The Altair 8800 Computer
The Start of the Personal Computer Revolution

Stephen A. Edwards

April 11, 2018
Announcing
a new era
of integrated
electronics

A micro-
programmable
computer
on a chip!

Intel introduces an integrated CPU complete with a 4-bit parallel adder, sixteen 4-bit registers, an accumulator, and a push-down stack on one chip. It's one of a family of four new ICs which comprise the MCS-4 microcomputer system — the first system to bring you the power and flexibility of a dedicated general-purpose computer at low cost in as few as two dual-in-line packages.

MCS-4 systems provide complete computing and control functions for test systems, data terminals, billing machines, measuring systems, numeric control systems, and process control systems.

The heart of any MCS-4 system is a Type 4004 CPU, which includes a powerful set of 45 instructions. Adding one or more Type 4001 ROMs for program storage and data tables gives you a fully functioning microprogrammed computer. To this you may add Type 4002 RAMs for read/write memory and Type 4003 registers to expand the output ports.

Using no circuitry other than ICs from this family of four, you can create a system with 4096 6-bit bytes of ROM storage and 5120 bits of RAM storage. When you require rapid turn-around or need only a few systems, Intel's versatile and repro-programmable ROM, Type 1701, may be substituted for the Type 4001 mask-programmed ROM.

MCS-4 systems interface easily with switches, keyboards, displays, teleprinters, printers, readers, A-D converters and other popular peripherals.

The MCS-4 family is now in stock at Intel's Santa Clara headquarters and at our marketing headquarters in Europe and Japan. In the U.S., contact your local Intel representative for technical information and literature in Europe, contact Intel at Avenue Louise 276, B-1050 Brussels, Belgium; Phone 490003. In Japan, contact Intel Japan, Inc., Parkside Flat Bldg. No. 4-3-2, Sendagaya, Shinjuku Ku, Tokyo 151; Phone 03-523-6747.

Intel Corporation now produces microcomputers, memory devices and memory systems at 3000 Bowers Avenue, Santa Clara, Calif. 95051; Phone (408) 245-7751.

1971: Intel's 4004. The first single-chip processor. 4-bit
1972: Intel’s 8-bit 8008
1974 Ford Pinto

Base price $2292
Consumer Guide’s Best Buy Subcompact of the Year
1974: Intel’s 8-bit 8080

Initial price: $360

Roughly $1900 in 2018
PROJECT BREAKTHROUGH!
World’s First Minicomputer Kit to Rival Commercial Models...
“ALTAIR 8800”  SAVE OVER $1000

ALSO IN THIS ISSUE:
• An Under-$90 Scientific Calculator Project
• CCD’s—TV Camera Tube Successor?
• Thyristor-Controlled Photoflashers

TEST REPORTS:
Technics 200 Speaker System
Pioneer RT-1011 Open-Reel Recorder
Tram Diamond-40 CB AM Transceiver
Edmund Scientific “Kirlian” Photo Kit
Hewlett-Packard 5381 Frequency Counter
EXCLUSIVE!

ALTAIR 8800
The most powerful minicomputer project ever presented—can be built for under $400

BY H. EDWARD ROBERTS AND WILLIAM YATES
1974: Complete kit: $397; Assembled and tested: $498
Sold thousands: 2500 by May 1975; 5000 by August.
“Roberts was able to acquire the new and powerful Intel 8080 CPU for $75 each in large volume, when they normally sold for over $300 each. These cosmetically blemished chips worked just as well as the more expensive ones, and allowed the Altair 8800 to be released at a very low price.”

—oldcomputers.net
Fig. 1. Basic block diagram of computer parts and operation.
Intel 8080 Block Diagram
Fig. 3. The logic associated with the CPU (ICI) is shown at left. All of the buffers and latches are on a single pc board. Connecting wiring is through a 100-line buss.
Altair 8800 CPU Board

Power regulator, 2 MHz crystal, 8080 CPU, 8212 system status latch
Fig. 5. The basic memory contains up to eight 256 x 4 RAM's.
1K RAM Board

8 Intel 8101 256 × 4-bit static RAMs
Altair 8800 Front Panel
Altair 8800 with Terminal
1975: MITS ALTAIR BASIC

1964: BASIC language developed at Dartmouth

$150 (4K) or $200 (8K)

10 INPUT A,B
20 IF A<=B THEN 50
30 PRINT "A IS BIGGER"
40 GOTO 10
50 IF A<B THEN 80
60 PRINT "THEY ARE THE SAME"
70 GOTO 10
80 PRINT "B IS BIGGER"
90 GOTO 10

10 Read about Altair in *Popular Electronics*
20 Contact MITS founder Ed Roberts
30 Offer to demo BASIC interpreter
40 Roberts agrees to meet
50 Write interpreter on Harvard’s PDP-10
60 Present (working) interpreter to Roberts
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If any immediate problems with MITS software are encountered, feel free to give us a call at (505) 265-7553. The Software Department is at Ext. 3; and the joint authors of the ALTAIR BASIC Interpreter, Bill Gates, Paul Allen and Monte Davidoff, will be glad to assist you.

—ALTAIR BASIC reference manual, 1975
### The S-100 Bus

<table>
<thead>
<tr>
<th>Count</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>address lines (originally 16)</td>
</tr>
<tr>
<td>8</td>
<td>data-in lines</td>
</tr>
<tr>
<td>8</td>
<td>data-out lines</td>
</tr>
<tr>
<td>8</td>
<td>status lines</td>
</tr>
<tr>
<td>11</td>
<td>control lines</td>
</tr>
<tr>
<td>8</td>
<td>interrupt lines</td>
</tr>
<tr>
<td>8</td>
<td>DMA lines</td>
</tr>
<tr>
<td>16</td>
<td>“utility” lines</td>
</tr>
<tr>
<td>9</td>
<td>power lines ($\pm 8V$, $\pm 16V$)</td>
</tr>
<tr>
<td>100</td>
<td>pins</td>
</tr>
</tbody>
</table>

Standardized as IEEE 696–1983

Cromemco SCC, c. 1978
December 1975: The IMSAI 8080. Kit w/ 1K, $439

IMSIAI AND ALTAIR OWNERS

INTERCHANGEABLE CPU, MEMORY, and I/O BOARDS

<table>
<thead>
<tr>
<th>Component</th>
<th>Kit</th>
<th>Assembled</th>
</tr>
</thead>
<tbody>
<tr>
<td>8080 CPU BOARD</td>
<td>$119</td>
<td>$209.00</td>
</tr>
<tr>
<td>4K 8111 RAM ON 4K BOARD</td>
<td>116.00</td>
<td>199.00</td>
</tr>
<tr>
<td>1K 8111 RAM ON 4K BOARD</td>
<td>69.00</td>
<td>98.00</td>
</tr>
<tr>
<td>8080 COMPUTER BOARD</td>
<td>175.00</td>
<td>199.00</td>
</tr>
<tr>
<td>16 K MEMORY BOARD (with Prim)</td>
<td>119.00</td>
<td>138.00</td>
</tr>
<tr>
<td>16 K MEMORY BOARD</td>
<td>119.00</td>
<td>138.00</td>
</tr>
<tr>
<td>16 K MEMORY BOARD</td>
<td>119.00</td>
<td>138.00</td>
</tr>
</tbody>
</table>

MULTIPROCESSOR/SHARED MEMORY FACILITY

ALLOWS UP TO 3 IMSAI 8080's OR ALTAIR 8800's TO SHARE THE SAME MEMORY.

$295.00 KIT AND $335 ASSEMBLED

PERIPHERALS AND CONTROLLERS

FOR IMSAI 8080 AND ALTAIR 8800 COMPUTERS

<table>
<thead>
<tr>
<th>Component</th>
<th>Kit</th>
<th>Assembled</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 COLUMN ALPHABERIC PRINTER</td>
<td>$119</td>
<td>$139.00</td>
</tr>
<tr>
<td>22 COLUMN PRINTER INTERFACE BD.</td>
<td>$119</td>
<td>$139.00</td>
</tr>
<tr>
<td>FLOPPY DISK DRIVE IN CABINET</td>
<td>105.00</td>
<td>119.00</td>
</tr>
<tr>
<td>FLOPPY DISK CONTROLLER N &amp; 4 DRIVES</td>
<td>264.00</td>
<td>315.00</td>
</tr>
<tr>
<td>DIALON TYPE PRINTER CAB &amp; P'S</td>
<td>115.00</td>
<td>142.00</td>
</tr>
<tr>
<td>4-16 TYPE CONTROLLLER BOARD</td>
<td>115.00</td>
<td>142.00</td>
</tr>
<tr>
<td>200 LPS LINE PRINTER, CAB &amp; P'S</td>
<td>195.00</td>
<td>249.00</td>
</tr>
<tr>
<td>LINE PRINTER CONTROLLER</td>
<td>260.00</td>
<td>340.00</td>
</tr>
<tr>
<td>30 MEGABYTE DISK CONTROLLER, CABINET AND DBS</td>
<td>27,800</td>
<td>29,500.00</td>
</tr>
</tbody>
</table>

IMSIAI 8080 COMPUTER

ALL BOARDS AND SOFTWARE INTERCHANGEABLE BETWEEN IMSAI 8080 AND ALTAIR 8800

BASIC COMPUTER INCLUDES: CPU, 1K RAM (64K), FRONT PANEL CONTROL BOARD, LIGHTS AND SWITCHES, POWER SUPPLY, EXPANDER BOARD & CASE

$430.00 KIT
$521.00 ASSEMBLED

CHIPS: (FACTORY TESTED, FIRST RUN, PRIME)

<table>
<thead>
<tr>
<th>Chip Name</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>7402</td>
<td>$17.00</td>
</tr>
<tr>
<td>7416</td>
<td>$17.00</td>
</tr>
<tr>
<td>7424</td>
<td>$17.00</td>
</tr>
<tr>
<td>7427</td>
<td>$17.00</td>
</tr>
<tr>
<td>7432</td>
<td>$17.00</td>
</tr>
<tr>
<td>74HCT245</td>
<td>$17.00</td>
</tr>
<tr>
<td>74S74HC245</td>
<td>$17.00</td>
</tr>
</tbody>
</table>

7400 SERIES T.T.L.
PINOUT HANDBOOK

COVERS ENTIRE 5400/7400 SERIES D.P. I.C.'S PIN CONNECTIONS FUNCTIONAL SPECIFICATIONS

CROSS REFERENCE

$3.95

Registered Trademark:

IMS ASSOCIATED INC

1929 REPUBLIC AVE., SAN LEANDRO, CALIF., 94577

TERMS: CHECK/M.O., BANKAMERICA, MASTER CHARGE 2% DEPOSIT ON C.O.D.

ADD 5% POSTAGE AND HANDLING.

CANCELLATIONS AND RESTOCKS SUBJECT TO CHANGE WITHOUT NOTICE.

CIRCLE ON READER SERVICE CARD
Four ways to get more out of (or into) your computer

Here are four of our most popular computer peripherals. Let you do a lot more with your Altelor 8080 or IMASAI 8080. They are simple to use and simple to install. And they all have the combined quality and low price that has made Cromemco the leading name in microcomputer peripherals. Cromemco's delivery is prompt too. Watch this space for other exciting new Cromemco products to come.

Let your color TV be your display terminal. You can have a full-color computer display terminal at unbelievable low cost with the Cromemco TV Dazzle®. You can display multi-colored charts, graphs, educational material, games. Requires only 2KB memory for 128 x 128-element picture. Kit (Model CGt-K): $215. Assembled (Model CGt-W): $350.

Fast analog I/O with 7 channels. Couples your digital computer to an analog world. This advanced board lets you input 7 channels of analog to your computer and output 7 channels of analog to output devices. Also has an 8-bit parallel I/O part. Very fast conversion — only 5 microseconds. Kit (Model D-7A-K): $145. Assembled (Model D-7A-W): $340.


This is the industry’s most powerful microcomputer (it’s also a powerful Z-80 µP development system)

Uses high-speed Z-80 µP
You see here a major new development in microcomputers: the Cromemco Z-1.

It is the fastest and most powerful microcomputer available.

It gets its speed and power from a selected version of the new Z-80 microprocessor that can operate at a 4 MHz clock rate. (The Z-1 also lets you switch to 2 MHz to be compatible with older systems.)

µP development system

In addition to being a powerful microcomputer the Z-1 is a major µP development system. It will give you a big head start in developing your circuits around the Z-80 µP.

All you need to do is plug your breadboards into the Z-1’s 16 or more extra sockets. You’re right into the computer bus.

Broad “S-100” support
What’s more, the Z-1 offers you all kinds of peripherals and software. It uses the standard “S-100” bus supported by over a dozen manufacturers. And all Cromemco peripherals (PRAM memory and program, RAM memory, analog I/O, color TV interface, etc.) just plug into the Z-1’s extra sockets.

Cromemco also provides complete software support: a monitor, assembler, BASIC interpreter and more to come soon.

Another thing: you can bet the Z-1 won’t be obsolete. Future CPU cards can plug in for the present CPU card.

Not a kit
The Z-1 comes completely assembled and tested. It’s a quality, commercial-grade microcomputer. It is not available as a kit. Just plug it into the 110-volt line and you’re ready to go.

The Z-1’s ready, too. It’s being shipped. And for all you get, the low $2495 price is a pleasant surprise. It’s especially pleasant when you compare it with the price of any complete, assembled microcomputer with all the Z-1’s features.

Call now and get your brochure on this new system which is so important in working with the Z-80.

Cromemco Z-1

Z-1 components
• Z-80/4 CPU
• 8K static RAM
• Capacity for 8K PROM
• PROM programmer
• Resident monitor in PROM
• RS-232 I/O
• Full 22-slot motherboard and connectors
• Fan installed
• Not a kit; completely assembled

Cromemco

Specialists in computer peripherals

2432 Charleston Rd., Mountain View, CA 94043 • (415) 964-7400

Cards (Byte, September 1976)

Computers (January 1977)
### Cromemco Systems and Processor Cards

<table>
<thead>
<tr>
<th>Z-80 System</th>
<th>Year</th>
<th>Slots</th>
<th>Floppies</th>
<th>Hard Disk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z-1</td>
<td>1976</td>
<td>21</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Z-2</td>
<td>1977</td>
<td>21</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>System Two Z-2D</td>
<td>1978</td>
<td>21</td>
<td>2 × 5.25&quot;</td>
<td>-</td>
</tr>
<tr>
<td>System Three</td>
<td>1978</td>
<td>21</td>
<td>4 × 8&quot;</td>
<td>-</td>
</tr>
<tr>
<td>System Zero</td>
<td>1980</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>System Two Z-2H</td>
<td>1980</td>
<td>12</td>
<td>2 × 5.25&quot;</td>
<td>11 MB</td>
</tr>
<tr>
<td>System One CS-1</td>
<td>1981</td>
<td>8</td>
<td>2 × 5.25&quot;</td>
<td>-</td>
</tr>
<tr>
<td>System One CS-1H</td>
<td>1981</td>
<td>8</td>
<td>1 × 5.25&quot;</td>
<td>5 MB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Card</th>
<th>Year</th>
<th>Processor</th>
<th>Clock</th>
<th>Whetstones</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZPU</td>
<td>1976</td>
<td>Z-80A</td>
<td>4 MHz</td>
<td>7,000</td>
</tr>
<tr>
<td>DPU</td>
<td>1982</td>
<td>Z-80A + MC68000</td>
<td>4 + 8 MHz</td>
<td>40,000</td>
</tr>
<tr>
<td>XPU</td>
<td>1984</td>
<td>Z-80B + MC68010</td>
<td>5 + 10 MHz</td>
<td>50,000</td>
</tr>
<tr>
<td>XXU</td>
<td>1986</td>
<td>MC68020</td>
<td>16.7 MHz</td>
<td>1,050,000</td>
</tr>
</tbody>
</table>

The CP/M Operating System

1974: Gary Kildall develops CP/M to run on an Intel 8080 development board with a 5.25" floppy

1976: Glenn Ewing approaches Kildall on behalf of IMSAI to port CP/M to their machines with floppies.

1977: IMSAI releases CP/M (DOS-A)

1980: IBM approaches Digital Research to license CP/M for the forthcoming IBM PC. Talks fail and IBM instead contracts with Microsoft to produce MS-DOS.

Ultimately, CP/M sold over 250,000 copies
CP/M’s Greatest Hits

Many important commercial programs started on CP/M.

Programs very portable across CP/M machines (3,000 machine configurations)

<table>
<thead>
<tr>
<th>Program</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>WordStar</td>
<td>word processor</td>
</tr>
<tr>
<td>dBase II</td>
<td>database</td>
</tr>
<tr>
<td>Zork</td>
<td>text adventure</td>
</tr>
<tr>
<td>Turbo Pascal</td>
<td>compiler</td>
</tr>
<tr>
<td>SuperCalc</td>
<td>spreadsheet</td>
</tr>
<tr>
<td>AutoCAD</td>
<td>computer-aided design</td>
</tr>
</tbody>
</table>
August 1981: The IBM PC (Intel 8088-based)
Altair-Duino

$150 from http://www.altairduino.com

Built with an Arduino Due

32-bit ARM Cortex M3 processor

84 MHz

96 KB RAM

512 KB Flash

Runs an 8080 emulator

SD card for storage