3A/15V Synchronous Switching Mode 1/2cell Li-ion Chargers With Power Path Selector

General Description

The LP28400 is a complete constant-current/ constant- voltage Switch mode charger for 1cell or 2cell lithium-ion batteries. 1.5MHz Synchronous Switching Charger with 3A Integrated MOSFETs. No external blocking diodes is required. The Switch mode charger uses a high switching frequency to reduce power dissipation during charging eliminate heat and allow tiny external components. It can operate from a single input that accepts. All power switches for charging and switching the load between battery and external power are included on-chip that can be embedded in a wide range of handheld applications, Built-in power path controller, easily installation with external MOSFETs, Dynamic power management, better thermal performance. The LP28400 includes complete charge termination circuitry, automatic recharge and a ±1% output voltage. Fault condition protection includes cycle -by -cycle current limiting and thermal shutdown. Other safety features include battery temperature monitoring, charge status indication and programmable timer to cease the charging cycle.
The LP28400 is available in a low profile (0.75mm) 10-lead (4mm × 4mm) TDFN package.

Features

- Up to 95% efficiency
- 4.5-15V Operating voltage(Vin)
- Vin Over Voltage Protection:6.8V/16.5V
- Short-circuit protection
- Programmable Charge Current Up to 3000mA
- Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- Charges 1Cell and 2cell Li-Ion Batteries Directly with same chip, Chargers with power path selector
- Internal Fixed 7Hrs timer
- Drainage Charge Current Thermal Regulation Status Outputs for LED or System Interface
- Indicates Charge and Fault Conditions
- Optional Battery Temperature Monitoring Before and During Charge Automatic Sleep Mode for Low-Power
- Consumption Available in 4mm × 4mm TQFN-20 Package
- RoHS Compliant and 100% Lead (Pb)-Free

Order Information

LP28400 □ □ □ □ □

- F: Pb-Free
- Package Type
  - QV: TQFN-20
- Output voltage
  - Default: 4.2V/8.4V

Marking Information

Device	Marking	Package	Shipping
LP28400	LPS LP28400 XXXXX	QV: TQFN-20	
X: Batch numbers.			

Applications

- Portable Media Players
- Cellular and Smart mobile phone
- Car GPS
- Handheld Battery-Powered Devices
- Handheld Computers
- Charging Docks and Cradles

Typical Application Circuit

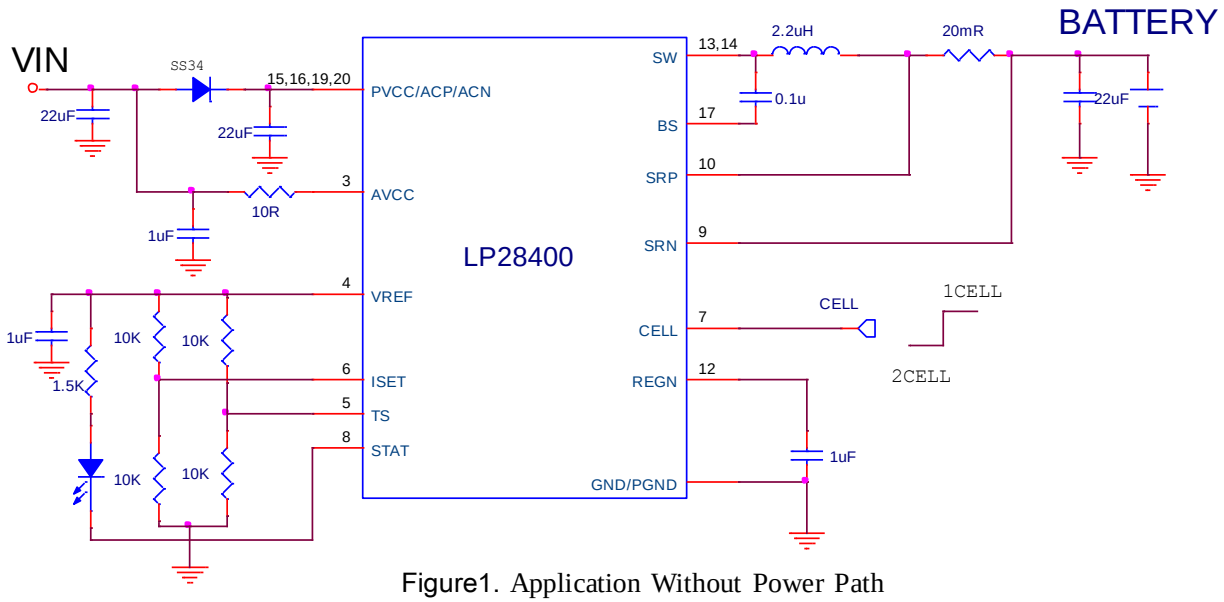


Figure1. Application Without Power Path

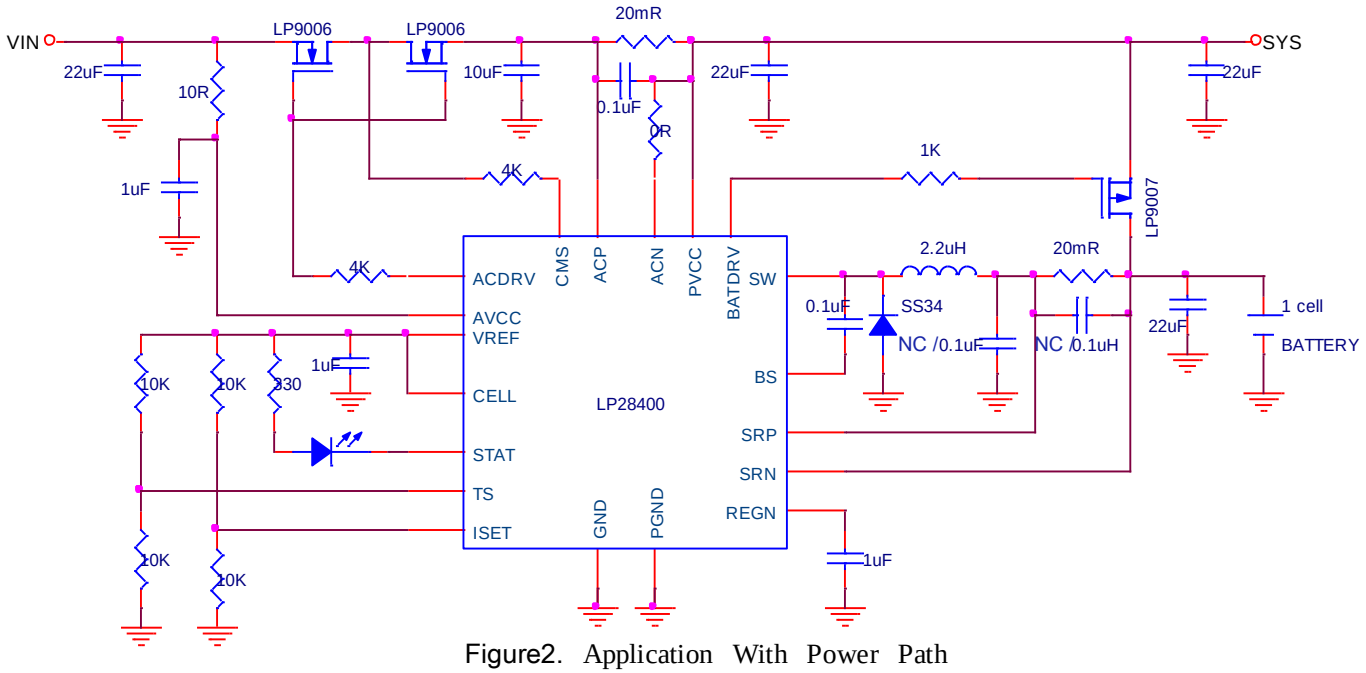
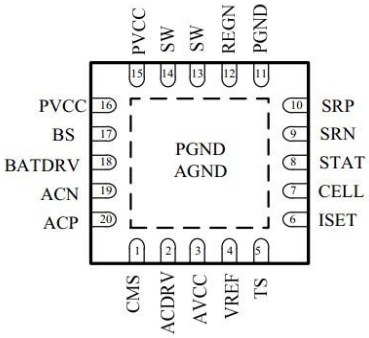


Figure2. Application With Power Path

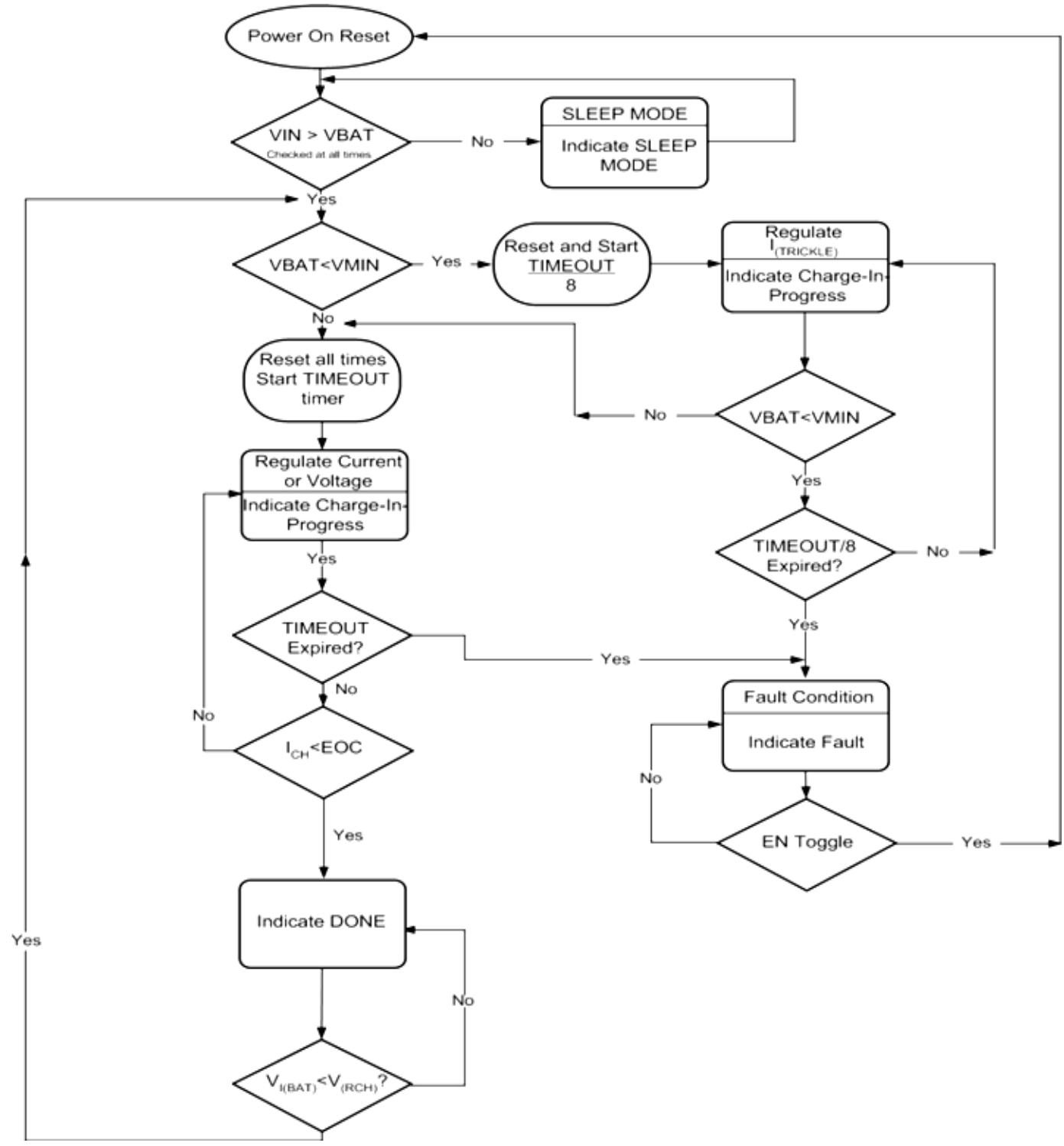
Functional Pin Description

Package Type	Pin Configurations
TQFN- 20	

Pin Description

PIN	PIN NO.	DESCRIPTION
CMS	1	Connect to common source of Nch ACFET and reverse blocking Nch RBFET. Place 4K resistor from CMS pin to the common source of ACFET and RBFET to control the turn-on speed.
ACDRV	2	AC adapter to system switch driver output.
AVCC	3	IC power supply of internal bias. Put 1uF MLCC from AVCC to AGND. Add 10Ω resistor to filter the nois of power line.
VREF	4	3.3V reference output. A 1uF MLCC is placed from VREF to GND to make it stable.
TS	5	NTC resistor connection.
ISET	6	Fast charge current set pin.
CELL	7	Cell selection pin. Set CELL pin LOW or floating for 2-cell, HIGH for 1-cell.
STAT	8	Open-Drain Charge Status Output.
SRN	9	Charge current sense negative input.
SRP	10	Charge current sense positive input. A 0.1-uF is recommended for common mode filtering from SRP to AGND. A 0.1uF is placed from SRP to SRN for differential mode filtering.
GND	11	Power ground.
REGN	12	5V power supply output, Bypass 1uF MLCC to AGND.
SW	13.14	Switching node, charge current output inductor connection. Connect a 47-nF BS capacitor from SW to BS.
PVCC	15.16	IC power supply of power device of Charger. Put 10uF MLCC from PVCC to PGND.
BS	17	Boostrap pin. Place a 0.047u-F MLCC from SW to BS.
BATDRV	18	Battery discharge MOSFET gate driver output. Connect a 1kohm resistor to the gate of the P-channel power MOSFET(BATFET). Connect the source of the BATFET to the system load voltage node. Connect the drain of the BATFET to the battery pack positive node. The internal gate drive is asymmetrical to allow a quick turn-off and slower turn-on. The internal break-before-make logic with respect to ACDRV. There is an internal 50k pull-down resistor from BATDRV to ground.
ACN	19	Adaptor current sense resistor negative input. A 0.1-uF from ACN to AGND is recommended for commo mode filtering. A 0.1uF is placed from ACN to ACP for differential mode filtering.
ACP	20	Adaptor current sense resistor positive input. A 0.1-uF from ACP to AGND is recommended for commo mode filtering. A 0.1uF is placed from ACN to ACP for differential mode filtering.

Operating Flow Chart



Typical Application Circuit

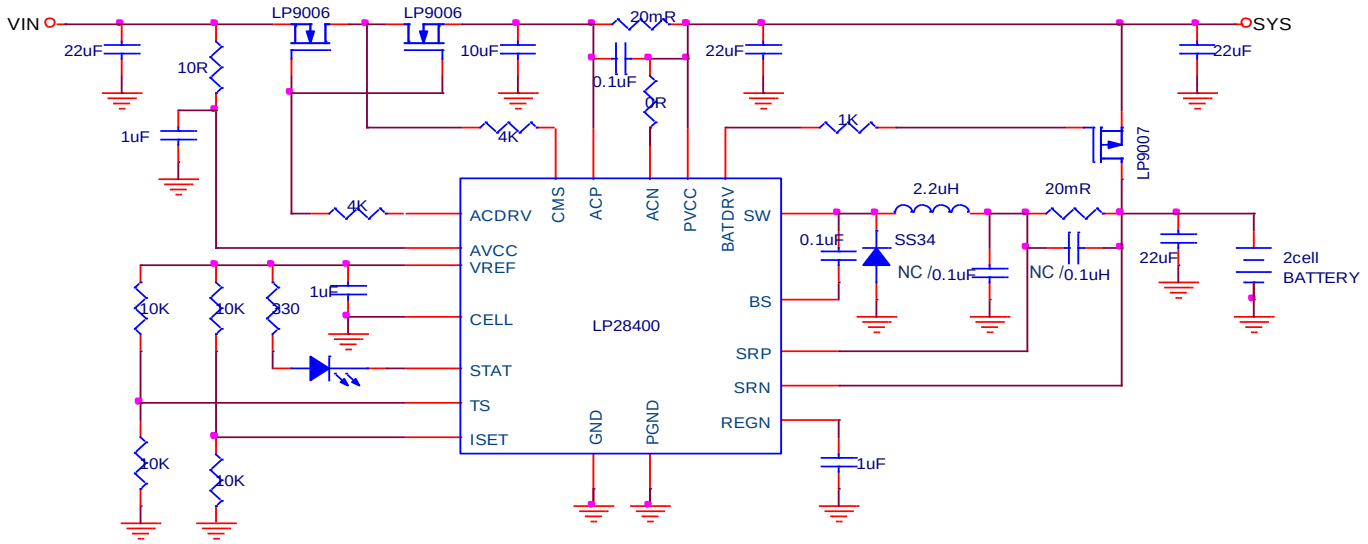


Figure3. LP28400 application 2CELL circuit

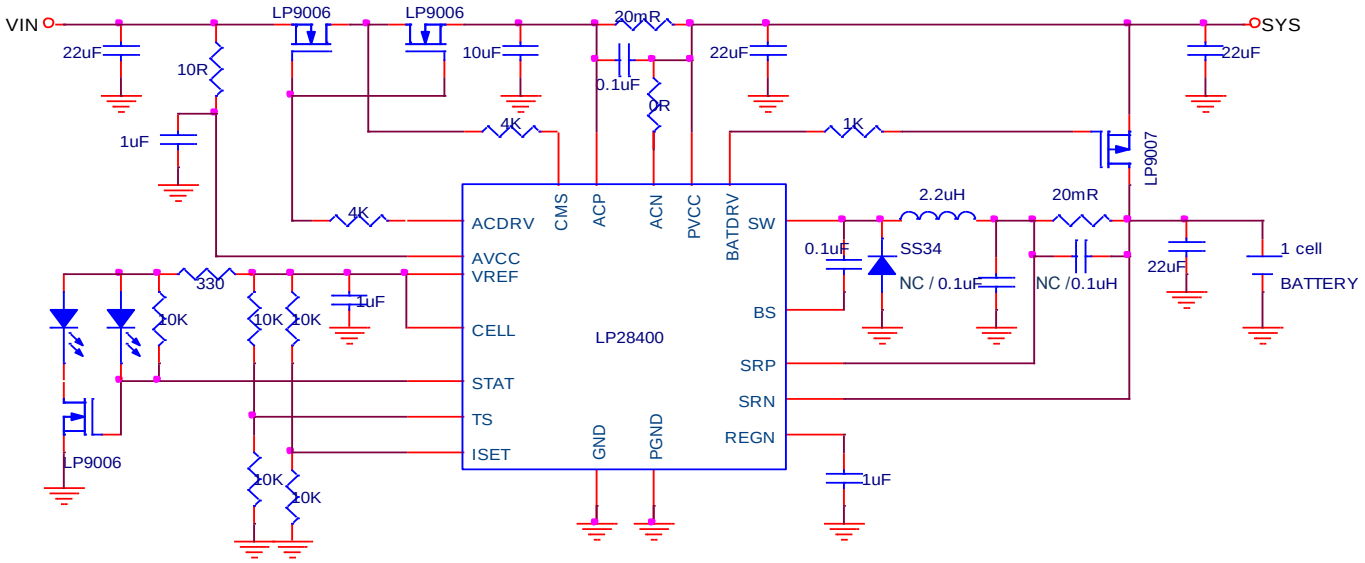


Figure4. LP28400 application 2LED circuit

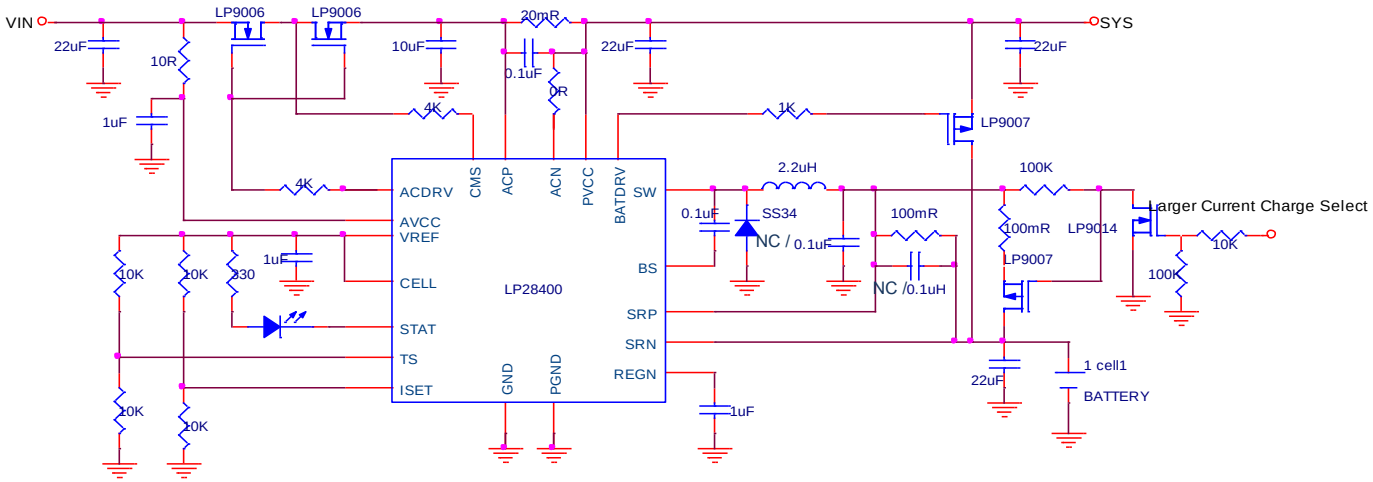
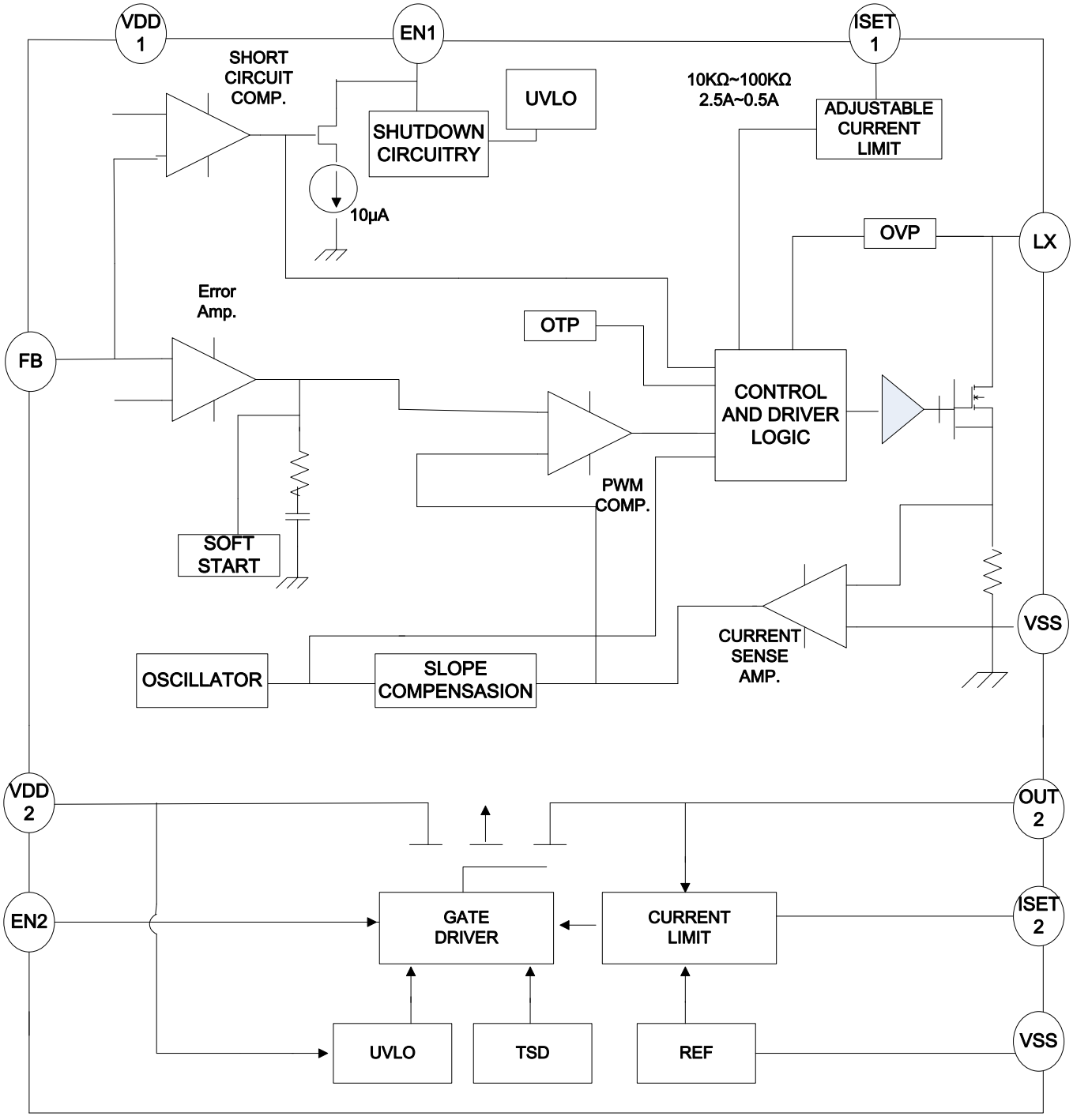


Figure5. LP28400 application of charger circuit and USB Power

Function Block Diagram



Absolute Maximum Ratings

- ✧ Input Voltage to GND (VIN) ---------- 20V
- ✧ ACDRV, BS----------26V
- ✧ ACP, ACN, CMS, STAT, BATDRV, SRP, SRN ,SW ----------0.3V to VIN+0.3V
- ✧ REGN, TS, CELL---------- -0.3Vto 7V
- ✧ BAT Short-Circuit Duration ---------- Continuous
- ✧ BAT Pin Current ---------- 3000mA
- ✧ ISET Pin Current ---------- 800μA
- ✧ Maximum Junction Temperature ---------- 125°C
- ✧ Operating Junction Temperature Range (TJ) ---------- -40℃ to 85°C
- ✧ Maximum Soldering Temperature (at leads, 10 sec) ---------- 260°C

Thermal Information

- ✧ Maximum Power Dissipation (PD,TA<40°C) ---------- 2W
- ✧ Thermal Resistance (JA) ---------- 40℃/W

Electrical Characteristics

4.5V≤V(PVCC, AVCC)≤15V, –20°C < TJ + 125°C, typical values are at TA= 25°C, with respect to AGND (unless otherwise noted)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP.	MAX	UNITS
VIN	Adapter/USB Voltage Range		4.5	5	15	V
VUVLO	AC under-voltage rising	Measure on AVCC		3.3		V
VUVLO_HYS	AC under-voltage			300		mV
VSLEEP	SLEEP mode threshold	VAVCC – VSRN falling		100		mV
VSLEEP_HYS	Hysteresis	VAVCC – VSRN rising		200		mV
VACSET	ACSET Voltage Range	RSENSE = 20mΩ	0		VREF	V
IACSET	ACSET Input Bias Current		25		-25	uA
VACP-ACN	AC Current Full Scale Sense Voltage	VACSET=VREF, RSENSE = 20mΩ	95	100	105	mV
		VACSET=Float, RSENSE = 20mΩ	71	75	79	mV
		VACSET=GND, RSENSE = 20mΩ	46	50	54	mV
Icc	Input Supply Current	VAVCC > VUVLO, VAVCC > VSRN, VBAT=4.2V/8.4V, Charge disabled		1.2	1.5	mA
		VAVCC > VUVLO, VAVCC > VSRN, Charge enabled, switching		15		mA
IBAT	BAT Pin Current	Sleep Mode, VAVCC>VUVLO,VSRN>VAVCC		15		uA
		BTST, SW, SRP, SRN, VAVCC > VUVLO, VAVCC > VSRN, ISET < 40mV, VBAT=4.2V/8.4V, Charge disabled		25		uA

		BTST, SW, SRP, SRN, VAVCC > VUVLO, VAVCC > VSRN, ISET > 120mV, VBAT=8.4V, Charge done		25		uA
VFLOAT	Regulated Output (Float) Voltage	CELL = VREF, TJ = 0°C to 85°C LP28400	4.158	4.2	4.242	V
		CELL = GND, TJ = 0°C to 85°C LP28400	8.358	8.4	8.442	V
Fsw	PWM Switching Frequency		1.32	1.5	1.68	MHz
VISET	ISET Voltage Range		0		VREF	V
IISET	ISET Input Bias Current		25		-25	uA
VSRP-SRN-CC	Charge Current Full Scale Sense Voltage	VISET=VREF	71	75	79	mV
		VISET=Float	46	50	54	mV
		VISET=AGND	21	25	29	mV
VSRP-SRN-CP	Charge Current Full Scale Sense Voltage in Pre-Charge	VISET=VREF	7.1	7.5	7.9	mV
		VISET=Float	4.6	5.0	5.4	mV
		VISET=AGND	2.1	2.5	2.9	mV
TTERM_DEG	Deglitch time	VSRN > VRECH and ICHG < ITERM		100		mS
VLOWV	Precharge to fast charge transition threshold	CELL = VREF, measured on SRN	2.85	2.9	2.95	V
		CELL = AGND, measured on SRN	5.7	5.8	5.9	V
VLOWV_HYS	Fast charge to precharge hysteresis	CELL = VREF, measured on SRN		200		mV
		CELL = AGND, measured on SRN		400		mV
KTERM	Termination set factor	Termination of fast charge current		10%		
VRECHG	Recharge Threshold, below regulation voltage limit, VBAT_REG-VSRN	CELL=VREF ,measured on SRN	100	130	160	mV
		CELL=GND, measured on SRN	200	260	320	mV
TPRE-CHARGE	Pre-Charge Timer		1848	2100	2352	S
TFAST-CHARGE	Fast-Charge Timer		22176	25200	28224	S
VVREF_REG	VREF regulator voltage	VAVCC > VUVLO, No load	3.13	3.3	3.47	V
IVREF_LIM	VREF current limit	VVREF=0V,VAVCC> VUVLO		40		mA
VREGN_REG	REGN regulator voltage	VAVCC > 10 V	5	5.3	5.6	V
IREGN_LIM	REGN current limit	VREGN = 0 V, VAVCC > 10V		50		mA
RDS	High-Side Ron	VBS-VSW=5V			110	mΩ
	Low-Side Ron	VREGN=5V			110	mΩ
RDS_BAT_OFF	BATFET Turn-off Resistance	VAVCC > 5V		100		Ω
RDS_BAT_ON	BATFET Turn-on Resistance	VAVCC > 5V		20		KΩ
VBATDRV_REG	BATFET Drive Voltage	VBATDRV_REG =VACN - VBATDRV when VAVCC >	4.2		7	V

		5V and BATFET is on				
IOCP_HSFET	Current limit on HSFET	Measure on HSFET		6		A
VIN OVP	Over voltage protection	CELL = VREF	6.4	6.6	6.8	V
		CELL = GND	16.1	16.5	16.9	V
VACOV_HYS	AC over-voltage falling hysteresis	CELL = VREF		200		mV
		CELL = GND		500		mV
TACOV_RISE_DEG	AC Over-Voltage Rising Deglitch to turn off ACFET and Disable Charge	AVCC rising		1		μs
TACOV_FALL_DEG	AC Over-Voltage Falling Deglitch to Turn on ACFET	AVCC falling		25		mS
VLTF	Cold Temperature Threshold, TS pin Voltage Rising Threshold	Charger suspends charge. As percentage to VREF	72.5	73.5	74.5	%
VLTF_HYS	Hot Temperature Hysteresis, TS pin voltage Falling	As percentage to VVREF	0.2	0.4	0.6	%
VHTF	Hot Temperature TS pin voltage rising Threshold	As percentage to VVREF	46.6	47.2	47.8	%
VTCO	Cut-off Temperature TS pin voltage falling Threshold	As percentage to VVREF	44.2	44.7	45.2	%
TJ_REG	Junction Temperature	Charging		125		℃
TSHUT	Thermal shutdown temperature	Temperature rising		160		℃
TSHUT_HYS	Thermal shutdown hysteresis			30		℃

Typical Operating Characteristics

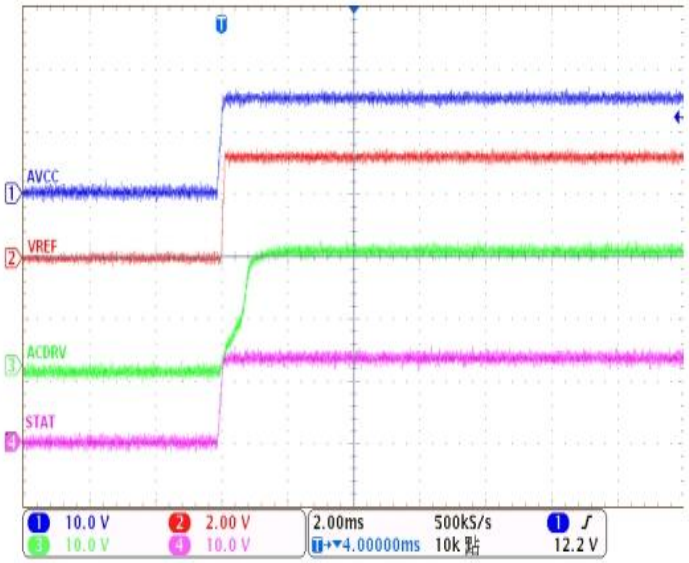


Figure6. Power UP

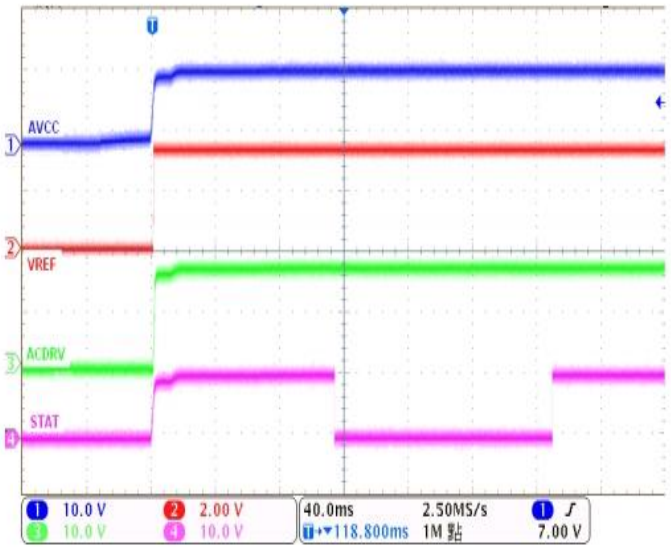


Figure7. Power UP(NO BATT)

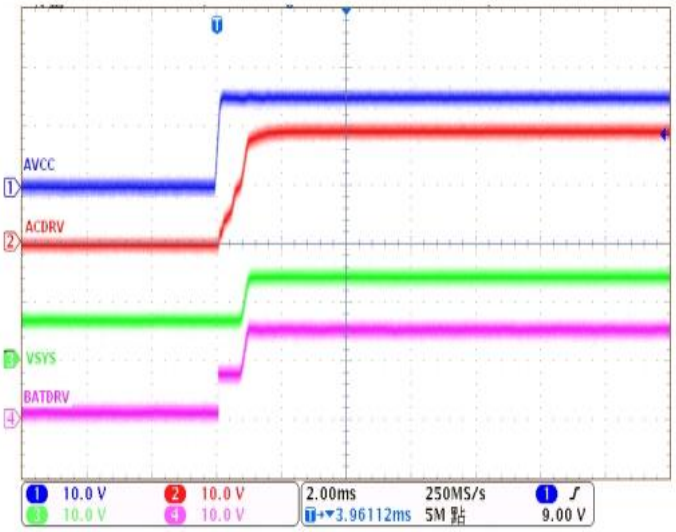


Figure 8. BATFET to ACFET Transition During Powerup

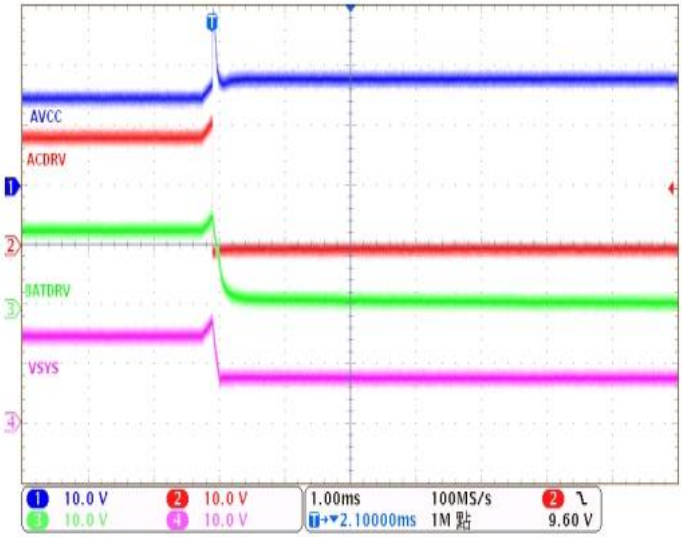


Figure 9. Over-voltage Protection

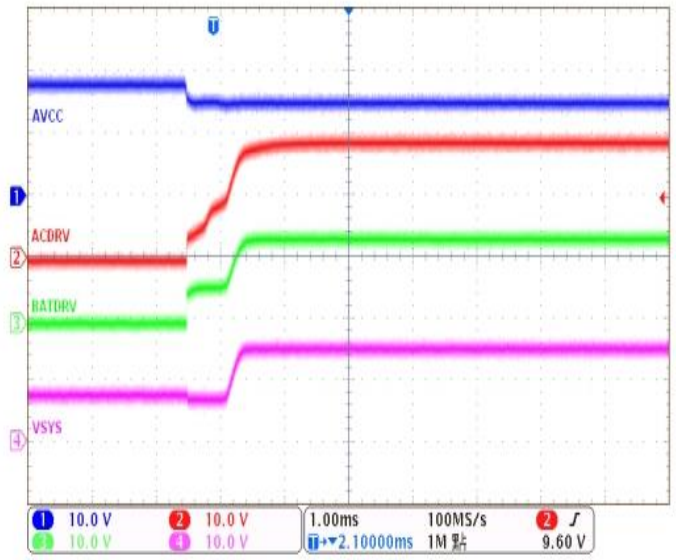


Figure10. Over-voltage Release

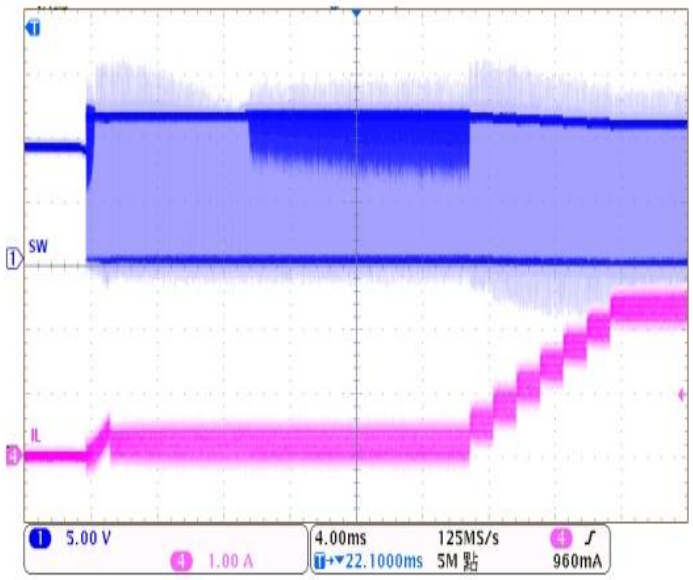


Figure11. Soft Start

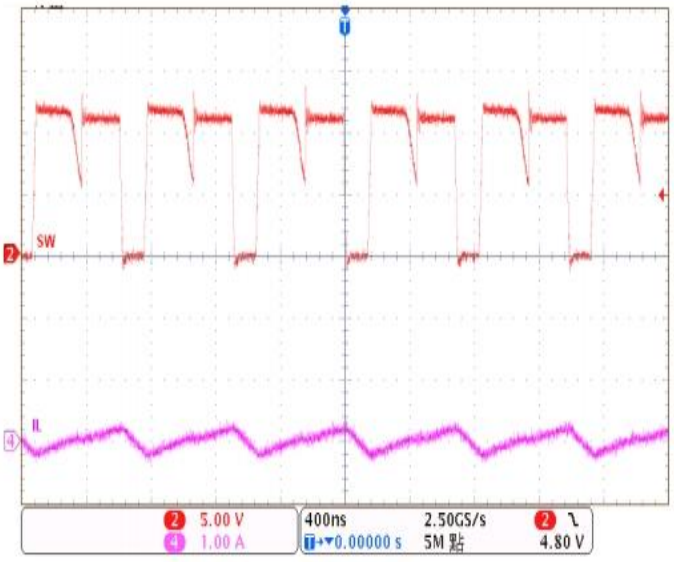


Figure12. Discontinuous Conduction Mode Switching

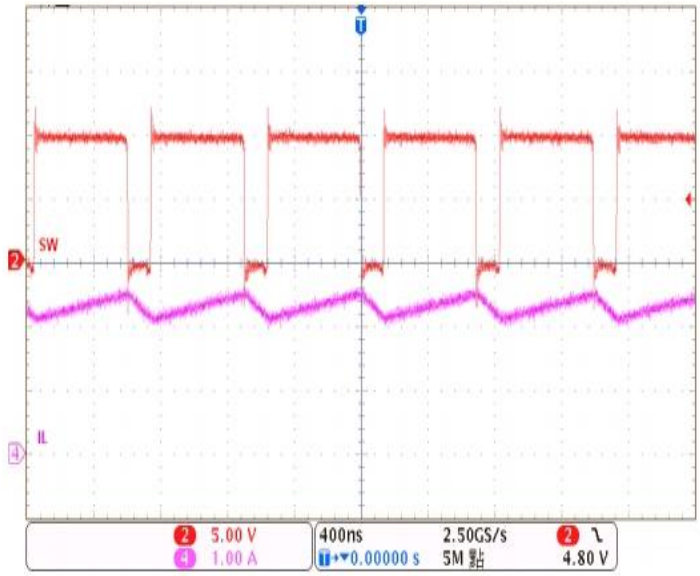


Figure13. Continuous Conduction Mode Switching

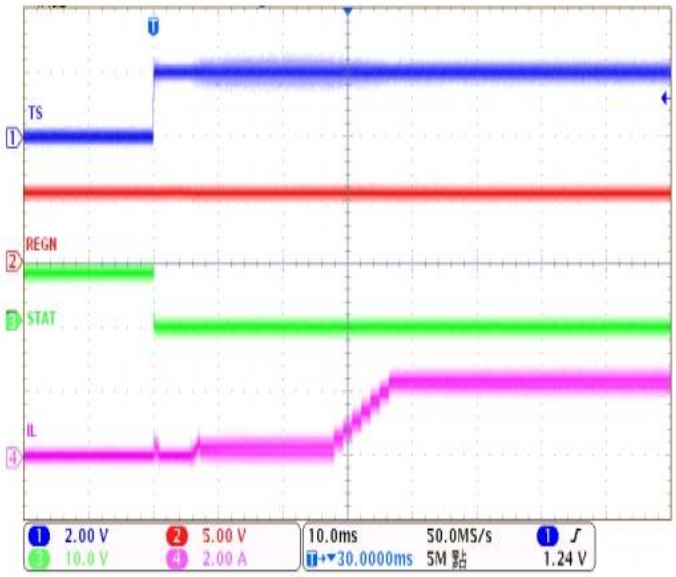


Figure 14. Charge Enable by TS

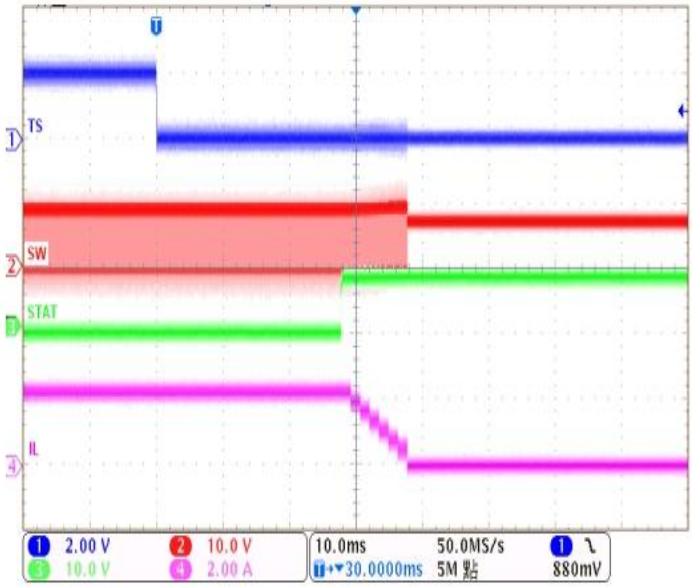


Figure 15. Charge Disable by TS

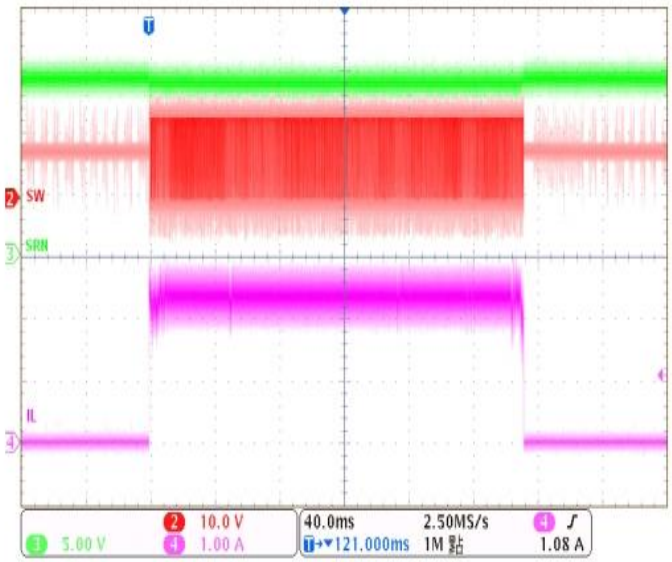


Figure 16. Battery Insertion and Removal

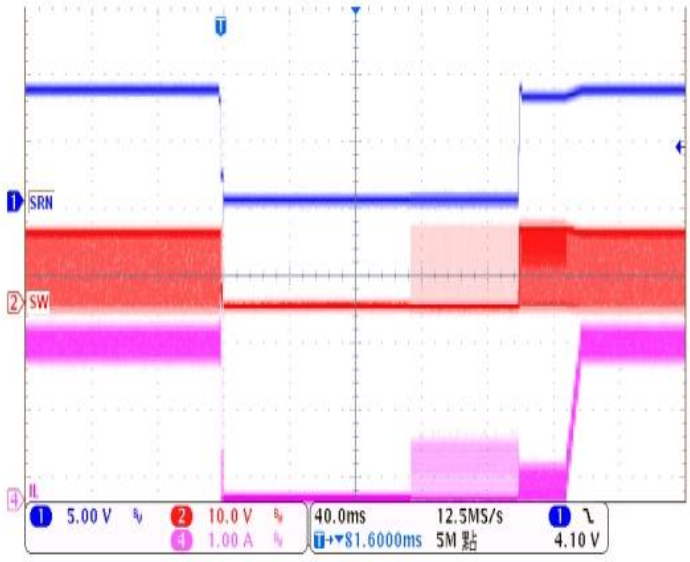
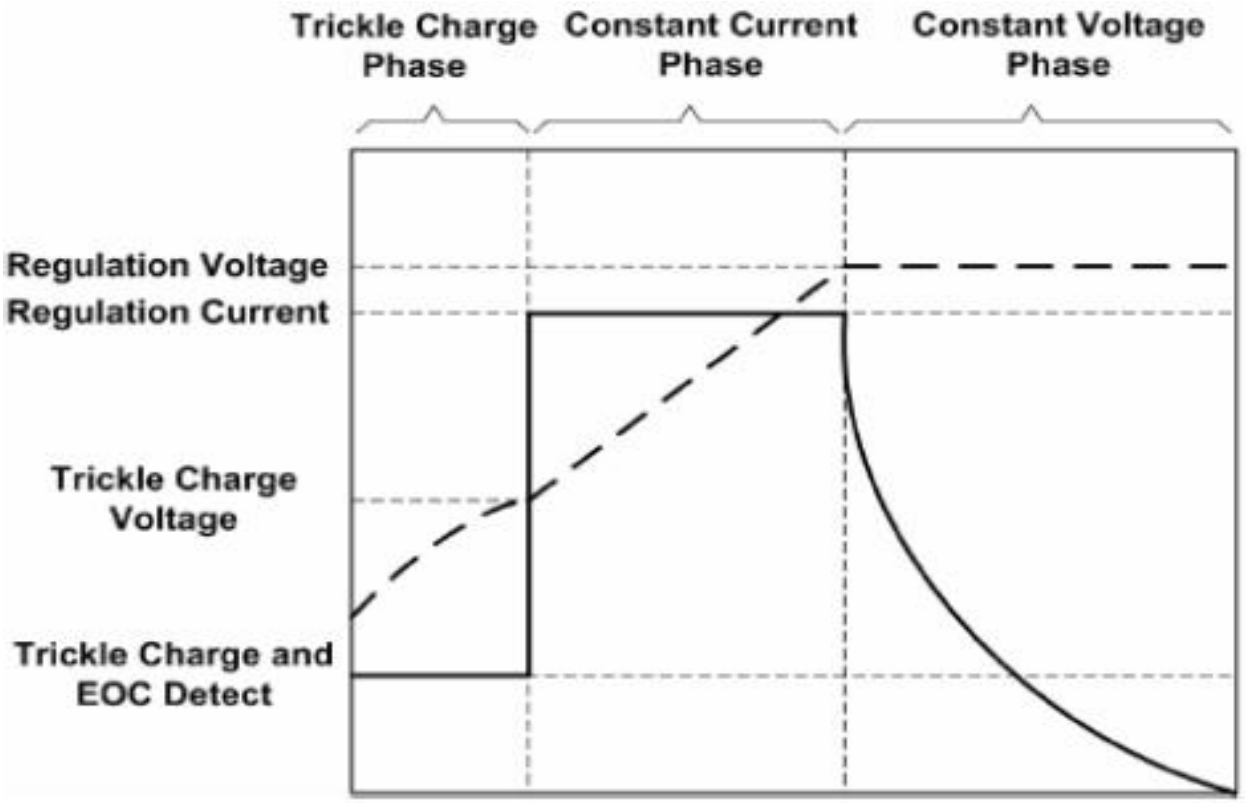
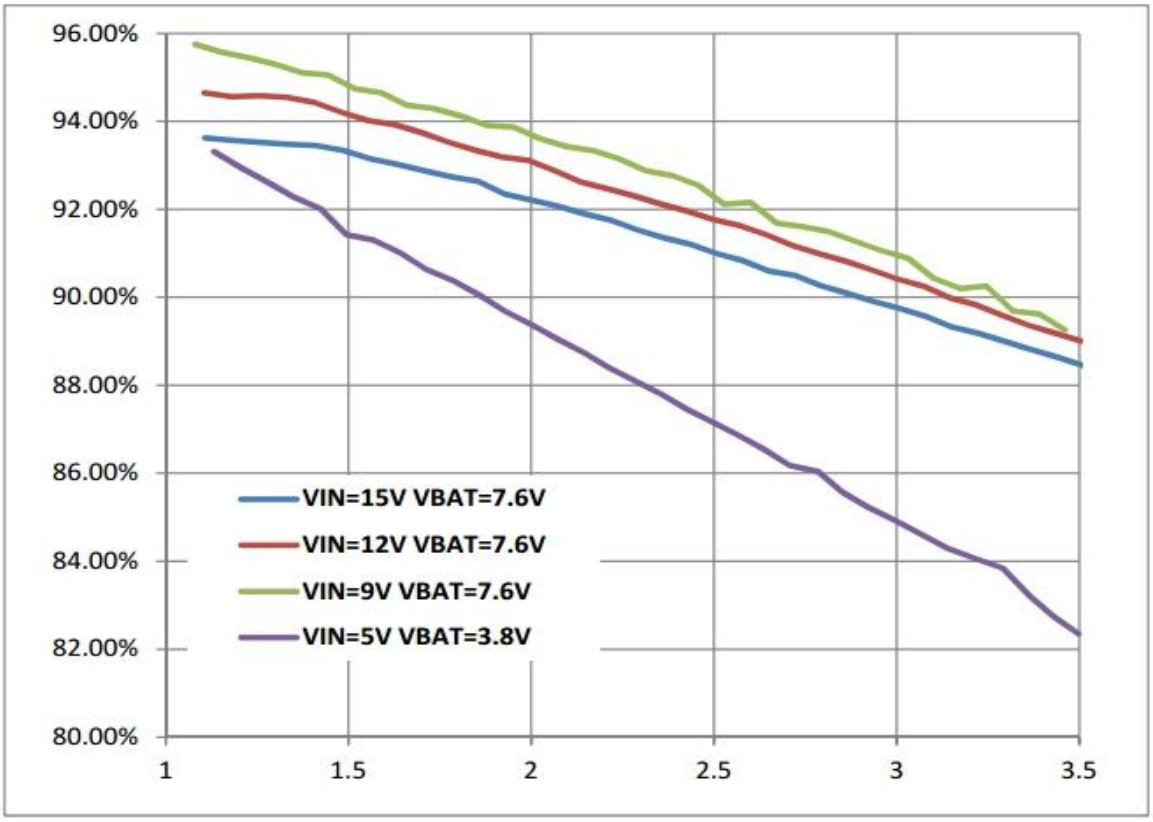


Figure 17. Battery to Ground Short Protection

Typical Charge Profile



Efficiency VS Output Current



Operation Application

The LP28400 is a constant current, constant voltage 1-cell and 2-cell Li-Ion battery charger controller that uses a current mode PWM step-down (buck) switching architecture. The charge current is set by an external sense resistor across the SRP and SRN pins. Voltage amplifier and the resistor divider provide regulation with ±1% accuracy.

Normal Charge Cycle

The LP28400 series offers a high accuracy voltage regulator on for the charging voltage. The LP28400 uses CELL pin to select number of cells with a fixed 4.2V/cell. Connecting CELL to AGND or floating CELL sets 2 cell output, and connecting to VREF sets 1 cell output

CELL PIN	VOLTAGE ULATION
GND or Floating	8.4V
VREF	4.2V

Normal Charge Cycle

A charge cycle begins when the voltage at the V_{CC} pin rises above the UVLO threshold level and when a battery is connected to the charger output. If the BAT pin is less than 2.9V/5.8V, the charger enters trickle charge mode. In this mode, the LP28400 supplies approximately 1/10 the ISET rammed charge current to bring the battery voltage up to a safe level for full current charging.

When the BAT pin voltage rises above 2.9V/5.8V, the charger goes into the full- scale constant current charge mode. In constant current mode The charge current is set by an external sense resistor across the SRP and SRN charge current is supplied to the battery. When the BAT pin approaches the final float voltage (4.2V/8.4V), LP28400 enters constant-voltage mode and the charge current begins to decrease. When the charge current drops to 1/10 of the ISET rammed value, the charge cycle ends.

Charge Current Regulation

The ISET input sets the maximum charging current. Battery current is sensed by current sensing resistor RSR connected between SRP and SRN. The full-scale differential voltage between SRP and SRN is 75mV max.

$$I_{CHG} = \frac{1}{R_{SR}}\left[\left(\frac{V_{ISET}}{V_{REF}} + 0.5\right)/20\right]$$

Under high ambient temperature, the charge current will fold back to keep IC temperature not exceeding 125°C

Input Current Regulation

The total input current from an AC adapter or other DC sources is a function of the system supply current and the battery charging current. System current normally fluctuated as portions of the systems are powered up or down. Without Dynamic Power Management (DPM), the source must be able to supply the maximum system current and the maximum available charger input current simultaneously. By using DPM, the input current regulator reduces the charging current when the summation of system power and charge power exceeds the maximum input power. Therefore, the current capability of the AC adapter can be lowered, reducing system cost., the sense voltage between ACP and ACN is 75mV typ.

The ACP and ACN pins are used to sense across RAC with default value of 20mΩ. However, resistors of other values can also be used. A larger sense resistor will give a larger sense voltage and higher regulation accuracy, at the expense of higher conduction loss.

Charge Termination

A charge cycle is terminated when the charge current falls to 1/10th the SRP and SRN rammed value after the final float voltage is reached. This condition is detected by using an internal, filtered comparator to monitor the SRP and SEN pin. When the SRP and SEN pin voltage falls below 1/10 for longer than TTERM_DEG, charging is terminated. The charge current is latched off and the LP28400 enters standby mode, where the input supply current drops to 1.2mA. (Note: C/10 termination is disabled in trickle charging and thermal limiting modes).

When charging, transient loads on the VSRP-SRN can cause the VSRP-SRN to fall below 1/10 for short periods of time before the DC charge current has dropped to 1/10th the VSRP-SRN rammed value. The 100ms filter time (TTERM_DEG) on the termination comparator ensures that transient loads of this nature do not result in premature charge cycle termination. Once the average charge current drops

below 1/10th the VSRP-SRN rammed value, the LP28400 terminates the charge cycle and ceases to provide any current through the BAT pin. In this state, all loads on the BAT pin must be supplied by the battery.

Charge Status Indicator (STAT)

The open-drain STAT output indicate various charger operations as shown in the following table. these status pins can be used to driver LEDs or communicate to the host processor. Note that OFF indicates the open-drain transistor is turned off. A microprocessor can be used to distinguish between these three states—this method is discussed in the Applications Information section.

Charge STATE	STAT
Charging	ON
Charge done	OFF

Safety Timers

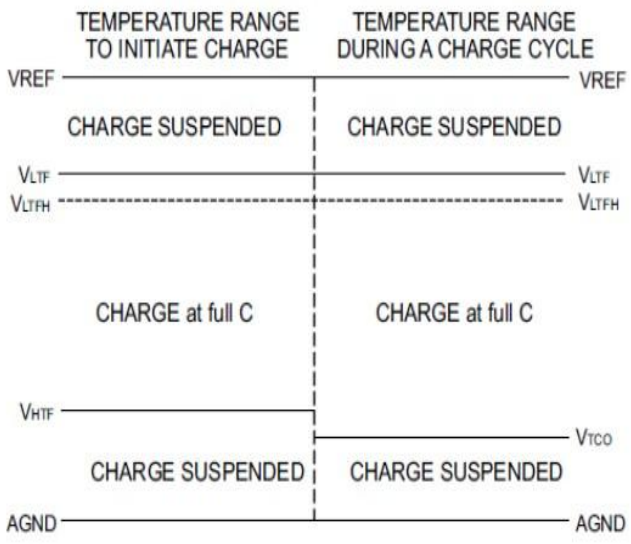
As a safety backup, the charger also provides an internal fixed 35 minutes pre-charge safety timer and an internal fixed 7 hours fast charge timer

Soft-Start Charger Current

The charger automatically soft-starts the charger regulation current every time the charger goes into fast-charge to ensure there is no overshoot or stress on the output capacitors or the power converter. The soft-start consists of stepping-up the charge regulation current into 8 evenly divided steps up to the programmed charge current. Each step lasts around 1.4ms, for a typical rise time of 11.2ms. No external components are needed for this function.

Battery Temperature Detection

The controller continuously monitors battery temperature by measuring the voltage between the TS pin and AGND. A negative temperature coefficient resistance (NTC) and an external voltage divider typically develop this voltage. The controller compares this voltage against its internal thresholds to determine if charging is allowed. To initiate a charge cycle, the battery temperature must be within the VLTF to VHTF thresholds. If battery temperature is outside of this range, the controller suspends charge and waits until the battery temperature is within the VLTF to VHTF range. During the charge cycle the battery temperature must be within the VLTF to VTCO thresholds. The controller suspends charge by turning off the PWM charge MOSFETs.

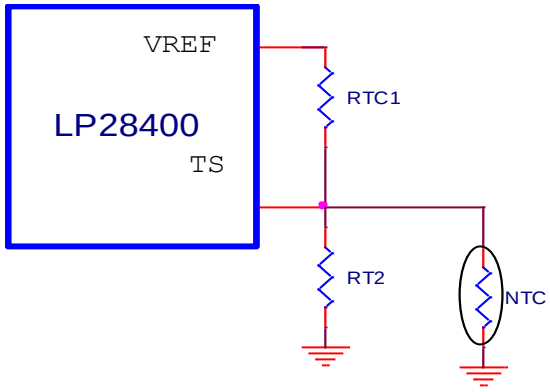


Assuming a NTC thermistor on the battery pack have resistance at 0°C and 45°C are RTHCOLD and RTHHOT, the values of RT1 and RT2 can be determined by using below equations

$$RT2 = \frac{V_{VREF} \times RTH_{COLD} \times RTH_{HOT} \times \left(\frac{1}{V_{LTF}} - \frac{1}{V_{TCO}}\right)}{RTH_{HOT} \times \left(\frac{V_{VREF}}{V_{TCO}} - 1\right) - RTH_{COLD} \times \left(\frac{V_{VREF}}{V_{LTF}} - 1\right)}$$

$$RT1 = \frac{\frac{V_{VREF}}{V_{LTF}} - 1}{\frac{1}{RT2} + \frac{1}{RTH_{COLD}}}$$

Temperature Sensing Configuration



System Power Selector

The IC automatically switches adapter or battery power to the system load. The battery is connected to the system by default during power up or during SLEEP mode. When the adapter

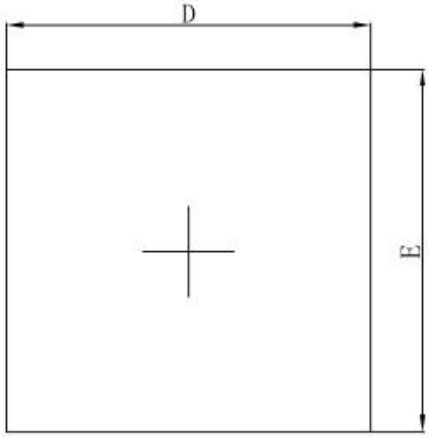
plugs in and the voltage is above the battery voltage, the IC exits SLEEP mode. The battery is disconnected from the system and the adapter is connected to the system after exiting SLEEP. An automatic break-before-make logic prevents shoot-through currents when the selectors switch. The ACDRV is used to drive a pair of back-to-back n-channel power MOSFETs between adapter and ACP with sources connected together to CMS. The n-channel FET with the drain connected to the ACP (Q2, RBFET) provides reverse battery discharge protection, and minimizes system power dissipation with its low-RDSON. The other n-channel FET with drain connected to adapter input (Q1, ACFET) separates battery from adapter, and provides a limited dI/dt when connecting the adapter to the system by controlling the FET turn-on time. The /BATDRV controls a p-channel power MOSFET (Q3, BATFET) placed between battery and system with drain connected to battery.

Before the adapter is detected, the ACDRV is pulled to CMS to keep ACFET off, disconnecting the adapter from system. /BATDRV stays at ACN-5V (clamp to ground) to connect battery to system.

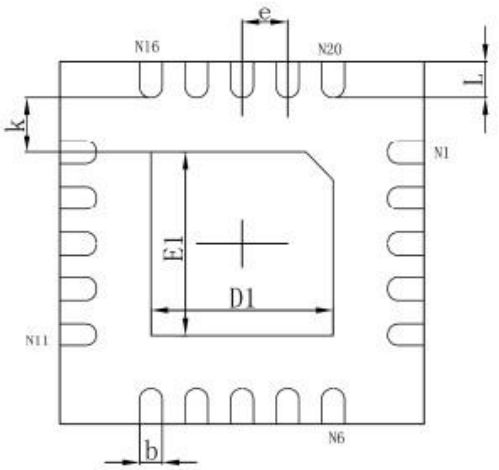
After the device comes out of SLEEP mode, the system begins to switch from battery to adapter.

When the adapter is removed, the IC turns off ACFET and enters SLEEP mode to turn on p-channel BATFET, connecting the battery to the system

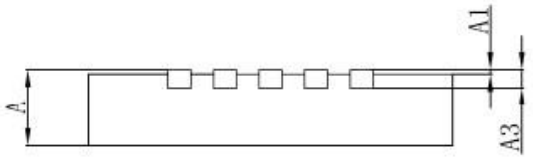
Packaging Information



Top View



Bottom View



Side View

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	3.900	4.100	0.154	0.161
E	3.900	4.100	0.154	0.161
D1	1.900	2.100	0.075	0.083
E1	1.900	2.100	0.075	0.083
k	0.200MIN.		0.008MIN.	
b	0.180	0.300	0.007	0.012
e	0.500TYP.		0.020TYP.	
L	0.300	0.500	0.012	0.020