TI Designs: TIDA-00587
Charger Booster Pack

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Design Resources

TIDA-00587	Design Folder
bq24250RGER	Product Folder
TS3A44159PWR	Product Folder
DAC8560IDDGK	Product Folder
OPA334AIDBV	Product Folder
REF3225AIDBVR	Product Folder

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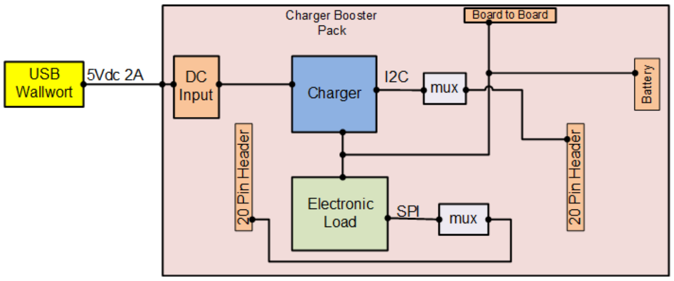
Block Diagram



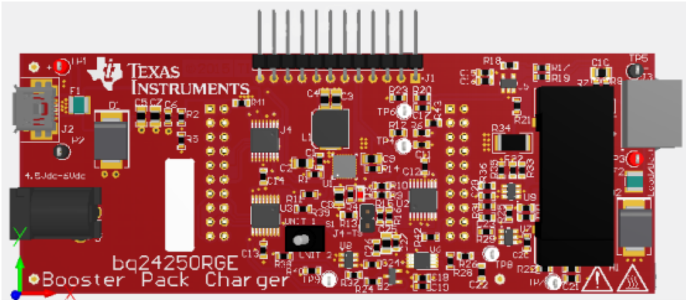
Design Features

- bq24250 Booster Pack Charger
- 1A Electronic Load on board
- Use this booster pack board with any Launchpad or operate in stand-alone mode
- Use both booster pack boards (charger and gauge) with a TM4C DK-TM4C129X Launchpad for a complete battery management solution
- Resettable fuse and reverse polarity protection on the board for power in and battery connections
- Complete charger solution on one board
- Promotes a fast learning curve to understand charging
- Connect your own controller board or a Launchpad to:
  - Test your code
  - Charge and discharge your battery for cycle testing

Featured Applications

- Battery Operated Instruments
- Hand Held Electronics
- IoT (Internet of Things)

Board Image



1 Key System Specifications

Charger			
bq24250	**Value**	**Ref**	**Description**
VINmin	4.35	Vdc	Minimum Startup input voltage
VINmax	10.5	Vdc	Maximum operating input voltage
Iq	5	mA	Quiescent current
I_out	2	A	Maximum output current
Default_OVP	10.5V	Vdc	Input over voltage protection
Default_Voreg	4.2	Vdc	Output voltage regulation
VBAT_UVLO	2.5	Vdc	Battery Under voltage lockout threshold
VBATSHRT	2	Vdc	Trickle charge to pre-charge threshold
Electronic Load			
DAC8560			
Vin_min	2.7	Vdc	Minimum input voltage
Vin_max	5.5	Vdc	Maximum input voltage
Resolution	16	bits	Total bits of resolution
Accuracy	4	+/- bits	Relative accuracy
Zero-code error	4	+/- mV	Output voltage when code 0
Slew rate	1.8	V/us	Output slew rate
REF3225			
Vin_min	3.0	Vdc	Minimum input voltage
Vin_max	5.5	Vdc	Maximum input voltage
Vref	2.5	Vdc	Output reference volltage
Imax	40	mA	Max charge current
Drop out V	50	mV	Max continuous current
Load regulation	20	uA/mA	Voltage error do to load
Accuracy	0.2	%	Initial Accuracy
Noise	33	uVpp	Peak to peak noise in the reference voltage

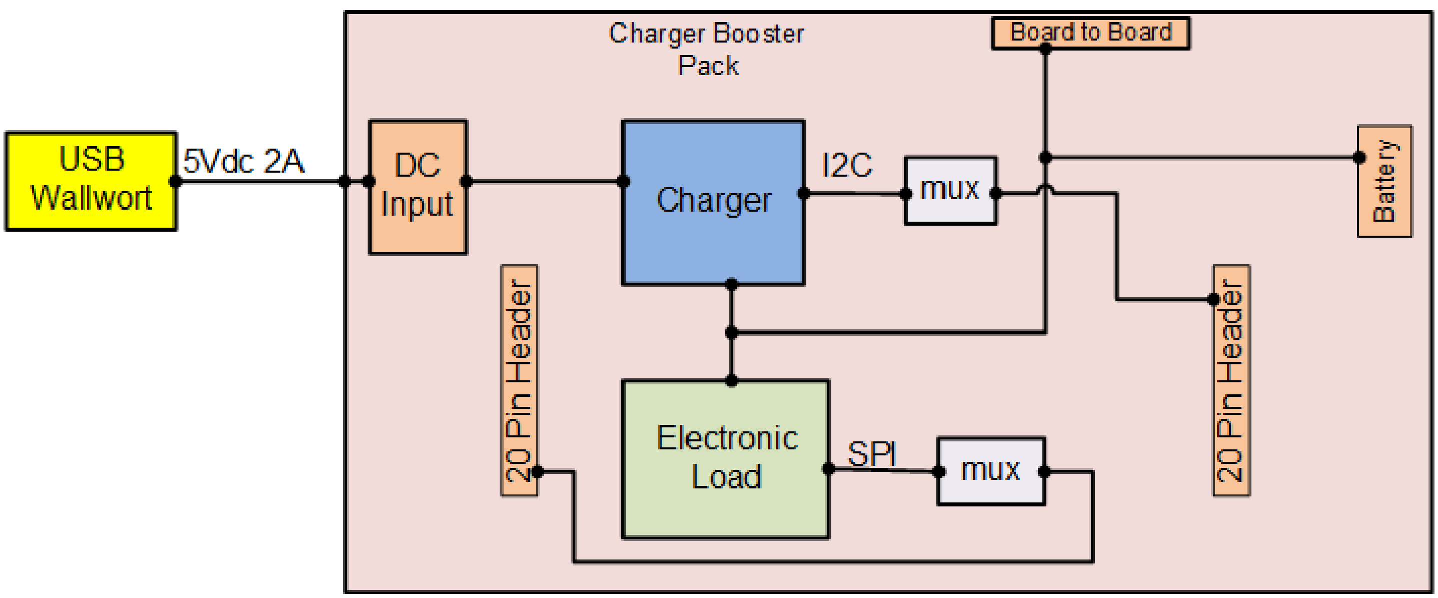
2 System Description

The booster pack series of boards allows the user to connect the desired circuitry directly to a Launchpad for easy test and code development. All Launchpad's have a standard header pin configuration. The standardized headers make it possible to use different Launchpad's with different Booster Packs to build, test and create new designs very quickly.

The bq24250 Charger Booster Pack board was designed to provide a means to test and develop with the bq24250 charger IC in a simple easy to use booster pack board. You can connect your battery directly to the battery connector of the charger board or connect your gauge and battery to the battery connector.

This booster pack board has a digital controlled electronic load that can discharge your battery. This will allow for charging and discharging batteries for cell testing and cycling. There is a two port mux on this board that will allow the user to stack two charger booster pack boards on the same Launchpad and by using a chip select method one Launchpad can control both charger booster pack boards at the same time. If you choose not to use the mux you can simply set the mux ID switch to the desired position and set chip select one time for the one board. Use a 5V 2A wall plug in supply or a bench power supply to use the charger booster pack board. There is a board to board connector on this board that will allow you to pug in the Gauge Booster Pack board (TIDA-00586) then connect both of them to the TM4C Launchpad providing a complete charger and gauge battery management system.

The charger uses I2C and the electronic load uses SPI to communicate with the Launchpad. This booster pack can also operate independently without the use of any controller. The bq24250 uses resistors to program the default charging current. This unit was setup to default to a 2A charging rate, but can easily be changed to charge at your desired current. The bq24250 has input current regulation that will limit how much current that it will draw to prevent the input voltage from being collapsed. These features make this board very versatile and adaptable to any application.

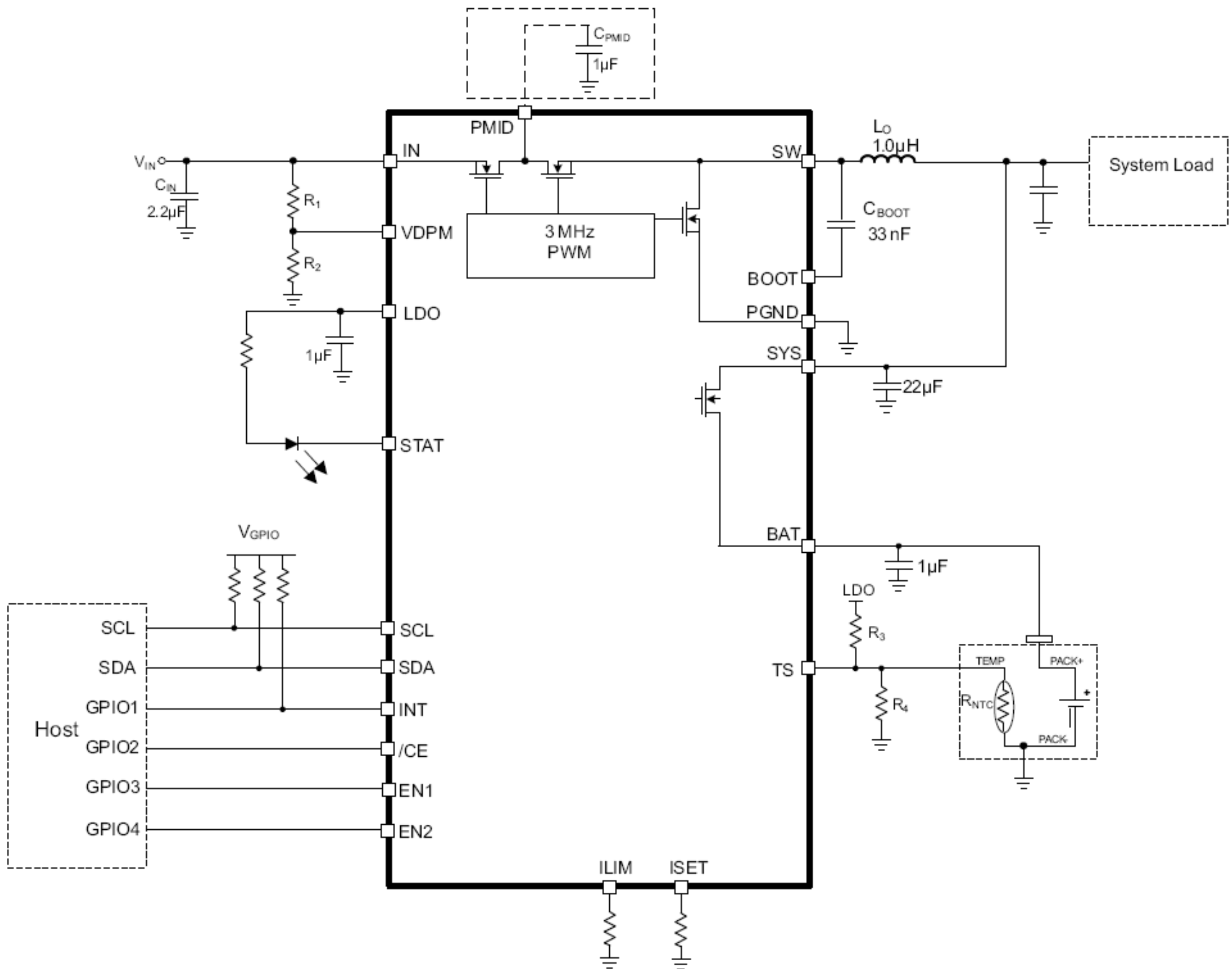


2.1 Bq24250

The bq24250 is a highly integrated single-cell Li-Ion battery charger and system power-path management device targeted for space-limited, portable applications with high capacity batteries. The single cell charger has a single input that operates from either a USB port or AC wall adapter for a versatile solution.

The power path management feature allows the bq24250 to power the system from a high efficiency DC/DC converter while simultaneously and independently charging the battery. The charger monitors the battery current at all times and reduces the charge current when the system load requires current above the input current limit. This allows for proper charge termination and enables the system to run with a defective or absent battery pack. Additionally, this enables instant system turn-on even with a totally discharged battery or no battery. The power-path management architecture also permits the battery to supplement the system current requirements when the adapter cannot deliver the peak system currents. This enables the use of a smaller adapter.

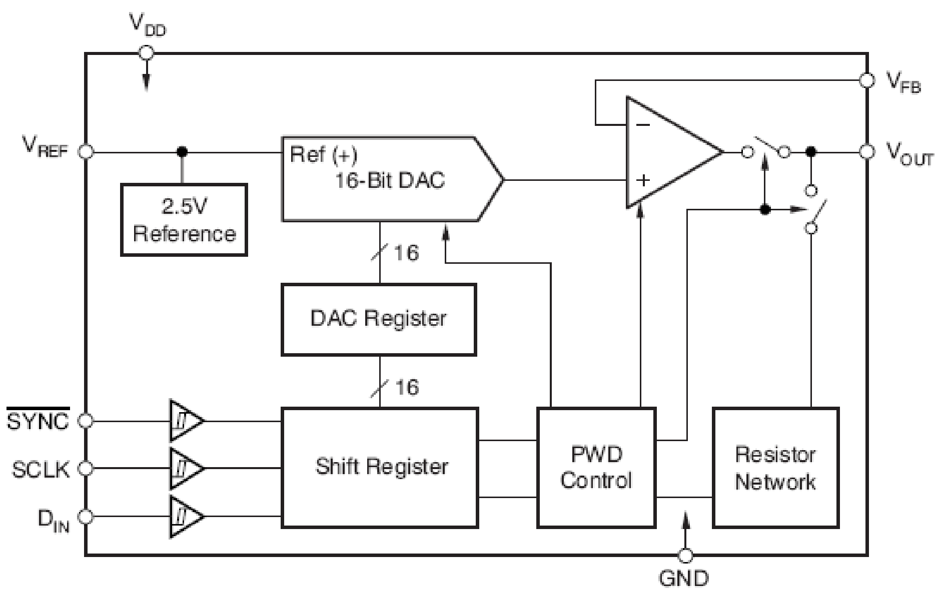
The battery is charged in four phases: trickle charge, pre-charge, constant current and constant voltage. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if the internal temperature threshold is exceeded. Additionally, a voltage-based, JEITA compatible battery pack thermistor monitoring input (TS) is included that monitors battery temperature for safe charging.



2.2 DAC8560

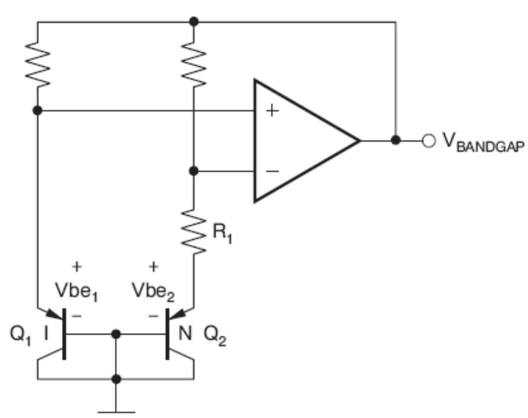
The DAC8560 is a low-power, voltage output, 16-bit digital-to-analog converter (DAC). The DAC8560 includes a 2.5V, 2ppm/° C internal reference (enabled by default), giving a full-scale output voltage range of 2.5V. The internal reference has an initial accuracy of 0.02% and can source up to 20mA at the V_{REF} pin. The device is monotonic, provides very good linearity, and minimizes undesired code-to-code transient voltages (glitch). The DAC8560 uses a versatile 3-wire serial interface that operates at clock rates up to 30MHz. It is compatible with standard SPI™, QSPI™, Microwire™, and digital signal processor (DSP) interfaces. The DAC8560 incorporates a power-on-reset circuit that ensures the DAC output powers up at zero-scale and remains there until a valid code is written to the device. The DAC8560 contains a power-down feature, accessed over the serial interface that reduces the current consumption of the device to 1.2 µ A at 5V.

The low-power consumption, internal reference, and small footprint make this device ideal for portable, battery-operated equipment. The power consumption is 2.6mW at 5V, reducing to 6 µ W in power-down mode.



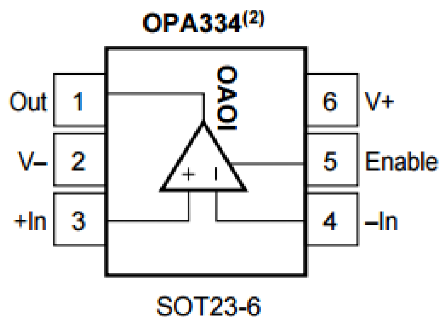
2.3 REF3225

The REF3225 is a very low drift, micro-power, low-dropout, precision voltage reference. The small size and low power consumption (120 µ A max) of the REF3225 make it ideal for portable and battery-powered applications. This reference is stable with any capacitive load. The REF3225 can be operated from a supply as low as 5mV above the output voltage, under no load conditions. All models are specified for the wide temperature range of -40° C to +125° C.



2.4 OPA334

The OPA334 and OPA335 series of CMOS operational amplifiers use auto-zeroing techniques to simultaneously provide very low offset voltage (5µV max), and near-zero drift over time and temperature. These miniature, high-precision, low quiescent current amplifiers offer high input impedance and rail-to-rail output swing. Single or dual supplies as low as +2.7V (±1.35V) and up to +5.5V (±2.75V) may be used. These op amps are optimized for low-voltage, single-supply operation. The OPA334 family includes a shutdown mode. Under logic control, the amplifiers can be switched from normal operation to a standby current of 2µA. When the Enable pin is connected high, the amplifier is active. Connecting Enable low disables the amplifier, and places the output in a high impedance state.



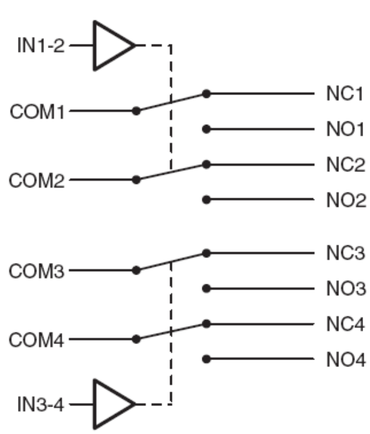
2.5 TS3A44159

The TS3A44159 is a quad single-pole double-throw (SPDT) analog switch with two control inputs, which is designed to operate from 1.65 V to 4.3 V. This device is also known as a dual double-pole double-throw (DPDT) configuration. It offers low ON-state resistance and excellent ON-state resistance matching with the break-before-make feature, to prevent signal distortion during the transferring of a signal from one channel to another. The device has an excellent total harmonic distortion (THD) performance and consumes very low power. These features make this device suitable for portable audio applications.

FUNCTION TABLE

IN	NC TO COM, COM TO NC	NO TO COM, COM TO NO
L	ON	OFF
H	OFF	ON

LOGIC DIAGRAM



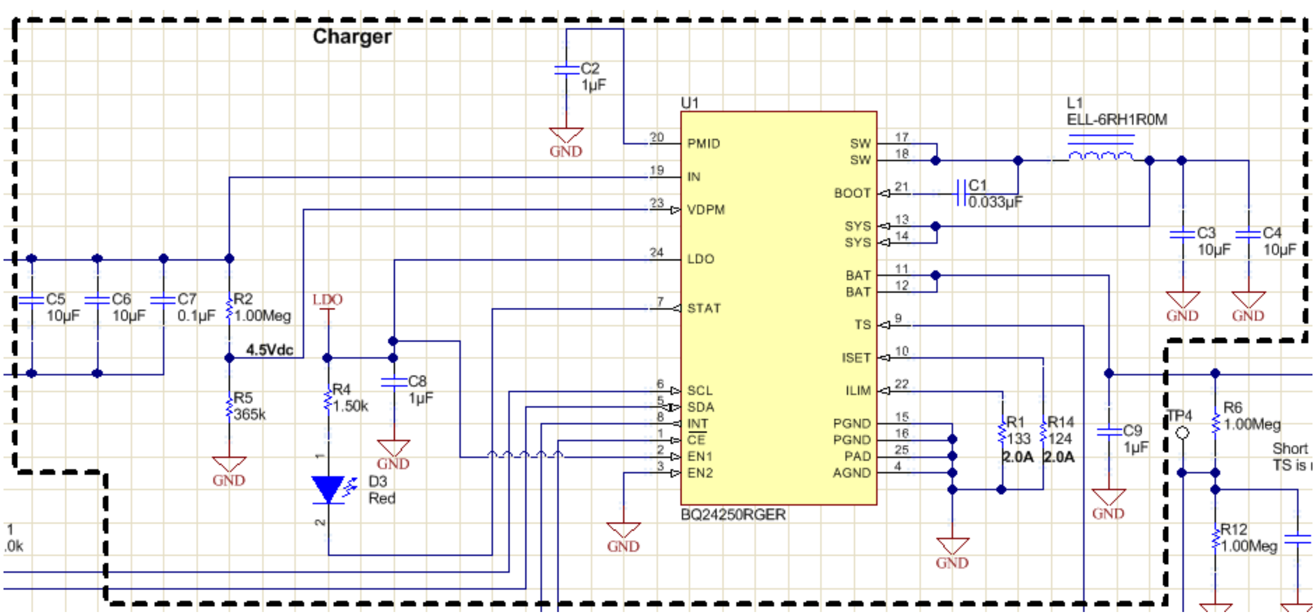
3 Getting Started

The charger boost pack design can be broken down into key operations or functions. Each area will be isolated and described to help a user understand the full functionality of this board.

3.1 Charger

The charger is a single IC solution that incorporates a switch mode buck charger with power-path management. Note: that the charger booster pack board does not use the power-path management circuit as there is not a system connected. Instead the electronic load and gauge are connected directly to the battery out pins of the IC. If a user wants to connect the charger board to a system, modifications to the board will be necessary, but are very easy to make. Add a positive wire to the L1, C3, C4 connection point and add a ground wire to the opposite end of C3 and C4.These wires can then be used to provide system power with power-path capabilities to you device.

The entire charger circuit consists of a charger IC, Inductor, input and output capacitors, a PMID capacitor, an LDO capacitor, a few resisters for setting the desired input and output currents and thresholds, and the temperature sensing network for monitoring the temperature of the cell that will be charged.



3.2 Electronic Load

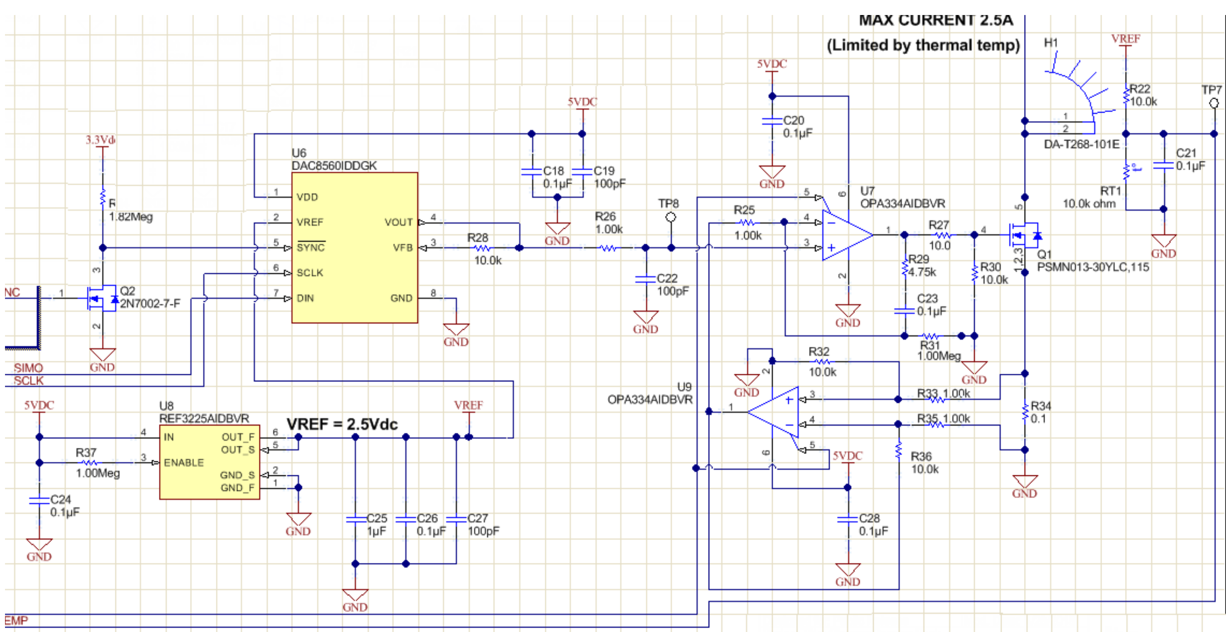
The electronic load is a digital input, closed loop Mosfet controlled electronic load. Any micro-controller can control the electronic load using a SPI interface. The SPI will set the output value of a 16bit DAC. The DAC places a voltage on the op-amp input positive pin. This sets the reference for the closed loop current feedback that will drive the Mosfet in the linear region to set the current across the current shunt. The current across the shunt will be amplified and feed back to the controlling op-amp completing the loop.

The voltage reference to output current is approximately 1mV = 1mA. This means that 2.5V (max DAC output voltage) is equal to 2.5A. The electronic load can be used up to 1A with no fan or little air movement. It can be driven to 2.5A with the proper air movement from a high volume fan placed close to and pushing air across the heat sink. There is an ADC on the board that will provide the heat sink temperature via a thermistor connected to the heat sink. (See the ADC section on information on using the ADC)

WARNING: It is up to the user to monitor the temperature of the heat sink and turn down or shut down the electronic load if the temperature goes above 85C on the Mosfet (that' about 70C on the heat sink) . Failure to do so will end up in destroying the electronic load.

There is an external 2.5V VREF that drives the DAC and the current measuring ADC on this board. There is an enable line that will enable or disable the op-amps to prevent false startups and prevent current sinking when not in use.

When driving or setting the electronic load there will be an offset error, slope error, and a gain error. These errors mean that you can't just set the DAC to 1000mV and expect the load to be 1A with any kind of accuracy. The simplest method of correcting for these errors is to use a PI control loop in your software routine. It is necessary to use a P control loop at a minimum and its preferred use a PI control loop. If you feel adventures try a full PID control loop.



3.2.1 PID Control Loop

This is the PID control loop that was used in testing the electronic load. The TM4C is a 32 bit floating point controller.

NOTE: This routine can be converted to fixed point processing with a 32bit processor. It is not possible to make this routine work with 16bits. There are P and PI control loops out here that will run on 16 bits. Please research these methods if needed.

```
// C code for floating point PID Control loop
int desired_value = 1000;          // Set the value you want to achieve i.e. 1A set in milli-amps
int measured_value = 0;                    // This is the measured value, typically comes from ADC or other feedback

double actual_error_1 = 0;
double error_previous_1 = 0;
double P_1 = 0;                            // These values must start at zero when beginning the PID loop
double I_1 = 0;                            // These values must start at zero when beginning the PID loop
double D_1 = 0;                            // These values must start at zero when beginning the PID loop
double Kp_1 = 0.09;                        // set these values to achieve the desired results in the control loop
double Ki_1 = 0.06;                        // set these values to achieve the desired results in the control loop
double Kd_1 = 0.05;                        // set these values to achieve the desired results in the control loop

// PID Control loop proportional-integral-derivative controller----------------------------------------------

        int PID_Controller_1 (int set_point_1, int measured_value_1)
        {
                error_previous_1 = actual_error_1;                  //error_previous_1 holds the previous error
                actual_error_1 = set_point_1 - measured_value_1;

                P_1  = actual_error_1;                      // Current error
                I_1 += error_previous_1;                    // Sum of previous errors
                D_1  = actual_error_1 - error_previous_1;   // Difference with previous error

                return ((Kp_1*P_1) + (Ki_1*I_1) + (Kd_1*D_1));  // adjust Kp, Ki, Kd empirically or by using online method
        }

// too call the PID controller and send the values to correct to (this should be setup in a continuous loop in your code)

new_set_value = PID_Controller_1(desired_value, measured_value));
```

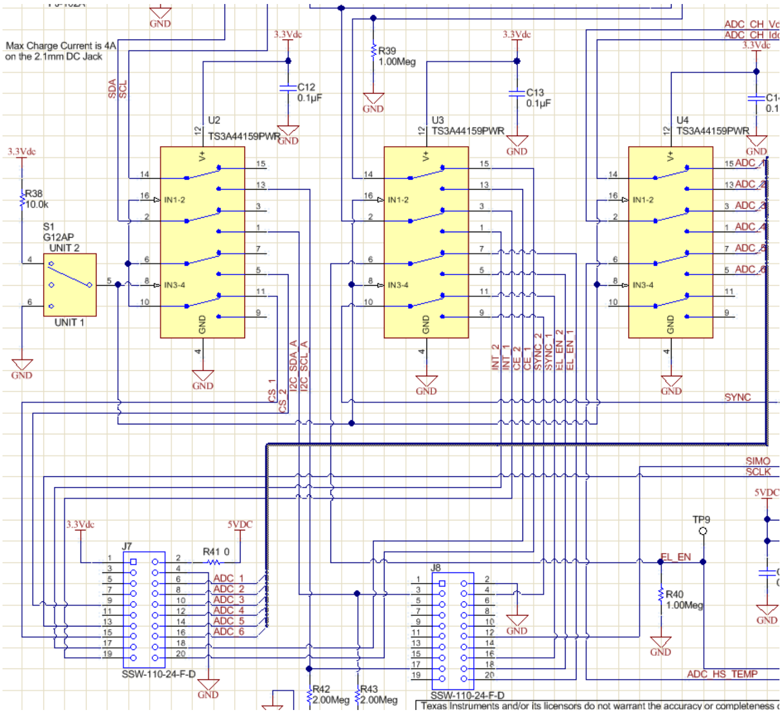
// send the “new_set_value” variable to the DAC in your loop. I ran a loop every 250mS to correct the load value 4 times a second. You will need to add a read from the ADC to get the present measured value. Calculate the new value, then write the new value to the DAC.

The DAC is 16bits. That’s 65536 total bits. The volts per bit is 0.00003815. Setting a bit value to 26214 will set the DAC to 1000mV = 1000mA load. The desired current load will be corrected if the PID control loop is used.

DO NOT operate the electronic load without monitoring the heat sink temperature.

3.3 Mux

The mux is a series of analog switches that will allow the selected board to see the communications based on the board ID selected. The user can set one board to chip select 1 and a second board to chip select 2. This will allow communications with both boards by using only a single chip select line. You do not have to steer the communication lines this is done for you in the mux. If you have only one board then select the unit ID and use the proper chip select pin. The mux controls the communications lines for the charger, electronic load and the ADC's for voltage, current and the heat sink temperature. When using the charger circuit for your design you do not need the mux circuitry.



3.4 ADC (Current, Voltage and Temperature)

There are three ADC circuits on this board. The voltage is a direct measurement at the BATT pin of the charger IC. The current is a direct measurement of the current in and out of the external battery connection. (Note: If connecting to the header marked for direct connect to the gauge board, then this current measurement circuit will not show a current) The battery current will come from the gauge IC. The temperature that is being measured by the ADC is the actual temperature of the heat sink for the electronic load. It is recommended to operate the mico-controllers ADC VREF at 2.5V.

3.4.1 ADC Voltage

The voltage measurement is a simple resistor divider to set the output voltage to a value that can be measured by the controller ADC. For a max voltage range of 0V-5V scaled to 0V-2.5V there are two 1Meg Ohm resisters that are used as the voltage divider. The ADC will provide a bit value that will need to be multiplied by 2, and then multiply by 0.00003815V. (If the ADC is not 16bits. Change this value to volts per bit based on the ADC that is being used)

3.4.2 ADC Current

The current measurement is a bi-direction current reading showing current in both directions while charging and discharging. There is an averaging or accumulator filter across the current shunt that will help to average current spikes into the measured current. The op-amp that is providing the measured voltage from the current shunt has a 5V rail and has an offset center of 2.5V that comes from the VREF IC. This means that 2.5V is zero current. When a discharge current is applied the voltage will move from zero (2.5V) towards 0.0V. When a charge current is applied the voltage from the op-amp will move from zero (2.5V) towards 5V. This will provide a full scale reading of +/- 2.5V for a full scale current of +/-2.5A. The output of the op-amp is divided by half to adjust the full scale op-amp voltage output of 0V-5V to 0V-2.5V to be within the range of the controllers ADC.

Take the measured bit value and multiple it by 2, then multiple that by 0.00003815V (If the ADC is 16bits. Change this value to volts per bit based on the ADC that is being used) to get the actual voltage out of the op-amp. This value will need to be subtracted by 2.5V to give you zero current. The value left over will be a positive voltage to show that the unit is charging or a negative value to show that the unit is being discharged. 1mV = 1mA of current approximately. There will be an offset error and a slope error due to the characteristics of the op-amp and a current measurement error due to the tolerances of the shunt resister.

3.4.3 ADC Heat Sink Temperature

The temperature measurement circuit is a simple resister divider with the lower resister being a 10k Thermistor. The voltage biasing the thermistor is 2.5V from the VREF circuit. The easiest method of getting the actual temperature reading is a simple lookup table. Convert the measured bit value to a voltage and look up the temperature based on the voltage drop across the thermistor.

The most accurate method is to use the Steinhart-Hart equation to calculate the temperature value.

$(1/T = A + B(\ln R) + C(\ln R)^3)$, T in degrees Kelvin

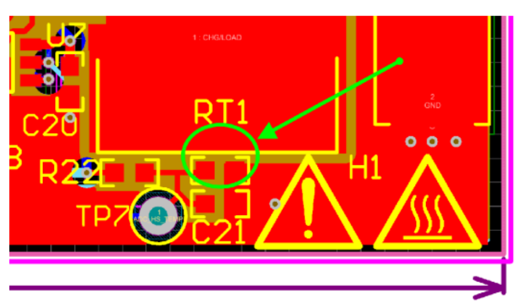
T is the absolute temperature (in Kelvin) and A, B, and C are constants which can be determined from measured values of resistance and temperature.

A, B, C = constants based on the co-efficient of the temperature slope
R = NTC resistance
Ln = Natural Log
T = Temperature in Kelvin
C = Celsius (Kelvin - 273.15)

It's up to the user to research and determine the best method of resolving the temperature measurements.

DO NOT operate the electronic load without monitoring the heat sink temperature.

In order to measure the temperature of the heat sink you must make a thermal connection between the thermistor and the heatsink. Place a 200mil spot of Loctite Output 315 over RT1 and the exposed area on the heatsink copper pad (You must use the recommended activator). This is thermally conductive glue that is electrically isolating. You must cover RT1 and exposed copper. Allow to cure the recommended time.



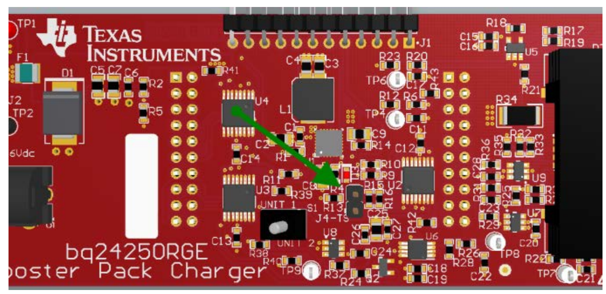
3.5 Input / Output and Protection

There is a PTC and a protection TVS diode on the Input and output connectors of this board. The TVS diode will protect the circuit from transient voltages above 6.8V and reverse polarity. You must remove the Input TVS(D1) if you plan on operating the input voltage up to the max of 10.5Vdc. The PTC is a Polyswitch resettable fuse rated at 1.9A hold and 4.9A trip current. The PTC will open on currents that short the current flow in the input or output connectors. Once the short has been eliminated the PTC will reset. This protects this circuit and your circuit against high currents and shorts.

Warning: There is no cell or battery protection on this board. It is up to the user to provide the proper protection based on the cell or battery used and the type of testing that this board is intended for.

3.6 Thermal Protection Jumper

J4-TS is the temperature sensor bypass jumper. It is located in the middle of the board. When using a cell that has an internal thermistor, you must remove the J4-TS jumper. If your cell only has two wires (positive and negative) then add the J4-TS jumper. Adding the jumper will bypass the thermistor and use a fixed 10k resistor to fool the charger into thinking there is a thermistor attached to the cell.



Warning: It is the responsibility of the user to take all precautions to monitor the cell temperature during charging or discharging of the cells.

3.7 Headers

There are two 20 pin headers that use standardized pin functions. Below is the pin connections used for the charger booster pack.

Booster Pack 40Pin (Charger/Load)

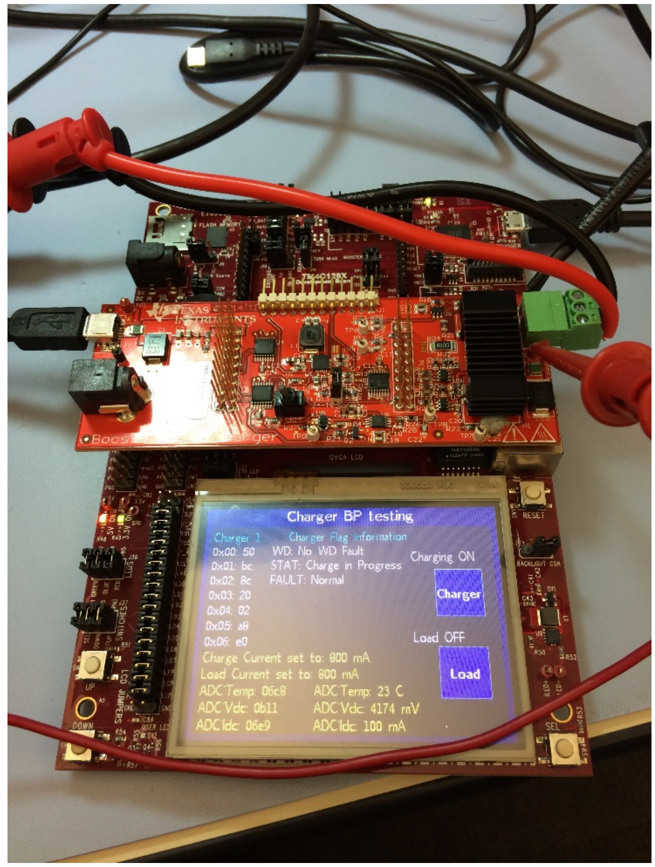
J29	IC Pin Name	Function	IC Pin #	J29	IC Pin Name	Function	IC Pin #	J30	IC Pin Name	Function	IC Pin #	J30	IC Pin Name	Function	IC Pin #
A1	3.3V_Main			C1	5V			D1	PM5/T4CCP1		G15	B1	GND		
A2	PE2/AIN01		G1	C2	GND			D2	PD3/I2C8SDA	I2C_A_SDA	D1	B2	PS2/T3CCP0	SYNC_2	B14
A3	PH6/U5RX		U2	C3	PE3/AIN00	ADC_CH_Idc_1	G2	D3	PS3/T3CCP1		A14	B3	PQ7/LED_G		M3
A4	PH7/U5TX		V2	C4	PE6/AIN20	ADC_CH_Idc_2	A7	D4	PL5/T0CCP1		G19	B4			
A5	PN7	CS_2	U12	C5	PK0/AIN16	ADC_CH_Vdc_1	J1	D5	PL4/T0CCP0		H18	B5	RESET		
A6	PF3/SSI3CLK		T7	C6	PK1/AIN17	ADC_CH_Vdc_2	J2	D6	PS0/T2CCP0		D12	B6	PG5/SSI2XDAT0	SPI_MOSI	K15
A7	PG7/SSI2CLK	SPI_SCLK	U14	C7	PK2/AIN18	ADC_HS_TEMP_1	K1	D7	PS1/T2CCP1		D13	B7	PG4/SSI2XDAT1		K17
A8	PJ2	CS_1	H17	C8	PK3/AIN19	ADC_HS_TEMP_2	K2	D8	PQ3/T7CCP1		M4	B8	PN0	SYNC_1	C10
A9	PB4	INT_1	C6	C9	PE0/AIN03	CE_2	H3	D9	PD2/I2C8SCL	I2C_A_SCL	D2	B9	PN1	EL_EN_2	B11
A10	PJ7	INT_2	K5	C10	PE1/AIN02	CE_1	H2	D10	PM7/T5CCP1		N18	B10	PN2	EL_EN_1	A11

4 Test Setup

5 Description of the test setup

Test equipment:

- TDS2024B Tektronix Scope
- 189 Fluke Multi-meter
- 2400 Keithley Source Meter
- DI-158U Dataq Data Acquisition Module
- 1 TM4C Launchpad (code written in C using TI's CCS studio)
- 5V 2A USB wall power supply
- 3.6V LI-ION battery pack rated at 1260mAh



A utility set of C code was written to allow the use of the TM4C Launchpad as a test platform. The charger booster pack was attached to the Launchpad and the ID was set to unit 1. A battery was connected to the right output connector. A USB 5V 2A wall power supply was used to power the charger and TM4C Launch pad.

6 Test Data

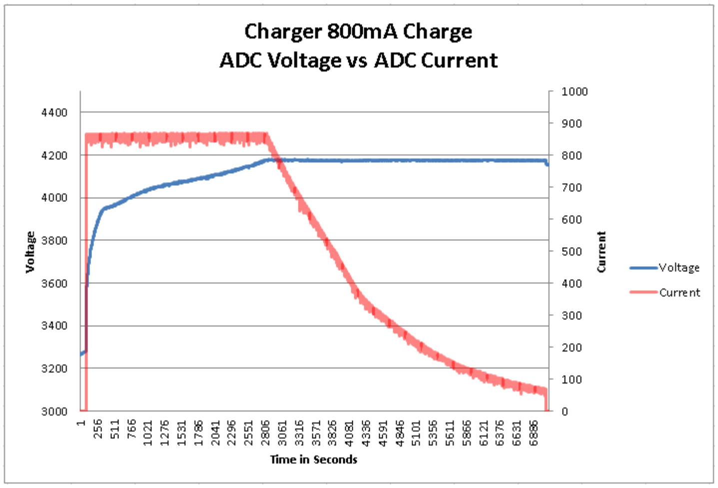
The following description explains the test plots that show the process of charging and discharging using the charger booster pack as the charger and the on board electronic load as the method of discharge.

The first plot is a charge test. This was a full charge from 0% SOC to a full charge that was terminated by the charger with no input from the Launchpad or other source.

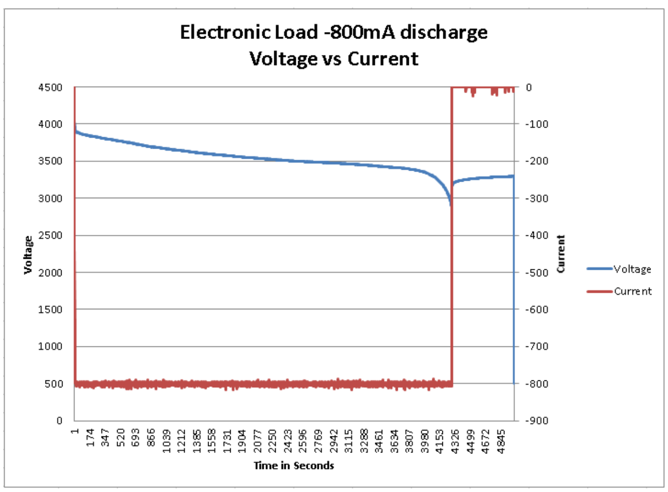
The second plot is a discharge test using the electronic load to discharge the cell from 100% SOC to the designated minimum discharge voltage of 3.2V. The second plot in this category shows the temperature rise of the heat sink while discharging the cell.

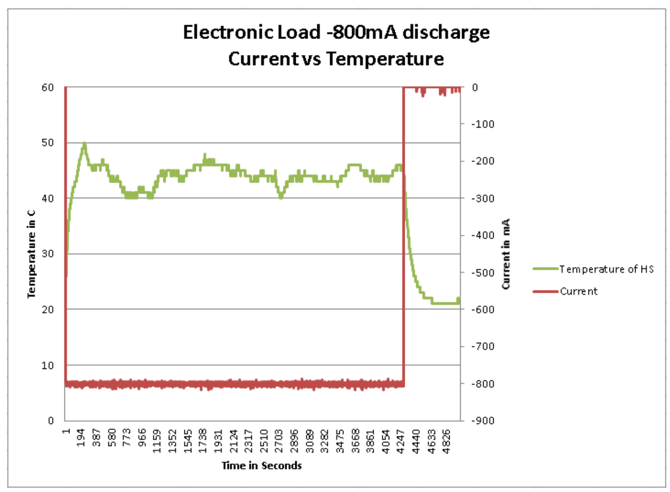
The third plot shows the charger booster pack operating in a standalone mode. Power in and a battery on the output connector is the only sources connected. The cell voltage and current was plotted with the DAQ. Note: the load is turned off by default when there is no controller to communicate with the DAC.

6.1 800mA Charge

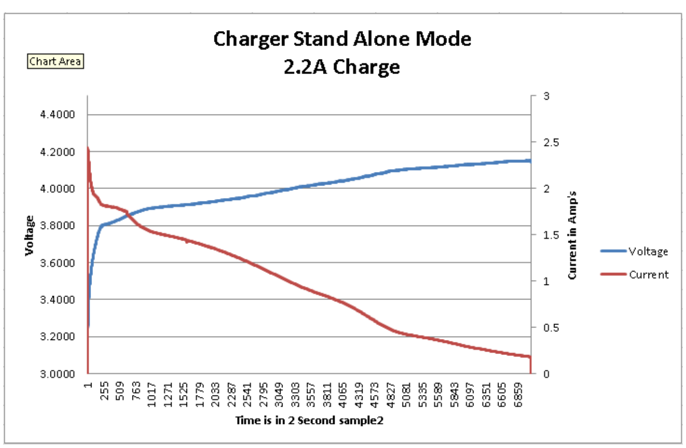


6.2 800mA Discharge





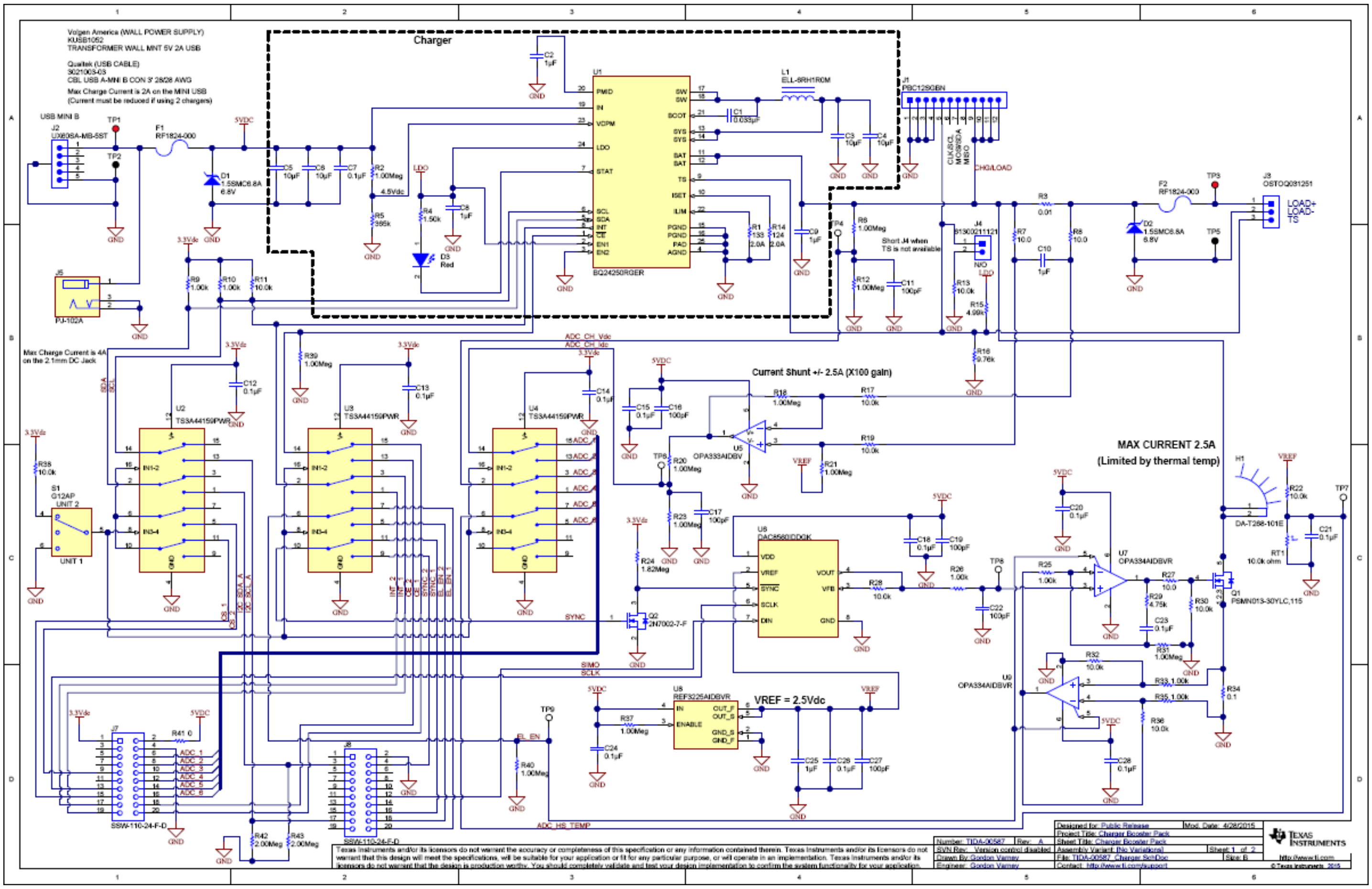
6.3 Standalone charge default current of 2.0A



7 Design Files

7.1 Schematics

To download the Schematics for each board, see the design files at http://www.ti.com/tool/TIDA-00587



7.2 Bill of Materials

Texas Instruments

Bill of Materials

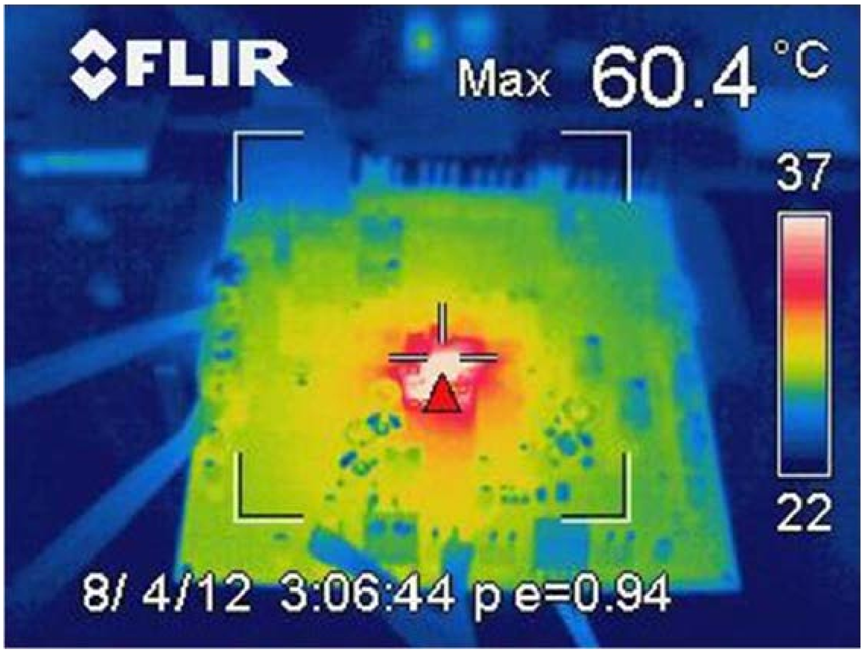
TI DESIGNS
Charger Booster Pack
TIDA-00587

Designator	Description	Manufacturer	PartNumber	Quantity
!PCB1	Printed Circuit Board	Any	TIDA-00587	1
C1	CAP, CERM, 0.033uF, 50V, +/-10%, X7R, 0603	MuRata	GRM188R71H333KA61D	1
C2, C8, C9, C10, C25	CAP, CERM, 1uF, 25V, +/-10%, X7R, 0805	MuRata	GRM21BR71E105KA99L	5
C3, C4, C5, C6	CAP, CERM, 10uF, 10V, +/-10%, X5R, 0805	MuRata	GRM21BR61A106KE19L	4
C7, C12, C13, C14, C15, C18, C20, C24, C26, C28	CAP, CERM, 0.1uF, 25V, +/-10%, X7R, 0603	Kemet	C0603C104K3RACTU	10
C11, C17, C22	CAP, CERM, 100pF, 50V, +/-5%, C0G/NP0, 0603	Kemet	C0603C101J5GACTU	3
C16, C19, C27	CAP, CERM, 100pF, 50V, +/-5%, C0G/NP0, 0603	MuRata	GRM1885C1H101JA01D	3
C21, C23	CAP, CERM, 0.1uF, 25V, +/-10%, X7R, 0603	MuRata	GRM188R71E104KA01D	2
D1, D2	Diode, TVS, Uni, 6.8V, 1500W, SMC	Littelfuse	1.5SMC6.8A	2
D3	LED, Red, SMD	Lite-On	LTST-C190CKT	1
F1, F2	Fuse, Resettable, 1.9A, 6V, SMD	TE Connectivity	RF1824-000	2
FID1, FID2, FID3	Fiducial mark. There is nothing to buy or mount.	N/A	N/A	3
H1	Heatsink, TO-268 [D3]SMT	Ohmite	DA-T268-101E	1
J1	Header, 12x1, 100mil, R/A, TH	Sullins Connector Solutions	PBC12SGBN	1
J2	Connector, Receptacle, Mini-USB Type B, R/A, Top Mount SMT	Hirose Electric Co. Ltd.	UX60SA-MB-5ST	1
J3	Header, 3x1 3.5mm, TH	On-Shore Technology	OSTOQ031251	1
J4	Header, 2.54 mm, 2x1, Gold, TH	Wurth Elektronik	61300211121	1
J5	Connector, DC Jack 2.1X5.5 mm, TH	CUI Inc.	PJ-102A	1
J7, J8	Connector, Receptacle, 100mil, 10x2, Gold plated, TH	Samtec	SSW-110-24-F-D	2
L1	Inductor, Shielded Drum Core, Ferrite, 1uH, 3A, 0.019 ohm, SMD	Panasonic	ELL-6RH1R0M	1
LBL1	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	Brady	THT-14-423-10	1
Q1	MOSFET, N-CH, 30V, 32A, LFPAK	NXP Semiconductor	PSMN013-30YLC,115	1
Q2	MOSFET, N-CH, 60V, 0.17A, SOT-23	Diodes Inc.	2N7002-7-F	1
R1	RES, 133 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603133RFKEA	1
R2, R6, R12, R18, R20, R21, R23, R31, R37, R39, R40	RES, 1.00Meg ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06031M00FKEA	11
R3	RES, 0.01 ohm, 0.5%, 0.5W, 1206	Ohmite	LVK12R010DER	1
R4	RES, 1.50k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06031K50FKEA	1
R5	RES, 365k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603365KFKEA	1
R7, R8, R27	RES, 10.0 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060310R0FKEA	3
R9, R10, R25, R26, R33, R35	RES, 1.00k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06031K00FKEA	6
R11, R13, R17, R19, R22, R28, R30, R32, R36, R38	RES, 10.0k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060310K0FKEA	10
R14	RES, 124 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603124RFKEA	1
R15	RES, 4.99k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06034K99FKEA	1
R16	RES, 9.76k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06039K76FKEA	1
R24	RES, 1.82Meg ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06031M82FKEA	1
R29	RES, 4.75k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06034K75FKEA	1
R34	RES, 0.1 ohm, 1%, 1W, 2010	Stackpole Electronics Inc	CSRN2010FKR100	1
R41	RES, 0, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA	1
R42, R43	RES, 2.00Meg ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06032M00FKEA	2
RT1	Thermistor NTC, 10.0k ohm, 1%, 0603	Panasonic	ERT-J1VG103FA	1
S1	Switch, Toggle, SPDT 1Pos, TH	NKK Switches	G12AP	1
TP1, TP3	Test Point, Miniature, Red, TH	Keystone	5000	2
TP2, TP5	Test Point, Miniature, Black, TH	Keystone	5001	2
TP4, TP6, TP7, TP8, TP9	Test Point, Miniature, White, TH	Keystone	5002	5
U1	2A Single Input I2C, Standalone Switch-Mode Li-Ion Battery Charger with Power-Path Management, RGE0024H	Texas Instruments	BQ24250RGER	1
U2, U3, U4	0.45 ohm QUAD SPDT ANALOG SWITCH QUAD-CHANNEL 2:1 MULTIPLEXER/DEMULTIPLEXER WITH TWO CONTROLS, PW0016A	Texas Instruments	TS3A44159PWR	3
U5	1.8-V, microPower, CMOS Operational Amplifiers, Zero-Drift Series, DBV0005A	Texas Instruments	OPA333AIDBV	1
U6	16-Bit, Ultra-Low Glitch, Voltage Output Digital-to-Analog Converter with 2.5V, 2ppm/°C Internal Reference, DGK0008A	Texas Instruments	DAC8560IDDGK	1
U7, U9	0.05 uV/C Max, Single-Supply CMOS Operational Amplifier, 2.7 to 5.5 V, -40 to 125 degC, 6-pin SOT23 (DBV0006A), Green (RoHS & no Sb/Br)	Texas Instruments	OPA334AIDBVR	2
U8	2.5 V, 4 ppm / degC, 100 uA Series (Bandgap) Voltage Reference, -40 to 125 degC, 6-pin SOT-23 (DBV), Green (RoHS & no Sb/Br)	Texas Instruments	REF3225AIDBVR	1
ZZ2	This is the mating Plug for Connector J3	On-Shore Technology	OSTTJ0311530	1
ZZ3	Transformer Wall Mnt 5V 2A	Volgen America	KUSB1052	1
ZZ4	CBL USB A-Mini B Con 3' 28/28 AWG	Qualtek	3021003-03	1

7.3 PCB Layout Recommendations

7.3.1 Thermal Performance

This section shows a thermal image of the bq24257 running at 6-V input and 1-A system load, a 3.8-V battery is used and charging at rate 1000 mA. There is no air flow and the ambient temperature is 25°C. The peak temperature of the IC (60.4°C) is well below the maximum recommended operating condition listed in the data sheet.



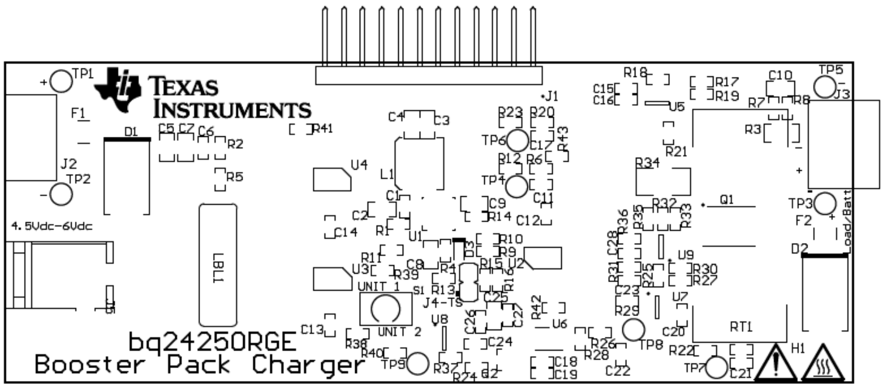
Thermal Image

7.3.2 Printed-Circuit Board Layout Guideline

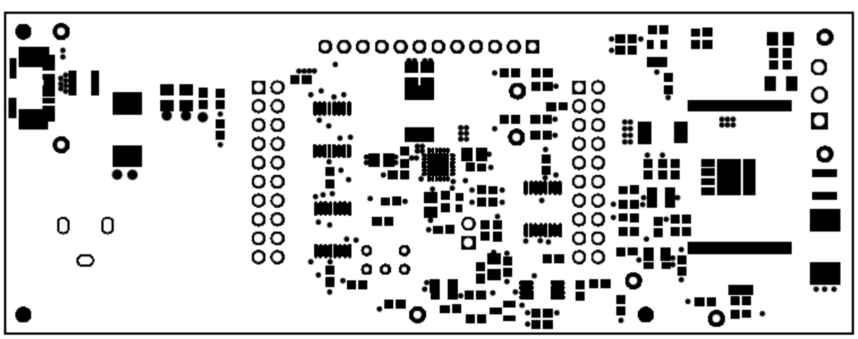
1. Place the BOOT, PMID, IN, BAT, and LDO capacitors as close as possible to the IC for optimal performance.
2. Connect the inductor as close as possible to the SW pin, and the CSIN cap as close as possible to the inductor minimizing noise in the path.
3. Place a 1-μF PMID capacitor as close as possible to the PMID and PGND pins, making the high frequency current loop area as small as possible.
4. The local bypass capacitor from SYS/CSIN to GND must be connected between the SYS/CSIN pin and PGND of the IC. This minimizes the current path loop area from the SW pin through the LC filter and back to the PGND pin.
5. Place all decoupling capacitors close to their respective IC pins and as close as possible to PGND (do not place components such that routing interrupts power-stage currents). All small control signals must be routed away from the high-current paths.
6. To reduce noise coupling, use a ground plane, if possible, to isolate the noisy traces from spreading its noise all over the board. Put vias inside the PGND pads for the IC.
7. The high-current charge paths into IN, Micro-USB, BAT, SYS/CSIN, and from the SW pins must be sized appropriately for the maximum charge current to avoid voltage drops in these traces.
8. For high-current applications, the balls for the power paths must be connected to as much copper in the board as possible. This allows better thermal performance because the board conducts heat away from the IC.

7.4 Layout Prints

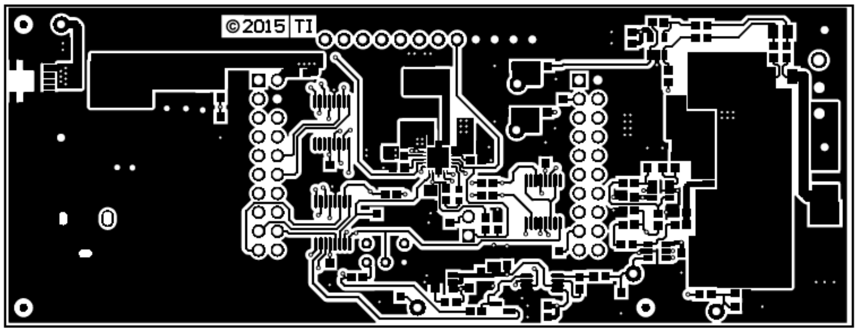
To download the Layout Prints for each board, see the design files at http://www.ti.com/tool/TIDA-00587



ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00587	REV: A	SVN REV: Not In VersionControl
LAYER NAME = Top Overlay			
PLOT NAME = Top Overlay	GENERATED : 6/17/2015 2:58:49 PM		TEXAS INSTRUMENTS



ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00587	REV: A	SVN REV: Not In VersionControl
LAYER NAME = Top Solder			
PLOT NAME = Top Solder Mask	GENERATED : 6/17/2015 2:58:50 PM		TEXAS INSTRUMENTS



ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00587	REV: A	SVN REV: Not In VersionControl
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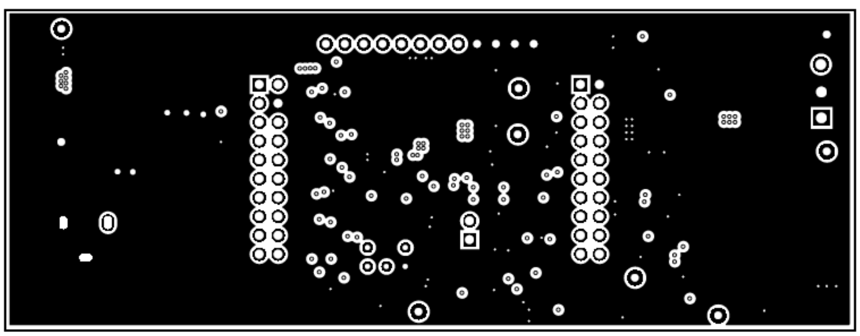
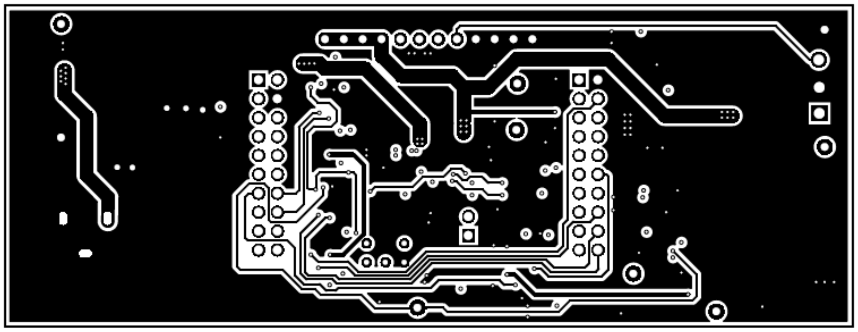
PLOT NAME = Top Layer	GENERATED : 6/17/2015 2:58:51 PM		TEXAS INSTRUMENTS



ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00587	REV: A	SVN REV: Not In VersionControl
LAYER NAME = M1 Board Outline			
PLOT NAME = Middle Layer 1	GENERATED : 6/17/2015 2:58:52 PM		TEXAS INSTRUMENTS



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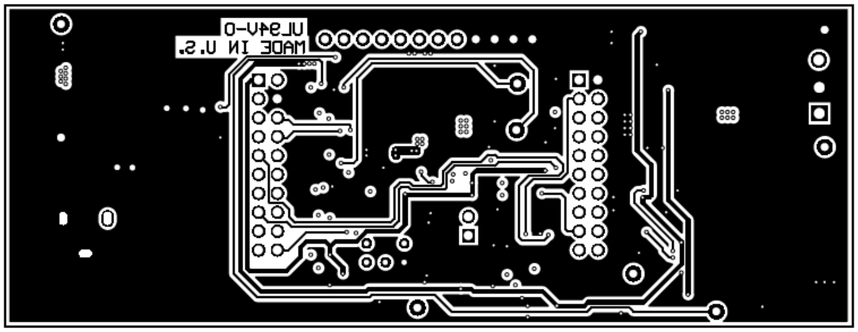
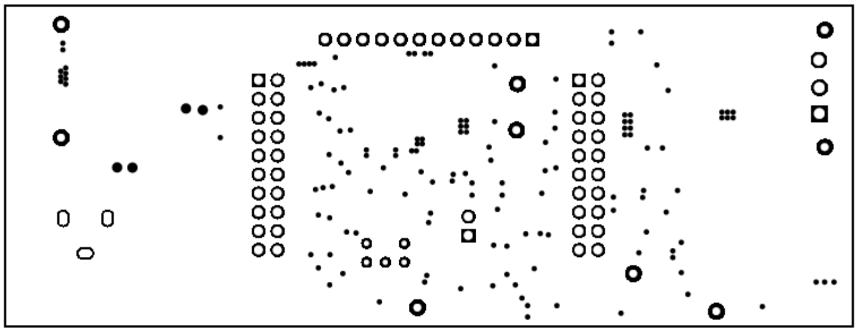
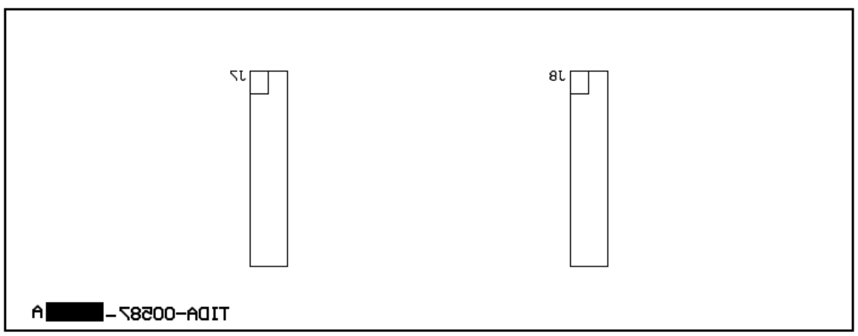
PLOT NAME = Middle Layer 2	GENERATED : 6/17/2015 2:58:53 PM		TEXAS INSTRUMENTS



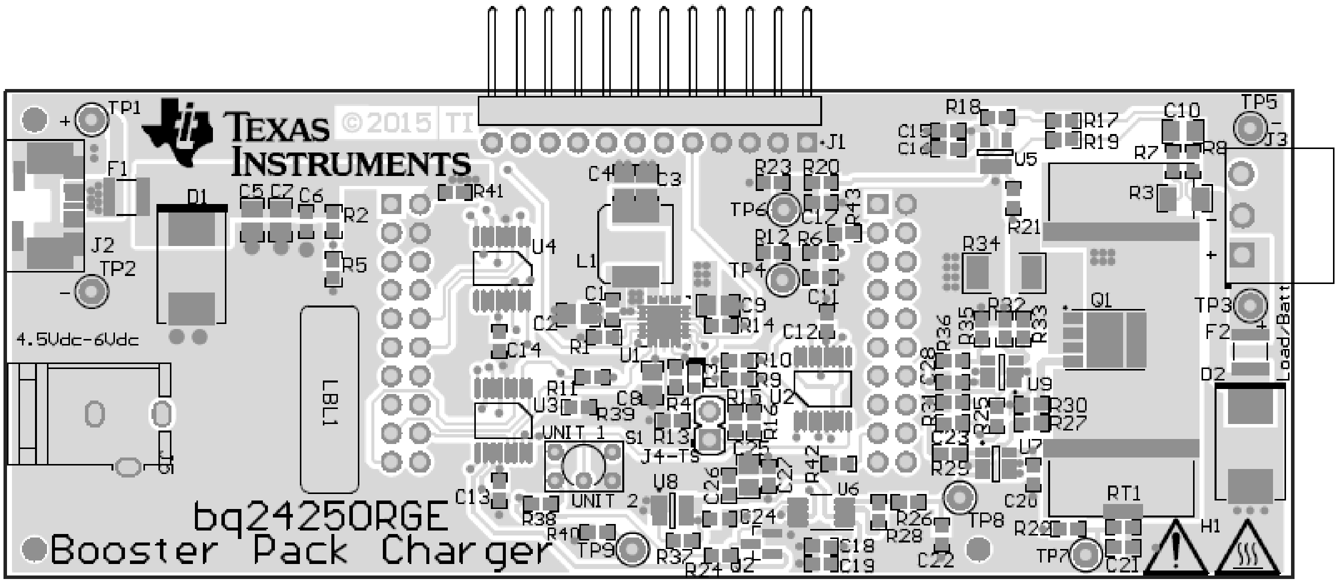
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00587	REV: A	SVN REV: Not In VersionControl
LAYER NAME = Bottom Layer			
PLOT NAME = Bottom Layer	GENERATED : 6/17/2015 2:58:54 PM		TEXAS INSTRUMENTS

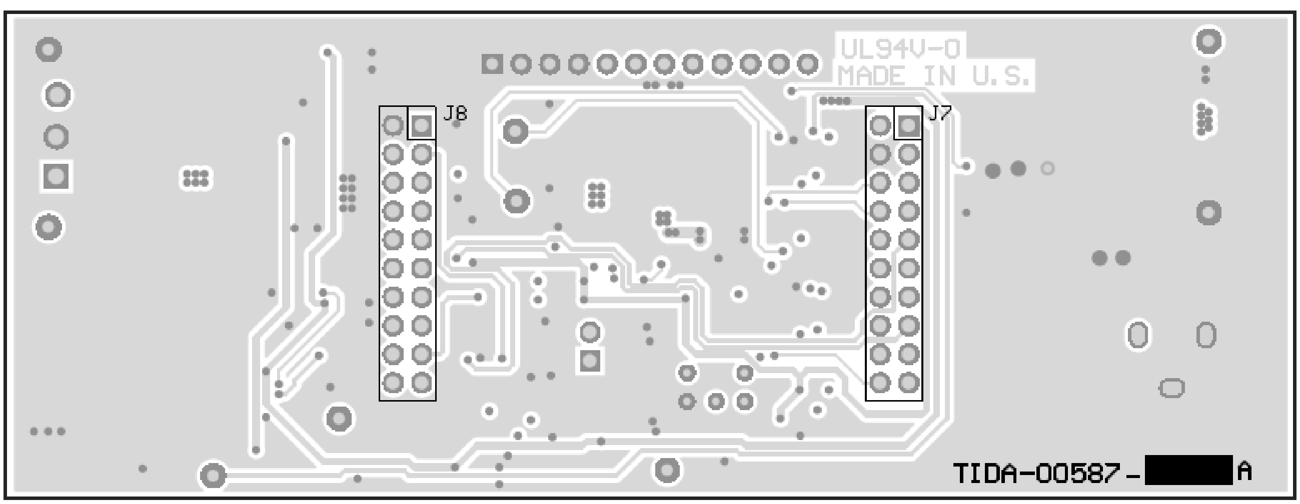


ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00587	REV: A	SVN REV: Not In VersionControl
LAYER NAME = Bottom Solder			
PLOT NAME = Bottom Solder Mask	GENERATED : 6/17/2015 2:58:56 PM		TEXAS INSTRUMENTS



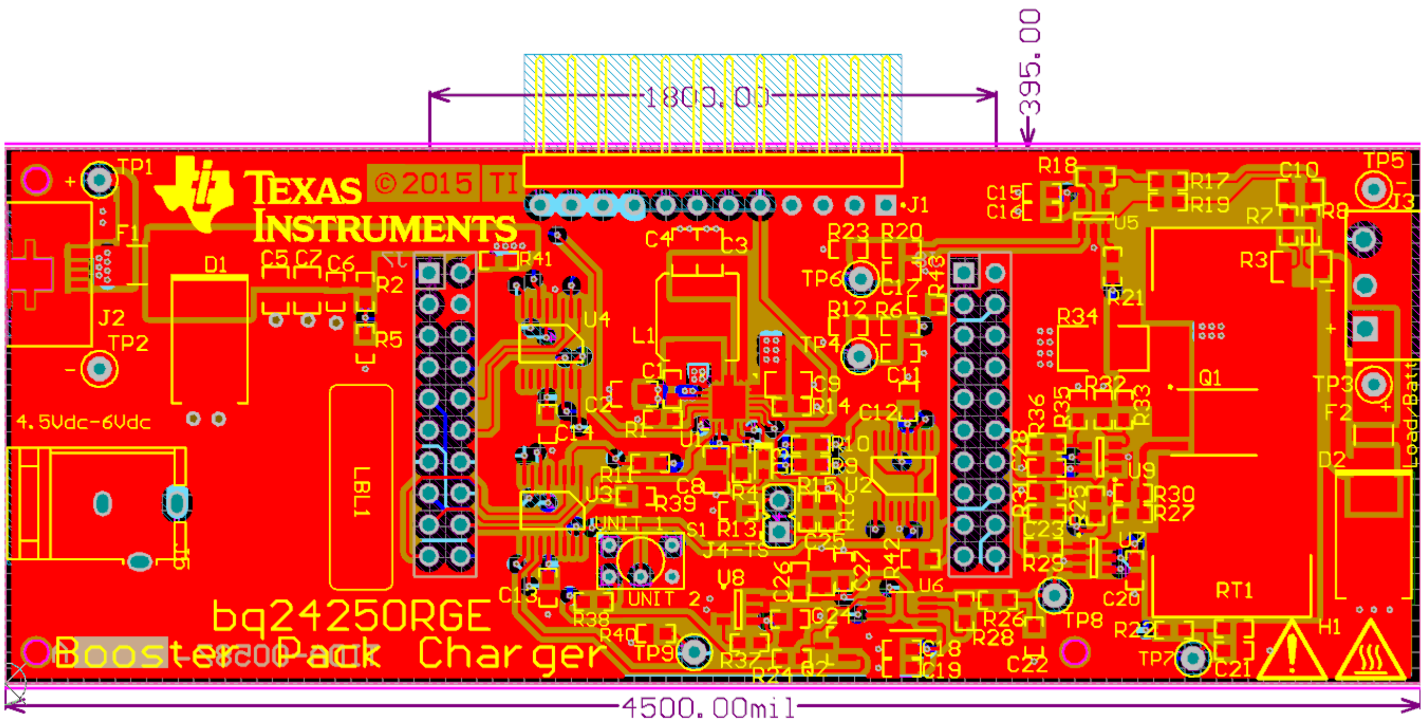
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00587	REV: A	SVN REV: Not In VersionControl
LAYER NAME = Bottom Overlay			
PLOT NAME = Bottom Overlay	GENERATED : 6/17/2015 2:58:57 PM		TEXAS INSTRUMENTS

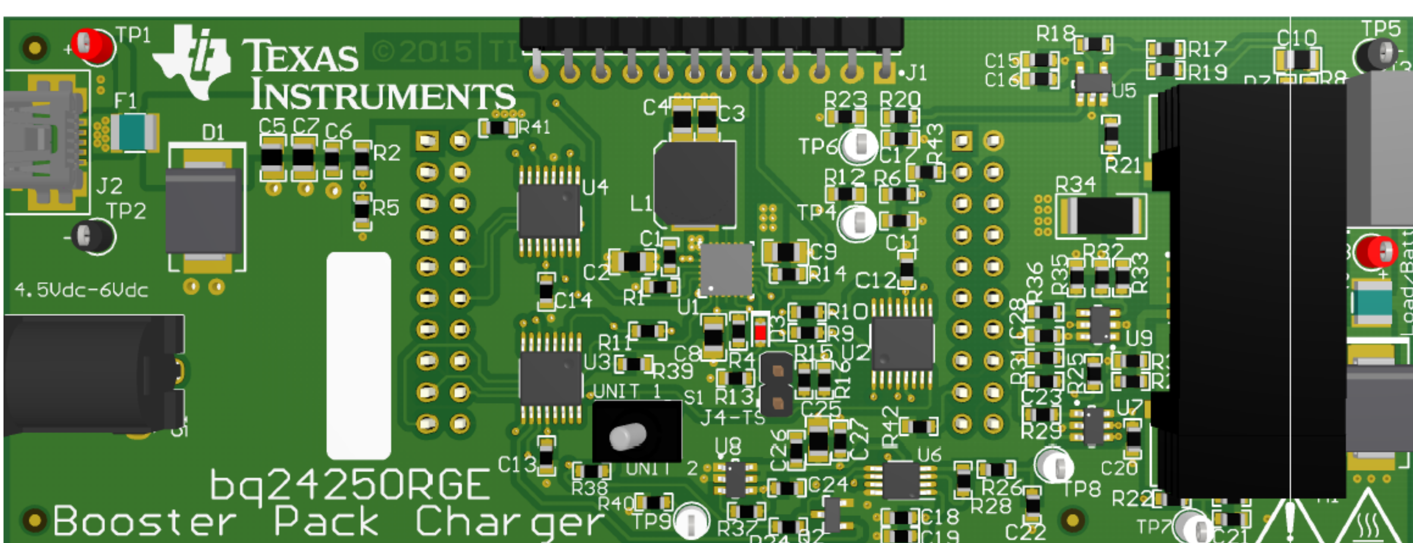

TEXAS INSTRUMENTS
©2015 TI
4.5Vdc-6Vdc
LBL1
bq24250RGE
Booster Pack Charger
Load/Batt


UL94V-0
MADE IN U.S.
J8
J7
TIDA-00587-[redacted]A

7.5 Altium Project

To download the Altium project files for each board, see the design files at http://www.ti.com/tool/TIDA-00587





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