design innovations in personal computers

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Introduction

There is little question that the current enthusiasm in personal computing was catalyzed by the introduction of the MITS Altair computer kit in January 1975. This computer kit demonstrated by its cost (originally less than $400) that individuals could now afford a computer. And by its design the Altair established a standard bus structure for the personal computing industry.

Less than six months after MITS announced the Altair computer, other manufacturers were announcing compatible memory boards, interface boards, and peripherals. Within the year bus-compatible mainframes were also introduced.

Today over 50 manufacturers support what is known as the Standard 100 or S-100 bus derived from the 100-wire bus used in the original Altair computer. Over 20,000 mainframes using the S-100 bus are now in the field. One key reason for the rapid growth of the personal computer industry can be found in the widespread adoption of a standard microcomputer bus. A second key reason can be found in the design innovations in mainframes, memories, and I/O interfaces designed for the S-100 bus.

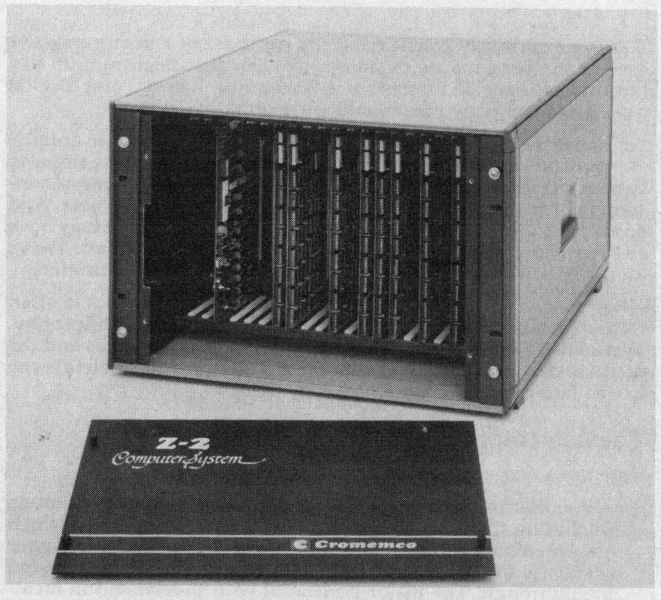

Figure 1. The basic personal computer can accept a number of standard 5" x 10" cards designed for the industry standard S-100 microcomputer bus. A large selection of CPU, memory, and interface cards offers a great deal of flexibility in system design.

Mainframes

The basic personal computer mainframe consists of a CPU, computer bus, and power supply. Most mainframes are sold in kit form (Figure 1).

Without exception in the personal computing industry a microprocessor serves as the CPU. In fact, the microprocessor is the technological development that made personal computing possible. The most popular microprocessors used in personal computing today are the Z-80, 8080, and the 6800. CPU cards using each of these three processors are available for the S-100 computer bus. As newer processors have come available (such as the Z-80), manufacturers are quick to mate them to this standard bus. In this way a user can upgrade to a newer processor at a relatively small incremental cost. As an illustration of manufacturer support for the S-100 bus, no fewer than five manufacturers are producing replacement CPU cards based on the Z-80 microprocessor (Figure 2).

The computer bus itself consists of a bank of printed-circuit card edge connectors soldered to a common mother board. The connectors are used to accept the CPU card, memory cards, and I/O cards for the computer system. The standard size for an S-100 bus card is 5" x 10" with a 100-contact edge connection (50 on each side of the card). In order to accommodate a large number of cards, a large mother board with long bus traces is required. To

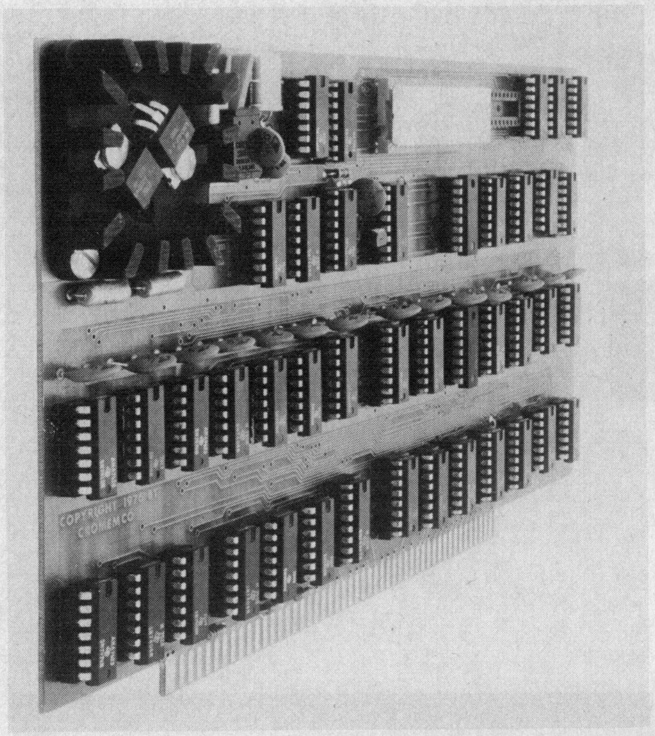

Figure 2. This CPU card from Cromemco uses the Z-80 microprocessor. All signal decoding and buffering are performed on the card to mate the Z-80 with the S-100 bus. CPU cards using the 8080, 6800, and Z-80 are all available for the S-100 bus.

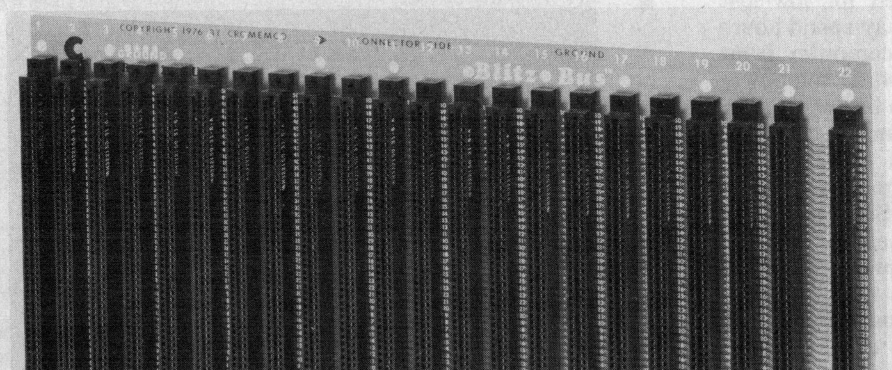

Figure 3. The S-100 microcomputer bus consists of a bank of 100-contact connectors wired in parallel on a common mother board. The 100 lines of the bus carry address, data, and control signal information. Several of the lines are left undefined for use in customized systems. A ground trace between the signal lines is used for shielding to reduce cross-talk and assure reliable operation.

avoid problems associated with capacitive coupling between traces, shielded mother boards (Figure 3) are being introduced to provide adequate noise margins and improved system expandability.

To keep the cost of the mainframe low, an unregulated power supply is normally used. Each computer card provides distributed regulation via three-terminal regulators. The S-100 bus requires nominal supply voltages of +8 volts, +18 volts, and −18 volts. The existence of three supply voltages on the bus is important in providing flexibility in mating with a variety of memory and I/O interface cards.

Memories

In many personal computer systems, especially those that support a high-level language, the cost of memory can easily dominate the system cost—even though intense competition, particularly for the RAM market, has forced prices at the card level to less than three cents per byte.

During 1976 the most common RAM cards contained either 4K or 8K bytes of static memory. The ubiquitous 2102 was the mainstay memory chip in personal computing systems. Now the 16K RAM card using 4K dynamic memories is rapidly becoming the most popular memory card.

Surprisingly, many computer hobbyists are finding that the 64K of memory that can be directly addressed by most microprocessors is just not sufficient for their application. This has led to the incorporation of *memory bank select* in RAM memory cards. An eight-position DIP switch on such cards is used to select one (or more) of eight "banks" of memory in which the card is to reside. Each bank consists of a maximum of 64K bytes of memory. One output port address of the microprocessor is reserved for selecting the active bank (or banks) of memory. With eight banks of 64K, microprocessor memory space can be expanded to a half-megabyte! Not only is bank select useful for expanding memory; it is also convenient in implementing small timeshared systems. In such a system each user is restricted to just one bank of memory, thus protecting against accidental accessing of another user's memory space.

As microprocessors become faster, memory systems must keep pace. Avid computer hobbyists find the use of wait states in synchronizing memory to be an embarrassing admission that their memory is too slow. The WAIT light on the front panel of the computer glows during execution as a constant and agonizing reminder. One answer is dynamic memory cards, which offer higher speeds. Another solution is the technique of "address anticipation," which permits slower memories to operate at much higher speeds.

Address anticipation circuitry, now being introduced in personal computer memory cards, takes advantage of the fact that the memory locations addressed by a

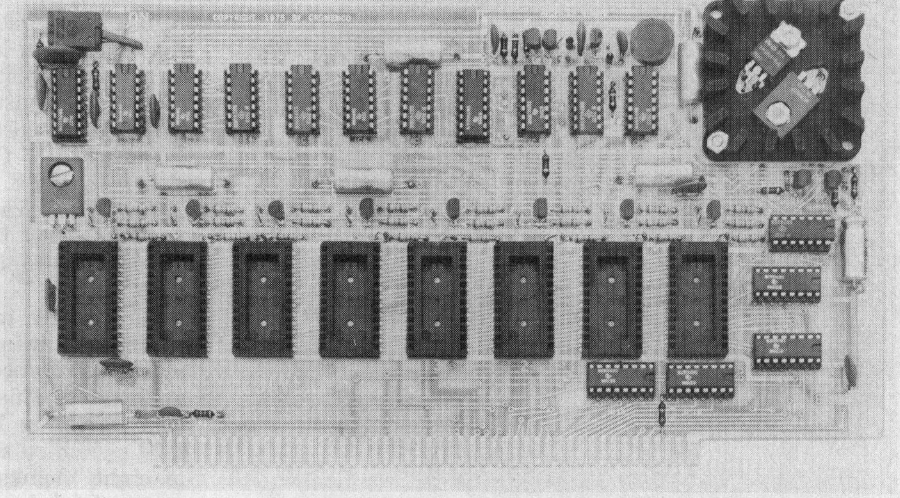

Figure 4. This S-100 bus PROM memory card, known as the 8K Bytesaver, is unique in that it has an integral PROM programmer, This provides a convenient means for a hobbyist to save his programs and have up to 8K bytes of PROM memory storage on one card.

microprocesssor are usually sequential. Address anticipation circuitry on the memory card can thus apply the next sequential address to the memory chips long before the actual address appears on the data bus. Relatively fast computer circuitry is used to compare the actual address with the anticipated address. A wait state is required only when the addresses are not sequential.

Whereas, RAM memory typically occupies most personal computer memory space, there is a need for low-cost non-volatile memory as well. A hobbyist may spend hours laboriously developing software for the computer front panel only to lose the fruits of his work when the power is turned off. One solution to this problem has come with battery back-up, a feature offered on many personal computer RAM cards. Another solution has been the development of a "Bytesaver" PROM memory card with integral PROM programmer (Figure 4). Such a PROM board resides in memory space and allows PROM programming through conventional memory write instructions. Programs can thus be easily saved in non-volatile PROM memory. The most common PROM used is the industry standard 2708. The 2708 can be erased with intense UV light so that it may be used repeatedly.

For mass memory storage the inexpensive audio cassette is by far the most common medium in personal computing. Here again, early standardization has been of great benefit to personal computing. A meeting of manufacturers and technical editors in Kansas City produced the so-called "Kansas City Standard" for computer data encoding on standard audio cassettes using standard cassette recorders. The computer interface required is simple and inexpensive. By using audio cassettes, a hobbyist can easily store long programs, such as a Basic interpreter, and load them into his computer in less than 30 seconds.

If the data transfer rate of a cassette is too slow, the computer hobbyist has his choice of several floppy disk systems that have been mated to the S-100 bus (see, for example, Figure 5). Unfortunately, the cost of most systems is still beyond the reach of many hobbyists. Here the most exciting news is in Shugart's development of the mini-floppy disk drive. Although the performance of the mini-floppy is well below that of the full-sized floppy, its relatively low cost will likely make it the standard for the personal computer industry.

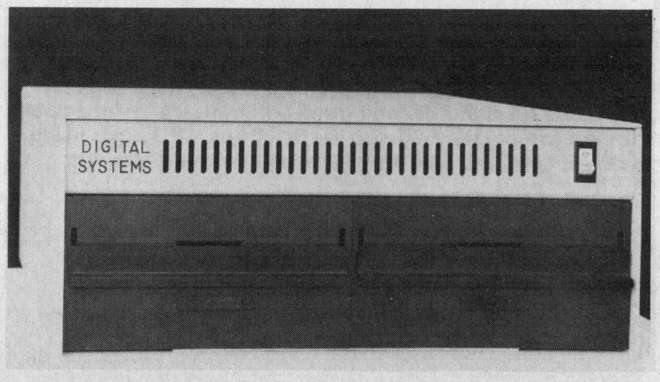

Figure 5. Digital Systems' FDC-1 provides an IBM-compatible format and interface to the S-100 bus and a dual disk drive for $2545. A disk operating system modeled on the PDP-10 timesharing system is available for $70 and includes an assembler, an editor, and a number of high-level language processors.

I/O interfaces

A major hurdle in personal computing has been in the development of low-cost methods to input and output computer data. The design innovations in this area have been very impressive.

A CRT terminal is certainly a desirable addition to any personal computer system, but the cost is high. The solution to this problem is in the application of the home TV as a "TV typewriter." Several S-100 interface cards are now in production that can use a standard black-and-white TV for alphanumeric display. One interface, known as the "Dazzler," is designed to be used with a color TV set for full-color graphics or alphanumerics (Figure 6). By FCC regulation a video signal cannot legally be used to modulate an RF carrier for input to the antenna terminals of the TV set. As a result the computer hobbyist often finds that he must modify his TV set to provide for direct video injection.

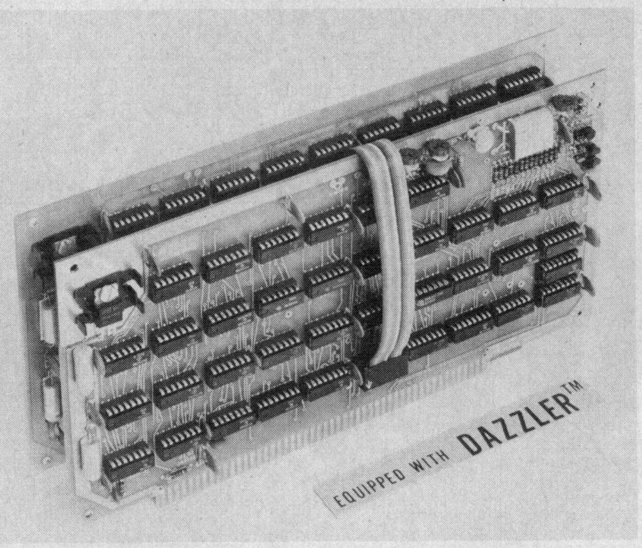

Figure 6. Offering a low-cost means for system display, the Cromemco Dazzler interface couples any S-100 bus to a standard black and white or color TV. This provides full color graphics for games, computer art, or alphanumeric displays.

The venerable ASR-33 teletype can be found in many personal computer installations. The teletype offers hard-copy output and paper tape read and punch capability. Punched paper tape usage is common in personal computer systems.

For the hobbyist who cannot afford a teletype yet wishes to read paper tape programs, there is a fast and easy alternative. A low-cost optical paper tape reader is available that can read paper tape "as fast as you can pull!" (Figure 7).

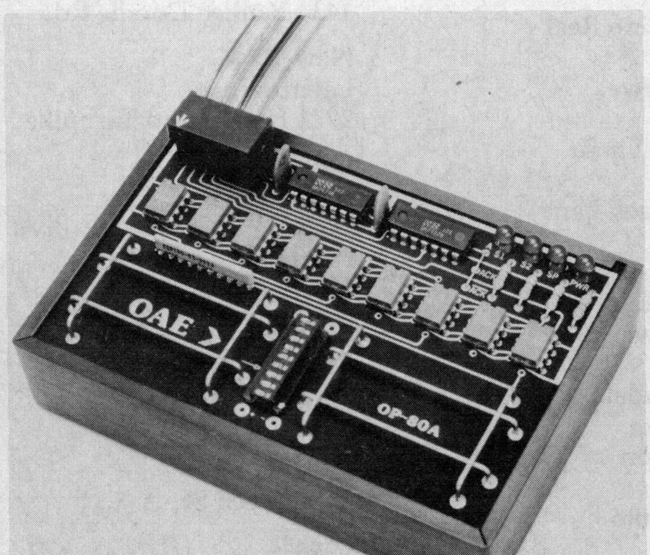

Figure 7. This low-cost paper tape reader from Oliver Audio Engineering provides the hobbyist with an easy way to enter programs to his computer from punched paper tape.

A complete array of more exotic I/O peripherals, all of them compatible with the S-100 bus, are also available. These include, for example, voice synthesizers, bar code readers, optical digitizers, A/D and D/A converters, and music synthesizers. And the list seems to be growing daily.

Conclusion

A standard microcomputer bus supported by a large number of manufacturers is central to the personal computer industry. The design innovations achieved in bus-compatible products have brought inexpensive and often unique computing capabilities within the reach of the personal computerist. ■

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