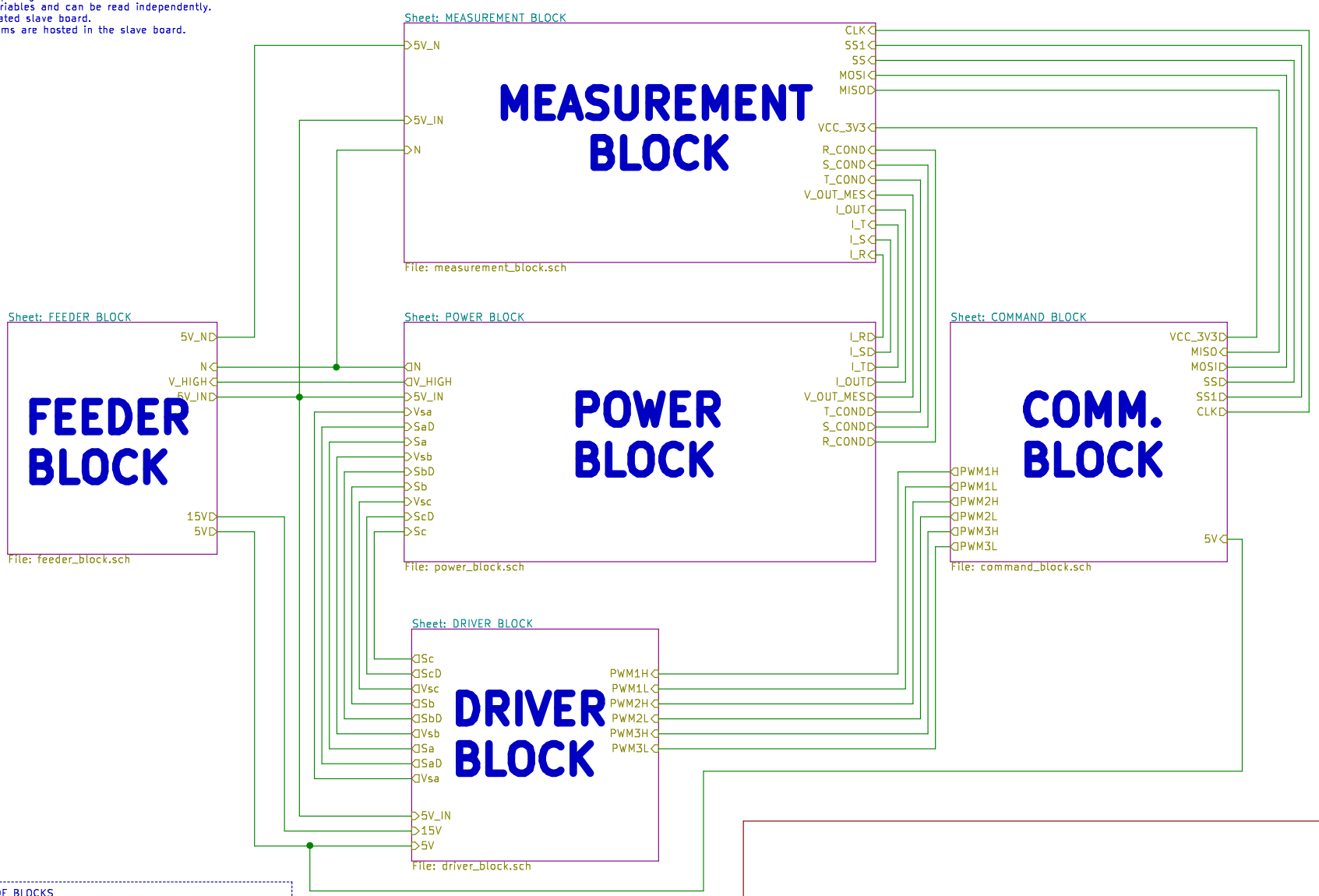
OWNTECH POWER BOARD

These schematics detail the blocks composing the OwnTech Wind Board.
Each block has its own input/output variables and can be read independently.
This board has a connector for a dedicated slave board.
The microcontroller and control algorithms are hosted in the slave board.



LIST OF BLOCKS

POWER BLOCK – Power Electronics components, Power Connectors and measuring sensors
MEASUREMENT BLOCK – Operational Amplifiers and data isolation
MICROCONTROLLER BLOCK – 36 pin connector for the slave board
DRIVER BLOCK – Digital Isolator, MOSFET Driver
FEEDER BLOCK – Input up to 60V, Output +15V, +5V and isolated +5V

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BLOCK INTPUTS

5V_IN
Vsa
SaD
Sa
Vsb
SbD
Sb
Vsc
ScD
Sc

NEUTRAL CONNECTOR

This converter has a separate neutral connector for AC implementation

J1 N

NOTE TAKING SPACE

This space is left blank for note taking while debugging.

BLOCK OUTPUTS

I_R
I_S
I_T
I_OUT
V_OUT_MES
T_COND
S_COND
R_COND
N
V_HIGH

CONVERTER INPUT CONNECTORS

The OwnTech 3-phase converter has 3 input connectors (R, S and T).
Each input connector is shown here with its input capacitor and inductor.

J5 R — L3 100u — I_R_IN — C38 470u — GND
J6 S — L1 100u — I_S_IN — C43 470u — GND
J7 T — L2 100u — I_T_IN — C37 470u — GND

MEASUREMENT PIN

This pin should be placed in a convenient spot for easy bebugging and probe connection.

TP17 GND

CONVERTER OUTPUT

The OwnTech 3-phase converter has a single output connector (VOUT).
Here, the output capacitors (C13, C14, C44 and C45) are shown together with the output current measurement and output voltage measurement.
The output resistor divider is calculated on a similar base as those below.

VOUT — C13 470u, C14 470u, C44 470u, C45 470u — GND

VOUT — I_VOUT_OUT — U4 (IP-, IP+, GND, FILTER, VCC, VIOUT) — I_VOUT_IN — J2 (+VOUT_GND) — GND
5V_IN — C19 100n — GND
C18 1n — GND
I_OUT

VOUT — R13 150k — R97 150k — R95 150k — V_OUT_MES
R47 10k, R81 10k, R96 10k, R14 10k — C20 1u — GND

CURRENT MEASUREMENTS

These hall-effect sensors are are connected to the input connectors of each phase.

5V_IN — C3 100n — GND
I_R — U3 ACS712xLCTR-05B (VIOUT, FILTER, VCC, GND, IP+, IP-) — C6 1n — GND
I_R_IN — I_R_OUT

5V_IN — C1 100n — GND
I_S — U1 ACS712xLCTR-05B — C4 1n — GND
I_S_IN — I_S_OUT

5V_IN — C2 100n — GND
I_T — U2 ACS712xLCTR-05B — C5 1n — GND
I_T_IN — I_T_OUT

VOLTAGE MEASUREMENTS

The OwnTech converter is multi-function. This means it can handle DC-DC and DC-AC conversions.
This creates a challenge for its voltage measurements.
These resistor bridges ARE NOT REFERENCED TO THE GROUND.
Instead, they are referenced to a NEUTRAL which can be used to measure AC line voltages.
In case of DC operation, the NEUTRAL can be connected to the GROUND for referencing.
The values of the resistances were calculated for a base of 700V measurements:

VR: R18 150k — R21 150k — R19 150k — R_COND
R16 10k, R17 10k, R20 10k, R28 10k — C48 1u — N

VS: R31 150k — R38 150k — R32 150k — S_COND
R29 10k, R30 10k, R33 10k, R39 10k — C49 1u — N

VT: R42 150k — R45 150k — R43 150k — T_COND
R40 10k, R41 10k, R44 10k, R46 10k — C50 1u — N

3-PHASE SYNCHRONOUS BUCK TOPOLOGY

The 3-phase synchronous buck topology allows for the use of both DC-DC and DC-AC conversions.
In this implementation, a series of experimental snubbers have been connected in parallel to each inverter leg.
Their values are not correct and they will be later used for experimental validation.

V_HIGH — VOUT — I_VOUT_OUT

SaD — Q1 — D1 — R1 10k — I_R_OUT — Vsa — Q2 — D2 — R2 10k — Sa — GND
R3 10k — C7 100n — R4 10k — C8 100n — C16 100n — EXPERIMENTAL SNUBBER

SbD — Q3 — D3 — R5 10k — Vsb — Q4 — D4 — R6 10k — Sb — GND
R7 10k — C9 100n — R8 10k — C10 100n — C15 100n — EXPERIMENTAL SNUBBER

ScD — Q5 — D5 — R9 10k — Vsc — Q6 — D6 — R10 10k — Sc — GND
R11 10k — C11 100n — R12 10k — C12 100n — C17 100n — EXPERIMENTAL SNUBBER

I_S_OUT
I_T_OUT

Vmeas/VIN = Rmeas/450k

If Rmeas = 10k, Vmeas/VIN = 1/46, VIN_max = 150V
If Rmeas = 5k, Vmeas/VIN = 1/91, VIN_max = 300V
If Rmeas = 3.3k, Vmeas/VIN = 1/136, VIN_max = 450V
If Rmeas = 2.5,, Vmeas/VIN = 1/181, VIN_max = 600V

Sheet: /POWER BLOCK/
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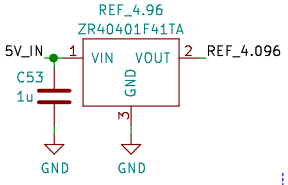
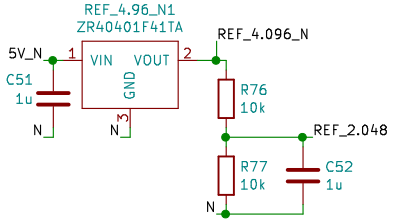
BLOCK INPUTS

5V_IN → 5V_IN
5V_N → 5V_N
R_COND → R_COND
S_COND → S_COND
T_COND → T_COND
N → N
I_R → I_R
I_S → I_S
I_T → I_T
I_OUT → I_OUT
V_OUT_MES → V_OUT_MES
CLK → CLK
MOSI → MOSI
SS → SS
SS1 → SS1
VCC_3V3 → VCC_3V3

VOLTAGE REFERENCES

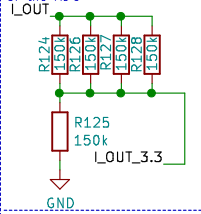
These references are used to provide a fixed reference value to the ADCs. One reference connected to the GND and the other to the NEUTRAL.
The NEUTRAL reference is used to generate a fixed 2.048V offset used by the voltage measurements.





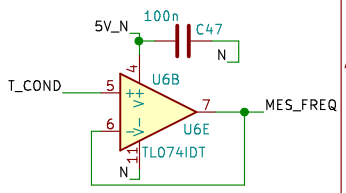
OUTPUT CURRENT

These resistors adapt the output current meas. from 5V to 4.096V of the ADC



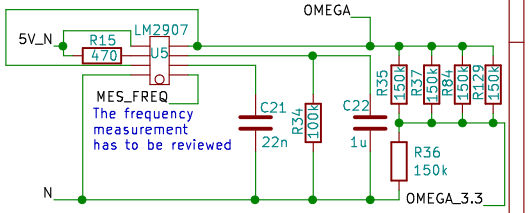
ZERO CROSS MEASUREMENT

This circuit is used to measure the zero crossing of phase T. MUST BE VALIDATED.



BLOCK OUTPUTS

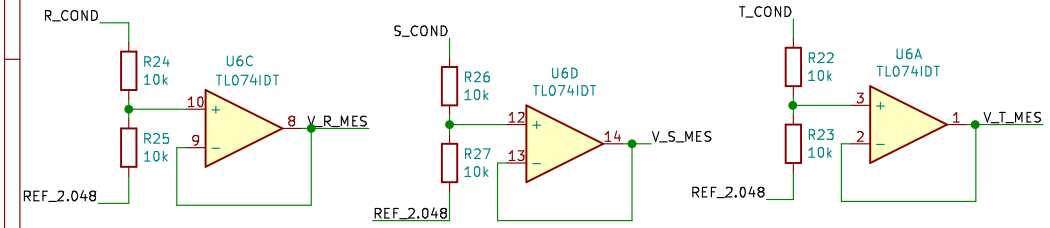
MISO → MISO



R CHANNEL MEASUREMENTS

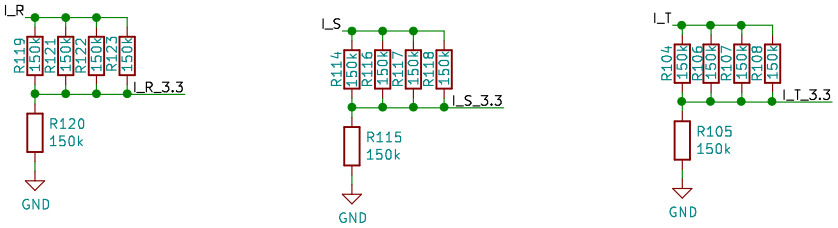
VOLTAGE MEAS.

X_COND is the input from the bridge divider in the power block.
REF_2.048 is an offset introduced to render the measurement voltage bi-directional.
This should only be used for AC applications.



CURRENT MEAS.

I_X is the current measurement input from the hall-effect sensor in the power block.
These resistances are needed to bring the voltage from 5V to 4.096V and make it compatible with the external ADC reference.



S CHANNEL MEASUREMENTS

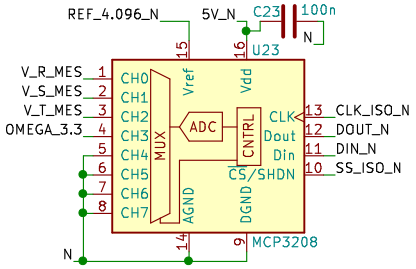
T CHANNEL MEASUREMENTS

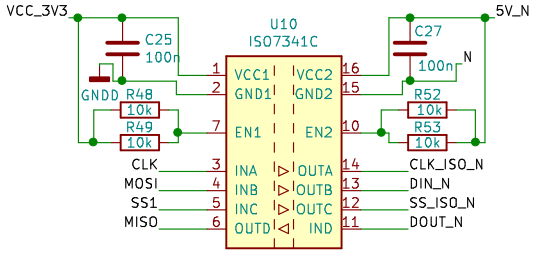
ADC AND ISOLATOR

This power converter uses 2 external ADC as a low cost solution to measuring voltage and current accross its different channels.

A pair of ADC + isolator is referenced to the NEUTRAL and measures the voltages of the system together with zero crossing.

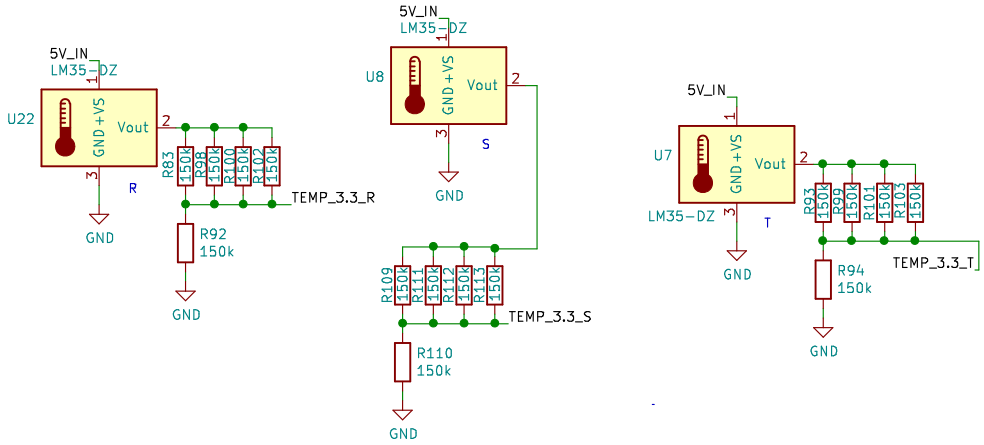
The other pair of ADC + isolator is referenced to the GND and measures the currents of all phases, the output current, all temperatures and the output voltage.

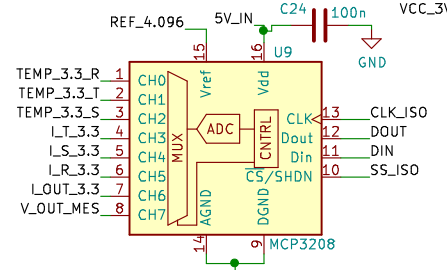


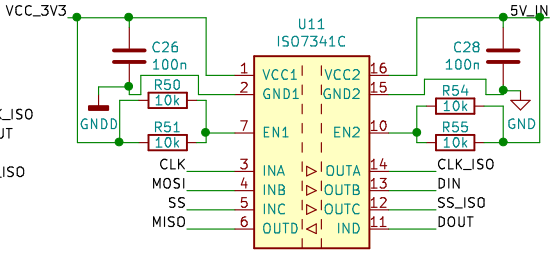


TEMPERATURE MEAS.

TEMP_3.3_X is the temperature output that goes to the external ADC.
These resistances are needed to bring the voltage from 5V to 4.096V and make it compatible with the external ADC reference.







Sheet: /MEASUREMENT BLOCK/
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BLOCK INTPUTS

15VD — 15V
5V_IND — 5V_IN
5VD — 5V
PWM1HD — PWM1H
PWM1LD — PWM1L
PWM2HD — PWM2H
PWM2LD — PWM2L
PWM3HD — PWM3H
PWM3LD — PWM3L

DRIVER BLOCK

This circuit connects the microcontroller
to the power transistors.
It uses a digital isolator to separate the grounds from both sides.
The digital isolator has a non-inverter output.

Based on these components
the system operates at 100kHz

DIGITAL ISOLATOR

The digital isolator chosen for this
converter is a SI8660which
has a VCC of +5V and can easily go up
to 100kHz for low power applications

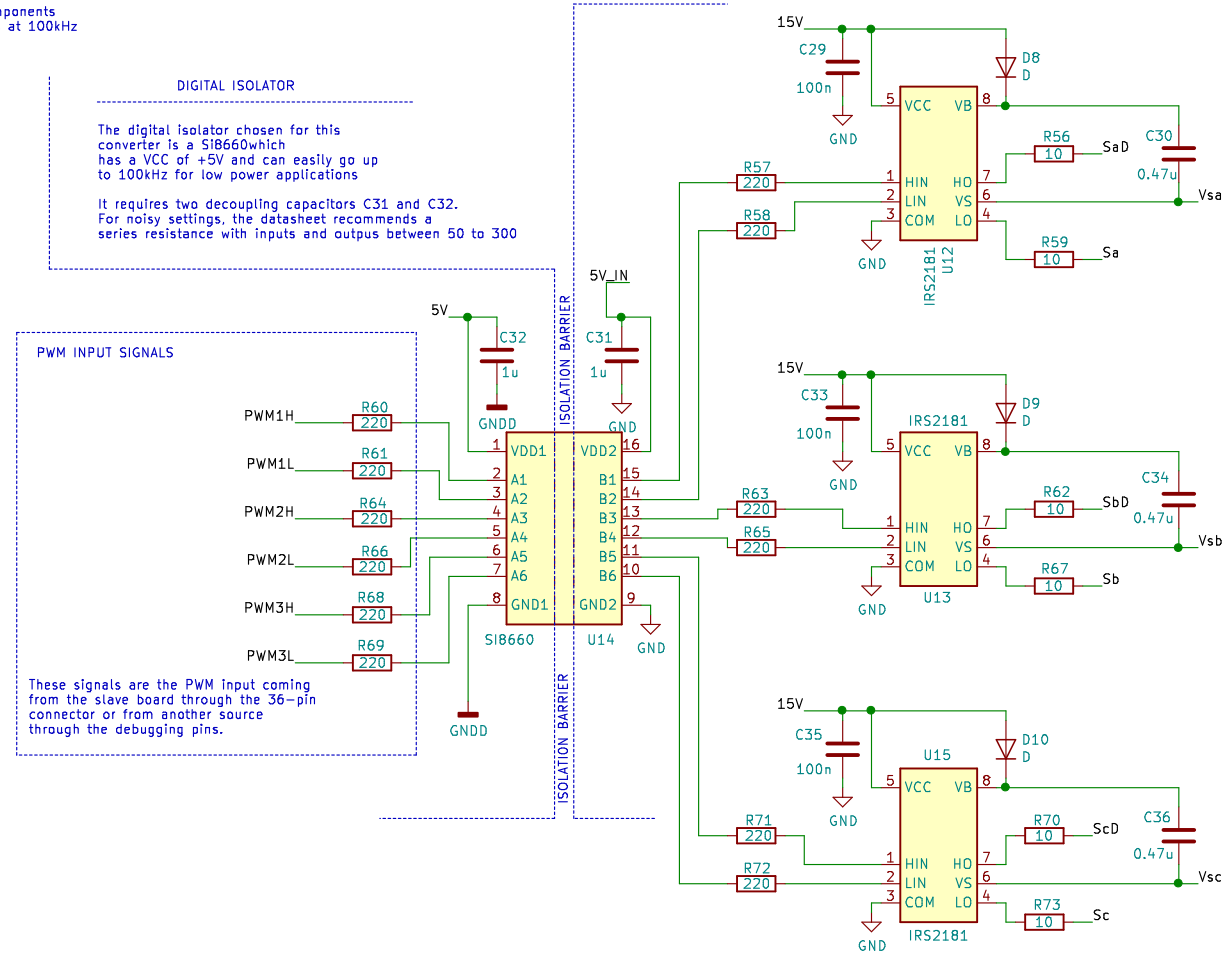
It requires two decoupling capacitors C31 and C32.
For noisy settings, the datasheet recommends a
series resistance with inputs and outpus between 50 to 300

PWM INPUT SIGNALS

These signals are the PWM input coming
from the slave board through the 36-pin
connector or from another source
through the debugging pins.

DRIVER CIRCUIT

The power driver chosen for this converter is the
IR2186 capable of driving a transitor up to 4A at a time.
This solution comprises a bootstrap which allows driving
both the high and low side transistors from the same IC.



IMPLEMENTATION COMMENTS

The series resistance at the output of HO and LO
(R56, R59, R62, R67, R70 and R72)
should be adapted to the MOSFET being used.
If the MOSFET is 200Vmax, then this resistance
should be around 2.2Ohm.
For a 600V MOSFET, this resistance is 10Ohm.

The bootstrap capacitor should be
non-polarized. It should hold up
some charge as to kick-start the
high-level MOSFET. (see datasheet)

The value chosen here was 470nF.

The bootstrap diodes
(D8, D9 and D10)
must have a maximum
reverse voltage must be compatible
with the VOUT max voltage.
Failure to do so will destroy the
feeder circuit.

BLOCK OUTPUTS

SaD — SaD
Sa — Sa
SbD — SbD
Sb — Sb
ScD — ScD
Sc — Sc
Vsa — Vsa
Vsb — Vsb
Vsc — Vsc

Sheet: /DRIVER BLOCK/
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BLOCK INPUTS

N
V_HIGH

MAGIC INPUT

V_HIGH can be as high as 600V for some applications. The maximum input voltage of the LMR16010 is 60V, which is a problem.

To avoid delaying the development of the board, a connector was introduced for now.

Eventually it will be necessary to develop a tiny power converter that goes from 600V to 60V in order to supply the board under any circumstance.

FEEDER BLOCK

This block regroups all the feeder circuits used with this converter.
- There is a main feeder that converts 15V down from 60V in its input.
- There is a 5V NEUTRAL referenced feeder that supplies energy to the voltage measurement chains
- There is a 5V GROUND referenced feeder that supplies energy to the current and temperature measurement chains.
- There is an ISOLATED 5V that supplies energy to the slave board.

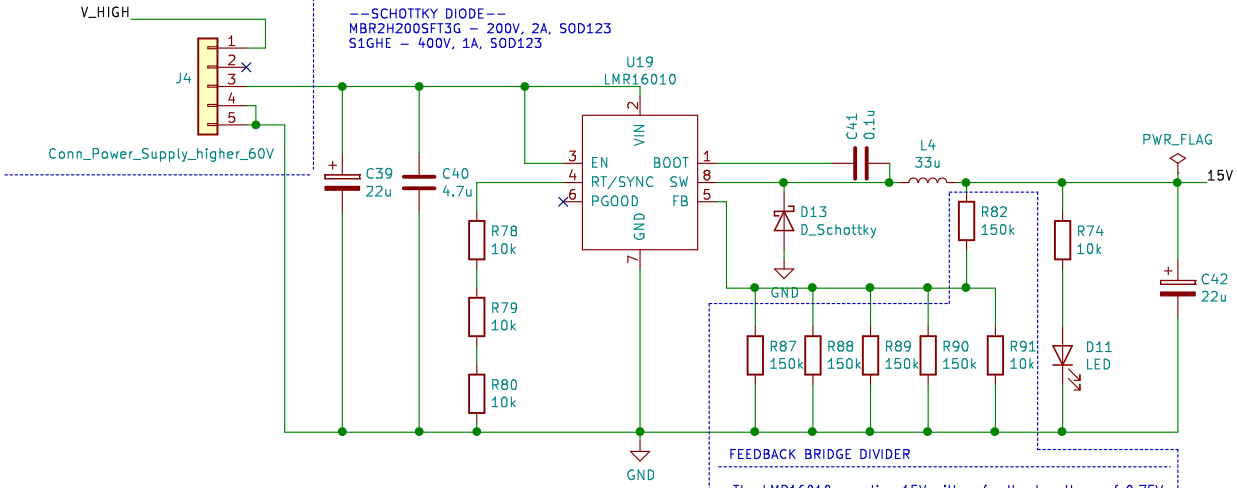
MAIN FEEDER Design Notes

Vin 17V to 60V // Vout 15.8V, 1A
---INDUCTOR AND CURRENT---
Inductor = 12LRS333C (Murata) (or higher)
DiL = 0.5A

---FEEDBACK ELEMENTS---
FB = 0.75V (Quite precise with the bridge divider)
RT = 30k (3x10k) (for an operation around 700kHz)

--CAPACITORS VOLTAGE----
C39 = 20u (should hold between 100V and 600V, thin-film)
C40 = 4.7u (should hold between 100V and 600V, ceramic)
C42 = 20u (150% bigger than the minimum, should hold up to 35V)
Cb = 100n (ceramic, X7R, for good thermal stability)

--SCHOTTKY DIODE--
MBR2H200SFT3G - 200V, 2A, SOD123
S1GHE - 400V, 1A, SOD123



FEEDBACK BRIDGE DIVIDER

The LMR16010 supplies 15V with a feedback voltage of 0.75V in its fb pin. This bridge divider was designed to provide these 0.75V using only 150k and 10k resistors.

$$\frac{Vout}{Vin} = \frac{1}{21} = \frac{0.75}{15+0.75}$$

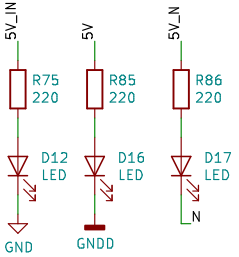
Using 150k on top gives a resistor of 7.5k on the bottom

Using the 5 resistances in parallel gives:

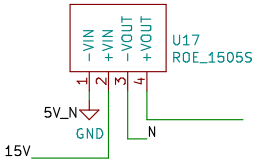
150k divided by 4 = 37.5k
37.5k in parallel with 10k = 7.89k
Which should give 0.749V.

FEEDER OPERATION LEDs

These LEDs show if the feeders are operational.
There is one of the GND referenced 5V,
one for the NEUTRAL referenced 5V,
and one for the isolated 5V.



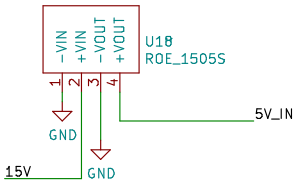
NEUTRAL REFERENCED 5V



BLOCK OUTPUTS

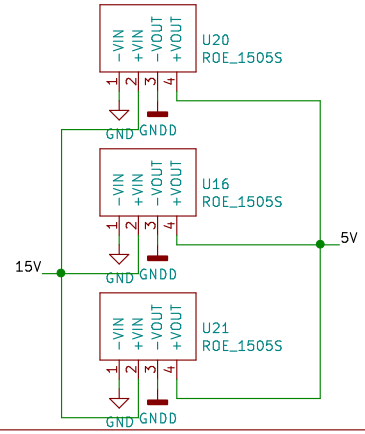
15V
5V_IN
5V
5V_N

NEUTRAL REFERENCED 5V



ISOLATED 5V

These 3 ROE1505 are connected in parallel because each can only supply up to 200mA. The microcontroller can consume up to 500mA, requiring at least 3 of them.



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BLOCK INTPUTS

MISO
5V

36-PIN CONNECTOR

This connector allows the connection between the power and the slave boards. Its pinout and the purpose of each pin is described below.

BLOCK OUTPUTS

PWM1L
PWM1H
PWM2L
PWM2H
PWM3L
PWM3H
MOSI
SS
SS1
CLK
VCC_3V3

POWER CONNECTION POINTS

These pins feed the slave board with +5V from the power board onboard feeder. The VCC_3V3 pin sends the 3.3V created by the slave board back into the power board to power the isolators.

SPI CONNECTION POINTS

These pins allow the slave board to communicate with the external ADCs via SPI.

ANALOG CONNECTION POINTS

Some extra analog I/O ports were made available in case the user needs to acquire some other data or need if from some other purpose.

PWM CONNECTION POINTS

These connectors allow the slave board to send the PWM signals to the driver block.

ANALOG TEST POINTS

These test points allow the user to connect with other devices such as sensors, through I/O pins of the slave board.

SPI TEST POINTS

These test points allow the user to debug which SPI is being handled through the SS and SS1 pins.

PWM TEST POINTS

These test points allow the debugging of the PWM signals arriving from the slave board. They also allow the user to send signals from some other device into the power board.

DIGITAL GROUND TEST PIN

This pin should be placed in a convenient spot for easily connecting oscilloscope probes for debugging.

LED TEST PIN

The slave board has an onboard LED for all purpose debugging. This pin allows to test it and its output port.

Sheet: /COMMAND BLOCK/	
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