Power Bank IC with 0.8A Linear Charger and 1A Boost Converter

General Description

The FP6801 is a highly integrated Power Bank IC with a Linear Li-Ion Charger up to 0.8A and a 1A Boost Converter. With few external components, FP6801 is well suited for portable power bank applications. In sleep mode, reverse battery current I_{BAT} will be reduced to below 4uA. Other features include UVLO, automatic recharge, LED status indicators, automatic booster shutdown when light-load and booster over-current protection.

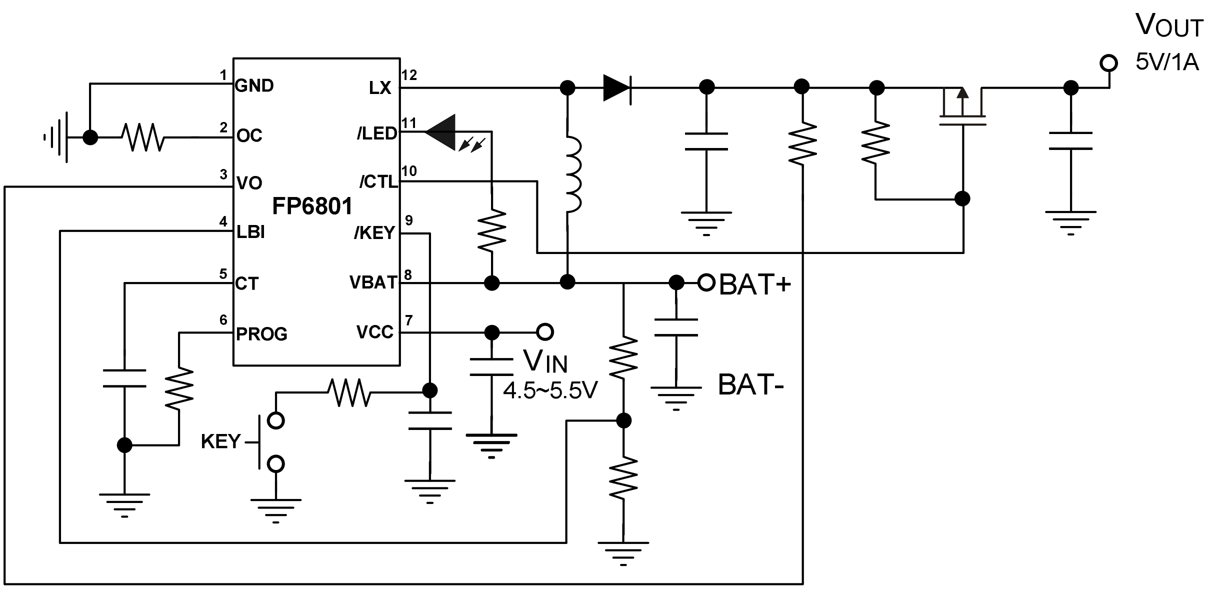
Features

- Up to 0.8A Programmable Battery Charging Current
- Preset Charge Voltage with ±1% Accuracy and Boost output Voltage: 5.0V (±2%)
- Automatic Recharge
- Very Low Sleep-Mode I_{BAT} Current
- Up to 90% Boost Conversion Efficiency
- Up to 1A Boost Output Current
- Booster Adjustable Over Current Protection: 0.5A ~ 1.5A
- SCP & OCP for Boost Output
- Thermal Protection

Applications

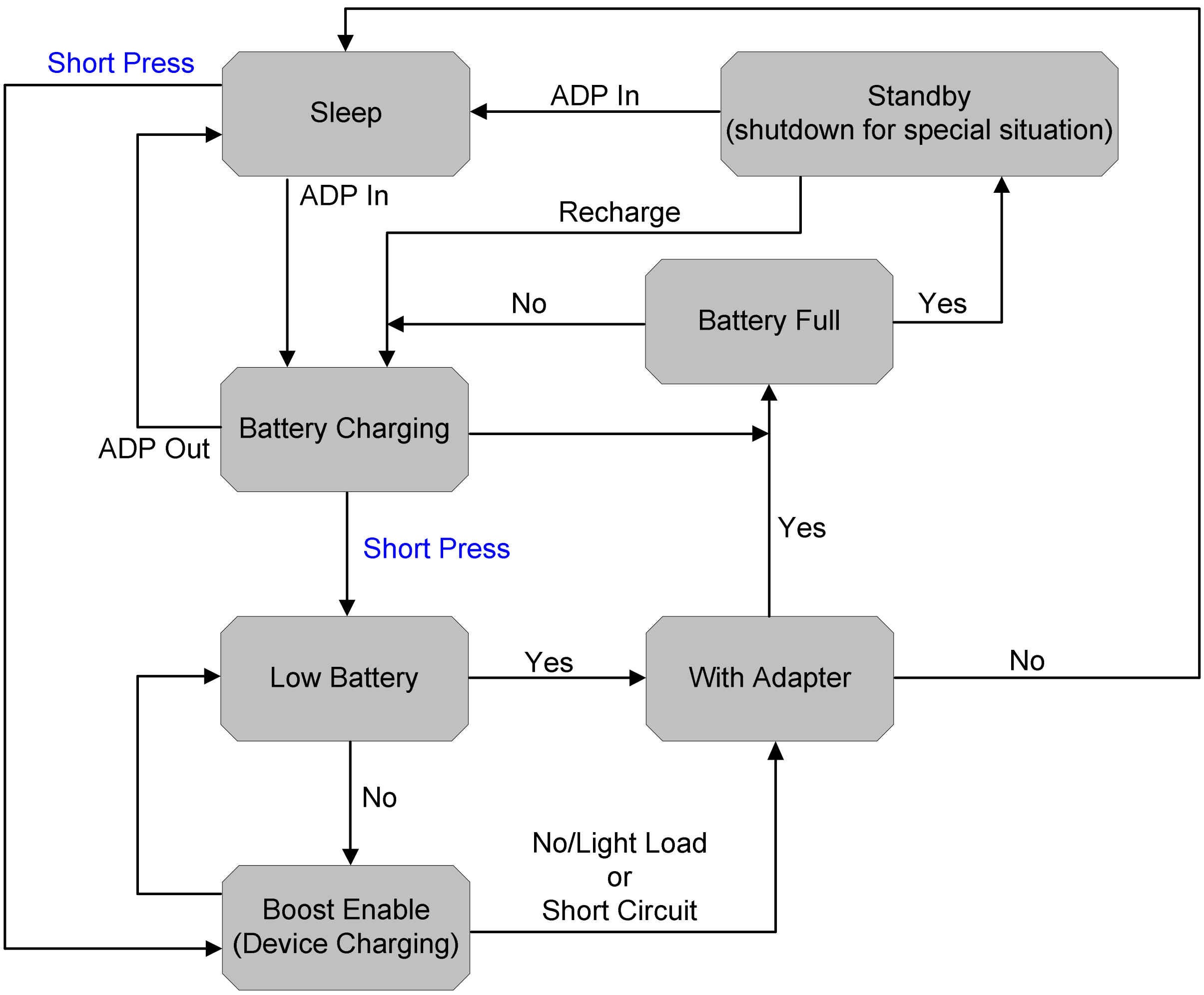
- Portable Power Bank Applications

Typical Application Circuit

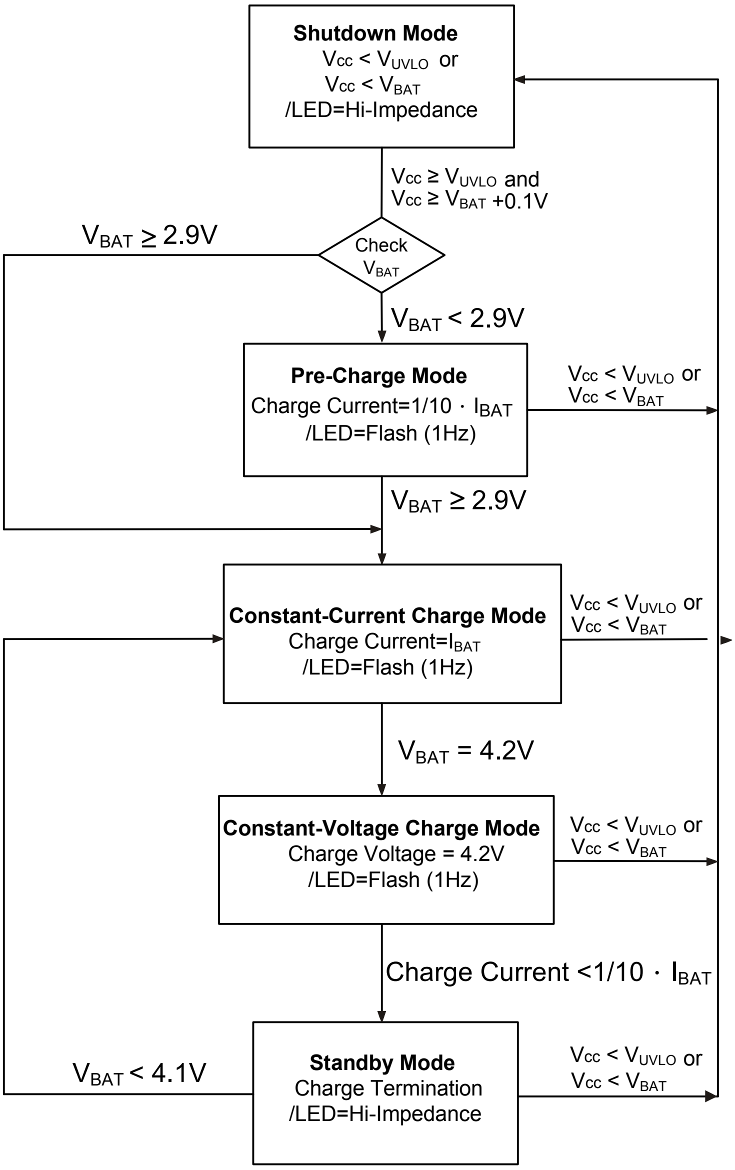


State Diagram

For Whole Chip Control



For Battery Charging



Battery Charging Status Indicators

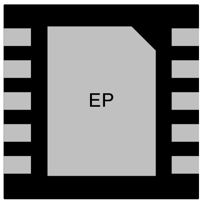
Charge Status	/LED
In Charging	Flash (1Hz)
Charge Termination	OFF
UVLO, OverT, UnderT, NoBat	OFF

Pin Descriptions

DFN-12L (EP)

Top View

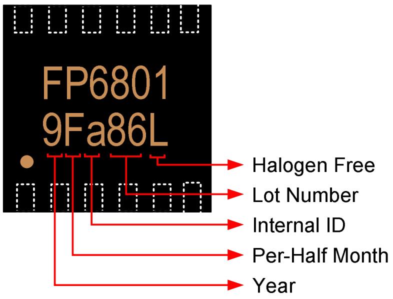
Bottom View



Name	No.	I / O	Description
GND	1	P	IC Ground
OC	2	I	Adjustable Current Limit (Floating Available)
VO	3	I	Booster Output Voltage
LBI	4	I	Booster Low Battery Threshold Setting
CT	5	I	Capacitor connection pin for Internal Timer
PROG	6	I	CC Charge Current Setting & monitor
VCC	7	P	Supply Voltage
VBAT	8	P	Battery Voltage
/KEY	9	I	Active-Low Enable
/CTL	10	O	external PMOS Control
/LED	11	O	Charging and Electrical Volume Indicator
LX	12	I	Switch node and inductor connection pin
EP	13	P	Exposed PAD-Must connect to Ground

Marking Information

DFN-12L (EP)



Halogen Free: Halogen free product indicator

Lot Number: Wafer lot number's last two digits

For Example: 132386TB → 86

Internal ID: Internal Identification Code

Per-Half Month: Production period indicated in half month time unit

For Example: January → A (Front Half Month), B (Last Half Month)

February → C (Front Half Month), D (Last Half Month)

Year: Production year's last digit

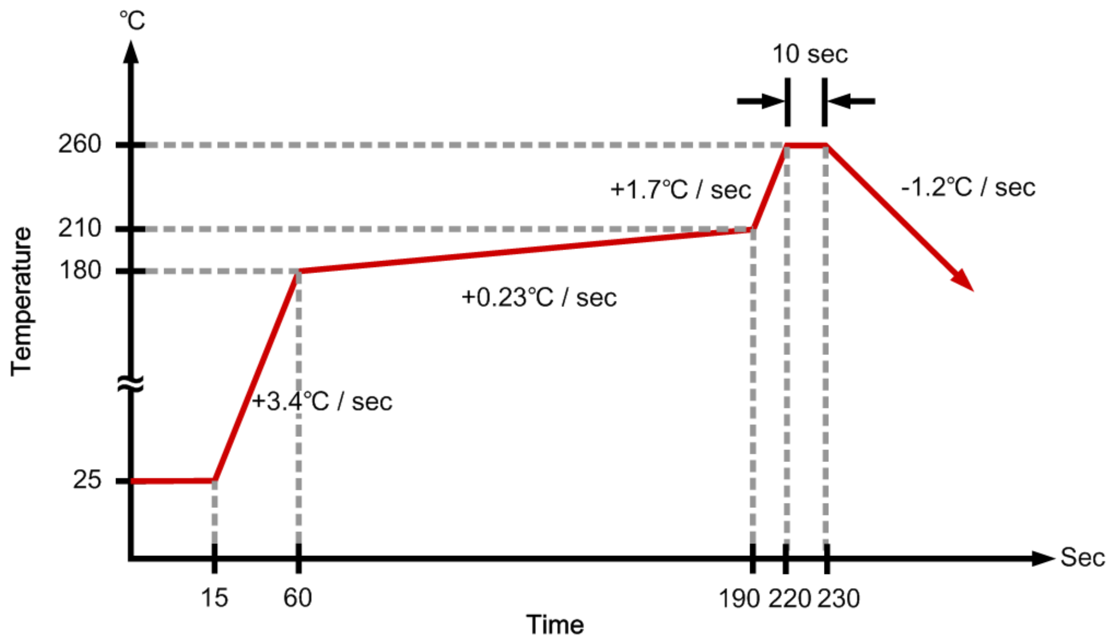
Ordering Information

Part Number	Operating Temperature	Package	MOQ	Description
FP6801dR-G1	-40℃ ~ +85℃	DFN-12L(EP)	2500EA	Tape & Reel

Absolute Maximum Ratings

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{IN}		-0.3		6	V
LX Voltage	V_{LX}		0		10	V
All Other Pins			-0.3		6	V
BAT Pin Current	I_{BAT}				1.2	A
Junction Temperature	T_J				+150	℃
Storage Temperature	T_S		-65		+150	℃
Thermal Resistance	θ_{JA}	DFN-12L(EP)			60	℃ / W
	θ_{JC}				10	℃ / W
Operating Temperature			-40		+85	℃
Lead Temperature (Soldering, 10 Sec)					+260	℃

Suggested IR Re-flow Soldering Curve



Recommended Operating Conditions

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{IN}		4.35		5.5	V
Operating Temperature		Ambient Temperature	-40		85	℃

DC Electrical Characteristics (V_{IN}=5V, T_A= 25℃, unless otherwise noted)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
V_{IN} Standby Current	I_{SB}	Charge Termination		200	300	µA
V_{IN} Shutdown Supply Current	I_{SHDN}	V_{IN}< V_{BAT} , V_{IN}< $V_{ADP,UV}$ V_{BAT}< $V_{BAT,UV}$, No Operation		50	100	µA
BAT Pin Current	I_{BAT}	R_{PROG}=2.4K	450	500	550	mA
		R_{PROG}=1.5K	720	800	880	mA
		Standby-Mode, V_{BAT}=4.2V	0	-2.5	-6	µA
		Shutdown-Mode,		±4	±6	µA
		Sleep-Mode, V_{IN}=0V		-4	-6	µA
BAT CV Output (Float) Voltage	V_{FLOAT}	0℃<T_A<85℃	4.158	4.2	4.242	V
V_{IN} Charge Under Voltage Lockout Threshold	$V_{IN,UV}$	V_{IN} Rising	3.5	3.7	3.9	V
V_{IN} Charge Under Voltage Lockout Threshold Hysteresis	$V_{IN.UVHYS}$			500		mV
V_{IN}-V_{BAT} Charge Lockout Threshold	V_{ASD}	V_{IN} Rising		100		mV
		V_{IN} Falling		10		mV
C/10 Charge Termination Current Threshold	I_{TERM}			50		mA
/LED Pin Output Low Voltage	V_{LED}	I_{LED}=5mA		0.35	0.6	V
Battery Recharge Threshold Voltage	V_{RECHRG}	V_{FLOAT}-V_{RECHRG}		150		mV
Recharge Comparator Filter Time	T_{RECHRG}	V_{BAT} High to Low		0.8		mS
C/10 Charge Termination Comparator Filter Time	T_{TERM}	I_{BAT} Falling below I_{TERM}		0.8		mS
Booster Operation Supply Range	V_{BAT}		3.0		4.2	V
Booster Operation Frequency	F_{OSC}		0.8	1.0	1.2	MHz
Frequency Change with Voltage	△f / △V	V_{BAT}=3.0V to 4.2V		5		%
Maximum Duty Cycle	T_{DUTY}			90		%
Booster Output Voltage	V_O		4.9	5.0	5.1	V
Line Regulation		V_{BAT}=3.3V ~ 4.2V		0.2		% / V
On Resistance of Driver	$R_{DS (ON)}$	I_{LX}=2A		0.25		Ω
OCP Current	I_{OCP}			2.5		A
Adjustable OCP Current	I_{OCP}	With External Resistor : 19k~96k	0.5		2.5	A
Light-Load Detection Threshold	I_{LLD}			50		mA
Thermal Shutdown	T_{LIM}			145		℃
/KEY Enable Voltage	$V_{TAPN,L}$				0.3*V_{BAT}	V
/KEY Shutdown Voltage	$V_{TAPN,H}$		0.7*V_{BAT}			V
/CTL Sink Impedance				20		

Function Description

For Battery Charging

Operation

The FP6801 is with a linear battery charger designed primarily for charging single cell lithium-ion battery.The charger uses a constant-current/constant-voltage charging algorithm with programmable current. Charging current can be programmed up to 0.8A by an external single resistor. The FP6801 includes an internal P-channel power MOSFET and thermal regulation circuitry. No blocking diode or external sense resistor are required. Thus, the basic charger circuit requires only two external components. Furthermore, The FP6801 is capable of operating from a USB power source.

Normal Charge Cycle

A charge cycle begins when the voltage at the V_{IN} pin rises above the UVLO threshold. If the BAT pin voltage is smaller than 2.9V, the charger enter trickle charge mode. In this mode, the FP6801 supplies approximately 1/10 the programmed charging current to bring the battery voltage up to a safe level for full current charging. When the BAT pin voltage rises above 2.9V, the charger enters constant-current mode, where the full programmed charge current is supplied to the battery. When the BAT pin approaches the final float voltage (4.2V), the FP6801 enters the constant-voltage mode and the charge current begins to decrease. When the charge current drops to 1/10 of the programmed value, the charge cycle ends.

Programming Charge Current

The charge current is programmed by a single resistor connected from the PROG pin to ground. The battery charging current is 1000 times the current flowing out of the PROG pin. The required resistor value can be calculated from the charge current with following equation:

$$R_{PROG}=\frac{1000}{I_{CHG(MAX)}}$$

The instantaneous charging current may differ from above equation in trickle or constant voltage modes. The instantaneous charging current provided to the battery can be determined by monitoring the PROG pin voltage at any time with the following equation:

$$I_{CHG}=\frac{V_{PROG}}{R_{PROG}}\times 1000$$

Charge Termination

A charge cycle is terminated when the charge current falls to 1/10 the programmed value after the final float voltage is reached. The charge current is shut off and the FP6801 enters standby mode, where the input supply current drops to 55uA. The FP6801 draws no current from the battery in standby mode. This feature reduces the charge and discharge cycles on the battery, further prolong the battery life.

Thermal Protection when charging

An internal thermal feedback loop reduces the fixed charge current if the die temperature rises above a preset value of approximately 100℃. This feature protects the FP6801 from excessive temperature and allows the user to push the limits of the power handing capability of a given circuit board without risk of damaging the FP6801. The charge current can be set according to typical ambient temperature with the assurance that the charge will automatically reduce the current in worst case condition.

V_{IN} Under Voltage Lockout (UVLO)

An internal under voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{IN} rises above the under voltage lockout threshold. The UVLO circuit has a built-in hysteresis of 500mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit force FP6801 to enter shutdown mode if V_{IN} falls to within 10mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{IN} rises 100mV above the battery voltage.

Automatic Recharge

Once the charge cycle is terminated, the FP6801 continuously monitors the voltage on the BAT pin using a comparator with a 0.8ms filter time ($T_{RECHARGE}$). A charge cycle restarts when the battery voltage falls below 4.1V (which corresponds to approximately 80% to 90% battery capacity).This ensures that the battery is kept at or near a fully charged condition and eliminated the need for periodic charge cycle initiations. /LED output enters a 1Hz flash state during recharge cycles.

For Booster

Operation

The FP6801 is with a current mode boost converter. The constant switching frequency is 1MHz and operates with pulse width modulation (PWM). Build-in 10V / 1.5A MOSFET provides a high output voltage. The control loop architecture is peak current mode control; therefore slope compensation circuit is added to the current signal to allow stable operation for duty cycles larger than 50%.

Soft Start Function

Soft start circuitry is integrated into FP6801 to avoid inrush current during power on. After the IC is enabled, the output of error amplifier is clamped by the internal soft-start function, which causes PWM pulse width increasing slowly and thus reducing input surge current.

Current Limit Program

A resistor between OC and GND pin programs peak switch current. The resistor value should be between 19K and 96K. The current limit will be set from 1.5A to 0.5A. Keep traces at this pin as short as possible. Do not put capacitance at this pin. To set the over current trip point according to the following equation:

$$I_{OCP} = \frac{48000}{R3}$$

Automatic Booster Light-Load Shutdown Function

Automatic Booster Light-Load Shutdown circuitry is integrated into FP6801 to decrease power consumption when device charging seems no need anymore. The Light-Load threshold is around 50mA. When the device charging light-load/no-load happens, the Booster will be disabled and the battery charging function will be enabled if the battery is not full and the adaptor is on.

The Timimg Capacitor (CT pin)

The CT pin determines the oscillation period by connecting a timing capacitor between this pin and GND. The oscillator provides a time reference to enable the light-load detection of booster and LED display. The default value of a timing capacitor is 0.1uF and the time period to enable light-load detection after the booster start-up is around 16 second.

Booster Lockout for Programmable Battery under Voltage

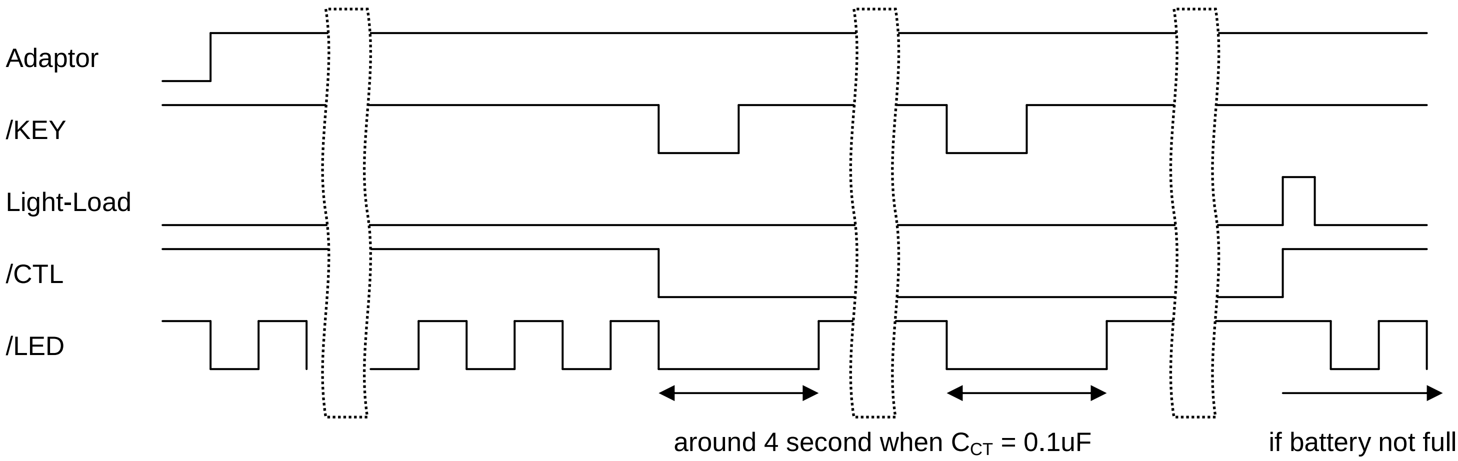
An internal booster lockout for battery under voltage circuit monitors the battery voltage and keeps the booster in shutdown mode until V_{BAT} rises above the booster lockout threshold. This threshold is programmed by a single resistor connected from the RBL pin to ground.

Over Temperature Protection (OTP)

FP6801 will be shutdown automatically when the internal junction temperature is over 145℃. The IC wake up when the junction temperature drops 30℃ under the OTP threshold temperature.

Timing between /KEY, external PMOS Control /CTL and /LED

/LED will flash with 1Hz in battery charge mode. It will also turn on 4 second when pushing button in booster mode. /CTL will be pull-low to activate the external PMOS as power path device when the booster enables.



Application Information

Power Dissipation

The conditions that cause the FP6801 to reduce charge current through thermal feedback can be approximated by considering the power dissipated in the IC. For high charge current, the FP6801 power dissipation is approximately:

$$P_D = (V_{IN} - V_{BAT}) \cdot I_{BAT}$$

Where P_D is the power dissipated, V_{CC} is the input supply voltage, V_{BAT} is the battery voltage and I_{BAT} is the charge current. It is not necessary to check any worst-case power dissipation scenarios because the FP6801 will automatically reduce the charge current to maintain the die temperature under 145℃ approximately. The approximate ambient temperature at which the thermal feedback begins to protect the IC is:

$$T_A = 145℃ - P_D \theta_{JA}$$
$$= 145℃ - (V_{IN} - V_{BAT}) \cdot I_{BAT} \cdot \theta_{JA}$$

For example: Consider an FP6801 operating from a 5V wall adapter providing 0.5A to a 4.0V Li-Ion battery. The ambient temperature above which the FP6801 will begin to reduce the 0.5A charge current is approximately:

$$T_A = 145℃ - (5V - 4.0V) \bullet (0.5A) \bullet 60℃/W$$
$$= 145℃ - 0.5W \bullet 60℃/W = 145℃ - 30℃$$
$$= 115℃$$

The FP6801 can be used above 75℃, but the charge c urrent will be reduced to smaller than 500mA. The approximate current at a given ambient temperature can be calculated:

$$I_{BAT} = \frac{145°C - T_A}{(V_{IN} - V_{BAT}) \bullet \theta_{JA}}$$

Using the previous example with an ambient temperature of 90℃, the charge current will be reduced to approximately:

$$I_{BAT} = \frac{145°C - 90°C}{(5V - 3.6V) \bullet 60°C/W} = \frac{55°C}{84°C/A} = 654mA$$

Furthermore, the voltage at the PROG pin will change proportionally with the charge current as discussed in the Programming Charge Current section. It is important to remember that FP6801 applications do not need to be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately 145℃.

Board Layout Considerations

Because of the small size of the DFN-12L, it is very important to apply a good thermal conduction PC board layout to maximize the available charge current. The thermal path for the heat generated by the IC is from the die through the package leads(especially the ground lead) to the PC board copper. The PC board copper is the heat sink. The copper pads footprint should be as large as possible and expand out to large copper areas to spread and dissipate the heat to the surrounding ambient. Feed-through vias to inner or backside copper layers are also useful in improving the overall thermal performance of the charger. Other heat source on the board, not related to the charger, must also be consider when designing a PC board layout because they will affect overall temperature rise and the maximum charge current.

V_{IN} Bypass Capacitor

Many types of capacitors can be used for input bypassing, however, caution must be exercised when using multilayer ceramic capacitors. Because of the self-resonant and high Q characteristics of some types of ceramic capacitors, high voltage transients can be generated under some start-up conditions, such as connecting the charger input to a live power source. Adding a 0.4Ω resistor in series with an X5R ceramic capacitors (as shown in Figure 1) will minimize start-up voltage transients.

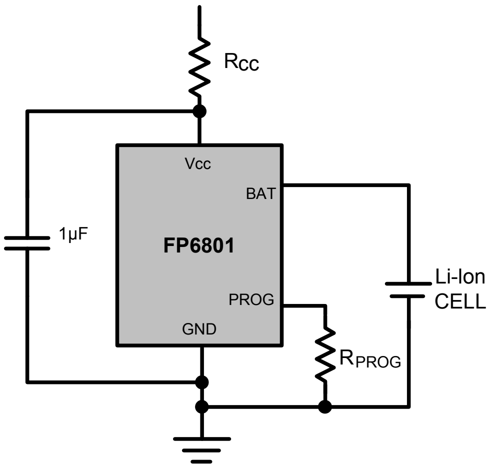


FIGURE 1

USB and Wall Adapter Power

Although the FP6801 allows charging from a USB port, a wall adapter can also be used to charge Li-ion batteries. Figure 2 shows an example of how to combine wall adapter and USB power inputs. A P-channel MOSFET, MP1, is used to prevent back conducting into the USB port when a wall adapter is present. The schottky diode, D1, is used to prevent USB power loss through the 10kΩ pull-down resistor.

Typically, a wall adapter can supply significantly more current than the 500mA-limited USB port. Therefore, an N-channel MOSFET, MN1, and an extra program resistor are used to increase the charge current to 600mA when the wall adapter is present.

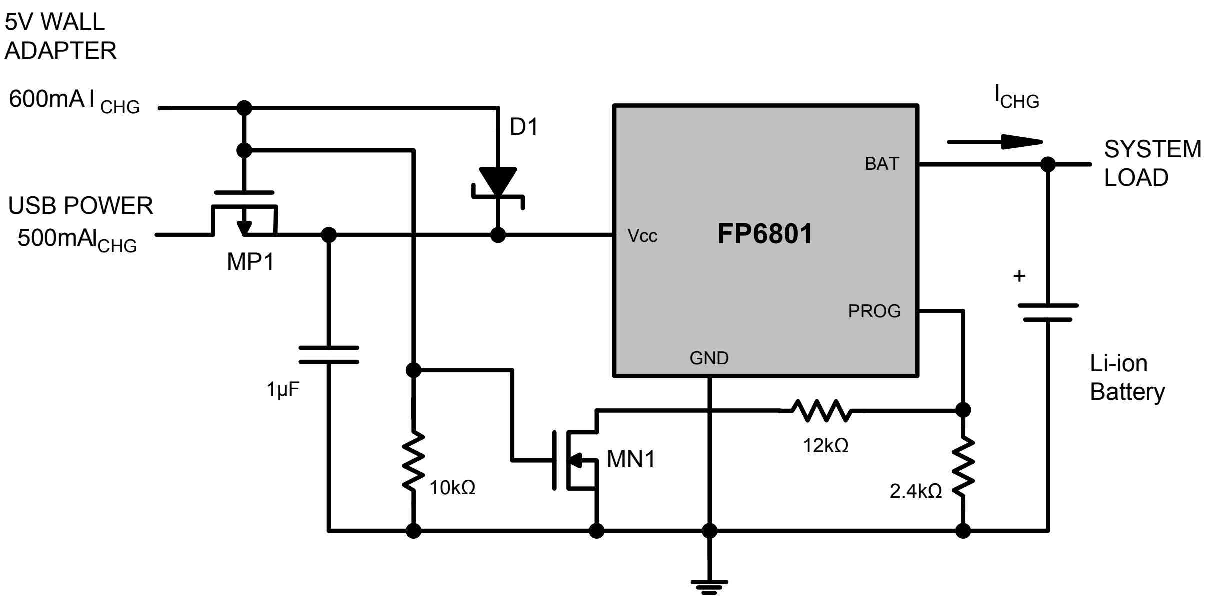


FIGURE 2

Inductor Selection

Inductance value is decided based on different condition. 3.3uH to 4.7µH inductor value is recommended for general application circuit. There are three important inductor specifications, DC resistance, saturation current and core loss. Low DC resistance has better power efficiency. Also, it avoid inductor saturation which will cause circuit system unstable and lower core loss at 1 MHz.

Capacitor Selection

The output capacitor is required to maintain the DC voltage. Low ESR capacitors are preferred to reduce the output voltage ripple. Ceramic capacitor of X5R and X7R are recommended, which have low equivalent series resistance (ESR) and wider operation temperature range.

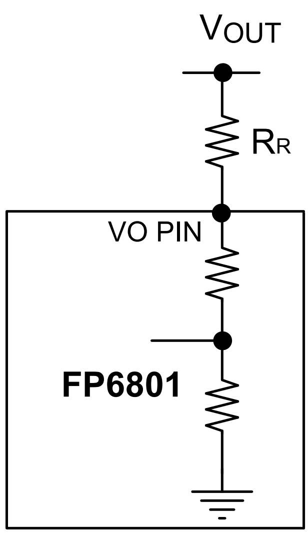
Diode Selection

Schottky diodes with fast recovery times and low forward voltages are recommended. Ensure the diode average and peak current rating exceed the average output current and peak inductor current. In addition, the diode's reverse breakdown voltage must exceed the output voltage.

Booster Output Voltage Programming

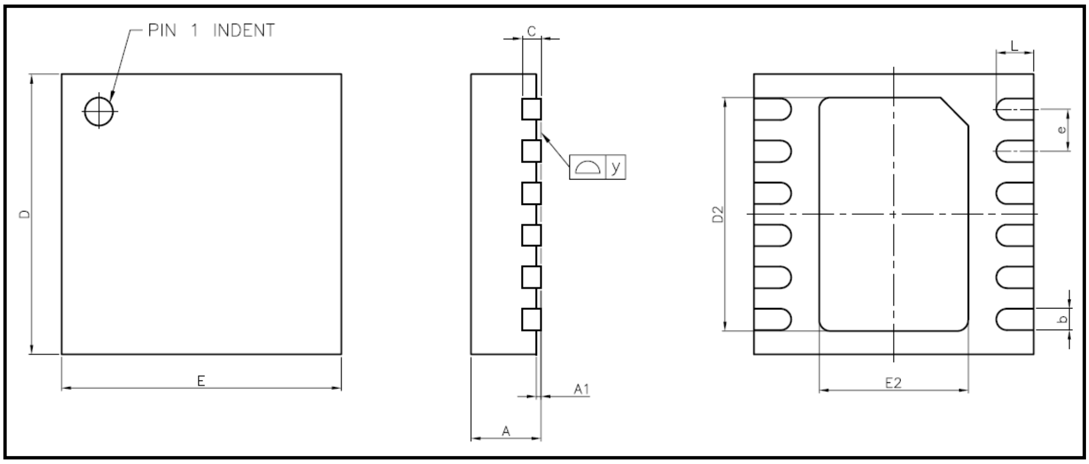
The booster output voltage could be slightly increased by a small resistor R_R from the output voltage to VO. The output voltage is:

$$V_{OUT} = 0.6V\left(8.3 + \frac{R_R}{20000}\right)$$



Package Outline

DFN-12L(EP)



UNIT: mm

Symbols	Min. (mm)	Max. (mm)
A	0.700	0.800
A1	0.000	0.050
b	0.180	0.280
c	0.200 REF.	
D	2.900	3.100
D2	2.450	2.550
E	2.900	3.100
E2	50	1.650
e	0.450	
L	0.350	0.450
y	0.000	0.075

Note:

1. JEDEC Outline :N/A
2. Dimensions “D” does not include mold flash, protrusions or gate burrs mold flash
3. Protrusions and gate burrs shall not exceed .15mm (.006in) per side.
   Dimensions “E” does not include inter-lead flash or protrusions inter-lead flash and protrusions
4. Shall not exceed 25mm (.010in) per side.