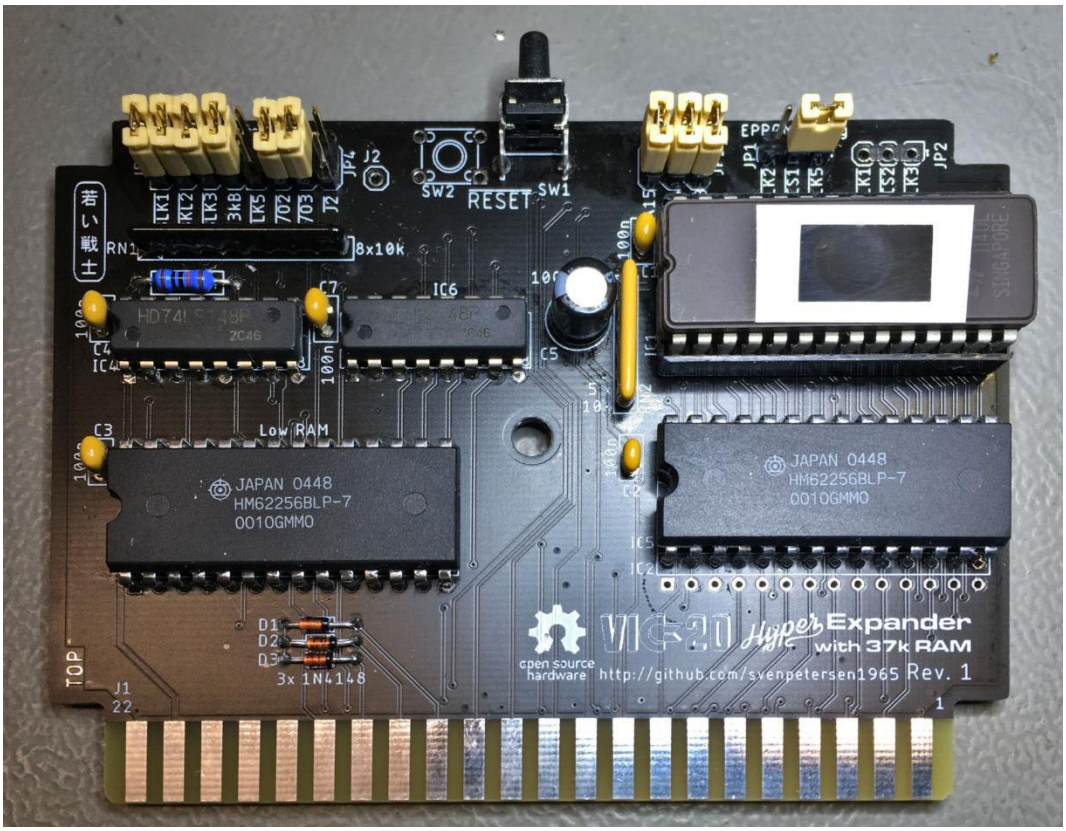
Project Documentation

Commodore VIC-20: Hyper Expander

Project number: 172

Revision: 1

Date: 05.05.2021



Commodore VIC-20: Hyper Expander Rev. 1

Module Description

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Introduction

The Hyper Expander is a cartridge for the Commodore VIC-20, which provides up to 16kB EPROM and up to 37kB RAM. It is a super-set of the original Commodore VIC-1211A Super Expander, which provides only 3k of RAM.

The Hyper Expander can hold up to two 27C512 EPROMs, the 8k memory bank of both EPROMs (A13...A15) can be selected for both EPROMs. The same selection applies to both of them. Each EPROM (IC1 and IC2) can be jumpered to two chip selects. That is $\overline{\text{BLK2}}$ or $\overline{\text{BLK5}}$ for IC1 and $\overline{\text{BLK1}}$ or $\overline{\text{BLK3}}$ for IC2.

The RAM consists of two 32kB 62256 type static RAMs. The memory is divided into four banks each. Two 74LS148 decode the active chip selects to one of each memory bank. The used chip selects can be configured with JP4 and JP5.

Configuration

Note

The chip selects of the EPROM and the RAM can be concurrent. The same chip select must not be used for RAM and EPROM at the same time.

EPROM Chip selects

EPROM	*Jumper*	*Chip Select*	*VIC-20 Address*
IC1	*JP1*	*$\overline{BLK2}$*	*$4000 - $5FFF*
		$\overline{BLK5}$	*$A000 - $BFFF*
IC2	*JP2*	*$\overline{BLK1}$*	*$2000 - $3FFF*
		$\overline{BLK3}$	*$6000 - $7FFF*

Table 1: Configurable Chip Selects

In case an EPROM should be deactivated, it is only required to pull JP1 and/or JP2. The chip select then is HIGH (inactive) due to new pull-up resistors.

RAM Chip Selects

JP5

JP5 activates the chip select signals, that are then decoded and address the respective RAM bank of IC3.

Pin	Chip Select	Addresses
1-2	$\overline{BLK1}$	$2000 - $3FFF
3-4	$\overline{BLK2}$	$4000 - $5FFF
5-6	$\overline{BLK3}$	$6000 - $7FFF
7-8	$\overline{CS3K}$	*$0400 - $0FFF*

Table 2: Jumper settings JP5

JP4

JP4 activates the chip select signals, that are then decoded and address the respective RAM bank of IC5.

Pin	Chip Select	Addresses
1-2	$\overline{BLK5}$	$A000 - $BFFF
3-4	$\overline{I/O2}$	$9800 - $9BFF
5-6	$\overline{I/O3}$	$9C00 - $9FFF
7-8	$\overline{J2}$	*Unused (experimental)*

Table 3: Jumper settings JP5

BYTES FREE

Be aware, that not all RAM configurations will lead to a more BASIC memory (the BYTES FREE) on switch on. The BASIC memory has to be **coherent**.

The memory map (screen RAM, BASIC RAM) of the VIC-20 depends on the memory expansion. It will be different for internal RAM and 3k Expansion.

RAM Configuration	BYTES FREE
$\overline{\text{CS3K}}$	6655
$\overline{\text{BLK1}}$	11775
$\overline{\text{CS3K}}$ and $\overline{\text{BLK1}}$	11775
$\overline{\text{BLK1}}$ and $\overline{\text{BLK2}}$	19967
$\overline{\text{BLK1}}$, $\overline{\text{BLK2}}$ and $\overline{\text{BLK3}}$	28159
$\overline{\text{BLK1}}$, $\overline{\text{BLK2}}$, $\overline{\text{BLK3}}$, $\overline{\text{CS3K}}$ and $\overline{\text{BLK5}}$	28159
$\overline{\text{CS3K}}$, $\overline{\text{BLK2}}$, $\overline{\text{BLK3}}$	6655

Table 4: Reported BASIC RAM

RAM that is not visible as BASIC RAM can of course still be accessed. In case an $\overline{\text{BLK1}}$ is selected, the lowest 3k are not visible as BASIC RAM. In case a memory gap is configured (like $\overline{\text{BLK2}}$ and $\overline{\text{BLK3}}$ are configured, but $\overline{\text{BLK1}}$ is missing, the BASIC RAM consists of the internal RAM and the 3k RAM expansion.

The **Super Expander** Software (in ROM) requires 136 bytes of RAM. In case this software is activated (it is associated to $\overline{\text{BLK5}}$) the BASIC memory will be reduced by this number of bytes.

Memory Bank Select (EPROM)

There are two different types of addresses mentioned in this document:

- VIC-20 Address
- EPROM Offset Address

Both types must not be confused! The EPROM Offset Address is the address of the selected memory bank within (the program buffer of the EPROM). This is, where you load the different binary files to the EPROM buffer. One of those memory banks is selected with the Jumper JP3. This appears in/is mapped to the VIC-20 memory at the address determined by the chip select $\overline{\text{BLK1/2/3/5}}$ (see Table 1).

JP3			Address Bits			EPROM Address
A15	A14	A35	A15	A14	A13	(Offset)
SET	SET	SET	L	L	L	0x0000 – 0x1FFF
SET	SET	OPEN	L	L	H	0x2000 – 0x3FFF
SET	OPEN	SET	L	H	L	0x4000 – 0x5FFF
SET	OPEN	OPEN	L	H	H	0x6000 – 0x7FFF
OPEN	SET	SET	H	L	L	0x8000 – 0x9FFF
OPEN	SET	OPEN	H	L	H	0xA000 – 0xBFFF
OPEN	OPEN	SET	H	H	L	0xC000 – 0xDFFF
OPEN	OPEN	OPEN	H	H	H	0xE000 – 0xFFFF

Table 5: 8k cartridges memory banks

EPROMs

Four different types/sizes of EPROMs can be used with the Super Expander II, not all settings make sense with them. Their pin out is shown in Table 6.

The effect of the settings and the recommended configurations are shown in Table 7.

27C64										
	27C128									
		27C256								
			27C512							
				SOCKET						
Vpp	Vpp	Vpp	A15	1	A15	VCC	28	VCC	VCC	VCC	VCC
A12	A12	A12	A12	2	A12	A14	27	A14	A14	/PGM	/PGM
A7	A7	A7	A7	3	A7	A13	26	A13	A13	A13	n.c.
A6	A6	A6	A6	4	A6	A8	25	A8	A8	A8	A8
A5	A5	A5	A5	5	A5	A9	24	A9	A9	A9	A9
A4	A4	A4	A4	6	A4	A11	23	A11	A11	A11	A11
A3	A3	A3	A3	7	A3	/OE	22	/G/Vpp	/G	/G	/G
A2	A2	A2	A2	8	A2	A10	21	A10	A10	A10	A10
A1	A1	A1	A1	9	A1	GND	20	/E	/E	/E	/E
A0	A0	A0	A0	10	A0	D7	19	D7	D7	D7	D7
D0	D0	D0	D0	11	D0	D6	18	D6	D6	D6	D6
D1	D1	D1	D1	12	D1	D5	17	D5	D5	D5	D5
D2	D2	D2	D2	13	D2	D4	16	D4	D4	D4	D4
GND	GND	GND	GND	14	GND	D3	15	D3	D3	D3	D3

Table 6: EPROM pin compatibility

EPROM	Size	A15	A14	A13
27C512	64kx8	yes	yes	yes
27C256	32kx8	HIGH	yes	yes
27C128	16kx8	HIGH	HIGH	yes
27C64	8kx8	HIGH	HIGH	HIGH

Table 7: Settings per EPROM type

In case Vpp is located at a dedicated pin (pin 1), A15 has no effect anymore. A HIGH level is recommended (switch is off). The /PGM Pin should be set HIGH. The n.c. (not connected) pin should be HIGH (with pull-up resistor) or open.

Using parallel EEPROMs

There are ***parallel*** EPROMs, which fit into the EPROM sockets. They do not require erasing with a UV eraser, like EPROMs, but the price is higher.

Since they can be written, which is controlled by the $\overline{WE}$ signal, but the Super Expander II cartridge is lacking of this functionality, this signal has to be HIGH (inactive). The 28C256 has the A14 signal connected to Pin 1, which is A15 of the EEPROM socket. This is no problem, but it has to be kept in mind, that the jumper for A15 has effect on the bank select A14 of the EPROM.

28C64					
	28C256				
		SOCKET			
n.c.	A14	1 A15	VCC 28	VCC	VCC
A12	A12	2 A12	A14 27	/WE	/WE
A7	A7	3 A7	A13 26	A13	n.c
A6	A6	4 A6	A8 25	A8	A8
A5	A5	5 A5	A9 24	A9	A9
A4	A4	6 A4	A11 23	A11	A11
A3	A3	7 A3	/OE 22	/G/Vpp	/OE
A2	A2	8 A2	A10 21	A10	A10
A1	A1	9 A1	GND 20	/E	/CE
A0	A0	10 A0	D7 19	D7	D7
D0	D0	11 D0	D6 18	D6	D6
D1	D1	12 D1	D5 17	D5	D5
D2	D2	13 D2	D4 16	D4	D4
GND	GND	14 GND	D3 15	D3	D3

Table 8: EEPROM pin compatibility

EEPROM	Size	A15	A14	A13
28C256	32kx8	=A14	OPEN	yes
28C64	8kx8	OPEN	OPEN	OPEN

Table 9: Settings per EEPROM type

Dimensions

The dimensions of the Hyper Expander are identical to those of the original Super Expander PCB.

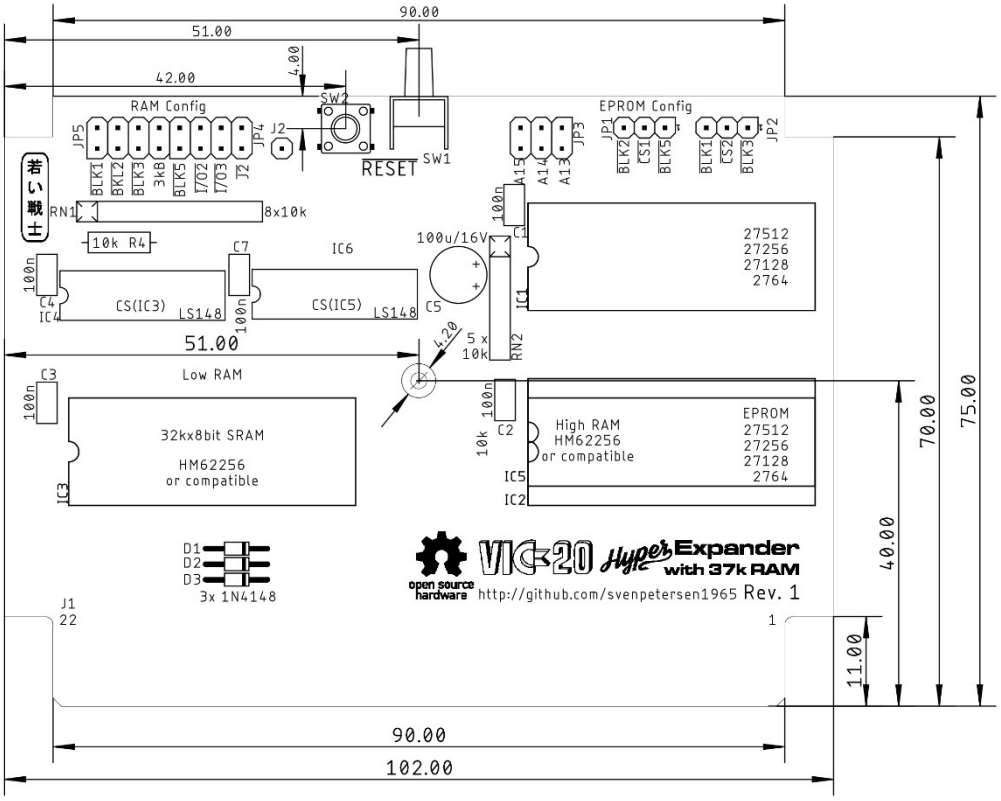


Figure 1: Dimensions of the Super Expander II

The PCB fits the original Super Expander cartridge case, another VIC-20 cartridge case from Commodore or the tfw8bit.com cartridge case.

The VIC-20 cartridge cases are high enough to fits the Super Expander II PCB even with the ICs on sockets and vertical jumpers. This has been verified for the Super Expander case and the tfw8bit case. The tfw8bit case and the "other Commodore VIC-20" cases require two T-shaped board supports in the middle of the lower shell to be removed.

Assembly and BOM

The High RAM (IC5) cannot be installed together with the 2nd EPROM (IC2).

2 EPROM Build

Do not place: JP4, IC5 and IC6, C7

Full RAM Build

Do not place: JP2, IC2

No RAM, just EPROM

Do not place: IC3, C3, IC4, C4, IC5, IC6, C6, RN1, D1-3, R4, JP5, JP4

Other Options

SW2 is a vertical RESET switch, while SW1 is the horizontal option. It is only required to place one.

JP4 and JP5 are in the same grid. If bother are required (for full RAM), one 8x2 pin header can be installed.

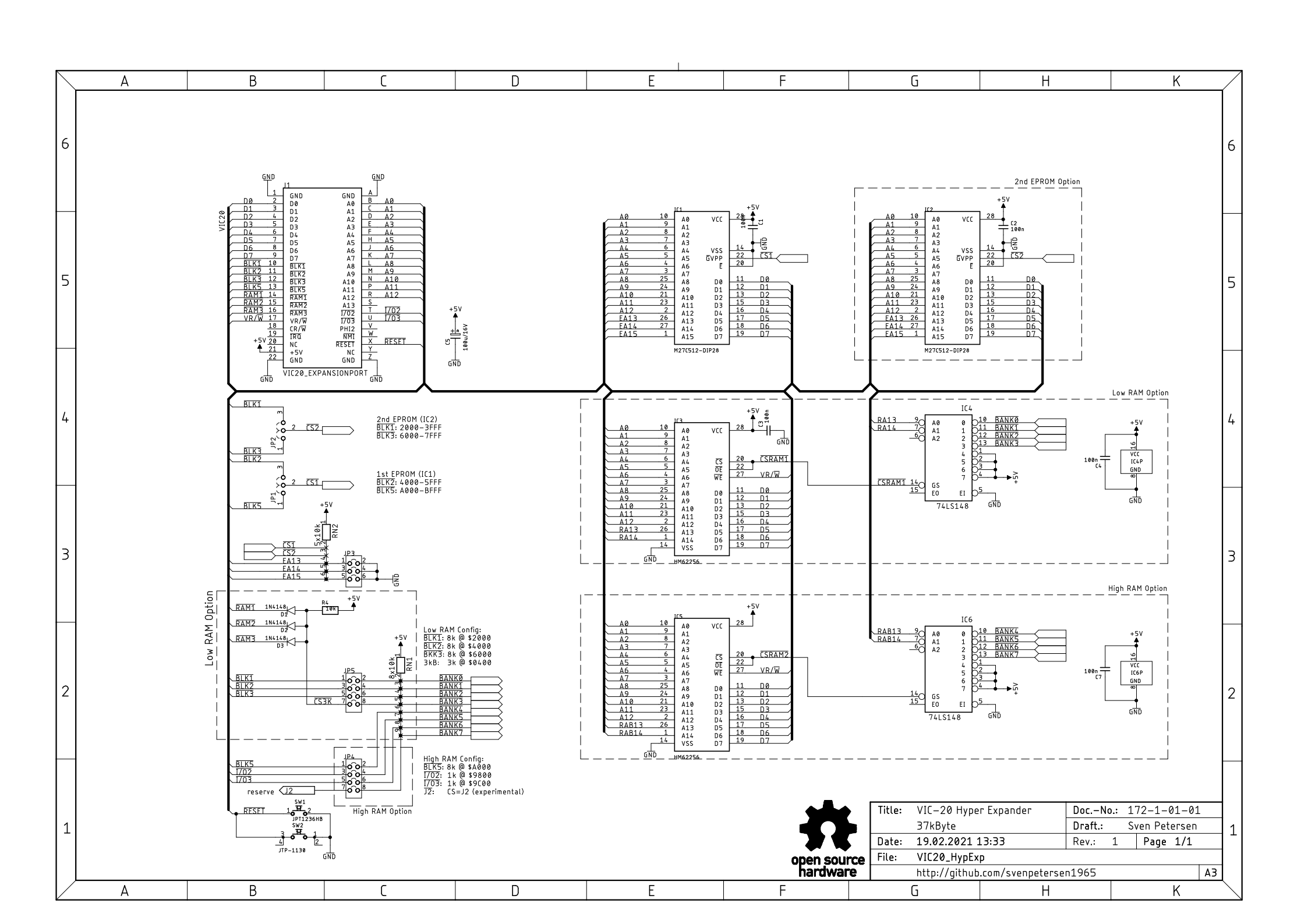
Revision History

Rev. 0

- Prototype: Fully functional.

Rev. 1

- Second optional RAM (IC5, “High RAM”) to provide the maximum possible RAM
- All jumpers moved to the front edge, so they can be accessed while the cartridge is installed
- Optional vertical RESET switch
- Resistor networks for many pull ups reduce the required space
- Pull ups for the EPROM chip selects


VIC20_EXPANSIONPORT
M27C512-DIP28
2nd EPROM Option
Low RAM Option
High RAM Option
2nd EPROM (IC2)
BLK1: 2000–3FFF
BLK3: 6000–7FFF
1st EPROM (IC1)
BLK2: 4000–5FFF
BLK5: A000–BFFF
Low RAM Config:
BLK1: 8k @ $2000
BLK2: 8k @ $4000
BKK3: 8k @ $6000
3kB: 3k @ $0400
High RAM Config:
BLK5: 8k @ $A000
I/O2: 1k @ $9800
I/O3: 1k @ $9C00
J2: CS=J2 (experimental)
HM62256
74LS148
open source hardware
Title: VIC–20 Hyper Expander 37kByte
Doc.–No.: 172–1–01–01
Draft.: Sven Petersen
Date: 19.02.2021 13:33
Rev.: 1
Page 1/1
File: VIC20_HypExp
http://github.com/svenpetersen1965
A3

Sven Petersen 2021	Doc.-No.: 172-2-01-01	
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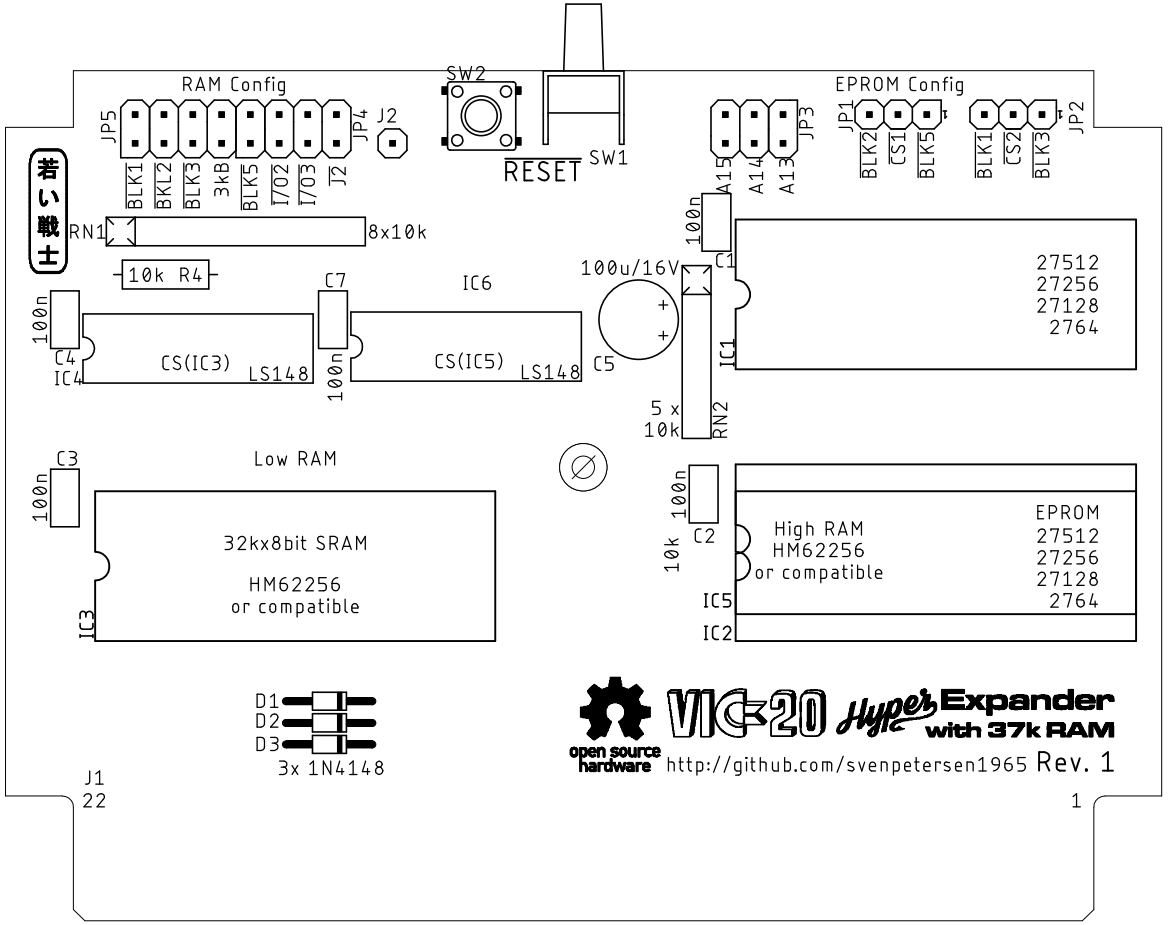
19.02.2021 11:07		Rev.: 1
placement component side		



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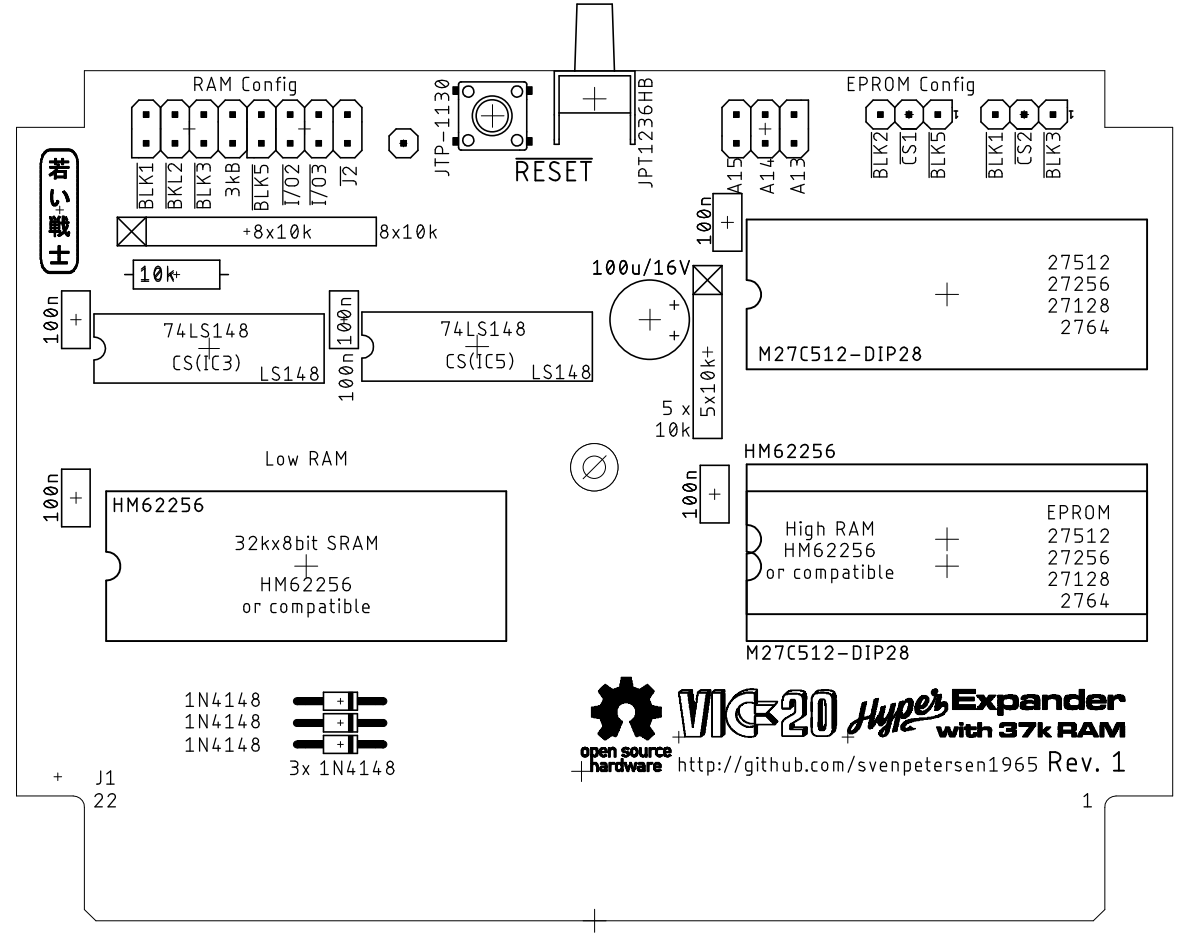

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nicht gespeichert!		Rev.: 1
placement solder side		

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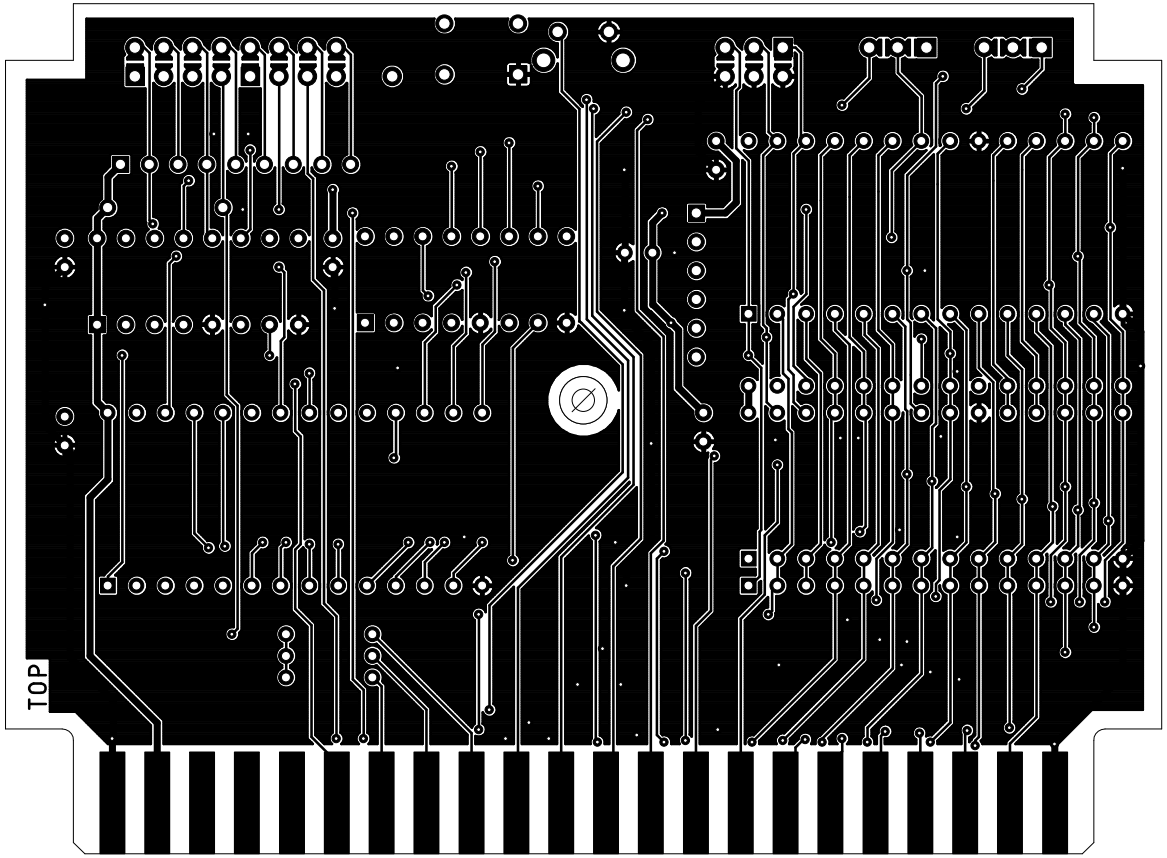
top		



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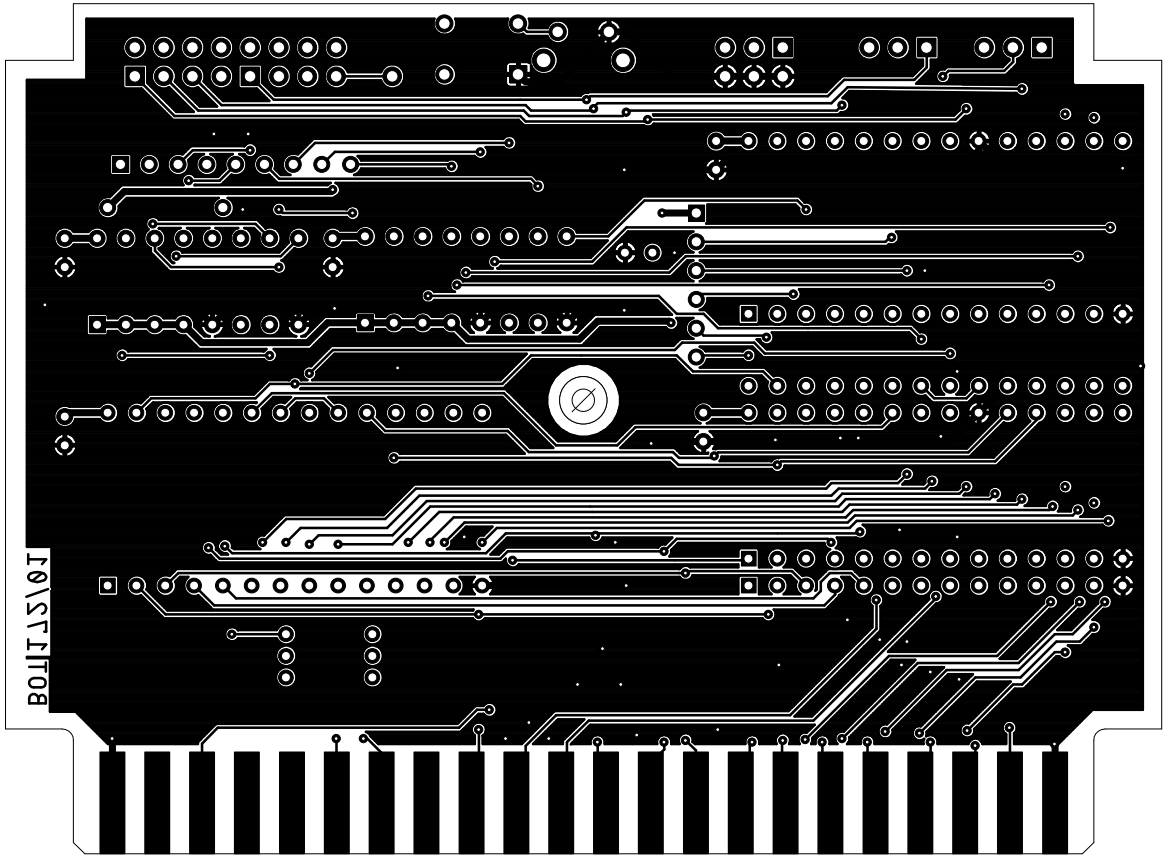
bottom		



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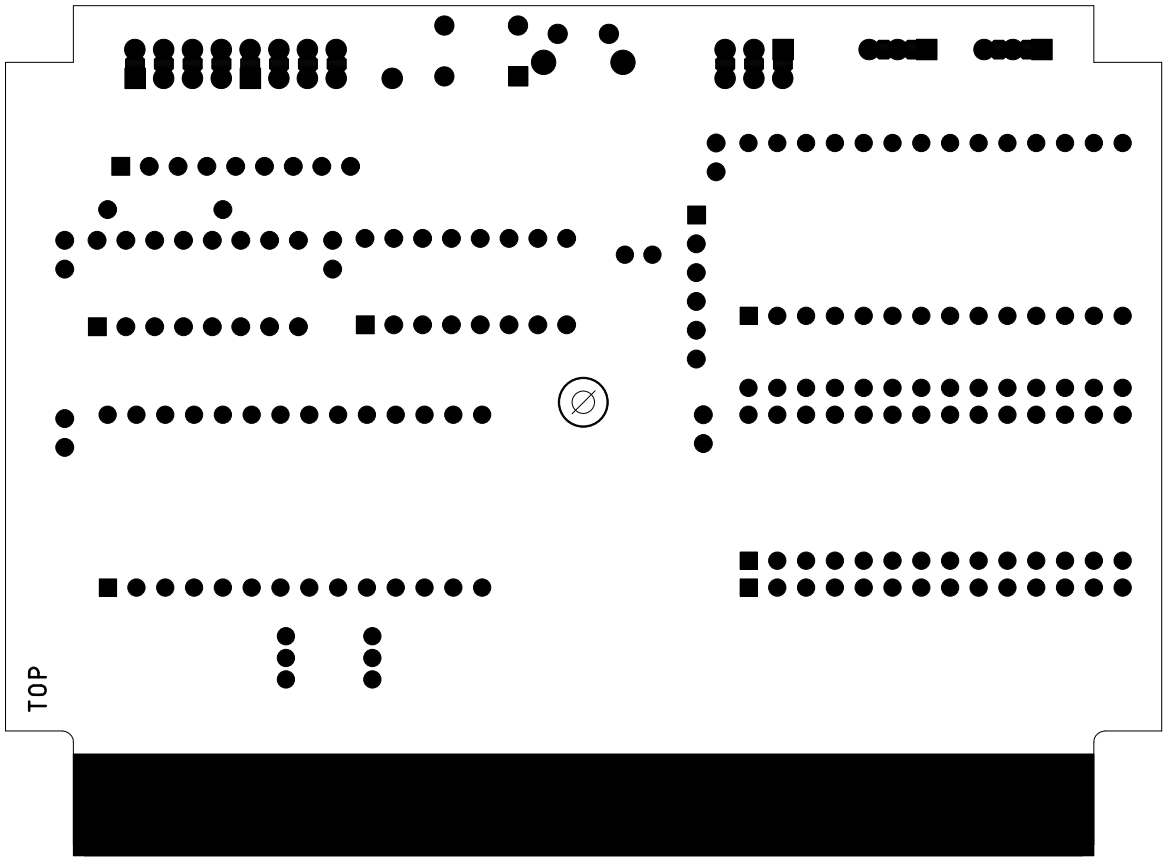
VIC20_HypExp		
19.02.2021 13:31		Rev.: 1
stopmask component side		



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19.02.2021 13:31		Rev.: 1
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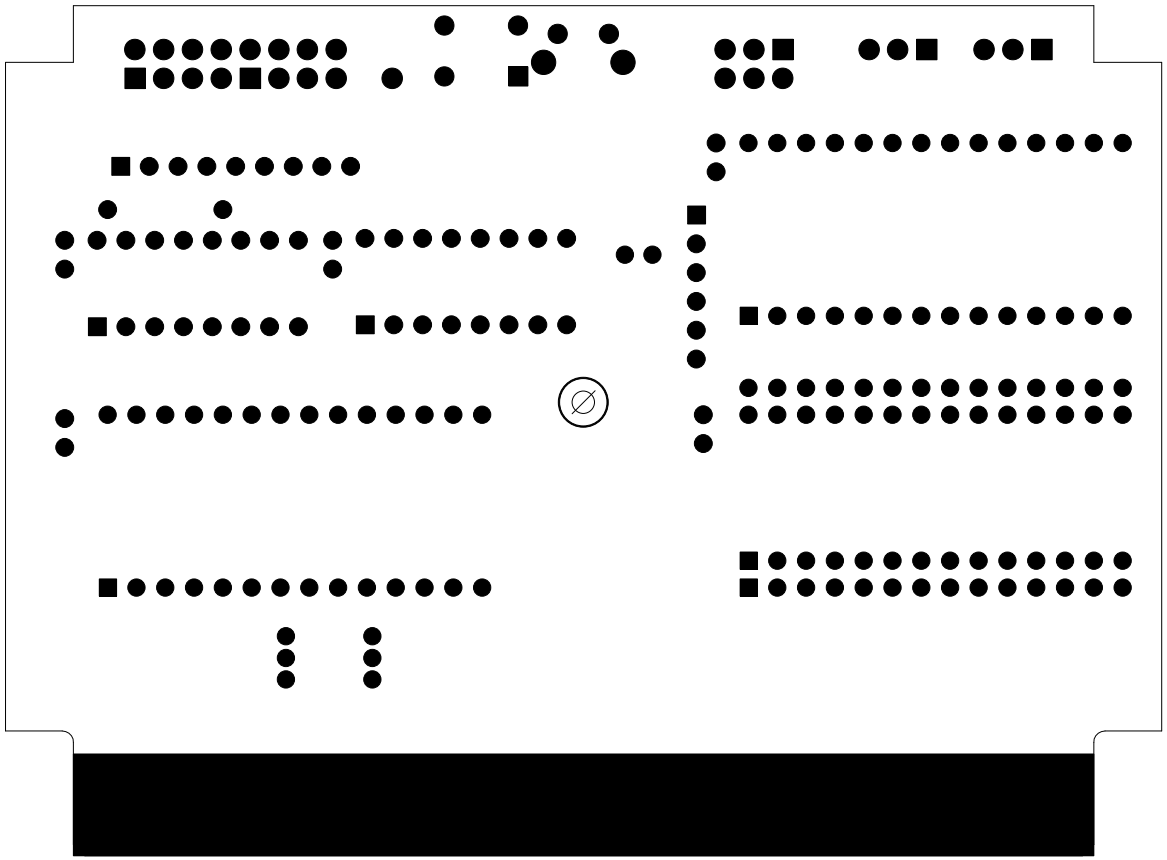

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VIC20_HypExp		
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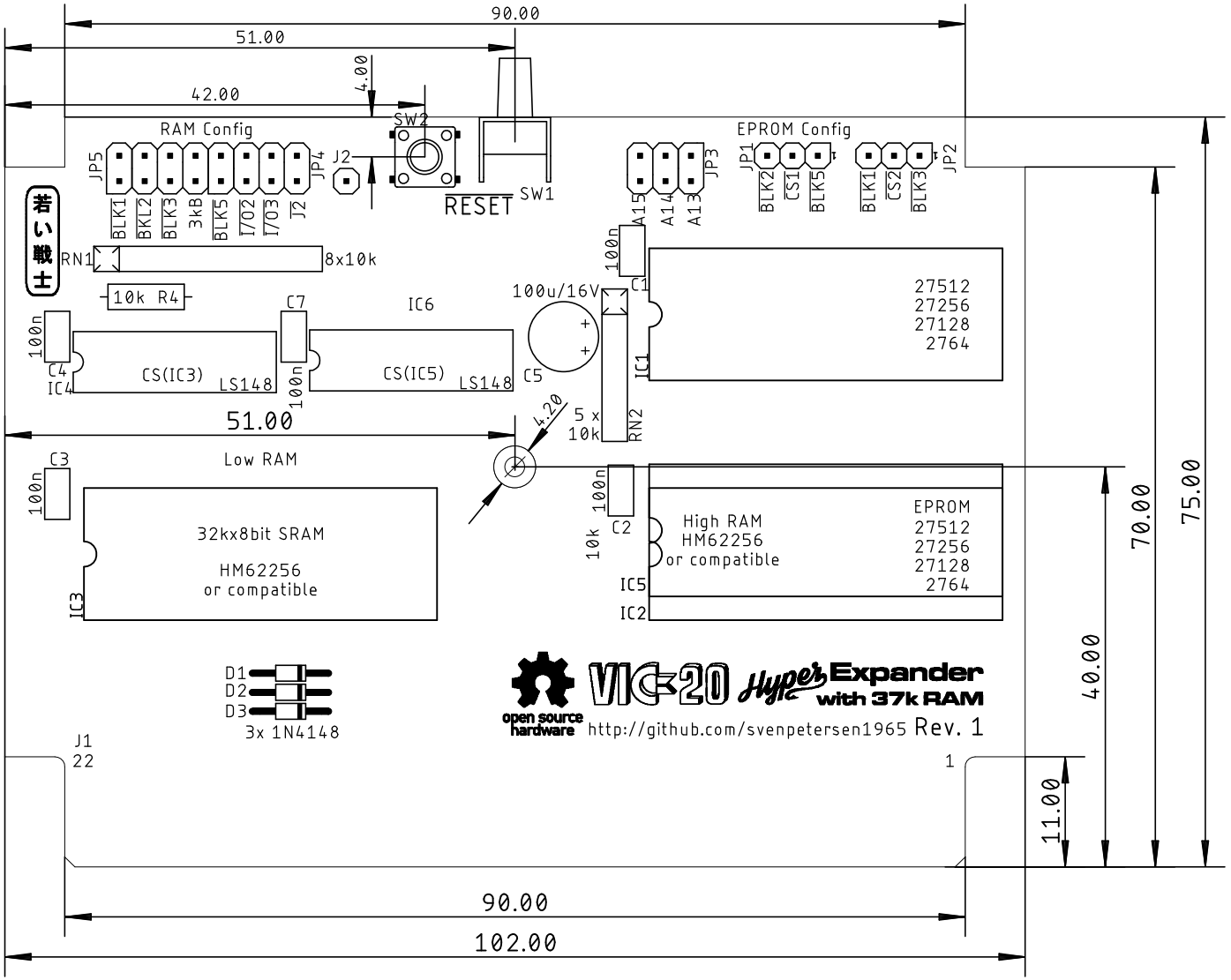
placement component side measures		



Commodore VIC-20: Hyper Expander Rev. 1

Functional Description

The EPROM part with IC1 and IC2 is pretty much a straight forward VIC-20 EPROM cartridge. The data bus (D0…D7) and the address bus (A0…A12) are connected to the EPROM. This allows to address 8k of memory. The address bit A13…A15 can be jumpered (JP3), which results in selectable 8k memory banks.

The chip selects can be set for each EPROM differently (JP1 and JP2). It is not every chip select possible to use with IC1 and IC2.

IC3 and IC5 are static RAMs (32kByte each). Again, the data bus (D0…D7) and the address bus (A0…A12) is connected to both ICs, which results in an 8k RAM bank size. These four RAM banks are selected with the signals RA13 and RA14 (IC3 = Low RAM)) and RAB13 and RAB14 (IC5 = High RAM)). Those additional address signals are generated by the 8 to 3 decoder IC4 and IC6 for the High RAM). If one of the chip selects gets LOW, the signal $\overline{\text{CSRAM1}}$ or $\overline{\text{CSRAM2}}$ gets LOW, too. This is forming the chip select signal of IC3/IC5.

The three chip select signals for the 3k RAM expansion are originally made for addressing 2114 1kx4 RAMs. Since the 4th RAM block is addressed with the 3k chip selects $\overline{\text{RAM1..3}}$, those need to be combined to a single chip select, which is accomplished with D1, D2 and D3 and the pull-up resistor R4. In case one of those signals is LOW, the combined $\overline{\text{CS3K}}$ is LOW as well.

The 2nd EPROM IC2 is optional and can only be installed, in case the High RAM IC5 is not installed. In this case, IC6 and JP4 are not required.

Commodore VIC-20: Hyper Expander Rev. 1

Testing

Test Setup

The tests were conducted with a VickyTwenty (a reproduction of the VIC-20 ASSY 250403) and a Hyper Expander cartridge (Rev. 1) with two HN61256BLP-7 RAM and up to two 27C512 EPROMs.

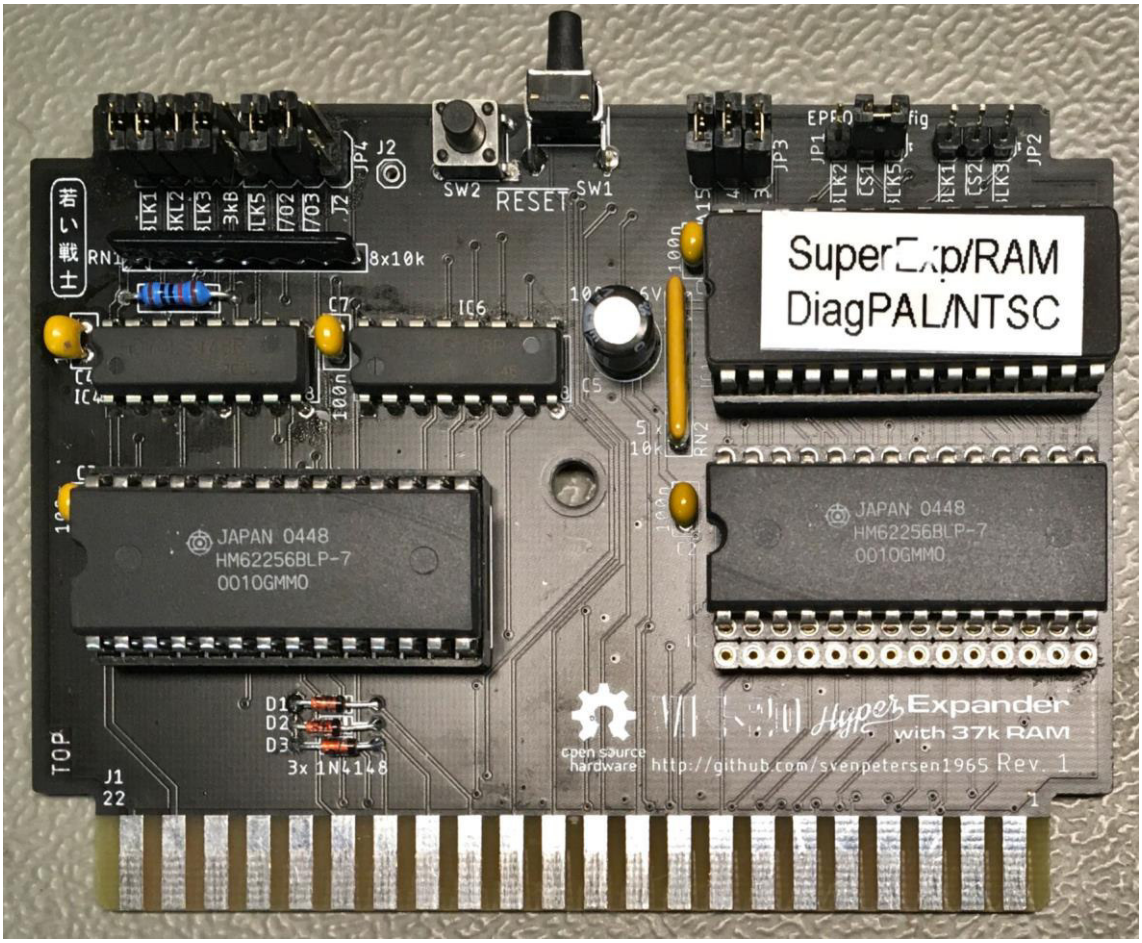


Figure 1: Prototype of Hyper Expander Rev. 1

Test Execution

Super Expander Software

First, the original Super Expander Software from zimmers.net and the VIC-MON for $B000 were programed to an EPROM. These two programs fit into one 8k memory bank, since the Super Expander software is a 4k software. The EPROM was inserted the in IC1 socket and $\overline{\text{CS1}}$ (JP1) was set to $\overline{\text{BLK5}}$ ($A000-$BFFF). The RAM was configured to 3k RAM expansion only (JP4=3k, J5: 7-8 only = BLK5/3k).

The cartridge was inserted into the VIC-20 and the computer was switched on. It booted normally and 6519 Bytes Free were reported. The Super Expander requires bytes in RAM, so this is correct.

Figure 2: Test with Super Expander Firmware and full RAM expansion

The function keys produce some of the additional Super Expander instructions. A short program, which is using those instructions, was executed successfully.

- ✓ **Function of RAM and EPROM IC1 with $\overline{\text{BLK5}}$ and the Super Expander Software verified.**

SYS11*4096 (which is $B000) started the VIC-MON.

- ✓ **Additional test.**

The Super Expander Software was tested with all other RAM configurations, the VIC-20 always booted properly.

RESET Button

The RESET button (SW1) was pressed. The VIC-20 rebooted properly. The same applies to SW2.

- ✓ **RESET button verified**

VIC-20 Diagnostic Software

The software (PAL) also origins from zimmers.net. It was programmed into the 2nd 8k of the said EPROM, a different version of this software (NTSC) was programmed to the 3rd 8k.

The jumpers on JP3 were set to the 2nd 8k (A15...A13: set open), JP1 remained at $\overline{\text{BLK5}}$.

The RAM was configured to 3k Expansion only.

The diagnostics software started and executed properly (together with the VIC-20 diagnostics harness). For the 2nd version of the diagnostic software, JP3 was set to the 3rd 8k bank (A15...A13: set open set). This software executed properly, too.

- ✓ Bank select (000, 001, 010) on JP3 verified

Game Cartridge Donkey Kong

This game is a 16k game and requires both EPROMs.
The software for $A000 was programmed in a fresh EPROM, which was inserted into IC1. JP1 remained at $\overline{\text{BLK5}}$. The other part of the software, which is located at $2000 was programmed into another fresh EPROM, which was then inserted into the IC2 socket.

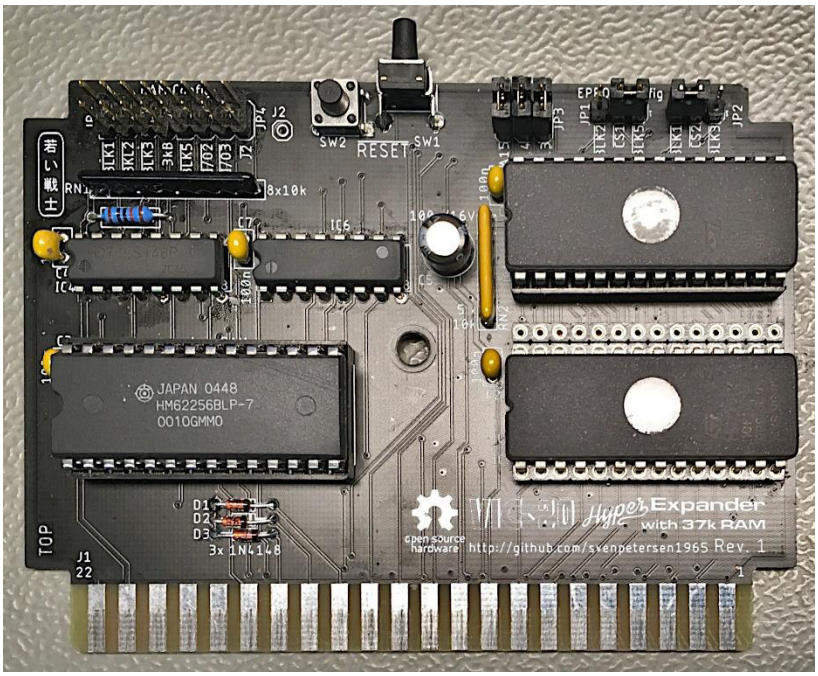


Figure 3: Configuration withn two EPROMs

JP2 was set to $\overline{\text{BLK1}}$. All jumpers on JP3 were set. The software started properly and the game could be played.

- ✓ EPROM IC2 with $\overline{\text{BLK1}}$ verified

Game Cartridge AE

The software origins from zimmers.net. It consisted of two images, one for $A000 and one for $6000. The images were programmed into two EPROMs, the $A000 software was inserted into IC1, the $6000 software into IC2. Jumper JP1 was set to $\overline{\text{BLK5}}$, JP2 to $\overline{\text{BLK3}}$. The software started properly and the game could be played.

- ✓ EPROM IC2 with $\overline{\text{BLK3}}$ verified

VIC-MON (for $4000)

The source of this software is once again zimmers.net. It was programmed into the 5th 8k memory bank (@ buffer address $8000) of an EPROM. The EPROM was inserted into IC1 and JP1 was set to $\overline{\text{BLK2}}$.

SYS4x1022 started the software properly.

- ✓ Bank select (100) on JP3 and $\overline{\text{BLK2}}$ (JP1) verified

RAM Test

The RAM configuration was tested with the RAM Expansion Test Software Rev. 1.0 (https://github.com/svenpetersen1965/VIC-20-RAM-Expansion-Test-Software)

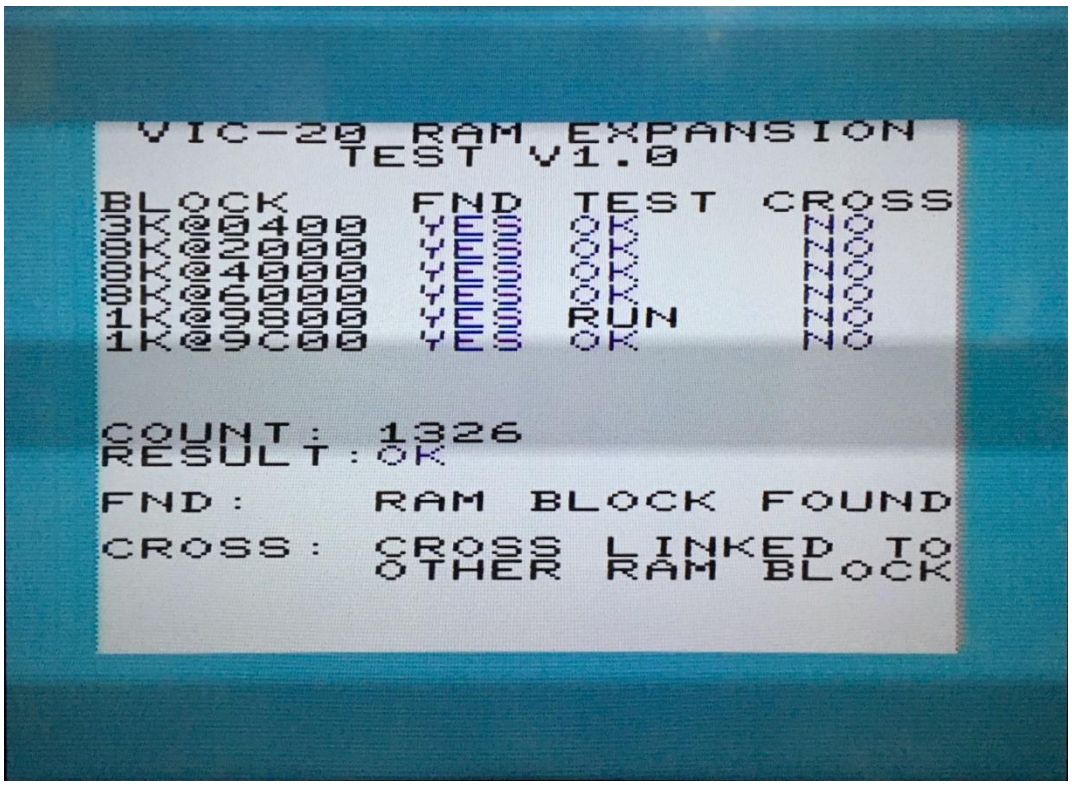


Figure 4: RAM Expansion Test running from EPROM

The version v1.0 of the RAM Test Software is capable of testing the RAM blocks attached to $\overline{I/O2}$ and $\overline{I/O3}$. This software tests every bit in a RAM block for LOW and for HIGH. Also address line conflicts and a cross talk to other RAM blocks are detected.

In the first pass, the RAM Test was running from the on-board EPROM IC1, configured to $A000 with BLK5). The test was running several thousand times without reporting any problems.

To test the 7th RAM bank configured at $A000, the EPROM was removed and the JP4 was set to BLK5. This test configuration did not report any problems, either.

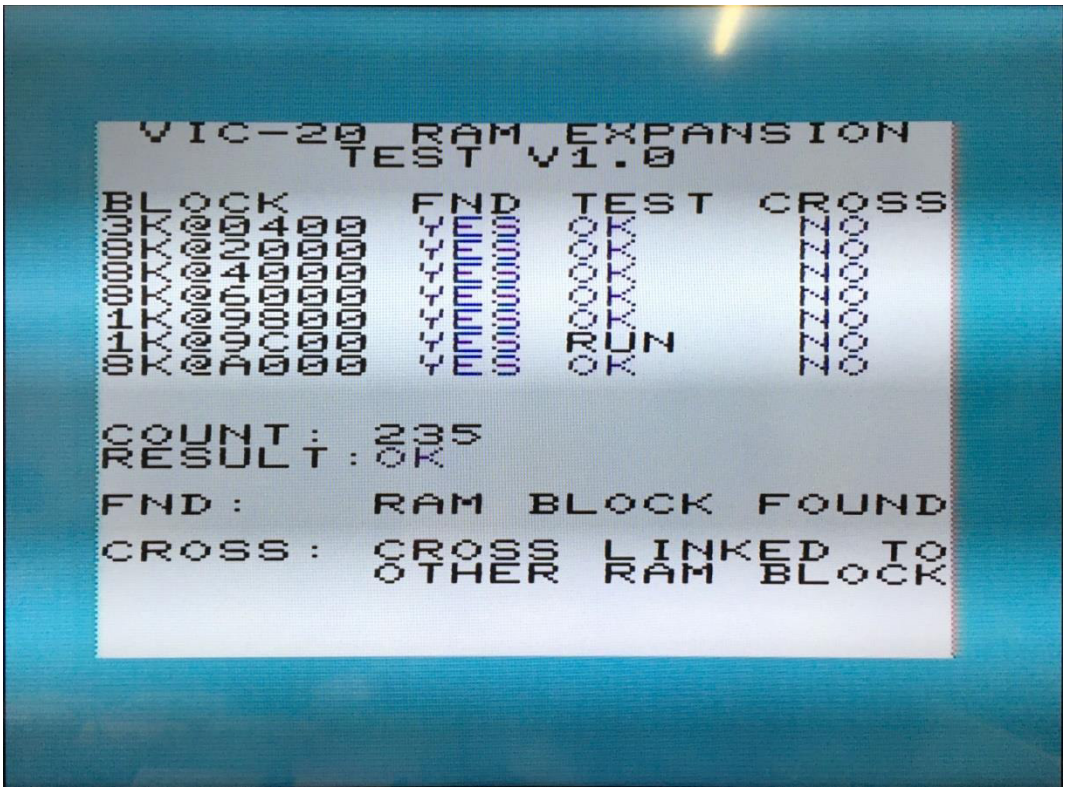


Figure 5: RAM Expansion Test running from a disk image

The game DOOM for VIC-20 requires 35k of RAM. It was played with all RAM activated and the EPROM deactivated.

Figure 6: DOOM running on the VIC-20 with the Hyper Expander configured to maximum RAM

- ✓ RAM function verified

Installation in cartridge cases

The fully assembled Hyper Expander PCB (all ICs on sockets and all vertical jumpers) was installed in the **original Commodore Super Expander cartridge case**. This could be accomplished without a problem.

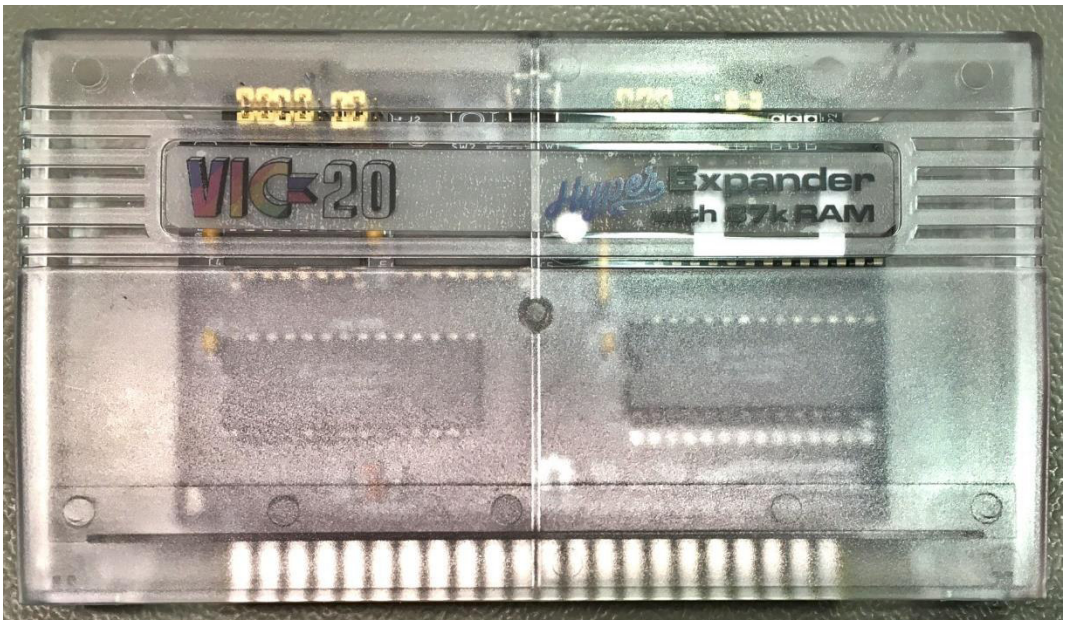


Figure 7: Installation in a tfw8bit case

The **original Commodore Game cartridge case** required removing some support structures for small PCBs, after that, it also fit.

The **tfw8bit.com VIC-20 cartridge case** fits after removing the support structures for the short PCBs.

In case the RESET switch is desired, the cases require a modification (5mm hole in the back)

- ✓ Dimensions verified

Conclusion

The Hyper Expander Rev. 1 is fully functional

Commodore VIC-20: Hyper Expander Rev. 1
Bill of Material Rev. 1.0

Pos.	Qty	Value	Footprint	Ref.-No.	Comment
1	1	172-2-01-01	2 Layer	PCB Rev. 1	2 layer, Cu 35µ, HASL, 102.0mm x 75.0mm, 1.6mm FR4
2	5	100n	C-2,5	C1, C2, C3, C4, C7	Ceramic capacitor, pitch 2.5mm (25V or 50V)
3	1	100u/16V	C07/2,5	C5	Electrolytic cap, pitch 2.5mm, Ø 7mm
4	1	10k	R-10	R4	Metal film resistor, 10% or better
5	3	1N4148	DO-35	D1, D2, D3	Diode
6	2	74LS148	DIL-16	IC4, IC6	TI or other
7	2	1x3 pin header (2.54mm pitch)	COMBI-3P	JP1, JP2	standard pin header (option, can be configured with solder bridge)
8	1	3X2 pin header (2.54mm pitch)	COMBI-3X2	JP3	standard pin header (option, can be configured with solder bridge)
9	1	8X2 pin header (2.54mm pitch)	COMBI-4X2	JP4 and JP5	standard pin header (option, can be configured with solder bridge), JP4 and JP5 share the same raster, one component can be püopulated
10	2	HM62256	DIL28-6	IC3, IC5	Hitachi SRAM, 32k or compatible. E.G. AliExpress https://www.aliexpress.com/item/4001203718996.html?spm=a2g0s.9042311.0.0.22cb4c4dLFzppg, or Reichelt 62256-80
11	1	JPT1236HB	JTP_1236HB	SW1	Namae Electronics, e.g. Reichelt TASTER 3305B, tme.eu: TACTA-68N-F
12	1	6x6mm tact switch		SW2	alternative to SW1
12	1	M27C512-DIP28	DIL28-6	IC1	EPROM: 27C64, 27C128, 27C256 possible. Refere to document 172-6-01-**
13	1	M27C512-DIP28	DIL28-6	IC2	option, not required for super expander, do not populate for full RAM
14	3	DIP28-Sockets		(IC1), (IC2), (IC3 or IC5)	option, refer to IC1, IC2 and IC3
15	1	pinheader 1 pin	1X01	J2	do not populate
16	1	5x10k	RN-6	RN2	resistor network, 5 resistors, 6 pins
17	1	8x10k	RN-9	RN1	resistor network, 8 resistors, 9 pins

Please refer to the Module Description to determin the BOM required for your application