First Person Report:

Assembling an Altair 8800

by
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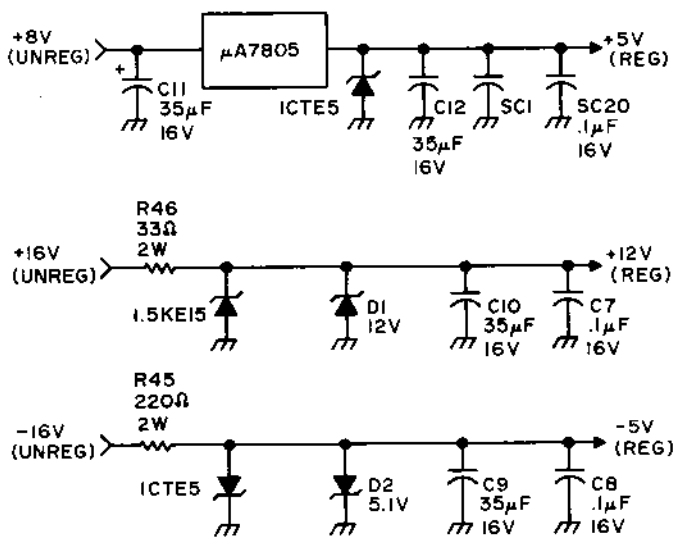
My adventure with microprocessors began rather late in the hobby game, at the end of 1974. It was about this time, or so it seemed to me, that micros became the topic of conversation in anything related to computers and automation. With the IMP-16, the 8080, 8008, 4004, etc., it became clear that this was what the computer market was waiting for. However, it was the article on the MITS Altair in the January 1975 issue of *Popular Electronics* which finally did it. Although inaccurate and vague, it certainly decided me – I was definitely going to own a micro. The next few months saw hurried mailings of information requests to any company which produced a product even remotely connected with a microprocessor. I immediately got out my checkbook, and mailed all my hard earned dollars to every newsletter that was published, in my frantic search for the "right" processor.

The results were both rewarding and disappointing. I found that there were some fantastic processors, but since my hardware background is not all that hot, I decided that I would have to opt for a kit with one of the most powerful micros I could find. I figured that this would enable me to get on line quickly, learn enough hardware to keep up with the state-of-the-art, and permit me to evaluate new micros as they came out, so I could build my "dream machine" when the right parts became available.

I decided to build the Altair 8800. Although the instruction set looked rather impressive, what convinced me was seeing a process control system which used the 8080; I was truly impressed with its capability.

Fig. 1. The schematic diagram of power supply circuitry, showing additional protection diodes.



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The Order

After calling in my order to MITS, I waited nearly seven weeks for delivery. MITS did make it within the advertised 60-day delivery time. All was not roses for those seven weeks, however; it seems that either MITS or BankAmericard got their signals crossed and couldn't get a credit authorization (they both eventually declined to accept responsibility). You can imagine what it was like getting a call during dinner, explaining that my unit was

ready to ship, but unfortunately ... Luckily they agreed to ship it COD, and I quickly ran down to my bank to get a certified check. Every morning I left my wife with the admonition not to miss the delivery, and every day at lunch I called to determine whether or not my "computer" had arrived. (Did you ever try to ask your insurance agent whether you needed extra renter's insurance "You keep a computer at home??!! What for?")

Assembly

Within a week of that call, I had the Altair in my hot little hands. "Are those little plastic parts all you get for $500.00?", my wife exclaimed, peering over my shoulder. Undaunted, I shooed her out and locked myself in the back room all weekend soldering PC boards. It took three weekends to complete the assembly (was it my fault I came down with pneumonia in the middle?).

Ah yes, assembly. In general, I found that the MITS assembly instructions were well written. However, their additions were sometimes in the manuals in the wrong place (e.g., page 68A after 69). In at least one case (front panel control board) I had already tightened the panel in place (bolts on numerous switches), when I read that the nut on the little screw holding the voltage regulator to the board (accessible only with the panel out) had to be removed to add a grounding strap. Therefore it pays to check the manual pages carefully, and look two or three pages ahead to see if there are any little tricks sneaking up on you.

As for the parts, only one resistor was missing; however, out of all the screws and bolts supplied with the kit, I could never find the right one to fit. Maybe it was my own stupidity, but it seemed that the last bolt of any given size was always supposed to be used in at least 10 more places. I found that it pays to have a good assortment of screws and bolts (number 6, various lengths ¼" to ¾") to permit frustrationless assembly.

All soldering and component placement was easily accomplished — positions were clearly marked on the boards and in the manual. This is high praise since I hadn't built many kits before; and of these, none were this large. Of all the assembly, the worst (and easiest to mess up) part was correctly connecting the 60 bus wires between the display/control board and the chassis motherboard. I used an Ohmmeter to assure that each connection was correct and that there were no solder bridges to the other bus lines. There's got to be a better way. I hear Processor Technology, Inc., is currently marketing a 16-slot motherboard (on the Altair you have to jumper four of the four slot boards together, only one of which comes with the kit), and an improved connector for the display/control board. These will definitely be my first additions.

I made only one modification to the circuit during assembly. That modification was to add three protection zeners to the CPU board. Fig. 1 shows the electrical connections for this change. These were inserted to protect the 8080 chip (still pretty expensive in singles) from power supply failure. These zeners should ground out overvoltages at currents up to 100 Amps. ICTE5s were used for the +5 V and -5 V lines to the 8080 and a 1.5KE15 for the +12 V. The zeners on the CPU board are illustrated in Fig. 2.

I also added sockets for the 8101 RAMs, cleaned all boards with trichloroethylene solvent, and inspected the finished boards with a magnifying glass. I would highly recommend these procedures as they helped me find more than one solder splash and cold solder joint.

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The Big Test

On the fourth weekend I got up the courage to mount the 8080 and 8101s. Then came turning on the power and checking voltages. Everything looked good, with very little ripple from the

Fig. 2. Detail of the additional protective diodes mounted on the Altair CPU board.

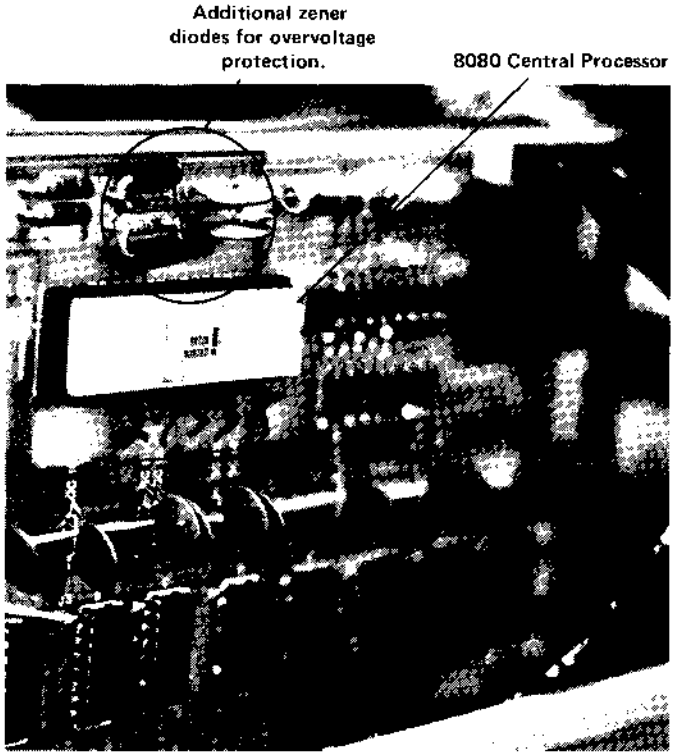
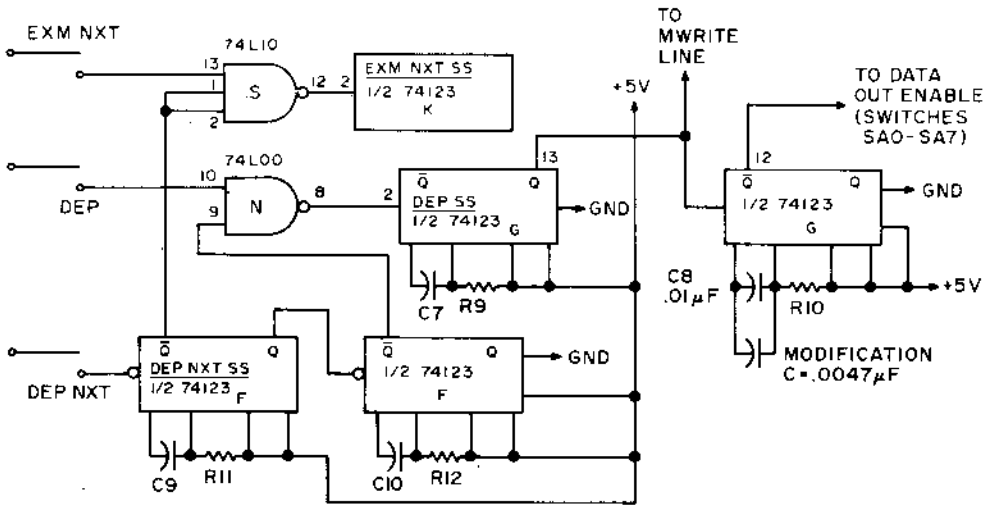


Fig. 3. Adding a parallel capacitance of .0047 uF to C8 of the Altair CPU board schematic lengthens the data out enable line time so that memory write does not extend longer than the data out time.



on-card voltage regulators. Finally the big test: Run a program. This is where the only problem finally showed up. I stopped and reset the CPU, set the switches for my spectacular program (JMP 0) and would you believe it, "deposit" wouldn't work. An hour later I had determined that all other panel switches worked correctly (including deposit next), and that the deposit switch itself was in good order. In order to initially get around the problem I had to examine location 177777 (all address bits 1), then use deposit next to get to location 0.

A study of the schematics showed that deposit and deposit next use the same circuitry, except that deposit next first does an examine next. You can verify this visually by loading all ones into the first 10 locations of memory. Then, if you use deposit next to change all the locations to zero, by carefully watching the data LEDs, you will notice that they all flash on as the switch is activated (examine next) and immediately go off again as the deposit is performed.

I concluded that the problem had to be in the timing, since the circuits were otherwise identical. Sure enough, when I looked at the signals on a scope, lo and behold, when a deposit was performed, the memory write line was enabled for approximately 20 ns more than the data out line. There are two oneshots in the deposit circuit; the first enables the memory write line, and the second enables the data out line. The memory write problem was cured by increasing the capacitance on the second deposit oneshot. An increase of .0047 uF (which increases the data out enable time by at least 30 ns) proved sufficient. This was obtained by adding the .0047 uF capacitor as shown in Fig. 3. When building the Altair, this means that C8 (front panel control board) should be approximately .0147 uF; if the board is already assembled into the case, a .0047 uF capacitor can easily be soldered onto the back of the board without removing any components from the case. (Be sure to unplug the computer before making the change, however.) Fig. 4 shows placement of the new capacitor and the change to the Altair schematic diagram.

I feel that the kit is reasonably well made and a good buy – at least at the current 8080 single lot prices, though the add-on options may cost somewhat more than elsewhere.

My plans for my unit currently involve addition of vectored interrupts (a 9318 or 74148 8-bit to 3-bit priority decoder is about all that's needed to translate the eight vectored interrupt lines on the bus into an RST instruction), a real-time clock, monitor clock and some type of I/O (teletype, CRT, etc.). ■

Fig. 4. The additional .0047 uF capacitor is mounted on the rear of the control panel board.