THE ART AND SCIENCE OF PCB DESIGN

IAP 2025

Lecture 11 - PCB CASE STUDY

Looking at the SEVT BMS

@ MIT

Outline

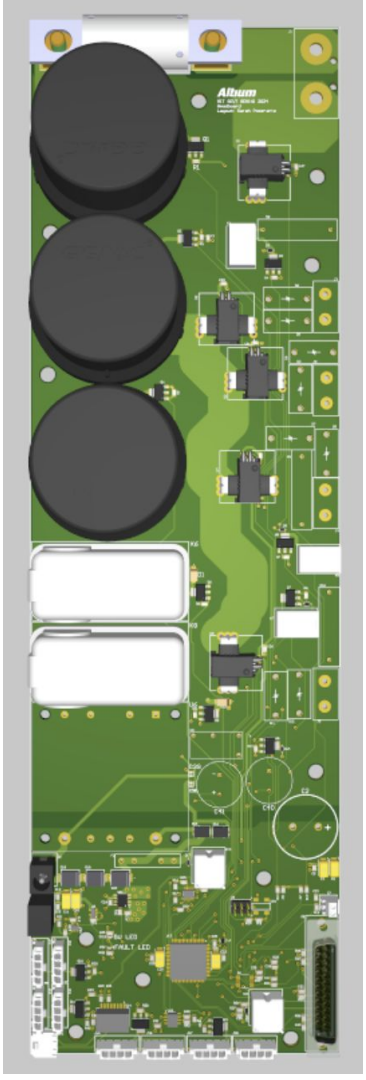
THE ART AND SCIENCE OF PCB DESIGN
IAP 2025

- Introduction
- Schematic
- Layout

Solar Car BMS

The “Headboard”

- **Massive Board**
- **Weird Size Constraints**
- **High Cost of Failure**



THE ART AND SCIENCE OF PCB DESIGN

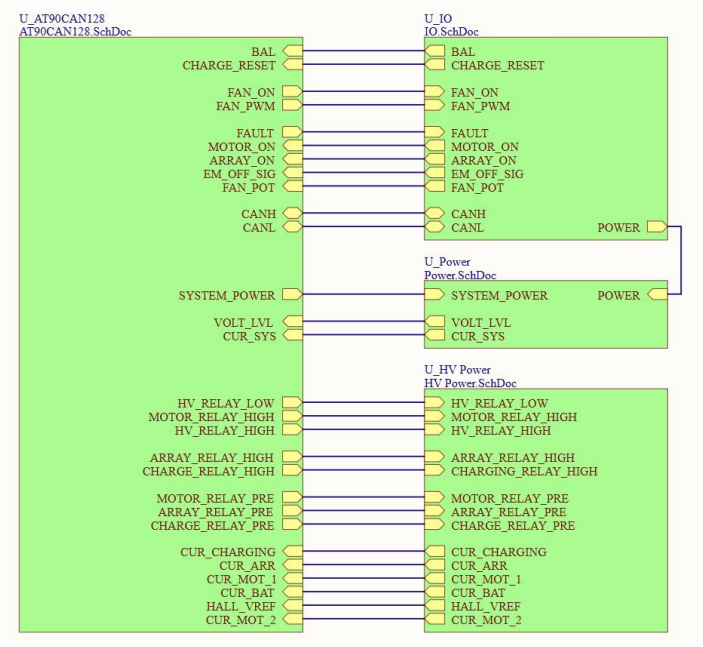
IAP 2025

Schematic

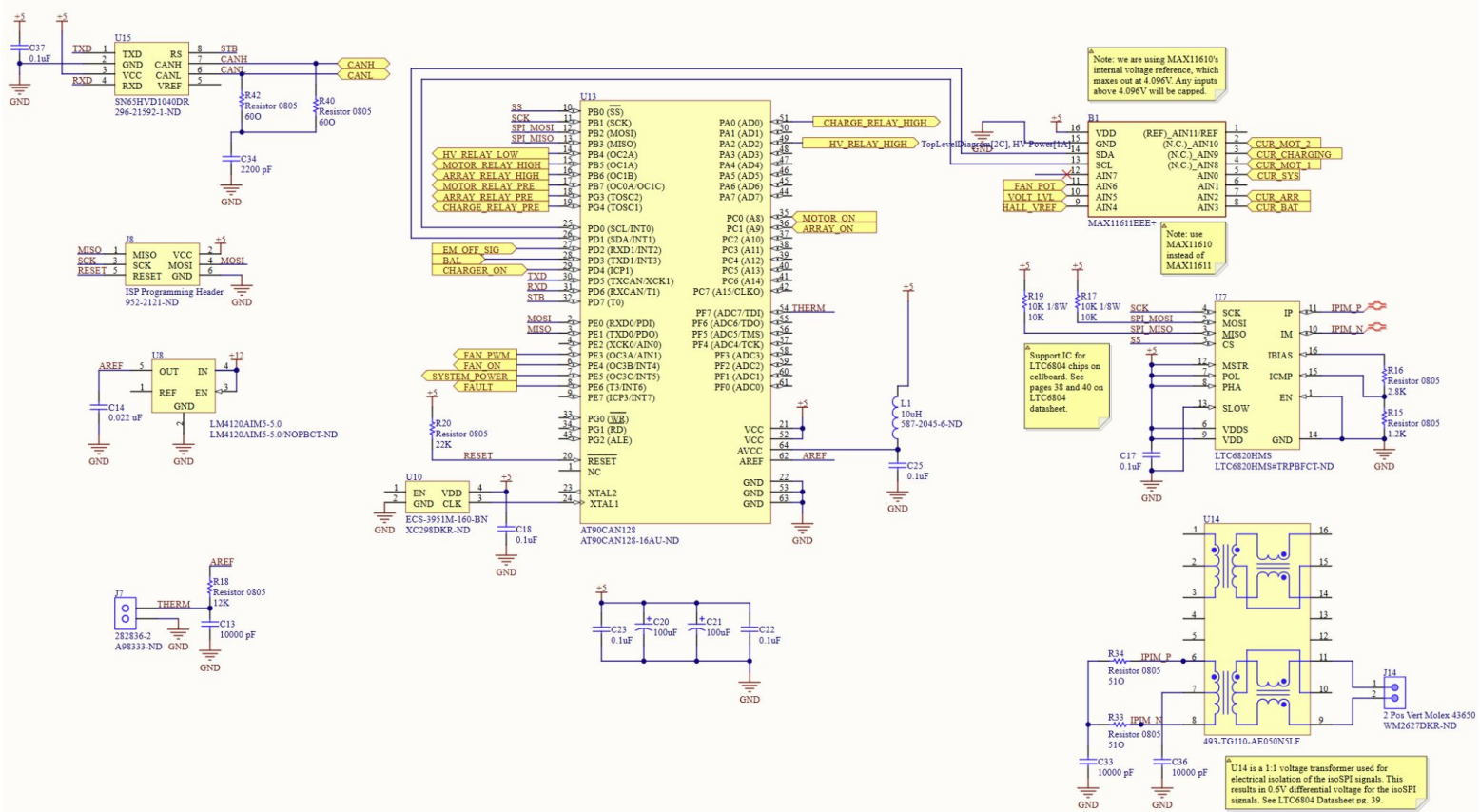
Top Level!

4 Schematics

- AT90CAN128
- IO
- Power
- HV_Power



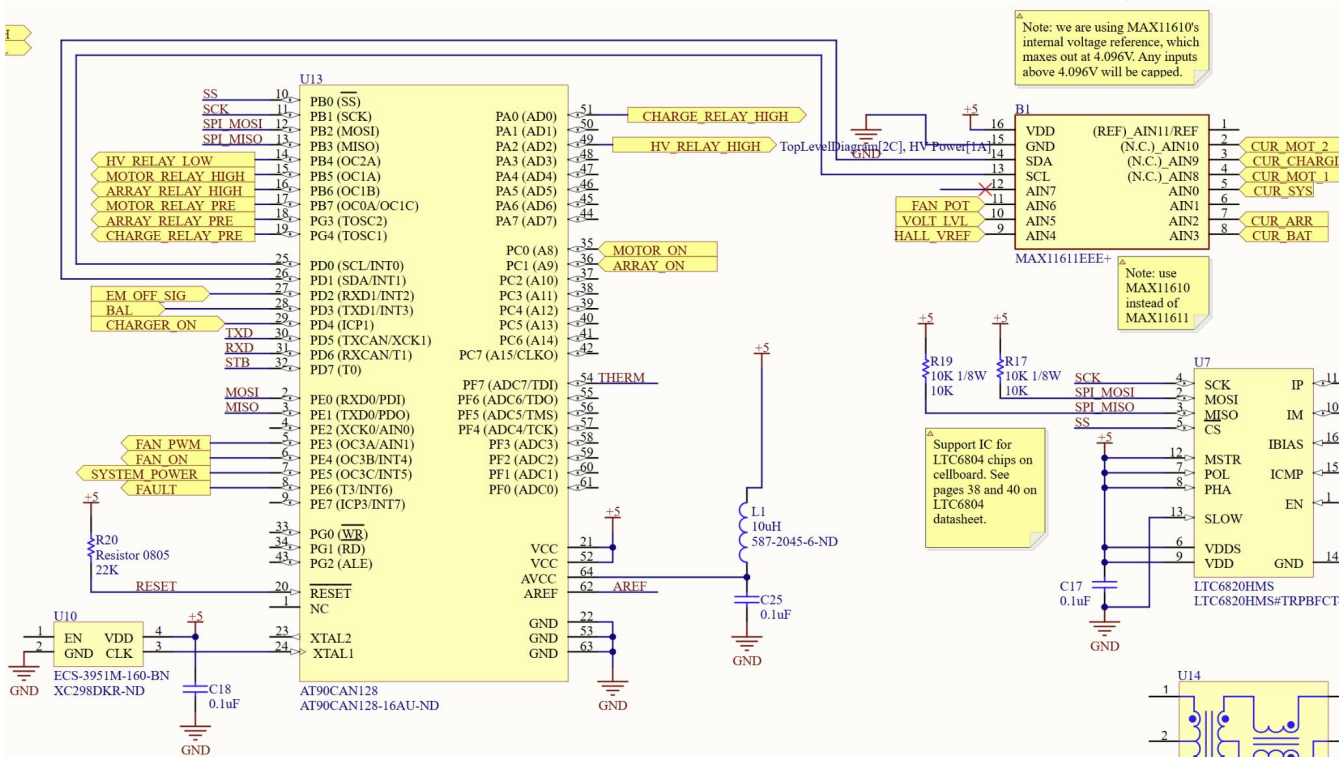
AT90CAN128


U15
SN65HVD1040DR
296-21592-1-ND
U13
AT90CAN128
AT90CAN128-16AU-ND
U8
LM4120AIM5-5.0
LM4120AIM5-5.0/NOPBCT-ND
U10
ECS-3951M-160-BN
XC298DKR-ND
J8
ISP Programming Header
952-2121-ND
J7
282836-2
A98333-ND
B1
MAX11611EEE+
Note: we are using MAX11610's internal voltage reference, which maxes out at 4.096V. Any inputs above 4.096V will be capped.
Note: use MAX11610 instead of MAX11611
U7
LTC6820HMS
LTC6820HMS#TRPBFCT-ND
Support IC for LTC6804 chips on cellboard. See pages 38 and 40 on LTC6804 datasheet.
U14
493-TG110-AE050N5LF
2 Pos Vert Molex 43650
WM2627DKR-ND
U14 is a 1:1 voltage transformer used for electrical isolation of the isoSPI signals. This results in 0.6V differential voltage for the isoSPI signals. See LTC6804 Datasheet pg. 39.
CHARGE_RELAY_HIGH
HV_RELAY_HIGH
HV_RELAY_LOW
MOTOR_RELAY_HIGH
ARRAY_RELAY_HIGH
MOTOR_RELAY_PRE
ARRAY_RELAY_PRE
CHARGE_RELAY_PRE
MOTOR_ON
ARRAY_ON
EM_OFF_SIG
BAL
CHARGER_ON
FAN_PWM
FAN_ON
SYSTEM_POWER
FAULT
CANH
CANL
THERM
RESET
AREF
CUR_MOT_2
CUR_CHARGING
CUR_MOT_1
CUR_SYS
CUR_ARR
CUR_BAT
IPIM_P
IPIM_N

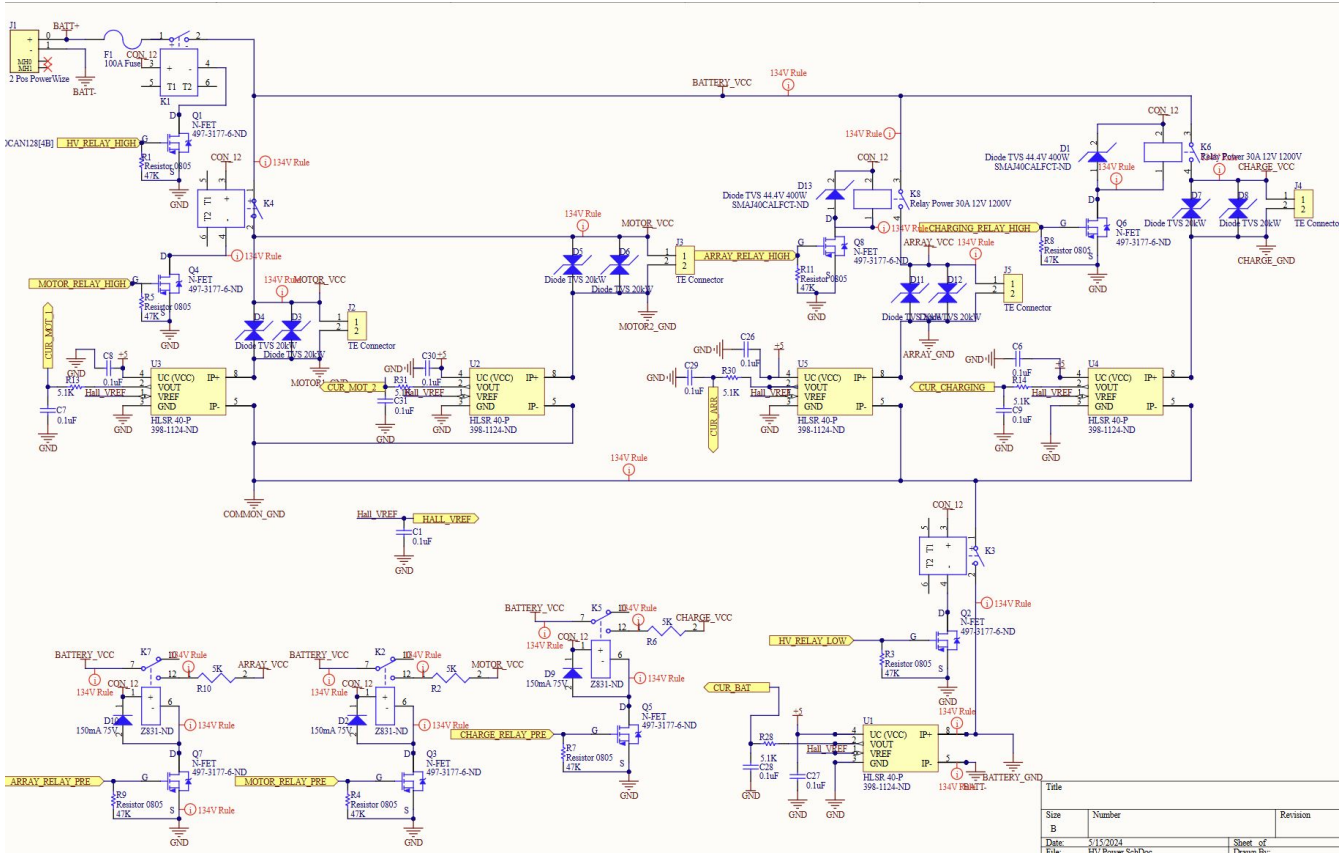
AT90CAN128

External ADC

- Most pins are bidirectional IO
- Different pins have different functions as stated in the datasheet
- Added external ADC



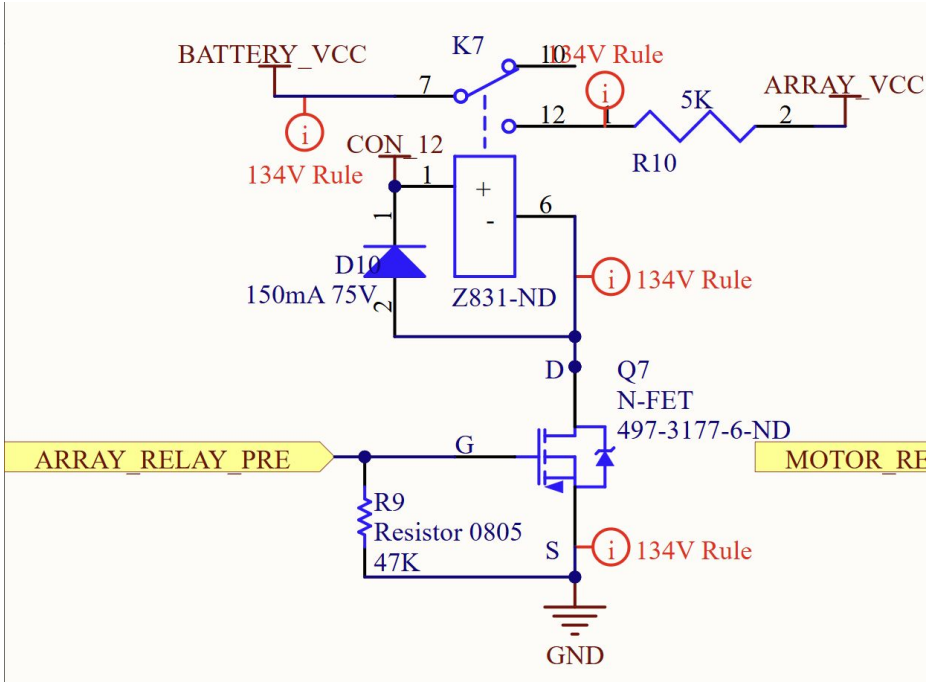
HV Power



HV Power

Pre-Charge Circuits

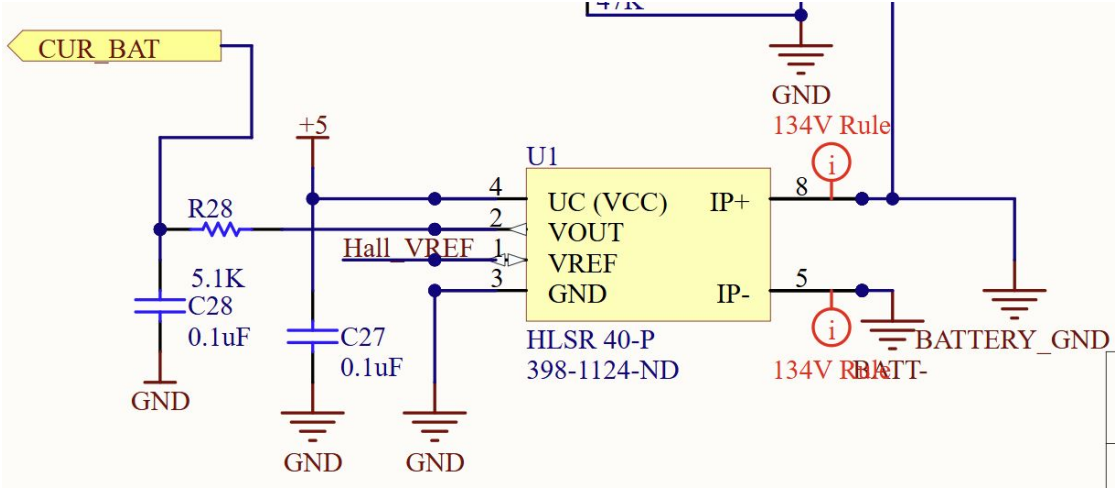
- Get to correct voltage before connecting to main circuit
- Have for each major battery input & output
  - Array, motors, external charging



HV Power

Hall Effect Sensors

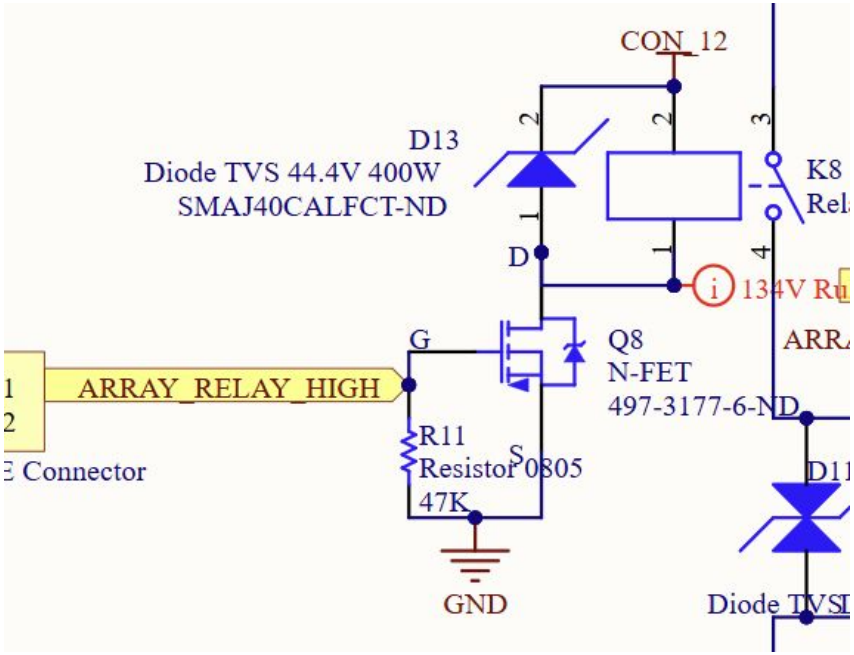
- **Common type of current sensor**
- **Have throughout the board**
- **Was difficult to find one of this size**



HV Power

Contactors

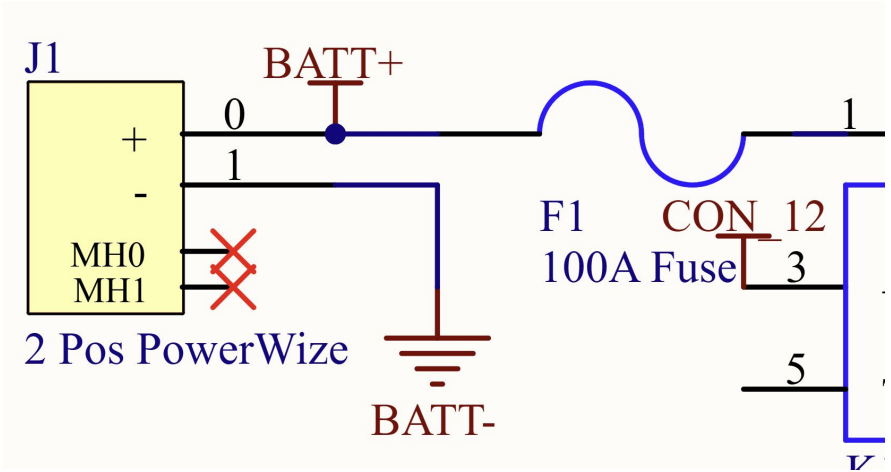
- **Basically big power switches**



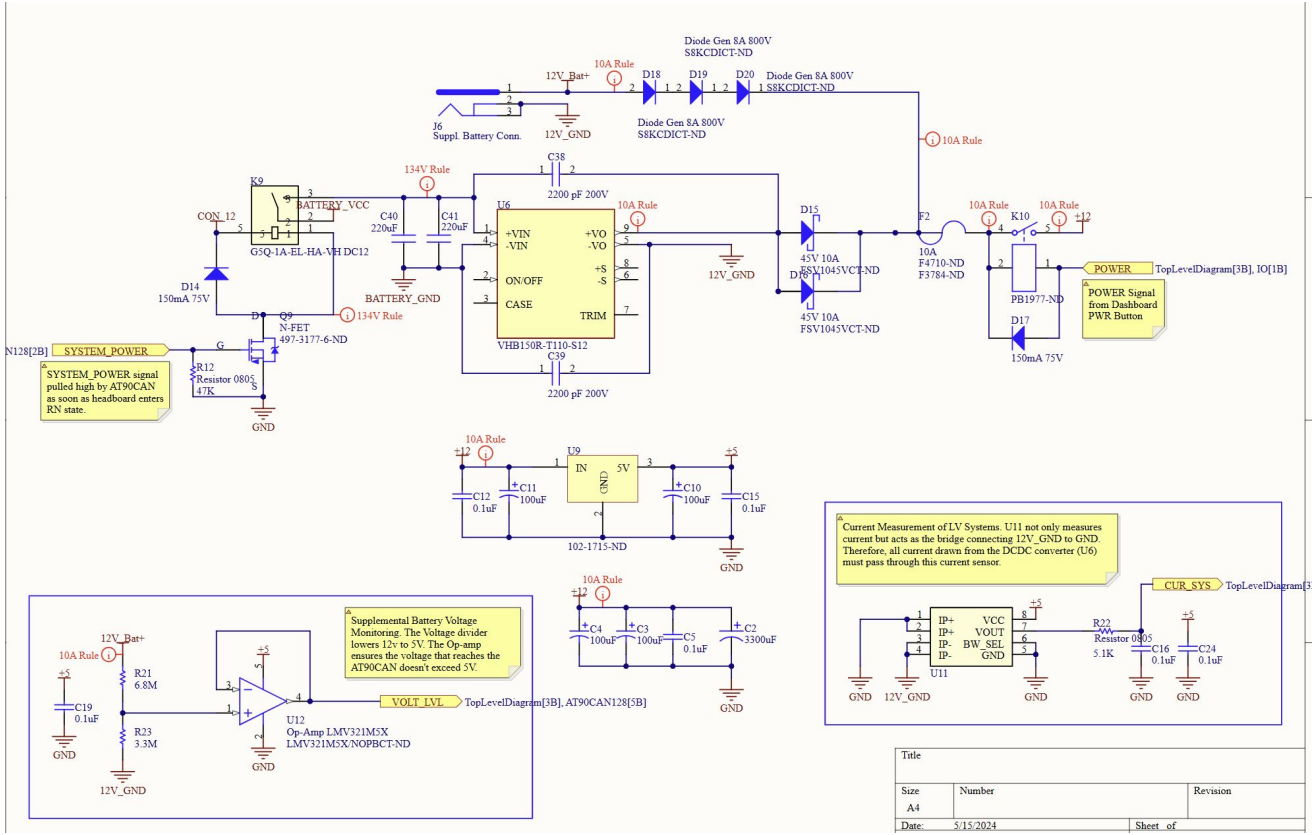
HV Power

Big Fuse!

- **Will blow up before the board does**



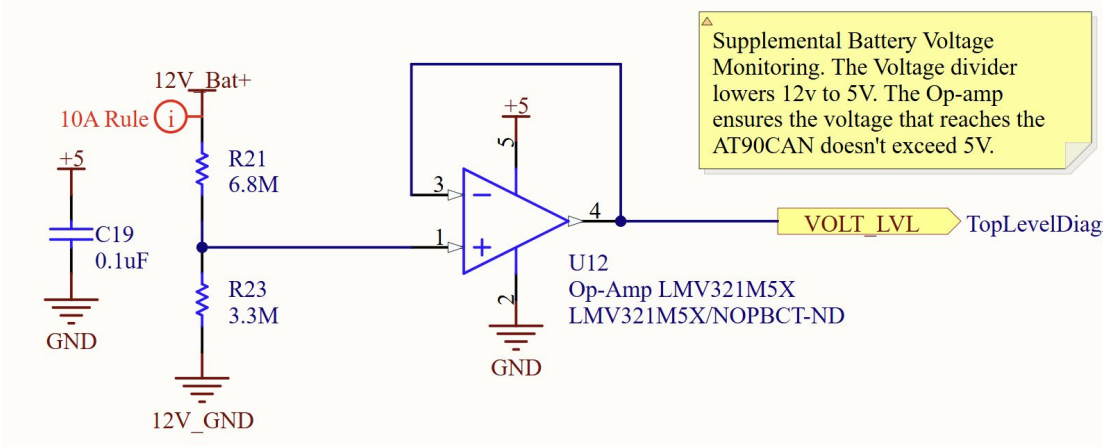
Power


Diode Gen 8A 800V
S8KCDICT-ND
12V_Bat+
10A Rule
D18
D19
D20
J6
Suppl. Battery Conn.
12V_GND
134V Rule
C38
2200 pF 200V
K9
BATTERY_VCC
CON_12
G5Q-1A-EL-HA-VH DC12
C40
220uF
C41
220uF
U6
+VIN
-VIN
ON/OFF
CASE
+VO
-VO
+S
-S
TRIM
VHB150R-T110-S12
C39
2200 pF 200V
D15
45V 10A
FSV1045VCT-ND
F2
10A
F4710-ND
F3784-ND
K10
PB1977-ND
D17
150mA 75V
POWER
TopLevelDiagram[3B], IO[1B]
POWER Signal from Dashboard PWR Button
D14
150mA 75V
Q9
N-FET
497-3177-6-ND
BATTERY_GND
N128[2B]
SYSTEM_POWER
SYSTEM_POWER signal pulled high by AT90CAN as soon as headboard enters RN state.
R12
Resistor 0805
47K
GND
U9
IN
5V
GND
C12
0.1uF
C11
100uF
C10
100uF
C15
0.1uF
102-1715-ND
Current Measurement of LV Systems. U11 not only measures current but acts as the bridge connecting 12V_GND to GND. Therefore, all current drawn from the DCDC converter (U6) must pass through this current sensor.
IP+
IP+
IP-
IP-
VCC
VOUT
BW_SEL
GND
U11
R22
Resistor 0805
5.1K
C16
0.1uF
C24
0.1uF
CUR_SYS
Supplemental Battery Voltage Monitoring. The Voltage divider lowers 12v to 5V. The Op-amp ensures the voltage that reaches the AT90CAN doesn't exceed 5V.
R21
6.8M
R23
3.3M
C19
0.1uF
U12
Op-Amp LMV321M5X
LMV321M5X/NOPBCT-ND
VOLT_LVL
TopLevelDiagram[3B], AT90CAN128[5B]
C4
100uF
C3
100uF
C5
0.1uF
C2
3300uF
Title
Size
A4
Number
Revision
Date:
5/15/2024
Sheet of

Power

Battery Voltage Monitoring

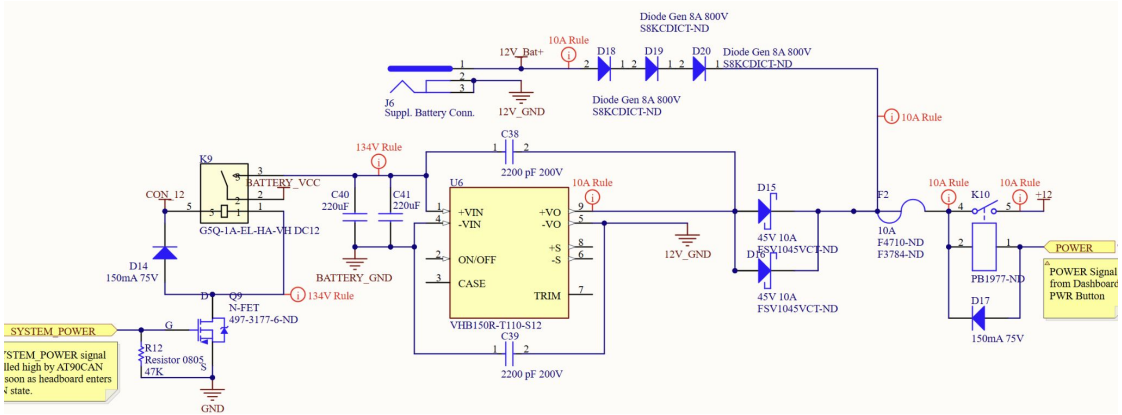
- Have a supplemental battery for some stuff
- Voltage divider to lower the voltage
- Op amp for extra protection for the IC

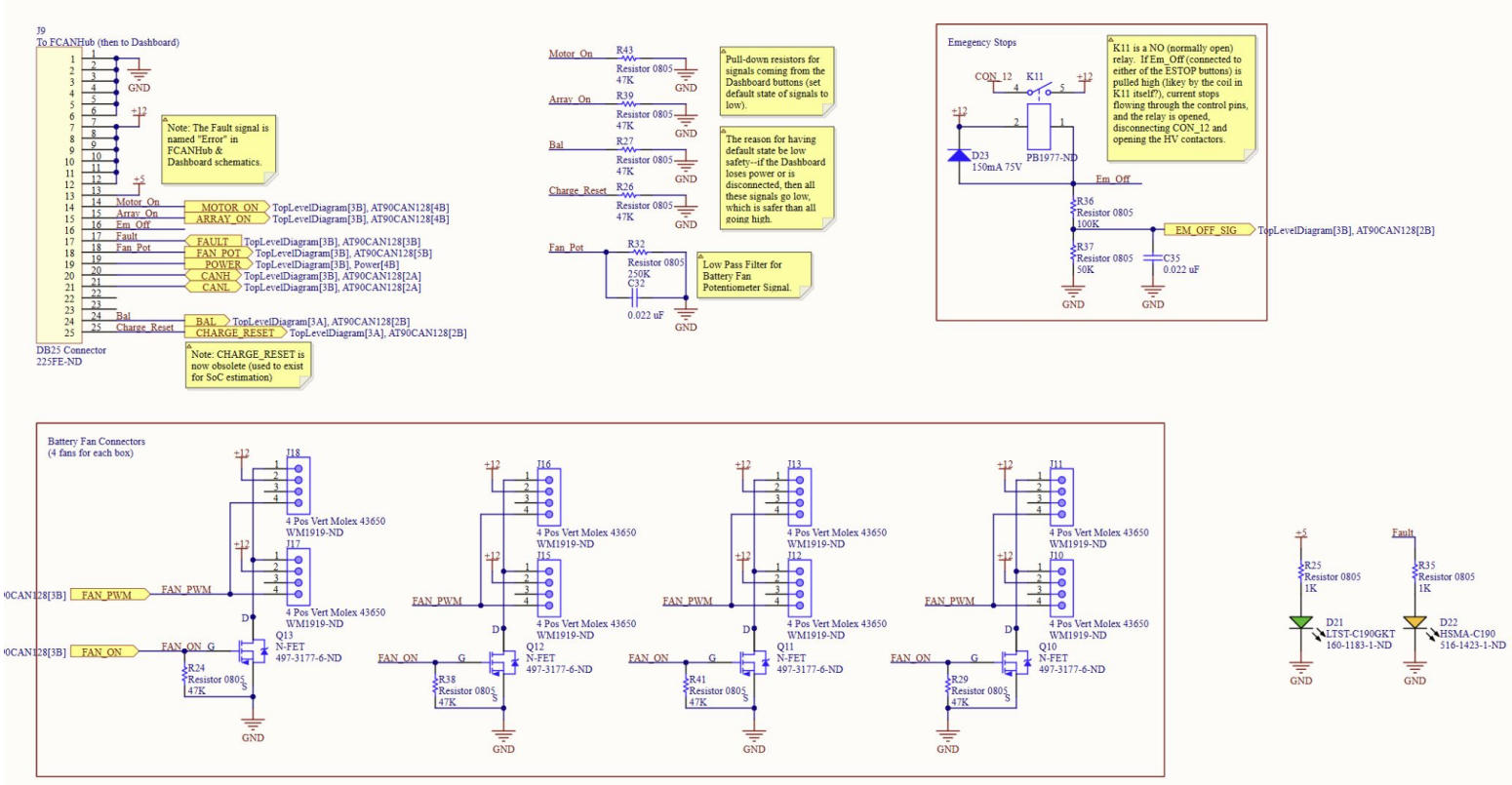


Power

Power Conversion

- **Changing from HV to LV**
- **Using big DCDC Converter**

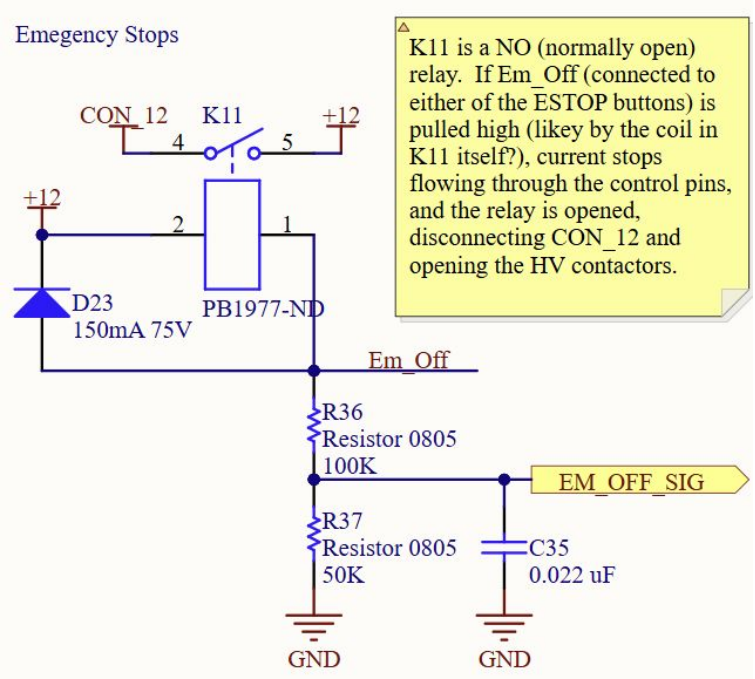



J9
To FCANHub (then to Dashboard)
GND
+12
+5
Note: The Fault signal is named "Error" in FCANHub & Dashboard schematics.
Motor_On
Array_On
Em_Off
Fault
Fan_Pot
Bal
Charge_Reset
MOTOR_ON
ARRAY_ON
FAULT
FAN_POT
POWER
CANH
CANL
BAL
CHARGE_RESET
TopLevelDiagram[3B], AT90CAN128[4B]
TopLevelDiagram[3B], AT90CAN128[3B]
TopLevelDiagram[3B], AT90CAN128[5B]
TopLevelDiagram[3B], Power[4B]
TopLevelDiagram[3B], AT90CAN128[2A]
TopLevelDiagram[3A], AT90CAN128[2B]
DB25 Connector
225FE-ND
Note: CHARGE_RESET is now obsolete (used to exist for SoC estimation)
Motor_On
Array_On
Bal
Charge_Reset
Fan_Pot
R43
R39
R27
R26
R32
Resistor 0805
47K
250K
C32
0.022 uF
Pull-down resistors for signals coming from the Dashboard buttons (set default state of signals to low).
The reason for having default state be low safety--if the Dashboard loses power or is disconnected, then all these signals go low, which is safer than all going high.
Low Pass Filter for Battery Fan Potentiometer Signal.
Emegency Stops
CON_12
K11
D23
150mA 75V
PB1977-ND
Em_Off
R36
100K
R37
50K
C35
0.022 uF
EM_OFF_SIG
TopLevelDiagram[3B], AT90CAN128[2B]
K11 is a NO (normally open) relay. If Em_Off (connected to either of the ESTOP buttons) is pulled high (likey by the coil in K11 itself?), current stops flowing through the control pins, and the relay is opened, disconnecting CON_12 and opening the HV contactors.
Battery Fan Connectors
(4 fans for each box)
J18
J17
J16
J15
J13
J12
J11
J10
4 Pos Vert Molex 43650
WM1919-ND
FAN_PWM
FAN_ON
Q13
Q12
Q11
Q10
N-FET
497-3177-6-ND
R24
R38
R41
R29
Fault
R25
R35
D21
LTST-C190GKT
160-1183-1-ND
D22
HSMA-C190
516-1423-1-ND

IO

Emergency Stop

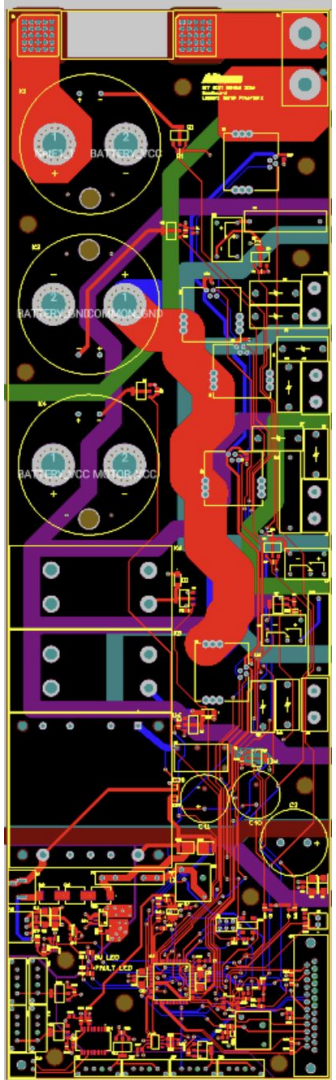
- **Using a relay**



Layout

Layout

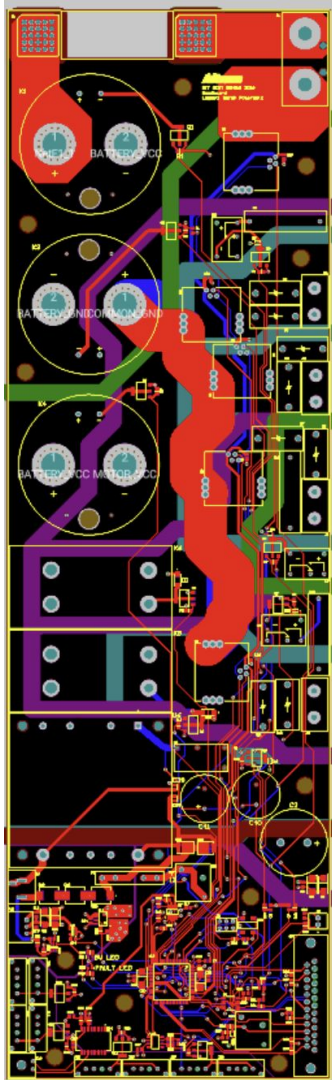
- 6 layers
  - 4 internal power planes
  - 2 external signal layers



Layout

Things to look at

- Sizing of traces, pours, and split planes
- Size constraints on board
- Placement of components
- Motor footprint issues



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Questions?

Final Notes

Things to look at

Time to finish boards

- **Lab open today until 5pm and Sunday 1-11:45pm**
- **No recitation today, just extra lab time**
- **Talk to us about any issues**

Fill Out Course Evaluations Please