**PCB Manufacturing Constraints**

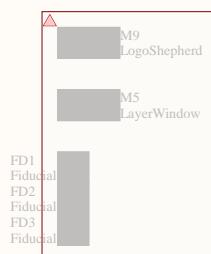
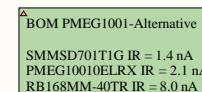
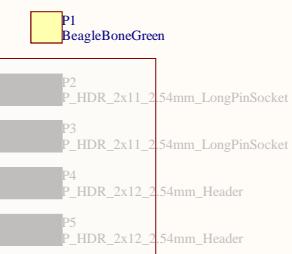
- Size 54.1 x 75.2 mm, 6 Layer
- 0.15 mm Track Width
- 0.15 mm Copper Clearance
- 0.38 mm Edge Clearance
- 0.35 mm Toolsize / non plated Hole
- 0.25 mm Plated Hole (End-)Size
- 0.125 mm Annular Ring
- 2.54 mm milling radius
- Solder Paste Pads are optimized for a 70 - 110 um Stencil

Assembly (v2.4)

- 2 Variations, recorder / emulator are self-contained and optional
- with Rec & Emu => 353 parts, 53 unique
- with Emu => X parts, X unique
- Mech-15 contains assembly notes / Pick and Place
- marking origin of part: cross (+) on assembly notes layer
- marking pad 1 of ICs: chamfered edge and circle (assembly notes) and filled triangle (silk)
- marking cathode of diodes: "C" or chamfered edge (assembly notes) and filled triangle (silk)
- Mech-2 contains Top Part Designators
- smallest part 0402
- smallest pitch 0.35 mm, XSON8
- only top layer populated

Manual Assembly

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

Misc**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

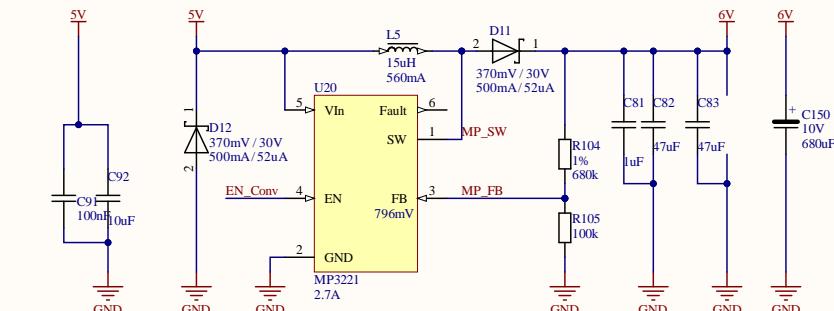
Pinheader Connection BBone Variants
2x23 Header > 7731-802-4LF 1.3 €
2x23 LongPinSocket
Samtec SSQ-123-23-G-D or 03-G-D 6 € (Default in BOM)
Major League SSHQ-123-D-10-G-LF 3 €
2x12 LongPinSocket & 2x12 Header
Samtec SSQ-111-03-G-D 3 €
Amphenol 10129381-924003BLF 0.4 €

Title Shepherd - Overview
NES Lab / TU Dresden

Size	Number	Revision
A4		
Date: 11.18.2022	Sheet of shepherd_v2.PriPcb	Drawn By: Ingmar

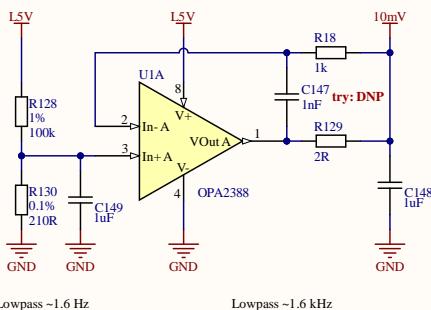
1 2 3 4 5 6

BoostConverter



$V_{out} = 6.2088 \text{ V}, 1\% \text{ range is } [6.102; 6.318] \text{ V}$
 $I_{out} [36; 166] \text{ mA}$
 $dV_{out} <= 9.2 - 42 \mu\text{V}$ (min/max load)
Output-Ripple
 $L_{Opt} = 20 \mu\text{H}$

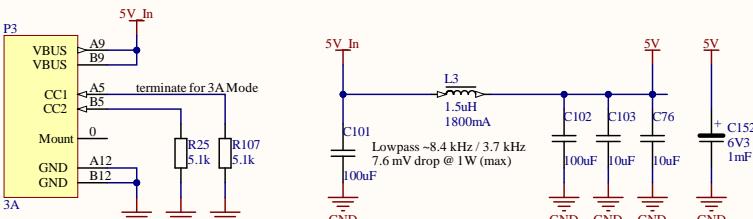
Reference-Offset



Lowpass ~1.6 Hz

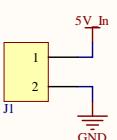
Lowpass ~1.6 kHz

External Power Input

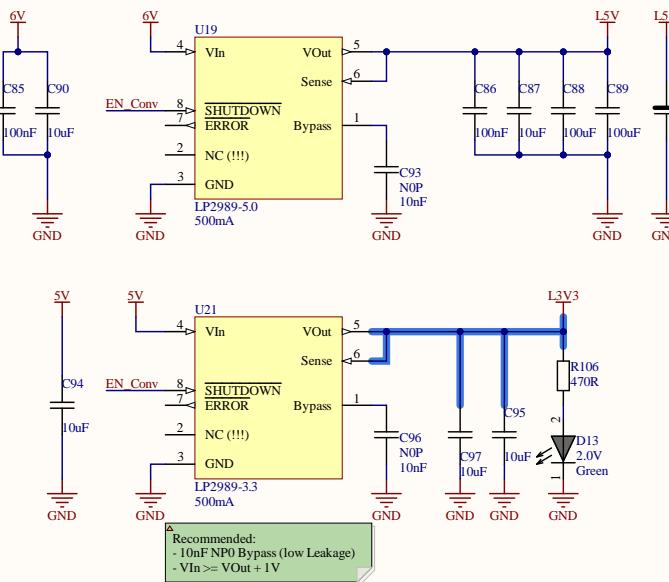


terminate for 3A Mode

MAX 5V



LowNoise LDOs

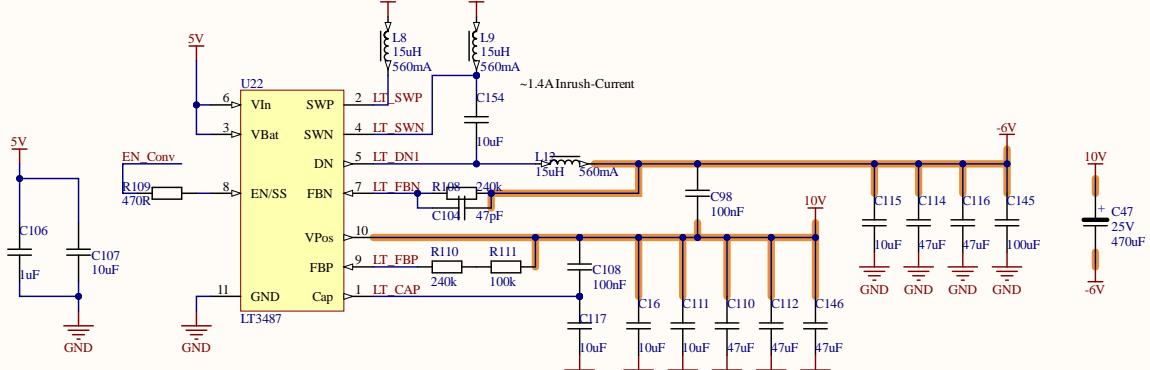


A Consumption:
- Disabled < 2 mA
- Enabled 67 mA @ 5.1 V (Emu & Rec)
- BB 390 mA during boot, 170 to 240 mA later

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

Boost & Inverter



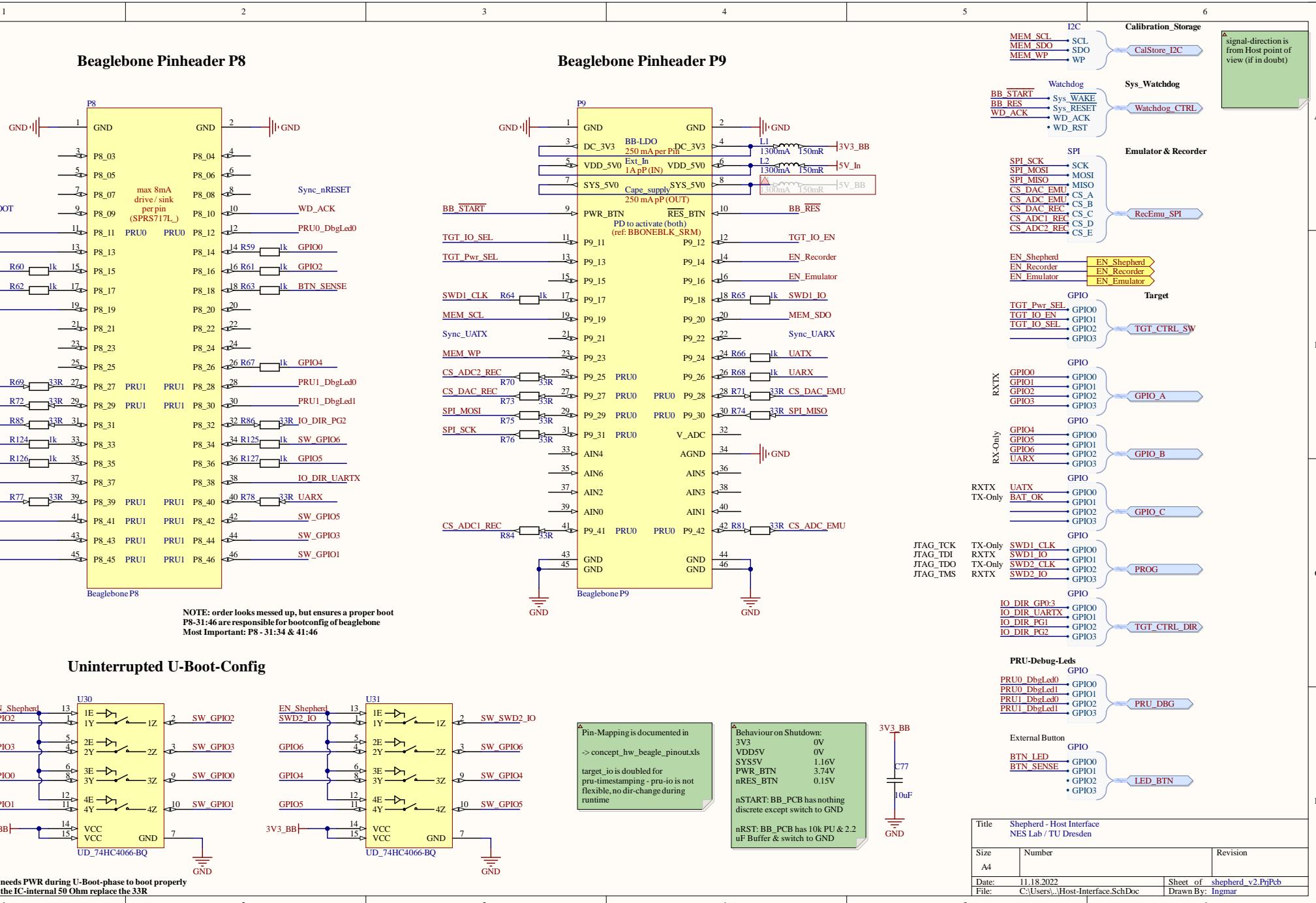
$R_1 = (V_p - 1.23V)/25\mu\text{A}$
 $R_1 = 350.8 \text{ k}\Omega \text{m} (10V)$
 $340\text{k}\Omega \text{m} > 9.73V @ 1\%$
 $R_2 = V_n/25\mu\text{A}$
 $R_2 = 240 \text{ k}\Omega \text{m} (-6V)$

Regulator drives at least 50mA on both Outputs

Title Shepherd - Power Supplies
NES Lab / TU Dresden

Size	Number	Revision
Date: 11.18.2022		Sheet of shepherd_v2.PriPcb
File: C:\Users\...\PowerSupplies.SchDoc		Drawn By: Ingmar

1 2 3 4 5 6



Signal-Propagation-Delay
DAC8562 7-10 us Settling, 0.75 V/us Slew
OPAx388 2 us Settling (0.01%), 50 V/us Slew rate
INA190 0.8 us Settling (0.001%), 35 V/us Slew rate
ADSS691 665 ns conversion, 335 ns acquisition

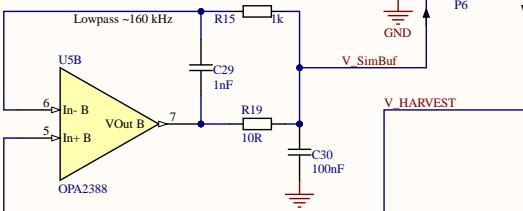
Noise-Estimate
ADSS691:
- unipolar mode 0 .. 5.12V @ 18bit, LSB = 19.53 uV
- integral nonlin +/- 2 LSB
- 90 dB SNR
AD8421:
- Inp. Voltage Noise 3.2 nV/sqrtHz
- Outp. Voltage Noise 60 nV / sqrtHz
OPA388 / OPA2388:
- Noise 7nV/sqrtHz, 100fA/sqrtHz
- no 1/f-Noise: 140 nVpp
DAC8562:
- noise density 90 nV / sqrtHz
- output noise 2.6 uV/PP
- crosstalk 5 / 15uV (Ext / Int Reference)
- 16 bit LSB = 76 uV

InAmpNoise Peak2Peak Voltage with 1kHz BW and variable Input-Resistor
> see maxima-sheet "OpAmpNoiseCalculation.wxm"

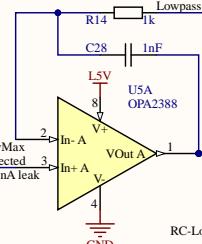
InpRes AD8421 AD8429
0.1 kOhm 2.9 uV 1.76 uV
1 kOhm 5.05 uV 4.72 uV
10 kOhm 14.0 uV 21.1 uV
100 kOhm 48 uV 167 uV

Signal Ranges
DAC8562 > 0 .. AVDD (max) ->
default Gain=1 for VRefExt or 2 for VRefInt (modd
V_out = (Din / 2^16) * VRef * Gain

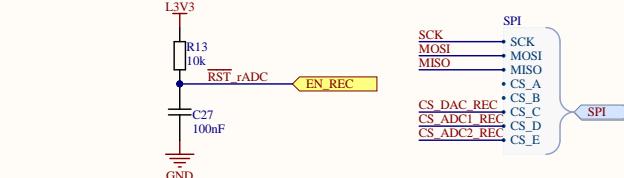
Emulate V_Sim of Converter



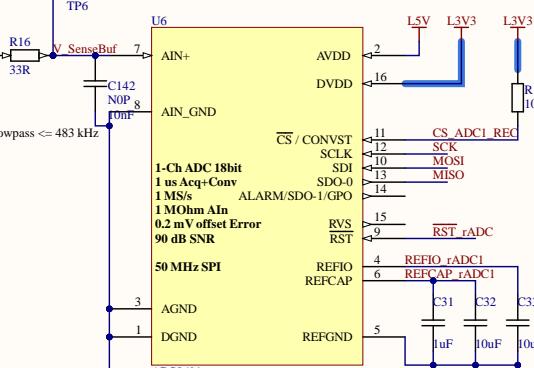
Harvest-Port



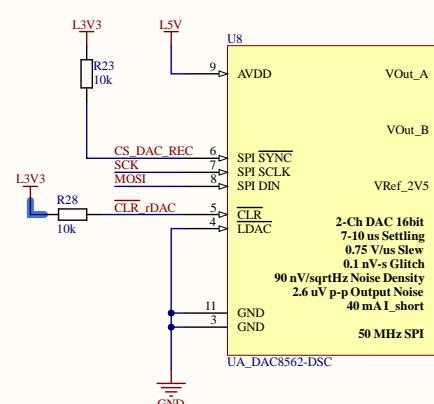
Voltage Buffer



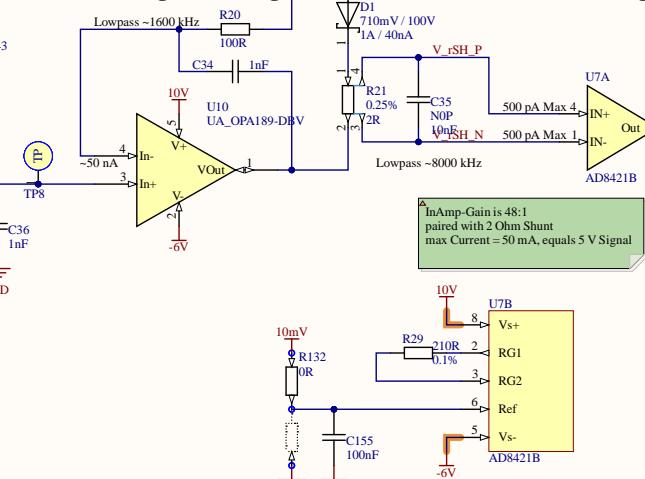
precision ADCs



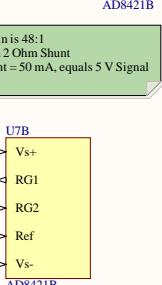
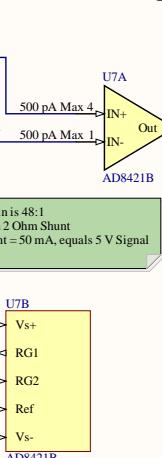
precision DAC



Harvest Voltage-Matching

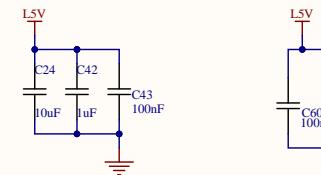


Current Sensing

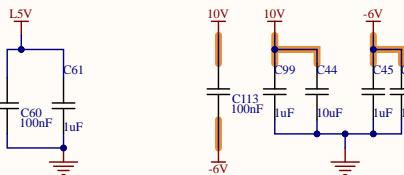


InAmp-Gain is 48:1 paired with 2 Ohm Shunt max Current = 50 mA, equals 5 V Signal

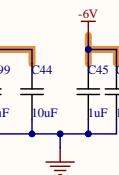
DAC



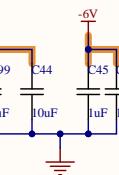
OPA2388



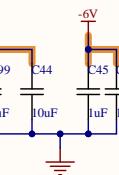
OPA189



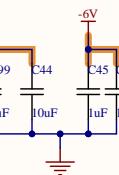
AD8421



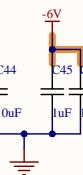
Upper ADC



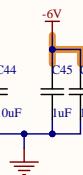
Lower ADC



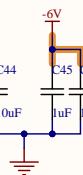
Title



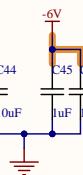
Shepherd - Recorder



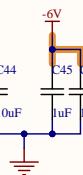
NES Lab / TU Dresden



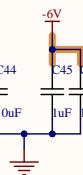
Size



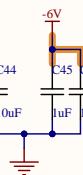
Number



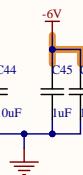
Revision



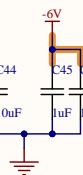
Date



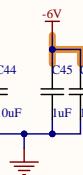
File



Drawn By

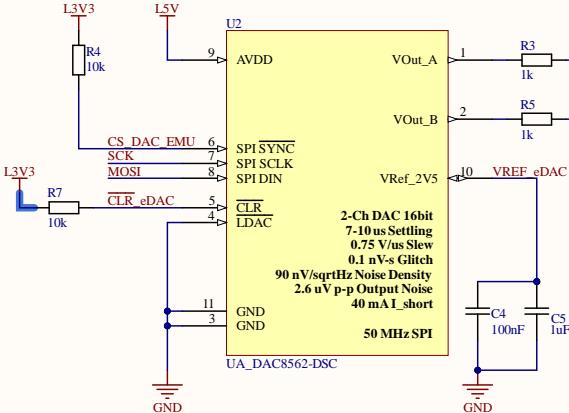
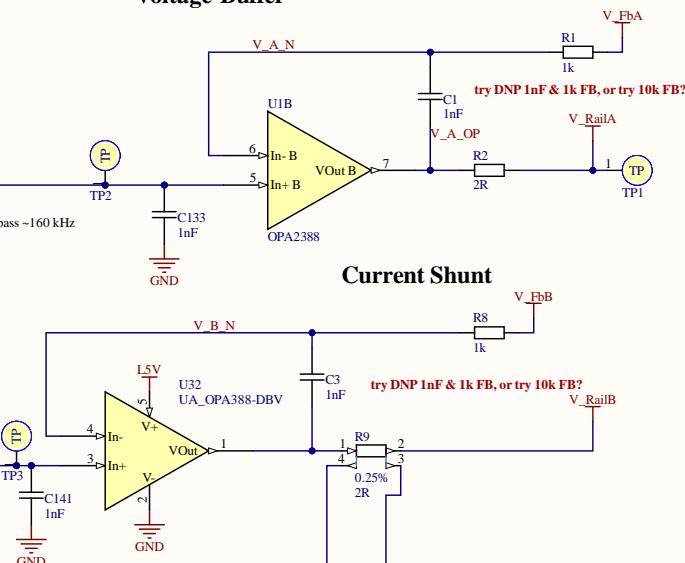
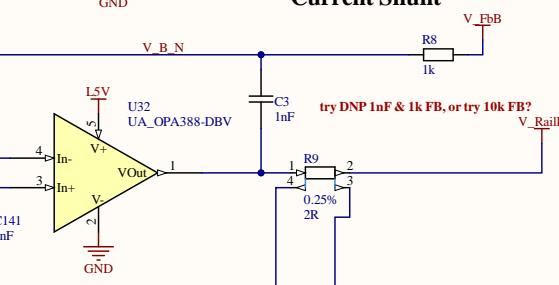
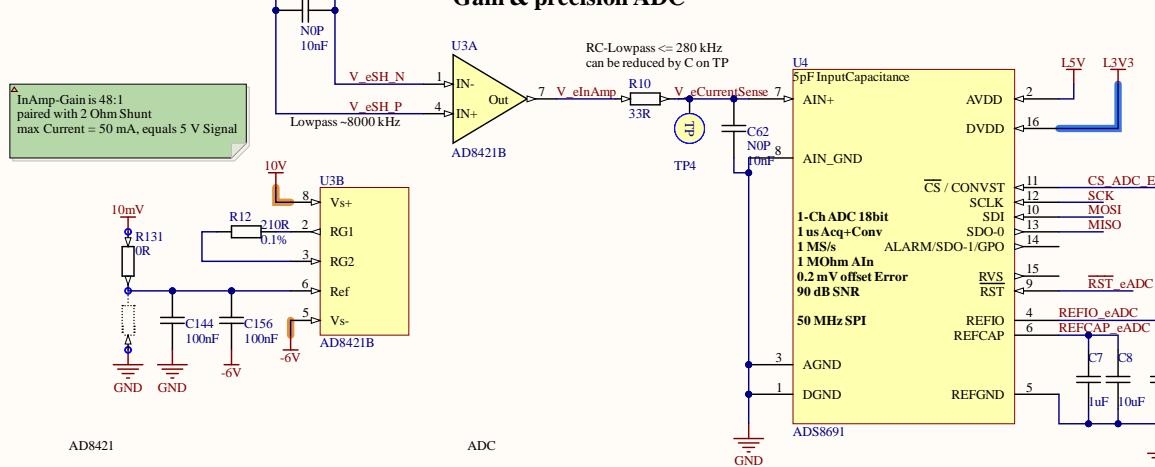


Kai



8

1 2 3 4 5 6

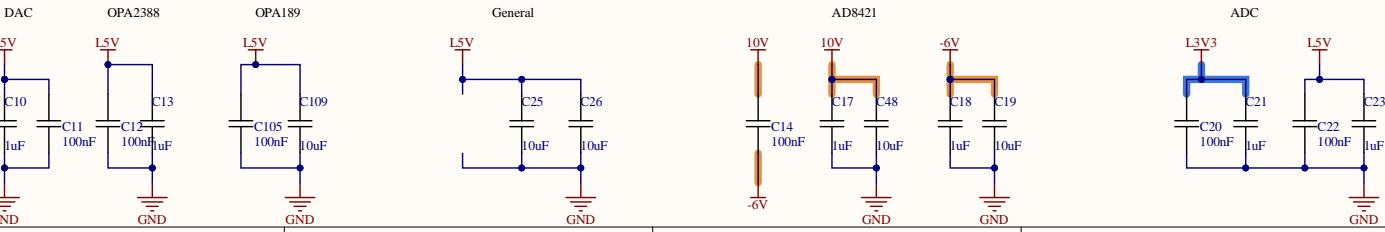
precision DAC**Voltage-Buffer****Current Shunt****Gain & precision ADC**

Replaceable by Version with 500 kS & 100 kS

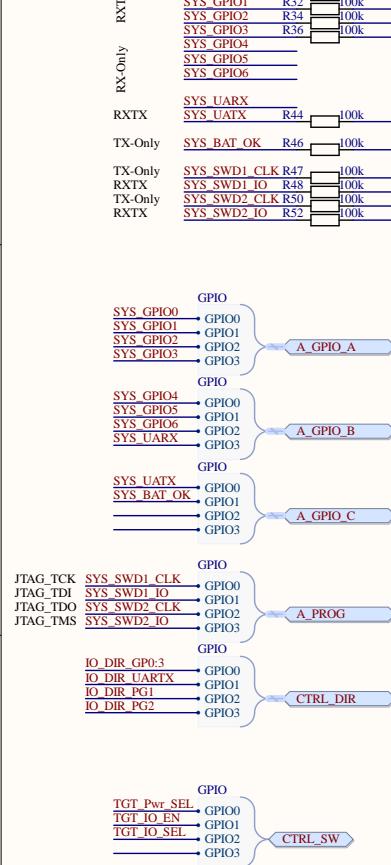
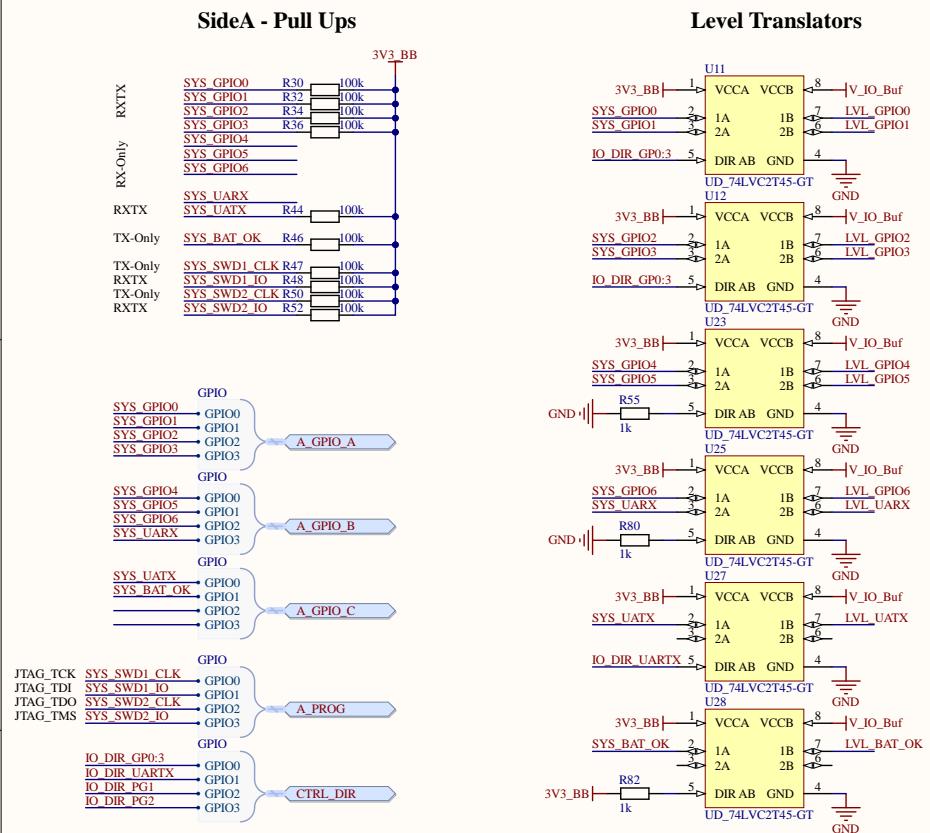
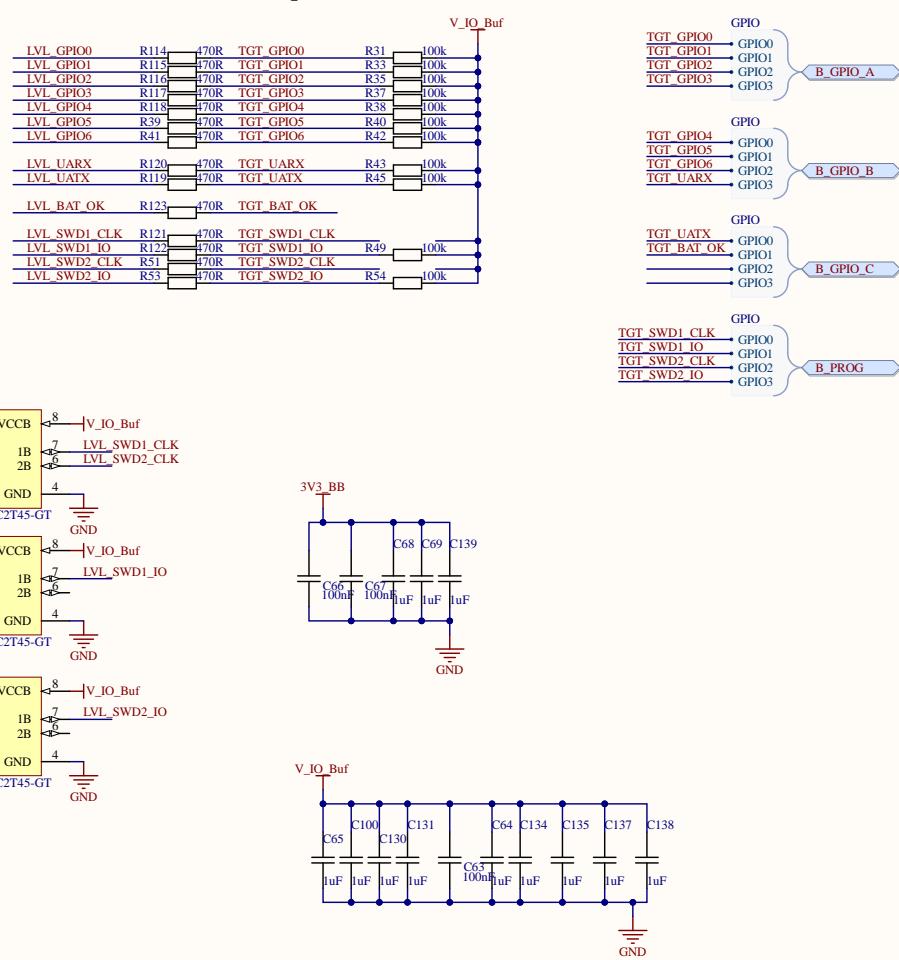
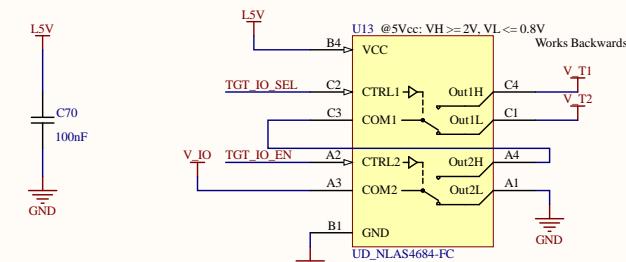
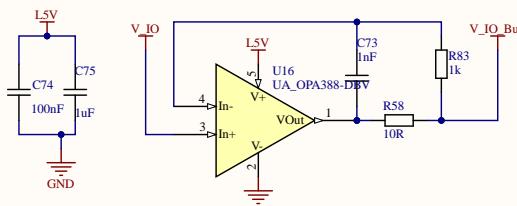
Title Shepherd-Emulator NES Lab / TU Dresden		
Size A3	Number	Revision
Date: 11.18.2022		Sheet of shepherd_v2.PjPcb
File: C:\Users\...\Emulator.SchDoc		Drawn By: Ingmar

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

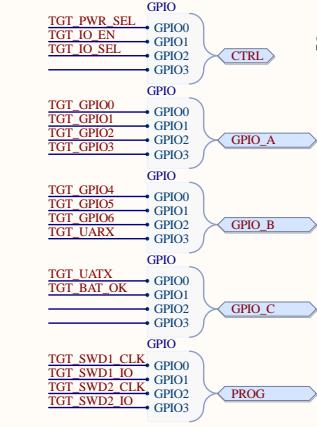


1 2 3 4 5 6

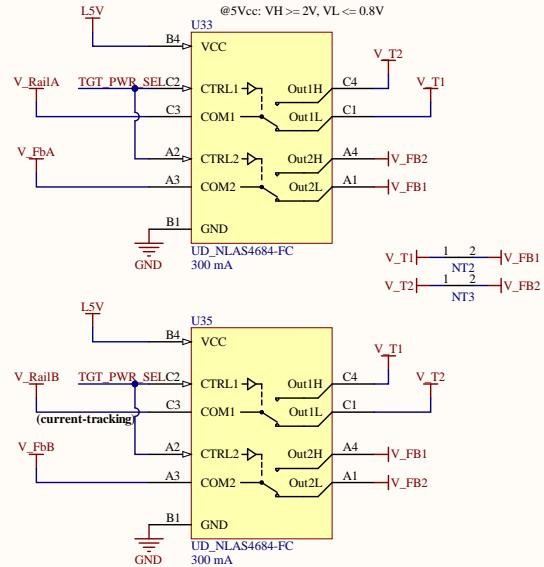
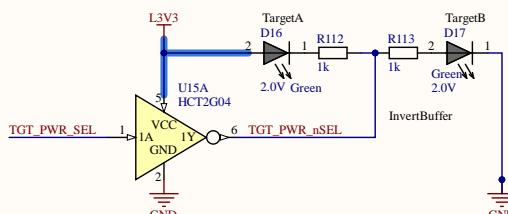
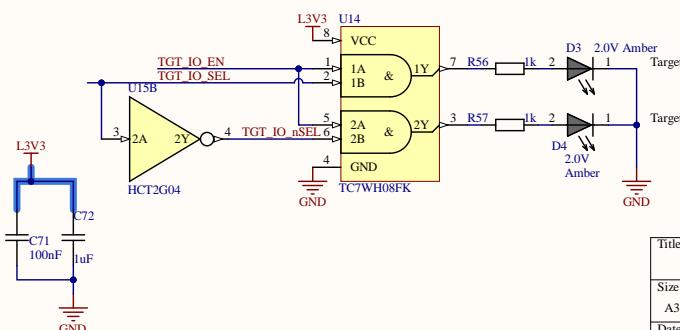
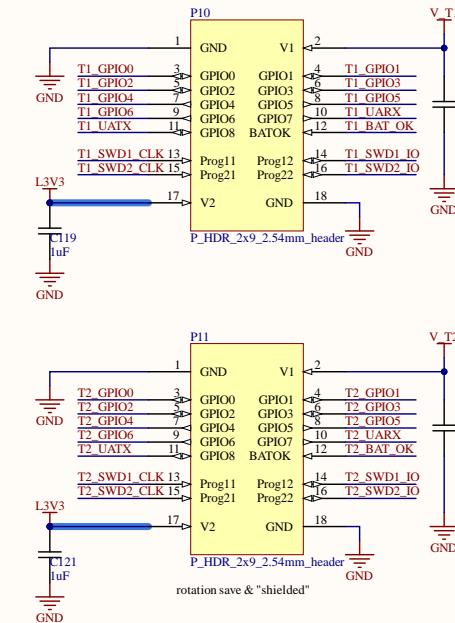
SideA - Pull Ups**Level Translators****SideB - Pull Ups****IO-Voltage - Reverse Routing Switch****IO-Voltage - Buffer**

Title: Shepherd - Level Translators
NES Lab / TU Dresden

Size	Number	Revision
A3		
Date:	11.18.2022	Sheet of shepherd_v2.PnjPcb
File:	C:\Users...\LevelTranslators.SchDoc	Drawn By: Ingmar

Signal Switches

SEL Tar1 Tar2
0 VA VB
1 VB VA
only VB has current-tracking
> so SEL=0 enables tracking of Target 1
only VB has current-tracking
> so SEL=1 enables tracking of Target 2

Power Switches**LED-Feedback for PWR-State****LED-Feedback for IO-State****Target Ports**

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:

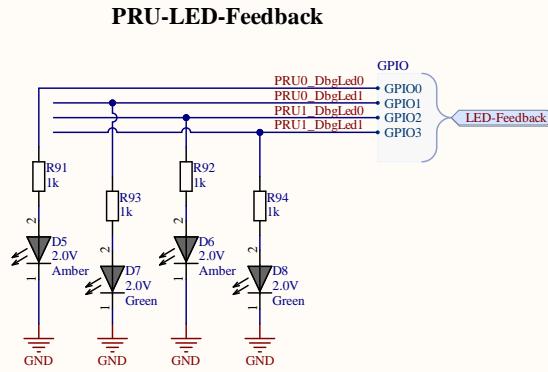
Target Switches	300mA
3V3 (unmonitored)	250mA
V_Tar -> OPA#388 VoltageBuffers source	30-60mA, current measurement up to 50mA

Programming Target:

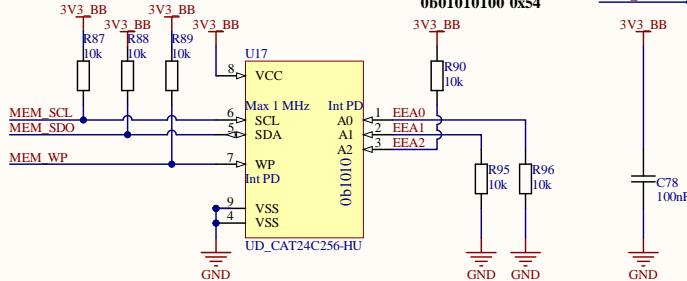
SWD	-> nRF52, STM32L4
SBW	-> MSP430, MSP432, CC430
SBW-TDIO	-TCK (nRST/NMI)

Title Shepherd - Target Interface NES Lab / TU Dresden		
Size A3	Number	Revision
Date: 11.18.2022	Sheet of shepherd_v2.PnjPcb	
File: C:\Users\...\Targets.SchDoc	Drawn By: Ingmar	

A



Calibration-EEPROM



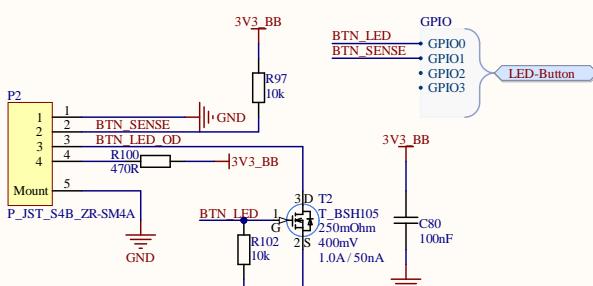
Calibration_Storage

I2C
MEM_SCL
MEM_SDO
MEM_WP
SCL
SDO
WP

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

Local Control Button

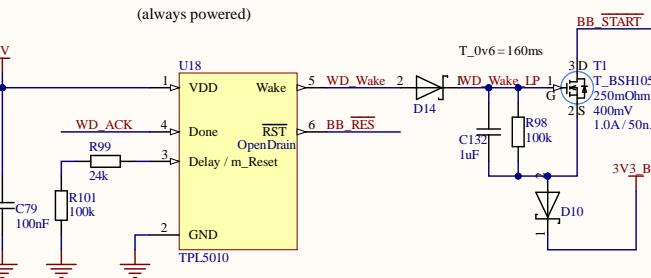


Note: compatible to HWRev1.x
(the JST-Footprint is flipped there)

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
BB_START
BB_RES
Sys_WAKE
Sys_RESET
WD_ACK
• WD_RST

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 asks 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 preferred, but both functions are only triggered ONCE without interaction. So if the BB gets woken but fails to boot then it will never be a reset.

Title Shepherd - Misc NES Lab / TU Dresden		
Size A4	Number	Revision
Date: 11.18.2022		Sheet of shepherd_v2.PriPcb
File: C:\Users\...\Misc.SchDoc		Drawn By: Ingmar

