



Librem 5 Mobile Phone – Embedded Developer View

**Telefon Librem 5 očima vývojáře automobilové, laboratorní,
medicínské a robotické techniky**

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Pages: <https://www.pikron.com/>



Presentation Outline

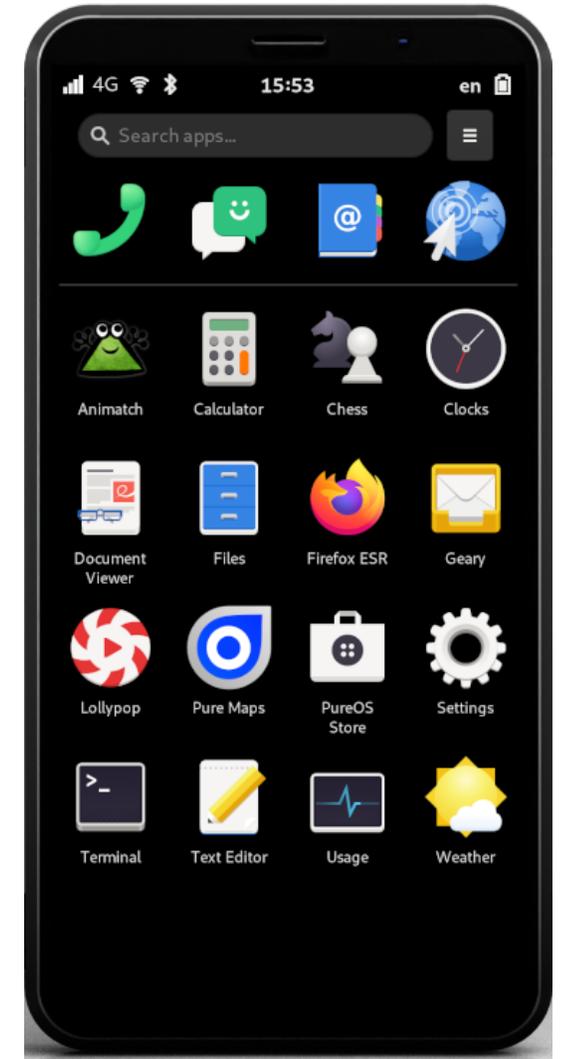
- Librem 5 Origin and Specification, HW Challenges and Production
- Under the Hood – What is on the Main Board
- Power Management
- GNSS Issues, Repair Options, geoclue Setup
- Qt5 Pinch-to-Zoom Addition
- Qt5 Select Satellite Positioning Methods



Librem 5 Specification and Initial Crowdfunding

- At campaign start (August 24, 2017)
 - firm promise that SoC with **open source drivers** including **GPU** will be used, limited options, **Etnaviv** i.MX 6 (32-bit only) and may be i.MX8 available
- Final specification:
 - screen 5.7" IPS TFT 720×1440
 - memory 3 GB RAM
 - storage 32 GB eMMC
 - battery 4,500 mAh User-Replaceable
 - processor **NXP i.MX 8M** (64-bit ARM) **IMX8MQ6DVAJZAB Quad Cortex-A53** up to 1.5 GHz and Cortex-M4

Source: <https://puri.sm/products/librem-5/>





Librem 5 Key Design Decisions about Radios

- Main CPU and SoC with fully open-source support, goal to gain Free Software Foundation (FSF) **Respect Your Freedom** (RYF) certification
- **GSM/LTE/4G** baseband radio processor with open firmware unavailable
chosen **M.2 KEY B** industrial modem connected by **USB**, interfaces
 - USB 2.0 – data, control, high power consumption
 - PCM – digital synchronous serial audio for GSM
 - SIM and ANTCTL
 - WoWWAN – **Wake on the host** WWAN_WAKE GPIO3 15
- Modem with included firmware and API considered as non user fixable component by FSF
- **M.2 KEY E** Redpine Signals RS9116 – **SDIO ×4**, I2S, UART, (USB not used)
WiFi/BT 802.11a/b/g/n/ac + Bluetooth 4.1/ EDR



GNSS Receiver, SmartCard and Cameras

- **STM Teseo-LIV3 GNSS Module** – UART, power enable, reset GPIO
 - GPS, A-GPS, Galileo, GLONASS, BeiDou, QZSS
- **SmartCard** with separate STM32L432KC MCU – UART
- **Back Camera:** 13 MPixel w/LED flash – MIPI CSI
 - Samsung S5K3L6XX 7 13.25 MP, CMOS, 1/3", 4224×3136 pixels, 4K@30fps, FHD@60fps, HD@120fps, f/1.9, 28mm, auto-focus: 10cm - ∞, 81.5° FOV, LED flash
- **Front Camera:** 8 MPixel – MIPI CSI
 - SK hynix YACG4D0C9SHC 7 8.0 MP, CMOS, 1/4", 3264×2448 pixels, QUXGA@30fps, FHD@60fps (crop), HD@90fps, focusing range: 28.9-65.0cm, 83.3° FOV



Sensors and Accessories

- Magnetometer STM LSM9DS1 – I2C
9-axis iNEMO inertial module (**IMU**): 3D magnetometer, 3D accelerometer, 3D gyroscope with I2C and SPI
- **Proximity** & ambient light – Vishay VCNL4040 – I2C
- HALL Effect Sensor – single GPIO
- USB 2.0 hub and micro-SD card reader bridge – Microchip/SMSC USB2642
 - USB to M.2 KEY B for 4G, USB to M.2 KEY E for WiFi (not used on Redpine Signals RS9116)
- Vibrator motor CQ3610BL-100
- Extension Connector – EXT CON (in a theory NFC can be added)
 - SPI 1× chip select (MISO, MOSI shared with onboard SPI Flash)
 - 1× I2C, 1× UART 3v3, VDD 3v3 and 1v8, NFC_EN GPIO



Kill Switches – Really Force Subsystem Power Off

- **Kill switches** control directly power supplies for given modules/devices
 - The **Modem** switch controls power to the M.2 modem card.
 - The WLAN/Bluetooth switch controls power to the combined M.2 **WiFi/Bluetooth** module.
 - The **Camera/Microphone** switch controls power to the camera and microphone.
- When **all three kills** active
 - Global Navigation Satellite System (GNSS) unit – GPS and other networks
 - Inertial Measurement Unit (IMU) – accelerometer, gyroscope, magnetometer
 - Ambient light and proximity sensors
- Verified in the design schematics, **power** supplies for respective devices **stopped** and main SoC informed over GPIO

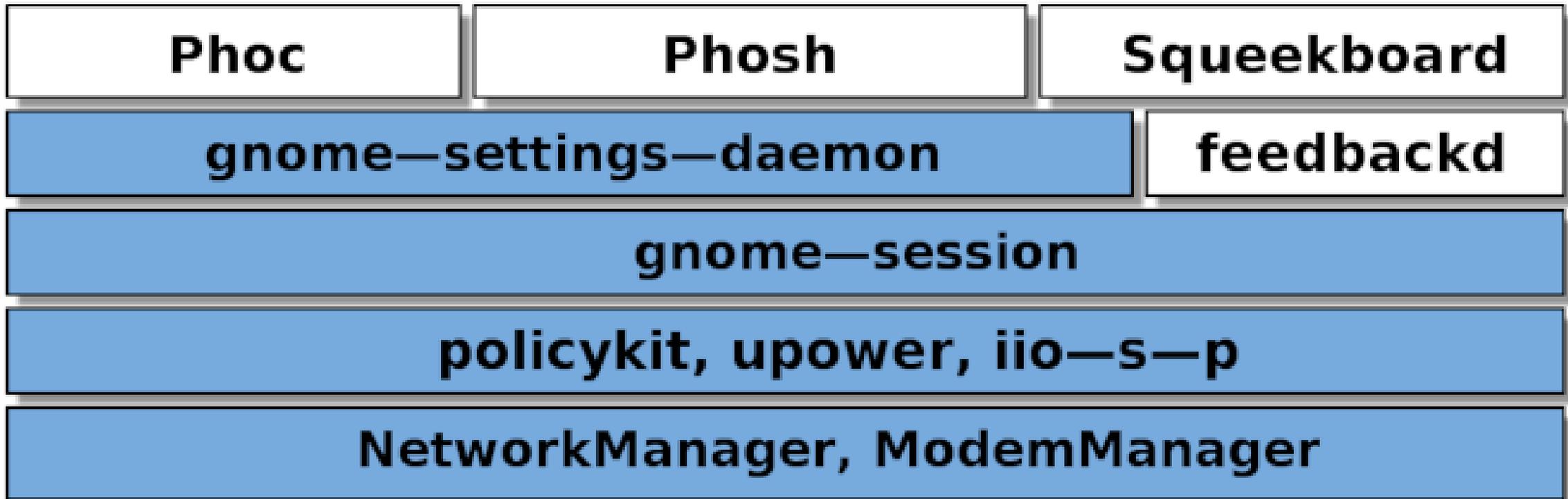


USB-C Connectivity

- **USB 3.0** – dual role
- **Power Delivery** – source 5v0 and Battery Charging 1.2
 - **5Vx3A** (15W), disabled 9Vx2A (18W) & 12Vx2A (24W)
- DisplayPort alt-mode 1 over USB-C
 - max 4K@60fps 1, (usable up to FullHD) using DCSS 1, TI TPS65983 1 converts DP 1.3 to DP alt-mode
 - realized by i.MX8 M HDMI output
- Default USB gadget mode interfaces
 - CDC Abstract Control Model (ACM)
 - CDC ACM Data
 - CDC Ethernet Control Model (ECM)
 - CDC Ethernet Data



Librem 5 User Space Software Stack



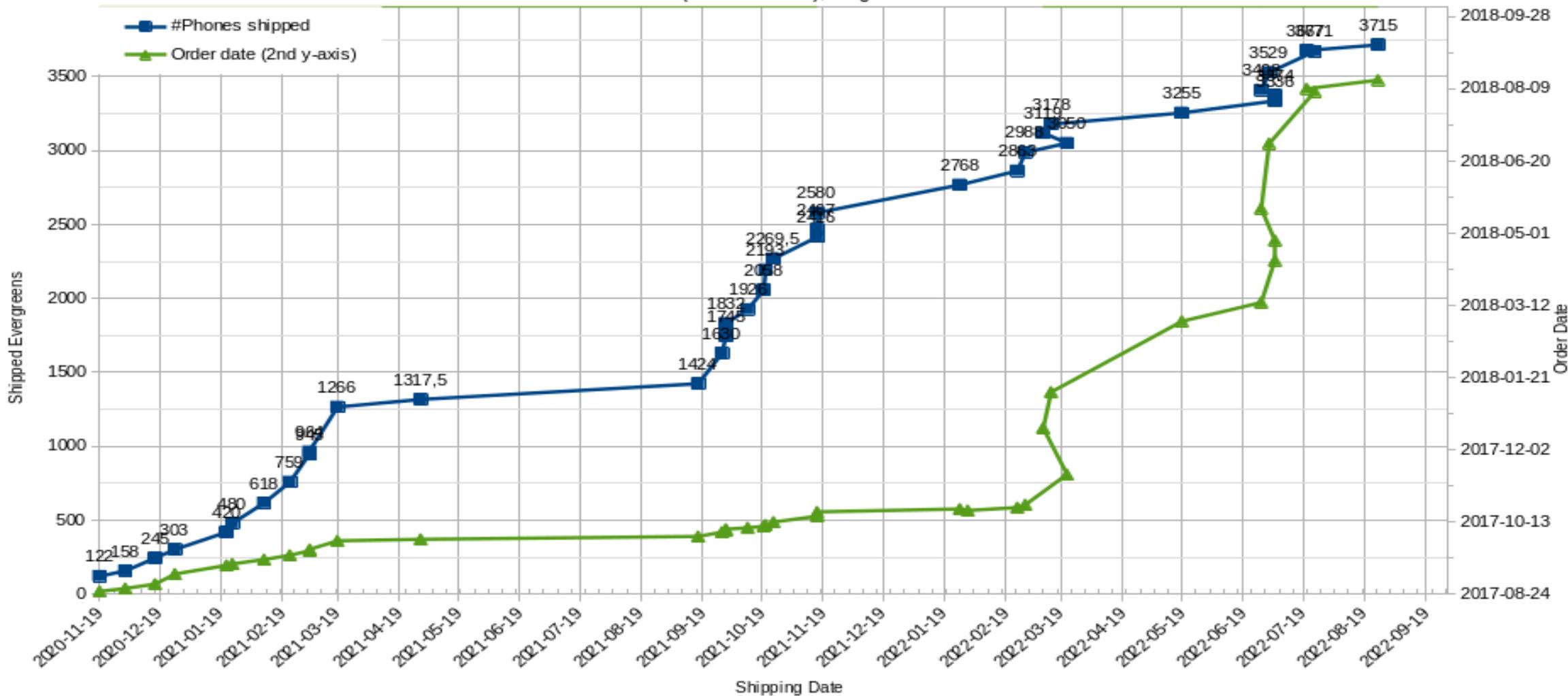
Source: <https://puri.sm/posts/thank-you-for-joining-us/>



Shipment of Librem 5 – As Estimated from Reports

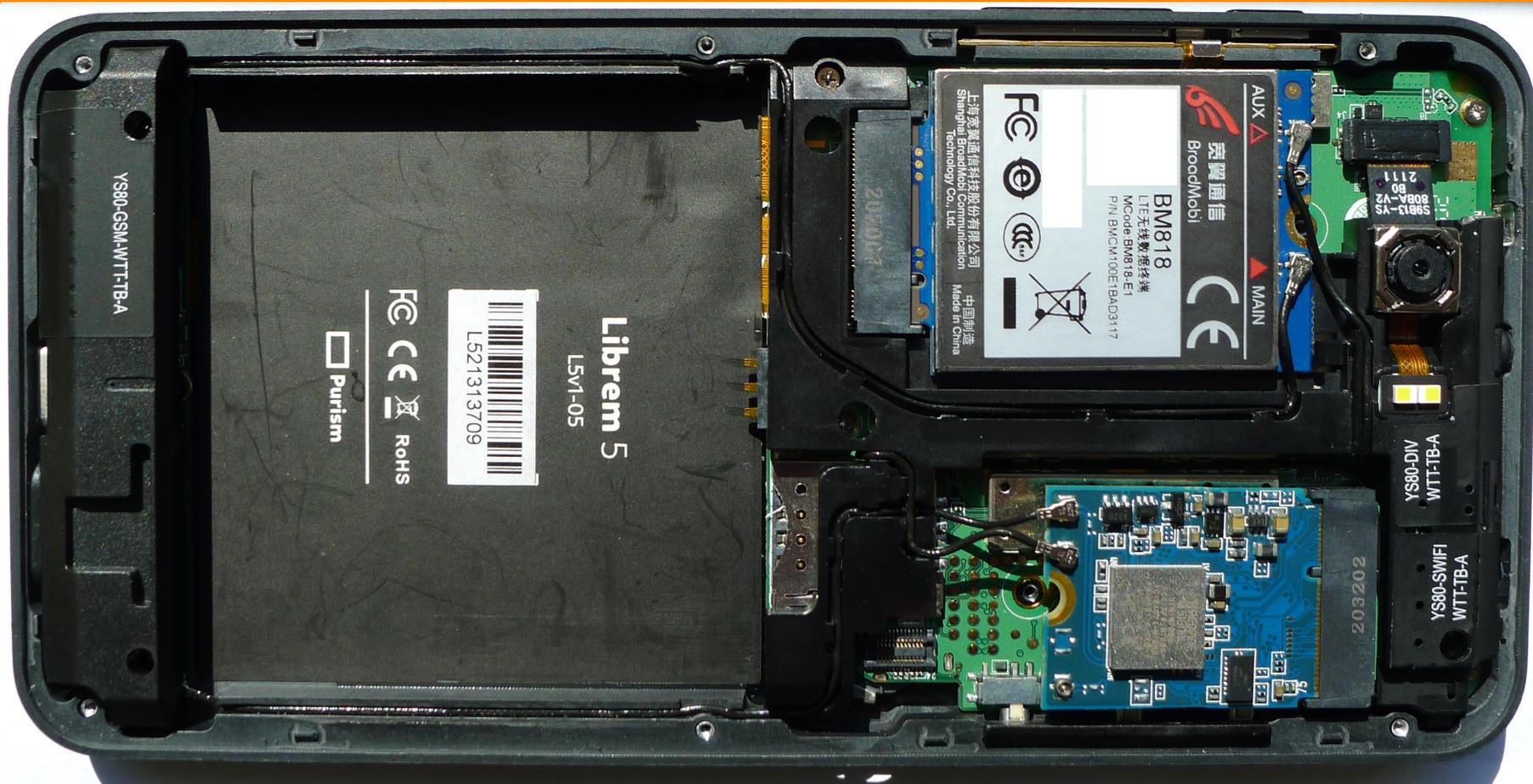
Shipping (3975 ordered Evergreens)

Based on <https://forums.puri.sm/t/estimate-your-librem-5-shipment/11272>
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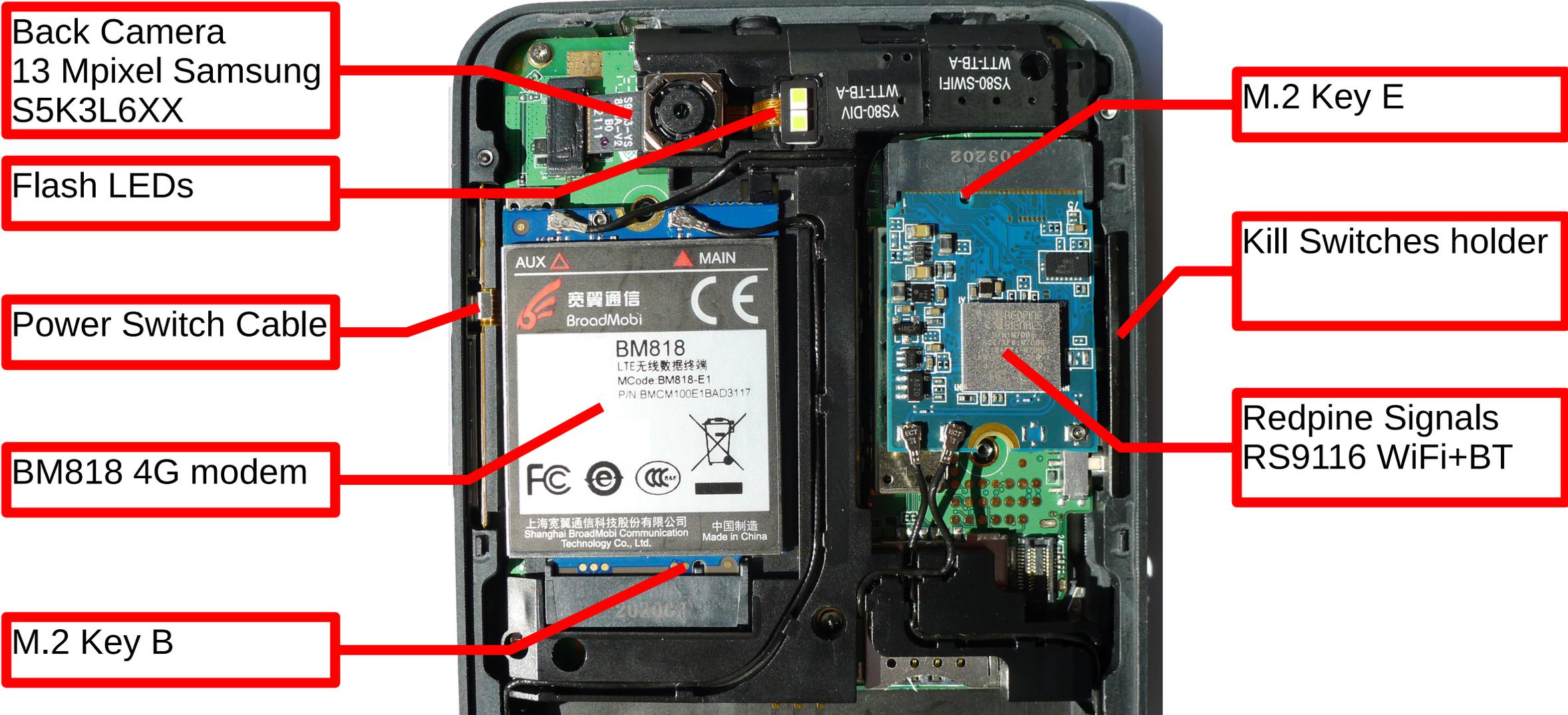
Frame Around Back Side and M.2 Cards Taken Off



When you assemble device do not put M.2 modem and M.2 WiFi+BT card in the slots before placing plastic back frame which separates them from mainboard. Be careful to route antennas wires in the right ribbons



Detail of M.2 Cards and Back Camera





Main Board – Back Side Commented

GNSS Frame Contact 1

GNSS Screw to Antenna

Back Camera Connector

Vibration Motor

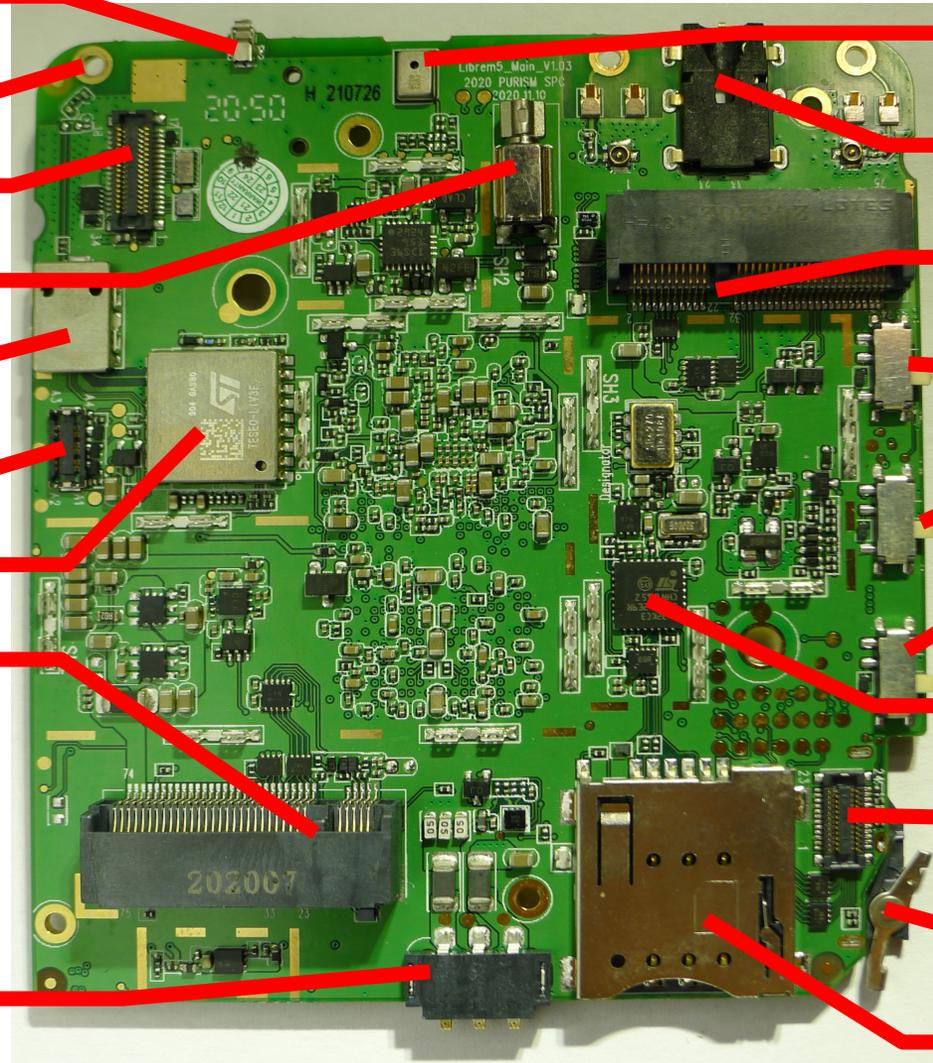
GNSS LNA

Power Switch Connector

STM Teseo-LIV3 GNSS

M.2 Key B for Modem

Battery Contacts



Internal Top Microphone

Audio Jack

M.2 Key E for WiFi + BT

4G Kill

WiFi+BT Kill

Camera+mic Kill

STM32L432KCI

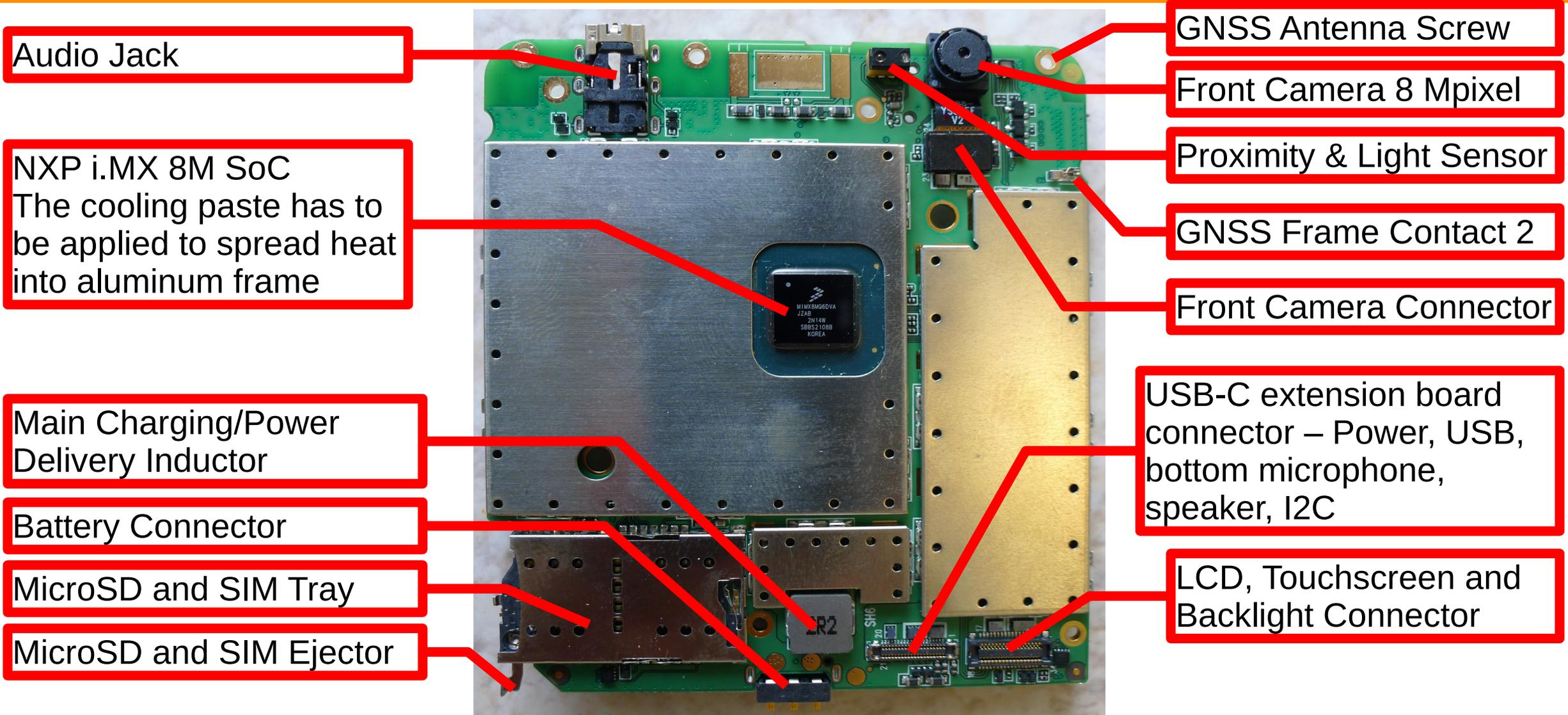
Extension Connector

MicroSD and SIM Ejector

SmartCard

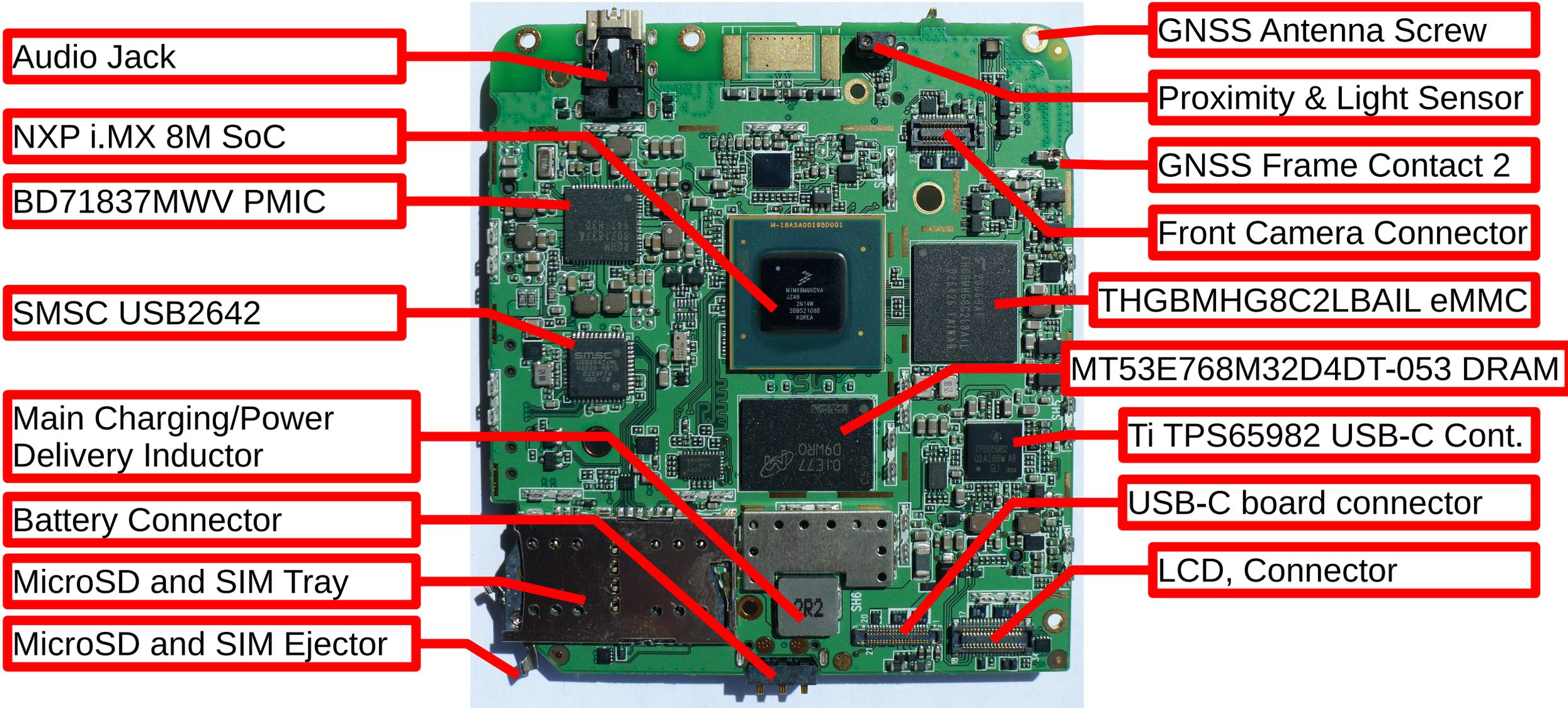


Main Board – Front Side with Shielding





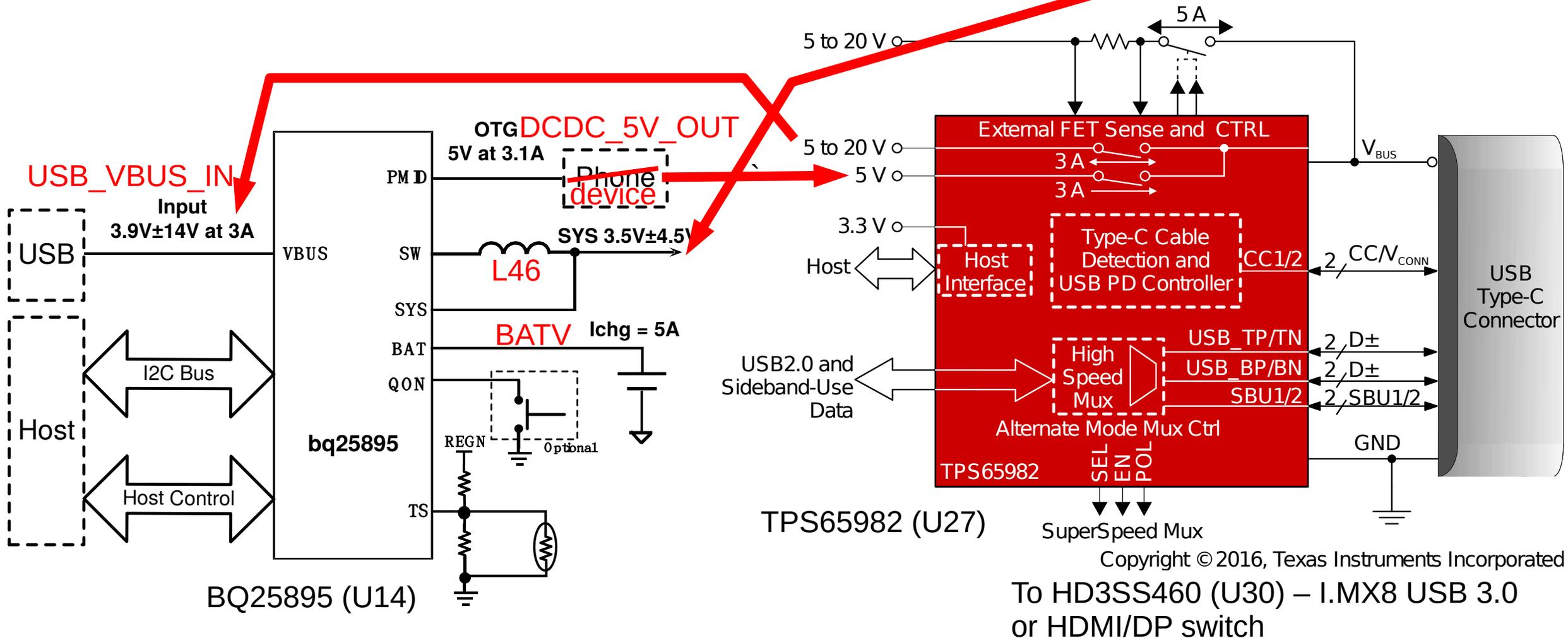
Main Board – Front Side – Shielding Removed





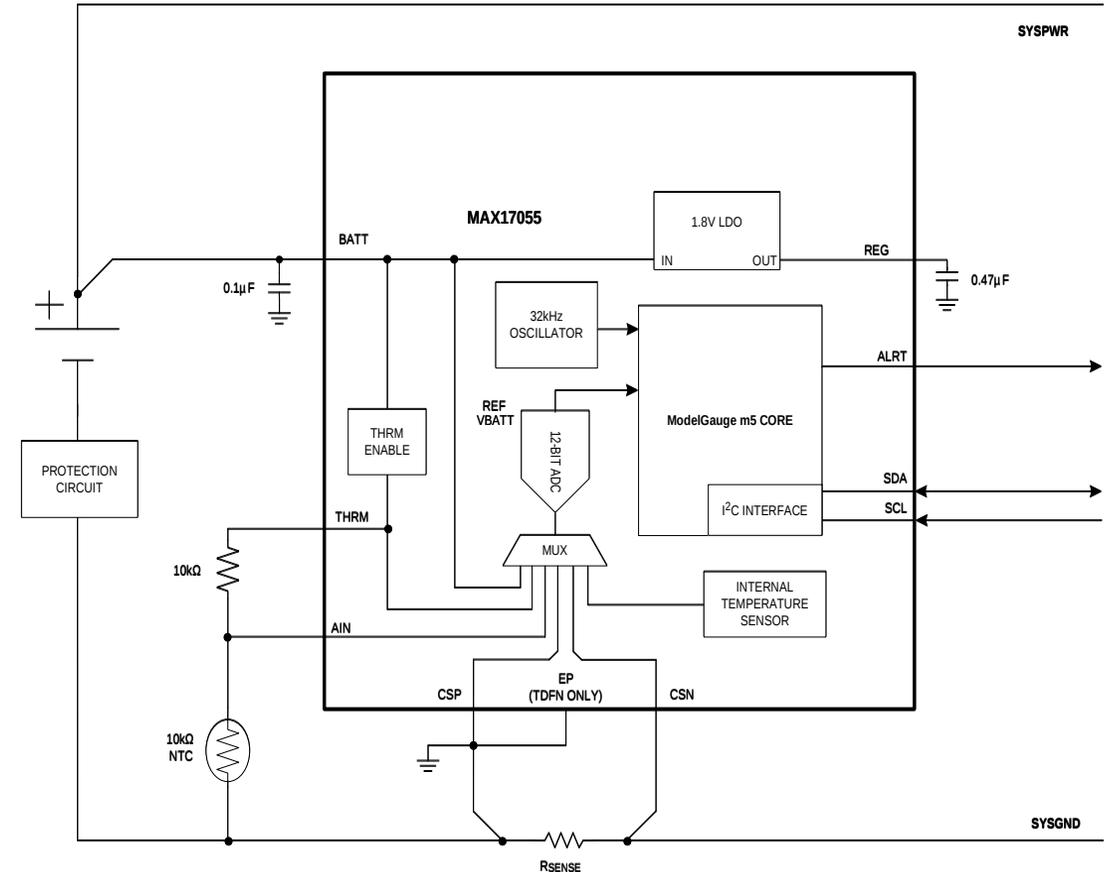
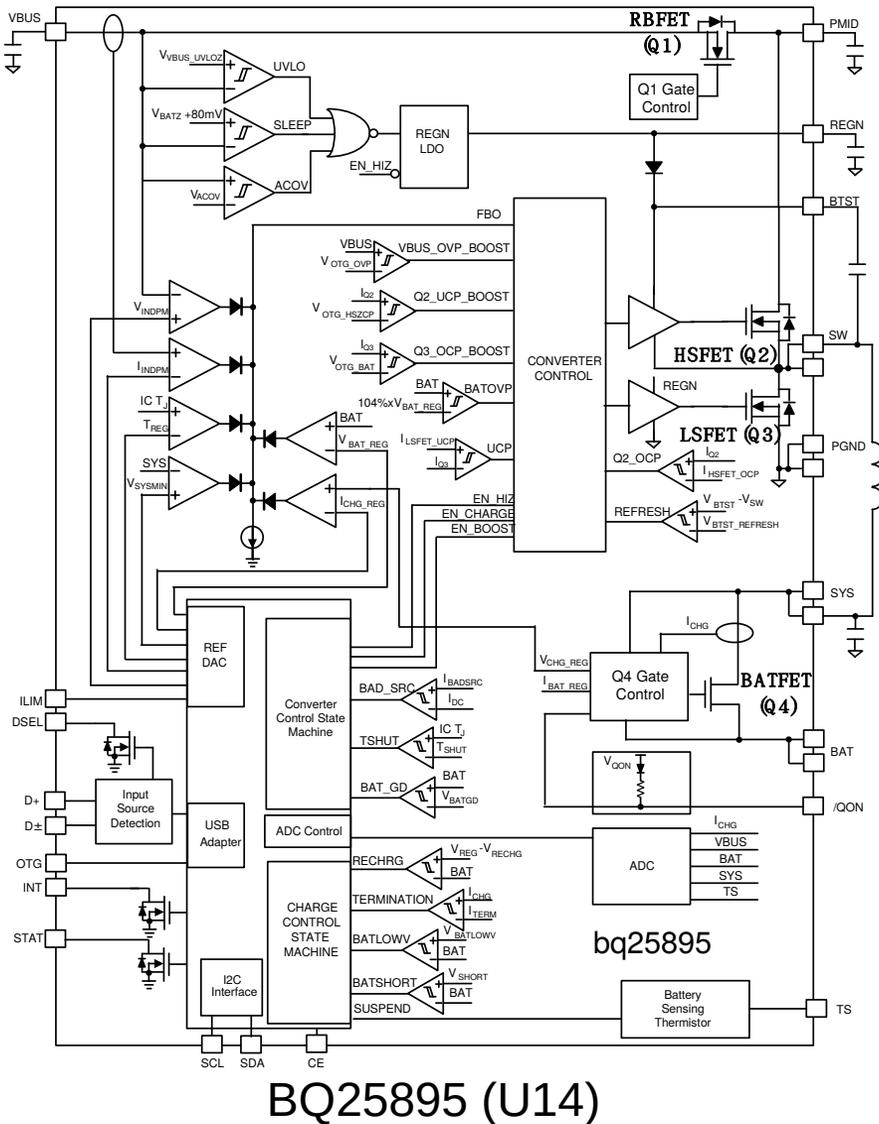
USB-C Power Delivery and Battery Charger

- System voltage is directly battery cell 3.4 to 4.3 Voltage VSYS_3V4_4V3





Detail of Battery Charger and Gauge Chips





GNSS Engineering Change Order (ECO) for V 1.03

- GNSS Issue – Low Carrier to Noise Ratio – reported in NMEA lines
\$GPGSV,3,1,10,07,68,167,21,09,57,075,17,20,44,301,21,11,41,264,15*7D
\$--GSV,<GSVAmount>,<GSVNumber>,<TotSats>,
 <Sat1PRN>,<Sat1Elev>,<Sat1Azim>,<Sat1CN0>,,,,,
 <Sat4PRN>,<Sat4Elev>,<Sat4Azim>,<Sat4CN0>*<checksum><cr><lf>
- SatxCNx Decimal, 2 digits, from 00 till 99
Carrier to Noise Ratio for satellite x in dB
- [STM Teseo-LIV3 GNSS Module Software Manual](#) for more information
- Librem 5 - Teseo-LIV3 GNSS Module reports weak carrier to noise ratio - probably HW/design problem
<https://source.puri.sm/Librem5/OS-issues/-/issues/252>
- [GNSS_sensitivity_ECO_for_customers.pdf](#)



GNSS Testing – Setup Services

- Simple open and read of `/dev/gnss0` should power on module and provide NMEA records

```
sudo cat /dev/gnss0
```

- Install `gnss-share` (make `/dev/gnss0` available as socket for multiple readers and control applications) and `geoclue-2` (D-BUS position API)

```
sudo apt install gnss-share geoclue-2.0
```

- Check `gnss-share` `/etc/gnss-share.conf` to reference `/dev/gnss0`
- Check `geoclue-2` configuration `/etc/geoclue/geoclue.conf`

```
[network-nmea]
enable=true
# use aa nmea unix socket as the data source
nmea-socket=/var/run/gnss-share.sock
```



GNSS Testing – Regular geoclue-2 Access

- Services should be enabled and started, if not use (repeat for geoclue)

```
sudo systemctl enable gnss-share.service  
sudo systemctl start gnss-share.service
```

- The position should be available from gnss-share socket now

```
sudo socat unix-client:/var/run/gnss-share.sock -
```

- Can be redirected to the file and converted to GPX

```
gpsbabel -i nmea -f tmp.nmea -o gpx -F tmp.gpx
```

- If the geoclue-2 works then Pure Maps, GpxSee and other applications can use service out of box

- It can be needed to provide permissions for applications to access geoclue which can be done globally in /etc/geoclue/geoclue.conf

```
[gpxsee]  
allowed=true  
system=false
```



Librem 5 – ECO Realization

- It is quite problem because 0201 SMD deices (0.6 mm by 0.3 mm) has to be replaced in the dense populated printed circuit board area
- Replace R136 with a 27nH 0201 SMD inductor Murata ElectronicsLQP03TN27NJ02D
- Remove R106 (R106 → DNI), R144 replaced by direct connection (R144 → 0 Ohm), R163 change to 16K (R136 → 16K)
- To small to do at PiKRON. Our PCB production and assembly partners can populate 0201 with SMD automation assembly but rework problematic
- Look for the real mobile hones repair services
 - PrimeSolder <https://primeservis.cz/> in Prague, Czech Republic done the repair



Start and Debug Wayland Application over SSH

- Used to debug GpxSee (<https://github.com/tumic0/GPXSee-maps>) on Librem 5
- Local PureOS ARM debootstrap with QEMU user mode static used for application build
- Application copy over SCP to the target (Librem 5)
- Connect over SSH and run prepared `wayland.env`

```
export XDG_CURRENT_DESKTOP=Phosh:GNOME
export XDG_SESSION_TYPE=wayland
export WAYLAND_DISPLAY=wayland-0
export MOZ_ENABLE_WAYLAND=1
export QT_QPA_PLATFORM=wayland
```

- Run application with GDB server

```
. ./wayland.env
gdbserver :12345 path_to_executable
```



Connect from the Host System to gdbserver

- even regular `gdb-multiarch` can be used to connect to system from x86

```
gdb-multiarch /srv/nfs/pureos-arm64/devel/gpxsee/gpxsee-build/gpxsee
```

- connect from gdb to remote system

```
target remote venti:12345  
b main  
run
```



Pinch-to-Zoom in Qt 5 Application

- Solution based on the help and example code by Jan Salus and Frantisek Vacek from Elektroline.cz where large systems based on Qt 5 are developed
- Enable gestures in the QGraphicsView descendant

```
--- a/src/GUI/mapview.cpp
+++ b/src/GUI/mapview.cpp
@@ -57,6 +57,9 @@ MapView::MapView(Map *map, POI ...
    _scene = new QGraphicsScene(this);
    setScene(_scene);
    setDragMode(QGraphicsView::ScrollHandDrag);
+   setAttribute(Qt::WA_AcceptTouchEvents);
+   grabGesture(Qt::PinchGesture);
+   grabGesture(Qt::TapAndHoldGesture);
    setViewportUpdateMode(QGraphicsView::FullViewportUpdate);
    setVerticalScrollBarPolicy(Qt::ScrollBarAlwaysOff);
    setHorizontalScrollBarPolicy(Qt::ScrollBarAlwaysOff);
```



Pinch-to-Zoom in Qt 5 Application – Cont.

- Add next methods into QGraphicsView descendant

```
+ bool gestureEvent(QGestureEvent *ev);  
+ bool tapAndHoldTriggered(QTapAndHoldGesture *ev);  
+ bool pinchTriggered(QPinchGesture *ev);  
+ bool event(QEvent *ev);
```

- Methods implementation

```
bool MapView::tapAndHoldTriggered(QTapAndHoldGesture *ev)  
{  
    QContextMenuEvent eev(QContextMenuEvent::Other,  
                           ev->position().toPoint());  
    contextMenuEvent(&eev);  
    return true;  
}
```



Pinch-to-Zoom in Qt 5 Application – Cont.

```
bool MapView::pinchTriggered(QPinchGesture *ev)
{
    QPinchGesture::ChangeFlags changeFlags = ev->changeFlags();
    if (changeFlags & QPinchGesture::ScaleFactorChanged) {
        //qreal sc = ev->scaleFactor();
        //qreal lsc = ev->lastScaleFactor();
        qreal tsc = ev->totalScaleFactor();
        QPoint pos = viewport()->rect().center();
        int z = 0;
        while ((tsc > 1.25) && (z < 5)) {
            tsc *= 0.8;
            z += 1;
        }
        while (tsc < 0.8 && (z > -5)) {
            tsc *= 1.25;
            z -= 1;
        }
    }
}
```



Pinch-to-Zoom in Qt 5 Application – Cont.

```
if (z) {
    ev->setTotalScaleFactor(tsc);
    zoom(z, pos, false);
}
if (changeFlags & QPinchGesture::CenterPointChanged) {
    // no action required
}
if (ev->state() == Qt::GestureFinished) {
    // no action required
}
return true;
}
```



Pinch-to-Zoom in Qt 5 Application – Cont.

```
bool MapView::event(QEvent *ev)
{
    if (ev->type() == QEvent::Gesture) {
        return gestureEvent(static_cast<QGestureEvent*>(ev));
    }
    return QGraphicsView::event(ev);
}
```

```
bool MapView::gestureEvent(QGestureEvent *ev)
{
    Q_FOREACH(QGesture* gst, ev->activeGestures()) {
        switch (gst->gestureType()) {
```



Pinch-to-Zoom in Qt 5 Application – Cont.

```
case Qt::TapAndHoldGesture:
    if (gst->state() == Qt::GestureFinished) {
        QTapAndHoldGesture* taphold = qobject_cast <
            QTapAndHoldGesture*>(gst);
        if (taphold == nullptr)
            return false;
        if (tapAndHoldTriggered(taphold)) {
            ev->accept(gst);
        }
    }
    break;
```



Pinch-to-Zoom in Qt 5 Application – Cont.

```
case Qt::PinchGesture: {
    QPinchGesture* pinch = qobject_cast<QPinchGesture*>(gst);
    if (pinch == nullptr)
        return false;
    if (pinchTriggered(pinch)) {
        ev->accept(gst);
    }
}
break;
default:
    break;
}

}

return true;
}
```



Rough Position Used Instead of GNSS Position

Constant	Value	Description
<code>QGeoPositionInfoSource::NoPositioningMethods</code>	<code>0x00000000</code>	None of the positioning methods.
<code>QGeoPositionInfoSource::SatellitePositioningMethods</code>	<code>0x000000ff</code>	Satellite-based positioning methods such as GPS or GLONASS.
<code>QGeoPositionInfoSource::NonSatellitePositioningMethods</code>	<code>0xffffffff00</code>	Other positioning methods such as 3GPP cell identifier or WiFi based positioning.
<code>QGeoPositionInfoSource::AllPositioningMethods</code>	<code>0xffffffff</code>	Satellite-based positioning methods as soon as available. Otherwise non-satellite based methods.

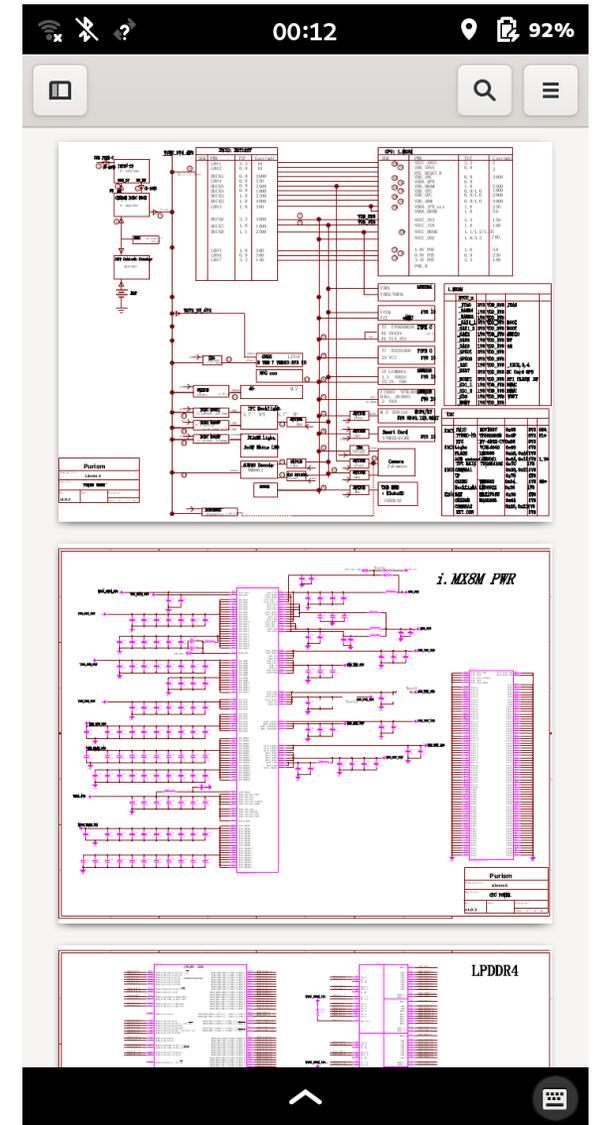
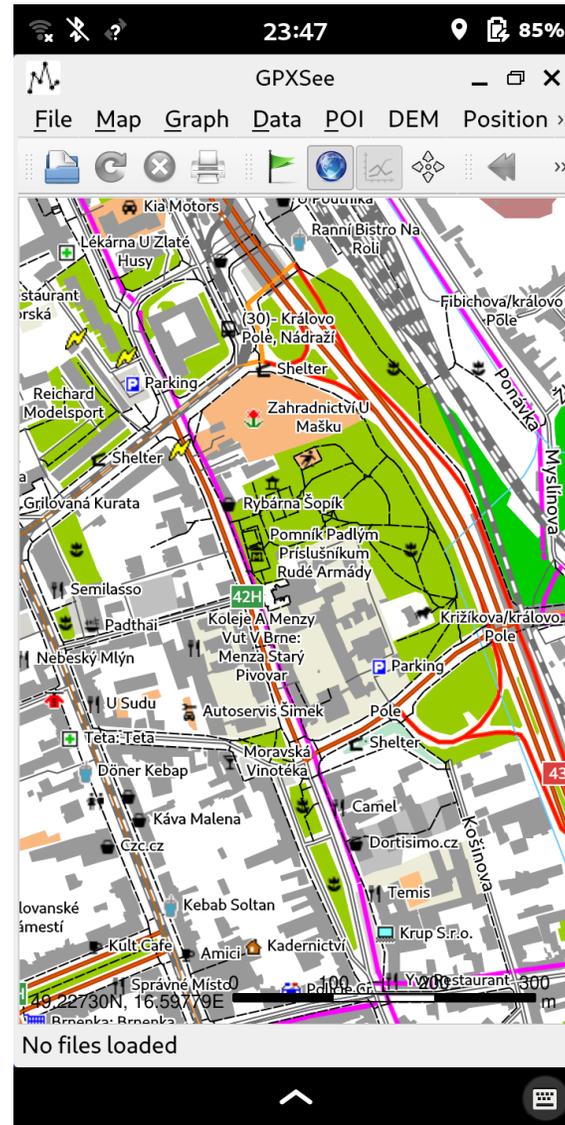
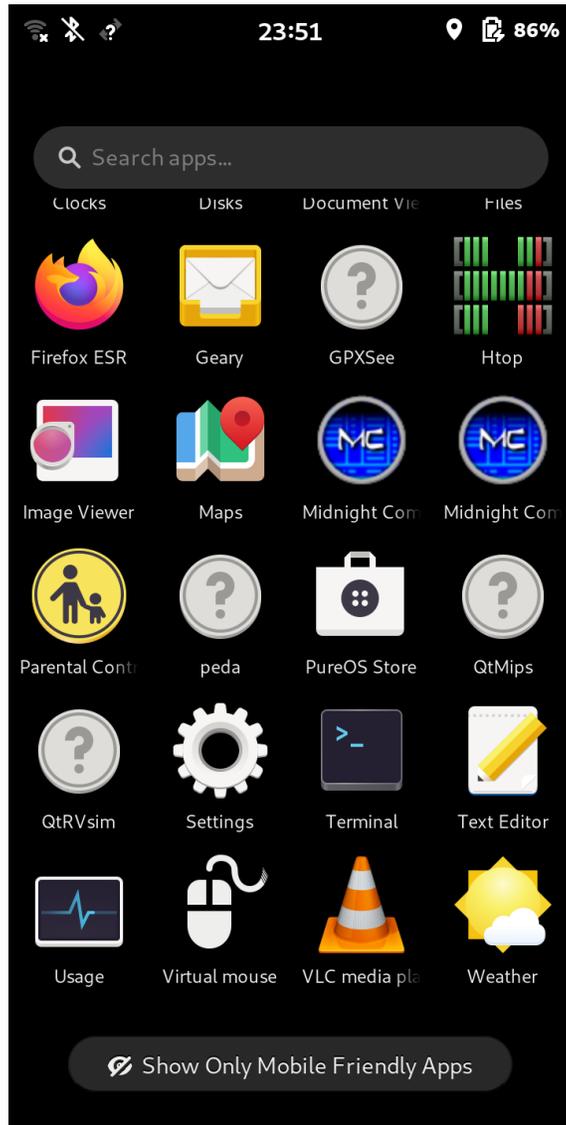
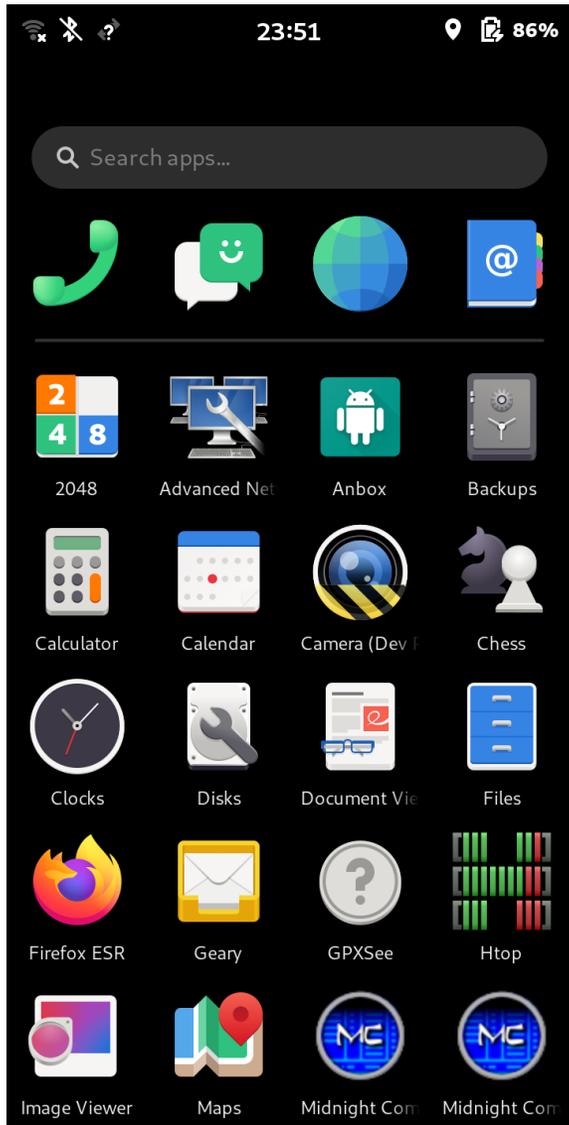


Rough Position Used Instead of GNSS Position Cont.

```
QGeoPositionInfoSource *source = QGeoPositionInfoSource::createSource(  
    options.plugin, options.pluginParams.value(options.plugin),  
    this);  
if (source)  
    source->setPreferredPositioningMethods(QGeoPositionInfoSource::  
        SatellitePositioningMethods);
```



Librem 5 – Screen Shots





References and Future

- Purism <https://puri.sm/>
- <https://forums.puri.sm/c/librem/phones/11>
- Better times on the horizon, all major accelerated graphics solutions except Nvidia are supported by open-source stack. Even PowerVR, SGX new open from Imagination Technology, older NDA chains released
- May it be some other RISC-V based design?
 - Do you want to know, how RISC-V executes instruction? Then
<https://comparch.edu.cvut.cz/>
<https://comparch.edu.cvut.cz/qtrvsim/app>