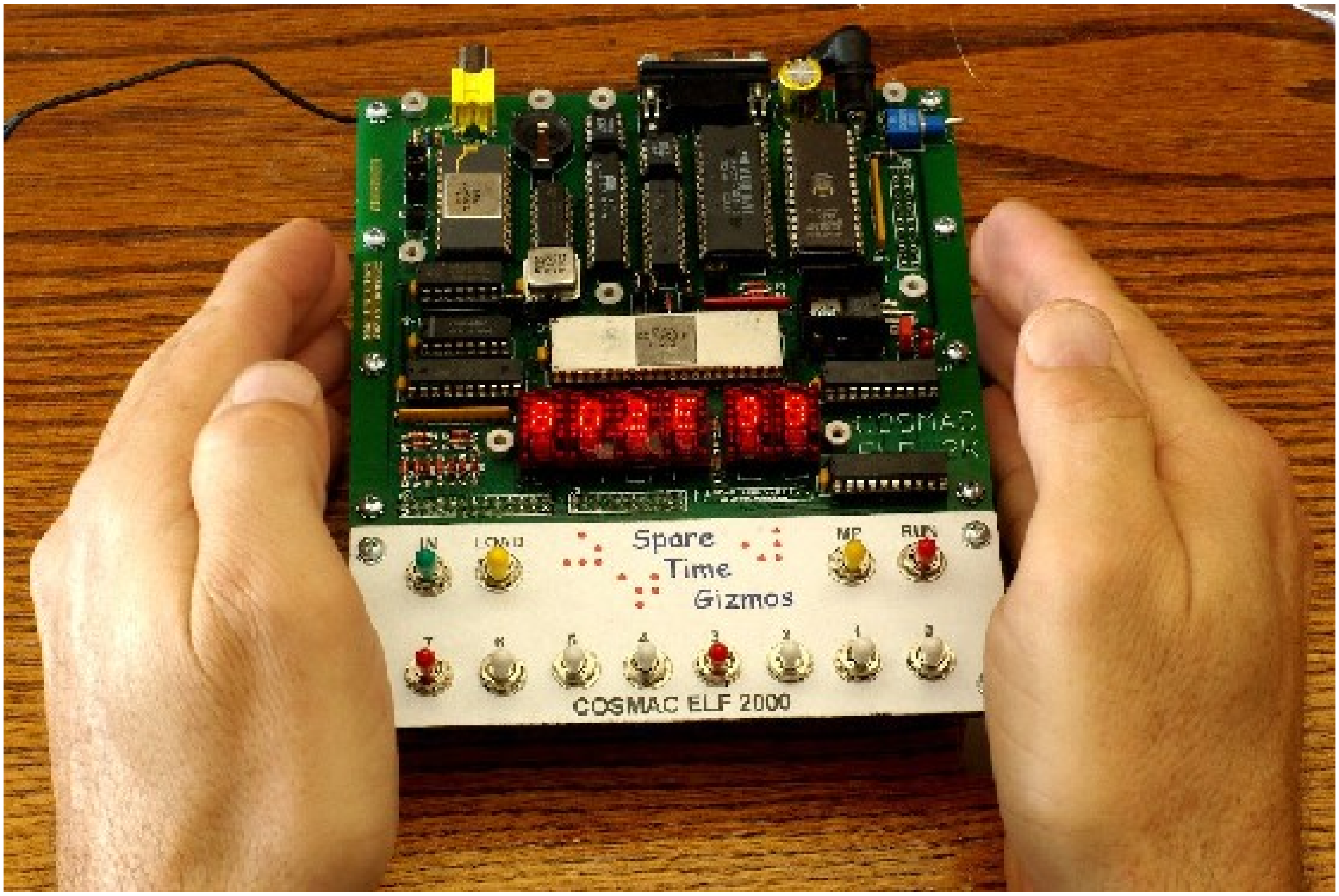
Spare Time Gizmos

COSMAC ELF 2000 USER'S MANUAL



Sixth Edition

CONTENTS

CONTENTS

1 OVERVIEW

The Spare Time Gizmos' COSMAC Elf 2000 is a reproduction of the original COSMAC Elf as published in the pages of Popular Electronics magazine, August 1976. Although we tried to keep the look and feel of the original, we had no hesitation about updating the Elf 2000 with the "latest" in hardware. Unlike its ancestor, the Spare Time Gizmos' COSMAC Elf 2000 features

- An expanded memory to 32K RAM and an optional 32K EPROM. The EPROM, if installed, contains a power on self test, extended hardware diagnostics, an Editor/Assembler, interpreters for the BASIC, FORTH and CHIP-8 languages, and a BIOS and bootstrap for the ElfOS disk operating system. A jumper is included to allow the CPU to start up at address 0x8000 (EPROM) rather than the normal 0x0000 (RAM).
- An included CDP1861 Pixie chip video display circuit. If you don't have an 1861, the Elf 2000 has space and standoffs to mount a daughter board that plugs into the 1861 socket and contains a discrete logic replacement for the 1861.
- An I/O expansion connector and mounting holes for I/O daughter cards that fit on top of the main board.

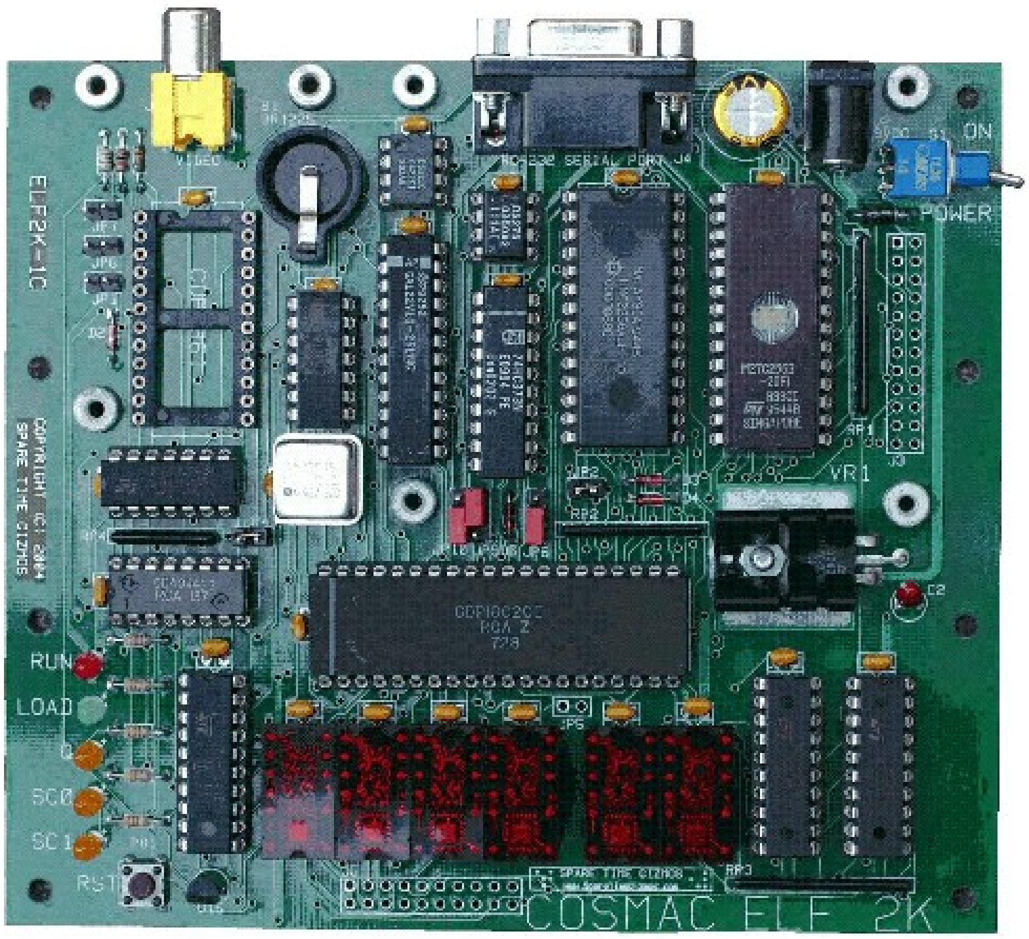


Photo 1 - The COSMAC Elf 2000

- An optional lithium coin cell and a Dallas DS1210 NVR controller to make the RAM non-volatile. Any programs you toggle in or download today will still be there tomorrow!
- A true RS-232 compatible serial port using a DS275 EIA level shifter and a DE9F connector.
- Fully decoded I/O ports, including the CDP1861, switches and display, so there will be no conflicts with any add on peripherals. In addition, all I/O decoding, memory mapping and other control functions are implemented in a 22V10 GAL so they can be easily changed without any wiring modifications.
- Six TIL311 displays for a full address and data display.
- Switches mounted on a separate piece of plastic or aluminum, like the original ELF, that connect to a header on the Elf 2000 PC board. If you don't like toggle switches, the Elf 2000 can also accommodate a Super Elf style hex keypad and push button controls.
- An automatic bootstrap to allow the Elf 2000 to be used without any switches or keypad. On power up, it can wait for download from a PC, or automatically begin running a program stored in EPROM or non-volatile RAM. A V_{CC} low voltage monitor in the Elf 2000 ensures that the CPU is reset on power up and power down regardless of the switch settings.
- A circuit that works with either the original CDP1802 chip or any of the later CDP1804/1805/1806 chips. The classic Elf "load" mode, of course, requires a genuine 1802 chip.

1.1 Regulatory Warning

In the United States, the Federal Communications Commission requires that devices that use and radiate radio frequency energy be certified in accordance with CFR Title 47, Parts 2 and 15. Other countries will have different requirements.

The COSMAC Elf 2000 design is not in finished product form and has NOT been approved by the FCC or any other regulatory agency worldwide. The user understands that approvals may be required prior to the operation of the Elf 2000, and agrees to utilize the Elf 2000 in keeping with all laws governing its operation in the country of use.

1.2 Safety Warning

The COSMAC Elf 2000 board uses a Lithium coin cell battery. There is a danger of explosion if this type of battery is incorrectly replaced. Replace with only the same or equivalent type recommended by the manufacturer. Dispose of used batteries only in accordance with the manufacturer's instructions.

1.3 Warranty

Spare Time Gizmos offers no warranty, express or implied, as to the reliability or accuracy of the COSMAC Elf 2000 ("Elf 2000") design. Spare Time Gizmos offers no warranty, express or implied, as to the accuracy of the information presented in this document. Spare Time Gizmos offers no warranty, express or implied, as to the suitability or correctness of any software or firmware supplied in conjunction with the Elf 2000.

Spare Time Gizmos makes no representations as to the suitability of the Elf 2000 for any application. It is solely and exclusively your responsibility to evaluate the accuracy, completeness, and usefulness of the Elf 2000 and all related designs, software, and other information provided by Spare Time Gizmos. The entire risk as to the use and performance of the Elf 2000 is assumed solely by you.

No representation or other affirmation of fact, including, but not limited to, statements regarding capacity, performance of products, or suitability for use, whether made by

2 ASSEMBLY

Many thanks to the Elf 2000 builders who have contributed their experiences, suggestions and frustrations to this chapter.

2.1 ERRATA

There are no known errors in Revision C and later of the COSMAC Elf 2000 board. To determine the revision of your PC board, look for the text "ELF2K-1x" printed in copper along the edge of the PC board. You'll find it near the video/CDP1861 section. In this text, the "x" is the revision of your PC board – for example, "ELF2K-1C" for revision C.

2.2 PART SELECTION

The complete parts list for the Elf 2000 is contained in Appendix A and, with the exception of the CPD1802 CPU and the CDP1861 "Pixie", all parts are common, modern, devices that should be readily available. Most part values are non-critical and substitutions should not be a problem, however when changing connectors or switches use care that the replacements will fit the footprint on the PC board.

2.2.1 CPU Selection

The Elf 2000 is intended to use the CDP1802CE CPU; however this chip comes in many variations that will also work. In particular, the ACE and the ACD and even the CD versions will work just fine with no changes. ***If you are using an 1802 CPU of any type, then be aware that jumper JP5 must be installed*** (see section 3.2.3). JP5 is installed by default.

The enhanced versions of the CDP1802, the CDP1805 and CDP1806 may also be used in the Elf 2000 ***provided that jumper JP5 is removed*** (see section 3.2.3). The 1805/6 offer many additional extended instructions which were not available in the standard 1802, however the 1805/6 implement IDLE mode in a way which is incompatible with the CDP1861 Pixie chip or the STG1861 replacement. This may cause problems for any graphics software which uses the IDL (0x00) instruction. Finally, *the 1805/6 CPUs do not implement the "Load Mode" of the 1802, and this will render the LOAD toggle switch useless*. For this reason, *the CDP1805/6 CPUs are recommended for use without the toggle switch panel only*.

The CDP1804 is a CDP1805 with an internal program ROM. In principle, a special startup sequence can be

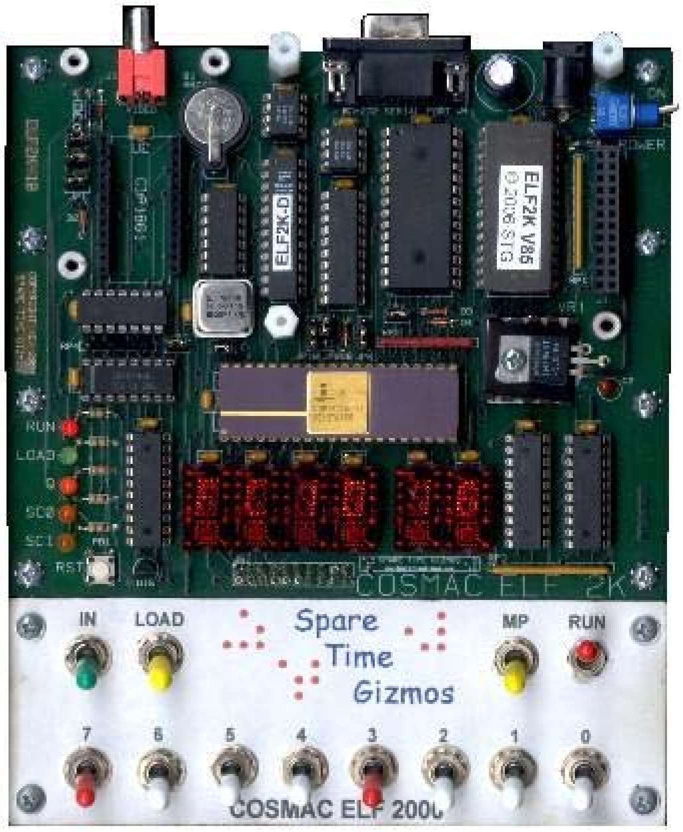


Photo 2 - Assembled Elf 2000

used with the 1804 to disable the internal ROM and force program execution from external memory; however the Elf 2000 has no provisions for doing this. If you have an actual CDP1804 chip that you're willing to part with, please contact Spare Time Gizmos and we'll see what can be done about making it work.

2.2.2 CDP1861 "Pixie" Chip

The CDP1861 is the standard video generation chip used by the original COSMAC Elf and by a generation of video games powered by the 1802 CPU, including the RCA VIP. Unfortunately CDP1861 chips have become quite scarce in recent years and you may have difficulty finding one. If you do happen to have a real CDP1861 chip, then by all means use it – it's intended to work in this circuit.

However, if you don't have a CDP1861, then there's no need for despair. Spare Time Gizmos makes a replacement for the 1861 which consists of a small daughter PC board that plugs directly into the 1861 socket on the Elf 2000. The STG1861, as it's called, contains two GALs and two 74HC parts and is functionally equivalent to the original CDP1861. The software cannot tell the difference.

If you use either the CDP1861 or the STG1861, be sure to install jumpers JP1, JP7 and JP8 (see section 3.2.1) to enable the DMA, INTERRUPT and EF1 outputs from the Pixie.

WARNING

If you don't have a CDP1861 chip and you plan to use the STG1861 at some point in the future, then *do not install a socket at U2*. The STG1861 uses a special header to make connections and can not be used if a standard DIP socket has been installed.

Of course, if you don't want video output from your Elf 2000 then there's no reason why you need either the CDP1861 or the STG1861 replacement. Just leave these parts unpopulated and your Elf will work just fine without them.

2.2.3 SRAMs

If you intend to use a battery backup for your Elf 2000, be sure to use an LP ("low power") suffix SRAM chip. The standard 62256 SRAMs chips have stand by currents 100 times that of the low power versions, and will drain the Lithium cell in a few hours. If you do not intend to use battery backup, then any 62256 SRAM may be used.

2.2.4 EPROM

A 27C256 EPROM is used to hold the monitor program, power on self test, diagnostics, programming languages, and disk operating system BIOS/bootstrap. The EPROM is optional and may be omitted if you intend to only toggle in programs with the switches. If the EPROM *is* installed, be sure to insert jumper JP4 to force execution to begin at address 0x8000 (the first byte in the EPROM) after a RESET. If the EPROM is not used, remove JP4 so that execution will begin at 0x0000 (the first byte in RAM) after a RESET. Refer to section 3.2.2 for more information on JP4.

2.2.5 GALs

One GAL is used in the Elf 2000 to decode I/O addresses, memory addresses, and some of the status LEDs. Not only does this save a great deal of random logic, but it also makes reconfiguration of I/O addresses and/or the memory map a simple matter. Refer to section 3.4 for more information on reconfiguring your GAL.

If you are concerned about power consumption, you'll want to use an Atmel "Q" suffix part – this device uses approximately ¼ the power of a conventional 22V10.

2.2.6 LED displays

Six TIL311 hexadecimal LED displays are used to display the current address and data. Either or both (address and data) of these displays are optional and may be omitted without harm (refer to section 2.3.6). Note that the TIL311 devices are bipolar logic, not CMOS, and use a tremendous amount of power. Eliminating them from your Elf can easily reduce the power consumption by a factor of 10!

2.2.7 Oscillator

The Elf 2000 uses one half sized “can” TTL crystal oscillator to generate the clock for both the CPU and the Pixie chip. Notice that the oscillator frequency is divided in half before it is applied to the CPU; that would mean that a standard CDP1802ACE could tolerate a maximum oscillator frequency of 6 MHz (a 3 MHz CPU clock).

If you intend to use the CDP1861 video generator, or the STG1861 “clone” *you must use a crystal oscillator with the frequency 3.579545 MHz in order to generate the correct NTSC video timing*. In this case the CPU clock will be 1.7897725 MHz. You’ll find that crystals for this rather arcane looking value are actually quite easy to obtain since it is the standard NTSC color burst frequency.

2.2.8 DS1233

There is some confusion between the DS1233 part and the DS1233M. The “M” suffix indicates a special version of the DS1233 which has the same pin out as some Motorola parts and because of the different pin out, ***the DS1233M cannot be used directly in the Elf 2000***. Electrically the DS1233 and DS1233M are identical, so it should be possible to use the “M” version if you twist the pins around to fit the PC board.

2.3 Optional Subsystems

Many subsystems of the Elf 2000 are optional and may be omitted without affecting the function of the remaining parts. In some cases when optional subsystems are omitted special jumpers or connections may be required to enable the rest of the logic to continue functioning. This section discusses the optional subsystems in the Elf 2000 and how to safely remove them.

You may also want to consider the option of building your first Elf with one or more of these subsystems omitted to save both money and time. In this case you can always go back and add the missing parts at any time.

2.3.1 Video (CDP1861 Pixie)

If you don’t want video from your Elf 2000, you can safely omit U2 (CDP1861), D2, R2, R3, R4, J1 and jumpers JP1, JP7 and JP8.

To disable video temporarily but leave the hardware installed, simply remove jumpers JP1, JP7 and JP8 (see section 3.2.1).

2.3.2 EPROM

You may omit the EPROM, U3, so long as you also remove jumper JP4. In this case the CPU will always start executing from address 0x0000 after a RESET, and you’ll need to ensure that the SRAM contains valid data at that location. One way to do this would be to toggle in a program using the switches.

2.3.3 Battery Backup

If you don’t require non-volatile RAM you can safely omit the DS1210 NVR controller, U5, and the Lithium coin cell B1. However, ***if you do this you must connect two jumpers to enable the***

SRAM. First, connect a jumper between U5 pin 8 and U5 pin 1 – this connects VBAT directly to VCC so that the SRAM will receive power. Second, connect a jumper between U5 pin 5 and U5 pin 6 – this ties SAFE CS RAM L to CS RAM L to enable the SRAM.

2.3.4 Toggle Switches

The entire switch panel, including the eight data switches and the LOAD, RUN, MP and INPUT switches, are completely optional. If they are omitted, the DS1233 will hold the CPU in the RESET state for approximately 300ms after power up and then release the CPU to RUN mode. The CPU will begin executing instructions at either location 0x0000 or 0x8000 as determined by jumper JP4 (see section 3.2.2).

If you don't want the switch panel, then in addition to omitting all the switches you may also omit U14, and J5. Note that RP4, RP3 and U9 are still required; don't be tempted to omit those!

If you use your Elf 2000 without any switch panel or keypad, then you need to solder two short jumpers to the board in place of J5. The first connects pin 4 ("LOAD NC") to pin 19 ("GND") and the second should connect pin 8 ("INPUT NC") to pin 20 ("GND"). Since J5 is not needed if you aren't installing a switch panel or keypad, you can solder these two jumpers directly to the pads reserved for J5. *These two jumpers ensure that the INPUT and LOAD signals remain inactive at all times*. You may find that your Elf 2000 runs without them, but it's not recommended.

You may also wish to jumper J5 pins 3, 5, 7, 9, 11, 13, 15 and 17 to ground as well (pin 12 will do) – this will ensure that an INP 4 instruction always reads all zero bits, however this is not really necessary. Of course, if you do this you'll also need to keep U14 as well.

Another tip – if you want to use your Elf 2000 sometimes with a switch panel/keypad and sometimes without, then go ahead and install the header for J5 anyway. When you are using the Elf without a keypad you can use a wire wrap tool to jumper the necessary pins, and then later remove the wire when you want to connect a switch panel.

2.3.5 Address Display

To delete the address display, omit DISP1 thru 4 and also U12. Note that U13 is still required.

2.3.6 Data Display

To delete the data display, omit DISP5, 6 and U13.

Before you decide that you don't need the data display, remember that the power on self test in the standard EPROM software uses the data display to show test results!

2.3.7 RS-232 Port

If you don't want the onboard RS-232 port (if, for example, you have a UART on an I/O expansion daughter board) then you can safely omit parts D16, J4, D6, JP6, JP9, and JP10.

2.3.8 Status LEDs

The status LEDs, LED1-5, may be omitted simply by removing the LEDs and the associated resistors (R1, R5, R6, R7, and R8).

2.3.9 Expansion Bus Connector

If you don't plan on adding any daughter cards, you can omit the expansion bus connector, J3.

2.3.10 Power Supply Regulator

If you *always plan to use your Elf 2000 with an external, regulated 5V power supply*, then you can omit VR1 (along with any heat sink). Be sure to solder a jumper wire between the input (pin 1) and output (pin 3) pins of VR1 to provide continuity for the power. If you use an external regulated supply, you must also replace D5 with a wire jumper – otherwise the drop in V_{CC} across D5 would be excessive.

If you eliminate VR1 you can also get by without C1, however it is recommended that you keep C2 in all cases.

WARNING

If you make this change, your Elf will have no protection against reverse or over voltage inputs. ***Connect the wrong power supply just once and you can easily fry all the chips in your Elf 2000!*** You have been warned!

2.4 SOCKETS AND SOLDERING

The instructions for every kit that I have ever built, all the way from the legendary Heathkit[1] on down, have always said that "90% of the kits that don't work after they're assembled fail because of the soldering." The Elf 2000 PC board was laid out with "8 and 8" design rules, which means that the traces are only 8 mils (that's 0.008 inches!) wide and, in some places, there is only 8 mils of "air gap" between adjacent traces or pads. The Elf 2000 is definitely *not* a "learn to solder" project – if you've never soldered a board like this before, then it'd be a good idea to find something cheaper to practice on!

When it comes to soldering, having the proper tools makes all the difference. A temperature controlled soldering station with a 30 mil tip will can be purchased for about $100 and will make the job much more pleasant. The right solder is important too – "63/37" solder is preferable to the traditional "60/40" because it has a slightly lower melting point and requires less heat. You should not be using anything larger than 31 mil (0.031 inch) diameter solder. And finally, you'll want a nice pair of wire cutters for trimming the leads on components after you've soldered them. Get the kind that's made for trimming wires on PC boards – they have a special cutting face that cuts flush with the PC board without leaving any wire "stubs" sticking up.

You'll want to wash the bare PC board before you start soldering to remove any grease or oils from fingerprints. If you don't wash them off, these oils will make the solder take longer to "flow" and will require more heat and flux to get a good solder joint. I prefer to use a mildly abrasive cleaner such as a Brillo pad, or Comet cleanser with a sponge, for cleaning. They do a better job removing oils, but remember to rub *ever so gently* – heavy scrubbing will remove the silkscreen, the solder mask, and even the plating! Just one, light, wipe with a wet and soapy Brillo pad is all it takes! Lastly and most importantly, make sure the board is *completely* dry before you start soldering. Even a tiny amount of water left in a hole will turn to steam when soldering heat is applied and blow the solder right out of the hole! If you have it, "canned air" is ideal for removing water from the holes and can be used to accelerate the drying process.

Use care to avoid solder bridges to adjacent traces and pads. Some of the bypass caps are also very close to traces and, when you nip the leads on these, check that your cutters cut cleanly and don't cause shorts. And finally, be careful not to use too much solder on the pins; excessive solder can "wick" up the pin to the top side of the board and cause invisible (because they're hidden under the IC socket) shorts there.

[1] Yes, I'm old enough to have built one or two. I missed their golden years, though.

I strongly advise using good, high quality machined pin sockets for all ICs[2]. These sockets are admittedly expensive; a 16 pin DIP socket might cost 50 cents and a 40 pin DIP more than dollar, but they're worth it if you ever need to replace an IC. Some people may object to the idea of putting a 25 cent 74HC74 IC into a 50 cent socket, but it's not the IC you are protecting – it's the PC board. If you ever fry that 74HC74 (and a single slip of the scope probe is all it takes!) then it will require significant skill and equipment to unsolder that dead IC without damaging the board. With a socket it takes only a few seconds to pop out the dead one a pop in a new one.

When soldering IC sockets and connectors, especially the larger ones, start by holding the part tightly to the board and then soldering only two pins on diagonal corners. This will hold the part in place temporarily while you turn the board over and make sure the part is flush against the PC board. If it isn't, then apply pressure to the part while using your iron to re-melt the solder on the closest pin. The worst thing is to solder all 40 pins on an IC socket only to turn it over and find that it's skewed. It's pretty difficult to desolder all those pins and repair the error at that point.

Lastly, clean the board again after you're finished soldering by using a commercial flux remover or, if you've used a solder with water soluble flux, by washing with a toothbrush and warm water. ***Water soluble fluxes are corrosive in the long term and should never be left on the board.*** Traditional rosin fluxes won't actually hurt anything if left behind, but the residue obscures the traces and makes it harder to find shorts. Make sure everything is completely dry before you begin installing parts in the sockets; once again, compressed or canned air can be used to accelerate the drying process.

2.5 ASSEMBLY HINTS

- ✓ Twenty-one 0.1µF 50VDC monolithic bypass capacitors are used in the Elf 2000. These are identified by a box only on silk screen.
- ✓ Notice that capacitors C1 and C2 are *polarized* devices and must be installed correctly. The polarization is shown on the silk screen of all PC boards.
- ✓ Header J5 *should be mounted on the bottom* (solder side) of the PC board with the pins facing "down" (i.e. on the solder side). Because of the limited space available, a shrouded header is not recommended for J5.
- ✓ Remember to use a heat sink with VR1.
- ✓ If you intend to use the STG1861 "Pixie" emulator, then *do not* install a dip socket at U2 (the CDP1861 socket). The STG1861 daughter board uses special 0.1" female headers (which are included in the STG1861 kit) and will not mate correctly with a standard DIP socket.

2.6 SWITCH PANEL

The switch panel is not part of the PC board and is constructed on a separate 5 ½" x 2" x 1/8" thick piece of ABS plastic. Appendix D of this manual contains a full sized template for the switch panel which you can print on a piece of adhesive decal stock and then use as a drilling guide. Once you are done drilling, leave the decal in place as the remainder serves to label the various switches.

Mount ten SPST toggle switches for D0 thru D7, RUN and MP. Note that all switches should be mounted so that they are "ON" with the lever in the down (i.e. zero) position, *except for the MP switch*. This includes the RUN switch; the MP switch alone should be installed so that it is ON with the lever in the UP position.

[2] ***Please don't solder your 1802 chip or your 1861 chip to the board***! And, of course, you always want to socket the GAL and EPROM chips so that you can reprogram them if need be.

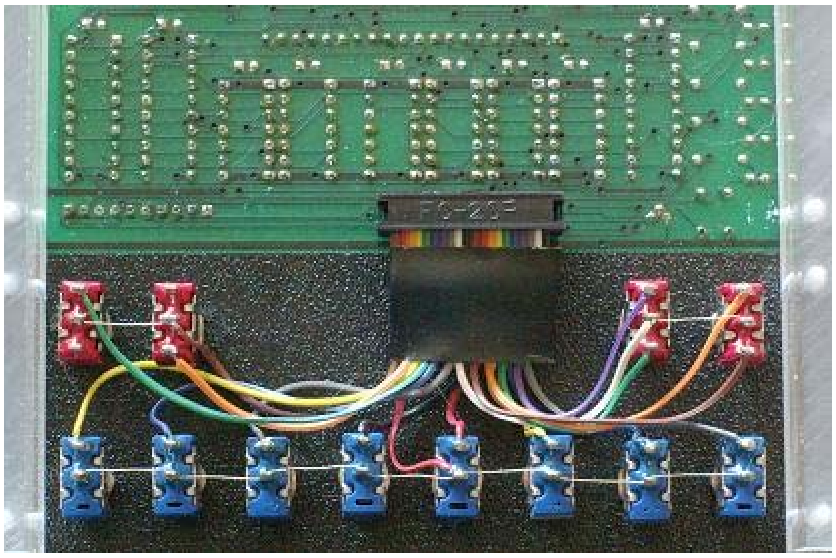


Photo 3 - Switch Panel (Rear View)

Mount a SPDT toggle switch in the LOAD position, and either an SPDT push button or a SPDT momentary toggle switch in the INPUT position. If you use a momentary toggle switch for INPUT, mount it so that the momentary position is UP.

The switches are wired using a short piece of 20 conductor ribbon cable terminated with a 20 pin IDC female connector. This connector plugs into J5 on the main PC board, which you should have installed on the *bottom* of the PC board. It's recommended that you use rainbow colored ribbon cable for the switch panel connections, and install the connector so that the BROWN wire corresponds to pin 1 of J5, RED to pin 2 of J5, and so on.

Remember that pin 1 of J5 is the one with the square pad, and remember to count the pins of J5 while looking at it from the *bottom* of the PC board! If you hold the Elf 2000 PC board upside down (i.e. solder side up) with the DE9 serial, RCA video and coaxial power connectors pointing *away* from you, then the ribbon cable attached to J5 should have a BROWN conductor at the far right side and a BLACK wire on the far left side.

If you do it this way then wiring the switch panel is easy – Table 1 summarizes the wiring between the switches and J5; you may also wish to refer to the Elf 2000 schematic, page 3, for more detailed information. Notice that there are three ground connections in J5 – normally, pin 19 is used as a ground for the eight data switches, pin 12 for the LOAD and INPUT switches, and pin 20 for the RUN and MP switches. There's no magic to this, though, and you can assign the grounds any way you wish.

The RUN switch is "upside down" because the associated function is really RESET (i.e. "NOT RUN"!). When the RUN switch is down, the RUN/RESET input should be grounded (i.e. the switch is ON) and when the RUN switch is UP (i.e. processor running) the RUN/RESET input should be open (i.e. the switch is OFF). MP (memory protect) works the way you'd expect – when the MP switch is UP the MP input is grounded (i.e. switch ON) and memory is protected.

PIN	Switch	Color	PIN	Switch	Color
1	N/C (V_{CC})	BROWN	2	N/C (V_{CC})	RED
3	D7	ORANGE	4	LOAD (NC)	YELLOW
5	D6	GREEN	6	LOAD (NO)	BLUE
7	D5	VIOLET	8	INPUT (NC)	GREY
9	D4	WHITE	10	INPUT (NO)	BLACK
11	D3	BROWN	12	GND	RED
13	D2	ORANGE	14	N/C (unused)	YELLOW
15	D1	GREEN	16	RUN/RESET	BLUE

PIN	Switch	Color	PIN	Switch	Color
17	D0	VIOLET	18	MP	GREY
19	GND	WHITE	20	GND	BLACK

Table 1- Switch Wiring

The LOAD and INPUT switches, both SPDT, have a common terminal (both connected to ground in this circuit) and normally closed (NC) and normally open (NO) terminals. The normally closed terminal corresponds to the "OFF" state of the switch (i.e. LOAD mode off, or INPUT not pressed). In the case of a push button this generally isn't an issue, but if you use a momentary toggle for the INPUT switch then you'll have to be sure get it the right way around. The same thing is true for the LOAD switch, which is always a toggle. If you're unsure of the internal wiring of your switches, an ohmmeter will give a quick answer!

WARNING

SPDT toggle switches invariably have the common terminal in the center, but *push buttons frequently do not!* Generally the switch will be labeled, but if there's any doubt, dig out your ohmmeter!

2.7 HEX KEYPAD

A push button hexadecimal keypad may also be used as an alternative to the toggle switch panel. The keypad consists of 21 keys total – sixteen hexadecimal keys and five function keys, RESET, GO (RUN), LOAD, MEMORY PROTECT and INPUT. The five function keys are illuminated from behind by T1 LEDs, and there is a small beeper that generates a short key beep whenever any key is pressed. Photo 4 shows an Elf 2000 keypad assembled by Ken Rother.

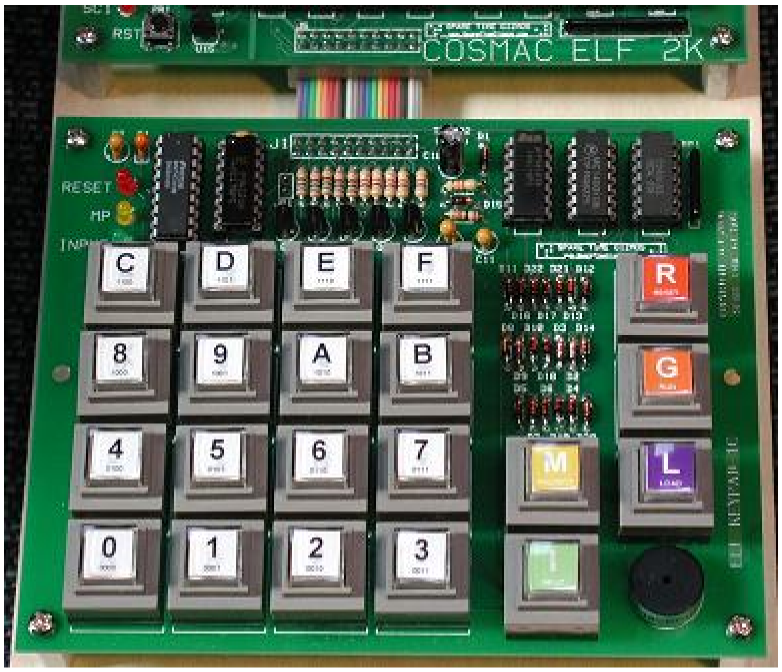


Photo 4 - Elf 2000 Keypad

There are three different types of pushbuttons which may be supplied with the keypad kit. One has a white insert inside the button; one has a gray insert, and the last has a red insert. Some of the kits are supplied with all white buttons, and some are supplied with a mix of white and gray or red. Since these are surplus switches the selection is limited to the supply on hand and Spare Time Gizmos doesn't have enough of any one type to fill all the orders with the same buttons.

All the buttons accept a printed insert for a legend, and after you've installed the insert the button color won't show any more. Notice that the gray and red buttons have their pins is a different location than the white buttons. The PC board is designed so that each switch position has two sets of pads to accommodate either type of button. Also notice that only the white buttons have a hole in the back for a LED or lamp - don't use gray or red buttons for any of the five function keys unless you intend to forgo back lighting them.

Two tips for installing the legends in the buttons. First, look closely at the buttons – there’s a small slot on the side, just underneath the top of the cap. The slip of paper with the printing slides in that slot. ***Do not try to disassemble the buttons!*** Also, it’s much easier to insert the legends in the buttons before they’re soldered to the PC board. The space between the buttons is a little tight once they’re in place, and they’re difficult to work on.

It's a good idea to do a "dry run" with the buttons and insert them all into the PC board before you solder anything. Make sure that you have the right set of pads for each button type and that all the buttons line up. Finally, make sure that the back light LEDs or lamps fit in the five function keys. The five function keys accept either a T1 LED or a grain of wheat light bulb for back lighting. If you use LEDs, you'll want to pick colors that complement that color of the button legends. I've found that the LED back lighting is a little disappointing – it isn't quite bright enough and the effect is a subtle in a normally lit room. It works great in the dark, however!

WARNING

Once the push button is soldered into place there's no way to install or change the back light, so be sure you insert the LED or lamp first! Be sure that the LED or lamp doesn't stick up so far that it interferes with the operation of the push button.

Each back light has a separate transistor driver that can stand up to 100mA and voltages well above VCC. This is especially useful if you use lamps instead of LEDs. If you do use lamps, you may want to replace the LED current limiting resistors (R3, R5, R6, R9 and R12) with wire links instead. Jumper JP1 connects VLED to VCC – if you elect to use lamps instead you may wish to break this connection and supply VLED separately with a higher voltage and/or higher current supply. Needless to say, VLED doesn't need to be regulated.

IMPORTANT

Look closely at JP1 and you'll see that there is a trace on the solder side which connects the two pins by default. Normally nothing, not even a header or shorting block, needs to be installed at JP1. If you want to use a separate VLED supply you'll need to cut this trace first.

Remember that it's going to be difficult to replace one of the back light lamps if it ever burns out, so it'd be wise to operate these bulbs well below their rated voltage. Whether you use LEDs or lamps, the LOAD and RUN ("GO") back lights are simply connected to the corresponding LEDs on the main ELF 2000 PC board. *There is no decoding for the RUN and LOAD states on the keypad PC board* and if you want to use these two LEDs/lamps you'll need to connect TP1 (LOAD) on the keypad PC board to U7 pin 16 on the main Elf 2000 PC board. Likewise, you'll need to connect TP2 to U7 pin 15 on the Elf 2000 board.

It's not necessary to use the back lighting at all – you can simply omit the LEDs/lamps and all the associated components if you choose. There are also alternate mounting locations for the RESET, MEMORY PROTECT and INPUT LEDs in the upper left corner of the keypad PC board. These will line up nicely with the LEDs already on the Elf 2000 PC board and you can install these in place of the back lights if you prefer.

The function buttons RESET, GO, LOAD and MEMORY PROTECT all light up when the associated condition is true. The INPUT button lights when any numeric key is pressed and then goes out when INPUT is pressed. Notice that RESET button will also be lit while in LOAD mode. This is normal.

Note that the MEMORY PROTECT button is *not* a toggle – pressing this button always sets the MEMORY PROTECT flip flop. This condition is cleared by pressing any one of the RUN, LOAD or RESET buttons.

The keypad contains a power on clear circuit that should cause it to always power up with RESET on and LOAD, GO, MEMORY PROTECT and INPUT all off. The power on clear also causes a short key beep whenever the power is switched on.

2.8 MOUNTING RAILS

The original COSMAC Elf was mounted on two strips of wood; the Elf 2000 uses two 6 ¾" x 1" x 3/8" thick strips of clear acrylic plastic instead. Drill small pilot holes in your plastic rails to line up with the holes in the Elf 2000 PC board (there are four on each side) and the plastic switch panel (two holes on each side). Mount the PC board and the switch panel to the plastic rails using twelve 3/8" self tapping screws.

If you purchased a kit from Spare Time Gizmos, note that the mounting rails are part of the switch panel kit and are not included in the basic Elf 2000 kit.

2.9 FINAL CHECKOUT

After you finish assembly, apply power before installing any ICs[3]. Place a DC milliammeter inline with the power supply; with no ICs installed the current consumption should be essentially zero. Use a DC voltmeter to verify that the voltage between pins 20 (negative) and 40 (positive) on the microprocessor (CDP1802) socket; you should read 4.9 to 5.1V.

Next remove power and install all ICs *except* the CDP1802, CDP1861 (if you have it) and the TIL311 displays. Install the TTL oscillator and the 22V10 GAL at this time. Turn on the power and check the power consumption – it should be 100mA or less[4]. The Q, SC0 and SC1 LEDs may or may not light, or they may glow faintly. Don't worry about this. If you have access to an oscilloscope, check that pin 1 of the CDP1802 has a 1.7897725MHz square wave.

Turn the power off and install the CDP1802 and (if you have it) CDP1861[5] chips. Turn on the power and check the milliammeter – the power consumption should still be under 100mA, and probably more like 50-75mA. Ensure that the RUN and LOAD switches are both set to OFF and only the SC0 LED should be illuminated. Flip the LOAD switch ON and the green LOAD LED should light; flip LOAD back to OFF and flip RUN to ON and, after a slight pause, the RUN LED should light.

Finally, remove power one more time and install the six TIL311 displays. Notice that the TIL311s have two notches on one end and one notch on the other end; the end with two notches is the "top" (towards the CDP1802 socket) side. Flip the power on and check the milliammeter; the TIL311s are TTL chips and are huge power hogs – the current drain will now be something around 600mA! Use your voltmeter to double check the VCC one more time and verify that it's still between 4.9 and 5.1VDC.

If you don't get these results, and especially if the current drain is significantly more than predicted, then stop and figure out what's wrong before proceeding.

If all's well and your Elf 2000 has a switch panel then proceed to section 2.9.1, *Switch Panel Checkout*. If your Elf has no switch panel but you are using the Spare Time Gizmos monitor EPROM, proceed with section 2.9.2, *EPROM Checkout*.

[3] You *did* socket all the ICs, didn't you?

[4] Assuming you are using the Atmel "Q" quarter power GAL specified in the parts list.

[5] If you're using the STG1861 replacement, *do not* install it at this time.

2.9.1 Switch Panel Checkout

Set all switches to the OFF position, including D0-D7 and flip LOAD to the ON position. The LOAD LED should light and the address display should show **0000** (the data display will be random). Flip/press INPUT and the display should read **0000 00**. Now set the D0-D7 switches to ON and flip/press INPUT again; the display should now read **0001** FF.

Next, set the data switches to 0xA5 (D7 ON, D6 OFF, D5 ON, D4 OFF, D3 OFF, D2 ON, D1 OFF, and D0 ON), flip/press INPUT and the display should show **0002 A5**. Finally, set the data switches to 0x5A, flip/press input, and verify that the display shows **0003 5A**.

Set LOAD to OFF; set MP to ON, and then flip LOAD back to ON. The display will show **0000 5A**. Flip/press INPUT and the display will show the contents of location 0 – **0000 00**. Flip/press INPUT three more times and you'll see the next three bytes that you just entered; **0001 FF**, **0002 A5**, and **0003 5A**.

If you are also using the Spare Time Gizmos monitor EPROM, then proceed with the next section.

2.9.2 EPROM Checkout

Turn the power off and ensure that all jumpers are set as described in section 4.2 for monitor EPROM compatibility. Connect an RS-232 terminal[6] to J4 and set the terminal for 2400 baud, 8-N-1 (8 data bits, no parity and 1 stop bit). Set all switches to OFF except RUN, which should be set to ON. Turn on the power.

The RUN LED should light (if it doesn't make sure you've set the RUN switch to ON!) and the data display should show 99[7], followed by 98, and then gradually count down to 16. This means that the monitor is ready for auto baud; press the ENTER (carriage return) key on the terminal. The data LEDs will read 00 and on the terminal you should see something like this:

```
COSMAC ELF 2000  EPROM V15 CHECKSUM BA24  SRAM 32K  INITIALIZED
Copyright (C) 2004 by Spare Time Gizmos.  All rights reserved.
ElfOS BIOS Copyright (C) 2004 by Mike Riley.

For help type HELP.
>>>
```

If the LEDs stop counting at some number before 16, then refer to section 4.3, *Power On Self Test (POST)*, for help in diagnosing the problem.

[6] A PC running terminal emulation software (e.g. KERMIT or HyperTerm) works fine.

[7] Many of the numbers in this sequence, including the 99, go by so fast that you can't see them.

3 HARDWARE DESCRIPTION

3.1 CONNECTORS

3.1.1 Power

J2 is the main power connector. It is a standard 2.1mm ID, 5.5mm long coaxial power connector and the center conductor is positive. Diode D5 protects against accidental reverse polarity. Using a standard 7805 regulator for VR1, the applied power may be anywhere from 9 to 12VDC. Use care when applying voltages higher than 12V not to exceed the power dissipation limits of VR1.

A fully populated Elf 2000, including all six TIL311 displays and the STG1861 video chip substitute, uses approximately 600mA. Removing the six LED displays and the STG1861 will reduce the current requirements to only about 100mA.

3.1.2 Console

J4 is a standard DB9 *female* connector. The wiring of this DE9F is such that it can connect directly to a standard PC serial port (which uses a DB9 9 pin *male* connector) using a "straight thru" (i.e. *not* a null modem) cable. Note that only **TXD**, **RXD**, and ground are connected.

Pin	Signal
2	**TXD**
3	**RXD**
5	**GND**

Table 2 – RS-232 Connector

3.1.3 I/O Expansion

J3 is a general purpose expansion connector which can be used to connect to one or more daughter boards mounted on top of the Elf 2000. Four mounting holes for #4-40 swage standoffs to support the daughter board are also provided on the Elf 2000. Note that these daughter boards are intended for I/O expansion only – J3 does not contain any memory address or control signals. There's hardly any need, since the Elf 2000 already contains 64K of memory! Table 3 shows the pin out of the I/O expansion header.

Pin	Signal	Type	Pin	Signal	Type
1	**VCC**	PWR	2	**VCC**	PWR
3	**D0**	TRI[8]	4	**N2**	O
5	**D1**	TRI	6	**N1**	O
7	**D2**	TRI	8	**N0**	O
9	**D3**	TRI	10	**MRD L**	O
11	**D7**	TRI	12	**EF4 L**	OD
13	**D6**	TRI	14	**TPA**	O
15	**D5**	TRI	16	**TPB**	O
17	**D4**	TRI	18	**RUN**	O
19	**Q**	O[9]	20	**INTREQ L**	OD

[8] Tri-State.

Pin	Signal	Type	Pin	Signal	Type
21	`EF2 L`	OD[10]	22	`EF3 L`	OD
23	`GND`	PWR	24	`GND`	PWR

Table 3 – I/O Expansion Header (J3)

3.2 JUMPERS

3.2.1 JP1, JP7 and JP8

Jumpers JP1, JP7 and JP8 are used in conjunction with the CDP1861 video generator chip. JP7 connects the 1861 DMA REQ to the CPU's DMA OUT input; JP8 connects the 1861 INT REQ output to the CPU's INT REQ input, and JP1 connects the 1861's DISPLAY STATUS output to the CPU's EF1 input.

Normally all three of these jumpers would be installed if the CDP1861 chip is being used, and all three would be removed if the 1861 is not installed or not used.

Photo 5 shows the position of jumpers JP1, JP7 and JP8.

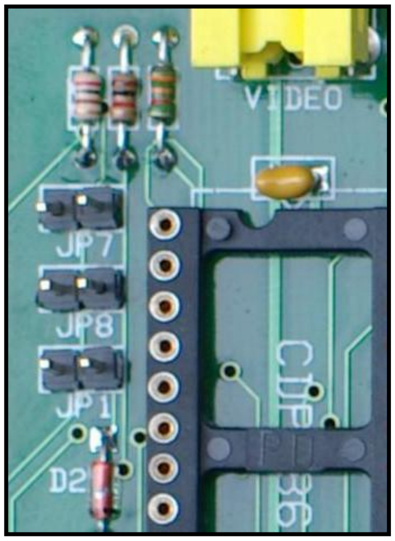


Photo 5 - JP1, JP7 and JP8

3.2.2 JP4

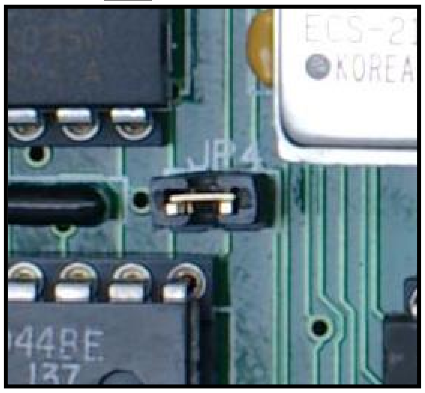


Photo 6 - JP4

Jumper JP4 enables the "auto bootstrap" feature of the Elf 2000. If JP4 is installed, then the CPU begins executing instructions at address 0x8000 after a hardware reset. Since 0x8000 is the first location in the EPROM, installing this jumper has the effect of causing the CPU to execute the EPROM bootstrap after a reset.

If jumper JP4 is not installed, then the 1802 CPU begins executing instructions at location 0x0000 after a reset. This address is normally mapped to the first location in the SRAM. Needless to say, it's your job to ensure that the RAM contents are meaningful, either by using the toggle switch bootstrap or some other means, before using this option.

Photo 6 shows the position of jumper JP4.

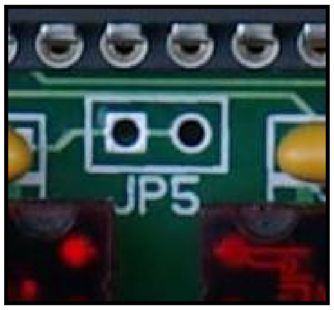


Photo 7 - JP5

3.2.3 JP5

Jumper JP5 is used to select the type of CPU installed in the Elf 2000. JP5 *must be installed* for a CDP1802 CPU. If a CDP1805 or CDP1806 chip is being used for the CPU instead, JP5 *must be removed*.

[9] Output (driven by the ELF 2000 board).

[10] Open-Drain with a 10K pull up resistor on the ELF 2000 PC board.

IMPORTANT!

As shipped from the factory, revision C and later of the ELF2K PC board have a small trace shorting JP5 on the top side of the PC board. If you plan to install a jumper at JP5, you must very carefully cut this trace with a small knife first!

This means that by default, your Elf 2000 PC board is wired for an 1802 chip and, if you are using an 1802, you don't need to do anything. You don't need to install a jumper at JP5 at all! If you want to use an 1805/6 CPU, then you must first *cut* the trace between the two pins of JP5. If you want to be able to select between the two CPU types, first cut the trace connecting the two pins of JP5 and then install a jumper there.

Photo 7 shows jumper JP5.

3.2.4 JP2

When installed, jumper JP2 connects the INPUT switch to EF4. This is the standard arrangement used by the original Elf; however you may remove this jumper if you wish to use EF4 for some other purpose. Note that the INPUT switch still functions in LOAD mode regardless of this jumper.

Photo 8 shows the location of JP2.

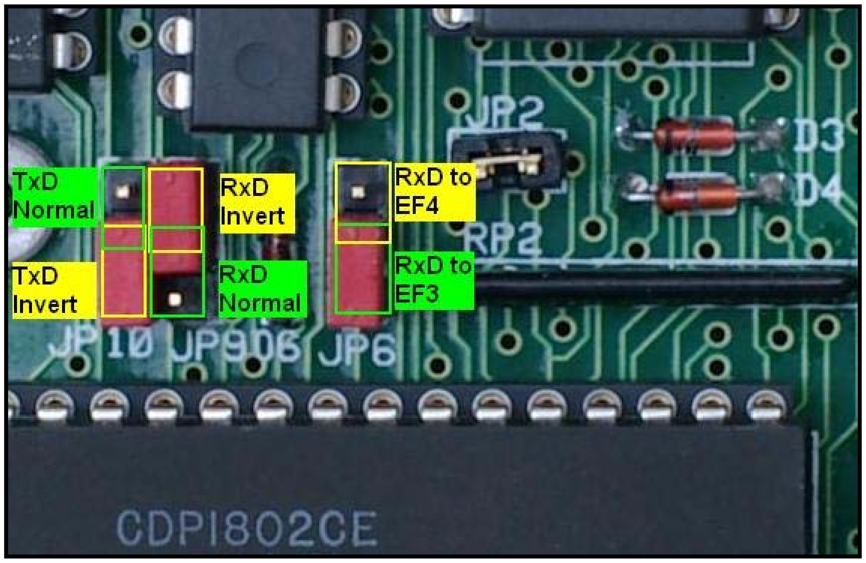


Photo 8 - JP2, JP6, JP9 and JP10

3.2.5 JP9 and JP10

JP9 and JP10 are two position jumpers which determine the polarity of the RS-232 serial input and output signals. Remember that a "proper" RS232 to TTL level shifter inverts the polarity of the signal (i.e. the "active" or marking RS232 state is the more negative voltage and corresponds to a TTL "high" level) and the "normal" polarity position of jumpers JP9 and JP10 is used by software that originally expected the CDP1802 Q and EFx signals to be interfaced with a real (e.g. MAX232) RS232 driver.

However, many Elf circuits attempted to interface RS-232 devices directly to the Q and EFx signals without a proper RS-232 level shifter. In this case a 0V TTL signal corresponded (assuming that the external RS232 device was willing to accept it) to the "active" or marking RS232 state and a +5V TTL signal corresponded to a RS-232 space. Software written for this kind of interface will expect JP9 and JP10 to be set to the "invert" position.

Notice that the two jumpers, JP9 and JP10 are "flipped" with respect to each other – that is, the invert position on one corresponds to the normal position on the other and vice versa.

Photo 8 shows the location and the normal/invert positions of JP9 and JP10.

3.2.6 JP6

JP6 connects the RS-232 serial input to either EF3 or EF4. To disable the serial port input completely (i.e. to leave both EF3 and EF4 free for other purposes), simply remove JP6 completely.

Photo 8 shows the location of JP2.

3.2.7 Other Jumpers

Note that jumper JP3 does not exist. It was used in an earlier revision of the PC board only.

3.3 BOOTSTRAP FLAG

Under normal conditions, the CLEAR (RESET) state sets the 1802 internal registers X=P=IE=R(0)=0 and then the processor begins executing instructions at location 0 with R(0) as the PC. If we want to start executing code directly from the EPROM after a RESET, it's necessary to "trick" the processor somehow into starting at location 0x8000 rather than 0x0000.

The 22V10 GAL, U7, is responsible for decoding the chip selects for both RAM and EPROM. Ordinarily is uses A15 to do this; A15 = 0 selects the RAM and A15 = 1 selects the EPROM. The hardware also contains a special "bootstrap" flag implemented by U9 section C; this flag is always set (i.e. BOOTSTRAP = 1) by a RESET condition. This BOOTSTRAP flag is also an input to U7, and when BOOTSTRAP is 1 the GAL modifies its chip select decoding so that the EPROM is always selected regardless of the state of A15.

Once again, as long as the BOOTSTRAP flag is set, the EPROM will be selected for all memory references. Address bit A15 becomes a "don't care." *The RAM can never be selected under these circumstances*. This combination causes the processor to execute instructions from the EPROM after a reset, even though the PC = 0x0000. As soon as possible after RESET, the EPROM code should execute a long branch to the correct 0x8xxx address and then clear the bootstrap flag.

Clearing the BOOTSTRAP flag is also up to the GAL via the CLR_BOOTSTRAP output. The current GAL programming will assert this output any time N != 0, thus the first I/O instruction of any kind after a RESET clears the bootstrap flag. This works well with the current EPROM code since one of the first actions after a reset is to load POST code 99 into the displays, and the I/O output instruction that loads the data display will also clear BOOTSTRAP as a side effect.

The entire BOOTSTRAP mechanism may be defeated by removing jumper JP4 (see section 3.2.2) which prevents the BOOTSTRAP flag from getting to the GAL in the first place. If JP4 is removed, then RAM is always addressed from 0x0000 to 0x7FFF and the processor will be executing instructions from RAM immediately after a RESET. This is most useful when you intend to hand toggle in programs using the switches; however it can also be useful if the backup battery is installed and the RAM contents are known to be valid.

3.4 RECONFIGURING THE GAL

The 22V10 GAL is responsible for most of the random logic, address and I/O decoding in the Elf 2000. In particular, the GAL is responsible for:

- Decoding the EPROM and SRAM chip selects
- Decoding the I/O select for the switch register and data display
- Decoding the I/O select for VIDEO ON and VIDEO OFF
- Handling and clearing the BOOTSTRAP flag (see section 3.3)
- Deciding when the RUN and LOAD LEDs are illuminated

Besides the simple fact that it saves a handful of discrete logic chips, the other really wonderful thing about this is that it is possible to change the way the ELF 2000 operates simply by reprogramming the GAL.

For example, suppose you wanted to change the I/O address for the switch register from its current default (4) to 3. No problem – just reprogram the GAL and it's done. *Absolutely no wiring changes are required!*

Or maybe your Elf 2000 doesn't have any TIL311 displays, and you'd like to add some extra I/O instructions so that the firmware can blink the RUN and/or LOAD LEDs? Easy – just add the new I/Os to the GAL and you're done. No need to even warm up the soldering iron.

Or, for another example, currently the BOOTSTRAP flag is cleared by the first I/O, any I/O, after a RESET. Suppose you wanted to change the system so that the BOOTSTRAP flag could be cleared only by an I/O to a specific port? Or maybe you'd rather not have it cleared by any I/O but instead by the first real memory reference to an address ≥ $8000? You guessed it – just reprogram the GAL!

Or, for one more example, currently SRAM is mapped from $0000 to $7FFF and EPROM from $8000 to $FFFF. Suppose you wanted to change that around? Yep, no problem – just reprogram the GAL!

If you have a particular piece of software that you want to run on your Elf 2000, then the GAL gives you tremendous flexibility in changing the hardware configuration to accommodate the software, all without changing a single wire…

3.5 SERIAL PORT

The DS275 chip used in the Elf 2000 provides true EIA (i.e. +/- 15V) signaling levels for the RS-232 port, however it has one significant limitation. *The DS275 is capable of half duplex operation only.* That is, the serial port can receive characters and it can transmit characters, but it cannot do both at the same time. Since the serial port in the Elf 2000 is intended to be used with a "software" UART algorithm in the 1802 CPU, this is not a serious limitation.

Except, that is, on one situation. There are some UART algorithms that implement the echo of characters read at the bit level. That is, the character read routine attempts to echo each bit back to the Q bit output as each bit is being read. That's full duplex and will not work (you'll get unexplained garbage characters) with the DS275. The solution is to change to a character level echo instead – read an entire 8 bit character and assemble all the bits into a byte, and then echo the entire 8 bit character *after* input is finished. This algorithm works fine with the DS275 and the different is imperceptible to the user.

4 SOFTWARE DESCRIPTION

You can program a 27C256 EPROM with any 1802 code you like and install it at U3, or you can use the standard EPROM software provided by Spare Time Gizmos. The standard EPROM contains several distinct software modules, including

- A monitor written by Spare Time Gizmos which provides hardware diagnostics, program debugging and downloading features.
- A VT52 terminal emulator for use with the Spare Time Gizmos VT1802 80 column video card. The video card is described in chapter 12.
- A disk BIOS written by Mike Riley and compatible with the ElfOS disk operating system. The BIOS contains many useful functions that you are free to call from your own assembly language programs. Please refer to Appendix E for references to BIOS and ElfOS documentation. Appendix A describes the procedure for installing ElfOS on your Spare Time Gizmos Elf 2000 platform.
- A simple text editor and a load-and-go assembler, written by Mike Riley, which allows you to type in, edit, assemble and then run 1802 assembly language programs. The Editor/Assembler is documented in Chapter 6.
- A full featured BASIC interpreter, written by Mike Riley. BASIC is documented in Chapter 7.
- A Forth interpreter, also written by Mike Riley and described in Chapter 8.

The remainder of this chapter will describe the Spare Time Gizmos monitor for the Elf 2000.

4.1 MONITOR FEATURES

The Spare Time Gizmos monitor is a multipurpose piece of software which lives in the EPROM and adds a number of useful features to the Elf 2000.

- A power on self test (POST) that performs a basic test of all Elf 2000 components.
- A more extensive diagnostic that performs in depth tests of certain Elf 2000 subsystems.
- A down loader that can receive Intel .HEX format files over the console serial port and load them directly into memory.
- Basic memory examination and modification commands.
- A program break point feature, including a register dump and the ability to continue execution after the break.
- A bootstrap for the ElfOS disk operating system.
- A simple command line interpreter.

4.2 SETTING THE JUMPERS FOR THE MONITOR

The monitor requires that some of the COSMAC Elf 2000 be configured properly before it can run. Table 4 summarizes the jumper settings required to run the EPROM monitor.

NOTE

The photos shown in section 3.2 all depict the jumpers in the correct positions for the EPROM monitor!

Jumper	Expected setting for Monitor EPROM
JP1	Installed if you have a CDP1861/STG1861. Otherwise removed.
JP2	Installed.
JP3	Unused (doesn't exist!)
JP4	Installed (automatically start the monitor).
JP5	As required by your CPU chip.
JP6	RxD to EF3.
JP7	*See JP1.*
JP8	*See JP1.*
JP9	RxD invert.
JP10	TxD invert.

Table 4 - Jumper Settings for Monitor EPROM

4.3 Power On Self Test (POST)

Immediately after a RESET, provided that jumper JP4 is installed (see section 3.2.2), the CPU begins executing instructions from the EPROM, and the first thing the EPROM code does is to execute a simple test of the Elf 2000 components. This power on self test (aka POST) displays a different two digit number on the data display for each test; if a particular test fails, the processor will halt leaving the code for that test visible on the display. Thus it's easy to identify the cause of a failure from the two digit POST code shown.

Appendix B gives a list of the current POST codes and their meanings. These are current as of EPROM monitor version 76. Note that many of these codes are not necessarily errors – they simply show progress thru the sequence of tests. A POST code is only a problem if the system halts while it is displayed.

4.4 Serial Console Auto Baud

After the majority of the POST is completed, the monitor will attempt to determine the console terminal port and baud rate by waiting for you to type either a *carriage return* (CR) or a *line feed* (LF) character[11]. A carriage return will also enable monitor echo of all future input; a line feed does not. In the latter case it's presumed that your terminal has a local echo feature.

The data display (POST code) will show ***16*** *while the monitor is waiting for you to type CR or LF.*

Either the serial port on the main board or the UART serial port on the Disk Expansion card may be used for the console terminal and, during the auto baud phase, the Elf 2000 will respond to which ever port receives a CR character first. With a 3.579545 MHz clock, *the Elf 2000 mother board serial port is able to support any baud rate up to 2400bps*. The UART serial port supports any standard baud rate from 2400bps thru 19,200bps regardless of the CPU clock. The character format used by both ports is 8-N-1 (8 data bits, no parity, and 1 stop bit) regardless of the baud rate. After recognizing your terminal's port and baud rate, the monitor will print a sign on message that looks something like this:

```
COSMAC ELF 2000  EPROM V48 CHECKSUM BA24  SRAM 32K  INITIALIZED
```

The monitor will remember the console port baud rate in RAM, and if your Elf 2000 has the Lithium battery backup option installed *on subsequent startups the monitor will skip the auto baud step and re-use the last baud rate memorized*. If your Elf has the Disk Expansion card installed with the Non-volatile RAM (NVR) option, then the monitor will remember the console port and

[11] The line feed/no local echo option may be used with the mother board serial port only. The UART serial port supports only the CR/local echo option.

baud rate in NVR even if the main memory does not have the battery backup option. If this should become a problem, set the toggle switches to 0100 0011 (see section 4.7) before rebooting to erase the memory (see section 4.7).

4.5 VIDEO CONSOLE EMULATION

If *both* the VT1802 80 column video card (Chapter 12) and the GPIO card (Chapter 13) are installed and pass the power on self test, then the monitor will automatically use them to emulate a VT52 style terminal as the Elf 2000 console. The VT1802 card provides the display output and the PS/2 interface on the GPIO provides the keyboard input. Additionally, the speaker on the GPIO card, if it is installed, will be used as the console terminal's "bell".

When both cards are installed and working, *the monitor always uses the VT1802/GPIO combination as the console terminal*. No serial console auto baud is performed; post step 16 will be skipped, and both serial ports are ignored by the monitor. The POST and initialization for the UART chip is still executed if the Disk/UART/RTC card is present and you can of course still write your own programs which use the UART.

NOTE

The "bit banged" motherboard serial port cannot be used when the VT1802 is installed. This is because the DMA and interrupt overhead associated with the VT1802 precludes accurate timing for the software serial port emulation.

Console emulation works only if both the VT1802 and GPIO cards are installed. If only one is present, then the POST will still execute the self test and initialization for that card, however the monitor will attempt to use either the motherboard serial port or the UART as the console. If the GPIO card is installed alone, you can still write programs which use the PS/2 keyboard port, but the monitor will ignore it.

And if the VT1802 card is installed alone, the POST will initialize it and start the screen refresh DMA and interrupts running, but the monitor will ignore it. You can, however, still write your own programs which call the VT52 emulator firmware in the Elf 2000 EPROM directly and use that to display text on the VT1802.

4.6 MONITOR DATA

The monitor reserves one page of RAM memory from $7F00 to $7FFF. Modifying bytes in this page with the DEPOSIT command may cause unpredictable results including system hangs and monitor crashes. Any machine language programs you write should avoid this page of memory and, naturally, you should not attempt to download any data to it.

If you do manage to corrupt the monitor's data page and you happen to have the battery backup option, then even a reset or power cycle may not clear the problem! In this case you can try setting the switch register to 0100 0011 (see section 4.7) and rebooting – this will force RAM to be cleared. If *that* doesn't work (or if you don't have a switch register) then the only other option is to turn the power off, remove the Lithium backup battery, wait a few minutes for the RAM to discharge, and then turn the power back on again.

Any time the VT1802 video card is installed, whether or not the GPIO is also installed, the monitor also reserves 2048 bytes of RAM memory from $7700 to $7EFF for use as a frame buffer and to hold local variables for the VT52 emulator code. Any programs you write should also avoid using this area of memory if you plan to use the VT1802.

The BIOS f_freemem function (see Appendix E) for the Elf 2000 knows about the monitor's data page at $7F00 and always adjusts the amount of free memory accordingly. Better yet, the BIOS is also able to determine whether the VT1802 option is installed and, if it is, adjust the amount of free memory downward to allow for the VT1802 frame buffer. Thus the safest and most portable option is to always use the BIOS f_freemem function to determine the amount of available RAM.

4.7 STARTUP OPTIONS

During the power up sequence, the monitor can recognize several special patterns of the toggle switches in the switch register and perform special startup actions. Currently three such special patterns are recognized:

SWITCHES	Startup Action
1000 0001	special CHM startup mode
0100 0010	force SRAM to be initialized
0100 0011	force SRAM and NVR both to be initialized

Table 5 - Special Startup Options

To use one of these options, the switches must be set to this pattern before the CPU is reset or power applied. For a normal startup sequence, the switches may be set to any other pattern; all zeros are recommended.

4.8 USING THE MONITOR BREAKPOINT FEATURE

Whenever the monitor starts one of your machine language programs running, whether it is with the CALL or the RUN command, it will initialize R1 with the address of a breakpoint routine that is a part of the monitor. Provided that *your program does not change the contents of R1*, and provided that *your program keeps a valid stack pointer in R2*, a break point can be placed in your program with this two byte sequence:

```
MARK        ; $79
SEP  R1     ; $D1
```

When a break point occurs, the monitor's break point routine will save the CPU's context, including X, P, D, DF and registers 2 thru F, into the monitor's data segment. *This process requires three bytes on your stack before control can be transferred to the monitor's stack*. Registers R1 and R0 are not saved by the break point routine. Presumably this is not a problem in the case of R1 (since you were using it for the break point program counter anyway!) but you might regret the loss of R0. And in particular, this precludes the use of the break point feature with any code that uses either interrupts or DMA or both.

WARNING!

Let's say that again – the monitor's break point feature does not save (and hence the CONTINUE command cannot restore) the contents of registers R0 or R1. *All other CPU state is saved*.

After saving the CPU state, the monitor's break point routine will print out the entire CPU status:

```
BREAKPOINT  @ XP=23 D=AA DF=1
R0=0000 R1=0000 R2=7F7D R3=0102
R4=FA7B R5=FA8D R6=82A0 R7=7FA8
R8=0000 R9=82DE RA=8CF7 RB=FEFF
RC=7FAF RD=0100 RE=1100 RF=7FB7
```

and then a command prompt. You can use the EXAMINE and or DEPOSIT commands to poke around in what your program is doing, and you can also use the CONTINUE command to restore the CPU's state and continue execution of your machine language program. If you do elect to continue, execution will resume at the next instruction after the SEP R1.

Note that the monitor prints the contents of all sixteen registers after a breakpoint, however (one more time!) *the values printed for R0 and R1 have no significance*.

Since this break point feature requires some cooperation from your program (unlike other, more powerful CPUs, which can implement a completely transparent break point) it's worth while to go over once again the requirements for making it work. To use the break point feature, your program must

- Not use or care about the contents of R0
- Not change the contents of R1
- Keep a valid stack pointer in R2
- Ensure that there are at least three free bytes on the R2 stack

So long as it meets these conditions, your program can contain any number of break points and you'll be able to continue execution of your program after it hits one.

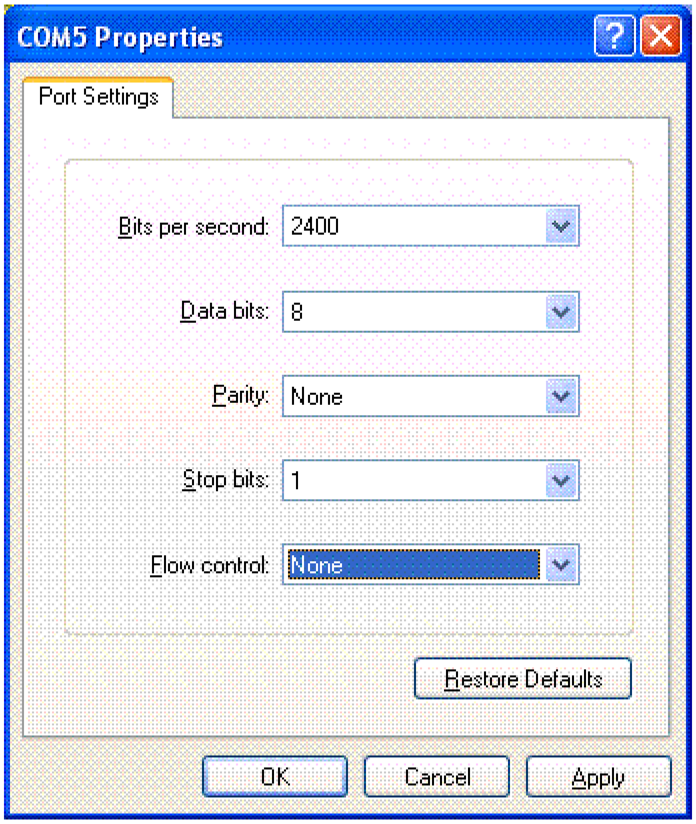
WARNING!

The break point feature requires the use of registers R0 and R1, which is incompatible with the VT1802 video card. If the VT1802 is installed, the break point feature and all related commands are disabled.

4.9 Cross Assembling and Downloading Programs

There are several cross assemblers for the 1802 which run on the IBM PC and other systems. Two particularly useful examples are TASM and rcasm – refer to Appendix E for links to both of these. Since the Elf 2000 ROM monitor has the ability to load Intel HEX format records directly (see section 5.15), the output from any cross assembler in this format can be downloaded directly to the Elf 2000 over the console serial port. And because each HEX file record contains its own checksum, which is verified by the Elf 2000 monitor, this method even provides simple protection against corrupted files or downloads.

Downloading HEX files to the Elf 2000 is simple with the exception of one caveat – since there is no handshaking between the Elf and the PC, the PC terminal program must implement some form of *transmit pacing* (i.e. a fixed delay between characters) to prevent overrunning the relatively slow Elf 2000. The HyperTerminal program can do this; a free (or at least no additional cost!) version of this program has been shipped with every version of Microsoft Windows since Windows 95. Other communications programs can undoubtedly do the same thing.


COM5 Properties

Port Settings

Bits per second: 2400

Data bits: 8

Parity: None

Stop bits: 1

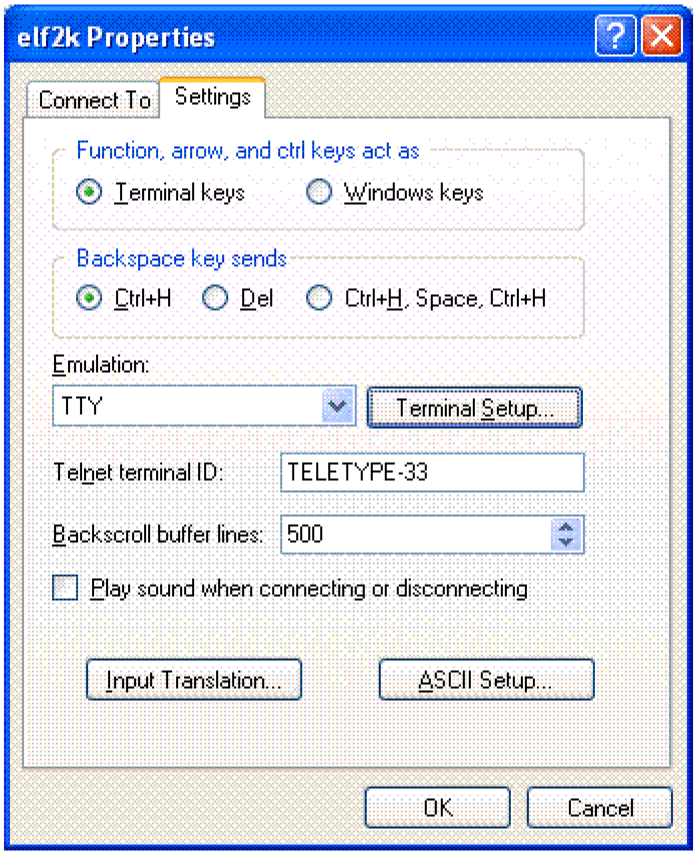
Flow control: None

Figure 2 - HyperTerminal Port Properties

To set up HyperTerminal for downloading directly to an Elf 2000, follow these instructions:

1. Run HyperTerm (*START MENU >> ALL PROGRAMS >> ACCESSORIES >> COMMUNICATIONS >> HyperTerminal*)

2. In the *Connection Description* Dialog, enter a name for the connection (e.g. "elf2k") and pick an icon from the list. Click *OK*.
3. In the *Connect To* Dialog, select the PC COM port from the *Connect Using* drop down list. Leave the other fields (e.g. area code, phone number, etc) blank. Click *OK*.
4. In the *COMx Properties* Dialog (see Figure 2), pick **2400** *Bits per Second*, **8** *Data Bits*, **None** (sic) *Parity*, 1 Stop Bits, and None *Flow control*. Click *OK*.
5. At this point the main HyperTerminal window opens. Before proceeding, Pick *File >> Properties* from the HyperTerminal menu bar.
6. In the *elf2k Properties* window (see Figure 3) that appears, be sure the *Backspace key sends Ctrl+H* radio button is selected, set the *terminal emulation* to *TTY* and click the *ASCII Setup…* button.
7. In the *ASCII Setup* Dialog (see Figure 4), under *ASCII Sending*, ensure that *Send line ends with line feeds* and Echo *typed characters locally* are both unchecked. Enter ***150*** in the *Line delay* edit box and ***15*** for the *Character delay*. For *ASCII Receiving*, ensure that *Force incoming data to 7-bit ASCII* is checked. Click *OK* here, and then click *OK* again in the *elf2k Properties* window.


elf2k Properties

Connect To | Settings

Function, arrow, and ctrl keys act as: [✓ Terminal keys] Windows keys

Backspace key sends: [✓ Ctrl+H] Del Ctrl+H, Space, Ctrl+H

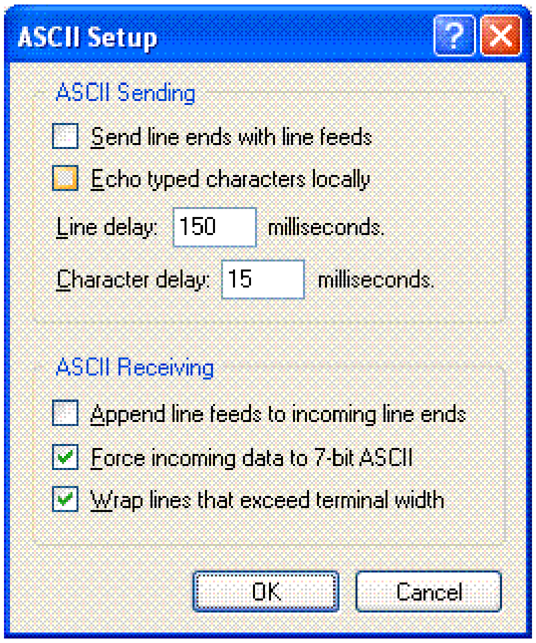
Emulation: TTY

Telnet terminal ID: TELETYPE-33

Backscroll buffer lines: 500

☐ Play sound when connecting or disconnecting

Figure 3- elf2k Properties


ASCII Setup

ASCII Sending

☐ Send line ends with line feeds

☐ Echo typed characters locally

Line delay: 150 milliseconds.

Character delay: 15 milliseconds.

ASCII Receiving

☐ Append line feeds to incoming line ends

☑ Force incoming data to 7-bit ASCII

☑ Wrap lines that exceed terminal width

Figure 4 - ASCII Setup

Be sure to save these settings (*File >> Save*) so that you won't have to do it again next time! Once you've completed this setup, to send a HEX file to the Elf 2000 first be sure that the monitor is ready (press *ENTER* and you should receive the ">>>" prompt), and then use *Transfer >> Send Text File…* to send the .HEX file to the Elf. Note that the HyperTerminal *Send Text File* Dialog defaults to showing only .TXT files, and so to see .HEX files you'll have to select *All Files (*.*)* from the *Files of Type…* drop down list.

WARNING!

Be sure that the HEX file you are sending is in MSDOS text format – that is, each line ends with both a carriage return ***and*** line feed character. Files that are in UNIX text format (i.e. lines end with a line feed only and no carriage return) ***will not*** transmit correctly!

5 MONITOR COMMAND REFERENCE

5.1 COMMAND REFERENCE

The Elf 2000 monitor understands simple one word commands such as “EXAMINE” or “BASIC”. Some commands require one or more parameters, usually but not always hexadecimal numbers. Parameters are separated from the main command and each other by spaces, for example:

```
>>>EXAMINE 0 100
```

If you make a mistake while typing a command you can rub out (erase) previous characters with the backspace key, and you can abort the entire command line by entering CONTROL-C. Command lines are always terminated with a CR (carriage return) character.

In general command names may be abbreviated to their shortest unique length. For example, you may enter any one of “CONT”, “CONTI”, “CONTIN”, “CONTINU” or “CONTINUE” for the CONTINUE command; in the following command descriptions this would be shown as “CONT[inue]” to signify this. Occasionally some commands allow ambiguous abbreviations – for example, “B” is always BOOT, “E” is always EXAMINE, and “D” is always DEPOSIT.

5.2 B[OOT]

The BOOT command (what else?) attempts to boot a disk operating system from the primary IDE device[12]

```
>>>BOOT
Booting primary IDE ...
Starting...

Elf/OS Ready
$
```

5.3 BAS[IC], ASM, AND FOR[TH]

The BASIC command invokes the BASIC interpreter, and the ASM and FORTH commands invoke the Editor/Assembler and FORTH languages. In all three cases, simply typing the command and a carriage return invokes the prompt:

```
>>>BASIC
NEW OR OLD?
```

which you should answer with either the word “NEW” or “OLD”. If you answer NEW, then memory will be initialized for a new program, but if you answer “OLD”, BASIC/ASM/Forth will attempt to recover any existing program that may be left in RAM. Of course, if there is no program in RAM, it will most likely crash! Note that all three languages work exactly the same way in this respect.

The “OLD” option is especially useful when your Elf 2000 has the battery backup option for SRAM; in this situation you can enter a long program into SRAM, turn your Elf off, and then later turn it on and recover your original program by using the “OLD” option.

Optionally, you can shorten this dialog to a single command, e.g.

```
>>> FORTH OLD
```

[12] Currently it is not possible to boot from an IDE slave device.

5.4 CALL <*ADDR*> AND RUN <*ADDR*>

Both of these commands are used to transfer control to a machine language program that you have loaded into RAM, presumably by downloading it from a PC (see section 4.9) or possibly by entering it directly into RAM with the DEPOSIT command. Both commands require a single hexadecimal argument to indicate the starting address of the machine language program, for example

```
        >>>RUN 100
```

begins running the machine language program at location $0100.

The difference between these two commands is in the way the machine language program is started. The CALL command invokes the program using the SCRT (RCA's "standard call and return technique") subroutine linkage; this effectively makes your machine language program subroutine of the monitor. In particular, the program counter will be R3, and R4, R5 and R6 will be set up with their usual call, return and argument list pointers. R2 will point to a valid stack in the monitor's data page. A machine language program invoked this way can return to the monitor by executing a SEP R4 (i.e. "subroutine return") instruction.

On the other hand, the RUN command simulates the action of a hardware reset before invoking the machine language program. For programs started with RUN, the program counter will be R0 and the contents of the other registers will be undefined. The only way a machine language program invoked with the RUN command can return control to the monitor is by executing a long branch ("LBR") to address $8000, the monitor's cold start entry point.

5.5 CONT[INUE]

The CONTINUE command is used after a break point (see section 0) to restore the original CPU state and register contents. Execution continues at the next instruction after the break point.

WARNING!

Remember that the monitor break point feature does not preserve or restore registers R0 or R1, and cannot be used with code that depends on these registers. That includes any code that uses interrupts or DMA!

5.6 E[XAMINE] <*ADDR*> AND E[XAMINE] <*ADDR*> <*ADDR*>

The EXAMINE command is used to display the contents of one or more memory bytes in both hex and ASCII. For example, the command

```
        >>>e 8000 80ff
```

produces this output:

```
               0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
        8000>  C0 80 AA C0 80 0C C0 FF 06 C0 FF 6C E2 C0 FF 4E  @.*@..@..@.lb@.N
        8010>  0D 0A 43 4F 53 4D 41 43 20 45 4C 46 20 32 30 30  ..COSMAC ELF 200
        8020>  30 20 00 43 6F 70 79 72 69 67 68 74 20 28 43 29  0 .Copyright (C)
        8030>  20 32 30 30 34 20 62 79 20 53 70 61 72 65 20 54   2004 by Spare T
        8040>  69 6D 65 20 47 69 7A 6D 6F 73 2E 20 20 41 6C 6C  ime Gizmos.  All
        8050>  20 72 69 67 68 74 73 20 72 65 73 65 72 76 65 64   rights reserved
        8060>  2E 0D 0A 45 6C 66 4F 53 20 42 49 4F 53 20 43 6F  ...ElfOS BIOS Co
        8070>  70 79 72 69 67 68 74 20 28 43 29 20 32 30 30 34  pyright (C) 2004
        8080>  20 62 79 20 4D 69 6B 65 20 52 69 6C 65 79 2E 0D   by Mike Riley..
        8090>  0A 0D 0A 0A 46 6F 72 20 68 65 6C 70 20 74 79 70  ....For help typ
        80A0>  65 20 48 45 4C 50 2E 0D 0A 00 E0 64 99 71 00 E0  e HELP....`d.q.`
        80B0>  64 98 F8 80 BF F8 00 AF F8 00 BD AD EF 8D F4 AD  d.x.?x./x.=-o.t-
        80C0>  9D 7C 00 BD 60 9F 3A BD E0 E0 64 97 F8 FF BF F8  .|.=`.:=``d.x.?x
        80D0>  FE AF EF 9D F7 3A D5 60 8D F7 3A DA E0 E0 64 89  ~/o.w:U`.w:Z``d.
        80E0>  F8 00 BF AF EF F0 AD FB FF 5F 8D F4 FC 01 3A F5  x.?/op-{._.t|.:u
        80F0>  8D 5F 1F 30 E5 2F E0 E0 64 88 9F FB 7F 3A FD 8F  ._.0e/``d..{.:}.
```

The EXAMINE command may also be used with a single argument, in which case only one byte is displayed (always in hex this time). For example:

```
>>>e 100
0100> 79
```

5.7 D[EPOSIT] <ADDR> <DATA> [<DATA> ...]

The DEPOSIT command (what else?) deposits one or more bytes of data in memory. It requires a minimum of two arguments – the memory address to change and the byte to be deposited. For example,

```
>>>d 100 7f
>>>e 100
0100> 7F
```

Additional arguments may be given to change sequential bytes after the first one. For example,

```
>>>d 101 1 2 3 4 5 6 7
>>>e 100 10f
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
0100>  7F 01 02 03 04 05 06 07 FF 00 00 FF 00 00 FF 00  ................
```

5.8 IN[PUT] <PORT>

The INPUT command reads a data byte from the specified I/O port and prints the data obtained. For example,

```
>>>in 4
Port 4 = 8C
```

reads the console switches.

5.9 OUT[PUT] <PORT> <DATA>

The OUTPUT command writes the specified data byte to the I/O port given. For example,

```
>>>out 4 a5
```

displays “A5” on the data LEDs.

5.10 SHOW COMMANDS

5.10.1 SHO[w] TERM[inal]

The SHOW TERMINAL command prints the current console port terminal settings. BAUD1 contains the software baud rate used by the mother board “bit banged” serial port. The LSB of BAUD1 also contains the terminal echo flag – this will be 1 if input should be echoed back to the terminal. BAUD0 contains the hardware serial port (the disk expansion card UART) settings as used by the BIOS F_USETBD function. If BAUD0 is zero, then the software port is the console, and if the upper 7 bits of BAUD1 are zero the hardware serial port is the console.

```
>>>show terminal
BAUD1=0x11 BAUD0=0x00
```

If the VT1802 and GPIO combination is being used as the console terminal (see section 4.5) then the output from SHOW TERMINAL gives the current versions of the VT52 emulator firmware and the GPIO PS/2 keyboard APU firmware. For example

```
>>>show terminal
VT1802 Video Card Firmware V23
PS/2 Keyboard APU Firmware V2
```

5.10.2 SHO[w] RTC

The SHOW RTC command prints the contents of the real time clock and non-volatile RAM memory. This command is intended for debugging the higher level BIOS functions that access the RTC/NVR (e.g. "SHOW DATIME", "SHOW RESTART", etc) and because of that SHOW RTC performs no error checking of any kind. If you use the SHOW RTC command when no RTC is installed, all 0xFF bytes will be printed. If you use SHOW RTC when a 64 byte RTC/NVR chip (e.g. the DS1287) is installed, then the contents of the first 64 bytes will be repeated twice as they are in this example.

```
>>>show rtc
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
7D00>  02 00 17 00 11 00 02 0E 03 21 20 07 50 80 FF 11  .........! .P...
7D10>  00 E0 74 65 73 74 20 64 61 74 61 20 2D 20 31 2C  .`test data - 1,
7D20>  20 32 2C 20 33 20 2D 20 42 6F 62 20 41 72 6D 73   2, 3 - Bob Arms
7D30>  74 72 6F 6E 67 20 30 32 F0 32 33 2F 30 35 75 1E  trong 02p23/05u.
7D40>  02 00 17 00 11 00 02 0E 03 21 20 07 00 80 FF 11  .........! .....
7D50>  00 E0 74 65 73 74 20 64 61 74 61 20 2D 20 31 2C  .`test data - 1,
7D60>  20 32 2C 20 33 20 2D 20 42 6F 62 20 41 72 6D 73   2, 3 - Bob Arms
7D70>  74 72 6F 6E 67 20 30 32 F0 32 33 2F 30 35 75 1E  trong 02p23/05u.
```

5.10.3 SHO[w] REG[isters]

The SHOW REGISTERS command will display the contents of application program's registers saved at the last break point. If no break point has been encountered, then these values are meaningless. See section 4.8 for more information on the monitor's break point feature.

```
>>>show registers
BREAKPOINT  @ XP=23 D=AA DF=1
R0=0000 R1=0000 R2=7F7D R3=0102
R4=FA7B R5=FA8D R6=82A0 R7=7FA8
R8=0000 R9=82DE RA=8CF7 RB=FEFF
RC=7FAF RD=0100 RE=1100 RF=7FB7
```

5.10.4 SHO[w] IDE

The SHOW IDE command will probe the IDE bus for attached devices. Each device (there are a maximum of two, master and slave) is reset, and then its size and identification printed. For example,

```
>>>show ide
IDE Master: 122Mb SanDisk SDCFJ-128
IDE Slave:  ?Fail
```

5.10.5 SHO[w] MEM[ory]

The SHOW MEMORY command shows the SRAM size, in bytes, as returned by the BIOS f_freemem function. Notice that the result is a few (256 to be exact) bytes less than 32K because of the monitor's data page.

```
>>>show memory
32512 bytes free
```

5.10.6 SHO[w] VER[sion]

The SHOW VERSION command prints the Monitor/EPROM version, the BIOS version, and the BIOS configuration.

```
>>>show version
Monitor v50 - BIOS v1.0.4 - BIOS features 0x003D
```

5.10.7 SHO[w] RES[tart]

The SHOW RESTART command prints the current restart settings (see section 5.11.3).

```
>>>show restart
NONE
```

5.10.8 SHO[w] DP

The SHOW DP command prints the contents of the Monitor's data page. It's just a shorthand for the "E 7F00 7FFF" command.

```
>>>show dp
         0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
7F00>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7F10>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7F20>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7F30>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7F40>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7F50>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7F60>  00 00 00 00 00 00 00 00 00 00 00 00 00 05 00 00  ................
7F70>  05 00 00 86 40 86 40 7F 86 40 7F 70 C8 84 C8 84  ....@.@..@.pH.H.
7F80>  72 6C 61 02 4B 00 00 00 00 00 00 00 00 00 00 00  rla.K...........
7F90>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7FA0>  00 00 00 00 00 00 00 00 6C D3 D3 11 00 03 0E 21  ........lSS....!
7FB0>  11 16 00 00 00 00 00 00 00 00 01 00 73 68 6F 77  ............show
7FC0>  20 64 70 00 74 61 72 74 00 6F 6E 65 00 30 30 00   dp.tart.one.00.
7FD0>  20 31 37 3A 32 32 3A 30 30 00 00 00 00 00 00 00   17:22:00.......
7FE0>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
7FF0>  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
```

5.10.9 SHO[w] DA[time]

The SHOW DATIME command prints the current date and time of day according to the RTC chip on the disk expansion card. If the expansion card is not installed, or if the RTC chip is not installed, then an error message is printed instead.

```
>>>show datime
03/14/2005 17:24:07
```

5.10.10 SHO[w] EF

The SHOW EF command prints the current state of all four EF inputs. For example,

```
>>>show ef
EF1=0 EF2=0 EF3=1 EF4=0
```

This command prints the logical state of the EF inputs, as the programmer would see it. Thus, "EF1=0" implies that the –EF1 input is *HIGH* and "EF3=1" implies that the -EF3 input is *LOW*.

5.10.11 SHO[w] CPU

The SHOW CPU command reports the type, either CDP1802 or CDP1804/5, of the CPU chip in use. Better yet, if the RTC option (part of the Disk/RTC/NVR card) is installed[13], SHOW CPU will also compute and report the CPU clock speed.

```
>>>show cpu
CDP1802 - SPEED=3000000
```

In this case the CPU clock speed is 3000000Hz or 3MHz. The result is especially interesting if the VT1802 video card is installed, because the SHOW CPU command does not turn off the

[13] The RTC is needed so we can have a time base with a known frequency that's independent of the CPU clock speed.

video during the measurement. The CPU speed reported in that case is the effective CPU speed *after* the video refresh overhead is taken out.

5.11 SET COMMANDS

5.11.1 SET Q

The “SET Q 1” and “SET Q 0” commands set and reset the Q output, respectively. These commands *cannot* be used if the Elf 2000 onboard (bit banged) serial port is used for the console[14].

5.11.2 SET [DA]time

The SET DATIME command will set the current time and date stored in the real time clock chip. If no disk expansion card, or no RTC chip, is installed then an error message is printed instead.

```
>>>set datime 3/14/2005 17:22:00
03/14/2005 17:22:00
```

Note that the format of the argument for SET DATIME is exactly the same format that SHOW DATIME uses to print the current time and date.

5.11.3 SET RES[tart]

If your Elf 2000 system has some form of non-volatile memory, either in the form of battery backup for the mother board SRAM, or in the form a NVR chip on the disk expansion card, then it is possible to select one of three different Monitor actions on a power up or reset.

```
>>>set restart none
>>>show restart
NONE
```

The SET RESTART NONE command disables the auto restart mechanism. The Monitor enters the command mode after either a reset or a power up.

```
>>>set restart boot
>>>show restart
BOOT
```

The SET RESTART BOOT command instructs the monitor to attempt an IDE bootstrap after a reset or power up. This is equivalent to the BOOT command.

```
>>>set restart 100
>>>show restart
RESTART @0100
```

The SET RESTART <address> command causes the monitor to transfer control to the address given after the self test completes. This command can only be used if the main memory (mother board SRAM) battery backup option is installed and working.

To bypass any of the auto restart options and force the monitor to enter command mode after a power up or reset, set the console switches to 0100 0011 before resetting. Refer to section 4.7 for the complete story.

5.11.4 SET NVR DEFAULT

The SET NVR DEFAULT command resets the contents of non-volatile RAM, either battery backed up memory on the motherboard or the NVR chip in the Disk/UART/RTC option board, to

[14] I trust that it’s obvious why this is so!

the factory default settings. This is useful if you've somehow managed to screw up your NVR contents and want to get everything back to a known state.

Note that there are no other SET NVR commands – DEFAULT is the only option – and also notice that this command has no legal abbreviations. You must spell it out exactly as shown.

5.12 TES [T] COMMANDS

5.12.1 TES[t] RAM

This command will perform an exhaustive test on all of SRAM using the "Knaizuk and Hartmann" algorithm[15]. This algorithm first fills memory with all ones ($FF bytes) and then writes a byte of zeros to every third location. These values are read back and tested for errors, and then the procedure is repeated twice more, changing the position of the $00 bytes each time. After that, the entire algorithm is repeated three more times, this time using a memory fill of $00 and every third byte is written with $FF. Strange as it may seem, this test can actually detect any combination of stuck data and/or stuck address bits.

Each pass (six iterations) requires about 30 seconds for 32K RAM on a 1.7 MHz CDP1802 and produces the following output:

```
>>>test ram
Testing RAM ...... Pass 1 Errors 0
Testing RAM ...... Pass 2 Errors 0
Testing RAM ...... Pass 3 Errors 0
Testing RAM ...... Pass 4 Errors 0
…
```

NOTE

This test repeats endlessly. The only way out is to reset the Elf 2000!

5.12.2 TES[t] PIX[ie]

The TEST PIXIE command attempts to exercise CDP1861 or STG1861 video subsystem. The test command first examines EF1 (normally the STATUS output from the 1861) for a once per frame square wave. If no CDP1861/STG1861 is installed (or if it is not working) then no change in EF1 will be detected and the monitor prints

```
>>>test pixie
EF1 test... no CDP1861 detected
>>>
```

If a square wave is detected, then the monitor measures the period of EF1 and then attempts to display a video test pattern. In this case, the test pattern is the familiar picture of the spaceship *Enterprise*!

```
>>>test pixie
 EF1 test... 466 OK
The COSMAC Elf Enterprise - Joseph Weisberger P-E 1976
[Toggle INPUT to continue]
>>>
```

5.12.3 TES[t] VT1802

The TEST VT1802 command displays a test pattern on the VT1802 video screen, and it can be used even if the VT1802 is also being used for the console. To exit from the test press any key. Note that this is a visual test only and it doesn't actually evaluate the VT1802 hardware, which is already tested to the best of our ability by the POST.

[15] *Proceedings of the IEEE,* April 1977.

5.13 HEL[P]

The HELP command prints a short list of monitor commands and their arguments.

5.14 CLS

The CLS ("Clear Screen") command will clear the terminal screen if the VT1802/GPIO console terminal is in use. It has no effect if a serial console is being used.

5.15 LOADING INTEL HEX RECORDS

The monitor contains a built in loader for standard Intel format HEX records. No special command is required – simply transmit one or more HEX records to the Elf 2000 and the monitor will decode and load them. If the HEX record is successfully decoded, the monitor prints "OK" and another prompt. For example:

```
>>>:1802000090B1B2B3B4F82DA3F8F8A2F811A1D37270C422782252F80009
OK
>>>
```

In case you've forgotten, the standard format for a HEX record is

`:llaaaattdddddddddddddddddddddddddddddddddddd..cc`

where *`ll`* is the number of data bytes in this record, *`aaaa`* is the loading address of the data, *`tt`* is the record type, *`dddd..dd`* are the actual data bytes, and *`cc`* is the checksum of the entire record. Currently the only two record types recognized by the monitor are *`00`* (normal data) and *`01`* (end of file).

It's possible to download entire programs to the Elf 2000 this way – refer to section 4.9.

5.16 SEDIT

The SEDIT command invokes Mike Riley's disk Sector Editor, which is resident in EPROM.

```
>>>sedit
SEDIT>R1A
SEDIT>H

0100: 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 ................
0110: FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF ................
0120: FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF ................
0130: 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 ................
0140: FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF ................
0150: FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF ................
0160: 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 ................
0170: FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF ................
0180: FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF ................
0190: 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 ................
01A0: FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF ................
01B0: FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF ................
01C0: 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 ................
01D0: FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF ................
01E0: FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF ................
01F0: 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 FF FF 00 ................
SEDIT>Q
>>>
```

Table 6 summarizes the SEDIT commands.

IMPORTANT!

SEDIT currently only understands *upper case* commands!

Command	**Action**
`L`	Show Low 256 bytes of loaded sector
`H`	Show High 256 bytes of loaded sector
`R`*`sect`*	Read specified sector (*sect* is in hex)
`N`	Load the Next sector
`P`	Load the Previous sector
`D`	Display current sector number
`E`*`ofs byte byte ...`*	Enter bytes into sector at specified offset
`W`	Write sector back to disk
`A`*`au`*	Load first sector of specified AU
`C`*`au`*	Show AU Chain for specified AU
`Q`	Quit (return to the Elf 2000 monitor)

Table 6- SEDIT Commands

6 EDITOR AND ASSEMBLER

The Elf 2000 Monitor EPROM contains a simple text editor along with a "load and go" assembler, both written by Mike Riley. The text editor allows the user to type simple assembly language programs into memory, and then when you're ready the assembler assembles the program directly to memory (hopefully a different part of memory!) and starts it. The rest of the chapter documents the Editor/Assembler and was contributed by Mike.

Edt/Asm is a basic editor with integrated in memory assembler. Edt/Asm was designed so that it could be run from ROM, with the text editor buffer at $1000. In this configuration programs can be assembled in the space from $0000h to $0FFF.

6.1 EDITOR COMMANDS

A	Assemble the program
B	Move to bottom of buffer
D	Move down one line
,nD	Move down n lines
Itext	Insert text at current location
nItext	Move to line n, then insert text
I	Enter multi-line insert mode, end with <CTRL><C>
nI	Enter multi-line insert mode starting at line n, end with <CTRL><C>
nG	Make line n the current line
K	Kill (delete) the current line
nK	Move to line n, and then delete line
,nK	Kill n lines starting from current line
n,mK	Kill m lines starting from line n, n becomes current
N	New file - clears buffer
P	Print the current line
nP	Print line n
,nP	Print n lines starting from current line
n,mP	Print m lines starting from line n
R	Run program
T	Move to top line of buffer
U	Move up one line
,nU	Move up n lines

Table 7- Editor/Assembler Commands

6.2 ASSEMBLER LINE FORMAT:

label: OPCODE ARGUMENTS ; Comments

Labels and comments are optional, and not all opcodes have arguments. In addition to the 1802 instruction set, Edt/Asm provides these 4 pseudo opcodes:

ORG	**addr**	; Specify address for assembly
DB	**b1,b2,...bn**	; Define a list of bytes in memory
DW	**w1,w2,...wn**	; Define a list of words in memory
END	**start**	; End of assembly, also specifies start address

Edt/Asm currently only supports simple arguments, arithmetic expressions cannot be used. When specifying registers, the register number may (but need not) begin with R, for example:

```
LDN     R8
```

The high byte of a value can be obtained by adding "**.1**" to the end of a label, for example:

```
LDI     STACK.1
```

will load the high byte of the address of STACK. In the same way,"**.0**" will obtain the low byte of a value, for example:

```
LDI     STACK.0
```

6.3 EXAMPLES

To be added.

7 BASIC

7.1 INTRODUCTION

The Elf 2000 EPROM contains a very powerful BASIC Language Interpreter, written by Mike Riley, and in addition to the software, Mike has contributed this chapter which documents his BASIC language.

BASIC is an acronym for Beginners All purpose Symbolic Instruction Code. BASIC was developed in the early 70s in order to provide an easy means for writing software for people new to computers, hence Beginners in the name. BASIC is a very easy language to learn and is capable of performing a wide range of tasks, hence all purpose. Early computers were programmed in codes that were difficult to use and required a lot of for thought on the part of the programmer on how data and program code is stored in memory. This made early programs difficult to write and very difficult to modify.

Higher level languages were developed in order to abstract away the specifics on how the computers actually worked and making it easier for programmers to write and maintain their software. There are two basic types of higher level languages, compilers and interpreters. A compiler takes the program that the developer wrote and translates it into the machine code that the computer understands. Interpreters typically use intermediate code rather than direct machine language. A line of a program is tokenized or converted to the intermediate code and then the interpreter looks at the codes and executes subroutines in the interpreter to handle each token.

BASIC is an interpreted language. It accepts input from the user and either immediately executes the command or stores it in memory for later execution. The advantage of an interpreter is that it allows you to quickly see what your commands will do. With a compiler you would have the steps of converting your code into machine language before you could see the results of your commands.

7.2 ENTERING PROGRAMS

7.2.1 Direct Mode

BASIC has two modes of operation: direct and stored program. In direct mode BASIC will attempt to execute what you type immediately:

```
PRINT "HELLO WORLD"
HELLO WORLD
```

Direct mode can also be used for doing calculations, in other words, it can be used as an elaborate calculator. Here are some more examples:

```
PRINT 5*4
    20
A=10
B=20
PRINT A*B
    200
```

In direct mode you can use variables in addition to numbers. It is important to know however that any values stored in variables will be cleared whenever a program is RUN.

7.2.2 Program Mode

In stored program mode lines that are entered are not immediately executed, but are stored into program memory as part of a whole program. To store a line into memory you just add a line number in front of the command:

```
10 PRINT"HELLO"
```

This line would then be added to the stored program. The numbers in front of the command specify where in the program this line should be inserted. The lower the number is, the more towards the beginning of the program. So for instance, line 10 will be executed before line 20.

If a line already exists with the same line number then it will be overwritten:

```
10 PRINT "HELLO"
LIST
10 PRINT "HELLO"
10 PRINT "BYE"
LIST
10 PRINT "BYE"
```

This is how your programs are edited. If you have a mistake in a line, all you have to do is type the line again and it will be replaced.

If you specify a line number without any command, then that line will be deleted from the program:

```
10 PRINT"HELLO"
20 PRINT"BYE"
LIST
10 PRINT "HELLO"
20 PRINT "BYE"
10
LIST
20 PRINT "BYE"
```

As in the example above it is customary not to number each line right after another, but rather to leave space between the line numbers. This way if you need to insert something between two lines of your program there will still be line numbers available for the new line.

BASIC allows you to put multiple commands on the same line. Each command needs to be separated by the ":" character. For example:

```
10 FOR I=1 TO 10: PRINT I: NEXT I
```

The length of any line is limited to 252 characters.

7.2.3 Numbers

BASIC uses 16 bit integers for numeric computation. The range of numbers allowed is from -32768 through +32767. When numbers are used in expressions, if there is no leading - sign the number is considered positive. A + sign is not needed before positive numbers.

7.2.4 Variables

BASIC allows two types of variables, integers and strings. BASIC allows for multiple character names which must start with A through Z and then can use A through Z as well as 0-9. Variable names are limited in length to 248 characters, but for performance reasons should be kept to shorter lengths.

String variables must have a $ appended to the variable name, for example A$. String variables can hold strings of characters of up to any length up to the maximum available memory. The storage for string variables does not need to be allocated before use; they are dynamically created on the heap.

7.3 EXPRESSIONS

In nearly all places where numbers are expected you can use arithmetic expressions in place of the numbers, even in the destinations of GOTO and GOSUB. Relational operators may also be used in expressions. When a relational operator evaluates true its result is -1 otherwise it results in 0.

The following operators and relations are valid in expressions:

Operator	Operation
*	Multiplication
/	Division
+	Addition
-	Subtraction
AND, &	Logical AND
OR, |	Logical OR
=	Equality
<>	Inequality
<	Less than
>	Greater than
<=	Less than or equal
>=	Greater than or equal

Table 8 - BASIC Operators

7.3.1 Order of Precedence

Expressions are evaluated with a given precedence to the operators. Operators that have the same precedence level are processed from left to right. BASIC follows the standard convention for operator precedence:

Operator	Precedence
1	Functions and variable references
2	*, /
3	+, -
4	AND, OR, &, |
5	=, <>, <, >, <=, >=

Table 9 - BASIC Operator Precedence

Precedence can be altered by the use of parentheses.

7.3.2 Expression Examples

Here are some expressions and their results to help illustrate these rules:

Expression	Result
2*5+3	13
2*(5+3)	16
5 OR 2	7
5 AND 3	1
5 * (3 < 4)	-5
5 * (3 = 4)	0
(3 < 4) AND (5 < 6)	-1

Table 10 - Examples of BASIC Expressions

In addition to numbers and variable references the following functions can also be utilized in expressions: ASC, FLG, FRE, INP, LEN, PEEK, RND, USR, VAL, and VARPTR. These functions are described in section 7.4.

7.3.3 String Expressions

The only valid operator for string expressions is the concatenation operator which is the + symbol. The concatenation operator will create a new string that consists of both strings that are arguments of the concatenation. For example:

```
10 A$="ABC"
20 B$="DEF"
30 C$=A$+B$
40 PRINT C$

RUN
    ABCDEF
```

In addition to the concatenation operator there are the following string functions which may be used in string expressions: CHR$, LEFT$, MID$, RIGHT$, and STR$. These functions are described in section 7.4. For example:

```
10 A$="ABCDEF"
20 B$="XYZ"
30 C$=LEFT$(A$,3)+B
40 PRINT C$

RUN
    ABCXYZ
```

7.4 Built in Functions

7.4.1 ASC(string-expression)

This function will return the ASCII value for the first character in the specified string expression. For example:

```
PRINT ASC("ABC")
    65

PRINT ASC("1")
    49
```

7.4.2 CHR$(numeric-expression)

This function takes the expression and produces a 1 character string that is the ASCII character for the specified expression. For example:

```
10 A$=CHR$(65)
20 PRINT A$

RUN
    A
```

7.4.3 FLG()

This function will read the four CDP1802 EF inputs and produce a merged result, with EF1=1, EF2=2, EF3=4, and EF4=8. For example, if EF1 and EF3 were active then FLG() would return 5.

7.4.4 FRE()

This FRE function allows you to determine how much memory is left. To be more precise, it returns the memory that is above program/variable space and below the stack/heap space. For example:

```
PRINT FRE()
    16274
```

7.4.5 INP(port)

This function will read the specified input port and return the result. The Port number argument must be between 1 and 7. Note that carelessly reading the wrong port may crash your Elf 2000!

7.4.6 LEFT$(string-expression, length)

This function will return the specified number of characters on the left side of the specified string expression. For example,

```
PRINT LEFT$("ABCDEFG",3)
   ABC
```

7.4.7 LEN(string-expression)

This function will return the length of the given string expression. For example:

```
PRINT LEN("ABCD")
    4
```

7.4.8 MID$(string-expression, start-position, length)

This function will extract the middle portion of a string expression. The resulting string will start at the specified position and be the specified length. For example:

```
PRINT MID$("ABCDEFG",2,3)
    BCD
```

7.4.9 PEEK(address)

The PEEK function allows the program to retrieve a 1 byte value from memory.

7.4.10 RIGHT$(string-expression, length)

This function will return the specified number of characters on the right side of the specified string expression. For example:

```
PRINT RIGHT$("ABCDEFG",3)
   EFG
```

7.4.11 RND(range)

The RND function will generate a random number from 0 to 1 less than the specified range. For example, if RND(6) were used, it would return a random number from 0 to 5.

7.4.12 STR$(numeric-expression)

This function will produce a string representation of a numeric expression. This function is used to convert numbers to strings, for example:

```
10 A$=STR$(5*100)
20 PRINT A$

RUN
   500
```

7.4.13 USR(address) or USR(address, expression)

The USR function is used to call a Machine Language subroutine. The address argument is required in both versions and specifies the address of the ML routine to be executed. If the second argument is provided, this value will be loaded into RF prior to the ML routine being called. The return value of this function is the value in RF when the ML routine returns.

See section 7.6.2, Machine Language Subroutines, for more information on using this function.

7.4.14 VAL(string-expression)

This function will return an integer equivalent for the specified string expression. This is the function used to convert a string representation of an integer to binary integer format. For example:

```
10 A$="123"
20 I=VAL(A$)
30 PRINT I

RUN
   123
```

7.4.15 VARPTR(variable-name)

This function returns the address of the data field for the specified variable. See section 7.6.1, Using VARPTR, for more on how to use this function.

7.5 Program Statements

7.5.1 CLEAR

The CLEAR statement will remove all variables, variable values, strings, string values and arrays from the heap. Essentially the CLEAR command will leave memory in the same state as if RUN had just been executed. For example:

```
10 A=5
20 PRINT A
30 CLEAR
40 PRINT A

RUN
   5
   0
```

7.5.2 DATA value, value, value, ,...

The data command provides a means to store data values inside your program. These values can then be read using the READ command. The current version of BASIC only allows for integer values in DATA statements.

See the READ statement, section 7.5.18, for examples and further information on DATA.

7.5.3 DIM variable(dimension[, dimension, ...]), ...

The DIM statement allows you to create integer arrays. Multidimensional arrays are allowed. Each dim argument specifies the largest valid index for the specified array and axis. A dimensioned variable is considered a distinct entity from a scalar variable by the same name; therefore A and A() do NOT refer to the same entity. As such you can use the same name for both simple variables as well as arrays.

For example:

```
10 DIM A(5)
20 FOR A=0 TO 5:A(A)=A*2:NEXT
30 FOR I=0 TO 5:PRINT A(I);" ";:NEXT

RUN
   0 2 4 6 8 10


10 DIM A(10,10)
20 FOR Y=1 TO 10:FOR X=1 TO 10:A(X,Y)=X*Y:NEXT:NEXT
30 FOR Y=1 TO 10:FOR X=1 TO 10
40 IF A(X,Y)<10 PRINT"   ";
50 IF A(X,Y)>9 IF A(X,Y)<100 PRINT"  ";
60 IF A(X,Y)=100 PRINT" ";
70 PRINT A(X,Y);
80 NEXT:PRINT:PRINT

RUN
     1   2   3   4   5   6   7   8   9  10
     2   4   6   8  10  12  14  16  18  20
     3   6   9  12  15  18  21  24  27  30
     4   8  12  16  20  24  28  32  36  40
    ...
    10  20  30  40  50  60  70  80  90 100
```

7.5.4 END

This statement will cause the program to terminate.

7.5.5 FOR variable=start TO end [STEP step] and NEXT [variable]

The FOR statement allows you to build controlled loops into your programs. FOR requires a variable to store the current loop value in as well as the start and ending values for the loop. The loop will end when the value in the loop variable exceeds the end value.

STEP is optional and if omitted a step of 1 is assumed. If STEP is provided then the expression following STEP is added to the loop variable each time through the loop.

NEXT provides the endpoint of the loop. The variable reference in NEXT is optional if the NEXT is referring to the FOR at the same level. It is also possible to specify a variable for NEXT that is in an outer loop, in this case all loops inside of the referenced outer loop will cease to exist and execution continues with the referenced loop.

Here are some examples of the FOR/NEXT statement:

```
10 FOR I=1 TO 10
20 PRINT I;" ";
30 NEXT I

RUN
   1 2 3 4 5 6 7 8 9 10


10 FOR I=1 TO 10 STEP 3
20 PRINT I;" ";
30 NEXT I

RUN
   1 4 7 10
```

This next example may require a bit of explanation so that you will understand why the results are the way they are. In line 40 we are testing for J=2 and if so we execute NEXT I. At this point loop J is the innermost nested loop, but by using NEXT I this will terminate the J loop right where it is and start the next iteration of the I loop. When the I loop finishes the END following the NEXT I is the next executed statement, which ends the program so the print at line 60 will never be seen.

```
10 FOR I=1 TO 5
20 FOR J=1 TO 10
30 PRINT I,J
40 IF J=2 NEXT I:END
50 NEXT J
60 PRINT "WILL NEVER SEE THIS"
70 NEXT I

RUN
   1       1
   1       2
   2       1
   2       2
   3       1
   3       2
   4       1
   4       2
   5       1
   5       2
```

7.5.6 GOSUB line-number

The GOSUB command allows normal program execution to be interrupted so that a subroutine could be executed. Like GOTO, BASIC allows for computed GOSUB, for example:

```
GOSUB B*100
```

If the target line of GOSUB does not exist, then an error 3 will result.

When a RETURN command, section 7.5.21, is encountered program execution will continue with the statement following the GOSUB.

7.5.7 GOTO line-number

The GOTO command changes the order of execution. Normally a program is executed from the lowest numbered line to the highest numbered line. When a GOTO is encountered a jump is taken to the specified line. BASIC allows for computed GOTO, for example:

```
GOTO A*1000
```

If the target line of a GOTO, either explicit or computed, does not exist then an error 3 will result and program execution will be terminated.

GOTO can also be used in direct mode in order to start a program from a specified line. For example:

```
10 A=5
20 PRINT A

RUN
   5

A=100
GOTO 20
   100
```

Note that when GOTO is used to start execution that variable and heap space are not cleared as they are when using RUN to start a program.

7.5.8 IF expression [THEN] statement

The IF command allows for decisions within a program. In BASIC the THEN is optional. If when the expression is evaluated and results in a nonzero value the statements following THEN will be executed. If the results of the expression are zero then execution will follow through to the line following the line containing the IF statement. For example:

```
10 A=5
20 IF A<10 PRINT "A":PRINT"B"
30 PRINT "C"

RUN
   A
   B
   C
```

Change line 10 to:

```
10 A=100

RUN
 C
```

Note that IF/THEN statements may be nested.

7.5.9 INPUT ["prompt";] variable[, variable, ...]

This statement allows a program to get input from the user. If the optional prompt is specified, it will be printed before the program queries for input. Multiple variables may be input at the same time and the BASIC expression evaluator is used when reading input values, so you can specify expressions for input values.

If not enough values were given for the number of variables specified in the INPUT command, then multiple queries will be made of the user. If the user gives more values than INPUT is expecting, remaining values will be read by the following INPUT commands.

For example:

```
10 B=5
20 INPUT "VALUE=";A
30 PRINT A

RUN
   VALUE=? 10
   10

RUN
   VALUE=? B*5
   25


10 INPUT "VALUES=";A,B
20 PRINT A,B

RUN
   VALUES=? 4,5
   4       5

RUN
   VALUES=? 4
   ? 5
   4       5


10 INPUT "VALUE 1=";A
20 INPUT "VALUE 2=";B
30 PRINT A,B

RUN
   VALUE 1=? 5
   VALUE 2=? 7
   5      7

RUN
   VALUE 1=? 5,7
   VALUE 2=
   5      7
```

7.5.10 LET variable = value

The LET statement assigns values to variables; however the use of the LET keyword is optional in BASIC. For example:

```
LET A=5*(2+7)
A=10*B
```

7.5.11 LIST

This command will list the entire program in memory. The usage “LIST line” will list only the specified line number. If the specified line number does not exist, then an error will be generated. The longer form of this statement, “LIST start-end”, will list all lines between the specified starting and ending line numbers. Neither the starting or ending lines themselves need to exist.

The shorthand “LIST start-“ will list lines starting from the specified line up to the end of the program. The specified line does not need to exist. If it does not exist then the first line to be listed will be the next highest line number that does exist. The “LIST -end” shorthand will list from the start of the program up to and including the specified line number. The ending line number need not exist.

7.5.12 NEW

NEW clears the program space of the current program. Issue this command when you desire to erase the current program and begin a new one. If this command is used inside of a program, it will cause memory to be cleared and program execution to end.

7.5.13 ON expression GOTO line1, line2, line3, ...,

This form of the GOTO command will evaluate the given expression to see which of the specified line number to jump to. If the expression evaluates to 1 then the first line will be jumped to, if the expression evaluates to 2 then the second line will be jumped to and so forth. If the expression evaluates to less than 1 or greater than the number of line numbers given execution will fall through to the next statement. For example:

```
10 A=2
20 ON A GOTO 100,200,A*100
30 PRINT "NONE"
99 END
100 PRINT "100":GOTO 99
200 PRINT "200":GOTO 99
300 PRINT "300":GOTO 99

RUN
    200
```

Change line 10 to

```
10 A=0

RUN
   NONE
```

Change line 10 to

```
10 A=4

RUN
   NONE
```

Change line 10 to

```
10 A=3

RUN
   300
```

Note that just as in the standard GOTO, the line numbers may be computed.

7.5.14 OUT port, value

The OUT command allows you to write the specified value out to the specified port. The port number must be a value from 1 to 7. Note that carelessly writing to the wrong port may crash your Elf 2000!

7.5.15 POKE address, value

POKE will write the specified value into the specified address in memory. Care must be taken when using POKE – if you POKE a value into a critical location it could crash your Elf 2000 and require a reset.

7.5.16 PRINT expression_list

The print command allows a program to output values to the terminal. The expression list may consist of no elements or multiple elements. When no expressions are given PRINT will just move the cursor down a line on the terminal, and when multiple expressions are provided, each expression must be separated by either a "," or ";" character. Whenever a "," is encountered a <TAB> character is sent to the terminal which will tell the terminal to move the cursor to the next tab stop. When ";" is used no cursor movement will occur. Either "," or ";" may also be the last character of the expression list and will have the effect of preventing the automatic carriage return at the end of the PRINT statement.

Here are a few examples of PRINT:

```
10 PRINT "ANSWER=";5+7

RUN
   ANSWER=12


10 PRINT "A","B";"C"

RUN
   A      BC


10 PRINT "A"
20 PRINT "B"

RUN
   A
   B


10 PRINT "A";
20 PRINT "B"

RUN
   AB


10 PRINT "A",
20 PRINT "B"

RUN
   A      B
```

7.5.17 RANDOM

This statement allows the random number generator to be reseeded. The user will be prompted for a value to reseed the generator with. The same seed value will always generate the same string of random numbers.

7.5.18 READ variable, variable, variable, ...

The READ statement will read values from the current DATA pointer into the specified variables. It is not necessary to match the number of variables in the READ list to a specific DATA statement. For all practical purposes it does not matter how many DATA statements the data is spread over; it is all considered linear to the READ statement.

If an attempt to read a data element beyond the last DATA statement is made then an error 9 will occur.

The READ/DATA set of statements makes it easy to initialize variables. For example:

```
10 DATA 5,10,15,20,25,30
20 READ A,B,C
30 PRINT A,B,C
40 READ A,B
50 PRINT A,B
60 READ A
70 PRINT A
80 READ A

RUN
   5       10      15
   20      25
   30

   ERROR:9 in line 80
```

7.5.19 REM remarks

This statement marks everything else on the same line as being a remark. Remarks are ignored by BASIC and program execution will continue with the next line of the program.

7.5.20 RESTORE [line]

The RESTORE command will reset the DATA pointer used by the READ statement. If no line is specified, then the DATA pointer will be set to the first data item of the first DATA statement in the program. If a line number is specified then the DATA pointer will be set to the first item of the first DATA statement line that is on or later than the specified line. Note that it is not necessary to specify the DATA line number exactly, however the line referenced by the RESTORE command must exist, even if it is not a DATA line. If the line does not exist at all an error 3 will result.

For example:

```
10 DATA 1,2,3,4,5
20 DATA 10,11,12,13
30 READ A,B,C
40 PRINT A,B,C
50 RESTORE
60 READ A,B,C
70 PRINT A,B,C
80 RESTORE 20
90 READ A,B,C
100 PRINT A,B,C

RUN
   1      2      3
   1      2      3
   10     11     12
```

7.5.21 RETURN

This command will return execution back to the statement following the last executed GOSUB command. If there are no more GOSUB targets left on the stack then an error 4 will result and the program will be terminated. For example:

```
10 PRINT "A"
20 GOSUB 100
30 PRINT "C"
99 END
100 PRINT "B"
110 RETURN

RUN
    A
    B
    C
```

7.5.22 RUN

RUN begins execution of the program in memory. Execution always starts with the lowest line number, and all variables and heap space is cleared. This command may be used inside of a program in order to restart the program from the cleared state.

7.6 Advanced Techniques

7.6.1 Using VARPTR

VARPTR is a function that allows you to determine where in memory something is stored. The following sections describe what the VARPTR function returns for the different variable types in BASIC.

7.6.1.1 An Integer Variable – VARPTR(A)

When obtaining the address of an integer variable, VARPTR will return the address where the variables value is actually stored. Here is an example:

```
10 I=5
20 PRINT PEEK(VARPTR(I))
30 PRINT PEEK(VARPTR(I)+1)

RUN
   0
   5
```

Integer variables are stored with the MSB first in memory and then the LSB second. Using the address you get from VARPTR, you can also change the data in a variable.

```
10 I=5
20 POKE VARPTR(I)+1,10
30 PRINT I

RUN
   10
```

7.6.1.2 A String Variable – VARPTR(A$)

When using VARPTR on a string variable, the address returned points to the address of where the string data is stored. Unlike integer variables, there is one level of indirection in the address. For example:

```
10 A$="ABC"
20 M=VARPTR(A$)
30 M=PEEK(M)*256+PEEK(M+1)
40 POKE M,49
50 PRINT A$

RUN
   1BC
```

In this example, line 30 is what takes the address that VARPTR returned and then reads the address of the actual string data. Just like in integer values, address values are stored MSB first. Unlike many other BASICs, Elf 2000 BASIC does not use a length byte for strings. This has the benefit that strings can be longer than 255 characters. Strings are terminated with a zero byte; for example "ABC" would be stored in memory as 0x41, 0x42, 0x43, and 0x00.

7.6.1.3 An Array Variable – VARPTR(A(0))

When using VARPTR on an array element, the address where that element's data is stored is returned. Here is an example:

```
10 DIM A(10)
20 A(0) = 5
30 POKE VARPTR(A(0))+1,10
40 PRINT A(0)

RUN
   10
```

7.6.2 Machine Language Subroutines

Using USR() it is possible to extend the capabilities of BASIC with your own machine language subroutines. When writing ML subroutines for use with BASIC you must make sure that all registers modified by the ML subroutine be preserved on return back to BASIC. Control will be transferred to the ML subroutine with R3 as the active program counter. R2 will point to BASIC's stack. R4, R5, and R6 will all have the values for using SRET and SCAL from the BIOS. In order to return back to BASIC you must execute a SEP RD.

Strings make a good place to store small machine language programs. Since when the string is created the space in memory is allocated and you no longer need to worry if the subroutine gets clobbered by the stack, heap, or variable storage.

There are two basic techniques for doing this, dynamic strings and static strings. In dynamic strings, you want to create space on the heap where the string will be stored; if you create the string using a string expression, the resulting string is guaranteed to be on the heap. After the string is created you just poke your ML subroutine into the string space. The advantage of using dynamic strings is that the original program source is not affected by the poking of the ML subroutine. The disadvantage is that the ML subroutine must be loaded into the string every run. Here is an example of a program using the dynamic string technique:

```
10 A$="     "+" "
20 M=VARPTR(A$)
25 M=PEEK(M)*256+PEEK(M+1)
30 FOR I=0 TO 4:READ N:POKE M+I,N:NEXT
40 I=USR(M)
50 DATA 227,100,174,226,221
```

In the static string technique, you want strings that are fixed into the program space. Normally when a string is assigned as a constant in the program the string in the program code is used as the string space for the variable, and it is not allocated on the heap. The advantage of this method is that once the strings are loaded with the ML routine, you need not load them again between runs. When the program is saved, it will be saved with the ML routines intact in the strings. The disadvantage is that you usually end up with unprintable characters in the strings which when the program is listed can cause havoc with the terminal. Here is an example of using the static strings method:

```
10 A$="     "
20 M=VARPTR(A$)
25 M=PEEK(M)*256+PEEK(M+1)
30 FOR I=0 TO 4:READ N:POKE M+I,N:NEXT
50 DATA 227,100,174,226,221
```

Notice the difference in the definition of A$ – in this version since the assignment does not involve an expression, the string pointer will point to the constant in the program text itself.

After running this program, take a look at line 10

```
LIST 10
10 A$="cd.b]"
```

The values now in the string were put there by the POKEs and now constitute the ML subroutine as part of the program code. Now delete line 30 and change line 50:

```
30
50 I=USR(M)
```

and you should have this:

```
10 A$="cd.b]"
20 M=VARPTR(A$)
25 M=PEEK(M)*256+PEEK(M+1)
40 I=USR(M)
```

This program will now do what the first program did, but now you can save this and not ever need to load the ML subroutine again since it is now part of the program.

7.7 ERROR CODES

Table 11 summarizes the error codes used by BASIC

Error Code	Explanation
0	Break (IN button or Control-C)
1	Statement not allowed in direct mode
2	Syntax Error
3	Invalid line number
4	RETURN without GOSUB
5	Value of range
7	INVLP
8	NEXT without FOR
9	No DATA for READ
10	Out of Memory
11	Bad Dimension
12	Unsupported feature

Table 11 BASIC Error Codes

8 FORTH

In addition to the Editor/Assembler and BASIC, the Elf 2000 Monitor EPROM contains an interpreter for the Forth language, also written by Mike Riley. This chapter, documenting the Elf 2000 Forth language, was contributed by Mike.

8.1 STACK REPRESENTATION

In the instructions listed below, the state of the stack is shown in parentheses. Symbols before the → represent the stack before the instruction is executed; symbols after the → represent the stack after execution. The top of stack is to the right. Example: (1 2 → 3) This shows that 2 is on the top of the stack, and 1 is 2nd from the top, after the instruction is executed 3 will be on the stack, the 1 and 2 will be consumed.

8.2 ARITHMETIC OPERATORS

+	(a b → c)	Add top 2 stack entries
-	(a b → c)	Subtract top 2 stack entries
*****	(a b → c)	Multiply top 2 stack entries
=	(a b → c)	Check equality, 1=equal, 0=unequal
<>	(a b → c)	Check inequality, 1-unequal, 0=equal
and	(a b → c)	Logically and top 2 stack values
or	(a b → c)	Logically or top 2 stack values
xor	(a b → c)	Logically xor top 2 stack values

Table 12 - Forth Arithmetic Operators

8.3 CONTROL OPERATORS

BEGIN	(→)	Beginning of BEGIN-UNTIL loop
UNTIL	(B →)	Ending of BEGIN-UNTIL loop
WHILE	(B →)	Beginning of while-repeat loop
REPEAT	(→)	End of while-repeat loop
DO	(T S →)	Start of DO LOOP
I	(→ c)	Put current loop count onto stack
LOOP	(→)	End of DO LOOP
+LOOP	(v →)	End of loop with specified increment
IF	(B →)	Beginning of IF-ELSE-THEN structure
ELSE	(→)	ELSE portion of IF-ELSE-THEN
THEN	(→)	End of IF-ELSE-THEN
>R	(a →)	Move top of data stack to return stack
R>	(→ a)	move top of return stack to data stack

Table 13 - Forth Control Operators

8.4 VARIABLES

VARIABLE *name*		Create a variable (not allowed in functions)
@	(a → v)	Retrieve value from address
!	(v a →)	Store value at address
C@	(a → v)	Retrieve byte value from address

`C!`	(v a →)	Store byte value at address
`ALLOT`	(n →)	Increase the last defined vars storage space

Table 14 - Forth Variables

8.5 Function Definition

`: name`	(→)	Create a function
`;`	(→)	End of function definition

Table 15 - Forth Function Definitions

8.6 Stack Operators

`DUP`	(a → a a)	Duplicate top stack value
`DROP`	(a →)	Drop top stack value
`SWAP`	(a b → b a)	Swap top 2 stack entries
`OVER`	(a b → a b a)	Copy 2nd stack value to top
`ROT`	(a b c → b c a)	Rotate 3rd stack item to top
`-ROT`	(a b c -- c a b)	Rotate top of stack to 3rd position
`DEPTH`	(→ a)	Get number of items on stack
`.`	(a →)	Print top of stack as signed integer
`U.`	(a →)	Print top of stack as unsigned integer
`EMIT`	(a →)	Print top of stack as ASCII character
`KEY`	(→ v)	Read a char from the keyboard and place on stack

Table 16 - Forth Stack Operators

8.7 Other Functions

`CR`	(→)	Print a CR/LF pair
`MEM`	(→ a)	Return amount of memory
`WORDS`	(→)	Display vocabulary words
`SEE name`	(→)	See what is bound to a name
`FORGET name`	(→)	Remove a variable or function
`." text "`	(→)	Print specified text on the terminal
`INP`	(p → v)	Read I/O port “p” and push the value
`OUT`	(p v →)	Write value “v” to I/O port P
`EF`	(→ v)	Read the 4 EF inputs
`BYE`	(→)	Return to the Elf 2000 Monitor

Table 17- Other Forth Functions

8.8 Extended Functions

These extended functions are implemented as pre-loaded Forth programs. As such they can be viewed with the **`SEE`** command and removed with the **`FORGET`** command.

`1+`	(v → v)	Add 1 to the top of stack
`1-`	(v → v)	Subtract 1 from the top of stack
`2+`	(v → v)	Add 2 to the top of stack
`2-`	(v → v)	Subtract 2 from the top of stack
`FREE`	(→)	Display free memory
`LSHIFT`	(v c →)	Left shift value v by c bits

`RSHIFT`	(v c →)	Right shift value v by c bits
`FILL`	(ad ch cn →)	Fill cn bytes with ch starting at ad
`CLEAR`	(→)	Clears the stack of all entries
`SPACES`	(v →)	Display specified number of spaces
`+!`	(v a →)	Add value to specified variable address
`-!`	(v a →)	Subtract value from specified variable address
`*!`	(v a →)	Multiply specified variable address by value
`NOT`	(v → v)	Return 0 if TOS <> 0, otherwise 1
`0=`	(v → v)	Returns 1 if TOS is zero, otherwise 0
`@+`	(a → a v)	Like @ except preserve address incremented by 2
`>0`	(v → v)	Return 1 if TOS > 0 else 0
`<0`	(v → v)	Return 1 if TOS < 0 else 0
`>`	(a b → v)	Return 1 if a > b else 0
`<`	(a b → v)	Return 1 if a < b else 0
`>=`	(a b → v)	Return 1 if a >= b else 0
`<=`	(a b → v)	Return 1 if a <= b else 0
`..S`	(→)	Display entire contents of stack
`?`	(a →)	Display value at address
`NEG`	(v → v)	Negate a number
`MAX`	(a b → v)	Return largest of 2 numbers
`MIN`	(a b → v)	Return smallest of 2 numbers
`?DUP`	(a → a | a a)	Duplicate TOS if nonzero
`ABS`	(v → v)	Return absolute value of a number
`BL`	(→ 32)	Place a blank on the stack
`SPACE`	(→)	Display a single space
`NIP`	(b a → a)	Drop 2nd item from stack
`TUCK`	(b a → a b a)	Place copy of TOS before 2nd on stack
`TRUE`	(→ 1)	Place true value on stack
`FALSE`	(→ 0)	Place false value on stack
`CLS`	(→)	Clear screen
`MOD`	(a b → v)	Get remainder of a/b
`INVERT`	(a → v)	Invert the bits of TOS
`TYPE`	(a v →)	Display v bytes from address a
`SGN`	(v → v)	Return sign of number
`2DUP`	(b a → b a b a)	Duplicate top 2 stack values
`PICK`	(a → v)	Duplicate a'th element of stack on top
`/MOD`	(a b → r q)	Perform both mod and remainder functions

Table 18 - Extended Forth Functions

8.9 A Basic Forth Tutorial

Forth is primarily a stack based language. Arguments for functions are first pushed onto the stack and then the instruction is executed. Pushing a number onto the stack is done merely by mentioning the number:

```
ok 5
```

This instruction will leave 5 on the top of the stack. The '.' command will take the top of the stack and display it in signed integer notation:

```
ok .
5 ok
```

The '.' took the 5 we pushed earlier, removed it from the stack and printed it. If we execute the command again:

```
ok .
stack empty
ok
```

the interpreter will complain about an empty stack and abort any further processing. Commands can be placed multiply on a line, with just spaces separating each command:

```
ok 5 4 . .
4 5 ok
```

In this example, 4 was the last value pushed onto the stack, therefore the first value popped off by the first '.' command. To keep the prompt off the line with the answers, you can use the **CR** command:

```
ok 5 4 . . CR
4 5
ok
```

Note also that commands are executed from left to right, and there is never any order of operations other than left to right. It is also possible to display text using the **."** operator:

```
ok ." HELLO WORLD!!!" CR
HELLO WORLD!!!
ok
```

Arithmetic can be performed as well. Try this example:

```
ok 5 4 + . CR
9
ok
```

Again, notice all the arguments are pushed onto the stack before the command is executed. Equality is tested with the **=** operator:

```
ok 5 4 = . CR
0
ok 5 5 = . CR
1
```

Note that when two numbers are equal, a 1 is left on the stack, whereas 0 is left when they are not equal. The **DEPTH** command will place onto the top of the stack the number of items on the stack:

```
ok 4 5 6 DEPTH . CR
3
ok
```

Note that the depth command does not include its own answer in the total. The top two stack values can be swapped using the **SWAP** command:

```
ok 2 3 . . CR
3 2
ok 2 3 SWAP . . CR
2 3
ok
```

The top of the stack can be duplicated using the **DUP** command:

```
ok 2 . . CR
2 stack empty
ok 3 DUP . . CR
3 3
ok
```

The **IF** command can be used for conditional execution. **IF** examines the top of the stack to determine what to execute:

```
ok 1 IF 1 . THEN 2 . CR
1 2
ok 0 IF 1 . THEN 2 . CR
2
ok
```

When **IF** finds 0 on the stack, execution begins after the matching **THEN**. It is also possible to have an **ELSE**. Try these:

```
ok 1 IF 1 . ELSE 2 . THEN 3 . CR
1 3
ok 0 IF 1 . ELSE 2 . THEN 3 . CR
2 3
```

If an **ELSE** is found before the next **THEN** on a failed **IF** test, the **ELSE** code block will be executed. There are 3 looping constructs in FORTH. The first is the **DO LOOP**. This is a controlled loop with a specific start and a specific end. The **I** command can be used inside of a loop to retrieve the loop counter:

```
ok 10 0 DO I . LOOP CR
0 1 2 3 4 5 6 7 8 9
ok
```

Notice that the loop terminates once the end condition is reached. The test occurs at the **LOOP** command, therefore the loop is not executed again when **I** reaches 10. Notice also that a loop is always executed at least once:

```
ok 10 15 DO I . LOOP CR
15
ok
```

To increment the loop counter by something other than 1, use the **+LOOP** command:

```
ok 10 0 DO I . 2 +LOOP CR
0 2 4 6 8
ok 10 0 DO I . 3 +LOOP CR
0 3 6 9
```

The next two loop types are uncontrolled; these loops are executed so long as the top of stack is non-zero at the time of test. The **BEGIN UNTIL** loop has its test at the end, and therefore just like **DO** loops, the loop will always be executed at least once:

```
ok 5 BEGIN DUP . 1 - DUP UNTIL CR
5 4 3 2 1
ok
```

Notice we used the **DUP** command here first to make a duplicate of our counter for the **.** command, and then a second **DUP** before the **UNTIL**. **UNTIL** takes the top of the stack in order to determine if another loop is needed. The second uncontrolled loop is the **WHILE REPEAT** loop. This loop has its test at the beginning, therefore if **WHILE** finds a 0 on the stack the loop will not even execute the first time:

```
ok 5 DUP WHILE DUP . 1 - DUP REPEAT CR
5 4 3 2 1
ok 0 DUP WHILE DUP . 1 - DUP REPEAT CR
ok
```

Variables can be created with the **VARIABLE** command. Notice that variables should not be given the same names as built in commands. Here are some example variables:

```
ok VARIABLE A
ok VARIABLE B
```

If you execute a **WORDS** command, you will see that your new variable names now appear in the list. To store a value in a variable we use the **!** command. First we push the value we want to store on the stack, and then mention the variable:

```
ok 5 A !
ok 10 B !
```

This stores 5 into A and 10 into B. To retrieve the values of variables, use the @ command:

```
ok A @ . CR
5
ok B @ . CR
10
ok A @ B @ + . CR
15
```

To immediately print the value in a variable, you can use the **SEE** command:

```
ok SEE A
5
ok
```

Note that the **SEE** command provides its own CR/LF.

```
ok SEE A SEE B
5
10
ok
```

The real power of forth is that it allows you to define your own commands! Commands are defined using the **:** command and are terminated with the **;** command. Note that Forth requires the entire command to be created in one input cycle. Try this one:

```
ok : STARS 0 DO 42 EMIT LOOP ;
ok
```

If you look at the **WORDS** now, you will see another new name: **STARS**. You can also use the **SEE** command on functions to see their definitions:

```
ok SEE STARS
: STARS 0 DO 42 EMIT LOOP ;
```

This command can now be used just like any other forth command:

```
ok 5 STARS CR
*****
ok
```

Custom functions can even be used inside other custom functions:

```
ok : PYRAMID 1 DO I STARS CR LOOP ;
ok
```

Now run it:

```
ok 5 PYRAMID
*
**
***
****
```

8.10 DEFINITIONS OF EXTENDED FUNCTIONS

This section reproduces the exact definitions (in Forth, of course) of the extended functions described in section 8.8.

```
: 1+ 1 + ;
: 1- 1 - ;
: 2+ 2 + ;
: 2- 2 - ;
: 0= 0 = ;
: >0 DUP IF -32768 AND IF 0 ELSE 1 THEN ELSE DROP 0 THEN ;
: <0 DUP IF -32768 AND IF 1 ELSE 0 THEN ELSE DROP 0 THEN ;
: > - DUP IF -32768 AND IF 0 ELSE 1 THEN ELSE DROP 0 THEN ;
: < - DUP IF -32768 AND IF 1 ELSE 0 THEN ELSE DROP 0 THEN ;
: >= - DUP IF -32768 AND IF 0 ELSE 1 THEN ELSE DROP 1 THEN ;
: <= - DUP IF -32768 AND IF 1 ELSE 0 THEN ELSE DROP 1 THEN ;
: CLEAR DEPTH WHILE DROP DEPTH REPEAT ;
: FREE MEM U. CR ;
: SPACES 0 DO 32 EMIT LOOP ;
: +! DUP ROT SWAP @ + SWAP ! ;
: -! DUP ROT SWAP @ SWAP - SWAP ! ;
: *! DUP ROT SWAP @ * SWAP ! ;
: /! DUP ROT SWAP @ SWAP / SWAP ! ;
: NOT IF 0 ELSE 1 THEN ;
: @+ DUP @ SWAP 2 + SWAP ;
: .S 8206 @ 1 + DEPTH 1 - 0 DO DUP @ . 2 + LOOP DROP ;
: ? @ . ;
: NEG 0 SWAP - ;
: MAX DUP ROT DUP ROT > IF SWAP DROP ELSE DROP THEN ;
: MIN DUP ROT DUP ROT > IF DROP ELSE SWAP DROP THEN ;
: ?DUP DUP IF DUP THEN ;
: ABS DUP <0 IF 0 SWAP - THEN ;
: BL 32 ;
: SPACE 32 EMIT ;
: NIP SWAP DROP ;
: TUCK SWAP OVER ;
: TRUE 1 ;
: FALSE 0 ;
: CLS 27 EMIT 91 EMIT 50 EMIT 74 EMIT ;
: MOD DUP ROT DUP ROT / ROT * - ;
: LSHIFT DUP WHILE SWAP 2 * SWAP 1 - DUP REPEAT DROP ;
: RSHIFT DUP WHILE SWAP 2 / SWAP 1 - DUP REPEAT DROP ;
: FILL SWAP -ROT DUP IF 0 DO OVER OVER C! 1 + LOOP ELSE DROP THEN DROP DROP ;
: INVERT -1 XOR ;
: TYPE DUP IF 0 DO DUP C@ EMIT 1 + LOOP ELSE DROP THEN DROP ;
: SGN DUP IF -32768 AND IF -1 ELSE 1 THEN THEN ;
: 2DUP OVER OVER ;
: PICK DUP DEPTH 1 - < IF 2 * 8206 @ 1 + + @ ELSE DROP 1 ERROR THEN ;
: /MOD OVER OVER MOD -ROT / ;
```

9 THE STG1861 VIDEO BOARD

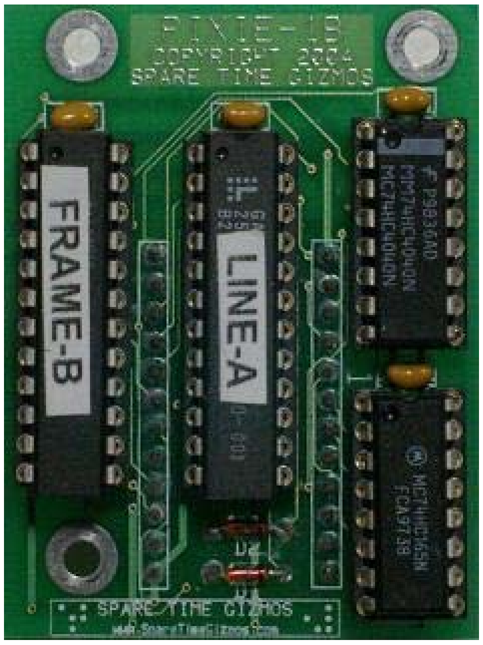


Photo 10 - The STG1861 Board

The Spare Time Gizmos CDP1861 emulator (aka the STG1861) is built on a small daughter card that fits on top of the main Elf 2000 board and plugs into the U2 socket. You should build and test the Elf 2000 first, before beginning construction on the STG1861. It's necessary to do a trial fitting of the STG1861 daughter board to the Elf 2000 main board in order to get the pin length correct, and this is much easier to do *before* you've assembled the STG1861.

When you are using the STG1861, *do not install a conventional DIP socket at U2*; instead install a pair of twelve pin 0.1" female header strips. These strips are not part of the Elf 2000 kit but are included in the STG1861 full kit. The female header strips mount on the top side of the Elf 2000 PC board and point up, just as you'd expect.

The STG1861 daughter board is physically attached to the Elf 2000 main board by three solder in swage standoffs, three ½" stand offs, and three #4-40 screws. All of these parts are included in the STG1861 full kit. You should solder the swages directly to the Elf 2000 PC board in the three large holes surrounding the U2 socket. The swages are installed with the threaded part on the top (component) side of the PC board and are soldered on the bottom (solder) side.

Photo 9 - The Classic Pixie Demo

Note that the swages require a considerable amount of heat to solder properly and your regular iron probably won't be enough!

After the female headers and swages are mounted, install the three ½" #4-40 standoffs and insert the two 12 pin wire wrap header strips into the female headers. Place the STG1861 bare PC board on top (component side up!) of the wire wrap headers and be sure that they're inserted thru the correct holes for J1. You'll find that the wire wrap pins are much longer than needed and that the STG1861 PC board is way above the tops of the standoffs. *Gently* press down on the STG1861 PC board – the plastic strips on the wire wrap headers will slide down – until the board rests on top of the standoffs. The black plastic strips that hold the wire wrap headers together should be flush against the bottom of the STG1861 PC board.

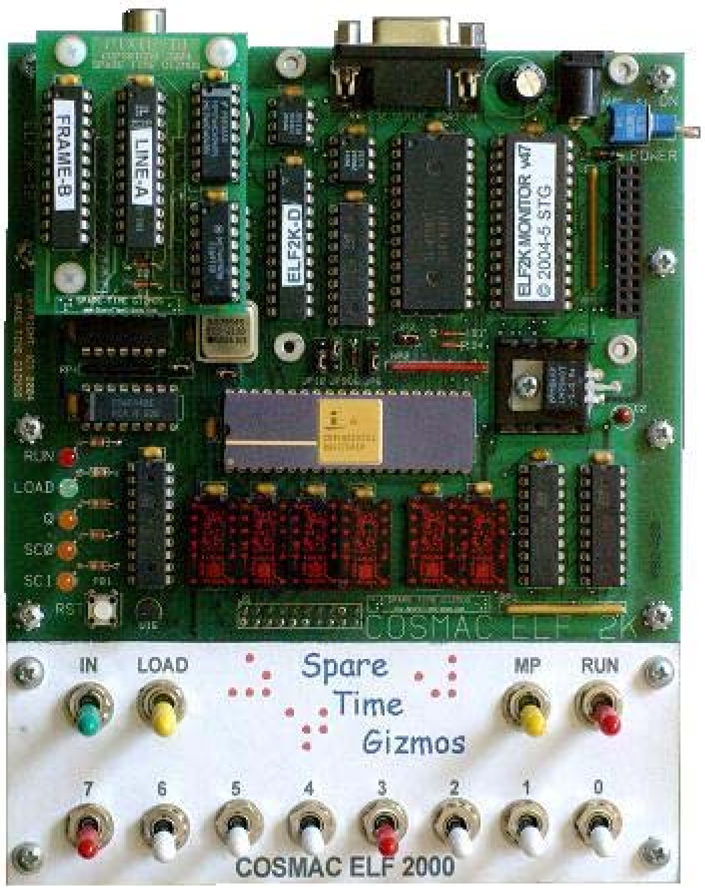


Photo 11 - STG1861 installed on the ELF 2000

While you have everything arranged just so, solder the 24 wire wrap pins to the top of the STG1861 PC board. Now you can remove the STG1861 board, wire wrap pins and all, and cut off the tops of the wire wrap pins flush with the PC board. Only now can you solder the rest of the components to the STG1861 and finish assembling it. When it's all done, return it to its original position on top of the Elf 2000 board and secure it in place with three #4-40 screws.

Note that the STG1861 also requires that the Elf 2000 jumpers JP1, JP7 and JP8 be installed (see section 3.2.1). It's probably easiest if you install these *before* mounting the STG1861 for the last time.

If you are lucky enough to have a real CDP1861 Pixie chip and you want to use it with your Elf 2000, then install a standard 24 pin DIP socket at U2 and plug in your chip. It'll work just fine! Be sure you also install jumpers JP1, JP7 and JP8 (see section 3.2.1).

10 THE EMBEDDED ELF

10.1 INTRODUCTION

The Embedded Elf is a slightly simplified and much smaller version of the Elf 2000. The Embedded Elf is exactly the same size and form factor as the Elf 2000 daughter cards, such as the Disk/UART/RTC card, the VT1802 80 column video card, or the GPIO General Purpose I/O card. The Embedded Elf has the same expansion bus as the Elf 2000 and stacks perfectly with the daughter cards to form a cute little "cube". The Embedded Elf can run the same software as the Elf 2000 and, in fact, uses the exact same monitor firmware EPROM as the Elf 2000.

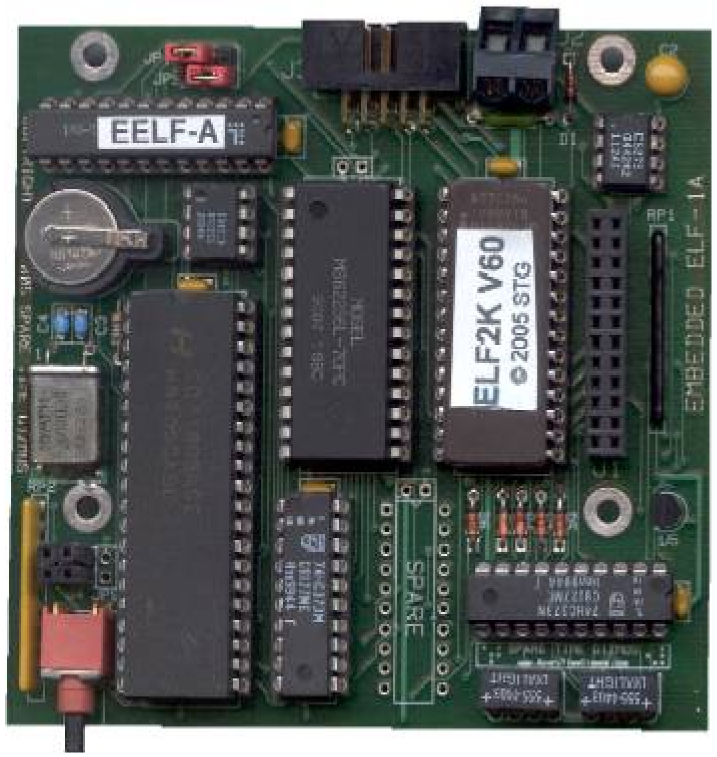


Photo 12 - Embedded Elf

The primary differences between the Elf 2000 and the Embedded Elf are that the latter lacks the switch interface and the TIL311 displays, although the Embedded Elf does have eight LEDs that are used to display the POST results. The Embedded Elf also lacks an on board voltage regulator and requires an external 5 volt regulated power supply. Finally, the Embedded Elf lacks the CDP1861 Pixie circuit and cannot be used with either the CDP1861 chip or the STG1861 module; however the Embedded Elf will work with the VT1802 80 column video card. The Embedded Elf does have the same non-volatile memory and bit banged serial port with EIA level shifter as the Elf 2000.

10.2 ASSEMBLY

Assembling the Embedded Elf is very straight forward, but here is some additional information that may be useful:

JP5 is actually shorted by a small trace on the back of the PCB. If you don't need JP5 (and you probably don't!) then it's not necessary to install anything there. Conversely, if you do want to use JP5, you'd better cut the small trace between the two pins.

J4 (the 4 pin female header) is there for the 80 column video card (see Chapter 12). You don't really need to install it unless you intend to use that card.

F1 (the picofuse) is shown on the schematic but isn't on the PC board.

The 0.1uF bypass capacitors aren't labeled on the PC board but they are shown on the schematic as C11-C16. Note that the schematic shows seven, however only six are actually used on the PC board. You don't need to install the bypass above the "SPARE" chip location.

Dallas Semiconductor doesn't recommend a bypass capacitor on the output of the DS1210[16] because it can cause instability. So don't install C1, either - that's the 0.1 bypass above the SRAM chip. In the end, there are actually eight bypass caps shown on the schematic (seven on page 3, and one for the SRAM on page 2), but only five are actually installed. Of course, nothing really bad will happen if you install the extras anyway.

The "official" power connector is a Mode Electronics 37-6302-0 (2 pin, right angle) and the mating shell is a 37-602-0, from http://www.mode-elec.com. Lots of other 0.1" connectors will also fit.

If you don't want battery backup for the SRAM, you don't need B1 or U9, but you'll have to install a couple of jumpers to bypass U9 so the SRAM still works. The instructions are the same as the Elf 2000 and can be found in section 2.3.3 of this manual.

Unlike the Elf 2000 where the crystal frequency is divided by two, the Embedded Elf crystal frequency is the CPU frequency. You can use 2MHz, 3MHz or even 5MHz, provided that your 180x chip is fast enough.

10.3 INSTALLATION

Remember that your Embedded Elf requires a regulated 5 volt power supply!

The odd jumper designations (JP5, JP9 and JP10) are used because their function corresponds to the Elf 2000 jumpers of the same name. Refer to sections 3.2.3 and 3.2.5 for a complete description of these jumpers. To work with the standard Elf 2000 EPROM, the RS-232 polarity jumpers JP10 and JP9 should be set with JP10 pins 1-2 shorted and JP9 pins 2-3 shorted. In other words on JP10 install the shorting block on the two pins towards the edge of the board (away from J3) and in JP9 install the shorting block on the two pins closest to J3.

The pin out for J3 (the serial port and I/O connector) is such that you can use a standard PC style 10 pin IDC to DB9 cable ***but be careful that your PC only connects to TXD, RXD and ground!*** That's because the Embedded Elf has other signals (e.g. EF1-4 and Q) on other pins in this connector and ***they won't like being connected to RS232 voltages!*** If you use a PC style cable, the best thing would be to cut out all the other wires.

10.4 PROGRAMMER'S REFERENCE

With the exception of the missing subsystems (switch register, TIL311 displays, and Pixie video) programming the Embedded Elf is exactly the same as the Elf 2000. The monitor EPROM is the same; the commands and languages are the same, and (with the exception of the STG1861) all the same daughter cards can be used.

[16] Sorry - I didn't know that when I designed the board!

11 THE DISK EXPANSION BOARD

11.1 INTRODUCTION

11.2 ASSEMBLY

If you didn't build your Elf 2000, or if it's been a while since you did, it would be a good idea to review the generic construction tips in sections 2.4 "Sockets and Soldering" and 2.5 "Assembly Hints".

Here are a few assembly tips that are unique to the Disk Expansion Board:

- ❖ The serial port connector, J3, *is intended to be a **male** DB9* and is wired the same as a PC serial port connector. Therefore, if you want to connect J3 to a PC serial port, you'll need to use a null modem cable. *This differs from the mother board serial port*, which uses a female connector and interfaces to a PC with a straight thru cable.
- ❖ The baud rate oscillator crystal, Y1, should be 2.4576MHz. Other values will work and are commonly used with the 8250/16450 UARTs, however the Elf 2000 firmware calculates baud rates based on 2.4576MHz.

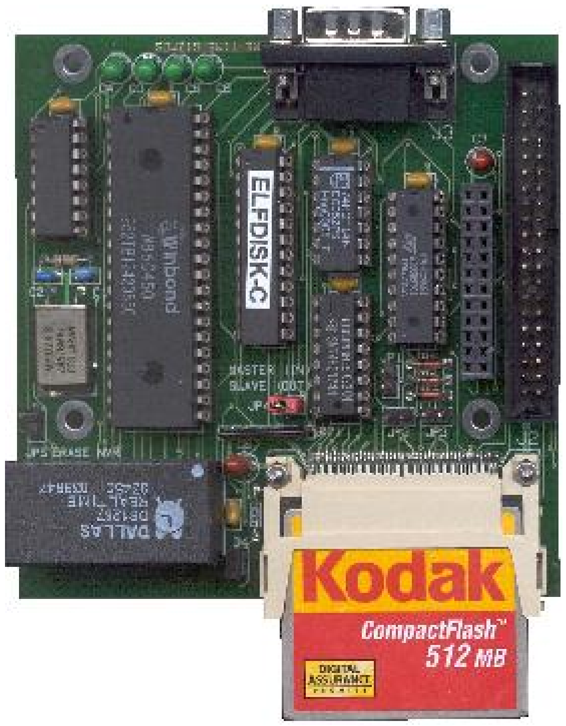


Photo 13 - Disk Expansion Board

11.2.1 Installing the CompactFlash Connector

Mounting and installing the CF socket is not a task for the faint of heart, but with patience and the right equipment you can get thru it. Here are a few tips to help you:

- ❖ *Mount the CompactFlash socket first*, before you solder anything else. You'll find that it's much more difficult to work on SMD pins when they're surrounded by a forest of taller, thru hole, parts.
- ❖ The CF socket has two little alignment nipples next to the screw holes. *Unfortunately the Revision 1B PC board dimensions for these holes are incorrect and they will not fit.* Use an Xacto knife or razor blade to trim off these little nibs. Be sure the bottom surface of the socket is flat and smooth; otherwise some of the pins may not touch the PC board.
- ❖ You can use #2 (English) machine screws or M1 (Metric) screws to mount the socket. With M1 hardware you can actually fit the hex nut on the top (socket) side - it'll fit down into the little hexagonal cutouts in the socket. #2 English hex nuts are too large, and you'll have to put the nuts on the bottom side of the PC board.
- ❖ There are some traces on the bottom of the PC board which run too close to the socket card mounting holes. *Use nylon washers on the bottom side to ensure that there are no shorts*.
- ❖ Assemble all the screws, CF socket and PC board and tighten the screws finger tight. Carefully check the socket pins for the correct alignment with their pads - the socket pins and the pads are exactly the same size and all 50 of them should line up perfectly. Slide the socket around a little if necessary to fix the alignment and, as a last resort, use a small probe

to bend one or more of the socket pins. You will need a magnifying lens and a good light to make this check!

❖ When you're happy with the pin alignment, tighten the screws and then go back and double check the alignment again to make sure it didn't slip. When all is well, solder the two metal feet at the front of the socket (one on the left and one on the right) first. Be careful not to melt the socket, but apply enough heat long enough for the solder to wick all the way under the socket and cover the pad completely. Between the soldered feet and the screws, the socket should now be firmly locked into place.

❖ To solder each pin, just touch the tip of the iron (you are using an ultra fine 0.015" diameter tip, right?) to the pad on the PC board. Count to three while it heats up, and then touch the solder (you are using 0.020" ultra fine solder, right?) to the end of the CF socket pin. Try to avoid touching the iron tip with the solder if you can. If you do it right, the solder will only melt on the one pad/pin that's hot, and it'll wick up between the pin and the pad.

❖ If you look carefully at the cut ends of the CF card pins with a magnifier, you'll see that each end is copper colored where the pin was cut off after it was tinned. When this little copper colored end disappears because it's covered with solder, you've used enough solder.

❖ If you use too much solder and short to an adjacent pin (and you will do this before you're done with all 50 pins; take my word for it!) use your super fine solder wick to remove the excess. Solder wick generally leaves enough solder behind for a good connection and you shouldn't need to add more solder when you're done.

11.2.2 Testing the CompactFlash Connector

After you've gone to all the trouble of soldering on the CompactFlash socket, you really should invest fifteen or twenty minutes in testing it before you proceed. *The CompactFlash socket is extremely difficult to work on after the other parts have been mounted*, and if there are any shorts or opens you want to find out now, not later.

❖ To check for opens, use a small sharp tool such as a dental pick to gently push on each and every pin. If the pin moves then you need to fix it; a pin that's firmly solder in place won't budge when you poke it.

❖ Checking for shorts requires that you use an ohmmeter or continuity tester to check every pair of adjacent pins for a short. Note that pins 13 and 38 are both connected to V_{CC} and these two pins are adjacent. Don't panic when they show up as shorted! There are no other instances of adjacent pins that are connected together.[17]

11.3 INSTALLATION

The Disk daughter board is physically attached to the Elf 2000 main board by four solder in swage standoffs, four ½" stand offs, and four #4-40 screws. The swages should be soldered directly to the Elf 2000 PC board in the four large mounting holes provided. One hole is on the rear edge immediately to the right of the power connector; another hole is immediately to the left of the DB9 serial port connector; the third hole is just above VR1 and just below J3, and the final swage mounts immediately below the GAL (U7). If you have any doubts, use the expansion card as a template to ensure that you've found all the right spots! Note that the swages require a considerable amount of heat to solder properly and your regular iron probably won't be enough!

[17] It goes without saying that there should be no CF card in the socket when you perform this test, and this also assumes that there are no other components installed on the PC board. If there are other components or a CF card present then other spurious low resistance paths may show up.

The daughter board electrically connects to the main board with a 24 pins stacking bus connector. These connectors are similar to the stacking connectors used on the PC/104 bus and are special order parts, but you can order one from Spare Time Gizmos. You can undoubtedly improvise some sort of connection using standard male and female 0.100" headers, but the stacking connectors will allow you to stack up multiple expansion boards, one above the other. Note that two stacking bus connectors are required to install the first daughter card – one for the daughter card itself and one for the main COSMAC Elf 2000 PC board. The pins on the latter will hang down below the Elf 2000 PC board, but if you've mounted your board in the usual way on side rails then these pins shouldn't cause a problem. If the extra pin length is a problem, you can always cut them off. Needless to say, *do not* cut the pins on any of the daughter cards – they won't make contact with the mating connector if you do!

11.3.1 Connecting an External Drive

Connector J4 is a standard 40 pin header that electrically conforms[18] to the standard ATA-3 specification and can be used to attach an external disk drive. The hardware is compatible with pretty much any ATA device, however the current Monitor EPROM, BIOS, and ElfOS operating system only work with IDE devices that

a. Support 8 bit transfer mode
b. Support logical block addressing (LBA) mode

All CompactFlash cards, except some very, very old ones, meet these requirements. Unfortunately there are very few hard disk drives around that implement 8 bit transfer mode, and most of those that do date from the PC/XT days and do not implement LBA mode. If you are lucky you may be able to find a disk drive which meets these requirements, however you'll probably only be able to use this connector to attach an external CompactFlash card.

ATAPI devices, like CDROM drives and ZIP disks, have no chance of working with the current firmware and software.

11.4 JUMPER SETTINGS

Revision 1B of the Disk Expansion card contains five jumpers labeled JP1 thru JP5. The following table summarizes the function of these jumpers and the proper default setting to work with the Spare Time Gizmos Monitor EPROM:

Jumper	Default	Function
JP1	*Removed*	Enables disk (Compact Flash) interrupt requests.
JP2	*Removed*	Enables real time clock interrupt requests.
JP3	*Removed*	Enables UART interrupt requests.
JP4	*Installed*	When installed the onboard CF card is the IDE Master. When removed the onboard CF is the IDE Slave.
JP5	*Removed*	When installed erases the NVR (see section 11.4.1)

Table 19 - Disk/UART/RTC/NVR Card Jumpers

11.4.1 Erasing NVR

Jumper JP5 can be used to erase the non-volatile RAM *provided that a DS12887A chip is used. This jumper has no effect on any other RTC/NVR chips*, including the DS12887.

To erase the NVR, first remove power from the Elf 2000 computer and then install jumper JP5. Wait a second or two, remove JP5, and re-apply power. JP5 works only when the DS12887A is

[18] More or less!

operating on battery power and not when V_{CC} is applied. *Do not attempt to operate the Elf 2000 and disk card with JP5 installed!*

11.5 PROGRAMMER'S REFERENCE

To the programmer, a standard IDE disk interface appears as sixteen separately addressable registers (although not all of these are implemented). Likewise, the 16450/550 UART contains ten addressable internal registers, and the DS12887A RTC has 128 addressable registers, 14 of which track the current date and time, and the remaining 114 are general purpose non-volatile memory cells.

Needless to say, cramming all this into the 1802's I/O space, which can support at most seven (yes, seven!) addressable devices requires a few compromises. The Elf 2000 Disk board uses a two level I/O scheme, in which the programmer first outputs a device/register select code to one port, and then accesses the selected device and register with another port. Any pair of 1802 ports may be used by reprogramming the Elf 2000 Disk board GAL, but by default, these two are used:

	Input	**Output**
Port 2	read status register	write device/register select
Port 3	read selected device/register	write selected device/register

Table 20 –Disk Board I/O Ports

11.5.1 Status Register

Reading the status register returns 8 bits as shown in Table 21.

IMPORTANT!

Disk Expansion PC Boards revision B and later *do not implement the status register*. This includes the vast majority of boards shipped to customers! On these boards reading the status register returns all 1 bits regardless of the expansion board status. The Elf 2000 Monitor and ElfOS BIOS do not use this register.

Elf 2000 Disk Board Status Register							
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*
X	**X**	**CD1**	**CD2**	**DASP**	**UART IRQ**	**RTC IRQ**	**DISK IRQ**

Table 21 - Disk Board Status Register

X → Unused bits (state is indeterminate).

CD1, **CD2** → Card detect inputs from the Compact Flash card socket. Normally these bits will both be zero when no CF card is inserted, and both will be one when a CF card is inserted.

DASP → This bit reflects the state of the DASP output from the selected IDE disk or CF card. This bit is normally one while the disk is busy, and zero when it is idle. This same bit also controls the disk activity LED located next to the CF card socket.

UART IRQ → This bit will be zero if the 16450/50 is requesting an interrupt and one if it is not. Note that the sense of this bit is backwards from the RTC and DISK IRQ bits! This bit always reflects the state of the IRQ output from the UART chip, however before an interrupt can actually occur jumper JP3 on the Elf 2000 Disk board must be installed and the software must enable the 1802 interrupt system.

RTC IRQ → This bit is one if the DS12887A RTC/NVR is requesting an interrupt and zero if it is not. This bit always reflects the state of the IRQ output from the RTC/NVR chip, however before an interrupt can actually occur jumper JP2 on the Elf 2000 Disk board must be installed and the software must enable the 1802 interrupt system.

DISK IRQ → This bit is one if the IDE or CF card is requesting an interrupt and zero if it is not. This bit always reflects the state of the IRQ output from the IDE/CF subsystem, however before an interrupt can actually occur jumper JP1 on the Elf 2000 Disk board must be installed and the software must enable the 1802 interrupt system.

11.5.2 Device and Register Select

Bytes written to the device/register select port use one of three different formats depending on the device selected. To select the IDE or Compact Flash interface, use the format shown in Table 22.

Elf 2000 Disk Board IDE and CF Register Selection							
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*
0	**X**	**X**	**0**	**-CS1 /CS3**	**RS2**	**RS1**	**RS0**

Table 22 - Disk Board IDE and CF Register Selection

-CS1/CS3 → If this bit is *zero*, the first IDE register set (corresponding to IBM PC I/O addresses 01FxH) is selected. If this bit is *one*, the second IDE register set (corresponding to IBM PC I/O addresses 03FxH) is selected instead.

RS2-RS0 → select an individual IDE register, 0..7.

X → "don't care" bits (should be zero for future compatibility).

Once an IDE/CF register is selected by writing to the device/register select port (port 2), the software can then read or write the contents of that register by accessing port 3. To select the 16450/550 UART, the software should write a byte to the device/register select port with the format shown in Table 23

Elf 2000 Disk Board UART Register Selection							
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*
0	**X**	**X**	**1**	**X**	**RS2**	**RS1**	**RS0**

Table 23- Disk Board UART Register Selection

RS2-RS0 → select an individual UART register, 0..7.

Again, once the UART has been selected the software can access the UART register by reading or writing from 1802 port 3. And finally, Table 24 shows the format used to access the DS12887A.

Elf 2000 Disk Board RTC/NVR Register Selection							
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*
1	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

Table 24 - Disk Board RTC/NVR Register Selection

A6-A0 → address one of 128 internal registers in the RTC/NVR chip.

Once the DS12887A has been selected, the software can read or write the addressed memory location by reading or writing 1802 I/O port 3.

WARNING!

A quirk of the clock/calendar chip requires that the address register be rewritten after *every* RTC/NVR access. For example, it is not possible to load the address, write a byte, and then read that byte back. You must load the address, write a byte, *reload the same address*, and only then can you read back the same byte.

11.6 Programming Tips and Observations

11.6.1 IDE

To be added.

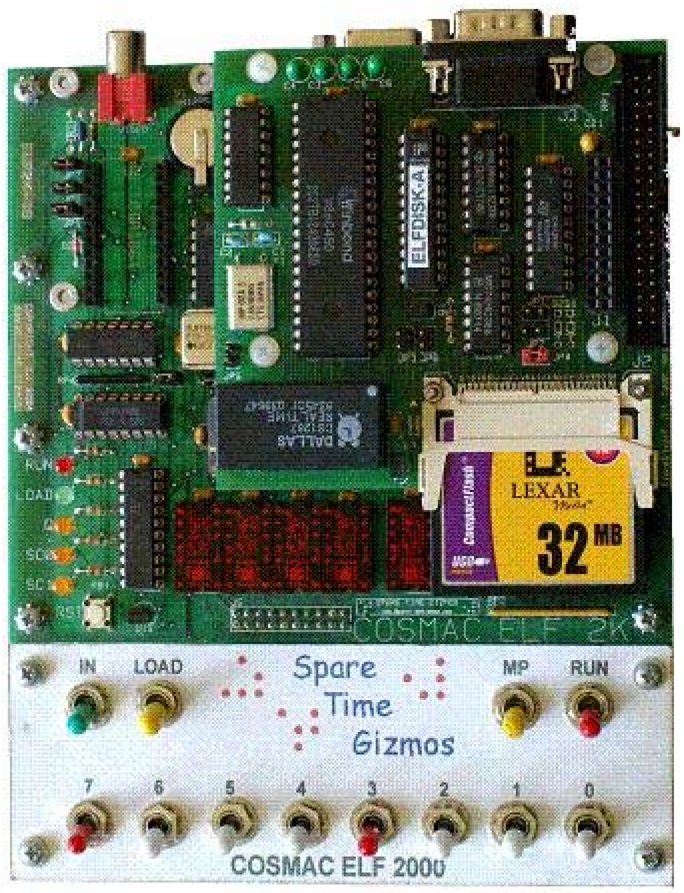


Photo 14 - Disk Board Installed on Elf 2000

11.6.2 UART

The 16450/550 UART features an internal baud rate generator which the software must program before the UART can be used. In the case of the Elf 2000 Disk board, the baud rate clock used is 2.4576Mhz, not the 3.072MHz that's shown on some 16450/550 data sheets. 2.4576 MHz will give an integral baud rate divisor for all standard baud rates from 300bps thru 153,600bps.

The only difference between the 16450 and the 16550 UART is that the 16550 contains an internal 16 byte FIFO and the 16450 does not. Either can be used in this circuit so long as the software supports it.

Refer to the 16450/550 data sheet for more information.

11.6.3 RTC/NVR

The DS12887A NVR/RTC chip internally uses addresses 0x00 to 0x0D to address real time clock and calendar registers. Addresses 0x0E to 0x7F address 114 bytes of general purpose non-volatile RAM that can be used for any purpose; Elf/OS and the BIOS use these bytes to save setup and configuration information such as the console port baud rate.

The DS12887A supports a "reset CMOS memory" feature. To use this, first remove power from the Elf 2000 and the Disk board, then install jumper JP5 on the Elf 2000 Disk board, count to ten, and then remove JP5. This action will reset all 114 general purpose RAM locations to 0xFF (*not zero!*) and can be used to clear the current configuration. By the way, the only difference between the DS12887A and the DS12887 is that the latter does not support the reset jumper. A DS12887 (no "A") may be used in this circuit and everything will work except for jumper JP5.

And the only difference between the DS12887 and the DS1287 is that the latter only contains 64 bytes of NVR. RAM addresses 0x40 to 0x7F are not implemented with the DS1287. The DS1287 and its equivalent, the Motorola MC146818A, were very commonly used in PC/AT machines and within their limitations any of these chips will work in the Elf 2000 Disk board.

If jumper JP2 is installed and the software enables the 1802 interrupt system, the DS12887A can be programmed to generate periodic interrupts over a wide range of intervals ranging from milliseconds to hours.

Refer to the DS12887A, DS12887, DS1287 or MC146818A data sheet for more information.

12 THE VT1802 VIDEO BOARD

12.1 INTRODUCTION

The Spare Time Gizmos Elf 2000 VT1802 video board is able to generate a real 80 column by 24 line text display on a CGA compatible CRT or RS-170 composite video monitor. Other display formats, including 25 lines, are possible by modifying the video timing. The hardware supports reverse video, underline, and blinking video attributes and four different character sets may be selected and simultaneously displayed under software control. With the proper character generator ROM, the hardware is also capable of displaying simple line and box drawing graphics characters.

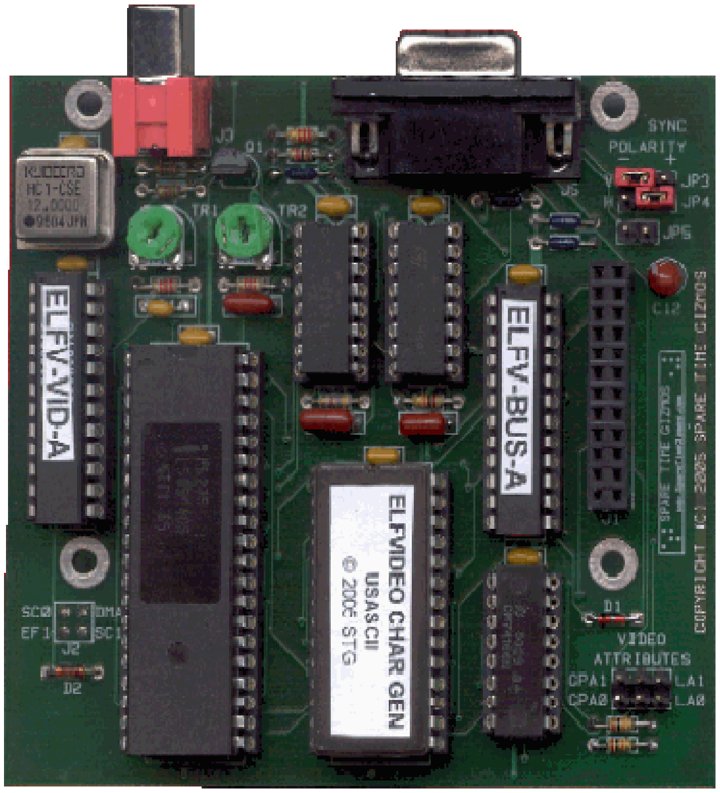


Photo 15 – VT1802 Card

The VT1802 uses the 1802's DMA system to fetch ASCII characters directly from a 1920 byte (80x24) buffer anywhere in RAM or EPROM. Unlike the CDP1861 Pixie video, the video timing for the video card is independent of the CPU clock and any CPU crystal frequency up to the CPU's maximum may be used. With a 3 MHz CPU clock, the DMA and interrupt service for the 80 column card uses approximately 50% of the total CPU time.

The card outputs include a standard 9 pin female DE9F for connection to a CGA monochrome or color monitor, and a standard RS-170 composite video output for use with a high resolution monochrome monitor. Both CGA horizontal and vertical sync outputs can be jumper selected for either polarity, and an analog one shot delay gives a continuously adjustable horizontal and vertical position for either the CGA or composite output.

The Spare Time Gizmos Elf 2000 Monitor EPROM contains a VT52 terminal emulator that works with the VT1802 and takes care of all the work necessary for maintaining the display. The firmware allows the video display to be used independently of the console terminal or, if the PS/2 Keyboard Interface is also present, as a replacement for the console terminal. The video display works with BASIC, Forth, Edit/ASM, or ElfOS.

12.2 ASSEMBLY

If you didn't build your Elf 2000, or if it's been a while since you did, it would be a good idea to review the generic construction tips in sections 2.4 "Sockets and Soldering" and 2.4 "Assembly Hints".

To be added.

12.3 INSTALLATION AND SETUP

Installing the VT1802 card is very straight forward and is essentially the same as any other daughter card, such as the Disk/UART/RTC/NVR card (refer to section 11.3). The VT1802 card has one unique problem, however, because it requires connection to four signals which are *not* on the standard 24 pin Elf 2000 expansion connector. These four signals are *DMA OUT*, *SC0*, *SC1* and *EF1*. On the video card these four signals are brought out to a four pin header, J2, just to the left of the 8275 chip and just below the VIDEO GAL (U5).

If you are installing your VT1802 card on the COSMAC Elf 2000, you will need to solder four short pieces of wire, approximately 3-4" long, to J2. Solder a single pin to the other end of each wire and insert them into the proper holes of the CDP1861 socket (U2) on the Elf 2000. This table summarizes the connections:

Signal	CDP1861 Socket (U2)
DMA OUT	Pin 2
SC0	Pin 21
SC1	Pin 22
EF1	Pin 9

Table 25 - Video Connections

Be sure to also install jumpers JP1 and JP7 on the Elf 2000 board!

If you are lucky enough to have one of the Embedded Elf 2000 board, then you'll notice that the Embedded Elf PC board has a four pin header conveniently located directly under J2 on the VT1802 video board. Using a combination of a 2x2 female header and some extra long wire wrap pins, it's possible to rig up a direct connection between the two similar to the one used to install the STG1861 PC board (see chapter 9). Of course, this connection will not "stack" as the main bus connector does, but it's unnecessary since the video card is the only one which requires these extra connections.

WARNING!

For a number of reasons, the VT1802 video card is incompatible with the CDP1861 Pixie graphics chip. At any time you can have one or the other installed, *but never both*.

12.3.1 Jumper Settings

Table 26 summarizes the jumpers present on the VT1802 card. Note that none of these jumpers affect the interface to the 1802 CPU, and so the COSMAC Elf 2000 Monitor EPROM, BIOS, and ElfOS disk operating system don't care how any of them are set.

Jumper	Default	Function
JP1	*Removed*	Selects GPA or LA to address character generator.
JP2	*Removed*	Selects GPA or LA to address character generator.
JP3	*Negative*	Selects the polarity of the vertical sync pulse.
JP4	*Positive*	Selects the polarity of the horizontal sync pulse.
JP5	*Removed*	When installed connects the video output to J5 pin 7.

Table 26 – VT1802 Card Jumpers

The 2764 EPROM used for the character generator (U3) has enough room for four complete 256 glyph character sets. Normally, if JP1 and JP2 are both removed, the upper two address bits for this EPROM are always zero and only the first character set is used. These jumpers may be installed to allow either the 8275 General Purpose Attribute (GPA0/1) outputs or the 8275 Line

Attributes outputs (LA0/1) to provide the upper two address bits. With careful programming of the character generator EPROM, this feature could be used to implement the 8275 line drawing functions, or it can be used to implement three alternate character sets.[19]

12.3.2 Adjustments

Trimmer TR1 adjusts the horizontal position of the video on the screen and TR2 adjusts the vertical position. You can use these along with the controls on your monitor to position the video correctly. If you are unable to center the video with these controls, then you might want to try changing the sync polarity jumper(s).

Jumpers JP2 and JP3 (see section 12.3.1) select the polarity of the CGA sync signals. Most CGA monitors are happy with positive going horizontal sync pulses and negative vertical sync, but if yours is different then you can change these settings. Note that these two jumpers have no effect on the composite video (J3) output.

12.3.3 Video Outputs

J5 is a standard CGA compatible video output connector, which you should be able to plug directly into any CGA compatible monitor.[20] Since CGA is normally a color standard and this card is monochrome, the VT1802 card always outputs the same TTL video signal to pins 2, 3 and 4 of the DB9 connector. These are the normal Red, Green and Blue connections for a color monitor and will cause the monitor to display white text on a black background.

There are monochrome monitors that conform to the CGA standard; some of these monitors expect monochrome video to be on pin 7 of the DB9 connector. This is a non-standard usage, however if your monitor is one of them you can make it happy by installing jumper JP5. Color monitors use this pin for intensity modulation, so you don’t want to install this jumper unless you need it.

Connector J3 outputs RS-170 compatible composite video. Although the video timing is the same as standard broadcast television,[21] the video bandwidth required to display 80 column text is 3 or 4x what a standard television can handle. *You won't be able to display 80 column video on an ordinary TV, even less so with an RF modulator, so don't even consider it!* However, if you happen to have a genuine computer monitor with at least 10 to 12 MHz of video bandwidth and a composite video input then you should be able to use it.

12.3.4 CPU Clock Selection

The standard Elf 2000 uses a 3.579545 MHz crystal so that the CDP1861 Pixie chip can generate the correct NTSC video timing. If you’re using the VT1802, then you have no need for Pixie compatibility and you can safely increase the clock frequency. In fact, it’s a good idea to do so since the video refresh overhead of the VT1802 would use almost all of the available CPU time.

How fast you can go depends upon the CPU chip that you have. The standard “ACE” version of the 1802 is rated for 3 MHz operation – remember that the Elf 2000 divides the crystal oscillator frequency by two, so in this case you could safely use a 6 MHz oscillator.

[19] The VT1802 firmware has escape sequence hooks for both of these options, but the standard character generator EPROM image supplied by Spare Time Gizmos has only one, US ASCII, character set. Sorry, but please feel free to add more!

[20] Remember, *CGA* – not EGA or VGA. There are (or were) multi-standard monitors that could accommodate both EGA and CGA, but they are uncommon.

[21] At least in the United States!

12.4 VIDEO TIMING

The actual timing is strictly a function of the software and, except for the pixel clock, can easily be changed. Table 27 summarizes the video timing used by the standard Monitor EPROM for 80x24 VT52 terminal emulation.

Character Timing		
Pixel Clock	12.00000	MHz
Pixel Time	83.33	ns
Pixels per Character	8	pixels
Character Clock	1.50	MHz
Character Time	666.7	ns
Line Timing		
Characters per line	80	characters
Retrace Time	16	characters
Horizontal Total	96	characters
Active Scan Time	83%	
Line Time	64.00	us
Horizontal Frequency	15.63	kHz
Error	0.79%	(from 15.750 kHz)
Frame Timing		
Lines per Row	10	scan lines per character row
Rows per Frame	24	character rows
Retrace Time	2	character rows
Vertical Total	26	character rows
Vertical Total	260	scan lines
Active Scan Time	92%	
Frame Time	16.64	ms
Vertical Frequency	60.10	Hz
Error	0.16%	(from 60.00 Hz)

Table 27 - Default 80x24 Video Timing

12.5 PROGRAMMER'S REFERENCE

Table 28 lists the 1802 I/O ports used by the VT1802 video card; in addition to these ports, it also uses the EF1 status flag. The CRTC parameter, status and command registers all directly access the internal registers of the 8275 CRTC, and if you wish to program the video card directly you'll want a copy of the data sheet for that chip.

	Input	**Output**
Port 1	read CRTC parameter	write CRTC parameter
Port 5	read CRTC status	write CRTC command

Table 28- Ports used by the VT1802

Normally there's no need to ever access the VT1802 directly – support for the VT1802 is fully integrated into Elf 2000 monitor EPROMs version 73 and later. If the VT1802 is installed, the monitor's power on self test (see section 4.3) will both test and initialize the VT1802 hardware. If both the VT1802 and the PS/2 Keyboard Interface (part of the GPIO card described in section

13.1) are present, the monitor will automatically redirect the Elf 2000 console to these two devices (section 4.5).

Console redirection is done thru the BIOS, and any program which does console I/O thru the standard BIOS functions F_READ and F_TYPE will automatically be redirected to the VT1802 with no software changes. This includes all the languages and utilities built into the Elf 2000 EPROM (e.g. Forth, BASIC, Edt/Asm, etc) as well as the ElfOS disk operating system.

12.6 ESCAPE SEQUENCES

A programmer would normally interact with the VT1802 in the same way he would with any video terminal connected to the Elf – by sending escape sequences. The firmware in the Elf 2000 EPROM attempts to emulate the escape sequences of a Digital Equipment VT52 terminal and most of the escape sequences used mimic that terminal; however there are a few additional escape sequences unique to the VT1802 as well as a few VT52 sequences that are unsupported

12.6.1 Standard VT52 Compatible Escape Sequences

Table 29 summarizes the VT52 compatible escape sequences supported by the VT1802.

Escape Sequence	Function
<ESC>[22] A	Cursor Up
<ESC> B	Cursor Down
<ESC> C	Cursor Left
<ESC> D	Cursor Right
<ESC> H	Cursor Home
<ESC> I	Scroll Up (Reverse Line Feed)[23]
<ESC> J	Erase to End of Screen
<ESC> K	Erase to End of Line
<ESC> Y <row> <col>	Direct Cursor Addressing
<ESC> F	Select Graphics Character Set
<ESC> G	Select Normal Character Set

Table 29 - VT52 Compatible Escape Sequences

The <ESC>Y sequence is followed by two data bytes which indicate the line and column (in that order) that the cursor is to move to. Both values are biased by 32 so that they appear as printing ASCII characters. The line number character should be in the range 32 to 55 (decimal), and the column number character may range from 32 to 112 (decimal). If either byte is out of range, then the cursor will only move as far as the margin.

12.6.2 VT1802 Extended Escape Sequences

Table 30 summarizes the extended escape sequences supported by the VT1802. These are not present on the VT52.

Escape Sequence	Function
<ESC> E	Home Cursor and Erase Screen
<ESC> R <char>	Raster Test

[22] The symbol <ESC> refers to the ASCII code \033.

[23] There is no escape sequence for a normal scroll up operation, but it's invoked by the standard ASCII LF (line feed) code.

<ESC> N <fac>	Store Field Attribute Code
<ESC> O <ldc>	Store Line Drawing Code

Table 30 - VT1802 Extended Escape Sequences

The Home Cursor and Erase Screen (<ESC>E) function is equivalent to the two escape sequences <ESC> H and <ESC> J (Home Cursor and Erase to End of Screen).

The <ESC>Q sequence should be followed by a single printing character, and the cursor is then moved to the home position and the entire screen is filled with this character.

The <ESC>N sequence stores an 8275 field attribute byte into screen memory. It should be followed by a single ASCII character, the lower six bits of which are the desired field attributes code. Field attributes are used to select video features such as blink, underline, and reverse. Table 31 summarizes some of the common 8275 field attribute codes and their corresponding ASCII character for this escape sequence; for more complete information, refer to the 8275 data sheet.

<fac>	Attribute
@	Normal
<space>	Underline
P	Reverse
B	Blinking

Table 31 - Field Attribute Codes

Field attribute codes may be “OR”ed together to select more than one attribute at the same time. Once selected, a field attribute continues until the end of the screen unless a Normal attribute is written some where after it. Finally, note that field attribute codes occupy a character location in screen memory just as do ordinary characters – this location will be blanked so that nothing is shown on the screen in that spot, but no other character can be written to that location either.

Field attribute codes can also be used to select one of three alternate character sets in the VT1802 character generator EPROM, however the standard character generator supplied by Spare Time Gizmos contains only the default character set. You’re always welcome to add your own! Note that the JP1/2 jumpers (see section 12.3.1) on the VT1802 must be set to select the GPA0/1 outputs before alternate character sets can be used.

The <ESC>O write line drawing code sequence works much the same way, however instead of a field attribute it stores an 8275 line drawing code. The character generator EPROM must be programmed for the 8275 line drawing codes before this option can be used, and sadly the default character generator image supplied by Spare Time Gizmos does not support line drawing. You are of course welcome to add it! Note that the JP1/2 jumpers (see section 12.3.1) on the VT1802 must be set to select the LA0/1 outputs before alternate character sets can be used.

12.6.3 VT52 Escape Sequences not Supported by the VT1802

Table 32 summarizes the VT52 escape sequences that are not implemented by the VT1802. These will all be ignored if sent to the VT1802.

Escape Sequence	Function
<ESC> =	Enter Alternate Keypad Mode
<ESC> >	Exit Alternate Keypad Mode
<ESC> Z	Identify

Table 32- Unsupported Escape Sequences

12.6.4 Standard ASCII Control Characters Recognized by the VT1802

In addition to the escape sequences, the VT1802 firmware recognizes many standard ASCII control characters. Table 33 summarizes these characters and their actions.

Code	Character	Function
0x00	NUL	ignored
0x7F	DEL	ignored
0x07	BEL	Ring the Bell on the GPIO card
0x08	BS	Backspace (same as Cursor Left)
0x09	HT	Horizontal Tab
0x0A	LF	Line Feed
0x0B	VT	Vertical Tab (same as Line Feed)
0x0C	FF	Home Cursor and Erase Screen (Same as <ESC>E)
0x0D	CR	Carriage Return
0x0E	SO	Select Graphics Character Set (“Shift Out”)
0x0F	SI	Select Normal Character Set (“Shift In”)
0x1B	ESC	Escape Sequence Prefix

Table 33 - Standard Control Characters

All other control characters not listed in this table are ignored.

13 THE GPIO CARD

13.1 INTRODUCTION

The Spare Time Gizmos Elf 2000 General Purpose I/O board (*GPIO*), integrates three independent I/O functions onto a single card. The GPIO contains:

- ❖ A PS/2 keyboard interface. A single chip microprocessor on the GPIO card handles the PS/2 protocol, converts the keystrokes to ASCII, and presents the data the 1802 as if it were a simple parallel ASCII keyboard.
- ❖ An 8255 programmable parallel I/O (PPI) chip. The 8255 is a very popular general purpose parallel interface chip that provides 24 I/O bits. The bits can be configured as inputs, outputs, or as an 8 bit bidirectional port with or without handshaking.
- ❖ A speaker for generating tones. Arbitrary tones and even simple music may be generated by 1802 software either by toggling the Q bit or thru an output port. The speaker logic also contains a fixed frequency oscillator that may be used to generate simple beeps without any software intervention.

These three GPIO subsystems are functionally independent and if you don't require all of them you can easily build your GPIO card and omit the unused parts.

13.2 ASSEMBLY

If you didn't build your Elf 2000, or if it's been a while since you did, it would be a good idea to review the generic construction tips in sections 2.4 "Sockets and Soldering" and 2.4 "Assembly Hints".

Note that C4 is normally unused and can be omitted. There's a place for it on the PC board and no harm will be done if you install it, but it's unnecessary.

You can use either a piezo or a dynamic speaker of any reasonable size for SP1, and the PC board contains several holes for this device to accommodate different lead spacings. If you use a piezo speaker, be sure that it is of the passive variety and doesn't already contain a built in oscillator. Be aware that piezo speakers have limited frequency response and are loudest around their resonant frequency – you may wish to adjust the value of C3 to change the 7555 oscillator frequency to match

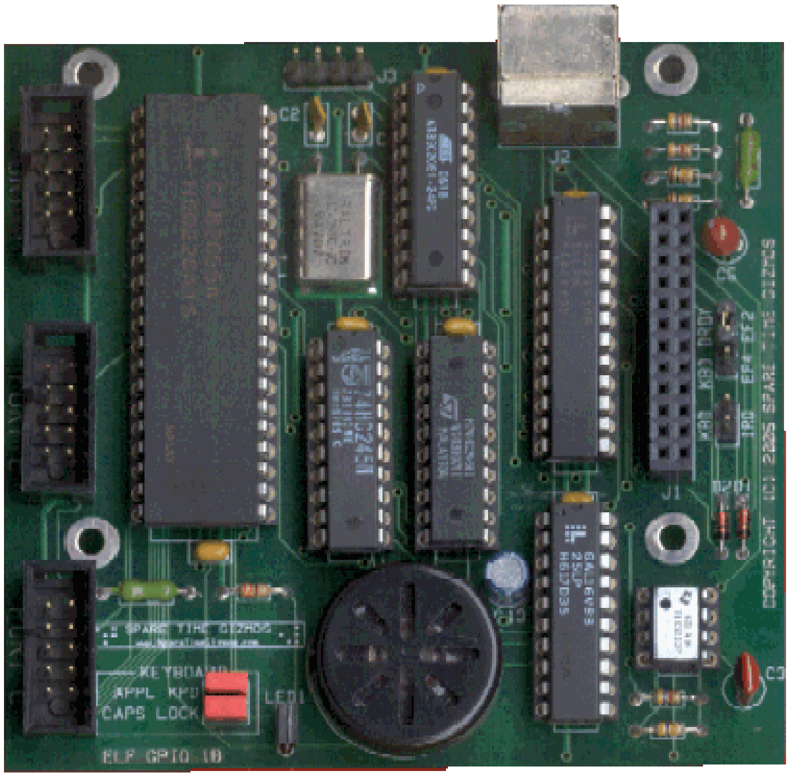


Photo 16 - Elf 2000 GPIO Card

the piezo speaker you use. If you intend to play music, you'll be much happier with a miniature dynamic loudspeaker.

To be added.

13.2.1 Optional Subsystems

If you don't want the PS/2 keyboard interface, you can omit U1, U2, LED1, J2, and the associated passive components (R1-3, F1, C1-2, Y1, etc) from the GPIO.

If you don't want the PPI, you may omit U5 and the associated headers, J5-7. Note that you still need U4 and U6 even if you don't have the PPI, unless you also intend to omit the speaker too.

If you don't need the speaker, you can omit SP1 and U7 along with the associated passive components (R4-5, and C3). You still need U4 and U6 unless you intend to omit the PPI also.

If you don't need either the PPI or the speaker (i.e. you want a PS/2 keyboard interface only) then you can also omit U4 and U6 in addition to the components listed above.

13.3 INSTALLATION

Installing the GPIO card on either the Elf 2000 or the Embedded Elf is simple and is pretty much the same as installing any other expansion card. Refer to the description of the Disk/UART/RTC card (section 11.2.1) for more details on the standoffs and mounting screws used.

If you are using the 8255 PPI, then notice that the three PPI ports are brought out to three ten pin headers on the left side of the GPIO card. Each of these headers has the same pin out and contains the eight data bits from the GPIO port plus ground and V_{CC}. You'll need to make up some ribbon cables to connect these headers to whatever external hardware you have.

13.4 JUMPER SETTINGS

The GPIO card contains four jumpers labeled JP1 thru JP4. The following table summarizes the function of these jumpers and the proper default setting to work with the Spare Time Gizmos Monitor EPROM:

Jumper	Default	Function
JP1	*EF2*	Connects the PS/2 keyboard data available flag to either EF2 or EF4.
JP2	*Removed*	Allows the PS/2 keyboard data available flag to interrupt the 1802.
JP3	-	Functionally swaps the CAPS LOCK and CTRL keys.
JP4	-	Enables PS/2 numeric keypad "application" mode.

Table 34 - GPIO Card Jumpers

13.5 PROGRAMMER'S REFERENCE

The GPIO card uses two ports from the 1802's I/O address space. The default port assignments and their usage is summarized Table 35. Like the Elf Disk/RTC/UART board, the GPIO Disk board uses a two level I/O scheme for accessing the PPI. The programmer first writes a device/register select code to one port, and then accesses the selected register with another port.

	Input	Output
Port 6	Read PPI data	Write PPI Data
Port 7	Read Keyboard data	Write GPIO Control Register

Table 35 – GPIO Board I/O Ports

13.5.1 GPIO Control Register

The GPIO control register is used to control the speaker and select the 8255 PPI port.

Elf 2000 GPIO Board Control Register							
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*
X	**X**	**SPEN**	**SP1**	**SP0**	**PPIEN**	**PPI A1**	**PPI A0**

Table 36 - GPIO Control Register

SPEN → This bit must be a 1 to enable loading the SP0-1 bits. If this bit is a zero during and output instruction, then the current SP0-1 values will not change. This allows the firmware to change the PPI address without affecting the speaker state.

SP0-1 → These two bits select the current speaker state according to Table 39.

PPIEN → This bit must be a 1 to enable loading the PPI A0-1 bits. If this bit is a zero during and output instruction, then the current PPI A0-1 values will not change. This allows the firmware to change the speaker state without affecting the PPI address.

PPI A0-1 → These two bits select the PPI port addressed by 1802 port 6.

X → "don't care" bits (should be zero for future compatibility).

13.5.2 The PS/2 Keyboard Interface

From the 1802 side the PS/2 keyboard interface is very simple. The microcontroller on the GPIO card handles the PS/2 serial protocol and converts the keyboard scan codes into ASCII. When a character is ready, the interface asserts either EF2 or EF4, depending on the state of JP1 and then waits. The 1802 software can read the current ASCII keystroke by executing an input from port 7. This clears the keyboard data available flag and de-asserts EF2/4, and then the whole process repeats with the next keystroke.

The microcontroller implements a 16 byte buffer for keystrokes to give a little “breathing room” in the event you can type faster than the 1802 program can read. During normal operation, LED1 lights whenever there are one or more keystrokes waiting, and goes out when the key buffer is empty. This gives a visual indication of whether the keyboard and 1802 software are cooperating.

Resetting the 1802, with the switch panel, keypad, or the RESET button, also resets the PS/2 keyboard microcontroller which clears the keystroke buffer. After a reset, the microcontroller also executes a simple internal diagnostic – if the diagnostic fails, then LED1 will flash rapidly.

13.5.3 PS2 to ASCII Translation

All printing characters on the PS/2 keyboard send their corresponding ASCII codes, as do TAB (0x09), ENTER (0x0D), BACKSPACE (0x08), and ESC (0x1B). The SHIFT (both left and right), CTRL (*left* control only!) and CAPS LOCK keys work as you would expect. Note that CAPS LOCK is a "CAPS LOCK", and *not* a "SHIFT LOCK" (i.e. it affects only alphabetic characters). This is standard for PCs, but not all ASCII terminals behave this way. The right CTRL (if your keyboard has one) and ALT keys (both left and right) do nothing.

If JP3 is installed on the GPIO card (see Table 34) then the CAPS LOCK and CTRL key functions will be swapped. This is convenient for most modern PS/2 keyboards, which have the CAPS LOCK key where the CONTROL key ought to be.

If JP4 is installed on the GPIO card (see Table 34) then keypad “Application Mode" option is selected, then the PS/2 numeric keypad keys send escape sequences that map approximately to the VT52 keypad. If JP4 is not installed then the numeric keypad sends normal characters ('0'..'9', '/', '*', '+', '-' and ENTER). The escape sequences used in application mode are summarized in Table 37. In either case, the NUM LOCK key is not implemented and never does anything.

Key	Escape Sequence
Keypad 0	<ESC>?p
Keypad 1	<ESC>?q
Keypad 2	<ESC>?r
Keypad 3	<ESC>?s
Keypad 4	<ESC>?t
Keypad 5	<ESC>?u
Keypad 6	<ESC>?v
Keypad 7	<ESC>?w
Keypad 8	<ESC>?x
Keypad 9	<ESC>?y
Keypad .	<ESC>?z
Keypad +	(not used)
Keypad /	<ESC>P (VT52 F1 BLUE key)
Keypad *	<ESC>Q (VT52 F2 RED key)
Keypad -	<ESC>R (VT52 F3 GRAY key)
Keypad ENTER	<ESC>?M

Table 37 - Application Keypad Escape Sequences

The four arrow keys always send the corresponding VT52 escape sequences shown in Table 38, regardless of the keypad application mode option.

Key	Escape Sequence
UP ARROW	<ESC>A
DOWN ARROW	<ESC>B
LEFT ARROW	<ESC>C
RIGHT ARROW	<ESC>D

Table 38- Arrow Key Escape Sequences

All the remaining keys do nothing. This includes the function keys (F1 thru F12), the Windows keys (left, right and menu), the editing keypad (INSERT, DELETE, HOME, PAGE UP, PAGE DOWN, and END), NUM LOCK, SCROLL LOCK, PAUSE/BREAK and PRINT SCREEN.

The keyboard LEDs are not used, including CAPS LOCK.

13.5.4 Programming the PPI

The 8255 PPI is a very versatile device and entire books have been written about using it to interface with all manner of peripherals. This manual won't even attempt to cover all the things that can be done – the reader is referred to one of the many books or web pages on the topic.

13.5.5 Programming the Speaker

The two speaker bits, SP0 and SP1, in the GPIO control register (see section 13.5.1) control the speaker state as shown in Table 39.

SP1	SP0	Speaker
0	0	Off
0	1	Fixed frequency tone
1	0	Follows the 1802 Q output

SP1	SP0	Speaker
1	1	On

Table 39 - Speaker Control Bits

Speaker Off (state 00) is just that – no sound will be heard. Speaker On (11) causes a click, and the software can toggle between the Off and On states at audio frequencies to generate arbitrary tones and play simple music. State 10 is essentially the same, except that the software can toggle the speaker on and off with the 1802's Q bit output. This is a little easier and is compatible with many simple music playing programs for the 1802. Needless to say, this mode should only be used if you aren't using the Q bit for something else.

WARNING!

Remember that the Elf 2000 mother board serial port uses Q to transmit serial data!

The fixed frequency tone (state 01) is determined by the 7555 oscillator on the GPIO card. This state generates a continuous tone without any need for software bit toggling, and the tone continues indefinitely until the software changes the speaker state to something else.

A hardware reset will clear both SP0 and SP1 and turn the speaker off regardless of its current state.

A. INSTALLING ELFOS

Mike Riley's has written an excellent disk operating system for the COSMAC Elf microprocessor called ElfOS (see Appendix E for more information). The Elf 2000 monitor ROM already contains the ElfOS BIOS and, if you have the Disk Expansion Card, you can run ElfOS quite well on the Elf 2000.

To install ElfOS on the Elf 2000, you first need to obtain an image of the ElfOS System Builder Utility customized for the Elf 2000 from Mike Riley's web site. This file, called *elfos2k.hex*, is in standard Intel HEX format for downloading to the Elf 2000 as described in section 4.9. Once you have downloaded elfos2k.hex you may proceed as follows. Note that this example uses a 128Mb compact flash card for the system disk – the numbers you see may vary depending on the system device you are using.

1. Install the Disk Expansion card in your Elf 2000, either insert a CompactFlash card or connect a real IDE hard disk, and connect your Elf 2000 serial port (either one) to your PC. Power up the Elf 2000.

```
COSMAC ELF 2000  EPROM V50 CHECKSUM 024B  SRAM 32K  INITIALIZED

Copyright (C) 2004-2005 by Spare Time Gizmos.  All rights reserved.
ElfOS BIOS Copyright (C) 2004 by Mike Riley.

IDE Master: 122Mb SanDisk SDCFJ-128
03/14/2005 16:28:43
For help type HELP.
```

2. Download the *elfos2k.hex* file as described in section 4.9. At 2400 baud using the motherboard serial port, this will take about twenty minutes.
3. After the download has completed, start the ElfOS System Builder utility

```
>>>run 3000

 Elf/Os Installation

1> Run hard drive init tool
2> Run filesystem gen tool
3> Run sys tool
4> Install binaries
5> Boot Elf/OS


   Option ?
```

4. Initialize the hard disk.

```
Option ? 1

IDE Disk Initialization Utility
<Q>uick or <F>ull ? q

formating...
Sectors: 54272
Complete
```

5. Initialize the file system.

```
Option ? 2
IDE File System Gen Utility

Total Sectors: 54272
AU Size: 8
Total AUs: 31360
```

```
Master Dir Sector: 144
File system generation complete
```

6. Install the operating system kernel.

```
Option ? 3
System copied.
```

7. Install system utilities.

```
   Option ? 4
Binary utilities installer

Install DIR ? y Installing...
Install DUMP ? y Installing...
Install MINIMON ? y Installing...
Install LOAD ? y Installing...
Install FREE ? y Installing...
Install DEL ? y Installing...
Install STAT ? y Installing...
Install HEXDUMP ? y Installing...
Install COPY ? y Installing...
Install RENAME ? y Installing...
Install TYPE ? y Installing...
Install EDIT ? y Installing...
Install EXEC ? y Installing...
Install INSTALL ? y Installing...
Install MKDIR ? y Installing...
Install RMDIR ? y Installing...
Install CHDIR ? y Installing...
Install PATCH ? y Installing...
Install VER ? y Installing...
Install ASM ? y Installing...
Install SAVE ? y Installing...
```

8. And then boot!

```
   Option ? 5
Starting...

Elf/OS Ready
$ DIR -S

DIR             03/04/2005 00:00:00  500
DUMP            03/04/2005 00:00:00  307
MINIMON         03/04/2005 00:00:00  201
LOAD            03/04/2005 00:00:00  180
FREE            03/04/2005 00:00:00  226
DEL             03/04/2005 00:00:00  90
STAT            03/04/2005 00:00:00  139
HEXDUMP         03/04/2005 00:00:00  218
COPY            03/04/2005 00:00:00  212
RENAME          03/04/2005 00:00:00  75
TYPE            03/04/2005 00:00:00  149
EDIT            03/04/2005 00:00:00  1361
EXEC            03/04/2005 00:00:00  34
INSTALL         03/04/2005 00:00:00  274
MKDIR           03/04/2005 00:00:00  90
RMDIR           03/04/2005 00:00:00  93
CHDIR           03/04/2005 00:00:00  127
PATCH           03/04/2005 00:00:00  553
VER             03/04/2005 00:00:00  287
ASM             03/04/2005 00:00:00  3489
SAVE            03/04/2005 00:00:00  338

Elf/OS Ready
$
```

Once you've built a system disk, in the future you can boot ElfOS directly from the Elf 2000 monitor EPROM using the BOOT command

```
COSMAC ELF 2000  EPROM V50 CHECKSUM 024B  SRAM 32K  INITIALIZED
Copyright (C) 2004-2005 by Spare Time Gizmos.  All rights reserved.
ElfOS BIOS Copyright (C) 2004 by Mike Riley.

IDE Master: 122Mb SanDisk SDCFJ-128
03/14/2005 16:55:16
For help type HELP.
>>>BOOT
Booting primary IDE ...
Starting...

Elf/OS Ready
$
```

Even better, you can use the auto restart feature of the Elf 2000 Monitor EPROM to automatically boot ElfOS any time the system is reset or power is applied. To enable automatic booting, type this Monitor EPROM command:

```
>>>SET RESTART BOOT
```

B. POST CODES

POST	Description
99	Basic CPU checks
98	Calculating EPROM checksum
97	EPROM checksum wrong
89	sizing SRAM
88	SRAM size wrong (no monitor data page)
87	Testing SRAM key
86	Monitor data page failure (bad SRAM)
85	Clearing memory
84	Initializing monitor data page
76	NVR/RTC initialization
75	RTC clock not ticking
74	RTC battery fail
69	UART Reset
68	UART initialization
67	UART loop back failure (waiting for THRE set and DR clear)
66	UART loop back failure (THRE won't clear)
65	UART loop back failure (waiting for DR set)
64	UART loop back failure (wrong data)
63	UART loop back failure (waiting for THRE set and DR clear)
59	PPI control register failure
58	PPI data bus failure
57	PPI address bus failure
54	Testing for GPIO PS/2 keyboard APU
53	Waiting for PS/2 APU version
52	No PS/2 keyboard attached
40	Initializing SCRT
39	CRTC status register test
38	CRTC command/error test
37	Initialize video frame buffer
36	Enable video interrupts
35	No video DMA
34	No video end of frame interrupt
18	Console terminal failure or polarity wrong
17	Special CHM bootstrap mode
16	Waiting for auto baud
15	Printing system sign on message
14	Initializing master IDE drive
13	Initializing slave IDE drive
12	Printing date/time
11	Auto restart
10	Auto boot
0F-01	Used by ElfOS
00	startup completed

C. Parts List

Elf 2000 Main Board Parts List

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
Resistors					
R1, R5, R6, R7, R8			Anchor		330 ohm 1/8W 5% carbon resistor
R2			Anchor		1K ohm 1/8W 5% carbon resistor
R3			Anchor		200 ohm 1/8W 5% carbon resistor
R4			Anchor		3.3K ohm 1/8W 5% carbon resistor
RP1, RP3			Anchor		10K x 9 10 pin SIP
RP2			Anchor		10K x 7 8 pin SIP
RP4			Anchor		10K x 5 6 pin SIP
Capacitors					
C1			Anchor		1000uF 16V radial lead aluminum electrolytic capacitor
C2			Anchor		10uF 6V tantalum capacitor
C3			Anchor		*unused*
C4-C24			Anchor		0.1uF ceramic monolithic bypass capacitor (0.1" LS)
Semiconductors					
D2, D3, D4, D6		1N914	Anchor		Small signal switching diode
D5		1N4001	Anchor		50PIV 1A power diode
D1					*unused*
VR1		7805	Anchor		5.0V fixed output TO-220 regulator
U1	Intersil	CDP1802ACD3	STG		8 bit microprocessor
U2	RCA	CDP1861D			video co-processor
U3		27C256	Anchor		32K 8 bit EPROM
U4	Hitachi	HM62256LP	Digi-Key		32K 8 bit low power SRAM 150ns

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
U5	Dallas	DS1210	Digi-Key		Nonvolatile SRAM controller
U6		74HC373	Anchor		Octal D Latches
U7	Atmel	ATF22V10CQZ	Digi-Key		Flash GAL (quarter power)
U8		74HC04	Anchor		Hex inverter
U9		CD4044	Anchor		Quad S-R Latches
U10		74HC74	Anchor		Dual D Flip Flop
U11					*unused*
U12, U13, U14		74HC244	Anchor		Dual Quad Buffer
U15	Dallas	DS1233[24]	JDR		5V 10% TO-92 EconoReset
U16	Dallas	DS275	Digi-Key		RS-232 transceiver
DISP1-6		TIL311	Jameco		LED Hexadecimal Display
LED1-5			Anchor		Red T1 LEDs
OSC1	ECS	2100A-035	Digi-Key	XC235	3.579545Mhz DIP8 crystal oscillator
MISCELLANEOUS					
B1		CR1225	Mouser		Lithium coin cell
		BH1225	Digi-Key	500K	CR1225 coin cell holder
PB1	Panasonic	EVQ-PAD05R	Digi-Key	P10890S	PCB mount push button switch
S1	C&K	T101MH9ABE	Digi-key	CKN1067	SPDT Tiny Toggle Switch, PCB Mount Right Angle
J1			Anchor		PCB mount phono jack (Video)
J2	Cui-Stack	PJ-102AH	Digi-Key	CP-102AH	high current coaxial power jack (2.1 x 5.5mm)
J3	CommConn	1184-24G2			24 pin dual row stacking header
J4			Anchor		PCB mount DE9F
J5			Anchor		20 pin 0.1" dual row header
			Anchor		DIP8 machined pin IC socket
			Anchor		DIP8 machined pin oscillator socket
			Anchor		DIP14 machined pin IC socket

[24] *Don't* use the DS1233M!

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
			Anchor		DIP16 machined pin IC socket
			Anchor		DIP20 machined pin IC socket (0.300")
			Anchor		DIP24 machined pin IC socket (0.300")
			Anchor		DIP24 machined pin IC socket (0.600")
			Anchor		DIP28 machined pin IC socket (0.600")
			Anchor		DIP40 machined pin IC socket
					#4-40 mounting hardware for VR1
			Digi-Key	HS104-1	Heat sink for VR1
	STG	ELF2K-1C			Printed circuit board

Table 40 – Elf 2000 Parts List

Switch Panel Parts List

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
D0-7, RUN, MP			Jameco	76523CR	SPST toggle switch
LOAD			Jameco	21936CR	SPDT toggle switch
INPUT			Jameco	28062CR	SPDT toggle switch (momentary) or push button
			Anchor		20 pin 0.1" dual row header
			Anchor		20 pin IDC connector
			Anchor		6" 20 conductor ribbon cable
			Tap		5 1/2" x 2" x 3/16" ABS (switch panel)
			Tap		6 3/4" x 1" x 3/8" Acrylic (side rails)
	STG				Front panel decal (see Appendix D)

Table 41 - Switch Panel Parts List

Hexadecimal Keypad Parts List

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
RESISTORS					
R1, R2, R8, R10, R11			Anchor		4.7K ohm 1/8W 5% carbon resistor
R3, R5, R6, R9, R12			Anchor		150 ohm 1/8W 5% carbon resistor
R4			Anchor		10K ohm 1/8W 5% carbon resistor
R7			Anchor		47K ohm 1/8W 5% carbon resistor
RP1			Anchor		10K x 5 6 pin SIP
CAPACITORS					
C1			Anchor		0.1uF ceramic monolithic capacitor
C2, C11			Anchor		2.2uF 6V tantalum capacitor
C3			Anchor		1uF 6V tantalum capacitor
C4-C8			Anchor		0.1uF ceramic monolithic bypass capacitor (0.1" LS)
C9					*unused*
C10			Anchor		10uF 6V tantalum capacitor
SEMICONDUCTORS					
D1-D22		1N914	Anchor		Small signal switching diode
LED1-5			Anchor		T1 LEDs
Q1-Q5		2N2222	Anchor		GP NPN switching transistor
U1		74C9222	Digi-Key		16 Key Encoder
U2		74C175	Anchor		Quad D Flip Flops
U3		CD4011	Anchor		Quad 2 Input NAND Gates
U4		74C14	Anchor		Hex Schmitt Trigger
MISCELLANEOUS					
BZ1			RadioShack	273-0074	Mini PC mount Piezo Beeper 3-12V

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
PB0-PBF	Grayhill	82-101-71	Jameco	472948	Unlighted Push Button
PBINPUT, PBMP, PBLOAD, PBRUN, PBRESET	Grayhill	82-150-38	Unknown[25]		Lighted Push Button
			Anchor		DIP14 machined pin IC socket
			Anchor		DIP16 machined pin IC socket
			Anchor		DIP18machined pin IC socket (0.300")
	STG	KEYPAD-1C			Printed circuit board

Table 42 - Hexadecimal Keypad Parts List

STG1861 Parts List

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
CAPACITORS					
C1-C4			Anchor		0.1uF ceramic monolithic bypass capacitor (0.1" LS)
SEMICONDUCTORS					
D1, D2		1N914	Anchor		Small signal switching diode
U1, U2	Atmel	ATF22V10CQZ	Digi-Key		Flash GAL (quarter power)
U3		74HC4040	Anchor		12 bit counter
U4		74HC165	Anchor		8 bit parallel in serial out shift register
MISCELLANEOUS					
			Anchor		DIP16 machined pin IC socket
			Anchor		DIP24 machined pin IC socket (0.300")
			Anchor		12 pin female header strip
			Anchor		12 pin wire wrap header strip

[25] At the moment there is no known retailer for the lighted push buttons. You can always use the unlighted ones and omit the LEDs.

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
			Anchor		Shorting plugs
	Keystone	1560A	Mouser	534-1560A	#4-40 swage stand offs, 0.125" high, 0.250" diameter
			Olander		4-40 1/2" hex nylon M/F standoffs
			Olander		4-40 1/4" Philips pan head nylon screws
	STG	PIXIE-1B			Printed circuit board

Table 43 - STG1861 Parts List

Disk/UART/RTC/NVR Daughter Board Parts List

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
Resistors					
R1			Anchor		10M ohm 1/8W 5% carbon resistor
R2			Anchor		330 ohm 1/8W 5% carbon resistor
RP1			Anchor		4.7K 6 pin 5 resistor SIP
Capacitors					
C1, C2			Anchor		22pf 0.1" 50V mono ceramic capacitor
C3-C6			Anchor		1uF 35V tantalum capacitor
C7, C8					47uF 6V tantalum capacitor
C9, C10					*unused*
C11-C17			Anchor		0.1uF ceramic monolithic bypass capacitor (0.1" LS)
Semiconductors					
D1, D2, D3		1N914	Anchor		Small signal switching diode

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
D4	Dialight	555-2301	Digi-Key		Green 2mm LED (right angle PCB mount)[26]
U1	Atmel	ATF22V10CQZ	Digi-Key		Flash GAL (quarter power)
U2		74HC245	Anchor		Octal bus transceivers
U3		74HC174	Anchor		Hex D flip flops w/clear
U4	Dallas	DS12887A	Jameco		Nonvolatile RAM and Real Time Clock
U5	Maxim	MAX232	Anchor		RS232 Line Driver/Receiver
U6					*unused*
U7		16C450	Anchor		Asynchronous Communication Element (UART)
U8		74HC04	Anchor		Hex Inverter
MISCELLANEOUS					
Y1			Anchor		2.4576Mhz HC18 crystal
J1	CommConn	1184-24G	STG		24 pin stacking bus connector
J2	GC/Waldom	53856-5010	Digi-key	WM18505	Type I CF connector, SMT right angle top mount
J3			Anchor	DB9M	DB9 male PCB mount
J4			Anchor		40 pin 0.1" shrouded header (IDE)
			Anchor		DIP16 machined pin IC socket
			Anchor		DIP20 machined pin IC socket (0.300")
			Anchor		DIP24 machined pin IC socket (0.300")
			Anchor		DIP24 machined pin IC socket (0.600")
			Anchor		DIP40 machined pin IC socket
JP1-JP5			Anchor		2 pin 0.1" header (jumper)
			Anchor		Shorting plugs
	STG	ELFDISK-1B			Printed circuit board

Table 44 - Disk/UART/RTC/NVR Parts List

[26] You can also use the Dialight 555-2303 LED – this LED has an integral dropping resistor for operation on 5V. If you use the 2303 LED, replace resistor R2 with a wire link.

Embedded Elf Parts List

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
RESISTORS					
R1			Anchor		10M ohm 1/8W 5% carbon resistor
RP1, RP2			Anchor		10K x 9 10 pin SIP
CAPACITORS					
C1, C11, C12, C12, C14, C15, C16, C20			Anchor		0.1uF ceramic monolithic bypass capacitor (0.1" LS)
C2			Anchor		10uF 6V tantalum capacitor
C3, C4			Anchor		22pF ceramic monolithic capacitor
SEMICONDUCTORS					
D1		1N4734	Anchor		5.6V 1W DO-41 Zener diode
D2-D6		1N914	Anchor		Small signal switching diode
DISP1-2	Dialight	555-4403	Digi-Key	350-1371	Quad LED indicator with integral resistors
U1	Intersil	CDP1802ACD3	STG		8 bit microprocessor
U2		27C256	Anchor		32K 8 bit EPROM
U3	Hitachi	HM62256LP	Digi-Key		32K 8 bit low power SRAM 150ns
U4, U6		74HC373	Anchor		Octal D Latches
U5	Dallas	DS1233[27]	JDR		5V 10% TO-92 EconoReset
U7	Atmel	ATF22V10CQZ	Digi-Key		Flash GAL (quarter power)
U8	Dallas	DS275	Digi-Key		RS-232 transceiver
U9	Dallas	DS1210	Digi-Key		Nonvolatile SRAM controller
MISCELLANEOUS					
Y1			Anchor		3.000 MHz HC18 crystal
B1		CR1225	Mouser		Lithium coin cell

[27] *Don't* use the DS1233M!

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
		BH1225	Digi-Key	500K	CR1225 coin cell holder
PB1	Panasonic	EVQ-PAD05R	Digi-Key	P10890S	PCB mount push button switch
J1	CommConn	1184-24G2			24 pin dual row stacking header
J2	Mode Electronics	37-6302-0			2 pin right angle PCB mount header
J3	3M	2510-5002	Digi-Key	MHD10K	10 pin low profile right angle shrouded header
			Anchor		DIP8 machined pin IC socket
			Anchor		DIP20 machined pin IC socket (0.300")
			Anchor		DIP24 machined pin IC socket (0.300")
			Anchor		DIP28 machined pin IC socket (0.600")
			Anchor		DIP40 machined pin IC socket
	STG	EELF-1B			Printed circuit board

Table 45 - Embedded Elf Parts List

VT1802 80 Column Video Card Parts List

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
Resistors					
R1, R2, R3, R8			Anchor		10K ohm 1/8W 5% carbon resistor
R4					*unused*
R5, R7, R9			Anchor		2.2K ohm 1/8W 5% carbon resistor
R6			Anchor		4.7K ohm 1/8W 5% carbon resistor
R10			Anchor		680 ohm 1/8W 5% carbon resistor
R11, R14, R15, R16			Anchor		1K ohm 1/8W 5% carbon resistor
R12			Anchor		47 ohm 1/8W 5% carbon resistor
R13			Anchor		150 ohm 1/8W 5% carbon resistor
TR1, TR2			Anchor		50K PCB mount trimmer resistor
Capacitors					
C1			Anchor		470pF ceramic monolithic capacitor

Reference Designator	Manufacturer	Part Number	Supplier	Stock Number	Description
C2			Anchor		0.001uF ceramic monolithic capacitor
C3			Anchor		0.047uF ceramic monolithic capacitor
C4			Anchor		0.1uF ceramic monolithic capacitor
C12			Anchor		47uF 6V tantalum capacitor
C14			Anchor		0.0022uF Mylar
C5-C11, C13			Anchor		0.1uF ceramic monolithic bypass capacitor (0.1" LS)
Semiconductors					
D1-D3		1N914	Anchor		Small signal switching diode
Q1		2N3904	Anchor		GP NPN switching transistor
U1, U5	Atmel	ATF22V10CQZ	Digi-Key		Flash GAL (quarter power)
U2	Intel	8275	Jameco		CRT Controller
U3		27C64			8K x 8 EPROM
U4		74HC166	Anchor		8 bit shift register
U6, U7		74HC221	Anchor		Dual Monostable Multivibrator
U8		74HC132	Anchor		Quad Schmitt Trigger Dual Input NAND Gate
OSC1	CTS	MXO45HS-12.0000	Digi-Key	CTX164	12.000Mhz DIP8 crystal oscillator
Miscellaneous					
J1	CommConn	1184-24G2			24 pin dual row stacking header
J2					*See section 12.3*
J3			Anchor		PCB mount phono jack (RS-170 Video)
J5			Anchor		PCB mount DE9F connector (CGA)
			Anchor		DIP8 machined pin oscillator socket
			Anchor		DIP16 machined pin IC socket
			Anchor		DIP14 machined pin IC socket
			Anchor		DIP24 machined pin IC socket (0.300")
			Anchor		DIP28 machined pin IC socket (0.600")
			Anchor		DIP40 machined pin IC socket

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
	STG	ELFVIDEO-1D			Printed circuit board

Table 46 - VT1802 80 Column Video Card Parts List

General Purpose I/O (GPIO) Card Parts List

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
RESISTORS					
R1			Anchor		330 ohm 1/8W 5% carbon resistor
R2, R3, R4			Anchor		4.7K ohm 1/8W 5% carbon resistor
R5			Anchor		470K ohm 1/8W 5% carbon resistor
R6, R7			Anchor		10K ohm 1/8W 5% carbon resistor
CAPACITORS					
C1, C2			Anchor		22pF ceramic monolithic capacitor
C3			Anchor		0.0022uF Mylar capacitor
C5					47uF 6V tantalum capacitor
C13			Anchor		3.3uF 16V aluminum electrolytic capacitor
C6-C11			Anchor		0.1uF ceramic monolithic bypass capacitor (0.1" LS)
SEMICONDUCTORS					
D1-D2		1N914	Anchor		Small signal switching diode
U1	Atmel	89C2051	Digi-Key		Microprocessor
U2, U4		74HC245	Anchor		Octal bus transceivers
U3	Intel	82C55A	Jameco	52425	CMOS Programmable Peripheral Interface (5MHz)
U5	Atmel	ATF22V10CQZ	Digi-Key		Flash GAL (quarter power)
U6	Atmel	ATF16V8CQZ	Digi-Key		Flash GAL (quarter power)
U7	Intersil	7555	Anchor		CMOS Timer
MISCELLANEOUS					

REFERENCE DESIGNATOR	MANUFACTURER	PART NUMBER	SUPPLIER	STOCK NUMBER	DESCRIPTION
LED1	Dialight	555-2301	Digi-Key		Green 2mm LED (right angle PCB mount)[28]
F1, F2	Littelfuse	473.500	Digi-Key	F1200CT	0.5A picofuse
SP1					PCB mount dynamic speaker
Y1			Anchor		11.0592MHz HC18 crystal
J1	CommConn	1184-24G2			24 pin dual row stacking header
J2	Cui Stack	MD-60SM	Digi-Key	CP-2260	6 pin female right angle PCB mount DIN connector
J3			Anchor		4 pin SIP 0.1" header
J4					*unused*
J5, J6, J7			Anchor		10 pin dual row 0.1" shrouded header
			Anchor		DIP8 machined pin IC socket
			Anchor		DIP20 machined pin IC socket
			Anchor		DIP24 machined pin IC socket (0.300")
			Anchor		DIP40 machined pin IC socket
	STG	ELFGPIO-1B			Printed circuit board

Table 47 - GPIO Card Parts List

[28] You can also use the Dialight 555-2303 LED – this LED has an integral dropping resistor for operation on 5V. If you use the 2303 LED, replace resistor R1 with a wire link.

D. SWITCH PANEL ARTWORK

Print this page onto a sheet of self adhesive label stock and then carefully cut out Figure 5. It should measure exactly 5 ½" by 2". Paste Figure 5 onto a similarly sized piece of 1/8" thick ABS plastic stock and then drill as shown. The remaining text stays behind to label your control panel.

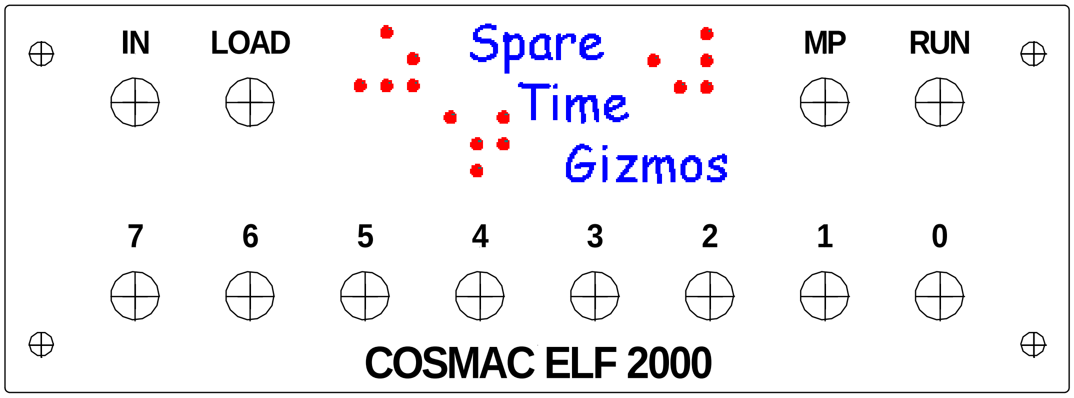


Figure 5 - Switch Panel Artwork

Figure 6 shows the actual size legends used for the keycaps on the Elf 2000 keypad. Print it on regular paper, cut out each individual squares, and slide the slips of paper under the corresponding keycaps.

C 1100	D 1101	E 1110	F 1111		R RESET
8 1000	9 1001	A 1010	B 1011		L LOAD
4 0100	5 0101	6 0110	7 0111	M PROTECT	G RUN
0 0000	1 0001	2 0010	3 0011	I INPUT	

Figure 6 - Keycap Legends

E. RESOURCES AND REFERENCES

Spare Time Gizmos Elf 2000 home page, http://elf2k.SpareTimeGizmos.com.

COSMAC ELF and 1802 Micro Computing Group, http://groups.yahoo.com/group/cosmacelf/.

Spare Time Gizmos User's Group, http://groups.yahoo.com/group/sparetimegizmos/.

TASM Cross Assembler, http://home.comcast.net/~tasm/.

ElfOS Disk Operating System, http://www.elf-emulation.com/elfos.html.

Rc/Asm cross assembler, http://www.elf-emulation.com/rcasm.html.

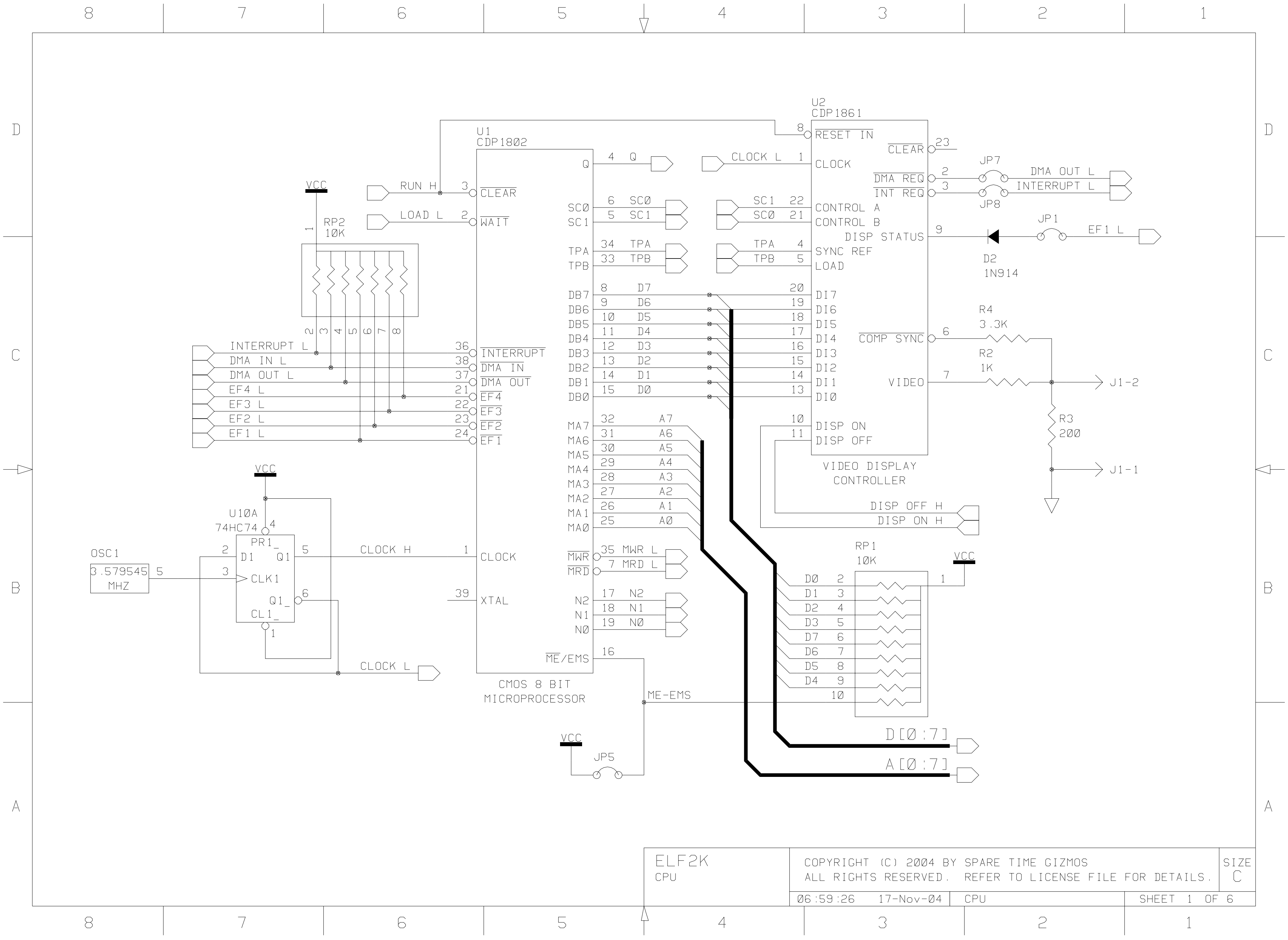
HyperTerm, http://www.hilgraeve.com/htpe/.

Kermit, http://www.columbia.edu/kermit/.

F. SCHEMATICS

This section contains the schematics for the Spare Time Gizmos COSMAC Elf 2000 and various options.

Spare Time Gizmos Product	PCB Revision
COSMAC Elf 2000	**1C**
Embedded Elf	**1B**
Disk/UART/RTC daughter card	**1B**
Hexadecimal Keypad	**1C**
STG1861 Pixie replacement	**1B**
VT1802 80 column video card	**1D**
GPIO General Purpose I/O card	**1B**

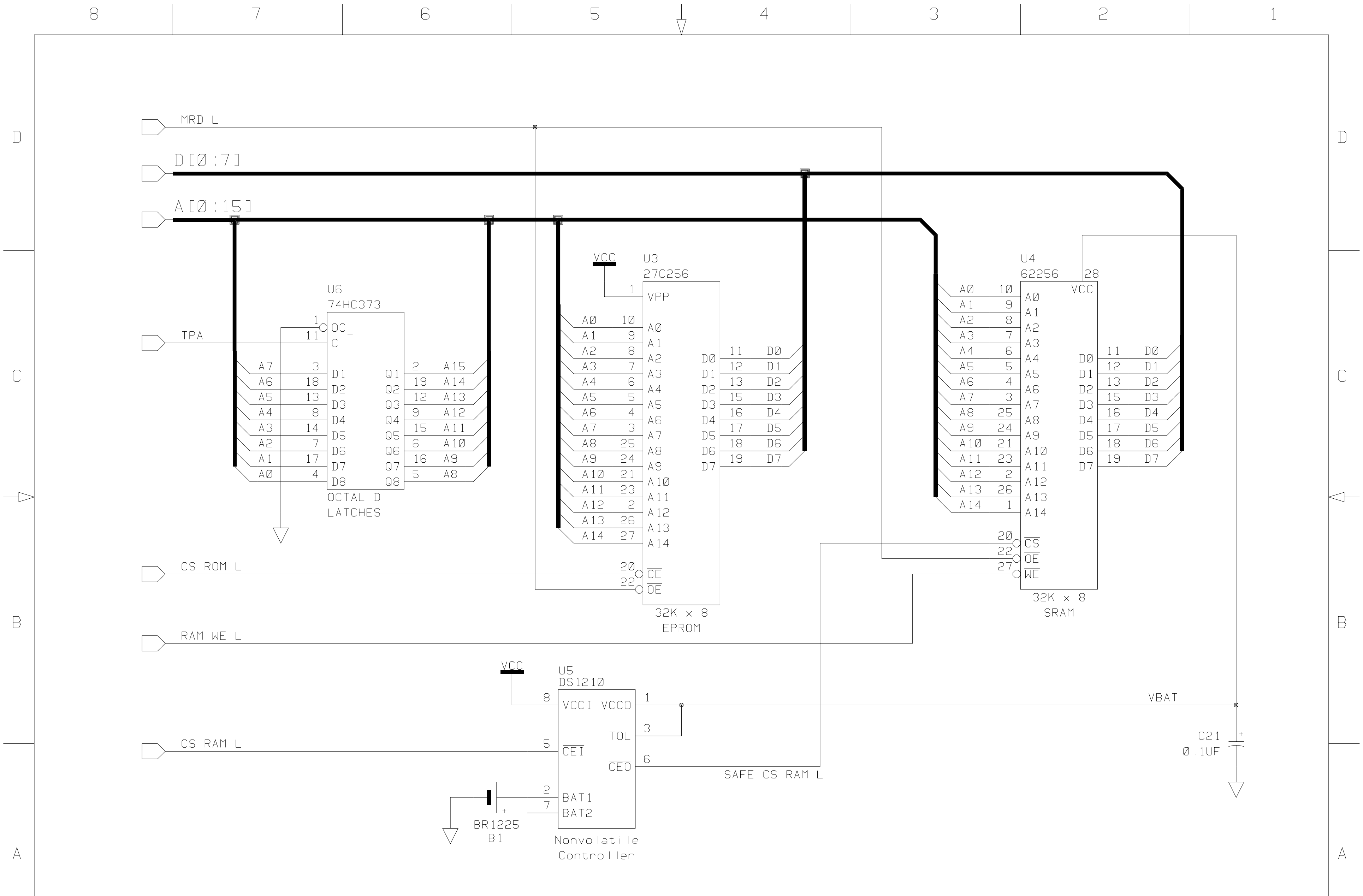


ELF2K
CPU

COPYRIGHT (C) 2004 BY SPARE TIME GIZMOS
ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.

SIZE C

06:59:26 17-Nov-04 CPU SHEET 1 OF 6

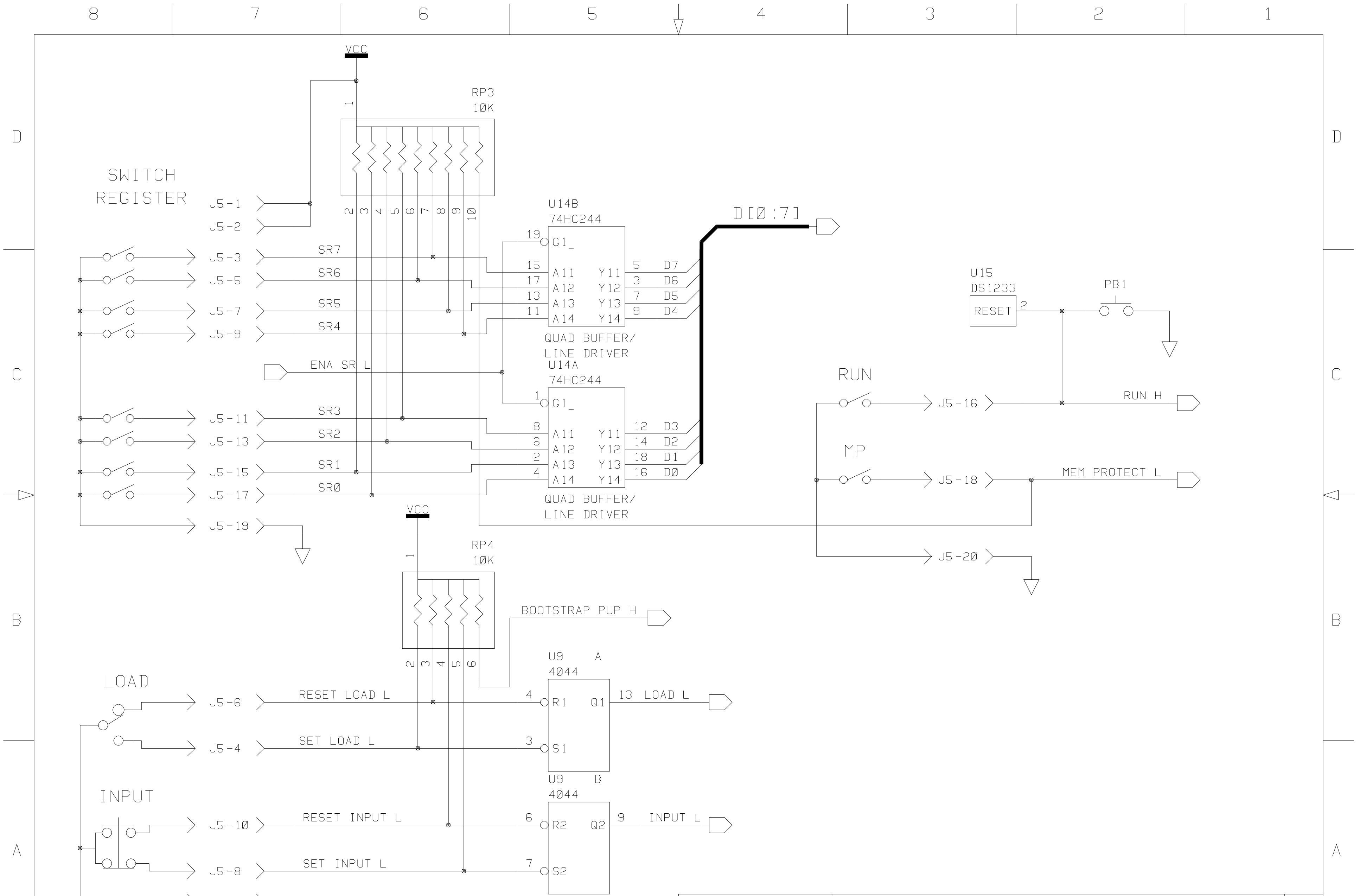


ELF2K
MEMORY

COPYRIGHT (C) 2004 BY SPARE TIME GIZMOS
ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.

SIZE C

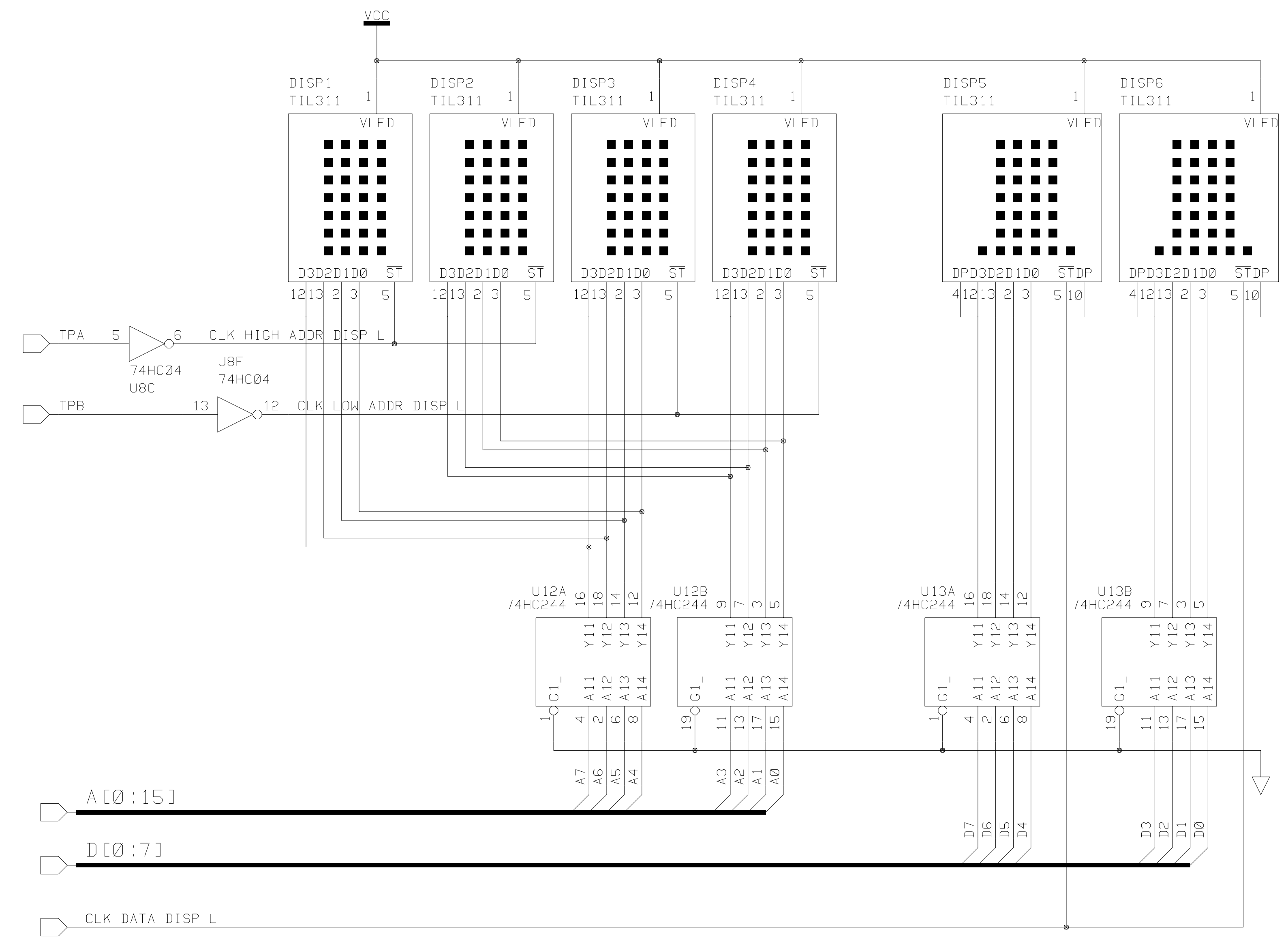
Ø6:59:31 17-Nov-Ø4 MEMORY SHEET 2 OF 6



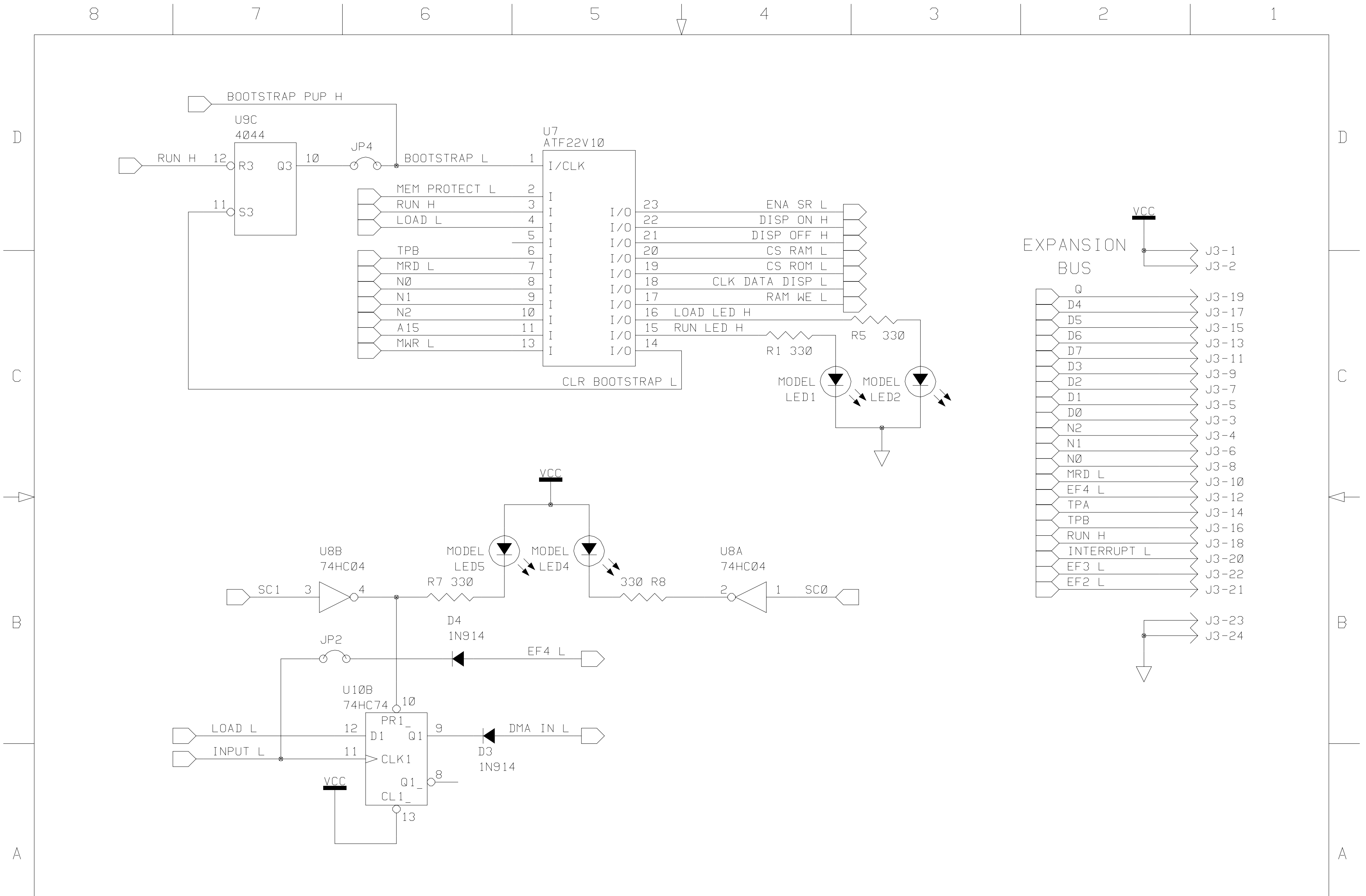
ELF2K
SWITCHES

SIZE C

06:59:44 17-Nov-04 SWITCHES SHEET 3 OF 6



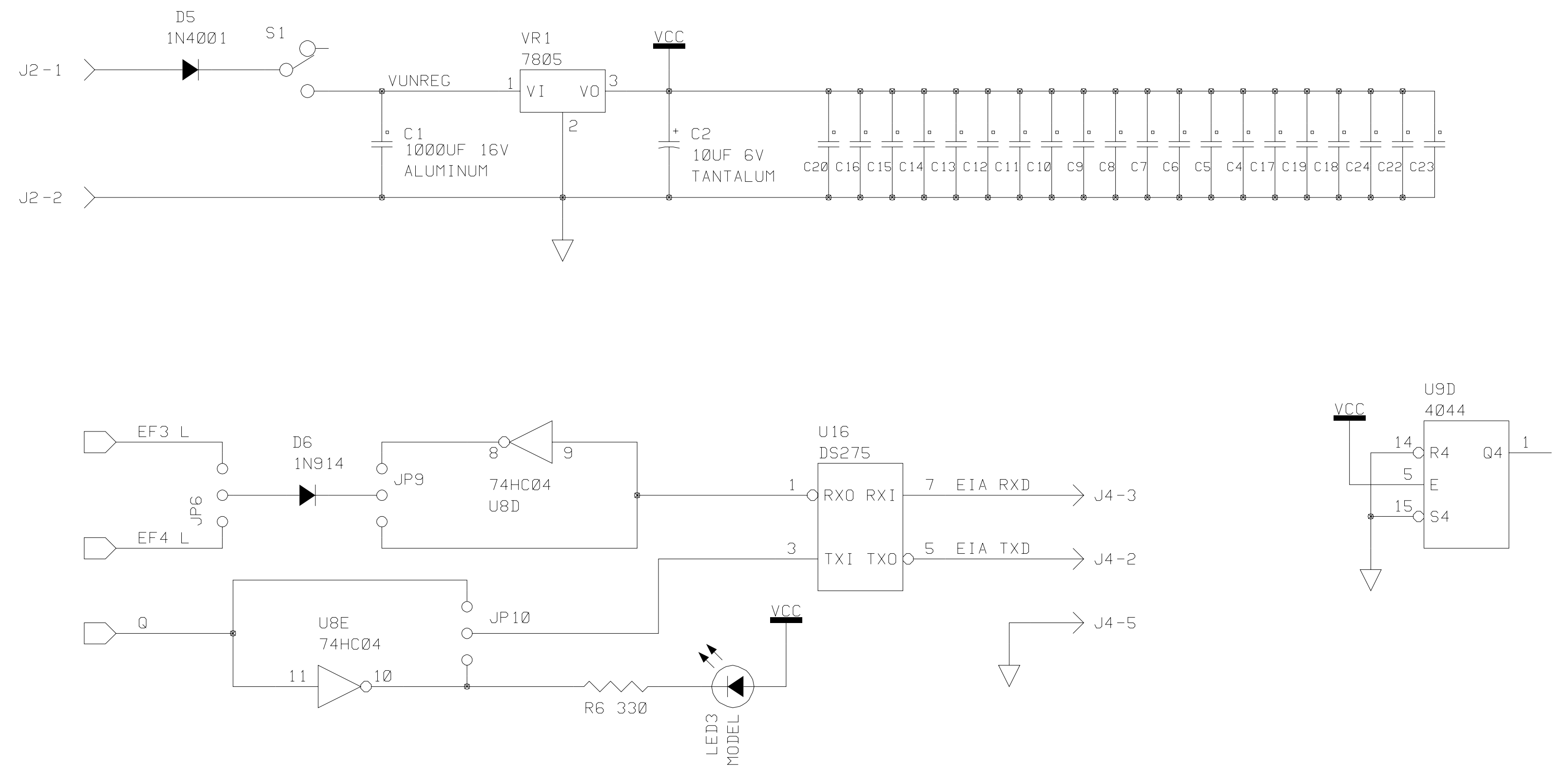
ELF2K DISPLAY	COPYRIGHT (C) 2004 BY SPARE TIME GIZMOS ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.	SIZE C
	Ø6:59:59 17-Nov-Ø4 DISPLAY	SHEET 4 OF 6



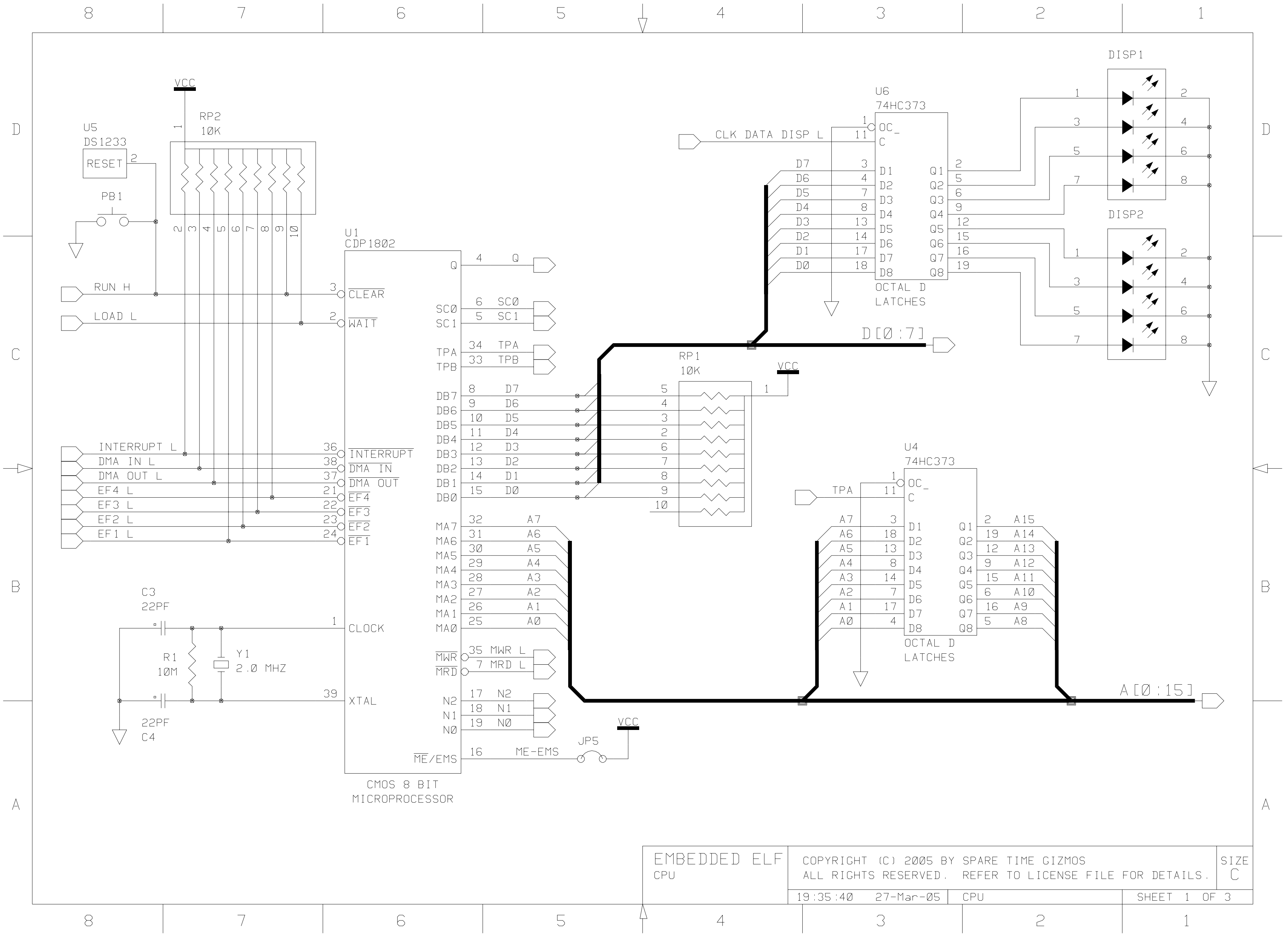
ELF2K
CONTROL

SIZE C

07:00:10 17-Nov-04 CONTROL SHEET 5 OF 6



ELF2K CONTROL	COPYRIGHT (C) 2004 BY SPARE TIME GIZMOS ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.		SIZE C
	07:00:18 17-Nov-04	POWER	SHEET 6 OF 6

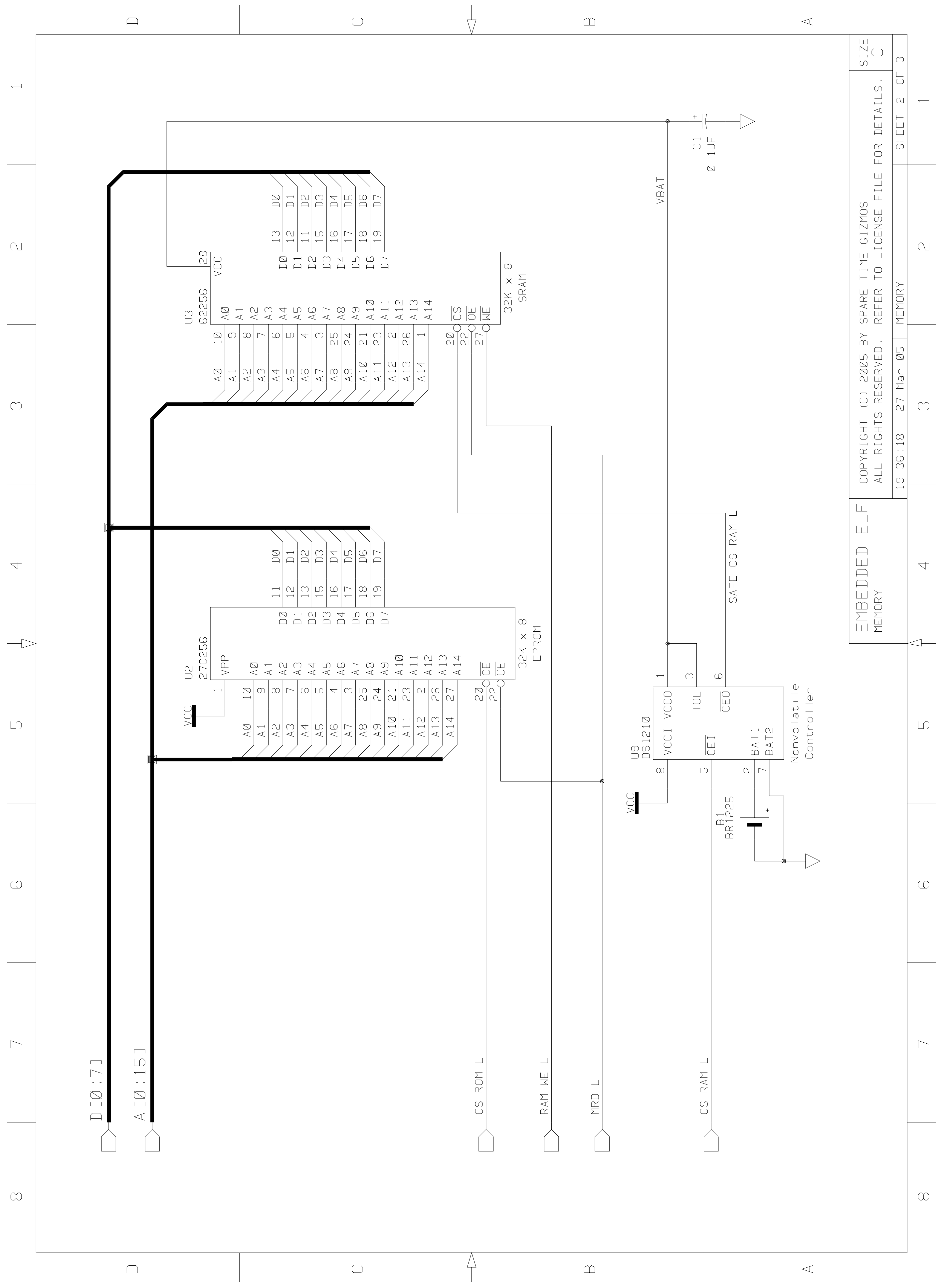


EMBEDDED ELF
CPU

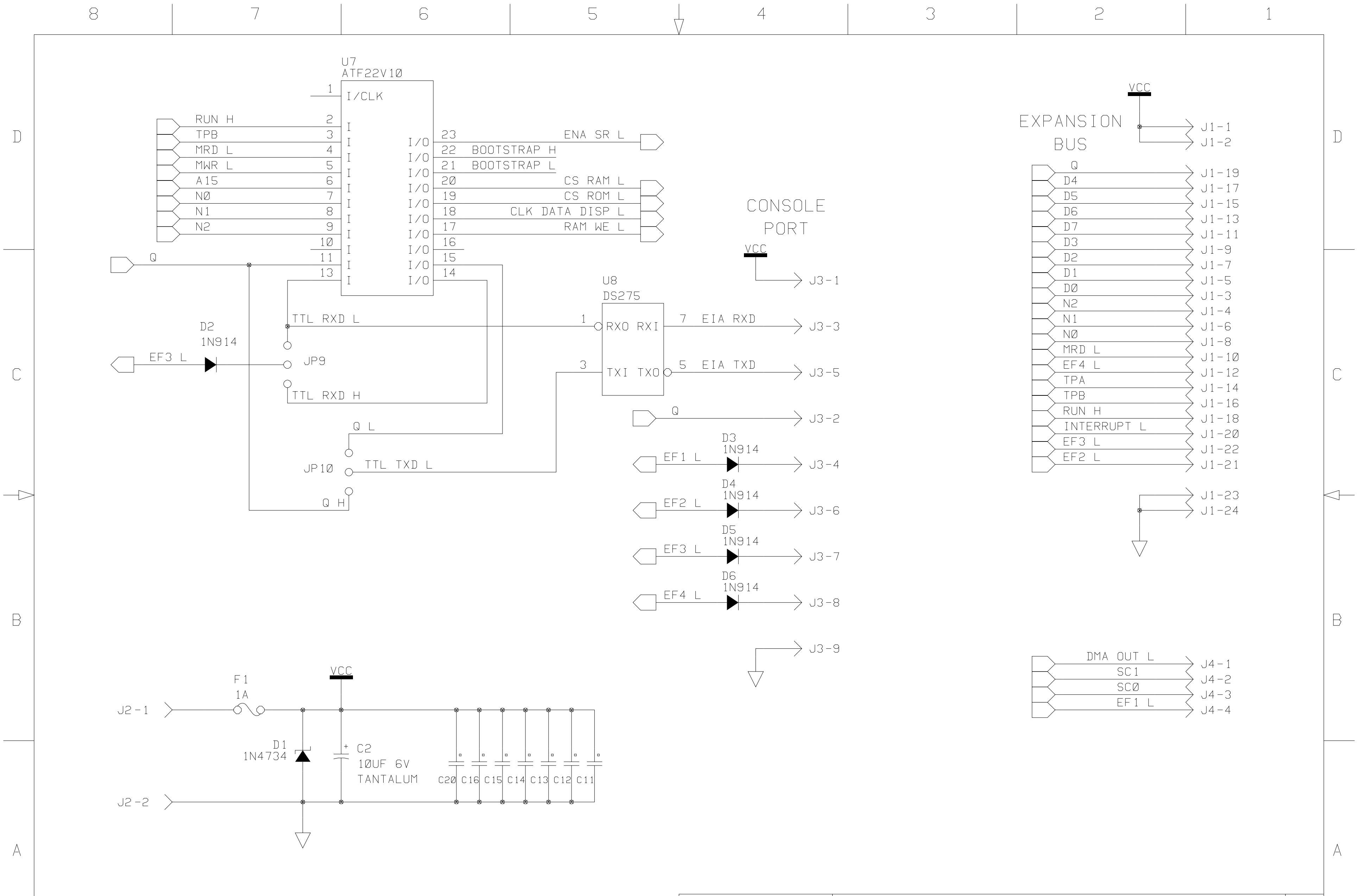
COPYRIGHT (C) 2005 BY SPARE TIME GIZMOS
ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.

SIZE C

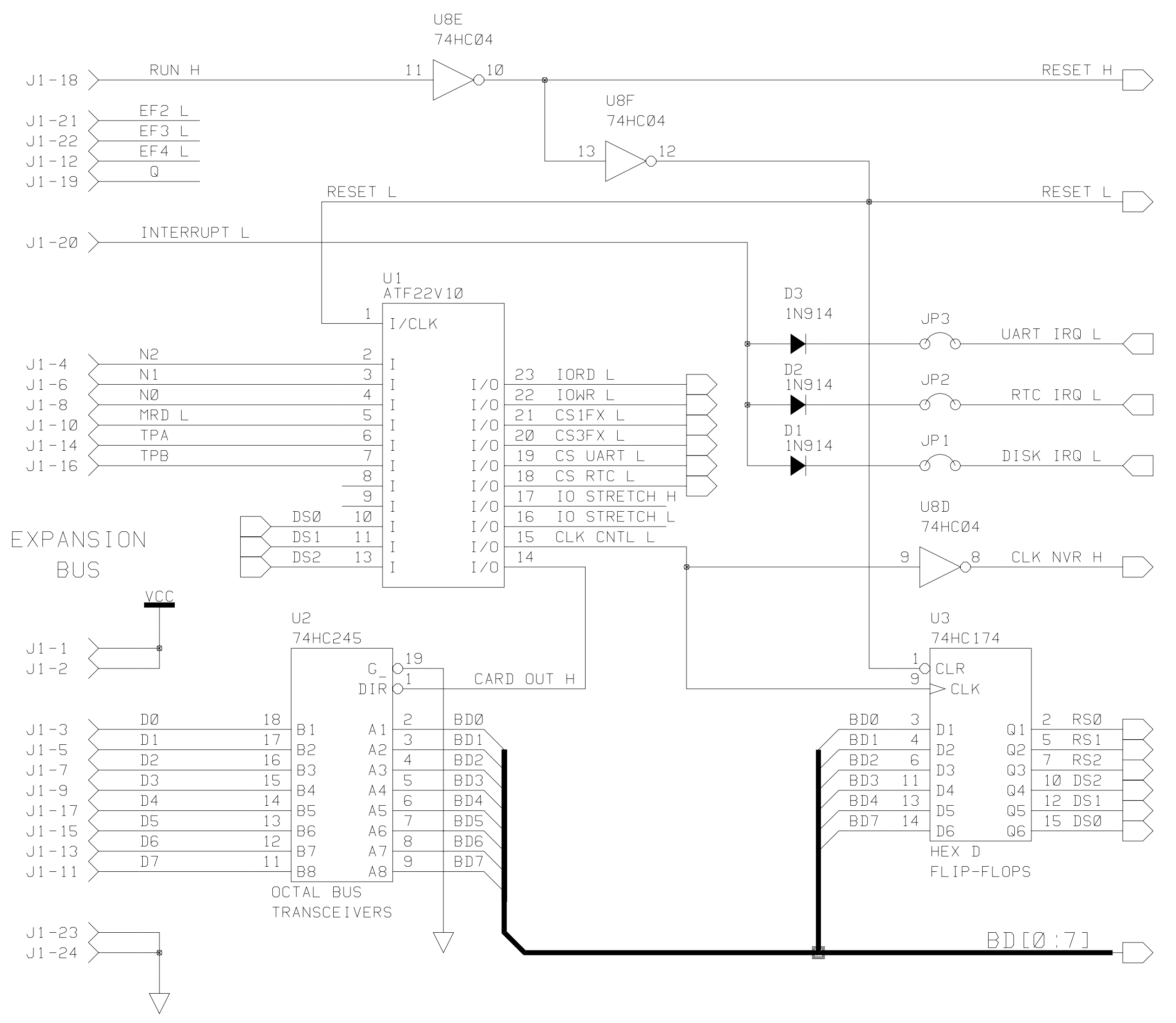
19:35:40 27-Mar-05 CPU SHEET 1 OF 3



EMBEDDED ELF
MEMORY
COPYRIGHT (C) 2005 BY SPARE TIME GIZMOS
ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.
SIZE C
SHEET 2 OF 3
19:36:18
27-Mar-05
MEMORY
U3 62256 32K x 8 SRAM
U2 27C256 32K x 8 EPROM
U9 DS1210 Nonvolatile Controller
C1 Ø.1UF
B1 BR1225
VBAT
VCC
SAFE CS RAM L
D[Ø:7]
A[Ø:15]
CS ROM L
RAM WE L
MRD L
CS RAM L



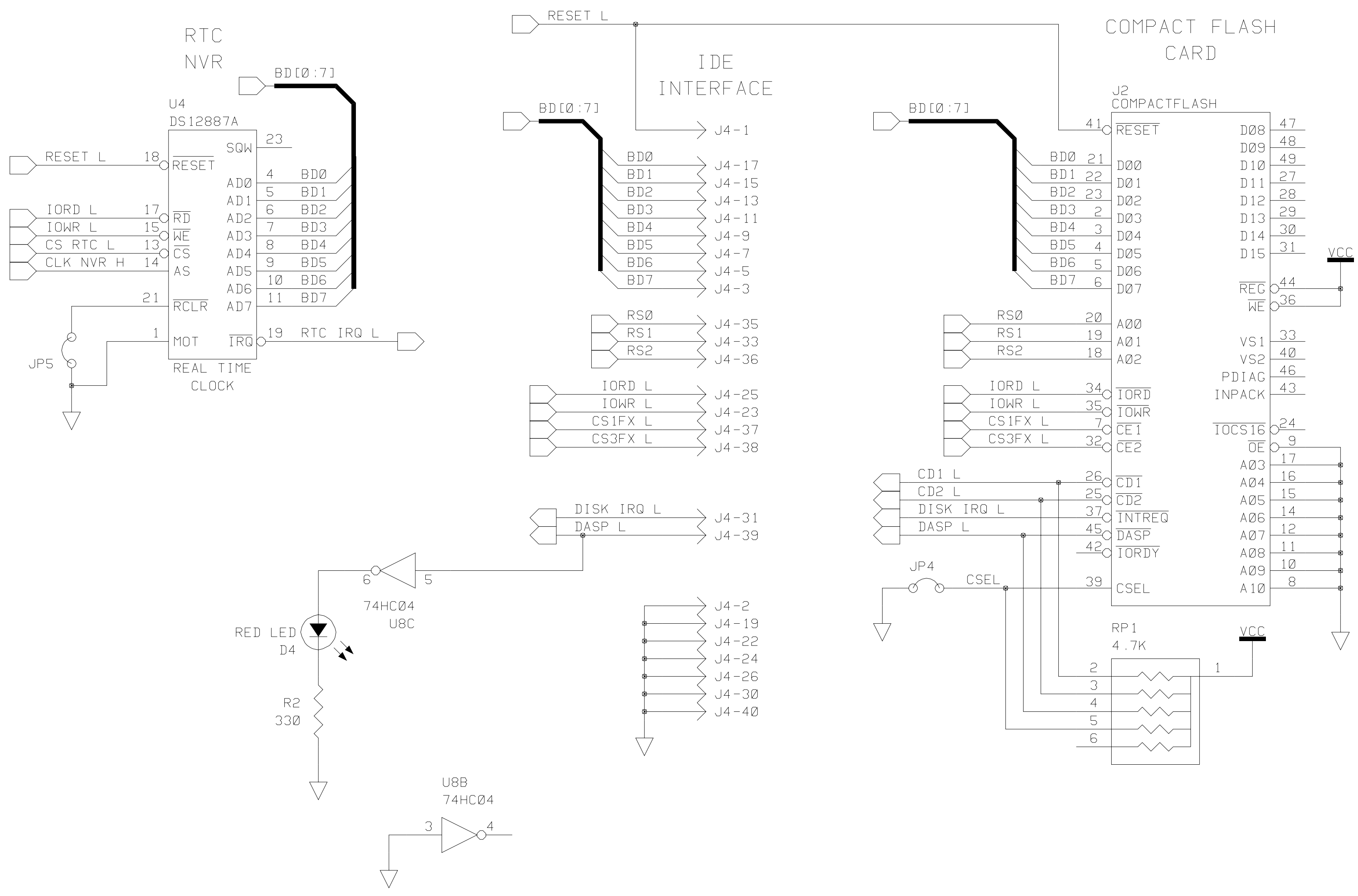
EMBEDDED ELF CONTROL	COPYRIGHT (C) 2005 BY SPARE TIME GIZMOS ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.		SIZE C
	2Ø:21:12 27-Mar-Ø5	CONTROL	SHEET 3 OF 3



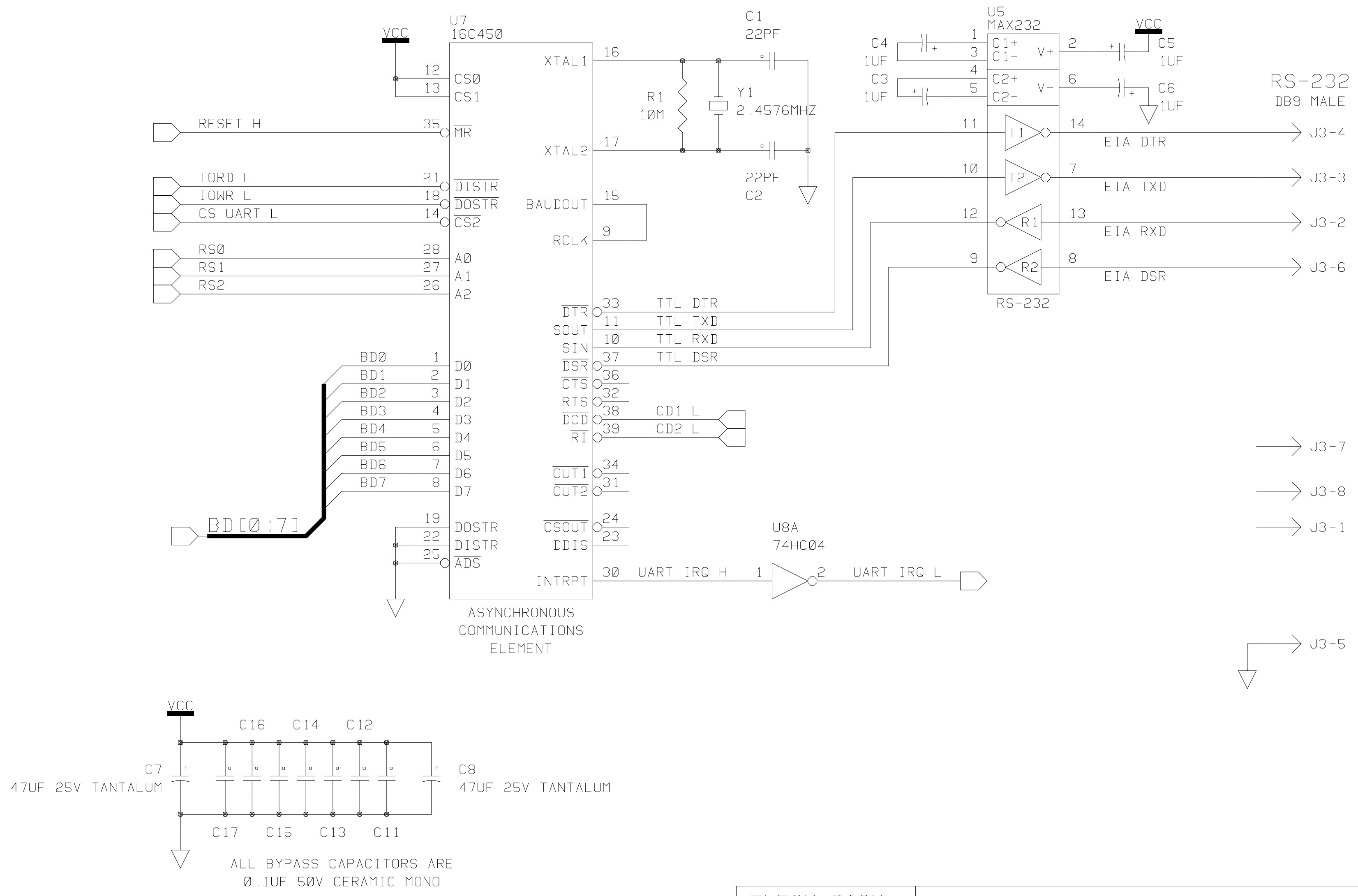
ELF2K DISK
BUS

SIZE C

22:11:09 24-Apr-05 BUS SHEET 1 OF 3



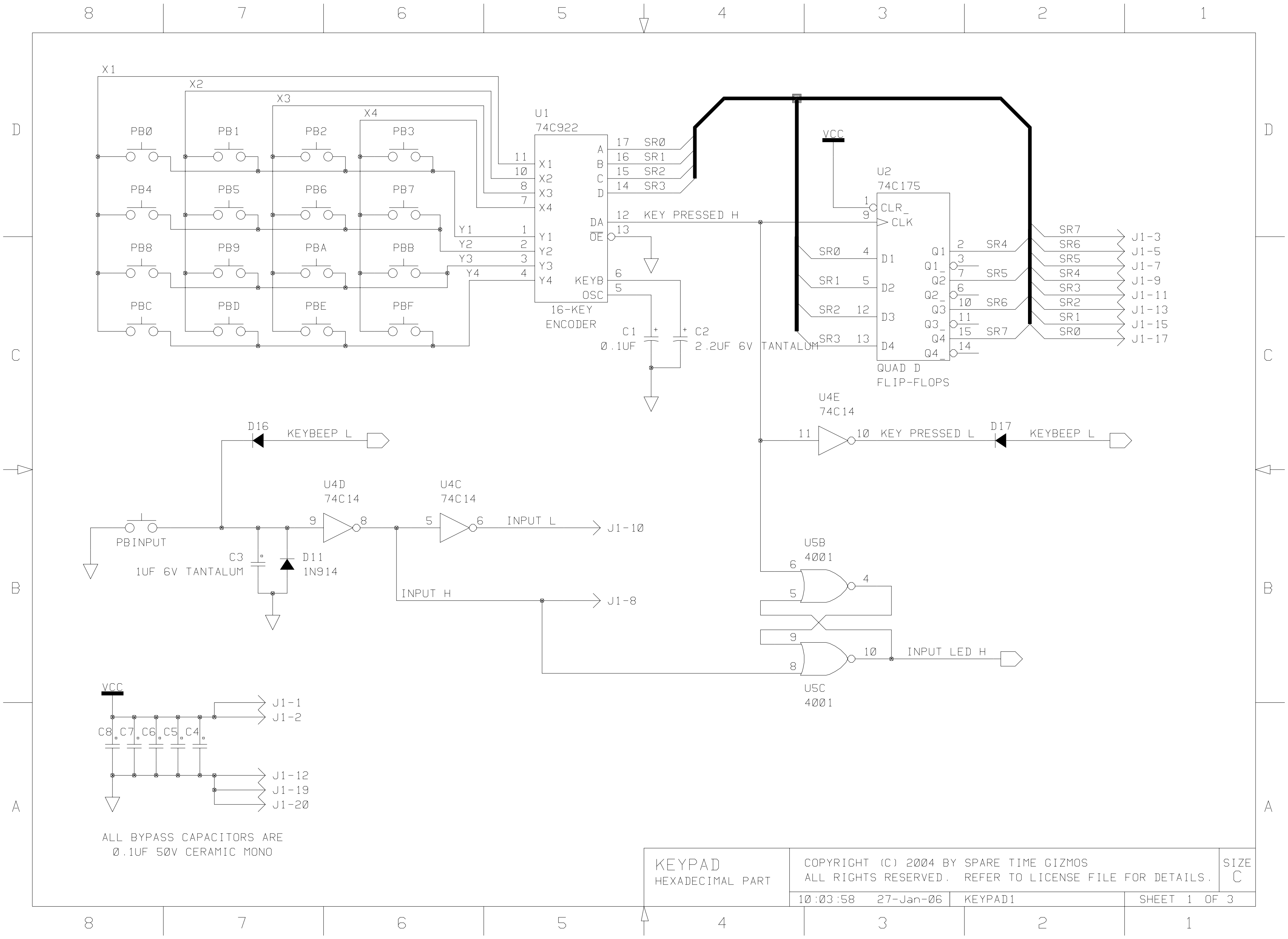
ELF2K DISK IO	COPYRIGHT (C) 2004 BY SPARE TIME GIZMOS ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.	SIZE C
	22:11:13 24-Apr-05 IO	SHEET 2 OF 3



ELF2K DISK
SERIAL

SIZE C

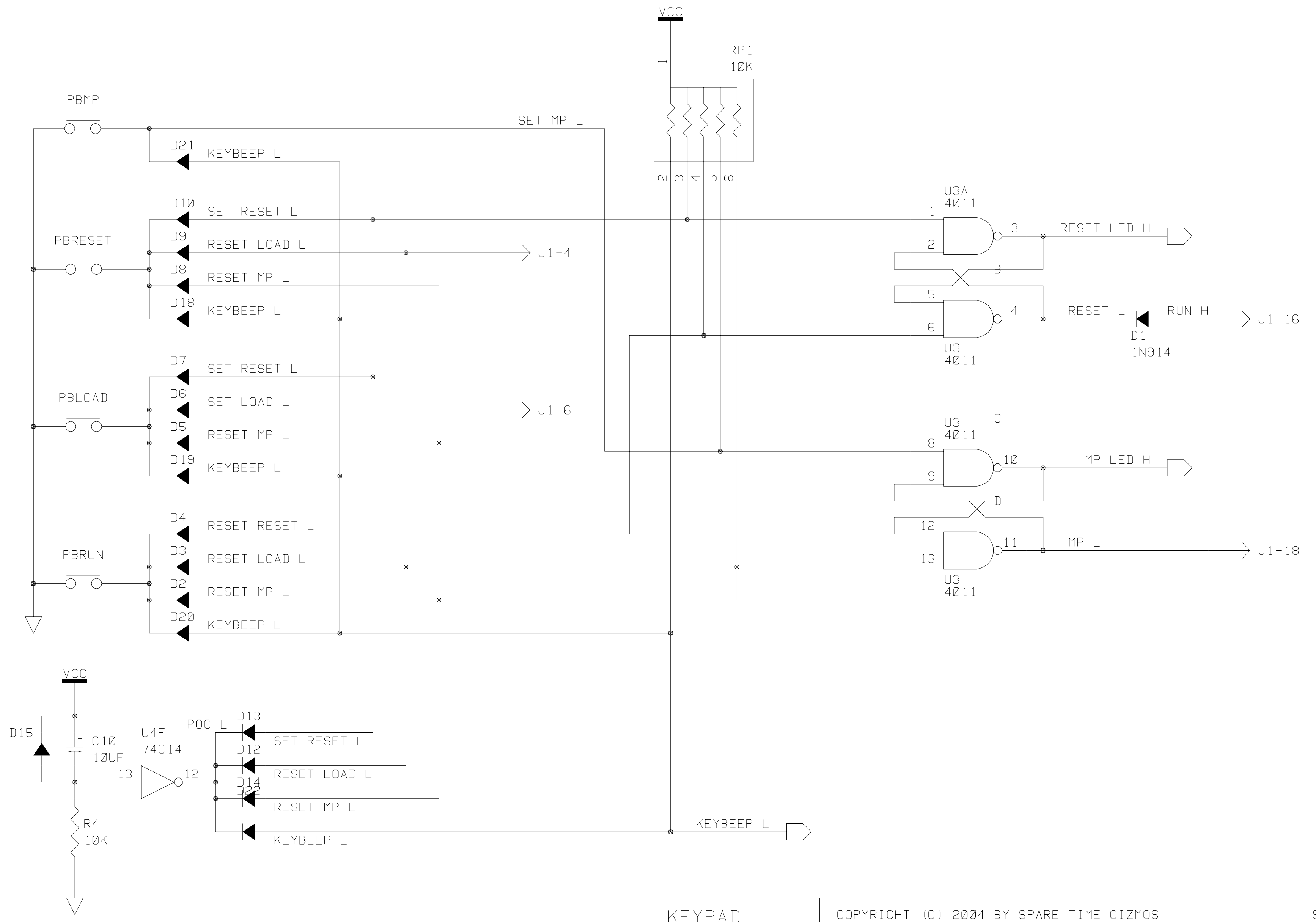
22:11:17 24-Apr-05 SERIAL SHEET 3 OF 3



KEYPAD
HEXADECIMAL PART

SIZE C

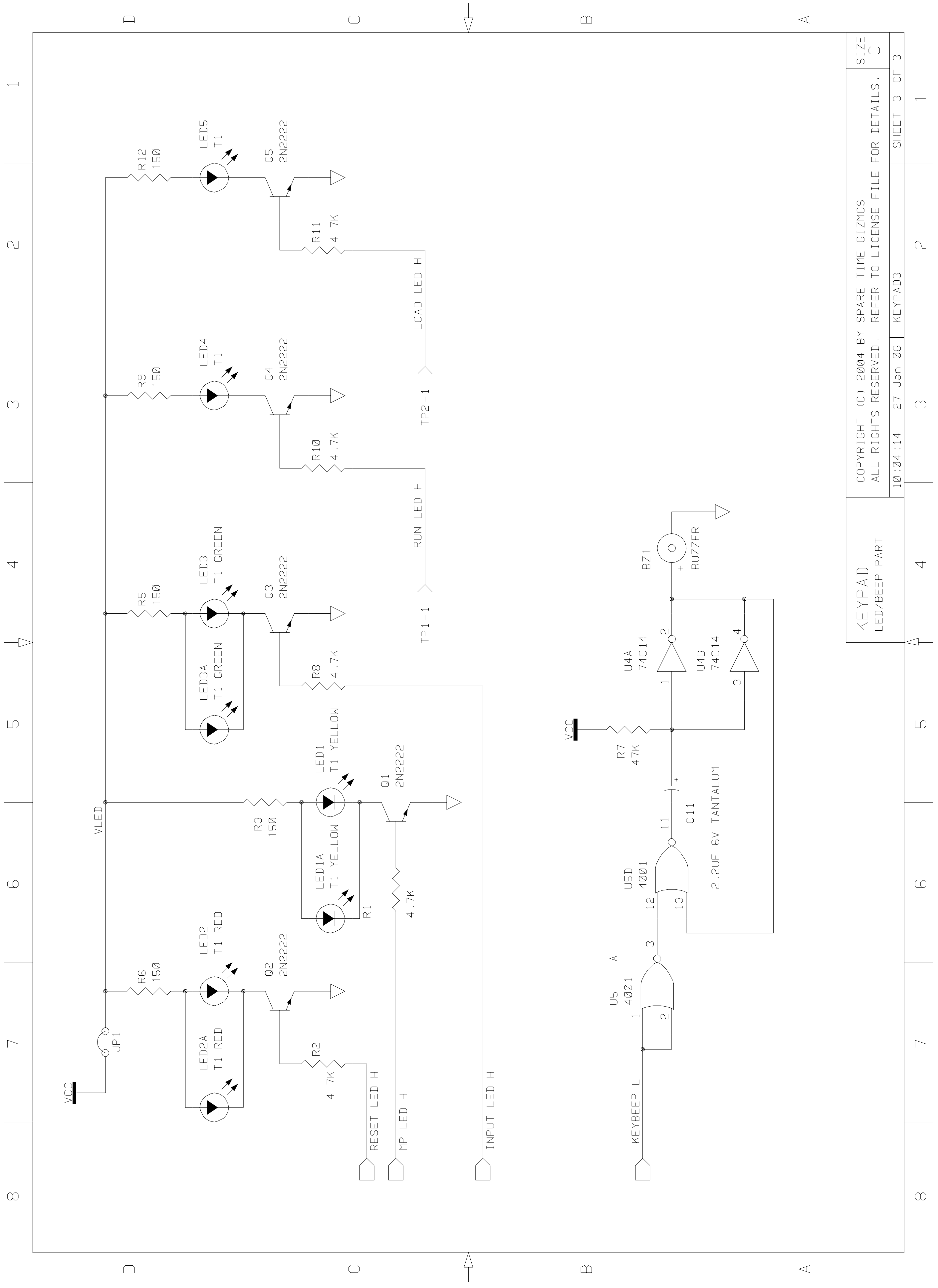
10:03:58 27-Jan-06 KEYPAD1 SHEET 1 OF 3



KEYPAD
CONTROL PART

SIZE C

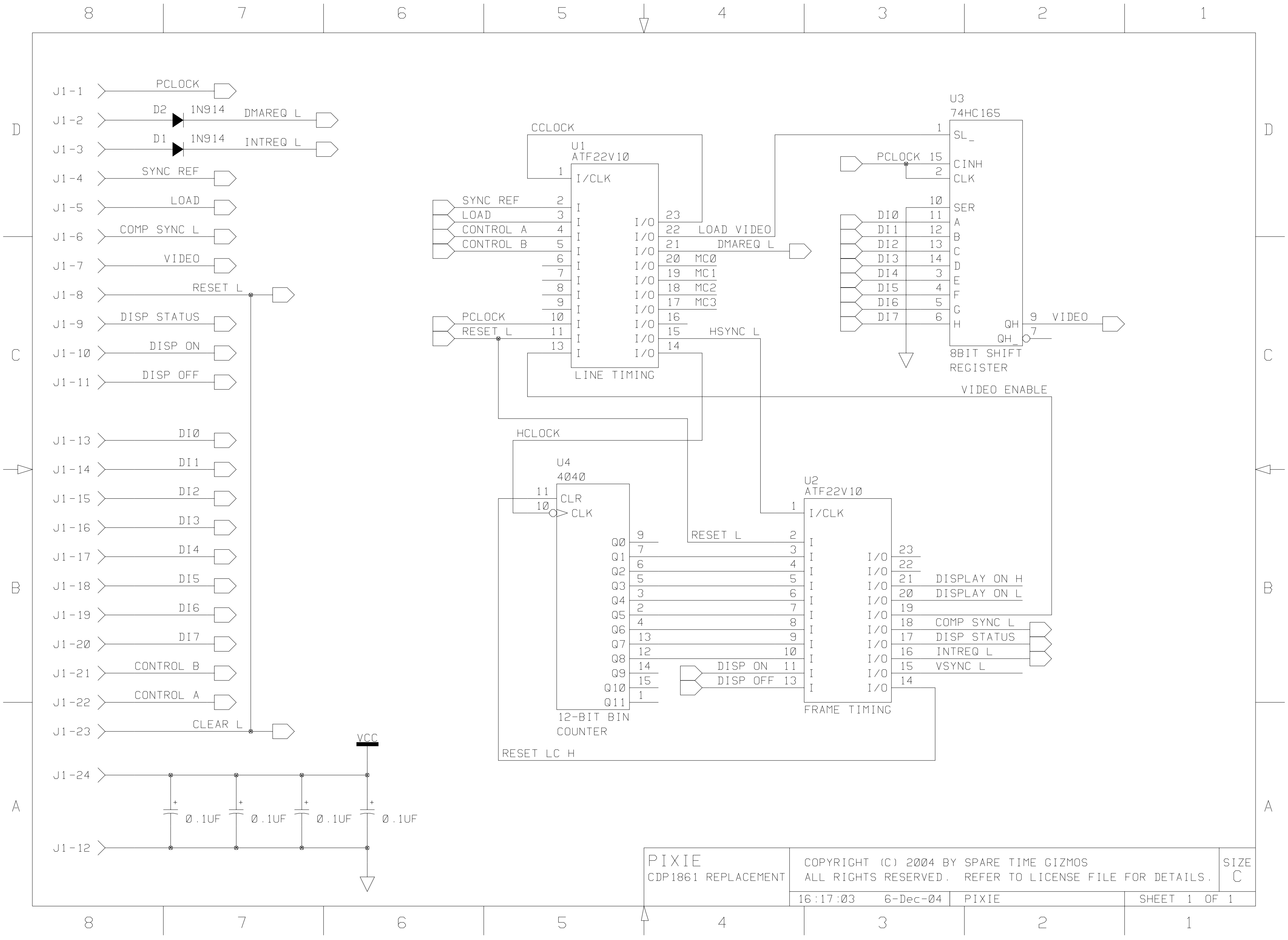
10:03:49 27-Jan-06 KEYPAD2 SHEET 2 OF 3



KEYPAD
LED/BEEP PART

10:04:14	27-Jan-06	KEYPAD3	SHEET 3 OF 3

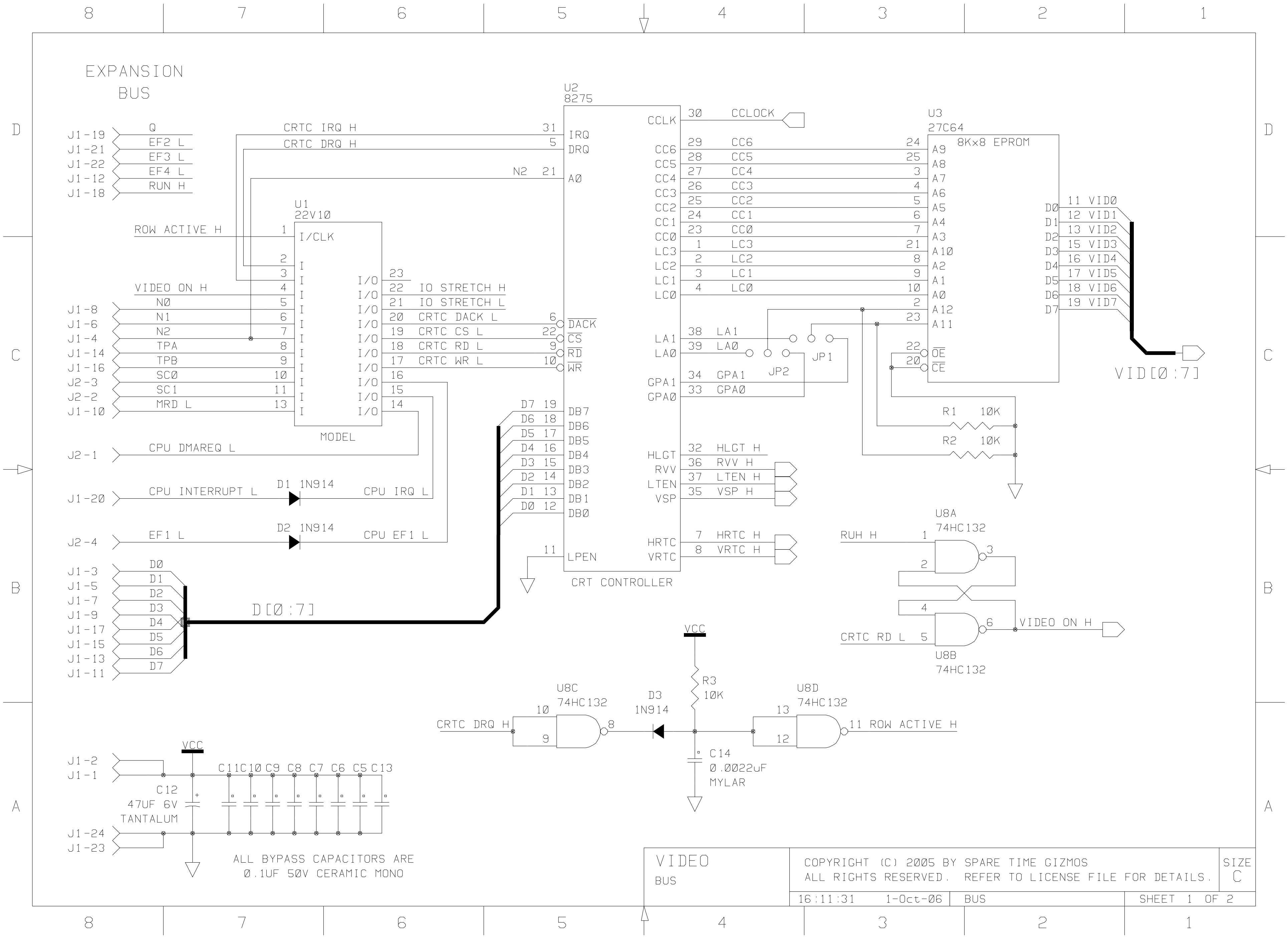
SIZE C



PIXIE
CDP1861 REPLACEMENT

SIZE C

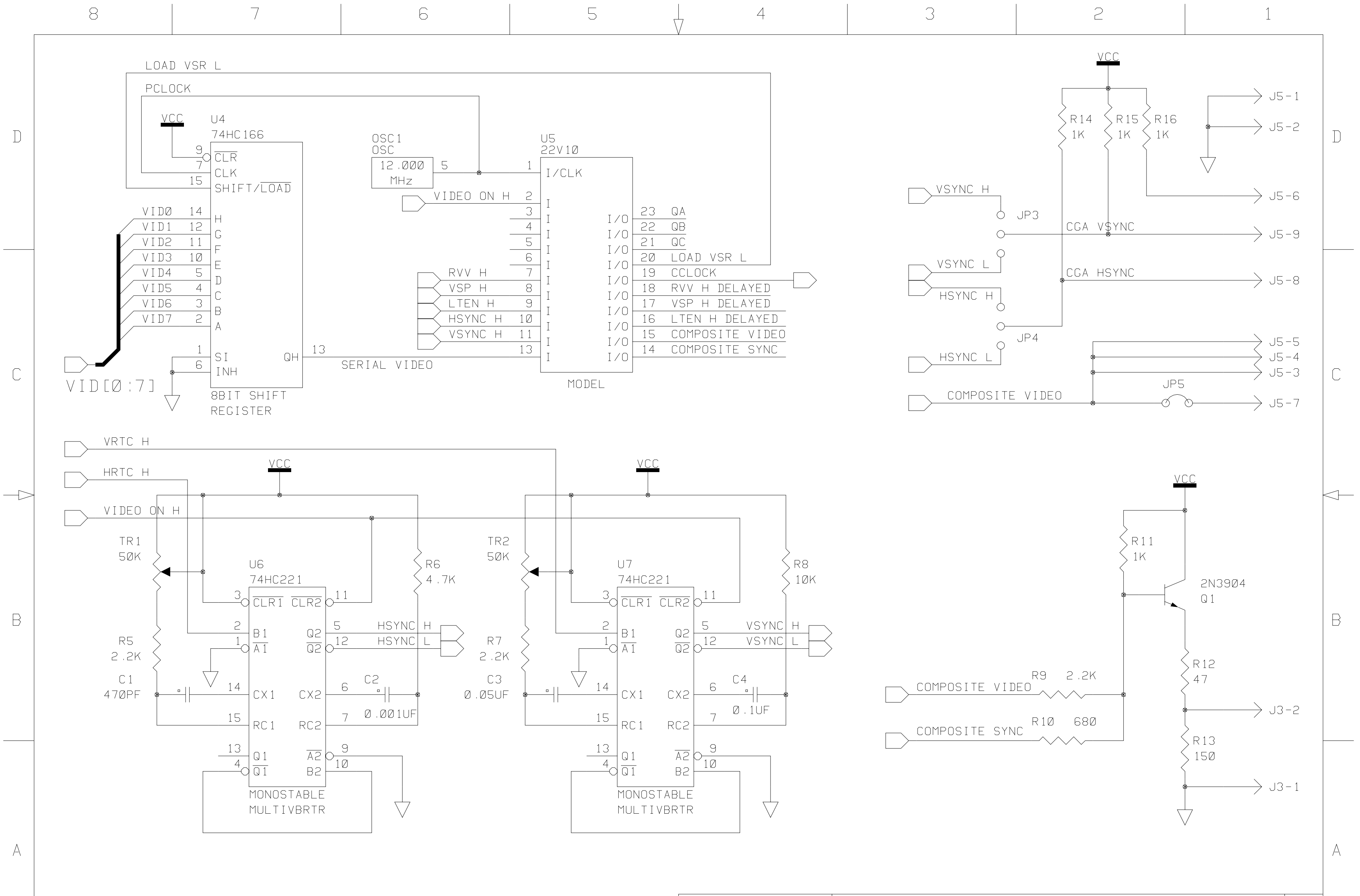
16:17:03 6-Dec-04 PIXIE SHEET 1 OF 1



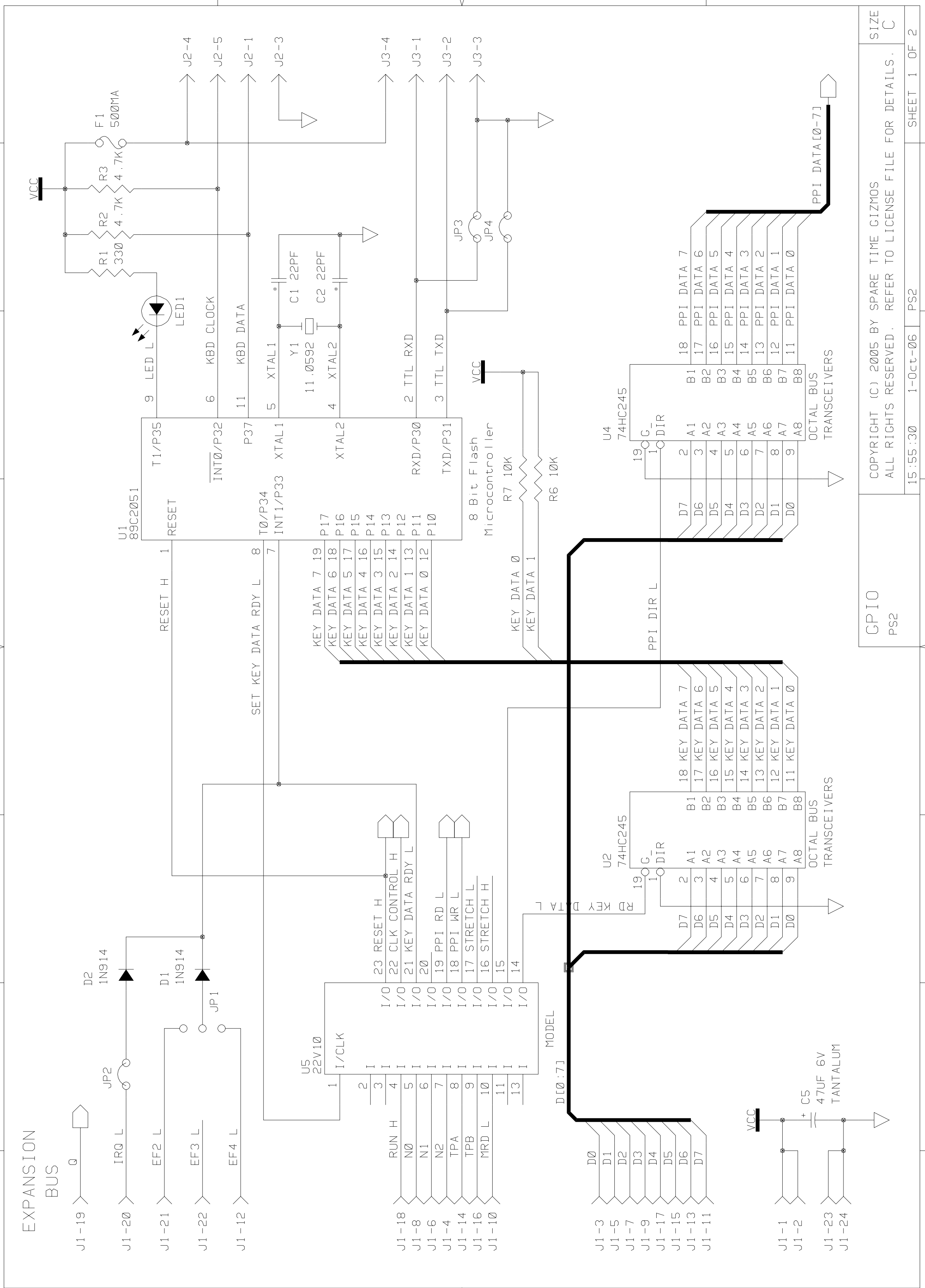
VIDEO
BUS

SIZE C

16:11:31 1-Oct-Ø6 BUS SHEET 1 OF 2



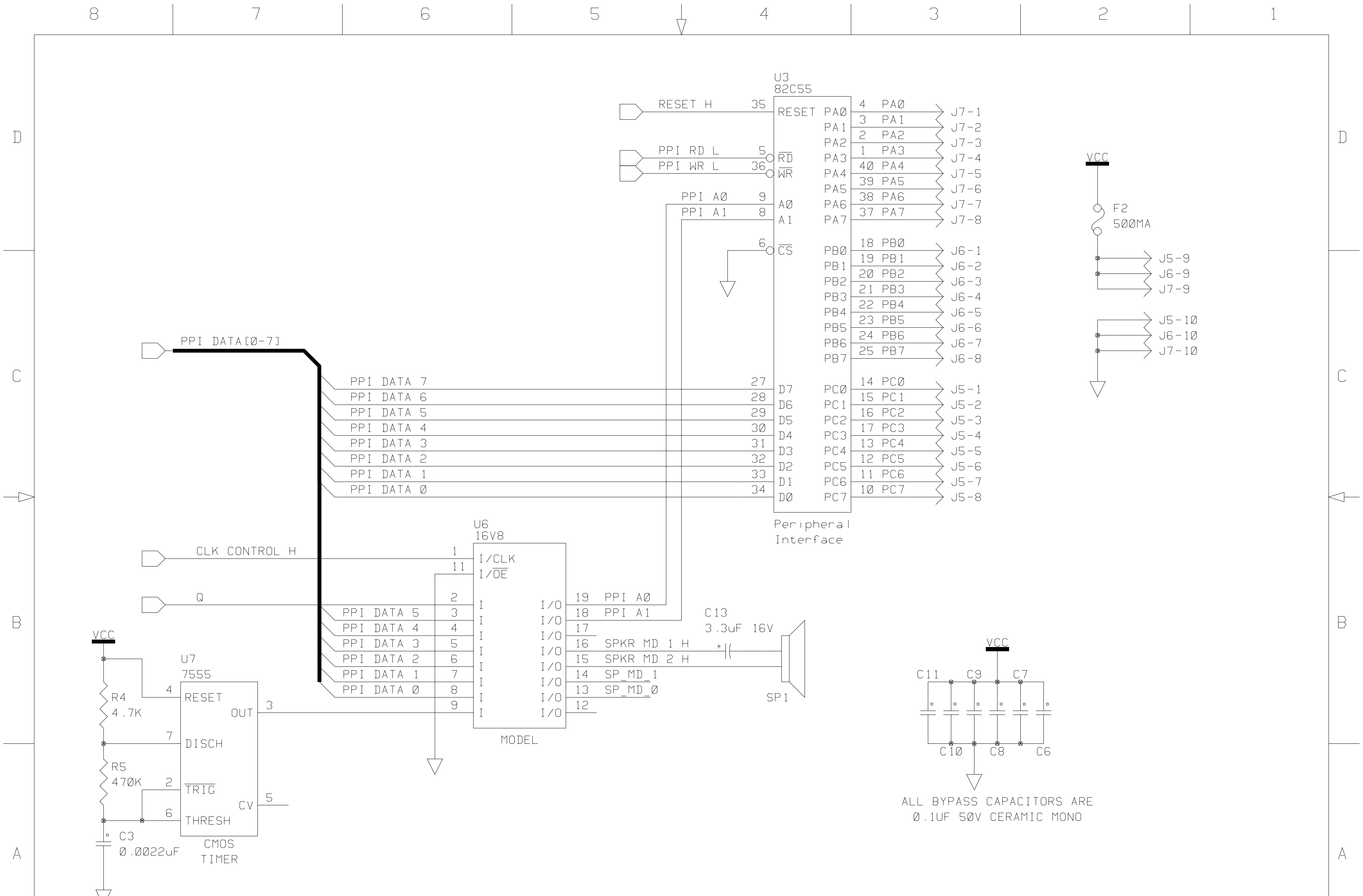
VIDEO VIDEO	COPYRIGHT (C) 2005 BY SPARE TIME GIZMOS ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.	SIZE C
	15:52:45 1-Oct-06 VIDEO	SHEET 2 OF 2



GPIO
PS2

COPYRIGHT (C) 2005 BY SPARE TIME GIZMOS
ALL RIGHTS RESERVED. REFER TO LICENSE FILE FOR DETAILS.

15:55:30	1-Oct-06	PS2
SIZE C	SHEET 1 OF 2	



GPIO
PARALLEL
INTERFACE

SIZE C

15:57:25 1-Oct-06 PPI

SHEET 2 OF 2