

DESCRIPTION

The EC3655 is a buck boost converter targets HVDC fast charging system. The EC3655 supports 1 to 3 cells Li-ion battery, the full charge voltage and charge current can be programmed through external resistor. The EC3655 implements the Buck Boost converter with an H-bridge. The integrated low RDS(on) MOSFET minimizes physical footprint, maximizes charge efficiency. Built-in loop compensation simplifies the circuit and design. PFM is engaged to maintain high efficiency at light load current. EC3655 guarantees robustness with thermal protection and battery under voltage lockout.

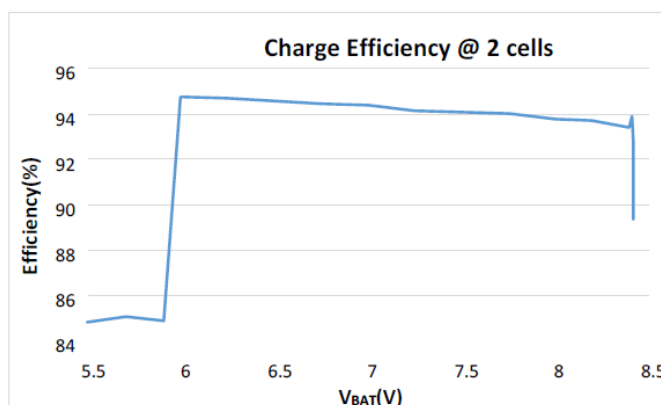
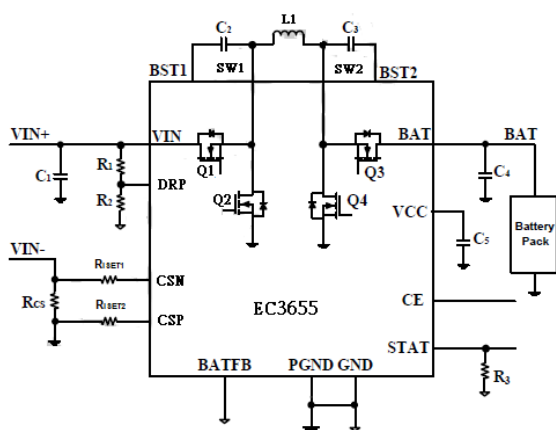
Features

- ◆ Integrate low RDS(on) power MOSFET
- ◆ Wide input range: 4.2V-20.0V, support 1 to 3 cells battery charge
- ◆ Full charge voltage: 1.2V-20.0V through external resistor or selectable by BATFB pin
EC3655A (4.2V/cell)/EC3655A1 (4.35V/cell)
- ◆ High efficiency buck-boost transition
- ◆ 450kHz Switching frequency
- ◆ Programmable charge current, up to 3A
- ◆ Quiescent current: <60uA
- ◆ Integrate battery short protection
- ◆ Integrate thermal protection
- ◆ QFN3*4 package

Applications

- ◆ Power bank systems
- ◆ Battery and super capacitor charging
- ◆ USB power delivery
 - ◆ Industrial applications
- ◆ Automotive systems

Typical application





Ordering/Marking Information

EC3655XX XX X

A : 4.2V/cell
A1 : 4.35V/cell

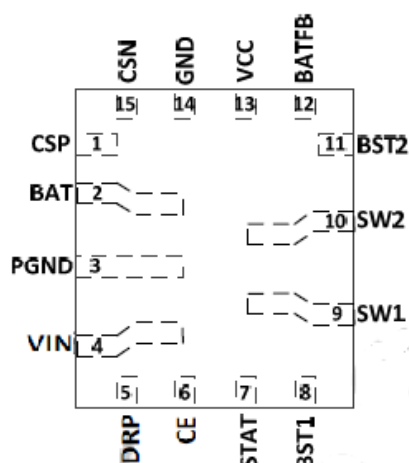
Package Type :
Q4=QFN3*4-15L

R : Tape & Reel

Device	Marking	Package
EC3655AQ4R	JW3655A XXXXXX	QFN3*4-15L
EC3655A1Q4R	JW3655A-1 XXXXXX	

Pin Configurations

TOP VIEW



Absolute Maximum Ratings

VBUS, BAT, SW1, SW2 Pin	-0.3V to 24V
BST1-SW1, BST2-SW2	-0.3V to 6.5V
All Other Pins.....	-0.3V to 6.5V
Junction Temperature (T _J)	150°C
Lead Temperature	260°C
Storage Temperature.....	-65°C to +150°C
ESD Susceptibility (Human Body Model)	2Kv

Recommended Operating Conditions

Input Voltage VIN	4.2V to 20V
BUS Voltage VBUS.....	3.0V to 20V
Operation Junction Temp (T _J).....	-40°C to +125°C



Thermal Performance

	θ_{JA}	θ_{JC}
QFN3X4-15.....	48	11°C/W

Note

- 1) Exceeding these ratings may damage the device.
- 2) The EC3655 guarantees robust performance from -40°C to 150°C junction temperature. The junction temperature range specification is assured by design, characterization and correlation with statistical process controls.
- 3) The EC3655 includes thermal protection that is intended to protect the device in overload conditions. Thermal protection is active when junction temperature exceeds the maximum operating junction temperature. Continuous operation over the specified absolute maximum operating junction temperature may damage the device.
- 4) Measured on JESD51-7, 4-layer PCB.



High Efficiency, 3A, Multi-Cells Li-Ion Battery Charger

EC3655

Electrical Characteristics

VIN=5V, TA=25°C, unless otherwise stated						
Item	Symbol	Condition	Min.	Typ.	Max.	Units
Power supply						
V _{BAT} voltage range	V _{BAT}		3.0		20	V
V _{CC} output voltage	V _{CC}		4.7	5.0	5.3	V
V _{CC} output current limit	I _{VCC}	V _{CC} >2.7V		50		mA
Supply current in shut-down mode	I _Q	V _{BAT} =4V, EN=0V	30		60	μA
Controller						
Switch frequency	F _{sw} ⁵⁾		350	450	450	kHz
Switch minimum off time	T _{off_min} ⁵⁾		80	100	120	ns
CE Logic HIGH	V _{ENH}	V _{BAT} =8V			2.5	V
CE Logic LOW	V _{ENL}	V _{BAT} =8V	1.6			V
Buck top switch on-resistance	R _{dsbkTG} ⁵⁾			20	28	mΩ
Buck bottom switch on-resistance	R _{dsbkBG} ⁵⁾			20	28	mΩ
Boost top switch on-resistance	R _{dsbstTG} ⁵⁾			20	28	mΩ
Boost bottom switch on-resistance	R _{dsbstBG} ⁵⁾			20	28	mΩ
Charge						
Floating BAT Voltage	V _{CV}	V _{BATFB} = GND, EC3655A	8.358	8.4	8.442	V
		V _{BATFB} = GND, EC3655A1	8.656	8.7	8.743	
		Set by divider resistor	3.0	-	20	
BAT feedback voltage	V _{BATFB}	External resistor divider	1.191	1.2	1.212	V
BAT Recharge threshold	V _{REC}	V _{BATFB} = GND	8.118	8.2	8.282	V
BAT recharge feedback threshold	V _{RECFB}	EC3655A	1.159	1.171	1.183	V
		EC3655A1	1.120	1.131	1.142	V
CC mode charge current	I _{CC}	R _{CS} =10mΩ, R _{ISSET1} =2K R _{ISSET2} =1.5K	1.92	2	2.08	A
Charge termination current	I _{TER}	R _{CS} =10mΩ, R _{ISSET1} =2K R _{ISSET2} =1.5K		10%		ICC
Battery full charge deglitch time	T _{FULL}	I _{CC} < I _{TER}		5		s
Trickle mode charge current	I _{TRI}		13%	25%	37%	ICC
Trickle mode battery threshold	V _{TRI}	V _{BATFB} = GND	5.9	6.0	6.1	V
Trickle mode feedback threshold	V _{TRIFB}	EC3655A		0.857		V
		EC3655A1		0.828		V
Trickle charge time-out duration	T _{TRI}		50	55	60	min
VIN UVP threshold	V _{IN_UVP}	V _{IN} rising	4.0	4.2	4.3	V



High Efficiency, 3A, Multi-Cells Li-Ion Battery Charger

EC3655

		VIN falling	3.8	4.0	4.1	V
VIN delay to start charging	t_{chg_delay}			150		ms
DRP reference voltage for adaptive current limit	V_{DRP}		0.885	0.9	0.915	V
Battery current sensing ratio	K_{RATIO}	$R_{CS}=10m\Omega$, $R_{ISET1}=2K$ $R_{ISET2}=1.5K$		3		$\mu A/A$
Protection						
Thermal shutdown threshold ⁵⁾	$T_{SHUT}^{5)}$			150		°C
Thermal recovery threshold ⁵⁾	$T_{REC}^{5)}$			130		°C

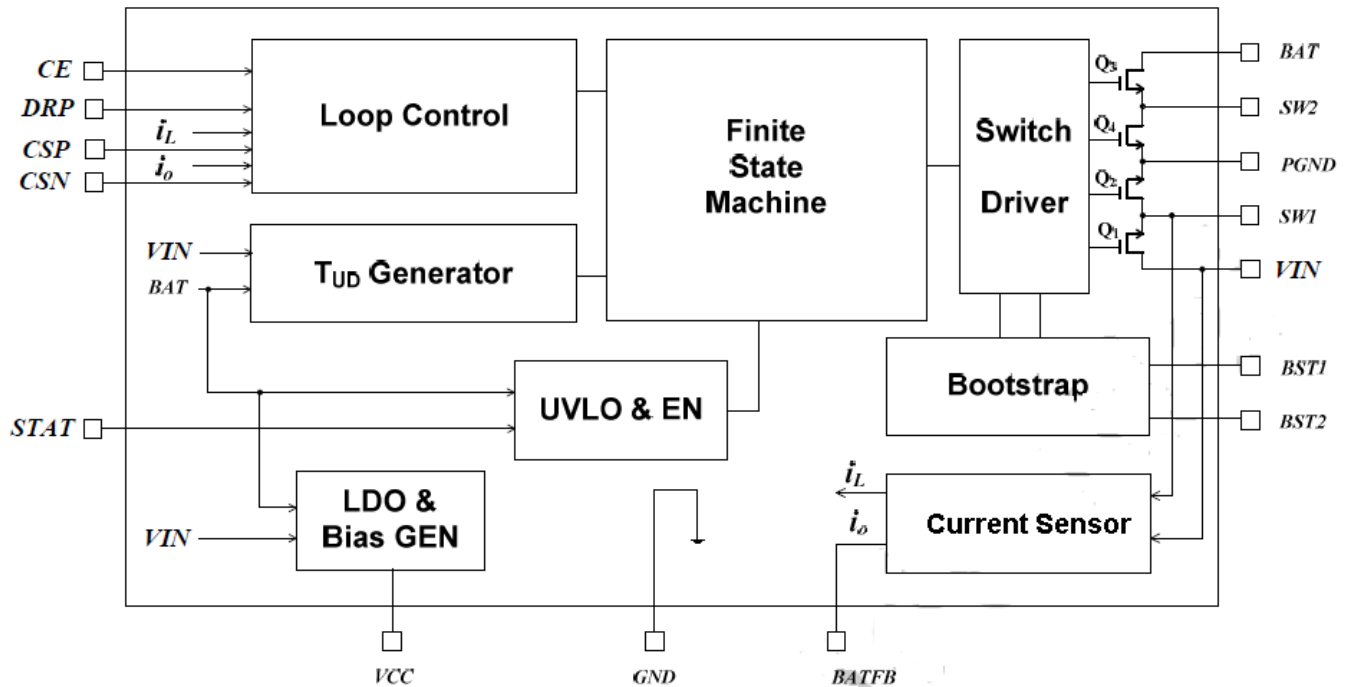
Notes:

5) Guaranteed by design.

Pin Description

Pin No.	Name	Description
1	CSP	Positive terminal of battery charge current sense.
2	BAT	Battery positive terminal.
3	PGND	Power Ground.
4	VIN	Main supply pin, connect to adaptor.
5	DRP	VIN droop allowance program pin.
6	CE	Charge enable pin, a logic High on this pin will enable charge.
7	STAT	This is a multi-purpose Pin. When charge enabled, in the CC charge mode, the pin source current is 6 μA . In the full charge mode, the pin is pulled to high. And the pin also as Fault state output pin, asserted during over temperature or trickle charge time out conditions.
8	BST1	VIN side bootstrap supply pin for top switch. 0.1 μF capacitor is connected between BST1 and SW1 pins.
9	SW1	VIN side power switching node. connect to SW2 with inductor
10	SW2	BAT side power switching node.
11	BST2	BAT side bootstrap supply pin for top switch. 0.1 μF capacitor is connected between BST2 and SW2 pins.
12	BATFB	Battery float voltage configuration pin. 1. This pin tied to GND, sets 2 cells float voltage. Pin short to GND: 8.4V/8.7V. 2. And the float voltage could be set to any value (3.0V - 20.0V) by the external divider resistor.
13	VCC	5V LDO for power driver and internal circuit. Must be bypassed to GND with a minimum of 10 μF ceramic capacitor for stable operation.
14	GND	Signal GND.
15	CSN	Negative terminal of battery charge current sense.

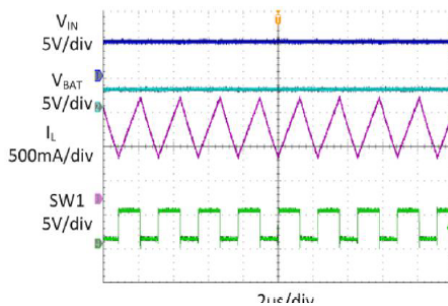
Block Diagram



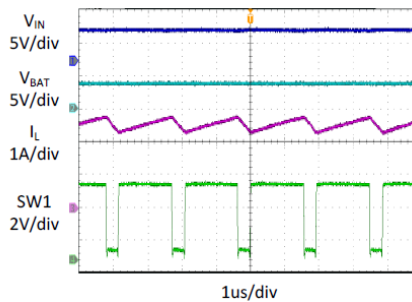
Typical Performance Characteristics

$V_{IN} = 5V$, $L = 3.3\mu H$, $C_{IN} = 20\mu F$, $C_{OUT} = 20\mu F$, $T_A = +25^\circ C$, unless otherwise noted

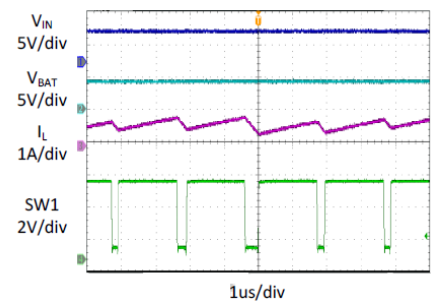
Trickle charge @ 1 cell



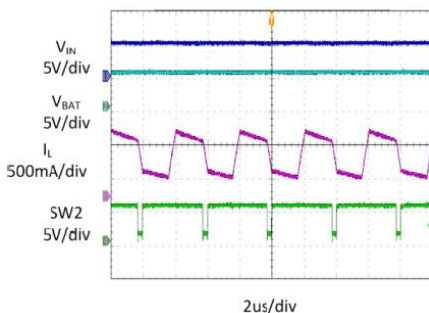
Constant current charge @ 1 cell



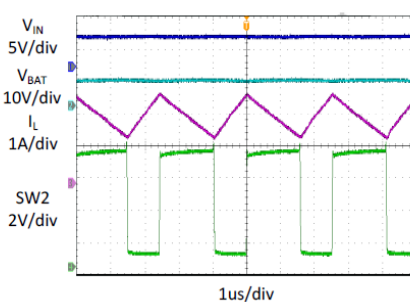
Constant voltage charge @ 1 cell



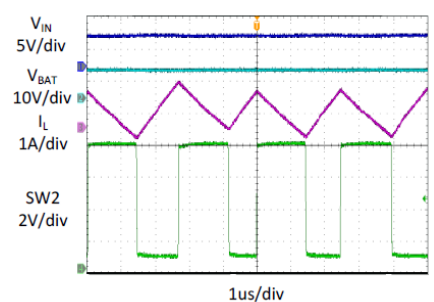
Trickle charge @ 2 cells



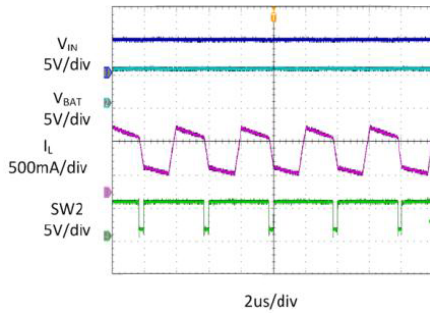
Constant current charge @ 2 cells



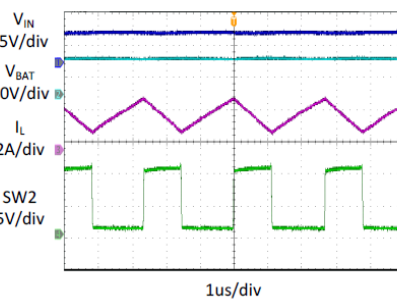
Constant voltage charge @ 2 cells



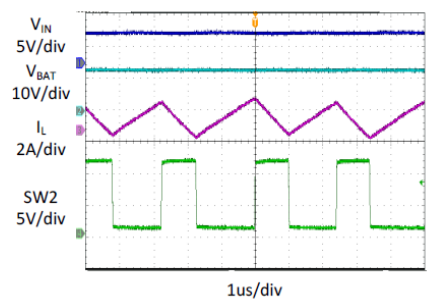
Trickle charge @ 3 cells



Constant current charge @ 3 cells



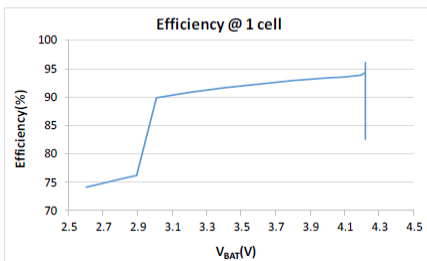
Constant voltage charge @ 3 cells



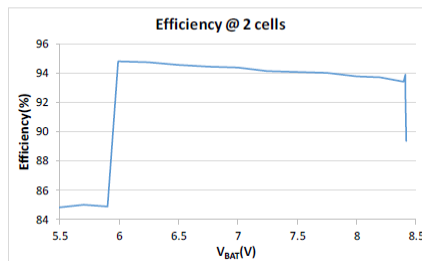
Typical Performance Characteristics(Continued)

VIN = 5V, L = 3.3μH, CIN = 20μF, COUT = 20μF, TA = +25°C, unless otherwise noted

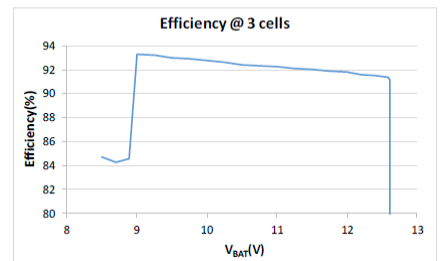
Charge efficiency @ 1 cell



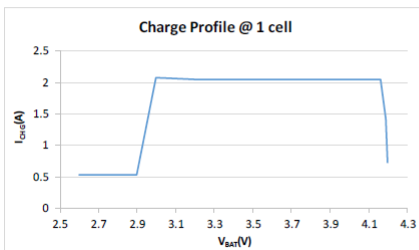
Charge efficiency @ 2 cells



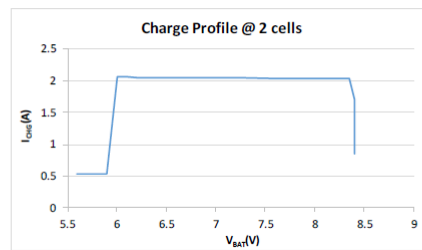
Charge efficiency @ 3 cells



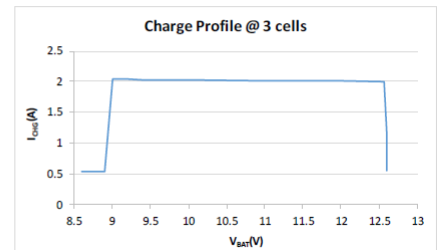
Charge current vs. VBAT @ 1 cell



Charge current vs. VBAT @ 2



current vs. VBAT @ 3 cells



Functional Description

EC3655 is a monolithic buck-boost charger that can operate over a wide input voltage range of 4.2V to 20V. The full Charge voltage and charge current can be programmable through external resistor. Low $R_{DS(on)}$ N-channel power switches reduce the solution complexity and improve the efficiency. The DC-DC converter utilizes proprietary single inductor current-mode control to guarantee smooth transition between buck and boost

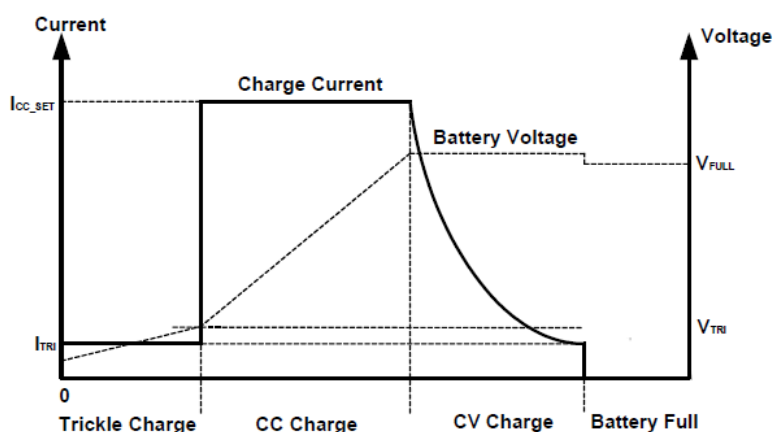
operation with better dynamic

response and cycle-by-cycle current protection. Compensation is done internally on the chip. The EC3655 operates in PFM mode at light load. In PFM mode, switching frequency is continuously controlled in proportion to the load current, i.e. switch frequency is decreased when load current drops to boost power efficiency at light load by reducing switching-loss, minimizing the circuit. The EC3655 can operate in charge mode if a logic High is on CE pin. In charge mode, if the VIN voltage is lower than battery voltage, it is a buck converter. When the VIN voltage is larger than battery voltage, it is a boost converter.

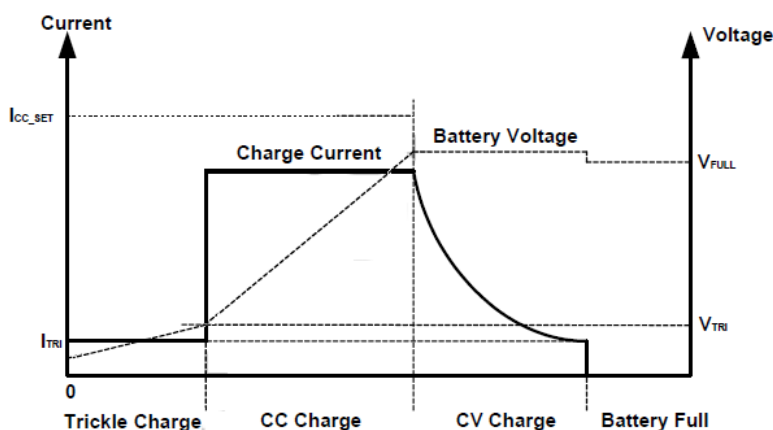
Charge mode

In charge mode, EC3655 regulates the battery current according to input voltage and battery voltage.

It charges battery with three phases: trickle charge, constant current charge, constant voltage charge and charge termination. Figure 1(a) is a typical charge profile. Figure 1(b) is a charge profile with input current limit. When the input current is limited, the system decreases the charge current.



a) Without input



b) With input current limit

Figure 1 Typical Charge Profile

Trickle charge

The EC3655 charges the battery with I_{TRI} when battery voltage is less than V_{TRI} . If charging remains in TC mode beyond the trickle-charge time T_{TRI} , charging terminates.

CC charge

When the battery is higher than V_{TRI} , the device charges the battery with I_{CC} if the input current is sufficient. When input current limit is hit, the device reduces the charge current automatically. The EC3655 can set the charge current through R_{SET1} and R_{SET2} , we recommend R_{SET1}/R_{SET2} is around 4/3. The maximum charge current is up to 3.4A.

$$I_{CC}(A) = \frac{10(A)R_{SET1}(k\Omega)}{R_{CS}(m\Omega)}$$

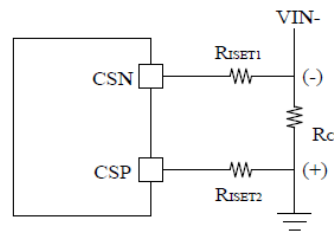


Figure 2 Typical Charge Profile

For 1A cc charge current, we recommend $R_{SET1}=2k$, $R_{SET2}=1.5k$, $R_{CS}=20m\Omega$; and for 2A cc charge current, we recommend $R_{SET1}=2k$, $R_{SET2}=1.5k$, $R_{CS}=10m\Omega$.

CV charge

When battery voltage equals to V_{CV} , the device regulates the battery voltage and reduces the charge current. The customer can select 2 cells or program the V_{CV} through $BATFB$ pin. Connect $BATFB$ to GND selects 2 cells. The V_{CV} can also be programmable by resistor divider connected to $BATFB$, when the EC3655 detect a resistor connect to this pin. We recommend the 1% accuracy resistor should be used in order to achieve the accuracy of full charge voltage. The full charge voltage configure shows in figure 3.

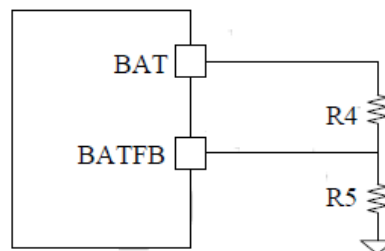


Figure 3 Full Charge Voltage Configure

$$V_{CV}(V) = \frac{1.2V \times (R_4 + R_5)}{R_5}$$

Charge termination

If the battery voltage is higher than VFULL, and the charge current is less than charge termination current ITER for TFULL, the charge process terminates. Once the battery charge cycle completes, the charger remains off. A new charge cycle automatically begins when the battery voltage falls below the auto-recharge threshold VREC if the input adaptor is present. The idle mode to charge mode transition also restarts the charge cycle.

Charging status indication description

In charge mode, the charge current is monitored continuously through STAT pin. In the CC charge mode, the pin source current is 6μA, and if the ICC is 2A, the current sensing ratio is 3μA/A. When Charge process terminates, the STAT pin is pulled to high. If over temperature protection or trickle charge time beyond TTTR1, the EC3655 is in fault mode. the STAT pin will send out high and low voltage alternatively with 1.25Hz.

Dynamic input Current Tracking Scheme

After the CE pin is pulled high, the device detects the VIN pin, if the VIN pin voltage is higher than VIN_UMP rising threshold for 150ms, the EC3655 starts charging with a limited charging current. When the adaptor is over load, the DRP pin drops below the internal reference 0.9V, EC3655 will decrease the charging current. We recommend the ratio of R1/R2 is around 4 and R1 need less than 10kΩ. The input voltage sense shows in figure 4, choose R1, R2 to set the input voltage threshold.

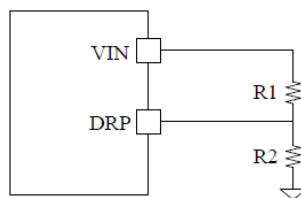


Figure 4 VIN Droop Voltage Configure

$$V_{IN_ALLOWANCE}(V) = \frac{V_{DRP}(V) \times (R_1 + R_2)}{R_2}$$

Thermal Control

When the junction temperature of the EC3655 rises above 135°C, it begins to reduce the output power to prevent the temperature from rising further. If the junction temperature of the EC3655 rises above 150°C, the discharging process stops.

Shut-down Mode

The EC3655 shuts down when voltage at CE pin is below 0.8V. The entire regulator is off.

PCB Layout Note

For minimum noise problem and best operating performance, the PCB is preferred to following the guidelines as reference.

1. Place the input decoupling capacitor as close to EC3655 (VIN pin and PGND) as possible to eliminate noise at the input pin. The loop area formed by input capacitor and GND must be minimized.
2. Put the current sense resistor RCS as close as possible to the current set resistors Riset for better current accuracy.
3. The ground plane on the PCB should be as large as possible for better heat dissipation

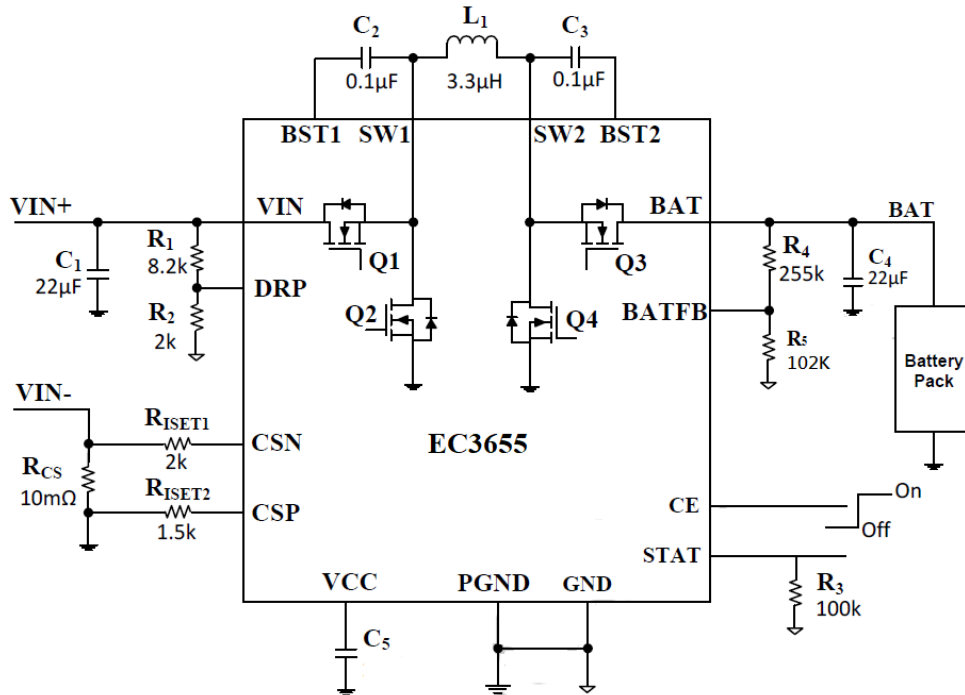
Reference Design

Reference 1 : Single cell charge with input current limit

VIN: 4.6V ~ 20V

VBAT: 3V ~ 4.2V

IIN_LIM : 2A

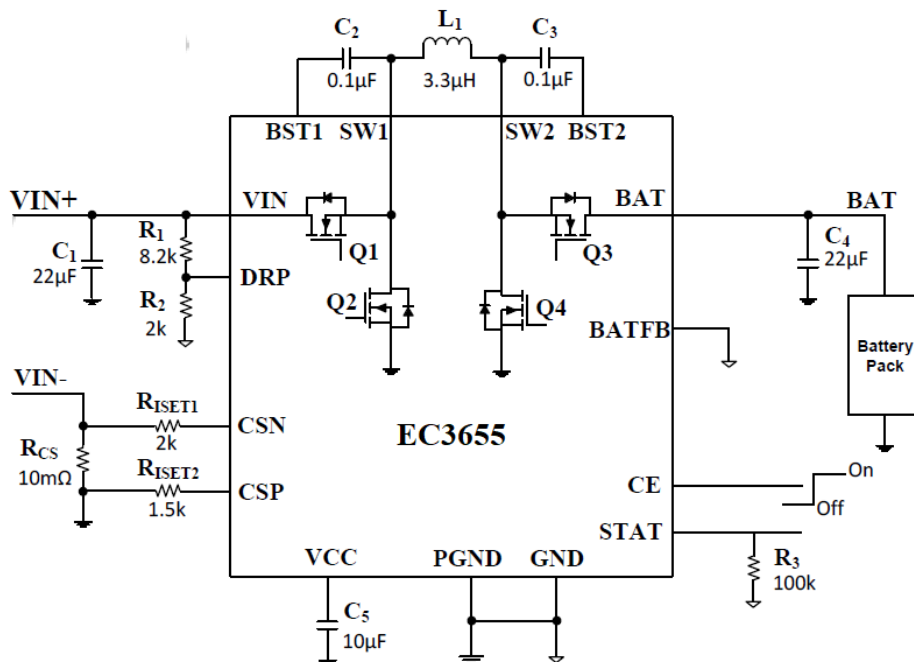


Reference 2 : 2 cells charge with input current limit

VIN: 4.6V ~ 20V

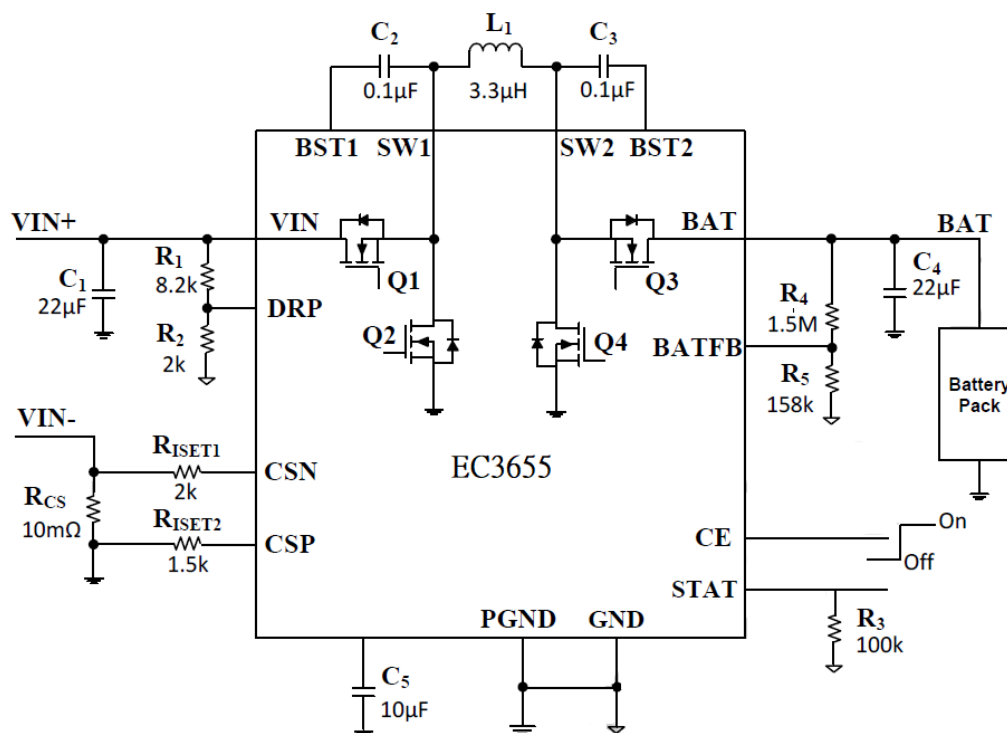
VBAT: 6V ~ 8.4V

IIN_LIM : 2A



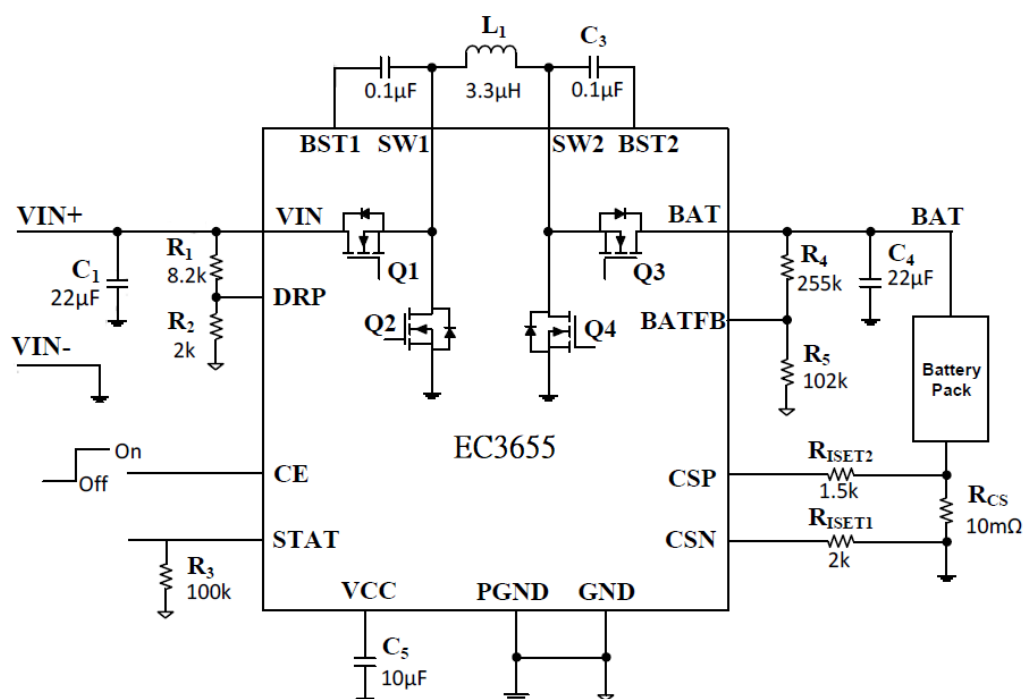
Reference 3 : 3 cells charge with input current limit

VIN: 4.6V ~ 20V
 VBAT: 9V ~ 12.6V
 IIN_LIM : 2A



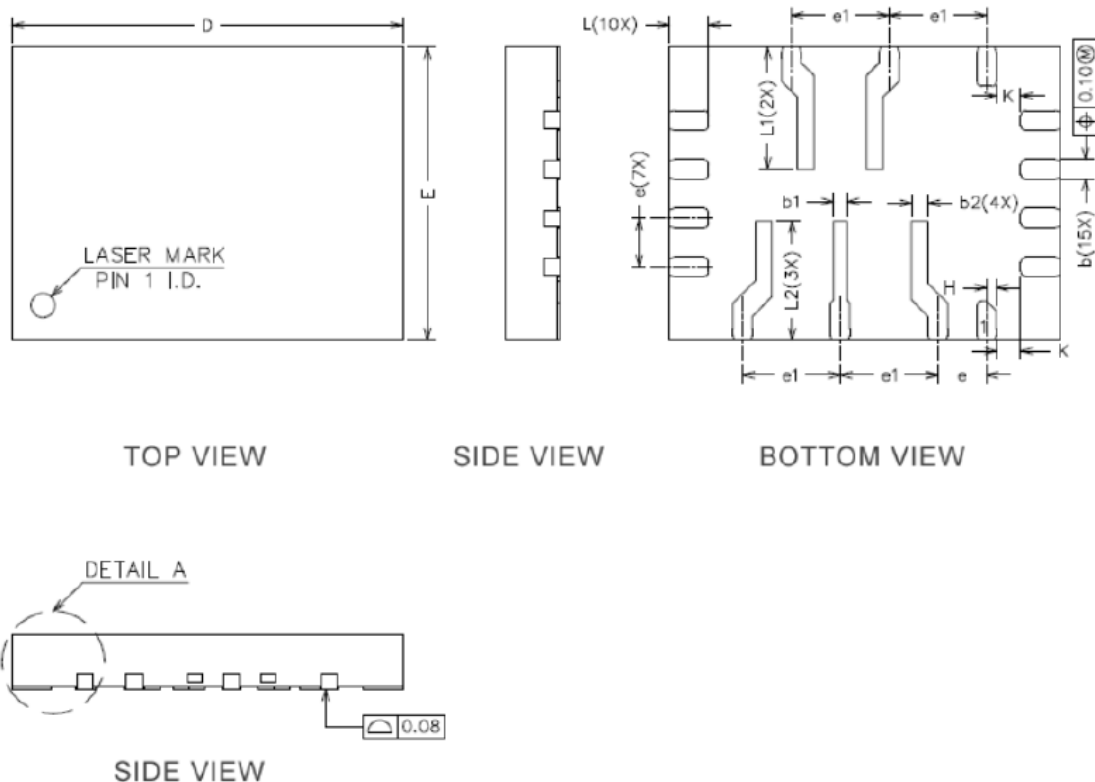
Reference 4 : Single cell charge with battery current limit

VIN: 4.6V ~ 20V
 VBAT: 3V ~ 4.2V
 IBAT_LIM : 2A



Package Outline

QFN3X4-15



E-CMOS C

SYMBOL	MIN	NOM	MAX
A	0.50	0.55	0.60
A1	0.00	0.02	0.05
A3	0.15REF		
b	0.15	0.20	0.25

01



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