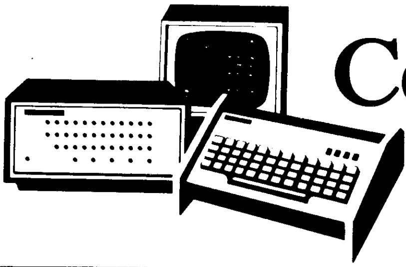

Computer Bits

By Robert M. Marsh

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 1⅞ 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 radioteletypewriter 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 as 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-

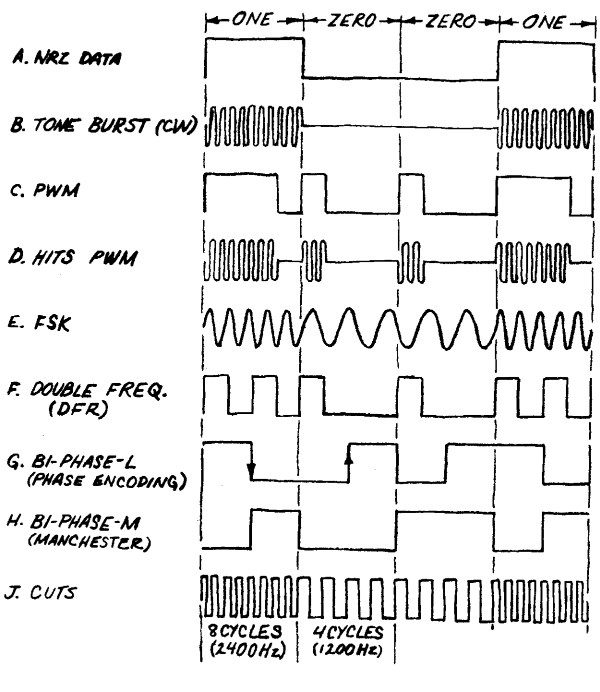

Fig. 1. Methods of recording data on cassette recorders.

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

COMPARISON CHART

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

*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.

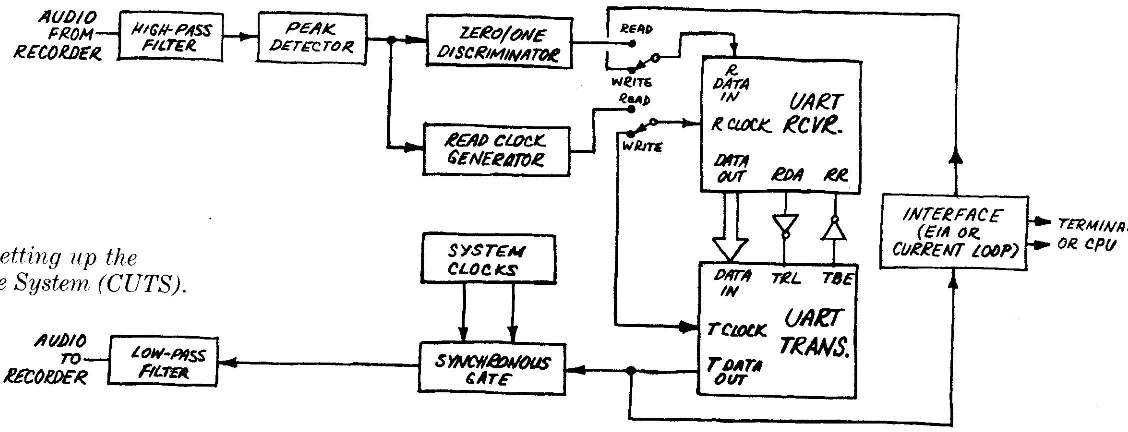

Fig. 2. One way of setting up the Computer Users Tape System (CUTS).

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 Asychronous 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 continuous 2400 Hz should be recorded at the beginning of each cassette. When multiple blocks are recorded, there will be a 5-second gap between them.

Motor Control: The interface should provide for switching the tape recorder motor so that the computer can start and stop the machine under program control.

Basic Circuit. One suggested approach to mechanizing the CUTS system is shown in Fig. 2. In the write mode, data is accepted from a terminal EIA/current loop interface and converted from serial to parallel by the UART receiver. The parallel data is transferred to the UART transmitter when a complete data character is received. The UART transmitter then converts the signal to serial form to gate either a 2400-Hz tone for 1's or a 1200-Hz tone for 0's. The tones are then passed through an output filter which rounds off the waveform and reduces the output level to about 0.5-volt peak-to-peak. This signal is then passed to the tape recorder auxiliary (or microphone) input for recording on the cassette.

In the read mode, the output from the recorder earphone jack is filtered to remove any low-frequency noise, and the waveform is squared up and synchronized with the system clock by the zero/one discriminator. The clock signal for the UART receiver is derived from the recorded information itself by the read clock generator. Parallel data from the UART receiver is transferred to the UART transmitter when a complete character is received. The reconverted serial data is then coupled to the terminal or CPU via the appropriate EIA or current loop.

Data transmitted from the computer or terminal could be sent directly to the synchronizing gate during write operations, but successive serial/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 Raritan Road, Scotch Plains, NJ 07076

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

Texas
El Paso Computer Group, Jack O. Coats, Jr., 213 Argonaut, Apt. 27, El Paso, TX 79912. ◈