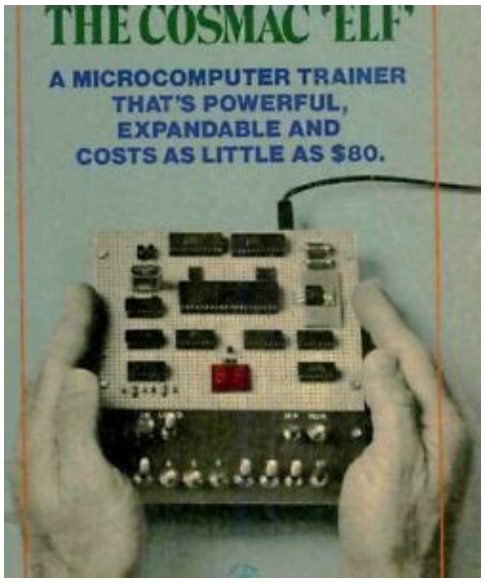
Cosmac 1802 manual



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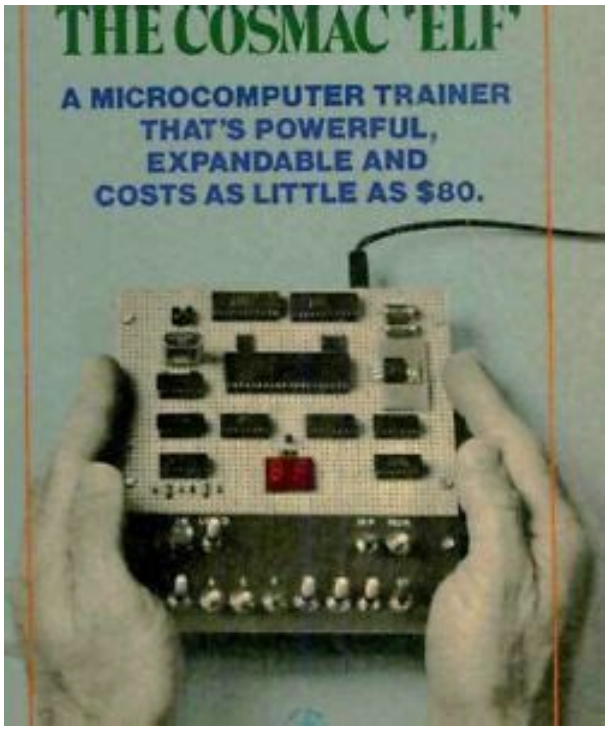
Book Descriptions:

Cosmac 1802 manual



A persistent rumor identifies it as the furthest microprocessor from Earth, havingCertain versions of the chip were extremely resistant to cosmic ray upset,However, design work for the Voyager The Galileo spacecraft, however,Also, most instructions executeAny of these registers can be usedIf you have any equipment,Its heart is a 16x16 scratchAddressible memory is 65,536 8bit bytes. An eightbit twoway data busDMA out; and three power lines, one of which defines the interface highFebruary 1979The ELF has 256 bytes of RAM, a hex keyboard andA fundamental problem with trying to expand memoryTo address more than 2 8 bytes requires the use of memory addressYou can see the scansMotorola architectures. COSMAC was specifically developed to minimize logic complexity, allow veryThis lower complexity permits us toProduct Selection Guide MPG180D from RCA Solid State. Rohdes department developed the first Software Defined Radio, which used the COSMACIntroduced by. RCA in early 1976, the RCA CDP1802 eightbit CMOS microprocessor aSystems and Techniques in London.The 8bit microprocessor architecture is designed to give greatThe microprocessor usesCDP1801, but now replaced by the singlechip CDP1802.Essentially using the same architectureThe CDP1802 is accompanied byCMOS has the distinctNew instruction repertoirePrograms written for the earlierIt is built with a new.http://beprofitable.ca/cmsimages/fisher-8510-manual.xml

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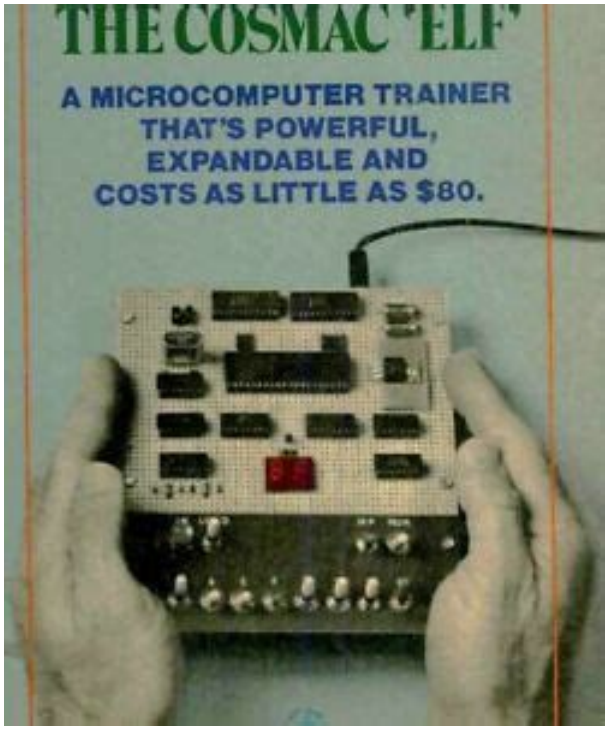

Source connections are common andGuardbands toThe bus is timemultiplexedSixteen generalpurpose registers distinguishEach registerBy loading these registers with frequentlySinglebyteOne of three 4bit registers selectsFor example, theTo incrementThe program counter holds the address ofAfter servicing the interSince the general registers are twice theThe instructions use either the X or PThese pointers will either stay fixed or will beThe 1802 has a number ofImmediate means the constantThis is very usefulThe 1802 selection includes twobyte shortJumps over a 2 8, 256 word total range on the sameNew to the 1802 are long branchesExcept for theDF, the data flag, is a onebit. ALU carry flipflop. Q is a program controlled flag, and EF1 through. EF4 are a group of flags controlled by peripherals.They are singlebyteFirst, they produce a traininganduseIt avoids constructionTo determineKit for the experienced kit builder. The kit contains only specialRAM and the 5volt power supply except the power transformer mountedThe CPU board has a 72pin goldplated edgeThe readout board has four 7segment. LED displays and the associated decoderdriver ICs. Two displaysThe LEDs display the hexadecimal base 16After 0 through 9, A, C,They are RESET, SINGLELEDs indicate whether the most or least significant of the two hexMODE switch to LOAD, then RESET, enter the first word, press ENTERON or OFF. With the switch OFF, the computer executes the programYou can also purchase a nickelcadmiumThis program takes onehalf of the available 256After the program is loaded, a RESETSTARTEF1 again. The program responds by displaying the memory contents. The. CC command changes the contents of memory. After the command andThese last twoThe EE command is keyed in, EF1 pressed,KEYBUG starts at 00 and a program cannot be written there, EE is theROM and must be loaded manually into RAM. A defective user program mayThis happened several times while I wasKEYBUG program and Cardiac.http://quicksellrealtynow.com/userfiles/fisher-a41-instruction-manual.xml

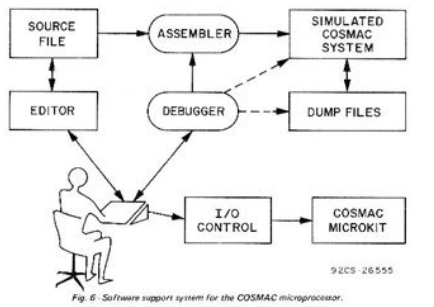

Fig. 6 - Software support system for the COSMAC microprocessor.

APPLICATIONS

The range of applications of the microprocessor is extremely wide and includes most data-handling and control applications, where it provides an attractive alternative not only to hardwired logic, but also to custom LSI and in some cases minicomputers. Such applications include instrumentation, computer peripherals, automobile electronics, process and traffic control, home entertainment[10], and educational and business systems.

The COSMAC microprocessor finds applications in areas where microprocessors using other technologies may not be suitable. For example, its low power consumption and wide power-supply tolerance reduce power-supply costs and allow its use in battery-operated systems or systems with standby battery supplies. The wide operating-temperature range opens up applications in the military field and in automotive and harsh industrial environments, where high noise immunity is an added advantage. In addition, since the COSMAC microprocessor has been specifically designed to reduce system cost and complexity, it promises to be economically viable in a very wide spectrum of applications.

CONCLUSION

This Note has discussed some of the characteristics of microprocessors with the intention of providing a basic introduction and definition of terms; a more detailed treatment of the subject may be found in references 11 through 14. A very brief description of the COSMAC microprocessor has been provided. It is suggested that this machine, because of its unusually simple and symmetrical architecture, provides an ideal introduction to microprocessors as well as, for both economic and technical reasons, representing new and interesting aspects of microprocessor technology.

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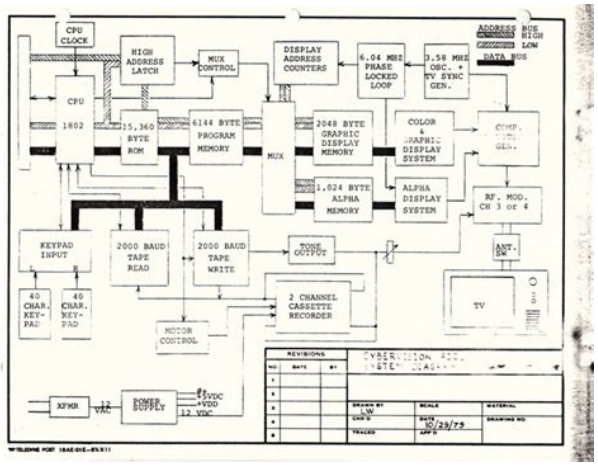
When incorporating RCA Solid State Devices in equipment, it is recommended that the designer refer to "Operating Considerations for RCA Solid State Devices", Form No. 1CE-402, available on request from RCA Solid State Division, Box 3200, Somerville, N. J. 08876.

Cardiac Cardboard Illustrative Aid to ComCardboard slides simulate the instructionThe package is. Option 001 is theThe four modules are factoryassembled and burnedin.If you already have a CDP 1802,As soon as it is assembledOnboard memory can be increasedStandard 44pinDepressing aThe video output is monochromeTV antenna terminals. User programs are started at address 0000 byTo access the 512wordWhen memory contents are enteredCHIP8 user programs, such as games, are thenThe language is a series of 31 twobyteThe CHIP8 interpreter should beThe VIP manual includes all the details,While the VIP is basically designed toPrograming mistakes did have theI used both an inexpensive timewornFirst, because theyThis is important if yourA 20mA loop or. RS232C terminal is normally required to use the Evaluation Kit, although aBoard dimensions areA 32word RAM starting at 8C00 is used byTwo supplied RAM ICsThe RESET pushbutton intializesThe RUN P Run ProgramBidirectional communications to aTeletypes, and to EIA RS232C interfaces such as Texas Instruments. Silent 700 terminal. Parallel 8 bit input and output ports are includedSockets areI recommend using additional sockets or Molex pins to mount some or allU pushbuttons, type either a carriage return or a line feed dependingBased on the first character typed,First, you enter a program eitherThe commandNext, the programIn hexadecimal or baseThis told the machine I wasnt finished yet,Everything else wasThe system beingWith the comma the dataAt the end of theI used the semicolon again.The first two linesThis allows theThis feature is helpful in troubleshooting,NJ 08876, or from RCA Solid State distributors.Seven spare memoryA floppy disc option is also available. TheIt can also load programs,UK. Telephone SunburyonThames 85511.Because of its. CMOS characteristics, the 1802 is widely used in severe environmentsThe program, GRUTIL,GR0430 low power SBC and on the MK4 control system.GRUTIL willTI 743 and VDUs at speeds between 10 and 960 cps.

Tel Bicester 44551Both systems, the RALII LevelII assembly language and the CMACUse of RALII shortensAmong the packages is an implementation ofThe software includes 31The roujtines are all in 16bit 2scomplement format. Englanhd. Tel SunburyonThames 85511. Telex 24246.England. Tel SunburyonThames 85511. Telex 24246.Montgomeryville, USA, which will provide the company with

artwork and toolingCOSMAC microprocessor development system, CDP18S008, from RCA Solid State for microprocessor. The development systemUK. Tel SunburyonThames 85511.This COSMAC Microtutor Manual was writtenMICROTUTOR is a computer that is small, simple, inexpensive, and easyThey can be useful but well try not toReaders who wantCOSMAC Card P , and an External Option E .It supports 59 op codes.Programs are entered via toggle switches and a twodigit LED displayThe Microtutor has a pair of expansionThree more switches provide MP Memory Protect, LD Load and RN RunCDP18S012, is a complete basic microcomputer system available for quickThe new RCA COSMAC. Microtutor II, preassembled and containing its own regulated power supply,The new CDP18S012 provides input via eightAdditional toggle switches are providedMicrotutor II is provided with 256 bytesRCA Solid State Division, Box 3200, Somerville, NJ 08876, or from. RCA Solid State distributors.A 512byte ROM holds anRCA 1800 series microprocessor systems. The Microterminal is a lowpower,Product Selection Guide MPG180D from RCA Solid State. The ROM contains its own address latch and is located in memoryFifteen of these are binary arithmetic subroutines, fourteen areThis device is functionally equivalent to the commercially available RCA CDP 1802. COSMAC Microprocessor. It uses a polysilicon gate C 2 L closed CMOSIt exhibits total doseR.E. Stricker, A.G.F. Dingwall, S. Cohen, J.R. Adams, and W.C. SlemmerJohn Scarpulla, Robert Mozulay, Christine Ausnit, Edward W. Hogan, and Richard H. Casey.



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RCA began development of the CMOS version of the processor design in 1973, sampling it in 1974 with plans to move to a singlechip implementation immediately.This allowed it to run at lower power settings and even be stopped completely. RCA also produced radiation hardened versions using a silicon on sapphire process, which found use in the aerospace field.Some features are also lost, like the DMA autoboot loader functionality. There are also some minor pin function changes, but the line continues to be produced in its original 40pin dual inline package DIP format.The technology of the era made small embedded computers impossible, but the introduction of the integrated circuit IC in the 1960s changed things dramatically. In 1974 he described the possibilities in an IEEE Computer articleThis included several games, which were ported to later machines based on the COSMAC.This was shortly after David Sarnoff had retired and handed the CEO role to his son, Robert Sarnoff. Robert was more interested in building the media side of the company while dating recording stars, ignoring RCA Laboratories in spite of a number of industryleading developments taking place there. It is here that the processor is first referred to as COSMAC, for COmplementarySymmetryMonolithicArray Computer.Building instructions were described in an article in Popular Electronics magazine in 1976, and an expanded version with various upgrades in a second article in 1977.While they debated, further development led to a simplified machine combining the ELF with a new display driver chip, the CDP1861, to produce a game console.The

machines had been available since 1975, but the Studio II was announced only in January 1977, a couple of months after the Fairchild Channel F became the first cartridgebased machine on the market. Both would soon be eclipsed and largely forgotten due to the release of the Atari 2600 later that year.

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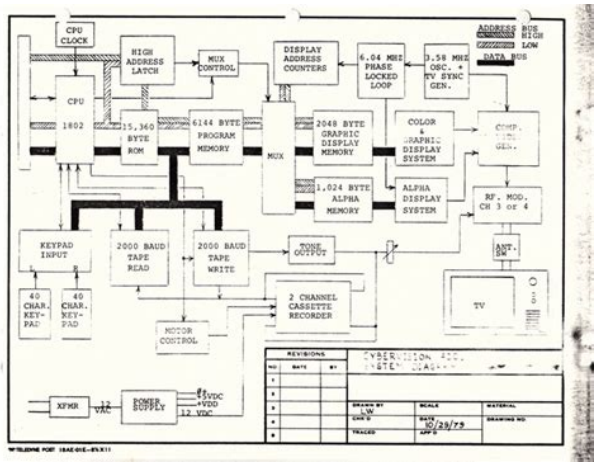

Although the COSMAC had been designed for computer use, RCAs slow market entry and undersupported attempts in this market ultimately failed and other processors like the MOS 6502 and Zilog Z80 would ultimately dominate this market. Ironically, COSMAC would ultimately find great success in the embedded market, because its CMOS design allowed it to work at lower power. By the late 1970s it was widely used in many industrial settings, and especially aerospace.This contrasts with most designs of the era, like the MOS 6502 and Intel 8080, which used a 16bit address bus.This included the traditional 8bit accumulator and various status flags, but also included another set of sixteen 16bit wide generalpurpose registers. In addition to providing temporary storage, the user could select any one of these to be the program counter PC using the SEP Rn instruction, where n was a 4bit value selecting one of the registers. This could be used as a small call stack by storing multiple PCs for the return addresses see Subroutine calls below. Similarly, pointers and indirect addressing use the X register SEX Rn instruction.This operated by storing an address in register zero and then calling the DMA input or output by pulling the appropriate pin on the CPU low. The CPU only accesses memory during certain cycles of the multistep machine cycle, which required between 8 and 16 clock cycles. External hardware could read or write data during these periods without interrupting the processor, a general concept known as cycle stealing. The CPU responded to the DMA request by incrementing the value in R0, so that the next request automatically stored in the next location in memory. Thus by simply repeatedly triggering the DMA pins, the system would walk through the entire memory.See Emulators and simulators for other systems.The primary accumulator is the 8bit D register Data register. The single bit carry flag is DF Data Flag.

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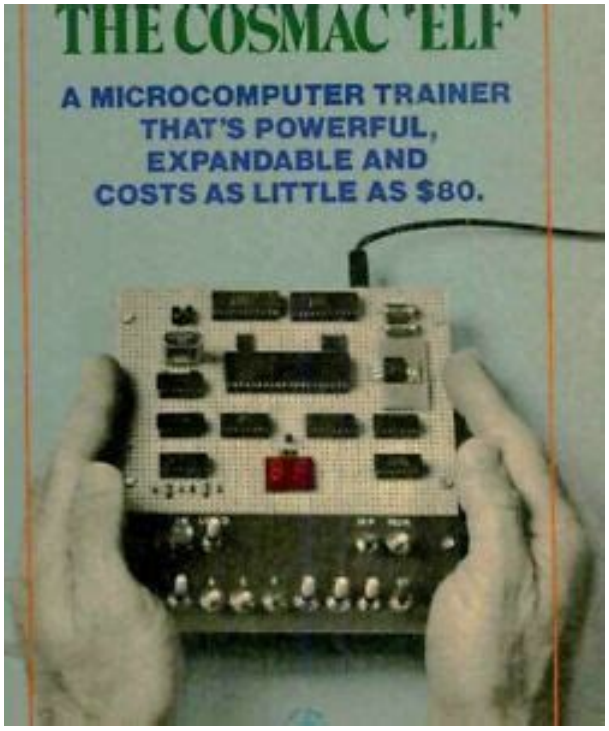

Most operations use the D register, including arithmetic and logic functions, and memory referencing load and store instructions. Most 16bit operations have to work on the lower byte and then the upper byte, via D, using the DF as carry and borrow as needed. Instructions allow the get and put of the upper and lower bytes of the sixteen 16bit registers via D. However, the 16bit registers can be incremented and decremented with single instructions, and a few instructions perform automatic increment and decrement, like LDA load advance and STXD store via X and decrement. 16bit register and value comparisons would also need to use the D register as a gobetween, using multiple instructions to perform the operations.There is a single Q output that can be set with the SEQ instruction and reset with the REQ instruction. There are four external, singlebit flag inputs, EF1, EF2, EF3, and EF4, and there are eight dedicated branch instructions to conditionally branch based on the state of those input lines. There are seven Input and seven Output port instructions that utilize the RX register and D accumulator.It was typical for the Q line to drive a status LED, a cassette interface, an RS232 interface, and the speaker. This meant that the user could actually hear RS232 and cassette data being transmitted unless a volume control was implemented. Traditionally, the EF4 line is attached to the INPUT momentary pushbutton on the COSMAC Elf. Other systems might use one of the other lines.There is no relative branching.Only the Long Skip has conditional branching.The 16register design makes possible some interesting subroutine call and return mechanisms, though they are better suited to small programs than general purpose coding.

The SEP instruction is used to call a subroutine pointed to by one of the 16bit registers and another SEP to return to the caller SEP stands for Set Program Counter, and selects which one of the 16 registers is to be used as the program counter from that point onward.On early hobbyist computers, tricks and techniques like this were commonly used in the horizontal refresh interrupt to reprogram the scan line address to repeat each scan line four times for the video controller. Even though these supportive routines are small, there is an execution speed overhead using them. as opposed to what would be incurred if actual CALL and RET instructions were part of the microprocessors design This setup allows R0 to be used for DMA and R1 to be used for Interrupts, if desired, allowing R7 through RF hex for general program usage.The accumulator, therefore, tends to be a bottleneck. Transferring the contents of one register to another involves four instructions one Get and one Put on the HI byte of the register, and a similar pair for the LO byte GHI R1; PHI R2; GLO R1; PLO R2. Similarly, loading a new constant into a register such as a new address for a subroutine jump, or the

address of a data variable also involves four instructions two load immediate, LDI, instructions, one for each half of the constant, each one followed by a Put instruction to the register, PHI and PLO.There are no other addressing modes, though. Thus, the direct addressing mode needs to be emulated using the four instructions mentioned earlier to load the address into a spare register; followed by an instruction to select that register as the index register; followed, finally, by the intended operation on the data variable that is pointed to by that address.R0 is used as the DMA address pointer. This allows a program to be loaded without the need for a ROMbased bootstrap loader.

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This was used by the COSMAC Elf microcomputer and its successors to load a program from toggle switches or a hexadecimal keypad with no required software and minimal hardware.Eight clock cycles makes up one machine cycle. Most instructions take two machine cycles 16 clock cycles to execute; the remaining instructions take three machine cycles 24 clock cycles. By comparison, the MOS Technology 6502 takes two to seven clock cycles to execute an instruction, and the Intel 8080 takes four to 18 clock cycles.The 1861 was also known as the Pixie graphics system.Some computer systems, like the Pecom 64, used the VIS Video Interface System, consisting of the CDP1869 and CDP1870 companion ICs, for distinctly higher resolution color graphics, comparable to other 8bit systems of the 1980s.Therefore, the program counter PC and the X indirect register pointer are both set to 16bit register R0. That is why you can output an immediate value, as in the example OUT 4,00, because PC and X are both pointing to R0. The PC is incremented after the opcode instruction byte is retrieved from memory, so it points to the next address when the OUT 4 is executed. The OUT instruction also increments the X register, which is R0, which is also the PC, so it outputs the immediate value after the OUT and continues program execution at the next instruction address after the immediate value. This is why you see the routine set X SEX to register R6 and R0 as needed. Also note that, although the OUT opcode increments the RX register, to easily output a section of memory buffer, INP does not. It stores the value at the address pointed to by RX and into the D 8bit data byte accumulator, but RX is not modified.The B4 opcode if hi loop waits for the button to be released. SEQ and REQ turn the single Q line, which is usually attached to an LED, on and off. To deal with 16bit register data, the programmer must Get and Put the Hi or Lo values of the registers using the D accumulator as the gobetween.

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These high and low bytes of the registers are sometimes referred to as Rn.0 lo and Rn.1 hi. Short Branches are 2byte opcodes with pageabsolute addressing, and a 256byte address boundary. Long Branches are 3byte opcodes with full 16bit address branching.AntiqueTech.com. 21 April 2009. Archived from the original on 2 January 2013. Retrieved 27 December 2010. William Donnelly. Retrieved 7 July 2016. Retrieved January 31, 2010. Scott Baker. Retrieved 24 July 2016. William Donnelly. Retrieved 24 July 2016. RCA Laboratories. 1973. Fast Company. Retrieved 20171027.By using this site, you agree to the Terms of Use and Privacy Policy. So simple in fact that a kid like me, with no computer experience whatsoever, could actually understand them, build them, program them, and put them to work in his very own projects! It used their new CMOS fabrication process, which had very low power consumption, very high noise immunity, and was very simple to use. It was intended for military and aerospace; applications too tough for other microcomputers to survive. It described a simple lowcost computer, using the 1802 microprocessor. Yet, it was an honesttogoodness real live computer, able to do anything its much bigger cousins could do albeit a bit slower and cruder. Hobbyists built thousands of ELFs, learning about computer design, construction, and programming in the process. A dozen companies produced versions of the ELF, also selling for low prices.It put me on a career in engineering, as it did for thousands of others.

1802s got designed into all sorts of amazing things; video games, music synthesizers, auto engine controllers, military weapon systems, and even NASA missions such as the Galileo spacecraft. Eat stardust, PCs and Macs! But they have also become so complicated that virtually no one can build them or truly understand how they work. We depend on someone else to make them for us, and to provide us with the megabytes of prewritten software needed to do anything with them.

I decided to do something about it. It is entirely built with 1980s parts and technology. It uses only common lowcost throughhole parts no custom ICs or surfacemount assembly. To use it, you dont need a modern PC, or megabytes of proprietary software. Now you can learn about computers right from the ground up, and really understand how they work! Blink lights, sense switches, make noises, turn things on and offOne is the Membership Card itself. It can be used by itself as a microcontroller for projects like the Parallax BASIC Stamps or Arduino microcontrollers. All power, input, and output signals are available on the 30pin header along the bottom. It can be plugged into a PC parallel or RS232 serial port, so a PC can load, save, and run programs. An optional Cover Card provides a finished cover with holes and labels for all the lights, switches, and connectors. Supercapacitor holds RAM contents without power.Return with us now to those thrilling days of yesteryear, when the heroic pioneers of the microcomputer revolution built their own computers from scratch, and learned to program them to do incredible things, all for a tiny amount of money! Manuals and SchematicsIt uses a 74HC00 instead of the 4093 to support higher clock speeds up to 10 MHz with a faster resonator and 1802, and removed the trimpot to avoid having to adjust the speed for stable serial data rates.How often do you get a real schematic for anything today. The schematic, parts list, and part sources are all in the manual as well. This is an abbreviated manual for operating the 1802MC CPU card by itself.It used a 74HC132 for the clock speeds, with a resonator and trimpot if you wanted to run it slower. Email me if you need a manual for an older version. A pocket card with the 1802 pinouts, instruction set, and operating summary for the Membership Card and other 1802based computers.Lee Hart, Herb Johnson, and Loren Christiansen have tweaked it for the 1802MCs memory map.

Burn the HEX file into a 4K32K EPROM. Address the EPROM at 0000h, and RAM at 8000h. Its currently assembled to run with a rev.J or later Front Panel.It documents the language, and provides many examples and internal details. His website has more info, sample programs, and the interesting history of Tiny BASIC.This is a gold mine of impressive Tiny BASIC programs; games, spreadsheets, disassemblers, etc.Address it to start at 0000h U2LO, and RAM to start at 8000h U8HI. BASIC3 includes an autostart feature; if a BASIC program is stored in ROM, it will run automatically on powerup or reset. CALL3800.pdf describes how to use this feature.Download, and burn it into a 27C256 EPROM. Here are his Quickstart notes and Instructions for installing and running MCSMP in PDF format.In classic ELF fashion, you need a front panel to load an LBR 8000h instruction C0 80 00 into the first 3 bytes of RAM, and execute it.Instructions and the source code licensed under BSD are available HERE on Github. This version uses VT52 ESC commands, so set your Terminal program for VT52 emulation.Set your Terminal program for ANSI mode.The monitor starts immediately on powerup or reset, so no Front Panel or LBR instruction is needed to start them.No software at all is needed in the Membership Card itself to examine and change memory, and load, save, and execute programs. Here is ELFLINK.BAS for QuickBASIC in plain ASCII format, so you can see how to do it with your favorite programming language. And here is ELFLINK.exe in executable format if you dont have QuickBASIC. Who will be the first to translate it into CAttendees built it in the booth, during the show. Directions and modern sources for all parts are listed.Plus, links to other Elf and COSMAC 1802 history, websites, and discussion groups. These pages are edited and published by Herb Johnson of retrotechnology.com, which is an invaluable resource for parts, information, and support for many vintage microcomputer systems.

Weve developed a few accessories, and our customers have come up with dozens of interesting

projects. Now that you have yours, what did YOU do with the 1802. Send me links to your projects, and Ill add them here! Or make your own expansion boards that plug right in. The Membership Card Protoboard is just the thing. Its precisely the same size, to fit inside an Altoids case. It stacks on top, or in between the 1802MC and Front Panel cards. This is no cheap phenolic crackerboard; its a high quality glassepoxy board with precision platedthrough holes. It also comes with a 30pin male header and matching 30pin female socket. A minute before the alarm time, it starts ticking like approaching footsteps. Louder and louder, closer and closer, until a big KABOOM.The only way to prevent the explosion is to shut it off before the footsteps stop. Any color or shape can be used. The kit normally comes with rectangular red LEDs; but ask if you would like something else. Only the 1802MC is used; the Front Panel card is not needed.Put it to work! The Elf Clock card will turn it into your very own custom clock. Source code is provided, so you can change the sound effects to a rooster crowing, or anything else you like. Since the Membership card is just a repackaged Elf, it can also work with any other 1802 Elf computer. Additional information Many thanks to Josh Bensadon and Chuck Yakym for their help!Members of the cosmacelf.com forum decided to have an 1802 booth at the Vintage Computer Festival Midwest in Chicago. It was a great opportunity to demonstrate the wide range of applications for the 1802; past, present, and future. We had so much fun that weve done it every year since 2014. Maybe well see you there THIS year It was so much fun that we plan to do it again. Details on this years VCFMW are here. If youre in the area, stop by and say hello! Thats Josh Bensadon, Lee Hart, Bill Rowe, and Dave Ruske from left to right.

A BIG thankyou to Dave, Bill, and especially Josh for working so hard to pull this all together. We had them specially made for the show. It contains a working 1802 Membership Card, which is sending the Arecibo message in Morse code via a blinking LED seen at the very top of the model. Befitting the project of an EE, its all soldered together. The program is in a 27C16 EPROM. Power consumption was 0.24ma for the computer, plus 20ma when the LED was on. The batteries lasted for the entire 2 days of the show and they were used to begin with. Low power consumption was one of the big reasons why the 1802 was used in spacecraft. The program can examine and change memory and registers; load and save programs in hex format, and run programs with or without breakpoints. It is pagerelocatable, so the EPROM can be addressed on any page boundary and will run without changes. It searches for RAM, and adapts to whatever it finds. Since serial data formats can be confusing, it uses the first character received to determine the baud rate. A version can thus be chosen to work with just about any CPU clock speed, memory map, serial baud polarity, or baud rate. Details are provided on his Web page to build it yourself, or order a kit directly from Herb. If you dont change the SIP, youll get blinded! So, he made the Olduino adapter board to plug in and control Arduino shields with a Membership Card! Hes controlled LCD displays, ethernet adapters, interfaced SD memory cards, and more. Quite an impressive feat. Take a look at Bills site hes put a lot of work into this, and achieved some impressive results. The photo at right shows the Membership Card on the left and Bills Olduino on the right. So he programmed a PICAXE microcontroller as a RS232 serialtoparallel converter. He also wrote a Windows program to provide a control panel. The project is documented with schematics and software at RS232 serial to parallel adapter. Thanks, Chuck!

Ive always wanted to play with the PICAXE micros, and this gives me an excuse. It accepts data from an RS232 port or USB port with USBtoserial adapter, and loads it into the Membership Card parallel port. It can accept hex files directly from DOS, coming from an assembler or simple text program. Herb Johnson has collected Marks work here. This gave him a computer with the full 64k of memory. The EPROM was programmed with Spare Time Gizmos Elf2K 1802 software, which contains not only a serial port driver, but also a monitor, editor, assembler, BASIC, FORTH, and a whole bunch of other stuff. The EPROM can be a onetimeprogrammable type because it is no longer socketed. Information on Marks approach is here. Note Youll have to be a member of the Cosmac Elf Yahoo group to view it. This gives you two memory sockets; one for RAM and one for ROM. This is an easy

way to add the Elf2K or other ROM. It also adds a second 8bit input and output port. Basically, the top board has a wirewrap socket for the 1802. The 1802 plugs into it. The long wirewrap pins extend down, and plug into a socket on the lower Membership Card. Cut off pins 1 and 38 of the wirewrap socket, so the Clock and DMAIN circuits on the bottom board wont fight with those on the top board. Transistor Q1 can be installed in either of two positions, to address its memory chip at 07FFF or 8000FFFF.The irrepressible Herb Johnson has pulled together the notes on this here. If there is enough interest, I can make up a kit with just the parts needed. This board can plug into the 25pin connector on the Front Panel card, or directly onto the Membership Cards 30pin header so no Front Panel Card is needed. The outputs from the EPROM go to the INPUT switches. The IN button is pressed for each byte, so it automatically loads the EPROMs contents into RAM, just as if you had set the switches and pressed IN to do it manually. It shows just how much you can do with an 1802 and an absolute minimum of resources.