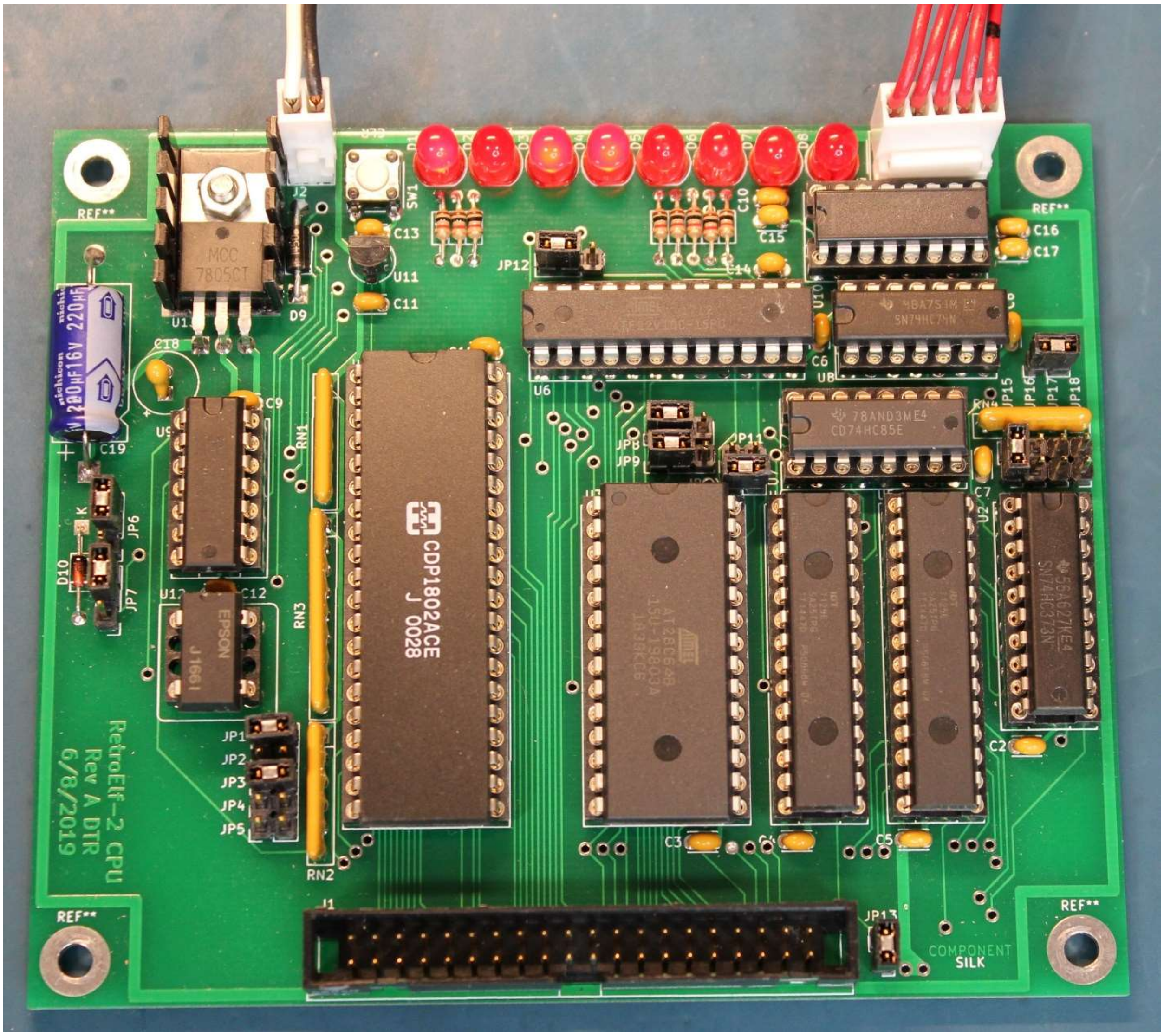
Retro Elf



Retro Elf 2 – CPU Board Revision A

1 – About the Retro Elf 2 CPU board

The CPU board contains the heart of Retro Elf System, the CDP1802 microprocessor and all its supporting electronics.

This CPU board is the third version in the Retro Elf series. Dubbed the Retro Elf 2 CPU board, in this version Shadow ROM is added which allows programs to access the full 64K of addressable RAM. The Shadow ROM concept is simple. When the system is first booted, the ROM monitor located in high memory is enabled with all memory reads to come from the firmware located in the ROM. The ROM firmware can performs any required operations like power-on self-tests. While all reads come from ROM in shadow ROM mode, any memory writes will be written to the RAM located at the same relative address location as the ROM. This allows any portion of ROM firmware to copy itself in to RAM at any location including same physical address location where the data is being read from within the ROM.

Once coping of any needed code from the ROM in to RAM is completed, a write to a specified output port will disable the shadow ROM mode which disables the reads from the ROM and uses only the RAM for all future reads and writes.

The nice feature in having a Shadow ROM capability, is once you turn off the ROM, you get to use the full 64K of available RAM for any memory intensive programs like BASIC.

This CPU board also supports a power up boot-strap circuit. When enabled, the 1802 is tricked in to start execution from one of several user selectable entry points after a system clear (aka reset). A jumper selectable boot-strap clear signal from either a high on the 1802's Q line or any I/O operation, disables the boot-strap.

Like all the original versions of the Retro Elf CPU boards, low power CMOS components helps keep the board's power needs to a minimum. The CPU board uses less than 150mA of current with a 12-volt DC power supply. A simple on board 5-volt DC voltage regulator is implemented to power the CPU board. This regulator can supply 5 volts at up to half an amp when an 8-12 volts DC input is supplied to the board. A protection diode is used to help protect against accidental reversal of input power.

The system clock is provided by an on-board oscillator module. One interesting feature of the 1802's CMOS architecture is the capability to operation at any frequency from DC up to the processor's rated frequency. You can even very the frequency at any time. The optional Slow Clock board takes advantage of this and can adjust the processor frequency during operation allowing you to see each fetch and execute cycle operation of running code via the front panel.

Simple software (bit-banging) serial can be provided using the 1802's Q output line and one of the four jumper selectable EF input lines. Both the serial input and output can be setup as normal or inverted again via on board jumpers. A MAX232A integrated circuit is use to create standard RS232 signal level on the serial lines. This allows for easy connection to most terminals or computer serial ports supporting RS232 signaling.

The 40-pin expansion header brings out most of the 1802's signal lines as well as a 5-volt DC power source. It is via this header that the front panel will be connected in addition to any other future expansion boards that my come.

2- Assembly

Before you begin, some helpful hints

Follow the instructions carefully and read the entire step before you perform the operation. Solder a part or group of parts only when you are instructed to do so.

Each circuit part in an electronic kit has its own component number (R2, C4, etc.). Use these numbers when you want to identify that same part in the various sections of the Manual. These numbers, which are especially useful if a part has to be replaced, appear:

- In the Parts List
- At the beginning of each step where a component is installed
- In the schematic

SAFETY WARNING: Safety glasses are recommended. Avoid eye injury when you cut off excess lead lengths. Hold the leads so they cannot fly toward your eyes.

Soldering

Soldering is one of the most important operations you will perform while assembling your kit. A good solder connection will form an electrical connection between two parts, such as a component lead and a circuit board foil. A bad solder connection could prevent an otherwise well-assembled kit from operating properly.

It is easy to make a good solder connection if you follow a few simple rules:

- Use the right type of soldering iron. If available, a temperature controlled soldering iron is recommended. Otherwise us a 25 to 40-watt pencil soldering iron. In either case use a 1/8" or 3/16" chisel or pyramid tip for best results.
- Keep the soldering iron tip clean. Wipe it often on a wet sponge or cloth; then apply solder to the tip to give the entire tip a wet look. This process is called tinning, and it will protect the tip and enable you to make good connections. When solder tends to "ball" or does not stick to the tip, the tip needs to be cleaned and retinned.
- Use only a high quality rosin-core, 62/36/2 silver-bearing solder with a 0.020 or 0.015 inch diameter.
- A good solder connection is made when you heat the component lead and the foil on the circuit board at the same time. This will allow the solder to flow evenly onto the lead and foil. The solder will then make a good electrical connection between the lead and the foil.

The method used during the board assembly phase is based around installing parts in the order from lowest to the highest profile. So part the mount closest to the board like resisters and diodes, are mounted first.

This method allows the board being assembled to be placed on a flat surface to help hold the parts in place during soldering of the components from the solder side of the board.

Board Assembly

Before we begin the assembly process, please take a moment to located the words *COMPONENT* and *SOLDER* located of different sides of the printed circuit board.

Unless noted in the assembly text in this manual, all parts are inserted through holes from the COMPONENT side of the printed circuit board and soldered from the SOLDER side.

Also refer to the silk screen on the printed circuit board or the Board Layout drawing for help with parts locations on the board.

Install the eight 1/8 watt resistors at the following locations.

( ) R1: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) R2: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) R3: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) R4: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) R5: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) R6: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) R7: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) R8: 1K ohm, 1/8-watt, 5% (brown-black-red)

( ) Solder the leads to the foil and cut off the excess lead lengths

NOTE: The next two diodes are polarized and need to be installed with the banded end matching the silk screen outline on the printed circuit board or the board layout. As another reference point, the lead on the banded end should be inserted into the square hole on the printer circuit board.

( ) D9: Black diode labeled 1N4001

( ) D10: Orange colored glass diode labeled 1N4148

( ) Solder the leads to the foil and cut off the excess lead lengths.

Install the seventeen capacitors at the following locations.

( ) C1: 0.1uF ceramic (sometimes labeled 104)

( ) C2: 0.1uF ceramic (sometimes labeled 104)

( ) C3: 0.1uF ceramic (sometimes labeled 104)

( ) C4: 0.1uF ceramic (sometimes labeled 104)

( ) C5: 0.1uF ceramic (sometimes labeled 104)

( ) C6: 0.1uF ceramic (sometimes labeled 104)

( ) C7: 0.1uF ceramic (sometimes labeled 104)

( ) C8: 0.1uF ceramic (sometimes labeled 104)

( ) Solder the leads to the foil and cut off the excess lead lengths.

( ) C9: 0.1uF ceramic (sometimes labeled 104)

( ) C10: 0.1uF ceramic (sometimes labeled 104)

( ) C11: 0.1uF ceramic (sometimes labeled 104)

( ) C12: 0.1uF ceramic (sometimes labeled 104)

NOTE the different capacitor value on the next part.

( ) C13: 0.001uF ceramic (sometimes labeled 102)

( ) C14: 0.1uF ceramic (sometimes labeled 104)

( ) C15: 0.1uF ceramic (sometimes labeled 104)

( ) C16: 0.1uF ceramic (sometimes labeled 104)

( ) C17: 0.1uF ceramic (sometimes labeled 104)

( ) Solder the leads to the foil and cut off the excess lead lengths.

NOTE: Capacitors C18 and C19 will be installed in a later step.

NOTE: 14-pin, 16-pin, 20-pin, 28-pin and 40-pin integrated circuit sockets are used in this kit. Make sure all pins are straight. Carefully insert the socket pins in to the circuit board holes. Make sure that the index notch on the socket is on the same end as pin one (a square pad indicates pin 1) of that integrated circuit 's location.

All sockets are placed on the component side and soldered on the solder side of the board.

Start by soldering only a single pin to the board. Verify that the socket is aligned and tight against the component side of the board. If not, carefully reheat the pin and reposition the socket as needed. Once the socket is correctly placed, solder the remaining pins.

( ) U1: Install a 40-pin IC socket.

( ) U2: Install a 20-pin IC socket.

( ) U3: Install a 28-pin wide IC socket.

( ) U4: Install a 28-pin narrow IC socket.

( ) U5: Install a 28-pin narrow IC socket.

( ) U6: Install a 24-pin IC socket.

( ) U7: Install a 16-pin IC socket.

( ) U8: Install a 14-pin IC socket.

( ) U9: Install a 14-pin IC socket.

( ) U10: Install a 16-pin IC socket.

NOTE: The next three parts are single-inline-package or SIP resistors. These parts must be oriented correctly for the Retro Elf CPU to work. On each SIP resistor there will be a small dot or line indicating pin one on the SIP. The SIP must be oriented so the indicated pin one is placed into the hole with the square pad outlined by a square box in the silkscreen around this pad. Like the sockets above, start by soldering only a single pin to the board. Verify that the SIP is aligned and tight against the component side of the board. If not, carefully reheat the pin and reposition the SIP as needed. Once the SIP is correctly placed, solder the remaining pins.

( ) RN1: Install a 6-Pin, 10K x 5-pin, SIP resistor.

( ) RN2: Install a 6-Pin, 10K x 5-pin, SIP resistor.

( ) RN3: Install a 6-Pin, 22K x 9-pin, SIP resistor.

CAUTION: The oscillator module you will be installing in the next step is a CMOS device that can be damaged by static electricity. Use the following sequence when you install this oscillator integrated circuits.

1. Pick up the conductive foam block with the oscillator mounted on it.
2. Hold the oscillator in one hand and pull the conductive foam pad from the pins and set the foam pad aside.
3. Pick up the circuit board while you hold the oscillator.
4. Carefully insert the oscillator in indicated holes. Make sure to install the oscillator in the correct orientation on the board. Carefully bend the leads just enough to hold the oscillator in place before you set the circuit board down in to your work surface for soldering.
5. Verify that the oscillator is in the correct orientation and solder the four oscillator leads to the board and trim as needed.

The oscillator is now protected by circuit board's sockets foil.

( ) U12: Install the crystal oscillator module.

NOTE: The next two capacitors are polarized and have positive and negative leads. Make sure that the positive lead is inserted into the hold marked + (the square hole) on the board.

( ) C18: 1uF polarized tantalum capacitor.

( ) C19: 220uF polarized aluminum electrolytic capacitor.

NOTE: Installing the LEDs, position the flat side as shown to match the outline on the board. Note that the short LED lead is in the square hole on the board. Hold the LEDs tight to the board and solder the leads to the foil and cut off the excess lead lengths.

( ) D1: Red LED at location labeled PWR.

( ) D2: Red LED at location labeled BOOT.

( ) D3: Red LED at location labeled SHA.

( ) D3: Red LED at location labeled TXD.

( ) D4: Red Green at location labeled RUN.

( ) D5: Red Yellow at location labeled WAIT.

( ) D6: Red LED at location labeled CLR.

( ) D7: Red LED at location labeled RXD.

( ) D8: Red LED at location labeled TXD.

Note: When installing the next 40-pin header, make sure to install the 40-pin header so that pin 1 is in the hole with the square pad on the board. Solder only one pin then verify that the header is align and tight to the board and pin 1 is in the correct hole. Then solder the remaining pins.

( ) J1: Install a 40-pin header

( ) J2: 2-pin header. Match the silk screen or board layout and solder.

( ) J3: 5-pin header. Match the silk screen or board layout and solder.

( ) JP1: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP2: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP3: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP4: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP5: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP6: 3-pin jumper header. Match the silk screen or board layout and solder.

( ) JP7: 7-pin jumper header. Match the silk screen or board layout and solder.

( ) JP8: 3-pin jumper header. Match the silk screen or board layout and solder.

( ) JP9: 3-pin jumper header. Match the silk screen or board layout and solder.

( ) JP10: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP11: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP12: 3-pin jumper header. Match the silk screen or board layout and solder.

( ) JP13: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP14: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP15: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP16: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP17: 2-pin jumper header. Match the silk screen or board layout and solder.

( ) JP18: 2-pin jumper header. Match the silk screen or board layout and solder.

NOTE: The next part installed is a DS1233. This integrated circuit is packaged in a transistor TO-92 style case and look like a transistor.

CAUTION: If the DS1233 is installed backwards, it will be destroyed on powerup. When installing the DS1233, make sure to align the 3-pin package so the flat side of the part matches the outline on the board's silk screen or the board layout in the appendix.

( ) U11: Align the DS1233 IC to the silk screen on the board or board layout. Insert each of the 3-pin in to their respective holes and carefully push the part to about 0.1 inches above the board. Bend the leads slightly on the back to hold the part in place.

( ) SW1: Install the CLR (CLEAR) button.

( ) U13: Locate the following four parts used to assemble the 7805 voltage regulator to the board:

- Phillips machine screw, M3 x 8mm
- Hex Nut, M3
- TO-220 heatsink
- IC, 7805 5 volt regulator in a TO-220 case

( ) The three leads on the 7805 need to be pre-bent before installation. Notice that the leads on the 7805 are wider where they exit the black body of the 7805 and then narrow down. Where the transition from wide to narrow occurs, bend the three leads down towards the metal heat sink side of the 7805 to an angle of 90 degrees. Temporarily set the 7805 aside until required.

( ) From solder side of the board, insert the M3 x 8mm machine screw through the mounting hole at U13. On the component side of the board, Place the TO-220 heatsinks mounting hole over the protruding M3 machine screw. Make sure to align the heatsink so that it fits best on the large foil area for U13.

( ) Install the 7805 at U13 so that the three pre-formed leads pass through the correct holes and the mounting hole on the metal heatsink tab passes through the protruding M3 machine screw. Do not solder.

( ) Secure the heatsink and 7805 regulator to the board using the M3 machine screw with the M3 hex nut. Torque the nut on to the screw just enough to secure the parts. Do not over tighten.

( ) Verify the correct placement and alignment of the 7805 assembly and, solder the leads to the foil and cut off the excess lead lengths.

Testing

Before we install the ICs, we will perform a few basic powerup tests.

( ) Carefully check for any solder bridges between pins and foil pads. If a solder bridge has occurred, hold the circuit board solder side down and hold the soldering iron tip between the two points that are bridged. The solder will flow down the soldering iron tip.

( ) Verify that all parts are in their correct locations.

( ) Set an ohm meter to read the lowest resistance setting and measure across the two pins on J2. If the resistance reading in close to zero then some form of electrical short exists. Carefully inspect the board assembly for solder bridges or parts installed backwards or at incorrect locations. Correct and issues found and re perform this test.

( ) Reverse the meter leads on J2 and reread the resistance. Like before, if the reading is close to zero then some form of electrical short exists. Carefully inspect the board assembly for solder bridges or parts installed backwards or at incorrect locations. Correct and issues found and re perform this test.

( ) In this step we will be using a bench or other 8 to 16-volt DC power supply able to supply ½ amp of current. Make sure the power supply is off. Connect the positive lead from the power supply to pin 1 on J2 (the pin with the square pad) and the negative lead to pin 2.

( ) Set a voltmeter to a DC range allowing a reading for a positive 5-volts. Connect the positive lead of the voltmeter to pin 40 on U1 and the negative lead to pin 20.

( ) Turn on the power supply and note the reading on the voltmeter. You should be reading a positive DC voltage between 4.9 and 5.1 volts. The PWR (power) LED should be on. Turn off the power supply.

( ) Continue to test for the 4.9 to 5 volts reading for the remainder of the IC using the following power pinout table:

Integrated Circuit	+5 Volt pin	Ground pin
U2	20	10
U3	28	14
U4	28	14
U5	28	14
U6	24	12
U7	16	8
U8	14	7
U9	14	7
U10	16	15

( ) This completes the testing. Turn off the power supply. Disconnect the meter and power supply leads to J2.

Final assembly

NOTE: In the following steps, install ICs (integrated circuits) in the designated sockets. Be careful to match the pin 1 end of each integrated circuits to the index mark on the socket. Before you apply downward pressure to an integrated circuit, make sure each integrated circuits pin is centered in its proper socket hole. Handle integrated circuits with care, as their pins bend very easily.

CAUTION: The integrated circuits that you will install are CMOS or MOS devices that can be damaged by static electricity. Use the following sequence when you install the integrated circuits.

1. Pick up the conductive foam block with the desired integrated circuits mounted on it.
2. Hold the IC in one hand and pull the conductive foam pad from the pins.
3. Pick up the circuit board while you hold the integrated circuits.

4. Carefully insert the IC in its socket before you set the circuit board down in to your work surface.

The IC is now protected by circuit board's sockets and foil.

NOTE: DIP = Dual Inline Package.

( ) U1: CDP1802 - , 40-pin DIP

( ) U2: 74HC373 - , 20-pin DIP

( ) U3: AT28xxx - , 28-pin DIP

( ) U4: AS7C256B - , 28-pin narrow DIP

( ) U5: AS7C256B - , 28-pin narrow DIP

( ) U6: Pre-Programmed GAL 22V10 labeled "Retro ELF 2 CPU Ver:A" - , 24-pin narrow DIP

( ) U7: 74HC85 - , 14-pin DIP

( ) U8: 74HC74 - , 14-pin DIP

( ) U9: 74HC04 - , 14-pin DIP

( ) U10: MAX232 - , 16-pin DIP

This completes the assembly of the Retro Elf CPU Board. Now is the time to take a last look over the finished assembly once more looking for any issues like bent pins under ICs, unsoldered connections, cold solder joints and parts in wrong locations.

3 – Theory of operation

The core of the CPU board, is the CDP1802 microprocessor (U1) originally developed by RCA in 1975. All other electronics on the CPU board are designed to support the operation of U1.

Over time variants of the 1802 where created that where mostly pin compatible to the original. Jumper JP1 is provided to allow support for these other versions of the family. If a classic CPD1802 is used, JP1 must be installed.

System clock

The 1802's clock is supplied by the clock circuit made up of an 3.2MHz oscillator module (U12) and one of the 74HC04, inverters (U9). The 74HC04 is setup to provide a higher drive current for the Elf's system clock.

Process reset (CLEAR) and signal shaping

The 1802's -CLEAR is held high using one of the 10K resisters in resistor network RN1. Resetting the 1802 is then accomplished by pulling the –CLEAR line low. Power-on-clear and on-board reset button debouncing is supplied by a DS1233 (U11). The DS1233 has an open collector output. It monitors the power supply voltage and will pull and hold the 1802's –CLEAR line low until a safe operational voltage is restored. The DS1233 will also act as a debounce circuit for CLEAR button (SW1). The 0.001uF (C13) capacitor helps the DS1233 setup proper debounce timing when SW1 is pressed to clear the 1802.

The 1802's eight data bus lines are pulled high by the 22K resistor network RN3. This helps place the data bus in a known state during high impedance operations when no device is using the data bus. Likewise, 10K resistor networks RN1 and RN2 are uses to pull high all four EF inputs along with the -CLEAR, -WAIT, -INTERRUPT, -DMA IN and -DMA OUT signals.

There is a special jumper labeled JP13 use to connect the 1802's MWR line to the SRAM. This jumper must be inserted any time the CPU board is not used with the optional front panel. If the front panel is used, JP13 must be removed since the front panel augments the MWR function.

High address latching

Since the 1802 uses a multiplexed address bus, some form of high address range latch is needed to latch the high address lines A8-A15. This operation is handled by a 74HC373 (U2). The 1802 uses the TPA control line to signal latching. The falling edge of TPA latches the high eight bits of the address in to the 74HC373.

On-board 5 Volt power supply

Five-volt power regulation is provided by is simple analog voltage regulator circuit made up of D9, C19, U13 and C18. Power is presented via connector J2. The positive side is passed through the 1N4001 diode (D9). The 1N4001 helps prevent accidental reversals on the power supply input voltage. In normal operation the 1N4001 is forward biased allowing current to flow through. If the voltage becomes reversed, the diode will be reverse biased blocking current flowing in to the regulator circuits. The 220uF electrolytic capacitor in location C19 provided some DC input voltage ripple stabilization. The 7805 regulator (U13) is used to regulate any input voltage between 8 and 12 volts DC down to a regulated 5 volts DC at up to one half an amp. The 7805 should be mounted to an appropriate heat sink when input voltage are at 12 volts DC and the optional front panel is installed. The 1uF capacitor (U18) is used to stabilize the final regulated output voltage of the 7805. Twelve 0.1uF capacitors (C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11 and C12) are used to help decuple IC generated power line noise on the 5-volt supply.

A power monitor LED is provided and is made up of LED D1 and the 1K ohm current limiting resistor R1.

Bit-banging serial

The Retro Elf CPU board supports a simple software (bit-banging) serial port at J3. Driver hardware is provided to support the 1802's Q output line and one of the four jumper selectable EF input lines for this function. Two inverter stages in the 74HC04 (U9) are used for both the serial input and output to setup for normal or inverted singling. Jumpers JP7 is used for serial out and JP6 is used for serial in. RS232 voltage level conversion is supplied by a MAX232A (U10) and four 0.1uF capacitors (C14, C15, C16 and C17). The four capacitors allow the MAX232A to create a voltage pump and also a voltage inverter used to create the standard RS232 signal level on the serial lines present at J3. This allows for easy connection to most terminals or computer serial ports supporting RS232 signaling. The four jumper JP2 (EF1), JP3 (EF2), JP4 (EF3) and JP5 (EF4) are used to select which of the four 1802 EF lines will be used to monitor serial inputs. The 1N4148 switching diode (D10) is place in line between the selected 1802 EF line and the serial input driver. This allows for a simple diode OR gate on the selected EF line allowing that line to be shared if needed.

Two LEDs are provided to monitor both the serial receive and send serial signals. LED D7 and 1K current limiting resistor R7 monitor the RXD (receive) signal while LED D8 and 1K current limiting resistor R8 are for TXD (send).

ROM address range decoding

ROM address decoding is performed with the use of a 74HC85 4-bit magnitude comparator (U7). The four most significant address bit A12 through A15 are compared to the four jumpers JP15 through JP18. When a jumped is installed, the corresponding address select bit is low (0) while a missing jumper will be pulled high (1) through one of the four 4.7K resisters within RN4.

ROM addressing is placed in high memory and will start form the location configured by the jumper JP15 through JP18 and continue to the last memory address FFFF.

While sixteen possible ROM address starting points are possible with this arrangement, in practice only four starting ranges are practical when standard ROMs, EPROMs or EEPROMs are used. The following table shows all the possible address starting ranges with the bolded entries being the most common ones used:

JP18 (A15)	JP17 (A14)	JP16 (A13)	JP15 (A12)	ROM Address range/size
OUT	**OUT**	**OUT**	**OUT**	**F000-FFFF / 4K (27C32)**
OUT	**OUT**	**OUT**	**IN**	**E000-FFFF / 8K (27C64, 28C64)**
OUT	OUT	IN	OUT	D000-FFFF / 12K
OUT	**OUT**	**IN**	**IN**	**C000-FFFF / 16K (27C128)**
OUT	IN	OUT	OUT	B000-FFFF / 20K
OUT	IN	OUT	IN	A000-FFFF / 24K
OUT	IN	IN	OUT	9000-FFFF / 28K
OUT	**IN**	**IN**	**IN**	**8000-FFFF / 32K (27C256, 28C256)**
IN	OUT	OUT	OUT	7000-FFFF / 36K
IN	OUT	OUT	IN	6000-FFFF / 40K

IN	OUT	IN	OUT	5000-FFFF / 45K
IN	OUT	IN	IN	4000-FFFF / 49K
IN	IN	OUT	OUT	3000-FFFF / 53K
IN	IN	OUT	IN	2000-FFFF / 57K
IN	IN	IN	OUT	1000-FFFF / 61K
IN	IN	IN	IN	0000-FFFF / 64K

So why is the 0000-FFFF 64K starting point for ROM not listed as a “practical” range? While it is posable to start ROM addressing form 0000, there is no method of setting up the on board ROM socket to support such a addressing range given that A15 is not presented to the ROM. Any ROM staring from 0000 would have its addressing duplicated twice from address 0000-7FFF and again from 8000-FFFF.

Also the first 32K of RAM would conflict on memory reads with the ROM and given that the upper 32K of RAM would be inhibited for any reads while in shadow mode there would be in essence no readable RAM.

Okay with all that said and while I have not tested this, in theory if you remove the first 32K of RAM (U5), disable shadow ROM and by removing JP14 then disable the boot-strap first thing in ROM code; you could boot from ROM in low memory with 32K of RAM available in high memory.

The GAL (Gate Array Logic) IC on the board

An ATF22V10 GAL (U6) is used to reduce logic chip count and provide flexibility for possible future design changes. In this design, U6 support four functions.

The first operation supported by U6 is decode memory ranges and chip selects for ROM (U3), upper SRAM (U4) and lower SRAM (U5).

The second function is supporting the shadow ROM.

Memory reads from memory location 8000 to FFFF are handled differently depending status of the shadow ROM future and the starting location of the ROM setup by the 74HC85 4-bit magnitude comparator (U7) covered above. When the SHADOW LED at D3 lit, the shadow ROM is enabled and all memory reads will be from the ROM in socket U3 while all memory writes will be to the sister SRAM at U4. When the SHADOW LED D3 is off, the shadow ROM is disabled removing the ROM at U3 completely from memory and using only SRAM U4 for all memory reads and writes.

Shadow ROM control is handles by the programmable logic (GAL) device at U6 and one half of a 74HC74 at U8. The 74HC74 is used as a single bit R/S flip-flop controlled by the logic setup within the GAL at U6.

Removing the jumper at JP14 allows one of the 10K resister element in RN2 to pull high the shadow enabled input on U6, permanently disabling the shadow ROM feature forcing all memory reads to come only from the ROM at U3.

The status of the shadow LED at D3 is controlled by the 1K-ohm current limit at R3 and one section of a 74HC04 hex inverter (U9). The input of the inverter is connected to the shadow enable input on GAL U6.

The third function is supporting the on half of the 74HC74 (U8) in creating the bootstrap loader. After the CLEAR signal is cycled, the bootstrap disables U4 and places U3 in to the lower memory address between 0000 and 7FFF. Depending of the setting of JP12, the bootstrap state is cleared by setting the 1802's Q output line or performing any type of input/output operation. BOOT LED D2 and current 1K current limiting resistor R2 provide a bootstrap status indicator. The LED will be on while the bootstrap is enabled.

The final job of U6 is creating three process status outputs allowing the user to monitor what mode the 1802 is currently in. Each monitored channel is made up of an LED and a 1K current limiting resistor. RUN consists of D4 and R4, WAIT consists of D5 and R5 and finally CLEAR (aka Reset) consists of D6 and R6.

4 – Technical details

J1 – Retro Elf Bus

Pin	Type	Label	Description
1	Power	+5VDC	Regulated positive five volt power supply.
2	Power	+5VDC	Regulated positive five volt power supply.
3	BiDir	D0	Main system data bus bit 0.
4	BiDir	D1	Main system data bus bit 1.
5	BiDir	D2	Main system data bus bit 2.
6	BiDir	D3	Main system data bus bit 3.
7	BiDir	D4	Main system data bus bit 4.
8	BiDir	D5	Main system data bus bit 5.
9	BiDir	D6	Main system data bus bit 6.
10	BiDir	D7	Main system data bus bit 7.
11	Output	MA0	Memory Address line 0 for bits 0 or 8.
12	Output	MA1	Memory Address line 1 for bits 0 or 9.
13	Output	MA2	Memory Address line 2 for bits 0 or 10.
14	Output	MA3	Memory Address line 3 for bits 0 or 11.
15	Output	MA4	Memory Address line 4 for bits 0 or 12.
16	Output	MA5	Memory Address line 5 for bits 0 or 13.
17	Output	MA6	Memory Address line 6 for bits 0 or 14.
18	Output	MA7	Memory Address line 7 for bits 0 or 15.
19	Output	CLEAR	Main system CLEAR (aka RESET) signal.
20	Output	WAIT	Main system processor WAIT (HALT) signal.
21	Input	DMA IN	Direct Memory Access Input.
22	Output	DMA OUT	Direct Memory Access Output.
23	Output	N0	Input / output select line 0.
24	Output	N1	Input / output select line 1.
25	Output	N2	Input / output select line 2.
26	Output	TPA	Timing Pulse A.
27	Output	TPB	Timing Pulse B.
28	Output	CLOCK	Main system Clock.
29	Output	-MRD	Memory Read signal.
30	Output	-WE	Memory Write Enable.
31	Output	-MWR	Memory Write signal.
32	Output	SC0	
33	Output	SC1	
34	Input	INT	Main system Interrupt.
35	Output	Q	Processor Q line output.
36	Input	EF1	Processor External Flag One input.
37	Input	EF2	Processor External Flag Two input.
38	Input	EF3	Processor External Flag Three input.
39	Ground	GND	System Ground.
40	Ground	GND	System Ground.

J2 – CPU board power

Pin	Type	Label	Description
1	Power	+V	Main expansion board power supply +8 to 16VDC at 1A maximum.
2	Ground	Ground	Power ground.

J3 - RS232 Serial port pinout

The connector J3 is used as a simple RS-232-C interface for the CPU board. This connector conforms to the EIA (Electronic Industries Association) RS-232-C (August 1969) standards and should work with many terminal or computer serial interfaces that support this standard.

The RS-232-C standard defines the voltage levels that correspond to logical one and logical zero levels for the data transmission and the control signal lines. Valid signals are either in the range of +3 to +15 volts or the range −3 to −15 volts with respect to the Common Ground (GND) pin. The range between −3 to +3 volts is not a valid RS-232-C level.

The MAX232A serial interface integrated circuits (U10) used within the interface, fully supports RS-232-C serial input signals covering the complete range defined in the standard. The MAX232A drives the serial outputs levels of about +9 for a space (0) and –9 for a mark (1). These output signal levels again fall nicely within the RS-232-C standard.

Pin	Type	Label	Label
1	Input	RCV	RS232 serial data receive.
2	Input	DSR/CTS	Not Used by the CPU board.
3	Output	XMT	RS232 serial data transmit.
4	Output	DTR/RTS	Not Used by the CPU board and is held to a space (logic low) state.
5	Ground	Ground	Common ground.

JP8 through JP11 – ROM type configuration

The Retro ELF CPU board is setup to support several different sizes and types of Read Only Memories. Only one ROM is support at location U3. Remember for any type of ROM used, please make sure that it is compatible with standard 5-volt CMOS logic levels. Use the following table to configure the CPU board to support your selected device:

ROM type	JP8	JP9	JP10	JP11
28C256 – 32K EEPROM	2 - 3	2 - 3	IN	OUT
27C256 – 32K EPROM	1 – 2	2 – 3	OUT	IN
28C128 – 16K EEPROM	2 – 3	1 – 2	IN	OUT
27C128 – 16K EPROM	2 – 3	1 – 2	IN	OUT
28C64 – 8K EEPROM	1 – 2	1 – 2	IN	OUT
27C64 – 8K EPROM	1 – 2	1 – 2	IN	OUT
27C32 – 4K EPROM	1 – 2	OUT	OUT	OUT

JP15 through JP8 - ROM address range decoding

The four most significant address bit A12 through A15 are compared to the four jumpers JP15 through JP18. When a jumped is installed, the corresponding address select bit is low (0) while a missing jumper will be pulled high (1).

ROM addressing is placed in high memory and will start form the location configured by the jumper JP15 through JP18 and continue to the last memory address FFFF.

While sixteen possible ROM address starting points are possible with this arrangement, in practice only four starting ranges are practical when standard ROMs, EPROMs or EEPROMs are used. The following table shows all the possible address starting ranges with the bolded entries being the most common ones used:

JP18 (A15)	JP17 (A14)	JP16 (A13)	JP15 (A12)	ROM Address range/size
OUT	**OUT**	**OUT**	**OUT**	**F000-FFFF / 4K (27C32)**
OUT	**OUT**	**OUT**	**IN**	**E000-FFFF / 8K (27C64, 28C64)**
OUT	OUT	IN	OUT	D000-FFFF / 12K
OUT	**OUT**	**IN**	**IN**	**C000-FFFF / 16K (27C128)**
OUT	IN	OUT	OUT	B000-FFFF / 20K
OUT	IN	OUT	IN	A000-FFFF / 24K
OUT	IN	IN	OUT	9000-FFFF / 28K
OUT	**IN**	**IN**	**IN**	**8000-FFFF / 32K (27C256, 28C256)**
IN	OUT	OUT	OUT	7000-FFFF / 36K
IN	OUT	OUT	IN	6000-FFFF / 40K
IN	OUT	IN	OUT	5000-FFFF / 45K
IN	OUT	IN	IN	4000-FFFF / 49K
IN	IN	OUT	OUT	3000-FFFF / 53K
IN	IN	OUT	IN	2000-FFFF / 57K
IN	IN	IN	OUT	1000-FFFF / 61K
IN	IN	IN	IN	0000-FFFF / 64K

Retro Elf

Appendix A - CPU board Parts List

Ref	Value	Manufacturer	MFG Part #	Vendor	DK Part #
C1	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C2	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C3	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C4	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C5	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C6	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C7	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C8	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C9	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C10	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C11	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C12	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C13	0.001uF	KEMET	C320C102M5R5TA	Digi-Key	399-9770-ND
C14	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C15	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C16	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C17	0.1uF	KEMET	C315C104M5U5TA	Digi-Key	399-4151-ND
C18	1uF	AVX Corporation	TAP105K035SCS	Digi-Key	478-1835-ND
C19	220uF	Nichicon	TVX1C221MAD	Digi-Key	TVX1C221MAD-ND
D1	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D2	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D3	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D4	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D5	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D6	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D7	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D8	1 ¾ Red LED	Kingbright	WP7113LID	Digi-Key	754-1266-ND
D9	Diode 1N4001	Comchip Tech	1N4001-G	Digi-Key	641-1310-1-ND
D10	Diode 1N4148	ON Semiconductor	1N4148	Digi-Key	1N4148FS-ND
J1	Conn 02x20 Odd/Even	Omron Electronics	XG4C-4031	Digi-Key	OR950-ND
J2	Conn header 2-pin	TE Connectivity	640456-2	Digi-Key	A1921-ND
J3	Conn header 5-pin	TE Connectivity	640456-5	Digi-Key	A19471-ND
JP1	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP2	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP3	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP4	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP5	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP6	Jumper 3-pin Open	3M	961103-6404-AR	Digi-Key	3M9457-03-ND
JP6	2-Pin jumper black	Harwin Inc.	M7582-05	Digi-Key	952-2881-ND
JP7	Jumper 3-pin Open	3M	961103-6404-AR	Digi-Key	3M9457-03-ND
JP7	2-Pin jumper black	Harwin Inc.	M7582-05	Digi-Key	952-2881-ND

JP8	Jumper 3-pin Open	3M	961103-6404-AR	Digi-Key	3M9457-03-ND
JP8	2-Pin jumper black	Harwin Inc.	M7582-05	Digi-Key	952-2881-ND
JP9	J Jumper 3-pin Open	3M	961103-6404-AR	Digi-Key	3M9457-03-ND
JP9	2-Pin jumper black	Harwin Inc.	M7582-05	Digi-Key	952-2881-ND
JP10	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP11	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP12	Jumper 3-pin Open	3M	961103-6404-AR	Digi-Key	3M9457-03-ND
JP12	2-Pin jumper black	Harwin Inc.	M7582-05	Digi-Key	952-2881-ND
JP13	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP14	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP15	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP16	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP17	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
JP18	Jumper 2-pin Open	3M	61102-6404-AR	Digi-Key	3M9457-02-ND
R1	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
R2	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
R3	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
R4	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
R5	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
R6	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
R7	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
R8	Resistor 1K,1/8watt,5%	Stackpole	CF18JT1K00	Digi-Key	CF18JT1K00CT-ND
RN1	Resistor network 10K x5	Bourns Inc.	4606X-101-103LF	Digi-Key	4606X-1-103LF-ND
RN2	Resistor network 10K x5	Bourns Inc.	4606X-101-103LF	Digi-Key	4606X-1-103LF-ND
RN3	Resistor network 22K x8	Bourns Inc.	4609X-101-223LF	Digi-Key	4609X-101-223LF-ND
RN4	Resistor network 4.7K x4	Bourns Inc.	4605X-101-472LF	Digi-Key	4605X-101-472LF-ND
SW1	Switch button	Omron Electronics	B3F-1000	Digi-Key	SW400-ND
U1	40-Pin Socket	Assmann WSW	AR 40 HZL-TT	Digi-Key	AE10018-ND
U1	CDP1802 microprocessor	Harris/Intersel	CDP1802-ACE	Ebay	CDP1802-ACE
U2	20-Pin Socket	Assmann WSW	AR 20 HZL-TT	Digi-Key	AE10015-ND
U2	74HC373	Texas Instruments	SN74HC272N	Digi-Key	296-1591-5-ND
U3	28-Pin Socket	Assmann WSW	AR 28 HZL-TT	Digi-Key	AE10017-ND
U3	AT28C64*	Microchip	AT28C64B-15PU	Digi-Key	AT28C64B-15PU-ND
U4	28-Pin Socket, 0.3inch	Assmann WSW	AR 28 HZL/01/7-TT	Digi-Key	AE10029-ND
U4	71256SA25TPG	IDT	71256SA25TPG	Digi-Key	800-1433-5-ND
U5	28-Pin Socket, 0.3inch	Assmann WSW	AR 28 HZL/01/7-TT	Digi-Key	AE10029-ND
U5	71256SA25TPG	IDT	71256SA25TPG	Digi-Key	800-1433-5-ND
U6	24-Pin Socket,0.3inch	Assmann WSW	AR 24 HZL/01/7-TT	Digi-Key	AE10027-ND
U6	22V10	Microchip	ATF22V10C-15PU	Digi-Key	ATF22V10C-15PU-ND
U7	16-Pin Socket	Assmann WSW	AR 16 HZL-TT	Digi-Key	AE10013-ND
U7	74HC85	Texas Instruments	CD74HC85E	Digi-Key	296-12821-5-ND
U8	14-Pin Socket	Assmann WSW	AR 14 HZL-TT	Digi-Key	AE10012-ND
U8	74HC74	Texas Instruments	SN74HC74N	Digi-Key	296-1602-5-ND

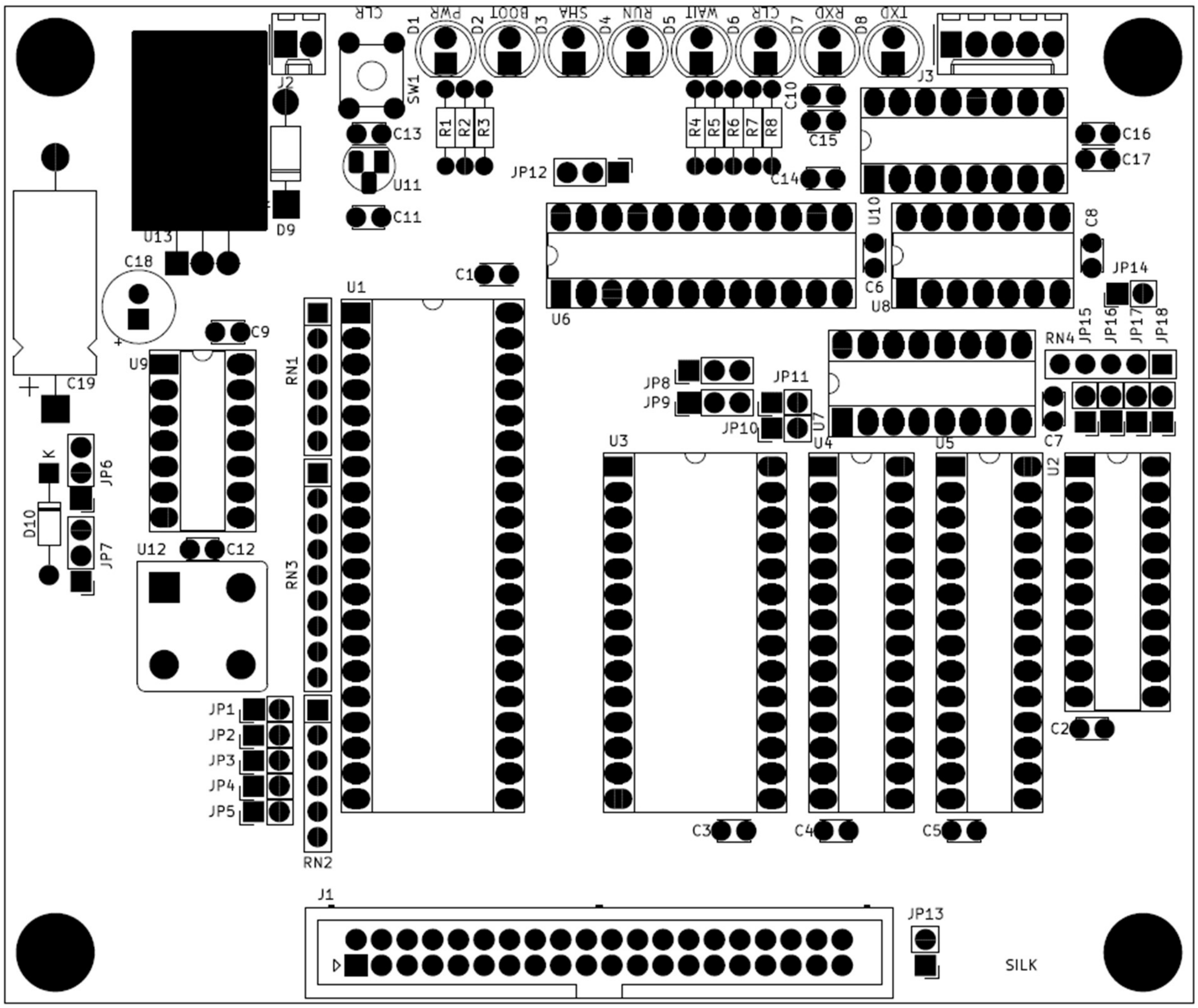
U9	14-Pin Socket	Assmann WSW	AR 14 HZL-TT	Digi-Key	AE10012-ND
U9	74HC04	Texas Instruments	SN74HC04N	Digi-Key	296-1566-5-ND
U10	16-Pin Socket	Assmann WSW	AR 16 HZL-TT	Digi-Key	AE10013-ND
U10	MAX232	Maxim Integrated	MAX232ACPE+	Digi-Key	MAX232ACPE+-ND
U11	DS1233A-10+	Maxim Integrated	DS1233A-10+	Digi-Key	DS1233A-10+-ND
U12	3.2MHz**	EPSON	SGR-8002DC-PHM	Digi-Key	SGR-8002DC-PHM-ND
U13	M3 Nut	B&F Fastener	MHNZ 003	Digi-Key	H762-ND
U13	M3 Screw	PM Hexseal	RM3X8MM 2701	Digi-Key	335-1149-ND
U13	Heat Sink	Aavid	577202B00000G	Digi-Key	HS107-ND
U13	MC7805CT	Micro Commercial	MC7805CT-BP	Digi-Key	MC7805CT-BPMS-ND
PCB	PC Board	DTR Engineering	RetroElf2-CPU	DTR	RetroElf2-CPU

*The component selected here fits the current RCBOS and DTR ROM monitor. The type and size of ROM device you chose may vary depending on your specific need.

**This component needs to be programed to the correct frequency of 3.2MHz. If you order this part from Digi-Key, they will program the part to your requested frequency as part of your order. You can also substitute with any type of CMOS compatible crystal oscillator with a frequency less than 3.2MHz.

Appendix B – Retro Elf 2 CPU board details

Assembly drawing



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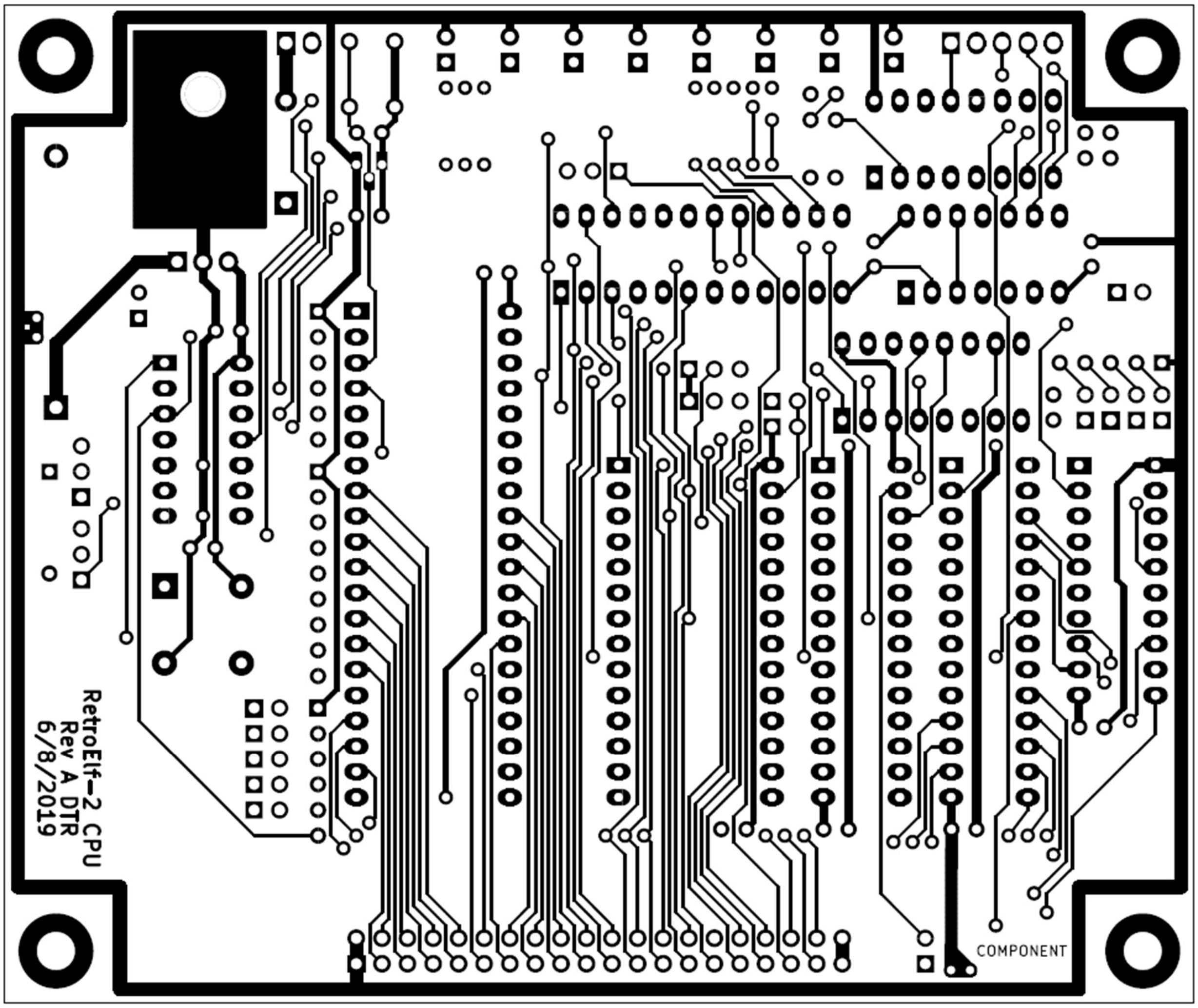
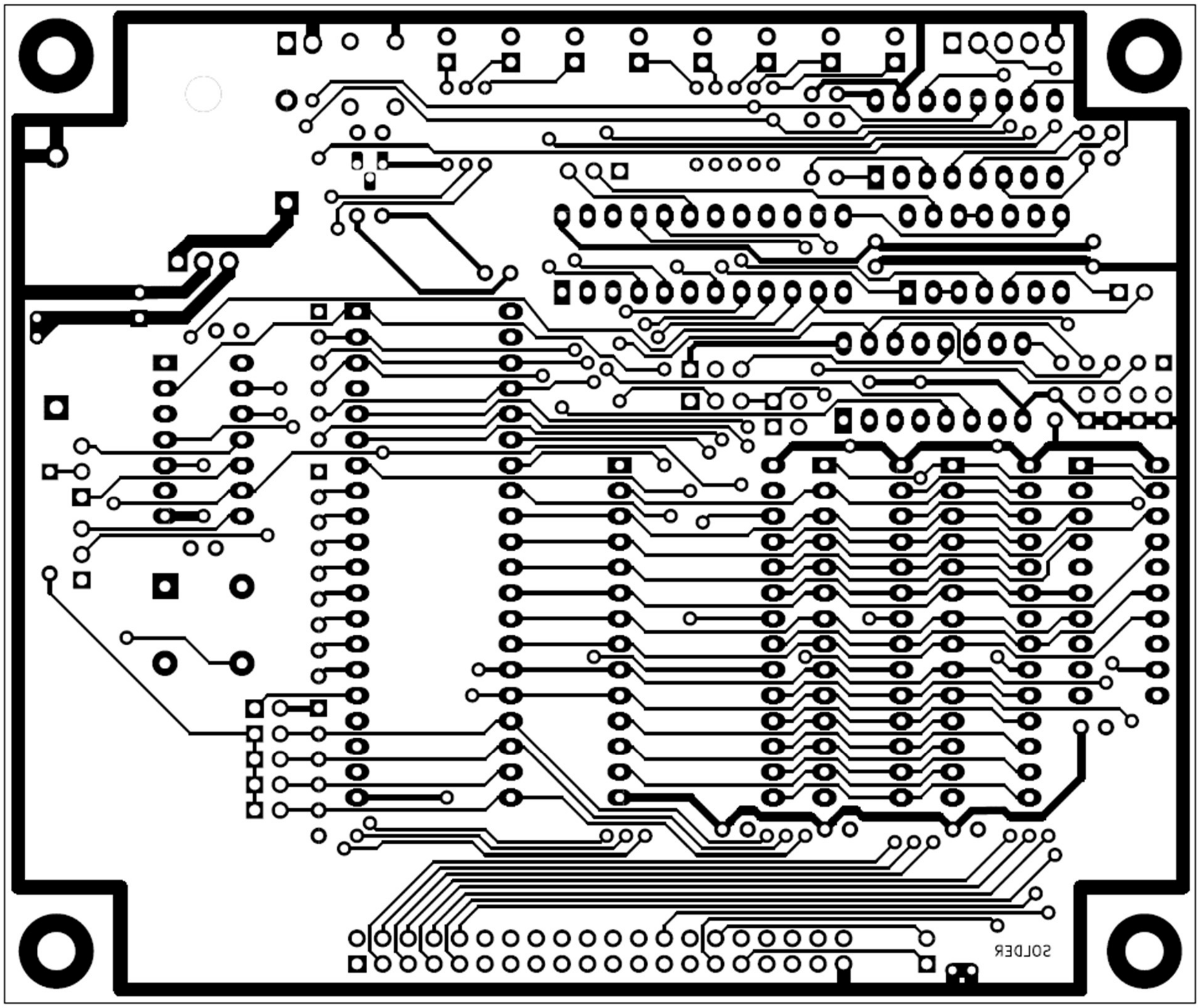
Component side

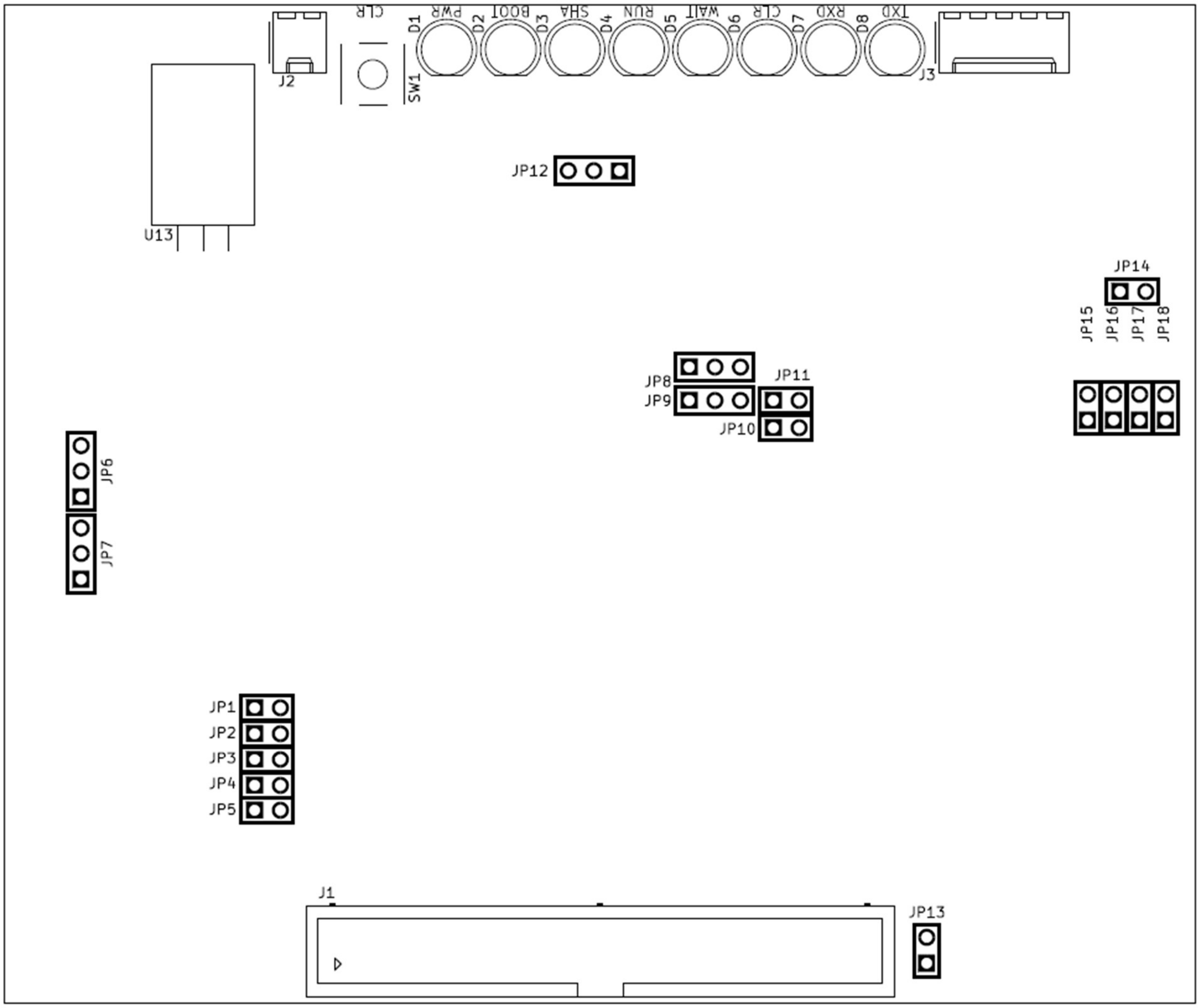


Solder side



Appendix C – Jumpers

Jumper locations



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Standard Retro Elf 2 with Elf OS support default jumper settings