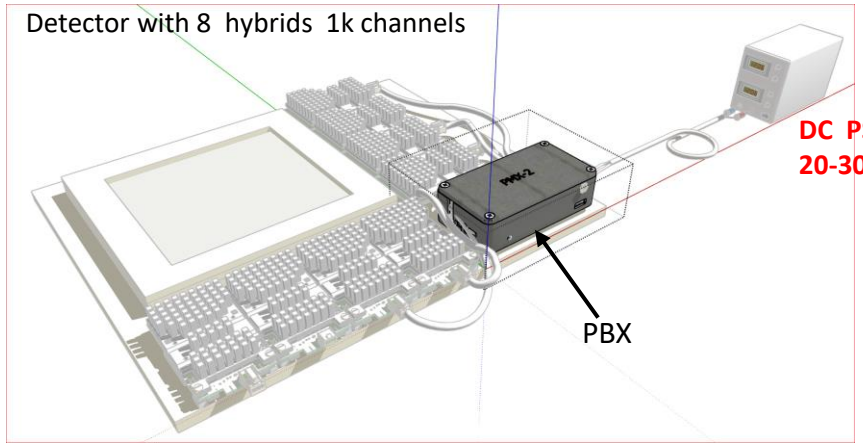
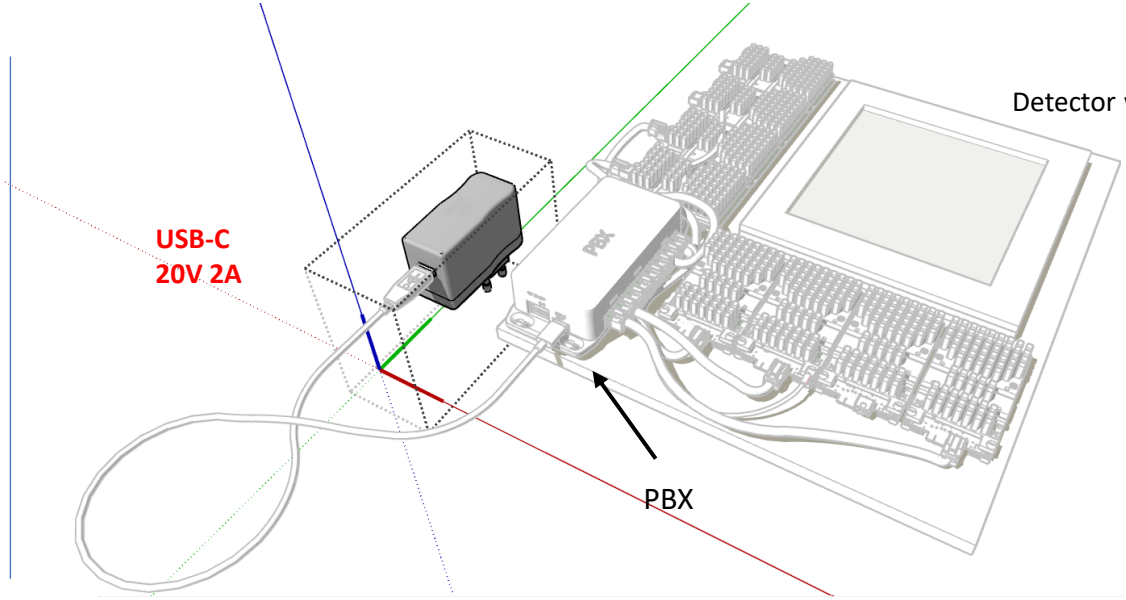
Powerbox PBX

external power for SRS frontends



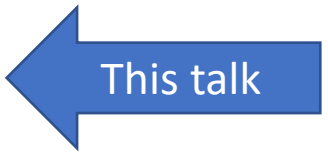


Power scenarios for SRS-VMM frontends

1.) direct power over HDMI

2.) direct power via a passive PMX multiplexer (PMX) close to the detector

3.) **external power via an active PBX powerbox near the detector**



VMM3a hybrids require 2 supply voltages P1 and P2 for a total of 4.5 Watt/hybrid with full 1.6A current return via the digital Ground of the hybrids.

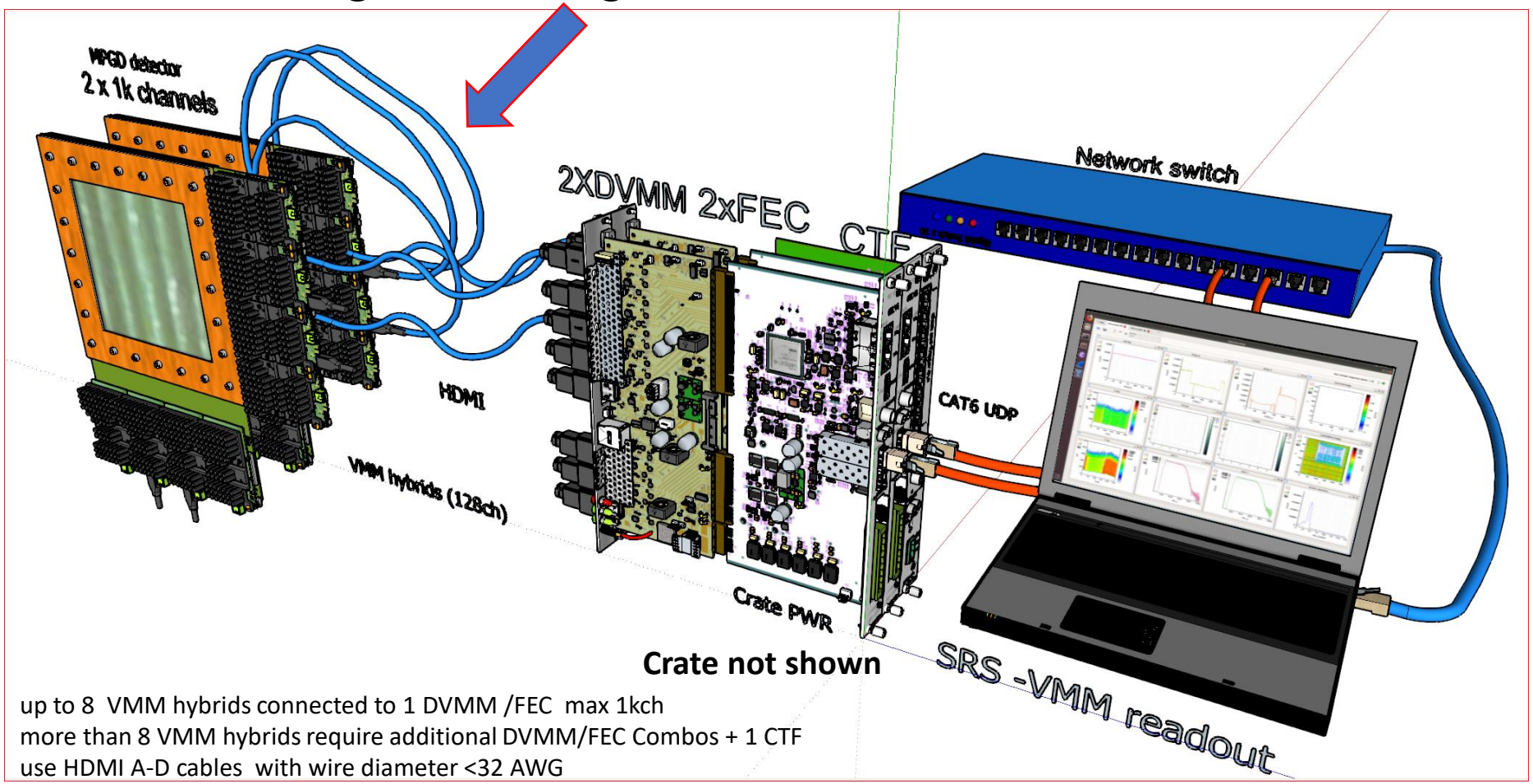
Powering 8 hybrids from the crate backend means to bring 36 Watt to the VMM frontend with voltage drops less than 50mV RMS to prevent from LVDS bit flips on the data links. The Voltage drops depend on cable length and wire diameters. Adding thick copper braids between the crate and the frontend mitigates voltage drops.

The new PBX eliminated the need for low impedance copper braids and allows for long HDMI links by providing external P1 and P2 power from external power supplies to the frontend.

1.) direct power over HDMI

Advantage: plug and play, frontend power included

Disadvantage: max. length HDMI cables limited 2-5m

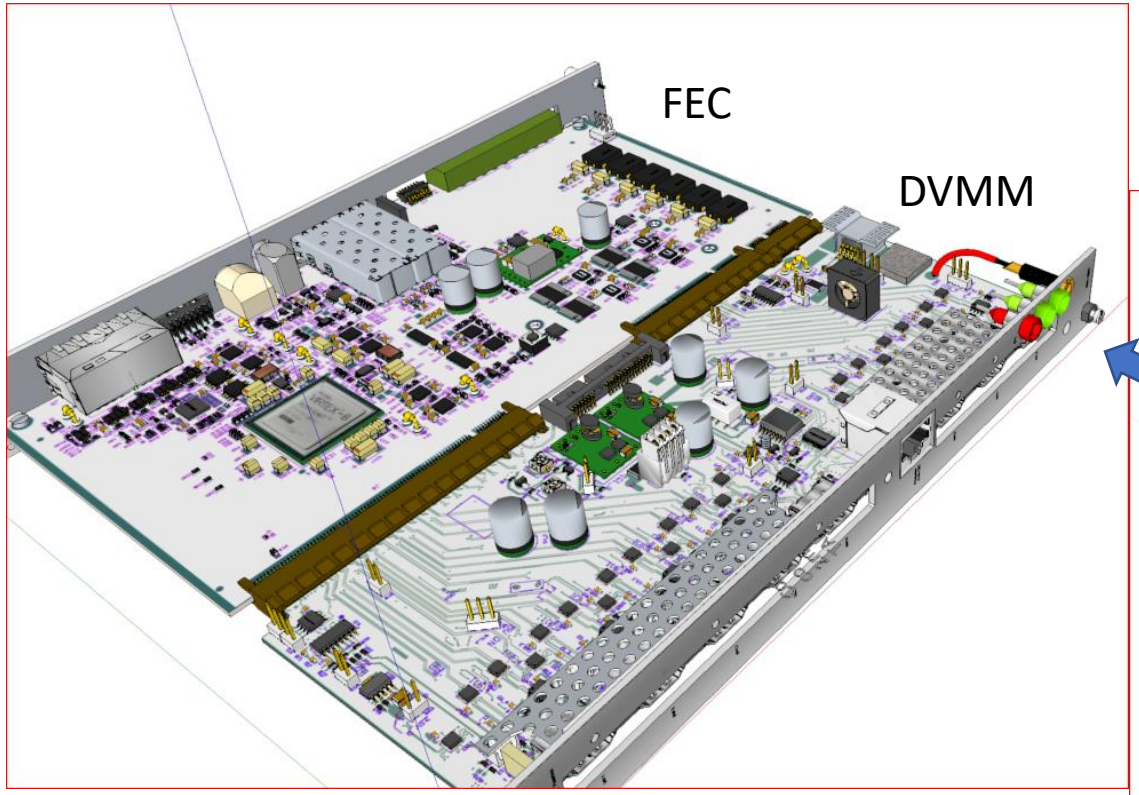


up to 8 VMM hybrids connected to 1 DVMM /FEC max 1kch
more than 8 VMM hybrids require additional DVMM/FEC Combos + 1 CTF
use HDMI A-D cables with wire diameter <32 AWG

2.) direct power via PMX multiplexer (PMX)

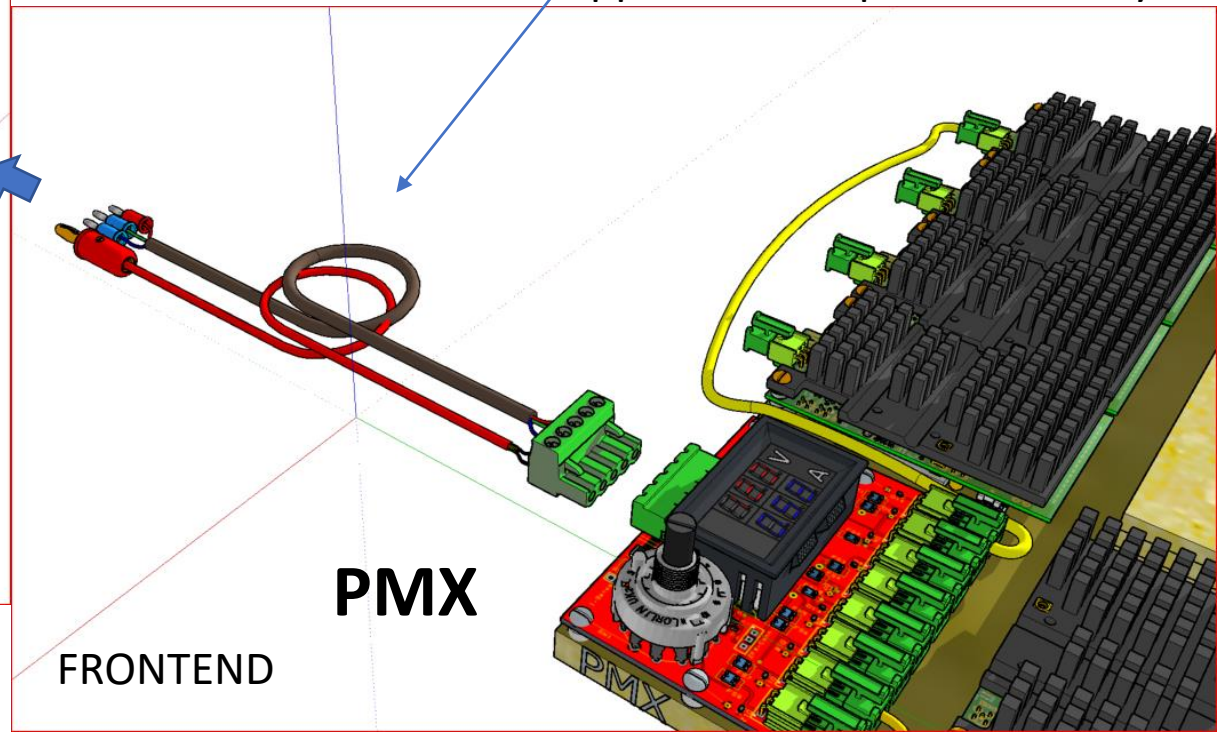
Advantage: Power from DVMM, up 10 m HDMI links

Disadvantage: heavy copper braids required between detector and crate



BACKEND

Power /GND cable up 10m from DVMM to PMX
additional GND return copper braid required for >2 hybrids

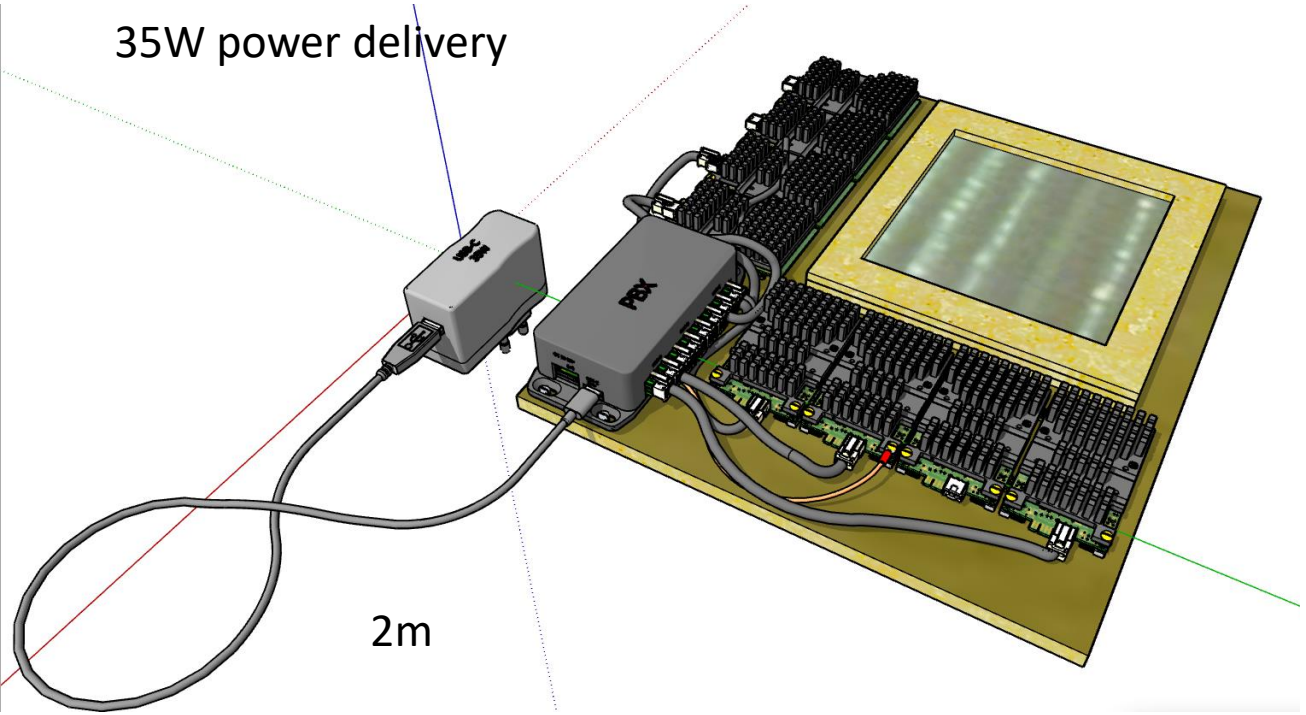


FRONTEND

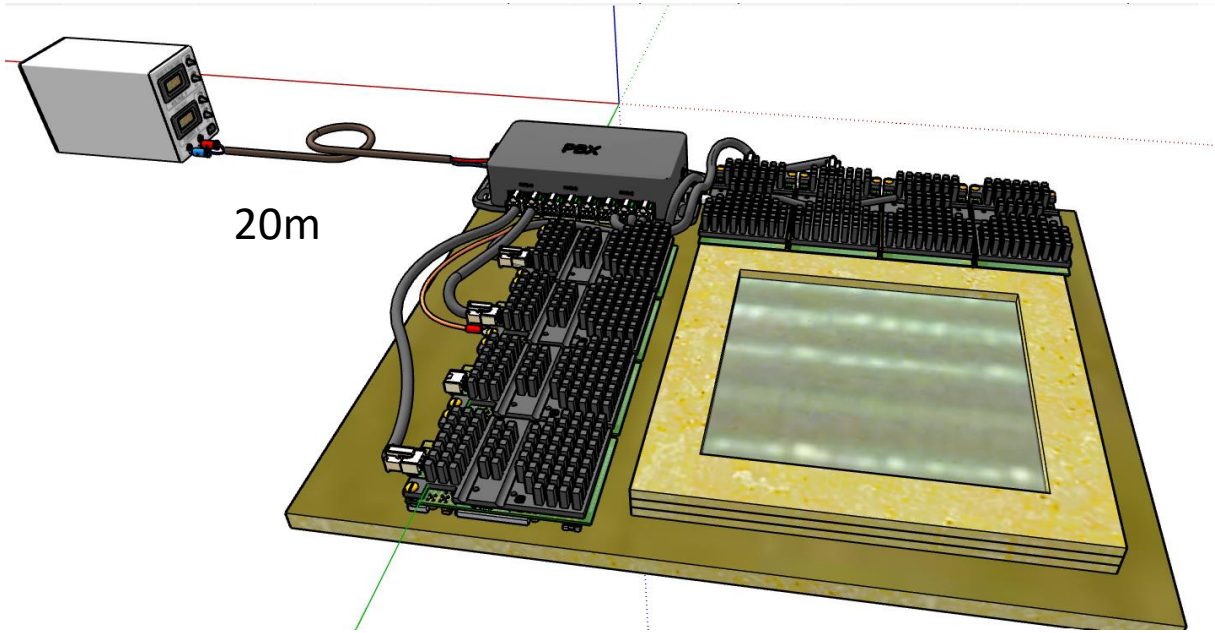
3.) *NEW*: PBX powerbox for external power options

Advantage: **up 25m HDMI links, no heavy copper braids**
Disadvantage: extra power supply, USB-C or DC power supplies 40W

USB-C
35W power delivery

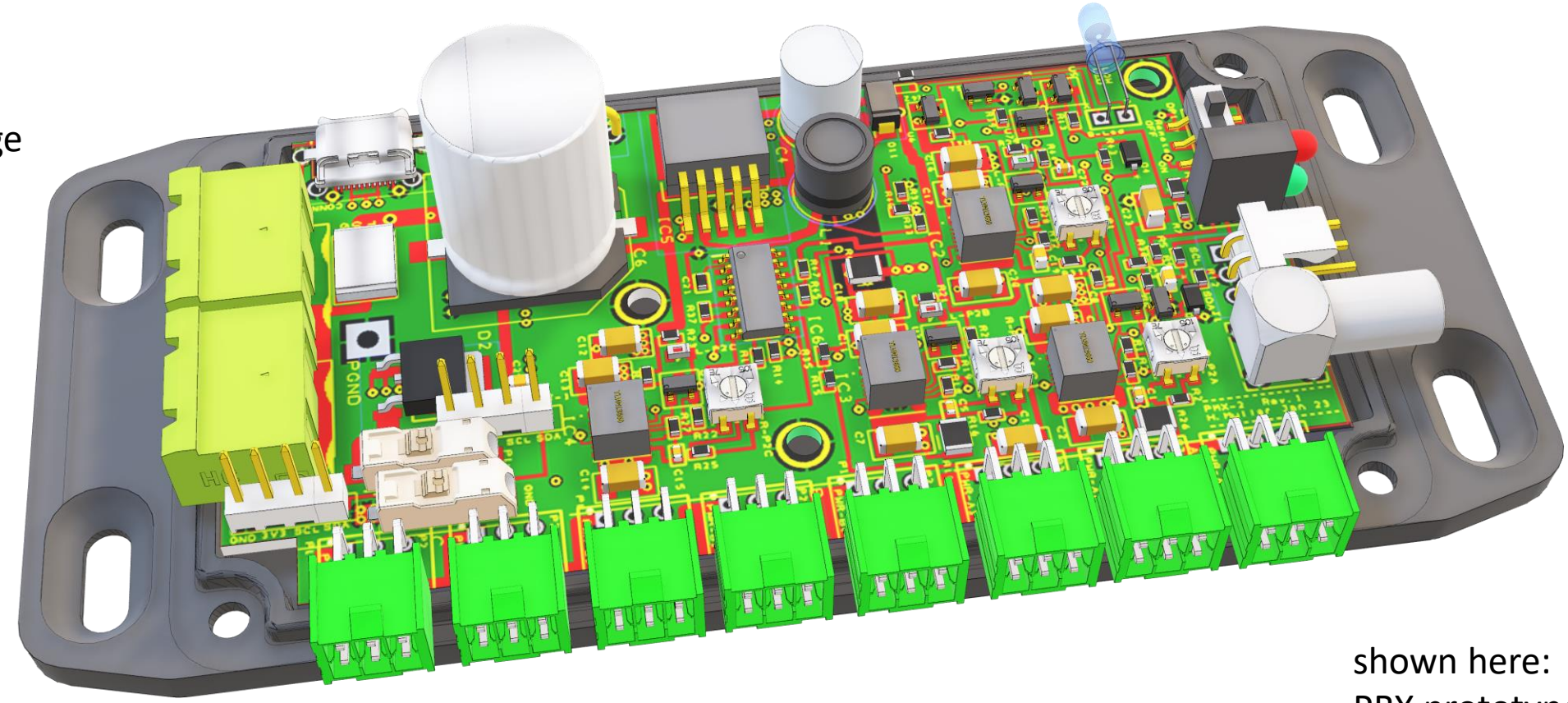


DC Power supply 20-30V 40W



PBX power electronics 3D

Click
on the image
and rotate
the icon

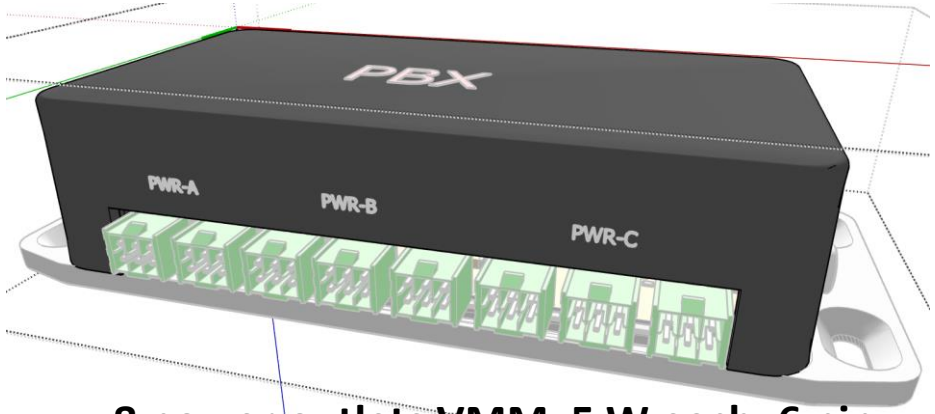


shown here:
PBX prototype Jan 23

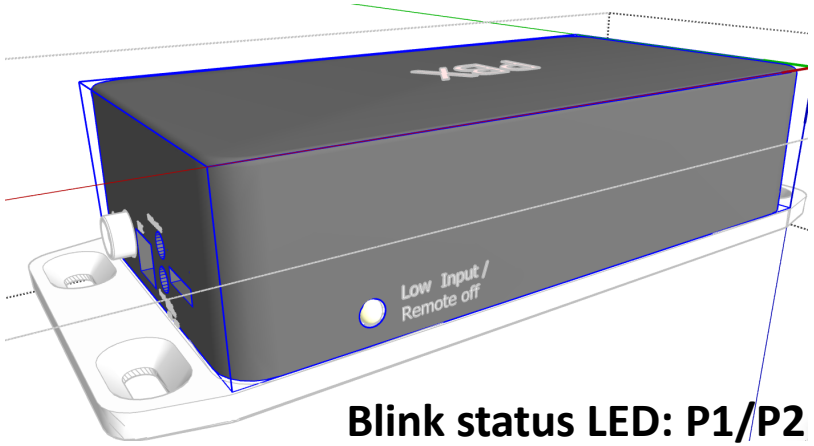
Final feature list Powerbox PBX

1. **On-detector, remote-enabled, 35 W power fanout for 8x on-detector VMM hybrids**
2. 8 x power outlets (P1,P2, GND) for jumper cables to hybrids (default 1m)
3. 4Watt to VMM per outlet: P1 (3.2V @ 0.2A), P2 (1.8V@1.6A)
4. Voltage adjustment trimmers +/- 10% for P1 and P2 Voltages
5. **filters suppress buck switching noise (~1MHz) and external DC/USB input noise**
6. **Power– On sequencing P1-> P2a -> P2b -> P2c avoid dropouts during Flash boot of hybrids**
7. **6-way cables for low impedance GND with max 60mV drop over 0.8m powercables**
8. **Portable metal box with mounting flanch for 5Watt cooling to support frames**
9. Power supplies 20 -32 V requiring ~ 4.5 W / hybrid (35 W for 8 hybrids)
10. power conversion efficiency ~ 85 % , for 8 hybrids total ~ 5 W heat loss
11. Option A: Power via DC cables 2.5 mm dia up to 20m length
12. **Option B: Power from USB-C charger, 2m cable with 40 Watt power delivery**
13. Full input protection circuits (polarity, transients, overvoltage, USB vs PS conflict)
14. solid-state auto-fuses 2A on DC input and all 8 indiv. power outlets
15. Temperature, Voltage and Current monitoring via external I2C bus master
16. power- ON/OFF via external I2C command
17. **remote power- ON/OFF via coax cable, daisy chainable with other PBX and SRS crate**
18. status LEDs: input voltage OK, output voltages active, remote/On-Off, low input voltage

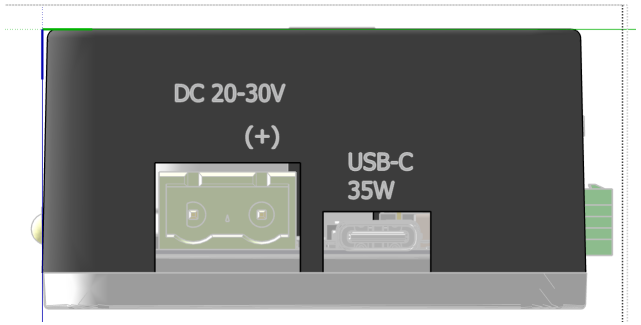
Powerbox sides



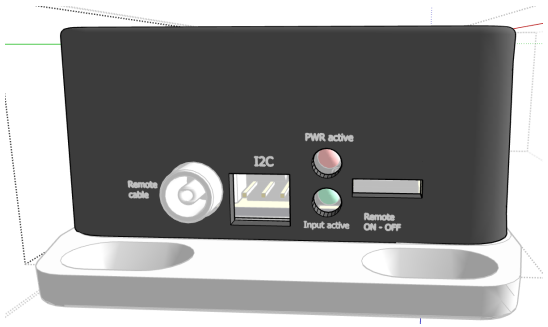
8 power outlets VMM 5 W each, 6 pin



Blink status LED: P1/P2 off

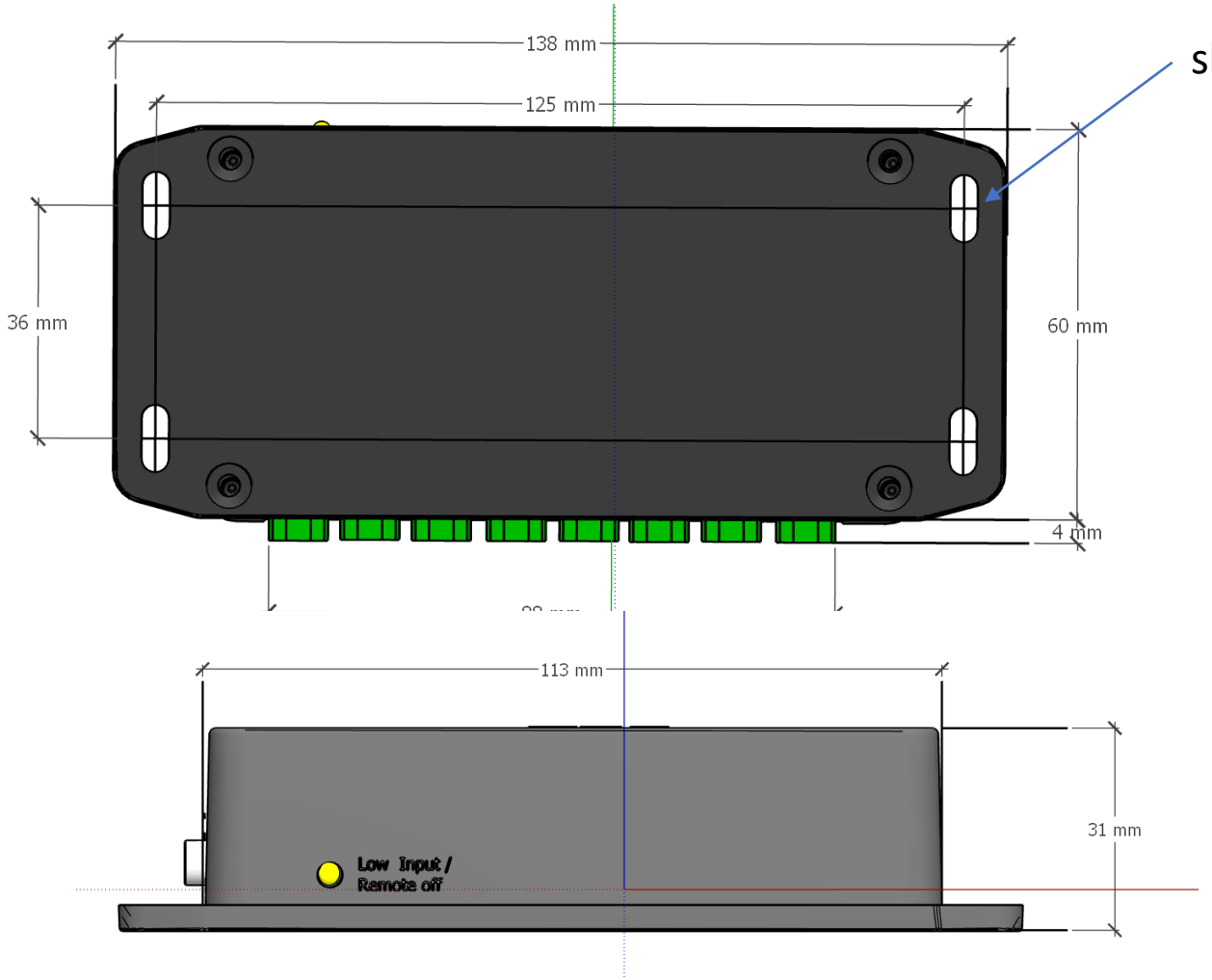


Input power options: DC-PS and USB-C



Control and status: Remote On/Off, I2C ctrl.

PBX dimensions



slide holes for M5

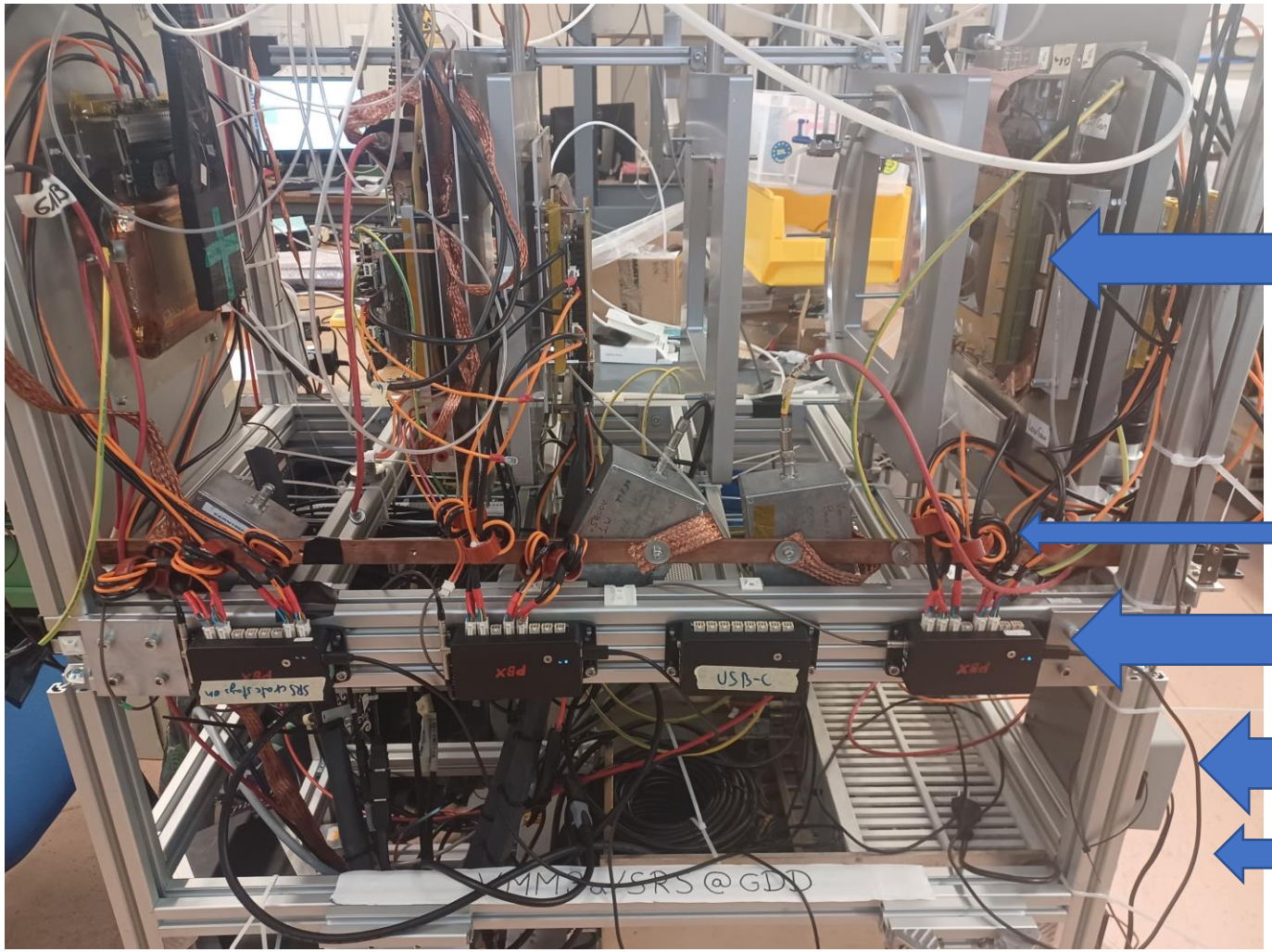
- **black ALU Hammond 1590BFL1 Bottom Flanch surface 138 x 60mm2**
- **cooling through bottom flanch surface 80 cm2**

  8 hybrids ~ 6 Watt

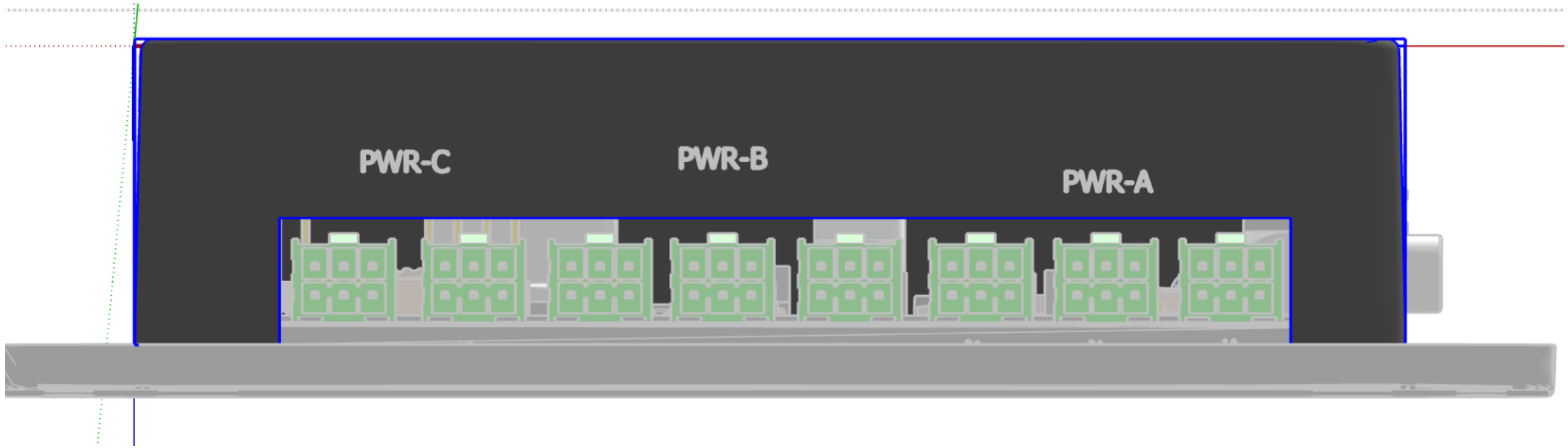
-> flux 75mW/cm2

- **dust , EMI and humidity shield**

PBX tests on GEM tracker -> K.J. Floethner



Power outlets for 8 VMM's



Connectors: 6 pin IPL1-103-01-D-RA-K fitting with IPD1-03-D-K cable housings

Group C (2x)
3rd in power sequence

Group B (3x)
2nd in power sequence

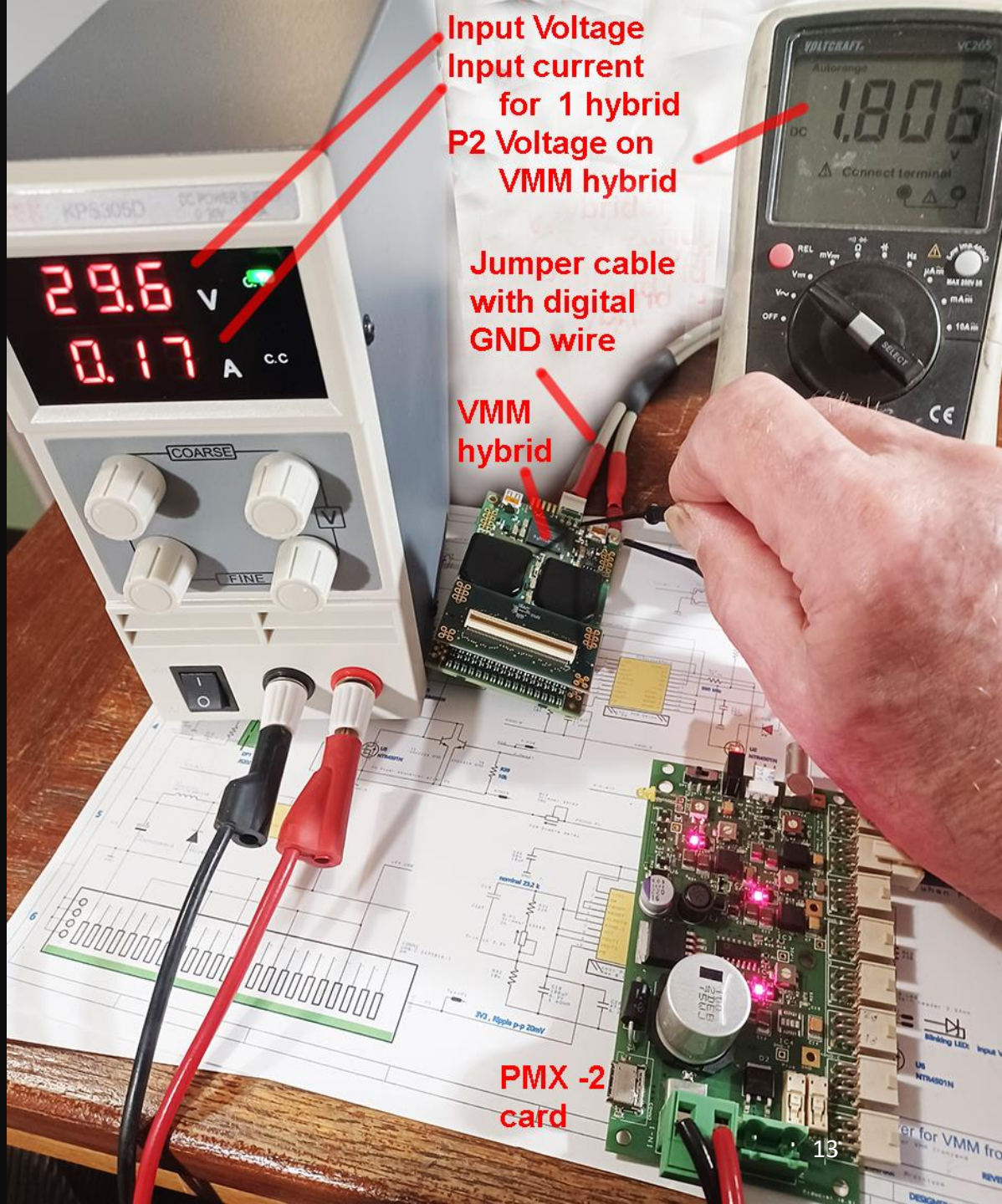
Group A (3x)
1st in power sequence

Connecting VMM hybrids to the PBX

1. HDMI readout link (HDMI black) from DVMM readout ports. With PBX min. 20m possible
2. Black power cables from PMX + optional ferrite clips connected to VMM via white Samtec lock-in-connectors.
3. GND cable (orange) from PBX via red Faston fork to digital GND point of VMM hybrid

DC power for VMM

- Photo: bench test DC power with 1 VMM hybrid : 5 Watt input
- DC max 32V -> lower supply currents
- 1.4A @ 30V for 8 hybrids: up 20 m PBX <- >PS via 2-wire cables (not grounded, no sense wires)
- Input voltage drop over 20m, 1.25A, 30V 2x 0.25mm^2 = 0.35V



USB power for VMM

- USB-C can deliver >40Watt via its programmable power delivery schemes
- PBX is programmed to select the 20V scheme which normally can deliver min. 2.3 Ampere (~45Watt)
- The PBX requires 40 Watt for 8 hybrids including 15% conversion losses in the PBX
- The heat produced in the power conversion for 8 hybrids is ca 5 Watt and flows as heat through the bottom PBX metal Flanch. This should always be fixed to a metal frame (M5 screw holes in Flanch)

Long HMDI link cables with PBX

Min. 20 m standard A-A HDMI cables from a DVMM backend with patch cable HDMI A to HDMI D (Micro) at the frontend VMM side.

Existing short AD cables can be connected via HDMI couplers

Otherwise use short HDMI AD pigtails without adapters

test results with different cable brands available/in preparation

VMM current matching

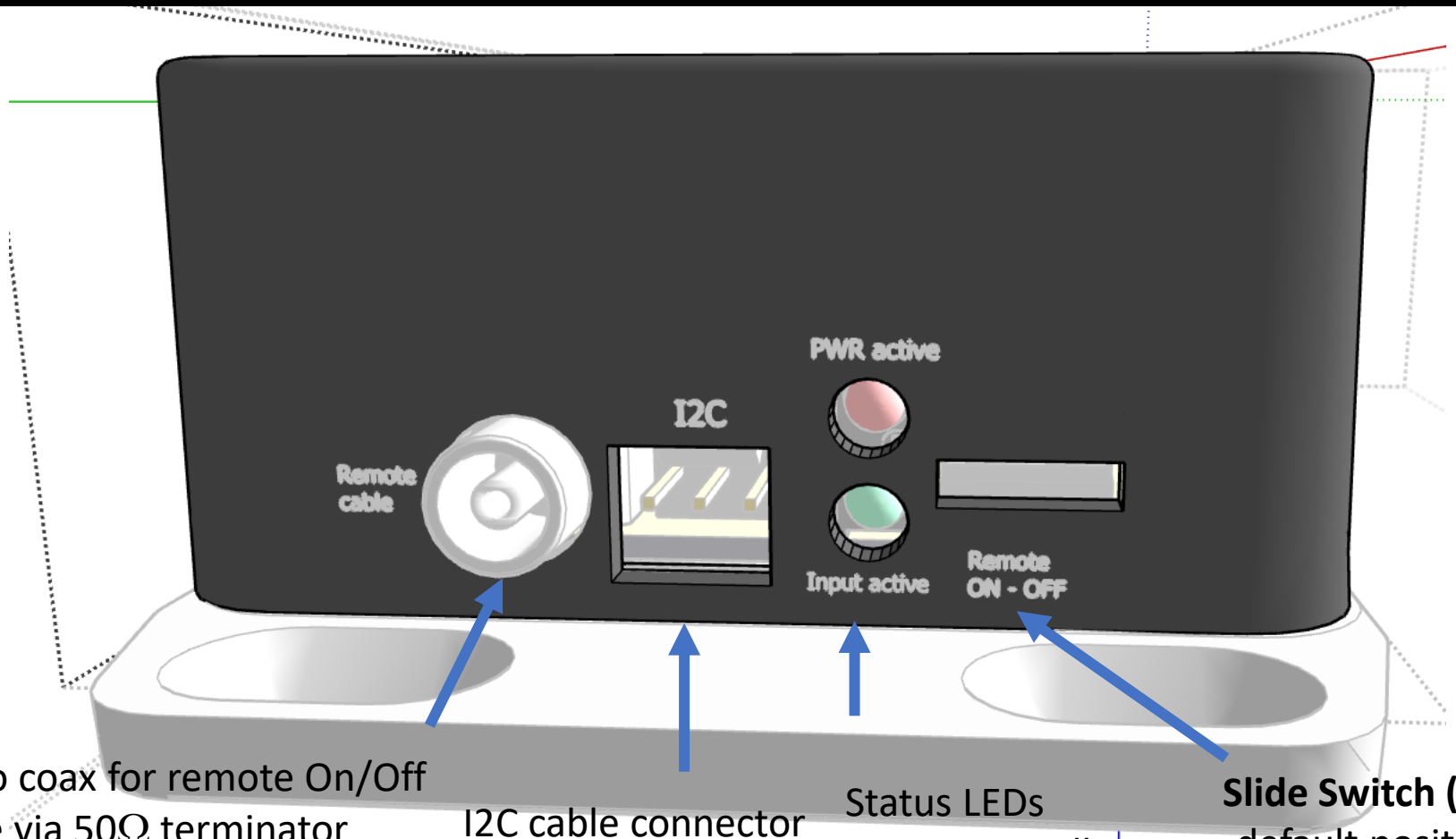
Clamp-meter measurement (here 1.56A) across the P1+P2 cables to the VMM after initialization.

Ideally the same current should flow back trough the GND wire to the PBX. Adjustment of P2 Voltage allows to get close.

Big differences of in/out currents indicate current leakage over the detector which increased noise.

Remove spurious grounds until in/out currents are within 10%

Control and status side



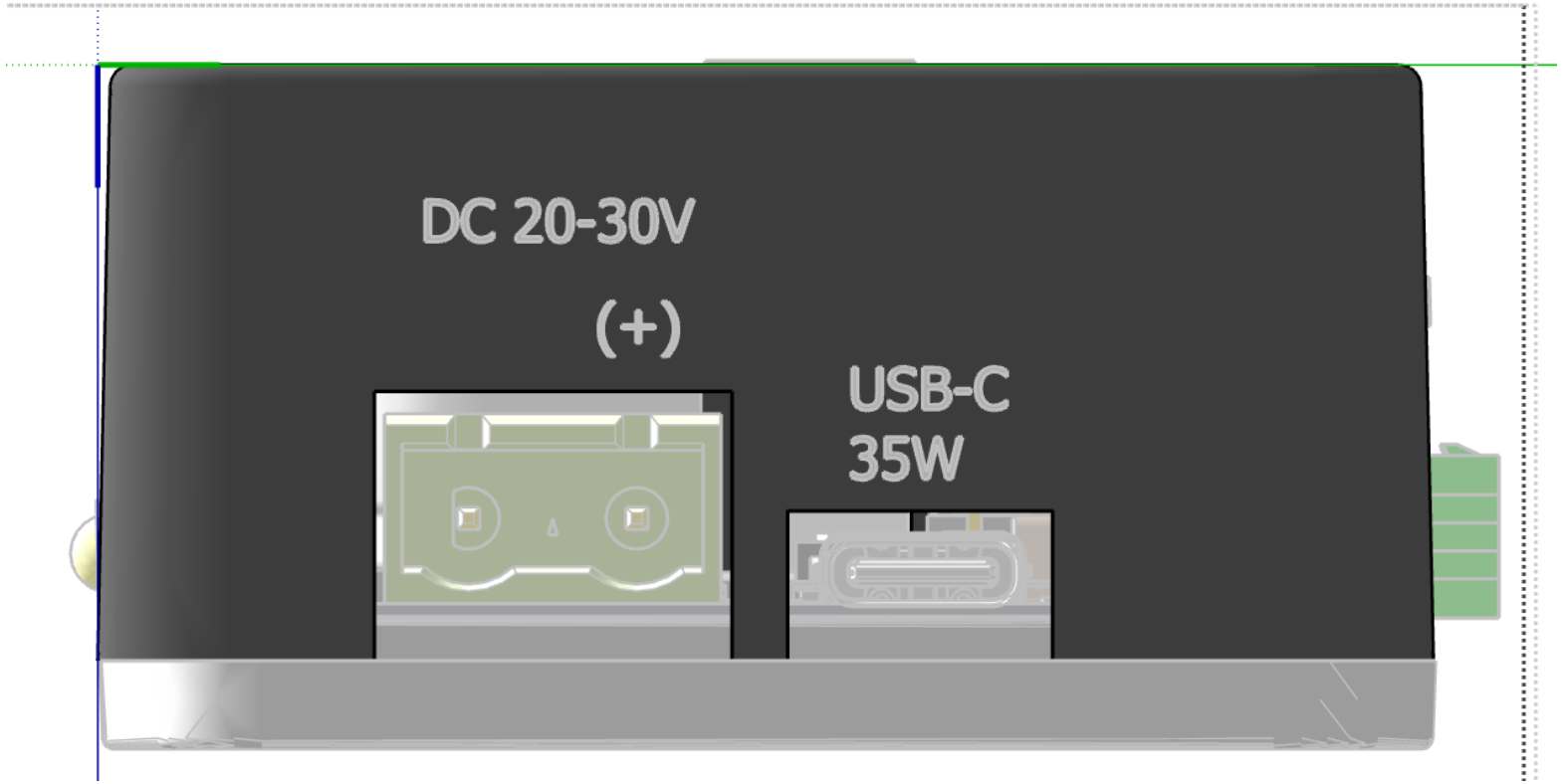
Lemo coax for remote On/Off cable via 50Ω terminator
Daisy-chainable with Other PMX and SRS Crate

I2C cable connector to ext. I2C master 3.3V

Status LEDs
GREEN: standby OK
RED: P1/P2 OK

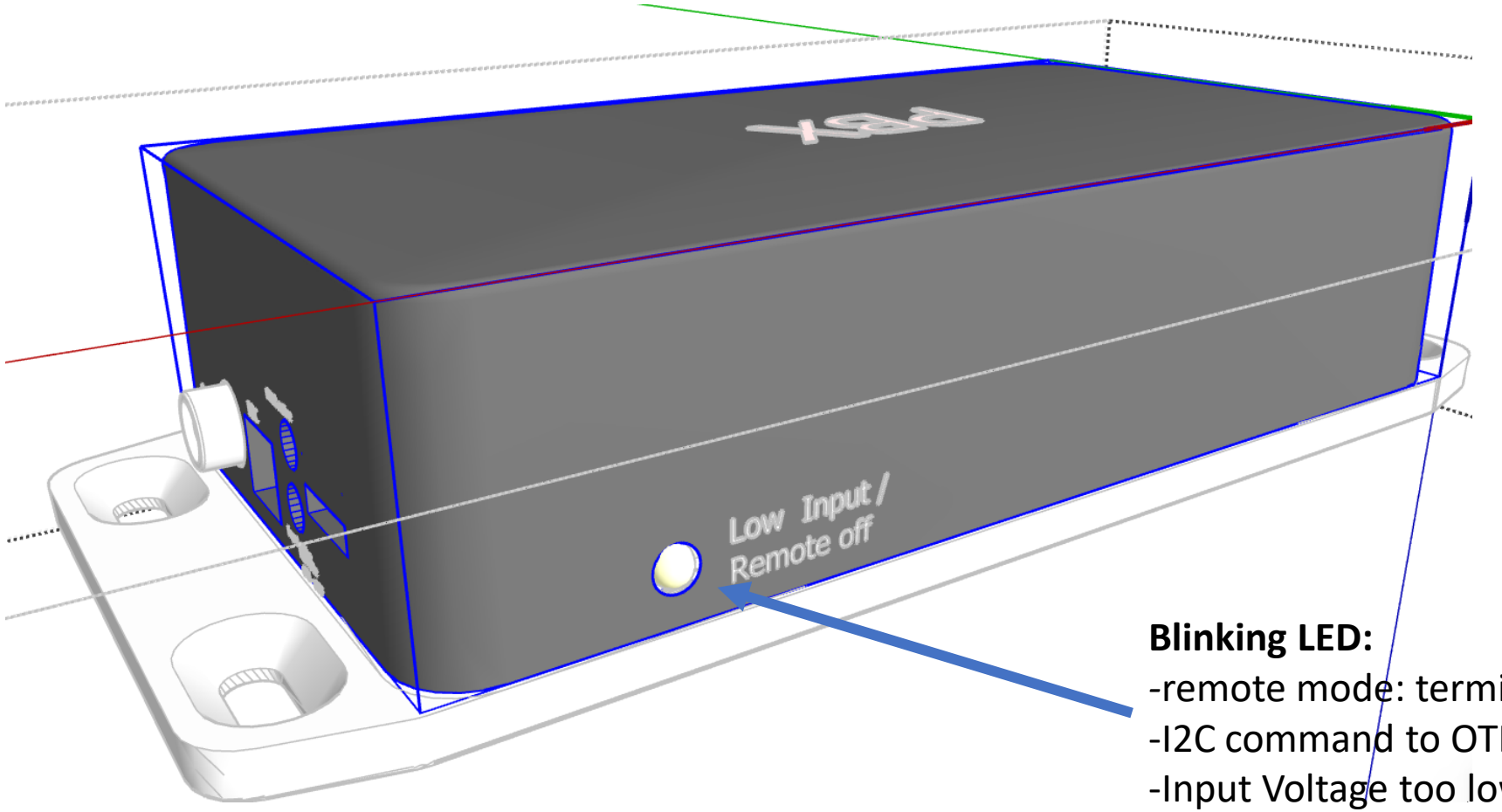
Slide Switch (inside)
-default position left = P1/P2 ON
-right: OFF (ON via coax terminator)

Power input side



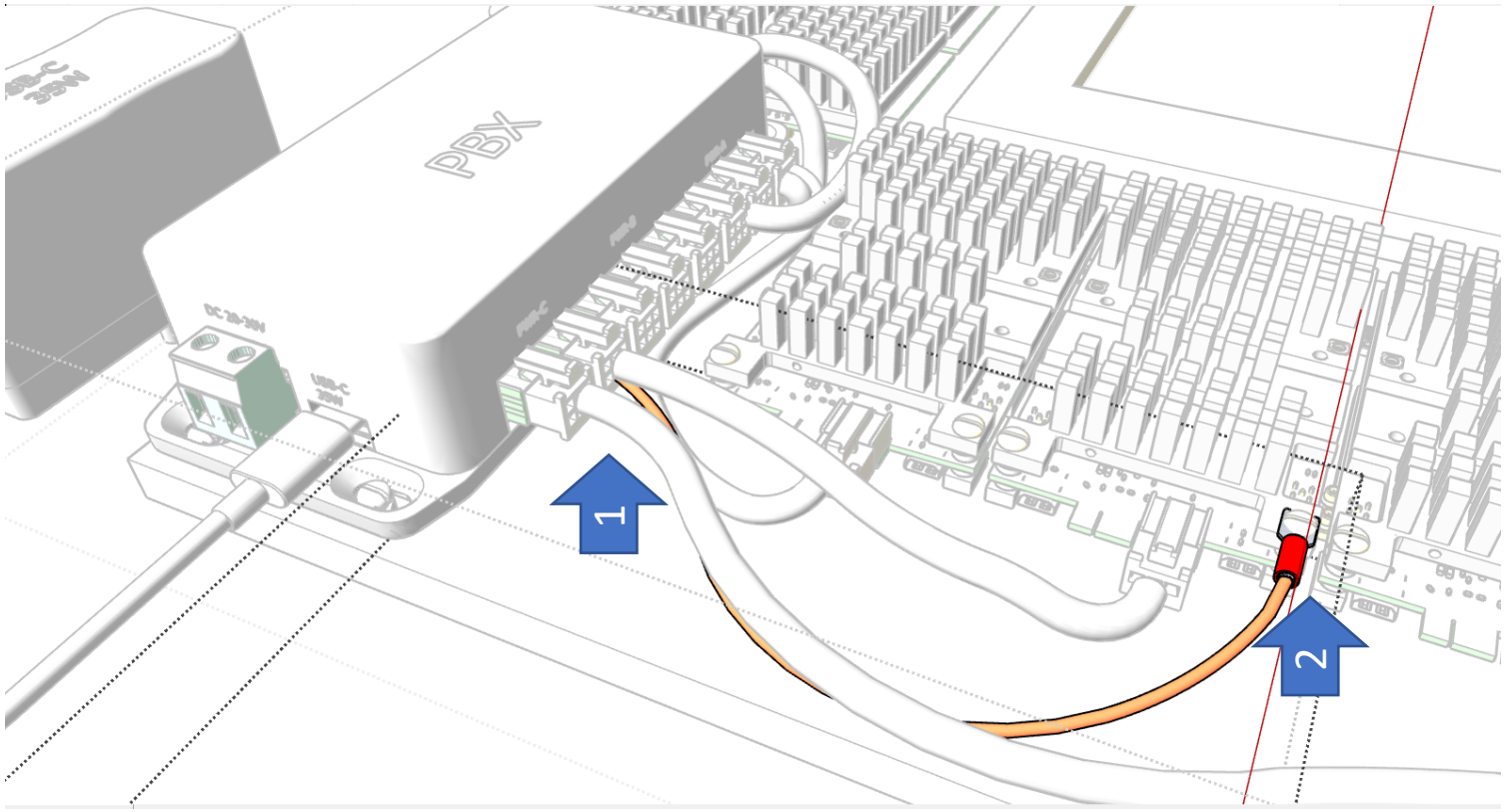
DC input: 7.62mm pitch Power connectors
for cable connectors Phoenix 1766990, 12A max

USB-C input (reversible) 2m power cable from
USB-C 35W charger with 20V@ 2.5A power delivery (PD)



Blinking LED:
-remote mode: terminator off
-I2C command to OTI: Power off
-Input Voltage too low < 15V

PBX GND wires to VMM hybrid

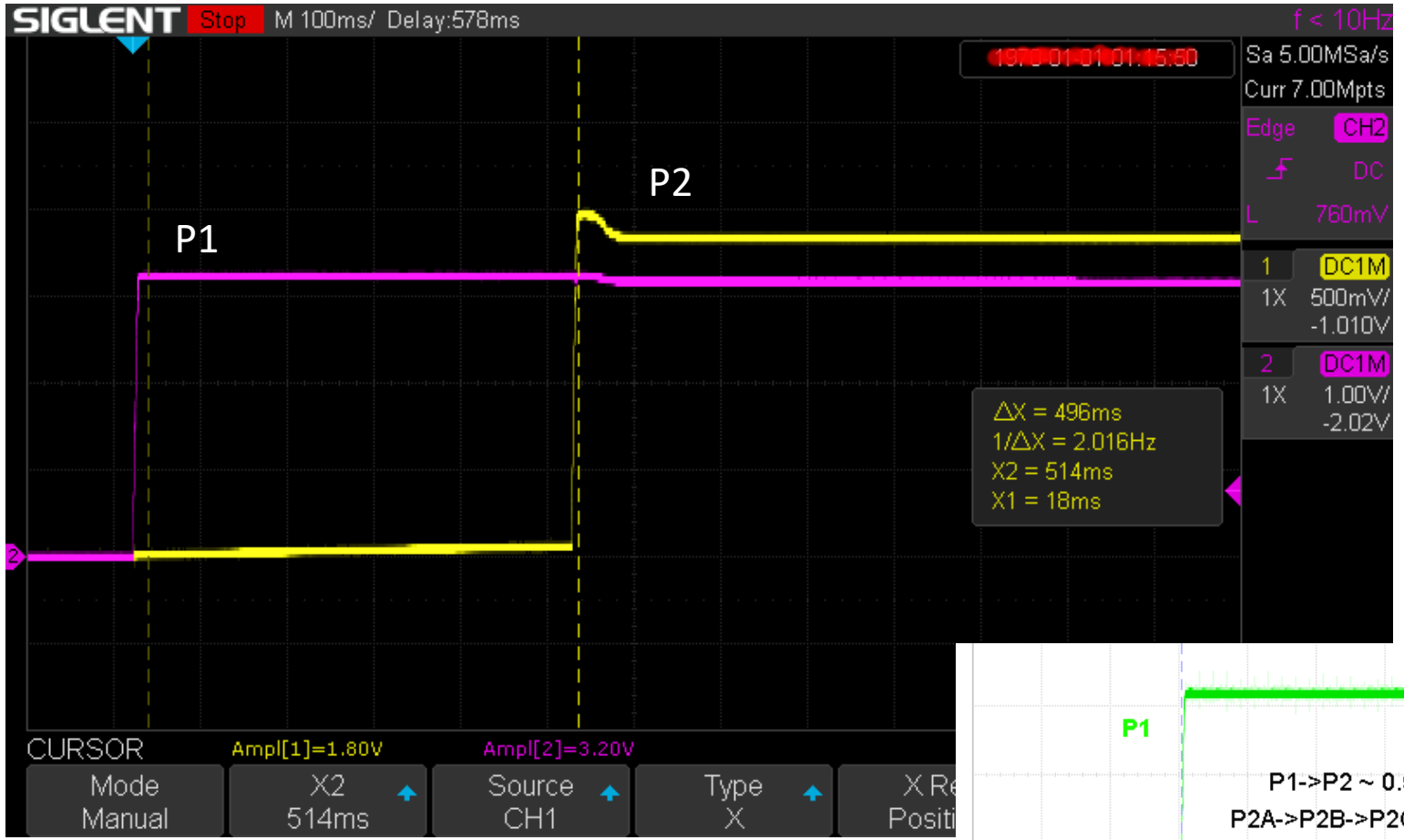


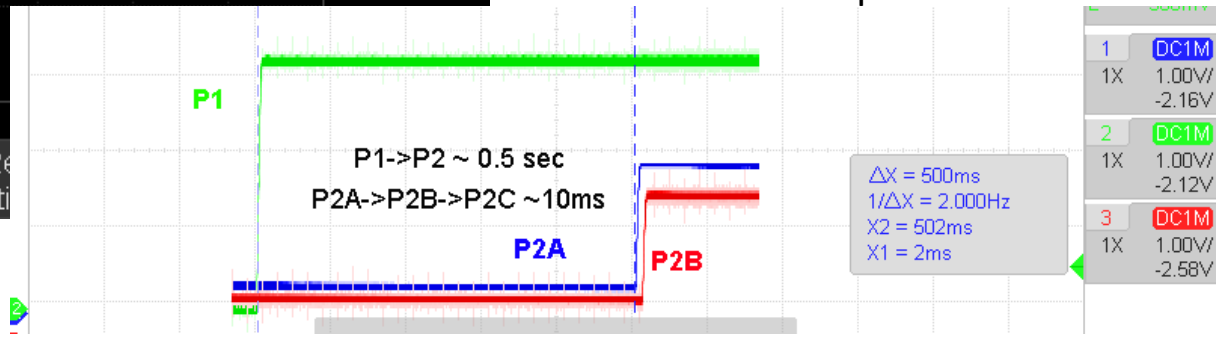
1. flex wires (orange AWG22) on the lower 3 GND pins of the PMX-2 outlets for a low-ohmic GND connection to the hybrids. Splice the flex wire in 3 crimpable ends. Connect each to one of the 3 lower IPL1 GND pin.
2. On the hybrid side, crimp the AWG22 wire together into a Faston Fork connector (red =max 1.5mm2 AWG16)and insert/ screw the Fork below the M2.5 brass cooler screws of the same hybrid as the jumper cable.

Note: **Don't cross GND cables with other hybrids**.

Photo cables for PBX

P1->P2 startup sequence





Full load: 3 x VMM hybrids connected via power cables 80 cm

Startup measured on one hybrid Power connector

1st Power sequence:

P1 -> 3.2V (FPGA + Flash boot)

ca 500 ms later

P2 -> 1.8V (2 x VMM ASICs)

P1 drop at P2 startup negligible

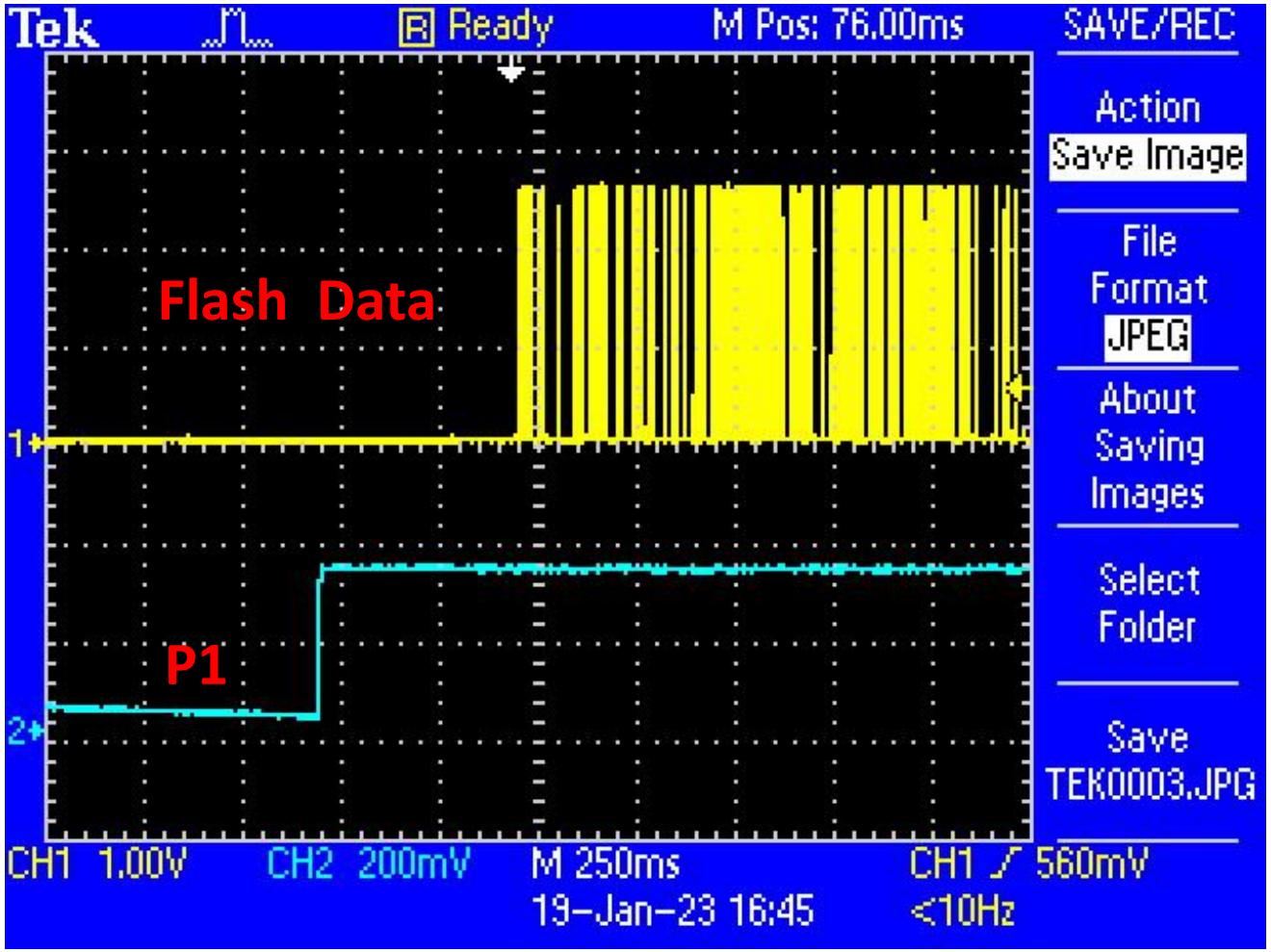
-> Flash boot safe

2nd Power sequence:

P2A->P2B->P2C

ca. 10 ms separation to distribute initial P2 current peaks

VMM hybrid Flash boot



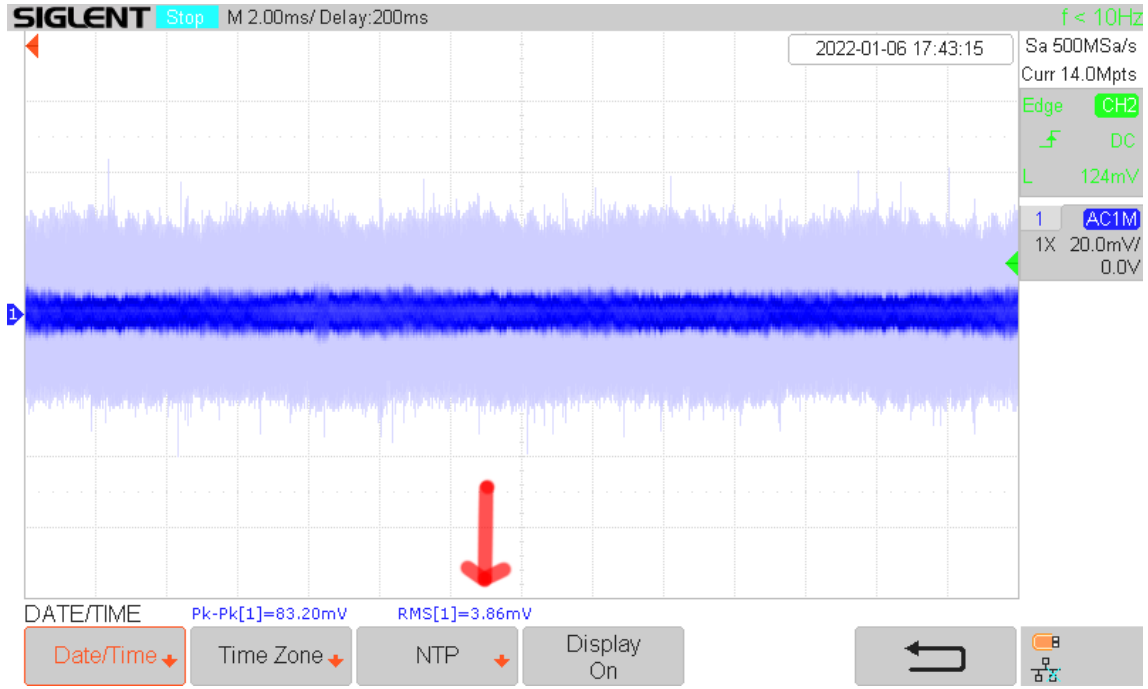
The Spartan on the VMM3 hybrid loads from the Flash ca. 0.5 s after the PBX asserts P1

The loading of Spartan-6 FPGA takes ~ 1.5 s *

* ! expect factor 2 for new VMMs with Spartan-7

1st PBX proto Jan 23: noise measurement at 350 kHz

P1 vs digital GND measured on hybrid
RMS 3.86 mV, PkPk 83.2 mV **!**



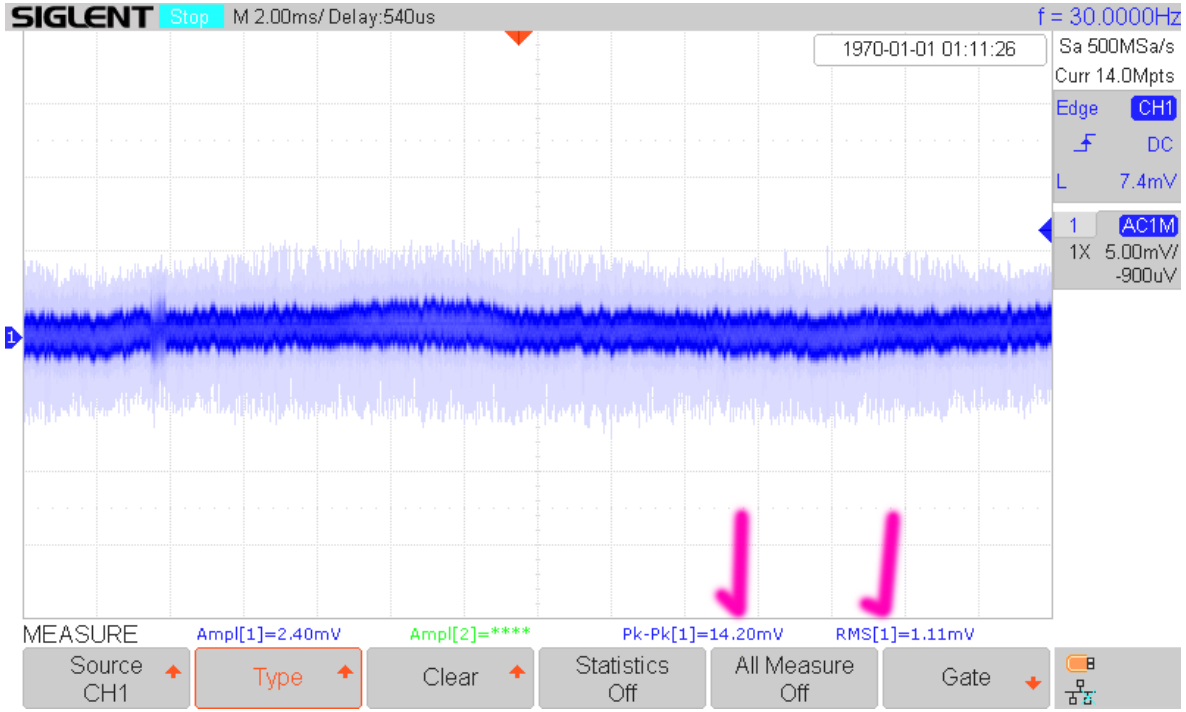
P2 vs digital GND measured on hybrid
RMS 3.04 mV, PkPk 81.4 mV !

Note : dominant VMM ASIC pickup is from peak-peak O (82mV) !!

PBX –revised June 23: noise measurement at 1MHz

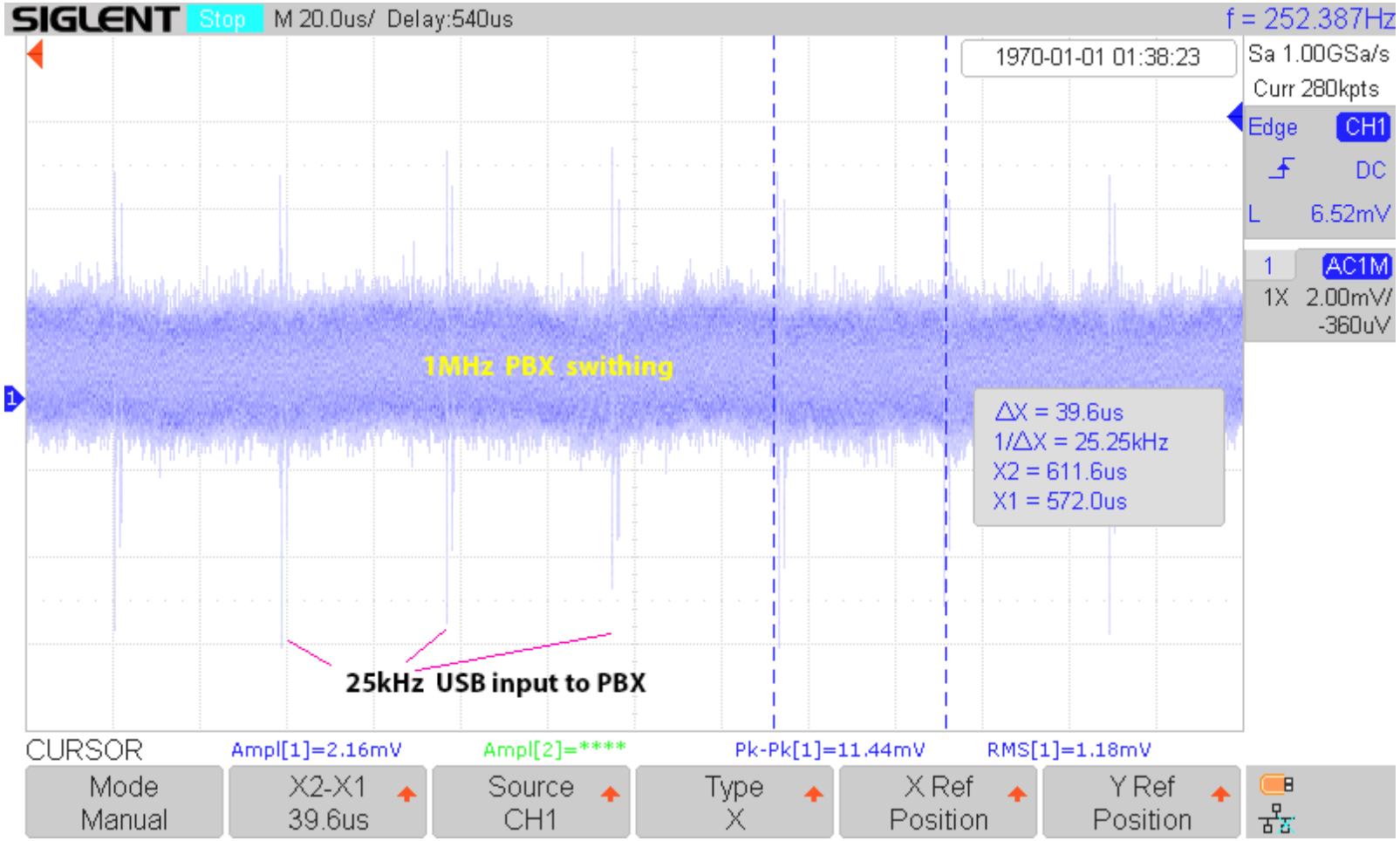
P1 vs digital GND measured on hybrid
RMS 1.2 mV , PkPK **16.2mV**

P2 vs digital GND measured on hybrid
RMS 1.1 mV , PkPK **14.2mV**



Note : major improvement peak-peak O (16mV) !
VMM now picks up dominant noise from several other noise sources => see Karl's talk

Imminent noise improvements for final PBX



Current PBX bucks switch
at 1.08 MHz:
Still visible is a factor 4 higher
P-P noise @ 25kHz
from the USB-C input.

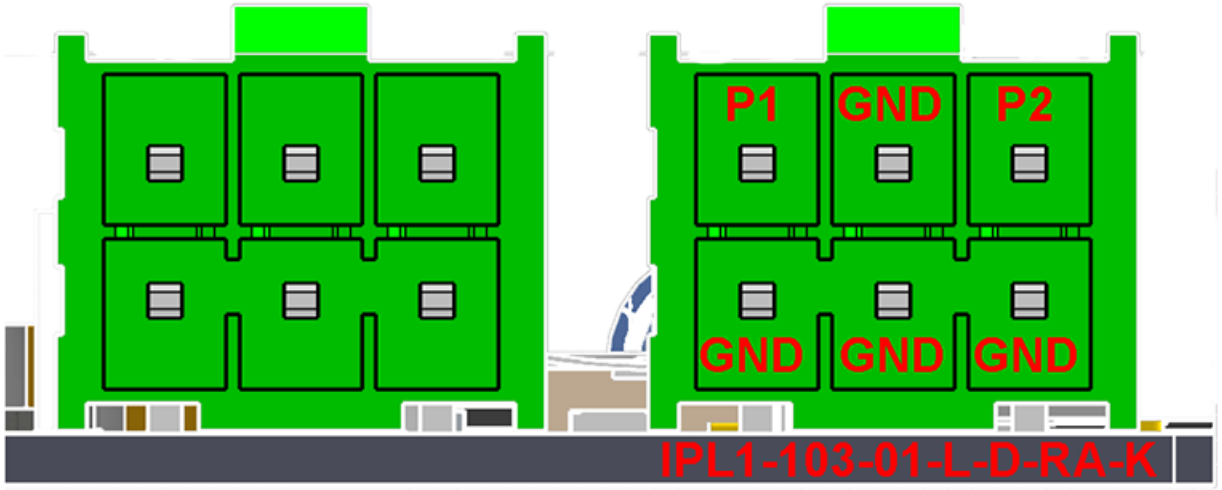
Now adding a new input filter
to reduce input noise by factor 2

Status and plans PBX

- 8 prototypes V0 produced , 1 damaged during production
- 4 PBX V0 on NMX (to be revised)
- 3 PBX V0 partially revised on GEM tracker
- 2 new PBX V1 produced, 1 added to GEM tracker
- Finalize PBX tests on tracker GDD lab -> prep for test beam
- ========== we are here ==========
- Input noise filter upgrade on the two V1 versions
- Final user documentations -> Google drive
- Shipment of V1 to GSI for complementary tests:
  longer power cables, B-field , etc
- production of 2 more “final” PBX V1.1 before green light for production via SRS tech.

Technical backups

Power outlets



The PMX-2 provides P1 and P2 power via eight, IPL1 Samtec Minimate connectors of type IPL1-103-01-L-D-RAK. The bottom row provides triple GND via a separate GND cable to the hybrids.

The pinout and connector details are shown In the picture. The mating 2-row cable connector is IPD1-03-D-K.

For a nominal P2 current of 1.7A the P2 voltage drop is 0.24V over a 0.5 mm dia wire of standard length of 0.8m.

To avoid GND lifts over a single GND wire, there are 3 additional GND wires, bringing the **total GND lift for P2 to 0.06V.**

For the P1 pin the nominal current is 250 mA.

Voltage Drop Calculator

Wire / cable voltage drop calculator and how to calculate.

Wire type:	Copper	
Resistivity:	1.72e-8	Ω·m
Wire diameter size:	0.5	mm
Wire/cable length (one way):	0.8	meters
Current type:	DC	
Voltage in volts:	3.3	V
Current in amps:	0.25	A
	Calculate Reset	
Voltage drop in volts:	0.0350396	V
Percentage of voltage drop:	1.0618	%
Wire resistance:	0.140158	Ω

Voltage Drop Calculator

Wire / cable voltage drop calculator and how to calculate.

Wire type:	Copper	
Resistivity:	1.72e-8	Ω·m
Wire diameter size:	0.5	mm
Wire/cable length (one way):	0.8	meters
Current type:	DC	
Voltage in volts:	1.9	V
Current in amps:	1.7	A
	Calculate Reset	
Voltage drop in volts:	0.238269	V
Percentage of voltage drop:	12.5405	%
Wire resistance:	0.140158	Ω

https://www.rapidtables.com/calc/wire/voltage-drop-calculator.html

DC Powersupply U_{in} = 30V , 8 VMM hybrids simulated for PBX buck frequencies 350 kHz

- 1 x P1 (8):
  Output: 3.3V x 8 x 270mA = **7.3W**
  350 kHz @ 93% eff -> heat **0.55 W**
  max input current for 8 hybrids = 7.3W/(0.93 *30V) = **0.262 A**

- 2 x P2 (6):
  Output each: 1.9V x 3 x 1.7A = **9.7 W (x2)**
  350 kHz @ 86% eff -> heat **1.6 (x 2)**
  max input current for 3 hybrids = 9.7W/(0.86 *30V) = **0.376 A**
  max input current 2 bucks = 6 hybrids **0.75 A**

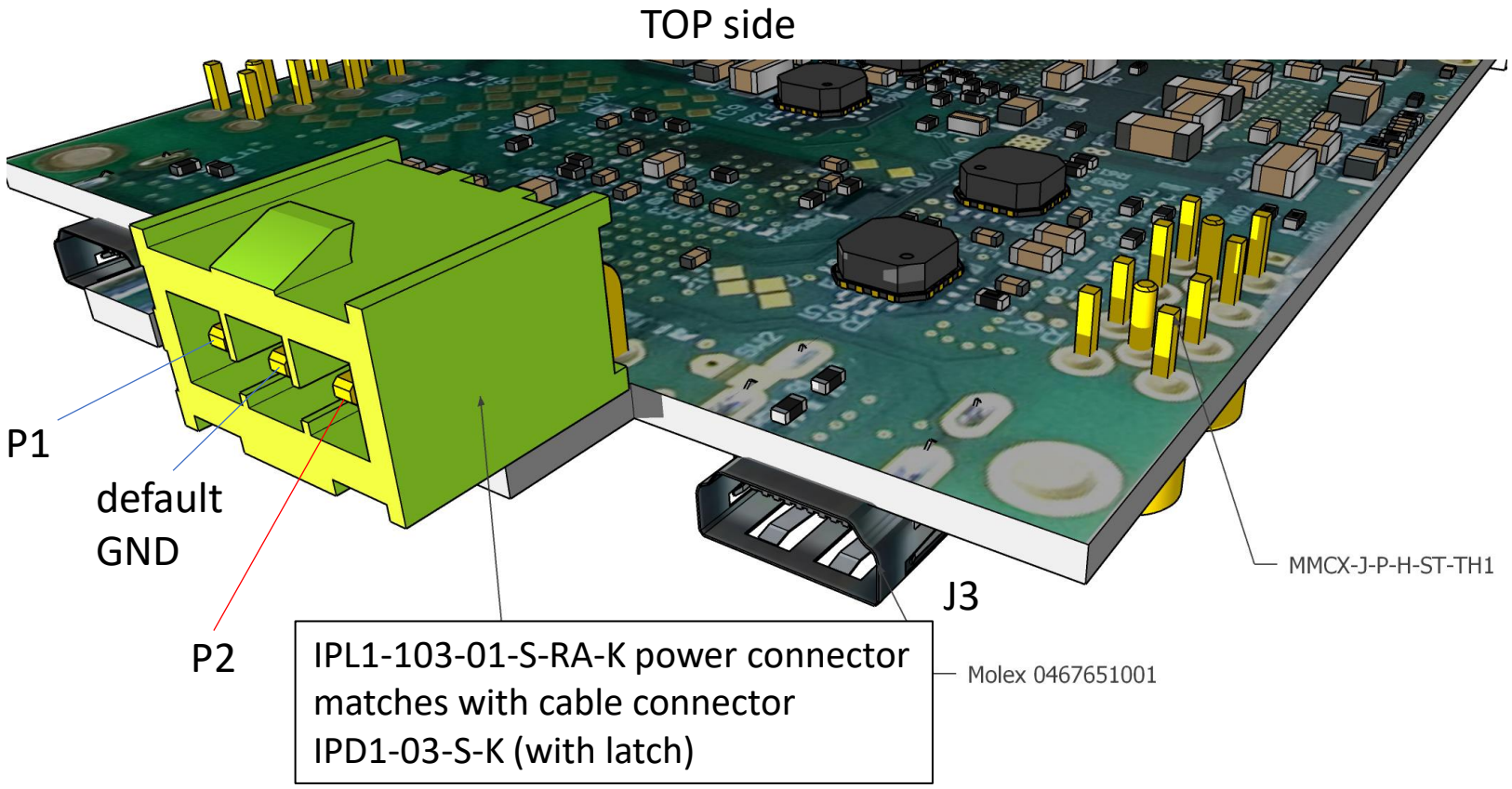
- 1 x P2 (2):
  Output: 1.9V x 2 x 1.7A = **6.46 W**
  350 kHz @ 90% eff => heat **0.75 W**
  max input current 2 hybrids = 6.46/(0.9 x 30 V) = **0.24A**

Example: **U_{in} = 30V(effectively 29.65V over 20m)**
Power consumption 8 hybrids: 33.16W
max total input current to PMX-2 for 8 hybrids
$I_{in\text{-}max}$ = **1.25A**

Power delivered by 30V power-supply
Pmax= 30Vx1.25A = **37.5 W**
Inp. voltage drop 20m 2x 0.25mm^2 =2x 0.175V
Power loss in cable 1.25A * 0.35V= 0.44W
Total input power ~ **38W**

The total heat dissipation in PMX-2: ~ **4.5W**

VMM hybrid, power connector



VMM power connector

recommended Voltages with PMX and clock via HMDI cable.

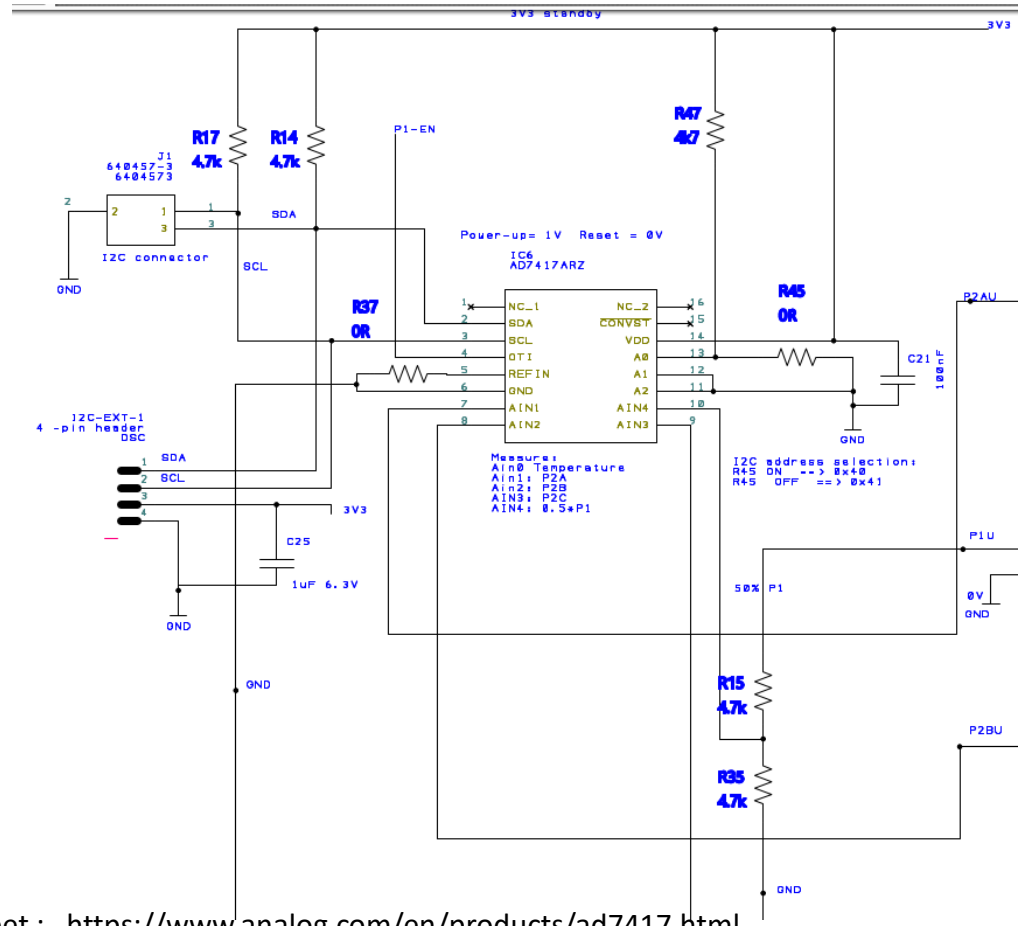
P2 = min. 1.75V -> IC5,6,7,9 -> 1.2V
2x VMM chips ~ 1.6A

GND = low impedance cable

P1 = min 3 V ->IC8 -> 2.5V
FPGA/Flash/ADC ~ 0.2A

IMPORTANT:
do not apply P1 , P2 voltages higher than > 3.6V (limit of LDO regulators on hybrid)

Monitoring and Reset chip on PBX
(requires external I2C bus master 3V3)

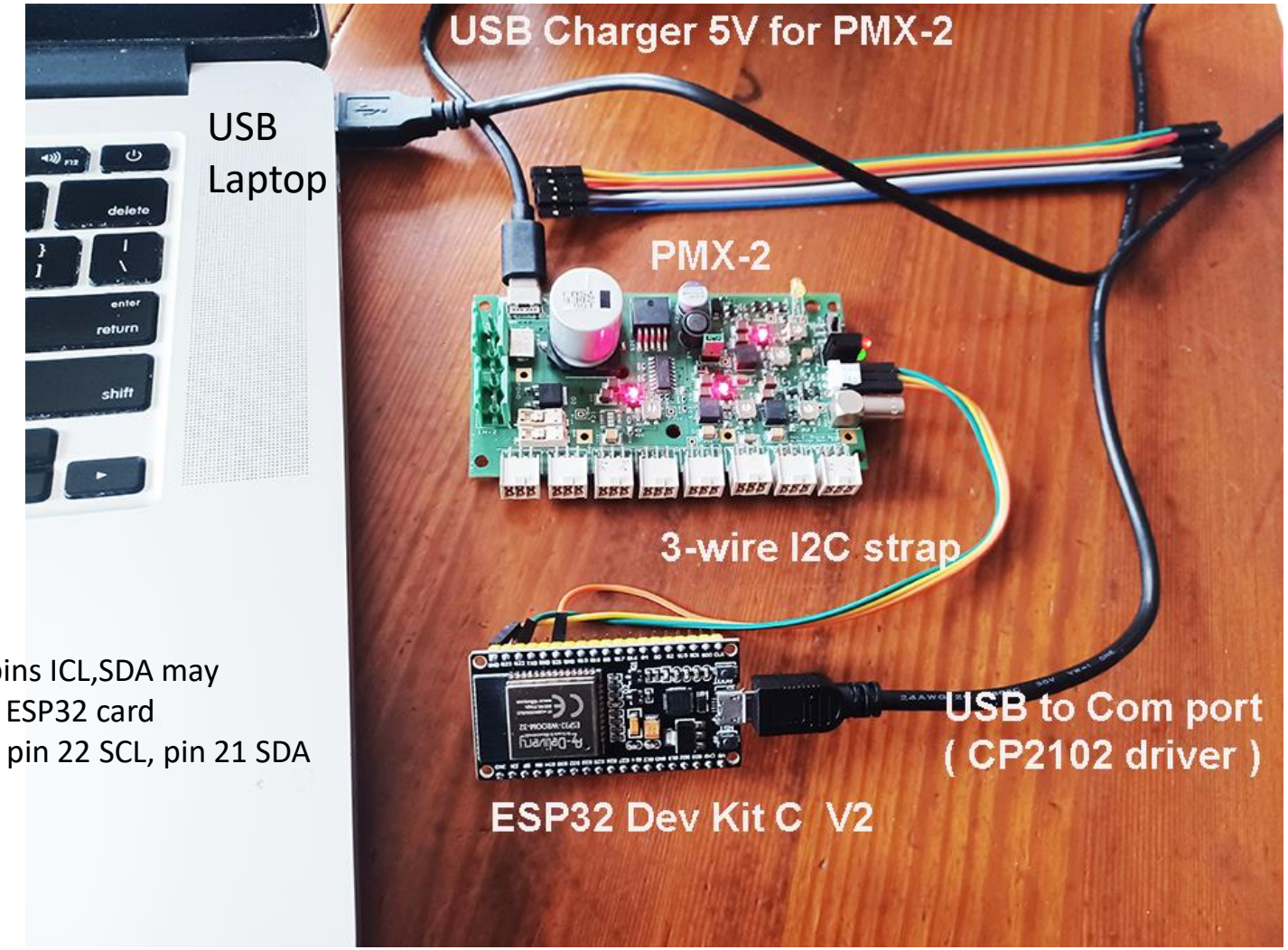


* AD7417 datasheet : https://www.analog.com/en/products/ad7417.html

Test setup: Power up PMX-2
put Jumper JMP-1 for 3V3 I2C signals
remove Jumper for 2.7V I2C signals
Connect I2C master cable J1: SCL,SDA, GND
Perform I2C scan:
OK if AD7417 reply at ADR = 40 dec (0x28)

Short instructions*
set lower 3 bits of address pointer register:
[0,0,1]= Configuration register 05h R/W
[0,0,0] =Temperature register 00h R-only
[1,0,0] = 10 bit ADC (16 bit word ,
lower 6 bit masked)
-Read voltages via 4 channels:
P2A: AIN1 write 20h to config Reg
P2B: AIN2 write 40h to config Reg
P2C: AIN3 write 60h to config Reg
½*P1: AIN4 write 80h to config Reg
-Read 10 bit temperature via 2 bytes
T= upper byte + 1/64 * lower byte

I2C master example: ESP32 / uPython



Note: I2C pins ICL,SDA may depend on ESP32 card
Used here: pin 22 SCL, pin 21 SDA

Used here as I2C master:
ESP32 Dev Kit C V2
https://www.az-delivery.de/

Micropython binaries from Micropyton.org
v1.19.1 (2022-06-18) .bin

Python development IDE incl. binary loader:
https://thonny.org/

Virtual COM port driver for USB bridge chip CP2102
https://www.silabs.com/developers/usb-to-uart-bridge-vcp-drivers

Tutorials uPython ESP32 with various peripherals, sensors, displays etc
https://randomnerdtutorials.com/

Example
ESP 32 Dev board

Supply Voltage: 5V from USB

I/O Voltages: 3.3V

SoC chip: ESP32-WROOM 32

CPU: Xtensa® single-dual-core 32-bit LX6

Clock: 80MHz / 240MHz

RAM: 512kB

Ext. Flash: 4MB

I/O pins: 34

ADC channels: 18 x 12 bit

DAC channels: 2 x 8 bit

Interface protocols: SPI,I2C, I2S, CAN, UART

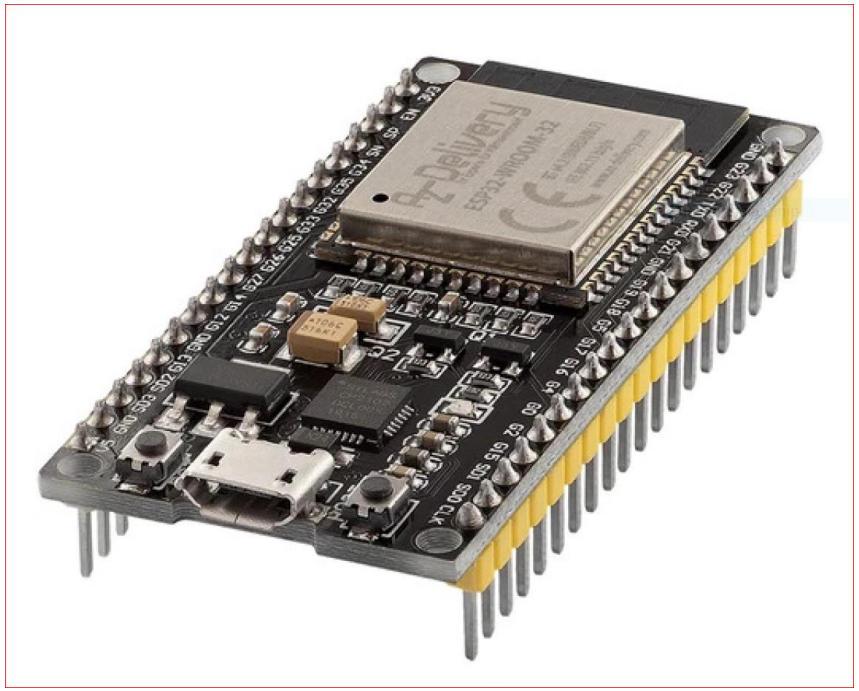
Wifi: 802.11 b/g/n (802.11n up to 150 Mbps)

Wifi Frequencies 2.4 GHz - 2.5 GHz

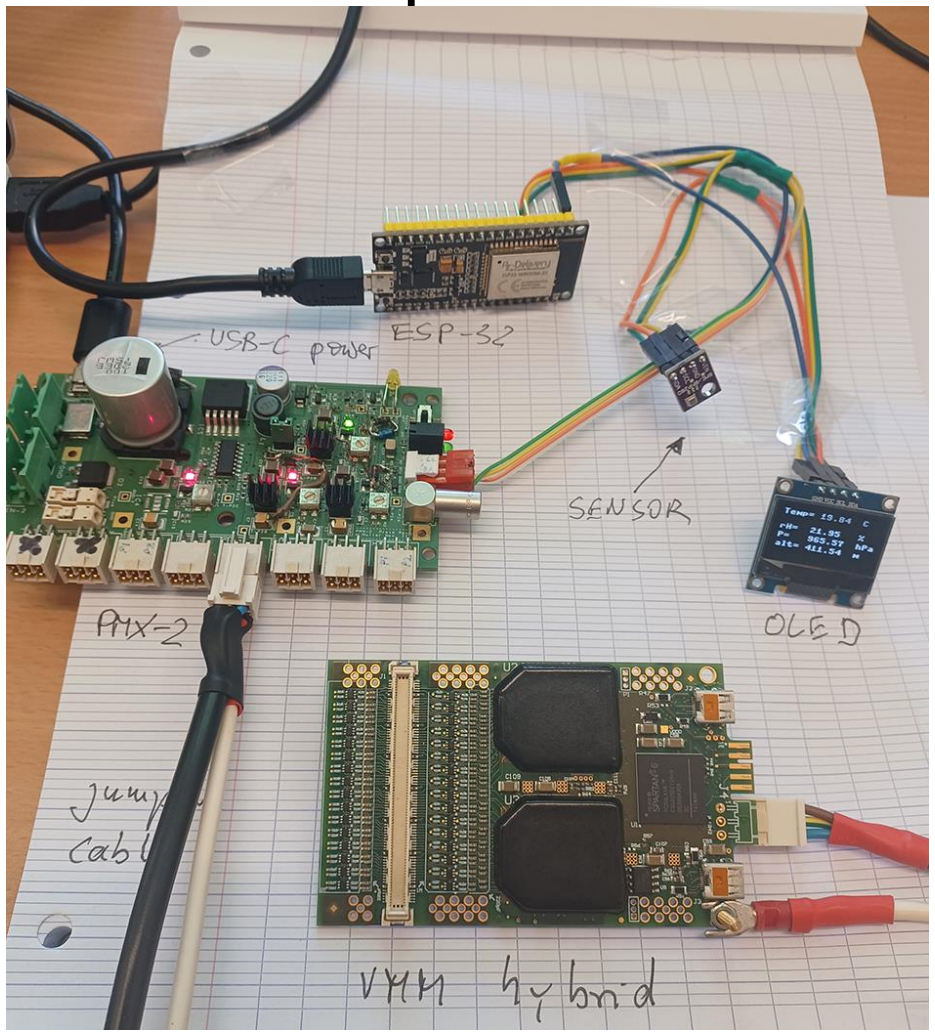
Bluetooth: V4.2 - BLE und Classic Bluetooth

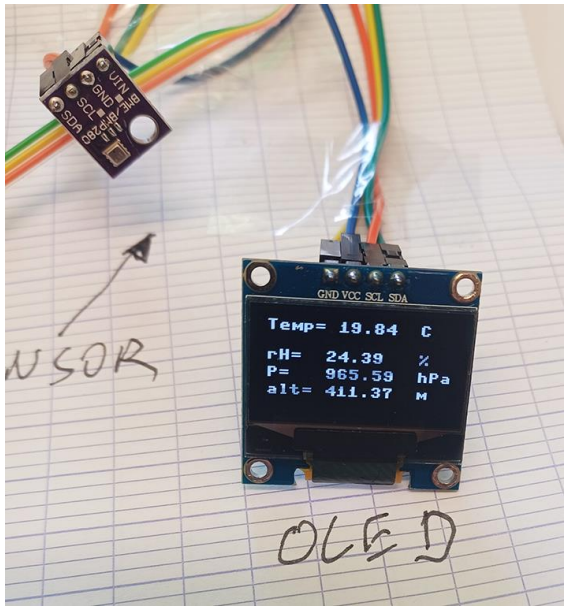
Antenna: on PCB

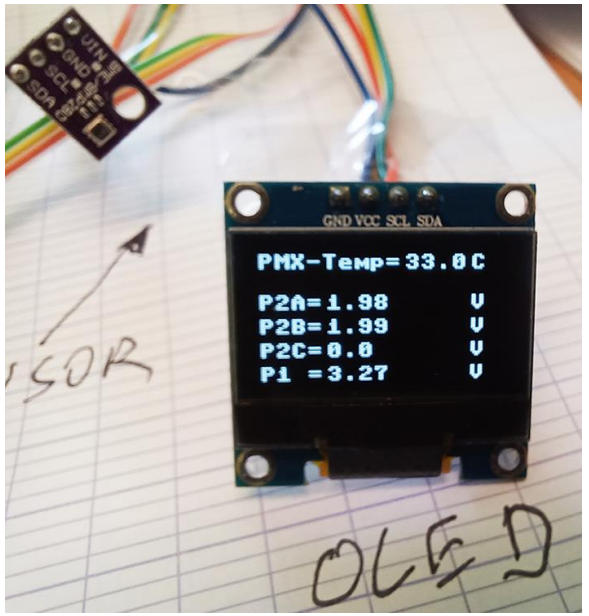
Dimensions: 56x28x13mm



PBX test w. OLED display for P1,P2 voltages, PCB temperature + environment sensor



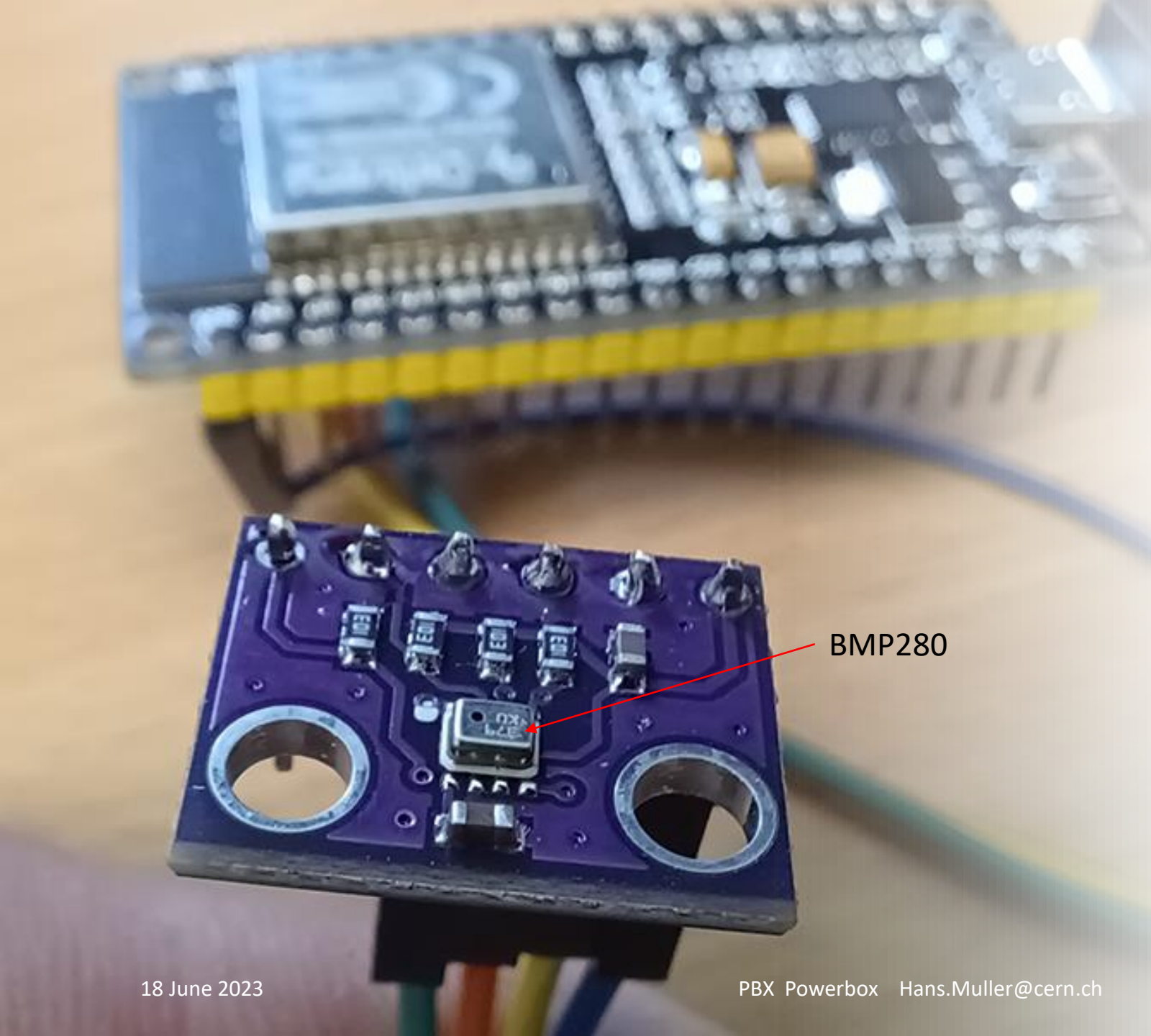




Alternating OLED display (every 5 sec)
left: environmental Temperature, rel. humidty, pressure, altitude
right: PMX Temperature, Voltages P2A,P2B,P2C*, P1

*on this prototype, P2C is not populated => 0

Barometric pressure sensor Bosch BME280*



- Precision sensor for humidity, temperature and pressure in a temperature range -40 … +85 °C +/-1.

Relative humidity ±3 % . Atmospheric pressure between floor and ceiling of a room in a hPa pressure range 300 … 1100 hPa with an absolute accuracy typ. ±1 hPa and a relative accuracy ±0.12 hPa corresponding to a height of +/- 1m.

Added BME280 to the box-cover of PMX-2 for measuring surrounding temperature, pressure and external temperature. Altitude was added via the barometric formula

* Photo shows previous version BMP280 w.out humidity