Synthesis on the Nord Stage 2

Version 1.0 DRAFT

Contents

Introduction

This is a guide to using the synth section on the Clavia **Nord Stage 2** and **Nord Stage 2EX** keyboard instruments.
It is not an official document, and is not affiliated with or endorsed by Clavia.
There may be several mistakes – please feel free to let me know via an instant message on the forum above.
You use this guide at your own risk. If you die of boredom or blow your mind, I am in no way held responsible.

Synth manuals are usually worded in such a way that even the writer sounds bored. I'm going to use the same (standard) terminology, but I'll try to make it easier to digest.

I'm assuming you have read the Stage 2 user manual, and you are familiar with the basic operation like activating/deactivating different sound sections (Organ, Piano, Synth, External), creating keyboard zones/splits, how to switch between slots A & B or activate them both at once, and how to store programs.

I've tried to write this so it makes sense to someone who's never owned a synth before, but still useful to people who know quite a bit already. Also, the FM section is aimed equally at owners who are new to FM and also those who have previous experience with Yamaha DX synths.

Boring science bit about modulation and stuff

There are a few concepts used in synthesis that are really important to understand, or you won't get anything later – especially when we get into FM synthesis, so lets get this out of the way now.

An **OSCILLATOR** (OSC) is something that changes from what state to another in a repetitive way. In a synthesizer, an oscillator is a device that varies the voltage it outputs – imagine turning a dimmer switch backwards and forwards really quickly, and you get the idea.
When a wave on the sea moves up and down, it oscillates slowly. If you hit a tuning fork, the prongs are oscillating very quickly. The faster they oscillate, the higher the pitch.

If you attached a tiny pen to the tip of the tuning fork, and drew it along a sheet of paper, it would make a wiggly line in the shape of a perfect sine wave.
If you mark the piece of paper when you start moving the tuning fork, and again after 1 second, the distance between the two marks shows the number of waves in 1 second. A low-pitched tuning fork would have waves appearing less frequently than a high-pitched one.
How frequent the waves are is called the **FREQUENCY.**
(This experiment was actually done nearly 200 years ago by a German guy called Helmholtz).
A tuning fork is tuned to note A, which has a frequency of 440Hz – this means there are 440 waves in 1 second. Waves per second is called Hertz (Hz).

Hit a key on a piano, the sound goes quickly from zero volume to a certain level (depending how hard you hit it), then slowly falls back to zero. This amount of volume level at any point is called **AMPLITUDE**.

Most synths have a modulation wheel (or similar control such as a joystick). A popular misconception is that it adds vibrato to a sound. Not necessarily. It's just a control which you might use for making vibrato… you will see it can do lots of things, especially on a Nord.

MODULATION just means changing or tweaking.

Hold a key on an organ. If you turn the volume control slowly backwards and forwards, the sound changes in volume up and down over time. It's modulating its amplitude so we call it **AMPLITUDE MODULATION**.

If a sound changes its pitch over time instead of its volume, it's modulating its frequency. We call it **FREQUENCY MODULATION** or **FM** for short.

If these changes in frequency happen in a repetitive way like a police siren, then the change in pitch between low to high and back again is quite slow. It's being modulated by a low frequency oscillator or **LFO**.

If the frequency of this modulating oscillator starts to get faster, the ear can't detect the differences and you hear a new tone, the LFO has become audible just like a normal oscillator and so we call it self-oscillating.
What if we don't want the amplitude or frequency to wobble up and down? What we want to make a percussive sound like a piano is for the amplitude to go up to maximum level really quickly, then slowly drop back to zero. If you could communicate with the oscillator, you could write those instructions on a piece of paper:

"Start at zero, go up to maximum volume in 1/1000th of a second, then drop back to zero over 5 seconds."

You could put this piece of paper in an envelope and give it to the oscillator. That's what an **ENVELOPE** is. A set of instructions:

ATTACK: how fast to go from zero to maximum
DECAY: how fast to go from maximum to zero while they key is held down
RELEASE: how fast to go from whatever level you are at to zero when the key is released. (If the decay has already got to zero, the release will have no effect.)

***Note**: Other synthesisers often have a SUSTAIN stage between decay and release, some have a DELAY stage before attack, and some have multiple stages. Since the Nord only has these 3 stages, I won't go into what the others do. We can live without them.*

Because the synth generates the envelope, it's called an **ENVELOPE GENERATOR** or **EG** for short.

The other important thing to say about envelopes, is that you can use them for different things. They are instructions for modulating (changing) things, so we call them **MODULATION ENVELOPES** or **MOD ENV** for short.

Envelopes can be used to modulate amplitude (AEG), pitch (PEG), filter (FEG) or even other modulators. We'll come back to some of these later…

Overview of Synth Section

Here's the synth section. I'll do a quick overview of what each bit does, but I'll try not to repeat what's already in the user manual.

The way the synth section is laid out is different to normal 'synth workflow', but I'll do it in a logical order:

OSC

Stands for OSCILLATOR. See page 2.

Waveform Selector Button

You have to start with something that makes a noise. It could be an electronically generated waveform (SQUARE, SAW or TRIANGLE icons), a sampled sound (SAMP) that you loaded in, frequency modulated waveforms (FM) or wavetable waveforms (WAVE).

Waveform Selector Dial

I had to dig around the manual to find out what they call this, as it is not labeled (it's the knob under the red display), but it allows various options for each waveform type – cycling through the sampled sounds being the most obvious use.

Shape Knob

This knob is labeled a little misleadingly, as it does different things depending on the type of waveform you are using. Because of that, I'm not going to describe it here, but come back to it later.

Shape Mod Knob

When you turn the shape knob with your hand, you are ***modulating*** the shape of the wave.
Instead of doing this modulation with your hand on the shape knob, you might want to automate this tweak so it happens whenever you play a key. That's what this knob does. We'll come back to how that all happens later.

AMP ENV and MOD ENV

I already talked about this on page 3. AMP ENV is dedicated to controlling the amplitude (volume) of the sound, MOD ENV can control different types of modulation, such as the amount of filter to apply etc.

Filter

I'm leaving this to write at a later date. The surprising news is that in FM synthesis you won't be using it much, if it all.

I think the manual covers all the other bits like LFO, Unison, Glide etc., so I'm at risk of repeating it.

Subtractive Synthesis

I will write this section later… it's the best starting point for complete beginners so worth doing in detail.

FM Synthesis

I spent ages figuring out how to approach this without getting too boring too quickly. This is a first draft anyway, so I'll get stuck in.

If you are the impatient sort, here's a quick heads-up: we are going to make a bunch of representative sounds (patches/programs/etc.) that should give you enough of an understanding of how the FM synth works to start producing good sounds of your own.
I'm not going to go into every possible algorithm and I'm not going to get 'mathsy or sciency' any more than I have to. Firstly, you can get books on this stuff, secondly my knowledge on this topic is just enough to make the sounds I want, and no more. There are some infinitely more clever guys on the unofficial Nord forum, but they are probably busier than me.

Here's the 'menu of the day' for what we'll create:

- **Hammond Organ** type sound – it's a great starting point as you have a the organ section Hammond to compare it with. You may even have a real one. Lucky you.
- **E Piano** – slightly harder than the Hammond, but again, great for comparison as you have the Piano section right there.
- **FM Bass** – not sure where this will end up, but you can make some nice bass sounds with FM.
- Some basic acoustic instrument sounds: **Strings**, **Reed**, **Flute**, **Brass**. Don't expect these to sound amazing, but they will show you some important envelope and harmonic characteristics.
- Some metallic **bells** and gongs.
- A nice fat **pad** sound.

*Note: We are going to try to **avoid using the filter altogether**. It's actually really powerful when used in combination with FM, but for our purposes it disguises the sound that FM is making, and over complicates things. So we should "**Keep It Simple, Stupid!**" for now, at least.*

I suggest you make space for a few new programs or prepare to over-write some. By default, the factory Banks A and D are identical, so you can chose Bank D and write over any programs.

Let's start with a completely blank slate:

1. Turn OFF the Piano, Organ and External sections in both slots A & B.
2. Turn ON the Synth section in both slots A & B.
3. Turn off ALL effects in slots A & B, including the master/global compressor and reverb effects, and the rotary speaker in the organ section.
4. Select slot A and press SHIFT and Sound Init in the Synth section. Do the same with slot B.

5. In the master section, turn off the keyboard zones LEDs so we have no keyboard splits.
6. Make sure slot A is active and slot B is inactive. (if both are active, press A, then press B and B should become inactive).
7. Save this program – call it "Init Synth" or whatever you like.

TIP: *We'll be starting from this point quite often, so don't overwrite this program! Save any magical sounds you make along the way in a new program location and keep this "**init**" program as a handy shortcut.*

Making the first FM program – a Hammond Organ.

I think the best way to approach a new topic is to start in your comfort zone. As you are a Nord Stage 2 owner, chances are you bought it partly for the Hammond B3 organ emulation. If you understand how that works, then you can apply some of that know-how.

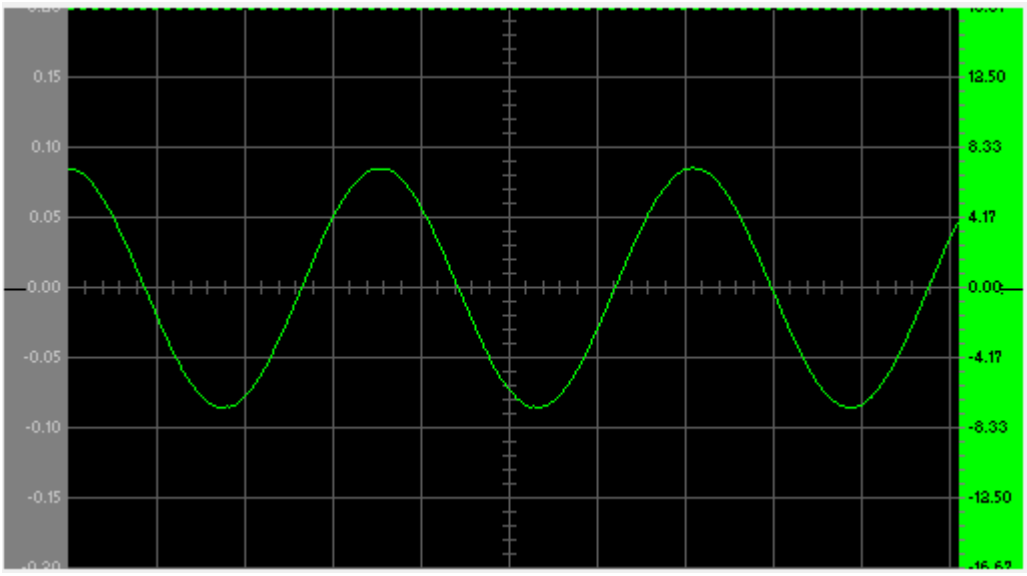
In the **Synth** section press the **Waveform Selector Button** until you have **FM** active, and turn the **Waveform Selector Dial** counter-clockwise until the display reads "**Sin**".

This is what the Synth settings should look like now:

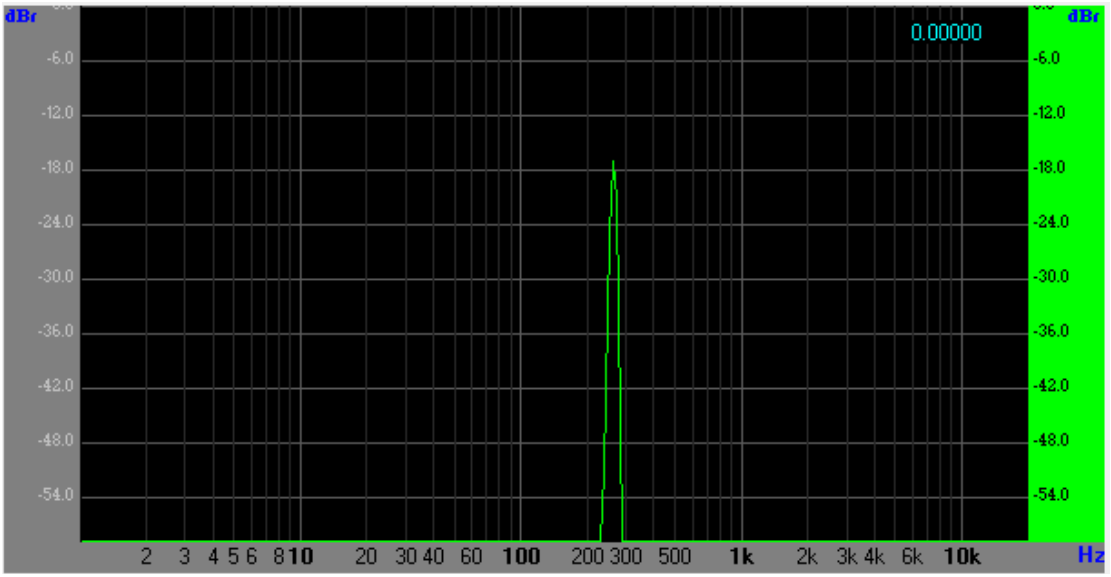
Play a middle C – it sounds about as simple a sound as you can make – and it really is.
"Sin" has nothing to do with straying from the righteous path – it's short for SINE, which produces a pure tone.

What you are hearing is the pure fundamental note C4 with absolutely no overtones. Overtones or harmonics are what you add to give the sound more character.

Here's what the wave looks like on an oscilloscope:



Below are the frequencies involved in the sound. There are no harmonics, just the pure tone at 261.6Hz, which is the frequency for middle C.

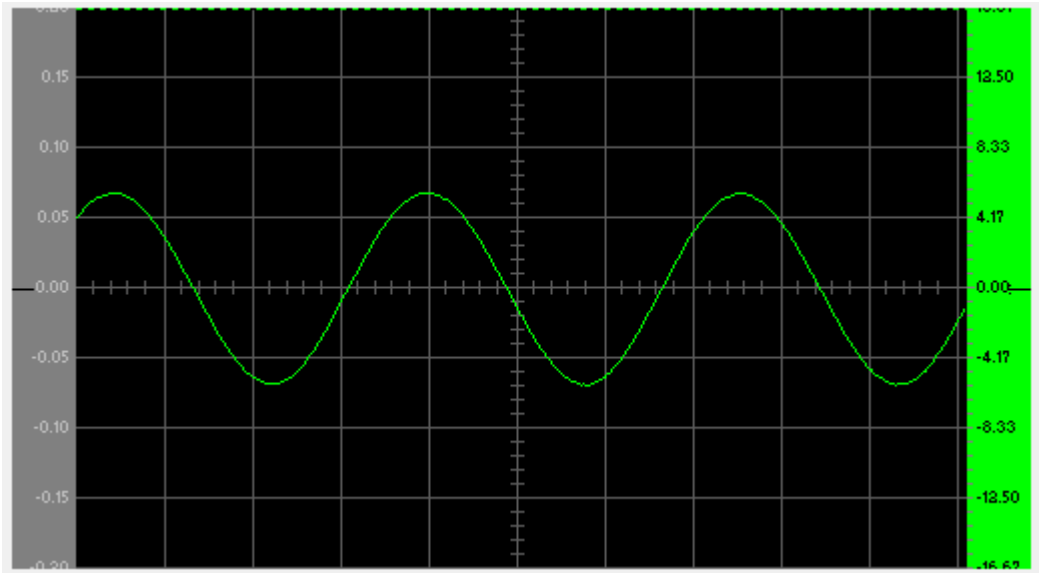


For comparison, switch to Slot B and turn off everything except the Organ section. Choose a Hammond B3, and turn off the rotary speaker, turn off any chorus/vibrato type settings and turn off percussion.
Set the drawbars: **0 0 8 0 0 0 0 0 0**

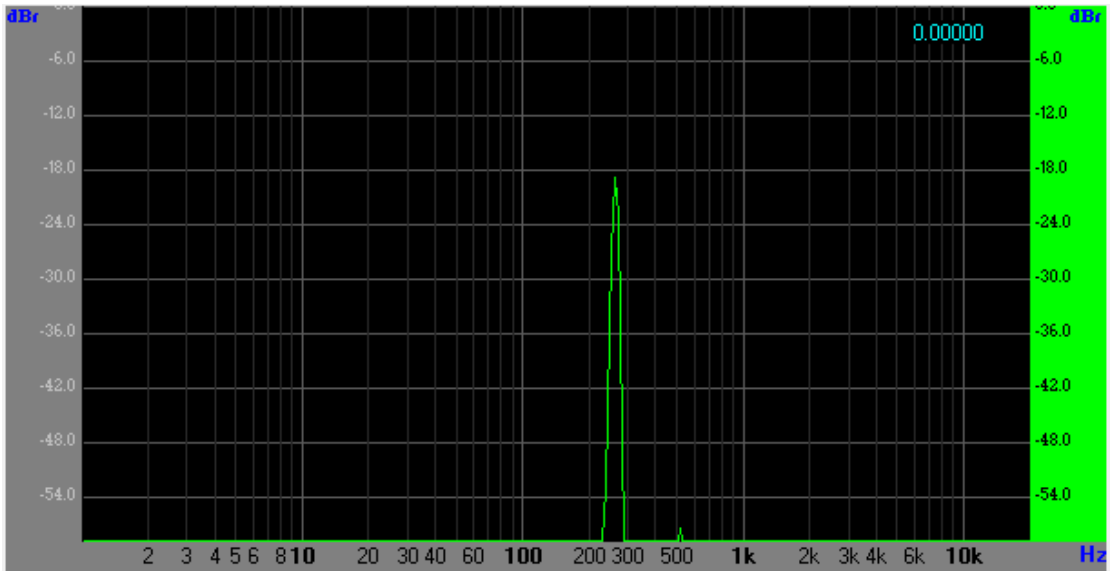
Play a middle C again, and it should sound pretty identical to the FM Synth init sound!

I made an audio file to compare the sounds – it's in the ZIP file, called "**B3 - FM - 008000000.mp3**". The Hammond is first, the FM synth shortly afterwards.

Here's an oscilloscope picture of the B3 waveform…:

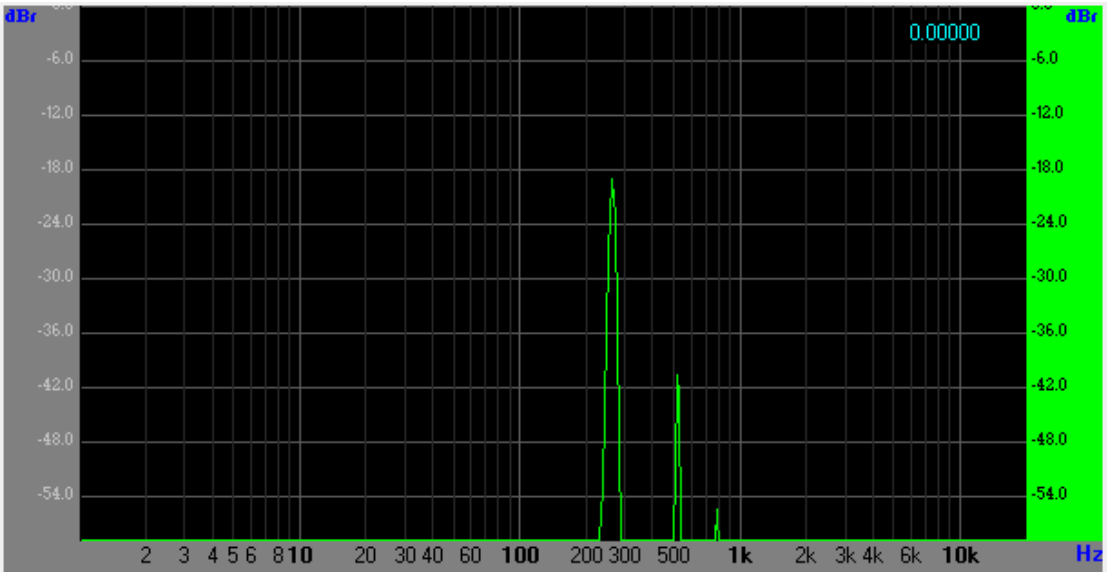


…and frequencies/harmonics (below). Notice there is an additional spike at 522Hz, but it's amplitude is so small it has has only a faint effect on the overall sound (the x-axis is logarithmic, not linear – trust me, it is 522hz!).



Now change the drawbar settings to: **0 0 8 3 1 0 0 0 0**

Here's the picture of the frequencies – you can see the sound is now made up of two main frequencies – one around 261Hz (the fundamental) and one around 522Hz which is the 2nd harmonic for middle C – it's actually an octave above the fundamental.

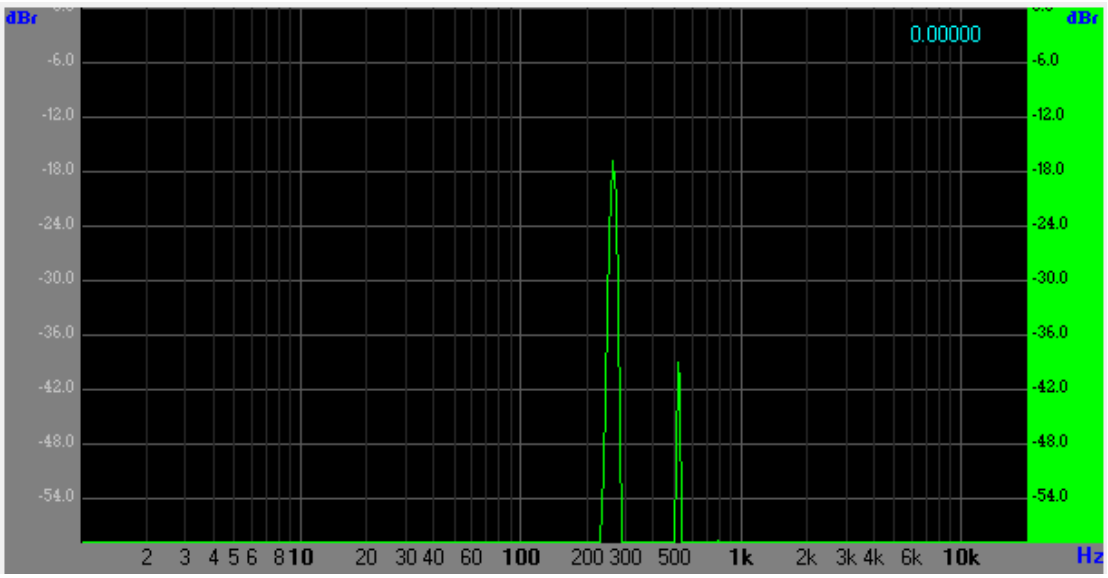


Go back to Slot A where you have your Synth section enabled.
To make this kind of sound on the FM Synth, we need a way to add harmonics to the SINE wave.
*(With 'traditional' analog synthesisers, you use multiple oscillators that produce sounds rich in harmonics, and you use the filter to remove the ones you don't want. That's why it's usually called '**subtractive synthesis**' as you are **subtracting** from, or **filtering** out some of the sound.)*

Anyway, this is FM. To add harmonics, the simplest way is to add some **feedback** to your SINE wave. Turn the **OSC SHAPE** knob just a bit so the main display reads "1.4"

Now switch backwards and forwards between slots A and B, comparing the 'real' organ, with the one we are making. They sound pretty close?

Here's the frequency chart for the FM Synth:



The sound comparison file is called "**B3 - FM - 008310000.mp3**", once again with the Hammond playing first followed by the FM synth.

Play this FM synth sound through a rotary speaker (set to synth instead of organ), with a bit of drive too.
Not bad for a **single sine wave oscillator**, eh?
Save this program, we'll develop it in a minute after this next boring section:

FM explained a bit more…

The next thing to enhance that sound might be to bring in another oscillator or two, so let's look at that.
But first we have to cover some of the boring sciency stuff. Also I should probably mention the DX7 and how the Nord does things differently.

In FM, the way that you can generate more interesting sounds than a sine wave as by using one oscillator wave to **modulate** another (see Synth Overview above for a quick summary of modulation). The one that carries the audio signal is called the **carrier**. The one that modulates is called the **modulator.** Whether it's a carrier or a modulator, it goes by the name of an **operator**, for historical reasons known best to Yamaha. An operator is more than just a single oscillator, it also has parameters such as frequency, the amount of effect it has on other operators, the rate at which that effect takes place… more later.

The FM synth comes with a bunch of different algorithms, which are different configurations of carriers and modulators. You access them with the **Wave Selector Dial** under the red LED screen. Some of them involve a modulator modulating another modulator, which modulates the carrier. Some feedback the output wave into the carrier, others don't.

The user manual lists all of these on page 31, but not in a way that is easily understandable if you are new to FM.

The Yamaha DX7 (which was the first generally available FM synth), had 32 algorithms – each was a different arrangement of the DX7's 6 operators.
The Nord Stage 2 has 38 algorithms, but only 3 operators. Even Yamaha's budget DX synths had 4 operators, so what were Clavia thinking?
The answer is: *avoiding complexity*.
The Stage 2 is meant to be a tool for musicians to quickly craft the sound they are looking for in a live situation, not go wading through menus.
The way you went about programming a DX7 involved choosing an algorithm, then setting the frequencies, detune, rates, levels for each of those 6 operators, which is not something you did quickly or easily, even if you knew what you were doing.
There was a great deal of flexibility but it came with a steep learning curve.

So where does that leave the Nord? It has much less flexibility to make noises like steam-trains, lazer guns and flying saucers, but Clavia instead appears to have focused on an architecture geared more towards musical tones.
While there are only 3 operators, there are also slots A and B, so you can have 6-operator sounds by layering both slots. There is also the Unison control, which adds between 2 and 4 oscillators for each slot. So that's up to 12 oscillators! (2 slots x 1 carrier osc + 2 modulator oscs + 4 unison oscs), although the 2 modulators aren't audible on their own, they modulate the carrier remember? But that still leaves 10!
You also have a filter which the DX7 didn't have, so you can combine FM tones with analog filtering.
Add the various effects like the rotary speaker, the amp sim, phaser, chorus, delay, reverb etc. and you start to leave the DX7 spluttering in your dust trail!

Algorithms

So lets take a quick look at the algorithms on the Nord and what they are.
Unlike the DX7, the Nord's algorithms do not allow individually setting the frequency and other parameters of each operator. You can only set the parameters for the carrier. However, this turns out to be not such a bad thing when it comes to frequency: sounds which are 'harmonious' to the ear involve frequencies which are at a specific ratio to the fundamental tone (which is the note you play – e.g. middle C). These harmoniously related tones (to the fundamental) are called **harmonics**.
The Nord Stage 2 provides algorithms that contain pre-baked ratios of frequencies. If you look at the list of algorithms, you will see a pattern and it becomes less confusing:

- You have always have 1 carrier.
- You can have zero, 1 or 2 modulators.
- The carrier can either feedback into itself, or not
- If there's a dot in the display, the algorithm includes feedback.

- No dot = no feedback (except Sin, where you can disable feedback by turning the OSC Shape knob fully counter-clockwise).

Parameters

I'll put **DX7** parameters in **purple**, and the **Nord** parameters in **red** so you can try to relate the Nord to the DX7:

- The **algorithm** is set via the **OSC Waveform selector knob**.
- The **frequency** is determined by the **ratio** in the algorithm.
- You can't set the individual **modulator levels**, but you can adjust the amount of affect they have using the **OSC Shape knob.** You are also simultaneously adjusting the **feedback** with this knob (assuming the algorithm has feedback).
- You can't set individual **modulator rates** either, but you can affect the rate at which the modulators affect the carrier via the **Shape Mod** and **Mod Env knobs**
- You set the **rates** and **levels** for the **carrier** operator using the **Amp Env knobs**
- **Break points** can be approximated with a **filter** and **keyboard zones**. *Perhaps – need to check this*
- **Pitch EG** can't be done, but you can do some things with **Glide** and **Vibrato**

Back to making sounds

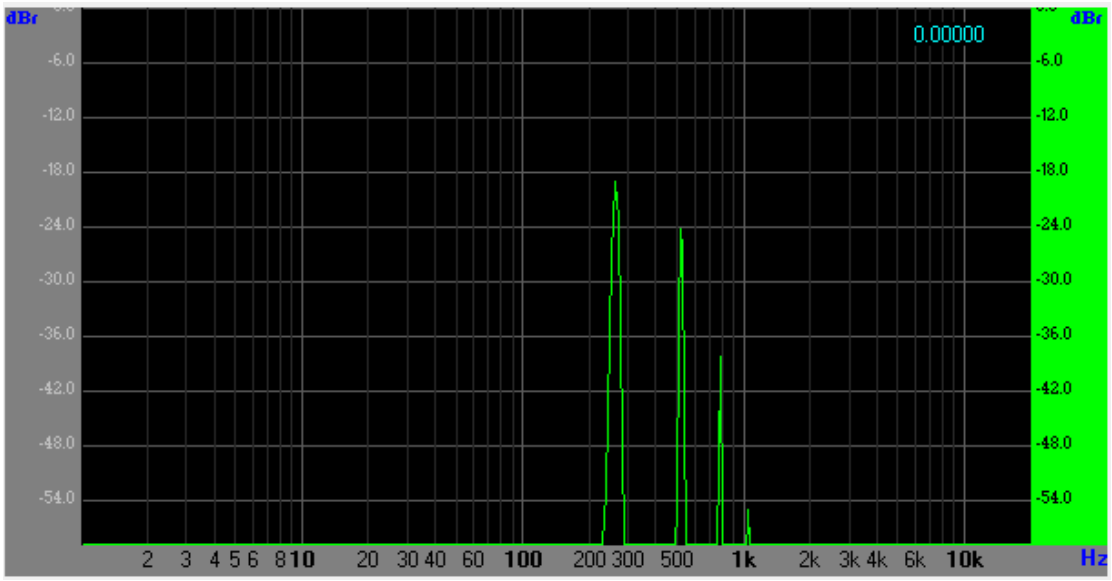
Let's go back to that organ.
So we now know that by choosing another algorithm, we can bring in more oscillators and make the sound richer.
Change the algorithm so the display reads: 1.1
This means the modulator is the same frequency as the carrier, as the ratio is 1:1.
The dot also tells us there is feedback control.
This has even more harmonics.

Adjust the **OSC Shape knob** down to about 0.9 – generally you don't often need high values on this knob – feedback is usually best in small doses.

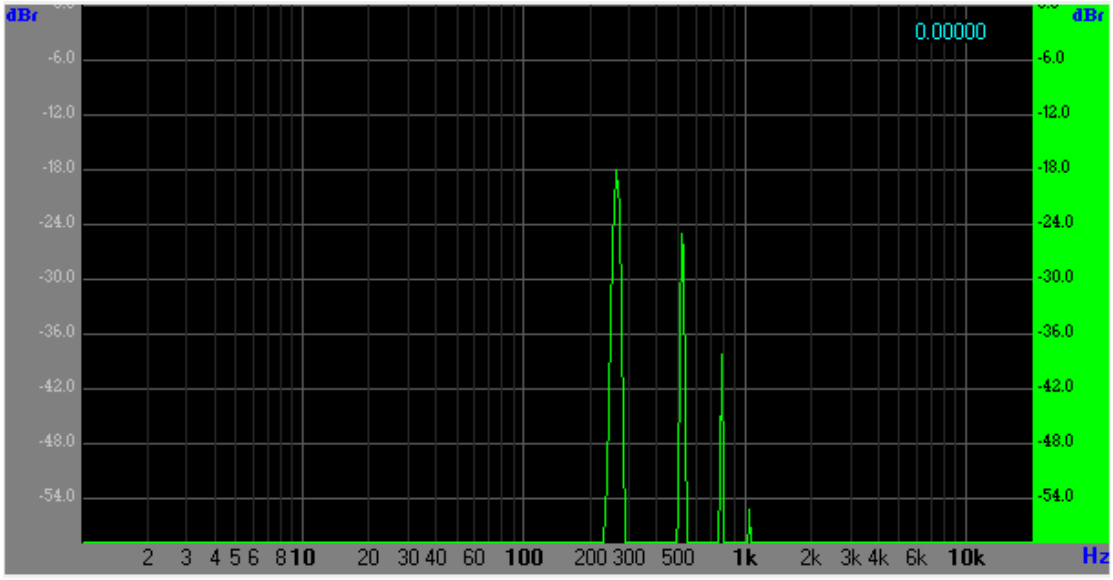
This matches fairly closely a Hammond with the drawbars set to **008741000**

Once again, a couple of harmonics charts to compare:

The Hammond:



…and the FM Synth:



Play this through a rotary speaker and it sounds pretty good.

Another way to fatten up the sound is to set the Unison control to 1 or 2 – this adds another oscillator that is a slightly detuned copy of the carrier. This was a common trick in DX7 programming, except you had to do it tediously by hand. On the Nord you just press 1 button!

The next algorithm to give us another operator and also feedback is 1.11
By now, the combined effect of two modulators has taken us away from organ territory, so you can see, sometimes less is more (the same goes for unison).

Incidentally, if you wanted to add harmonics *below* the fundamental frequency, you can on the Hammond with drawbars 1 and 2, but you can't with the FM

synth. However, you could add another FM synth in Slot B, but transposed down an octave, then play both slots together.

The last thing we are going to do with this sound before moving on is to reproduce that percussive click you get with electric organs.
I think this is caused by a momentary surge of voltage when the key is first pressed (*please correct me if I'm wrong!).* Anyway, we can reproduce this by means of the Modulation Envelope (**Mod Env**) – see the overview to the synth section above if you are hazy).
The **Mod Env** allows us to vary the way the Modulator affects the carrier.
Set the **Mod Env - Decay** to about 12ms. Now turn the **Shape Mod Env knob** fully clockwise. If you play a note, there's a hefty click at the beginning. This is because the modulator and the feedback are initially applied as though you had the **OSC Shape knob** set to the full amount. However, the Mod Env has protected your ears by dropping it almost immediately (over 12ms) to the value you set it at – about 1.4. We need this to be less dramatic, so instead of starting with the full amount of modulator/feedback, we just want a slight peak above the level we set –so turn the **Shape Mod Env knob** back to 2.0.
Now the sound starts with a modulator/feedback level of 2.0 and drops to 1.4 in 12ms.

That's it with the organ – we've covered quite a lot of ideas.
To be honest, you already have a top-of-the-range Hammond organ simulation in the Nord Stage 2, so you probably won't be needing this FM organ much, but it was a good starting point and allowed for easy comparison.
Let's continue that theme by creating a Rhodes piano sound – the DX7 became famous partly because of its distinctive version of the Rhodes.

(to be continued…)

Wavetable and single-cycle waveforms

To do…

Tips and tricks

To do…