POWER CONVERTER

This sheet gives an overview of a power converter module.
Each block is responsible for a different task and they are linked together through inputs and outputs.
The external communication block uses the RS485 protocol to communicate with other elements.

LIST OF BLOCKS

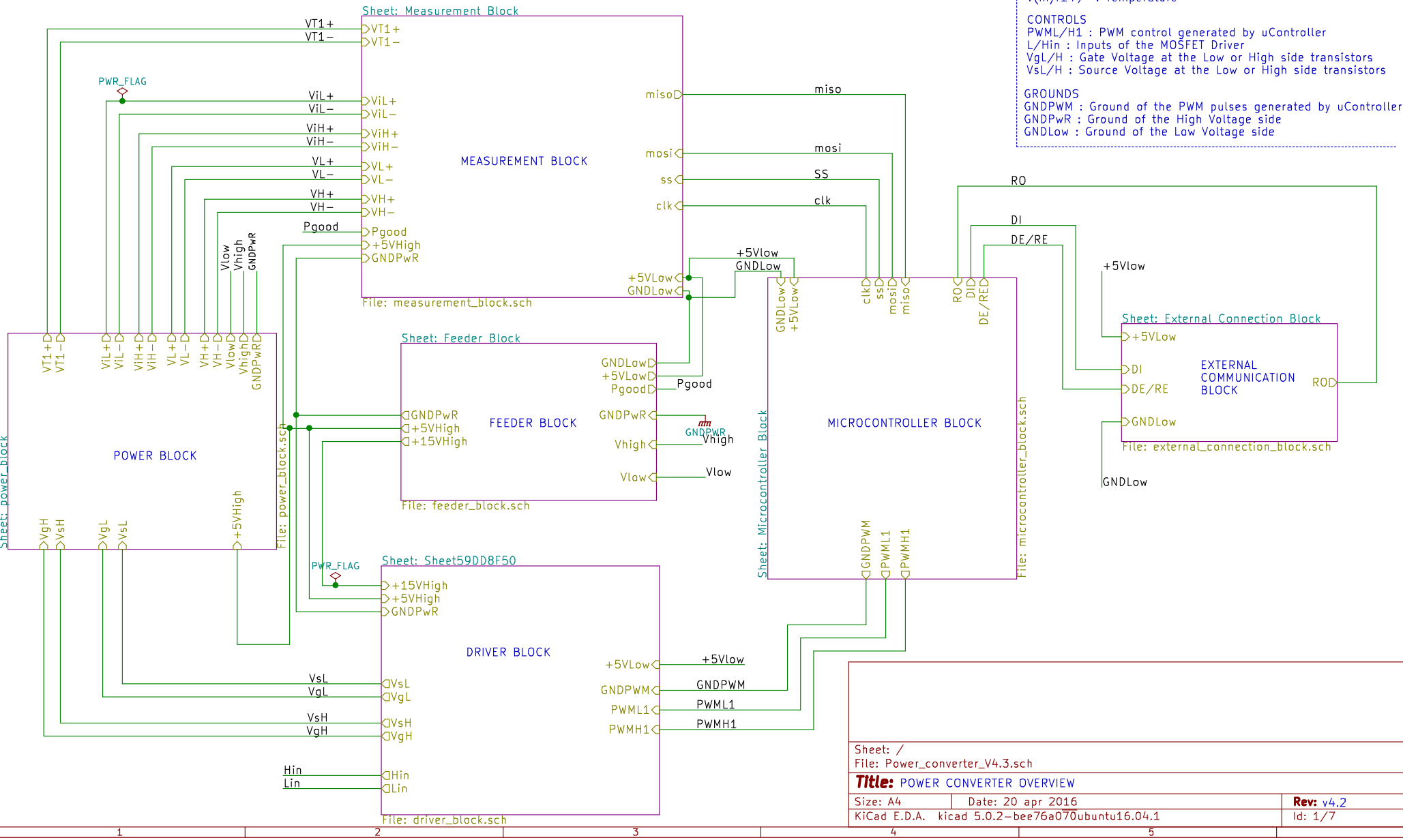
POWER BLOCK – Power Electronics components, Power Connectors and measuring sensors
MEASUREMENT BLOCK – Operational Amplifiers and data isolation
MICROCONTROLLER BLOCK – Arduino Nano shield
DRIVER BLOCK – Digital Isolator, MOSFET Driver
FEEDER BLOCK – Input up to 120V, Output +15V, +5V and isolated +5V
EXTERNAL COMMUNICATION BLOCK – Connectors for an external RS485 shield

LIST OF VARIABLES

MEASUREMENTS
(m) = variable after the OPAMP
V(m)iL+/– : Low side current
V(m)iH+/– : High side current
V(m)L+/– : Low side Voltage
V(m)H+/– : High side Voltage
V(m)T1+/–: Temperature

CONTROLS
PWML/H1 : PWM control generated by uController
L/Hin : Inputs of the MOSFET Driver
VgL/H : Gate Voltage at the Low or High side transistors
VsL/H : Source Voltage at the Low or High side transistors

GROUNDS
GNDPWM : Ground of the PWM pulses generated by uController
GNDPwR : Ground of the High Voltage side
GNDLow : Ground of the Low Voltage side



Sheet: /
File: Power_converter_V4.3.sch

Title: POWER CONVERTER OVERVIEW

Size: A4	Date: 20 apr 2016	**Rev:** v4.2
KiCad E.D.A. kicad 5.0.2-bee76a0~ubuntu16.04.1		Id: 1/7

BLOCK INPUTS

miso ▷ miso

RO ▷ RO

+5VLow ▷ +5VLow

GNDLow ▷ GNDLow

DETAILS OF THE MICROCONTROLLER BLOCK

This blocks connects the power converter with an Arduino nano shield.

INPUTS:
miso – SPI communication wires linking with the external ADC
RO – RS485 pin connecting to the external communication module
+5Vlow – either from the USB or from an isolated source
GNDLow – Low voltage ground

OUTPUTS:
ss, mosi, clk – SPI communication wires linking with the external ADC
DI, DE/RE – RS485 pins connecting to the external communication module
PWMH/L – PWMs signals
GNDPWM – PWM ground

BLOCK OUTPUTS

PWMH ▷ PWMH1

PWML ▷ PWML1

ss ▷ ss

mosi ▷ mosi

clk ▷ clk

DI ▷ DI

DE/RE ▷ DE/RE

GNDPWM ▷ GNDPWM

MICROCONTROLLER TEST POINT

A0 is used for debugging the microcontroller time constraints

A0 1 Tu1

GNDPWM 1 Tu2

PWML 1 Tu3

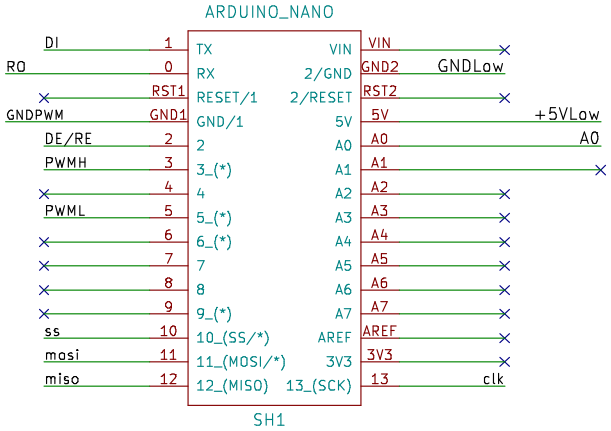
PWMH 1 Tu4

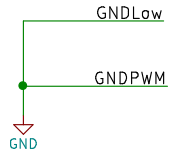
clk 1 Tu5

ss 1 Tu6

mosi 1 Tu7

miso 1 Tu8





Sheet: /Microcontroller Block/ File: microcontroller_block.sch		
Title: MICROCONTROLLER BLOCK		
Size: A4	Date: 20 apr 2016	**Rev:**
KiCad E.D.A. kicad 5.0.2-bee76a070ubuntu16.04.1		Id: 2/7

Input Variables

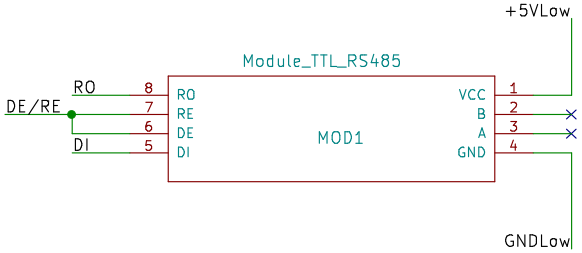
+5VLow
GNDLow
DI
DE/RE

COMMUNICATION BLOCK

DI – Driver inpout (to Tx pin of arduino)
DE/RE –Driver Output Enable (high to enable)/Receiver output Enable (Low to enable)
RO – Receiver Output (to Rx pin or Arduino)

Output Variables

RO



Sheet: /External Connection Block/
File: external_connection_block.sch

Title: EXTERNAL COMMUNICATION BLOCK

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 5.0.2-bee76a0~ubuntu16.04.1		Id: 3/7

BLOCK INPUTS

Vlow ▷ Vlow

Vhigh ▷ Vhigh

GNDPwR ▷ GNDPwR

FEEDER DETAILS

This is the global feeder circuit.
In this solution, the feeder is composed of a DC-DC converter that regulates 15V out of the Vlow.
These 15V are used to create 5V for the high side and 5V for the low side.
The masses are separated.

FEEDER TEST POINTS

Tf1: 1 — +15VHigh

Tf2: 1 — +5VHigh

Tf3: 1 — +5VLow

Tf4: 1 — GNDLow

Tf5: 1 — GNDPwR

BLOCK OUTPUTS

+5VLow ▷ +5VLow

GNDLow ▷ GNDLow

Pgood ▷ Pgood

+15VHigh ▷ +15VHigh

+5VHigh ▷ +5VHigh

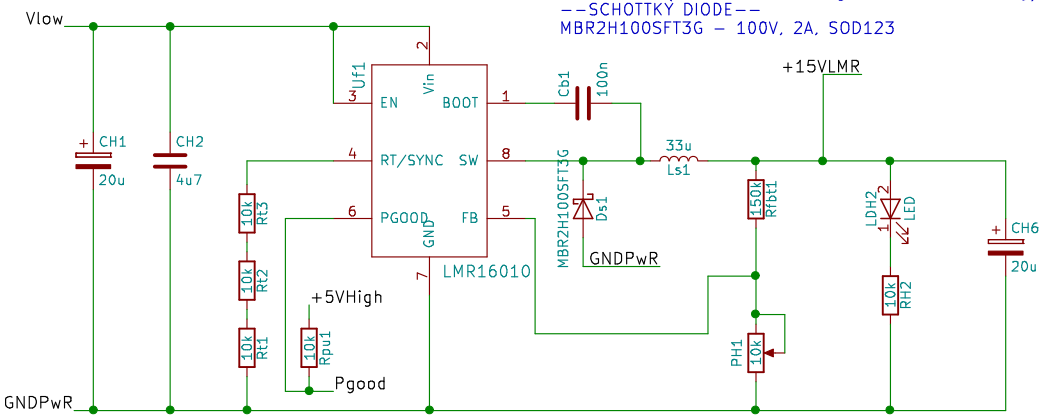
GNDPwR ▷ GNDPwR

DC-DC CONVERTER

This buck converter can take a maximum input of 60VDC to produce 15VDC. It is used to feed all of the power module.

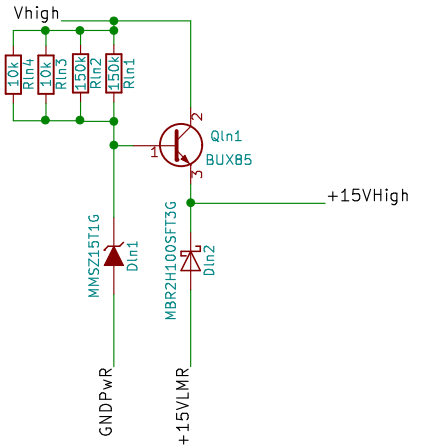
DC-DC converter Design Notes

Vin 17V to 60V // Vout 15.8V, 1A
---INDUCTOR AND CURRENT---
Inductor = 12LRS333C (Murata) (or higher)
DiL = 0.5A
---SETUP-ELEMENTS---
FB = 0.75V (Potentiometer for bettter precision)
RT = 30k (3x10k) (for an operation around 700kHz)
Rpg = 10k (pull-up which sends the "power good" signal to the Arduino)
--CAPACITORS-VOLTAGE----
CH1 = 20u (should hold up to 100V, thin-film)
CH2 = 4.7u (should hold up to 100V, ceramic)
CH3 = 20u (150% bigger than the minimum)
Cb = 100n (ceramic, X7R, for good thermal stability)
--SCHOTTKY DIODE--
MBR2H100SFT3G - 100V, 2A, SOD123



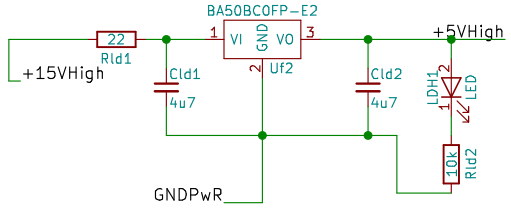
BLACK START LINEAR FEEDER

This linear feeder drivers energy from the +120V in the case of a black start from the high voltage level.
It generates +14.8V from the 120V with a very low efficiency allowing the system to start-up before the +15.8V from the LMR can take over the feeding of the board.
75k - 1/4 W (2x 150k - 1/8 W in parallel)
Extra resistors are available in case the system is run at lower voltages
Zener - MMSZ15T1G - 500mW, SOD123
Schottky - MBR2H100SFT3G - 100V, 2A, SOD123



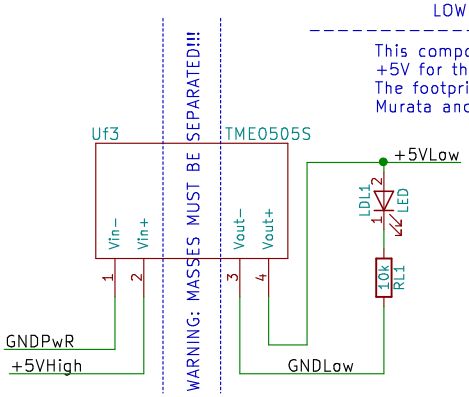
DC low drop out linear regulator 5V supply on the high side

This linear regulator has a low drop out and can take 16.5V input.
A 22 ohm, 1/4W resistance is added in series to regulate input voltage and to serve as a fuse in case of overpower



LOW VOLTAGE SIDE FEEDER

This component generates +5V for the low voltage side reference.
The footprint is compatible with both Murata and Traco components.



Sheet: /Feeder Block/
File: feeder_block.sch

Title: FEEDER BLOCK

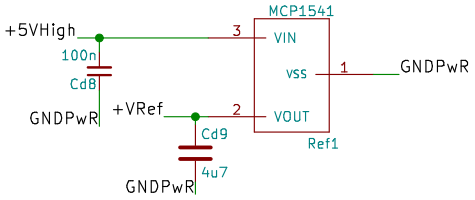
Size: A4 | Date: 20 apr 2016 | **Rev:**
KiCad E.D.A. kicad 5.0.2-bee76a0~ubuntu16.04.1 | Id: 4/7

Input Variables

ViL+ ViL2+
ViL− ViL−
ViH+ ViH2+
ViH− ViH−
VL+ VL+
VL− VL−
VH+ VH+
VH− VH−
VT1+ VT1+
VT1− VT1−
clk clk
ss ss
mosi mosi
+5VLow +5VLow
GNDLow GNDLow
+5VHigh +5VHigh
GNDPwR GNDPwR
Pgood Pgood

VOLTAGE REFERENCE

Provides a stable 4,096V reference



MEASUREMENT TEST POINTS

Pins used for measuring while debugging

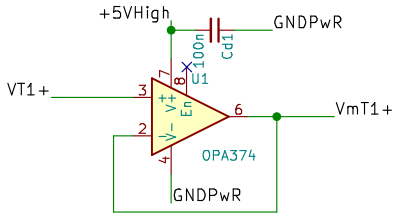
TM1 VmiL+
TM2 VmiH+
TM3 VmL+
TM4 VmH+
TM5 VmT1+
TM6 Pgood
TM7 Voffset

Output Variables

miso miso

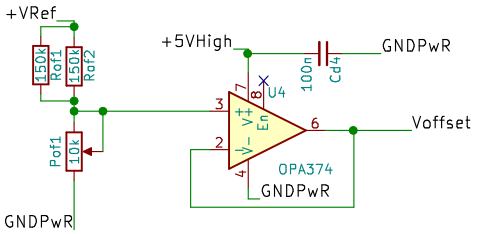
TRANSISTOR TEMPERATURE SENSING CHAIN

Senses the voltage issued from the temperature sensor.



CURRENT MEASUREMENT OFFSET

Implements a current offset



CURRENT MEASUREMENT

The current measurement chain has three elements:
- An input filter for the signal
- An offset for bi-directional current measurement
- A gain relative to the shunt value

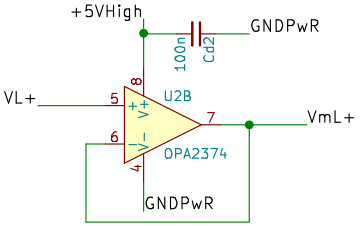
INPUT RC FILTER
R = 150k
C = 100n
fc = 66.66Hz

INPUT OFFSET
Resistor bridge
Upper part – 75kOhm
Lower part – 10kOhm
Trimmer
RANGE – 0V – 481mV
TARGET OFFSET – 325mV

GAIN – Non-inverter (1 + (Rg2/Rg1))
Input voltage step = 13mV per Amp
Input Current Range = −20A to +20A
Output current step = 100mV per Amp
Output Meas. Voltage range = 0.5V to 4.5V
Gain = 100mV/13mV = 7.63
Rration = (7.63 * 2) – 1 = 14.38
Rg1 = 10k
Rg2 = 150k
Offset = 2.5V/7.65 = 325mV

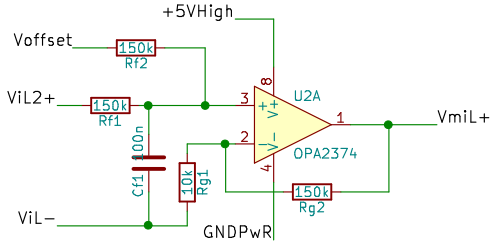
LOW-SIDE VOLTAGE SENSING CHAIN

Senses the voltage isolated from high power side.



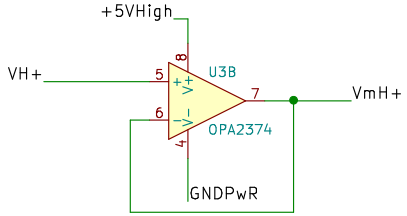
LOW-SIDE CURRENT SENSING CHAIN

Senses the current isolated from high power side.



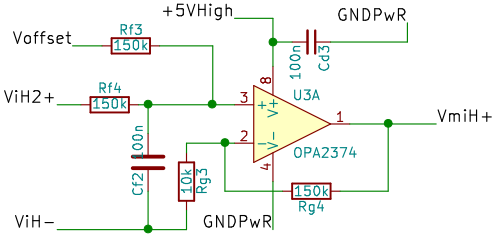
HIGH-SIDE VOLTAGE SENSING CHAIN

Senses the voltage isolated from high power side.



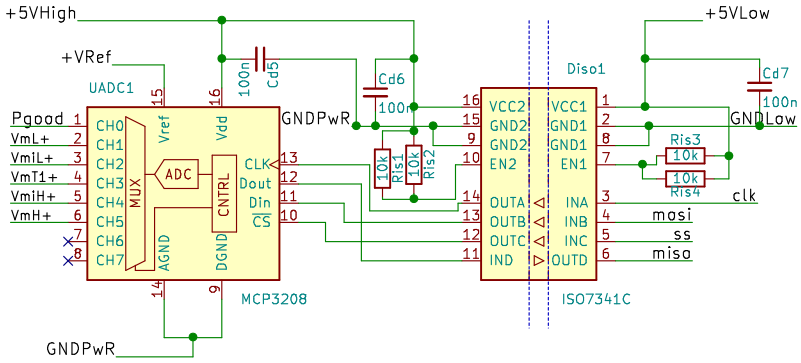
HIGH-SIDE CURRENT SENSING CHAIN

Senses the current isolated from high power side.



A/D CONVERTER AND DIGITAL ISOLATOR UNIT

The ADC is done through an isolated chain which is implemented by two components. On the left is the 12bit ADC and on the right is the digital isolator. The communication with the microcontroller is done through SPI. Two 10k resistors are used on both sides to simplify the system.



BUG Comments

There's a net error with ViL+ and ViH+. To compensate, these are transformed into ViL2+ and ViH2+, respectively.

Sheet: /Measurement Block/
File: measurement_block.sch

Title: MEASUREMENT BLOCK

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 5.0.2-bee76a070ubuntu16.04.1		Id: 5/7

BLOCK INPUTS

VgH
VsH
VgL
VsL
+5VHigh

DETAILS OF THE POWER BLOCK

This topology employs capacitors both at the input and the output. The inductance in the middle allows it to be a fully reversible buck-boost.

This version of the converter uses 200V MOSFETS capable of handling up to 20A. This converter was designed to have a high-side up to 120V making its low-side reasonable up to 60V. The power in this structure HAS NOT BEEN TESTED beyond 500W.

BLOCK OUTPUTS

ViL+
ViL-
ViH+
ViH-
VL+
VL-
VH+
VH-
VT1+
VT1-
Vlow
Vhigh
GNDPwR

CONVERTER INPUT

The inputs of this block are the gate-source voltages for the high-side (H) and low-side (L) transistors.
(VgH-VsH/VgL-VsL)

MEASUREMENTS

There are 3 measurements spread among the power elements:

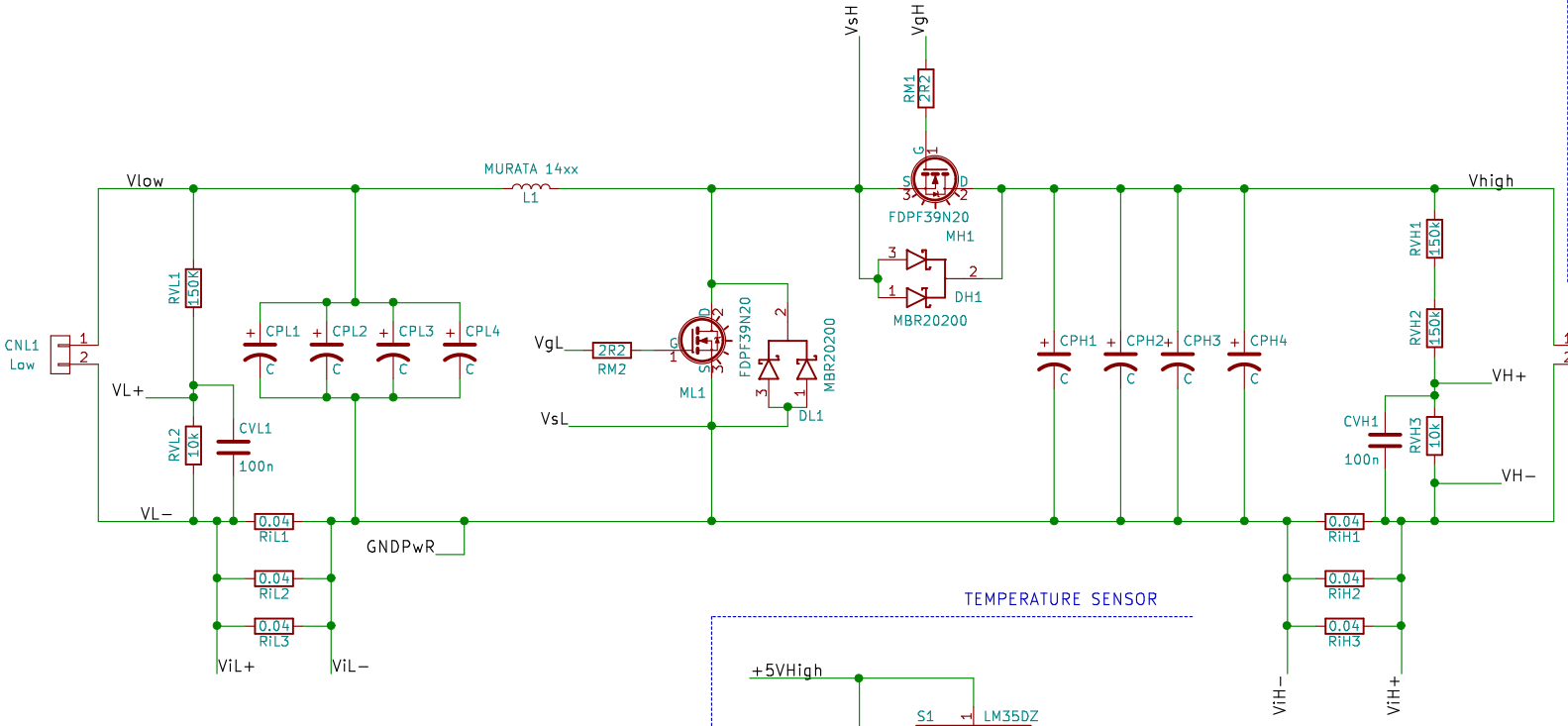
ViL+ and ViL- is the voltage drop of the shunt resistance reading low side current
EQUIVALECE: 1 Amp = 13mV (3 shunts)

ViH+ and ViH- is the voltage drop of the shunt resistance reading high side current
EQUIVALECE: 1 Amp = 13mV (3 shunts)

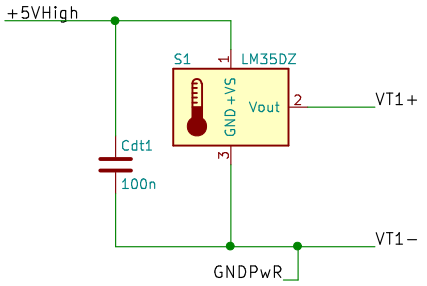
VL+ and VL- is the voltage drop of the resistance reading low side voltage
EQUIVALECE: 1/15 = 60V = 4V
IMPLEMENTED: 1/16 = 60V = 3.75V

VH+ and VH- is the voltage drop of the resistance reading high side voltage
EQUIVALECE: 1/30 = 120V = 4V
IMPLEMENTED: 1/31 = 120V = 3.87V

Temperature
10mV per °C as per the component's datasheet



TEMPERATURE SENSOR



Sheet: /power_block/	
File: power_block.sch	
Title: POWER BLOCK	
Size: A4	Date: 20 apr 2016
KiCad E.D.A. kicad 5.0.2-bee76a070ubuntu16.04.1	Id: 6/7

BLOCK INPUTS

PWMH1 — PWMH
PWML1 — PWML
GNDPWM — GNDPWM
+5VLow — +5VLow
+5VHigh — +5VHigh
+15VHigh — +15VHigh
GNDPwR — GNDPwR

DETAILS OF THE 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

BLOCK OUTPUTS

VgH — VgH
VsH — VsH
VgL — VgL
Hin — Hin
Lin — Lin
VsL — VsL

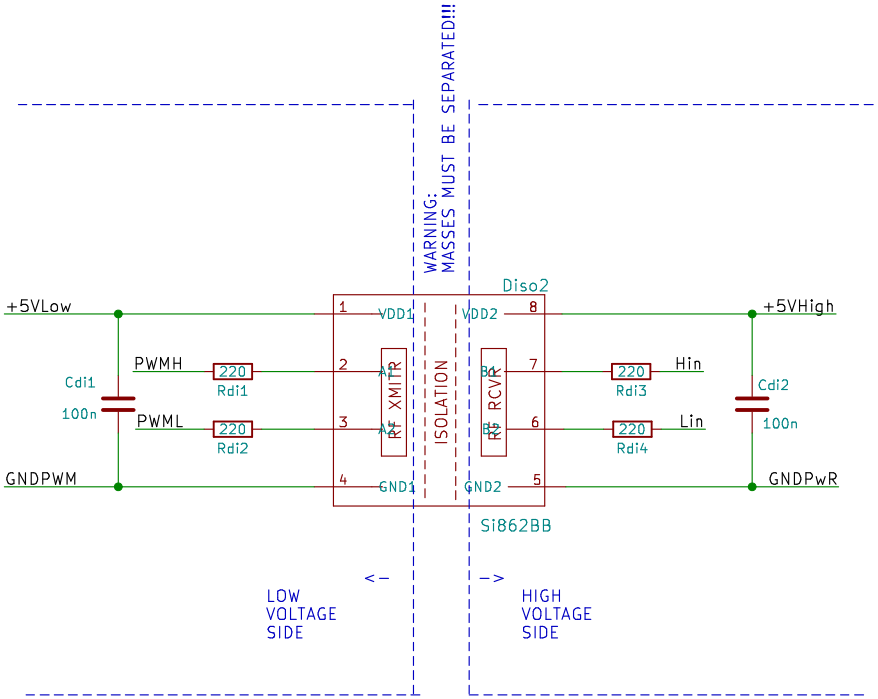
DRIVER TEST POINTS

TD1: 1 — Hin
TD2: 1 — Lin

DIGITAL ISOLATOR

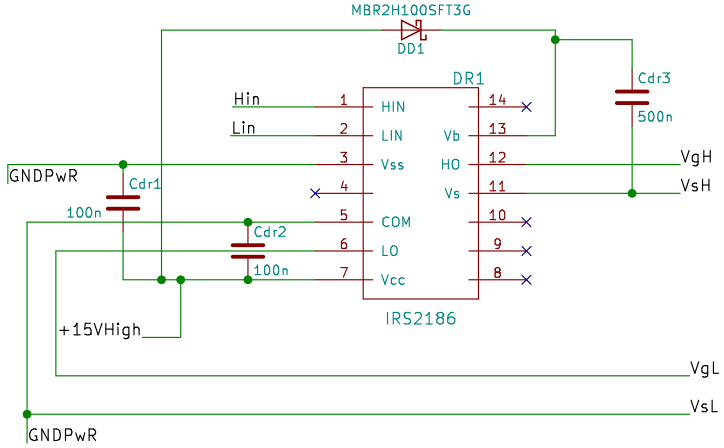
The digital isolator chosen for this
converter is a Si862BB which
has a VCC of +5V and can easily go up
to 100kHz for low power applications

It requires two bypass capacitors Cdi1 and Cd2.
For noisy settings, the datasheet recommends a
series resistance with inputs and outpus between 50 to 300



POWER DRIVER

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.



Sheet: /Sheet59DD8F50/
File: driver_block.sch

Title: DRIVER BLOCK

Size: A4	Date: 20 apr 2016	**Rev:**
KiCad E.D.A. kicad 5.0.2-bee76a070ubuntu16.04.1		Id: 7/7