

1. Introduction

Module A-196 contains a so-called **Phase Locked Loop** circuit (**PLL**). A PLL consists of three parts: **VCO** (linear voltage-controlled oscillator with rectangle output), **phase comparator** (**PC**), and **low-pass filter** (**LPF**). The three parts are connected in the A-196 with normalised sockets to form the standard closed-loop PLL frequency-feedback system. The normalised sockets allow individual access to each part of the PLL and enable other patches than the standard PLL (e.g. insertion of external modules).

The **VCO** is equipped with the controls **Range** and **Offset**. The range switch is used to select one of three frequency ranges. The Offset control defines the maximum frequency of the VCO.

The module contains three **different types of phase comparators** that are selected with a 3-position switch.

The **LED** indicates if the PLL is locked for PC2 , i.e. if the frequency of the internal VCO is the same as the frequency of the external input signal.

The frequency of the built-in **low pass filter** is manually adjusted with the **frequency control**.

2. Basic principles

The three units **VCO**, phase comparator (**PC**) and low pass filter (**LP**) form a standard closed-loop frequency-feedback system: The **VCO** output (linear response, rectangle output) is **compared** with an **external signal** (e.g. A-110 VCO) in the **PC**. The PC output is a digital high/low signal that indicates if the frequency resp. phase difference of the two input signals is negative, zero or positive. This signal is processed by the **LP** to generate a **smooth control voltage** that **controls** the **frequency** of the **VCO**. The units VCO, PC and LPF form a **frequency feedback loop** that works like this: The CV (LP output) increases (decreases) as long as the external frequency is higher (lower) than the frequency of the internal VCO and stops increasing as soon as both frequencies become identical.

But there are some stumbling blocks: **Different types of phase comparators** with advantages and disadvantages can be made. Some phase comparators e.g. even lock at harmonics, i.e. if the two frequencies to be compared are integer multiples. For some applications this "fault" may be used to create interesting effects. The A-196 contains 3 different types of phase comparators: PC1 is a simple exclusive OR, that even locks at harmonics. PC2 is a so-called RS flipflop and PC3 a more complex digital memory network. The user can select one of the three phase comparators with a

3-position switch. When PC2 is used a LED displays the "locked" state, i.e. when the frequency of the internal VCO is identical to the external frequency.

Special attention has also to be directed to the **frequency of the LP**. To obtain a smooth control voltage for the VCO the frequency of the LP has to be much smaller than the lowest frequency of the internal or external audio signal. Otherwise the frequency of the internal VCO will jitter or wobble around the correct frequency. But for special effects this frequency jitter can be used intentionally.

Example: frequencies in the range 50Hz...1kHz have to be processed with the PLL. Therefore the frequency of the LP has to be about 10Hz or even less. Such a low frequency of the LPF causes a noticeable slew of the internal VCO. When the frequency of the external signal jumps e.g. between 50Hz and 1kHz it takes about 0.1 second until the internal VCO reaches the new frequency (like portamento). Consequently one has to find a compromise between the frequency jitter and portamento. But these remarks are valid only for the "ideal" working PLL. As the A-196 is used in a musical environment these "problems" and "disadvantages" with jitter and slew time lead to additional musical applications like portamento effects, wobbling frequencies or harmonic locking according to the type of frequency comparator and time constant of the PLL low pass filter.

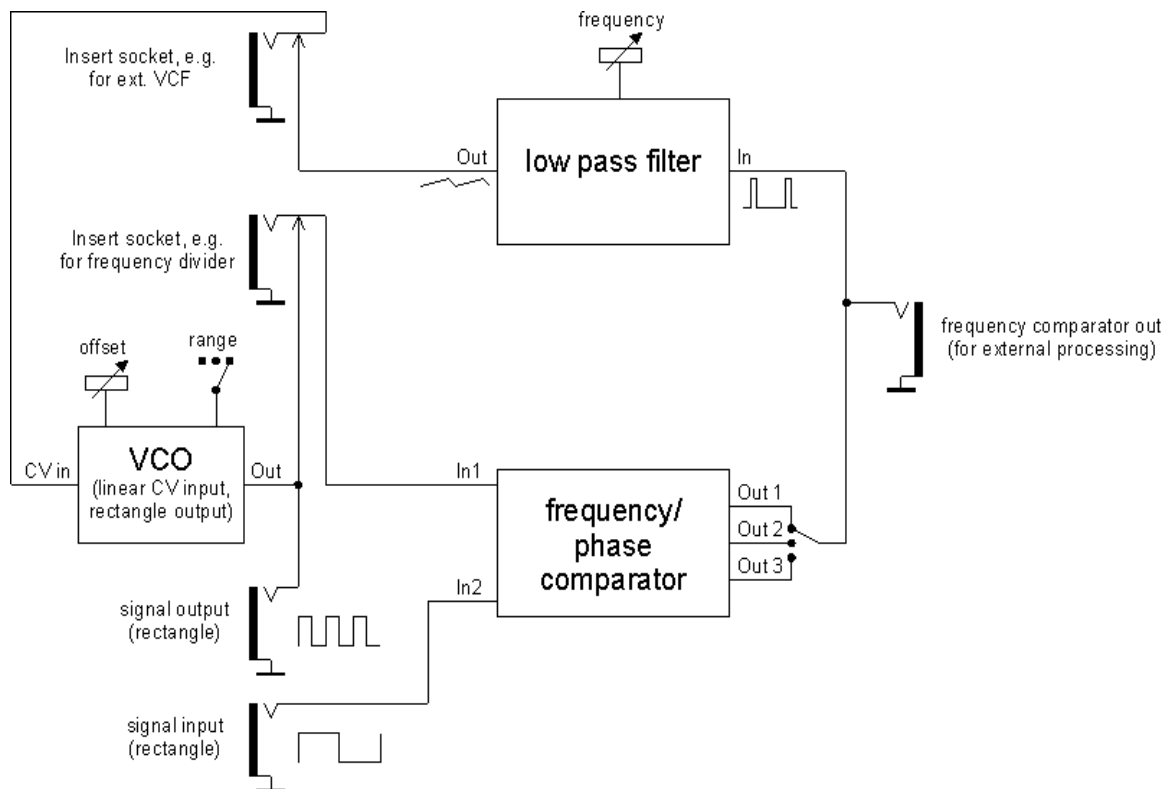
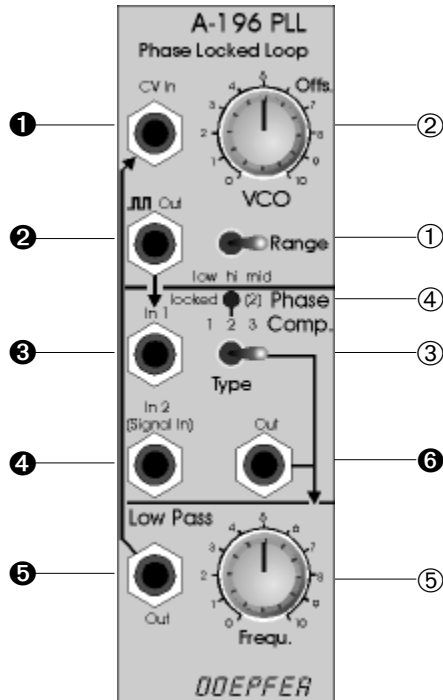


Fig. 1: Internal construction of the A-196

3. Overview



Controls:

- ① **Range :** Three-position frequency range switch for the VCO
- ② **Offs. :** Frequency offset control
- ③ **Type :** Three-position switch to select one of the three phase comparators
- ④ **LED :** lock display for PC2
- ⑤ **Frequ.:** Frequency control of the low pass filter

In- / Outputs:

- ① **CV In :** Control voltage input of the VCO, internally normalised to socket ⑤
- ② **Out :** VCO output (rectangle), internally normalised to socket ③
- ③ **In 1 :** Signal input 1 of the PC, internally normalised to socket ②
- ④ **In 2 :** Signal input 2 of the PC for external signal
- ⑤ **Out :** PC output, internally connected to the low pass filter input
- ⑥ **Out :** Low pass filter output

4. Controls

① Range • ② Offs.

The **frequency range** of the internal **VCO** is selected with the **switch** ①.

Control ② is used to adjust the frequency **offset**, i.e. the **maximum frequency** within the range selected with the switch ①. The table shows the VCO frequencies obtainable with different settings of range and offset (with a control voltage ~ 0...+5V at input ❶).

Range	Offset = 0	Offset = 5	Offset = 10
low	2 Hz - 50 Hz	2 Hz - 200 Hz	2 Hz - 1 kHz
mid	20 Hz - 500 Hz	20 Hz - 2 kHz	20 Hz - 10 kHz
high	200 Hz - 5 kHz	200 Hz - 20 kHz	100 Hz - 100 kHz

③ Type

The **type of Phase Comparator (PC)** is selected with this switch. Three PC types are available:

- **PC 1** Exclusive or gate (Exor)
- **PC 2** RS Flipflop
- **PC 3** more complex digital network

Each phase comparator has its special advantages and disadvantages. E.g. PC1 locks even at harmonics, i.e. integer frequency multiples of the external signal and the internal VCO. This is a disadvantage for the standard PLL idea but may be useful for certain musical effects. One has to find the most suitable PC for each application.

④ LED

This LED lights up if the PLL is **locked** for **PC2**, i.e. if the frequency of the external signal is identical to the frequency of the internal VCO.

⑤ Frequ.

This control is used to adjust the **frequency** of the internal low pass filter.

The internal LP can be replaced by an external LP. The external LP has to be DC coupled and work even at very low frequencies (some Hz range)! Consequently normal audio VCFs are not suitable. The VC slew limiter A-171 can be used instead. The "raw" PC output ❷ or the pre-filtered output ❸ can be used as input for the external filter/slew limiter. In this case the output of the external filter/slew limiter is used as control input ❶ for the VCO.

5. In- / Outputs

① CV In

This socket is the control voltage input of the internal VCO. The socket is normalled to the internal filter output, i.e. the CV for the VCO comes from the filter output provided that no plug is inserted into socket ①.



The VCO of the A-196 can be used as a simple **rectangle VCO with linear control response**. To control the VCO frequency a suitable voltage has to be fed into socket ①. To obtain scale and offset control an A-129-3 or A-167 can be used.

② Out

Socket ② is the VCO output signal (**rectangle waveform**). Internally this signal is connected to input 1 of the phase comparator.

③ In 1

This socket is input 1 of the **phase comparator**. The socket is normalled to the internal VCO output ②, i.e. input 1 of the PC comes from the internal VCO provided that no plug is inserted into socket ③.

④ In 2 (Signal In)

This socket is the second signal input of the PC. The **external PLL signal input** (e.g. VCO A-110 or frequency divider A-163) is connected to this socket.

⑥ Out

This socket is the output of the currently selected **phase comparator** (selected with switch ④). It is a digital signal (high/low/tri state) that is internally connected to the low pass filter input. This output can be used to process the PC signal with external modules (e.g. VC slew limiter A-171). The processing modules have to be DC coupled as sub-audio frequencies have to be processed ! Only for special effects even AC-coupled modules (e.g. normal audio filter) may be used.

⑤ Out

This socket is the **low pass filter output**. The socket is internally connected to the control input of the the VCO via the normalling socket ①. The same notes as in the preceeding paragraph are valid. But the PC output is already pre-filtered with the internal low pass. A combination of the internal low pass and an external processing module (e.g. A-171) can be used to generate the desired VCO control voltage.

6. User examples

Frequency Multiplication

A very important application of the A-196 is **frequency multiplication**. For this the output of the internal VCO is connected to the input of an external frequency divider (e.g. the VC frequency divider A-163 or the A-160). The output of the divider is connected to input ② of the phase comparator (see fig. 2). By this the internal VCO oscillates at a multiple of the frequency of the external signal. The multiple is defined by the setting of the frequency divider. For this application PC2 is recommended as it does not lock at harmonics.

Example: Setting the A-163 to a dividing factor 5 causes the fivefold frequency at the VCO output of the A-196 compared to the frequency of the external signal fed into input 2 of the PC (multiple A-180 at the VCO out of A-196 required, not shown in fig.2).

Using the A-163 consequently leads to a voltage controlled frequency multiplication. Modulating the A-163 dividing factor passes through several *pseudo-harmonics*, "pseudo" as the waveform of the A-196 VCO is rectangle in contrast to real sine shaped harmonics.

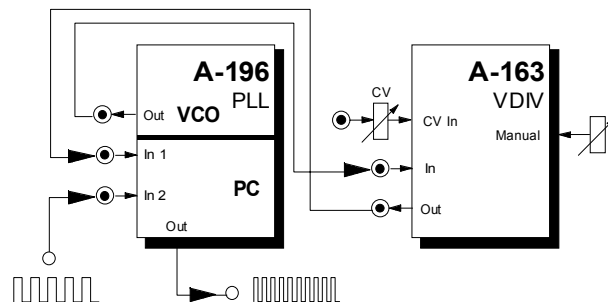


Fig. 2: Frequency multiplication with A-163

Graphic VCO

Frequency multiplication can be used to generate the **clock signal for a graphic VCO**. For this e.g. the A-155 can be used even though it is equipped with rotary controls instead of faders as usual for graphic VCOs.

For this the Clock input of the A-155 is connected to the A-196 VCO output. The frequency of an external VCO (e.g. A-110) is multiplied with the A-196 by 8 - as the A-155 has 8 steps. The waveforms of the audio signals that appear at the two Pre-Outputs of the A-155 can be adjusted with the analog controls of the A-155 like a graphic VCO. The audio frequency is identical to the controlling "master" VCO (e.g. A-110).

A very interesting variant of this patch is the usage of the 8 external inputs of the lower A-155 row. Connect these inputs to 8 different automatically changing control voltages (e.g. LFO A-145/146/147, ADSR A-140/141/142, Random voltages A-118/A-149-1, morphing controller A-144) or even audio signals. Automatically varying waveforms will appear.

Another application is the generation of clock signals for **switched capacitor filters (SCF)**. For these types of filters the filter frequency is defined by the frequency of an external clock signal. So far no filters of this type are available as A-100 modules but we are about to experiment with SCFs.

The A-196 is a very **experimental module** and some of its functions cannot be described straight forward as for other modules. Rather the user should try out the possibilities by trial and error.

E.g. the frequency jitter (i.e. actually too high LP frequency for optimal PLL operation) or frequency slew (i.e. actually too low LP frequency) can be used intentionally to obtain certain effects.

Even the upper frequency limits of the VCOs can be used on purpose ("frequency clipping").

Usually the three phase comparators behave completely different within the same patch so that this peculiarity leads to additional sound experiments.

More patches and audio examples can be found on our web site www.doepfer.com on the A-196 info page.