General Description

The EC3653 is a buck boost converter targets HVDC fast charging and discharging power bank.

The EC3653 supports 1 to 3 cells Li-ion battery, the output voltage can be programmable up to 16.0V through external resistor.

The EC3653 implements the Buck Boost converter with an H-bridge, which can maintain output regulation for Input voltage whether greater or less than output voltage.

The integrated low Rds(on) MOSFET minimizes physical footprint, maximizes charge/discharge efficiency, which reduces the power dissipation during discharge. Constant current control is utilized to protect the device from overshooting in unwanted conditions. Built-in loop compensation simplifies the circuit and design. PFM is engaged to maintain high efficiency at light load current.

EC3653 guarantees robustness with thermal protection and battery under voltage lockout.

Features

◆Integrate low RDS (on) power MOSFET

◆Wide input range: 4.2V-16.0V, Support 1 to 3

◆cells battery charge/discharge.

◆Wide output range:0.9V-16.0V

◆High efficiency buck-boost transition

◆500kHz Switching frequency

◆Programmable output current limit(up to 3A)

◆Output Constant Current Control.

◆Quiescent current: <50uA

◆Integrate output overvoltage protection and

◆output short protection

◆Integrate thermal protection

◆QFN3*4 package

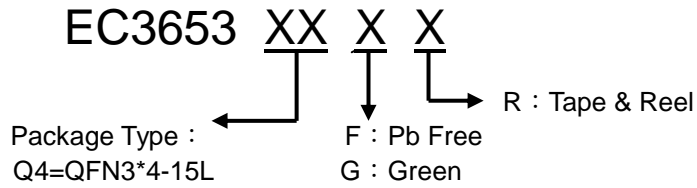## Applications

◆Power bank systems

◆Battery and Super Capacitor Charging

◆USB Power Delivery

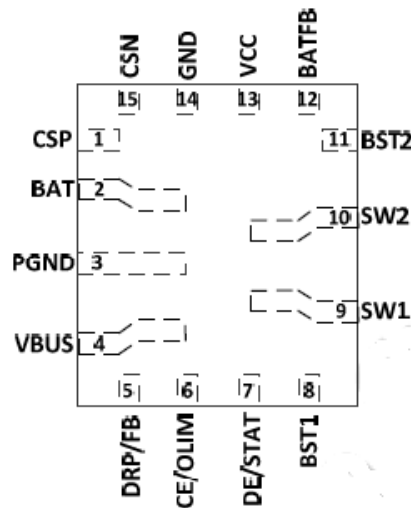◆Industrial applications

◆Automotive Systems

Typical application
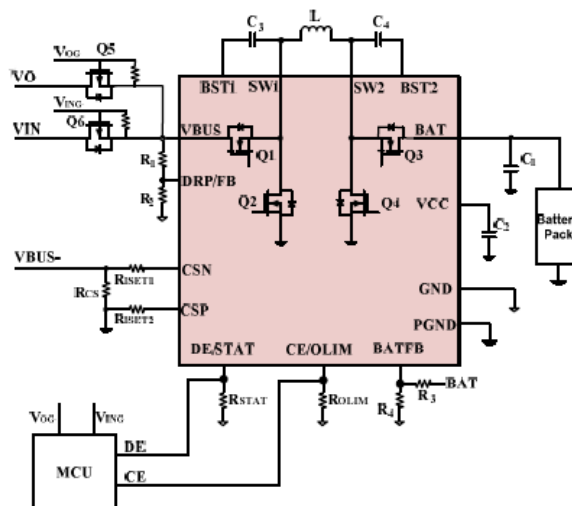
Ordering/Marking Information

EC3653 XX X X

R：Tape & Reel

F：Pb Free
G：Green

Package Type：
Q4=QFN3*4-15L

Device	Marking	Package	Shipping
EC3653Q4XR		QFN3*4-15L	

Pin Configurations

TOP VIEW

Absolute Maximum Ratings

VBUS,BAT, SW1, SW2 Pin	-0.3Vto 20V
BST1-SW1, BST2-SW2	-0.3Vto 6.5V
All Other Pins..	-0.3Vto 6.5V
JunctionTemperature2)3)	150ºC
Lead Temperature	260ºC
Storage Temperature..	-65ºC to +150ºC
ESD Susceptibility (Human Body Model)	2Kv

Recommended Operating Conditions

BUS Voltage VBUS..	0.9Vto 16V
Battery Voltage VBAT...	3.0Vto 16V

Thermal Performance

	θ_{JA}	θ_{JC}
Operation Junction Temp (TJ)..	-40ºCto +125ºC	
QFN3X4-15...	48	11ºC/W

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Note

1) Exceeding these ratings may damage the device.

2) The EC3653 guarantees robust performance from -40°Cto 150°C junction temperature. The junction temperature range specification is assured by design, characterization and correlation with statistical process controls.

3) The EC3653 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.

Electrical Characteristics

VBUS=12V, TA=25   , unless otherwise stated

Item	Symbol	Condition	Min.	Typ.	Max.	Units
Power supply						
VBAT voltage range	VBAT		3.0		16	V
VCC output voltage	VCC	IVCC=2mA	4.85	4.9	4.95	V
VCC output current limit	IVCC	VCC>2.7V	40	50	60	mA
Supply current in shut-down mode	IQ	VBAT=8V, EN=0V	40	50	60	µA
Controller						
Switch frequency	Fsw		450	500	550	kHz
Switch minimum off time	Toff_min		80	100	120	ns
DE/STAT, CE/OLIM Logic HIGH	VENH	VBAT=8V	2.0			V
DE/STAT, CE/OLIM Logic LOW	VENL	VBAT=8V			0.4	V
Bucktop switch on-resistance	RdsbkTG			20	28	m
Buck bottom switchon-resistance	RdsbkBG			20	28	m
Boost top switch on-resistance	RdsbstTG			20	28	m
Boost bottom switch on-resistance	RdsbstBG			20	28	m
Charge						
Floating BAT Voltage	VCV	VBATFB =GND, EC3653	8.358	8.4	8.442	V
		VBATFB =GND, EC3653-1	8.656	8.7	8.743	V
		VBATFB = VCC, EC3653	12.53	12.6	12.67	V
		VBATFB = VCC, EC3653-1	12.98	13.05	13.12	V
		Set by divider resistance	3.0	-	16	V
BAT feedback voltage	VBATFB	External resistor divider	1.188	1.2	1.212	V
BAT Recharge threshold	VREC	VBATFB = GND	7.95	8.0	8.05	V
		VBATFB = VCC	11.25	12.0	12.12	V
BAT recharge feedback threshold	VRECFB		1.136	1.143	1.15	V
CC mode charge current	ICC	RCS=10m , RISET1=2K RISET2=1.5K	1.8	2	2.2	A
Charge termination current	ITER	RCS=10m , RISET1=2K RISET2=1.5K		200		mA
Battery full charge deglitch time	TFULL	ICC< ITER		25		s

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Trickle mode charge current	ITRI	RCS=10m , RISET1=2K RISET2=1.5K		200		mA
Trickle mode battery threshold	VTRI	Referred to one battery cell		3.0		V
Trickle charge time-out duration	TTRI		50	55	60	min
VBUS UVP threshold	VBUS_UVP	VBUS increasing	3.98	4.1	4.22	V
		VBUS decreasing	3.7	3.85	4	V
VBUS delay to start charging	tchg_delay			150		ms
Initial charge current	ICHG_ini			300		mA
Charge current increase step	ISTEP1		75	100	125	mA
Charge current increase period	tSTEP1		20	25	30	ms
VBUS droop voltage to foldback charge current	VDRP		R1*3.8 µA	R1*4 µA	R1*4.2 µA	V
Charge current limit decline step	ISTEP2			100		mA
Charge current limit decline period	tSTEP2		2.25	2.5	2.75	s
Discharge mode						
VBAT UVLO voltage	VBAT_UVLO	VBAT increasing	2.97	3.0	3.03	V
		VBAT decreasing	2.54	2.6	2.66	V
Feedback voltage	VFB		0.800	0.9	0.910	V
OLIM pin output current sense ratio	KOLIM	RCS=10m , RISET1=2K RISET2=1.5K	2.7	3	3.3	µA/A
OLIM pin regulate voltage	VOLIM		390	400	410	mV
Output average current limit	IO_LIM	RCS=10m , RISET1=2K RISET2=1.5K ROLIM=26K	1.8	2	2.2	A
Protection						
VBUS OVP threshold	VBUS_OVP	VBUS increasing		23.2		V
		VBUS decreasing		21.5		V
VBUS OVP deglitch time	tBUS_OVP		1.8	2	2.2	µs
VBAT OVP threshold	VBAT_OVP	VBUS increasing		23.2		V
		VBUS decreasing		21.5		V
VBAT OVP deglitch time	tBAT_OVP		1.8	2	2.2	µs
Thermal shutdown threshold5)	TSHUT			150		°C
Thermal recovery threshold5)	TREC			130		°C

Notes:
5) Guaranteed by design.

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Pin Description

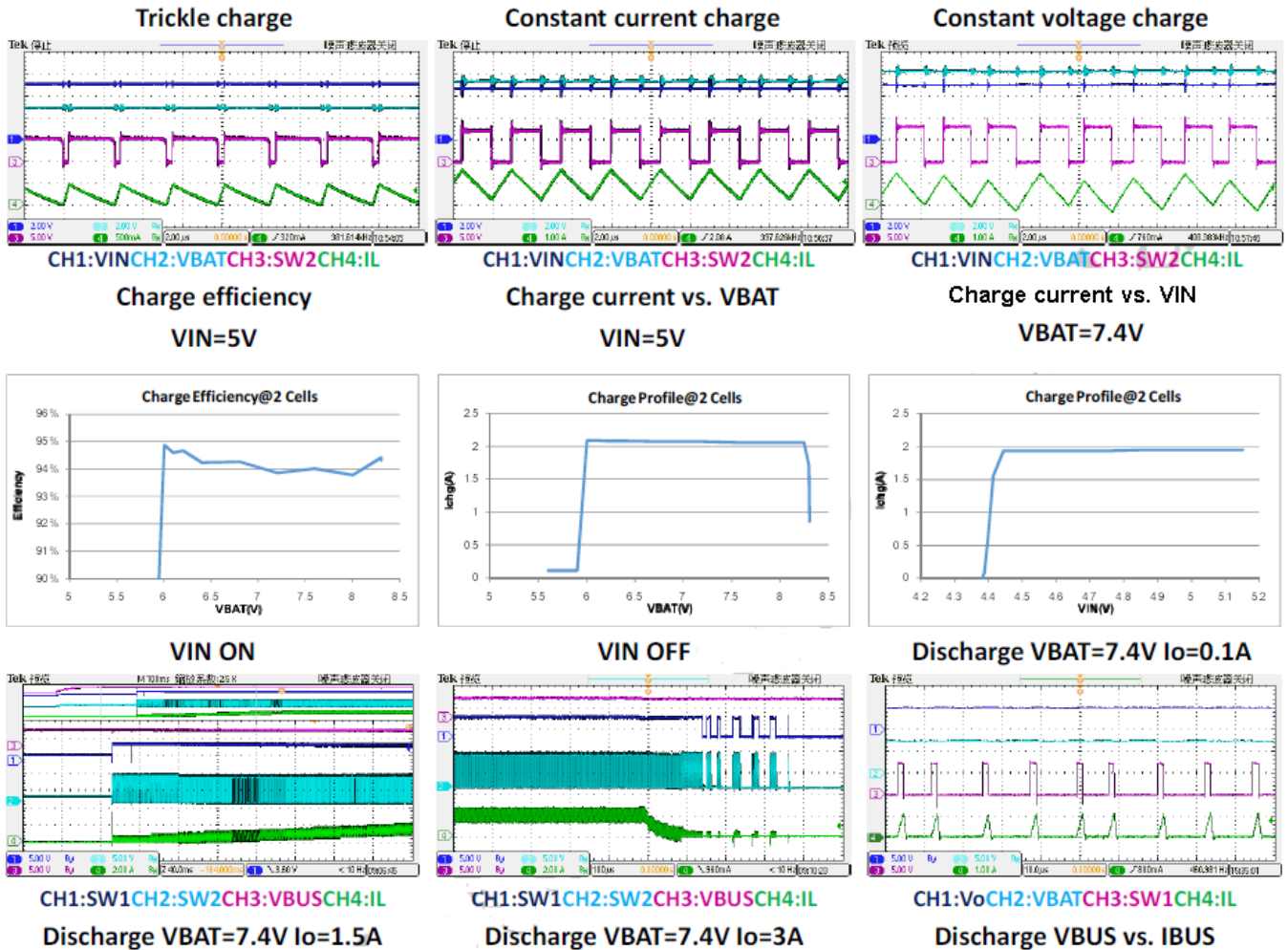| Pin No.	Name	Description
1	CSP	Positive terminal of battery charge current sense.
2	BAT	Battery positive terminal.
3	PGND	Power Ground.
4	VBUS	In charge mode, main supply pin, connect to adaptor. In discharge mode, output voltage sense pin, connect this pin to Vout.
5	DRP/FB	In charge mode, VBUS droop allowance program pin. In discharge mode, Output feedback pin.
6	CE/OLIM	Charge Enable control pin or Discharge output current limit program pin. This is a dual purpose Pin. When the CE/OLIM pin rises above 2.0V, the IC charge is enabled. When the charge is not used, in discharge mode, the pin set output average current limit. Connect a resistor to GND to set the maximum average current. And in the light
7	DE/STAT	Discharge Enable control pin or Fault state output pin or Charge state detection output pin. This is also a multi-purpose Pin. When the DE/STAT pin is above 2.0V and the CE/OLIM pin below 1.7V, the IC discharge is enabled. When the discharge is not used, in charge mode, the pin as Fault state output pin, asserted during over temperature or VBUS over voltage or trickle charge time out conditions. And the pin also as charge state detection output pin. In the CC charge mode, the pin source current is 6µA. In the full charge mode, the pin is pulled to high.
8	BST1	VBUS side bootstrap supply pin for top switch. 0.1µF capacitor is connected between BST1 and SW1 pins.
9	SW1	VBUS side power switching node. connect to SW1 with inductor
10	SW2	BAT side power switching node.
11	BST2	BAT side bootstrap supply pin for top switch. 0.1µF capacitor is connected between BST2 and SW2 pins.
12	BATFB	Battery float voltage configuration pin. 1. This pin tied to GND or VCC, sets different float voltage. Pin short to GND: 8.4V/8.7V. Pin short to VCC:12.6V/13.05V. 2. And the float voltage could be set to any value (3.0V-16.0V) by the external divider resistor.
13	VCC	4.9V LDO for power driver and internal circuit. Must be bypassed to GND with a minimum of 10µF ceramic capacitor for stable operation.
14	GND	Signal GND.
15	CSN	Negative terminal of battery charge current sense.

Notes: Highlighted pins are high current pins

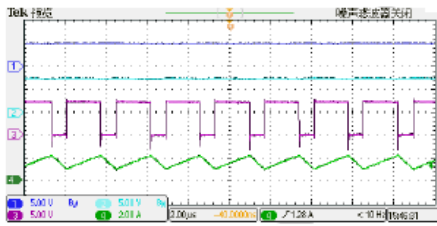E-CMOS Corp. (www.ecmos.com.tw)   7I11N-Rev. F001

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Block Diagram
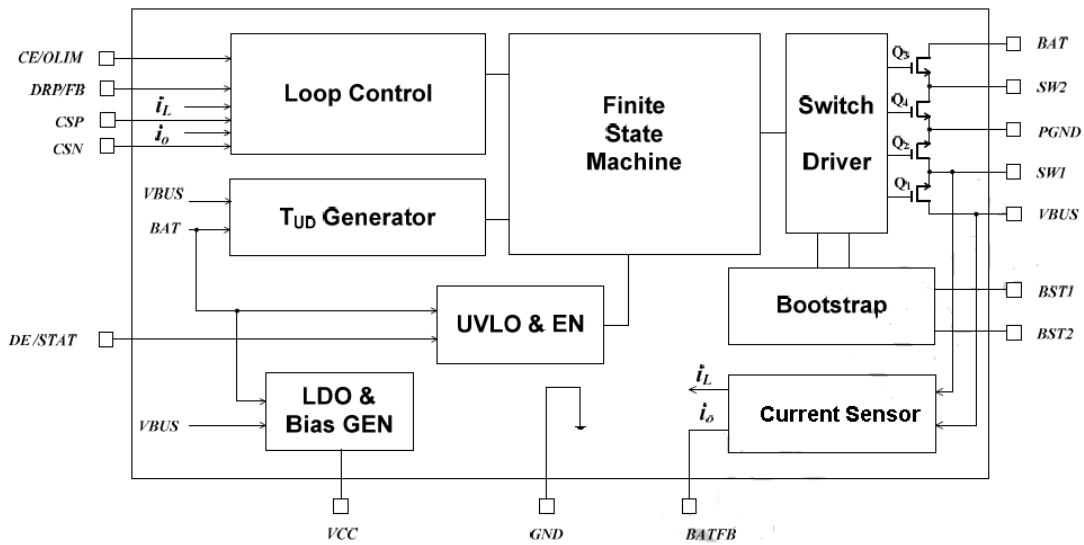
Typical Performance Characteristics

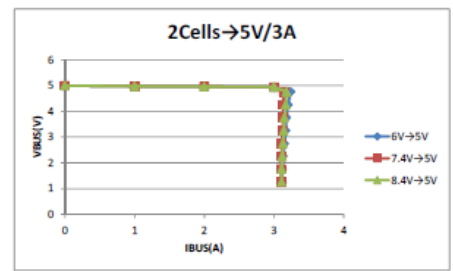Vin = 5V, L = 3.3μH, CIN = 140μF, CBAT=40uF, 2 Cells, TA = +25°C, unless otherwise noted.

Trickle charge

CH1:VIN CH2:VBAT CH3:SW2 CH4:IL

Constant current charge

CH1:VIN CH2:VBAT CH3:SW2 CH4:IL

Constant voltage charge

CH1:VIN CH2:VBAT CH3:SW2 CH4:IL

Charge efficiency

VIN=5V

Charge current vs. VBAT

VIN=5V

Charge current vs. VIN

VBAT=7.4V

VIN ON

Discharge VBAT=7.4V Io=1.5A

VIN OFF

CH1:SW1 CH2:SW2 CH3:VBUS CH4:IL

Discharge VBAT=7.4V Io=3A

Discharge VBAT=7.4V Io=0.1A

CH1:Vo CH2:VBAT CH3:SW1 CH4:IL

Discharge VBUS vs. IBUS

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Discharge efficiency VBUS=5V

Discharge efficiency VBUS=9V

Discharge efficiency VBUS=12V
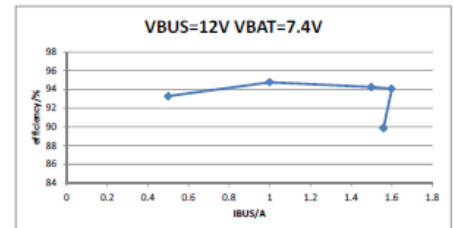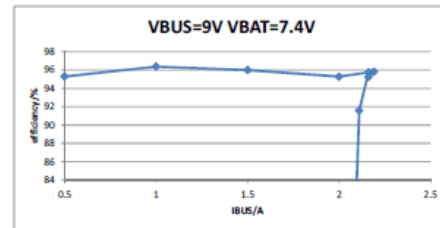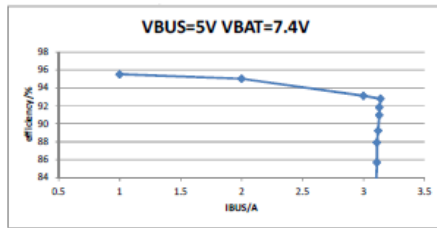
Functional Description

EC3653 is a monolithic buck-boost DC to DC converter that can operate over a wide input voltage range of 4.2V to 16V. The output voltage can be programmed between 0.9V to 16V. Internal low RDSON N-channel power switches reduce the solution complexity and efficiency.

Flexible Bidirectional Buck-Boost Converter

The EC3653 contains flexible bidirectional DC-DC converter for either buck or boost converter. When battery voltage is higher Than output voltage, it is a buck converter. When input voltage is lower than battery voltage, it is a boost converter.
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 EC3653 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 increase power efficiency at light load by reducing switching-loss, minimizing the circuit. The EC3653 can operate in charge, discharge and shutdown mode according to CE/OLIM, DE/STAT and VBUS voltage. The state is given by table1:

| CE	DE	VBUS	State
1	1/0	>4V, delay 150ms	Charge
1	1/0	<4V, delay 2s	Shutdown
0	1		Discharge
0	0		Shutdown

Table1: operating states

If the DE/STAT is high and the CE/OLIM is low, the device operates in discharge mode. If the CE/OLIM is high and the VBUS is larger than VBUS_UVP for 150ms, the EC3653 operates in charge mode. Either in charge or discharge mode, the EC3653 can operate in buck or boost state. In charge mode, if the VBUS voltage is lower than battery voltage it is a boost converter. When the VBUS voltage is larger than battery voltage, it is a buck converter. Similarly, the EC3653 can operate as a buck or boost converter according to VBUS voltage and battery voltage in discharge mode.

Charge mode

In charge mode, EC3653 regulates the input 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.

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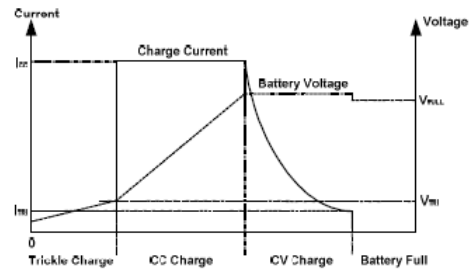
a) Without input current limit
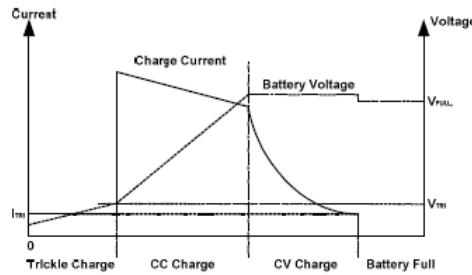
b) With input current limit

Figure 1 Typical Charge Profile

Trickle charge

The EC3653 charges the battery with ITRI when battery voltage is less than VTRI. If charging remains in TC mode beyond the trickle-charge time TTRI, charging terminates. And meanwhile the DE/STAT pin will send out continuous clock signals with 20kHz switching frequency to inform MCU the fault state.

CC charge

When the battery is higher than VTRI, the device charges the battery with ICC if the input current is sufficient. When input current limit is hit, the device reduces the charge current automatically. In charge mode, the VBUS current is monitored continuously through CSP and CSN pins. As shown in Figure2, the external resistors RISET and RCS program the charge current. The maximum charging current is up to 3.4A.In the CC charging mode, the charging current is given by:

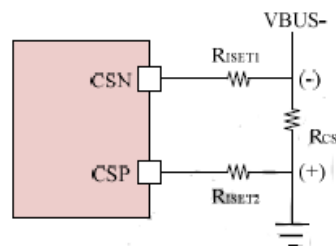$$I_{CC}(A) = \frac{10(\mu A)R_{ISET1}(K\Omega)}{R_{CS}(m\Omega)}$$

Figure 2 Typical Charge Profile

And in the CC charge mode, a source current 2µA will be sent to DE/STAT pin to inform MCU the charge state conveniently.

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CV charge

When battery voltage equals to VCV, the device regulates the battery voltage and reduces the charge current automatically. The customer can select 2 or 3 cells or program the VCV through BATFB pin. Connect BATFB to GND selects 2 cells. Connect BATFB to VCC selects 3 cells. The VCV also can be programmed by resistor divider connected to BATFB when the EC3653 detects a resistor connected to this pin.

$$V_{CV}(V) = \frac{1.2\,V \times (R_3 + R_4)}{R_4}$$

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, and the DE/STAT pin is pulled to high.

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 VREC if the input adaptor is present. The idle mode to charge mode transition also restarts the charge cycle.

Dynamic input Current Tracking Scheme

When the adaptor is plugged in for 150ms, the EC3653 starts charging with a limited charging current, in the meanwhile, the adaptor voltage is detected and stored as initial input voltage. Then the EC3653 increases charge current step by step. During this process, VBUS is continuously monitored. As long as VBUS drops preset level (VDRP) below VBUS initial voltage, the system step by step lower the input current limit to bring back VBUS100mV higher to maintain a healthy adaptor output. After that the new input current limit is locked up unless the adaptor is plugged out. This is proprietary dynamic input current tracking scheme.
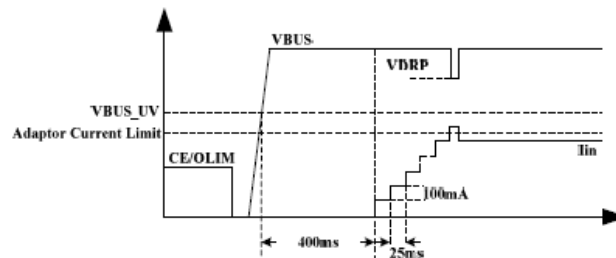
$$\Delta V_{DRP} = R_1 \times 4uA$$

Figure 3 Charge **Current Tracking Scheme**

Discharge Mode

In discharge mode, EC3653 regulates the output voltage and output current.

Output current sensing

The EC3653 senses the output current through CE/OLIM pin when the output current is less than IO_LIM. If the output current is larger than IO_LIM, the CE/OLIM output a fixed voltage 400mV, the output current limit can be programmed through the resistor on CE/OLIM pin.

Battery UVLO

When battery voltage decreases to VBAT_UVLO1, the discharging process is terminated. When the battery voltage recovers and is larger than VBAT_UVLO2, the EC3653 can re-discharge if the DE/STAT is still high.

Output constant current control

In discharge mode, the output voltage is regulated to setting value which can be programmed through FB pin.

$$V_O = \frac{0.9(V) \times (R_1 + R_2)}{R_2}$$

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The output current limit can be programmed by ROLIM.

$$I_{OLIM} = \frac{0.4(V)}{R_{OLIM}(K\Omega)} \times \frac{R_{ISET2}(K\Omega)}{R_{CS}(m\Omega)}$$

If the output current equals to the IO_LIMIT, the output current loop begins to work, it turns down output voltage to limit the output power.

When output is shorted to ground, the EC3653 works as a buck converter, the output current is continuously sensed and Limited to IO_LIMIT. When the output short is removed, the regulator comes into normal operation again.

Thermal Control
When the junction temperature of the EC3653 rises above 135°C, it begins to reduce the output power to prevent the Temperature from rising further. If the junction temperature of the EC3653 rises above 150°C, the discharging process stops.

Shut-down Mode
The EC3653 shuts down when voltage at CE/OLIM pin and DE/STAT pin is below 0.4V. The entire regulator is off.

BST UVLO
If the BST1-SW1 or BST2-SW2 voltage is lower than BST UVLO Voltage, the switch is turned off.

Protection
VBUS Over-Voltage Protection
If the adaptor voltage exceeds the VBUS over-charge threshold VBUS_OVP for tBUS_OVP, charging process suspends and the device generates a fault flag.

Battery Over-Voltage Protection
If the battery voltage exceeds the battery over-charge threshold VBAT_OVP for tBAT_OVP, charging process suspends and the device generates a fault flag.
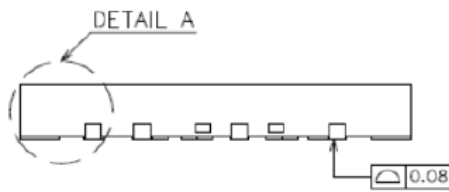
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Package Outline

QFN3X4-15
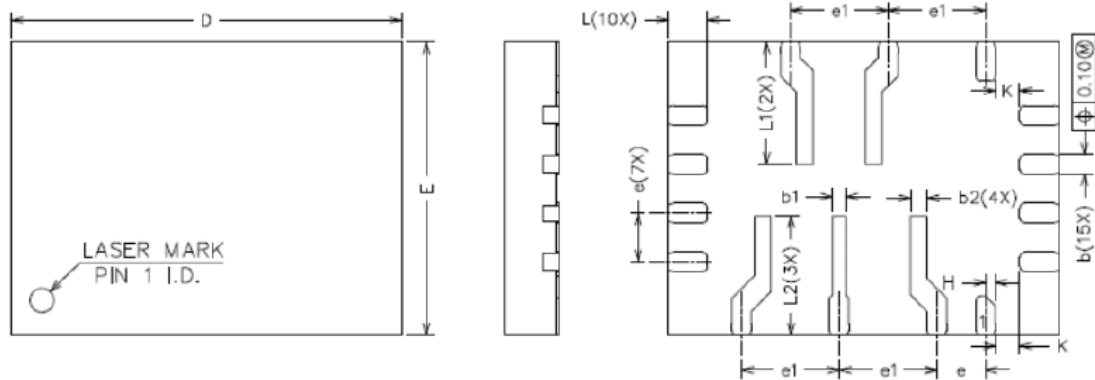
TOP VIEW

SIDE VIEW

BOTTOM VIEW

DETAIL A

SIDE VIEW

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
b1	0.09	0.14	0.19
b2	0.12	0.17	0.22
D	3.90	4.00	4.10
E	2.90	3.00	3.10
e	0.40	0.50	0.60
e1	0.90	1.00	1.10
H		0.10REF	
K	0.15	0.25	0.35
L	0.30	0.40	0.50
L1	1.15	1.25	1.35
L2	1.12	1.22	1.32

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