

LTC3556EUFD: High Efficiency USB Power Manager with Dual Buck and Buck-Boost DC/DCs

DESCRIPTION

Demonstration Circuit DC1296A is a High Efficiency USB Power Manager + Dual Buck + Buck-Boost Converters featuring the LTC[®]3556. The LTC3556 is a highly integrated power management and battery charger IC for Li-Ion/polymer battery applications. It includes a high efficiency current limited switching PowerPath manager with automatic load prioritization, a battery charger, an ideal diode and three general purpose synchronous step-down switching regulators. Designed specifically for USB applications, the LTC3556's switching power manager automatically limits input current to a maximum of either 100mA or 500mA for USB applications or 1A for AC-powered applications. Unlike linear PowerPath controllers, the LTC3556's switching input stage transmits nearly all of the 2.5W available from the USB port to the system

load with minimal power wasted as heat. This feature allows the LTC3556 to provide more power to the application and eases the constraint of thermal budgeting in small spaces. The two buck switching regulators can provide up to 400mA while the buck-boost regulator can deliver 1A. The output voltage of one buck and the buck-boost can be adjusted, over a 2 to 1 range, via the I²C channel. The entire product can be started from an external push button and subsequently controlled via I²C. The LTC3556EUFD is available in a 28-pin (4mm × 5mm × 0.75mm) QFN surface mount package. Design files for this circuit board are available, call the LTC factory.

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PERFORMANCE SUMMARY Specifications are at T_A = 25°C

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|-------------------|-------------------------------|--|------|-----|------|-------|
| VBUS | Bus Input Voltage Range | | 4.35 | | 6 | V |
| LD03V3 | 3.3V LDO Output Voltage Range | | 3.1 | | 3.4 | V |
| VBAT | Battery Float Voltage | Constant Voltage Mode | 4.15 | | 4.23 | mA |
| I _{BAT} | Battery Charge Current | Constant Current Mode, R _{PROG} = 2.00k | 485 | | 515 | mA |
| V _{OUT1} | Regulator 1 Output Voltage | I _{OUT1} ≤ 400mA | 0.8 | | 1.6 | V |
| V _{OUT2} | Regulator 2 Output Voltage | I _{OUT2} ≤ 400mA | 1.7 | 1.8 | 1.9 | V |
| V _{OUT3} | Regulator 3 Output Voltage | I _{OUT3} ≤ 1A | 2.65 | | 3.3 | V |

OPERATING PRINCIPLES

The LTC3556 is a Li-Ion battery charger/power manager with two Buck regulators and Buck-Boost regulator. The LTC3556 also contains an integrated Buck regulator that can provide the pre-regulation function, called Bat-Track™, from the USB input supply. This allows for minimal power dissipation in the charger. The load presented to the USB port can be programmed to comply

with the USB standards. This load can be set to 100mA, or 500mA, as negotiated with the USB host, and is programmed using the I²C channel and the CLPROG pin resistance.

The current that the charger supplies to the battery is also programmable via the PROG pin resistance. The current available, simultaneous to charging the battery, is

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the difference between the allowable USB load and the battery charging current.

The LTC3556 also has an ideal diode function which allows the maximum energy to be extracted from the battery. The ideal diode function supports an optional external MOSFET for higher battery currents.

The output voltage of one of the Buck regulators (VOUT1) and the Buck-Boost can be changed via the I²C channel, providing a 2 to 1 range of control.

The output regulators can be enabled, as a group, by the ENALL pin, or individually over the I²C channel. In addition, the sequence of regulator startup can be controlled via the SEQ pin.

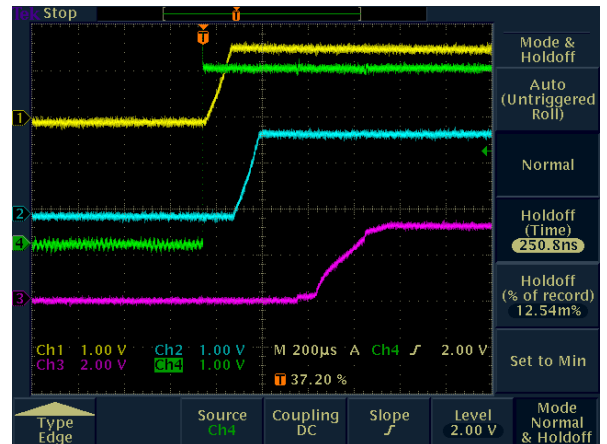


Figure 1: Y=VOUT1, BLU=VOUT2, PK=VOUT3, GRN = ENALL, SEQ = 0V

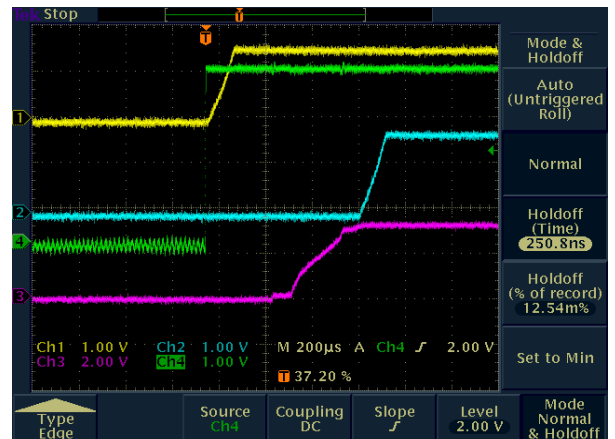
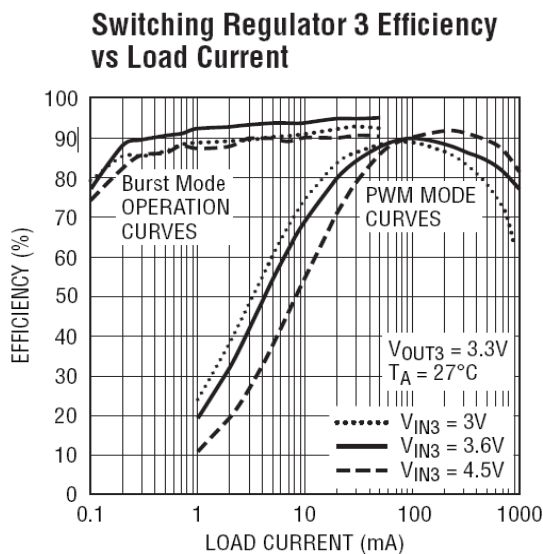


Figure 2: Y=VOUT1, BLU=VOUT2, PK=VOUT3, GRN = ENALL, SEQ = VOUT

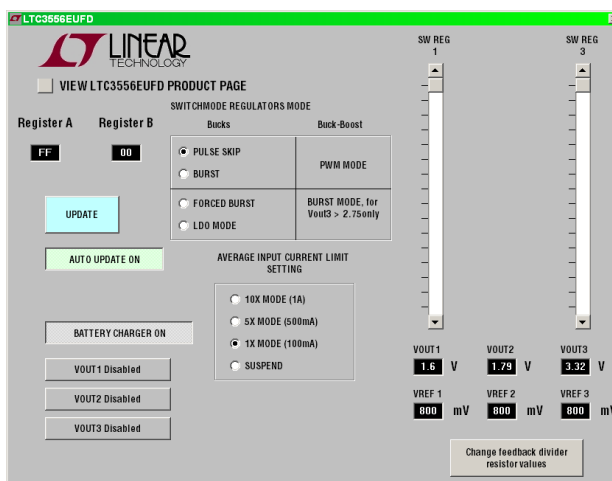
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SOFTWARE GUI

The DC1296A Demo Circuit can be controlled from a software GUI. Most of the features of the LTC3556EUFD are only accessible via the I²C channel. When the QuikEval program is active and a DC590 with a DC1296A connected and attached to the USB cable, the “LTC3556” 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 LTC3556. Please note that the SEQ has no I²C channel equivalent. And that the ENALL signal is wire OR'ed with individual regulator enable/regulator signals from the I²C channel. Consequent to this, if the ENALL signal is high, the regulators will be enabled regardless of the state of the I²C channel regulator control bits.

Register A and Register B display

These are not writeable and are provided as a programming aid. The current value of the I²C A and B register are displayed.

Update button

Forces an immediate update of the I²C registers.

Autoupdate button

If enabled (default) will update the I²C channel whenever something is changed.

Battery charger button

If enabled (default) the battery charger in the LTC3556 will be enabled, and vice versa.

VOUT1~VOUT3 buttons

Individually enable or disable the three voltage regulators. These only function if the ENALL pin is held low.

Switchmode Regulators mode

Set the mode of operation of all the switchmode regulators. Since VOUT3 is a Buck-Boost regulator, the interpretation of the bits is different.

VOUT1 and VOUT3 sliders

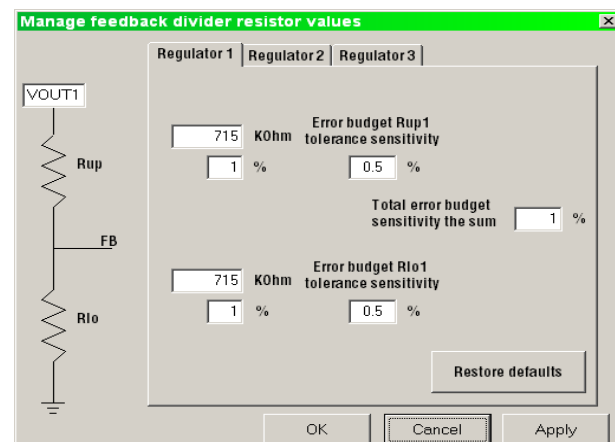
Allow control of voltage regulator 1 and 3 output voltages by adjusting the respective reference DACs.

VOUT1~3 output and reference voltages

These are not writeable, but reflect the current state of the reference DACs, and feedback resistors.

Change feedback divider resistor values button

This opens the form:



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This form allows the feedback resistor divider network on each regulator to be changed. The information changed here, is saved, and is durable from session to session. However, the factory values can

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.

Refer to Figure 2 for the proper measurement equipment setup and jumper settings and 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 PS1 to 5.0V, and PS2 to 3.6V. Using the LTC3556 GUI click on “5X Mode(500mA)”. Increase Ld2 to 200mA. Measure VOUT (VM6) \approx 3.68V, and I(VBUS) (AM1) \approx 454mA.

VBUS is 5V, and can supply up to 500mA, or 2.5W. VOUT is being loaded at 200mA + \approx 454mA (battery charge current) \approx 654mA, so VOUT will be $2.5W/0.654A \approx 3.80V$.

2. Using the LTC3556 GUI click on “10X Mode(1A)” under Average Input Current Limit Setting. Measure VOUT (VM6) and IBAT. Measure VOUT (VM6) \approx 3.97V, and I(VBUS) (AM1) \approx 510mA. The input power limit is now higher than the power load at VOUT, so VOUT rises to $3.97V \approx (V(BAT) + 0.35V)$.
3. Set V(BAT) (PS2) to 2.5 V. Measure the battery Current IBAT in trickle charge mode. Remove the NTC jumper (JP1) and observe the CHRG LED slow blinking rate (1.5Hz at 50% Duty Cycle). Reinstall the NTC jumper (JP1). When

be recovered by pressing the “Restore defaults” button

V(BAT) is below 2.85V (Typ.), the battery charger attempts to trickle charge the battery up above this threshold at $\approx I_{CHARGE}/10 = 50mA$.

When the battery charger detects a fault such as the NTC pin signaling the battery is too cold or too hot, it signals this by pulsing the \overline{CHRG} pin at a frequency and duty cycle that identifies the reported fault.

4. Set the voltage on the BAT pin (PS2) to 4.21V. Once the battery reaches the float voltage, the battery charger switches from Constant Current (CC) mode to Constant Voltage (CV) mode. The purpose of Constant Voltage mode is keep the battery “topped off” at the float voltage. If the battery is unloaded, this current should be very small.
5. With PS1 set at 5V, set the voltage on BAT (PS2) to 3.6V. Set Ld1 to zero current and set ENALL jumper (JP2) to “LO. Verify that the GOODALL LED is lit. The GOODALL LED lights red when one or all of the regulators is out of regulation, or when all the regulators are off.
6. Set the ENALL jumper (JP2) to “Hi” to turn on VOUT1-VOUT3. Observe the start-up sequence with an oscilloscope, measure VOUT1, VOUT2 and VOUT3 and observe the state of the POWERGOOD ALL LED. The sequencing of regulators VOUT1, 2, & 3 is controlled by the state of the SEQ pin. The SEQ pin is a three state input to the LTC3556, and three sequences are programmable. There is no equivalent to the SEQ pin in the I²C channel. SEQ is grounded so the power supply sequence should be VOUT1 then VOUT2, then VOUT3.
7. Move the SEQ jumper (JP3) to “3->1->2”.
8. Set ENALL jumper (JP2) to “LO.
9. Set the ENALL jumper (JP2) to “Hi” to turn on VOUT1-VOUT3. Observe the start-up sequence

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with an oscilloscope and the state of the POWERGOOD ALL LED. The SEQ is floating so the power supply sequence should VOUT3 then VOUT1, then VOUT2.

10. Move the SEQ jumper (JP3) to “1->3->2”.
11. Set ENALL jumper (JP2) to “LO”.
12. Set the ENALL jumper (JP2) to “Hi” to turn on VOUT1-VOUT3. Observe the start-up sequence with an oscilloscope and the state of the POWERGOOD ALL LED. The SEQ pin is now at VOUT, so the power supply sequence should be VOUT1 then VOUT3, then VOUT2.
13. Move the SEQ jumper (JP3) to “1->2->3”, and set ENALL jumper (JP2) to “LO”. Use the LTC3556 demonstration software to turn on all three regulators simultaneously. Do this by ensuring that “AUTOUPDATE OFF” is displayed, selecting “VOUT1 ON”, “VOUT2 ON”, and “VOUT3 ON”, then clicking “UPDATE ALL”. Observe Startup sequence of regulators, and verify that the PGOODALL LED is unlit. This demonstrates that startup sequence of the regulators is controlled by the SEQ pin, even when the regulators are enabled via the I²C channel. However, there is an enable bit for each regulator, as opposed to the ENALL pin, in the I²C channel, so some care must be taken to enable all three regulators simultaneously.
14. Ensure that PS1 is 5V, PS2 is 4.21V. Set the GUI autoupdate mode to “AUTOUPDATE ON”. With the load on VOUT1 (Ld5) at 400mA, VOUT2 (Ld3) at 400mA, and VOUT3 (Ld4) at 1A. Measure VOUT (VM6) \approx 4.2V, VOUT1 (VM10) \approx 1.6V \pm 3%, VOUT2 (VM8) \approx 1.8V \pm 3% and VOUT3 (VM9) \approx 3.27V \pm 3%. Observe the state of PGOODALL LED. VOUT1, VOUT2, and VOUT3 load VOUT. The load on VOUT is $(1.6V * 0.4A) + (1.8V * 0.4A) + (3.3V * 1.0A) = 4.67W$. The power available from the VBUS input is $5V * 1A = 5W$, but the efficiency of the VOUT regulator is not 100%. VOUT should be a $4.35V \approx (V(BAT) +$

0.35V), but has drooped to 4.2V because the load is at the maximum power available from the VBUS input.

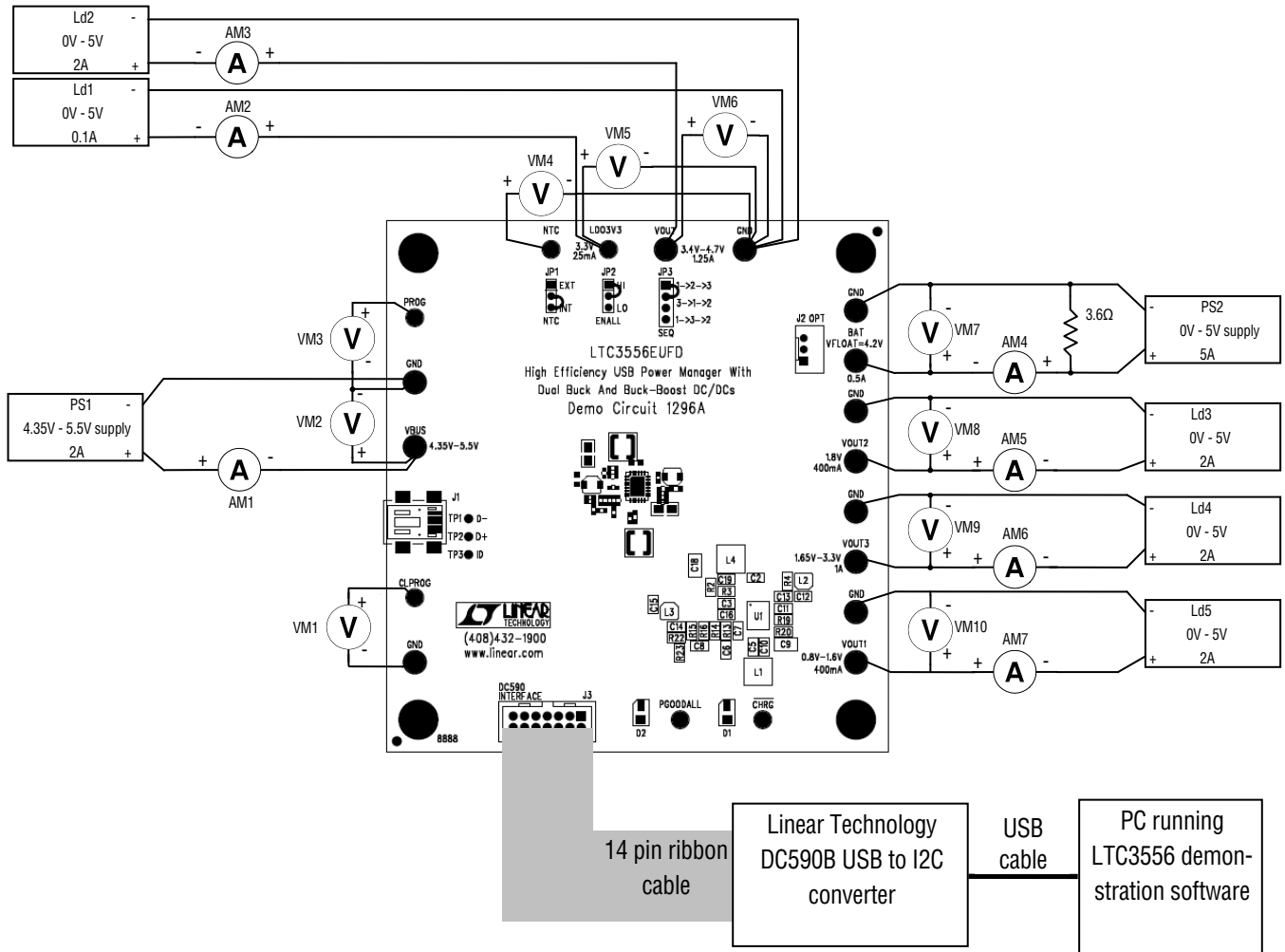
15. Using the LTC demonstration software set VOUT1 and VOUT3 reference voltage to 425mV. Setting VOUT3 reference voltage to 425mV, may require enabling operation below 2.75V. Do this in the Voltage regulator tab of the “Set resistor values dialogue”. Dismiss any efficiency warning that is posted. Measure VOUT (VM6) \approx 4.2V, VOUT1 (VM10) \approx 0.85V \pm 3%, VOUT2 (VM8) \approx 1.8V \pm 3% and VOUT3 (VM9) \approx 1.65V \pm 3%. Observe state of PGOODALL LED. The feedback reference voltages of regulators VOUT1 and VOUT3 have been approximately halved to 425mV. Consequently the output voltage will approximately halve as well.
16. Set VOUT1 load (Ld5), VOUT2 load (Ld3), and VOUT3 load (Ld4), to 0.
17. Set PS1 and PS2 to 0V. Disconnect all test equipment, and close LTC3556 GUI software window.
18. Reset the Jumpers to their default position.

See the LTC3556 data sheet for more information on how this part performs.

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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 1. Proper Measurement Equipment Setup for DC1296A

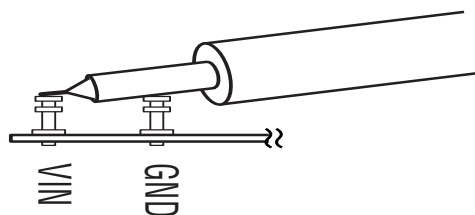


Figure 2. Measuring Input or Output Ripple

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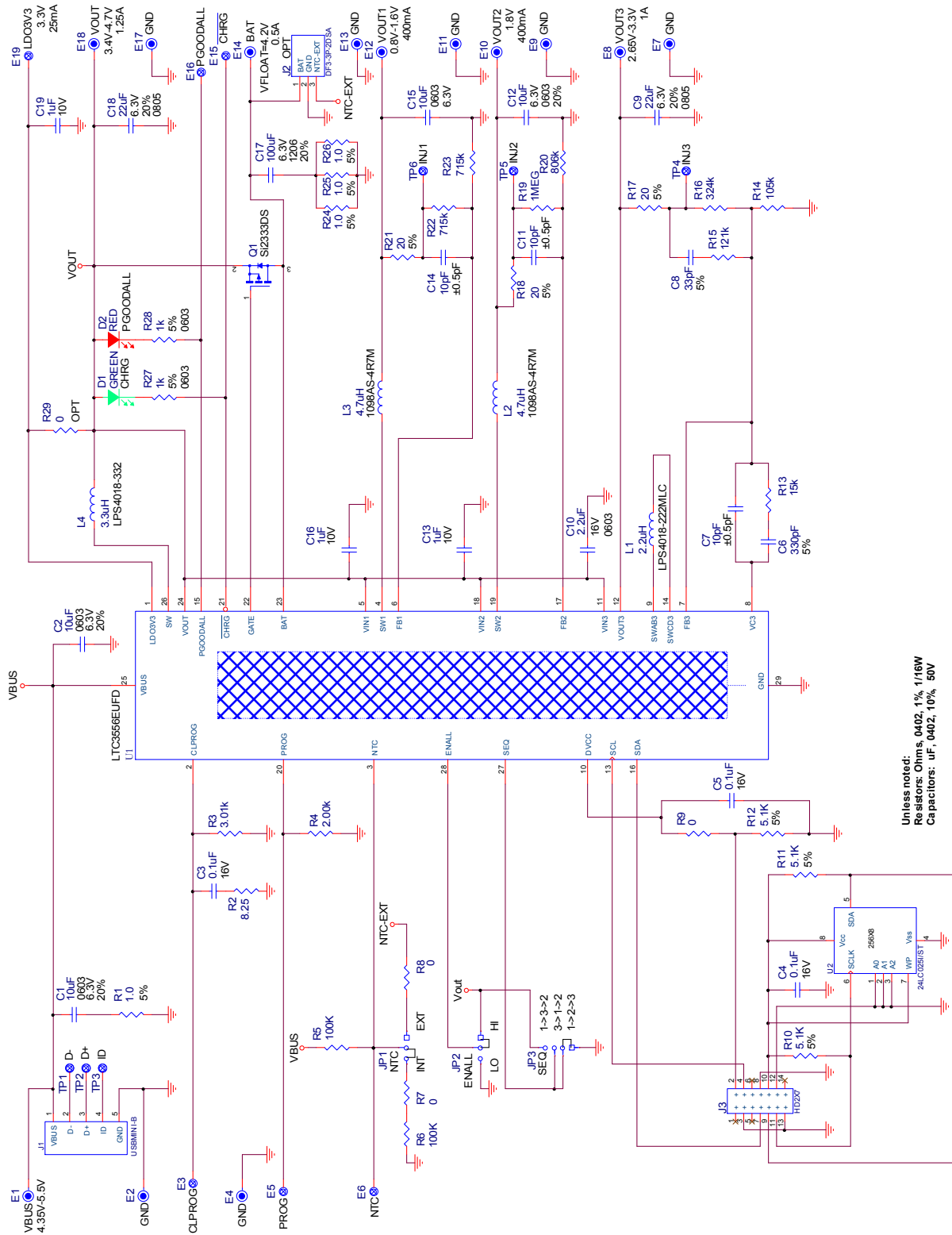


Figure 3. Circuit Schematic

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| Qty | Reference | Part Description | Manufacture / Part # | |
|--|-----------|--|--|----------------------------|
| REQUIRED CIRCUIT COMPONENTS: | | | | |
| 1 | 3 | C2,C12,C15 | CAP, CHIP, X5R, 10µF, ±20%, 6.3V, 0603 | TDK, C1608X5R0J106M |
| 2 | 2 | C3,C5 | CAP, CHIP, X7R, 0.1µF, ±10%, 16V, 0402 | MURATA, GRM155R71C104KA88 |
| 3 | 1 | C6 | CAP, CHIP, C0G, 330pF, ±5%, 50V, 0402 | VISHAY, VJ0402A331 |
| 4 | 3 | C7,C11,C14 | CAP, CHIP, C0G, 10pF, ±0.5pF, 50V, 0402 | VISHAY, VJ0402A100 |
| 5 | 1 | C8 | CAP, CHIP, C0G, 33pF, ±5%, 50V, 0402 | VISHAY, VJ0402A330 |
| 6 | 2 | C9,C18 | CAP, CHIP, X5R, 22µF, ±20%, 6.3V, 0805 | TAIYO-YUDEN, JMK212BJ226MG |
| 7 | 1 | C10 | CAP, CHIP, X5R, 2.2µF, ±10%, 16V, 0603 | MURATA, GRM188R61C225KE15D |
| 8 | 3 | C13,C16,C19 | CAP, CHIP, X5R, 1µF, ±10%, 10V, 0402 | MURATA, GRM155R61A105KE15D |
| 9 | 1 | L1 | IND, SMT, 2.2µH, ±20%, 2.5A, 4.4mmX4.4mm | COILCRAFT, LPS4018-222MLC |
| 10 | 2 | L2,L3 | IND, SMT, 4.7µH, ±20%, 1.2A, 3.6mmX3.0mm | TOKO, 1098AS-4R7M |
| 11 | 1 | L4 | IND, SMT, 3.3µH, ±20%, 2.2A, 4.4mmX4.4mm | COILCRAFT, LPS4018-332MLC |
| 12 | 1 | R2 | RES, CHIP, 8.25Ω, 1/16W, 1%, 0402 | VISHAY, CRCW04028R25FKED |
| 13 | 1 | R3 | RES, CHIP, 3.01kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW04023K01FKED |
| 14 | 1 | R4 | RES, CHIP, 2.00kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW04022K00FKED |
| 15 | 1 | R13 | RES, CHIP, 15kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW040215K0FKED |
| 16 | 1 | R14 | RES, CHIP, 105kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW0402105KFKED |
| 17 | 1 | R15 | RES, CHIP, 121kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW0402121KFKED |
| 18 | 1 | R16 | RES, CHIP, 324kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW0402324KFKED |
| 19 | 1 | R19 | RES, CHIP, 1.0MEGΩ, 1/16W, 1%, 0402 | VISHAY, CRCW04021M00FKED |
| 20 | 1 | R20 | RES, CHIP, 806kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW0402806KFKED |
| 21 | 2 | R22,R23 | RES, CHIP, 715kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW0402715KFKED |
| 22 | 1 | U1 | High Efficiency USB Power Manager with Dual Buck and Buck-Boost DC/DCs | LINEAR TECH., LTC3556EUFD |
| ADDITIONAL DEMO BOARD CIRCUIT COMPONENTS: | | | | |
| 1 | 1 | C1 | CAP, CHIP, X5R, 10µF, ±20%, 6.3V, 0603 | TDK, C1608X5R0J106M |
| 2 | 1 | C4 | CAP, CHIP, X7R, 0.1µF, ±10%, 16V, 0402 | MURATA, GRM155R71C104KA88 |
| 3 | 1 | C17 | CAP, CHIP, X5R, 100µF, ±20%, 6.3V, 1206 | MURATA, GRM31CR60J107ME39L |
| 4 | 1 | D1 | LED, SMT, GREEN, 1206 | PANASONIC, LN1351CTR |
| 5 | 1 | D2 | LED, SMT, RED, 1206 | PANASONIC, LN1251CTR |
| 6 | 1 | Q1 | MOSFET, -12V, 35mΩ, -5.3A, SOT-23 | VISHAY, Si2333DS |
| 7 | 4 | R1,R24, R25, R26 | RES, CHIP, 1.0Ω, 1/16W, 5%, 0402 | VISHAY, CRCW04021R00JNED |
| 8 | 2 | R5,R6 | RES, CHIP, 100kΩ, 1/16W, 1%, 0402 | VISHAY, CRCW0402100KFKED |
| 9 | 3 | R7,R8,R9 | RES, CHIP, 0Ω, 1/16W, 0402 | VISHAY, CRCW04020000Z0ED |
| 10 | 0 | R29-OPT | RES, CHIP, 0Ω, 1/16W, 0402 | VISHAY, CRCW04020000Z0ED |
| 11 | 3 | R10,R11,R12 | RES, CHIP, 5.1kΩ, 5%, 1/16W, 0402 | VISHAY, CRCW04025K10JNED |
| 12 | 3 | R17,R18,R21 | RES, CHIP, 20Ω, 1/16W, 5%, 0402 | VISHAY, CRCW040220R0JNED |
| 13 | 2 | R27,R28 | RES, CHIP, 1kΩ, 5%, 1/10W, 0603 | VISHAY, CRCW06031K00JNED |
| 14 | 1 | U2 | I2C EEPROM | MICROCHIP, 24LC025-I/ST |
| HARDWARE FOR DEMO BOARD ONLY: | | | | |
| 1 | 13 | E1,E2,E4,E7,E8,E9,E10,E11 E12,E13,E14,E17,E18 | Turret, 0.09" | MILL-MAX, 2501-2 |
| 2 | 6 | E3,E5,E6,E15,E16,E19 | Turret, 0.061" | MILL-MAX, 2308-2 |
| 3 | 1 | J1 | CONN, USB MINI-B | TYCO, 1734035-2 |
| 4 | 0 | J2-OPT | CONN, Battery | HIROSE, DF3-3P-2DSA |
| 5 | 1 | J3 | CONN, I2C header | MOLEX, 87831-1420 |
| 6 | 2 | JP1,JP2 | 3 Pin Jumper, 2mm | SAMTEC, TMM-103-02-L-S |
| 7 | 1 | JP3 | 4 Pin Jumper, 2mm | SAMTEC, TMM-104-02-L-S |
| 8 | 3 | JP1,JP2,JP3 | | SAMTEC, 2SN-BK-G |
| 9 | 4 | | STAND-OFF, NYLON 0.375" tall (SNAP ON) | KEYSTONE, 8832 (SNAP ON) |

Figure 4. Bill of Materials