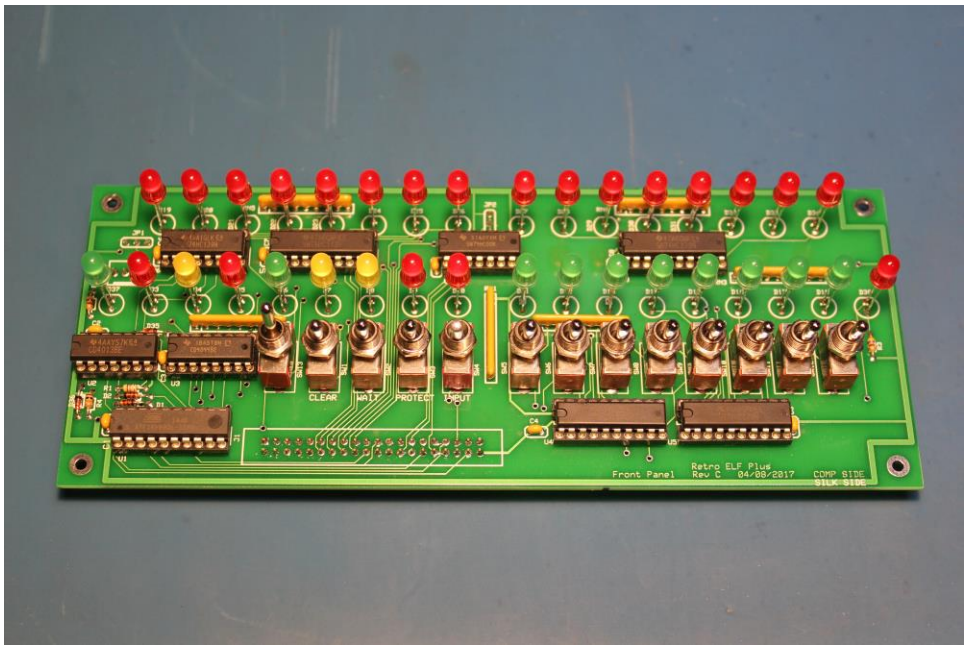


Retro Elf Plus – Front Panel - Revision C

1 – About the front panel board

The front panel gives the user a window in to the operations going on within the 1802. Key information is provided via LEDs that monitor the memory address, processor state (fetch, execute, DMA or Interrupt) and process mode (load, wait, reset and run). An additional eight LEDs are used as an output port. In addition, the eight output LEDs can be configured to display the current 1802 instruction being executed when used with the slow clock option.

Thirteen toggle switches are used for system control and data input. Four toggles handle Clear, Wait, Memory Protect and Input. One toggle is used to support the Slow Clock option. The remaining eight toggle switches are used for user data port input OR data to be written to the current memory location while in processor load mode. The Input toggle switch is a spring return type returning it to the down position for each operational cycle for the switch.

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.

Board Assembly

Refer to the silk screen on the printed circuit board or the Board Layout in Appendix C for parts locations on the board.

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

( ) R1: 47K ohm, 1/8-watt, 5% (yellow-violet-orange)

( ) R2: 470 ohm, 1/8-watt, 5% (yellow-violet-brown)

( ) R3: 470 ohm, 1/8-watt, 5% (yellow-violet-brown)

( ) R4: 10K ohm, 1/8-watt, 5% (brown-black-orange)

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

NOTE: *The next four diodes are polarized and need to be installed with the banded end matching the outline on the PC board or the board layout. The lead on the banded in should be inserted into the square hole on the PC board.*

( ) D1: Orange diode labeled 1N4148

( ) D1: Orange diode labeled 1N4148

( ) D35: Orange diode labeled 1N4148

( ) D36: Orange diode labeled 1N4148

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

Install the fourteen capacitors at the following locations.

( ) C1: 0.1uF ceramic

( ) C2: 0.1uF ceramic

( ) C3: 0.1uF ceramic

( ) C4: 0.1uF ceramic

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

( ) C5: 0.1uF ceramic

( ) C6: 0.1uF ceramic

( ) C7: 0.1uF ceramic

( ) C8: 0.1uF ceramic

( ) C9: 0.1uF ceramic. Note – This capacitor is not labeled on the board. It is the unmarked capacitor next to the U9 IC label.

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

NOTE: *14-pin, 16-pin and 20-pin IC (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 IC socket is on the same end as pin one (a square pad indicates pin 1) of that IC's location. All sockets are placed on the compunet side and solder 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 IC socket as needed. Once the IC socket is correctly placed, solder the remaining pins.*

( ) U1: Install a 20-pin IC socket.

( ) U2: Install a 14-pin IC socket.

( ) U3: Install a 16-pin IC socket.

( ) U4: Install a 20-pin IC socket.

( ) U5: Install a 20-pin IC socket.

( ) U6: Install a 16-pin IC socket.

( ) U7: Install a 20-pin IC socket.

( ) U8: Install a 20-pin IC socket.

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

NOTE: *The next six parts are serial-inline-package or SIP resistors. These parts must be oriented correctly for the Retro Elf 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 10-Pin, 10K ohm x 9, SIP resistor.

( ) RN2: Install a 10-Pin, 10K ohm x 9, SIP resistor.

( ) RN3: Install a 10-Pin, 470-ohm x 9, SIP resistor.

( ) RN4: Install a 10-Pin, 470-ohm x 9, SIP resistor.

( ) RN5: Install a 10-Pin, 470-ohm x 9, SIP resistor.

( ) RN6: Install a 10-Pin, 470-ohm x 9, SIP resistor.

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 pins 1 and 40 on 40-pin header J1. If the resistance reading close to zero (less than 100 ohms) then some form of electrical short may 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 J1 and re-read 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.

Final assembly

Note: We will need to install the *ICs (integrated circuits) before the switches or LEDs are installed.*

NOTE: *In the following steps, install ICs 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: Pre-programmed GAL 16V8 labeled "Retro ELF Front V:C" - , 20-pin DIP

( ) U2: 4013 - 14-pin DIP

( ) U3: 4044 - 16-pin DIP

( ) U4: 74HC244 - 20-pin DIP

( ) U5: 74HC373 - 20-pin DIP

( ) U6: 74HC139 - 16-pin DIP

( ) U7: 74HC373 - 20-pin DIP

( ) U8: 74HC373 - 20-pin DIP

( ) U9: 74HC00 - 14-pin DIP

PLEASE READ THE FOLLOWING INSTRUCTIONS BEFORE YOU INSTALL THE LEDS OR SWITCHES!

Mounting of the LEDs and toggle switches can be a little tricky. Some have contacted me for help on how best to make sure all lines up correctly. The best way I have found to mount these devices is to use the cases plastic front panel as an alignment guide.

First mark out all of the holes needed in the cases front panel. Then drill and clean all the holes using the proper drill bit sizes.

Hint: I have found that I get the best results using a small pilot drill to first drill all the holes and then follow up with the correct drill bit size. I also use only a drill press and drill press guide to help assure proper alignment. Take your time and measure to make sure your holes are correct.

Once the front panel is completely drilled out, mount all the toggle switches to the panel. Remember that there are two nuts, a lock washer and an alignment washer for each switch. The alignment washers are not used and can be discarded.

First place one of the nuts and the lock washer on each toggle switch's mounting shaft before installing the toggle in a hole of the case front panel. When a toggle switch is correctly mounted on the case front panel, the front side nut can then be installed. The final result should place the front side nut flush with the top of each toggle switch's threaded mounting shaft. Make sure that each switch is aligned and the switch's alignment keyway (notch) are all pointing to the top of the panel. I.E. facing the LED holes.

When you install each of the switches in to their assigned mounting holes on the front panel, note that of the thirteen switches to be installed, two of them are different form the others.

The switch to be installed at SW4 should be an automatic spring return type . When SW4 is installed in to place, the toggle should return down position.

Likewise, the switch to be installed at SW13 should have three distinct passions. Up, middle and down.

Now noting the above information, mount each of the toggle switch SW1 through SW13 to the front panel.

Do not solder the switches to the board at this time.

When done set the front panel assemble aside temporarily.

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.*

Now place each of the LEDs in their desired locations as listed below.

Do not solder the LEDs in to place at this time.

( ) D3: Place a Red LED.

( ) D4: Place a Yellow LED.

( ) D5: Place a Red LED.

( ) D6: Place a Green LED.

( ) D7: Place a Yellow LED.

( ) D8: Place a Yellow LED.

( ) D9: Place a Red LED.

( ) D10: Place a Red LED.

( ) D11: Place a Green LED.

( ) D12: Place a Green LED.

( ) D13: Place a Green LED.

( ) D14: Place a Green LED.

( ) D15: Place a Green LED.

( ) D16: Place a Green LED.

( ) D17: Place a Green LED.

( ) D18: Place a Green LED.

( ) D19: Place a Red LED.

( ) D20: Place a Red LED.

( ) D21: Place a Red LED.

( ) D22: Place a Red LED.

( ) D23: Place a Red LED.

( ) D24: Place a Red LED.

( ) D25: Place a Red LED.

( ) D26: Place a Red LED.

( ) D27: Place a Red LED.

( ) D28: Place a Red LED.

( ) D29: Place a Red LED.

( ) D30: Place a Red LED.

( ) D31: Place a Red LED.

( ) D32: Place a Red LED.

( ) D33: Place a Red LED.

( ) D34: Place a Red LED.

( ) D37: Place a Green LED.

( ) D38: Place a Red LED.

Remember do not solder the LEDs in to place at this time.

Using the front panel assembly set aside, position it so that all the toggle switch pins pass through the correct holes on the front panel PC board. DO NOT SOLDER yet. Realign the toggle switches as need for a proper look on the front of your panel.

Carefully turn the hole assembly over so that gravity help you slide each of the LEDs placed on the PC board, in to each of corresponding holes in the front panel assembly. The LEDs will have their pins through the front panel PC board holes and the LEDs body through the front panel assembly.

Check the alignment and spacing for both the switches and LEDs one more time. If all looks correct, first solder each switches center leads and versify positions again. If all still looks good, solder all the switch leads.

Verify that all the LEDs are still fully through the correct front panel holes and solder each of the LEDs in place.

Note: *Both the 40-pin and the 3-pin connectors to be installed next, are installed ON THE BACK (SOLDER) SIDE of the board!*

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 on the back (solder) side.

( ) J2: 3-pin header on the back (solder) side. Match the silk screen that is on the front (component) side of the board and solder.

This completes the assembly of the Retro Elf Front Panel. 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

Details on the revision B front panel such as part locations, parts list and schematics, are located in appendix B.

The interface between the CPU board and the front panel is made via a 40-pin ribbon cable connected to J1 of the front panel board.

Sixteen LEDs are used to display the 1802's current address. The upper eight bits are made up of LEDs D19-D26, 1K current limiting resister network RN5 and the 8-bit latch a 74HC373 (U7). The 1802's TPA line is used by the 74HC373 to latch the upper bits. Likewise, the lower eight bits are made up of LEDs D27-D34, 1K current limiting resister network RN6 and 8-bit latch another 74HC373 (U8). The lower bits are signaled by the 1802's TPB line.

Eight LEDs are used to display the 1802's status (fetch, execute, DMA and Interrupt) and its mode (load, clear, wait and run).

The status is determined by decoded the state of the 1802's -CLEAR and -WAIT control signals. The control signal is decoding using half of 2-to-4 line decoder a 74HC139 (U6). The decoded status is then passed in to LEDs D3- D6 and four 1K current limiting resister within RN4 for display.

Likewise, the 1802's mode is determined by decoding the SC0 and SC1 signals. The second half of the 2-to-4 line decoder in the 74HC139 (U6) is used. The decoded mode is then passed in to LEDs D7-D10 and the remaining four 1K current limiting resister within RN4 are used.

Eight more LEDs are used to construct a simple eight-bit data output port. The data bus output is latched via the -WRLED signal provided by U1 in the 8-bit latch a 74HC373 (U5). The eight latched bits are then passed to LEDs D11-D18 and current limited via the eight 1K resisters within resister network RN3.

Toggle switches SW5-SW12 are used to construct a simple eight-bit input port. When the toggles are switched down (low state), the corresponding data bit is connected to ground. A 10K resistor network (RN2) is used to pull high any bits where the corresponding toggle switch is toggled up (high) which disconnects that corresponding bit from ground. The octal buffer a 74HC244 (U4) interfaces the switches to the 1802's data bus. When the 74HC244 is not selected, it outputs are placed in to high impedance isolating the switches from the data bus. U4 remains in high impedance until the -RDSW like from U1 is set true. The switch data is then placed on to the data bus for reading.

The front panel provides five SPDT toggle switches to control the operation of the system. The first switch SW1 is used to manage the system wide clear (reset) signal while SW2 is used to manage the system wide wait signal.

SW3 signals U1 places any RAM placed in U3 in to a write protect mode. Finally, SW4 is used to strobe the 1802's EF4 line as well as clocking the next byte in to RAM when the 1802 is in the load mode. SW4 is the only toggle switch to have a spring return to down. The center common pin of each of these four toggles are connect to ground while the NO and NC pins are connected to one of the eight 10K pull up resistors in resister network RN1. The CD4044 (U3) contains four R/S latches. Each of the four toggle switch channels are connecter to one of the four R/S latch channels for switch de-bouncing. The 1802's clear line is held high via a 10K resistor on the CPU board. It is possible for more than one device to pull the clear line low indicating a processor clear. D35 is a 1N4148 switching diode. It is placed on the

output side of the R/S latch within the CD4044 that supports the clear signal toggle switch. This diode prevents a short type condition when the output of the CD4044 is high (toggle switch not set to clear condition) and another device requesting a -CLEAR by goes low.

The final toggle switch (SW13) is a three position, on-off-on, designed to control the Slow Clock option. This toggle is a pin-for-pin connection to the 3-pin connector J2. A three-wire interconnection cable is used to connect J2 of the Front Panel to J1 on the Slow Clock board. If the Slow Clock option is not used, this toggle may be omitted or used for other user defined purposes.

To allow the Retro Elf to be programmed without any software support, a hardware method to load RAM memory is needed. When both the 1802's -CLEAR and -WAIT inputs are low (true), the 1802 is placed in to the load mode. A DMA cycle is setup to take data from the input port toggle switches (SW5-SW12) and place it on to the data bus. This byte is then written in to the current memory location pointed to by the address bus. It is via this process that a user can use the input port toggle switches to place programs in the RAM. This process also places the content of the data bus on to the output port LEDs (D11-D18) allowing the users to see what data byte is there. The DMA logic used to control the load mode function is provided using half of a CD4013 flip-flop (U2). The 1802's –DMA-IN signal is strobed each time the user toggles the Input switch (SW4). This strobe increments the 1802's address count to the next location and then cycles the current data byte on the data bus in to RAM. If the user has enabled the memory protect toggle switch, all RAM writes are inhibited. This would allow the current contents of RAM to be displayed on the output port after each cycle of the Input toggle switch (SW4) without destroying the data in the RAM.

The final section of the front panel is the select and control logic. This function is handled by U1 an AFT16V8B. The GAL (Gate Array Logic) receives the 1802's control signals (-MRD, TPB, -WAIT, -CLEAR, -MWR, N0, N1, N2), the Q signal and the user enabled protect (-PROTECT) signal. The internal logic then generates outputs to select the input toggle switches (-RDSW), latch the data LEDs (-WRLED), write the SRAM if the system is not in a protect mode (-WE), drive LED D38 and 1K resistor R3 indicate the system is in memory protect or drive LED D37 and 1K resistor R2 to show the status of the 1802's Q line.

4– Technical details

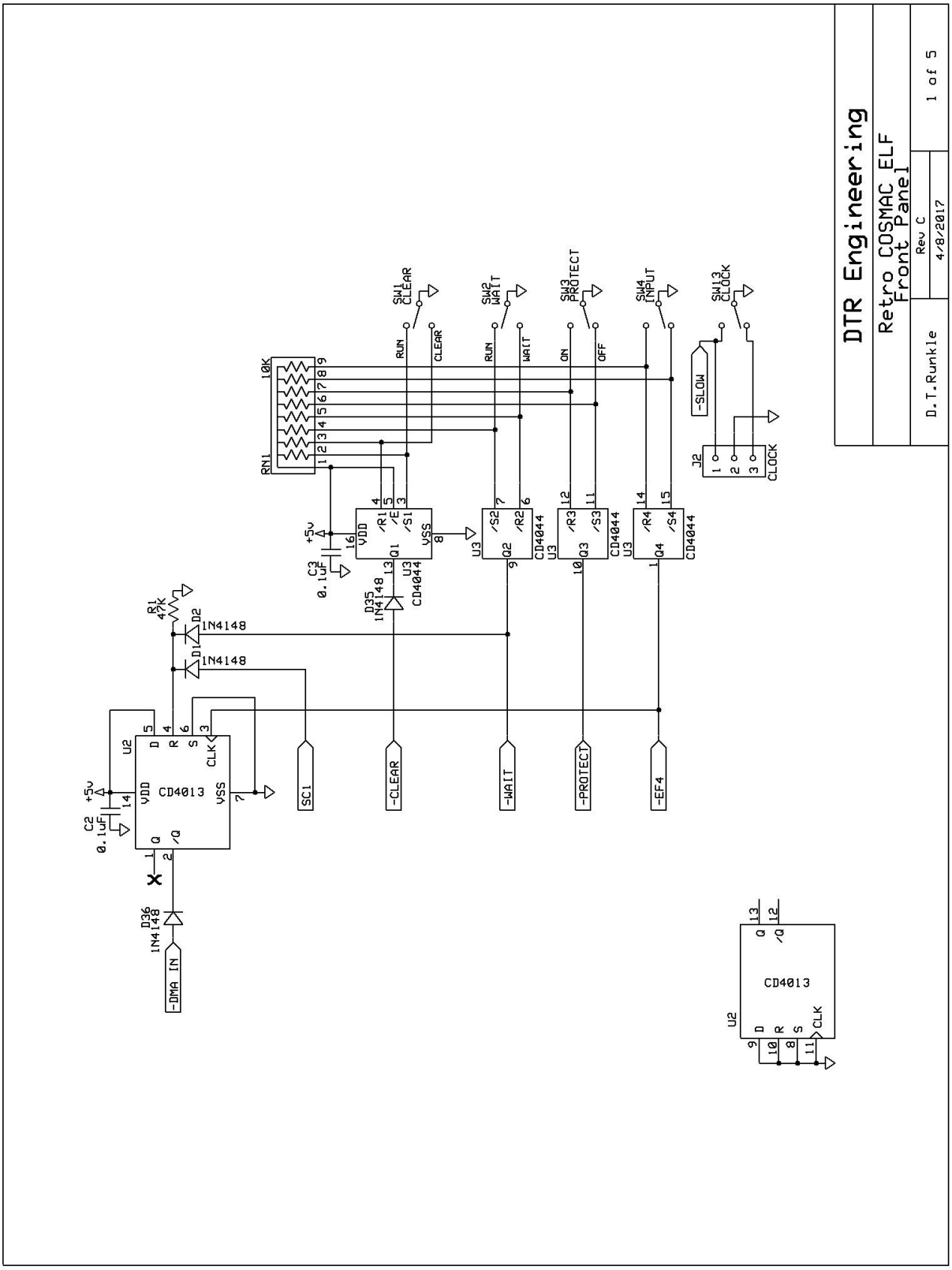
J1 – Retro Elf Bus

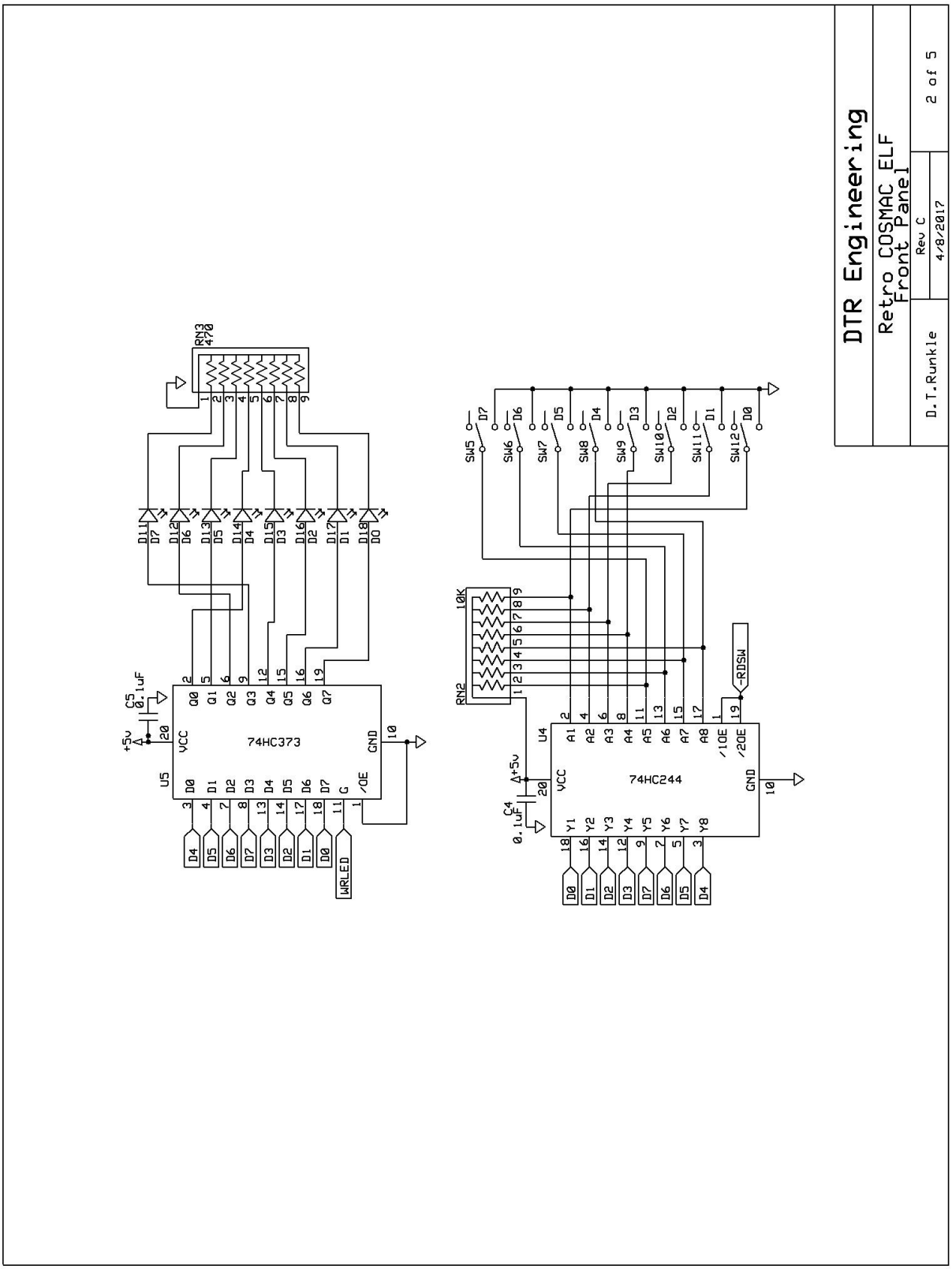
Pin	Type	Label	Description
1	Power	+5VDC	Regulated positive five volt power supply.
2	Power	+5VDC	Regulated positive five volt power supply.
3	BiDir	D0	Main system data bus bit 0.
4	BiDir	D1	Main system data bus bit 1.
5	BiDir	D2	Main system data bus bit 2.
6	BiDir	D3	Main system data bus bit 3.
7	BiDir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

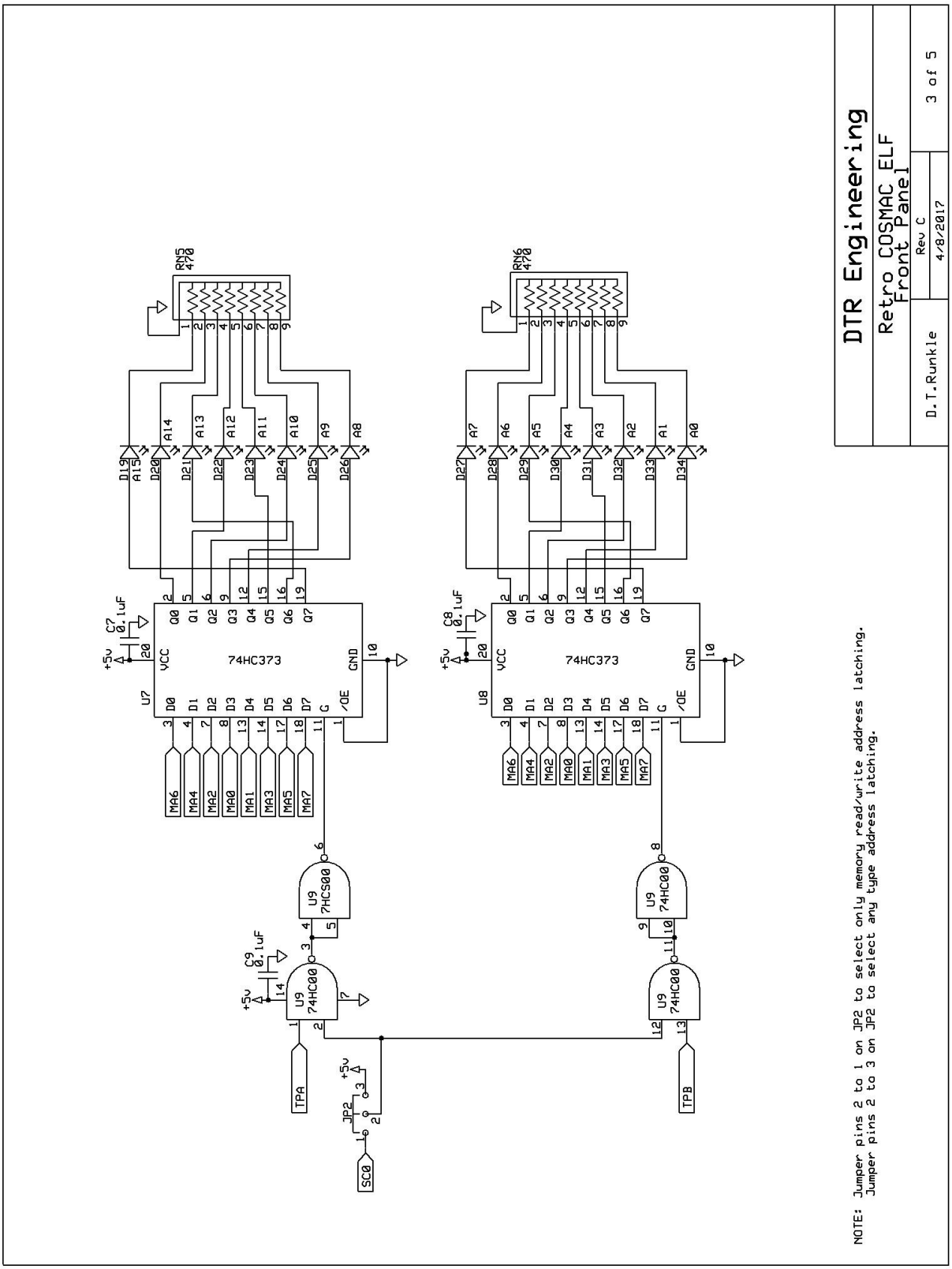
J2 – Slow clock selector switch

Pin	Type	Label	Description
1	Output	SELECT A	Clock speed selection output A.
2	Power	GROUND	Ground.
3	Output	SELECT B	Clock speed selection output B.

Appendix A - Front panel schematics




DTR Engineering
Retro COSMAC ELF
Front Panel
D.T.Runkle
Rev C
4/8/2017
2 of 5
74HC373
74HC244
RN3
470
RN2
10K
SW5
SW6
SW7
SW8
SW9
SW10
SW11
SW12
-RDSW
WRLED
+5v
0.1uF


DTR Engineering
Retro COSMAC ELF
Front Panel
D.T.Runkle
Rev C
4/8/2017
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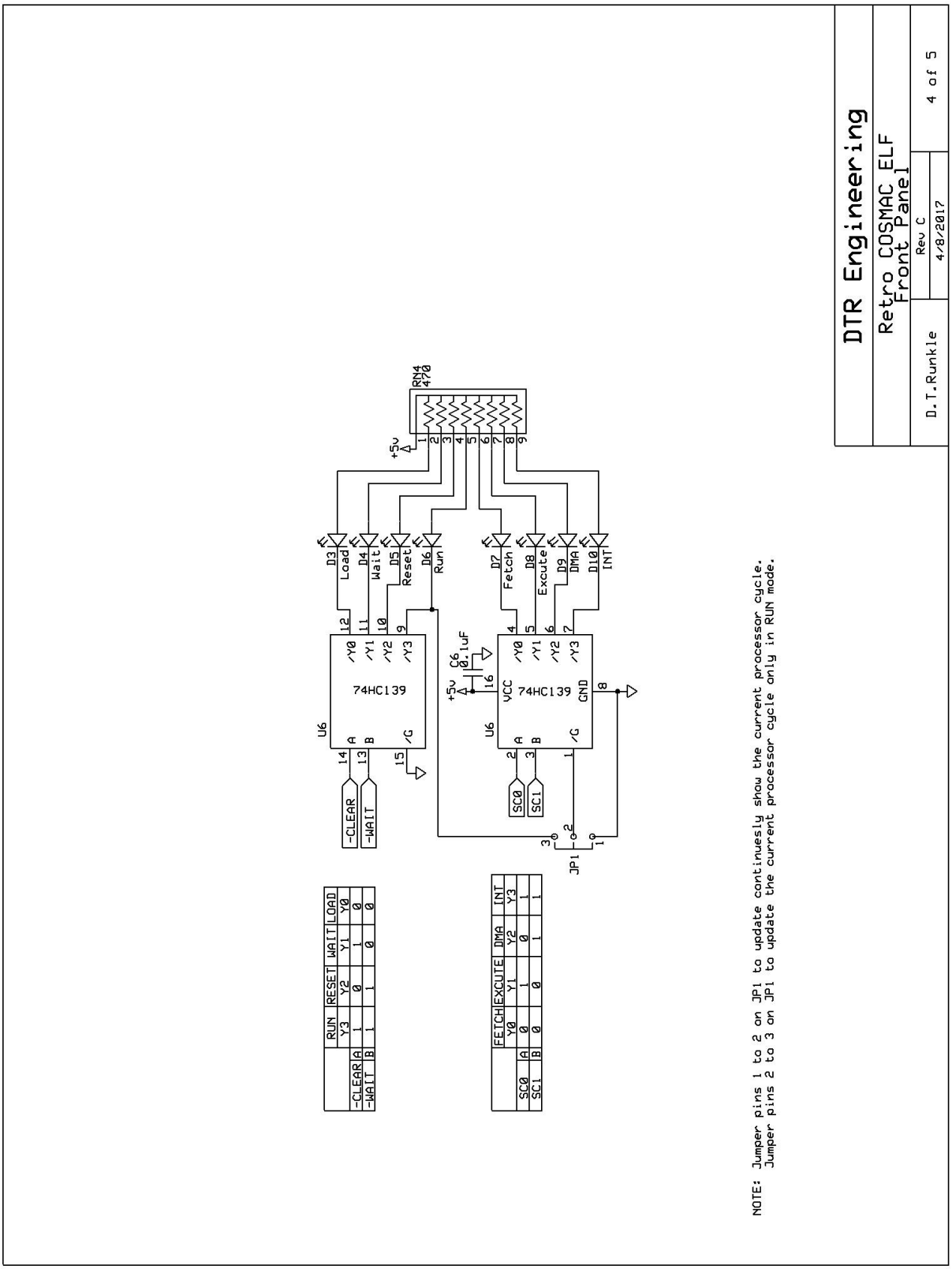
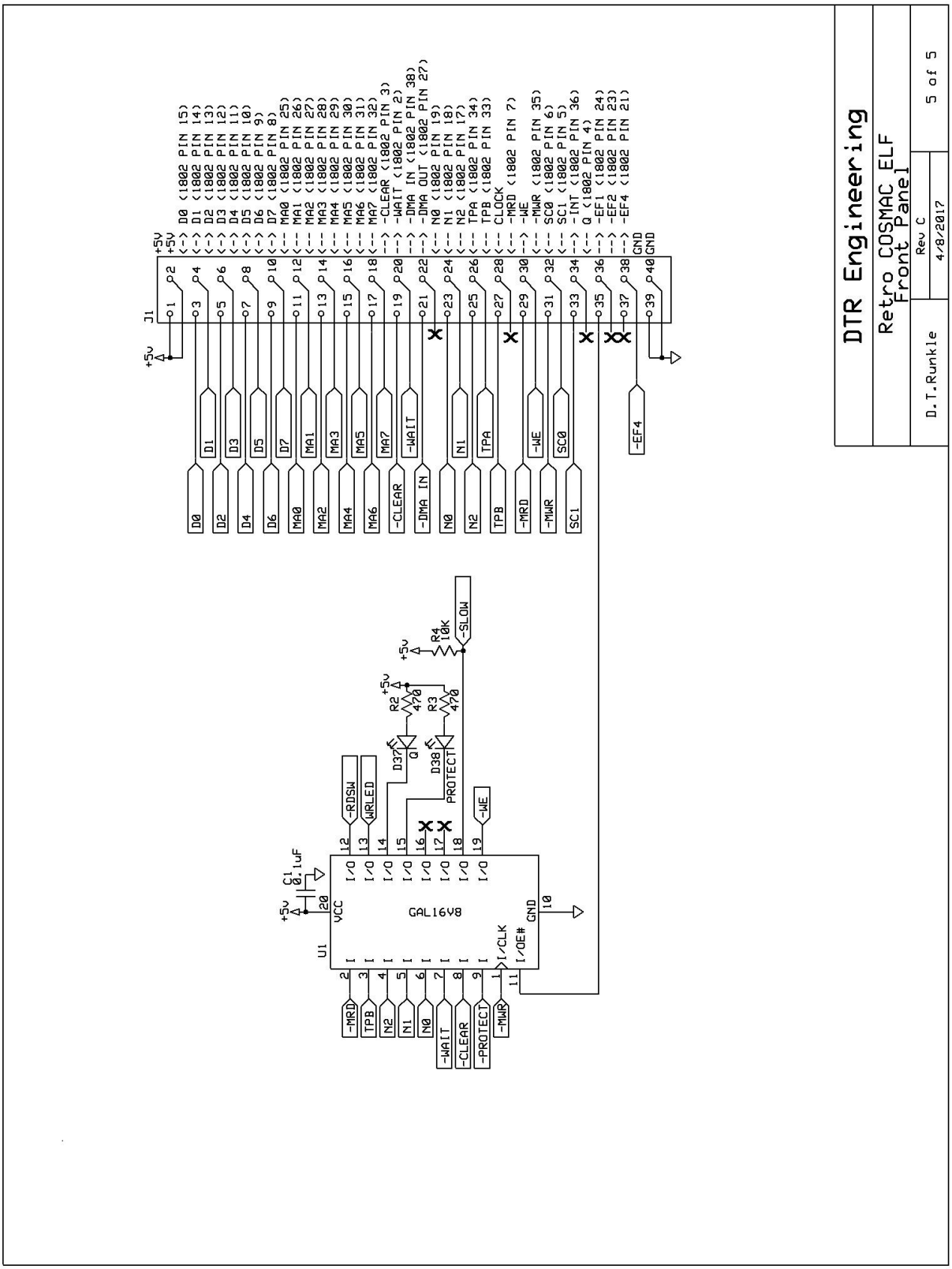
NOTE: Jumper pins 2 to 1 on JP2 to select only memory read/write address latching.
Jumper pins 2 to 3 on JP2 to select any type address latching.
RN5
470
RN6
470
74HC373
U7
U8
74HCS00
74HC00
U9
C7
C8
C9
0.1uF
+5V
JP2
TPA
TPB
SC0
MA0
MA1
MA2
MA3
MA4
MA5
MA6
MA7



		RUN	RESET	WAIT	LOAD
		Y3	Y2	Y1	Y0
-CLEAR	A	1	0	1	0
-WAIT	B	1	1	0	0

		FETCH	EXCUTE	DMA	INT
		Y0	Y1	Y2	Y3
SC0	A	0	1	0	1
SC1	B	0	0	1	1


DTR Engineering
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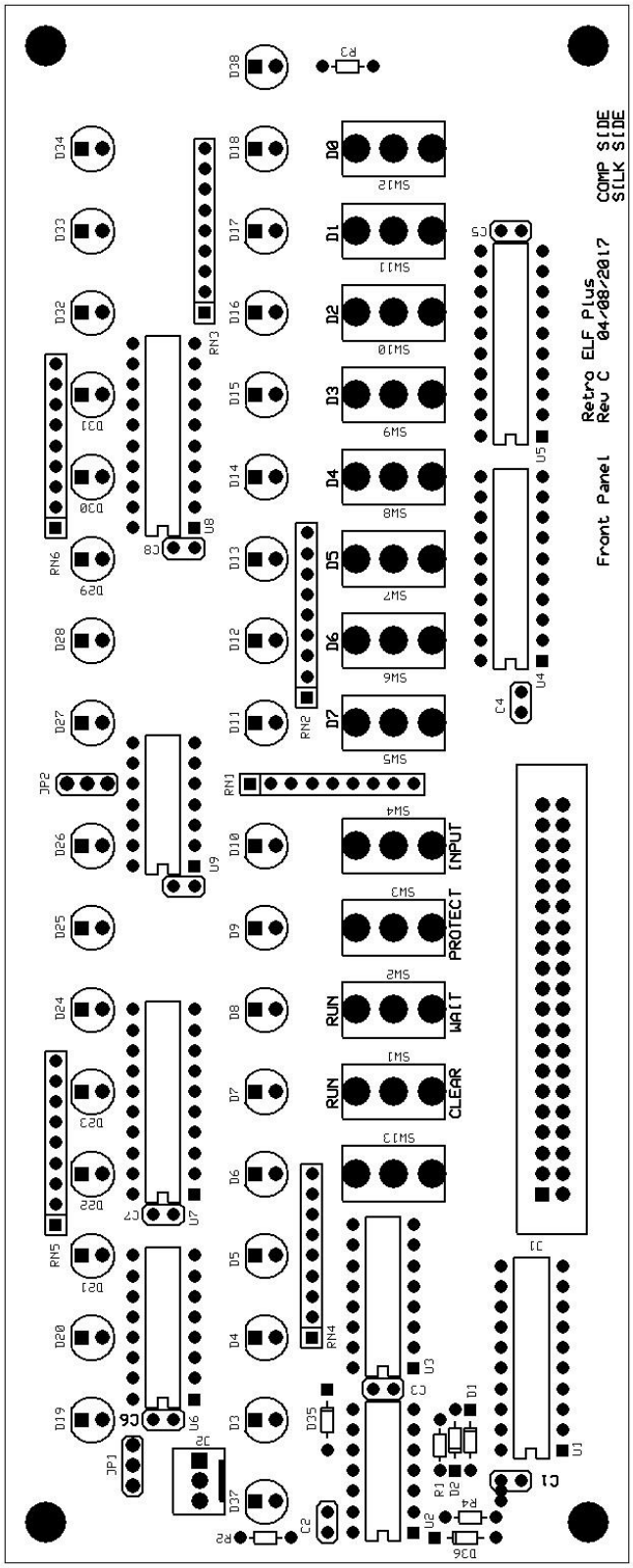
J1
GAL16V8
U1
C1
0.1uF
R2
470
R3
470
R4
10k
D37
Q
D38
PROTECT
-SLOW
-RDSW
WRLED
-WE
-MRD
TPB
N2
N1
N0
-WAIT
-CLEAR
-PROTECT
-MWR
D0
D1
D2
D3
D4
D5
D6
D7
MA0
MA1
MA2
MA3
MA4
MA5
MA6
MA7
-CLEAR
-WAIT
-DMA IN
N0
N1
N2
TPA
TPB
-MRD
-WE
-MWR
SC0
SC1
-EF4

Appendix B – Front panel parts list

Location	Qty	Description	Vendor	Vendor PN	MFG	MFG PN
C1, C2, C3, C4, C5, C6, C7, C8, C9	9	Capacitor CER 0.1uF 50V 20% Radial	Digi-Key	399-4151-ND	Kemet	C315C104M5U5TA
D1, D2, D35, D36	4	Diode 1N4148	Digi-Key	1N4148TACT-ND	Fairchild	1N4148TA
D3, D5, D9, D10, D19, D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D38	21	1 ¾ Red LED	Digi-Key	754-1266-ND	Kingbright	WP7113LID
D6, D11, D12, D13, D14, D15, D16, D17, D18, D37	10	1 ¾ Green LED	Digi-Key	754-1265-ND	Kingbright	WP7113GD
D4, D7, D8	3	1 ¾ Yellow LED	Digi-Key	754-1268-ND	Kingbright	WP7113YD
J1	1	Header 40 pin 2 x 20, 0.1 pitch	Digi-Key	WM8134-ND	Molex Inc	901310140
J2	1	Connector header 3 position 0.1 pitch vertical tin	Digi-Key	WM4201-ND	Molex Inc	0022232031
JP1, JP2	2	JUMPER SKT BLACK	Digi-Key	952-2165-ND	Harwin Inc	M7567-46
JP1, JP2	2	3-Pin	Digi-Key	3M9448-ND	3M	961103-6404-AR
R1	1	Resistor 47K ohm 1/8-watt 5% CF axial	Digi-Key	CF18JT47K0CT-ND	Stackpole	CF18JT47K0
R2, R3	2	Resistor 470 ohm 1/8-watt 5% CF axial	Digi-Key	CF18JT470RCT-ND	Stackpole	CF18JT470R
R4	1	Resistor 10K ohm 1/8-watt 5% CF axial	Digi-Key	CF18JT10K0RCT-ND	Stackpole	CF18JT10k0
RN1, RN2	2	Resistor Network 10K x 8 SIP 9	Digi-Key	4609X-101-103LF-ND	Bourns Inc	4609X-101-103LF
RN3, RN4, RN5, RN6	4	Resistor Network 470 ohm x8 SIP-9	Digi-Key	4609X-101-471LF-ND	Bourns Inc	4609X-101-471LF
SW1, SW2, SW3, SW5, SW6, SW7, SW8, SW9, SW10, SW11, SW12	11	Switch toggle SPDT 5A 120V	Digi-Key	CKN1004-ND	C&K	7101SYCQE
SW4	1	Switch toggle SPDT, Spring return, 5A 120V	Digi-Key	CKN1473-ND	C&K	7108SYCQE
SW13	1	Switch toggle SPDT, Senter 5A 120V	Digi-Key	CKN1005-ND	C&K	7103SYCQE
U1, U4, U5, U8	4	Socket IC 20 Pin	Digi-Key	AE10015-ND	Assmann WSW	AR-20-HZL-TT
U2, U9	2	Socket IC 14 Pin	Digi-Key	AE10012-ND	Assmann WSW	AR-14HZL-TT
U3, U6	2	Socket IC 16 Pin	Digi-Key	AE10013-ND	Assmann WSW	AR16-HZL-TT
U1	1	GAL16V8 "Retro ELF Front V:C"	Digi-Key	ATF16V8B-15PU-ND	Atmel	ATF16V8B-15PU
U2	1	CD4013	Digi-Key	296-2033-5-ND	Texas Instruments	CD4013BE
U3	1	CD4044	Digi-Key	296-2051-5-ND	Texas Instruments	CD4044BE
U4	1	74HC244	Digi-Key	296-1582-5-ND	Texas Instruments	SN74HC244N
U5, U7, U8	3	74HC373 - IC OCT TRANSP D LATCH 20-DIP D	Digi-Key	296-1591-5-ND	Texas Instruments	SN74HC373N
U6	1	74HC139	Digi-Key	296-8230-5-ND	Texas Instruments	SN74HC139N
U9	1	74HC00	Digi-Key	296-1563-5-ND	Texas Instruments	SN74HC00N

Appendix C – Front panel parts locations



Appendix D – Connectors and jumpers