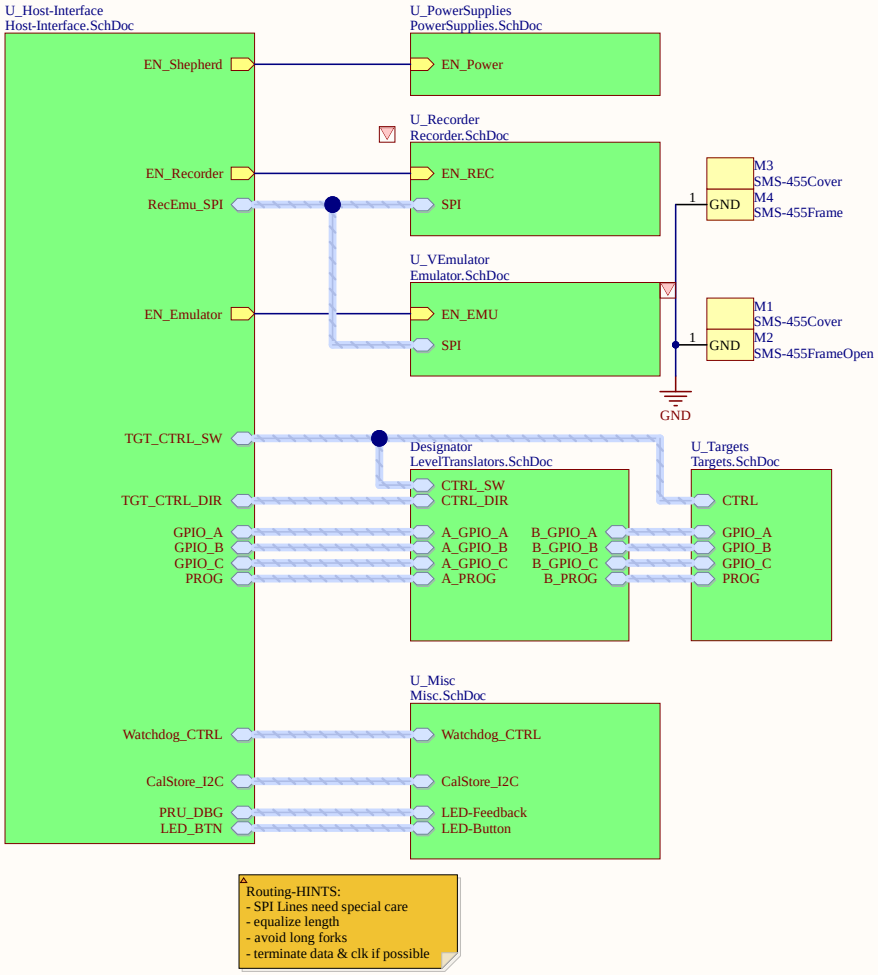
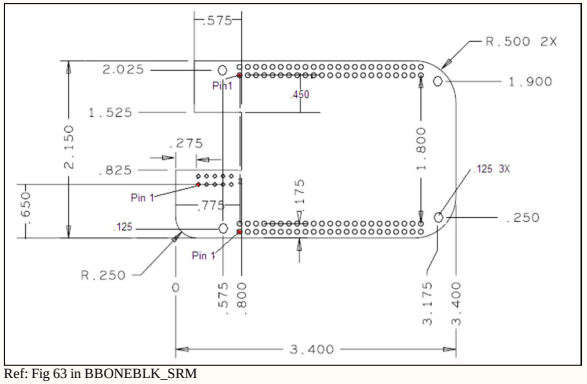


Routing-HINTS:
- SPI Lines need special care
- equalize length
- avoid long forks
- terminate data & clk if possible



Ref: Fig 63 in BBONEBLK_SRM

PCB Manufacturing Constraints

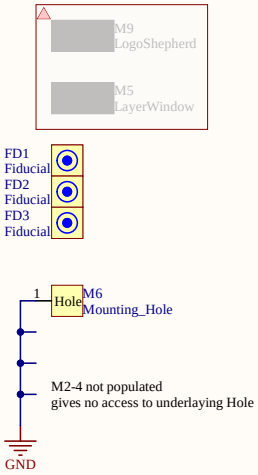
- Size 54.1 x 75.2 mm, 4 Layer
- 0.25 mm Track Width
- 0.15 mm Copper Clearance
- 0.38 mm Edge Clearance
- 0.35 mm Toolsize / non plated Hole
- 0.25 mm Plated Hole (End-)Size
- 0.125 mm Annular Ring
- 2.54 mm milling radius
- Solder Paste Pads are optimized for a 90 - 110 um Stencil

Assembly (v2.2)

- 2 Variations, recorder / emulator are self-contained and optional
  - with Rec & Emu -> 276 parts, 42 unique
  - with Emu -> 253 parts, 46 unique
- Mech-15 contains Pick and Place Info
  - cross (+) marks origin of part,
  - chamfered edge and circle mark pad 1 of ICs
  - "C" marks cathode of diodes
- Mech-2 contains Top Part Designators
- smallest part 0402
- smallest pitch 0.5 mm, QFN
- only top layer populated

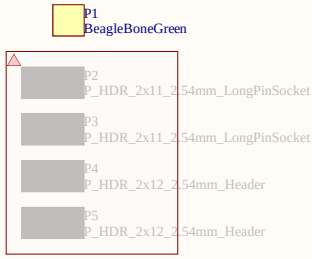
Manual Assembly
- Mech-13 contains info about non-reflow parts (8 items)

Misc



M2-4 not populated
gives no access to underlaying Hole

BOM-Additions



External-BOM

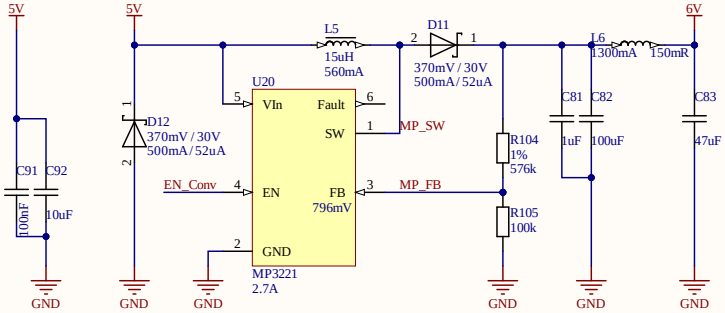
USB-Stick 256 GB
Ethernet Cables
POE-Adapter
uSD-Card (for flashing)

Calibration Resistors
1k-0603-0.05% 667-ERA-3ARW102V
100R-0603-0.05% 754-RG1608N-101-W-T1

Pinheader Connection BBone Variants
2x23 Header -> 77313-802-46LF 1.3 €
2x23 LongPinSocket
Samtec SSQ-123-23-G-D or 03-G-D 6 € (Default in BOM)
Major League SSHQ-123-D-10-G-LF 3 €
2x11 LongPinSocket & 2x12 Header
Samtec SSQ-111-03-G-D 3 €
Amphenol 10129381-924003BLF 0.4 €

Title	Shepherd - Overview NES Lab / TU Dresden	
Size: A4	Number	Revision
Date: 11.30.2021	Sheet of	shepherd_v2.PrjPcb
File: C:\Users\..\overview.SchDoc	Drawn By:	Ingmar

BoostConverter

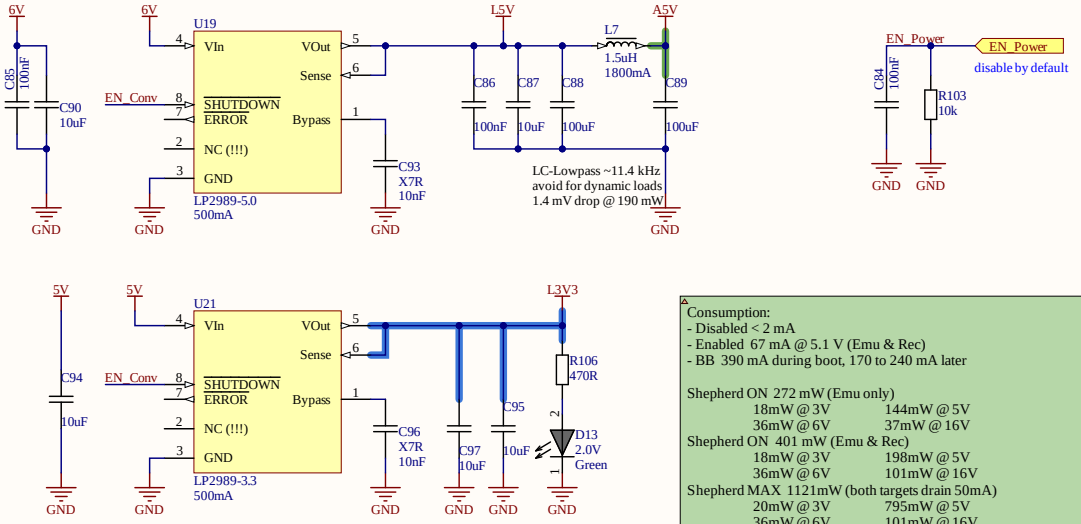


Output-Voltage:
Vout: 0.796/100e3 * (100e3 + 576e3);
Vout 5.381 V, 1% range is [5.290; 5.474] V

Output-Ripple-Calculation:
I_out: 0.15;
V_fw: 0.37;
V_in: 5.0;
f_sw: 1.2e6;
C_out: 157e-6;
dV_out: I_out * (V_out + V_fw - V_in) / (f_sw * (V_out + V_fw) * C_out);
dV_out <= 27 - 104 uV (min/max load)

Inductor-Calculation
L: V_in * (V_out + V_fw - V_in) / (f_sw * (V_out + V_fw) * 0.3*I_out);
L 12 uH

LowNoise LDOs



Consumption:
- Disabled < 2 mA
- Enabled 67 mA @ 5.1 V (Emu & Rec)
- BB 390 mA during boot, 170 to 240 mA later

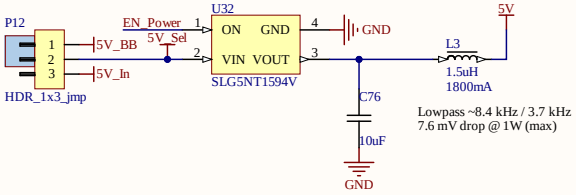
Shepherd ON 272 mW (Emu only)
18mW @ 3V 144mW @ 5V
36mW @ 6V 37mW @ 16V
Shepherd ON 401 mW (Emu & Rec)
18mW @ 3V 198mW @ 5V
36mW @ 6V 101mW @ 16V
Shepherd MAX 1121mW (both targets drain 50mA)
20mW @ 3V 795mW @ 5V
36mW @ 6V 101mW @ 16V

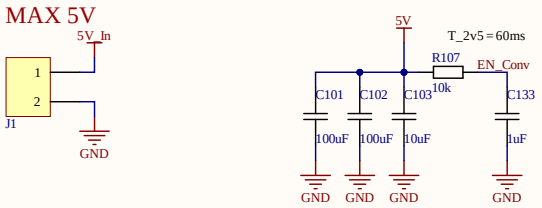
Main Voltages:
A5V/L5V -> 5.000 V Should be Spot On
L3V3 -> 3.300 V Should be Spot On
6V -> 5.38 V [5.29; 5.47] V with 1% Res
10V -> 9.73 V [9.56; 9.90] V with 1% Res
-6V -> -6 V, [5.94; 6.06] V with 1% Res

External Power Input & PWR-Selection

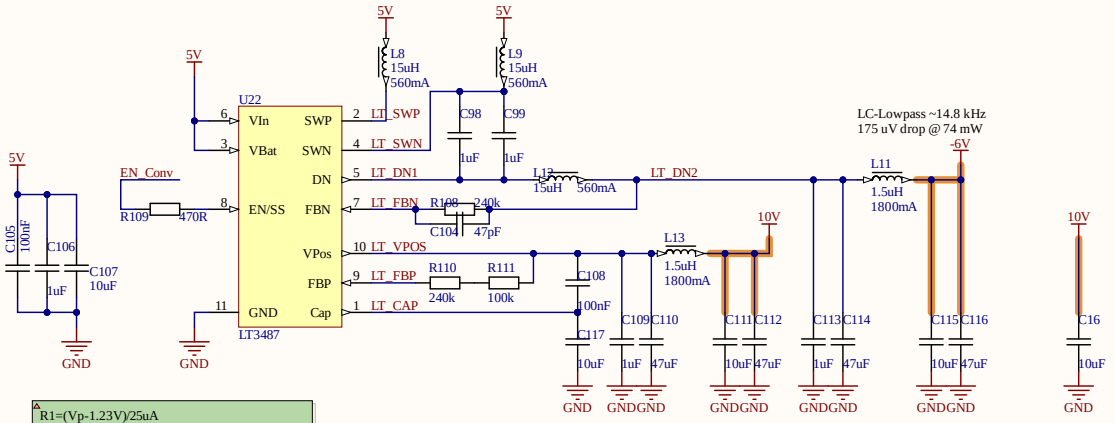
Jumper 1:2 - Shepherd is powered by BBone
Jumper 2:3 - Shepherd is powered by Screw-Connector (Ext)

There are Holes for soldering a 1 mF 6V3 Cap! (647-UVR0J102MPD1TD)





Boost & Inverter



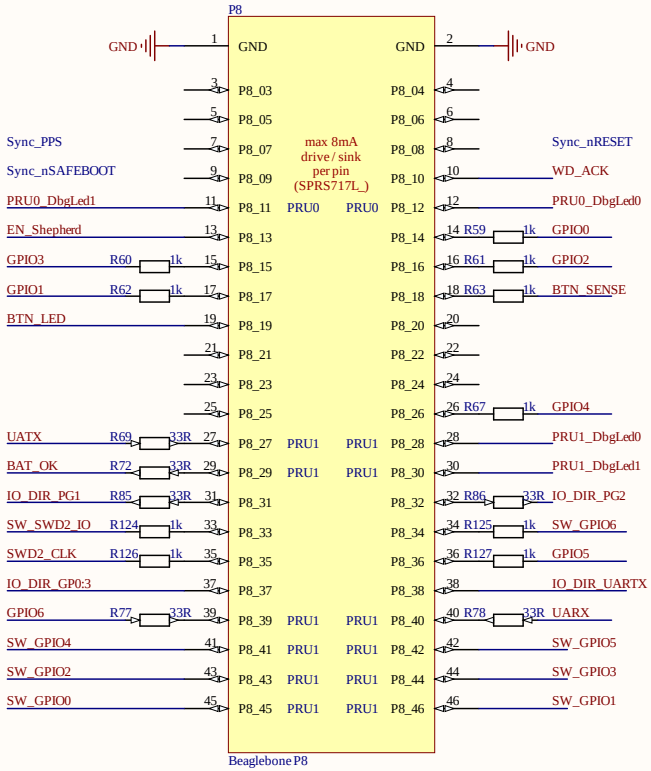
R1=(Vp-1.23V)/25uA
R1=350.8 kOhm (10V)
340kOhm -> 9.73V @1%

R2=-Vn/25uA
R2=240 kOhm (-6V)

Regulator drives at least 50mA on both Outputs

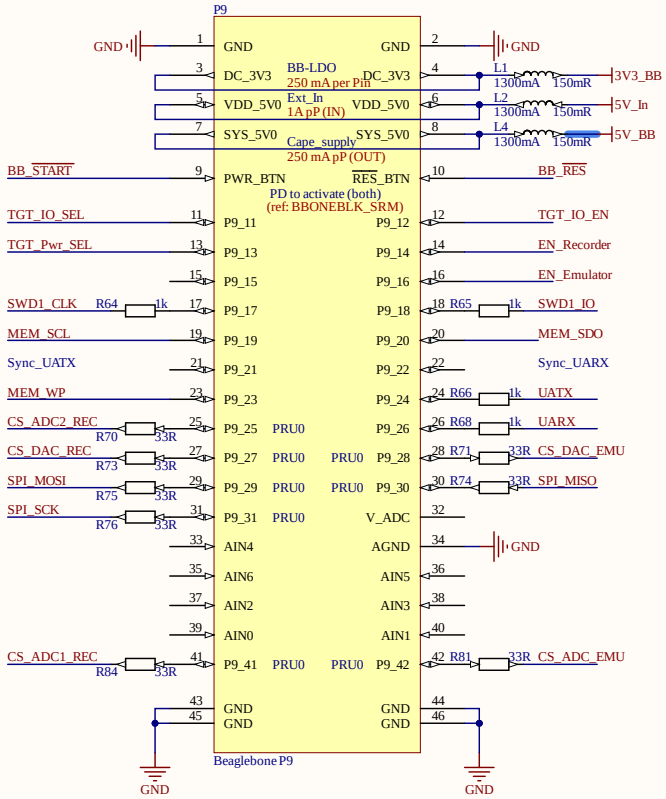
Title	Shepherd - Power Supplies NES Lab / TU Dresden	
Size A4	Number	Revision
Date: 11.30.2021	Sheet of	shepherd_v2.PrjPcb
File: C:\Users\..\PowerSupplies.SchDoc	Drawn By:	Ingmar

Beaglebone Pinheader P8

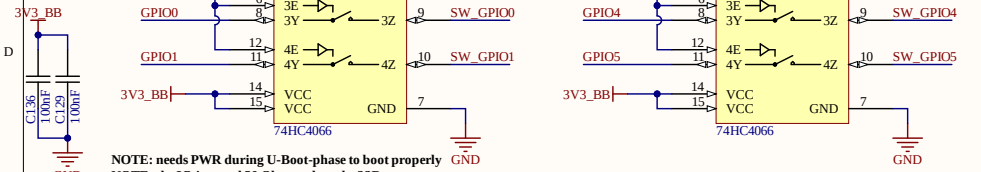


NOTE: order looks messed up, but ensures a proper boot
P8-31:46 are responsible for bootconfig of beaglebone
Most Important: P8 - 31:34 & 41:46

Beaglebone Pinheader P9



Uninterrupted U-Boot-Config



NOTE: needs PWR during U-Boot-phase to boot properly
NOTE: the IC-internal 50 Ohm replace the 33R

Pin-Mapping is documented in

-> concept_hw_beagle_pinout.xls

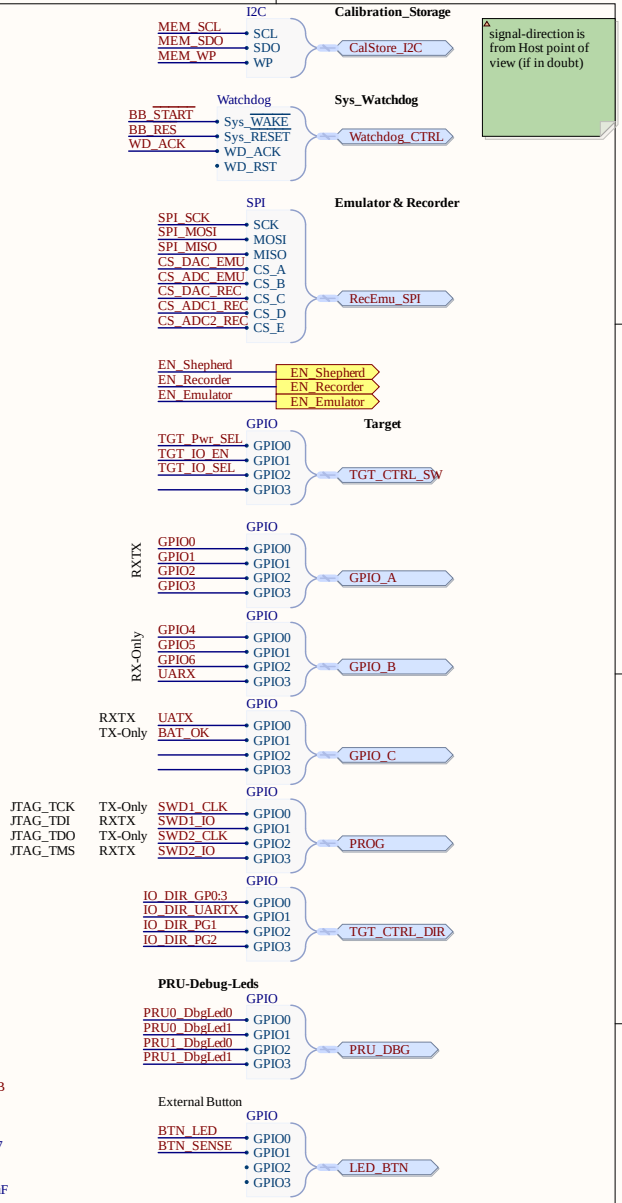
target_io is doubled for pru-timestamping - pru-io is not flexible, no dir-change during runtime

Behaviour on Shutdown:

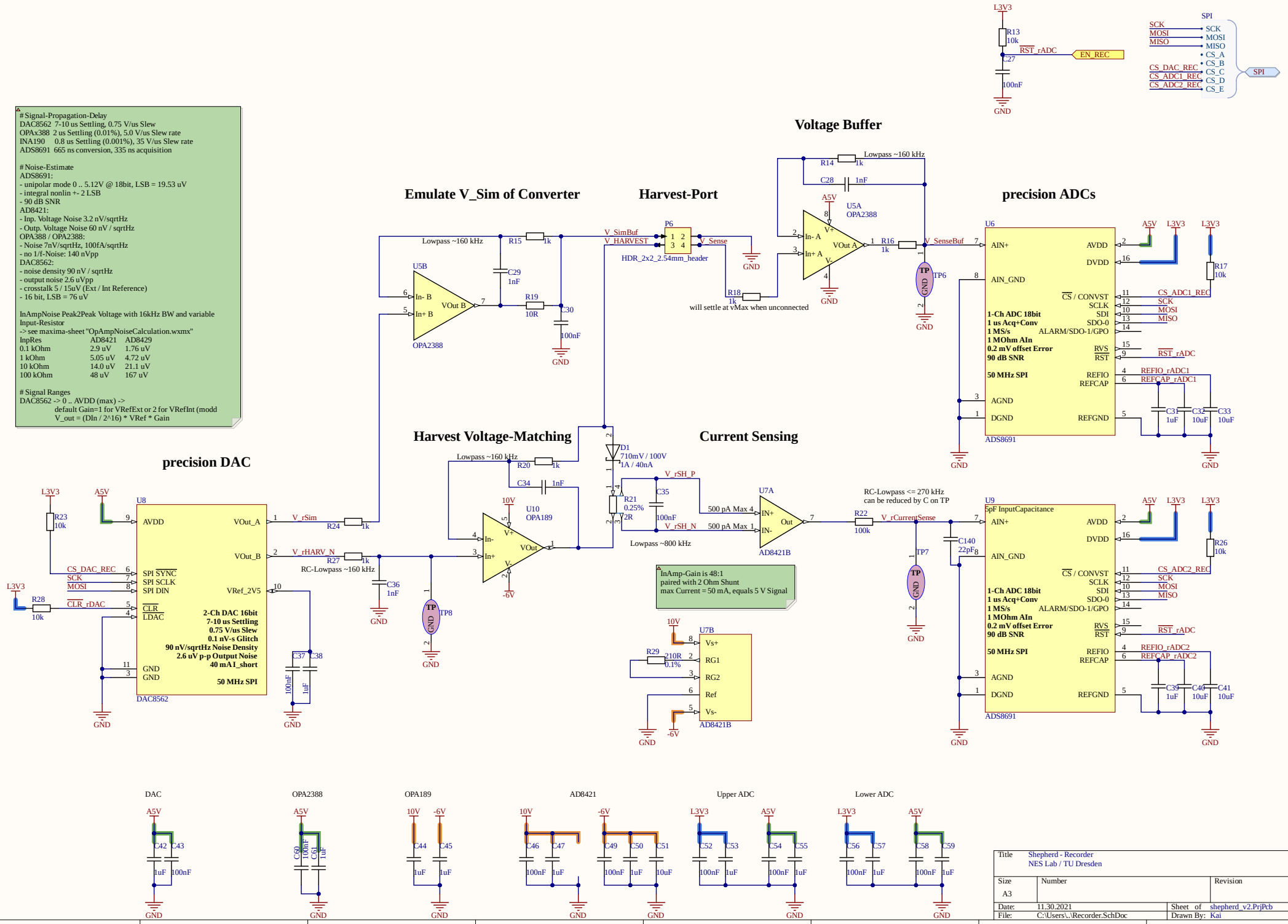
3V3	0V
VDD5V	0V
SYS5V	1.16V
PWR_BTN	3.74V
nRES_BTN	0.15V

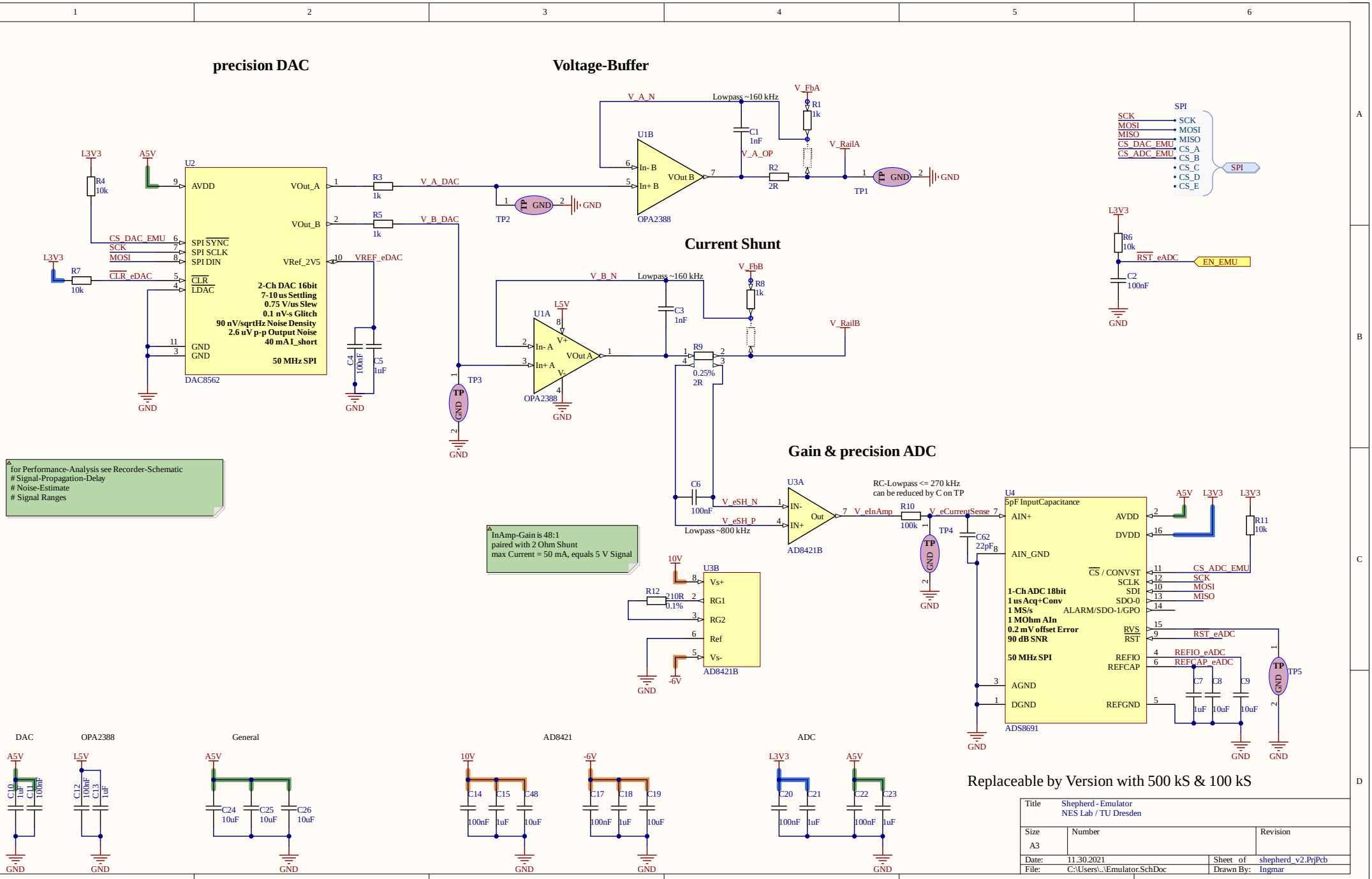
nSTART: BB_PCB has nothing discrete except switch to GND

nRST: BB_PCB has 10k PU & 2.2 uF Buffer & switch to GND

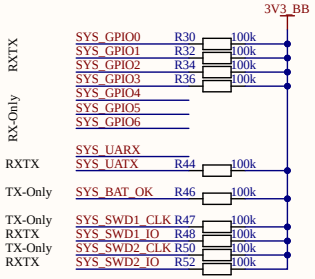


Title	Shepherd - Host Interface NES Lab / TU Dresden		
Size A4	Number		Revision
Date:	11.30.2021	Sheet of	shepherd_v2.PrjPcb
File:	C:\Users\..\Host-Interface.SchDoc	Drawn By:	Ingmar

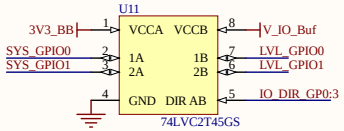

Signal-Propagation-Delay
DAC8562 7-10 us Settling, 0.75 V/us Slew
OPAx388 2 us Settling (0.01%), 5.0 V/us Slew rate
INA190 0.8 us Settling (0.001%), 35 V/us Slew rate
ADS8691 665 ns conversion, 335 ns acquisition
Noise-Estimate
ADS8691:
- unipolar mode 0 .. 5.12V @ 18bit, LSB = 19.53 uV
- integral nonlin +- 2 LSB
- 90 dB SNR
AD8421:
- Inp. Voltage Noise 3.2 nV/sqrtHz
- Outp. Voltage Noise 60 nV / sqrtHz
OPA388 / OPA2388:
- Noise 7nV/sqrtHz, 100fA/sqrtHz
- no 1/f-Noise: 140 nVpp
DAC8562:
- noise density 90 nV / sqrtHz
- output noise 2.6 uVpp
- crosstalk 5 / 15uV (Ext / Int Reference)
- 16 bit, LSB = 76 uV
InAmpNoise Peak2Peak Voltage with 16kHz BW and variable Input-Resistor
-> see maxima-sheet "OpAmpNoiseCalculation.wxmx"
InpRes AD8421 AD8429
0.1 kOhm 2.9 uV 1.76 uV
1 kOhm 5.05 uV 4.72 uV
10 kOhm 14.0 uV 21.1 uV
100 kOhm 48 uV 167 uV
Signal Ranges
DAC8562 -> 0 .. AVDD (max) ->
default Gain=1 for VRefExt or 2 for VRefInt (modd
V_out = (Dln / 2^16) * VRef * Gain
Emulate V_Sim of Converter
Harvest-Port
Voltage Buffer
precision ADCs
Harvest Voltage-Matching
Current Sensing
precision DAC
Lowpass ~160 kHz
R15 1k
C29 1nF
R19 10R
C30 100nF
U5B
OPA2388
V_SimBuf
V_HARVEST
P6
HDR_2x2_2.54mm_header
V_Sense
R18 1k
will settle at vMax when unconnected
R14 1k
C28 1nF
U5A
OPA2388
R16 1k
V_SenseBuf
TP6
U6
ADS8691
1-Ch ADC 18bit
1 us Acq+Conv
1 MS/s
1 MOhm AIn
0.2 mV offset Error
90 dB SNR
50 MHz SPI
R17 10k
C31 1uF
C32 10uF
C33 10uF
CS_ADC1_REC
RST_rADC
REFIO_rADC1
REFCAP_rADC1
L3V3
A5V
GND
SPI
SCK
MOSI
MISO
CS_A
CS_B
CS_C
CS_D
CS_E
CS_DAC_REC
CS_ADC1_REC
CS_ADC2_REC
R13 10k
C27 100nF
RST_rADC
EN_REC
U8
DAC8562
2-Ch DAC 16bit
7-10 us Settling
0.75 V/us Slew
0.1 nV-s Glitch
90 nV/sqrtHz Noise Density
2.6 uV p-p Output Noise
40 mA I_short
50 MHz SPI
R23 10k
R28 10k
R24 1k
R27 1k
C36 1nF
C37 100nF
C38 1uF
V_rSim
V_rHARV_N
RC-Lowpass ~160 kHz
TP8
Lowpass ~160 kHz
R20 1k
C34 1nF
U10
OPA189
D1
710mV / 100V
1A / 40nA
R21 0.25% 2R
C35 100nF
V_rSH_P
V_rSH_N
500 pA Max 4
500 pA Max 1
Lowpass ~800 kHz
U7A
AD8421B
InAmp-Gain is 48:1
paired with 2 Ohm Shunt
max Current = 50 mA, equals 5 V Signal
R22 100k
V_rCurrentSense
RC-Lowpass <= 270 kHz
can be reduced by C on TP
TP7
C140 22pF
U9
5pF InputCapacitance
R26 10k
C39 1uF
C40 10uF
C41 10uF
R29 210R 0.1%
U7B
AD8421B
DAC
OPA2388
OPA189
AD8421
Upper ADC
Lower ADC
C42 C43 1uF 100nF
C60 100nF C61 1uF
C44 C45 1uF 1uF
C46 C47 100nF 1uF
C49 C50 C51 100nF 1uF 10uF
C52 C53 C54 C55 100nF 1uF 100nF 1uF
C56 C57 C58 C59 100nF 1uF 100nF 1uF
Title Shepherd - Recorder
NES Lab / TU Dresden
Size A3
Number
Revision
Date: 11.30.2021
Sheet of shepherd_v2.PrjPcb
File: C:\Users\..\Recorder.SchDoc
Drawn By: Kai

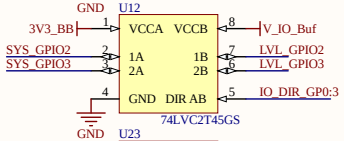

precision DAC
Voltage-Buffer
Current Shunt
Gain & precision ADC
U2
DAC8562
2-Ch DAC 16bit
7-10 us Settling
0.75 V/us Slew
0.1 nV-s Glitch
90 nV/sqrtHz Noise Density
2.6 uV p-p Output Noise
40 mA I_short
50 MHz SPI
U1B
OPA2388
U1A
OPA2388
U3A
AD8421B
U3B
AD8421B
U4
ADS8691
1-Ch ADC 18bit
1 us Acq+Conv
1 MS/s
1 MOhm AIn
0.2 mV offset Error
90 dB SNR
50 MHz SPI
for Performance-Analysis see Recorder-Schematic
Signal-Propagation-Delay
Noise-Estimate
Signal Ranges
InAmp-Gain is 48:1
paired with 2 Ohm Shunt
max Current = 50 mA, equals 5 V Signal
RC-Lowpass <= 270 kHz
can be reduced by C on TP
Lowpass ~160 kHz
Lowpass ~800 kHz
SPI
DAC
OPA2388
General
AD8421
ADC
Replaceable by Version with 500 kS & 100 kS
Title Shepherd - Emulator
NES Lab / TU Dresden
Size A3
Number
Revision
Date: 11.30.2021
Sheet of shepherd_v2.PrjPcb
File: C:\Users\..\Emulator.SchDoc
Drawn By: Ingmar

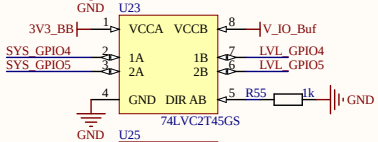
SideA - Pull Ups

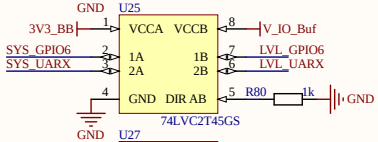


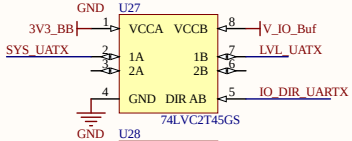
Level Translators

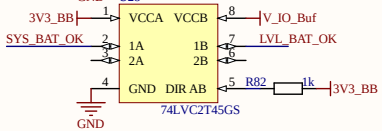




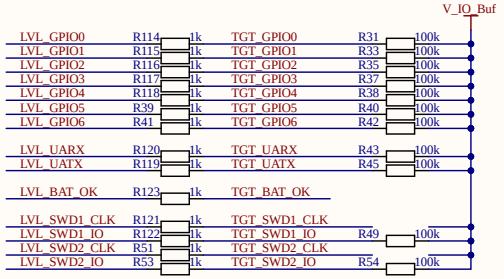


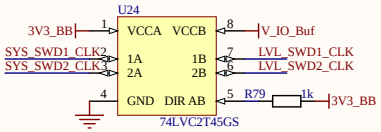


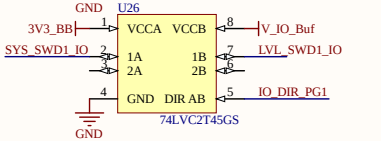


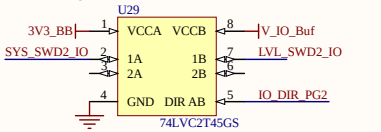


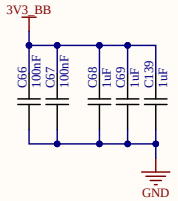
SideB - Pull Ups

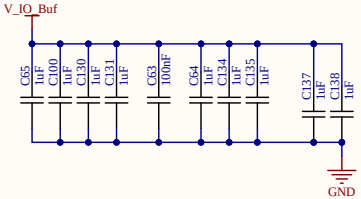




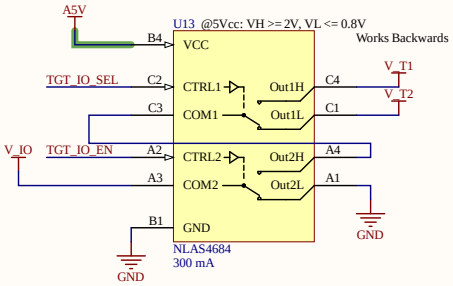




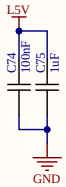


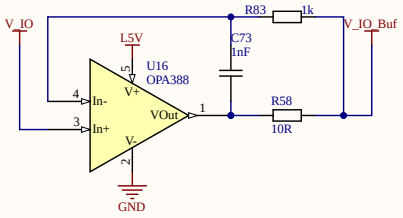


IO-Voltage - Reverse Routing Switch

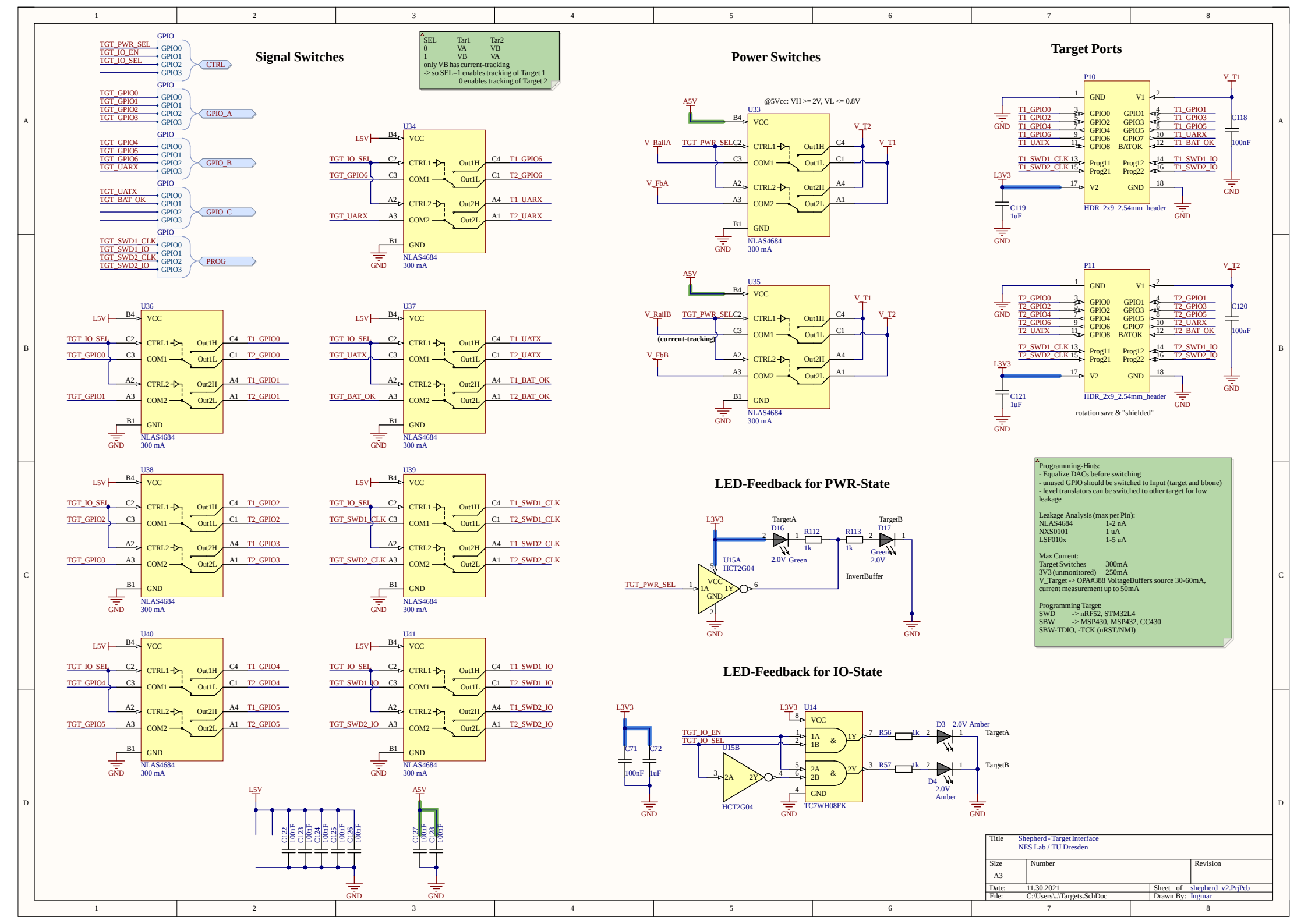


IO-Voltage - Buffer





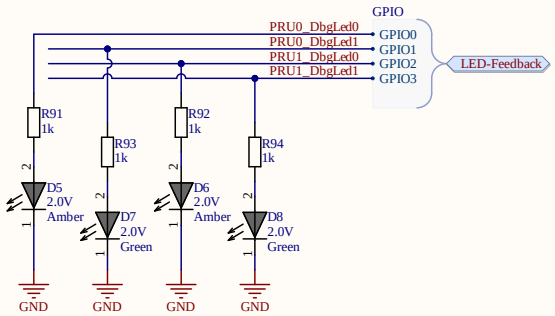
Title	Shepherd - Level Translators NES Lab / TU Dresden	
Size A3	Number	Revision
Date: 11.30.2021	Sheet of shepherd_v2.PrjPcb	
File: C:\Users\..\LevelTranslators.SchDoc	Drawn By: Ingmar	


Signal Switches
Power Switches
Target Ports
SEL Tar1 Tar2
0 VA VB
1 VB VA
only VB has current-tracking
-> so SEL=1 enables tracking of Target 1
0 enables tracking of Target 2
GPIO
TGT_PWR_SEL
TGT_IO_EN
TGT_IO_SEL
CTRL
TGT_GPIO0
TGT_GPIO1
TGT_GPIO2
TGT_GPIO3
GPIO_A
TGT_GPIO4
TGT_GPIO5
TGT_GPIO6
TGT_UARX
GPIO_B
TGT_UATX
TGT_BAT_OK
GPIO_C
TGT_SWD1_CLK
TGT_SWD1_IO
TGT_SWD2_CLK
TGT_SWD2_IO
PROG
U34
U36
U37
U38
U39
U40
U41
L5V
VCC
CTRL1
CTRL2
COM1
COM2
Out1H
Out1L
Out2H
Out2L
GND
NLAS4684
300 mA
T1_GPIO6
T2_GPIO6
T1_UARX
T2_UARX
T1_GPIO0
T2_GPIO0
T1_GPIO1
T2_GPIO1
T1_UATX
T2_UATX
T1_BAT_OK
T2_BAT_OK
T1_GPIO2
T2_GPIO2
T1_GPIO3
T2_GPIO3
T1_SWD1_CLK
T2_SWD1_CLK
T1_SWD2_CLK
T2_SWD2_CLK
T1_GPIO4
T2_GPIO4
T1_GPIO5
T2_GPIO5
T1_SWD1_IO
T2_SWD1_IO
T1_SWD2_IO
T2_SWD2_IO
C122 100nF
C123 100nF
C124 100nF
C125 100nF
C126 100nF
C127 100nF
C128 100nF
A5V
U33
U35
V_RailA
V_RailB
V_FbA
V_FbB
TGT_PWR_SEL
(current-tracking)
@5Vcc: VH >= 2V, VL <= 0.8V
V_T1
V_T2
P10
P11
HDR_2x9_2.54mm_header
L3V3
C118 100nF
C119 1uF
C120 100nF
C121 1uF
rotation save & "shielded"
LED-Feedback for PWR-State
TargetA
TargetB
D16
D17
R112 1k
R113 1k
2.0V Green
Green 2.0V
U15A HCT2G04
InvertBuffer
Programming-Hints:
- Equalize DACs before switching
- unused GPIO should be switched to Input (target and bbone)
- level translators can be switched to other target for low leakage
Leakage Analysis (max per Pin):
NLAS4684 1-2 nA
NXS0101 1 uA
LSF010x 1-5 uA
Max Current:
Target Switches 300mA
3V3 (unmonitored) 250mA
V_Target -> OPA#388 VoltageBuffers source 30-60mA, current measurement up to 50mA
Programming Target:
SWD -> nRF52, STM32L4
SBW -> MSP430, MSP432, CC430
SBW-TDIO, -TCK (nRST/NMI)
LED-Feedback for IO-State
C71 100nF
C72 1uF
U14
U15B
TC7WH08FK
HCT2G04
R56 1k
R57 1k
D3 2.0V Amber
D4 2.0V Amber
Title Shepherd - Target Interface
NES Lab / TU Dresden
Size A3
Number
Revision
Date: 11.30.2021
Sheet of shepherd_v2.PrjPcb
File: C:\Users\..\Targets.SchDoc
Drawn By: Ingmar

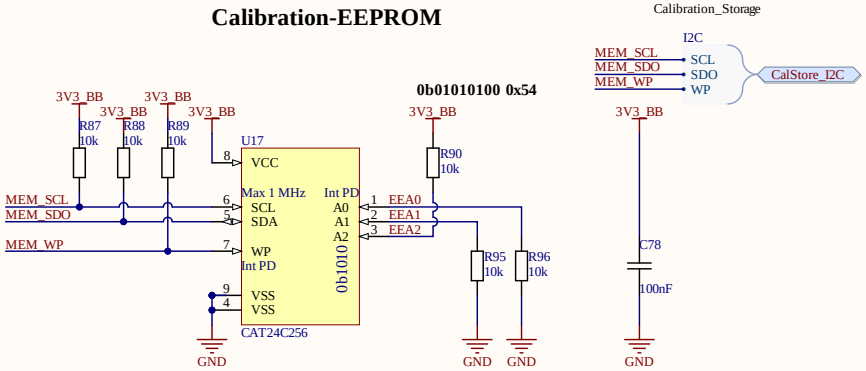
TODO:
Separate into smaller Individual Schem

Possible Changes:
- LED Button could be designed with just 3 Leads, or even 2
- One LED per PRU is enough

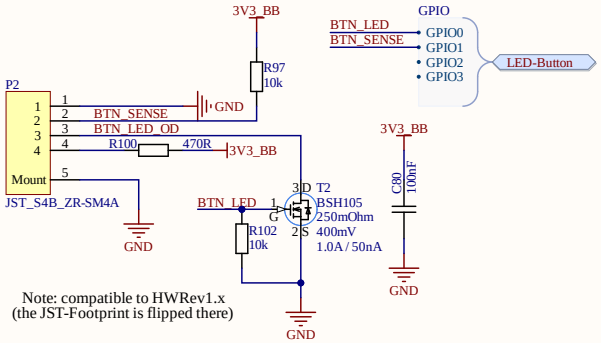
PRU-LED-Feedback



Calibration-EEPROM



Local Control Button

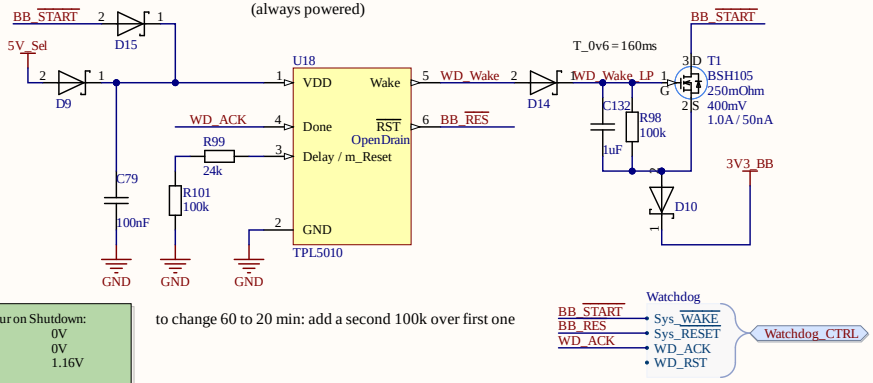


Note: compatible to HWRev1.x
(the JST-Footprint is flipped there)

schematic changed to avoid internal voltages on cable

Watchdog

(always powered)



BB-Behaviour on Shutdown:

3V3	0V
VDD5V	0V
SYS5V	1.16V

nSTART: BB_PCB has nothing discrete except pull-switch to GND, normally 5V Signal
-> use 3V3 as Pull-Down to only get affected by wake-signal when BB is powered off -> seems fine

nRST: BB_PCB has 10k PU & 2.2 uF Buffer & pull-switch to GND

to change 60 to 20 min: add a second 100k over first one

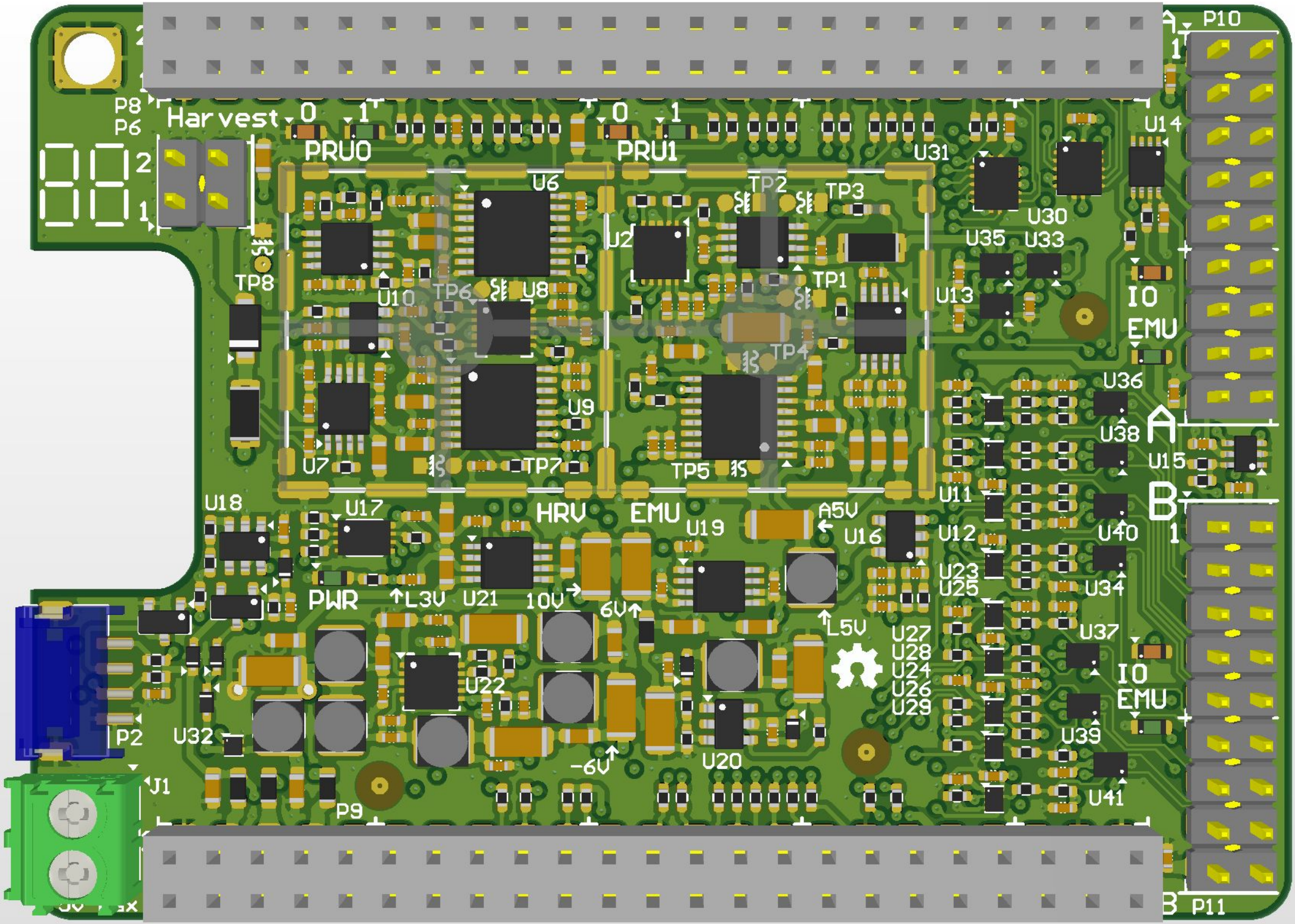
Watchdog - Advantages:
- nodes are in remote rooms, often without access
- Fallback if we can't control POE-Power of ports (most likely)
- with a WD the BB can shut down and be woken up periodically
- routine: BB aks server for tasks, waits or goes to sleep if NOP

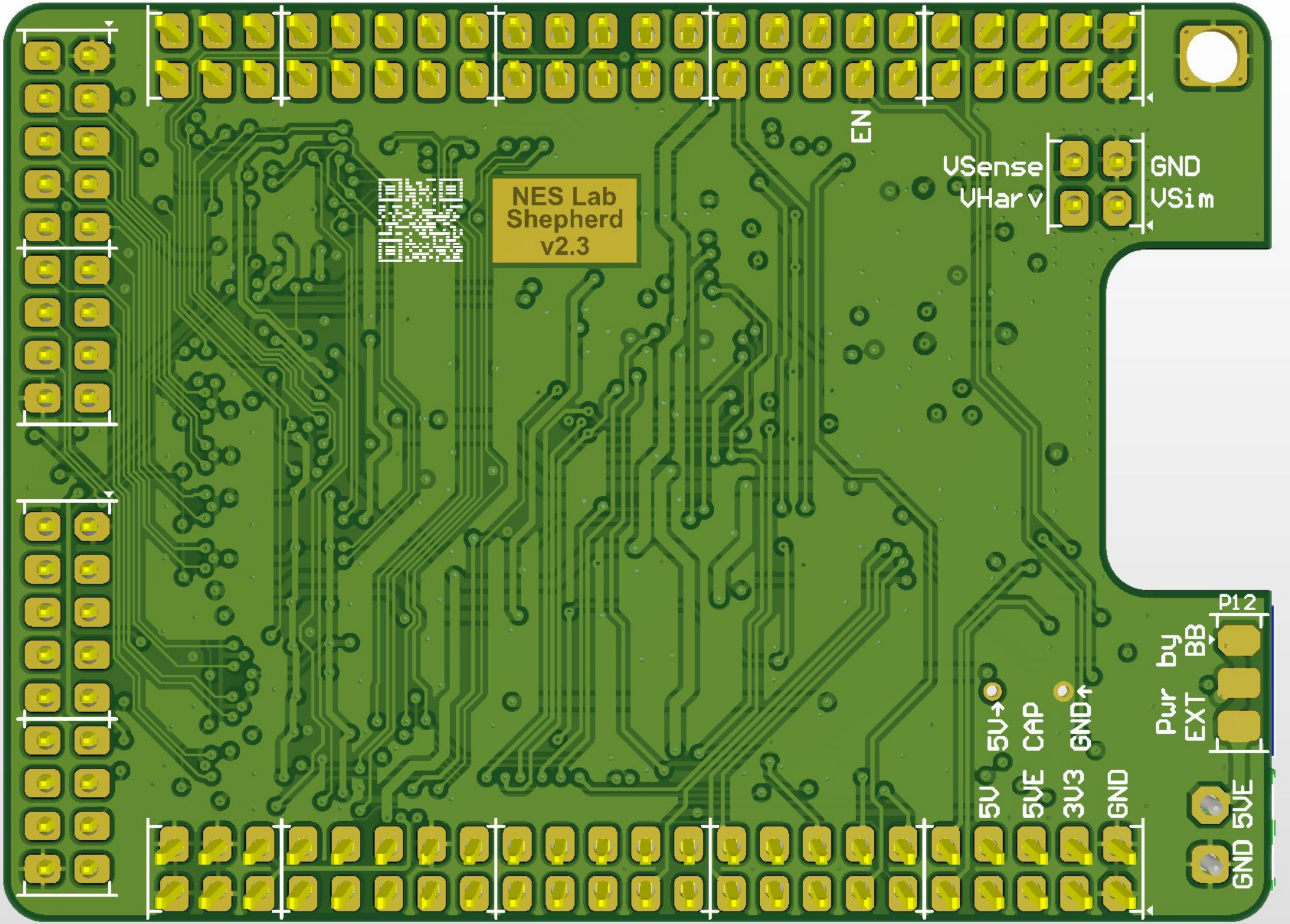
TPL5000 Watchdog behaviour:
- time-delay is configured via resistor (100ms .. 2h)
- "wake" is triggered for 31 ms on timer-match -> LowPass to 150 ms
- wake only reaches BB if 3V3_BB is at GND-Level (BB Shutdown)
- system has to confirm wake by triggering "done"
- if "done" is not triggered before next "wake" a reset occurs

R_Delay	T_Delay
057 kOhm	10 min
077 kOhm	20 min
092 kOhm	30 min
125 kOhm	60 min
150 kOhm	90 min
170 kOhm	120 min

A RTC (i.e. PCF2129 with Linux-Drivers) with alarm-timer and watchdog would be prefered, but both functions are only triggered ONCE without interaction. So if the BB gets woken but fails to boot there will never be a reset.

Title	Shepherd - Misc NES Lab / TU Dresden	
Size: A4	Number	Revision
Date: 11.30.2021	Sheet of	shepherd_v2.PrjPcb
File: C:\Users\..\Misc.SchDoc	Drawn By:	Ingmar


P8
P6
Harvest
0
1
PRU0
PRU1
U6
U2
TP2
TP3
U31
U30
U14
U35
U33
TP8
U10
TP6
U8
TP1
U13
IO
EMU
TP4
U36
U9
U38
U15
U7
TP7
TP5
U18
U17
HRV
EMU
U19
A5V
U16
U11
U12
U40
PWR
L3V
U21
10V
6V
L5V
U23
U25
U34
U27
U28
U24
U26
U29
U37
U22
P2
U32
-6V
U20
U39
J1
P9
U41
P10
P11


NES Lab
Shepherd
v2.3
EN
VSense
VHarv
GND
VSim
P12
Pwr by
EXT
BB
5V
5V→
5VE CAP
3V3
GND↑
GND
GND 5VE