

## 13.5V/3A, 1-Cell Battery Charger with Power Path Management

### DESCRIPTION

ETA6964A is a highly-integrated 3A switch-mode battery charge management and system power path management device for single cell Li-Ion and Li-polymer battery. It features fast charging with high input voltage support for a wide range of smart phones, tablets and portable devices. Its low impedance power path optimizes switch-mode operation efficiency, reduces battery charging time and extends battery life during discharging phase. Its input voltage and current regulation deliver maximum charging power to battery. The solution is highly integrated with input reverse-blocking FET (Q1), high-side switching FET (Q2), low-side switching FET (Q3), and battery FET (Q4) between system and battery. It also integrates the bootstrap diode for the high-side gate drive for simplified system design. The device supports a wide range of input sources: standard USB host port, USB charging port, and USB compliant high voltage adapter. To support fast charging using high voltage adapter. The device is compliant with USB 2.0 and USB 3.0 power spec with input current and voltage regulation. The device also meets USB On-the-Go (OTG) operation power rating specification by supplying 5.15 V on BUS with constant current limit up to 1.2A.

The power path management regulates the system slightly above battery voltage but does not drop below 3.5 V minimum system voltage. With this feature, the system maintains operation even when the battery is completely depleted or removed. When the input current limit or voltage limit is reached, the power path management automatically reduces the charge current to zero. As the system load continues to increase, the power path discharges the battery until the system power requirement is met. This Supplement Mode prevents overloading the input source.

ETA6964A is available in a QFN4x4-24 package.

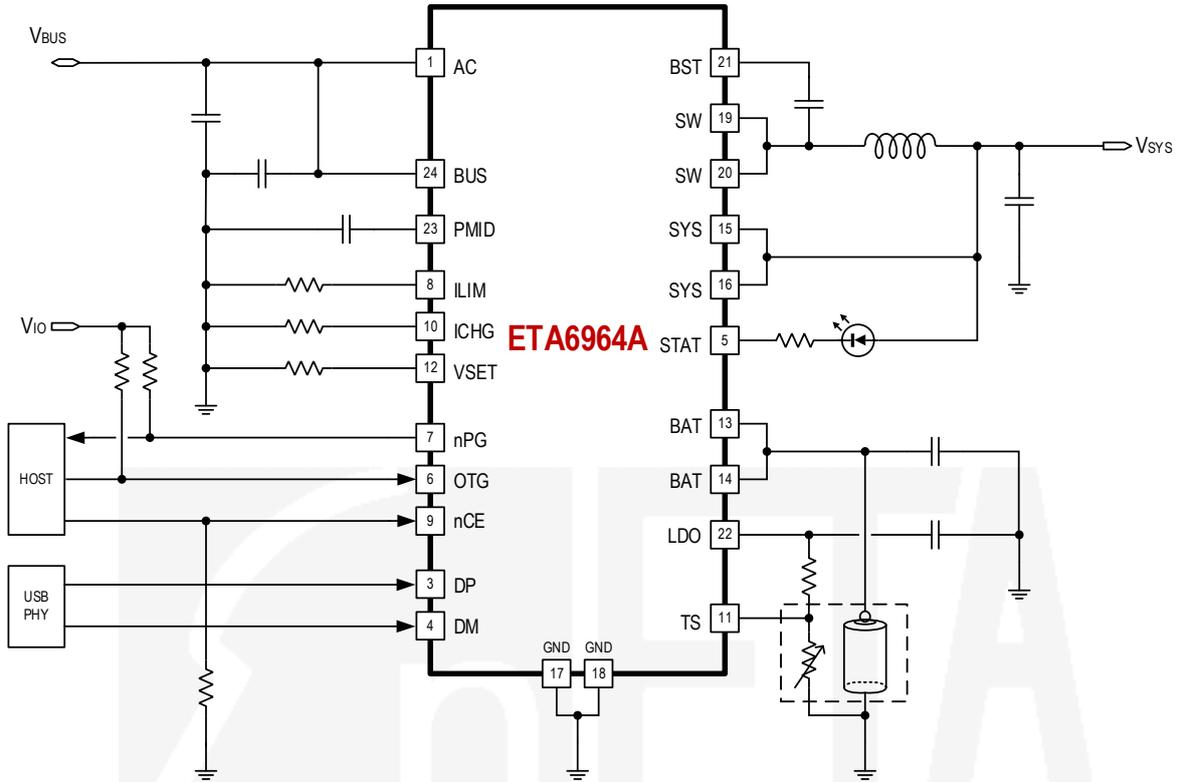
### FEATURES

- ◆ High-Efficiency, 1.5MHz Synchronous Switching Buck Charger
  - 91% Charge Efficiency at 2A from 5V Input
  - Programmable PFM Mode for Light Load Conditions
- ◆ Supports USB On-The-Go (OTG)
  - Boost Converter with Up to 1.2A Output
  - 91% Boost Efficiency at 1A Output
  - Output Short Circuit Protection
- ◆ Wide Range Single Input to Support both USB Input and High Voltage Adapters
  - Support 3.9V to 13.5V Input Voltage Range with 22V Absolute Maximum Input Voltage Rating
  - Maximum Power Tracking by Input Voltage Limit Up to 4.5V ( $V_{INDPM}$ )
  - Auto Detect USB BC1.2, SDP, CDP, DCP and Non-Standard Adaptors
- ◆ High Battery Discharge Efficiency with 27mΩ Battery Discharge MOSFET
- ◆ Narrow VDC (NVDC) Power Path Management
- ◆ High Integration Includes All MOSFETs, Current Sensing and Loop Compensation
- ◆ Safety
  - Battery Temperature Sensing for Charge and Boost Mode
  - Thermal Regulation and Thermal Shutdown
- ◆ Input UVLO and Overvoltage Protection
- ◆ Available in a QFN4x4-24 package

### APPLICATIONS

- ◆ Tablet PC, Smart Phone, Internet Devices
- ◆ Portable Audio Speaker
- ◆ Handheld Computers, PDA, POS

TYPICAL APPLICATION

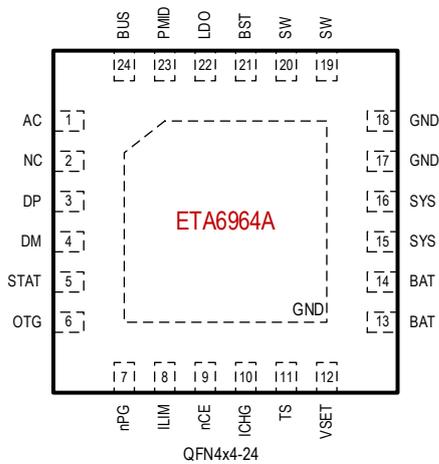


ORDERING

INFORMATION

PART No.	PACKAGE	TOP MARK	Pcs/Reel
ETA6964AQ4Y	QFN4x4-24	ETA6964A YWWXL	5000

PIN CONFIGURATION



ABSOLUTEMAXIMUM RATINGS

(Note: Exceeding these limits may damage the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

AC, BUS to GND Voltage .....	-2V to 22V
PMID, SW to GND Voltage.....	-0.3V to 22V
SYS, BAT to GND Voltage.....	-0.3V to 6V
BST to SW Voltage .....	-0.3V to 6V
All Other Pin to GND Voltage.....	-0.3V to 6V
SW, BUS, BAT, SYS to PGND Current.....	Internally limited
Operating Temperature Range.....	-40°C to 85°C
Storage Temperature Range.....	-55°C to 150°C
Thermal Resistance	$\theta_{JA}$ $\theta_{JC}$
QFN4x4-24.....	35..... 10..... °C/W
Lead Temperature (Soldering 10sec) .....	260°C

## ELECTRICAL CHARACTERISTICS

(V<sub>BAT</sub> = 3.6V, unless otherwise specified. Typical values are at T<sub>A</sub> = 25°C.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
<b>QUIESCENT CURRENTS</b>					
Battery discharge current (BAT, SW, SYS) in buck mode	V <sub>BAT</sub> = 4.5V, V <sub>BUS</sub> < V <sub>BUS-UVLOZ</sub> , leakage between V <sub>BAT</sub> and V <sub>BUS</sub> , T <sub>J</sub> < 85°C			5	μA
Battery discharge current (BAT, SW, SYS)	V <sub>BAT</sub> =4.5V, No V <sub>BUS</sub> , T <sub>J</sub> < 85°C		80	160	μA
Input supply current (V <sub>BUS</sub> ) in buck mode	V <sub>BUS</sub> > V <sub>BUS-UVLO</sub> , V <sub>BUS</sub> > V <sub>BAT</sub> , converter switching, V <sub>BAT</sub> = 3.8V, I <sub>SYS</sub> = 0A		5		mA
Battery Discharge Current in boost mode	V <sub>BAT</sub> = 4.2V, boost mode, I <sub>BUS</sub> = 0A, converter switching		2		mA
<b>BUS, AC AND BAT PIN POWER-UP</b>					
V <sub>AC</sub> operating range	V <sub>AC</sub> rising	3.9		13.5	V
Sleep mode falling threshold(V <sub>BUS</sub> – V <sub>BAT</sub> )	V <sub>BUS_MIN_FALL</sub> ≤ V <sub>BAT</sub> ≤ V <sub>REG</sub> , V <sub>BUS</sub> falling	15	85	165	mV
Sleep mode rising threshold(V <sub>BUS</sub> – V <sub>BAT</sub> )	V <sub>BUS_MIN_FALL</sub> ≤ V <sub>BAT</sub> ≤ V <sub>REG</sub> , V <sub>BUS</sub> rising	110	220	330	mV
V <sub>AC</sub> Overvoltage rising threshold	V <sub>AC</sub> rising	13	14	15	V
V <sub>AC</sub> Overvoltage hysteresis	V <sub>AC</sub> falling		500		mV
Battery Depletion Threshold	V <sub>BAT</sub> falling	2.17		2.62	V
Battery Depletion Threshold	V <sub>BAT</sub> rising	2.35	2.58	2.8	V
Battery Depletion rising hysteresis	V <sub>BAT</sub> rising		180		mV
Bad adapter detection falling threshold	V <sub>BUS</sub> falling	3.6		3.9	V
Bad adapter detection hysteresis			80		mV
Bad adapter detection current source	Sink current from BUS to GND		30		mA
<b>POWER-PATH</b>					
System regulation voltage	V <sub>BAT</sub> < 3.5V		3.68		V
System Regulation Voltage	I <sub>SYS</sub> = 0A, V <sub>BAT</sub> = 4.4V		V <sub>BAT</sub> + 70mV		mV
Top reverse blocking MOSFET on-resistance between BUS and PMID - Q1	-40°C ≤ T <sub>A</sub> ≤ 125°C	20	40	60	mΩ
Top switching MOSFET on-resistance between PMID and SW - Q2	V <sub>LDO</sub> = 5V, -40°C ≤ T <sub>A</sub> ≤ 125°C	35	70	105	mΩ
Bottom switching MOSFET on-resistance between SW and GND - Q3	V <sub>LDO</sub> = 5V, -40°C ≤ T <sub>A</sub> ≤ 125°C	21	43	65	mΩ
SYS-BAT MOSFET on-resistance – Q4	Measured from BAT to SYS, V <sub>BAT</sub> = 4.2V, T <sub>J</sub> = -40°C~125°C	13	27	40	mΩ
BATFET forward voltage in supplement mode			30		mV
<b>BATTERY CHARGER</b>					
Charge voltage setting	R <sub>VSET</sub> > 50kΩ, -40 °C ≤ T <sub>J</sub> ≤ 85°C	4.187	4.208	4.229	V
	R <sub>VSET</sub> < 500Ω, -40°C ≤ T <sub>J</sub> ≤ 85°C	4.33	4.352	4.374	V

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
	$R_{VSET} = 10k\Omega, -40^\circ C \leq T_J \leq 85^\circ C$	4.378	4.4	4.422	V
Charge voltage setting accuracy	$-40^\circ C \leq T_J \leq 85^\circ C$	-0.5		+0.5	%
Charge current regulation range		0		3000	mA
Charge current regulation setting	$R_{ICHG} = 4K\Omega, V_{BAT} = 3.8V$	1.8	2	2.2	A
Charge current regulation accuracy	$I_{CHG} = 240\text{ mA}, V_{BAT} = 3.8V$	-10		+10	%
Charge current regulation setting ratio	$R_{ICHG} = 4K\Omega, V_{BAT} = 3.8V$		8000		$A \times \Omega$
Battery LOWV falling threshold	Fast charge to Pre-charge		2.8		V
Battery LOWV rising threshold	Pre-charge to fast charge		3.1		V
Pre-charge current regulation	$V_{BAT} = 2.6V$	120	180	240	mA
Termination current regulation	$V_{BAT} = 4.208V$	120	180	240	mA
Battery short voltage	$V_{BAT}$ falling	1.8	2	2.2	V
Battery short voltage	$V_{BAT}$ rising	2.05	2.25	2.45	V
Battery short current	$V_{BAT} = 1V$		145		mA
Recharge Threshold below $V_{BAT\_REG}$	$V_{BAT}$ falling		120		mV
<b>INPUT VOLTAGE AND CURRENT REGULATION</b>					
Input voltage regulation limit		4.38	4.5	4.74	V
Input voltage regulation accuracy		-4		4	%
Input current regulation limit	$V_{AC} = 5V, R_{ILIM} = 1.35K\Omega, -40^\circ C \leq T_J \leq 85^\circ C$	1.8	2	2.2	A
Input current regulation limit accuracy	$V_{AC} = 5V, R_{ILIM} = 1.35K\Omega, -40^\circ C \leq T_J \leq 85^\circ C$	-10		10	%
Input current setting ratio, $I_{LIM} = K_{LIM} / R_{LIM}$	$V_{AC} = 5V, R_{LIM} = 1.35K\Omega, -40^\circ C \leq T_J \leq 85^\circ C$		2700		$A \times \Omega$
Input current limit during system start-up sequence			200		mA
<b>BAT PIN OVERVOLTAGE PROTECTION</b>					
Battery overvoltage threshold	$V_{BAT}$ rising, as percentage of $V_{BAT\_REG}$		108		%
Battery overvoltage threshold Hysteresis	$V_{BAT}$ falling, as percentage of $V_{BAT\_REG}$		103		%
<b>THERMAL REGULATION AND THERMAL SHUTDOWN</b>					
Junction Temperature Regulation Threshold	Temperature Increasing		110		$^\circ C$
Thermal Shutdown Rising Temperature			160		$^\circ C$
Thermal Shutdown Hysteresis			30		$^\circ C$
<b>JEITA Thermistor Comparator (BUCK MODE)</b>					
T1 ( $0^\circ C$ ) threshold, Charge suspended T1 below this temperature.	Charger suspends charge. As Percentage to $V_{LDO}$		73.3		%
Falling	As Percentage to $V_{LDO}$		71.5		%
T2 ( $10^\circ C$ ) threshold, Charge back to $I_{CHG}/5$ and 4.2 V below this temperature	As Percentage to $V_{LDO}$		68		%
Falling	As Percentage to $V_{LDO}$		66.8		%

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
T3 (45°C) threshold, charge back to I <sub>CHG</sub> above this temperature.	Charger suspends charge. As Percentage to V <sub>LDO</sub>		44.7		%
Falling	As Percentage to V <sub>LDO</sub>		45.7		
T5 (60°C) threshold, charge suspended above this temperature.	As Percentage to V <sub>LDO</sub>		34.2		%
Falling	As Percentage to V <sub>LDO</sub>		35.3		%
<b>COLD OR HOT THERMISTOR COMPARATOR (BOOST MODE)</b>					
Cold Temperature Threshold, TS pin Voltage Rising Threshold	As Percentage to V <sub>LDO</sub> (Approx. -20°C w/ 103AT), T <sub>J</sub> = -20°C~125°C	78	80.0	82	%
Falling	T <sub>J</sub> = -20°C - 125°C		79.0		%
Hot Temperature Threshold, TS pin Voltage falling Threshold	As Percentage to V <sub>LDO</sub> (Approx. 60°C w/ 103AT), T <sub>J</sub> = -20°C~125°C	29.2	31.2	33.2	%
Rising	T <sub>J</sub> = -20°C ~125°C		34.4		%
<b>CHARGE OVERCURRENT COMPARATOR (CYCLE-BY-CYCLE)</b>					
HSFET cycle-by-cycle over-current threshold			5.8		A
System over load threshold			5.2		A
<b>CHARGE UNDER-CURRENT COMPARATOR (CYCLE-BY-CYCLE)</b>					
LSFET under-current falling threshold	From sync mode to non-sync mode		250		mA
<b>PWM</b>					
PWM switching frequency	Oscillator frequency		1500		kHz
Maximum PWM duty cycle			97		%
<b>BOOST MODE OPERATION</b>					
Boost mode regulation voltage	V <sub>BAT</sub> = 3.8 V, I <sub>PMID</sub> = 0 A	5	5.15	5.3	V
Boost mode regulation voltage accuracy	V <sub>BAT</sub> = 3.8 V, I <sub>PMID</sub> = 0 A	-3		3	%
Battery voltage exiting boost mode	V <sub>BAT</sub> falling	2.6	2.8	3.0	V
	V <sub>BAT</sub> rising	2.8	3	3.2	V
OTG mode output current		1.2	1.4		A
OTG overvoltage threshold	Rising threshold	5.6	6	6.4	V
HSFET under current falling threshold			100		mA
<b>V<sub>LDO</sub> REGULATION</b>					
LDO output voltage	V <sub>BUS</sub> = 9V, I <sub>LDO</sub> = 40mA		5		V
LDO output current limit	V <sub>BUS</sub> = 9V, V <sub>LDO</sub> = 4V		80		mA
<b>LOGIC I/O PIN CHARACTERISTICS (nCE, OTG)</b>					
Input low threshold				0.4	V
Input high threshold		1.3			V
High-level leakage current	Pull up rail 1.8 V			1	μA
<b>LOGIC I/O PIN CHARACTERISTICS (nPG, STAT)</b>					
Low-level output voltage				0.4	V
<b>V<sub>BUS</sub>/V<sub>BAT</sub> POWER UP</b>					

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Bad adapter detection duration			30		ms
<b>BATTERY CHARGER</b>					
Deglitch time for charge Termination			7		s
Deglitch time for recharge			32		ms
System over-current deglitch time to turn off Q4			1		ms
Battery over-voltage deglitch time to disable charge			10		μs
Typical Charge Safety Timer Range			10		Hr
<b>DP/DM DETECTION</b>					
V <sub>DP/DM_600MVSRC</sub>	Voltage source (600 mV)		600		mV
R <sub>DM_19K</sub>			19		kΩ
V <sub>DP/DM_0P325</sub>			0.325		V
V <sub>2P7_VTH</sub>	DP/DM Threshold for non-standard adapter	2.55	2.7	2.85	V
V <sub>2P0_VTH</sub>	DP/DM Threshold for non-standard adapter	1.85	2.0	2.15	V
V <sub>1P2_VTH</sub>	DP/DM Threshold for non-standard adapter	1.05	1.2	1.35	V

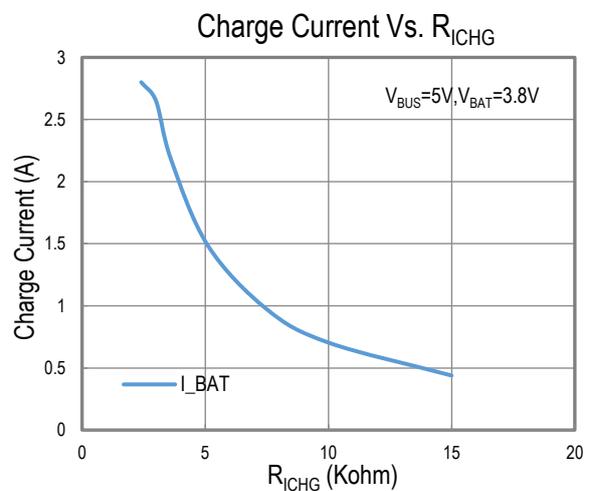
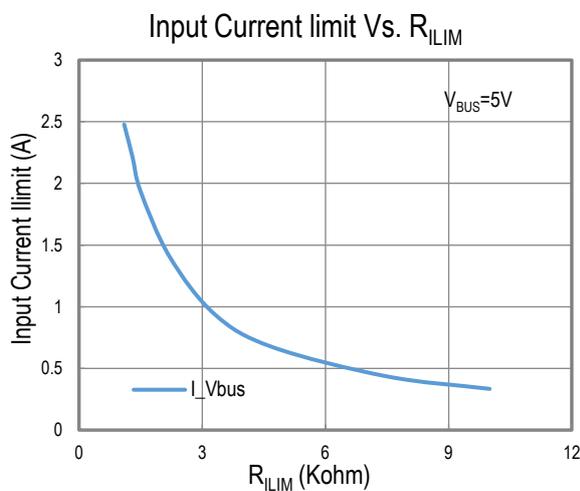
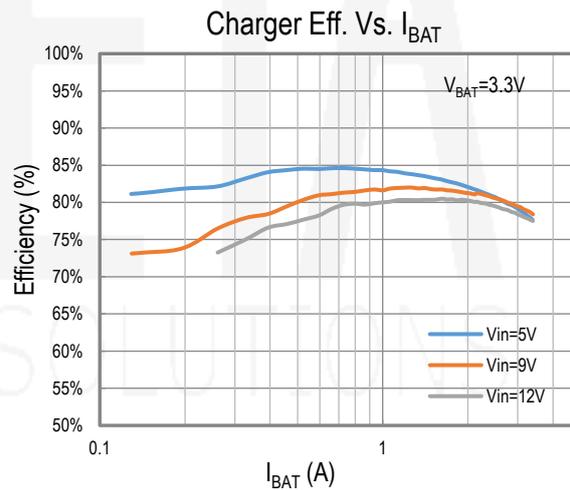
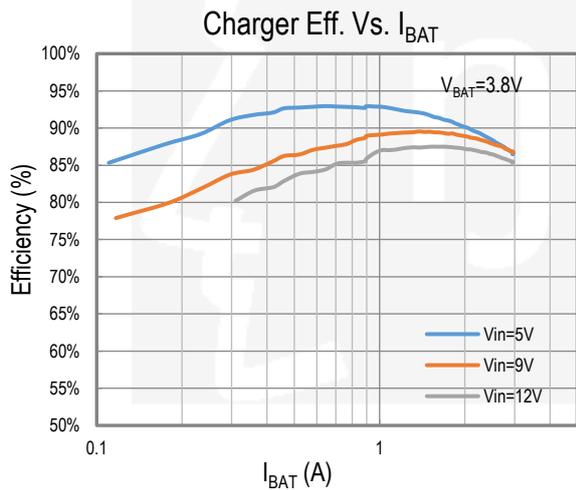
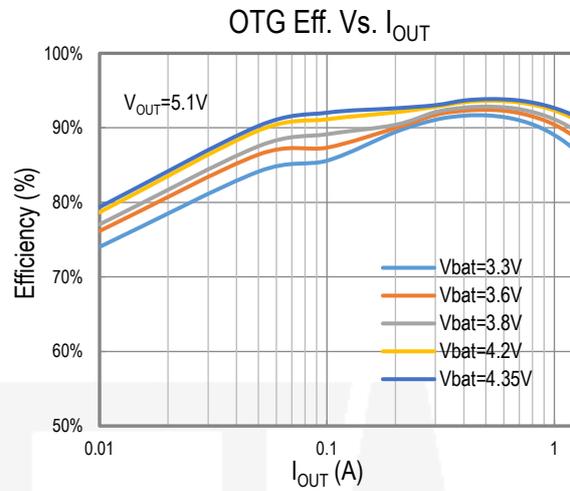
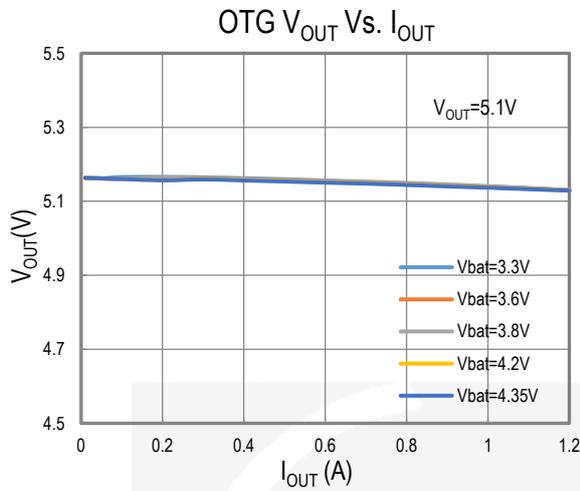
## PIN DESCRIPTION

PIN NAME	PIN #	DESCRIPTION
AC	1	Input voltage sensing. It needs to be connected to BUS pin.
BUS	24	Charger input voltage. Bypass it with a 10 $\mu$ F ceramic capacitor from BUS to PGND. The capacitor should be close to BUS pin.
NC	2	No Connection
DP	3	Positive line of the USB data line pair. DP/DM based USB host/charging port detection. The detection includes data contact detection (DCD), primary and secondary detection in BC1.2 and non-standard adaptors
DM	4	Negative line of the USB data line pair. DP/DM based USB host/charging port detection. The detection includes data contact detection (DCD), primary and secondary detection in BC1.2 and nonstandard adaptors
STAT	5	Open-drain charge status output. Connect the STAT pin to a logic rail via 10k $\Omega$ resistor. The STAT pin indicates charger status. Connect a current limit resistor and a LED from a rail to this pin. Charge in progress: LOW Charge complete or charger in SLEEP mode: HIGH Charge suspend (fault response) or No bat: 1Hz, 50% duty cycle Pulses
OTG	6	Boost mode enable pin. When this pin is pulled HIGH, OTG is enabled. OTG cannot be floating.
nPG	7	Open drain active low power good indicator. Connect to the pull up rail through 10k $\Omega$ resistor. LOW indicates a good input source if the input voltage is between UVLO and OVP threshold, above SLEEP mode threshold, and current limit is above 30 mA.
ILIM	8	ILIM sets the input current limit. A resistor is connected from ILIM pin to ground to set the input current limit as $I_{INDPM} = K_{ILIM} / R_{ILIM}$ . The acceptable range for ILIM current is 500 mA - 3200 mA. The resistor based input current limit is effective only when the input adapter is detected as unknown. Otherwise, the input current limit is determined by D+/D- detection outcome.
nCE	9	Charge disable control pin. nCE=0, charge is enabled. nCE=1, charge is disabled.
ICHG	10	ICHG pin sets the charge current limit. A resistor is connected from ICHG pin to ground to set charge current limit as $ICHG = K_{ICHG} / R_{ICHG}$ . The acceptable range for charge current is 300 mA – 3000 mA.
TS	11	Temperature qualification voltage input to support JEITA profile. Connect a negative temperature coefficient thermistor. Program temperature window with a resistor divider from LDO to TS to GND. Charge suspends when either TS pin is out of range. When TS pin is not used, connect a 10k $\Omega$ resistor from LDO to TS and connect a 10k $\Omega$ resistor from TS to GND. It is recommended to use a 103AT-2 thermistor.
VSET	12	VSET pin sets default battery charge voltage in ETA6964A. Program battery regulation voltage with a resistor pull-down from VSET to GND. $R_{PD} > 50k\Omega$ (float pin) = 4.208 V, $R_{PD} < 500\Omega$ (short to GND) = 4.352 V, $5k\Omega < R_{PD} < 25k\Omega$ = 4.4 V

PIN NAME	PIN #	DESCRIPTION
BAT	13, 14	Positive battery terminal. The internal BATFET and current sensing is connected between SYS and BAT. Connect a 10 $\mu$ F close to the BAT pin.
SYS	15, 16	Converter output connection point. The internal current sensing network is connected between SYS and BAT. Connect a 20 $\mu$ F close to the SYS pin.
GND	17, 18	Power Ground
SW	19, 20	Switching node output. Connected to output inductor. Connect the 10nF bootstrap capacitor from SW to BST
BST	21	Bootstrap capacitor connection for the high-side FET gate driver. Connect a 10nF ceramic capacitor from BST pin to SW pin.
LDO	22	LDO Output Voltage. Bypass the pin with 4.7 $\mu$ F capacitor from LDO to GND. The capacitor should be closed to the pin
PMID	23	Connection point between reverse blocking FET and high-side switching FET. Bypass it with a minimum of 10 $\mu$ F capacitor from PMID to PGND. This capacitor should be close to the PMID pin.
EP	EP	Thermal pad and ground reference. This pad is ground reference for the device and it is also the thermal pad used to conduct heat from the device. This pad should be tied externally to a ground plane through PCB vias under the pad.

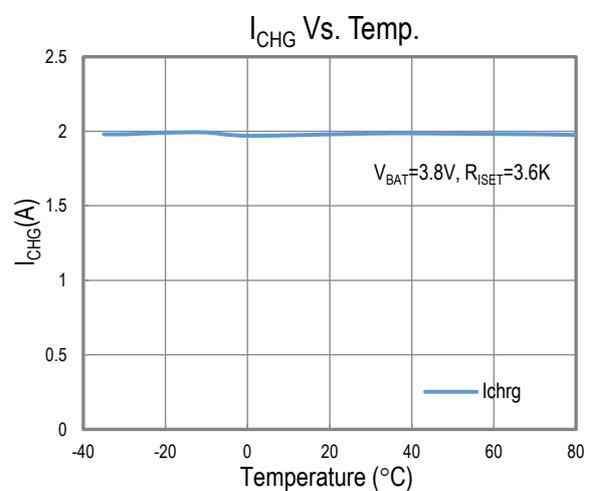
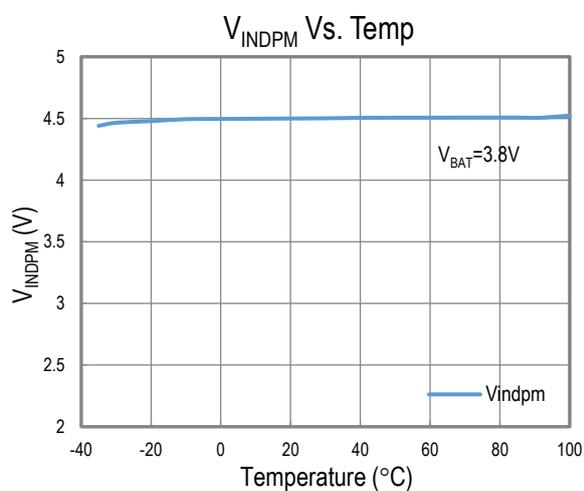
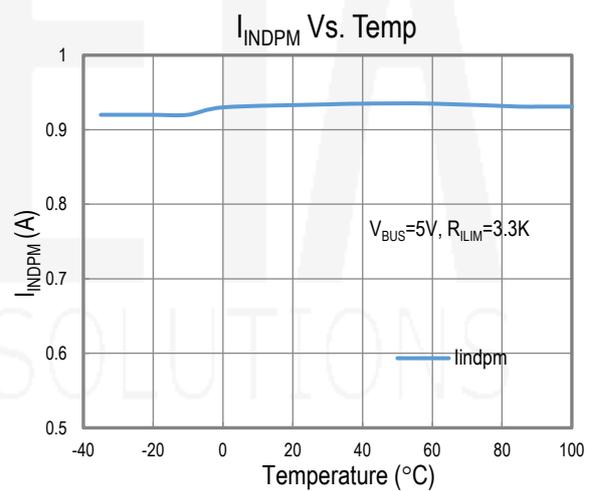
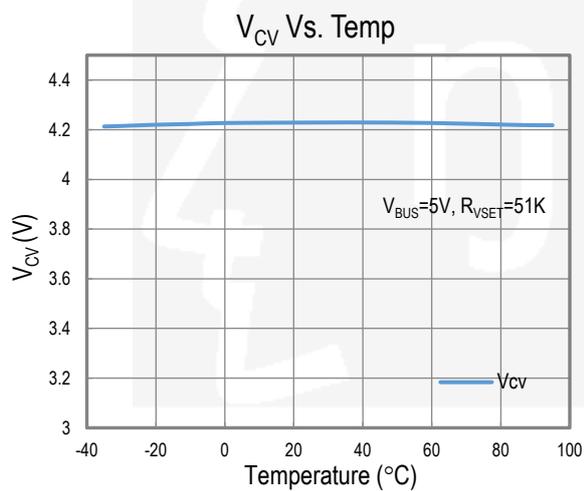
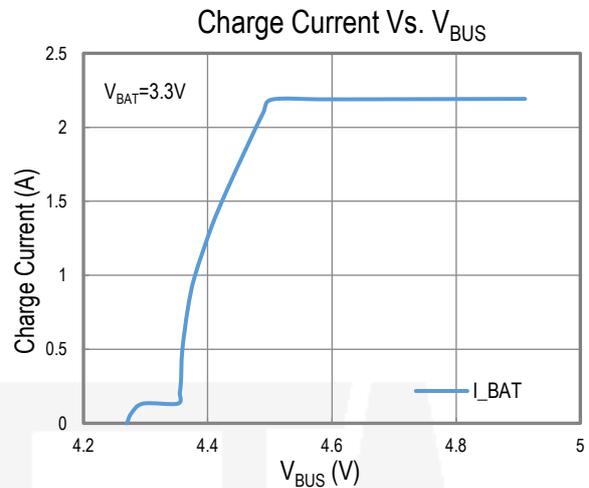
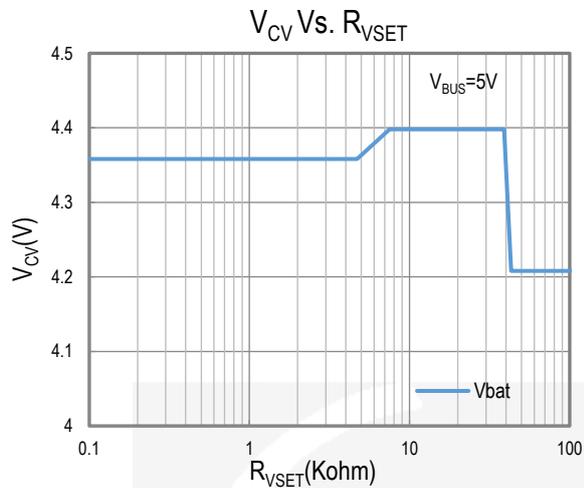
TYPICAL PERFORMANCE CHARACTERISTICS

(Typical values are at  $T_A = 25^\circ\text{C}$  unless otherwise specified.)



## TYPICAL PERFORMANCE CHARACTERISTICS cont'

(Typical values are at  $T_A = 25^\circ\text{C}$  unless otherwise specified)



## FUNCTION DESCRIPTION

The ETA6964A device is a highly integrated 3A switch-mode battery charger for single cell Li-Ion and Li-polymer battery. It includes the input reverse-blocking FET (Q1), high-side switching FET (Q2), low-side switching FET (Q3), and battery FET (Q4), and bootstrap diode for the high-side gate drive.

### POWER UP FROM BATTERY WITHOUT INPUT SOURCE

When a battery is applied without other input, the device checks the battery voltage to turn on BATFET but not  $V_{LDO}$  to minimize the supply current, especially for NTC resistor network. All supply will be directly from battery.  $V_{LDO}$  is disabled until BOOST is enabled. Anyway, in order to optimize the discharge current from battery at light load, BATFET gate charge pump operates with lower frequency.

### POWER UP WITH INPUT SOURCE

When an input source is plugged in, the device checks the input source voltage to turn on REGN LDO and all the bias circuits. It detects and sets the input current limit before the buck converter is started. The power up sequence from input source is as listed:

1. Power up  $V_{LDO}$
2. Poor Source Qualification
3. Input Voltage Limit Threshold Setting ( $V_{INDPM}$  threshold)
4. Converter Power-up

### LDO POWER UP

LDO is enabled when the below conditions are met:

1.  $V_{AC}$  is above 3.65V
2.  $V_{AC}$  is above  $V_{BAT} + V_{SLEEP}$  (200mV) in Buck mode or  $V_{AC}$  below  $V_{BAT} + V_{SLEEP}$  in Boost mode

Right after two above conditions are valid,  $V_{LDO}$  is powered up right away

### POWER SOURCE QUALIFICATION

After LDO powers up, the device checks the current capability of the input source. The input source has to meet the following requirements in order to start the buck converter.

1. 200mS delay after LDO enable
2.  $V_{AC}$  voltage below the  $V_{AC\_OVP}$  threshold
3.  $V_{AC}$  voltage above 3.8V when pulling down 30mA at AC pin

If the device fails the poor source detection in 30ms, it repeats poor source qualification every 2 seconds.

### DP/DM DETECTION SETS INPUT CURRENT LIMIT IN ETA6964A

The ETA6964A contains a DP/DM based input source detection to set the input current limit at  $V_{BUS}$  plug-in. The DP/DM detection includes standard USB BC1.2 and non-standard adapter. When input source is plugged in, the device starts standard USB BC1.2 detections. The USB BC1.2 is capable to identify Standard Downstream Port (SDP), Charging Downstream Port (CDP) and Dedicated Charging Port (DCP). When the Data Contact Detection (DCD) timer expires, the nonstandard adapter detection is applied to set the input current limit. The non-standard detection is used to distinguish vendor specific adapters (Apple and Samsung) based on their unique dividers on the DP/DM pins. Base on DP/DM configuration, the input current limit will be set following the below table:

Table 1: Non-standard Adapter Detection

NON-STANDARD ADAPTER	DP THRESHOLD	DM THRESHOLD	INPUT CURRENT LIMIT (A)
Divider1	$V_{DP}$ within $V_{2P7\_VTH}$	$V_{DM}$ within $V_{2P0\_VTH}$	2.1
Divider2	$V_{DP}$ within $V_{1P2\_VTH}$	$V_{DM}$ within $V_{1P2\_VTH}$	2
Divider3	$V_{DP}$ within $V_{2P0\_VTH}$	$V_{DM}$ within $V_{2P7\_VTH}$	1
Divider4	$V_{DP}$ within $V_{2P7\_VTH}$	$V_{DM}$ within $V_{2P7\_VTH}$	2.4

Table 2: Input Current Limit Setting from D+/D- Detection

D+/D- DETECTION	INPUT CURRENT LIMIT (A)
USB SDP	0.5
USB CDP	1.5
USB DCP	2.4
Divider1	2.1
Divider2	2
Divider3	1
Divider4	2.4
Unknown Adapter	$I_{INLIM}$ Setting

### INPUT VOLTAGE LIMIT THRESHOLD SETTING ( $V_{INDPM}$ )

The device's  $V_{INDPM}$  is set at 4.5V. The device supports dynamic  $V_{INDPM}$  tracking which tracks the battery voltage. The device's  $V_{INDPM}$  tracks battery voltage with 200mV offset such that when  $V_{BAT} + 200mV$  is greater than 4.5V, the  $V_{INDPM}$  value is automatically adjusted to  $V_{BAT} + 200mV$ .

### BUCK POWER UP

After the input current is set, the device starts Buck converter and allow HSFET and LSFET switching. ETA6964A provide soft-start time,  $V_{SYS}$  short protection to avoid overshoot current. When switching is over the soft-start time, BATFET starts turning on then allows charging progress. The device provides soft-start when system rail is ramped up. When the system rail is below 2.2 V, the input current limit is set to the lower of 200 mA. After the system rises above 2.2 V, the device limits input current to the value of  $R_{ILIM}$  setting. As a battery charger, the device deploys a highly efficient 1.5 MHz step-down switching regulator. The fixed frequency oscillator keeps tight control of the switching frequency under all conditions of input voltage, battery voltage, charge current and temperature, simplifying output filter design.

In order to improve light-load efficiency, the device switches to PFM control at light load when battery is below minimum system voltage setting or charging is disabled. During the PFM operation, the switching duty cycle is set by the voltage ratio of  $V_{SYS}$  and  $V_{BUS}$ .

## BOOST POWER UP

ETA6964A provide boost converter up to 1.2A output current. The boost is enabled when the below conditions are valid:

1.  $V_{BAT}$  above the battery voltage exiting boost mode threshold
2.  $V_{BUS}$  is less than  $V_{BAT}+V_{SLEEP}$  (200mV)
3. OTG pin is high
4. TS pin is within acceptable range ( $V_{BHOT} < V_{TS} < V_{BCOLD}$ )

During boost mode,  $V_{BUS}$  output is 5.15 V by default and 1.5MHz Frequency. The output current can reach up to 1.2 A. The boost output is maintained when BAT is above  $V_{OTG\_BAT}$  threshold. When OTG is enabled, the device starts up with PFM and later transits to PWM to minimize the overshoot.

## AUTONOMOUS BATTERY CHARGER

The device charges 1-cell Li-Ion battery with up to 3A charge current for high capacity tablet battery. The 27m $\Omega$  BATFET improves charging efficiency and minimize the voltage drop during discharging.

With battery charging is enabled (nCE pin is LOW), the device autonomously completes a charging cycle without host involvement

A new charge cycle starts when the following conditions are valid:

- Converter starts
- Battery charging is enabled (nCE is low)
- No thermistor fault on TS
- No safety timer fault

The charger device automatically terminates the charging cycle when the charging current is below termination threshold, charge voltage is above recharge threshold, and device is not in DPM mode or thermal regulation.

When a full battery voltage is discharged below recharge threshold, the device automatically starts a new charging cycle. After the charge is done, toggle nCE pin can initiate a new charging cycle.

The STAT output indicates the charging status: charging (LOW), charging complete or charge disable (HIGH) or charging fault (Blinking).

## BATTERY CHARGER PROFILE

The device charges the battery in five phases: battery short, preconditioning, constant current, constant voltage and top-off trickle charging (optional). At the beginning of a charging cycle, the device checks the battery voltage and regulates current and voltage accordingly.

If the charger device is in DPM regulation or thermal regulation during charging, the actual charging current will be less than the programmed value. in this case, termination is temporarily disabled and the charging safety timer is counted at half the clock rate.

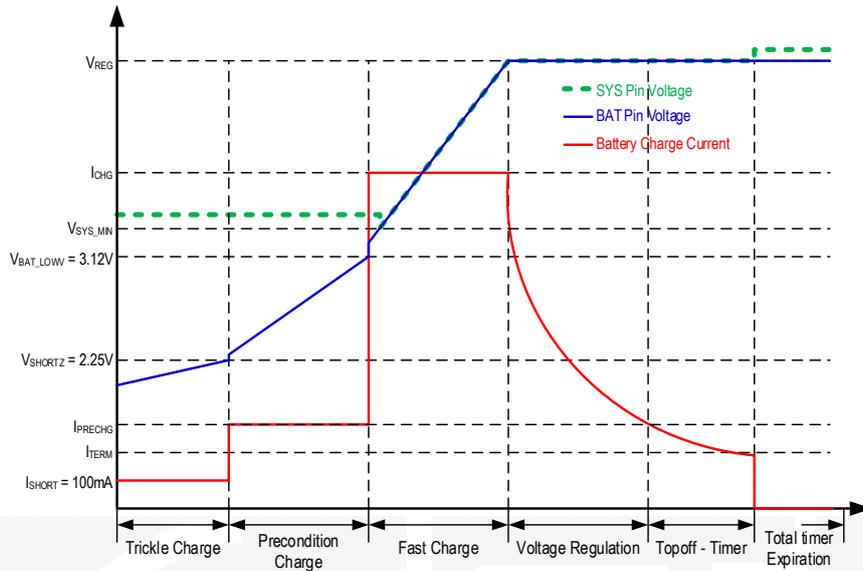


Figure 1: Battery Charger Profile

### CHARGE TERMINATION CONFIGURATION

When battery voltage reach regulation level set by VSET pin, the device allow charger enter termination. In this state, when charge current falls below  $I_{TERM}$  level, charger will be terminated. After the charging cycle is completed, the BATFET turns off. The converter keeps running to power the system, and BATFET can turn on again to engage Supplement Mode.

### CHARGE SAFETY TIMER

The device has built-in safety timer to prevent extended charging cycle due to abnormal battery conditions. The safety timer is 2 hours when the battery is below  $V_{BAT\_LOW}$  threshold and is 10 hours when the battery below  $V_{TERM}$ .

### MINIMUM SYS VOLTAGE

Because the rail that provide power to system is SYS voltage, so to make sure the system always has enough voltage even with a fully depleted battery, the system is regulated above the minimum system voltage 3.5V.

When the battery is below minimum system voltage setting, the BATFET operates in linear mode (LDO mode), and the system is typically 180 mV above the minimum system voltage setting. As the battery voltage rises above the minimum system voltage, BATFET is fully on and the voltage difference between the system and battery is the  $V_{DS}$  of BATFET.

When the battery charging is disabled and above minimum system voltage setting 3.5V or charging is terminated, the system is always regulated at typically 70mV above battery voltage.

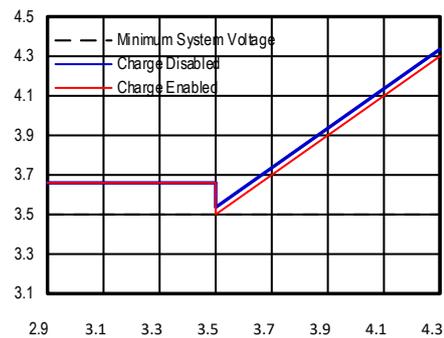


Figure 2: System Voltage vs Battery Voltage

### DYNAMIC POWER MANAGEMENT

To meet maximum current limit in USB spec and avoid over loading the adapter, the device features Dynamic Power

management (DPM), which continuously monitors the input current and input voltage. When input source is over-loaded, either the current exceeds the input current limit ( $I_{INDPM}$ ) or the voltage falls below the input voltage limit ( $V_{INDPM}$ ). The device then reduces the charge current until the input current falls below the input current limit and the input voltage rises above the input voltage limit.

When the charge current is reduced to zero, but the input source is still overloaded, the system voltage starts to drop. Once the system voltage falls below the battery voltage, the device automatically enters the supplement mode where the BATFET turns on and battery starts discharging so that the system is supported from both the input source and battery.

### SUPPLEMENT MODE

When the system voltage falls 10 mV ( $V_{BAT} > V_{SYS\_MIN}$  when Q4 is full on. In this condition, discharge current is almost 1A) or 20mV ( $V_{BAT} < V_{SYS\_MIN}$  when Q4 is in regulation. In this condition, gate of Q4 is regulated at about only threshold voltage of the FET, then discharge current is almost zero) below the battery voltage, the BATFET turns on and the BATFET gate is regulated the gate drive of BATFET so that the minimum BATFET  $V_{DS}$  stays at 30 mV when the current is low. This prevents oscillation from entering and exiting the supplement mode.

As the discharge current increases, the BATFET gate is regulated with a higher voltage to reduce  $R_{DS(on)}$  until the BATFET is in full conduction. At this point onwards, the BATFET  $V_{DS}$  linearly increases with discharge current. Following figure shows the V-I curve of the BATFET gate regulation operation. BATFET turns off to exit supplement mode when the battery is below battery depletion threshold.

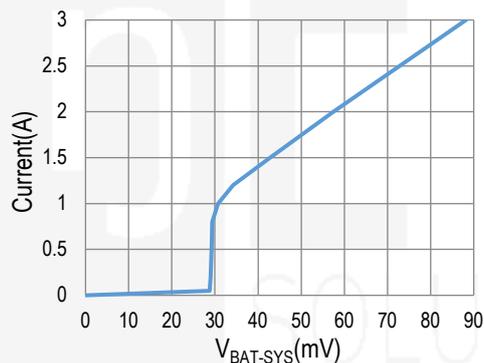


Figure 3: BATFET Current at Entering Supplement Mode

### THERMISTOR QUALIFICATION DURING CHARGING MODE

The charger device provides a single thermistor input for battery temperature monitor.

To improve the safety of charging Li-ion batteries, JEITA guideline was released on April 20, 2007. The guideline emphasized the importance of avoiding a high charge current and high charge voltage at certain low and high temperature ranges.

To initiate a charge cycle, the voltage on TS pin must be within the  $V_{T1}$  to  $V_{T5}$  thresholds. If TS voltage exceeds the T1-T5 range, the controller suspends charging and waits until the battery temperature is within the T1 to T5 range.

At cool temperature (T1-T2), JEITA recommends the charge current to be reduced to half of the charge current or lower. At warm temperature (T3-T5), JEITA recommends charge voltage less than 4.1V.

The charger provides flexible voltage/current settings beyond the JEITA requirement. The voltage setting at warm temperature

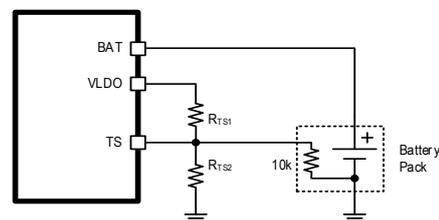


Figure 4: Thermistor Configuration

(T3-T5) can be VREG . The current setting at cool temperature (T1-T2) can be further reduced to 20% of fast charge current.

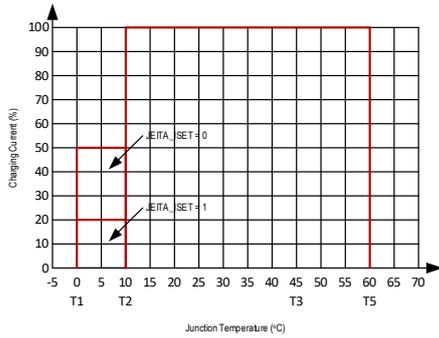


Figure 5: JEITA Profile: Charging Current

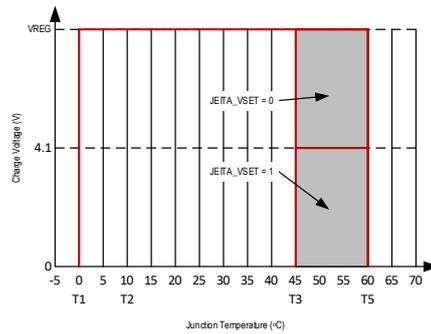


Figure 6: JEITA Profile: Charging Voltage

The resistor bias network has been updated as below.

$$R_{TS1} = \frac{\left(\frac{V_{LDO}}{V_{T1}} - 1\right)}{\frac{1}{R_{TS2}} + \frac{1}{R_{THCOLD}}}$$

$$R_{TS2} = \frac{V_{LDO} \times R_{THCOLD} \times R_{THHOT} \times \left(\frac{1}{V_{T1}} - \frac{1}{V_{TS}}\right)}{R_{THHOT} \times \left(\frac{V_{LDO}}{V_{TS}} - 1\right) - R_{THCOLD} \times \left(\frac{V_{LDO}}{V_{T1}} - 1\right)}$$

### THERMISTOR QUALIFICATION DURING BATTERY DISCHARGE MODE

For battery protection during boost mode, the device monitors the battery temperature to be within the  $V_{BCOLD}$  to  $V_{BHOT}$  thresholds. When temperature is outside of the temperature thresholds, the boost mode is suspended.

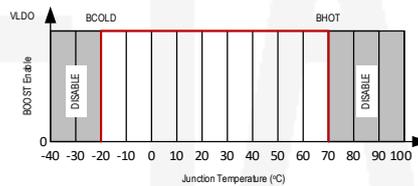


Figure 7: TS Pin Thermistor Sense Threshold in Boost Mode

### INDICATION OUTPUT

#### POWER GOOD INDICATION ON nPG PIN

The nPG pin goes LOW to indicate a good input source when:

- $V_{BUS}$  above  $V_{BUS\_UVLO}$
- $V_{BUS}$  above battery (not in sleep)
- $V_{BUS}$  below  $V_{AC\_OV}$  threshold
- $V_{BUS}$  above  $V_{BUS\_MIN}$  (typical 3.8 V) when  $I_{BADSRC}$  (typical 30 mA) current is applied (not a poor source)

#### CHARGING STATUS INDICATION ON STAT PIN

The device indicates charging state on the open drain STAT pin. The STAT pin can drive LED. STAT indication operates as shown as in below table.

Table 2: STAT Indication table

CHARGE STATE	STAT INDICATION
Charging in progress (including recharge)	LOW
Charging complete	HIGH
Sleep mode, charge disable	HIGH
Charge suspend (input overvoltage, TS fault, timer fault or system overvoltage)	Blinking at 1Hz (0.5s LOW / 0.5s HIZ)
Boost Mode suspend (due to TS fault)	

### INPUT OVERVOLTAGE PROTECTION IN CHARGE MODE (ACOV)

If  $V_{BUS}$  exceeds over voltage threshold  $V_{AC\_OV}$ , the device stops switching immediately. The device will automatically resume normal operation once the input voltage drops back below the OVP threshold.

### SYSTEM OVERVOLTAGE PROTECTION IN CHARGE MODE (SYSOVP)

The charger device clamps the system voltage during load transient so that the components connect to system would not be damaged due to high voltage. SYSOVP threshold is 14% above system regulation voltage. Upon SYSOVP, converter stops immediately to clamp the overshoot.

### VBUS OUTPUT SHORT PROTECTION IN BOOST MODE

The device monitors boost output voltage and other conditions to provide output short circuit and overvoltage protection. The Boost build-in accurate constant current regulation to allow OTG to adaptive to various types of load. If short circuit is detected on BUS, the Boost turns off and retry 7 times. If retries are not successful, OTG is disabled.

### VBUS OVERVOLTAGE PROTECTION IN BOOST MODE

When the  $V_{BUS}$  rises above regulation target and exceeds the over voltage threshold  $V_{OTG\_OVP}$ , the device enters overvoltage protection which stops switching.

### THERMAL REGULATION IN BUCK MODE

ETA6964A monitors the internal junction temperature  $T_J$  to avoid overheat the chip and limits the IC surface temperature at 110°C in buck mode. When the internal junction temperature exceeds thermal regulation limit (110°C), the device lowers down the charge current. During thermal regulation, the actual charging current is usually below the programmed battery charging current. Therefore, termination is disabled, the safety timer runs at half the clock rate.

### THERMAL SHUTDOWN

The device monitors the internal junction temperature to provide thermal shutdown during any mode. When IC surface temperature exceeds  $T_{SHUT}$  (160°C) BATFET and Converter are disabled.

When IC temperature is  $T_{SHUT\_HYS}$  (30°C) below  $T_{SHUT}$  (160°C), The BATFET is enabled automatically to restore system.

### BATTERY OVER-VOLTAGE PROTECTION

The battery overvoltage limit is clamped at 8% above the battery regulation voltage. When battery over voltage occurs, the charger device immediately disables charge.

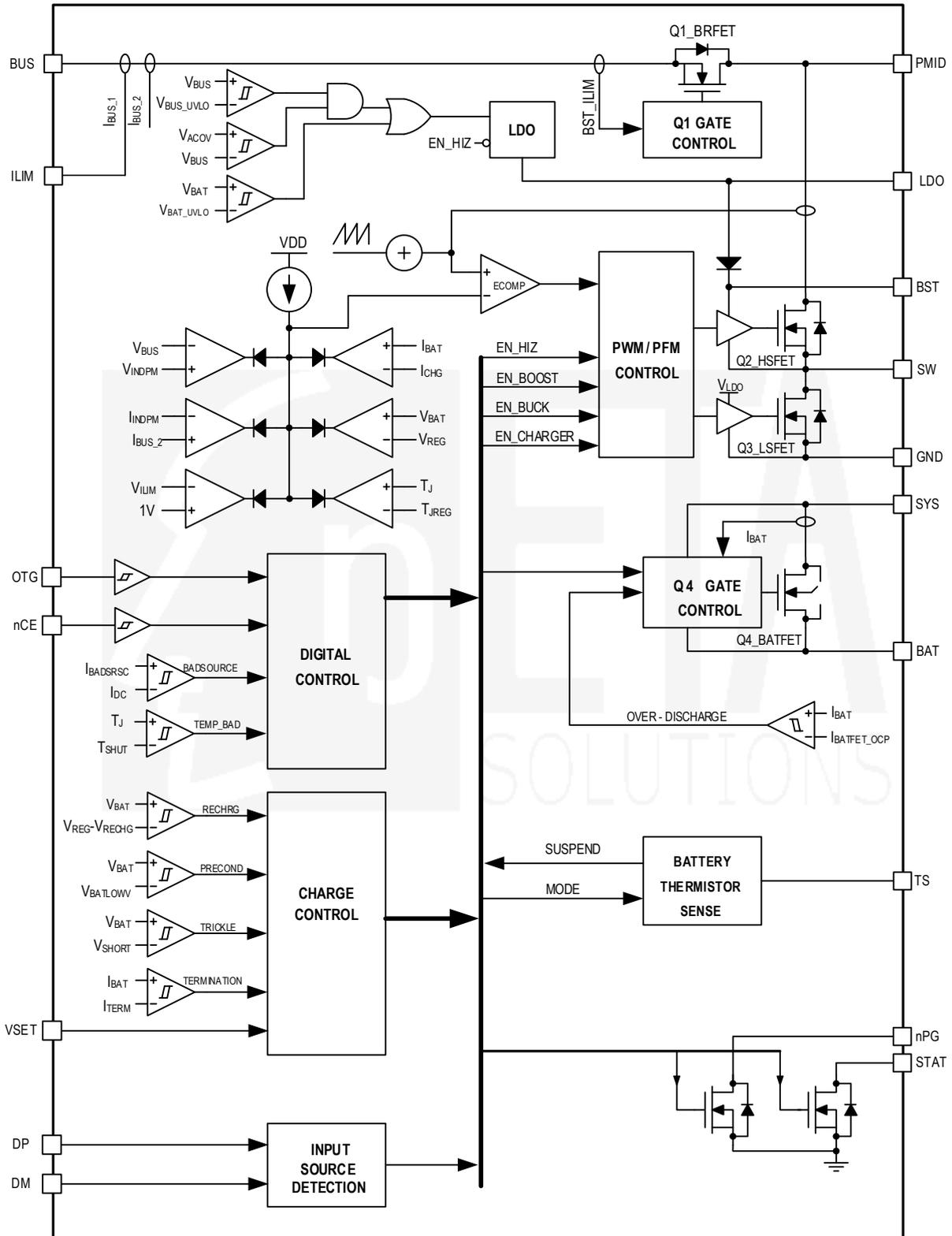
### BATTERY OVER-DISCHARGE PROTECTION

When battery is discharged below the battery depletion falling threshold  $V_{BAT\_DPL\_FALL}$ , the BATFET is turned off to protect battery from over discharge. To recover from over-discharge, an input source is required at BUS pin. When an input source is plugged in, the BATFET turns on. The battery is charged with  $I_{SHORT}$  (typically 150 mA) current when the  $V_{BAT}$  is smaller than the trickle charge voltage threshold  $V_{SHORT}$ , or pre-charge current when the battery voltage is between  $V_{SHORT}$  and the pre-charge voltage threshold  $V_{BAT\_LOW}$ .

### SYSTEM OVER-CURRENT PROTECTION

When the system is shorted or significantly overloaded ( $I_{BAT} > I_{BATOP}$ ) so that its current exceeds the over-current limit, the device latches off BATFET. To recover from over-discharge latch-off, an input source plug-in is required at BUS.

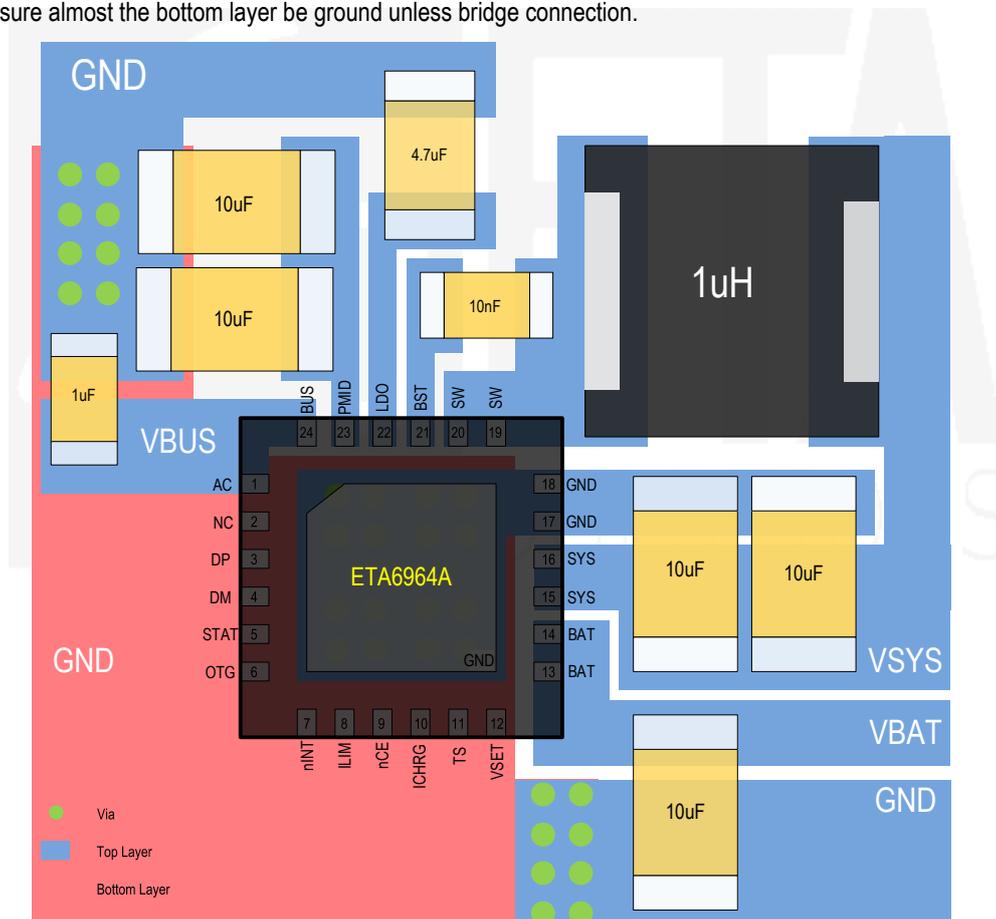
FUNCTION BLOCK DIAGRAM



## PCB DESIGN GUIDELINE

In order to have as clean as possible supply for converter, please follow following suggestion:

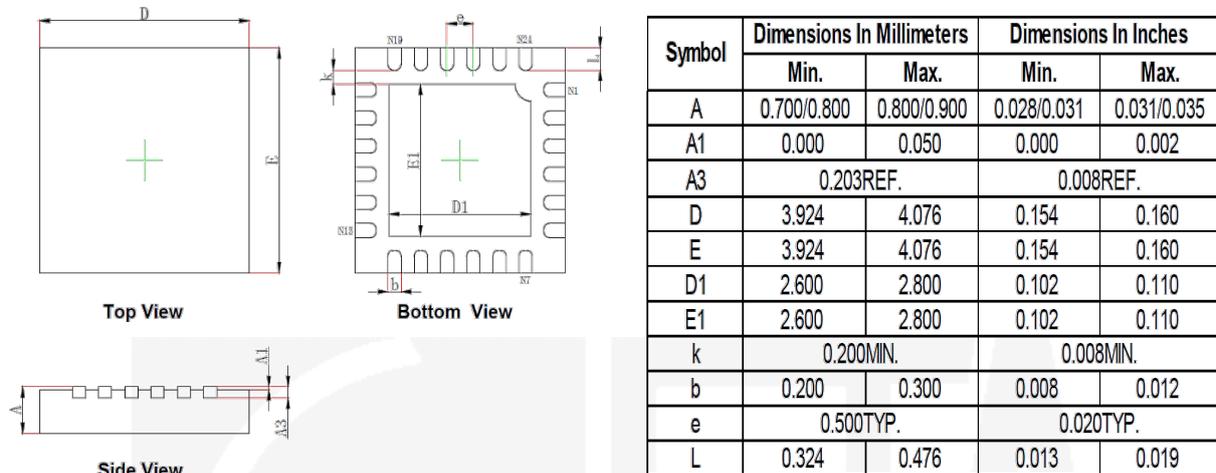
1. Place the BUS, PMID, BAT, SYS, LDO capacitor as close as possible to the pins and wide bottom layer for PGND connections. Also add as much as possible vias for PGND to minimize copper resistance added to PMID capacitor.
2. Place inductor input pin to SW pin as close as possible. Minimize the copper area of this trace to lower electrical and magnetic field radiation but make the trace wide enough to carry the charging current. Do not use multiple layers in parallel for this connection. Minimize parasitic capacitance from this area to any other trace or plane.
3. Put output capacitor near to the inductor and the device. Ground connections need to be tied to the IC ground with a short copper trace connection or GND plane.
4. Use thermal pad as the single ground connection point.
5. Use single ground connection to tie charger power ground to charger analog ground. Just beneath the device. Use ground copper pour but avoid power pins to reduce inductive and capacitive noise coupling.
6. Place decoupling capacitors next to the IC pins and make trace connection as short as possible.
7. It is critical that the exposed thermal pad on the backside of the device package be soldered to the PCB ground. Ensure that there are sufficient thermal vias directly under the IC, connecting to the ground plane on the other layers.
8. Ensure that the number and sizes of vias allow enough copper for a given current path.
9. Ensure almost the bottom layer be ground unless bridge connection.



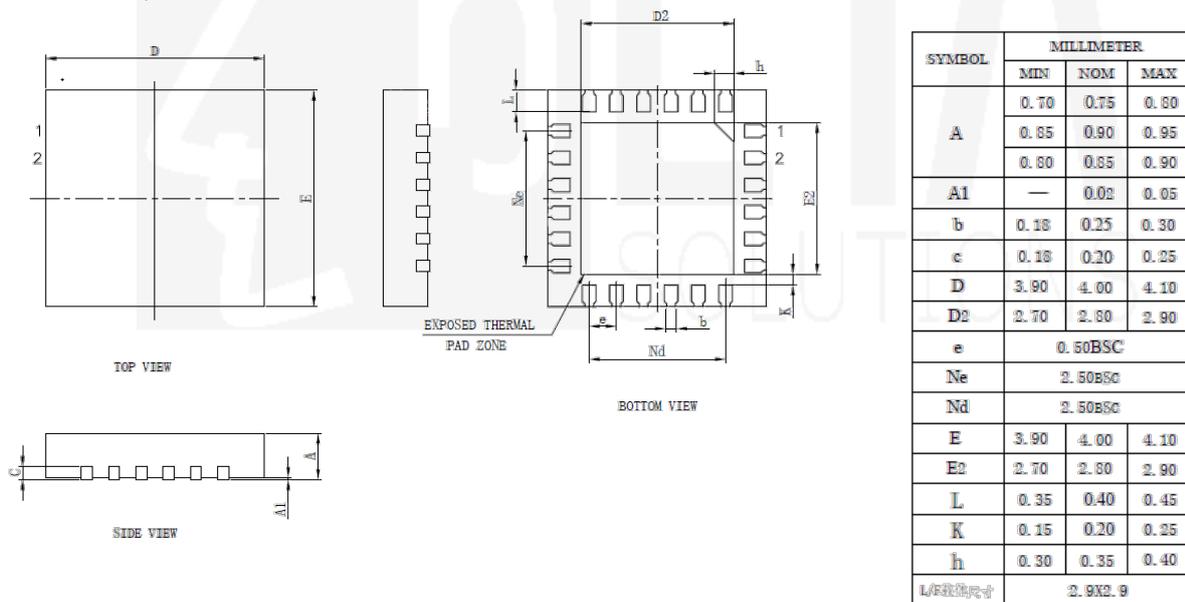
## PACKAGE OUTLINE

QFN4x4-24

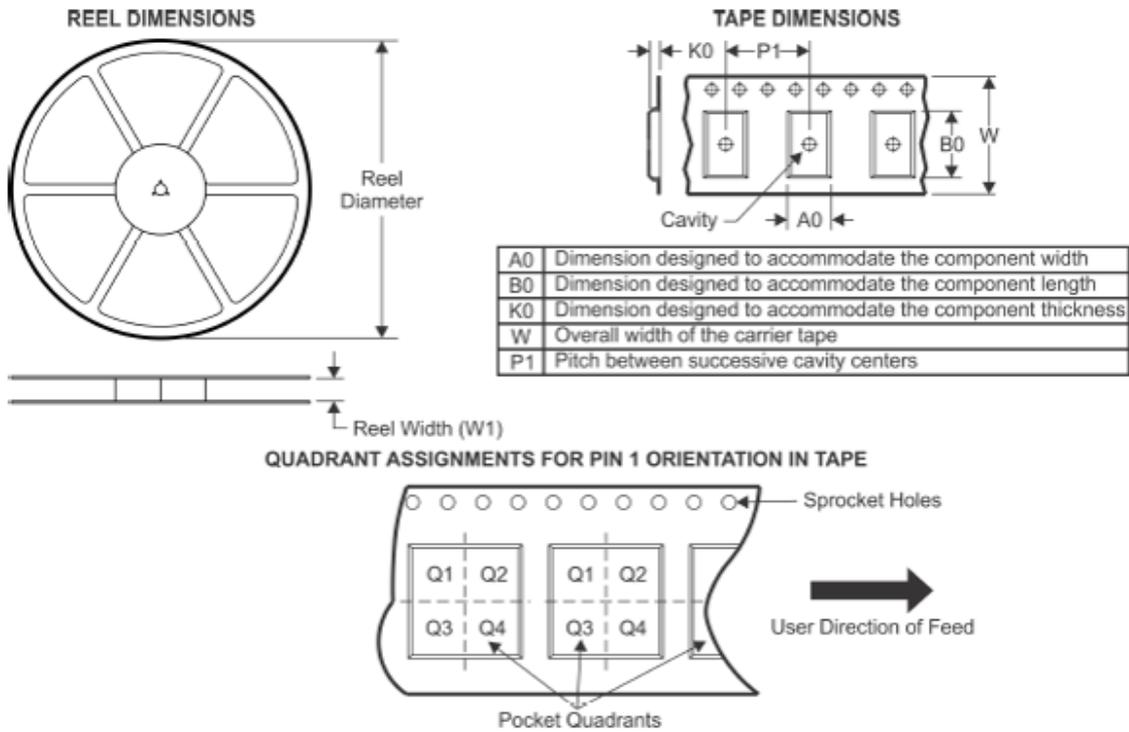
From assembly house 1:



From assembly house 2:



## TAPE AND REEL INFORMATION



Device	Package Type	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
ETA6964AQ4Y	QFN4+4-24	24	5000	330	12.4	4.3	4.3	1.1	8	12	Q1