TSI Detailed Design

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Brakes

Brake Overtravel Switch

The brake overtravel switch is a manual reset limit switch that will actuate a normally open relay in the safety loop. Voltage and signal will be sent and received from the TSI box.

Brake Pressed Signal

The brake pressed signal comes from a pressure-actuated switch in the pedal cluster. This is treated like a normally open switch, and will be brought into the PCB and microcontroller to be used in throttle control and system state decisions.

Brake Light

The brake light is controlled by the brake pressed signal, and is displayed using a 12V, 74 cm^2 golf cart red brake light compliant with DOT FMVSS 108 as a brake light (as required by the Formula Hybrid Rules T7.4).

Throttle

Accelerator Pedal Plausibility System (APPS)

The APPS consist of two piston potentiometers connected to the throttle pedal. These two potentiometers are offset from one another by 5V, with their wiper outputs used in a series of checks used to ensure that a valid throttle value is sent to the motor controller. For one check, the two signals are put through a differential op-amp, followed by a window comparator in order to confirm the two signals remain within 10% of one another (0.5V). Separate checks are made on each APPS signal individually, sending each signal through two other window comparators, making sure that the signals are not open/short-circuited.

Throttle to Motor Controller

The throttle to the motor controller is sent from the low voltage side of the board to the high voltage side by means of an isolated differential amplifier. This is a 0-5V signal fed directly into the motor controller. On the low-voltage side, the throttle can be sourced from one of two

locations. First, the analog voltage passed from the APPS may be sent through an analog switch. The second option, which facilitates VSCADA control, is a PWM signal sent from the microcontroller which is low-pass filtered (integrator with time constant of 1.6ms) then sent to the switch. Selection of the throttle is done by the microcontroller. This gives the microcontroller the ability to cut the throttle to the motor controller, by outputting 0V and selecting the microcontroller output on the analog switch.

Acceptance of VSCADA Throttle Control

TSI has the ability to accept VSCADA throttle control over the CAN bus. VSCADA may request to increase or decrease speed, which the TSI microcontroller may do by altering the PWM throttle output. This allows the TSI to maintain safety checks, while still allowing VSCADA to remotely request control of the throttle.

IMD

Connected to Safety Loop

The IMD we are using is the Bender ISOMETER IR155-3204 to meet Formula Hybrid Rule EV7.9.2. This has two signal coming out of it that will be used for interacting with the safety loop and TSI system. One of these is the OK_{HS} high or low voltage. Under normal operating conditions, this is set to 24V as this is the GLV power the board will be receiving. If the IMD senses the high voltage connections have connected to low voltage ground, this signal will change to 0V. We will be using this to control the IMD safety loop relay.
The other signal we are using from the IMD is the PWM output of the measured resistance. This will be sent through a low pass filter and into the microcontroller. It will then be decoded to determine the resistance based on the duty cycle. This value will be sent over CAN to the SCADA team.

IMD Fault Light

The IMD fault light will activate when the IMD is the reason the safety loop is broken. This will be achieved by using the second output from the IMD relay used for the safety loop. The relay we are using has two outputs based on the control signal so if the OK_{HS} goes to 0V, the output of the relay will flow to the fault light instead of the safety loop.

Voltage and Current Measuring

Read Voltage and Current Values from TSV

To read the current provided from the TSV system, we will be using an Ametes BBM-01 current sensor mounted to the metal power bar inside of the TSI box. For the voltage, we will be using an isolated differential op-amp.

High Voltage Present Lights

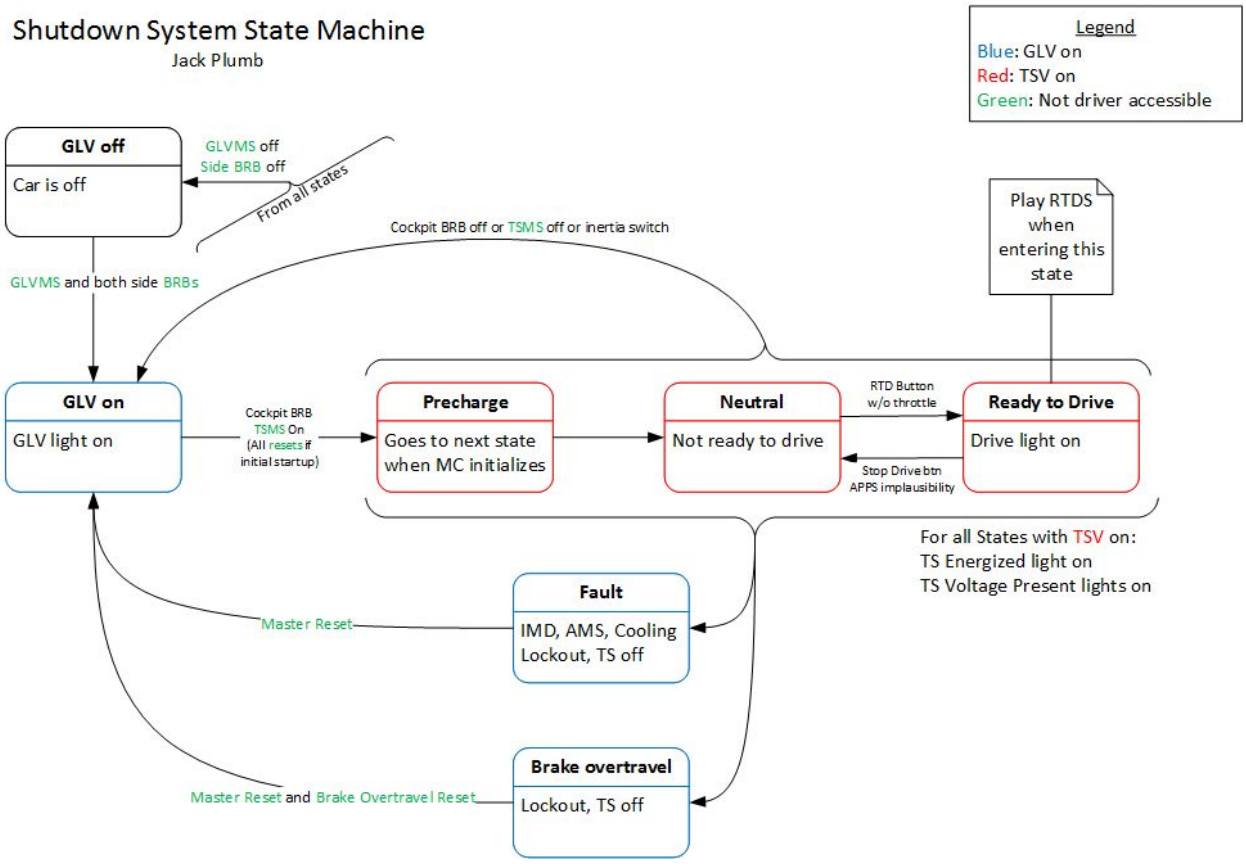
The high voltage present lights will be activated by a DC-DC convertor. The TSV voltage will go through buck converter, and will be scaled down to 24V. The buck converter will be set to have an on voltage of 30V. The 24V will go to an isolated DC/DC converter that will scale it down to 12V, which will be used to power the lights.

TSMP

The TSMP will be mounted to the front of the TSI box. The inputs to each of the banana jacks will be taken from the metal bars running through the box. At the beginning of the cables going from the bars to the measuring points, a 10k ohm resistor will be added in series with a power rating of 5W to meet Formula Hybrid rule EV10.3.5.
The third banana jack will be connected to the chassis ground provided to the TSI box for intentionally causing a ground fault in the IMD.

Shutdown System

State Diagram Compliant with Formula Hybrid Rules



Ready to Drive Button

The ready to drive button will be mounted on the dashboard and accessible to the driver. This is the last step in the startup sequence. In order for the button press to be accepted, the driver must have his/her foot on the brake so the car will not move on startup.

RTDS

The RTDS will activate when the drive button is pressed and the microcontroller is in the state to allow for driver control. It will sound for 2 seconds to meet Formula Hybrid rule EV9.2.1.

Drive light

The drive light will be active after the drive button is pressed and the RTDS activates. This light will be mounted on the dashboard to let the driver know they are able to move the car. This will be controlled by the microcontroller that is in charge of the startup sequence.

Motor Controller

FWD/REV key

A single-pull double-throw keyswitch will be used to select forward or reverse motion of the motor controller. This will be mounted on the TSI box, out of reach of the driver. Voltage will be supplied by the motor controller, with the signal sent directly back into the motor controller.

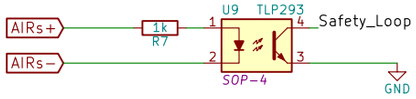
Precharge relay

The precharge relay is automatically actuated by the motor controller after the internal start-up sequence when TSV is applied.

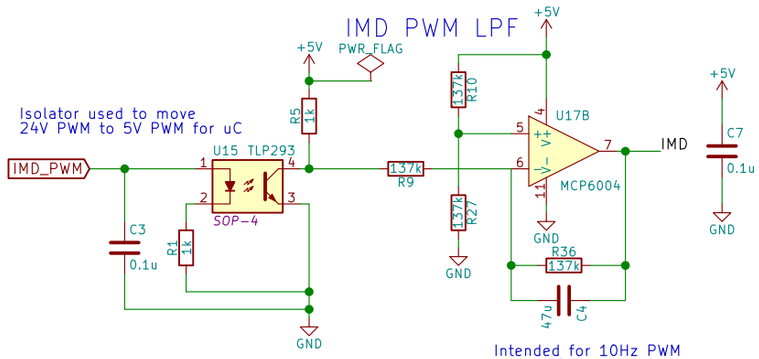
Interface via CAN bus/control system cable

The motor controller is connected to the system-wide CAN bus via a CAN bus isolator. This allows motor controller information to be sent directly to VSCADA.

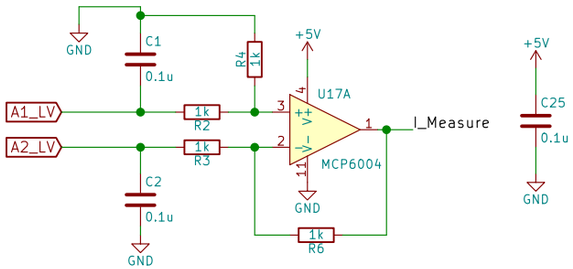
AIRs Measurement



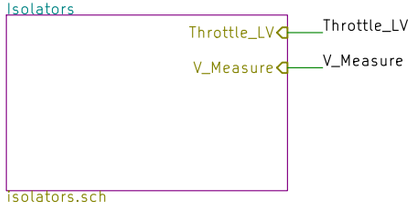
IMD PWM LPF



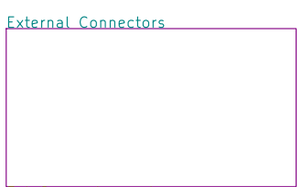
Current Measurement



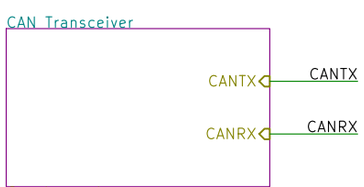
Isolators

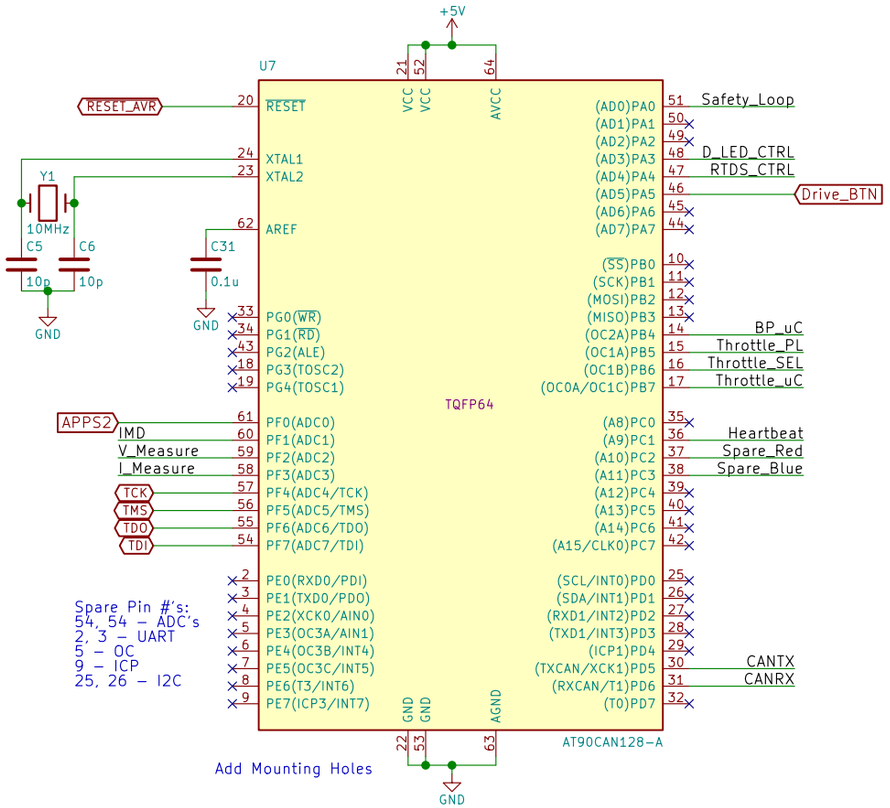


CONNECTORS

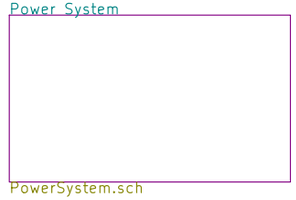


CAN TRANSCEIVER

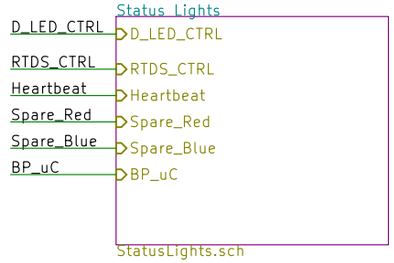




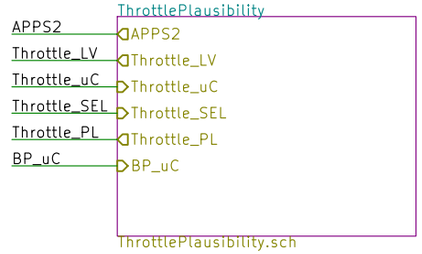
DC DC Converters



Status Lights



Throttle Plausibility



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Sheet: /
File: Circuit_layout.sch

Title: Tractive System Interface

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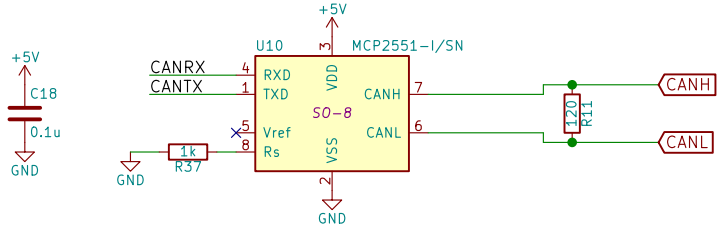
CANTX

CANRX

CAN Tranceiver



NOTE: DO NOT populate R11.

R11 provides the ability to use this board
as a terminating CAN node in development only.

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Sheet: /CAN Transceiver/
File: Can_tcvr.sch

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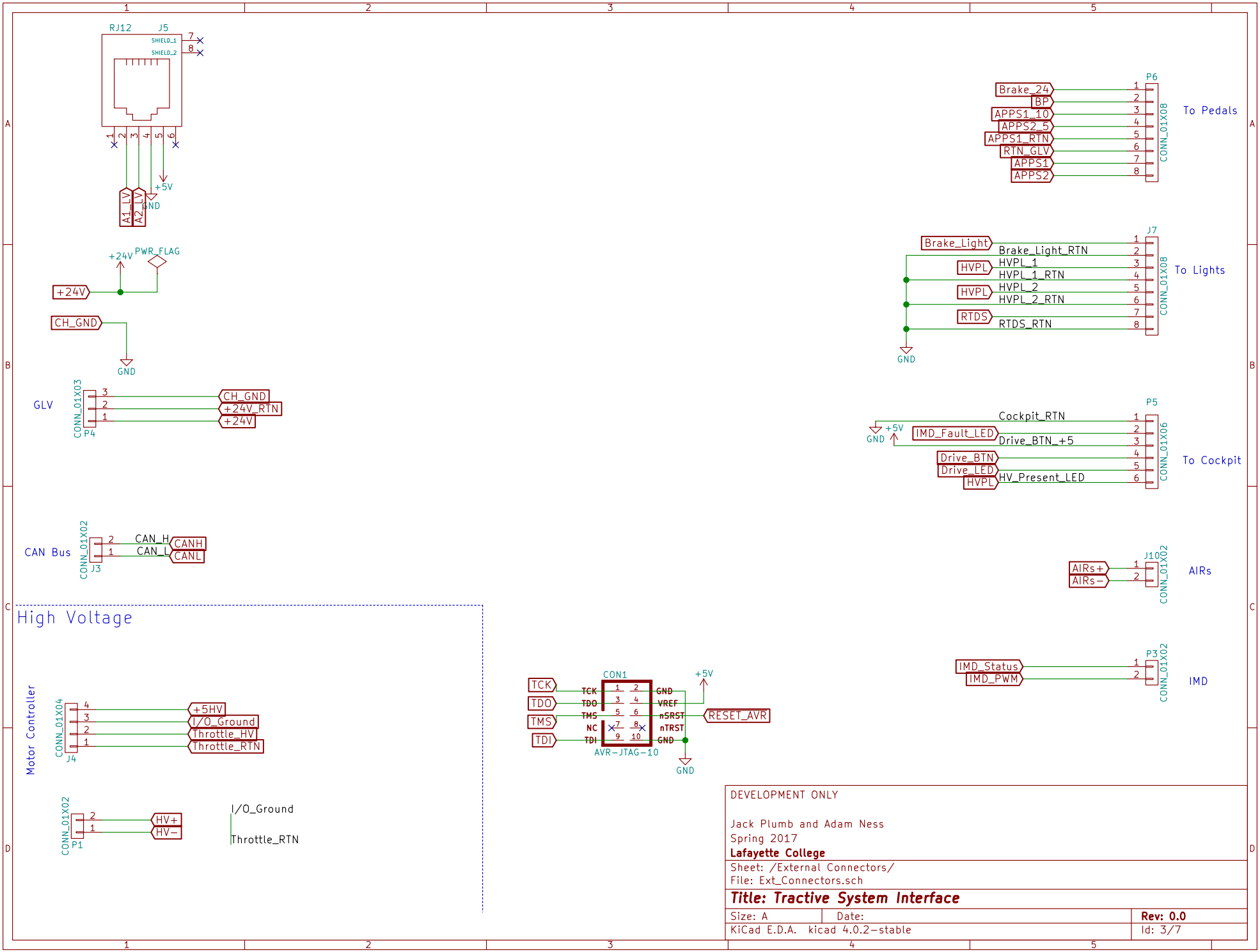
RJ12
J5
SHIELD_1
SHIELD_2
7
8
1
2
3
4
5
6
+5V
GND
A1_LV
A2_LV
+24V
PWR_FLAG
+24V
CH_GND
GND
GLV
CONN_01X03
P4
3
2
1
CH_GND
+24V_RTN
+24V
CAN Bus
CONN_01X02
J3
2
1
CAN_H
CAN_L
CANH
CANL
High Voltage
Motor Controller
CONN_01X04
J4
4
3
2
1
+5HV
I/O_Ground
Throttle_HV
Throttle_RTN
CONN_01X02
P1
2
1
HV+
HV-
I/O_Ground
Throttle_RTN
CON1
TCK
TDO
TMS
TDI
TCK
TDO
TMS
NC
TDI
GND
VREF
nSRST
nTRST
GND
+5V
RESET_AVR
AVR-JTAG-10
GND
P6
Brake_24
BP
APPS1_10
APPS2_5
APPS1_RTN
RTN_GLV
APPS1
APPS2
CONN_01X08
To Pedals
J7
Brake_Light
Brake_Light_RTN
HVPL
HVPL_1
HVPL_1_RTN
HVPL
HVPL_2
HVPL_2_RTN
RTDS
RTDS_RTN
CONN_01X08
To Lights
GND
P5
Cockpit_RTN
GND
+5V
IMD_Fault_LED
Drive_BTN_+5
Drive_BTN
Drive_LED
HVPL
HV_Present_LED
CONN_01X06
To Cockpit
J10
AIRs+
AIRs-
CONN_01X02
AIRs
P3
IMD_Status
IMD_PWM
CONN_01X02
IMD
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Rev: 0.0
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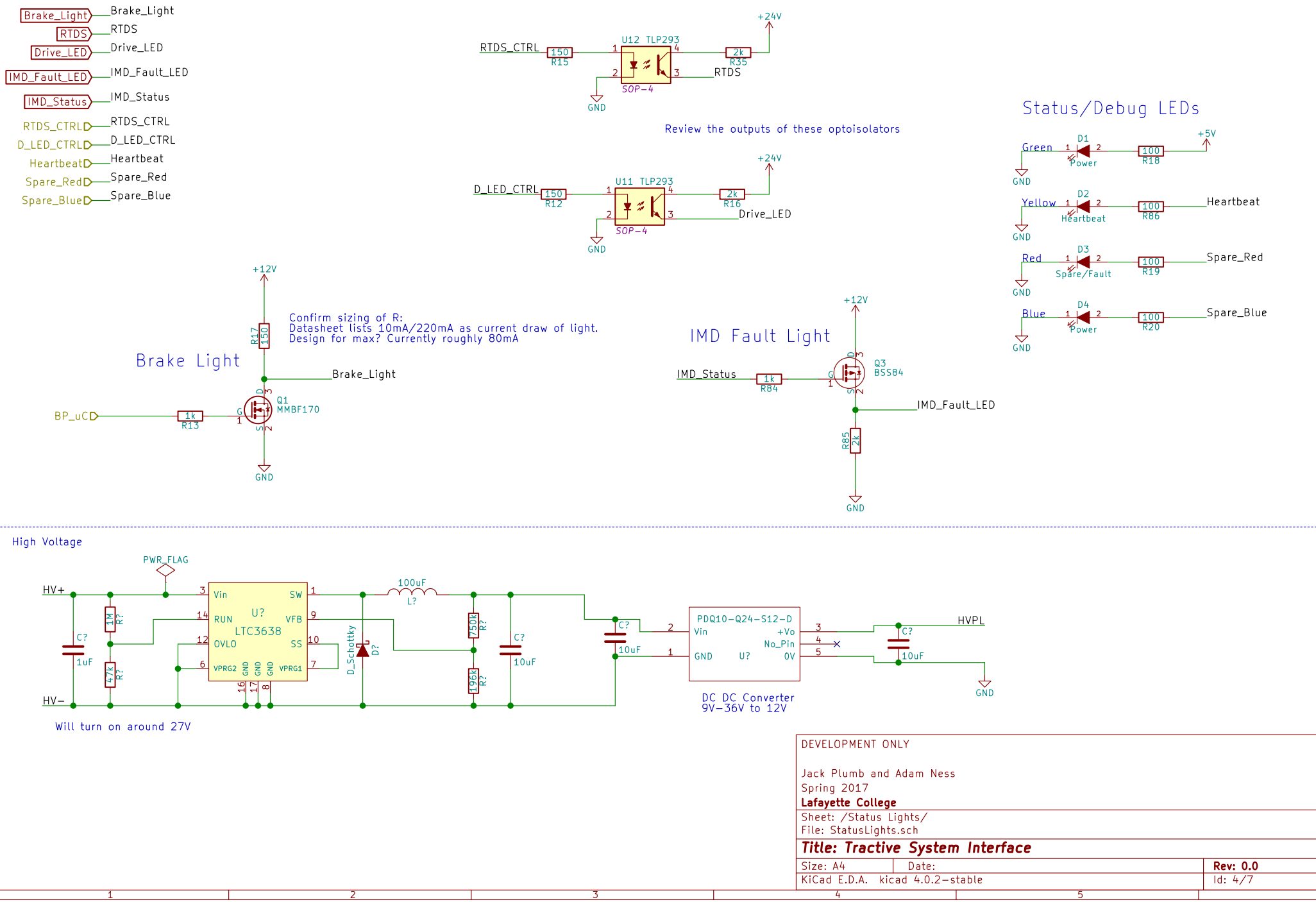
Id: 3/7


Brake_Light
RTDS
Drive_LED
IMD_Fault_LED
IMD_Status
RTDS_CTRL
D_LED_CTRL
Heartbeat
Spare_Red
Spare_Blue
RTDS_CTRL
150
R15
U12 TLP293
SOP-4
2k
R35
+24V
RTDS
GND
Review the outputs of these optoisolators
D_LED_CTRL
150
R12
U11 TLP293
SOP-4
2k
R16
+24V
Drive_LED
GND
Status/Debug LEDs
Green
D1
Power
100
R18
+5V
GND
Yellow
D2
Heartbeat
100
R86
Heartbeat
GND
Red
D3
Spare/Fault
100
R19
Spare_Red
GND
Blue
D4
Power
100
R20
Spare_Blue
GND
Brake Light
+12V
R17
150
Confirm sizing of R:
Datasheet lists 10mA/220mA as current draw of light.
Design for max? Currently roughly 80mA
Brake_Light
BP_uC
1k
R13
Q1
MMBF170
GND
IMD Fault Light
+12V
IMD_Status
1k
R84
Q3
BSS84
IMD_Fault_LED
R85
2k
GND
High Voltage
PWR_FLAG
HV+
HV−
C?
1uF
1M
R?
47k
R?
U?
LTC3638
Vin
SW
RUN
VFB
OVLO
SS
VPRG2
GND
VPRG1
100uF
L?
D_Schottky
D?
750k
R?
196k
R?
C?
10uF
C?
10uF
PDQ10-Q24-S12-D
Vin
+Vo
No_Pin
GND
U?
0V
DC DC Converter
9V-36V to 12V
C?
10uF
HVPL
GND
Will turn on around 27V
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Sheet: /Status Lights/
File: StatusLights.sch
Title: Tractive System Interface
Size: A4
Date:
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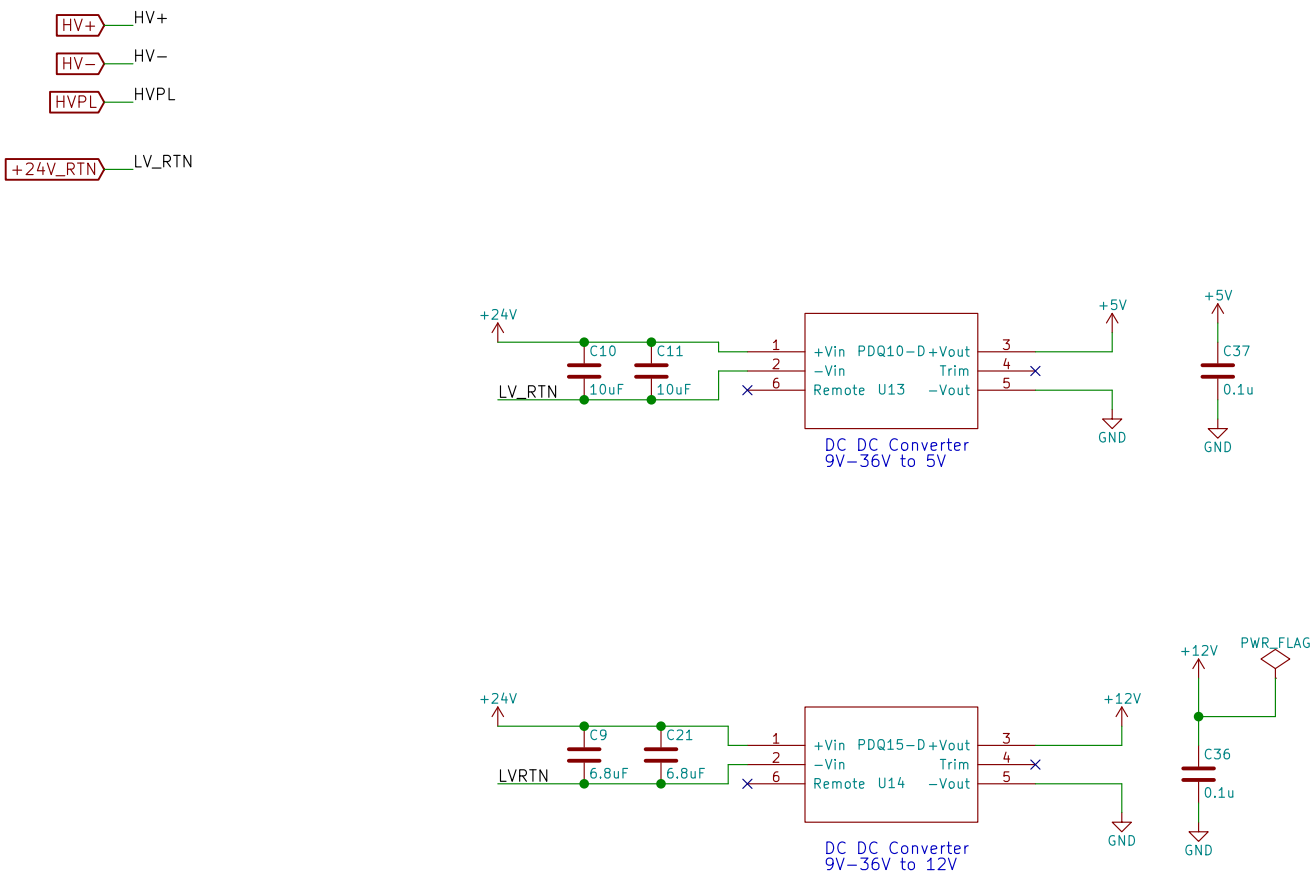

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Sheet: /Power System/
File: PowerSystem.sch

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Size: A	Date:	**Rev: 0.0**
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APPS1_10
APPS2_5
APPS1_RTN
RTN_GLV
BP
BP_uC
Throttle_SEL
Throttle_uC
Throttle_LV
Throttle_PL
+24V
Brake_24
C14
0.1u
GND
APPS1
C15
APPS2
C16
APPS_10
C39
C13
R23
1k
R21
R22
U1A
LM7332
APPS1_ISO
R24
HS1
513002B02500G
U2
LM7810CT
IN
OUT
C12
Alt. Option:
12V Lin. Reg. w/ 0.3V Dropout
BAJ0CC0FP-E2
Rt Junc-to-Case: 5C/W
Rt Junc-to-Air: 65C/W
R25
2k
R26
APPS1_10
APPS2_5
APPS1
2k pot.
APPS1_RTN
APPS2
2k pot.
RTN_GLV
C17
R28
R29
R30
R31
U5A
LM7332
R32
4.75k
R33
499
R34
4.75k
U6A
U6B
LM339
R40
10k
R41
10k
C20
15p
C24
C38
Plausibility Window
(0.5V)
Used for 10V
rail-to-rail ability
Check footprint
Open/Short Window
(90% travel)
R79
499
R80
4.31k
R84
499
U17D
U3A
MCP6004
Resistors Set for maximum
of 90% travel (> will trigger fault)
R82
499
R83
499
R38
4.31k
U3B
U3C
Brake Pressed
R51
0
R52
0
R50
10k
C22
DNP
APPS2
R46
1k
Q2
MMBF170
U4D
MCP6004
Pedal_Out
Used for rail-to-rail
on 5V
C44
0.1u
R48
1k
U8
74ACT11030
Throttle_PL
C43
SW1
TS5A3159-Q1
NO
NC
COM
Throttle_LV
Throttle_SEL
uC Throttle PWM LPF
R47
16k
R45
16k
R49
16k
Throttle_uC
U4A
R53
16k
C26
0.1u
C42
C45
Intended for 40kHz PWM
tau=1.6ms
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Sheet: /ThrottlePlausibility/
File: ThrottlePlausibility.sch
Title: Tractive System Interface
Size: B
Date: 2017-02-13
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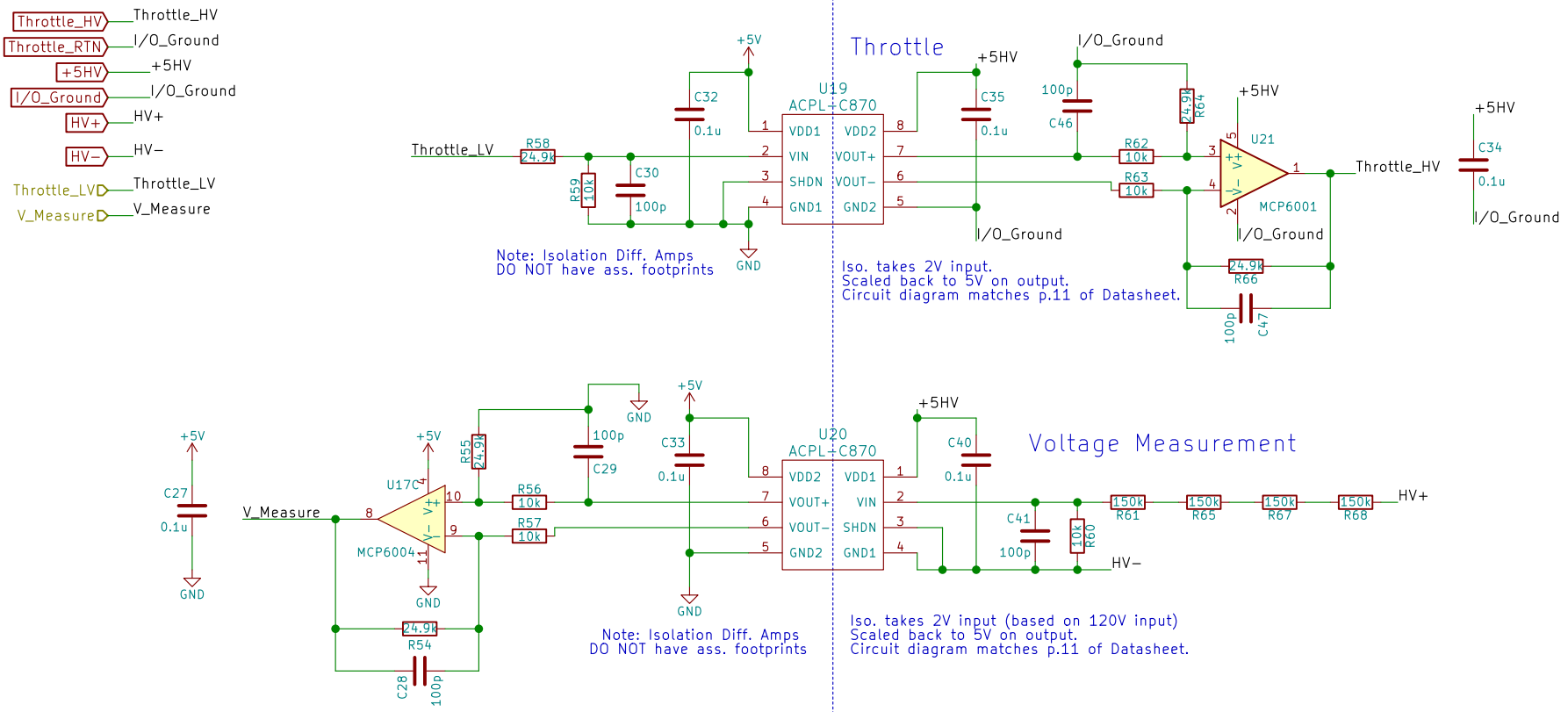

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