Tech Note No. 9

by Pete Stark

I sometimes have trouble thinking of a good topic for discussion, and Fred Henn always comes to the rescue with some suggestions. Here are two:

The BBS

A few people have asked about my BBS at ... *(I have deleted this section, because the BBS no longer exists now that we have the Internet)*

Outputs in Parallel

Some time ago, Fred Henn asked me a question which makes a good subject for discussion. He is expanding his Theatre Organ, and wants to make more stops available for all his manuals. To do that, he wants to install a second #11235 stop filter board. Since each filter board has two outputs (one Solo output, and one Accompaniment output), he is wondering how to connect those four outputs to a single preamplifier-vibrato board.

Actually, we have to look at the problem from two different sides:

1. When several outputs are connected together, will they add, or will they cancel each other out?

2. Can he connect multiple outputs together without loading them down or causing short circuits?

This is an interesting problem, and it makes a good springboard for a much more general discussion of organ sounds.

Cancellation and Adding

First, let's look at the cancellation problem. Audio signals are called AC or alternating current, which means that they alternate between being positive voltages and negative voltages. The speed at which they alternate back and forth is called the frequency, and it determines the pitch of the note -- the faster they alternate, the higher the pitch. The maximum voltage that they reach is called the amplitude, and it determines the volume -- a signal which becomes only slightly positive and negative is soft, whereas a signal which reaches big positive and negative voltages (alternating between them, of course) is loud.

A third characteristic of the signal, its waveshape -- the pattern of how it alternates from positive to negative and so on -- determines its sound quality or timbre. For example, a trumpet playing middle C and a saxophone playing middle C at the same volume might both have the same frequency and same amplitude, but they still sound different because they alternate voltages in different ways.

Now, suppose you put two different microphones in front of one trumpet. You get two different signals, but because they both came from the same source, they will both have exactly the same frequency. The volumes and waveshapes might be slightly different (for instance, the two microphones might be slightly different, or they might be in different places, or one might have more distortion than the other), but the frequencies are identical because both signals are playing exactly the same note.

On the other hand, consider two trumpets, with one mike before each. Even if they are playing the same note the two signals will never be exactly the same frequency because the two trumpets will never be tuned exactly the same way.

Now consider what happens when the signals from the two microphones are mixed. First, let's take the case of one trumpet and two mikes. Suppose the two signals are such that they both go positive at the same time, and both go negative at the same time; this is called in-phase. Then their two voltages will add to produce a bigger voltage. So now you still hear one trumpet, but it sounds louder than before. Now remember -- the two signals are exactly the same frequency, that is, they both go positive and negative at the same speed. So if they both go up and down together now, they will still be both moving together a second or a minute from now, and so they will stay in phase all the time. You get one loud trumpet sound, even though it came from two microphones.

But suppose one mike is farther away from the trumpet than the other. Since sound travels relatively slowly, the signal coming from that mike will be delayed. So suppose the signal from one mike is going positive just as the signal from the other mike is going negative; this is called out-of-phase, and it's not such a ridiculous idea -- at middle C, all you have to do is put one mike 2 feet farther than the other to get the sound delayed by just the right amount to get this. When they are mixed, the positive voltage from one mike cancels the negative voltage from the other, and we get a smaller signal than before. So the volume of the trumpet seems to drop.

If the signals from the two mikes were exactly the same but opposite, then we could get complete cancellation and would hear nothing. In general, this is not going to happen because the two signals would not be exact opposites. One mike might have more distortion, or might hear different echoes, so we would get only partial cancellation because these differences would still come through uncanceled. However, the sound quality would change because the shape of the wave -- the way it alternates between positive and negative -- changes. So we would get a somewhat softer trumpet, and it would also sound a bit strange.

Now consider the other case -- two trumpets and two microphones. Since the two trumpets will never be tuned exactly the same, they will not always add or always cancel each other. At one particular instant, they might add, but a fraction of a second later they might partially cancel, and then add again. This would produce a rhythmical variation in the volume which is called a beat note.

We all know that a chorus sounds different from a single singer whose voice is just amplified. In a symphony orchestra, a violin section with a dozen violins all playing the same note sounds very different from an amplified single violin. In a piano, playing a single key actually results in a hammer striking two or three strings, all of them tuned slightly differently. It is this variation which makes music interesting and gives it color, and it is sometimes called a "chorus effect." So what does all this have to do with organs?

In a pipe organ, playing a middle C with two stops drawn may actually play two (or even more) pipes. Those pipes will never be tuned exactly the same; even if you tried to tune them the same, you couldn't achieve it because as soon as the temperature changes, they go out of tune. As you add more stops or turn on some couplers, even a single note becomes a rich combination of sounds which almost randomly add and cancel. (In fact, some stops intentionally add a "celeste" effect by having a second set of pipes, intentionally out of tune, playing along at the same time.)

You have a similar situation on an older Allen electronic organ, for example, which uses separate oscillators for different stops. Playing one note in two or more stops results in random combinations of signals which provide a richness to the sound. You can hear that there are two or more different sounds playing at the same time.

But having separate oscillators for each note, and also for each different stop, is expensive. For example, even the smallest Allen analog organ (as opposed to the newer digital organs) might have 200 separate oscillators, and some larger ones have thousands of oscillators. And so organ makers have developed various kinds of shortcuts.

One method is unification, a technique that dates back to the early days of real pipe organs. For example, suppose you have an 8' Tibia stop and a 4' Tibia stop. Since both of these sound similar, with one just being an octave lower than the other, these two stops can share the same set (called a rank) of pipes (or oscillators). That same rank might also be used for a 32' stop in the pedal, as well as a 2' or 2-2/3' stop, and maybe even a few other stops on another manual. Such a rank of pipes (or oscillators) might therefore translate into a batch of stop tablets (some of which might not even be called Tibia). Of course, when a rank of pipes is used for everything from a 32' pitch to a 2' or 1' pitch, it needs to have both very high and very low notes. And so it might have more than 61 pipes; 73 or 85 pipes might be common if there is an extra octave or two extension at the top or bottom.

A simple pipe organ might only have two or three actual ranks of pipes, but still look very impressive with two or three keyboards, pedals, and dozens of stop tablets. The disadvantage, of course, is that there is still a limited number of pipes. For example, suppose you play two C notes an octave apart, in a 8" and a 4" Tibia stop. Theoretically, there should be four pipes playing. In reality, only three would actually play.

Although unification can drastically drop the cost of a pipe or electronic organ, it is still not cheap. And so most electronic organs (including Schober) go two steps further. First, there is one common set of oscillators for all ranks/stops of the organ, and further, each of the oscillators provides several different notes at the same time. For example, one master oscillator in the Schober organ generates all the C notes for all stops, another generates all the D notes, and so on. In this way you only need one set of twelve oscillators, instead of the 61 (or 73 or 85) if each note required a separate oscillator, or instead of several hundred -- or more -- if there were different oscillators for each different type of sound (i.e., for each different rank.)

If you only play one note in one stop at a time, then this simplification makes little difference. But as soon as you play a chord, or as soon as you play two or more stops at one time, this creates problems.

When each of the notes comes from a different oscillator, slight tuning differences will mean that you will never get constant cancellation or constant adding of the two waveforms. Like the sounds from different trumpets, the sounds will gradually change between cancellation and addition, and there will be a richness to the sound -- the chorus effect.

But if the notes come from the same oscillator, then they will always occur in step with each other. If they start off cancelling, then they will always cancel; if they start adding, then they will always add; if they start off partially cancelling, then they will always partially cancel. In other words, their combined effect will again be a constant sound, different perhaps from the original, but constant. In still different words, playing two notes like this does not necessarily sound like two pipes; it sounds like one pipe, somewhat similar to the two original pipes, but more of a mixture between them than two different pipes combining.

There isn't much you can do to work around the problem within the organ -- short of installing multiple oscillators -- but there are a few things that can be done outside it. Anything that adds variety and adds some of that chorus effect will help -- Leslie speakers to "throw the sound around the room", adding reverb, splitting the organ into channels so different sounds come from different places, perhaps even having the reverb coming from a different direction.

Ooops ... it looks like I've run out of room. I guess I'll have to make like a famous detective story writer, and leave you hanging ... 'til next time.