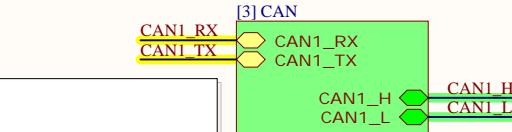
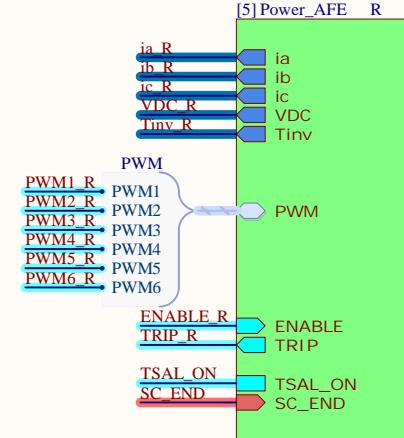
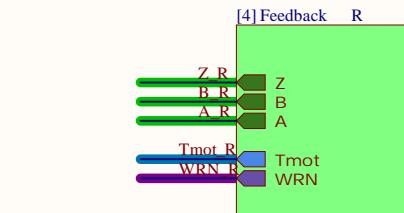
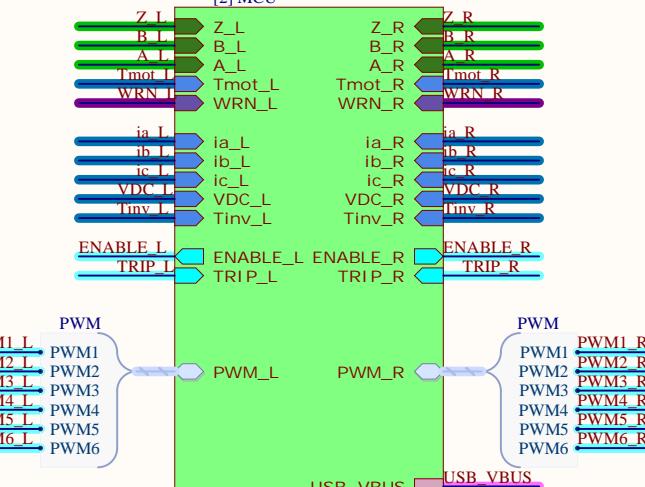
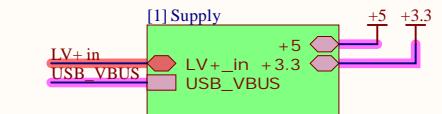


- ① Cyan nets indicate external signals.
- ① Purple nets indicate internal 3.3V signals.
- ① Blue nets indicate analog signals read by the ADC.
- ① Red nets indicate 20-30V.
- ① Pink nets indicate treated supply.
- ① Light green nets indicate CAN.
- ① Yellow nets indicate serial communication.
- ① Dark green nets indicate input capture.

**Known issues:**

- DCDC101 not tested yet.
- L101 has a very low current rating. Choose new part with a rating of at least 3A.
- Q101 and USB in general not tested yet.
- U501 not working as expected.
- U201 dot in silkscreen might be misleading. Check the orientation very carefully.
- 3.3V OVP should be added to all non-5V-tolerant MCU pins.
- Most if not all 15R resistors could very well be OR or solder bridges.
- 10uF 50V 0805 caps are expensive and should be replaced with 10uF 50V 1206 or 10uF 50V 1210.



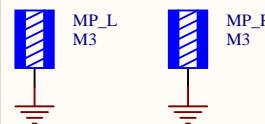
#### Changelog:

##### Version 1.0:

- Base version, sent to production 21-02-2024

##### Version 1.1:

- Pull-up and pull-down added for BOOT0 control
- Added I2C pull-ups
- LV+\_sns deleted, VBAT connected to 3.3V
- Extras LED color and names changed
- Added layers physical logo
- Moved supply filter to +5V
- Some silkscreen

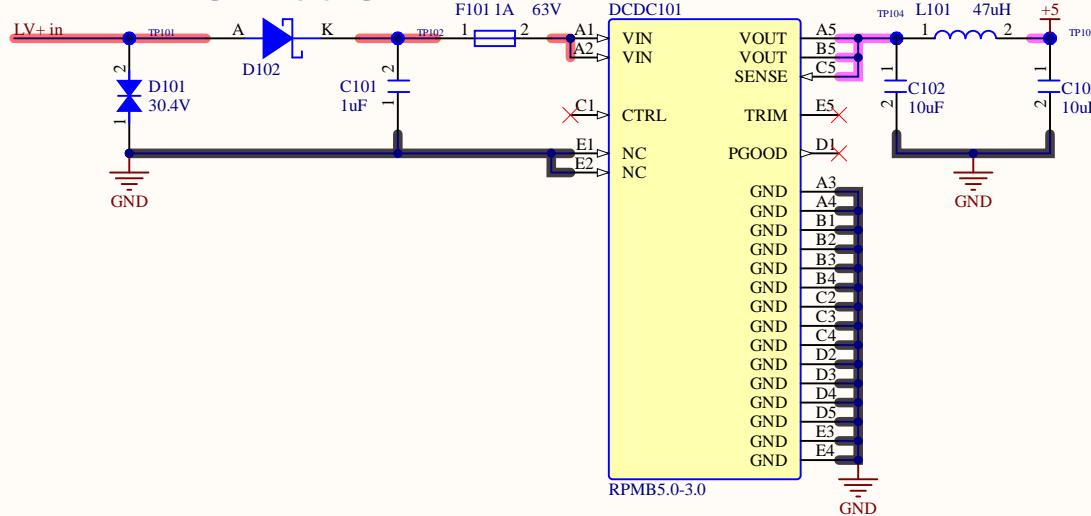


**4 Layers**

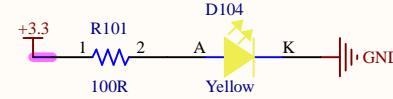
HW1

Company:	e-Tech Racing	e-techracing.es	
Project:	Inverter Control	Variant: [No Variations]	
Size:	Page Contents: Inverter_Control.SchDoc	Version: 1.1	
		Department: Powertrain	
Author:	David Redondo	dredondovinolo@gmail.com	Sheet 1 of 1
Checked by:		Date: 20/05/2024	

## LV battery supply



## Supply OK



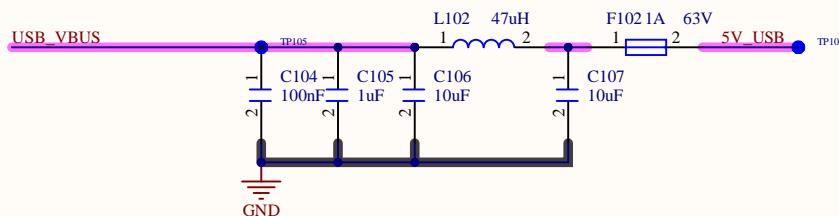
## INPUTS/OUTPUTS

**LV+\_in**

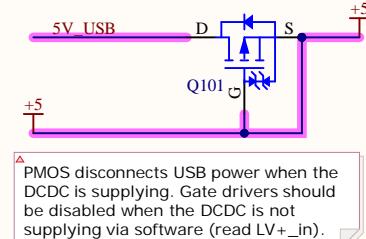
**USB\_VBUS**

**+5**  
**+3.3**

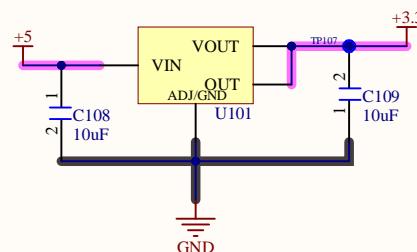
## USB supply



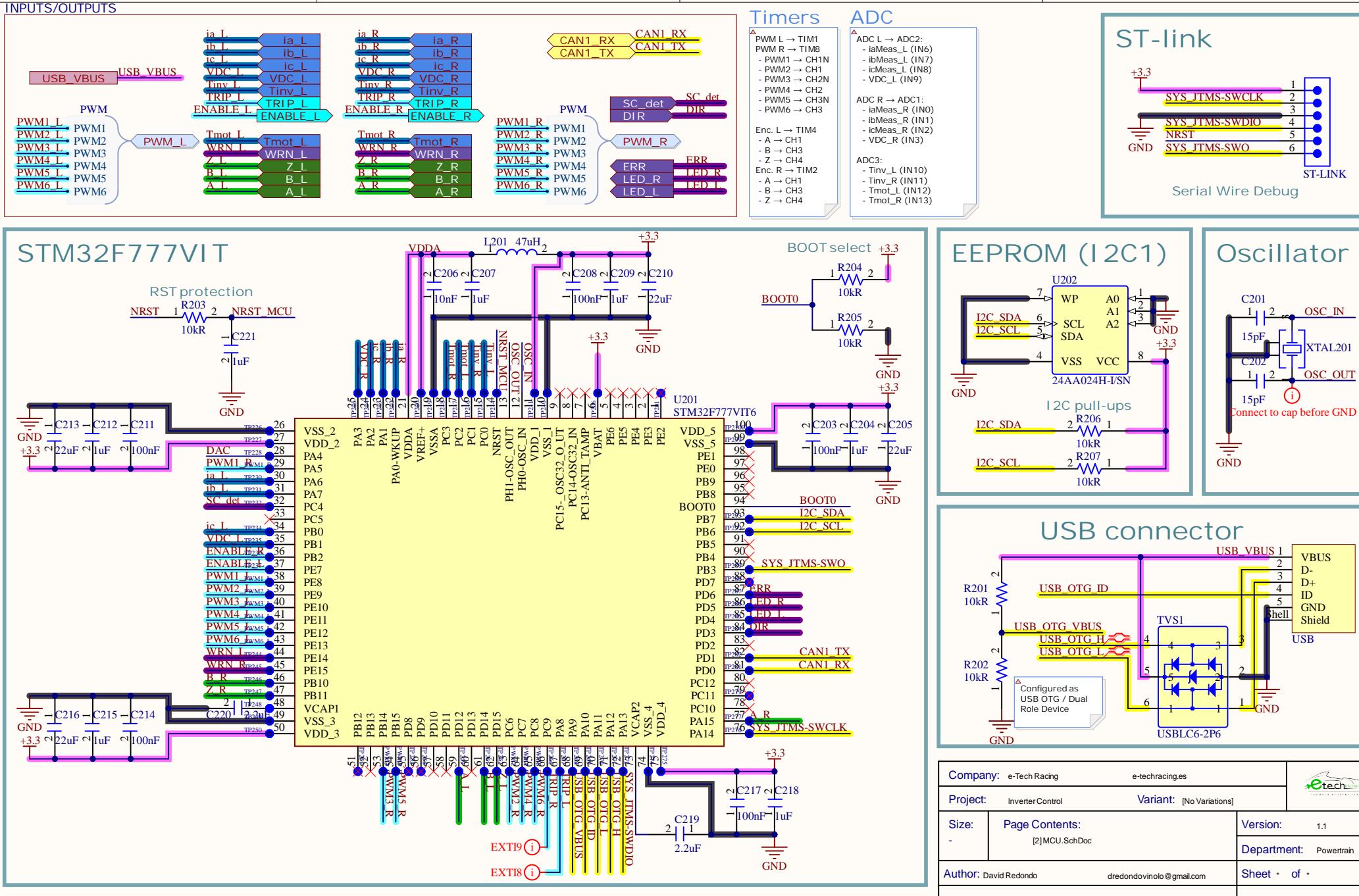
## 5 V selection



## LDO

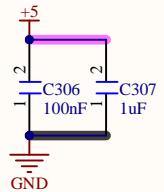


Company:	e-Tech Racing	e-techracing.es	
Project:	Inverter Control	Variant: [No Variations]	
Size:	Page Contents: [1]Supply.SchDoc	Version: 1.1	
-		Department: Powertrain	
Author:	David Redondo	dredondovinolo@gmail.com	Sheet * of *
Checked by:	*	Date: 20/05/2024	

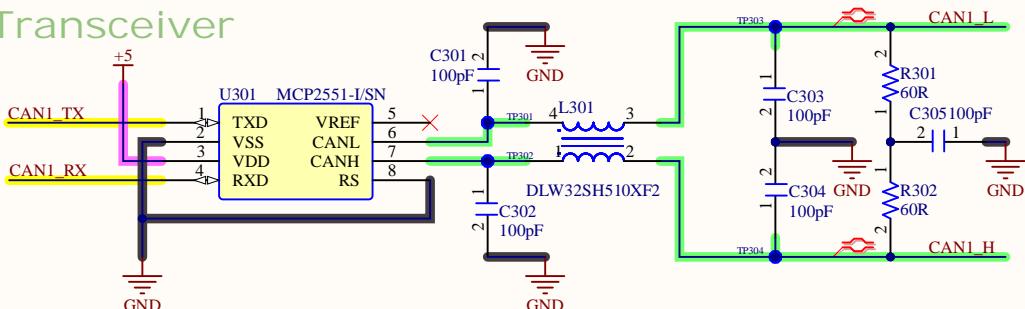


A

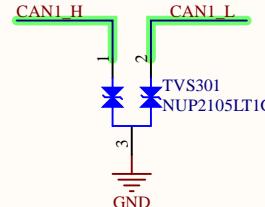
## Decoupling



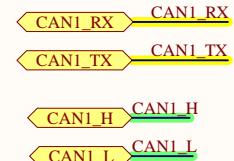
## Transceiver



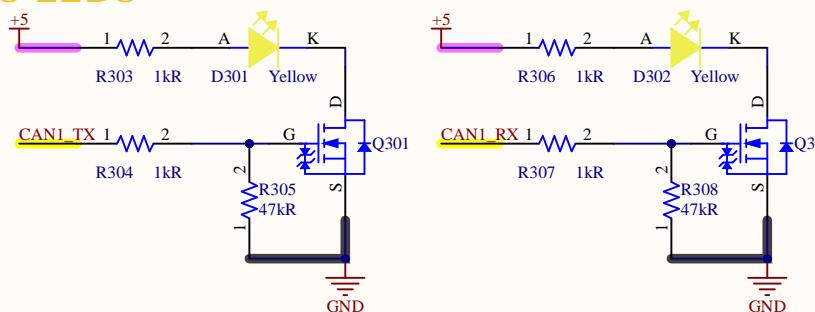
## ESD



## INPUTS/OUTPUTS



## Status LEDs



Company: e-Tech Racing e-techracing.es



Project: Inverter Control Variant: [No Variations]

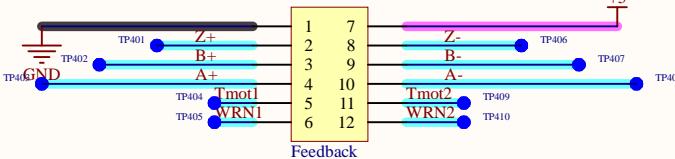
Size: - Page Contents: [3]CAN.SchDoc Version: 1.1

Department: Powertrain

Author: David Redondo dredondovinolo@gmail.com Sheet: \* of \*

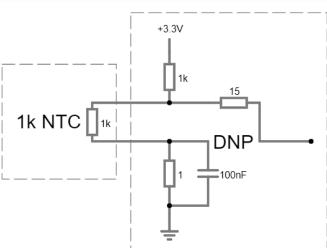
Checked by: \_ Date: 20/05/2024

## Feedback connector

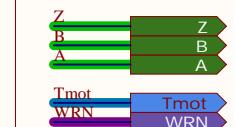


As the motors' temperature sensors are not specified, the user may modify the resistor combination to find a suitable input for the ADC, then load a custom lookup table to have an appropriate reading.

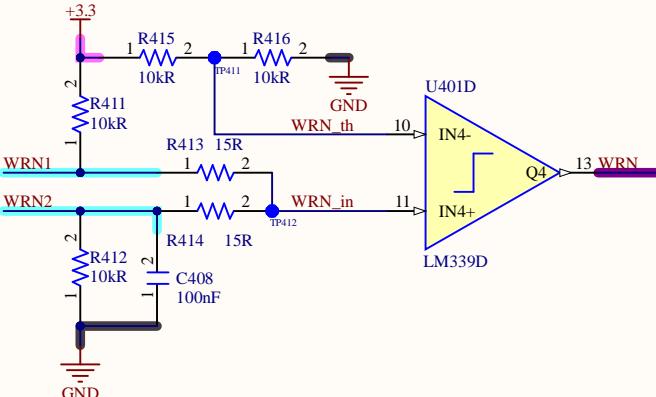
### Example



### INPUTS/OUTPUTS

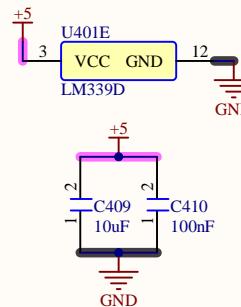


## Auxiliary warning (WRN)



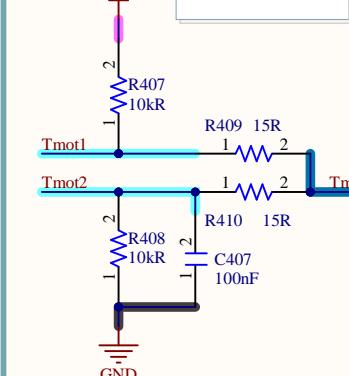
The WRN circuit can be used so that the MCU can detect a specified alarm. A resistive sensor can be used to detect any physical signal, such as overtemperature in any component (e.g. water outlet, gearbox, ...), underpressure of the cooling system, etc. Similar to the motor temperature sensors, the user may modify the resistor combination to have a suitable reading and adjust the voltage divider in order to set the threshold. Other types of sensors can be used, given a previous study and correct implementation.

## Comparator supply

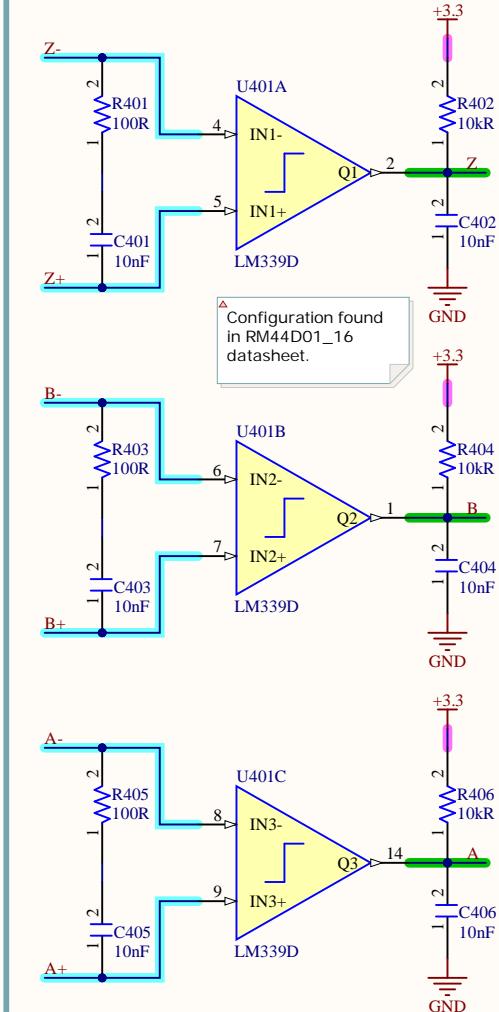


## Motor thermistor

Only compatible with resistive temperature sensors.



## Incremental encoder



Company: e-Tech Racing e-techracing.es



Project: Inverter Control Variant: [No Variations]

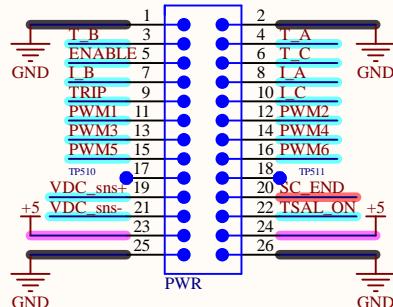
Size: - Page Contents: [4]Feedback.SchDoc Version: 1.1

Department: Powertrain

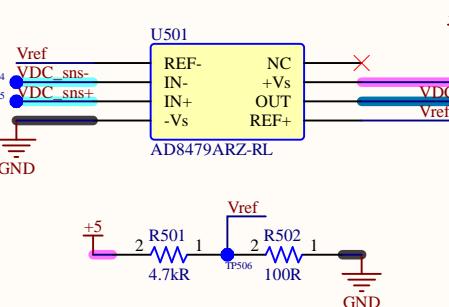
Author: David Redondo dredondovinolo@gmail.com Sheet: \* of \*

Checked by: \_ Date: 20/05/2024

## Power PCB Connector



## VDC sense AFE



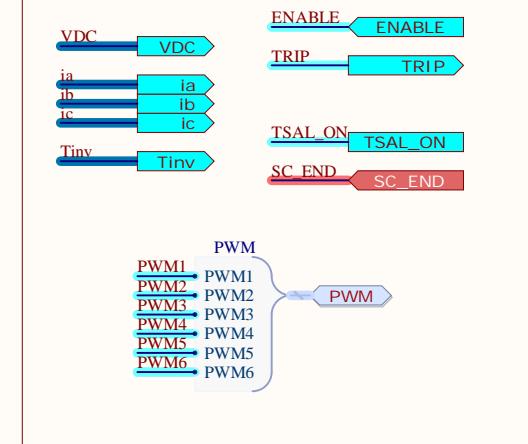
△ Difference amplifier

LT SPICE simulation for reference.

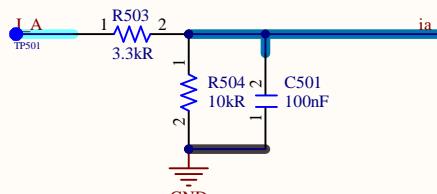
$$VDC = Vref + (VDC_{sns+} - VDC_{sns-}) = Vref + \frac{1}{3} \cdot 0.011388 \cdot (TS+ - TS-)$$

Maximum error due to using a voltage divider as a voltage reference is 1.79mV in ADC, which translates to 0.47V in (TS+ - TS-). Lowering the resistance values (while keeping proportionality) will reduce the error, but more current will be drawn.

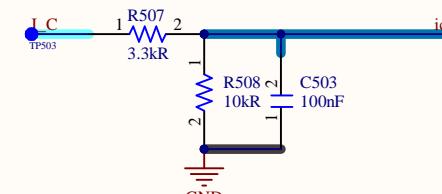
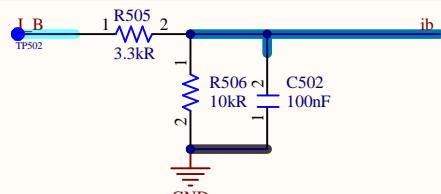
## INPUTS/OUTPUTS



## Current sense



△ Resistor combination can be adjusted for increased measuring range at the cost of lower resolution.

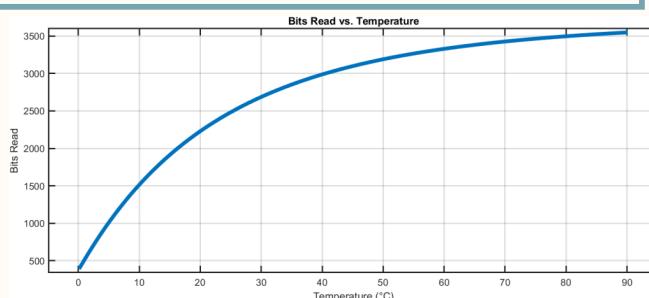


△ ENABLE is output directly from the MCU, it has been checked that UC21732 is able to detect it at 3.3V. Similarly, TRIP comes at 5V, and uses a 5V tolerant GPIO in the MCU.

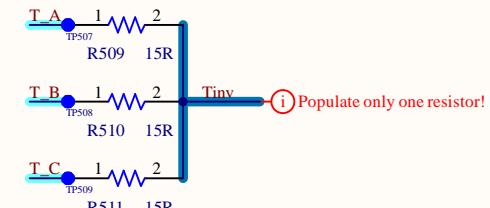
△  $VDC\_offset = Vref \cdot 2^{12} \text{ bits} / (3.3V) = 0.02083 \cdot 2^{12} \text{ bits} / (3.3V) = 2333 \text{ bits}$   
 $VDC\_gain = 1 / ((1/3 \cdot 0.011388 \text{ V/V}) \cdot (2^{12} \text{ bits} / 3.3 \text{ V})) = 0.0484609962 \text{ A/bit}$   
 $VDC\_max = 0.212240269 \text{ V/bit} \cdot 2^{12} \text{ bits} = 869.34 \text{ V}$

△  $ix\_offset = (10k / (3.3k + 10k)) \cdot 2.5V \cdot 2^{12} \text{ bits} / (3.3V) = 0.02083 \cdot 2^{12} \text{ bits} / (3.3V) = 129 \text{ bits}$   
 $ix\_gain = (10k / (3.3k + 10k)) / (12.5 \text{ mV/A} \cdot (2^{12} \text{ bits} / 3.3 \text{ V})) = 0.0484609962 \text{ A/bit} \cdot 2^{12} \text{ bits} / 2 = +/- 99 \text{ A}$

△ Inverters temperature should be calculated with a lookup table according to this graph. The lookup table and graph is generated with a MATLAB script which can be found in the simulations folder.



## Temperature selection



△ Tiny is a pulsed signal that can read directly as a PWM input or be passed through an RC filter (in Inverter\_Power) to convert it into an analog signal. This board intends to read it with the ADC. The reading itself is in the TS part of the power board and connected to the AIN pin of UCC21732.

Based on the sensed voltage, the duty cycle (D) of the UCC21732 isolated output signal is calculated using the following relationship:  $D = -20 \cdot V_{AIN} + 100$

If filtered, the voltage at Tiny is calculated as:  $V_{Tiny} = VCC\_GD \cdot D/100 = 5V \cdot (-20 \cdot V_{AIN} + 100)/100$

Company:	e-Tech Racing	e-techracing.es	e-techracing FORMULA STUDENT TEAM
Project:	Inverter Control	Variant: [No Variations]	
Size:	Page Contents: [5] Power_AFE.SchDoc	Version: 1.1	
Author:	David Redondo	dredondovinolo@gmail.com	
Checked by:		Sheet * of *	Date: 20/05/2024

A

B

C

D

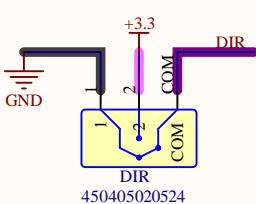
A

B

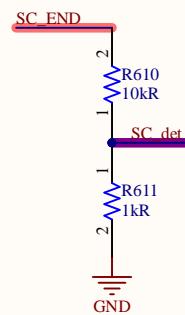
C

D

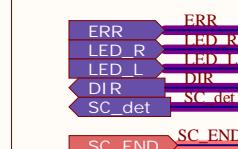
### Reverse direction



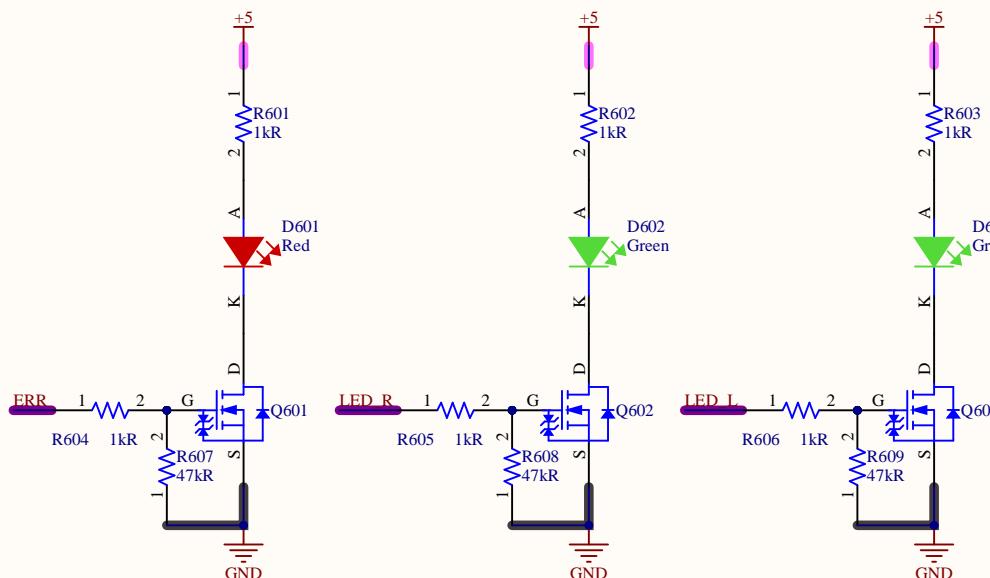
### SC detection



### INPUTS/OUTPUTS



### Status LEDs

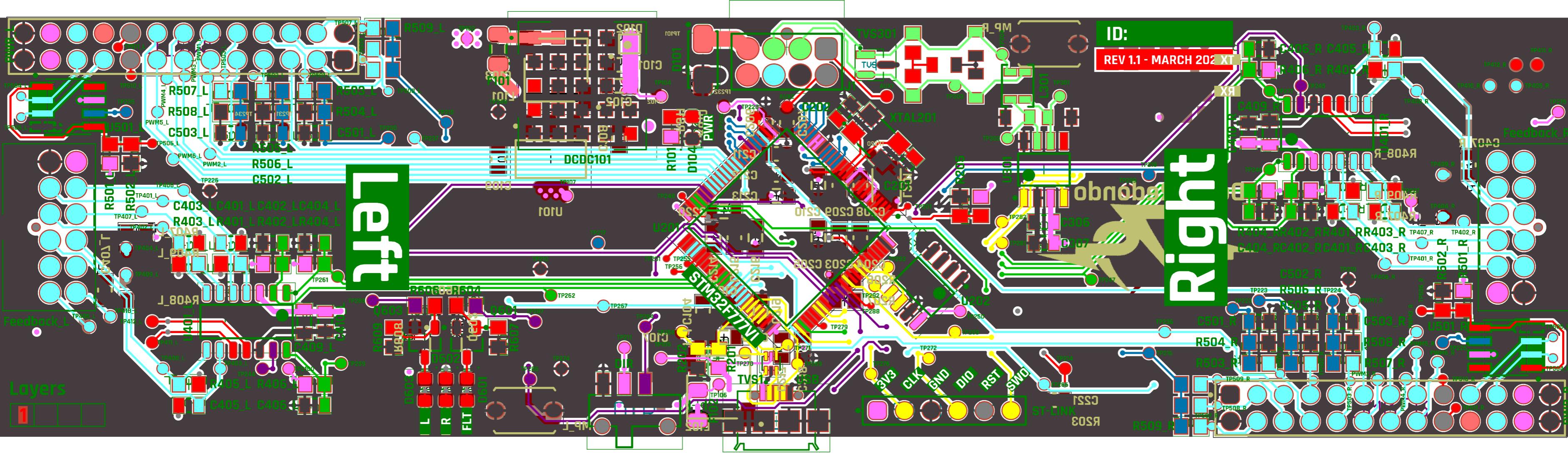


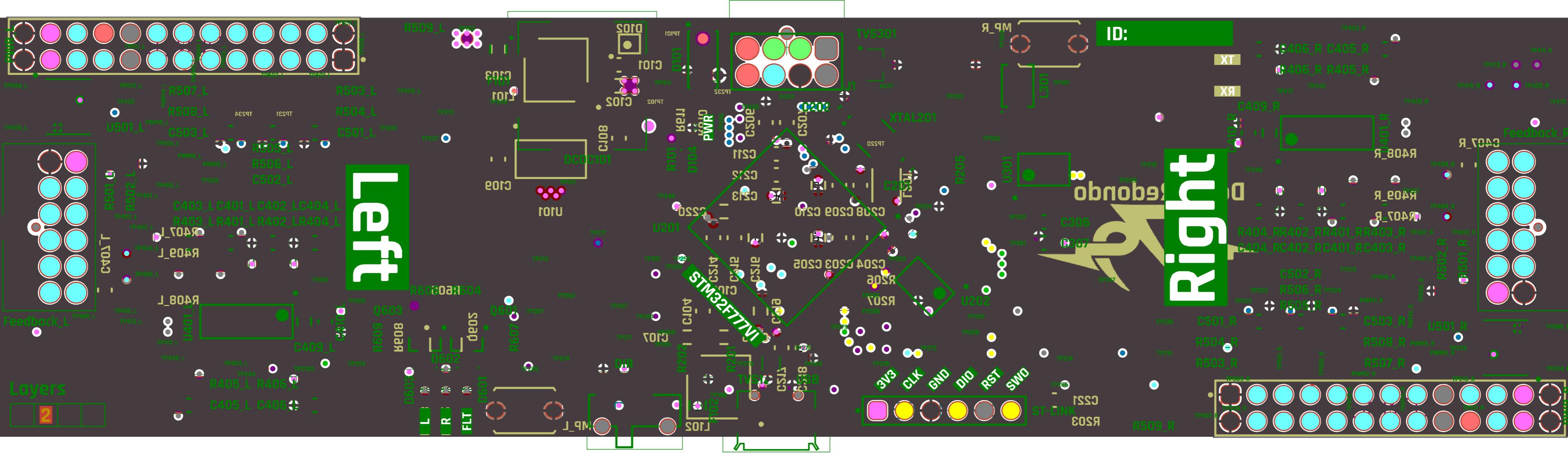
Company: e-Tech Racing e-techracing.es

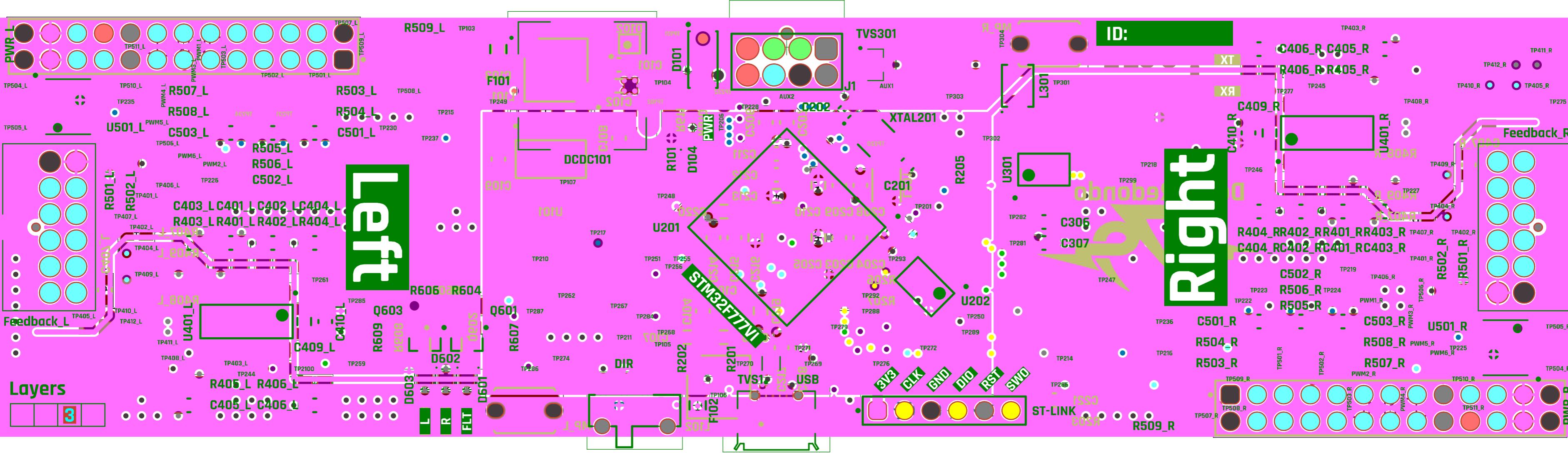


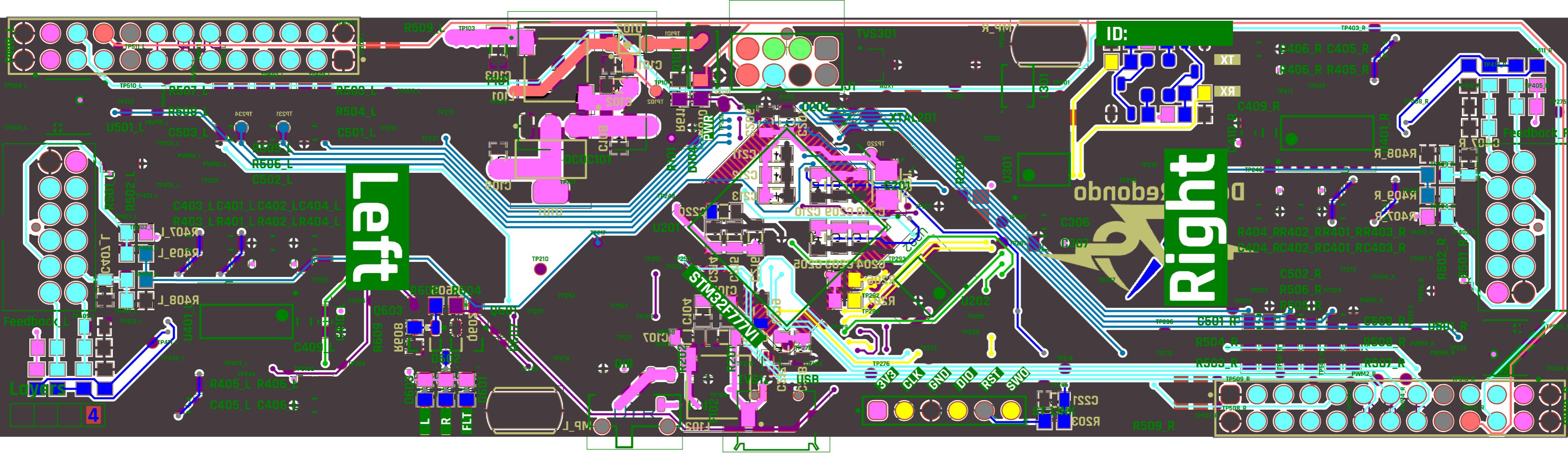
Project: Inverter Control Variant: [No Variations]

Size:	Page Contents: [6] Extras.SchDoc	Version: 1.1
-		Department: Powertrain
Author:	David Redondo dredondovinolo@gmail.com	Sheet * of *
Checked by:	*	Date: 20/05/2024









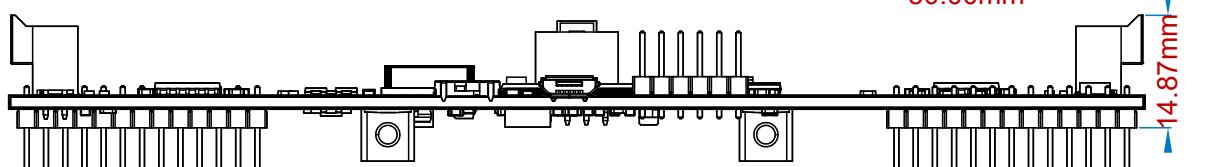
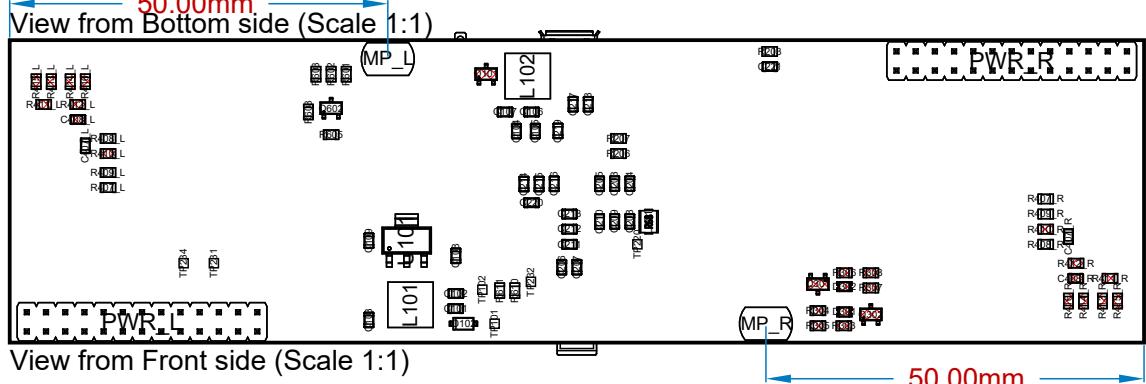
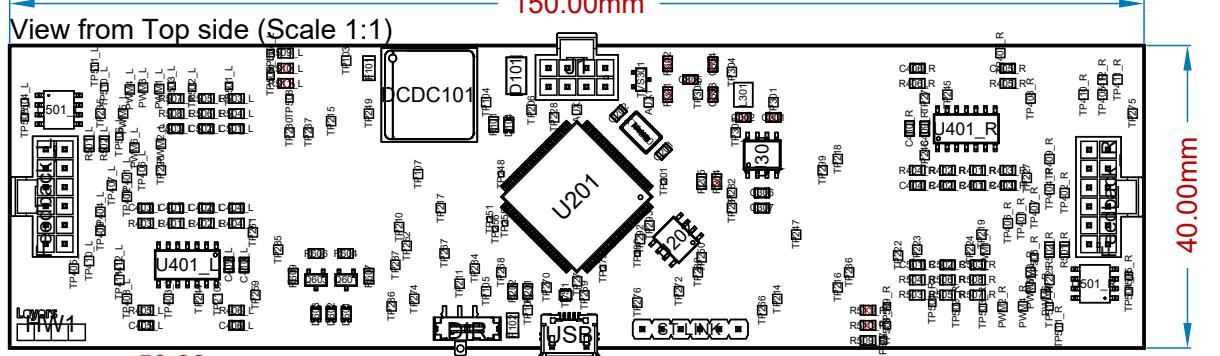
# Inverter Control

## Bill Of Materials

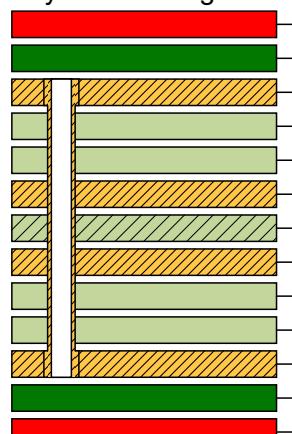
Designator	Name	Quantity
C101, C105, C204, C207, C209, C212, C215, C218, C221, C307	885012207103	10
C102, C103, C106, C107, C409_L, C409_R	10uF	6
C104, C203, C208, C211, C217, C306, C407_L, C407_R, C410_L, C410_R, C501_L, C501_R, C502_L, C502_R, C503_L, C503_R	885012207098	17
C108, C109	885012107014	2
C205, C210, C213, C216	885012007052	2
C206, C401_L, C401_R, C402_L, C402_R, C403_L, C403_R, C404_L, C404_R, C405_L, C405_R, C406_L, C406_R	885012107011	4
D101	885012107092	13
D102	2.2uF	2
D104	824501261	1
D601	MBR0530	1
D602, D603	150080YST5000	1
DIR	150080RS75000	1
F101, F102	150080GS75000	2
Feedback_L, Feedback_R	RPMB5.0-3.0	1
HW1	450405020524	1
J1	0437001.WRA	2
L101, L102	1053101112	2
L201	LOGO CAPAS (4)	1
L301	105310-1108	1
MP_L, MP_R	47uH	2
PWR_L, PWR_R	744764147	1
Q601, Q602, Q603	DLW32SH10XF2	1
R101, R401_L, R401_R, R403_L, R403_R, R405_L, R405_R, R502_L, R502_R	M3	2
R201, R202, R203, R205, R206, R207, R402_L, R402_R, R404_L, R404_R, R406_L, R406_R, R504_L, R504_R, R506_L, R506_R, R508_L, R508_R, R610	61302621121	2
R407_L, R407_R, R601, R602, R603, R604, R605, R606, R611	CPH3455-TL-H	3
R408_L, R408_R, R409_L, R409_R, R509_L, R509_R	CR0805-FX-1000ELF	9
R501_L, R501_R, R503_L, R503_R, R505_L, R505_R, R507_L, R507_R	CR0805-JW-103ELF	19
R607, R608, R609	CR0805-JW-102ELF	9
ST-LINK	CPF0805B15RE	6
TVS1	61300611121	1
TVS301	USBLC6-2P6	1
U101	Diode 4D	1
U201	LM1117IMP-3.3/NOPB	1
U202	STM32F777VIT6	1
U301	24AA024H-I/SN	1
U401_L, U401_R	MCP2551-I/SN	1
U501_L, U501_R	LM339D	2
USB	AD8479ARZ-RL	2
XTAL201	629105136821	1
	20MHz	1

Material	Layer	Thickness	Dielectric Material	Type	Gerber
Surface Material	Top Overlay				GTO
CF-004	TOP	0.035mm	Solder Resist	Signal	GTS
Prepreg		0.100mm	PP-006	Dielectric	GTL
Prepreg		0.100mm	PP-006	Dielectric	G1
Copper	GND	0.035mm		Signal	G2
Prepreg		1.040mm	FR-4	Dielectric	G1
Copper	PWR	0.035mm	PP-006	Signal	G2
Prepreg		0.100mm	PP-006	Dielectric	G2
Prepreg		0.100mm	PP-006	Dielectric	GBL
CF-004	BOT	0.035mm	Solder Resist	Signal	GBS
Surface Material	Bottom Overlay	0.010mm			GBO

Total thickness: 1.600mm



### Layer Stack Legend



A

B

C

D

E