EconoPET 40/8096

Open Hardware Commodore PET/CBM Mainboard

Hardware Rev. A - 2025-08-23

"Daddy, can we make a computer?"
—Milo, age 8

Please Don’t Sue Me

This project is provided "**as is**," without warranty of any kind, express or implied. Use of this project is at your own risk. The authors and contributors are **not liable for any damages, injuries, including serious injury or death, or losses resulting from its use.**

⚠️ Safety Warning

If you are not experienced with high-voltage electronics, seek guidance or supervision before proceeding. Always **unplug the system before opening it** and be aware that **the CRT can retain a deadly high-voltage charge even when unplugged**.

PCBs can contain hazardous materials, including lead-based solder. Use appropriate personal protective equipment (PPE). **Do not eat, drink, or smoke while handling PCBs.** The **CRT is under vacuum and may implode** if physically damaged. Commodore PET/CBM machines may contain **sharp metal edges**.

Soldering involves high heat, molten metal, fumes, and burn risk — work in a ventilated area, wear safety glasses, keep flammables away, and unplug the iron when not in use.

⚠️ Handling and Care Guidelines

When installing or servicing, **hold the board by its edges** and **avoid flexing or bending**. **Keep boards away from moisture, dust, direct sunlight, and extreme temperatures** to ensure long-term reliability.

Be gentle with PCB mounted connectors and note that the microSD card slot uses a push-to-eject mechanism.

To protect both the EconoPET and your original PET/CBM mainboard, **handle all boards using proper ESD precautions**. Always work on an ESD-safe surface or wear a grounded wrist strap. Avoid touching circuitry directly and store boards in anti-static bags when not in use.

⚠️ Not for Mission Critical Applications

The EconoPET is an amateur/hobbyist project that seemed worth sharing. **The EconoPET is not certified by any standards or regulatory authority for any purpose.**

ℹ️ Trademark and Copyright Notice

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Introduction

The EconoPET 40/8096 is an open hardware recreation of the Commodore PET/CBM mainboard. It can be used to repair or upgrade a 2001, 30xx, 40xx or 80xx series machine. The EconoPET can also be used independently with an HDMI display and USB keyboard.

EconoPET as mainboard replacement

EconoPET as stand-alone computer

Features

Functionally, the EconoPET 40/8096 hardware is most similar to the Universal Dynamic PET v2 mainboard with a 64KB Expansion Memory Board installed.

- 96KB RAM (32KB base + 64KB banked expansion)
- Compatible I/O:
    - IEEE-488 port
    - User port (with optional 5V supply on pin 2)
    - Two Cassette ports (with configurable device #s)
- Native PET video generator:
    - Supports both 40 and 80 columns
    - Supports 9” (15 kHz) and 12” (20 kHz) monitors
    - Programmable CRTC (when using 12” monitor only)
- Support for both US graphics and business keyboard layouts

- Small internal speaker

The EconoPET also adds some modern conveniences. These include:

- Menu selectable ROM set with 40/80 column switching.
- 3.5mm Audio Jack (requires amplified speakers)
- USB-C port for use with an ANSI/ISO keyboard
- HDMI port for use with modern displays (720x480p 60Hz)
- Updateable firmware via microSD card

For troubleshooting (and hackers) the EconoPET breaks out most board signals on pin headers. For more details, refer to the schematics in *Appendix A*.

Limitations

Limitations of the EconoPET mainboard replacement include:

- The EconoPET is **not compatible with expansion boards that connect to IC sockets** (Custom ROMs, RAM boards, SuperPET boards, etc.)

- **The CRTC is only programmable when using a 12" monitor**. When using a 9" monitor, the CRTC registers are not writable to prevent accidental damage.

- **ROMs have been patched** to fix bugs and support hardware combinations not originally produced by Commodore.

- **Only US keyboards are supported currently.** This applies to both the USB keyboard and native PET keyboard.

The EconoPET CPU operates at 3V3 instead of 5V logic levels, making the EconoPET incompatible with any original accessories that connect to the CPU socket.

There are also no ROM ICs. ROMs are loaded from the microSD card to SRAM at power on. Hackers will have little difficulty figuring out how to load custom ROMs on the EconoPET, but this is not currently documented as 'config.yaml' is unstable and overwritten by firmware upgrades.

Setup and Installation

This section describes the process of getting the EconoPET board up and running. There are three main steps to follow:

1. **Initializing the microSD card** describes the process of downloading the board firmware and copying it to a formatted microSD card.
2. **Board Configuration** involves setting various switches and jumpers to configure the EconoPET for your CBM/PET model.
3. **Board Installation** gives instructions for opening the CBM/PET case, removing the original mainboard, and installing the EconoPET board.

Each step is described in the following sections.

Initializing the microSD Card

The EconoPET uses a microSD card to configure the system at power on and reset. To prepare a microSD card for the EconoPET, or upgrade the firmware in the future, you will need to perform the following steps:

- Download and unzip the latest firmware from the EconoPET site: https://dlehenbauer.github.io/econopet/40-8096-A.html
- Format the microSD card with the **FAT32** or **exFAT** filesystem
- Copy the unzipped contents of the firmware archive to the root of the microSD card

If you have trouble trouble formatting the microSD card, try the SD Memory Card Formatter tool from the SD Association: https://www.sdcard.org/downloads/

⚠️ **Note** – The microSD card reader uses a *push-to-eject* mechanism for card removal. **Do not remove the card by pulling.** Please be gentle with PCB mounted connectors.

⚠️ **Note** – "Hot insertion" is not recommended. **Please ensure the CBM/PET is powered off when removing/inserting the microSD card.**

⚠️ **Note** – Formatting permanently erases the contents of the drive. Be sure you have the intended drive selected before starting the format.

Board Configuration

First read the **Safety Warnings** and **Handling and Care Guidelines** at the beginning of this manual before proceeding. *If you are not experienced with high-voltage electronics, seek guidance or supervision before proceeding.*

Before installing the EconoPET replacement board, there are several important configurations that need to be completed:

- You must assign device numbers to the cassette ports
- You must select the appropriate video configuration for your monitor
- You must select the appropriate layout for your keyboard
- You must choose whether user port pin 2 will provide a video signal or 5V

Each of these options is described in the following sections.

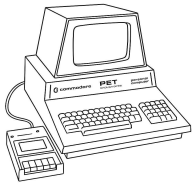
Cassette Port Device Number

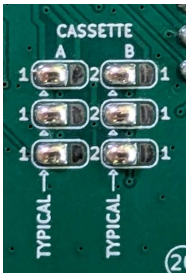
For most CBM/PET models, the cassette port on the back of the machine is assigned to device #1, while the other cassette port is assigned to device #2. The exception is the original PET model with a built-in Datassette. These machines make the built-in Datassette the primary device by assigning it device #1.

On the EconoPET the cassette ports are assigned to device #1 and #2 using solder jumpers on the back of the PCB.

Typical – Bridge all left and middle solder pads.

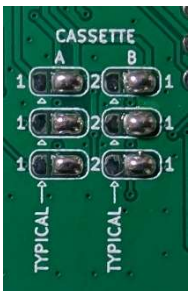
External Datassette is device #1





Built-in Datassette – Bridge all right and middle solder pads.

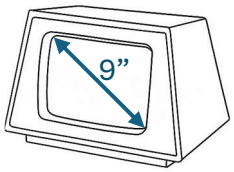
Built-in Datassette is device #1

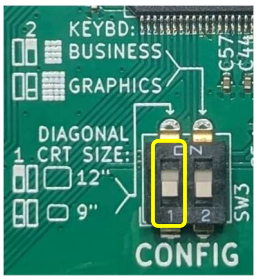


Monitor Type

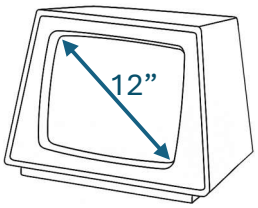
CBM/PET machines with 9" and 12" monitors use different and incompatible video signals. To select the correct video signal for your setup, use the DIP switch #1 located on the top of the EconoPET PCB.

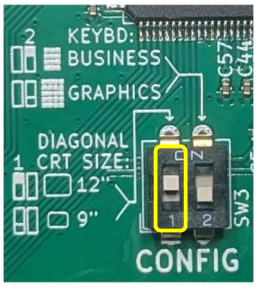
9” Monitor – Put DIP switch 1 in the down/off position.





12” Monitor – Put DIP switch 1 in the up/on position.





⚠️ **Important** - If when powering on the CBM/PET you see a “bright spot” or “line” or hear a repeated ticking sound, **turn the machine off immediately to prevent damage**.

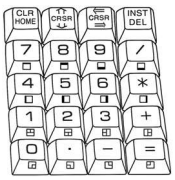
Keyboard Type

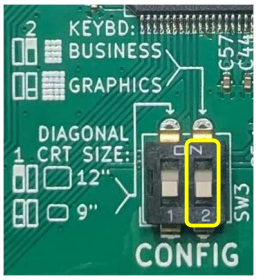
The CBM/PET series machines shipped with two different keyboard layouts: the “graphics” keyboard layout and the “business” keyboard layout.

The graphics keyboard layout can be identified by the PETSCII graphics symbols and 16-key numeric keypad. The business keyboard layout can be identified by number keys in the top row and 11-key numeric keypad.

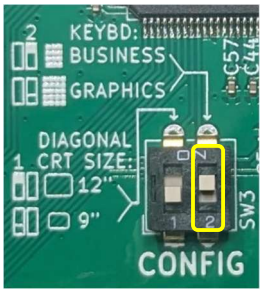
The keyboard matrices of the graphics and business keyboards are incompatible with each other. To select the correct keyboard layout for your setup, use DIP switch #2 located on the top of the EconoPET PCB.

Graphics – Put DIP switch 2 in the down/off position.





Business – Put DIP switch 2 in the up/on position.

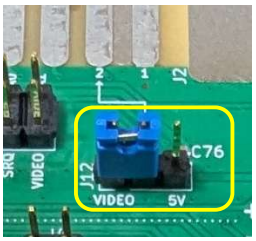


User Port Pin 2

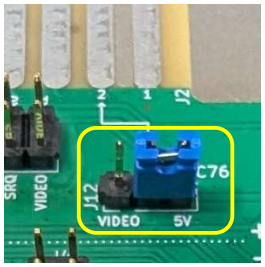
The CBM/PET series machines did not provide a 5V supply at the user port. As a result, many user port peripherals require an adapter that pulls 5V from the cassette port, or a separate power supply.

For convenience, the EconoPET allows you to convert Pin 2 to a 5V supply using a jumper, allowing you to power some peripherals directly from the user port. (Notably, the TexElec SNES adapter.)

Normal – Use the jumper shunt to bridge the left and middle pins. This connects pin 2 of the user port to the CBM/PET video signal.



5V – Use the jumper shunt to bridge the right and middle pins. This connects pin 2 of the user port to the +5V supply.



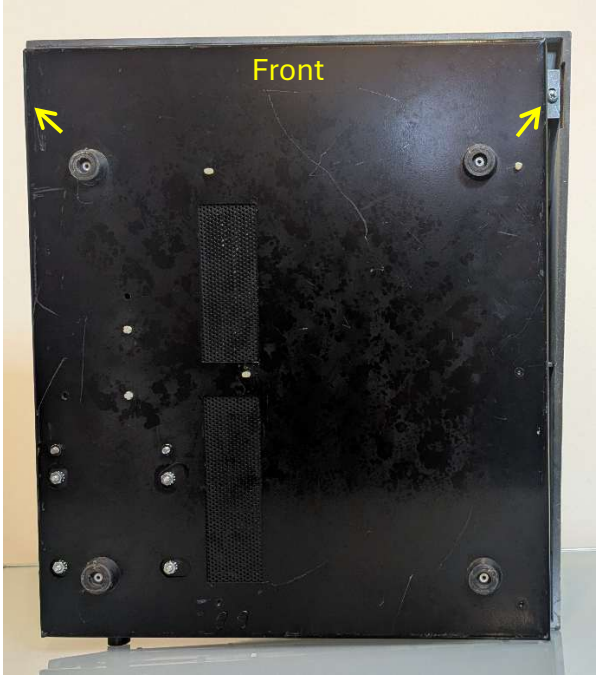
Board Installation

First read the **Safety Warnings** and **Handling and Care Guidelines** at the beginning of this manual before proceeding. *If you are not experienced with high-voltage electronics, seek guidance or supervision before proceeding.*

Step 1 – Make sure the machine is turned off and unplugged, then disconnect all external peripherals.

Step 2 – Unscrew and remove the expansion cover on the right side of the machine.

Step 3 – With the machine resting on its back, remove the two screws at the front that connect the bottom to the front.



Step 4 – Setting the machine upright, the case should now open like a clamshell.

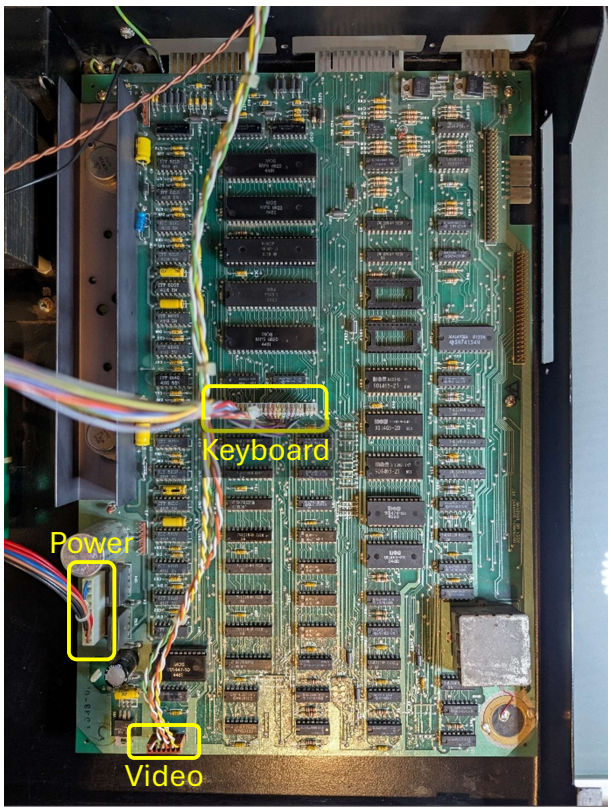
⚠️ **High Voltage Warning**
Never insert fingers, tools, or any objects through the hole accessing the monitor compartment. **Cathode Ray Tubes (CRTs) can retain a deadly high-voltage charge even when unplugged.**

If you are not experienced with high-voltage electronics, seek guidance or supervision before proceeding.

Step 5 – Disconnect the internal power, keyboard, and video connectors.

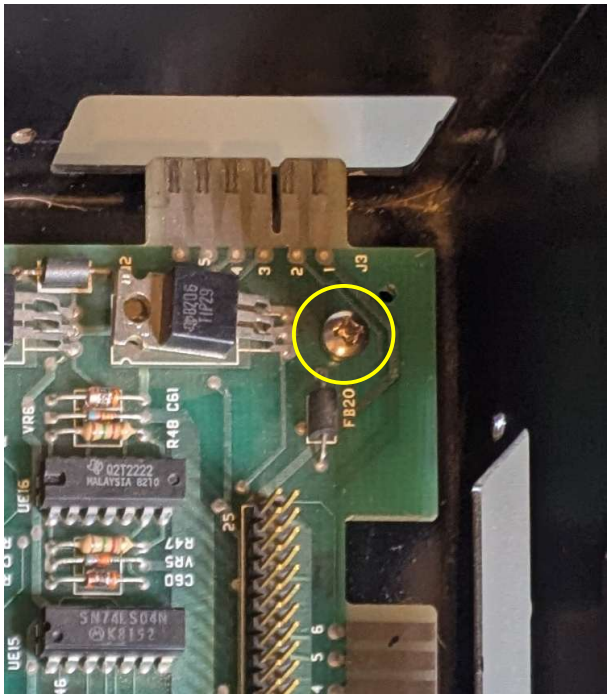
Note: The placement of the power, keyboard, and video connections varies between CBM/PET models.

Be gentle and support the board with your fingers. **Bending or flexing the PCB can damage the traces or solder joints.**



Step 6 – Remove the screws that secure the mainboard to the case. (Save the screws, you'll need them later).

Note: The location and type of mounting hardware varies between CBM/PET models.



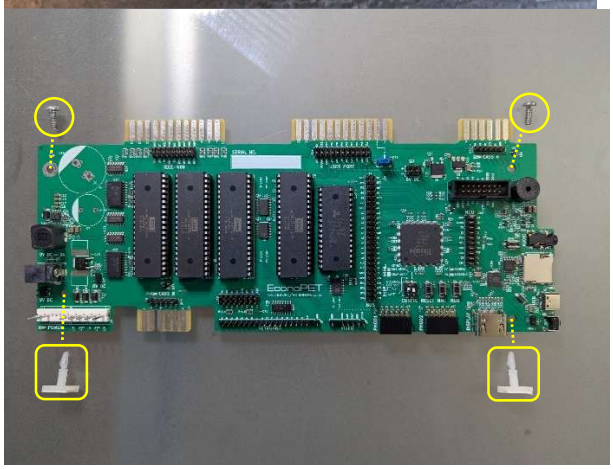
Step 7 – In addition to screws, the mainboard may be connected to the case by plastics tabs.

Pinch the tabs flat with a pair of pliers while gently working the PCB free one hole at a time.

Step 8 – Prepare to install EconoPET

Before installing the EconoPET **check that you have completed the configuration steps** from the *Board Configuration* section.

To secure the EconoPET to the case, you will need two of the mounting screws from the original PCB as well as two 11mm nylon spacers to support the front of PCB.



Step 9 – Mount the EconoPET PCB at the back of the case.

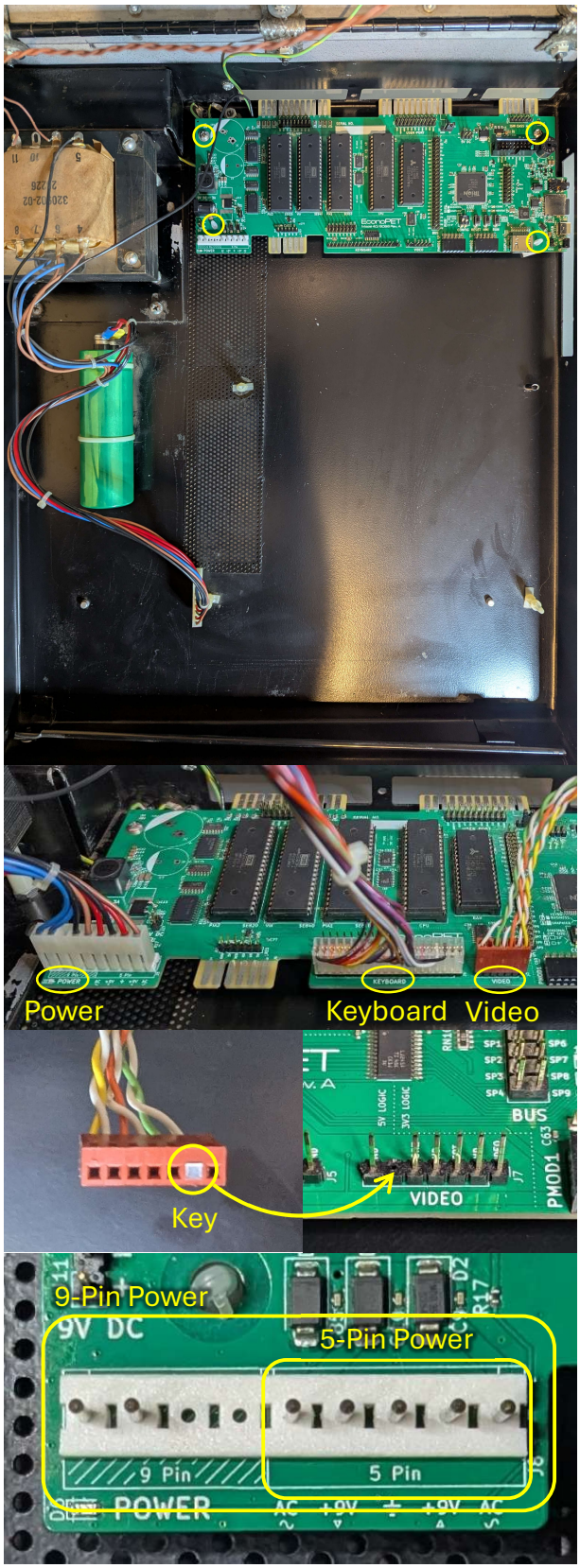
- Place the nylon spacers through the mounting holes near the power and HDMI connectors.
- Insert the top left screw through the PCB into the mounting hole, but do not tighten it.
- Rotate the board until the top right screw hole aligns with the mounting hole and insert screw.
- Tighten the two mounting screws until *just* snug. Be gentle and do not overtighten.

Step 10 – Reconnect the Power, Keyboard and Video cables.

The keyboard, video, and 9-pin power connectors are keyed and can only be connected one way.

If your CBM/PET's power connector has only 5-pins, use the right-most 5-pins on the EconoPET. (The 5-pin connector is symmetrical, so the orientation does not matter.)

Note: To avoid flexing the PCB when pressing down to insert connectors, gently support the underside of the PCB.



Step 11 – Close the CBM/PET case and reconnect power, leaving other peripherals disconnected for the time being.

Turn the CBM/PET power on. After a short pause, you should here a friendly 4-note beep and see the power on menu.

⚠️ **Important** - If when powering on the CBM/PET you see a "bright spot" or "line" or hear a ticking sound, **turn the machine off immediately to prevent damage**.

Troubleshooting

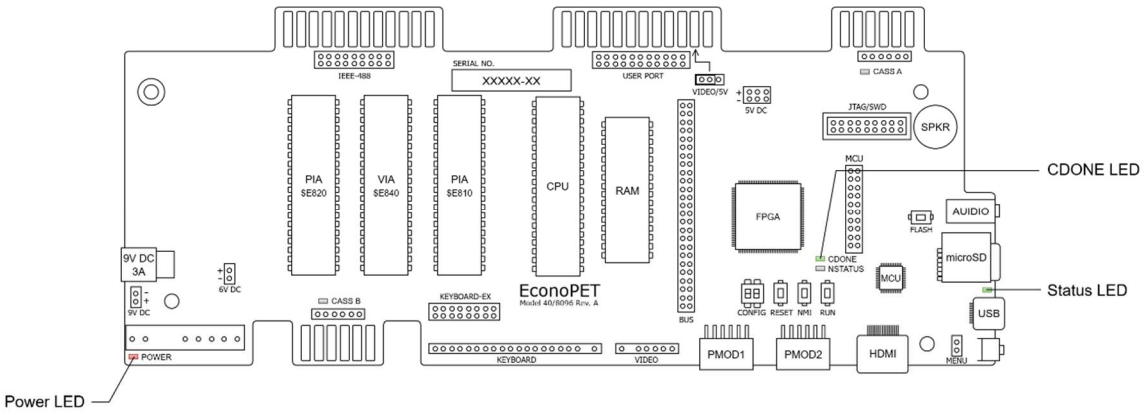
First read the **Safety Warnings** and **Handling and Care Guidelines** at the beginning of this manual before proceeding. *If you are not experienced with high-voltage electronics, seek guidance or supervision before proceeding.*

If you encounter issues with the EconoPET, the first step in troubleshooting is to **disconnect all peripherals**. This includes anything connected to the IEEE-488 port, User port, Cassette ports, USB-C port, and audio jack. By removing these connections, you can isolate the problem and determine if the issue lies with the EconoPET board or with one of the connected devices.

Diagnosing Boot Failures

If the EconoPET does not successfully boot to the Power-On Menu, the next step in troubleshooting is to open the CBM/PET case. With the case open, you will be able to observe the system's internal LED indicators, which provide information about how far the boot sequence progresses and help identify where the startup process may be failing.

The three main indicators are the Power LED, the Status LED, and the CDONE LED. The location of these LEDs is shown in the following diagram.



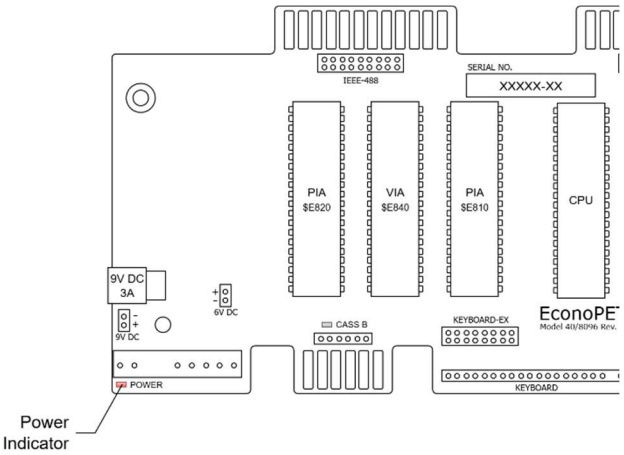
Under normal circumstances, the Power LED will be lit and the Status and CDONE LEDs will progress through the following states during power on:

Status LED	**CDONE LED**	**Meaning**
One short blink	Off	Bootloader has completed / Firmware starting
On (solid)	Off	Firmware is initializing EconoPET hardware
Off	On	EconoPET initialized

At this point you would normally hear a happy 4-note beep and the Power-On menu will appear on both the CBM/PET monitor and the HDMI display. If that is not the case, consult the following sections.

Power LED Does Not Light

The first LED to light is the red power indicator in the lower left corner, just below the CBM/PET power connector.



If the Power Indicator LED fails to illuminate when the system is switched on, check the following:

- With the power off and machine unplugged, **disconnect all peripherals** as described at the beginning of the Troubleshooting section.

- **Verify that the machine is plugged in** and that the outlet is working outlet. Try eliminating any extension coords or power strips.

- **Check that the internal power connector is correctly connected** to the EconoPET (see Board Installation section).

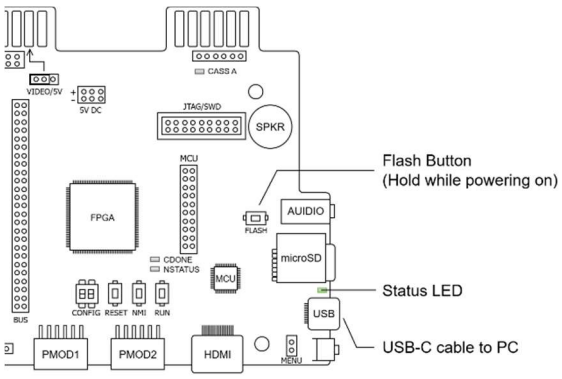
- **Ensure that the CBM/PET power switch is in the *ON* position**. Note that the ON / OFF orientation of the CBM/PET power switch may be counter intuitive.

If the issue is still not identified, the problem is likely to be the CBM/PET power supply. At this point, you will want to refer to online troubleshooting guides.

Green Status LED Inactive

Under normal circumstances, the green Status LED located next to the microSD card will show activity shortly after power on. If the Status LED remains unlit, this indicates that the EconoPET firmware is missing or corrupted.

Because the EconoPET firmware includes the bootloader that enables microSD card updates, you must first use the USB-C port to install the bootloader before firmware updates from the microSD card will succeed.



To do this, first **prepare a microSD card as described in the *Initializing the microSD Card* section**. (Once the EconoPET bootloader is restored, the microSD card will be used to finish the firmware update.)

To restore the EconoPET bootloader, do the following:

1. **Power off the CBM/PET.**
2. **Connect a USB cable** from the EconoPET's USB-C port to your computer.
3. **Enter flash mode:**
    - Press and hold the **FLASH** button on the EconoPET.
    - **While holding FLASH**, power on the CBM/PET.
    - After a couple of seconds, you can release the FLASH button.
4. The EconoPET will appear on your PC as a **USB mass storage device** named RPI-RP2.
5. **Copy the bootloader file:** Drag and drop the bootloader.uf2 file into the RPI-RP2 drive. (bootloader.uf2 is contained in the same .zip used to initialize the microSD card.)
6. After the file is copied, the EconoPET will automatically reboot and finish the firmware update from the microSD card. (Green LED will blink rapidly during this process.)

7. Disconnect the USB cable and proceed with troubleshooting (if necessary).

Status LED Error Indications

Under normal operation, the green **Status LED** next to the microSD card reader will:

- **Blink once** at power-on.
- **Turn on solid** while the EconoPET hardware is initializing.
- **Turn off** once initialization is complete.

If instead the Status LED blinks in a **continuous repeating pattern**, this indicates that the EconoPET has halted due to a critical error.

CDONE LED	Status LED	Description
Off	— ▪	The EconoPET bootloader could find the file 'firmware.uf2' at the root of the microSD card. 1. Turn off the machine 2. Prepare the microSD card as described in the *Initializing the microSD Card* section 3. Reinsert the microSD card into the EconoPET 4. Turn on the machine.

Beep with No Video / Bad Video

If you hear the startup beep but do not see the boot menu on the CRT, verify that the CBM/PET video cable is securely connected and that **DIP switch #1** is set for the correct monitor type (see the *Monitor Type* section for more details).

⚠️ **Important** - If when powering on the CBM/PET you see a "bright spot" or "line" or hear a ticking sound, **turn the machine off immediately to prevent damage**.

Error Message at Power On

If an error message appears at power-on, it usually indicates a problem with the contents of the microSD card. To resolve this, reformat and reinitialize the card as described in the *Initializing the microSD Card* section.

Keyboard Issues

If you have successfully booted to BASIC but find that typing on the CBM/PET keyboard produces the wrong characters, you probably have misconfigured the keyboard type. Power off the machine and toggle DIP switch #2 and see if this corrects the problem.

Also note that some CBM/PET programs that read the key matrix state directly from the PIA are only compatible with a specific keyboard layout (generally, it is games that assume the graphics keyboard layout). There's no good solution other than to fix the software.

However, when using a USB keyboard, you can work around the issues using the Num Lock key. Num Lock will toggle the USB keyboard between the business and graphics layout.

Cassette Ports Issues

If the cassette ports do not function as expected, verify that the device numbers are correctly assigned. The device number for each cassette port is set using the solder pads on the back of the EconoPET board. Refer to the *Cassette Port Device Number* section for instructions on selecting the correct configuration.

User Port Video Output Issues

If you are using a device that generates video from the User Port (such as a composite video adapter) and the output appears blank or incorrect, confirm that video output has been enabled on **User Port Pin 2**. Refer to the *User Port Pin 2* section for details on selecting and configuring this output.

Other Issues

If you've reached this section of the manual, I'm sorry. :-(

If the problem is with the EconoPET replacement board, please create an issue on GitHub and let me know what went wrong:

https://github.com/DLehenbauer/econopet/issues

The EconoPET is an open hardware / public domain hobbyist project. For those with a background in electronics, schematics for the EconoPET board are provided in *Appendix A*. The firmware source code and KiCad hardware project files are available on GitHub.

Help is always warmly appreciated.

For **general troubleshooting and repair of Commodore PET/CBM machines** (such as power supply or video display issues), I highly recommend the Commodore PET / CBM Enthusiasts group on Facebook:

https://www.facebook.com/groups/214556078753960

Acknowledgements

This project would not have been possible without the advice and encouragement of the Commodore PET / CBM Enthusiasts community on Facebook. I am particularly grateful to the following members, who were generous in sharing their time and expertise:

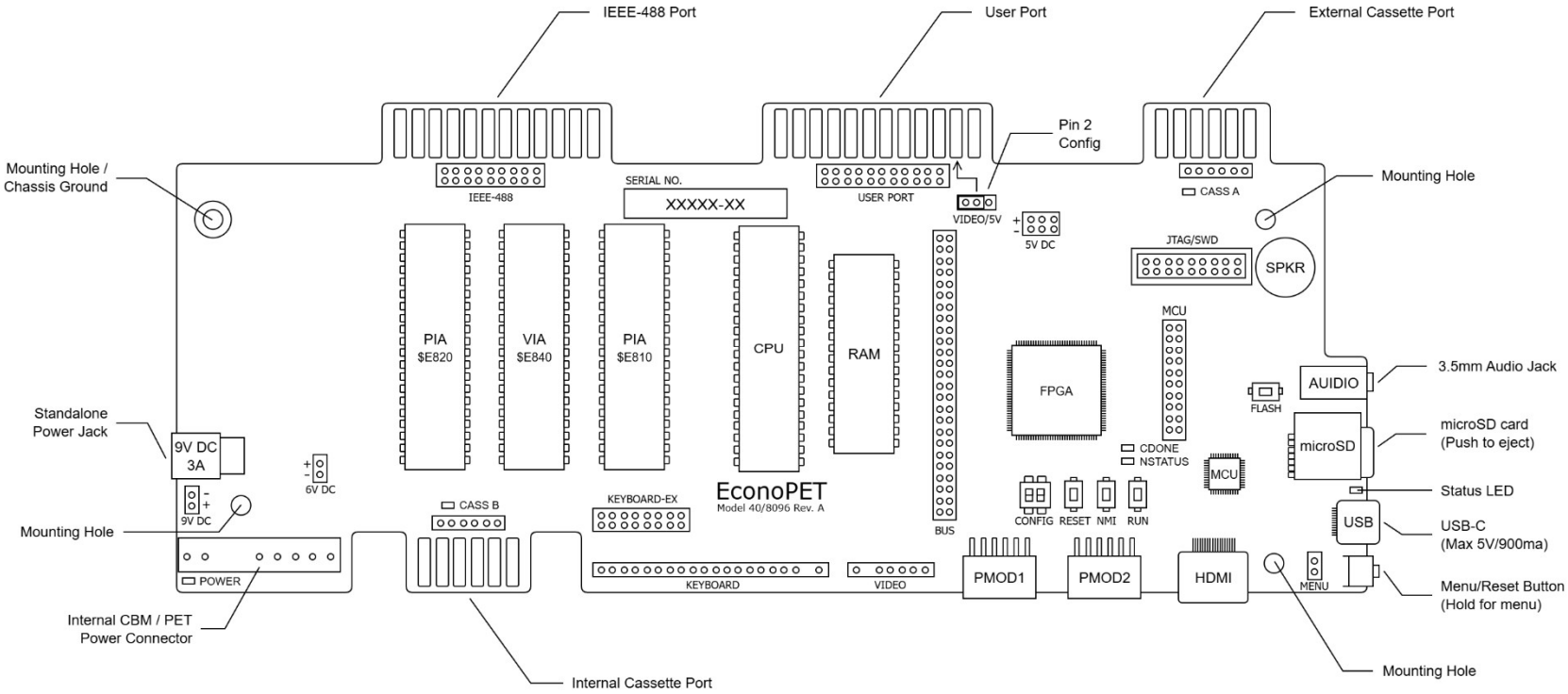
Gavin Andrews
Ethan Dicks
Steve Gray
Chuck Hutchins
Mia Magnusson
Sven Petersen
Jannie Van Zyl

These individuals guided me through schematics, probed machines with oscilloscopes and multimeters, and answered many technical questions about the CBM/PET.

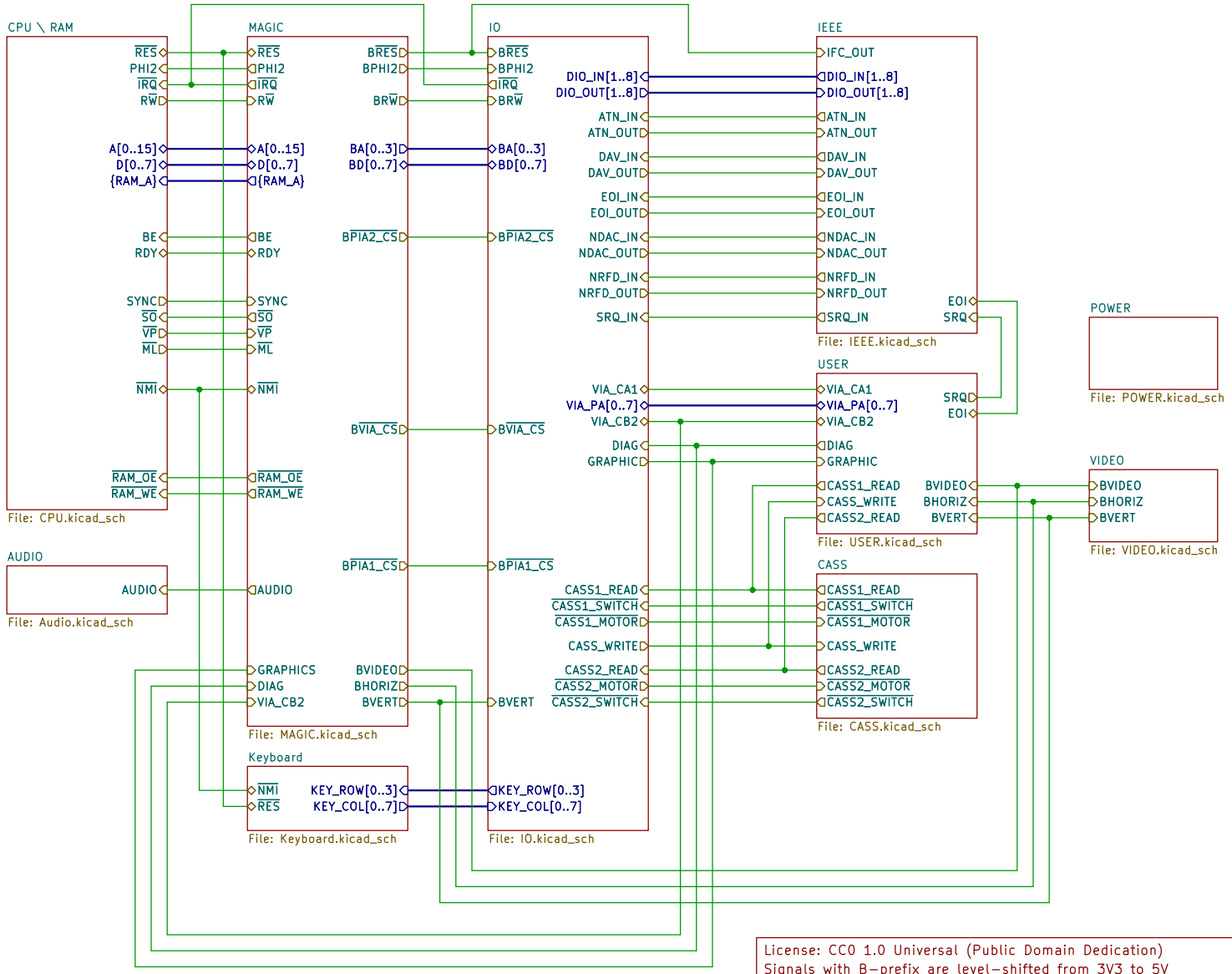
I am also grateful for the patience and support of my family. The project started with a simple question from my son (and became much more ambitious when he asked to run ORB's *No Pet's Allowed* demo.) I am thankful for my wife, Bonnie, who — together with her brother and sister-in-law — helped acquire the CBM 8032 shown in the photos. This made it possible for me to test the EconoPET in a real machine.

Appendix A

Board Layout and Schematics



System Block Diagram



"If you don't use a current limiting resistor the LED will light up orange! Because of the fire! Because sometimes Daddy makes mistakes."

– Milo, Age 4.5

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Signals with B–prefix are level–shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /
File: Mainboard.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023–10–01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 1/17

CPU and RAM operate at 3V3 so that the system bus and CPU control signals can be directly shared with the FPGA.

Level shifters are used for connections to the 5V I/O section. This design avoids needing level shifters for A[5..16].

The FPGA deasserts BE (Bus Enable) to transition the CPU's Address, Data, and RW buffers to high-Z when the FPGA drives the bus.

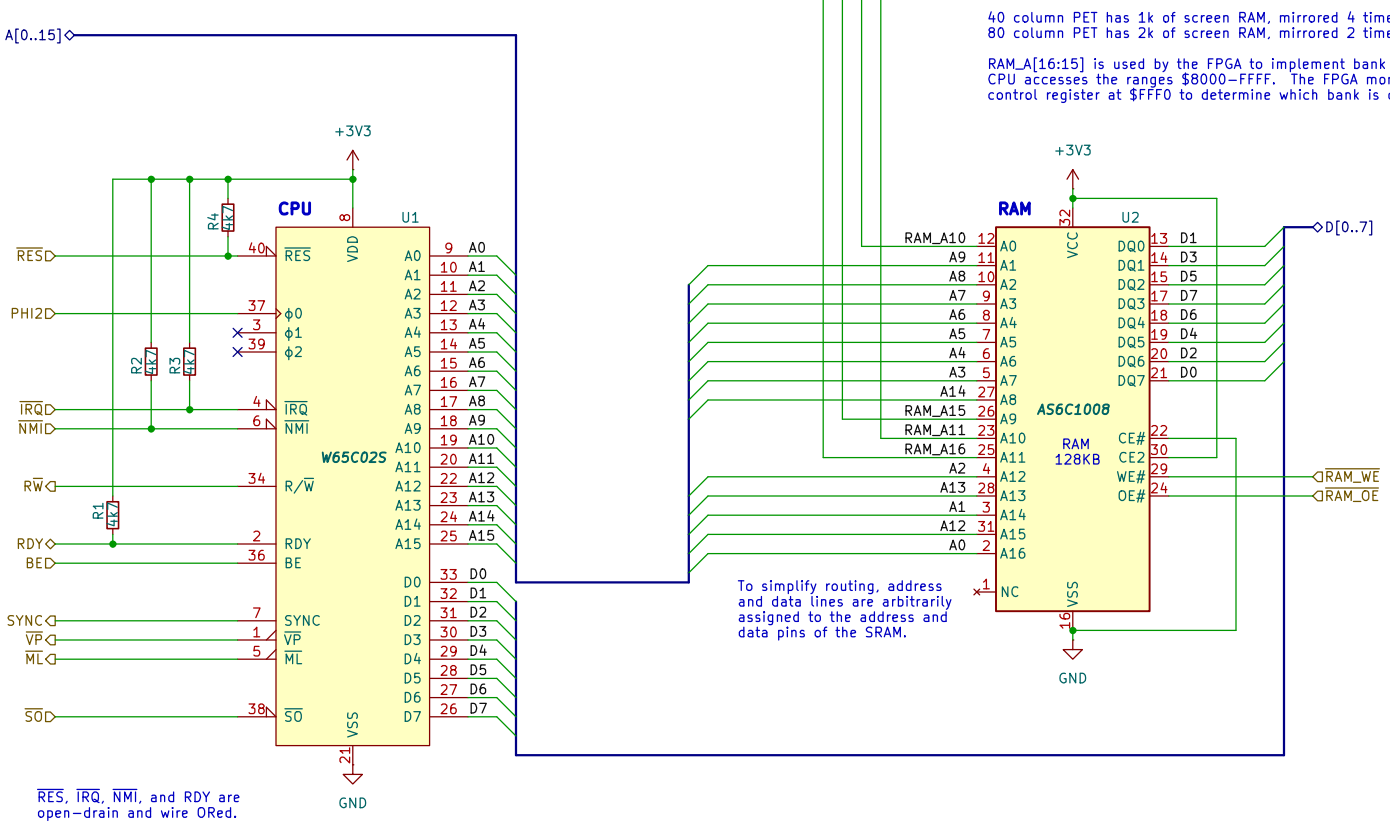
A single 128KB SRAM chip is used for the 32K main RAM, 64K expansion RAM, 2K display RAM, 2K character ROM and 26K system ROM. ROMs are initialized by the MCU on POR (via SPI -> bus bridge provided by the FPGA).

A[15:0] are the address of the shared system bus, which is connected to the CPU, IO, FPGA and most RAM address pins. The exceptions are RAM_A[16:15,11:10], which are driven exclusively by the FPGA.

RAM_A[11:10] is used by the FPGA to mirror display RAM when the CPU accesses the range $8000-8FFF.

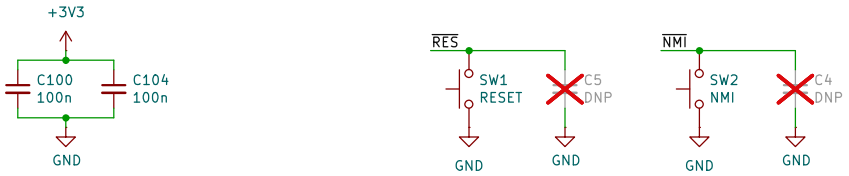
40 column PET has 1k of screen RAM, mirrored 4 times.
80 column PET has 2k of screen RAM, mirrored 2 times.

RAM_A[16:15] is used by the FPGA to implement bank switching when the CPU accesses the ranges $8000-FFFF. The FPGA monitors writes to the control register at $FFF0 to determine which bank is currently selected.



$\overline{RES}$, $\overline{IRQ}$, $\overline{NMI}$, and RDY are open-drain and wire ORed.

$\overline{SO}$ is driven high by the FPGA.



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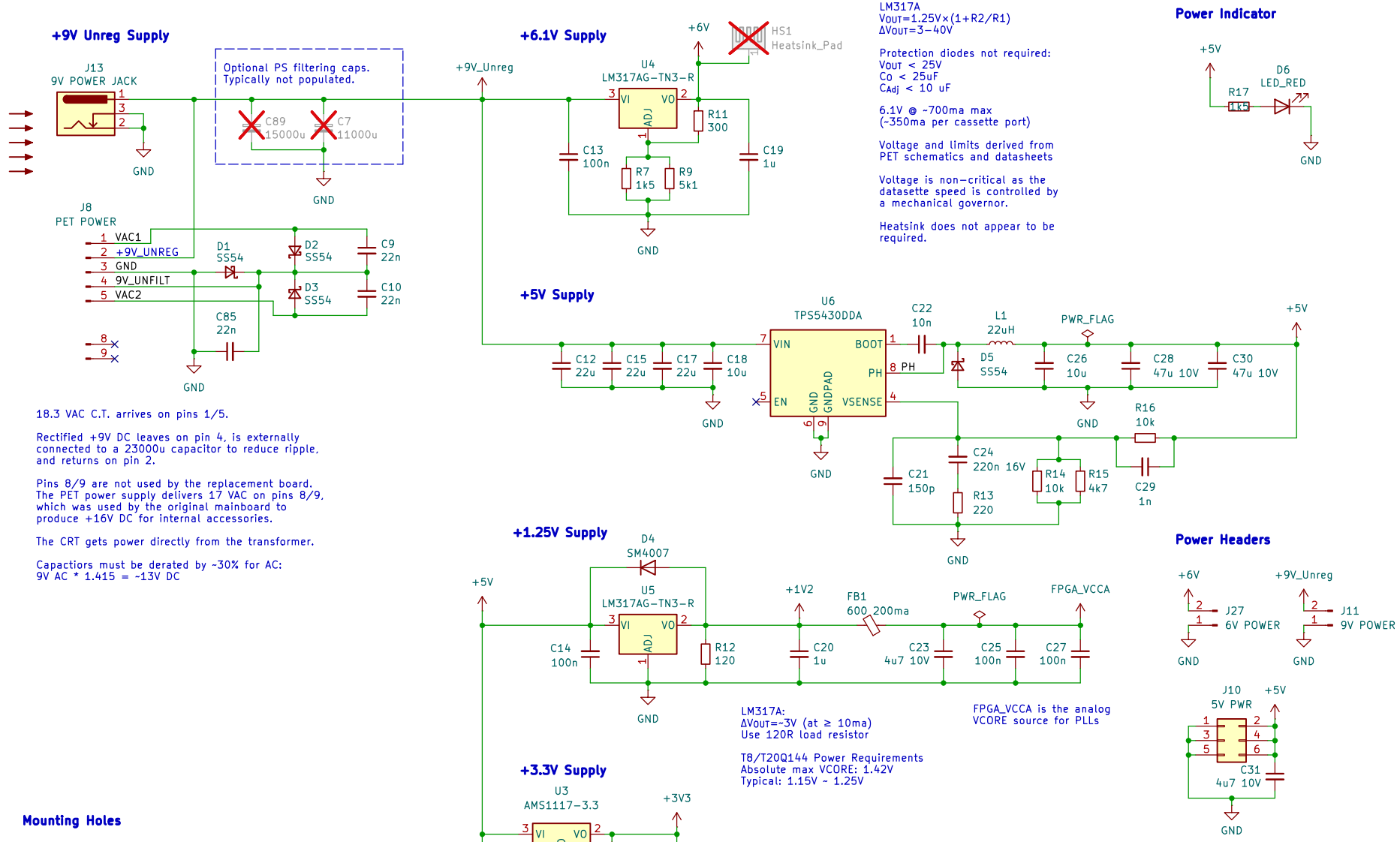
Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /CPU \ RAM/
File: CPU.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 2/17



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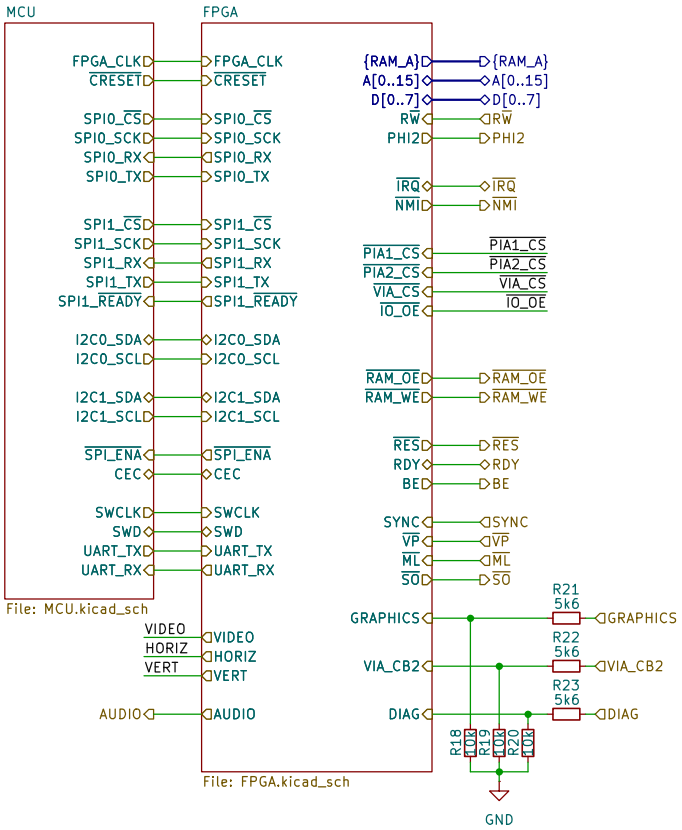
Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /POWER/
File: POWER.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 3/17

Magic



MCU responsibilities:
- Generate FPGA_CLK
- Configure FPGA at POR
- Initialize SRAM with ROM images
- Read back video RAM and output to HDMI (bit-banged DVI)
- Report USB keyboard matrix to FPGA

FPGA responsibilities:
- Timing / address decoding
- Native PET video generation / CRTC
- Expose sysem bus to MCU (via SPI)
- Intercept PIA1 to inject USB keyboard

SRAM is shared between the 6502 and the FPGA by using an effective bus speed of 8 MHz taking turns in round-robin fashion.

From the CPU and I/O chip's perspective, PHI2 is "stretched" with a 1/8th duty cycle. From the FPGA's perspective, there is an 8 MHz clock and 8 clock enable signals, which are used as follows:

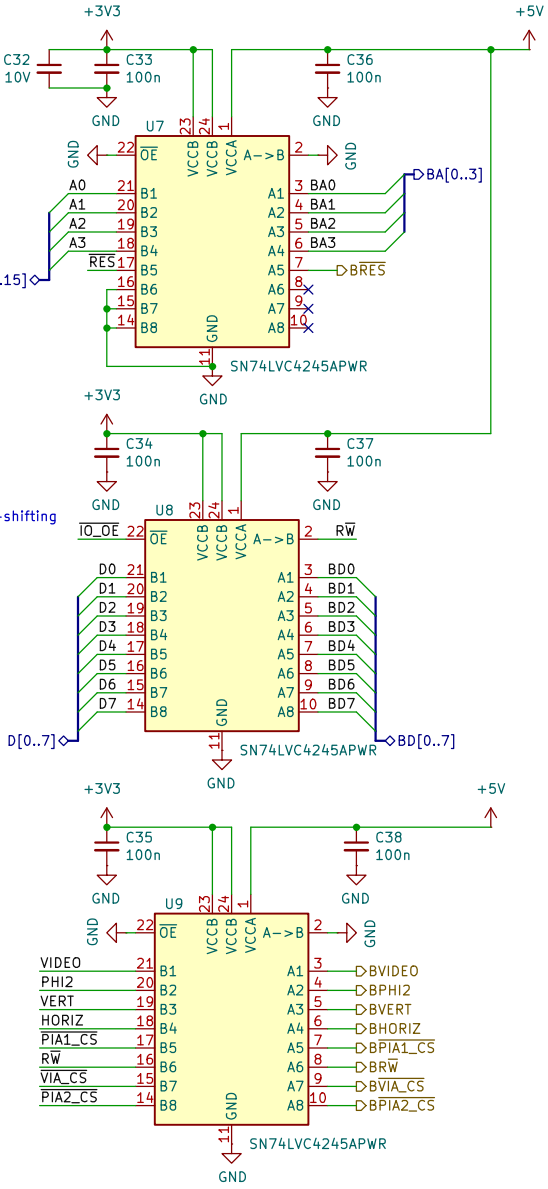
0: Read/write to SRAM to service SPI request from MCU
1: Read even character from VRAM
2: Read even character bitmat from "ROM"
3: Read odd character from VRAM
4: Read odd character from "ROM"
5: Read/write to SRAM to service SPI request from MCU
6: Setup for next CPU cycle
7: Pulse PHI2

(Note: Above subject to change with firmware updates.)

Shift 5V -> 3V3:

VOUT = VIN * (R2 / (R1 + R2)
VIN = 5.1V
R1 = 5.6k - 1%
R2 = 10k + 1%
VOUT = 3.29V

Level Shifting



IO_OE does not require level-shifting (high @ 2V)

PIAs and VIA operate at 5V logic levels for compatible I/O.

CPU and RAM operate at the same 3V3 logic levels as the FPGA and MCU to reduce the amount of level shifting required.

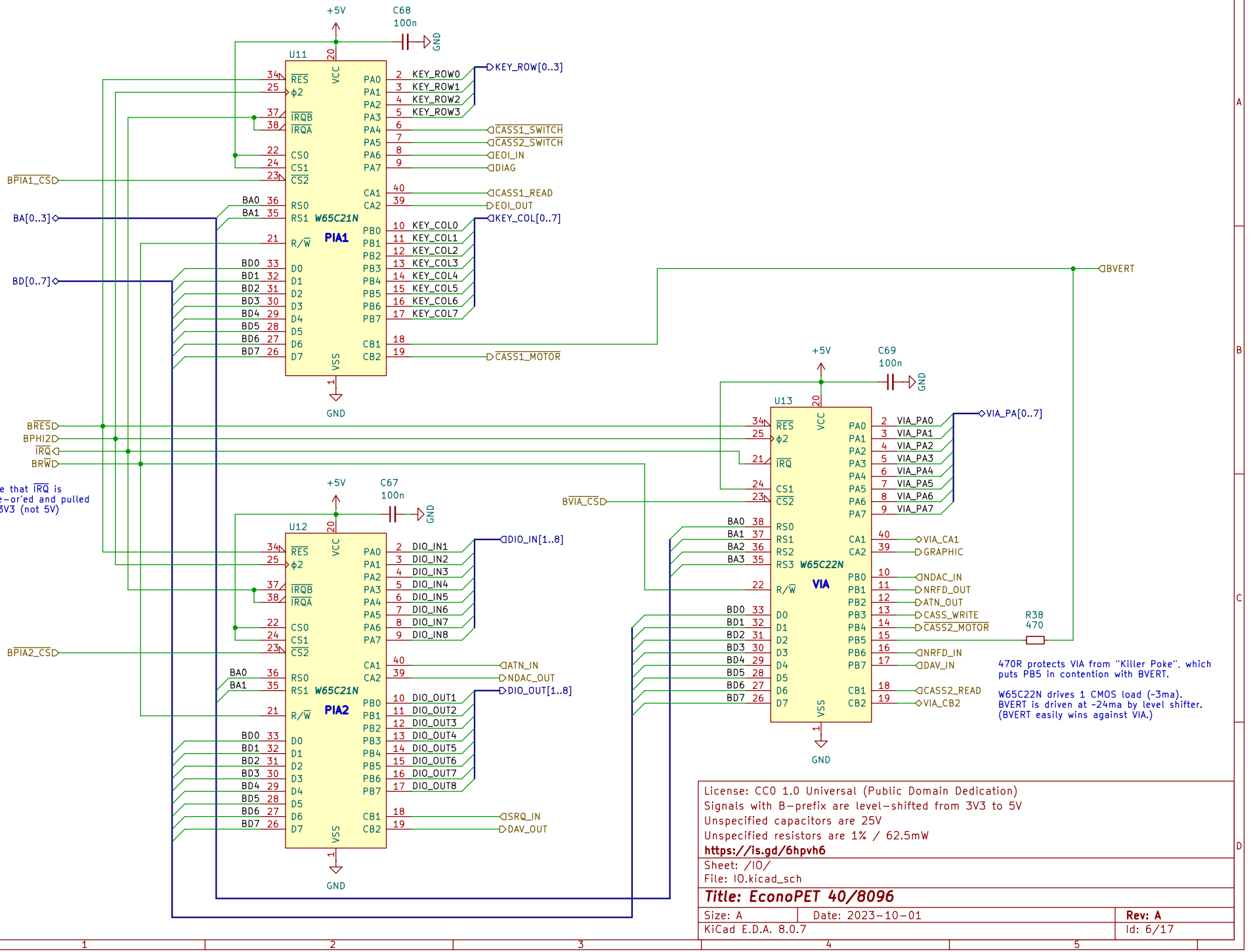
D[0..7] are the only bidirectional lines that need to be shifted. The direction of D[0..7] is controlled by RW.

Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /MAGIC/
File: MAGIC.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 4/17



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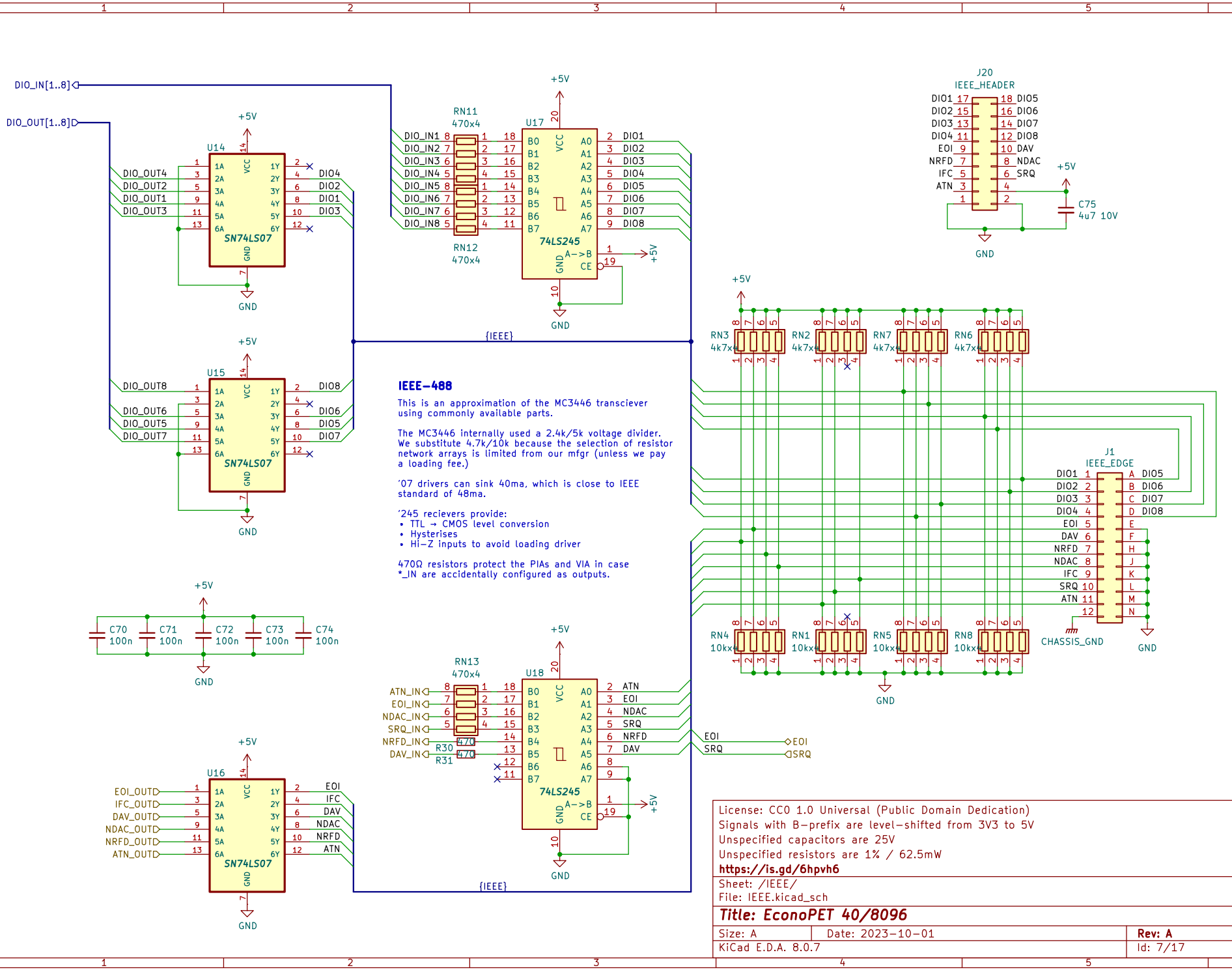
Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /IO/
File: IO.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 6/17



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Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /IEEE/
File: IEEE.kicad_sch

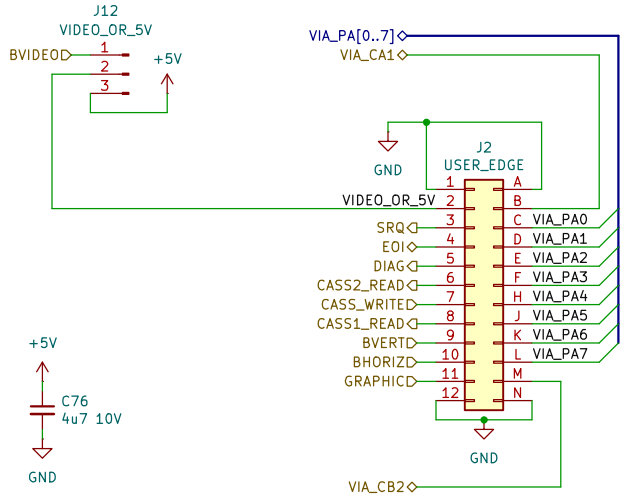
Title: EconoPET 40/8096

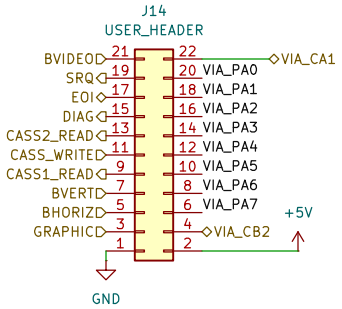
Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 7/17

USER PORT

The VIDEO_OR_5V jumper allows partial compatibility
with VIC-20 and C64 user port peripherals by delivering
+5V on PIN_2 instead of PET video.

(Example: TexElec SNES adapter)





Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

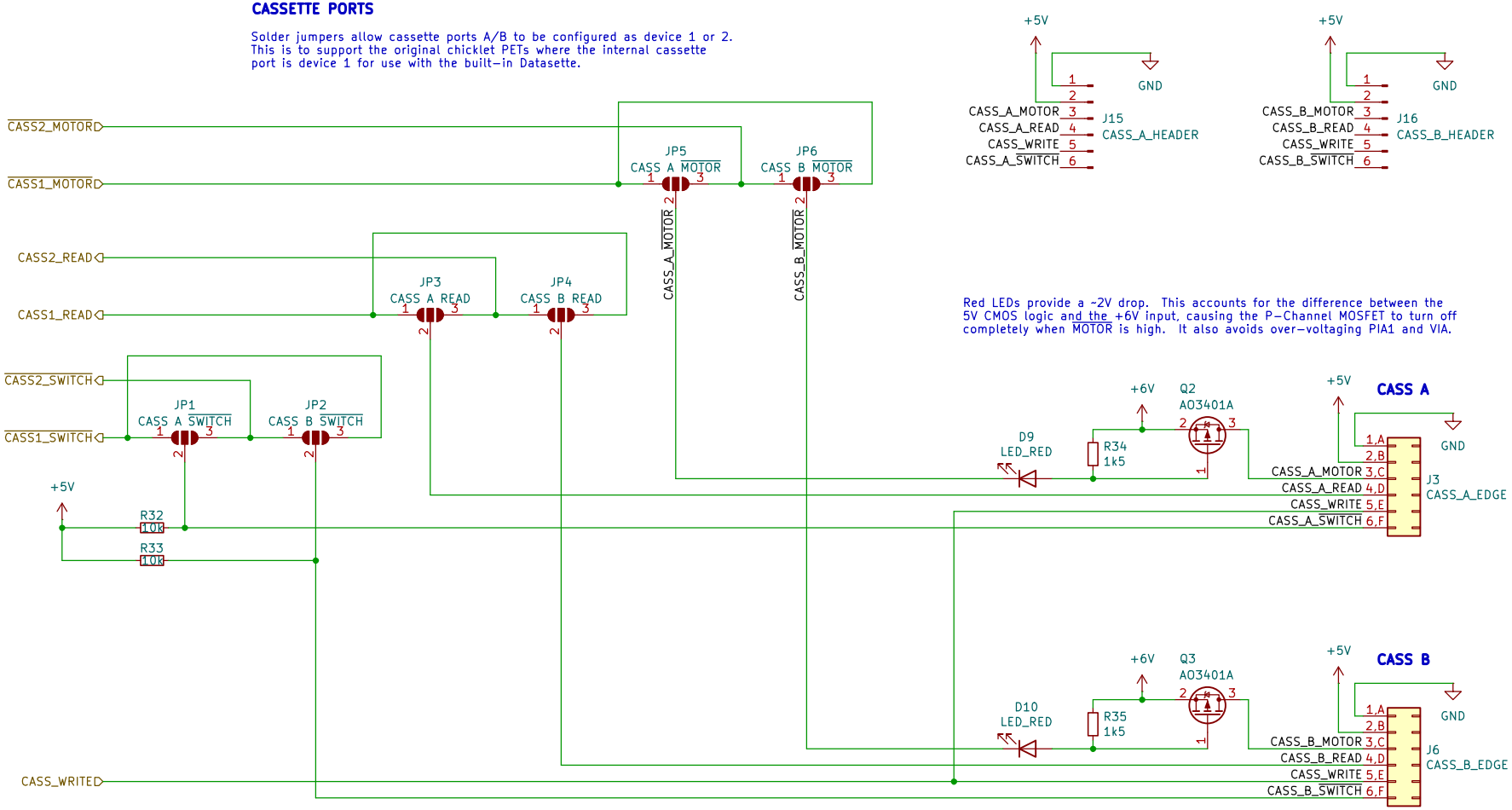
Sheet: /USER/
File: USER.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 8/17

CASSETTE PORTS

Solder jumpers allow cassette ports A/B to be configured as device 1 or 2.
This is to support the original chicklet PETs where the internal cassette
port is device 1 for use with the built-in Datasette.



Place decoupling cap near CASS_B connector.
CASS_A has sufficient decoupling nearby.

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Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
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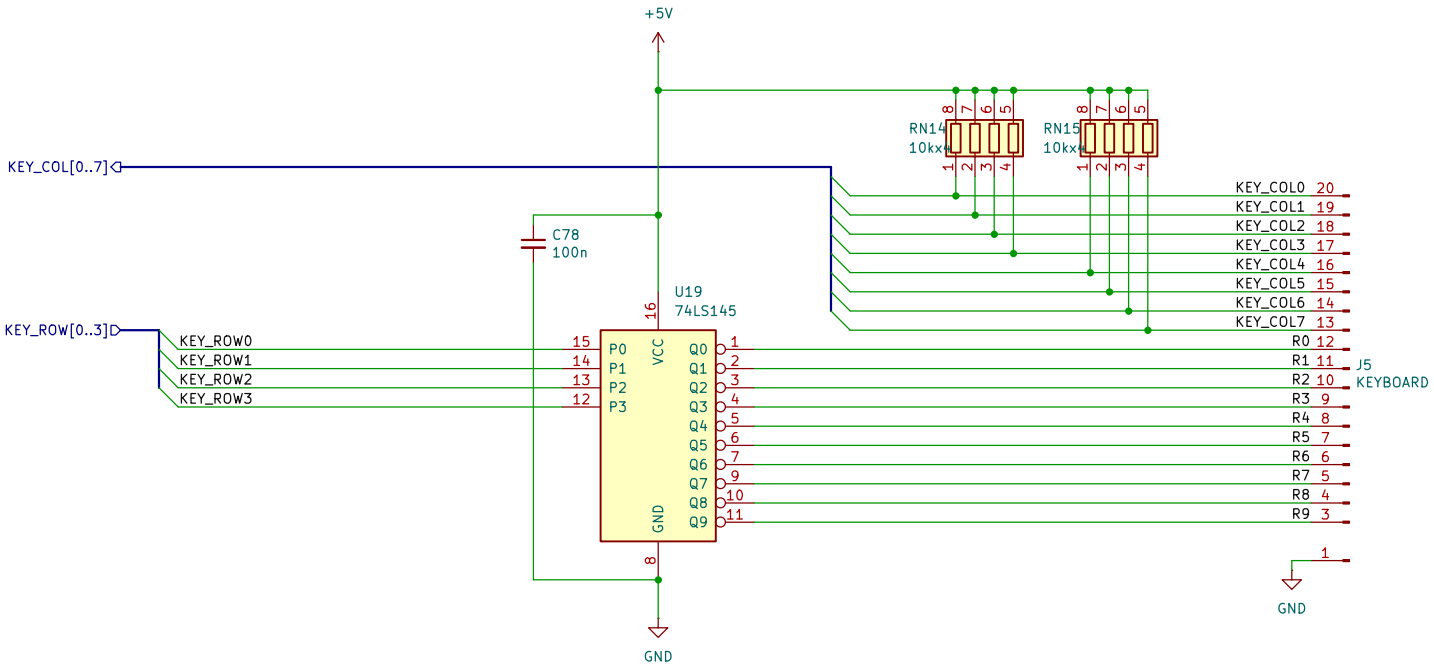
Sheet: /CASS/
File: CASS.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 9/17



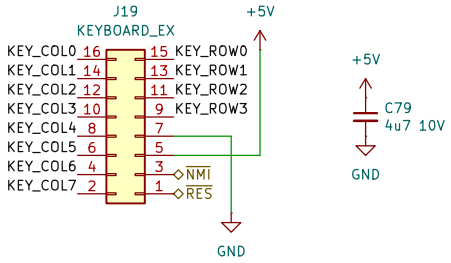
KEYBOARD

The PET uses a 74LS145 BCD-to-decimal to sink the active row of an 8x10 keyboard matrix. When a key in the selected row is pressed, it sinks the 10k pullup of the corresponding column.

The '145 is active low / open collector, capable of sinking an excessive 80ma for driving lamps in the pre-LED era. This is more than enough to sink all eight of the 10k pullups if the user pushes all keys for currently select row.

The KEYBOARD_EX header conveniently exposes the PA[3:0] and PB[7:0] lines for users interested in building adapters to support non-PET keyboards. It also exposes NMI for RESTORE and RES for reset.

http://www.6502.org/users/sjgray/projects/petexpkbd/index.html



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Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
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Sheet: /Keyboard/
File: Keyboard.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 10/17

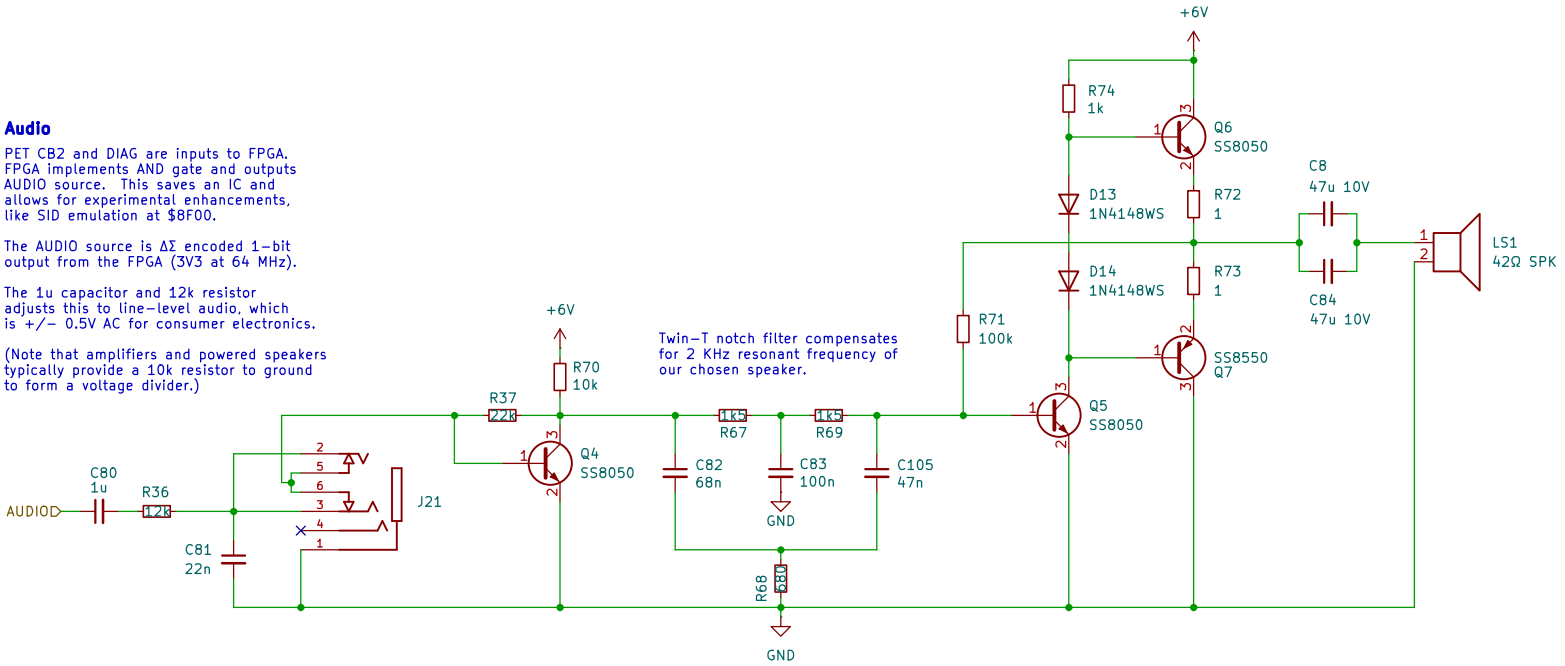
Audio

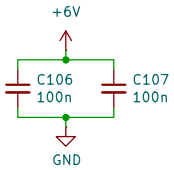
PET CB2 and DIAG are inputs to FPGA.
FPGA implements AND gate and outputs
AUDIO source. This saves an IC and
allows for experimental enhancements,
like SID emulation at $8F00.

The AUDIO source is ΔΣ encoded 1-bit
output from the FPGA (3V3 at 64 MHz).

The 1u capacitor and 12k resistor
adjusts this to line-level audio, which
is +/- 0.5V AC for consumer electronics.

(Note that amplifiers and powered speakers
typically provide a 10k resistor to ground
to form a voltage divider.)





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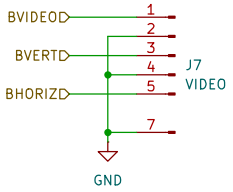
Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /AUDIO/
File: Audio.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 11/17

VIDEO HEADER



Not too much to see here. :-)

If you're looking for the modern DVI video output over an HDMI connector, look under Magic / MCU / DVI.

Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /VIDEO/
File: VIDEO.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 12/17

MCU

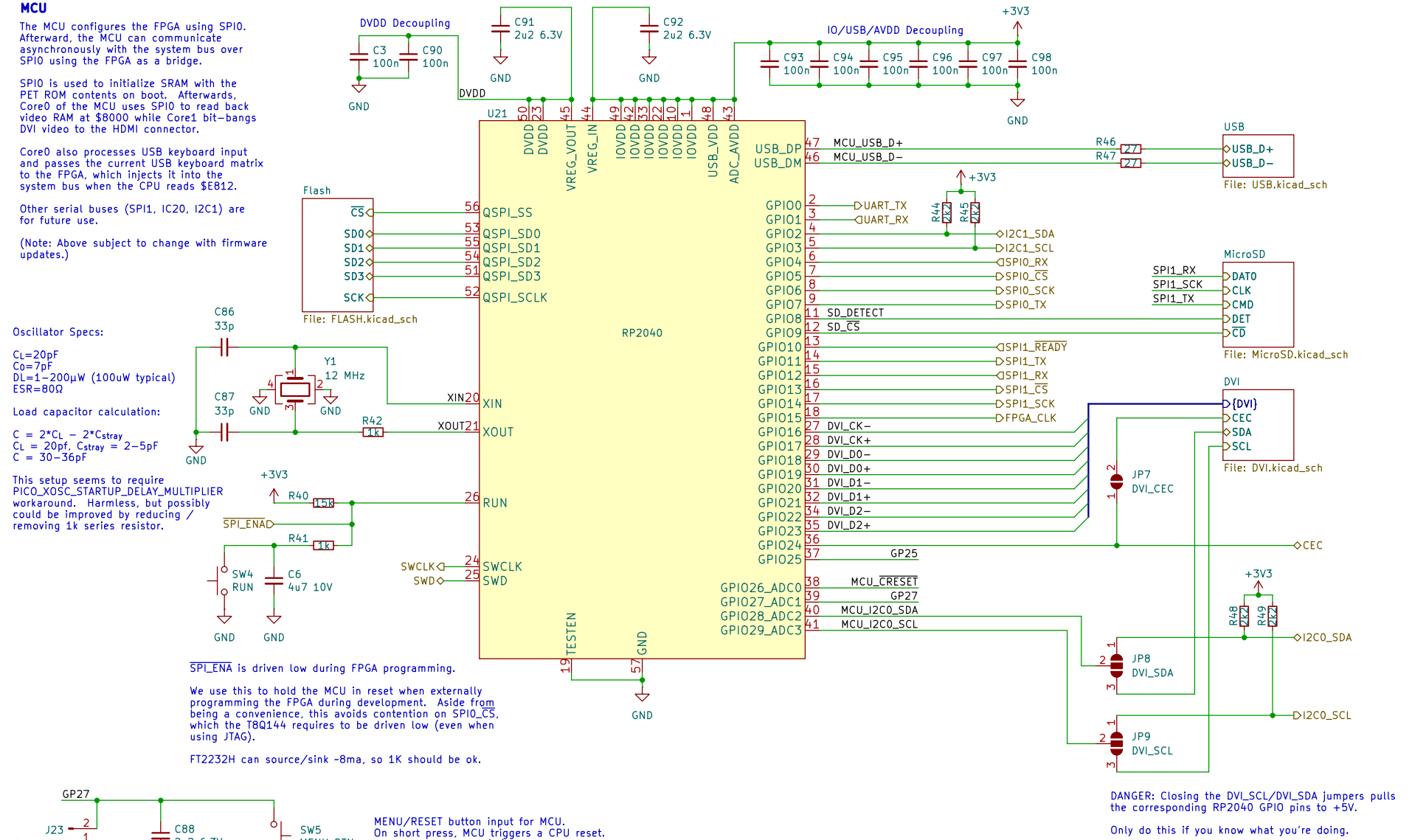
The MCU configures the FPGA using SPI0. Afterward, the MCU can communicate asynchronously with the system bus over SPI0 using the FPGA as a bridge.

SPI0 is used to initialize SRAM with the PET ROM contents on boot. Afterwards, Core0 of the MCU uses SPI0 to read back video RAM at $8000 while Core1 bit-bangs DVI video to the HDMI connector.

Core0 also processes USB keyboard input and passes the current USB keyboard matrix to the FPGA, which injects it into the system bus when the CPU reads $E812.

Other serial buses (SPI1, IC20, I2C1) are for future use.

(Note: Above subject to change with firmware updates.)



Oscillator Specs:

C_L=20pF
C_O=7pF
DL=1-200µW (100uW typical)
ESR=80Ω

Load capacitor calculation:

$C = 2*C_L - 2*C_{stray}$
C_L = 20pf, C_{stray} = 2-5pF
C = 30-36pF

This setup seems to require PICO_XOSC_STARTUP_DELAY_MULTIPLIER workaround. Harmless, but possibly could be improved by reducing / removing 1k series resistor.

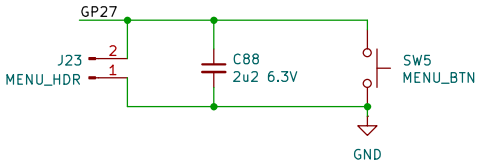
$\overline{SPI\_ENA}$ is driven low during FPGA programming.

We use this to hold the MCU in reset when externally programming the FPGA during development. Aside from being a convenience, this avoids contention on SPI0_$\overline{CS}$, which the T8Q144 requires to be driven low (even when using JTAG).

FT2232H can source/sink ~8ma, so 1K should be ok.

DANGER: Closing the DVI_SCL/DVI_SDA jumpers pulls the corresponding RP2040 GPIO pins to +5V.

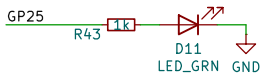
Only do this if you know what you're doing.



MENU/RESET button input for MCU.
On short press, MCU triggers a CPU reset.
On long press, MCU (re)enters boot menu.

10k resistor on $\overline{CRESET}$ enables programmer to override MCU during development.

MCU status LED visible when looking into the PET expansion slot. (Other LEDs are only visible when the PET case is open.)



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Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

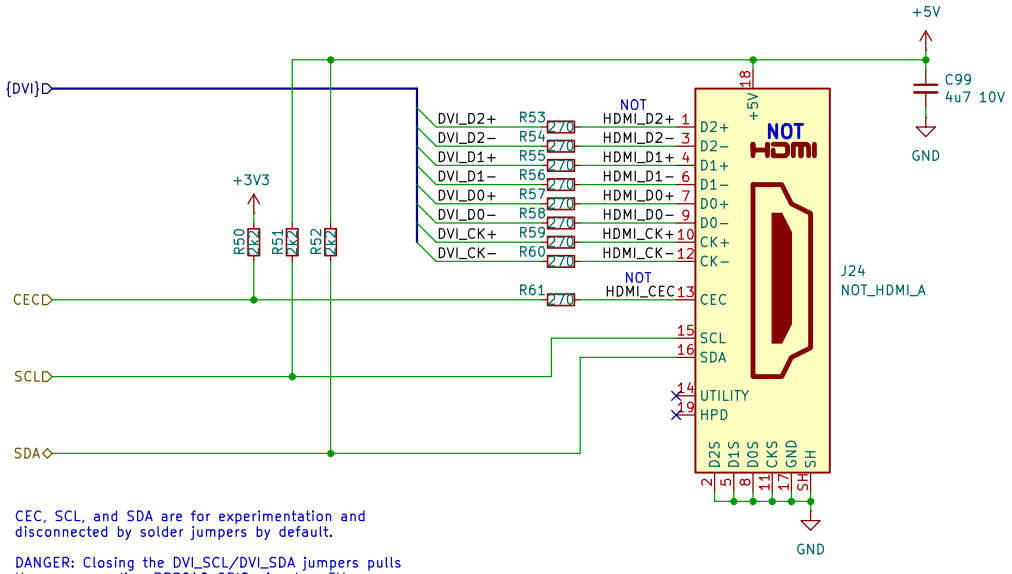
Sheet: /MAGIC/MCU/
File: MCU.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 13/17

DVI VIDEO

Uses legacy DVI TMDS protocol over an HDMI connector.
See: https://github.com/Wren6991/PicoDVI



CEC, SCL, and SDA are for experimentation and disconnected by solder jumpers by default.

DANGER: Closing the DVI_SCL/DVI_SDA jumpers pulls the corresponding RP2040 GPIO pins to +5V.

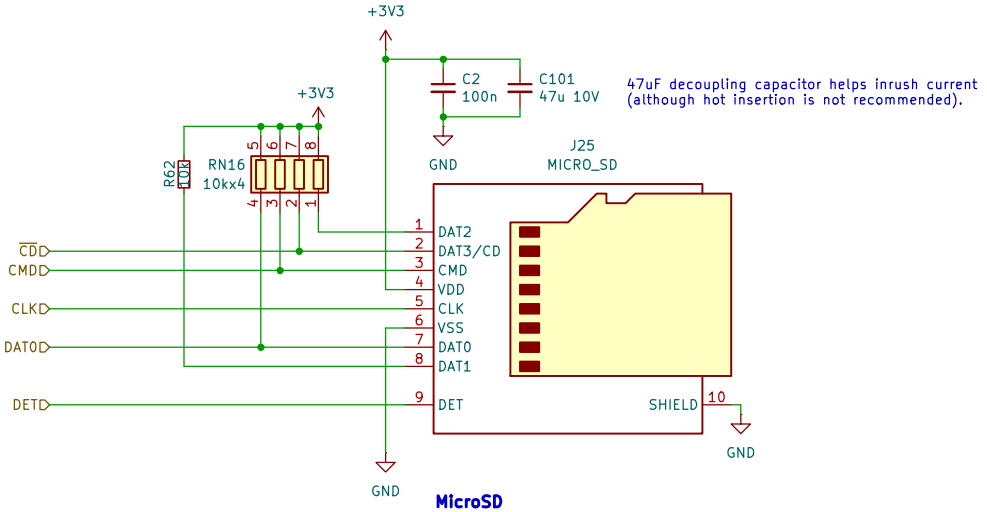
Only do this if you know what you're doing.

Signals with B−prefix are level−shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /MAGIC/MCU/DVI/
File: DVI.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023−10−01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 14/17



MicroSD

DAT[0] : (POCI) is open-drain output that requires pullup.
DAT[2:1] : Unused inputs in SPI mode. Pullups recommended to avoid current draw due to metastablitiy.
DAT[3] : (CS) has built-in 22-50k pullup to ensure card is deselected by default.
CMD : (PICO) input in SPI mode.
CLK : (SCK) always an input. Never gets pullup.

For reference, CM1624 uses:
25k pullup for DAT[0:3] and CMD
40 Ohm termination for DAT[0:3], CMD, and CLK

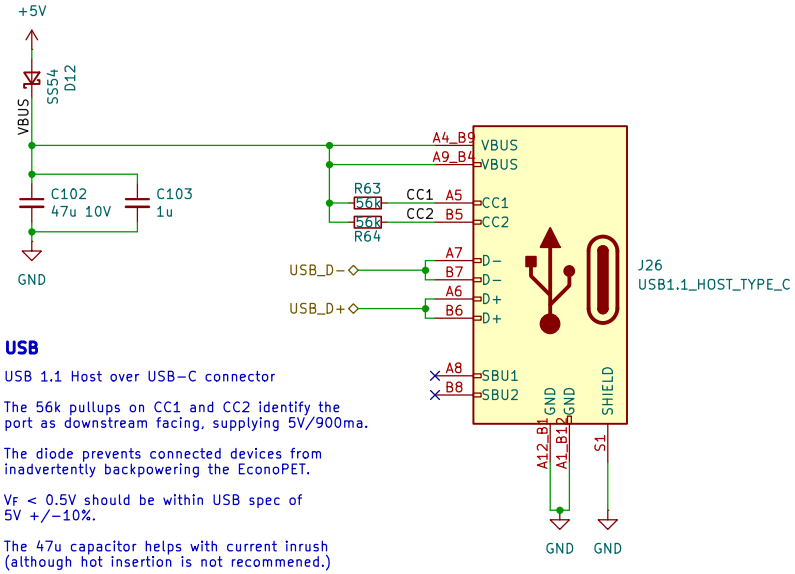
10k pullups common (e.g., ExpressIf documentation).

Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /MAGIC/MCU/MicroSD/
File: MicroSD.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 15/17



USB

USB 1.1 Host over USB−C connector

The 56k pullups on CC1 and CC2 identify the port as downstream facing, supplying 5V/900ma.

The diode prevents connected devices from inadvertently backpowering the EconoPET.

V_F < 0.5V should be within USB spec of 5V +/−10%.

The 47u capacitor helps with current inrush (although hot insertion is not recommened.)

Consider using an independently powered USB hub as an extra layer of protection.

Signals with B−prefix are level−shifted from 3V3 to 5V

Unspecified capacitors are 25V

Unspecified resistors are 1% / 62.5mW

https://is.gd/6hpvh6

Sheet: /MAGIC/MCU/USB/

File: USB.kicad_sch

Title: EconoPET 40/8096

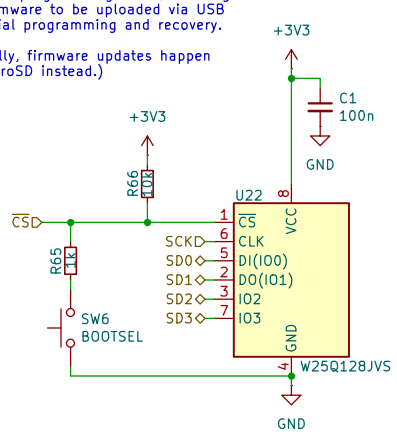
Size: A	Date: 2023−10−01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 16/17

Flash

16MiB Quad SPI flash memory for MCU.

Holding BOOTSEL at power on puts the MCU into programming mode, allowing new firmware to be uploaded via USB for initial programming and recovery.

(Typically, firmware updates happen via microSD instead.)



Signals with B-prefix are level-shifted from 3V3 to 5V
Unspecified capacitors are 25V
Unspecified resistors are 1% / 62.5mW
https://is.gd/6hpvh6

Sheet: /MAGIC/MCU/Flash/
File: FLASH.kicad_sch

Title: EconoPET 40/8096

Size: A	Date: 2023-10-01	**Rev: A**
KiCad E.D.A. 8.0.7		Id: 17/17