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 to1 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
LDO3V3	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	IOUT1 ≤ 400mA	0.8		1.6	V
V_{OUT2}	Regulator 2 Output Voltage	IOUT2 ≤ 400mA	1.7	1.8	1.9	V
V_{OUT3}	Regulator 3 Output Voltage	IOUT3 ≤ 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 LTC3566 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

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.
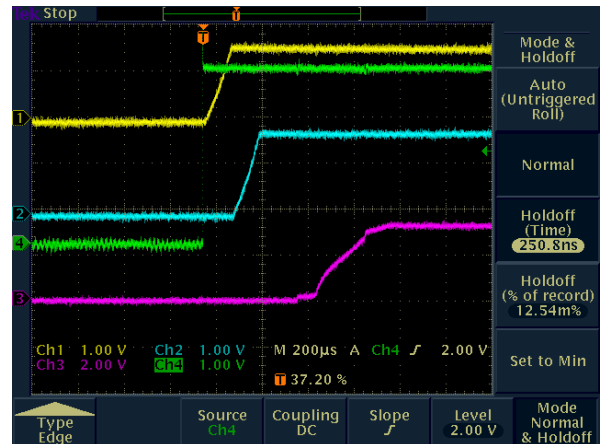

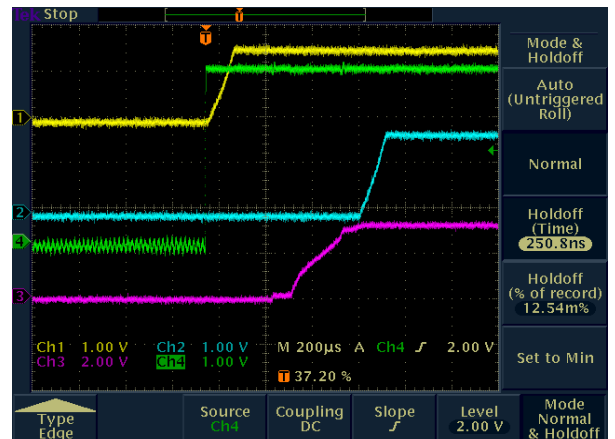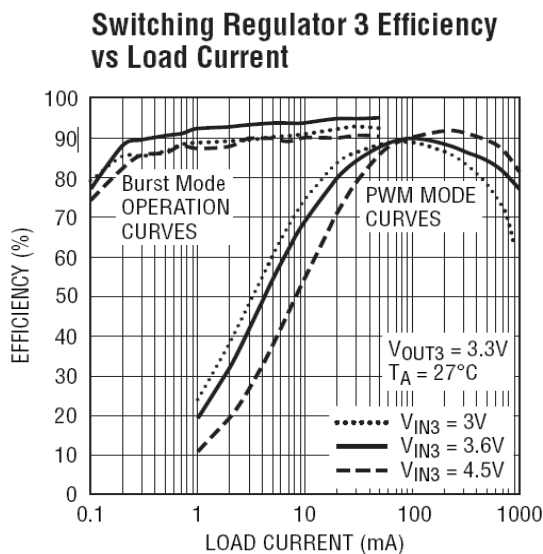**Figure 1: Y=VOUT1, BLU=VOUT2, PK=VOUT3, GRN = ENALL, SEQ = 0V**

Switching Regulator 3 Efficiency vs Load Current

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

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 I^{2}C 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:
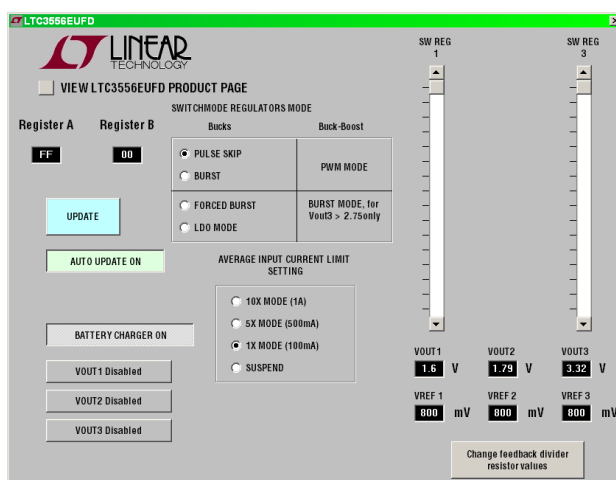
SOFTWARE OPERATION

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 I^{2}C channel equivalent. And that the ENALL signal is wire OR'ed with individual regulator enable regulator signals from the I^{2}C channel. Consequent to this, if the ENALL signal is high, the regulators will be enabled regardless of the state of the I^{2}C 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.
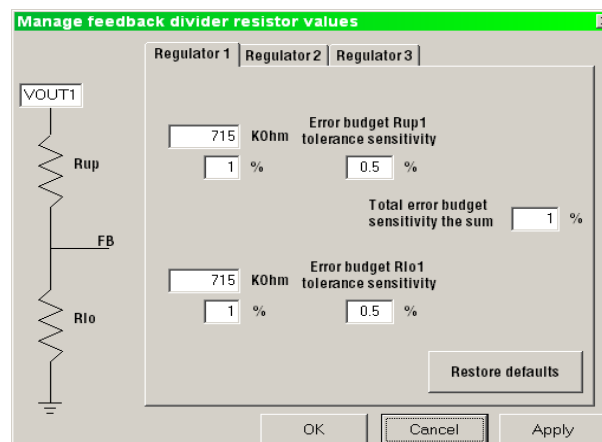
VOUT1 and VOUT3 sliders
Allow control of voltage regulator 1 and 3 output voltages by adjusting the respective reference DACs.

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:

3

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 be recovered by pressing the "Restore defaults" button

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) ≈ 3.68V, and I(VBUS) (AM1) ≈ 454mA.

   VBUS is 5V, and can supply up to 500mA, or 2.5W. VOUT is being loaded at 200mA + ≈454mA (battery charge current) ≈654mA, so VOUT will be 2.5W/0.654A ≈ 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) ≈ 3.97V, and I(VBUS) (AM1) ≈ 510mA. The input power limit is now higher than the power load at VOUT, so VOUT rises to 3.97V ≈ (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 V(BAT) is below 2.85V (Typ.), the battery charger attempts to trickle charge the battery up above this threshold at ≈ 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

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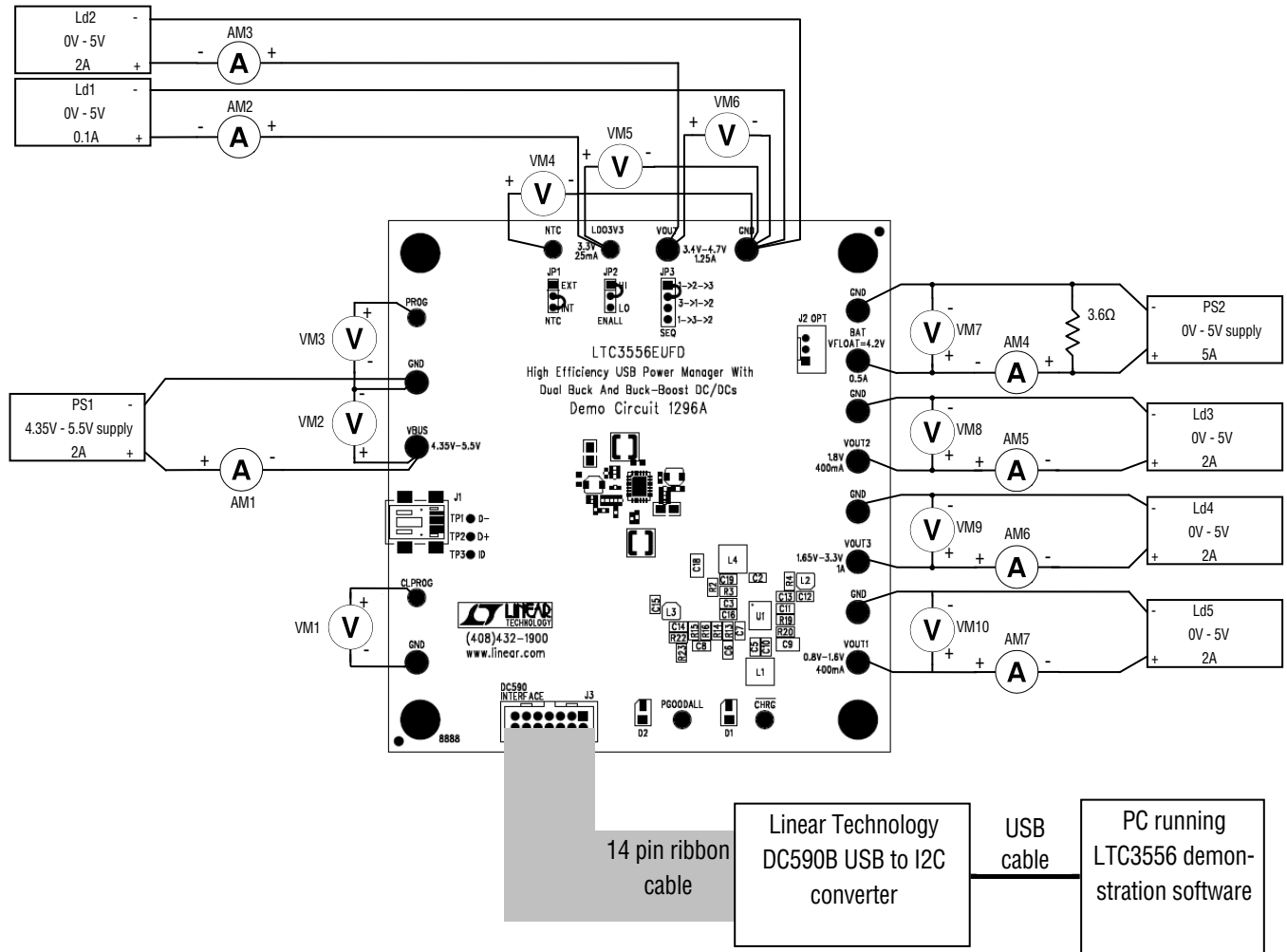
Note: All connections from equipment should be Kelvin connected directly to the board pins which they are connected on this diagram and any input or output leads should be twisted pair.

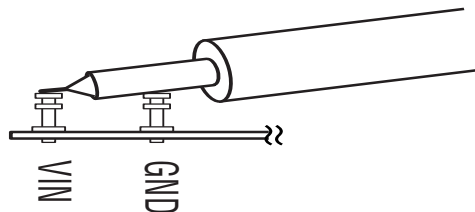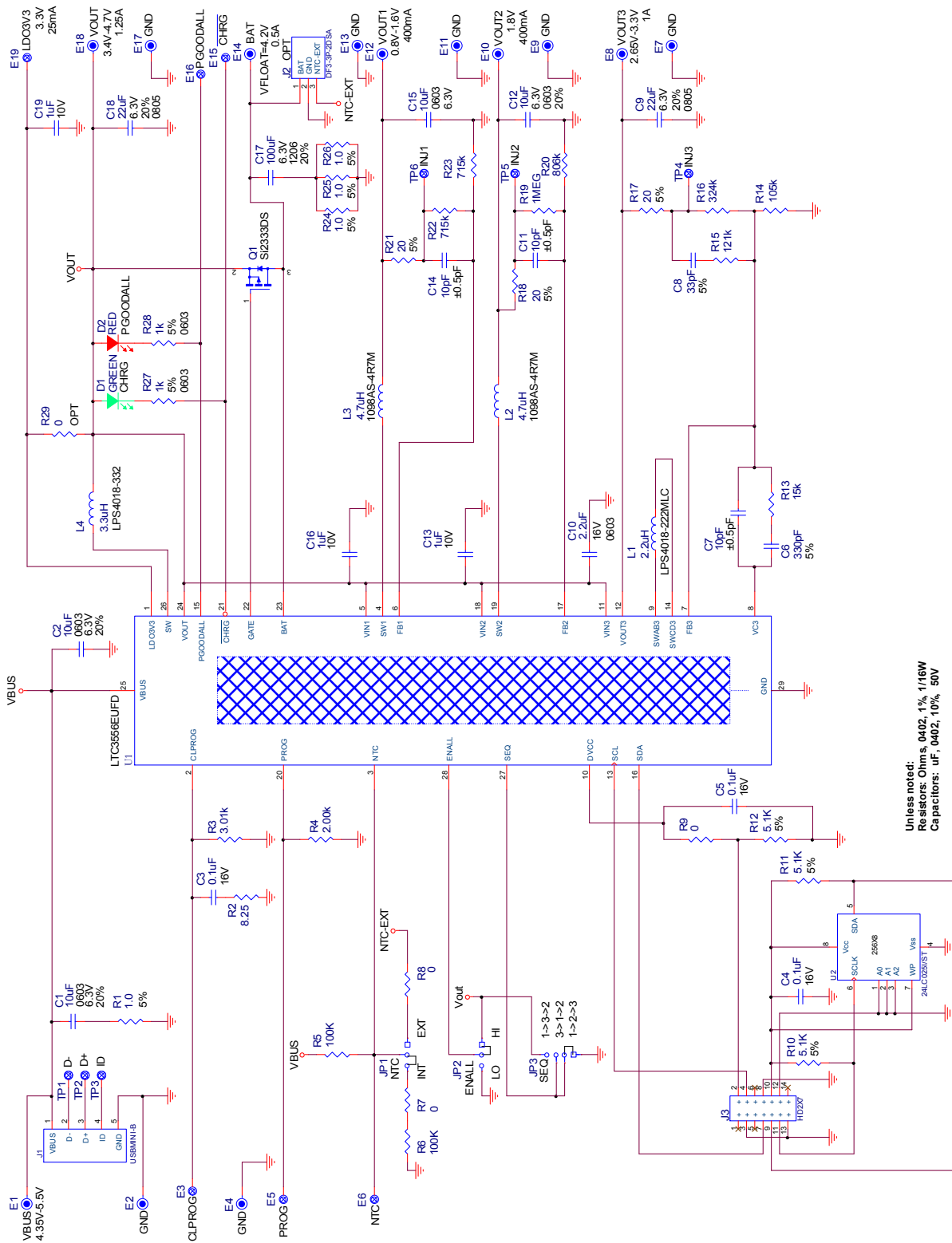**Figure 1. Proper Measurement Equipment Setup for DC1296A**

Figure 2. Measuring Input or Output Ripple

Figure 3. Circuit Schematic

	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