Plume

Variant: Released

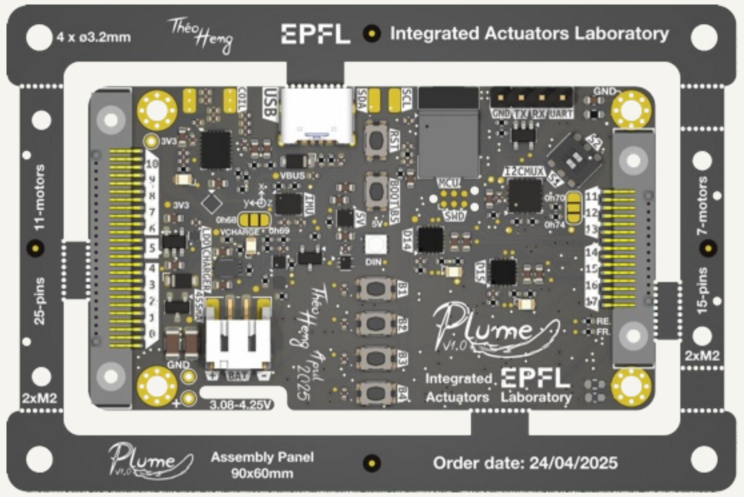
Integrated Actuators Laboratory (LAI)

Semester project: 02/2025 - 06/2025
Student: Théo Heng - theoheng@icloud.com
Supervisors: Maël Dagon, Paolo Germano

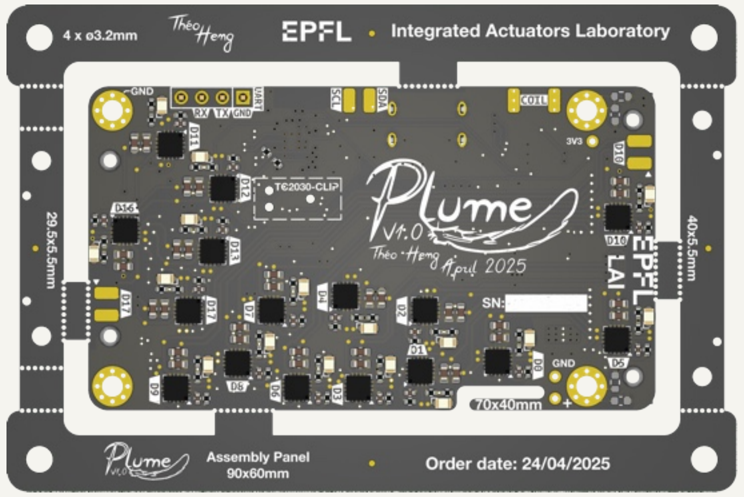
2025-05-27

Rev 1.0

TOP VIEW



BOTTOM VIEW



NOTES

MULTIPLE MOTOR CONTROLLER WITH SENSORLESS POSITION CONTROL

Not fitted components are marked as ✗

DRAFT - Very early stage of schematic, ignore details.
PRELIMINARY - Close to final schematic.
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.
RELEASED - A board with this schematic has been sent to production.

Released - 24/04/2025

DESIGN CONSIDERATIONS

DESIGN NOTE: Example text for informational design notes.

DEBUG NOTE: Example text for debug notes.

DESIGN NOTE: Example text for cautionary design notes.

DESIGN NOTE: Example text for critical design notes.

LAYOUT NOTE: Example text for critical layout guidelines.

Comments: KiCad Template by Vincent Nguyen	Laboratory: Integrated Actuators Laboratory EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Cover Page	File Name: Plume.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /		Supervisor: Maël Dagon, Paolo Germano	Size: A3	Sheet: 1 of 31

[2] Block Diagram

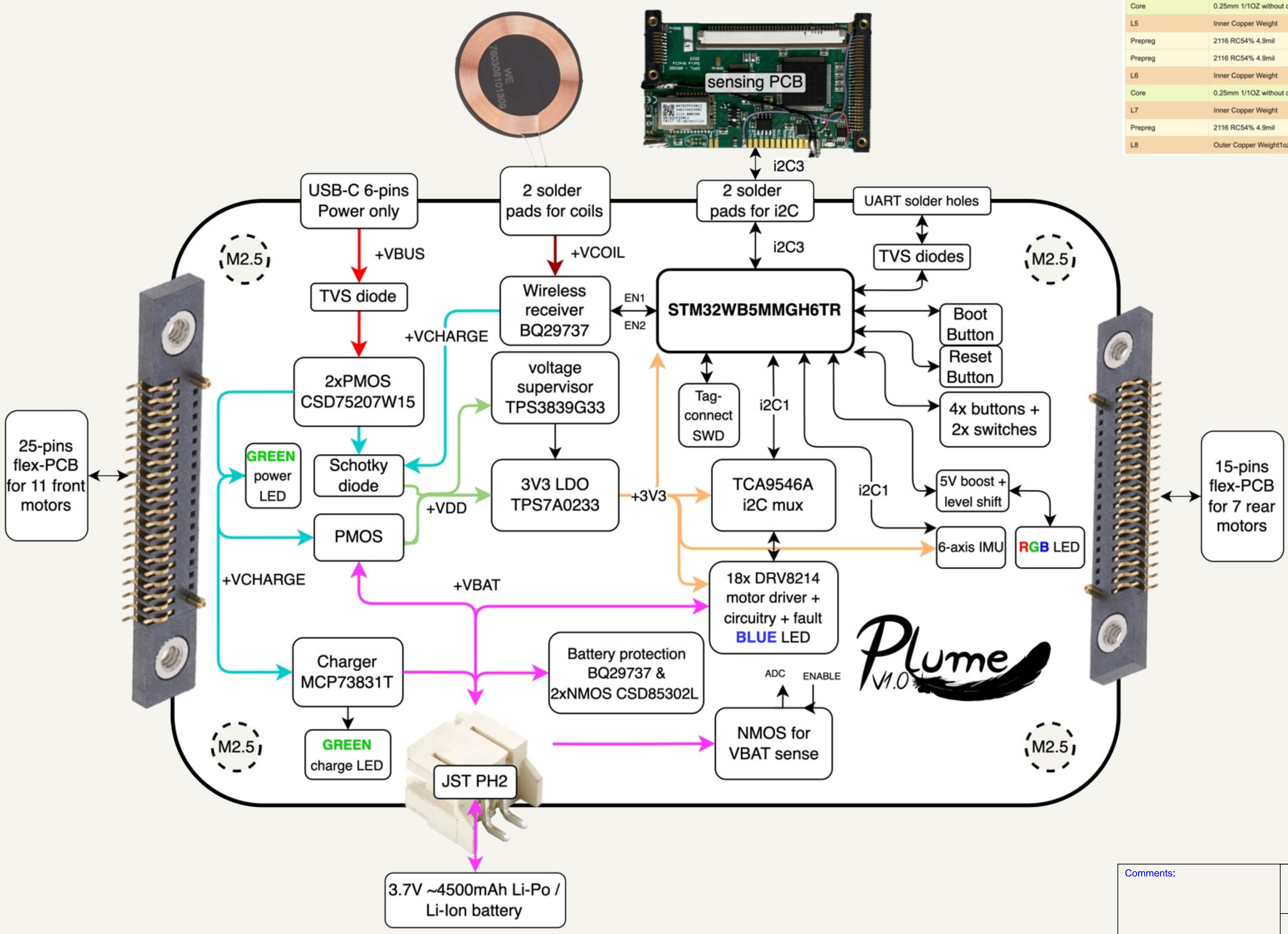
Finished thickness1.64mm±10%) | JLC081611-7628(Special/Finished thickness1.59mm±10%) | JLC081611-2116(Standard /Finished thickness 1.65mm±10%)

Impedance (Ω)	Type	Signal Layer	Top Ref	Bottom Ref	Trace Width	Trace Spacing	Impedance trace to copper
50	Single Ended (Non coplanar)	L1	/	L2		/	/

Layer	Material	Thickness (mil)	Thickness (mm)
L1	Outer Copper Weight1oz	1.38	0.0350
Prepreg	2116 RC54% 4.9mil	4.29	0.1090
L2	Inner Copper Weight	1.18	0.0300
Core	0.25mm 1/1OZ without copper	9.84	0.2500
L3	Inner Copper Weight	1.18	0.0300
Prepreg	2116 RC54% 4.9mil	4.29	0.1090
Prepreg	2116 RC54% 4.9mil	4.29	0.1090
L4	Inner Copper Weight	1.18	0.0300
Core	0.25mm 1/1OZ without copper	9.84	0.2500
L5	Inner Copper Weight	1.18	0.0300
Prepreg	2116 RC54% 4.9mil	4.29	0.1090
Prepreg	2116 RC54% 4.9mil	4.29	0.1090
L6	Inner Copper Weight	1.18	0.0300
Core	0.25mm 1/1OZ without copper	9.84	0.2500
L7	Inner Copper Weight	1.18	0.0300
Prepreg	2116 RC54% 4.9mil	4.29	0.1090
L8	Outer Copper Weight1oz	1.38	0.0350

Current Recommanded Stackup:

8 layer, 1oz out/1oZ:
JLC081611-2116 (Finished thickness 1.65mm±10%)

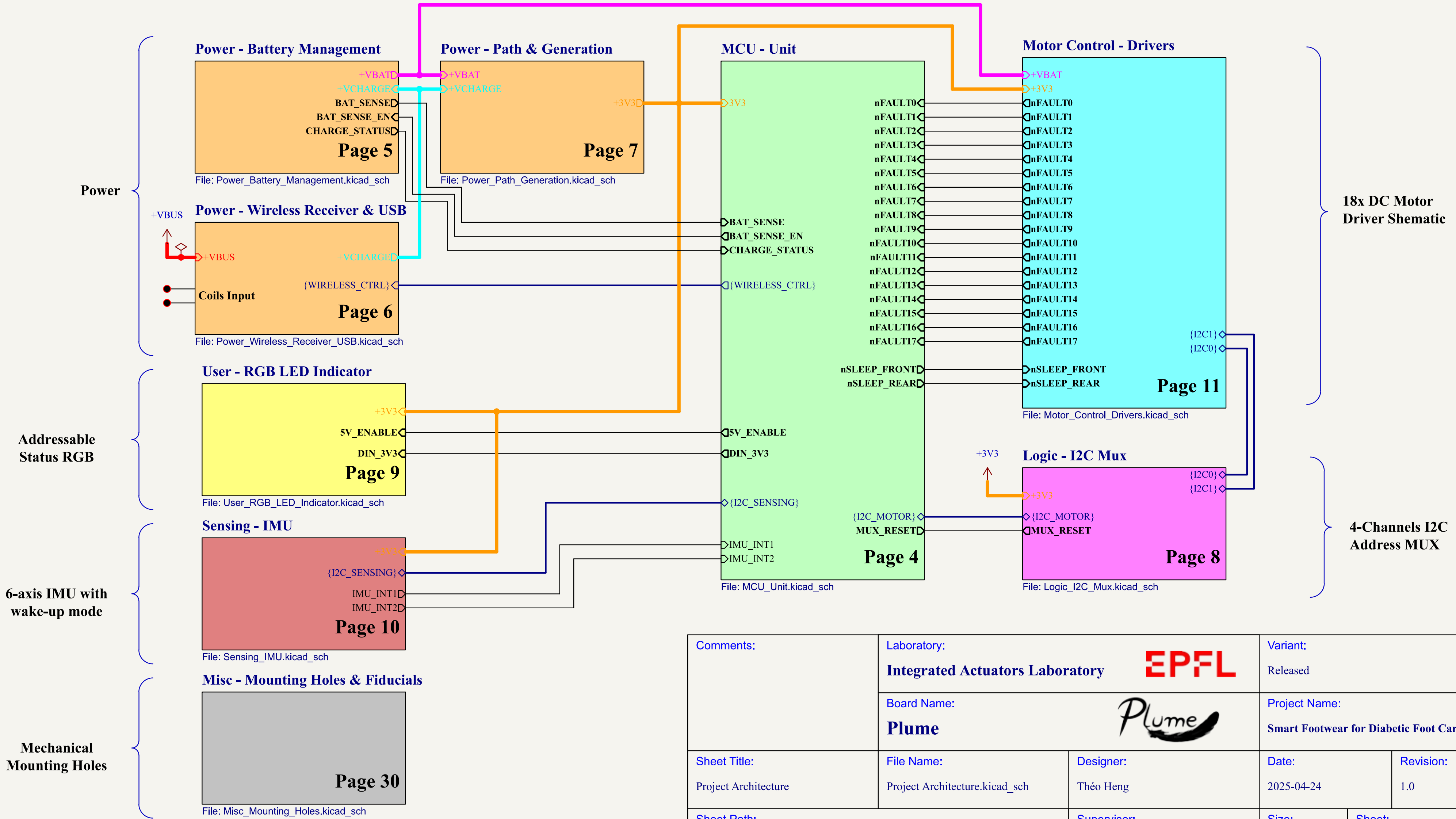


Target specifications:

Battery Input voltage:	3.08 - 4.25 V
Max charge current:	455 mA
Nb of controlled motors:	18
Max load current:	4.54 A
Standby Current:	50 mA
Sleep Current:	15 uA

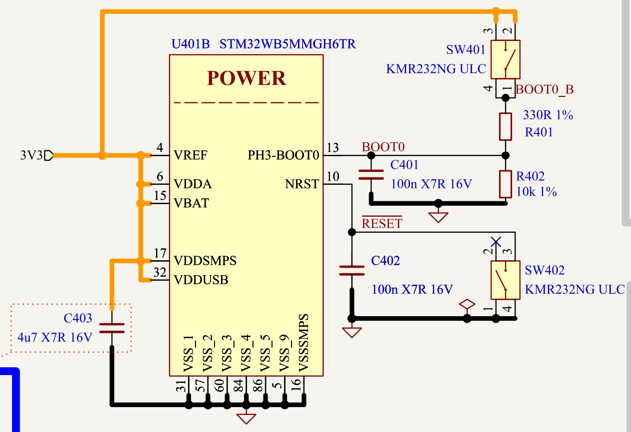
Comments:	Laboratory: Integrated Actuators Laboratory EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Block Diagram	File Name: Block Diagram.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Block Diagram/		Superviser: Maël Dagon, Paolo Germano	Size: A3	Sheet: 2 of 31

[3] Project Architecture



Comments:	Laboratory: Integrated Actuators Laboratory		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Project Architecture	File Name: Project Architecture.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 3 of 31

[4] MCU - Unit



DESIGN NOTE:
PH3_BOOT0 is tied low through an internal pull-down to enable start from flash memory. However, it can be tied high with a low resistive pull-up if required.

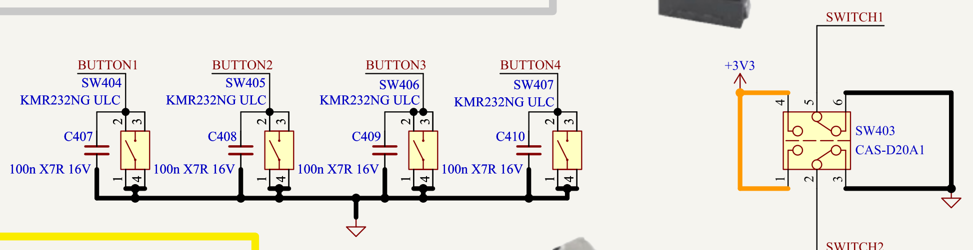
A low-pass filter is added for debouncing purposes, to have and extra user button after startup.

DESIGN NOTE:
A reset pull-up is already implemented in the STM32WB Series microcontrollers. The reset circuitry only requires an external capacitor for filtering purpose

LAYOUT NOTE:
An additional capacitor of 4.7 uF is added to eliminate ripple from the SMPS power supply. Place close to the VDDSMPS pin.

MCU - Power

DESIGN NOTE:
The STM32 needs to configure the buttons and switches GPIO as input with pull-up. The internal pull equivalent resistor have a value of 40kΩ. -> 82.5uA



DESIGN NOTE:

I/Os with wake-up from Standby/Shutdown capability: PA0, PC13, PC12, PA2, PC5.

MCU - User Buttons & Switches

DESIGN NOTE:

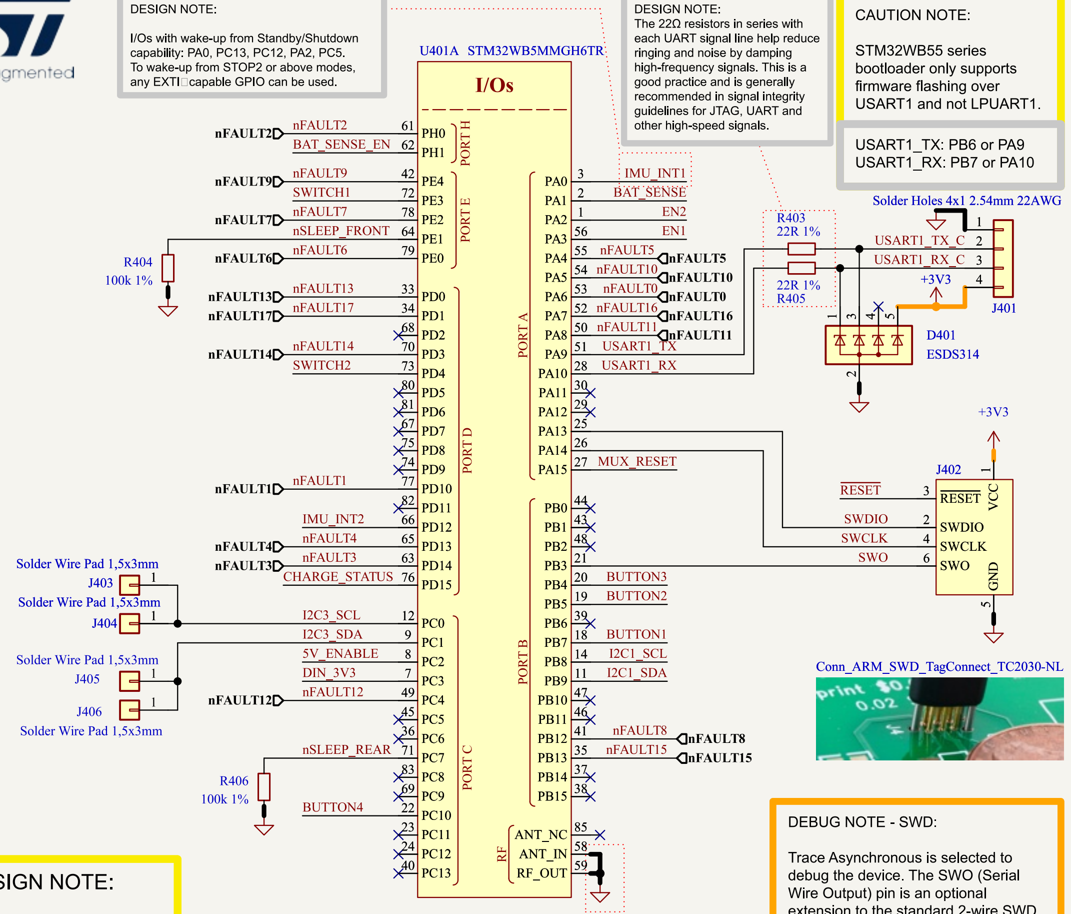
I/Os with wake-up from Standby/Shutdown capability: PA0, PC13, PC12, PA2, PC5.
To wake-up from STOP2 or above modes, any EXTI capable GPIO can be used.

DESIGN NOTE:
The 22Ω resistors in series with each UART signal line help reduce ringing and noise by damping high-frequency signals. This is a good practice and is generally recommended in signal integrity guidelines for JTAG, UART and other high-speed signals.

CAUTION NOTE:

STM32WB55 series bootloader only supports firmware flashing over USART1 and not LPUART1.

USART1_TX: PB6 or PA9
USART1_RX: PB7 or PA10



DESIGN NOTE:

PB0 and PB1 are only available for revision X parts.

I2C_1 SDA: PB9 or PB7 or PA10
I2C_1 SCL: PB8 or PA9 or PB6

I2C_3 SDA: PC1 or PB4 or PB14 or PB11
I2C_3 SCL: PC0 or PA7 or PB10 or PB13

DESIGN NOTE:
ANT_IN and RF_OUT pins must be connected to GND. This module already integrates an antenna, so no external antenna required

DEBUG NOTE - SWD:

Trace Asynchronous is selected to debug the device. The SWO (Serial Wire Output) pin is an optional extension to the standard 2-wire SWD debugging interface used with STM32 microcontrollers. While SWD alone supports core debugging (breakpoints, stepping, memory access), adding the SWO pin enables real-time tracing and non-intrusive data logging. This allows to use features like ITM printf-style debugging, event tracing, and performance monitoring without halting program execution, making it very interesting for diagnosing complex or time-sensitive embedded applications.

MCU - I/Os

DESIGN NOTE:

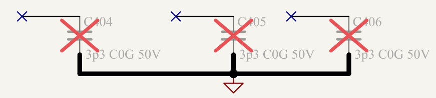
Any floating input pin can also settle to an intermediate voltage level or switch inadvertently, as a result of external electromagnetic noise. To avoid current consumption related to floating pins, they must either be configured in analog mode, or forced internally to a definite digital value. This can be done either by using pull-up/down resistors or by configuring the pins in output mode.

LAYOUT NOTE:
The TC2030-CTX-NL is a 6-pin "No Legs" Plug-of-Nails™ programming cable from Tag-Connect, designed for ARM Cortex processors. Unlike the legged variant, it requires an external retention mechanism to maintain contact with the PCB during programming or debugging sessions.

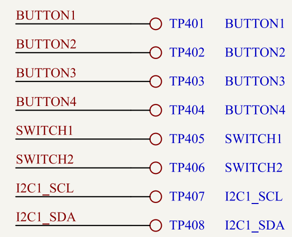
Tag-Connect offers the TC2030-CLIP, a retention clip designed to hold the cable securely in place. This clip attaches from the underside of the PCB, engaging with the three alignment holes specified in the TC2030 footprint. Therefore ensure a clearance of at least 5mmx10mm at the back of the PCB.

DESIGN NOTE - sensitive GPIOs:
This board contains three sensitive GPIOs as defined below:
- PB10
- PB11
- PC5

When PB10, PB11 and/or PC5 are used, a 3.3 pF capacitor in a small package such as the 0201 or smaller, must be placed as close as possible to the output pin. Also border the GPIO tracks with the ground plane.

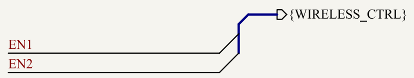


Sensitive GPIOs

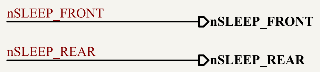


Test Points

Battery Management



Wireless Control

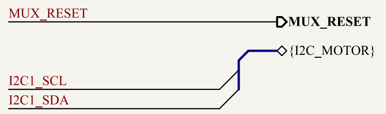


Motor Sleep Control

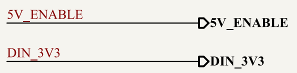
CAUTIOUS NOTE:

This board contains three sensitive GPIOs: PB10, PB11, PC5

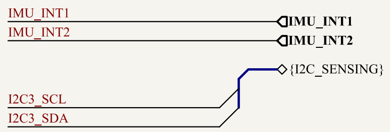
When PB10, PB11 and/or PC5 are used, a 3.3 pF capacitor in a small package such as the 0201 or smaller, mustbe placed as close as possible to the output pin. Also border the GPIO tracks with the ground plane.



Motor Control I2C Bus



RGB LED Control



6-axis IMU

TC2030-NL is not easy to buy. it can be found here but requires an adapter.
v: https://www.digikey.ch/fr/products/detail/tag-connect-llc/TC2030-MCP-NL/2666489
SPY-BI-TAG: https://www.digikey.ch/fr/products/detail/tag-connect-llc/SPY-BI-TAG/2605370
STLINK-V3SET: https://www.digikey.ch/fr/products/detail/stmicroelectronics/STLINK-V3SET/9636028

Comments: AN5165 Application Note: How to develop RF hardware using STM32WB microcontrollers; AN2606 Application Note: STM32 microcontroller system memory boot mode; Debounce a Switch - Texas Instrument	Laboratory: **Integrated Actuators Laboratory**		Variant: Released	
	Board Name: **Plume**		Project Name: **Smart Footwear for Diabetic Foot Care**	
Sheet Title: MCU - Unit	File Name: MCU_Unit.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/MCU - Unit/		Superviser: Maël Dagon, Paolo Germano	Size: A3	Sheet: 4 of 31

[5] Power - Battery Management

Current analysis:

Normal:
BQ29737: 4uA
MCP73831: 100nA

Shutdown:
BQ297377: 100nA
MCP73831: 100nA

DESIGN NOTE - gate-source resistors:

TI recommends placing a high impedance 5MΩ across the gate source of each external FET to deplete any charge on the gate-source capacitance.

DESIGN NOTE - EXTERNAL PROTECTION FETs:

The external FET selection is important to ensure the battery pack protection is sufficient and complies to the requirements of the system.

BQ29737 charge overcurrent threshold: -50mV
BQ29737 discharge overcurrent threshold: 100mV

The CSD85302L when driven at 3.7V at the gate, have a source to source resistance of ≈22 mΩ.

Resulting charge overcurrent protection:
50mV / 22mΩ ≈ 2.27A

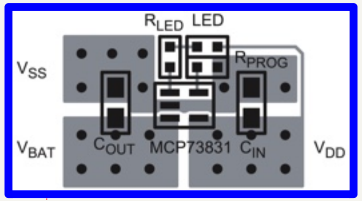
Resulting discharge overcurrent protection:
100mV / 22mΩ ≈ 4.54A

LAYOUT NOTE:
The input RC filter on the BAT pin should be close to the terminal of the IC

DESIGN NOTE - CHARGE STATUS LED:

APT1608CGCK has a typical luminous intensity of 50mcd (millicandela) @20mA, and 25mcd @10mA.
Typ. Vf = 2V @10mA,

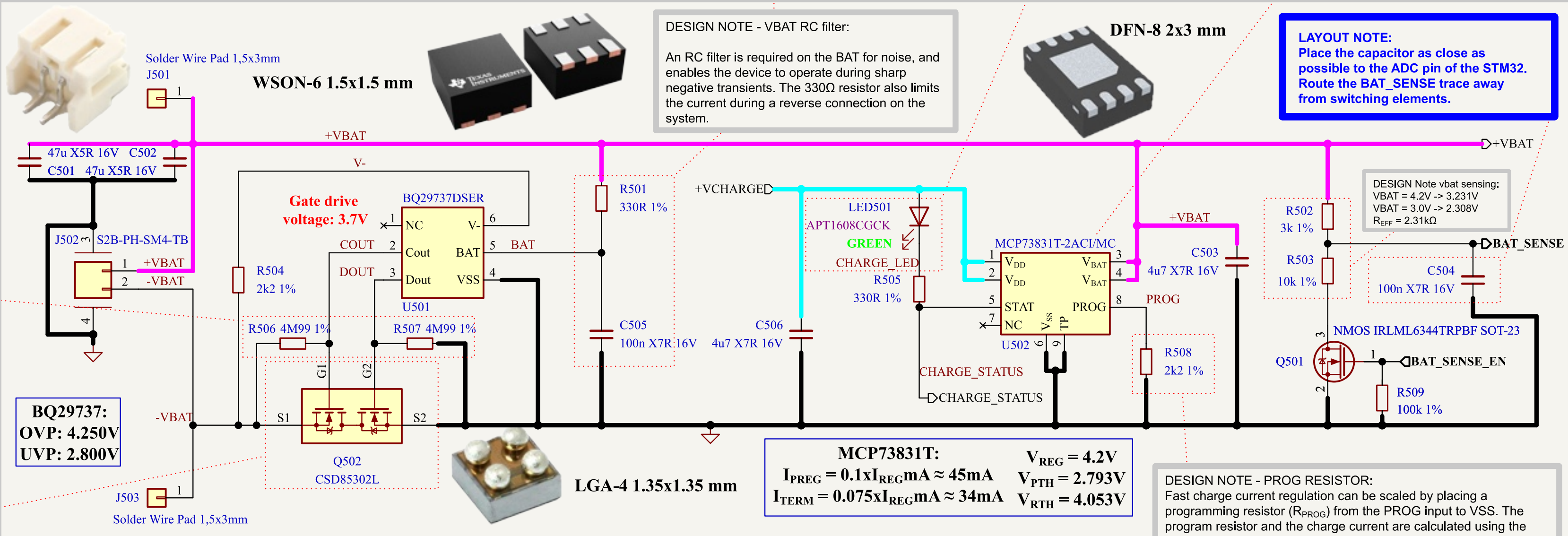
Typ. If = (5V - 2V)/330hm ≈ 9 mA
P = 2V×9mA ≈ 18 mW < 75 mW (max rating)



DESIGN NOTE - VBAT RC filter:

An RC filter is required on the BAT for noise, and enables the device to operate during sharp negative transients. The 330Ω resistor also limits the current during a reverse connection on the system.

LAYOUT NOTE:
Place the capacitor as close as possible to the ADC pin of the STM32. Route the BAT_SENSE trace away from switching elements.



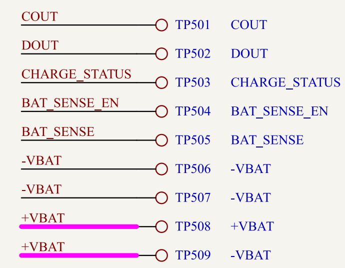
MCP73831T:

$I_{PREG} = 0.1xI_{REG}mA \approx 45mA$ $V_{REG} = 4.2V$
$I_{TERM} = 0.075xI_{REG}mA \approx 34mA$ $V_{PTH} = 2.793V$
$V_{RTH} = 4.053V$

DESIGN NOTE - PROG RESISTOR:
Fast charge current regulation can be scaled by placing a programming resistor (R_{PROG}) from the PROG input to VSS. The program resistor and the charge current are calculated using the following equation:

$I_{REG} = 1000V / R_{PROG}$
$I_{REG} = 1000V / 2200 \approx 455mA$

Voltage and Current Protection Integrated Circuit for Single-Cell Li-Ion and Li-Polymer Batteries and Miniature Single-Cell, Fully Integrated Li-Ion, Li-Polymer Charge Management Controller



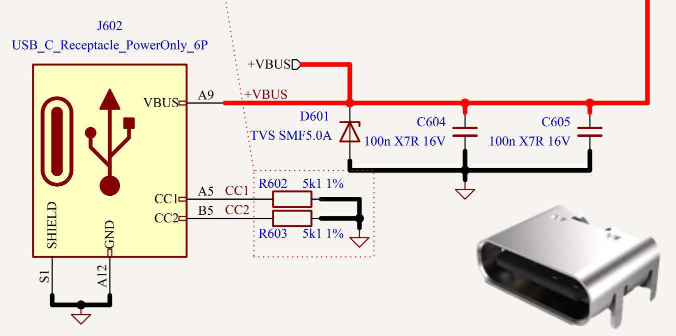
Test Points

Comments:	Laboratory: Integrated Actuators Laboratory		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Power - Battery Management	File Name: Power_Battery_Management.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Power - Battery Management/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 5 of 31

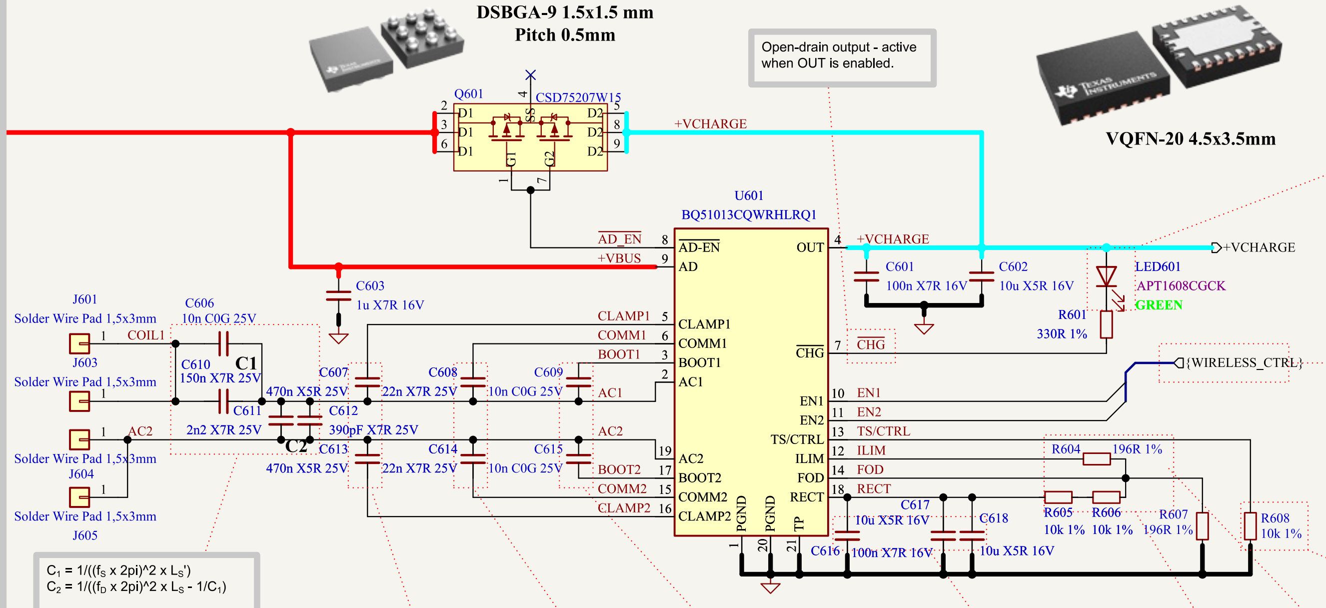
[6] Power - Wireless Receiver & USB

DESIGN NOTE - USB-C Configuration Channel pins:

Device Detection: When the CC1 and CC2 pins have pull-down resistors, the USB-C power source detects that a "sink" device is connected and needs power. This signals to the power source to supply the default 5V over the VBUS line.
Power Negotiation: The 5.1kΩ resistors indicate that the device is a standard USB device that only requires 5V, which is the default voltage for USB-C.
Orientation Detection: Since USB-C is a reversible connector, the CC1 and CC2 pins help determine which way the connector is inserted. Only one of the pins will be connected to the host's CC line when inserted. By tying both to ground through pull-down resistors, the device can receive power regardless of orientation, with the host powering up the correct side.



6-Pins, Power-Only, USB-C connector



DESIGN NOTE - CHARGE STATUS LED:

APT1608CGCK has a typical luminous intensity of 50mcd (millicandela) @20mA, and 25mcd @10mA.
Typ. Vf = 2V @10mA,

Typ. If = (5V - 2V)/330hm ≈ 9 mA
P = 2V×9mA ≈ 18 mW < 75 mW (max rating)

EN1	EN2	STATUS
0	0	Wireless charging is enabled unless AD voltage > VAD_{Pres} (3.6V).
0	1	Dynamic communication current limit disabled.
1	0	AD-EN pulled low, wireless charging disabled
1	1	Wired and wireless charging disabled.

EN1 and EN2 have internal pulldown resistors.

Output: 5V, 0.7A ->3.5W

C_1 = 1/((fS x 2pi)^2 x L_S')
C_2 = 1/((fD x 2pi)^2 x L_S - 1/C_1)

where:
f_S = 100 kHz
f_D = 1 MHz
L_S = 10 uH
L_S' = 16 uH

Therefore:

C_1 ≈ 158.3nF
-> 150nF + 10nF = 160nF

C_2 ≈ 2.57nF
-> 2.2nF + 0.39nF ≈ 2.59nF

The CLAMP capacitors are used to aid in the clamping process to protect against overvoltage. These capacitors are from AC1 to CLAMP1 and from AC2 to CLAMP2 and must have a minimum 25-V rating. A 0.47-μF capacitor with a 25-V rating is chosen.

The COMM capacitors are used to facilitate the communication from the RX to the TX. This selection can vary a bit more than the BOOT and CLAMP capacitors. In general, a 22-nF capacitor is recommended.

The BOOT capacitors are used to allow the internal rectifier FETs to turn on and off properly. These capacitors are from AC1 to BOOT1 and from AC2 to BOOT2 and must have a minimum 25-V rating. A 10-nF capacitor with a 25-V rating is chosen.

RECT capacitance is used to smooth the AC to DC conversion and to prevent minor current transients from passing to OUT. For this 1-A IMAX, select two 10-μF capacitors and one 0.1-μF capacitor. These should be rated to 16 V.

The current limit and foreign object detection functions are related. The current limit is set by R1 + RFOD. RFOD and Ros are determined by FOD calibration. Default values of 20 kΩ for Ros and 196 Ω for RFOD are used

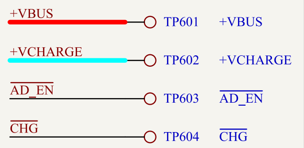
DESIGN NOTE - ILIM resistor:

$I_{ILIM} = K_{ILIM}/(R_{ILIM})$
$I_{ILIM} = K_{ILIM}/(R_1 + R_{FOD})$
I_{ILIM} = 314/(196 + 196) ≈ 0.8 A
$I_{MAX} = I_{ILIM}$ / 1.2 ≈ 0.66 A

If the NTC function is not desired, connect to PGND with a 10-kΩ resistor.

From Datasheet

Automotive Highly Integrated Wireless Receiver Qi (WPC v2.0) Compliant Power Supply With Dual P-Channel MOSFETs PowerPath.

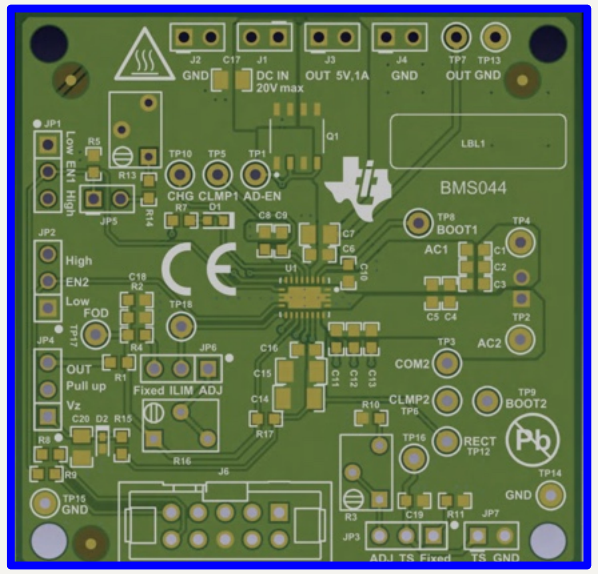


Test Points

SELECTED COIL: 10uH
diam: 26.3mm

760308101309 Wireless Charging Coil

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	125 kHz/ 10 mA	10	µH	±10%
Rated Current	I_R	ΔT = 40 K	1.5	A	max.
Q-Factor	Q	125 kHz/ 10 mA	20		typ.
Power Capability	P	V_{DC} = 20 V	20	W	typ.
DC Resistance	R_{DC}	@ 20 °C	350	mΩ	typ.
DC Resistance	R_{DC}	@ 20 °C	450	mΩ	max.
Self Resonant Frequency	f_{res}		19	MHz	typ.



Suggested layout from BQ51013CQWRHLRQ1 evaluation board.

Comments: EVM User's Guide: BQ51013C-Q1EVM BQ51013C-Q1 Evaluation Module	Laboratory: Integrated Actuators Laboratory		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Power - Wireless Receiver & USB	File Name: Power_Wireless_Receiver_USB.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Power - Wireless Receiver & USB/		Supervisor: Maël Dagon, Paolo Germano	Size: A3	Sheet: 6 of 31

[7] Power - Path & Generation

Design Note - Simple Power-Path with PMOS and Schottky diode:

When no USB-C supply nor coil power is present, this simple circuit will by default conduct the battery to the LDO, through the PMOS.

But if USB-C supply or coil power is active, the PMOS will turn off, and the LDO will use the power from the external power supply through the schottky diode.

Design Note - Power Path Schottky diode:

A diode is required to prevent reverse current from flowing to the power source. Selecting the right diode can minimize the leakage current and the forward voltage drop from the power source to the system load. A schottky diode, which has lower forward voltage drop, is recommended.
Forward voltage @ If = 200mA: 420mV
Reverse current @ Vr = 5V: 70nA

Active-low reset output. RESET has a push-pull output drive and is capable of directly driving input pins. RESET is low as long as VDD remains below the factory threshold voltage of 3.08V, and until the delay time (td = 200ms) elapses after VDD rises above the threshold voltage.

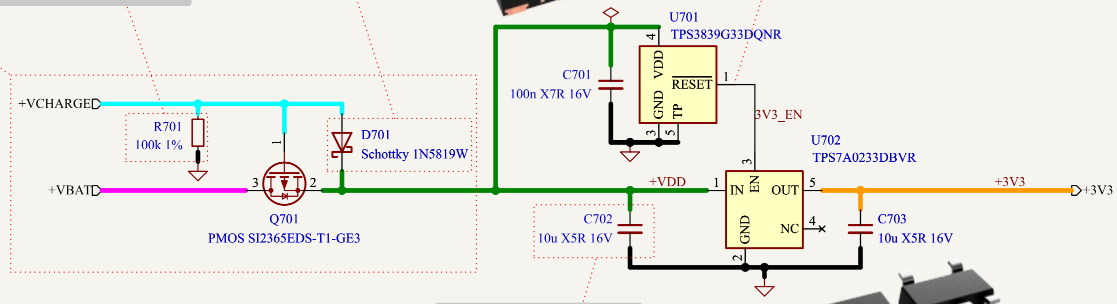
Current analysis:

Normal:
TPS3839: 150nA
TPS7A02: 25nA
PMEG60T20ELR: 65nA

Shutdown
TPS3839: 150nA
TPS7A02: 3nA
PMEG60T20ELR: 60nA

This pull down resistor ensures that the gate is properly pulled to GND when VBUS and VCOIL are not connected.

X2SON-4 1x1mm



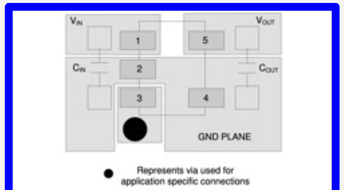


Figure 8-7. Layout Example for the DBV Package

A higher value capacitor is selected to anticipate the large, fast rise-time load transients (motor stall & inrush).

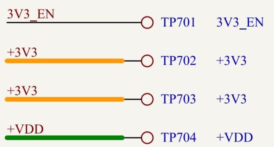
SOT-23-5 2.9mm×2.8mm

3.3V current draw estimation:

STM32 absolute max: <= 130mA
Pull-ups: 33uA/Pull-up -> max 1mA
I2C MUX: <1mA
I2C Pull-ups: 2.2mAx2 ~5mA
Fault LEDs: 2mA/LED -> max 36mA
RGB LED: (1mA + 3x5mA)x1.25 = 20mA
IMU: max 1mA

Total Max: 194mA < 200mA

Nanopower IQ, 25-nA, 200-mA, Low-Dropout Voltage Regulator With Fast Transient Response paired with 150-nA, Ultralow Power, Supply Voltage Monitor



Test Points

Comments:	Laboratory: Integrated Actuators Laboratory (EPFL)		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Power - Path & Generation	File Name: Power_Path_Generation.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Power - Path & Generation/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 7 of 31

[8] Logic - I2C Mux

DESIGN NOTE - I2C pull-Up resistors:

R_{MIN} = (VDD_{MAX} - VOL_{MAX}) / IOL
System I/O voltage: VDD = 3.3V +- 5% -> 3.47V
Low level output volatge (I2C specs): VOL_{MAX} = 0.4V
Low level output current (I2C specs): IOL = 3mA
Rmin = (3.47V - 0.4V) / 3mA ≈ 1kΩ

R_{MAX} ≈ (1.18 x tr_{MAX}) / Cb_{MAX}
Standard mode (I2C specs): tr_{MAX} = 1000ns
Fast mode (I2C specs): tr_{MAX} = 300ns

The maximum bus capacitance for an I2C bus must not exceed 400 pF for fast-mode operation. The bus capacitance can be approximated by adding the capacitance of the STM32, C_{STM}, the TCA9546A, C_{TCA}, the capacitance of wires/connections/traces, C_{TRACE}, and the capacitance of each individual slave (driver) on a given channel C_{DRV}. If multiple channels will be activated simultaneously, each of the slaves on all channels will contribute to total bus capacitance.

C_{STM} worst case = (not speciefied in the datasheet, we assume 10pF x 2 = 20pF)
C_{TCA_IN} worst case = 19pF x 2 = 38pF on the SCL, SDA lines
C_{TCA_OUT} worst case = 8pF x 2 = 16pF on the SC3-SC0, SD3-SD0 lines
C_{DRV} worst case = (not speciefied in the datasheet, we assume 8pF x 2 = 16pF)
C_{TRACE} = nb of traces x (lenght of a trace / 25mm) X 2.5pF
C_{TRACE} = 2 x (75mm / 25mm) X 2.5pF = 15pF

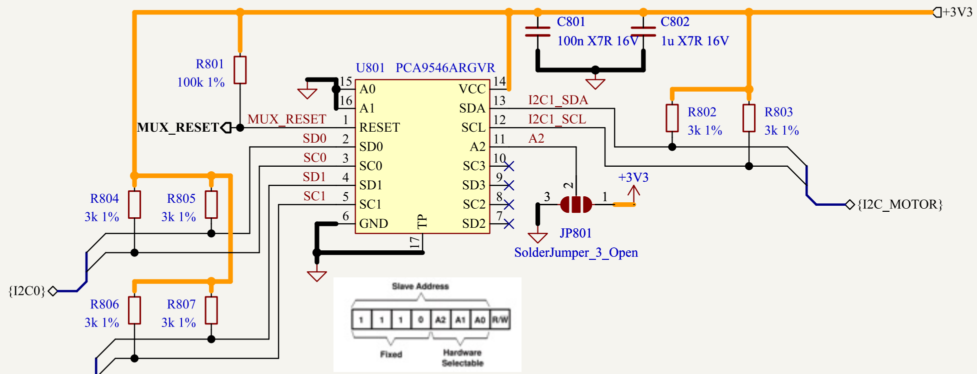
For one active channel:
Cb_{MAX} = C_{STM} + C_{TCA_IN} + C_{TCA_OUT} + 9 x C_{DRV} + C_{TRACE}
Cb_{MAX} = 20pF + 38pF + 16pF + 9 x 16pF + 15pF ≈ 233pF
-> R_{MAX} = (1.18 x 300ns) / 113pF ≈ 1519Ω

To be safe, a value of 1k5Ω is chosen. Since both the master I2C lines and fanned channels need pull ups, there will be 2 resistors in parallel, when a channel is activated. Therefore, 3kΩ resistors are chosen, in order to get 1k5Ω.

For two active channel:
Cb_{MAX} = C_{STM} + C_{TCA_IN} + 2x C_{TCA_OUT} + 18 x C_{DRV} + 1.66 x C_{TRACE}
Cb_{MAX} = 20pF + 38pF + 32pF + 18 x 16pF + 25pF ≈ 403pF > 400

Therefore, only one channel can be enabled at a time, meaning that 9 drivers only can be driven simultaneously.

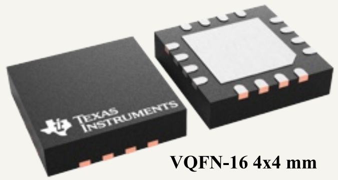
Smaller resistors decrease rise time but increase power consumption. In our case: I = 3V3 / 1500 ≈ 2.2mA



if A2 to GND: Device 7-bits Adress: 0b1110000 = 0h70
Device 8-bits Write Adress: 0b11100000 = 0hE0
Device 8-bits Read Adress: 0b11100001 = 0hE1

or

if A2 to 3V3: Device 7-bits Adress: 0b1110100 = 0h74
Device 8-bits Write Adress: 0b11101000 = 0hE8
Device 8-bits Read Adress: 0b11101001 = 0hE9



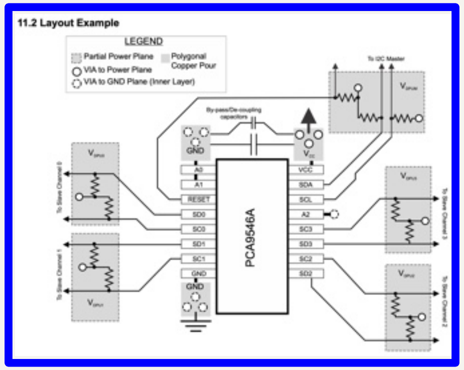
VQFN-16 4x4 mm

Low Voltage 4-Channel I2C and SMBus Switch with Reset Function

Current analysis:
Normal:
PCA9546A = 3uA
Pull-ups = (3.3/1500) x 2 x 0.5 = 2.2mA
Standby:
PCA9546A = 1uA
Pull-ups: = 0uA

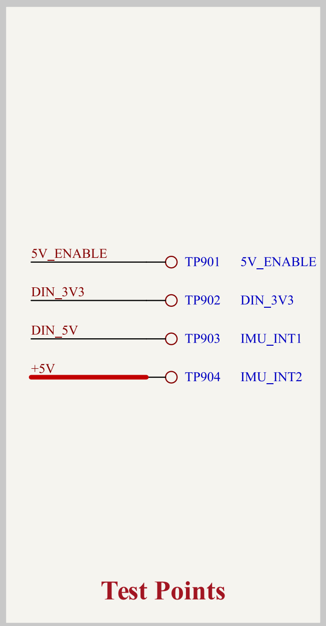
MUX_RESET TP801 MUX_RESET

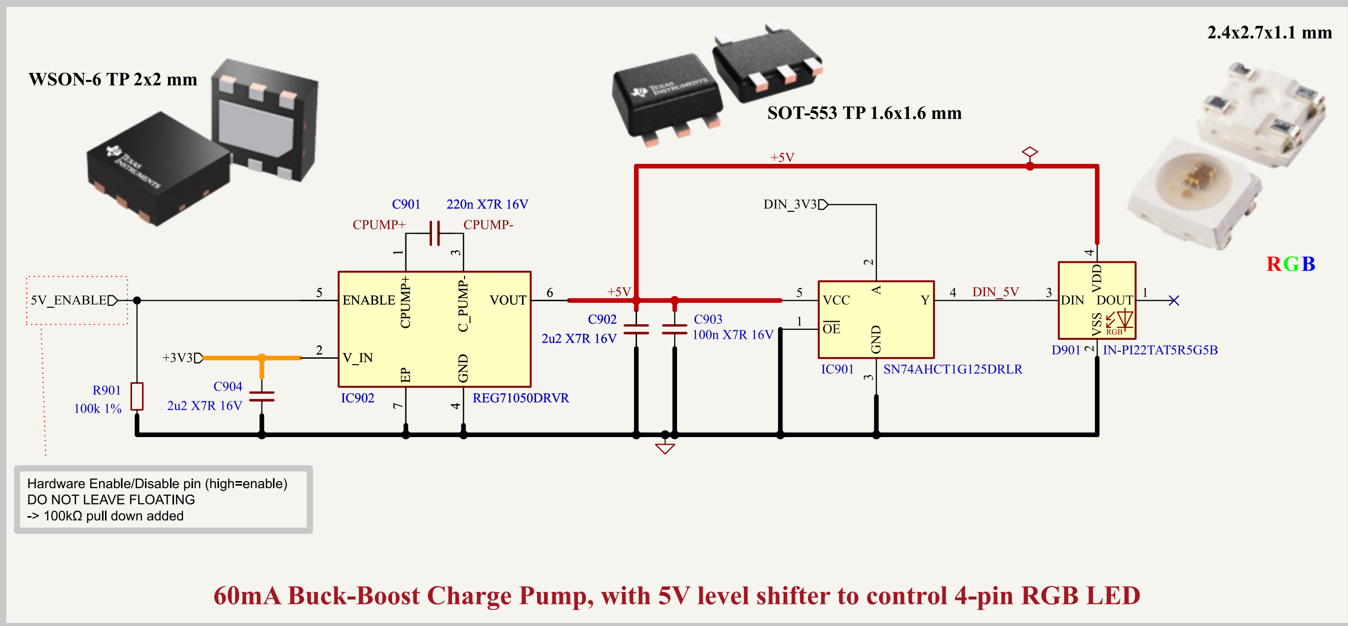
Test Points



Comments:	Laboratory: Integrated Actuators Laboratory			Variant: Released
	Board Name: Plume			Project Name: Smart Footwear for Diabetic Foot Care
Sheet Title: Logic - I2C Mux	File Name: Logic_I2C_Mux.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Logic - I2C Mux/		Superviser: Maël Dagon, Paolo Germano	Size: A4	Sheet: 8 of 31

[9] User - RGB LED Indicator





Current analysis:

Normal:
REG71050: 65uA
SN74AHCT1G125: 10uA
IN-PI22TAT5R5G5B: 1mA

Shutdown:
REG71050: 10nA
SN74AHCT1G125: OFF
IN-PI22TAT5R5G5B: OFF

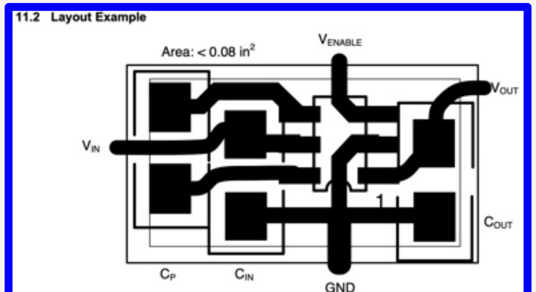
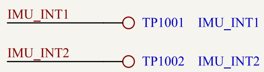


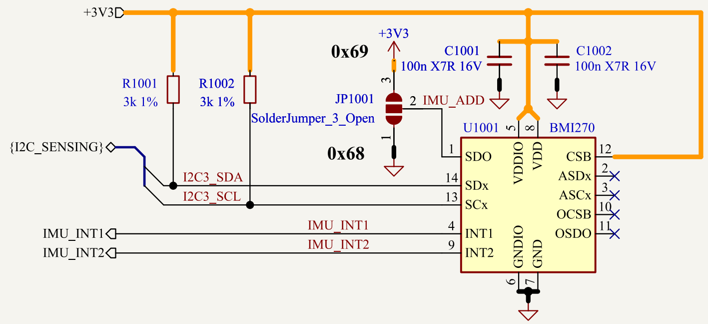
Figure 24. Suggested PCB Design for Minimum Ripple

Comments: This LED was chosen as it is relatively small compared to other well-known alternatives (e.g. WS2812B). The saved space is used to provide proper 5V supply and logic. This LED might work with 3V3 but this approach is safer.	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: User - RGB LED Indicator	File Name: User_RGB_LED_Indicator.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/User - RGB LED Indicator/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 9 of 31

[10] Sensing - IMU



Test Points



LGA-14 2.5x3x0.83 mm

Current analysis BMI270:

Normal:
A+G Performance mode: 970uA

Wake-up mode: 5uA

Sleep: 3uA

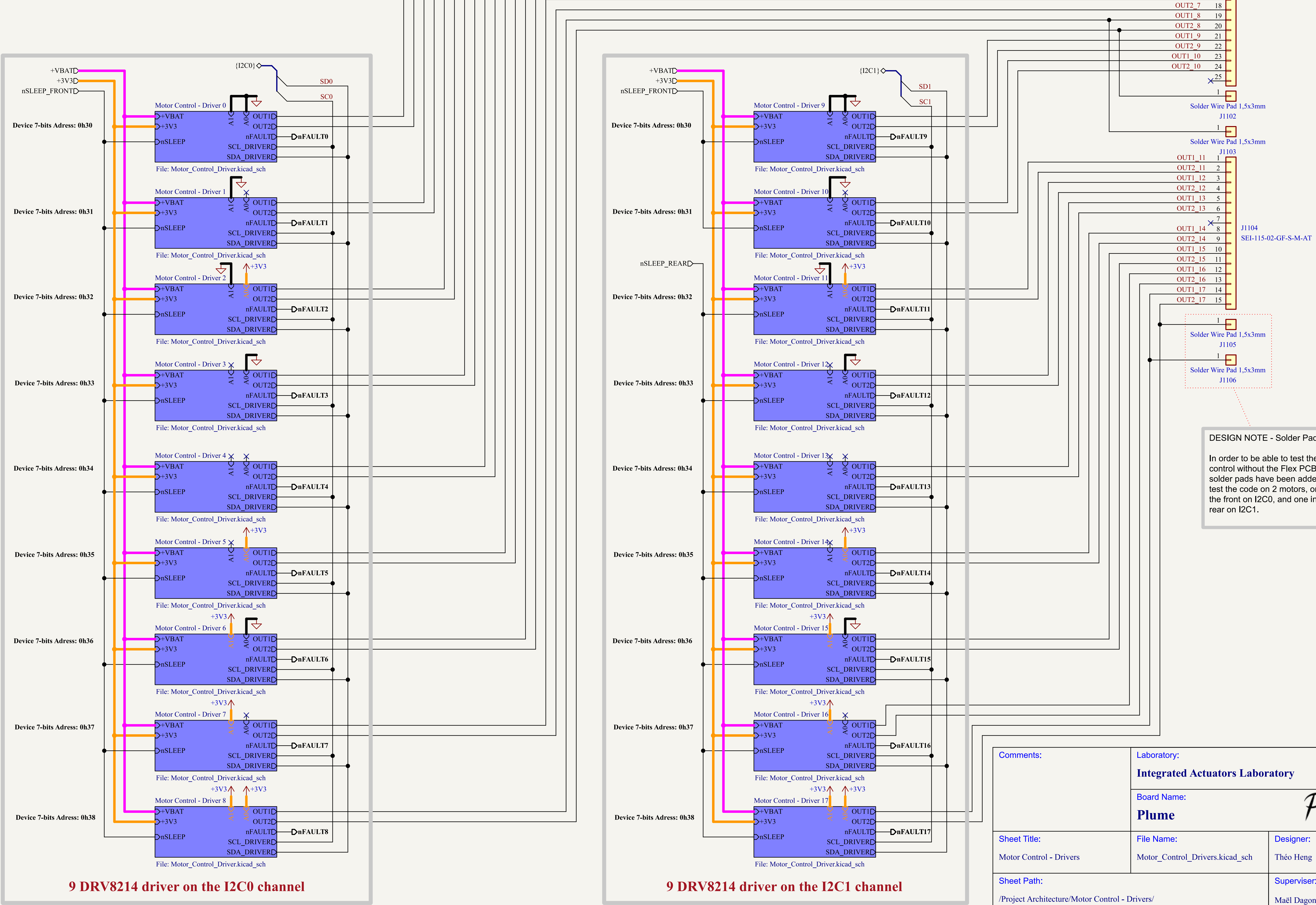
DESIGN NOTE - i2C address:

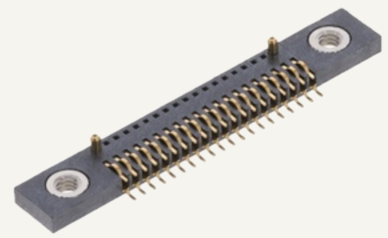
The default I²C address of the device is 0b1101000 (0x68). It is used if the SDO pin is pulled to 'GND'. The alternative address 0b1101001 (0x69) is selected by pulling the SDO pin to 'VDDIO'.

6-axis, smart, low power Inertial Measurement Unit for high-performance applications

Comments:	Laboratory: EPFL		Variant: Released
	Board Name: **Plume**		Project Name: **Smart Footwear for Diabetic Foot Care**
Sheet Title: Sensing - IMU	File Name: Sensing_IMU.kicad_sch	Designer: Théo Heng	Date: 2025-04-24 / Revision: 1.0
Sheet Path: /Project Architecture/Sensing - IMU/		Supervisor: Maël Dagon, Paolo Germano	Size: A4 / Sheet: 10 of 31

[11] Motor Control - Drivers x18





30 positions with screw: 44.48mm wide
25 positions with screw: 39.48mm wide
15 positions with screw: 29.48mm wide

DEBUG NOTE:

The specific Samtec connectors used on this PCB are not usually in stock on Mouser/Digikey so they are directly ordered from Samtech's website.

LAYOUT NOTE:

Use the "Replicate Layout" KiCad Plugin to layout copy-paste the layout of each driver unit.

DESIGN NOTE - Solder Pads:

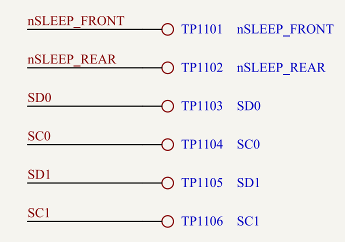
In order to be able to test the motor control without the Flex PCBs, solder pads have been added to test the code on 2 motors, one in the front on I2C0, and one in the rear on I2C1.

DESIGN NOTE:

This first iteration implements 18 drivers module, with 11 of them used at the front of the foot, and 7 at the rear.

Each module is similar, with the DRV8214RTER IC, decoupling and bulk capacitors, test points, fault LED, and current sense resistor.

For the layout, every module are routed in the exact same way.



Test Points

Comments:	Laboratory: Integrated Actuators Laboratory (EPFL)	Variant: Released
	Board Name: Plume	Project Name: Smart Footwear for Diabetic Foot Care
Sheet Title: Motor Control - Drivers	File Name: Motor_Control_Drivers.kicad_sch	Designer: Théo Heng
Date: 2025-04-24	Revision: 1.0	
Sheet Path: /Project Architecture/Motor Control - Drivers/	Supervisor: Maël Dagon, Paolo Germano	Size: A3
Sheet: 11 of 31		

[12] Motor Control - Driver 12

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

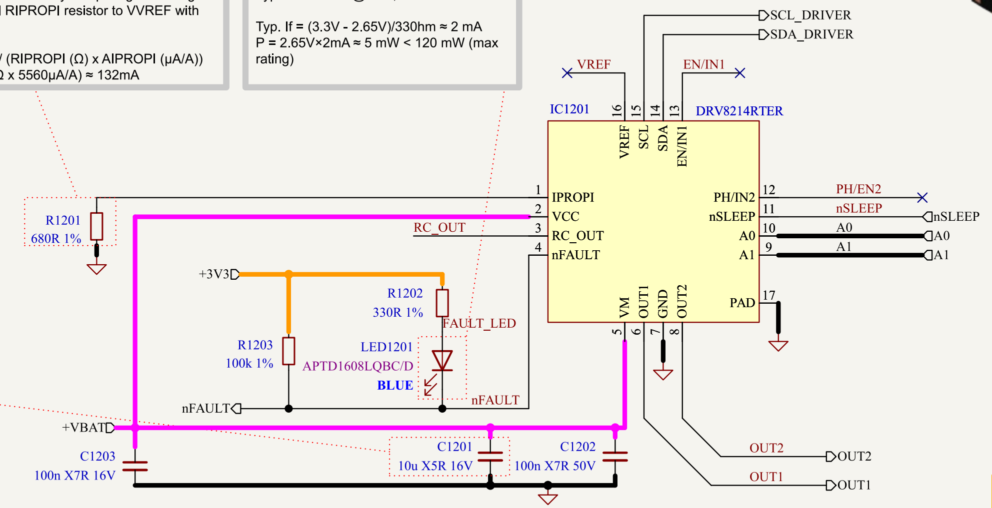
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

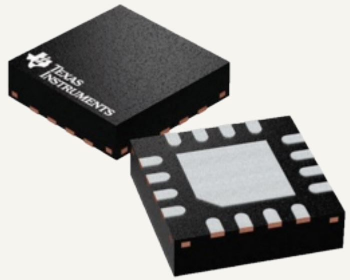
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (μA/A))
ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





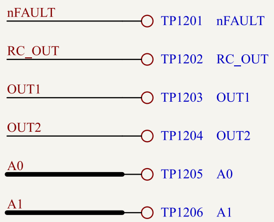
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory:		Variant:	
	Board Name: **Plume**		Project Name: **Smart Footwear for Diabetic Foot Care**	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 0/		Supervisor: Maël Dagon, Paolo Germano	Size: **A4**	Sheet: **12** of **31**

Variant: Released

[13] Motor Control - Driver 13

DESIGN NOTE - Bulk Capacitance:

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• The highest current required by the motor system
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• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

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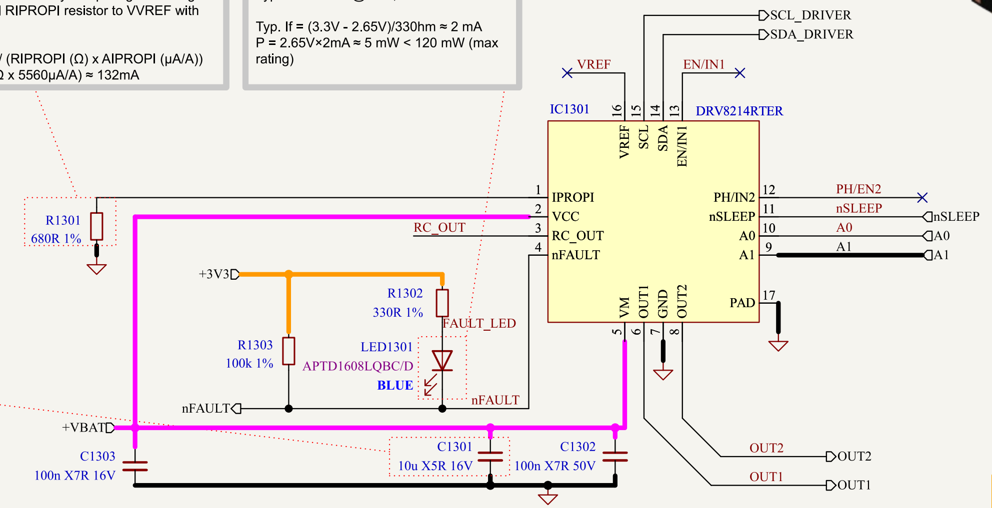
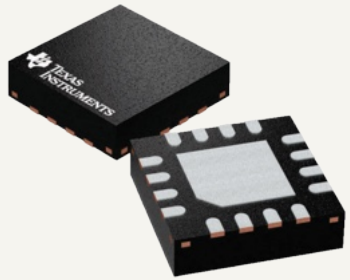
ITRIP (A) = 0.5V / (680Ω x 5560µA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)



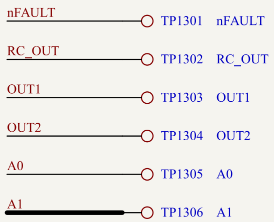


Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL	Variant: Released
	Board Name: Plume	Project Name: Smart Footwear for Diabetic Foot Care

Sheet Title:	File Name:	Designer:	Date:	Revision:
Motor Control - Driver	Motor_Control_Driver.kicad_sch	Théo Heng	2025-04-24	1.0

Sheet Path:	Supervisor:	Size:	Sheet:
/Project Architecture/Motor Control - Drivers/Motor Control - Driver 1/	Maël Dagon, Paolo Germano	A4	13 of 31

[14] Motor Control - Driver 14

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
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The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

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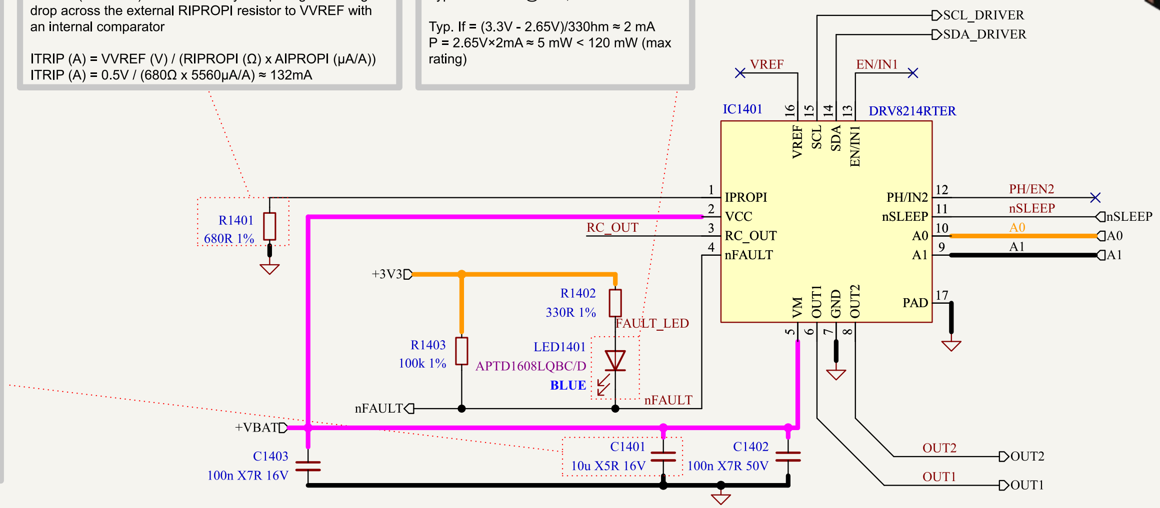
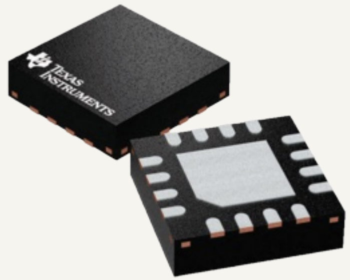
ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





WQFN-16 3x3 mm

Current analysis DRV8214:

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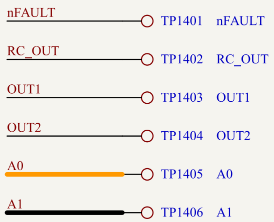
Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 2/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 14 of 31

[15] Motor Control - Driver 15

DESIGN NOTE - Bulk Capacitance:

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DESIGN NOTE - FAULT LED:

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Typ. Vf = 2.65V @2mA,

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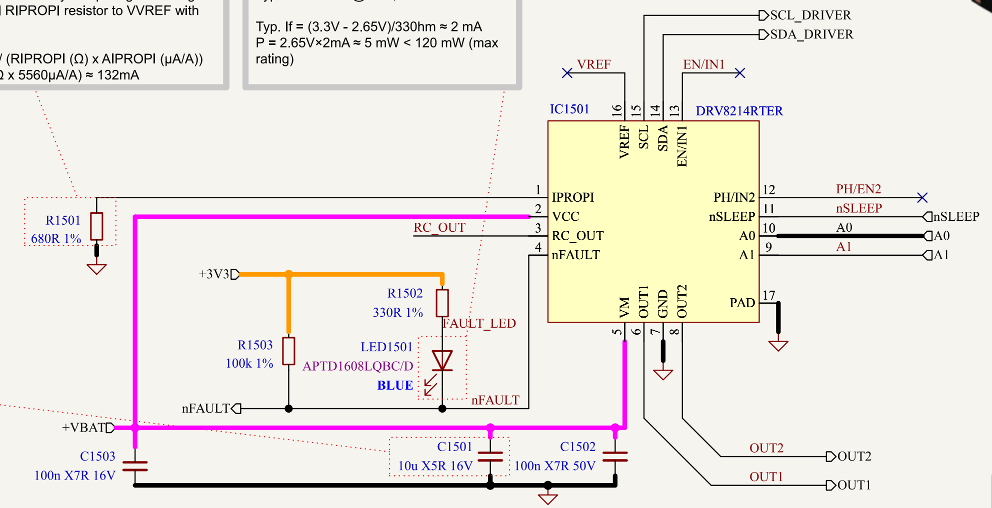
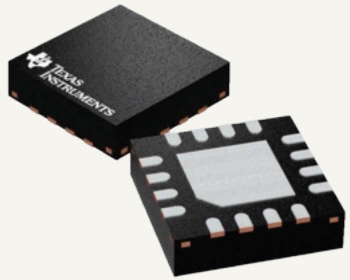
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





WQFN-16 3x3 mm

Current analysis DRV8214:

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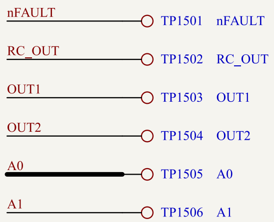
Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL	Variant: Released
	Board Name: Plume	Project Name: Smart Footwear for Diabetic Foot Care
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng
Date: 2025-04-24	Revision: 1.0	
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 3/	Supervisor: Maël Dagon, Paolo Germano	Size: A4
Sheet: 15 of 31		

[16] Motor Control - Driver 16

DESIGN NOTE - Bulk Capacitance:

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DESIGN NOTE - FAULT LED:

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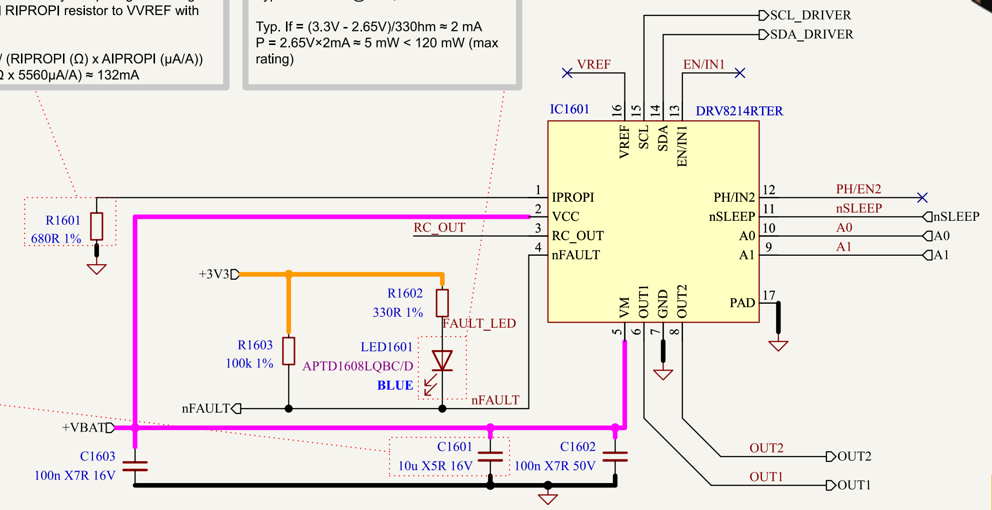
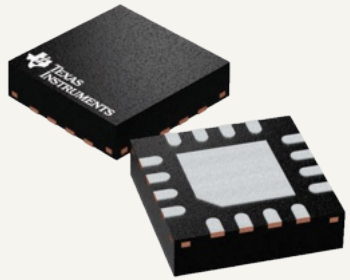
Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





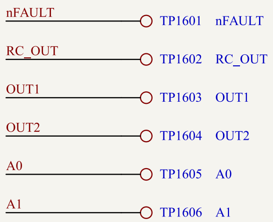
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 4/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 16 of 31

[17] Motor Control - Driver 17

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

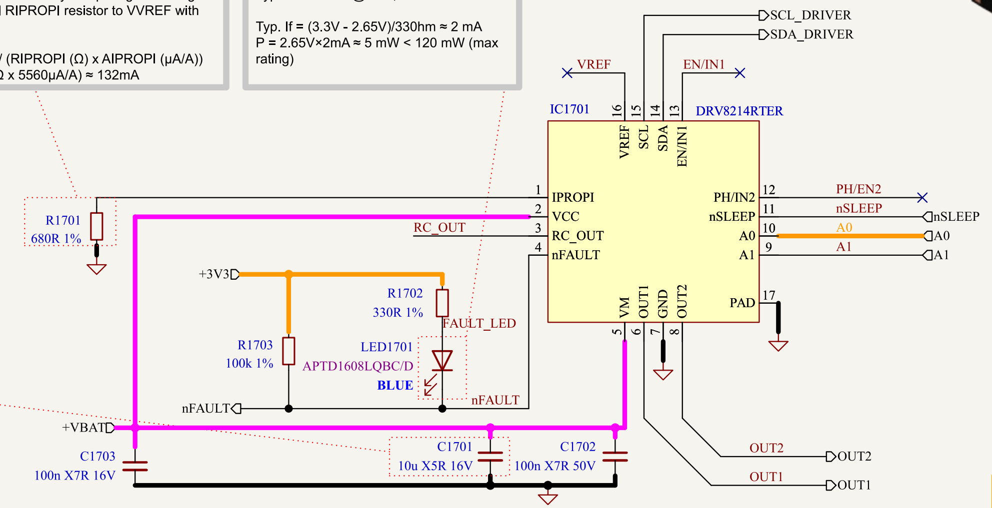
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

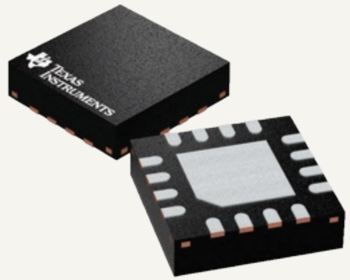
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (µA/A))
ITRIP (A) = 0.5V / (680Ω x 5560µA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





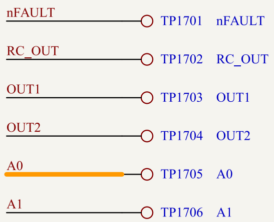
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 5/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 17 of 31

[18] Motor Control - Driver 18

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

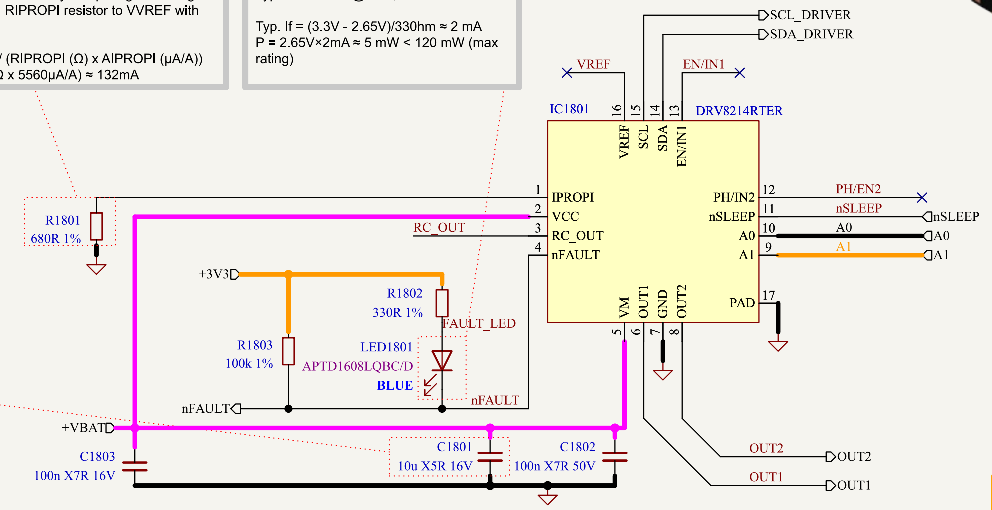
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

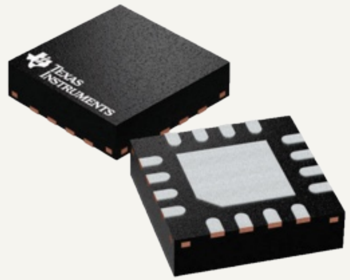
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (μA/A))
ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





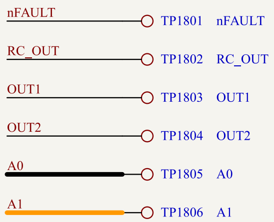
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL	Variant: Released
	Board Name: Plume	Project Name: Smart Footwear for Diabetic Foot Care
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng
Date: 2025-04-24	Revision: 1.0	
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 6/	Supervisor: Maël Dagon, Paolo Germano	
Size: A4	Sheet: 18 of 31	

[19] Motor Control - Driver 19

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

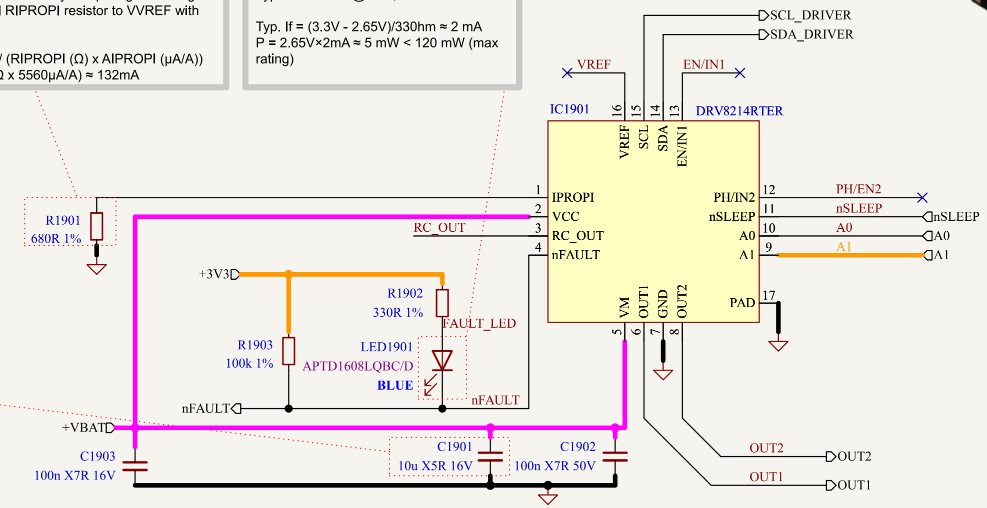
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

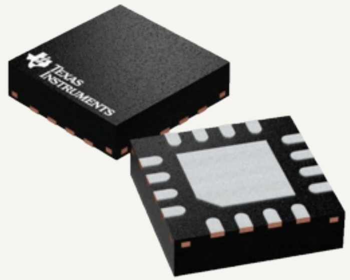
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (μA/A))
ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





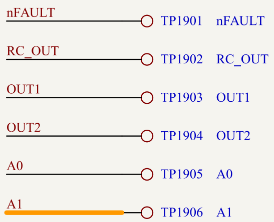
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 7/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 19 of 31

[20] Motor Control - Driver 20

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

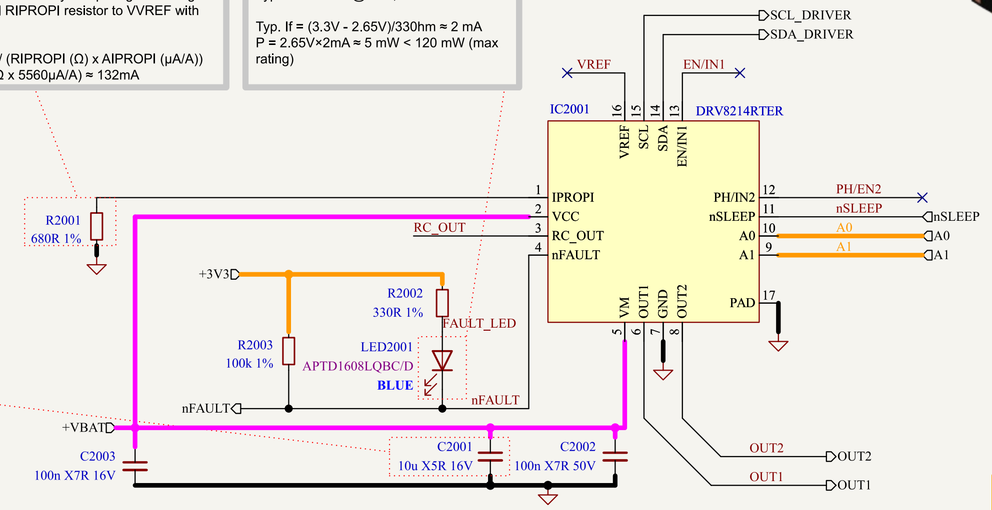
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

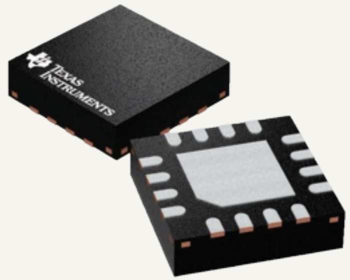
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (μA/A))
ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





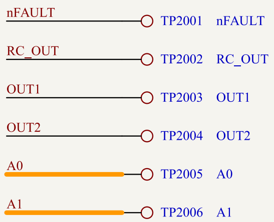
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 8/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 20 of 31

[21] Motor Control - Driver 21

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
- The highest current required by the motor system
- The capacitance of the power supply and ability to source current
- The amount of parasitic inductance between the power supply and motor system
- The acceptable voltage ripple
- The type of motor used (brushed DC, brushless DC, stepper)
- The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

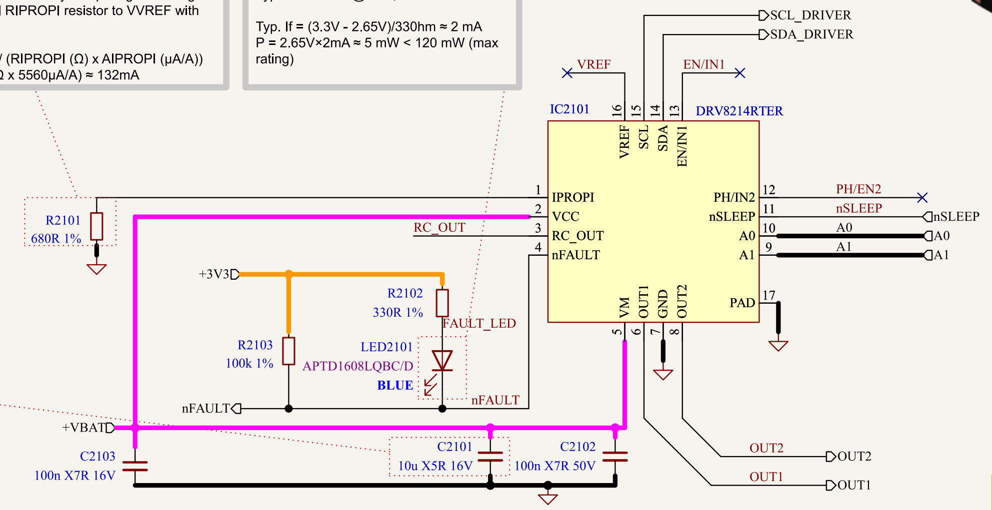
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

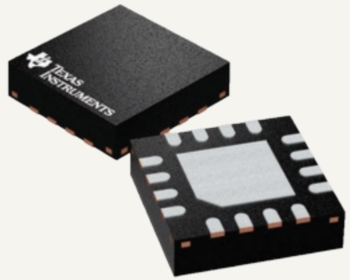
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (μA/A))
ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





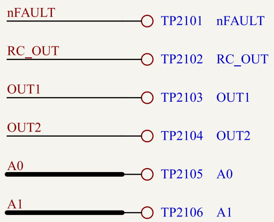
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 9/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 21 of 31

[22] Motor Control - Driver 22

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

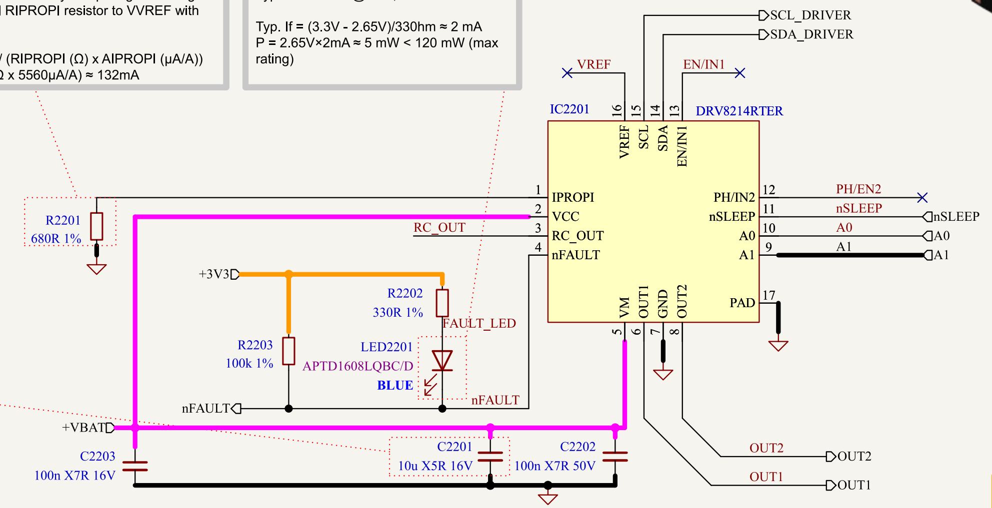
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

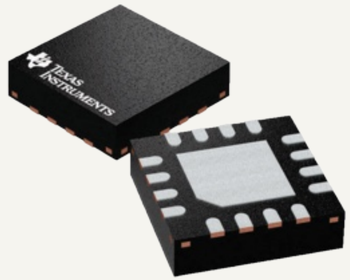
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (µA/A))
ITRIP (A) = 0.5V / (680Ω x 5560µA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





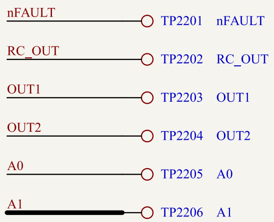
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released		
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care		
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0	
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 10/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 22 of 31	

[23] Motor Control - Driver 23

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

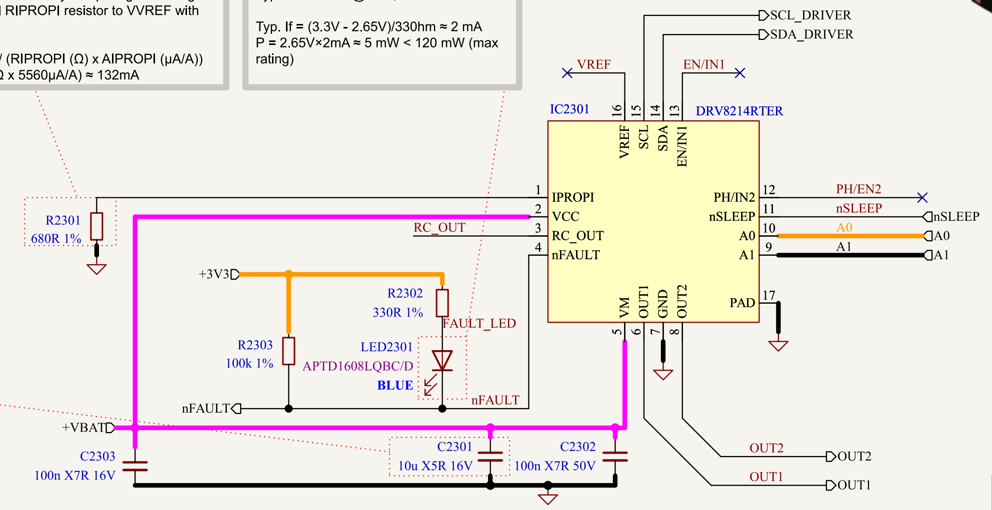
The current regulation threshold (ITRIP) is set through a combination of the VREF voltage and IPROPI output resistor (RIPROPI). This is done by comparing the voltage drop across the external RIPROPI resistor to VVREF with an internal comparator

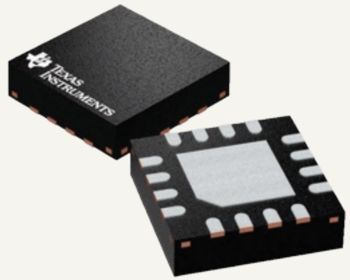
ITRIP (A) = VVREF (V) / (RIPROPI (Ω) x AIPROPI (μA/A))
ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

APTD1608LQBC/D has a typical luminous intensity of 20mcd (millicandela) @2mA
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





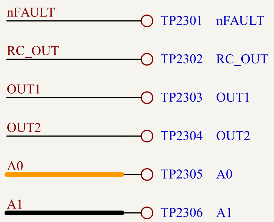
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 11/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 23 of 31

[24] Motor Control - Driver 24

DESIGN NOTE - Bulk Capacitance:

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
• The capacitance of the power supply and ability to source current
• The amount of parasitic inductance between the power supply and motor system
• The acceptable voltage ripple
• The type of motor used (brushed DC, brushless DC, stepper)
• The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

DESIGN NOTE - IPROPI Resistor:

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ITRIP (A) = 0.5V / (680Ω x 5560μA/A) ≈ 132mA

DESIGN NOTE - FAULT LED:

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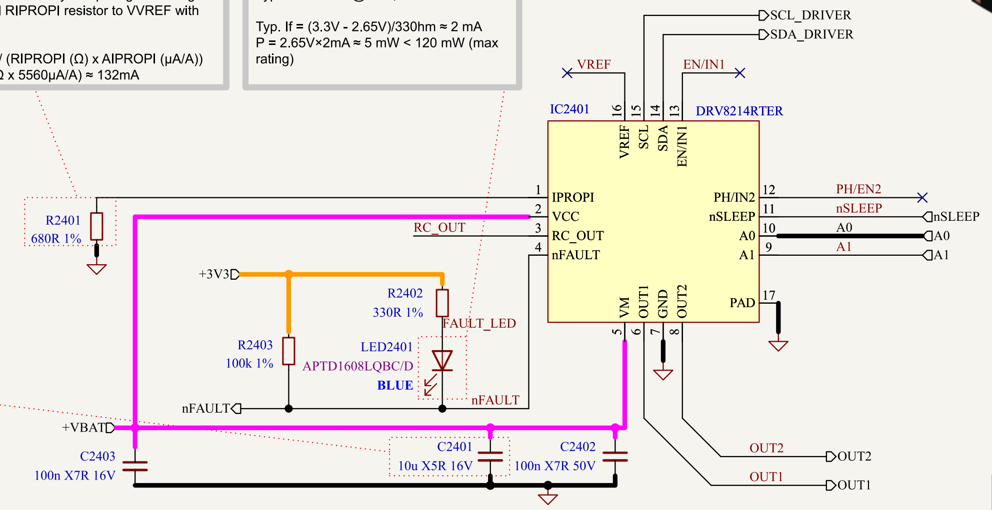
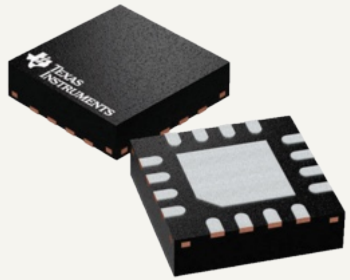
Typ. Vf = 2.65V @2mA,

Typ. If = (3.3V - 2.65V)/330hm ≈ 2 mA
P = 2.65V×2mA ≈ 5 mW < 120 mW (max rating)





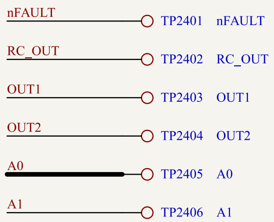
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 12/		Superviser: Maël Dagon, Paolo Germano	Size: A4	Sheet: 24 of 31

[25] Motor Control - Driver 25

DESIGN NOTE - Bulk Capacitance:

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The amount of local capacitance needed depends on a variety of factors, including:
• The highest current required by the motor system
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• The acceptable voltage ripple
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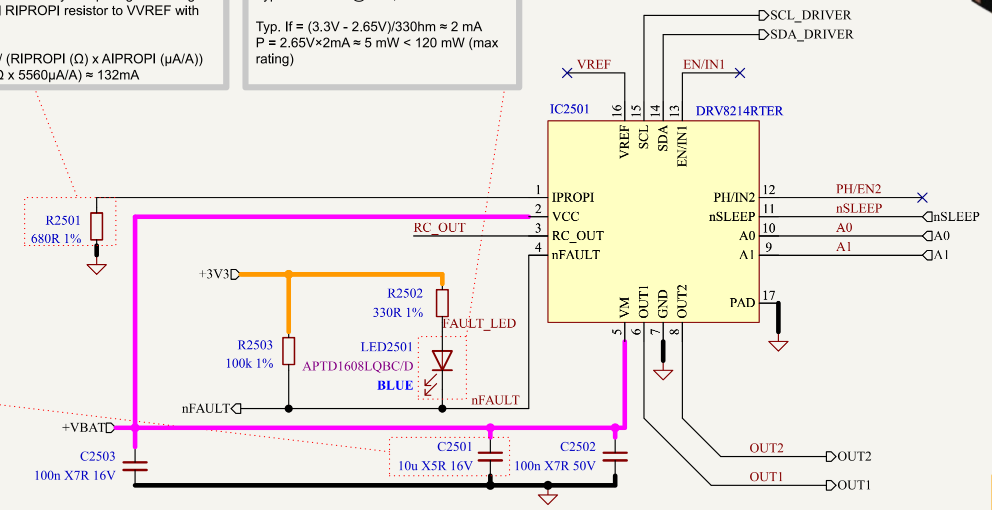

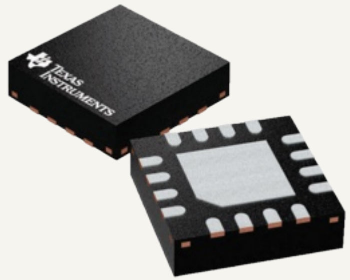

WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation

nFAULT	TP2501	nFAULT
RC_OUT	TP2502	RC_OUT
OUT1	TP2503	OUT1
OUT2	TP2504	OUT2
A0	TP2505	A0
A1	TP2506	A1

Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 13/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 25 of 31

[26] Motor Control - Driver 26

DESIGN NOTE - Bulk Capacitance:

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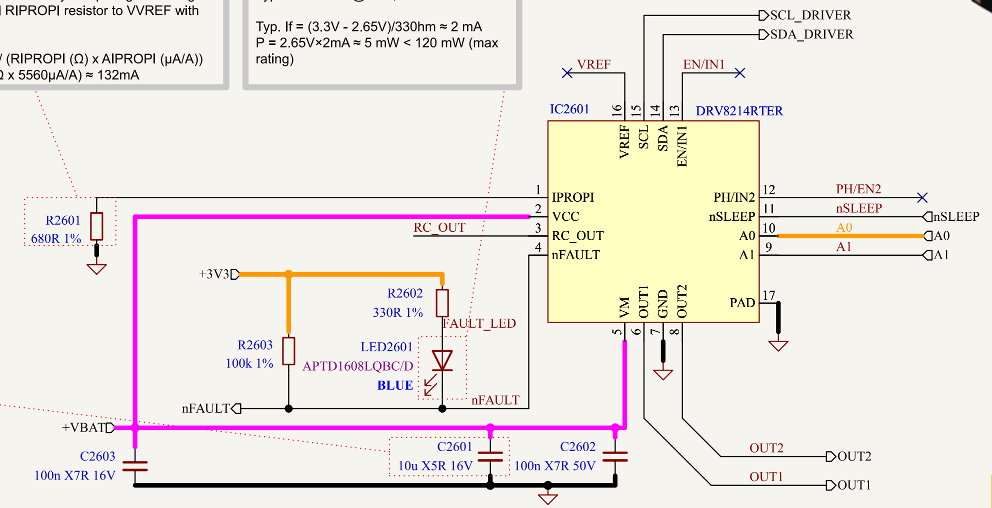
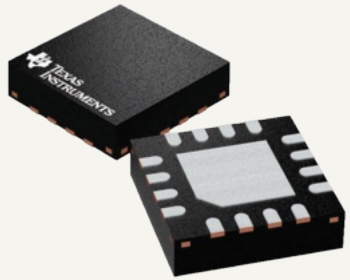




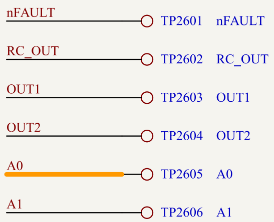
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:

Laboratory: EPFL

Variant: Released

Board Name: Plume

Project Name: Smart Footwear for Diabetic Foot Care

Sheet Title: Motor Control - Driver

File Name: Motor_Control_Driver.kicad_sch

Designer: Théo Heng

Date: 2025-04-24

Revision: 1.0

Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 14/

Superviser: Maël Dagon, Paolo Germano

Size: A4

Sheet: 26 of 31

[27] Motor Control - Driver 27

DESIGN NOTE - Bulk Capacitance:

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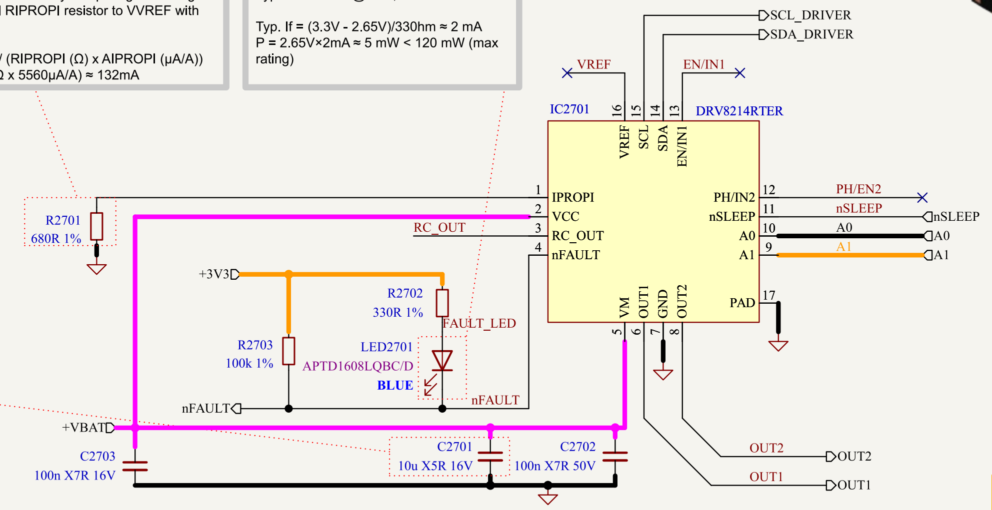
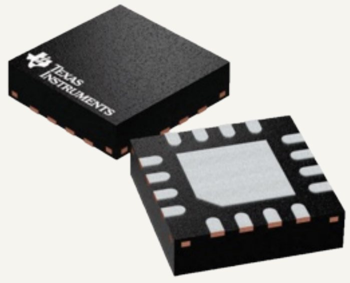




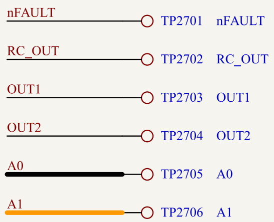
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 15/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 27 of 31

[28] Motor Control - Driver 28

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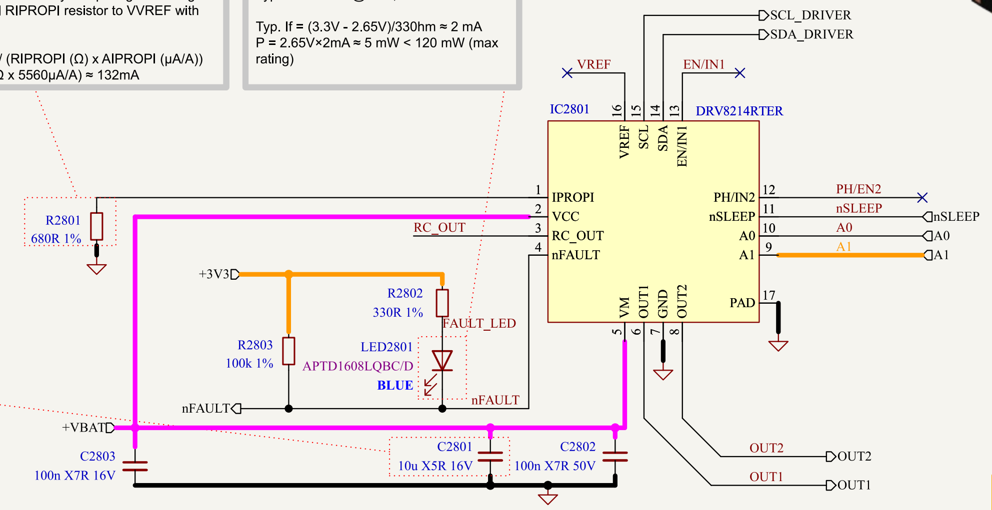
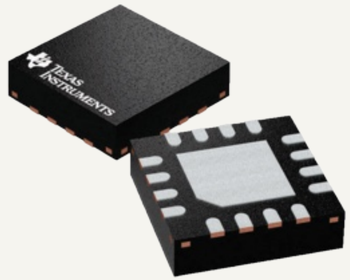




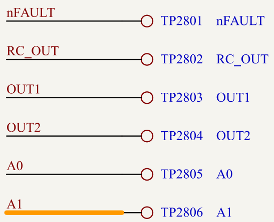
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL	Variant: Released
	Board Name: Plume	Project Name: Smart Footwear for Diabetic Foot Care

Sheet Title:	File Name:	Designer:	Date:	Revision:
Motor Control - Driver	Motor_Control_Driver.kicad_sch	Théo Heng	2025-04-24	1.0

Sheet Path:	Supervisor:	Size:	Sheet:
/Project Architecture/Motor Control - Drivers/Motor Control - Driver 16/	Maël Dagon, Paolo Germano	A4	28 of 31

[29] Motor Control - Driver 29

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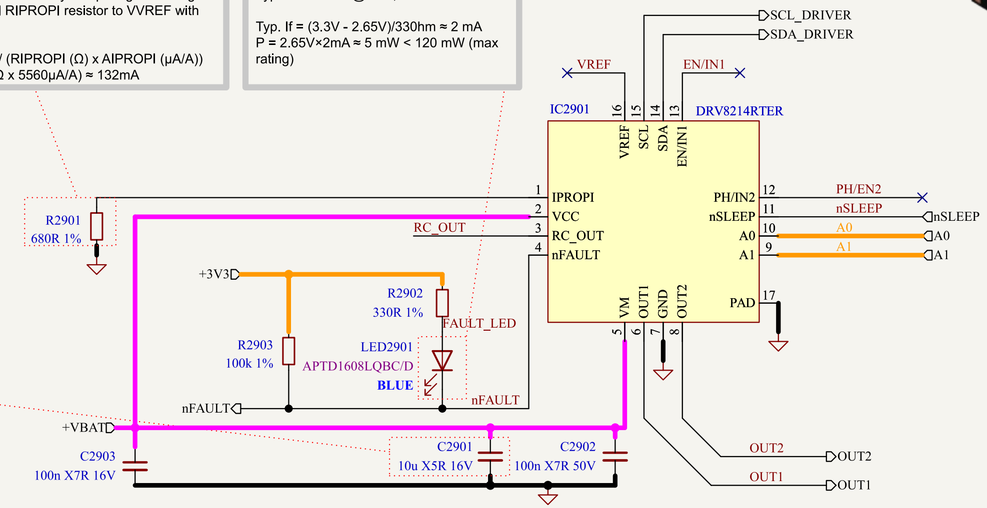
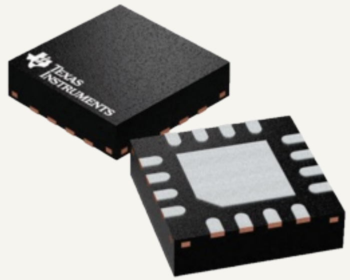




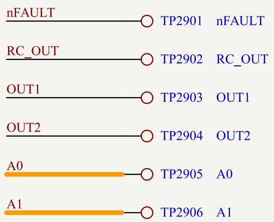
WQFN-16 3x3 mm

Current analysis DRV8214:

Normal mode motor stopped: 2.8 mA

Sleep: 100nA

DRV8214 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation



Test Points

Comments:	Laboratory: EPFL		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Motor Control - Driver	File Name: Motor_Control_Driver.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Project Architecture/Motor Control - Drivers/Motor Control - Driver 17/		Superviser: Maël Dagon, Paolo Germano	Size: A4	Sheet: 29 of 31

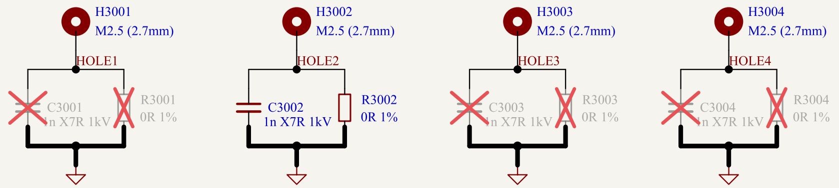
[30] Misc - Mounting Holes

DEBUG NOTE:

HOLE 1 is connected to GND and can be very useful if used as a GND reference for multimeter debug.

DESIGN NOTE:

Fiducials are ommited due to space constraints and are in any case unecessary in the forseable future because manual assembly is required since the DRV8214 ICs, among others, are unavailable on JLCPCB parts store.



Mechanical Mounting holes

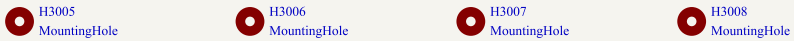
DESIGN NOTE:

In general, do not ground mounting holes that are connected to chassis if there is a risk that the chassis sends current into the PCB and dammages it or if the PCB works with high voltage and there is a risk for the user which is in contact with the chassis.

For a PCB in a metallic enclosure, the enclosure can act like a big antenna. The cavities (space between the ground plane on the pcb and the bottom metallic plane of the enclosure) cause capacitive coupling. This is because we have two metallic planes separated by a dielectric, at a separated potential, causing common mode noise. and result in the noise being amplified by the metal enclosure. Ideally, in this case, the case should be grounded. But the grounding will cause multiple return paths if multiples mounting holes are connected to GND. In that case, some current will flow in the enclosure and can give a little choc when the user touch it. This can be fine for small battery operated devices.

The best option is therefore to ground only one mounting hole.

Fiducials Front



Assembly Frame Mounting Holes

Fiducials Rear

Comments:
Inspired by Amulet controller Schematics by Vincent Nguyen
How to connect mounting holes.
PCB Mounting Holes

Laboratory: EPFL

Variant: Released

Board Name: **Plume**

Project Name: **Smart Footwear for Diabetic Foot Care**

Sheet Title:	File Name:	Designer:	Date:	Revision:
Misc - Mounting Holes	Misc_Mounting_Holes.kicad_sch	Théo Heng	2025-04-24	1.0

Sheet Path:	Superviser:	Size:	Sheet:
/Project Architecture/Misc - Mounting Holes & Fiducials/	Maël Dagon, Paolo Germano	A4	30 of 31

[31] Revision History

DD.MM.YYYY - xxx Revision
Variant: V1.0 -> V1.1
Ordered 24/04/2025: 5 PCB for 232.48$
Components for 4 PCB on Mouser: 300 CHF

- ● - Changed Silkscreen for motor testpoints from D10 to D8
- ✗ - GND test point next to battery connector isn't actually a GND test point -> changed to BAT-
- ✗ - Make the slot for the battery cables wider, move the connector further inside the PCB.
- ✗ - Move R & C of holes further in the bottom
- ✗ - Power LED is not ON when VBUS is present
- ✗ - Paste mask of the STM32 MCU is bad apparently
- ✗ - Need to short +VBAT and DOUT/COUT to enable the device
- ✗ - Switch 1 and switch2 needs to be routed to different GPIO to have them as interrupt
- - ______________________
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DD.MM.YYYY - xxx Revision
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● **Done**
✗ **Not done yet**

Comments:	Laboratory: Integrated Actuators Laboratory		Variant: Released	
	Board Name: Plume		Project Name: Smart Footwear for Diabetic Foot Care	
Sheet Title: Revision History	File Name: Revision History.kicad_sch	Designer: Théo Heng	Date: 2025-04-24	Revision: 1.0
Sheet Path: /Revision History/		Supervisor: Maël Dagon, Paolo Germano	Size: A4	Sheet: 31 of 31