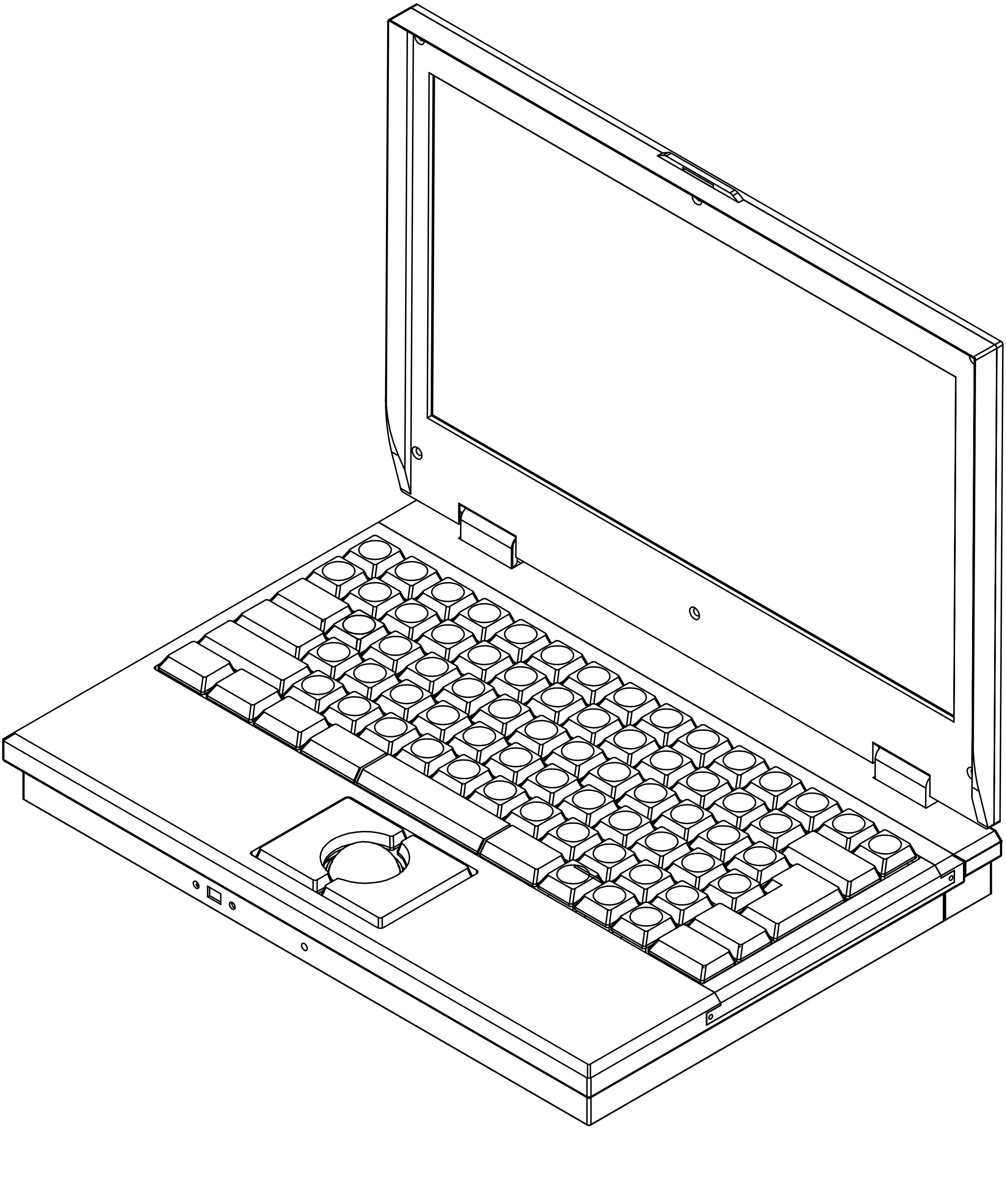
REFORM

OPERATOR HANDBOOK



CONTENTS

CHAPTER ONE

QUICK START

Thank you for acquiring MNT Reform, a portable open-source computer system.

Reform can be powered either by the internal LiFePo4 battery or by the 5V wall adapter. The wall adapter will automatically charge the battery if present. For safety reasons, the battery cable is not connected by default. To use the battery, unscrew the bottom lid and plug the white battery cable plug into the battery connector on the motherboard. Then reattach the bottom lid.

To switch the system on, push the power switch (located on the front of the device) to the right. The i.MX6 QuadPlus System-on-Chip will try to boot from the internal SD card.

You should be greeted by U-Boot and the MNT logo in the upper right corner of the display. If not interrupted by a keypress, Reform will boot into the Debian GNU/Linux operating system that is preinstalled on the SD card. The kernel will show diagnostic information as it activates all the devices in the system, and you'll end up at the login prompt if everything is OK.

To log in, enter *root* as the username. There is no default password, so you should secure the root account by setting a password. After completing the setup process, you can do this by executing:

```
passwd
```

After the first login, the *setup* script will run and guide you through a few steps like setting the timezone, keyboard layout, network settings and so on.

From the console environment, you can:

- Format an mSATA SSD drive (if you put one in the mSATA slot) and install an OS to it
- Create standard user accounts
- Inspect or repair the system

To start the X windowing system, type:

```
xinit
```

By default, when using the root account, this will start the OpenBox window manager. You can change this by editing the file */root/.xinitrc*.

You can install additional software and desktop environments by using *apt*, for example *apt install firefox*. You can find more information about using apt by reading its manual page. Manual pages are accessed by executing *man programname*, for example:

```
man apt
```

Enjoy your Reform computer!

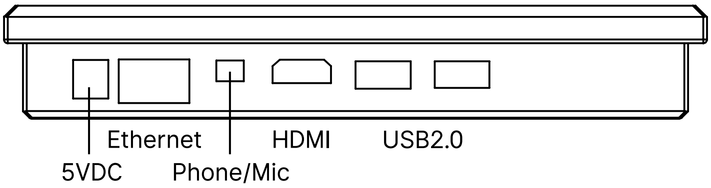
CHAPTER

TWO

THE CASE

Reform has 9 case parts:

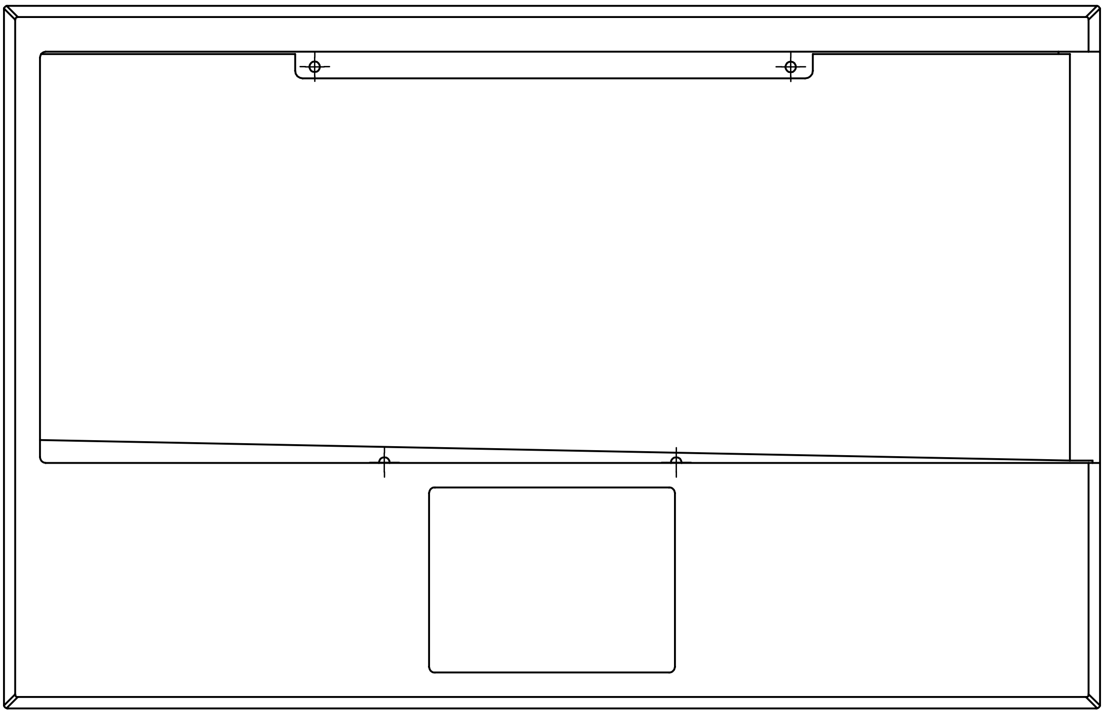
2.1 Main Box



The main box contains most of the electronics:

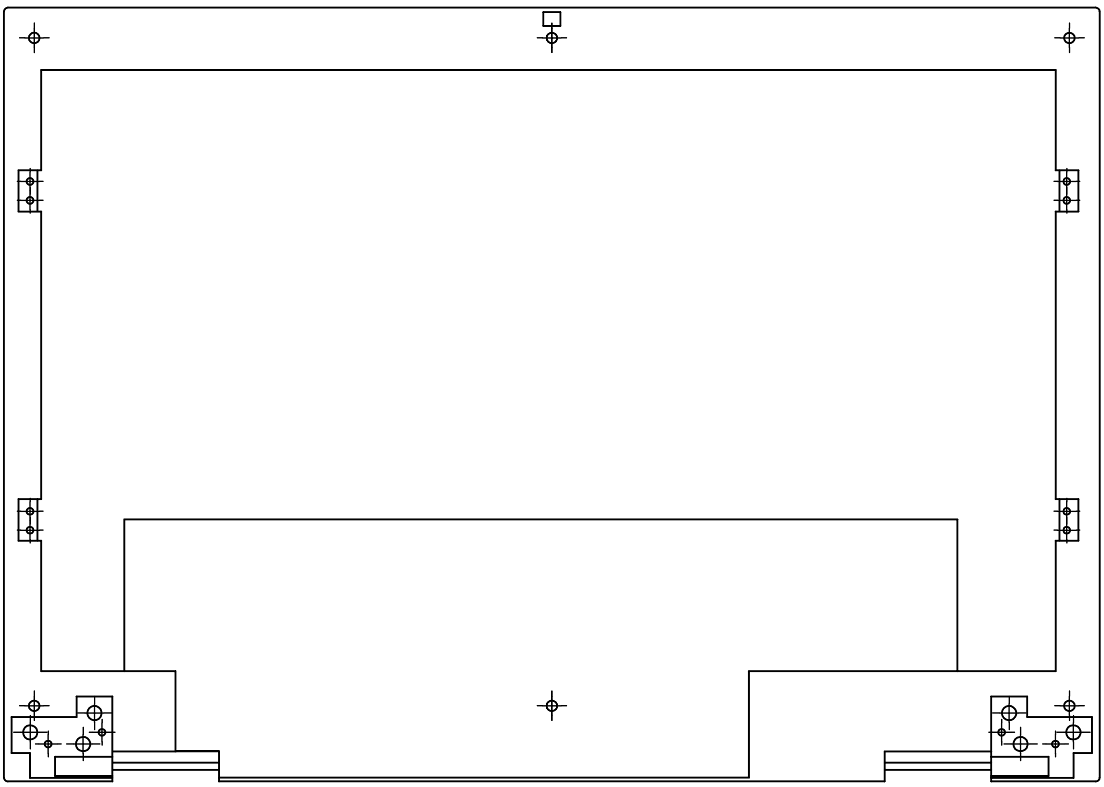
- Reform Motherboard, exposing ports through openings on the left
- Power switch/cable assembly, connecting to motherboard header J22
- LiFePo4 battery, connecting to header J33
- Reform Keyboard, connecting to header J12 (internal USB)
- Reform Trackball, connecting to header J9 (internal USB)

2.2 Main Box Top



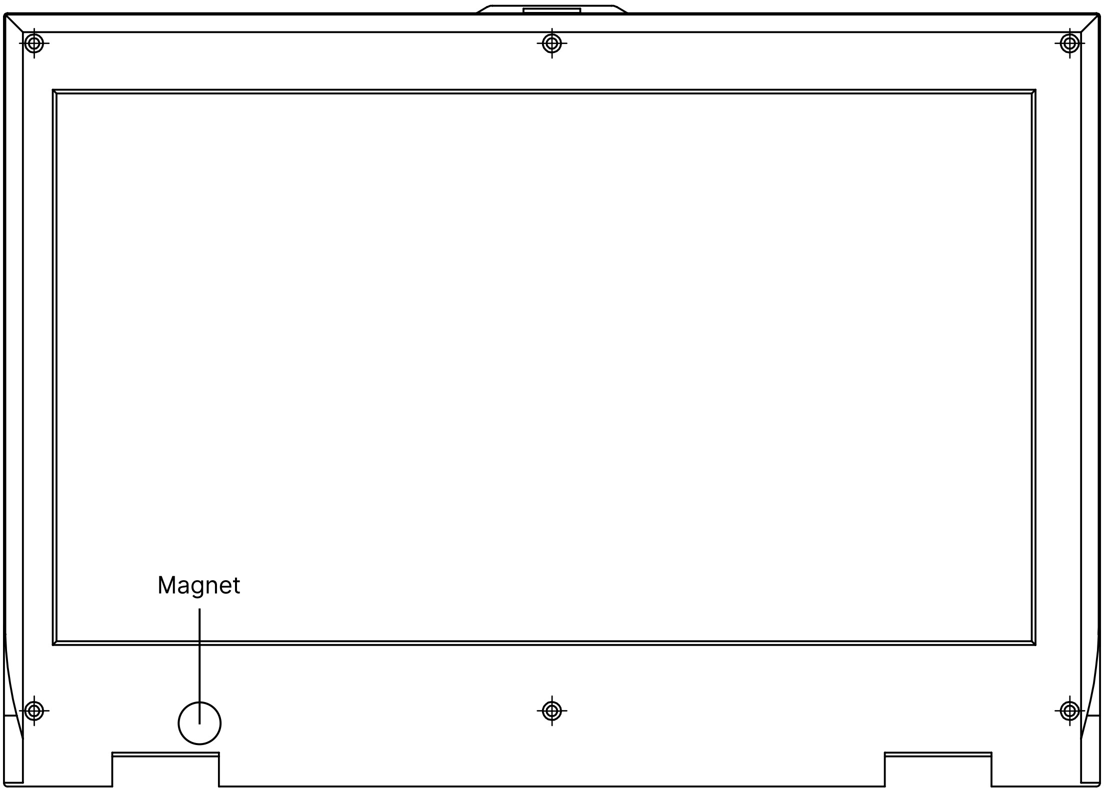
The main box top is pressed onto the main box to close it from the top. It acts as a palm rest and bezel for the keyboard and trackball. The keyboard is slided into this part's keyboard slot from the right.

2.3 Screen Back



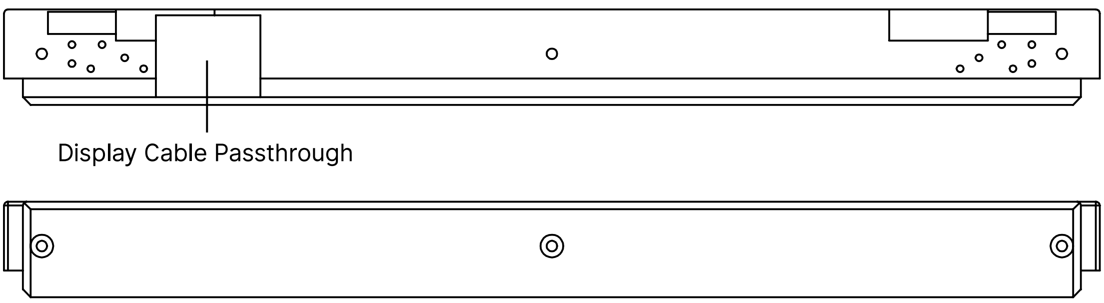
The display is mounted on the screen back with M2x4 screws. The left and right hinges are mounted in the bottom left and right corners with M4x5 screws.

2.4 Screen Front



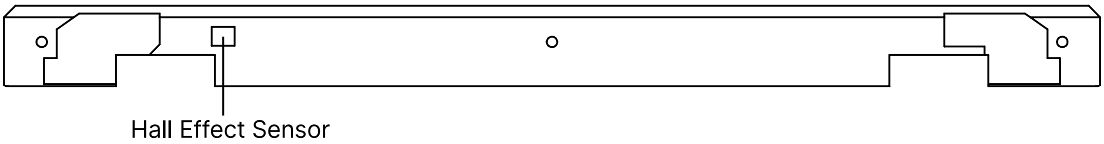
This part serves as a bezel for the display and holds the case closing strap. It also has a magnet attached to it on the lower left that is sensed by the lid sensor. The screen front is mounted to the back with M3x6 screws.

2.5 Screen Support



The screen support connects the main box to the screen via the hinges. The display's LVDS (motherboard header J14) and power cable (motherboard header J26) is passed through this part, as well as the lid sensor cable (J34).

2.6 Screen Support Lid



This is a thin part covering the screen support's top. On the left, it contains a pocket for the hall effect sensor that detects the magnet on the screen front. The sensor signals opening and closing of the lid.

2.7 Keyboard Closure

This part is inserted into the main box top after the keyboard to secure it in place.

2.8 Grid Plate

This lasercut acrylic part is sandwiched between the main box' inner top and the motherboard. It has the mounting holes for the motherboard and other internal devices and isolates the motherboard from the keyboard.

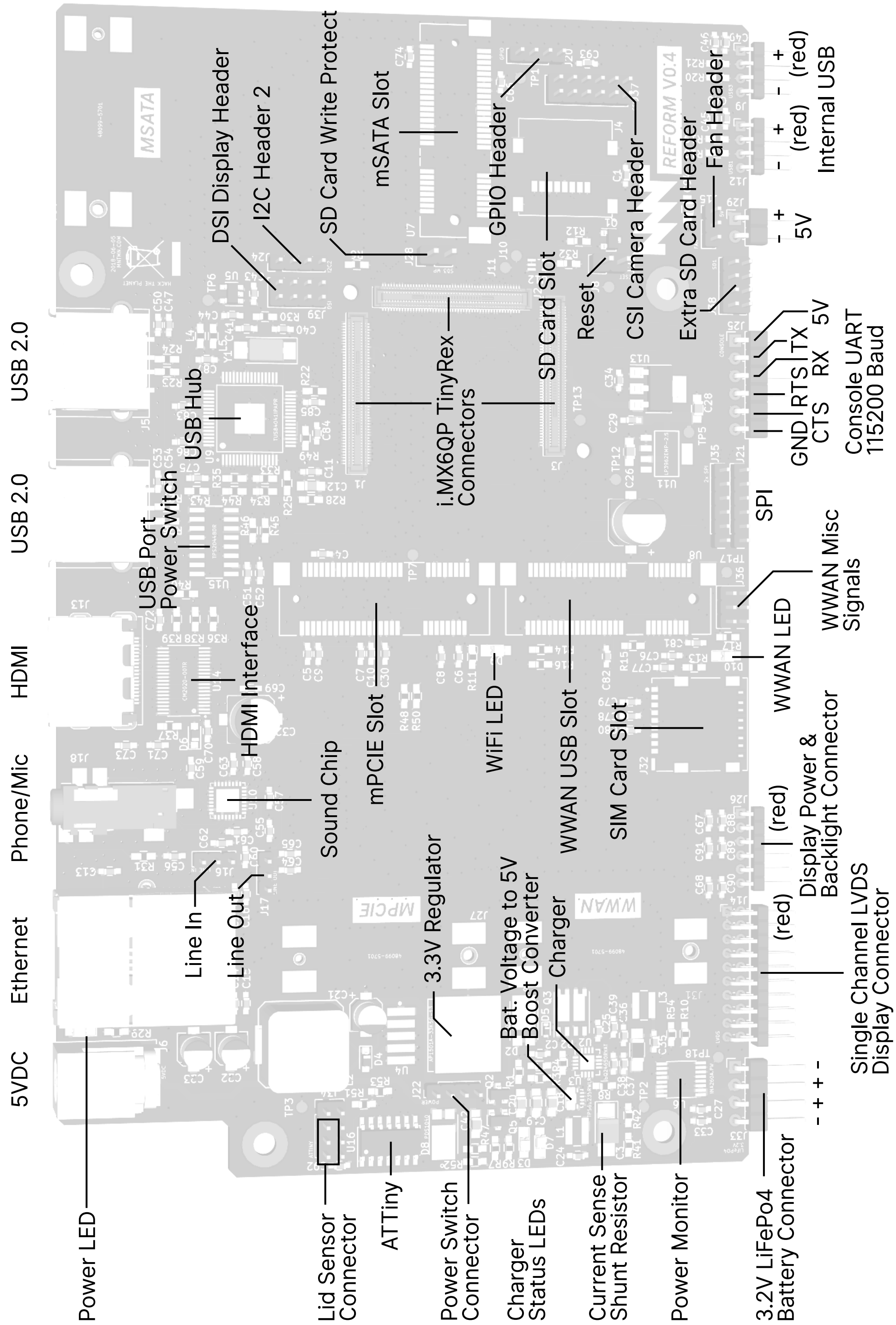
2.9 Bottom Plate

The bottom plate closes the main box from the bottom. It contains mounting holes for the fan and vent holes for the fan's air intake. The fan is connected to motherboard header J15 before screwing in the plate.

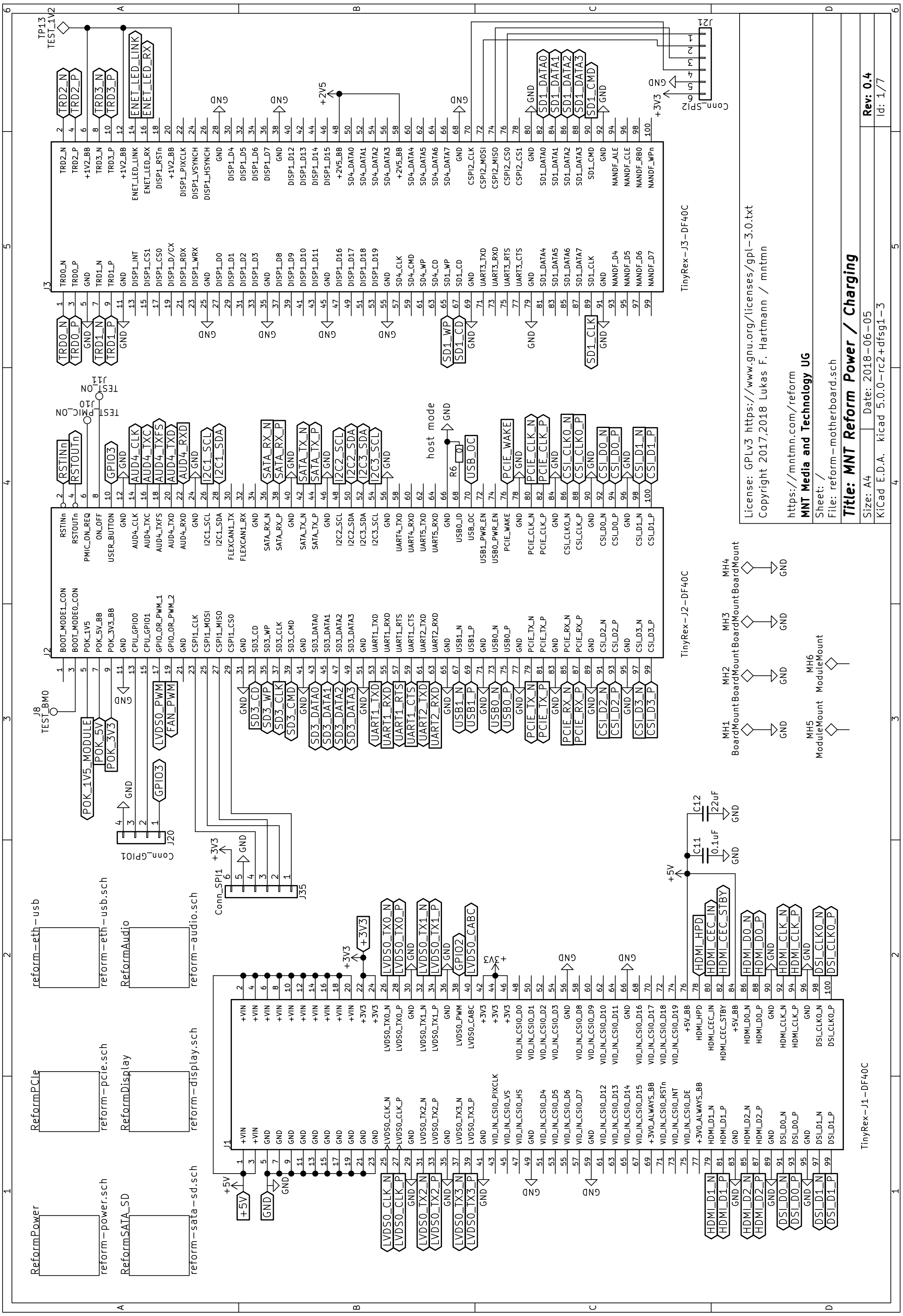
CHAPTER

THREE

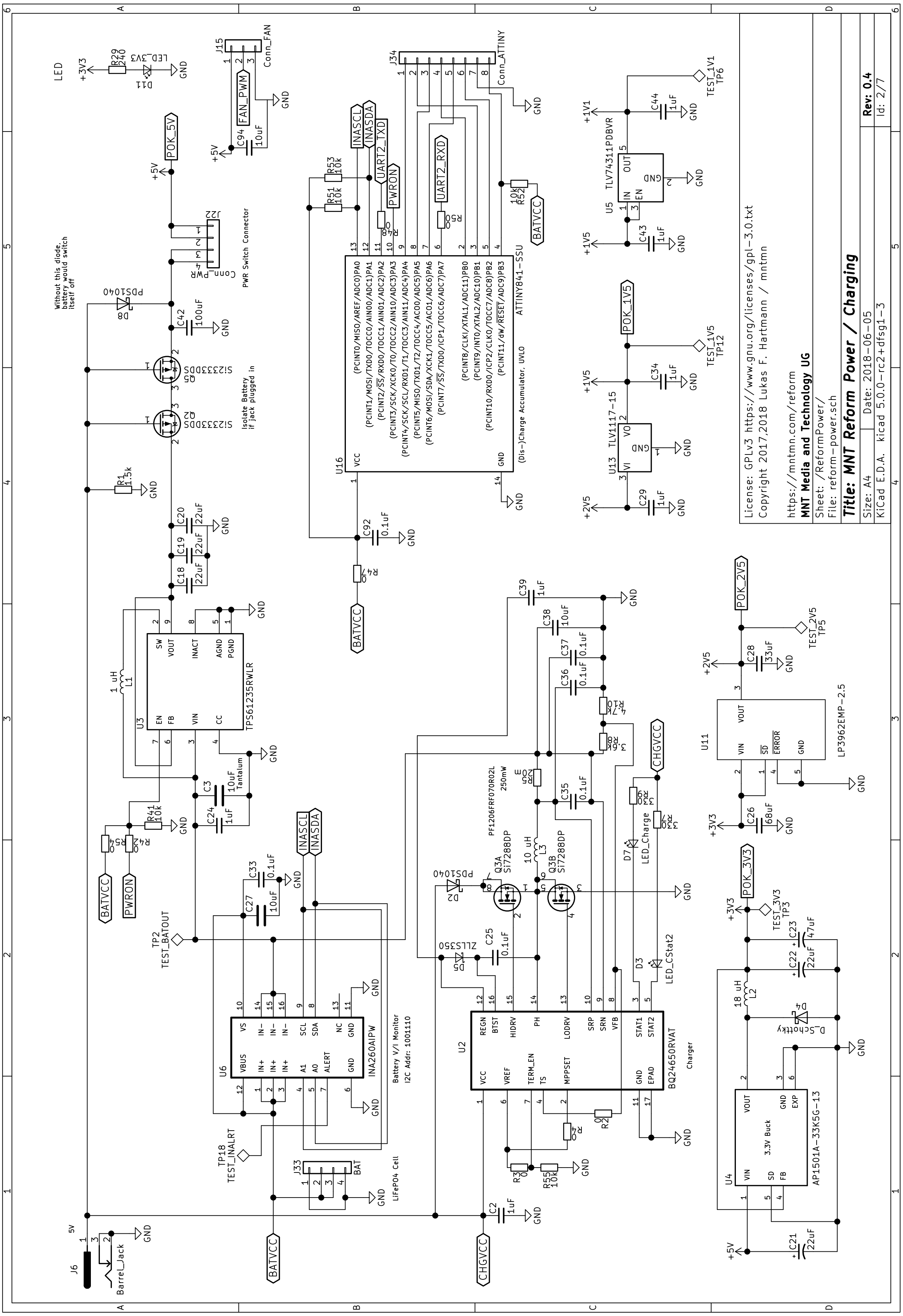
THE MOTHERBOARD



3.1 Schematics



3.2 Power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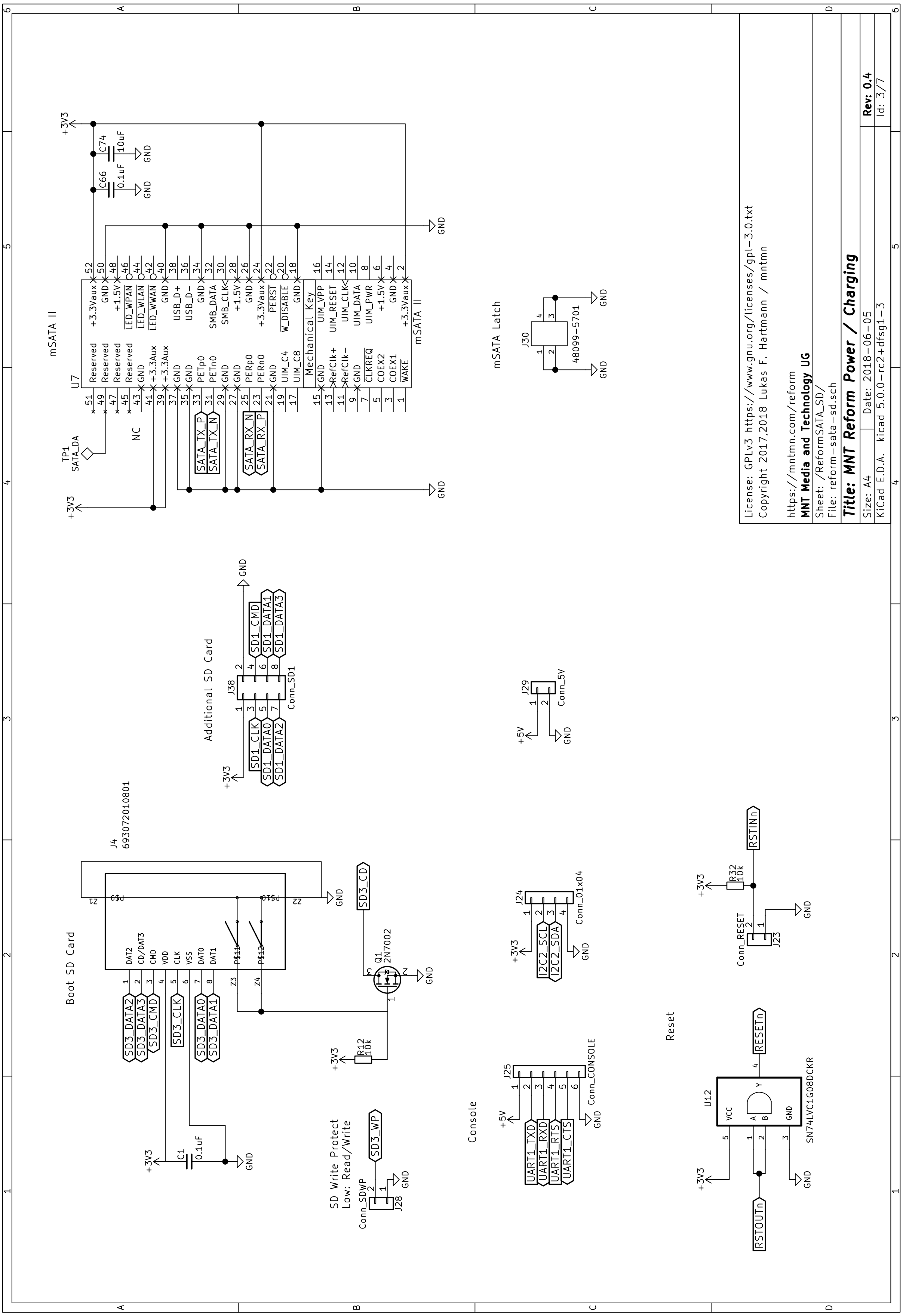
https://mntmn.com/reform
MNT Media and Technology UG
Sheet: /ReformPower/
File: reform-power.sch
Title: MNT Reform Power / Charging
Size: A4
Date: 2018-06-05
Rev: 0.4
KiCad E.D.A. kicad 5.0.0-rc2+dfsg1-3
Id: 2/7

3.3 Storage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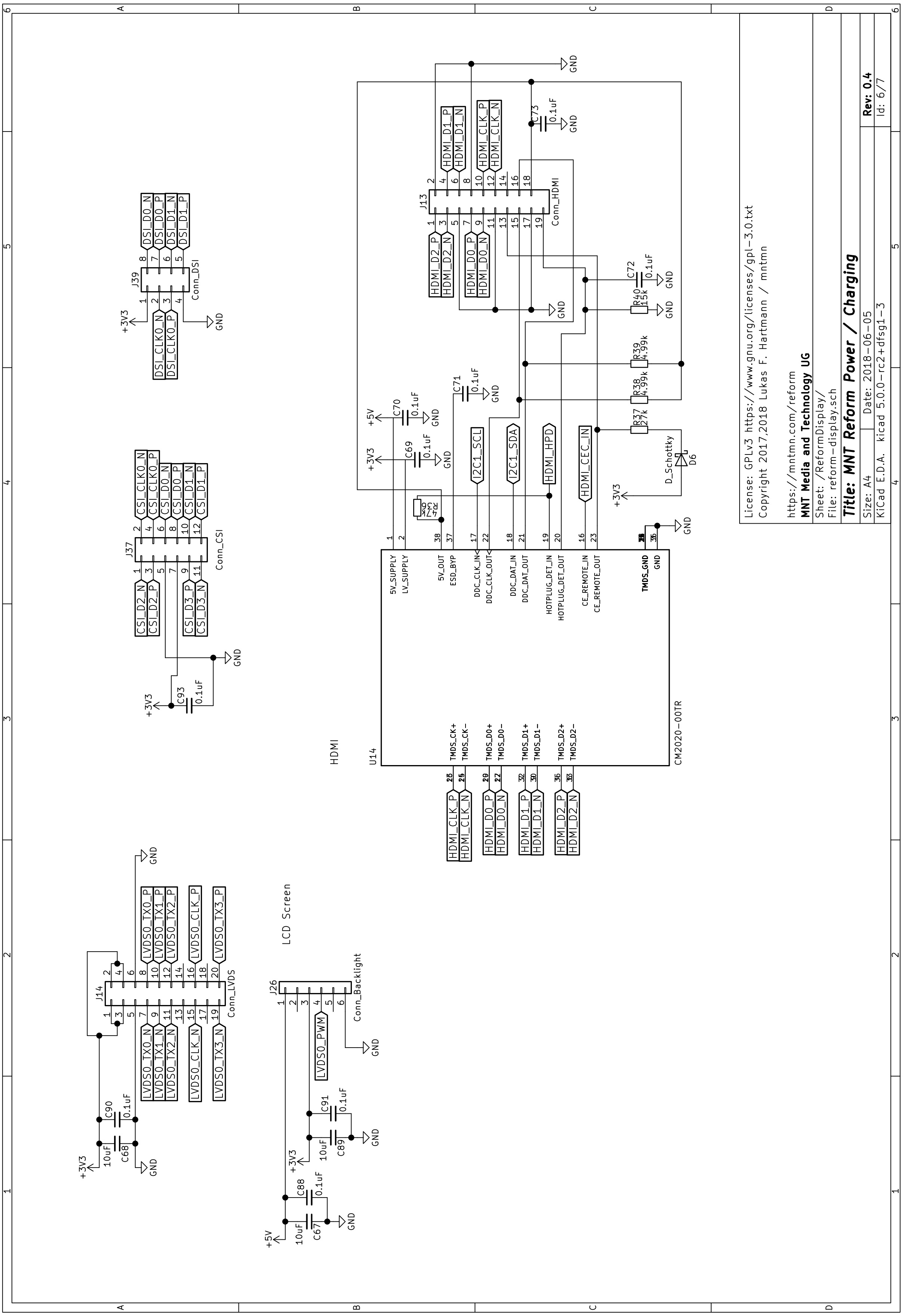
https://mntmn.com/reform
MNT Media and Technology UG
Sheet: /ReformSATA_SD/
File: reform-sata-sd.sch
Title: MNT Reform Power / Charging
Size: A4
Date: 2018-06-05
Rev: 0.4
KiCad E.D.A. kicad 5.0.0-rc2+dfsg1-3
Id: 3/7
mSATA II
mSATA Latch
Additional SD Card
Boot SD Card
SD Write Protect
Low: Read/Write
Console
Reset

3.4 Display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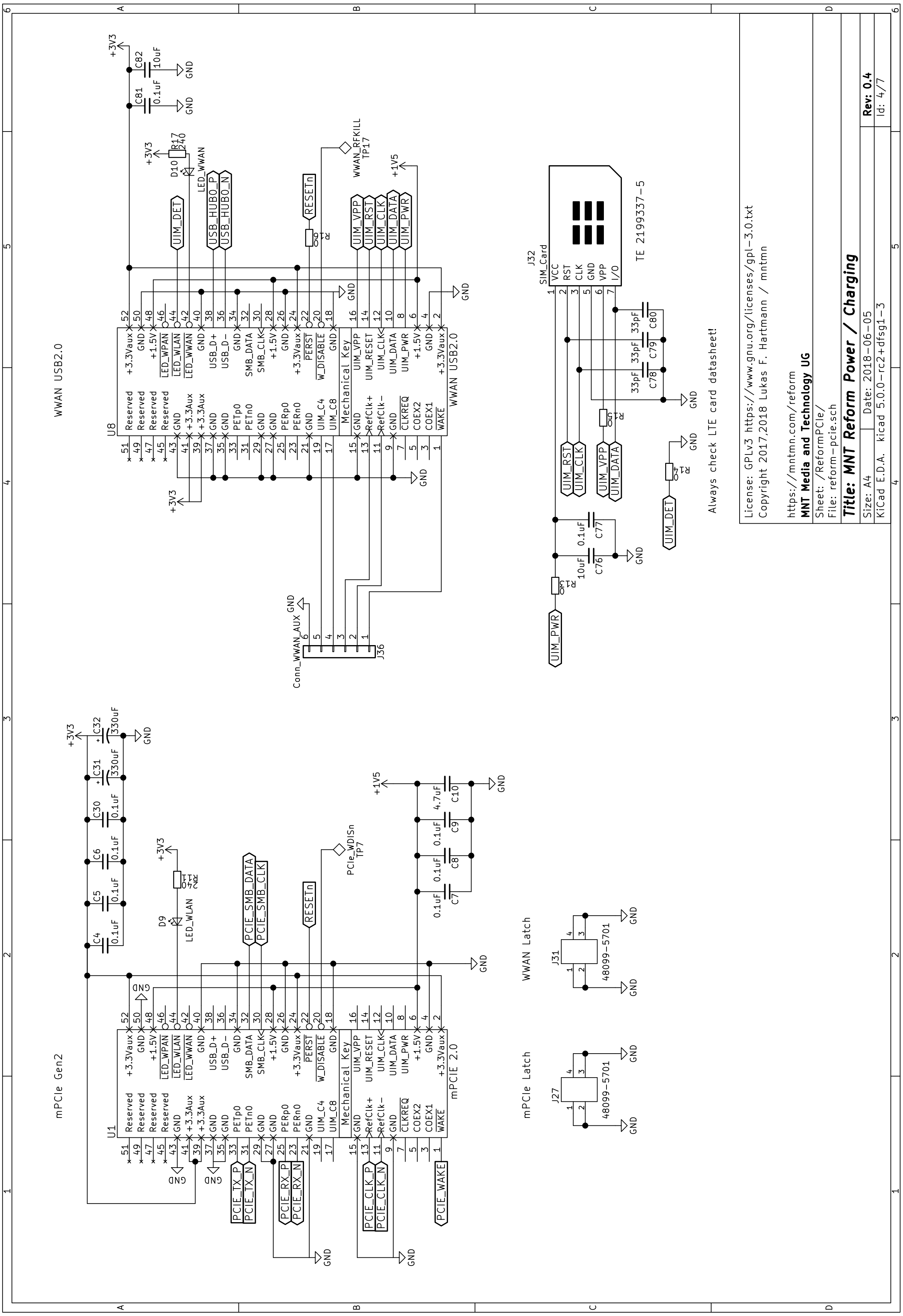
https://mntmn.com/reform
MNT Media and Technology UG
Sheet: /ReformDisplay/
File: reform-display.sch
Title: MNT Reform Power / Charging
Size: A4
Date: 2018-06-05
KiCad E.D.A. kicad 5.0.0-rc2+dfsg1-3
Rev: 0.4
Id: 6/7
HDMI
U14
CM2020-00TR
J13
Conn_HDMI
J39
Conn_DSI
J37
Conn_CSI
J14
Conn_LVDS
LCD Screen
J26
Conn_Backlight
D_Schottky

3.5 PCIe



WWAN USB2.0
mPCIe Gen2
Always check LTE card datasheet!
WWAN Latch
mPCIe Latch
License: GPLv3 https://www.gnu.org/licenses/gpl-3.0.txt
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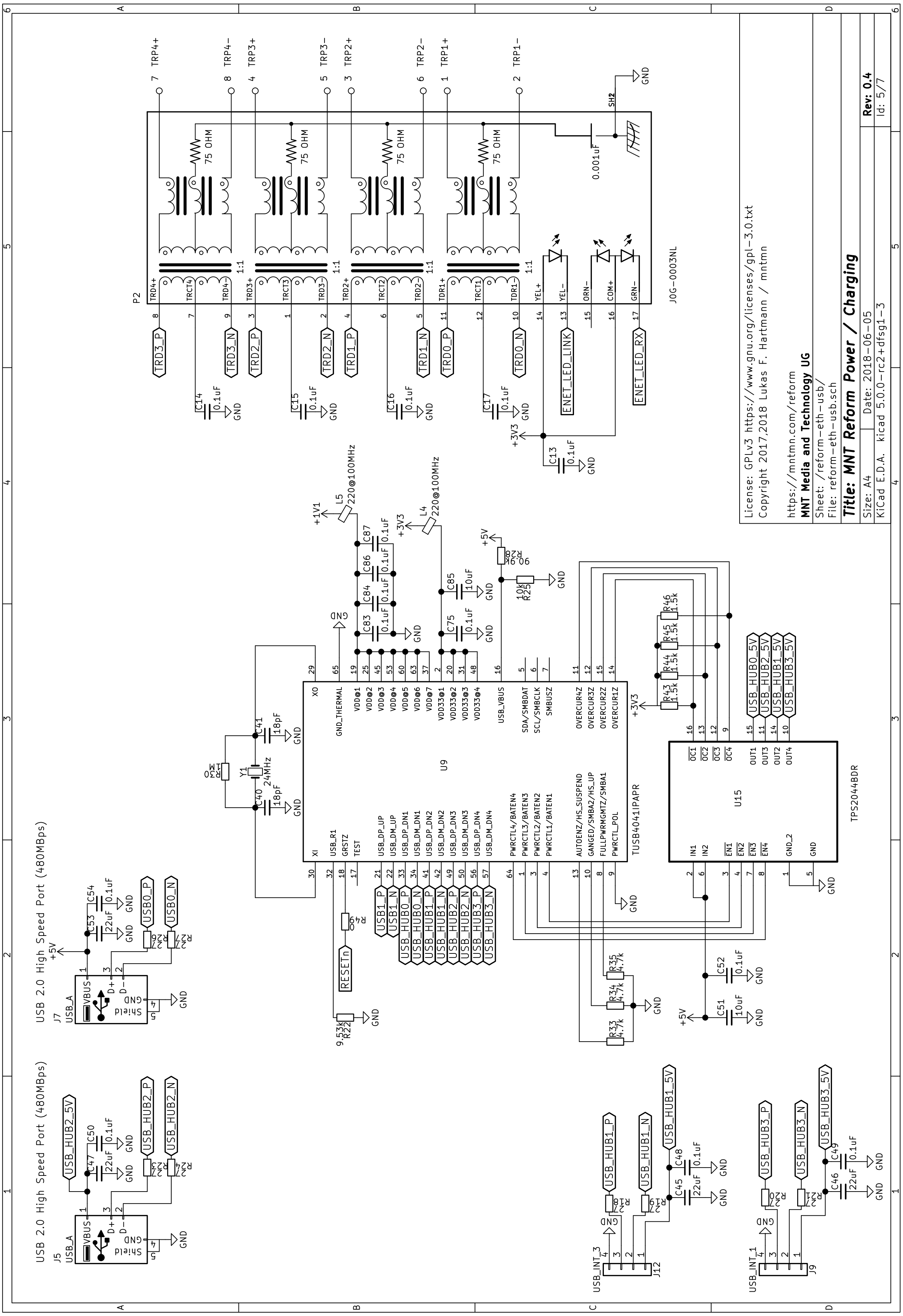
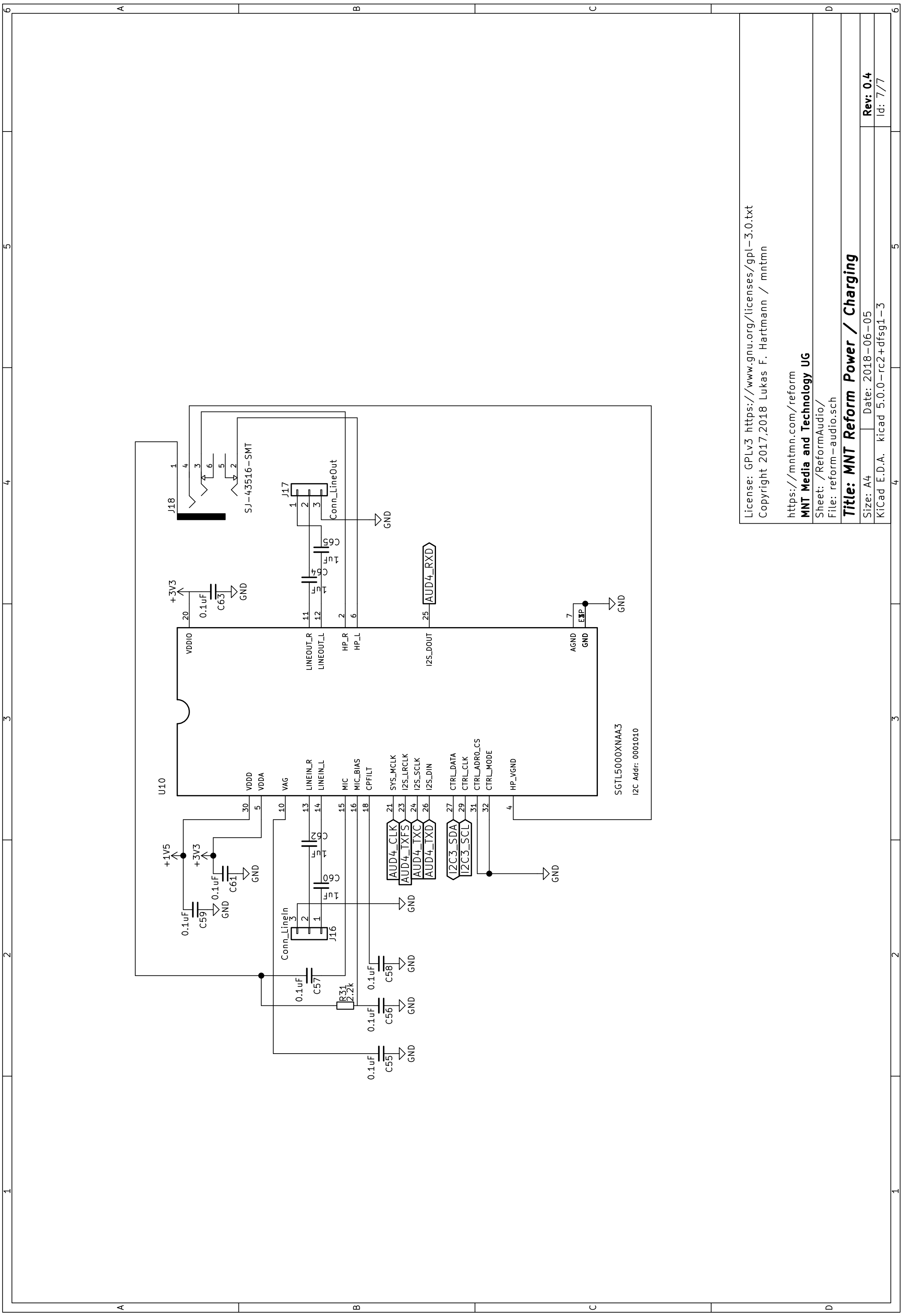
https://mntmn.com/reform
MNT Media and Technology UG
Sheet: /ReformPCIe/
File: reform-pcie.sch
Title: MNT Reform Power / Charging
Size: A4
Date: 2018-06-05
Rev: 0.4
KiCad E.D.A. kicad 5.0.0-rc2+dfsg1-3
Id: 4/7

3.6 Ethernet, USB



3.7 Audio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https://mntmn.com/reform
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Title: MNT Reform Power / Charging
Size: A4
Date: 2018-06-05
KiCad E.D.A. kicad 5.0.0-rc2+dfsg1-3
Rev: 0.4
Id: 7/7
U10
SGTL5000XNAA3
I2C Addr: 0001010
J18
SJ-43516-SMT
J17
Conn_LineOut
J16
Conn_LineIn
AUD4_RXD
AUD4_CLK
AUD4_TXFS
AUD4_TXC
AUD4_TXD
I2C3_SDA
I2C3_SCL
GND
+3V3
+1V5

CHAPTER

FOUR

THE BATTERY/LID CONTROLLER

4.1 Introduction

The Atmel ATTiny841 (U16) is a 8-bit microcontroller that uses very little power and is always on when there is battery power in the system. Its job is to keep track of how much current is going in and out of the battery and what voltage the battery has. It does this with the help of the voltage/current monitor chip INA260 that is connected to the ATTiny via I2C.

The ATTiny works as:

- Battery voltage and current monitor/gauge
- System current monitor
- Lid sensor

4.2 Communication

The ATTiny is permanently connected to the i.MX6 UART2 (/dev/ttymxc1 in Linux). If you want to interrupt this connection, you can desolder resistors R48 and R50.

The ATTiny firmware configures its serial port to 9600 baud 8N1. You can talk to it using the program screen (or another serial terminal):

```
screen /dev/ttymxc1 2400
```

It accepts commands in the form of a single letter followed by return. The current commands are:

- *p*: Get battery power information (estimated capacity in amp hours, voltage, current)
- *l*: Get lid state (0: open, 1: closed)
- *h*: Get hall sensor raw analog value

In addition, these commands can be prefixed with a decimal number (up to four digits):

- *600c: Reset the battery capacity counter to 10Ah (600 Amp minutes)
- *500t*: Set the lid sensor open/closed threshold to the value 500
- *10w*: Set the lid sensor open/closed hysteresis to 10

4.3 Undervoltage Protection (UVLO)

The microcontroller is supposed to detect a dangerously low voltage on the battery and switch the 5V boost converter off via its PWRON output when the voltage is below 2.8V. This way, the system will not draw power from the battery until it is charged to a reasonable level again. This functionality is still being tested and not activated in the beta boards.

4.4 Lid Sensor

The ATTiny senses if the lid is open or closed using the hall effect sensor (Honeywell SS495A). The lid is considered closed when a magnet is close to the sensor. The ATTiny outputs the string “wake” via its serial port which can wake the i.MX6 up from sleep.

4.5 Flashing the Firmware

You can find the source code of the firmware in the folder “reform-attiny-fw” of the Reform source repository.

To change (flash) the firmware of the ATTiny, you need an Atmel ISP (In System Programmer) compatible programmer/cable. An easy way is to use an Arduino to emulate an ISP.

The relevant pins of J34 on the Reform motherboard for connecting the ISP cable are as follows:

Upper row (left to right):

7	5	3	1
GND	MOSI	MISO	SCK

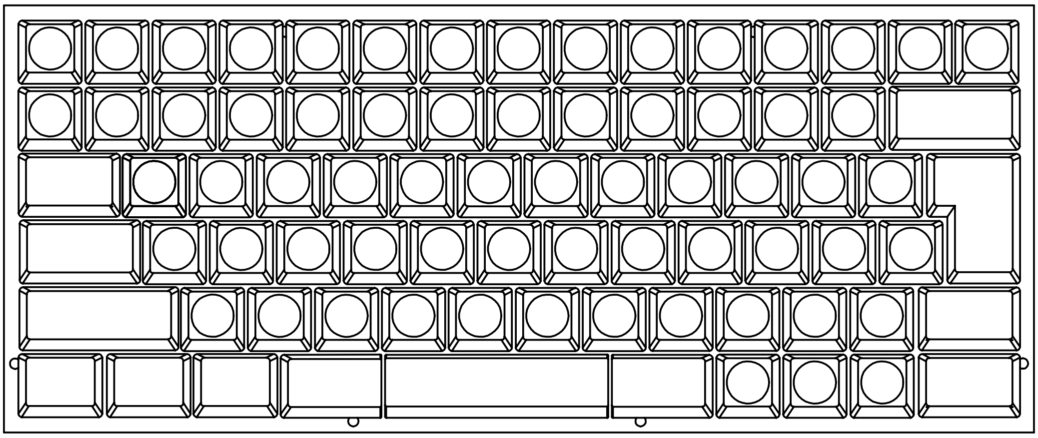
Lower row (left to right):

8	6	4	2
RESET	None	None	None

CHAPTER

FIVE

THE KEYBOARD



The keyboard is a row/column matrix scanner with anti-ghosting diodes on each switch. Each row and column is connected to one pin of the ATMega32U4 8-bit microcontroller. This microcontroller runs a firmware based on LUFA. This converts the scanned out keycodes to the USB HID protocol.

5.1 Firmware

You can find the Reform keyboard firmware in the source folder "reform-keyboard-fw".

To modify the scancodes of the keyboard matrix, edit the file Keyboard.c and rebuild the firmware by typing the following command in a terminal:

```
make
```

To be able to flash the firmware to the keyboard, the ATMega has to be in a special mode where it identifies as an "Atmega DFU bootloader" USB device. This is achieved by shorting the pins HWB and GND with a jumper and then briefly shorting the RESET pin to ground.

The RESET pin is pin 2 of J1, pin 1 is GND.

HWB and GND are pins 3 and 4 of J3, respectively. Start counting at the "J3" label.

The keyboard will reappear as a Atmel DFU bootloader USB device. You can then upload your new firmware by executing:

```
./flash.sh
```

5.2 Replacing a Keycap

The keycaps of the Reform beta units are printed with Clear Resin on Formlabs Form2 printers and then sanded by hand. Small irregularities are normal and a result of this process. The stems of the square 1x1 keycaps are slightly wider than the stems of other keycaps to make them more stable. This makes them harder to remove without breaking a stem. If a stem breaks inside of the keyswitch, you'll have to replace the keyswitch (see the following section).

To pull out bigger keycaps, use pincers and try to push them between the top of the switch and the cap and wiggle very carefully and evenly until you can pull out the cap.

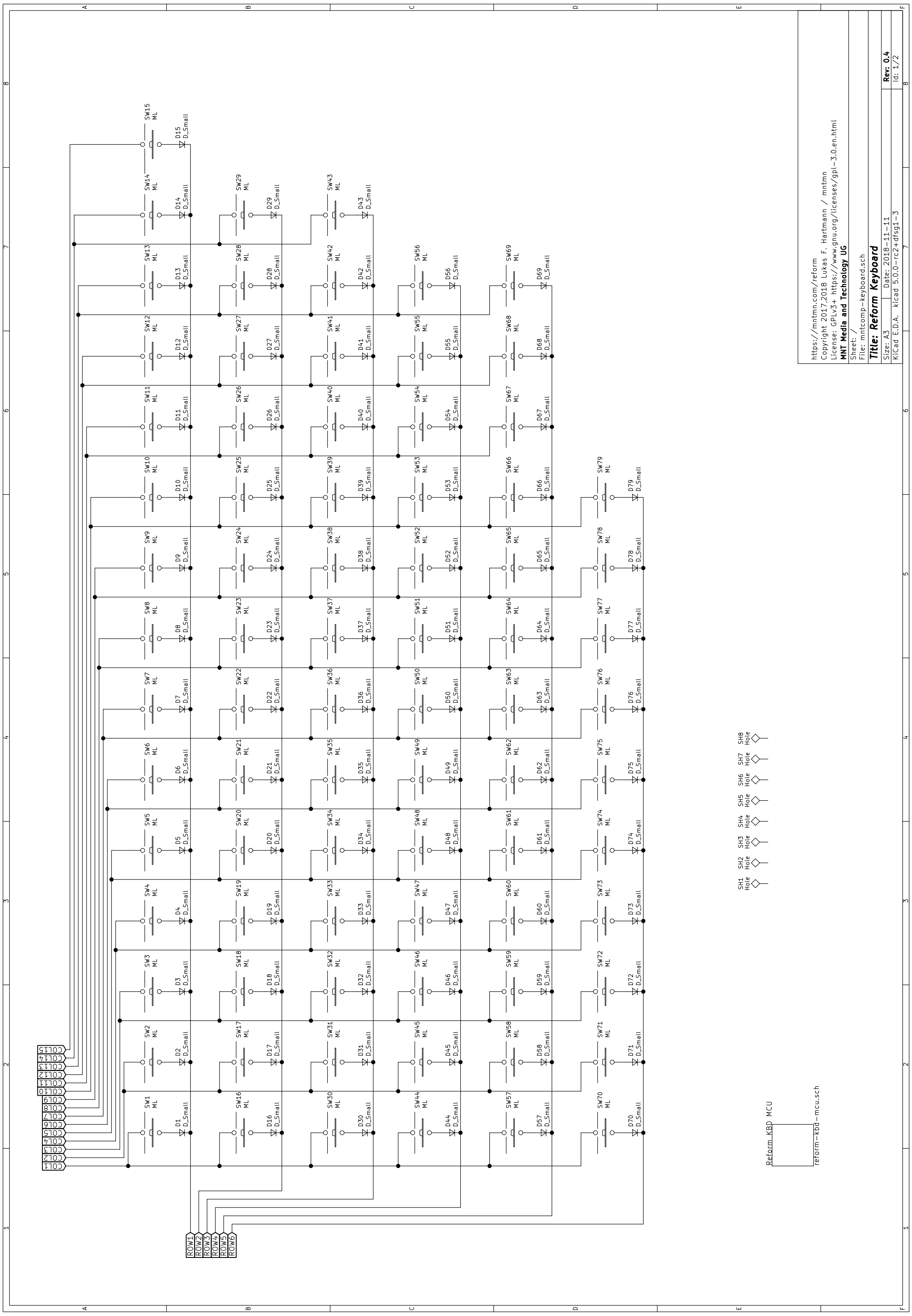
There are some companies who produce "standard" Cherry ML keycaps, such as GMK.

5.3 Replacing a Keyswitch

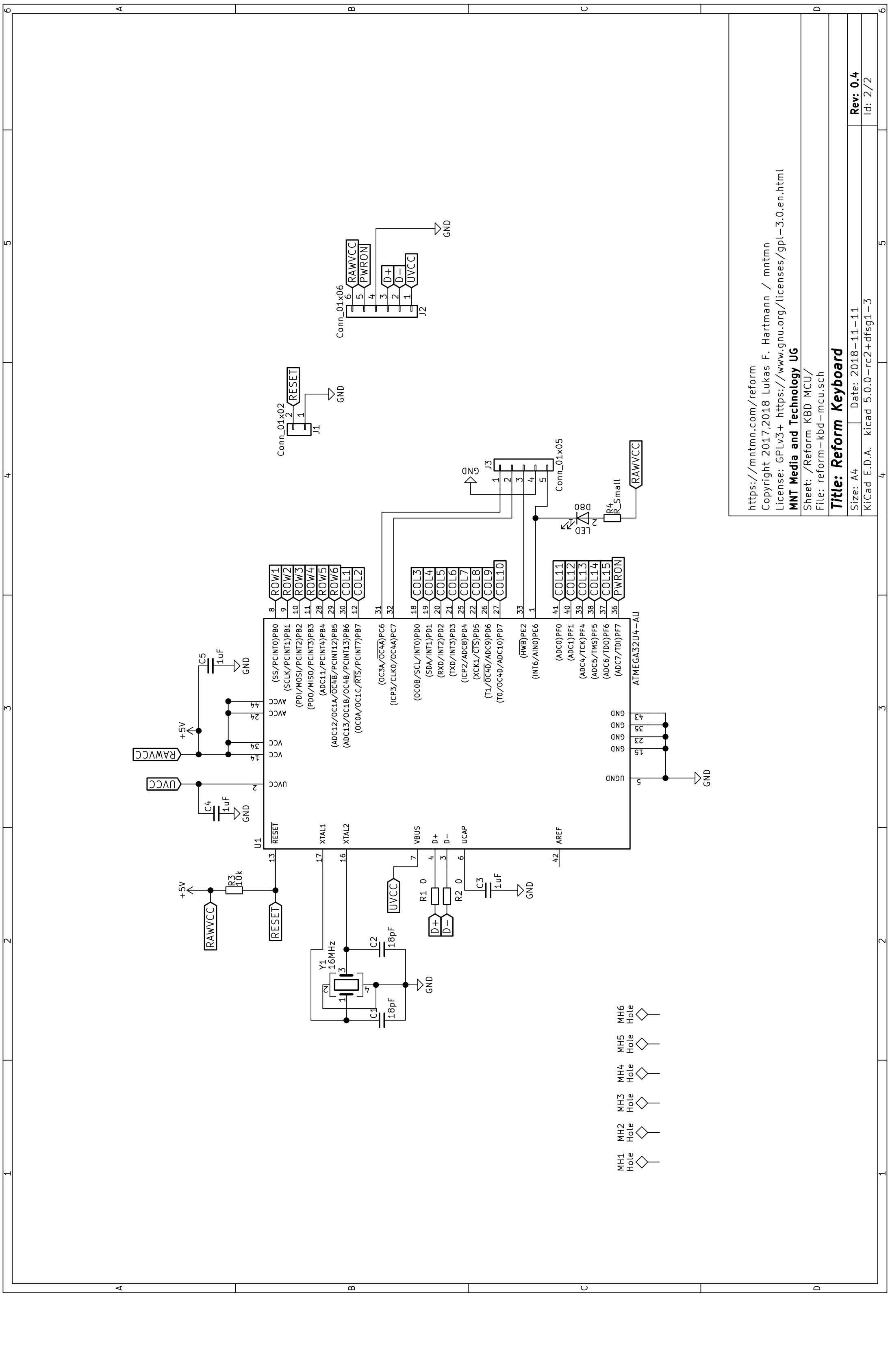
Only 2 of the 4 Cherry ML switch pins are soldered in to make it easier to swap switches with just a soldering iron. Set your iron/station to 380 degrees and dissolve the solder of one pin. Try to pull out the corresponding side of the switch from the top while continuing to heat the pin. Repeat the same for the other pin and go back and forth until you can remove the switch.

Replace with model Cherry ML1A-11JW.

5.4 Keyboard Schematics (Matrix)



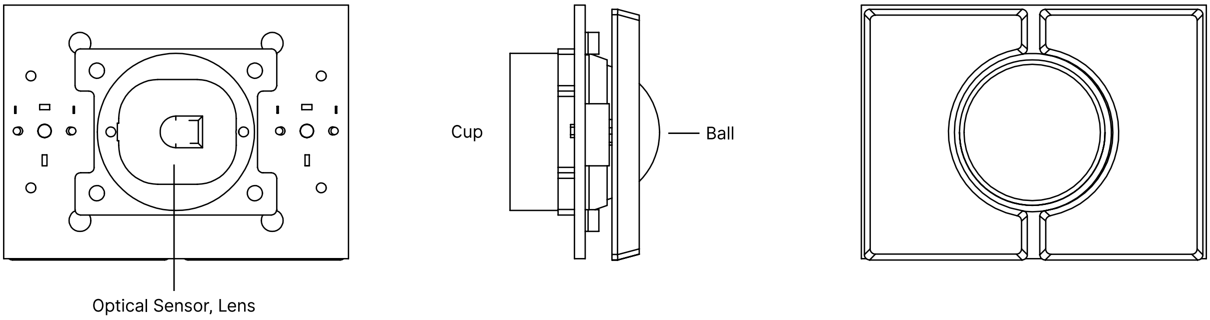
5.5 Keyboard Schematics (Controller)

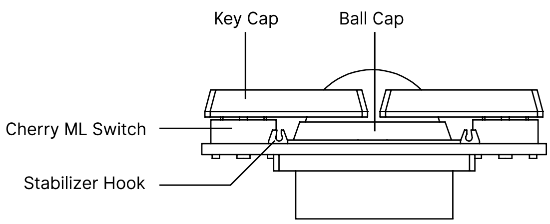


CHAPTER

SIX

THE TRACKBALL





The trackball uses the same microcontroller and LUFA framework as the keyboard, but instead of scanning a matrix of switches, it gets X and Y movement coordinates from the PMW3360DM-T2QU optical sensor that is connected via SPI.

6.1 Wheel Mode, Middle Click

The trackball firmware has a special "wheel mode" that allows you to use it like a mouse wheel for scrolling or to perform a middle mouse click.

You can enter wheel mode by pressing the left button and then pressing the right button while keeping the left button pressed. Release both buttons. Rolling the ball up and down will send wheel up/down commands. Clicking the right button will perform a middle click. Clicking the left button will exit wheel mode.

6.2 Firmware

You can find the Reform trackball firmware in the source folder "reform-trackball-fw".

The trackball firmware is based on the LUFA USB device library and implements a USB HID Mouse. To modify the behaviour of the trackball, edit the file Mouse.c and rebuild the firmware by typing the following command in a terminal:

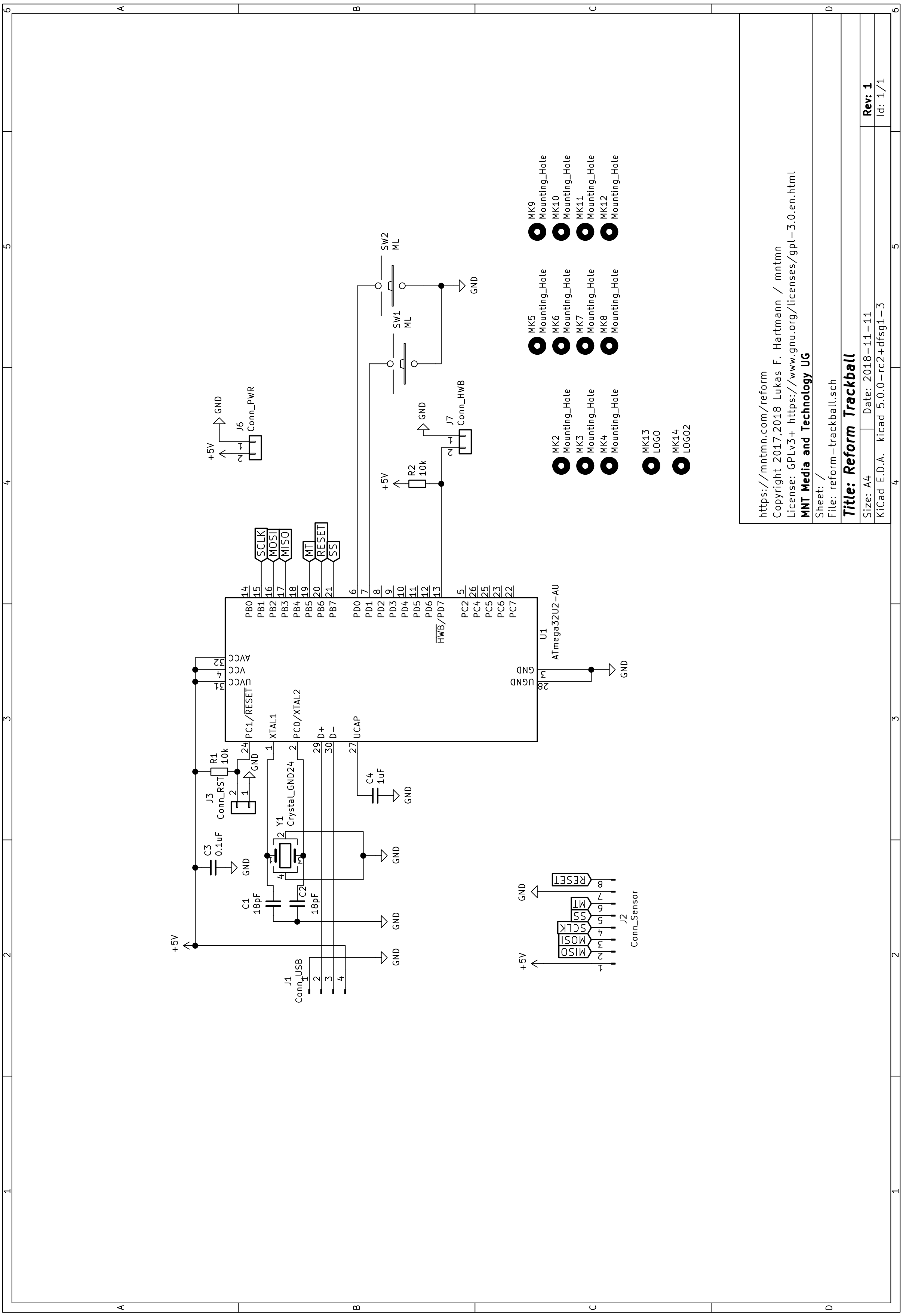
```
make
```

As with the keyboard, the trackball's MCU has to be in "Atmega DFU bootloader" USB mode. This is achieved by shorting the pins HWB and GND with a jumper and then briefly shorting the RESET pin to ground. The pins are marked on the silkscreen of the main trackball PCB.

After a reset with HWB pulled to ground, The trackball will reappear as a Atmel DFU bootloader USB device. You can then upload your new firmware by executing:

```
./flash.sh
```

6.3 Schematics



CHAPTER SEVEN

THERMAL

The main source of heat inside Reform is the i.MX6 SoC and its memory chips. Most of the heat goes into the blue passive heatsink that is glued to it. A fan which is mounted to the bottom plate then blows air over the heatsink into the direction of the ports, where it can escape through gaps in the case.

The fan is needed to push hot air out of the case, preventing overheating of the system. Normally, its full power is only needed when the system is under heavy load, for example when the GPU (3D graphics processor) is very active or all 4 cores are busy compiling code. The fan should turn on to full power when the SoC temperature is over 65 degrees celcius.

One of the three fan cables (orange) connects to the PWM1 pin of the i.MX6. The fan's speed can be controlled via pulse width modulation. This is usually the job of the reformd script, which monitors the core temperature and sets the fan to full power when the temperature is over 65 degrees Celcius.

To check the temperature of the system, you can use the command:

```
cat /sys/class/thermal/thermal_zone0/temp
```

The following is an example of commands that reformd uses to change the fan speed (in this instance, to set it to 75%):

```
# make the first PWM device available
echo 0 > /sys/class/pwm/pwmchip1/export
# define what a full period is
echo 10000 > /sys/class/pwm/pwmchip1/pwm0/period
# set how much of this period should be in the "ON" state (75%)
echo 7500 > /sys/class/pwm/pwmchip1/pwm0/duty_cycle
# enable the PWM output
echo 1 > /sys/class/pwm/pwmchip1/pwm0/enable
```

CHAPTER EIGHT

SYSTEM BOOT DETAILS

8.1 Powering Up

When the power switch is turned on, the TinyRex module (the little red board that contains the i.MX6 and the memory chips) receives power. If it is happy with the applied voltages (POWEROK signals are present), the green LED on the TinyRex module will light up. If only the red LED lights up, there is a problem with the power supply.

Next, the i.MX6 chip will jump to internal boot ROM code at memory address *0x00000000*. The boot ROM looks for an SD card on port SD1 and reads the DCD (Device Configuration Data) table from physical address 0x400 (1024 decimal, or the second physical block) on the SD card. This means that you can only use the MBR partition scheme on the boot disk, as it only occupies the first disk block. The more modern GPT partition format could work in theory, but most GPT tools and parsers do not understand GPT structures where the second block is in an alternative location.

We recommend to use the SD card as a boot and rescue disk, and set up an mSATA SSD disk with your actual operating system and data. You can then use alternative partition schemes and encryption.

Reform ships with U-Boot. It is installed onto the SD card and includes the DCD block that configures the DDR memory parameters and clocks.

8.2 U-Boot

U-Boot is a mini operating system and shell that allows you to inspect parts of the system (like PCIe, USB devices and Harddisks) and set up parameters to be passed to a "big" operating system kernel such as Linux, and start such an operating system.

U-Boot itself has to be compiled with the board support files for Reform. This is done by mkuboot.sh. The resulting file is u-boot.imx.

U-Boot is installed to the second block of the SD card using the "dd" utility by mkreform.sh.

U-Boot needs 2 files to boot Linux:

- The Linux kernel itself, normally called "zImage".
- The device tree blob (DTB), normally called "imx6qp-mntreform.dtb". It is a data structure that lists the addresses of and parameters for all the devices in the system that Linux needs to drive.

Both files are created when building Linux from source with the "imx6qp-mntreform.dts" source file included in the kernel tree. The helper script mkkernel.sh from https://github.com/mntmn/reform-bootstrap does it for you.

8.3 Booting the Linux Kernel

Theoretically, you could boot other operating systems besides Linux, such as FreeBSD, NetBSD, OpenBSD or anything else that supports the i.MX6QP SoC. So far, we didn't have the time to test them, though. We'll happily expand this guide with your contributions if you've managed to run an alternative OS on Reform.

The default boot commands for U-Boot are specified at https://github.com/mntmn/u-boot/blob/mntreform/include/configs/mntreform.h#L104

If you want to boot manually, these are the steps.

1. Configure the kernel command line to use no initial ram disk, use the first partition of the first SD card as the root volume (read/write), and wait for the root device. Also, set the continuous memory allocation (CMA) pool to 256MB and disable message signaled interrupts (MSI) for PCI express. The CMA pool is needed by the etnaviv GPU drivers. MSI has to be disabled for some expansions like ath9k-based WiFi cards.

```
setenv bootargs noinitrd root=/dev/mmcblk0p1 rw rootwait cma=256M pci=nomsi no_
↪console_suspend=1
```

2. Set the maximum address/size for the device tree structure (called FDT in U-Boot, DTS/DTB in Linux). The kernel can fail to start without this.

```
setenv fdt_high 0xffffffff
```

3. Load the Kernel (zImage) to address 0x10008000 from the SD card (also called "MMC") device 0, partition 1 (there is no partition 0, 1 is the first). ext4load works for ext4 formatted partitions. For FAT, you would use fatload.

```
ext4load mmc 0:1 0x10008000 zImage
```

4. Load the device tree (FDT/DTB) to address 0x18000000 from the same partition.

```
ext4load mmc 0:1 0x18000000 imx6qp-mntreform.dtb
```

5. Tell U-Boot where you just loaded the FDT and to please resize it.

```
fdt addr 0x18000000
fdt resize
```

6. Start Linux from the load address and pass the FDT address to it.

```
bootz 0x10008000 - 0x18000000
```

CHAPTER

NINE

DEBUGGING

9.1 Power

The TinyRex module has a red and a green LED. Both have to light up to signal good power.

To troubleshoot power, disconnect the internal battery and all internal and external peripherals, connect the 5V wall adapter. If you want to unplug the TinyRex module, you should take the motherboard out of the case first.

Turn the power switch on. Get a multimeter and find the following voltages in the system:

- 5V The main input rail. Can be found on pin 1 of J25 or J29.
- 3.3V The big regulator U4 (AP1501A-33) turns 5V into 3.3V. Check test point TP3 next to the big coil L2.
- 2.5V Regulated by U11 (LP3962EMP-2.5). Check TP5 next to it.
- 1.5V Regulated by U13. Check TP12. Needed for PCIe.
- 1.1V Regulated by U5 near the USB hub U9. Check TP6.

If voltages are way off, there can be a short somewhere on the board which usually generates heat.

9.2 Serial Console

The motherboard connector labelled CONSOLE is a serial port (UART) to which U-Boot and the Linux kernel output diagnostic information on startup. The baud rate is 115200.

Wire up a generic USB-to-UART adapter to the following pins of J25 (pin 1 is next to the J25 label):

- 1 5V, don't connect
- 2 UART1_TXD, connect to RX of your adapter
- 3 UART1_RXD, connect to TX of your adapter
- 4 UART1_RTS, don't connect
- 5 UART1_CTS, don't connect
- 6 GND, connect to GND of your adapter

Then, use a terminal program such as screen on your host computer:

```
screen /dev/ttyUSB0 115200
```

If you then switch on Reform with a prepared SD card inserted, you should see the U-Boot console in *screen*.

CHAPTER TEN

CREDITS

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Inter UI Font rsms

PCB Production PCBWay

Aluminum Milling Shandong Jiepurui Model Technology Co., Ltd.

3D Printer BCN3D Sigma R17

Reflow Oven ReflowR

Stereolitography Formlabs Form2

Lab Tools Rigol DS1054Z, Fluke 117. Weller WD-1, Toolcraft SMD Rework Station

Parts Suppliers Mouser, DigiKey, Conrad, Voelkner (Fans), GMK Electronic Design (Switches), Schraubenhandel Machholz (Screws), Smooth Group (Hinges), Palm Stream International (Displays), HereWin (Batteries)

Chips Used NXP (MCIMX6Q5EYM10AC, SGTL5000XNAA3), Micron (MT41K512M16HA-125), Texas Instruments (BQ24650RVAT, INA260AIPW, TPS61235RWLR, TUSB4041IPAPR, TPS2044BDR, TLV70012, TLV1117-15, LP3962EMP-2.5), ON Semiconductor (CM2020-00TR), Microchip (KSZ9031RNXIA, ATTINY841-SSU, ATMEGA32U4), Diodes Inc. (AP1501A-33K5G-13), Rohm (BR24L02NUX-WTR)

Software Used Debian GNU/Linux, KiCAD, Inkscape, GIMP, Emacs, Vim, Git, Arduino, LUFA, Blender, Cura, slic3r, Solidworks, FreeCAD, OpenSCAD, Sphinx

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