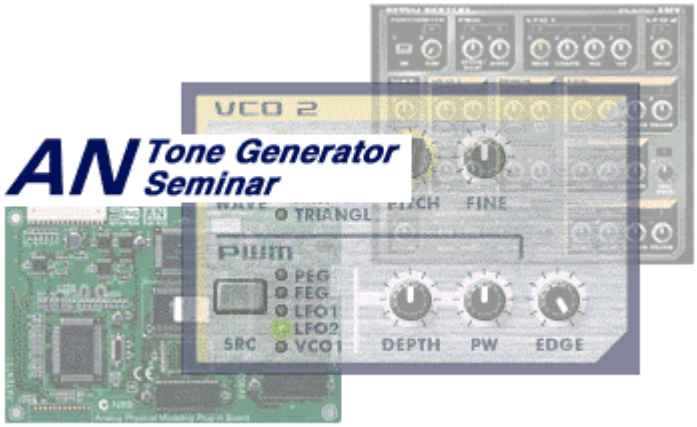


How the AN tone generator works

How the AN tone generator works In three sessions, this seminar introduces the popular Analog Physical Modeling tone generator (usually known as the AN tone generator) featured on synthesizers such as the AN1x and EX5/7 and on the recently-released PLG150-AN plug-in board (*1). You will learn about how the AN tone generator works, and see examples of actual sound-editing using the AN tone generator.

*1: By installing this board, an AN tone generator can be added to synthesizers or tone generator modules that support the Modular Synthesis Plug-in System or the XG Plug-in System.

Models that support Modular Synthesis: CS6x, CS6R, S80, etc. Models that support XG Plug-in System: MU2000, MU1000, MU128, MU100, SW1000XG, etc.

Demo data produced by: DIPSS Satoshi Kamiuchi

1. The structure of the Analog Physical Modeling tone generator

Sound consists of three main elements.

- **Pitch**
- **Tone**
- **Volume**

These are referred to as the "three elements of sound."

In order to control these three main elements, the AN tone generator provides the following three basic units (circuits), just as does as a conventional analog synthesizer.

- **Oscillator (controls the pitch and timbre)**
- **Filter (controls the tone)**
- **Amplifier (controls the volume)**

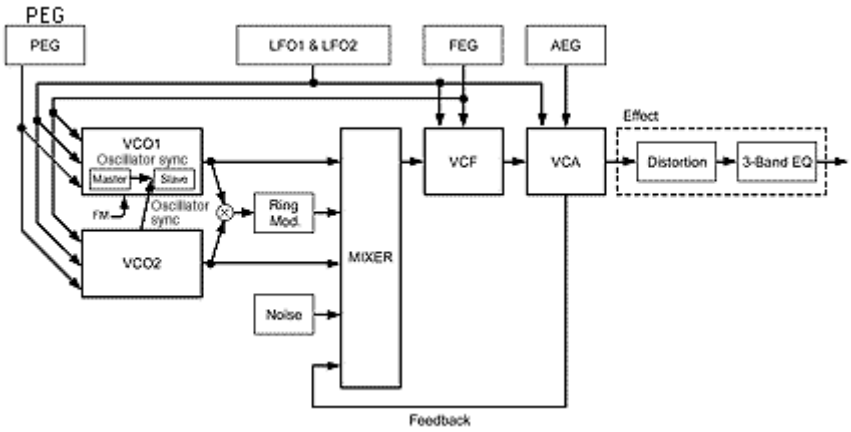
On an analog synthesizer, each unit is generally controlled by voltage, and so these units are respectively called

- **VCO (Voltage Controlled Oscillator)**
- **VCF (Voltage Controlled Filter)**
- **VCA (Voltage Controlled Amplifier)**

The AN tone generator produces the effect of these units digitally. However since proprietary Analog Physical Modeling technology is used to faithfully simulate the characteristics of an analog synthesizer, these units are called "VCO," "VCF," and "VCA," just as on an actual analog synthesizer.

Other units include an EG (envelope generator) that applies a variety of time-variant changes to the sound between its beginning and end, an LFO that applies cyclic changes such as vibrato and tremolo, oscillator sync and FM that can be used to create a diverse range of sounds, a ring modulator that produces metallic timbres, a noise oscillator to add noise, and distortion to distort the sound.

These units are connected as follows.



2. The AN tone generator's VCO…
Specifying the pitch and timbre

Of the three elements of sound, the VCO section determines the pitch and timbre.

The AN tone generator has two oscillators, VCO1 and VCO2. The pitch (oscillator frequency) you specify here will determine the pitch of the sound.

In addition, you can use the following functions to modify the sounds in various ways. By using the MIXER section to adjust the output level balance of the two VCO's, you can create a diverse range of sounds.

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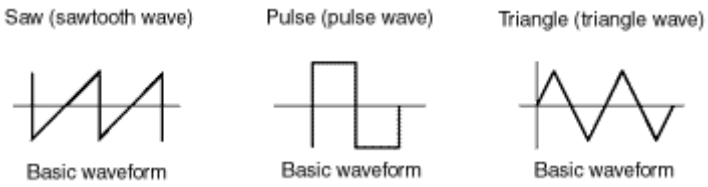
(1) VCO waveform

Generally, the waveform of an analog synthesizer VCO is a simple waveform such as the following.



It's a simple thing to categorize waveforms in this way. However, the waveforms of the classic analog synthesizers of the past actually had idiosyncrasies due to characteristics of their circuitry, such as a portion of the waveform being distorted or a slight amount of noise being present, and these gave each instrument its own unique character.

Although the AN tone generator uses digital processing to produce its VCO waveforms, the points mentioned above have been taken into consideration in the design of its waveforms. Furthermore, you can adjust PW, PWM, and Edge (described below) to create a broadly diverse range of waveforms.

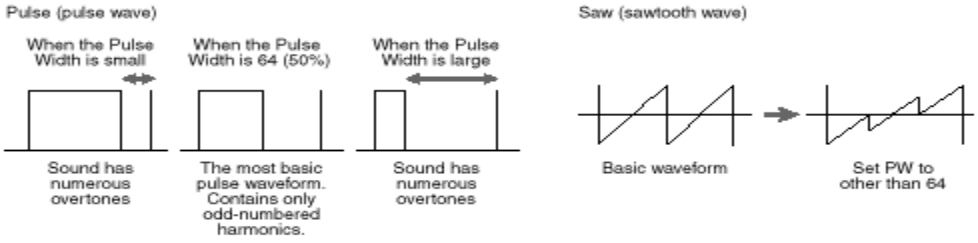
---

(2) PW (Pulse Width) and PWM (Pulse Width Modulation)

On conventional analog synthesizers, the width (PW) of the waveform can be modified only if the VCO is producing a Pulse (square) waveform. This modifies the overtones that are included in the waveform, allowing a variety of timbres to be produced even though the same waveform is selected.
Using an LFO etc. to cyclically modify the Pulse Width is called PWM.

On the AN tone generator, you can use PW or PWM not only when the VCO waveform is Pulse, but even when Saw (sawtooth) or Mix (mixture of Saw and Pulse) waveforms are selected.

PWM can be used not only to produce "cyclical change in overtones" as described above, but also allows you to create chorus effects (where multiple sounds of slightly different pitches are modulated together).



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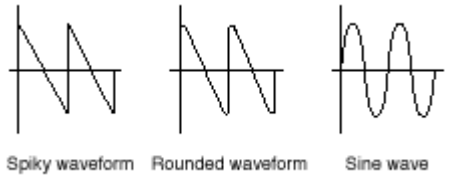
(3) Edge

This is a fine adjustment to the VCO waveform.
Higher settings of Edge will produce a sharper-sounding waveform, with a harder sound that contains more overtones.
Conversely, lowering this value will make the waveform sound more mellow, with a rounder tone. (Setting Edge to the minimum value will produce the same waveform as Sine (sine wave).)



What are "overtones"?

Most sounds consist of multiple pitches (frequencies) sounding together. Of these, the frequency that determines the basic pitch of the overall sound is called the "fundamental," and the remaining

frequencies are called "overtones" ("harmonics" or "upper partials").

Sine (sine wave) contains only the fundamental, but all other sounds (i.e., all sounds occurring in the natural world) contain overtones.
In general, sounds with more overtones will be brighter. Conversely, the sound will be darker as the overtones decrease. The sound is also dramatically affected by the location of the overtones. For example, a sound with numerous high overtones will have a sparkling character, while a sound with more energy in the lower overtones will have a solid character.

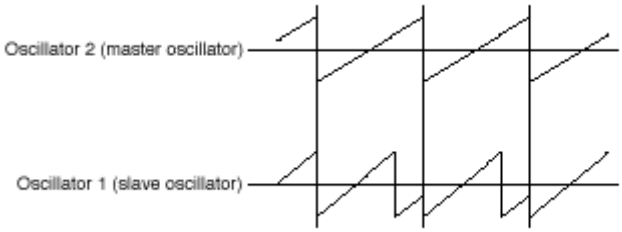
---

(4) Oscillator sync

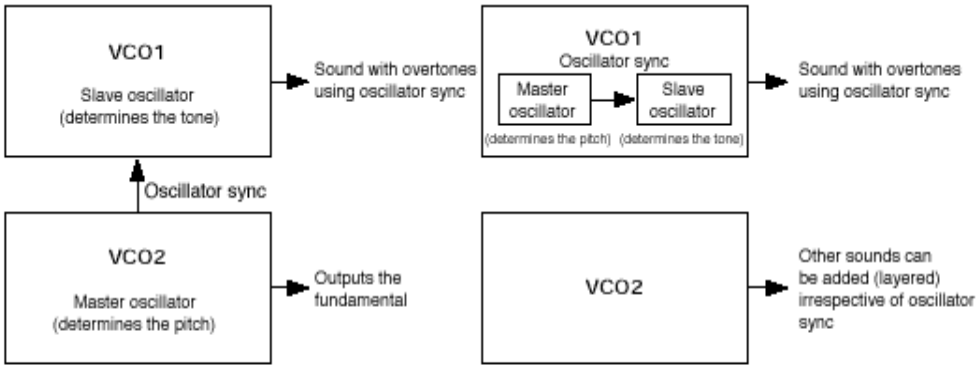
Analog synthesizers provide a function called "oscillator sync" that allows one oscillator to be synchronized to another oscillator. (See the diagram below.)

In the diagram below, the waveform of oscillator 1 is reset to the initial phase (the position from which each cycle begins) at the frequency of oscillator 2.
The result is that the oscillator 1 waveform will be more complex than normally, and will contain overtones that are not present in the unmodified waveform.
(In the example of the following diagram, oscillator 1 will sound more brilliant than normal.)

In the following diagram, oscillator 1 is the "slave oscillator" and oscillator 2 is the "master oscillator." When the pitch of the master oscillator is changed, the pitch of the overall sound will change. When the pitch of the slave oscillator is changed, the overall timbre (overtone structure) will change.



Like a conventional analog synthesizer, the AN tone generator allows VCO1 to be synchronized to VCO2 (oscillator sync). However in addition to this, you can internally divide VCO1 into two oscillators (only when oscillator sync is used), allowing you to create oscillator sync sounds using just VCO1 alone.



(a) Oscillator sync from VCO2 -> VCO1
This is the same as on a conventional analog synthesizer.
The pitch of VCO1 and VCO2 can be linked to create a tone.

(b) Oscillator sync within VCO1
This method is unique to the AN tone generator.
Sounds can be created using VCO1 and VCO2 as independent oscillators
(just as when oscillator sync = OFF)

---

(5) FM (Frequency Modulation)

"FM" (Frequency Modulation) refers to the technique of using the sound of one oscillator (A) to change (modulate) the pitch of another oscillator (B).
In this case, oscillator (A) is called the "modulator," and oscillator (B) is called the "carrier."

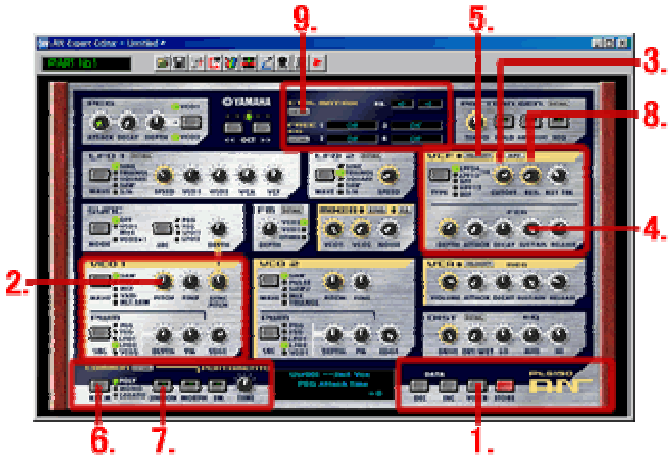
The sound of FM is output from the carrier, but the pitch (frequency) ratio between the modulator and the carrier will change the type of overtones that are added to the carrier.

On the AN tone generator, the carrier is fixed at VCO1, but the modulator can be switched between VCO2, LFO, or one of the EG's.

Let's create a synth bass

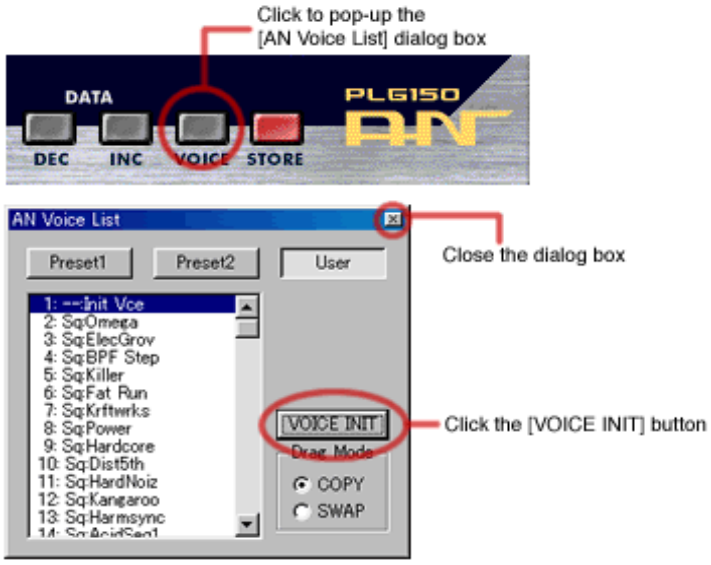
We're going to use the AN Expert Editor to create this sound.

From the XGworks menu, choose [Plug-in]→[AN Expert Editor] to start up the AN Expert Editor.



First let's create a basic synth bass sound.

1) We will start with a basic, initialized voice (INIT VOICE).



Press the [VOICE INIT] button in the voice list dialog box, and the voice will be set to a simple sawtooth wave sound.

2) The bass is a low-pitched instrument, so we will lower the frequency of the oscillator.

Rotate PITCH in the VCO1 group to set it to -12. This lowers the pitch by 1 octave.

At this time, the name and value of the parameter being adjusted will appear in the LCD located at the bottom.

3) Now we'll change the bright sound to a somewhat more mellow tone.

Rotate the VCF group CUTOFF to about 60.

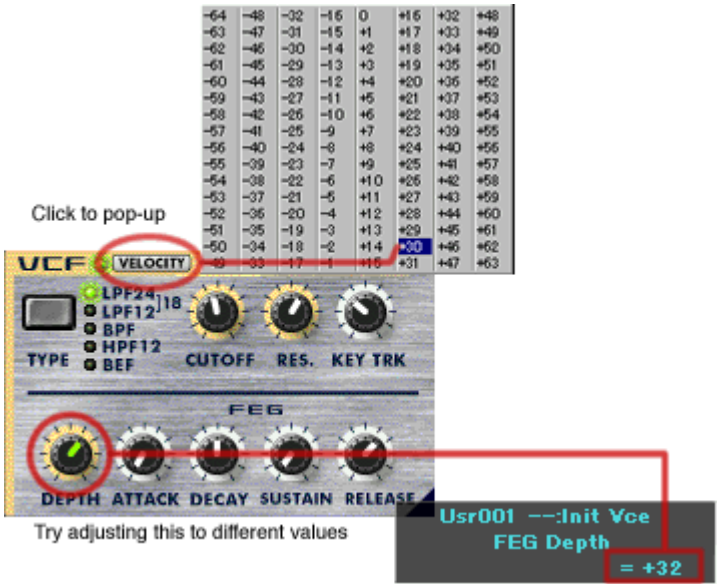
4) Next we will give the sound a "plucked" character.

In the same VCF group, rotate FEG-SUSTAIN to lower the setting to about 5.

Our settings so far have produced a basic synth bass sound.

Now we're going to add some more advanced touches.

5) Let's make the sound change in response to velocity (velocity sensitivity).



In the VCF group, click the [VELOCITY], and select a value of approximately +30.
In the same VCF group, you can also try adjusting CUTOFF and FEG-DEPTH to your taste.
Velocity sensitivity indicates the amount by which changes in velocity will affect FEG-DEPTH.
This means that the FEG-DEPTH setting will also affect the range of tonal change.

6) Now we will make settings to produce the legato character typical of synth bass.

Press the [KEY M.] (Key Assign Mode) button located at the lower left, so that the LEGATO LED is lit.
Now it will no longer be possible to play chords. When you play legato, each note will be smoothly connected to the previous note.

7) We will use Unison to make a fatter sound.

Press the [UNISON] button located at the right to turn Unison on. The button LED will light.

With this setting, five "copies" of the voice will be sounded for each note you play, producing a fatter sound.

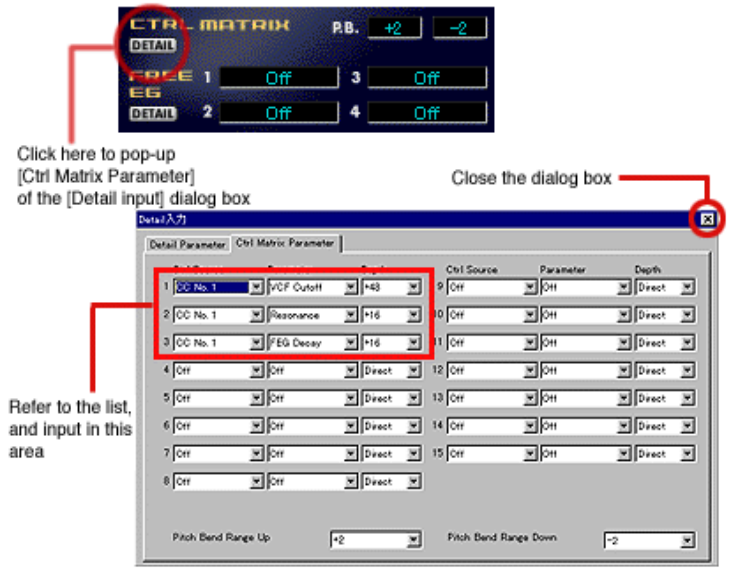
8) Next we'll use Resonance to add the tonal character that is typical of a synth bass.

In the VCF group, rotate RESONANCE to a setting of approximately +60.

Now we have arrived at the popular "resonance bass" sound.

Now we'll move on to some even more advanced possibilities.

9) Let's use the modulation wheel (subsequently referred to as MW) to control the filter.



So that we can control the tone as we play, we'll assign the filter to the MW.
In the CTRL MATRIX group, press the [DETAIL] to open the Ctrl Matrix window.
Make the following settings for Ctrl Matrix 1-3, and then try moving the MW.

Ctrl Source	*Parameter*	*Depth*
1 Mod Wheel	VCF Cutoff	+48
2 Mod Wheel	Resonance	+16
3 Mod Wheel	FEG Decay	+16

For your reference

[Typical synth bass sounds of the PLG150-AN]

Preset1 PrgNo.002	Cream
Preset1 PrgNo.057	BirdWrld
Preset1 PrgNo.050	X-Bass
Preset2 PrgNo.004	Knives
Preset1 PrgNo.008	Monty

3. Using other units to modify the sound

(1) Ring Modulator

The ring modulator multiplies the output of two oscillators, letting you produce metallic (bell-like) resonances.

On the AN tone generator, the output of VCO1 and VCO2 can be ring-modulated. The output of the ring modulator and the outputs of VCO1 and VCO2 are summed in the MIXER section, so if you find it difficult to hear the effect of the ring modulator, try lowering the level of VCO1 or VCO2.
By setting either VCO1 or VCO2 to an extremely low pitch, you can produce a more metallic (bell-like) character.

---

(2) Noise Oscillator

This is used when you wish to add unpitched noise to the sound (in contrast to the pitched sound produced by VCO1 or 2.

Broadly speaking there are two types of noise: white noise (equal energy at each frequency), and pink noise (noise that is limited in some way by frequency band).
The AN tone generator provides white noise.

For strings or synth pad sounds, it is effective to mix just a bit of noise with the sound of the VCO. You can also use the VFO to apply a filter with resonance to the noise, or use the AEG to apply a rapid decay to the noise.

---

(3) Feedback

On the AN tone generator, feedback is the portion of the VCA output that is returned to the MIXER section.

If you raise the feedback level, the low-frequency range of the sound will be particularly rich, producing a very solid sound.

[Caution]
If the feedback level is raised excessively, abnormal oscillation may occur in the ultra-low frequency range, which can damage your speakers. Be sure to raise the feedback level gradually.

If you hear any abnormal vibration from your speakers, lower the feedback level immediately.

---

4. The AN tone generator's VCF …

Using the filter to modify the tone / Applying time-variant change to the tone

Of the three principal elements of sound, the tone is the main aspect determined by the VCF. The VCF of an analog synthesizer is a very important unit that, along with the VCO, has a decisive effect on the sound.

---

(1) Cutoff (cutoff frequency) and Resonance

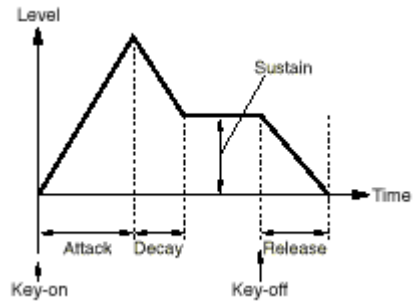
By selecting a filter type and adjusting its cutoff frequency in the VCF section, you can regulate the amount of overtones produced by the VCO section, and pass or block specific frequency ranges.
Although the filter of the AN tone generator is implemented digitally, it was developed by analyzing the filters of analog synthesizers. It has a very broad range, from an extremely low cutoff frequency where the sound becomes completely inaudible to an extremely high cutoff frequency where the VCO waveform is not affected at all.

Even when the resonance is dramatically raised to emphasize the region at the cutoff frequency, the sound will not be unpleasant --- you will get the identical character of filter resonance available on an analog synthesizer (self-oscillation at a specific pitch).

---

(2) FEG (Filter Envelope Generator)

This controls the filter cutoff frequency (vertical axis) according to note-on/off events on the keyboard, as shown in the following diagram.



In particular by setting the cutoff frequency fairly low, setting a high resonance value, and applying the FEG, you can create the typical "analog synthesizer bass sound with resonance."

As mentioned in 6, the AN tone generator can use the FEG to control parameters other than the filter cutoff frequency, allowing you even wider creative possibilities.

---

5. The AN tone generator's VCA …
Adjusting the volume / Applying time-variant change to the volume

Of the three main elements of sound, volume is determined mainly by the VCA section.
In addition to adjusting the volume that is output by the AN tone generator, the AEG can also be used to modify the character of the sound.

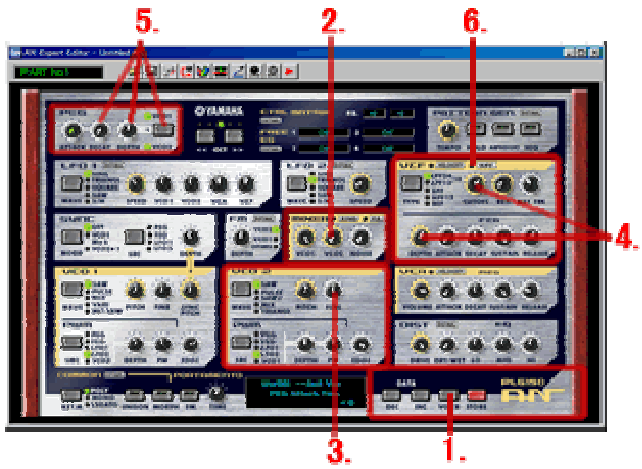
(1) AEG (Amplitude Envelope Generator)

The AEG controls the volume (vertical axis) according to note-on/off events on the keyboard, as shown in the diagram above.

Let's create a synth brass

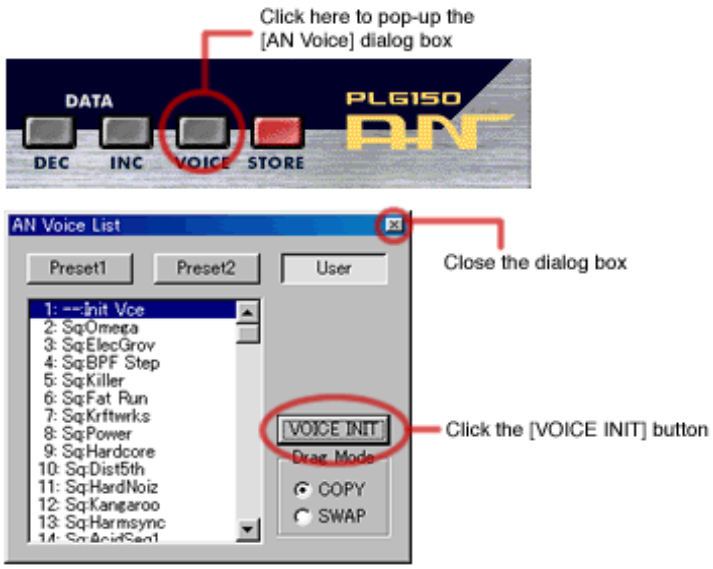
We're going to use the AN Expert Editor to create this sound.

From the XGworks menu, choose [Plug-in]→[AN Expert Editor] to start up the AN Expert Editor.



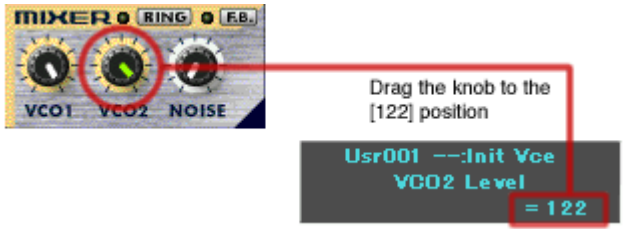
First let's create a basic synth brass sound.

1) We will start with the initialized voice (INIT VOICE).



In the voice list dialog box, press the [VOICE INIT] button, and the voice will be set to a simple sawtooth wave sound.

2) Synth brass imitates the sound of numerous brass instruments being played together. To create the sensation of multiple players, we will use not only VCO1 but also VCO2.

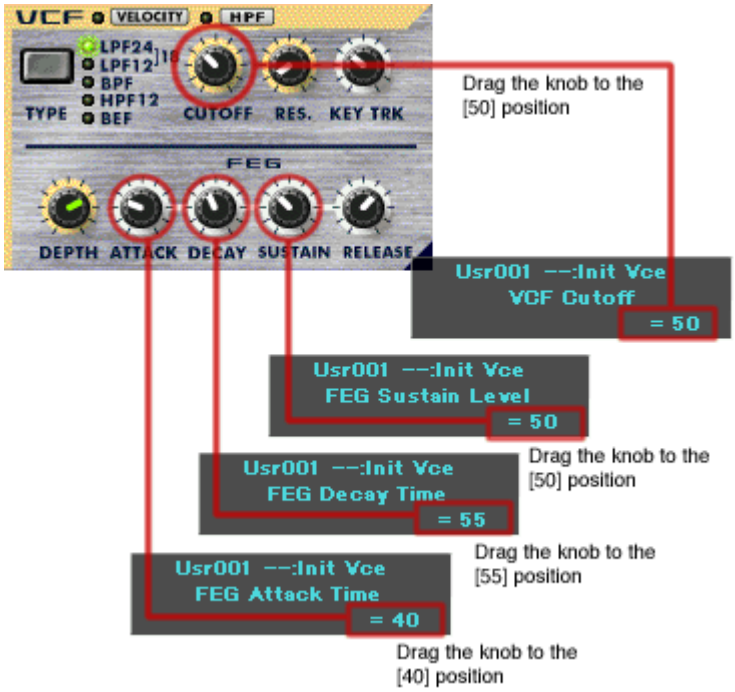


In the MIXER group, rotate VCO2 to approximately 122.

3) To enhance the impression of multiple instruments, we will add a slight skew to the VCO2 pitch.

In the VCO2 group, rotate FINE to approximately -3.

4) By making the filter move over time, we will simulate the development in tone that is characteristic of horns.

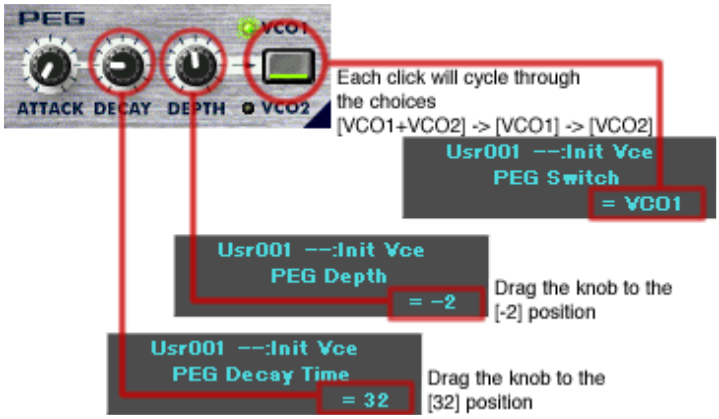


In the VCF group, rotate FEG-ATTACK to approximately 40, DECAY to approximately 55, and SUSTAIN to approximately 50. Also in the VCF group, set CUTOFF to about 60, and FEG DEPTH to about +55.

We now have a basic synth brass sound.

Let's move on to some more advanced settings.

5) By using the Pitch EG to give VCO1 a slight "hiccup," we will intensify the brass-like character of the sound.

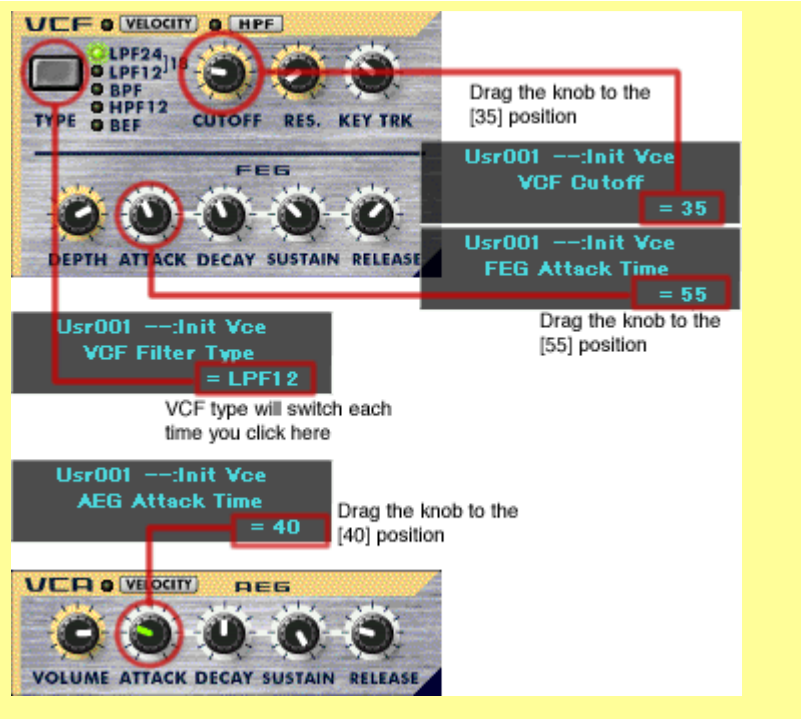


In the PEG group, rotate DECAY to approximately 32, and DEPTH to approximately -2. Also in the PEG group, press the button located at the right so that only the VCO1 LED is lit.

6) From this sound, we can create a synth brass sound of a very different character simply by making slight adjustments to the filter etc.

For example by setting the VCF group CUTOFF to approximately 90 . . .

Alternatively, if we set the VCF group CUTOFF to about 35, FEG-ATTACK to about 55, the VCA group AEG-ATTACK to about 40, and the Filter TYPE to the slightly more gentle LPF12 (-12dB/oct.), . . .



7) For the finishing touch, we will use the plug-in platform instrument (such as the CS6x or MU128 to apply reverb.

By adding the reverberation of a hall, we have created a synth brass sound with a nice sense of spatial depth.

his completes our synth brass sound.

For your information

[Typical synth brass sounds of the PLG150-AN]

Preset1 PrgNo.018	HardBrss
Preset1 PrgNo.106	Fatty
Preset1 PrgNo.019	ToToHorn
Preset2 PrgNo.024	ProBrass

---

6. Making the sound change over time … Using LFO and EG's effectively

(1) LFO1, LFO2 (Low Frequency Oscillator 1, Low Frequency Oscillator 2)

The LFO is a unit that oscillates at a relatively low frequency, and is used to apply cyclic change to the sound parameters.

Generally, an LFO is used to control

- **oscillator pitch (Pmod or Vibrato)**
- **filter cutoff frequency (Fmod)**
- **amplifier level (Amod)**

However on an analog synthesizer, it can also be used to control

- **PWM (pulse width modulation)**
- **Sync Pitch**
- **FM Depth**

Of course, you can create even more interesting sounds by controlling Pmod (Vibrato) / Fmod / Amod simultaneously with these parameters (i.e., PWM etc.).

The AN tone generator gives you great freedom in selecting LFO control destinations. For details refer to "Signal flow" at the end of this seminar.

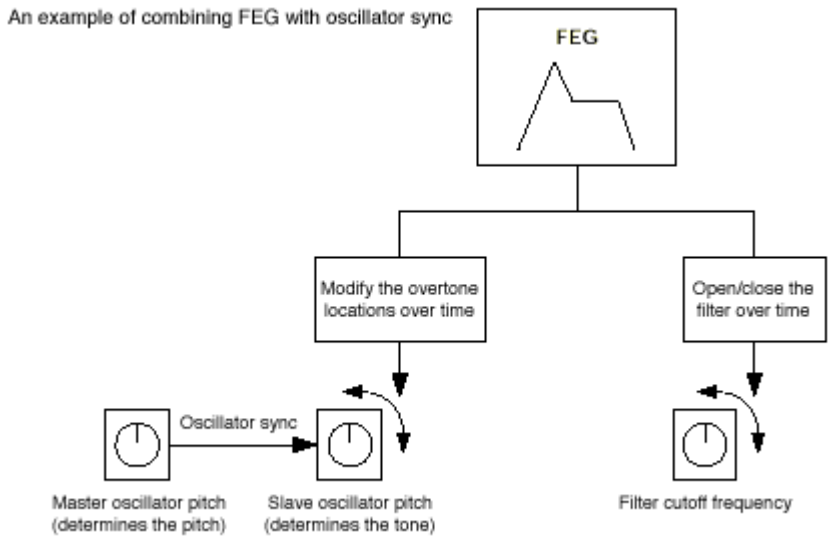
---

(2) Using PEG and FEG in conjunction with various types of modulation

Just as you can flexibly select the control destination of the LFO, you can also specify the control destination of the PEG or FEG to be a parameter other than oscillator pitch or filter cutoff frequency.

A particularly interesting example is when the FEG is used in an oscillator sync setup to simultaneously control the pitch of the slave oscillator and the change in cutoff frequency over time, as shown in the diagram below.

As mentioned in session 2 part (3), modifying the pitch of the oscillator sync slave oscillator will shift the position of its characteristic overtones. However by using the FEG to control this, we can do things like applying oscillator sync to generate extreme overtones at the very moment that the filter cutoff frequency is highest (i.e., at the moment that the filter is open). (A good example of this is Preset1 bank voice No.77 "ANSyncHd.")



One of the real enjoyments of using an analog synthesizer to create sounds lies in skillfully combining limited resources such as LFO and EG to obtain tonal changes that could not be produced by using these individually.

---

7. Modifying the sound in additional ways … Distortion and EQ

(1) Distortion

This unit is used to intentionally distort the output waveform.
By adjusting the Drive parameter you can regulate the degree of distortion.

As mentioned in session 2 part (1) in our discussion of the VCO, the classic analog synthesizers of the past produced output waveforms that were distorted by the characteristics of their electrical circuitry. This unit can be used to simulate these characteristics.

---

(2) EQ (Equalizer)

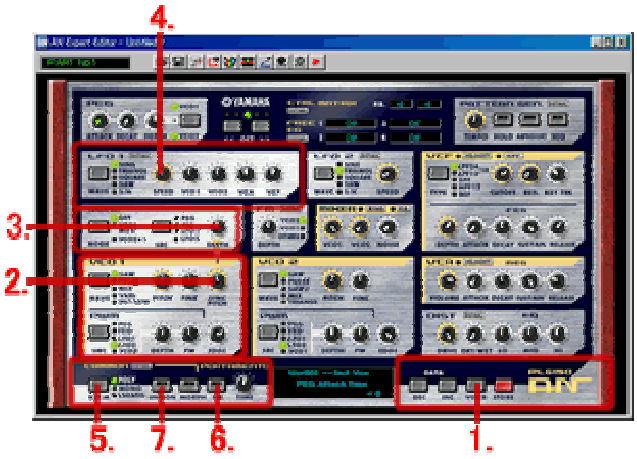
Here you can adjust the cutoff frequency and the amount of boost/cut for each of three frequency regions (Low, Mid, High).

For example you might produce a more solid bass sound by boosting the low frequency range (Low). Or if a synth pad had just a bit too much mid-range, you could slightly cut the Mid frequency.

Let's create a synth lead

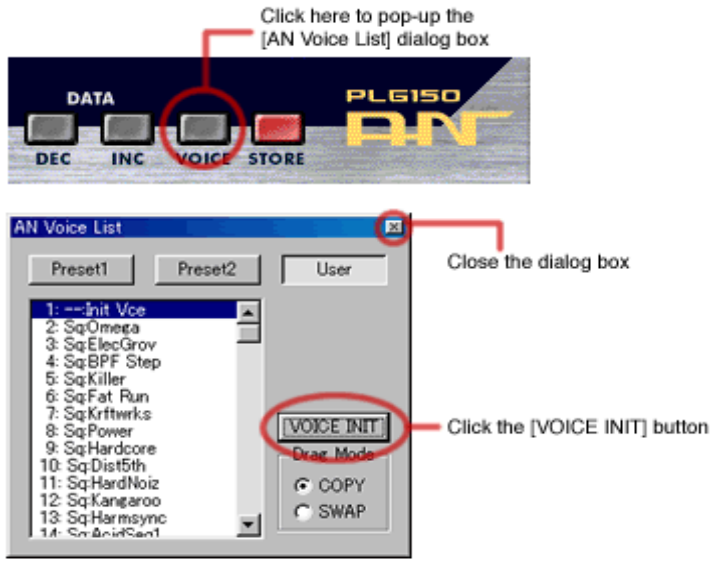
We're going to use the AN Expert Editor to create this sound.

From the XGworks menu, choose [Plug-in]→[AN Expert Editor] to start up the AN Expert Editor.



We will start by creating a basic synth lead sound.

1) We'll begin with the initialized voice (INIT VOICE).



In the voice list dialog box, press the [VOICE INIT] button. The voice will be a basic sawtooth wave sound.

2) There are many types of synth lead sounds, but in this example we're going to use [oscillator sync](#) to create a brilliant tone.

In the VCO1 group, rotate SYNC PITCH to about +20. We will produce a brilliant tone by using this parameter to adjust the pitch difference between the master oscillator and the slave oscillator.

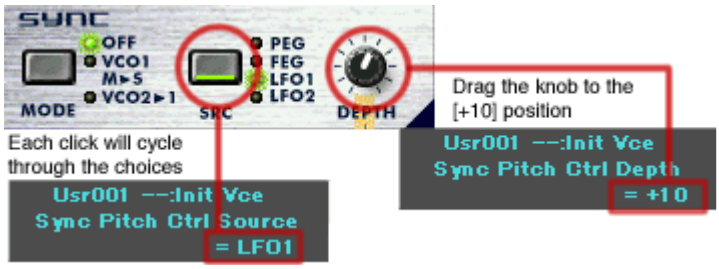
Although this is somewhat of a detour, take a minute here to try out different WAVE (waveform) settings for the VCO1 group. Oscillator sync will add various overtones to the character of each waveform, producing some highly idiosyncratic sounds.

Try the following settings for VCO1 group WAVE ...

Saw → Pulse → Inner1 → Inner2 → Inner3 → Square → Noise

and listen to the result.

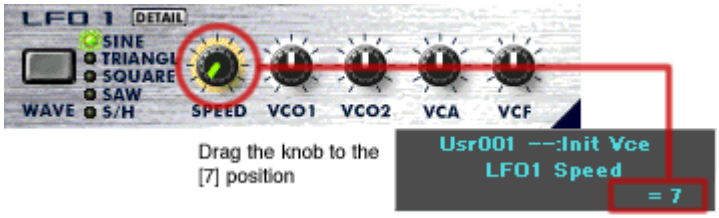
3) Then we'll apply a slow cyclic change to the Sync Pitch.



In the SYNC group, rotate DEPTH (Sync Pitch Control Depth) to about +10.

Also in the SYNC group, press the [SRC] button (Sync Pitch Control Source) so that the LFO1 LED is lit.

4) Set LFO1 to a slow speed.



In the LFO1 group, rotate SPEED to about 7.

We now have a basic synth lead sound.

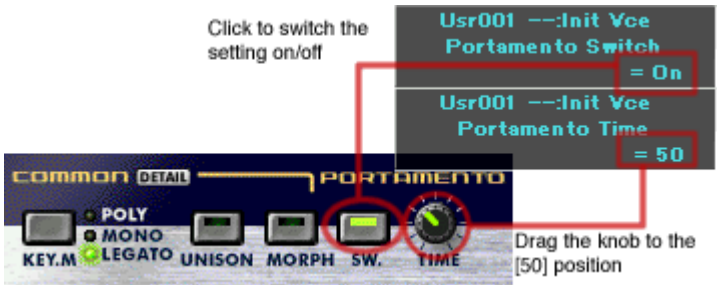
Now we're going to edit the sound in some more advanced ways.

5) Let's make the legato settings that are typical for synth lead.

Press the Key Assign Mode button so that the LEGATO LED is lit.

Now it will not longer be possible to play chords. When you play legato, the notes will be connected smoothly.

6) Let's apply some portamento.



At the left of the LCD, press the [PORTAMENTO] button to turn it on. The button LED will light.
At its right, rotate TIME to about 50.

7) We will use Unison to make the sound fatter.

Press the [UNISON] button located at the right to turn Unison on. The button LED will light.

With this setting, five "copies" of the voice will be sounded for each note you play, producing a thick and rich sound.

8) Finally we will use the plug-in platform (CS6x or MU128, etc.) to apply a delay effect.

Applying a delay time of 400～500 msec will produce a sparkling feel that is ideal for solos.

Our synth lead sound is now complete.

For your information

[Typical synth lead sounds of the PLG150-AN]

Preset1 PrgNo.085	J.Hammer
Preset1 PrgNo.011	Bombastic
Preset1 PrgNo.081	P-5 Saw
Preset2 PrgNo.013	Squeamer
Preset2 PrgNo.071	Pulser