COMPUTER USERS TAPE SYSTEM

The lack of standardization is the bane of many industries. For example, three basic four-channel audio systems (SQ, QS, and CD-4), instead of a universal system, have impeded progress in that field. The same holds true for computer hobbyists, where a host of methods for exchanging programs or data have been introduced, including the HiT system published in Popular Electronics, September 1975.

Rather than stifle this user-created “program explosion,” a group of hobby computer manufacturers and other interested parties (Popular Electronics, among them), met in Kansas City, MO, last November to explore standardization in general and hopefully to agree on a single method of recording data. There was general agreement that cassette tape represented the best route to go for a hobbyist computer-data exchange system. These tapes are low-cost and widely available, and cassette machines are owned by most people.

The use of inexpensive cassette recorders was not viewed as a serious limitation as long as the record/playback exchange method adopted allowed for certain inherent machine deficiencies. The two most common considerations with low-cost cassette machines are: (1) the automatic level control incorporated in some machines, and (2) variations in average speed, nominally 1½ inches/second. Both drawbacks could be easily overcome, it was decided.

Another important consideration in using low-cost cassette tapes is that some tapes would likely cause dropouts (momentary loss of signal) due to a lack of uniform distribution of oxide particles. At this time, the user would have to “certify” the best tape brand and model for him to use. There are also “data cassettes” certified by tape manufacturers. Prices are not too much higher than those for consumer premium tapes.

Cassette Data Recording Methods. Various methods have been used by computer enthusiasts and manufacturers to record data on audio cassette recorders. These fall into five categories: (1) simple tone burst, (2) pulse-width modulation such as used in the Popular Electronics HiT program, (3) frequency shift keying (FSK) as used in radio-teletypewriter or phone-line communications modems, (4) double-frequency pulse recording as used in most floppy disc systems, and (5) phase encoding as used in ANSI standard magnetic tape transports of all major computer manufacturers.

Most of these methods record data serially; that is, one bit after another. Serial recording requires a conversion from parallel to serial form (and vice versa) when used with a computer. Fortunately, most computers and terminals already have a standardized serial communications channel that transmits in a form called “non-return to zero” (NRZ), shown in Fig. 1A.

Tone-burst (or cw) recording may be the simplest way of recording data, where data “1” is the presence of a tone and data “0” the absence of a tone, as shown in Fig. 1B. Because this system is basically an amplitude-modulation scheme, and very susceptible to noise, reliability suffers above 150 bits per second.

Pulse-width modulation may be recorded in its pure form (Fig. 1C) or as a burst of tone with varying duration, as used in the HiT system (Fig. 1D). Both methods are self-synchronizing and are highly independent of speed and amplitude variations. However, in the original HiT proposal, data was recorded synchronously so that each data word had to follow the previous word immediately, thus making HiT impractical for use with stand-alone asynchronous terminals such as TV typewriters and teleprinters. In addition, “pure” pulse-width modulation is patented as a data recording method, which might be seen as a drawback by manufacturers.

Ordinary frequency shift keying (FSK), shown in Fig. 1E, is by far the most common method used to transmit data over phone lines and radio links. It would be a useful feature of a cassette recorder interface if it could transmit data over phone lines if it were a FSK Bell-103 compatible modem. However, while FSK is fairly insensitive to AM noise and level changes, it is susceptible to loss of data when overall frequency changes exceeding ±5% of the nominal value occur. The 5% frequency, or speed tolerance is not sufficient for reliable data storage on many cassette re-

**Fig. 1. Methods of recording data on cassette recorders.**

A. NRZ DATA
B. TONE BURST (CW)
C. PWM
D. HI T PWM
E. FSK
F. DOUBLE FREQ. (DFR)
G. BI-PHASE-L (PHASE ENCODING)
H. BI-PHASE-M (MANCHESTER)
J. CUTS
corders. In addition, FSK is more expensive to implement than many other methods.

Double-frequency recording (DFR), shown in Fig. 1F, is often used on disc memories at high data rates. When used on a cassette, however, it requires a relatively high bandwidth for a given data rate. This method is insensitive to speed variation since each bit is self-clocked, but it is only moderately free from problems created by noise and amplitude changes. DFR is, therefore, not as reliable as other methods at data rates higher than 500 bits/second, making future expansion and improvement difficult.

Phase encoding has many variants and has been in use in many different types of magnetic tape data systems for many years. The most common forms are Bi Phase-L, usually called “phase encoding,” and Bi Phase-M, often called “Manchester” code. Both methods are self-clocking and, at first glance, resemble simplified FSK. In fact, phase modulation does create a form of frequency modulation. All phase-encoded methods are independent of frequency changes over a wide range, and can be made highly resistant to AM noises and level shifts.

Bi Phase-L is shown in Fig. 1G. You can see that there is a transition in the middle of each bit cell and that the polarity of the transition determines whether the bit is a logic 1 or 0. Bi Phase-M, or Manchester, shown in Fig. 1H, has a transition at the beginning of each bit cell. Logical 1’s have another transition in the middle of the cell, whereas logical 0’s do not.

Manchester code is extremely easy to generate, decode, and synchronize, and is the basis for the CUTS (Computer Users Tape System) recording method proposed as an outgrowth of the meeting in Kansas City.

The CUTS method employs a variation of the Manchester code in which a

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**COMPARISON CHART**

<table>
<thead>
<tr>
<th></th>
<th>Level, Noise Tolerance</th>
<th>Frequency Speed Tolerance</th>
<th>Self clocking</th>
<th>Cost*</th>
<th>Future Upgrading**</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW (Fig. 1B)</td>
<td>Poor</td>
<td>Poor</td>
<td>No</td>
<td>Very Low</td>
<td>No</td>
<td>Susceptible to noise. Reliability suffers over 150 baud.</td>
</tr>
<tr>
<td>PWM (Fig. 1C)</td>
<td>Good</td>
<td>Very Good</td>
<td>Yes</td>
<td>Low</td>
<td>To 1500 Baud</td>
<td>Patented. Requires higher bandwidth than Bi-phase for same baud rate.</td>
</tr>
<tr>
<td>HITS (Fig. 1D)</td>
<td>Good</td>
<td>Very Good</td>
<td>Yes</td>
<td>Low</td>
<td>To 600 Baud</td>
<td>Requires higher bandwidth than CUTS for same baud rate (see PE, Sept. 1975).</td>
</tr>
<tr>
<td>FSK*** (Fig. 1E)</td>
<td>Very Good</td>
<td>Poor-Fair</td>
<td>No</td>
<td>Moderate</td>
<td>To 450 baud (with Bell 103 tones)</td>
<td>Can be transmitted over phone lines to any modem.</td>
</tr>
<tr>
<td>DFR (Fig. 1F)</td>
<td>Moderate</td>
<td>Good</td>
<td>Yes</td>
<td>Low to Moderate</td>
<td>To 800 Baud</td>
<td>See “Computer Hobbyist” Vol. 1, No. 5, 6, 1975.</td>
</tr>
<tr>
<td>Bi-Phase-L (Fig. 1G)</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Yes</td>
<td>Low to Moderate</td>
<td>To 1500 Baud</td>
<td>Proposed ANSI standard. Subject to phase inversion.</td>
</tr>
<tr>
<td>Bi-Phase-M (Fig. 1H)</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Yes</td>
<td>Low to Moderate</td>
<td>To 1500 Baud</td>
<td>Widely used. Easily decoded.</td>
</tr>
<tr>
<td>CUTS (Fig. 1J)</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Yes</td>
<td>Low</td>
<td>To 1200 Baud</td>
<td>Very easily decoded. Can be transmitted by phone to other CUTS units.</td>
</tr>
</tbody>
</table>

*Cost is estimated for devices which do not require a CPU for reading and writing. Cost may be quite low if CPU decodes mostly by software.
**Future upgrading implies minimal hardware modification at low cost.
***Especially Bell-103 compatible.
logical 1 consists of eight cycles of 2400 Hz, and a logical 0 is four cycles of 1200 Hz. A 4800-Hz clock is derived from the recorded data itself as the tapes are read, and is used to clock a UART (Universal Asynchronous Receiver Transmitter) which performs the serial/parallel and parallel/serial conversions necessary to interface with the computer's data bus. It is not necessary to use a UART. Also, in some simple applications, a less expensive circuit can be used.

The standard data rate is 300 bits/second, and can be expanded to 600 or even 1200 bits/second with slightly higher error rates. Each bit is self-synchronizing because every bit time frame starts with a positive transition and contains an even number of tone cycles. Each data character is resynchronized by a logic 0 start bit that precedes the data bits. Therefore, data can be transferred asynchronously from any computer, terminal or modem with a serial data channel, as long as the serial channel is set up for 300 bits/second, eight data bits, and two "stop" bits.

**Recording Method.** The following specifications were adopted with the goal of optimizing versatility, reliability, low cost, and future expandability.

*Mode:* asynchronous by character.

*Character Format:* 11 bits; one start bit (a 0); least significant data bit first (if less than 8 bits are used as with Baudot 5-level code, then all bits not specified by the code will be set to 1). The interval between characters, if any, will be 1's.

*Modulation Method:* 1's will be 8 cycles of 2400 Hz; 0's will be four cycles of 1200 Hz tones. Sine-wave signals are preferred, although not always necessary.

*Leader:* Five seconds of continuous 2400 Hz (all 1's) will precede any block of valid data. At least 30 seconds of

parallel and parallel/serial conversions guarantee an accurate 300 bits/second data rate. This type of conversion and reconversion effectively eliminates the possibility of cumulative speed errors when duplicating tapes, and makes for a cleaner and more precise signal whether reading or writing.

Based on observations made at the meeting, most manufacturers agreed to shelve their personal systems for the good of the industry, although some might still offer their systems, with CUTS made available as an alternative.

**More Hobbyist Clubs.** Here are additional computer hobbyist clubs reported to us:

- **California**
  - Bay Area Microprocessor Users Group, 4565 Black Ave., Pleasanton, CA 94566.
  - 29 Palms Area, Sgt. Wesley B. Isrigg, 74055 Casita Dr., 29 Palms, CA 92277 (address change).

- **Colorado**
  - Denver Amateur Computer Society, P.O. Box 6338, Denver, CO 80206.

- **Georgia**
  - Atlanta Area Microcomputer Hobbyist Club, Jim Dunion, Pres., 421 Ridgecrest Rd., Atlanta, GA 30307.

- **Illinois**
  - Computer Hobbyist Exchange, P.O. Box 36, Vernon Hills, IL 60061

- **New Jersey**
  - Amateur Computer Group of New Jersey, Union County Technical Institute, 1776 Rantin Road, Scotch Plains, NJ 07076

- **New York**
  - Long Island Computer Club, c/o Popular Electronics, One Park Ave., New York, NY 10016

- **Texas**