Project Documentation

Pi1541 HAT

Project number: 111

Revision: 2

Date: 29.11.2019

Pi1541-HAT Rev. 2

Module description

Description

The Pi1541 HAT is the required electrical and user interface for the Raspberry Pi (Model 3, 3+ or better) to emulate the Commodore 1541 floppy disk drive in conjunction with Steve White's software project (https://cbm-pi1541.firebaseapp.com/). This software is a cycle exact, real-time emulation of the 1541. The disk images are stored on the SD-card of the Raspberry Pi and the switches and the display (of the HAT) allow the user to navigate through his disk archive. Since Pi1541 emulates the exact hardware of the 1541, it is compatible to every speed loader, that work with the original disk drive.

This Pi1541 HAT is one of many possible variants. It holds the original I/O-driver configuration of the 1541, which is then adapted to the Raspberry Pi. The user interface consists of an OLED-display, six switches and a piezo buzzer, which resembles the sound of the working stepper motor.

Further on, it is designed to offer a good flexibility. The display can be either connected to a 4 pole receptable on the board or it can be detached and connected with a small piece of ribbon cable. The switches can also be soldered on the PCB or on a little extra PCB (Pi1541-Switch), which also holds two LEDs and is designed for a front panel mount. The two IEC-connectors can be mounted on this PCB or a separate PCB (Pi1541-IEC), which also holds a RESET switch and a barrel connector for a 5V power supply.

Pin outs

IEC-Bus

J1 and J2 – Lumberg 010599 06, 6p DIN receptables

Pin	Signal
1	/SRQ (not used in this design)
2	GND
3	ATN
4	CLK
5	DATA
6	/RESET

IEC Bus (break out board)

X1 – 10p Micro Match receptible, female, vertical, through hole, e.g. MPE Garry 369-1-010

X1 can be assembled instead of J1 and J2

Pin	Signal
1	/SRQ (not used in this design)
2	GND
3	ATN
4	CLK
5	DATA
6	/RESET
7	+5V
8	+5V
9	GND
10	GND

Display

M2 - A 0.96" OLED display (I^2C) can be connected to the 4p receptable M2 (0.1" pin distance). This connector provides +3.3V supply voltage. It is important to check the pinning of the display. Some might have swapped +3.3V and GND, so inserting those displays will destroy them.

From left to right:

Pin	Signal
1	VCC
2	GND
3	SCL
4	SDA

External Display

In case the display is desired to be mounted externally or it is bigger than the footprint (e.g. 1.3") or it has a different pin sequence such as GND, VCC etc. it can be attached to this connector.

X2 – 4p Micro Match receptible, female, vertical, through hole, e.g. MPE Garry 369-1-004

Pin	Signal
1	VCC
2	GND
3	SCL
4	SDA

External Switches

X3 – 8p Micro Match receptible, female, vertical, through hole, e.g. MPE Garry 369-1-008

Pin	Signal
1	/SW1
2	/SW2
3	/SW3
4	/SW4
5	/SW5
6	LED_OUT (LD1)
7	+3V3
8	GND

Raspberry Pi Connector

A 2x20 Pin receptible, assembled on the solder side of the PCB.

Pin	GPIO	Signal	Comment
1	-	+3.3V	Supply voltage
2	-	+5V	Supply voltage
3	SDA	SDA (I²C)	I²C-Bus (display)
4	-	+5V	Supply voltage
5	SCL	SCL (I²C)	I²C-Bus (display)
6	-	GND	Ground
7	4	/SW4_IN	Switch 4, active low
9	-	GND	Ground
11	17	/CLK_OUT	/CLK_(output to IEC-Bus driver)
12	18	/DATA_OUT	/DATA (output to IEC-Bus driver)
13	27	/SW1_IN	Switch 1, active low
14	-	GND	Ground
15	22	/SW2_IN	Switch 2, active low
16	23	/SW3_IN	Switch 3, active low
17	-	+3.3V	Supply voltage
18	24	ATN_IN	ATN (IEC-Bus), 3.3V-level
20	-	GND	Ground
22	25	DATA_IN	DATA (IEC-Bus), 3.3V-level
25	-	GND	Ground
27	ID_SD	ID_SD	Secondary I²C: SDA
28	IC_SC	ID_SC	Secondary I²C: SCL
29	5	/SW5_IN	Switch 5, active low
30	-	GND	Ground
33	13	SND_OUT	Sound/Piezo buzzer
34	-	GND	Ground
36	16	LED_OUT	Activity LED
37	26	CLK_IN	CLK (IEC-Bus), 3.3V-level
38	20	/RESET_IN	/RESET (IEC-Bus), 3.3V-level
39	-	GND	Ground

Rotary Encoder connector

J3 – 5-pin pin header (2.54mm pitch) vertical or 90°.

Pin	Signal
1	GND
2	+3V3
3	SW (/SW1_IN)
4	DATA (/SW3_IN)
5	CLK (/SW2_IN)

Jumpers

JP1 and JP2 are SMD jumpers (to be bridged by a 0603 resistor/0Ω). The I²C bus for the display can be selected. For a proper function, they should both be bridged between 1-2. This selects the primary I²C-bus.

Switches

Switch	Function
SW1 (left)	Select/Reset
SW2	Move Up/Previous Disk
SW3	Move Down/Next Disk
SW4	Exit Folder
SW5 (right)	Insert Disk

SW6 is a RESET switch for the IEC-Bus

Configuration

The configuration of the software can be found in the root directory of the micro SD-card (options.txt). It has to be edited before powering up the Raspberry Pi for the first time.

Since there are input and output drivers, for the bidirectional IEC-Bus signals signal, the parameter has to be set in the following way:

```
splitIECLines = 1
```

There is a buzzer acting as a sound device for resembling the working stepper motor of the real drive:

```
SoundOnGPIO = 1
```

```
SoundOnGPIODuration = 70 // Length of buzz in micro seconds
```

```
SoundOnGPIOFreq = 900 // Frequency of buzz in Hz
```

The I²C-Bus for the display requires this configuration:

```
i2cBusMaster = 1 //SDA - pin 3 SCL - pin 5
```

More information about the configuration and setup can be found on the Pi1541 project website mentioned above. It is highly recommended to read the instructions there before setting up the SD card.

The (optional) rotary encoder is activated with

```
RotaryEncoderEnable = 1
```

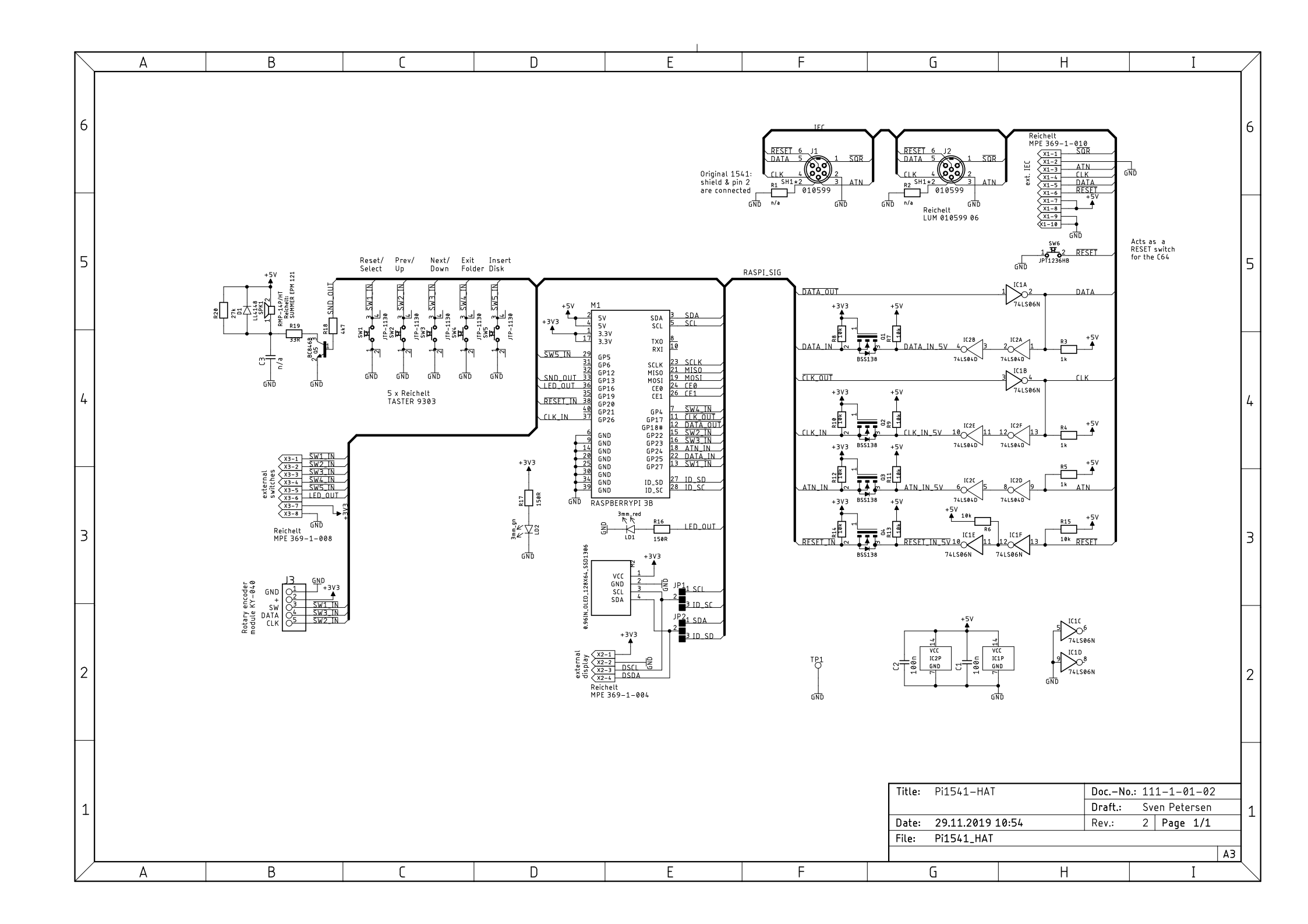
Revision history

Rev. 0 → Rev. 1

- R20 added, due to the SND_OUT being High during idle
- X1 became 10p to enable a power supply being connected on the external IEC-Board
- Added TP1 as a ground connection for measurement

Rev. 1 → Rev. 2

- J3 for an optional rotary encoder added (supported by the Firmware/Kernel v1.21 and later)



Title:	Pi1541-HAT	Doc.-No.:	111-1-01-02
		Draft.:	Sven Petersen
Date:	29.11.2019 10:54	Rev.:	2 Page 1/1
File:	Pi1541_HAT		
			A3

Sven Petersen 2019	Doc.-No.: 111-2-01-02	
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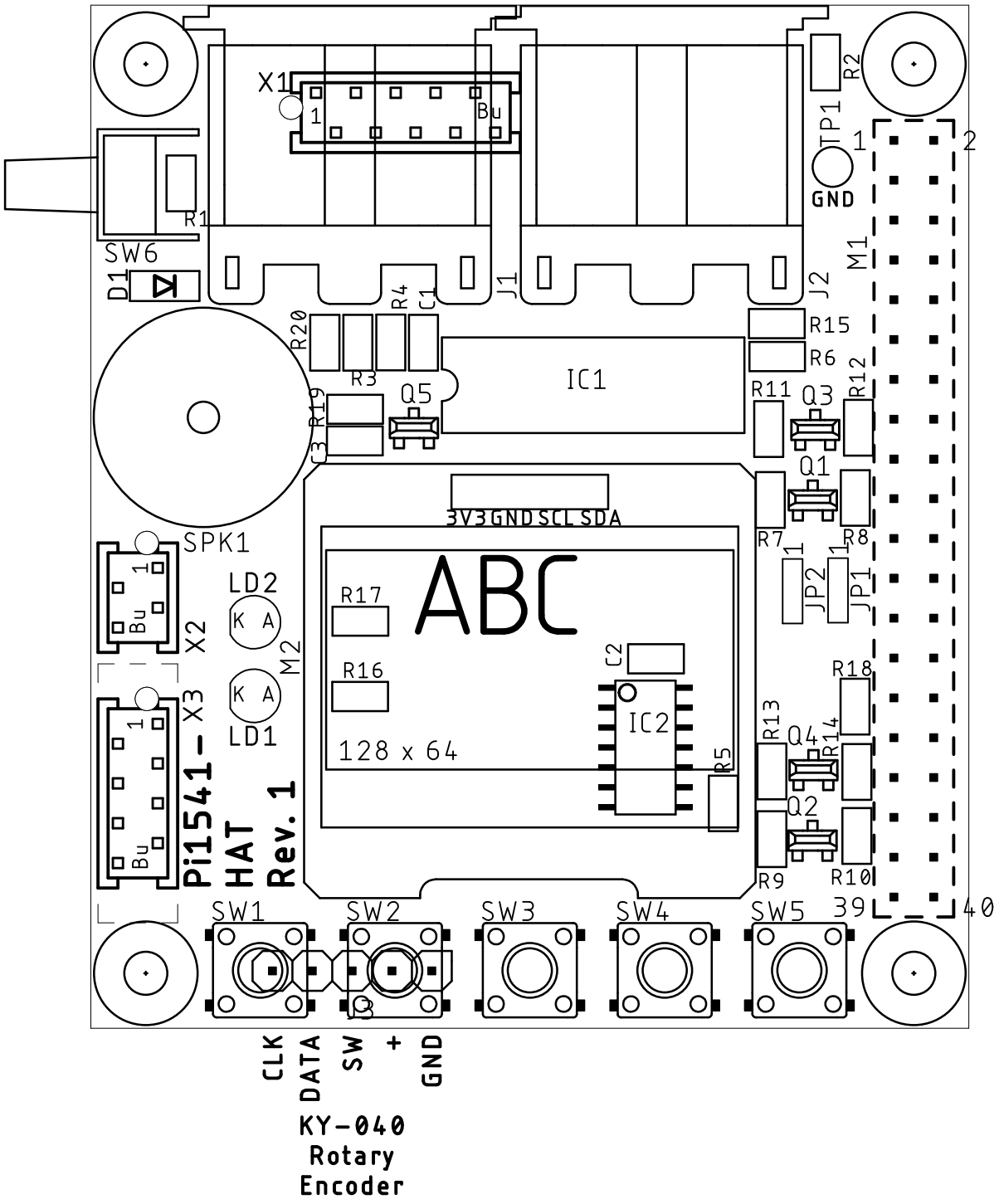
Pi1541_HAT		
29.11.2019 16:34		Rev.: 2
placement component side		



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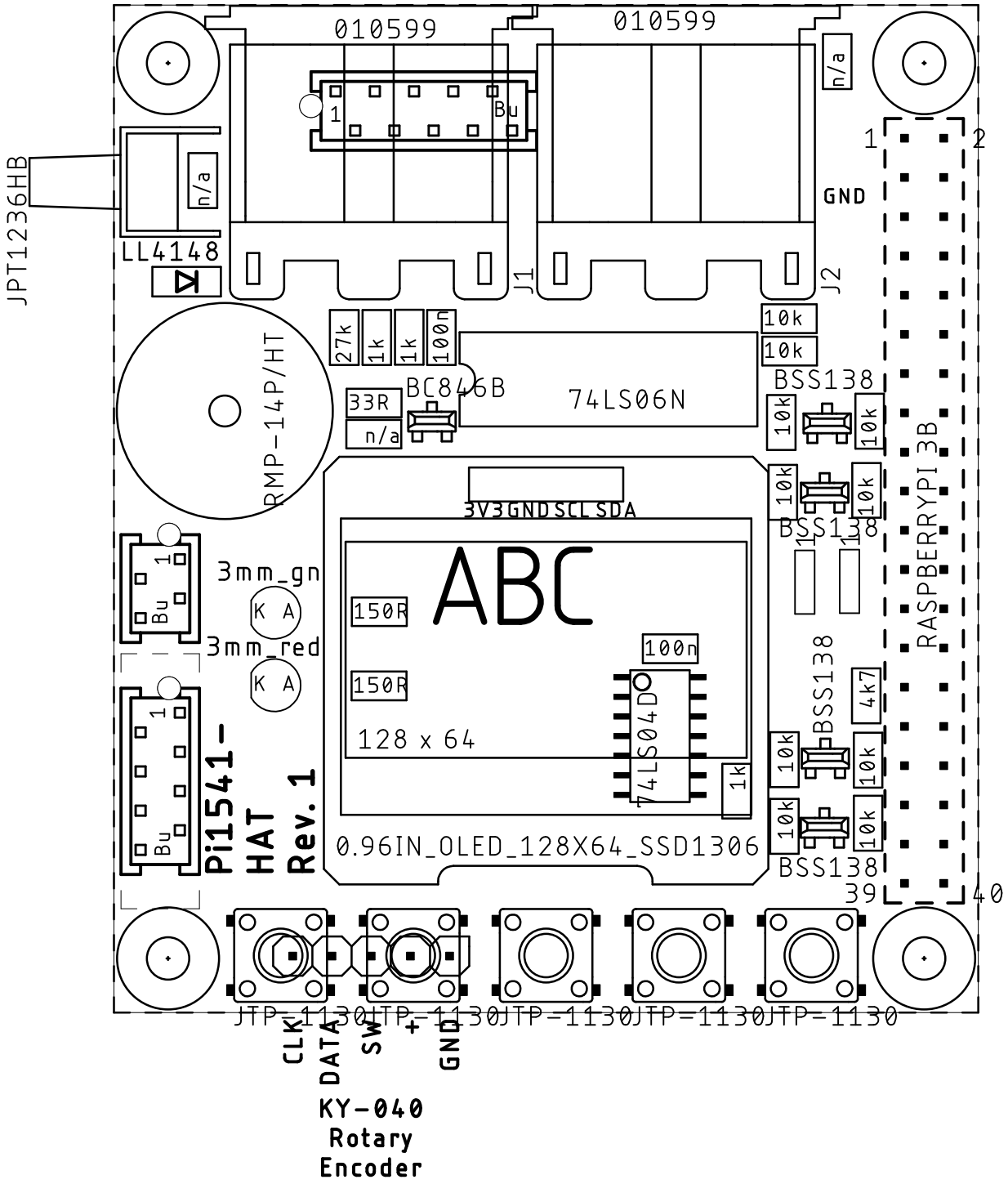
29.11.2019 16:34		Rev.: 2
placement component side		



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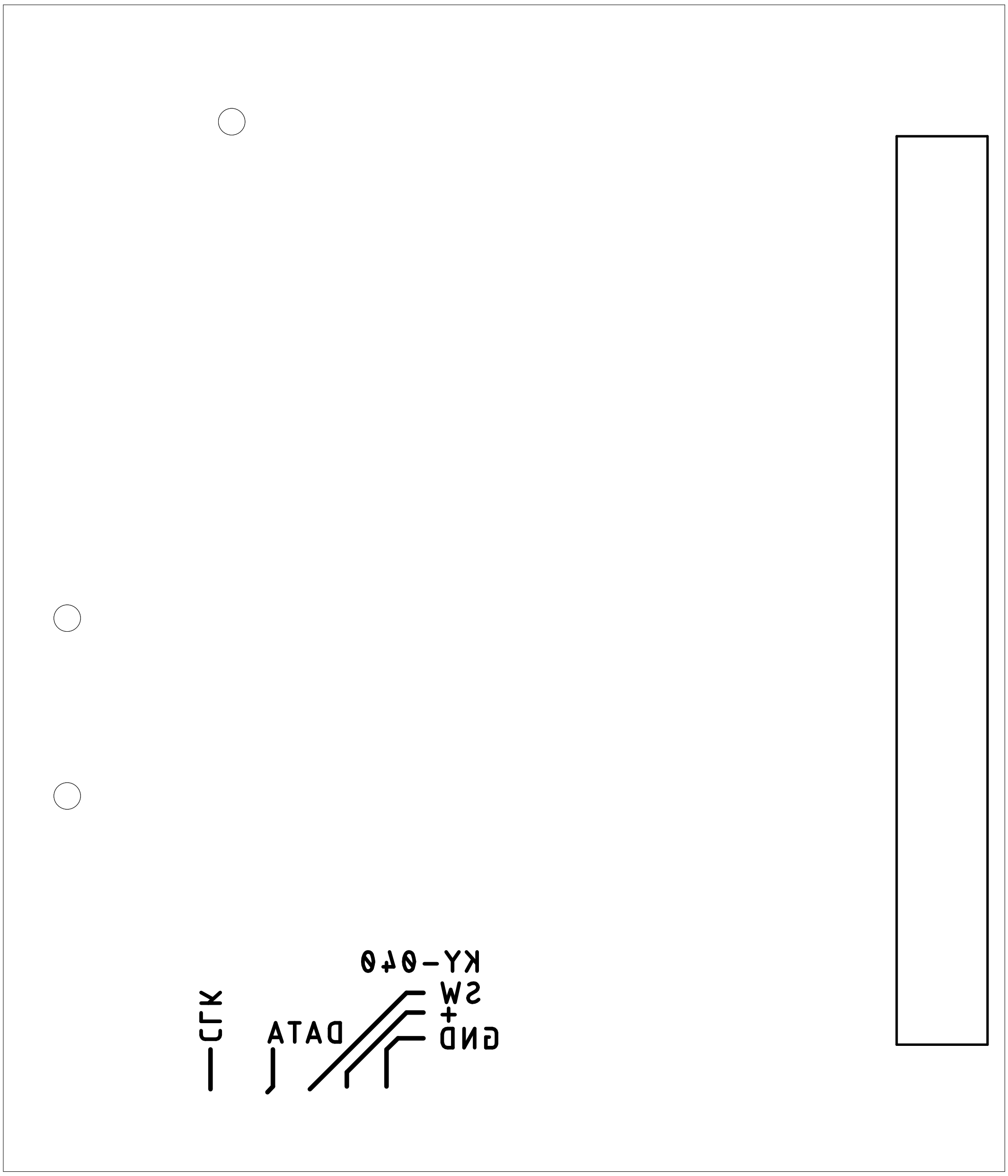
29.11.2019 16:34	Rev.: 2	
placement solder side		



Sven Petersen 2019	Doc.-No.: 111-2-01-02	
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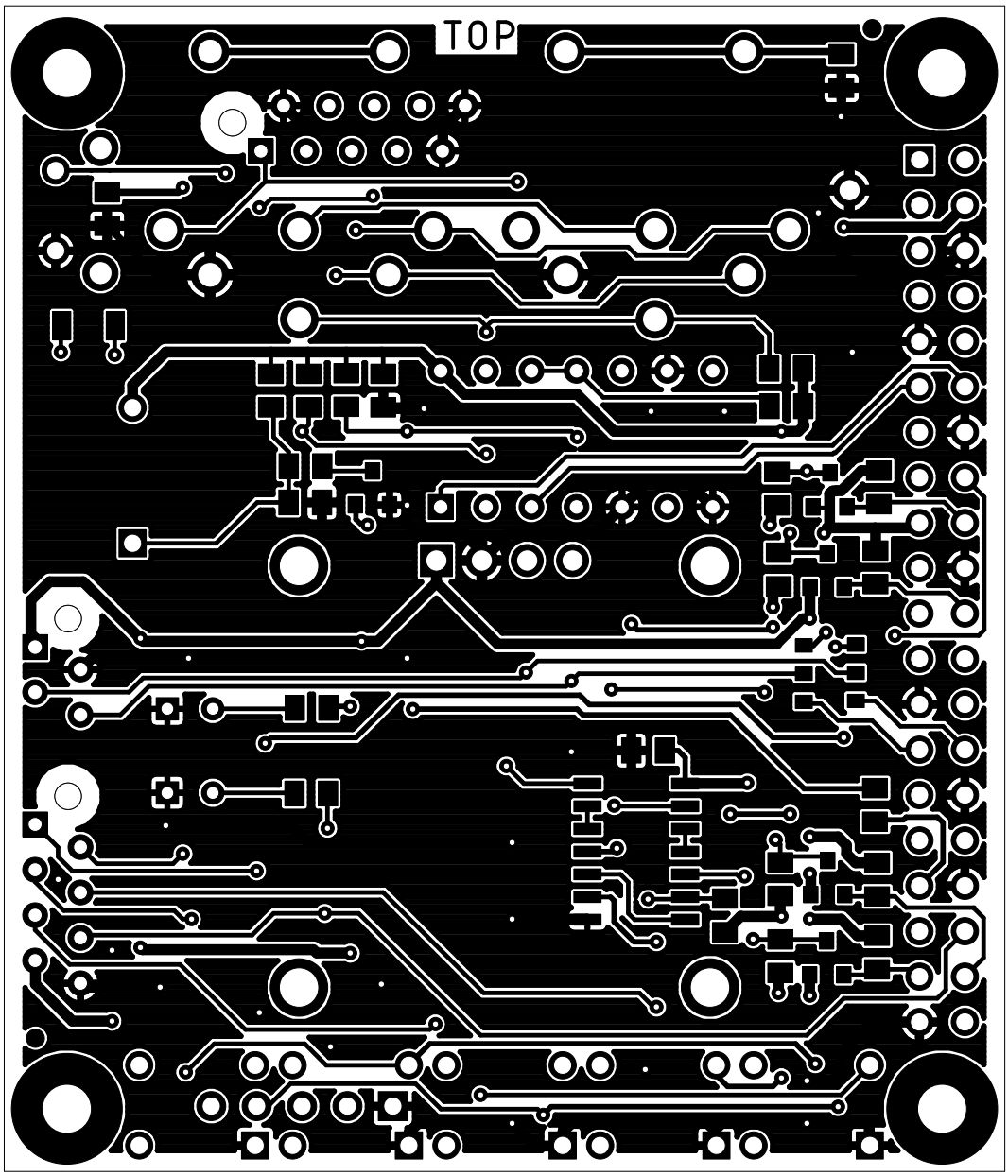
Pi1541_HAT		
29.11.2019 16:37		Rev.: 2
top		



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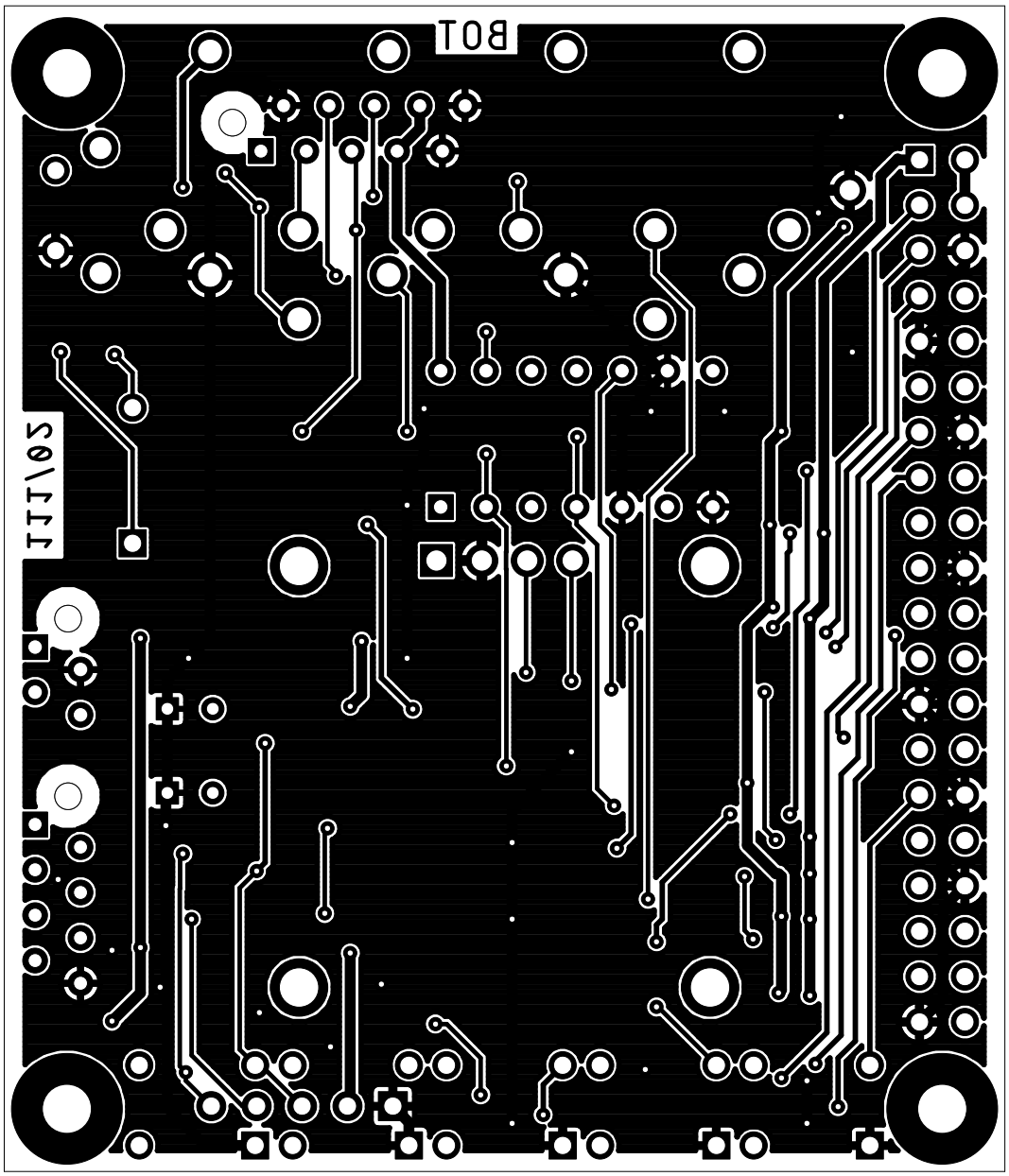
Pi1541_HAT		
29.11.2019 16:37		Rev.: 2
bottom		



Sven Petersen 2019	Doc.-No.: 111-2-01-02	
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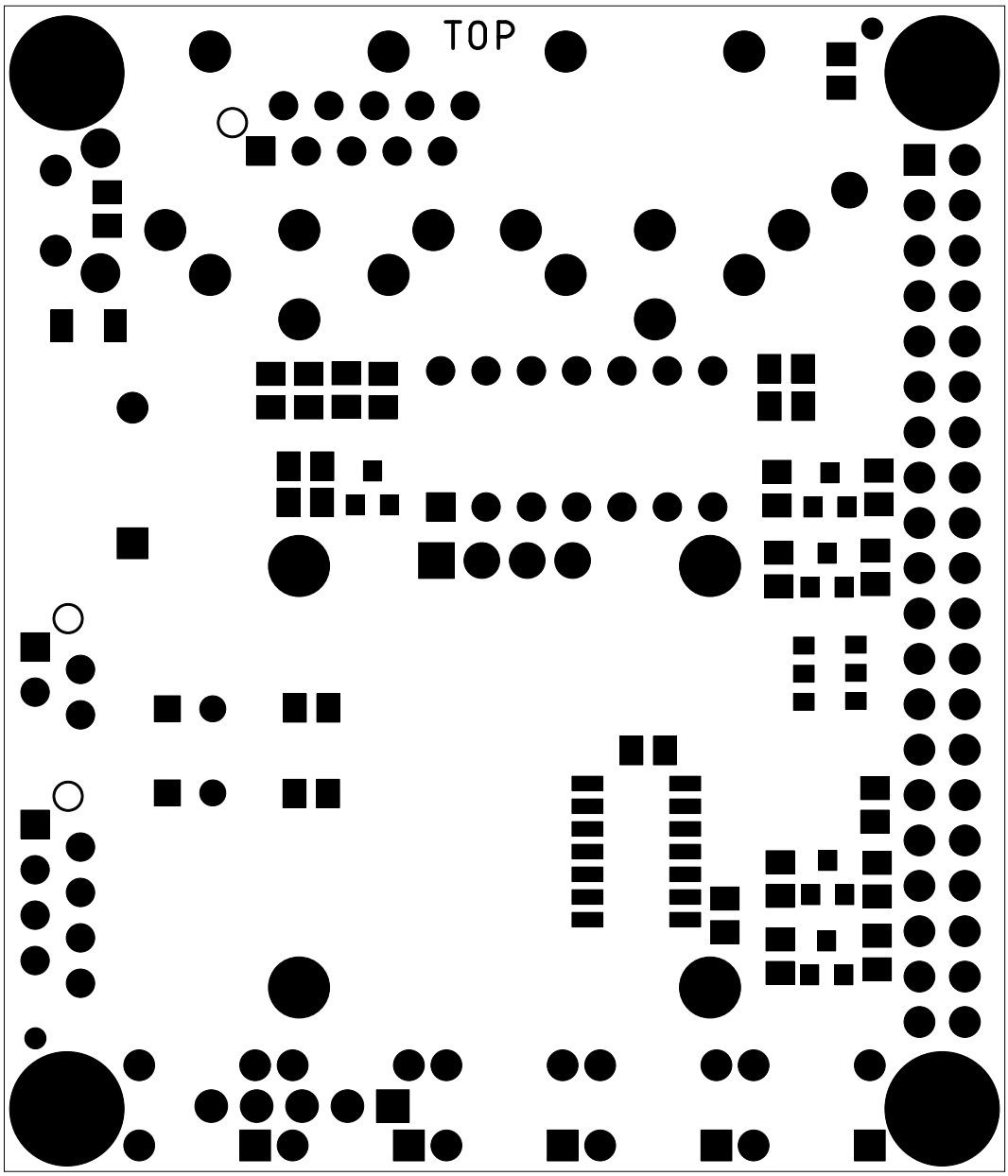
Pi1541_HAT		
29.11.2019 16:37		Rev.: 2
stopmask component side		



Sven Petersen 2019	Doc.-No.: 111-2-01-02	
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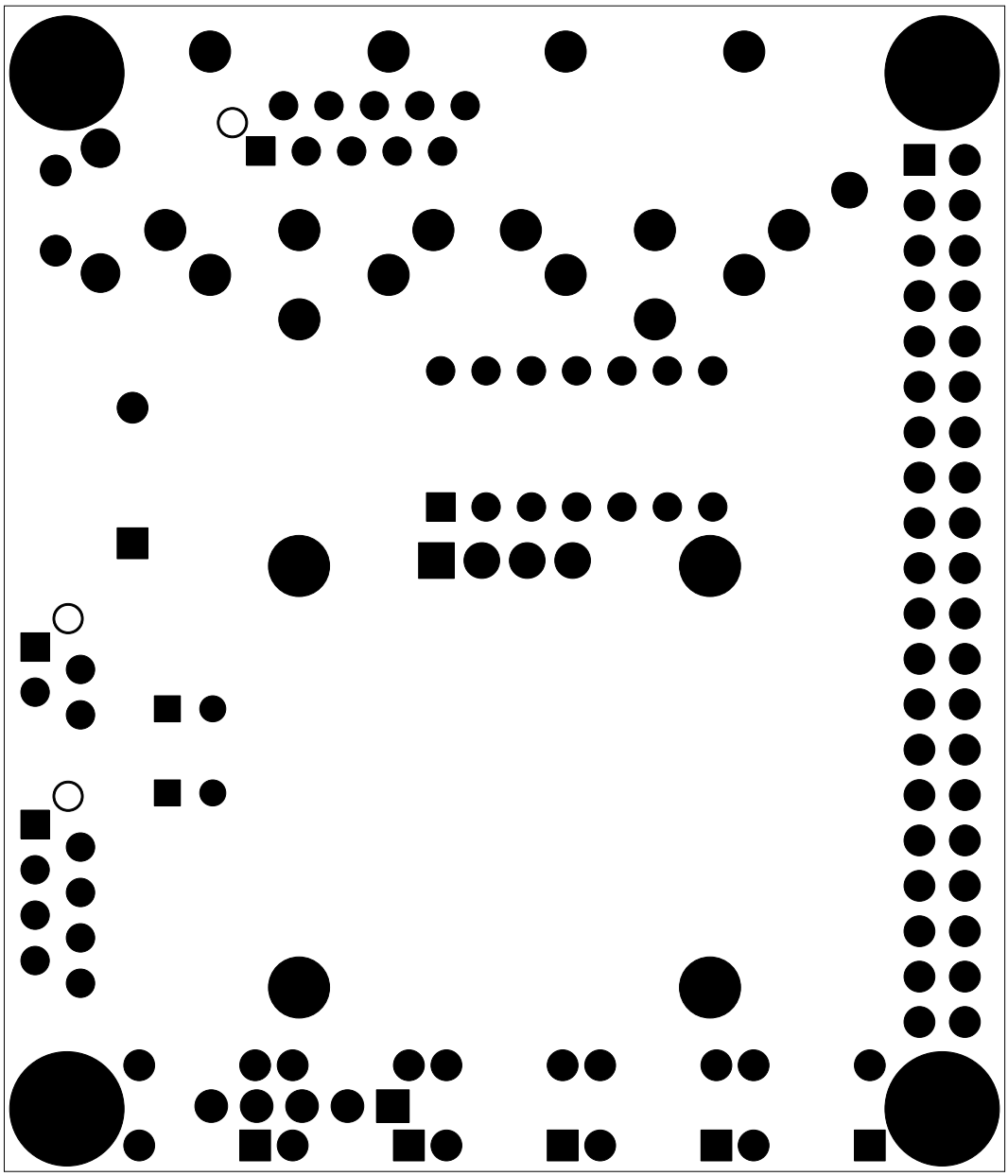
Pi1541_HAT		
29.11.2019 16:37		Rev.: 2
stopmask solder side		



Sven Petersen 2019	Doc.-No.: 111-2-01-02	
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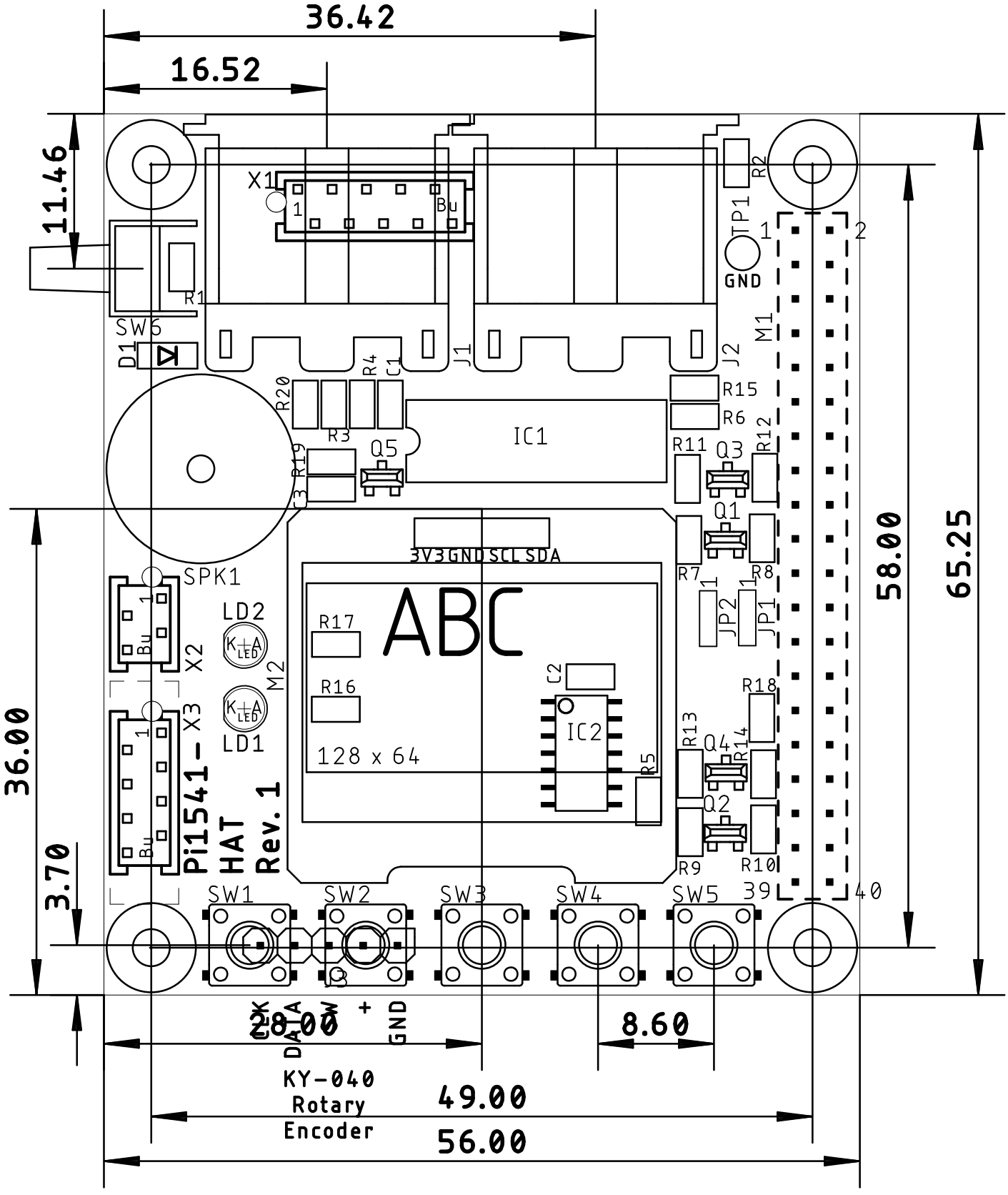
Pi1541_HAT		
29.11.2019 16:34		Rev.: 2
placement component side measures		



Pi1541-HAT Rev. 2

Functional Description

J1 and J2 are the IEC-Bus connectors for the Commodore computers. X1 can be assembled instead of J1 and J2 to make use of an external IEC-Bus PCB.

SW6 is an IEC-Bus RESET switch.

IC1A is the bus driver for the IEC-Bus DATA signal. R3 is the required 1k pull-up-resistor. Since DATA is a bi-directional signal, there is an input stage (IC2A and IC2B), too. This circuit resembled the original 1541 input circuitry. The input signals are inverted twice (which is not required, since the Pi1541 can be configured to use inverted input signals). Q1 in conjunction with R7 and R8 is acting as a 5V/3.3V level shifter. This is a common level shifter circuit as suggested for I²C-bus level shifting by NXP.

The circuit for the CLK signal of the IEC-bus is the same. ATN and /RESET do not have an output stage. The input stage of the /RESET signal is making use of the 74LS06 (IC1). Thus, the pull-up-resistor R6 is required.

M1 is the Raspberry Pi connector.

LD1 is the activity LED. LD2 is the power LED.

Both jumpers JP1 and JP2 should be jumpered 1-2 to drive the display M2 with the primary I²C-Bus of the Raspberry Pi.

A 0.96" OLED-Display can be connected to M3. In case a 1.3" display is used, the LED and the switches cannot be populated anymore and an external Pi1541-Switch board is required.

The display can also be connected to the MicroMatch connector X2.

SW1 to SW5 are the user interface for navigating through the directories of the disk archive on the SD-card.

Q5 is driving the piezo buzzer. D1 is acting as a protection, since piezo crystals are generating a voltage, when they are moved/compressed. R20 is required, since the idle level of the SND_OUT signal is HIGH. C3 can be used for sound shaping and additional protection.

TP1 is a ground connection for measurement/debugging.

J3 is for attaching a rotary encoder module. The pinning matches the wide spread KY-040.

Pi1541-HAT Rev. 2

Prototype Testing

Test set-up

The testing setup was a C64G (ASSY 250469), standard kernel, no cartridge, connected to the Pi1541 (Device 8) which was then connected to a 1541-II (device 9).

Firmware version of Pi!541 was v1.19 (ROM: CBM DOS V2.6).

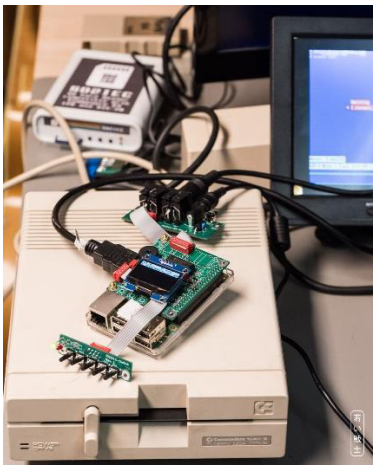


Figure 1: Test set-up

The external keyboard "Pi1541 Switch Rev. 1" was attached to the HAT with a ribbon cable (length 15cm) and the external IEC-connectors "Pi1541-IEC Rev. 0" was attached via a ribbon cable of approximately 15cm. The Pi1541 was powered with a 5V/4A PSU via the barrel connector on the Pi5141-IEC.

Test

Test	Result	Testing
Powering from Micro-USB	Pi1541 boots and is functional	ok
Powering from Barrel connector	Pi1541 boots and is functional	ok
1.3" OLED Display	Shows graphics and lists	ok
SW1 (select/Reset)	Selects Images and leaves them again	ok
SW2 (up)	Scrolling lists works	ok
SW3 (down)	Scrolling lists works	ok
SW4 (Exit Folder)	Exits Folder	ok
SW5 (Insert Disk)	In Browser mode, it enters a directory and leaps to the end of the list. Adding multi disks to a list.	ok
Power LED	Lights up while Pi1541 is powered	ok
Activity LED (LD1)	Lights while drive active	ok
Speaker	Produces sound on track stepping	ok
Loading "Ghost'n'Goblins"	Game loads and plays normally	ok
Loading "Barbarian II"	Loading, flipping disks works, game plays normally	ok

Test	Result	Testing
Loading “Creatures 2”	Loading, flipping disks works, game plays normally	ok
Loading “Defender of the crown”	Disk 1 loads normally and runs. Hooks up on flipping to disk 2. See addendum.	ok
Copying Disk from Pi1541 to 1541-II with DraCopy	Worked several times	ok
Copying Disk from 1541-II to Pi1541 with DraCopy	Worked	ok
Loading the X’2018 demo “drinking buddy”	Demo loads and runs normally	ok
Copying “drinking buddy” to a floppy disk using DraCopy	Disk copied successfully, demo loads and runs normally from a floppy disk (temporarily: Pi1541 disconnected, 1541-II set to device 8)	ok
Copying “drinking buddy” from floppy disk to Pi1541using DraCopy	Disk copied successfully, demo loads and runs normally	ok
Loading X’2018 demo “dsr-x2018.d64”	Demo loads and runs normally	ok
Loading X’2018 demo “frantic4bhf.d64”	Demo loads and runs normally	ok
Loading X’2018 demo “unboxed side1.d64”	Demo loads and runs until inserting the image “unboxed side 2.d64”, then hooks up. See addendum.	ok
Loading X’2018 demo “rewind.d64”	Demo loads and runs normally	ok
Loading X’2018 demo “starwars_s1.d64”	Demo loads and runs normally, flipping to disk 2 (s2): system hooks up” See addendum.	ok
Loading Galencia with Final Cartridge III+	Game loads and plays normally	ok
Loading L’Abbaye des Morts with Final Cartridge III+	Game loads and plays normally	ok

Conclusion

The Pi1541 HAT and all attached boards seem to work properly. The problem with flipping disks occurs with modern software, that is assumed to detect the disk automatically. Leaving the disk image with “select” (SW1), navigating to the other disk image and selecting is again is not working in this case. A similar problem was observed when accidentally trying to load something from the P1541, while no disk image was selected. This causes a hook-up of the C64 even in plain BASIC mode. This is considered to be a software issue or a matter of the applied method of flipping disks.

Addendum:
Adding the disks of a multi-disk game or demo works with adding them to a list with SW5. Then flipping disks can be achieved with SW2 and SW3 and select.

The system is fully functional.

Rev. 2

Revision 2 was not yet tested, the modification is considered to be low risk. The Eagle design passed the Design Rule Check (DRC) and the Gerber Data was checked with a Gerber Viewer.

Pi1541-HAT Rev. 2
Bill of Material Rev. 2.0

Pos.	Qty	Value	Footprint	Ref.-No.	Comment
1	1	111-2-01-02	2 Layer	PCB Rev. 2	2 layer, Cu 35µ, HASL, 56.0mm x 65.25mm, 1.6mm FR4
2	1	369-1-008	MICMA08B	X3	MicroMatch MPE, e.g. Reichelt MPE 369-1-008
3	1	372-1-008		(X3)	option: MicroMatch MPE, e.g. Reichelt MPE 372-1-008
4	1	0.96IN_OLED_128X64_SSD1306	OLED_0.96_SSD1306	M2	0.96" OLED Display 128x64, controller: SSD1306 or 1.3" OLED Display 128x64, controller SH1106
5	1	115-1-004		(M2)	option: MPE Garry, e.g. Reichelt MPE 115-1-004
6	2	010599	10599	J1, J2	Lumberg, e.g. Reichelt 010599 06
7	3	100n	0805	C1, C2, C3	
8	10	10k	0805	R6, R7, R8, R9, R10, R11, R12, R13, R14, R15	
9	2	150R	0805	R16, R17	
10	3	1k	0805	R3, R4, R5	
11	1	33R	0805	R19	
12	1	3mm_gn	3MM	LD2	LED 3mm, green
13	1	3mm_red	3MM	LD1	LED 3mm, red
14	1	74LS04D	SO-14	IC2	
15	1	74LS06N	DIL-14	IC1	
16	1	BC846B	SOT23	Q5	
17	4	BSS138	SOT23	Q1, Q2, Q3, Q4	
18	2	JMP_0603	CP3P	JP1, JP2	Jumper, default: 0R/0603 (1-2)
19	2	0R	0603	(JP1), (JP2)	
20	1	JPT1236HB	JTP_1236HB	SW6	Namae Electronics, e.g. Reichelt TASTER 3305B
21	5	JTP-1130	JTP-1130	SW1, SW2, SW3, SW4, SW5	Namae Electronics, e.g. Reichelt TASTER 9303
22	1	LL4148	SOD80C	D1	Diode
23	1	369-1-004	MICMA04B	X2	MicroMatch MPE, e.g. Reichelt MPE 369-1-004
24	1	372-1-004		(X2)	option: MicroMatch MPE, e.g. Reichelt MPE 372-1-004
25	1	369-1-010	MICMA06B	X1	MicroMatch MPE, e.g. Reichelt MPE 369-1-010
26	1	372-1-010		(X1)	option: MicroMatch MPE, e.g. Reichelt MPE 372-1-010
27	1	RASPBERRYPI 3B		M1	Raspberry Pi 3B or better

Pi1541-HAT Rev. 2
Bill of Material Rev. 2.0

Pos.	Qty	Value	Footprint	Ref.-No.	Comment
28	1	MPE 094-2-040		(M1)	MPE, e.g. Reichelt MPE 094-2-040
29	1	RMP-14P/HT	RMP-14P/HT	SPK1	KM, e.g. Reichelt SUMMER EPM 121
30	1	4k7	0805	R18	
31	2	dnp	0805	R1, R2	option 0R, not placed
32	1	27k	0805	R20	
33	1	1.3mm/2mm		TP1	not assembled
34	1	1x5p, 2.54mm	1x5	J3	option: for rotary encoder, replaces SW1 to SW3, straight or 90°
35	1	KY-040		(J3)	option: rotary encoder module.
36	1	DuPont wire (5 wires)			optional for the rotary encoder module

Pos.	Rev. 1 ® Rev. 2
1	PCB revision
34	new, option
35	new, option
36	new, option