Synth Patching – Lesson Plan

Overview

This lesson plan should be used in conjunction with Nina Richards's Interactive Online Synth.

Intro: What Is Sound?

Does anyone know what sound is?

When something moves back and forth lots of times every second, it squishes the air back and forth, and that squishes our ears back and forth. This is what we think of as sound.

Try placing your hand gently on the front of your neck, and singing for a little bit. Can you feel it buzzing?

When we speak or sing, we use our vocal cords, in our neck. We move them back and forth very quickly, without even having to think about it.

You'll find a speaker in every TV, radio, phone, tablet, and almost every laptop. These work a bit differently, using electricity and magnets, but they do the same thing: move back and forth very quickly.

Does anyone know what frequency is?

It's how often something happens. How *frequently*.

We hear sounds that happen between about twenty times a second, through to about twenty *thousand* times a second.

Scientists and engineers talk about frequencies, while musicians talk about notes and pitches… but they're the same thing! For example, take the "A" note above middle C on a keyboard. Musicians call it "A-4". Engineers say that it squishes air "440 times every second". But they're talking about the exact same thing, just wording it differently.

"Hertz" is a fancy term meaning how many times something happens every second. So we can say that A-4 has a frequency of 440 Hertz. This is often written down as "Hz".

Making Sounds: Oscillators and Waveforms

On the software synthesiser provided, click on "start sound". You should hear a tone.

"Gain" is the volume, how loud it is. Go ahead and adjust the slider. Hear how it makes the sound louder or quieter. If you scroll down, the green-and-black oscilloscope at the bottom left shows you the actual pattern the speaker is moving in. Note how the vertical distance it moves gets further apart or closer together.

That's what the speaker's doing too: it moves further, the more you turn the volume up.

The vertical part of these shapes represents where the speaker is. The horizontal part represents time. It's kind of like if you taped a pen to a clock pendulum, and pulled some paper along beneath it, so the pendulum drew a line to show where it had been. That pendulum would draw a sine shape.

The different "waveform" shapes change the back-and-forth pattern the speaker makes. Try selecting different waveform shapes, and hear how they sound a bit different. See how the oscilloscope in the bottom-left corner matches the shape you choose, but it isn't quite perfect, because the speaker can't quite move and stop quickly enough to make vertical lines.

Underneath the waveform shapes, "frequency" is how many times a second we want to make the speaker move back and forth. So you can make your speaker zigzag hundreds or thousands of times every second. Try adjusting the frequency slider, to hear the same shape sped up or slowed down. See how the oscilloscope shows more or less movement at once. The higher the frequency, the more bunched together the shapes.

Try playing the keyboard by clicking on its notes. See how those notes are just certain frequencies.

Finally, we'll try the fun part that makes synthesisers sound so different: filters!

Changing Sounds: Filters

Try singing a long sound, aaah. At the same time, make different shapes with your mouth, and listen to how it changes the sound you're making. (It's also fun to make different mouth-shapes while brushing your teeth.) Say "Wow!" Again, but slower.

The sound changes, but it's not just the frequency, or how loud you are… it's something else. Your mouth *filters* your voice. By making different shapes with your mouth, you're making different shapes of sound.

This is called filtering, and synthesisers are really good at this. There are different types of filtering. The most common are low-pass, which only lets the lowest frequencies of a sound through, muffling it… and hi-pass, which only lets the highest frequencies of a sound through, making it sound tinny. There's also bandpass, which only lets the middle ones through (filtering out both the lows and highs at once), and notch, which lets everything *but* the middle ones through.

This synthesiser can do all of these types of filtering. First, let's try low-pass, which can remove the higher, faster parts of the sound, leaving only the lower, slower parts. Just like your mouth. First, select the sawtooth waveform. This is a good one for filtering. (We'll look at why later on.) Try moving the filter frequency back and forth, to remove more or less of the higher frequencies in the sound. See and hear how it affects the sound.

Then try the other filter types. Hear and see how the high-pass filter removes the lower frequencies. The band-pass and notch filters are a bit harder to see in this example, but generally band-pass filters only let a few frequencies through near the filter frequency, and notch filters let all the rest past, *except* those near the filter frequency.

This is what synthesisers do. In fact, you're using a synthesiser right now, just like Daft Punk or Björk, Deadmau5 or Lady Gaga.

Some Theory: What's Happening Here?

If you want to know how filtering works, this is where things get really weird: each sound is sort of made up of lots of other sounds. If you were to mix together a sine wave, and another one at twice the frequency, and another one at three times, and another at four times, and so on… you'd end up with a sawtooth wave. The higher frequency waveforms are called *harmonics*, because they're multiples of the lowest one, in harmony with it. They work together to make a single shape, and we only hear it as one sound. Building up a waveform like that is called *additive synthesis*, because it involves adding sounds together.

Most synthesisers, like this one, do the opposite, called *subtractive synthesis*: they start with a waveform that has lots of harmonics, like a sawtooth or square wave, and then remove some of those harmonics using the filter. If you select any waveform, and low-pass filter almost everything out, it turns into a sine wave: the lowest harmonic, called the *fundamental harmonic*.

By changing the filter frequency while a sound is playing, we can change the shape of that sound over time, by removing different harmonics at different times.

This is easier to see than to put into words, which is what the yellow-on-black spectrum analyser is for, at the bottom right. You can see how the sine wave is a very simple sound, whereas the sawtooth wave has lots of different parts to it. When you filter it, you remove some of these parts, while leaving others in.

The *filter frequency* or *cutoff point* is where you draw the line between what you're removing and what you're keeping. If you increase the *resonance*, you increase the volume of just the frequencies near that cutoff point.

For example, if you make a sawtooth wave with a frequency of A4 (440Hz), then that sound actually has parts at 440Hz, 880Hz (doubled), 1320Hz (tripled), 1760Hz (quadrupled), and so on. These parts, all combined, give you the distinctive sawtooth shape. But if we lowpass filter it somewhere between about 500Hz and 700Hz, then we're making those faster parts quieter again, changing the shape to something in between a sine wave and a sawtooth wave. And if we increase the filter's resonance, then we make the parts near 500Hz to 700Hz even louder than the others. As we increase the cutoff point, the filter frequency, we're letting more of the higher parts of the sound in, and making those louder instead, changing the shape of the waveform.

And that's the main part of synthesis: making and changing shapes, to move a speaker back and forth in interesting ways.

If you'd like to learn more about how synthesis works, there's lots of information on the Internet. Gordon Reid's guide Synth Secrets is especially good. But to start with, you don't need to know that much in order to play a synthesiser. Many musicians start off playing around with all the sliders and dials until it sounds good. Try things out, experiment, and if you enjoy playing with synthesisers, keep exploring.