Video cassette recorders for disk backup

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Easily interfaced VCRs can provide slow but reliable backup for 5¼- and 8-in. Winchesters

Video cassette recorders are being used for disk backup at nearly 1000 computer installations around the world, but their computer-related capabilities are still not generally known. Mass-market VCRs can store as much as as 100M bytes on a single video cassette, yielding a media cost of 12¢ per megabyte and an equipment cost of 50¢ per megabyte, both equal to or better than corresponding costs for other backup devices, including streaming cartridge-tape drives (MMS, August, 1982, p. 213). VCRs have serious limitations as well. They are bigger and heavier than diskette, Philips cassette and tape-cartridge drives and, more importantly, can take hours to save or restore a complete video cassette's worth of data—with all users denied disk access while backup is in progress. Despite these limitations, Alpha Micro Systems has combined video interfacing, redundant recording and special software to create VCR disk-backup systems that are practical and reliable for many applications.

The video connection

To the host computer, the VCR subsystem appears to be a comparatively low-performance but high-capacity disk. To the VCR, the host computer appears to be a TV camera that is generating a standard black-and-white video signal—including the usual horizontal and vertical synchronization signals (Fig. 1). The fact that a digital data stream is being reliably recorded in essentially analog form separates the VCR backup system from all other magnetic-tape applications.

The backup-and-restore data path between disk and cassette includes the host computer. During backup, selected files are read from disk stored in computer memory and transferred to the VCR at a rate that will sustain continuous "streaming" of the video tape. The process is reversed during a restore operation.

To achieve maximum data storage per cassette, data must be transferred to the VCR at a rate of 60K bytes per sec. (If data are not available for recording, the video tape continues to stream, but without recording any data.) Assuming a 6:1 copy ratio, this is equivalent to 10K bytes of new data per sec.

The same figures apply to a restore operation. In most cases, therefore, host and disk can stay comfortably ahead of the VCR. To make disk-host and host-controller transfers more efficient, however, the controller is equipped with a 4K-byte RAM and is designed to accept and transmit data at rates as high as 43K bytes per sec.

VCRs are designed to store a video signal that represents (by U.S. standards) a series of television "fields" with a repetition rate of 60 fields per sec. and approximately 240 visible raster lines within each field. Assuming that, even with marginal performance, a VCR can record at least 200 distinguishable pixels (bits) along each raster line, the potential capacity of a two-hour video cassette is more than 2G bytes—far beyond the backup requirements for most microcomputer applications.

The VCR subsystem sacrifices potential capacity and performance for reliability. Instead of storing 20 or more bytes along each 200-bit raster line, only 5 bytes (separated by start and stop bits) are recorded. Most importantly, however, stored data are organized into 512-byte blocks, and each block is recorded six or more times to ensure that at least one copy of each block is error free. Two cyclic redundancy check characters at the end of each block validate the record during the restore operation.

Reliable, redundant recording

The six-times redundancy results from extensive testing and field experience with dropouts and other types of media-related faults that can be encountered with consumer-grade cassette tape. These faults tend to be randomly distributed along the length of the tape and are rarely concentrated within the span of a few contiguous blocks. Statistical analysis indicates that with just one repetition of a block record, the frequency of "hard" errors (all copies in error) drops below the equivalent figure for flexible disks. With three copies of each block, data integrity exceeds that of the Winchester itself. Doubling this number to six virtually eliminates any chance of a tape-fault error. Capacity of the tape is reduced to one-sixth its potential, but a single cassette still provides more than enough backup capacity for most applications.

This assumes that the tape has not been severely worn by repeated store-and-retrieve operations. To track this deterioration, common to all magnetic-tape media, the VCR controller monitors every read operation, counts the occurrence of "soft" CRC errors (when one of the copies is in error) and reports on demand the ratio between the total number of copies that have been read and the error count. A typical value for this soft-error "confidence test" is 300:1. When a cassette demonstrates a confidence-test value below 100:1, system software automatically sends a warning message to an operator.

The corrective action is to replace the worn cassette, but the user has other options. For added capacity, for example, the tape speed of the VCR may have been set at "long play" or "extended long play." A new backup operation with the VCR switched to a "standard" tape-speed setting can enhance the reliability by spreading the data and blocks further along the tape.

Fig. 1. The VCR-to-computer interface *is a plug-in controller board that combines controller functions with a signal interface. The host computer sees the VCR as a low-performance disk, and the VCR sees the host computer as a video camera.*

Another alternative is to increase the number of copies of each block. The user can select any number as high as 255—escalating the theoretical integrity of the data toward infinity (except for equipment failure or physical destruction of the video cassette). Tape-speed setting and number of copies can be traded to meet special system requirements. For example, the user can increase the capacity of cassettes by switching to a longer playing mode and maintain data integrity by using a part of the added capacity to store extra copies of each block. Controller firmware prevents the user from decreasing redundancy below the six-copy minimum to expand capacity.

During normal operations, the fact that extra copies of each block have been recorded is completely transparent to the host computer but gives the user added interfacing flexibility. Each recorded data block is prefaced by a sync byte and a 6-byte header containing a sequential identification number (Fig. 2). Only the first error-free copy containing the expected sequential number is transferred to the host and disk when the cassette is read. Preceding copies in error and all subsequent copies, with or without errors, are "discarded" by the controller's microprocessor. The CRC calculation that validates each block includes the header data to ensure that an incorrectly recorded identification number does not confuse the block count.

The controller's on-board RAM stores as many as seven unique data blocks (not copies) to buffer small mismatches between the data transfers and the rate at which data are being recorded or read. Larger differences can be accommodated by using extra copies of each block as "padding" to lower the rate at which "new" data are being written or read. In a "verify" restore operation, for example, the host reads and verifies blocks of data as they are stored on disk, significantly reducing the effective host-disk transfer rate.

Added padding is particularly important when data are backed up from one disk and restored on another, slower disk or are transferred to another system with an unknown disk. The number of copies, in this case, should reflect the worst-case condition. For reliability reasons, the same rule applies when cassette-stored data are to be read by another VCR, perhaps from a different manufacturer. A video cassette that is acceptable on one VCR may be marginally acceptable on another VCR with slightly different operating characteristics. Added redundancy usually compensates for

any increase in the soft-error rate that might occur.

VCRs in action

Backup operations are initiated by a single host-computer command. Arguments included in this command specify the source disk, destination VCR and all the disk files that are to be transferred. The disk-file list serves as a directory, or "table of contents," for the backup video cassette and is automatically recorded at the beginning of each cassette. Subsequently, the system can read and display the contents of the cassette. The directory lists the number of blocks of data occupied by each file, allowing users or application programs to access a file or a file record by instructing the VCR subsystem to advance to a specified block number before transferring the data to the host. Moreover, the header at the front of each block (Fig. 2) also includes a "type" identificaton byte so that, by appropriate commands, the controller can be directed to search for and restore not only a selected group of files, but also files of a specific type. The controller reads intervening files and blocks of data but does not transfer them to the host. Data are transmitted to the host only when the desired files or blocks have been reached.

VCR tapes can also include warm-start data, allowing the VCR to be used as a system booting device. The controller (Fig. 1) includes a PROM containing the VCR controller firmware that can include an optional cold-start boot. In addition, standard system software permits the user to define a warm-start boot and store it on cassette tape immediately after the file directory.

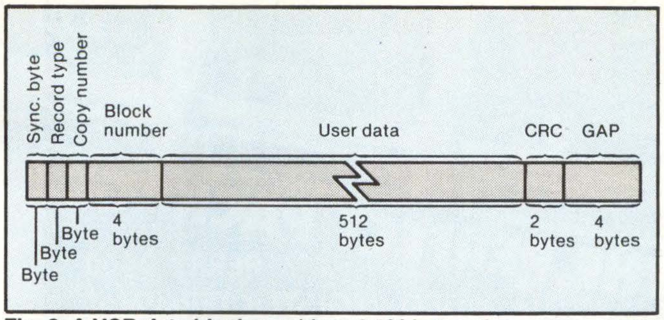
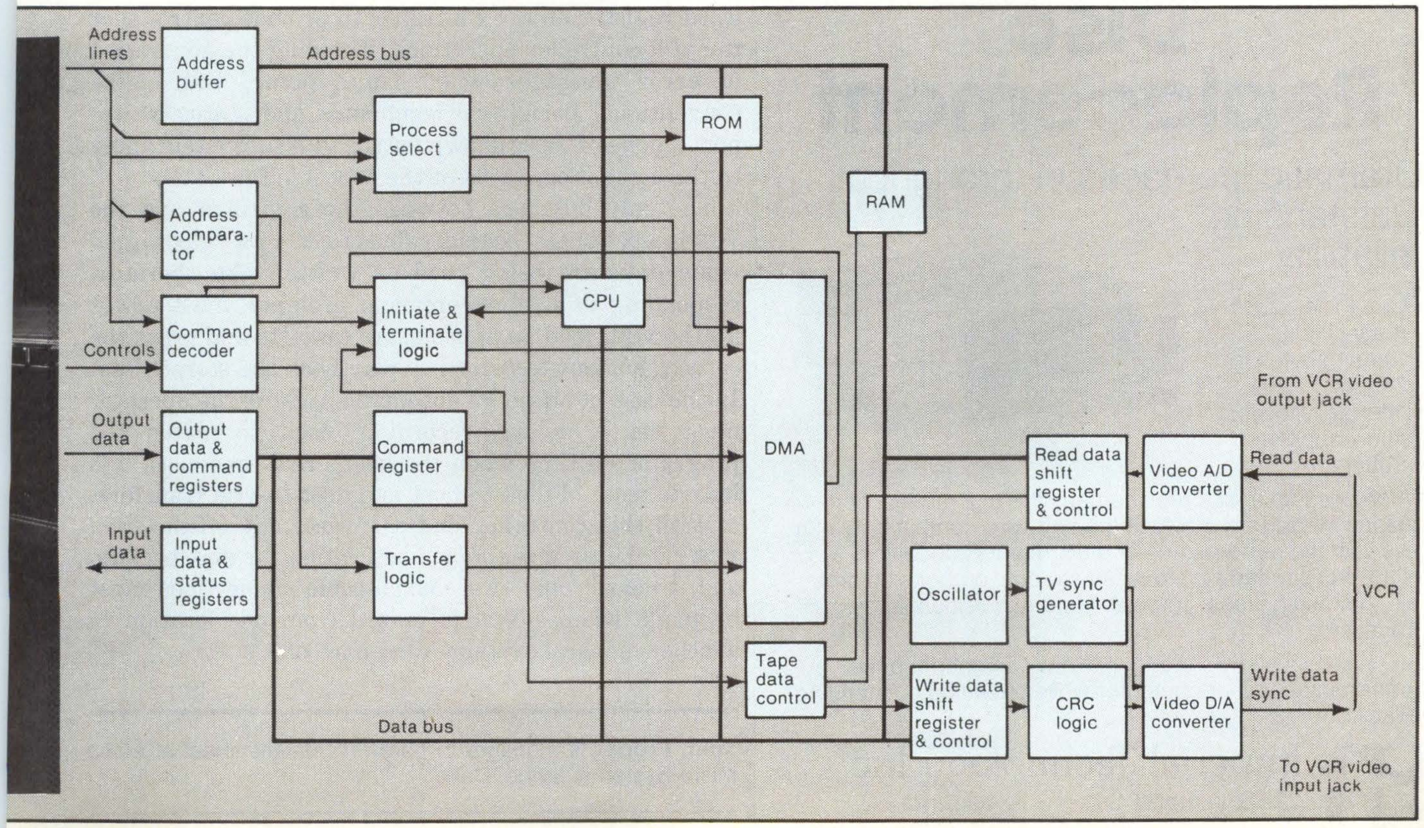


Fig. 2. A VCR data block *combines 0.5M bytes of user data with 13 bytes of synchronization, address and error-correction information. Data blocks are recorded repeatedly in sequence for reliability through redundancy. During tape read operations, only the first error-free copy containing the expected block number is read. All subsequent copies are ignored.*

To assure near-absolute integrity of this boot program, all of its data blocks are copied 16 times—independent of the number of copies the user specifies for the balance of data on the tape.

The user controls the VCR with Alpha Micro-supplied subroutines, including:

- CRT610: checks and verifies the quality of video cassettes for use as disk file backup media and optionally creates a warm-boot monitor cassette using a warm-boot monitor file built by WRMGEN.
- SLEEPR: allows automatic file backup using a VCR that can be programmed to record at a specified time.
- VCRDIR: displays a list of the files on a video tape cassette and can create a disk file containing the video tape directory.
- VCRRES: writes files from video cassette tape to disk and allows a user to restore file-oriented disk



backup from video cassette to disk.

- VCRSAV: writes copies of disk files to video tape cassettes.
- WRMGEN: creates a warm-boot monitor file on disk for transfer to a video tape cassette.

The six acronyms are part of the AMOS system-command language and can be entered at the keyboard in an interactive mode with prompts and help responses or incorporated into an application program.

The VCR system commands facilitate backing up and restoring data. Special training and programming techniques are not required. The characteristic file structures of AMOS are preserved intact, independent of whether the data are on disk, in host-computer memory or on video-cassette tape. The VCR controller responds to 17 single-byte commands that are used by the operating-system device driver to transfer data to and from the video cassete. These include: read tape record, read tape continuous, write tape record, write tape continuous, reset controller and parameters, read the user RAM pointer, load the user RAM pointer, read RAM indirectly via user RAM pointer, write RAM indirectly via user RAM pointer, execute RAM indirectly via user RAM pointer, turn off buffered tape-read flag, turn on buffered tape-read flag, read RAM current buffer - start at header area, read RAM current buffer - start at data area, read RAM parameters, write RAM parameters and abort read/write tape operation. The device-driver VCR commands interact with information stored in a status-word register on the controller to provide control over the VCR controller operations, including the generation of error messages when faults occur. But unlike conventional peripheral commands and status-bit reports, none of those shown for the VCR subsystem apply to the control or status of the VCR itself.

The only interface between the controller and the VCR is a set of two coaxial cables to carry a video signal when data are being read or written. An operator, responding to system-command prompts, must power up the VCR, load an appropriate cassette and press the correct buttons to record or play back the stored data. In the case of off-hours automatic backup, the operator must set a delayed-recording clock to match the programmed time when the host's real-time clock will initiate a set of disk-to-host and host-to-VCR transfers.

With this controller and software, any off-the-shelf VCR can be used without modification for disk backup, and, because only two coaxial-cable connections must be made when a VCR is moved from one location to another, several systems can share one VCR. □

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