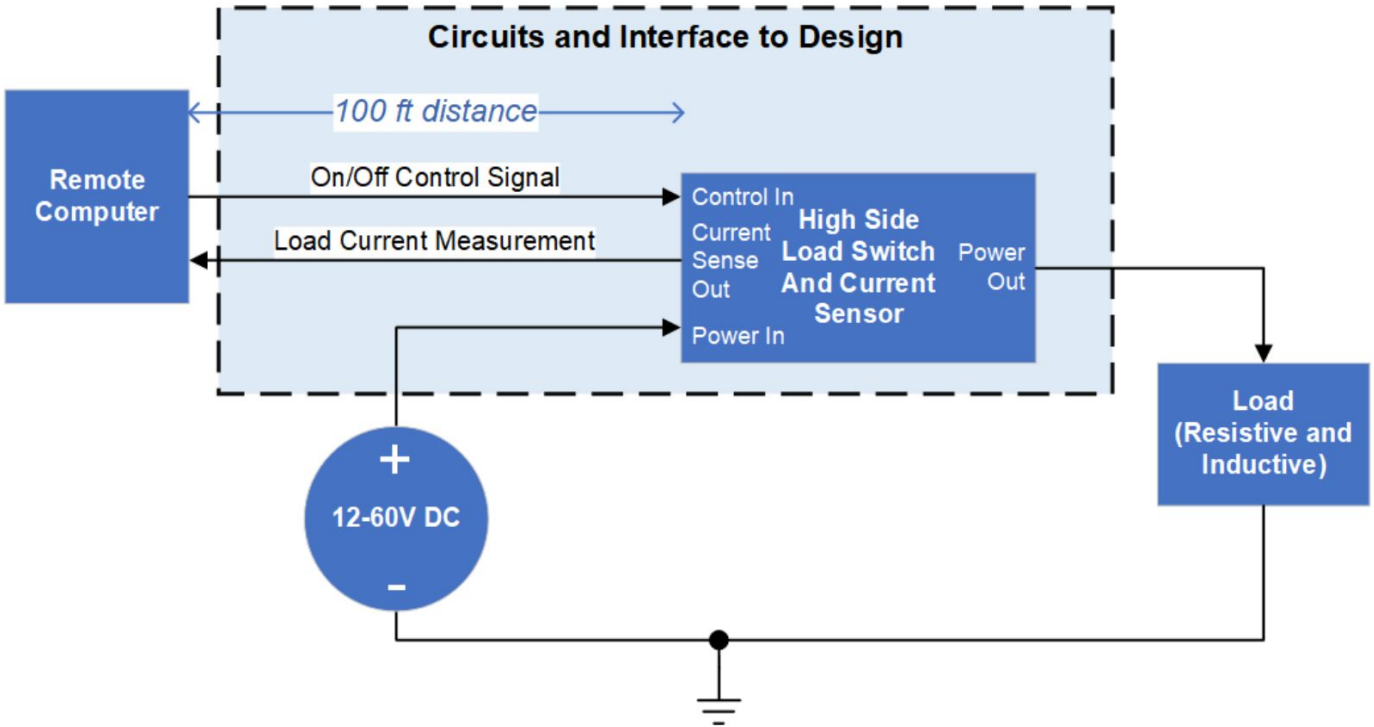
Design Challenge: Remote Load Switch



Power Requirements

Parameter	Value			Units	Note
	Min	Typ	Max		
V_{supply}	12		60	VDC	Voltage of supply to be switched.
I_{load}			10	A	Current into load.
L_{load}			5	mH	Load inductance.
f_{switch}			1	Hz	Continuous switching frequency.

- Probably want to switch high-side with a PMOS so load is at 0V when OFF.
- Inductive load needs flywheel diode for protection. No optimizations required for fast turn-off.
- Should oversize V_{ds} and I_{ds} of switching MOSFET to be safe.
- Gate drive requirements are pretty loose (not doing high frequency switching).

Environmental Requirements

Parameter	Value			Units	Note
	Min	Typ	Max		
$T_{ambient}$	-40		70	°C	Ambient temperature.
p_{atm}	100		10	kPa	Atmospheric pressure.
EMI			Some		Conducted / radiated EMI.
Shock / Vibe			Moderate		Mechanical shock and vibration.

- Most industrial / commercial / automotive components meet the temperature spec.
- Don’t need to qualify for vacuum, but maybe add pressure relief to enclosures?
- Add filters to power supply for reduced EMI in and out.
- Use differential signals, galvanically isolate comms to reduce ground loops.
- Need to be careful with component mass and dimensions, may need potting or celastic on big / dangly stuff, lots of PCB mounting points. Test for vibe modes.

Measurement and Communication Requirements

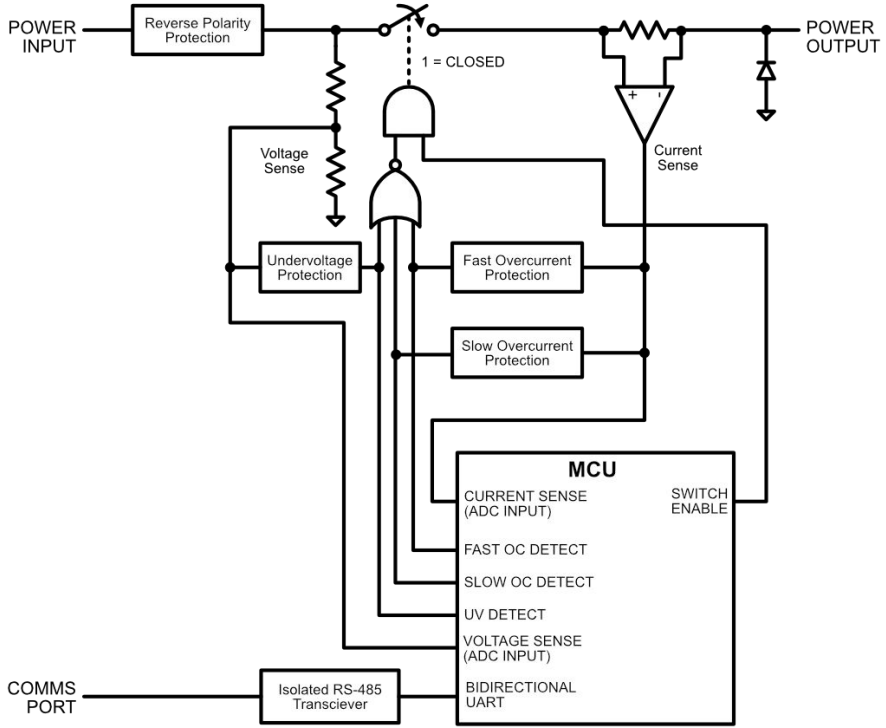
Parameter	Value			Units	Note
	Min	Typ	Max		
d_{comms}			100	ft	Communication link distance.
$e_{current}$	-10		10	mA	Current measurement error.
f_{data}	100			Hz	Data sample and reporting rate.

- Long data link distance, probably need differential signals with decent transceivers. Digitize analog signals for lower noise and simpler combined interface.
- Need pretty high resolution and accuracy for current measurement. Need to pay attention to component tolerances and ADC resolution. Dynamic range is ~1:1000 (12-bit ADC only has 4096 counts, and the last few bits aren't usable).
- Data reporting rate is rather low, could probably get away with UART -> RS-485.

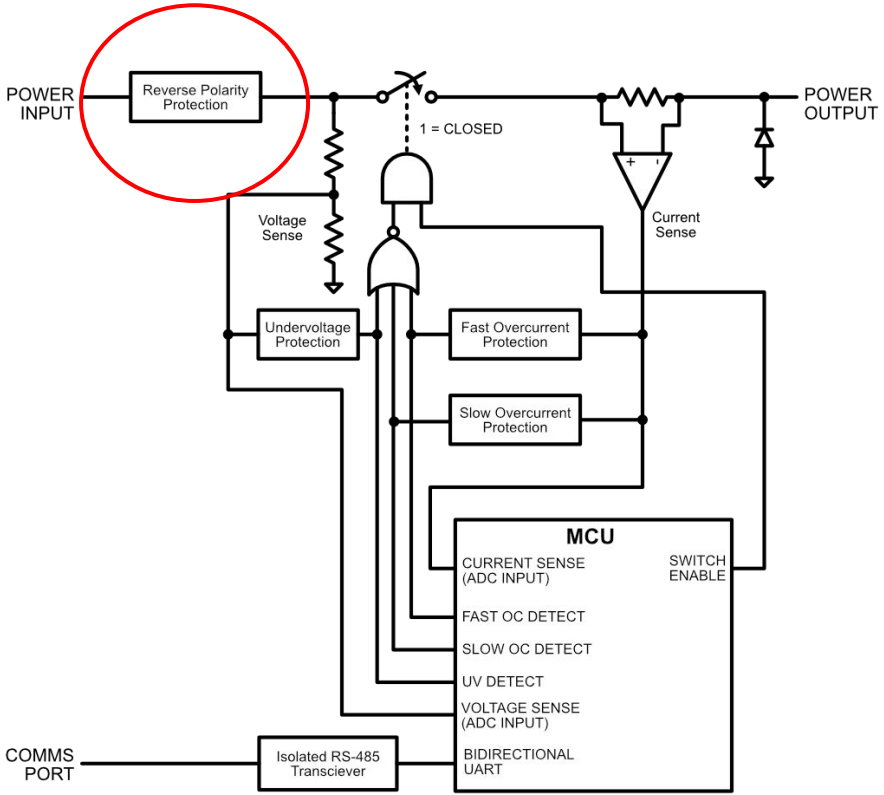
Additional Thoughts

- Power switch needs to be fail-safe and difficult to damage.
  - Reverse polarity protection, undervoltage protection, overcurrent protection.
  - Need overcurrent protection to be fast-acting for short-circuits but compatible with capacitive loads.
  - Unprotected failure modes should result in the switch failing open (load is OFF).
- Switch should self-recover from faults.
- Switch should be able to report fault conditions when / after they occur.
- Switch should be able to report bus voltage.

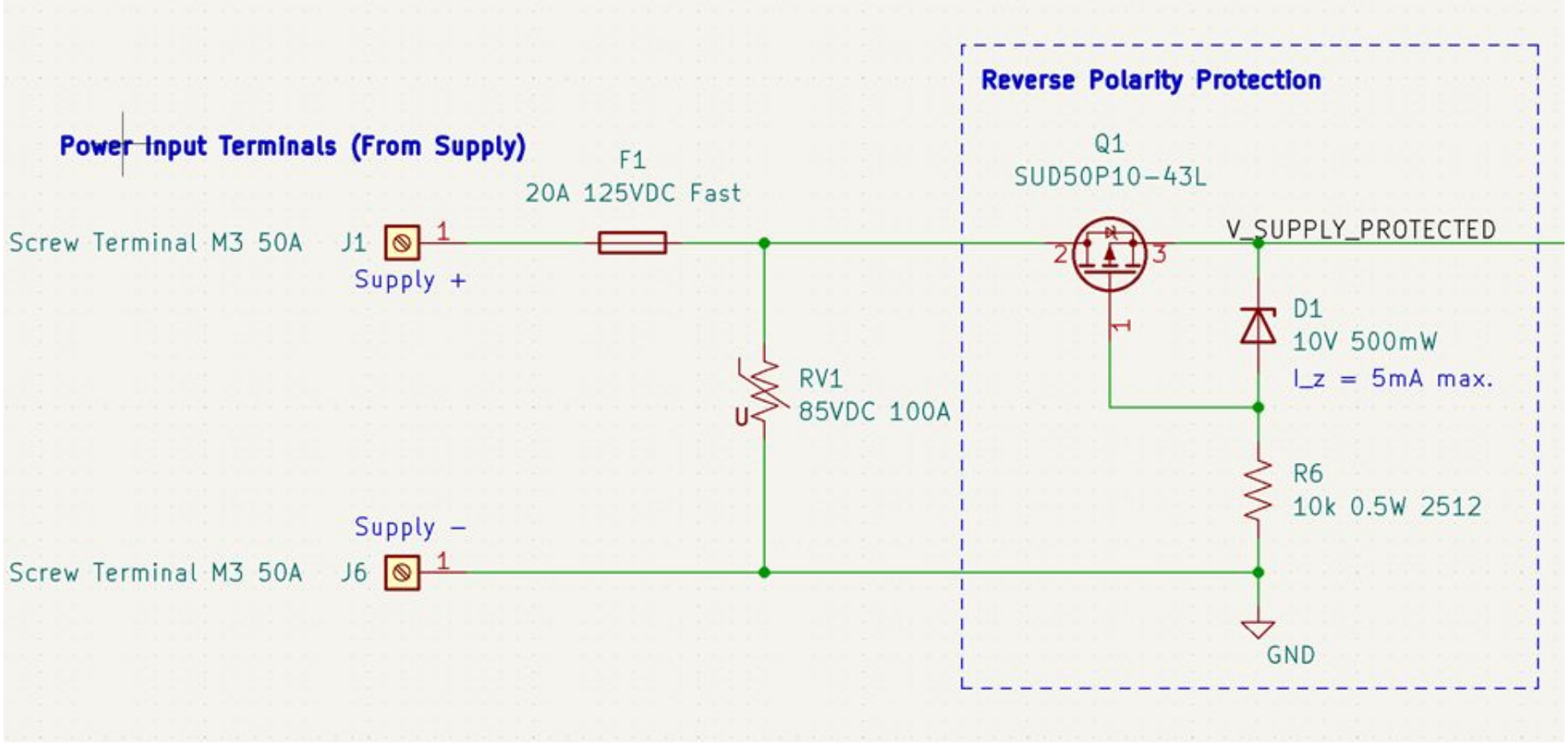
Simplified Block Diagram



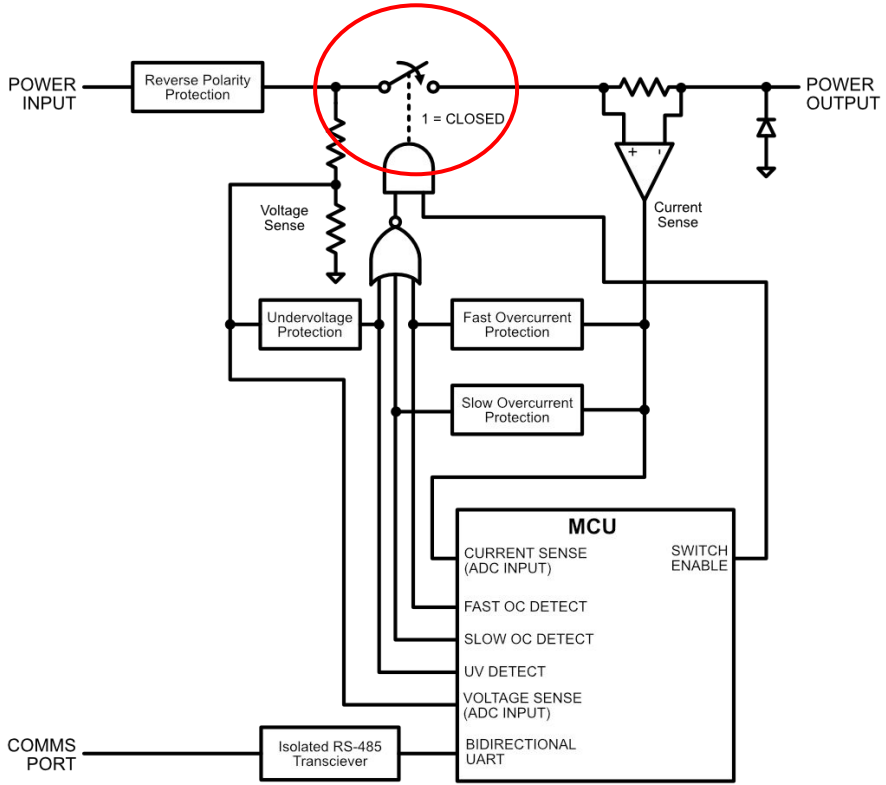
Simplified Block Diagram: Power Input



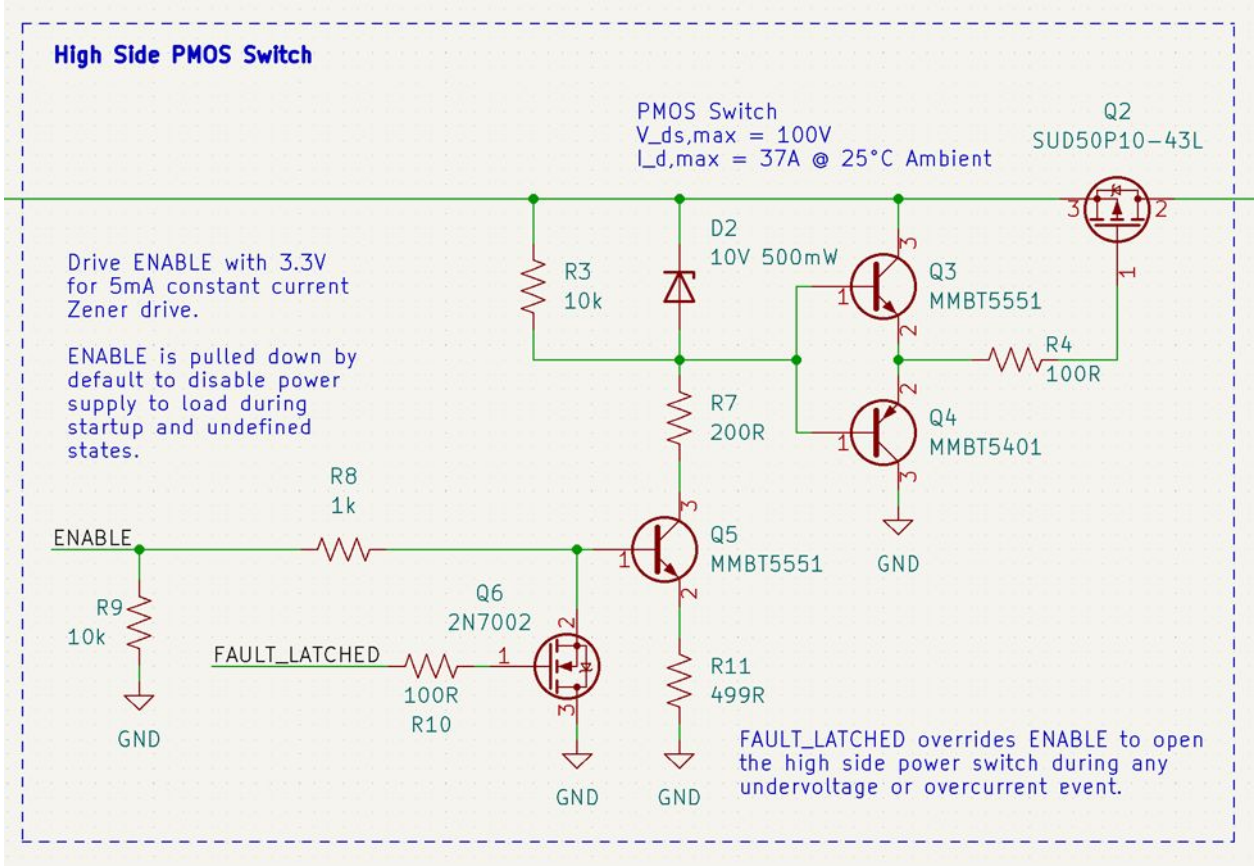
Power Input


Power Input Terminals (From Supply)
Screw Terminal M3 50A
J1
1
Supply +
F1
20A 125VDC Fast
RV1
85VDC 100A
Supply –
Screw Terminal M3 50A
J6
1
Reverse Polarity Protection
Q1
SUD50P10-43L
2
3
1
V_SUPPLY_PROTECTED
D1
10V 500mW
I_z = 5mA max.
R6
10k 0.5W 2512
GND

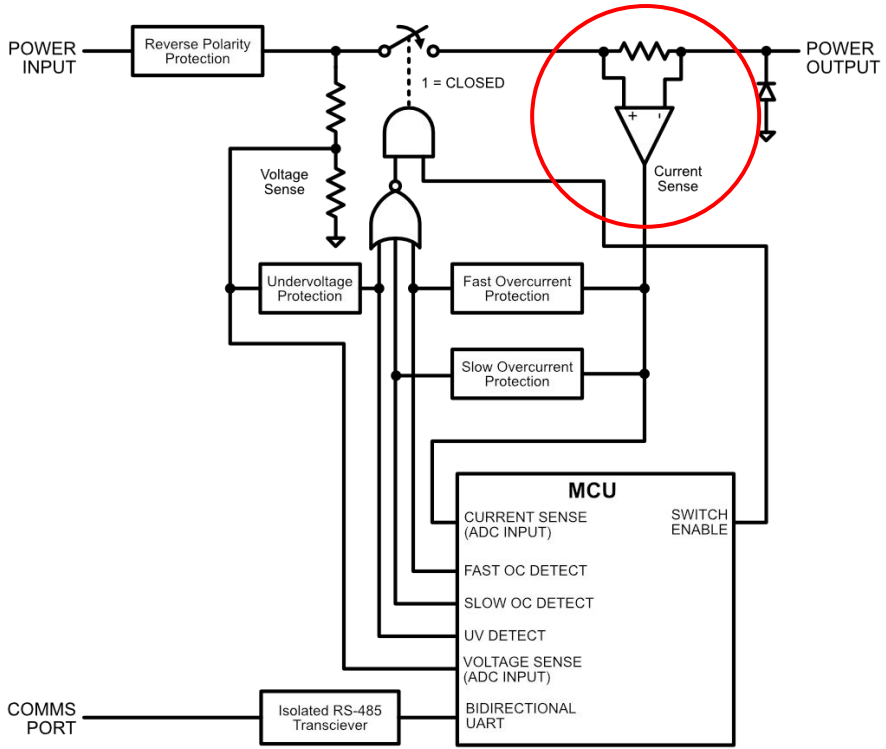
Simplified Block Diagram: Load Switch



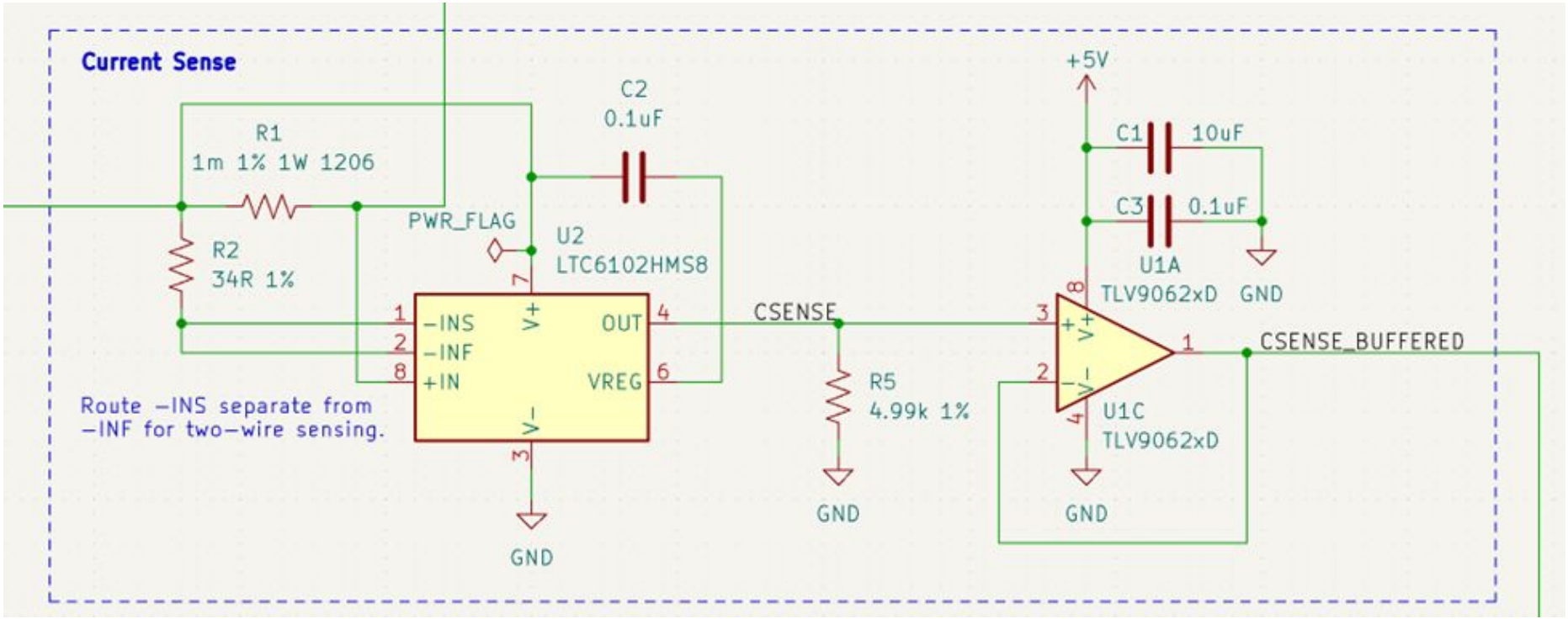
Load Switch


High Side PMOS Switch
PMOS Switch
V_ds,max = 100V
I_d,max = 37A @ 25°C Ambient
Q2
SUD50P10-43L
Drive ENABLE with 3.3V for 5mA constant current Zener drive.
ENABLE is pulled down by default to disable power supply to load during startup and undefined states.
R3
10k
D2
10V 500mW
Q3
MMBT5551
R4
100R
R7
200R
Q4
MMBT5401
GND
R8
1k
ENABLE
Q5
MMBT5551
R9
10k
Q6
2N7002
FAULT_LATCHED
100R
R10
R11
499R
GND
GND
GND
FAULT_LATCHED overrides ENABLE to open the high side power switch during any undervoltage or overcurrent event.

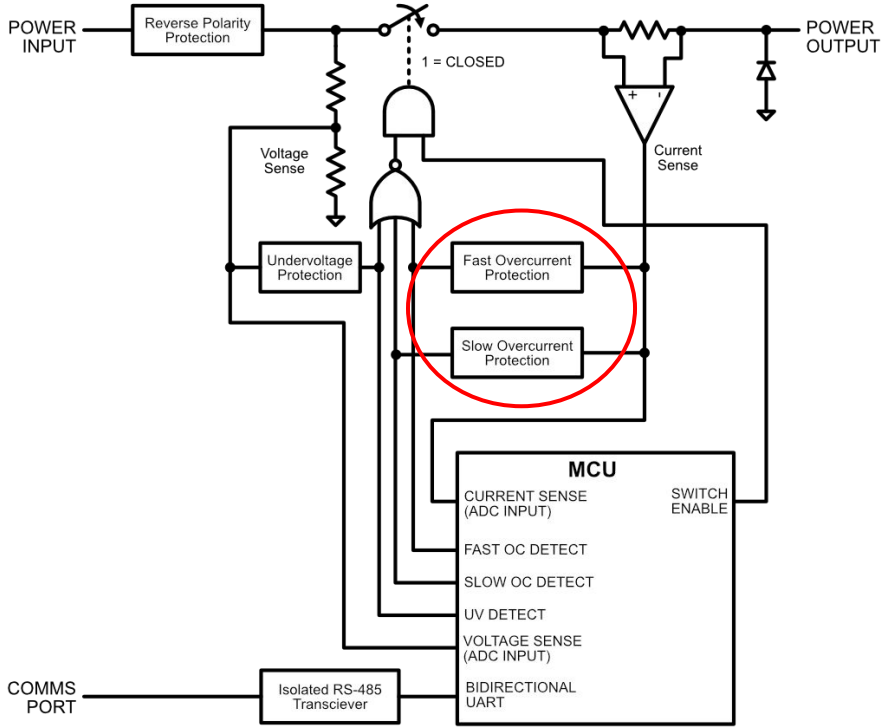
Simplified Block Diagram: Current Sense



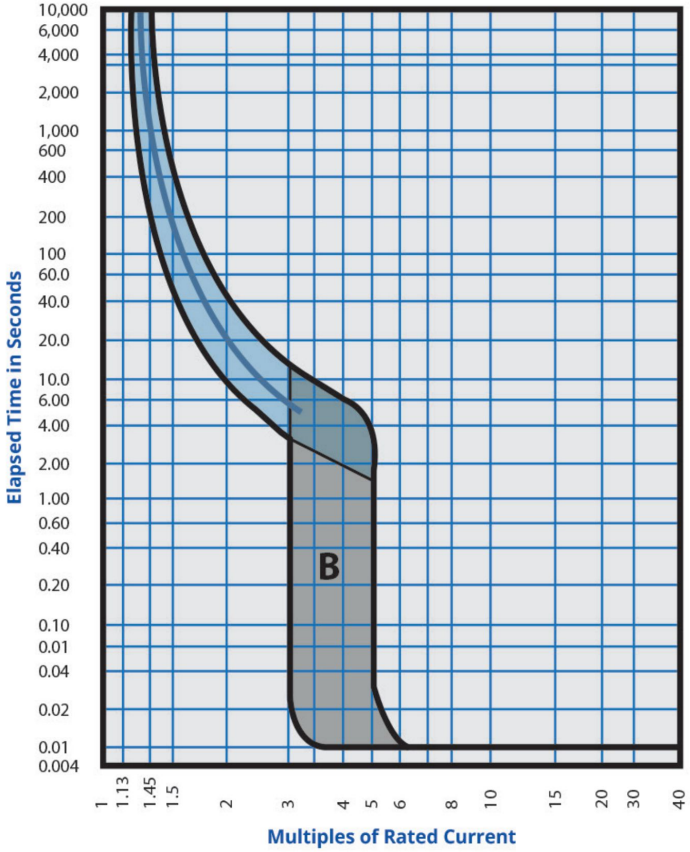
Current Sense

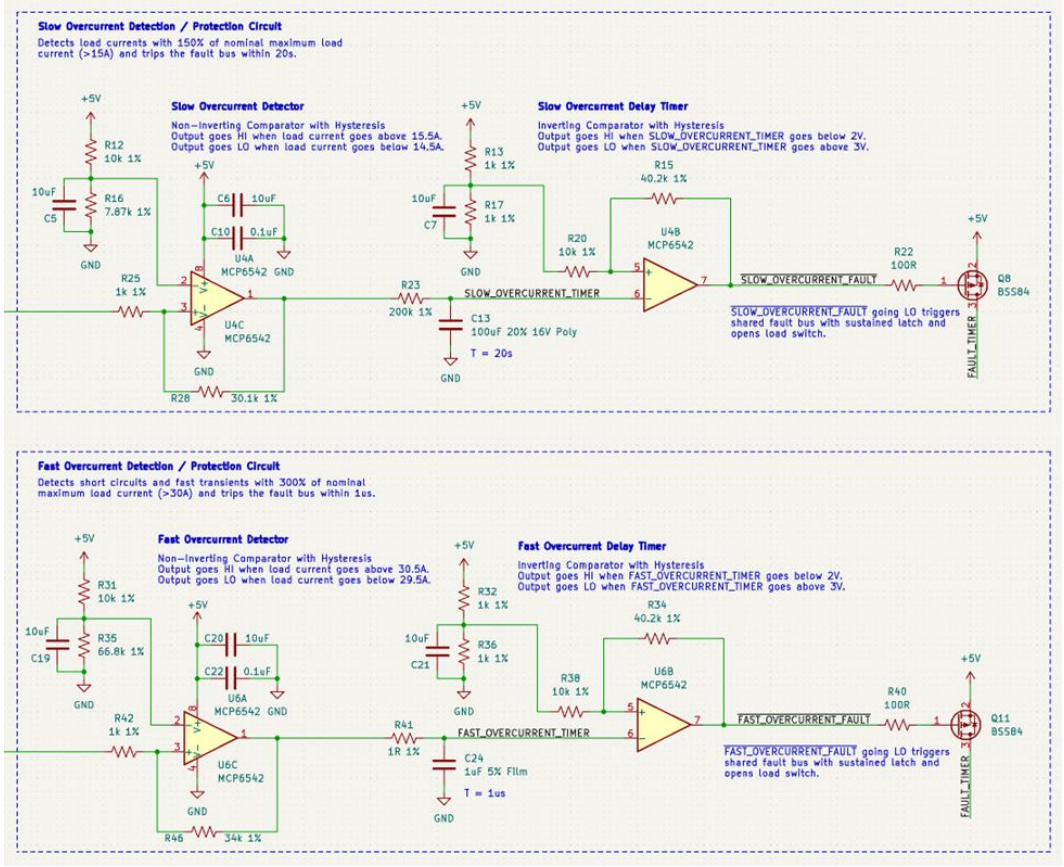


Simplified Block Diagram: Overcurrent Detection

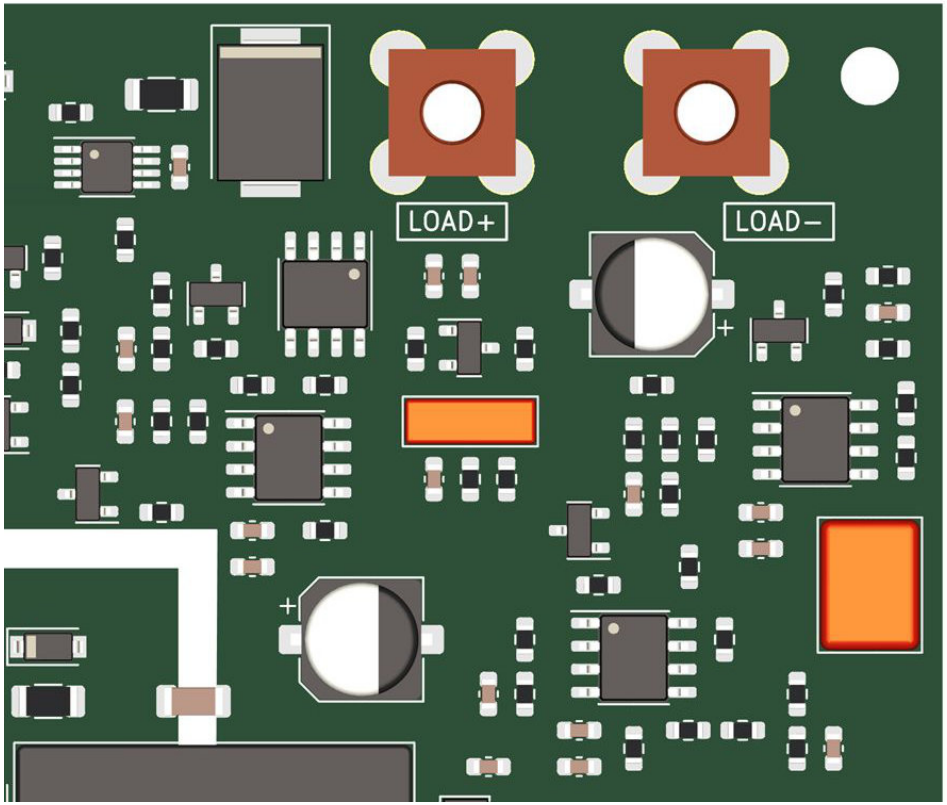


Overcurrent Detection

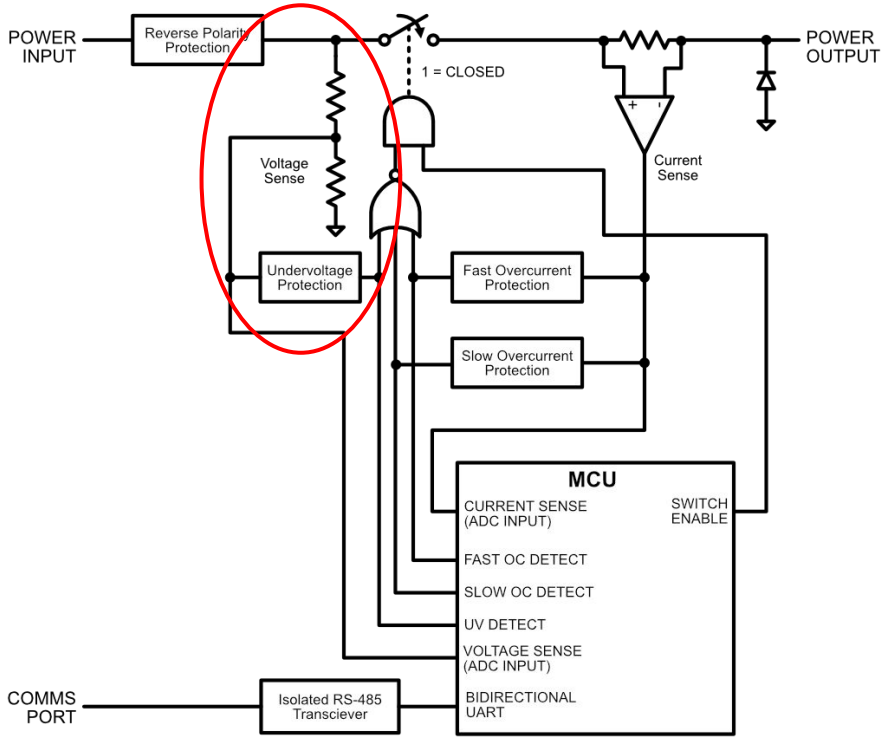




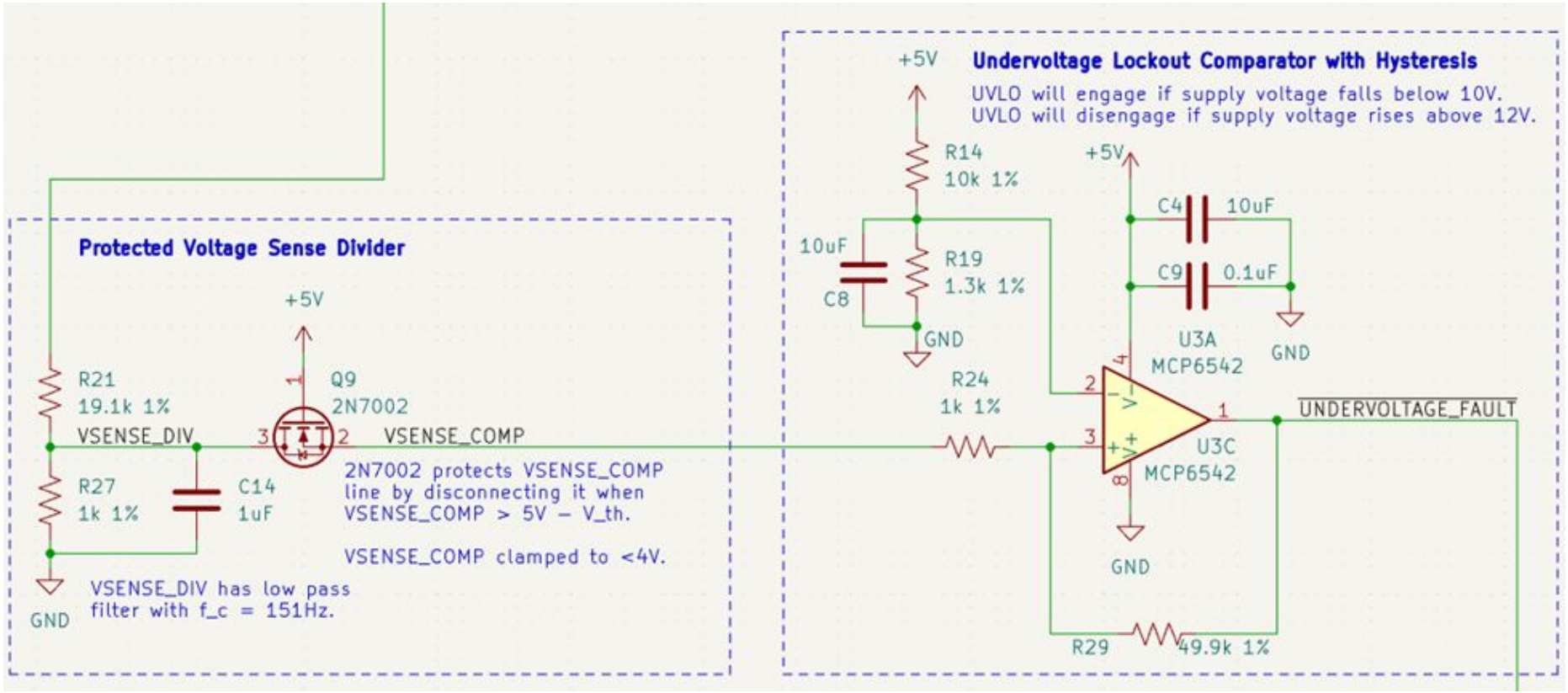
Overcurrent Detection: PCB Layout



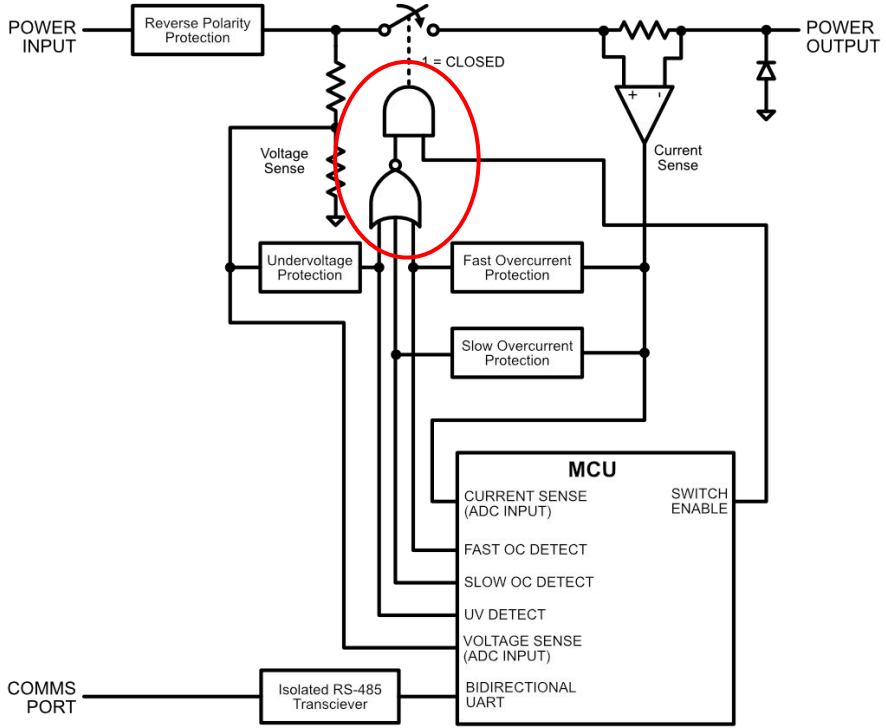
Simplified Block Diagram: Voltage Sense / UVLO



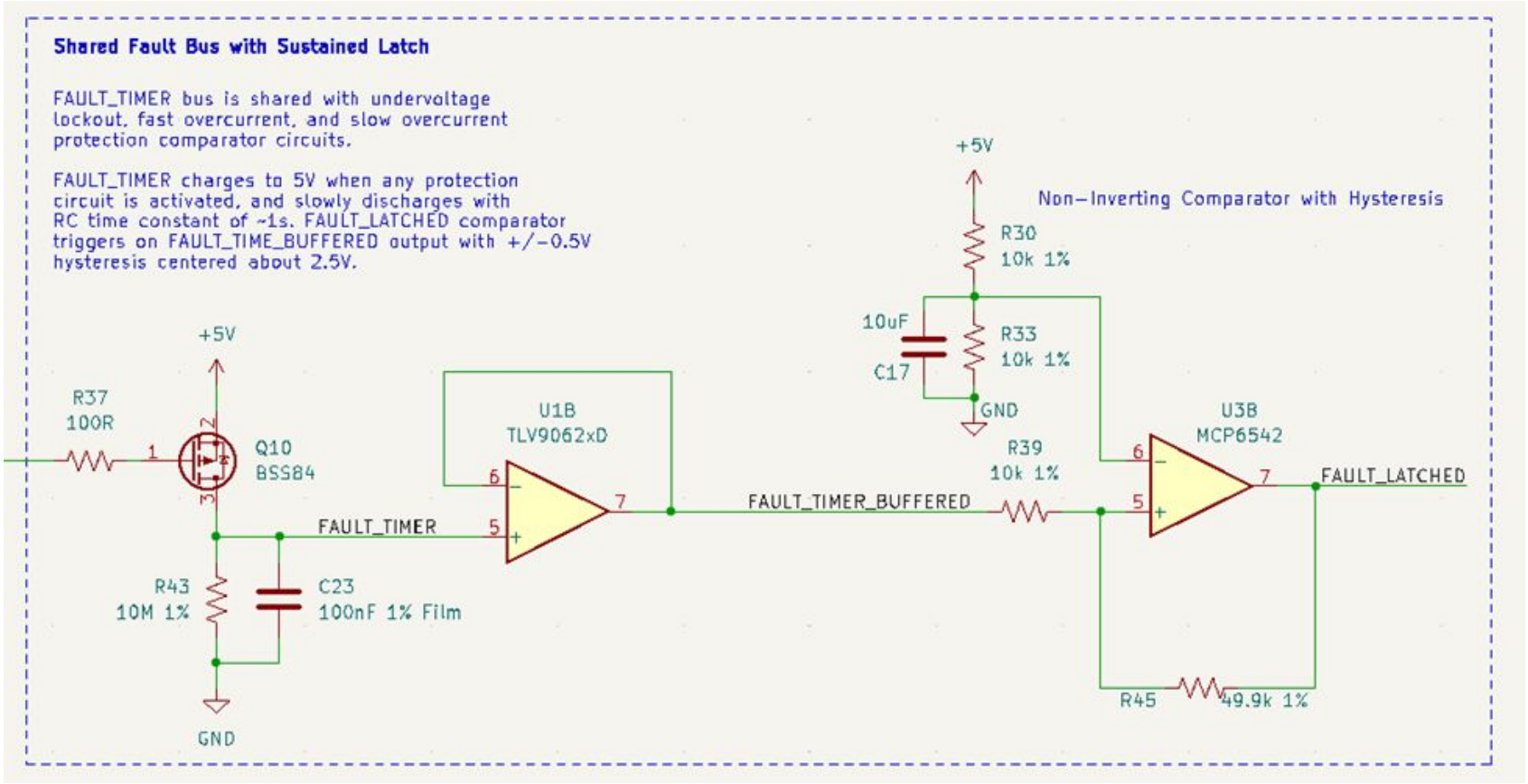
Voltage Sensing and Undervoltage Detection



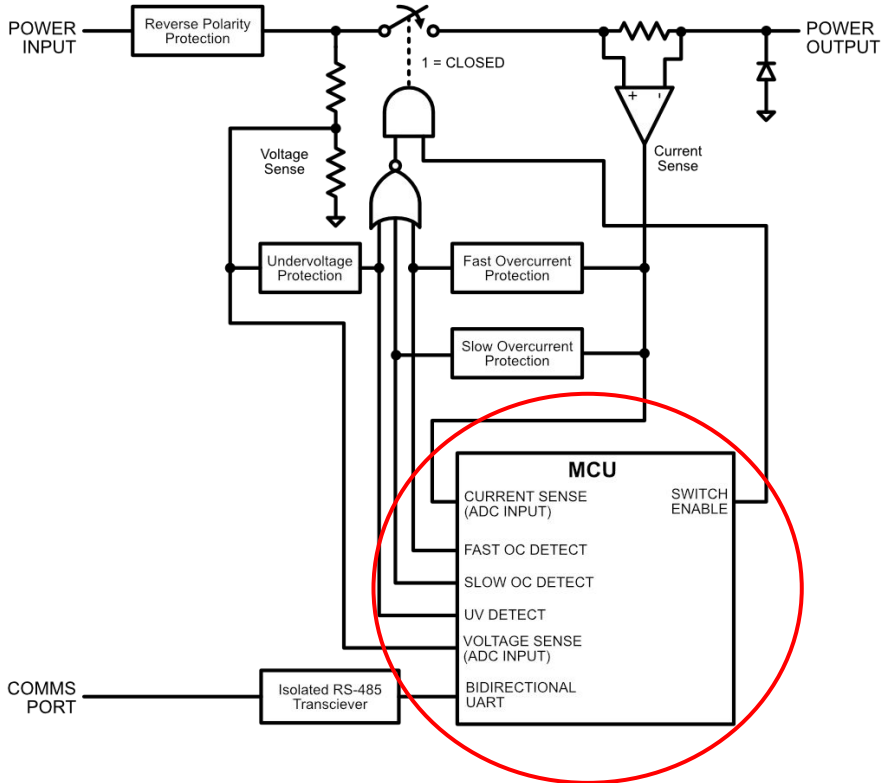
Simplified Block Diagram: Fault Bus



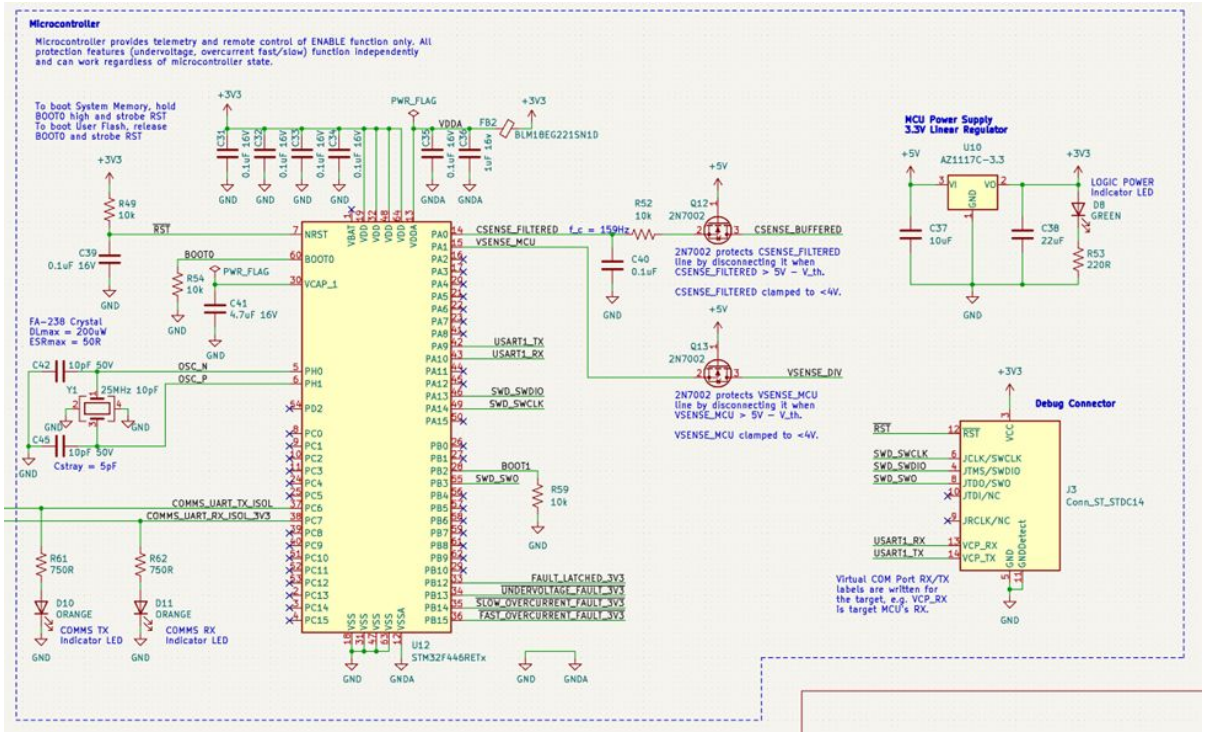
Shared Fault Bus with Sustained Latch

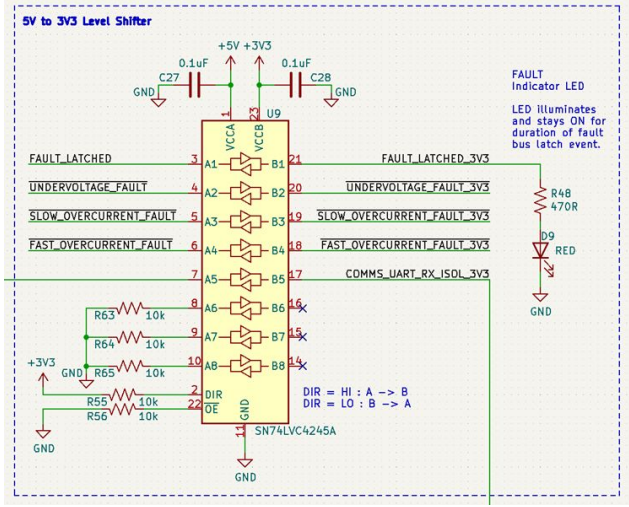


Simplified Block Diagram: Microcontroller

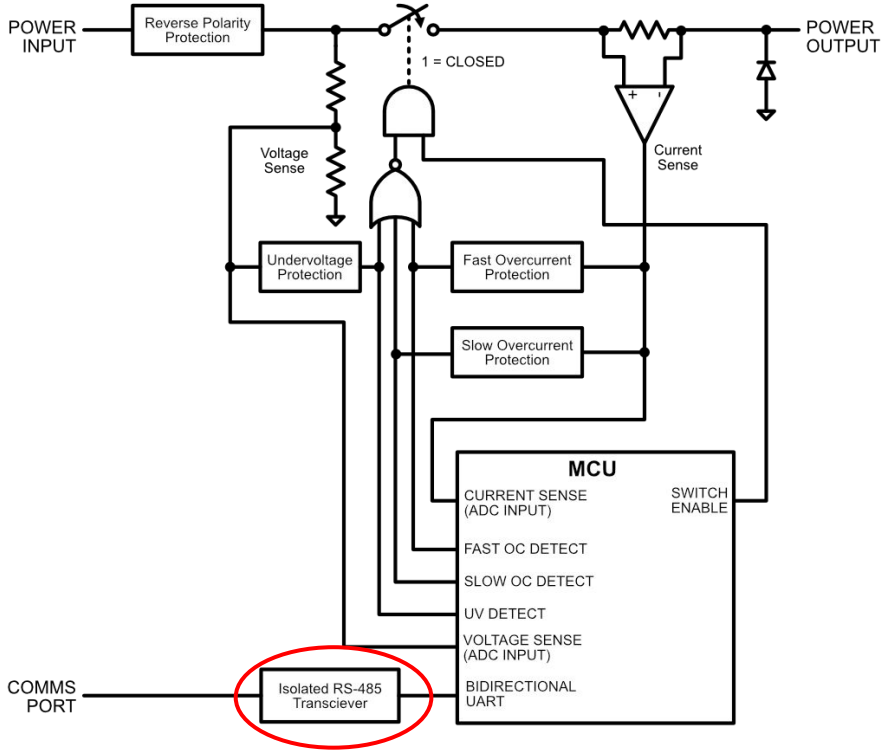


Microcontroller

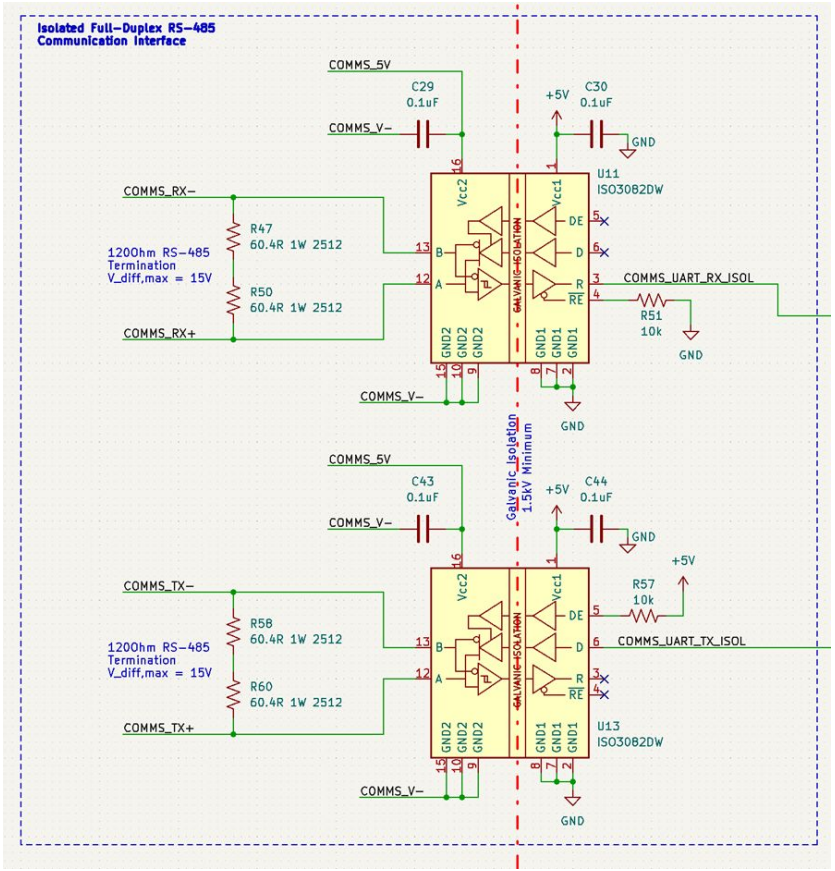




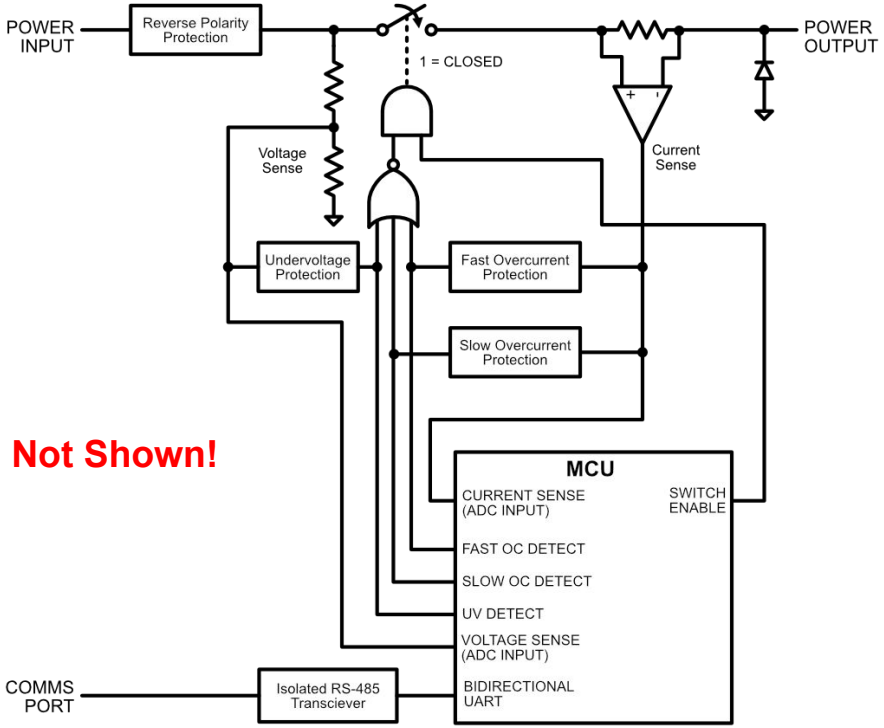
Simplified Block Diagram: RS-485 Transciever



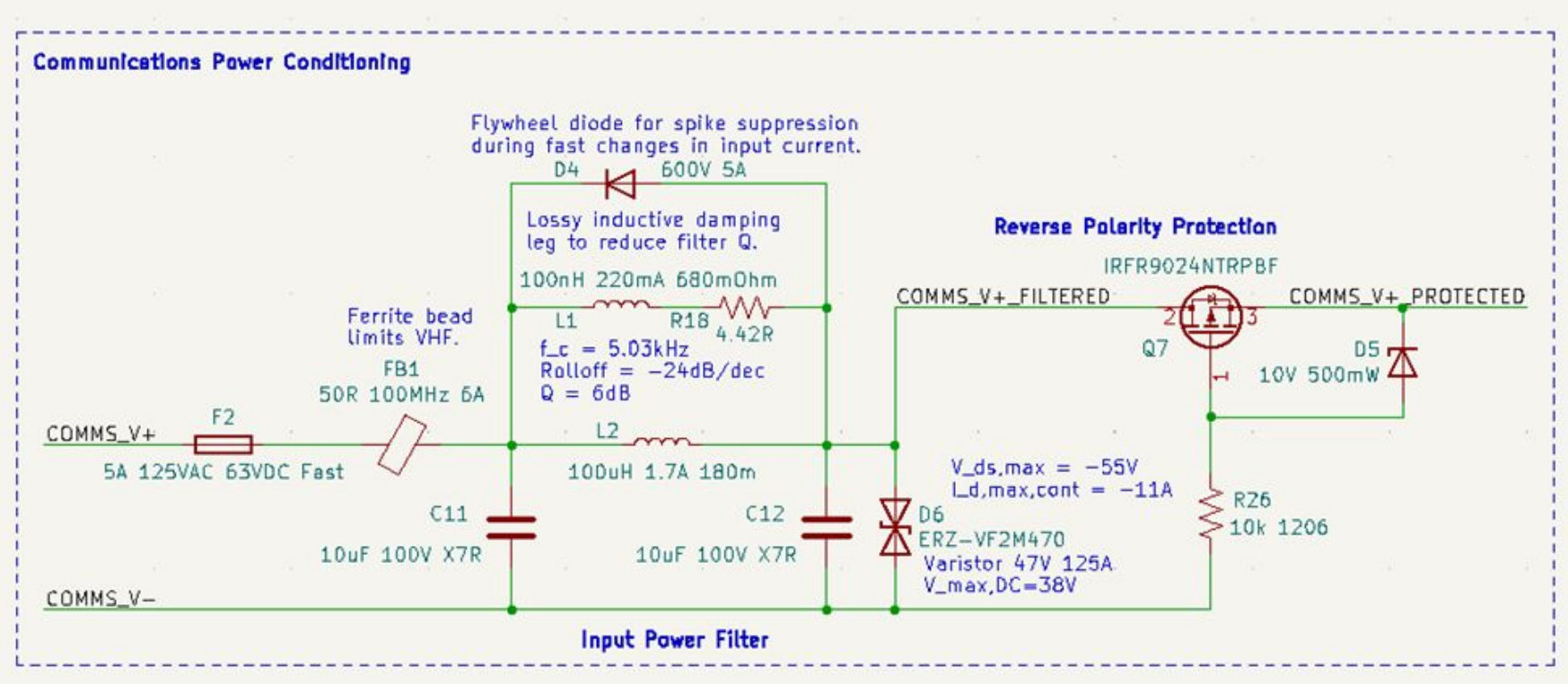
Isolated RS-485 Comms Interface



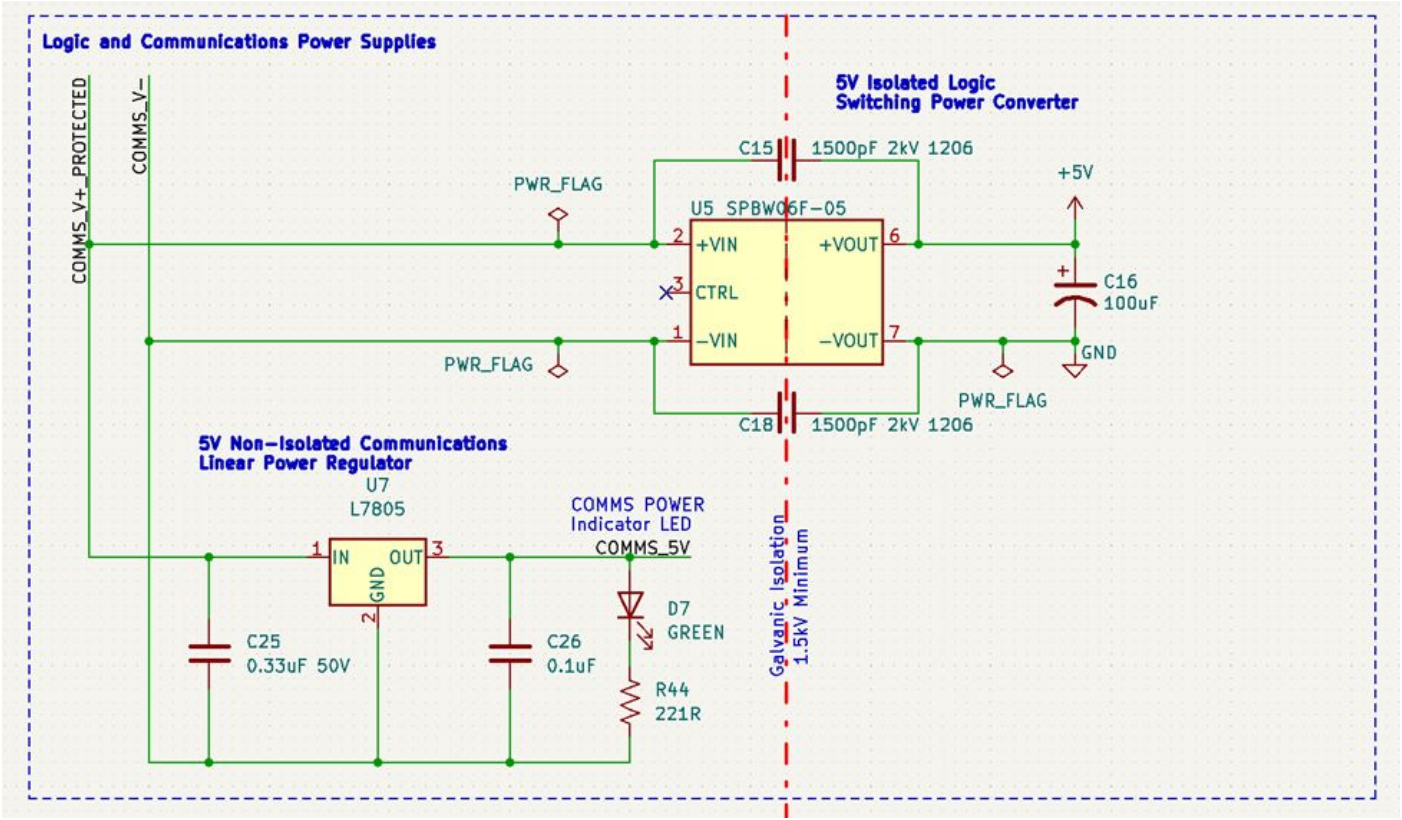
Simplified Block Diagram: Power Supplies



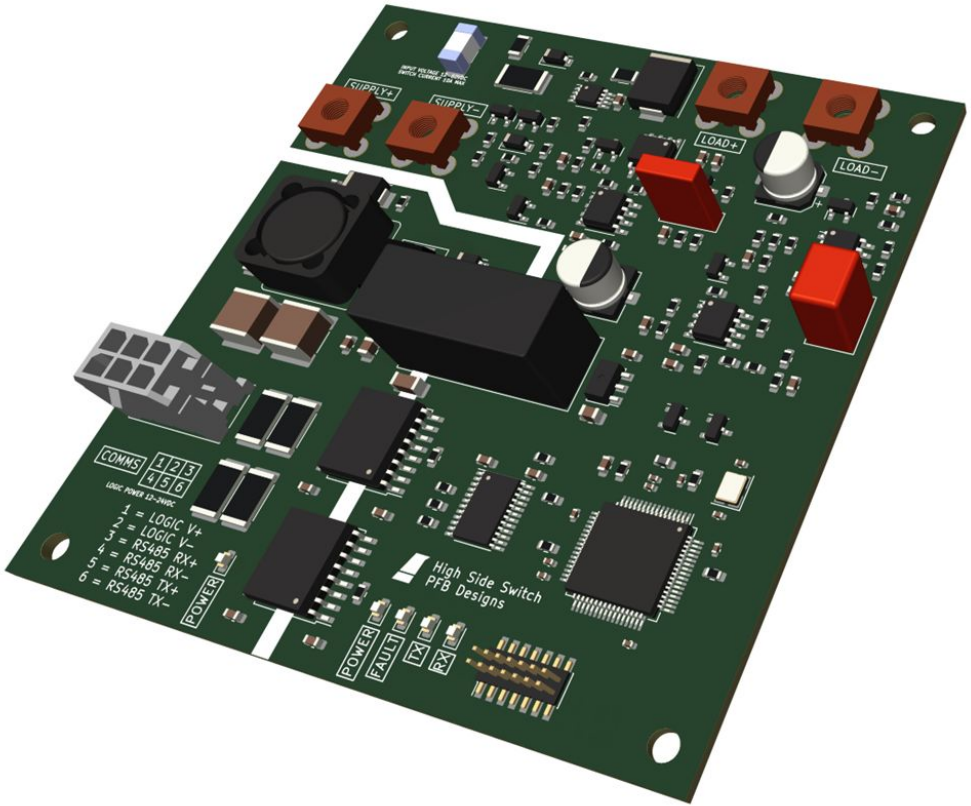
Power Supply Protection and Filtering

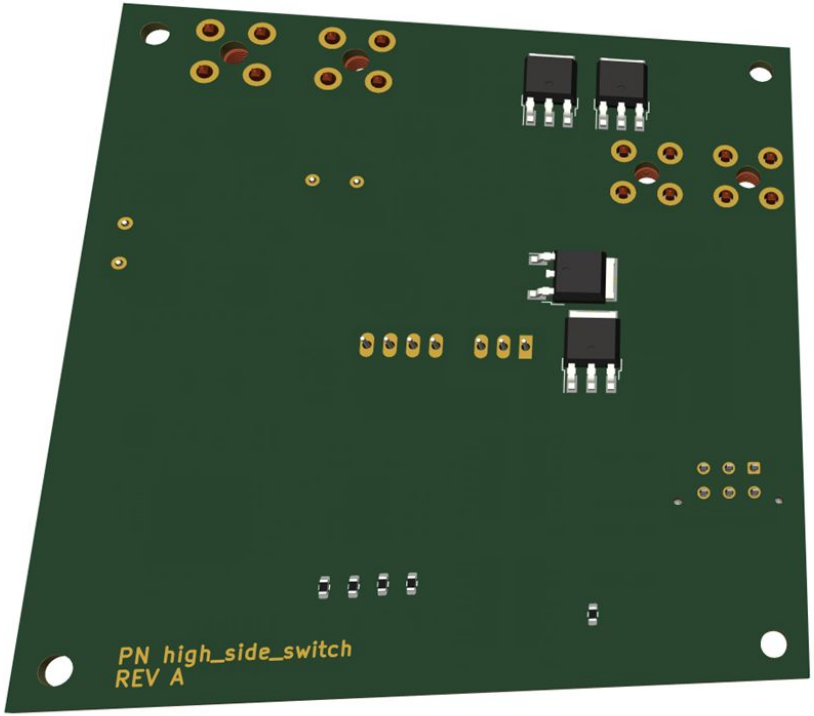


Power Supplies



PCB Layout


SUPPLY+
SUPPLY−
LOAD+
LOAD−
COMMS
1 2 3
4 5 6
1 = LOGIC V+
2 = LOGIC V−
3 = RS485 RX+
4 = RS485 RX−
5 = RS485 TX+
6 = RS485 TX−
POWER
High Side Switch
PFB Designs
POWER
FAULT
TX
RX


PN high_side_switch
REV A

Backup Slides

Beep beep beep

Project Links

Project Github: https://github.com/CoolNamesAllTaken/high-side-switch