CelWise

CW5053

Brushed DC Motor Smart Controller

Features

- BDC Motor Controller with MOSFET Pre-driver
- Input Voltage Range: 5.5V to 42V
- Supports 3/4/5s Li-ion Battery Cells
- Motor Over Current Protection:
  - 3 Over Current Settings with Configurable Threshold and Delay
  - "True Motor Current" Technique Compensates PWM Duty-cycle Effects
- Short Circuit Protection
  - Threshold from 40mV to 240mV
- Battery Over Discharge Protection:
  - Threshold from 1.90V to 3.16V
- Two NTC Based Over Temperature Protections
  - One for High&Low Temperature Protection
  - One for Over Temperature Protection
- BDC Motor Control:
  - PWM Duty-cycle Control with Digital Deglitch and Soft Start
  - 12V MOSFET Pre-drive
- Lighting LED Driver with Alarm Indication
- 3-LEDs Battery Gas Gauge Indication

Applications

- Portable Power Tools
- E-bikes
- Battery Powered Home Appliance

General Description

CW5053 integrates brushed DC motor control, discharge current and voltage protection to provide a safe and high compact total solution for power tools application.

IC is suitable for 3~5 battery cells connected in series, and can be extended to as maximum as 10 cells application by adding an external resistor divider.

CW5053 provides an accurate PWM signal for motor control, the logic high output voltage of PWM is clamped to 12V to simplify the design and protect the MOSFET gate. Output duty cycle can be adjusted from the minimum start-up duty cycle to 100%.

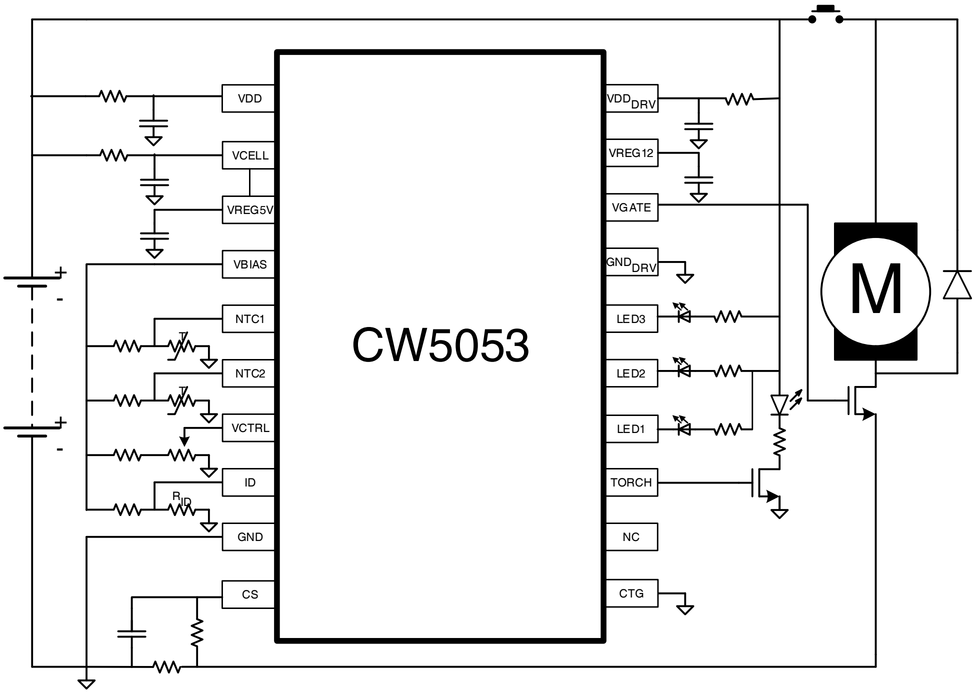
A soft-start function is also embedded to reduce the inrush current during motor start-up.

CW5053 integrates a discharge current and voltage protection to ensure the battery safety. Besides voltage and current protection, IC also offers over temperature and under protection for battery pack and motor.

3 LEDs are used to indicate the remaining capacity of the battery pack.

CW5053 employs SSOP20, QFN16 and QFN20 packages for different requirements.

Typical Application



Ordering Information

PART	OPERATING TEMPERATURE	PACKAGE	TOP MARK
CW5053ALAQ	-40°C to 85°C	QFN16 (3x3mm^2)	CW5053ALAQ
CW5053ALBS		SSOP20	CW5053ALBS
CW5053ALCF		QFN20 (4x4mm^2)	CW5053ALCF

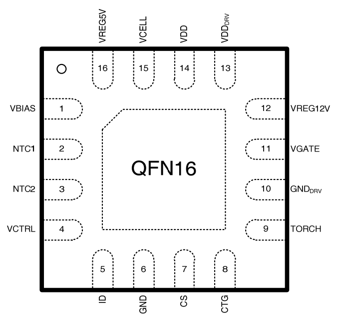
PART	CELLS	PWM FREQ	MIN DUTY CYCLE	SS STEP DELAY[1]	UT [2] RATIO	UT DELAY	UNDER VOLTAGE	UV DELAY
CW5053ALAQ	3	2kHz	12.5%	4ms	77.5%	16ms	2.700V	1200ms
CW5053ALBS	5	4kHz	20%	0.25ms	77.5%	500ms	2.500V	1200ms
CW5053ALCF	5	2kHz	3.13%	4ms	77.5%	500ms	2.500V	1200ms

PART	OC 1[3]	OC 2	OC 3	SP[4]	OC 1 DELAY	OC 2 DELAY	OC 3 DELAY	SP DELAY
CW5053ALAQ	0.04V	0.08V	0.12V	0.24V	960ms	200ms	100ms	0.5ms
CW5053ALBS	0.05V	0.10V	0.15V	0.24V	960ms	100ms	40ms	0.5ms
CW5053ALCF	0.015V	0.025V	0.035V	0.060V	960ms	200ms	100ms	0.5ms

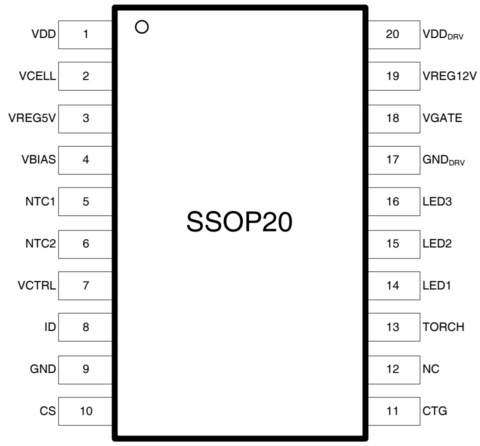
(1) SS stands for soft start
(2) UT stands for under temperature
(3) OC stands for over current
(4) SP stands for short circuit protection

Pin Configuration

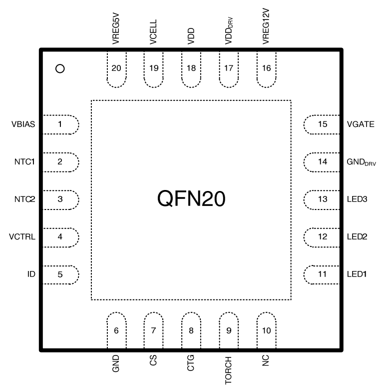
QFN16 Package



SSOP20 Package



QFN20 Package



Pin Descriptions

QFN16 PIN	SSOP PIN	QFN20 PIN	NAME	DESCRIPTION
1	4	1	VBIAS	5V bias voltage for NTC, VCTRL and ID resistor divider.
2	5	2	NTC1	Thermistor sense input 1.
3	6	3	NTC2	Thermistor sense input 2.
4	7	4	VCTRL	PWM control voltage sense input.
5	8	5	ID	ID resistor sense input.
6	9	6	GND	Analog ground.
7	10	7	CS	Analog input connected to current sense resistor.
8	11	8	CTG	Connect to ground.
9	13	9	TORCH	Output to driver torch LED pull down MOS.
10	17	14	GNDDRV	Ground for MOSFET gate driver.
11	18	15	VGATE	MOSFET gate driver output.
12	19	16	VREG12V	12V output. Decouple with minimum 0.22μF capacitor.
13	20	17	VDDDRV	Supply for MOSFET gate driver.
14	1	18	VDD	Input voltage for internal regulator.
15	2	19	VCELL	Battery voltage measurement. Decouple with 0.1μF capacitor.
16	3	20	VREG5V	5V regulator output. Decouple with minimum 0.22μF capacitor.
	12	10	NC	NC
	14	11	LED1	Battery capacity indicator LED driver 1
	15	12	LED2	Battery capacity indicator LED driver 2
	16	13	LED3	Battery capacity indicator LED driver 3

Absolute Maximum Ratings

		VALUE		UNITS
		MIN	MAX	
PIN voltage range respect to GND	VDDDRV, VDD, VCELL, LED1, LED2, LED3	-0.3	50	V
	VREG12V, VGATE	-0.3	14	V
	GNDDRV	-0.3	0.3	V
	Others	-0.3	6.3	V
Operation Temperature	T_A	-40	105	°C
Junction Temperature	T_J	-40	150	°C
Storage Temperature	T_{STG}	-55	150	°C
ESD	NTC1, NTC2, VCTRL, ID. HBM model.	4		kV
	Others	2		kV

Caution:

Stresses beyond "Absolute Maximum Ratings" condition may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Recommended DC Operating Conditions

5.5V ≤ VDD ≤ 42V, T_A = -40°C to 105°C, typical values are at 25°C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
VDD Input Voltage Range	V_{DD}		5.5		42	V
VDDDRV Input Voltage Range	V_{DDDRV}		5.5		42	V
VCELL Input Voltage Range	V_{CELL}				22	V
POR Voltage	V_{POR}			5.5		V

Electrical Characteristics

5.5V ≤ VDD ≤ 42V, T_A = -40°C to 105°C, typical values are at 25°C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Currents						
Normal Operation Current	I_{CCA}	V_{DD} = 18V, switch active		60		µA
Standby Current	I_{SDB}	V_{DD} = 18V, switch release		25		µA
Hibernate Current	I_{HIB}	V_{DD} = 4.5V		1		µA
PWM Output						
PWM Frequency	f_{PWM}			4000		Hz
PWM Frequency Error		T_A = -20°C to 85°C	-5%		5%	
Voltage and Current Protection Function						
Over Current Threshold	V_{OCx}	V_{DD} = 18V	10		155	mV
Over Current Accuracy	ΔV_{OCx}	V_{OC} = 10mV	-0.3		0.3	mV

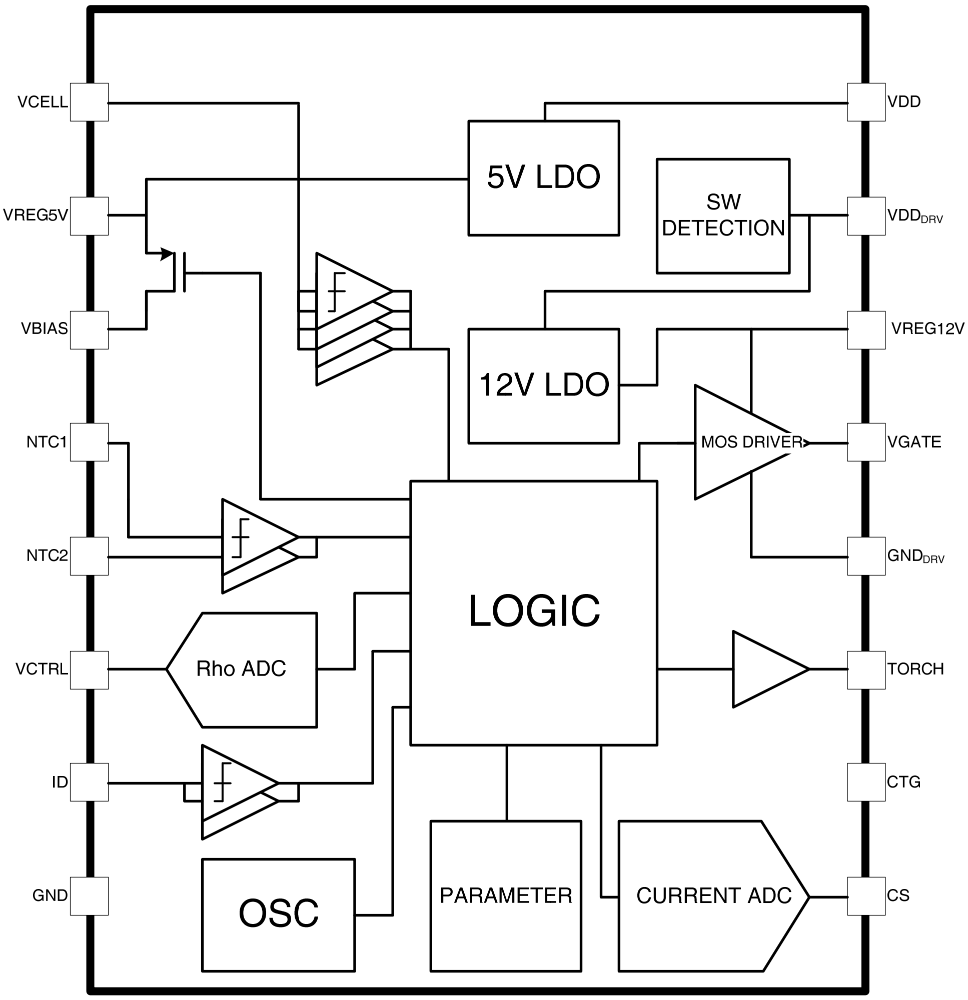
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
		V_{OC} = 155mV	-1.5		1.5	mV
Over Discharge Threshold	V_{DU}	For single cell	1.9		3.16	V
Over Discharge Accuracy	Δ V_{DU}	For single cell	-25		25	mV
Stall Protection						
Short Circuit Protection Threshold	V_{SC}	V_{DD} = 18V	40		240	mV
Threshold Accuracy	Δ V_{SC}		-5		5	mV
5V Voltage Regulator						
Regulator Output Voltage	V_{5V}	V_{DD} = 18V	4.75	5	5.25	V
Regulator Current Limit	I_{LIM}		2		4	mA
12V Voltage Regulator						
Regulator Output Voltage	V_{12V}	V_{DD} = 18V	10.8	12	13.2	V
		V_{DD} <= 12V		V_{DD}-0.1		V
Regulator Current Limit	I_{LIM}		1.5	3	4.5	mA
MOSFET Gate Driver						
Low Level Output Voltage	V_{GL}	I_G = 20mA		0.1		V
High Level Output Voltage	V_{GH}	I_G = -20mA		VREG12 -0.1		V
Peak Pull-up Current	I_{PU}	V_{GATE} = 0V		2		A
Peak Pull-down Current	I_{PD}	V_{GATE} = 12V		2		A
Minimum Duty Cycle						
Minimum Start Duty Cycle	D_{DC}	V_{DD} = 18V	3.13		25	%
Temperature Protection						
OT Protection on NTC1	T_{1OT}	R_{NTC} = 10kΩ, R = 23kΩ		65		°C
UT Protection on NTC1	T_{1UT}	R_{NTC} = 10kΩ, R = 23kΩ		3		°C
OT Protection on NTC2	T_2	R_{NTC} = 10kΩ, R = 23kΩ		65		°C
Internal OT Protection Threshold	T_{IOT}			125		°C
VBIAS Output						
VBIAS Output Voltage	V_{BIAS}			V_{5V}		V
VBIAS Output Frequency	V_{BIAS}	Switch is release, V_{DD}> V_{POR}	0.4	0.5	0.6	Hz
Torch Output						
Output Voltage	V_{TOR}	V_{DD} = 18V		5		V
Output Continues Time	t_{TOR}	V_{DD} = 18V, after switch release		32		s
Alarm Indicate						
Output Frequency	F_{ALM}	V_{DD} = 18V, Set to flashing		2		Hz
SOC LED						
Output Voltage Low	V_{SOCL}	V_{DD} = 18V		0		V

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage High	V_{SOCH}	V_{DD} = 18V		HiZ		V
Output Current Limit	I_{SOC}	Open Drain			2	mA
SOC Voltage Threshold	V_{SOCT}		3		4.26	V
Protection Delay Time						
Under Voltage Protection	t_{OD}	Sweep V_{DD} from 18V to 7.5V	90% *t_{OD}	t_{OD}	110% *t_{OD}	ms
Over Current Protection[1]	t_{OCx}	V_{DD} = 18V, sweep CS from 0 to above V_{OCx}	90% *t_{OCx}	t_{OCx}	110% *t_{OCx}	ms
Over Temperature 1 Protection	t_{OT1}	V_{DD} = 18V	90% *t_{OT1}	t_{OT1}	110% *t_{OT1}	ms
Over Temperature 2 Protection	t_{OT2}	V_{DD} = 18V	450	500	550	ms
Under Temperature Protection	t_{UT}	V_{DD} = 18V	90% *t_{OT1}	t_{OT1}[2]	110% *t_{OT1}	ms
Torch After Switch Release	t_{TORCH}	V_{DD} = 18V		32		s
SOC Indicate Maintain Time	t_{SOC}	V_{DD} = 18V		2		s

(1) All the over current and short circuit protection delay time have the same accuracy.

(2) Under temperature protection and over temperature 1 protection share a common delay time t_{OT1}.

Functional Block Diagram



Detailed Description

Overview

CW5053 is a total solution IC embedded motor controller with MOSFET pre-driver and battery discharge protection. Different from the traditional software solution schemes, smart and useful functions make CW5053 a very cost-effective total solution for portable power tools application.

5V Regulator

CW5053 has a built-in 5V regulator which can output as maximum as 4mA current. At least a 0.22µF capacitor is recommended to connect to the output pin. Regulator provides the power to the VBIAS pin and other internal modules.

12V Regulator

CW5053 also integrates a 12V regulator. This regulator provides a 12V voltage for MOSFET drive use. It means that the high-level voltage output of MOSFET pre-driver is equal to the regulator's output. Clamped output voltage can improve the safety and reliability of the MOSFET. At least a 0.22µF capacitor is recommended to connect to the output pin.

PWM Output

PWM signal is used to drive the switch MOSFET of the tools to control the motor speed. PWM frequency is determined by the different product part number, and the duty cycle is determined by the input voltage of the VCTRL pin.

Voltage input range of VCTRL is 0~1.25V, and the corresponding PWM duty cycle is 0%~100%. Regardless of the minimum start-up duty cycle, duty cycle versus VCTRL voltage is close to linearity. Below figure shows the relationship.

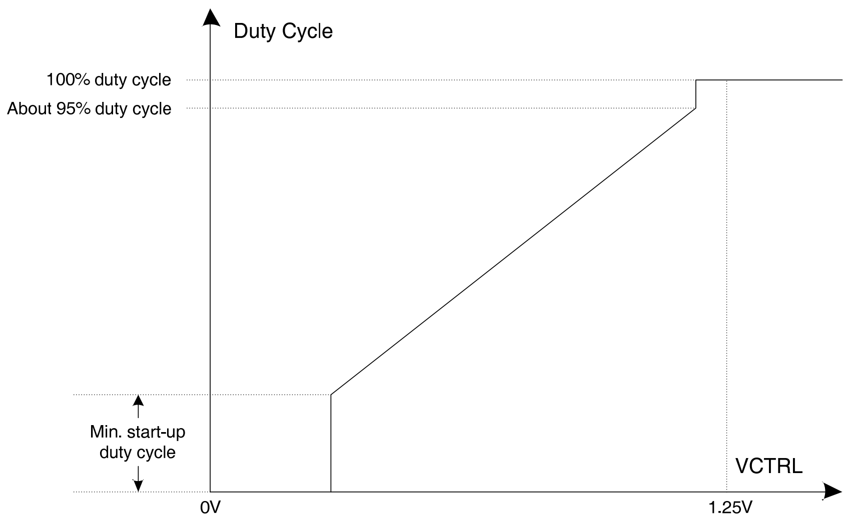


Figure 1. Duty Cycle vs. VCTRL

And you can find in the picture, once the duty cycle achieves about 95%, it will directly jump to 100%, and this means the motor is connected to battery pack directly.

Input voltage of VCTRL is generated by a resistor net, and the net is powered by the VBIAS pin. Detailed resistor value and ratio should be optimized according to the different switches in different application.

Minimum PWM Duty Cycle

Duty cycle is not start from the absolute zero but the minimum duty cycle.
Minimum PWM duty cycle is determined by the product part number.

Soft-start

The PWM output has a soft-start function to prevent high inrush current during start-up.
The duty cycle ramp up step size is fixed to 1/256 (about 0.4%) in the soft-start status, and the ramp up delay time between each step has several options. Different delay time means different soft-start speed.
Relationship between step size and delay time is illustrated as below:

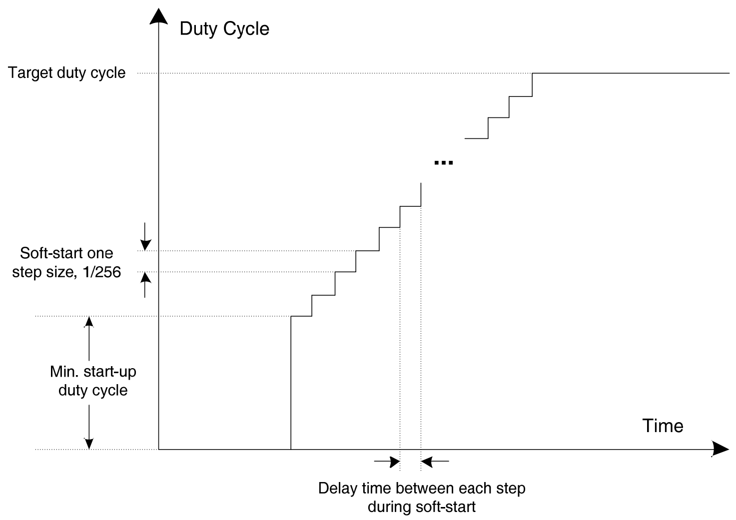


Figure 2. Soft-start Function

Under Voltage Protection

If the battery pack voltage becomes lower than over discharge threshold (V_{DU}) and stays longer than over discharge protection delay time (T_{DU}), CW5053 will cut off the PWM output and enter the under voltage protection state.
The under voltage protection state will release when all the cell voltages become higher than V_{DU} and the switch is released for 2s.

Over Current Protection

CW5053 embedded 4-level over current protection, over current 1, over current 2, over current 3 and stall protection. The protection mechanism and sequence are all the same. Here we take over current 1 for example.
Discharging current is vary with the external load, when the voltage dropped on the current sense resistor is bigger than the excess current protection threshold (V_{OC1}) and stays longer than the delay time (t_{OC1}), CW5053 will cut off the PWM output and enter the over current protection state.
The over current protection state will release when the switch is released for 2s.
Voltage drop on current sense resistor cannot accurately reflect the current in the motor, because of the PWM duty cycle, current sense only samples the current when the PWM outputs a high-level voltage. See as below.
The valid line is the motor current, and the dash line is the current on the sense resistor.

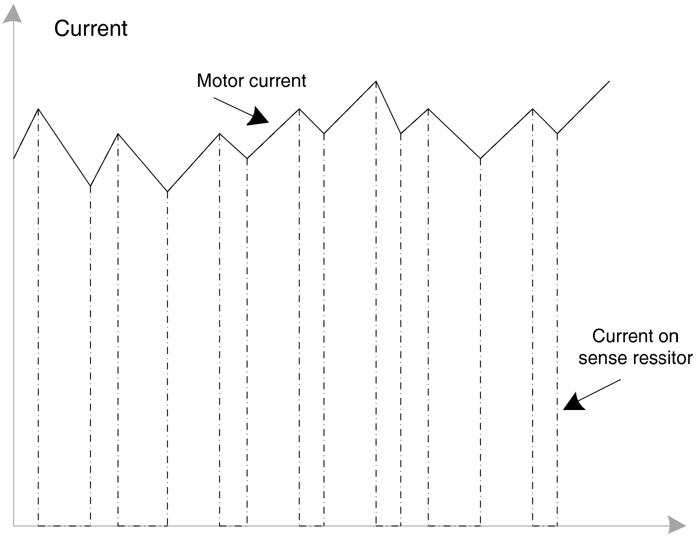


Figure 3. Current in Motor and Current on Sense Resistor

In the period that the PWM outputs a low-level voltage, the current on the sense resistor is zero, but actually, there is still a current flowing in the motor and generating heat, so in theory, this portion of the current should be added in to the calculation when system implements the current protection judgment. But it is difficult to achieve if the current is a discrete value illustrated as the dash line in figure 3. Discontinues current and the zero value interfere in the current sample and the delay time accumulation.

"True motor current technology" also samples the current flow through the sense resistor, but CW5053 will calculate a new average current in the motor by compensating the error caused by the duty cycle. The difference between them is showed as below. CW5053 takes the average motor current to implement the current protection function.

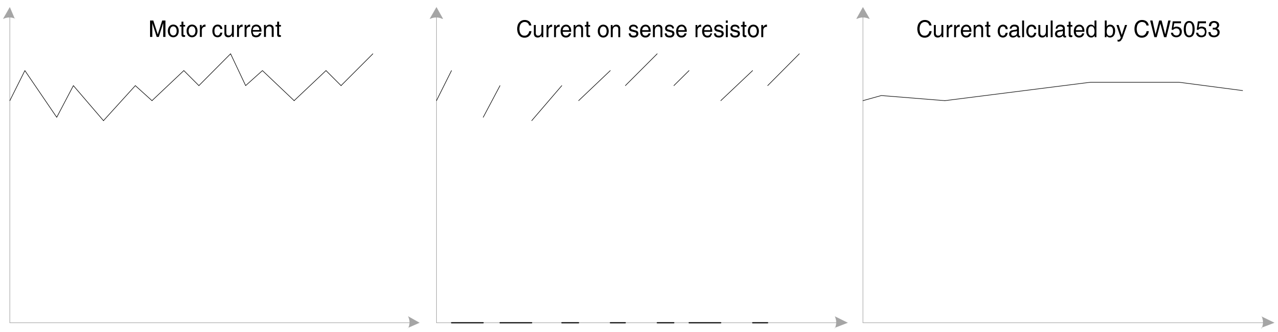


Figure 4. True Motor Current Technology and the Difference

Temperature Protection

CW5053 provides two temperature protection input ports: NTC1 and NTC2, each port needs a NTC resistor.

NTC1 owns over temperature protection function, while NTC2 owns over temperature and under temperature protection functions. We can freely configure the NTC ports to protect any device we want to protect from over or under temperature. For example, we can use NTC1 for motor or MOSFET protection and NTC2 for battery protection.

Once the temperature protection triggers, CW5053 will cut off the PWM output and enter the over current protection state.

The over current protection state releases when the switch is released for 2s.

ID Resistor Match

Resistor in the battery pack should be equal to the resister in the tools body.
This action is used to identify the battery pack is the original one or not.

Torch Output

CW5053 integrates LED driver for torch usage. This function provides an assistant lighting for tools. TORCH output is just a drive signal that used to drive an external MOSFET to control the torch LED. To set the appropriate LED current, a current limitation resistor should be added in the route.
Drive signal will output once the switch triggers, and will provide a 32s continuous output after the switch released.

Battery Capacity Indicator

CW5053 uses 3 LEDs to indicate the battery remaining capacity, and the display maintains t_{SOC} time after triggered. In order to eliminate the influence of the voltage noise and give the users a quick report, CW5053 samples the battery voltage and calculates the SOC in the standby mode. All data is saved in the internal register and will be refreshed in a constant frequency. CW5053 lightens the LED to report the battery capacity when there is a trigger signal, this action is capable of reduce the report delay time and improve the accuracy of the remaining capacity estimation.

Alarm Indicator

Alarm function multiplexes the torch output pin to indicate the abnormal conditions.
When an unexpected status triggers the protection, for example, over temperature, CW5053 will cut off the PWM output and set the torch to flash mode to inform the users.

State Machine

Operation state machine of CW5053.

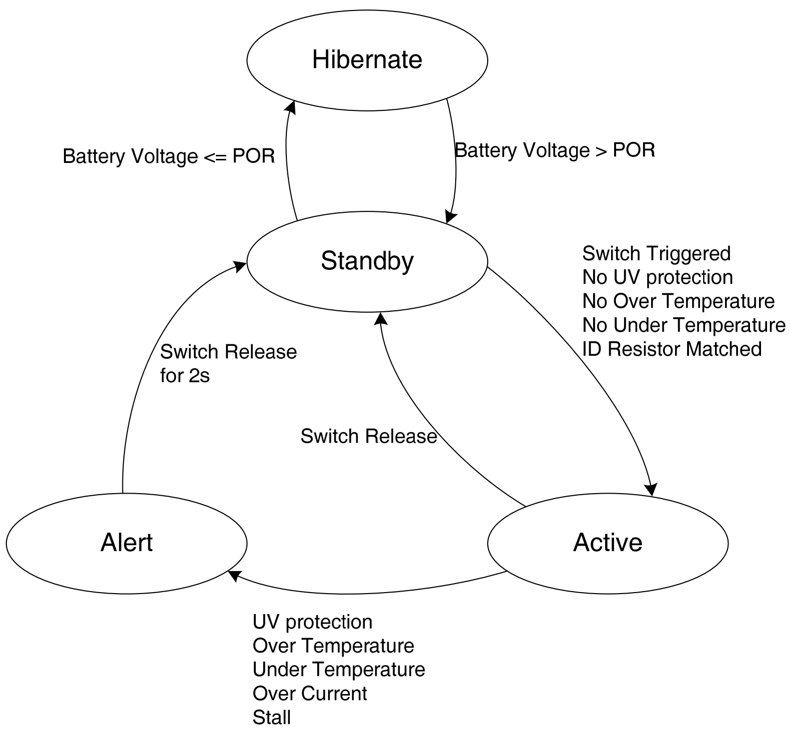


Figure 5. State Machine

The CW5053 has 4 different states: Hibernate, Standby, Active and Alert. In Hibernate state, all the operation of CW5053 is held to minimize the power dissipation. In standby mode, CW5053 is periodically measures the data and implement the corresponding actions. In active mode, CW5053 is fully powered and can execute any allowable task. In alert mode, CW5053 shuts down the motor, and then outputs an alert signal.

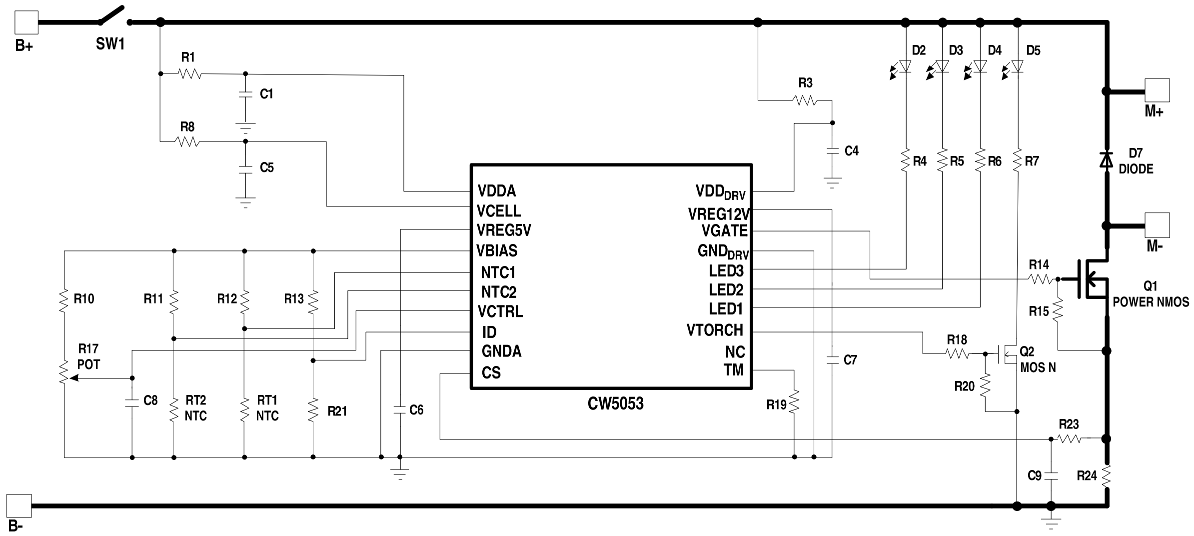
CW5053 enters the active state if there is no abnormal condition protection.

While in the active state, any protection such as over temperature or UV protection, will force the CW5053 enter the alert state.

Alert state will release when the switch releases and maintains more than 2s.

Hibernate state is automatically entered while the battery voltage is lower than the POR threshold.

Reference Schematic



Recommended Parameters

SYMBOL	TYPICAL VALUE	UNIT
R1/R3	200	Ω
R4/R5/R6	18	kΩ
R7	3.3	kΩ
R8	1	kΩ
R10(1)	150	kΩ
R11(2)	8.87	kΩ
R12(2)	20.0	kΩ
R13/R21(3)	200	kΩ
R14/R18	100	Ω
R15/R20	1	MΩ
R17	50	kΩ
R19	100	Ω
R23	1	kΩ
R24	1	mΩ
C1	0.47	µF
C4	0.47	µF
C5	0.22	µF
C6	1	µF
C7	1	µF
C8	4.7	nF
C9	0.1	µF
D2/D3/D4/D5	LED lights	
D7	Diode M7	

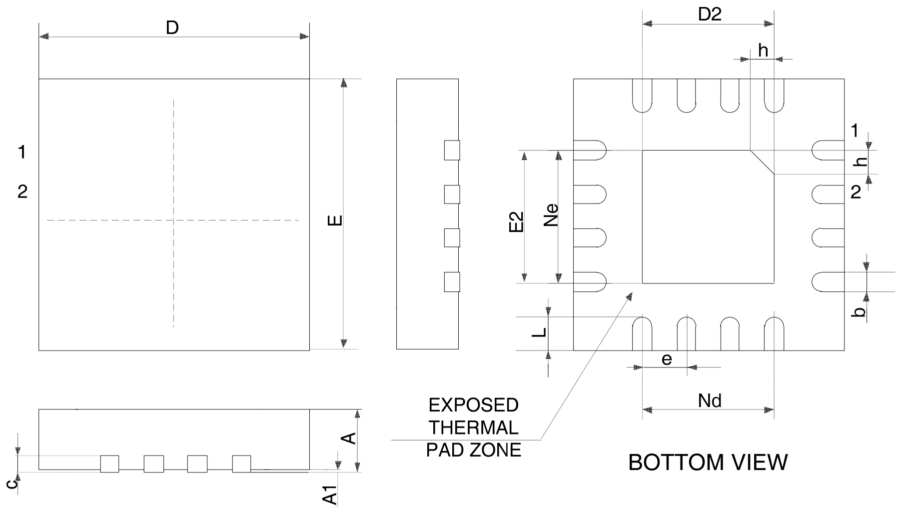
(1) Value of R10 is determined by the rheostat in the switch

(2) Value of R11/R12 is determined by the character of NTC and the setting protection temperature

(3) R13 and R21 are ID identification resistors, the ration of R13:R21 should be 1:1

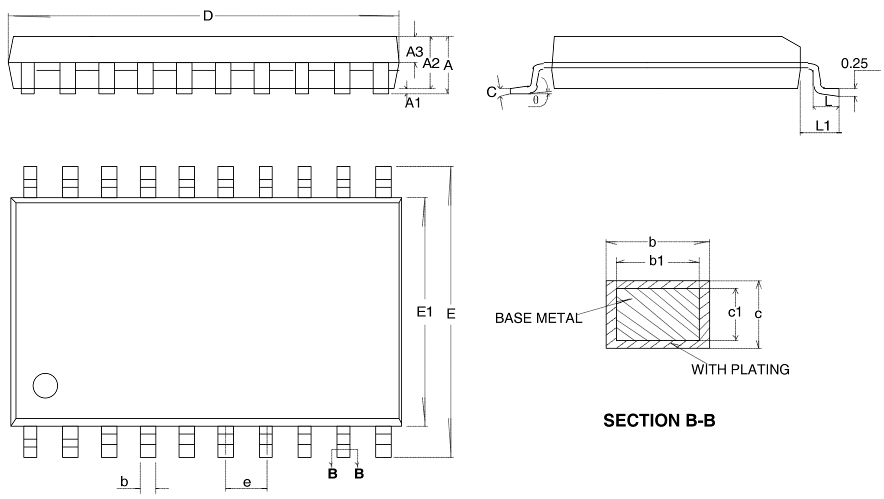
Package Information

QFN16 Package



SYMBOL	MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	---	0.06
b	0.18	0.30
c	0.18	0.25
D	2.90	3.10
D2	1.40	1.60
e	0.50BSC	
Ne	1.50BSC	
Nd	1.50BSC	
E	2.90	3.10
E2	1.40	1.60
L	0.35	0.45
h	0.25	0.35

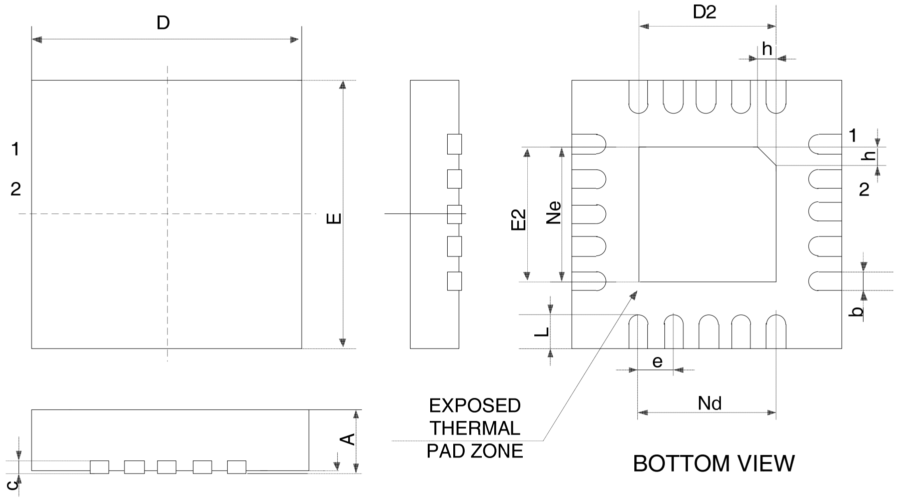
SSOP20 Package



SYMBOL	MILLIMETER	
	MIN	MAX
A	---	1.85
A1	0.05	0.25
A2	1.40	1.60
A3	0.62	0.72
b	0.29	0.37
b1	0.28	0.33
c	0.15	0.20
c1	0.14	0.16
D	7.00	7.40
E	7.60	8.00
E1	5.10	5.50
e	0.65BSC	
L	0.75	1.05
L1	1.25BSC	
θ	0°	8°

Package Information

QFN20 Package



SYMBOL	MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	----	0.05
b	0.18	0.30
c	0.18	0.25
D	3.90	4.10
D2	1.90	2.10
e	0.50BSC	
Ne	2.00BSC	
Nd	2.00BSC	
E	3.90	4.10
E2	1.90	2.10
L	0.35	0.45
h	0.25	0.35

Revision History

Release No.	Date	Revision Description
1.0	2015-08-20	Initial Release
1.1	2016-6-29	1. Add QFN20 Package 2. Add Temperature protection delay 3. Add other protections delay accuracy data

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