High Input Voltage Single Cell Charger

1 FEATURES

- **Charge Voltage: 4.20V/4.30V/4.35V**
- **Automatic Recharge Voltage: 4.05V/4.15V/4.20V**
- **No external Blocking Diode Required**
- **Temperature Sense Function**
- **Maximum Voltage Power Input: 19.2V**
- **Input Over-Voltage Protection: 6.5V**
- **Programmable Charge Current: 4mA~400mA**
- **Programmable Full-of-Charge Current**
- **Status Indication: Charging and Fault Conditions**
- **Fixed Safety Timer**
- **OUT Short-Circuit Protection and IREF short detection**
- **Available in the DFN2X2-8 Package**

2 APPLICATIONS

- **IOT Gadgets**
- **Wearable Devices**
- **Credential Keys**
- **Wireless Remote**

3 DESCRIPTIONS

The RS4040 is a fully integrated high input voltage single-cell Li-Ion battery charger. The charger uses a CC/CV charge profile required by Li-Ion battery. The charger accepts an input voltage up to 19.2V but is disabled when the input voltage exceeds the OVP threshold, typically 6.5V, to prevent excessive power dissipation. The 19.2V rating eliminates the overvoltage protection circuit required in a low input voltage charger.

The charge current and the full-of-charge (FOC) current are programmable with external resistors. When the battery voltage is lower than pre-charge to constant current charge transition threshold, the charger preconditions the battery with typically 20% of the programmed charge current. When the charge current reduces to the programmable FOC current level during the CV charge phase, an FOC indication is provided by the $\overline{\text{CHG}}$ pin, which is an open-drain output.

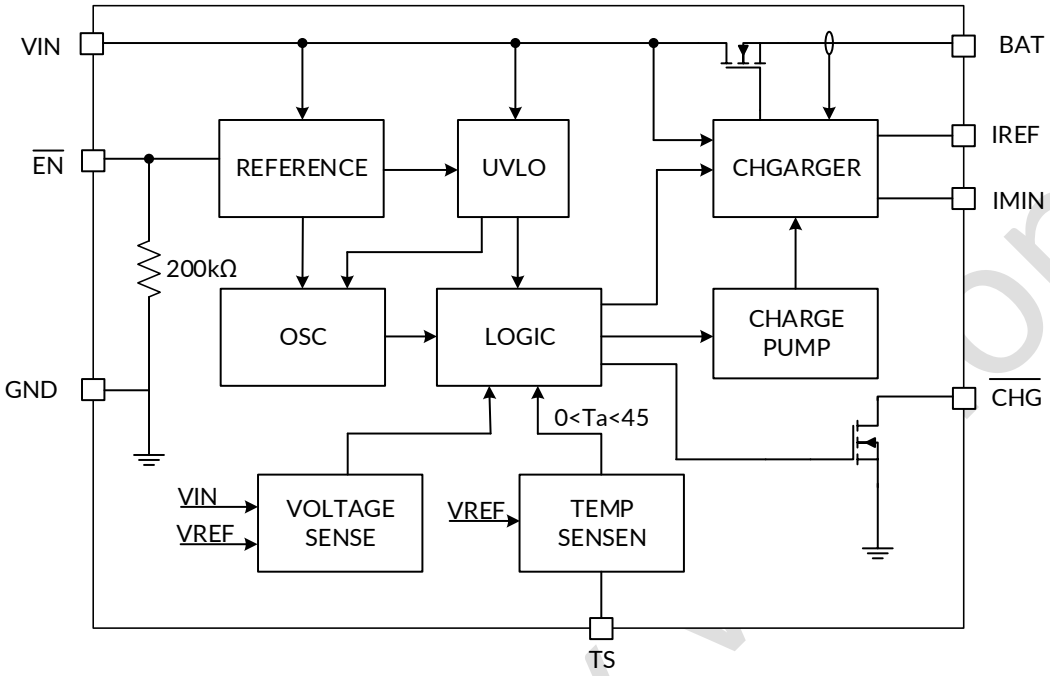
$\overline{\text{CHG}}$ indication pins allow simple interface to a microprocessor or LEDs.

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS4040	DFN2X2-8	2.00mm×2.00mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

4 FUNCTION BLOCK DIAGRAM



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5 Revision History

Note: Page numbers for previous revisions may different from page numbers in the current version.

VERSION	Change Date	Change Item
A.0	2024/03/18	Preliminary version completed

6 PACKAGE/ORDERING INFORMATION (1)

PRODUCT	ORDERING NUMBER	V_{CH} (V)	TEMPERATURE RANGE	PACKAGE LEAD	PACKAGE MARKING (2)	MSL(3)	PACKAGE OPTION
RS4040	RS4040YTDE8	4.20	-40°C ~+85°C	DFN2X2-8	4040	MSL3	Tape and Reel,3000
	RS4040AYTDE8	4.30	-40°C ~+85°C	DFN2X2-8	4040A	MSL3	Tape and Reel,3000
	RS4040BYTDE8	4.35	-40°C ~+85°C	DFN2X2-8	4040B	MSL3	Tape and Reel,3000

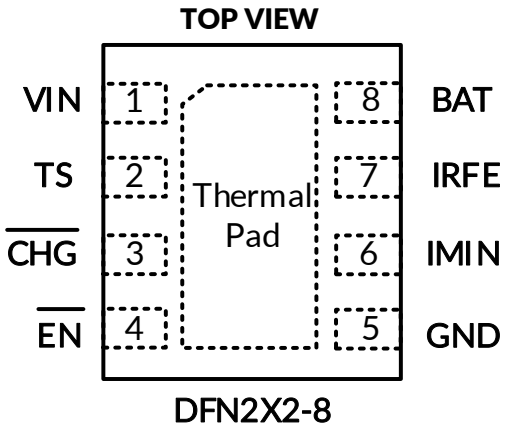
NOTE:

(1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.

(2) There may be additional marking, which relates to the lot trace code information (data code and vendor code), the logo or the environmental category on the device.

(3) MSL, The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications.

7 PIN CONFIGURATIONS



PIN DESCRIPTION

PIN	NAME	FUNCTION
1	VIN	Power Input. The absolute maximum input voltage is 19.2V. A 1μF or larger value X5R ceramic capacitor is recommended to be placed very close to the input pin for decoupling purpose. Additional capacitance may be required to provide a stable input voltage.
2	TS	Temperature sense terminal connected to 10k at 25°C NTC thermistor, in the battery pack. If NTC sensing is not needed, connect this terminal to VSS through an external 10kΩ resistor. Floating TS terminal or pulling terminal Low/High disables the IC.
3	$\overline{CHG}$	Open-Drain Charge Indication. The FET on resistor is about 350Ω. Low (FET on) indicates charging and Open Drain (FET off) indicates no Charging or Charge complete.
4	$\overline{EN}$	Enable Input. This is a logic input pin to disable or enable the charger. Drive to high to disable the charger. When this pin is driven to low or left floating, the charger is enabled. This pin has an internal 200kΩ pull-down resistor.
5	GND	System Ground.
6	IMIN	Full-of-Charge (FOC) Current Programming Pin. Connect a resistor between this pin and the GND pin to set the FOC current. The FOC current IMIN can be programmed by the following equation: $I_{MIN}=\frac{3280}{R_{IMIN}}$ (mA) where R_{IMIN} is in kΩ. $R_{IMIN} > R_{IREF}$
7	IREF	Charge-Current Programming and Monitoring Pin. Connect a resistor between this pin and the GND pin to set the charge current limit determined by the following equation: $I_{REF}=\frac{3280}{R_{IREF}}$ (mA) where R_{IREF} is in kΩ. The resistor should be located very close to this pin. The IREF pin voltage also monitors the actual charge current during the entire charge cycle, including the trickle, constant-current, and constant-voltage phases. When disabled, V_{IREF} = 0V.
8	BAT	Charger Output Pin. Connect this pin to the battery. A 1μF or larger X5R ceramic capacitor is recommended for decoupling and stability purposes. When the EN pin is pulled to logic high, the BAT output is disabled.
-	Thermal Pad	Thermal pad (exposed center pad) to alleviate thermal stress. Tie to GND.

8 SPECIFICATIONS

8.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
VIN, $\overline{CHG}$ to GND		-0.3	19.2	V
TS, $\overline{EN}$, IMIN IREF BAT to GND		-0.3	6	V
Package thermal impedance, θ_{JA} (2)	DFN2X2-8		118	°C/W
Junction Temperature, T_J (3)			150	°C
Storage Temperature Range, T_{stg}		-65	150	

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) The package thermal impedance is calculated in accordance with JESD-51.

(3) The maximum power dissipation is a function of $T_{J(MAX)}$, $R_{\Theta ja}$, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A) / R_{\Theta ja}$. All numbers apply for packages soldered directly onto a PCB.

8.2 ESD Ratings

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human body model (HBM), MIL-STD-883K METHOD 3015.9	±2000	V
	Charged-device model (CDM), ANSI/ESDA/JEDEC JS-002-2018	±2000	
	Machine Model (MM), JESD22-A115C(2010)	±100	

ESD SENSITIVITY CAUTION

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	MAX	UNIT
$\overline{CHG}$	0	VIN	V
Maximum Supply Voltage		16	V
Programed Charge Current	4	400	mA
Operating Temperature Range	-40	85	°C

8.4 Electrical Characteristics

VIN=5V, T_J=25°C, over recommended operating condition unless otherwise noted.

PARAMETER		TEST CONDITION	MIN(1)	TYP(2)	MAX(1)	UNIT
INPUT VOLTAGE						
VIN	VIN input voltage range		3.5		16	V
V_{UVLO_RISE}	Undervoltage lock-out Exit	VIN: 0V→4V		3.3		V
V_{HSY_UVLO}	Hysteresis on V_{UVLO_RISE} falling			250		mV
V_{OVP_VIN}	VIN over-voltage protection threshold	VIN: 5V→12V		6.5		V
V_{HYS_OVP}	Hysteresis on V_{OVP_VIN} falling	VIN: 12V→5V		200		mV
V_{INOK}	Minimum charging voltage difference between VIN and BAT	VIN: 3.6V→4.5V@ VBAT=3.6V		380		mV
V_{HYS_INOK}	Hysteresis on V_{DIF_CHG} falling	VIN: 4.5V→3.6V@ VBAT=3.6V		70		mV
STANDBY CURRENT						
I_{VIN}	VIN input current	Charge full		70		μA
		Charging exclude BAT output current		1		mA
I_{SHD}	Disable IC	$\overline{EN}$=5V, disable IC		7		μA
I_{BAT}	BAT Pin sink current	VIN floating		0.5		μA
		Charger disabled		0.1		μA
CHARGE CURRENT						
I_{CHG_CC}	Constant Charge Current	R_{IREF}=8.2kΩ, VBAT=3.6V		400		mA
I_{CHG_TRK}	Trickle Charge Current	R_{IREF}=8.2kΩ, VBAT=2.4V		80		mA
I_{MIN}	Full-of-Charge Current Threshold	R_{IMIN}=820kΩ		4		mA
IREF SHORT CIRCUIT PROTECTION						
R_{IREF_SHORT}	Highest resistor value considered a fault (short)	IREF short to GND $\overline{CHG}$ oscillate		4.1		kΩ
I_{BAT_CLAMP}	Maximum OUT current limit Regulation (clamp)	VIN =5V, VBAT=3.6V, R_{IREF}=1kΩ		735		mA
PRECHARGE VOLTAGE THRESHOLD						
$V_{PRECHG\_4.2}$	Pre-charge to constant current charge transition threshold	VBAT=3.6V, R_{IREF}=82kΩ		2.55		V
$V_{PRECHG\_4.3}$				2.6		
$V_{PRECHG\_4.35}$				2.635		
V_{HYS_PRECHG}	Pre-charge Voltage Hysteresis	VBAT=2.7V→VBAT=2.4V		100		mV
CHARGE-of-FULL VOLTAGE						
$V_{CHF\_4.2V}$	Output regulation voltage	R_{IREF}=82kΩ, VIN=5V, Charge current=4mA		4.2		V
$V_{CHF\_4.3V}$				4.3		V
$V_{CHF\_4.35V}$				4.35		V
$V_{RECH\_4.2V}$	Re-charge voltage after charge-of-full	VIN=5V, VTS=1V, V_{OUT}: 4.25→VRECH_4.x $\overline{CHG}$ terminal change low		4.05		V
$V_{RECH\_4.3V}$				4.15		V
$V_{RECH\_4.35V}$				4.2		V
BATTERY CHARGE SAFETY TIMER VALUE						
T_{MAXCH}	Charge safety timer value	Terminate charging		8000		s
BATTERY-PACK NTC MONITOR; TS terminal: 10k NTC						
I_{NTC_10k}	NTC bias current	VTS = 1V		100		μA
V_{TS_LT}	Low temperature Disable	VTS: 2V→ 3V		2.7		V
$V_{TS\_HYS\_LT}$	Hysteresis at low temperature	VTS: 3V→2V		220		mV

V_{TS_HT}	High temperature Disable	VTS: 0.4V→0.2V		0.5		V
$V_{TS\_HYS\_HT}$	Hysteresis at high temperature	VTS: 0.2V→0.4V		40		mV
V_{TS_DIS}	The TS threshold voltage of disable charge	Terminate charging			0.15	V
THERMAL REGULATION						
TTSD	Thermal shutdown temperature	VIN=5V		135		°C
THYS	Thermal shutdown hysteresis			15		°C
EN logic						
V_{IH}	EN Pin Logic Input High	VIN=5V		2.7		V
		VIN=16V		3.65		V
V_{IL}	EN Pin Logic Input Low	VIN=5V		1.65		V
		VIN=16V		2.25		V
R_{dson_CHG}	CHG Pin On-Resistance when LOW	VIN=5V		350		Ω
I_{lkg_CHG}	CHG Leakage Current when High Impedance	VIN=5V		0.1		μA
Timing Requirement						
$t_{DGL(OVP-SET)}$	Input over-voltage blanking time	VIN: 5V→12V		120		μs
$t_{DGL(OVP-REC)}$	Deglitch time exiting OVP	VIN: 12V→5V		110		μs
T_{DLY_CH}	Delay time after enable to charge	VIN=5V, $\overline{EN}$=5V→0		16		ms
T_{DGL_TS}	Deglitch time for TS threshold	TS: 0.4V→0.2V or 2.4V→2.6V		60		μs
		TS: 0.2V→0.4V or 2.6V→2.4V		32		ms
T_{EXIT_CHG}	Delay time of exit charge mode after Charge-of-Full	From Charge-of-Full to terminate charging		32		s

(1) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.

(2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.

8.5 TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

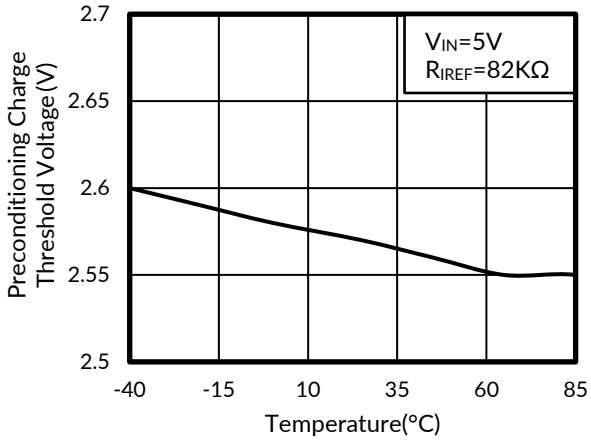


Figure 1. Preconditioning Charge Threshold Voltage vs Temperature

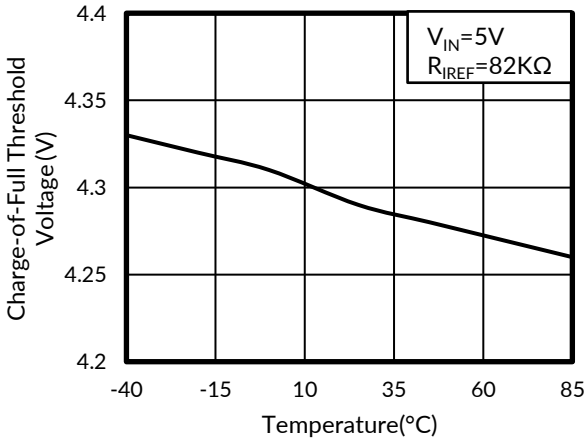


Figure 2. Charge-of-Full Threshold Voltage vs Temperature

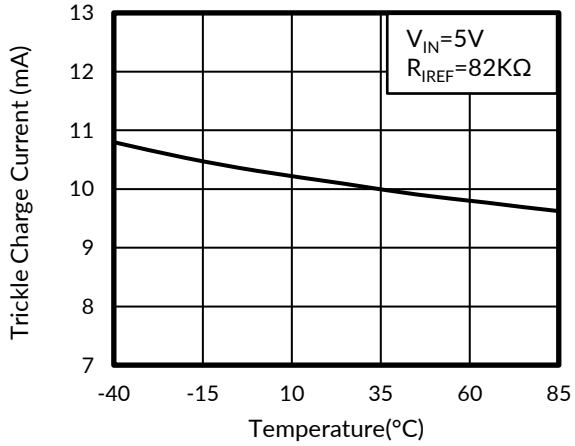


Figure 3. Trickle Charge Current vs Temperature

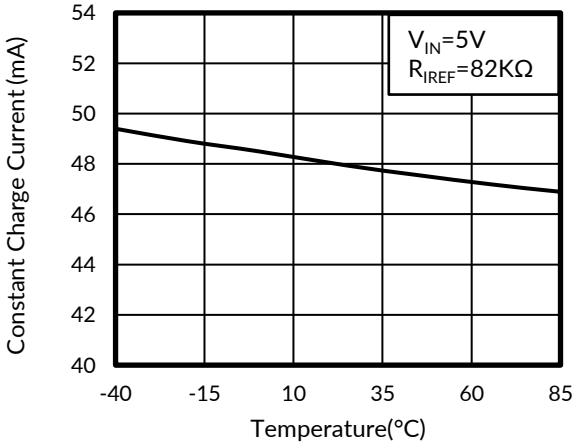


Figure 4. Constant Charge Current vs Temperature

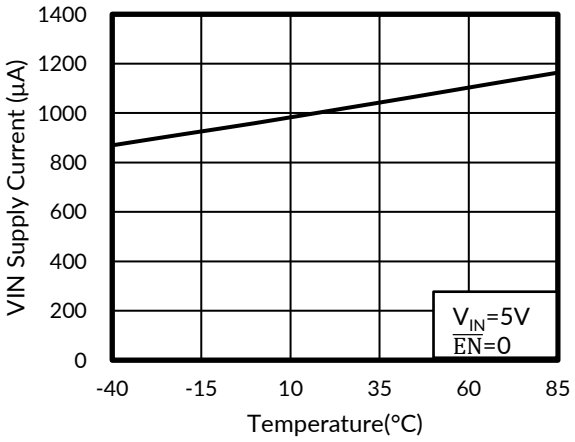


Figure 5. VIN Supply Current vs Temperature

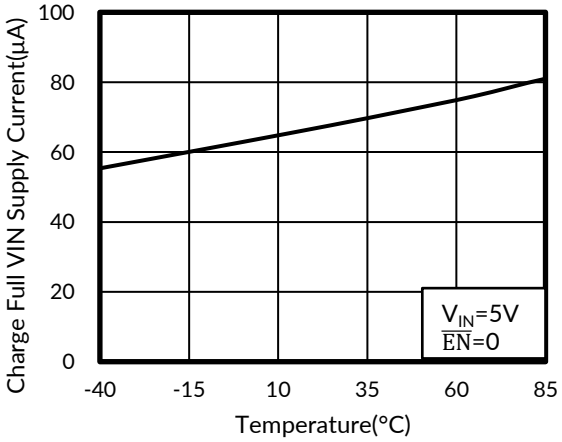


Figure 6. Charge Full VIN Supply Current vs Temperature

TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

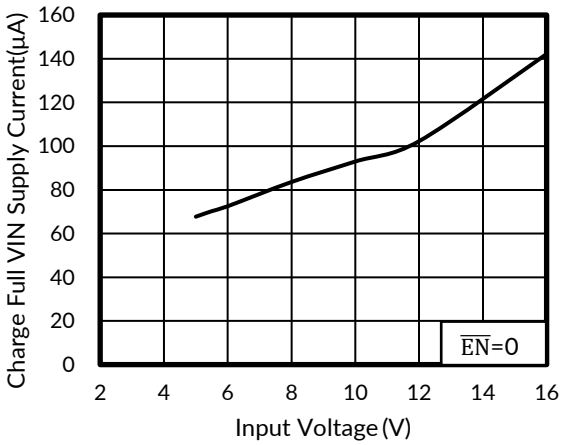


Figure 7. Charge Full VIN Supply Current vs Input Voltage

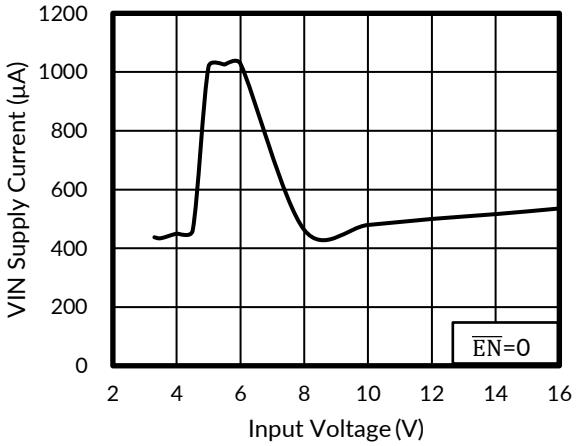


Figure 8. VIN Supply Current vs Input Voltage

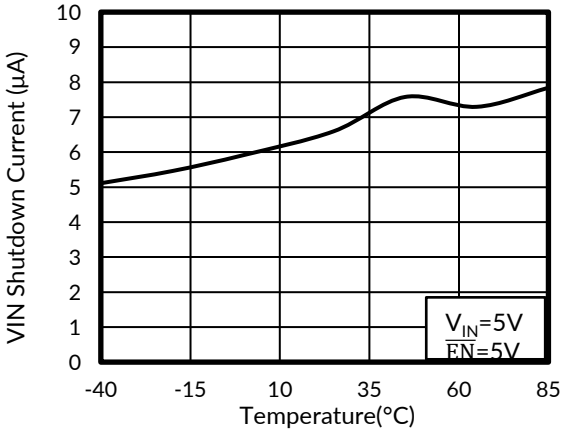


Figure 9. VIN Shutdown Current vs Temperature

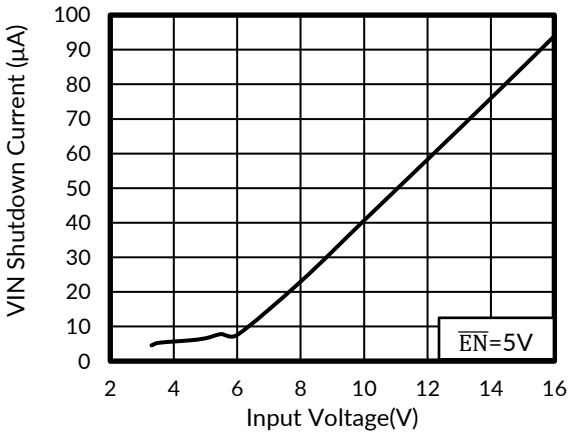


Figure 10. VIN Shutdown Current vs Input Voltage

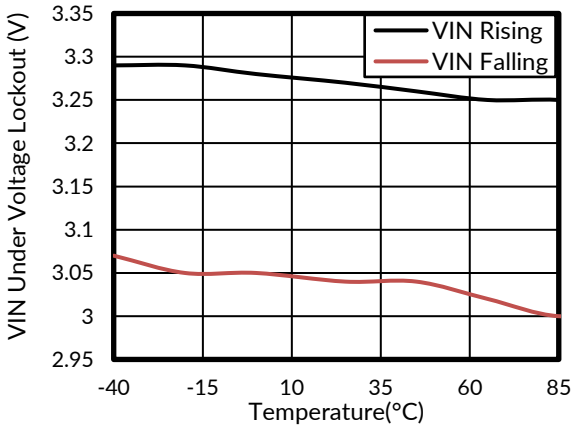


Figure 11. VIN Under Voltage Lockout vs Temperature

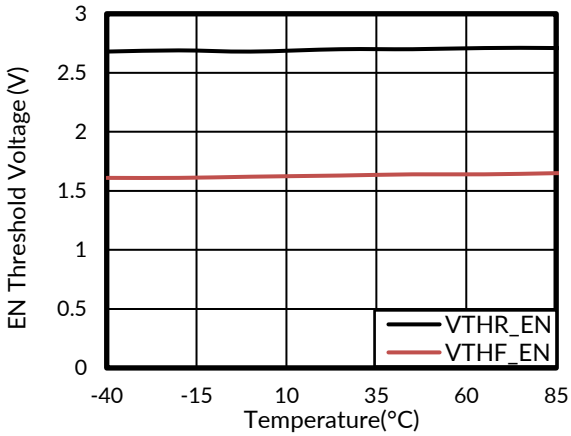


Figure 12. EN Threshold Voltage vs Temperature

TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

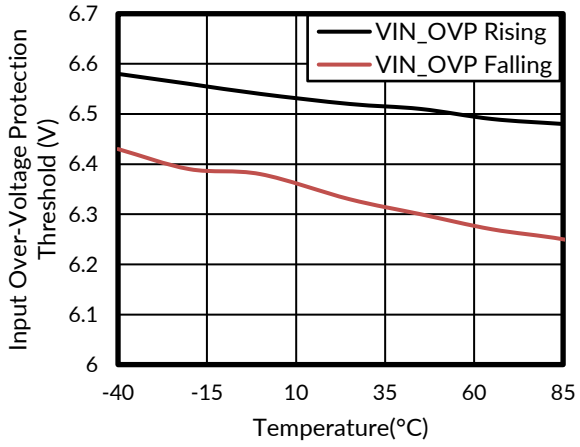


Figure 13. Input Over-Voltage Protection Threshold vs Temperature

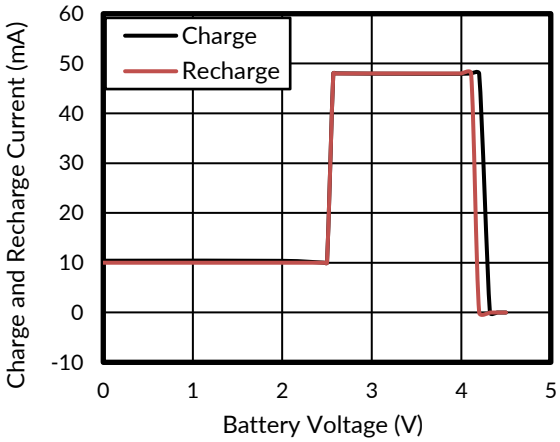


Figure 14. Charge and Recharge Current vs Battery Voltage

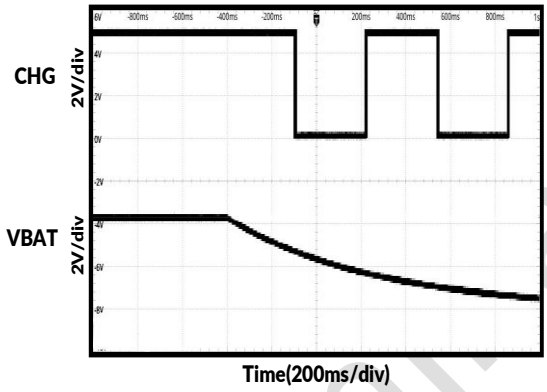


Figure 15. Enter Over Temperature

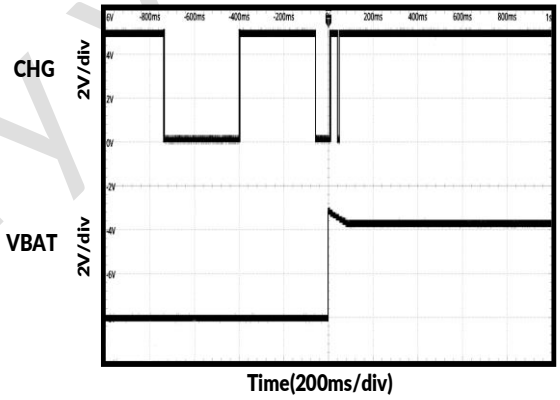


Figure 16. Exit Over Temperature

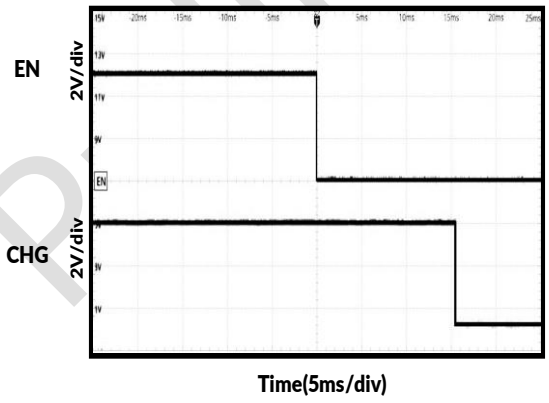


Figure 17. Delay time after enable to charge

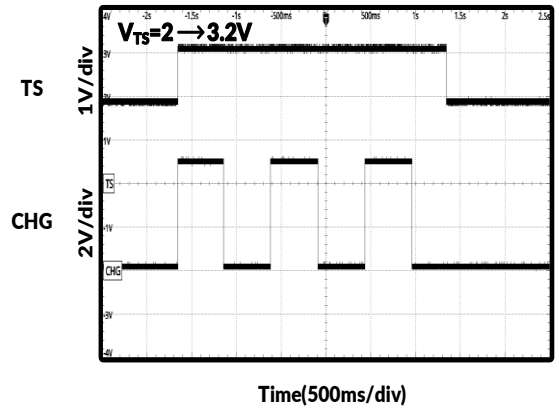


Figure 18. Deglitch time for TS threshold

9 Feature Description

9.1 Overview

The RS4040 is a fully integrated high input voltage single-cell Li-Ion battery charger. The charger uses a CC/CV charge profile required by Li-Ion battery. The charger accepts an input voltage up to 19.2V but is disabled when the input voltage exceeds the OVP threshold, typically 6.5V, to prevent excessive power dissipation. The 19.2V rating eliminates the overvoltage protection circuit required in a low input voltage charger.

The charge current and the full-of-charge (FOC) current are programmable with external resistors. When the battery voltage is lower than pre-charge to constant current charge transition threshold, the charger preconditions the battery with typically 20% of the programmed charge current. When the charge current reduces to the programmable FOC current level during the CV charge phase, an FOC indication is provided by the $\overline{CHG}$ pin, which is an open-drain output.

$\overline{CHG}$ indication pins allow simple interface to a microprocessor or LEDs.

9.2 Power On Sequency

After VIN power on and $\overline{EN}$ pull low , the reference module and input voltage detection module start working, confirming that the VIN is not over voltage and not under voltage, and then the oscillator starts working. Then, the battery voltage detection module and TS temperature detection module start working, detecting whether the battery is over discharged or fully charged, and whether the temperature is too high or too low. If RS4040 is not in abnormal state (1), the charge pump module starts working after power on. After a further delay, the charging module starts working, starts charging, and the CHG becomes low. After the battery is fully charged (2), the CHG becomes high. After a delay of 32s, the charging stops and the charge pump stops working. The charging mode is exited and the standby mode is entered. During standby mode, the battery voltage is detected every second. If the battery is detected to be greater than the recharge threshold voltage VPRECHG, it will continue to be in standby mode. Otherwise, it will start recharging and the CHG will continue to be low until the battery is fully charged again.

NOTE:

(1) Abnormal state refers to the following situations: VIN-BAT voltage difference is less than VINOK; The temperature detected by TS is above VTS_LT or below VTS_HT; IREF pin short circuited to GND; The internal temperature of the chip exceeds 135°C; VIN overvoltage. When in abnormal state, RS4040 stops charging, and CHG will vary in frequency from high to low at 1Hz.

(2) When the battery is fully charged, it indicates that VBAT is greater than 4.1V and the charging current is less than IMIN and remains for 16ms.

9.3 IREF: Programming Charge Current

An external resistor is used to Program the charge current ICHG_CC (4mA to 400mA) and can be used as a current monitor.

$$ICHG\_CC = \frac{3280}{R_{IREF}} \ (mA) \qquad (1)$$

Where:

- ICHG_CC is the desired fast charge current;
- R_{IREF} is the external resistor connected to IREF and GND, in kΩ.

When：

1. VBAT> VPRECHG, Constant charge current is ICHG_CC;
2. VBAT< VPRECHG, Constant charge current is Trickle charge current ICHG_TRK (ICHG_TRK = ICHG_CC/5);

The IREF resistor is short protected and will detect a resistance lower than about 4.1kΩ If a “short” is detected, then $\overline{CHG}$ port will oscillate at 1Hz. The charge current is internally clamped to a maximum current which is IBAT_CLAMP.

9.4 IMIN: Programming Full-of-Charge Current

Full-of-Charge (FOC) Current Programming Pin. Connect a resistor between this pin and the GND pin to set the FOC current. The FOC current IMIN can be programmed by the following equation:

$$I_{MIN} = \frac{3280}{R_{IMIN}} \text{ (mA)} \quad (2)$$

where R_{IMIN} is in kΩ. $R_{IMIN} > R_{IREF}$.

9.5 $\overline{CHG}$ Indication

The $\overline{CHG}$ is an open-drain output. The inside FET on resistor is about 350Ω. A pull-up resistor is used between VIN and $\overline{CHG}$ to indicate the charge status.

Charging: CHG is pulled down after charging starts
Fully charged or not charged: CHG becomes high resistance
Abnormal state: 1Hz high and low changes (VIN-BAT voltage difference is less than VINOK; The temperature detected by TS is above VTS_LT or below VTS_HT; IREF pin short circuited to GND; The internal temperature of the chip exceeds 135°C; VIN overvoltage)

9.6 TS

The TS function is designed to follow JEITA temperature standard for Li-Ion batteries. Normal operation occurs between 0°C and 45°C. If below 0°C or above 45°C the IC will stop charging.

The TS feature is implemented using an internal 100μA current source to bias the NTC thermistor (SEMITEC 103AT-2 or Mitsubishi TH05-3H103F) connected from the TS terminal to GND.

If this feature is not needed, a fixed 10kΩ can be placed between TS and GND to allow normal operation. This may be done if the host is monitoring the NTC thermistor and then the host would determine when to pull the TS terminal low or high to disable charge.

9.7 VINOK

The constant current can not be maintained when VIN-BAT voltage difference is less than VINOK.

9.8 Undervoltage Lockout (UVLO)

An internal undervoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until VIN rises above the undervoltage lockout threshold. The UVLO circuit has a built-in hysteresis of 250mV.

9.9 VIN Overvoltage Lockout (VIN OVP)

The RS4040 is disabled when the input voltage exceeds the OVP threshold, typically 6.5V, to prevent excessive power dissipation.

9.10 Automatic Recharge

If reset the VIN or the battery is detected to be less than the recharge threshold voltage VPRECHG, the RS4040 will start recharging and the CHG will continue to be low until the battery is fully charged again.

9.11 Charging Safety Timer

The RS4040 will start timing and then stop charging after timing about 8000 seconds when CHG pulls low. Reset the VIN, the charging safety timer will be reseted.

10 Typical Applications

10.1 Power Supply Recommendations

The RS4040 is designed to operate from an input voltage supply range between 3.5V and 19.2V. This input supply should be well regulated. If located more than a few inches from the RS4040 VIN and GND terminals, a larger capacitor is recommended.

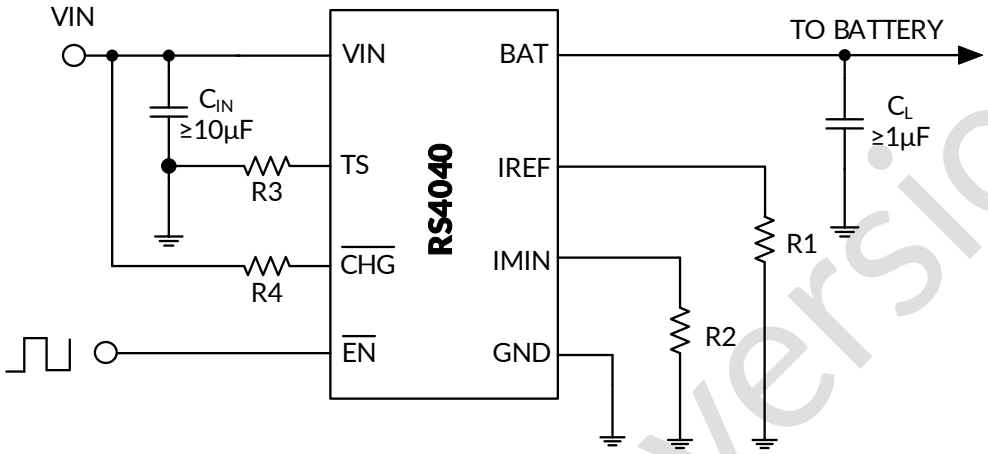


Figure 19. Typical Application Circuit

11 Layout

To obtain optimal performance, the programmed resistor from IREF, IMIN to GND and the capacitors from VIN, BAT to GND, should be placed as close as possible to the RS4040, with short trace runs to both IREF, IMIN, VIN, BAT and GND.

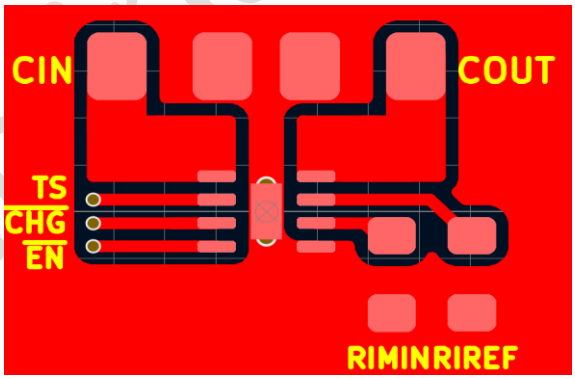
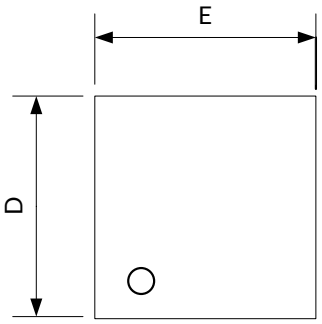


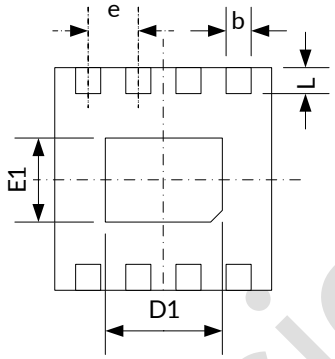
Figure 20. Layout Example

12 PACKAGE OUTLINE DIMENSIONS

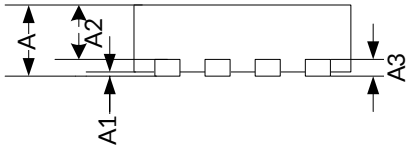
DFN2X2-8 (4)



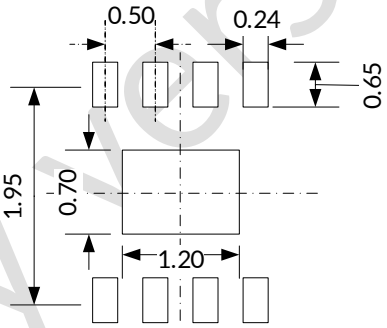
TOP VIEW



BOTTOM VIEW



SIDE VIEW



RECOMMENDED LAND PATTERN

(Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.550 TYP		0.022 TYP	
A3	0.203 REF (2)		0.008 REF (2)	
b	0.200	0.300	0.008	0.012
D (1)	2.000 BSC (3)		0.079 BSC (3)	
E (1)	2.000 BSC (3)		0.079 BSC (3)	
e	0.500 BSC (3)		0.020 BSC (3)	
D1	1.500	1.700	0.059	0.067
E1	0.800	1.000	0.031	0.039
L	0.250	0.350	0.010	0.014

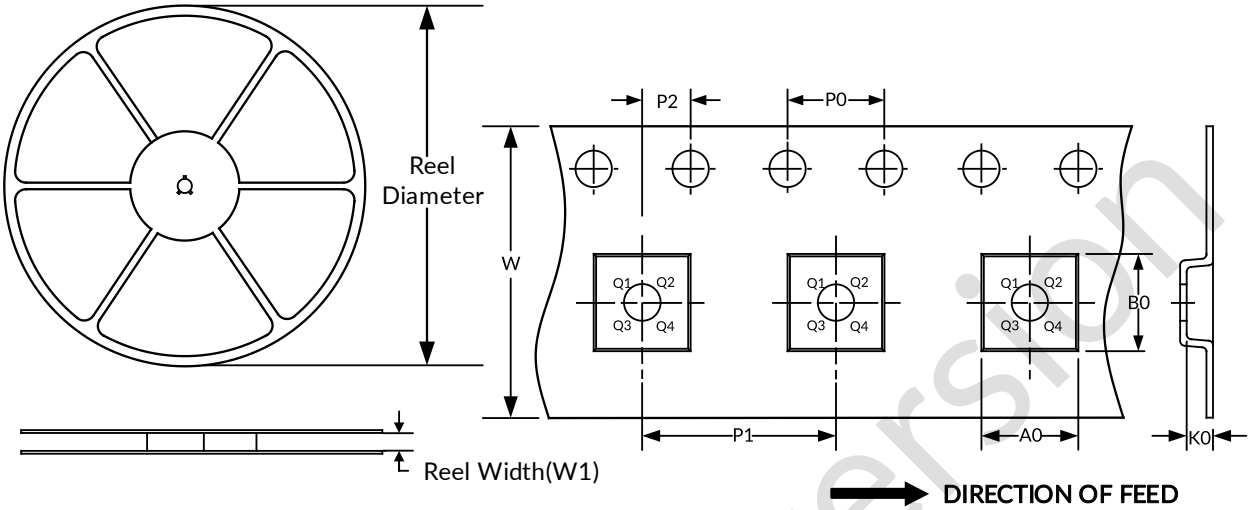
NOTE:

1. Plastic or metal protrusions of 0.075mm maximum per side are not included.
2. REF is the abbreviation for Reference.
3. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
4. This drawing is subject to change without notice.

13 TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSION



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width(mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
DFN2X2-8	7”	9.5	2.30	2.30	1.10	4.0	4.0	2.0	8.0	Q2

NOTE:
1. All dimensions are nominal.
2. Plastic or metal protrusions of 0.15mm maximum per side are not included.

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