LTC3305EFE
Lead Acid Battery Balancer

DESCRIPTION

Demonstration circuit 2043A is a lead Acid Battery Balancer featuring the LTC®3305. The LTC3305 balances up to 4 lead acid batteries connected in series and incorporates all voltage monitoring, gate drive and fault detection circuitry. The LTC3305 employs an auxiliary battery or an alternative storage cell to transfer charge to or from each individual battery within the stack. There are two operating modes, TIMER mode and CONTINUOUS mode, selected by the MODE pin. In TIMER mode, once the balancing operation is complete, the LTC3305 goes to a low power state for a programmed time and then periodically rebalances the batteries. In CONTINUOUS mode, the balancing operation continues even after the batteries are balanced to their programmed termination voltage.

The LTC3305EFE is available in a 7mm × 7mm 38-lead TSSOP surface mount package with exposed pad.

Design files for this circuit board are available at http://www.linear.com/demo/DC2043A

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BOARD PHOTO

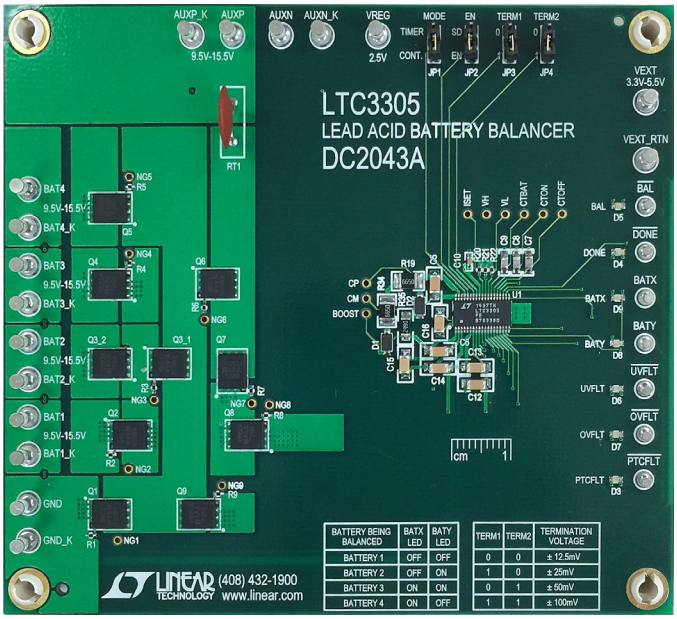


Figure 1. DC2043A Demo Board

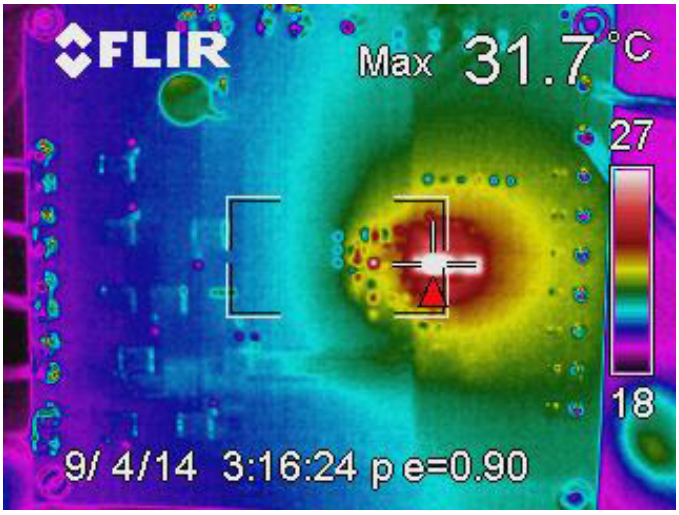


Figure 2. Thermal Image of DC2043A

PERFORMANCE SUMMARY

Specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS	MIN		MAX	UNITS
V_{BAT}	Battery Voltage Range		4.0	to	16.0	V
$V_{TERMINATE}$	Termination Voltage Range	TERM2 = 0, TERM1 = 0	±5	to	±20	mV
$V_{TERMINATE}$	Termination Voltage Range	TERM2 = 0, TERM1 = 1	±17.5	to	±32.5	mV
$V_{TERMINATE}$	Termination Voltage Range	TERM2 = 1, TERM1 = 0	±42.5	to	±57.5	mV
$V_{TERMINATE}$	Termination Voltage Range	TERM2 = 1, TERM1 = 1	±90	to	±110	mV
V_{REG}	Regulator Output Voltage Range	I_{VREG} = 200µA	2.4	to	2.6	V

OPERATING PRINCIPLE

Refer to the block diagram within the LTC3305 data sheet for its operating principle.

The LTC3305 balances batteries using an auxiliary cell or an alternate storage cell as a charge reservoir. The LTC3305 controls external N Channel MOSFET switches in a preprogrammed sequence to connect a battery in the stack to an auxiliary cell. Charge is transferred to or from the auxiliary cell when it is connected to a battery.

The LTC3305 can operate in one of two modes, TIMER mode or CONTINUOUS mode, programmable via the MODE pin. Balancing operation begins once the CBOOST capacitor is charged to at least 6.95V. The EN1 and EN2 pins select the number of batteries in the stack.

EN1	EN2	Application
0	0	SHUTDOWN
0	1	2 Battery Stack
1	0	3 Battery Stack
1	1	4 Battery Stack

With the MODE pin set to 0 the LTC3305 will operate in the TIMER Mode. The $\overline{BAL}$ pin will be pulled low, indicating that the part is enabled and balancing the battery stack. The balancing operation begins with the terminal of the auxiliary cell connected to the negative terminal of BAT1, the lowest battery in the stack. The bottom switches that connect the negative terminals of BAT1 to the Auxiliary cell's negative terminal are turned on. After a 50ms delay, the voltages across the auxiliary cell and BAT1 are compared by the termination sense comparator. If the voltage difference between the auxiliary cell and BAT1 is less than the selected termination voltage, the battery is deemed to be in a balance state with respect to the auxiliary cell. The bottom switches will be turned off and the next battery within the stack will be connected.

If the voltage difference between the auxiliary cell and BAT1 is greater than the selected termination voltage, the top switches that connect the positive terminal of BAT1 to the auxiliary cell's positive terminals through the PTC thermistor are turned on. Current is limited by the PTC thermistor. Figure 3 shows the startup battery current where the PTC is limiting as it heats up. Figure 4 is the steady state battery current after the PTC has reached its thermal equilibrium. After a 50ms delay, the termination sense comparator starts to monitor the voltage across the auxiliary cell and the battery. The battery will remain connected to the auxiliary cell until the voltage difference decreases to the selected termination voltage or a t_{BAT} timeout occurs.

At this point all switches are turned off and the second battery in the stack will be connected to the auxiliary cell after a 50ms delay. This 50ms delay provides a break before make function before the next battery is connect-ed. The cycle will be repeated for each battery in the stack.

OPERATING PRINCIPLE

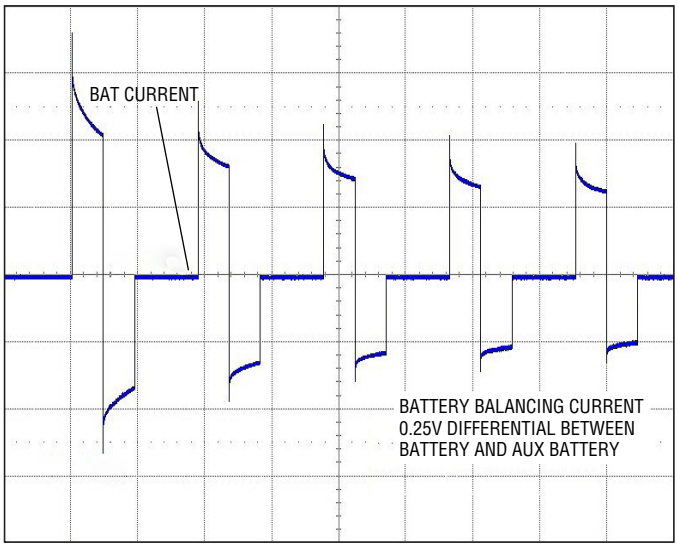


Figure 3. Start-Up Battery Balancing Current

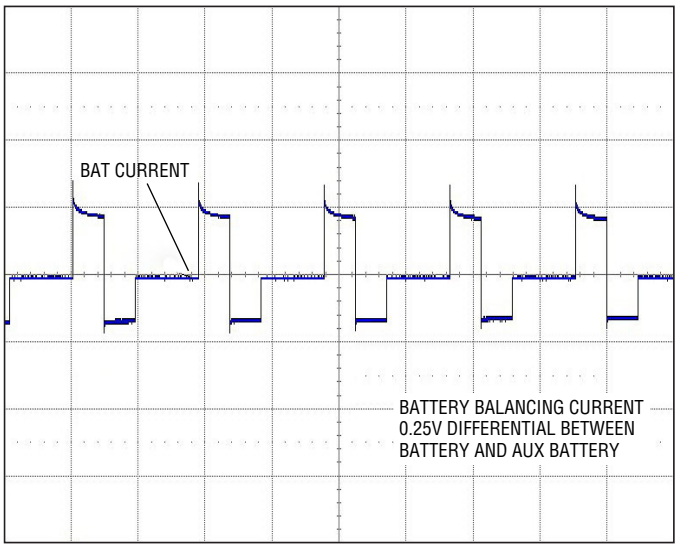


Figure 4. Steady State Battery Balancing Current

Once all batteries in the stack are balanced the $\overline{DONE}$ pin is pulled low, the $\overline{BAL}$ pin is in its high state and the LTC3305 is put into a low power off state. The stack is deemed balanced when for a four battery stack, the termination sense comparator detects $V_{TERMINATE}$ on five consecutive cycles that connects each of the batteries to the auxiliary cell using the bottom switches only.

In TIMER mode, the balancing operation continues for a maximum of the programmed t_{ON} time. After the t_{ON} time, LTC3305 is put into a low power off state for a programmed t_{OFF} time, even though the batteries may not be balanced. Once the t_{OFF} time expires, the LTC3305 is put into the ON state and normal operation resumes. The $\overline{BAL}$ pin is in its high impedance state if the part is in the OFF state or when the part is in shutdown.

With the MODE pin set to 1, the LTC3305 will operate in the CONTINUOUS Mode. The part functions in much the same way as in the TIMER mode with the following differences.

1. There are no ON or OFF states. The balancing operation continues even if the stack is in balance. The balancing operation is terminated only if the part is put into shutdown. The $\overline{BAL}$ pin is always pulled low.
2. In CONTINUOUS mode, the top switches are turned on and balancing operation on a battery is terminated by the t_{BAT} time out. Since the auxiliary cell remains connected to the battery until a t_{BAT} time out, its voltage can change before it connects to the next battery in the stack. As a result, when the stack is balanced and the DONE pin is pulled low, the voltages across individual batteries in the stack may differ by more than the programmed $V_{TERMINATE}$. In the worst case, when the capacity of the auxiliary cell is much smaller than the battery, the individual battery voltages will differ by twice the programmed $V_{TERMINATE}$ when balanced.

The LTC3305 provides undervoltage and overvoltage threshold detection that can be programmed using resistors that are connected between the I_{SET}, VL and VH pins and ground. The voltages set on VL and VH are scaled by a factor of 10, setting the battery undervoltage and overvoltage thresholds, respectively.

When an undervoltage or overvoltage fault condition is detected, the corresponding $\overline{UVFLT}$ or $\overline{OVFLT}$ pin is pulled low. The balancing operation is not interrupted during this time. If the fault condition goes away during balancing, the corresponding fault pin is put into its high impedance state.

QUICK START PROCEDURE

Using short twisted pair leads for any power connections, with all loads and power supplies off, refer to Figure 5 for the proper measurement and equipment setup.

Follow the procedure below:

1. Before connecting PS1-PS5 to the DC2043A, the power supplies must have its current limit set to 5A . For most power supplies with a current limit adjustment feature the procedure to set the current limit is as follows. Turn the voltage and current adjustment to minimum. Short the outputs terminals and turn the voltage adjustment to maximum. Adjust the current limit to 5A for PS1. Turn the voltage adjustment to minimum and remove the short between the output terminals. Repeat for PS2-PS5 The power supplies are now current limited to 5A .

   a. Initial Jumper and PS settings:

   JP1(MODE) = CONT **JP2 (EN)** = SD
   JP3(TERM1) = 1 **JP4 (TERM2)** = 1
   PS1 = Off **PS2** = Off **PS3** = OFF
   PS4 = OFF **PS5** = Off **PS6** = Off

2. Connect power supplies, load resistors and meters as shown in Figure 5. Turn on PS1 and slowly increase voltage to 2.0V while monitoring the input current. If the current remains less than 200mA, increase PS1 to 12.0V. Repeat for PS2-PS4.

3. Turn on PS5 and slowly increase voltage to 2.0V while monitoring the input current. If the current remains less than 200mA, increase PS5 to 11.8V. Turn on PS6 and slowly increase voltage to 2.0V while monitoring the input current. If the current remains less than 20mA, increase PS6 to 5.0V.

4. Measure the voltage from the VREG Turret to ground. The voltage should read approximately 2.6V. Measure the voltage from the BOOST Test Point to V4. The voltage should read approximately 0V. No LED should be on.

5. Set JP2 to EN. Measure the voltage from the BOOST Test Point to V4. The voltage should read approximately 8.5V.

6. Measure the voltage from the I_{SET} Test Point to ground. The voltage should read approximately 1.2V.

7. Measure the voltage from the VH Test Point to ground. The voltage should read approximately 1.52V.

8. Measure the voltage from the VL Test Point to ground. The voltage should read approximately 0.95V.

9. With JP1 set to CONT, JP2 set to EN, JP3 set to 1 and JP4 set to 1, observe that the BATX and BATY LEDs are cycling through their four states.

BATX LED	BATY LED	Active Battery
OFF	OFF	BAT1
OFF	ON	BAT2
ON	ON	BAT3
ON	OFF	BAT4

10. Decrease PS1 and PS5 to 9.4V and observe that while the BATX and BATY are off, the $\overline{\text{UVFLT}}$ LED is on.

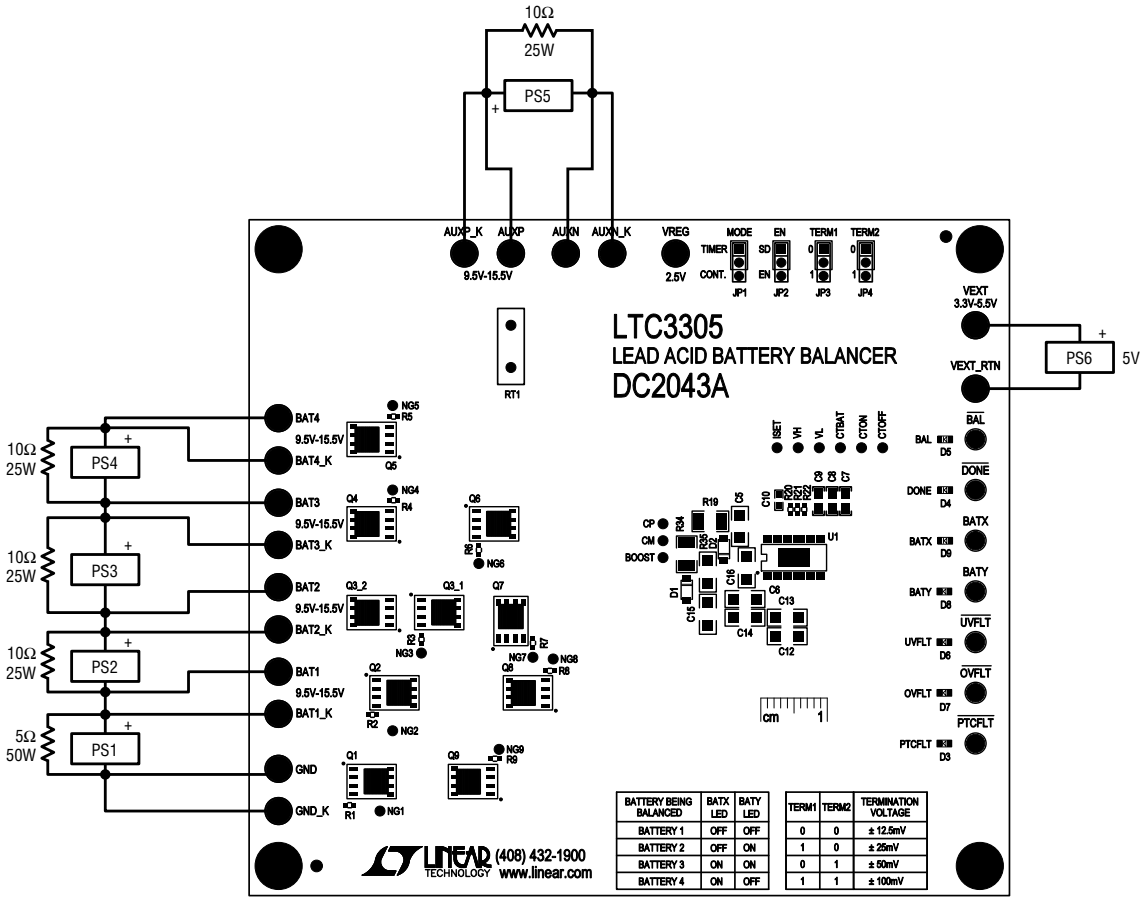
11. Increase PS1 and PS5 to 15.9V and observe that while the BATX and BATY are off, the $\overline{\text{OVFLT}}$ LED is on. Decrease PS1and PS2 to 12.0V.

12. Decrease PS2 to 11.5V. Set JP1 to TIMER. Observe that the BATX LED is off and BATY LED is on the majority of the time .Increase PS2 to 12V and observe that the balancing action stops. The BAL LED will be off and the DONE LED will be on.

13. Set JP1 to CONT and JP2 to SD. Set PS5 to 11.8V. Observe that balancing action has stopped and no LEDs are on. Set JP2 to EN and observe that balancing action starts.

14. Turn off all power supplies

QUICK START PROCEDURE



BATTERY BEING BALANCED	BATX LED	BATY LED
BATTERY 1	OFF	OFF
BATTERY 2	OFF	ON
BATTERY 3	ON	ON
BATTERY 4	ON	OFF

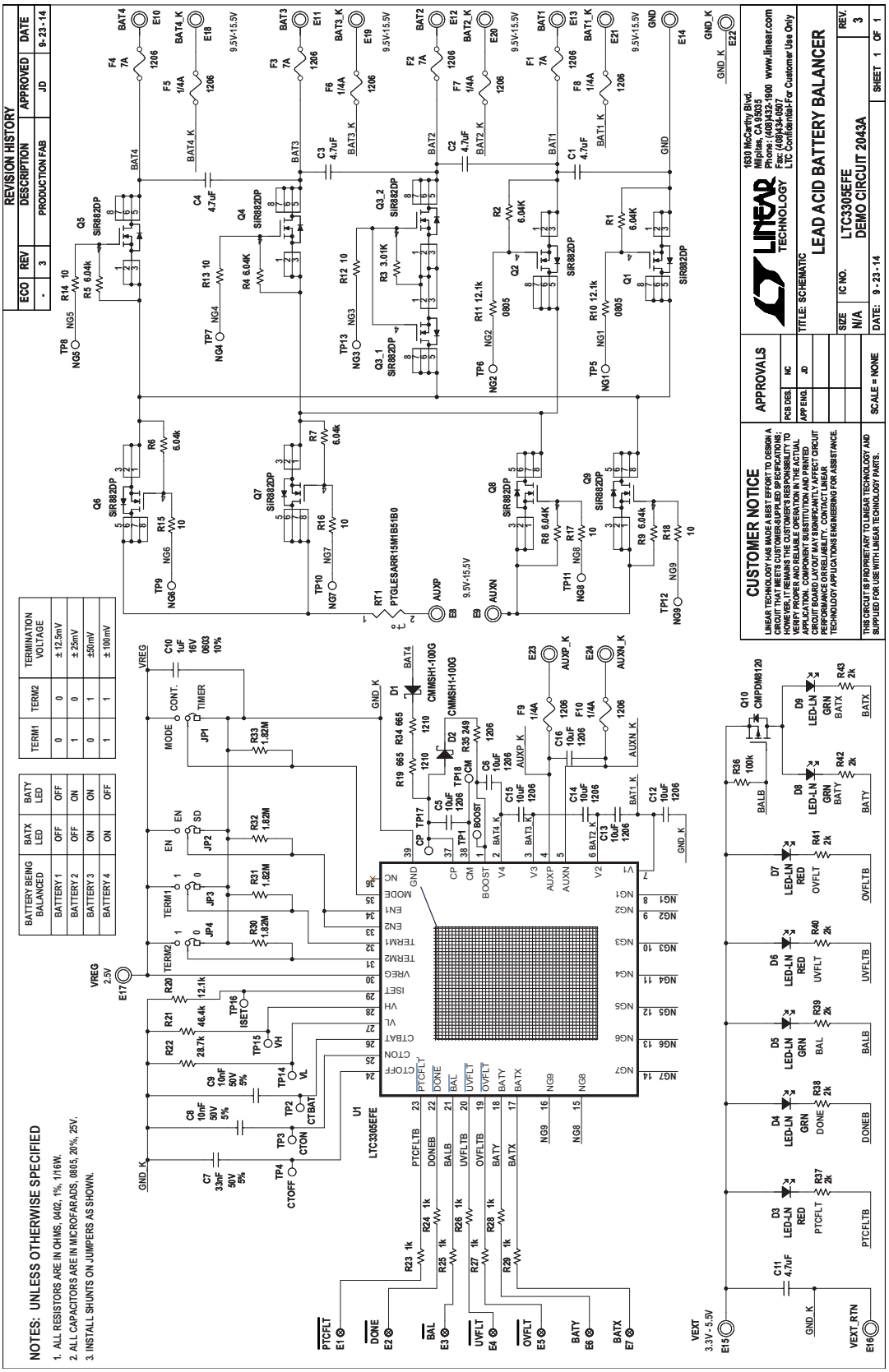
TERM1	TERM2	TERMINATION VOLTAGE
0	0	± 12.5mV
1	0	± 25mV
0	1	± 50mV
1	1	± 100mV

Figure 5. Proper Measurement Equipment Set-Up

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	4	C1-C4	CAP.,X7R, 4.7µF, 25V, 20%, 0805	TDK, C2012X7R1E475M
2	7	C5, C6, C12-C16	CAP.,X7R, 10µF, 25V, 20%, 1206	MURATA, GRM31CR71E106KA12
3	1	C7	CAP.,C0G, 0.033µF, 50V, 5%, 0805	TDK, CGA4J2C0G1H333J125AA
4	2	C8, C9	CAP.,C0G, 0.01µF, 50V, 5%, 0805	TDK, CGA4C2C0G1H103J060AA
5	1	C10	CAP., X7R, 1.0µF, 16V, 10%, 0603	MURATA, GRM188R71C105KA12D
6	2	D1-D2	SMD, SCHOTTKY DIODE, 1A, 100V, SOD123	CENTRAL SEMI, CMMSH1-100G
7	10	Q1-Q3_1, Q3_2, Q4-Q9	MOSFET, 100V, 0.009Ω, 60A,POWERPAK-SO-8	VISHAY, SiR882DP
8	8	R1, R2, R4-R9	RES, CHIP, 6.04k, 1/16W, 1%, 0402	VISHAY, CRCW04026K04FKED
9	1	R3	RES, CHIP, 3.01k, 1/16W, 1%, 0402	VISHAY, CRCW04023K01FKED
10	2	R10, R11	RES, CHIP,12.1k, 1/8W, 1%, 0805	VISHAY, CRCW080512K1FKED
11	7	R12-R18	RES, CHIP, 10.0, 1/16W, 1%, 0402	VISHAY, CRCW040210R0FKED
12	2	R19, R34	RES, CHIP, 665, 1/2W, 1%, 1210	VISHAY, CRCW1210665RFKED
13	1	R20	RES, CHIP, 12.1k, 1/16W, 1%, 0402	VISHAY, CRCW040212K1FKED
14	1	R21	RES, CHIP, 46.4k, 1/16W, 1%, 0402	VISHAY, CRCW040246K4FKED
15	1	R22	RES, CHIP, 28.7k, 1/16W, 1%, 0402	VISHAY, CRCW040228K7FKED
16	4	R30-R33	RES, CHIP, 1.82M, 1/16W, 1%, 0402	VISHAY, CRCW04021M82FKED
17	1	R35	RES, CHIP, 249, 1/4W, 1%, 1206	VISHAY, CRCW1206249RFKED
18	1	RT1	DISC, TH, PTC, 0.15Ω, 16V, 10.1mm DIA,	MURATA, PTGLESARR15M1B51B0
19	1	U1	IC,SMT, LEAD ACID BATTERY BALANCER/EFE	LINEAR, LTC3305EFE#PBF
Additional Demo Board Circuit Components				
1	1	C11	CAP., X7R, 4.7µF, 25V, 20%, 0805	TDK, C2012X7R1E475M
2	3	D3, D6, D7	SMD, RED LED, 0603	LITE ON, LTST-C193KRKT-5A
3	4	D4, D5, D8, D9	SMD, GREEN LED, 0603	LITE ON, LTST-C193KGKT-5A
4	4	F1-F4	SMD, FUSE, 7A, FAST ACTING, 1206 32VDC	BUSSMANN, 3216FF7-R
5	6	F5-F10	SMD, FUSE, 1/4A, FAST ACTING, 1206 32VDC	BUSSMANN, 3216FF250-R
6	1	Q10	MOSFET, P-CHANNEL, 20V, 0.085Ω, 0.95ASOT-23	CENTRAL SEMI, CMPDM8120
7	7	R23-R29	RES, CHIP, 1.00k, 1/16W, 1%, 0402	VISHAY, CRCW04021K00FKED
8	1	R36	RES, CHIP, 100k, 1/16W, 1%, 0402	VISHAY, CRCW0402100KFKED
9	7	R37-R43	RES, CHIP, 2.00k, 1/16W, 1%, 0402	VISHAY, CRCW04022K00FKED
Hardware: For Demo Board Only				
1	7	E1-E7	Turret, 0.061"	MILL-MAX, 2308-2-00-80-00-00-07-0
2	17	E8-E24	Turret, 0.09"	MILL-MAX, 2501-2-00-80-00-00-07-0
3	4	JP1-JP4	HEADER, 3PINS, 2mm	SAMTEC, TMM-103-02-L-S
4	4	JP1-JP4	SHUNT 2mm	SAMTEC, 2SN-BK-G
5	6		STAND-OFF, NYLON 0.375" tall	KEYSTONE, 8832 (SNAP ON)

SCHEMATIC DIAGRAM



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