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EXCLUSIVE! First Computer Terminal You Build From A Kit

This is a special report on a 4-page computer terminal in kit form. It can be connected to a computer directly or via telephone lines.

by THOMAS W. DURSTON

THE LOW COST MINI-COMPUTER IS A reality today. Together with time-sharing systems, they are performing an increasing number of tasks in all types of applications.

However, the relatively high cost of terminals has slowed both the acceptance and the use of the computer in small businesses, homes, and schools. The MITS Comter 256 (CT256) computer terminal described here can be built for less than ½ the cost of most terminals and offers many unusual features not found in terminals costing several times as much.

The terminals important features include:

A built in acoustic coupler making computer connection simpler and saving added cost.

An auto-transmit that allows transmitting data or program material to the computer from memory, line by line.

Complete cursor control by software as well as by manual control via the keyboard.

A tape recorder input/output jack to enable taping of frequency shift keyed (FSK) tones during telephone connection to a computer. This gives virtually unlimited memory capability. Almost any type of tape recorder may be used.

A 32-character Burroughs display with a soft orange, highly legible readout.

Standard ASCII encoded keyboard with TTY-33 format.

Internal memory capability of 256 characters per page and up to 4 pages of memory.

Automatic page change at the end of each page for a total of 1024 character storage for a 4-page unit.

Flexible power requirements. Operable from line voltage of 100 to 130 volts or 200 to 260 volts.

A 25 pin input/output accessory jack for hardwire computer connection and add-on accessories.

Data flow in the terminal

The block diagram of the Comter 256 (Fig. 1) represents considerable digital circuitry (91 logic IC's in a 4-page unit). The data path starts at the keyboard. When a character key is depressed, the character is encoded into a 7-bit binary code and is sent in parallel form on 7 lines to the UART (Universal Asyncronous Receiver-Transmitter—a 40-pin MOS chip) which converts the character data to serial information. The serial data is sent to the FSK modulator which converts a binary 1 to 1270 Hz and a binary 0 to 1070 Hz.

These tones are transmitted from the acoustic coupler to the computer, via the telephone lines. The computer processes the data and returns it back over the telephone wires to the terminal at a different frequency (binary 1 = 2225 Hz, binary 0 = 2025 Hz). The data is fed to the acoustic coupler where the tones are amplified, filtered and demodulated back into serial binary coding.

From the demodulator, the serial data goes to the UART and is converted to parallel form where it waits to be loaded into memory. When a data available signal from the UART coincides with the 32nd character display time for the self-scan (right hand end of display), the first 6 bits of the character are entered into memory (the seventh bit is not used in the CT 256 memory) and the data position is automatically moved one position to the left.

The self-scan display is connected to the memory so that as a character is entered into memory it is simultaneously displayed along with the other characters in memory. This process is repeated for every character transmitted from the keyboard, plus the computer can also transmit its own characters to the terminal as the software requires.

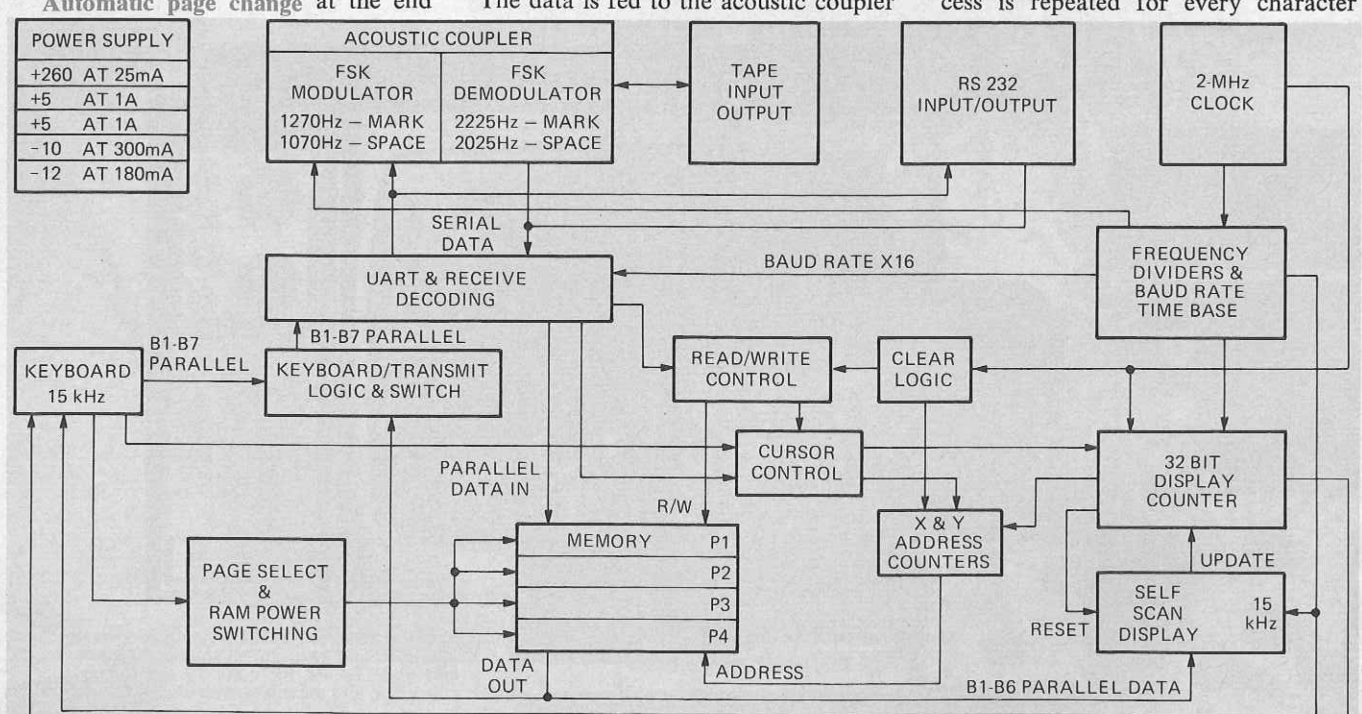
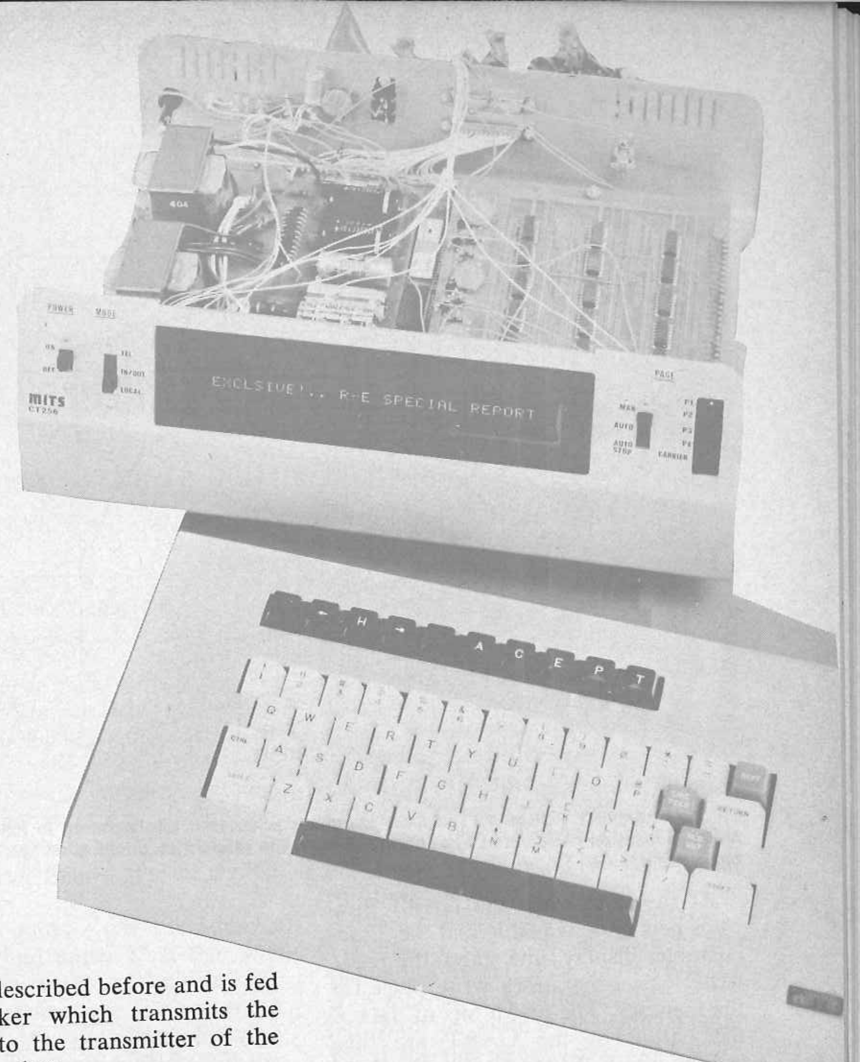


FIG. 1—COMTER 256 COMPUTER TERMINAL block diagram showing data flow. Data flow starts at the keyboard, which is shown at the left side of the diagram.



How it works

The most important single circuit in the CT256 is the clock oscillator. It is a 2-MHz crystal oscillator that provides the time base for the logic, and is also used in the modulator of the acoustic coupler to provide the FSK tones. A crystal oscillator was chosen for its stability. The 2-MHz clock is divided down to provide 1 MHz, 62.5 kHz, and 15.625 kHz for logic time base. It is also used to determine baud rate (data transmission rate) for the UART. The baud-rate switch selects either 1760 Hz (110 baud X16) or 4800 Hz (300 baud X16) for the UART clock by setting a programmable counter to divide the 2-MHz clock by 1136 or 416 respectively. The modulator in the acoustic coupler works in a similar manner. Instead of setting a switch to set a programmable counter to divide by different rates, it uses the binary logic 1 or 0 of the data to derive the two divide rates.

Starting with the data path, the keyboard encodes the character by feeding a 15-kHz signal to a 4-bit binary counter that is connected to a 4-to-16 line decoder. The character keys are connected to the 16 lines according to the first 4 bits determined by the ASCII code. When a key switch is closed, and the line it's connected to is strobed, the 4-bit counter is halted. The 4-bit count where the counter stopped is the first 4 bits of the 7-bit ASCII code and the other 3 bits are encoded by a series of logic gates. After a 30-ms debounce period, a load signal is sent to the UART, where the parallel 7-bit character code is entered into registers and transmitted out serially at the selected baud rate. The serial data is sent to the modulator where it is converted into audio frequencies as described before and is fed into a speaker which transmits the FSK audio to the transmitter of the telephone handset.

When the computer returns the data or originates its own, it is received as a 2225-Hz or 2025-Hz tone. The signal is picked up by a ceramic microphone adjacent to the receiver in the telephone handset, and is amplified and converted to a low-impedance output by a JFET-NPN transistor circuit. This low-impedance circuit feeds the tape output and a two-stage op-amp active filter.

The two-stage filter removes noise and interference and provides a gain of about 400. The filter output feeds a carrier detector circuit that turns on the carrier LED, enables the transmit circuit, and enables the FSK demodulator which consists of an XR210 IC phase locked loop. The output of the op-amp filter also feeds the XR210 and the signal is demodulated into serial binary form. This serial binary data is fed into the UART and is sampled at the set baud rate. If the serial data is valid, it is converted into a 7-bit parallel format corresponding to the ASCII code for the character received.

The UART also indicates that it has new data available. Meanwhile, the receive decoding determines if the new 7-bit character is a display character or a control character. If it is a display character, it is allowed to be entered into memory, if it is a control character (bell signal, cursor control char; see table of control characters) the receive decoder inhibits memory loading and initiates the necessary operation.

Memory operation

Probably the most involved circuitry in the CT256 centers around the 5-bit (32 count) display counter and 4-bit (16 count) X-Y memory address counters. The X-Y memory address counters are both 4-bit (16 count) up-down, presettable counters, making a total combination of 256 addresses (16X by 16Y). For reference sake, the Y addresses are called lines and X addresses are called character positions (see Fig. 2 & 3). The start of the page is called "home" (see Fig. 4) and has address ∅, ∅ (line ∅, position ∅). When the black "H" key (home) is depressed, it homes the data to the cursor position (right hand end of display—32nd character) and results in the X-Y address counters being at ∅, ∅ during the 32nd character display time.

The cursor position is very important because it is during this 32nd-character display time that; new data is entered into memory, data is shifted right or left in the display, data is homed, memory is cleared, and many other timing chains are based.

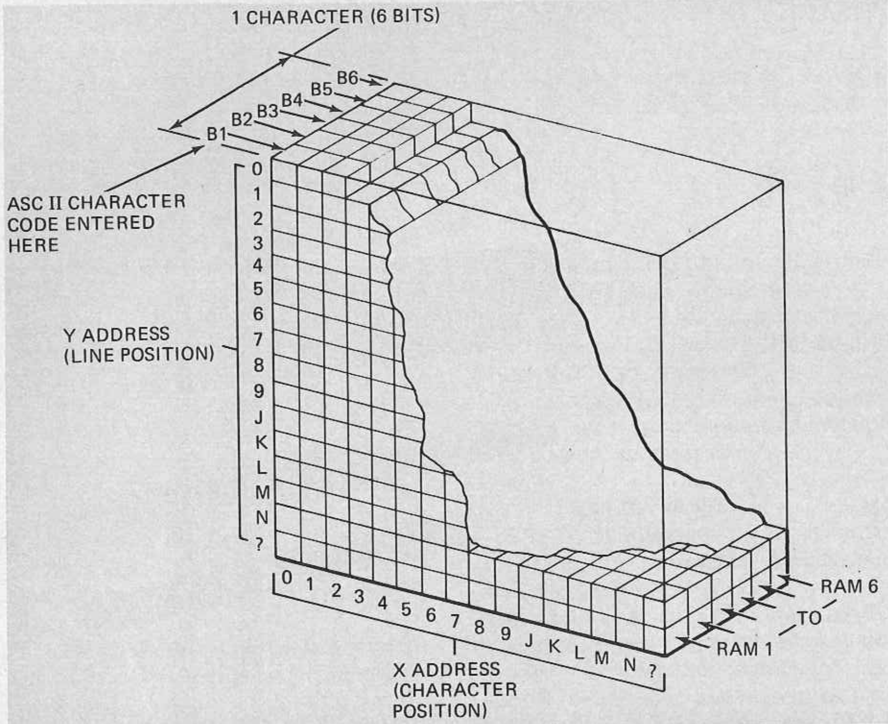


FIG. 2—MEMORY FORMAT. The 6-bit character is entered into memory in ASC11 code. The memory location is selected in accordance with the respective position on the page (line and character position.)

At the time when the UART indicates new data available and the 32nd-character display time starts, the read/write logic generates a write pulse for the memory. The first 6 bits of data at the output of the UART are then written into 6 RAMs (Random Access Memory) at that address. The write pulse also goes to the cursor control logic, where, upon completion of the write pulse, the X-address is incremented one position, shifting the data one position to the left on the display. The write pulse also triggers a circuit that resets the data available line from the UART.

The clear circuit, activated by either pressing the black "C" key or receiving a control "L", enters the ASCII code for a blank into all 256 positions of memory for that page. It works by holding the write circuit on and forcing the data input lines to the memory to coding for a blank. This only takes place during the 32nd-character display time during which it "homes" the X & Y counters and advances the X-counter 256 positions (one complete page) at a 1-MHz rate.

The auto transmit circuit works by depressing the black "T" key which activates logic that switches the transmit data lines from the keyboard to the data output lines from the memory. Whatever character is in the cursor position of the display is transmitted out to the computer. As that character is received back, it is re-written into the same position in memory, the data is shifted left one position and the next character in memory is transmitted.

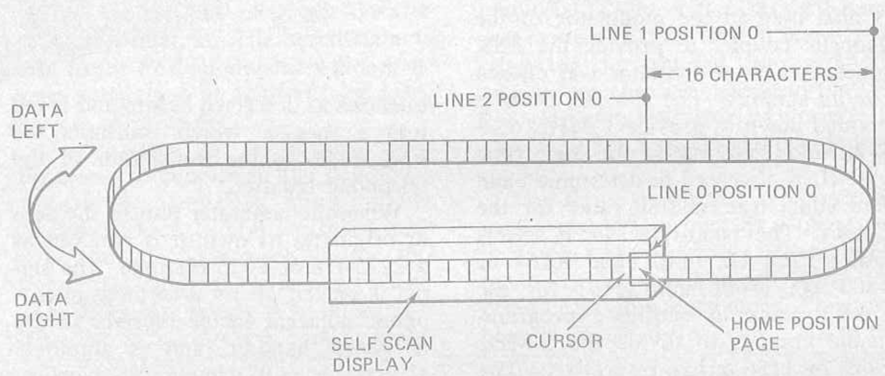


FIG. 4—PAGE FORMAT shows how the page is displayed on the Self Scan display. Each line of the page is 16 characters long and the page is displayed one line at a time.

Since the memory only stores the first 6 bits of the 7-bit ASCII code, the 7th bit must be derived by logic gating.

This is one reason why the CT256 cannot auto-transmit control characters.

The 7th bit cannot be derived for control characters, and since the memory does not receive and store them anyway, they have to be transmitted manually via the keyboard. To allow entry of control characters such as carriage return, the detection of the @ symbol will cause auto-transmit to stop and the desired character may be manually transmitted. The @ symbol is detected in the cursor position and auto transmit cannot take place unless it is shifted out by manually entering a new character.

The address function is initiated by pressing the black "A" key or by receiving a control "O". It sets up the receiving decoding to accept the next two characters and use their first four-bits of ASCII code to locate a particular address in memory and display it in the cursor position. The first character received after the address function is initiated, selects the line number (1-16) by setting the Y address counter equal to the first 4 bits of that character's ASCII code. The second character received selects the position in the line (1-16) by setting the X address counter equal to the first 4 bits of that character's ASCII code. These two characters are used only for address location and are not loaded into memory. For Y (line) and X (position) identification see Fig. 3.

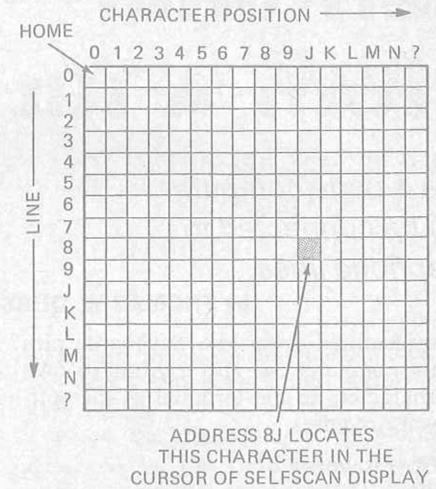


FIG. 3—MEMORY FORMAT shows the page position and character location respectively. Address 0, 0 is the "home" position on the page.

Page circuitry

The page control circuit for a multi page unit consists of two circuits for each page. The first set of circuits enables each set of 6 RAM's, making them active for the page selected; the second set of circuits reduces power to the unused pages to standby levels, reducing current drain by 75%.

The operation of the page control circuit is determined by the setting of the PAGE switch. In MANUAL, the page can only be changed by depressing the black "P" key. Pressing the black "P"

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Digital Multimeter Roundup

The digital multimeter has finally moved out of the laboratory and onto the service bench. Here's a rundown on those that sell for $300 or less.

by ROBERT F. SCOTT
TECHNICAL EDITOR

FOR YEARS THE MULTIMETER HAS BEEN the principal—and sometimes the only—test instrument used by the service technician for voltage, current and resistance measurements. Many old-timers have an almost continuous squint acquired from peering at a meter and trying to read the voltage indicated by a pointer that has banged against its pins once-too-many times.

Digital meters—presenting the metered quantities in large easy-to-read numbers—have been used in laboratories, industrial plants, etc. for years but have just recently been developed to the point that they are priced within the reach of electronic service technicians and many experimenters.

The digital multimeter, often called a dmm or dvm, offers many advantages to the busy service technician. For example, in some dmm's, range selection, polarity indication and decimal point placement are performed automatically. The indications are often large enough to be easily read from up to 20 feet away. Parallex does not exist so it cannot affect reading accuracy. The accuracy of the instrument is much greater than a typical analog vom or vtvm.

There are quite a few new dmm's in the $300 and under class that will appeal to the service technician and advanced experimenter. We are going to discuss the features and operating principles of the dmm and present the pertinent specifications of the instruments you should consider before making your selection.

How the dmm works

The analog instrument takes the metered quantity—voltage, current or resistance—and converts it into a voltage that is read on the meter in the proper values and terms. A precision voltage divider attenuates the test voltage so it is within the basic voltage range of the meter movement. The dmm is similar except that the moving-coil meter is replaced by an analog-to-digital converter whose output drives a digital display or readout.

Compare the block diagram of the Ballantine model 3/24 dmm (Fig. 1) with that of your Simpson 260, Triplett 630 or similar instrument and you'll see the resemblance. The dmm is basically a dc instrument with a scaled-down portion of the input voltage applied to the display through the analog-digital (A-D) converter. Resistance is measured by passing a constant current through the unknown resistor and measuring the voltage drop across it. Current is metered by measuring the voltage drop across a current shunt. When measuring ac voltage or current, a rectifier is inserted between the input attenuator and the A-D converter.

The A-D converter is the interface between the analog dc input and the digital display device. There are a number of different ways of converting an analog dc voltage to a digital value. Among these are: voltage-controlled oscillator, single-ramp and double-ramp integration, charge balancing and successive approximation. All have advantages and disadvantages that affect accuracy, resolution, and the rate at which the display can follow or track a changing input signal. The study of A-D converters as applied to dmm's is quite interesting; but is beyond the scope of this article. If enough of you are interested, we'll cover A-D converters in a future issue.

Displays

The three types of displays in com-

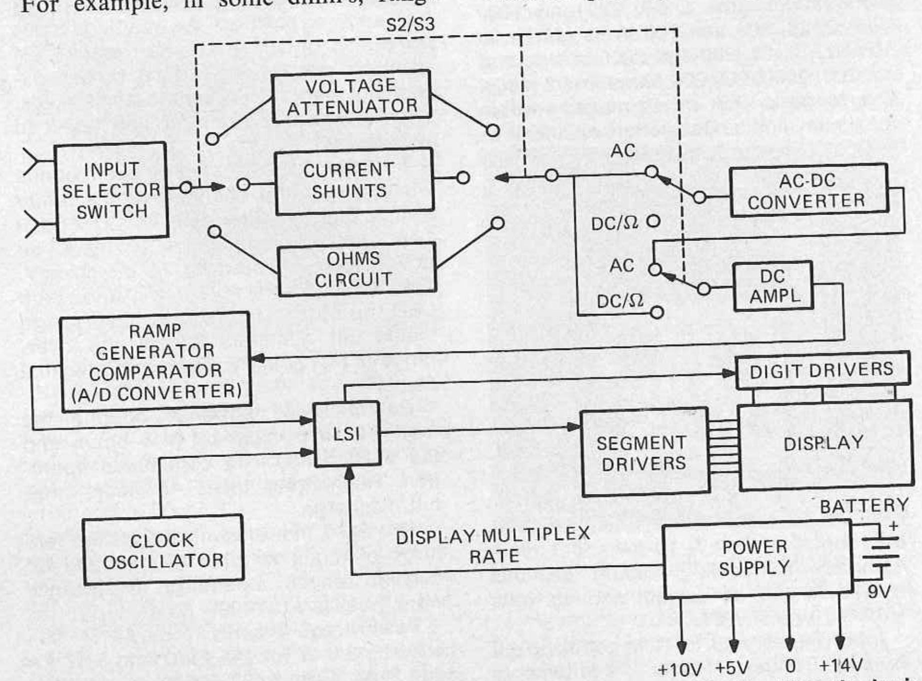

FIG. 1—BLOCK DIAGRAM OF BALLANTINE MODEL 3/24 digital multimeter. Note the basic similarities between this and an analog multimeter.

COMPUTER TERMINAL

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key sends a pulse to the 2-bit page counter which increases its count by 1 and advances the page controls 1 step.

In AUTO, the page will automatically change every time a character is entered into the last position in a page. The instant after the page change, the new page's home position is at the cursor position. The black "P" key can still be used to change pages in the AUTO mode.

In the AUTO STOP mode, the operation is identical except that the automatic page change can be stopped on any page desired by wiring from the PAGE switch to one of four points. This gives the operator the advantage of being able to receive data into memory in the automatic mode and retain it, say, in the first 3 pages, and work on the 4th page without writing over it, and not having to change any switches.

In either automatic mode, pressing the clear key (black "C") will have the same effect as entering data into memory in the last position. This results in a page change every time you clear a page in automatic. This gives the operator the advantage of clearing all 4 pages with 4 key strokes of the clear key.

Power supply

The power supply consists of two paralleled power transformers (for added current and packaging requirements), a +250 volt unregulated supply, two +5 volt regulated supplies, a -10 volt an -12 volt Zener regulated supply.

The +250 volt supply runs the self scan plasma display. One of the +5 volt supplies runs all logic on the main board, and the other runs the keyboard, modem/coupler board, and add on memory board. The -10 volt supply powers only the memory, while the -12 volt supply is connected to the UART and to the modem/coupler board to power the op-amp and XR210 demodulator.

Tape recorder memory

Using the tape record feature to record and play tapes from the CT-256, a medium quality (cost greater than $50) or better cassette recorder is advisable along with a good quality recording tape. Of course a good reel to reel machine would insure better data integrity but good results are obtainable from a cassette machine.

Making a recording is as simple as connecting a miniature phone plug to the jack on the back of the CT-256 and the other end to the "mic." input on your tape recorder. Once you have

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COMPUTER TERMINAL

(continued from page 91)

connected to the computer and the phone is in the top of the terminal, you can set your audio level. If the recorder used has an automatic level control, use it; if not, record at a "0" dB level (maximum undistorted level).

To play a tape back, the MODE switch should be in the IN/OUT position and the playback level should be twice as high as to cause the CARRIER LED to light. Make sure the baud rate is set for the proper data rate on the recording. The connection to the CT-256 stays the same, just change the connection on the recorder from MIC. input to LINE out or EXT. SPEAKER.

Assembly

Building a one page CT 256 includes parts installation and wiring of 2 large double sided circuit boards, one medium and one small single sided board. For a multipage unit there is a third large double sided board containing up to three additional pages of memory plus power switching circuitry. First, parts are installed on all boards. (Be sure to follow handling instructions for MOS chips.) Switches and connectors are wired to the main board before its installation. Once the main board is installed in the chassis, the power supply board is wired in, the 5 volt regulators are installed and wired, and wiring to the acoustic coupler board completed (the kit comes with the acoustic coupler board assembled, tested, adjusted and installed in top cover of main case). Next, the switches, connectors and displays are mounted.

The keyboard assembly should be completed at this time, including assembly and wiring of keyboard connector and cable.

After a final wiring check and inspection for solder bridges, connect keyboard to main unit, connect self scan display to the main board, and set MODE switch to LOCAL. Connect to a 115 Vac power source and turn power switch to on. The page 1 LED should light, and characters should be entered from the keyboard. If problems arise, isolate the problems and analyze them using information from the text and diagrams. An oscilloscope is indispensable in trouble shooting this type of circuitry.

The following items are available from MITS, Micro-Instrumentation Telemetry Systems Inc., 6328 Linn, N.E., Albuquerque, NM 87108.

Complete kit of all parts $495.00
Kit less cabinet & power supply $395.00
Assembled Terminal $695.00

TABLE OF CONTROL CHARACTERS AND THEIR FUNCTION IN CT256

Control G—Bell signal—used to alert operator—a ½ second 1-kHz audible tone.

Control H—Backspace—moves data in display one position to the right—does not change data in memory.

Control I—Advance space—moves data in display one position to the left—does not change data in memory.

Control J—Control character for line-feed. Since it has no meaning in the CT-256 it is decoded and entered into memory as a space.

Control K—Home—homes memory address counters to cursor position.

Control L—Home and clear—homes memory address and clears page.

Control M—Control character for carriage return—has no meaning for the CT256. It is decoded and entered into memory as a space.

Control N—Control character for cursor up—has no meaning for the CT256 and is decoded and entered into memory as a space.

Control O—Address function—sets up receive circuitry to use the next two characters to shift data address to a selected line and position. (See explanation of address function.)

DEFINITIONS FOR SWITCHES AND CONNECTORS

CT256 KEYBOARD

Special Key Functions (Top Row of Black Keys)

[←] **Shift left**—Moves data left one position (advance).

[H] **Home**—Returns data to 0, 0 position.

[→] **Shift right**—Moves data right one position (backspace).

[A] **Address**—Three keystrokes are necessary to select an address (an exact position on a page). Operator goes to desired position on the page by pressing [A], then presses the specific key for line position (1-16), then presses the third key which selects data position in the line (1-16). Characters are not entered until address sequence has been completed.

[C] **Clear**—Clears page and returns data to 0, 0 position (home).

[T] **Transmit**—Automatically transmits character in cursor position to computer and is used to transmit information line by line from the terminal memory to the computer. Since the terminal memory does not store carriage returns (end of line), the "@" symbol (shift [P]) is placed in memory at the end of each line. The "@" symbol stops transmission and the operator can manually press "return" to indicate end of line.

Other Special-Function Keys

Rept **Repeat**—Causes a character to be entered repeatedly. Press character key and Rept. key.

Rub Out **Deletes previous character.** When working with computer.

Shift **Allows entry of upper-case characters** indicated on keytops. Press shift, then upper-case character desired.

Ctrl **Control**—Allows entry of special control signals to computer, i.e., Ctrl and G is bell signal.

INDICATORS on FRONT of CT256.

P1-P4 Indicates page displayed.

Carrier Indicates when 2-kHz tone is received from computer via telephone or tape recording. **R-E**