M.I.D.I.

(musical instrument digital interface)

What it is, What it means to you

By Bob Moog

WHEN MUSICIANS first began using electronic instruments to create and record music, they developed new ways of dealing with musical sound by setting up 'networks,' or interconnection patterns, of devices that produce and modify audio material. Later (about twenty years ago), musicians were introduced to the concept of voltage control, which enabled them to set up networks to handle 'information' on how the audio material is shaped (contoured). Most recently, microprocessor technology has enabled musicians to deal comprehensively with information and control in music systems by establishing digital communications networks among instruments that transfer information not only on the contours of musical changes (data), but on the locations within a system (addresses) where the contours are to be applied. With each advance in technology, musicians found that greatly increased sonic resources became available to them. They also found that musical manipulations such as level control (dynamics), pitch shifting (transposition), and combining sound sources (layering and orchestrating) became more versatile and convenient.

With each technological advance, there were points at which standard interconnection specifications were adopted by the audio industry. The specifications enabled musicians to interconnect instruments without having to worry about compatibility. With such standards in common usage, the full benefits of networking became available, not only to technical experimenters but to all working musicians. The VU level indicator which is now universally used in professional recording studios and the one-volt-per-octave pitch control voltage in analog synthesizers are two of the many examples of the type of standardization that greatly enhanced the utility of new technology. For electronic musicians, trying to work without such standards is equivalent to the frustration a traditional composer would endure if he set out to orchestrate a piece of music at some hypothetical time in history when there were many musicians but no two musicians played the same instrument or tuned their instruments in the same way!

Bob Moog's name has been a household word among musicians since his groundbreaking work with voltage-controlled synthesizers in the 1960s. His On Synthesizers column has been a regular part of Keyboard *since our first issue. This month Bob expands from his usual column format to present this in-depth look at the most recent (and most far-reaching) advance in synthesizer interfacing. On Synthesizers will return next month in our Workshop section.*

We are now at a point in techno-history at which electronic music makers generally agree that a standard specification for connecting digitally-controlled musical instruments would be of tremendous benefit. Several standards are possible. The computer industry alone has several interesting contenders. Musical instrument manufacturers such as Digital Keyboards, Rhodes, and Oberheim, have developed and are using their own interface systems. But a more universally adaptable, yet musically useful interface could be developed specifically for electronic musical instruments.

MIDI (Musical Instrument Digital Interface) is an interface specification that has been developed and proposed by several prominent equipment manufacturers. It is not a universal standard, and it is certainly not the only possible electronic musical interface. However, even at this point it shows promise of being a powerful yet convenient way of hooking instruments together. So let's take a look at MIDI — some facts on its history, what the interface does, a bit on how it works, and how it is currently being implemented by equipment manufacturers. We will have occasion to compare it with other interface possibilities. As you will see, MIDI is not a simple specification. That is, it is not a matter of just stating a voltage or an impedance level. MIDI is capable of doing a great deal. However, it is not without its compromises. I'll get into the technical side of MIDI just enough to shed some light on what its capabilities and limitations are. The complete specification as it now exists is set forth in a ten-page document. Those of you who are interested in obtaining a copy of the specification, along with some applications information, should order 'The Complete SCI MIDI' from Customer Service Department, Sequential Circuits Inc., 3051 N. First St., San Jose, CA 95134-2093. Enclose a check or money order for $10.00 to cover printing and handling.

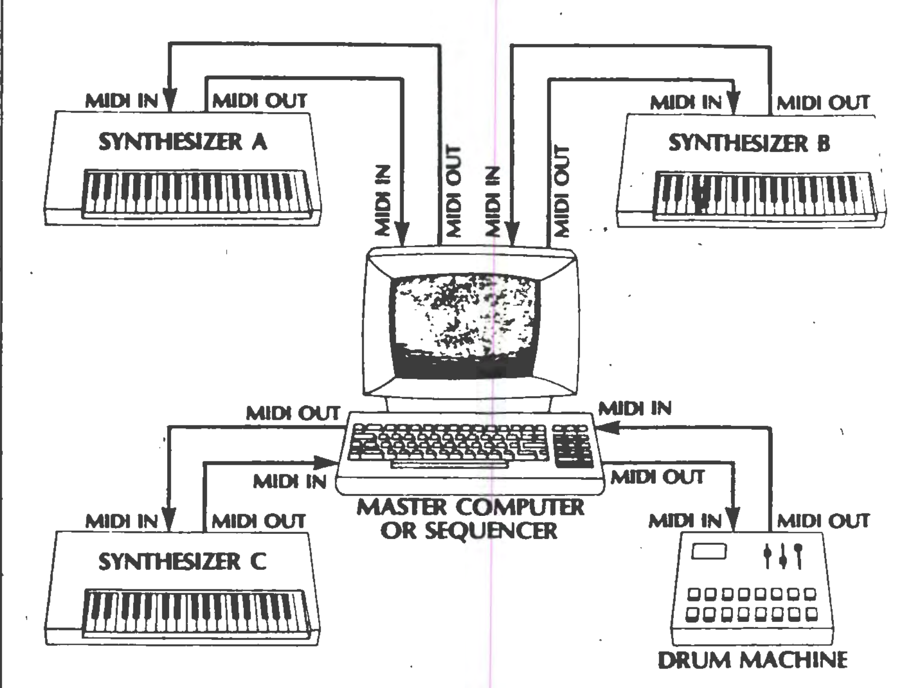
MIDI History

ELECTRONIC KEYBOARD players and equipment manufacturers alike have long seen the need for a practical equipment interface standard. Computer musicians are accustomed to using standard computer interfaces (such as RS-232) to interconnect equipment. However, standard computer interfaces generally require expensive multi-pin connectors and cables, and would therefore drive up the cost of musical instruments that incorporate them. From the equipment manufacturer's point of view, the hardware of a musical instrument interface should be as inexpensive as possible. In particular, the connectors should cost about the same as the phone plugs which are now universally used in our industry for audio signal interconnection. By comparison, a single RS-232 interconnection costs a manufacturer about $20 just for the connectors and cable alone, and that's not counting the additional circuitry and assembly labor!

The first formal proposal for a musical instrument interface that I am aware of was made by Dave Smith and Chet Wood at the Fall 1981 Audio Engineering Society convention in New York City. Smith and Wood called their specification 'Universal Synthesizer Interface' (USI). Smith, who is president of Sequential Circuits, then began to collect comments and suggestions from other equipment manufacturers. Representatives of many manufacturers met at the January 1982 National Association of Music Merchants (NAMM) convention in Anaheim, at which several improvements and modifications were added to the specification.

Spurred by the conclusions reached at the Anaheim meeting, several Japanese equipment manufacturers met to contribute the results of their research to the interface specification. Their results were forwarded to Smith and Wood, who then drew up a preliminary draft of MIDI. The word 'universal' was dropped from the name of the specification in order to avoid legal repercussions, while the word 'digital' was added to clarify the nature of the interface itself. Representatives of Sequential Circuits, Roland, Korg, Yamaha, and Kawai exchanged MIDI drafts until a consensus was reached. The 'final' version of the specification was offered to all equipment manufacturers late last year, at no charge and with no strings attached. Although the MIDI specification now exists as a formal, complete document, it does not 'belong' to any one company, and may be revised and extended as field experience is accumulated and suggestions are submitted and evaluated by the equipment manufacturers.

Figure 1. MIDI star network.



ARMBRUSTER

What MIDI Does

MIDI-EQUIPPED instruments may be interconnected so that information on sound changes and operating modes is shared by the networked instruments. Electronic keyboard instruments, sequencers, rhythm machines, auxiliary manual controllers, and personal computers are all examples of devices for which MIDI was designed. In its simplest application, MIDI permits a musician to play two or more instruments from a single keyboard, in order to layer tone colors. In its most comprehensive application, MIDI provides the means for realizing a multi-track recorder or a computer-based composing system by connecting several instruments to a master computer or controller.

Most information is transmitted over a MIDI network on one of sixteen 'channels.' These are not physical channels such as separate cables, but rather are electrical labels that are attached to packets of information. According to the MIDI specification, each equipment manufacturer has the option of determining whether or not a given instrument has the ability to select which channel(s) it will respond to. Three modes of operation of MIDI instruments are provided: *omni*, *poly*, and *mono*. The modes are defined in terms of how an instrument responds to channel select information. If an instrument is in omni mode, it responds to information that is sent over any channel. If it is in poly mode, it will respond to information on the channel to which it is assigned. If it is in the mono mode, each voice within the instrument may be programmed to respond to a different channel.

Let's illustrate this with some specific examples. First, suppose we have three MIDI-equipped keyboard instruments. Instruments B and C are receiving keyboard information from A. If B and C are in omni modes, they respond to all keyboard information. The player has thus 'ganged' all three instruments so that they all play from the A keyboard. Keyboard information may include which key has been depressed, the velocity at which it was depressed, which key was just released, the velocity of release, and the value of the key pressure (after touch). If A does not have a touch-sensitive keyboard, then no velocity or pressure information is transmitted. Similarly, if the voice circuitry of B or C is not equipped to respond to key velocity information (for instance to make the note loud or soft), then it simply ignores that information.

Now suppose A is a two-keyboard instrument, and that the top keyboard transmits on channel 1 and the bottom instrument transmits on channel 2. If the instruments are in poly mode, B is assigned to channel 1 and C is assigned to channel 2, so the musician is able to play B from the top keyboard of A, and C from the bottom keyboard of A. Each instrument may or may not have the ability to select which channel it responds to in the poly mode. If an instrument is not equipped with channel-select capability, then the specification says that it must be permanently assigned to channel 1.

Finally, let's suppose that instrument A is replaced with a personal computer that is programmed to implement the functions of a multi-track recorder. Let's further suppose that B is a polyphonic synthesizer in which the parameters of each voice are individually addressable by its microprocesser, but that the voices in C are internally ganged so they all produce the same tone color. What this means is that B is capable, by virtue of the flexibility of its hardware, of producing many different tone colors simultaneously, whereas C is not. Now, if the computer sends a signal to B that tells it to switch to mono mode, the computer can send data for different tone colors over different channels (as many as one per B voice) to instrument B. C, however, must continue to receive in poly mode. That is, all keyboard information comes to it on one channel.

Of course, equipping an instrument with a MIDI interface does not expand its sound-producing capability. A MIDI-equipped monophonic synthesizer, for instance, will play no more than one note at a time, even though the MIDI information says that several keys are down. Similarly, a MIDI-connected drum machine will respond to timing and program select information, but has no use for keyboard information. In general then, MIDI-equipped instruments will respond to information that is applicable to them and ignore the rest.

In addition to key information, MIDI allows voice parameter, mode select, program change, and auxiliary controller information (like pitch-bend, modulation amount, and volume) to be transmitted over a specific channel. The specification tells what codes stand for which keyboard keys, so playing Middle C on instrument A will produce the same note from instrument B as if Middle C on the B keyboard were played. However, the specification says nothing about codes for voice parameters. The reason is simple: While synthesizers all use the same type of keyboard, their panel controls are unique, and not standardized at all. One manufacturer may have a four-part envelope generator where another has a two-part envelope generator. Or the filter controls on two instruments may be radically different, even if they are different models of the same brand. Thus, manufacturers are free to assign their own codes to their instruments' voice parameters, but are required to list these codes in their instruction books.

In addition to the types of information that I've listed above, all of which can be sent through specific channels, the MIDI specification provides for several types of information which are transmitted without channel labels. The first of these is timing information by which drum machines, sequencers, and other real-time controllers can be synchronized. Then there are some labels that can be used to call up portions of a piece of music ('measure,' 'tune,' and 'song') that have been preprogrammed. Finally, a block of codes is reserved for use by individual manufacturers to implement functions not explicitly defined in the specification.

Inside MIDI

FIRST OF ALL, MIDI IS a bi-directional interface. According to the specification, a MIDI-equipped instrument must have an input port and an output port. MIDI input and output ports both use 5-pin DIN sockets, the kind that are frequently found on stereo equipment, cassette recorders, and electronic musical instruments. MIDI cables (which, according to the spec, may be up to 50 feet long) are terminated in mating DIN connectors. To play the tone generators of one keyboard instrument (the 'slave') from the keyboard of another instrument (the 'master'), one simply runs a MIDI cable from the MIDI output of the master to the MIDI input of the slave. To play either instrument from the other's keyboard, one uses two MIDI cables to connect master output to slave input, and master input to slave output. Figure 1 shows four MIDI-equipped tone-producing instruments connected to a master sequencer in a 'star' network. Here, the master sequencer can receive performance information from any of the keyboards, and can program any synthesizer selectively without first transmitting a channel select code.

The MIDI spec suggests, but does not require, that a third 'thru' port be provided in MIDI instruments. The thru port provides a signal that is a replica of that fed to the instrument's input port. Thus it is practical to control several slaves from one master by means of a chain network like that shown in Figure 2. In this system, a master sequencer or controlling computer can provide keyboard or voice parameter information to any of the synthesizers, as well as timing information to the drum machine. In addition, the keyboard of the first synthesizer can provide information to the sequencer.

Either a star or a chain network allows a musician to configure a multi-track recording and playback system in which only MIDI signals are recorded by the sequencer. The chain network requires fewer MIDI cables, but channel selection codes must be transmitted by the sequencer if individual synthesizers are to be selectively addressed.

Second, MIDI (as the name makes clear) is a *digital* interface. That is, information is passed from one instrument to another as a series of digital codes. In many modern electronic keyboard instruments, especially the larger polyphonic instruments, virtually all control within the instrument is in digital form, and under the direction of one or more microprocessors. A MIDI interface merely taps this information (also under microprocessor direction) and dispatches it according to the rules laid down by the specification.

Third, MIDI is a *serial* interface. Digital bits follow one another in single file through a cable containing a single pair of wires. In contrast, a parallel interface (which, by the way, several equipment manufacturers currently use) uses a whole bunch of wires, through which the digital information marches eight or sixteen bits abreast. In a MIDI interconnection, the bits are spaced precisely 32 microseconds (millionths of a second) apart in time. The basic packet of MIDI information consists of ten bits: an initial 'start bit,' a 'flag' bit that identifies whether the packet is data (a number) or status (what a data number is supposed to mean), a seven-bit code for the status or data itself, and finally a 'stop bit' bringing up the rear. It takes 320 microseconds for a byte (packet of information) to transmit through a MIDI interconnection. In contrast, several dozen bytes can be transmitted through a parallel interface in a same amount of time.

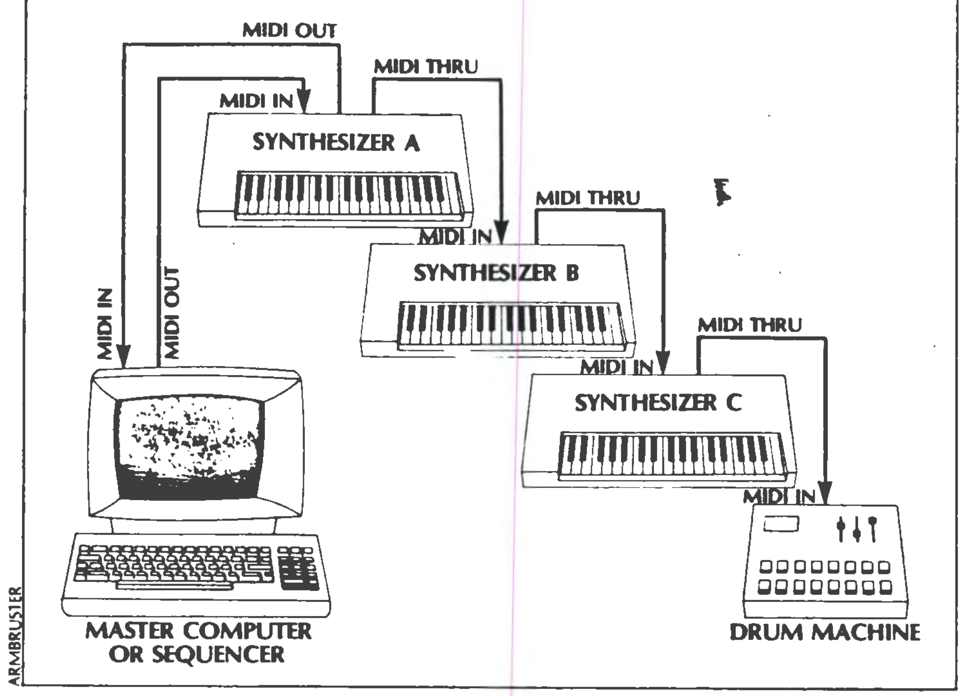


Figure 2. MIDI chain network.

Pushing our 'marching' analogy a little harder, let's compare MIDI information to a Boy Scout troop marching single file through the woods. This particular scout troop was sent out by the microprocessor when the musician played Middle C loudly on his MIDI-equipped axe. The troop is divided into 'patrols' (packets) of ten. The first patrol is headed by the patrol leader (start bit). Next in line is the carrier of the 'status' flag. After him comes seven marchers bearing the message "key data, channel #1" (it takes seven 'scouts' just to carry that message!). The assistant patrol leader (stop bit) brings up the rear, just so everyone knows where one patrol stops and the next one starts. Next come two more patrols of the same size, both with flags saying 'data.' The second patrol carries the message, "Middle C," while the third patrol carries the message "loud." Soon the troop emerges from the woods (the MIDI interconnection cable) and arrives at the microprocessor of the slave synthesizer. The slave microprocessor (perhaps like politicians on a reviewing stand) identifies the troop by examining the first patrol, then sends the second and third patrols through the slave synthesizer circuitry to tell a voice generator to make a loud Middle C. The whole 'march' takes about a thousandth of a second.

When you play a MIDI-interconnected system, you never have to deal with the individual bits. Unless you get into computer programming, you don't have to know codes, or worry about status and data. All that is taken care of by the microprocessors of the instruments you are playing. The MIDI scouts that I described above are closely related to those that march off your bank card when you use a 24-hour teller. However, unlike the bank machine that coughs up money when you need it, a MIDI network should be able to carry a great deal of information, some with very high accuracy, but all of it so fast that the delay is imperceptible. Under some conditions the delay in transferring information may become audible. We'll have more to say about this below, when we discuss some specific MIDI implementations.

MIDI In The Marketplace

AS OF THE DATE OF this writing, the finished version of the MIDI specification is barely four months old. Only a few manufacturers are making MIDI-equipped instruments, and they, of course, began designing their MIDI interfaces even before the specification was complete. Most manufacturers who plan to implement MIDI in their instruments are testing the waters of the marketplace with instrument designs that they have already developed, to which they have added MIDIs. In these instruments, some functions may not be accessible to the MIDI, while others may be accessible through 'buried codes' entered by pressing unlikely combinations of panel switches. Dave Smith refers to this as the 'first level of MIDI.' "This will be a wait-and-see period. We all want to see how these instruments talk to each other. The June NAMM show will be the first time that many of the manufacturers will have an opportunity to connect their MIDI-equipped instruments into a MIDI network," Dave told me.

In preparing this article, I talked to representatives of most of the electronic musical instrument manufacturers. I asked them how they viewed MIDI itself, what their plans were for incorporating MIDI into their products, and whether or not they would be introducing MIDI-equipped products at the NAMM show this month. The tone of their answers ranged from forceful (when I talked to the head honchos of the smaller manufacturers) to circumspect or downright evasive (when I talked to local representatives of some of the larger manufacturers). On the basis of their answers, I divided the manufacturers into three categories: (a) those who now have, or are about to introduce, MIDI products, (b) those who will probably not show MIDI products in June, but who are actively working on MIDI-equipped designs, and (c) those who have no firm plans to implement MIDI in forthcoming products. Here is what I learned:

Roland, Sequential Circuits, and Yamaha will be showing several MIDI-equipped products. Roland's roster of MIDI instruments includes their JX-3P and JP-6 polyphonic synthesizers; the HP-300 and HF-400 velocity-sensitive electronic pianos; a 5,000-note sequencer for the pianos, which will record and play back key velocity, pitch-bend, patch change, and pedal status; and a new rhythm unit that will be capable of starting and stopping external sequencers and event generators through the MIDI. In addition, Roland is offering MIDI retrofits to their Juno-60 and JP-8 synthesizers. The retrofits will plug into the JP-8 and Juno-60 computer ports, and will provide access to key and patch change information.

Sequential Circuits has equipped their Prophet-5, Prophet-10, Prophet-600, and T8 with MIDI interfaces. Of particular interest is the fact that the T8 keyboard is velocity- and pressure-sensitive, and complete keyboard information can be transferred through MIDI to, for instance, another T8. Sequential Circuits is also developing a MIDI interface card to plug into a Commodore 64 computer, which they plan to show in June.

Yamaha is showing their DX7 and DX9, two new polyphonic synthesizers with MIDI. The instruments employ Yamaha's FM technology, and are therefore completely digital. Yamaha has also developed MIDI-oriented software for the Apple II computer, which they will show at NAMM.

Digital Keyboards, Moog, and Octave-Plateau are each showing a previously-introduced instrument which they have equipped with a MIDI. Digital Keyboards' Synergy will be shown with a universal interface box that has three digital data ports — two standard computer interfaces (RS-232 and IEEE 488) and a MIDI. DK's Charlie Bright told me that the interface box enables the entire keyboard and digital oscillators of the Synergy to be efficiently controlled by an external computer, thereby enabling the Synergy to perform as a full-blown computer music system. The Memorymoog is equipped with a new polyphonic-sequencer-plus-MIDI package which mounts inside the instrument and is controlled from the LFO section of the Memorymoog front panel. The package will also be available as a retrofit. Octave-Plateau is equipping their Voyetra-8 with MIDI. In addition, they will be showing a peripheral-board-plus-software package for the Apple II that will provide MIDI input and output, store voice settings on disk, and implement a 16-track sequencer.

Among manufacturers who are planning to introduce MIDI products after the NAMM show are Crumar, Korg, Linn, PAIA, and Passport Designs. The Crumar Spirit lead synthesizer, already equipped with a computer interface to its keyboard, will have a MIDI input that will be able to 'take over' the keyboard. Korg is, of course, actively working on new instruments. Their representative told me that Korg is "committed to MIDI," and that "all new synthesizer-oriented instruments will be MIDI-equipped." Linn is currently working on MIDIfying their drum machine. In a few months, PAIA will introduce a combination MIDI-SMPTE interface card that will plug into a Commodore VIC 20 computer. Passport is devoting much of its effort to developing MIDI-oriented software for sale through other equipment manufacturers.

Oberheim and Rhodes are continuing to develop their own proprietary parallel interfaces for their synthesizer equipment. Representatives of both companies told me that they consider MIDI to be fine for undemanding applications, especially interfacing simple electronic keyboards. For getting the most out of a Rhodes Chroma or an Oberheim OB-8, however, MIDI slows down data transmission and taxes the host microprocessor. Marcus Ryle, Oberheim's chief engineer, illustrated his point this way: "With MIDI, you need 320 microseconds to transmit one byte of data. The information for one key depression takes three bytes. If key pressure is being transmitted, that's another three bytes per key pressure update. Updating pitch-bend and panel controls takes at least three bytes each per update. So you can see that, with complex, fast-moving music, you could easily slip behind many milliseconds. And this is just the delay in MIDI transmission. The transmitting microprocessor has to put all the information in order, and the receiving microprocessor has to unravel it all. Now I admit that we're talking about some pretty complex, fast-moving music. But our experience has been that this is what our customers are interested in doing. There is a rule of thumb that musicians can't detect a delay of less than ten milliseconds. But we try very hard to minimize the total delay of information flow in our instruments. We keep the total delay from keyboard to onset of tone down to seven milliseconds. Musicians say they like the way our keyboard feels. We use the same keyboard mechanisms as everybody else. What musicians mean is that they like the speed with which our keyboards react! We don't want to give up that edge. That's why we're sticking with our parallel interface, which transfers data faster and doesn't tax the microprocessors as much as a serial interface.

"Of course," Ryle continued, "if demand for MIDI continues to grow, we would consider adding it to our new models. However, we would still retain the parallel interface which we now use."

Syntauri is also adopting a wait-and-see position. Their Alpha Syntauri system software can easily be modified and expanded to drive a MIDI peripheral card, should the demand arise.

Little immediate interest in MIDI exists among manufacturers of modular and experimental equipment. Don Buchla told me that he has been using the standard computer interfaces for many years and, for his work, he feels that they are more versatile and less limiting than MIDI. E-mu is currently evaluating the technical performance of MIDI for use on their Drumulator. However, they have no plans to implement the interface at the present time. Serge has an open mind, but sees no need to incorporate MIDI into his modular line just now.

Is There A MIDI In Your Future?

MUSICIANS' EXPERIENCE with MIDI instruments and networks will tell a lot in the near future. Equipment manufacturers will be watching closely as musicians discover MIDI's strong and weak points. The MIDI spec itself will undoubtedly be honed to remove as-yet-unseen rough edges. In addition, musicians will discover ways of using the interface to minimize the shortcomings, especially the inherent time delay. For instance, as Dave Smith points out, "The star network is much less demanding on MIDI capability than the chain network. This is because information for only one instrument goes through an interconnection in the star network. Therefore, there is less data, you don't need channel identification bytes, and the link to the master controller is direct."

An especially attractive aspect of MIDI is that there is very little hardware associated with the interface. A complete MIDI interface adds $25 or so to the list price of an instrument that already incorporates a microprocessor. Furthermore, future specification updates are not likely to involve hardware changes, so that, hardware-wise, the 1983 MIDI will probably not go out of date for a good long time. Software changes in microprocessor-based instruments are usually accomplished by changing the ROM (Read Only Memory) that contains the instrument's operating system. It's a modification that can easily be made in the field.

How about the effect of a standard interface on electronic musical instrument development? If MIDI (or any other interface, for that matter) evolves into a truly universal musical instrument standard, I believe it will mean a dramatic reduction in the size of the typical keyboard stack. The keyboard performer of the future will buy a beautifully-crafted, touch-sensitive keyboard controller or two (which may be free-standing like a single electronic piano, or hand-held like a guitar), a master programmer full of 'friendly' programs that are called up with good-feeling switches and controls, and a selection of voice generators that are rack-mounted and placed out of sight. It will no longer be necessary to combine keyboard, control panel, and voice circuitry in one clumsy, heavy case. For studio work, the musician will hook up his personal computer with hard disk information storage, MIDI, and interactive screen, and 'write' his music as fast as he can move his hands. And music students across the land will plug into computer-aided keyboard instruction, and perhaps even indulge in ensemble playing over long-distance MIDI networks.

We're closer to this than you think! ■

WHAT IS MIDI?

by Stanley Jungleib, Sequential Circuits, Inc.

The Musical Instrument Digital Interface (MIDI) is a hardware and software system specification which enables manufacturers to design electronic musical instruments that are compatible. MIDI offers the musician two important benefits. First, in being made compatible with forseeable microcomputer technology, the useful lifetime of the musician's equipment is greatly multiplied. As MIDI-compatible equipment is introduced, players will be able to choose keyboards, sequencers, and rhythm units from a variety of manufacturers with confidence that the units will work together in one programmable system.

The second main benefit lies in the actual use of the (home) computer as a musical tool. More than anything else, the advent of the home computer has forced music manufacturers to address the issue of compatibility. For example, the keyboard interface to the computer terminal offers these possibilities:

> Synthesizers can be easily connected to a "master" sequencer computer, allowing entire compositions, consisting of monophonic and polyphonic sequences and rhythm, to be played at one touch.
>
> The computer terminal can be used for composing, sequence creation and editing.
>
> Graphic-quality printers can print the "hardcopy" manuscript of an improvisation or composition.
>
> Video synthesis can be integrated with music synthesis.
>
> Parts of musical education can be automated, e. g. learning to read music, scale recognition, and ear training.

MIDI will make musical computing more affordable. For example, we are presently demonstrating how a $200 home computer system can sequence our synthesizers.

MIDI has arisen as a cooperative effort among music manufacturers who first met to discuss the matter at the January, 1982 Anaheim NAMM show. The MIDI specification which resulted from these discussions neither possesses nor claims any authority over equipment design. Rather, it is an informal agreement on interface circuitry and the "grammar" of a non-proprietary language which can carry meaningful information between instruments.

Physically, MIDI appears as two or three jacks on the instrument (IN, OUT, and "THRU"). To simplify cabling between instruments, the interface is serial. It operates at 31.25 kBaud (thousand-bits-per-second), asynchronous. This is considered a high speed for serial operation--in comparison to the typical RS-232 maximum of 19.2 kBaud--and was chosen to prevent objectionable delays between equipment.

MIDI does not transcend equipment limitations or differences. The total control features available still depend on the design of each piece of equipment. For example, specific programmed sounds can't be transferred directly between different models of synthesizers because of inherent design differences, but keyboard information and program selections can be communicated.

In December of 1982, SCI began shipping the Prophet-600, the first commerically available instrument to include the MIDI. MIDI will also be available on the forthcoming Prophet-T8. Modification kits for retrofitting MIDI to the Prophet-5 (Rev 3 series) and the Prophet-10 will soon be available.

SEQUENTIAL CIRCUITS, INC. MIDI SEQUENCER

Announcing Sequential Circuits' Sequencer/Drum Interface Cartridge! This cartridge allows you to interface the inexpensive Commodore-64 computer with the Prophet-600 or Prophet-T8*, creating a powerful new music system which features:

* Synchronization with most drum machines (Linn, Oberheim, Drumulator, Roland).
* Expanded sequencer memory; up to **6000 notes.**
* Up to 9 sequences storable, each with several tracks **(overdub).**
* Auto-correction of the sequence played.
* Transpose and use of pitch-bend and modulation wheels (also storable).
* Save your sequences on cassette or disk.

All you need is an inexpensive Commodore-64 computer (with datasette or disk drive to save sequences), two MIDI cables, and the SCI interface cartridge. A TV monitor is not required. For further information, or to order, please contact Sequential Circuits Inc., 3051 N. First St., San Jose CA 95134. (408) 946-5240. Suggested retail price for the cartridge is $195.00. Two 6' MIDI cables are $28.00.

*Also interfaceable with MIDI equipped Prophet-5's and Prophet-10's.