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BUILD

SOL An Intelligent Computer Terminal

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Based on an 8080 MPU, this hobbyist's computer terminal can compete with most commercial units

THERE are essentially two types of video computer terminals in common use. The "dumb" terminal—little more than a "glass Teletype®"—is a simple data transmitter/receiver whose only stand-alone function is its use as a TV typewriter. The "intelligent" (also known as "smart") terminal, on the other hand, offers powerful stand-alone features. Built around a sophisticated microprocessor, intelligent terminals allow you to write, store, and edit programs for transmission to a computer or a hard-copy device. It also provides very powerful word processing at relatively low cost.

The SOL video terminal project presented here is one of the most advanced of intelligent terminals. It can interface with any mini- or microcomputer via its built-in RS-232 or 20-mA current-loop interfaces, in either serial or parallel format. It can also tie into a time-sharing computer via a telephone line and a modem (such as the Pennywhistle described in the March 1976 issue of POPULAR ELECTRONICS). In fact, it is even possible for two SOL terminals to communicate with each other without human supervision.

The key to SOL's versatility is its integral 8080 microprocessor (μP) chip. The μP operates on instructions stored in PROM's (programmable

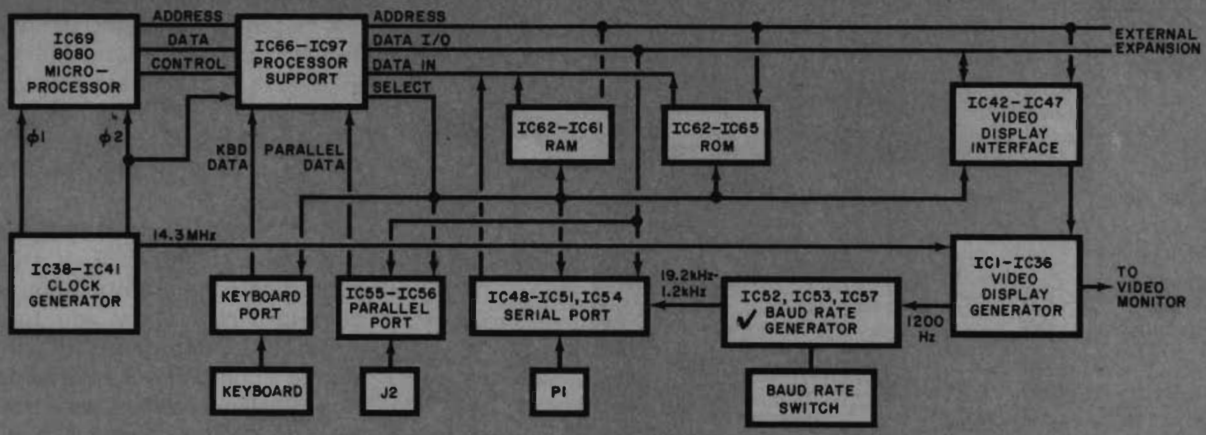


Fig. 1. Terminal accepts data from keyboard, parallel port, and RS-232 or 20-mA serial port. Output is 1 volt p-p for conventional TV requirements. Memory can be externally expanded to 65 k.

PARTS LIST

C1—10-pF disc capacitor
C2, C11, C21, C22—0.001-µF disc capacitor
C3, C7, C15, C16, C17, C18, C20, C27 through C63—0.1-µF disc capacitor
C4, C5—680-pF mica capacitor monolithic
C6—1.5-µF, 25-volt ceramic capacitor
C8, C13—1-µF, 35-volt dipped tantalum capacitor
C9, C10—15-µF, 20-volt dipped tantalum capacitor
C12—0.01-µF disc capacitor
C14, C23—680-pF disc capacitor
C19—100-µF, 16-volt upright aluminum electrolytic capacitor
C24—0.1-µF Mylar tubular capacitor
C25—0.001-µF Mylar tubular capacitor
C26—0.01-µF Mylar tubular capacitor
D1, D2, D4 through D9—1N4148 diode
D3—5.1-volt, 1-watt zener diode (1N5231B or similar)
IC1, IC8, IC11, IC12, IC23, IC39, IC73, IC74—74LS175N quad latch IC
IC2, IC79—74LS20N dual 4-input NAND gate IC
IC3—74LS86N quad exclusive-OR gate IC
IC4, IC42, IC45, IC47, IC71, IC72, IC94—74LS02N quad 2-input NOR gate IC
IC5, IC51—7406N open-collector hex inverter IC
IC6—DC4049AE CMOS hex inverter IC
IC7, IC14, IC25, IC26, IC53, IC57—74LS161 or 74LS163 4-bit synchronous counter IC
IC9—6575 MOS character generator IC
IC10—74166N 8-bit parallel-in shift register IC
IC13, IC24—CD4029AE 4-bit up/down counter IC
IC15—74L161, 74L163, or 93L16 4-bit synchronous counter IC (do not substitute)
IC16, IC93—74LS10N triple 3-input NAND gate IC
IC17—CD4001AE CMOS quad 2-input NOR gate IC
IC18 through IC21, IC29 through IC32—21L01-1 or 91L02APC MOS 1024-bit RAM IC
IC22, IC33, IC40, IC46, IC66, IC67, IC68, IC75, IC80, IC81, IC82—8T97 hex tristate buffer IC
IC27, IC48, IC78, IC95—74LS109N dual JK flip-flop IC
IC28, IC50, IC89, IC96—74LS04N hex inverter IC
IC34, IC35, IC36—74LS157N quad 2-input data selector IC
IC37—74H00N high-speed quad 2-input NAND gate IC (do not substitute)
IC38—74S04N Schottky hex inverter IC (do not substitute)
IC41—MH0026P MOS clock driver IC
IC43, IC87, IC90—74LS74N dual D flip-flop IC
IC44, IC83, IC86—74LS00N quad 2-input NAND gate IC
IC49, IC88—74LS08N quad 2-input AND gate IC
IC52—CD4046AE CMOS phase-locked loop IC
IC54—TR1602B, AY-5-1013, or S1883 UART IC
IC55, IC56—74173N quad tristate latch IC
IC58 through IC61—21L01 or 91L01PC 256 × 4 MOS RAM IC
IC62, IC63, IC64, IC65—S5204A or MM5204Q 512 × 8 MOS erasable PROM IC (optional; write to address below for details)
IC69—8080, 8080A, or 9080A microprocessor IC
IC70, IC77, IC84, IC91—74LS253N dual 4-input tristate data selector IC
IC76—DM8836N quad 2-input NOR gate IC
IC85, IC92—74LS155 dual 2-to-4 line decoder IC
J1—Right-angle PC mount (AMP206584-1 or DB25S)
Q1, Q2, Q3—2N2907 transistor
The following resistors are ¼-watt, 10% tolerance:
R1, R2—330 ohms
R3, R9, R10, R21, R23 through R30, R80—10,000 ohms
R4, R5, R6, R14 through R20, R22, R31 through R35, R37, R39, R41, R43, R45, R46, R48, R52, R56, R57, R58, R65, R72, R73, R74, R76, R77, R78, R79, R82, R83, R84, R89 through R98, R100, R101—1500 ohms
R7, R8—47 ohms
R36, R67, R68, R99—4700 ohms
R38, R40, R42, R47, R49, R53, R55—2200 ohms
R44, R60, R81—3300 ohms
R50, R54, R64, R87—100 ohms
R51—200 ohms
R59, R63—33,000 ohms
R61, R62, R66—1000 ohms
R69—15,000 ohms
R70, R71, R113—100,000 ohms
R75, R88—3.3 megohms
R85—75 ohms
R103, R105, R107, R109, R110, R111, R112—8200 ohms
R106, R108—39,000 ohms
R11, R12, R13—100-ohm 1-watt, 10% tolerance resistor
R86—330-ohm, ½-watt, 10% tolerance resistor
R102, R104—50,000-ohm trimmer potentiometer (Bourns No. 3352-1-503 or similar)
S1 through S4—Four-position dual in-line switch
S5—Momentary-action spst switch
S6—Single-pole, seven-position rotary switch
S7, S8, S9—Spst switch
S10—Spdt switch
XTAL—14.318-MHz, 0.01% or better tolerance, series-resonant crystal in HC18U case
Misc.—Two 40-pin, five 24-pin, 54 16-pin, and 31 14-pin IC sockets (optional); 75-ohm coaxial cable; TV monitor; ASCII keyboard; power supply; suitable chassis; mounting hardware; hookup wire; solder; etc.

Note: The following items are available from Processor Technology Corp., 6200 Hollis St., Emeryville, CA 94608: Complete SOL-PC kit of parts (does not include case, power supply, or keyboard) for $297.00. Available separately are SOL-PCB etched and drilled printed circuit board for $40.00; SOL-SS set of IC sockets for $40.00; and SOL-FAN fan for $20.00. A complete kit that includes all parts, pc board, power supply, ASCII keyboard, all cables and plugs, and a case is available for $497.00; specify kit SOL-1. **Free copies of the complete schematic, etching and drilling guide, and component placement guide are available from the same source on request when accompanied by a self-addressed stamped (26¢) envelope (9" × 12").**

read-only memories). In its basic configuration, the SOL terminal consists of a printed circuit assembly that contains the μP, 512 eight-bit bytes of PROM, 2048 eight-bit words of RAM (random-access memory), 1024-character video display generator, keyboard interface, serial and parallel interfaces for connection to external devices, and an edge connector for memory expansion. All you add are a power supply, TV receiver or video monitor, ASCII keyboard, and a case.

Since the SOL terminal is 8080 based, its memory capability can be expanded to 65k bytes. Hence, one might ask, is the SOL an intelligent terminal or a powerful microcomputer? In essence, it is both.

How It Works. The complete schematic diagram for the SOL terminal is much too large to be reproduced in this article. Therefore, a complete schematic, an etching and drilling guide, and component layout diagram for the printed circuit board are available on request simply by sending a self-addressed stamped (26¢) envelope (9"×12") to the source given in the Parts List.

The block diagram shown in Fig. 1 will be used to explain circuit operation. Notice the similarity of this diagram to that of a conventional 8080 microcomputer. The 8080 (or 8080A or 9080A) microprocessor, *IC69*, is the "heart" of the terminal. It is supported by *IC66* through *IC97*, which include address and data line drivers and selectors; "wait state" timers; flag latches for data ports; and partial address decoding. Both address and data I/O (input/output) ports are available for expansion using currently available 8080-type memory cards.

As many as four PROMS (*IC62* through *IC65*) allow up to 2048 bytes of program to be installed in the terminal. Up to 512 bytes of RAM can also be installed and are designated *IC58* through *IC61*.

SOL TERMINAL SPECIFICATIONS

Display: 16 lines of 64 characters per line. Black characters on white background or reverse.

Character set: 96 printable ASCII upper-and lower-case characters. Plus 32 control characters (optional).

Display position: Continuously adjustable both horizontally and vertically.

Cursor: Solid video inversion (switch selectable blink), cursors are programmable.

Serial interface: RS-232 and 20-mA current loop, 75 to 9600 baud, synchronous.

Parallel interface: Eight data bits for input and output; output bus is tri-state for bidirectional interfaces; levels are standard TTL.

Keyboard interface: Seven-level ASCII encoded, TTL levels; requires strobe pulse with data stable for approximately 100 μs following positive edge.

Microprocessor: 8080, 8080A, or 9080A.

On-card memory: 512 bytes PROM (expandable to 2048 bytes), 1280 bytes RAM (expandable to 1560 bytes).

External Memory: Expandable to 56k bytes total ROM, PROM, and RAM.

Signal output: 1.0 to 2.5 volts peak-to-peak with composite negative sync; nominal bandwith is 7 MHz.

Power required: +5 volts at 2.5 amperes, +12 volts at 150 mA, and −12 volts at 200 mA; all buses must be well regulated.

The heart of the video display section is character generator ROM *IC9*. The generator provides both upper- and lower-case characters in a 7 × 9 dot matrix format. Descenders on lower-case characters g, j, p, q, and y go below the base line to provide true typewriter character formatting. The remainder of the IC's in the video section (*IC1* through *IC36*) produce the horizontal and vertical sync, cursor options, video inversion (black characters on white background), and all video "handshake" requirements.

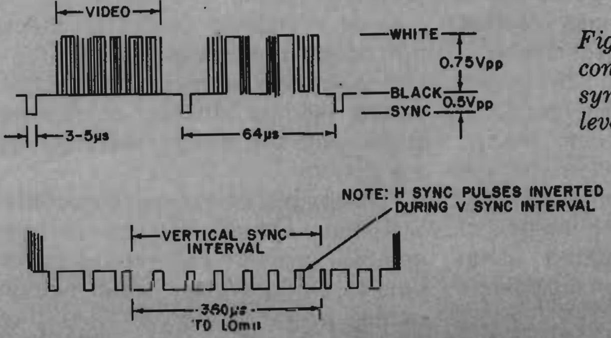


Fig. 2 Video output is conventional with negative sync and 1-volt p-p signal level.

The video output has a maximum bandwidth of 7.15 MHz. It contains a composite sync to allow operation with any conventional video monitor or monochrome TV receiver converted for video input (Fig. 2). Color TV receiver CRT's may not be capable of providing the resolution required for a clean video display, although the authors have obtained acceptable results using a type-approved r-f modulator to feed color receivers through the antenna input. (CAUTION: Do *not* use a transformerless video monitor or TV receiver unless a line-isolating transformer is installed.)

The *IC54* UART is used in the terminal for data transmission and reception. It is supported by *IC48* and *IC51*. Clock pulses for the UART are provided by the baud-rate generator made up of *IC52, IC53,* and *IC57*. Phase-locked loop *IC52* operates with dividers to produce the required clock signals. A switch is provided for setting the baud rate for 75, 110, 150, 300, 600, 1200, 2400, 4800, or 9600 baud (data bits per second). The serial port has both RS-232 and 20-mA current-loop provisions.

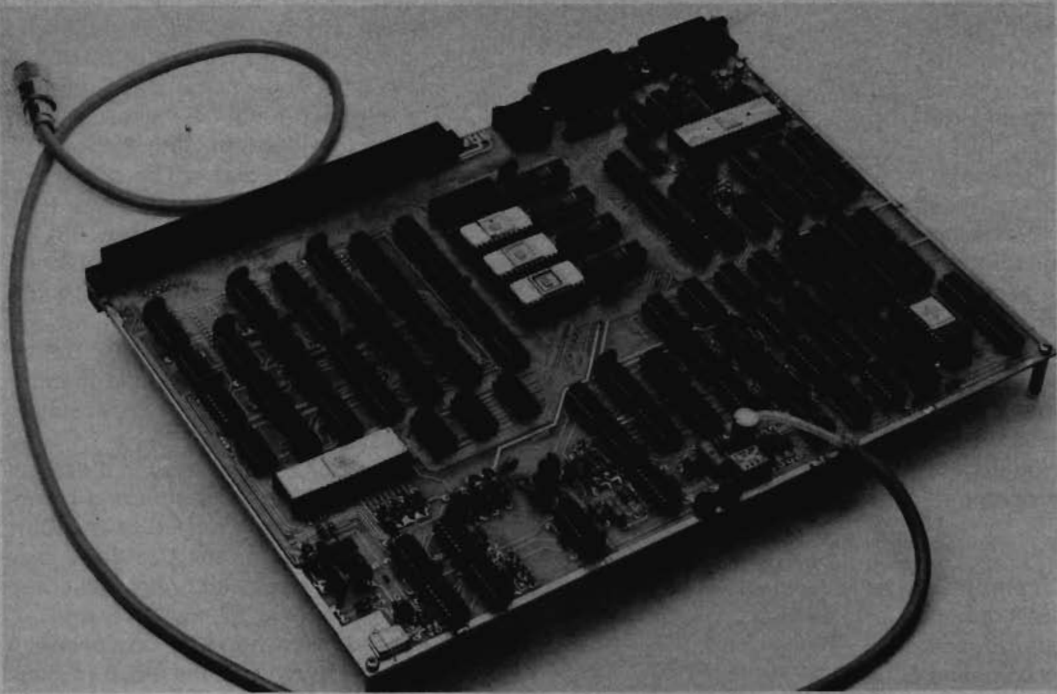
The parallel port consists of an eight-bit latch made up of *IC55* and *IC56*. These IC's have tristate outputs that enable their use with a bidirectional parallel data channel if desired. Signals are eight data bits wide at standard TTL levels at the input and output.

The ASCII keyboard connects to the main terminal board by a single connector that provides power to the keyboard and accepts signals from the keys. The interface requires seven-level ASCII at TTL levels and a strobe pulse with the data stable for approximately 100 μs following the positive edge.

Power for the main board must be 5 volts dc at 2.5 amperes, +12 volts at 150 mA, and −12 volts at 200 mA. The power bus lines must be well regulated.

Construction. Since the printed circuit board measures 13" × 11" (33 × 28 cm) and has numerous traces and pads that require careful registration, home fabrication of the board is not recommended unless you are highly experienced in making complex double-sided boards. Once you have the board and are ready to start mounting components, save IC installation for the last.

Start wiring the board by mounting



Large connector at left rear of assembled circuit board assembly is for external memory; coax cable is for composite video output. All input and output connectors are on rear edge.

IC sockets (recommended for all IC's to make removal and replacement easy) in place. Next, mount and solder into place the resistors, capacitors, diodes, and transistors. Then mount the baud rate switch and connectors flush to the surface of the board; make sure they do not sit askew after soldering them down.

Once the crystal is mounted and soldered into place, pass a length of bare hookup wire over its case and into the holes flanking the case. Solder the wire to the crystal's case and board pads. Install and solder into place the coaxial cable for the terminal's output.

Carefully check the board assembly for poor soldered connections, solder bridges between closely spaced pads and traces, and proper polarization of diodes and capacitors and basing of the transistors.

Checkout. Before installing any IC's, power up the circuit board assembly to verify that no short circuits exist. Measure the potential across zener diode *D3*; it should be −5 volts. Check the fine foil traces near *R85* (at the video output) for short circuits on the +12-volt line. If everything checks out, turn off the power.

Insert *IC37* through *IC41* in their sockets, making sure you properly orient them. Install jumpers from pad A to pad B and pad D to pad E (next to *IC37*). Turn on the power and use an oscilloscope to check the 47-ohm resistors next to *IC41* for the clock pulses. When you obtain the pulses, turn off the power.

Install *IC1* through *IC36*. Be particularly careful when handling *IC9* to avoid static discharges. After removing this IC from its protective foam carrier, be sure to touch the pc board with your other hand *before* bringing the IC into contact with its socket. Seat the IC carefully in its socket and gently press it home. (Note: If you encounter excessive resistance when trying to install *IC9*, replace the IC in its foam carrier. Then loosen the socket pin receptacles by repeatedly inserting and removing a non-MOS IC or piece of bare 24 gauge wire.) Install *IC9*.

Set horizontal and vertical sync controls *R104* and *R102* to midposition and the four-position dual in-line switch so that *S1* and *S4* are off and *S2* and *S3* are on. Connect SOL's video output cable to the video monitor and turn on the power to both monitor and terminal board. Displayed on the screen should be at least one line of random characters and white cursor blocks. Adjust the V and H controls on the terminal board for proper sync and the contrast and brightness controls on the monitor for the best display.

Set *S3* to off and *S4* to on; the cursor should flash at a slow rate. Set *S2* to off; the background should change from black to white. Set *S1* to on; the control characters (symbols or abbreviations, depending on the type of character generator being used) should disappear. Turn off the board's power supply.

Install *IC42* through *IC50* and *IC66* through *IC97*. Practice the same precautions for *IC69*, the microprocessor chip, that you took for *IC9* above. Connect the "wait state" jumper at *IC71* from pad W to pad 1.

With the video monitor still connected to the terminal and operational, turn on the board's power. The CRT screen should display one or more lines of alternating 9 and "null" characters and should flicker every few seconds. This indicates that the µP is working. If there is any doubt, briefly operate the RESET switch. If you observe no activity on the screen, turn off and remove power from the board and check that all IC's are in their proper sockets and properly oriented.

Install *IC52* through *IC61* and program PROM *IC62*. Use the same precautions detailed above for *IC9* and *IC69* when handling and installing *IC54*, *IC58* through *IC61*, and *IC62*. Make sure that the socket for UART *IC54* is not too tight. If you encounter difficulties during insertion, use a non-MOS IC or 24 gauge wire to loosen the socket pin receptacles.

Once everything seems to check out, power up the board. If the program is running properly, the monitor screen should display a blanked screen with the proper "message" at the bottom.

This completes construction of the SOL video terminal. You can now add an ASCII keyboard and hook up to the outside world via the serial and/or parallel ports. ◈