Discussion

The answers were provided by W. Burkhart, Chief of Electronics Division, Monroe Calculating Machine Co., Inc., Orange, N.J.

Question: While entering unit price, what does the operator do if she makes an error?

Mr. Burkhart: The method of correcting errors depends on the particular program used. At worst, the error will have affected daily balances, in which an error program would correct it.

Question: What is the memory capacity of your computer?

Mr. Burkhart: The memory capacity is fourteen registers of eighteen decimal digits each. Through programming, these may be split. The average arithmetic speed for multiplication and division is 1.6 seconds for a five-digit multiplier or quotient. Actual addition time is 2.5 milliseconds, while average access time is 10 milliseconds. The actual speed generally is governed by the speed of input and output on the electric typewriter.

Question: How many program steps are available? What arithmetic operations can be performed? Can the machine be used for scientific use?

Mr. Burkhart: Fifty-two program steps are available on each program. Eight basic programs are available, and through the use of extra program selection keys, as many as thirty-two programs are possible. The machine can be used for scientific use if the programs involved are within the capacity of the machine.

Question: With so many VT in a confined area, what means is used to control temperature?

Mr. Burkhart: There are only seventy-eight tubes in the machine, and the total power dissipation is about 600 watts, so that a small fan suffices to keep the interior cool. Since the vacuum tubes themselves are near unwired portions of the printed circuits, there has been no component deterioration due to heat.

Question: What provisions are made by circuit design or computer logic to prevent errors in computation to be printed and invalidate correct work already processed?

Mr. Burkhart: There is no means for preventing the printing of errors due to operator mistake or computation error.

A Self-Checking System for High-Speed Transmission of Magnetic-Tape Digital Data

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SEVERAL years ago it became evident that high-speed communications facilities were required as part of many future data-processing systems. The need had appeared in the planning phases of several systems and certainly, as the speeds of computer operation increased, it would be desirable to centralize computing systems to take maximum advantage of them. Situations indicating its need are:

1) Real time surveillance and control systems of military significance.
2) Faster computers which are able to do the total data processing for a large business so the data from the many sources must be brought to the computer site.
3) The necessity for prompt sending of data to a central location to permit over-all control, even if the development of small internally programmed computers permits many geographically separated computer installations.
4) There is a gross difference between the new and the old data-processing speeds.

Important practical considerations in the selection of a data-transmission facility as part of a data-processing system are that the media to hold the transmitted and received data, and its code and format must be compatible with the rest of the data-processing system. Although an "on-line" data code and format significantly different than that on the input and output media are possible, the present state of the art indicates that those of the data-processing media be retained with minimum alteration for the data transmission.

The quantity of data to be transmitted in future systems, when the facility for rapid, accurate data transmission is widely available, naturally is unknown now. The situation may be compared to that in earth moving. The number of millions of yards of dirt that needed to be moved when shovels and wheelbarrows were the only tools was much different than the number that "needs to be moved" today, now that huge power shovels, long conveyor belts, and large tractor-scrapers are available. Even today, data transfer by some concerns involves 5 to 30 million characters per day; while this accomplishment with techniques used may be likened to the *tour de force* of the Egyptian in pyramid building, it does indicate that ten to one hundred times as much is not out of line for future needs.

The "state of the art" digital transmission speeds may be compared with theoretically possible data rates by noting that a fairly low quality phone channel of 1700 cps bandwidth and 22-db signal-to-noise ratio should, by the $B = W \log_2 (1 + S/N)$ formula yield an error-free transmission rate of approximately 12,000 bits per second, but present practicabilities offer more like 750 bits per second. Compared to teletype and telegraph service of 30 informa-

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tion bits per second in 60-wpm service, this is a significant increase (25x). With a 7-bit code, 750 bits per second could yield 80 to 100 characters per second. A 30 million character-per-day transmission load, at 100 characters per second, would need this kind of line for 300,000 seconds per day, or three of these lines would be needed to transmit this much information per day. A large industrial complex may have only 3000 to 300,000 characters per day to send from each location, so many lines could be involved but for only a few hours per day.

One of the most important aspects of digital-data transmission is the accuracy—the accuracy needed by the user and the accuracy given by the digital-data-transmission service. The present indications concerning the phone-line error characteristic is that on the average, between one in 10,000 bits to one in 100,000 bits will be in error. These data are derived mostly from teletype and telegraph experiences. The redundancy planned for digital-data communications and the extensive "intelligence" built into the terminal equipment will detect these errors and can ask for a repeat of the message; so even if the error rate on the line should remain as indicated, the error rate in the records submitted to the user will be dramatically less. The checking features of the digital-data-transmission systems can be evaluated thoroughly only after detailed analysis involving as yet unavailable detail error characteristics of the line and modem equipment, or by months of actual "on-line" testing. Then, with good records kept of those errors found by other checking, as with a large computer, and traced to the records submitted by the digital-data-transmission equipment to the data-processing center, the accuracy can be evaluated. To indicate in terms of present-day media, punched cards and magnetic tape, the accuracies expected in checked digital data transmission, one hole punched wrong in one of 80,000 eighty or ninety-column cards and not caught by the checking facilities, would yield a probability of error of one in 40,000,000. This quantity corresponds to sending eight cards per minute, twenty-four hours per day for one week. This is about 1/1000 of the rate indicated as the error rate on the line. Similarly, for a magnetic tape-transmission system at ninety characters per second for 168 hours (one week), one bit in error in the submitted record would indicate a probability of undetected error of one in 400,000,000 or 1/10,000 the rate indicated above as the "on-line" error rate.

The MTM Transrecorder, which transmits data from one magnetic tape via voice-band facilities to another, is an example of a facility for providing high-speed, accurate, automatic, digital-data transmission. The source media can be any Univac tape from 200-foot perfect tape reels to 1500 or 2400-foot reels with random bad areas or splices. Data are recorded in C10 code, in blockette or high-speed printer format on both source and receiving tapes, and so is compatible with other system equipment.

The philosophy of error correction in the Transrecorder is to introduce into the transmitted message sufficient redundancy to detect errors and have the receiver check the received message, and if it is erroneous, request a retransmission. This is accomplished by:

1) Dividing the total message of 100 to 2000 blocks of information into submessages each consisting of an integral number—1 to 16—of blocks of information. A block consists of 720 characters which in the high-speed printer format, used with the Transrecorder, is divided into six blockettes of 120 characters each.
2) Sending one submessage from transmitter to receiver and awaiting reply.
3) Checking the incoming data at the receiver during submessage reception and checking the recorded data corresponding to this submessage to insure that they satisfy the proper checks, which are:
   - Character parity.
   - Correct character count/blockette.
   - Long parity check during reception.
   - Proper number of blockettes/submessage.
4) Receiver sending a reply to the transmitter indicating that the last submessage was received and recorded correctly, or that it is to be retransmitted.
5) Continue sending submessages until the end of the total message.

This is error correction by error detection at the receiver and then use of feedback from receiver to transmitter to advise the transmitter that the data have either been received satisfactorily, or was received with errors and is to be retransmitted. It is to be differentiated from error correction by error correcting codes as discussed by Shannon, Fano, and others, which would permit reconstruction of the information from mutilated incoming signals without the necessity for reverse transmission.

From the time the operators initiate transmission until end of rewind, at both transmitting and receiving locations, the operation is automatic.

Some of the automatic features of the Transrecorder are as follows:

1) After mounting the reels of tape on the tape handlers and initiating operation, the control automatically advances both source and receiving reels far enough to insure that good magnetic tape will be under the heads. The receiving station simultaneously erases the leader and tape which feature permits reuse of tapes without requiring pre-erasure. The transmitting tape advances ten feet prior to initiating "read" to avoid noise due to clips and leader-tape junctions, and the receiving advances fifteen feet before recording to permit adequate tolerances between the various tape handler-control combinations of a data-processing system.
2) The data read from the tape at the transmitting station are checked for character parity and for 120 characters per blockette. This data is stored in a 120-character magnetic core buffer.

3) In transmitting the data from the buffer to the modem and line, the character parity is again checked and a "horizontal parity" character, the 121st character sent for each blockette of information, is generated to indicate the sum modulo 2 of the "ones" for each information level.
4) The control unit sends before each submessage, a submessage preamble consisting of a train of alternate one-zero pulses. This alerts the receiver that a submessage is to be sent, prepares the phone line for propagation in the transmitter to receiver direction, *i.e.,* reverses possible echo suppressors and stabilizes compandors enroute, and establishes proper receiving-clock phasing. This receiving clock establishes what we might call "bit synchronization."
5) The preamble is followed by one or more special characters which effect a "character synchronization," which lets the receiving control unit know the first bit of each of the incoming serialized characters. This special character both provides this "character synchronization" and a time-buffering action which permits proper fitting of the tape-unit advance and bad-area traversal times to the required bit and character synchronization during the submessage. Each "on-line" blockette of 121 characters is preceded and succeeded by a special character to permit the receiving station to effect a character count check on the incoming data. It also permits a long parity character to be generated from the first 120 characters of the incoming blockette. This is then compared with the 121st incoming character.
6) At the end of each submessage or block group, which may be chosen by a switch to be from about 5000 information bits to about 80,000 information bits long, the transmitting station stops transmitting and awaits a reply from the receiving station. If all the information sent since the last "answer back" was received *and recorded* correctly, the receiving station sends back a train of alternate 1-0 signals long enough to reverse the direction of propagation on the line and to register the "resume" order in the transmitting site's control circuits. If errors were detected in the submessage as it was received, or if after three read tries the recorded submessage at the receiving site fails to check properly, the receiving MTU repositions the receiving tape to the beginning of the submessage improperly received or recorded, and sends back a train of alternate 2 "1" 's—2 "0" 's. This is sent long enough to stabilize the line transmission in the reverse direction and register the "retransmit" signal in the control circuitry. If the answer back was "resume," the transmitter proceeds to send the next submessage, if "retransmit," it repositions to the beginning of the last submessage and proceeds to retransmit it.
7) The "end of message" indication on the transmitting tape is five feet of erased tape beyond the last blockette of the message. The transmitting control unit senses this and after insuring that the last information sent was received and recorded correctly at the receiving site, it sends an "end of message" signal. Then the receiving and transmitting MTU's rewind the tapes onto the original reels and indicate the completed message condition to the attendant.

The Transrecorder consists of basically three units, a Control Unit (CU), a Magnetic Tape Unit (MTU), and a modulator-demodulator (Modem) to take the "square-wave" voltages from the CU and apply signals to the line at the transmitting site, and to receive the signals from the line and change to "digital signal" form at the receiving end. The Univac Modem was designed for use on customer owned lines and to permit gaining experience and insuring compatibility between the facility "Modem" service and the CU of the Transrecorder. When the Transrecorder is used on public communications facilities, the facility's modem will be in a separate cabinet to the left of the CU. Any Transrecorder installation can be used to transmit data or to receive by switch selection on the control panel at the top of the CU so an installation at a regional office or remote factory can first submit a reel of tape data to the Data Center and later switch to the receive mode and receive data, instructions, shipping schedules, etc., from the center.

With the exception of the Modem, the total CU is transistorized. The MTU involves both tube circuitry for tape-transport control and reading and writing and transistor circuitry for logical control functions.

The maintenance requirements due to plug-ins and components have been very low in installations using this type of construction; these plug-in circuit designs are used also in the perforated paper tape to magnetic tape converter, in the magnetic tape to perforated paper tape converter, and in an a/d converter and recorder. Provision is made for convenient preventative maintenance by altering supply voltages to selected racks of machine in the test mode and observing limits. Supply variations of ± 25 per cent and more on entire racks are permissible when all components are within limits, and the maintenance-panel indicators, the selective alteration of supply voltages, and the plug-in construction allows detailed analysis and prompt correction of a fault if it occurs during scheduled operation.

The Transrecorder operates on 115-volt 60-cps phase power, the total average power requirements being less than 3 kw, and it is capable of operating in 90°F ambient temperatures.

The author wishes to credit C. W. Fritze, B. L. Meyer, and R. Goossens with the majority of the control and logical features of the Transrecorder and the continuing effort to bring this development to its present stage.

Discussion

Question: What percentage of the total number of bits transmitted are redundancy bits for error detection?

Answer: In the Univac data automation system, each character is composed of six information bits and one odd parity bit. This error checking feature is retained in the high-speed digital data transmission system where it is often referred to as the "vertical parity" check. Hence in each block of 720 characters, 720 of the 720 x 7 bits are "vertical parity" redundancy bits. To each blockette of information, an additional "horizontal parity" character is added, giving 42 additional bits per block. Hence, about 15 per cent of the transmission consists of error checking bits. In addition, timing bits and special spacing characters introduced for purposes other than error checking are checked against the *a priori* knowledge that they should be present at particular intervals, and so also serve as "error checking" bits. But, this latter feature is a sort of bonus, since their primary purposes are for timing and inter-blockette and interblock spacing.

Question: Will the equipment handle both metal and plastic tape?

Answer: Yes.

Question: Is the equipment now available?

Answer: The equipment is undergoing laboratory and system testing and is not available for immediate delivery. For delivery and similar information, please contact the Communication Department, Remington Rand, 315 Fourth Ave., New York, N. Y.

Question: Will the equipment transmit data over standard telephone lines?

Answer: Yes, and this was an important consideration in the design. The goal was that any phone line over which satisfactory voice communication could be obtained should be suitable for digital-data transmission.

Question: Can the blockette generally be arranged by computers of other manufacturers?

Answer: This question has several ramifications. The logical structure of a blockette, *i.e.,* 120 characters per group, odd parity characters, particular bits significance in each character, etc., could be prepared by any computer. The problem would arise in the magnetic head structure, writing densities, writing mmf, read-back signals, track orientations with respect to tape edge, head gap staggering for various tracks, etc. Hence for most practical purposes, the Transrecorder could be expected to accept only tapes prepared on Univac equipment.

Question: What is the form of the transmission on the line, the signal representations of the "0"'s and "1"'s?

Answer: This probably will vary with each different manufacturer's Modem, or each different communication company. The Univac Modem uses 100 per cent amplitude modulation of a tone carrier of about 1500 cps, "1"'s represented as full amplitude and "0"'s as zero amplitude signal. The signal levels on the line can be varied but are generally considered as about 0 dbm into a 600-ohm balanced phone line. A binary or two-state FM system is being developed by others, with one tone near the lower edge of the phone channel pass band for one digital state and a tone near the upper edge of the band for the other; the tones are put on the line one at a time. The binary FM appears to have some advantages in increased S/N, for ease of implementation of gain control, and for bit detection implementation, since a comparison should be more reliably made between the power in the two tones on a variable loss link than can the determination of whether the incoming power level on such a line exceeds a preset level. Other systems use mutiple tones, or different phases of a "continuous" tone, all presently known ones having the tones in the audio phone band at the modulator output and at the demodulator input. In the normal trunking facilities where a given channel may be subjected to frequency or time multiplexing techniques, the power spectrum and type of modulation may be very different at enroute points than at the Modem terminals. It should be mentioned that the Transrecorder (less Univac Modem which is furnished for use only where a communications company facility, with its own Modems, is not available) is not interested in the "on-line" signal representation, if the Transrecorder-Modem interconnection signals are appropriate.

Question: What reasons led to the selection of a serial rather than parallel mode of line transmission of the bits comprising the characters?

Answer: Primarily, this decision was based on ease and simplicity of instrumentation and the consequent economy. Also, with the normal type frequency separation techniques, the percentage loss of total useful bandwidth due to "guard bands" makes for less efficient bandwidth utilization in multiple tone systems, and the ratio of peak power to average or rms power on the channel increases when more than one tone at a time is impressed on the channel. Since generally, actual channels have a peak power limitation as well as an rms power limitation, the rms signal that can be impressed is higher for single tone modulation than for multiple tone. The development of new frequency separation techniques and the increase in duration of each signal interval as the number of simultaneous bits per signal interval is increased, which increase minimizes the effects of certain kinds of noise, suggests a multiple tone system. But, the economy of Modem implementation seems still to be in favor of serial transmission.

Question: On a low-grade phone circuit of about 1200-cps bandwidth, did you mean that theoretically this should handle 12,000 bits/second?

Answer: The example given was for a 1700-cps channel bandwidth having a 22-db S/N ratio ($S = 159.N$ and the transmission channel degraded only by additive noise) and this facility then should, per Shannon's formula $B = W \log_2 (1 + S/N)$, give a "long time average" bit rate of in excess of 12,000 bits/second. The actual accomplishment of this rate of transmission on the above phone channel awaits the development of considerably more sophisticated methods than we have at present.

Question: What is the transmission medium employed?

Answer: When the Modem is furnished by the communication facility, the medium is of no interest to the Transrecorder proper; but in normal installations it is expected that it will consist of a 2 or 4 wire, one-half or full duplex phone channel facility. When the Univac Modem is employed, a 2 or 4 wire, 600-ohm nominal characteristic impedance, preferably balanced to ground, with inputs to the phone line from the Modem of between +3 and −6 dbm, and outputs from the line to the Modem of between +3 dbm and approximately −25 dbm, is required. After the 2 or 4 wire lines leave the vicinity of the Modem, especially if long-distance transmission is involved, it is expected that frequency or time multiplexing techniques will be used, and the channel may go on open wire lines, coaxial cables, microwave links, or similar trunking facilities, but will reappear on 2 or 4 wire lines in the vicinity of the Univac Modem at the remote location.

Question: Are blocks and blockettes so recorded on the sending tape or does the control unit do the subdivision and control the tape feed?

Answer: In the system implemented, the information on the magnetic tape at the sending end is divided into blocks and blockettes (so-called high-speed printer format) and is reproduced in the same fashion on the receiving end tape.

Question: What is the bit rate over the line in the existing system?

Answer: The existing equipment is working at 750 bits/second and at 800 bits/second. The change from one to the other involves a change in transmitting clock generator, and receiving clock recovery circuit plug-ins. Since the maximum transmission speeds are so intimately associated with the transmission channels, it is planned that the transmitting Modem will establish the bit rate by furnishing a "transmitting clock" signal to the Transrecorder and the receiving Modem will recover a "receiving clock" from the incoming signal and supply it, with the received data, to the receiving Transrecorder. As accurate transmission at higher speeds is accomplished, due either to more sophisticated methods on given channels or the installation of wider band facilities, the Transrecorder then can very conveniently utilize the higher speeds.

Question: Is it necessary to have two sets of Modems on long-distance transmission, one furnished by Univac and the other by the telephone company?

Answer: No. The Univac Modem is a self-contained, panel-mounted unit easily removed from the control unit in situa-