MEMORY DATA STORAGE VIA DECTAPE*

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We have developed digital logic systems and computer software to use DECTape^R transports as data transfer devices for pulse-height analyzer memories. We have a mini-computer controlled system that transfers data between fifteen analyzer memories and DECTapes and other systems that transfer directly from one or two memories to transports.

In the first system a PDP8E^R is the controller that sends data either way between DECTape and up to fifteen multichannel analyzer memories. A user selects one, or more, analyzer memories from which data is to be transferred, then types instructions at the user's console. A spectrum is transferred to DECTape if it is non-zero and then is subtracted from the analyzer memory. For errorless transmission the resultant memory contents should be zero. This is checked by the user and can also be checked by the control computer. The tape transport and user's console interfaces are commercially available Omnibus^R interfaces. The Battelle developed analyzer interface consists of three elements: the Omnibus interface card, the analyzer I/O controller and the isolator and logic shifter.

A commercially available foundation module, that is similar to DEC's M1709 Omnibus interface module, provides buffered I/O data paths, IOT's and data transfer strobes and interrupt and skip functions for the analyzer I/O controller.

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The analyzer I/O controller accepts information from the 8e as instruction sets and as data to be forwarded to the MCAs. The instructions consist of MCA identification, notification to add or subtract from memory, address reset, a start pulse to initiate readin or readout from the MCA, and general enabling or disabling of the controller. The data, which are to be read back into the MCA (in ADD or SUBTRACT mode) as a performance or error check, is clocked into a register in the controller by digit, along with decade information. The controller then relays the information in serial form to the MCA. This is one link in the chain of data extraction from the MCA: read the data out, read it back in the subtract mode, and read it back out again while checking for zero values.

The controller accepts information from the MCA scaler registers by decade, controlled by an IOT pulse and the instruction register. On receipt of another IOT, the data are put on a bus from the controller to the 8e. Data from a status register are also put on the above bus. The status register asynchronously monitors several switch functions on, and overflows from, the MCA. A non-zero status register causes an interrupt, and a subsequent IOT strobes the data onto the bus and clears the register.

The controller is built with standard TTL and prototype cards on a chassis. All transmission lines are terminated to avoid ringing. This was necessary as the furthest MCA was over 100 feet from the controller. At each MCA is a small box containing optical isolators, a few ICS for decoding and a few

discrete components for level shifting to suit the older MCA memories in use. Some of the power required is taken from the MCA, the balance from a small local supply. Cabling is via Spectrastrip^R twisted pairs and connectors to the boxes in a daisy chain configuration. Unused slots are filled with dummy boxes.

PDP8E software provides user interaction to specify data collection, provides data collection control and performs a minimal amount of data processing. Software on our PDP15 reads the tapes from the PDP8E and translates them to a format which is compatible with the spectrum analysis and reporting programs that are routinely run on the PDP15. A 1200 baud CRT terminal with a keyboard allows the computer rapidly to type lengthy messages that describe the responses expected of the user. The user transmits his decisions, directives or identification data with a few key strokes. Having the computer type complete formats for the user's responses eliminates the need for extensive training in the use of the system. The user must specify the analyzer memory from which a spectrum will come, the tape transport on which it is to be written, and a unique identification code for the spectrum.

A/^{typical} spectrum consists of 4096, six-digit numbers which are transmitted between the analyzer memory and the computer, a digit at a time. Each digit is a 4 bit binary coded decimal (BCD) digit. Spectra are transferred between the computer and DECTape as 8192, 12-bit words, with three BCD digits in each word of a pair. A file on DECTape consists of a spectrum with its identification data. To transfer data to tape, the program

determines if there is a clear area on the user selected tape, then in a buffer constructs the words ^{binary} from the individual digits transferred from the analyzer memory. When the buffer is full, the program transfers a block of data to tape and checks each block for non-zero data. This continues until an entire spectrum and its identification are transferred. If at least one block of data was non-zero the program assumes valid data were transferred. Otherwise, the directory entry for the spectrum is cleared, and an error message is printed for the user. For transfers to analyzer from tape, each word from tape is sent as three individual/digits. After each spectrum transfer to tape, the program changes the analyzer memory mode to subtract and then transmits the same spectrum from tape back to the analyzer. This results in all zeros in the memory for errorless transmission. Another transfer from the analyzer memory to the computer is now made and each character is checked for zero. Checking for non-zero on the first transmission from the analyzer, then subtracting and checking for zero on the second analyzer to computer transfer gives us a quality check on the electronics each time data are transferred.

Data processing performed on the PDP8E is limited to performing quality assurance checks and generating tapes for the data processing center. Periodically, a standard spectra is collected in each of the analyzer memories and transferred to the PDP8E, which sums selected portions of the spectrum and displays them for user recording and analysis. This tells the user if the analyzer system is performing properly, or not. Other spectra are also processed in a manner similar to those used for quality assurance checks, but the sums are written to

tape for extensive processing at the data processing center. The center uses a PDP8I to convert from DECTape to industry standard magnetic tape for processing on a large batch processing system. For both these cases, the BCD coded numbers are converted to floating point representation in the computer and are written this way on DECTape.

Other DECTape recording systems use a hard-wired controller to transfer data only one way from the analyzer memory to the tape. The user readies the tape and then initiates a fixed number of consecutive data transfers before mounting a clean tape to repeat. Spectra are identified by their position on tape and a record kept by the user. Computer readable identification data are recorded when the tapes are initially processed on the PDP15 laboratory computer.

The user initiates a transfer by manipulating switches on the analyzer memory to generate a transfer signal to the controller. The controller starts the tape moving and then transfers the first data word after the tape is up to speed. After each 24 bit word from the memory is transferred, the controller sends a signal to the memory to cause it to supply the next data word. The controller continues to request data from the memory and transfer it to DECTape until 4096 analyzer data words have been transferred. After the last transfer to tape, the controller turns off the tape drive motors and waits for the next transfer request. Timing signals from the DECTape timing track allow the controller to write the data bytes on tape so that they can be read properly by the PDP15. After

mounting a fresh tape on the transport, the user resets the controller, so it will stop writing data after 15 spectra are recorded. He also manually advances the tape until he is sure the tape has advanced beyond the beginning of tape marks.

Fresh tapes are prepared by using a standard DECTape format program to generate timing marks. Then a program is used to zero the data tracks between the beginning and end of tape marks. Before writing the spectrum data onto this fresh tape, the controller writes a header consisting of a fixed number of consecutive ones. The PDP15 program for reading a tape scans the tape until a non-zero word is encountered, which will be some part of the header. The fixed number of bits in the header then allows the program to select the data words out of the byte stream from tape. A detailed explanation follows.

Spectrum data consisting of 4096 words, each 24 bits long (6-BCD digits), are transferred to the controller, which then writes consecutive 3-bit bytes on the tape. Each 24 bit word from the analyzer memory is written on tape as a group containing eight 3-bit bytes. These bytes for different words follow each other with no separation. Since the PDP15 reads data from DECTape as consecutive 18-bit words, a header consisting of 27 one bits are written at the beginning of the data stream in order to find the individual 24 bit words of the analyzer memory. The first non-zero word encountered on tape would not contain all ones from the header, in general. However, since the header has a fixed number of ones, the end of

the header can be found, which indicates the first bit in the 24 from the analyzer. It is a fairly simple matter to select consecutive 24-bit words out of the consecutive 18-bit words that are read from the tape by the PDP15. Once the original BCD number is retrieved from DEctape, it can be converted to a computer compatible integer or floating point value.

DEctape transports have proven reliable as computer peripherals and we expected the same reliability in the systems where we have applied them. Operating experience has shown negligible errors due to faults directly attributable to the tape and transports. While our current use of DEctape is not standard, the transport electronics and the computer peripheral instructions have proven adequate to meet our requirements for special purpose interfaces and programs.