New theme: music on a cathode-ray tube

Graphic console and light-pen give computer composer a new form of score pad and pencil.

Roger Kenneth Field
News Editor

There may come a time when a small boy will pick up his baseball glove and bat and go home to practice music on his computer.

At least so says Dr. Max Mathews, director of behavioral research at Bell Laboratories, Murray Hill, N.J. He has developed an easy system for composing and playing music electronically.

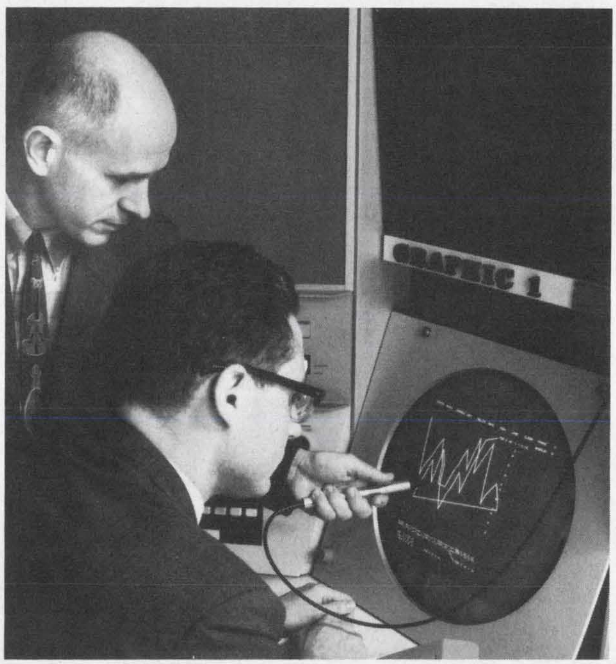
For a number of years engineers have been able to summon music from the cores of a computer. But they had to use an enormous number of punched cards to do it, and it helped if the composer was also a programer.

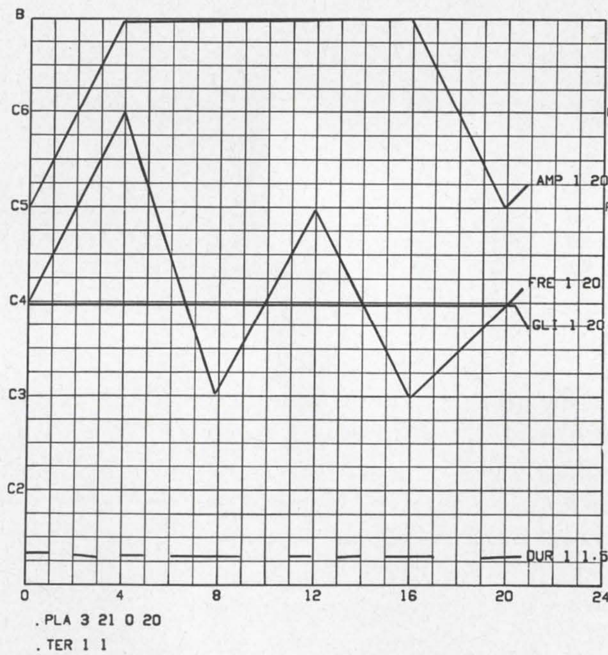
Now a composer can make a few strokes across the face of a cathode-ray tube with a light-pen and type a few simple directions on a keyboard. After a brief computation, the computer plays his new composition. The strokes of the light-pen describe the amplitude, frequency and duration of each note (see illustrations on this page).

Dr. Mathews' notation system gives the composer enormous flexibility. With great effort he could, of course, translate well-known pieces for string ensemble (or even the entire orchestra) into this notation for the computer. But the real strength of electronic music lies in its ability to fabricate completely new sounds—sounds that couldn't possibly be produced on any mechanical musical instrument. Here the composer isn't limited by the agility of the performer, by the tone color of available instruments or traditional meters and rhythms.

(continued on p. 36)

It takes a light touch to be a 20th-century Beethoven





At left: Dr. Max Mathews of Bell Laboratories and a programer, Lawrence Rosler, compose music the new computer way. Instructions are written as a series of "frames" with a light-pen on a cathode-ray tube. **Right:** An actual music pattern, or frame, as seen on the tube face. The markings on the right vertical scale refer to the musical terms pianissimo (PP), or very soft; mezzoforte (MF), or medium loud, and fortissimo (FF), or very loud. These markings are used in conjunction with the amplitude curve (AMP 1 20, in which "1" tells the computer that one instruction number—namely "20"—follows, and the "20" tells it that this amplitude pattern covers 20 beats). Similarly FRE stands for frequency, or pitch in music; DUR for duration of each note, and GLI for glissando, a term that indicates a slide up to a note. The markings along the left vertical scale represent the frequencies of notes—in this case, the note C. The B in the upper lefthand corner is a letter used to identify this particular frame. Instructions to the computer in the lower lefthand corner mean: PLA (play) 3 (three numbers to follow) 21 (waveform number 21) 0 (starting at beat 0) 20 (ending on the 20th beat). TER 1 1 simply tells the computer to stop when it has finished. Two or more frames like this can be played simultaneously. This frame required about two minutes of time on an IBM 7090.

(music *continued*)

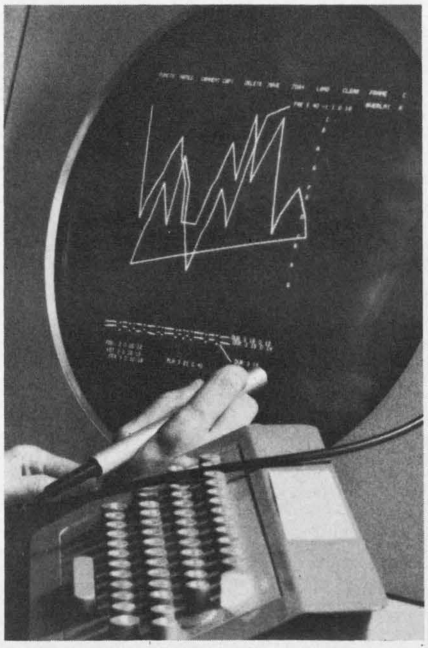
On the other hand, a great deal of detail must go into each frame on the display tube. For, in this case, the composer is also the conductor and all the musicians. Where a traditional composer would specify the notes to be played by each instrument during each beat, a computer composer must do far more. At present musicians use discretion and rely on their training to decide just how to form the beginning of each note, how to sustain the note, and how to end it tastefully. The conductor uses hand signals to control the loudness of the various sections of the ensemble and to set the tempo. But all these details must be specified by the computer composer in the instructions for the machine. The computer doesn't know Beethoven from a high-pitched bird whistle; to it, every sound is nothing more than a series of pulses. In fact, this is precisely how it makes music.

Dr. Mathews, aided by the Bell staff, programed an IBM 7090 to convert the lines on the scope into a series of pulses. These pulses pass through a digital-to-analog converter, which smooths them into a continuous waveform. This wave can be amplified and played on a loudspeaker.

At the very least, two pulses (one negative and one positive) are needed to approximate one cycle of a wave. If the digital equipment is to cover the audio spectrum—0 to 15,000 Hz—then it must be capable of producing 30,000 pulses per second.

The heights of these pulses must be accurately controlled. Dr. Mathews uses 12 bits to describe each pulse. This is an accuracy of one part in 10,000 and is equivalent to a signal-to-noise ratio of 72 dB.

This means that a digital computer that makes music in real time must maintain an output of 720,000 bits/second. Many computers can do this (Scientific Data System's Sigma 7 can deliver 26 million bits/second, and IBM's 360 can maintain 10.4 million bits/second), but to save computer time, Dr. Mathews has restricted the bandwidth to 5000 Hz for his present experiments. With good control of the heights of these closely spaced



Console keyboard labels even the most complicated curves for the 7090.

pulses, the computer composer can simulate just about any waveform that he can imagine.

These waveforms determine the "color" or "texture" of the sound. Made up by blending a frequency with various of its harmonics, a waveform is entered into the computer's memory on a punched card. Dr. Mathews feeds in a couple of dozen different sounds to give him a bit of a selection. Some sounds are relatively simple combinations of just a few frequencies, but others synthesize portions of the white noise spectrum to create various kinds of percussive sounds.

In addition to aiding the composer, the computer can join itself in the creative process of writing music. For example, the composer can give a melody two sets of rhythmic patterns instead of the usual single set and then direct the computer to repeat the melody many times, while proceeding gradually from one rhythm to the other.

It is important to note that not all electronic music is computer generated. Much of the most modern electronic music consists of artfully edited tapes that contain interesting sounds, and tones made with various kinds of signal generators. But Dr. Mathews feels that the computer will play a big part in electronic music of the future.

"During the next few decades," he says, "computers may very well become as commonplace in the home as pianos are today." ■ ■