

*Parameters Subject to Change Without Notice*

### DESCRIPTION

The JW<sup>®</sup>3655E is a buck boost converter targets HVDC fast charging system.

The JW3655E supports 1 to 4 cells Li-ion battery, the full charge voltage and charge current can be programmed through external resistor.

The JW3655E implements the Buck Boost converter with an H-bridge. The integrated low  $R_{DS(on)}$  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.

JW3655E guarantees robustness with thermal protection and battery under voltage lockout.

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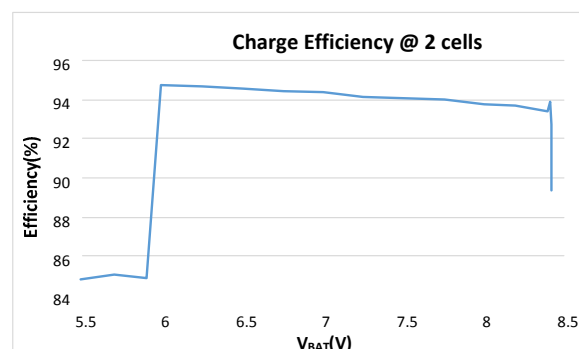
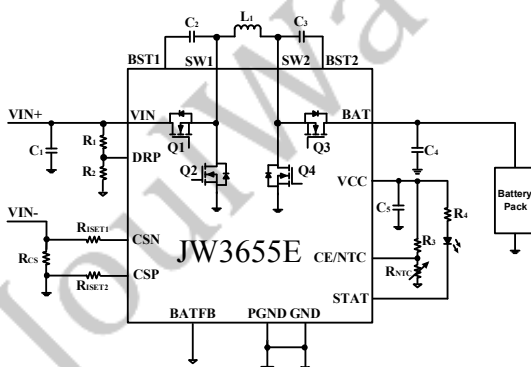
### FEATURES

- Integrate low  $R_{DS(on)}$  power MOSFET
- Wide input range: 4.2V-21.0V, support 1 to 4 cells battery charge
- Full charge voltage: 1.2V-17V through external resistor or selectable by BATFB pin
- High efficiency buck-boost transition
- 450kHz Switching frequency
- Programmable charge current, up to 3A
- Quiescent current: <5uA
- Integrate battery short protection
- Integrate thermal protection
- QFN3\*4 package

### APPLICATIONS

- Power bank systems
- Battery and supercapacitor charging
- USB power delivery
- Industrial applications
- Automotive systems

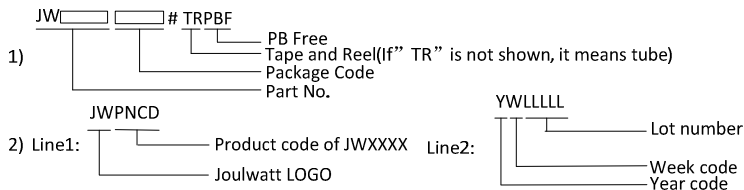
### TYPICAL APPLICATION



**ORDER INFORMATION**

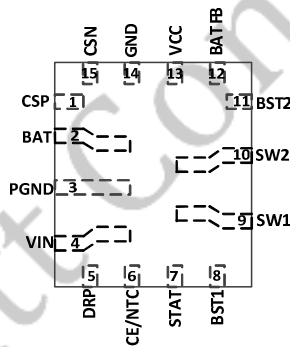
DEVICE <sup>1)</sup>	PACKAGE	TOP MARKING <sup>2)</sup>
JW3655EQFNE#TRPBF	QFN3X4-15	JW3655E YWLLLLL

**Notes :**



**PIN CONFIGURATION**

**TOP VIEW**



**ABSOLUTE MAXIMUM RATING<sup>1)</sup>**

VIN, 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 <sup>2)3)</sup> .....	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 21V
Battery Voltage VBAT .....	3.0V to 17V
Operation Junction Temp (T <sub>J</sub> ) .....	-40°C to +125°C

**THERMAL PERFORMANCE<sup>4)</sup>**

	$\theta_{JA}$	$\theta_{JC}$
QFN3X4-15.....	48.....	11°C/W

**Note:**

- 1) Exceeding these ratings may damage the device.
- 2) The JW3655E 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 JW3655E 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.

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**ELECTRICAL CHARATERISTICS**

<i>VIN=5V, TA=25 °C, unless otherwise stated</i>						
Item	Symbol	Condition	Min.	Typ.	Max.	Units
<b>Power supply</b>						
VBAT voltage range	V <sub>BAT</sub>		3.0		21	V
VCC output voltage	V <sub>CC</sub>		4.7	5.0	5.3	V
VCC output current limit	I <sub>VCC</sub>	VCC>2.7V		50		mA
Supply current in shut-down mode	I <sub>Q</sub>	V <sub>BAT</sub> =8V, CE=0V		3	5	µA
<b>Controller</b>						
Switch frequency	F <sub>sw</sub> <sup>5)</sup>		350	450	450	kHz
Switch minimum off time	T <sub>off_min</sub> <sup>5)</sup>		80	100	120	ns
Charge enable Threshold	V <sub>CE</sub>		14.7%	16.7%	18.7%	V <sub>CC</sub>
Bucktop switch on-resistance	R <sub>dsbkTG</sub> <sup>5)</sup>			20	28	mΩ
Buck bottom switchon-resistance	R <sub>dsbkBG</sub> <sup>5)</sup>			20	28	mΩ
Boost top switch on-resistance	R <sub>dsbstTG</sub> <sup>5)</sup>			20	28	mΩ
Boost bottom switch on-resistance	R <sub>dsbstBG</sub> <sup>5)</sup>			20	28	mΩ
<b>Charge</b>						
Floating BAT Voltage	V <sub>CV</sub>	V <sub>BATFB</sub> = GND	8.358	8.4	8.442	V
		Set by divider resistor	3.0	-	17	
BAT feedback voltage	V <sub>BATFB</sub>	External resistor divider	1.191	1.2	1.212	V
BAT Recharge threshold	V <sub>REC</sub>	V <sub>BATFB</sub> = GND	8.118	8.2	8.282	V
BAT recharge feedback threshold	V <sub>RECFB</sub>	External resistor divider	1.159	1.171	1.183	V
CC mode charge current	I <sub>CC</sub>	R <sub>CS</sub> =10mΩ, R <sub>ISET1</sub> =2K R <sub>ISET2</sub> =1.5K	1.9	2	2.1	A
Charge termination current	I <sub>TER</sub>	R <sub>CS</sub> =10mΩ, R <sub>ISET1</sub> =2K R <sub>ISET2</sub> =1.5K		10%		I <sub>CC</sub>
Battery full charge deglitch time	T <sub>FULL</sub>	I <sub>CC</sub> < I <sub>TER</sub>		500		ms
Trickle mode charge current	I <sub>TRI</sub>		10%	20%	30%	I <sub>CC</sub>
Trickle mode battery threshold	V <sub>TRI</sub>	V <sub>BATFB</sub> = GND	5.9	6.0	6.1	V
Trickle mode feedback threshold	V <sub>TRIFB</sub>			0.857		V
Trickle charge time-out duration	T <sub>TRI</sub>			55		min
VIN UVP threshold	V <sub>IN_UVP</sub>	VIN rising	4.0	4.2	4.3	V
		VIN falling	3.8	4.0	4.1	V
VIN delay to start charging	T <sub>chg_delay</sub>			150		ms
DRP reference voltage for adaptive current limit	V <sub>DRP</sub>		0.885	0.9	0.915	V
<b>Protection</b>						

Battery under temperature protection threshold	$V_{UTP}$		70.2%	72.2%	74.2%	$V_{CC}$
Battery over temperature protection threshold	$V_{OTP}$		27.2%	29.2%	31.2%	$V_{CC}$
Thermal shutdown threshold <sup>5)</sup>	$T_{SHUT}^{5)}$			150		°C
Thermal recovery threshold <sup>5)</sup>	$T_{REC}^{5)}$			130		°C

**Notes:**

5) Guaranteed by design.

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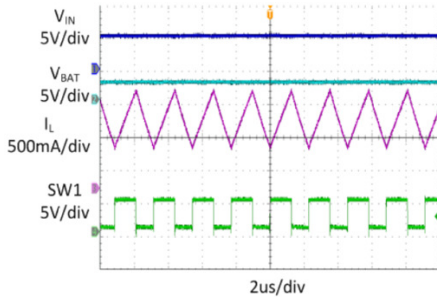
**PIN DESCRIPTION**

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/NTC	This is a multi-purpose pin. 1. Charge enable pin. 2. Battery temperature protection pin.
7	STAT	Open-drain charge status output. Connect the STAT pin to a logic rail via 10kΩ resistor. The STAT pin indicates charger status. Connect a current limit resistor and a LED from VCC to this pin. Charge in progress: LOW Charge complete or charger in SLEEP mode: HIGH Charge suspend (fault response): 1-Hz, 50% duty cycle pulses.
8	BST1	VIN side bootstrap supply pin for top switch. 0.1uF 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. 0.1uF 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. 2. And the float voltage could be set to any value (3.0V-17V) by the external divider resistor.
13	VCC	5V LDO for power driver and internal circuit. Must be bypassed to GND with a minimum of 10uF ceramic capacitor for stable operation.
14	GND	Signal GND.
15	CSN	Negative terminal of battery charge current sense.

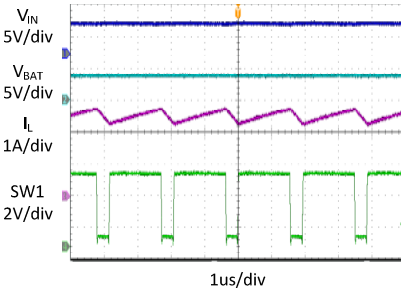
TYPICAL PERFORMANCE CHARACTERISTICS

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

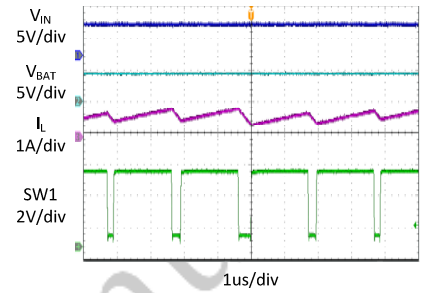
Tricklecharge @ 1 cell



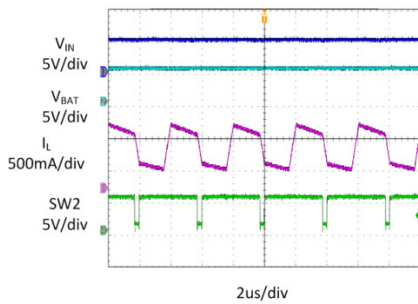
Constantcurrentcharge@ 1 cell



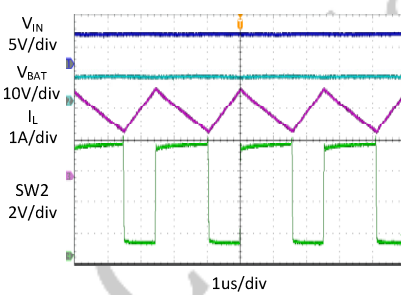
Constantvoltagecharge@ 1 cell



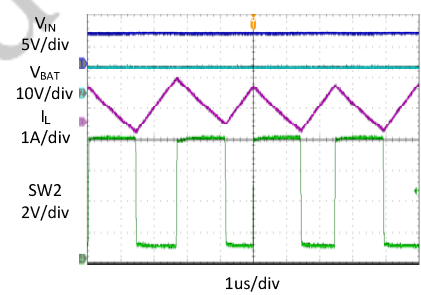
Tricklecharge @ 2 cells



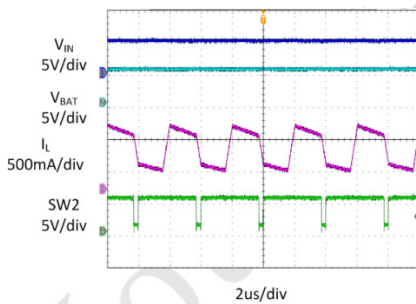
Constantcurrentcharge@ 2 cells



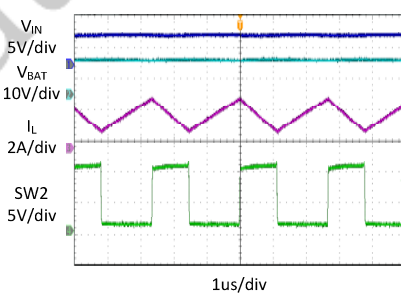
Constantvoltagecharge@ 2 cells



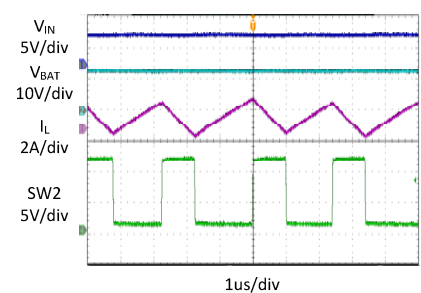
Tricklecharge @ 3 cells



Constantcurrentcharge@ 3 cells



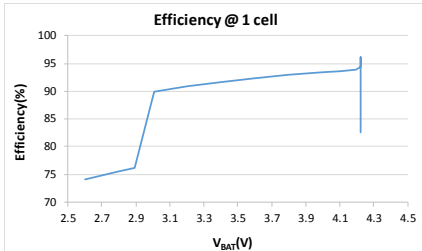
Constantvoltagecharge@ 3 cells



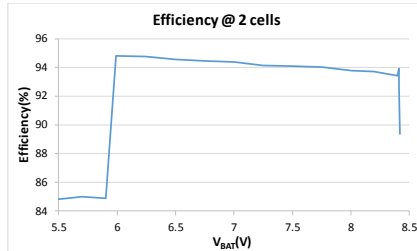
**TYPICAL PERFORMANCE CHARACTERISTICS(Continued)**

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

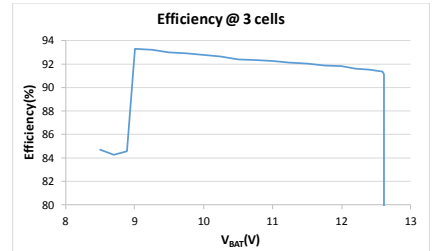
**Charge efficiency @ 1 cell**



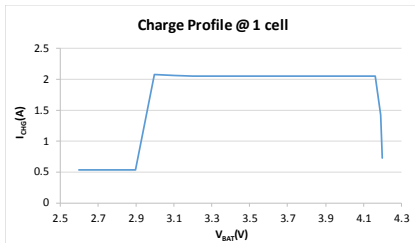
**Charge efficiency @ 2 cells**



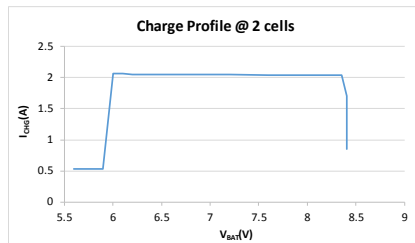
**Charge efficiency @ 3 cells**



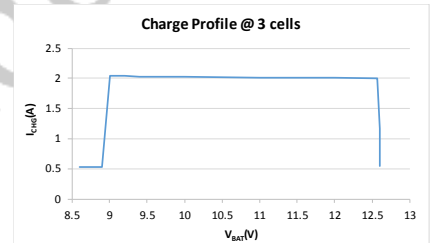
**Charge current vs. VBAT @ 1 cell**



**Charge current vs. VBAT @ 2 cells**



**Charge current vs. VBAT @ 3 cells**



## FUNCTIONAL DESCRIPTION

JW3655E is a monolithic buck-boost charger that can operate over a wide input voltage range of 4.2V to 17V. 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 JW3655E 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 JW3655E 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 boost converter. When the VIN voltage is higher than battery voltage, it is a buck converter.

### Charge mode

In charge mode, JW3655E 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.

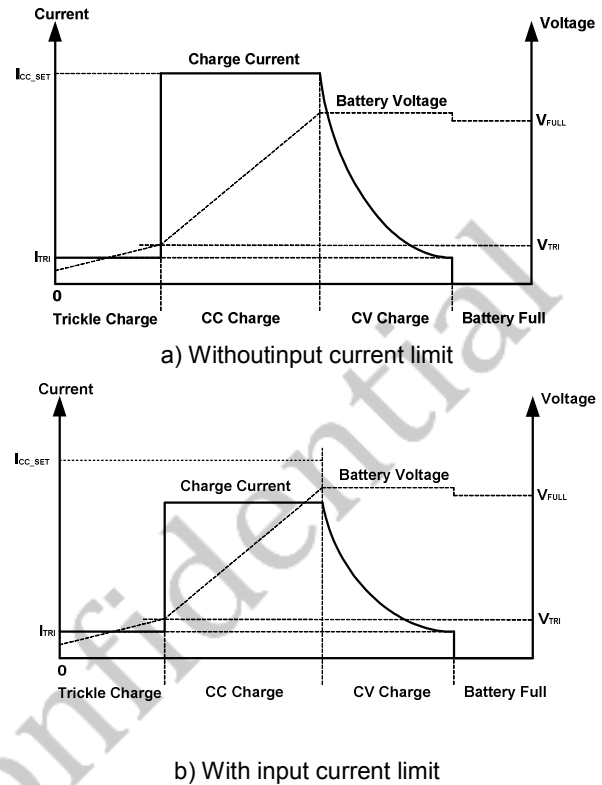


Figure 1 Typical Charge Profile

### Trickle charge

The JW3655E 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 JW3655E can set the charge current through  $R_{ISET1}$  and  $R_{ISET2}$ , we recommend  $R_{ISET1}/R_{ISET2}$  is around 4/3. The maximum charge current is up to 3A.

$$I_{CC}(A) = \frac{10(A)R_{ISET1}(k\Omega)}{R_{CS}(m\Omega)}$$

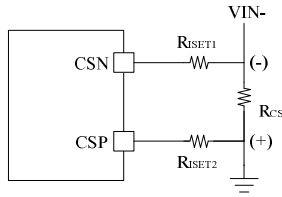


Figure 2 Typical Charge Profile

For 1A cc charge current, we recommend  $R_{ISET1}=2k$ ,  $R_{ISET2}=1.5k$ ,  $R_{CS}=20m\Omega$ ; and for 2A cc charge current, we recommend  $R_{ISET1}=2k$ ,  $R_{ISET2}=1.5k$ ,  $R_{CS}=10m\Omega$ .

**CV charge**

When battery voltage equals to  $V_{CV}$ , the device regulates the battery voltage and reduces the charge current reduces automatically.

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 JW3655E 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 configuration shows in figure 3.

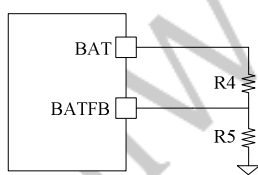


Figure 3 Full Charge Voltage Configure

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

**Charge termination**

If the battery voltage is higher than  $V_{FULL}$ , and the charge current is less than charge termination current  $I_{TER}$  for  $T_{FULL}$ , the charge process terminates.

**Auto recharge**

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  $V_{REC}$  if the input adaptor is present. The idle mode to charge mode transition also restarts the charge cycle.

**Charging status indication**

The JW3655E has open-drain output for charge status. Connect a current limit resistor and a LED from VCC to this pin can.

When charge is in progress, the STAT pin output LOW. When charge is completed or charger is in sleep mode, the STAT pin is output HIGH. When charge suspend at fault condition, the STAT pin blinks at 1Hz.

**Dynamic input Current Tracking Scheme**

JW3655E detects the VIN pin, if the VIN pin voltage is higher than  $V_{IN\_UVP}$  rising threshold for 150ms, the JW3655E starts charging with a limited charging current. When the adaptor is over load, the DRP pin drops below the internal reference 0.9V, JW3655E will decrease the charging current. We recommend the ratio of  $R1/R2$  is around 4.1. The input voltage sense shows in figure 4, choose  $R1$ ,  $R2$  to set the input voltage threshold.

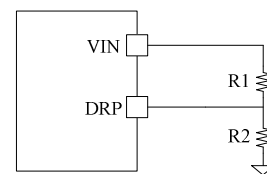


Figure 4 VIN Droop Voltage Configure

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

**Thermal Control**

When the junction temperature of the JW3655E

rises above 135°C, it begins to reduce the output power to prevent the temperature from rising further. If the junction temperature of the JW3655E rises above 150°C, the discharging process stops.

### **Shut-down Mode**

The JW3655E shuts down when voltage at CE pin is below charge enable threshold. The entire regulator is off.

### **Battery temperature protection**

For battery protection during charge mode, the device monitors the battery temperature through NTC pin. When the voltage of the NTC pin is outside the thresholds, the charge progress is suspended. In addition, STAT pin blinks at 1Hz to inform fault condition. Once temperature

returns within thresholds, the charge is recovered.

### **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 JW3655E (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  $R_{CS}$  as close as possible to the current set resistors  $R_{ISET}$  for better current accuracy.
3. The ground plane on the PCB should be as large as possible for better heat dissipation

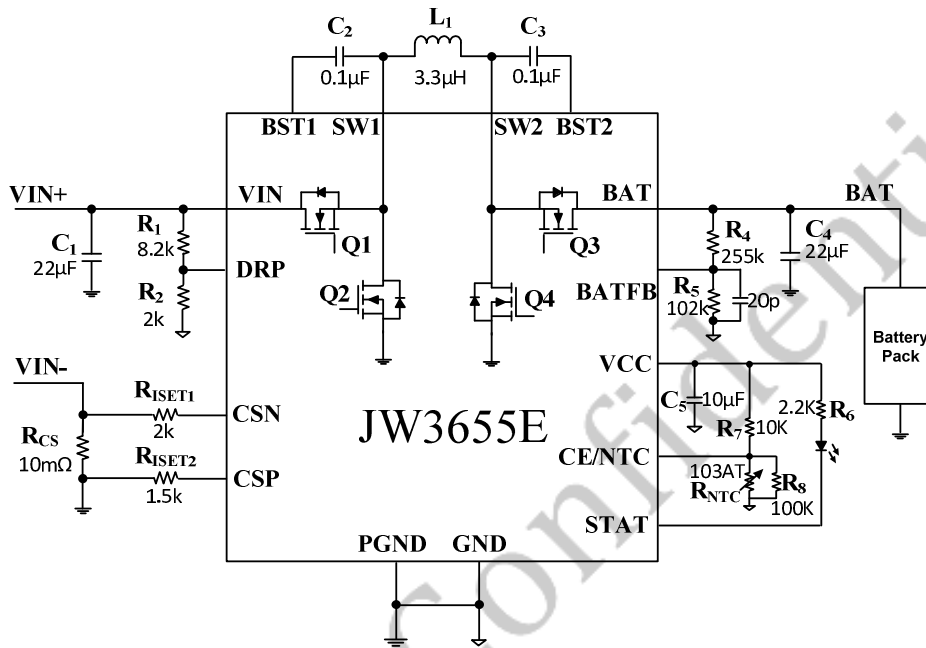
REFERENCE DESIGN

Reference 1: Single cell charge with input current limit

$V_{IN}$ : 4.6V ~ 20V

$V_{BAT}$ : 3V ~ 4.2V

$I_{IN\_LIM}$ : 2A

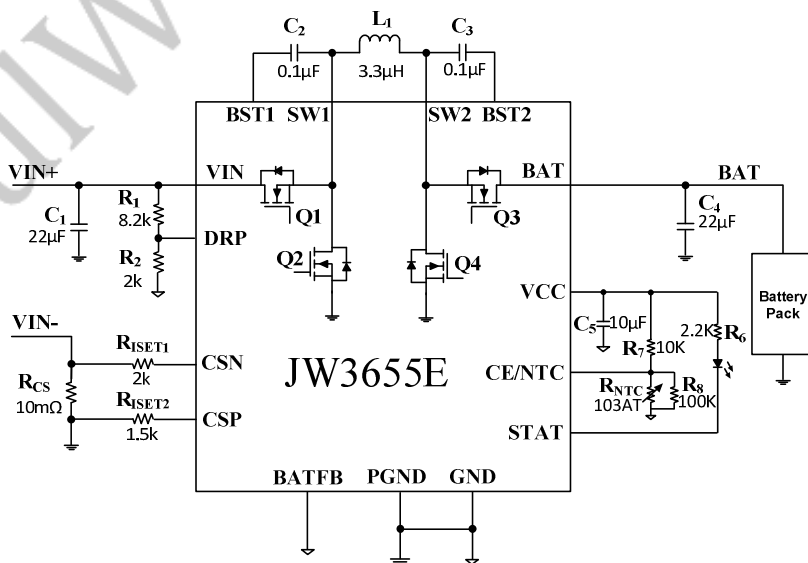


Reference 2: 2 cells charge with input current limit

$V_{IN}$ : 4.6V ~ 20V

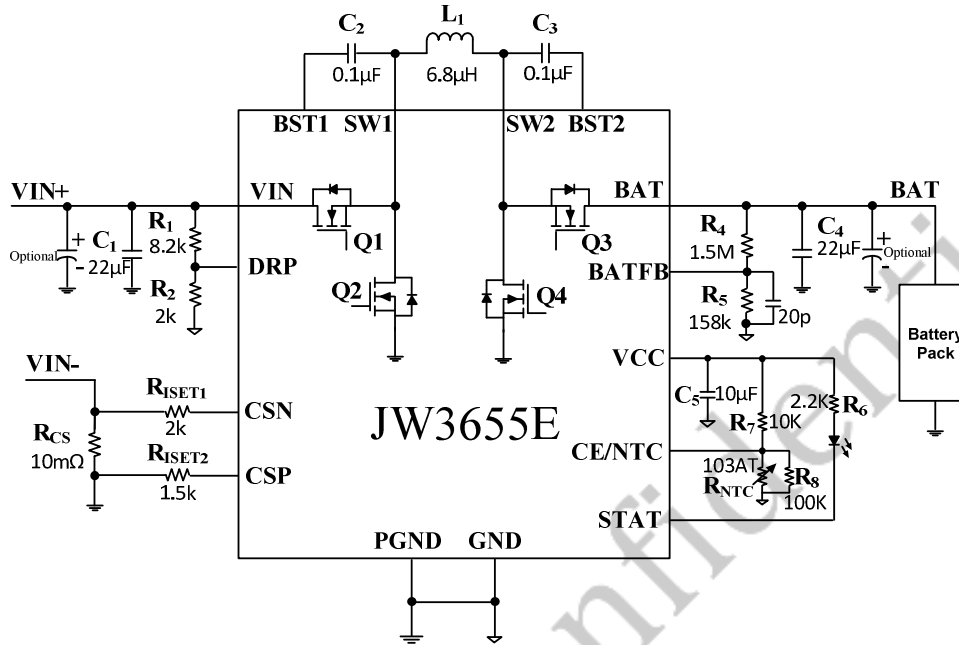
$V_{BAT}$ : 6V ~ 8.4V

$I_{IN\_LIM}$ : 2A



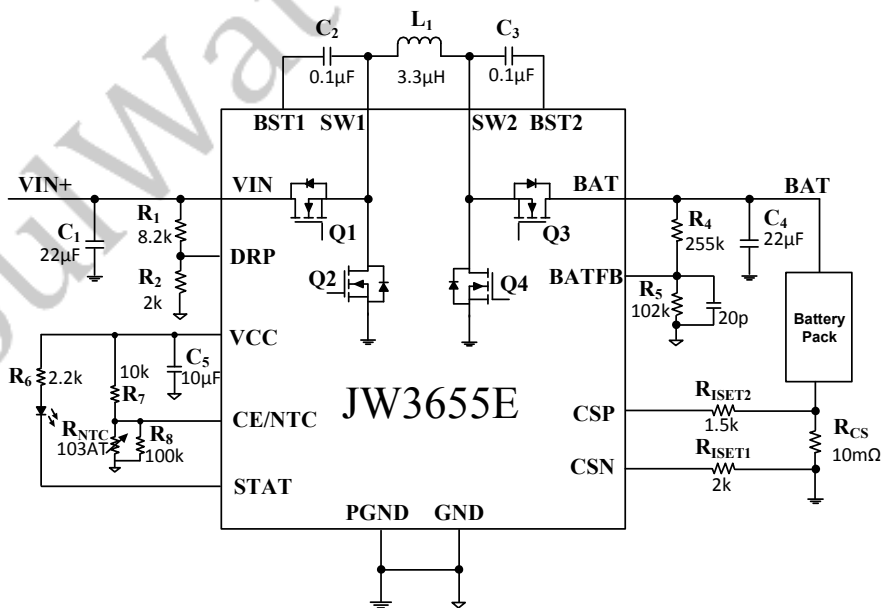
**Reference 3: 3 cells charge with input current limit**

$V_{IN}$ : 4.6V ~ 20V  
 $V_{BAT}$ : 9V ~ 12.6V  
 $I_{IN\_LIM}$ : 2A

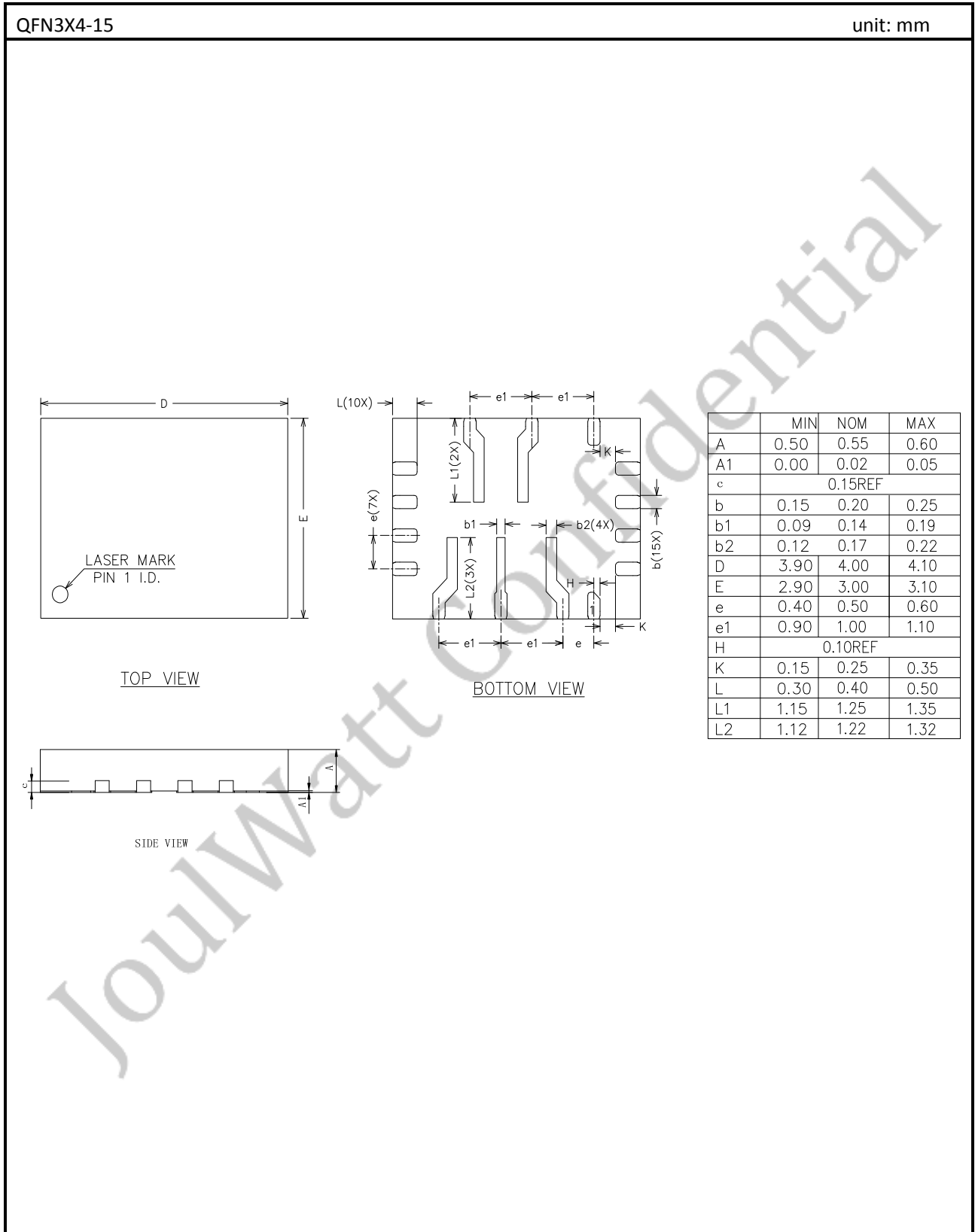


**Reference 4: Single cell charge with battery current limit**

$V_{IN}$ : 4.6V ~ 20V  
 $V_{BAT}$ : 3V ~ 4.2V  
 $I_{BAT\_LIM}$ : 2A



PACKAGE OUTLINE



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