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TYNEMOUTH SOFTWARE MINI PET KIT B BUILD INSTRUCTIONS

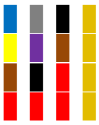
PARTS LIST

CAPACITORS – ALL RATED 16V OR HIGHER

2 x 22pF *(or to match crystal, usually marked 220 or 220J)*
23 x 100nF axial *(usually marked 100n or 104)*
1 x 100µF *(axial electrolytic rated 25V or higher)*

RESISTORS – ALL ¼W 5% OR BETTER (4 BAND RESISTOR COLOUR CODES SHOWN)

1 x 68Ω
4 x 470Ω
1 x 1KΩ
1 x 2.2KΩ



RESISTOR ARRAYS (PIN 1 MARKED BY DOTS ON PACKAGE AND PCB)

2 x 4K7 7 bussed resistor array, 8 pin *(usually marked 8X-1-472)*
5 x 10K 8 bussed resistor array, 9 pin *(usually marked 9X-1-103)*

SEMICONDUCTORS - NEW TEXAS INSTRUMENTS CHIPS RECOMMENDED.

2 x 6.8V Zener diodes 500mW
3 x 1N4001 rectifier diodes
2 x 5mm LED *(optional)*
2 x TIP29 / TIP29A or similar NPN power transistor
3 x 74LS07
1 x 74HC00
1 x 74HC10
1 x 74HC74
1 x 74HC86
2 x 74HC138
1 x 74LS145
1 x 74HC166
1 x 74HC393
1 x WDC W65C02S *(do not fit anything else into this position other than a W65C02S, it will not work, the pinout is different)*
2 x WDC W65C21N *(not W65C21S)*
1 x WDC W65C22N *(not W65C22S)*
1 x 62256 32K SRAM 600mil wide (e.g. Alliance AS6C62256 or Cyprus CY62256)
1 x 1K Dual Port RAM (IDT7130)
1 x 27C256 EPROM *(font ROM)*
1 x 27C020 EPROM *(OS/BASIC ROM)*
1 x ATmega164P (*pre-programmed*)
1 x 7805 or 7805 switching replacement (*rated at least 250mA, more if adding accessories*)
1 x 16 MHz Crystal (*HC-49/U package*)

CONNECTORS / SWITCHES / SOUNDER

2 x miniature tactile switch 6x6mm *(e.g. Diptronics DTS-61N)*
1 x Piezo AC transducer *(not a buzzer or any sounder that has internal circuitry)*
1 x 8 way DIP switch
4 x 16 pin, 8 x 14 pin IC sockets *(optional, turned pin recommended)*
1 x 48 pin, 5 x 40 pin, 1 x 32 pin, 2 x 28 pin IC sockets *(turned pin recommended)*
1 x 7 way 0.1" connector for video *(pin 2 removed)*
1 x 20 way 0.1" connector for keyboard *(pin 2 removed)*
2 x 2 way 0.1" connector for external reset and NMI switches *(optional)*
1 x 9 way 0.156" connector *(pin 3 removed) or* 1 x 5 way 0.156" connector for power

OPTIONAL PARTS

The parts in the section highlighted in blue on the PCB diagram are optional, and can be used to add an alternative 9V DC power in and composite video out. These are not required if you are using the PETs internal monitor, and so can be omitted. It could be useful for testing if you have monitor problems (select the 9" monitor settings to use composite output).

COMPOSITE VIDEO OUTPUT

1 x 1uF *(usually marked 1u or 105)*
2 x 75Ω
1 x 2.2KΩ
1 x 4.7KΩ
1 x 1N4148 signal diode
1 x BC548B or similar NPN transistor
1 x Phono jack *(e.g. CUI RCJ-011 – Digi-Key CP-1400-ND)*

9V DC IN

2 x 2 way header with jumper *(optional or fit wire links)*
1 x 2.1 mm DC Jack

NOTES ON IC SELECTION

This board has been designed to work with 74HC series logic and modern WDC 65Cxx series chips. The W65C02S is not pin compatible with the original NMOS 6502, and so nothing designed to plug into a 6502 socket should be used with the Mini PET. No PET ROM/RAM, PET Diagnostics, 64K RAM boards or Super PET boards or anything else will work in that socket.

The chips that act as external driver chips, the 74LS07s used to drive the IEEE-488 bus and the 74LS145 used to drive the keyboard are not available in 74HC series, but this is not an issue as they all have open collector outputs and are driven from NMOS outputs on the W65C21N / W65C22N.

ASSEMBLY

Assembly should follow standard procedures for this sort of kit. The following is offered as a guide to the order parts should be assembled:

1. Single resistors, small capacitors and diodes (*support board in a frame and solder from above can be easier than soldering from below and having to keep flipping the board over*)
2. Crystal and Logic ICs (*if not fitting sockets, noting orientation of pin 1 circles or indents, all pin 1's are to the left*)
3. IC sockets for remaining chips (*noting orientation of pin 1 indents, all pin 1's to the left hand side of the board*)
4. Resistor arrays (*noting the dot for pin 1 on the package and the board*)
5. Transistors / voltage regulator (*bend the legs at right angles at the point they get thin for perfect alignment. Can be left alone, or bolted or riveted to the board. Heatsinks should not be necessary*)
6. Large capacitor, LEDs, buzzer, switches, jumpers, connectors etc.

Clean the board after assembly and check for any shorts or dry joints before inserting the ICs. Check jumpers and DIP switches are set appropriately before powering on.

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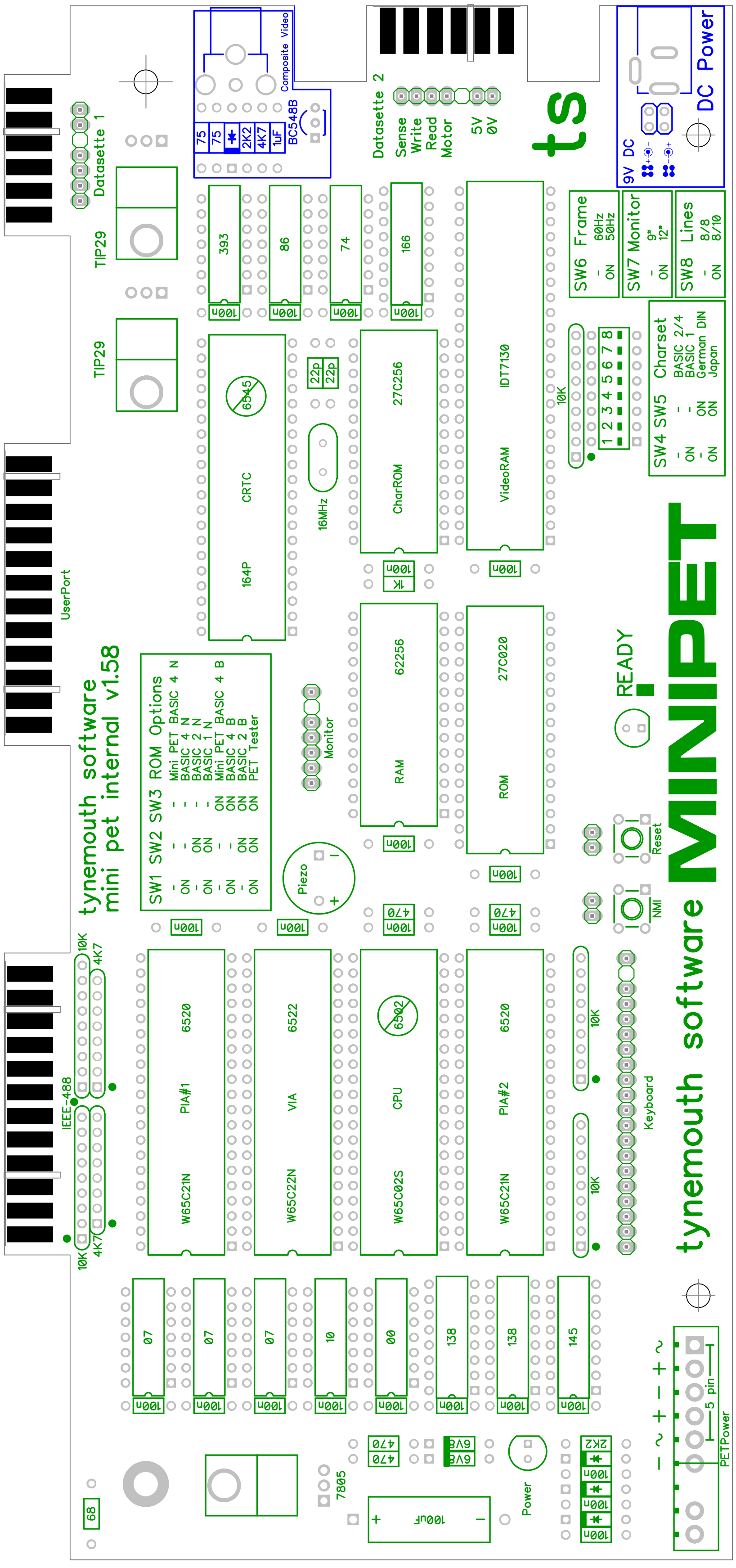
COMPONENT PLACEMENT

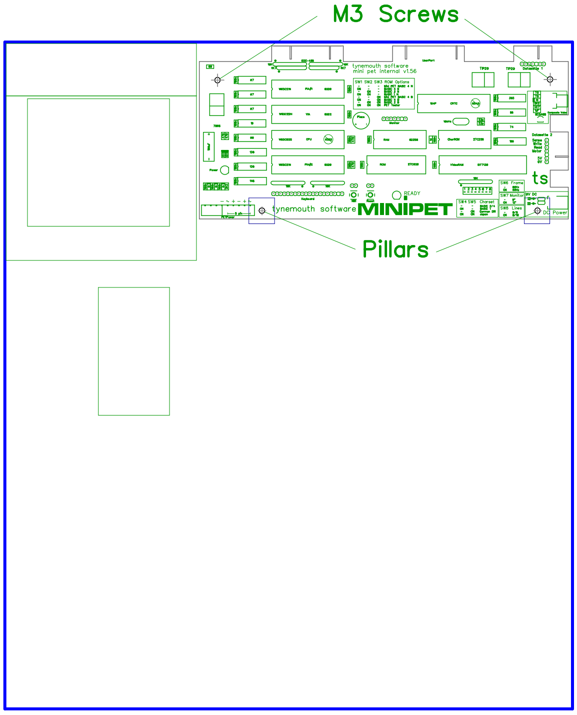


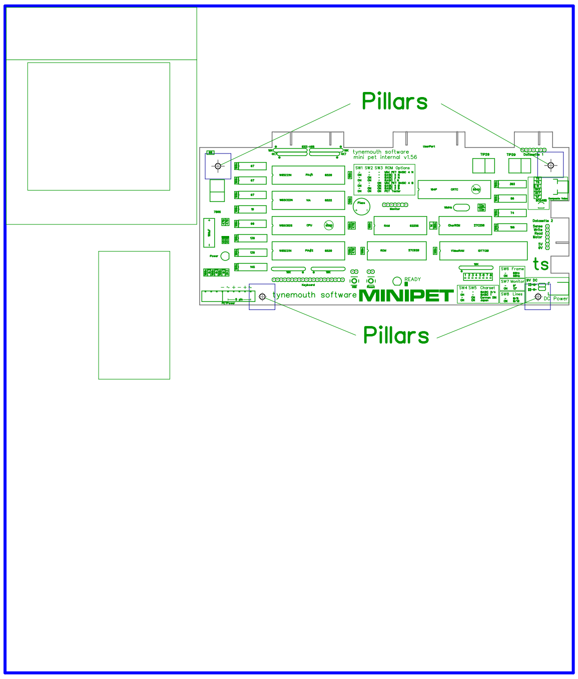
MOUNTING

The board should be suitable to be installed in high or low profile cases used from the 2001 to the 8032. The board can be installed in two positions inside the PET case.

REAR MOUNT

This mounts the board at the back of the case with the edge connectors accessible through the holes in the rear as the original board would have had. Two M3 pillars should be present at the back of the case, and the two holes in the board should line up with those. Self-adhesive mounting pillars should be used for the two at the front. It is not necessary to remove the backing and stick the board down unless you want this to be a permanent fixture. The screw hole on the left hand side of the board is used to attach to chassis ground. The screw hole on the right is insulated.





MID MOUNT

The alternative is to mount the board further into the case. The side datasette port should still be accessible via the slot in the side of the case, but the rear ports will only be accessible internally. This can be useful to install an SD2PET SD card drive inside the case.

8032-SK / 8092-SK

The Mini PET board can be mounted in these cases, either with the two rear mounting screws as with the original board, or can be mounted centrally in the case, which would allow an SD2PET to be installed within the case.

DIP SWITCHES

Settings are controlled from a single DIP switch. Recommended settings for a 9" PET are highlighted in green, all switches off.

ROM SETTINGS

The Mini PET can run a selection of ROM sets. Most 40 column PET ROMs will work (and are included below). 80 column ROMs should not be used, neither should CRTC PET ROMs (CBM machines).

Switch 1	Switch 2	Switch 3	ROM set	Keyboard
OFF	OFF	OFF	MINI PET BASIC 4	Normal / Graphics
ON	OFF	OFF	BASIC 4	Normal / Graphics
OFF	ON	OFF	BASIC 2	Normal / Graphics
ON	ON	OFF	BASIC 1	Normal / Graphics
OFF	OFF	ON	MINI PET BASIC 4	Business
ON	OFF	ON	BASIC 4	Business
OFF	ON	ON	BASIC 2	Business
ON	ON	ON	PET Tester	None

*** COMMODORE BASIC ***

BASIC version 1 was supplied on the first 2001 PETs, and only supported the normal / graphics keyboard. It is provided for completeness, and would not be recommended for general use due to a number of bugs, particularly in the IEEE-488 support. The version here is usually referred to a 1r, which patched a few of those bugs.

COMMODORE BASIC

BASIC 2 was the standard version on the 2001N or 30xx machines, and has support for normal and business keyboards. *(You sometimes see these referred to as 1, 1r and 2, and other times as 1,2 and 3. None of these versions are numbered until 4.0, so use whichever numbers you prefer).*

*** COMMODORE BASIC 4.0 ***

BASIC 4 was supplied as an upgrade to 2001N and 30xx machines and also on the 40xx machines. It has additional disk commands over BASIC 2.

*** MINI PET BASIC 4.0 ***

Mini PET BASIC is a custom version of BASIC 4, specifically adapted for the Mini PET with help from Steve Gray's editor ROM project. This version has added support for the sounder (normally only found in later CRTC based PETs) and also there is a built in DOS Wedge (see later). This is the recommended ROM to use. It terms of hardware, the Mini PET is closest to the original 4032 with the 2001N-32 board, but with many of the tweaks from the later machines, so the BASIC also sits between the BASIC 4.0 used on the original 4032 with the 2001N-32 board and 9" monitor, and the later version of BASIC 4.0 used on the later 4032 with the 'universal dynamic' board and 12" monitor. *(yes, the naming schemes are confusing, and I haven't even mentioned PET/CBM)*

PET TESTER

PET Tester is a simple test ROM which tests the first 1K of RAM and for each byte, display **b** for bad or **g** for good. It alternates this with a screen showing the full character set. This is useful for testing monitors as it gives you an easy way to get a screen full or characters. This version has been specially modified to respond to the NMI button to toggle between uppercase / graphics and lowercase / uppercase fonts.

FONT SETTINGS

The character ROM can be changed using switches 4 and 5 way. The default character ROM font is that found on BASIC 2 and BASIC 4 PETs. The older BASIC 1 set, and two international sets are provided as alternatives. The BASIC 1 set can be useful if when running software written to use lowercase mode on the PET 2001, and you see tHE iNCORRECT cASE. *(the BASIC 1 set seems more logical, not sure why they changed it?, but the BASIC 2/4 set should be used in most cases for the compatibility)*

Switch 4	Switch 5	Character Set	Charset 1	Charset 2
OFF	**OFF**	**901447-10 (BASIC 2/4)**	Uppercase / Graphics	Lowercase / Uppercase
ON	**OFF**	**901447-08 (BASIC 1)**	Uppercase / Graphics	Uppercase / Lowercase
OFF	**ON**	**German DIN**	Uppercase / Graphics	Lowercase / Uppercase
ON	**ON**	**Japanese**	Uppercase / Graphics	Uppercase / Symbols

VIDEO OPTIONS

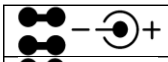
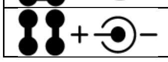
Video options are set using switches 6 to 8. The original PETs had a fixed output of 60Hz and 15.625KHz line, this is compatible with composite video inputs on most NTSC TVs and monitors. Later CRTCs PETs with 12" monitors changed that to 20KHz, which is not compatible with composite video. The Mini PET can generate both versions, but not at the same time, so you can select 9" and composite or 12" only. Both can be generated at 50Hz or 60Hz (60Hz is recommended if your TV supports it). On later CRTC PETs, when entering text mode (upper and lower characters available rather than upper and graphics), the screen spacing was changed to introduce a 2 pixel gap between rows to make the text easier to read. On all screen options except composite / 9" NTSC, this can be replicated on the Mini PET using switch 8.

Switch 6	Switch 7	Switch 8	Monitor	Composite Video	Frame	Line	Line Height
OFF	**OFF**	**OFF**	9" 60Hz	NTSC (240p60)	60Hz	15.625KHz	8 / 8
ON	**OFF**	**OFF**	-	PAL (288p50)	50Hz	15.625KHz	8 / 8
OFF	**ON**	**OFF**	12" 60Hz	-	60Hz	20KHz	8 / 8
ON	**ON**	**OFF**	12" 50Hz	-	50Hz	20KHz	8 / 8
OFF	**OFF**	**ON**	9" 60Hz	NTSC (240p60)	60Hz	15.625KHz	8 / 8
ON	**OFF**	**ON**	-	PAL (288p50)	50Hz	15.625KHz	8 / 10
OFF	**ON**	**ON**	12" 60Hz	-	60Hz	20KHz	8 / 10
ON	**ON**	**ON**	12" 50Hz	-	50Hz	20KHz	8 / 10

Switch 7 selects between the two different lines rates (64us / 15.625Khz or 50us / 20KHz). This option is only read when the reset button is pressed. The other options can be changed when in use.

JUMPERS

The jumpers near the DC power connector set the polarity of the DC jack power input if fitted, and can be ignored if that connector is not fitted.

	Centre negative, used by optional TFW8b.com supply (also Spectrum and Commodore 16 computers)
	Centre positive, used by pretty much every other power supply

Power requirements are 9V DC. Current consumption is around 200mA for the board, more if using a datasette or powering an SD2PET. Currently heatsinks are not required on the 7805 or TIP29 transistors. Power can be connected via the DC jack or the 2 pin header for an alternate 9V DC source.

DOS WEDGE

Nils Eilers' CBM DOS Wedge gives a number of additional shortcut commands to access a disk drive, and is particularly suited to use with the SD2PET SD card disk drive.

This is built in to the Mini PET BASIC ROMs, and is automatically activated at power on.

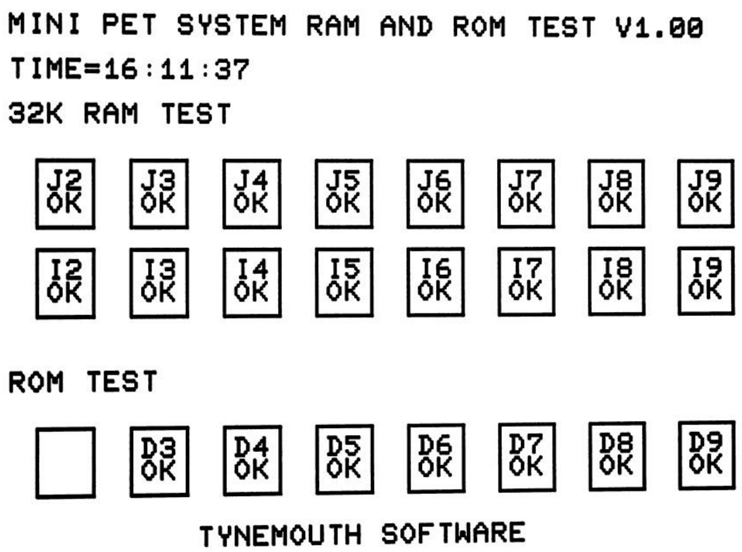
The standard BASIC 2 and BASIC 4 ROMs also contain the wedge as an option ROM, at 0x9000. To activate those versions, type **SYS 36864** (or it can be easier to remember to type **SYS 9*4096**).

COMMANDS:

- **/***filename* – load the program *filename*
- **↑***filename* – load and run the program *filename*
- **@** - Display drive status (at power on, this will show drive version information)
- **@$** - Display a directory of files (does not overwrite the current program like **LOAD"$",8** does)
- **@CD :** *folder* – change into a subdirectory on the SD card
- **@CD :** *name.d64* – mount a disk image
- **@CD←** – unmount a disk image (if mounted) or change to the parent folder
- **@C :** *new=source* – create a copy of '*source*' called '*new*' in the current folder
- **@R :** *new=old* – rename a file from '*old*' to '*new*' in the current folder
- **@S :** *filename* – scratch (delete) the file *filename* (you **will not** be asked for confirmation)

BUILT IN SELF TEST

The Mini PET BASIC ROM sets and BASIC 4 ROM sets include a built in self-test in ROM at 0xA000.
To activate this, type **SYS 40960**.
This is based on Commodore's 4032 test program, updated to run from ROM and with the checksums of the new ROMs added. The chip numbers are based on the original 2001N-32 boards, and are not really relevant, other than to indicate the areas involved. There is only one RAM chip and only one ROM chip.



The display alternates between inverted and not inverted. This is done by reading each character, inverting it and writing it back, so any invalid characters on the screen will be down to a fault in the video RAM.
The time shown is elapsed time in hours:minutes:seconds *(yes, the above screenshot was taken after a 16 hour burn in test).*

RESET BUTTON

The Mini PET reset button controls the video microcontroller. When reset, this provides a clean reset pulse to the 65C02S processor. The READY LED is off during reset to indicate this.

NMI BUTTON

The Mini PET has a button wired to the NMI line of the 65C02S processor. This can be used to run code when the button is pressed. It is level triggered, and when activated, will processor will jump to the address stored at address 0xFFFA. On the default ROM sets, this is set to 0xFD49. This in turn checks address 0x0094 and jumps to the address that points to. By default, this is 0xB3FF, which causes a BASIC warm reset and the READY prompt will appear. You can change the values at 0x0094 (and the higher byte at 0x0095) to run different code. This could be used for a menu system or to run some pre-determined function.

MACHINE CODE MONITOR

All BASIC version apart from 1 have a built in machine language monitor. This is activated by the break handler, so is called at any point the BRK instruction is executed. This is code `00`, so the monitor can be launched by jumping to anywhere there is a `00` stored in memory. There is usually a `00` at address 4, so you can launch the monitor by typing `SYS 4` (`SYS 1024` is also commonly used).
The monitor is fairly simple, but allows you to view, modify, load or save memory and also to run code.

- All addresses must be entered as four hex digits, including any leading zeroes (e.g. `M 0094,0095`).
- All drive IDs must be two hex digits (e.g. `L "TEST",08`)
- All data must be two hex digits (e.g. `: 0094 78 D4 00 0D 00 D3 01 FF`)
- Any errors will either do nothing, or a `?` will appear in the line you have typed to indicate the error.

COMMANDS:

- `M` *start,end* - display memory between these addresses, 8 bytes per row
- `:` *start data* – write 8 bytes to memory, all 8 bytes must be present (*hint: cursor up to the output from a previous* `M` *command and overwrite any values you want to change)*
- `R` - display register status
- `;` *pc irq sr ac xr yr sp* – pre set register status at exit (*hint: cursor up to output of previous* `R` *command and overwrite any values you want to change*)
- `L` `"`*filename*`"`*,deviceID* – load *filename* from the device into memory at it's saved load address
- `S` `"`*filename*`"`*,deviceID,start,end+1* - Save memory between addresses to disk
- `G` *address* – jump to *address*
- `X` – exit to BASIC

PINOUTS

All connectors are viewed from what would be the outside of the PET, pin 1 to the right as you look from the keyboard. The grey lines indicate the slots in the edge connector or pin gaps in the pin headers.

IEEE-488 EDGE CONNECTOR

The IEEE-488 connector provides a fast parallel databus to connect an external disk drive or printer.

Top		**Bottom**	
1	DIO 1	A	DIO 5
2	DIO 2	B	DIO 6
-	-	-	-
3	DIO 3	C	DIO 7
4	DIO 4	D	DIO 8
5	EOI	E	REN*
6	DAV	F	GND
7	NRFD	H	GND
8	NDAC	J	GND
9	IFC	K	GND
-	-	-	-
10	SRQ	L	GND
11	ATN	M	GND
12	Chassis GND	N	GND

* REN is connected directly to ground on all PET models

USER PORT

The user port provides general user IO functionality, video and datasette signals. There is a full 8 bit parallel IO port driven from the 6522 VIA. This is not compatible with VIC20 or C64 userports.

Top		**Bottom**	
1	GND	A	GND
-	-	-	-
2	Video	B	CA1
3	SRQ In	C	PA0
4	EOI	D	PA1
5	Diag *[1,5]	E	PA2
6	Cassette Read #2	F	PA3
7	Cassette Write *[2]	H	PA4
8	Cassette Read #1	J	PA5
9	Vertical Sync	K	PA6
10	Horizontal Sync*[3]	L	PA7
-	-	-	-
11	Graphic *[4]	M	CB2 *[5]
12	GND	N	GND

*[1] Tie to ground to start the Mini PET in machine code monitor mode

*[2] The same write signal is fed to both datasette ports

*[3] The signal polarity depends on the monitor selection (the same is true of the original PET motherboards)

*[4] This is low for the normal uppercase / graphic character set, high for lowercase / uppercase

*[5] The piezo sounder is driven from CB2 NANDed with Diag (as it is on later PETs). Diag is pulled high via a 10K resistor to ensure a valid signal.

DATASETTES

The datasette connector is the same as that used on the VIC20 and Commodore 64, so you can use a C2N or 1530 datasette to load or save programs. The PET supports two datasettes. The rear edge connector is drive 1, and the side is drive 2. An internal drive can be connected via the 7 pin headers near the drive 1 or 2 connectors.

Top	Bottom	Internal Header	Signal
1	A	1	GND
2	B	2	+5V
-	-	-	-
3	C	4	Motor
4	D	5	Read
5	E	6	Write
6	F	7	Switch

MONITOR

The monitor connector is used to drive the PETs internal monitor. The pinout is the same for both 9" and 12" monitors, but the signal polarity is different. This is automatically set when selecting 9" or 12" monitor via the DIP switches (which also sets the appropriate frame rate).

Pin	Signal	9" Monitor Polarity	12" Monitor Polarity
1	Video	Inverted	Normal
2	GND	-	-
3	Vertical Sync	Active Low	Active Low
4	GND	-	-
5	Horizontal Sync	Active High	Active Low
-	-	-	-
7	GND	-	-

The timing of PET monitors is quite unusual. On the 9" PET, the HSync pulse ends part way through the video signal. On the 12" PET, HSync starts before the end of the previous line. It is therefore unlikely any other type of monitor could be driven from this output, use the composite video output instead.

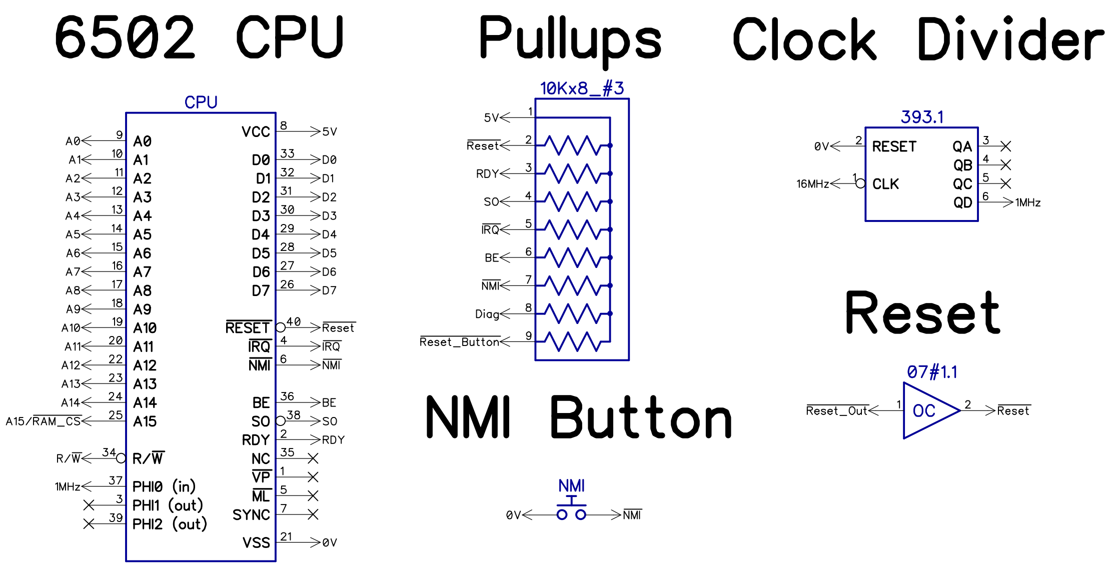
POWER CONNECTOR

Power is fed to the Mini PET using the original 5 pin or 9 pin power connector. If fitting a 5 pin connector, align it to the right as shown on the silkscreen. The 5 pin connector can be oriented either way as the connections are symmetrical. 9V DC is generated in the same way as the on the PET, using the 9V centre tapped winding and the large capacitor mounted in the PET. The second 16V winding on later PETs is not used. The LED indicates 9V is present. The actual value may be from 8V to 12V, depending on load.

9 Pin	5 pin	Wire colours	Signal
1	1	**Brown**	9V AC
2	2	**Red**	9V DC from capacitor
3	3	**Black**	0V (AC centre tap)
4	4	**Red**	9V DC to capacitor
5	5	**Brown**	9V AC
6	-	**Black**	0V
-	-	**-**	-
8	-	**Blue**	16V AC (not used)
9	-	**Blue**	16V AC (not used)

SCHEMATICS AND THEORY OF OPERATION

6502 CPU



The heart of the Mini PET is the 6502 processor. Here a WDC W65C02S is used. This is a modern version of the NMOS 6502. It is not pin compatible, and the read / write timing differs, so an original chip cannot be used with the Mini PET (nor can anything that would plug into the CPU socket).

The main changes here from the PET schematic are the removal of a number of buffer chips. The minimised chip count within the Mini PET reduces the loading on the address and data bus pins so they are no longer necessary.

The clock is also implemented differently. A 16MHz clock is supplied from the video circuitry, and this is divided down to 1MHz to be used by the CPU and associated components. The clock outputs from the CPU are not used.

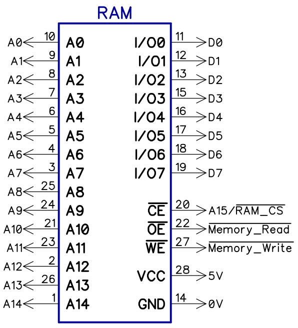
Reset_Out is generated by the video circuitry, and an open collector buffer is used to drive the reset pins of the CPU and accessories.

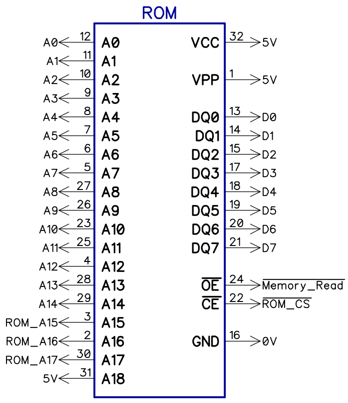
MEMORY MAP

The 64K address space is split as follows

Address Range	Size	Function
0000 - 7FFF	32K	Main RAM
8000 - 83FF	1K	Video RAM
8400 - 8FFF	3K	Mirrors of video RAM
9000 - AFFF	8K	Options ROMs
B000 - DFFF	12K	BASIC ROMs
E000 - E7FF	2K	Editor ROM
E800 - E8FF	256 bytes	IO Range
E900 - EFFF	1792 bytes	Editor Extension ROM
F000 - FFFF	4K	Kernal ROM

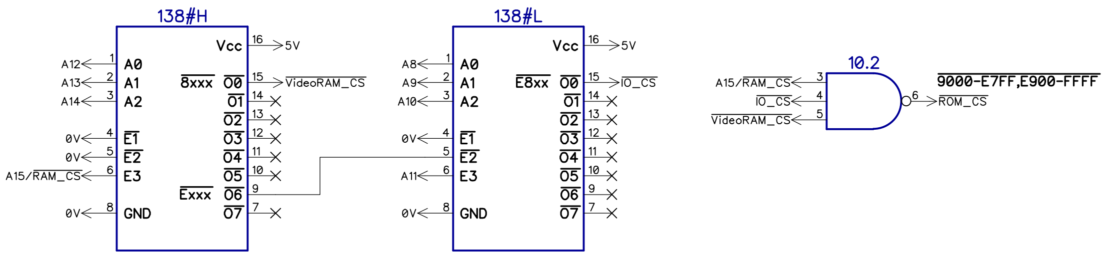
32K RAM 8x32K ROM





The Mini PET has the full 32K of RAM a PET can support (without paging). This is provided by a single 32K chip, which is decoded simply using the A15 line of the CPU to occupy 0000-7FFF. The ROM is mapped in 32K chunks with 1000-7FFF in the ROM being mapped into the address space as 9000-FFFF. Up to 8 sets of 32K ROM images can be stored in a 27C020 ROM chip and selected using the DIP switches.

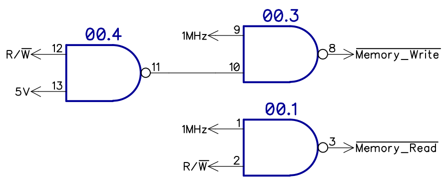
Address Decoding



The ROM chip provides ROM in two ranges, from 9000 through to E7FF and E900 through to FFFF. This is implemented here by decoding the video RAM (8000-8FFF) and the IO cut out (E800-E8FF) and selecting the ROM anywhere that is not RAM, video RAM or IO. (Thinking of it that way made the decoding much simpler).

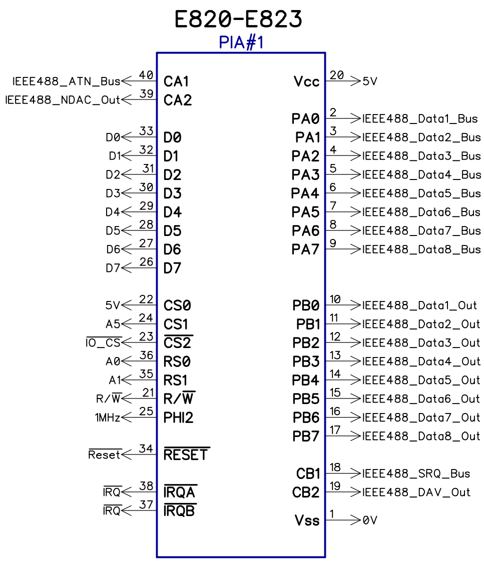
The timing requirements of the W65C02S are a little tighter than the NMOS 6502, so the read and write signals are gated with the 1MHz clock.

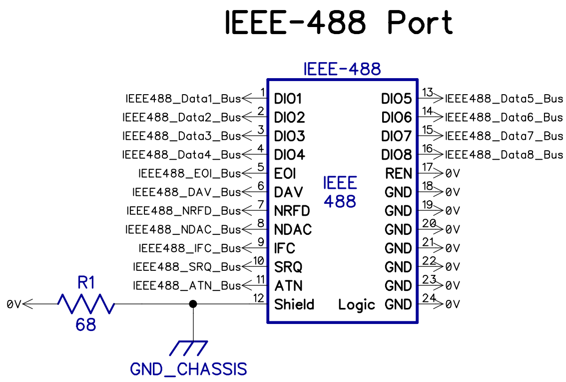
Read / Write Timing



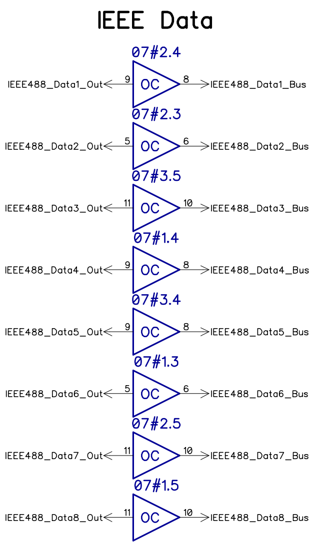
IEEE-488 PORT

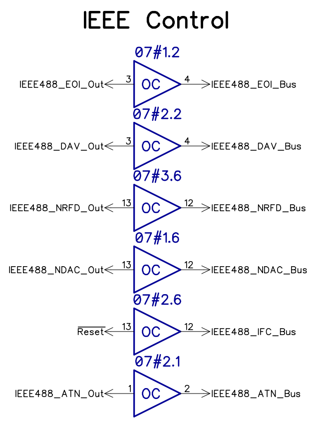
The IEEE-488 port signals are mainly provided by A W65C21N chip as the PIA#1 (the W65C21N being a modern version of the NMOS 6520). The remaining signals are provided by PIA#2 and the VIA (see later).

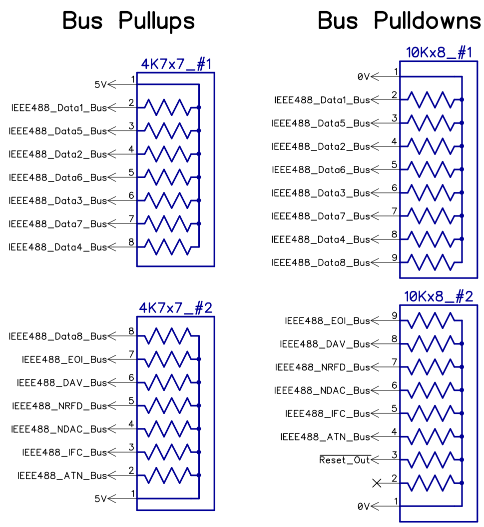




The IEEE-488 bus needs to be driven correctly. Between the IO chips and the edge connector there are the bus drivers. On the PET these were mainly MC3446 chips, with a few functions being implemented using a resistor divider and open collector buffer. Here all the pins have been implemented using the second option as the driver chips are no longer available. Board space is saved by using four resistor arrays in place of individual resistors. Two of these pull up to 5V, and two pull down to 0V. The bus then floats high unless driven low by the 7407 buffers or an external device. Nothing should ever drive the bus pins high.



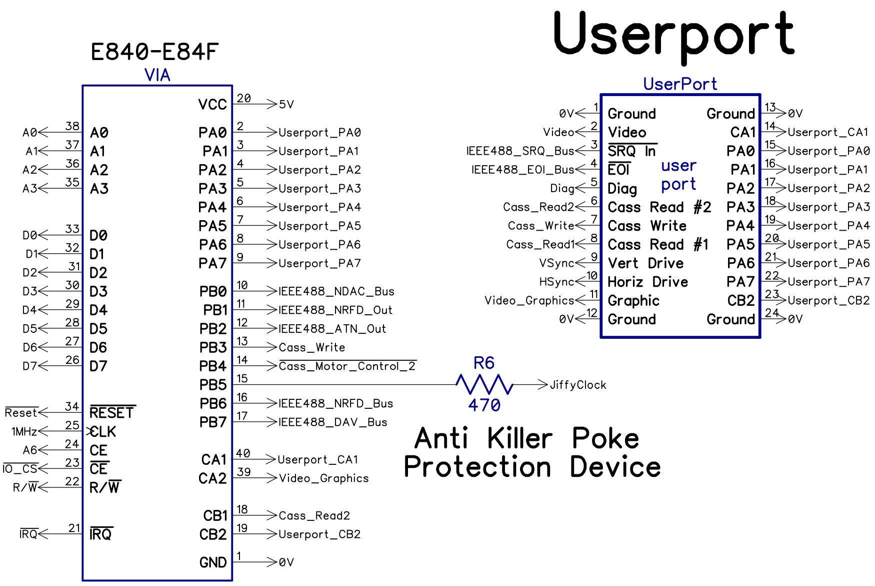




Note do not use the W65C21S or W65C22S versions as they have different electrical characteristics and totem pole outputs on the IRQ pins rather than the open collector versions on the NMOS compatible W65C21N and W65C22N.

USERPORT

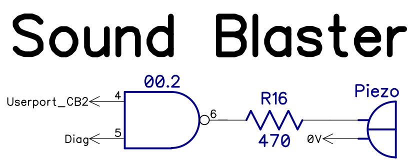
The userport is provided by a W65C22N VIA (a modern version of the NMOS 6522). This chip also provides further datasette and IEEE-488 signals. The PET userport is not compatible with Commodore 64 or VIC20 Userport peripherals.



The Jiffy Clock signal is a 60Hz pulse generated by the video circuitry. It was originally used to detect when the screen was not being drawn to allow access to the video RAM without generating 'snow' on the screen. That was no longer required in the later CRTC based PET, or in the Mini PET, and is used purely as a 60Hz timing signal.

Some early PET software achieved a speed increase by changing the input on the VIA chip to an output and driving that signal low so it would appear it was always safe to draw the screen, at the expense of visible 'snow'. This also has the effect of blocking the clock signal, so a highly complex 'anti killer poke' device (a 470Ω resistor) is used to stop the timing pulse being blocked if the poke is used.

PIEZO

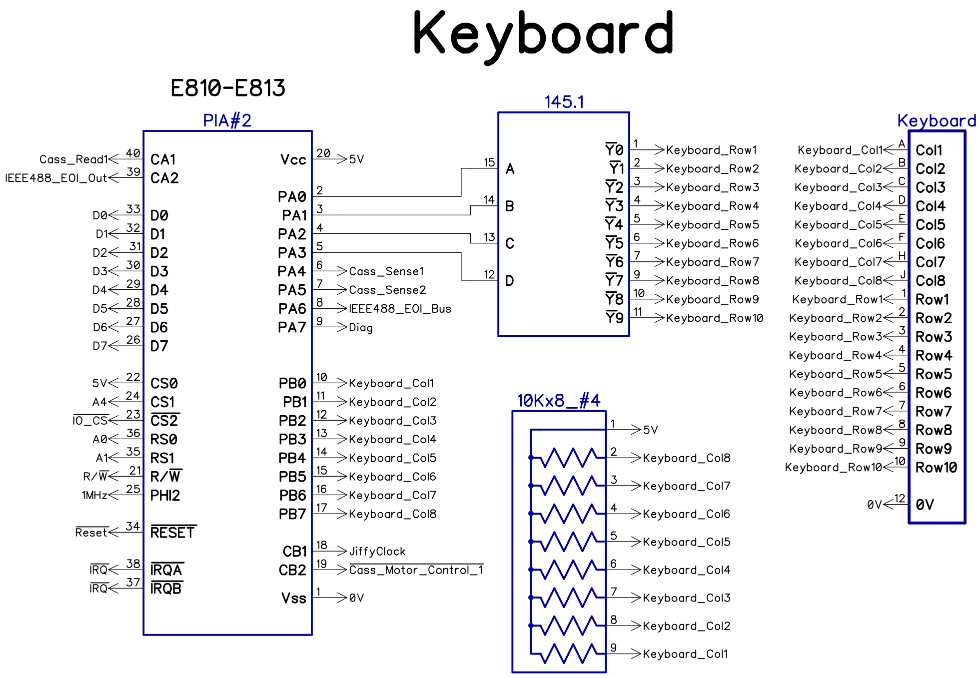


The PET 2001 had a very good version of Space Invaders, which was not only very playable, but added sound, with in game instructions to wire an audio amplifier to the CB2 pin on the userport.

Later PET models had a piezo speaker also driven by CB2, but NANDed with PA7 on PIA#2. This has been replicated here. A pullup has been added to PA7 (the Diag input) to ensure it is normally high and the output of the shift register in the VIA can drive the piezo. Diag is read at startup and if held low, with start the machine code monitor.

KEYBOARD

The final IO chip is another W65C21N, as PIA#2. This is mainly involved with the keyboard, but also provides the remaining datasette and IEEE-488 signals.



The keyboard is a 10x8 matrix, the rows drive the outputs of a 74LS145 4 to 10 line decoder. The columns are read into the PIA port B, pulled high via a 10K resistor array.

The PET had two main keyboard types. The PET 2001 chiclet keyboard and the normal / graphics keyboard from later machine are electrically compatible, using the same matrix of keys. The business keyboard used mainly (but not exclusively) on 80 column PETs had a different arrangement of keys with a different matrix. Even when the same key was present on both keyboards, they were not in the same matrix positions. To accommodate that, there were multiple versions of the editor ROM, which had different keyboard lookup tables to cope with the different keyboard matrixes. These can be selected by the DIP switches on the Mini PET (see the ROM selection table).

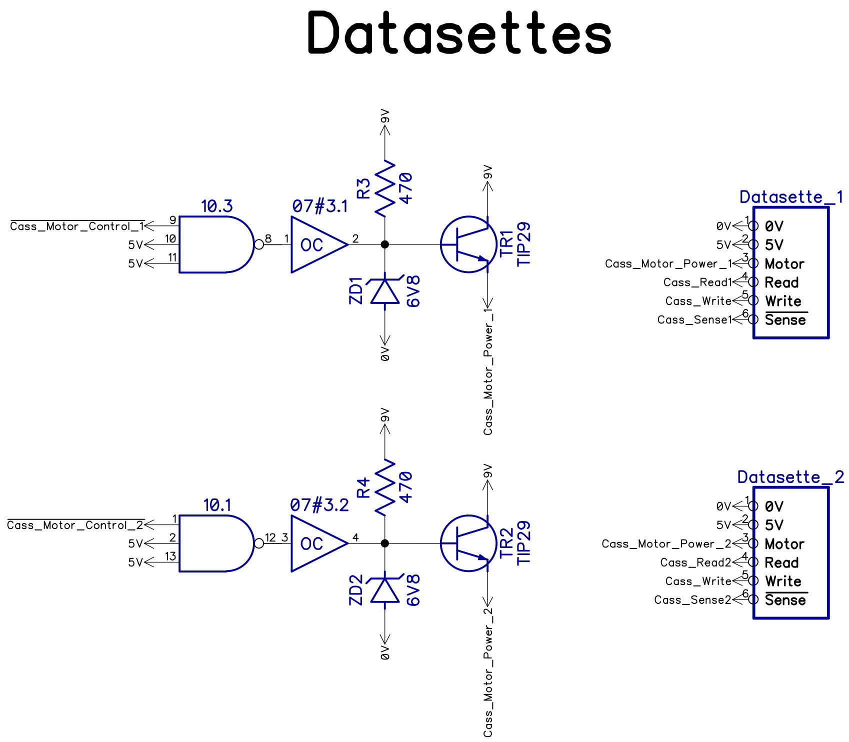
IO MEMORY MAP

The IO space from E800-E8FF is decoded in the same way as the PET, using address lines A4, A5 and A6 as select lines. That means that chips will be active anywhere in the E800-E8FF range that their address line is low, so there are multiple duplicates of each of the IO chips in the range, and addresses that will select multiple chips. These are the recommended addresses:

Address Range	Chip	Main Function
E810 - E813	PIA #2	Keyboard
E820 - E823	PIA #1	IEEE-488
E840 - E84F	VIA	Userport

DATASETTES

The Mini PET provides two datasette connections, driven by identical circuitry.



The datasette drives from on the PET continued to be used right through to the Commodore 128 and TED series of machines. The drive circuitry was simplified over time, from three transistors to control each motor line, down to one. The design used in the Mini PET is similar to that used on the C128 and TED series, although they used a 7406 inverting buffer rather than the separate inverter and 7407 non-inverting buffer which are used here to reduce chip count and use up available gates on existing chips.

When the Cass_Motor_Control lines are high, the 7407 open collector outputs are floating, and the resistor and Zener diode form a simple 6.8V regulator. The transistor works as an emitter follower, with the voltage at the output (the cassette motor) following that of its input (the regulated 6.8V). This gives a roughly 6.5V supply to drive the cassette motors.

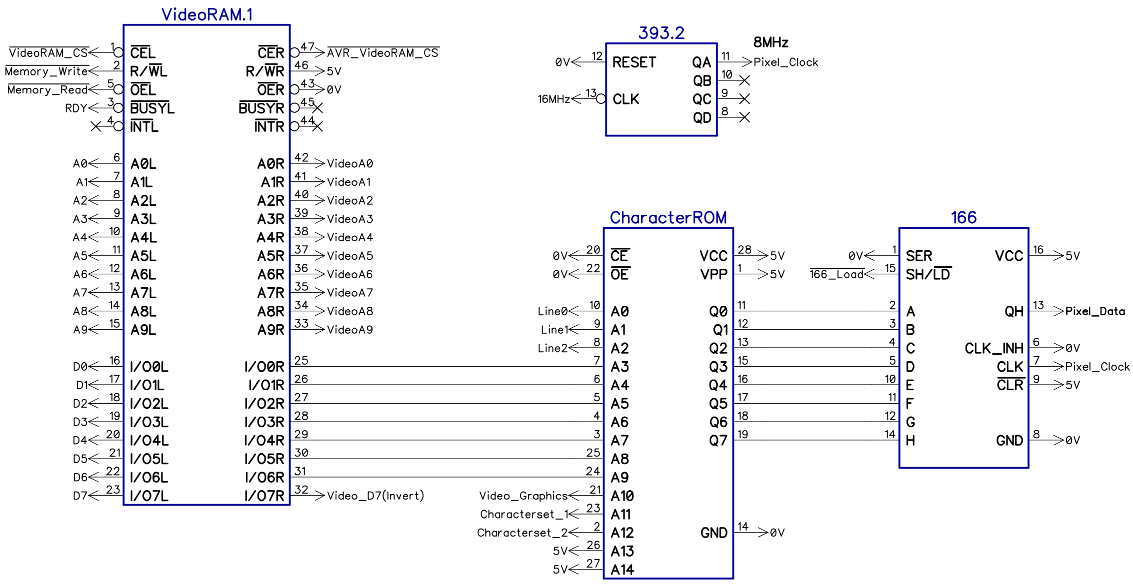
When one of the Cass_Motor_Control lines are low, that 7407 output is pulled low, and bypasses the Zener diode. This leaves the voltage at the base of the transistor close to 0V, and so the output follows and the motor drive voltage falls to 0V.

This is not an ideal circuit, as it leaves the 470Ω resistors across the 9V rail and drawing close to 20mA when the datasette is off, and 5mA when it is on. The transistors also need to drop 2.5V when the motor is running. A more efficient high side driver circuit could have been used, but this works and does the job in a similar manner to the original.

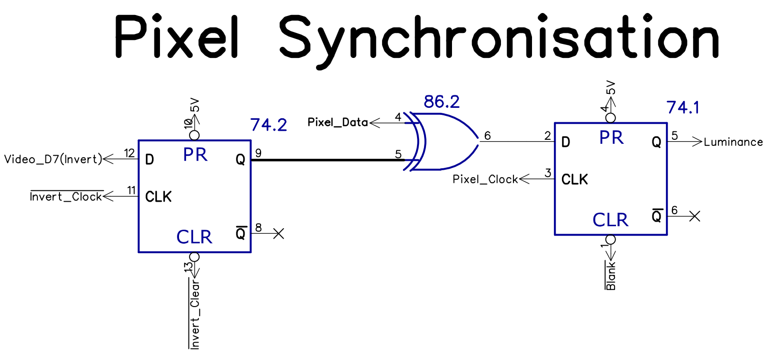
VIDEO

The video circuitry of the Mini PET is very different to that of an original PET, but implements the same functionality as a 2001 or closer to a 2001N PET. 1K of video RAM is used to store a screen made up of one byte for each of 40 x 25 characters. The highest bit of each byte controls whether the character is inverted. The remaining seven bits of this byte form the index into the character ROM. This is made up of 128 8 x 8 character bitmaps. These include graphical characters, but there is no pixel graphics control.

The video RAM used on the Mini PET is dual port RAM, meaning that the CPU and the video circuitry can access the video RAM without any conflicts*. To draw a character on the screen, the PET writes it to the appropriate location in the video RAM. The video circuitry continually reads the RAM and draws a screen. The two are therefore isolated and operate separately. The video circuit on an original PET will show a screen full of random characters even if the CPU is removed (or there is some fault which prevents it running code that will write to the video RAM). The Mini PET exhibits the same isolation.



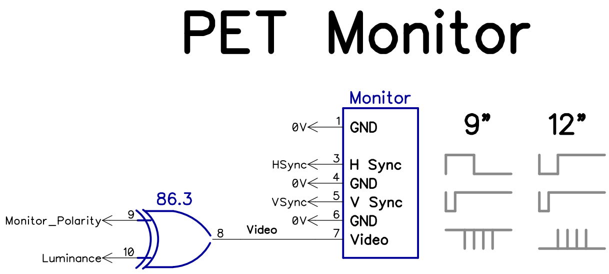
When a character is selected in the character ROM, it's databus contains the bits for one line of pixels that make up the selected character. This is latched into a shift register and clocked out at 8MHz. The pixel data is optionally inverted by an XOR gate controlled by a latch which holds the high bit of character data. The output from the XOR gate is fed via a flip flop which is also clocked at 8MHz, this ensure that all pixels are the same width.



almost no conflict. If the CPU and the video RAM access the same address at exactly the same time, the CPU will be halted for one or two clock cycles if the video controller was first, or a few pixels on the screen will be blacked out for a single frame if the CPU was first.

VIDEO OUTPUTS

The output of that flip flop is luminance picture data. This is used to generate two forms of video output.

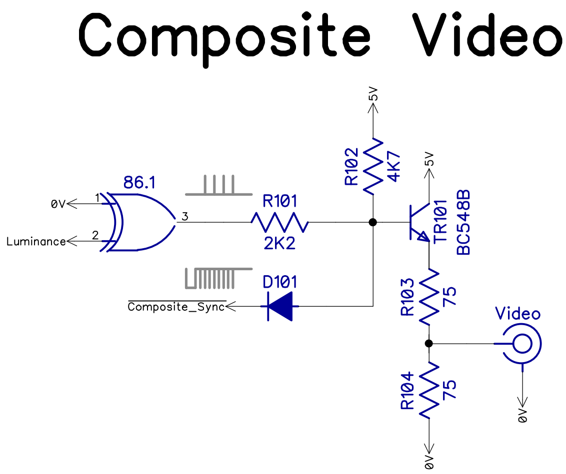


The PET has two main types of monitor, a 9" model used on the 2001 through to the first generation of 4032s, and a 12" model used on later 4032 and 8032 machines. These have very different drive requirements.

The 9" monitor has an active high horizontal sync that is a bit unusual in that it continues until part way through the video data portion of the line. The VSync is active low. Video data is inverted, high is off, and low is for illuminated pixels. As far as I am aware, all of these monitors were driven at 60Hz, even in 50Hz mains regions. The monitors were powered from DC, and the sync pulses were divided down from the 16MHz clock in the same way in all regions to get 60Hz. The lines were 64uS, 15.625KHz, compatible with normal composite video standards.

The 12" monitor has more normal active low sync pulses, but the HSync starts at the end of the previous lines video data. These monitors were region specific, with 50Hz and 60Hz versions, and an unusual 50uS line length, 20KHz, making their outputs incompatible with standard monitors.

The Mini PET drives both from the same connector; the video signal is selectively inverted depending on the DIP switch setting.



A composite video signal is generated with a sync mixer and video buffer. This is generated alongside the 9" monitor signal, at either 50Hz for PAL or 60Hz for NTSC. The signal has a front and back porch, but no colour burst. When the 12" monitor is selected, composite video is disabled as the 50uS line frequency is not supported. All parts shown above (other than the 74HC86) are optional and can be omitted if composite video output is not required.

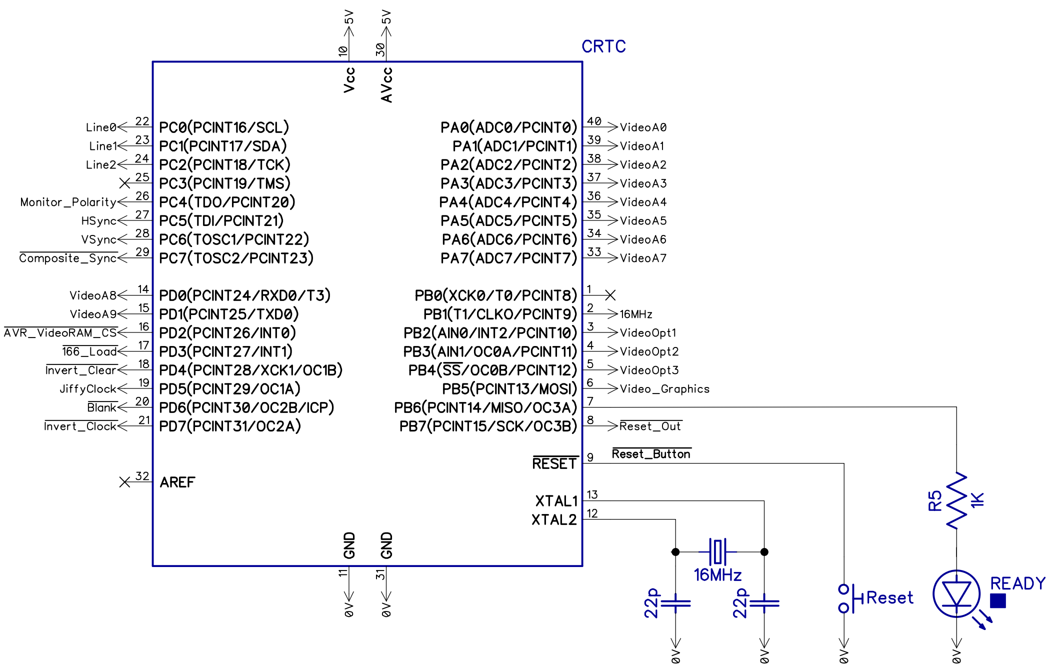
CRTC

On the PET 2001 and 2001N, quite a lot of the mainboard is dedicated to the video circuitry, part of which involves multiplexing the address bus, latching and buffering video data from both sides. That part is all replaced by the dual port video RAM chip. The remaining parts divide down the main clock to generate all the timing pulses required and count lines, rows and characters. On later PETs, that was partly controlled by a 6545 CRTC controller chip. On the Mini PET all the timing and counting is handled by an ATmega164P microcontroller, programmed as a sort of CRTC.

The code it is running is a fairly linear series of instructions, set an output, wait, set a different output, wait, etc. It has 16 instructions to deal with each character, whilst those 8 pixels are being drawn on the screen, so a lot of the code is very tight, and it is all cycle counted so that each loop lasts 64uS or 50uS depending on video mode.

The counting is complex to implement in logic due to the different regional and monitor timing requirements, but also to deal with storing the address at the end of a line. As each row of characters is make up of eight screen lines, it need to reset to the start of the line on all but that last line of each row. When drawing, the first line is characters 0-39, the second line 0-39 etc. until line 9 which is 40-79, then line 10 is 40-79 etc. These work out as addresses 8000-8027, 8028-804F etc. which is not easy to implement with discrete logic.

I Can't Believe It's not a 6545

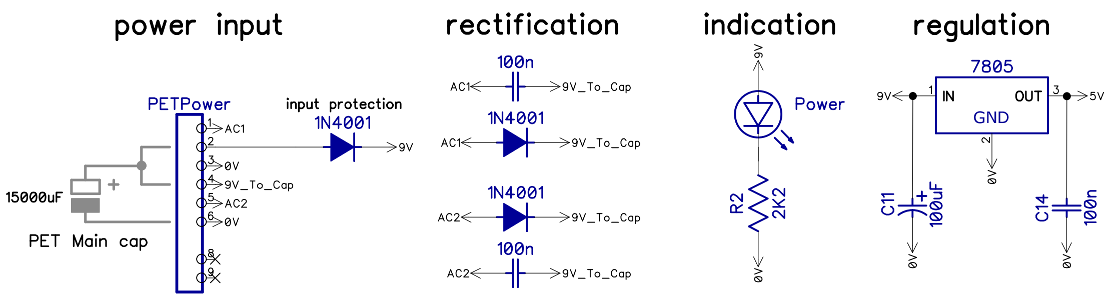


One main difference between that and the 6545 CRTC is this has no CPU control; it is in a fixed mode selected by the DIP switches. This is not usually a problem as very little software (other than demos) made any changes to the CRTC registers.

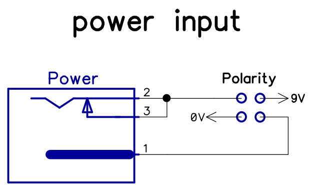
The microcontroller runs from its own 16Mhz crystal. The clock from this is output and is divided down to generate the 8MHz pixel clock and the 1MHz CPU clock. The microcontroller also generates a reset pulse that is used to drive the system reset pulse, and also the Ready LED, which is off during reset. The clock is divided down internally to generate a 60Hz clock that is fed to the VIA and PIA#2 for system timing.

POWER

Power is supplied by the original transformer inside the PET. This has two or three windings. One provides 12V or 19V AC for the monitor, and is usually connected directly to that. The second is the main 9V centre tapped winding, later PETs also have an additional 16V winding which is not used here.



The PET contains a main reservoir capacitor. This is connected to the board via two red wires in the power connector. One feeds 9V DC from the rectifiers to the capacitor, the other takes 9V DC from the capacitor into the circuit. There is a 1N4001 diode as input protection. Previously this was a reverse biased diode which would conduct if there was a negative voltage present. This has been switched to an inline diode to drop the voltage slightly and also protect against negative voltages.



If bench testing, power can be supplied by the optional 9V DC jack, with the polarity selected by the jumpers. This feeds the 9V via the input protection diode. It should not be used at the same time as the PET power connector, and will not power the internal monitor.

A red LED indicates 9V present, and will often light when you first plug in the power cable, even if the PET has been unplugged from the mains for several weeks. The capacitors inside the PET may be 40 years old, but they are more than fit for purpose, and rarely need changing.

5V is generated using a 7805 linear regulator. The current consumption on the 5V rail is around 140mA, more with a datasette or SD2PET, but usually not enough to require a heatsink.

The 9V is also used to power the datasette motors.

INTERNAL POWER CONNECTORS

There are no internal power connections as found on some PET motherboards. These are generally used to power expansion boards, and have not been included as 1) the CPU socket on the Mini PET is not compatible with any plug in boards, and 2) the Mini PET already had most of the upgrades you would need.