Music Hast Charms

By Ted Needleman

Most readers of *Modern Electronics* enjoy experimenting with electronic circuits and devices. One of the areas that seems to be perennially popular is electronic music. Various magazines (including this one, of course) have published music-oriented construction projects such as fuzz boxes, phase shifters, etc. The emergence of the personal computer changed the electronic generation of music from analog devices into a predominantly digital process.

Making music with a computer, whether that computer is contained within a keyboard, or resides in a PC, is now commonplace. There are a bewildering amount of products, both hardware and software, available at prices reasonable enough to justify their purchase by the hobbyist/musician. We'll take a look at some of these products in this and upcoming columns. Don't worry if you're at the level of proficiency where they *still* laugh when you sit down at the keyboard. I've played guitar for almost 25 years and I'm not much beyond that stage myself. The appeal of many of the products we'll be taking a look at is that they permit someone with little or even no musical background to create surprisingly good music.

Of course, if you're an accomplished musician, rather than just a doodler or listener, the process becomes an order of magnitude easier. If you do happen to fall into this category, just keep in mind that the reviews in next month's (and future) columns are being performed by someone who is interested in music, but not all that musically proficient. A professional or accomplished musician would almost certainly have a different opinion of the products I looked at.

A Little Bit of Background

Music has existed in one form or another almost has been around as long as mankind itself. The first musical instrument was the human voice, followed by percussion instruments such as rocks banged against various materials. Electronic music, while a comparatively recent development, has existed for longer than you likely imagine. Simple electrical and electro-mechanical instruments were developed during the late 1800s, though it wasn't until the early 1930s that the first well-known totally electronic musical instrument appeared.

This instrument, called the Theremin (after its inventor, Leo Theremin), provided an eerie sound, somewhere between a violin and a hand saw being played as a musical instrument. It was used on the sound tracks of numerous movies, the most notable being Hitchcock's "Spellbound," and myriad science-fiction and horror movies.

The Theremin was also a very striking instrument to watch being played, though physically it was just a large console with two antennas, one mounted vertically at the top of the console, the other sticking out horizontally from the side. The musician playing the instrument moved his hands near the antennas and, hopefully, an almost pure sine wave was generated. In most configurations of the Theremin, the vertical antenna controlled the pitch (that is, the frequency), while the side-mounted horizontal antenna controlled volume.

Aside from the fact that the Theremin was the first well-known electronic instrument, it is of importance because it employed several electronic techniques that are still being used today.

Compared to some of today's instruments, the Theremin was not very sophisticated. The sound source consisted of two simple oscillators, tuned 180 degrees out of phase. When properly tuned, this resulted in a phase cancellation and no output was produced. The pitch antenna consisted of a capacitive element of one of the oscillators. When a player's hand approached the antenna, it was capacitively coupled to the oscillator, changing the frequency. This resulted in a beat frequency being produced by the oscillator pair, and this beat frequency was the resultant output.

The same capacitive coupling was used for the volume antenna, except in this case it was used to control a voltage controlled amplifier (VCA). VCAs and VCOs (voltage controlled oscillators) were major components in analog synthesizers, and are still emulated in the digital versions of these instruments.

The Theremin is still a popular construction project. In fact, one of the many Theremin construction projects which appeared in the 1960s was authored by a graduate student whose name was to become even better known in the music industry than Theremin's—Robert Moog.

As technology progressed in the period of the '30s through the '60s, so did electronic music technology. Most of the instruments developed during the 1940s, '50s, and early '60s were electro-mechanical in nature. Perhaps the two best known of these are the Hammond organ and Rhodes electronic piano. The Hammond uses a rotating magnetic tone wheel for each key to induce a fluctuating voltage (that is, tone) in a coil. The tones are further modified by electronic filters controlled by switches (voicing keys) and linear potentiometers (drawbars). The Rhodes piano functions in a similar manner, except that the tones are generated by a vibrating magnetic reed which is struck by a key-activated hammer. As a piano works mechanically in the same manner, with a hammer striking a tuned string, characteristics of the generated sound can be made fairly similar to that of an acoustic piano.

There are four major waveform characteristics produced by a musical instrument which give each instrument its unique sound or identity. These are harmonic content, attack, duration, and decay. To a large extent, with acoustic instruments, the method used to generate the sound will determine the waveform characteristics. For example, percussion, string, and wind instruments all have similar characteristics within each individual class, even though the actual sound may be quite different (which is why a guitar doesn't sound like a piano, even though they are both string instruments).

A percussion instrument, such as a drum or blocks, features a very short attack; the volume reaches its maximum very quickly. The duration of the sound varies, depending on the particular instrument, from a short time period to almost instantaneous. The decay, which is the period the amplitude drops off, is often sharp. Some percussion instruments, though, such as cymbals, bells, gongs, and vibes are designed to have both rich harmonics and long decay times because the sound-producing materials continue to vibrate for some time.

String instruments, on the other hand, have very different characteristics. A guitar or piano has a very fast attack and, unless they are muted (the string is dampened), a slow decay and long duration. Because a string is freely vibrating between two points, and other strings are acoustically coupled through the body of the instrument, they also tend to be rich in harmonics. The instrument's body and soundboard, which amplifies the sound, also contributes to both the duration (sustain) and tonal qualities.

Wind instruments, which use a resonating column of air that produces a sound, have waveform characteristics different from the two preceding classes. As the initial sound is produced by a vibrating reed, the attack can be either fast or gradual. The duration lasts for as long as the player holds a note, and the decay, once the note is released, is rapid.

While the foregoing is a bit basic, and just begins to touch upon the physics of musical sound production, it does provide a quick look at how the major factors determine what an instrument sounds like. These are all important considerations in any discussion of electronic musical instruments.

Music & Computers

The totally electronic production of music really started to come into its own during the 1960s. The mid 60s saw the introduction and widespread adoption of electronic organs such as the Vox and Farfisa. Using transistorized oscillators and pre-set filters, these organs generated a variety of sounds ranging from mellow flute-like tones (with near sine wave output) to sharp biting notes (saw wave characteristics). Also popular during this period were guitar fuzz boxes, which introduced deliberate overdriven clipping and distortion, mechanical reverbs which used spring driven delay lines, and echo boxes, such as the Echoplex, which used a tape loop and movable tape heads. With the Echoplex, output from a guitar or other instrument was recorded by a standard record head, then played back by one or more play heads located along the tape loop. By varying the position of the playback head(s) or on some units, the tape speed, you could shorten or lengthen the delay of the echo.

By the late sixties, the first modular synthesizers began to appear. Perhaps the best known of these was the Moog, from Robert Moog's Moog Music. These modular units consisted of oscillators, white-noise generators, filters, ring modulators, phase shifting circuits, bandpass filters, and other waveform modifying circuitry as well as a keyboard. A particular sound was achieved by applying a control voltage from the keyboard into a voltage controlled oscillator (VCO), then routing the signal from this into other waveform modifying modules. This routing was accomplished by manually plugging audio cables into jacks to connect one module to another. As these were similar to the old style telephone switchboard patch cords, the process of setting up the modules for a specific sound quickly became known as a "patch." The term patch is still used to represent a specific sound setup on a synthesizer, even though switches or programming codes are now used.

By setting up the correct patch, tailoring the waveform (attack, sustain and decay), as well as the harmonic content of the waveform, it became possible to approximate the characteristics of many instruments. It also was possible to create musical sounds and tones which had never been produced before (such as those obnoxious bleeps and bloops that were tremendously over-used when synthesizers first became available).

Changing a sound could take quite a while with these patch cords, depending on how elaborate a patch was to be set up. Another major problem, at least as far as using one of these early synthesizers in live performances, was that they were monophonic instruments, capable of sounding only a single note at a time. Multi-note chords had to wait until more sophisticated technology (and instruments) became available. Multi-track recording techniques did much to alleviate this problem when recordings were made in a studio. For a vivid demonstration of this, take a listen to Wendy Carlos' classic "Switched on Bach" recording.

Today's Technology

The synthesizers available today are a whole different breed. The Casio MT-520 that will be discussed next month (as part of the CMS-1 MIDI Studio) has features and capabilities that Robert Moog could only dream about when he was assembling his early systems. And you can buy these capabilities for about $150, a small fraction of what the original synthesizers were priced at.

To a large extent, you can thank the advances in computer technology and integrated circuitry for this. Inexpensive RAM and ROM memory mean that synthesizers can store sounds, patches, and even record songs as you play them. Complex sound generating capabilities provide multiple note polyphony, with up to 10 or more notes sounding at once, or the sounds of several instruments simultaneously being generated.

Instrument synthesis is accomplished through one (or more) of three techniques. The oldest method, still used on many synthesizers today, is subtractive synthesis. A complex waveform is generated by a noise generator or oscillator, then "pared down" to the desired form by filters and other waveform modifiers. Other synthesizers use stored "images" of a particular instrument's waveform, which is shifted up or down in frequency to produce the desired note. Sampling keyboards are designed to digitally record and store samples of a desired sound or tone. Depending on the available memory, up to 40,000 samples per second can be taken and stored. Sampled sounds and notes are usually played back with a digital technique called Pulse Code Modulation (PCM).

The third technique, just starting to become widely used, is additive or resynthesis. With resynthesis, a sound, such as a piano note, is analyzed using a basic mathematical technique Fourier Analysis. The waveform can then be mathematically described, and it is this description which is stored, rather than the note itself. When a player wishes to play a note, say, middle C, the description is retrieved and used to generate a waveform which corresponds to the original (allowing, of course, for the degradation induced by mathematical approximation of the original).

The available technology also means that synthesizers have gone way beyond the familiar keyboard. Rack-mounted synthesizers, driven by computer are common, as are controllers (that select which notes and instruments will sound) in the form of drums, guitars, and even saxophones. Some of the products we'll look at in coming months allow you to generate music strictly through keyboard and mouse input, with the sound generation being accomplished by a peripheral card installed in one of your PC's expansion slots.

One of the greatest advances in electronic music, though, does not concern itself directly with the generation of sound. MIDI, an acronym for Musical Instrument Digital Interface, is a simple serial network which permits the control of one instrument (suitably equipped) by another instrument or computer. Most mid and high range electronic instruments available today are equipped with MIDI capability. These MIDI in and out ports serve two purposes. The MIDI in port allows the instrument to be controlled by any other MIDI controller. This can be another instrument, or a computer equipped with a MIDI interface and a program called a sequencer.

The sequencer, which can be either a computer software package or a standalone box containing the program and memory, can be thought of as being similar to a multitrack tape recorder. Each "track" in the sequencer represents one instrument. Most computer-based sequencer programs have at least 16 tracks or more, though the exact number of individual instruments that can be "played" depends upon both the number of MIDI channels the particular computer MIDI interface card offers and the specific MIDI instrument the signals are being sent to. For example, the Casio MT-520 has 10-note polyphony. This means that the keyboard can generate up to 10 individual notes or sounds (such as individual drum strikes) at the same time. If you have two instruments playing 3-note chords, such as a piano and guitar, this uses 6 of the 10 notes. Add another note for the bass line, an eighth note for the drum, and you are left with 2 notes that can be used for the lead melody.

With a sequencer program, each "track" contains certain information besides the note that is to be played. From the musical side, the sequencer must also specify which octave the note falls in, as well as the duration of the note. A track must also be able to tell the instrument which musical instrument, or voice, it represents. Some MIDI instruments also have thru ports, which pass the MIDI messages on to other instruments. If a particular track is to be played on a different instrument, "down stream" of the first, the sequencer must also transmit that information. These, and other "System Exclusive" messages, are passed into the MIDI network and are recognized by the receiving instrument.

MIDI, like most networks, is a two way street. The MIDI out port allows an instrument to transmit. This transmission can be used to control another MIDI instrument, or it can be directed to the MIDI interface card in the PC. Regardless of the destination, the messages are the same. They consist of the same type of information (note, duration, voice, MIDI channel, etc.) that the sequencer sends out to the instrument. This allows the keyboard (or other MIDI instrument) to "record" tracks within the sequencer. These tracks can then be modified and edited, then played back.

As with any network, MIDI is a fairly complex subject, made even more difficult since many of the messages are stored in binary, rather than the mnemonics used in low level programming languages like assembler. If you intend to do much with electronic music and MIDI, you'd be best off getting a good book or two on the subject. Craig Anderton's *MIDI for Musicians* is one good book, Michael Boom's *Music Through MIDI* is another. These books are available at many bookstores, music shops, and computer stores. Be prepared, though, to spend some time experimenting. After all, that's still the best way to learn. Next month we'll take a look at several MIDI products for the PC and Mac, including a complete MIDI package (synthesizer, interface board, and sequencer software) for under $400. See you then. **ME**