Application Note: SY20757

QC3.0, FCP, AFC, High Voltage / Current, 3IN1
Bidirectional Regulator for Li-Ion Battery Power Bank Application

General Description

The SY20757 is a 4.6-13.2V input bidirectional regulator designed for single cell Li-Ion battery power bank application. It supports multiple charging protocols, such as QC3.0, FCP, AFC, and Apple Mode. It also integrates the Battery Fuel Gauge Indicator Function, Light Load Detection and Load Insert Detection to provide fully scheme for power bank application.

Advanced bidirectional energy flow control is adopted to achieve battery charging and discharging alternately. If the external power supply is present, the SY20757 will run in Charging Mode with fully protection function; if the external power supply is absent, the SY20757 will run in Discharging Mode with total output capability up to 18W.

The SY20757 has 2 NMOS drivers for external port's MOSFETs to achieve discharging path management. A half bridge with quasi-fixed high switching frequency is integrated to achieve power conversion for battery charging and battery discharging. All of them adopt N-channel MOSFET with 18V rating and extremely low $R_{DS(ON)}$ to optimize operation efficiency and extend the life of battery.

The SY20757 is available in QFN5x5-34 package to minimize the size of PCB layout for wide portable applications.

Ordering Information

SY20757 □(□□)□

- Temperature Code
- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY20757VCC	QFN5x5-34	

Features

- Integrated N-Channel MOSFET with 18V Voltage Rating and Extremely Low $R_{DS(ON)}$
- Maximum 5A Battery Charging Current
- Support BC1.2
- Adaptive Input Current Limit
- Trickle Current / Constant Current / Constant Voltage Charging Mode.
- Maximum 18W Output Power in Battery Discharging Mode
- Programmable Boost Peak Current Limit
- 200kHz-500kHz Programmable Boost Switching Frequency
- Programmable Battery Internal Resister Compensation
- Up to 4 LEDs Battery Fuel Gauge Indicator with Programmable Threshold
- Support Smart Phone Fast Charge Protocols QC3.0, FCP and AFC
- Load Insert Detection
- Light Load Auto-shutdown
- Battery UTP/OTP Protection
- Output OVP/SCP/OCP Protection
- Thermal Shutdown Protection
- Max 50 μA Quiescent Current in Sleep Mode

Applications

- Single Cell Li-Ion Power Bank
- Portable Device with Single Cell Battery Pack

Typical Application

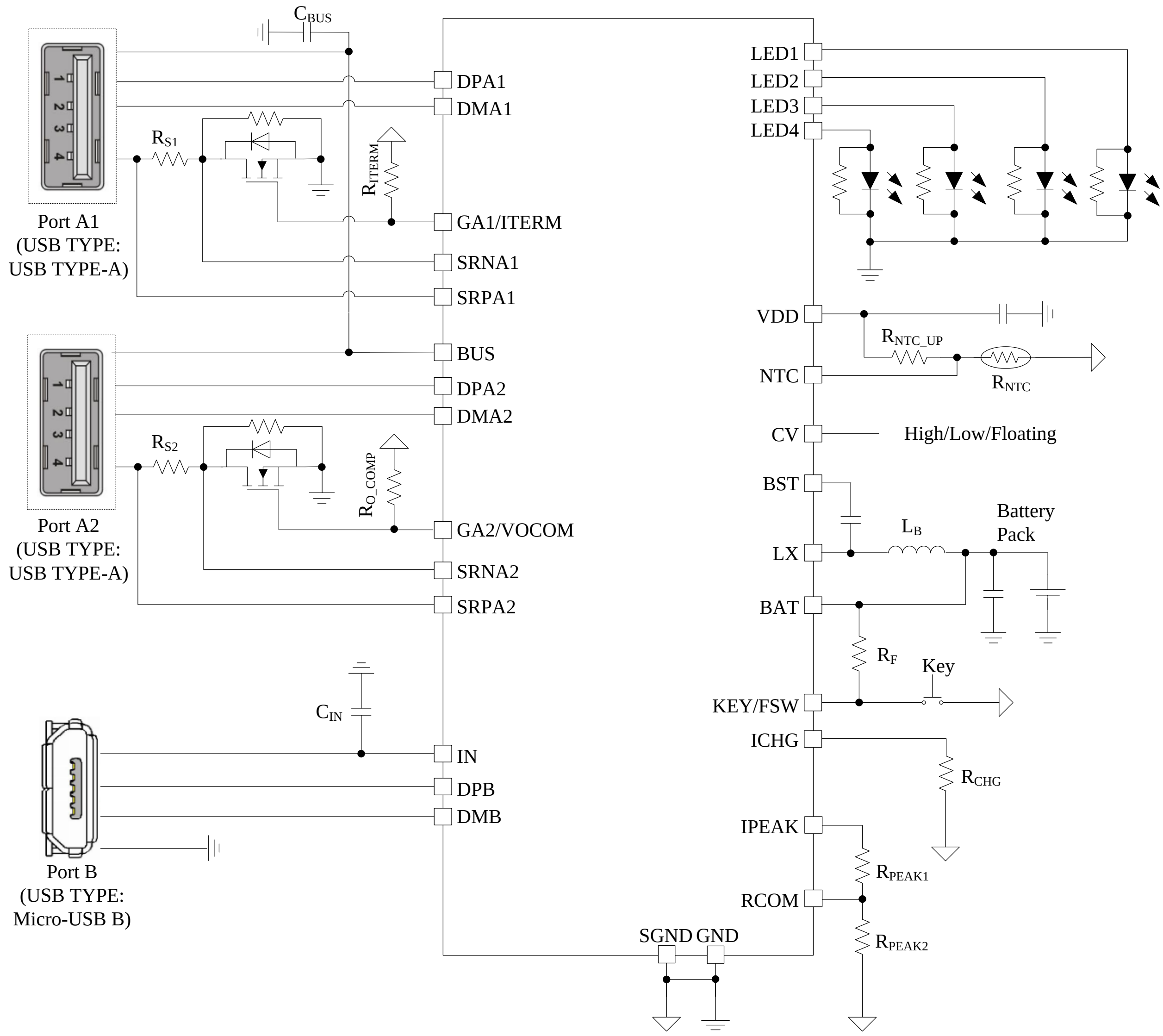
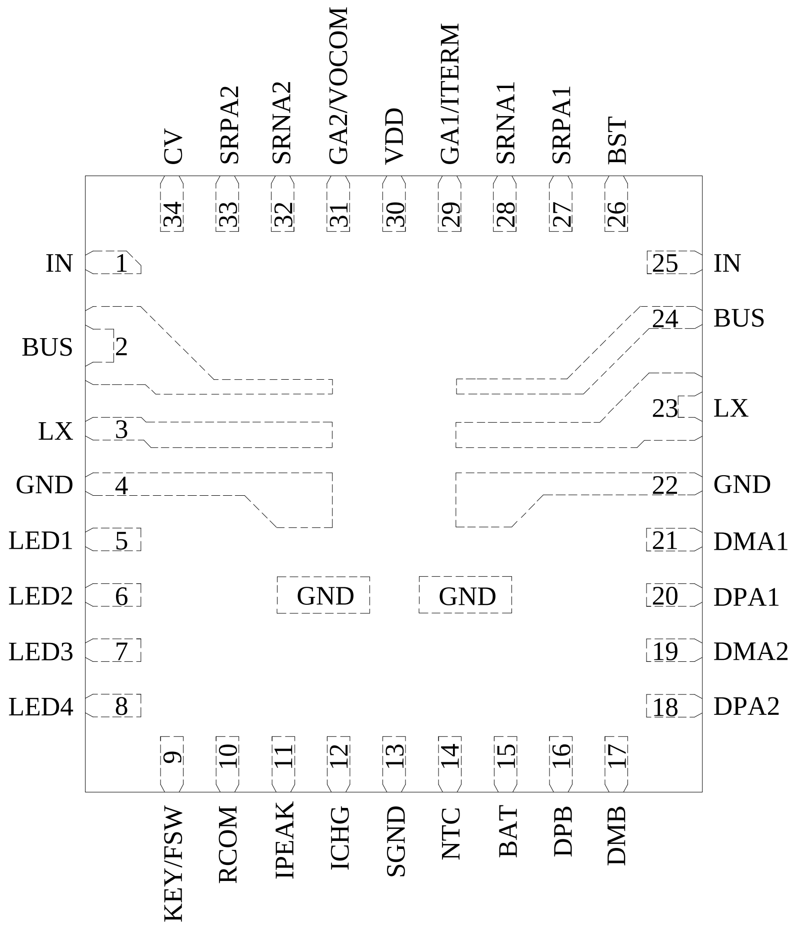


Figure1. Application for Single Cell Li-Ion Power Bank

Pinout(Top view)



(QFN5x5-34)

Top Mark: CNR*xyz* (device code: CMQ, ***x=year code, y=week code, z= lot number code)***

Pin Description

Name	PIN Number	Description
IN	1,25	Positive power supply input pins. These pins are shorted internally. Connect a MLCC from one pin to ground to decouple high frequency noise. The input pins have OVP and UVLO function to make the charger operate within safe input voltage area.
BUS	2,24	Input or output point of half bridge. These pins are shorted internally. Connect a MLCC from one pin to ground to decouple high frequency noise.
LX	3,23	Switch node pins. These pins are shorted internally. Connect an external inductor between one pin and BAT pin.
GND	4,22	Power ground pins.
LED1-4	5,6,7,8	LED drivers for battery level indicator. They are also used as battery level indication threshold adjustment.
KEY/FSW	9	Function1: KEY pin. Connect a key from this pin to ground. Function2: Switching frequency set pin. Connect a resister from BAT to KEY to set the switching frequency of Boost converter.
RCOM	10	Battery internal resister compensation pin. This pin is used as battery level indication threshold compensation in battery Discharging Mode.
IPEAK	11	Peak current limit set pin. Connect a resister from this pin to GND to set the peak current limit of Boost converter in Discharging Mode.
ICHG	12	Constant charging current set pin. Connect a resister from this pin to GND to set the constant charging current in Charging Mode.
SGND	13	Signal ground pin.
NTC	14	Battery thermal protection sense pin.
BAT	15	Battery positive pin. Also connect to the inductor terminal.
DPB	16	D+ pin for the input port.
DMB	17	D- pin for the input port. DPB/DMB supports BC1.2 detection.
DPA2	18	D+ pin for the output Port A2.
DMA2	19	D- pin for the output Port A2. DPA2/DMA2 supports QC3.0/2.0, FCP, AFC, and Apple Mode.
DPA1	20	D+ pin for the output Port A1.
DMA1	21	D- pin for the output Port A1. DPA1/DMA1 supports QC3.0/2.0, FCP, AFC, and Apple Mode.
BST	26	Bootstrap pin. Connect a 0.1 µF MLCC from this pin to LX.
SRPA1	27	The output current sense positive pin of Port A1.
SRNA1	28	The output current sense negative pin of Port A1. Connect a current sense resister from SRPA1 to SRNA1.
GA1 /ITERM	29	Function1: Output port A1 N-MOSFET gate driver pin. Function2: Termination charging current set pin.
VDD	30	Internal Linear regulator output. VDD is the output of 3.3V Linear regulator. Connect a 1 µF ceramic capacitor from VDD to GND.
GA2 /VOCOM	31	Function1: Output port A2 N-MOSFET driver pin. Function2: Boost output compensation voltage set pin.
SRNA2	32	The output current sense negative pin of Port A2.
SRPA2	33	The output current sense positive pin of Port A1. Connect a current sense resister from SRPA2 to SRNA2.
CV	34	Battery constant charging voltage set pin. Float to set 4.178V, pull low to set 4.328V and pull high to set 4.378V.

Block Diagram

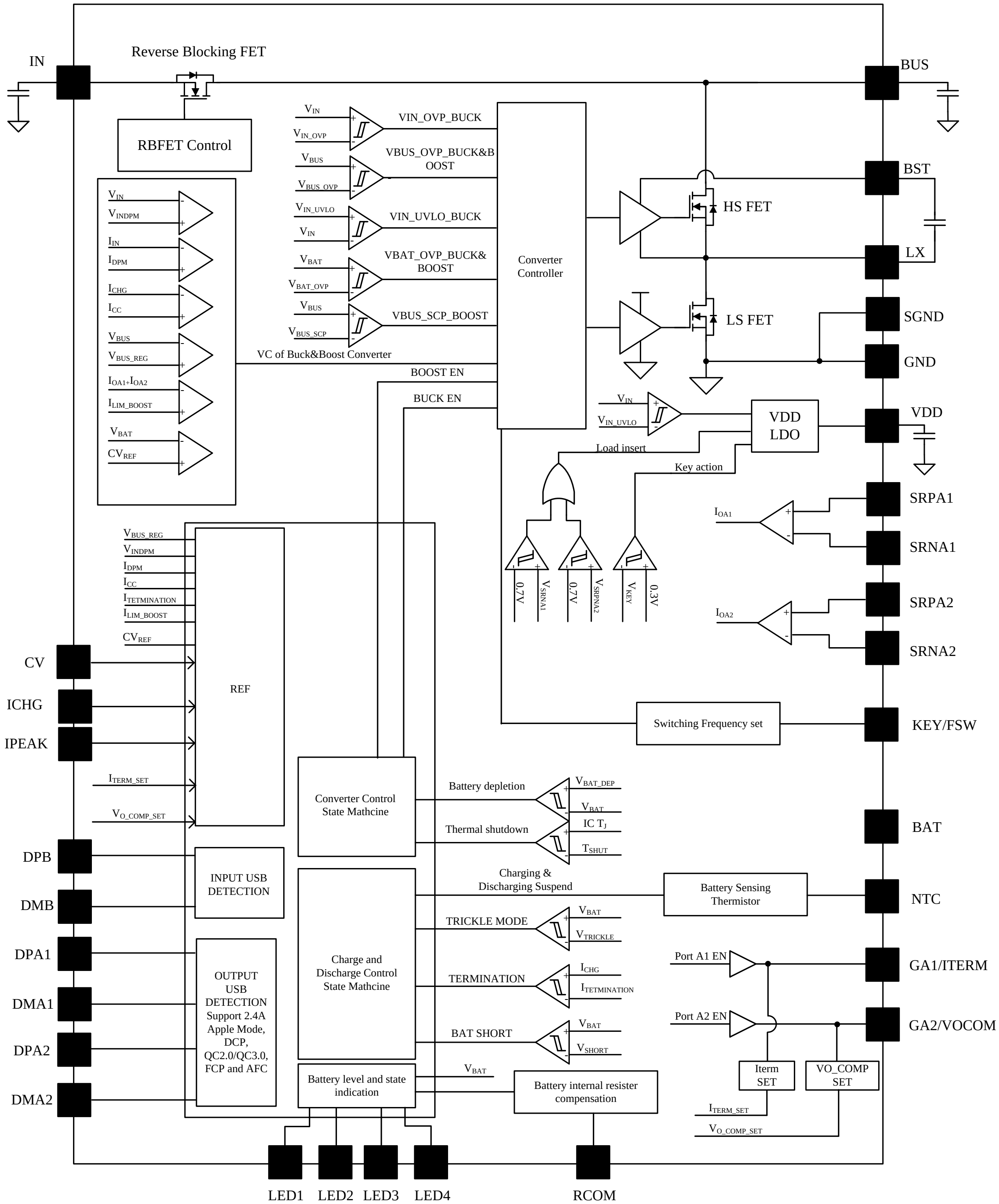


Figure2. Block Diagram

Absolute Maximum Ratings (Note 1)

IN, BUS, LX, RCOM, IPEAK, ICHG, DPB, DMB, DPA2, DMA2 -- -0.5V to 18V
DPA1, DMA1, SRPA1, SRNA1, GA1, GA2, SRNA2, SRPA2, CV --------------------------------------- -0.5V to 18V
VDD, BST-LX, NTC, LED1~LED4 -- -0.5V to 3.3V
KEY, BAT -- -0.5V to 5.5V
Power Dissipation, P_D @ T_A = 25 ℃ -- 3.6 W
Package Thermal Resistance (Note 2)
θ_{JA} -- 43 ℃/W
θ_{JC} -- 16 ℃/W
Junction Temperature Range --- -40 ℃ to +150 ℃
Lead Temperature (Soldering, 10 sec.) --- 260 ℃
Storage Temperature Range --- -65 ℃ to 125 ℃

Recommended Operating Conditions (Note 3)

IN, BUS, CV, DPB, DMB, DPA1, DMA1, DPA2, DMA2 --- 0V to 16V
SRPA1, SRPA2, SRNA1, SRNA2 --- 0V to 16V
LX -- -0.3V to 16V
KEY, BAT -- 0V to 5V
Others -- 0V to 3.3V
Junction Temperature Range --- -20 ℃ to 120 ℃
Ambient Temperature Range --- -40 ℃ to 85 ℃

Electrical Characteristics

T_A=25 ℃, T_A=T_J, V_{IN}=5V, GND=0V, C_{IN}=10µF, L_B=2.2µH, C_{BUS}=20µF, R_{S1}=R_{S2}=10mΩ, R_{NTC_UP}=10kΩ, R_{NTC}=10kΩ(103-AT), unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Quiescent Current						
I_{BAT}	Battery Discharge Current	No input DC source, Boost disabled, VDD off, $V_{BUS} \le V_{BAT}$			50	µA
I_{IN}	Input Quiescent Current	Charging disabled, measured from IN, V_{IN}> V_{IN_UVLO}		2		mA
Power Up						
V_{IN_UVLO}	Input Voltage UVLO Threshold	Rising edge	4.2		4.55	V
$V_{IN\_UVLO\_HYS}$	Input Voltage UVLO Hysteresis	Falling edge		100		mV
LDO Output						
V_{VDD}	VDD Voltage	V_{BUS}=5V	3.2	3.3	3.4	V
I_{VDD}	VDD Source Current	V_{VDD}=3V	80			mA
Ports Management and Protection						
V_{IN_OVP}	Input Voltage OVP Threshold for 5V Adapter	Rising edge	5.7		6	V
$V_{IN\_OVP\_HYS}$	Input Voltage OVP Hysteresis for 5V Adapter	Falling edge		0.1		V
I_{PORT_OCP}	Port A OCP Threshold	Rising edge, Discharging Mode	3.1		3.7	A
I_{LIGHT}	Port A Light Load Threshold	Falling edge	25	50	75	mA
Blocking FET						
R_{RBFET}	R_{DSON} of Reverse Blocking NFET			35		mΩ
Port Gate Driver						
V_{PORTA1_ON}	Port A1 Driver Voltage	V_{GA1} when Port A1 is on		V_{VDD}		
V_{PORTA2_ON}	Port A2 Driver Voltage	V_{GA2} when Port A2 is on		V_{VDD}		
Half-Bridge Power MOSFET						
R_{HSFET}	$R_{DS(ON)}$ of High-side NFET			18		mΩ
R_{LSFET}	$R_{DS(ON)}$ of Low-side NFET			9		mΩ
Half-bridge in Buck Mode						
Voltage Bias						
V_{CHG_OP}	Supply Voltage for Battery Charging		4.6		13.2	V
Input Voltage and Current Regulation						
V_{DPM}	Input Voltage Regulation	5V Charging Mode without BUS load, V_{DPM}=4.5V	-1.5%		1.5%	
I_{DPM}	Input Current Limit Tolerance	I_{DPM}=2A	-10%		10%	
Timer						
T_{TC}	Trickle Current Charge Timeout Tolerance			2		hrs
T_{FC}	Fast Charge (CC and CV) Timeout Tolerance		20			hrs

Switching Frequency						
f_{SWBK}	Buck Switching Frequency	V_{IN}=5V, V_{BAT}=3.5V		400		kHz
Battery Charging						
V_{CV}	Battery CV Voltage Tolerance	CV pin float	4.157	4.178	4.2	V
		CV pin low	4.306	4.328	4.35	V
		CV pin high	4.356	4.378	4.4	V
ΔV_{RCH}	Battery Voltage Threshold Hysteresis for Recharge	Falling edge		100		mV
V_{BATOVP}	Battery Voltage OVP Threshold	Rising edge	103%	105%	107%	V_{CV}
V_{BATOVP_HYS}	Battery Voltage OVP Hysteresis	Falling edge		2%		V_{CV}
V_{TRK}	Battery Trickle Charging Mode Voltage Threshold	Rising edge	2.7	2.8	2.9	V
I_{CHG}	Charging Current Accuracy for Constant Current Mode	I_{CHG}=5A,R_{CHG}=2.4Kω, V_{IN}=5V, V_{BAT}=3.5V	4.5	5	5.5	A
		I_{CHG}=2A,R_{CHG}=6kΩ, V_{IN}=5V,V_{BAT}=3.5V	1.8	2	2.2	
I_{TC}	Charging Current Accuracy for Trickle Current Mode	$V_{BATSHORT}<V_{BAT}<V_{TRK}$		10%		I_{CHG}
I_{TERM}	Termination Current Tolerance	V_{IN}=5V, R_{ICHG}=2.4kΩ	-20%		20%	
Battery Short Circuit Protection						
$V_{BATSHORT}$	Battery Short Circuit Protection Threshold		1.9		2	V
Half-bridge in Boost Mode						
Voltage and Current Bias						
V_{DEP}	Battery Depletion Voltage Tolerance	Falling edge, R_{LED1}=50kΩ	2.6		2.7	V
		Falling edge, R_{LED1}=100kΩ	2.95		3.05	V
V_{DEP_HYS}	Battery Depletion Voltage Hysteresis	Rising edge		200		mV
$V_{BUS\_REG\_ACC}$	BUS Voltage Tolerance in Boost Mode	Not in QC2.0 or QC3.0 mode	-2%		2%	V_{BUS_REG}
V_{BUS_COMP}	BUS Compensation Tolerance in Boost Mode	R_{O_COMP} =300kΩ, I_{BUS}=2A		0.25	0.3	V
$V_{BUS\_OVP\_OTG}$	BUS Voltage OVP Threshold in Discharging Mode	V_{BUS}>=5V	108%	110%	112%	V_{BUS_REG}
I_{LIM_BOOST}	Boost Output Current Limit in Discharging Mode		3.7	4	4.3	A
Switching Frequency						
f_{SWBST}	Boost Switching Frequency Tolerance	V_{BAT}=3.7V,V_{BUS}=5V	400	500	600	kHz
		V_{BAT}=3.7V,V_{BUS}=5V	200	250	300	kHz
Cold/Hot Thermistor Comparator(Use 103-AT thermistor)						
Battery NTC Thermal Protection in Charging Mode						
V_{COLD},V_{T1}	Cold (0 ℃,T1) Threshold	Rising edge	72.8%	73.4%	74%	V_{VDD}
	Cold Hysteresis	Falling edge		4%		
V_{COOL},V_{T2}	Cool (15 ℃,T2) Threshold	Rising edge	58.9%	59.5%	60.1%	
	Cool Hysteresis	Falling edge		2%		
V_{HOT},V_{T3}	Hot (45 ℃,T3) Threshold	Falling edge	32.3%	32.9%	33.5%	
	Hot Hysteresis	Rising edge		4%		

Battery NTC Thermal Protection in Boost Mode						
V_{COLD}	Cold (-20 ℃,T_{COLD}) Threshold	Rising edge	87.1%	87.6%	88.1%	V_{VDD}
	Cold hysteresis	Falling edge		0.8%		
V_{HOT}	Hot (60 ℃,T_{HOT}) Threshold	Falling edge	22.6%	23.15%	23.7%	
	Hot Hysteresis	Rising edge		0.8%		
KEY Active Voltage						
V_{KEY}	KEY Active Low Voltage	Falling edge			0.3	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.

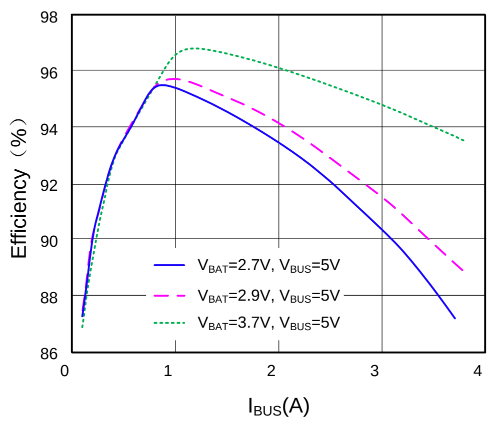
Note 2: θ_{JA} is measured in the natural convection at T_A = 25 ℃ on a high effective four-layer thermal conductivity test board of JEDEC 51-7 thermal measurement standard.

Note 3: The device is not guaranteed to function outside its operating condition

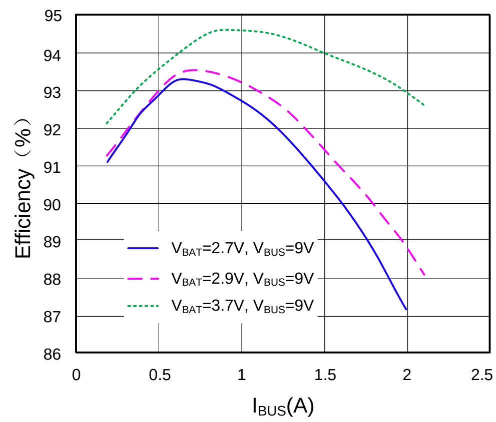
Typical Performance Characteristics

(TA=25 ℃, VIN=5V, unless otherwise specified.)

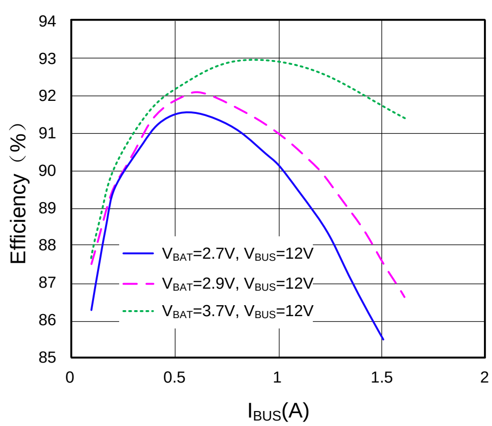
Efficiency vs. Output Current (Boost Mode)



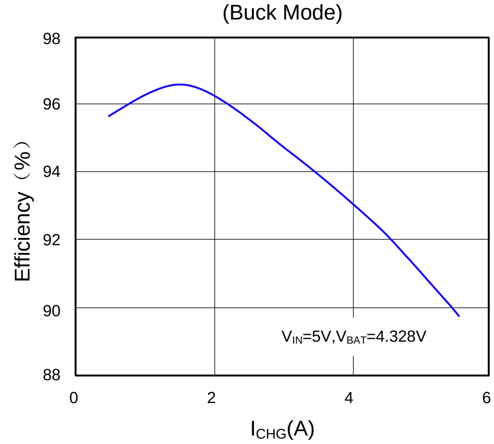
Efficiency vs. Output Current (Boost Mode)



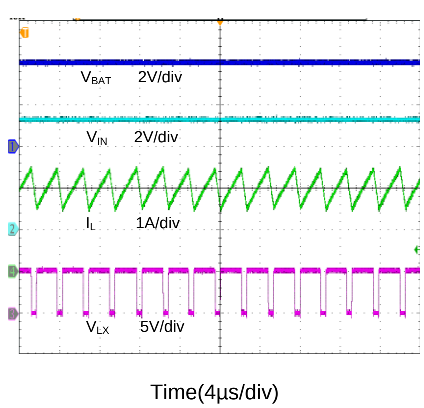
Efficiency vs. Output Current (Boost Mode)



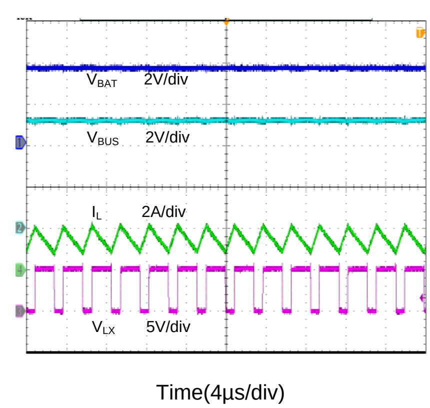
Efficiency vs. Charging Current
(Buck Mode)



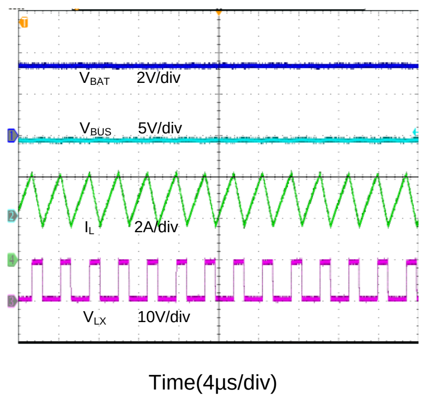
Buck Steady State
(VIN=5V, ICHG=2.0A, CV mode)



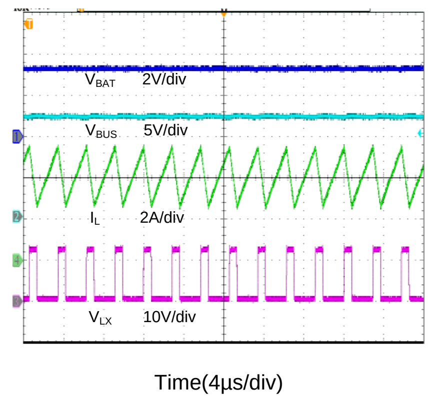
5V Boost Steady State
(VBAT=3.5V, IBUS=1.0A)



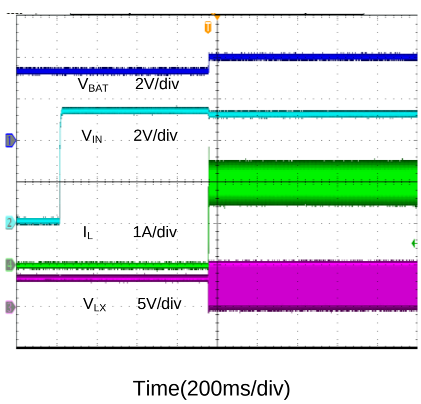
9V Boost Steady State
(V_{BAT}=3.5V, I_{BUS}=1.0A)



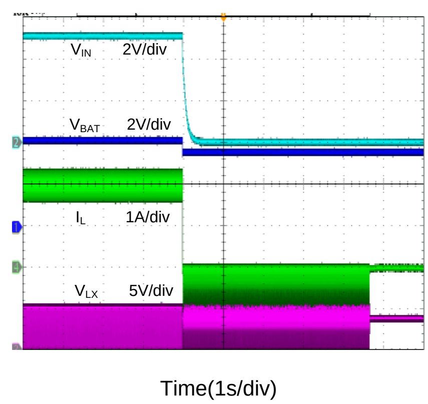
12V Boost Steady State
(V_{BAT}=3.5V, I_{BUS}=1.0A)



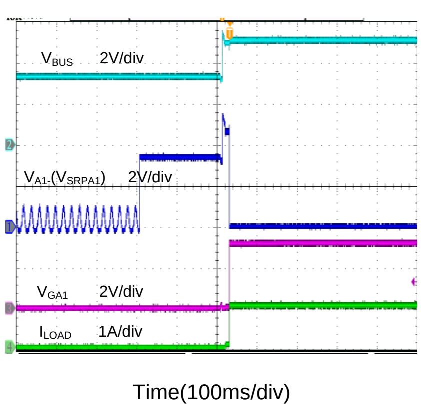
Buck VIN Power ON
(V_{IN}=5V, I_{CHG}=2.0A, CV Mode)



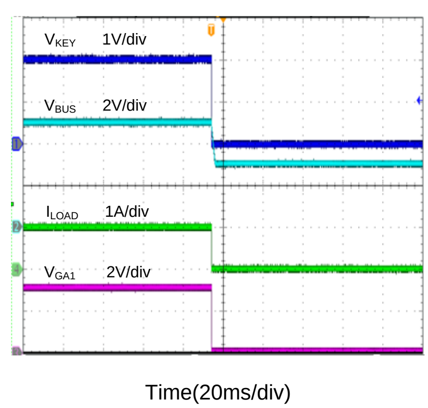
Buck VIN Power OFF
(V_{IN}=5V, I_{CHG}=2.0A, CV Mode)



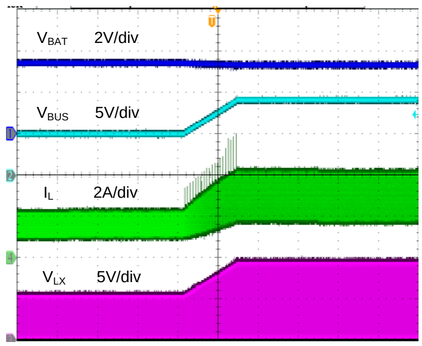
Port A1 ON
(V_{BAT}=3.5V, I_{BUS}=1.0A(Load Insert))



Port A1 OFF
(V_{BAT}=3.5V, I_{BUS}=1.0A(Key Press))

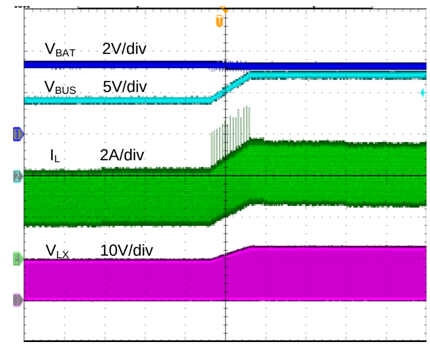


Boost 5V to 9V
(V_{BAT}=3.5V, I_{BUS}=1.0A)



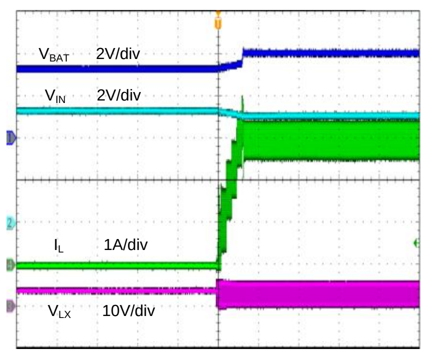
Time(40ms/div)

Boost 9V to 12V
(V_{BAT}=3.5V, I_{BUS}=1.0A)



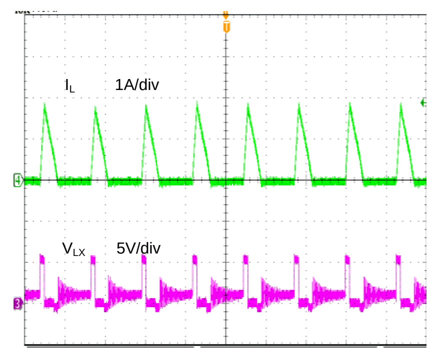
Time(40ms/div)

Inductor current soft start in charging mode
(V_{IN}=5V,I_{CHG}=3.0A)



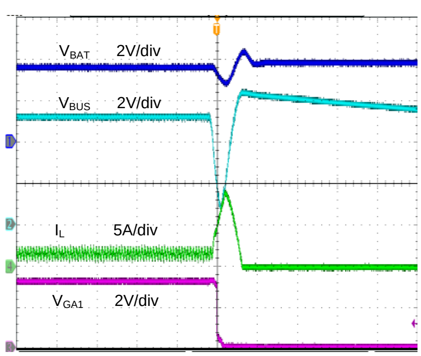
Time(10ms/div)

Battery Short in Charging Mode
(V_{IN}=5V, V_{BAT}=1.5V)



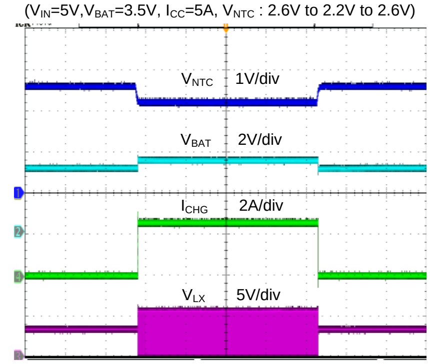
Time(10µs/div)

Port A1 SCP



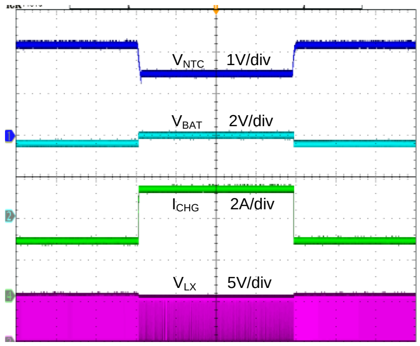
Time(40µs/div)

Charging NTC Protection (Temperature From cold to cool then to cold)
(V_{IN}=5V,V_{BAT}=3.5V, I_{CC}=5A, V_{NTC} : 2.6V to 2.2V to 2.6V)



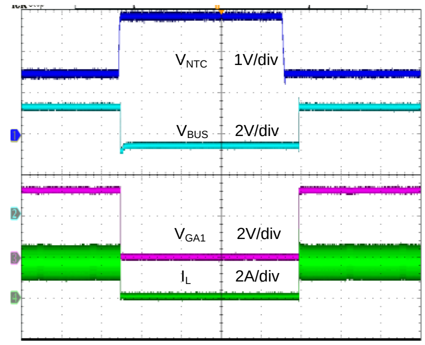
Time(1s/div)

Charging NTC Protection (Temperature From cool to normal then to cool)
(V_{IN}=5V,V_{BAT}=3.5V, I_{CC}=5A, V_{NTC} : 2.2V to 1.5V to 2.2V)



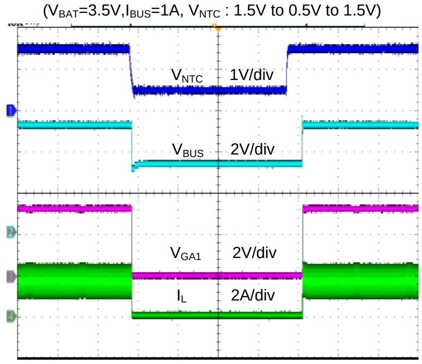
Time(1s/div)

Discharging NTC Protection (Temperature From normal to cold then to normal)
(V_{BAT}=3.5V,I_{BUS}=1A, V_{NTC} : 1.5V to 2.9V to 1.5V)



Time(2s/div)

Discharging NTC Protection (Temperature From normal to hot then to normal)
(V_{BAT}=3.5V,I_{BUS}=1A, V_{NTC} : 1.5V to 0.5V to 1.5V)



Time(2s/div)

Function Description

Charging and Discharging Description

The SY20757 adopts peak current mode control for Buck and Boost converter to implement the charging and discharging of battery. The peak current mode control simplifies the loop design of Buck and Boost converter, optimizes the stability and dynamic performance. There are 4 types of working status in the SY20757: Charging Mode, Discharging Mode, Bypass Mode and Sleep Mode.

Charging Mode Description

The SY20757 will work in Charging Mode when the input source is present on Port B and both Port A1 and A2 are off.

To meet the various input source type, the SY20757 integrates VDPM, IDPM, CC and CV loops in Charging Mode. When an adapter is inserted to Port B, the SY20757 will start the source type detection automatically. The SY20757 sets appropriate constant charging current, constant charging voltage, V_{DPM}, I_{DPM}, termination charging current to minimize the charge time. In normal charging cycle the SY20757 stops charging per 20s to measure the battery level.

Input Voltage Dynamic Power Management

When input voltage drops to V_{DPM}, the input voltage will be limited to V_{DPM} by regulating the duty cycle of Buck convertor. The V_{DPM} loop takes control of the Buck converter until the input voltage rises above V_{DPM}.

The V_{DPM} is set to 90% of the rated USB or adapter voltage in Charging Mode. For 5V adapter input, V_{DPM} is 4.5V.

Input Current Dynamic Power Management

After the USB type Detection, the SY20757 sets the input current limit automatically. When input current reaches I_{DPM}, the input current will be limited to I_{DPM} by regulating the duty cycle of Buck converter. The I_{DPM} loop takes control of the Buck converter until the input current decreases under I_{DPM}.

Constant Charging Current

The constant charging current is programmed by the resister connecting to ICHG pin with the following equation:

$$I_{CHG} = \frac{12\times10^3 V}{R_{CHG}}$$

Where R_{CHG} is the resistance connected to ICHG pin.

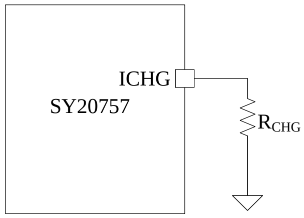


Figure3. Constant Charging Current Set Circuit

Constant Charging Voltage

The constant charging voltage is set by CV pin (described in Table 1).

Table 1 Constant charging voltage vs CV pin state

CV Pin State	Constant Charging Voltage (V_{CV})
Floating	4.178V
Low	4.328V
High	4.378V

Termination Current

When the SY20757 wakes up, the IC will check the resistance connected to GA1/ITERM. The termination current is set to 8% of I_{CHG} when R_{ITERM}>300kΩ, and the termination current is set to 4% of I_{CHG} when R_{ITERM}<50kΩ.

Discharging Mode Description

The SY20757 will work in Discharging Mode when the input source is removed from Port B and at least one of the output ports is on.

If one load insertion signal is detected, the SY20757 will start the Boost converter and turn on this port's N-MOSFET. The SY20757 can identify the charging protocol of the portable device and change the output voltage according to the request of the portable device.

If the 2nd load is detected by the SY20757, the SY20757 will supply these two ports with 5V only.

Boost Output Voltage Compensation

In Boost mode the BUS voltage will be adjusted according to its output current described in Figure4. When the SY20757 wakes up, the IC will check the resistance connected to GA2/VOCOM. The compensation voltage is set to 0.25V at 2A when R_{O_COMP}>300kΩ, the compensation voltage is set to 0.375V at 2A when R_{O_COMP}<50kΩ.

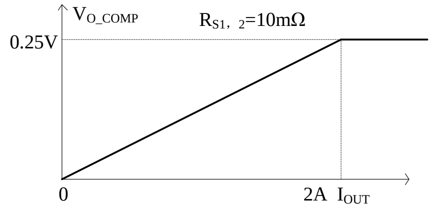


Figure4. Cable Voltage Drop Compensation Curve

Battery Internal Resister Compensation

In Boost mode, the SY20757 uses the RCOM pin to compensate the battery internal resister. The compensation voltage will be added to the battery voltage on BAT pin to get the actual battery voltage.

The compensated battery internal resistance is calculated by following equation:

$$R_{BAT\_INTER} = 45\times10^{-6}\times R_{PEAK2}$$

Where R_{PEAK2} is the resistance connected to RCOM pin.

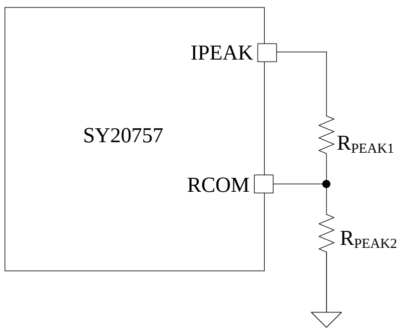


Figure5. Peak Current and Battery Internal Resister Compensation Circuit

Boost Peak Current Setting

I_{PEAK} pin is used for programming the peak current limit of Boost mode.

The peak current is programmed by following equation:

$$I_{PEAK} = \frac{20\times10^{3}V}{R_{PEAK1}+R_{PEAK2}}$$

Where R_{PEAK1} is the resistance connected to IPEAK pin and R_{PEAK2} is the resistance connected to RCOM pin.

Switching Frequency Control

The switching frequency of the SY20757 can be programmed by the pull-up resister on KEY/FSW pin in Boost mode.

The frequency is calculated by the following equation:

$$F_{SW} = \frac{18.5\times10^{9}\Omega\times1Hz}{R_F}$$

Where R_F is the resistance connected to KEY/FSW pin.

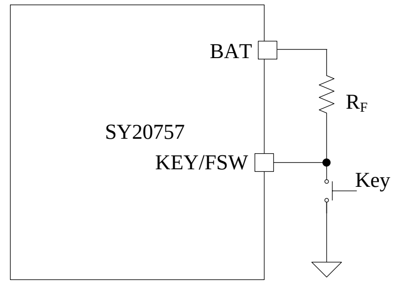


Figure6. Switching frequency set circuit

Output Current Limit of Port A

When the total current of Port A1 and Port A2 exceeds I_{LIM_BOOST}, the current will be limited to I_{LIM_BOOST} by regulating the duty cycle of Boost converter. The Boost CC loop takes control of the Boost converter until the total current of Port A1 and Port A2 is lower than I_{LIM_BOOST}.

Bypass Mode Description

The SY20757 will work in Bypass Mode when the input source is present and at least one of the output ports turns on.

When both the adapter and the portable device are inserted, the SY20757 will charge the battery and deliver power to the output port from the adapter at the same time.

In Bypass Mode the SY20757 disables the fast charging function.

Sleep Mode Description

The SY20757 can turn off the PortA1, PortA2, Port B, VDD, Boost and Buck converter to enter into Sleep Mode when both the adapter and the system load are removed.

Load Insert Detection

The rechargeable portable device insertion on Port A1 or Port A2 will trigger the Load Insert Detection. The IC will start charging the portable device once it is inserted to the SY20757.

Light Load Detection

If the discharging current of the output port is lower than I_{LIGHT} for 25s, the SY20757 will turn off this port.

LED Status Indication Description

Battery Fuel Gauge Indicator Description

The SY20757 indicates the battery level and converter status through 4 LEDs as the following table.

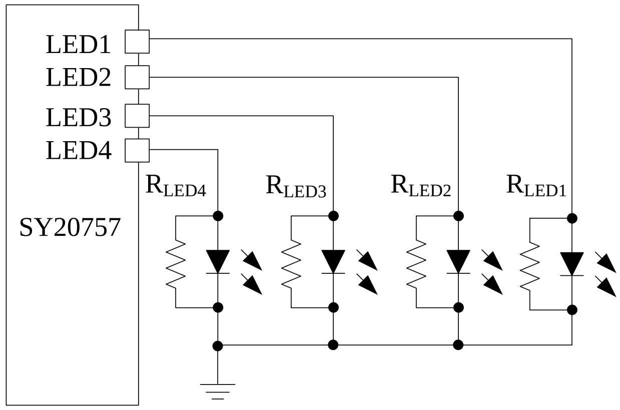


Figure7. LED indication circuit

Table 2 LED status

Operation Mode	Battery Level	V_{BAT}	LED Status			
			LED1	LED2	LED3	LED4
Charging	0-25%	$< V_{TH1}$	Flicker1	OFF	OFF	OFF
	25-50%	V_{TH1}~ V_{TH2}	ON	Flicker1	OFF	OFF
	50-75%	V_{TH2}~ V_{TH3}	ON	ON	Flicker1	OFF
	75-100%	V_{TH3}~V_{CV}	ON	ON	ON	Flicker1
	100%	$\geq V_{CV}$	ON	ON	ON	ON
Discharging	0-25%	V_{DEP} ~ V_{TH1}	Flicker2	OFF	OFF	OFF
	25-50%	V_{TH1}~ V_{TH2}	Flicker2	Flicker2	OFF	OFF
	50-75%	V_{TH2}~ V_{TH3}	Flicker2	Flicker2	Flicker2	OFF
	75-100%	$\geq V_{TH3}$	Flicker2	Flicker2	Flicker2	Flicker2
Sleep			OFF	OFF	OFF	OFF
Fault			Flicker1	Flicker1	Flicker1	Flicker1

Flicker1—ON 1280ms, OFF 1280ms.

Flicker2—ON 320ms, OFF 2240ms.

Battery Level Threshold Description

The resisters parallel to the LEDs are used for programming the battery depletion voltage threshold and the battery level thresholds.

R_{LED1} is used for selecting the battery depletion voltage threshold. Using a 100k(+/-20%) resistor to select 3.0V depletion threshold and 50k(+/-20%) to select 2.6V depletion threshold.

R_{LED2}, R_{LED3} and R_{LED4} are used for programming the battery level threshold V_{TH1}, V_{TH2} and V_{TH3} as below table.

Table 3 Battery Level Threshold

	Charging Mode	Discharging Mode
V_{TH1}	V_{TH1}=83%×V_{CV}+0.5V×R_{LED2}/R_{LED1}	V_{TH1}=80%×V_{CV}+ 0.5V×R_{LED2}/R_{LED1}
V_{TH2}	V_{TH2}=88%×V_{CV}+0.5V×R_{LED3}/R_{LED1}	V_{TH2}=85%×V_{CV}+ 0.5V×R_{LED3}/R_{LED1}
V_{TH3}	V_{TH3}=93%×V_{CV}+0.5V×R_{LED4}/R_{LED1}	V_{TH3}=90%×V_{CV}+ 0.5V×R_{LED4}/R_{LED1}

Key Function

There are 2 types of key action in the SY20757, 1-click action to reset the IC and 2-click action to disable the light load detection function for 2 hours.

Fast Charge Function

Both Port A1 and Port A2 of the SY20757 can support multiple fast charging protocols such as: QC2.0/QC3.0, FCP and AFC mode independently. If both Port A1 and Port A2 are turned on, the SY20757 will disable the fast charging protocols.

Protection Description

Buck Mode

During the half-bridge operating as synchronous Buck mode, the SY20757 has input over voltage protection, input under voltage protection, BAT over voltage protection, BAT short circuit protection, charging timeout protection, thermal shutdown protection and NTC protection for the Li-Ion battery and the IC.

Input Over Voltage Protection- When V_{IN} is higher than the over voltage protection threshold, the half bridge will stop Buck operation immediately. It will recover to normal work when the monitored voltage backs to normal level.

Input Under Voltage Protection- When V_{IN} is lower than V_{IN_UVLO}, the half bridge will stop Buck operation immediately. It will recover to normal work when the monitored voltage backs to normal level.

BAT Over Voltage Protection- When V_{BAT} is higher than the over voltage protection threshold, the half bridge will stop Buck operation immediately. It will recover to normal work when the monitored voltage backs to normal level.

BAT Short Circuit Protection- When V_{BAT} voltage is lower than $V_{BATSHORT}$, the SY20757 will wake the battery up with a small charging current.

Charging Timeout Protection- The SY20757 has two types timeout protection, 20 hours timeout protection for the fast charge mode and 2 hours timeout protection for trickle current mode. Once the timeout protection is triggered, the IC will stop the charge operation and latch off. Only re-plug in the input source can reset the latch logic and restart the normal charging work.

NTC Protection- The SY20757 adopts NTC pin to monitor the temperature of the battery to provide the protection of battery. The current setting at cool temperature (T1–T2) is 50% of the constant charging current. The SY20757 will stop charging when the temperature of the battery is lower than T1 or higher than T3.

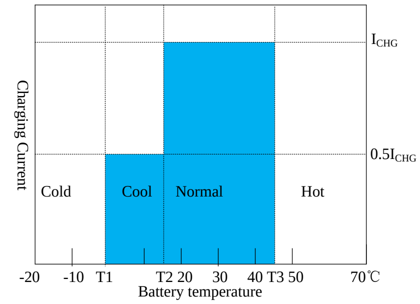


Figure8. Charging current vs Battery temperature

Thermal shutdown- The SY20757 will shut down the IC when the junction temperature exceeds 150 ℃. It will recover to normal work when the junction temperature drops to 130 ℃.

Boost Mode

During the half-bridge operating as synchronous Boost mode, the SY20757 has BUS over voltage protection, BAT depletion protection, BUS short circuit protection, BUS over current protection, DP/DM short to BUS protection, thermal shutdown protection and NTC protection for the Li-Ion battery and IC.

BUS Over Voltage Protection- When V_{BUS} is higher than the over voltage protection threshold, the half bridge will stop Boost operation immediately. It will recover to normal work when the monitored voltage backs to normal level.

Battery Depletion Protection- When the battery voltage is over discharged below V_{DEP}, the SY20757 will stop Boost operation immediately and enter into Sleep Mode.

BUS Short Circuit Protection- When BUS short circuit occurs, the SY20757 will turn off the gate drivers of the output ports immediately. The SY20757 will recover to normal work when the fault removes.

BUS Over Current Protection- When the current of the output port is over I_{PORT_OCP}, the SY20757 will turn off it immediately. The SY20757 will recover to normal work when the fault removes.

NTC Protection- The SY20757 adopts NTC pin to monitor the temperature of the battery to provide the protection of battery. The SY20757 will stop discharging when the temperature of battery is lower than T_{COLD} or higher than T_{HOT} and enters into Sleep Mode.

Applications Information

Because of the high integration of the SY20757, the application circuit based on this regulator IC is rather simple. Only input capacitor C_{IN}, BUS capacitor C_{BUS}, battery capacitor C_{BAT}, inductor L_B, need to be selected for the targeted application specifications.

Input Capacitor C_{IN}

The input capacitor reduces the surge current drawn from the input and the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent high-frequency-switching current from passing to the input.
To minimize the potential noise problem, a typical X7R or better grade ceramic capacitor should be placed really close to the IN and GND pins. Care should be taken to minimize the loop area formed by C_{IN}, and IN/GND pins. 10µF ceramic capacitor is suggested.

Bus Capacitor C_{BUS}

1. Buck mode
The capacitor C_{BUS} acts as the input capacitor of the Buck converter. The input current ripple RMS value is:

$$I_{CBUS\_RMS} = I_{CHG}\sqrt{D(1-D)}$$

where I_{CHG} is the charge current and D is the duty cycle of the Buck converter.

2. Boost mode
C_{BUS} is the output capacitor of Boost converter. C_{BUS} reduces the bus voltage ripple and ensures the stability of the Boost converter. The output current ripple rms value is:

$$I_{CBUS\_RMS} = I_{BUS}\sqrt{\frac{D}{1-D}}$$

where I_{BUS} is the output current of the Boost converter and D is its duty cycle.
At least 20µF ceramic capacitor is suggested.

Battery capacitor C_{BAT}

1. Buck mode
The battery capacitor C_{BAT} acts as the output capacitor of the Buck converter. C_{BAT} is selected to handle the output ripple noise requirements. For the best performance, it is recommended to use X7R or better grade ceramic capacitor. The output voltage ripple is calculated as below:

$$V_{RIP\_BAT\_BUCK} = \frac{(1-D)\times V_{BAT}}{8C_{BAT}F_{SW}{}^{2}L_B}$$

where F_{SW} is the switching frequency of the Buck converter, D is its duty cycle and L_B is its output inductance.

2. Boost mode
C_{BAT} acts as the input capacitor of the Boost converter. The input voltage ripple is calculated as below:

$$V_{RIP\_BAT\_BOOST} = \frac{D\times V_{BAT}}{8C_{BAT}F_{SW}{}^{2}L_B}$$

where F_{SW} is the switching frequency of the Boost converter, D is its duty cycle and L_B is its input inductance.
At least 20µF ceramic capacitor is suggested.

Inductor L_B

The inductor selection trades off between cost, size, and efficiency. A lower inductance value corresponds with smaller size, but results in higher ripple currents, higher magnetic hysteretic losses, and higher output capacitances. However, a higher inductance value benefits from lower ripple current and smaller output filter capacitors, but results in higher inductor DC resistance (DCR) loss. An inductor must not saturate under the worst-case condition.

1. Buck mode
1) Choose the inductance to provide the desired ripple current. It is suggested to choose the ripple current to be about 40% of the average input current. The inductance is calculated as:

$$L_B = \frac{V_{BAT}(1-V_{BAT}/V_{IN\_MAX})}{F_{SW}\times I_{CHG\_MAX}\times 40\%}$$

where F_{SW} is the switching frequency of the Buck converter, I_{CHG_MAX} is the maximum charge current and V_{IN_MAX} is the maximum input voltage.
The SY20757 is quite tolerant of different ripple current amplitude. Consequently, the final choice of inductance can be slightly off the calculation value without significantly impacting the performance.

2) The saturation current rating of the inductor must be selected to be larger than the peak inductor current under full load conditions.

$$I_{SAT\_MIN} > I_{CHG\_MAX} + \frac{V_{BAT}(1-V_{BAT}/V_{IN\_MAX})}{2\times F_{SW}\times L_B}$$

3) The DCR of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement.

2. Boost mode
1) Choose the inductance to provide the desired ripple current. It is suggested to choose the ripple current to be about 40% of the average input current. The inductance is calculated as:

$$L_B = \frac{V_{BAT}(1-V_{BAT}/V_{BUS\_MAX})}{F_{SW}\times I_{DIS\_MAX}\times 40\%}$$

where F_{SW} is the switching frequency of the Boost converter, I_{DIS_MAX} is the maximum discharge current and V_{BUS_MAX} is the maximum Boost output voltage. The SY20757 is quite tolerant of different ripple current amplitude. Consequently, the final choice of inductance can be slightly off the calculation value without significantly impacting the performance.

2) The saturation current rating of the inductor must be selected to be larger than the peak inductor current under full load conditions.

$$I_{SAT\_MIN} > I_{DIS\_MAX} + \frac{V_{BAT}(1 - V_{BAT} / V_{BUS\_MAX})}{2 \times F_{SW} \times L_B}$$

3) The DCR of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement.

Layout Design

The layout design of the SY20757 regulator is relatively simple. For the best efficiency and minimum noise problems, the following components should be placed close to the IC: C_{IN}, C_{BUS}, L_B.

1) It is desirable to maximize the PCB copper area connecting to GND pin to achieve the best thermal and noise performance. If the board space allowed a ground plane is highly desirable.

2) C_{BUS} must get close to Pins BUS and GND. The loop area formed by C_{BUS} and GND must be minimized.

3) C_{IN} should be close to Pins IN and GND. The loop area formed by C_{IN} and GND should be minimized. Figure9 is the recommended layout design.

4) The PCB copper area associated with LX pin must be minimized to avoid the potential noise problem.

5) In high current applications, a RC snubber circuit is suggested to be placed between LX and GND for better EMI.

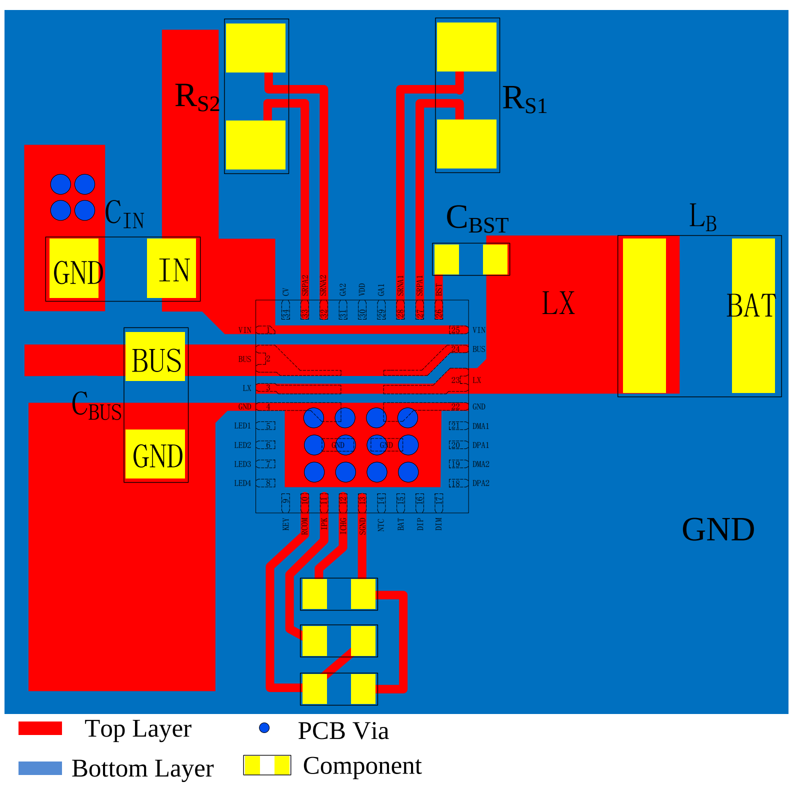
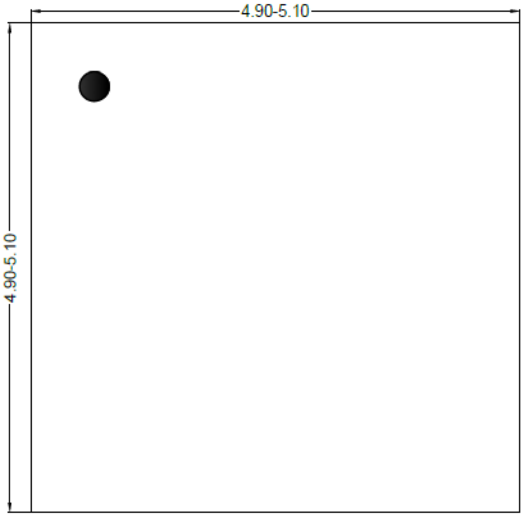
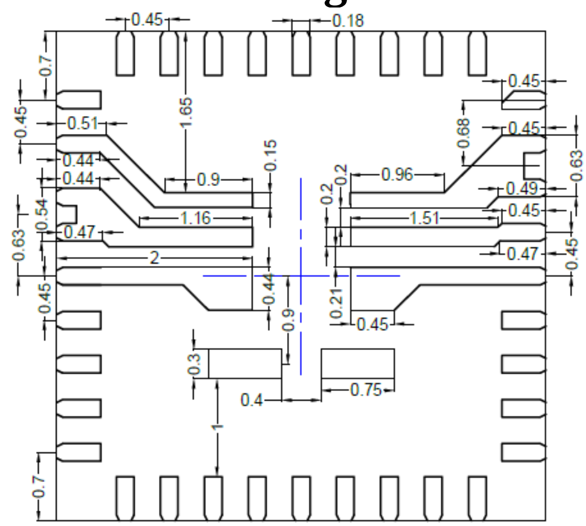


Figure9. PCB Layout

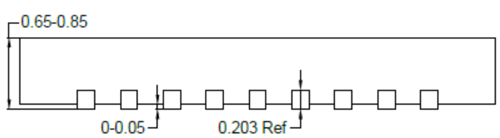
QFN5X5-34 Package Outline Drawing



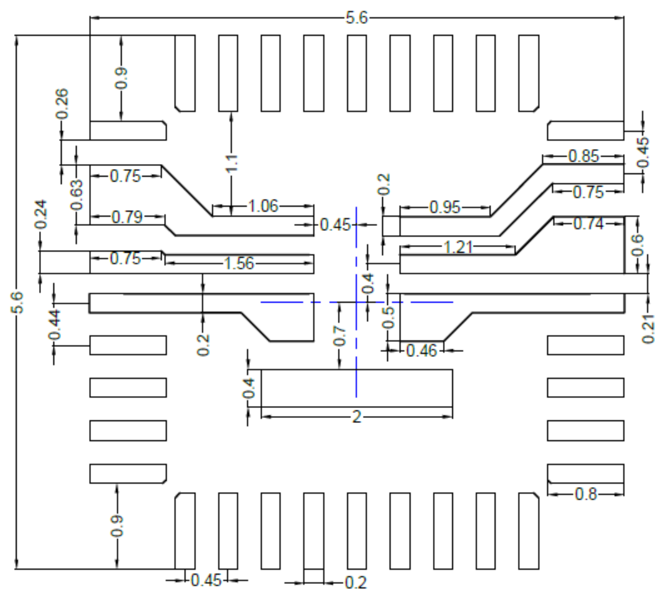
Top view



bottom view



Front view



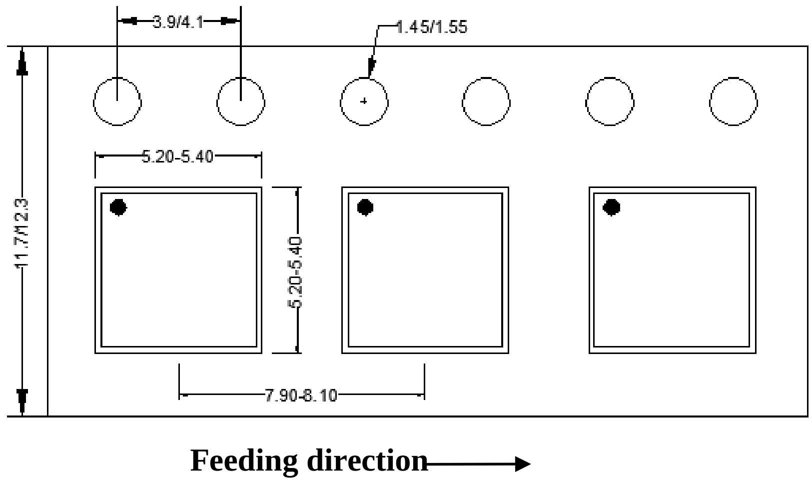
Recommended PCB layout
(Reference only)

Notes: 1, All dimension in millimeter and exclude mold flash & metal burr;
2, the center line refers the chip body center
3, the tolerance of bottom view is ±0.05 for x axis and ±0.1 for y axis;

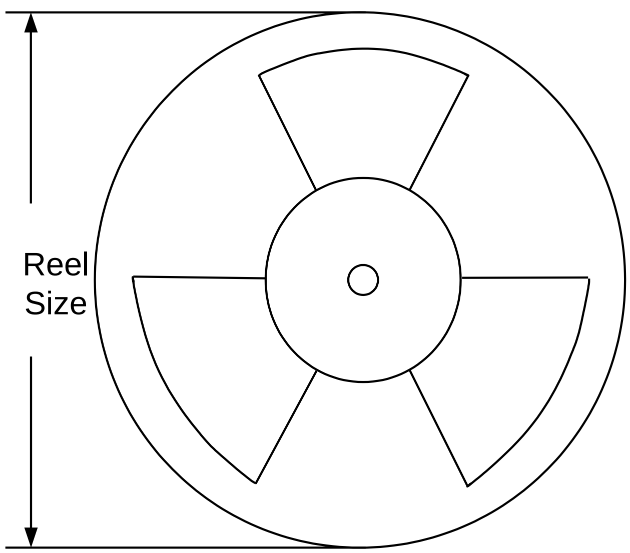
Taping & Reel Specification

1. Taping orientation

QFN5×5



2. Carrier Tape & Reel specification for packages



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length(mm)	Leader length (mm)	Qty per reel
QFN5×5	12	8	13"	400	400	5000

3. Others: NA

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