14278

BUILD A CHANCE/STRATEGY ELECTRONICS GAME

Popular Electronics®

WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE NOVEMBER 1976/$1.25

Build a "Westminster Chime" Digital Clock

Checking the Sun for Home Propagation Forecasts

How to Protect Power Supplies From Damage

The 35-mm Slide Syncer

AN AUDIO-VISUAL PROGRAMMER TO BUILD

TEST REPORTS:

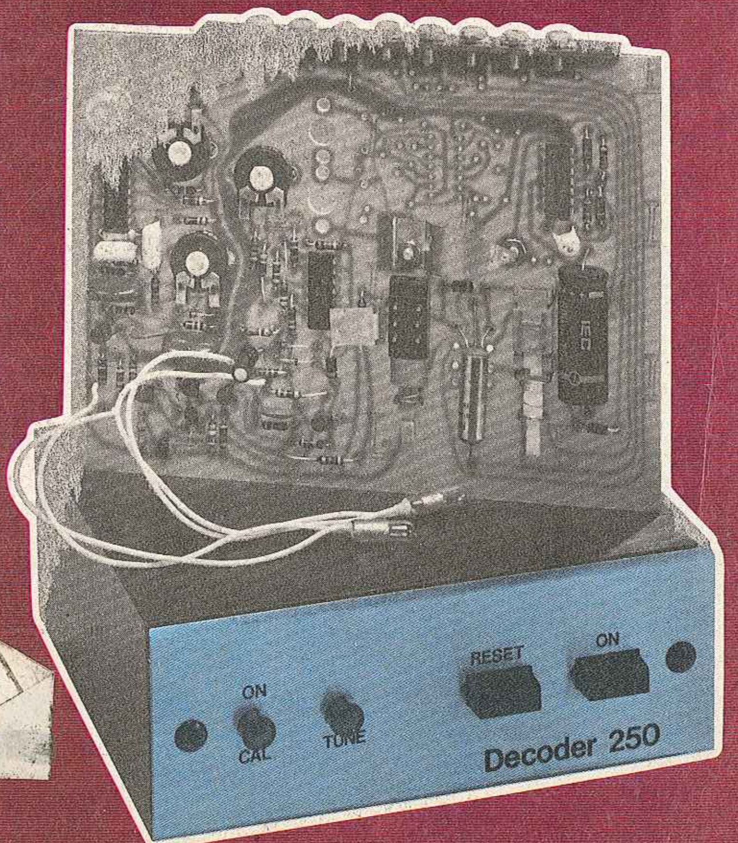
Spectro-Acoustics Stereo Equalizer

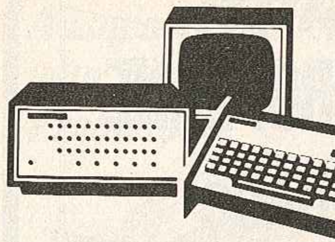
Pickering Stere[...]

Siltronix [...] Mobi[...]

A CB/Ham Selective Calling Project

- CODED TONE ACTIVATES RECEIVER
- SILENT CHANNEL UNTIL WANTED





Computer Bits

By Hal Chamberlin

MASS-STORAGE SYSTEMS

MANY interesting and useful applications of hobbyist computers require a program-controlled mass-storage device. Although a simple audio-cassette interface can be used, there are other more automatic, practical storage systems.

Applications Needing Mass Storage. Home accounting is a computer application that is often mentioned as needing a mass storage. One would expect a double-entry bookkeeping method to be used here, with all incomes and expenditures divided into a number of accounts according to the nature of the transaction. Once a week, or as needed, new transactions would be added to the appropriate accounts. Ideally, a verbal description of each transaction would be retained with the account record as well as the amount and date. Monthly, or as required, the system could be instructed to compute and print a personal financial statement. Also, if the accounts were set up properly, preparing a tax return could be a relatively simple task. The amount of mass storage needed, however, can become substantial. Assuming a moderately detailed system of 30 accounts and an average of 25 transactions per account per year, yields a total of 2250 transactions to save for the 3-year record-holding period required by the IRS. Allowing 30 bytes for a description, 4 bytes for a date and 4 bytes for an amount, gives a total of 85k bytes required for the application.

Learning games are an exciting application that benefit from mass storage. A learning approach to implementing complex game-playing programs such as checkers is often easier and can give better results than a direct approach. Such a program, when first run, would only be cognizant of the game rules. As it plays human opponents, files of data concerning fatal mistakes made by the program and winning tactics employed by the opponent would be accumulated. Eventually the program would acquire a skill level just below that of the best opponent and would not suffer from "stupid" mistakes. Additionally, intermediate data files at various skill levels may be retained. Such files may get rather large. They are also subject to frequent change as the program learns. High-speed access to the data is helpful in keeping the game moving along.

Text editing for letters, reports, and other documents is another mass-storage-oriented application. The editing process may involve frequent changes, insertions, and deletions of blocks of text in the document. Also, it may be desirable to move a block of text from one portion of a document to another. The amount of storage needed varies with the type of document. A thesis may require 300k bytes, an article 30k and a letter 3k. Large insertions in the middle of a document may cause problems with certain types of mass storage.

Mass-Storage Terminology. Over the years, many terms have been developed to describe mass-storage systems. Perhaps most fundamental is the *on-line storage capacity* of a system. On-line storage capacity is the amount of data that can be accessed automatically by the program without requiring human intervention to change tapes, etc.

On all mass-storage systems, data is organized into blocks called *records*. When a data transfer between the storage system and the computer is performed, an entire record must be transferred. Some systems utilize a fixed record size, which means that all records are of the same length. Most tape systems, however, allow a variable record size, which means that a record may be as short as one byte or as long as desired. Note that the use of short records may reduce the storage capacity substantially due to gaps between records.

The *transfer rate* of a system is a measure of how fast data can be read from, or written into, the storage media. Often this is qualified further by specifying a "burst" transfer rate and an "average" transfer rate. The burst rate is the actual speed during reading or writing. The average rate is measured for a long transfer of several thousand bytes. It is usually less than the burst rate because of the gaps between blocks of data or time spent searching for the next block of data.

In a *sequential access* storage system, all of the data is stored as one long string of records. The access mechanism (usually a magnetic head) can be located at any point in the string. In the simplest systems, only two operations are allowed; rewind (place the head at the beginning of the string); and read forward, starting at the current head position. Writing of new data is always done at the end of the string. More sophisticated sequential-access systems may allow reading backward and high-speed search in both directions. Some may even allow records in the middle of the string to be updated.

Data records in a *random-access* storage system are organized in a rectangular array consisting of a number of rows and columns. A particular record is read or written simply by giving its row and column numbers. The storage device goes directly to the requested location, usually without any searching. Individual records may be rewritten at will. Random-access storage systems almost always utilize fixed record lengths.

Tape Mass-Storage Systems. Tape, particularly in cassettes, is a popular, inexpensive mass-storage medium. The on-line storage capacity of a C60 cassette, for example, ranges from 50k bytes using the Computer Users Tape System or CUTS (see "Computer Bits," March, 1976) audio format (also known as Kansas City format) to approximately 600k bytes using the Digital Group's "group coded recording" digital format. Transfer rates range from about 25 bytes per second for standard audio to over 1000 bytes per second for high-performance digital recording. Most tape systems for hobbyist use allow variable-length records with perhaps a maximum allowable length.

Magnetic tape is inherently a sequential-access storage medium. Here, data records are strung out along the length of the tape with enough blank space between records to allow for starting and stopping the tape. Finding a desired record on the tape and reading it into the computer's memory is a fundamental operation. If the record's location is not known, about the best that can be done is to rewind the tape and start reading until the needed record is reached and read. This, of course, can take several minutes even on a high-performance digital cassette system. One possibility for speeding up is to maintain an "index record" at the beginning of the tape that contains the location of all of the other records on the tape. The program would keep the index in memory while that particular tape is loaded on the drive. Then, on a simple system, at least a decision between reading forward and rewinding and starting over can be made. On a system with read-backward capability, the average search time may be shortened further by reading backward when appropriate, rather than rewinding. A system with high-speed search allows records to be *counted* at two to ten times the normal tape speed in either direction. When the required number of records has been skipped, normal read speed is resumed and the desired record is read. Using the high-speed search feature allows average random-access times of less than 30 seconds on a 600k byte tape with one currently available cassette system.

All three applications described earlier required data records to be updated (read, modified, and rewritten) frequently. With a simple tape system the only possible method of updating is to make a copy of the "old" tape onto a "new" tape, changing the records to be updated during the copying. Besides requiring two tape drives, the process can be quite slow if individual, random updates are required, as in the game application. Some sophisticated systems will allow records to be updated in the middle of the tape provided the updated record length is the same as the original. One possibility, if records are expected to grow as in the accounting application, is to start with a long record padded with zeroes and then gradually replace the zeroes with new data as updates take place. Large insertions and deletions such as in the text-editing application are still best handled by the update/copy technique when using a tape mass-storage system.

Disk Mass-Storage Systems. A disk-based mass-storage system has several very desirable characteristics. On-line storage capacity ranges from about 300k bytes for a floppy-disk system to over 200M bytes for some high-performance commercial systems. The range on transfer rates is considerably less, being from 32k bytes per second for the floppy to about 1.5M bytes per second for large hard-surfaced disk systems.

Although most disk mass-storage systems are very expensive, floppy-disk systems are reasonable and are becoming much more numerous among hobbyist users. The components to build a floppy-disk system cost about $600 while complete kits list for around $1500. The disk itself is housed in a flexible plastic envelope measuring eight inches square and one-sixteenth-inch thick and costs seven to ten dollars each. Each disk holds over 300k bytes and can be inserted into or removed from the disk drive in a couple of seconds.

Unlike tape, mass-storage disks are random-access devices. The circular disk surface is divided into a number of concentric *tracks*. Each track is further subdivided into a number of *sectors*. This is equivalent to the rectangular array of records mentioned earlier. Each sector contains one data record which is fixed in size. To access a particular record, the magnetic head is first positioned to the correct track by moving it radially in or out. This is called *seeking*. Then the system waits for the proper sector to rotate under the head for reading. The amount of time necessary to do these operations varies but is relatively unaffected by where the data is on the disk. All disk systems allow individual sectors to be updated.

A floppy disk may have, for example, 77 tracks and 32 sectors on each track for a total of 2464 possible data records. Each record has 128 useful data bytes. Moving the head from one track to another takes about 10 milliseconds per track moved. At 360 rpm it takes 166 milliseconds for the disk to rotate one revolution. Thus the longest required time to find and read a record will be just under a second. The average time is less than half that figure. Since a search of the whole disk would take considerably longer than this, some kind of index is always maintained so that the exact track and sector numbers of the desired data are known.

A floppy-disk mass-storage system is nearly ideal for all three example applications. The accounting system, for example, can be set up so that each transaction would be stored on one sector. Thus three years of financial records may fit on one $7 floppy disk. In the game program, many random data accesses and updates can be performed in the time allowed for the computer to make its move. Even the large insertions and deletions required in the text-editing application are readily handled. With such quick random access to records, the inserted text may be stored in any unused positions on the disk. Deleted records are simply marked as unused and will later be overwritten. Sorting of records using a single disk drive is not only possible but is relatively easy. With a tape system, at least three drives and a number of update/copy operations are required to do sorting.

Error Handling. Unfortunately it is a fact of life that magnetic recording media can have defects and can be damaged by improper handling. The result of a defect is that data recorded over it is subject to error. Since alteration of even a single bit can be disasterous (such as a difference between $1081 and $9081 in the accounting application), methods must be employed to detect the presence of these errors and to allow recovery from them.

Errors can be detected in a number of ways. The most common employs a *checksum* byte at the end of a record. A checksum is simply the sum of all of the data bytes in the record with overflows ignored. If the sum of the data read back is the same as the checksum byte for the data written, then the data is assumed to have been read accurately.

To prevent writing over a bad spot on the media, the data is typically read back and compared immediately after it is written. If an error is detected, then the record is erased and rewritten further on or in another sector. ◈

More Hobbyist Clubs

Canada

Amateur Microprocessor Club of Kitchener—Waterloo, ℅ Reading Rm. Eng. II, Dept. Electrical Engineering, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1.

TRACE, Toronto Region Association of Computer Enthusiasts, Box 545, Streetville, Ontario, Canada L5M 2C1.

Connecticut

Southern New England Computer Society, 267 Willow St., New Haven, CT 06511.

Florida

Space Coast Microcomputer Club ℅ Ray O. Lockwood, 1825 Canal Ct., Merritt Island, FL 32952. (305) 452-2159.