Practical Snare Drum Synthesis

Synth Secrets

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By Gordon Reid

Published April 2002

Last month, we revealed just how hideously complex the sound-producing mechanism of the snare drum can be. Nevertheless, synthesizing the sound is not as hard as it seems, as we find out with the aid of a Roland SH101...

We finished last month's Synth Secrets with the diagram shown below, which depicts one possible model for using analogue synth modules to recreate the sound of a snare drum. This model includes five primary sound sources, numerous contour generators and VCAs, some filters, a couple of frequency-shifters, some preset mixers, and a voltage-controlled mixer that allows you to alter the contributions from each signal path.

If you decided to build this patch using an analogue modular synth, you'd have to spend about £2000 on racks and modules, but it's well known that you can generate acceptable 'analogue' drum sounds from small monosynths costing a fraction of this. Indeed, you can pick up a Roland TR808 or TR909 for a few hundred pounds, and each of these will give you a drum sequencer, bass drums, toms and all sorts of metalwork and percussion in addition to their snare drum sounds. So how do these machines achieve this?

In this article...

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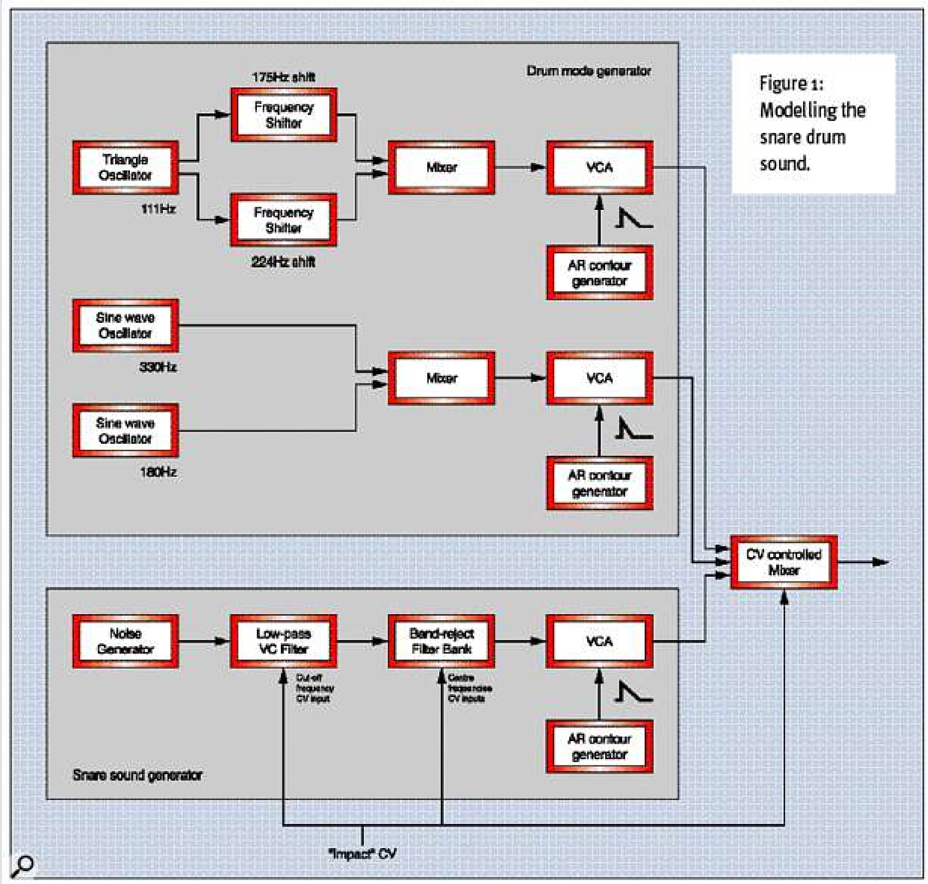

Figure 1: Modelling the snare drum sound.

The TR909 Snare

Let's start by looking at the snare drum in the Roland TR909 (see Figure 2). This doesn't look much like Figure 1 (above), but let's break it down into its components and see how close it is. We'll start with the subset of 11 blocks to the centre and right of the diagram, as shown in Figure 3.

To understand these more easily, we need to redraw Figure 3 in the format I've been using in Synth Secrets for the past three years. The result is Figure 4 (below).

Let's now compare this to the upper signal path in Figure 1. You may remember that the partials generated by the shell and air modes of the snare drum fell into two camps: two shifted harmonic series, plus a pair of enharmonic partials generated by the 0,1 mode. I devised two signal paths to recreate these: a triangle oscillator and two frequency-shifters to generate the shifted series, and two sine-wave oscillators to generate the 0,1 frequencies.

You may also remember that I admitted that the frequency-shifters in the upper path were an expensive solution to the problem of recreating the snare sound. Well, Roland's engineers found a cost-effective solution when they designed the TR909: they ignored the shifted series, and just employed two oscillators and two waveshapers to generate the 0,1 frequencies. So there's our first compromise... we've dispensed with the elements of the sound that occur as a consequence of all the shell modes except 0,1. This may seem rather Draconian, but it turns out that it's not a bad solution, as the sound of the TR909 demonstrates. It also shows that elements of a sound that may seem vital in an academic analysis can become dispensable when we actually begin to synthesize a sound.

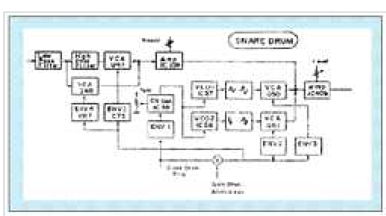

Figure 2: Roland's block diagram for the TR909 snare drum.

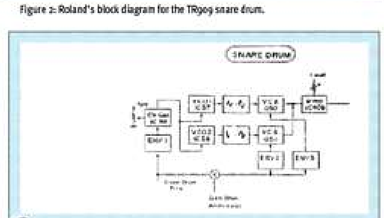

Figure 3: A subset of the block diagram for the TR909 snare drum.

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Figures 2 and 3: Roland's block diagram for the TR909 snare drum.

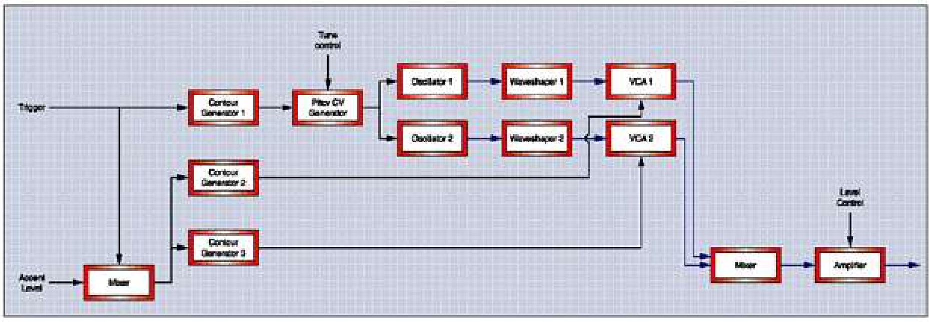

Figure 4: A different way to represent the architecture shown in Figure 3.

Figure 4: A different way to represent the architecture shown in Figure 3.

Returning to Figure 4, you may have noticed that Roland added an enhancement not present in Figure 1. Whereas I used a single VCA and contour generator for the 180Hz and 330Hz partials, they provided two VCAs and contour generators. These allow the two partials to have different amplitudes and decay at different rates, as they would on a real snare drum. On the other hand, the pitch CV and associated contour generator in Roland's architecture appear to be anomalous. Given that a real snare tends not to display a pronounced decay in pitch as the amplitude of the note decays, they seem to be unnecessary.

Despite these minor differences, I hope it's clear that this part of the TR909 conforms closely to the analysis I performed last month. So let's now look at the remainder of the sound-generating mechanism. Figure 5 shows the rest of Roland's block diagram, and Figure 6 (below) converts it into Synth Secrets format.

Here we can see that a low-pass filter modifies the output from the noise generator by removing the higher frequencies from the signal. The output from this filter then proceeds down two paths. The first takes it to a high-pass filter that removes the low frequencies from the signal, leaving a narrow band of noise that is then contoured by VCA 4 and Contour Generator 5. The second signal path travels through VCA 3, and its amplitude is shaped by Contour Generator 4 without any additional filtering. A mixer then recombines the two paths, after which another VCA further shapes the sound before it passes to the final mixer and the output.

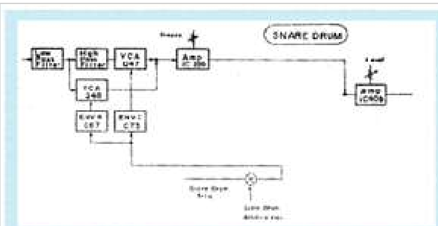

Figure 5: The noise signal path in the TR909 snare drum.

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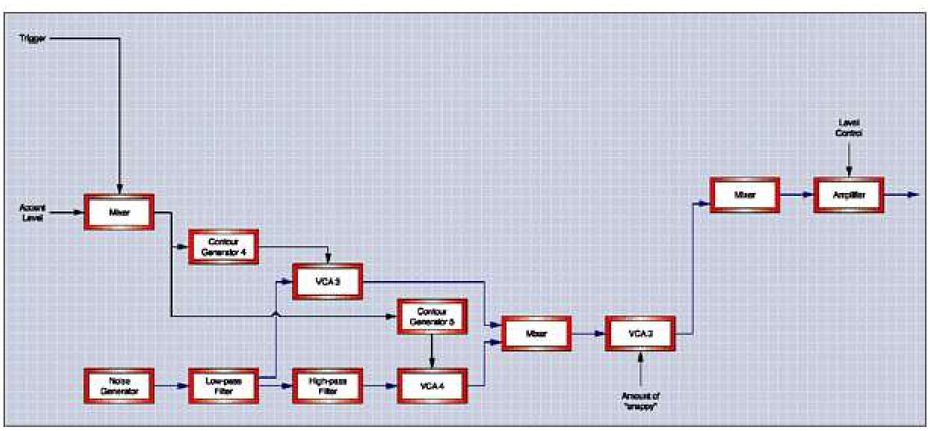

Figure 6: Figure 5 converted into Synth Secrets format.

Figure 6: Here Figure 5 is converted into Synth Secrets format.

This is quite clever, because it allows the TR909 to generate a noise spectrum with different amplitude and decay characteristics in the high- and low- frequency regions. And, while the

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result is not as sonically complex as the output from the filter bank in Figure 1, it nonetheless adds interest to the sound. Having accepted this difference, the rest of the 'noise' path in the TR909 snare sound is all but identical to Figure 1.

Let's now put Figures 4 and 6 together, making Figure 7. This may not look much like Figure 2, but it is functionally identical. More to the point, it doesn't look much like the snare model in Figure 1, but closer inspection shows it to be very similar indeed. So let's take our hats off to Roland's engineers, because for a tiny fraction of the price needed to create my patch, they created a snare sound that was cheap, conformed to theory, and sounded good too.

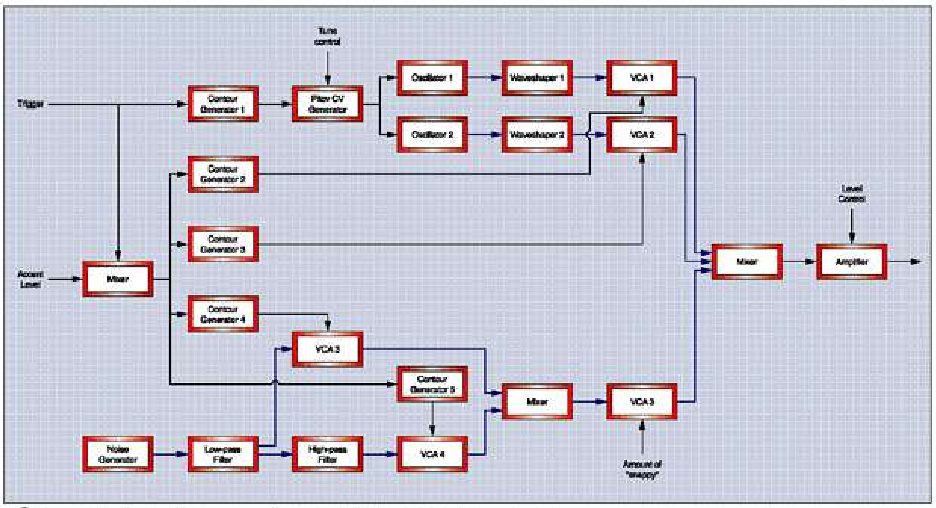


Figure 7: The Roland TR909 snare drum circuit laid out in Synth Secrets style.

Figure 7: The Roland TR909 snare drum circuit laid out in Synth Secrets style.

The TR808 Snare

Despite this, there's still no chance that you could patch Figure 7 on a Roland SH101, an ARP Axxe, a Minimoog, or any number of other common instruments. So is there an even simpler way to make passable snare sounds? Well, we'll have to take some short-cuts, but we need look no further than the Roland TR808 to find some of the techniques we need.

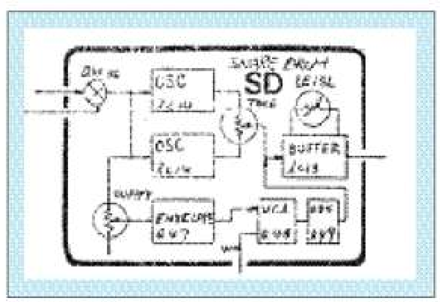
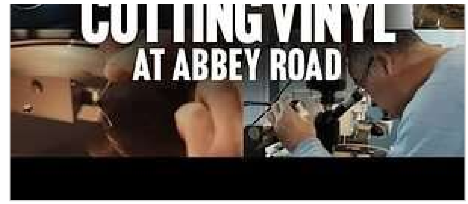


Figure 8: The Roland TR808 snare drum.

Figure 8: Roland's TR808 snare drum circuit diagram.

Figure 8 shows the TR808's snare drum generator. This is much simpler than the TR909's equivalent, so let's see what's happening. To make things a little clearer, I've laid out Figure 8 in Synth Secrets style (see Figure 9). This may look more complex than Roland's block diagram, but there is a reason for this: I have shown the trigger, the mixers and the external white noise generator.

As you can see, the trigger source has two jobs. Firstly, it fires a contour generator (left off the Roland diagram). The output from this (called the 'snappy' signal) is attenuated and added to the trigger itself, and the composite signal is then directed to both oscillators.



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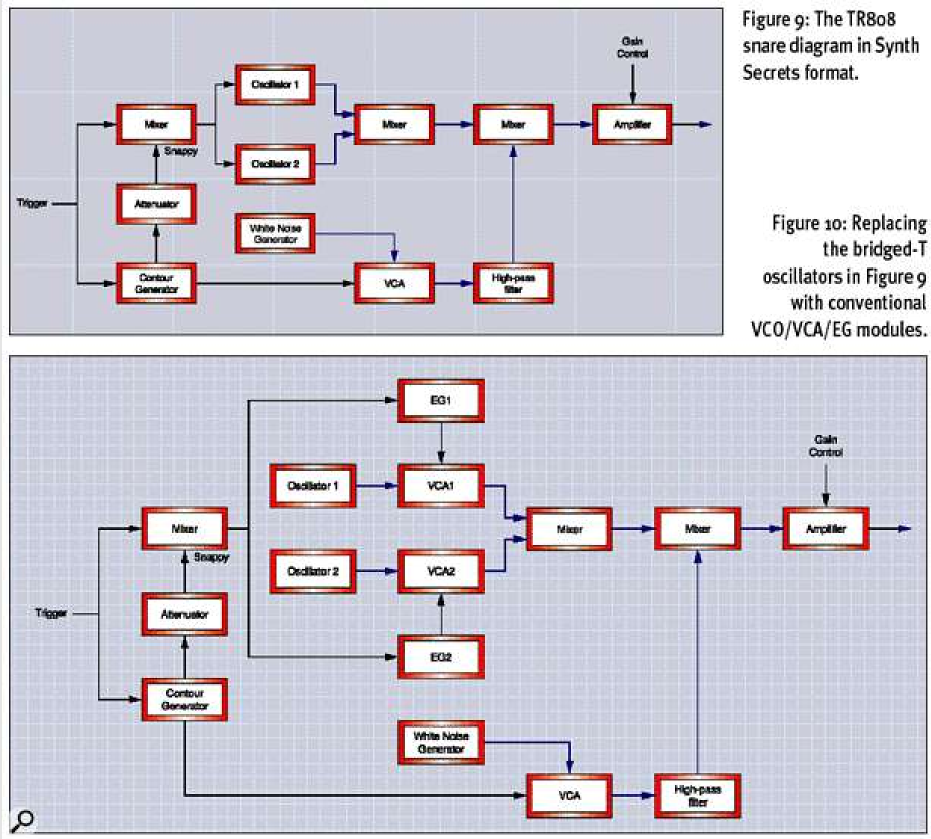

Figure 9 (top) shows the TR808 snare diagram in Synth Secrets format. Figure 10: Replacing the bridged-T oscillators of Figure 9 with conventional VCO/VCA/EG modules.

The oscillators, as you may have guessed, are of the 'bridged T' form that I described when I discussed the TR808 kick (see SOS February 2002 Synth Secrets). This means that you merely have to kick them into life, and they will then oscillate at the pitch, and decay at the rate, determined by their component values. The TR808 mixes the waves generated by the two oscillators in proportions that are again predetermined... this time by the factory values of the components in the mixer.

Simultaneous with all of this, the contour generator is determining the gain of a VCA that is itself controlling the amplitude of a white noise signal. The output from this VCA is then high-pass filtered and mixed with the oscillators' outputs before the final composite passes to the output amplifier.

The beauty of this architecture is again in its simplicity and its low cost. Even if we replace the bridged-T oscillators with more conventional VCOs, VCAs and EGs (as in Figure 10, above), it remains straightforward. And again, it conforms closely to the principles that led me to create Figure 1... two decaying oscillators for the important 0,1 modes, plus a contoured noise source to emulate the sound generated by the presence of the snare itself. OK, the shifted harmonic series are missing, as are the holes in the noise spectrum, so the TR808 is never going to fool you into thinking that you're listening to a real snare drum. Nevertheless, it does capture the essence of 'snareyness'.

Now let's look again at Figure 10. To patch this we will need two independently tuneable oscillators, three VCAs, three contour generators, two audio mixers and a CV mixer, a noise generator and a high-pass filter. Well, we can save on one of the audio mixers by combining the two shown in series in the main signal path, but it's still a significant chunk of hardware. Yet our experience of many cheap and cheerful synths tells us that we can obtain snare-like sounds from even the simplest instruments. So how do we do it?

Shapin' Some Noise

To answer this, we're going to travel even further back in time, to the 1970s, an era when drum machines (as they were then known) were ghastly little affairs that spat out rhythm sounds based on filtered noise. Static low-pass or band-pass filters determined the 'colour' of these sounds, and a VCA and AR contour generator shaped the signal amplitude (see Figure 11). This suggests that the simplest synths can generate recognisable percussion sounds, provided that they have a noise generator whose output can be treated by a filter and a contoured VCA.

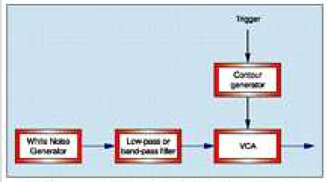

Figure 11: The simplest (and least authentic) way to create a snare drum sound.

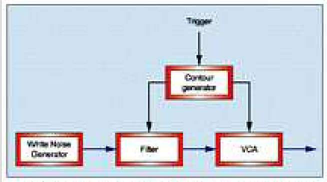

Figure 12: Almost the simplest way to create a snare drum sound.

Figure 11 (top): The simplest (and least authentic) way to create a snare drum sound. Figure 12. Almost the simplest way to create a snare drum sound.

Now, I don't know if there were any commercial drum machines that conformed to the diagram at the bottom of the page (see Figure 12) but a slightly more sophisticated unit might also have shaped the tone of the noise burst by contouring the frequency cutoff of the filter. If this looks familiar, I'm not surprised: with an extra couple of VCAs to control the amount of contour applied to the filter and the audio signal amplifier, it's the same as the block diagram I drew for the ARP Axxe and Roland SH101 a couple of months ago (see Figure 13).

So, let's program a snare sound on the Roland SH101, and see how close we can get to an authentic snare drum. Or, if that eludes us, let's see how close we get to the classic analogue snare sounds of the TR808 and TR909.

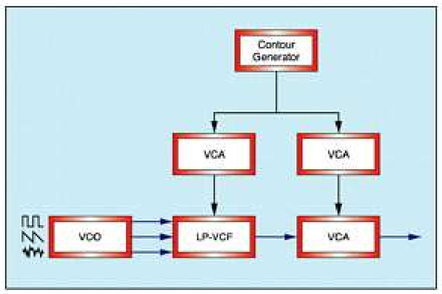

Figure 13: Some key elements of the ARP Axxe and Roland SH101.

Figure 13: Some key elements of the ARP Axxe and Roland SH101.

Snares On The Roland SH101

We'll start by creating a patch based on Figure 12. Since we want no conventional waveforms in the sound, we go straight to the source mixer in the centre of the control panel to set the pulse wave, sawtooth wave and sub-oscillator contributions to zero. We then raise the noise level to 10, ensuring that the noise generator drives the rest of the signal path as hard as it can. The remaining controls that determine the source waveforms now become irrelevant, and we end up with the simple settings shown in Figure 14 (below).

Now we must choose appropriate settings for the filter, and determine the amplitude contour. The noise burst generated by a real snare drum is rich in mid and high frequencies, so it is important that the synthesizer's low-pass filter is fully open for this sound. We achieve this by setting 'VCF Freq' to 10. However, the SH101 keeps a bit of cutoff frequency 'in reserve', so we can open it even more by setting the 'VCF Env' and 'VCF Kybd' sliders to 10, thus ensuring that the filter is at its most 'open' at the start of the sound, and that it closes slightly as the sound decays. This proves to be just what we want. However, it's important not to introduce any resonance ('Res') into the patch. This would make the sound go 'oowwww' as it decays, which would be quite inappropriate.

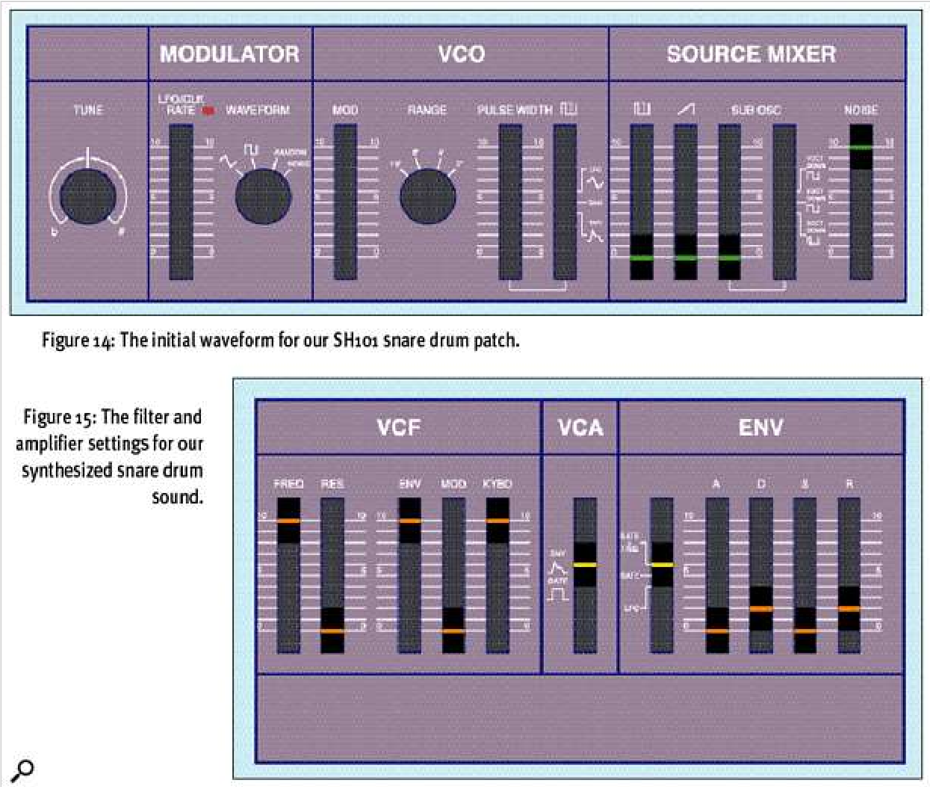

Figure 14: The initial waveform for our SH101 snare drum patch.

Figure 15: The filter and amplifier settings for our synthesized snare drum sound.

Figure 14 (top): The initial waveform for our SH101 snare drum patch. Figure 15: The filter and amplifier settings for our synthesised snare drum sound.

Moving on to the amplifier and envelope (contour) generator, we set the VCA to respond to the ADSR contour, and the keyboard triggering to 'Gate + Trig', which allows us to play fast snare drum rolls. Finally, we come to the ADSR envelope itself. The Attack should be as near-instantaneous as the synth can manage, so A=0. Likewise, a snare drum should never sustain, so S=0, too. This then leaves the Decay and Release times, which should be equal, ensuring that the sound decays consistently whether you release the keys or not. I find that setting Decay and Release times to '2' works just fine for this sound (see Figure 15, above).

Putting Figures 14 and 15 together then yields an acceptable analogue snare sound. Indeed, I find this patch to be far punchier than the early drum machines it emulates, for three reasons: the SH101 envelope is far snappier, the bandwidth is greater, and the noise generator slightly overdrives the filter input, contributing to a harsher timbre.

If you play this patch, you will be able to play single hits and snare rolls (by trilling on two adjacent notes). You can even imitate the inconsistencies with which a real drummer hits the batter head by reducing the 'Freq' setting (say, to 5 or 6) and playing a range of notes across the keyboard. With the keyboard tracking at maximum, you will find that notes at the top of the keyboard are brighter than those as the bottom. This adds a pleasing variation to the sound.

You can now EQ the result and add reverb to create a huge range of analogue snare sounds, from a booming deep-shell snare to bright military drums, to the gated excesses of everyone who copied Phil Collins throughout the '80s... you can obtain all of these from slight variations on this simple patch.

The Sound Of The Drum

Now let's find out what happens if we try to introduce a tonal element into our patch, to more closely approximate the upper halves of Figures 1 and 10. These are the parts which attempt to generate the sound of the drum itself, without its snare, as explained last month. Figures 1, 2, 3, 4, 7, 8, 9 and 10 all suggest that we need at least two oscillators for this, but the SH101 only has one. How can we use this to add realism to the sound?

Figure 13 (see earlier) shows that the SH101 can combine its pulse wave and/or the triangle wave with the noise generator. But, since they are just different waveforms produced by a single oscillator, they are at the same pitch. If we don't make the filter self-oscillate, the SH101 can't produce two pitches simultaneously. Or can it...?

Let's jump back to the left-hand side of the SH101 control panel. Apart from the master tune control (which is not of immediate interest) this is where we find the modulator. In general, we use this to generate vibrato (pitch modulation) or growl (frequency modulation). However, the maximum frequency of the SH101 modulator is just fast enough to encroach upon the bottom end of the audible frequency range, and this means that we can use it for frequency modulation, or FM.

Do you remember all of the horrid equations that you skipped in April 2000's Synth Secrets? Of course you don't... you skipped them. However, the ideas contained within them can be useful, as the following explanation might demonstrate. One of those equations (was it really two years ago?) described the series of frequencies generated as 'side-bands' when one sine-wave oscillator modulates the pitch of another. You may also remember (or more likely also skipped) the bit where I explained that, if the amount of modulation is low, only the first couple of side-bands are audible. The upshot of this simplification is that if you slightly frequency-modulate one signal (the carrier) with another (the resonator) the result is that you hear the original carrier and modulator signals, plus a couple of sidebands at the sum and difference frequencies of the carrier and modulator. If you're OK with maths, this can be expressed as the equation below, where 'w_{sb}' is the frequencies of the sidebands, 'w_c' is the carrier frequency, and 'w_m' is the frequency of the modulator.

Let's stick some numbers in here to make more sense of things. Imagine that the VCO carrier frequency is 200Hz. If the modulator frequency is 30Hz, we obtain no fewer than three audible frequencies in the output. These are the oscillator itself (200Hz), the oscillator plus the modulator (230Hz), and the oscillator minus the modulator (170Hz). Actually, 30Hz itself, as the modulator frequency, will also be present, but it's unlikely that you will hear this.

$$W_{sb} = W_c \pm W_m$$

Now, these three frequencies look very different from the partial series that we discussed in last month's analysis of the snare drum. But I have ignored a crucial point: the SH101 does not generate sine waves. The modulator offers triangle and square waves (both of which have extended harmonic series) and the oscillator offers sawtooth and pulse waves (both of which also have extended harmonic series). This means that every harmonic in the modulator waveform interacts with every harmonic in the oscillator waveform, and the SH101 will generate a huge number of low-amplitude FM partials.

Of course, the frequencies thus generated (and their amplitudes) are quite different from those generated by the shell of a naked snare drum. On the other hand, the drum's modes are so screwed up by their interaction with the snare mechanism that FM is as likely as any other method to generate an acceptable imitation of the shell.

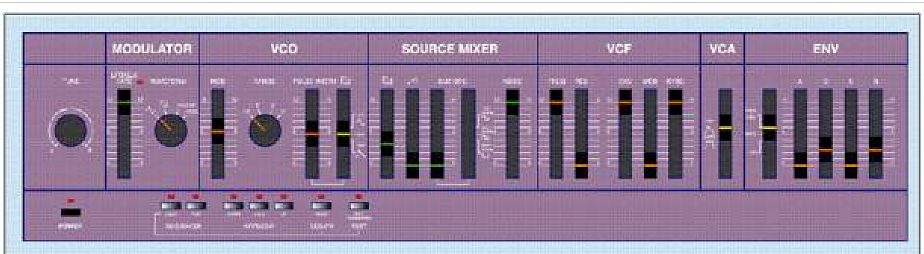

Figure 16: The SH101 'FM' snare drum.

Figure 16: The SH101 'FM' snare drum.

So, it's time to get empirical: that is, to experiment to find the settings for 'LFO Rate', 'Mod', and VCO frequency that give you the type of 'shell' sound you're looking for. I happen to like the settings in Figure 16 played on the uppermost 'G' of the keyboard. I have set the LFO rate to maximum, the 'Mod' amount to a middling value, and chosen a 25-percent pulse wave to be the carrier. I have then added about 35 percent of the resulting sound to the noise in the mixer. If these settings seem overly precise, they're not. This patch is very sensitive to tiny changes in the Mod and pulse-width settings, so — quite apart from personal preferences — the small differences between synths should guarantee that your patch will sound different from mine.

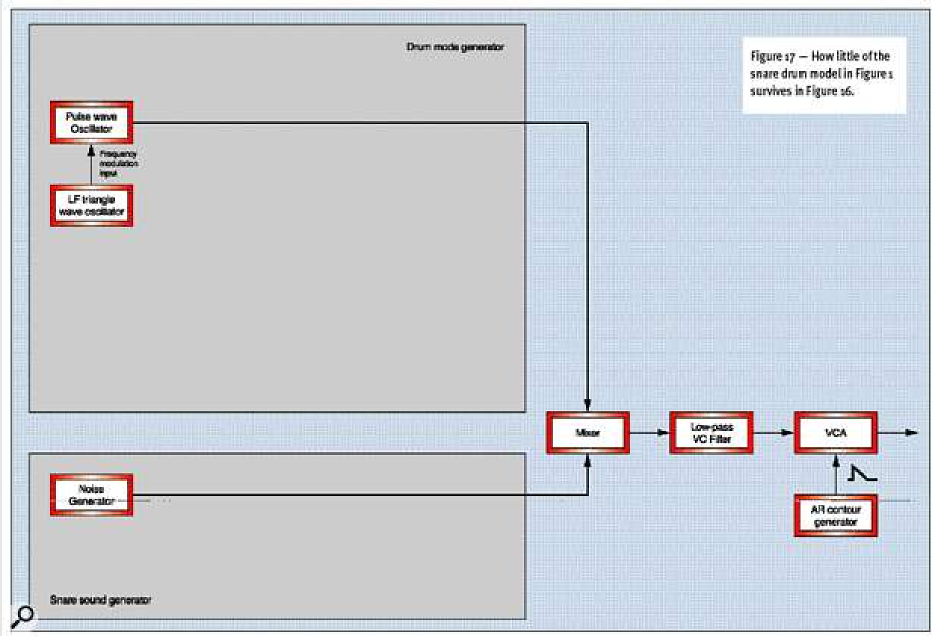

Figure 17: How little of the snare drum model from Figure 1 survives in Figure 16.

We'll finish by encapsulating the simple patch in Figure 16 as a block diagram, laid out in the same way and on the same scale as Figure 1. Figure 17 (above) shows how much (or rather, how little) we have retained from our original ideas. As you can see, most of this diagram is empty, and as well as losing control over the precise nature of the sound spectrum in the drum mode generator, we've lost all the independent VCAs and contour generators that allowed us to shape the various parts of the sound. And that is perhaps the most significant difference between a 'real' synthesized snare drum, and the analogue sounds that people use instead of snares in much of today's music.

And that's about it for this month... Sure, we could discuss in greater depth why we can dispense with some of the elements required by our theoretical analyses, but not others. I could also demonstrate how we can use the same principles to create similar sounds on synths such as the Axxe or the Minimoog, or even show you how to use the multiple filters and modulation routing on the Korg MS20 to get much closer to the sound of a real snare. But I reckon that, with all the theory from last month, plus the explanations of the TR909 and TR808, and this SH101 example, you should now be in a position to create some excellent snare drum patches of your own. So get twiddling...

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