QUICK START GUIDE FOR DC1140A

LTC3567EUF: High Efficiency USB Power Manager Plus 1A Buck-Boost Converter with I^2C Control

DESCRIPTION

Demonstration Circuit 1140A is a high efficiency USB Power/Li-Ion battery manager plus a 1A Buck-Boost regulator. The LTC3567EUF is available in a 24-pin (4mm × 4mm) QFN surface mount package.

PERFORMANCE SUMMARY Specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
VBUS	Bus Input Voltage Range		4.35		5.5	V
LDO3V3	3.3V LDO Output Voltage Range		3.1		3.4	V
VBAT	Battery Float Voltage	Constant Voltage Mode	4.15		4.23	V
I_{BAT}	Battery Charge Current	Constant Current Mode, R_{PROG} = 2.00k	485		515	mA
VOUT1	Regulator 1 Output Voltage	IOUT1 ≤ 1000mA	3.15		3.45	V

OPERATING PRINCIPLES

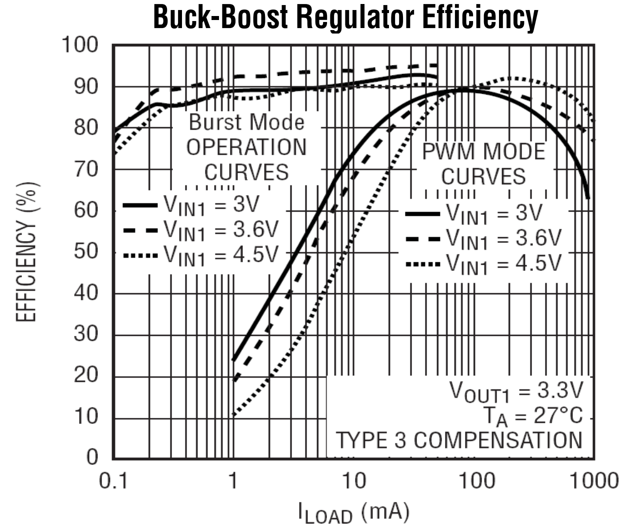
The LTC3567EUF is a full featured USB Power Manager and Li-Ion battery charger with a 1A Buck-Boost DC/DC regulator. The LTC3567EUF has an I^2C interface that allows adjustment of the Buck-Boost output voltage, operating mode, and USB power management control. The Bat-Track™ battery charger pre-regulator ensures the charger operates at the highest possible efficiency.

The LTC3567EUF is composed of 6 functional blocks, all working together: USB Power Manager, Pre-regulator, Battery Charger, Ideal Diode, 1A Buck-Boost DC/DC regulator, and I^2C.

USB Power Manager

The USB Power Manager is used to manage the load that the LTC3567EUF system presents to the USB interface. The load current can be programmed by changing the CLPROG resistor (R2), and by setting the operating mode to 1X, 5X or 10X with the I^2C interface.

Buck-Boost Regulator Efficiency



Pre-Regulator

The pre-regulator is a high efficiency buck regulator that produces a voltage at VOUT equal to the battery voltage plus 0.3V. By reducing the voltage across the charger to 0.3V the dissipation in the charger is greatly reduced, as compared with a linear charger.

Battery Charger

The battery charger operates in constant current mode, until the battery voltage rises to approximately the FLOAT voltage, of 4.2V, and then the charger switches to constant voltage mode.

The charge current is programmed by the PROG resistor (R3), and has been set to 500mA, on DC1140A, with a 2.00kΩ resistor. The battery charger implements trickle charging, for initial battery voltages less than 2.85V. It also implements a charge termination timeout of 4 hours, and a bad cell charging timeout of 30 minutes. An NTC input is used to determine if the battery temperature is suitable for charging, too hot or too cold.

The statuses of the charger, as well as any faults, are signaled with the $\overline{CHRG}$ pin.

Ideal Diode

The Ideal Diode block is composed of an internal Ideal Diode implemented with an on die MOSFET, as well as a MOSFET gate driver that allows the use of a parallel external MOSFET.

When the voltage on VOUT drops more than 15mV below the voltage at BAT, the Ideal Diode becomes active. This will happen when VBUS is not present, or the load on VOUT exceeds the power available from VBUS.

1A Buck-Boost DC/DC regulator

The Buck-Boost DC/DC regulator provides a regulated output that can be above and below the input voltage. The battery voltage will vary from VFLOAT (4.2V) to as low as 2.5V. The Buck-Boost regulator can supply a regulated 3.3V output over this entire battery voltage range.

The Buck-Boost is implemented with a full H-bridge switch, and proprietary control algorithm.

I²C Interface

The I²C interface is a 100kHz, write only serial interface that allows control of the USB input current limit, battery charger on/off, Buck-Boost regulator (VOUT1) on/off, Buck-Boost regulator operating mode, and Buck-Boost output voltage via an internal 4 bit DAC.

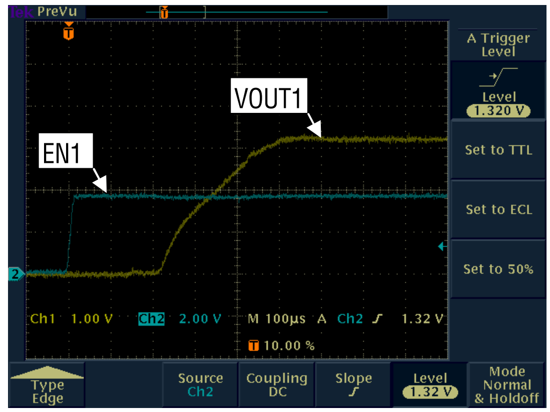


Figure 1. VOUT1 startup

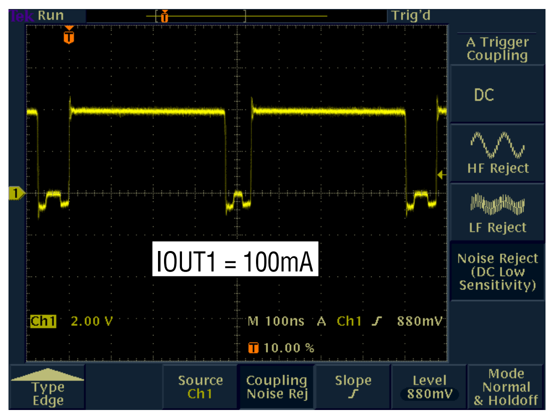


Figure 2. SWAB1 switching waveform

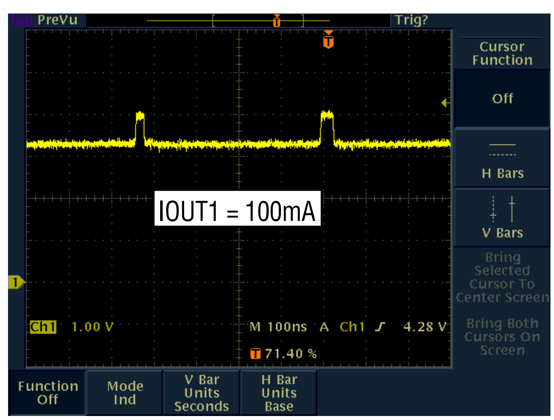


Figure3. SWCD1 switching waveform

APPLICATIONS INFORMATION

The parasitic inductance in some USB cables may cause the VUSB voltage to overshoot at plug in. If this is the case it is recommended that the network of C1, R1 and C2 be added to the board to damp out this overshoot. While, at first glance, it may appear that C1 + C2 exceeds the USB specification for capacitive load on VUSB, in fact this is not the case. For most MLCC capacitors, with X7R/X5R dielectric the capacitance will be below 4.7µF, for DC biases of 5V.

The battery charger must see low impedance to ground, which is the case when a battery is attached. In the event that a battery emulator is being used, or the impedance to ground is above 0.5Ω, the circuit of C7 and R14-16 is recommended.

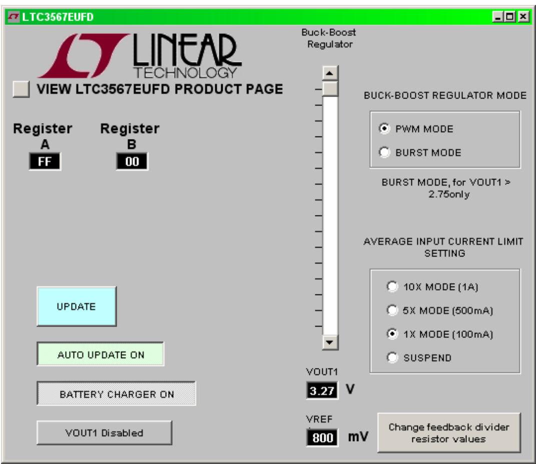
The Buck-Boost regulator should be compensated with a Type III compensator, as shown on the schematic. The Buck, Buck-Boost and pure Boost regions of operation have different poles/zeroes and PWM gains. In particular, the Buck-Boost and pure Boost regions have a RHP zero, that must be accommodated.

It is recommended that the stabilization be verified in all three regions of operation, with minimum and maximum load.

The /CHRGEN and EN1 pins are wire OR'ed with the corresponding bits from the I^2C channel. Consequently, if they are high the battery charger will be disabled and VOUT1 will be enabled. This is true regardless of the state of the I^2C bits. If control of the battery charger and VOUT1 through the I^2C bits is desired, please ensure that these pins are held low.

SOFTWARE GUI

The DC1140A Demo Circuit can be controlled from a software GUI. Most of the features of the LTC3567EUF are only accessible via the I^2C channel.
When the QuickEval program is active and a DC590 with a DC1140A connected and attached to the USB cable, the "LTC3567" form should automatically pop up and be fully operational:



SOFTWARE OPERATION
The software GUI automatically opens the control panel shown above. This control panel allows control of most major functions of the LTC3567. Please note that the EN1, and /CHRGEN signals are wire OR'ed with the corresponding bits from the I^2C channel. Consequent to this, if either is high, the corresponding bits of the I^2C channel will appear to be inoperative.

Register A and Register B display
These are not writeable and are provided as a programming aid. The current value of the I^2C A and B registers are displayed.

Update button
Forces an immediate update of the I^2C registers.

Autoupdate button
If enabled (default), the I^2C channel will update whenever something is changed.

Battery charger button
If enabled (default) the battery charger in the LTC3567 will be enabled, and vice versa.

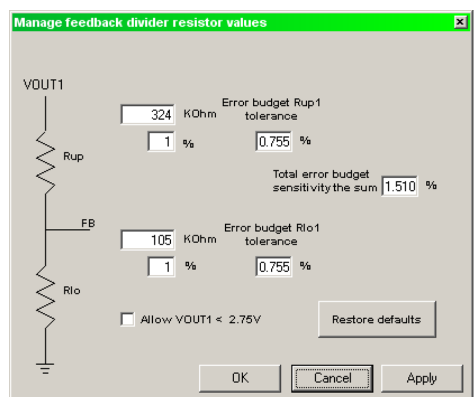
VOUT1 buttons
Enable or disable VOUT1. This button is only functional if the EN1 pin is held low.

Buck-Boost Regulator mode
Sets the mode of operation of the Buck-Boost regulator.

Buck-Boost Regulator slider
Allow control of Buck-Boost regulator output voltage by adjusting the reference DAC.

Buck-Boost Regulator output and reference voltage
These are not writeable, but reflect the current state of the reference DAC, and feedback resistors.

Change feedback divider resistor values button
This opens the form:



This form allows the feedback resistor divider network on the Buck-Boost regulator to be changed. The information changed here, is saved, and is durable from session to session. However, the factory values can be recovered by pressing the "Restore defaults" button. Note that operation of the Buck-Boost regulator below 2.75V must be explicitly enabled.

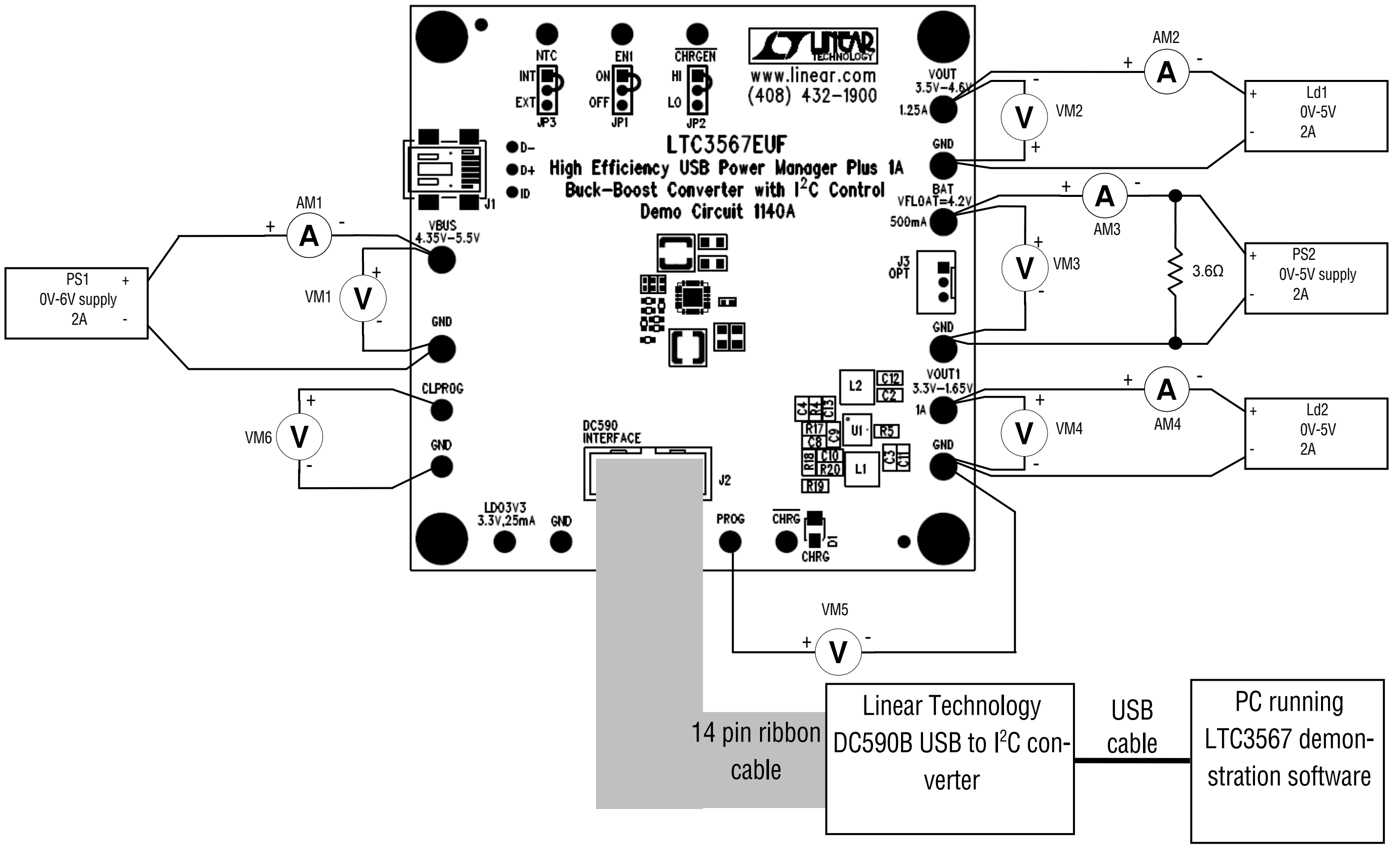
QUICK START PROCEDURE

Complete the Quick Start Procedure outlined in the Quick Start Guide for Demo Circuit 590 available from the Linear Technology Web Site, prior to proceeding.

Using short twisted pair leads for any power connections, with all loads and power supplies off. Refer to Figures 4 & 5 for the proper measurement and equipment setup. Follow the procedure below:

NOTE. When measuring the input or output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the input or output voltage ripple by touching the probe tip directly across the VBUS or VOUT(x) and GND terminals. See Figure 2 for proper scope probe technique.

1. Set EN1 (JP1) to "OFF" and /CHRGEN (JP4) to "Lo". Set PS1 to 5V, and PS2 to 3.6V. Start the GUI using QuickEval.
2. Observe that 95mA < I (VBUS) (AM1) < 100mA, 3.6V < VOUT(VM2) < 3.7V, 1.15V < V(CLPROG) (VM6) < 1.2V. The default state of the USB input current limit is 100mA, so although the charger is calling for 500mA, the USB input current is limited to 100mA. Consequent to this, VOUT drops until the charger only draws 100mA.
3. Use the GUI to set the USB input current limit to 5X (500mA). Observer that 460mA < I(VBUS) (AM1) < 500mA, 3.8V < VOUT (VM2) < 4.0V, and 0.95V < V(PROG) (VM5) < 1.0V. The USB current limit is now 500mA, so the charger can now deliver the full charge current. VOUT is now approximately equal to V(BAT) + 0.3V, and V(PROG) is a the servo voltage of 1.0V.
4. Use the GUI to set the USB input current limit to 10X (1A). Observe that 460mA < I(VBUS) (AM1) < 500mA, 3.8V < VOUT (VM2) < 4.0V, and 0.95V < V(PROG) (VM5) < 1.0V. The USB current limit is now 1A, so there is more than enough current to operate the charger at 500mA.
5. Set PS1 to 0V, and Ld1 to 1A. Observe that 3.5V < VOUT (VM2) <3.6V and V (VOUT, VBAT) < 200mV. The USB supply is off, and the only source of energy is the battery. With VOUT loaded at 1A, the ideal diode engages and energy is routed from the battery to VOUT.
6. Set Ld1 to 400mA and PS1 to 5V. Observe that 3.8V < VOUT (VM2) < 4.0V. The USB current limit is set to 1A, so both the charger load of 500mA, and 400mA into Ld1 can be supplied.
7. Set Ld1 to 0A, and use the GUI to enable VOUT1. Observe that 3.8V < VOUT (VM2) < 4.0V and 3.25V < VOUT1 (VM4) < 3.35V. The Buck-Boost regulator is now on, at no load. The Buck-Boost regulator operates from VOUT.
8. Set Ld2 to 400mA. Observe 3.8V < VOUT (VM2) < 4.0V, 3.25V < VOUT1 (VM4) < 3.35V. The combined load of the charger and the load on VOUT1, is still within the 1A current limit.
9. Use the GUI to turn off the battery charger, and set Ld2 to 1A. Observe that 3.8V < VOUT (VM2) < 4.0V, 3.25V < VOUT1 (VM4) < 4.0V. Because the battery charger is off, the LTC3567 can supply 1A through the Buck-Boost regulator, and stay within the 1A limit on USB current.
10. Set Ld2 to 0A, and use the GUI to turn on the battery charger. Set NTC (JP3) to "EXT". /CHRG LED should flash.
11. Set NTC (JP3) to "INT" and EN1 (JP1) to "ON". Shut off all supplies and loads.



Note: All connections from equipment should be Kelvin connected directly to the board pins which they are connected on this diagram and any input or output leads should be twisted pair.

Figure 4. Proper Measurement Equipment Setup for DC1140A

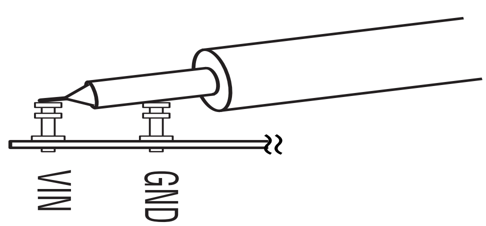


Figure 5. Measuring Input or Output Ripple

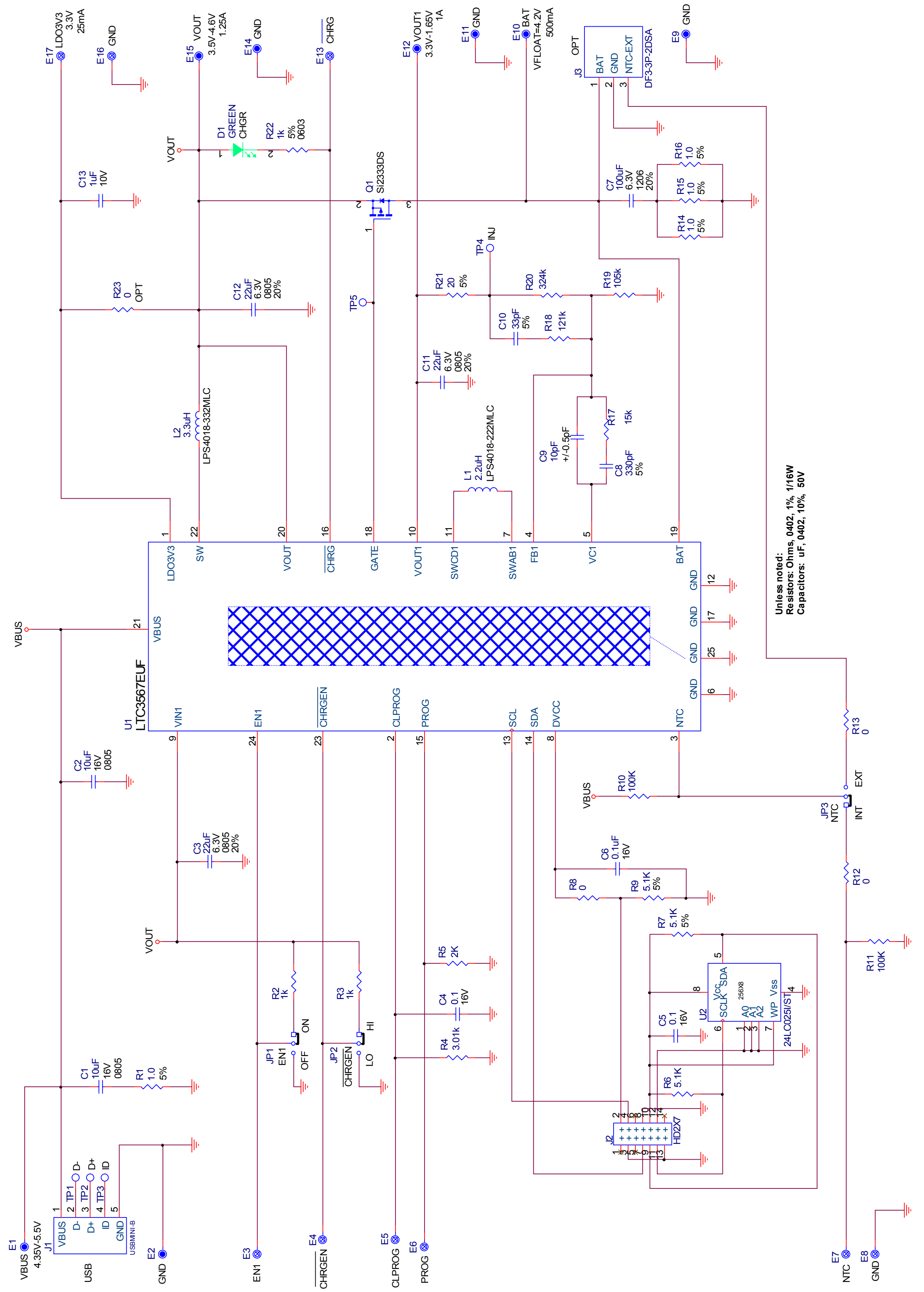


Figure 6. Circuit Schematic

	Qty	Reference	Part Description	Manufacture / Part #
		REQUIRED CIRCUIT COMPONENTS:		
1	1	C2	CAP, CHIP, X5R, 10µF, ±10%, 16V, 0805	MURATA, GRM21BR61C106KE15L
2	3	C3,C11,C12	CAP, CHIP, X5R, 22µF, ±20%, 6.3V, 0805	TAIYO-YUDEN, JMK212BJ226MG
3	1	C4	CAP, CHIP, X7R, 0.1µF, ±10%, 16V, 0402	MURATA, GRM155R71C104KA88
4	1	C8	CAP, CHIP, COG, 330pF, ±5%, 50V, 0402	VISHAY, VJ0402A331
5	1	C9	CAP, CHIP, COG, 10pF, ±0.5pF, 50V, 0402	VISHAY, VJ0402A100
6	1	C10	CAP, CHIP, COG, 33pF, ±5%, 50V, 0402	VISHAY, VJ0402A330
7	1	C13	CAP, CHIP, X5R, 1.0µF, ±10%, 10V, 0402	MURATA, GRM155R61A105KE15D
8	1	R4	RES, CHIP, 3.01kΩ, ±1%, 1/16W, 0402	VISHAY CRCW04023K01FKED
9	1	R5	RES, CHIP, 2.0kΩ, ±1%, 1/16W, 0402	VISHAY CRCW04022K00FKED
10	1	R17	RES, CHIP, 15kΩ, ±1%, 1/16W, 0402	VISHAY CRCW040215K0FKED
11	1	R18	RES, CHIP, 121kΩ, ±1%, 1/16W, 0402	VISHAY CRCW0402121KFKED
12	1	R19	RES, CHIP, 105kΩ, ±1%, 1/16W, 0402	VISHAY CRCW0402105KFKED
13	1	R20	RES, CHIP, 324kΩ, ±1%, 1/16W, 0402	VISHAY CRCW0402324KFKED
14	1	L1	IND, SMT, 2.2uH, ±20%, 70mΩ, 2.5A, 4.4mmX4.4mm	COILCRAFT, LPS4018-222MLC
15	1	L2	IND, SMT, 3.3uH, ±20%, 80mΩ, 2.2A, 4.4mmX4.4mm	COILCRAFT, LPS4018-332MLC
16	1	U1	High Efficiency USB Power Manager Plus 1A Buck-Boost Converter and I2C	LINEAR TECH., LTC3567EUF
		ADDITIONAL DEMO BOARD CIRCUIT COMPONENTS:		
1	1	C1	CAP, CHIP, X5R, 10µF, ±10%, 16V, 0805	MURATA, GRM21BR61C106KE15L
2	2	C5,C6	CAP, CHIP, X7R, 0.1µF, ±10%, 16V, 0402	MURATA, GRM155R71C104KA88
3	1	C7	CAP, CHIP, X5R, 100µF, ±20%, 6.3V, 1206	MURATA, GRM31CR60J107ME39L
4	1	D1	LED, GREEN	PANASONIC LN1351C-(TR)
5	1	Q1	XSTR, MOSFET P- CHANNEL	SILICONIX Si2333DS
6	1	R1,R14,R15,R16	RES, CHIP, 1.0Ω, ±5%, 1/16W, 0402	VISHAY, CRCW04021R00JNED
7	2	R2,R3	RES, CHIP, 1kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW04021K00JNED
8	3	R6,R7,R9	RES, CHIP, 5.1kΩ, ±5%, 1/16W, 0402	VISHAY, CRCW04025K10JNED
9	3	R8,R12,R13,R23-OPT	RES, CHIP, 0Ω jumper, 1/16W, 0402	VISHAY CRCW04020000Z0ED
10	2	R10, R11	RES, CHIP, 100kΩ, ±1%, 1/16W, 0402	VISHAY CRCW0402100KFKED
11	1	R21	RES, CHIP, 20.0Ω, ±5%, 1/16W, 0402	VISHAY CRCW040220R0JNED
12	1	R22	RES, CHIP, 1kΩ, ±5%, 1/10W, 0603	VISHAY, CRCW06031K00JNED
13	1	U2	I2C EEPROM	MICROCHIP, 24LC025-I/ST
		HARDWARE FOR DEMO BOARD ONLY:		
1	1	J1	CONN, USB MINI-B	TYCO, 1734035-2
2	1	J2	CONN, I2C header	MOLEX, 87831-1420
3	1	J3-OPT	CONN, DF3-3P-2DSA	HIROSE, DF3-3P-2DSA
4	3	JP1,JP2,JP3	HEADER,3 PINS 2mm	SAMTEC, TMM-103-02-L-S
5	3	JP1,JP2,JP3	SHUNT 2mm	SAMTEC, 2SN-BK-G
6	8	E1,E2,E9,E10,E11,E12,E14 E15	TURRET, 0.09 DIA	MILL-MAX, 2501-2
7	9	E3,E4,E5,E6,E7,E8,E13,E16, E17	TURRET, 0.061 DIA	MILL-MAX, 2308-2
8	4		STAND-OFF, NYLON 0.375" tall (SNAP ON)	KEYSTONE, 8832 (SNAP ON)

Figure 7. Bill of Materials