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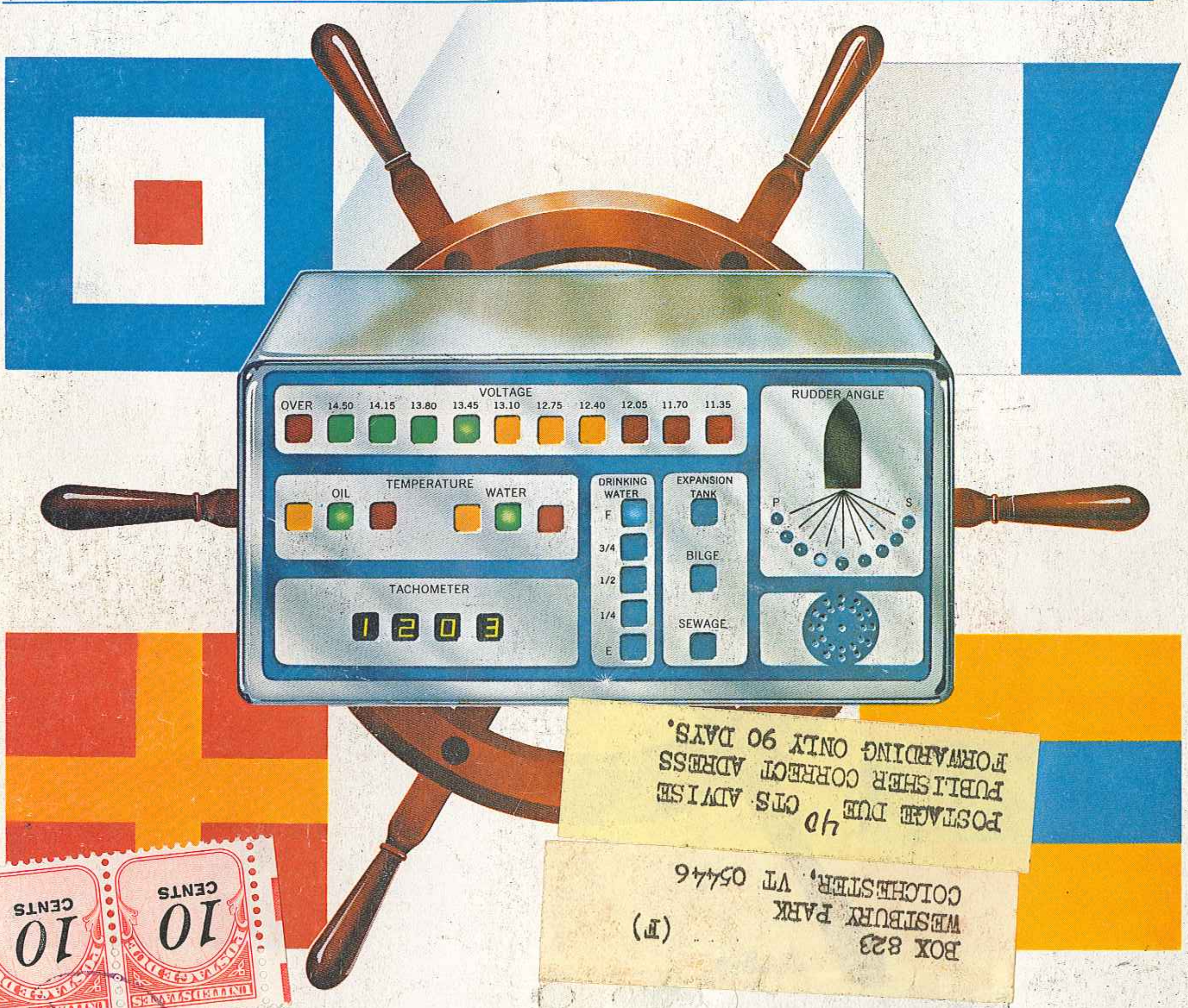
A Universal Charger for Batteries
Build a $10 In-Circuit Transistor Tester
How to Use Decibels for Audio & R-F

Space-Age Electronic Projects for Boats



Tested In This Issue

Sanyo
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Software Sources

By Leslie Solomon
Technical Director

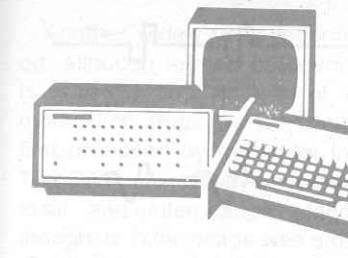
Graphic Games. A number of low-cost software games are now available for the TRS-80, POLY, and PET computers. Among them are WWII Bomber, Lunar Lander 5 and Biorhythm. Requiring only 4K of memory, these come on a cassette for $9.94. Specify computer. Software Industries, 902 Pinecrest, Richardson, TX 75080.

PET Utilities. The Micro-SET I provides five functions to help PET users. These are: CREATE TAPE that makes an ASCII file of a program, subroutine or collection of lines for addition to another program; ADD FROM TAPE that uses an ASCII file tape to add previously stored lines to the program; DELETE that removes lines numbered between your specified limits; PROGRAM INFO that reports the number of lines in a program, identifies the first and last lines and the number of free bytes; and RENUMBER that changes line numbers in a specified range. Micro-SET is used with PET's having at least 8K of RAM. Price is $15 per copy. Micro Software Systems, PO Box 1442, Woodbridge, VA 22193.

Video Software. EVIOS—extended video input/output system, written for the Vector Graphic Flashwriter II video board, can maximize the capabilities of any video terminal and is designed to allow complete control over every facet of software programming. The program includes cursor motion commands, selective screen erasing and five different fields: reverse video, horizontal line, vertical line, graphics and reduced intensity. It also features paging or scrolling, superseding or overlaying screen fields, printing special video characters and a mode that prints control sequences from BASIC as a normal character string. In addition, the input has control sequences to other programs without causing errors, allowing the screen to be cleared while in BASIC. Package includes manual, interfacing and programming examples, a source listing and a 2708 PROM. Price is $75. Vector Graphic Inc., 31364 Via Colinas, Westlake Village, CA 91361 (Tel: 213-991-2302).

6800 Language. STRUBAL+ (STRuctured BAsic Language plus), comprised of elements of BASIC, PL/M, COBOL and assembly language is compatible with existing BASIC software, provides structured programming, business-type record structures and file accessing methods, and includes assembly language for low-level system operations. Also available are EDIT68, a line oriented text editor; RA6800ML a two-pass macro assembler that generates relocatable and linkable object code; LNKEDT68 a linkage editor utility designed to work with STRUBAL+ and RA6800ML; XREF68 a utility designed to produce a cross-reference listing of an input cross-reference file; and a Cross Assembler for the specific microcomputer written for use on an M6800. Catalog available from Hemenway Associates, Inc., 151 Tremont St., Suite 8P, Boston, MA 02111.

Games. For the Exidy Sorcerer, there are six games; LEM (Lunar lander), Nuclear Reaction, Pie Lob, Bounce, Checkers (novice level) and Dodgem. Catalog CS-5001 at $7.95 plus 75¢ postage. For the Ohio Scientific Superboard II/Challenger 1P, there are four games; Dodgem, Tank Attack, Free-for-All, and Hidden Maze. Catalog CS-6001 at $7.95 plus 75¢ postage. Creative Computing, Software, Box 789-M, Morristown, NJ 07960 (Tel: 201-540-0445).



Computer Bits

By Hal Chamberlin

AUDIO CASSETTE RECORDING FORMATS

NOWADAYS many hobbyists take the audio-cassette recording format used by their computer systems for granted. However, four years ago this was not at all true since no really good technique was available and users at the time were screaming for something that simply worked. (The first hobbyist cassette data storage system called "Hobbyists Interchange Tape System" or HITS, was introduced in POPULAR ELECTRONICS in the "Computer Bits" column of September, 1975.) Audio and digital engineers were quick to respond and now there are over a dozen widely used formats. Although a standards conference was held in late 1975 to stem the tide, deficiencies in that standard and competitive pressures in the marketplace continue to produce an even wider variety of formats. In this column, we will be looking at some of the more distinctive recording techniques in use mostly as a matter of historical interest rather than critical evaluation of their strengths and weaknesses.

Characteristics of Recorders. Any viable method of recording digital data on an audio cassette recorder must take into account the various signal distortions inherent in the medium. A typical design goal is to be able to use virtually any kind of recorder, including a $30 "cheapie", since two recorders would be needed for any real file-handling application. Recorders in this price range are plagued by limited frequency response (300-3000 Hz), and very poor speed regulation (±10%). Also, most severely distort recorded waveforms because of the limited frequency response and phase shifts through low-quality audio amplifiers. To a lesser extent, all magnetic recording media are subject to sensitivity variations and even complete dropouts, although the use of higher quality and more expensive tape reduces this kind of problem.

Thus it is obvious that a straight digital bit system such as that shown in Fig. 1 cannot be recorded with any degree of success. To overcome waveform distortion and speed variation it is necessary instead to modulate the digital information onto some sort of carrier wave which is then recorded. During playback, the modulation is separated from the carrier to recover the original bit stream intact.

A complete data recording system actually operates at three levels of encoding. The lowest level, which was just discussed, addresses the problem of recording and recovering bits. The second level is concerned with combining these bits into bytes since blindly grouping them by eights is usually not satisfactory. The third level, which is software dependent, handles combined data and identification bytes in complete tape *records*. Even though only a handful of techniques are popular on each level, the number of combinations is almost infinite and each may have a specific advantage. In this discussion we will be concerned with the lowest level of individual bit-encoding techniques.

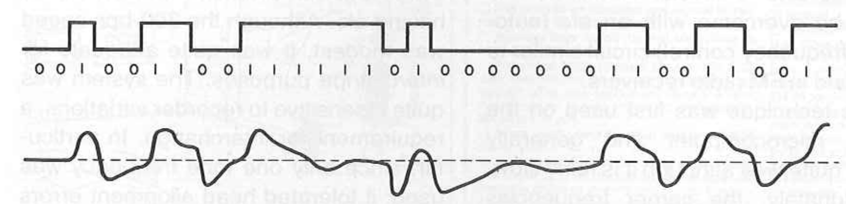


Fig. 1. Lower waveform illustrates typical distortion of a pure digital signal.

Modulation. When a steady carrier wave is modulated, something about it must be changed and that change must be recognizable at the receiver. Because of the limited frequency response of the recorder, only sine-wave carriers can be seriously considered. A sine wave has only three properties that can be modulated; amplitude, frequency and phase. Looking again at the recorder, we see that any one of these characteristics can be distorted by the recording process. Thus, no modulation process can be totally immune to recorder deficiencies. The key to acceptable performance is to make the modulation gross enough so that the "noise" due to the recorder is small in comparison.

Frequency Modulation. Frequency modulation is probably the most popular type of modulation. When used to encode binary data, it becomes *frequency shift keying.* Early audio cassette interfaces actually copied the frequency-modulation technique in wide use for communicating data over voice grade telephone lines. Unfortunately, the degree of modulation (binary 0 at 2225 Hz and binary 1 at 2025 Hz) was not sufficient to overcome tape speed variations in low-cost recorders. Another early interface used the international standard radio teletype frequencies (0=2975 Hz and 1=2125 Hz) which, being more widely separated, worked considerably better. A serious shortcoming of both methods was that *timing* information about the bits was not recovered. Thus, if a string of zeroes was encoded there was no way to tell, except by marking time, where one bit stopped and the next began. Marking time was subject to substantial error because tape speed variations distorted the timing.

All later methods provide for measuring time using the data itself. This is called *self clocking* because there is sufficient *redundant* information in the signal to tell where bit boundaries are regardless of speed variations. Because of the redundant information, however, the speed of these techniques is less than that theoretically possible with nonredundant recording. As a practical matter, the greater reliability of self-clocking methods outweighs their slower speed.

One popular self-clocking frequency-modulated encoding technique is called the Kansas City standard because it was designed by a committee that met in Kansas City in November of 1975. With this technique, a binary one was defined as 8 cycles of a 2400-Hz tone and a zero was 4 cycles of 1200 Hz. Bits were therefore timed by *counting cycles* of the carrier frequency. Because of the wide separation of frequencies, a simple single-shot circuit was sufficient to discriminate between them. A nice property of the standard was that it could be easily upgraded. The normal data rate of 300 bps (bits per second) could be increased to 600, 1200, or even 2400 bps by reducing the number of cycles for each bit. The 2400-bps rate is interesting in that a zero is only one-half a cycle of 1200 Hz. The resulting modulation is very similar to the popular "Tarbell" format which is known for its high-speed capability. A problem with these formats is that waveform distortion has to be low enough to allow accurate cycle counting, which is usually by zero-crossing detection.

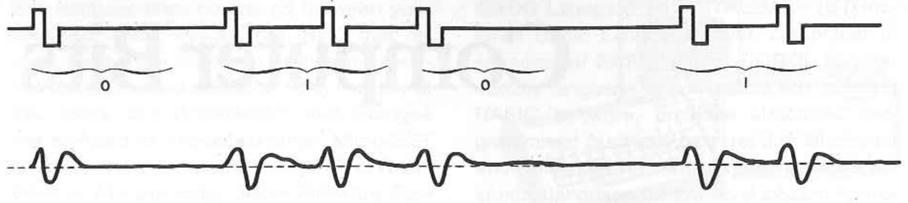


Fig. 2. "Pulse" modulation is actually another form of amplitude modulation.

There does exist a self-clocking frequency modulation technique that does not depend on cycle counting for timing. The trick is to convert each bit into *three* bits which are then recorded with a nonclocking frequency-modulation technique. If a zero is to be recorded, it is converted into 1-0-0 and if a one is to be recorded, it is converted into 1-1-0. Thus, the bit boundaries can be identified by noting the transitions from 0 to 1. The decision between 0 and 1 for the entire bit cell is arrived at by *comparing* the amount of time within the cell that is spent at a 1 level to that spent at a 0 level. Since the decision is based on a comparison rather than absolute timing, the technique is almost totally immune to speed variations! This method is also known as the "⅓-⅔" method or "ratio recording". The limit of speed-variation is reached where the FM detector can no longer accurately distinguish between 0 and 1 levels. However, this could be overcome with an afc (automatic frequency control) circuit similar to that used in FM radio receivers.

This technique was first used on the KIM-1 microcomputer and generally works quite well although it is fairly slow. Unfortunately, the carrier frequencies chosen (3700 Hz for 1 and 2400 Hz for 0) are a little high for reliable use with most low-cost cassette recorders. Like the Kansas City standard, methods are available to upgrade the normal 134 bps by factors of 3 and 6 to a respectable 800 bps without producing any serious loss in reliability.

Amplitude Modulation. Although amplitude modulation is less used than frequency modulation, it has some important technical advantages—and some disadvantages. The main advantage is that speed variations from one recorder to the next have no effect on the data recovery process. The primary disadvantage is that variations in recording level and tape output may require the recorder's volume control to be adjusted for accurate data recovery. Some may see this as an advantage over FM methods since volume controls are standard but speed controls are not.

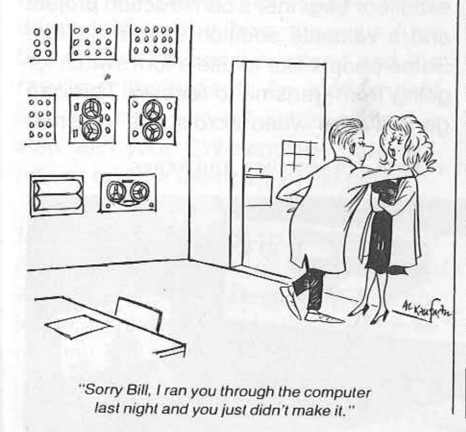
Amplitude modulation with binary data is often called tone-no-tone recording since that is the result of 100% modulation. One potential problem with amplitude modulation is that the automatic level control (alc) feature found in many cassette recorders tries to counteract changes in signal amplitude. To prevent alc problems, the selected format must avoid long periods of silence. With such a format, the alc feature (which only functions during recording) can become an advantage since it ensures that all tapes are recorded at the same volume level.

The basic idea of the HITS format, mentioned above, is the same as the ⅓-⅔ method except that a logic 1 is signified by the presence of a high-frequency tone while a logic-0 level is the absence of any tone. Since silence never lasted longer than ⅔ of a bit time, there was no problem with recorders having alc. Although the 300-bps speed was modest, it was quite adequate for *interchange* purposes. The system was quite insensitive to recorder variations, a requirement for interchange. In particular, since only one tone frequency was used, it tolerated head alignment errors (which severely alter the recorder's frequency response curve) quite well.

Another widely used recording method, although termed *pulse modulation*, is in reality another form of amplitude modulation (Fig. 2). The method was first proposed by the writer in 1975 in The Computer Hobbyist newsletter as a local and interchange standard. Although its initial usage was small, it was quietly adopted by Radio Shack for its TRS-80 computer and now is probably the most widely used format to be found.

In the system, a "pulse" is defined as exactly one cycle of a 4-kHz tone surrounded on both sides by silence. Every bit on the tape begins with a "mark" pulse. A zero bit is detected if the mark pulse is the only pulse seen within a 2-millisecond period which is the bit cell time. A one bit is signified by a second pulse occurring shortly (1 millisecond) after the first. The method has a speed variation tolerance of about ±20% which is limited by the ratio of the bit cell time to the spacing between the mark pulse and the "one" pulse. One interesting property of the method is that the bit rate need not be constant, although too big a gap between bits can cause problems with the alc. The standard speed of 500 bps can be reduced for better reliability (250 bps is used in the Level I TRS-80) and increased (2000 bps has been reported on a good-quality recorder) for faster operation.

Digital Recording. Even the fastest audio cassette interface is painfully slow when searching through files of tens or hundreds of thousands of bytes and even with all kinds of built-in error detection schemes still does not have the reliability needed for extensive business use. Direct *digital recording*, which avoids the distortions in audio circuitry, is the answer for high-speed, highly reliable recording on magnetic media. The recording techniques used in digital cassette systems and floppy disks will be discussed in a future column. ◇


"Sorry Bill, I ran you through the computer last night and you just didn't make it."