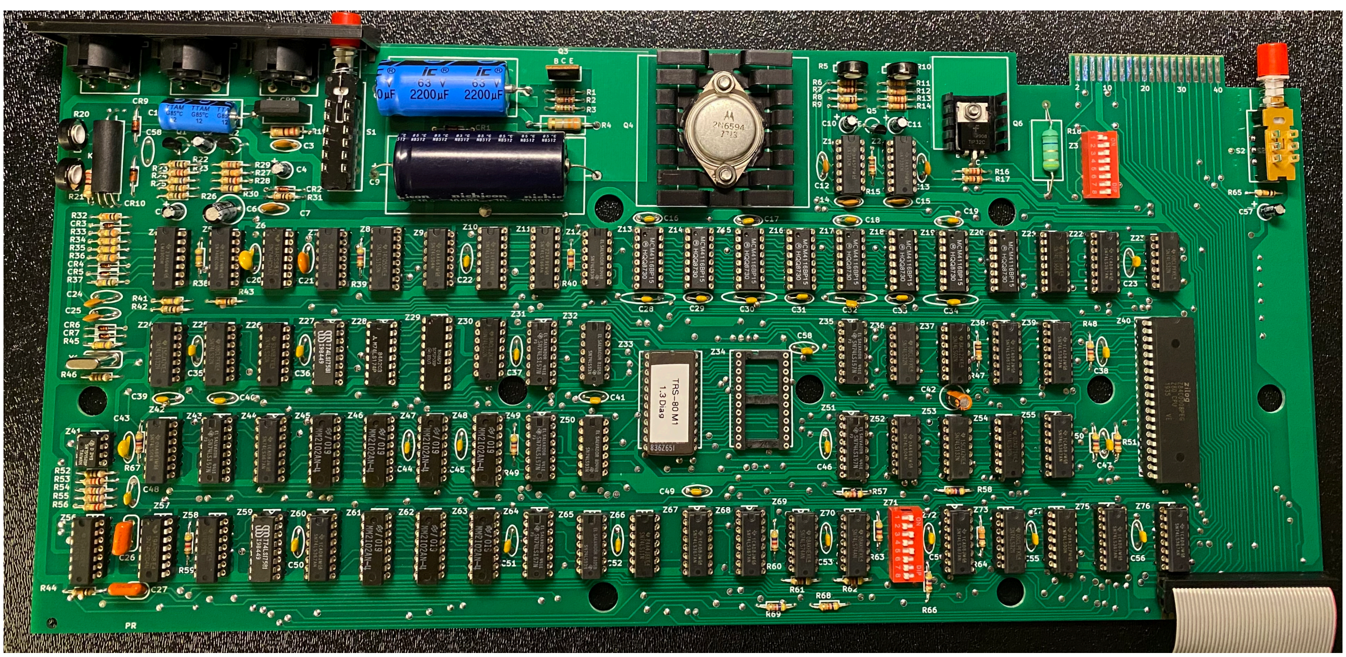
TRS-80-Model-I-G-E1 / README.md

Marcel Erz typos 148ed7d · 7 minutes ago History

Preview Code Blame 280 lines (218 loc) · 29.2 KB Raw

TRS-80 Model 1 (Rev G) Replica - E1

This project is a faithful reimplementation of the mainboard of the iconic TRS-80 Model 1 (Revision G) computer. My own revision, the E1, is designed to replicate the original system's functionality by using a PCB design 1-to-1 to the original, including components, interfaces, and even traces. The entire project is available under the MIT license.



Project Details

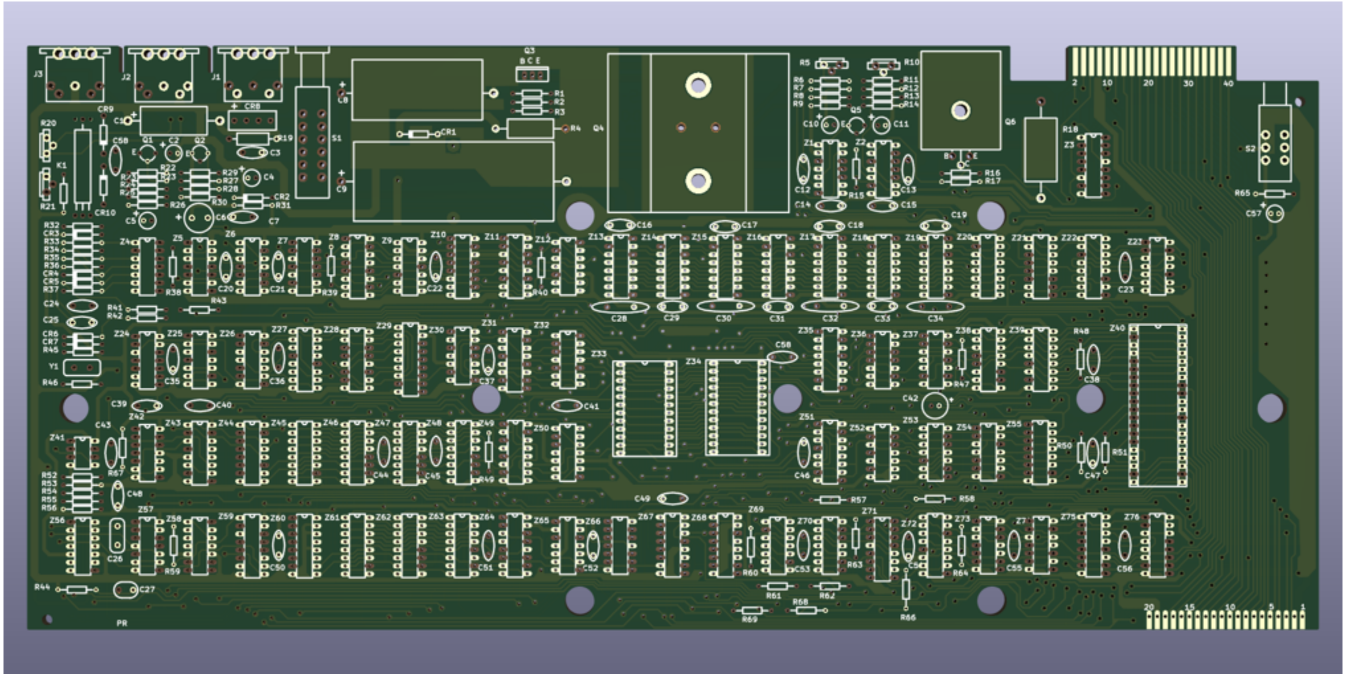
Latest Files

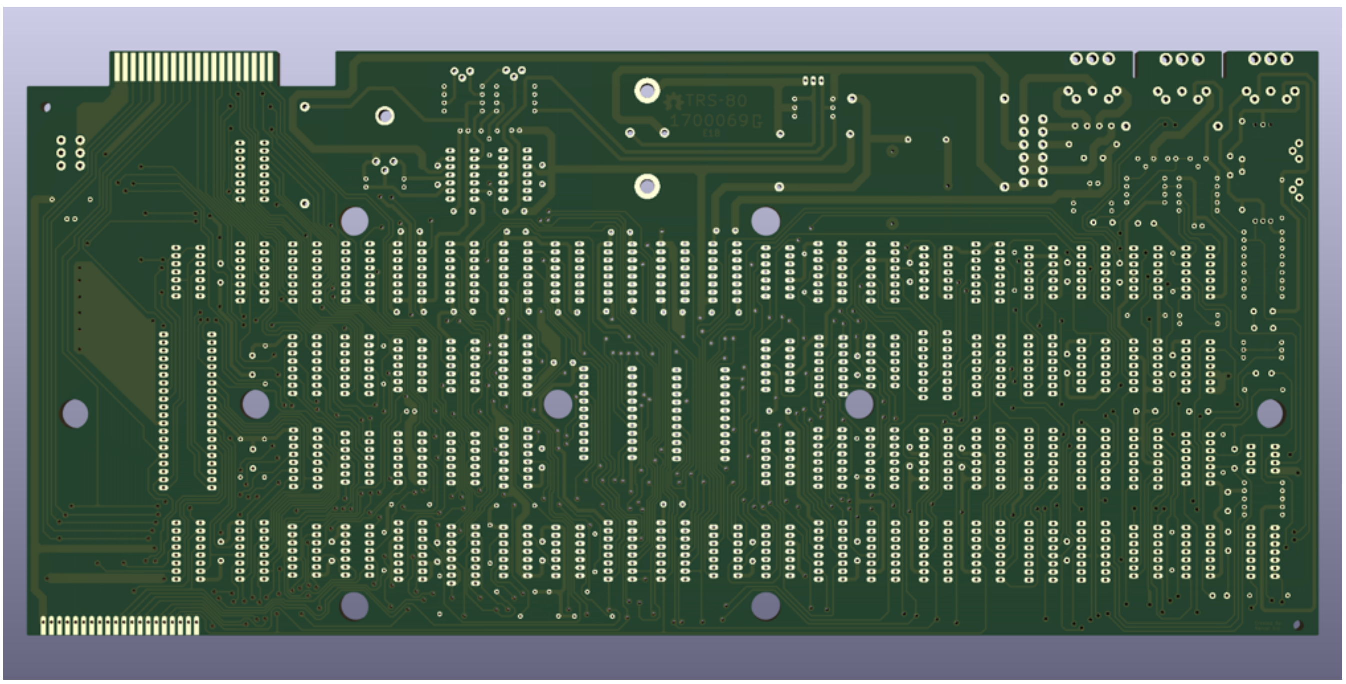
In the "Latest" folder, you'll find the most up-to-date design files, including:

- Gerber files suitable for popular online PCB manufacturers like PCBWay and JLCPCB. Most manufacturers should be fine with either.
- A Bill of Materials (BOM) in both CSV and PDF formats. (Also, see the list below.)
- Layers exported in PDF and SVG formats.
- If you have trouble identifying components, refer to the labels SVG.
- The full schematics of the E1 replica which is 1:1 to the original G board.
- A simple Assembly Guide in PDF format.

Implementation

E1 has been implemented using KiCAD 7. The KiCAD project files are included in this repository.





Assembly Instructions

For each step, check if there is a connection between pad 1, 8, 9, 16 on Z18 (all four corners of the dynamic RAM IC). That IC needs all 3 voltages with ground. If any of them are shorted, then you know what you did most recently. Finding the cause of the short should then be relatively easy.

1. (optional) Install sockets for all ICs. You probably want to skip Z3 and Z71, if you want to use DIP switches instead.

2. Install all diodes. These diodes are hard to read and if you accidentally mix them up, you might end up with incorrect voltages on the rails. Also, make sure to orient them correctly. There should be a black band on one side of the glass diode. Match this with the "thicker" side of the diode on the PCB. Installing first the shorter components will make sure you still can flip the board around and solder things easily.
3. Install all resistors. Resistors do not have an orientation. Skip the potentiometers for now. When installing the C_R67 (yes, there is a "C_"), this is an unmarked resistor between relay and the R21 potentiometer. This should be a 220 ohm 0.5W resistor (a bit larger than the others). There is another R67 which is next to Z42, which is a 4.7k Ohm resistor 0.25W (same size as most of the others).
4. Install all disc-like capacitors. Do not install the electrolytic capacitors yet! All other capacitors are rather small and orientation isn't important. The C58 next to the relay stays empty. Do not install it there. Instead, there is another (!!!) C58 next to the ROMs in the middle of the PCB.
5. Install all transistors, including the ones with the heatsinks. The TIP29 should go into Q3 (metal side away from board towards the Q3 label) while the TIP32C should go into Q6 (lay flat with heatsink; bend legs wit needle-nose pliers to fit). Don't forget to add thermal paste between heatsink and transistors. Make sure to add the screws and nuts and that it fits tightly as the screws themself connect traces. Not having them properly installed will result in a non-functioning system. The smaller black transistors have one flat side. These should all face towards the bottom of the board towards all the ICs (the middle leg needs to be bend slightly out to fit).
6. Install the crystal (no orientation), relay (match orientation on PCB; three legs towards the bottom), full-bridge rectifier (CR8; match "+" marking on component with PCB marking), all DIN connectors, both switches, keyboard connector (if bend, bend it upwards - towards the CPU to fit in the case), and potentiometers (only goes in one way). You can also install the DIP switches, if you go with that (numbers on the left side and "ON" label on the right).
7. Install all electrolytic capacitors. Make sure the orientation is correct! Modern capacitors mark the "-" side. On the PCB, the positive side is marked. All electrolytic capacitors on the PCB are oriented the same way EXCEPT C42 (!!!). Incorrect orientation may result in a small explosion (loud and smokey, but probably not dangerous).
8. Only install Z1 & Z2 to calibrate the power supply. Don't install any of the other ICs yet!!!
9. Get Multimeter ready in voltage mode. Connect power, turn on S1. If something starts

to smell burned, turn S1 off and disconnect power.

10. Check voltage between pad 1 (-5V) and pad 16 (GND) on Z18. It should be around -5.1V to -5.2V. Since this is clamped with a zener diode, this should be pretty accurate. There is nothing that needs to be calibrated here. If the voltage goes beyond -5.3V, check R19 (may be really hot! careful!). If R19 is hot to the touch, your power supply is probably broken. (I've seen this on one power supply while another one didn't have that problem.)
11. Check voltage between pad 8 (+12V) and pad 16 (GND) on Z18. It should be around +12.0V. If it isn't, change the R10 potentiometer. If it is +/-0.5V off, then this is fine. But, try to get it as close to the desired voltage as possible.
12. (You need to calibrate +12V first before going to this next step!!!) Check voltage between pad 9 (+5V) and pad 16 (GND) on Z18. It should be around +5.0V. If it isn't, change the R5 potentiometer. If it is +/-0.5V off, then this is fine. But, also here, try to get it close to the desired voltage.
13. Re-check all the voltages after calibration, just to be sure.
14. Turn off S1 and disconnect power. Do this for each of the following steps. After each change, re-check the voltages at Z18 to find shorts quickly.
15. Start inserting the ICs. Focus on the 74LSxx ICs first. They are cheap and are easily recoverable in case there is a short somewhere and you start frying ICs. May be do 2-4 chips at a time and re-check the voltages at Z18. Do this systematically from left to right and top to bottom, so you know which you inserted most recently. If one of the voltages changes significantly at Z18 (+/- 2V and more), then you probably have a short with the most recent ICs. Do not insert the CPU, ROMs, character generator, and RAMs (static (2102) and dynamic ones (4116)) for now. They are expensive to replace if they fry.
16. Insert the 74HCxx ICs. These ICs are also cheap, but they are very sensitive. If all voltages are good, then they are good to install.
17. Connect to a monitor. Use a CRT, if possible, as video calibration is easier. LCD works too, but the reaction time is slow and requires a longer wait time after each change.
18. After turning on monitor and S1, you should see white blocks on a black background. If you don't see it, try changing R20 (vertical sync) and R21 (horizontal sync). If all fails, try to center both potentiometer. This usually results in a non-optimal picture, but a picture non-the-less. You can then calibrate.
19. (Don't forget to turn off system!) Insert the static video RAM (2102). These ICs only require +5V.
20. Now you need to configure the memory addresses and the memory configuration. With

DIP switches, configure as follows:

- (memory location configuration) Z3: Switch 1 to the left, while all others are to the right. This is the configuration for 12k ROM and 16k RAM.
- (memory type configuration) Z71: Switch 1, 3, 5 to the right while all others are to the left. This is the configuration for 16k RAM modules.

21. Insert the dynamic RAM (41116). These ICs require all three voltages.
22. Insert CPU. Not much should have changed from the video calibration up until now. The next step will change that.
23. Insert character generator. Instead of white blocks, you should see (random) characters. The system doesn't clear the video memory yet since no ROM is installed.
24. Install ROM. This should be a Level II v1.3. If you don't have this, you probably need additional circuity to make these work. You can also burn the diag ROM on a 2k ROM to test the system. The diag ROM should work for all revisions of the TRS-80 Model 1.
25. At this point, you should see a prompt showing "Memory Size?" that keeps blinking (if it is the normal system ROM). The reason for the blinking is that the keyboard is not yet connected and the system recognizes keypresses. Install the keyboard with the IDC cable (if you installed a header).
26. Now, you should be able to use the system. Try to hold the left SHIFT key and press the right arrow key and the text size should increase, switching the video modes. (It is OK when some characters are skipped. That is normal.) The CLEAR key should reset it to the original video mode and clear the screen.
27. Try running a "Hello World!" program: 10 PRINT "Hello World!" (Return) 20 GOTO 10 (Return) RUN (Return). You can stop with the BREAK key.

Ordering Instructions

When ordering the board from a PCB manufacturer, you can select the following to get a more faithful version of the board:

```
Dimension: 407mm x 184mm
Layers: 2
Base Material: FR-4 TG 135-140 (and up)
PCB Thickness: 1.6mm
PCB Color: Green
Silkscreen Color: White
Via Covering: Untented
Surface Finish: Lead Free HASL
Outer Copper Weight: 1oz
Gold Fingers / Card Edge: yes (chamfer: 30 degrees)
Castellated Holes: no
```

Additionally, supply the following comment for the manufacturer:

> Card edge is only on the upper right. The bottom right is just a connector and does not need to be chamfered.
>
> There are some missing pads on the top layer. That is correct. Please leave them as-is.

This addresses recurring questions from some of the interesting designs that were used on the original board which was replicated. See the "Curiosities" section below.

Bill of Materials (BOM)

Below is a list of materials needed to assemble a complete system. Please note that the links and prices (scroll to the right to see them; as of January 22, 2024) will not be updated in the future and should only be used as a reference for locating the correct items.

Note: Links and alternatives are provided to assist you in finding the necessary components. I cannot guarantee the complete accuracy or reliability of all these links and alternatives. Please check it for yourself!

Reference	Quantity	Value	Component Name	Descrip
C1	1	220uF 16V	C_Polarized	Polarized cap
C2, C4,				

C5, C10, C11, C57	6	10uF 16V	C_Polarized	Polarized cap
C3, C7, C14, C15	4	0.01uF 24V	C (103)	Unpolarized c
C6	1	100uF 16V	C_Polarized	Polarized cap
C8	1	2200uF 35V	C_Polarized	Polarized cap
C9	1	10000uF 16V	C_Polarized	Polarized cap
C12, C13	2	470pF	C (471)	Unpolarized c
C16, C17, C18, C19, C22, C23, C28, C29, C30, C31, C32, C33, C34, C35, C36, C37, C38, C39, C40, C41, C44, C45, C46, C47, C48, C49, C50, C51, C52, C53, C54, C55, C56, C58	34	0.1uF 25V	C (104)	Unpolarized c
C20	1	330pF	C (331)	Unpolarized c
C21	1	750pF	C (750)	Unpolarized c

C24, C25	2	220pF	C (221)	Unpolarized c
C26	1	0.047uF	C (47nF)	Unpolarized c
C27	1	0.022uF	C (22nF)	Unpolarized c
C42	1	22uF 16V	C_Polarized	Polarized cap
C43	1	47pF	C (47)	Unpolarized c
CR1	1	1N4735	D_Zener	Zener diode
CR2	1	1N5231	D_Zener	Zener diode
CR3, CR4, CR5, CR6, CR7	5	1N4148	D	Diode
CR8	1	MDA202	D_Bridge_+AA-	Diode bridge, +ve/AC/AC/-v
CR9, CR10	2	1N982	D_Schottky	Schottky dioc
J1, J2, J3	3	Front View	DIN-5_180degree	5-pin DIN cor (5-pin DIN-5
J100	1	Connector	Conn_01x20	Generic conn single row, 01
K1	1	Relay_SPST-NO	TRS80_Model_I_Relay_NO	Relay SPST, N Open, EN500
Q1	1	2N3904	2N3904	0.2A Ic, 40V \ Signal NPN Tı

				TO-92
Q2, Q5	2	2N3906	2N3906	-0.2A Ic, -40V Small Signal P Transistor, TC
Q3	1	TIP29A	Q_NPN_BCE	NPN transistc base/collecto
Q4	1	2N6594	Q_PNP_BEC	PNP transistc base/emitter/
Q6	1	MJE34	Q_PNP_BCE	PNP transistc base/collecto
-	1			Q4 Heatsink
-	1			Q6 Heatsink
R1	1	68	R	Resistor 0.25
R2	1	2.7k	R	Resistor 0.25
R3	1	750	R	Resistor 0.25
R4	1	0.33	R	Resistor 2W
R5, R10	2	1k	R_Potentiometer	Potentiomete
R6, R7, R16, R53	4	1.2k	R	Resistor 0.25
R8	1	100k	R	Resistor 0.25
R9, R11, R12	3	3.3k	R	Resistor 0.25

R13	1	2.2k	R	Resistor 0.25
R14	1	12k	R	Resistor 0.25
R15	1	1.5k	R	Resistor 0.25
R17	1	2k	R	Resistor 0.25
R18	1	5.6	R	Resistor 3W
R19, C_R67	2	220	R	Resistor 0.5W
R20, R21	2	100k	R_Potentiometer	Potentiomete
R22	1	75	R	Resistor 0.25
R23	1	120	R	Resistor 0.25
R24	1	680k	R	Resistor 0.25
R25	1	1.6M	R	Resistor 0.25
R26, R42	2	1M	R	Resistor 0.25
R27, R64	2	330	R	Resistor 0.25
R28	1	270	R	Resistor 0.25
R29	1	1.8k	R	Resistor 0.25

R30	1	47	R	Resistor 0.25
R31	1	10	R	Resistor 0.25
R32, R43, R44, R47, R65	5	10k	R	Resistor 0.25
R33, R36	2	360k	R	Resistor 0.25
R34, R35, R38, R41, R45	5	470k	R	Resistor 0.25
R37	1	560k	R	Resistor 0.25
R39, R40, R48, R49, R50, R51, R57, R58, R59, R60, R61, R62, R63, R66, R67, R68, R69	17	4.7k	R	Resistor 0.25
R46, R52	2	910	R	Resistor 0.25
R54, R55	2	7.5k	R	Resistor 0.25
R56	1	220k	R	Resistor 0.25
S1	1	Power	SW_4PST	

S2	1	Reset	SW_DPST	
Y1	1	10.6445 MHz	Crystal	Two pin cryst
Z1, Z2	2	LM723C	LM723C_1	Linear Regula (adjustable)
Z3, Z71	2	Jumper	TRS80ModelIX71	8-Bit DIP Swi
Z4	1	LM3900	LM3900	Quad operati amplifier
Z5	1	74C00	74LS00	quad 2-input gate
Z6, Z57	2	74C04	74LS04	Hex Inverter
Z7, Z69, Z70	3	74LS74	74LS74	Dual D Flip-fl Reset
Z8	1	74LS153	74LS153	Dual Multiple:
Z9, Z42, Z52	3	74LS04	74LS04	Hex Inverter
Z10, Z11	2	74LS166	74LS166	Shift Register parallel load
Z12, Z32, Z50, Z65	4	74LS93	74LS93	Divide by 2 & counter
Z13, Z14, Z15, Z16, Z17, Z18, Z19, Z20	8	MK4116	4116	16kBit x 1 Bit RAM
Z21	1	74LS156	74LS156	Dual 2 to 4 lir Decoder/Dem

				Open Collect
Z22, Z38, Z39, Z44, Z55, Z60, Z67, Z68, Z72, Z75, Z76	11	74LS367	74LS367_Split	Hex buffer 3- outputs
Z23, Z25, Z36, Z73	4	74LS32	74LS32	Quad 2-input
Z24, Z53	2	74LS132	74LS132	Quad 2-input Schmitt trigg
Z26	1	74LS20	74LS20	Dual 4-input
Z27, Z59	2	74LS175	74LS175	4-bit D Flip-F
Z28	1	74LS174	74LS174	Hex D-type F reset
Z29	1	MCM6670	MCM6670P	128 x 7 x 5 Ch Generator
Z30, Z37	2	74LS02	74LS02	quad 2-input
Z31, Z35, Z43, Z49, Z51, Z64	6	74LS157	74LS157	Quad 2 to 1 li Multiplexer
Z33	1	2364_20L	2364_20L	2364 64kBit PROM
Z34	1	2332_20L_21L	2332_20L_21L	2332 32kBit PROM
Z40	1	Z80CPU	Z80	Z80 CPU
Z41	1	75452	75452	Dual-Periphe for High-Curr

				High-Speed S
Z45, Z46, Z47, Z48, Z61, Z62, Z63	7	2102	2102_1	1K Static RAM
Z54	1	74LS30	74LS30	8-input NANI
Z56, Z58	2	74LS92	74LS92	Divide by 12 c
Z66	1	74LS11	74LS11	Triple 3-input
Z74	1	74LS00	74LS00	quad 2-input gate
Machined DIP Socket 8 pin	1	DIP-8	DIP-8	DIP-8 Socket
Machined DIP Socket 8 pin	30	DIP-14	DIP-14	DIP-14 Socke
Machined DIP Socket 16 pin	39	DIP-16	DIP-16	DIP-16 Socke
Machined DIP Socket 18 pin	1	DIP-18	DIP-18	DIP-18 Socke
Machined DIP Socket 24 pin	2	DIP-24	DIP-24	DIP-24 Socke
Machined				

DIP Socket 40 pin	1	DIP-40	DIP-40	DIP-40 Socke

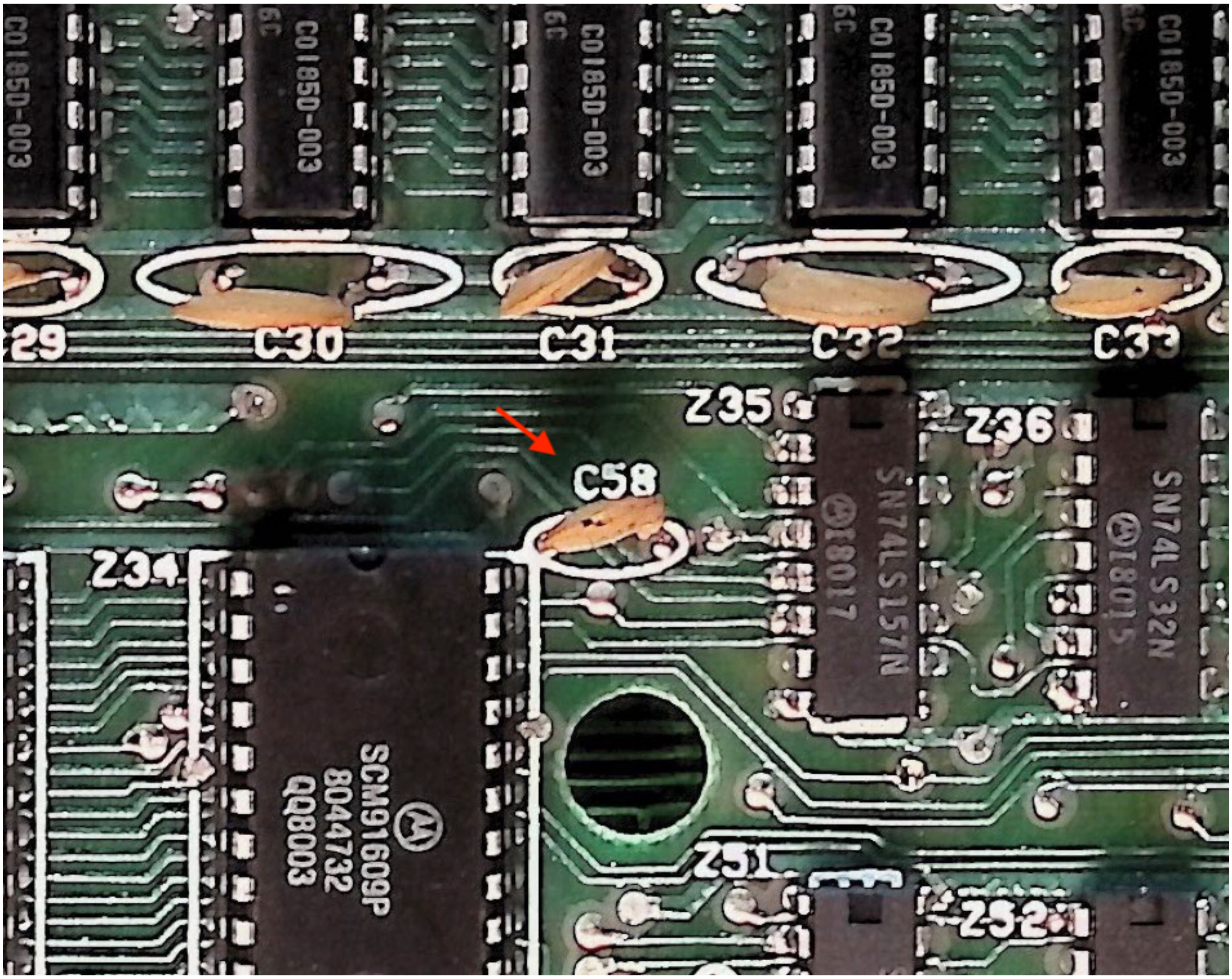
RetroStack Libraries

To work with this KiCAD project, you'll need the RetroStack libraries for KiCAD. Please follow this link to access and install these libraries.

Curiosities

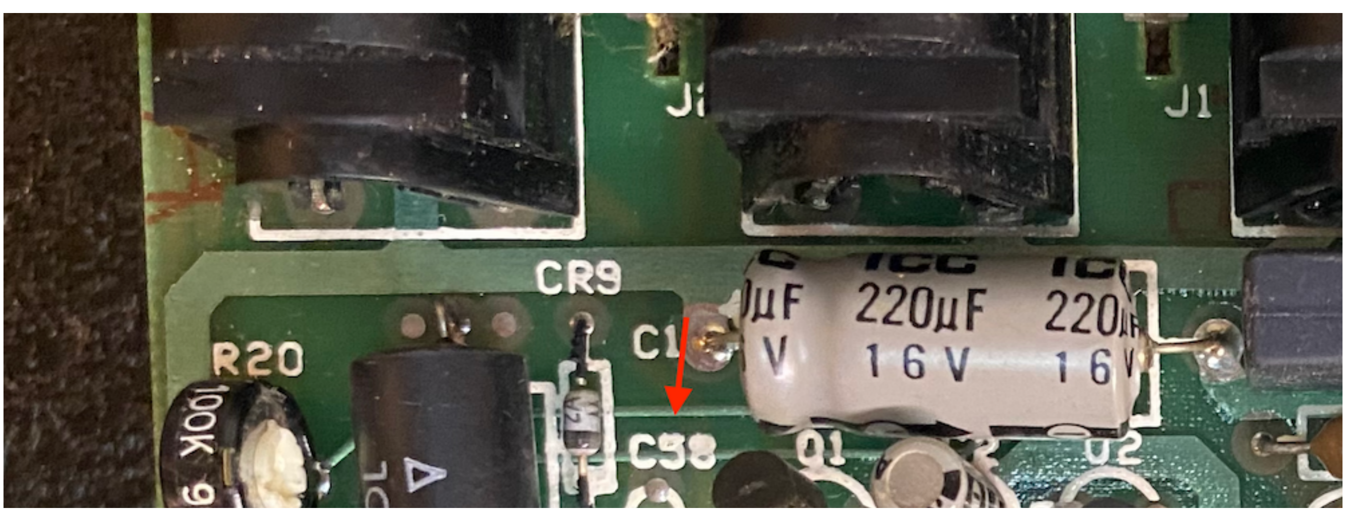
The original board had multiple errors and strange implementations, often caused by the limited capabilities of the manufacturing process, but also to save money. The following sections discuss some of the stranger features on the original PCB board, which were replicated when possible.

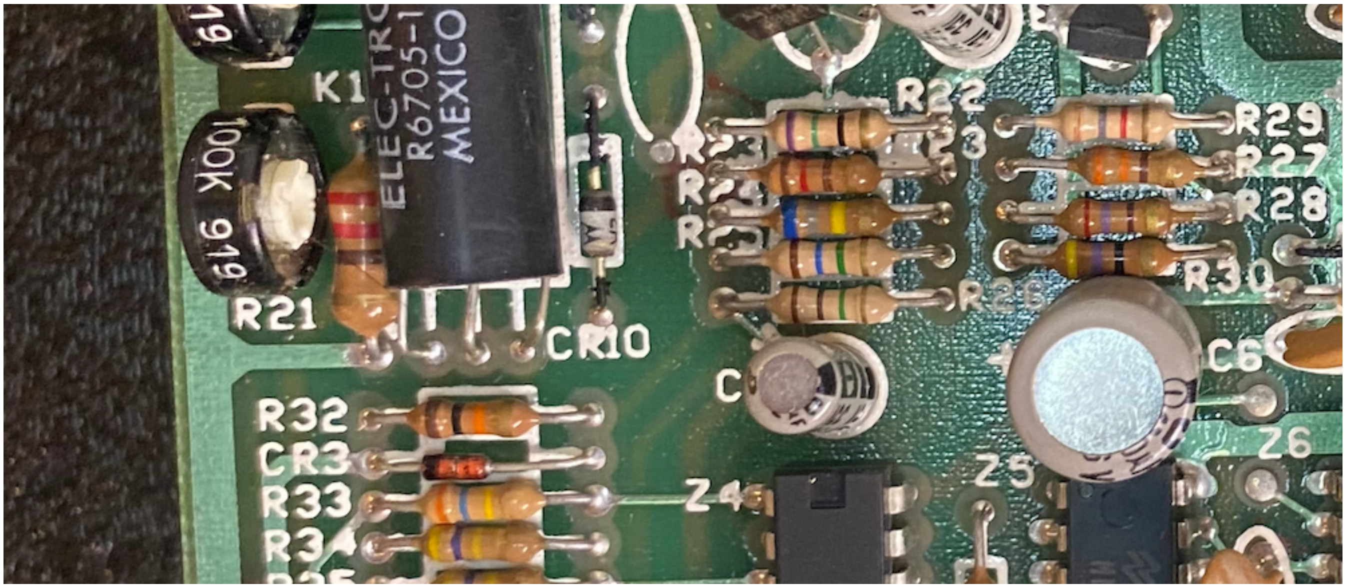
Additional Capacitor

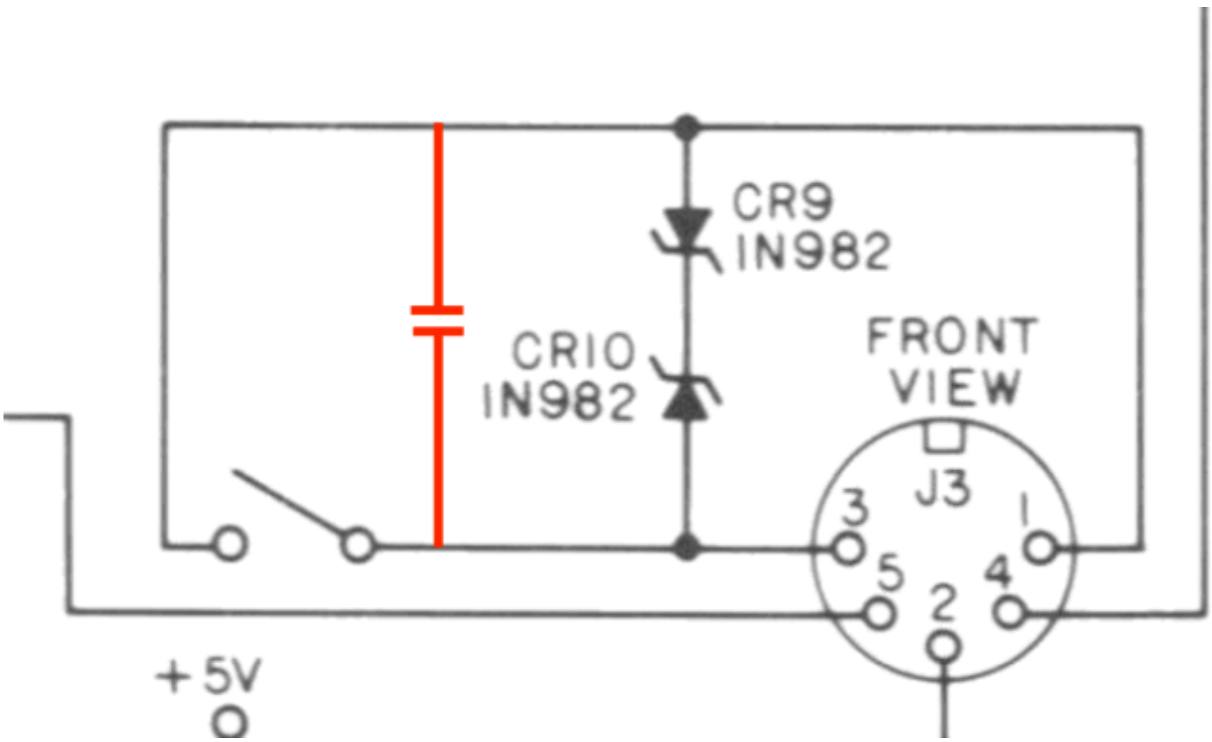


Capacitor C58, located next to the ROMs, was never documented in the technical reference manual. My guess is that it was added later.

Missing Capacitor

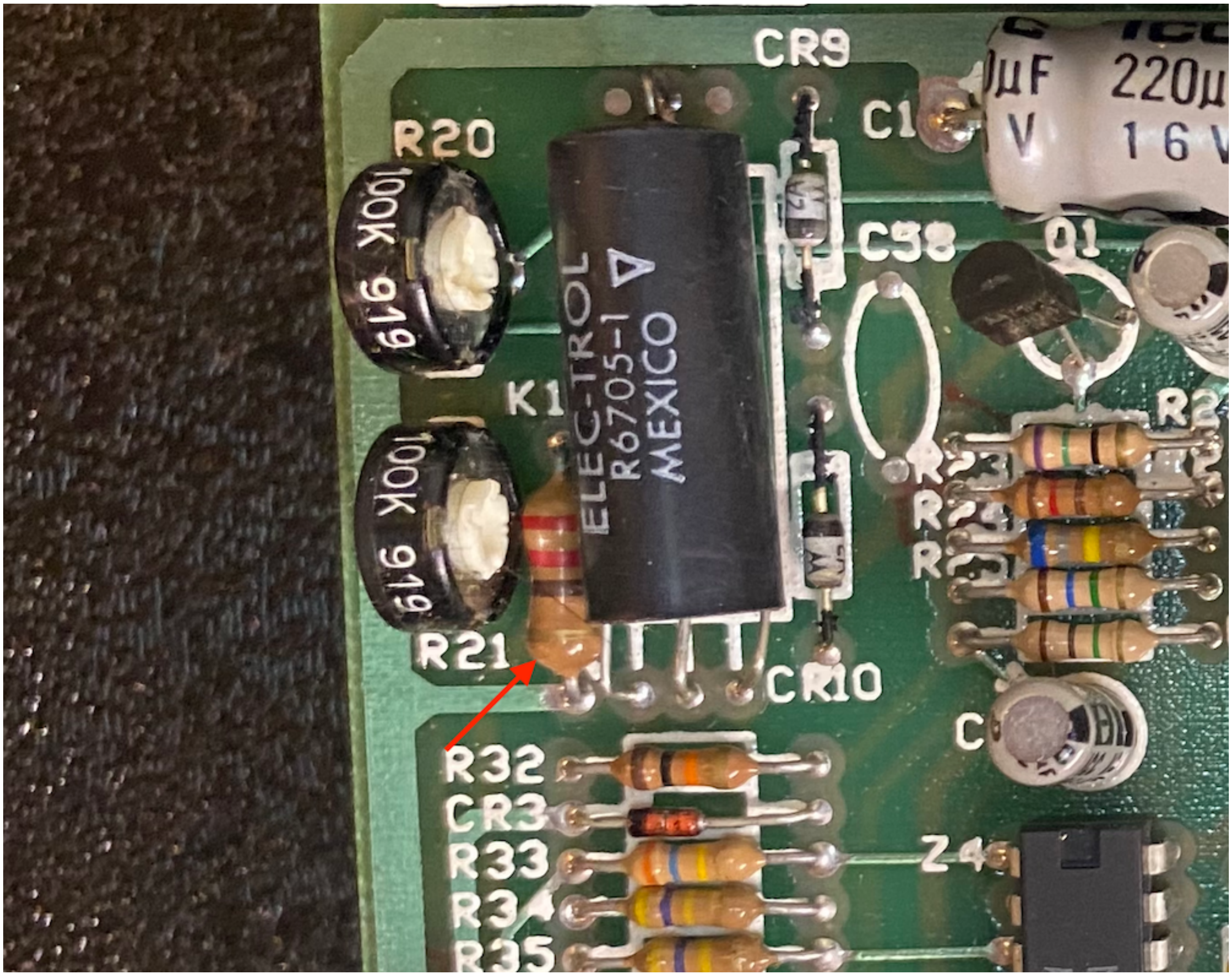


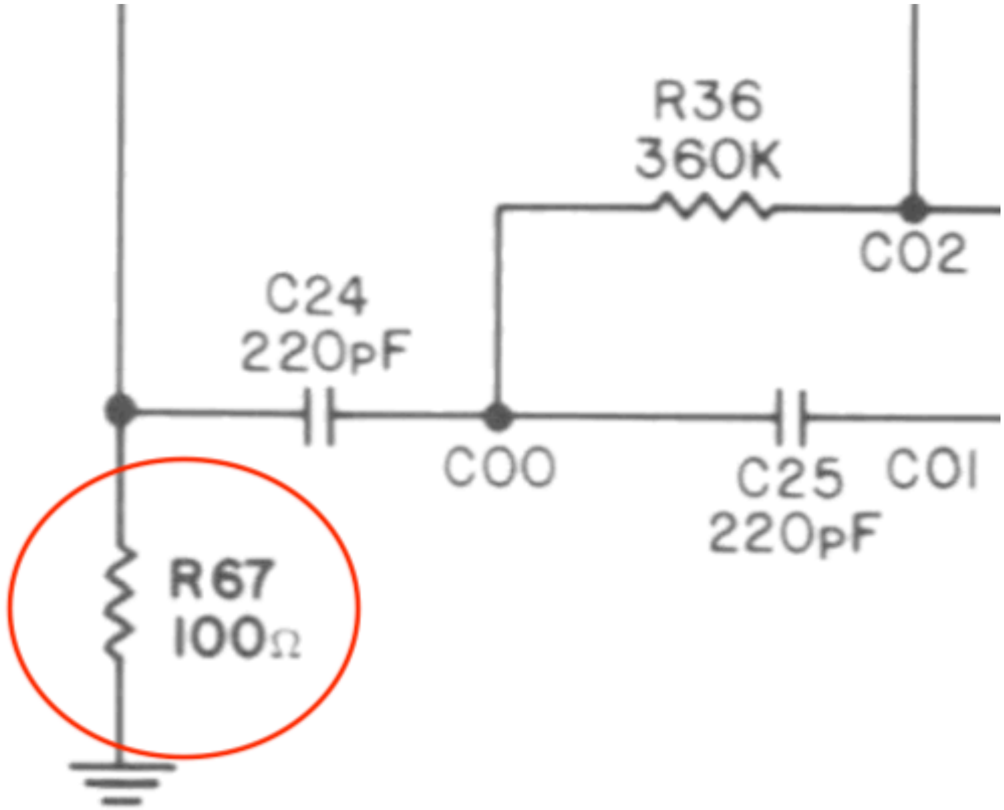




There is, however, a capacitor missing on the board. This capacitor is also called C58 (yes, there are two of them) and is located right next to the relay. It is missing on all the boards I've seen, but I have added it to the schematics and included a note that it is missing on the PCB. This capacitor is actually part of the Cassette Remote control circuit and seems out of place there.

Wrong Resistor


R20
CR9
C1
220µ
16 V
100K 919
ELEC-TROL
R67705-1
MEXICO
C58
Q1
K1
R21
CR10
R32
CR3
R33
R34
R35
Z4

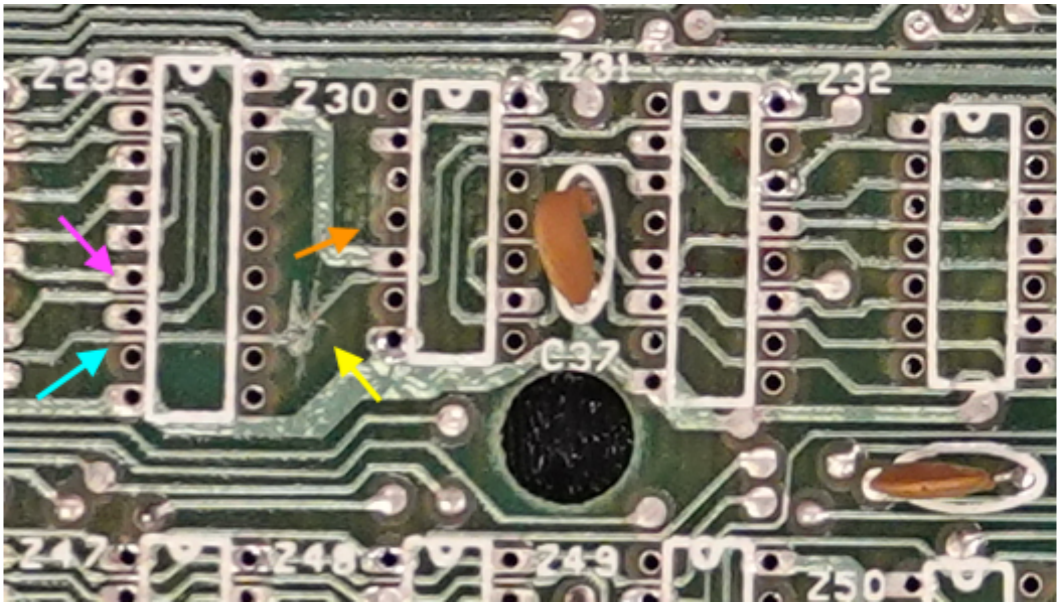


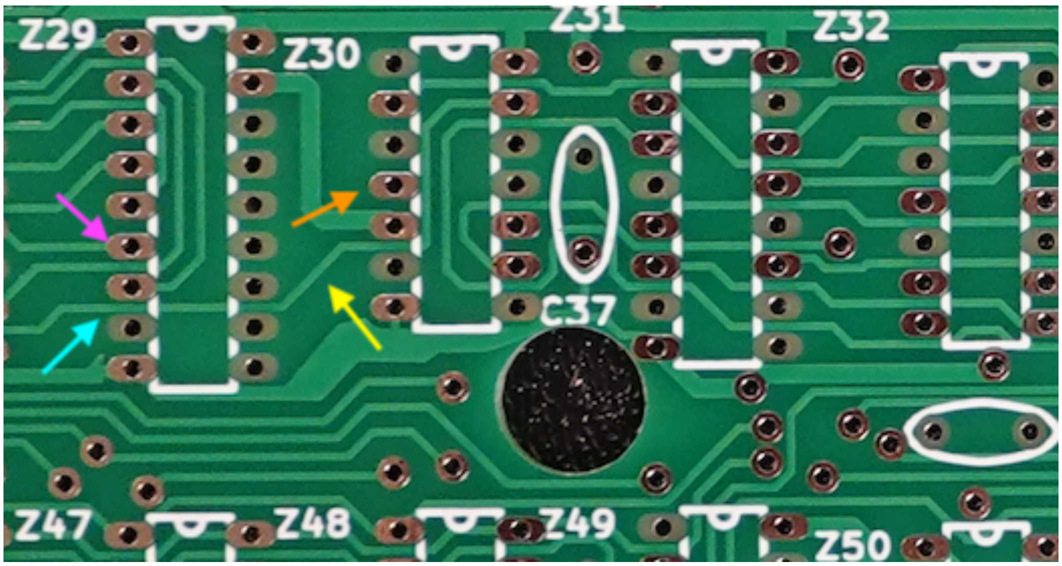
Next to the two potentiometers for the H- and V-Sync, there is supposed to be a 100 Ohm 0.25 Watt resistor, according to the technical documentation. However, on all the boards I have seen, there is actually a 220 Ohm 0.5 Watt resistor instead.

Undocumented 8k RAM support

The board actually supports two different kinds of 8k ICs for the dynamic RAM. This is not documented in the technical reference manual or the user documentation. See Page 7 of the new schematics.

Missing Pads (On the Top)





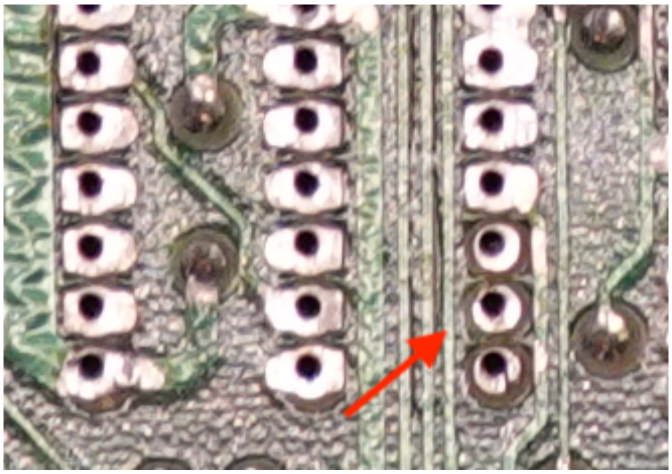
I’ve replicated the "missing pads" on the top of the board as they were on the original board. The pads are only connected at the bottom, so it's fine for them to be missing on the top.

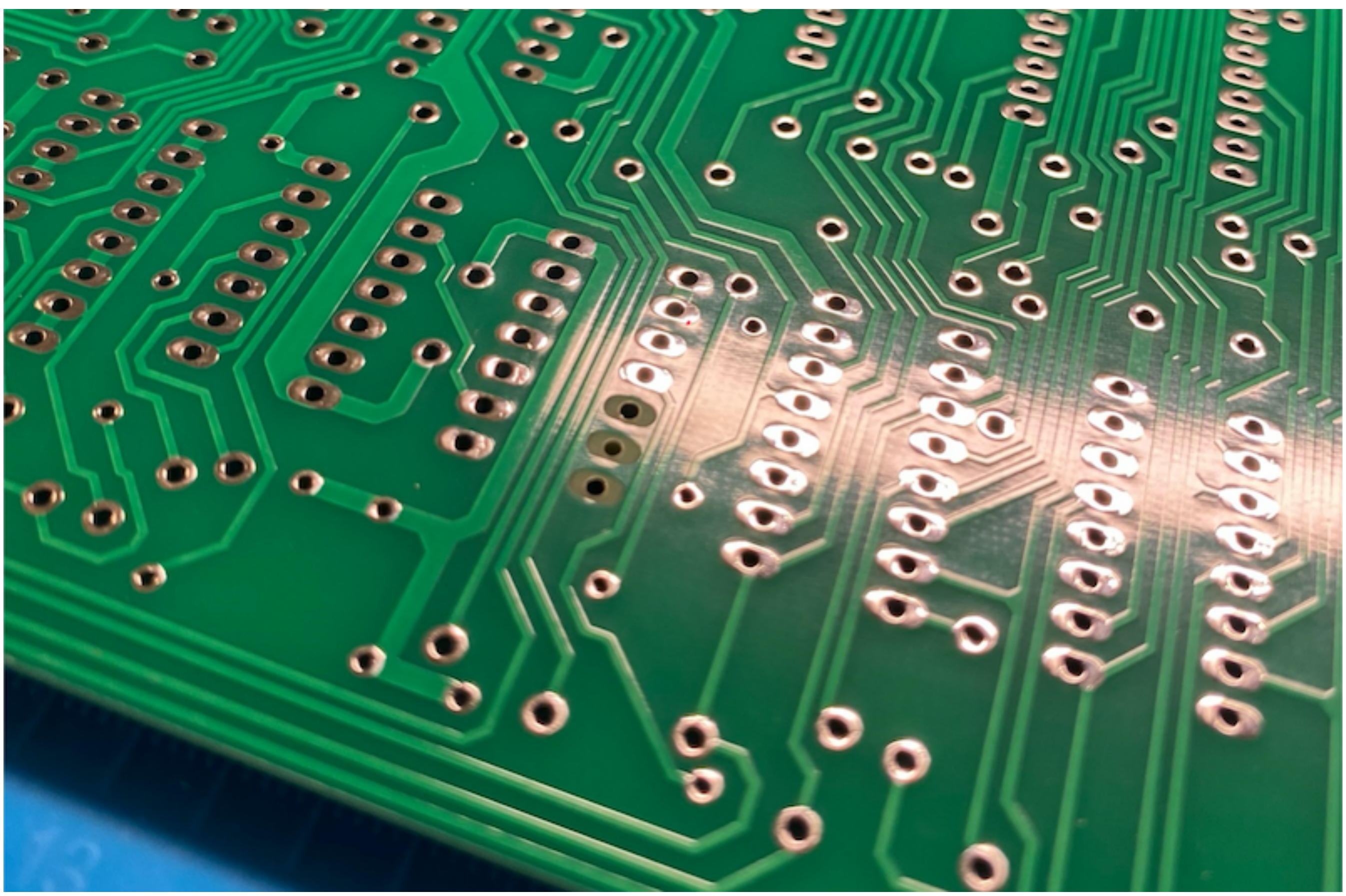
But why was it done this way? At the time, the solder masks weren’t as precise and couldn't adequately cover the traces between pads (see purple/magenta and blue arrow). Bridging those pads and traces during soldering was (and still is) a common issue on these older boards (especially the traces or purple/magenta arrow). That isn’t the case with modern boards, but I still replicated this for the pads only (not the traces in between) to stay closer to the original without the risk of accidental bridging. I guess it's a good compromise.

Completely unconnected pins usually lacked pads on the top as well, but KiCAD doesn't have an option for that, unfortunately. So, I kept them as they are (see orange arrow), meaning they have pads on both the top and bottom.

The yellow arrow is unrelated to this topic, but you can see the cut trace of the original board which is needed for the lower-case mod.

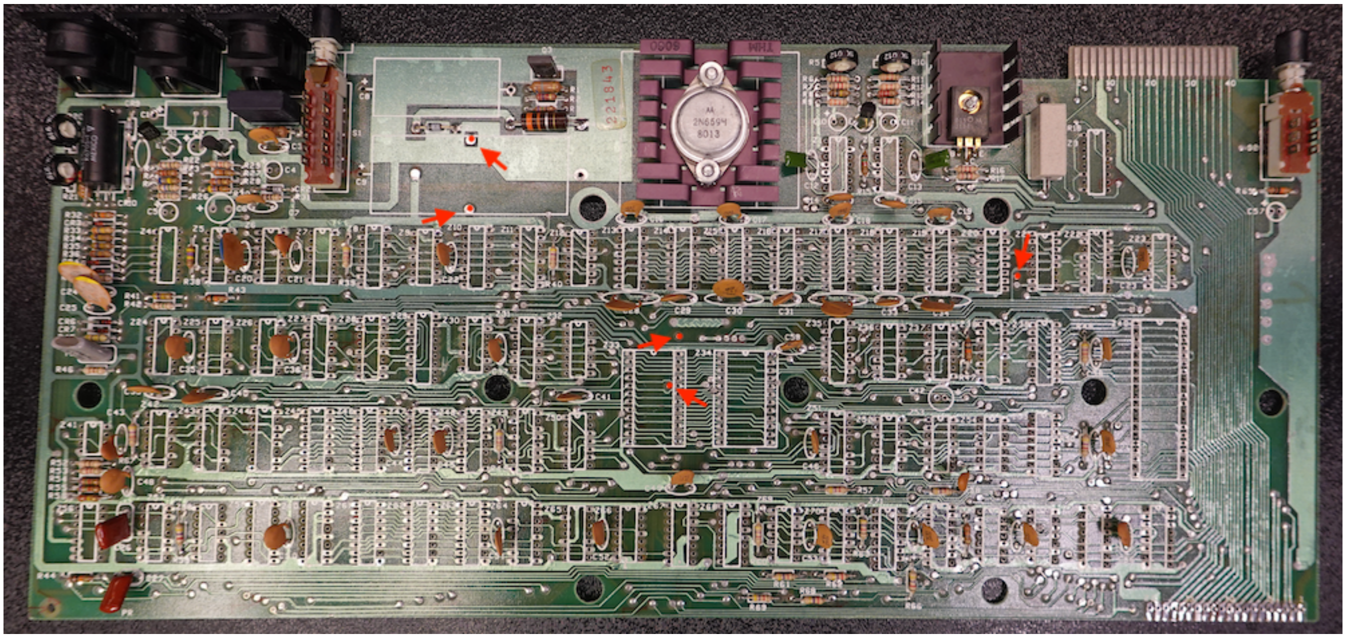
Missing Pads (On the Bottom)





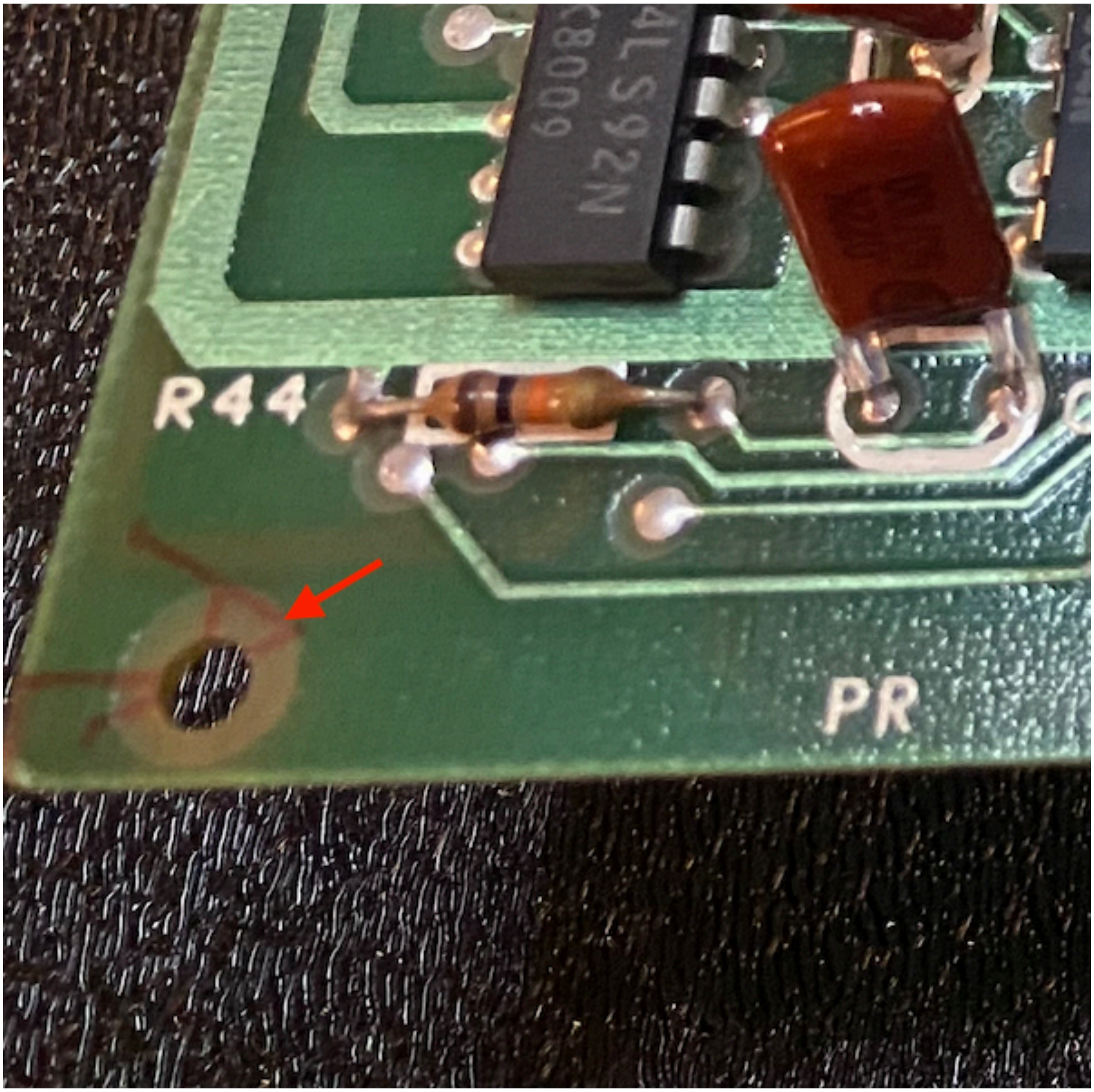
I replicated three missing pads on the bottom of the board at Z69. While accurate to the original, it was a pain to solder the sockets to the pads while they rested on top of the board. I don't use wave soldering as they did in the original, so that was just annoying. In the newest version of the board, I placed these pads back to make them easily solderable.

Unused Vias



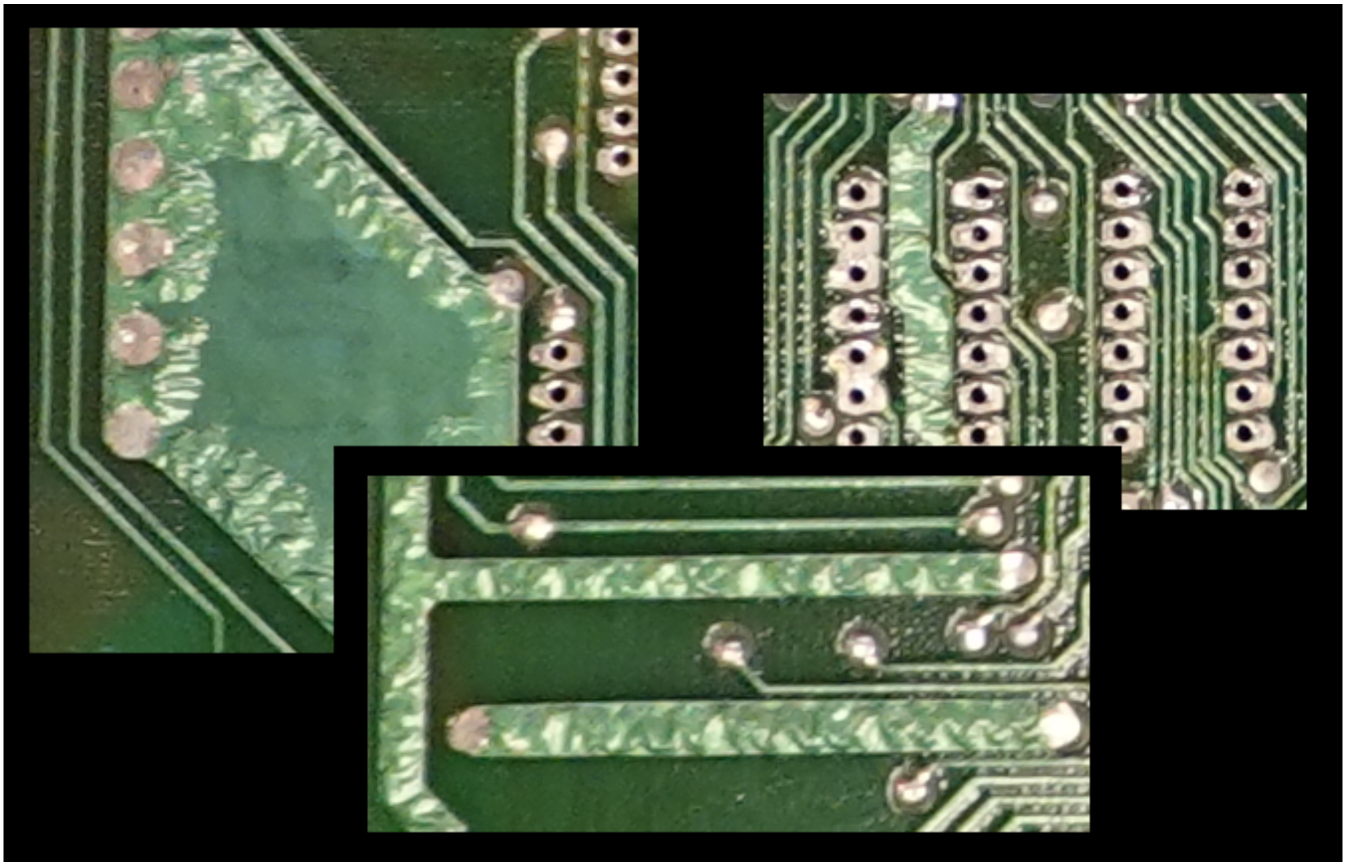
There are a bunch of unused vias on the board. I am not entirely sure why that is.

Small Holes



At the edges of the board, you can see two rather small holes. These were used during the manufacturing process to keep the board in a known position, enabling the machines to create and assemble the board.

Bumpy Traces and Zones



If you ever wonder what these "bumpy" traces and fill zones are, they are not dissolving or anything of that nature. This is how they are supposed to be. The boards were assembled in this way. The traces and zones were tinned, then solder mask was applied, covering nearly everything. When the board was wave soldered with the components in place, these tinned traces melted again due to the heat and solidified shortly after. The tension of the solder mask kept them in somewhat random shapes and caused these bumps. You can actually see this if you put your soldering iron to a pad close to these bumps; you will see that the tin beneath the solder mask liquifies and can even be sucked out by a desoldering iron or pump.

Since the method of tinning has changed (using HASL nowadays) and I don't wave solder, this isn't happening anymore, and it is difficult and probably costly to replicate.

Main TRS-80 Model 1 Repository

For additional resources related to the TRS-80 Model 1, be sure to check out the central page for the TRS-80 Model 1 on RetroStack.

Support this Project

RetroStack is passionate about exploring and preserving the legacy of older computer systems. My work involves creating detailed documentation and videos to share the knowledge. I am also dedicated to reviving these classic systems by reimplementing them and offering replacement parts at no cost. If you're keen on supporting this unique project, I invite you to visit my Patreon page. Your support would be immensely valuable and greatly appreciated!

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