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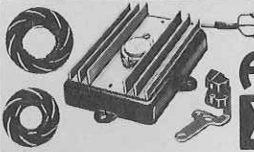

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CIRCLE 7 ON FREE INFORMATION CARD

computer corner

DAVID G. LARSEN, JONATHON A. TITUS and PETER R. RONY*

THIS MONTH'S COLUMN WILL FOCUS UPON THE concept of an interrupt. When used in the context of a computer, an *interrupt* can be defined as the suspension of normal program execution in order to handle a sudden request for *service,* i.e., assistance by the computer. At the completion of interrupt service, the computer resumes the interrupted program from the point where it was interrupted.[1] This specific interrupt use is consistent with the general meaning of the term: to stop a process in such a way that it can be resumed.

A given computer will typically communicate with a variety of external I/O devices. If it is a minicomputer, it may communicate with a teletype or alpha-numeric keyboard, a CRT display, a printer, a floppy disk, and perhaps one or more laboratory instruments. If it is a microcomputer, it may communicate with smaller devices—motors, solid-state relays, pushbutton switches, display lights, etc.—within a larger machine or instrument. When used as a replacement for discrete logic devices in a complex digital circuit, a microcomputer may communicate with other TTL integrated circuits such as latches, flip-flops, and three-state buffers.

When communicating with external I/O devices[2], microcomputers can operate in two general modes, *polled* and *interrupt.* Polling is the periodic interrogation of each I/O device that shares a communications link to the microcomputer to determine whether it requires servicing. A microcomputer sends a poll that has the effect of asking the selected device, "Do you have anything to transmit?", "Are you ready to receive data?", and similar questions. When a microcomputer services a polled device, it simply exchanges digital information with the device in a manner that is prescribed by software in a subroutine called a *software driver.*

In polled operation, the microcomputer sequences through the devices tied to the

continued on page 18

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*Mr. Titus is president of Tychon, Inc., a microcomputer consulting firm in Blacksburg, Virginia. Dr. Rony, Department of Chemical Engineering, and Mr. Larsen, Department of Chemistry, are with the Virginia Polytechnic Institute & State University.

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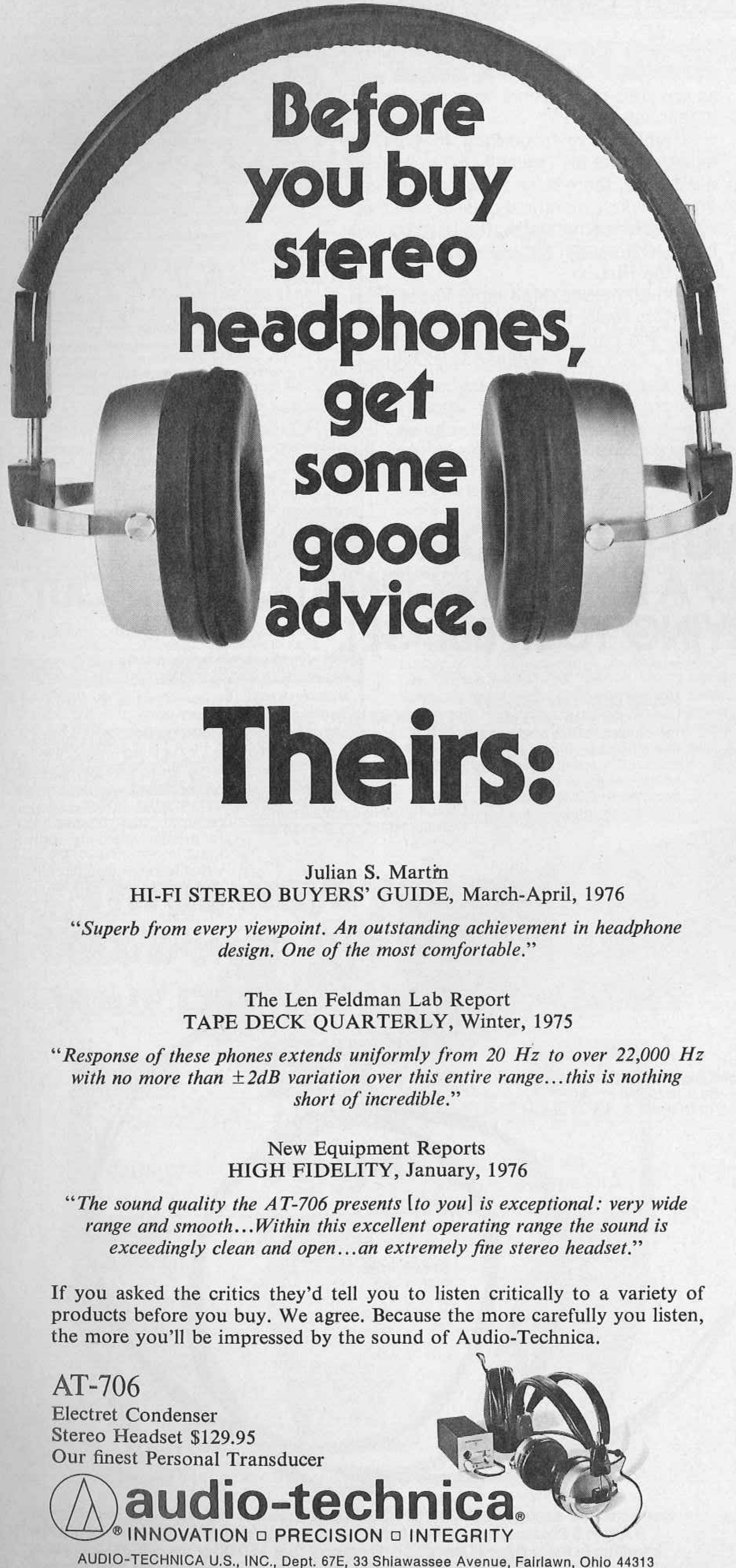

COMPUTER CORNER

continued from page 16

microcomputer looking for individual devices that need servicing. When it finds a device that requires service, it stops sequencing, calls a software driver, and services the device. Once it is finished, the microcomputer continues checking the devices. Polled operation is most useful with relatively slow devices that do not require frequent service, do not require attention from the microcomputer for excessive periods of time, and can wait to be serviced. Advantage is taken of the difference in speed of operations in the microcomputer and operations in the I/O device. Most common I/O devices are much slower than microcomputers. For example, in 100 ms (teletypewriter response time) an 8080A-based microcomputer can execute approximately 20,000 instructions when operated at a clock rate of 2 MHz. Although a microcomputer may give one the impression that it is doing several things simultaneously, this is only an illusion since it can manipulate data much faster than most I/O devices can respond to changes in data. *A single computer can perform only one task at a time.*

In interrupt operation, the microcomputer juggles the demands of the external I/O devices. There is a distinction between slow devices that require infrequent servicing and high-speed devices that demand the attention of the microcomputer for most of the time. The most appropriate description for interrupt operated systems is that they are *asynchronous,* i.e., they lack a common synchronizing signal and therefore give rise to generally unexpected or unpredictable program execution within the microcomputer. An *asynchronous device* is a device in which the speed of operation is not related to any frequency in the system to which it is connected.[3] The use of asynchronous devices is the rule rather than the exception.

There can exist *priority* in interrupt operation; all I/O devices can have an order of importance so that some devices take precedence over others. In contrast, there is usually no priority in polled operation; once a device is serviced, it waits its turn until all other devices are sequenced and, if necessary, also serviced. The time between the interrupt request by a device and the first instruction byte of the software that services it is known as the *interrupt response time.* For a high-speed device that has high priority, the response time can be very short—less than a millisecond. For a low-speed device that has low priority, the response time is variable since it depends upon the demands placed upon the microcomputer by all higher priority devices.

Interrupt Techniques

Three commonly used microcomputer interrupt techniques are the *single-line interrupt,* the *multilevel interrupt,* and the *vectored interrupt* (Fig. 1). In the single-line interrupt technique, multiple devices must be connected via an OR gate to a single interrupt line. Once an interrupt signal is received, all of the interrupt devices are polled to determine which one caused the interrupt. It is possible to assign software priorities to the various inerrupting devices, so that the first device polled that needs service is the one that receives the attention of the microcom-

continued on page 20

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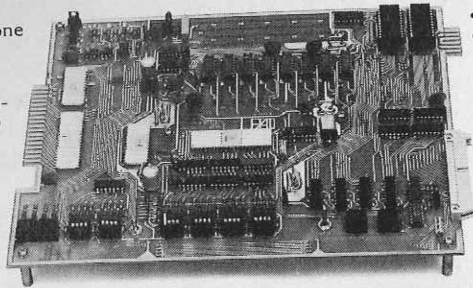

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continued from page 18

puter. A common term used for that part of a program that polls interrupt devices is *flag checking routine*. We shall discuss the concept of a flag in a subsequent column. At the moment, consider a flag to be a single-bit memory that indicates when an operation has been completed or when a condition has been attained.

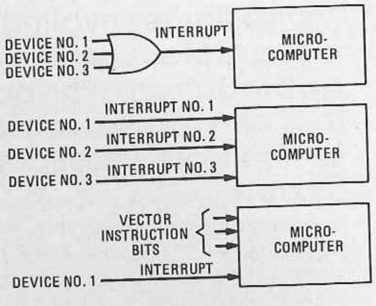

FIG. 1

In the multilevel interrupt technique, there exists several interrupt lines to the microcomputer, each line being tied to a separate I/O device flag. The microcomputer does not need to poll the devices to determine which one caused the interrupt. This is done internally within the microprocessor. Depending upon the nature of the microprocessor, this can be a very fast interrupt technique, but it is somewhat difficult to expand.

A vectored interrupt causes a direct branch

continued on page 22

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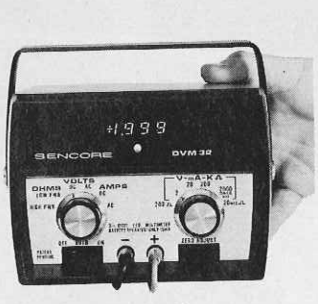

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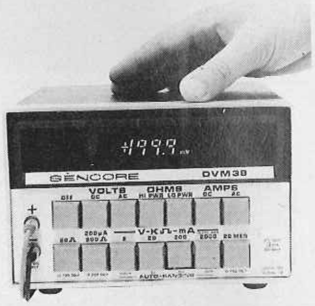

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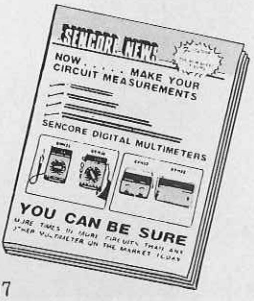

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continued from page 20

by the microcomputer to that part of the program that services the interrupt. This interrupt technique requires external IC's to supply the memory address of the *interrupt service routine* as well as to set the priority. With the 8080A microprocessor eight different service routine addresses can be readily specified, although one of these addresses coincides with the reset address for the microprocessor, location zero. If you are interested in vectored interrupts, we encourage you consider the Intel 8259 programmable interrupt controller, which became available commercially in July, 1976.

The use of interrupts should be considered very carefully. More complicated software is invariably required. For example, you will generally have to save the status of the microprocessor IC at the time that the interrupt occurred. This means placing the contents of the accumulator, the flags, and the registers into a specified region of memory where they can be retrieved at a later time, after the interrupting device has been serviced. Pay attention to priorities. Make certain that devices that require high priority and need immediate servicing are given the highest priority. Other devices, such as teletypes, should be low priority. Also, if you attempt to do too much with an interrupt system, you might find that your microcomputer becomes "interrupt bound," which means that the microcomputer is only working on interrupt tasks and is not working on the main task, which it should be doing while only infrequently servicing interrupt requests.

To end this column, we would like to provide one example of an interrupt system. Assume that your microcomputer is performing mathematical computations on 7-bit ASCII numbers that are entered via a UART IC[4] that is connected to a Teletype operated at 110 Baud, or ten ASCII numbers per second. The exchange of data between the microcomputer and the UART can be performed in 20 to 30 microseconds, which leaves 99.97 ms left for the microcomputer to do other things. With the Intel floating-point package, for example, each floating-point multiplication or division can be performed in 2 to 5 ms with an 8080A-based microcomputer operating at 2 MHz. Sixteen-bit binary multiplications and divisions can be performed even faster. Therefore, it is appropriate for you to consider that the main task of the microcomputer is to perform such computations, and that 0.05% to 0.10% of the time the microcomputer can service the interrupting teletype. **R-E**

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