

# LTC4000

## Battery Charger Controller and PowerPath Manager

### DESCRIPTION

Demonstration circuit 1830A is a battery charger controller and PowerPath™ manager featuring the LTC®4000. This board should be connected to a front-end DC/DC power supply for a complete charger solution.

The DC1830A is customizable to handle a wide variety of applications with output voltages from 3V to 30V and output currents up to 6.5A with the PFETs supplied, and up to 60V and/or 13A with higher voltage rating and/or added PFETs. The reference design provided with DC1830A is targeted at 4-cell LiFePO<sub>4</sub> (14.6V/5A) applications.

The DC1830A loop compensation values were proven with the LTC3845A buck power converter shown and are typical for other applications. The output of this demo board was specifically tailored for a Tenergy 10A-hour battery, P/N 30207. Other voltages can be set by changing ROFB2 and RBFB2. The desired nominal voltage can be accurately trimmed by using trim resistors ROFBX and RBFBX. For example, for 14.4V battery float voltage, change ROFB2 and RBFB2 to 86.6k, and add 7.5M at ROFBX and RBFBX for greater setpoint accuracy. Other parameters can be adjusted to suit specific applications with guidance provided in the LTC4000 data sheet. Table 1 provides a summary of parameter adjustments.

This circuit was designed to demonstrate the high levels of performance and small solution size attainable using

this IC to control a switch mode power converter to form a battery charger, intelligent PowerPath manager, and power supply system. It produces a regulated 5.0A/14.6V battery charger output as well as a system output of up to 5.5A: suitable for a wide variety of portable applications including instruments, industrial equipment, power tools and computers.

The DC1830A-A provides a solution complete with both battery charger control and PowerPath management. It includes a second PFET (Q2) between VOUT-SYS and BAT to provide Instant-On functionality which keeps VOUT-SYS within a narrow range regardless of battery voltage, and disconnects the battery when it is fully charged and power is available from the front-end DC/DC converter. Thermal regulation circuitry is also provided to limit the temperature of both PFETs. The DC1830A-B provides a simple battery-charger-controller only solution without the PowerPath manager. It deletes the second PFET and thermal regulation circuitry. In this case, the battery is always “online” and VOUT-SYS tracks the BAT Voltage.

**Design files for this circuit board are available at <http://www.linear.com/demo>**

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### PERFORMANCE SUMMARY

Specifications are at T<sub>A</sub> = 25°C

SYMBOL	PARAMETER	CONDITIONS/COMMENTS	MIN	TYP	MAX	UNITS
V <sub>IN</sub>	Input Supply Range	This Is the Input Voltage of the Front-End DC/DC Supply	20		60	V
I <sub>IN</sub>	Input Current Limit	This Is the Input Current Limit Set by the LTC4000		3.0		A
V <sub>FLOAT</sub>	Battery Float Voltage		14.4	14.6	14.8	V
V <sub>FLOAT</sub>	Output Regulation	Line and Load (20V to 60V, 0A to 4.5A)		±0.005		%
I <sub>BAT</sub>	Battery Charge Current			5.0		A
	Battery Charge Current—Trickle			0.6		A
t <sub>T</sub>	Charge Termination Time	V <sub>BAT</sub> = V <sub>FLOAT</sub>		2.9		Hours
V <sub>OUT-SYS</sub>	System Output Voltage		12.3	14.6	15.5	V
I <sub>OUT-SYS</sub>	System Output Current Range	*Input Current Limited Below 35V <sub>IN</sub>	0		5.5*	A

dc1830af

### QUICK START PROCEDURE

Demonstration circuit 1830 is offered for use in combination with a front-end DC/DC converter, and will need to be customized to suit the intended application. It has been supplied with components for a design as outlined in the performance summary, and tested in conjunction with the LTC3845A buck converter that it was tailored to. A separate demonstration board is available for the LTC4000/LTC3789 buck-boost combination, the DC1721A. The LTC4000 data sheet should be used for guidance in determining circuit values for the application at hand. You may follow the design example on page 26 of the data sheet. Table 1 provides a summary of parameter adjustments.

NOTE: The PFETs supplied on this board are rated at 30V.

Once the circuit has been customized to suit the application at hand, it is easy to set up to evaluate the performance of the LTC4000 when combined with a suitable switching power converter, such as the LTC3845A. See page 9 for the modified DC1619A/LTC3845A schematic. Voltages and currents cited in this procedure are for the design as delivered; if the design has been customized, substitute the appropriate values. Refer to Figure 1 for proper measurement equipment setup and follow the procedure below:

*Warning: Batteries Are Potentially Dangerous High Energy Sources. Improper Connection, Overcharge, or Rapid Discharge Could Result in Explosion and/or Fire.*

1. Set an input power supply that is capable of 60V and 3A, to 24V. Then turn off the supply.
2. With power off, connect the supply to the input terminals VIN and GND.

NOTE:

- a. Input voltages lower than 20V can keep the converter from turning on due to the undervoltage lockout feature of the LTC4000.
  - b. If efficiency measurements are desired, refer to Figure 1 for the test setup.
3. Set CHARGE jumper to ENABLE.
  4. Turn on the power at the input.

NOTE: Make sure that the input voltage never exceeds 60V.

5. Check for the proper BAT output voltage of 14.6V. Turn off the power at the input.
6. Now that the proper output voltage is established, connect a variable load capable of sinking 6A at 16V to the output terminals BAT and GND. Set the current for 0A.
7. Turn on the power at the input.

NOTE: If there is no output, temporarily disconnect the load to make sure that the load is not set too high.

8. Once the proper BAT output voltage is again established, adjust the load and/or source within the operating range and observe the battery float voltage regulation, charge current, and other desired parameters.
9. Set the load to constant voltage mode to more easily observe charge current and trickle charge current.

NOTE: The following applies to the DC1830A-A.

NOTE: Operation in the Instant-On region ( $V_{OUT} < 12.5V$ ) may engage thermal limit circuit to protect Q2 in the linear region.

NOTE: The optional thermal limit circuit for Q1 (Q5, RNTC3, R8-12 and U2) is included to protect Q1 in case of an extended short circuit on VOUT-SYS under adverse thermal conditions ( $T_A > 40^{\circ}C$ ). It may not be needed in applications with less severe thermal conditions, lower current available to VOUT-SYS, or where continuous short-circuit protection on VOUT-SYS is not required.

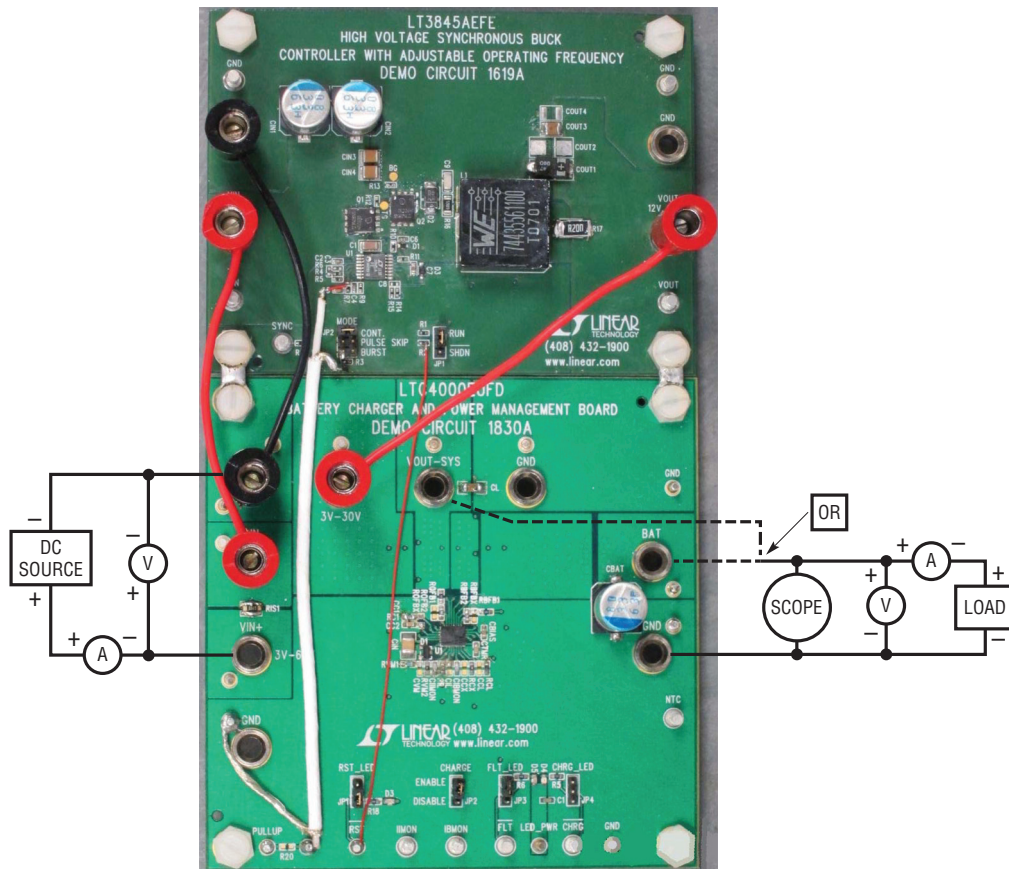
10. Turn off the power at the input.
11. Connect the output load and meters to the VOUT-SYS output.
12. Set CHARGE jumper to DISABLE.
13. Turn on the power at the input.
14. Once the proper VOUT-SYS is again established, adjust the load and/or source within the operating range and observe the output voltage regulation, ripple voltage, efficiency, input and output current limit, and other desired parameters.

### QUICK START PROCEDURE

**Table 1. LTC4000 Charger Setup Parameters and Reference Values**

REFERENCE	DESCRIPTION	NOMINAL VALUE (V)*	MIN/MAX	CONDITIONS
I <sub>IL</sub>	Input Current Regulation/Limit	(50μA • RIL)/20	45μA/55μA	50mV Max
I <sub>CL</sub>	Charge Current Regulation/Limit	(50μA • RCL)/20	45μA/55μA	50mV Max
	Trickle Charge Current Regulation/Limit	(5μA • RCL)/20	4.5μA/5.5μA	50mV Max
V <sub>BAT-FLOAT</sub>	Battery Float Voltage	1.136V	1.125V/1.147V	
V <sub>OUT</sub>	System Voltage	1.193V	1.181V/1.204V	Charger Off
		(Follows V <sub>BAT</sub> )		Charger Float
		(Follows V <sub>BAT</sub> )		Charging at I <sub>CL</sub> , 0.86 • V <sub>BAT-FLOAT</sub> < V <sub>BAT</sub> < V <sub>BAT-FLOAT</sub>
		0.86 • 1.136V	0.82/0.90	Instant-On, 0.68 • V <sub>BAT-FLOAT</sub> < V <sub>BAT</sub> < 0.86 • V <sub>BAT-FLOAT</sub>
	0.86 • 1.136V	0.82/0.90	Instant-On, Trickle, V <sub>BAT</sub> < 0.68 • V <sub>BAT-FLOAT</sub>	
VM	Input Voltage Monitor/UVLO	1.193V	1.181V/1.204V	Falling, (40mV Hysteresis)
CX	C/X Monitor/Charge Termination	(5μA • RCX – 10mV)/20	4.5μA/5.5μA	Short TMR to BIAS for C/X Termination
TMR	Charge Termination Timer	104s/nF	83s/nF/126s/nF	

\*Normalized to sense point



**Figure 1. Fixture Connections and Measurement Equipment Setup**

## QUICK START PROCEDURE

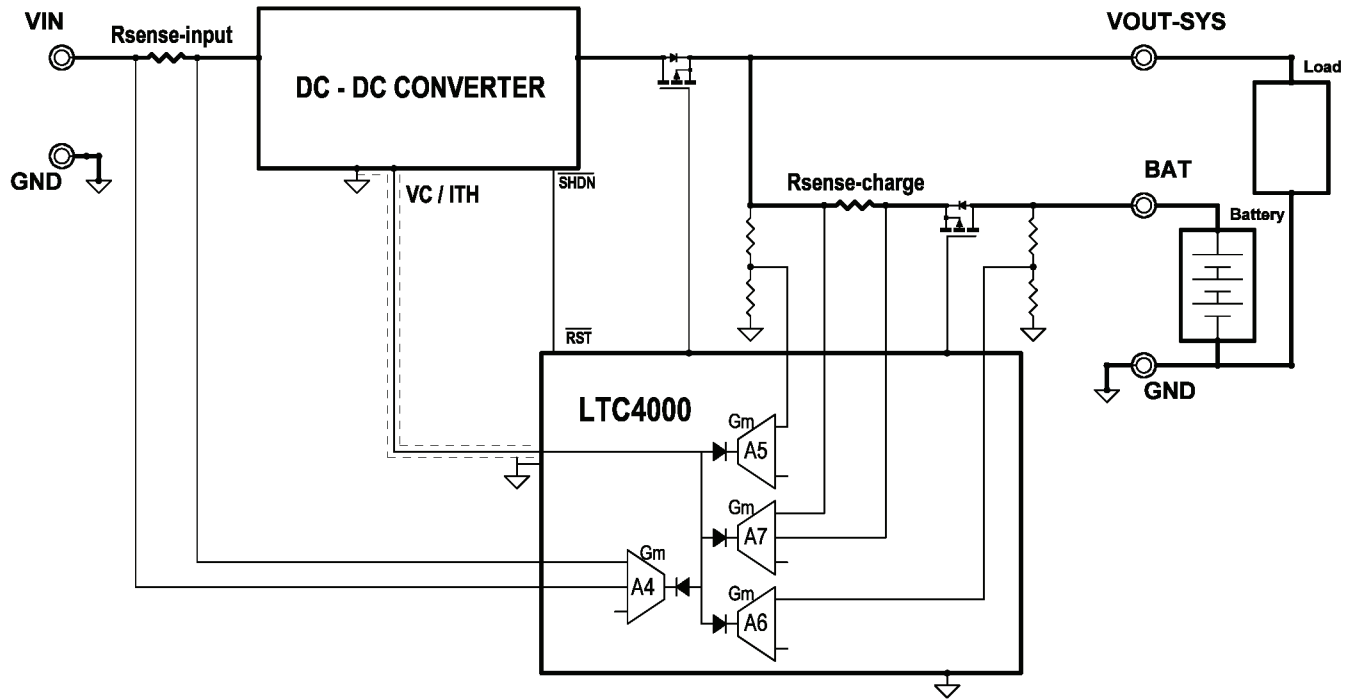


Figure 2. Block Diagram with Typical DC/DC Converter

### PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>DC1830A-A Required Circuit Components</b>				
1	1	C1	CAP., X5R, 4.7µF, 10V, 20% 0603	AVX, 0603ZD475MAT2A
2	1	CBAT	CAP., SMT ALUMINUM, 150µF, 35V	SUNCON, 35HVH150M
3	1	CBIAS	CAP., X7R, 1µF, 16V, 10% 0603	AVX, 0603YC105KAT2A
4	1	CBGATE	CAP., X7R, 10nF, 25V, 5% 0603	AVX, 06033C103JAT2A
5	2	CC2, CTMR	CAP., X7R, 0.1µF, 50V, 10% 0603	AVX, 06035C104KAT2A
6	2	CIIMON, CIBMON	CAP., COG, 1000pF, 25V, 5% 0603	AVX, 06033A102JAT2A
7	1	CIN	CAP., X7R, 1µF, 50V, 10% 1210	AVX, 12105C105KAT2A
8	1	CL	CAP., X7R, 2.2µF, 50V, 10% 1206	MURATA, GRM31CR71H225KA88L
9	1	D1	DIODE ZENER 3.0V 350MW SOT23-3	DIODE INC., BZX84C3V0-7-F
10	2	D3, D5	LED, RED HI BRT SS TYPE LO CUR SMT, 0603	PANASONIC, LNJ208R8ARA
11	1	D4	LED, GREEN, SMT, 0603	LITE-ON, LTST-C190KGKT
12	1	F2	FUSE 12A 32V T-LAG 1206 SMD	COOPER BUSSMAN, 3216TD12-R
13	2	Q1, Q2	MOSFET P-CHAN., 30V, POWERPAK-8	VISHAY, SI7135DP-T1-GE3
14	2	Q5, Q6	SMALL-SIGNAL MOSFET	ON SEMI., 2N7002LT1G
15	1	R5	RES., CHIP., 2.2k, 0.1W, 5% 0603	VISHAY, CRCW06032K2JKEA
16	2	R6, R18	RES., CHIP., 4.7k, 0.1W, 5% 0603	VISHAY, CRCW06034K7JKEA
17	4	R8, R13, RCX, RVM2	RES., CHIP., 10k, 0.1W, 1% 0603	YAGEO, RC0603FR-0710KL
18	1	R9	RES., CHIP., 46.4k, 0.1W, 1% 0603	VISHAY, CRCW060346K4FKEA
19	2	R10, R15	RES., CHIP., 20k, 0.1W, 1% 0603	VISHAY, CRCW060320K0FKEA
20	2	R11, R16	RES., CHIP., 38.3k, 0.1W, 1% 0603	VISHAY, CRCW060338K3FKEA
21	2	R12, R17	RES., CHIP., 1M, 0.1W, 1% 0603	VISHAY, CRCW06031M00FKEA
22	1	R14	RES., CHIP., 78.7k, 0.1W, 1% 0603	VISHAY, CRCW060378K7FKEA
23	2	RBFB1, ROFB1	RES., CHIP., 1M, 0.1W, 1% 0603	VISHAY, CRCW06031M00FKEA
24	2	RBFB2, ROFB2	RES., CHIP., 84.5k, 0.1W, 1% 0603	VISHAY, CRCW060384K5FKEA
25	1	RC1	RES., CHIP., 4.22k, 0.1W, 1% 0603	YAGEO, RC0603FR-07422KL
26	1	RCL	RES., CHIP., 24.3k, 0.1W, 1% 0603	VISHAY, CRCW060324K3FKEA
27	1	RIL	RES., CHIP., 18.2K, 0.1W, 1% 0603	VISHAY, CRCW060318K2FKEA
28	1	RCS	SENSOR RES., 0.01Ω 1W 2% 1508 SMD	SUSUMU, RL3720WT-R010-G
29	1	RIS1	SENSOR RES., 0.015Ω 1W 2% 1508 SMD	SUSUMU, RL3720WT-R015-G
30	2	RNTC2, RNTC3	THERMISTOR NTC 10k 5% 0603	VISHAY, NTHS0603N02N1002J
31	1	RVM1	RES., CHIP., 143k, 0.1W, 1% 0603	VISHAY, CRCW0603143KJKEA
32	3	R4, R7, R19	RES., CHIP., 100k, 0.1W, 5% 0603	VISHAY, CRCW0603100KJKEA
33	1	U1	I.C., LTC4000EUF, 28-PIN QFN	LINEAR TECH., LTC4000EUF#PBF
34	2	U2, U3	NANOPWR COMPARATOR, MSOP8	LINEAR TECH., LTC1540CMS8#PBF

# DEMO MANUAL

## DC1830A-A/DC1830A-B

### PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>DC1380A-A Additional Demo Board Circuit Components</b>				
1	0	CC1, CIGATE, CNTC, CCX, CCL, CIL, CVM	CAP.,0603	OPT
2	0	CL1, CL2, CL3, CL4, CL5	CAP.,1206	OPT
3	0	D2	DIODE ZENER, SOT23-3	OPT
4	0	F1, F3	FUSE 12A 32V T-LAG 1206 SMD	OPT
5	0	JUMPER	JUMPER WIRE (NO INSTALL)	
6	0	Q3	MOSFET P-CHAN., 30V, POWERPAK-8	OPT
7	0	Q4		OPT
8	0	R1, R2, R3, R20, RCL, RIG, RBG, RFBX, ROFBX, ROFB2	RES., 0603	OPT
<b>DC1380A-A Hardware—For Demo Board Only</b>				
1	14	E1-E6, E9-E14, E18, E19	TESTPOINT, TURRET, 0.061" PBF	MILL-MAX, 2308-2-00-80-00-00-07-0
2	5	E7, E8, E15, E16, E17	TESTPOINT, TURRET, 0.094" PBF	MILL-MAX, 2501-2-00-80-00-00-07-0
3	4	JP1, JP2, JP3, JP4	HEADER, 3-PIN 0.079 SINGLE ROW	SAMTEC, TMM-103-02-L-S
4	4	XJP1, XJP2, XJP3, XJP4	SHUNT, 0.079" CENTER	SAMTEC, 2SN-BK-G
5	9	J1, J2, J3, J4, J5, J6, J7, J8, J9	CONNECTOR, BANANA JACK	KEYSTONE, 575-4
6	4	MTG1, MTG2, MTG3, MTG4	STAND-OFF, NYLON (SNAP ON), 0.50" TALL	KEYSTONE, 8833(SNAP ON)
<b>DC1380A-B Required Circuit Components</b>				
1	1	C1	CAP., X5R, 4.7µF, 10V, 20% 0603	AVX, 0603ZD475MAT2A
2	1	CBAT	CAP., SMT ALUMINUM, 150µF, 35V	SUNCON, 35HVH150M
3	1	CBIAS	CAP., X7R, 1µF, 16V, 10% 0603	AVX, 0603YC105KAT2A
4	2	CC2, CTMR	CAP., X7R, 0.1µF, 50V, 10% 0603	AVX, 06035C104KAT2A
5	2	CIIMON, CIBMON	CAP., COG, 1000pF, 25V, 5% 0603	AVX, 06033A102JAT2A
6	1	CIN	CAP., X7R, 1µF, 50V, 10% 1210	AVX, 12105C105KAT2A
7	1	D1	DIODE ZENER 3.0V 350MW SOT23-3	DIODE INC., BZX84C3V0-7-F
8	2	D3, D5	LED, RED HI BRT SS TYPE LO CUR SMT, 0603	PANASONIC, LNJ208R8ARA
9	1	D4	LED, GREEN, SMT, 0603	LITE-ON, LTST-C190KGKT
10	1	F2	FUSE 12A 32V T-LAG 1206 SMD	COOPER BUSSMAN, 3216TD12-R
11	1	JUMPER	JUMPER WIRE (INSTALLED)	
12	1	Q1	MOSFET P-CHAN., 30V, POWERPAK-8	VISHAY, SI7135DP-T1-GE3
13	1	Q2	ZERO OHM THICK FILM JUMPER CHIP, 2010	IRC., LRC-LRZ-2010LF-R000
14	1	R5	RES., CHIP., 2.2k, 0.1W, 5% 0603	VISHAY, CRCW06032K2JKEA
15	2	R6, R18	RES., CHIP., 4.7k, 0.1W, 5% 0603	VISHAY, CRCW06034K7JKEA
16	1	RVM2	RES., CHIP., 10k, 0.1W, 1% 0603	YAGEO, RC0603FR-0710KL
17	2	RFB1, ROFB1	RES., CHIP., 1M, 0.1W, 1% 0603	VISHAY, CRCW06031M00FKEA
18	1	RFB2	RES., CHIP., 84.5k, 0.1W, 1% 0603	VISHAY, CRCW060384K5FKEA
19	1	RC1	RES., CHIP., 4.22k, 0.1W, 1% 0603	YAGEO, RC0603FR-07422KL

# DEMO MANUAL

## DC1830A-A/DC1830A-B

### PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
20	1	RCL	RES., CHIP., 24.3k, 0.1W, 1% 0603	VISHAY, CRCW060324K3FKEA
21	1	RIL	RES., CHIP., 18.2k, 0.1W, 1% 0603	VISHAY, CRCW060318K2FKEA
22	1	RCS	SENSOR RES., 0.01Ω 1W 2% 1508 SMD	SUSUMU, RL3720WT-R010-G
22	1	RCX	RES., CHIP., 0.0Ω, 0.1W, 0603	VISHAY, CRCW06030000Z0EA
23	1	RIS1	SENSOR RES., 0.015Ω 1W 2% 1508 SMD	SUSUMU, RL3720WT-R015-G
24	1	RVM1	RES., CHIP., 143k, 0.1W, 1% 0603	VISHAY, CRCW0603143KFEA
25	4	R4, R7, R14, R19	RES., CHIP., 100k, 0.1W, 5% 0603	VISHAY, CRCW0603100KJKEA
26	1	U1	I.C., LTC4000EUF, 28-PIN QFN	LINEAR TECH., LTC4000EUF#PBF

#### DC1380A-B Additional Demo Board Circuit Components

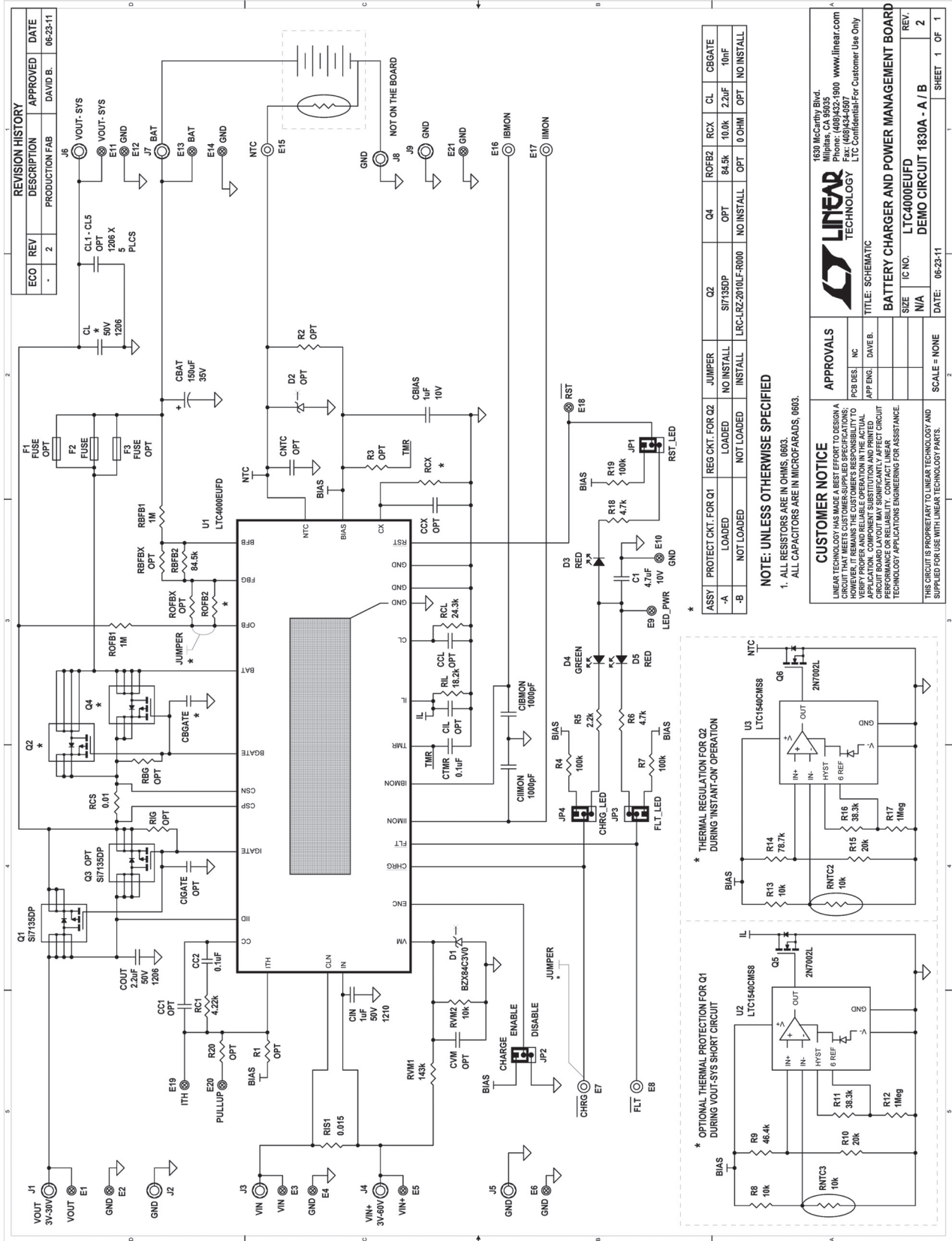
1	0	CC1, CIGATE, CNTC, CCX, CCL, CIL, CVM	CAP., 0603	OPT
2	0	CBGATE	NO INSTALL	
3	0	CL	CAP., 1206, 50V	OPT
4	0	CL1, CL2, CL3, CL4, CL5	CAP., 1206	OPT
5	0	D2	DIODE ZENER, SOT23-3	OPT
6	0	F1,F3	FUSE 12A 32V T-LAG 1206 SMD	OPT
7	0	Q3, Q4	MOSFET P-CHAN., 30V, POWERPAK-8	OPT
8	0	Q5, Q6	SMALL-SIGNAL MOSFET	OPT, ON SEMI., 2N7002LT1G
9	0	R1, R2, R3, R20, RCL, RIG, RBG, RFBX, ROFBX, ROFB2	RES., 0603	OPT
10	0	R8, R13	RES., CHIP., 10k, 0.1W, 1% 0603	OPT, YAGEO, RC0603FR-0710KL
11	0	R9	RES., CHIP., 68.1k, 0.1W, 1% 0603	OPT, VISHAY, CRCW060368K1FKEA
12	0	R10, R15	RES., CHIP., 20k, 0.1W, 1% 0603	OPT, VISHAY, CRCW060320K0FKEA
13	0	R11, R16	RES., CHIP., 38.3k, 0.1W, 1% 0603	OPT, VISHAY, CRCW060338K3FKEA
14	0	R12, R17	RES., CHIP., 1M, 0.1W, 1% 0603	OPT, VISHAY, CRCW06031M00FKEA
15	0	R14	RES., CHIP., 78.7k, 0.1W, 1% 0603	OPT, VISHAY, CRCW060378K7FKEA
16	0	RNTC2, RNTC3	THERMISTOR NTC 10k 5% 0603	OPT, VISHAY, NTHS0603N02N1002J
17	0	U2,U3	NANOPWR COMPARATOR, MSOP8	OPT, LINEAR TECH., LTC1540CMS8#PBF

#### DC1380A-B Hardware—For Demo Board Only

1	14	E1-E6, E9-E14, E18, E19	TESTPOINT, TURRET, 0.061" PBF	MILL-MAX, 2308-2-00-80-00-00-07-0
2	5	E7, E8, E15, E16, E17	TESTPOINT, TURRET, 0.094" PBF	MILL-MAX, 2501-2-00-80-00-00-07-0
3	4	JP1, JP2, JP3, JP4	HEADER, 3-PIN 0.079 SINGLE ROW	SAMTEC, TMM-103-02-L-S
4	4	XJP1, XJP2, XJP3, XJP4	SHUNT, 0.079" CENTER	SAMTEC, 2SN-BK-G
5	9	J1, J2, J3, J4, J5, J6, J7, J8, J9	CONNECTOR, BANANA JACK	KEYSTONE, 575-4
6	4	MTG1, MTG2, MTG3, MTG4	STAND-OFF, NYLON (SNAP ON), 0.50" TALL	KEYSTONE, 8833 (SNAP ON)

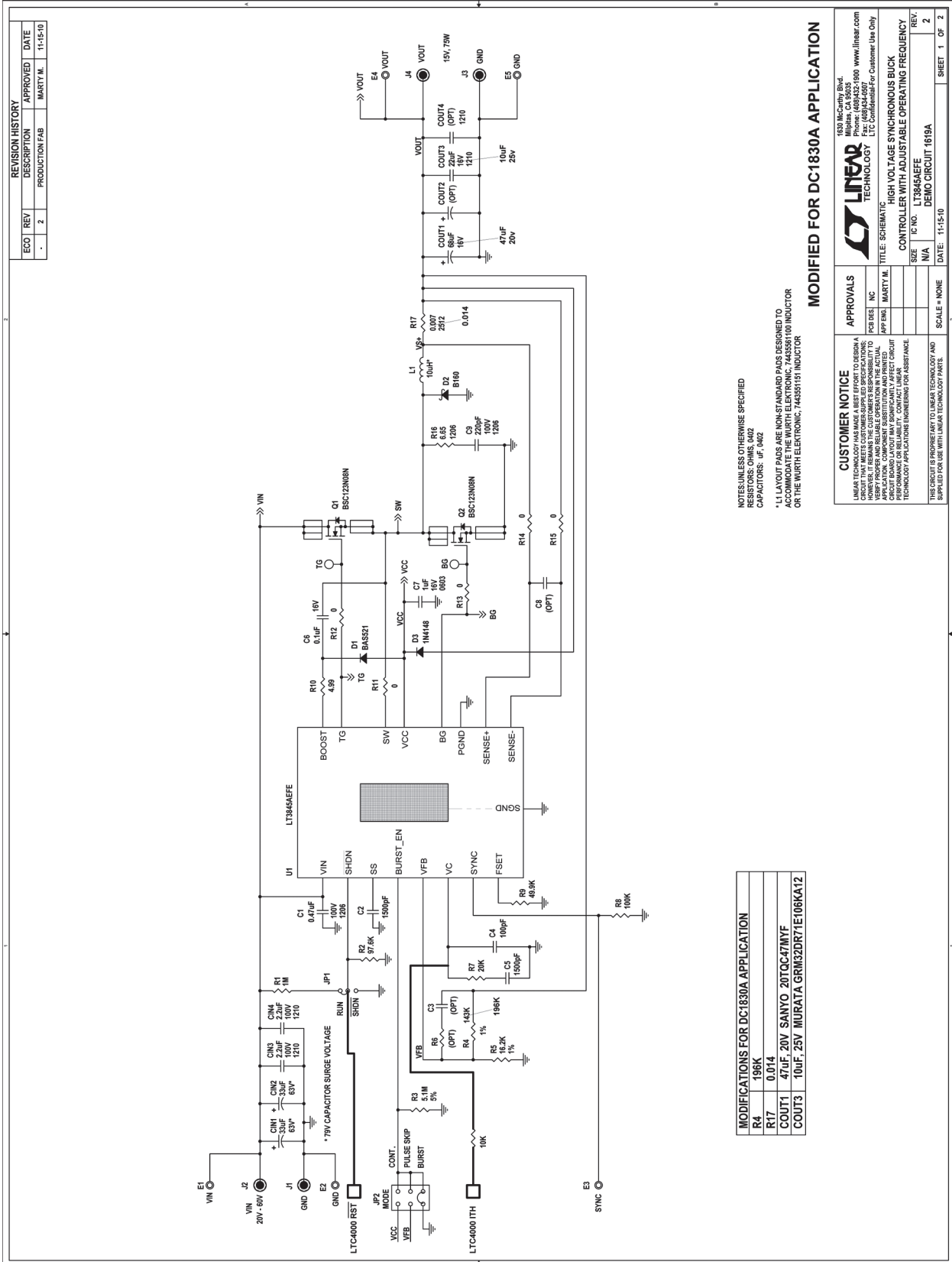
# DEMO MANUAL DC1830A-A/DC1830A-B

## SCHEMATIC DIAGRAM-DC1830A





## SCHEMATIC DIAGRAM—MODIFIED DC1619A AS USED WITH DC1830A



dc1830af

# DEMO MANUAL

## DC1830A-A/DC1830A-B

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### DEMONSTRATION BOARD IMPORTANT NOTICE

Linear Technology Corporation (LTC) provides the enclosed product(s) under the following **AS IS** conditions:

This demonstration board (DEMO BOARD) kit being sold or provided by Linear Technology is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not provided by LTC for commercial use. As such, the DEMO BOARD herein may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including but not limited to product safety measures typically found in finished commercial goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may or may not meet the technical requirements of the directive, or other regulations.

If this evaluation kit does not meet the specifications recited in the DEMO BOARD manual the kit may be returned within 30 days from the date of delivery for a full refund. **THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY THE SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THIS INDEMNITY, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.**

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user releases LTC from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. Also be aware that the products herein may not be regulatory compliant or agency certified (FCC, UL, CE, etc.).

No License is granted under any patent right or other intellectual property whatsoever. **LTC assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or any other intellectual property rights of any kind.**

LTC currently services a variety of customers for products around the world, and therefore this transaction **is not exclusive**.

**Please read the DEMO BOARD manual prior to handling the product.** Persons handling this product must have electronics training and observe good laboratory practice standards. **Common sense is encouraged.**

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

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