CPUville Z80 Computer Serial Interface Kit Instruction Manual

By Donn Stewart

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Introduction

The CPUville Z80 Computer Serial Interface Kit is intended for use with the CPUville Z80 computer. Once assembled, you can use the keyboard and display of a PC, or a dumb terminal, to communicate with the Z80 computer using text input and output. The serial interface connects to the computer with the same 16-pin ribbon cable connectors used to connect the bus display. It connects to the serial port on a PC with a straight-through DB9 (9-pin) serial cable. The interface is powered by +5V coming through the ribbon cables – it does not need a separate power supply.

The serial interface is designed to use a legacy communications protocol called RS-232. This protocol dates from the early days of computing. Originally used to connect Teletype machines to each other, it uses a 7-bit code termed ASCII. The code assigns a 7-bit numerical value to each of the characters used in ordinary English writing, and to some control actions, such as backspace. When connected with a serial interface, two Teletypes could transmit written messages short distances, such as inside a building. Early computers used Teletypes to take input and produce output. A modem could be used to convert the electrical serial signals to tones that could be transmitted over telephone lines, enabling long-distance text communication. Serial interfaces were also used for computer communication with printers or tape drives.

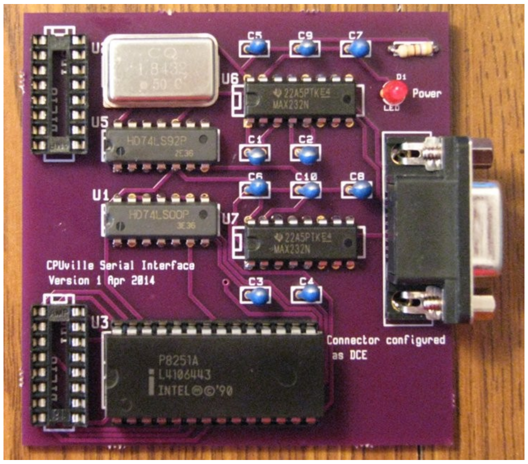
The serial interface protocol is limited in speed. Even high-speed RS-232 interfaces could only send data at about 15,000 characters (bytes) per second. This is not enough to satisfy the demands of modern computing, so this protocol has, like the 8-bit computer, become obsolete. However, it is more than adequate for our small Z80 computer, used in the hobby setting. The interface created by the kit runs at 9600 baud, and can transmit about 1000 characters per second. Since the Z80 computer only has 2K RAM space, you can fill its memory in about 2 seconds. So, we have no worries about the “slow” speed of the serial port compared to modern serial transfer protocols, like USB.

The serial interface needs software to run it. The original CPUville Z80 computer kit came with a pre-programmed ROM containing about 300 bytes of program code that allowed the user to run some simple tests and demonstrations, and enter programs bit-by-bit using switches (ROM versions up to 6). With the serial interface comes the potential to use an ordinary keyboard to enter data, and to use a display to receive program output. This greatly increases the power and ease of use of the computer system. However, much more program code is needed to realize this potential. An additional 1400 bytes of code has been added to the ROM (version 7 and higher) to realize this potential. The added code includes a small monitor program that accepts simple commands that allow the user to enter data into memory using hexadecimal characters typed on the keyboard, and execute programs so entered. The monitor also allows memory contents to be displayed on the screen. There are also commands that allow loading of binary program files though the serial port, making programming easier. The ROM also contains code for a variety of utility functions that can be used in programming, such as writing strings to the display, taking text input, and converting between hexadecimal characters and binary data. In all, it makes the Z80 computer begin to behave how most people expect a computer to behave.

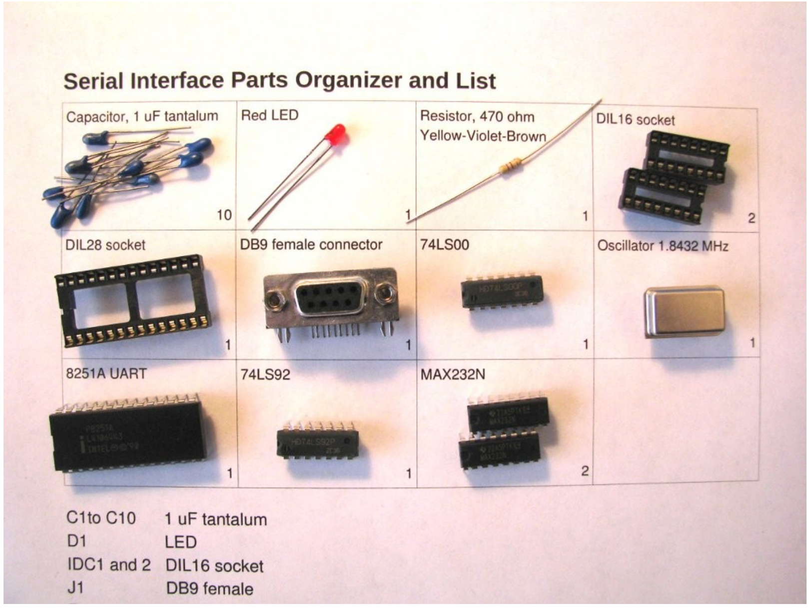
Building Tips

See the Building Tips section in the CPUville Z80 Computer Kit Instruction Manual.

Building the Serial Interface



Start by putting the parts on the organizer to make sure you have them all, and to get familiar with them.

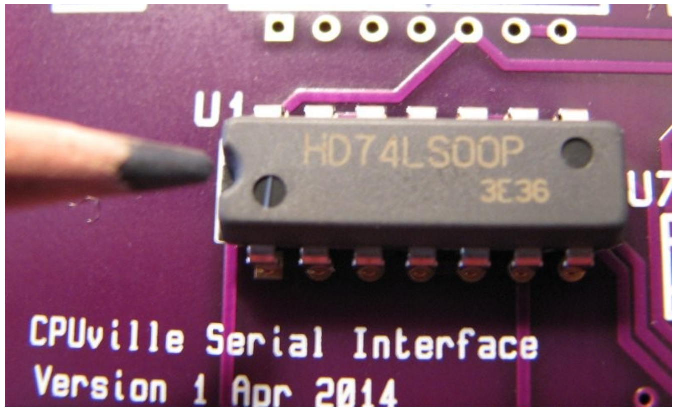


Once you have checked the parts you can start to solder them onto the circuit board.

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 resistor, ICs, sockets, oscillator, capacitors, LED, and DB9 connector. Some components need to be oriented properly, as described below.

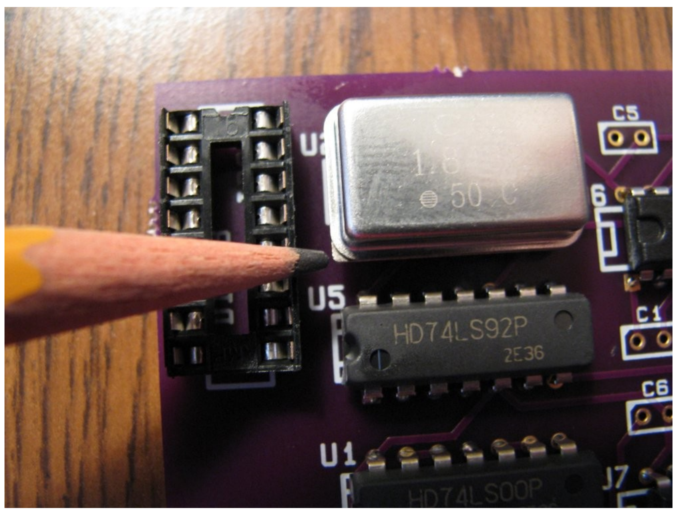
1. The resistor can be soldered first. It does not have to be oriented.

2. The ICs are soldered next (except the UART – it will be plugged into a socket). The ICs need to be placed with the little cut-out toward the left:

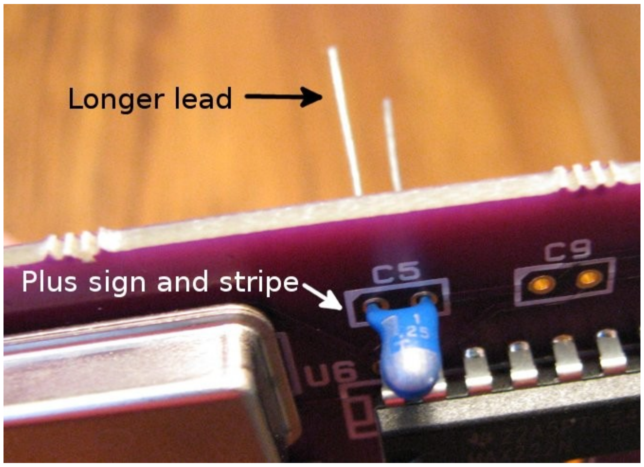


   The ICs can be soldered directly to the board without fear of damage if you use a 15-watt or smaller soldering iron.

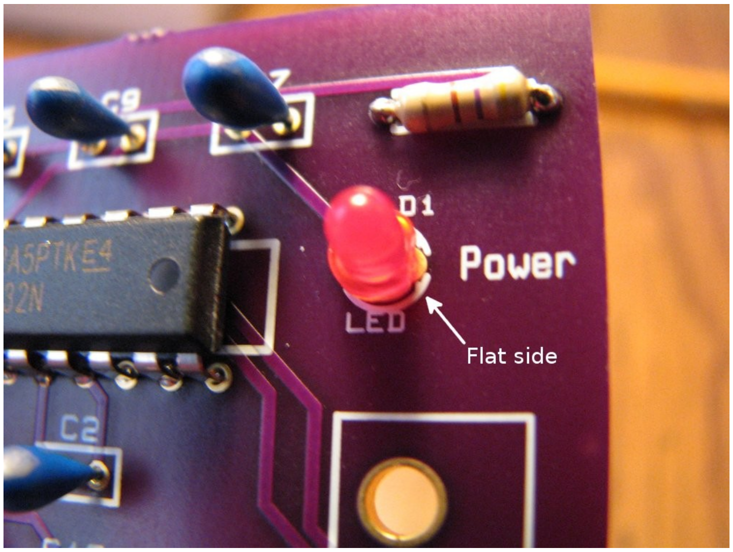
3. The two 16-pin and the 28-pin sockets are next. They do not need to be oriented.
4. The oscillator is next. It has to be placed with the sharp corner at the lower left:



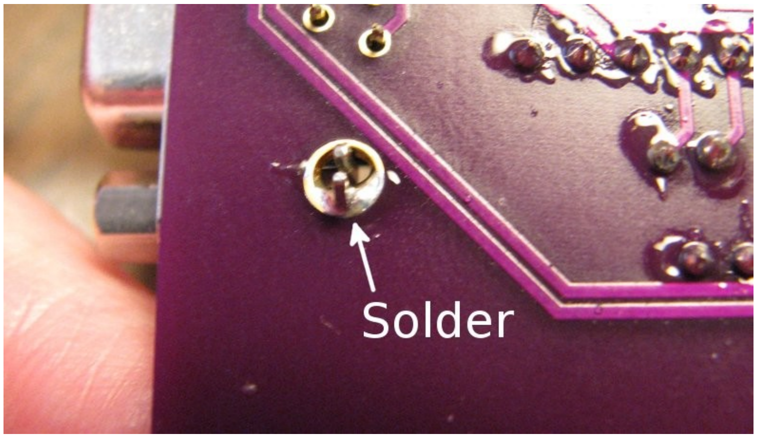
5. The capacitors are next. They need to be placed with the positive lead (the long lead, marked with a stripe) toward the left:



6. The LED is next. The flat side of the plastic base is oriented toward the right:



7. The DB-9 connector is the last piece. Put a little solder on the side of the clips to ground them to the copper plating of the holes:

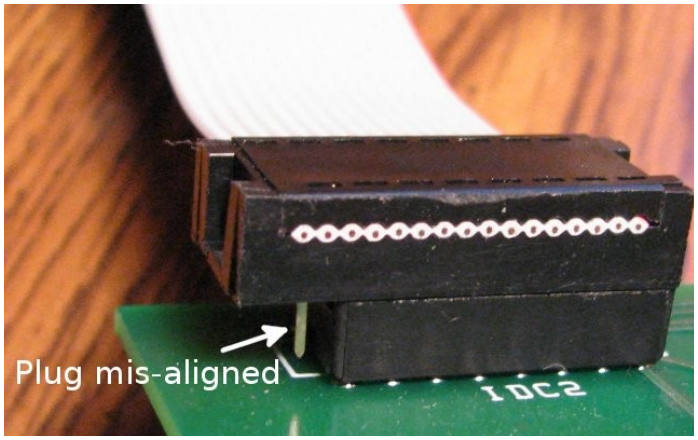


Then solder the 9 signal pins.

Once you have finished soldering all the pins on the serial interface board, inspect the board to make sure there are no solder bridges or unsoldered pins. Hold the finished board against a bright light. If you can see light coming through a pin hole, you know you forgot to solder it. 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 the Serial Interface

Connect the serial interface to the computer using the same ribbon connectors used to connect the bus display board. Make sure the connectors are not misaligned:



Connect power briefly to the computer board to make sure the Power indicator on the serial interface board lights up. Check the ICs to make sure none of them are getting hot. If everything is OK, disconnect the power and connect the interface to a PC serial port using a straight-through serial cable (not a "null modem" crossover cable).

On the PC, start a terminal emulation program. I will use the RealTerm program running on a Windows XP PC for these examples. I prefer RealTerm over Hyperterminal because RealTerm makes transfer of binary data over the serial port easy. Hyperterminal is designed mainly for communication over a modem, and it does not have the ability to do plain binary transfers. I will also give examples using an Ubuntu Linux system running Minicom, and using the command line for binary transfers.

Through the terminal emulation program, set the PC's serial port (usually designated COM1) to 9600 baud, 8-bit words, 1 stop bit, no parity (9600-8-N-1 for short). Set software and hardware flow control off. For terminal settings, set character echo off, and line wrap on. Both ANSI and VT100 or VT102 terminal emulations will work. With the Z80 computer in reset, and the fast clock selected, apply power to the Z80 computer. The power lights on both the computer and serial interface boards should light. You are now ready to go. But, the Z80 needs some software to communicate with the PC.

The CPUville Z80 computer ROM versions 7 and higher have software code for use with the serial port. Jump to the section on "Using the Serial Port with ROM version 7 and above" to see how to use this code if you have ROM version 7 or higher. If you have a CPUville Z80 computer with a ROM version 6 and below, you can still use the serial port without putting new code in the EPROM. Here is how to do it.

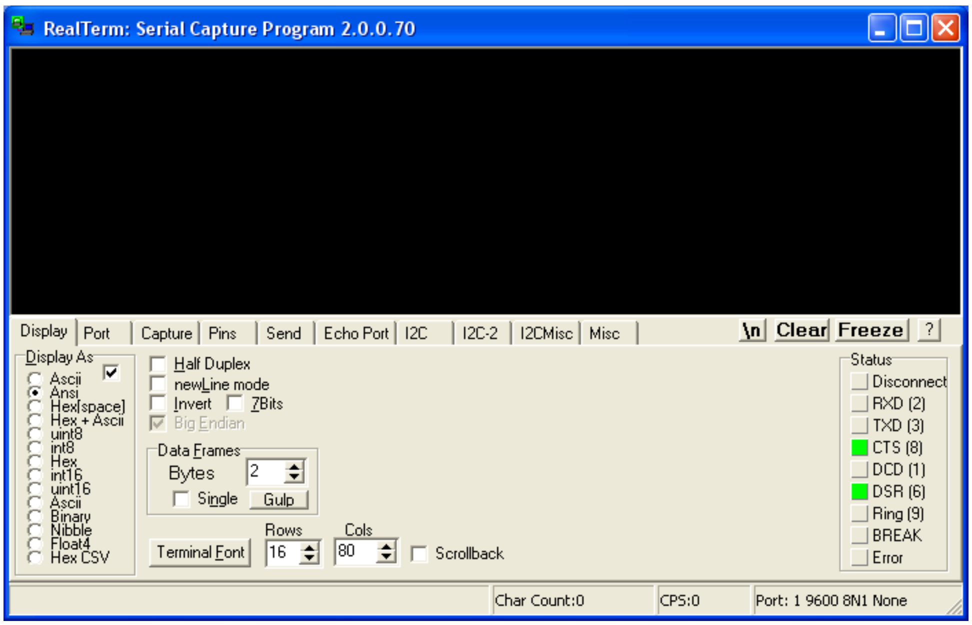
Using the Serial Port with ROM version 6 and lower

In the section titled User Program Listings there is a program you can use to test the serial port connection, `echo_char_test.` This program can be entered byte-by-byte into RAM using the `Program_loader`, which is at ROM location 0x0046. The program is only 30 bytes long, and is fairly easy to enter with the `Program_loader.` Once it is loaded in RAM and executed, it initializes the serial port and waits for input. Then, if all goes well, the characters you type on the PCs keyboard will be sent to the Z80 by the serial port, and the Z80 computer will echo them back to the display. The characters will also be displayed on the Z80 computer's port 0 LEDs. The following is some detail about how to do this.

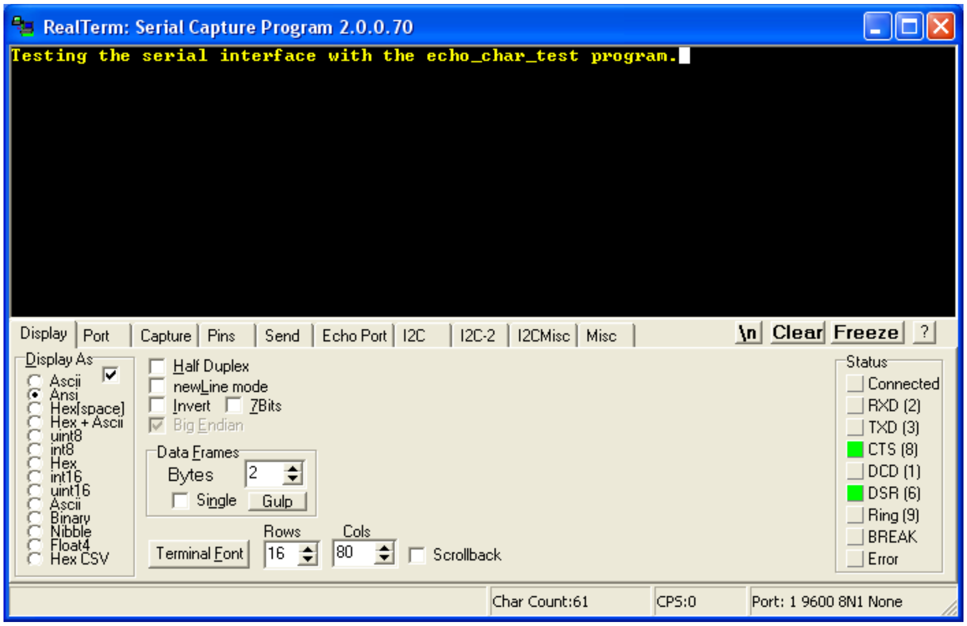
You should have the Z80 computer and serial interface connected to the PC serial port, a terminal emulation program such as RealTerm running with the proper communications parameters (see above), with the Z80 in reset, and the fast clock selected. Apply power to the Z80 and serial interface (the power light on the serial interface should light).

Put the `Program_loader` address on the input port switches (0x0046). Take the Z80 out of reset and load the 30 bytes of the `echo_char_test` program. The `Program_loader` is described in the CPUville Z80 Computer Instruction Manual. After the last byte has been entered, run the program (close the leftmost switch on input port 1).

Look at the terminal emulation program window. The CTS and DSR signals should now be active, indicating the the UART on the Z80 computer's serial interface has been initialized.



Click the mouse in the terminal program window. Type characters on the keyboard. They should appear on the terminal program display:



You might note some odd characters, depending on what the keyboard is sending. Up and down arrow may change lines, return may send the cursor back to the start of the line. If the characters are being echoed, you can be sure the serial port is set up properly and is working. Nothing you enter on the keyboard can physically damage the Z80 computer or the PC, so feel free to experiment.

But entering programs byte-by-byte with the input port switches is difficult, and it is easy to make a mistake. What one really wants is a way to load binary code generated by an assembler program directly into the Z80 computer's memory through the serial port, and execute it. For this, we can use the `boot_loader` program (see "User Program Listings"). This is another tiny program that can be entered into the Z80 computer's memory using the `Program_loader.` After it is entered, it can be used to load other programs. It will stay active and usable for entering programs, as long as the Z80 is powered on.

Once `boot_loader` is entered and executed, the Z80 initializes the serial port UART and waits for input from the PC. You start the binary transfer from the PC, and the Z80 computer will receive 256 bytes of code and place them in its memory starting at location 0900h. Then, the `boot_loader` jumps to that location to execute the code that was entered. If you don't overwrite it, the boot loader will remain in memory at 0x0800, and will start again after the computer is reset, if you put 0x0800 on the input port switches. This allows you to write, assemble, run, and debug Z80 assembly language programs.

To demonstrate how to use the `boot_loader` we first need to create a binary file that `boot_loader` can load and execute. We will use an assembler program running on the PC to create the binary file.

In the "User Program Listings" there is another `echo_char` program, but this one is designed for loading using the `boot_loader.` It is the same as `echo_char_test` except it lacks the port initialization commands, and has padding at the end to make the assembler output binary file greater than 256 bytes long (if it was less than that the `boot_loader` would hang). We will make a binary program file from this assembly language file using an assembler program.

A word about assemblers.

There are many assembler programs for the Z80 that are available for download. Most of them are free. Many of them date from the early days of personal computing, and they often have some quirks. I use the z80asm program running under Ubuntu Linux for most of my work, and the TASM assembler in Windows[1].

Most Z80 assemblers use the same, standardized mnemonics for the Z80 operation codes[2]. However, the various assemblers may use different variants or syntax for the assembler directives. In z80asm, directives are entered plain, but in TASM directives require a leading period. So, the z80asm **org** directive, is **.org** in TASM. z80asm has the defs (**def**ine **s**pace) directive, which fills a block with data, but TASM has the **.fill** directive. Also, TASM being a DOS-era command line program, wants input file names with no more than 8 characters in their names, and those 8 characters have to be unique to the directory the files are in. If you have more than 8 characters, and those characters are unique, it will complain with a source file read error. Strangely, if you have a well-behaved file name that is unique in its directory, like echo_ch, it will not complain if you give TASM the file name echo_char, even though that name has 9 characters. It simply ignores the last 2 characters and loads the echo_ch file! Took me a while to figure that out. Anyway, that is enough about assemblers.

Creating a binary machine code (object) file with an assembler

If you look at the `boot_loader` code, you see that it has the UART initialization codes. Once the UART has been initialized, other programs using it should not try to initialize it again. So, if we use the `boot_loader` to load another program, and that second program uses the serial port, it should not have the initialization codes. The `echo_char_test` program we entered directly using the `Program_loader` has initialization codes, so it is not an appropriate test program to load with the `boot_loader`. I wrote another program that will echo characters, but this program does not have the initialization codes. I will use TASM running under Windows to assemble the binary `echo_char` file, and will load and execute it using the `boot_loader` and RealTerm. Since I am using TASM for this exercise, I show the `echo_char` assembly language edited for compatibility with that assembler.

To start, create the assembly language file with a text editor like Notepad, and save that file as echo_ch.asm in the TASM directory:

1 This TASM is the "Telemark Assembler" for the Z80, not the Borland Turbo-assembler for x86 processors. Both assemblers have a TASM executable, but only the Z80 assembler will create the Z80 machine code.

2 There are some exceptions: the Z80 assembler by Joe Moore, AS8080, generates Z80 machine code, but uses Intel/TDL mnemonics for its assembly files.

```
;Program to test serial port.
;To be entered with boot_loader.
;No port initialization commands
;When running, should echo typed characters to display.
;Sends entered characters to output port 0 LEDs also.
                .org    0900h
echo_loop_1:    in      a,(3)           ;get status
                and     002h            ;check RxRDY bit
                jr      z,echo_loop_1   ;not ready, loop
                in      a,(2)           ;get char
                out     (0),a           ;data to LEDs
                ld      b,a             ;save received char in b reg
echo_loop_2:    in      a,(3)           ;get status
                and     001h            ;check TxRDY bit
                jr      z,echo_loop_2   ;loop if not set
                ld      a,b             ;get char back
                out     (2),a           ;send to output
                jr      echo_loop_1     ;start over
                .fill   250,000h        ;padding to make sure file is > or = 256 bytes
                .end
```

The TASM command line to assemble this program looks like this:

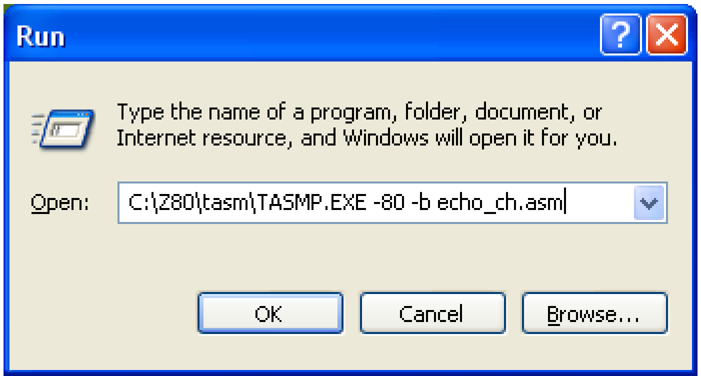
The TASMP executable file is used, because Windows XP runs in protected mode. In DOS, the TASM program is used instead (real mode). The -80 option tells TASM that we are assembling Z80 assembly language (TASM can assemble a wide variety of languages). The -b option tells TASM to create a binary object file output. Its default is a hex output file.

If TASM is successful it will show a window like this:

```
TASM Z80 Assembler.       Version 3.1  February, 1998.
 Copyright (C) 1998 Squak Valley Software
tasm: pass 1 complete.
tasm: pass 2 complete.
tasm: Number of errors = 0
```

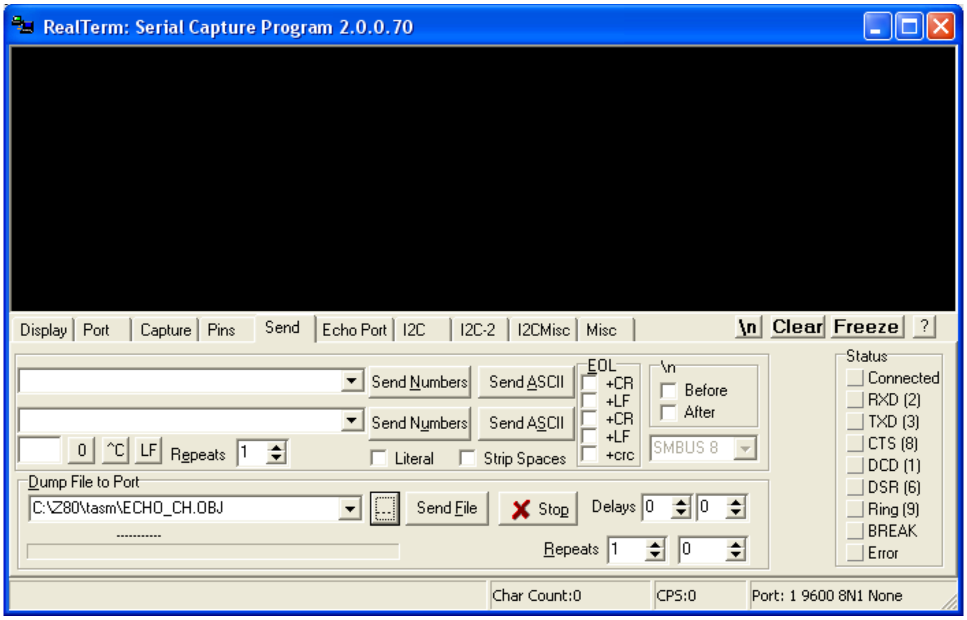
If your program has sytax errors, they will be shown here. Correct the errors as needed. When you have a successful assembly, you can close the window.

TASM should have put the binary output file, named echo_ch.obj in its directory. This is the file we will load into the Z80 computer, using the `boot_loader`.



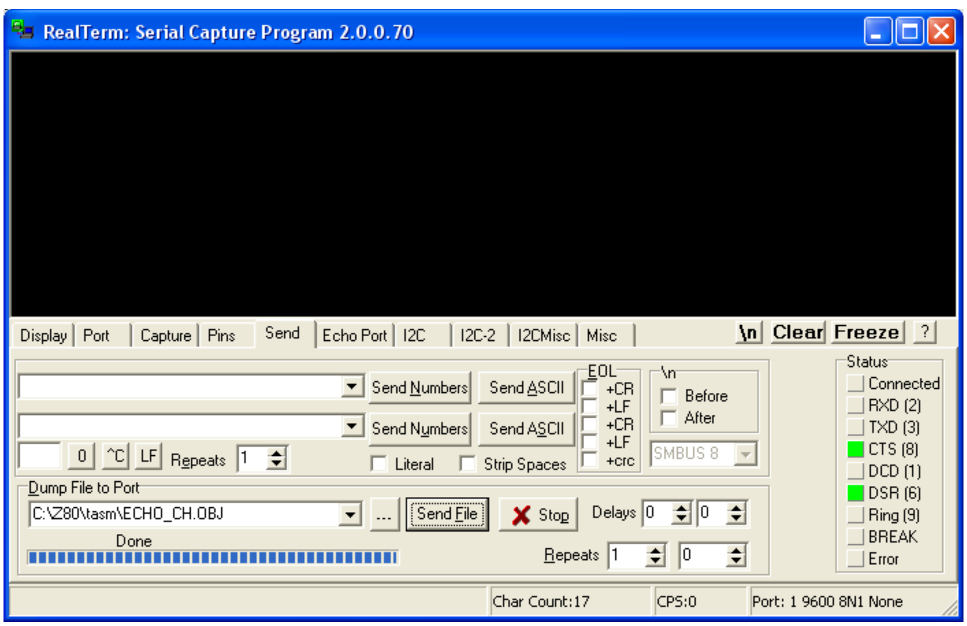
Using `boot_loader` *to load a binary program file*

Once you have created a binary program file using an assembler, it can be loaded and executed using the `boot_loader` program. We will use RealTerm to communicate with the Z80 computer. First, load the `boot_loader` into the Z80 using the `Program_loader` and the input port switches, like you did for the `echo_char_test` program. Do not execute the `boot_loader` yet. In RealTerm, click on the Send tab. Click on the … button and navigate to the echo_ch.obj file, and click Open. Now the RealTerm window should look like this:

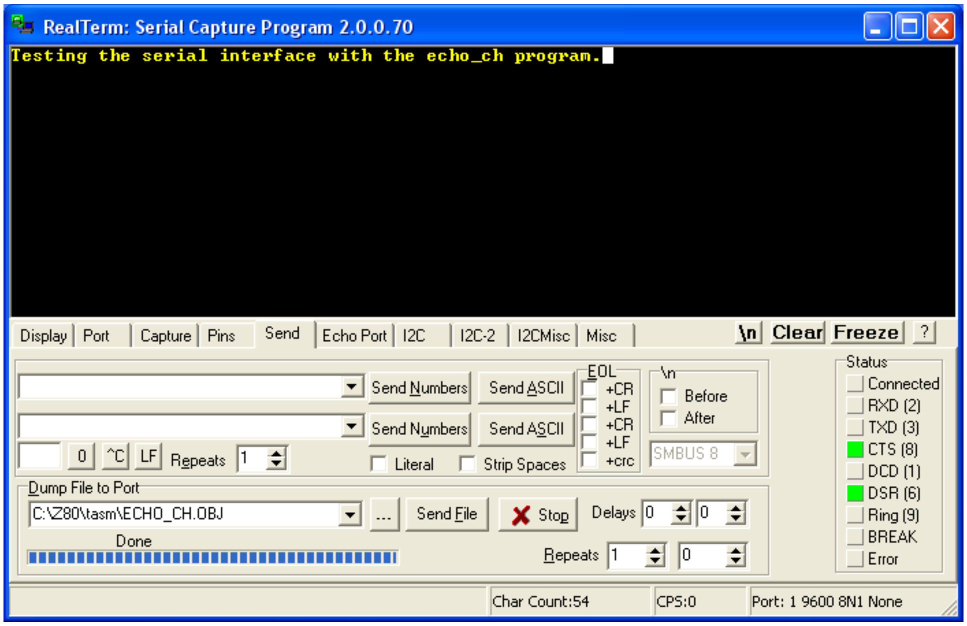


Now execute the `boot_loader` (close the leftmost switch on the Z80 input port 1). The CTS and DSR signals should come on indicating that the serial port has been initialized. The `boot_loader` is now ready to receive input.

Click on the Send File button. A progress bar will run across the window, and Done will appear:



Now click the mouse in the RealTerm display window, and type on the keyboard. You should see your characters being echoed onto the display (and on the port 0 LEDs):



If you feel limited by the 256-byte transfer size of the `boot_loader`, you can of course write a program that will in turn load a much larger program. This is the meaning of the "boot" in `boot_loader`: the computer is "pulling itself up by its own bootstraps", by running a tiny program entered using the switches, which loads a larger program, which in turn loads a larger program, up to the limits of the size of the memory.

But, what you really want is the equivalent of a boot_loader program (and others) in the ROM, so you don't have to mess with the input switches. The following section discusses using the serial port with ROM version 7 and above, which has code to run the serial port.

Using the Serial Port with ROM version 7 and above

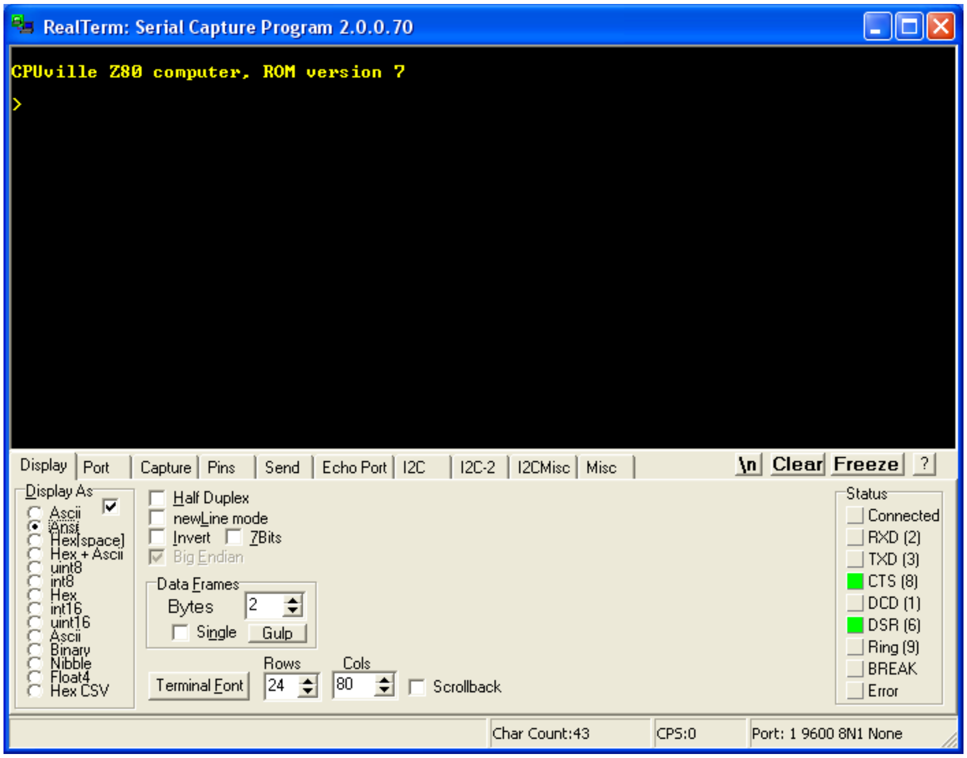
If you look at the "ROM Program Listing" below, you will see that starting at address 0x0100 a lot of code has been added compared to ROM version 6 and earlier. There are a variety of utility subroutines that are used with the serial port for getting input with line editing, writing lines (strings) to output, and converting between characters and values. You can use the subroutines in your own programs.

In addition to the utility subroutines, there is a primitive monitor program that takes some simple commands that allow you to enter and run programs on the Z80 computer without needing to use the input port switches. It can all be done using the keyboard and display, through the serial port.

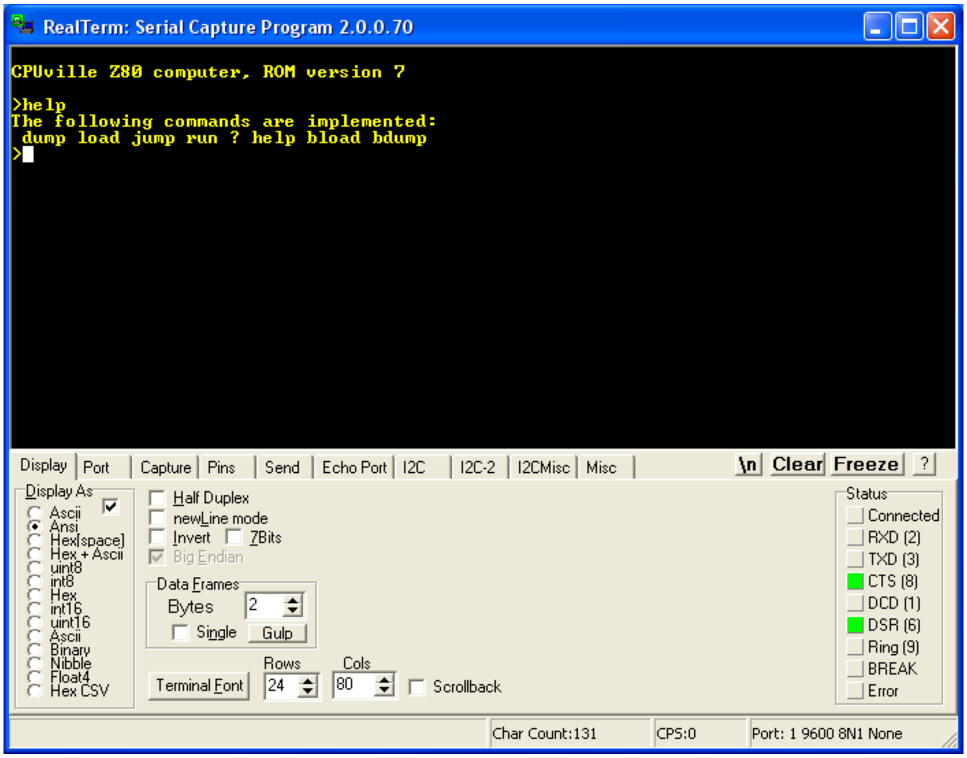
The monitor program has two entry points. The `monitor_cold_start` is used when the computer is taken out of reset. It has the UART initialization commands. The `monitor_warm_start` is used to hand control back to the monitor after a user program has been run.

I will show examples using the monitor program with a PC running the RealTerm program. Start RealTerm, and make sure it is set up for 9600 baud, 8-N-1 communications (under the Port tab). Select the display as Ansi option under the Display tab. Real term uses a default of 16 rows in its display window, but you should increase this to 24 rows.

With the Z80 in reset, place the monitor cold start entry address 0x04C0 on the input port switches, and take the Z80 out of reset. You should see the monitor greeting message on the display, and a > character as a prompt indicating the monitor is ready to take input:



You need to click in the display window to enter text into RealTerm. Type help or ? to get a display of the available monitor commands:



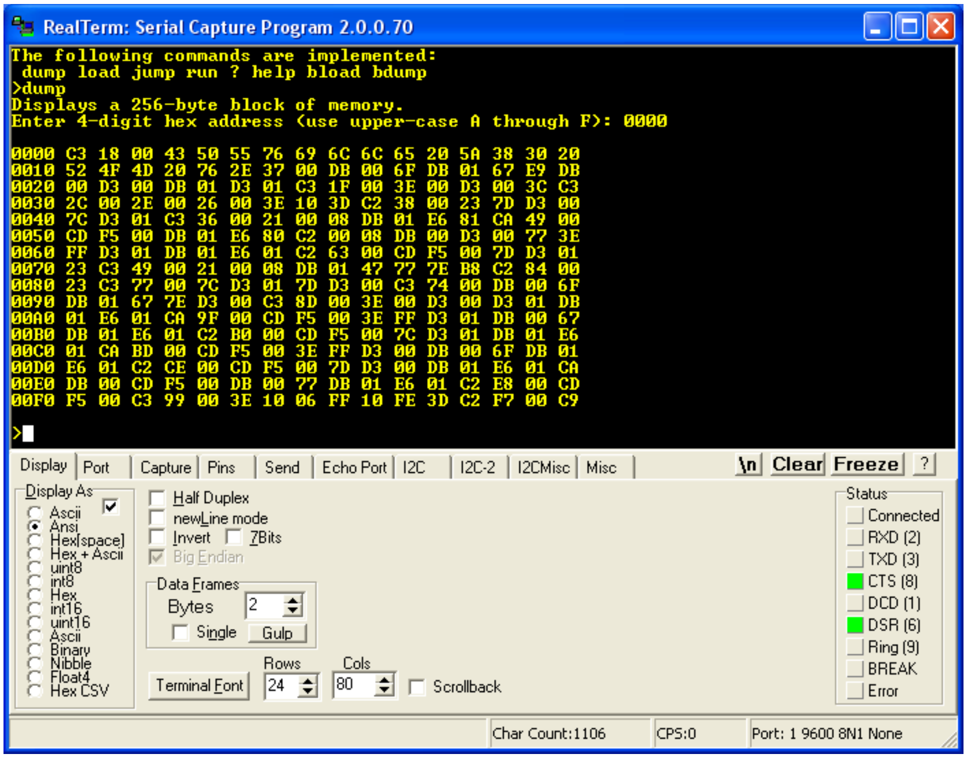
The monitor program is very simple. It has to be, to fit in 1.8 K of memory. Commands are case-sensitive (lower case only), and no arguments are accepted. Hexadecimal numerals need to be entered with upper-case A through F. There is little or no error checking or memory management. The input line buffer is located at memory location 0x0F88, and if you put in a huge input line, it will overwrite the stack and the system will fail. The 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, it seems to work 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 and examples using the various commands.

Help command

Displays a list of the available commands. The ? does the same thing.

Dump command

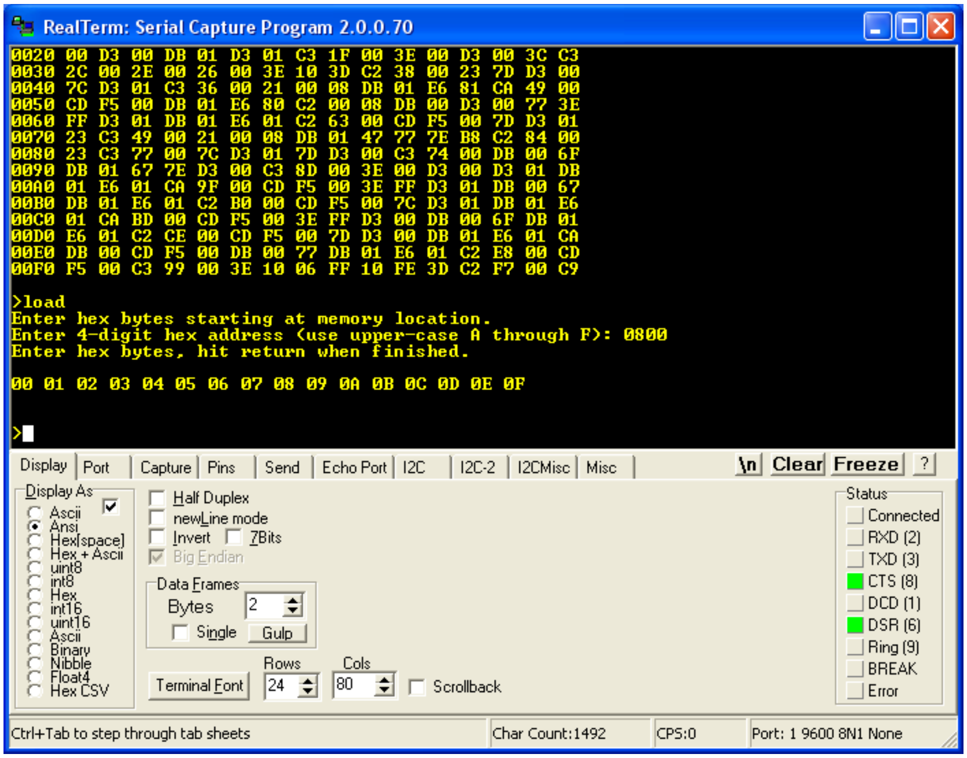
Displays a 256-byte block of the Z80 computer's memory. The command takes a 4-character hexadecimal address as input, with the A through F characters as upper case. The output display shows the 4-character hexadecimal address of the first byte of each row, then 16 bytes of data as hexadecimal characters.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



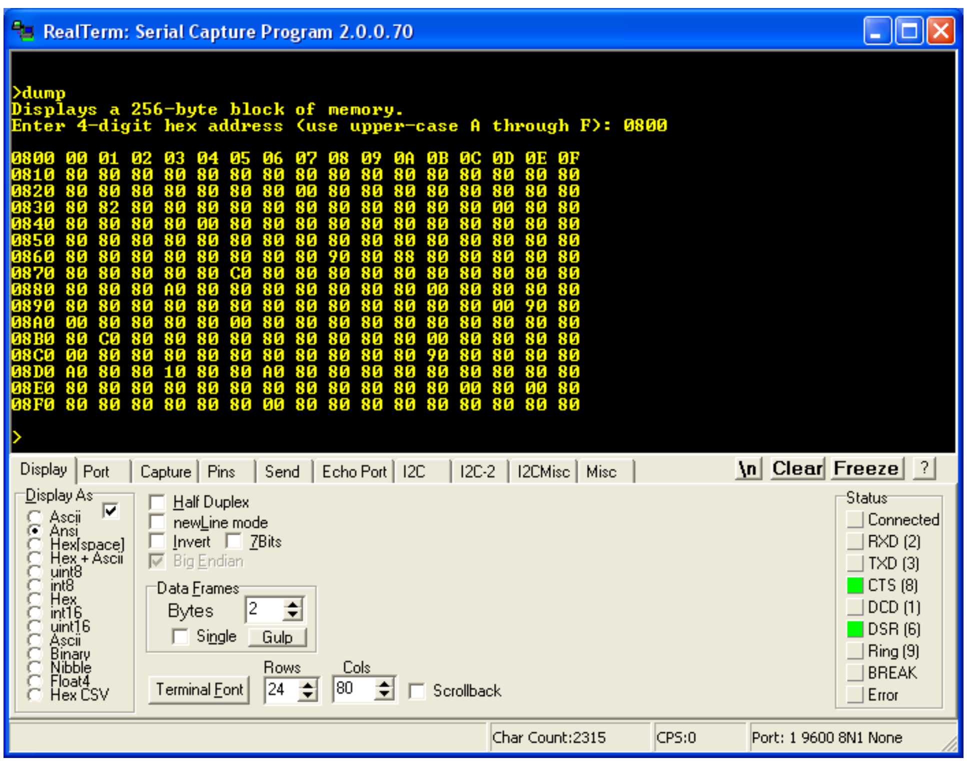
This command is very useful for debugging programs, as you can see the machine code, and the values of your variables.

Load command

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.

Run command

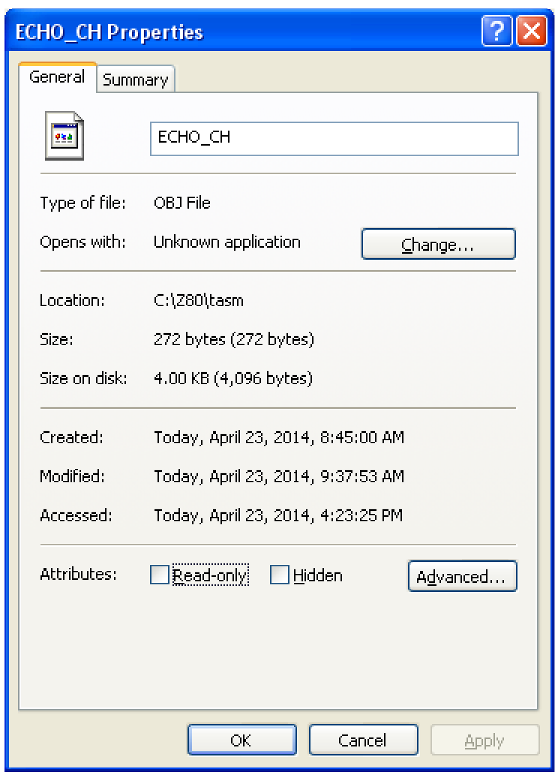
This command causes program control to be passed to the address you enter. It is the same as the Jump command.

Bload command

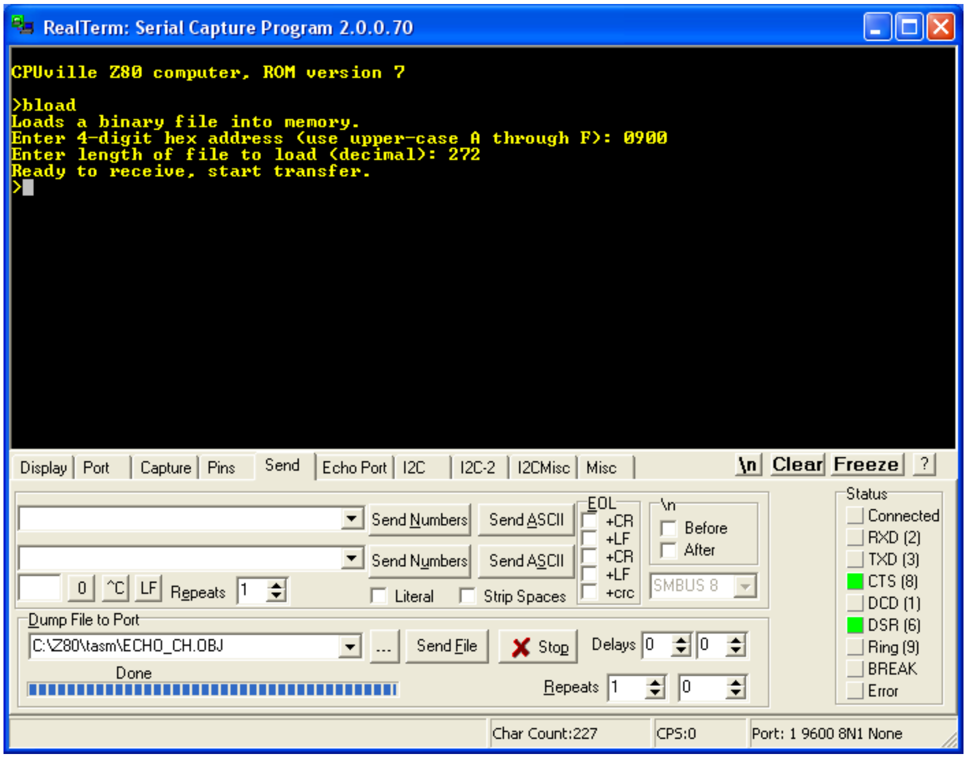
This command is for loading binary files (**b**inary **load**). The command takes a four-character hexadecimal address input, and a decimal file length input. Then, it waits for the file to be sent from the PC to the Z80. It works best if you enter the exact length of the binary file. The bload command 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 the `echo_ch` program that was assembled to test the `boot_loader` program (see the section above for details of how to assemble the file).

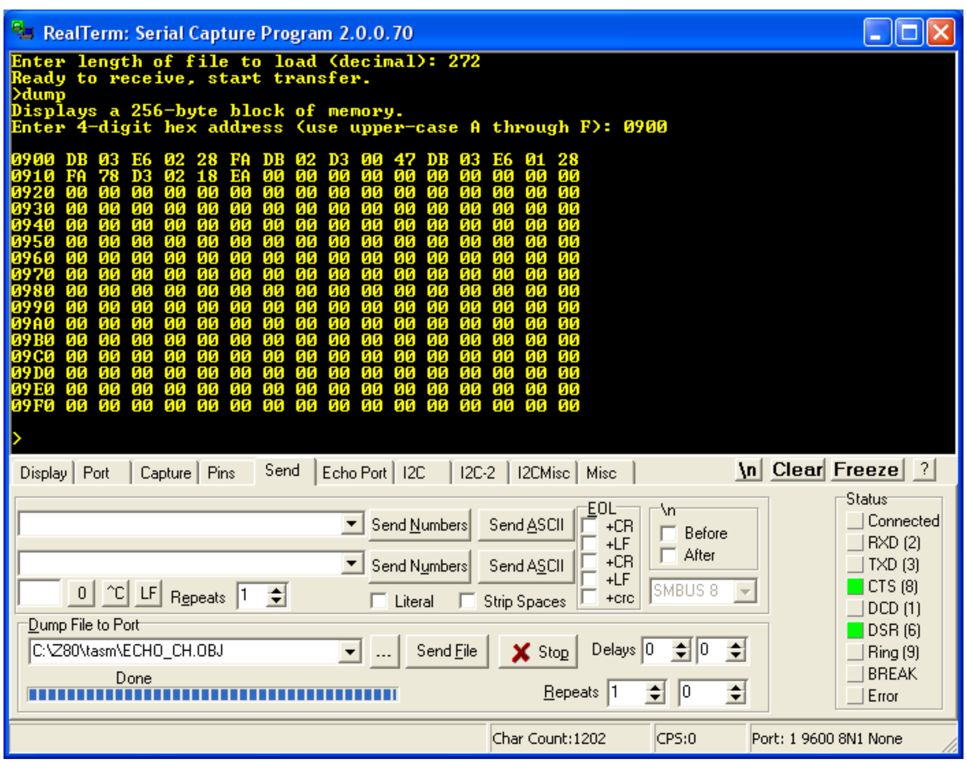
We can load the file anywhere in RAM, but let's load it at location 0x0900. First we need the exact file size, which we can obtain by hovering over the file name, or right-click-Properties:



We see the file is 272 bytes long. Now we run the bload command, and enter the target address 0900h (no need to type the “h” in the monitor), and the length as decimal 272. Hit return after entering the length, and it lets you know it is ready to receive the file. Now, in the RealTerm Send tab, navigate to the echo_ch.obj file using the … button, click Open, then click the Send button. After the file is sent "Done" should appear above the file progress bar, and the monitor prompt should reappear, letting you know the command was successfully executed:



You can examine the memory at 0900h using the dump command:



There you see the program bytes, followed by the padding zeros that were put in for the `boot_loader` program (see above – no padding needed for the bload command since it loads the number of bytes you enter).

You may now run the program using the run command, enter the address 0900h. 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 `echo_ch` program has no exit, so you need to reset the Z80 computer to get out of it. When you take the Z80 out of reset, the monitor program starts again, since you have the cold start entry point on the input port switches. Resetting the Z80 does nothing to the memory contents. After you reset the computer, You can see that the `echo_ch` program is still present at location 0900h using the dump program, 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 0x04C9 on program termination.

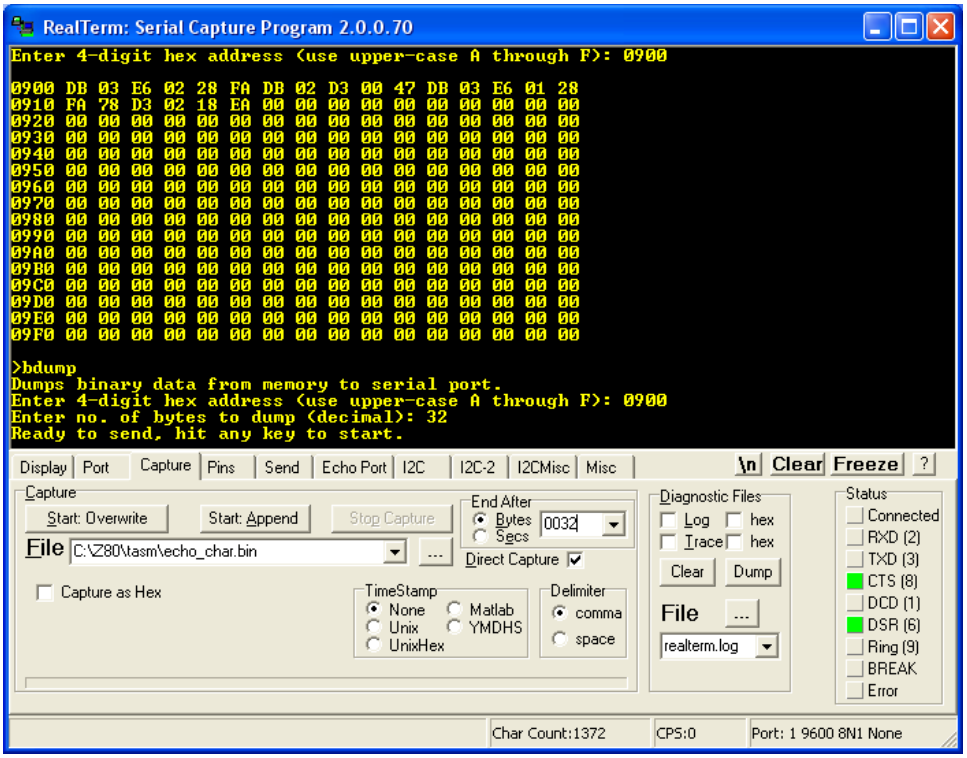
Bdump command

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.

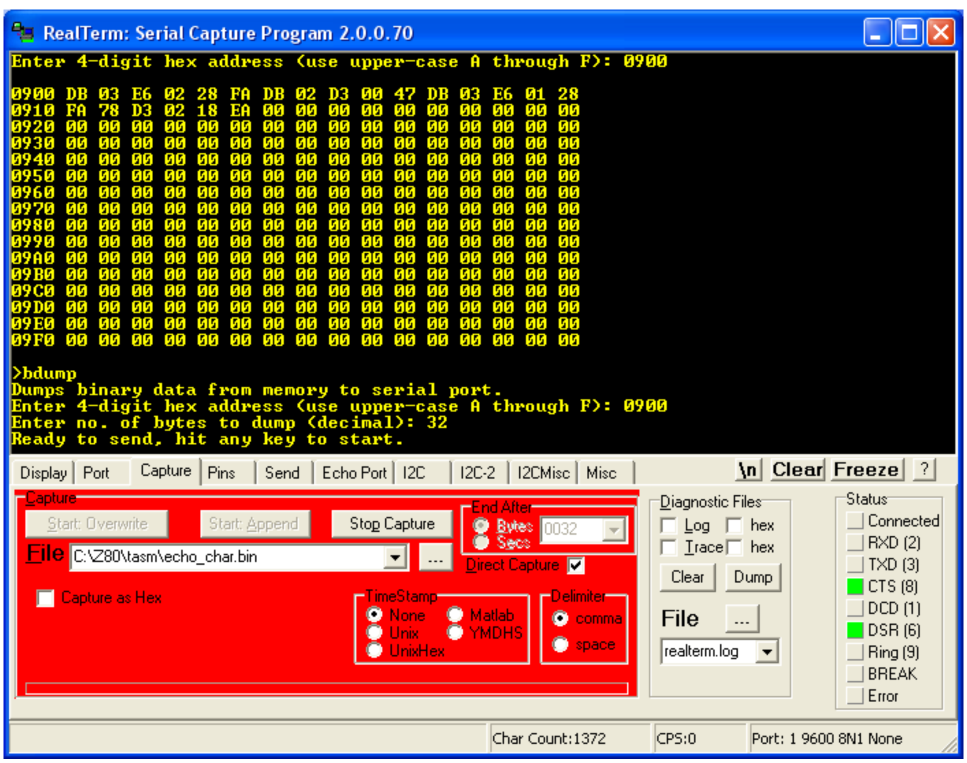
The `echo_ch` program we loaded has a lot of padding bytes, to make it useful for the `boot_loader`. We can create a shortened version of it using bdump.

If you look at the memory dump display (or the list file) for `echo_ch`, you can see that the last byte of the program is the EA at address 0915h, meaning the total number of program bytes is decimal 20 (you can use a calculator program with hexadecimal inputs if you need to figure out file lengths of longer programs). We can create a more compact file by dumping these first 20 bytes from memory to a file that we can name echo_char.bin (we don't need to worry about the length of the file name now because TASM will not be involved – see discussion above in “A Word About Assemblers”).

To create this compact echo_char.bin file, we first set up RealTerm to receive a file of this name. Click on the Capture tab. Write the file name (with complete path) in the File window. Make sure Direct Capture is checked. While RealTerm can capture a file of any length, I have found that it is most accurate if the number of bytes is a multiple of 16. Here I chose to capture 32 bytes. Enter the bdump command, address 0900, number of bytes to dump 32 and hit return. Now, the Z80 is ready to send those 32 bytes to the serial port with any keypress.

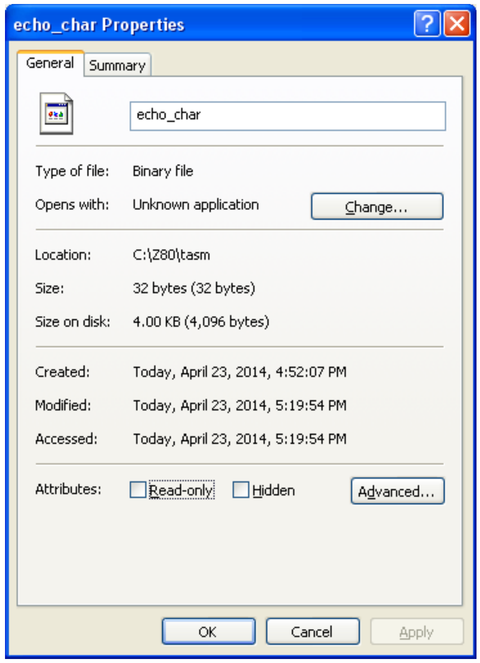


Click on the Overwrite button. The bottom of the display turns red, indicating that capture is underway. But, the Z80 computer has not sent any bytes yet.

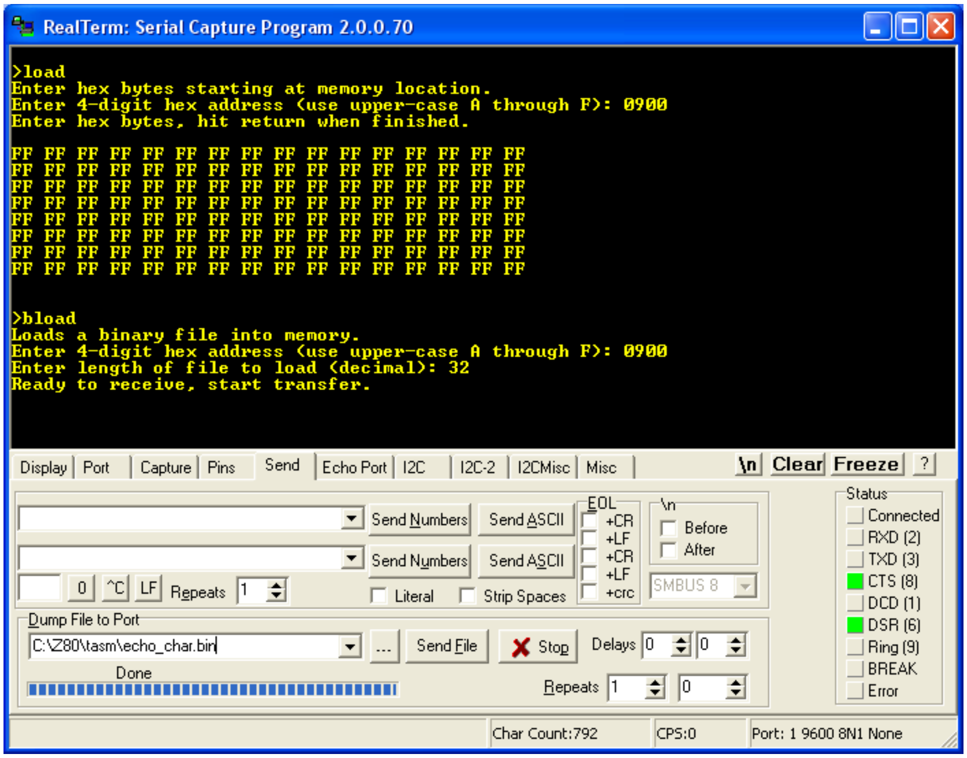


Now, click in the display window and hit any key. The 32 bytes will be transferred to the file echo_char.bin and the RealTerm display will go back to its normal color. The Char Count will show 32 bytes transferred. In the display window, the monitor prompt will re-appear.

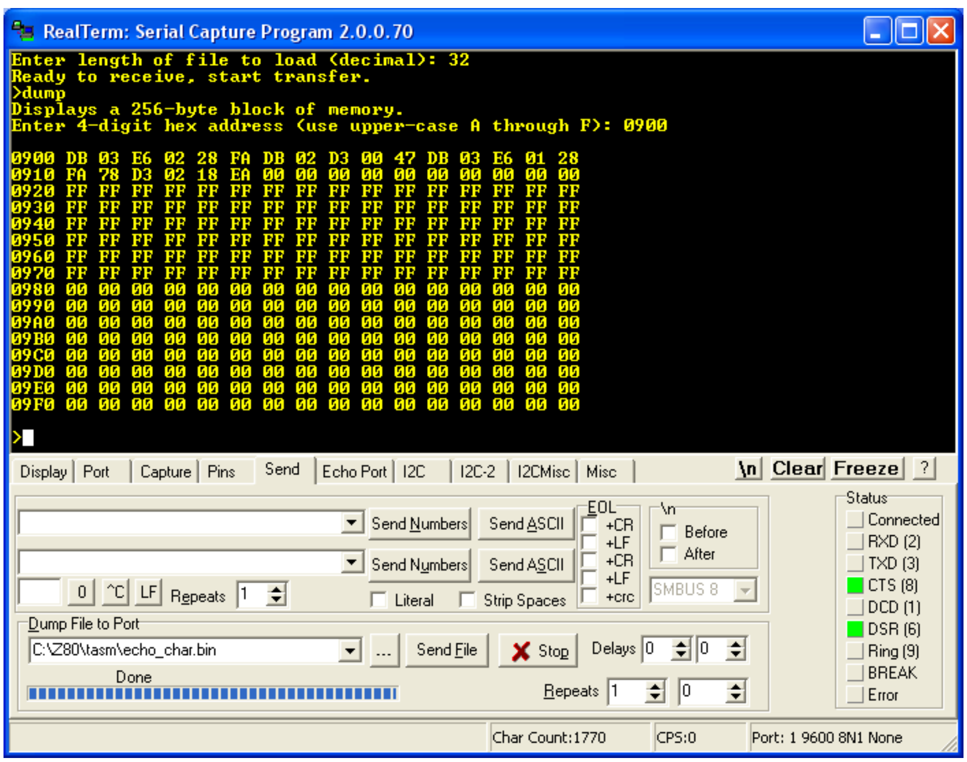
Navigate to the directory containing the echo_char.bin file, and check its size in the Properties window. You can see it is 32 bytes.



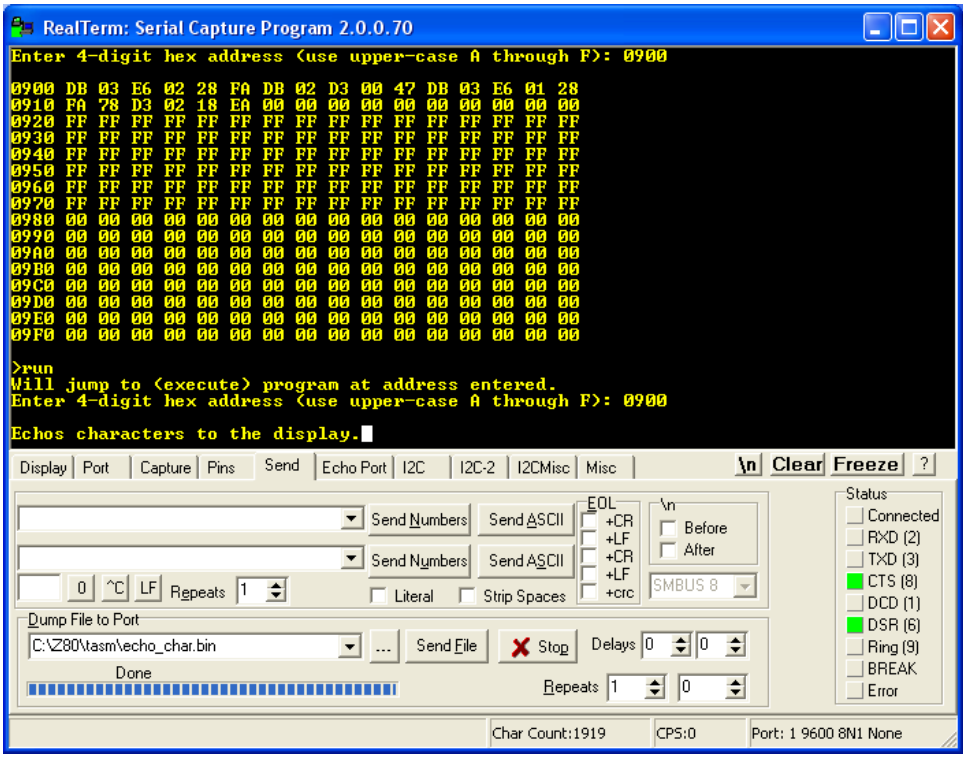
This file can be loaded back into the Z80 using bload. I first entered FFs into the Z80 memory at 0900h using the load command before loading back the file so you can see that it is really now just 32 bytes long:



Here is the dump display after loading the shortened echo_char.bin file:



Now you can run the program. Press the **\n** button on the RealTerm window to put the cursor down a couple of lines and type some text:

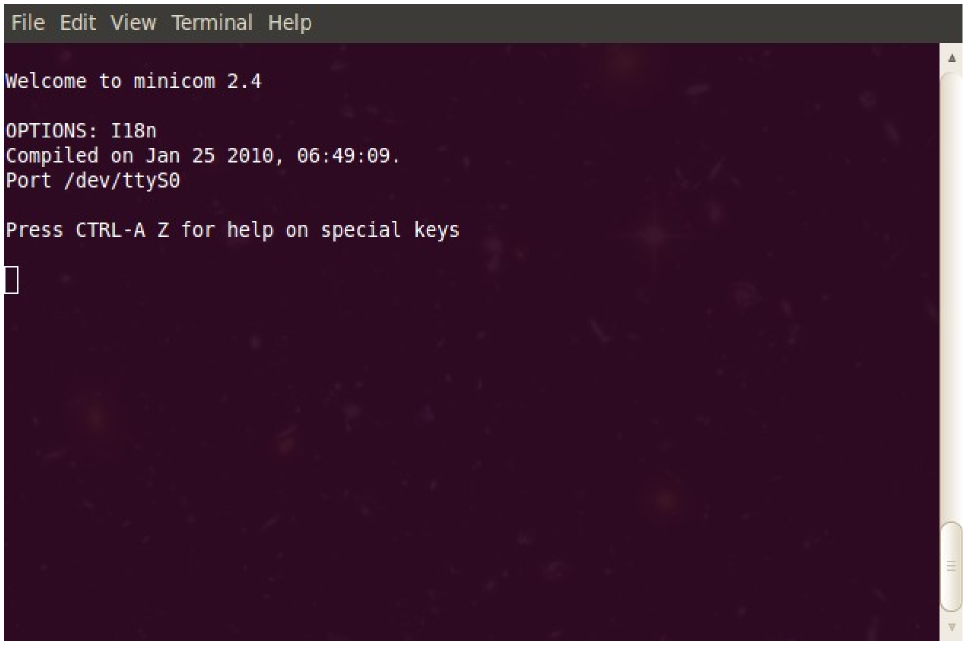


This concludes the discussion of using the monitor program commands with RealTerm, running under Windows XP. The next section shows how to use the monitor commands with Minicom running on a Linux system.

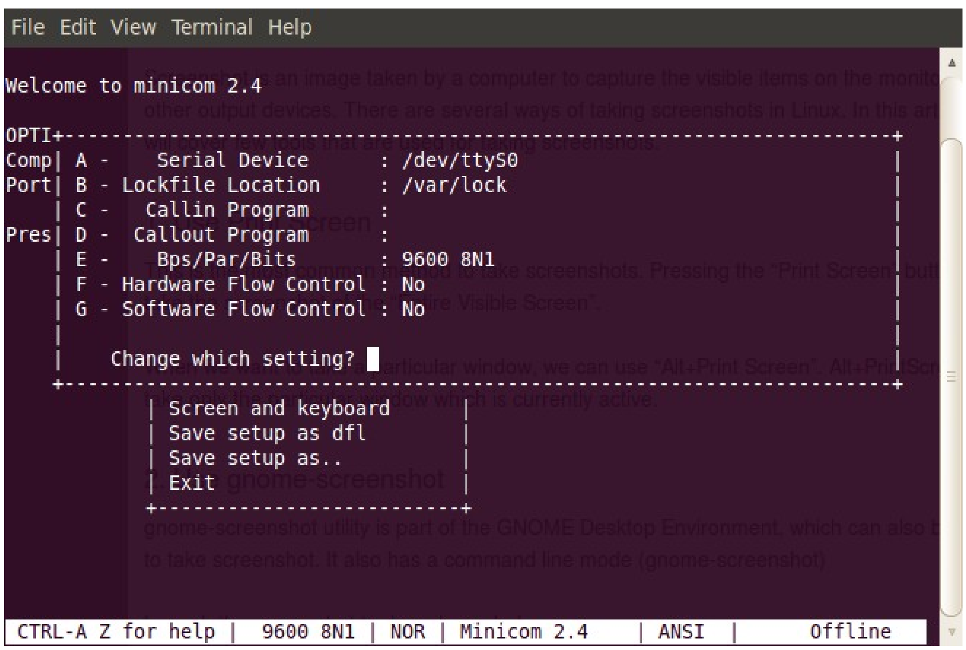
Binary transfers on a Linux system

I have used a Linux system for most of my work on this project, and I suppose many hobbyists use it too. The terminal emulation program I use is Minicom. It is not as capable as RealTerm in that it does not have built-in ability to do binary transfers. However, the Linux operating system itself has very robust command line functions that can accomplish this.

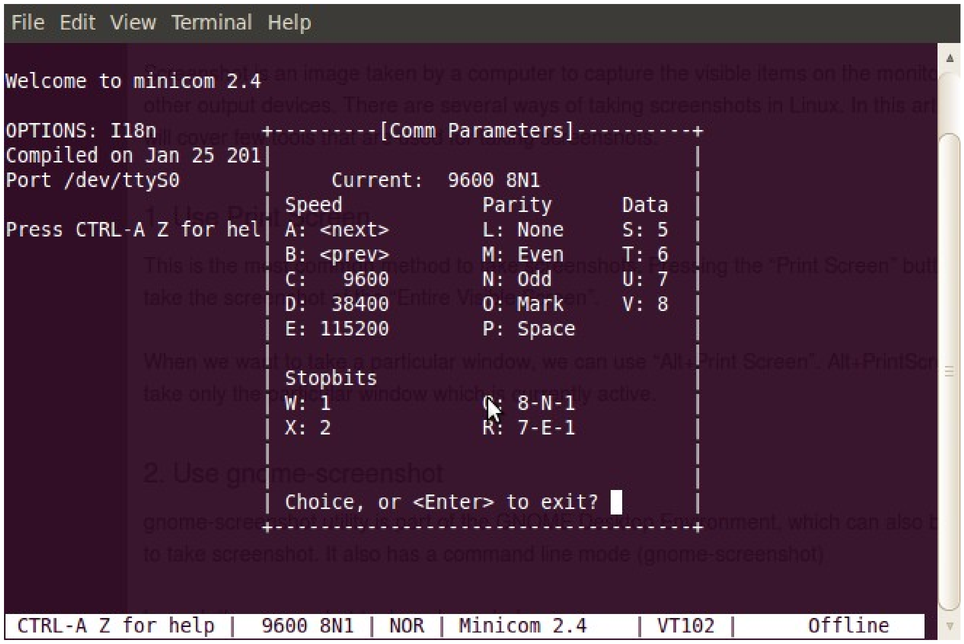
Open a terminal window and start Minicom:



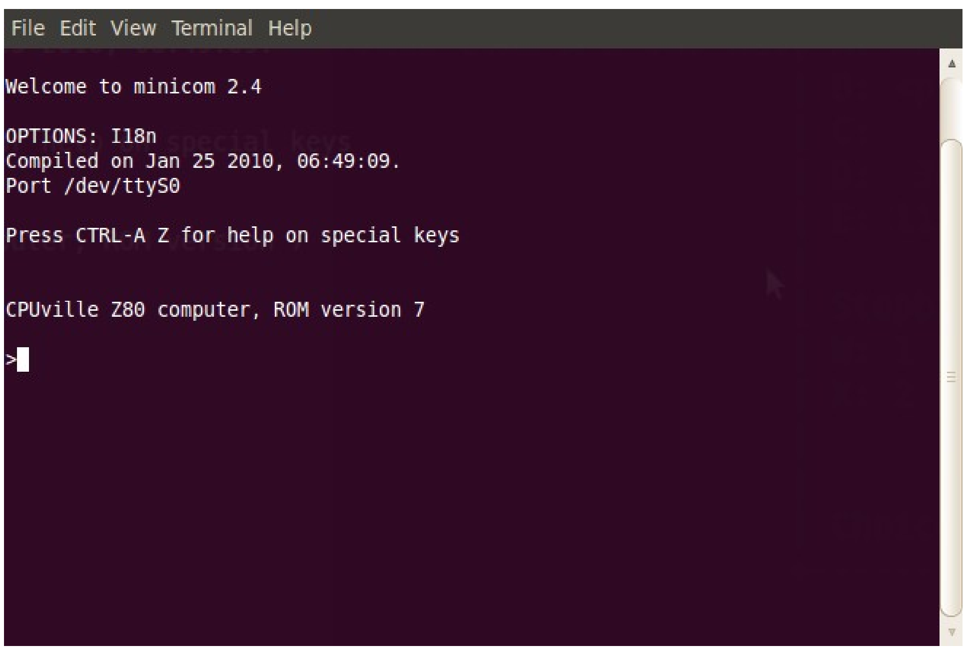
Using ctrl-A-Z, get to the cOnfiguration menu, and make sure you have the correct serial device designated, the correct baud rate, and 8-N-1 communications.



You can also set the communications parameters using the comm Parameters menu:

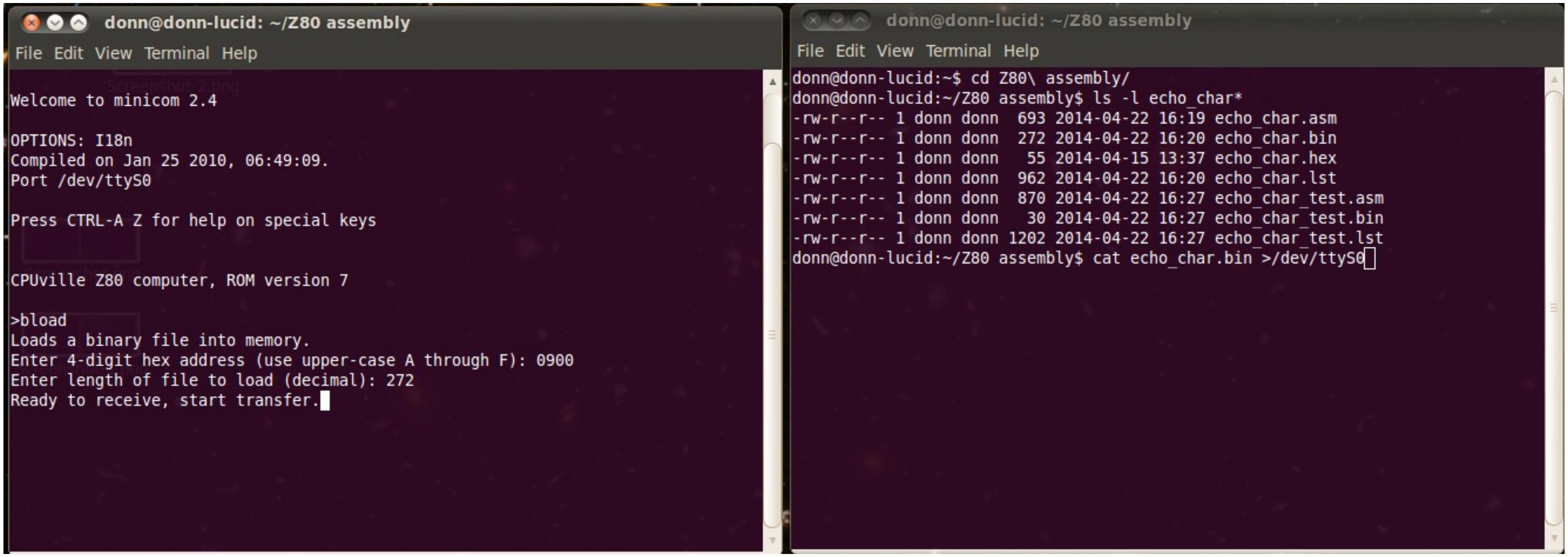


You can save these settings as the default. Once Minicom is configured you can take the Z80 computer out of reset, with the `monitor_cold_start` address 0x04C0 on the input port switches. You should see the monitor greeting message, followed by the monitor prompt and cursor:



The help, dump, and load commands work the same way as with RealTerm (see the sections above). However, Minicom has no ability to send or receive plain binary files, so some extra work needs to be done.

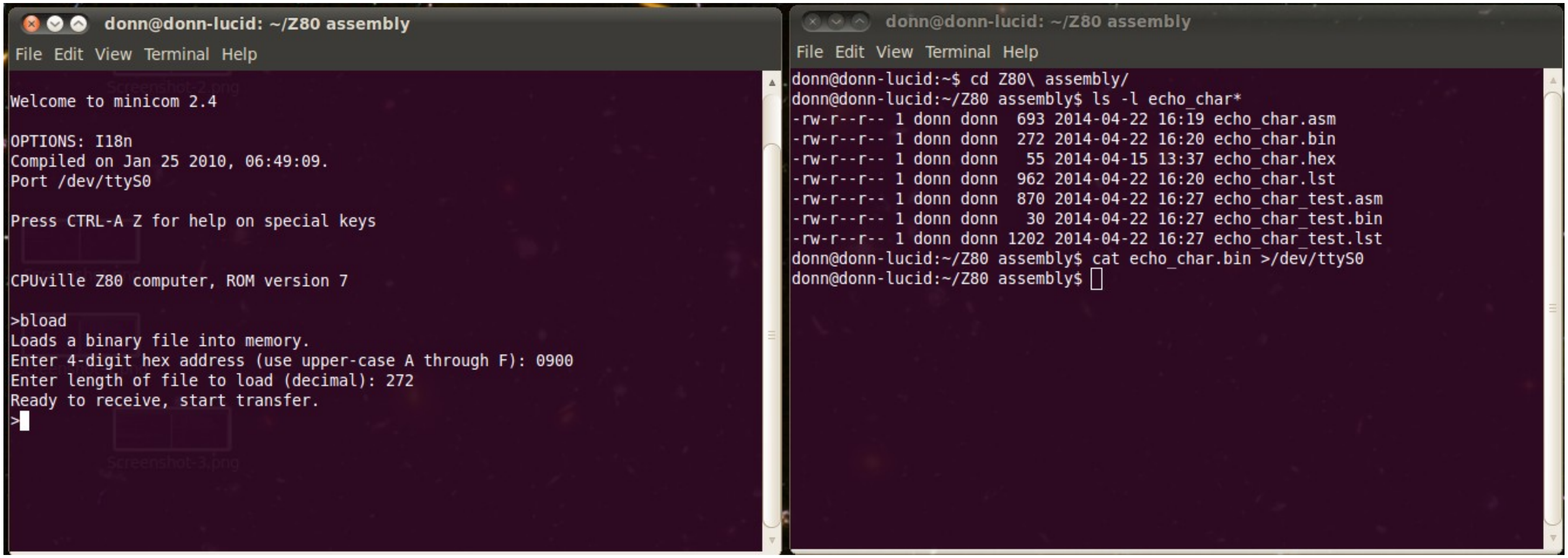
To send a binary file to the Z80 computer we still use the bload command. But, we have to switch from Minicom to the Linux command line in order to send the file over the serial port. We can do this easily by opening another terminal window next to the window running Minicom, and using the command line in the second terminal window to send the file using the Linux cat command. Here is an example using the echo_char file:



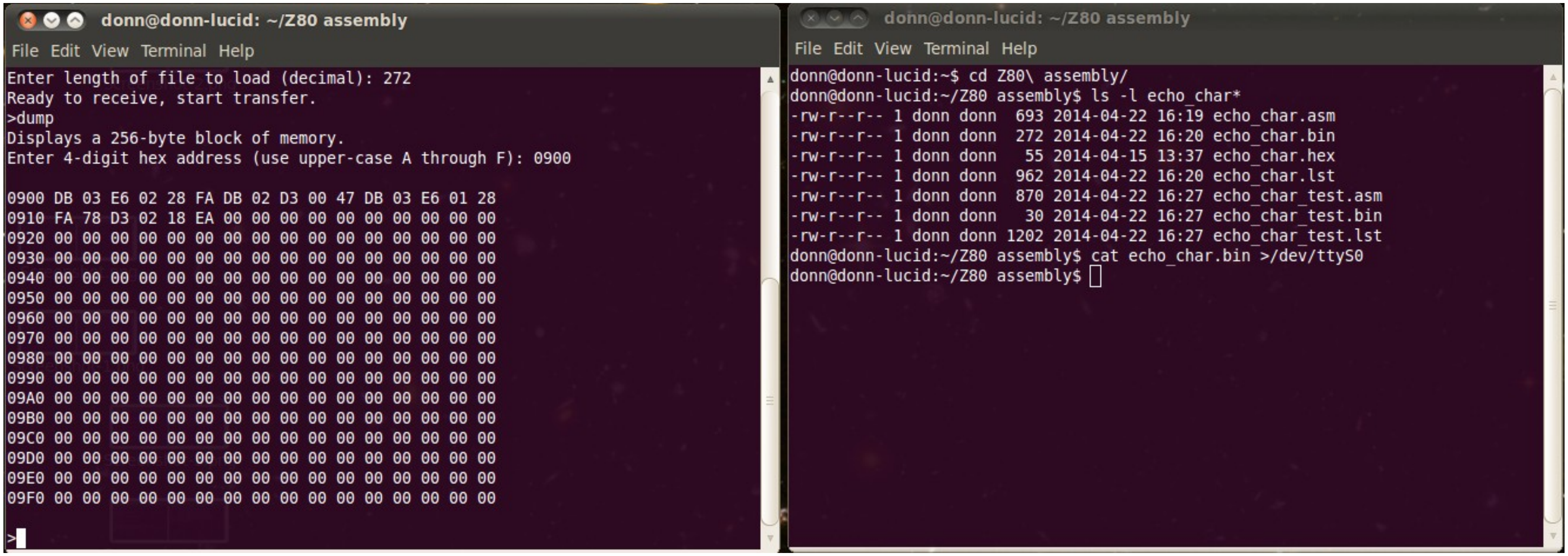
Here are the two terminal windows side-by-side. The left window is running Minicom, and the right is just a plain terminal. Whichever window you click in becomes the active window. Both windows can access the serial port, as long as only one is using it at a time.

We started in the right hand window, listing the files in the directory to make sure we have the correct file size. We see the echo_char.bin file, previously assembled using z80asm, with a size of 272 bytes. We will transfer this file.

Then, we switched to the left window and set up a binary load for this file using the bload command, as shown above. When bload gives the "Ready to receive, start transfer" message we switch back to the right window and enter the **cat** command as above. This command is normally used to dump a text file to the terminal display window, or to con**cat**enate files together. But, it will also dump a binary file. We redirect the cat command output to the serial port with the redirection symbol >, followed by the device name of the serial port. Hit return, and cat sends the contents of echo_char.bin to the serial port, and into the Z80 computer's memory as directed by bload. After the transfer, the right hand display returns to the terminal command line, and the left hand display to the monitor command line:



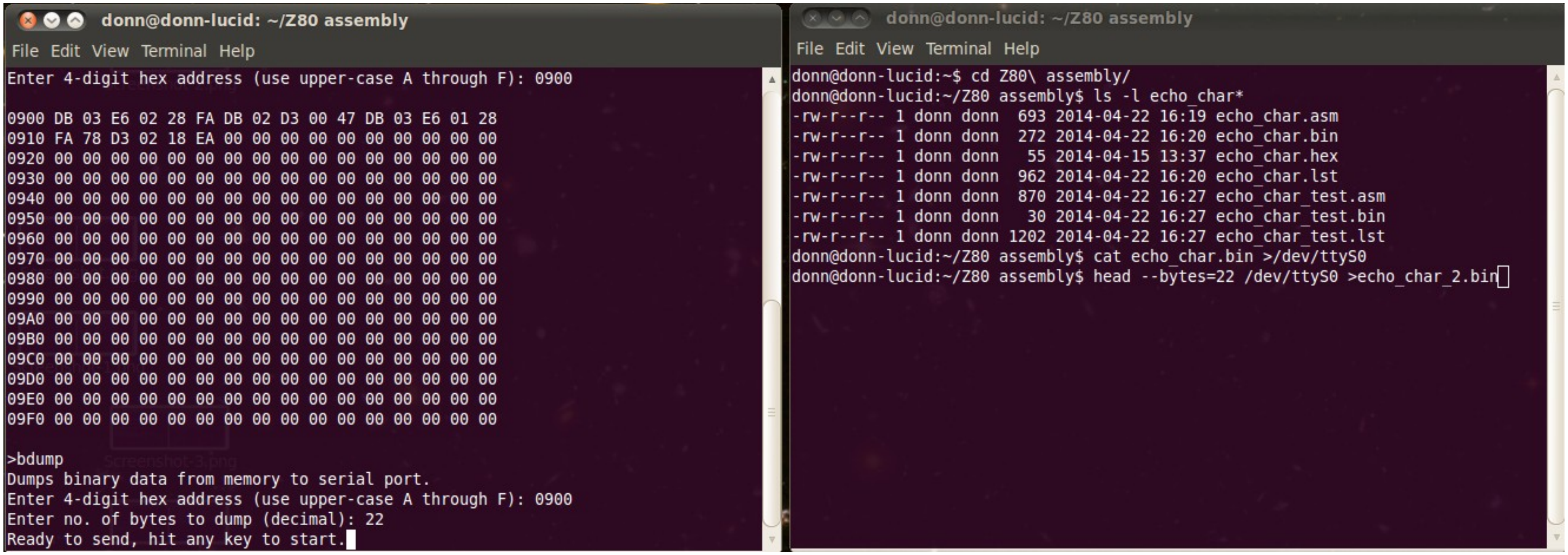
After the transfer, we can do a dump display to show that the file is in the Z80's memory:



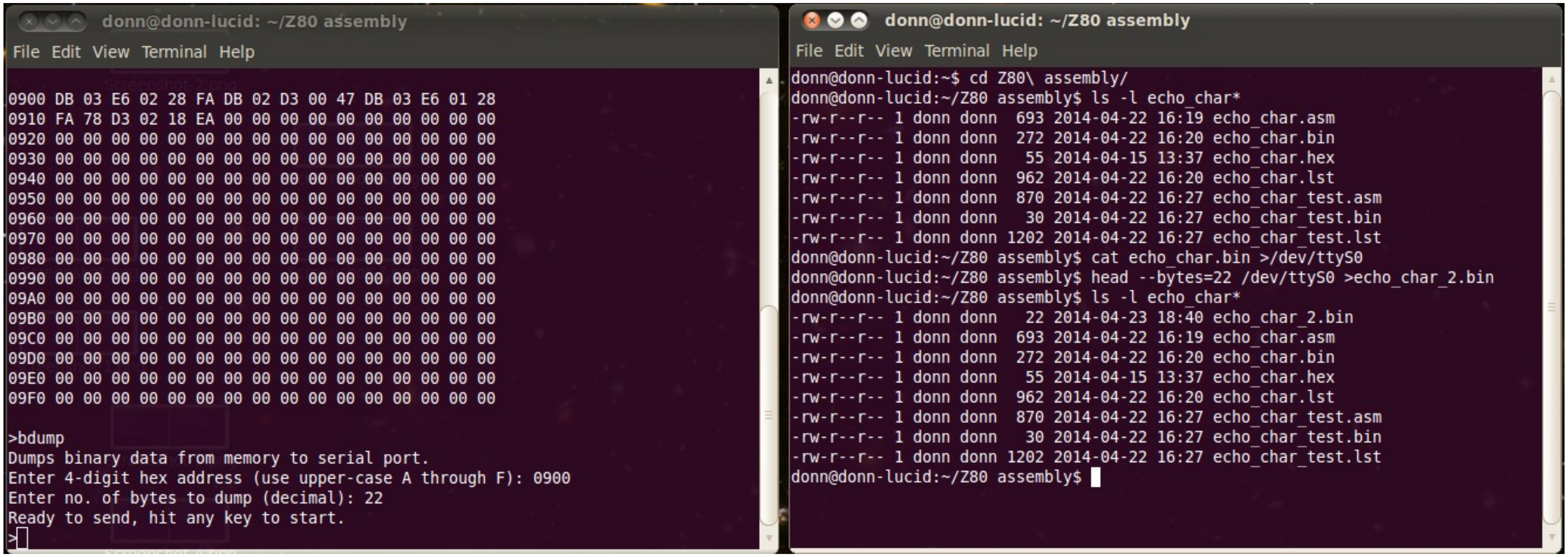
To do a binary transfer from the Z80's memory to a binary file on the PC, we use the monitor bdump command, and the Linux **head** command. The head command is from the Unix roots, and was used to display some number of characters (the **head**er) of a text file on the display screen. However, using redirection, we can send the “header” of the serial port output (everything's a file in Linux) to a file on the disk. We tell the head command how many bytes to get and put into the file.

By looking at the memory dump display you can see that only the first 22 bytes of the echo_char.bin file are program code. We can therefore dump these 22 bytes starting at memory location 0900h from the Z80 computer through the serial port to the PC, and the Linux head command running in the PC will put this data into a file. We will name the new file echo_char_2.bin.

We set up the transfer in the left-hand window, where Minicom is communicating with the Z80's monitor program. We get to the point where we see the message to hit any key, then go to the right hand window. There, we set up the head command to receive 22 bytes from the serial port device, and redirect these bytes into the echo_char_2.bin file. Here is the transfer ready to go:



To do the transfer, we go to the right hand window and hit return to start the head command. It is now waiting to receive 22 bytes from the Z80 through the serial port. Then, we go to the left hand window and hit any key. Once the transfer has finished, the left hand window will show the monitor prompt, and the right hand window will go back to the terminal command line. To see that the file has been successfully transferred, list the local directory in the right hand window:



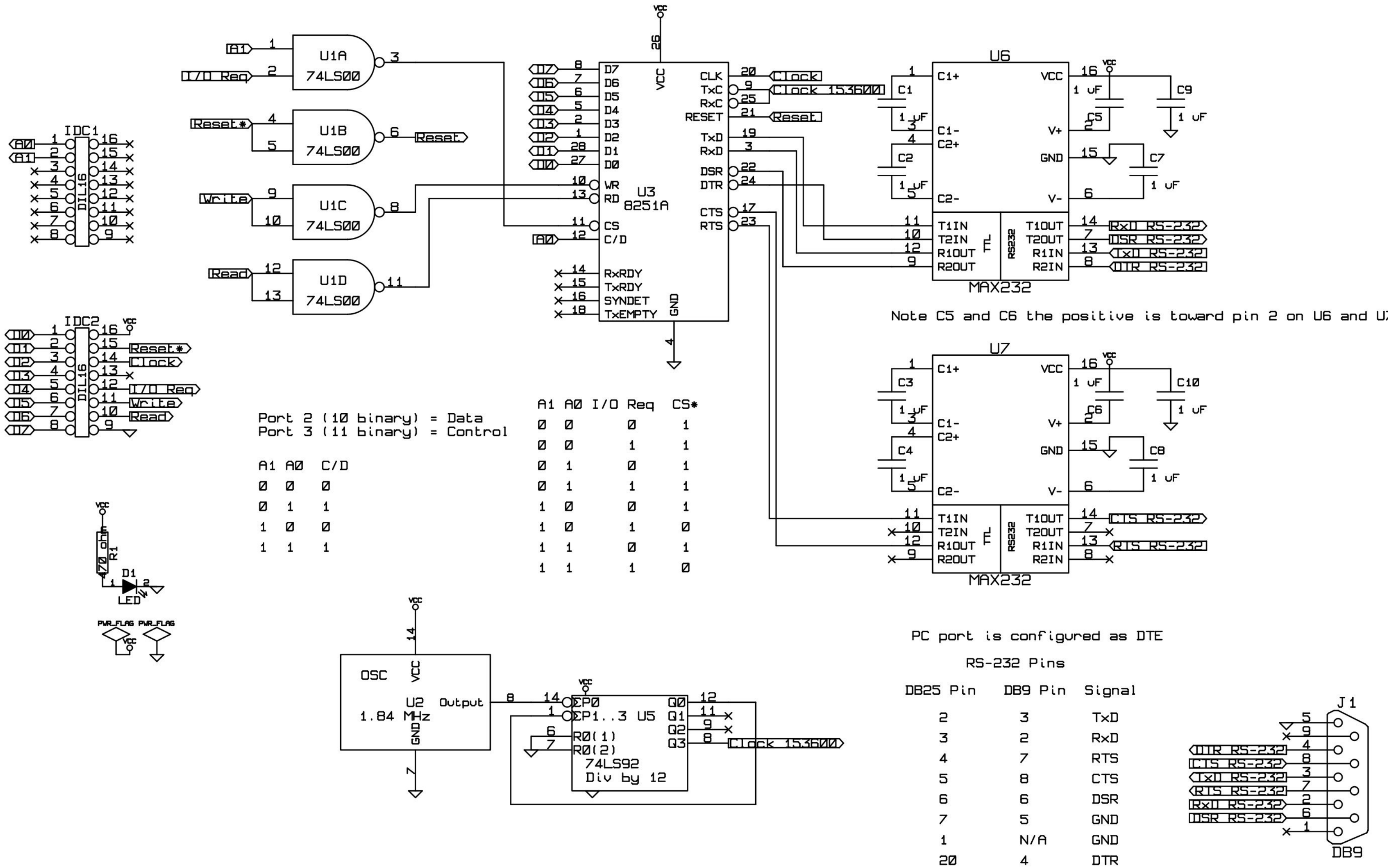
You can see the echo_char_2.bin file now, with the correct file size. This file can be loaded back into the Z80 using bload, and run, and its memory examined to verify that the transfer proceeded without error. On some systems, you may need to add the **-q** or **–quiet** option to the head command to do the transfer. There are probably other ways to do binary transfers (using the Linux **dd** command for example) but the cat and head commands seem to work well, and are simple to use. This concludes the section about using the Z80's monitor program commands.

There are many utility subroutines in ROM version 7 and above that you can use in writing your own programs. By examining the ROM listing you can see these subroutines. The ROM listing is commented, so you can probably figure out how the subroutines work, how to pass values, and how the subroutines return data to your program. To use a subroutine in your own programs, you need to put the subroutine entry point labels in a header, with the entry point addresses. For example, if you want to use the `get_line` subroutine, put this line in your assembly language file:

```
get_line:     equ     0149h
```

Then you can use call get_line in your code to call the subroutine, and get input data from the keyboard. The other subroutines can be used in a similar way. Feel free to contact me if you have any questions about the ROM subroutines, or how to use them in programs.

Serial Interface Schematic and Explanation



Note C5 and C6 the positive is toward pin 2 on U6 and U7

Port 2 (10 binary) = Data
Port 3 (11 binary) = Control

A1	A0	C/D
0	0	0
0	1	1
1	0	0
1	1	1

A1	A0	I/O Req	CS*
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

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 main IC is the UART (Universal Asynchronus Receiver/Transmitter). The heart of this device is shift register. The shift register accepts parallel input from the 8 data bus lines D7 to D0, and then, driven by a clock input, shifts this 8-bit word one bit at a time onto a single serial output, labeled TxD for transmitted data. Similary, a serial input can be clocked one bit at a time through the RxD input into the shift register, and the resulting 8-bit word read out onto the parallel data bus. The UART has bidirectional data inputs/outputs so it can be connected directly to the computer data bus.

The NAND gate U1 A is used for the chip select logic, to make sure the UART chip is selected only when the proper input/output instruction and port address are used. The other NAND gates are configured as inverters to create the proper Read, Write, and Reset inputs for the UART.

Standard RS-232 serial ports use defined baud (bits-per-second) rates to send and receive serial data. To create an acceptable baud rate, a 1.8432 MHz signal from the oscillator is divided by 12 by the 74LS92 chip to yield a 153600 baud signal. This signal is fed to the TxC and RxC (transmitter and receiver clock) inputs, and is divided by 16 inside the UART, to create the final 9600 baud rate used in the interface. The computer 2 MHz system clock is fed to the UART Clock input which is used for internal fine timing to find the center of the incoming and outgoing serial bits, and for timing inputs and outputs to the data bus. The system Reset signal, which resets the Z80, is also sent to the UART. After a reset, the UART needs to be initialized by writing mode and command words to its control port. See the ROM listing for details.

The RS-232 serial communication protocol requires the serial data bits to have voltage levels of + or – 5 to 25 V. The voltage range between + 3 and -3 V is invalid. This design helps reduce noise on the interface. However, the power supply for the Z80 computer can only supply +5V, not -5V, so it cannot be used directly for serial communication over this interface. The MAX232N chips are specially designed to create the proper voltages for RS-232 serial communications using a single +5V power source. They use the 1 uF capacitors and internal circuitry to create a “charge pump” to boost the voltage to proper levels. In this interface they create about + and – 8V.

Devices connected by a serial cable can be of two types, designated DTE (data terminal equipment) and DCE (data communication equipment). This comes from the early days when a Teletype (DTE) was connected to a modem (DCE) to allow text communication over phone lines. The serial signal transmitted from the Teletype on pin 2 of its 25-pin connector was received by the modem on the same pin. The signal was called TxD because the DTE defines the signal names. But inside the DCE, this signal had to be sent to the modem's UART RxD input, so it changes names once inside the interface. I designed this serial interface as DCE, because many people will have straight-through serial cables from connecting a PC (which has a DTE serial port) to a modem, and this same cable can be used to connect a PC to the Z80 computer. You can see that the RS-232 TxD signal on pin 3 of the 9-pin connector changes names inside the interface, and goes to the RxD input on the UART. The same is true of the TxD from the UART, going to the RS-232 RxD signal (pin 2) on the connector. The other signals, DSR, DTR, CTS, RTS are used by the connected devices to signal each other that they are able to receive or transmit. These signals can be read and written by the UART control/status port. The only one important in this interface is the RTS signal, which is fed to the CTS input on the UART. If this signal is not active, the UART will not send data. If your DTE cannot provide this signal for some reason you can just ground the UART pin 17 to allow transmission. The other signals can be used to allow hardware flow control, but this is not needed for this Z80 computer. In fact, if CTS on the UART is grounded, you can do serial communications with just three wires, TxD, RxD and ground.

Serial Interface Parts Organizer and List

Capacitor, 1 uF tantalum 10	Red LED 1	Resistor, 470 ohm Yellow-Violet-Brown 1	DIL16 socket 2
DIL28 socket 1	DB9 female connector 1	74LS00 1	Oscillator 1.8432 MHz 1
8251A UART 1	74LS92 1	MAX232N 2	

C1to C10	1 uF tantalum
D1	LED
IDC1 and 2	DIL16 socket
J1	DB9 female
R1	470 ohm
U1	74LS00
U2	OSC 1.8432 MHz
U3	8251A UART
U3 socket	DIL28 socket
U5	74LS92
U6 and U7	MAX232

Note: There is no U4

ROM Program Listing

```
# File 2K_ROM_7.asm
0000                                    org   00000h
0000              Start_of_RAM:         equ   0x0800
0000 c3 18 00                           jp    Get_address       ;Skip over message
0003 .. 00                              defm  "CPUville Z80 ROM v.7",0
0018 db 00        Get_address:          in    a,(0)             ;Get address from input ports
001a 6f                                 ld    l,a
001b db 01                              in    a,(1)
001d 67                                 ld    h,a
001e e9                                 jp    (hl)              ;Jump to the address
001f db 00        Port_Reflector:       in    a,(0)             ;Simple program to test ports
0021 d3 00                              out   (0),a
0023 db 01                              in    a,(1)
0025 d3 01                              out   (1),a
0027 c3 1f 00                           jp    Port_Reflector
002a 3e 00        Simple_Counter:       ld    a,000h            ;One-byte counter for slow clock
002c d3 00        Loop_1:               out   (0),a
002e 3c                                 inc   a
002f c3 2c 00                           jp    Loop_1
0032 2e 00        Count_to_a_million:   ld    l,000h            ;Two-byte (16-bit) counter
0034 26 00                              ld    h,000h            ;Clear registers
0036 3e 10        Loop_2:               ld    a,010h            ;Count 16 times, then
0038 3d           Loop_3:               dec   a
0039 c2 38 00                           jp    nz,Loop_3
003c 23                                 inc   hl                ;increment the 16-bit number
003d 7d                                 ld    a,l
003e d3 00                              out   (0),a             ;Output the 16-bit number
0040 7c                                 ld    a,h
0041 d3 01                              out   (1),a
0043 c3 36 00                           jp    Loop_2            ;Do it again
0046 21 00 08     Program_loader:       ld    hl,Start_of_RAM   ;Load a program in RAM
0049 db 01        Loop_4:               in    a,(1)
004b e6 81                              and   081h              ;Check input port 1
004d ca 49 00                           jp    z,Loop_4          ;If switches 0 and 7 open, loop
0050 cd f5 00                           call  debounce
0053 db 01                              in    a,(1)             ;Get input port byte again
```

```
0055 e6 80                          and   080h              ;Is the left switch (bit 7) closed?
0057 c2 00 08                       jp    nz,Start_of_RAM   ;Yes, run loaded program
005a db 00                          in    a,(0)             ;No, then right switch (bit 0) closed.
005c d3 00                          out   (0),a             ;Get byte from port 0, display on output
005e 77                             ld    (hl),a            ;Store it in RAM
005f 3e ff                          ld    a,0ffh            ;Turn port 1 lights on (signal that
0061 d3 01                          out   (1),a             ;a byte was stored)
0063 db 01        Loop_6:           in    a,(1)             ;Wait for switch to open
0065 e6 01                          and   001h
0067 c2 63 00                       jp    nz,Loop_6
006a cd f5 00                       call  debounce
006d 7d                             ld    a,l               ;Put low byte of address on port 1
006e d3 01                          out   (1),a
0070 23                             inc   hl                ;Point to next location in RAM
0071 c3 49 00                       jp    Loop_4            ;Do it again
0074 21 00 08     Memory_test:      ld    hl,Start_of_RAM   ;check RAM by writing and reading each location
0077 db 01        Loop_8:           in    a,(1)             ;read port 1 to get a bit pattern
0079 47                             ld    b,a               ;copy it to register b
007a 77                             ld    (hl),a            ;store it in memory
007b 7e                             ld    a,(hl)            ;read back the same location
007c b8                             cp    b                 ;same as reg b?
007d c2 84 00                       jp    nz,Exit_1         ;no, test failed, exit
0080 23                             inc   hl                ;yes, RAM location OK
0081 c3 77 00                       jp    Loop_8            ;keep going
0084 7c           Exit_1:           ld    a,h               ;display the address
0085 d3 01                          out   (1),a             ;where the test failed
0087 7d                             ld    a,l               ;should be 4K (cycled around to ROM)
0088 d3 00                          out   (0),a             ;any other value means bad RAM
008a c3 74 00                       jp    Memory_test       ;do it again (use a different bit pattern)
008d db 00        Peek:             in    a,(0)             ;Get low byte
008f 6f                             ld    l,a               ;Put in reg L
0090 db 01                          in    a,(1)             ;Get hi byte
0092 67                             ld    h,a               ;Put in reg H
0093 7e                             ld    a,(hl)            ;Get byte from memory
0094 d3 00                          out   (0),a             ;Display on port 0 LEDs
0096 c3 8d 00                       jp    Peek              ;Do it again
0099 3e 00        Poke:             ld    a,000h            ;Clear output port LEDs
009b d3 00                          out   (0),a
009d d3 01                          out   (1),a
009f db 01        Loop_9:           in    a,(1)             ;Look for switch closure
```

```
00a1 e6 01                          and   001h
00a3 ca 9f 00                       jp    z,Loop_9
00a6 cd f5 00                       call  debounce
00a9 3e ff                          ld    a,0ffh           ;Light port 1 LEDs
00ab d3 01                          out   (1),a
00ad db 00                          in    a,(0)            ;Get hi byte
00af 67                             ld    h,a              ;Put in reg H
00b0 db 01        Loop_11:          in    a,(1)            ;Look for switch open
00b2 e6 01                          and   001h
00b4 c2 b0 00                       jp    nz,Loop_11
00b7 cd f5 00                       call  debounce
00ba 7c                             ld    a,h              ;Show hi byte on port 1
00bb d3 01                          out   (1),a
00bd db 01        Loop_13:          in    a,(1)            ;Look for switch closure
00bf e6 01                          and   001h
00c1 ca bd 00                       jp    z,Loop_13
00c4 cd f5 00                       call  debounce
00c7 3e ff                          ld    a,0ffh           ;Light port 0 LEDs
00c9 d3 00                          out   (0),a
00cb db 00                          in    a,(0)            ;Get lo byte
00cd 6f                             ld    l,a              ;Put in reg L
00ce db 01        Loop_15:          in    a,(1)            ;Look for switch open
00d0 e6 01                          and   001h
00d2 c2 ce 00                       jp    nz,Loop_15
00d5 cd f5 00                       call  debounce
00d8 7d                             ld    a,l              ;Show lo byte on port 0
00d9 d3 00                          out   (0),a
00db db 01        Loop_17:          in    a,(1)            ;Look for switch closure
00dd e6 01                          and   001h
00df ca db 00                       jp    z,Loop_17
00e2 cd f5 00                       call  debounce
00e5 db 00                          in    a,(0)            ;Get byte to load
00e7 77                             ld    (hl),a           ;Store in memory
00e8 db 01        Loop_19:          in    a,(1)            ;Look for switch open
00ea e6 01                          and   001h
00ec c2 e8 00                       jp    nz,Loop_19
00ef cd f5 00                       call  debounce
00f2 c3 99 00                       jp    Poke             ;Start over
00f5              ;
00f5              ;Subroutine for a switch debounce delay
```

```
00f5 3e 10        debounce:              ld    a,010h            ;Outer loop
00f7 06 ff        debounce_loop:         ld    b,0ffh            ;Inner loop
00f9 10 fe                               djnz  $+0               ;Loop here until B reg is zero
00fb 3d                                  dec   a
00fc c2 f7 00                            jp    nz,debounce_loop
00ff c9                                  ret
0100              ;
0100              ;The following code is for a system with a serial port.
0100              ;Assumes the UART data port address is 02h and control/status address is 03h
0100              ;
0100              ;The subroutines for the serial port use these variables in high RAM:
0100              current_location:      equ   0x0f80            ;word variable in RAM
0100              line_count:            equ   0x0f82            ;byte variable in RAM
0100              byte_count:            equ   0x0f83            ;byte variable in RAM
0100              value_pointer:         equ   0x0f84            ;word variable in RAM
0100              current_value:         equ   0x0f86            ;word variable in RAM
0100              buffer:                equ   0x0f88            ;buffer in RAM -- up to stack area
0100              ;
0100              ;Subroutine to initialize serial port UART
0100              ;Needs to be called only once after computer comes out of reset.
0100              ;If called while port is active will cause port to fail.
0100              ;16x = 9600 baud
0100 3e 4e        initialize_port:       ld    a,04eh            ;1 stop bit, no parity, 8-bit char, 16x baud
0102 d3 03                               out   (3),a             ;write to control port
0104 3e 37                               ld    a,037h            ;enable receive and transmit
0106 d3 03                               out   (3),a             ;write to control port
0108 c9                                  ret
0109              ;
0109              ;Puts a single char (byte value) on serial output
0109              ;Call with char to send in A register. Uses B register
0109 47           write_char:            ld    b,a               ;store char
010a db 03        write_char_loop:       in    a,(3)             ;check if OK to send
010c e6 01                               and   001h              ;check TxRDY bit
010e ca 0a 01                            jp    z,write_char_loop ;loop if not set
0111 78                                  ld    a,b               ;get char back
0112 d3 02                               out   (2),a             ;send to output
0114 c9                                  ret                     ;returns with char in a
0115              ;
0115              ;Subroutine to write a zero-terminated string to serial output
0115              ;Pass address of string in HL register
```

```
0115                ;No error checking
0115 db 03          write_string:           in    a,(3)             ;read status
0117 e6 01                                  and   001h              ;check TxRDY bit
0119 ca 15 01                               jp    z,write_string    ;loop if not set
011c 7e                                     ld    a,(hl)            ;get char from string
011d a7                                     and   a                 ;check if 0
011e c8                                     ret   z                 ;yes, finished
011f d3 02                                  out   (2),a             ;no, write char to output
0121 23                                     inc   hl                ;next char in string
0122 c3 15 01                               jp    write_string            ;start over
0125                ;
0125                ;Binary loader. Receive a binary file, place in memory.
0125                ;Address of load passed in HL, length of load (= file length) in BC
0125 db 03          bload:                  in    a,(3)             ;get status
0127 e6 02                                  and   002h              ;check RxRDY bit
0129 ca 25 01                               jp    z,bload           ;not ready, loop
012c db 02                                  in    a,(2)
012e 77                                     ld    (hl),a
012f 23                                     inc   hl
0130 0b                                     dec   bc                ;byte counter
0131 78                                     ld    a,b               ;need to test BC this way because
0132 b1                                     or    c                 ;dec rp instruction does not change flags
0133 c2 25 01                               jp    nz,bload
0136 c9                                     ret
0137                ;
0137                ;Binary dump to port. Send a stream of binary data from memory to serial output
0137                ;Address of dump passed in HL, length of dump in BC
0137 db 03          bdump:                  in    a,(3)             ;get status
0139 e6 01                                  and   001h              ;check TxRDY bit
013b ca 37 01                               jp    z,bdump           ;not ready, loop
013e 7e                                     ld    a,(hl)
013f d3 02                                  out   (2),a
0141 23                                     inc   hl
0142 0b                                     dec   bc
0143 78                                     ld    a,b               ;need to test this way because
0144 b1                                     or    c                 ;dec rp instruction does not change flags
0145 c2 37 01                               jp    nz,bdump
0148 c9                                     ret
0149                ;
0149                ;Subroutine to get a string from serial input, place in buffer.
```

```
0149              ;Buffer address passed in HL reg.
0149              ;Uses A,BC,DE,HL registers (including calls to other subroutines).
0149              ;Line entry ends by hitting return key. Return char not included in string (replaced by zero).
0149              ;Backspace editing OK. No error checking.
0149              ;
0149 0e 00        get_line:               ld    c,000h              ;line position
014b 7c                                   ld    a,h                 ;put original buffer address in de
014c 57                                   ld    d,a                 ;after this don't need to preserve hl
014d 7d                                   ld    a,l                 ;subroutines called don't use de
014e 5f                                   ld    e,a
014f db 03        get_line_next_char:     in    a,(3)                     ;get status
0151 e6 02                                and   002h                      ;check RxRDY bit
0153 ca 4f 01                             jp    z,get_line_next_char      ;not ready, loop
0156 db 02                                in    a,(2)                     ;get char
0158 fe 0d                                cp    00dh                      ;check if return
015a c8                                   ret   z                         ;yes, normal exit
015b fe 7f                                cp    07fh                      ;check if backspace (VT102 keys)
015d ca 71 01                             jp    z,get_line_backspace      ;yes, jump to backspace routine
0160 fe 08                                cp    008h                      ;check if backspace (ANSI keys)
0162 ca 71 01                             jp    z,get_line_backspace      ;yes, jump to backspace
0165 cd 09 01                             call  write_char                ;put char on screen
0168 12                                   ld    (de),a                    ;store char in buffer
0169 13                                   inc   de                        ;point to next space in buffer
016a 0c                                   inc   c                         ;inc counter
016b 3e 00                                ld    a,000h
016d 12                                   ld    (de),a                    ;leaves a zero-terminated string in buffer
016e c3 4f 01                             jp    get_line_next_char
0171 79           get_line_backspace:     ld    a,c                       ;check current position in line
0172 fe 00                                cp    000h                      ;at beginning of line?
0174 ca 4f 01                             jp    z,get_line_next_char      ;yes, ignore backspace, get next char
0177 1b                                   dec   de                        ;no, erase char from buffer
0178 0d                                   dec   c                         ;back up one
0179 3e 00                                ld    a,000h                    ;replace last char with zero
017b 12                                   ld    (de),a
017c 21 e1 03                             ld    hl,erase_char_string      ;ANSI seq. to delete one char
017f cd 15 01                             call  write_string              ;backspace and erase char
0182 c3 4f 01                             jp    get_line_next_char
0185              ;
0185              ;Creates a two-char hex string from the byte value passed in register A
0185              ;Location to place string passed in HL
```

```
0185                ;String is zero-terminated, stored in 3 locations starting at HL
0185                ;Also uses registers b,d, and e
0185 47             byte_to_hex_string:     ld    b,a               ;store original byte
0186 cb 3f                                  srl   a                 ;shift right 4 times, putting
0188 cb 3f                                  srl   a                 ;high nybble in low-nybble spot
018a cb 3f                                  srl   a                 ;and zeros in high-nybble spot
018c cb 3f                                  srl   a
018e 16 00                                  ld    d,000h            ;prepare for 16-bit addition
0190 5f                                     ld    e,a               ;de contains offset
0191 e5                                     push  hl                ;temporarily store string target address
0192 21 eb 01                               ld    hl,hex_char_table ;use char table to get high-nybble character
0195 19                                     add   hl,de             ;add offset to start of table
0196 7e                                     ld    a,(hl)            ;get char
0197 e1                                     pop   hl                ;get string target address
0198 77                                     ld    (hl),a            ;store first char of string
0199 23                                     inc   hl                ;point to next string target address
019a 78                                     ld    a,b               ;get original byte back from reg b
019b e6 0f                                  and   00fh              ;mask off high-nybble
019d 5f                                     ld    e,a               ;d still has 000h, now de has offset
019e e5                                     push  hl                ;temp store string target address
019f 21 eb 01                               ld    hl,hex_char_table ;start of table
01a2 19                                     add   hl,de             ;add offset
01a3 7e                                     ld    a,(hl)            ;get char
01a4 e1                                     pop   hl                ;get string target address
01a5 77                                     ld    (hl),a            ;store second char of string
01a6 23                                     inc   hl                ;point to third location
01a7 3e 00                                  ld    a,000h            ;zero to terminate string
01a9 77                                     ld    (hl),a            ;store the zero
01aa c9                                     ret                     ;done
01ab                ;
01ab                ;Converts a single ASCII hex char to a nybble value
01ab                ;Pass char in reg A. Letter numerals must be upper case.
01ab                ;Return nybble value in low-order reg A with zeros in high-order nybble if no error.
01ab                ;Return 0ffh in reg A if error (char not a valid hex numeral).
01ab                ;Also uses b, c, and hl registers.
01ab 21 eb 01       hex_char_to_nybble:     ld    hl,hex_char_table
01ae 06 0f                                  ld    b,00fh                  ;no. of valid characters in table - 1.
01b0 0e 00                                  ld    c,000h                  ;will be nybble value
01b2 be             hex_to_nybble_loop:     cp    (hl)                    ;character match here?
01b3 ca bf 01                               jp    z,hex_to_nybble_ok      ;match found, exit
```

```
01b6 05                                 dec   b                       ;no match, check if at end of table
01b7 fa c1 01                           jp    m,hex_to_nybble_err     ;table limit exceded, exit with error
01ba 0c                                 inc   c                       ;still inside table, continue search
01bb 23                                 inc   hl
01bc c3 b2 01                           jp    hex_to_nybble_loop
01bf 79            hex_to_nybble_ok:    ld    a,c                     ;put nybble value in a
01c0 c9                                 ret
01c1 3e ff         hex_to_nybble_err:   ld    a,0ffh                  ;error value
01c3 c9                                 ret
01c4               ;
01c4               ;Converts a hex character pair to a byte value
01c4               ;Called with location of high-order char in HL
01c4               ;If no error carry flag clear, returns with byte value in register A, and
01c4               ;HL pointing to next mem location after char pair.
01c4               ;If error (non-hex char) carry flag set, HL pointing to invalid char
01c4 7e            hex_to_byte:         ld    a,(hl)            ;location of character pair
01c5 e5                                 push  hl                ;store hl (hex_char_to_nybble uses it)
01c6 cd ab 01                           call  hex_char_to_nybble
01c9 e1                                 pop   hl                ;returns with nybble in a reg, or 0ffh if error
01ca fe ff                              cp    0ffh              ;non-hex character?
01cc ca e9 01                           jp    z,hex_to_byte_err ;yes, exit with error
01cf cb 27                              sla   a                 ;no, move low order nybble to high side
01d1 cb 27                              sla   a
01d3 cb 27                              sla   a
01d5 cb 27                              sla   a
01d7 57                                 ld    d,a               ;store high-nybble
01d8 23                                 inc   hl                ;get next character of the pair
01d9 7e                                 ld    a,(hl)
01da e5                                 push  hl                ;store hl
01db cd ab 01                           call  hex_char_to_nybble
01de e1                                 pop   hl
01df fe ff                              cp    0ffh              ;non-hex character?
01e1 ca e9 01                           jp    z,hex_to_byte_err ;yes, exit with error
01e4 b2                                 or    d                 ;no, combine with high-nybble
01e5 23                                 inc   hl                ;point to next memory location after char pair
01e6 37                                 scf
01e7 3f                                 ccf                     ;no-error exit (carry = 0)
01e8 c9                                 ret
01e9 37            hex_to_byte_err:     scf                     ;error, carry flag set
01ea c9                                 ret
```

```
01eb ..          hex_char_table:        defm  "0123456789ABCDEF"      ;ASCII hex table
01fb             ;
01fb             ;Subroutine to get a two-byte address from serial input.
01fb             ;Returns with address value in HL
01fb             ;Uses locations in RAM for buffer and variables
01fb 21 88 0f    address_entry:         ld    hl,buffer               ;location for entered string
01fe cd 49 01                           call  get_line                ;returns with address string in buffer
0201 21 88 0f                           ld    hl,buffer               ;location of stored address entry string
0204 cd c4 01                           call  hex_to_byte             ;will get high-order byte first
0207 da 1d 02                           jp    c, address_entry_error  ;if error, jump
020a 32 81 0f                           ld    (current_location+1),a  ;store high-order byte, little-endian
020d 21 8a 0f                           ld    hl,buffer+2             ;point to low-order hex char pair
0210 cd c4 01                           call  hex_to_byte             ;get low-order byte
0213 da 1d 02                           jp    c, address_entry_error  ;jump if error
0216 32 80 0f                           ld    (current_location),a    ;store low-order byte in lower memory
0219 2a 80 0f                           ld    hl,(current_location)   ;put memory address in hl
021c c9                                 ret
021d 21 1f 04    address_entry_error:   ld    hl,address_error_msg
0220 cd 15 01                           call  write_string
0223 c3 fb 01                           jp    address_entry
0226             ;
0226             ;Subroutine to get a decimal string, return a word value
0226             ;Calls decimal_string_to_word subroutine
0226 21 88 0f    decimal_entry:         ld    hl,buffer
0229 cd 49 01                           call  get_line          ;returns with DE pointing to terminating zero
022c 21 88 0f                           ld    hl,buffer
022f cd 3c 02                           call  decimal_string_to_word
0232 d0                                 ret   nc                ;no error, return with word in hl
0233 21 93 04                           ld    hl,decimal_error_msg    ;error, try again
0236 cd 15 01                           call  write_string
0239 c3 26 02                           jp    decimal_entry
023c             ;
023c             ;Subroutine to convert a decimal string to a word value
023c             ;Call with address of string in HL, pointer to end of string in DE
023c             ;Carry flag set if error (non-decimal char)
023c             ;Carry flag clear, word value in HL if no error.
023c 42          decimal_string_to_word: ld   b,d
023d 4b                                 ld    c,e                     ;use BC as string pointer
023e 22 80 0f                           ld    (current_location),hl   ;store addr. of start of buffer in RAM
0241 21 00 00                           ld    hl,000h                 ;starting value zero
```

```
0244 22 86 0f                         ld    (current_value),hl
0247 21 8c 02                         ld    hl,decimal_place_value  ;pointer to values
024a 22 84 0f                         ld    (value_pointer),hl
024d 0b            decimal_next_char:      dec   bc                      ;next char in string (moving R to L)
024e 2a 80 0f                         ld    hl,(current_location)   ;check if at end of decimal string
0251 37                               scf
0252 3f                               ccf                           ;set carry to zero (clear)
0253 ed 42                            sbc   hl,bc                   ;cont. if bc > or = hl (buffer address)
0255 da 61 02                         jp    c,decimal_continue      ;borrow means bc > hl
0258 ca 61 02                         jp    z,decimal_continue      ;z means bc = hl
025b 2a 86 0f                         ld    hl,(current_value)      ;return if de < buffer address (no borrow)
025e 37                               scf                           ;get value back from RAM variable
025f 3f                               ccf
0260 c9                               ret                           ;return with carry clear, value in hl
0261 0a            decimal_continue:       ld    a,(bc)                  ;next char in string (right to left)
0262 d6 30                            sub   030h                    ;ASCII value of zero char
0264 fa 87 02                         jp    m,decimal_error         ;error if char value less than 030h
0267 fe 0a                            cp    00ah                    ;error if byte value > or = 10 decimal
0269 f2 87 02                         jp    p,decimal_error         ;a reg now has value of decimal numeral
026c 2a 84 0f                         ld    hl,(value_pointer)      ;get value to add an put in de
026f 5e                               ld    e,(hl)                  ;little-endian (low byte in low memory)
0270 23                               inc   hl
0271 56                               ld    d,(hl)
0272 23                               inc   hl                      ;hl now points to next value
0273 22 84 0f                         ld    (value_pointer),hl
0276 2a 86 0f                         ld    hl,(current_value)      ;get back current value
0279 3d            decimal_add:            dec   a                       ;add loop to increase total value
027a fa 81 02                         jp    m,decimal_add_done      ;end of multiplication
027d 19                               add   hl,de
027e c3 79 02                         jp    decimal_add
0281 22 86 0f      decimal_add_done:       ld    (current_value),hl
0284 c3 4d 02                         jp    decimal_next_char
0287 37            decimal_error:          scf
0288 c9                               ret
0289 c3 79 02                         jp    decimal_add
028c 01 00 0a 00 64 00 e8 03 10 27  decimal_place_value:    defw  1,10,100,1000,10000
0296               ;
0296               ;Memory dump
0296               ;Displays a 256-byte block of memory in 16-byte rows.
0296               ;Called with address of start of block in HL
```

```
0296 22 80 0f     memory_dump:         ld    (current_location),hl   ;store address of block to be displayed
0299 3e 00                             ld    a,000h
029b 32 83 0f                          ld    (byte_count),a          ;initialize byte count
029e 32 82 0f                          ld    (line_count),a          ;initialize line count
02a1 c3 d6 02                          jp    dump_new_line
02a4 2a 80 0f     dump_next_byte:      ld    hl,(current_location)   ;get byte address from storage,
02a7 7e                                ld    a,(hl)                  ;get byte to be converted to string
02a8 23                                inc   hl                      ;increment address and
02a9 22 80 0f                          ld    (current_location),hl   ;store back
02ac 21 88 0f                          ld    hl,buffer               ;location to store string
02af cd 85 01                          call  byte_to_hex_string      ;convert
02b2 21 88 0f                          ld    hl,buffer               ;display string
02b5 cd 15 01                          call  write_string
02b8 3a 83 0f                          ld    a,(byte_count)          ;next byte
02bb 3c                                inc   a
02bc ca 06 03                          jp    z,dump_done             ;stop when 256 bytes displayed
02bf 32 83 0f                          ld    (byte_count),a          ;not finished yet, store
02c2 3a 82 0f                          ld    a,(line_count)          ;end of line (16 characters)?
02c5 fe 0f                             cp    00fh                    ;yes, start new line
02c7 ca d6 02                          jp    z,dump_new_line
02ca 3c                                inc   a                       ;no, increment line count
02cb 32 82 0f                          ld    (line_count),a
02ce 3e 20                             ld    a,020h                  ;print space
02d0 cd 09 01                          call  write_char
02d3 c3 a4 02                          jp    dump_next_byte          ;continue
02d6 3e 00        dump_new_line:       ld    a,000h                  ;reset line count to zero
02d8 32 82 0f                          ld    (line_count),a
02db cd 86 03                          call  write_newline
02de 2a 80 0f                          ld    hl,(current_location)   ;location of start of line
02e1 7c                                ld    a,h                     ;high byte of address
02e2 21 88 0f                          ld    hl, buffer
02e5 cd 85 01                          call  byte_to_hex_string      ;convert
02e8 21 88 0f                          ld    hl,buffer
02eb cd 15 01                          call  write_string            ;write high byte
02ee 2a 80 0f                          ld    hl,(current_location)
02f1 7d                                ld    a,l                     ;low byte of address
02f2 21 88 0f                          ld    hl, buffer
02f5 cd 85 01                          call  byte_to_hex_string      ;convert
02f8 21 88 0f                          ld    hl,buffer
02fb cd 15 01                          call  write_string            ;write low byte
```

```
02fe 3e 20                      ld    a,020h                  ;space
0300 cd 09 01                   call  write_char
0303 c3 a4 02                   jp    dump_next_byte          ;now write 16 bytes
0306 3e 00        dump_done:    ld    a,000h
0308 21 88 0f                   ld    hl,buffer
030b 77                         ld    (hl),a                  ;clear buffer of last string
030c cd 86 03                   call  write_newline
030f c9                         ret
0310              ;
0310              ;Memory load
0310              ;Loads RAM memory with bytes entered as hex characters
0310              ;Called with address to start loading in HL
0310              ;Displays entered data in 16-byte rows.
0310 22 80 0f     memory_load:  ld    (current_location),hl
0313 21 4b 04                   ld    hl,data_entry_msg
0316 cd 15 01                   call  write_string
0319 c3 63 03                   jp    load_new_line
031c cd 7c 03     load_next_char: call get_char
031f fe 0d                      cp    00dh                    ;return char entered?
0321 ca 78 03                   jp    z,load_done             ;yes, quit
0324 32 88 0f                   ld    (buffer),a
0327 cd 7c 03                   call  get_char
032a fe 0d                      cp    00dh                    ;return?
032c ca 78 03                   jp    z,load_done             ;yes, quit
032f 32 89 0f                   ld    (buffer+1),a
0332 21 88 0f                   ld    hl,buffer
0335 cd c4 01                   call  hex_to_byte
0338 da 6e 03                   jp    c,load_data_entry_error ;non-hex character
033b 2a 80 0f                   ld    hl,(current_location)   ;get byte address from storage,
033e 77                         ld    (hl),a                  ;store byte
033f 23                         inc   hl                      ;increment address and
0340 22 80 0f                   ld    (current_location),hl   ;store back
0343 3a 88 0f                   ld    a,(buffer)
0346 cd 09 01                   call  write_char
0349 3a 89 0f                   ld    a,(buffer+1)
034c cd 09 01                   call  write_char
034f 3a 82 0f                   ld    a,(line_count)          ;end of line (16 characters)?
0352 fe 0f                      cp    00fh                    ;yes, start new line
0354 ca 63 03                   jp    z,load_new_line
0357 3c                         inc   a                       ;no, increment line count
```

```
0358 32 82 0f                         ld    (line_count),a
035b 3e 20                            ld    a,020h                  ;print space
035d cd 09 01                         call  write_char
0360 c3 1c 03                         jp    load_next_char          ;continue
0363 3e 00       load_new_line:       ld    a,000h                  ;reset line count to zero
0365 32 82 0f                         ld    (line_count),a
0368 cd 86 03                         call  write_newline
036b c3 1c 03                         jp    load_next_char          ;continue
036e cd 86 03    load_data_entry_error:  call  write_newline
0371 21 78 04                         ld    hl,data_error_msg
0374 cd 15 01                         call  write_string
0377 c9                               ret
0378 cd 86 03    load_done:           call  write_newline
037b c9                               ret
037c             ;
037c             ;Get one ASCII character from the serial port.
037c             ;Returns with char in A reg. No error checking.
037c db 03       get_char:            in    a,(3)             ;get status
037e e6 02                            and   002h              ;check RxRDY bit
0380 ca 7c 03                         jp    z,get_char        ;not ready, loop
0383 db 02                            in    a,(2)             ;get char
0385 c9                               ret
0386             ;
0386             ;Subroutine to start a new line
0386 3e 0d       write_newline:       ld    a,00dh                  ;ASCII carriage return character
0388 cd 09 01                         call  write_char
038b 3e 0a                            ld    a,00ah                  ;new line (line feed) character
038d cd 09 01                         call  write_char
0390 c9                               ret
0391             ;
0391             ;Strings used in subroutines
0391 .. 00       length_entry_string:   defm  "Enter length of file to load (decimal): ",0
03ba .. 00       dump_entry_string:     defm  "Enter no. of bytes to dump (decimal): ",0
03e1 08 1b .. 00 erase_char_string:     defm  008h,01bh,"[K",000h     ;ANSI seq. for BS, erase to end of line.
03e6 .. 00       address_entry_msg:     defm  "Enter 4-digit hex address (use upper-case A through F): ",0
041f .. 00       address_error_msg:     defm  "\r\nError: invalid hex character, try again: ",0
044b .. 00       data_entry_msg:        defm  "Enter hex bytes, hit return when finished.\r\n",0
0478 .. 00       data_error_msg:        defm  "Error: invalid hex byte.\r\n",0
0493 .. 00       decimal_error_msg:     defm  "\r\nError: invalid decimal number, try again: ",0
04c0             ;
```

```
04c0                ;Simple monitor program for CPUville Z80 computer with serial interface.
04c0 cd 00 01       monitor_cold_start:     call  initialize_port
04c3 21 da 05                               ld    hl,monitor_message
04c6 cd 15 01                               call  write_string
04c9 cd 86 03       monitor_warm_start:     call  write_newline     ;return here to avoid re-initialization of port
04cc 3e 3e                                  ld    a,03eh            ;prompt (cursor symbol)
04ce cd 09 01                               call  write_char
04d1 21 88 0f                               ld    hl,buffer
04d4 cd 49 01                               call  get_line          ;get monitor input string (command)
04d7 cd 86 03                               call  write_newline
04da cd de 04                               call  parse             ;interpret command, ret. With jump addr. in HL
04dd e9                                     jp    (hl)
04de                ;
04de                ;Parses an input line stored in buffer for available commands as described in parse table.
04de                ;Returns with address of jump to action for the command in HL
04de 01 9f 07       parse:                  ld    bc,parse_table    ;bc is pointer to parse_table
04e1 0a             parse_start:            ld    a,(bc)            ;get pointer to match string from parse table
04e2 5f                                     ld    e,a
04e3 03                                     inc   bc
04e4 0a                                     ld    a,(bc)
04e5 57                                     ld    d,a               ;de will is pointer to strings for matching
04e6 1a                                     ld    a,(de)            ;get first char from match string
04e7 f6 00                                  or    000h              ;zero?
04e9 ca 04 05                               jp    z,parser_exit     ;yes, exit no_match
04ec 21 88 0f                               ld    hl,buffer         ;no, parse input string
04ef be             match_loop:             cp    (hl)              ;compare buffer char with match string char
04f0 c2 fe 04                               jp    nz,no_match       ;no match, go to next match string
04f3 f6 00                                  or    000h              ;end of strings (zero)?
04f5 ca 04 05                               jp    z,parser_exit     ;yes, matching string found
04f8 13                                     inc   de                ;match so far, point to next char
04f9 1a                                     ld    a,(de)            ;get next character from match string
04fa 23                                     inc   hl                ;and point to next char in input string
04fb c3 ef 04                               jp    match_loop        ;check for match
04fe 03             no_match:               inc   bc                ;skip over jump target to
04ff 03                                     inc   bc
0500 03                                     inc   bc                ;get address of next matching string
0501 c3 e1 04                               jp    parse_start
0504 03             parser_exit:            inc   bc                ;skip to address of jump for match
0505 0a                                     ld    a,(bc)
0506 6f                                     ld    l,a
```

```
0507 03                             inc   bc
0508 0a                             ld    a,(bc)
0509 67                             ld    h,a               ;returns with jump address in hl
050a c9                             ret
050b            ;
050b            ;Actions to be taken on match
050b            ;
050b            ;Memory dump program
050b            ;Input 4-digit hexadecimal address
050b            ;Calls memory_dump subroutine
050b 21 4e 06   dump_jump:          ld    hl,dump_message         ;Display greeting
050e cd 15 01                       call  write_string
0511 21 e6 03                       ld    hl,address_entry_msg    ;get ready to get address
0514 cd 15 01                       call  write_string
0517 cd fb 01                       call  address_entry           ;returns with address in HL
051a cd 86 03                       call  write_newline
051d cd 96 02                       call  memory_dump
0520 c3 c9 04                       jp    monitor_warm_start
0523            ;
0523            ;Hex loader, displays formatted input
0523 21 75 06   load_jump:          ld    hl,load_message         ;Display greeting
0526 cd 15 01                       call  write_string            ;get address to load
0529 21 e6 03                       ld    hl,address_entry_msg    ;get ready to get address
052c cd 15 01                       call  write_string
052f cd fb 01                       call  address_entry
0532 cd 86 03                       call  write_newline
0535 cd 10 03                       call  memory_load
0538 c3 c9 04                       jp    monitor_warm_start
053b            ;
053b            ;Jump and run do the same thing: get an address and jump to it.
053b 21 a4 06   run_jump:           ld    hl,run_message          ;Display greeting
053e cd 15 01                       call  write_string
0541 21 e6 03                       ld    hl,address_entry_msg    ;get ready to get address
0544 cd 15 01                       call  write_string
0547 cd fb 01                       call  address_entry
054a e9                             jp    (hl)
054b            ;
054b            ;Help and ? do the same thing, display the available commands
054b 21 24 06   help_jump:          ld    hl,help_message
054e cd 15 01                       call  write_string
```

```
0551 01 9f 07                  ld    bc,parse_table    ;table with pointers to command strings
0554 0a         help_loop:     ld    a,(bc)            ;displays the strings for matching commands,
0555 6f                        ld    l,a               ;getting the string addresses from the
0556 03                        inc   bc                ;parse table
0557 0a                        ld    a,(bc)            ;pass address of string to hl through a reg
0558 67                        ld    h,a
0559 7e                        ld    a,(hl)            ;hl now points to start of match string
055a f6 00                     or    000h              ;exit if no_match string
055c ca 6f 05                  jp    z,help_done
055f c5                        push  bc                ;write_char uses b register
0560 3e 20                     ld    a,020h            ;space char
0562 cd 09 01                  call  write_char
0565 c1                        pop   bc
0566 cd 15 01                  call  write_string      ;writes match string
0569 03                        inc   bc                ;pass over jump address in table
056a 03                        inc   bc
056b 03                        inc   bc
056c c3 54 05                  jp    help_loop
056f c3 c9 04   help_done:     jp    monitor_warm_start
0572            ;
0572            ;Binary file load. Need both address to load and length of file
0572 21 d9 06   bload_jump:    ld    hl,bload_message
0575 cd 15 01                  call  write_string
0578 21 e6 03                  ld    hl,address_entry_msg
057b cd 15 01                  call  write_string
057e cd fb 01                  call  address_entry
0581 cd 86 03                  call  write_newline
0584 e5                        push  hl
0585 21 91 03                  ld    hl,length_entry_string
0588 cd 15 01                  call  write_string
058b cd 26 02                  call  decimal_entry
058e 44                        ld    b,h
058f 4d                        ld    c,l
0590 21 fc 06                  ld    hl,bload_ready_message
0593 cd 15 01                  call  write_string
0596 e1                        pop   hl
0597 cd 25 01                  call  bload
059a c3 c9 04                  jp    monitor_warm_start
059d            ;
059d            ;Binary memory dump. Need address of start of dump and no. bytes
```

```
059d 21 20 07     bdump_jump:             ld    hl,bdump_message
05a0 cd 15 01                             call  write_string
05a3 21 e6 03                             ld    hl,address_entry_msg
05a6 cd 15 01                             call  write_string
05a9 cd fb 01                             call  address_entry
05ac cd 86 03                             call  write_newline
05af e5                                   push  hl
05b0 21 ba 03                             ld    hl,dump_entry_string
05b3 cd 15 01                             call  write_string
05b6 cd 26 02                             call  decimal_entry
05b9 44                                   ld    b,h
05ba 4d                                   ld    c,l
05bb 21 50 07                             ld    hl,bdump_ready_message
05be cd 15 01                             call  write_string
05c1 cd 7c 03                             call  get_char
05c4 e1                                   pop   hl
05c5 cd 37 01                             call  bdump
05c8 c3 c9 04                             jp    monitor_warm_start
05cb              ;Prints message for no match to entered command
05cb 21 03 06     no_match_jump:          ld    hl,no_match_message
05ce cd 15 01                             call  write_string
05d1 21 88 0f                             ld    hl, buffer
05d4 cd 15 01                             call  write_string
05d7 c3 c9 04                             jp    monitor_warm_start
05da              ;
05da              ;Monitor data structures:
05da              ;
05da .. 00        monitor_message:  defm  "\r\nCPUville Z80 computer, ROM version 7\r\n",0
0603 .. 00        no_match_message: defm  "No match found for input string ",0
0624 .. 00        help_message:           defm  "The following commands are implemented:\r\n",0
064e .. 00        dump_message:           defm  "Displays a 256-byte block of memory.\r\n",0
0675 .. 00        load_message:           defm  "Enter hex bytes starting at memory location.\r\n",0
06a4 .. 00        run_message:            defm  "Will jump to (execute) program at address entered.\r\n",0
06d9 .. 00        bload_message:          defm  "Loads a binary file into memory.\r\n",0
06fc .. 00        bload_ready_message:    defm  "\n\rReady to receive, start transfer.",0
0720 .. 00        bdump_message:          defm  "Dumps binary data from memory to serial port.\r\n",0
0750 .. 00        bdump_ready_message:    defm  "\n\rReady to send, hit any key to start.",0
0777              ;Strings for matching:
0777 .. 00        dump_string:            defm  "dump",0
077c .. 00        load_string:            defm  "load",0
```

```
0781 .. 00        jump_string:           defm  "jump",0
0786 .. 00        run_string:            defm  "run",0
078a .. 00        question_string:       defm  "?",0
078c .. 00        help_string:           defm  "help",0
0791 .. 00        bload_string:          defm  "bload",0
0797 .. 00        bdump_string:          defm  "bdump",0
079d 00 00        no_match_string:       defm  0,0
079f              ;Table for matching strings to jumps
079f 77 07 0b 05 7c 07 23 05  parse_table:     defw  dump_string,dump_jump,load_string,load_jump
07a7 81 07 3b 05 86 07 3b 05                   defw  jump_string,run_jump,run_string,run_jump
07af 8a 07 4b 05 8c 07 4b 05                   defw  question_string,help_jump,help_string,help_jump
07b7 91 07 72 05 97 07 9d 05                   defw  bload_string,bload_jump,bdump_string,bdump_jump
07bf 9d 07 cb 05                               defw  no_match_string,no_match_jump
07c3
# End of file 2K_ROM_7.asm
07c3
```

User Program Listings

```
# File echo_char_test.asm
0000            ;Program to test serial port.
0000            ;To be entered with ROM Program_loader.
0000            ;Includes port initialization commands
0000            ;When running, should echo typed characters to display.
0000            ;Sends entered characters to output port 0 LEDs also.
0000                                    org   0800h            ;org not really needed, all jumps relative
0800 3e 4e                              ld    a,04eh           ;1 stop bit, no parity, 8-bit char, 16x baud
0802 d3 03                              out   (3),a            ;write to control port
0804 3e 37                              ld    a,037h           ;enable receive and transmit
0806 d3 03                              out   (3),a            ;write to control port
0808 db 03      echo_loop_1:            in    a,(3)            ;get status
080a e6 02                              and   002h             ;check RxRDY bit
080c 28 fa                              jr    z,echo_loop_1    ;not ready, loop
080e db 02                              in    a,(2)            ;get char
0810 d3 00                              out   (0),a            ;data to LEDs
0812 47                                 ld    b,a              ;save received char in b reg
0813 db 03      echo_loop_2:            in    a,(3)            ;get status
0815 e6 01                              and   001h             ;check TxRDY bit
0817 28 fa                              jr    z,echo_loop_2    ;loop if not set
0819 78                                 ld    a,b              ;get char back
081a d3 02                              out   (2),a            ;send to output
081c 18 ea                              jr    echo_loop_1      ;start over
081e
081e
# End of file echo_char_test.asm
081e

# File boot_loader.asm
0000            ;Minimal boot loader for system with ROM v. 6 and lower.
0000            ;Enter bytes on input port switches using Program_loader.
0000            ;Includes port initialization commands.
0000            ;When runs, will load 256 bytes from serial port into memory at 0900h and jump there.
0000                                    org   0800h            ;org not necessary, all jumps relative
0800 3e 4e                              ld    a,04eh           ;1 stop bit, no parity, 8-bit char, 16x baud
0802 d3 03                              out   (3),a            ;write to control port
```

```
0804 3e 37                               ld    a,037h            ;enable receive and transmit
0806 d3 03                               out   (3),a             ;write to control port
0808 21 00 09                            ld    hl,0900h          ;where to put received code
080b 06 ff                               ld    b,0ffh            ;number of bytes to receive
080d db 03        boot_receive_loop:     in    a,(3)             ;get status
080f e6 02                               and   002h              ;check Rx ready bit
0811 28 fa                               jr    z,boot_receive_loop    ;not ready, loop
0813 db 02                               in    a,(2)             ;ready, get byte
0815 77                                  ld    (hl),a            ;store in memory
0816 23                                  inc   hl                ;point to next location
0817 10 f4                               djnz  boot_receive_loop ;keep going
0819 c3 00 09                            jp    0900h             ;done, jump to received code block
081c
# End of file boot_loader.asm
081c
```

```
# File echo_char.asm
0000              ;Program to test serial port.
0000              ;Binary file can be entered using boot loader.
0000              ;When running, should echo typed characters to display.
0000              ;Sends entered characters to output port 0 LEDs also.
0000                                     org   0900h
0900 db 03        echo_loop_1:           in    a,(3)             ;get status
0902 d3 01                               out   (1),a             ;status to LEDs
0904 e6 02                               and   002h              ;check RxRDY bit
0906 ca 00 09                            jp    z,echo_loop_1     ;not ready, loop
0909 db 02                               in    a,(2)             ;get char
090b d3 00                               out   (0),a             ;data to LEDs
090d 47                                  ld    b,a               ;save received char in b reg
090e db 03        echo_loop_2:           in    a,(3)             ;get status
0910 e6 01                               and   001h              ;check TxRDY bit
0912 ca 0e 09                            jp    z,echo_loop_2     ;loop if not set
0915 78                                  ld    a,b               ;get char back
0916 d3 02                               out   (2),a             ;send to output
0918 c3 00 09                            jp    echo_loop_1       ;start over
091b 0x00...                             defs  250,000h          ;padding to make sure file is > or = 256 bytes
0a15
# End of file echo_char.asm
```