CPUville Z80 Single-Board Computer Kit Instruction Manual

"The Simple CP/M Computer"

By Donn Stewart

If you find any errors in this manual, please let me know. Thanks.

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Introduction

The CPUville Z80 Single-Board Computer Kit is a complete small computer in hobbyist kit form. Once assembled, you can use the keyboard and display of a PC, or a dumb terminal, through the Z80 computer's serial interface, to communicate with the Z80 computer using text input and output. With a compatible IDE disk drive, you can install the CP/M[1] operating system. The computer comes with a monitor program in ROM that has commands to read and write RAM memory, load files over the serial interface into RAM and execute programs, read and write disk sectors, and to execute CP/M if it is installed.

This manual assumes the reader is familiar with assembly language, binary and hexadecimal notation. You should be familiar with the concepts of basic binary logic (AND, OR, NOT etc.) and simple logic circuits. I assume the reader has a basic understanding of electricity and circuit elements such as resistors, LEDs, and capacitors.

The disk interface in this computer is an IDE interface (also known as parallel ATA, or PATA), that will accommodate an IDE-compatible drive, including compact flash and SD drives with the appropriate adapter (see the Table of Tested Drives on page 115). Only the lower 8 bits of each disk data word are transmitted to the Z80 system, so drives that operate in 16-bit mode will have only half the disk space available. This is a trade-off to keep the price of the kit low, because extra hardware would be needed to capture all 16-bits, and convert it to 8-bits for the Z80 data bus. However, since the PATA interface has been replaced by the serial ATA (SATA) interface in commercial computers, IDE drives are now obsolete, and IDE drives with sizes of hundreds of megabytes or even gigabytes are very inexpensive. 8-bit programs are very small, so literally thousands of Z80 programs would fit into a disk space of 100 megabytes. If you have an IDE drive of a few hundred megabytes or more, you can run CP/M and store all the 8-bit data you could reasonably want.

Power for a disk drive that requires only low-current +5V, such as a solid state drive, can be provided by the two-pin connector on the computer board, or by pin 20 on the IDE connector, as described in detail in "Building the Computer" below. Power for a drive that requires +12V, or a drive that draws a lot of current from the +5V supply, will need to be provided by an appropriate power supply. Usually, a hobbyist will have an old computer system power supply that can supply both the regulated +5V for the computer, and +12V for the disk drive. These power supplies can also be obtained cheaply. If two separate power supplies are used, they need to share a common ground.

The 64K memory has two configurations. Configuration 0 has 2K of ROM from location 0x0000 to 0x07FF, and 62K of RAM from 0x0800 to 0xFFFF. Configuration 1 is all-RAM, that is, it has 64K of RAM from location 0x0000 to 0xFFFF. The configurations are selected by software OUT instructions to port 0 or port 1, respectively. This system is necessary because the Z80 processor executes code starting at 0x0000 when taken out of reset, so we need ROM there when the computer starts. But, CP/M needs RAM in locations starting at 0x0000, and from this comes the need for the two memory configurations.

1 CP/M is a registered trademark, currently owned by Lineo, Inc.

Building Tips[2]

Thanks for buying a CPUville kit. Here is what you need to build it:

1. Soldering iron. I strongly recommend a pencil-tip type of iron, from 15 to 30 watts.
2. Solder. Use rosin core solder. Lead-free or lead-containing solders are fine. I have been using Radio Shack Standard Rosin Core Solder, 60/40, 0.032 in diameter. Use eye protection when soldering, and be careful, you can get nasty burns even from a 15-watt iron.
3. Tools. You will need needle nose pliers to bend leads. You will need wire cutters to cut leads after soldering, and possibly wire strippers if you want to solder power wires directly to the board. I find a small pen knife useful in prying chips or connectors from their sockets. A voltmeter is useful for testing continuity and voltage polarity. A logic probe is useful for checking voltages on IC pins while the computer is running, to track down signal connection problems.
4. De-soldering tool. Hopefully you will not need to remove any parts from the board, but if you do, some kind of desoldering tool is needed. I use a "Soldapullt", a kind of spring-loaded syringe that aspirates melted solder quickly. Despite using this, I destroy about half the parts I try to take off, so it is good to be careful when placing the parts in the first place, so you don't have to remove them later.

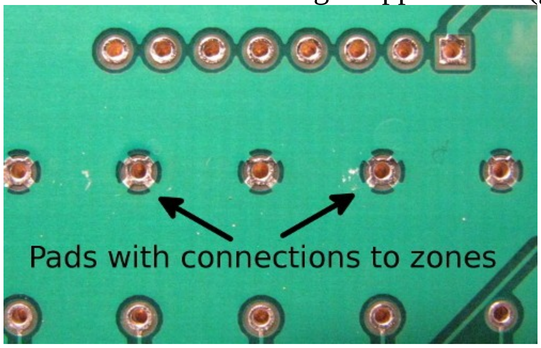
Soldering tips:

1. Before you plug in the iron, clean the tip with something mildly abrasive, like steel wool or a 3M Scotchbrite pad (plain ones, not the ones with soap in them).
2. Let the iron get hot, then tin the tip with lots of solder (let it drip off some). With a fresh coat of shiny solder the heat transfer is best.
3. Wipe the tinned tip on a wet sponge briefly to get off excess solder. Wipe it from time to time while soldering, so you don't get a big solder drop on it.
4. All CPUville kits have through-hole parts (no surface-mounted devices). This makes it easy for even inexperienced hobbyists to be successful.
5. The basic technique of soldering a through-hole lead is as follows:
    1. Apply the soldering iron tip so that it heats both the lead and the pad on the circuit board
    2. Wait a few seconds (I count to 4), then apply the solder.
    3. Apply only the minimum amount of solder to make a small cones around the leads, like this:

2 These are generic building tips that apply to all CPUville kits. The photos may not be from the same kit you have purchased.

This is only about 1/8th inch of the 0.032 inch diameter solder that I use. If you keep applying the solder, it will drip down the lead to the other side of the board, and you can get shorts. Plus, it looks bad.

4. Remove the solder first, wait a few seconds, then remove the soldering iron. Pull the iron tip away at a low angle so as not to make a solder blob.
5. There are some pads with connections to large copper zones (ground planes) like these:



These require extra heat to make good connections, because the zones wick away the soldering iron heat. You will usually need to let a 15-watt iron rest on the pin and pad for more time before applying the solder (count to 10). You also can use a more powerful (30 watt) soldering iron.

6. The three main errors one might make are these:
   1. Cold joint. This happens when the iron heats only the pad, leaving the lead cold. The solder sticks to the pad, but there is no electrical connection with the lead. If this happens, you can usually just re-heat the joint with the soldering iron in the proper way (both the lead and the pad), and the electrical connection will be made.
   2. Solder blob. This happens if you heat the lead and not the pad, or if you pull the iron up the lead, dragging solder with it. If this happens, you can probably pick up the blob with the hot soldering iron tip, and either wipe it off on your sponge and start again, or carry it down to the joint and make a proper connection.
   3. Solder bridge. This happens if you use too much solder, and if flows over to another pad. This is bad, because it causes a short circuit, and can damage parts.

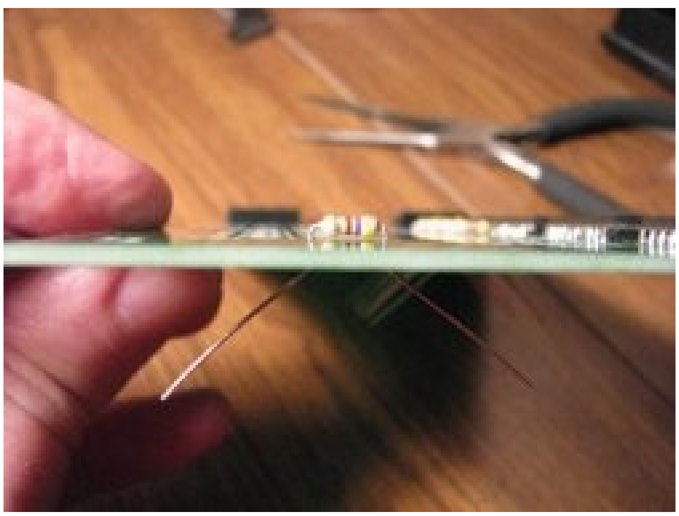
If this happens, you have to remove the solder with a desoldering tool, and re-do the joints.

Other tips:

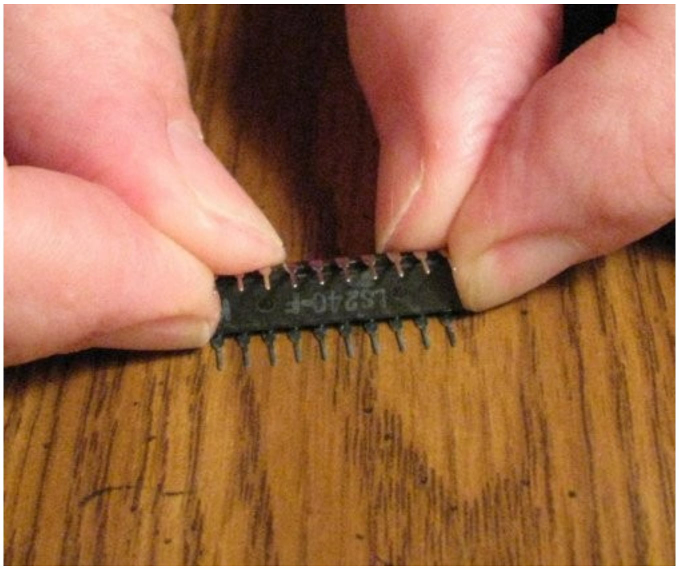
1. Be careful not to damage the traces on the board. They are very thin copper films, just under a thin plastic layer of solder mask (the green stuff). If you plop the board down on a hard

surface that has hard debris on it (like ICs, screws etc.) it is easy to cut a trace. Such damage can be fixed, if you can find it, but try to avoid it in the first place.

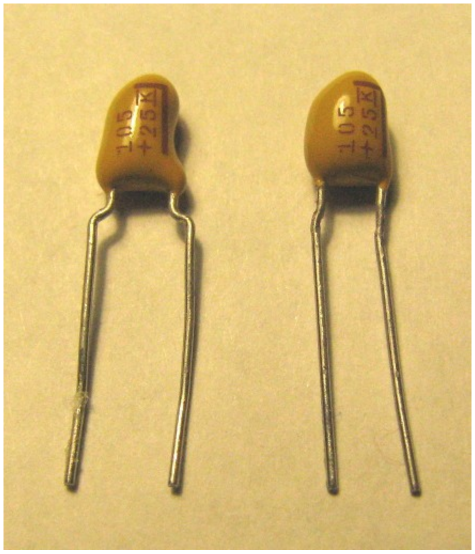
2. When soldering multi-pin components, like the ICs or IC sockets, it is important to hold the parts against the board when soldering so they aren't “up in the air” when the solder hardens. The connections might work OK, but it looks terrible. If you make a lot of connections on a part while it is up in the air it is very difficult to get it to sit back down, because you cannot heat all the connections at the same time. To prevent this, I like to solder the lowest profile parts first, like resistors, because when the board is upside down they will be pressed against the top of the board by the surface of the table I am working on. Then, I solder the taller parts, like the LEDs, sockets, and capacitors. Sometimes, I need to put something beneath the component to support it while the board is upside down to be soldered, like a rolled-up piece of paper or the handle of a tool. Another technique is to put a tiny drop of solder on the tip of the iron, press the part against the board with one hand, and apply the drop of solder to one of the leads. When the solder hardens, it holds the chip in place. Solder the other leads, then come back and re-solder the one you used to hold it. It is good to re-solder it because the original solder drop will not have had any rosin in it. The rosin in the cold solder helps the electrical connection to be clean.
3. The components with long bendable leads (capacitors, resistors, and LEDs) can be inserted, and then the leads bent to hold them in place:



4. You might have to bend the leads on components, ICs or IC sockets to get them to fit into the holes on the boards. For an IC, place the part on the table and bend the leads all at once, like this:

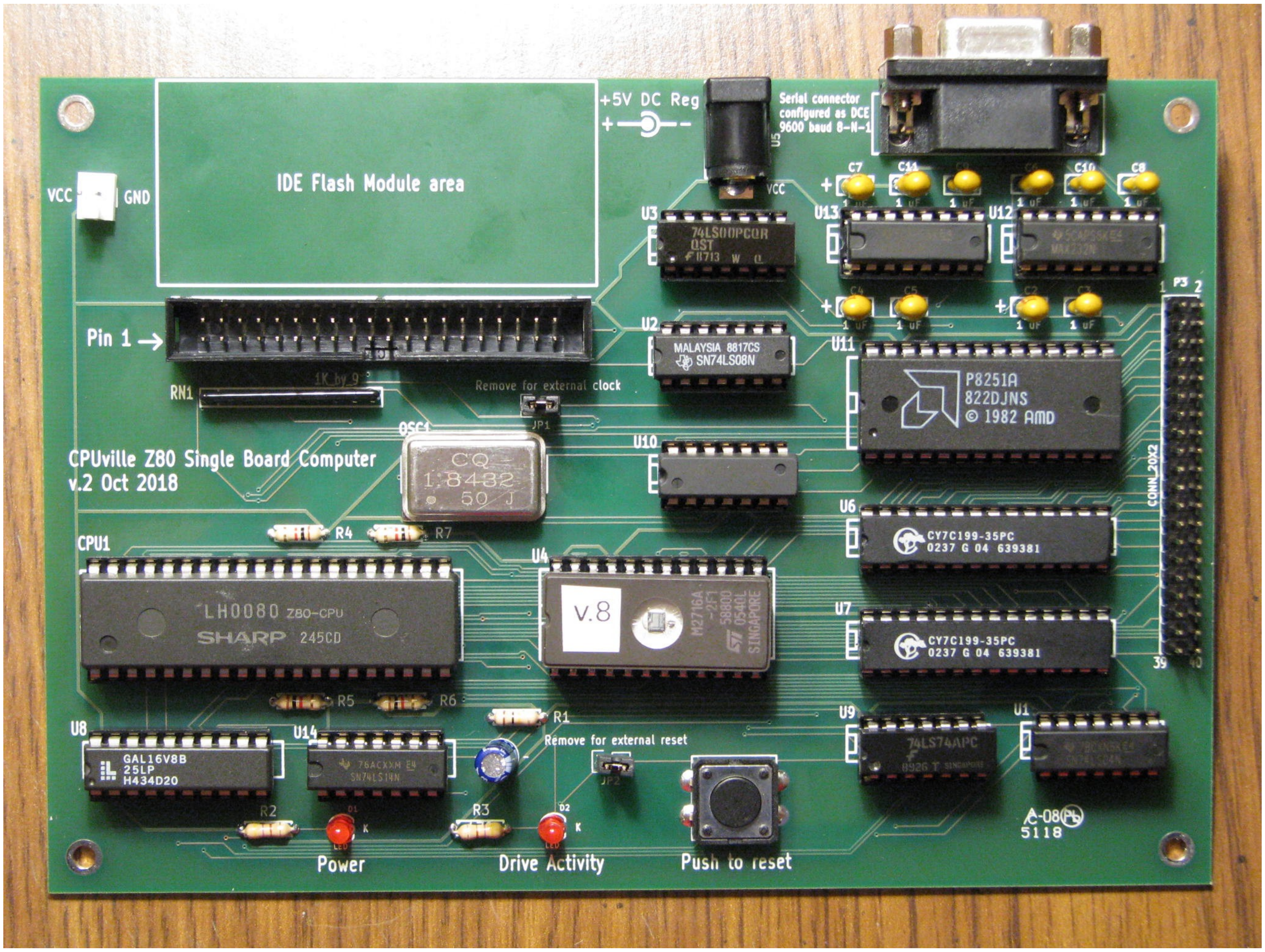


Bending the leads one-by-one or all together with the needle nose pliers doesn't work as well for some reason.
Also, some components have leads bent outward to fit in a certain printed circuit board footprint, but will fit a smaller footprint if you bend the leads in with a needle-nosed pliers. Here is a tantalum capacitor, one with wide leads, the other with narrow leads, from bending the wide leads in:

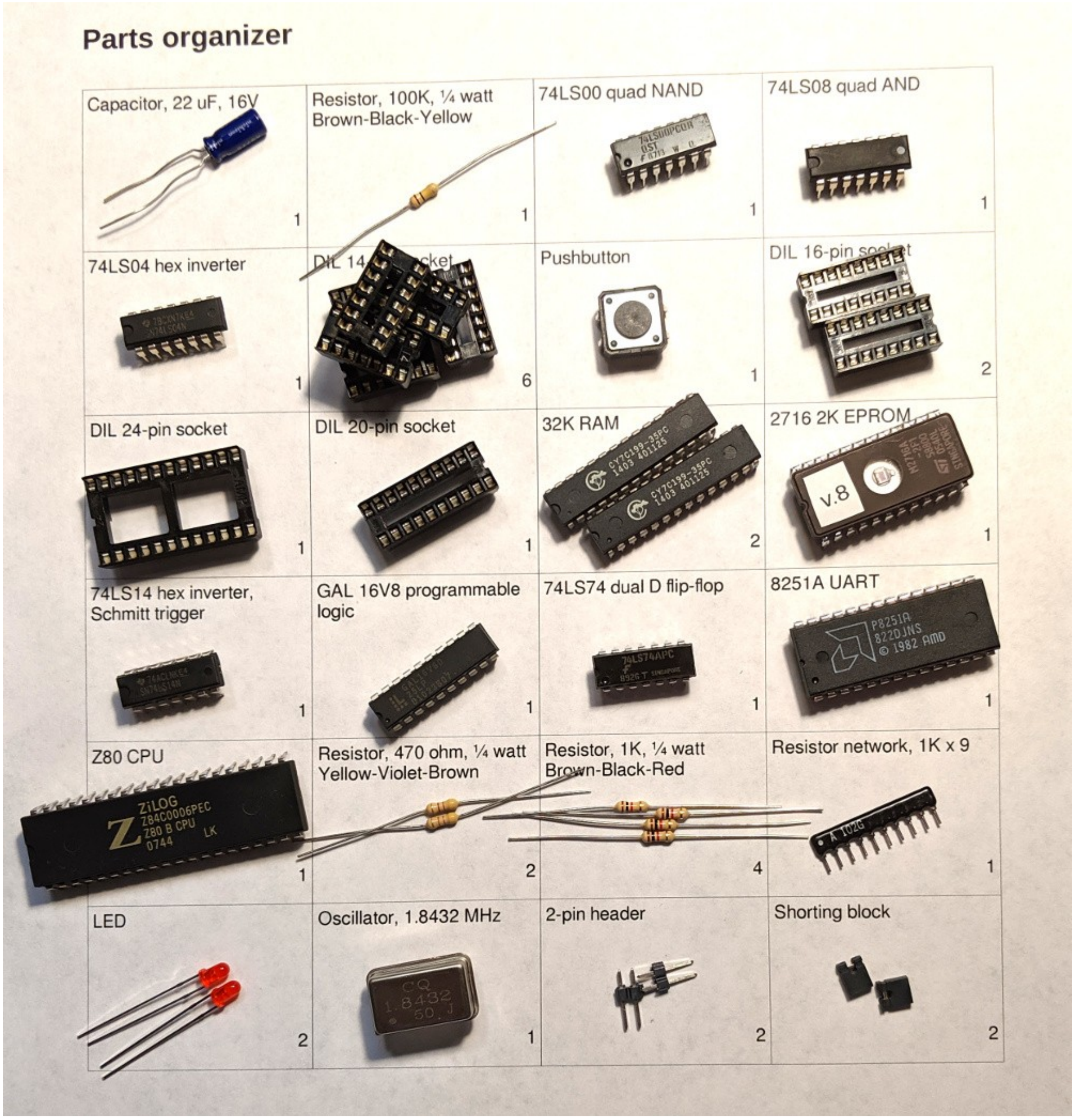


5. After you have soldered a row or two check the joints with a magnifying glass. These kits have small leads and pads, and it can be hard to see if you got the solder on correctly by naked eye. You can miss tiny hair-like solder bridges unless you inspect carefully. It is good to brush off the bottom of the board from time to time with something like a dry paintbrush or toothbrush, to get off any small solder drops that are sitting there.
6. The connectors, like the 40-pin IDE drive connector and the system connector in this kit have pins that are a little more massive than the IC socket or component pins. This means that more time, or perhaps more wattage, will be required to heat these pins with the soldering iron, to ensure good electrical connections.

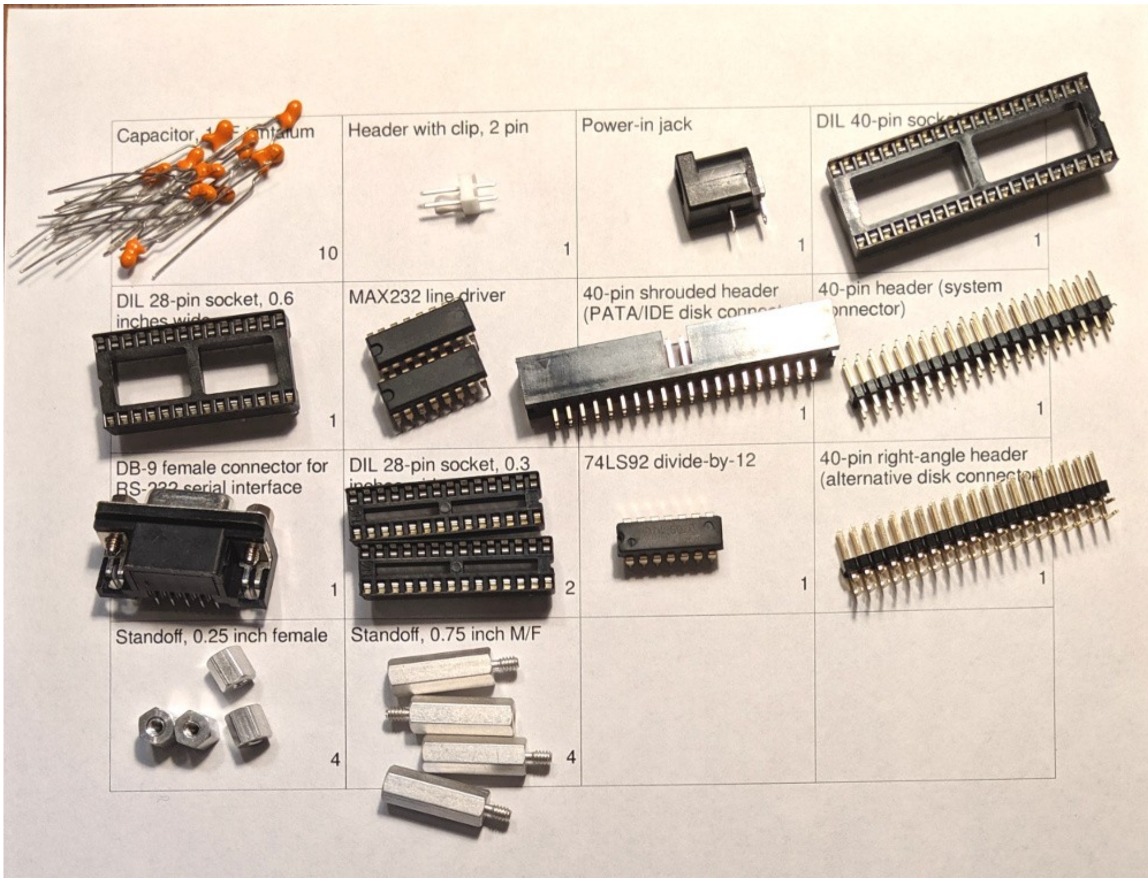
Building the Computer



Print out the Parts Organizer (pages 79 and 80) and put the parts on the organizer to make sure you have them all, and to get familiar with them.



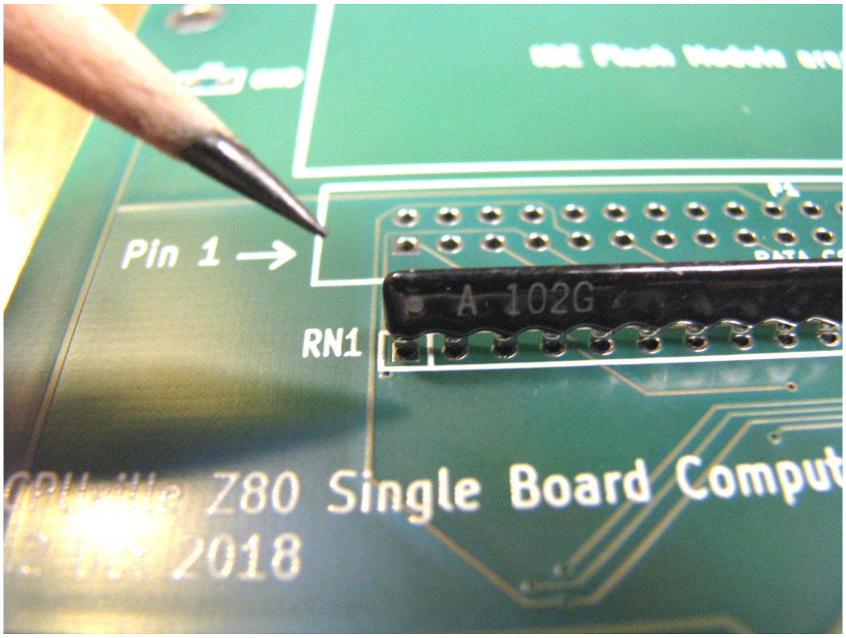
Parts organizer
Capacitor, 22 uF, 16V
1
Resistor, 100K, ¼ watt
Brown-Black-Yellow
1
74LS00 quad NAND
1
74LS08 quad AND
1
74LS04 hex inverter
1
6
Pushbutton
1
2
DIL 24-pin socket
1
DIL 20-pin socket
1
32K RAM
2
2716 2K EPROM
v.8
1
74LS14 hex inverter,
Schmitt trigger
1
GAL 16V8 programmable
logic
1
74LS74 dual D flip-flop
1
8251A UART
1
Z80 CPU
1
Resistor, 470 ohm, ¼ watt
Yellow-Violet-Brown
2
Resistor, 1K, ¼ watt
Brown-Black-Red
4
Resistor network, 1K x 9
1
LED
2
Oscillator, 1.8432 MHz
1
2-pin header
2
Shorting block
2



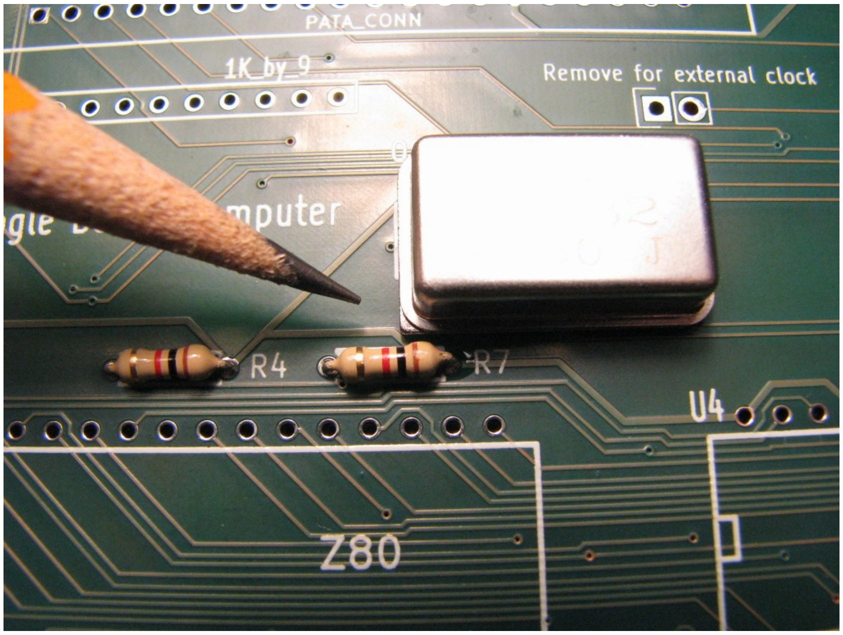
Once you have checked the parts you can start to solder them onto the circuit board.

The easiest way to solder the components is to start with the shortest (parts that lie closest to the board) and proceed to the tallest. The order is resistors, reset switch, resistor network, oscillator, IC sockets, LEDs, capacitors, 40-pin connectors, and serial interface connector. Some components need to be oriented properly, as described below.

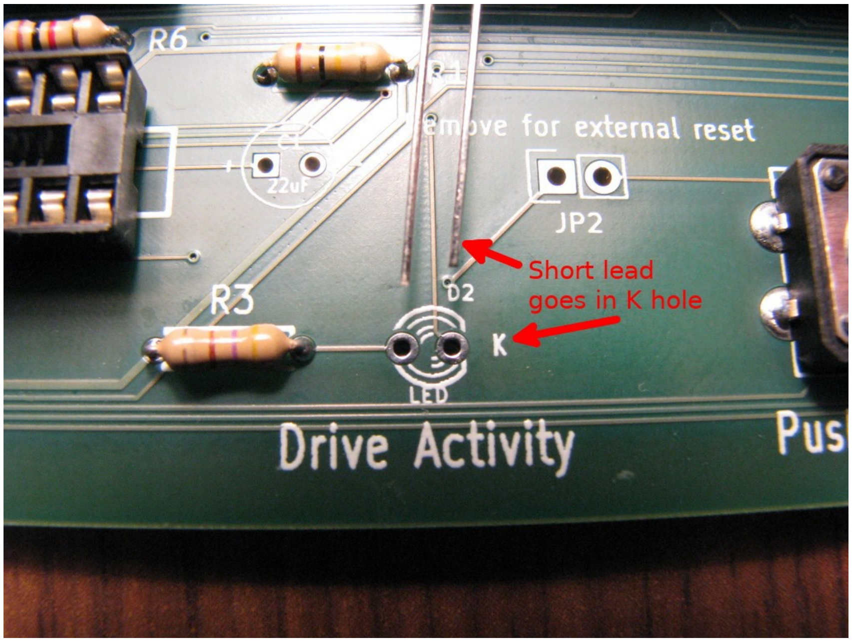
1. The resistors can be soldered first. They do not have to be oriented.
2. The reset switch is next.
3. The resistor network can be soldered next. Please note that the marked pin goes to the left, as shown here:

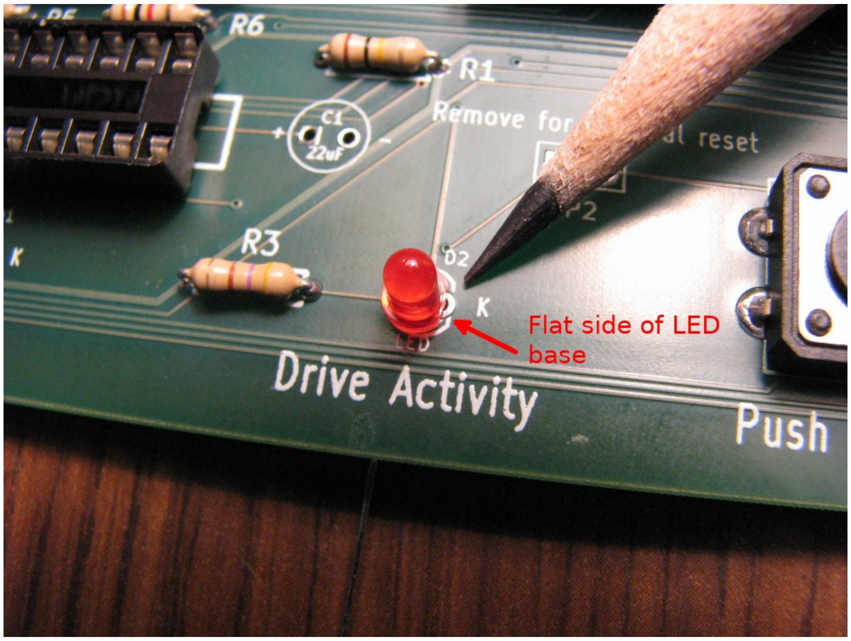


4. The oscillator is next. It has to be placed with the sharp corner at the lower left:

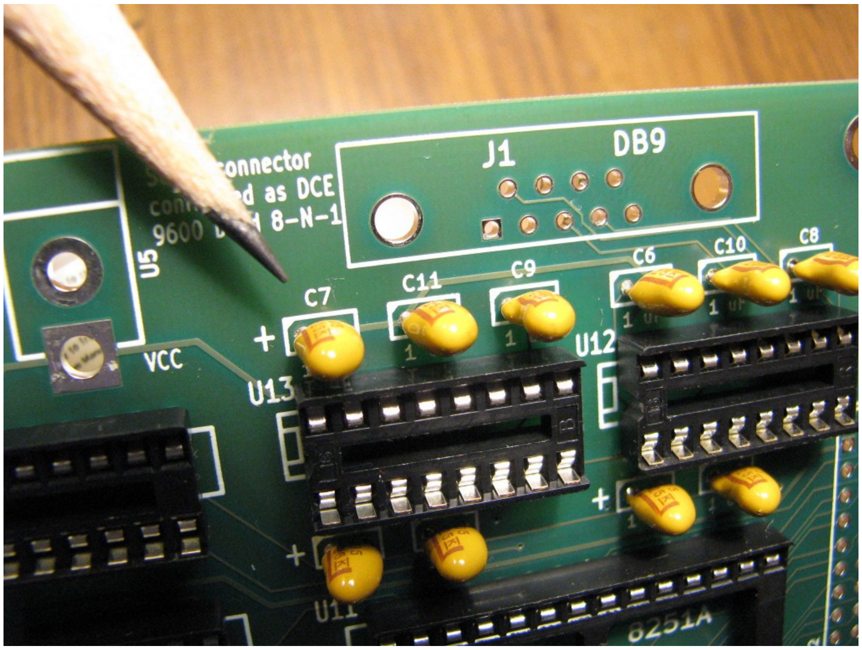


5. The IC sockets are next. They do not need to be oriented.
6. The LEDs are next. The cathode, which is side with the shorter lead, and the flat side of the plastic base, is oriented toward the right. There is a small “K” on the circuit board symbol by the cathode hole:

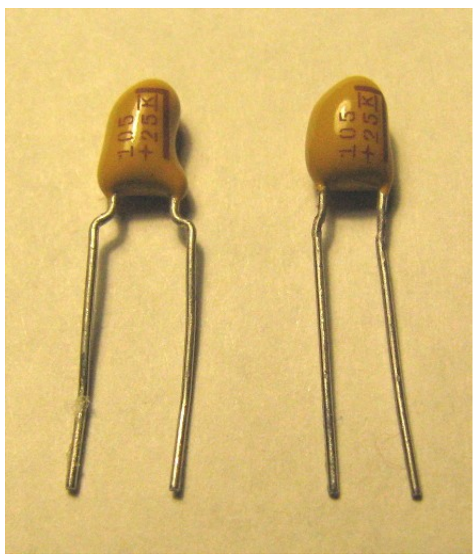




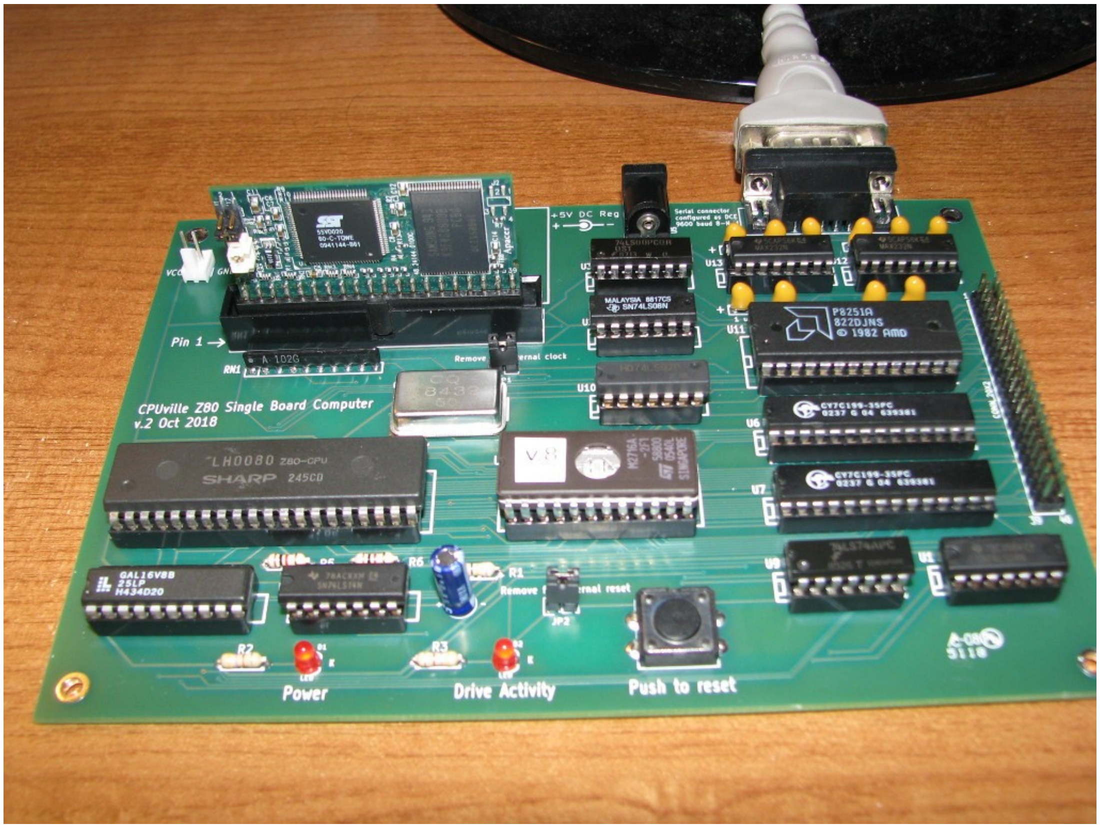
7. The tantalum capacitors for the serial interface are next. They need to be oriented as with the positive lead (the stripe) to the left, toward the "+" symbols on the circuit board, as shown:



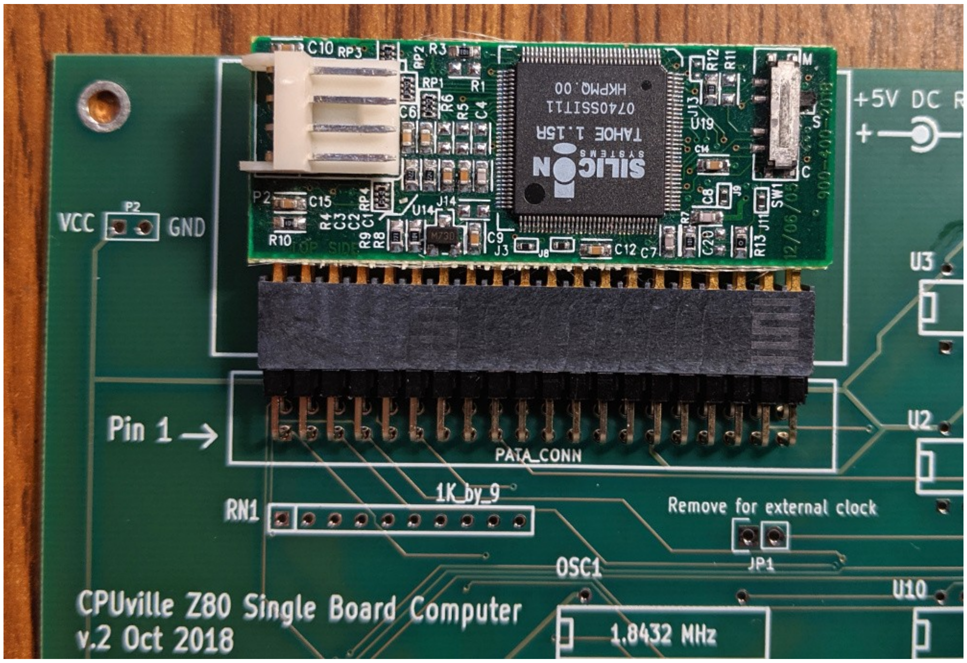
Also, depending on the type of capacitors shipped with your kit, you may have to bend the leads in to get the capacitors to fit the footprints on the circuit board. Here are two tantalum capacitors, one with wide leads, the other with narrow leads after bending the wide leads with a needle-nosed pliers:



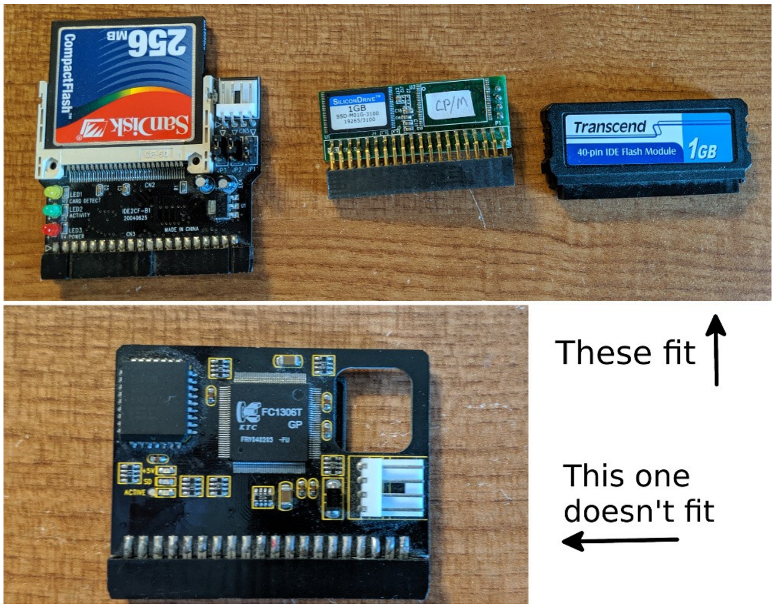
8. The 40-pin system connector on the right of the board, and 2-pin plain headers that serve as jumpers JP1 and JP2 are next. No orientation is necessary, but they have fairly large leads and may require more time and/or soldering iron wattage to solder.
9. The kit comes with two different disk drive connectors, a shrouded header and a right-angle header. The 40-pin shrouded header is a typical IDE connector. It is best for connecting a disk drive with a cable. If you plug an IDE flash module into the shrouded header, it will be standing up, like this:



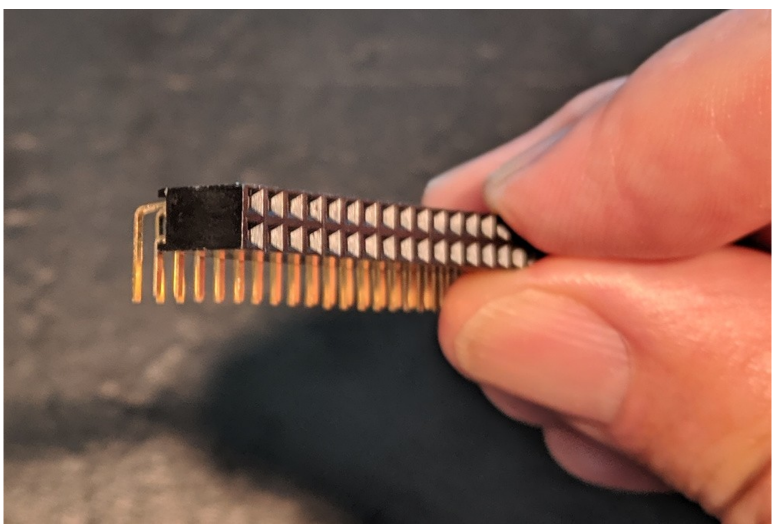
The right-angle header can be used if you plan to place the computer board in a stack, with a module lying down in the space provided for it:

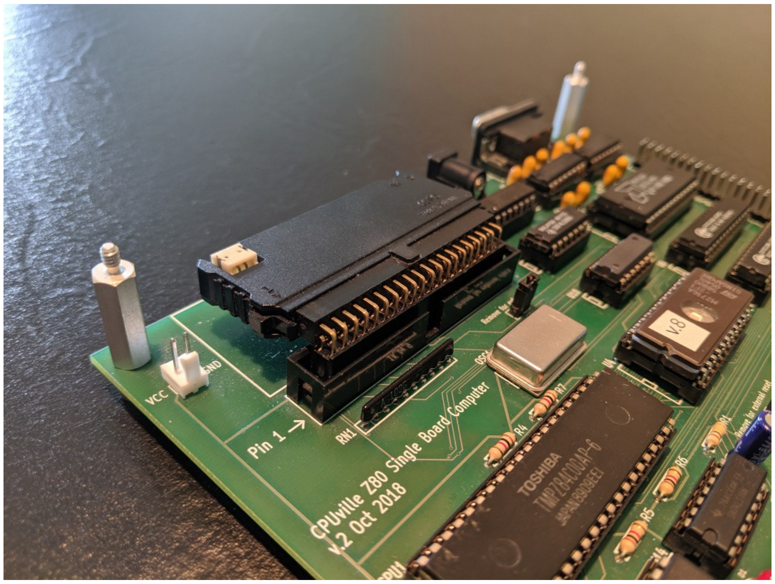


Most modules will fit lying down, but not all:



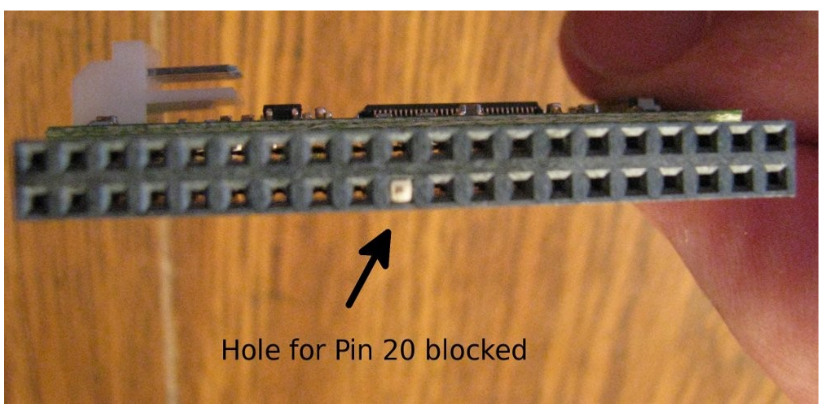
A third method of connecting a disk is to use the shrouded header together with a 40-pin female right-angle header (not included in the kit) as an adapter:



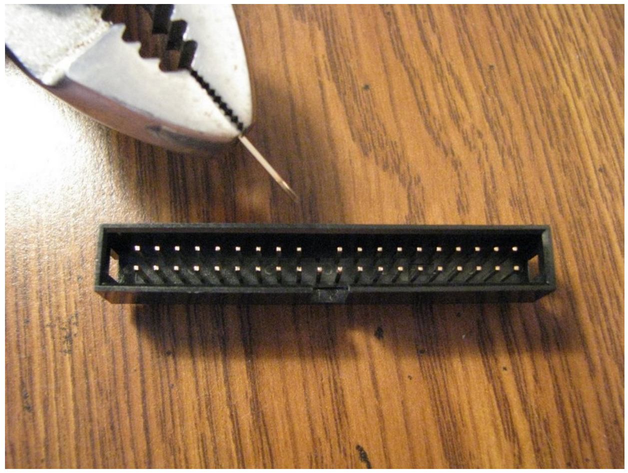


This is less than ideal, because there are two pin-plug interfaces between the module and board, but it is the most flexible, allowing for cable connections to the shrouded header, and also for modules lying down using the right-angle female header as an adapter. Also, some thick modules that will not fit lying down using the plain male right-angle header soldered to the circuit board will fit if using the right-angle female header.

10. Think about how you will supply power to your disk drive, and if the cable or drive plug you will use is “keyed”. The IDE specification allows for pin 20 to act as a key for orienting the plug in the connector. Here is an example of a keyed plug:



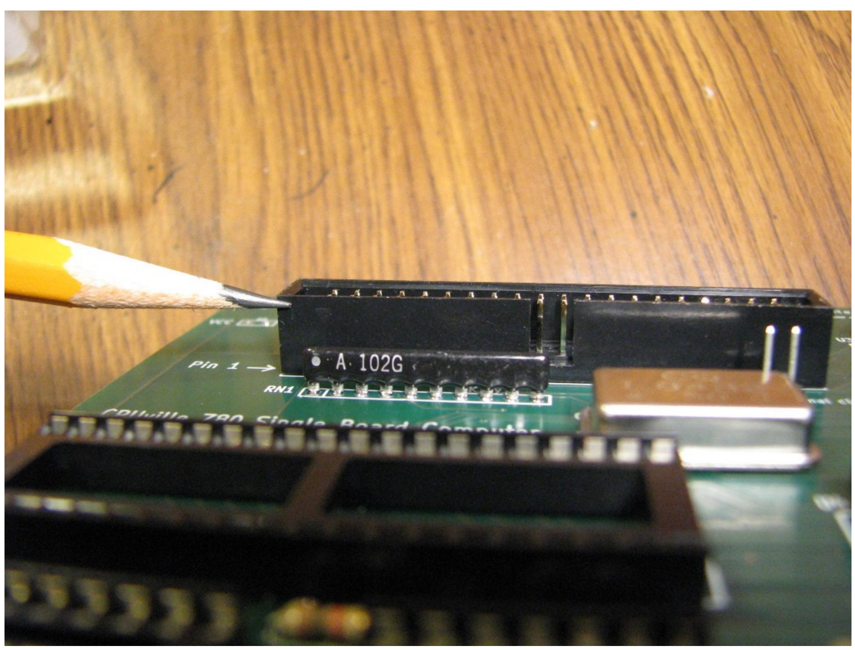
If you are using a keyed plug, and you want to leave the key blocker in its hole, then you should remove pin 20 from the shrouded header connector before you solder it in. You can push the pin through the plastic from the bottom with a flat hard object, like a screwdriver tip, and then pull it out the rest of the way with pliers:



You can also cut off pin 20 from the right-angle header with small metal snips. Alternatively, you can leave pin 20 in the connector, and remove the small key plug from the female socket on your adapter, drive or cable with a needle or pointed knife. The computer circuit board supplies +5V to pin 20, and most drives will either use the +5V to power them, or ignore the +5V. Interestingly, some adapters and flash modules that have the pin 20 hole blocked with a plug can provide power to the adapter through pin 20 if you remove the plug.

If you have a drive with a non-keyed plug, or one that can use the +5V supplied through pin 20, you should leave the pin in the connector. If you remove pin 20 without cutting it, you can put the pin back in the shrouded connector later if you want to, by pushing it back through the plastic with the pliers and screwdriver, like you did when you removed it.

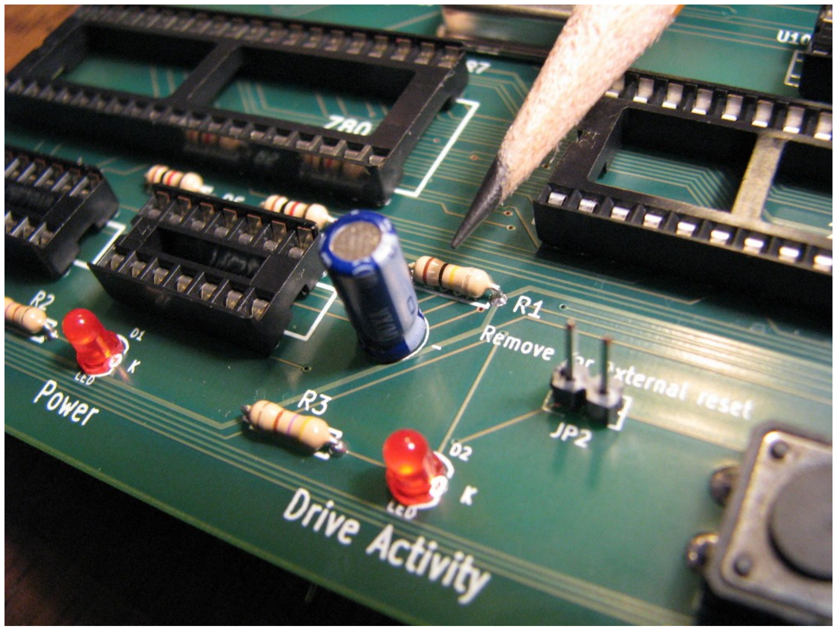
The shrouded 40-pin connector is oriented with pin 1 in the left front corner, as shown by the "Pin 1" label on the circuit board, and the small arrow etched into the plastic shroud:



The cut-out in the shroud should be toward the front of the board. If you install the right-angle header instead, it of course should point toward the back of the board. There is no keying with the right-angle header, so take a little extra care when plugging in a module to make sure you have pin 1 of the header going into the pin 1 hole in the module plug.

The pins of these headers are more massive that those of other components, and may require a little more time to heat with the soldering iron.

11. The two-pin header with the clip is next. Solder it with the clip toward the front of the board. This header can be used to connect a logic probe, or to supply +5V to a disk module if needed.
12. The tall electrolytic capacitor for the reset circuit is next. It needs to be oriented with the negative stripe to the right, toward the "-" symbol on the circuit board as shown:



13. The power-in jack is next. The jack has flat tabs, but the circuit board has circular holes (to save money – tab slots cost extra). Just fill up the holes with solder, like this:

14. The DB-9 connector is the last piece. Like the power connector, there are circular holes for the

holding clips. After you insert it into the board, put solder in the holes with the clips. Then solder the 9 signal pins.

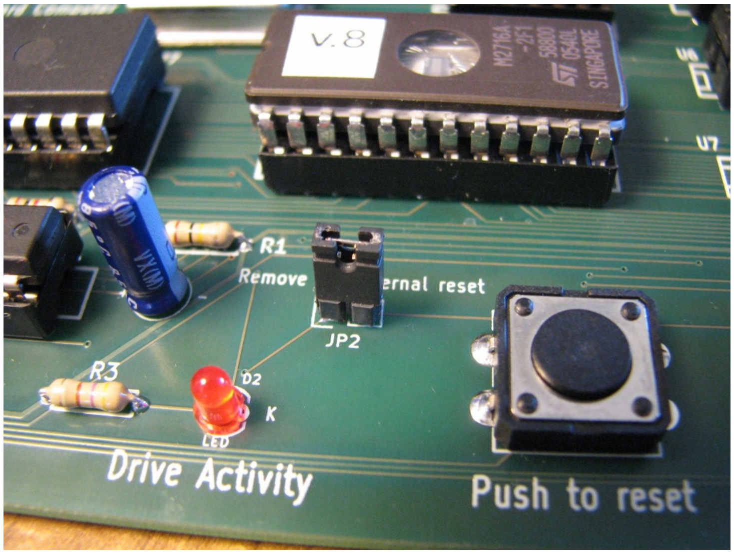
15. Once you have finished soldering all the pins on the computer, inspect the board to make sure there are no solder bridges or unsoldered pins. Lightly brush the back of the board with an old toothbrush or paintbrush to clear off loose debris or tiny solder hairs. Hold the finished board against a bright light. If you can see light coming through a pin hole, go back and solder it again, to make sure you have a good electrical connection. This does not apply to the vias, the plated holes where a trace goes from one side of the board to the other. These can be left open.

Testing and Using CPUville Z80 Single-board Computer

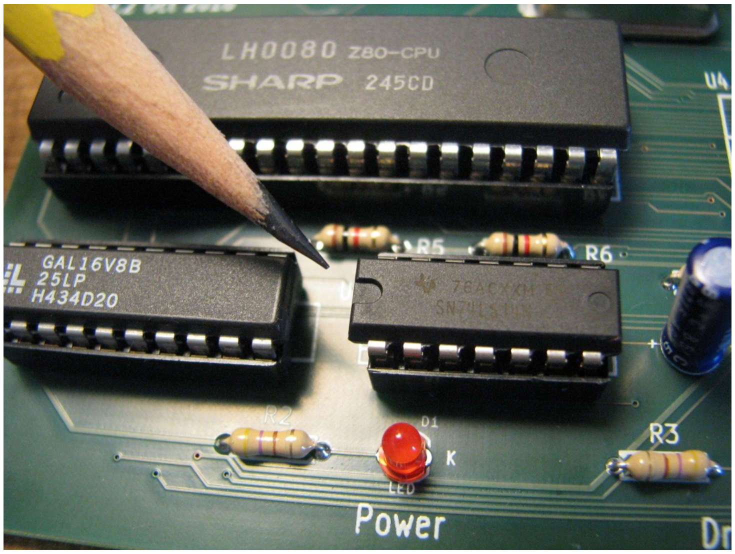
Before inserting the ICs in their sockets inspect the soldering to make sure there are no obvious omissions. It is easy to forget to solder a pin (or a whole row of pins!) when there are so many, as in this computer kit.

Without the ICs inserted, connect the board to a +5V DC regulated power supply of at least 2 mA current output. The Power indicator LED should come on. If it does not, you may have a short in the power traces, or a power supply problem. Once you have verified the power input remove the board from power.

Place the shorting blocks on the two-pin clock and reset jumpers:



Carefully insert the ICs in their sockets. Double check the IC labels to be sure you are putting the correct ones in the correct locations. They are oriented with the small cut-out toward the left:



You may have to bend the pins a little to make them go straight down, to better align with the pin holes in the sockets. Make sure you do not fold any pins under when inserting the ICs. This is easy to do if you are not careful, and can create a frustrating hardware bug that can be difficult to find. A folded-under pin can look exactly like a normally inserted pin from the top.

After inserting the ICs but before connecting the computer to a terminal, or a PC running a terminal emulation program, connect power to the computer board. The Power indicator should light up as before. Once the Power LED is on, check the ICs to make sure none of them are getting hot (can happen if you place one in backwards by mistake). If everything is OK disconnect the power.

The following sections show the computer being tested without a disk drive attached. Refer to the section "Connecting a disk drive" for testing the system that has a disk drive.

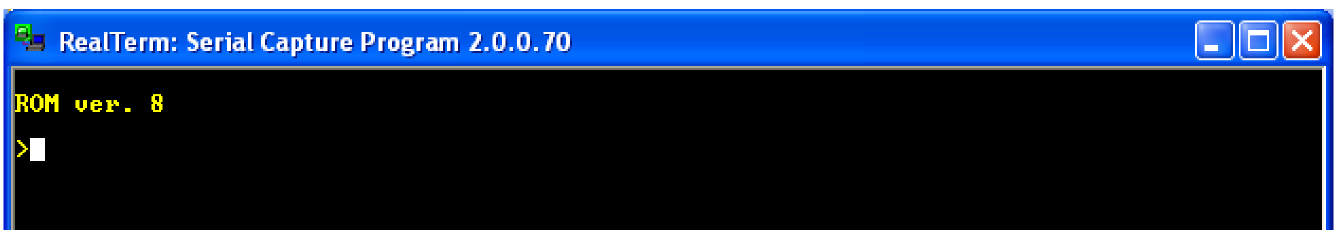
Connect the computer to a PC serial port using a straight-through serial cable (not a "null modem" crossover cable). You can also connect the Z80 computer to a PC using a serial-to-USB adapter[3]. The computer serial interface is configured as 9600 baud, 8 data bits, no parity, one stop bit (8-N-1)[4].

On the PC, start a terminal emulation program. I will use the RealTerm program running under Windows on a PC for these examples.

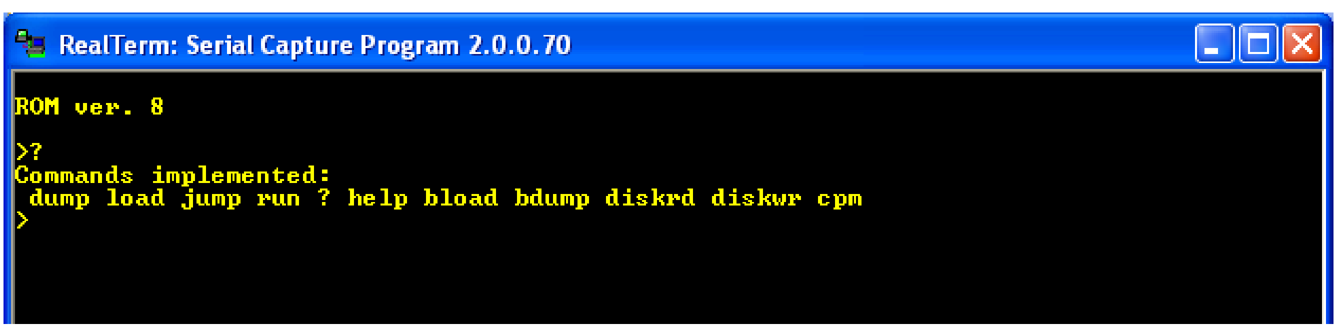
Using the terminal emulation program Realterm

Start RealTerm, and make sure it is set up for 9600 baud, 8-N-1 communications (under the Port tab). Select the ANSI option under the Display As tab. RealTerm uses a default of 16 rows in its display window, but you should increase this to 24 rows.

Apply power to the computer. It should come out of reset after a second or two and display the monitor greeting message and the monitor > prompt character. You can also press the Reset button to start again:



At the monitor prompt enter `?` Or `help` to see a list of available commands:



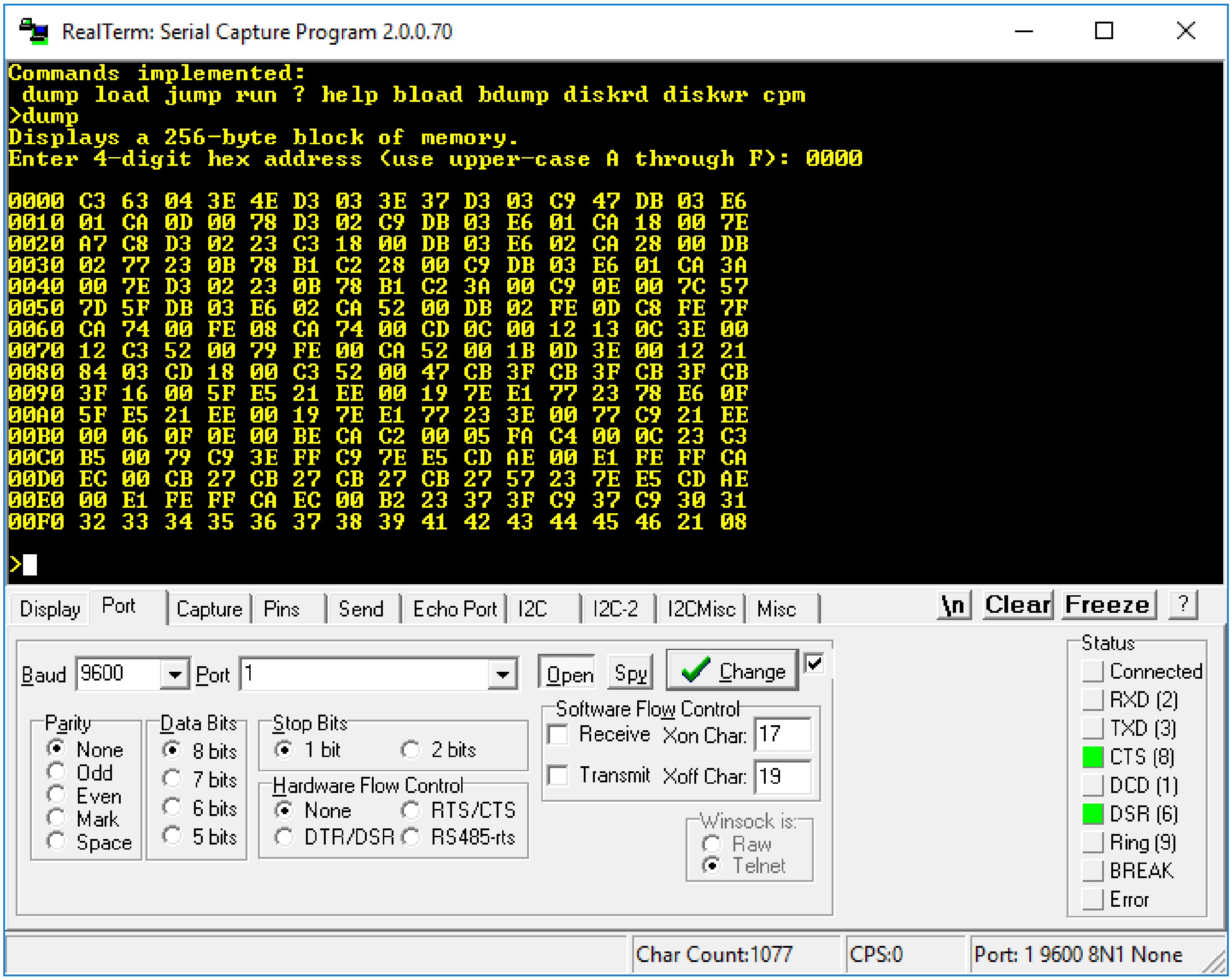
3 [Here is an example from Best Buy in the USA.]
4 The Z80 computer can also be connected to a "dumb terminal", such as a DEC VT-100, for text input and output, but of course such a terminal cannot store data on a disk.

The monitor program is very simple. It has to be, to fit in 2 K of memory. Commands are case-sensitive (lower case only), and no arguments are accepted with the command. The arguments are entered separately to queries. Hexadecimal numerals need to be entered with upper-case A through F. There is minimal error checking and no memory management. The input buffer is not cleared after most commands, so if you hit return on a blank line, you might find that you have re-executed your last command. But, the monitor program works well if you stay within reasonable limits. The worst you can do entering commands is to cause the Z80 system to fail. If that happens, just reset. Here is a discussion with examples for using the various commands.

Monitor commands

`dump`

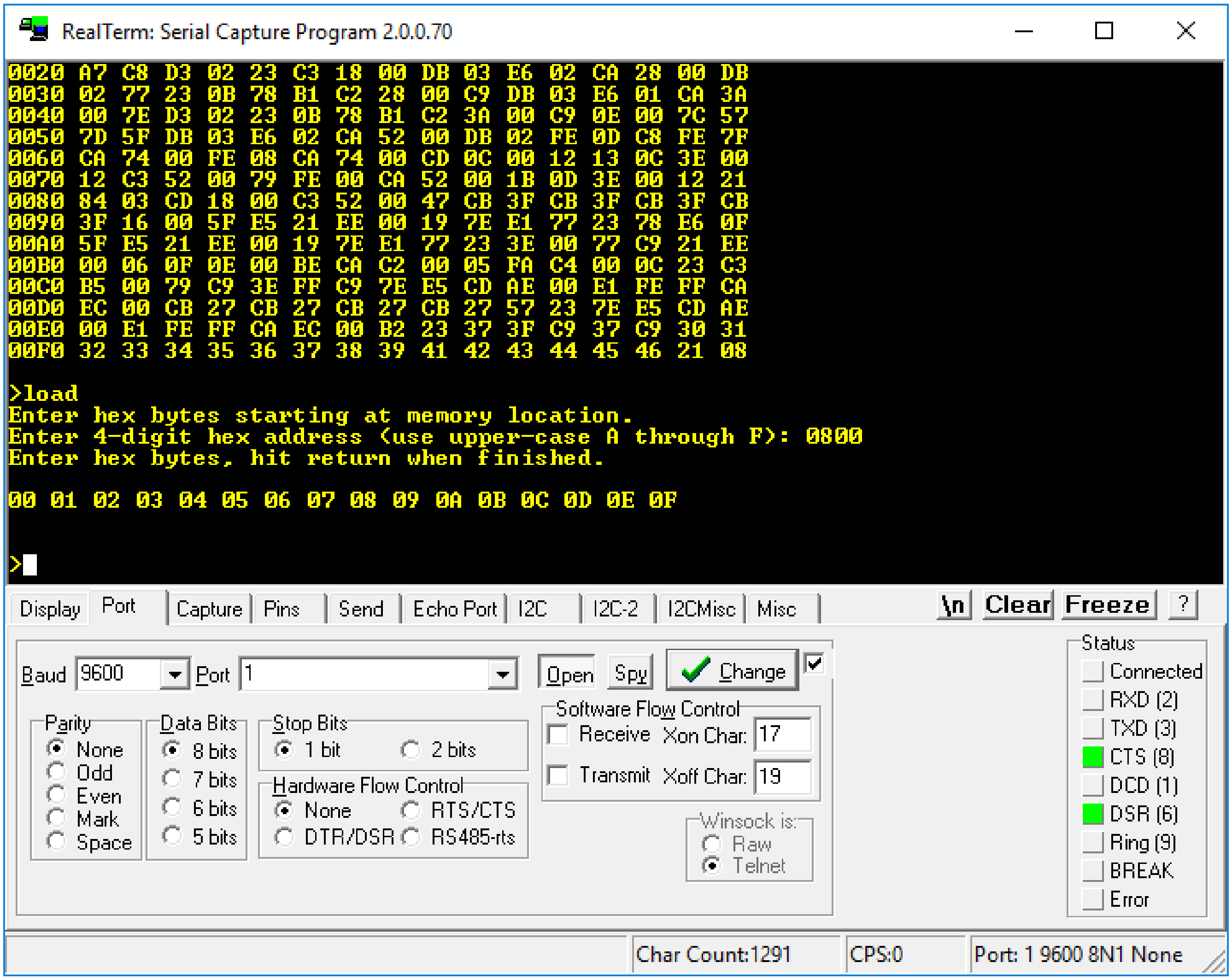
Displays a 256-byte block of the Z80 computer's memory. The command takes a 4-character hexadecimal address as input, with the A through F characters as upper case. The output display shows the 4-character hexadecimal address of the first byte of each row, then 16 bytes of data as hexadecimal characters. Here is a dump display of the first 256 bytes of the ROM:



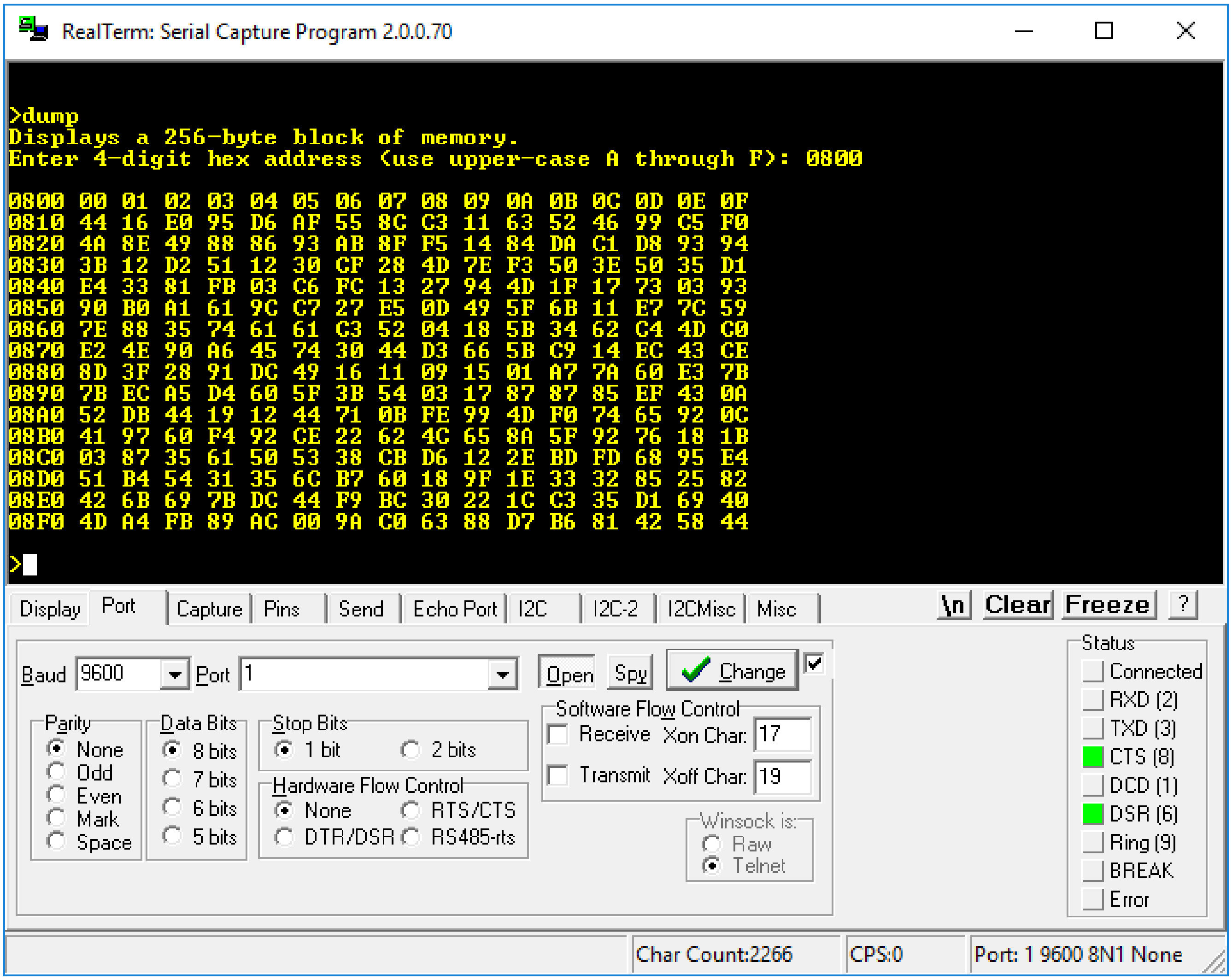
This command is very useful for debugging programs, as you can see the machine code, and the values of your variables.

`load`

This command takes input from the keyboard, as hexadecimal characters, and loads the input into memory as binary code. Hit return to stop the input. During the load, the display shows 16-byte rows of input data in a manner similar to the `dump` command, without the addresses. Here is an example, entering the first 16 hexadecimal numbers into RAM starting at location 0x0800:



Here is a dump display of RAM starting at location 0x0800. You can see the 16 bytes I entered:



The rest of the RAM has digital garbage in it.

You can use the `load` command to quickly change a byte of program code or a variable, to clear memory by putting in zeros (just hold down the zero key, the repeats from the keyboard are entered), and to load small programs by hand.

jump

This command causes program control to be passed to the address you enter. It is the same as the `run` command.

run

Same as the `jump` command.

?

Displays a list of the implemented commands. Same as `help`.

help

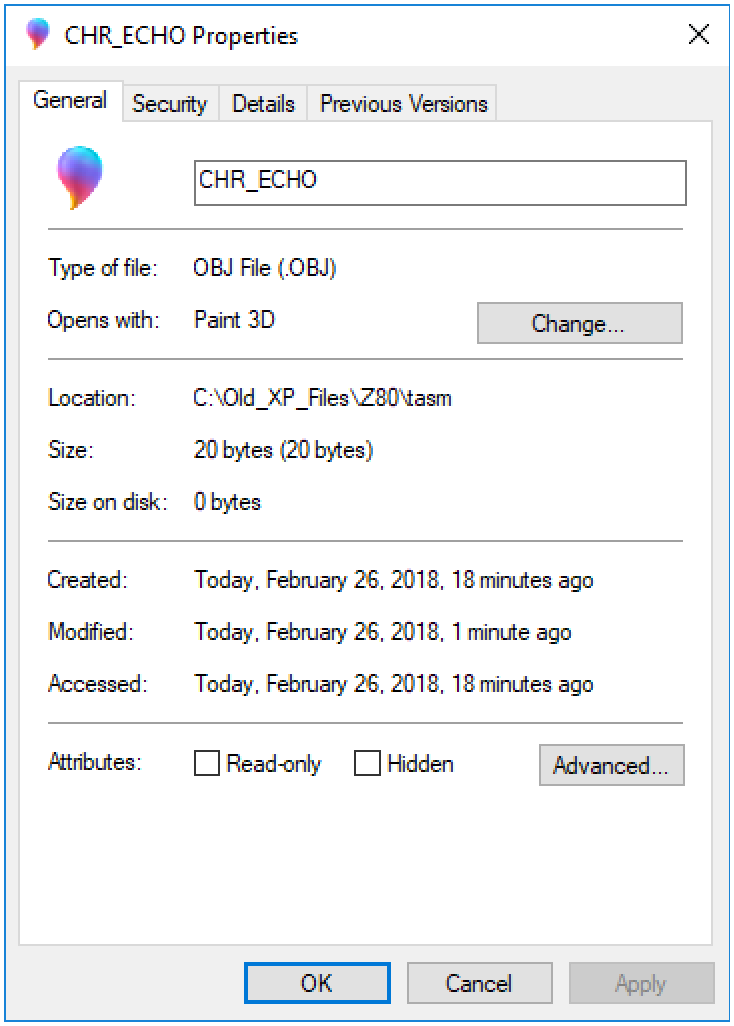
Same as `?`.

bload

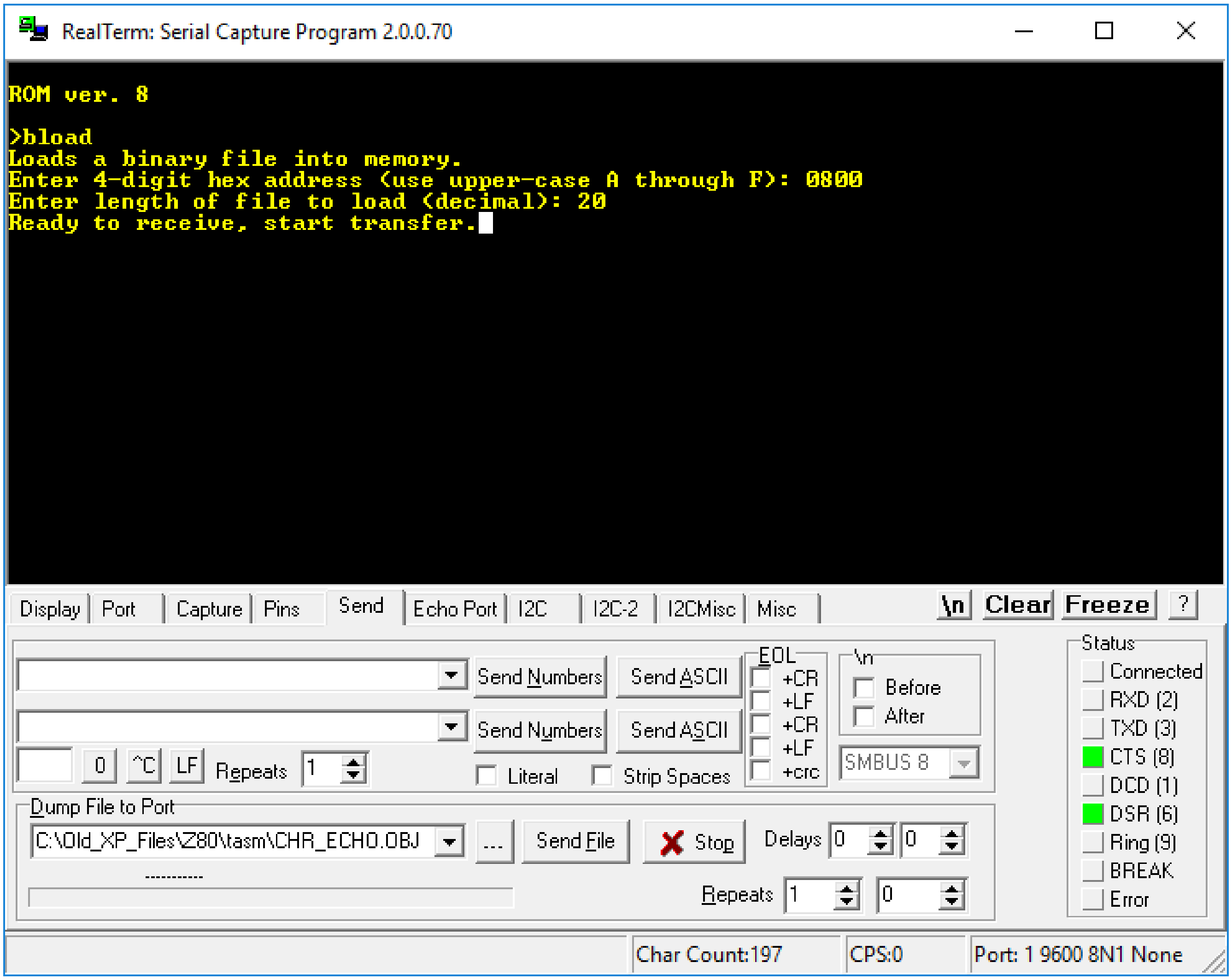
This command is for loading binary files (**b**inary **load**) over the serial interface into the Z80 computer memory. The command takes a four-character hexadecimal address input, and a decimal file length input. Then, it waits for the file to be sent from the PC to the Z80. It works best if you enter the exact length of the binary file. The `bload` command will hang if the file is shorter than the length you enter.

The following is an example of loading a binary file using the `bload` command. We will load and execute a small program named chr_echo which echoes characters from serial port input (the keyboard) to serial port output (the screen). The list for this program is in the Selected Program Listings at the end of this instruction manual.

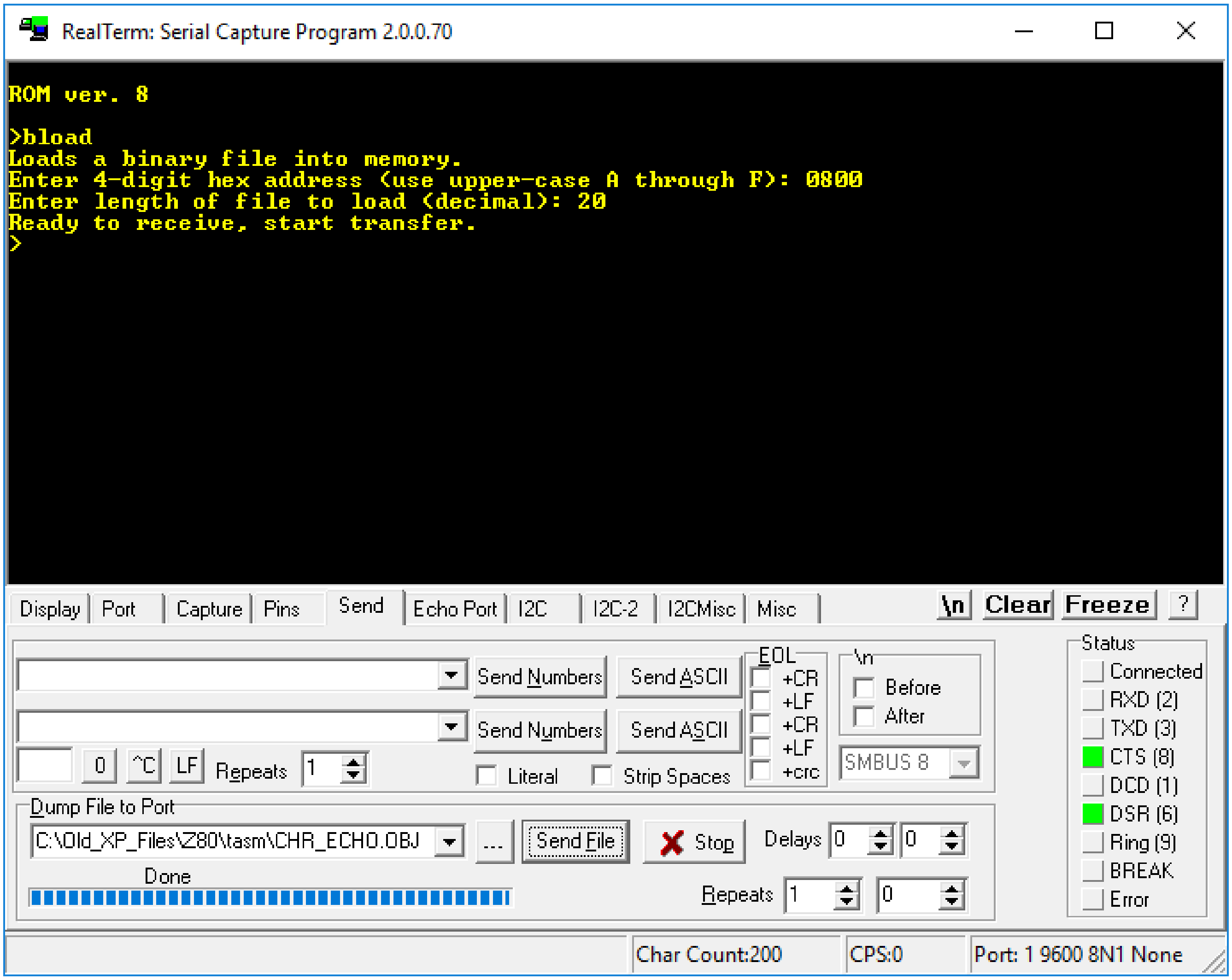
We can load the file anywhere in RAM, but let's load it at location 0x0800. First we need the exact file size, which we can obtain by hovering over the file name, or right-click-Properties:



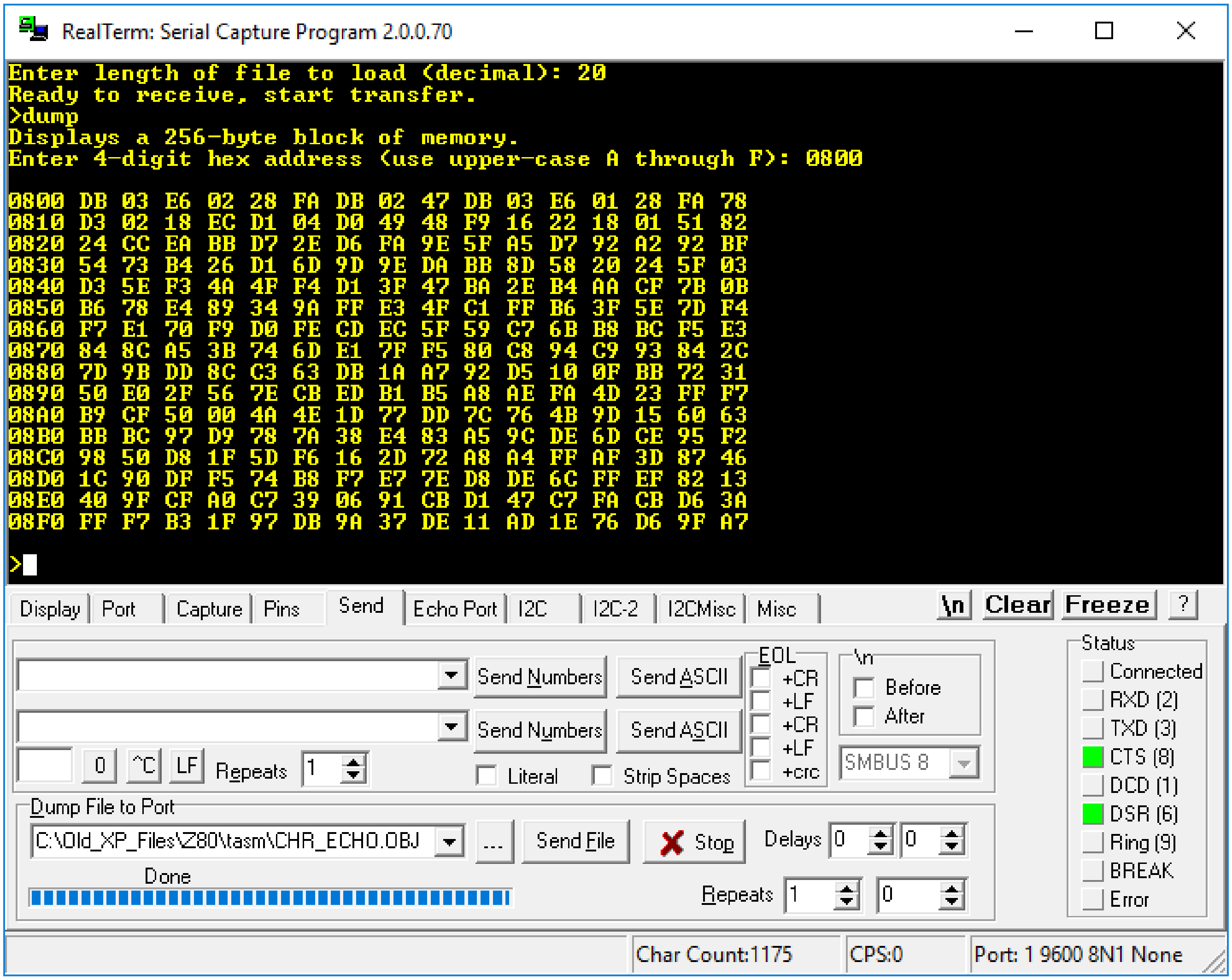
We see the file is 20 bytes long. Now we run the `bload` command, and enter the target address 0800h (no need to type the "h" in the monitor), and the length as decimal 20. Hit return after entering the length, and the monitor program lets you know it is ready to receive the file:



Now, in the RealTerm Send tab, navigate to the chr_echo.obj file using the … button, click Open, then click the Send button. After the file is sent "Done" should appear above the blue file progress bar, and the monitor prompt should reappear, letting you know the command was successfully executed:



You can examine the memory at 0800h using the `dump` command:



There you see the program bytes (the first 20 bytes, showing memory contents of DB, 03, E6, … EC), followed by random garbage bytes that were in the memory before we did the `bload` command.

You may now run the program using the `run` command. Enter the address 0800h. The characters you type are echoed to the screen. For a neater display click the **\n** button on the RealTerm display. This sends the cursor to a new line.

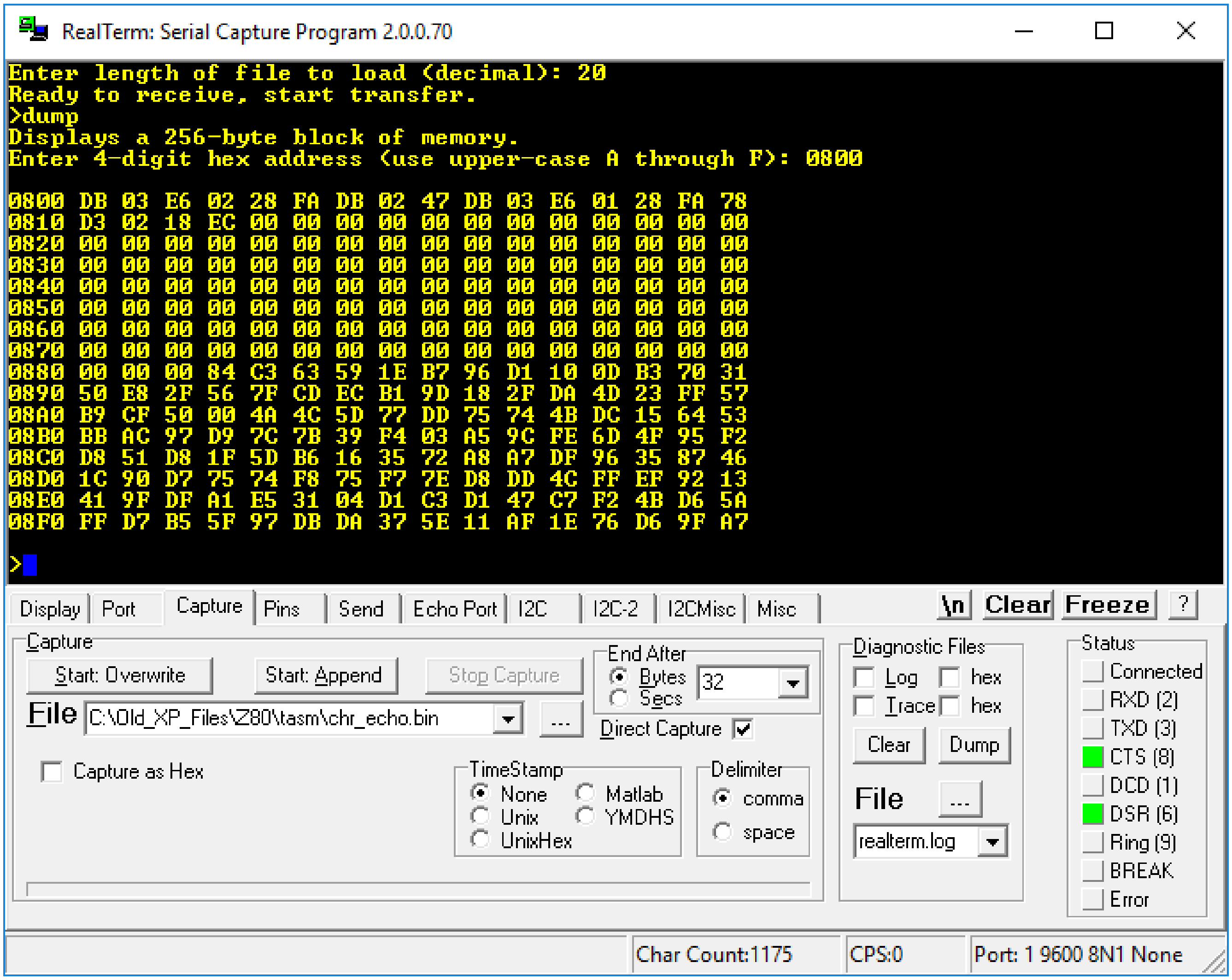
The `chr_echo` program has no exit, so you need to reset the Z80 computer to get out of it. When you reset the computer, the monitor program starts again. Of interest, resetting the Z80 does not clear the memory contents. After you reset the computer, You can see that the `echo_ch` program is still present at location 0800h using the `dump` command, and you can run it again using the `run` command. If you want to write a program to return to the monitor on exit, you need to put in an instruction to jump to the `monitor_warm_start` entry point at 0x046F on program termination.

bdump

This command dumps a segment of binary data from memory to the serial port. It is up to the PC on the other end to capture this output into a file. We can do this using RealTerm.

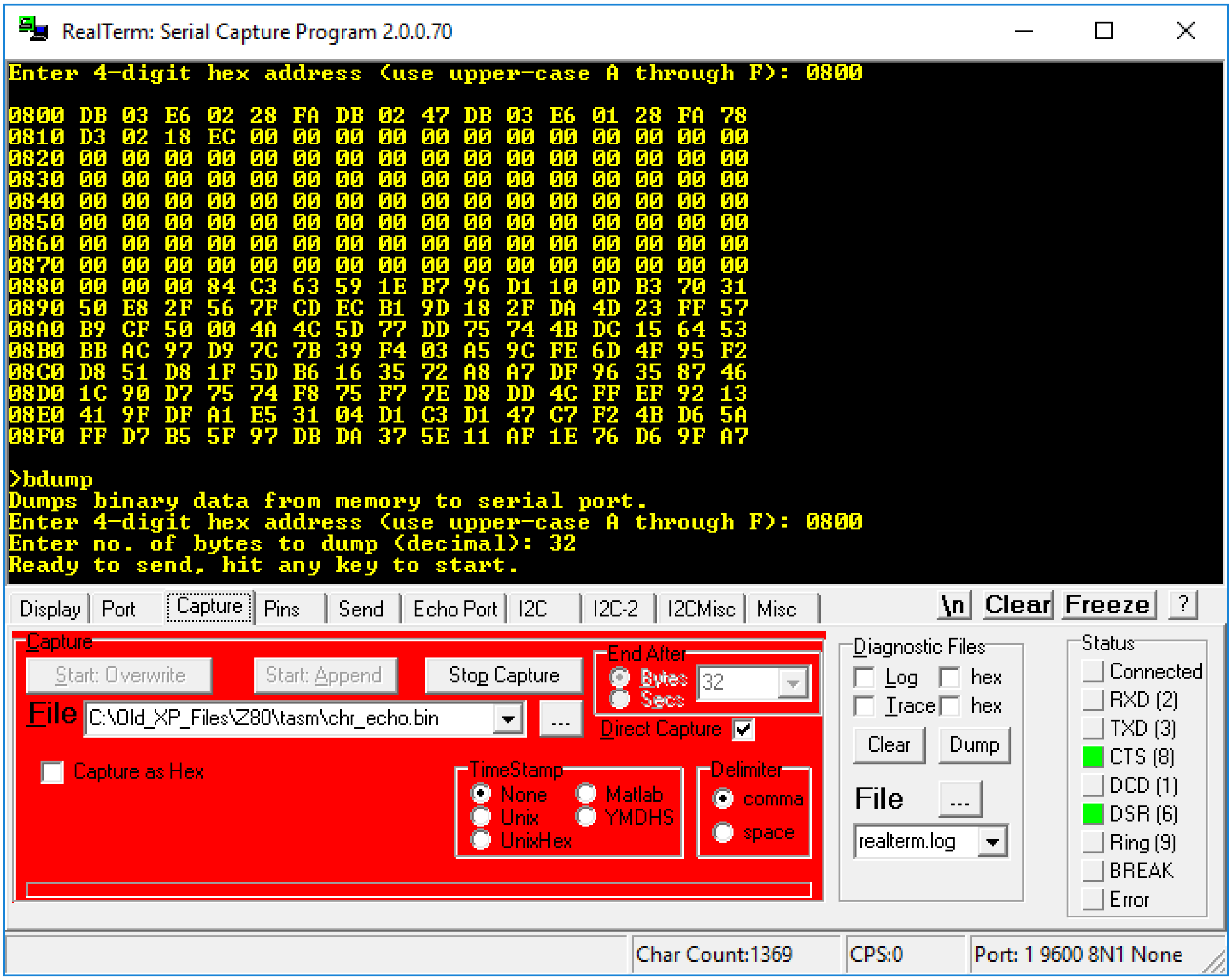
We can save the `chr_echo.obj` file which we placed in memory with `bload` as a new file named `chr_echo.bin`. First we set up RealTerm to receive a file of this name from the serial port. Click on the Capture tab. Write the file name (with complete path) in the File window (or use the … button to navigate to a file). Make sure Direct Capture is checked.

To tell RealTerm when to stop capturing transferred data, you can enter the number of bytes in the End After dropdown. For some reason, it is most accurate if you put a multiple of 16 in that window. I have set it up here to capture 32 bytes, which will be the 20 bytes of the program plus 12 garbage bytes to get to a multiple of 16.



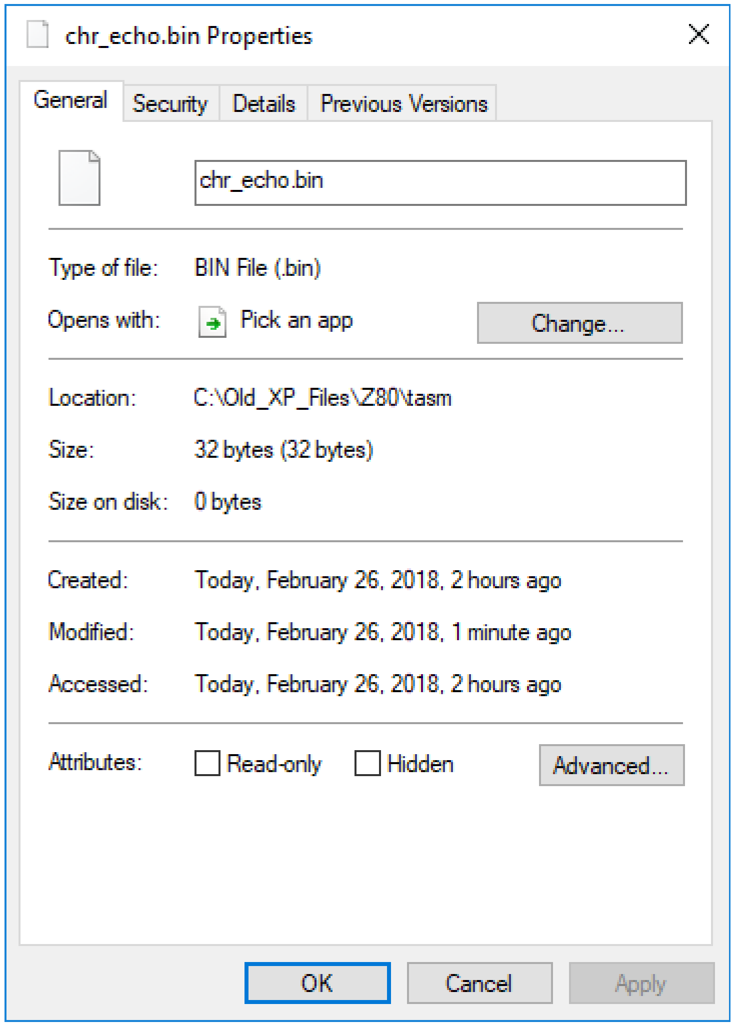
Now I enter the `bdump` command in the monitor window, address 0800, number of bytes to dump 32 and hit return. Now, the Z80 is ready to send those 32 bytes from the memory to the serial port with any keypress.

Click on the Start: Overwrite button in the RealTerm Capture window. The bottom of the display turns red, indicating that capture is underway. But, the Z80 computer has not sent any bytes yet.



Now, click in the display window (that will allow the RealTerm session with the Z80 computer to receive characters from the keyboard) and hit any key. The 32 bytes will be transferred to the file chr_echo.bin and the display will return to the monitor prompt.

Navigate to the directory containing the `chr_echo.bin` file, and check its size in the Properties window. You can see it is 32 bytes.



The following commands are for the Z80 computer with a disk drive attached, placed here with the commands summary for completeness.

`diskrd`

This command reads one sector from the disk and writes it into memory at a location you specify. IDE drives have 512-byte sectors, read as 256 16-bit words. However, this Z80 computer only reads or writes the lower 8-bits of these 16-bit words, so one sector will contain 256 bytes.

The `diskrd` command takes as input the memory address, as a 4-digit hexadecimal number, where the disk data is to be placed, and the sector number as a decimal logical block address (LBA) from 0 to 65,535[5]. It reads 256 bytes from the sector, and places this data into memory starting at the address you specified. Note that the command will read sectors using a 16-bit LBA, but the ROM subroutine underlying the command will take a full 24-bit LBA, and you can write programs using this subroutine to take advantage of this if you want.

5 Your disk may have more sectors than this, but the monitor command can only take an address up to 65,535.

diskwr

This commands takes 256 bytes of data from memory and writes it to one sector of the disk. Like the `diskrd` command, it takes as input the memory address of the data to be written as a 4-digit hexadecimal number, and a 16-bit decimal LBA for the sector to write. Both `diskrd` and `diskwr` need the LBA to be an ordinary decimal number without leading zeros – if you add them, the routines will hang.

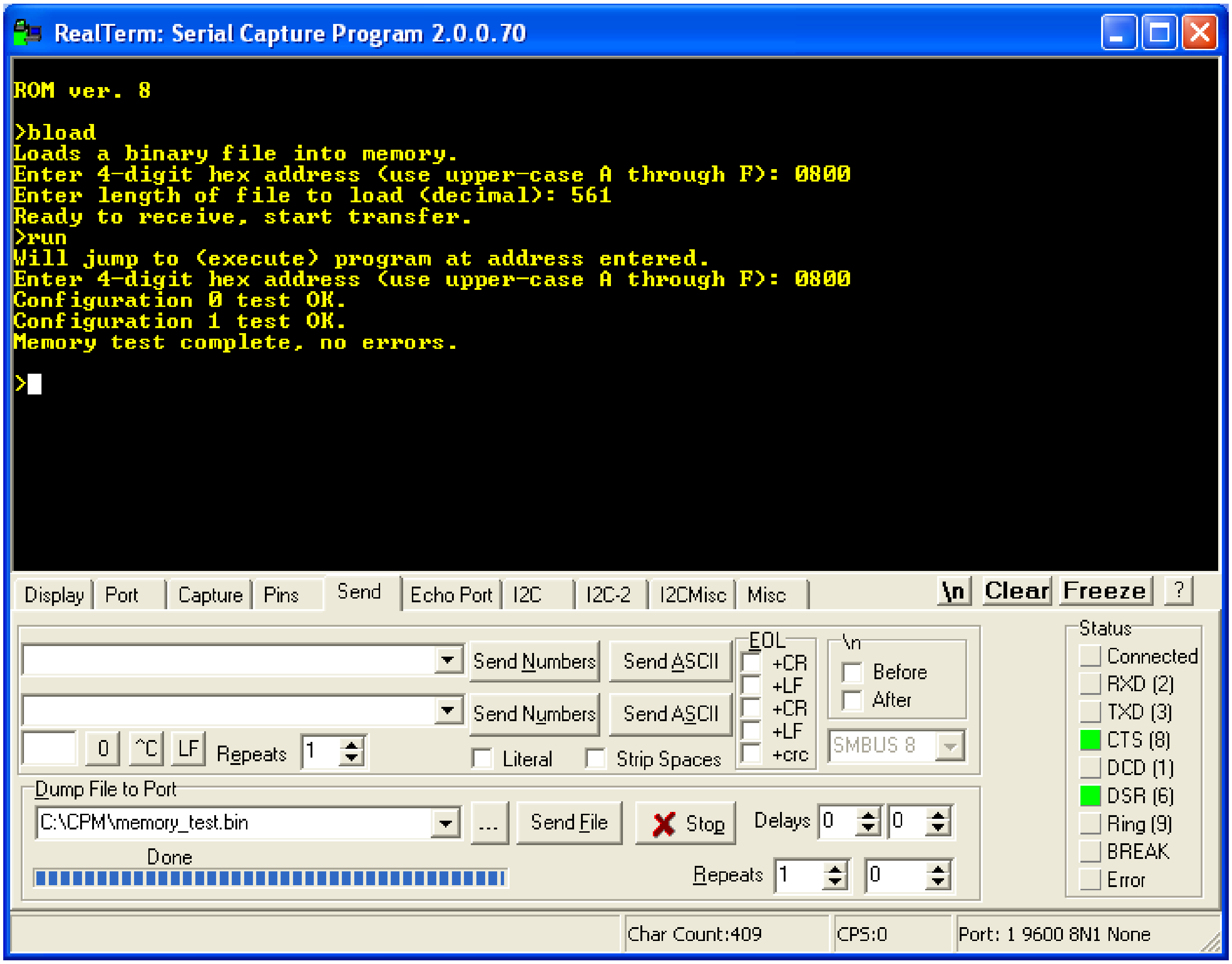
cpm

This command loads 256 bytes of data from the first sector of the disk (LBA 0x000000) into memory location 0x0800, then jumps to that location. The program in that sector is used to load and start CP/M, but can be used to start any other operating system the user might care to put on the disk.

Testing the memory

I have written a brief program to verify the presence of 64K RAM, and that the memory configuration flip-flop is working correctly. This program will work without a disk attached. Download the memory_test.bin file from the CPUville website http://cpuville.com/Code/CPM.html.

To do the test, use the `bload` command to load the memory_test.bin file into memory at location 0x0800, then the `run` command to execute it. It takes about 15 seconds to complete. If successful, it should print output as below:



If the memory test fails, recheck the pins of the RAM ICs to make sure they are seated properly. If you cannot get it to work, please contact me for advice.

If the memory test works, we can be confident that the board is built correctly. Now, disconnect the power, and connect a disk drive as described in the following section.

Connecting a disk drive

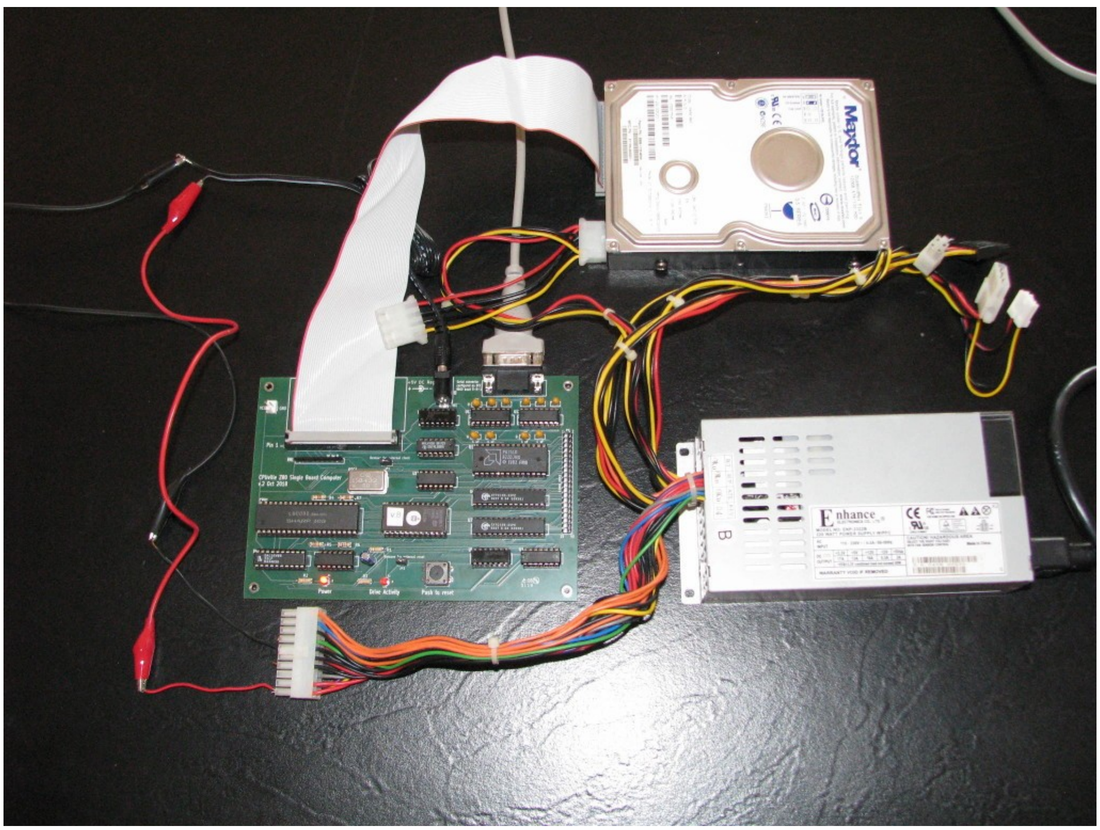
This Z80 computer will work with most IDE disk drives (see the Table of Tested Disk Drives at the end of this manual). The disk size should be 128 megabytes or higher if you want to install CP/M. This is not to have enough room, because a full-blown CP/M system uses only about 1 megabyte of disk space, but because the CP/M system described here uses simplified code that does not use disk space very efficiently[6]. In particular, it uses simplified arithmetic to map CP/M sectors onto the LBA sectors of the hard disk, which skips a lot of space. Also, the CP/M system I developed uses only 128 bytes of

6 Recently I have updated the CP/M system for this computer, increasing the disk size and changing the mapping algorithm to use disk space much more efficiently. Visit http://www.cpuville.com/Code/CPM.html#cpm-update for details, and to download the updated code.

each sector for data. This is the native sector size that CP/M uses, since it came out of the era in the mid-1970s when only floppy disks were used, and those disks used 128-byte sectors. CP/M offers blocking and deblocking code to more efficiently use disk space, by taking 256- or 512-byte sectors and breaking them into 128-byte pieces, but I did not use this code in my system, again out of a desire to make it as simple as possible.

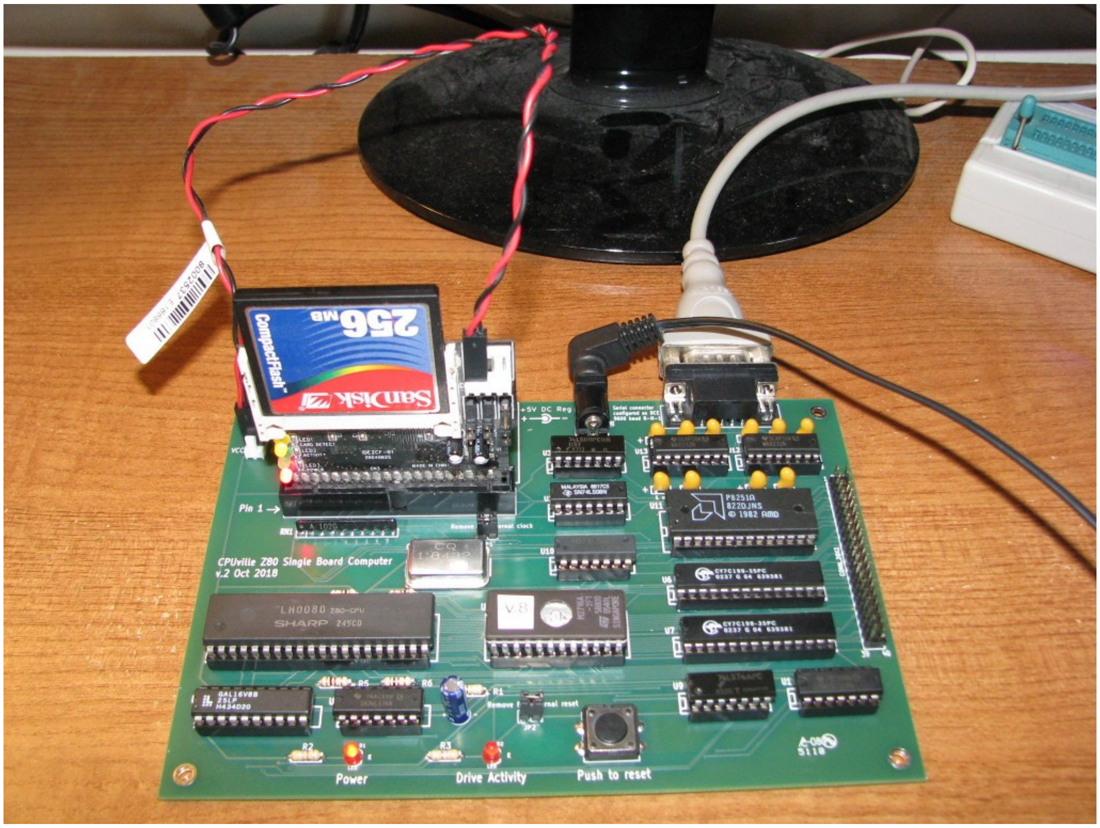
The disk drive plug needs to be oriented correctly. If keyed, as described above, it cannot go into the socket backwards. However, if it is not keyed, you need to take care that pin 1 of the plug goes onto pin 1 of the socket, as indicated by the “Pin 1” label on the circuit board, and by a small arrow engraved on the plastic shroud of the connector.

If using a mechanical disk drive, you can use a computer power supply to provide power to both the drive and the Z80 computer. Take the +5V and ground from the main power connector to the input jack on the Z80 computer board, or to the auxiliary power connector, and connect a power supply disk power connector to the drive. That way, both the computer and disk drive share the same ground, which is important to prevent damage to the computer or the drive electronics. Connect the hard disk to the circuit board IDE socket using a standard 40-conductor IDE cable. Make sure that pin 1 of the circuit board socket is connected to pin 1 of the disk drive socket.



Note in the above picture the AT-type computer power supply, with the hard disk drive receiving power from one of the plugs coming from the power supply. The +5V power and GND for the Z80 computer are coming from the proper pins of the main power supply plug. There is also a jumper wire between the power supply ON input (PS_ON#, pin 14) and ground which is needed for the power supply to turn on.

If you are using a solid-state IDE drive, or a compact flash drive in an adapter with a separate power connector, you can use the two-pin connector auxiliary power connector to supply low-current +5V power to the drive. You will have to use your own wires to make the connection. Here is a photo of a compact flash drive in an adapter[7] with attached power supply wires:



Many small solid state flash modules do not require a separate power input; you can get low-current +5V power from pin 20 of the drive connector instead. The photo on page 14 shows one such “disk-on-module” in the socket.

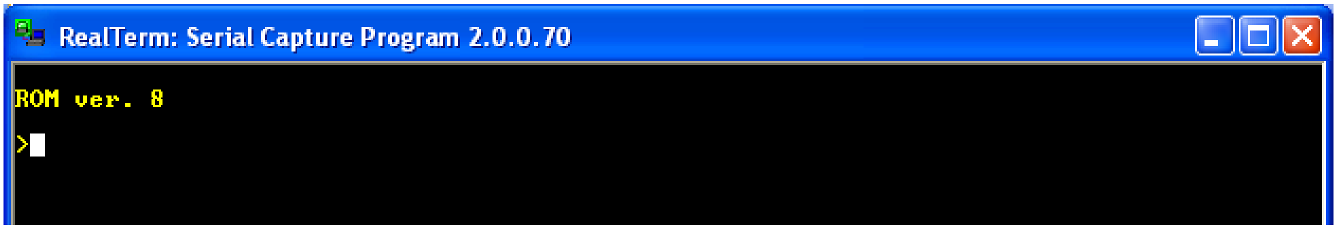
See the section above in Building the Computer for more details about pin 20 in the IDE socket.

Testing the disk drive

You can test the disk drive using the monitor `diskwr`, `diskrd`, and `dump` commands. Of course, once you write data to a disk sector, any data on that sector will be overwritten and lost. This is especially true of sector 0, which on disks salvaged from old PCs will have partition information. The `cpm` command in the ROM monitor reads disk sector 0 into memory, so you will need to place code into this sector if you want to use this command to start an operating system. I suggest you do not try to preserve partitions on your disk, but rather dedicate a disk for use on the Z80 computer for experimentation and to try the CP/M operating system.

With the disk drive connected, apply power to the computer and take it out of reset. You should again see the greeting message and get the monitor prompt.

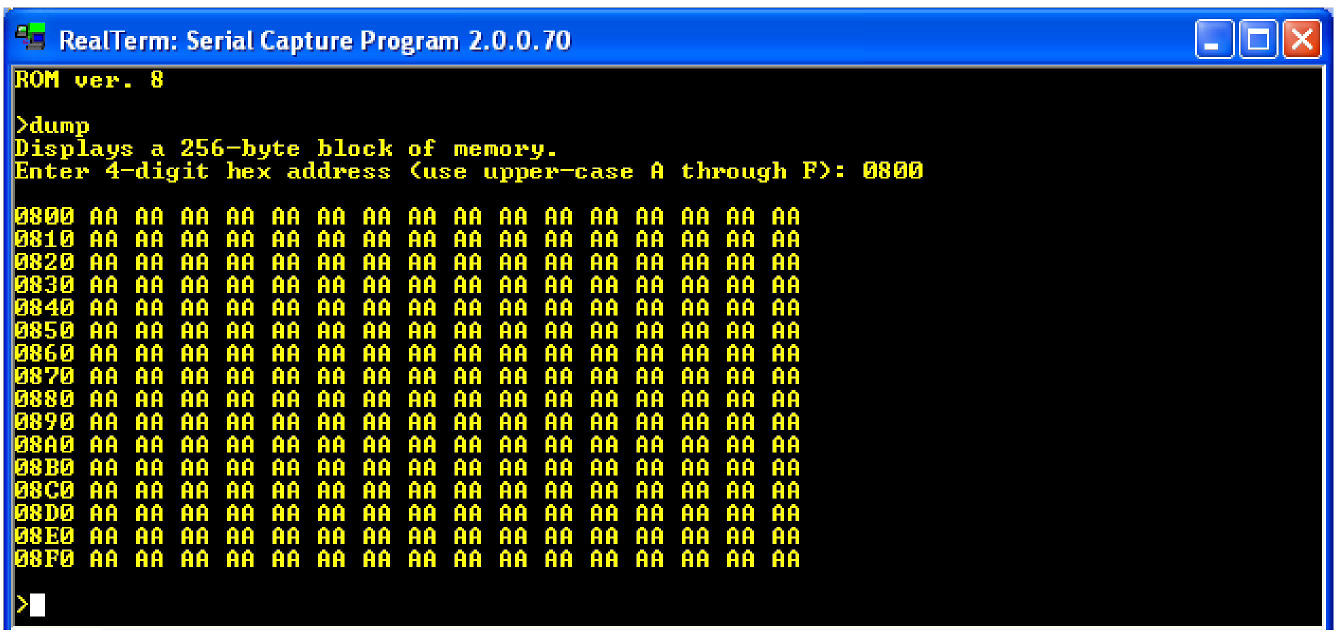
7 This brand and model adapter can also get power from pin 20, but it makes a nice photo to show how to connect the power supply wires for modules that require them.



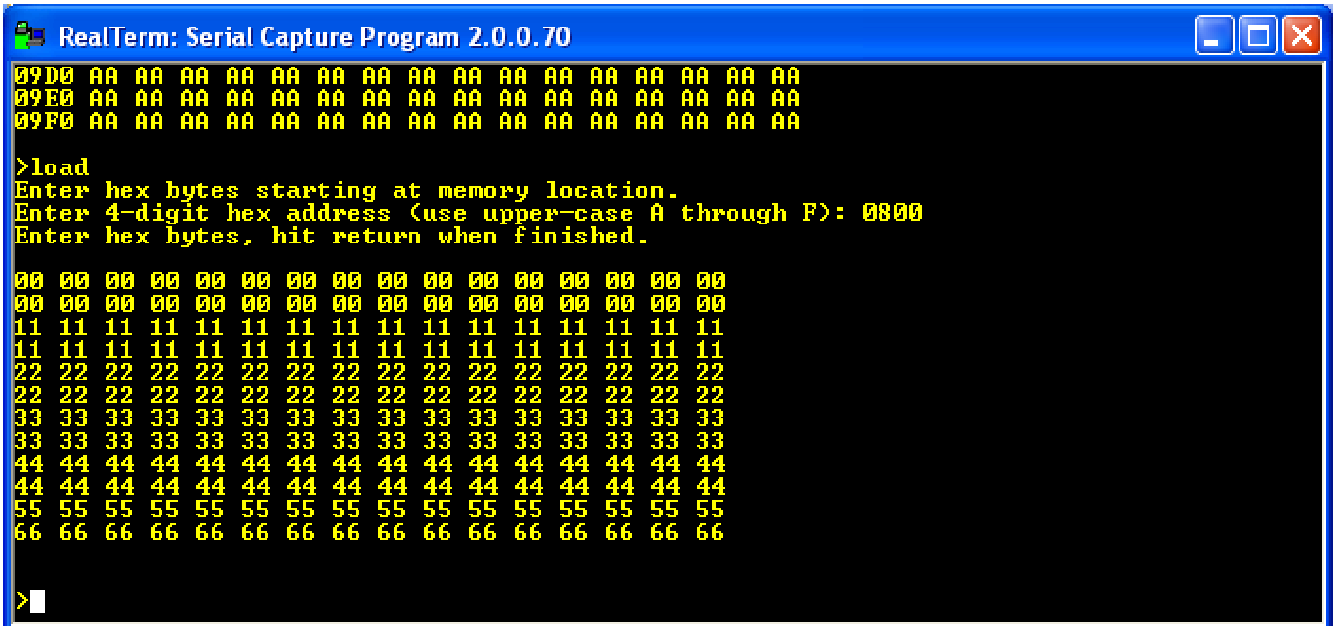
To test the disk, we will use the `load` command to place an easily recognizable data pattern into the computer memory, then write this pattern to a disk sector using the `diskwr` command. Next, we will read it from the disk and place it in a different area of memory using the `diskrd` command. Then, we will examine this second memory area with `dump`, and look for that data pattern. If we see the pattern, we know that the disk write and read commands worked correctly. Here is the detailed test procedure.

First, examine the memory pages (that is, the 256-byte blocks of memory) at 0x0800 and 0x0900 using the `dump` command:

The memory will contain random data at system power-on. Your memory data will probably look different than this.

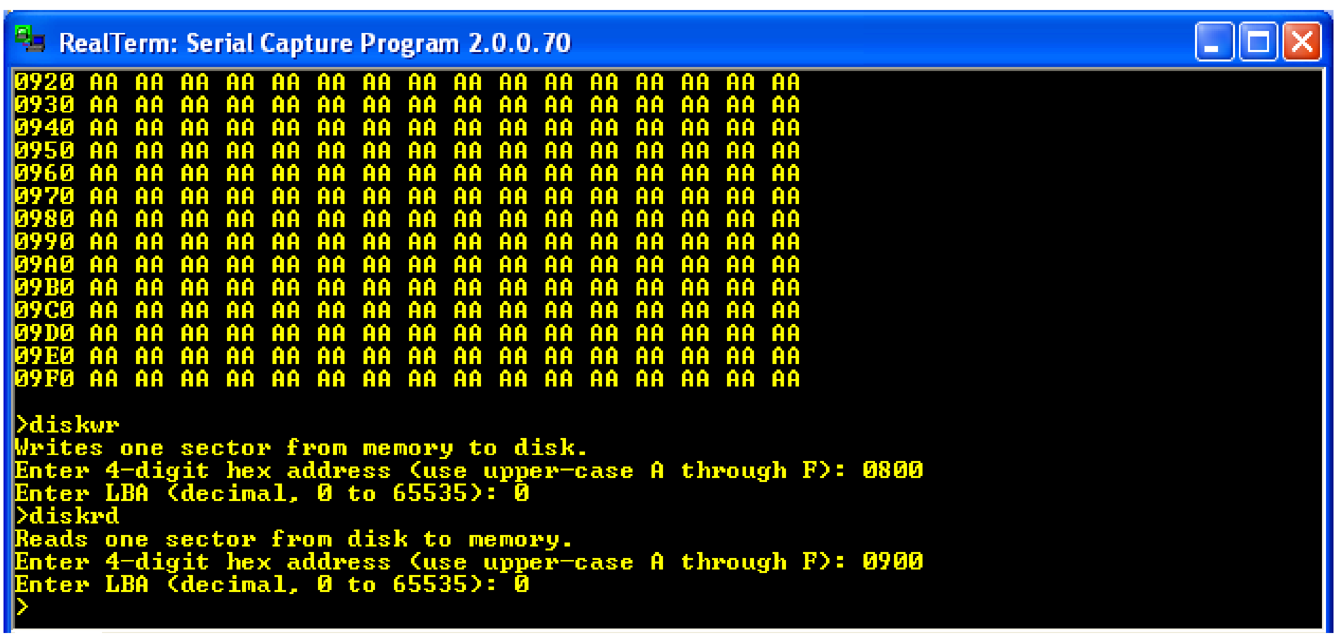


Now, load page 0x0800 of memory with an easily recognizable pattern of data using the `load` command:



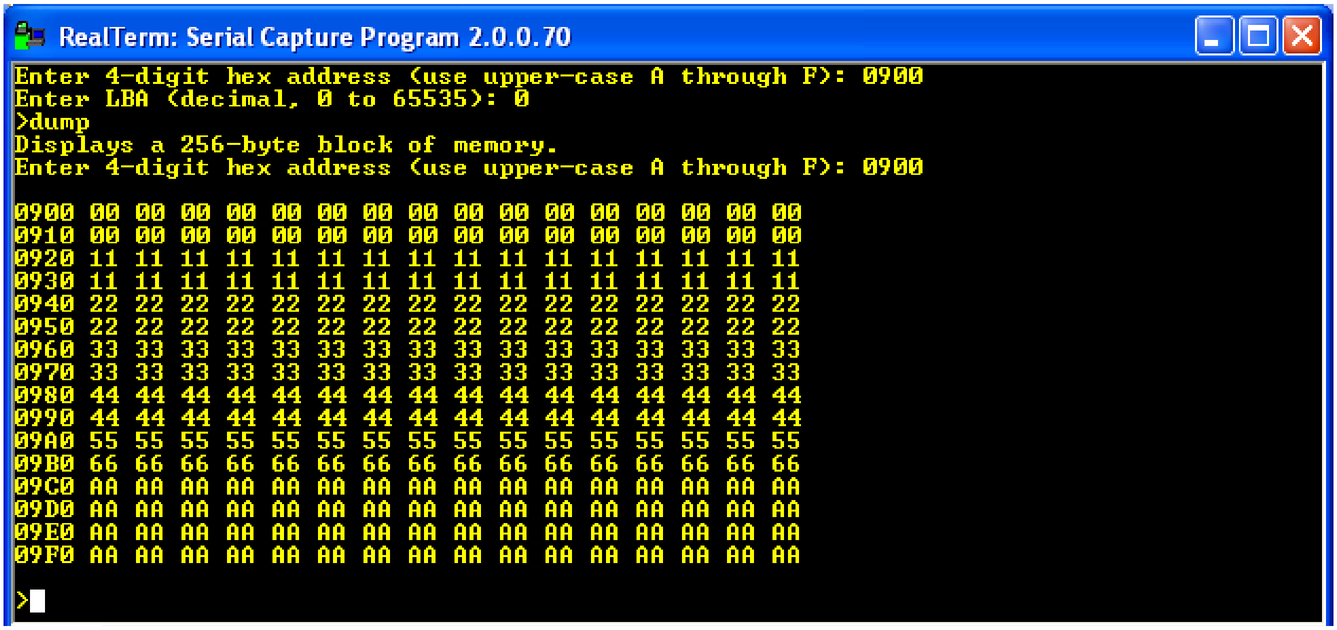
You can use whatever pattern you like, but it should be easily recognizable.

Now, write the memory page at 0x0800 to disk sector 0 using the `diskwr` command. You should see a brief flash on the Drive Activity LED on the computer circuit board when you do this[8]. Then, read the same sector back into memory at 0x0900 using the `diskrd` command (again, the Drive Activity LED should flash):



Now, display the memory page at 0x0900 using the `dump` command:

8 Some disk adapters have their own Disk Activity LED. If your are using one of these adapters, the LED on the computer board may not light up.



If you see your data pattern there, you know your disk is working properly, and you can read and write sectors. You can experiment with other patterns, other memory locations and other sectors.

Once the disk is working properly you can install CP/M onto the disk.

Installing CP/M version 2.2

CP/M system update

I have updated the CP/M CBIOS described in these sections to create larger CP/M disks, and to use disk space more efficiently. I also updated the support programs needed to install CP/M. The updated CP/M system is installed in the same way as the earlier system described here, except the file names and sizes have changed. The screenshot images and the instruction text in this section have not been changed to reflect the updated CP/M system. However, I have added footnotes in several places to clarify the differences you will see if you install the updated CP/M. Please visit http://www.cpuville.com/Code/CPM.html#cpm-update to get details, and to download the updated code.

About CP/M

The CP/M operating system was the first commercially successful disk operating system for microcomputers. As such, it received designation by the IEEE as a Milestone in Electrical Engineering and Computing. See the article at http://theinstitute.ieee.org/technology-focus/technology-history/groundbreaking-operating-system-is-named-an-ieee-milestone.

This operating system was designed by Gary Kindall in 1974, to run on microcomputers with an 8080 processor and 8-inch IBM floppy disks. However, it was designed to be portable to many different machine architectures, by having a machine-dependent, customizable basic input-output system (CBIOS) that had the software to operate the disks, console and other peripheral hardware, and a machine-independent basic disk operating system (BDOS) and console command processor (CCP), to process commands and to create and use a disk file system. Since the 8080 processor uses a subset of the same machine code as the Z80, CP/M could be used on both 8080 and Z80 machines. CP/M use spread to a wide variety of machines using a wide variety of disk drives and peripherals. Eventually, the introduction of 16-bit microcomputers using MS-DOS made 8-bit microcomputers (and CP/M) obsolete, but it is still used and enjoyed by hobbyists and educators running 8-bit Z80 or 8080 systems.

CP/M Source Code

Even though CP/M has been obsolete for many years, its status with respect to the source code was unclear, in part because the rights were transferred to a series of companies. The operating system was originally owned by Digital Research, Inc., then passed to a spin-off named Caldera, Inc., and then to Lineo, Inc. In 2001, the CEO of Lineo, Bryan Sparks, gave permission to Tim Olmstead to place the CP/M source code on his web archive of CP/M software, "The Unofficial CP/M Web Site" at http://www.cpm.z80.de/ for download for educational purposes. But, it was unclear if the code could be distributed by others, so I directed my customers to the Unofficial CP/M Web Site to download and assemble the CP/M code. Eventually, Lineo spun off the company DRDOS, Inc., which inherited the rights to CP/M. Bryan Sparks is CEO of DRDOS.

A recent e-mail exchange between Bryan Sparks and retired programmer Scott Chapman has clarified the status of CP/M, resulting in the granting of non-exclusive rights to distribute the CP/M source code. Here is the "license" agreement from Bryan Sparks' email:

> *"Let this paragraph represent a right to use, distribute, modify, enhance, and otherwise make available in a nonexclusive manner CP/M and its derivatives. This right comes from the company, DRDOS, Inc.'s purchase of Digital Research, the company and all assets, dating back to the mid-1990's. DRDOS, Inc. and I, Bryan Sparks, President of DRDOS, Inc. as its representative, is the owner of CP/M and the successor in interest of Digital Research assets."*

This new development was documented in a July 15, 2022 article in the Register.

So I am allowed to distribute the CP/M code from my website. You can download assembled binary files for the BDOS and CCP parts of CP/M 2.2 (the machine-independent parts) and the CBIOS (the custom machine-dependent part), and other binary helper files mentioned below, from the CPUville web site page at http://cpuville.com/Code/CPM.html. The binary file for CP/M 2.2 is cpm22.sys, and for the CBIOS is z80_cbios.bin. The other files you will need to install CP/M on the Z80 Single-board computer are format.bin, putsys.bin, cpm_loader.bin, and monitor.bin. A list file for the CBIOS is in this manual, and the CP/M source code is still available from the Unofficial CP/M Web Site if you are interested.

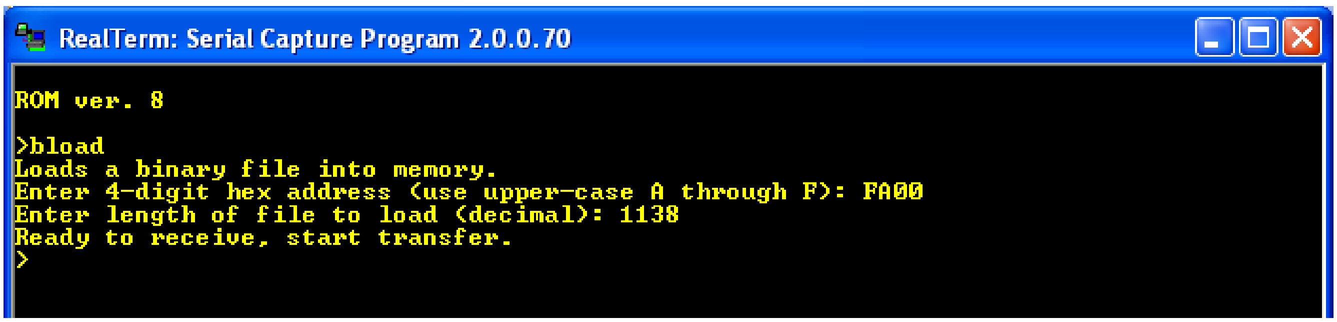
Preparing the disk for CP/M

The CP/M file system directory entries are very simple. The first byte of a directory entry gives the status of the entry. If the entry is inactive (the file has been deleted or not yet created), the status byte has a value of 0xE5. To prepare a disk for the CP/M system, one needs only create a number of directory entries that start with this value.

But it is easier than that, because if a directory entry is inactive, CP/M does not care what else is in the entry. It will create a completely new entry when it needs to. So, all we need to do is write the value 0xE5 to all the sectors of the CP/M disk in order to prepare it.

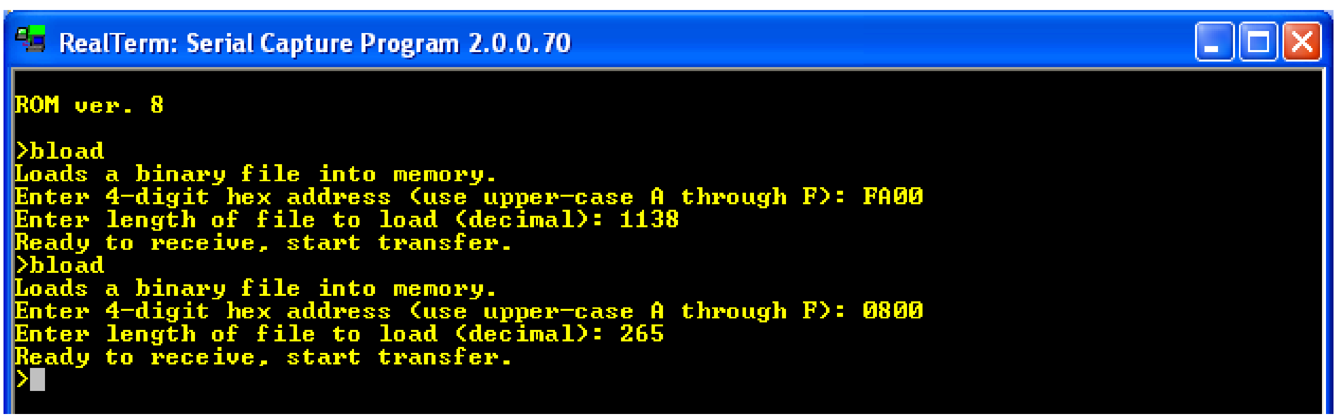
Note that I refer to the “CP/M disk”. This is a logical construct, created by the disk parameter tables in the CBIOS. These tables may or may not accurately represent the physical disk system. In the CBIOS I created, I left the CP/M disk system as it originally was, with four disks, each with 77 tracks, 26 sectors per track[9]. A CP/M call to read or write a particular disk, track, and sector is translated into a unique LBA address for the hard disk by the disk read and write subroutines in the CP/M CBIOS.

The format program calls the CBIOS routines to write 0xE5 to all the sectors of the four CP/M disks in our system. In order to work properly, the CBIOS code needs to placed into the system memory at location 0xFA00 before we load and execute the format program, since the CBIOS is assembled for that target address. Use the monitor `bload` command, and load the file z80_cbios.bin into the computer memory at 0xFA00:



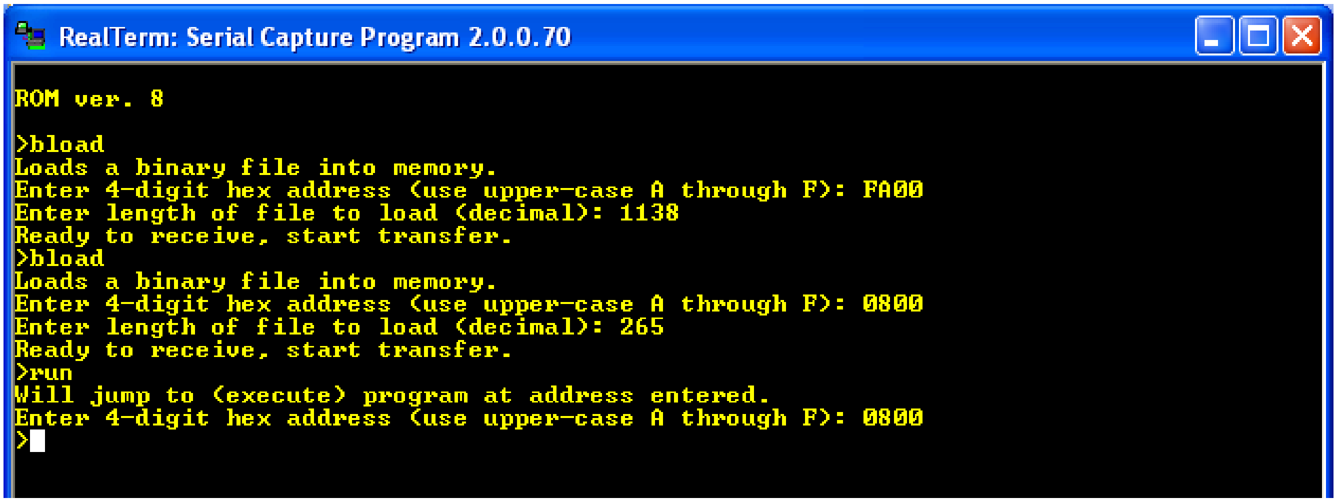
Note the file length in this example may be different from yours if you are using a later or customized version of z80_cbios.bin. Look at the file Properties to get the exact size before you make the transfer.

Next, load the format.bin file into memory at 0x0800:



Now, run the format program using the `run` command:

9 The updated CP/M system has 4 disks, each with 256 tracks of 64 sectors each.



The Drive Activity LED should light up for about a minute and a half while the format program fills the CP/M disk with 0xE5[10]. When the light goes off, the monitor prompt should re-appear. The disk is now ready for the CP/M files to be placed on it.[11]

Putting the CP/M System Files onto the disk

The CP/M file system set up in the CBIOS reserves the first 2 tracks of each CP/M disk for the system files[12]. This is important, because every time CP/M is started, whether from a cold boot or a warm restart, the system is loaded from the disk into memory. You can see this code in the CBIOS listing, in the WBOOT subroutine. Sector 1 of track 0 is reserved for boot code (not used in this system – the boot code is in LBA sector 0 of the IDE disk instead), and the rest of the sectors in tracks 0 and 1 have a memory image of the operating system.

To set this up properly, we need to use the CBIOS routines for disk writing to put the system onto the disk from memory. For this, I have written a putsys program. It is similar to the format program, in that is uses the CBIOS disk write subroutines, but differs in that it copies data from address 0xE400 to the end of memory, and places it on the disk.

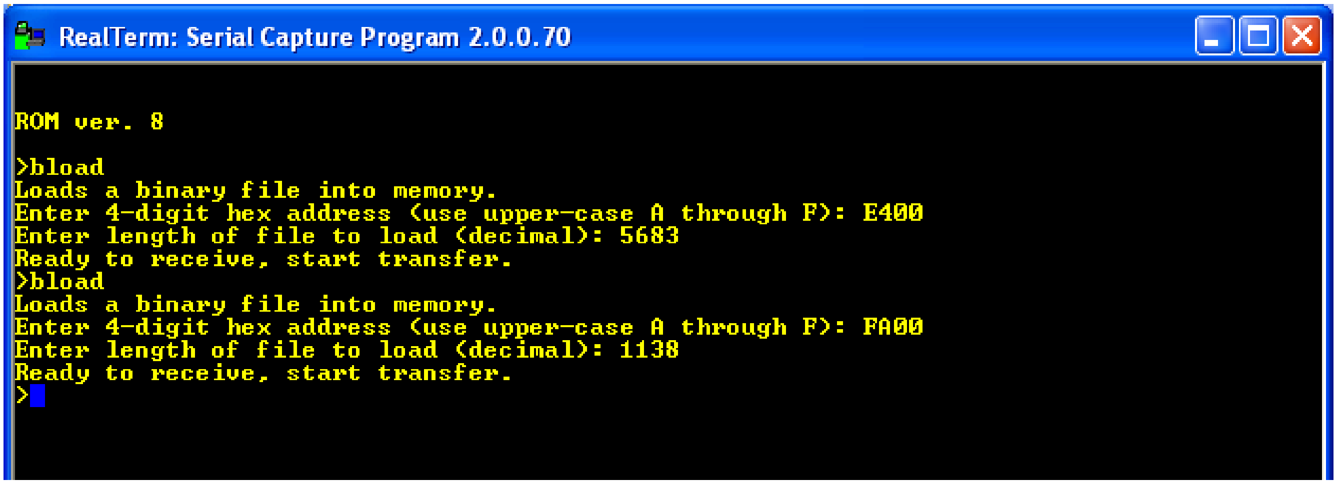
So first, we need to put CP/M into memory. The cpm22.sys file has the assembled code for the CCP and BDOS, with a dummy BIOS jump table at the end. It is important that we load cpm22.sys into memory first, then load the z80_cbios.bin file on top of it (after it), so that the true BIOS jump table from z80_cbios.bin will be present in memory at the locations previously occupied by the dummy BIOS jump table. We again use the monitor command `bload` to place these files into memory at the proper places.

First, place the cpm22.sys file at address 0xE400. Then place z80_cbios.bin at 0xFA00:

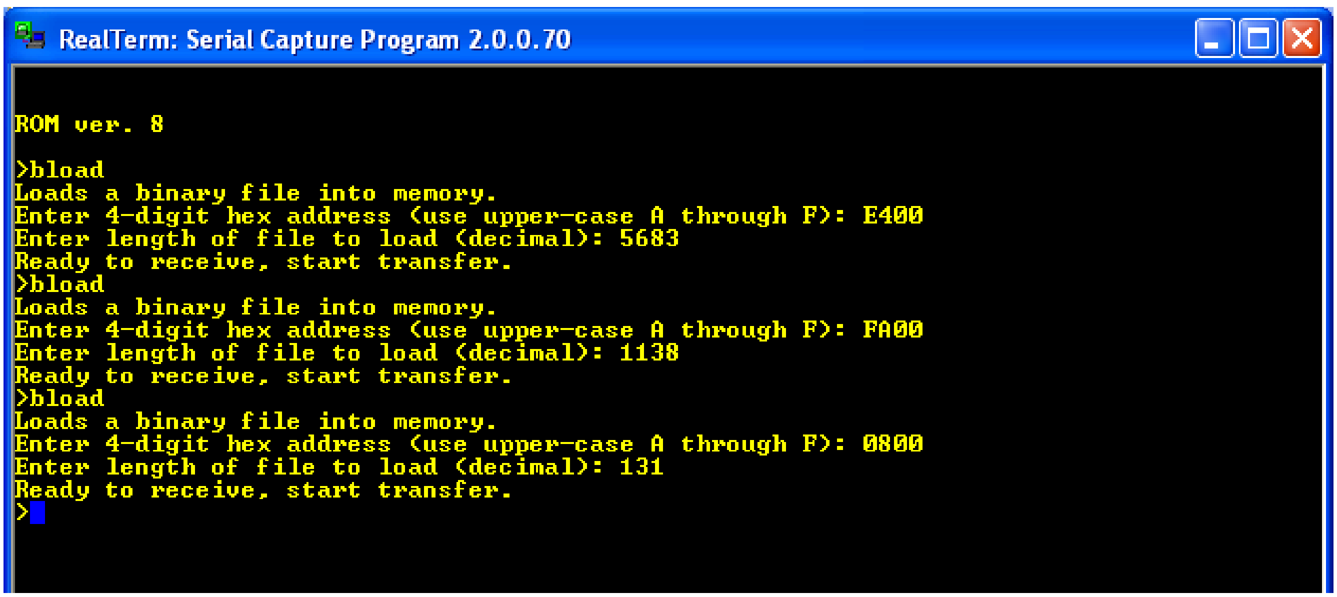
10 The updated CP/M system format program takes about 11 minutes to complete, and has terminal output showing progress.

11 With some experimentation I have found that it is not absolutely necessary to format the disk before installing CP/M. If you do not format the disk, when you list the CP/M disk directory, you may get a series of blank entries or jumbled strings displayed. You can fix this by erasing the entire directory of the disk with an ERA *.* command.

12 The updated CP/M system has tracks with 64 sectors, so only one track is reserved.



Then, use `bload` to place the putsys.bin file into memory at location 0x0800:

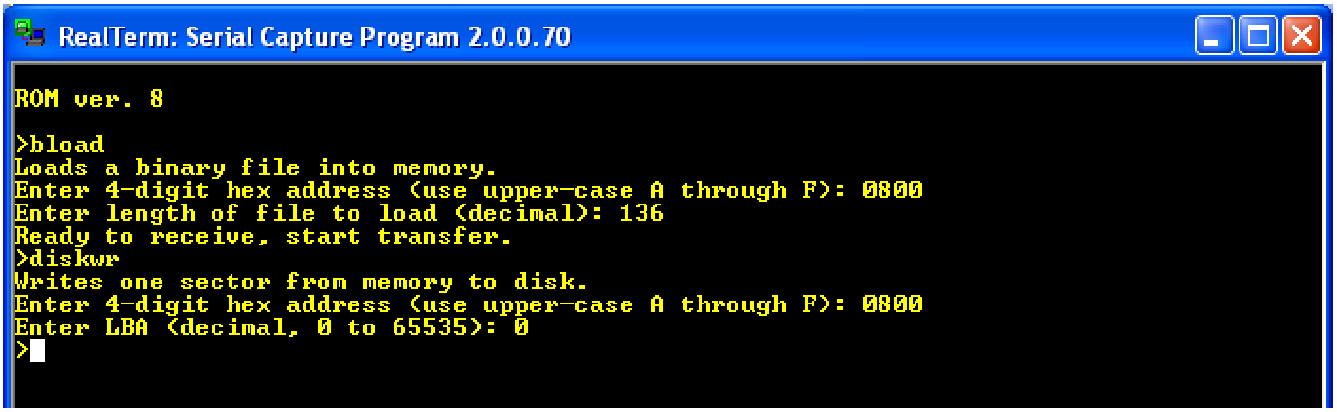


Now, run the putsys program at 0x0800. The drive activity light will light briefly – we are writing many fewer sectors than we wrote with the format program. Now, CP/M will be present on the disk system tracks.

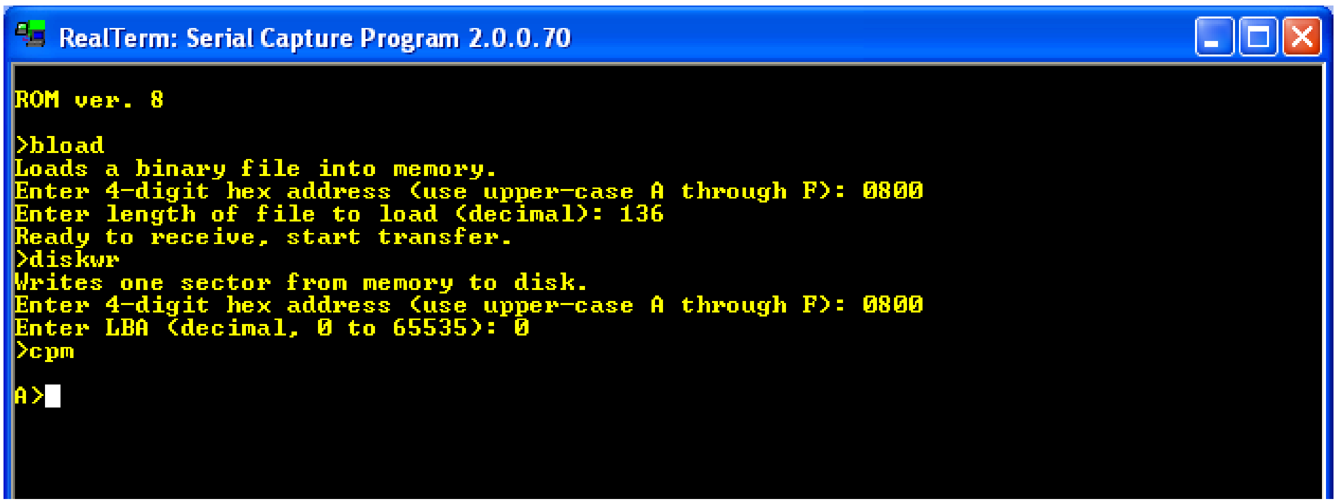
Installing the CP/M loader

The final piece of the puzzle is to place the cpm_loader program into sector 0 of the hard disk. This program is similar to the putsys program, but acts in reverse; that is, it gets the CP/M system from the disk and places it into memory. Unlike format and putsys, it is designed to run before the CBIOS is in memory, so uses its own versions of the CBIOS disk read routines, combined with ROM monitor subroutines, to get the code from the disk. When it is finished copying CP/M into from the disk into memory, it switches the memory configuration to all-RAM with an `OUT (1),A` instruction, then jumps to CP/M.

We will use the `bload` command to first place the file cpm_loader.bin into the computer memory, then use the `diskwr` command to put it into sector 0 on the hard disk:



Now that the disk is set up to run CP/M, reset the computer, and enter the `cpm` command at the monitor prompt:



You now see the CP/M prompt, A>, which indicates that CP/M is running, and that disk A is active.[13]

To summarize, these are the steps to install CP/M 2.2:

1. Load z80_cbios.bin at 0xFA00
2. Load format.bin at 0x0800
3. Run format.bin
4. Load cpm22.sys at 0xE400
5. Load z80_cbios.bin at 0xFA00
6. Load putsys.bin at 0x0800
7. Run putsys.bin

13 The updated CP/M system will also print a greeting message when started for the first time (cold boot).

8. Load cpm_loader.bin at 0x0800
9. Write the memory page 0x0800 to disk sector 0
10. Reset the computer
11. Start CP/M using the monitor `cpm` command.

Running CP/M

Built-in commands

I will not attempt to reproduce here a guide to running CP/M. The original Digital Research CP/M 2 system manual has been converted into a web page: http://www.gaby.de/cpm/manuals/archive/cpm22htm/. Here you can find all the details about using CP/M, with all the commands listed. However, we need to do a little more work here to create a truly usable CP/M.

CP/M 2.2 has only six built-in commands. These are DIR (list a disk directory), ERA (erase a file), REN (rename a file), SAVE (save memory to a file), TYPE (display a text file on the screen), and USER (change a user number). Note there is no command that will copy or move a file, no command to show how much disk space is available, or what the file sizes are (DIR only displays the file names). These functions can be added later using transient commands (see below).

To get used to the CP/M commands, start with DIR (you can enter commands as upper or lower case):

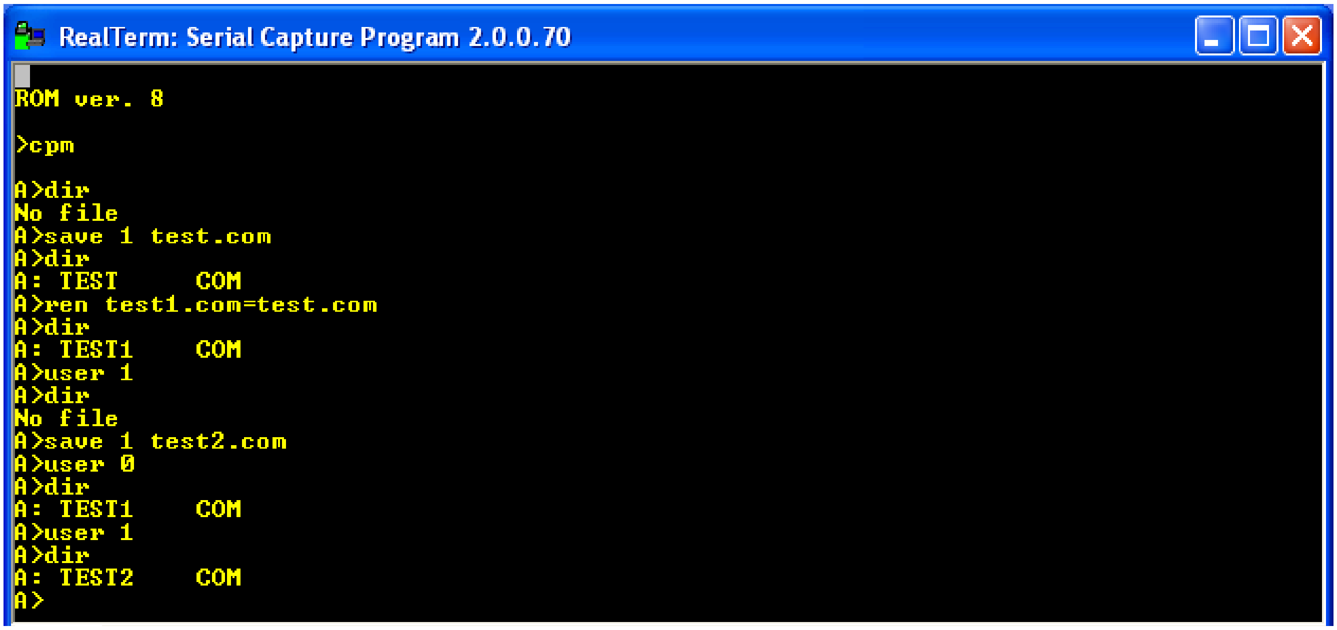
The “No file” output shows that there are no files in the directory of disk A. We can create a file using the SAVE command. This command will take a number of 256-byte memory pages, starting at 0x0100, and save them to the disk as a CP/M file. For an example, the command “save 1 test.com” will save one page (256 bytes) of memory, and give it the name TEST.COM. The file will of course contain garbage, but that is not a concern for now. After entering the SAVE command, enter the DIR command and you will see the directory entry for the file:

We can rename the file with the REN command:

Note that the target file name comes first in the argument for the REN command.

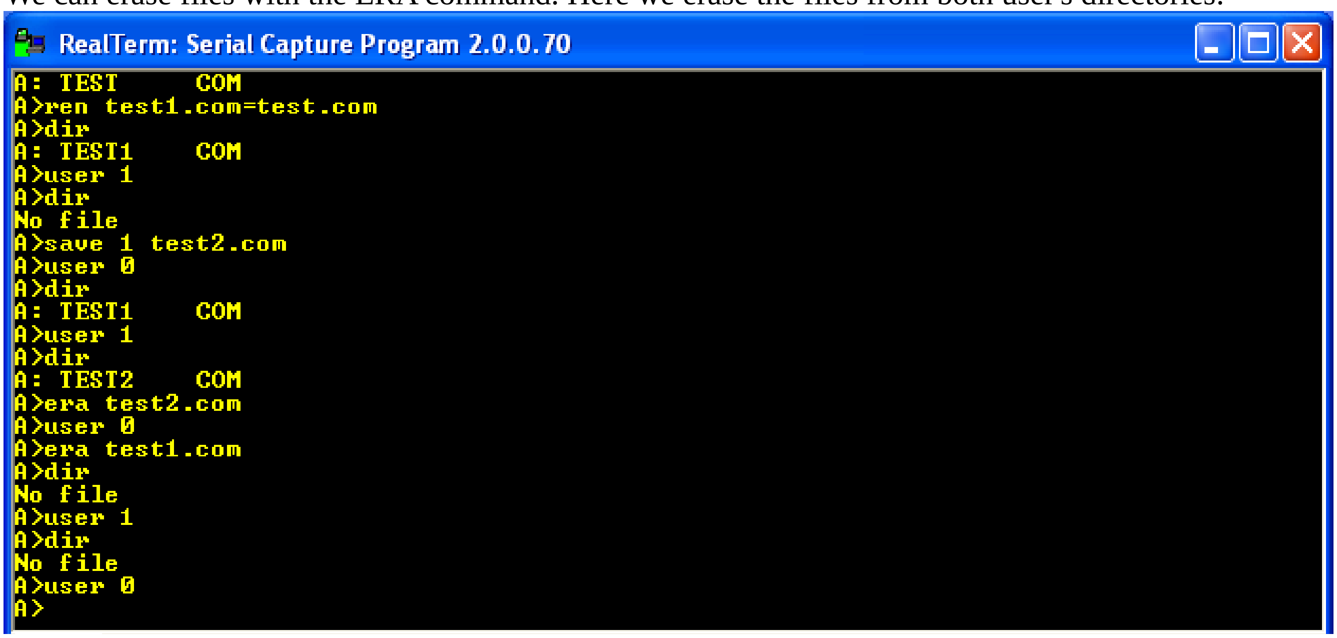
Each disk maintains a separate directory for each of multiple users, from 0 to 15. This feature is not of much use to us, but for completeness we can demonstrate it. Change to user 1 and enter the DIR command:

You can see user 1 has no files on disk A. Now create a file, with the name test2.com. Switch back to user 0, and display the directory. You see only test1.com. Switch to user 1, and do DIR, and you see that user's test2.com file.



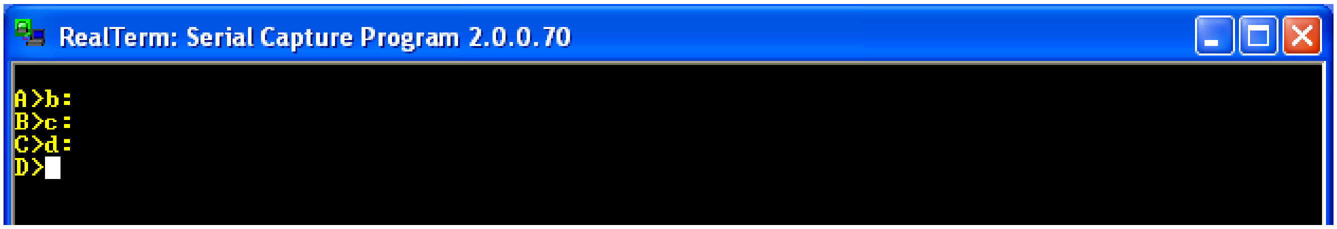
User 1's files are not visible to user 0, and vice-versa.

We can erase files with the ERA command. Here we erase the files from both user's directories:

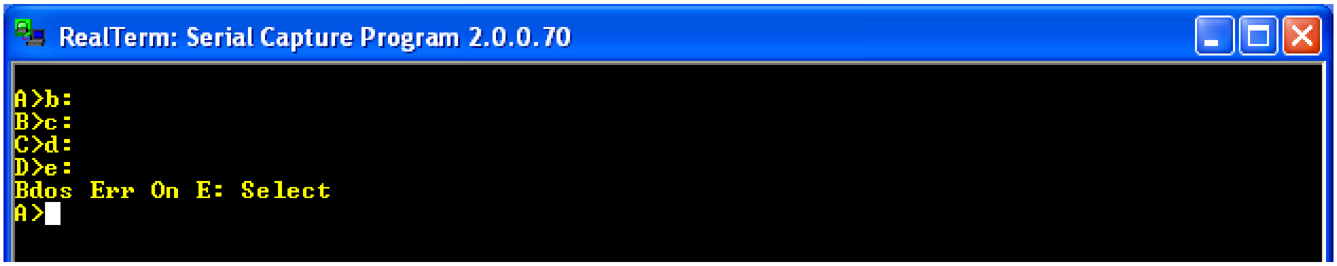


The TYPE command displays a text file to the console, but since we don't have any text file on the disk at present we won't demonstrate it now.

The system configuration set up in the CBIOS has 4 disks. To switch from one disk to another, enter the disk letter followed by a colon:



If you try to access a disk that is not available (here, for example disk E), you will get an error message. Hit return and the system will go back to the A disk:



This is a very limited set of commands. Many more commands are available as transient commands.

Transient commands

Originally, CP/M was created with multiple floppy disks, and the first disk came from the manufacturer with lots of programs (transient commands, or .COM files) that extended the system so that it was easy to create text files (with a text editor, ED.COM), assemble programs (ASM.COM), copy files (PIP.COM), and display disk statistics, such as file size and room remaining (STAT.COM). For example, if STAT.COM was on the A disk, entering STAT at the CP/M prompt would give a display of the room remaining on the disk. Essentially, a .COM file is a command that extends the functions of CP/M. When one enters the command, CP/M searches the directory of the current disk, and if it finds a file with the name of the command and a .COM extension, it loads that file into memory at location 0x0100 and jumps there to execute it. In the original CP/M, getting new programs was as simple as putting a disk in drive B, and copying the files from that disk using the PIP command.

But how can we get CP/M files into the CPUville Z80 system from outside? The CPUville Z80 computer has only one disk interface, and only one serial port. With CP/M running, the serial port is dedicated to the CP/M console, for character input and output, and cannot be used for binary file transfers. If we had two serial ports, we could perhaps use a program like XMODEM running under CP/M to do binary transfers using the second port, but we cannot do that here[14].

One answer is to use a RAM monitor program, that has the same commands as the ROM monitor, but runs in the CP/M environment – that is, with the memory in configuration 1 (all-RAM). Then we can do binary transfers into the Z80 memory through the single serial port using monitor commands.

I created the RAM monitor program by re-assembling the ROM monitor with a target address (code origin) of 0xDC00 instead of 0x0000. I had to put some additional code at the start that copies the rest

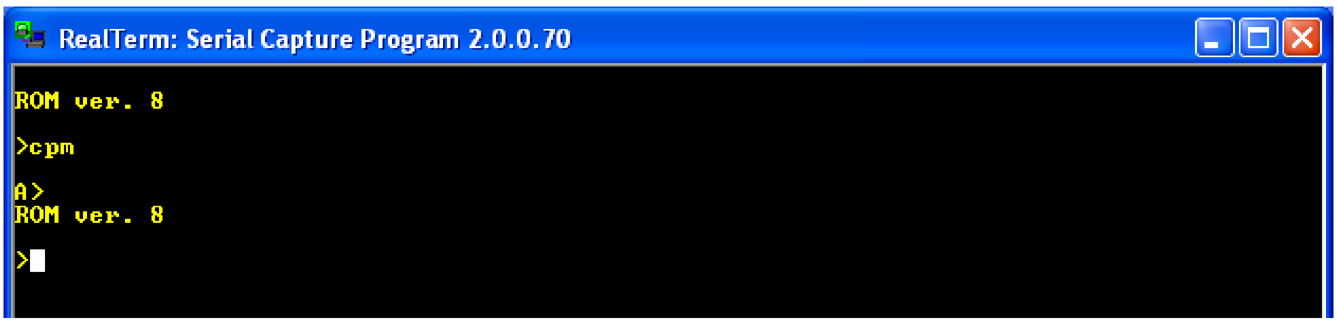
14 However, a CPUville Z80 computer user has written two utility programs, PCGET and PCPUT that will allow basic file transfer over the single serial port using the XMODEM protocol. See the section "Using the PCGET and PCPUT file transfer utilities" in this manual.

of the RAM monitor program from location 0x0100, where CP/M would load it, to high memory at 0xDC00, so it would be out of the way of any code that we might want to place into lower memory to save as a file with the CP/M SAVE command. Another important difference between the ROM and RAM monitors is that the `cpm` command given to the RAM monitor will do a warm boot of CP/M, so any code in memory will not be overwritten. The `cpm` command in the ROM monitor puts the cpm_loader in location 0x0800 first, then jumps to it, overwriting code that may be in RAM in that area. The RAM monitor file is named monitor.bin.

To get transient command files onto the CP/M disk, we will run the RAM monitor under CP/M, use the monitor command `bload` to place a command binary file into the Z80 computer's memory at 0x0100 , switch back to CP/M, and use the built-in SAVE command to create a .COM file.

So how do we get the RAM monitor program itself into memory, and onto the CP/M disk? We need to “bootstrap” it, using the RAM monitor program itself. It is a little complicated, but you only have to do this once. Here is how.

First, we start CP/M with the ROM monitor `cpm` command. This sets the memory configuration to 1 (all RAM), puts the CP/M system into the memory, and sets up memory page 0 (addresses 0x0000 to 0x00FF) with the data CP/M needs to operate. Then, we reset the computer. We see the ROM monitor greeting again. The system reset causes the memory configuration to switch back to configuration 0 (2K ROM and 62K RAM), so we can use the ROM monitor, but it does not disturb the CP/M data in RAM memory page 0, or the CP/M code in high memory.

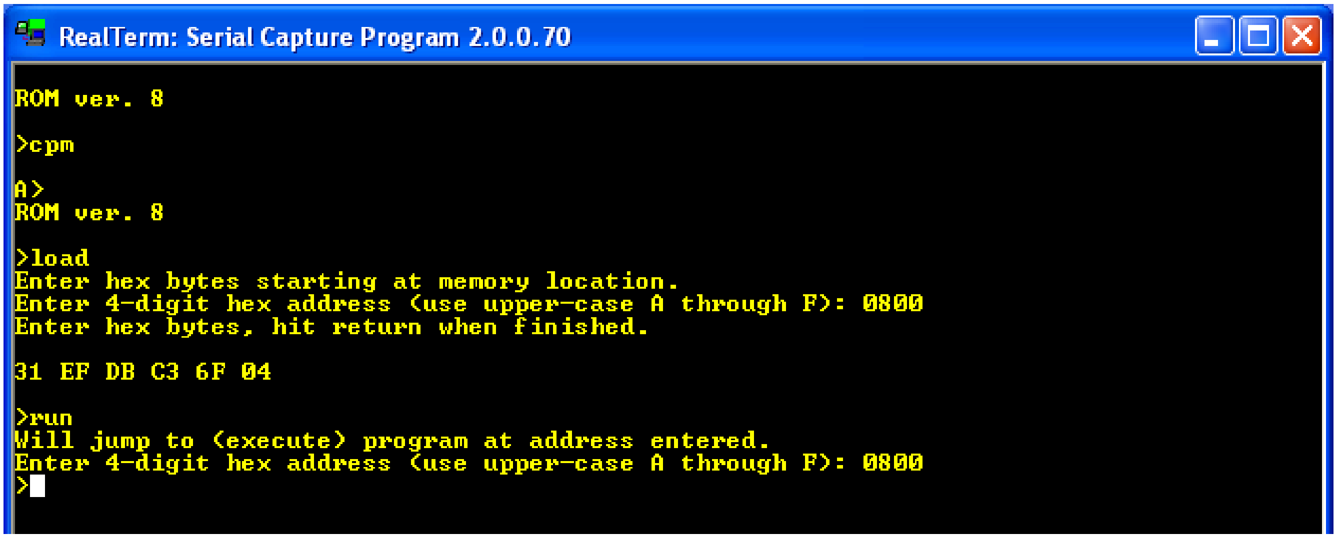


Now, using the ROM monitor, we will place the RAM monitor program, file name monitor.bin, into high memory, but below CP/M.

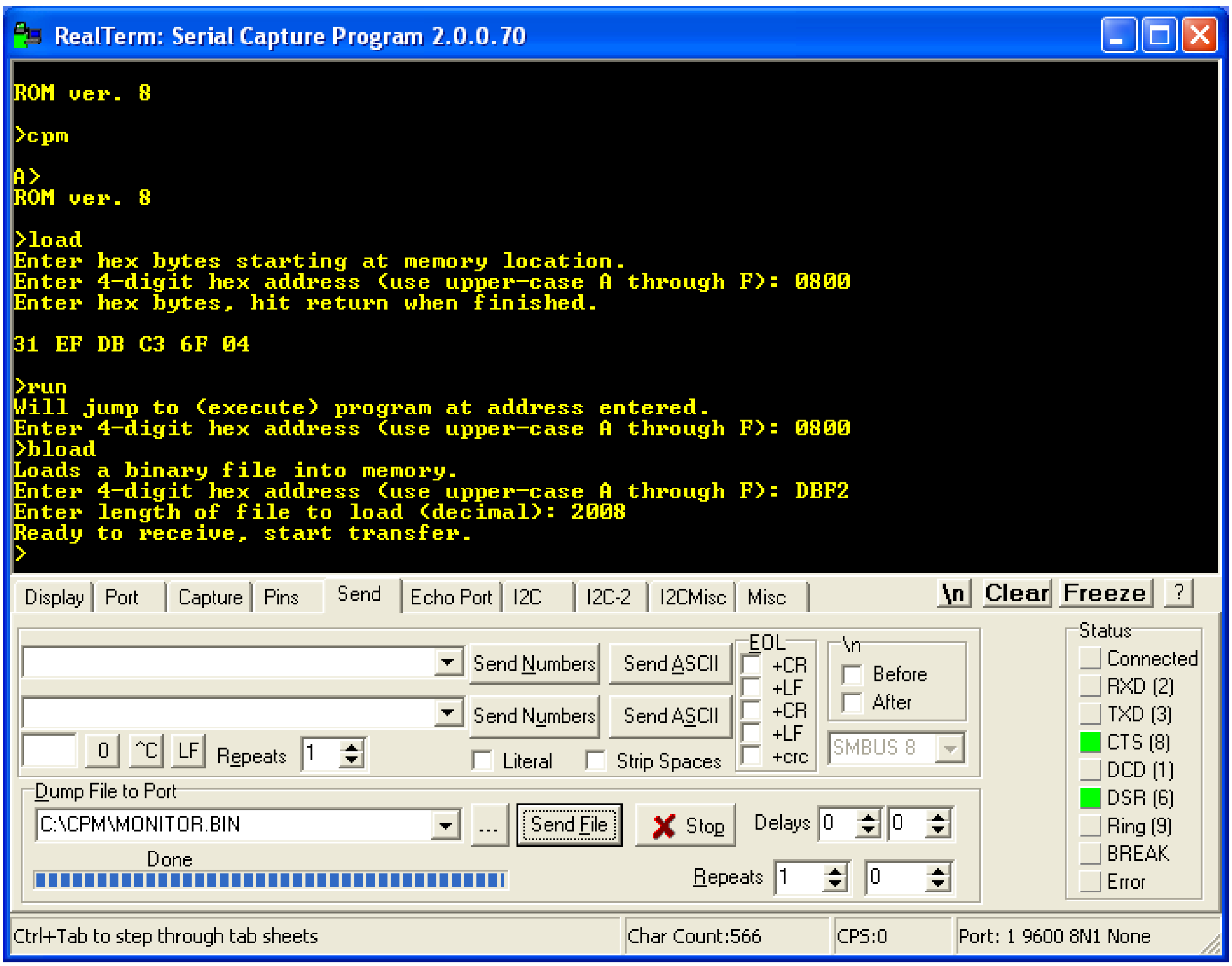
The RAM monitor code, has a short prefix, which will be used to relocate the file when we load it with CP/M. This means that we should load the monitor.bin file at 0xDBF2. Then, the RAM monitor code proper will start at 0xDC00 as designed. But, the ROM monitor uses stack space at 0xDBFF, so if we `bload` the file at 0xDBF2 the stack will be overwritten. To solve this problem, we just move the stack out of the way first with these commands:

```
0800 31 EF DB  ld sp,0DBEFh   ;move stack pointer out of the way
0803 C3 6F 04  jp 046Fh       ;ROM monitor warm start
```

We use the `load` command to put these bytes into memory at 0x0800 and execute them with `run`:

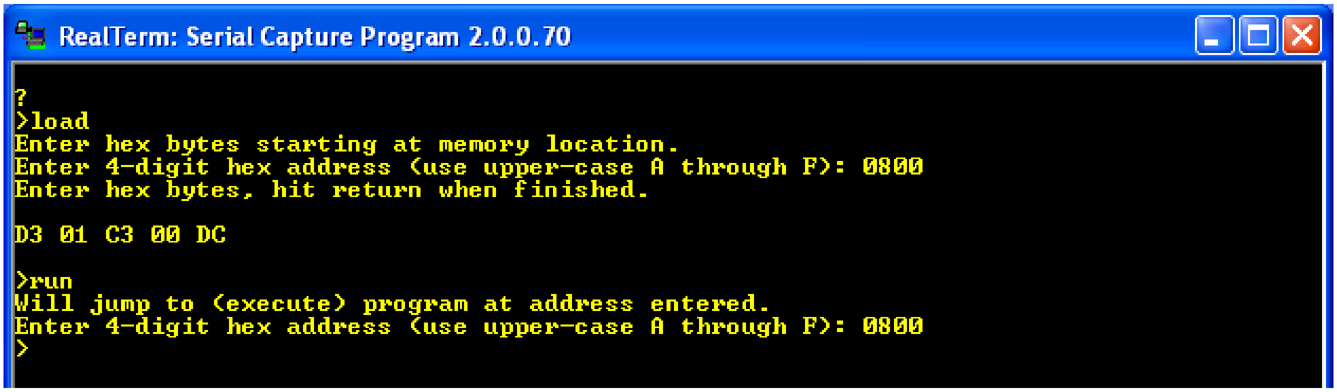


Now we can safely load the RAM monitor.bin file into memory at 0xDBF2:

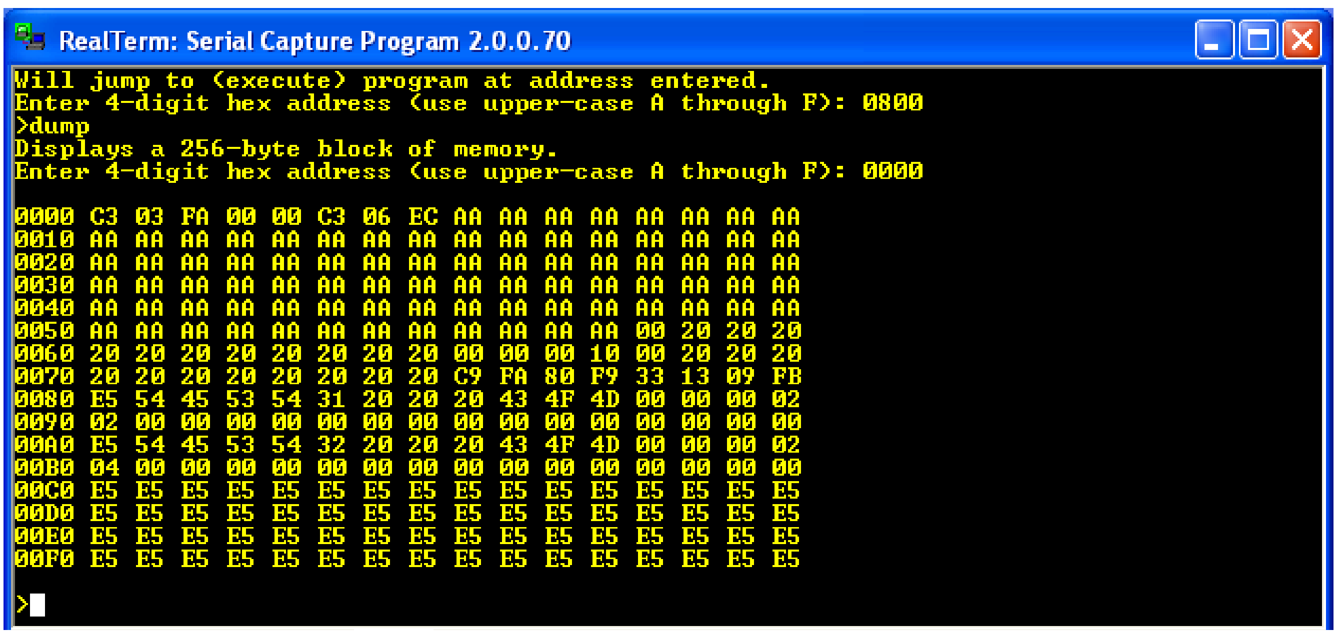


Then, we run some tiny code (again entered with the `load` command) to switch to memory configuration 1 and run the RAM monitor:

```
0800 D3 01     out (1),A ;switch to memory configuration 1 (all-RAM)
0802 C3 00 DC  jp 0DC00h ;jump to start of RAM monitor
```

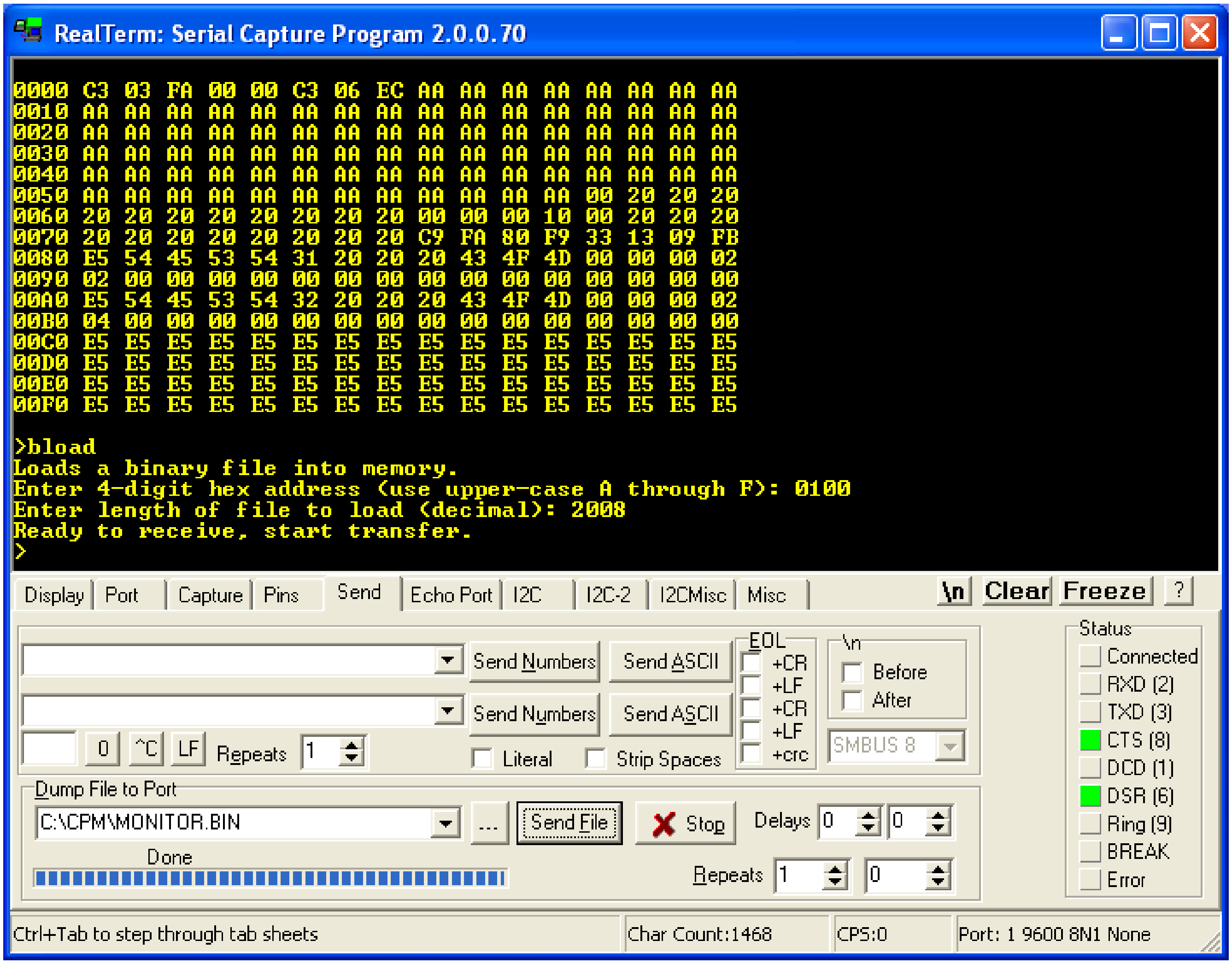


Now you see a monitor prompt (>), but it is now from the RAM monitor, running with the computer memory in configuration 1, and not the ROM monitor. To verify this, look at the first page of memory with the `dump` command:



There you see the CP/M warm start jump command at location 0x0000 with some other data. If we were still in memory configuration 0, this area would be filled with ROM code.

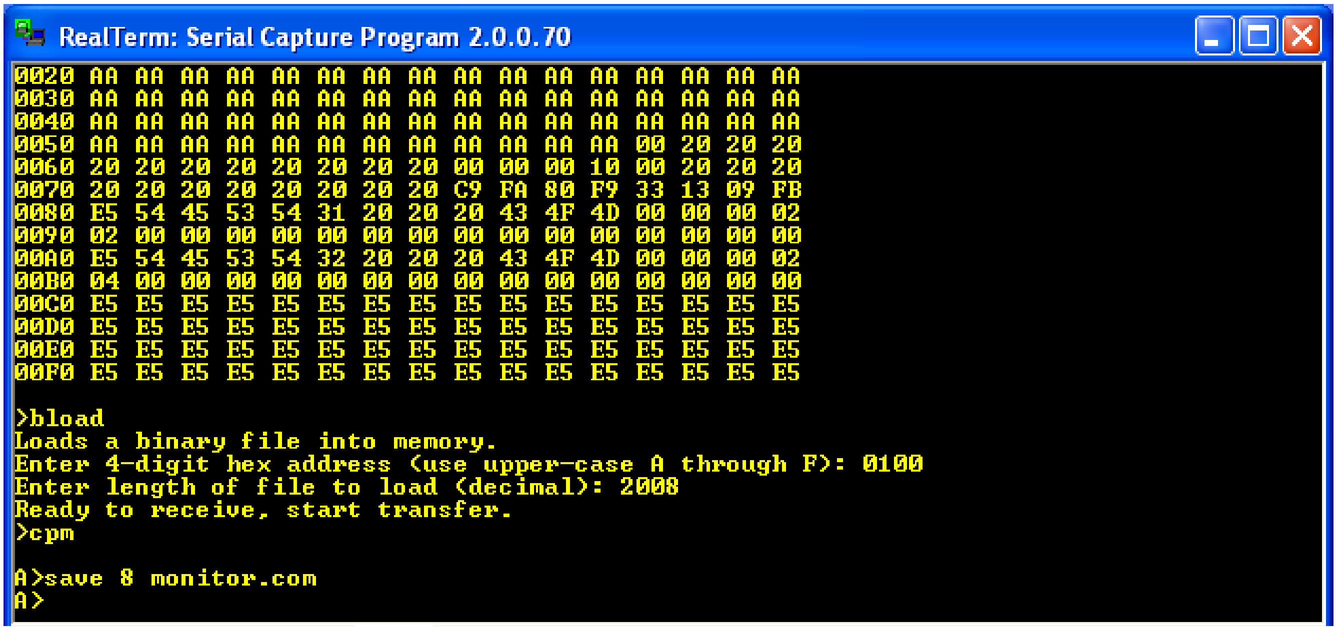
Now, using the RAM monitor, we can load the monitor.bin file again, this time at 0x0100:



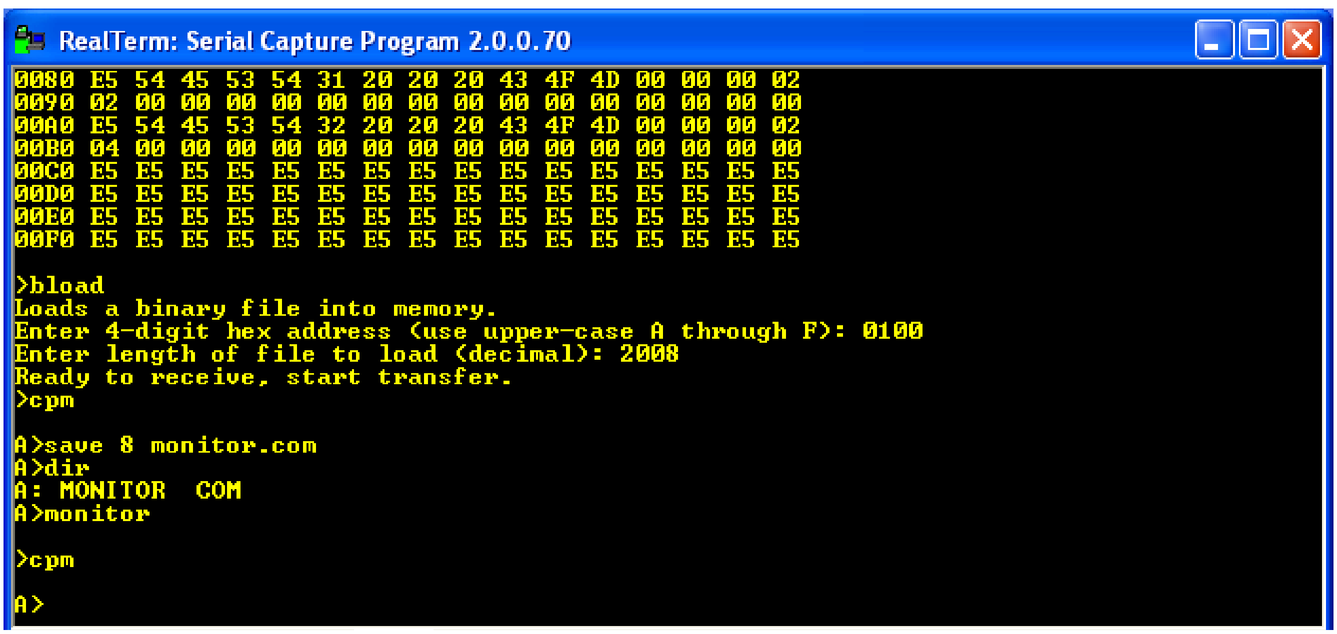
Now switch to CP/M by entering the RAM monitor `cpm` command. Unlike the ROM monitor `cpm` command, the `cpm` command in the RAM monitor does a CP/M warm start. When CP/M does a warm start it uses its own code in the CBIOS (which is in memory from 0xFA00 and above) to copy its BDOS and CCP code from the disk to the memory locations from 0xE400 and higher, but leaves the rest of the memory undisturbed[15]. So, the image of the RAM monitor at 0x0100 stays safe while CP/M reloads and restarts.

Now, we can use the CP/M SAVE command to create the disk file MONITOR.COM. We have to tell CP/M how many memory pages to save (one page = 256 bytes). If we divide the size of the monitor.bin file by 256 we get 2008/256 = 7.84. This means we need to save at least 8 pages of memory with the SAVE command. Give the file the name MONITOR.COM:

15 CP/M behaves this way to allow user programs to use the space from 0xE400 to 0xF9FF for their own code. When user programs return control to CP/M, it will load its code back in this space.



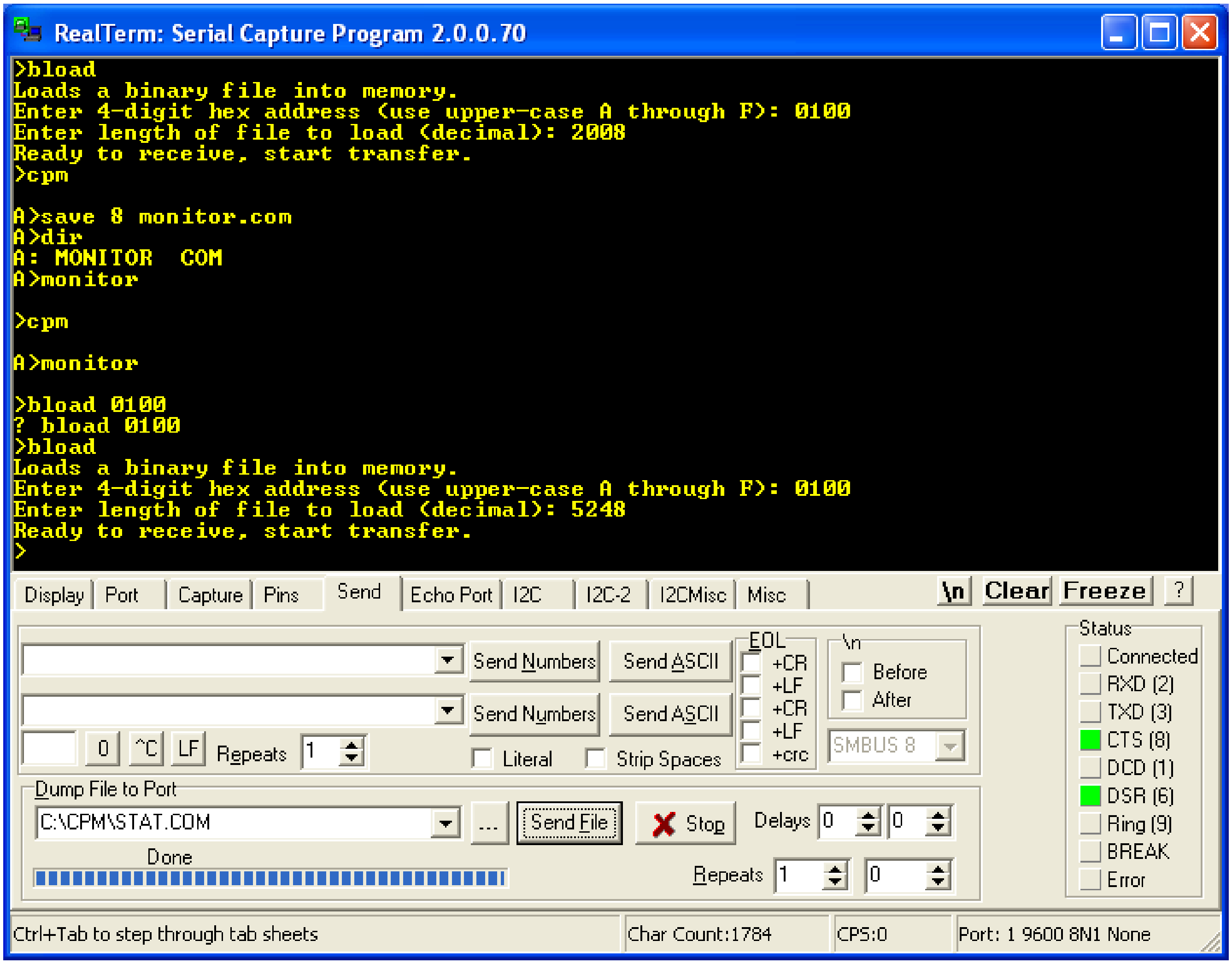
Check the disk directory, and you will see the MONITOR.COM file in place. Once this file is on the disk, all we need to do is enter MONITOR at the CP/M prompt, and we can use the monitor commands to do binary file transfers. When we are done with the monitor, we can enter the `cpm` command to return to CP/M:



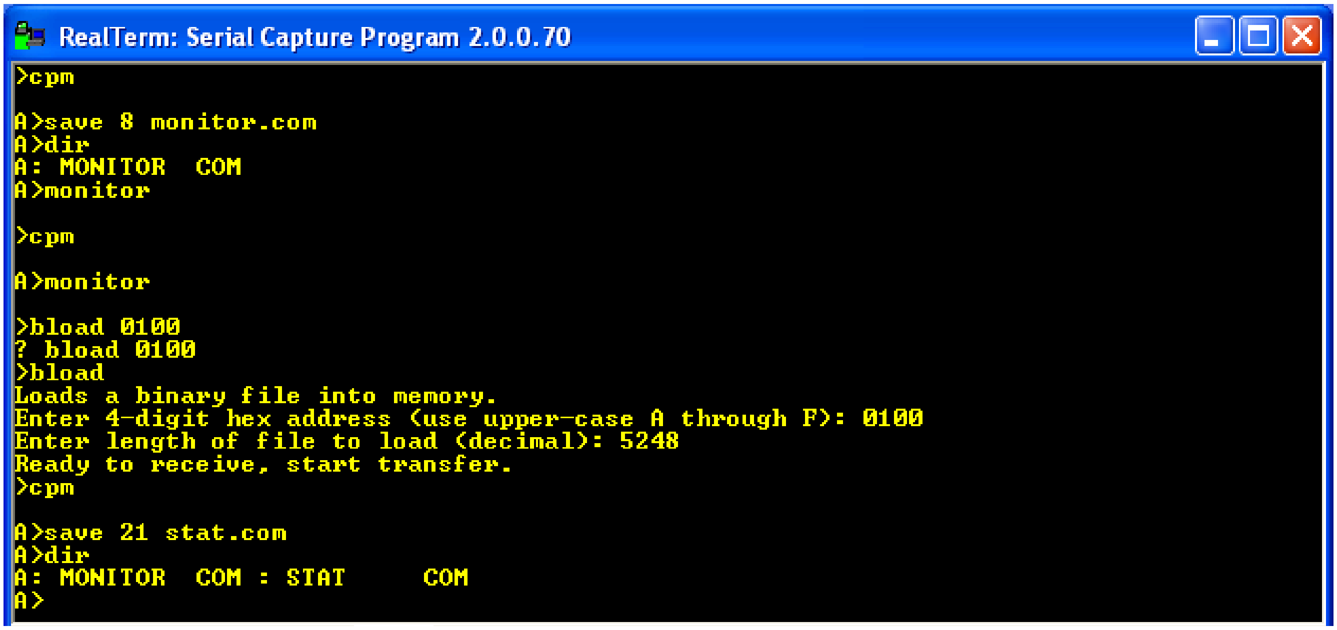
We can use the MONITOR.COM `bload` command to put any program we want into memory at 0x0100, provided it is not larger than 55,807 bytes (to keep it from running into monitor variables and stack space in page 0xDB00). Once a file is loaded, we can switch back to CP/M, and then SAVE the programs. We can load and save other types of files as well.

The first files we should load are the standard CP/M transient command files. The binary files for these commands can be obtained from The Unofficial CP/M Web Site. The binaries from a CP/M distribution disk are here: http://www.cpm.z80.de/download/cpm22-b.zip. The important ones are PIP.COM, ED.COM, ASM.COM, LOAD.COM, and STAT.COM. There is also DUMP.COM which displays file contents.

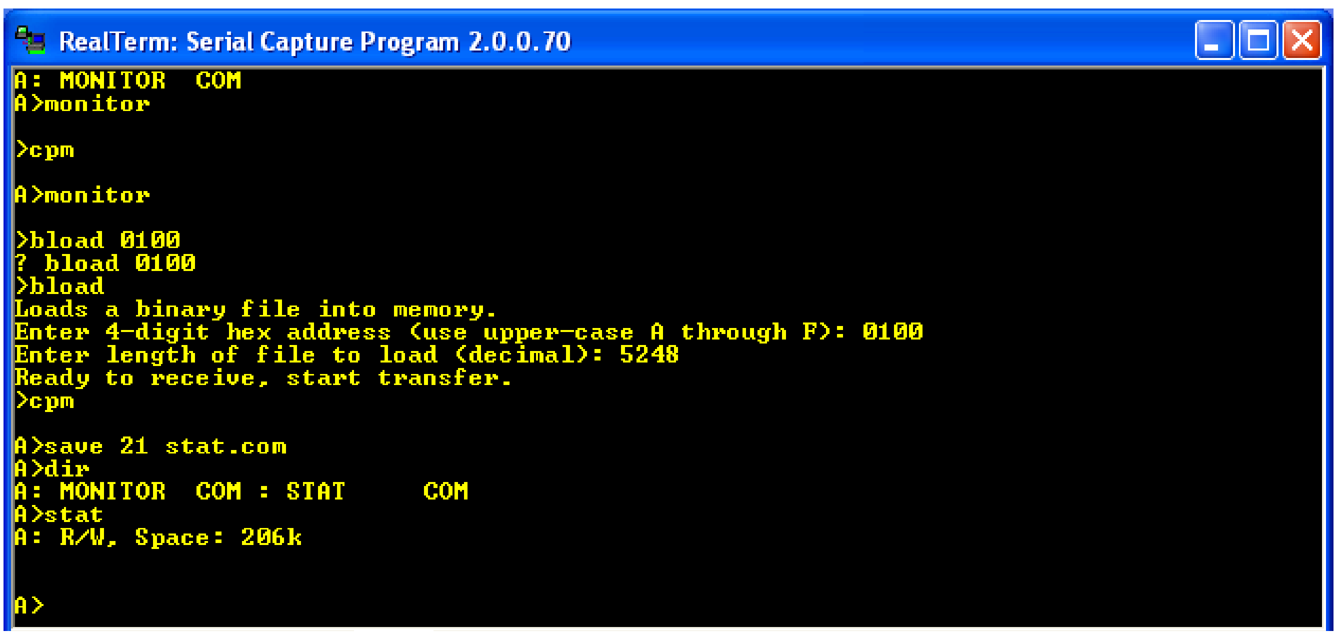
Let's use the MONITOR and SAVE commands to get STAT.COM onto our computer. Download a copy of STAT.COM from the above web site archive, enter the MONITOR command, and use the monitor `bload` command to put the file into the Z80 computer memory at 0x0100:



After the file has been loaded, switch back to CP/M using the monitor `cpm` command. From the File Properties dialog on the PC, you can see that the STAT.COM file is 5,248 bytes long; it takes up 5,248/256 = 20.5 pages. So we need to save 21 pages to get all of the file. After SAVEing the file, you can see the file in the directory:



If you execute the STAT command, you can see how much room is available on the active CP/M disk:



If you give STAT a file name argument, it will tell you how big the file is:

RealTerm: Serial Capture Program 2.0.0.70

```
>bload 0100
? bload 0100
>bload
Loads a binary file into memory.
Enter 4-digit hex address (use upper-case A through F): 0100
Enter length of file to load (decimal): 5248
Ready to receive, start transfer.
>cpm

A>save 21 stat.com
A>dir
A: MONITOR  COM : STAT     COM
A>stat
A: R/W, Space: 206k


A>stat monitor.com

 Recs  Bytes  Ext Acc
   16     2k    1 R/W A:MONITOR.COM
Bytes Remaining On A: 206k

A>
```

Using the PCGET and PCPUT file transfer utilities

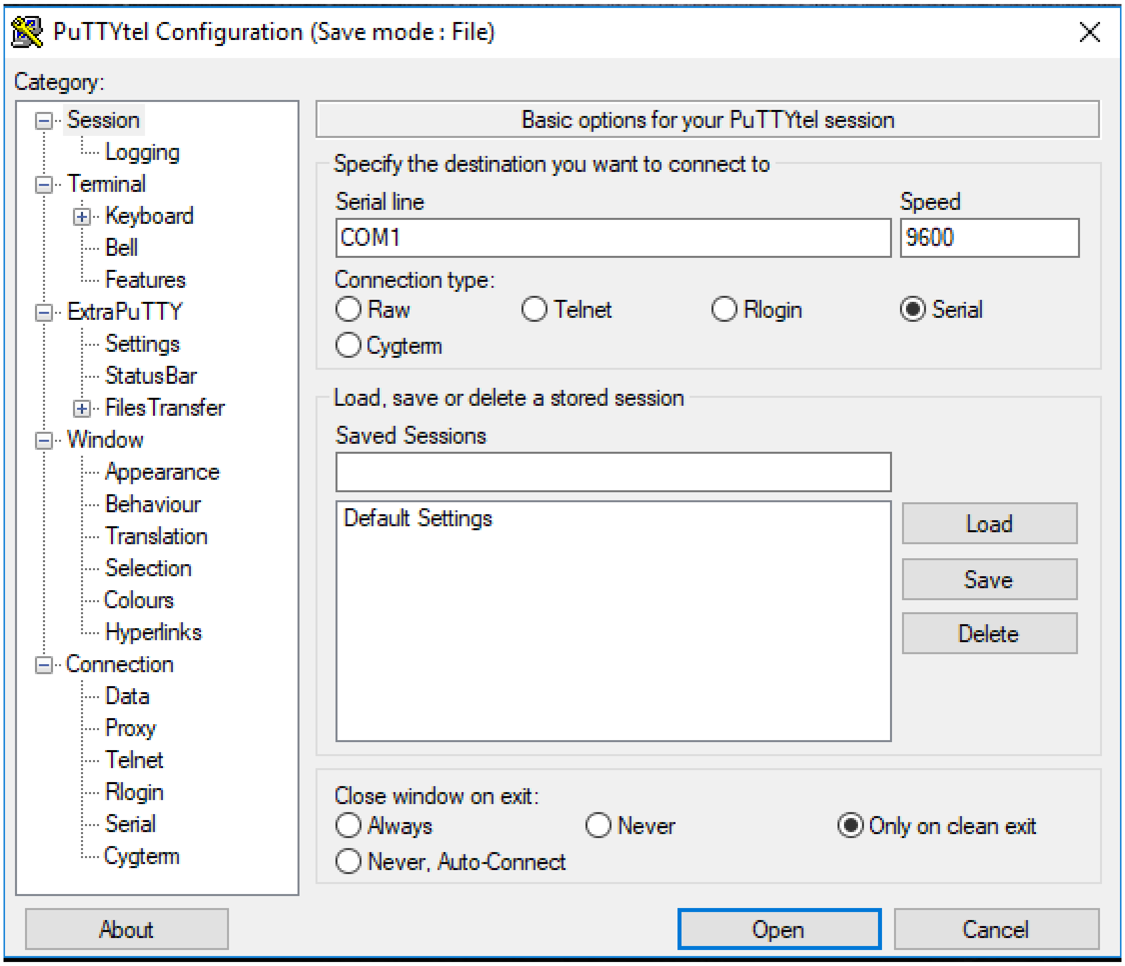
The method of using the MONITOR.COM program to do binary transfers is a little awkward. I had sought to use any of several XMODEM-type CP/M programs to do file transfers, but they all required a system with two serial ports, one for the terminal, and one for a modem to do the file transfer. However, customer Stephen Williams has modified two XMODEM CP/M utilities to perform file transfers from the PC to the CPUville Z80 kit computer over the single serial port. These utilities, PCGET and PCPUT were created by Mike Douglas for his Altair 8800 clone computer. He derived them from the original XMODEM-based file transfer utilities created by Ward Christensen in 1977 for his early bulletin board systems. With the permission of both Mike Douglas and Stephen Williams I have placed the code for these utilities on the CPUville CP/M code page for download.

PCGET will transfer a file from the PC over the serial interface onto the CP/M disk, and PCPUT will transfer a file from the CP/M disk to the PC. To do this, one must be using a terminal emulation program with the ability to do XMODEM-protocol file transfers. In the Linux environment, minicom will do this. In the Mac environment, the serial program will work. In Windows however, the Realterm program used frequently in this instruction manual does not do XMODEM transfers. Instead, you can use the ExtraPuTTY terminal emulation program.

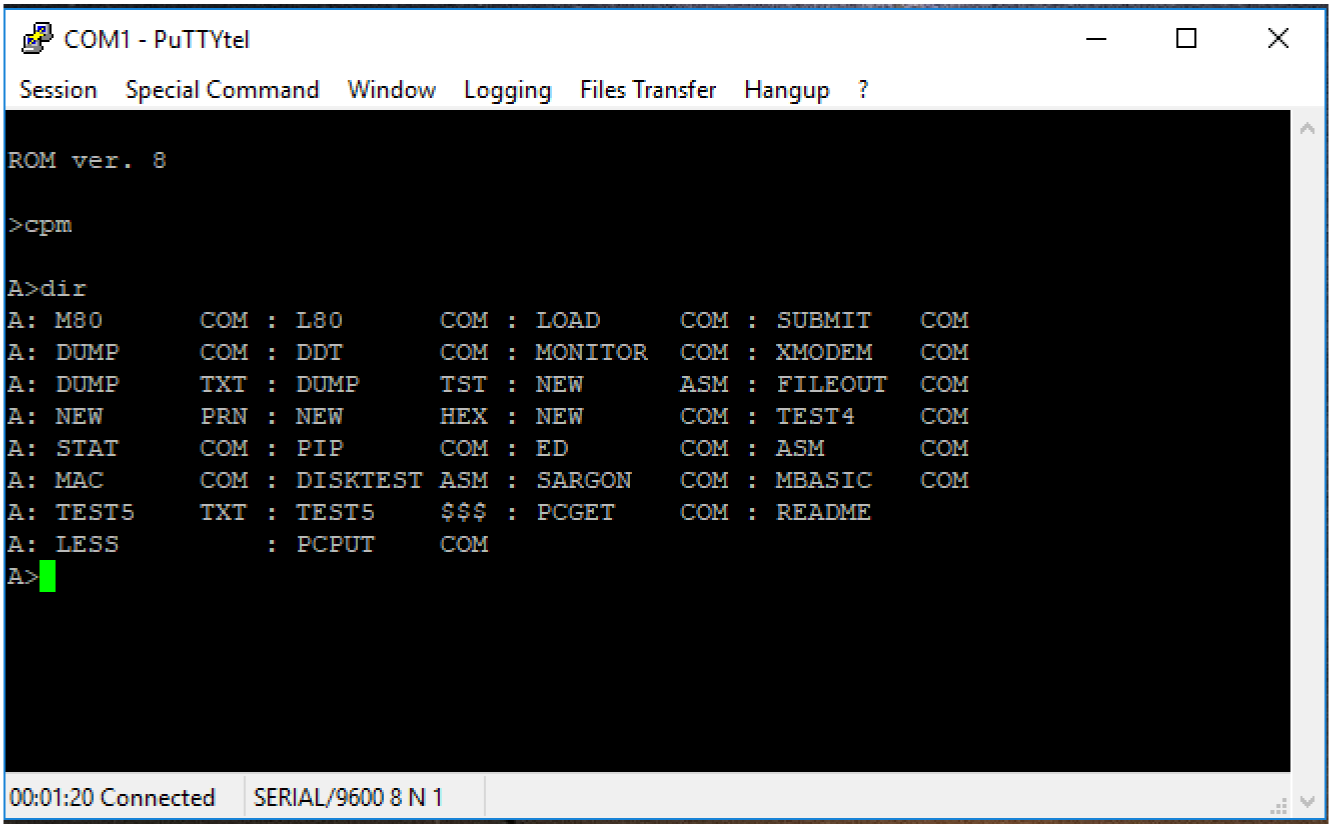
One last thing: to get PCGET.COM onto the CPUville computer you will have to do the MONITOR.COM binary transfer and CP/M SAVE procedure, as explained above. Transfer the PCGET.BIN binary file into memory at 0x0100 using the monitor `bload` command, then switch to `cpm` and use the CP/M SAVE command to create the file PCGET.COM on the CP/M disk. After that, you can use PCGET as a CP/M command to do file transfers for the rest of the CP/M transient commands and other files.

For an example, I will show using PCGET to transfer the file CAPTURE from the PC disk to a CP/M system, using the ExtraPuTTY terminal emulation program in the Windows environment.

Start ExtraPuTTY. On the initial window, select the Serial communication type, the COM port associated with your serial interface (COM1 here), and 9600 baud:

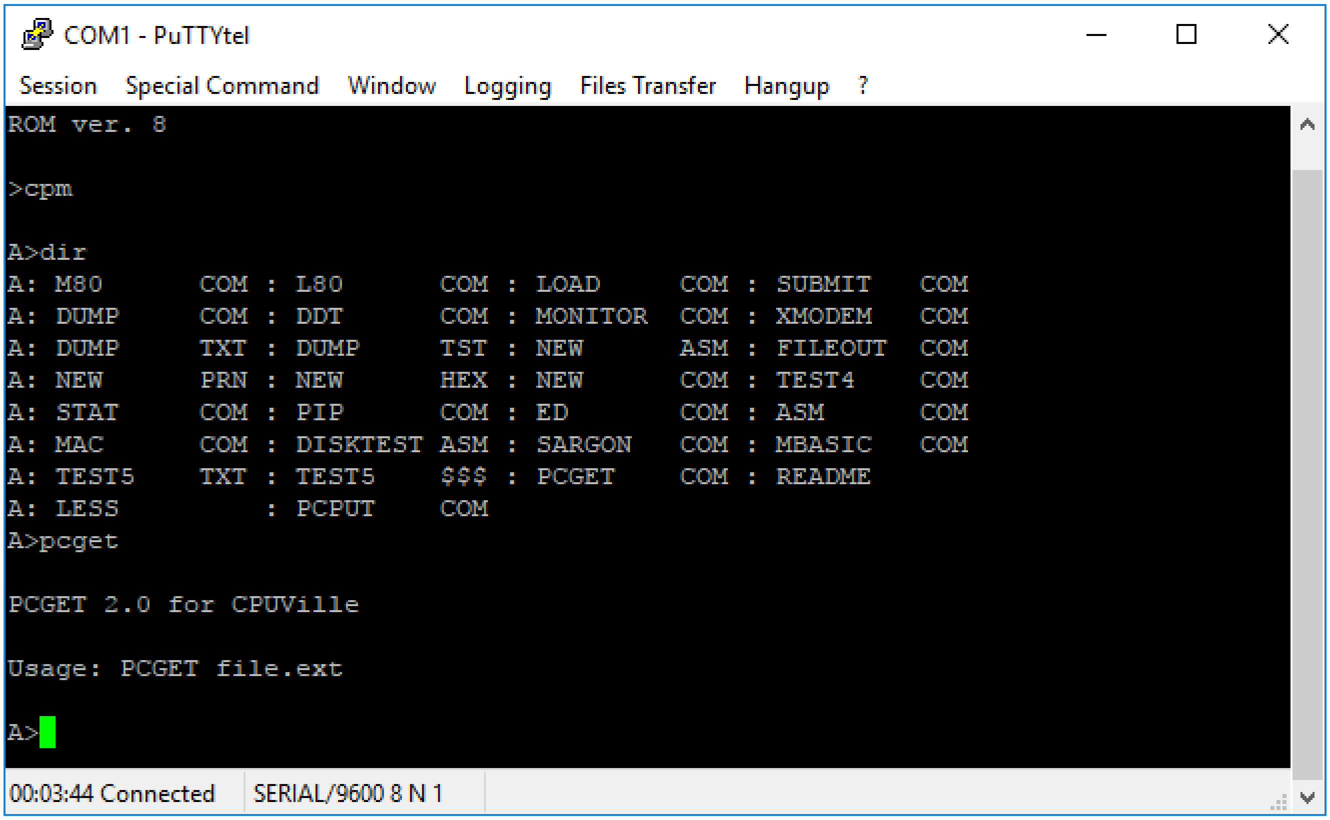


The terminal window opens. Take the Z80 computer out of reset, and you should get the ROM monitor greeting message and prompt. Here, I have started CP/M, and done a CP/M directory display:

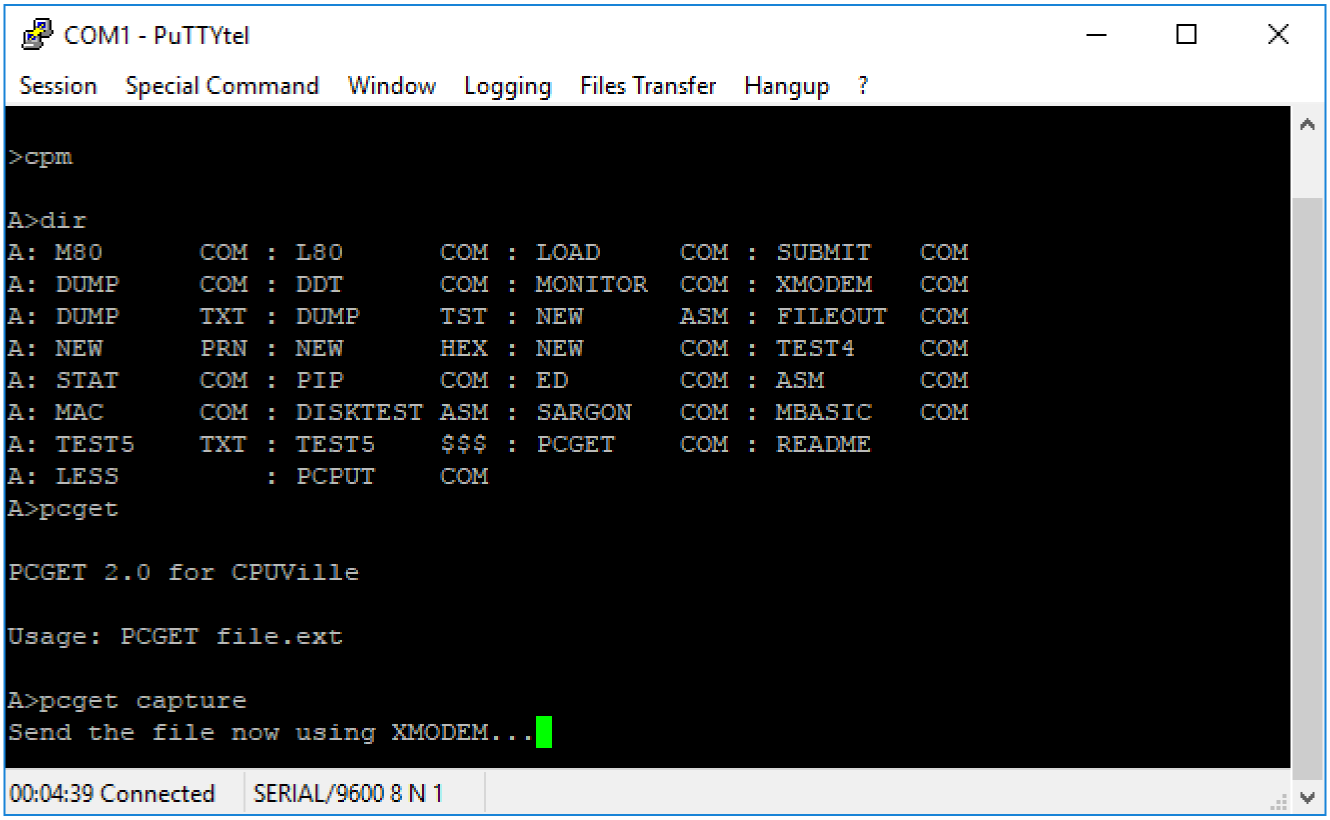


You can see I have already loaded PCGET.COM using the MONITOR.COM method.

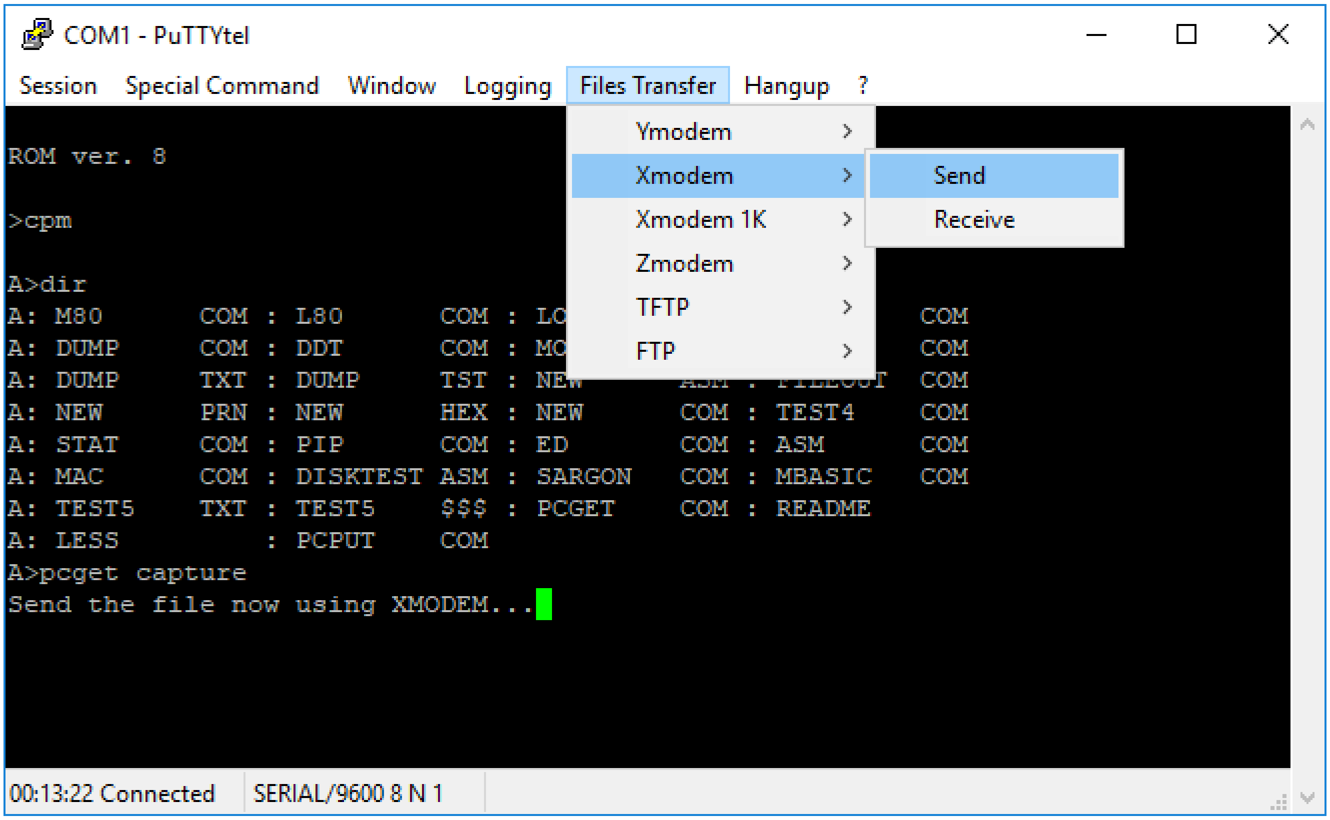
If you execute the PCGET command, a brief display reminds you of the usage:



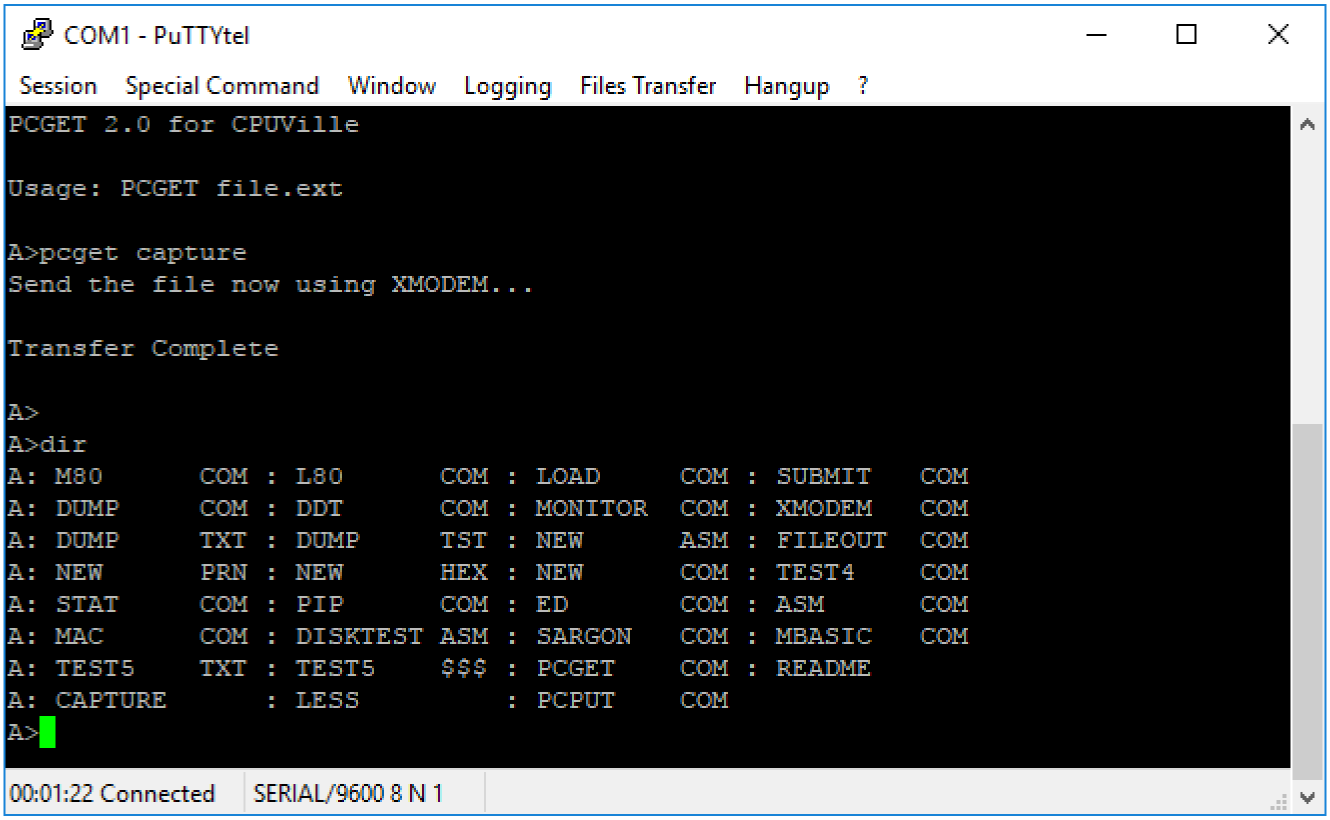
To load a file from the PC to CP/M, execute the PCGET command with a file name. Note that file names are not transferred by PCGET or PCPUT, so the file name you use as the argument for PCGET is the name CP/M will assign to the file, not the name that the file on PC currently has. In this example, the file name is “capture”:



At this prompt, navigate to the Files Transfer menu, and select Xmodem, Send (you want the Xmodem program in ExtraPuTTY to **send** the file to the serial port, and so to the Z80 computer):



A file menu opens that allows you to select the file to send. Click “Open”, and the transfer begins. Once the transfer is finished, PCGET quits with the message “Transfer complete” and sends you back to the CP/M prompt. Another `dir` command should show that the file “capture” is now on the CP/M disk:



PCPUT acts in a similar fashion, except you would select Xmodem, Receive for the file transfer.

Using minicom in Linux, the procedure is similar. To send the file from the PC to the Z80 computer, do ctrl-A, S to open the Send File menu. You select the XMODEM protocol, then a window to select the file opens. Once a file is selected, the transfer proceeds.

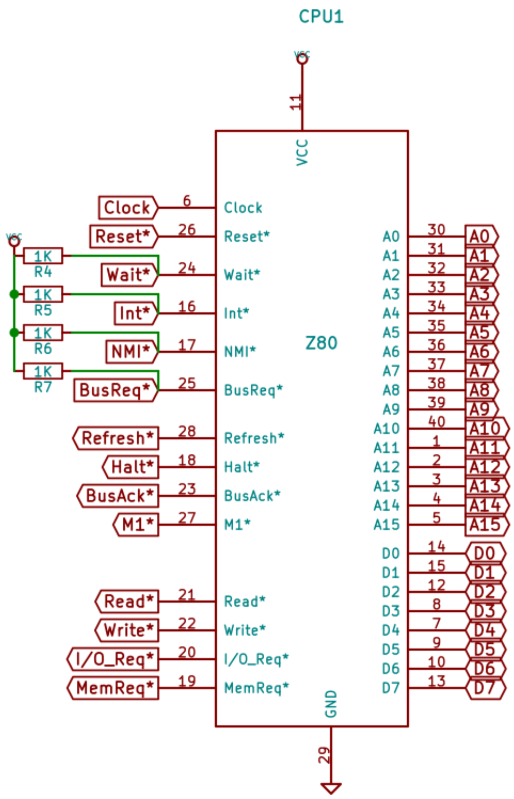
This concludes a description of the basics of using CP/M, including how to get binary files into the CP/M file system through the serial port of the Z80 computer. The Digital Research CP/M 2 System Manual, available on-line as stated above, explains how to use CP/M in full detail.

There are thousands of CP/M programs available, both on the web sites mentioned above, and on other archives. The Humongous CP/M Software Archives at http://www.classiccmp.org/cpmarchives/ is just one example. There is also Retrocomputing Archive at http://www.retroarchive.org/ There I found the Sargon program that plays chess better than I can.

Schematics and Explanations

The schematics in this section are the ones used to create the circuit board for the CPUville Single-board Z80 computer. They use global labels instead of wire symbols to show the connections to the various pins. This simplifies breaking the schematic into parts for explanation. I have also produced a schematic of the computer with wire symbols instead of the global labels, and it can be found on the CPUville website.

Z80 CPU



The Z80 CPU (central processing unit) is the heart of the computer. It takes in data or machine code instructions from the computer memory or input ports, operates on the data or interprets the machine code, and puts out data to the memory or output ports. The address outputs A0 to A15 express the address for the memory or input/output ports. The data bus D0 to D8 is bi-directional, and will either output data, or read data or machine code depending on the processor instruction being executed.

The system control lines, Read*, Write*, I/O_Req* (input-output request) and MemReq* (memory request) control the ports or memory that the CPU is communicating with. For example, if the processor is executing an instruction that requires it to read data from an input port, it activates the I/O_Req* and Read* control signals. The computer system looks at these signals, and the address output, and responds by placing data from the appropriate input port on the data bus.

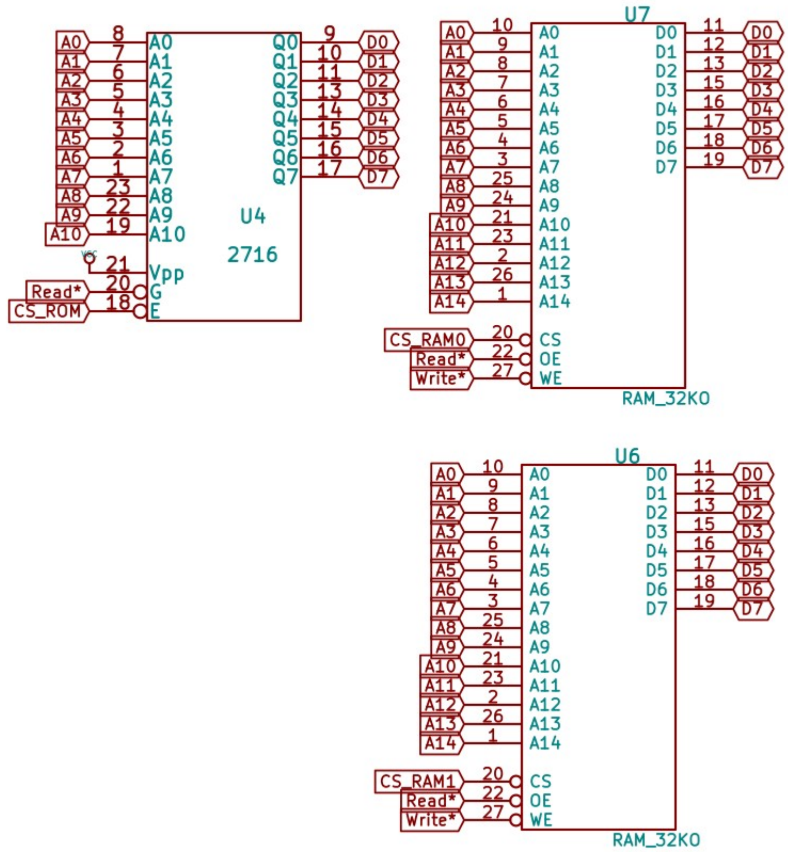
In these schematics, a control signal with an asterisk (*) is active-low, that is, when the signal is asserted by the CPU, it is low, or 0 volts. If a control signal label has no asterisk, it is active-high.

In addition to the address outputs, the bi-directional data bus, and the control outputs, there is the Reset* input, which when low causes the processor to enter the reset state. It will idle until Reset* goes high, then begin execution at address 0x0000.

The clock input is a simple square-wave oscillator. A Z80 can run as slow as a few cycles per second (HZ), or as fast as 2.5 million cycles per second (MHz). This computer has a 1.8432 MHz clock oscillator that provides both the CPU clock and the clock for the serial port. A jumper allows you to use different CPU clock speeds, fed in to the system connector, while the serial port remains functional with its 1.8432 MHz clock.

The other control outputs, Refresh*, Halt*, BusAck*, and M1*, and the control inputs Wait*, Int*, NMI*, and BusReq* are not used in this computer system, but are connected to pins on the system connector, for use by outside circuits or expansion boards.

ROM and RAM memory



The processor spends most of its time interacting with the computer memory, shown here. The 2716 IC is read-only memory (ROM), and contains the code the processor needs when it starts, and in this computer, a simple monitor program. The RAM ICs are random-access memory (RAM), and can be read or written. You will notice the Read* and Write* control signals from the processor are connected to these, but only the Read* signal to the ROM. Each memory unit has address inputs from the processor, and connections to the bi-directional data bus.

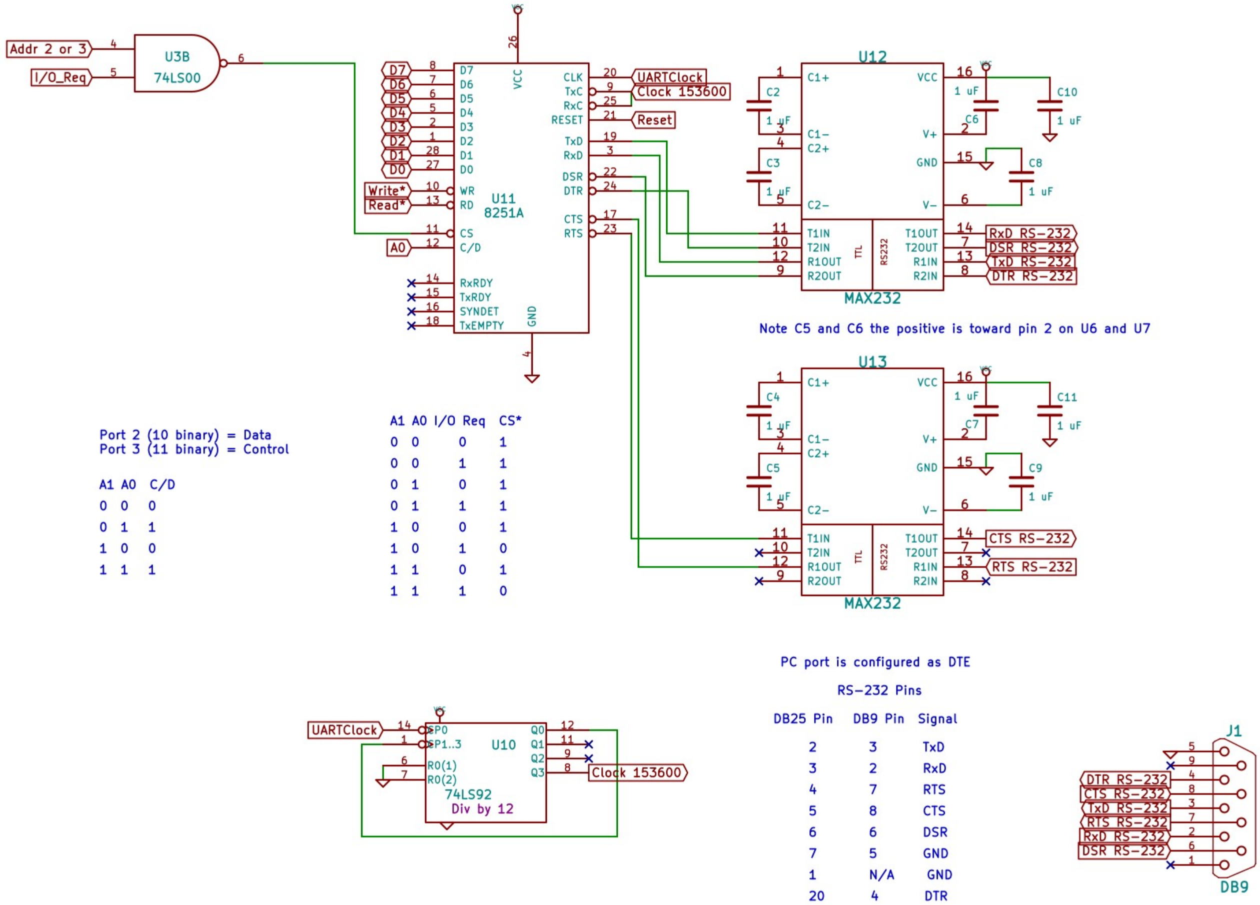
In digital electronics, outputs must not be connected to outputs, since if one output is high and the other low, the result will be somewhere in between, neither high or low, neither 1 or 0, and this is unacceptable. The solution is to have three-state output circuits on the devices with outputs that are connected together, like the ones connected to the data bus. These three-state outputs can be high, low or “third state”, which is a high-impedance state, like a cut wire. The processor, memory ICs, and port ICs in this computer all have built-in three-state outputs on their data lines. The chip select inputs (CS_ROM, CS_RAM0 and CS_RAM1) determine if the device outputs are third state or not. The control logic of the computer system must be arranged so that one and only one device is putting data onto the data bus at any time, meaning only one chip select logic signal is active.[16]

The computer has 64K RAM, but you see only A0 to A14 on the RAM ICs. This is because each RAM

16 The CS_ROM and CS_RAM signals are actually active low, and should have asterisks in there names, sorry for the omission.

IC holds 32K bytes, and the A15 signal is used in the chip select logic to decide which RAM IC is active. CS_RAM0 activates the RAM with data from address 0x0000 to 0x7FFF, and CS_RAM1 activates the RAM with data from 0x8000 to 0xFFFF.

Serial Interface



The serial interface is used by the computer to communicate with a terminal. A serial interface sends or receives data over one wire one bit at a time, but the computer uses parallel data transfers over its data bus 8 bits at a time. The bridge between the parallel and serial data streams is the 8251A universal asynchronous receiver-transmitter (UART). It takes parallel data from the computer system data bus, and then sends it out one bit at a time over the TxD output. Similarly, it receives data one bit at a time from the RxD input, and places it as parallel data on the data bus for the system to read.

The serial interface in this computer uses the RS-232 protocol, which defines how data is to be sent and received. This protocol is used by many different serial devices, so using it in this computer allows one to connect it to a variety of terminal types. RS-232 defines bit rates for input or output. A rate of one bit per second is one baud. This interface uses 9600 baud. To obtain this baud rate, the UART clock frequency of 1.8432 MHz is first divided down to 153600 Hz by a divide-by-12 IC, the 74LS92. This rate is further divided by circuitry in the UART to obtain the final 9600 baud rate that is used to transmit and receive data. In addition, the RS-232 protocol defines high and low voltages differently than the usual +5V and ground. It uses instead +12V and -12V. One could supply these voltages to the interface with a separate power supply, but the company Maxim created the Max232 ICs seen here to boost the voltages into the proper range for serial transmission. These chips use the capacitors and a charge-pump circuit to boost the voltage, and require only the same +5V and ground inputs as the rest of the ICs in the computer.

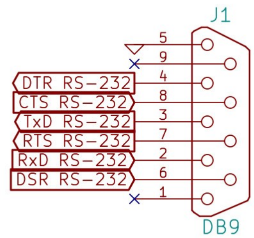
The UART communicates with the computer system through input and output ports. Port 2 is the data port, which is where the computer writes and reads data. Port 3 is the control port. Writing to port 3 configures the UART, and reading from port 3 checks the status, to see if there is incoming data to be read, or if the UART is ready to accept data to transmit. Since the UART is connected to the data bus, it has three-state data outputs, controlled by the chip select (CS) input. A truth table and some of the chip select logic circuitry is shown (the Addr_2_or_3 signal comes from the generic array logic (GAL) IC, explained below). Also, the UART has a Reset input which is active-high. When the computer processor is reset, the UART is reset too.

Serial Port Connector

PC port is configured as DTE

RS-232 Pins

DB25 Pin	DB9 Pin	Signal
2	3	TxD
3	2	RxD
4	7	RTS
5	8	CTS
6	6	DSR
7	5	GND
1	N/A	GND
20	4	DTR

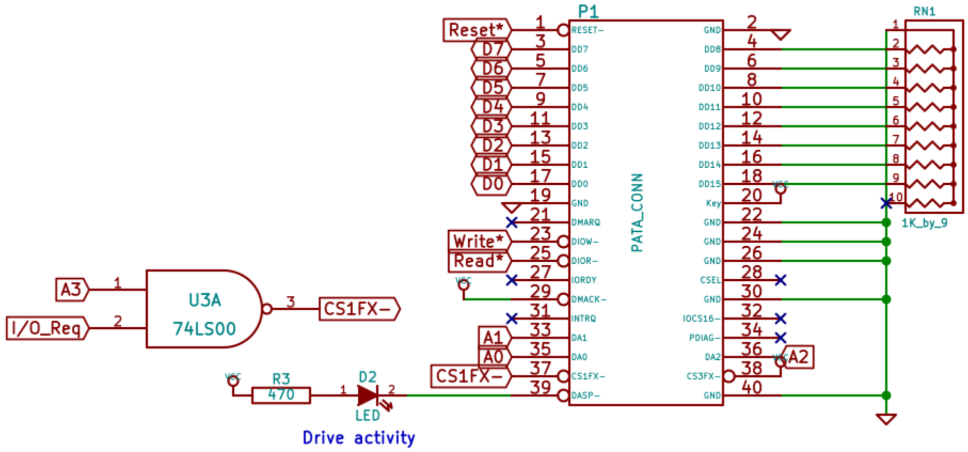


The serial port connector deserves its own explanation. You may have noticed in the serial interface schematic that the RS-232 signal line named TxD (transmitted data) is passed through the Max232 IC to the UART RxD (received data) input. Similarly, the UART TxD output is sent to the RS-232 RxD signal line. This is because there are two configurations for RS-232 connectors, called data communications equipment (DCE) and data terminal equipment (DTE). Originally, RS-232 was used to connect a data terminal to a modem. The data transmitted from the terminal was received by the modem, and the data transmitted from the modem was received by the terminal. It was decided to name the signals in the interface (and the plug pins) after their functions from the point of view of the data terminal equipment. So, RS-232 pin TxD has the data that is transmitted (sent) from the DTE, to be received by the DCE. The PC serial port is configured as DTE, and to make things simple I made the Z80 computer's port configured as DCE, like a modem would be. A straight-through serial cable is used to connect them.

Of course, it is possible to connect a DCE to a DCE, and a DTE to a DTE. It involves crossing over of the RS-232 RxD and TxD wires. These cables are called null modem or crossover cables.

The DTR (data terminal ready), DSR (data set ready), CTS (clear to send), and RTS (ready to send) signals are used by some DTE and DCE to configure the interface properly, and in schemes used to control the flow of data over the interface. The port handling software in this Z80 computer does not look at the DTR and RTS inputs, but does assert the DSR and CTS signals, in case your particular terminal or terminal emulation software requires them.

PATA Interface



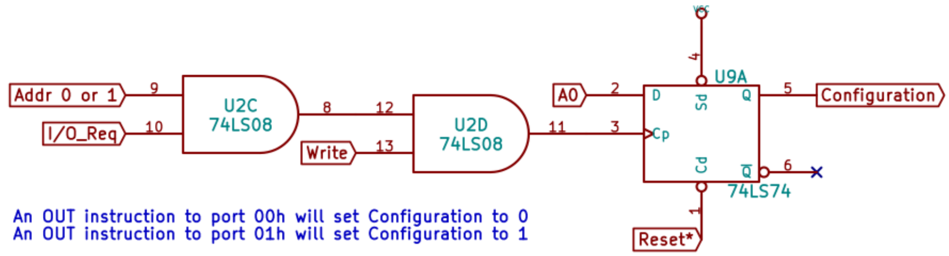
This is the parallel advanced-technology attachment (PATA) interface for the disk drive. This interface is also informally called an IDE (integrated drive electronics) interface, since it was almost exclusively used to connect disk drives with integrated drive controllers to a computer bus in the early days of personal computers. I have used this in the Z80 computer because it is very simple to implement (basically only requires a socket attached to the computer buses) and there are lots of surplus IDE drives and modules available that will work with it.

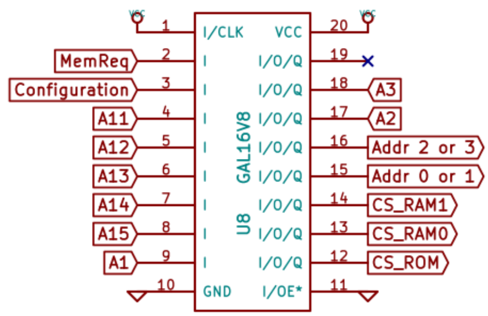
The pins on the interface create an input/output port arrangement of 8 ports, used to control the disk, and read and write data. Like other devices connected to the data bus, the data pins are three-state, controlled by chip select inputs (CS1FX- and CS3FX-). In this computer, the disk is mapped to ports 8 to 15. Address line A3 is used in the chip select logic (selected if 1), and A0 to A3 used to select the port being written or read. I will not discuss the details of how these ports are used, but one can see how the Z80 computer accesses the disk by looking at the Customized CBIOS listing in the Selected Program Listings section. Read* and Write* control signals from the CPU determine reading from or writing to the ports.

The disk contains data in 512-byte records called sectors, each has a unique address. To read a sector, the computer inputs though the ports the address of the sector to be read, and some configuration information. The disk seeks the sector, and when it is available, it signals the computer that it is ready, and the computer then reads the data bus 256 times in a row to obtain the data. Each data word from the disk is 16-bits wide. However, in this computer, I only read the lower 8-bits of each word, with the high bits being grounded through resistors.

There is a Reset* input to reset the drive controller (which is inside the disk), and an output for an LED to indicate drive activity.

Memory Configuration Logic



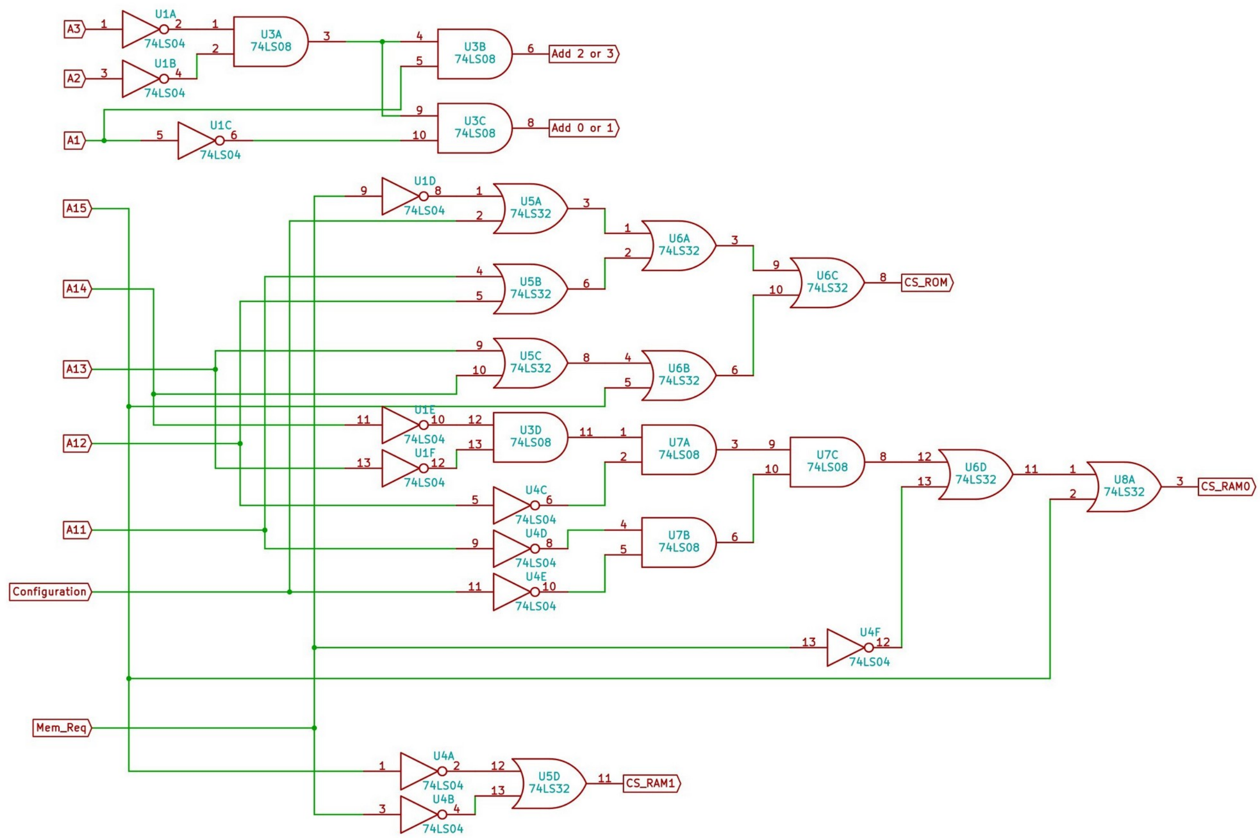


As mentioned in the introduction, the memory in this computer can be placed in one of two different configurations. The default configuration, configuration 0, is 2K ROM, and 62K RAM. The configuration used by the CP/M operating system, configuration 1, is all-RAM 64K. The circuits that set the two different configurations are shown here.

The configuration flip-flop, shown at top above, is a one-bit signal that is set to 0 by writing to output port 0, and set to 1 by writing to output port 1[17]. This flip-flop is also connected to the system Reset* control signal, to ensure that when the computer starts up the flip-flop is in configuration 0. This is important because the Z80 starts by reading data from address 0x0000, so it needs to find code there immediately, which is in the ROM. CP/M, on the other hand, expects to find RAM at low address locations from 0x0000 to 0x00FF.

The generic array logic (GAL) IC, GAL16V8, contains a logic network that takes as input the configuration bit, the upper address bits A11 to A15, and a memory request control signal, and produces the appropriate chip select outputs for the two different configurations. The extra space in the GAL is also used for logic arrays to produce the Addr_0_or_1 and Addr_2_or_3 signals used in chip control logic for the configuration flip-flop and the serial interface. If one were to implement these logic networks as individual logic gates, it would look like this (from an earlier version of the computer that used discrete logic ICs for the configuration logic):

17 The data in the OUT instruction is ignored, the execution of the instruction alone changes the configuration bit.



This would take 7 individual ICs. So, using the GAL saves space and expense.

The first, small logic circuit above has inputs A1, A2 and A3. One output of this circuit is the Addr 2 or 3 signal which is passed to the serial interface chip select logic as described in the serial interface section above. The other output is Addr 0 or 1 (“address zero or one”) that is an input to the memory configuration port circuit.

This logic circuit performs the following calculations (the Addr 0 or 1 and Addr 2 or 3 are active-high, that is, are logical 1 or +5V when asserted):

- Assert Addr 0 or 1 if A1 and A2 and A3 are all zero.
- Assert Addr 2 or 3 if A1 = 1 and, A2 and A3 are zero.

The formal logic equations for these two outputs are:

- Addr 0 or 1 = ~A3 ~A2 ~A1
- Addr 2 or 3 = ~A3 ~A2 * A1

The configuration bit is an input to the other, larger logic circuit in the GAL, which also has inputs A11 to A15, and Mem_Req. The outputs of this logic circuit are the chip select (CS) signals for the ROM and the two RAM ICs. The logic performs the following calculation (the CS signals are all active-low, that is, are logical 0 or GND when asserted – the asterisks on the labels in the schematic were unintentionally omitted):

- Assert CS_ROM if Configuration is 0, Mem_Req is asserted, and the address is 0x0000 to

0x07FF – that is, if A11 to A15 are all zero.

- Assert CS_RAM0 if Configuration is 0, Mem_Req is asserted, and the address is 0x0800 to 0x7FFF – that is, A15 is zero, and any of A11 to A14 is 1.
- Assert CS_RAM0 if Configuration is 1, Mem_Req is asserted, and the address is 0x0000 to 0x7FFF – that is, if A15 is zero
- Assert CS_RAM1 if Configuration is 0 or 1 (a “don't care”) and the address is 0x8000 to 0xFFFF – that is, A15 is one.

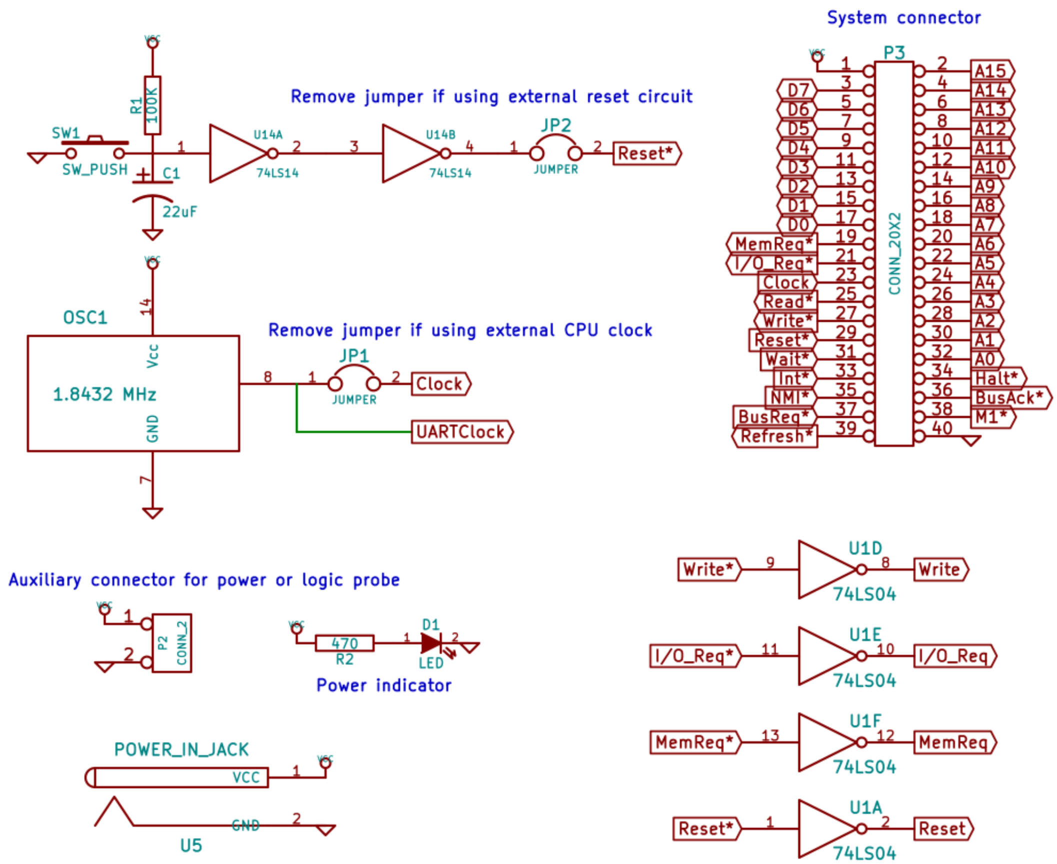
The formal logic equations are here:

- CS_ROM = ~Mem_Req + Config + A11 + A12 + A13 + A14 + A15
- CS_RAM0 = ~A14 ~A13 ~A12 ~A11 ~Config + ~Mem_Req + A15
- CS_RAM1 = ~A15 + ~Mem_Req

I used the Logisim program to help design these logic circuits, and the Galasm program to create the fuse map file used to program the GAL16V8. Here is the Galasam PLD file:

```
GAL16V8            ; this is the GAL type
Memory Logic 1     ; this is the signature
CLK MemReq Config A11 A12 A13 A14 A15 A1 GND           ;pin declaration
/OE CSROM CSRAM0 CSRAM1 Addr0or1 Addr2or3 A2 A3 A VCC
CSROM = /MemReq + Config + A11 + A12 + A13 + A14 + A15 ;pin definitions
CSRAM0 = /A14 * /A13 * /A12 * /A11 * /Config + /MemReq + A15
CSRAM1 = /A15 + /MemReq
Addr0or1 = /A3 * /A2 * /A1
Addr2or3 = /A3 * /A2 * A1
DESCRIPTION:
This is the memory select logic for the CPUville Single board computer, with the
addition of logic to produce the Add 0 or 1 and Add 2 or 3 outputs.
```

Connectors and miscellaneous circuit elements



The reset circuit pulls the Reset* signal low (asserted) when the button is pushed. The capacitor and resistor on the inverter input provide about a second of delay after the button is released (or the computer is powered on) for the Reset* signal to de-assert. The jumper allows one to use an external reset circuit, with the Reset* signal coming from the system connector.

The oscillator provides a square-wave signal for both the CPU and UART clocks. The CPU clock can be disabled by removing the clock jumper, and an external CPU clock can be used instead, with the signal coming in from the system connector.

The barrel jack connects power from the power supply to the computer power traces. The power indicator LED lights when power is present.

The auxiliary power connector (the two pins with a clip at the top of the circuit board) can be used, with connecting wires, to supply power to a disk drive that requires only +5V. Drives can also receive +5V from pin 20 of the PATA connector, as discussed in the section on Building the Computer. The auxiliary power connector can also be used to connect a logic probe.

The system connector presents the Z80 pins in an accessible form so that a user could connect an expansion board to the computer if desired. The connector outputs are unbuffered, and can only drive one TTL input each. Unused CPU signals, such as NMI*, BusAck* and Halt*, are passed to the system connector in case a user builds a peripheral that uses these controls. This connector can be used to connect an 8-bit processor other than the Z80 to the system, such as the CPUville 8-bit processor. In that case the Z80 should be removed from its socket before the other processor is connected.

The inverters (74LS04) create some inverted control signals for the various logic circuits.

Parts organizer

Capacitor, 22 uF, 16V 1	Resistor, 100K, ¼ watt Brown-Black-Yellow 1	74LS00 quad NAND 1	74LS08 quad AND 1
74LS04 hex inverter 1	DIL 14-pin socket 6	Pushbutton 1	DIL 16-pin socket 2
DIL 24-pin socket 1	DIL 20-pin socket 1	32K RAM 2	2716 2K EPROM 1
74LS14 hex inverter, Schmitt trigger 1	GAL 16V8 programmable logic 1	74LS74 dual D flip-flop 1	8251A UART 1
Z80 CPU 1	Resistor, 470 ohm, ¼ watt Yellow-Violet-Brown 2	Resistor, 1K, ¼ watt Brown-Black-Red 4	Resistor network, 1K x 9 1
LED 2	Oscillator, 1.8432 MHz 1	2-pin header 2	Shorting block 2

Capacitor, 1 uF tantalum 10	Header with clip, 2 pin 1	Power-in jack 1	DIL 40-pin socket 1
DIL 28-pin socket, 0.6 inches wide 1	MAX232 line driver 2	40-pin shrouded header (PATA/IDE disk connector) 1	40-pin header (system connector) 1
DB-9 female connector for RS-232 serial interface 1	DIL 28-pin socket, 0.3 inches wide 2	74LS92 divide-by-12 1	40-pin right-angle header (alternative disk connector) 1
Standoff, 0.25 inch female 4	Standoff, 0.75 inch M/F 4		

Parts list

I buy almost all my parts from Jameco. If you buy from a different supplier, you can check the datasheets for these parts on the Jameco website by referring to the part number.

Part	PCB Reference	Number	Jameco Part No.
Shorting block		2	22024
Osc 1.8432 MHz	OSC1	1	27879
Z80	CPU1	1	35561
Socket, 40-pin, 0.6		1	41111
74LS00	U3	1	46252
74LS04	U1	1	46316
74LS08	U2	1	46375
74LS14	U14	1	46640
74LS74	U9	1	48004
74LS92	U10	1	48143
UART 8251A	U11	1	52652
40-pin header	P3	1	53532
40-pin right angle header	P1	1	53605
Res net, 1K ohm x 9	RN1	1	97877
DB-9 connector	J1	1	104952
Socket, 20-pin, 0.3		1	112248
Socket, 28-pin, 0.6		1	112272
Socket, 28-pin, 0.3		2	112299
Push button switch	SW1	1	122973
Power-in jack	U5	1	137673
Standoff 0.25 inch female		4	139193
Standoff 0.75 inch M/F		4	139222
Cap 1uF, tantalum	C3 – C11	10	154860
40-pin header, shrouded	P1	1	181105
Molex header	P2	1	232266
32K RAM	U6,U7	2	242376
2716 EPROM	U4	1	308662
Socket, 24-pin, 0.6		1	683198
Resistor, 470 ohm	R2,R3	2	690785
Resistor, 1K ohm	R6,R7,R5,R4	4	690865
Resistor, 100K ohm	R1	1	691340
MAX-232N driver	U12,U13	2	698576
GAL 16V8-D	U8	1	876539
Cap, 22 uF	C1	1	1946295
LED (red)	D1,D2	1	2081932
2-pin header	JP2,JP1	2	2144884

Selected Program Listings

chr_echo

```
0000            ;Program to test serial port.
0000            ;Enter hex machine code with load command, or binary file with bload command.
0000            ;No port initialization commands
0000            ;When running, should echo typed characters to display.
0800                         .org  0800h
0800 DB 03      echo_loop_1: in    a,(3)          ;get status
0802 E6 02                   and   002h           ;check RxRDY bit
0804 28 FA                   jr    z,echo_loop_1  ;not ready, loop
0806 DB 02                   in    a,(2)          ;get char
0808 47                      ld    b,a            ;save received char in b reg
0809 DB 03      echo_loop_2: in    a,(3)          ;get status
080B E6 01                   and   001h           ;check TxRDY bit
080D 28 FA                   jr    z,echo_loop_2  ;loop if not set
080F 78                      ld    a,b            ;get char back
0810 D3 02                   out   (2),a          ;send to output
0812 18 EC                   jr    echo_loop_1    ;start over
0814                         .end
tasm: Number of errors = 0
```

ROM monitor[18]

```
# File 2K_ROM_8.asm
0000            ;ROM monitor for a system with serial interface and IDE disk and memory expansion board.
0000            ;Expansion board has 64K RAM -- computer board memory decoder disabled (J2 off).
0000            ;Expansion board uses ports 2 and 3 for the serial interface, and 8 to 15 for the disk
0000            ;Therefore the computer board I/O decoder is also disabled (J1 off)
0000            ;Output to port 0 will cause memory configuration flip-flop to activate 2K ROM 0000-07FF,
0000            ;with 62K RAM 0800-FFFF
0000            ;Output to port 1 will cause memory configuration flip-flop to activate all RAM 0000-FFFF
```

18 The RAM monitor program monitor.bin is identical to this ROM monitor, except it was assembled to target address 0xDC00, has a small code prefix to move the code to this location after CP/M loads it at 0x0100, and responds to the `cpm` command with a CP/M warm start, not a cold start as does the ROM monitor.

```
0000                ;
0000                                  org   00000h
0000 c3 63 04                         jp    monitor_cold_start
0003                ;
0003                ;The following code is for a system with a serial port.
0003                ;Assumes the UART data port address is 02h and control/status address is 03h
0003                ;
0003                ;The subroutines for the serial port use these variables in RAM:
0003                current_location: equ   0xdb00            ;word variable in RAM
0003                line_count:       equ   0xdb02            ;byte variable in RAM
0003                byte_count:       equ   0xdb03            ;byte variable in RAM
0003                value_pointer:    equ   0xdb04            ;word variable in RAM
0003                current_value:    equ   0xdb06            ;word variable in RAM
0003                buffer:           equ   0xdb08            ;buffer in RAM -- up to stack area
0003                ;Need to have stack in upper RAM, but not in area of CP/M or RAM monitor.
0003                ROM_monitor_stack:      equ   0xdbff            ;upper TPA in RAM, below RAM monitor
0003                ;
0003                ;Subroutine to initialize serial port UART
0003                ;Needs to be called only once after computer comes out of reset.
0003                ;If called while port is active will cause port to fail.
0003                ;16x = 9600 baud
0003 3e 4e          initialize_port:  ld    a,04eh            ;1 stop bit, no parity, 8-bit char, 16x baud
0005 d3 03                            out   (3),a             ;write to control port
0007 3e 37                            ld    a,037h            ;enable receive and transmit
0009 d3 03                            out   (3),a             ;write to control port
000b c9                               ret
000c                ;
000c                ;Puts a single char (byte value) on serial output
000c                ;Call with char to send in A register. Uses B register
000c 47             write_char:       ld    b,a               ;store char
000d db 03          write_char_loop:  in    a,(3)             ;check if OK to send
000f e6 01                            and   001h              ;check TxRDY bit
0011 ca 0d 00                         jp    z,write_char_loop ;loop if not set
0014 78                               ld    a,b               ;get char back
0015 d3 02                            out   (2),a             ;send to output
0017 c9                               ret                     ;returns with char in a
0018                ;
0018                ;Subroutine to write a zero-terminated string to serial output
0018                ;Pass address of string in HL register
0018                ;No error checking
```

```
0018 db 03        write_string:     in    a,(3)            ;read status
001a e6 01                          and   001h             ;check TxRDY bit
001c ca 18 00                       jp    z,write_string   ;loop if not set
001f 7e                             ld    a,(hl)           ;get char from string
0020 a7                             and   a                ;check if 0
0021 c8                             ret   z                ;yes, finished
0022 d3 02                          out   (2),a            ;no, write char to output
0024 23                             inc   hl               ;next char in string
0025 c3 18 00                       jp    write_string     ;start over
0028              ;
0028              ;Binary loader. Receive a binary file, place in memory.
0028              ;Address of load passed in HL, length of load (= file length) in BC
0028 db 03        bload:            in    a,(3)            ;get status
002a e6 02                          and   002h             ;check RxRDY bit
002c ca 28 00                       jp    z,bload          ;not ready, loop
002f db 02                          in    a,(2)
0031 77                             ld    (hl),a
0032 23                             inc   hl
0033 0b                             dec   bc               ;byte counter
0034 78                             ld    a,b              ;need to test BC this way because
0035 b1                             or    c                ;dec rp instruction does not change flags
0036 c2 28 00                       jp    nz,bload
0039 c9                             ret
003a              ;
003a              ;Binary dump to port. Send a stream of binary data from memory to serial output
003a              ;Address of dump passed in HL, length of dump in BC
003a db 03        bdump:            in    a,(3)            ;get status
003c e6 01                          and   001h             ;check TxRDY bit
003e ca 3a 00                       jp    z,bdump          ;not ready, loop
0041 7e                             ld    a,(hl)
0042 d3 02                          out   (2),a
0044 23                             inc   hl
0045 0b                             dec   bc
0046 78                             ld    a,b              ;need to test this way because
0047 b1                             or    c                ;dec rp instruction does not change flags
0048 c2 3a 00                       jp    nz,bdump
004b c9                             ret
004c              ;
004c              ;Subroutine to get a string from serial input, place in buffer.
004c              ;Buffer address passed in HL reg.
```

```
004c                ;Uses A,BC,DE,HL registers (including calls to other subroutines).
004c                ;Line entry ends by hitting return key. Return char not included in string (replaced by zero).
004c                ;Backspace editing OK. No error checking.
004c                ;
004c 0e 00          get_line:               ld    c,000h                  ;line position
004e 7c                                     ld    a,h                     ;put original buffer address in de
004f 57                                     ld    d,a                     ;after this don't need to preserve hl
0050 7d                                     ld    a,l                     ;subroutines called don't use de
0051 5f                                     ld    e,a
0052 db 03          get_line_next_char:     in    a,(3)                   ;get status
0054 e6 02                                  and   002h                    ;check RxRDY bit
0056 ca 52 00                               jp    z,get_line_next_char    ;not ready, loop
0059 db 02                                  in    a,(2)                   ;get char
005b fe 0d                                  cp    00dh                    ;check if return
005d c8                                     ret   z                       ;yes, normal exit
005e fe 7f                                  cp    07fh                    ;check if backspace (VT102 keys)
0060 ca 74 00                               jp    z,get_line_backspace    ;yes, jump to backspace routine
0063 fe 08                                  cp    008h                    ;check if backspace (ANSI keys)
0065 ca 74 00                               jp    z,get_line_backspace    ;yes, jump to backspace
0068 cd 0c 00                               call  write_char              ;put char on screen
006b 12                                     ld    (de),a                  ;store char in buffer
006c 13                                     inc   de                      ;point to next space in buffer
006d 0c                                     inc   c                       ;inc counter
006e 3e 00                                  ld    a,000h
0070 12                                     ld    (de),a                  ;leaves zero-terminated string in buffer
0071 c3 52 00                               jp    get_line_next_char
0074 79             get_line_backspace:     ld    a,c                     ;check current position in line
0075 fe 00                                  cp    000h                    ;at beginning of line?
0077 ca 52 00                               jp    z,get_line_next_char    ;yes, ignore backspace, get next char
007a 1b                                     dec   de                      ;no, erase char from buffer
007b 0d                                     dec   c                       ;back up one
007c 3e 00                                  ld    a,000h                  ;put zero in place of last char
007e 12                                     ld    (de),a
007f 21 84 03                               ld    hl,erase_char_string    ;ANSI seq. To delete one char from line
0082 cd 18 00                               call  write_string            ;transmits seq. to BS and erase char
0085 c3 52 00                               jp    get_line_next_char
0088                ;
0088                ;Creates a two-char hex string from the byte value passed in register A
0088                ;Location to place string passed in HL
0088                ;String is zero-terminated, stored in 3 locations starting at HL
```

```
0088                ;Also uses registers b,d, and e
0088 47             byte_to_hex_string:    ld    b,a               ;store original byte
0089 cb 3f                                 srl   a                 ;shift right 4 times, putting
008b cb 3f                                 srl   a                 ;high nybble in low-nybble spot
008d cb 3f                                 srl   a                 ;and zeros in high-nybble spot
008f cb 3f                                 srl   a
0091 16 00                                 ld    d,000h            ;prepare for 16-bit addition
0093 5f                                    ld    e,a               ;de contains offset
0094 e5                                    push  hl                ;temporarily store string target address
0095 21 ee 00                              ld    hl,hex_char_table ;use char table to get high-nybble character
0098 19                                    add   hl,de             ;add offset to start of table
0099 7e                                    ld    a,(hl)            ;get char
009a e1                                    pop   hl                ;get string target address
009b 77                                    ld    (hl),a            ;store first char of string
009c 23                                    inc   hl                ;point to next string target address
009d 78                                    ld    a,b               ;get original byte back from reg b
009e e6 0f                                 and   00fh              ;mask off high-nybble
00a0 5f                                    ld    e,a               ;d still has 000h, now de has offset
00a1 e5                                    push  hl                ;temp store string target address
00a2 21 ee 00                              ld    hl,hex_char_table ;start of table
00a5 19                                    add   hl,de             ;add offset
00a6 7e                                    ld    a,(hl)            ;get char
00a7 e1                                    pop   hl                ;get string target address
00a8 77                                    ld    (hl),a            ;store second char of string
00a9 23                                    inc   hl                ;point to third location
00aa 3e 00                                 ld    a,000h            ;zero to terminate string
00ac 77                                    ld    (hl),a            ;store the zero
00ad c9                                    ret                     ;done
00ae                ;
00ae                ;Converts a single ASCII hex char to a nybble value
00ae                ;Pass char in reg A. Letter numerals must be upper case.
00ae                ;Return nybble value in low-order reg A with zeros in high-order nybble if no error.
00ae                ;Return 0ffh in reg A if error (char not a valid hex numeral).
00ae                ;Also uses b, c, and hl registers.
00ae 21 ee 00       hex_char_to_nybble:    ld    hl,hex_char_table
00b1 06 0f                                 ld    b,00fh                  ;no. of valid characters in table - 1.
00b3 0e 00                                 ld    c,000h                  ;will be nybble value
00b5 be             hex_to_nybble_loop:    cp    (hl)                    ;character match here?
00b6 ca c2 00                              jp    z,hex_to_nybble_ok      ;match found, exit
00b9 05                                    dec   b                       ;no match, check if at end of table
```

```
00ba fa c4 00                          jp    m,hex_to_nybble_err     ;table limit exceded, exit with error
00bd 0c                                inc   c                       ;still inside table, continue search
00be 23                                inc   hl
00bf c3 b5 00                          jp    hex_to_nybble_loop
00c2 79            hex_to_nybble_ok:   ld    a,c                     ;put nybble value in a
00c3 c9                                ret
00c4 3e ff         hex_to_nybble_err:  ld    a,0ffh                  ;error value
00c6 c9                                ret
00c7               ;
00c7               ;Converts a hex character pair to a byte value
00c7               ;Called with location of high-order char in HL
00c7               ;If no error carry flag clear, returns with byte value in register A, and
00c7               ;HL pointing to next mem location after char pair.
00c7               ;If error (non-hex char) carry flag set, HL pointing to invalid char
00c7 7e            hex_to_byte:        ld    a,(hl)            ;location of character pair
00c8 e5                                push  hl                ;store hl (hex_char_to_nybble uses it)
00c9 cd ae 00                          call  hex_char_to_nybble
00cc e1                                pop   hl                ;ret. with nybble in A reg, or 0ffh if error
00cd fe ff                             cp    0ffh              ;non-hex character?
00cf ca ec 00                          jp    z,hex_to_byte_err ;yes, exit with error
00d2 cb 27                             sla   a                 ;no, move low order nybble to high side
00d4 cb 27                             sla   a
00d6 cb 27                             sla   a
00d8 cb 27                             sla   a
00da 57                                ld    d,a               ;store high-nybble
00db 23                                inc   hl                ;get next character of the pair
00dc 7e                                ld    a,(hl)
00dd e5                                push  hl                ;store hl
00de cd ae 00                          call  hex_char_to_nybble
00e1 e1                                pop   hl
00e2 fe ff                             cp    0ffh              ;non-hex character?
00e4 ca ec 00                          jp    z,hex_to_byte_err ;yes, exit with error
00e7 b2                                or    d                 ;no, combine with high-nybble
00e8 23                                inc   hl                ;point to next memory location after char pair
00e9 37                                scf
00ea 3f                                ccf                     ;no-error exit (carry = 0)
00eb c9                                ret
00ec 37            hex_to_byte_err:    scf                     ;error, carry flag set
00ed c9                                ret
00ee ..            hex_char_table:     defm  "0123456789ABCDEF"        ;ASCII hex table
```

```
00fe                ;
00fe                ;Subroutine to get a two-byte address from serial input.
00fe                ;Returns with address value in HL
00fe                ;Uses locations in RAM for buffer and variables
00fe 21 08 db       address_entry:          ld    hl,buffer               ;location for entered string
0101 cd 4c 00                               call  get_line                ;returns with address string in buffer
0104 21 08 db                               ld    hl,buffer               ;location of stored address entry string
0107 cd c7 00                               call  hex_to_byte             ;will get high-order byte first
010a da 20 01                               jp    c, address_entry_error  ;if error, jump
010d 32 01 db                               ld    (current_location+1),a  ;store high-order byte, little-endian
0110 21 0a db                               ld    hl,buffer+2             ;point to low-order hex char pair
0113 cd c7 00                               call  hex_to_byte             ;get low-order byte
0116 da 20 01                               jp    c, address_entry_error  ;jump if error
0119 32 00 db                               ld    (current_location),a    ;store low-order byte in lower memory
011c 2a 00 db                               ld    hl,(current_location)   ;put memory address in hl
011f c9                                     ret
0120 21 c2 03       address_entry_error:    ld    hl,address_error_msg
0123 cd 18 00                               call  write_string
0126 c3 fe 00                               jp    address_entry
0129                ;
0129                ;Subroutine to get a decimal string, return a word value
0129                ;Calls decimal_string_to_word subroutine
0129 21 08 db       decimal_entry:          ld    hl,buffer
012c cd 4c 00                               call  get_line          ;returns with DE pointing to terminating zero
012f 21 08 db                               ld    hl,buffer
0132 cd 3f 01                               call  decimal_string_to_word
0135 d0                                     ret   nc                      ;no error, return with word in hl
0136 21 36 04                               ld    hl,decimal_error_msg    ;error, try again
0139 cd 18 00                               call  write_string
013c c3 29 01                               jp    decimal_entry
013f                ;
013f                ;Subroutine to convert a decimal string to a word value
013f                ;Call with address of string in HL, pointer to end of string in DE
013f                ;Carry flag set if error (non-decimal char)
013f                ;Carry flag clear, word value in HL if no error.
013f 42             decimal_string_to_word: ld    b,d
0140 4b                                     ld    c,e                     ;use BC as string pointer
0141 22 00 db                               ld    (current_location),hl   ;save addr. of buffer start in RAM
0144 21 00 00                               ld    hl,000h                 ;starting value zero
0147 22 06 db                               ld    (current_value),hl
```

```
014a 21 8f 01                              ld    hl,decimal_place_value  ;pointer to values
014d 22 04 db                              ld    (value_pointer),hl
0150 0b             decimal_next_char:     dec   bc                      ;next char (moving right to left)
0151 2a 00 db                              ld    hl,(current_location)   ;check if at end of decimal string
0154 37                                    scf                           ;get ready to sub. DE from buffer addr.
0155 3f                                    ccf                           ;set carry to zero (clear)
0156 ed 42                                 sbc   hl,bc                   ;cont. if bc > or = hl (buffer address)
0158 da 64 01                              jp    c,decimal_continue      ;borrow means bc > hl
015b ca 64 01                              jp    z,decimal_continue      ;z means bc = hl
015e 2a 06 db                              ld    hl,(current_value)      ;return if de < buffer add. (no borrow)
0161 37                                    scf                           ;get value back from RAM variable
0162 3f                                    ccf
0163 c9                                    ret                           ;return with carry clear, value in hl
0164 0a             decimal_continue:      ld    a,(bc)                  ;next char in string (right to left)
0165 d6 30                                 sub   030h                    ;ASCII value of zero char
0167 fa 8a 01                              jp    m,decimal_error         ;error if char value less than 030h
016a fe 0a                                 cp    00ah                    ;error if byte value > or = 10 decimal
016c f2 8a 01                              jp    p,decimal_error         ;a reg now has value of decimal numeral
016f 2a 04 db                              ld    hl,(value_pointer)      ;get value to add an put in de
0172 5e                                    ld    e,(hl)                  ;little-endian (low byte in low memory)
0173 23                                    inc   hl
0174 56                                    ld    d,(hl)
0175 23                                    inc   hl                      ;hl now points to next value
0176 22 04 db                              ld    (value_pointer),hl
0179 2a 06 db                              ld    hl,(current_value)      ;get back current value
017c 3d             decimal_add:           dec   a                       ;add loop to increase total value
017d fa 84 01                              jp    m,decimal_add_done      ;end of multiplication
0180 19                                    add   hl,de
0181 c3 7c 01                              jp    decimal_add
0184 22 06 db       decimal_add_done:      ld    (current_value),hl
0187 c3 50 01                              jp    decimal_next_char
018a 37             decimal_error:         scf
018b c9                                    ret
018c c3 7c 01                              jp    decimal_add
018f 01 00 0a 00 64 00 e8 03 10 27  decimal_place_value:    defw  1,10,100,1000,10000
0199                ;
0199                ;Memory dump
0199                ;Displays a 256-byte block of memory in 16-byte rows.
0199                ;Called with address of start of block in HL
0199 22 00 db       memory_dump:           ld    (current_location),hl   ;store address of block to be displayed
```

```
019c 3e 00                                ld    a,000h
019e 32 03 db                             ld    (byte_count),a          ;initialize byte count
01a1 32 02 db                             ld    (line_count),a          ;initialize line count
01a4 c3 d9 01                             jp    dump_new_line
01a7 2a 00 db     dump_next_byte:         ld    hl,(current_location)   ;get byte address from storage,
01aa 7e                                   ld    a,(hl)                  ;get byte to be converted to string
01ab 23                                   inc   hl                      ;increment address and
01ac 22 00 db                             ld    (current_location),hl   ;store back
01af 21 08 db                             ld    hl,buffer               ;location to store string
01b2 cd 88 00                             call  byte_to_hex_string      ;convert
01b5 21 08 db                             ld    hl,buffer               ;display string
01b8 cd 18 00                             call  write_string
01bb 3a 03 db                             ld    a,(byte_count)          ;next byte
01be 3c                                   inc   a
01bf ca 09 02                             jp    z,dump_done             ;stop when 256 bytes displayed
01c2 32 03 db                             ld    (byte_count),a          ;not finished yet, store
01c5 3a 02 db                             ld    a,(line_count)          ;end of line (16 characters)?
01c8 fe 0f                                cp    00fh                    ;yes, start new line
01ca ca d9 01                             jp    z,dump_new_line
01cd 3c                                   inc   a                       ;no, increment line count
01ce 32 02 db                             ld    (line_count),a
01d1 3e 20                                ld    a,020h                  ;print space
01d3 cd 0c 00                             call  write_char
01d6 c3 a7 01                             jp    dump_next_byte          ;continue
01d9 3e 00        dump_new_line:          ld    a,000h                  ;reset line count to zero
01db 32 02 db                             ld    (line_count),a
01de cd 89 02                             call  write_newline
01e1 2a 00 db                             ld    hl,(current_location)   ;location of start of line
01e4 7c                                   ld    a,h                     ;high byte of address
01e5 21 08 db                             ld    hl, buffer
01e8 cd 88 00                             call  byte_to_hex_string      ;convert
01eb 21 08 db                             ld    hl,buffer
01ee cd 18 00                             call  write_string            ;write high byte
01f1 2a 00 db                             ld    hl,(current_location)
01f4 7d                                   ld    a,l                     ;low byte of address
01f5 21 08 db                             ld    hl, buffer
01f8 cd 88 00                             call  byte_to_hex_string      ;convert
01fb 21 08 db                             ld    hl,buffer
01fe cd 18 00                             call  write_string            ;write low byte
0201 3e 20                                ld    a,020h                  ;space
```

```
0203 cd 0c 00                           call  write_char
0206 c3 a7 01                           jp    dump_next_byte         ;now write 16 bytes
0209 3e 00       dump_done:             ld    a,000h
020b 21 08 db                           ld    hl,buffer
020e 77                                 ld    (hl),a                 ;clear buffer of last string
020f cd 89 02                           call  write_newline
0212 c9                                 ret
0213             ;
0213             ;Memory load
0213             ;Loads RAM memory with bytes entered as hex characters
0213             ;Called with address to start loading in HL
0213             ;Displays entered data in 16-byte rows.
0213 22 00 db    memory_load:           ld    (current_location),hl
0216 21 ee 03                           ld    hl,data_entry_msg
0219 cd 18 00                           call  write_string
021c c3 66 02                           jp    load_new_line
021f cd 7f 02    load_next_char:        call  get_char
0222 fe 0d                              cp    00dh                   ;return?
0224 ca 7b 02                           jp    z,load_done            ;yes, quit
0227 32 08 db                           ld    (buffer),a
022a cd 7f 02                           call  get_char
022d fe 0d                              cp    00dh                   ;return?
022f ca 7b 02                           jp    z,load_done            ;yes, quit
0232 32 09 db                           ld    (buffer+1),a
0235 21 08 db                           ld    hl,buffer
0238 cd c7 00                           call  hex_to_byte
023b da 71 02                           jp    c,load_data_entry_error ;non-hex character
023e 2a 00 db                           ld    hl,(current_location)  ;get byte address from storage,
0241 77                                 ld    (hl),a                 ;store byte
0242 23                                 inc   hl                     ;increment address and
0243 22 00 db                           ld    (current_location),hl  ;store back
0246 3a 08 db                           ld    a,(buffer)
0249 cd 0c 00                           call  write_char
024c 3a 09 db                           ld    a,(buffer+1)
024f cd 0c 00                           call  write_char
0252 3a 02 db                           ld    a,(line_count)         ;end of line (16 characters)?
0255 fe 0f                              cp    00fh                   ;yes, start new line
0257 ca 66 02                           jp    z,load_new_line
025a 3c                                 inc   a                      ;no, increment line count
025b 32 02 db                           ld    (line_count),a
```

```
025e 3e 20                                ld    a,020h                  ;print space
0260 cd 0c 00                             call  write_char
0263 c3 1f 02                             jp    load_next_char          ;continue
0266 3e 00       load_new_line:           ld    a,000h                  ;reset line count to zero
0268 32 02 db                             ld    (line_count),a
026b cd 89 02                             call  write_newline
026e c3 1f 02                             jp    load_next_char          ;continue
0271 cd 89 02    load_data_entry_error:   call  write_newline
0274 21 1b 04                             ld    hl,data_error_msg
0277 cd 18 00                             call  write_string
027a c9                                   ret
027b cd 89 02    load_done:               call  write_newline
027e c9                                   ret
027f             ;
027f             ;Get one ASCII character from the serial port.
027f             ;Returns with char in A reg. No error checking.
027f db 03       get_char:                in    a,(3)                   ;get status
0281 e6 02                                and   002h                    ;check RxRDY bit
0283 ca 7f 02                             jp    z,get_char              ;not ready, loop
0286 db 02                                in    a,(2)                   ;get char
0288 c9                                   ret
0289             ;
0289             ;Subroutine to start a new line
0289 3e 0d       write_newline:           ld    a,00dh                  ;ASCII carriage return character
028b cd 0c 00                             call  write_char
028e 3e 0a                                ld    a,00ah                  ;new line (line feed) character
0290 cd 0c 00                             call  write_char
0293 c9                                   ret
0294             ;
0294             ;Subroutine to read one disk sector (256 bytes)
0294             ;Address to place data passed in HL
0294             ;LBA bits 0 to 7 passed in C, bits 8 to 15 passed in B
0294             ;LBA bits 16 to 23 passed in E
0294             disk_read:
0294 db 0f       rd_status_loop_1:        in    a,(0fh)                 ;check status
0296 e6 80                                and   80h                     ;check BSY bit
0298 c2 94 02                             jp    nz,rd_status_loop_1     ;loop until not busy
029b db 0f       rd_status_loop_2:        in    a,(0fh)                 ;check      status
029d e6 40                                and   40h                     ;check DRDY bit
029f ca 9b 02                             jp    z,rd_status_loop_2      ;loop until ready
```

```
02a2 3e 01                              ld    a,01h                   ;number of sectors = 1
02a4 d3 0a                              out   (0ah),a                 ;sector count register
02a6 79                                 ld    a,c
02a7 d3 0b                              out   (0bh),a                 ;lba bits 0 - 7
02a9 78                                 ld    a,b
02aa d3 0c                              out   (0ch),a                 ;lba bits 8 - 15
02ac 7b                                 ld    a,e
02ad d3 0d                              out   (0dh),a                 ;lba bits 16 - 23
02af 3e e0                              ld    a,11100000b             ;LBA mode, select drive 0
02b1 d3 0e                              out   (0eh),a                 ;drive/head register
02b3 3e 20                              ld    a,20h                   ;Read sector command
02b5 d3 0f                              out   (0fh),a
02b7 db 0f        rd_wait_for_DRQ_set:  in    a,(0fh)                 ;read status
02b9 e6 08                              and   08h                     ;DRQ bit
02bb ca b7 02                           jp    z,rd_wait_for_DRQ_set   ;loop until bit set
02be db 0f        rd_wait_for_BSY_clear: in   a,(0fh)
02c0 e6 80                              and   80h
02c2 c2 be 02                           jp    nz,rd_wait_for_BSY_clear
02c5 db 0f                              in    a,(0fh)                 ;clear INTRQ
02c7 db 08        read_loop:            in    a,(08h)                 ;get data
02c9 77                                 ld    (hl),a
02ca 23                                 inc   hl
02cb db 0f                              in    a,(0fh)                 ;check status
02cd e6 08                              and   08h                     ;DRQ bit
02cf c2 c7 02                           jp    nz,read_loop            ;loop until cleared
02d2 c9                                 ret
02d3              ;
02d3              ;Subroutine to write one disk sector (256 bytes)
02d3              ;Address of data to write to disk passed in HL
02d3              ;LBA bits 0 to 7 passed in C, bits 8 to 15 passed in B
02d3              ;LBA bits 16 to 23 passed in E
02d3              disk_write:
02d3 db 0f        wr_status_loop_1:     in    a,(0fh)                 ;check status
02d5 e6 80                              and   80h                     ;check BSY bit
02d7 c2 d3 02                           jp    nz,wr_status_loop_1     ;loop until not busy
02da db 0f        wr_status_loop_2:     in    a,(0fh)                 ;check      status
02dc e6 40                              and   40h                     ;check DRDY bit
02de ca da 02                           jp    z,wr_status_loop_2      ;loop until ready
02e1 3e 01                              ld    a,01h                   ;number of sectors = 1
02e3 d3 0a                              out   (0ah),a                 ;sector count register
```

```
02e5 79                              ld    a,c
02e6 d3 0b                           out   (0bh),a                ;lba bits 0 - 7
02e8 78                              ld    a,b
02e9 d3 0c                           out   (0ch),a                ;lba bits 8 - 15
02eb 7b                              ld    a,e
02ec d3 0d                           out   (0dh),a                ;lba bits 16 - 23
02ee 3e e0                           ld    a,11100000b            ;LBA mode, select drive 0
02f0 d3 0e                           out   (0eh),a                ;drive/head register
02f2 3e 30                           ld    a,30h                  ;Write sector command
02f4 d3 0f                           out   (0fh),a
02f6 db 0f       wr_wait_for_DRQ_set:    in    a,(0fh)                ;read status
02f8 e6 08                           and   08h                    ;DRQ bit
02fa ca f6 02                        jp    z,wr_wait_for_DRQ_set  ;loop until bit set
02fd 7e          write_loop:         ld    a,(hl)
02fe d3 08                           out   (08h),a                ;write data
0300 23                              inc   hl
0301 db 0f                           in    a,(0fh)                ;read status
0303 e6 08                           and   08h                    ;check DRQ bit
0305 c2 fd 02                        jp    nz,write_loop          ;write until bit cleared
0308 db 0f       wr_wait_for_BSY_clear:  in    a,(0fh)
030a e6 80                           and   80h
030c c2 08 03                        jp    nz,wr_wait_for_BSY_clear
030f db 0f                           in    a,(0fh)                ;clear INTRQ
0311 c9                              ret
0312             ;
0312             ;Strings used in subroutines
0312 .. 00       length_entry_string:    defm  "Enter length of file to load (decimal): ",0
033b .. 00       dump_entry_string:      defm  "Enter no. of bytes to dump (decimal): ",0
0362 .. 00       LBA_entry_string:       defm  "Enter LBA (decimal, 0 to 65535): ",0
0384 08 1b .. 00  erase_char_string:     defm  008h,01bh,"[K",000h     ;ANSI seq. for BS, erase to end of line.
0389 .. 00       address_entry_msg:      defm  "Enter 4-digit hex address (use upper-case A through F): ",0
03c2 .. 00       address_error_msg:      defm  "\r\nError: invalid hex character, try again: ",0
03ee .. 00       data_entry_msg:         defm  "Enter hex bytes, hit return when finished.\r\n",0
041b .. 00       data_error_msg:         defm  "Error: invalid hex byte.\r\n",0
0436 .. 00       decimal_error_msg:      defm  "\r\nError: invalid decimal number, try again: ",0
0463             ;
0463             ;Simple monitor program for CPUville Z80 computer with serial interface.
0463 31 ff db    monitor_cold_start:     ld    sp,ROM_monitor_stack
0466 cd 03 00                        call  initialize_port
0469 21 dc 05                        ld    hl,monitor_message
```

```
046c cd 18 00                           call  write_string
046f cd 89 02     monitor_warm_start:   call  write_newline    ;re-enter here to avoid port re-init.
0472 3e 3e                              ld    a,03eh           ;cursor symbol
0474 cd 0c 00                           call  write_char
0477 21 08 db                           ld    hl,buffer
047a cd 4c 00                           call  get_line         ;get monitor input string (command)
047d cd 89 02                           call  write_newline
0480 cd 84 04                           call  parse            ;parse command, returns with jump add. in HL
0483 e9                                 jp    (hl)
0484              ;
0484              ;Parses (interprets) an input line in buffer for commands as described in parse table.
0484              ;Returns with address of jump to action for the command in HL
0484 01 ba 07     parse:                ld    bc,parse_table   ;bc is pointer to parse_table
0487 0a           parse_start:          ld    a,(bc)           ;get pointer to match string from parse table
0488 5f                                 ld    e,a
0489 03                                 inc   bc
048a 0a                                 ld    a,(bc)
048b 57                                 ld    d,a              ;de will is pointer to strings for matching
048c 1a                                 ld    a,(de)           ;get first char from match string
048d f6 00                              or    000h             ;zero?
048f ca aa 04                           jp    z,parser_exit    ;yes, exit no_match
0492 21 08 db                           ld    hl,buffer        ;no, parse input string
0495 be           match_loop:           cp    (hl)             ;compare buffer char with match string char
0496 c2 a4 04                           jp    nz,no_match      ;no match, go to next match string
0499 f6 00                              or    000h             ;end of strings (zero)?
049b ca aa 04                           jp    z,parser_exit    ;yes, matching string found
049e 13                                 inc   de               ;match so far, point to next char in match
string
049f 1a                                 ld    a,(de)           ;get next character from match string
04a0 23                                 inc   hl               ;and point to next char in input string
04a1 c3 95 04                           jp    match_loop       ;check for match
04a4 03           no_match:             inc   bc               ;skip over jump target to
04a5 03                                 inc   bc
04a6 03                                 inc   bc               ;get address of next matching string
04a7 c3 87 04                           jp    parse_start
04aa 03           parser_exit:          inc   bc               ;skip to address of jump for match
04ab 0a                                 ld    a,(bc)
04ac 6f                                 ld    l,a
04ad 03                                 inc   bc
04ae 0a                                 ld    a,(bc)
```

```
04af 67                             ld    h,a               ;returns with jump address in hl
04b0 c9                             ret
04b1                ;
04b1                ;Actions to be taken on match
04b1                ;
04b1                ;Memory dump program
04b1                ;Input 4-digit hexadecimal address
04b1                ;Calls memory_dump subroutine
04b1 21 06 06       dump_jump:      ld    hl,dump_message         ;Display greeting
04b4 cd 18 00                       call  write_string
04b7 21 89 03                       ld    hl,address_entry_msg    ;get ready to get address
04ba cd 18 00                       call  write_string
04bd cd fe 00                       call  address_entry           ;returns with address in HL
04c0 cd 89 02                       call  write_newline
04c3 cd 99 01                       call  memory_dump
04c6 c3 6f 04                       jp    monitor_warm_start
04c9                ;
04c9                ;Hex loader, displays formatted input
04c9 21 2d 06       load_jump:      ld    hl,load_message         ;Display greeting
04cc cd 18 00                       call  write_string            ;get address to load
04cf 21 89 03                       ld    hl,address_entry_msg    ;get ready to get address
04d2 cd 18 00                       call  write_string
04d5 cd fe 00                       call  address_entry
04d8 cd 89 02                       call  write_newline
04db cd 13 02                       call  memory_load
04de c3 6f 04                       jp    monitor_warm_start
04e1                ;
04e1                ;Jump and run do the same thing: get an address and jump to it.
04e1 21 5c 06       run_jump:       ld    hl,run_message          ;Display greeting
04e4 cd 18 00                       call  write_string
04e7 21 89 03                       ld    hl,address_entry_msg    ;get ready to get address
04ea cd 18 00                       call  write_string
04ed cd fe 00                       call  address_entry
04f0 e9                             jp    (hl)
04f1                ;
04f1                ;Help and ? do the same thing, display the available commands
04f1 21 ee 05       help_jump:      ld    hl,help_message
04f4 cd 18 00                       call  write_string
04f7 01 ba 07                       ld    bc,parse_table          ;table with pointers to command strings
04fa 0a             help_loop:      ld    a,(bc)                  ;displays command strings
```

```
04fb 6f                              ld    l,a                    ;getting the string addresses from the
04fc 03                              inc   bc                     ;parse table
04fd 0a                              ld    a,(bc)                 ;pass add. of string to HL through A reg
04fe 67                              ld    h,a
04ff 7e                              ld    a,(hl)                 ;hl now points to start of match string
0500 f6 00                           or    000h                   ;exit if no_match string
0502 ca 15 05                        jp    z,help_done
0505 c5                              push  bc                     ;write_char uses B reg, so save first
0506 3e 20                           ld    a,020h                 ;space char
0508 cd 0c 00                        call  write_char
050b c1                              pop   bc
050c cd 18 00                        call  write_string           ;writes match string
050f 03                              inc   bc                     ;pass over jump address in table
0510 03                              inc   bc
0511 03                              inc   bc
0512 c3 fa 04                        jp    help_loop
0515 c3 6f 04     help_done:         jp    monitor_warm_start
0518              ;
0518              ;Binary file load. Need both address to load and length of file
0518 21 91 06     bload_jump:        ld    hl,bload_message
051b cd 18 00                        call  write_string
051e 21 89 03                        ld    hl,address_entry_msg
0521 cd 18 00                        call  write_string
0524 cd fe 00                        call  address_entry
0527 cd 89 02                        call  write_newline
052a e5                              push  hl
052b 21 12 03                        ld    hl,length_entry_string
052e cd 18 00                        call  write_string
0531 cd 29 01                        call  decimal_entry
0534 44                              ld    b,h
0535 4d                              ld    c,l
0536 21 b4 06                        ld    hl,bload_ready_message
0539 cd 18 00                        call  write_string
053c e1                              pop   hl
053d cd 28 00                        call  bload
0540 c3 6f 04                        jp    monitor_warm_start
0543              ;
0543              ;Binary memory dump. Need address of start of dump and no. bytes
0543 21 d8 06     bdump_jump:        ld    hl,bdump_message
0546 cd 18 00                        call  write_string
```

```
0549 21 89 03                          ld    hl,address_entry_msg
054c cd 18 00                          call  write_string
054f cd fe 00                          call  address_entry
0552 cd 89 02                          call  write_newline
0555 e5                                push  hl
0556 21 3b 03                          ld    hl,dump_entry_string
0559 cd 18 00                          call  write_string
055c cd 29 01                          call  decimal_entry
055f 44                                ld    b,h
0560 4d                                ld    c,l
0561 21 08 07                          ld    hl,bdump_ready_message
0564 cd 18 00                          call  write_string
0567 cd 7f 02                          call  get_char
056a e1                                pop   hl
056b cd 3a 00                          call  bdump
056e c3 6f 04                          jp    monitor_warm_start
0571                 ;Disk read. Need memory address to place data, LBA of sector to read
0571 21 2f 07        diskrd_jump:      ld    hl,diskrd_message
0574 cd 18 00                          call  write_string
0577 21 89 03                          ld    hl,address_entry_msg
057a cd 18 00                          call  write_string
057d cd fe 00                          call  address_entry
0580 cd 89 02                          call  write_newline
0583 e5                                push  hl
0584 21 62 03                          ld    hl,LBA_entry_string
0587 cd 18 00                          call  write_string
058a cd 29 01                          call  decimal_entry
058d 44                                ld    b,h
058e 4d                                ld    c,l
058f 1e 00                             ld    e,00h
0591 e1                                pop   hl
0592 cd 94 02                          call  disk_read
0595 c3 6f 04                          jp    monitor_warm_start
0598 21 57 07        diskwr_jump:      ld    hl,diskwr_message
059b cd 18 00                          call  write_string
059e 21 89 03                          ld    hl,address_entry_msg
05a1 cd 18 00                          call  write_string
05a4 cd fe 00                          call  address_entry
05a7 cd 89 02                          call  write_newline
05aa e5                                push  hl
```

```
05ab 21 62 03                      ld    hl,LBA_entry_string
05ae cd 18 00                      call  write_string
05b1 cd 29 01                      call  decimal_entry
05b4 44                            ld    b,h
05b5 4d                            ld    c,l
05b6 1e 00                         ld    e,00h
05b8 e1                            pop   hl
05b9 cd d3 02                      call  disk_write
05bc c3 6f 04                      jp    monitor_warm_start
05bf 21 00 08     cpm_jump:        ld    hl,0800h
05c2 01 00 00                      ld    bc,0000h
05c5 1e 00                         ld    e,00h
05c7 cd 94 02                      call  disk_read
05ca c3 00 08                      jp    0800h
05cd              ;Prints message for no match to entered command
05cd 21 eb 05     no_match_jump:          ld    hl,no_match_message
05d0 cd 18 00                      call  write_string
05d3 21 08 db                      ld    hl, buffer
05d6 cd 18 00                      call  write_string
05d9 c3 6f 04                      jp    monitor_warm_start
05dc              ;
05dc              ;Monitor data structures:
05dc              ;
05dc .. 00        monitor_message:        defm  "\r\nROM ver. 8\r\n",0
05eb .. 00        no_match_message:       defm  "? ",0
05ee .. 00        help_message:           defm  "Commands implemented:\r\n",0
0606 .. 00        dump_message:           defm  "Displays a 256-byte block of memory.\r\n",0
062d .. 00        load_message:           defm  "Enter hex bytes starting at memory location.\r\n",0
065c .. 00        run_message:            defm  "Will jump to (execute) program at address entered.\r\n",0
0691 .. 00        bload_message:          defm  "Loads a binary file into memory.\r\n",0
06b4 .. 00        bload_ready_message:    defm  "\n\rReady to receive, start transfer.",0
06d8 .. 00        bdump_message:          defm  "Dumps binary data from memory to serial port.\r\n",0
0708 .. 00        bdump_ready_message:    defm  "\n\rReady to send, hit any key to start.",0
072f .. 00        diskrd_message:         defm  "Reads one sector from disk to memory.\r\n",0
0757 .. 00        diskwr_message:         defm  "Writes one sector from memory to disk.\r\n",0
0780              ;Strings for matching:
0780 .. 00        dump_string:            defm  "dump",0
0785 .. 00        load_string:            defm  "load",0
078a .. 00        jump_string:            defm  "jump",0
078f .. 00        run_string:             defm  "run",0
```

```
0793 .. 00        question_string:        defm  "?",0
0795 .. 00        help_string:            defm  "help",0
079a .. 00        bload_string:           defm  "bload",0
07a0 .. 00        bdump_string:           defm  "bdump",0
07a6 .. 00        diskrd_string:          defm  "diskrd",0
07ad .. 00        diskwr_string:          defm  "diskwr",0
07b4 .. 00        cpm_string:             defm  "cpm",0
07b8 00 00        no_match_string:        defm  0,0
07ba              ;Table for matching strings to jumps
07ba 80 07 b1 04 85 07 c9 04  parse_table:      defw  dump_string,dump_jump,load_string,load_jump
07c2 8a 07 e1 04 8f 07 e1 04                    defw  jump_string,run_jump,run_string,run_jump
07ca 93 07 f1 04 95 07 f1 04                    defw  question_string,help_jump,help_string,help_jump
07d2 9a 07 18 05 a0 07 43 05                    defw  bload_string,bload_jump,bdump_string,bdump_jump
07da a6 07 71 05 ad 07 98 05                    defw  diskrd_string,diskrd_jump,diskwr_string,diskwr_jump
07e2 b4 07 bf 05                                defw  cpm_string,cpm_jump
07e6 b8 07 cd 05                                defw  no_match_string,no_match_jump
07ea
# End of file 2K_ROM_8.asm
07ea
```

Customized BIOS

```
# File z80_cbios.asm
0000                ;     skeletal cbios for first level of CP/M 2.0 alteration
0000                ;     Modified for CPUville Z80 computer with IDE disk interface
0000                ;     Aug, 2014 by Donn Stewart
0000                ;
0000                ccp:        equ   0E400h           ;base of ccp
0000                bdos:       equ   0EC06h           ;bdos entry
0000                bios:       equ   0FA00h           ;base of bios
0000                cdisk:      equ   0004h      ;address of current disk number 0=a,... l5=p
0000                iobyte:     equ   0003h      ;intel i/o byte
0000                disks:      equ   04h        ;number of disks in the system
0000                ;
0000                            org   bios       ;origin of this program
fa00                nsects:     equ   ($-ccp)/128 ;warm start sector count
fa00                ;
fa00                ;     jump vector for individual subroutines
fa00                ;
fa00 c3 9c fa                   JP    boot  ;cold start
fa03 c3 a6 fa       wboote:     JP    wboot ;warm start
fa06 c3 18 fb                   JP    const ;console status
fa09 c3 25 fb                   JP    conin ;console character in
fa0c c3 31 fb                   JP    conout     ;console character out
fa0f c3 3c fb                   JP    list  ;list character out
fa12 c3 40 fb                   JP    punch ;punch character out
fa15 c3 42 fb                   JP    reader     ;reader character out
fa18 c3 47 fb                   JP    home  ;move head to home position
fa1b c3 4d fb                   JP    seldsk     ;select disk
fa1e c3 66 fb                   JP    settrk     ;set track number
fa21 c3 6b fb                   JP    setsec     ;set sector number
fa24 c3 77 fb                   JP    setdma     ;set dma address
fa27 c3 7d fb                   JP    read  ;read disk
fa2a c3 d7 fb                   JP    write ;write disk
fa2d c3 3e fb                   JP    listst     ;return list status
fa30 c3 70 fb                   JP    sectran    ;sector translate
fa33                ;
fa33                ;     fixed data tables for four-drive standard
```

```
fa33             ;     ibm-compatible 8" disks
fa33             ;     no translations
fa33             ;
fa33             ;     disk Parameter header for disk 00
fa33 00 00 00 00 dpbase:     defw  0000h, 0000h
fa37 00 00 00 00             defw  0000h, 0000h
fa3b 36 fc 8d fa             defw  dirbf, dpblk
fa3f 32 fd b6 fc             defw  chk00, all00
fa43             ;     disk parameter header for disk 01
fa43 00 00 00 00             defw  0000h, 0000h
fa47 00 00 00 00             defw  0000h, 0000h
fa4b 36 fc 8d fa             defw  dirbf, dpblk
fa4f 42 fd d5 fc             defw  chk01, all01
fa53             ;     disk parameter header for disk 02
fa53 00 00 00 00             defw  0000h, 0000h
fa57 00 00 00 00             defw  0000h, 0000h
fa5b 36 fc 8d fa             defw  dirbf, dpblk
fa5f 52 fd f4 fc             defw  chk02, all02
fa63             ;     disk parameter header for disk 03
fa63 00 00 00 00             defw  0000h, 0000h
fa67 00 00 00 00             defw  0000h, 0000h
fa6b 36 fc 8d fa             defw  dirbf, dpblk
fa6f 62 fd 13 fd             defw  chk03, all03
fa73             ;
fa73             ;     sector translate vector
fa73 01 07 0d 13 trans:      defm   1,  7, 13, 19    ;sectors  1,  2,  3,  4
fa77 19 05 0b 11             defm  25,  5, 11, 17    ;sectors  5,  6,  7,  6
fa7b 17 03 09 0f             defm  23,  3,  9, 15    ;sectors  9, 10, 11, 12
fa7f 15 02 08 0e             defm  21,  2,  8, 14    ;sectors 13, 14, 15, 16
fa83 14 1a 06 0c             defm  20, 26,  6, 12    ;sectors 17, 18, 19, 20
fa87 12 18 04 0a             defm  18, 24,  4, 10    ;sectors 21, 22, 23, 24
fa8b 10 16                   defm  16, 22            ;sectors 25, 26
fa8d             ;
fa8d             dpblk:      ;disk parameter block for all disks.
fa8d 1a 00                   defw  26                ;sectors per track
fa8f 03                      defm  3                 ;block shift factor
fa90 07                      defm  7                 ;block mask
fa91 00                      defm  0                 ;null mask
fa92 f2 00                   defw  242               ;disk size-1
fa94 3f 00                   defw  63                ;directory max
```

```
fa96 c0                 defm  192              ;alloc 0
fa97 00                 defm  0                ;alloc 1
fa98 00 00              defw  0                ;check size
fa9a 02 00              defw  2                ;track offset
fa9c              ;
fa9c              ;     end of fixed tables
fa9c              ;
fa9c              ;     individual subroutines to perform each function
fa9c              boot: ;simplest case is to just perform parameter initialization
fa9c af                 XOR   a                ;zero in the accum
fa9d 32 03 00           LD    (iobyte),A       ;clear the iobyte
faa0 32 04 00           LD    (cdisk),A        ;select disk zero
faa3 c3 ef fa           JP    gocpm            ;initialize and go to cp/m
faa6              ;
faa6              wboot:      ;simplest case is to read the disk until all sectors loaded
faa6 31 80 00           LD    sp, 80h          ;use space below buffer for stack
faa9 0e 00              LD    c, 0             ;select disk 0
faab cd 4d fb           call  seldsk
faae cd 47 fb           call  home             ;go to track 00
fab1              ;
fab1 06 2c              LD    b, nsects        ;b counts * of sectors to load
fab3 0e 00              LD    c, 0             ;c has the current track number
fab5 16 02              LD    d, 2             ;d has the next sector to read
fab7              ;     note that we begin by reading track 0, sector 2 since sector 1
fab7              ;     contains the cold start loader, which is skipped in a warm start
fab7 21 00 e4           LD    HL, ccp          ;base of cp/m (initial load point)
faba              load1:      ;load one more sector
faba c5                 PUSH  BC               ;save sector count, current track
fabb d5                 PUSH  DE               ;save next sector to read
fabc e5                 PUSH  HL               ;save dma address
fabd 4a                 LD    c, d             ;get sector address to register C
fabe cd 6b fb           call  setsec           ;set sector address from register C
fac1 c1                 pop   BC               ;recall dma address to b, C
fac2 c5                 PUSH  BC               ;replace on stack for later recall
fac3 cd 77 fb           call  setdma           ;set dma address from b, C
fac6              ;
fac6              ;     drive set to 0, track set, sector set, dma address set
fac6 cd 7d fb           call  read
fac9 fe 00              CP    00h              ;any errors?
facb c2 a6 fa           JP    NZ,wboot         ;retry the entire boot if an error occurs
```

```
face            ;
face            ;     no error, move to next sector
face e1                     pop   HL                ;recall dma address
facf 11 80 00               LD    DE, 128           ;dma=dma+128
fad2 19                     ADD   HL,DE             ;new dma address is in h, l
fad3 d1                     pop   DE                ;recall sector address
fad4 c1                     pop   BC                ;recall number of sectors remaining, and current trk
fad5 05                     DEC   b                 ;sectors=sectors-1
fad6 ca ef fa               JP    Z,gocpm           ;transfer to cp/m if all have been loaded
fad9            ;
fad9            ;     more  sectors remain to load, check for track change
fad9 14                     INC   d
fada 7a                     LD    a,d               ;sector=27?, if so, change tracks
fadb fe 1b                  CP    27
fadd da ba fa               JP    C,load1           ;carry generated if sector<27
fae0            ;
fae0            ;     end of      current track,    go to next track
fae0 16 01                  LD    d, 1              ;begin with first sector of next track
fae2 0c                     INC   c                 ;track=track+1
fae3            ;
fae3            ;     save  register state, and change tracks
fae3 c5                     PUSH  BC
fae4 d5                     PUSH  DE
fae5 e5                     PUSH  HL
fae6 cd 66 fb               call  settrk            ;track address set from register c
fae9 e1                     pop   HL
faea d1                     pop   DE
faeb c1                     pop   BC
faec c3 ba fa               JP    load1             ;for another sector
faef            ;
faef            ;     end of      load operation, set parameters and go to cp/m
faef            gocpm:
faef 3e c3                  LD    a, 0c3h           ;c3 is a jmp instruction
faf1 32 00 00               LD    (0),A             ;for jmp to wboot
faf4 21 03 fa               LD    HL, wboote        ;wboot entry point
faf7 22 01 00               LD    (1),HL            ;set address field for jmp at 0
fafa            ;
fafa 32 05 00               LD    (5),A             ;for jmp to bdos
fafd 21 06 ec               LD    HL, bdos          ;bdos entry point
fb00 22 06 00               LD    (6),HL            ;address field of Jump at 5 to bdos
```

```
fb03                ;
fb03 01 80 00                   LD    BC, 80h            ;default dma address is 80h
fb06 cd 77 fb                   call  setdma
fb09                ;
fb09 fb                         ei                       ;enable the interrupt system
fb0a 3a 04 00                   LD    A,(cdisk)          ;get current disk number
fb0d fe 04                      cp    disks              ;see if valid disk number
fb0f da 14 fb                   jp    c,diskok           ;disk valid, go to ccp
fb12 3e 00                      ld    a,0                ;invalid disk, change to disk 0
fb14 4f             diskok:     LD    c, a               ;send to the ccp
fb15 c3 00 e4                   JP    ccp                ;go to cp/m for further processing
fb18                ;
fb18                ;
fb18                ;     simple i/o handlers (must be filled in by user)
fb18                ;     in each case, the entry point is provided, with space reserved
fb18                ;     to insert your own code
fb18                ;
fb18                const:      ;console status, return 0ffh if character ready, 00h if not
fb18 db 03                      in    a,(3)              ;get status
fb1a e6 02                      and   002h               ;check RxRDY bit
fb1c ca 22 fb                   jp    z,no_char
fb1f 3e ff                      ld    a,0ffh             ;char ready
fb21 c9                         ret
fb22 3e 00          no_char:    ld    a,00h              ;no char
fb24 c9                         ret
fb25                ;
fb25                conin:      ;console character into register a
fb25 db 03                      in    a,(3)              ;get status
fb27 e6 02                      and   002h               ;check RxRDY bit
fb29 ca 25 fb                   jp    z,conin            ;loop until char ready
fb2c db 02                      in    a,(2)              ;get char
fb2e e6 7f                      AND   7fh                ;strip parity bit
fb30 c9                         ret
fb31                ;
fb31                conout:     ;console character output from register c
fb31 db 03                      in    a,(3)
fb33 e6 01                      and   001h               ;check TxRDY bit
fb35 ca 31 fb                   jp    z,conout           ;loop until port ready
fb38 79                         ld    a,c                ;get the char
fb39 d3 02                      out   (2),a              ;out to port
```

```
fb3b c9                    ret
fb3c             ;
fb3c             list: ;list character from register c
fb3c 79                    LD    a, c             ;character to register a
fb3d c9                    ret                    ;null subroutine
fb3e             ;
fb3e             listst:     ;return list status (0 if not ready, 1 if ready)
fb3e af                    XOR   a                ;0 is always ok to return
fb3f c9                    ret
fb40             ;
fb40             punch:      ;punch      character from    register C
fb40 79                    LD    a, c             ;character to register a
fb41 c9                    ret                    ;null subroutine
fb42             ;
fb42             ;
fb42             reader:     ;reader character into register a from reader device
fb42 3e 1a                 LD     a, 1ah          ;enter end of file for now (replace later)
fb44 e6 7f                 AND    7fh             ;remember to strip parity bit
fb46 c9                    ret
fb47             ;
fb47             ;
fb47             ;     i/o drivers for the disk follow
fb47             ;     for now, we will simply store the parameters away for use
fb47             ;     in the read and write   subroutines
fb47             ;
fb47             home: ;move to the track 00   position of current drive
fb47             ;     translate this call into a settrk call with Parameter 00
fb47 0e 00                 LD     c, 0            ;select track 0
fb49 cd 66 fb              call   settrk
fb4c c9                    ret                    ;we will move to 00 on first read/write
fb4d             ;
fb4d             seldsk:     ;select disk given by register c
fb4d 21 00 00              LD    HL, 0000h        ;error return code
fb50 79                    LD    a, c
fb51 32 35 fc              LD    (diskno),A
fb54 fe 04                 CP    disks            ;must be between 0 and 3
fb56 d0                    RET   NC               ;no carry if 4, 5,...
fb57             ;     disk number is in the proper range
fb57             ;     defs  10                   ;space for disk select
fb57             ;     compute proper disk Parameter header address
```

```
fb57 3a 35 fc              LD    A,(diskno)
fb5a 6f                    LD    l, a             ;l=disk number 0, 1, 2, 3
fb5b 26 00                 LD    h, 0             ;high order zero
fb5d 29                    ADD   HL,HL            ;*2
fb5e 29                    ADD   HL,HL            ;*4
fb5f 29                    ADD   HL,HL            ;*8
fb60 29                    ADD   HL,HL            ;*16 (size of each header)
fb61 11 33 fa              LD    DE, dpbase
fb64 19                    ADD   HL,DE            ;hl=,dpbase (diskno*16) Note typo here in original source.
fb65 c9                    ret
fb66                 ;
fb66                 settrk:     ;set track given by register c
fb66 79                    LD    a, c
fb67 32 2f fc              LD    (track),A
fb6a c9                    ret
fb6b                 ;
fb6b                 setsec:     ;set sector given by register c
fb6b 79                    LD    a, c
fb6c 32 31 fc              LD    (sector),A
fb6f c9                    ret
fb70                 ;
fb70                 ;
fb70                 sectran:
fb70                       ;translate the sector given by bc using the
fb70                       ;translate table given by de
fb70 eb                    EX    DE,HL            ;hl=.trans
fb71 09                    ADD   HL,BC            ;hl=.trans (sector)
fb72 c9                    ret                    ;debug no translation
fb73 6e                    LD    l, (hl)          ;l=trans (sector)
fb74 26 00                 LD    h, 0             ;hl=trans (sector)
fb76 c9                    ret                    ;with value in hl
fb77                 ;
fb77                 setdma:     ;set  dma address given by registers b and c
fb77 69                    LD    l, c             ;low order address
fb78 60                    LD    h, b             ;high order address
fb79 22 33 fc              LD    (dmaad),HL       ;save the address
fb7c c9                    ret
fb7d                 ;
fb7d                 read:
fb7d                 ;Read one CP/M sector from disk.
```

```
fb7d              ;Return a 00h in register a if the operation completes properly, and 0lh if an error occurs
during the read.
fb7d              ;Disk number in 'diskno'
fb7d              ;Track number in 'track'
fb7d              ;Sector number in 'sector'
fb7d              ;Dma address in 'dmaad' (0-65535)
fb7d              ;
fb7d 21 72 fd                             ld    hl,hstbuf                ;buffer to place disk sector (256 bytes)
fb80 db 0f        rd_status_loop_1:       in    a,(0fh)                  ;check status
fb82 e6 80                                and   80h                      ;check BSY bit
fb84 c2 80 fb                             jp    nz,rd_status_loop_1      ;loop until not busy
fb87 db 0f        rd_status_loop_2:       in    a,(0fh)                  ;check      status
fb89 e6 40                                and   40h                      ;check DRDY bit
fb8b ca 87 fb                             jp    z,rd_status_loop_2       ;loop until ready
fb8e 3e 01                                ld    a,01h                    ;number of sectors = 1
fb90 d3 0a                                out   (0ah),a                  ;sector count register
fb92 3a 31 fc                             ld    a,(sector)               ;sector
fb95 d3 0b                                out   (0bh),a                  ;lba bits 0 - 7
fb97 3a 2f fc                             ld    a,(track)                ;track
fb9a d3 0c                                out   (0ch),a                  ;lba bits 8 - 15
fb9c 3a 35 fc                             ld    a,(diskno)               ;disk (only bits
fb9f d3 0d                                out   (0dh),a                  ;lba bits 16 - 23
fba1 3e e0                                ld    a,11100000b              ;LBA mode, select host drive 0
fba3 d3 0e                                out   (0eh),a                  ;drive/head register
fba5 3e 20                                ld    a,20h                    ;Read sector command
fba7 d3 0f                                out   (0fh),a
fba9 db 0f        rd_wait_for_DRQ_set:    in    a,(0fh)                  ;read status
fbab e6 08                                and   08h                      ;DRQ bit
fbad ca a9 fb                             jp    z,rd_wait_for_DRQ_set    ;loop until bit set
fbb0 db 0f        rd_wait_for_BSY_clear:  in    a,(0fh)
fbb2 e6 80                                and   80h
fbb4 c2 b0 fb                             jp    nz,rd_wait_for_BSY_clear
fbb7 db 0f                                in    a,(0fh)                  ;clear INTRQ
fbb9 db 08        read_loop:              in    a,(08h)                  ;get data
fbbb 77                                   ld    (hl),a
fbbc 23                                   inc   hl
fbbd db 0f                                in    a,(0fh)                  ;check status
fbbf e6 08                                and   08h                      ;DRQ bit
fbc1 c2 b9 fb                             jp    nz,read_loop             ;loop until clear
fbc4 2a 33 fc                             ld    hl,(dmaad)               ;memory location to place data read from
```

```
disk
fbc7 11 72 fd                        ld    de,hstbuf              ;host buffer
fbca 06 80                           ld    b,128                  ;size of CP/M sector
fbcc 1a           rd_sector_loop:    ld    a,(de)                 ;get byte from host buffer
fbcd 77                              ld    (hl),a                 ;put in memory
fbce 23                              inc   hl
fbcf 13                              inc   de
fbd0 10 fa                           djnz  rd_sector_loop         ;put 128 bytes into memory
fbd2 db 0f                           in    a,(0fh)                ;get status
fbd4 e6 01                           and   01h                    ;error bit
fbd6 c9                              ret
fbd7
fbd7              write:
fbd7              ;Write one CP/M sector to disk.
fbd7              ;Return a 00h in register a if the operation completes properly, and 0lh if an error occurs
during the read or write
fbd7              ;Disk number in 'diskno'
fbd7              ;Track number in 'track'
fbd7              ;Sector number in 'sector'
fbd7              ;Dma address in 'dmaad' (0-65535)
fbd7 2a 33 fc                        ld    hl,(dmaad)             ;memory location of data to write
fbda 11 72 fd                        ld    de,hstbuf              ;host buffer
fbdd 06 80                           ld    b,128                  ;size of CP/M sector
fbdf 7e           wr_sector_loop:    ld    a,(hl)                 ;get byte from memory
fbe0 12                              ld    (de),a                 ;put in host buffer
fbe1 23                              inc   hl
fbe2 13                              inc   de
fbe3 10 fa                           djnz  wr_sector_loop         ;put 128 bytes in host buffer
fbe5 21 72 fd                        ld    hl,hstbuf              ;location of data to write to disk
fbe8 db 0f        wr_status_loop_1:  in    a,(0fh)                ;check status
fbea e6 80                           and   80h                    ;check BSY bit
fbec c2 e8 fb                        jp    nz,wr_status_loop_1    ;loop until not busy
fbef db 0f        wr_status_loop_2:  in    a,(0fh)                ;check      status
fbf1 e6 40                           and   40h                    ;check DRDY bit
fbf3 ca ef fb                        jp    z,wr_status_loop_2     ;loop until ready
fbf6 3e 01                           ld    a,01h                  ;number of sectors = 1
fbf8 d3 0a                           out   (0ah),a                ;sector count register
fbfa 3a 31 fc                        ld    a,(sector)
fbfd d3 0b                           out   (0bh),a                ;lba bits 0 - 7 = "sector"
fbff 3a 2f fc                        ld    a,(track)
```

```
fc02 d3 0c                          out   (0ch),a                ;lba bits 8 - 15 = "track"
fc04 3a 35 fc                       ld    a,(diskno)
fc07 d3 0d                          out   (0dh),a                ;lba bits 16 to 20 used for "disk"
fc09 3e e0                          ld    a,11100000b            ;LBA mode, select drive 0
fc0b d3 0e                          out   (0eh),a                ;drive/head register
fc0d 3e 30                          ld    a,30h                  ;Write sector command
fc0f d3 0f                          out   (0fh),a
fc11 db 0f       wr_wait_for_DRQ_set:    in    a,(0fh)           ;read status
fc13 e6 08                          and   08h                    ;DRQ bit
fc15 ca 11 fc                       jp    z,wr_wait_for_DRQ_set  ;loop until bit set
fc18 7e          write_loop:        ld    a,(hl)
fc19 d3 08                          out   (08h),a                ;write data
fc1b 23                             inc   hl
fc1c db 0f                          in    a,(0fh)                ;read status
fc1e e6 08                          and   08h                    ;check DRQ bit
fc20 c2 18 fc                       jp    nz,write_loop          ;write until bit cleared
fc23 db 0f       wr_wait_for_BSY_clear:  in    a,(0fh)
fc25 e6 80                          and   80h
fc27 c2 23 fc                       jp    nz,wr_wait_for_BSY_clear
fc2a db 0f                          in    a,(0fh)                ;clear INTRQ
fc2c e6 01                          and   01h                    ;check for error
fc2e c9                             ret
fc2f             ;
fc2f             ;     the remainder of the cbios is reserved uninitialized
fc2f             ;     data area, and does not need to be a Part of the
fc2f             ;     system      memory image (the space must be available,
fc2f             ;     however, between"begdat" and"enddat").
fc2f             ;
fc2f 00...       track:            defs  2           ;two bytes for expansion
fc31 00...       sector:           defs  2           ;two bytes for expansion
fc33 00...       dmaad:            defs  2           ;direct memory address
fc35 00...       diskno:           defs  1           ;disk number 0-15
fc36             ;
fc36             ;     scratch ram area for bdos use
fc36             begdat:           equ   $           ;beginning of data area
fc36 00...       dirbf:            defs  128         ;scratch directory area
fcb6 00...       all00:            defs  31          ;allocation vector 0
fcd5 00...       all01:            defs  31          ;allocation vector 1
fcf4 00...       all02:            defs  31          ;allocation vector 2
fd13 00...       all03:            defs  31          ;allocation vector 3
```

```
fd32 00...        chk00:      defs  16          ;check vector 0
fd42 00...        chk01:      defs  16          ;check vector 1
fd52 00...        chk02:      defs  16          ;check vector 2
fd62 00...        chk03:      defs  16          ;check vector 3
fd72              ;
fd72              enddat:     equ   $           ;end of data area
fd72              datsiz:     equ   $-begdat;   ;size of data area
fd72 00...        hstbuf: ds  256         ;buffer for host disk sector
fe72                    end
# End of file z80_cbios.asm
fe72
```

Format

```
# File format.asm
0000              ;Formats four classical CP/M disks
0000              ;Writes E5h to 26 sectors on tracks 2 to 77 of each disk.
0000              ;Uses calls to cbios, in memory at FA00h
0000              seldsk:                 equ   0fa1bh            ;pass disk no. in c
0000              setdma:                 equ   0fa24h            ;pass address in bc
0000              settrk:                 equ   0fa1eh            ;pass track in reg C
0000              setsec:                 equ   0fa21h            ;pass sector in reg c
0000              write:                  equ   0fa2ah            ;write one CP/M sector to disk
0000              monitor_warm_start:     equ   046fh
0000                                      org   0800h
0800 31 09 09                             ld    sp,format_stack
0803 3e 00                                ld    a,00h             ;starting disk
0805 32 64 08                             ld    (disk),a
0808 4f           disk_loop:              ld    c,a               ;CP/M disk a
0809 cd 1b fa                             call  seldsk
080c 3e 02                                ld    a,2               ;starting track (offset = 2)
080e 32 66 08                             ld    (track),a
0811 3e 00        track_loop:             ld    a,0               ;starting sector
0813 32 65 08                             ld    (sector),a
0816 21 69 08                             ld    hl,directory_sector     ;address of data to write
0819 22 67 08                             ld    (address),hl
081c 3a 66 08                             ld    a,(track)
081f 4f                                   ld    c,a               ;CP/M track
0820 cd 1e fa                             call  settrk
0823 3a 65 08     sector_loop:            ld    a,(sector)
```

```
0826 4f                                 ld    c,a                ;CP/M sector
0827 cd 21 fa                           call  setsec
082a ed 4b 67 08                        ld    bc,(address)       ;memory location
082e cd 24 fa                           call  setdma
0831 cd 2a fa                           call  write
0834 3a 65 08                           ld    a,(sector)
0837 fe 1a                              cp    26
0839 ca 43 08                           jp    z,next_track
083c 3c                                 inc   a
083d 32 65 08                           ld    (sector),a
0840 c3 23 08                           jp    sector_loop
0843 3a 66 08     next_track:           ld    a,(track)
0846 fe 4d                              cp    77
0848 ca 52 08                           jp    z,next_disk
084b 3c                                 inc   a
084c 32 66 08                           ld    (track),a
084f c3 11 08                           jp    track_loop
0852 3a 64 08     next_disk:            ld    a,(disk)
0855 3c                                 inc   a
0856 fe 04                              cp    4
0858 ca 61 08                           jp    z,done
085b 32 64 08                           ld    (disk),a
085e c3 08 08                           jp    disk_loop
0861 c3 6f 04     done:                 jp    monitor_warm_start
0864 00           disk:                 db    00h
0865 00           sector:               db    00h
0866 00           track:                db    00h
0867 00 00        address:              dw    0000h
0869              directory_sector:
0869 0xe5...                      ds    128,0e5h          ;byte for empty directory
08e9 00...                        ds    32                ;stack space
0909              format_stack:
0909                          end
# End of file format.asm
0909
```

Putsys

```
# File putsys.asm
```

```
0000              ;Copies the memory image of CP/M loaded at E400h onto tracks 0 and 1 of the first CP/M disk
0000              ;Load and run from ROM monitor
0000              ;Uses calls to cbios, in memory at FA00h
0000              ;Writes track 0, sectors 2 to 26, then track 1, sectors 1 to 25
0000              seldsk:           equ   0fa1bh           ;pass disk no. in c
0000              setdma:           equ   0fa24h           ;pass address in bc
0000              settrk:           equ   0fa1eh           ;pass track in reg C
0000              setsec:           equ   0fa21h           ;pass sector in reg c
0000              write:            equ   0fa2ah           ;write one CP/M sector to disk
0000              monitor_warm_start:     equ   046Fh ;Return to ROM monitor
0000                                org   0800h
0800 0e 00                          ld    c,00h            ;CP/M disk a
0802 cd 1b fa                       call  seldsk
0805              ;Write track 0, sectors 2 to 26
0805 3e 02                          ld    a,2              ;starting sector
0807 32 80 08                       ld    (sector),a
080a 21 00 e4                       ld    hl,0E400h        ;memory address to start
080d 22 81 08                       ld    (address),hl
0810 0e 00                          ld    c,0              ;CP/M track
0812 cd 1e fa                       call  settrk
0815 3a 80 08     wr_trk_0_loop:    ld    a,(sector)
0818 4f                             ld    c,a              ;CP/M sector
0819 cd 21 fa                       call  setsec
081c ed 4b 81 08                    ld    bc,(address)     ;memory location
0820 cd 24 fa                       call  setdma
0823 cd 2a fa                       call  write
0826 3a 80 08                       ld    a,(sector)
0829 fe 1a                          cp    26
082b ca 3f 08                       jp    z,wr_trk_1
082e 3c                             inc   a
082f 32 80 08                       ld    (sector),a
0832 2a 81 08                       ld    hl,(address)
0835 11 80 00                       ld    de,128
0838 19                             add   hl,de
0839 22 81 08                       ld    (address),hl
083c c3 15 08                       jp    wr_trk_0_loop
083f              ;Write track 1, sectors 1 to 25
083f 0e 01        wr_trk_1:         ld    c,1
0841 cd 1e fa                       call  settrk
0844 2a 81 08                       ld    hl,(address)
```

```
0847 11 80 00                 ld    de,128
084a 19                       add   hl,de
084b 22 81 08                 ld    (address),hl
084e 3e 01                    ld    a,1
0850 32 80 08                 ld    (sector),a
0853 3a 80 08    wr_trk_1_loop:   ld    a,(sector)
0856 4f                       ld    c,a                 ;CP/M sector
0857 cd 21 fa                 call  setsec
085a ed 4b 81 08              ld    bc,(address)        ;memory location
085e cd 24 fa                 call  setdma
0861 cd 2a fa                 call  write
0864 3a 80 08                 ld    a,(sector)
0867 fe 19                    cp    25
0869 ca 7d 08                 jp    z,done
086c 3c                       inc   a
086d 32 80 08                 ld    (sector),a
0870 2a 81 08                 ld    hl,(address)
0873 11 80 00                 ld    de,128
0876 19                       add   hl,de
0877 22 81 08                 ld    (address),hl
087a c3 53 08                 jp    wr_trk_1_loop
087d c3 6f 04    done:        jp    monitor_warm_start
0880 00          sector:      db    00h
0881 00 00       address:     dw    0000h
0883                          end

# End of file putsys.asm
0883
```

CP/M loader

```
# File cpm_loader.asm
0000             ;Retrieves CP/M from disk and loads it in memory starting at E400h
0000             ;Uses calls to ROM routine for disk read.
0000             ;Reads track 0, sectors 2 to 26, then track 1, sectors 1 to 25
0000             ;This program is loaded into LBA sector 0 of disk, read to loc. 0800h by ROM and executed.
0000             hstbuf:          equ   0900h       ;will put 256-byte raw sector here
0000             disk_read:       equ   0294h       ;in 2K ROM
0000             cpm:             equ   0FA00h            ;CP/M cold start entry
0000                              org   0800h
```

```
0800                ;Read track 0, sectors 2 to 26
0800 3e 02                            ld    a,2                 ;starting sector
0802 32 84 08                         ld    (sector),a
0805 21 00 e4                         ld    hl,0E400h           ;memory address to start
0808 22 86 08                         ld    (dmaad),hl
080b 3e 00                            ld    a,0                 ;CP/M track
080d 32 85 08                         ld    (track),a
0810 cd 61 08       rd_trk_0_loop:    call  read
0813 3a 84 08                         ld    a,(sector)
0816 fe 1a                            cp    26
0818 ca 2c 08                         jp    z,rd_trk_1
081b 3c                               inc   a
081c 32 84 08                         ld    (sector),a
081f 2a 86 08                         ld    hl,(dmaad)
0822 11 80 00                         ld    de,128
0825 19                               add   hl,de
0826 22 86 08                         ld    (dmaad),hl
0829 c3 10 08                         jp    rd_trk_0_loop
082c                ;Read track 1, sectors 1 to 25
082c 3e 01          rd_trk_1:         ld    a,1
082e 32 85 08                         ld    (track),a
0831 2a 86 08                         ld    hl,(dmaad)
0834 11 80 00                         ld    de,128
0837 19                               add   hl,de
0838 22 86 08                         ld    (dmaad),hl
083b 3e 01                            ld    a,1                 ;starting sector
083d 32 84 08                         ld    (sector),a
0840 cd 61 08       rd_trk_1_loop:    call  read
0843 3a 84 08                         ld    a,(sector)
0846 fe 19                            cp    25
0848 ca 5c 08                         jp    z,done
084b 3c                               inc   a
084c 32 84 08                         ld    (sector),a
084f 2a 86 08                         ld    hl,(dmaad)
0852 11 80 00                         ld    de,128
0855 19                               add   hl,de
0856 22 86 08                         ld    (dmaad),hl
0859 c3 40 08                         jp    rd_trk_1_loop
085c d3 01          done:             out   (1),a               ;switch memory config to all-RAM
085e c3 00 fa                         jp    cpm
```

```
0861
0861            read:
0861            ;Read one CP/M sector from disk 0
0861            ;Track number in 'track'
0861            ;Sector number in 'sector'
0861            ;Dma address (location in memory to place the CP/M sector) in 'dmaad' (0-65535)
0861            ;
0861 21 00 09                   ld    hl,hstbuf         ;buffer to place raw disk sector (256 bytes)
0864 3a 84 08                   ld    a,(sector)
0867 4f                         ld    c,a               ;LBA bits 0 to 7
0868 3a 85 08                   ld    a,(track)
086b 47                         ld    b,a               ;LBA bits 8 to 15
086c 1e 00                      ld    e,00h             ;LBA bits 16 to 23
086e cd 94 02                   call  disk_read         ;subroutine in ROM
0871            ;Transfer top 128-bytes out of buffer to memory
0871 2a 86 08                   ld    hl,(dmaad)        ;memory location to place data read from disk
0874 11 00 09                   ld    de,hstbuf         ;host buffer
0877 06 80                      ld    b,128             ;size of CP/M sector
0879 1a         rd_sector_loop: ld    a,(de)            ;get byte from host buffer
087a 77                         ld    (hl),a            ;put in memory
087b 23                         inc   hl
087c 13                         inc   de
087d 10 fa                      djnz  rd_sector_loop    ;put 128 bytes into memory
087f db 0f                      in    a,(0fh)           ;get status
0881 e6 01                      and   01h               ;error bit
0883 c9                         ret
0884 00         sector:         db    00h
0885 00         track:          db    00h
0886 00 00      dmaad:          dw    0000h
0888                        end


# End of file cpm_loader.asm
0888
```

Table of Tested Disk Drives

Drive	Year of manufacture	Size	Passed diskrd/diskwr test	CP/M installed successfully
Mechanical Hard Disk Drives				
Seagate ST3290A		261.3 Mb	Yes	Yes, but gave bad sector errors
Western Digital Caviar 32500	1996	2559.8 Mb	No	Not attempted
Seagate Medalist 4321	1999	4.3 Gb	No	Not attempted
Seagate Medalist 4310	1999	4.3 Gb	No	Not attempted
Western Digital WD200	2001	20.0 Gb	No	Not attempted
Western Digital WD400	2003	40.0 Gb	No	Not attempted
Western Digital Caviar 31600	1995	1624.6 Mb	No	Not attempted
Western Digital Caviar 153BA	2000	15.3 Gb	No	Not attempted
Maxtor 71626AP	1996	1630 Mb	Yes	Yes
Maxtor 90845D4	2000	8.5 Gb	Yes	Yes
Seagate Medalist 10232	1999	10 Gb	Yes	Yes
Seagate Barracuda ATA II	2000	15.3 Gb	Yes	Yes
Maxtor DiamondMax Plus 9	2003	120 Gb	Yes	Yes
Seagate U4 ST36421A	2000	6.4 Gb	Yes	Yes
Seagate U6 ST380020A	2002	80 Gb	Yes	Not attempted (I wanted to

				preserve disk contents)
Fujitsu MPE3102AT	1999	10.2 Gb	Yes	Yes
Seagate Barracuda ATA V Model ST380023A	2003	80 Gb	Yes	Yes
Maxtor DiamondMax Plus 8	2003	40 Gb	Yes	Yes
Seagate Barracuda 7200.7 Model ST380011A	2004	80Gb	Yes	Yes
SATA drive with SATA to IDE adapter[19]				
Fujitsu MHV2080BH PL HD SATA		80 Gb	Yes	
Solid State (Flash) IDE drives				
Silicon Drive SSD-M01G-3100		1 Gb	Yes	Yes
SimpleTech 94000-00964 solid state IDE drive			Yes	Yes
Transcend 40-pin IDE flash module[20]		1 Gb	Yes	Yes
Compact Flash drives in IDE Adapter[21]				
Sandisk CF SDCFB	2003	256 Mb	Yes	Yes
Canon FC-32MH	2002	32 Mb	Yes	Not attempted – drive too small
Iomega Microdrive DMDM-10340[22]		340 Mb	Yes	Yes

19 Generic IDE to SATA or SATA to IDE Adapter, purchased on Amazon $2.99
20 Some Transcend modules may not work. The tested module had identification number 145194R 0502 SS63 1G 0632.
21 SYBA SD-CF-IDE-DI IDE to Compact Flash Adapter (Direct Insertion Mode), purchased from Newegg $8.49
22 This is a mechanical drive in a CF enclosure and needs +12V to operate.

SD Card in IDE Adapter[23]				
Canon MultiMediaCard MMC-16M		16 Mb	Yes	Yes – only drive A (card too small for B, C, and D)

23 SLOA063 40-Pin Female IDE To SD Card Adapter made by Soarland, purchased on Amazon $18.98