Tech Note No. 7

by Pete Stark

I once heard someone say, "The sooner you fall behind, the more time you have to catch up!" The trouble is, I'm so far behind I've given up on even that. (So let's see whether I can get this installment to Fred in time for him to include it with his December newsletter; if not, you may not see this until 1995. Sorry...)

More on Thumps...

In response to my discussion of the thump Bill Bruce gets when he turns off his organ, Ray L. DeVault (president of Devtronix Organs, Inc.) sent me a very nice followup letter. In it he mentioned that he has run across the problem in many other organs (although he specifically mentioned "kit organs" in his letter.)

Ray indicated that in his experience the problem is caused by the sudden drop in the organ power supply voltage when the power goes off, and suggested that I look at the preamp output with an oscilloscope when the power is shut off to confirm the diagnosis. Unfortunately, Bill's organ is on the west coast while I'm on the east coast, and so I can't do that. I'm still not completely convinced that that's the problem in Bill's case (since he has confirmed several times that the thump occurs at the *very instant* he shuts off the power) but for now we will have to go with that.

Ray's letter mentioned a sure-fire fix which he uses to avoid the problem no matter what organ or amplifiers are used. His solution is a two-step delay circuit. When you turn on the power switch, the delay circuit turns on the organ first, and then three seconds later turns on the speaker. When turning off the power switch, the circuit turns off the speaker first, and then waits three seconds before turning off the organ power. In this way, the speaker is never connected at the instant the organ power goes on or off, and so you can never hear any thump even if it's there. (The wiring would have to be done very carefully with tube amplifiers, which can be damaged if operated without a load.) Altogether, a cute solution.

Devtronix Tone Generators

Much more interesting, Ray also included some information and a diagram of his 243-3 tone generator/keyer, along with a description. I was aware of his circuit, but until he sent me the info and diagram specifically for this column, I wasn't sure whether he'd mind my discussing it at length here. Now I can feel more free to do so.

Let's start by a quick review of how Schober generated their tones and keyed them.

The original Schober tone generator scheme uses 12 separate generators for the entire organ. One tone generator produces all the C notes for both manuals and the pedals, the next generator produces all the C# notes, and so on.

Each of the 12 generator circuits starts off with a single oscillator; between them, the 12 oscillators generate the top octave of the keyboard. Each generator then uses a series of transistorized "flip-flop" circuits which then take the top note, and successively divide the frequency down to produce the lower octaves of that note. This works because going down an octave divides the frequency of a note by exactly 2; flip-flops also divide a frequency by 2, and so passing any note signal through a flip-flop produces the note one octave down.

The output of each flip-flop is a square wave which has all the odd harmonics, but no even harmonics. To add those even harmonics (which are needed for most stops), the Schober circuit combines the various pitches from one generator into the now-famous staircase pattern we've all read about. This is done in a series of resistors, which do the required combining, but which also reduce the voltage level of the output signal.

This staircase signal is sent directly to the keyboard switch contacts, which select the notes to be played and then combine them into five output lines (on the Theatre organ) called *busses*. Thus there is a 16-foot bus, an 8-foot bus, a 4-foot bus, etc. This combining is again done with resistors (mounted in the keyboard), which further reduce the signal volume. The output is therefore sent to a set of bus amplifiers, which amplify the signal back to a more usable level (and which also recombine some of the outputs to remove the even harmonics for those stops that don't need them.)

This original scheme has several disadvantages:

First, because there are 12 separate oscillators, there are 12 separate tuning controls to adjust (and to drift out of adjustment.) So, when suitable integrated circuits (IC's) became available, Schober introduced a new tone generator board which ran the entire organ from just one master oscillator running at a very high frequency.

This board used two kinds of newly-introduced IC's. First, a Mostek MK50240 IC, called a *top octave generator*, took the high frequency output from a master oscillator, and divided it down into the twelve notes of the top octave (plus one additional note for the top C.) Since this was done digitally, the top octave was thus always in tune -- except that, by changing the frequency of the master oscillator, all the notes of the entire organ could easily be transposed up or down together. By placing the master tuning control within the organist's reach, you could play everything in the key of C (on the keyboard) yet have it come out in whatever key you wanted (except that you couldn't really transpose fast and accurately enough to switch keys in the middle of a piece.)

The circuit also used IC flip-flops to generate the lower octaves; this made it much smaller than the original tone generator board, which used separate transistors, capacitors, and resistors to do the frequency division. It thus fit on just one printed circuit board, instead of the separate 12 boards in the earlier Theatre organ. (I understand there was even an earlier vacuum tube version of the Theatre organ ... anyone still have one?)

But there was a more serious problem. The keyboard switch contacts were gold plated, but even so they picked up slight amounts of dirt and corrosion. This is not normally a problem in switches when there is enough current through the switch to burn off the dirt or corrosion, or when the switch contact can be sealed to keep out outside dirt and air. But the Schober keyboard and pedal contacts were wide open and switched only low voltage audio, and so there wasn't enough current there to keep the contacts clean.

As a result, sometimes two contacts would come together, but not actually make good contact. Then a note might not play, or might be lower than the expected volume, or might generate a scratchy sound as the key went down or back up.

This was aggravated by the fact that each keyboard key operated from three to five contacts, depending on the organ and manual. Sometimes one contact would connect, and another might not. Then a note might sound in one pitch, but not another.

There was an additional problem -- even when the contacts were clean, when you played a note they would open or close quickly, starting and stopping a note very suddenly. And depending on what the voltage of the wave was at the instant they opened or closed, the sudden change in voltage could sometimes generate a slight clicking sound (which was fortunately attenuated by the stop filters.)

Enter Ray DeVault to the rescue. Some years after the Schober organs were designed (and possibly even after Schober went out of business), some British manufacturer (and I've never been able to find out who) made an interesting organ IC (probably for some British organ manufacturer.) Ray discovered that IC, incorporated it into Devtronix organ tone generators, and also offered a modification kit for Schober organs. This IC combined the frequency dividers *and* the note on-off switching, all in one tiny package. Devtronix calls it a TDA-1008, though the original British number may have been different.

Using the TDA-1008, the Devtronix 243-3 tone generator/keyer generates all 61 notes on one printed circuit board, and also does all of the keying. Instead of using the keyboard contacts to switch audio, the keyboard now switches a +15-volt dc signal on and off; this signal is then sent to the appropriate TDA-1008, and *it* does the audio switching.

This has several advantages:

First, by keying +15 volts, there is more current in the keyboard contacts to keep them clean. So you get reliable switching and don't have to worry about dirt and corrosion.

Second, only one set of contacts is required on each keyboard key. Schober keyboards have from three to five contacts per key (depending on the model) since they switch not just an 8' tone but also 16', 4' and possibly others, so this is not of much significance to us. But when building a new organ, being able to use a simpler keyboard makes a big difference in cost.

Third, since all the switching is done inside the TDA-1008 IC in response to a single signal from the keyboard, all five bus signals switch at the exact same time.

Fourth, the TDA-1008 uses gradual switching, rather than a sudden on-off. Hence the organ notes come on and go off more gradually. This cuts down on key clicks, and makes the sound slightly more natural. (In fact, the IC permits a simple sustain by just adding two parts.)

Finally, the TDA-1008 has frequency dividers built-in, so given a note from the top octave, it can generate all the lower octave notes internally. It also has internal circuitry to steer the appropriate octave sound to the appropriate output bus, depending on which key is pressed. (The disadvantage, of course, is that a given TDA-1008 can only control octavely-related notes. So it can generate 16', 8', 4', 2', and 1' tones, but not 2-2/3' or 1-1/3' tones.)

There is one major fly in the ointment: an organ needs 13 of these TDA-1008 IC's for each keyboard (one for each note of the top octave plus a thirteenth for the top C), and you can't share a set for two keyboards; you also need another 13 for the pedals. To implement a complete Devtronix tone generator system for an organ, you need 39 of these IC's -- and they are no longer being made!

With this in mind, let's look at some details of the Devtronix tone generator board. There are actually two versions: the 243-3, which provides sawtooth (staircase) outputs, and the 243-4, which provides a square wave output for the pedals. (I believe there are also -3a and -4a versions which use slightly different keyboard connections.)

Each board starts with a high-frequency oscillator, which feeds a top-octave generator IC. Since the Mostek MK-50240 is no longer available (I wish I'd bought some when Radio Shack carried them!), Devtronix uses a MO86 IC (which may also, alas, no longer be made.) This, plus a common flip-flop IC, generates the thirteen notes of the top octave (including the top C.)

These 13 signals are fed to thirteen TDA-1008 IC's, which internally generate the square wave outputs, but only send them out the outputs when the appropriate keyboard note is pressed. A set of operational amplifier IC's then amplifies the output (and on the -3 board, also generate the staircase signals.) The output then goes directly to the bus amplifiers in the original organ.

The board is 4x16 inches, and comes with a 61-wire preformed cable that connects to the keyboard. Although building the board is probably fairly easy, I suspect that rewiring the keyboard can be quite messy. Although I haven't seen Devtronix's instructions, I suspect that the entire keyboard would have to be removed from the organ and totally rewired.

Does it make a difference? I don't have one of the Devtronix generators and haven't heard it either. But others tell me that it does. One can add one tone generator board (just for one keyboard) and keep the original Schober circuitry for the other (and the pedals), or go all the way. Either way, just splitting the organ so different manuals run from different oscillators adds variety that can't help but improve the sound.