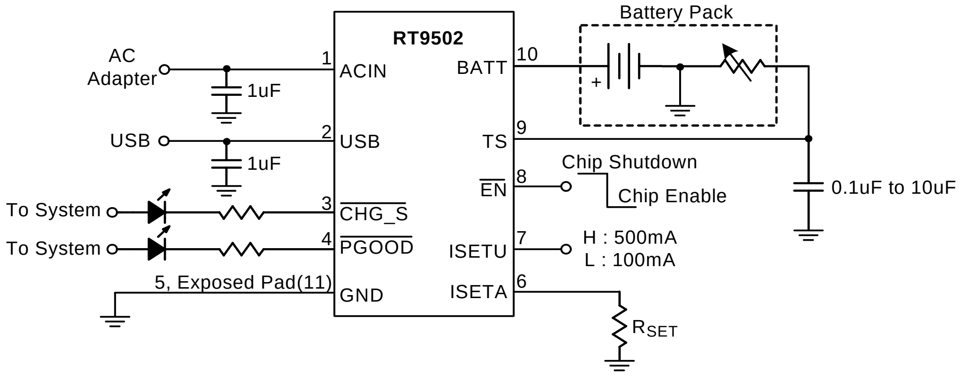
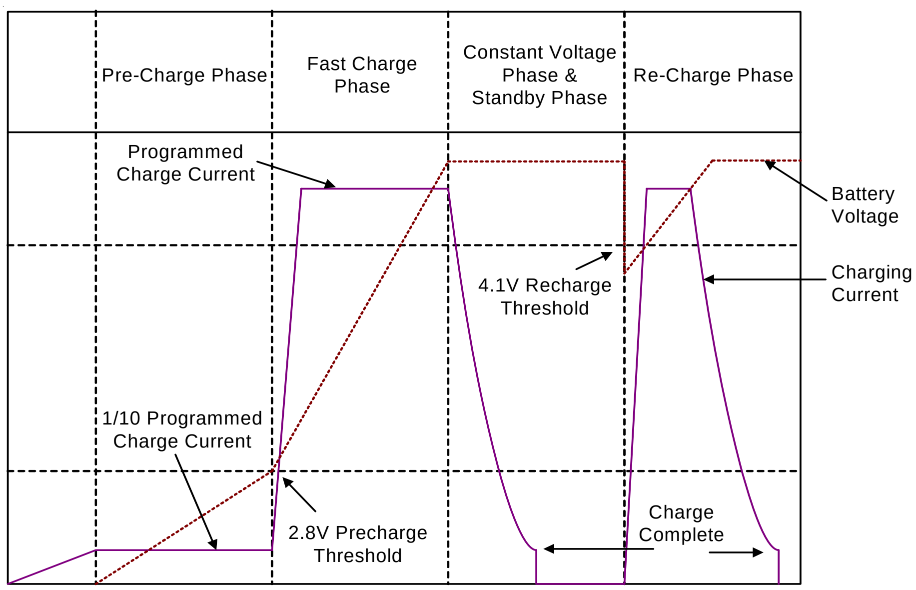
Typical Application Circuit

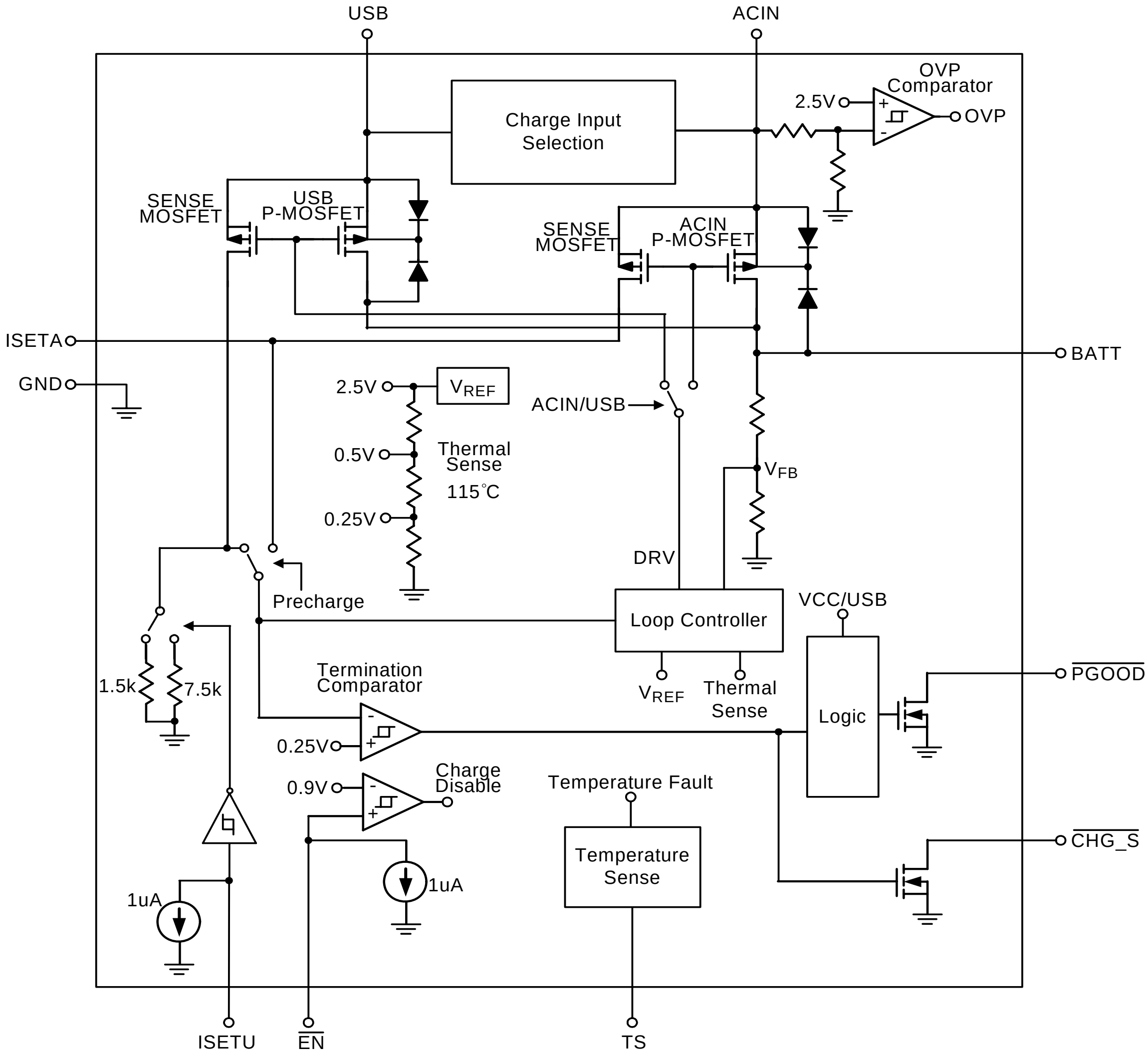




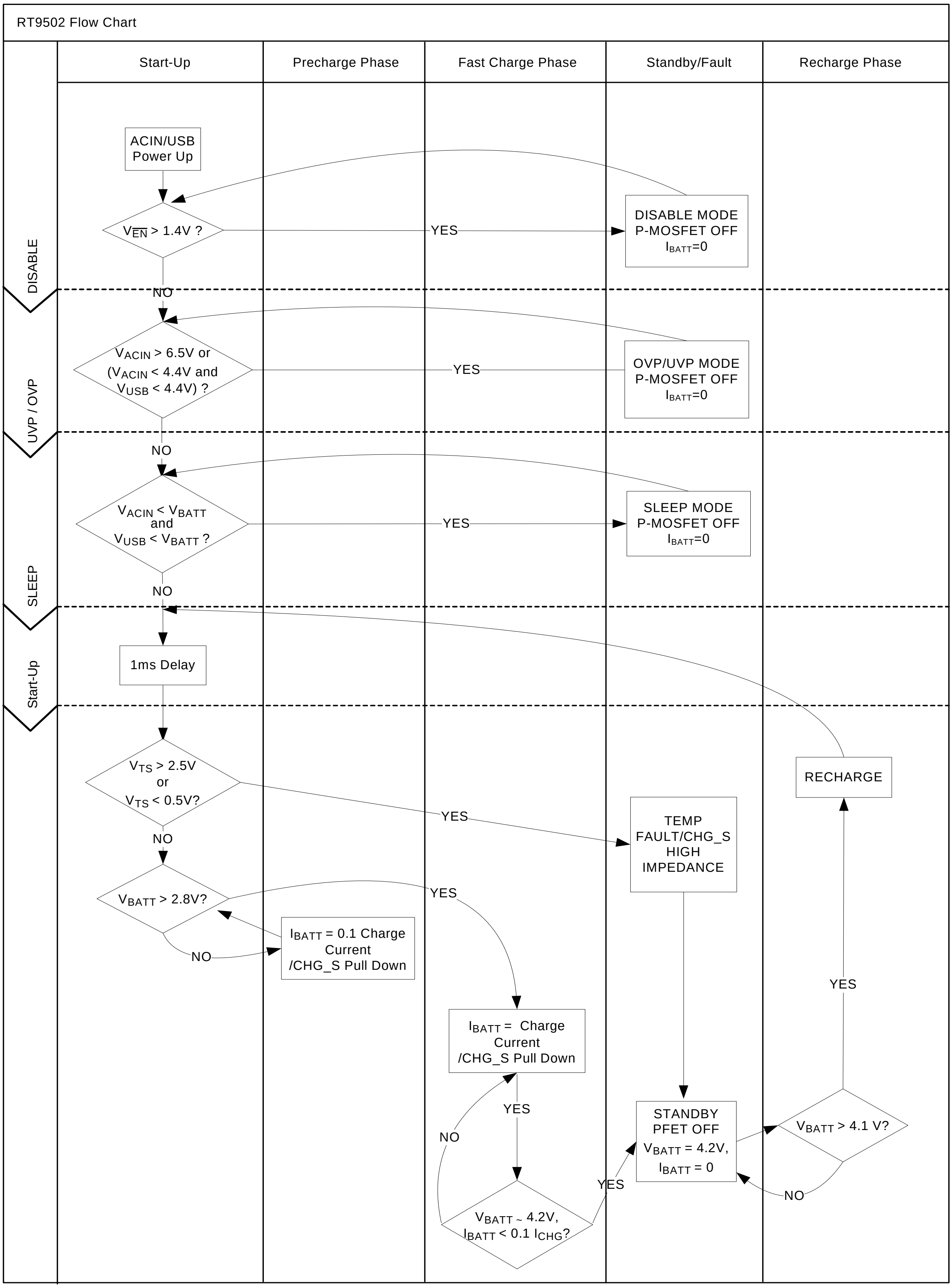
Functional Pin Description

Pin No.	Pin Name	Pin Function
1	ACIN	AC Adaptor Charge Input Supply.
2	USB	USB Charge Input Supply.
3	CHG_S	Charge Status Indicator Output (open drain).
4	PGOOD	Power Good Indicator Output (open drain).
5	GND	Ground.
6	ISETA	Wall Adaptor Supply Charge Current Set Point.
7	ISETU	USB Supply Charge Current Set Input (active low).
8	EN	Charge Enable Input (active low).
9	TS	Temperature Sense Input.
10	BATT	Battery Charge Current Output.
11 (Exposed Pad)	GND	The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

Function Block Diagram



Table


RT9502 Flow Chart
Start-Up
Precharge Phase
Fast Charge Phase
Standby/Fault
Recharge Phase
DISABLE
UVP / OVP
SLEEP
Start-Up
ACIN/USB Power Up
VEN > 1.4V ?
YES
DISABLE MODE P-MOSFET OFF IBATT=0
NO
VACIN > 6.5V or (VACIN < 4.4V and VUSB < 4.4V) ?
YES
OVP/UVP MODE P-MOSFET OFF IBATT=0
NO
VACIN < VBATT and VUSB < VBATT ?
YES
SLEEP MODE P-MOSFET OFF IBATT=0
NO
1ms Delay
VTS > 2.5V or VTS < 0.5V?
YES
TEMP FAULT/CHG_S HIGH IMPEDANCE
NO
VBATT > 2.8V?
YES
NO
IBATT = 0.1 Charge Current /CHG_S Pull Down
IBATT = Charge Current /CHG_S Pull Down
YES
NO
VBATT ~ 4.2V, IBATT < 0.1 ICHG?
YES
STANDBY PFET OFF VBATT = 4.2V, IBATT = 0
VBATT > 4.1 V?
NO
YES
RECHARGE

Absolute Maximum Ratings (Note 1)

- ACIN Input Voltage ---------- –0.3V to 18V
- USB Input Voltage ---------- –0.3V to 7V
- $\overline{EN}$ Input Voltage ---------- –0.3V to 6V
- Output Current ---------- 1.2A
- Power Dissipation, P_D @ T_A = 25°C
  WDFN-10L 3x3 ---------- 0.926W
- Package Thermal Resistance (Note 2)
  WDFN-10L 3x3, θ_{JA} ---------- 108°C/W
  WDFN-10L 3x3, θ_{JC} ---------- 8.2°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Mode) ---------- 2kV
  MM (Machine Mode) ---------- 200V

Recommended Operating Conditions (Note 4)

- ACIN, USB Input Voltage Range ---------- 4.5V to 6V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(ACIN = USB = 5V, T_A = 27°C, Unless Otherwise specification)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Input						
ACIN/USB UVP Rising Threshold Voltage	V_{UV_HIGH}		--	4.4	4.5	V
ACIN/USB UVP Hysteresis	V_{UV_LOW}		50	80	120	mV
ACIN/USB Standby Current	I_{STBY}	V_{BATT} = 4.5V	--	300	500	uA
ACIN/USB Shutdown Current	I_{SHDN}	$V_{\overline{EN}}$ = High	--	50	100	uA
ACIN/USB UVP Current	I_{UVP}	V_{ACIN} = 4V, V_{USB} = 4V, V_{BATT} = 3V	--	150	250	uA
BATT Sleep Leakage Current	I_{SLEEP}	V_{ACIN} = 4V, V_{USB} = 4V V_{BATT} = 4.5V	--	2	5	uA
Voltage Regulation						
BATT Regulation Voltage	V_{REG}	I_{BATT} = 60mA	4.158	4.2	4.242	V
Regulation Voltage Accuracy			–1	--	+1	%
ACIN MOSFET	$R_{DS(ON)\_ACIN}$	I_{BATT} = 500mA	--	600	--	mΩ
USB MOSFET	$R_{DS(ON)\_USB}$	I_{BATT} = 500mA	--	1200	--	mΩ
Current Regulation						
ISETA Set Voltage (Fast Charge Phase)	V_{ISETA}	V_{BATT} = 3.5V	2.42	2.5	2.55	V
Full Charge setting range	I_{CHG_ACIN}		100	--	1200	mA

To be continued

Parameter		Symbol	Test Conditions	Min	Typ	Max	Units
ACIN Charge Current accuracy		I_{CHG_ACIN}	V_{BATT} = 3.8V; R_{ISET} = 1.5kΩ	--	500	--	mA
Precharge							
BATT Pre-charge Rising Threshold		V_{PRECH}		2.6	2.8	3	V
BATT Pre-charge Threshold Hysteresis		ΔV_{PRECH}		50	100	200	mV
Pre-Charge Current		I_{PCHG}	V_{BATT} = 2V	8	10	12	%
Recharge Threshold							
BATT Re-charge Falling Threshold Hysteresis		ΔV_{RECH_L}	$V_{REG} - V_{BATT}$	60	100	150	mV
Charge Termination Detection							
ISETA Charge Termination Set Voltage		V_{TERM}	V_{BATT} = 4.2V	200	250	275	mV
Termination Current Ratio (default)		I_{TERM}	V_{BATT} = 4.2V	--	10	--	%
Logic Input/Output							
$\overline{CHG\_S}$ Pull Down Voltage		$V_{\overline{CHG\_S}}$	TBD; $I_{\overline{CHG\_S}}$ = 5mA	--	65	--	mV
$\overline{PGOOD}$ Pull Down Voltage		$V_{\overline{PGOOD}}$	TBD; $I_{\overline{PGOOD}}$ = 5mA	--	220	--	mV
$\overline{EN}$ Threshold	Logic-High Voltage	V_{IH}		1.5	--	--	V
	Logic-Low Voltage	V_{IL}		--	--	0.4	V
$\overline{EN}$ Pin Input Current		$I_{\overline{EN}}$	$V_{\overline{EN}}$ = 2V	--	--	2	uA
ISETU Threshold	High Voltage	V_{ISETU_HIGH}		1.5	--		V
	Low Voltage	V_{ISETU_LOW}		--	--	0.4	V
ISETU Pin Input Current		I_{ISETU}	V_{ISETU} =2V	--	--	2	uA
USB Charge Current & Timing							
USB Charge Current		$I_{CHG(USB100)}$	V_{USB} = 5V; V_{BATT} = 3.5V, I_{SETU} = 0V	--	--	100	mA
		$I_{CHG(USB500)}$	V_{USB} = 5V; V_{BATT} = 3.5V, I_{SETU} = 5V	400	450	500	
Battery Temperature Sense							
TS Pin Source Current		I_{TS}	V_{TS} = 1.5V	96	102	108	uA
TS Pin Threshold	Low Voltage	V_{TS_LOW}	Falling	0.485	0.5	0.515	V
	High Voltage	V_{TS_HIGH}	Rising	2.45	2.5	2.55	V
Protection							
Thermal Regulation				--	125	--	°C
OVP SET			Internal Default	--	6.5	--	V

Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

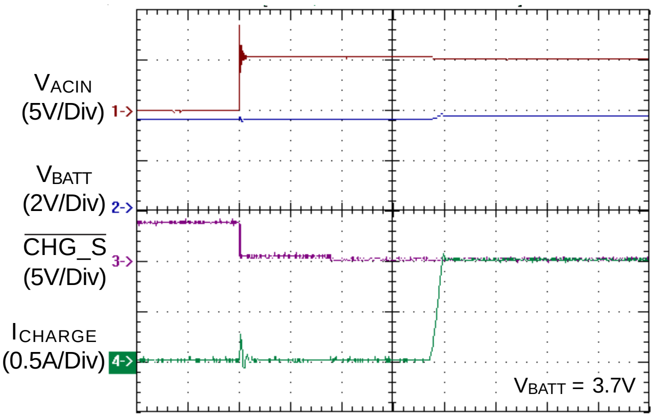
Note 2. θ_{JA} is measured in the natural convection at T_A = 25°C on a high effective thermal conductivity test board (4 layers, 1S) of JEDEC 51-7 thermal measurement standard. The case point of θ_{JC} is on the expose pad for the package.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

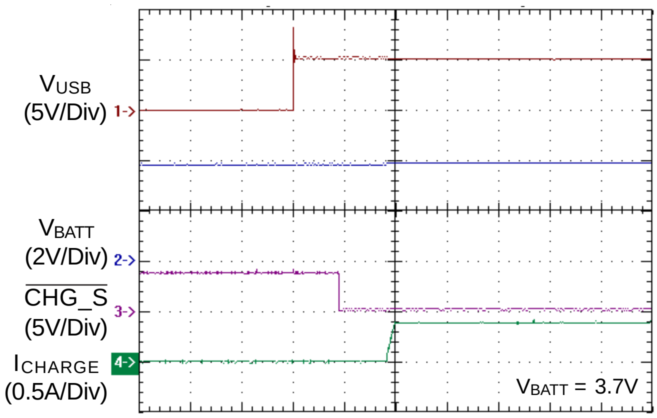
Typical Operating Characteristics

ACIN Power On



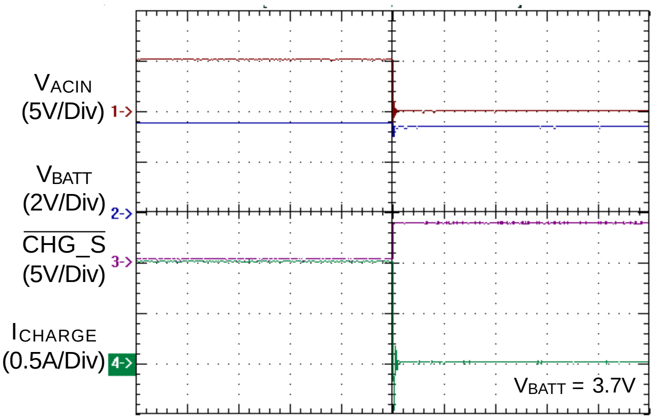
Time (250us/Div)

USB Power On



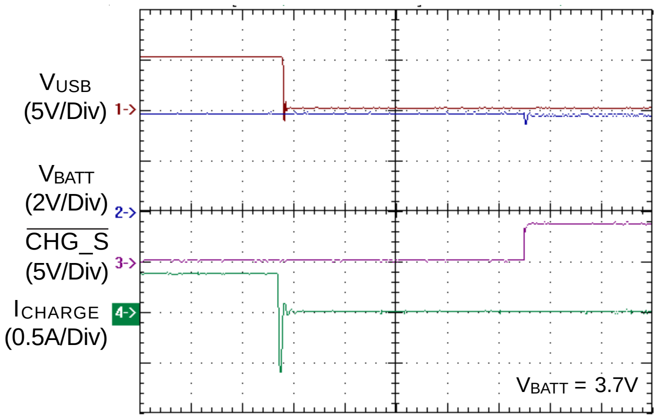
Time (250us/Div)

ACIN Power Off



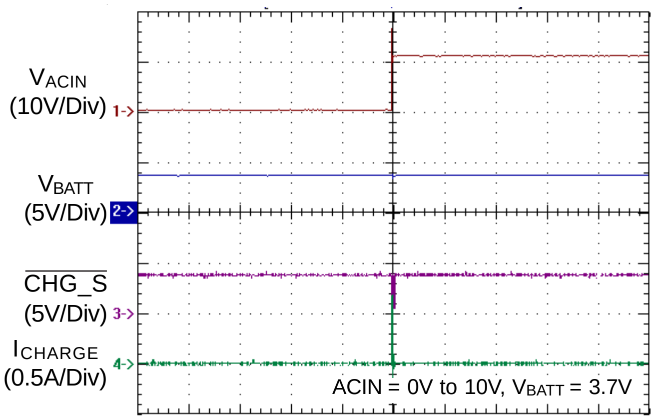
Time (500us/Div)

USB Power Off



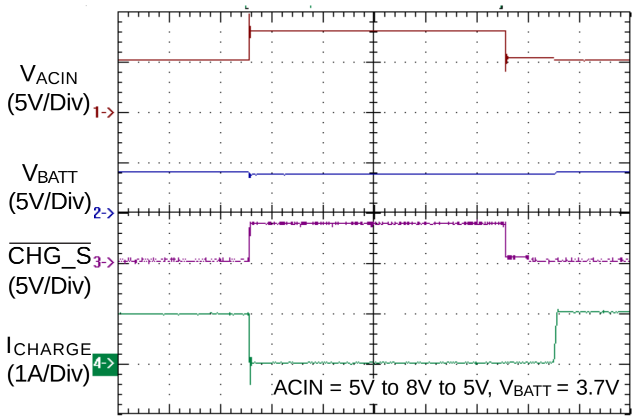
Time (200us/Div)

ACIN OVP



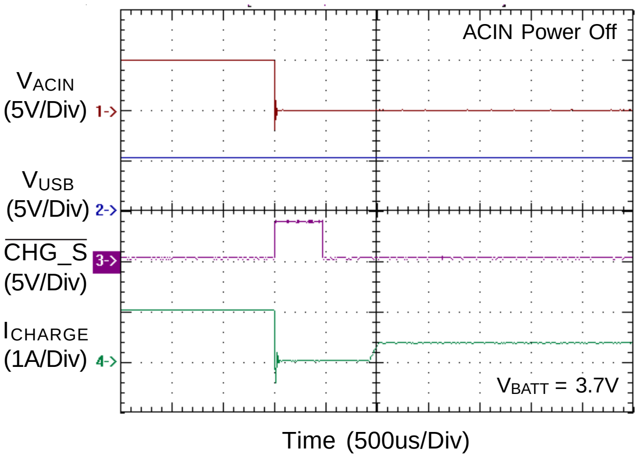
Time (1ms/Div)

ACIN OVP

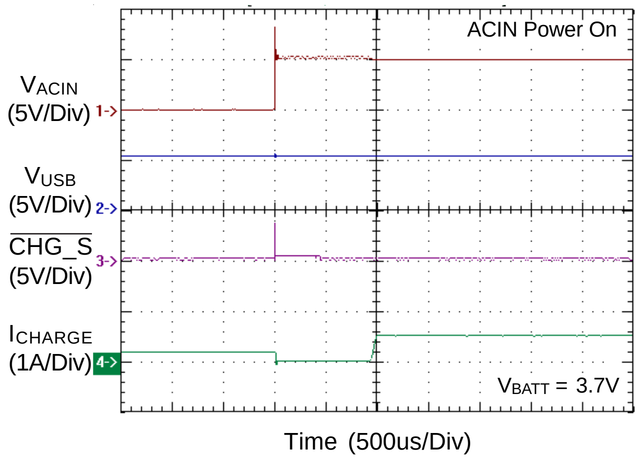


Time (1ms/Div)

Input Voltage Transition



Input Voltage Transition



Application Information

Automatically Power Source Selection

The RT9502 is a battery charger IC which is designed for Li-ion Battery with 4.2V rated voltage.

The RT9502 can be adopted for two input power source, ACIN or USB Input. It will automatically select the input source and operate in different mode as below.

ACIN Mode : When the ACIN input voltage (ACIN) is higher than the UVP voltage level (4.4V), the RT9502 will enter ACIN Mode. In the ACIN Mode, ACIN P-MOSFET is turned on and USB P-MOSFET is turned off.

USB Mode : When ACIN input voltage is lower than UVP voltage level and USB input voltage is higher than UVP voltage level (4.4V), the RT9502 will operate in the USB Mode. In the USB Mode, ACIN P-MOSFET is turned off and USB P-MOSFET is turned on.

Sleep Mode : The RT9502 will enter Sleep Mode when both ACIN and USB input voltage are removed. This feature provides low leakage current from the battery during the absence of input supply.

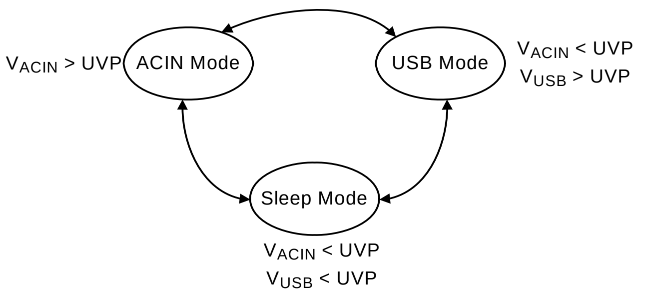


Figure 1. Input Power Source Operation Mode.

ACIN Over Voltage Protection

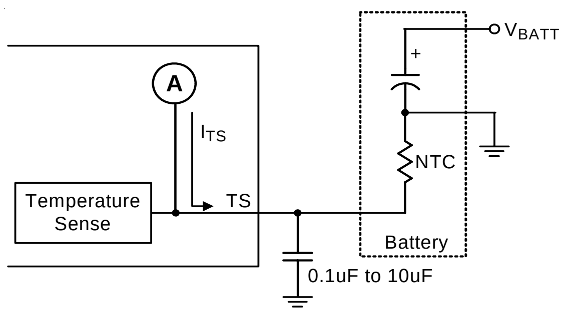
The ACIN input voltage is monitored by an internal OVP comparator. The comparator has an accurate reference of 2.5V from the band-gap reference. The OVP threshold is set by the internal resistive. The protection threshold is set to 6.5V. When the input voltage exceeds the threshold, the comparator outputs a logic signal to turn off the power P-MOSFET to prevent the high input voltage from damaging the electronics in the handheld system. When the input over oltage condition is removed (ACIN < 6V), the comparator re-enables the output by running through the soft-start.

Battery Temperature Monitoring

The RT9502 continuously monitors battery temperature by measuring the voltage between the TS and GND pins. The RT9502 has an internal current source to provide the bias for the most common 10kΩ negative-temperature coefficient thermal resistor (NTC) (see Figure 2). The RT9502 compares the voltage on the TS pin against the internal VTS_HIGH and VTS_LOW thresholds to determine if charging is allowed.

When the temperature outside the VTS_HIGH and VTS_LOW thresholds is detected, the device will immediately stop the charge. The RT9502 stops charge and keep monitoring the battery temperature when the temperature sense input voltage is back to the threshold between VTS_HIGH and VTS_LOW, the charger will be resumed. Charge is resumed when the temperature returns to the normal range. However the user may modify thresholds by the negative-temperature coefficient thermal resistor or adding two external resistors. (see Figure 3.)

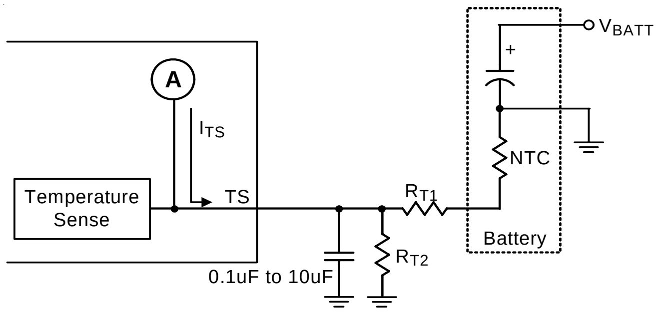
The capacitor should be placed close to TS(Pin 9) and connected to the ground plane. The capacitance value (0.1uF to 10uF) should be selected according to the quality of PCB layout. It is recommended to use 10uF if the layout is poor if prevent noise.



$V_{TS} = I_{TS} \times R_{NTC}$

Turn off when $V_{TS} \geq 2.5V$ or $V_{TS} \leq 0.5V$

Figure 2. Temperature Sensing Configuration



$$V_{TS} = I_{TS}\frac{R_{T2}\times(R_{T1}+R_{NTC})}{R_{T1}+R_{T2}+R_{NTC}}$$

Turn off when $V_{TS} \geq 2.5V$ or $V_{TS} \leq 0.5V$

Figure 3. Temperature Sensing Circuit

Fast-Charge Current Setting

Case 1 : ACIN Mode

The RT9502 offers ISETA pin to determine the ACIN charge rate from 100mA to 1.2A. The charge current can be calculated as following equation.

$$I_{charge\_ac} = K_{SET}\frac{V_{SET}}{R_{SETA}}$$

The parameter K_{SET} = 300 ; V_{SET} = 2.5V. R_{SETA} is the resistor connected between the ISETA and GND.

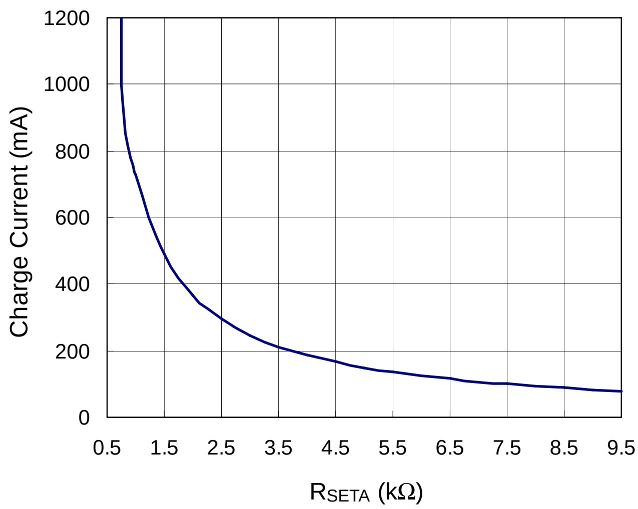


Figure 4. ACIN Mode Charge Current Setting

Case 2 : USB Mode

When charging from a USB port, the ISETU pin can be used to determine the charge current of 100mA or 500mA.

A low-level signal of ISETU pin sets the charge current at 100mA and a high level signal sets the charge current at 500mA.

Pre- Charge Current Setting

During a charge cycle if the battery voltage is below the VPRECH threshold, the RT9502 applies a pre-charge mode to the battery. This feature revives deeply discharged cells and protects battery life. The RT9502 internal determines the pre-charge rate as 10% of the fast-charge current.

Battery Voltage Regulation

The RT9502 monitors the battery voltage through the BATT pin. Once the battery voltage level closes to the VREG threshold, the RT9502 voltage enters constant phase and the charging current begins to taper down. When battery voltage is over the VREG threshold, the RT9502 will stop charge and keep to monitor the battery voltage. However, when the battery voltage decreases 100mV below the V_{REG}, it will be recharged to keep the battery voltage.

Charge Status Outputs

The open-drain $\overline{\text{CHG\_S}}$ and $\overline{\text{PGOOD}}$ outputs indicate various charger operations as shown in the following table.

These status pins can be used to drive LEDs or communicate to the host processor. Note that ON indicates the open-drain transistor is turned on and LED is bright.

Charge State		$\overline{\text{CHG\_S}}$	$\overline{\text{PGOOD}}$
ACIN	Charge	ON	ON
	Charge done	OFF	ON
USB	Charge	ON	OFF
	Charge done	OFF	OFF

Temperature Regulation and Thermal Protection

In order to maximize the charge rate, the RT9502 features a junction temperature regulation loop. If the power dissipation of the IC results in a junction temperature greater than the thermal regulation threshold (125°C), the RT9502 throttles back on the charge current in order to maintain a junction temperature around the thermal regulation threshold (125°C). The RT9502 monitors the junction temperature, T_J, of the die and disconnects the battery from the input if T_J exceeds 125°C. This operation continues until junction temperature falls below thermal regulation threshold (125°C) by the hysteresis level. This feature prevents the chip from damage.

Selecting the Input and Output Capacitors

In most applications, the most important is the high-frequency decoupling capacitor on the input of the RT9502. A 1uF ceramic capacitor, placed in close proximity to input pin and GND pin is recommended. In some applications depending on the power supply characteristics and cable length, it may be necessary to add an additional 10uF ceramic capacitor to the input. The RT9502 requires a small output capacitor for loop stability. A 1uF ceramic capacitor placed between the BATT pin and GND is typically sufficient.

Layout Consideration

The RT9502 is a fully integrated low cost single-cell Li-Ion battery charger ideal for portable applications. Careful PCB layout is necessary. For best performance, place all peripheral components as close to the IC as possible. A short connection is highly recommended. The following guidelines should be strictly followed when designing a PCB layout for the RT9502.

- Input capacitor should be placed close to IC and connected to ground plane. The trace of input in the PCB should be placed far away the sensitive devices or shielded by the ground.
- The GND should be connected to a strong ground plane for heat sinking and noise protection.
- The connection of R_{SETA} should be isolated from other noisy traces. The short wire is recommended to prevent EMI and noise coupling.
- Output capacitor should be placed close to IC and connected to ground plane to reduce noise coupling.
- The TS's capacitor should be placed close to TS (Pin 9) and connected to ground plane. The capacitance (0.1uF to 10uF) base on PCB layout. When PCB has poor layout, the 10uF is recommended to prevent noise.

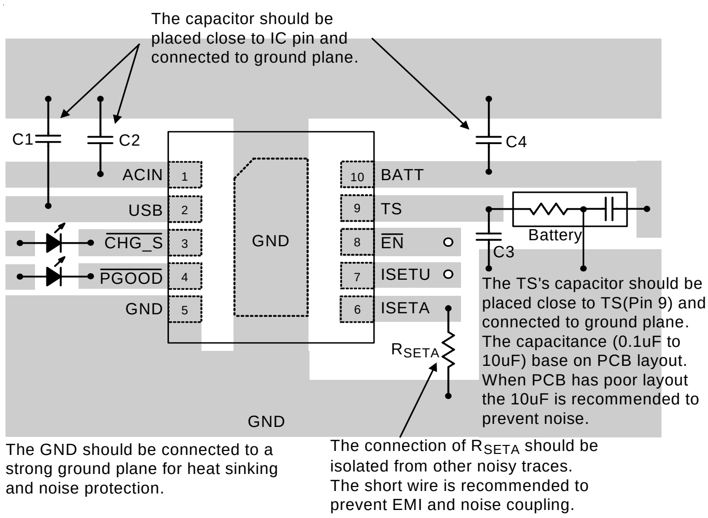
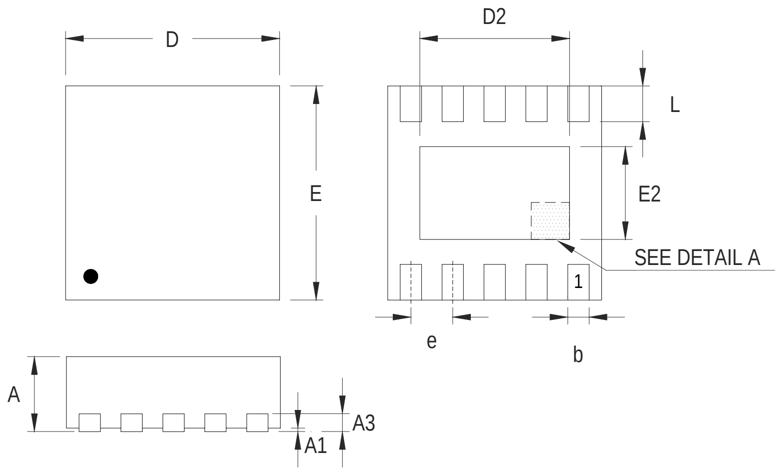
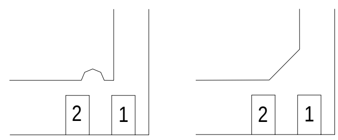


Figure 5

Outline Dimension





DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.180	0.300	0.007	0.012
D	2.950	3.050	0.116	0.120
D2	2.300	2.650	0.091	0.104
E	2.950	3.050	0.116	0.120
E2	1.500	1.750	0.059	0.069
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

W-Type 10L DFN 3x3 Package

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