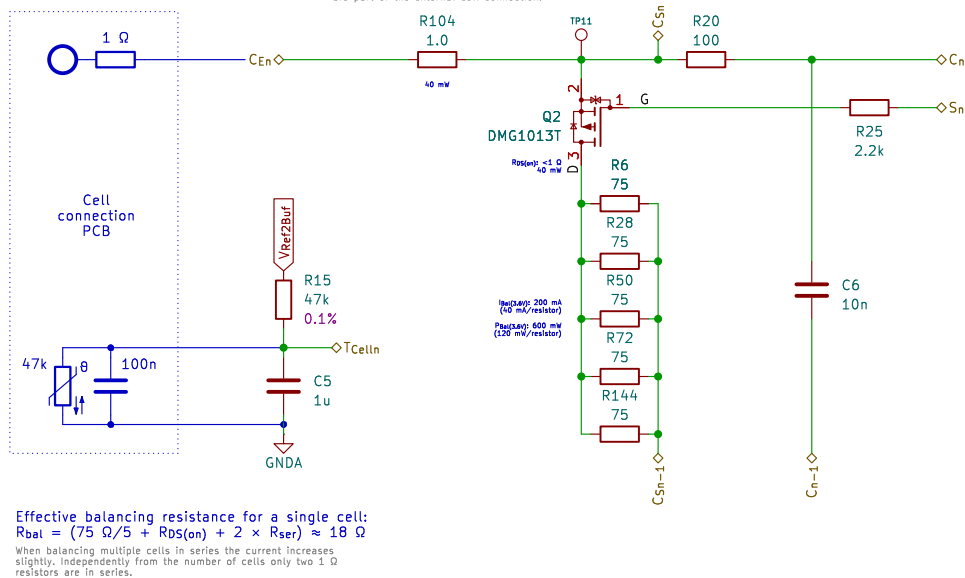


Use external 1 Ω resistor only if jumpers are assembled on this board. ↔ 1 Ω series resistors are used to check if balancing is functional. Assemble jumpers if these resistors are part of the external cell connection.



Improper use of batteries and high currents can lead to physical damage as well as material damage. All parts of this project may contain potentially dangerous errors and are published without assuming liability for any results. In slightest doubt, have your project checked by somebody qualified to do so.

Frank Bättermann ([frank /at/ ich-war-hier.de](mailto:frank@ich-war-hier.de))

Sheet: /CVTIN2/
 File: cvtin.kicad_sch

CERN-OHL-S
 2.0

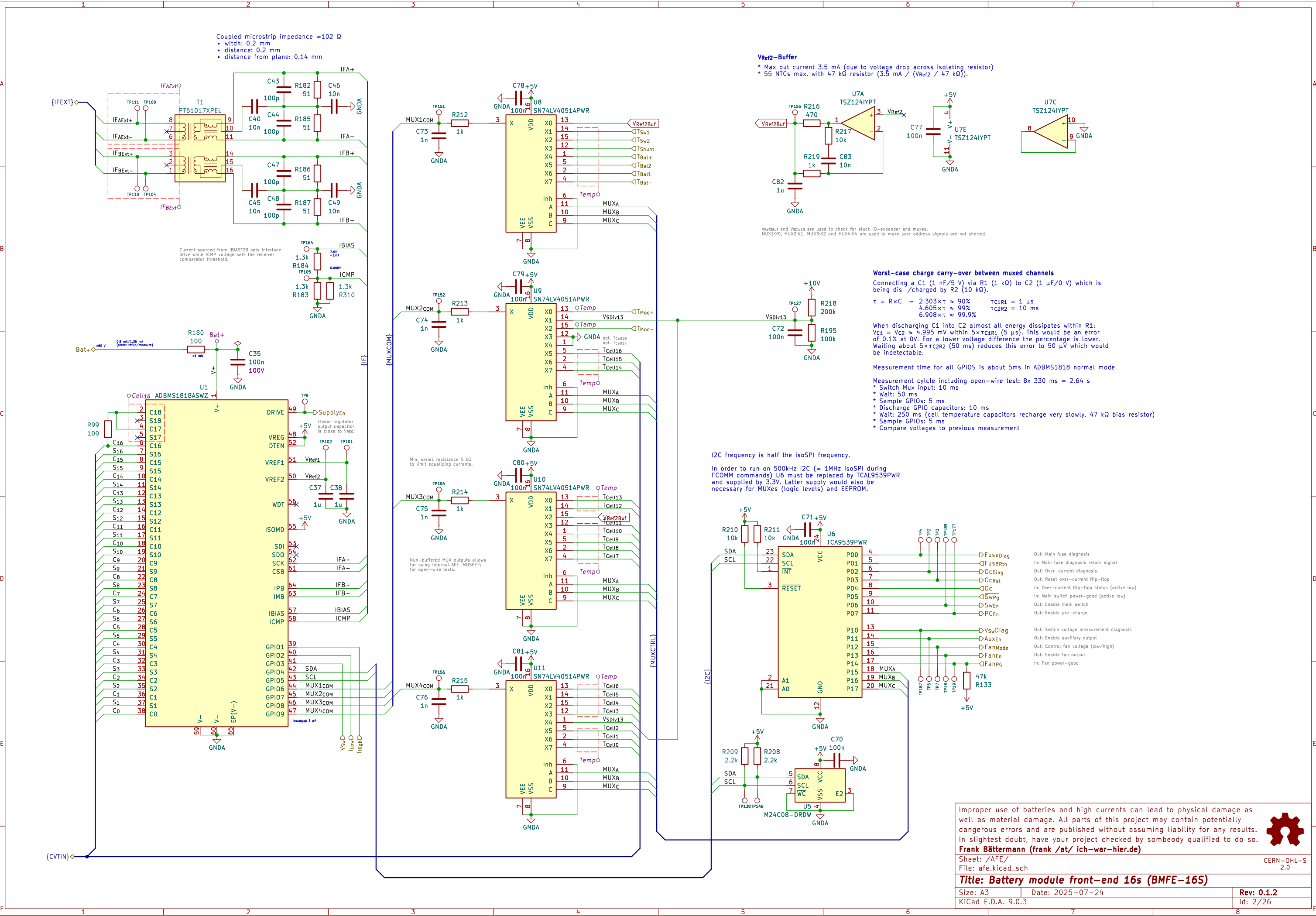
Title: Battery module front-end 16s (BMFE-16S)

Size: A5
 KiCad E.D.A. 9.0.3

Date: 2025-07-24

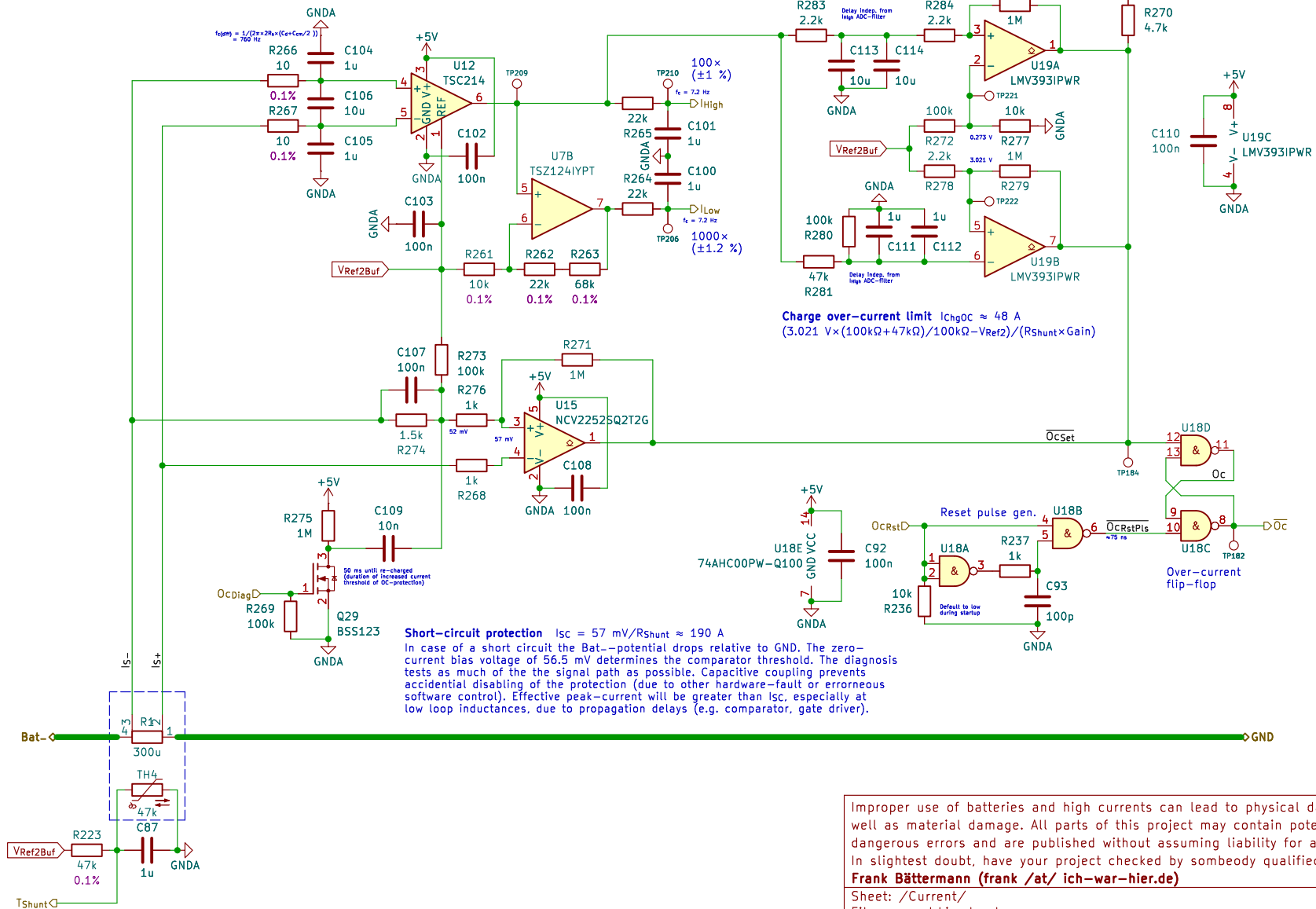
Rev: 0.1.2
 Id: 5/26





Current measurement

Dual-range current measurement with $0\text{ A} = V_{\text{Ref2}}$. Measurement ranges are determined by ADC input range, current shunt and amplification. Charge current is mapped to $V_{\text{Ref2}} \pm 5\text{ V}$ (positive values), discharge current to $V_{\text{Ref2}} - 0\text{ V}$ (negative values).
Theoretical ranges: $I_{\text{High}}: -100..66.7\text{ A}$ (discharge/charge), $I_{\text{Low}}: -10..6.67\text{ A}$



Improper use of batteries and high currents can lead to physical damage as well as material damage. All parts of this project may contain potentially dangerous errors and are published without assuming liability for any results. In slightest doubt, have your project checked by somebody qualified to do so.
Frank Bättermann (frank /at/ ich-war-hier.de)

Sheet: /Current/
File: current.kicad_sch

CERN-OHL-S
2.0

Title: Battery module front-end 16s (BMFE-16S)

Size: A4
KiCad E.D.A. 9.0.3

Date: 2025-07-24

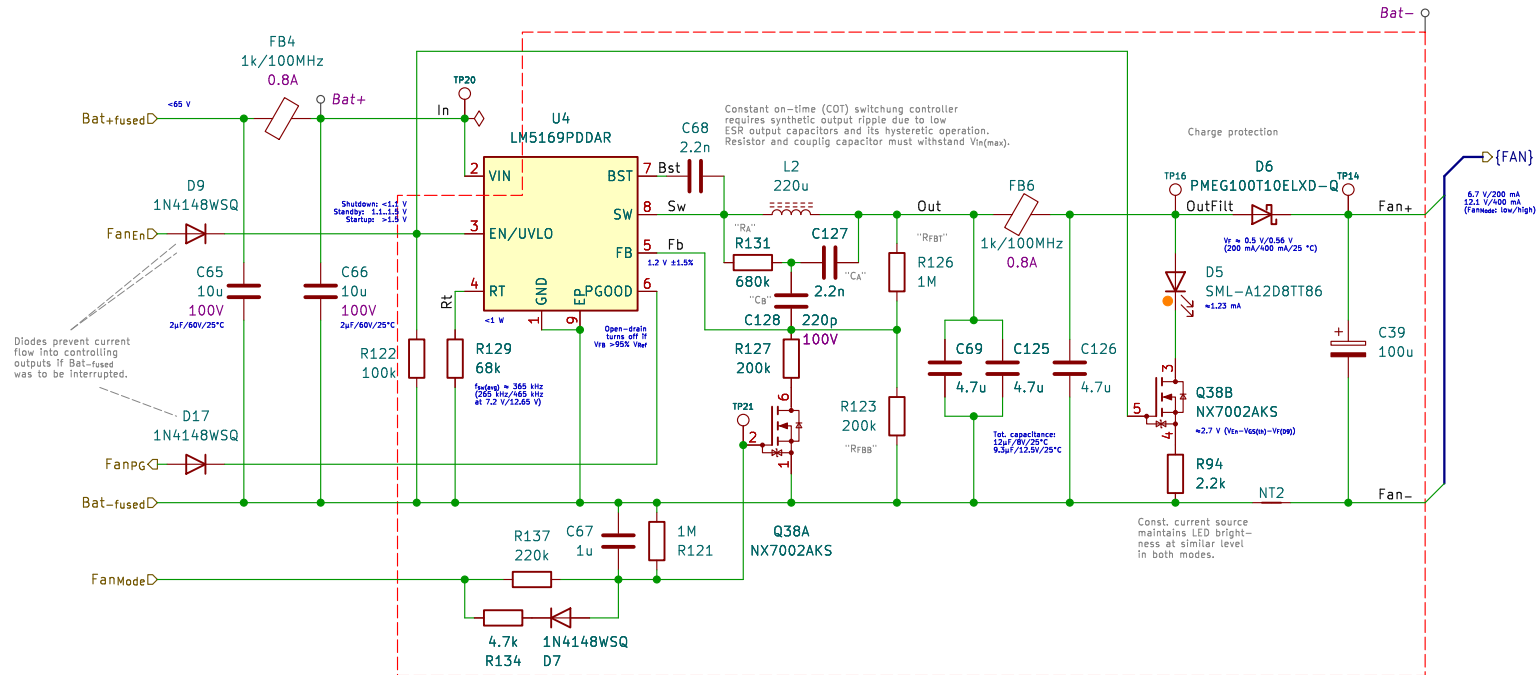
Rev: 0.1.2

Id: 24/26



Fan output (non-isolated)

Battery current (examples):
 $200 \text{ mA} \times 7.2 \text{ V} \div 76\% \approx 1.9 \text{ W} \rightarrow \approx 37 \text{ mA}/51.2 \text{ V}$
 $400 \text{ mA} \times 12.65 \text{ V} \div 85\% \approx 6.0 \text{ W} \rightarrow \approx 116 \text{ mA}/51.2 \text{ V}$



Gate voltage slope limiting to prevent the DCDC to enter current limiting/short-circuit protection when switching from low to high output voltage.

LM5169:

$$V_{out} = V_{Ref} \times (R_{FBT} / R_{FBB} + 1)$$

$$f_{sw} = V_{out} \times 2.5 \times 10^9 / R_T$$

Inductor calculation:

Assume $\Delta I_L = I \times 40\% \approx 80 \text{ mA}/160 \text{ mA}$, $V_{in} = 65 \text{ V}$
 $L = V_{out} / (f_{sw} \times \Delta I_L) \times (1 - V_{out}/V_{in}) \approx 302 \mu\text{H}/137 \mu\text{H} \rightarrow 220 \mu\text{H}$ (compromise)
 $\Delta I_L = V_{out} / (f_{sw} \times L) \times (1 - V_{out}/V_{in}) \approx 110 \text{ mA}/100 \text{ mA}$
 $I_{L(pk)} = I_{out} + \Delta I_L / 2 \approx 255 \text{ mA}/450 \text{ mA}$

Output capacitor calculation:

Assume $\Delta V_{out} = 144 \text{ mV}/253 \text{ mV}$ (2 % V_{out} drop on current transient)
 $C_{out} > L \times (I_{out} + \Delta I_L / 2)^2 \div (2 \times \Delta V_{out} \times V_{out}) \approx 6.9 \mu\text{F}/7.0 \mu\text{F}$
 $V_r \approx \Delta I_L \div (8 \times f_{sw} \times C_{out}) \approx 43 \text{ mV}/30 \text{ mV}$

Ripple network calculation (type-3):

Assume $V_{in(min)} = 40 \text{ V}$
 $CA > 10 \div (f_{sw} \times R_{FBB} \parallel R_{FBT}) \approx 415 \text{ pF}/237 \text{ pF} \rightarrow 2.2 \text{ nF}$ (already used elsewhere)
 $RA \approx (V_{in} - V_{out}) \times V_{out} \div (20 \text{ mV} \times V_{in} \times f_{sw} \times CA) \approx 506 \text{ k}\Omega/740 \text{ k}\Omega \rightarrow 680 \text{ k}\Omega$
 $CB \approx 50 \mu\text{s} \div (3 \times R_{FBT}) \approx 167 \text{ pF} \rightarrow 220 \text{ pF}$ (already used elsewhere)

Simulation shows $\geq 14.7 \text{ mV}$ feedback ripple at $V_{in(min)}$ and $V_{out(max)}$.
 According to the datasheet 12 mV shall be the very minimum at $V_{in(min)}$.

Improper use of batteries and high currents can lead to physical damage as well as material damage. All parts of this project may contain potentially dangerous errors and are published without assuming liability for any results. In slightest doubt, have your project checked by somebody qualified to do so.
Frank Bättermann (frank /at/ ich-war-hier.de)

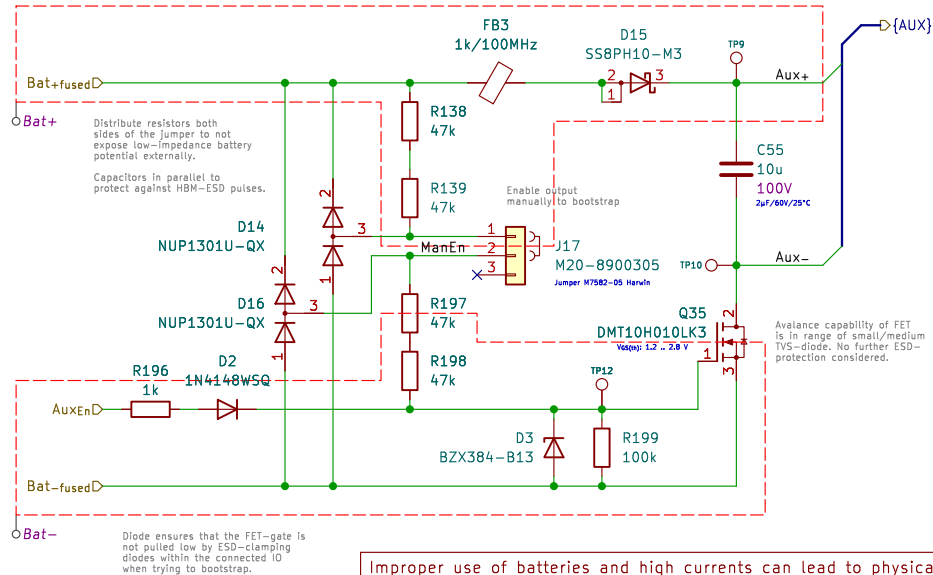


Sheet: /Fan/	CERN-OHL-S
File: fan.kicad_sch	2.0
Title: Battery module front-end 16s (BMFE-16S)	
Size: A4	Date: 2025-07-24
KiCad E.D.A. 9.0.3	Rev: 0.1.2
	Id: 27/26

Auxiliary power output (non-isolated)

Output can be enabled temporarily (!) by setting a jumper. This circumvents the BMS to allow to bootstrap a BMS-controller supplied from this module. After bootstrapping, the AFE can keep it enabled by AuxEn-signal.

Max. assumed output: $3A \times 5V \div 70\% \approx 22W \rightarrow \approx 0.42A$ at 51.2V



Improper use of batteries and high currents can lead to physical damage as well as material damage. All parts of this project may contain potentially dangerous errors and are published without assuming liability for any results. In slightest doubt, have your project checked by somebody qualified to do so.

Frank Bättermann (frank /at/ ich-war-hier.de)

Sheet: /Aux/

File: aux.kicad_sch

CERN-OHL-S
2.0

Title: Battery module front-end 16s (BMFE-16S)

Size: A5

Date: 2025-07-24

Rev: 0.1.2

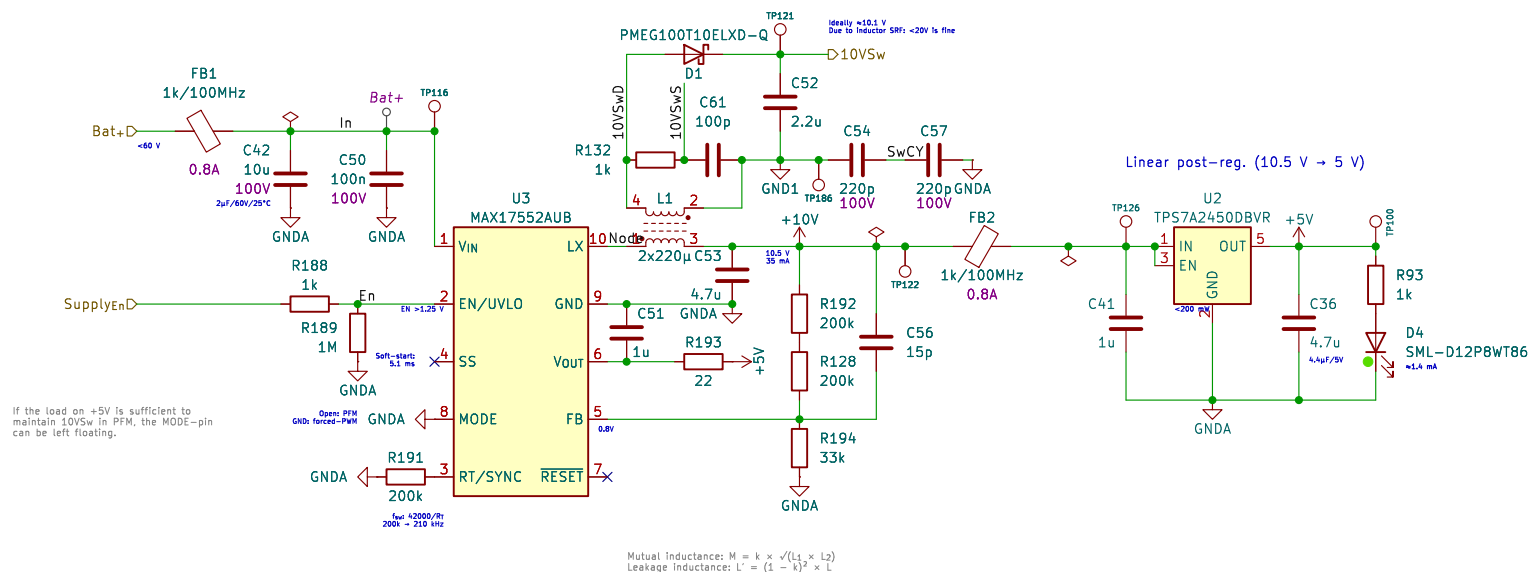
KiCad E.D.A. 9.0.3

Id: 28/26



Switching pre-regulator (60 V → 10.3 V) & Isolated gate driver supply

Isolated supply for gate driver is required to keep the main switch non-conducting in case Mod- is more negative than Bat- (trying to charge). Therefore, the required isolation voltage for the coupled conductor is about $V_{\text{Mod}} - V_{\text{Bat}}$. This voltage cannot be greater than 20–30V because the MOSFETs would avalanche in case of greater external voltages.



Improper use of batteries and high currents can lead to physical damage as well as material damage. All parts of this project may contain potentially dangerous errors and are published without assuming liability for any results. In slightest doubt, have your project checked by somebody qualified to do so.

Frank Bättermann (frank /at/ Ich-war-hier.de)

Sheet: /Supply/
File: supply.kicad_sch

CERN-OHL-S
2.0

Title: Battery module front-end 16s (BMFE-16S)

Size: A4 Date: 2025-07-24

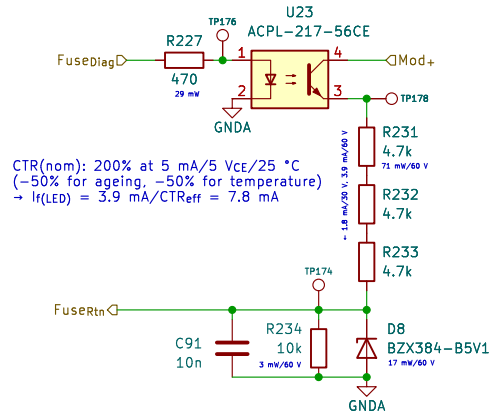
Rev: 0.1.2

KiCad E.D.A. 9.0.3

Id: 22/26



Diagnose the presence/conductivity of a fuse (by sinking current from Mod+) only works if
 * the main-switch is non-conducting,
 * no parallel current-source is connected



Improper use of batteries and high currents can lead to physical damage as well as material damage. All parts of this project may contain potentially dangerous errors and are published without assuming liability for any results. In slightest doubt, have your project checked by somebody qualified to do so.

Frank Bättermann (frank /at/ ich-war-hier.de)

Sheet: /Fuse test/

File: fuse_test.kicad_sch



CERN-OHL-S
2.0

Title: Battery module front-end 16s (BMFE-16S)

Size: A5

Date: 2025-07-24

Rev: 0.1.2

KiCad E.D.A. 9.0.3

Id: 23/26

Active DC-link precharge

I_{avg}: >350 mA, I_{pk}: 550 mA
f_{sw}(nom): 125 kHz (max. at the start of pre-charge process)

