Open source, Application datasheet, and design note

Super-capacitor controller (1)

Rongbo Hu

ABSTRACT

This device is a supercapacitor controller based on a 4-switch DC-DC converter. It can charge the parallel capacitor bank as much as possible while ensuring that the output on the battery side does not exceed the rated power, and it maintains the voltage measured at the motor around 24V. Additionally, this device can automatically detect the power measured at the motor (load) and provide feedback to the upper computer via CAN, allowing the upper computer to freely control the power of each motor (or load). In special cases, such as when the stored energy in the capacitors is depleted, this controller can automatically disconnect the capacitors and issue a warning to the upper computer through programmable CAN signals or UART signals.

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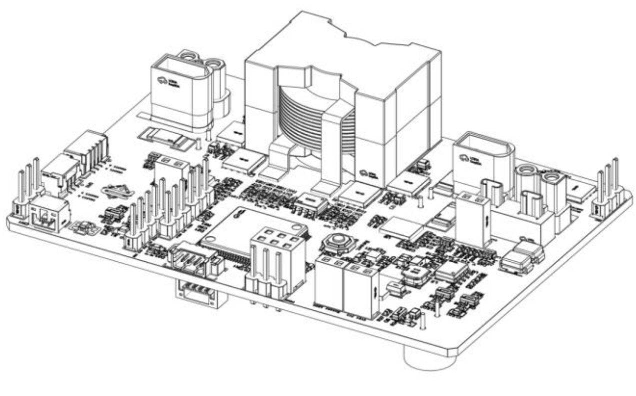


Thanks (All in a nickname or the username in the repository)

Luo, Lin

Purdue Robomaster
Great Lakes
IRM
VT
UBC

Open shouce
浙（竞争）
光速
老黄
深大

Feature and Description

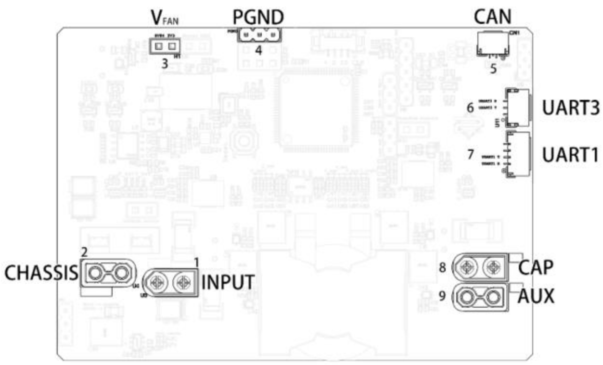
-Programmable output power with a response time of less than 100 milliseconds.
-Compatible with capacitors of different voltage ratings, with a default requirement of over 24V for the capacitor bank.
-Wide input voltage range from 15V to 28V.
-Can discharge capacitors down to 3V or even lower.
-PID controller with feedforward compensation, enabling faster response and ensuring that capacitor current does not spike after system restart, regardless of capacitor voltage.
-Competitive PID that automatically selects the most effective duty cycle within allowable conditions.
-Can detect the actual power of the motor for more control options.
-Can detect charging and discharging power of the capacitors, useful for calculating overall system efficiency.
-Rich communication interfaces for data transmission via UART and CAN.
-Interface reserved for remote debuggers (such as remote UART transceivers) that can use DMA for remote debugging.
-Multiple voltage outputs available for connecting different devices (such as fans).

Under standard conditions, the supercapacitor controller (hereinafter referred to as SCC) connects the battery, capacitors, and motor. When the motor is running slowly (below 45W, such as 20W), the SCC charges the capacitors with power at 25W. When the motor is running normally (at 45W), the SCC maintains the capacitors without charging or discharging. When the motor accelerates (above 45W), the SCC adjusts the duty cycle of the MOSFETs to discharge the capacitors slightly above 24V, compensating for the battery's power based on Kirchhoff's current law, thereby stabilizing the power on the battery side at 45W.

Revision History

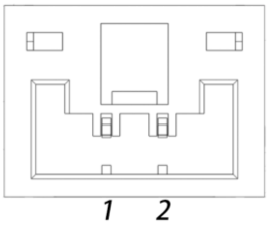
NON

Connector Configuration and Functions

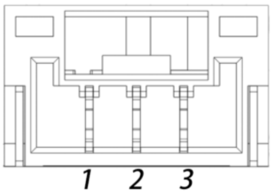


Connector		I/O	Describe	Device
Name	NO.			
INPUT	1	I (Power)	Connected to the battery	XT30-plug
CHASSIS	2	O (Power)	Connected to the chassis (or other loads)	XT30-socket
V_{FAN}	3	O	Can connect to a fan, providing two selectable voltages: 3.3V and 6.5V	2.54mm Pin
PGND	4	O	Ground link for the fan or other systems	2.54mm Pin
CAN	5	I/O	CAN communication connector	GH2P side in
UART3	6	I/O	UART3 communication connector	GH3P side in

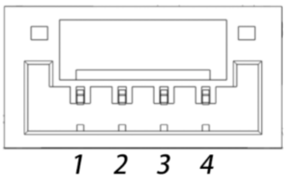
UART1	7	I/O	UART1 communication connector	GH4P side in
CAP	8	I/O (Power)	Connected to the capacitor bank	XT30-plug
AUX	9	O (Power)	Connected to the chassis in a specific mode (series topology), with no devices connected by default	XT30-socket



CAN bus (Connector 5)	
No.	Describe
1	CAN bus Low (CANL)
2	CAN bus High (CANH)



USART (Connector 6)	
No.	Describe
1	USART GND (GND)
2	USART Transmit (TX)
3	USART Receive (RX)



USART (Connector 7)	
No.	Describe
1	USART Receive (RX)
2	USART Transmit (TX)
3	USART GND (GND)
4	Not connect (NC)

Specifications

Absolute Maximum Ratings[1]

Over the Absolute Maximum Ratings will cause Irreversible damage to this device.

Symbol	Parameter	Value	Unit
V_{IN}	The voltage of INPUT to GND[2]	10 to 30	V

I_{IN}	The current input from INPUT	20	A
I_{OUT}	The current output from CHASSIS.	40	A
I_{CAP}	The current in and out from CAP.	20	A
I_{FAN} (3.3V)	The current output from FAN (3.3V)	500	mA
I_{FAN} (6.5V)	The current output from FAN (6.5V)	1	A

(1) All limit values depend on the limits of each component in the entire voltage rail or current path.

(2) 30V is the limit for the TVS diode (D10); if the diode is removed, the voltage rating can be increased to 42V.

Electrical Characteristics and Recommended Operating Conditions

Parameter	Condition	MIN	TYP	MAX	Unit
VIN, operating voltage input from INPUT					
V_{out}, The output voltage from CHASSIS	I_{OUT} = 0; I_{CAP} = 0; V_{IN} = 24V		24		V
VCAP,					
ICAP,					
I_{IN}(1), The input current from CHASSIS	V_{IN} = 24V; VCAP > 4V(2) // Write an expression here.	0	2	2.2	A

(1) When I_{OUT} is too high, I_{IN} will exceed MAX to ensure that I_{CAP} does not exceed the maximum rating.

(2) The capacitor voltage represents the charge of the capacitor.

Thermal Information(1)

Symbol	Parameter		Unit

Table 3: Thermal data

Symbol	Parameter	Value	Unit
$R_{thj\text{-}pcb}$ *(1)*	Thermal resistance junction-pcb max.	31.3	°C/W
$R_{thj\text{-}case}$	Thermal resistance junction-case max.	1.2	°C/W

Notes:

(1)When mounted on FR-4 board of 1 inch², 2oz Cu, t < 10 sec

(1) In this section, I directly referenced the datasheet of the main heating component, the MOSFET.

// Need to format the citation.

//Need test

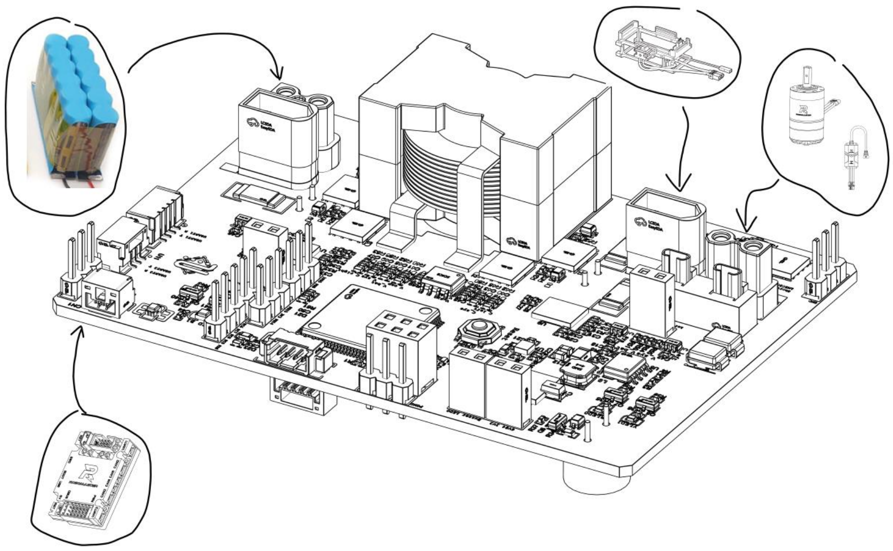
Figure. CHASSIS ripple

//Need test

Figure. CAP ripple

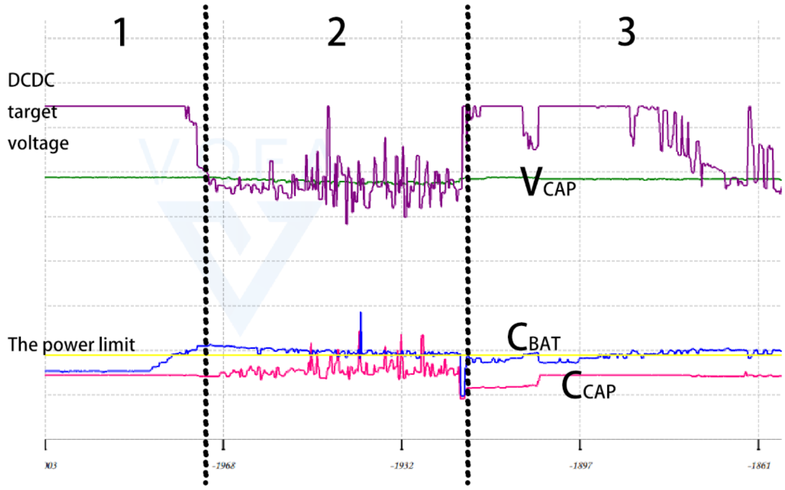
Figure. Voltage of MOSFET gate to GND

Typical Application and Usage Guidelines



//Redo for Art

Figure. Hardware connection



//Need rescreen shot

Figure. Waveform of classic operating conditions (short-term situation) [1]

(1) In Zone 1, the chassis does not consume power; in Zone 2, the chassis consumes power, resulting in a small power spike at the boundary between Zones 1 and 2. After that, the capacitors begin to compensate, ensuring that the power does not exceed the limit thereafter. In Zone 3, as the chassis no longer operates at high power, the capacitors start to charge.

//Need rescreen shot

Figure. Classic Charging Waveform

-Control guidelines

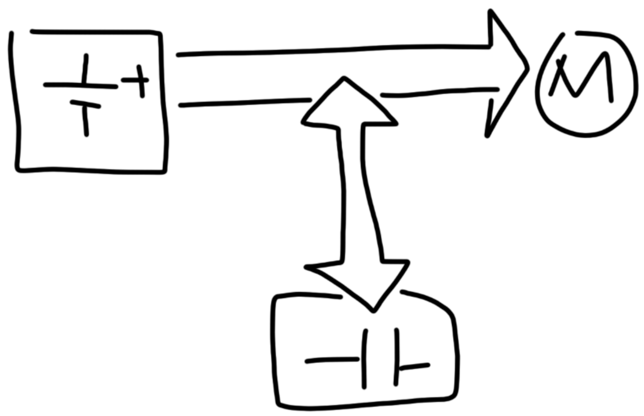
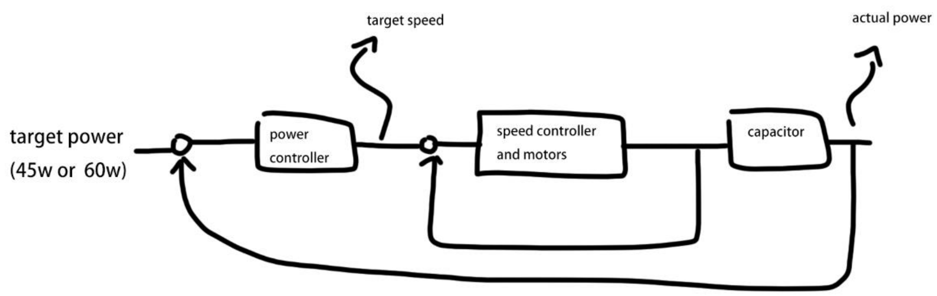
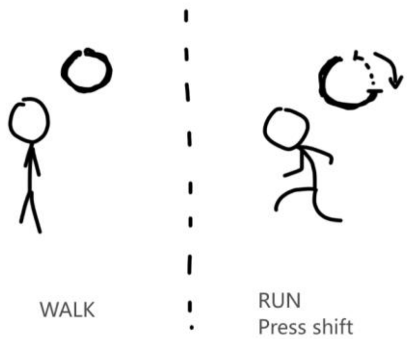


Figure. Power diagram



//Need Art

Figure Speed control diagram



//Need screen shot

Figure. The work status of robot like video game

	Super-cap receive	Super-cap Transmit
CAN ID (NA in UART)	0x2C8	0x2C7
DATA[0]	PowerLimit (W)	Cap maximum output power*100 (W)
DATA[1]	Power from IC in the battery * 100 (W)	Chassis actual power *100 (W)
DATA[2]	NA	Cap energy level (%)
DATA[3]	NA	State (NA in UART)

In this control system, the main controller communicates with the supercapacitor controller via CAN or UART. The main control board automatically decides whether to accelerate the robot based on operator commands (in practical applications, this is often done by pressing the shift key). At normal speed, the main controller adjusts the robot's speed based on feedback from the supercapacitor controller, ensuring that the robot does not consume energy from the capacitors. During acceleration, the robot consumes energy from the capacitors. The figure illustrates a video game as an example, where the character runs normally in a standard state, and when the shift key is pressed, the character starts to run faster while consuming energy. When the energy is depleted, the character can no longer continue running.

// This section needs to include a paragraph explaining that the feedback from the 3508 cannot directly obtain the current.

//introduce to FOC

Installation

Mechanical Information

//Mechanical Size

Figure. Mechanical Size

Installation Recommendations

-Please reserve space for the capacitors on the back.

-Please ensure ventilation and heat dissipation.

-Please follow the order of installation and removal.

-Please implement protection to prevent foreign objects from falling and causing a short circuit.

-Please ensure insulation on the back.

-Recommended installation: Install the 3D-printed box upside down under the chassis.

//Install example

Figure. Upside down installation

Part 2

Introduce and Learning Recommendation

When studying, it is helpful to combine block diagrams to clarify the functions of each module, and then examine the specific design and IC selection for each module one by one.

In circuit design, we often understand each module as a black box and analyze its functions.2. Existing Design and Topology

Figure. Series without boost

Figure. Series with boost

Figure. Parallel (//remember to mention the issue of the body diode preventing power disconnection).

Figure. Bidirectional DC-DC parallel connection.

// Keyword: Performance analysis of each topology, as well as potential issues that may arise after failure.

3. Subsystem Design Note

3.1. Power tree

// Key word: Starting from the SY8501, recommendations for the layout of this section include reducing the di/dt nodes.

// Key word: Remember to mention that the 1.65V OP AMP may experience loop control instability after adding the filter capacitor. Also, analyze the necessity of this OP AMP from a broader perspective: why can't we use a voltage divider directly?

3.1a. Introduce

3.1b. Method

3.1c. Result

3.1d. Conclusion

3.2. ADC and sampling

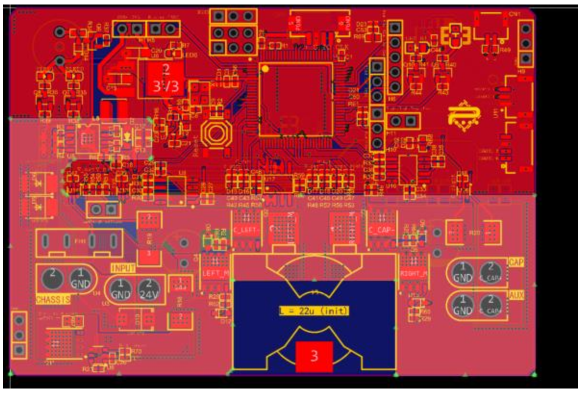
// Key word 1: Elaborate on ADC filtering and what a SAR ADC is.

// Key word 2: Point out that after the voltage division at the sampling point, in addition to directly connecting to the ADC, I have left two ADC interfaces to connect to the OPAMP. Subsequent experiments should quantitatively determine the different performances of these two schemes. 3.2a~d

3.3. EMC and SI Considerations

// Key word : Point out that I have left one ADC very close to the digital signal to test the crosstalk impact of the digital signal on the ADC signal.

// Emphasize that the digital ground and power ground need to be separated, and the ADC should be placed across them.



// To be studied: Relevant quantitative indicators for signal integrity and EMI testing.

3.3a~d

3.4. Firmware and communication interface and debugging methods

// Design logic of the GH3P interface on both the front and back—interface standardization.

// Application of DMA

// Tips for a simple operating system and checking system utilization.

3.4a~d

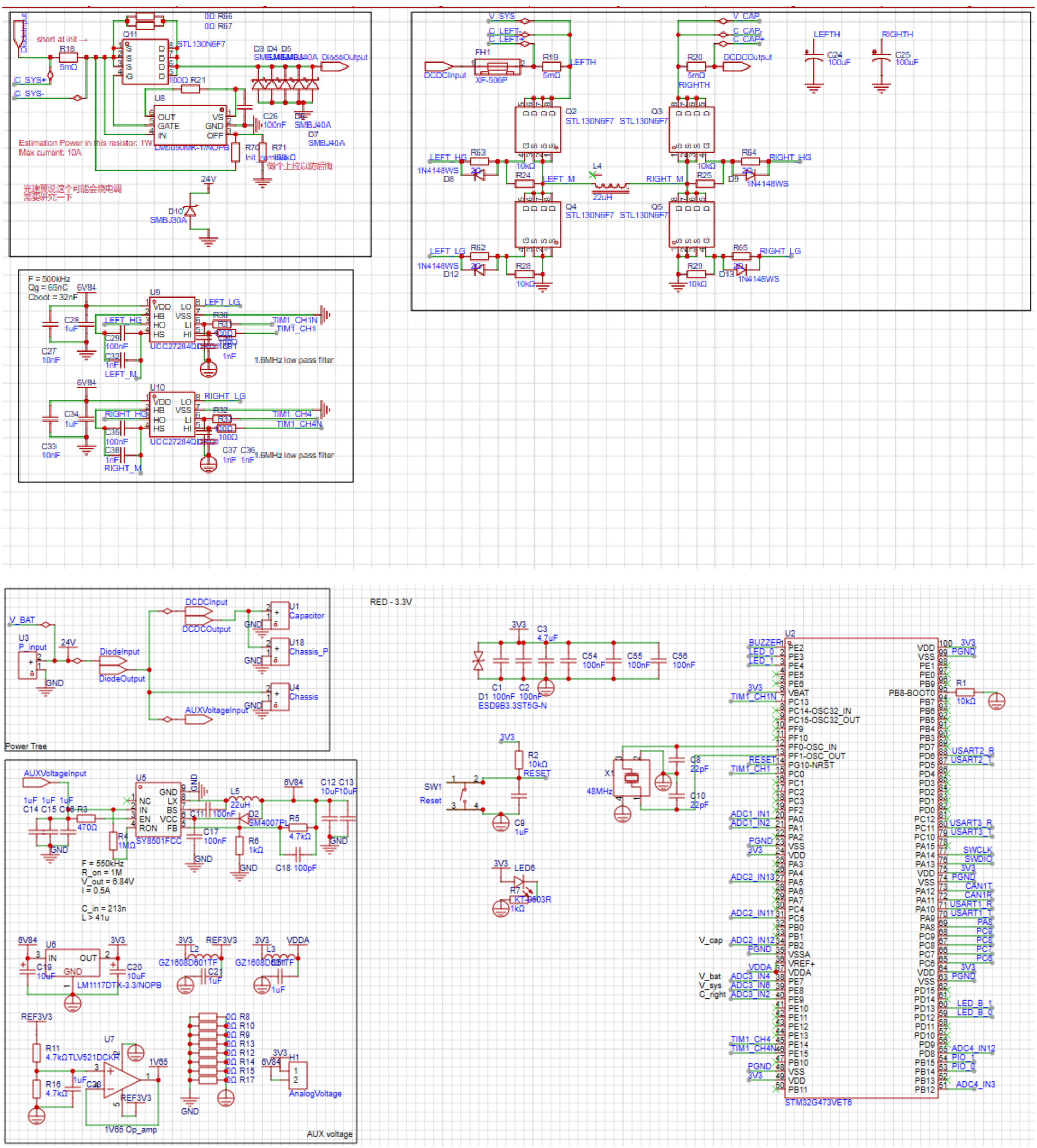
3.5. MOSFET driver

// Keyword: Formation of dead time and Miller plateau, simulation of the MOSFET turn-on process.

// Keyword: If time permits, quantitatively examine the impact of the diode next to the gate on switching time through experiments.

Future Outlook:

Multiphase DC-DC. Or Flyback power supply.


Estimation Power in this resistor: 1W
Max current: 10A
F = 500kHz
Qg = 65nC
Cboot = 32nF
1.6MHz low pass filter
Power Tree
RED - 3.3V
F = 550kHz
R_on = 1M
V_out = 6.84V
I = 0.5A
C_in = 213n
L > 41u
1V65 Op_amp
AUX voltage
STM32G473VET6