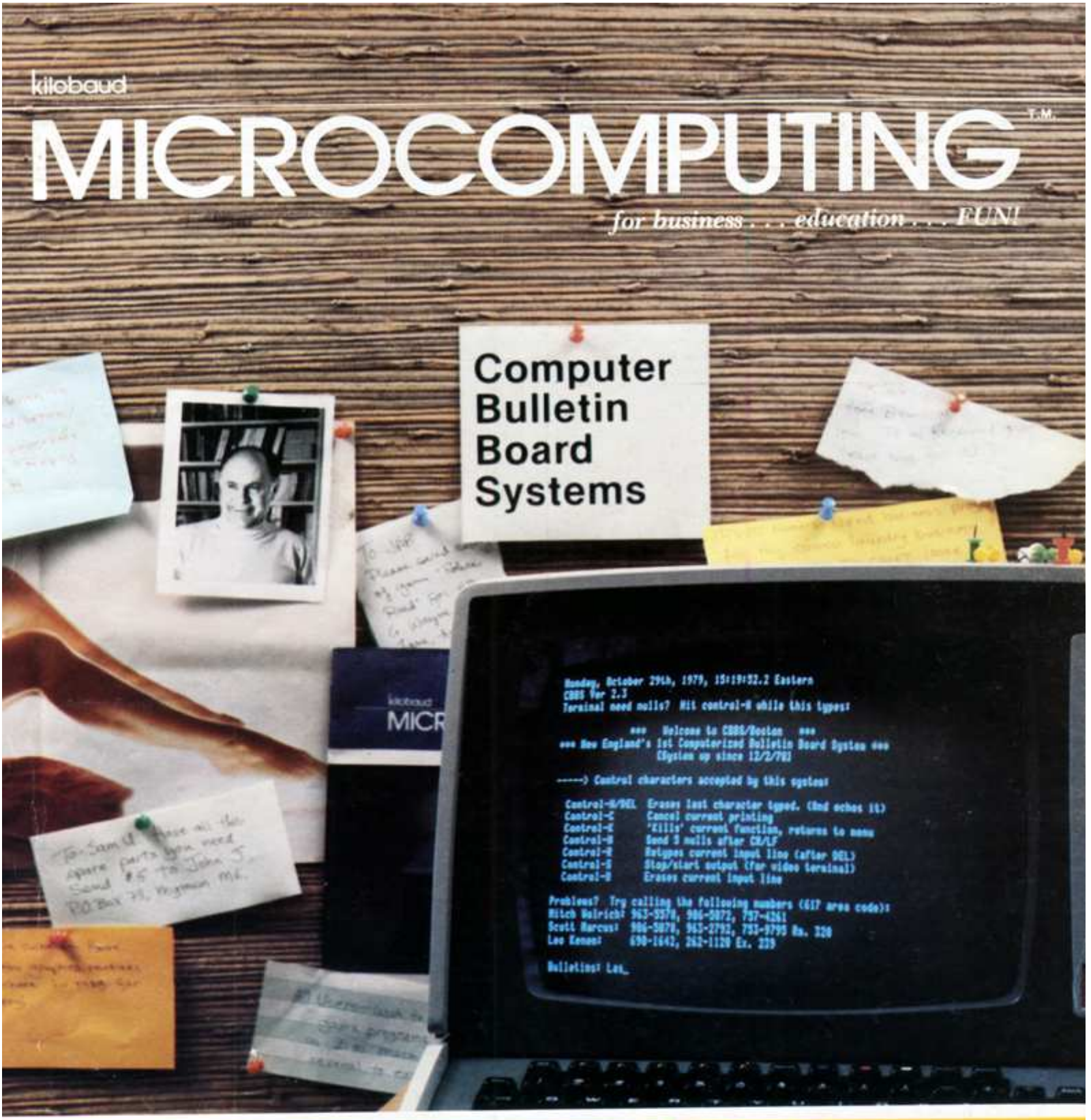
kilobaud

MICROCOMPUTING™

for business . . . education . . . FUN!



In This Issue—27 Articles

Including:

Complete Table of Contents on page 5.

01
0 74470 65945 0

TM990/189 University Board

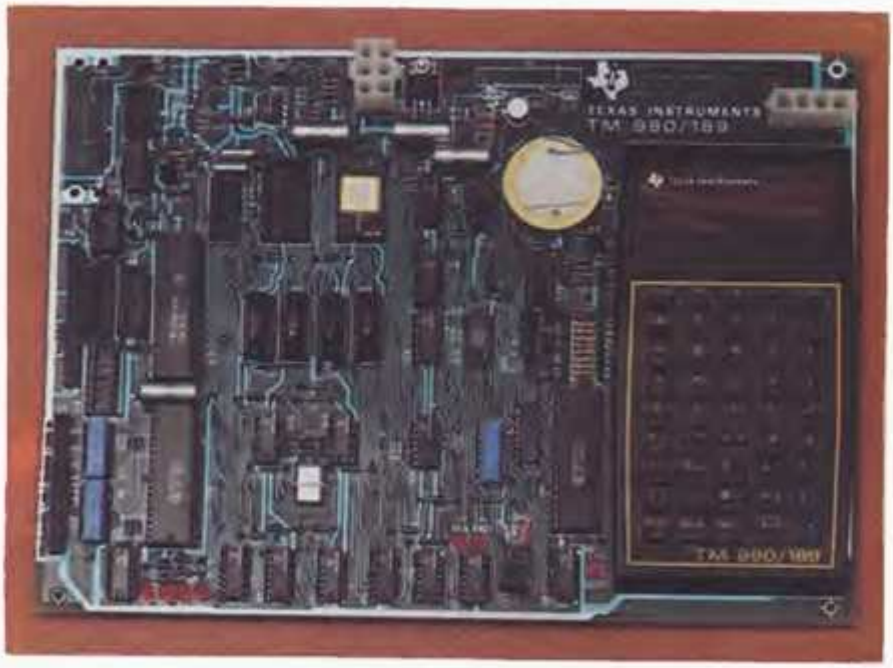
Is Texas Instruments' TM990/189 a microprocessor's microprocessor?

John Caulfield KOFUZ
2211 W. 119th Terrace
Leawood KS 66209

I don't know how many other hobbyists wait as long as I do to really get into something, but my major contact with the microcomputer world has been to read about it and just be satisfied, in a vicarious sort of way, with the fascination of the microprocessor. I've always thought that one of these days there'll emerge a microprocessor's microprocessor that I'll really learn on, become a veritable genius at and live happily ever after.

Texas Instruments' TM990/189 University Board comes closest to fitting my scenario. Time will tell if it emerges as a microprocessor's microprocessor, but you pay your money, you take your chances. TI has provided an approach that, for me, does it all: alphanumeric keyboard, display, monitor, assembler, audio cassette capability, EIA and TTY interface options, programmable I/O controller, addressable LEDs, a squeaker speaker (piezoelectric disk), matching power supply and a versatile 16 bit CPU, the TMS 9980.

One of its biggest drawing cards is 570 pages of a self-paced tutorial text. My previous reading about this sport has made me conscious of a checklist of features . . . TI seems to have packaged about all my novice mind and budget could imagine into its University Board.



TM990/189 University Board. (Photos courtesy of Texas Instruments)

Let's look at the features of this 8 3/16 × 11 inch (20.8 cm × 27.9 cm) printed circuit board, which is three-hole punched so you can slip it into a three-ring binder.

The brains of the board is a TMS9980, the microprocessor. This is a software-compatible member of TI's 9900 family of microprocessors. It is a single chip CPU that has an 8 bit data bus, on-chip clock and is a 40-pin device. Wait a minute, I can hear you saying, I thought this was a 16 bit CPU. Well, it is.

The TMS9980 has an external 8 bit data bus, but internally it has a 16 bit data bus. There's an 8 bit latch right inside the 9980. Each 8 bit data chunk that enters the 9980 via the external eight data bus pins is immediately paired up with the preceding eight bits. The combined 8 bit values form the 16 bit internal word.

Monitor Program

The EPROM resident monitor, called UNIBUG, enables you to communicate with the TMS9980. The monitor program provides fifteen commands and seven subroutines. The UNIBUG commands are shown in Table 1.

In addition to the monitor commands, there are seven utility subroutines that perform I/O functions. These subroutines are called through the XOP (extended operation) assembly-language instruction. Table 2 shows these user-accessible utilities.

The monitor program has a roommate inside the 4K PROM, a two character symbolic assembler. After entry of the A command from the keyboard, the monitor passes program control to the resident symbolic assembler. The assembler program interprets assembly-language source statements into object code. This saves you the laborious, and often error-prone, task of looking up hexadecimal op codes for any

Input	Results
A	Assembler Execute
B	Assembler Execute with current symbol table
C	CRU Inspect/Change
D	Dump memory to cassette
E	Execute to breakpoint
F	Status Register Inspect/Change
J	Jump to EPROM
L	Load memory from cassette
M	Memory Inspect/Change
P	Program Counter Inspect/Change
R	Workspace register Inspect/Change
S	Single Step
T	"Typewriter" program
W	Workspace pointer Inspect/Change
Ret	New Line request

Table 1. UNIBUG commands.

TM990/519 power supply.

one of the 69 instructions of the TMS9980, plus formatting them for various addressing modes. The resident assembler will save those of us in the microcomputer novitiate anywhere from two to three light-years of time and a like amount of debugging frustration.

Just like the "big ole computers," the University Board assembler has several versatile assembler directives (see Table 3).

Also, labels and comments can be used. Labels may consist of one or two characters—the first character must be alphabetic; the second character may be alphanumeric. Comments can be part of the source statement and may include any printable character.

Keyboard

So how do I, the lowly human, talk to this fantastic monitor, symbolic assembler and CPU? Simple, through the integral keyboard. Any breathing electronics jock knows that TI is in the calculator business. Well, they very niftily took one of their 45-key keyboards and a ten digit seven-segment display and interfaced it to the University Board. The 45 keys operate in both a shifted and unshifted mode. The keys are shifted when you depress the SHIFT key; in this mode, a shift LED is illuminated.

The keyboard display consists of ten seven-segment LEDs. All of the letters of the alphabet, numbers 0-9 and punctuations .''#.;:,?! + − ()@/>%^*'$=< are available. How can all this be done with seven segments?

TI uses a stylized font—which means that some of the letters and punctuations will look rather strange at first (see Example 1, which demonstrates a v, K and M). You may grow to prefer some of the stylized letters and adapt them to your everyday life. In fact, it will help keep your hobby just esoteric enough so you can still "amaze your friends."

Although the display is ten digits, it is capable of displaying any nine contiguous characters of a maximum 64 character line. The "shift display left" and "shift display right" keys rotate the display six characters at a time in a ring buffer to enable viewing the 64 character line.

If you are an advanced enthusiast and have an EIA or TTY terminal, you can populate the EIA or TTY options on the TM990/189. The printed circuit board is predrilled and etched for the few needed parts, and the *User's Guide* details their installations.

v SHOWS UP AS ⊔

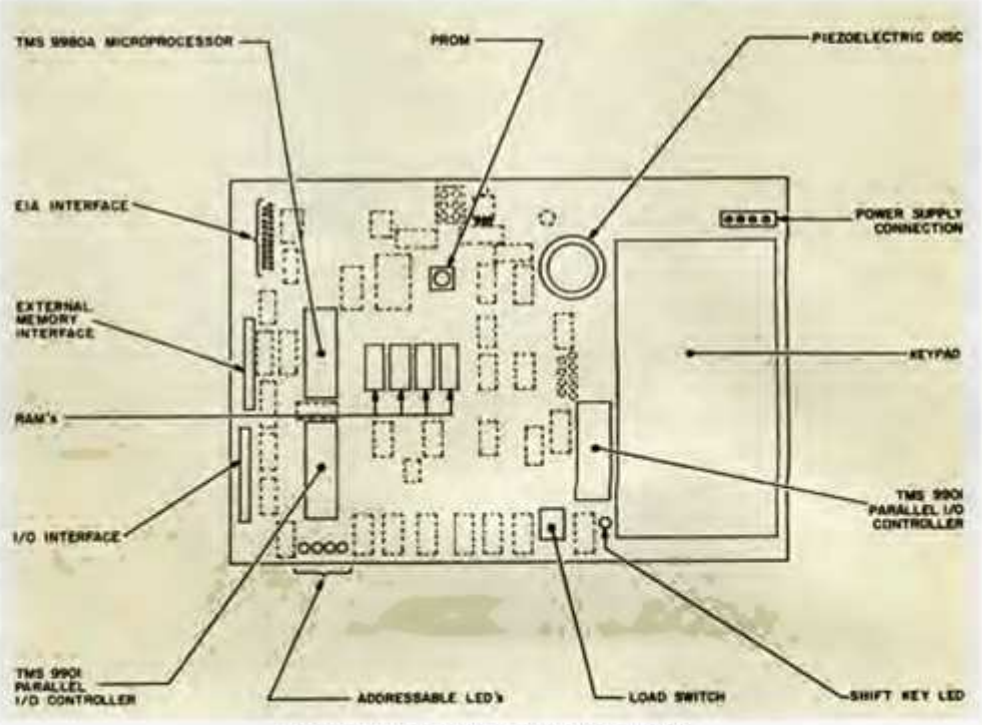
K SHOWS UP AS ⊦

M SHOWS UP AS ⊓

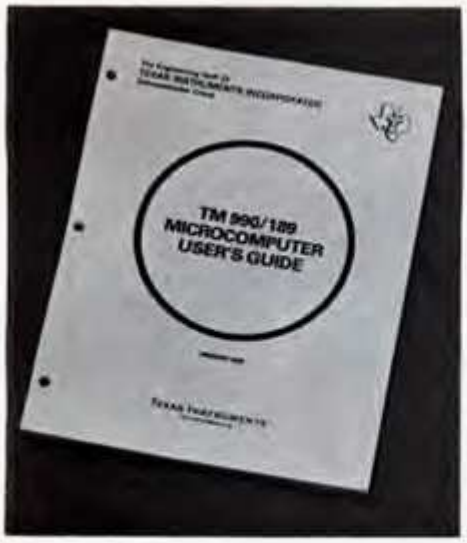
Example 1.

Memory

Every microcomputer system, by definition, has memory. The TM990/189 comes



Schematic depiction of power supply.



TM990/189 User's Guide.

with 1K bytes of RAM expandable on-board to 2K, and 4K bytes of PROM expandable on-board to 6K. The 4K PROM contains the UNIBUG Monitor and Symbolic Assembler. The user can add either a 1K × 8 or 2K × 8 EPROM in the expansion EPROM socket provided.

For memory expansion beyond what is on the board, all key address and data lines are brought to a 40-pin connector where additional memory may be interfaced. TI provides a bus expansion interface on the printed circuit board, which you populate to interface to off-board memory. This option will enable you to utilize the total memory address capability of the TM9980 CPU, 16K bytes.

The University Board may be interfaced to an audio cassette for mass program storage. The *User's Guide* gives the connection details and parts required. To accomplish this, again, the printed circuit board has the etches, but the user supplies the parts—a relay and a transient protection diode.

Ever since I first started reading about microprocessors, I've wondered about I/O, or, how can I get this circuit to actually do something? The University Board has two main vehicles to the outside workaday world. First, there is memory-mapped I/O that treats I/O as a memory location. Almost all microcomputer systems have this capability; the TMS9980 CPU is no exception.

CRU Interface

The second I/O vehicle is the communications register unit, or CRU. The CRU is a definite distinguishing factor of TI's TMS9900 family. It provides for a serial transfer of one or more bits in or out of the CPU via two dedicated pins on the 9980—CRUIN and CRUOUT. A clock, CRUCLK, is used as a time strobe to coordinate data transfers. Use of the CRU does not subtract from any available memory locations, and it is separate from the data bus.

The major advantage of the CRU is "bit diddling." A single bit (or multiple bits up to 16) may be changed in the CRU output scheme. A single bit is all that is necessary to monitor or change the status of a motor, relay, switch, etc., i.e., the outside world.

There are five instructions that program the CRU interface:

LDCR—Enables the user to load from memory a pattern of 1 to 16 bits and serially transmit this pattern through the CRUOUT pin.

STCR—Enables the user to store into memory a pattern of 1 to 16 bits obtained serially at the CRUIN pin.

SBO—Sends a "logical one" through the CRUOUT pin.

SBZ—Sends a "logical zero" through the CRUOUT pin.

TB—Tests the value at the CRUIN pin and reflects the test results in the equal bit of the Status Register.

The last three instructions, SBO, SBZ and TB, are the real aids to the control applications. They enable you to turn on and off loads as well as check their status. The CRU becomes a fascinating concept beyond the typical memory-mapped I/O systems.

Power Requirements

The nominal power requirement with the on-board memory options fully populated is +5 V @700 mA, +12 V @100 mA and −12 V @16 mA. Luckily for me, TI supplies a matching fossil-fuel-fired power plant, the TM990/519, to supply the required "juice." If you start adding off-board options, you'll soon run out of power supply. So keep your power budget in mind with respect to the TM990/519's capabilities.

Documentation

A major ingredient of the TM990/189 University Board package is the tutorial text, entitled *Introduction to Microprocessors—Hardware and Software.* This 500 plus page document stepped me through every inch of the system. It makes liberal use of illustrations, understandable and practical examples, and it is directly keyed to the TM990/189 for immediate hands-on reinforcement. (I especially enjoyed the illustration that built up to a Morse code translator. With a little bit of tweaking I'll be able to use it with my ham radio!)

The text is simple enough for the relative novice to use, but the book's authors (George Goode and Associates, Dallas, Texas) point out that the book can also be used as the central text in an introductory three-hour college course on microcomputer systems. The chapter titles are:

1. Overview of Computers, Microprocessors and Microcomputers
2. Arithmetic, Logic and the ALU
3. Introduction to Computer Addressing and Program Development
4. Assembly Language
5. Memory Systems
6. Input/Output Concepts
7. Input/Output Design
8. Modular Programming
9. Software Engineering
10. Product Development

In addition to the tutorial text, TI supplies a well-written 150 page user's guide. The documentation is of professional quality and highly readable.

The assembled board (no kits), tutorial text and *User's Guide* is $299. The tutorial text alone is $19.95; *User's Guide*, $5.95; TM990/519 power supply, $65. ■

TM990/189 tutorial text.

XOP#	Function
8	Write one hexadecimal character to the terminal
9	Read hexadecimal word from the terminal
10	Write four hex characters to the terminal
11	Echo character
12	Write one character to the terminal
13	Read one character from the terminal
14	Write a message to the terminal

Table 2. Utility subroutines.

Inputs	Functions
AORG	Absolute origin of the statement
BSS	Block of memory reserved with starting symbol
DATA	Sixteen bits of immediate value
END	End of program, exit to monitor, load program counter
EQU	Symbol equated to value in operand
TEXT	String of ASCII coded characters

Table 3. Symbolic assembler.