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LEDHLGEVB

Charge and LED Control Board Guidance Note

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EVAL BOARD USER'S MANUAL

Overview

LEDHLGEVB is an evaluation board for bicycle LED light systems. It uses a Lithium−ion battery to power the high−power LEDs that are used in bicycle headlights. The board's integrated DC/DC charging system can charge high power Lithium−ion batteries quickly and efficiently. Device supports the battery charging up to 2000 mA and MCU can be programmed to meet the customer's further charging requirements. Device boost operation is activated while battery is discharging to power−up the external LEDs. LEDHLGEVB supports charge/discharge and battery safety for 1−cell Lithium−ion / Polymer (Li+) batteries.

This guidance note is intended for users designing 1−cell Lithium−ion battery−based charge/discharge systems for a bicycle LED light.

Features

- DC/DC charging control from DC 5 V (USB−C) within a range of 25 mA to 2000 mA
- The LED brightness remains constant even if the battery voltage continuously degrades with long use
- Supports various modes of LED operation, such as: High mode, Medium mode, Low mode, and Flash mode
- Boost output (DC 4.2 V) control from 1−cell Lithium-ion/Polymer (Li+) battery
- Suppports pass−through charge topology, DC 5 V output directly powered to LED via USB when wall power is connected
- MCU with on−chip thermistor for providing safety to LED and device
- Ultra−low standby current consumption (including LIB protection IC)

Application

- Charge/discharge, safety and overall control function for bicycle LED light systems

Proposed Applications

- Charge/discharge control for bicycle rear light, smart home lighting systems and IoT controlled LEDs
- Charge/discharge control for LED lanterns

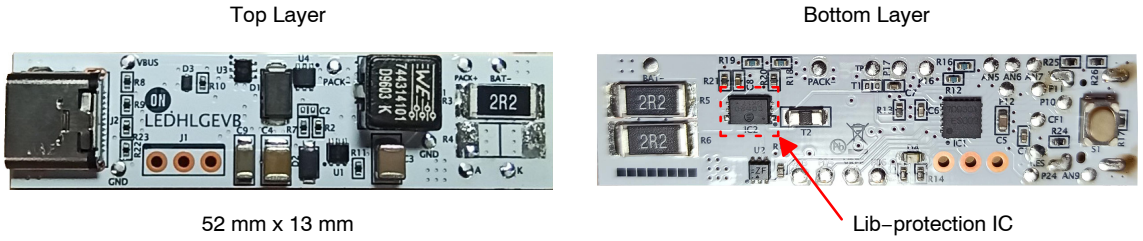


Figure 1. LEDHLGEVB Configuration

LEDHLGEVB SCHEMATICS

Schematics

(Please refer BOM List for Resistor and capacitor value)

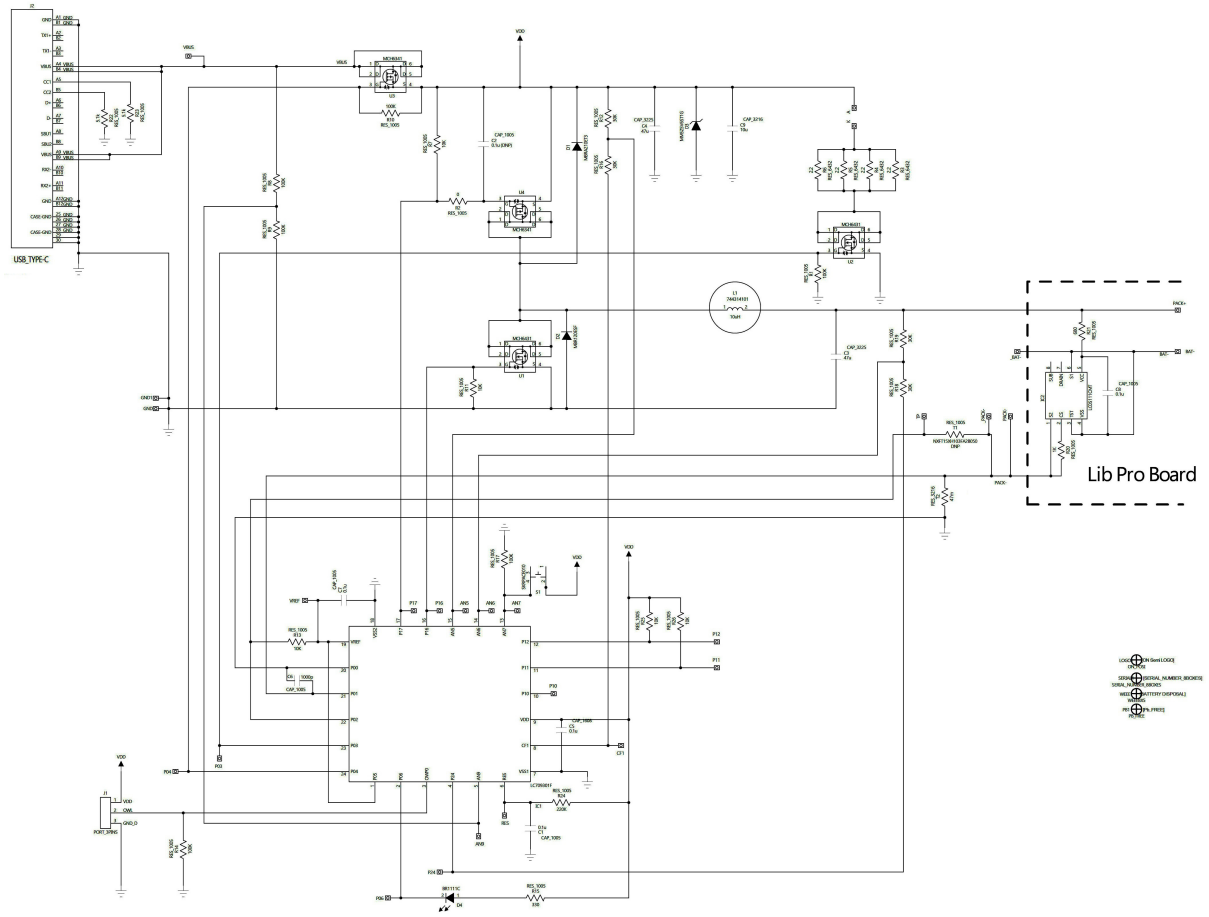


Figure 2.

BOM List

Table 1. BILL OF MATERIALS FOR THE LEDHLGEVB EVALUATION BOARD (20191211 VERSION)

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
IC1	1	Charge/Discharge controller	–	–	VCT24	ON Semiconductor	LC709301FRF−AUNH	No	Yes
IC2	1	Lib−Protection	–	–	WDFN6	ON Semiconductor	LC05111C13MTTTG	No	Yes
U3, U4	2	Pch MOSFET	–	–	MCPH6	ON Semiconductor	MCH6341	No	Yes
U1, U2	2	Nch MOSFET	–	–	MCPH6	ON Semiconductor	MCH6431	No	Yes
D1	1	Schottky Diode	–	–		ON Semiconductor	MBRA210ET3	No	Yes
D2	1	Schottky Diode	–	–		ON Semiconductor	MBR120ESFT1G	No	Yes
D3	1	Zenner Diode	–	–		ON Semiconductor	MM5Z5V6ST1G	No	Yes
D4	1	LED	Red	–	1608	Stanley	BR1111C	Yes	Yes
L1	1	Coil	10 μH	–		WE	744314101	Yes	Yes
C1 C7, C8	3	Chip Capacitor	0.1 μF	50 V, ±10%	CAP_1005	Murata	GRM155R71H104KE14D	Yes	Yes
C5	1	Chip Capacitor	0.1 μF	50 V, ±10%	CAP_1608	Murata	GRM188F11H104ZA01D	Yes	Yes
C2	1	Chip Capacitor	DNP		CAP_1005	Murata		Yes	Yes
C6	1	Chip Capacitor	1000 pF	50 V, ±10%	CAP_1005	Murata	GRM1552C1H102	Yes	Yes
C3, C4	2	Chip Capacitor	47 μF	16 V, ±10%	CAP_3225	Murata	GRM32ER61C476KE15L	Yes	Yes
C9	1	Chip Capacitor	10 μF	25 V, ±10%	CAP_3216	Murata	GRM31CB31E106KA75L	Yes	Yes
R1, R8−R10, R14, R17	6	Chip Resistor	100 kΩ	0.1 W, ±1%	RES_1005	Rohm	MCR01MZPJ104	Yes	Yes
R12, R16, R18, R19	4	Chip Resistor	30 kΩ	0.1 W, ±1%	RES_1005	KOA	RK73H1ETTP3002F	Yes	Yes
T2	1	Chip Resistor	47 m	1 W, ±1%	RES_3216	Panasonic	ERJ8BWFR047V	Yes	Yes
R4	1	Chip Resistor	DNP	1 W, ±1%	RES_6432	Panasonic	ERJ1TRQF2R2U	Yes	Yes
R3, R5, R6	3	Chip Resistor	2,2 Ω	1 W, ±1%	RES_6432	Panasonic	ERJ1TRQF2R2U	Yes	Yes
R7, R11, R13, R25, R26	5	Chip Resistor	10 kΩ	0.1 W, ±1%	RES_1005	Rohm	MCR01MRTJ103	Yes	Yes
R24	1	Chip Resistor	220 kΩ	0.1 W, ±1%	RES_1005	KOA	ERJ2RKD2203X	Yes	Yes
R21	1	Chip Resistor	680 Ω	0.125 W, ±5%	RES_1005	KOA	RK73B1ETTP681J	Yes	Yes
R20	1	Chip Resistor	1 kΩ	0.1 W, ±5%	RES_1005	Murata	MCR01MZPJ102	Yes	Yes
R22, R23	2	Chip Resistor	5.1 kΩ	0.1 W, ±5%	RES_1005	Rohm	RK73B1ETTP512J	Yes	Yes
R15	1	Chip Resistor	330 Ω	0.1 W, ±5%	RES_1005	Rohm	MCR01MRTF3300	Yes	Yes
R2	1	Chip Resistor	0 Ω		RES_1005	Rohm	MCR01MRTJ000	Yes	Yes
S1	1	TACT SWITCH	–	–	–	ALPS	SKRPACE010	Yes	Yes
T1	1	Thermistor	10 k	–	–	Murata	NXFT15XH103FA2B050	Yes	Yes
J1	1	3 pin Connector	–	–	–	JAE	IL−G−3P−S3T2−SA	Yes	Yes
J2	1	USB_TYPE−C	–	–	–	RoHs	DX07S024JJ2	Yes	Yes

Layout for PCB

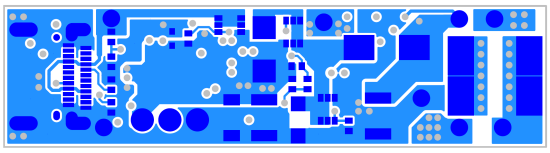


Figure 3. Pattern Layer (Top Layer)

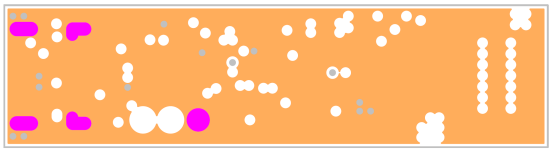


Figure 4. Pattern Layer (Inner Layer2)

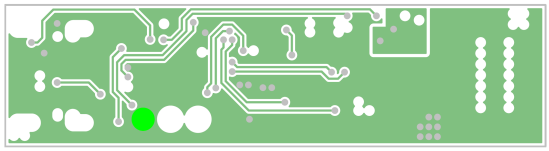


Figure 5. Pattern Layer (Inner Layer3)

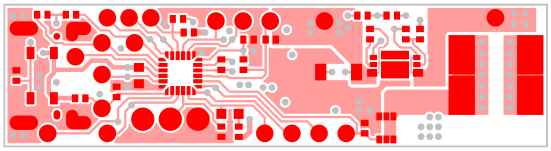


Figure 6. Pattern Layer (Bottom Layer)

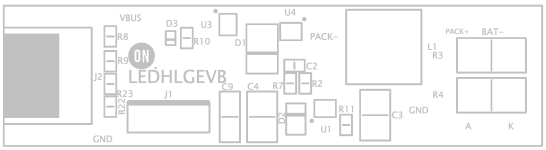


Figure 7. Silk Layer (Top Layer)

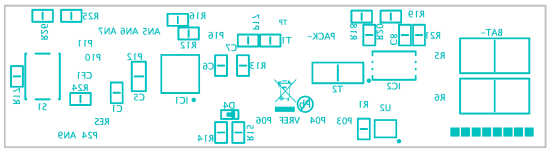


Figure 8. Silk Layer (Bottom Layer)

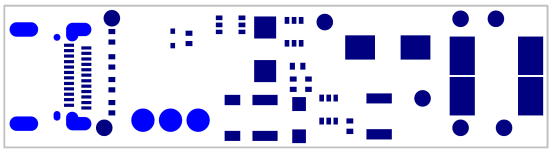


Figure 9. Solder Layer (Top Layer)

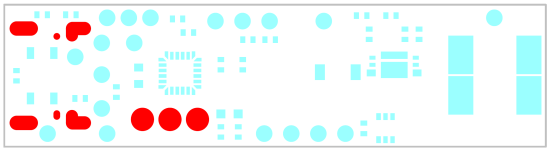


Figure 10. Solder Layer (Bottom Layer)

CHARGE MODE

USB Connection

- Connect a USB−C (DC 5 V) supply to the USB socket, and charge operation will start automatically to charge the 1−cell Lithium−ion/Polymer (Li+) batteries with 1000 mA charging current
- During the pre−charge state, the device charges the battery with a low predefined current to provide safety
- If the battery voltage reaches over 3.25 V, the operating mode changes from pre−charge mode to CC (constant−current) mode. (The indicator LED blinks at an interval of 1 Hz during the charge operation)

Battery Full Indication

- When the battery voltage reach 4.18 V, the charge mode changes to CV (constant voltage) mode and the charge current is reduced to 50 mA
- Charge operation is stopped if the battery current becomes less than 50 mA
- The indicator LED goes off when the battery is fully charged

NOTE:

- When a new battery is connected the LIB protection IC activates to prevent the battery from discharging, connecting to a USB supply for a few seconds will disable the LIB protection IC
- After a successful battery connection, don't forgot to connect USB charger to the evaluation board to deactivate the LIB protection IC

Figure 11.

Charging Specifications for LEDHLGEVB

- If the battery voltage is below 3.25 V, pre−charge mode is activated
- During pre−charge mode, 70 mA current is supplied as the charge IDD current to the battery
- The input supply voltage via USB must be in the range of 4.0 V to 5.5 V, if the input voltage is out of range, charge operation is disabled to keep the device safe
- It is not recommended to use batteries that are 4.3 V or above in applications
- If the LIB protection IC activates, the charge functions is stopped, to re−start the charge operation detach the USB cable from the USB socket and attach it again
- With the conditions below, charge operation is stopped and the indicator LED goes off
  - i) Voltage level from the USB power is below the battery voltage
  - ii) Temperature of the battery exceeds 58°C

DISCHARGE MODE

Push SW (S1) to Turn ON the LED, DC 4.2 V Power is Provide on the A Terminal

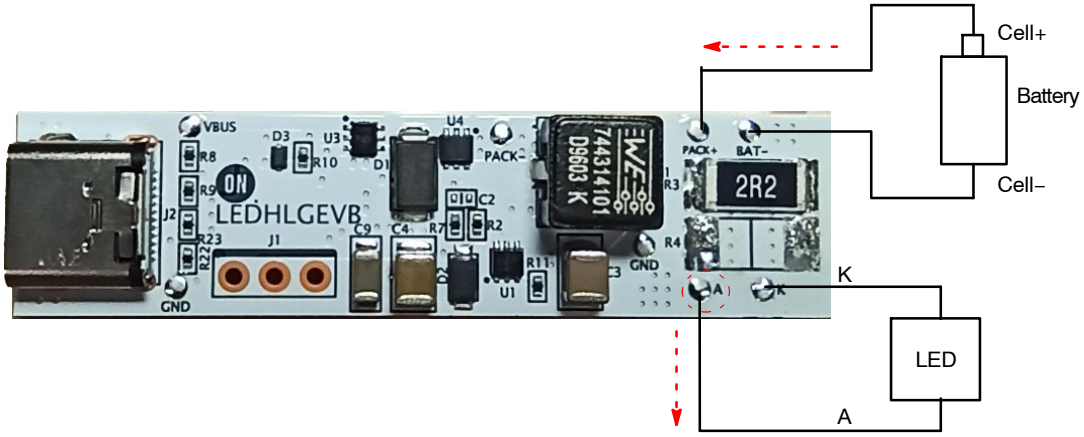


Figure 12.

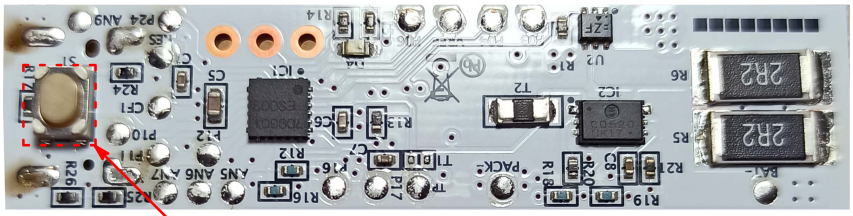


Figure 13.

Specifications for Discharge Operation

1. LED lighting operations
   - High mode: A terminal is 4.2 V (LED Current is 1500 mA)
   - Medium mode: A terminal is 4.2 V (LED Current is 600 mA)
   - Low mode: A terminal is at battery voltage (LED Current is 100 mA)
   - Flash1 mode: A terminal is at battery voltage (LED blinks at 10 Hz and current is 600 mA)
   - Flash2 mode: A terminal is at battery voltage (LED blinks at 0.5 Hz and Current is 100 mA)
2. Battery discharge operation is stopped to keep the system safe at 3.0 V
3. On pushing the SW during the lighting operation, device lighting modes changes from High mode to Flash2 mode respectively
4. The switching frequency for boost operation is about 150 kHz
5. With the conditions below, the discharge function is stopped, and the LED goes off
   - Battery voltage is under 3.0 V
   - IDD current from battery exceeds 3000 mA
   - The temperature of the battery exceeds 58°C
   - VOUT voltage goes over 6.2 V (on boost operation)

PASS−THROUGH CHARGE TOPOLOGY

If the USB (DC 5 V) is connected to the device keeping the LED ON, the system will automatically activate the Pass−through mode and the LED is powered from the 5 V USB wall charger. USB power is provided directly to the LED and battery in the pass−through charge topology. It is recommended to use a wall charger with a current rating of 2.5 A or above in pass−through.

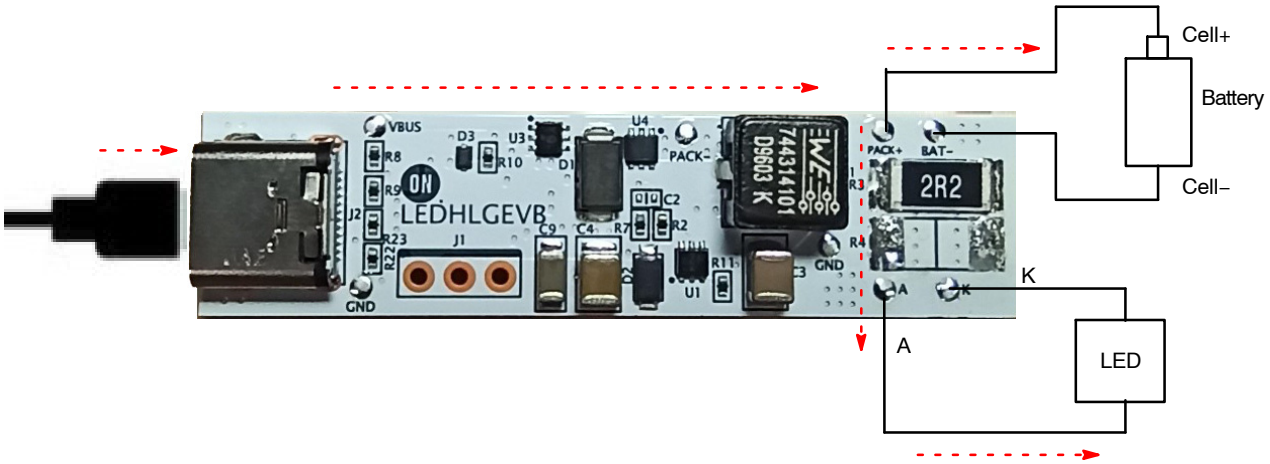


Figure 14.

LIB−PROTECTION IC

LEDHLGEVB includes a mounted Lib−protection IC: LC05111C20MTTTG, the specifications are given below

Table 2.

Device	Vov [V]	Vovr [V]	Vuv [V]	Vuvr [V]	Vuvr2 [V]	AWUP	Ioc [A]	Ioch [A]	Ioc2 [A]	0 V Charge
LC05111C20MTTTG	4.31	4.11	2.5	2.5	2.9	enable	3.0	2.0	15.0	enable

For details, please refer to the LC05111C20MTTTG datasheet LC05111CMT/D.

FLOW CHART

Flowchart for LED Light

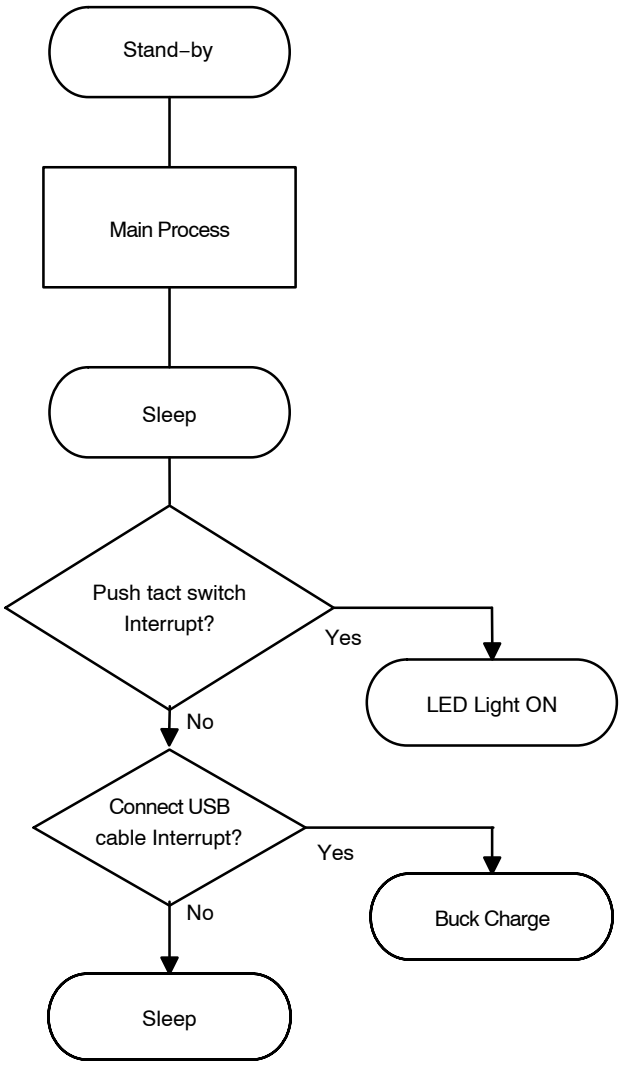


Figure 15.

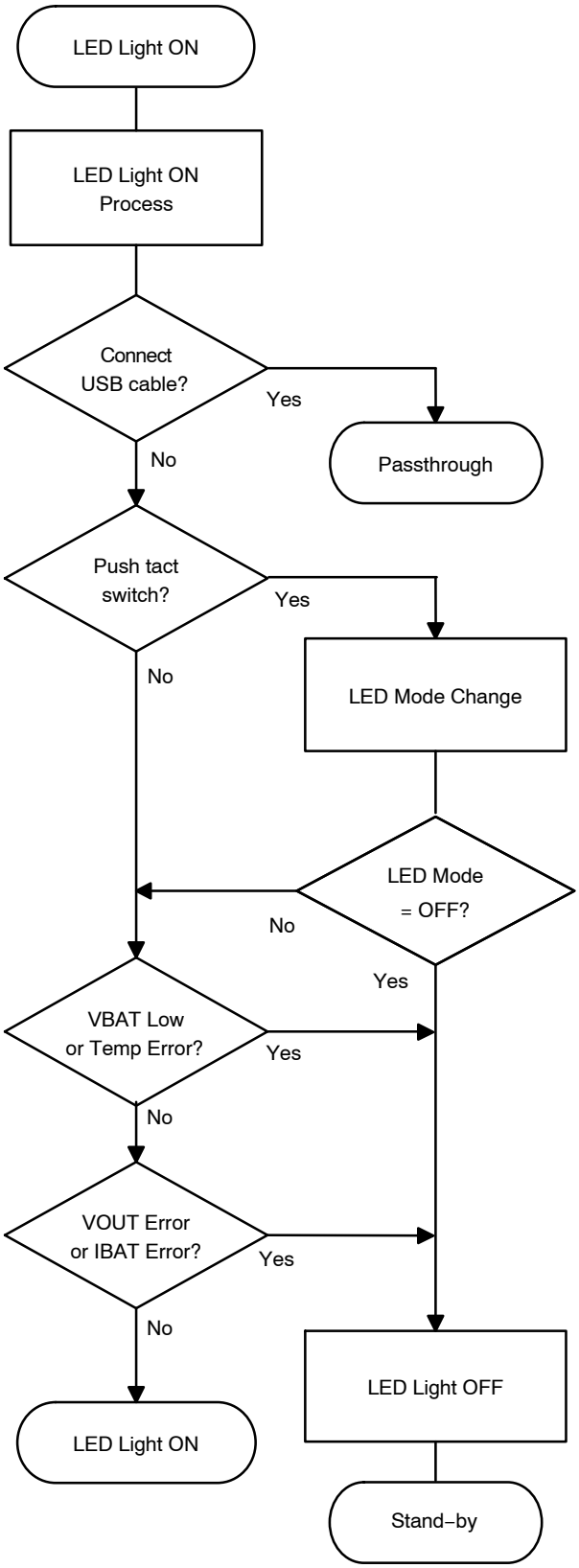


Figure 16.

Flowchart for Buck Charge and Passthrough Mode

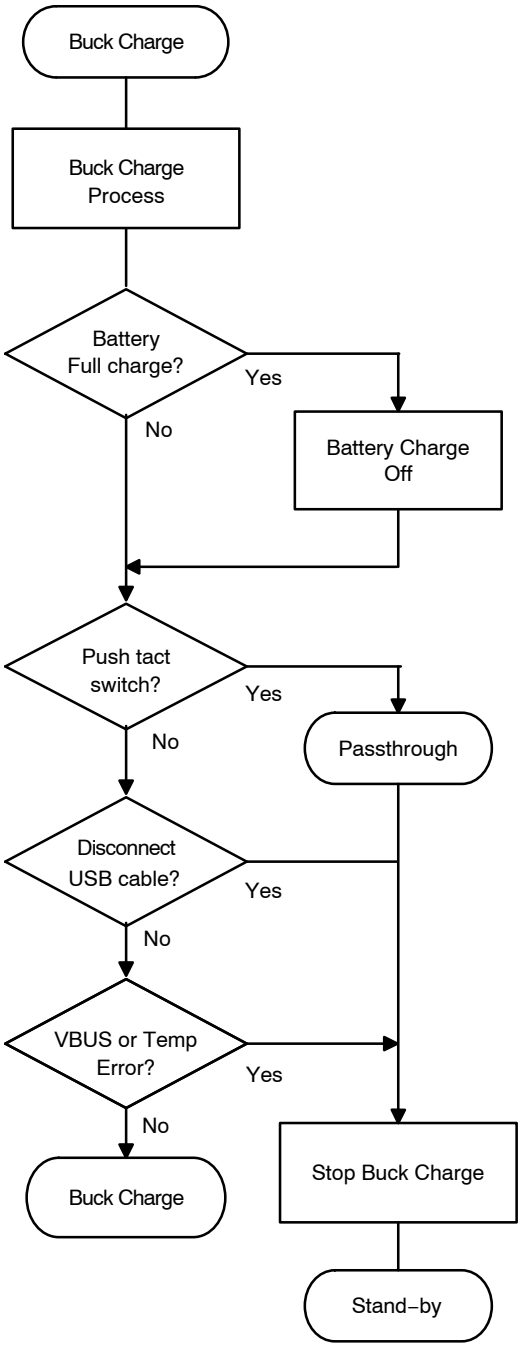


Figure 17.

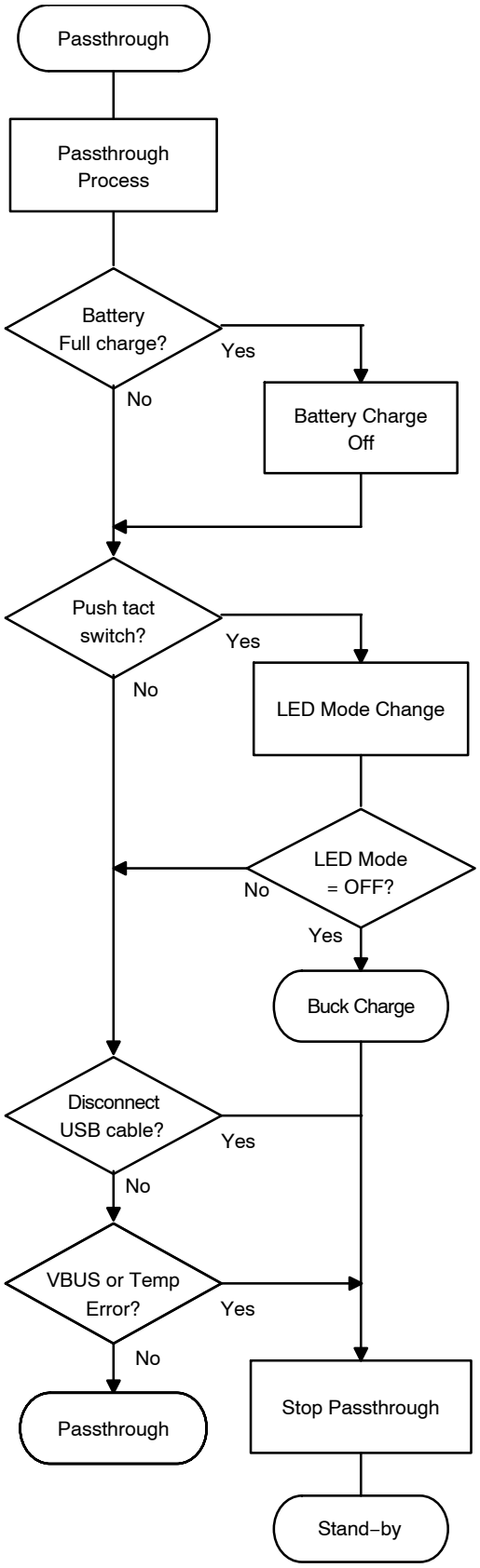


Figure 18.

STATE MODE TRANSITION

LED Light Mode Transition Diagram with Passthrough (Simple Version) 2019.12.13

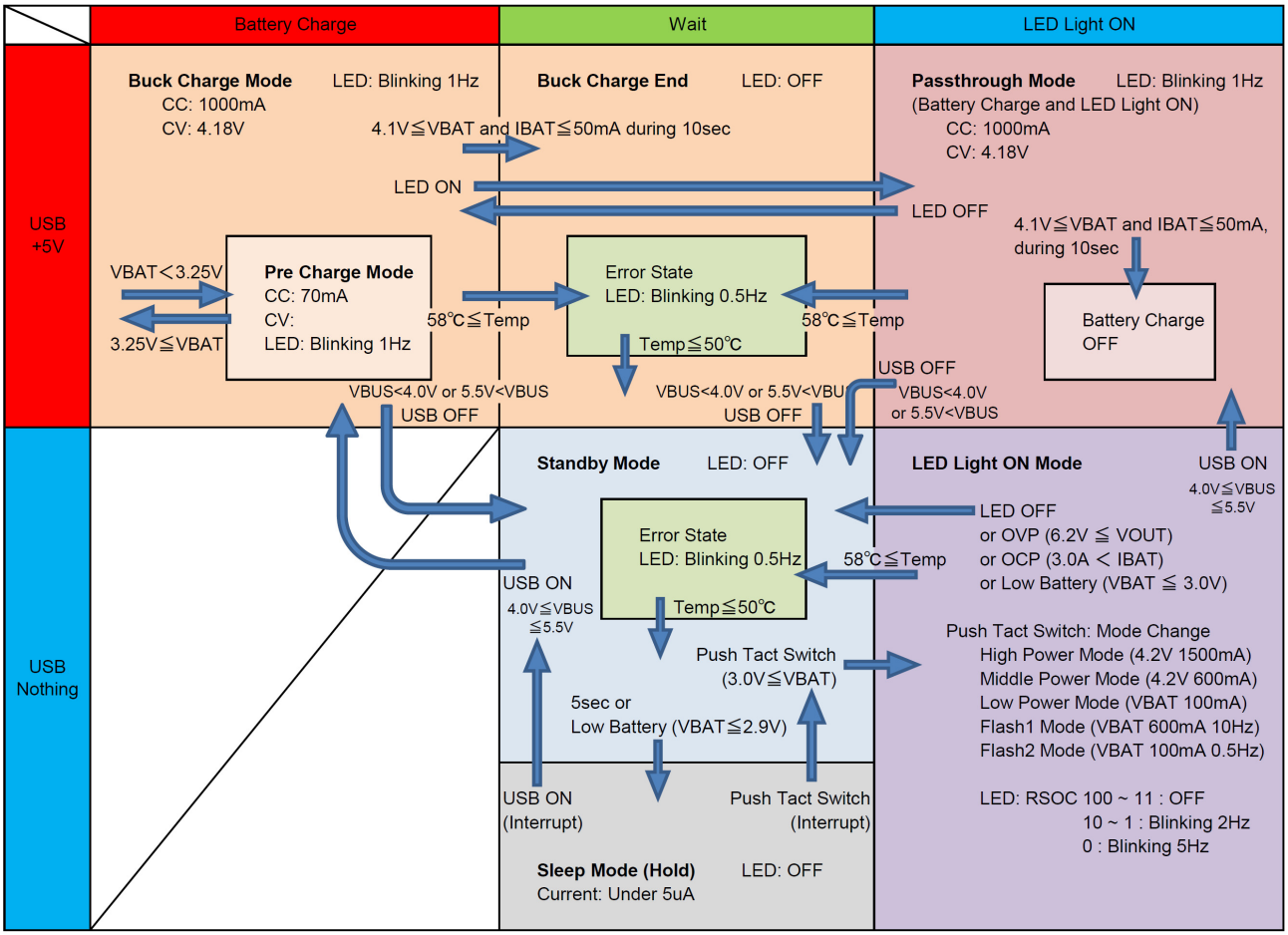


Figure 19.

INDICATOR LED

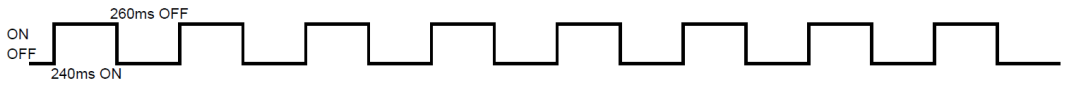
Stand-by, Sleep : LED indicator is lights out.

Buck Charge : LED indicator blinks ON and OFF every 500ms during Buck Charge operation..

LED Light ON : LED indicator blinks depends on RSOC.

RSOC = 100% to 11%

RSOC = 10% to 1%



RSOC = 0%

Temperature error, VBUS error : LED blinks 100ms ON and 1900ms OFF during error condition.

Figure 20.

PIN ASSIGNMENT

Table 3. PIN ASSIGNMENT

Pin No.	Terminal Name	Port Option	I/O	Function	Port Name	Summary	Active	Internal PullUp	Initial		Sleep		Stand−by		Buck Charge		LED Light ON	
									DDR	Latch	DDR	Latch	DDR	Latch	DDR	Latch	DDR	Latch
1	P05/T1PWML/ CK0	Nch	Out	P05	VREF_CNT	VREF Discharge	Low		In	Low	In	Low	In	Low	In	Low	In	Low
2	P06/T1PWMH	Nch	Out	P06	LED	LED Indicator Output	Low		Out	High	Out	High	Out	High	Out	High /Low	Out	High /Low
3	OWP0	–	–	OWP	OWP0	Debugger	–		–	–	–	–	–	–	–	–	–	–
4	P24/AN14/ VCPWM0	Nch	Out	AN14	VBAT_CNT	Divide Battery Voltage	Low		In	Low	In	Low	In /Out	Low	In /Out	Low	In /Out	Low
5	P70/INT0/ T0LCP/AN9	(Nch)	In	INT0 /AN9	VBUS	USB Voltage Input	–		In	Low	In	Low	In	Low	In	Low	In	Low
6	RES	–	In		RES	Reset	Low		–	–	–	–	–	–	–	–	–	–
7	VSS1	–	–		VSS1	GND	–		–	–	–	–	–	–	–	–	–	–
8	CF1/XT1	(Nch)	Out	CF1/XT1	VOUT_CNT	Divide VOUT Voltage	Low		In	Low	In	Low	In/ Out	Low	In/ Out	Low	In/ Out	Low
9	VDD1	–	–		VDD1	VDD / VDD Voltage Input	–		–	–	–	–	–	–	–	–	–	–
10	P10/SO1	Nch	In	P10	P10	NC	–		Out	Low	Out	Low	Out	Low	Out	Low	Out	Low
11	P11/SI1/SB1	Nch	Out	SB1	P11	I2C Slave SDA	–		Out (I2C)	Low	Out (I2C)	Low	Out (I2C)	Low	Out (I2C)	Low	Out (I2C)	Low
12	P12/SCK1	Nch	Out	SCK1	P12	I2C Slave SCL	–		Out (I2C)	Low	Out (I2C)	Low	Out (I2C)	Low	Out (I2C)	Low	Out (I2C)	Low
13	P13/INT4/ T1IN/AN7	Nch	In	P13/ INT4	KEY	Key Input	High		In	Low	In	Low	In	Low	In	Low	In	Low
14	P14/INT4/T1I N/AN6	Nch	In	AN6	VBAT	Battery Voltage Input	–		In	Low	In	Low	In	Low	In	Low	In	Low
15	P15/INT3/ T0IN/AN5	Nch	In	AN5	VOUT	LED Light Voltage Input	–		In	Low	In	Low	In	Low	In	Low	In	Low
16	P16/INT2/ T0IN/CPOUT/ HPWM2	CMOS	Out	HPWM2	PWM0	LED Light ON PWM (Q2)	High		Out	Low	Out	Low	Out	Low	Out	Low	Out	PWM
17	P17/BUZ/ INT1/T0HCP/ HPWM2	CMOS	Out	HPWM2	PWM1	Buck Charge PWM (Q4)	Low		Out	High	Out	High	Out	High	Out	PWM	Out	High
18	VSS2	–	–		VSS2	GND	–		–	–	–	–	–	–	–	–	–	–
19	VREF	–	Out	VREF	VREF	Ref Voltage	–		–	VDD	–	GND	–	VDD	–	VDD	–	VDD
20	P00/APIM	Nch	In	APIM	SENB−	Battery Current − Input	–		In	Low	In	Low	In	Low	In	Low	In	Low
21	P01/APIP	Nch	In	APIP	SENB+	Battery Current + Input	–		In	Low	In	Low	In	Low	In	Low	In	Low
22	P02/AN2/ CPIM	Nch	In	AN2	TSENSE	Thermistor Voltage Input	–		In	Low	In	Low	In	Low	In	Low	In	Low
23	P03/AN3/ VCPWM0	CMOS	Out	P03/ VCPWM0	GATE2	Gate2(Q3) Control	High		Out	Low	In	Low	Out	Low	Out	Low	Out	High/ PWM
24	P04/AN4/ VCPWM1	Nch	Out	P04	GATE1	Gate1(Q1) Control	Low		In	Low	In	Low	In	Low	Out	Low	In	Low

SOFTWARE DIAGRAM

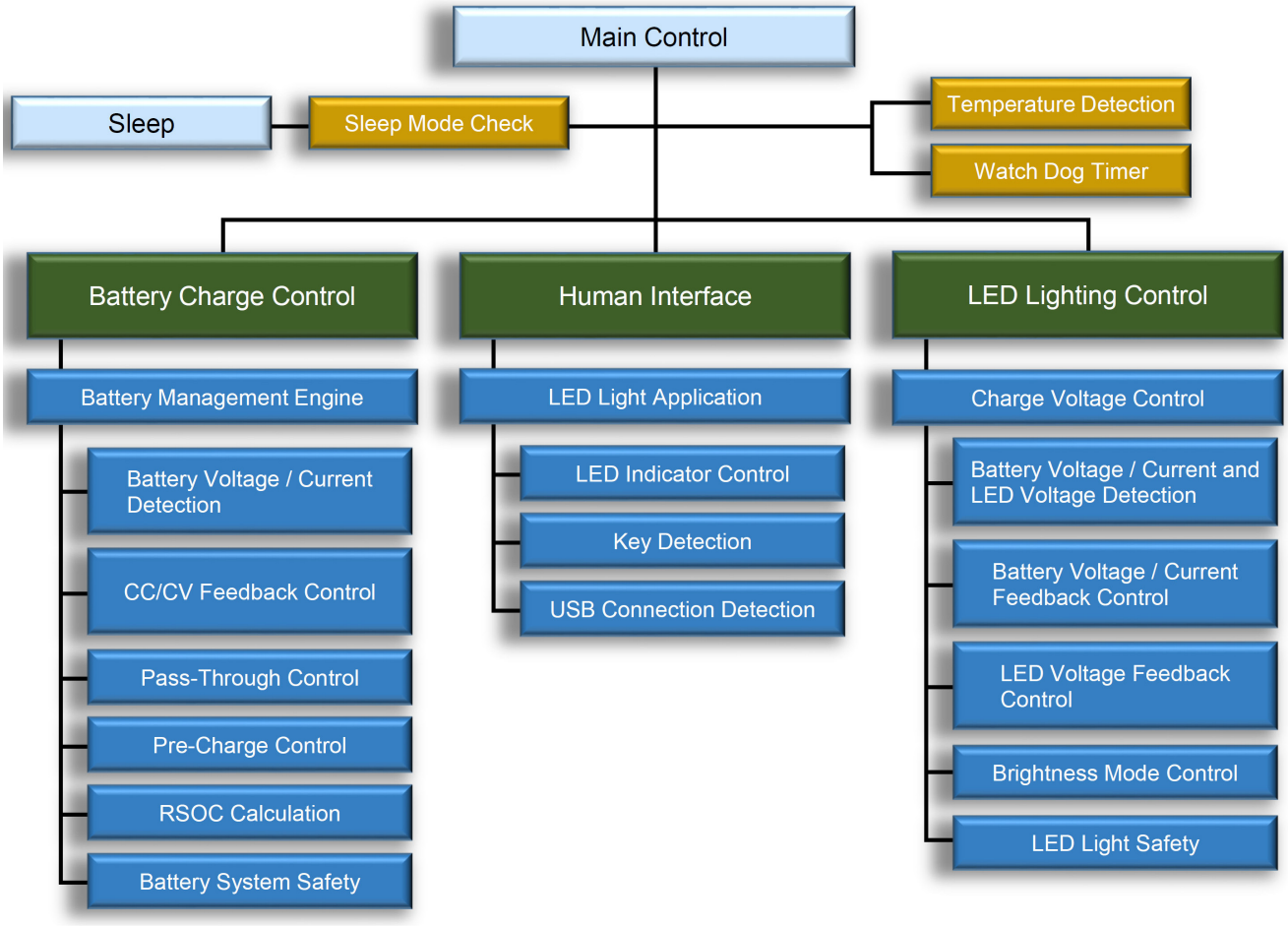


Figure 21.

BLOCK DIAGRAM

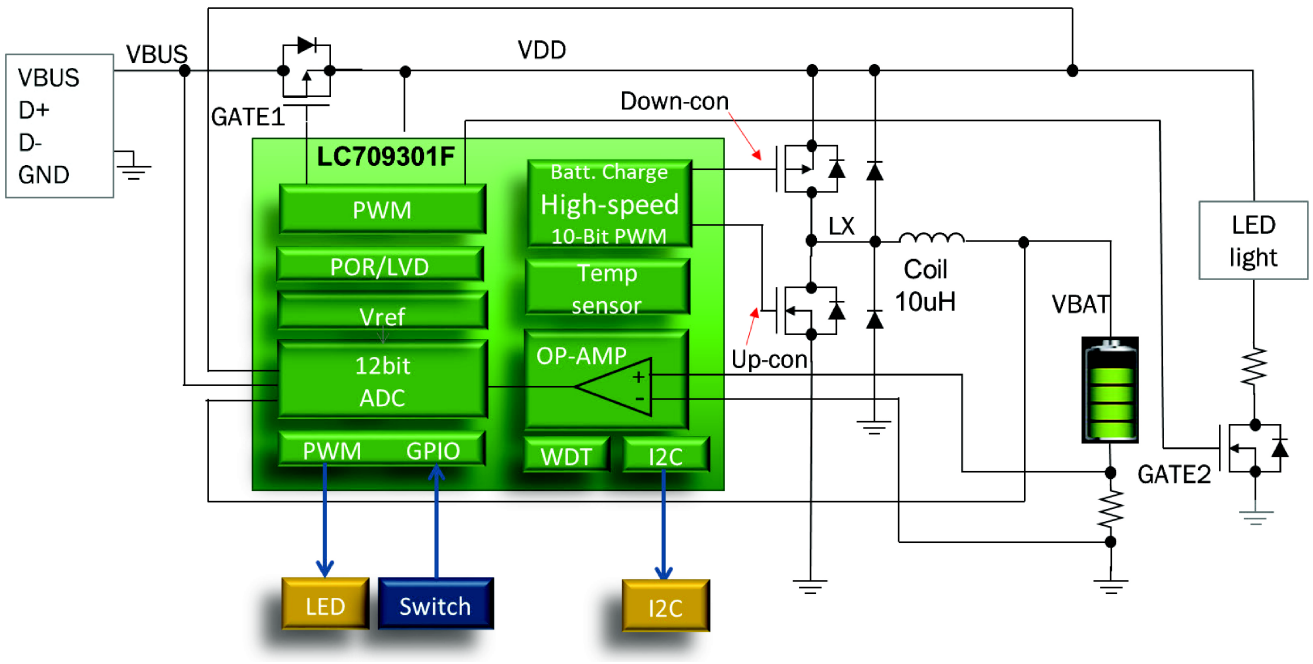


Figure 22.

WAVEFORMS SHOWING EFFICIENCY, STANDBY CURRENT AND CHARGE CHARACTERISTICS

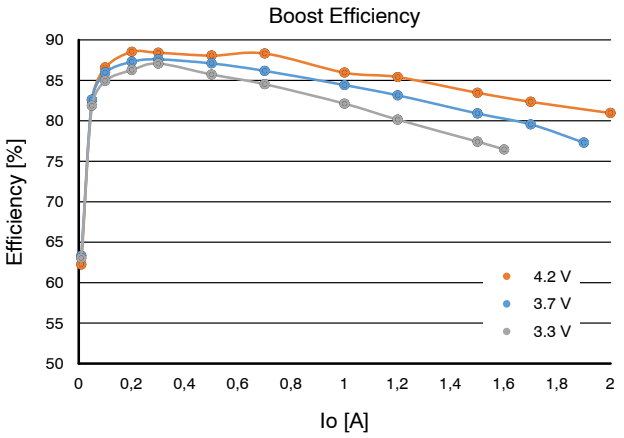


Figure 23. Boost Efficiency

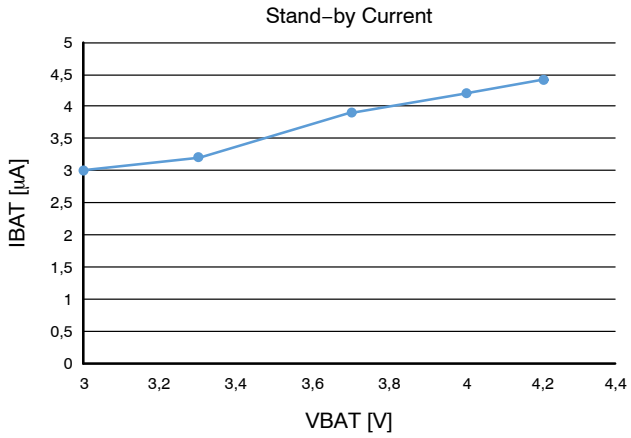


Figure 24. Stand−by Current (Lib−protection IC Included)

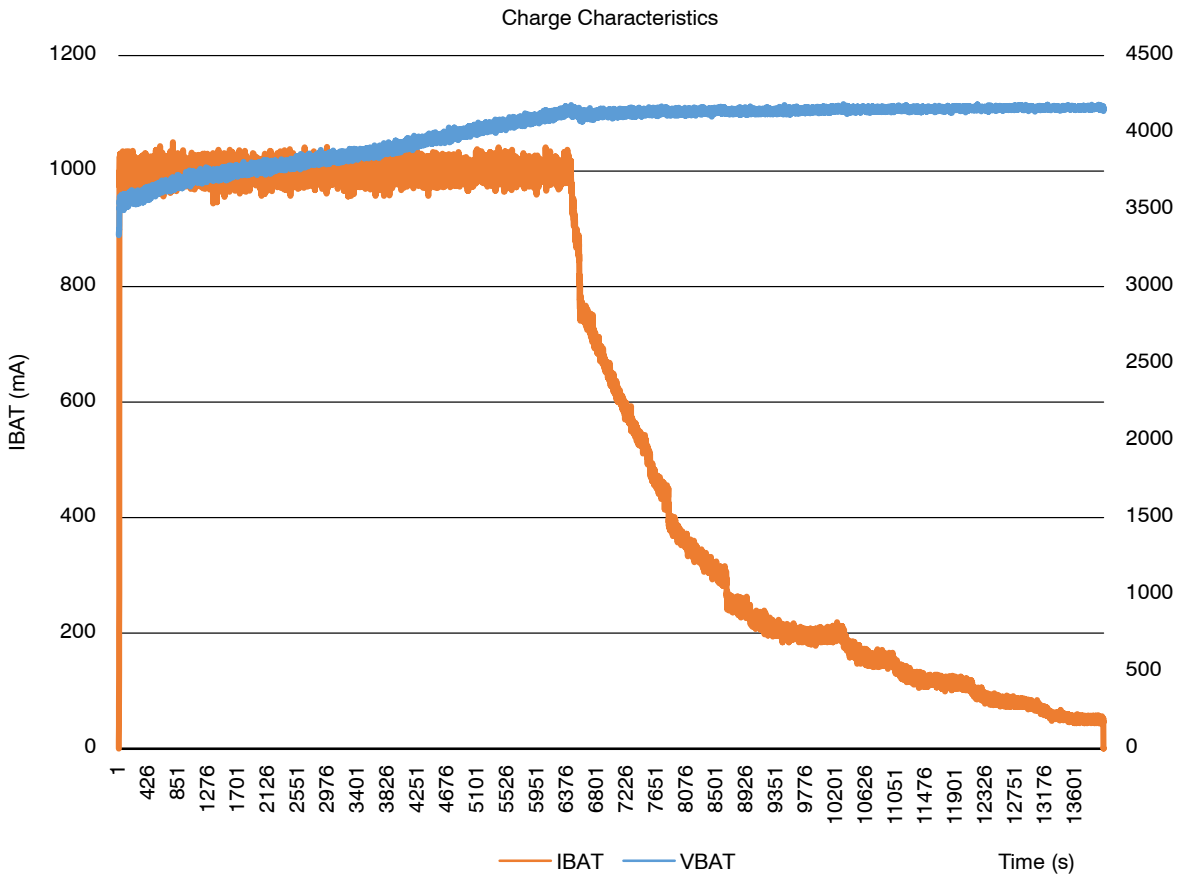


Figure 25. Charge Characteristic (Charge at 1000 mA)

BUCK CHARGE WAVEFORMS

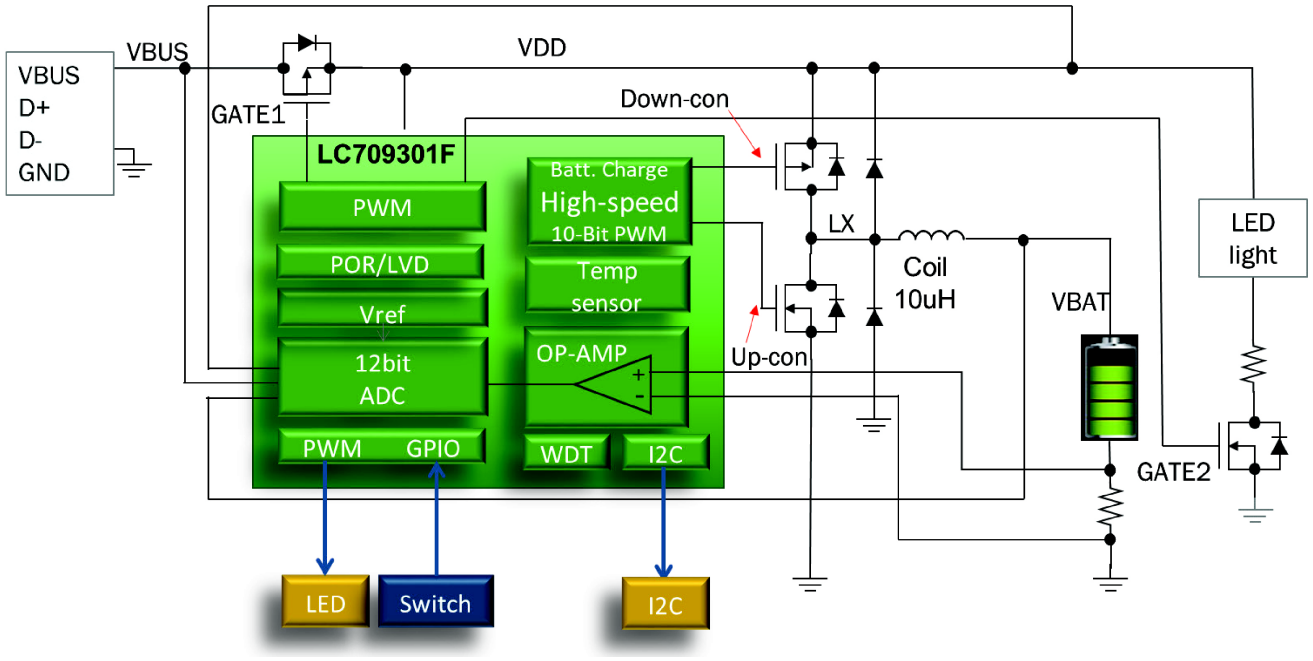


Figure 26.

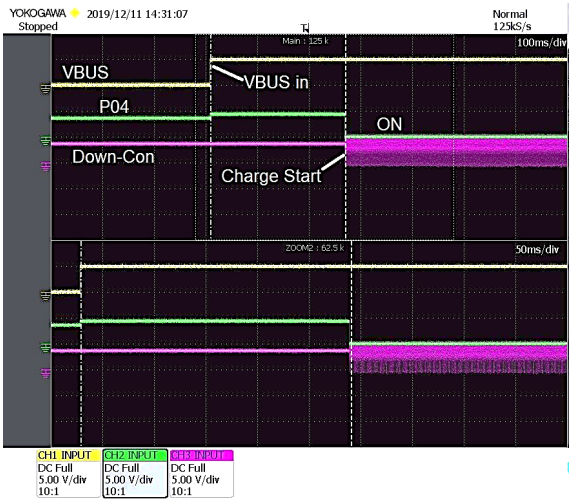


Figure 27. Connecting VBUS During Standby to Start the Buck Charge

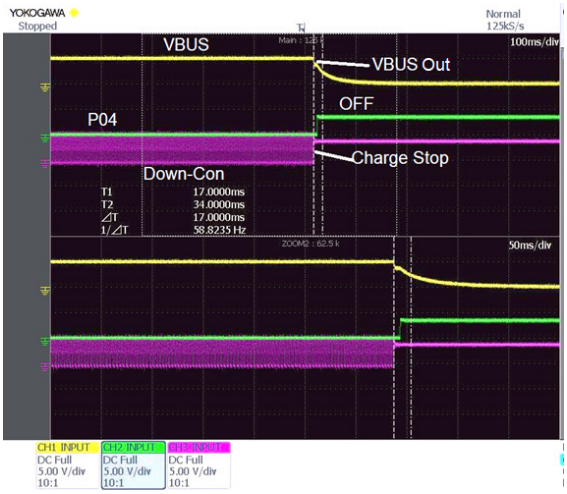


Figure 28. Disconnecting VBUS During Buck Charge Changes the Device to Standby Mode

LED MODES WAVEFORMS

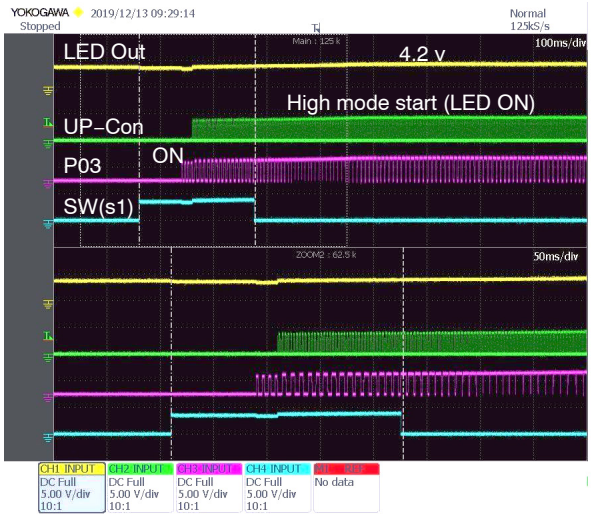


Figure 29. LED ON (High Power Mode) by Pressing Key During Standby

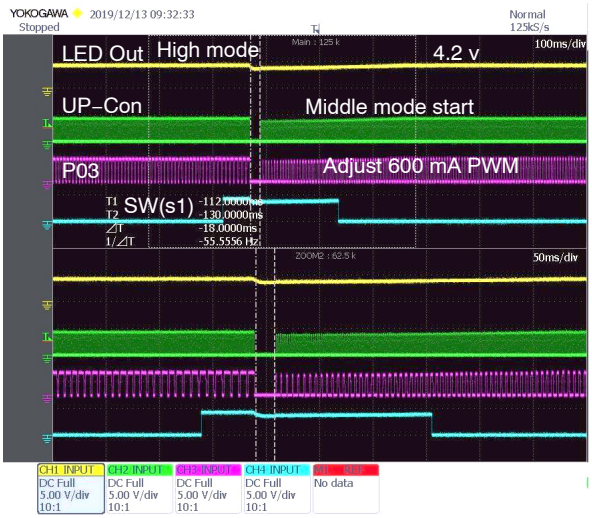


Figure 30. Switch to Middle Power Mode by Pressing Key During High Power Mode

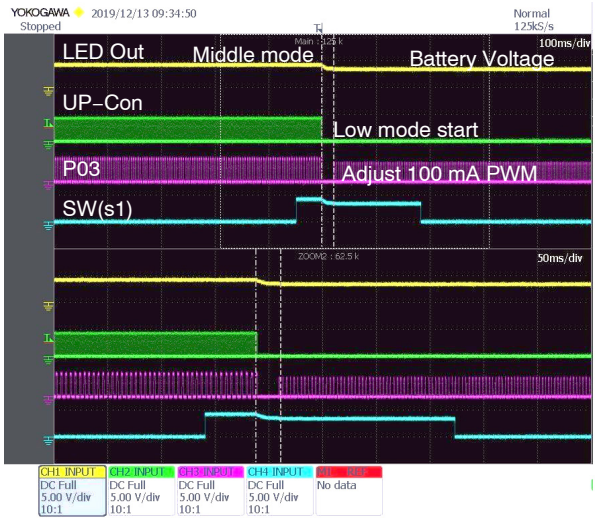


Figure 31. Press Key in Middle Power Mode to Switch to Low Power Mode (Up−con is Disabled on this Mode)

Table 4. TEST PARAMETERS

Indications	Test points on PCB
Up−Con	P16
Down−Con	P17
SW (S1)	AN7
LED Out	A
P03	P03
VBUS	VBUS
P04	P04

PASS−THROUGH MODE WAVEFORMS

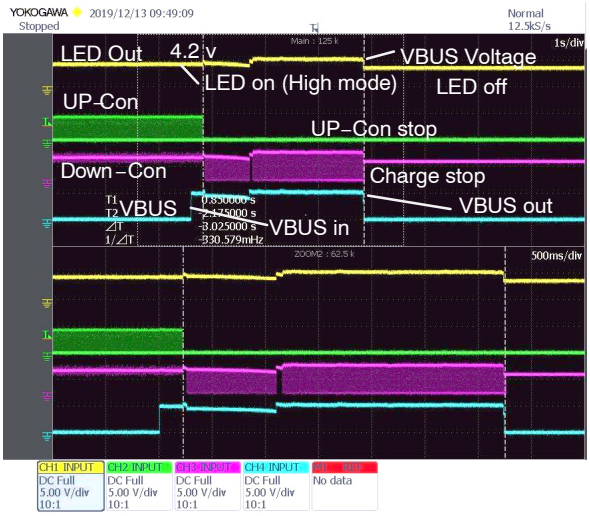


Figure 32. Pass−through Starts when VBUS is Inserted while LED is ON

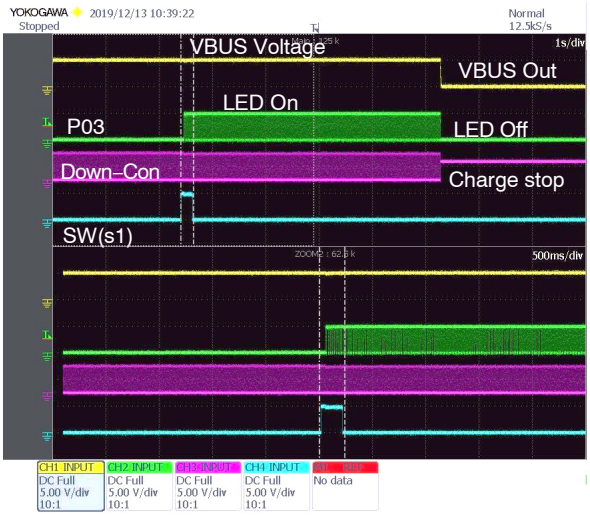


Figure 33. Initially LED is OFF and Battery is Charging. Pass−through Starts and the LED Turns ON when the Switch is Enabled

WAVEFORMS FOR VARIOUS LIGHTING MODES

Figure 34. Waveforms for High Mode (LED Current ~ 1500 mA)

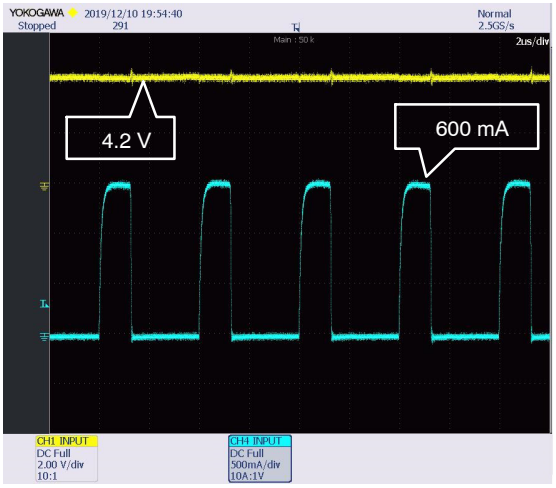


Figure 35. Waveforms for Medium Mode (LED Current ~600mA)

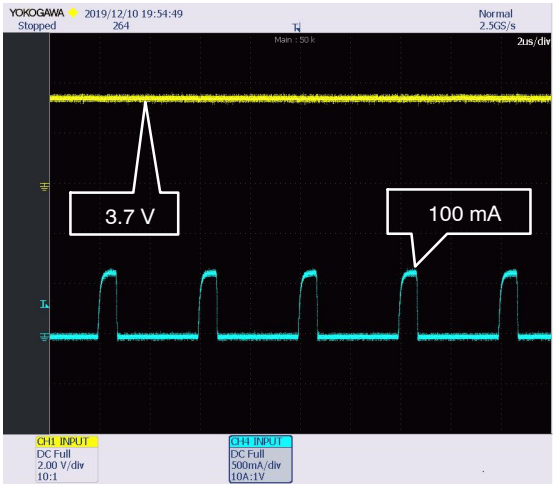


Figure 36. Waveforms for Low Mode (LED Current ~ 100 mA)

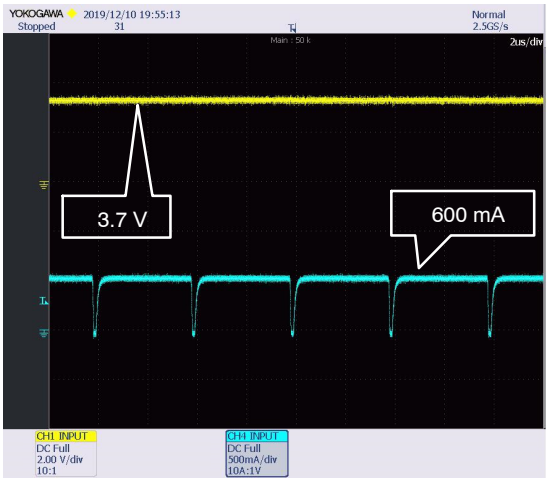
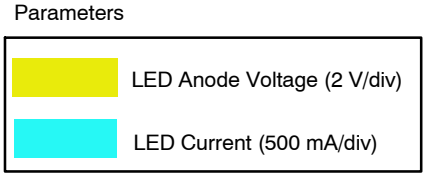


Figure 37. Waveforms for Flash1 Mode (LED Current ~ 600 mA)

Figure 38. Waveforms for Flash2 Mode (LED Current = 100 mA)



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