. With higher ratios $\frac{\omega_m}{\omega_0}$ F_{PM} will even predominate F_{FM} .

And vice versa accordingly to **Eq.5.1** and **Eq.3.1** we can find that

$$m_{PM} \cdot \Phi \leq m_{FM} \cdot \frac{\omega_0}{\omega_m}$$

must come true to compute that frequency, up to which the FM can provide the same or larger phase space as the PM here. Remodeled and plug in all numbers as above we obtain $\frac{\omega_m}{\omega_0} \leq 7$. As long as the modulation frequency is 7 times higher or less than the oscillator basic frequency, the phase space of the FM will be as large as for the PM or larger. That's the reverse of the medal!

One can examine infinite things, indeed, but there will be reached limitations very soon, that only numerical computer aided methods will come into question.

10. TECHNICAL SPECIFICATIONS AND RATINGS

10.1 Specifications (generally)

Input- and output-sockets:	mono jack sockets 3.5 mm (1/8")
Input sockets have grounded switch (0 V)	
Power:	-12 V / +12 V (polarity protection)
Power consumption:	max. 120 mA (for both supplies ± 12 V)
Proper ambient temperature:	0 °C – +55 °C / 32F – 131F
Net weight (module only):	approx. 260 g / 0,57 lbs
Dimensions (W x H x D):	24 PU (121.6 mm) x 3 HU (128.5 mm) x 33 mm
Installation depth (behind the panel)	<30 mm

10.2 Signals and ratings

Maximum input voltage at all input jacks ():	± 15 V
Oscillator frequency range (Omega):	0.001 Hz - 320 kHz
Oscillator frequency (Phi) -3db:	30 kHz