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Power Bank Application Note using the LC709511F

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APPLICATION NOTE

Overview

LC709511F is a Lithium ion switching charger controller for Power Bank. This device has all functions to control Power Bank application. It includes Type−C port control, Quick Charge 3.0 HVDCP and Smart switch. The built−in switching controller can output from 5 V up to 12 V for Quick Charge. The high power output for USB Type−C and Quick Charge is possible with appropriate external MOSFETs.

Features

- Easy Power Scaling with External MOSFETs
- Buck Charge to Built−in Battery / Boost Charge to USB Devices
- Supports Quick Charge 3.0 HVDCP Class A. 5 V up to 12 V
- Supports USB type−C Dual Role without External Port Control IC
- Smart Switch Applies 2.7 V or 2.0 V or DCP Short on USB Data Lines
- Automatically for Requirement of USB Devices
- Reference Software Supports Various Combination of USB port
- Supports USB BC1.2
- Controls an External Boost−IC for 2nd USB Output
- Battery Level Gauging
- Status & Battery Level Display with 4 LEDs
- Boost Auto Start−up
- Thermistor Sensing Function
- Over Voltage / Over Current Detection
- JEITA Compliance Battery Management
- Safety Timer
- Low Quiescent Current: 15 μA at Low Power Mode

Applications

- Power Bank
- USB−related Charging Application

EVALUATION BOARD

LC709511F−FW02 Evaluation Board: LC709511A02GEVB

PORT FUNCTION

	USB1	USB2	USB3
USB port type	Micro−B (input), 5 V / 2.4 A	Type−A (output), 5−12 V / 27 W	Type−A (output), 5 V / 2 A
Function	BC1.2 and Divided mode detection, Source capacity detection (Note 1)	QC3.0 up to 12 V Boost auto start−up (Note 2)	Boost auto start−up (Note 2) BC1.2(DCP) or Divided mode (Note 3)

1. This device sets maximum input current with D ± Detection and VBUS voltage drop.
2. When a device is connected, boost is started automatically without pushing the switch. Refer to the section 6 “Boost auto start−up”.
3. Initial mode is divided mode. At the insertion of device the appropriate mode for connected device is selected automatically.

MAIN COMPONENTS

Item	Manufacturer	Part Number	Function
Controller	ON Semiconductor	LC709511F−FW02	Buck charge, 1st Boost for USB2 port
FETs	ON Semiconductor	ECH8310 x 5 NTTFS4H05N x 2	For DD converter and Gate switch (Note 4)
Lib protection	ON Semiconductor	LC06111TMT x 2	
Inductor	Panasonic	ETQP6F4R6HFA	4.6 μH, for Buck charge & 1st Boost
2nd Boost IC	Silergy	SY7065A	2nd Boost IC for USB3 port (Note 5)

4. PWM frequency: 150 kHz
5. During insertion detection of USB3, this IC ports which connect to VBUS must be Hi−Z. Refer to the section 6 “Boost auto start−up”.

Other Functions

- 4 LEDs, Fuel gauge, Thermistor sensing, One push switch, On board programmer interface

LC709511A02GEVB Block Diagram

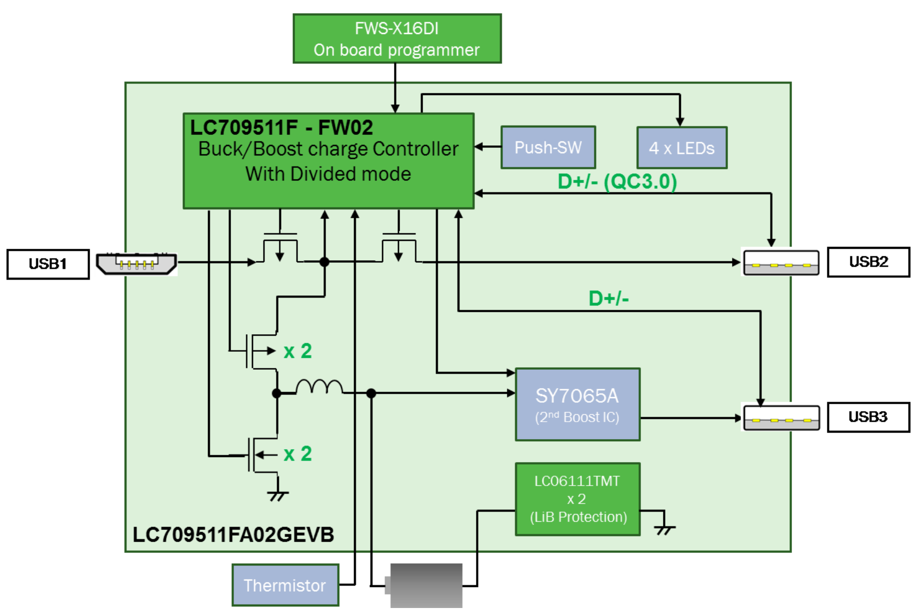

Figure 1. LC709511A02GEVB Block Diagram

LC709511A02GEVB Photos

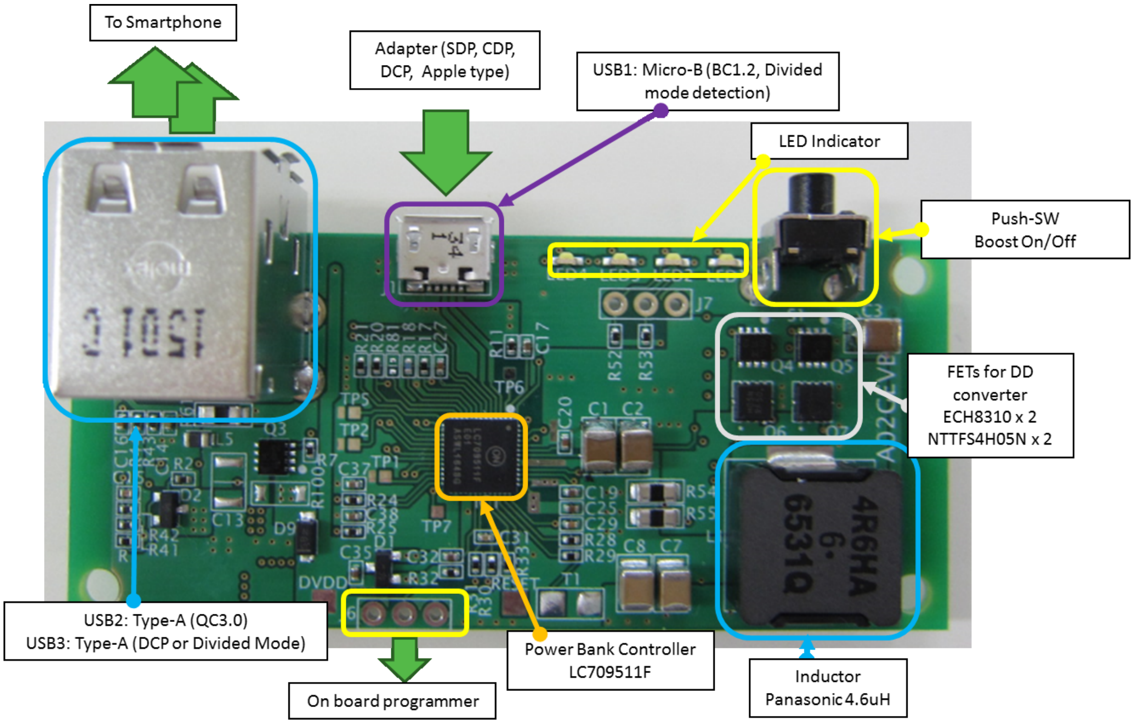

Figure 2.

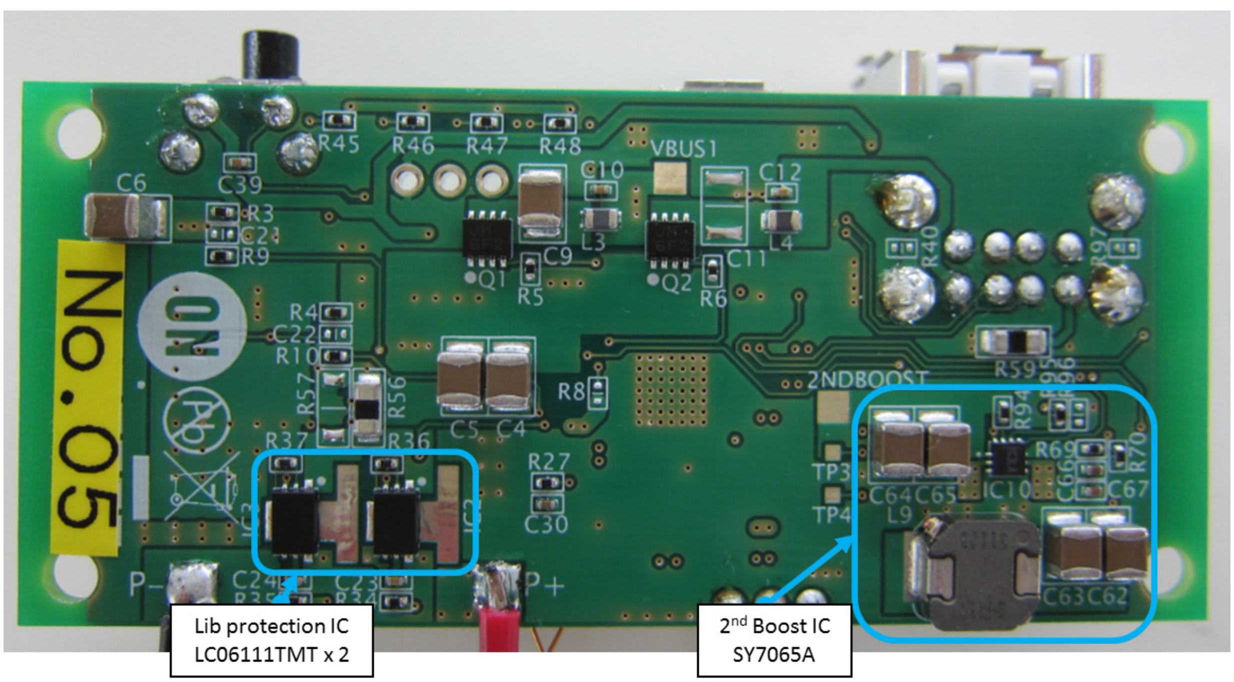

Figure 3.

LC709511F−FW05 Evaluation Board : LC709511A05GEVB

PORT FUNCTION

	USB1	USB2	USB3
USB port type	Type−C (Input and Output)	–	Type A (output), 5 V / 2 A
Function	Role and attach detection (Input or Output) (Note 2) Input: BC1.2 and Divided mode detection, Source capacity detection (Note 6) Output: QC3.0 up to 12 V	–	Boost auto start−up (Note 2) BC1.2(DCP) or Divided mode (Note 3)

6. When the other DRP device is connected, this device will negotiate for it to become the source.

MAIN COMPONENTS

Item	Manufacturer	Part Number	Function
Controller	ON Semiconductor	LC709511F−FW05	Buck charge, 1st Boost for USB2 port
FETs	ON Semiconductor	ECH8310 x 4 NTTFS4H05N x 2	For DD converter and Gate switch (Note 4)
Lib protection	ON Semiconductor	LC06111TMT x 2	
Inductor	Panasonic	ETQP6F4R6HFA	4.6 μH, for Buck charge & 1st Boost
2nd Boost IC	Silergy	SY7065A	2nd Boost IC for USB3 port

Other Functions

- 4 LEDs, Fuel gauge, Thermistor sensing, One push switch, On board programmer interface

LC709511A05GEVB Block diagram

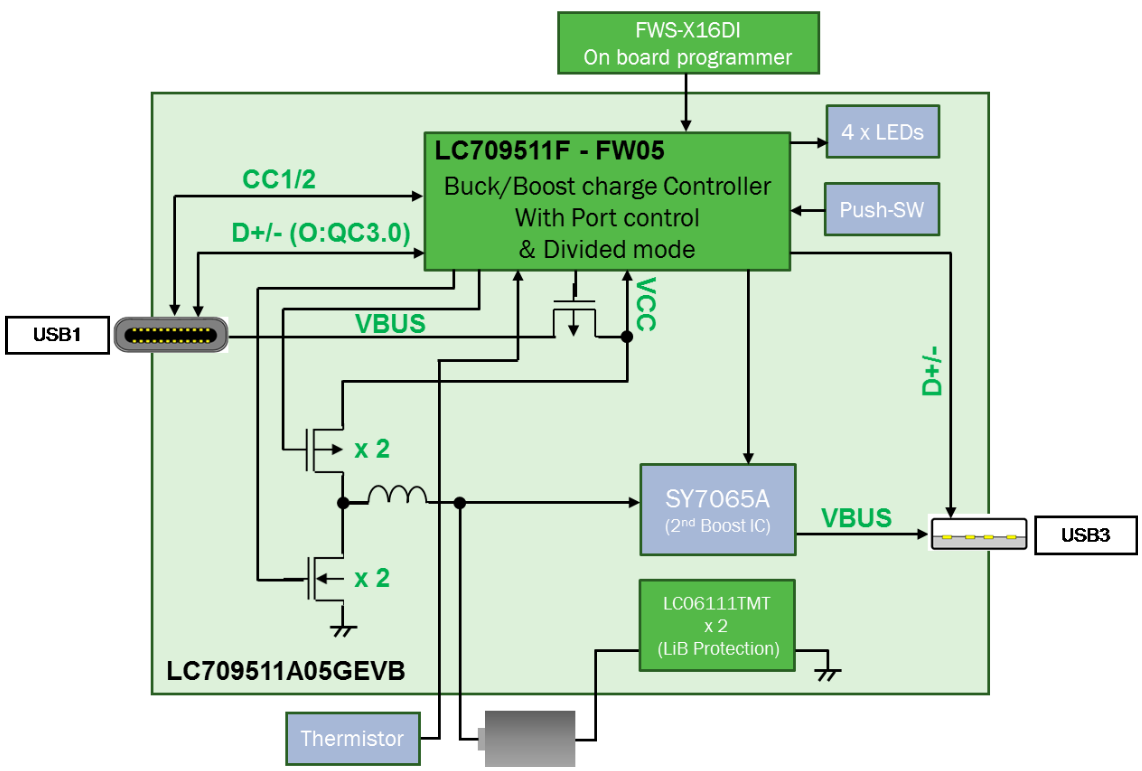

Figure 4. LC709511A02GEVB Block Diagram

LC709511A05GEVB Photos

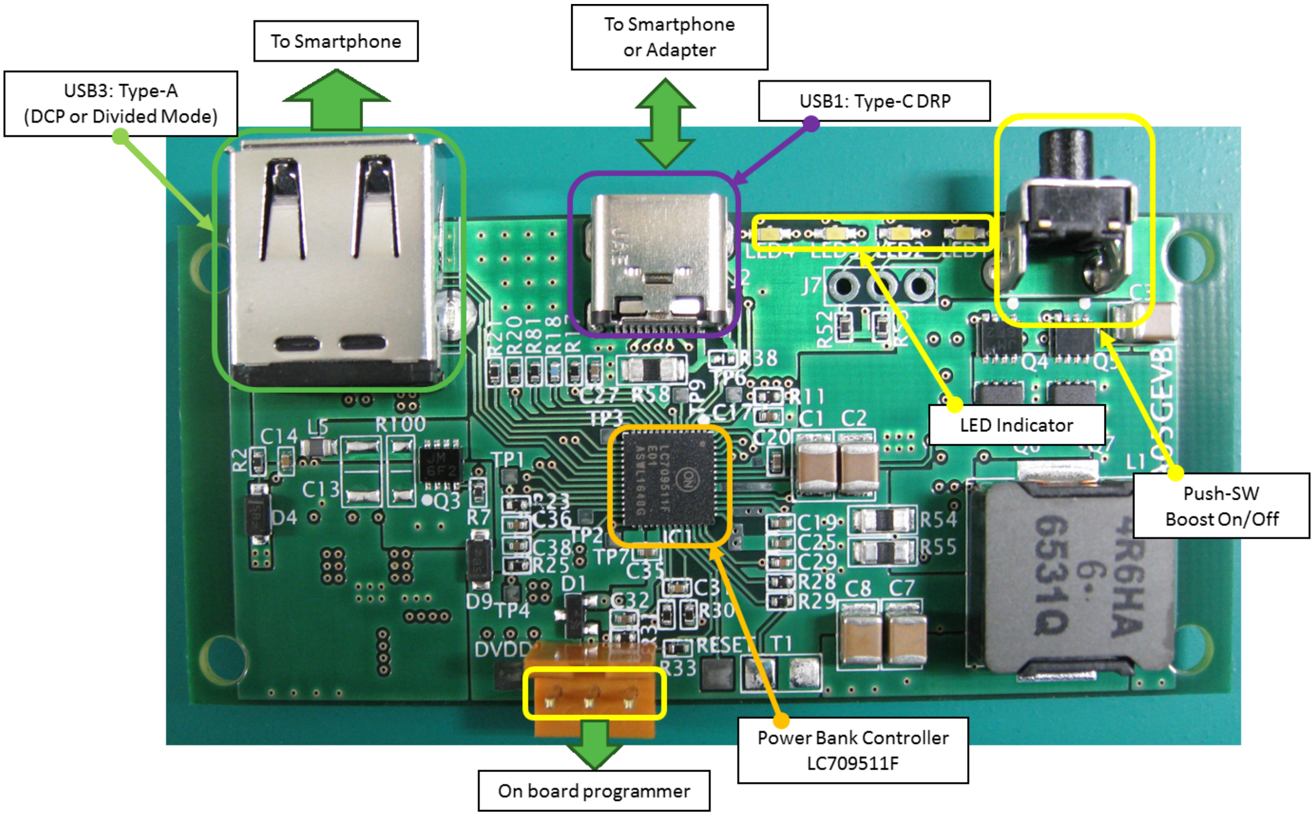

Figure 5.

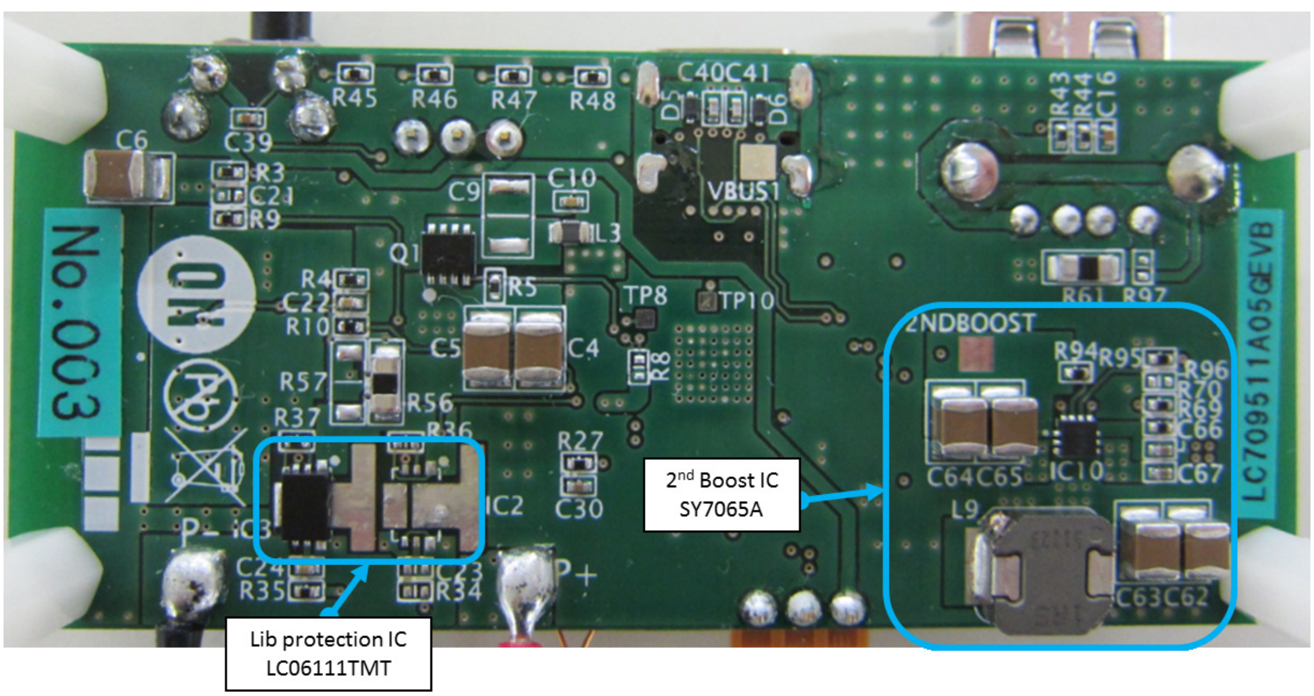

Figure 6.

CIRCUITS AND COMPONENTS AROUND CONVERTER

Up and Down Convert Current Path

Down Convert (Buck Charge: VBUS1 → Battery)

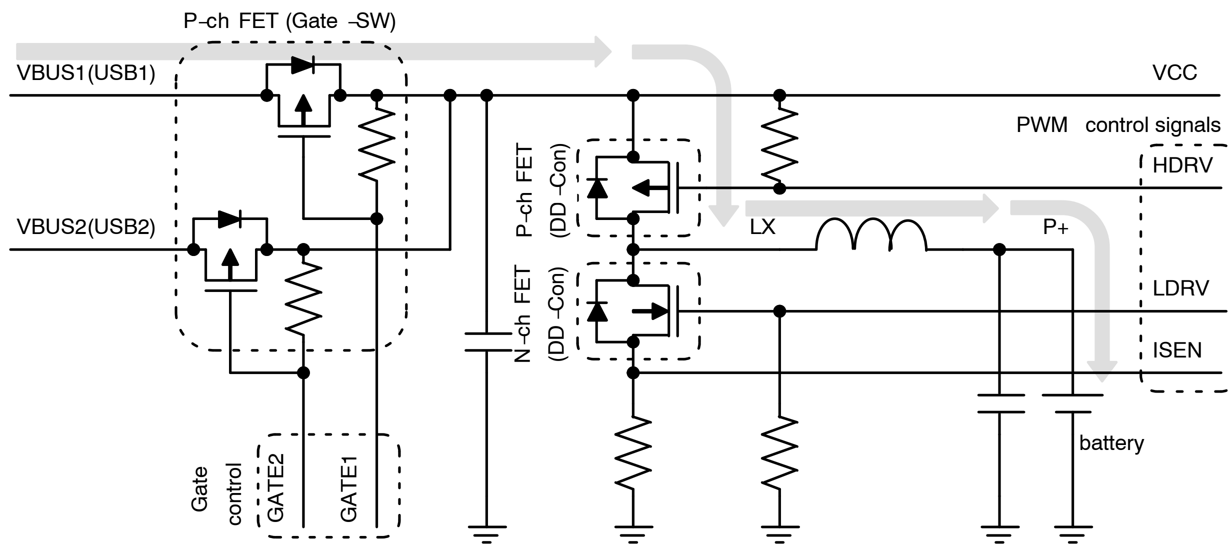

Figure 7.

Up Convert (Boost Charge : Battery → VBUS1 or VBUS2)

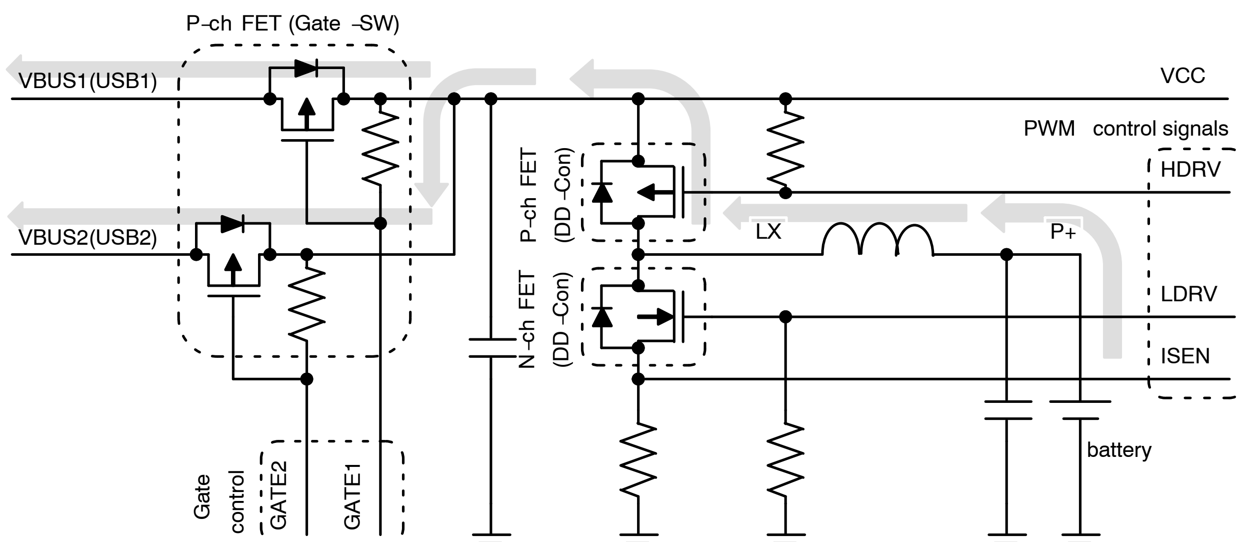

Figure 8.

FET Selection

- DD Converter
  N−ch High−Speed, Low−Rds−ON, Vt < 3 V
  P−ch High−Speed, Low−Rds−ON, 1 V < Vt < 3 V
- Gate switch
  Low−Speed, Low−Rds−ON, Vt < 4 V

N−ch FET (DD Converter)

Parameter	NTTFS4H05N
VDss	25
Vgs	±20
Vt	(1.65)
Vt−Min/Max	1.2 / 2.1
Ciss	1205
Rds ON (4.5 V)	3.8
Rds ON (10 V)	2.5
Qg (4.5 V)	8.7
Tdon	8.9
Tr	32
Tdoff	14.6
Tf	3

P−ch FET (DD Converter, Gate Switch)

Parameter	ECH8310
VDss	−30
Vgs	±20
Vt	(−1.9)
Vt−Min/Max	−1.2 / −2.6
Ciss	1400
Rds ON (4.5 V)	13
Rds ON (10 V)	−
Qg (4.5 V)	28 (10)
Tdon	10 (10)
Tr	45 (10)
Tdoff	134 (10)
Tf	87 (10)

Inductor selection

2.2 μH or 4.6 μH inductor can be applied for this device. Following inductors are recommended examples. Low DC resistance is desirable to prevent heat and improve efficiency.

RECOMMENDED INDUCTORS

Manufacturer	L (typ)	DCR (typ)	IMAX (40°C rise)	Size (mm)	Part Number
TDK	2.2 μH	17.3 mΩ	8.2 A	7.1 x 6.5 x 3.0	SPM6530T−2R2M
Coilcraft	2.2 μH	5.73 mΩ	17.8A	7.5 x 7.3 x 6.3	XAL7070−222MEC
Panasonic	4.6 μH	6.48 mΩ	9.3A	12.5 x 12.5 x 5.7	ETQP6F4R6HFA

T DK Coilcraft Panasonic

Figure 9.

Circuit Examples Around Converter

Select circuit configuration around converter according to the requests for target output power, efficiency, and temperature and PCB layout size. Following circuits are the example under the use of the inductors which is mentioned in section 2−3.

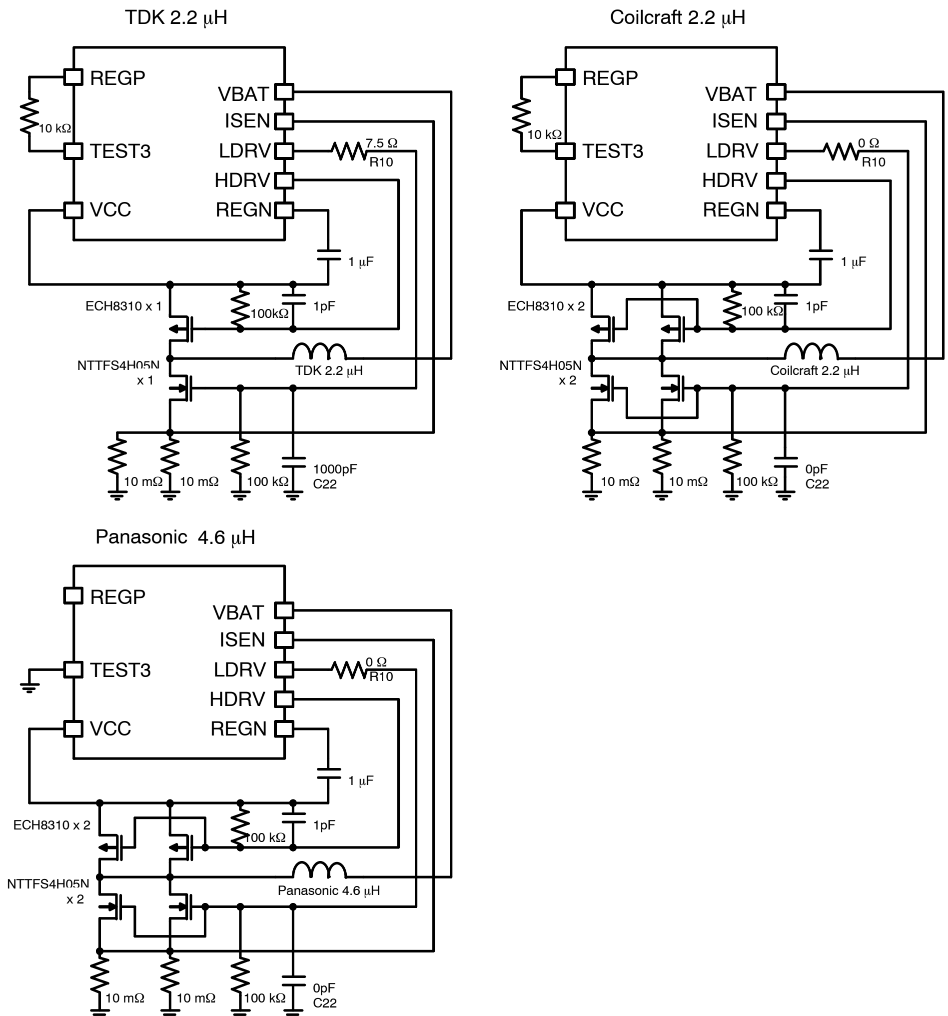

Figure 10.

CIRCUIT EXAMPLES AROUND CONVERTER

Inductor	L	PWM freq.	Switching FET	C22	R10
TDK	2.2 μH	300 kHz (Note 1)	ECH8310 x 1 NTTFS4H05N x 1	1000 pF	7.5 Ω
Coilcraft	2.2 μH	300 kHz (Note 1)	ECH8310 x 2 NTTFS4H05N x 2	0pF	0
Panasonic	4.6 μH	150 kHz	ECH8310 x 2 NTTFS4H05N x 2	0pF	0

- This device can choose PWM frequency of either 150 kHz or 300 kHz. 150 kHz is chosen when TEST3 input is low, and 300 kHz is chosen when the input is high. (Note below)
- Make the switching FETs a parallel array to suppress the heat generation at high power output
- Place indicated C and R on LDRV line when FETs array is single

NOTE: Reference software to make PWM frequency 300 kHz is planning. Only 150 kHz PWM frequency have been released.

TEST RESULT

Boost and Buck charge test result using LC709511A02GEVB Evaluation board. Each following results support the three circuitry example around converter in section Circuit examples around converter.

TDK 2.2 μH, 300 kHz, FET x 1 (Planning)

VBUS2 Boost Efficiency

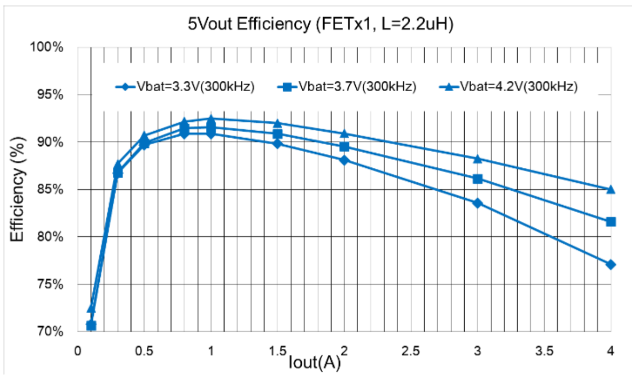

Figure 11.

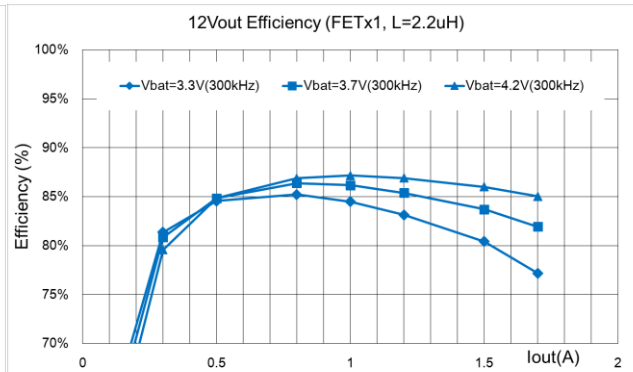

Figure 12.

VBUS2 Boost Temperature

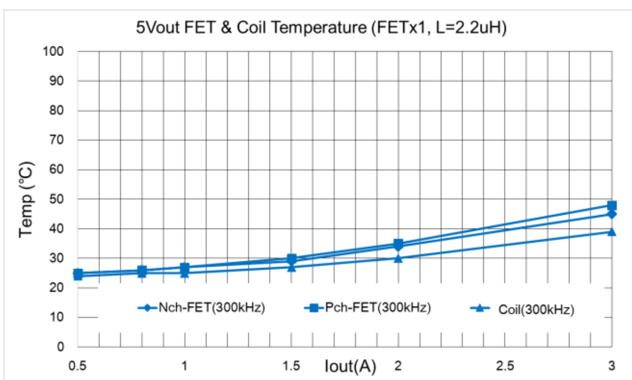

Figure 13.

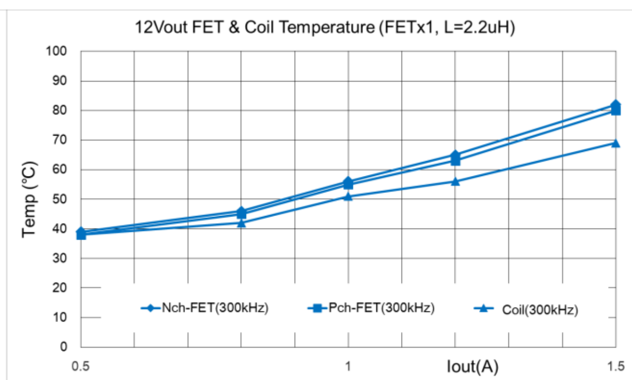

Figure 14.

VBUS2 Boost Switching Ripple

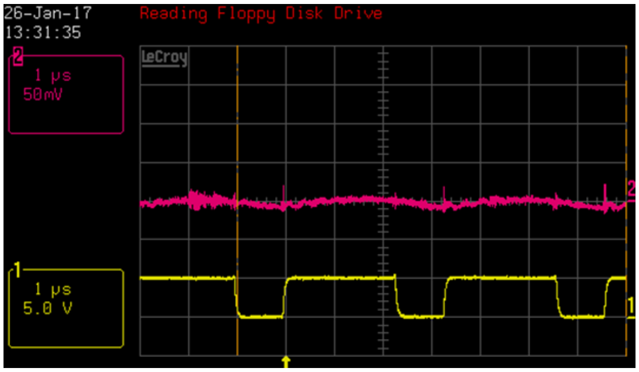

Figure 15. VBUS2 = 5 V / 1 A, VBAT = 3.7 V

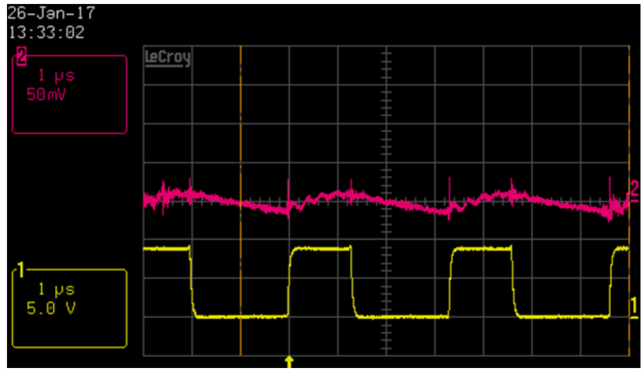

Figure 16. VBUS2 =9 V / 1 A, VBAT = 3.7 V

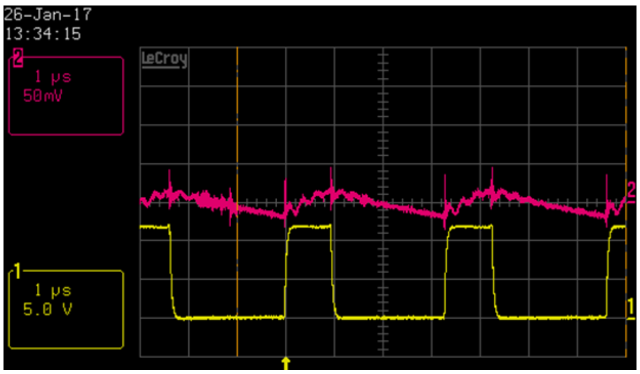

Figure 17. VBUS2 = 12 V / 1 A, VBAT = 3.7 V

VBAT Buck Charge Switching Ripple

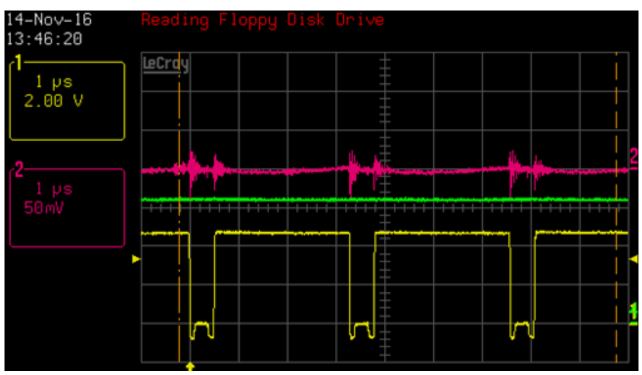

Figure 18. VBUS1 = 5 V, VBAT = 3.7 V

VBUS2 Boost Load Transit (1 A → 2 A)

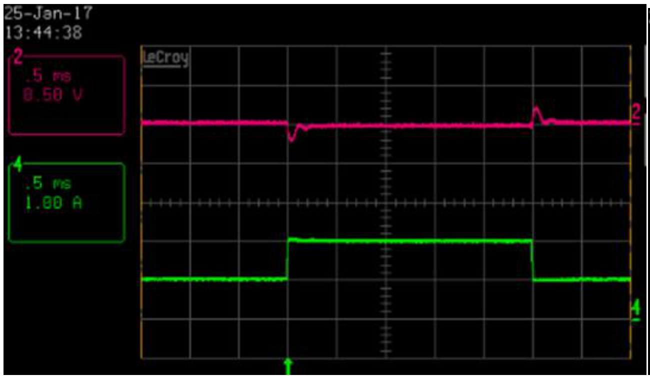

Figure 19. VBUS2 = 5 V, VBAT = 3.7 V

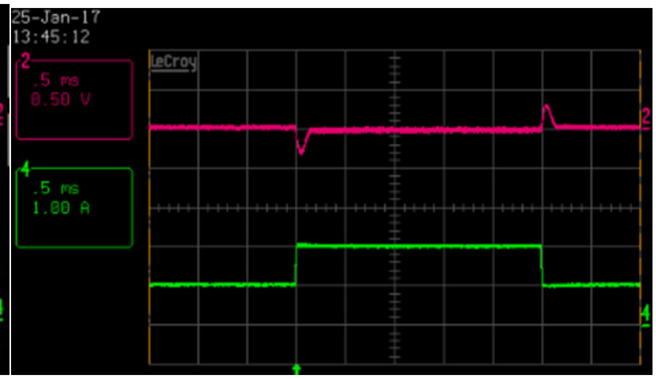

Figure 20. VBUS2 = 9 V, VBA = 3.7 V

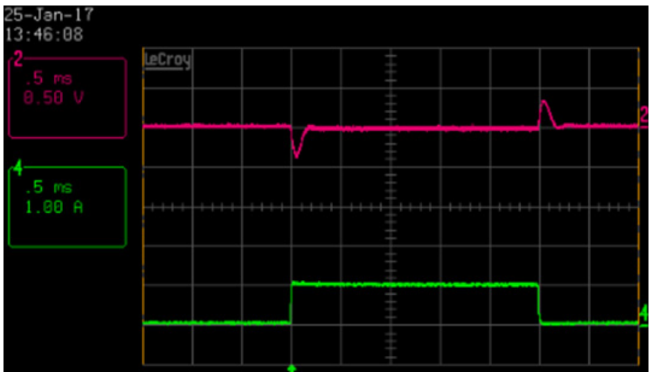

Figure 21. VBUS2 = 12 V, VBAT = 3.7 V

Coilcraft 2.2 μH, 300 kHz, FET x 2 (Planning)

VBUS2 Boost Efficiency

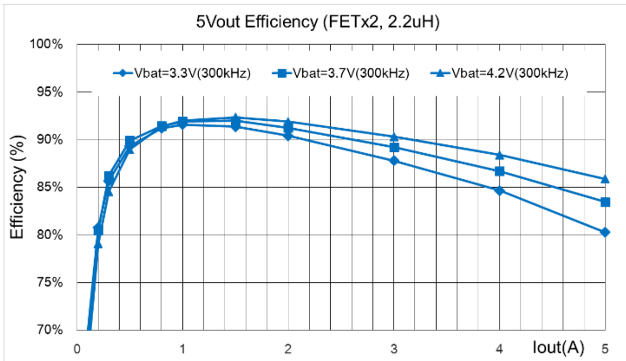

Figure 22.

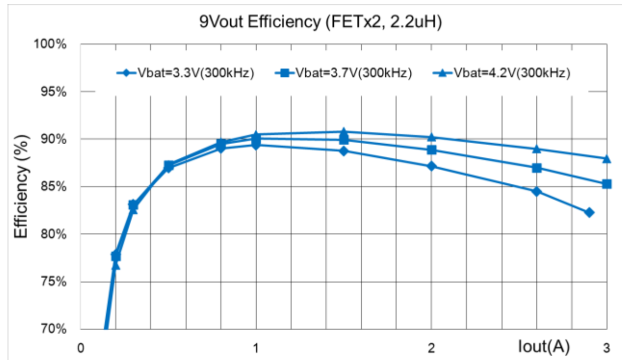

Figure 23.

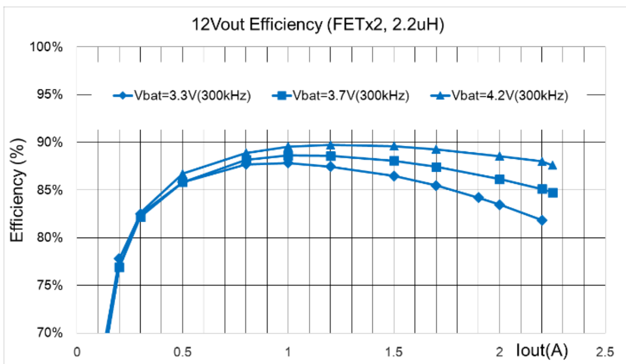

Figure 24.

VBUS2 Boost Temperature

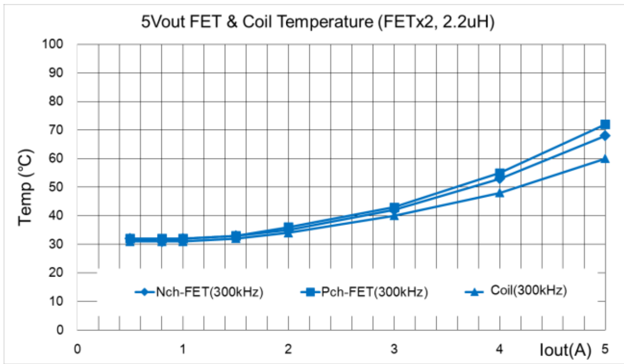

Figure 25.

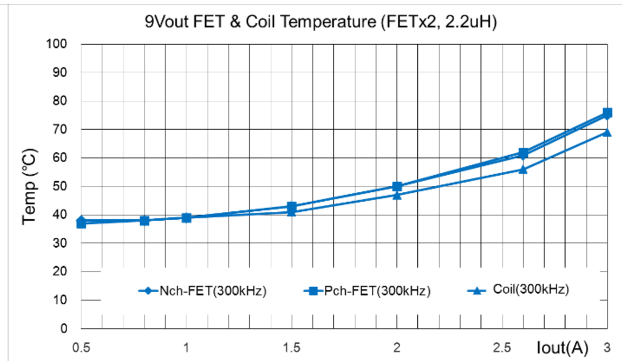

Figure 26.

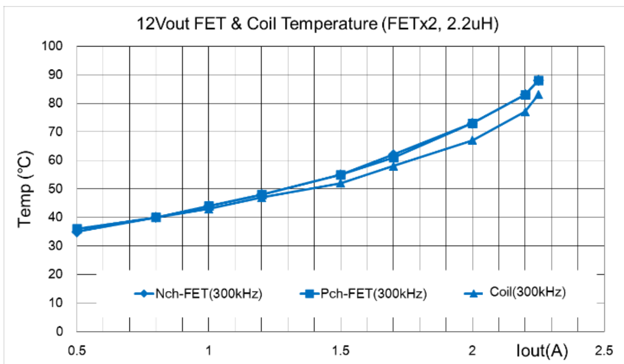

Figure 27.

VBUS2 Boost Switching Ripple

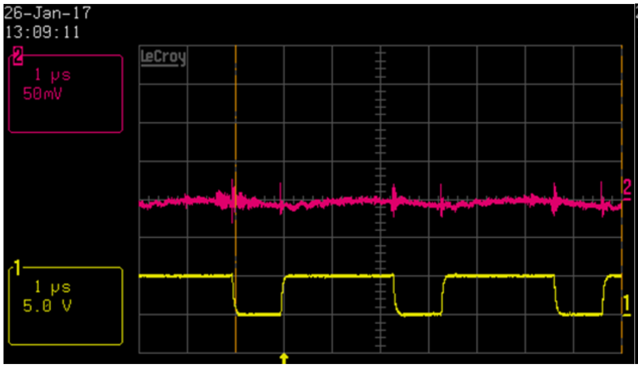

Figure 28. VBUS2 = 5 V / 1 A, VBAT = 3.7 V

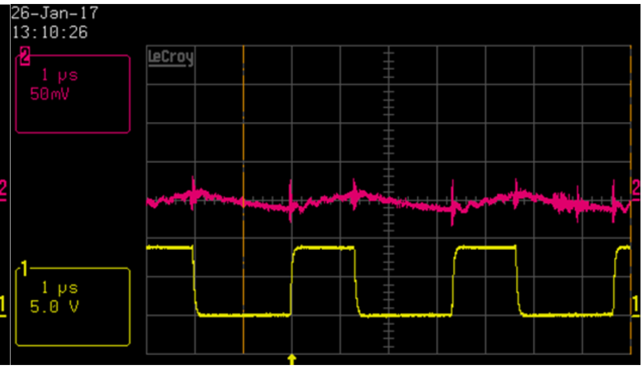

Figure 29. VBUS2 = 9 V / 1 A, VBAT = 3.7 V

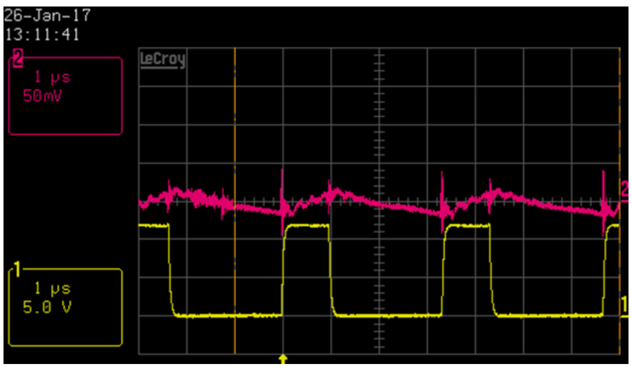

Figure 30. VBUS2 = 12 V / 1 A, VBAT = 3.7 V

VBAT Buck Charge Switching Ripple

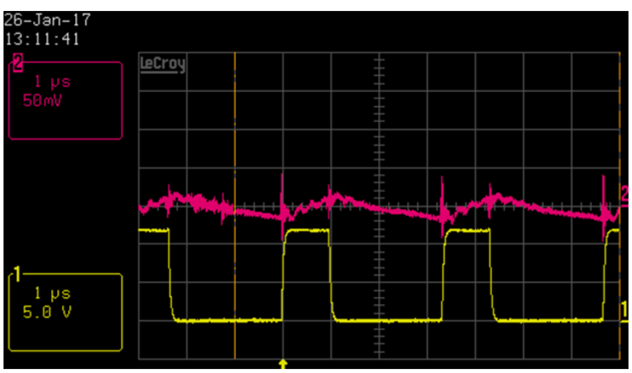

Figure 31. VBUS1 = 5 V, VBAT = 3.7 V

VBUS2 Boost Load Transit (1 A → 2 A)

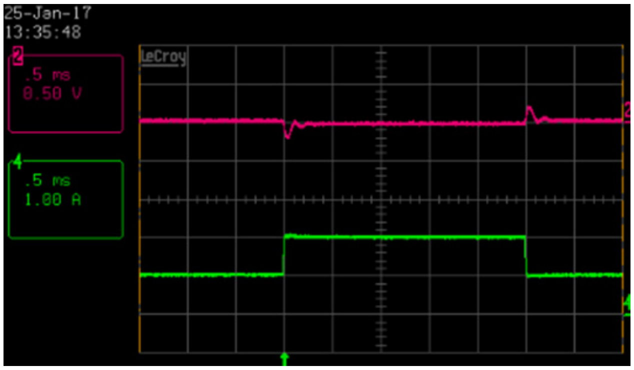

Figure 32. VBUS2 = 5 V, VBAT = 3.7 V

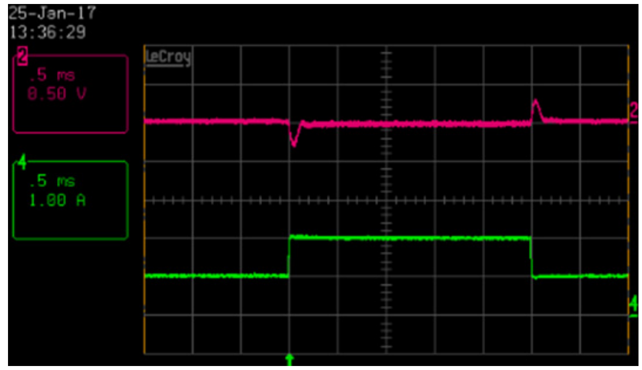

Figure 33. VBUS2 = 9 V, VBAT = 3.7 V

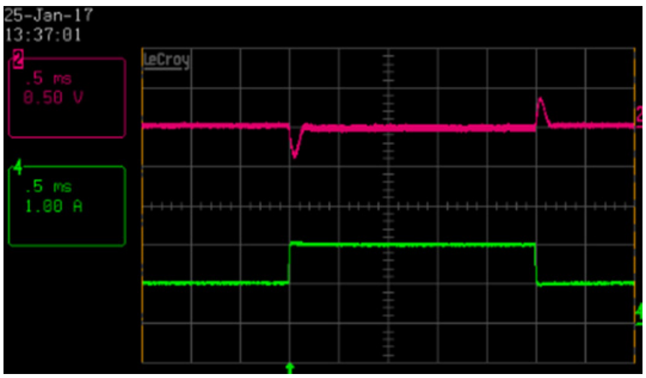

Figure 34. VBUS2 = 12 V, VBAT = 3.7 V

Panasonic 4.6 μH, 150 kHz, FET x 2

VBUS2 Boost Efficiency

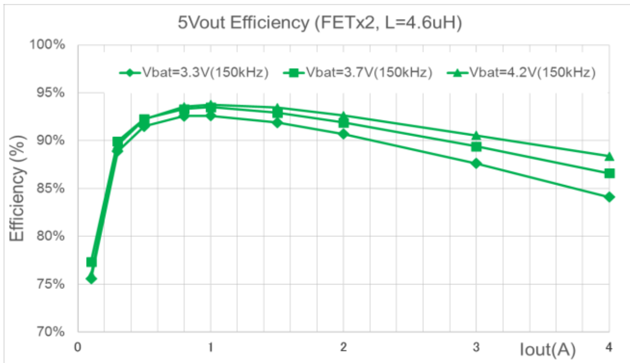

Figure 35.

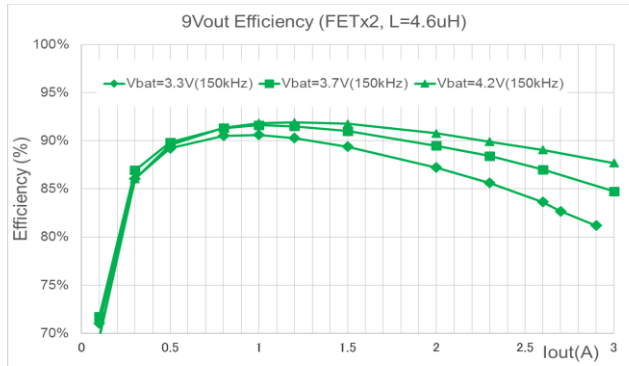

Figure 36.

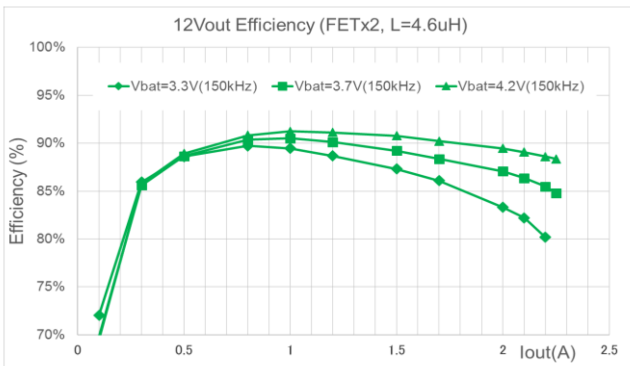

Figure 37.

VBUS2 Boost Temperature

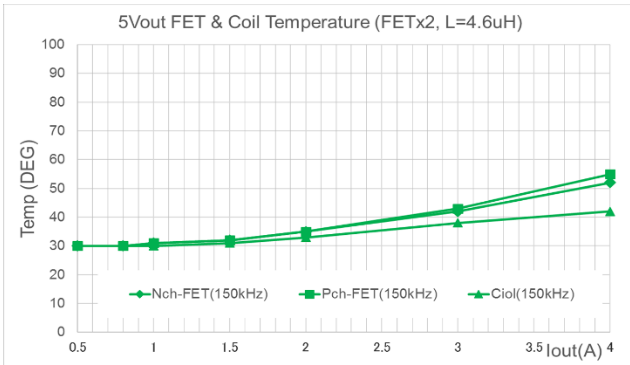

Figure 38.

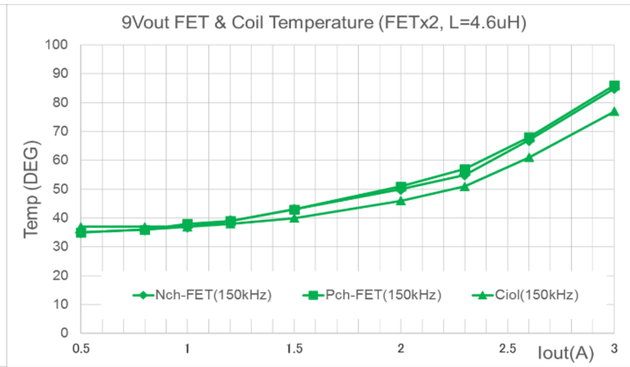

Figure 39.

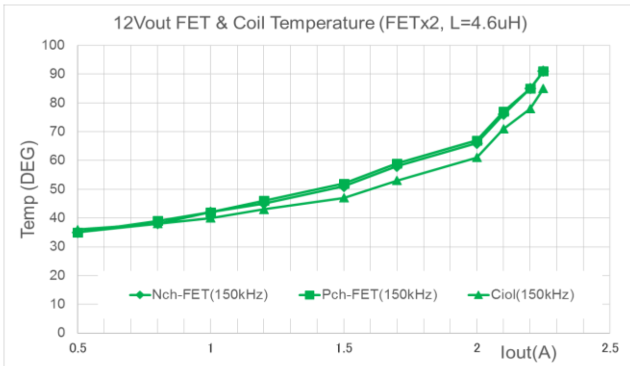

Figure 40.

VBUS2 Boost Switching Ripple

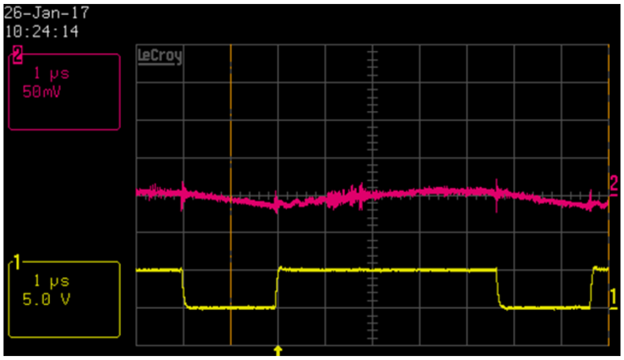

Figure 41. VBUS2 = 5 V / 1 A, VBAT = 3.7 V

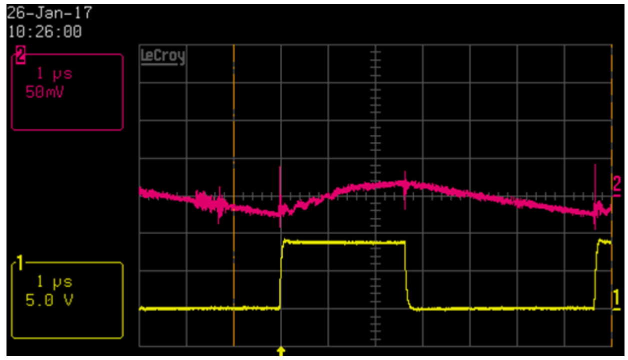

Figure 42. VBUS2 = 9 V / 1 A, VBAT = 3.7 V

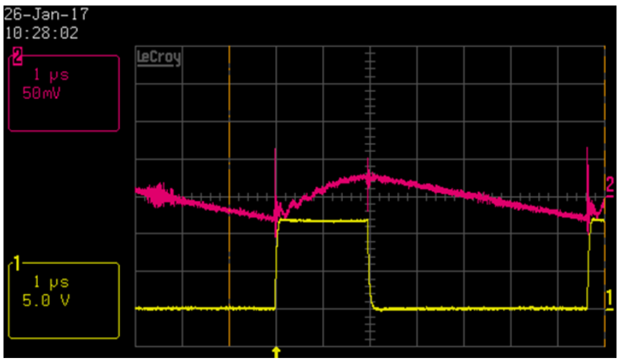

Figure 43. VBUS2 = 12 V / 1 A, VBAT = 3.7 V

VBAT Buck Charge Switching Ripple

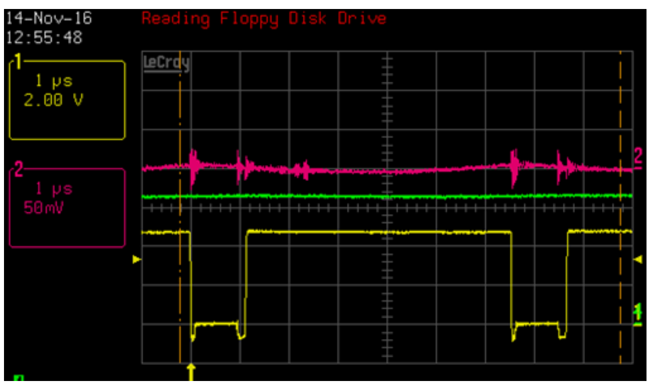

Figure 44. VBUS1 = 5 V, VBAT = 3.7 V

VBUS2 Boost Load Transit (1 A → 2 A)

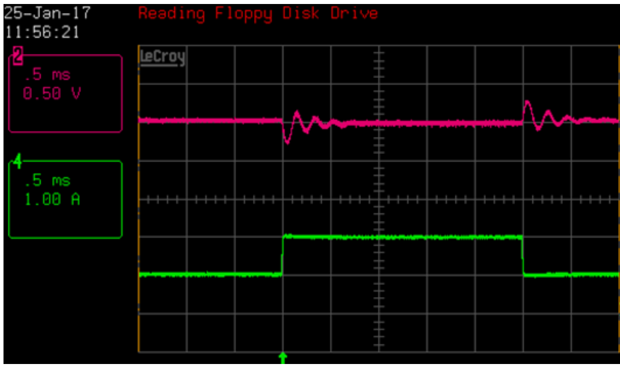

Figure 45. VBUS2 = 5 V

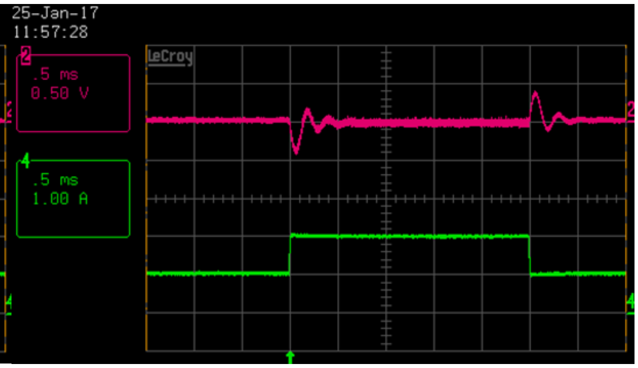

Figure 46. VBUS2 = 9 V

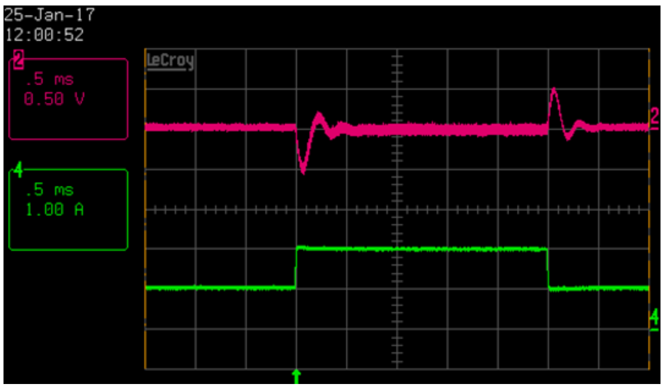

Figure 47. VBUS2 = 12 V

FUEL GAUGE

Features

Simple setting for various battery

- Set only three battery parameters for fuel gauging
    1. Design capacity
    2. Charging voltage 4.2 V or 4.35 V
- Unique algorithm to realize accurate battery monitoring in few parameters
- Set the parameters by Port configuration or Software configuration

Parameter	Port	Range	Resistance
Design capacity	FGADJ	2400 mAh – 24400 mAh	4.7 kΩ – 390 kΩ
Battery profile	*	4.2 V or 4.35 V	Software configuration

*Default battery profile is 4.2 V. 4.35 V can be selected by Software configuration.

Battery Level Result

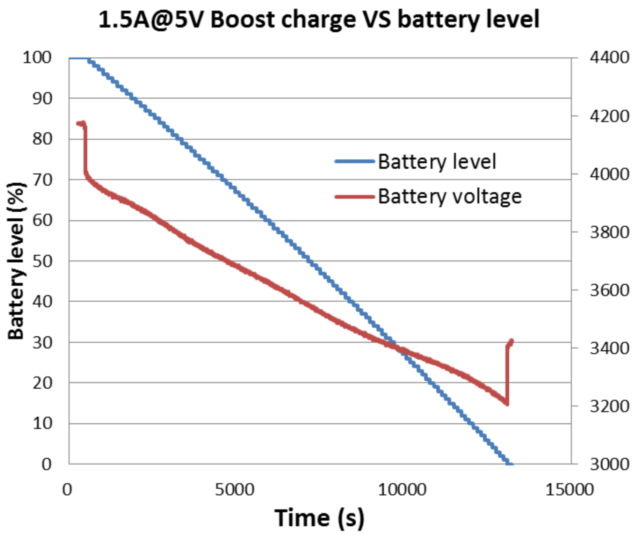

Figure 48.

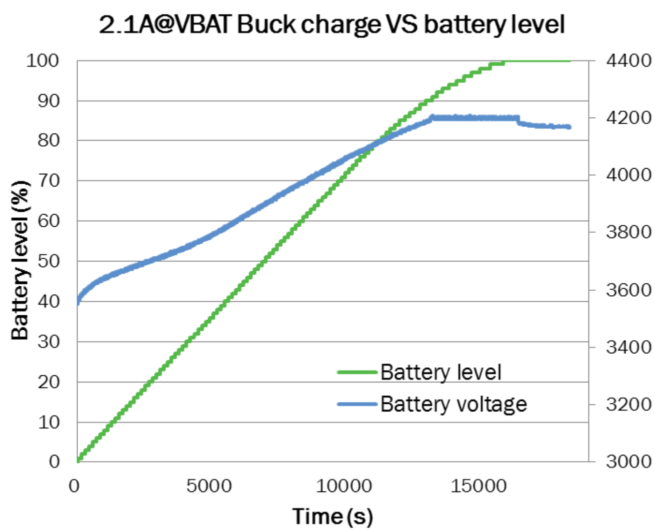

Figure 49.

- Design capacity of measured battery is 9600 mAh
- 1% step battery level is reported via USB 2.0 Full Speed interface

THERMISTOR

- T1 Thermistor is NTC thermistor to measure battery temperature, and it must be placed near the battery
- Match R36 resistance with a used thermistor resistance at 25 deg
- The default B constant of NTC thermistor is 3300K. Use Software configuration to change it. Then 2600K to 4700K is selectable

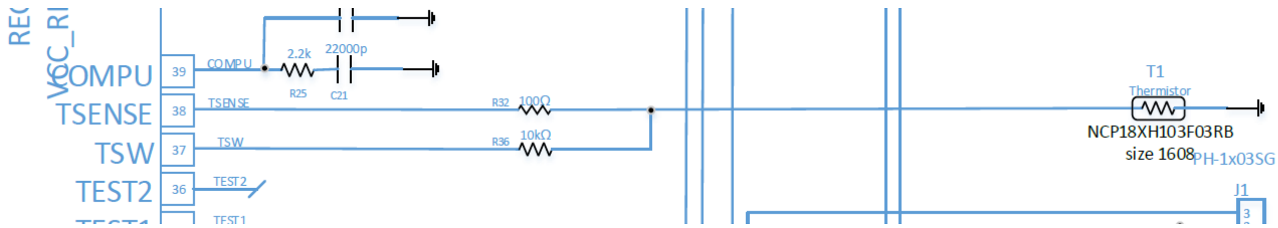

Figure 50.

Thermistor Terminals on Evaluation Board

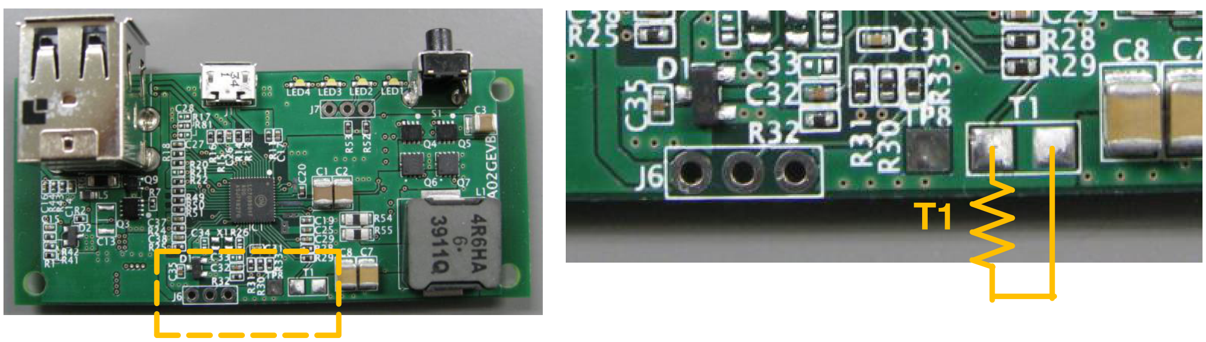

Figure 51.

BOOST AUTO START−UP

LC709511F can detect one or two Type−A USB plug insertion automatically. If it detects, starts Boost charge to connected port. Boost auto start−up needs next circuits per each port.

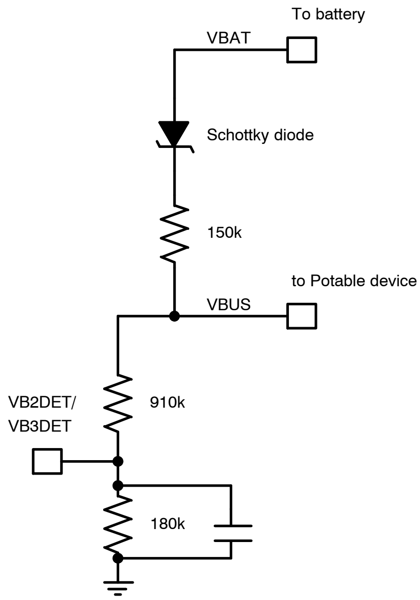

Figure 52. Case without the other Pull−down

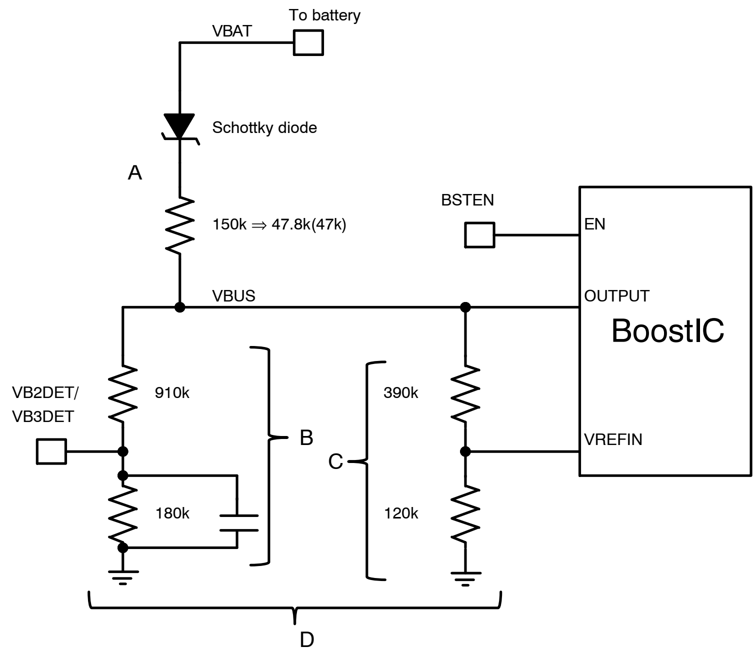

Figure 53. Case withdivided Resistor for Boost IC

If the other pull−down resistor (Ex. Divided resistor for Boost IC) is connected to VBUS, the pull−up resistance must be adjusted. Right side figure shows the case that 390 kΩ + 120 kΩ resistor for Boost IC is connected to VBUS. In this figure A is pull−up resistor, B is original pull−down resistor, and C is added pull−down resistor. D is the resistance that added B and C. The pull−up resistance must be adjusted as the ratio of A and B is equal to the ratio of A' and D.

$$A : B = 150\text{k}\Omega : (910\ \text{k}\Omega + 180\ \text{k}\Omega) = A' : (910\ \text{k}\Omega + 180\ \text{k}\Omega) \parallel (390\ \text{k}\Omega + 120\ \text{k}\Omega)$$

$$A' = 47.8\ \text{k}\Omega$$

In addition care the Boost IC ports which connect to VBUS during the insertion detection. When the Boost IC is disable (BSTEN = L), the ports must be Hi−Z. See the port status in the datasheet of Boost IC.

BATTERY LEAK CURRENT IN STANDBY

The board will minimize the battery leak current when no plug is inserted and it waits plug insertion. Main leak source at that time is shown next.

- ICs standby IDD

LC709511F (Low power mode) / Lib protection IC / Boost IC / Port control IC

- Boost auto start−up circuits × The number of Type−A plug

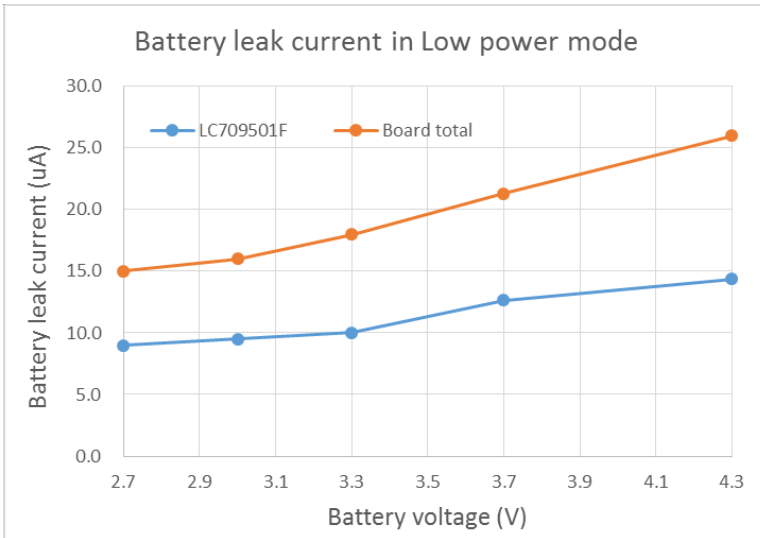

Figure 54. The Current of LC709511A02GEVB at Low Power Mode

PCB LAYOUT GUIDE

Converter Schematic

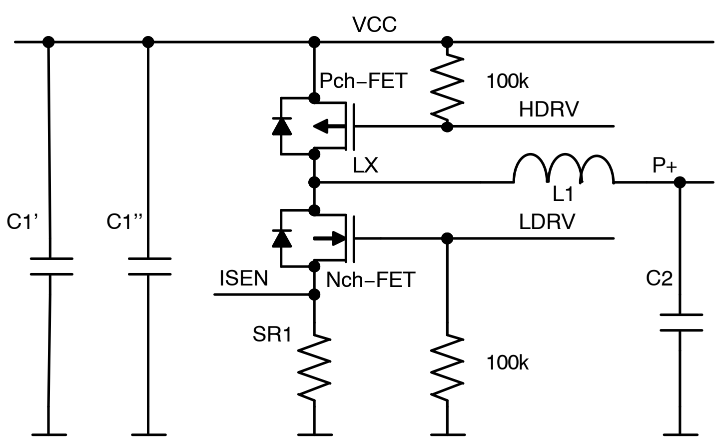

Figure 55.

Power Bank Application Layout

Top Layer

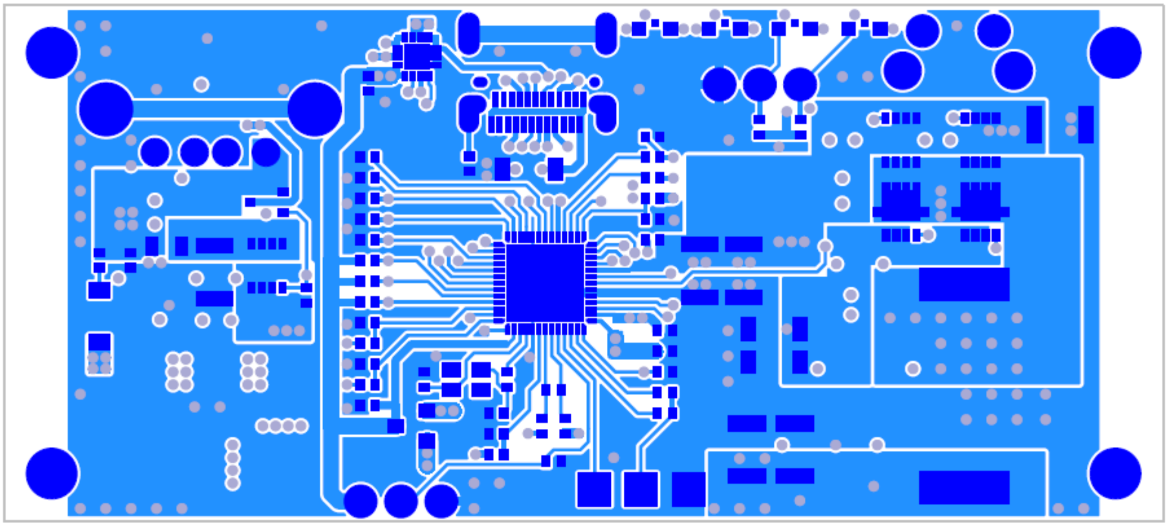

Figure 56.

Bottom Layer

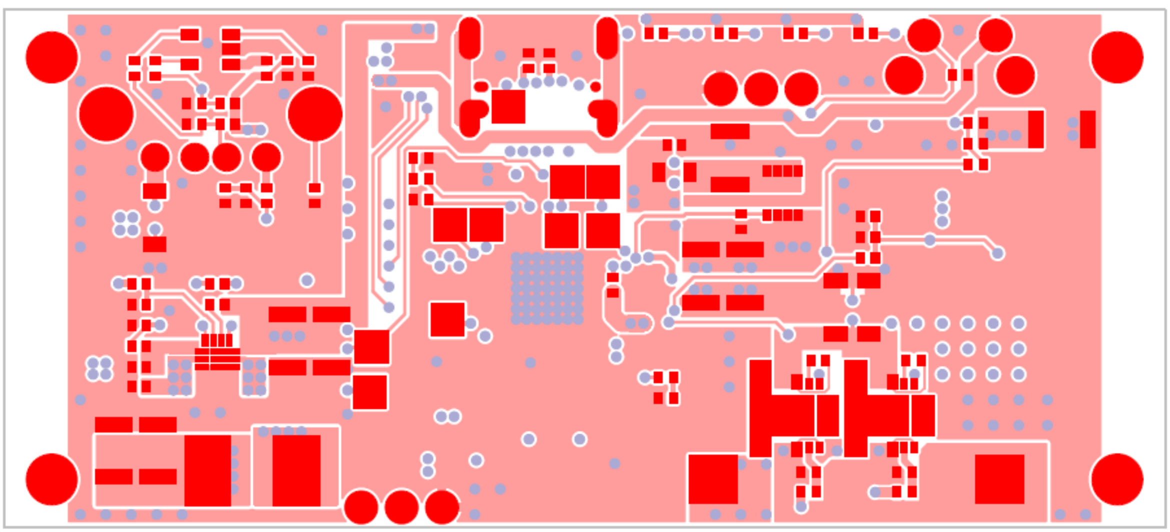

Figure 57.

- Separate VCC capacitor at the following approximate capacity ratios in C1' and C1''.
  C1' : C1'' = 2 : 1
- Place input capacitor C1' as close as possible to VCC pin and GND pins (AVSSS, AVSSP)
- Place input capacitor C1'' as close as possible to Pch FET
- Place coil as close as possible to the external transistor. Make the trace wide enough to carry the charging current. Do not use multiple layers in parallel for this connection
- Place output capacitor C2 as close as possible to coil, external power transistor, and IC
- It is critical for the external power transistor to have sufficient discharge performance
- Use via holes to secure sufficient current path

Bottom Layer around Lib-Protection IC

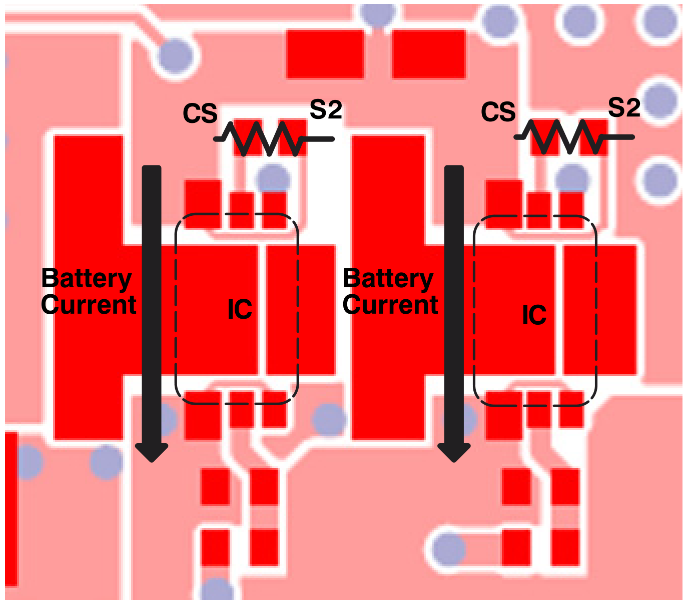

Figure 58.

- Connect the resistances between S2 & CS of Lib−Protection IC without Battery current path.

Bottom Layer around Sense Resistor

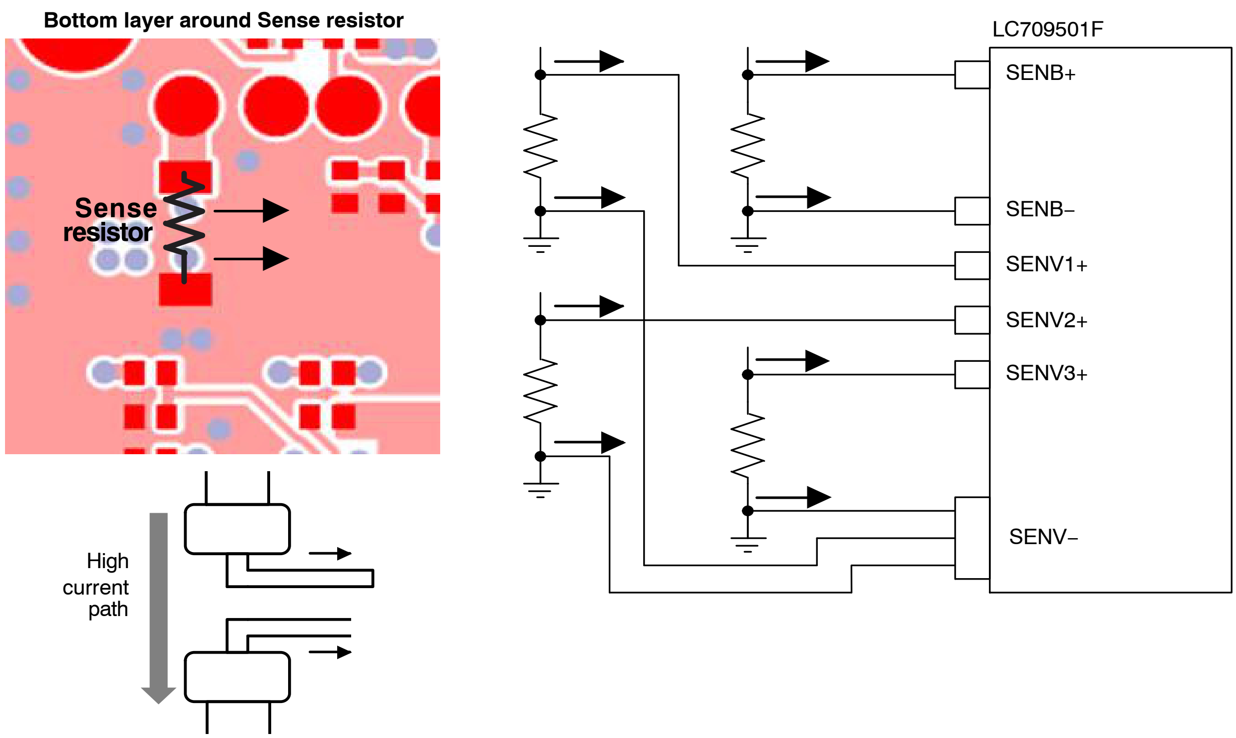

Figure 59.

- Extract SENV and SENB signals from the inner side of the sense resistance to remove influence of wire resistance
- Extract Ground side signals of SENV sense resistors with independent lines. Then short their lines near SENV− port of this IC

Down Convert (Buck Charge) Current Path vs Layout

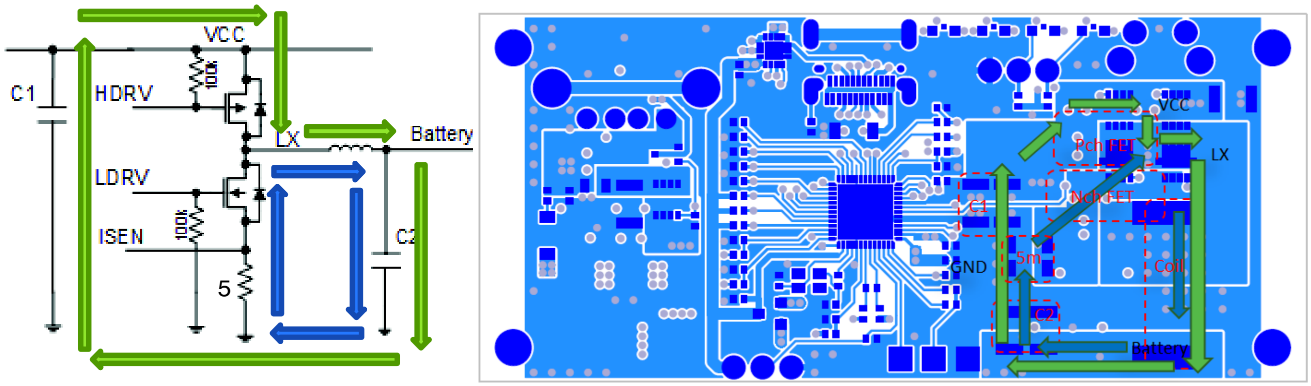

Figure 60.

In DC−DC down conversion, it is desirable to have short and wide enough line for large current to flow to the same direction.

Up Convert (Boost Charge) Current Path vs Layout

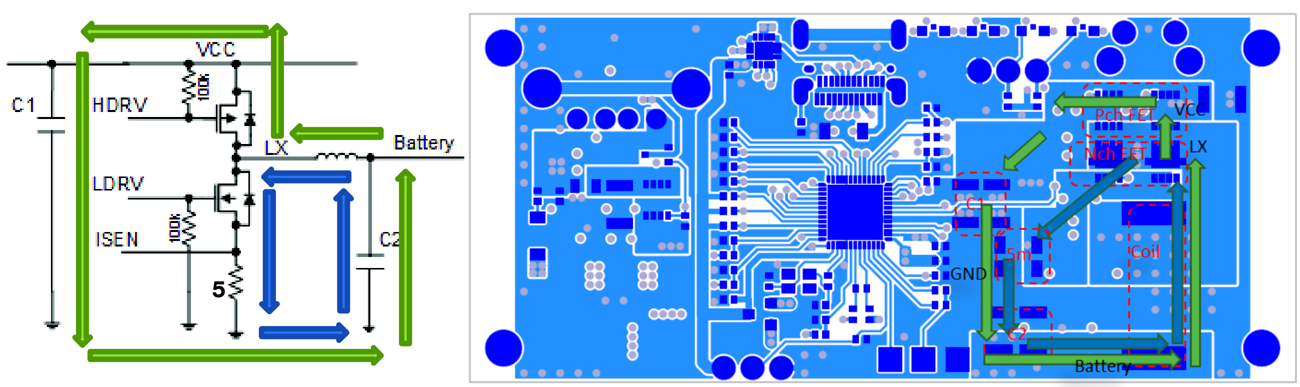

Figure 61.

In DC−DC up conversion, it is desirable to have short and wide enough line for large current to flow to the same direction.

ON−BOARD PROGRAMMING

On−board programming Tool: FWS−X16DI

FWS−X16DI is the on board programmer which ON Semiconductor provides. Built−in ROM of LC709511F on board can be programmed by the programmer. When programming, the device and programmer is connected by only 1 port and DVDD and GND. FWS−X16DI supports the operation with PC and Stand−alone. Download the manual and Application on ON Semiconductor HP.

Search "FWS−X16DI" on ON Semiconductor HP, and download the files.

Figure 62.

Connection

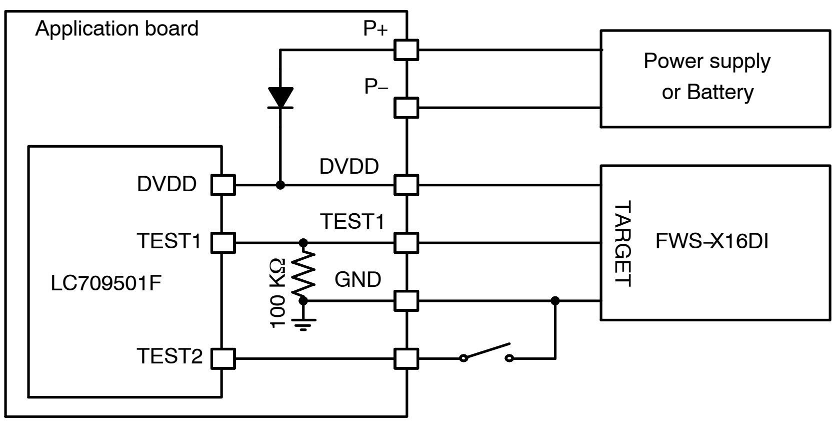

Figure 63.

On Board Programming Terminals on Evaluation Board

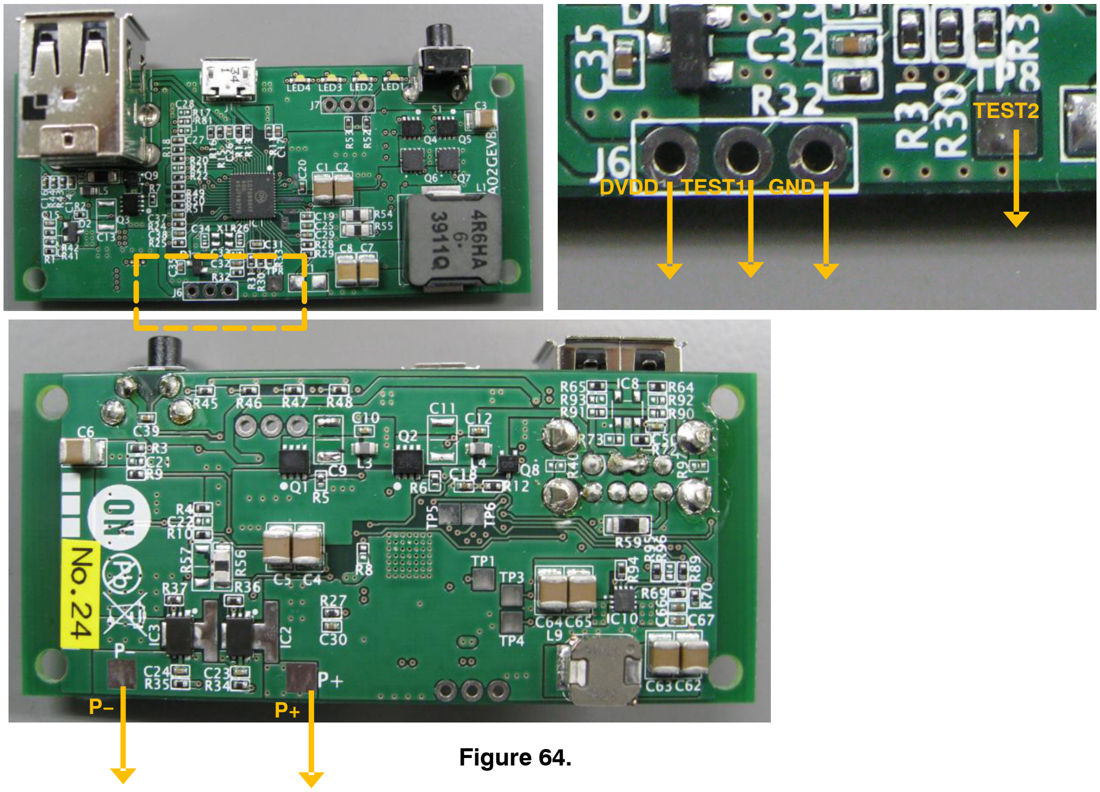

Figure 64.

Application Software

1. Execute "SscFWS" application software on PC
2. Select LC709511F from pull−down list of devices
3. Open target file
4. Programming + Verify
5. Check Success or Error

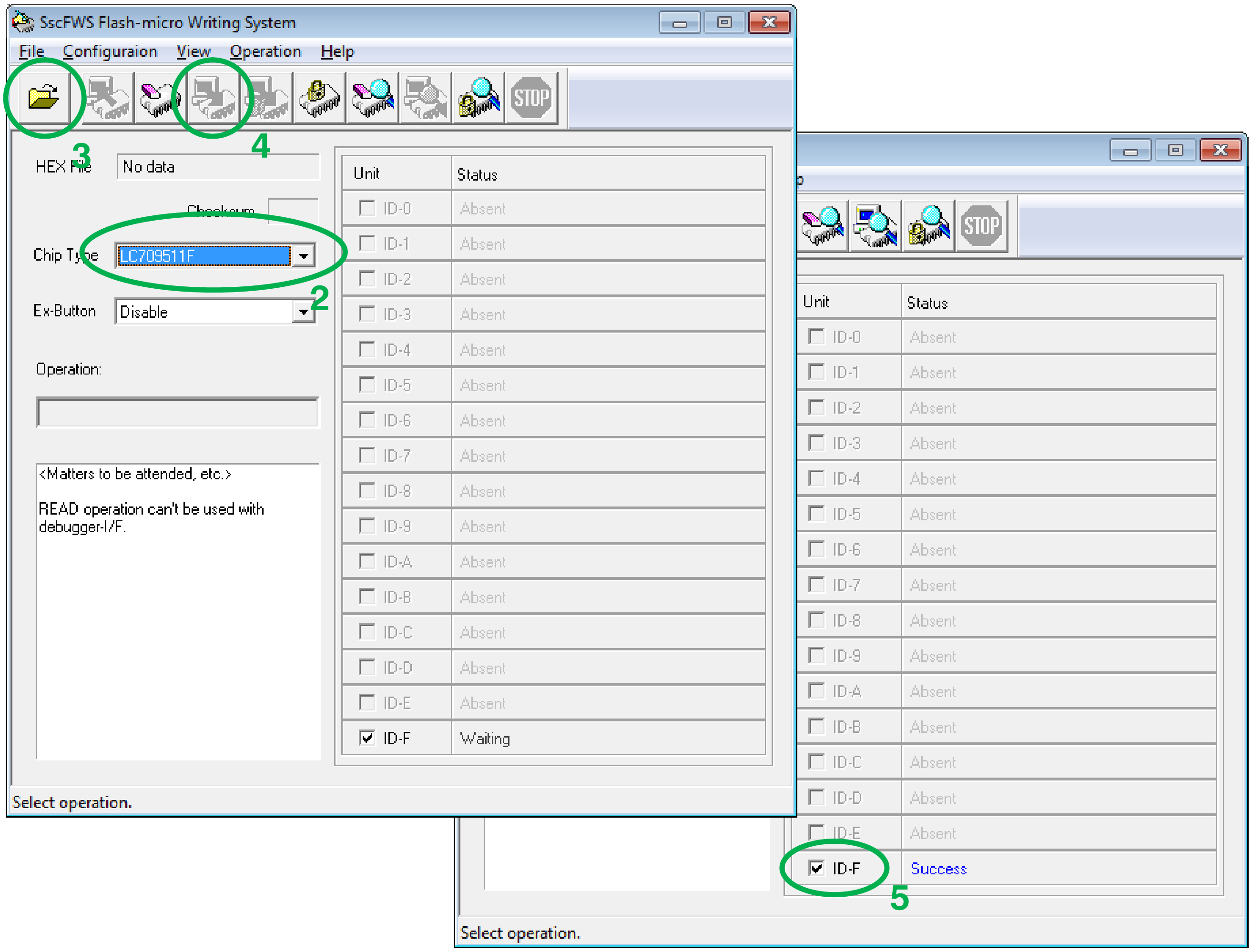

Figure 65.

Electrical Characteristics for Programming

ELECTRICAL CHARACTERISTICS at T_A = +10°C to +55°C

Parameter	Symbol	Pin	Min	Max	Unit
Operating P+ supply	VPPW	P+	3.3	4.5	V
Operating DVDD voltage	VVDDW	DVDD	3.0	4.5	V
Cycle number of Re−Writing	Wcyc	–	–	100	Cycle

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

7. Satisfy above condition during Programming.
8. Do not program more than above cycle number.

Initialization after Programming

Initialization of this device is necessary for correct operation after programming. It is done automatically by falling and rising of DVDD supply voltage which is showed below.

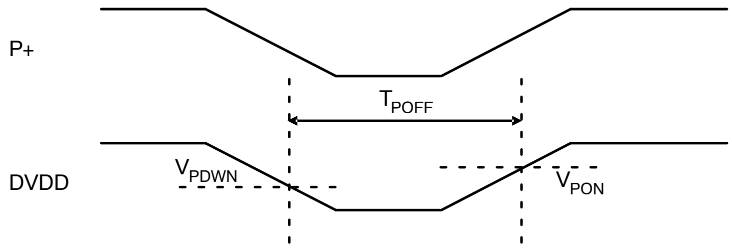

Figure 66.

Parameter	Symbol	Pin	Min	Max	Unit
Power down voltage	V_{PDWN}	DVDD		1.5	V
Power on voltage	V_{PON}	DVDD	2.7		V
DVDD low pulse width for Initialization	T_{POFF}		100		ms

If fixed battery makes supply stop difficult, initialize using TEST2 pin. The initialization is done during GND level is input to TEST2. After it, make TEST2 pin open.

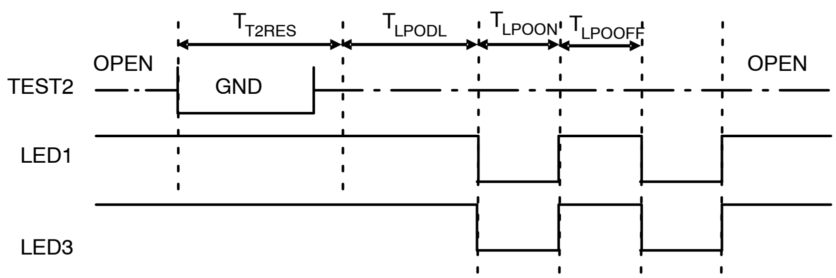

Figure 67.

Parameter	Symbol	Min	Typ	Max	Unit
TEST2 Initial pulse width	T_{T2INTZ}	50			ms
Delay from finish of initialization to lighting	T_{T2LDL}	200			ms
Lighting time during flashing	T_{FLS_L}		250		ms
Lights out time during flashing	T_{FLS_H}		250		ms

9. TEST2 pin is pulled−up to DVDD with 100 kΩ resistor in this device.
10. After finish of Initialization, LED1 and LED3 flash twice to make known that the initialization has be done.

On−board Debugging &Programming Tool: LC88FDEBUGGEVB (Ordering Information : LC88FDEBUGGEVB)

LC88FDEBUGGEVB is the on board debug and programmer for evaluation which ON Semiconductor provides. Built−in ROM of LC709511F on board can be programmed by the programmer. When programming, the device and programmer is connected by only 1 port and VDD and GND. LC88FDEBUGGEVB supports the operation with PC. Download the manual and Application on ON Semiconductor HP.

Search "Xstormy16" on ON Semiconductor HP, and download the files.

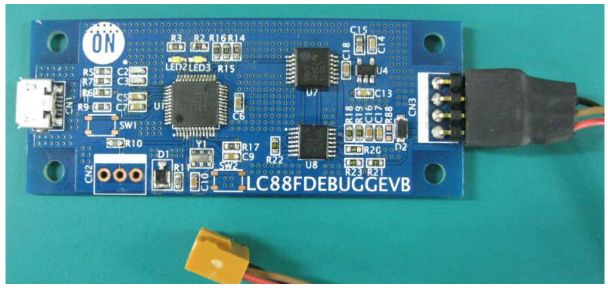

Figure 68.

Connection LC88DEBUGGEVB

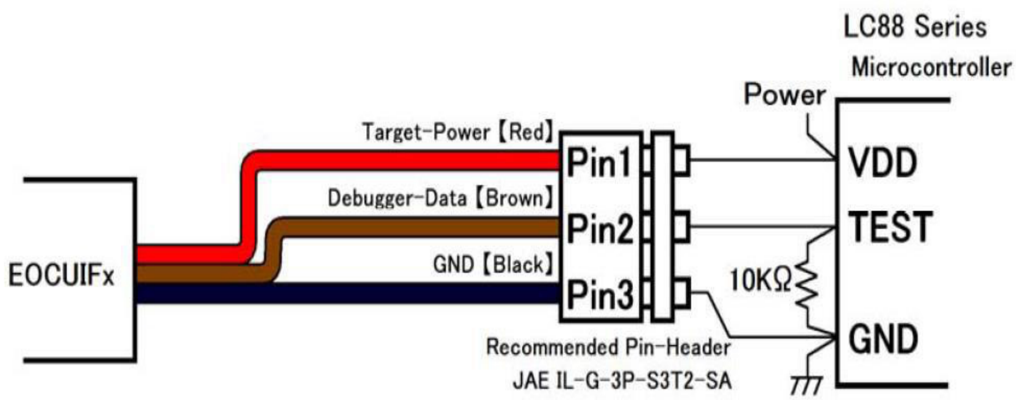

Figure 69.

On BoardProgramming Terminals on LC709511A02GEVB Evaluation Board

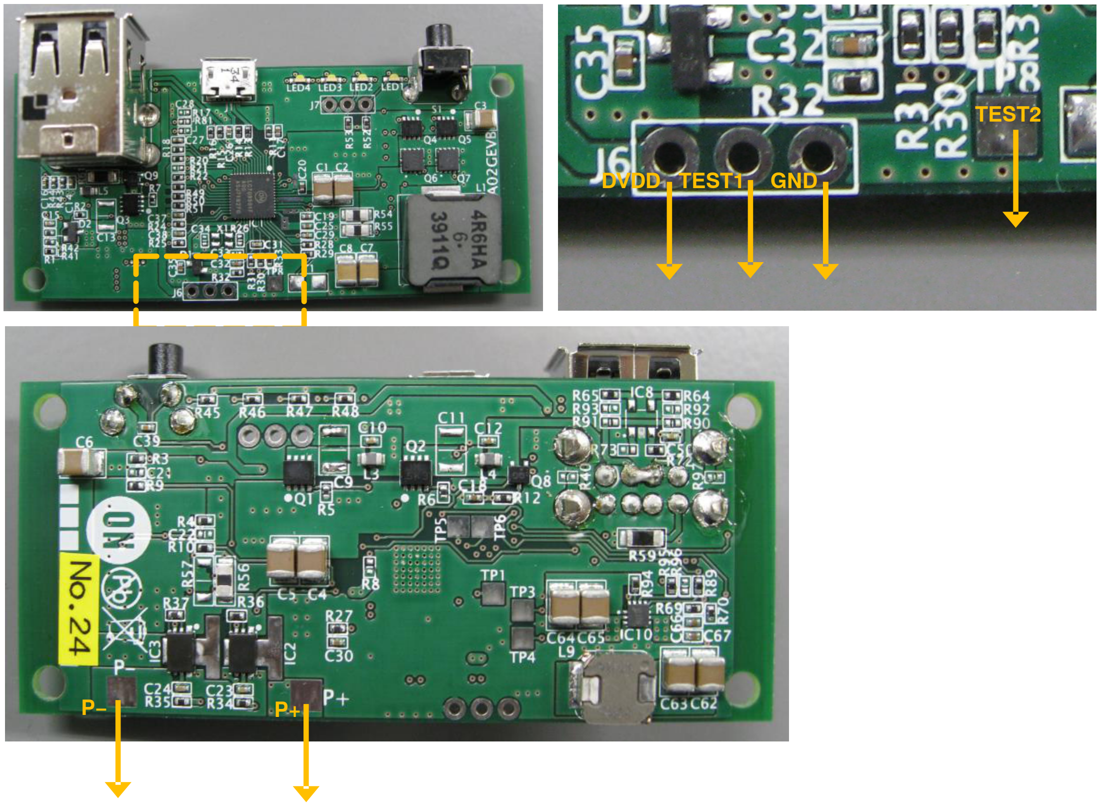

Figure 70.

Application Software LC88FDEBUGGEVB

1. Download reference software from ON Semiconductor HP https://www.onsemi.com/
   Search “Target IC” Target IC: LC7095xx −> [Software] −> “Target Software”
   Configurable_Software : Users are able to modify the software
   “Board_name”_software : Pre−installed software (NOT modify)
2. Execute “IDE” application software on PC.
   [Start] −> [All programs] −> [Xstormy16 Series Development Tool]−>[IDE]
3. When use configurable software
   Open Project: [File]−>[Open Project] Project File Path: LC709511F−RFxx\PRJ−RFxx\xxxx.epx
   When use Pre−installed software → Jump (5)
4. Modify the file Documentation Folder: DOC\
   Config.c : Parameter (Battery data, Safety function, temperature, etc)
   GpioControl.c: GPIO
   LedControl.c : LED
5. [Build] → [Build] or [Rebuild]
6. [Tool] → [Debugger] → [Target IC]
7. [File] → [Open Hex file] File Path: LC709511F−RFxx\PRJ−RFxx\Release\RE9999.hex
8. [Debug] [Reset], [Debug] → [Execute]

PUBLICATION ORDERING INFORMATION

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