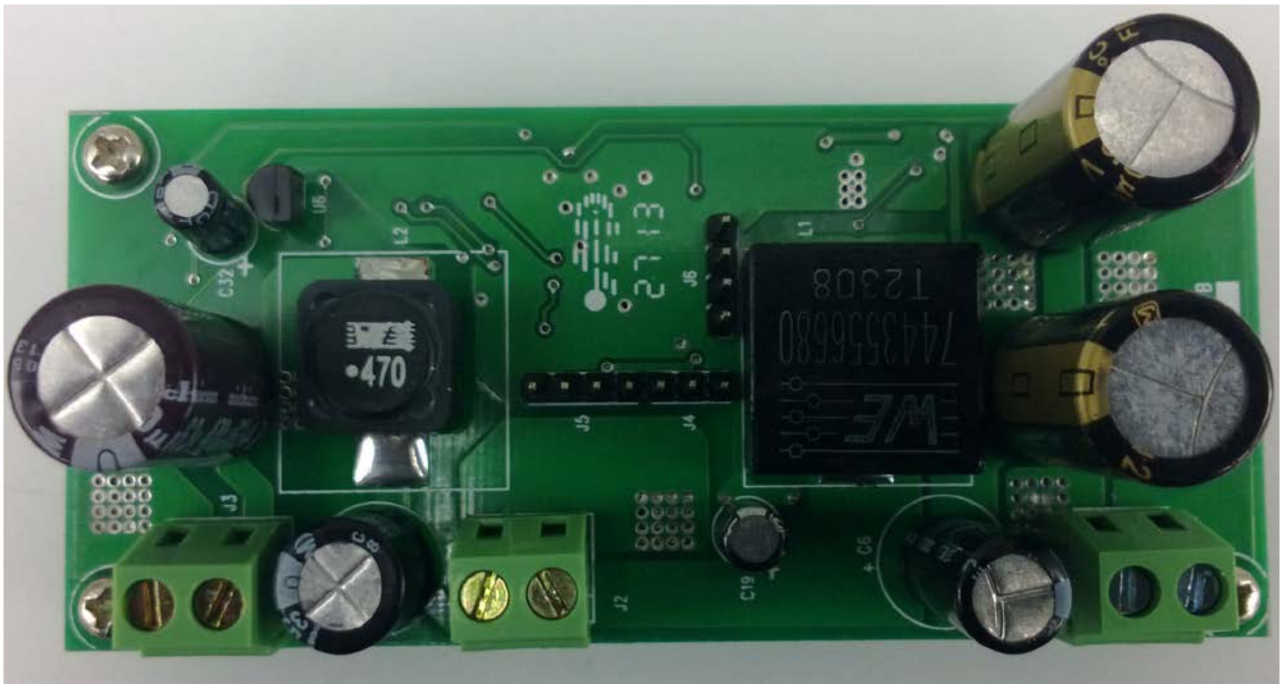
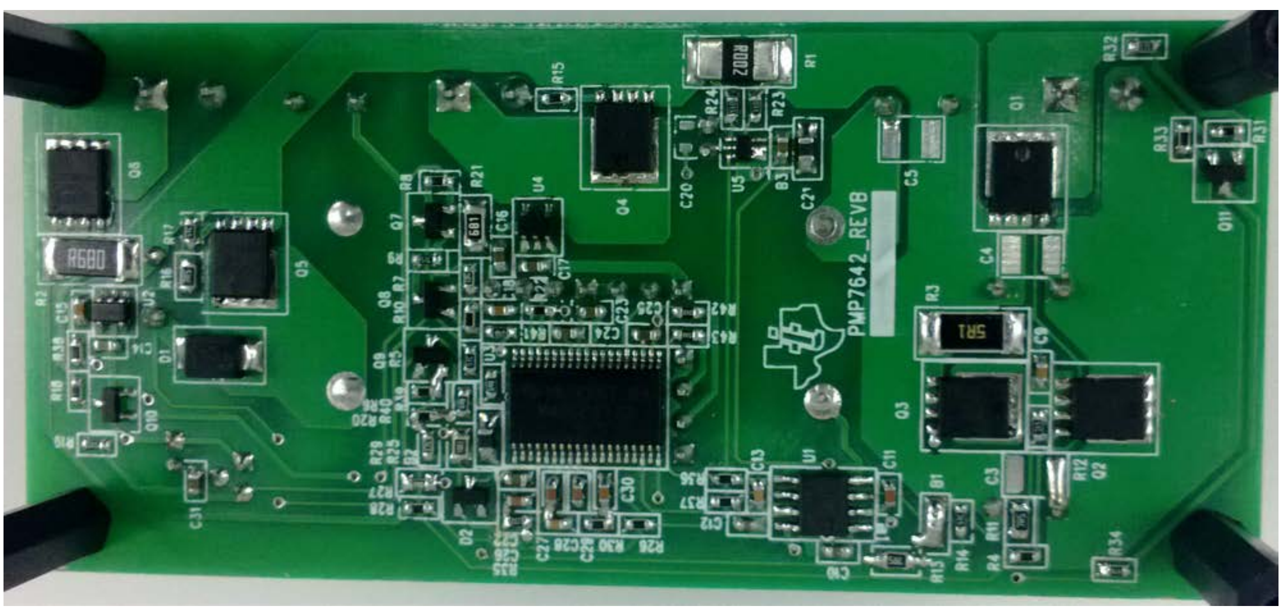
TEST REPORT OF MPPT & LED DRIVER

PMP 7647





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I. INTRODUCTION

The following document is a compilation of test results of the PMP7647 reference design, a 12A MPPT solar charge controller & 700mA LED driver. The test results are taken with simulated solar panel input corresponding to 12V panel.

II. DESCRIPTION

The PMP7647 is developed around the MSP430F5132 controller IC. The design is targeted for low power solar charger and LED driver solutions such as solar street lights. This design is capable of charging 12V batteries with up to 10A output current from 12V panels. However, it can be easily adapted to 24V systems by just changing the MOSFETs to 60V rated parts. Also, the design can drive up to 15 LEDs in series with 700mA of current. It is possible to adapt the design for LED currents up to 1.1A with minimum change in hardware.

The MPPT section has a typical electrical efficiency of 97% at full load. This efficiency figure includes the losses in battery reverse protection and panel reverse flow protection MOSFETs, which are part of the design. The high efficiency is the result of the low gate charge MOSFETs from TI used in the design, and also the optimum layout. Another feature is the relatively small sized components used, possible due to the high operating frequency (settable from 100 - 200 KHz). The design has built-in battery charge profile for 12V Lead acid batteries. The design presently uses ‘perturb and observe’ algorithm for MPP tracking. This gives fast acquisition of MPP operation.

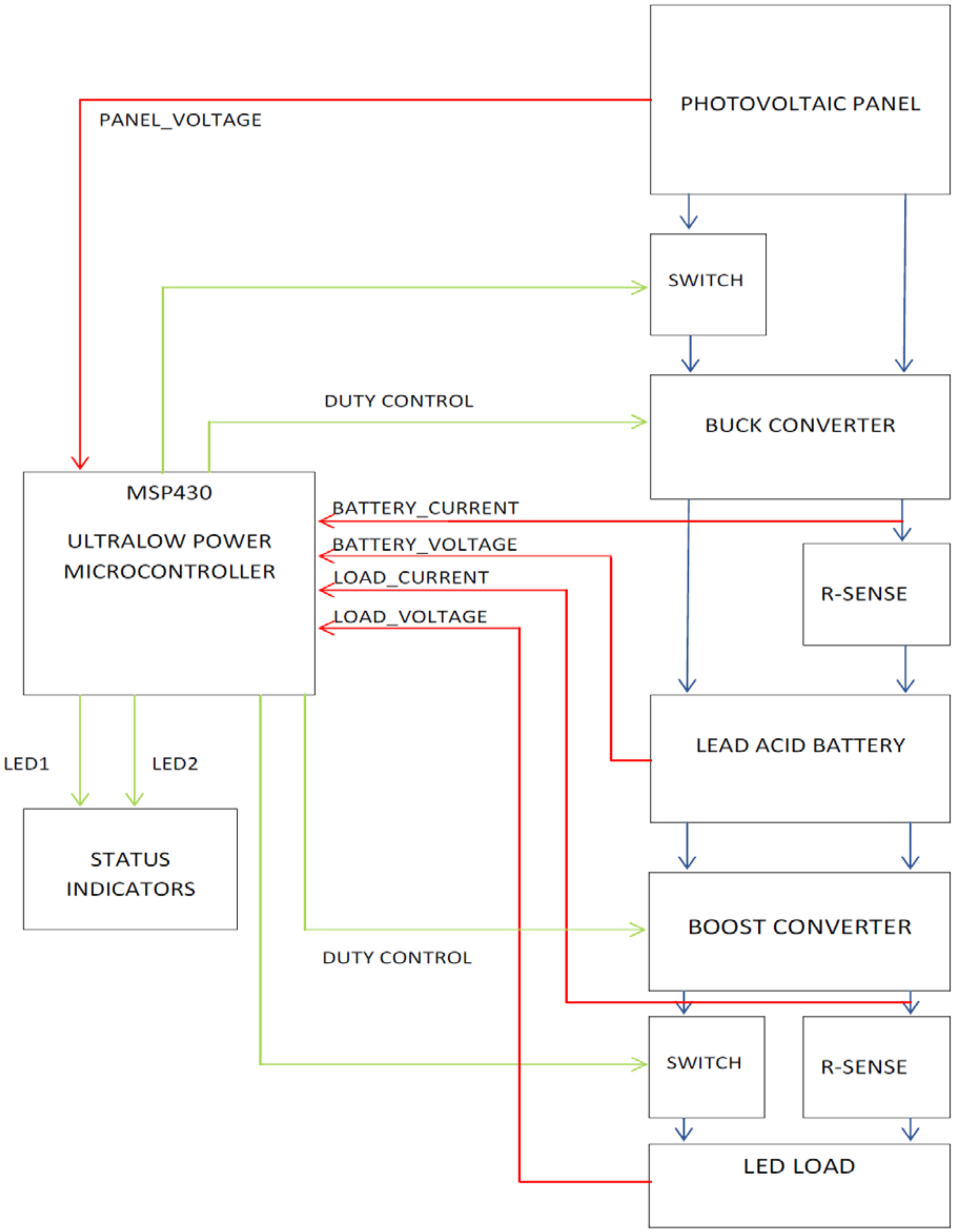
The LED driver section is a boost converter. The electrical efficiency of boost section is about 93% while driving 12 LEDs at 700mA, and is around 91% while driving 6 LEDs at 350mA. The section is protected with load and converter cut-off during overload, short circuit and load open fault situations. There is also provision to dim the output after specified time intervals. Though in a typical application the time intervals are in hours, the board is programmed for one minute intervals of 700mA and 350mA current drive for easy demonstration of the feature. The design is also capable of detection of ambient light based on the panel voltage, and taking appropriate decisions to turn on LEDs, charge battery in MPPT mode or go to standby accordingly. Low battery voltage protection by dimming the LEDs to 10% brightness and subsequently going to low power mode with further reduction in voltage is also implemented. The voltage levels at which these actions are taken can be set by software.

The various parameters of the circuit like battery charge current, load current, load timing pattern, battery under voltage set points etc can be set using a GUI made for the design. This makes customization a lot easier.

The circuit takes only under 4mA of standby current while operating from battery. This is further reduced to under 1mA while the circuit is in battery under voltage cut-off. Software programmable indications are provided in hardware, but are left non-configured.

Surge protection and EMI filtering components are not present on this design, and has to be added depending upon required specification levels.

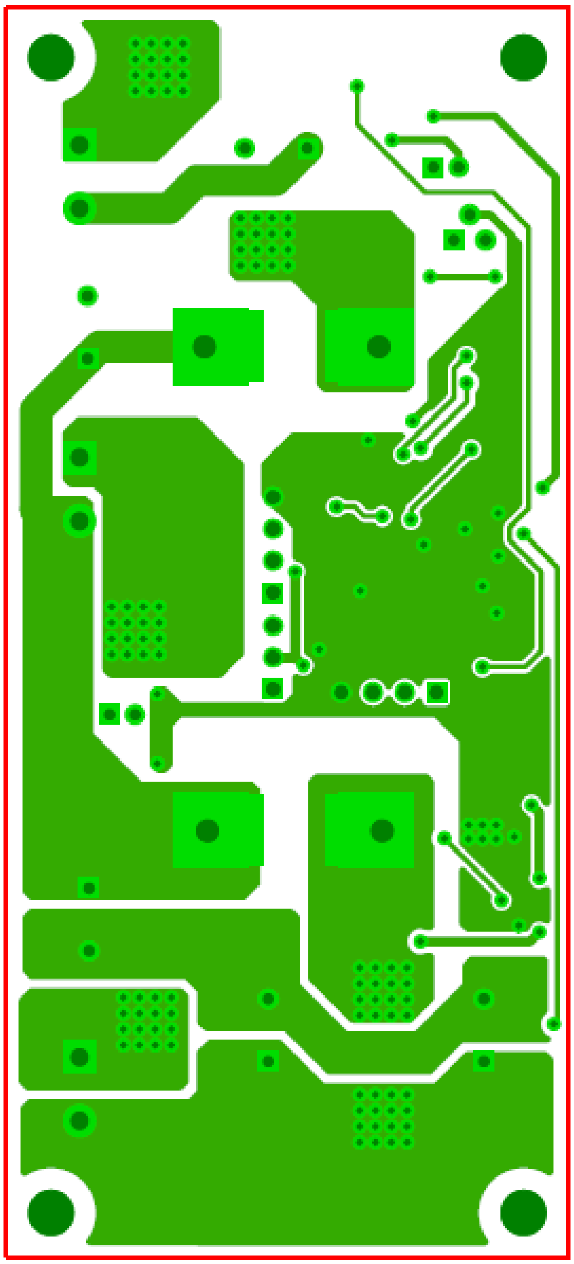
III. BLOCK DIAGRAM

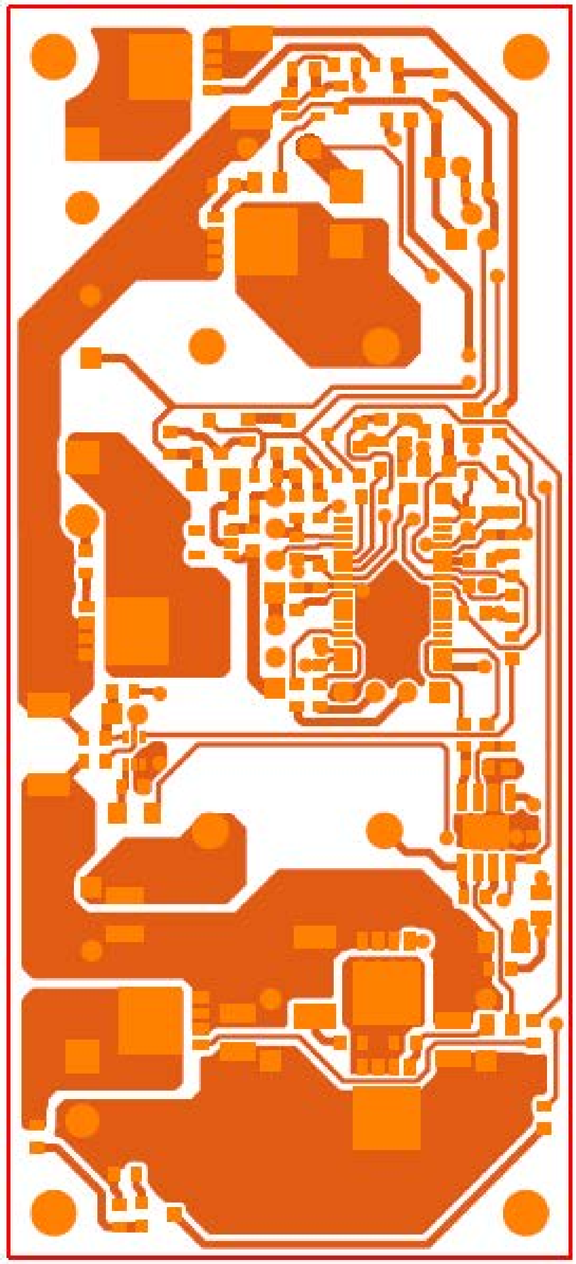


IV. SPECIFICATIONS

Input Voltage Range: 15VDC - 22VDC
Storage: 12V battery
Charging Current: 10A, with current limit set at 12A
Output: 12 LEDs at 700mA
Board Form Factor: 100 mm x 45 mm x 32 mm
Expected efficiency: >95% for MPPT charger, and >90% for LED driver

V. BOARD LAYOUT





VI. TEST SETUP

Input conditions:
Panel input: 15VDC to 22VDC
Set current limit to the short circuit current of panel when DC source is used instead of panel

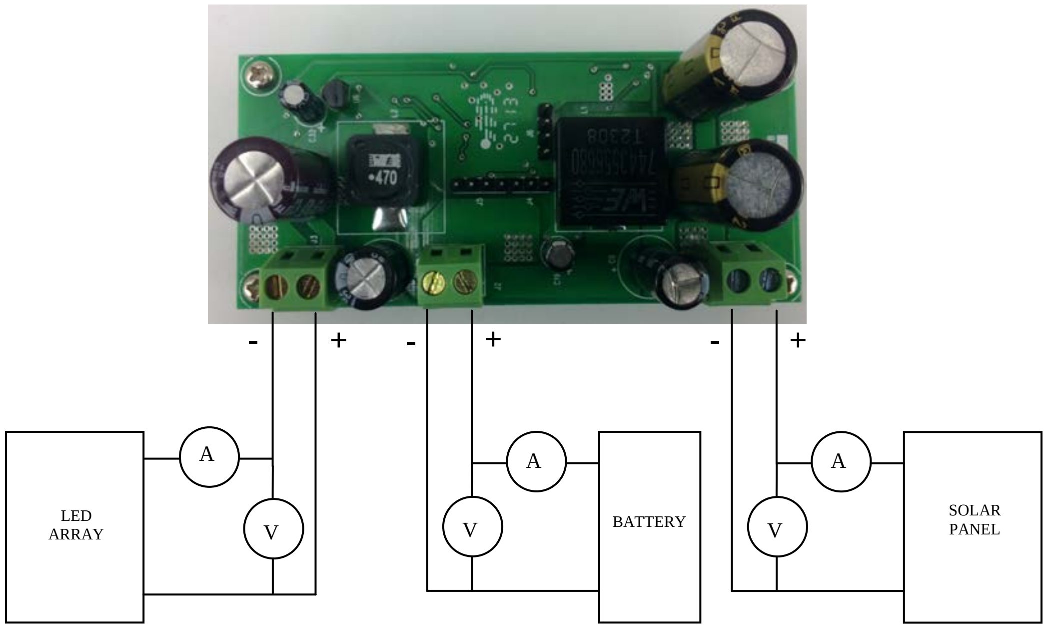
Storage:
12V battery

Output:
12 LED array

Equipment Used:
1. Current limited DC source simulating solar panel
2. Digital Oscilloscope
3. Multimeters
4. LED load/LED simulator

Procedure:
1. Connect appropriate battery to the battery terminals of the PMP7647 reference board, maintaining correct polarity.
2. Connect panel or current limited DC source to panel terminals, maintaining correct polarity.
3. Set the output voltage of DC source to slightly above the MPP voltage of the panel being simulated (if DC source is used instead of panel) and turn on.
4. Observe for gradual build-up of battery charge current.
5. Connect LED array to the load terminals with proper polarity.
6. Turn off the panel input to observe gradual build-up of LED current.

Connection Diagram:



VII. TEST DATA

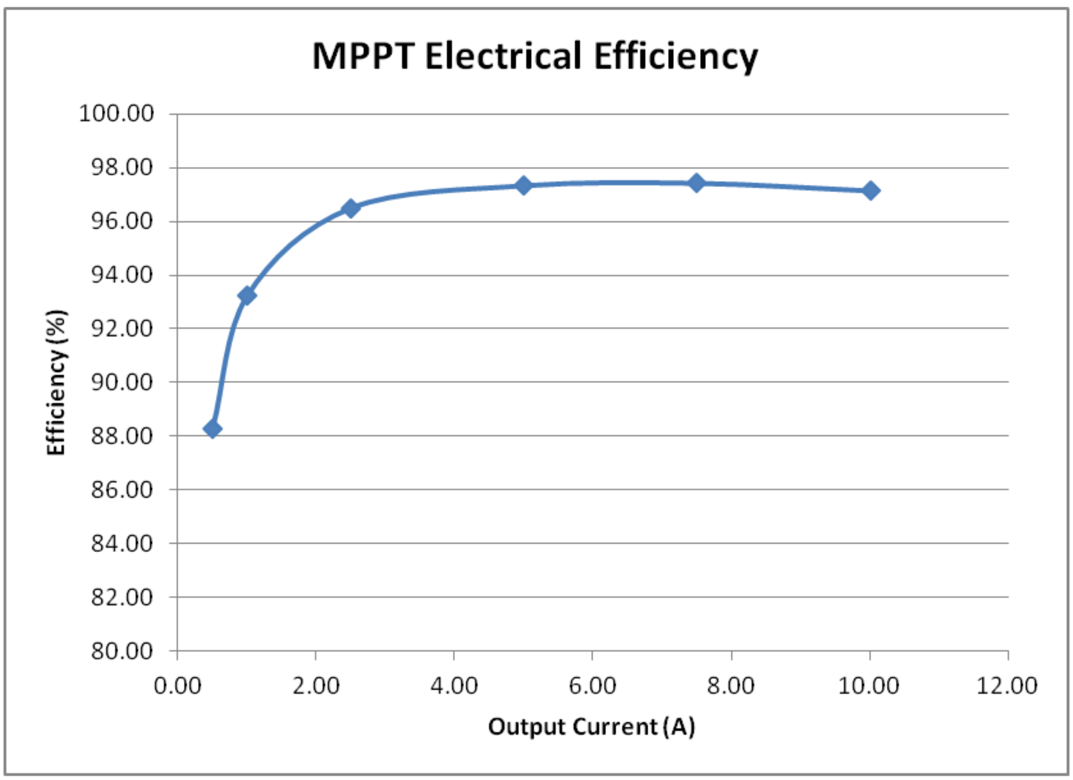
a. MPPT PERFORMANCE

Vi (V)	Ii (A)	Vo (V)	Io (A)	Pi (W)	Po (W)	Efficiency
17.04	0.44	13.04	0.50	7.43	6.56	88.29
17.38	0.81	13.11	1.01	14.13	13.18	93.25
17.18	2.01	13.33	2.50	34.53	33.33	96.51
16.87	4.17	13.68	5.00	70.28	68.41	97.34
17.01	6.35	14.03	7.50	108.00	105.23	97.43
16.62	8.93	14.39	10.02	148.42	144.19	97.15

b. LED DRIVER PERFORMANCE

Vi (V)	Ii (A)	Vo (V)	Io (A)	Pi (W)	Po (W)	Efficiency
11.23	2.775	41.23	0.702	31.16	28.94	92.88
12.15	0.708	21.55	0.365	8.60	7.87	91.44

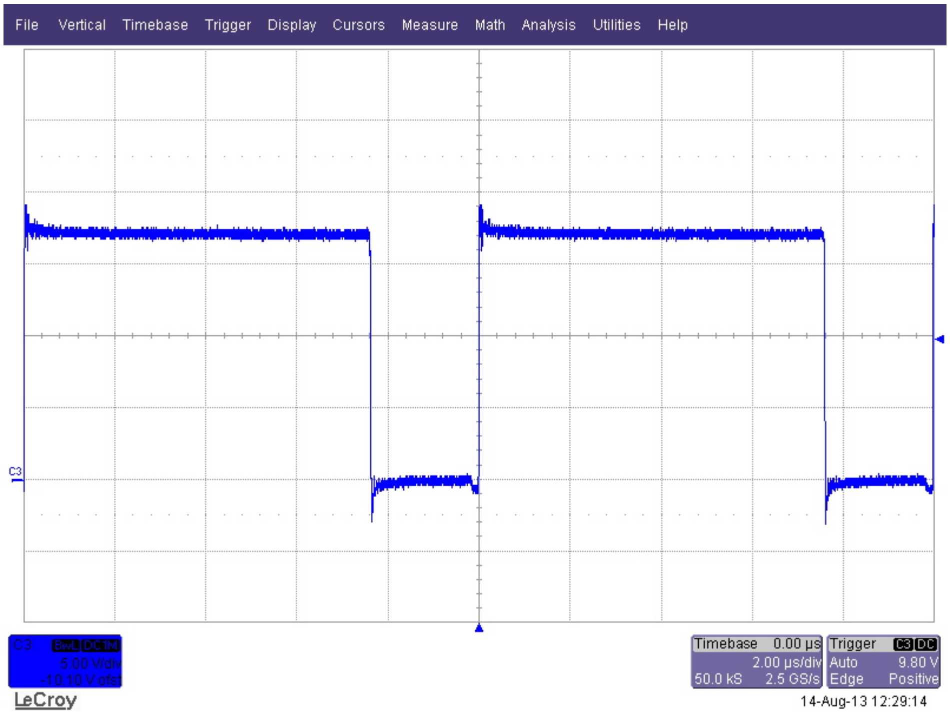
c. MPPT EFFICIENCY PLOT



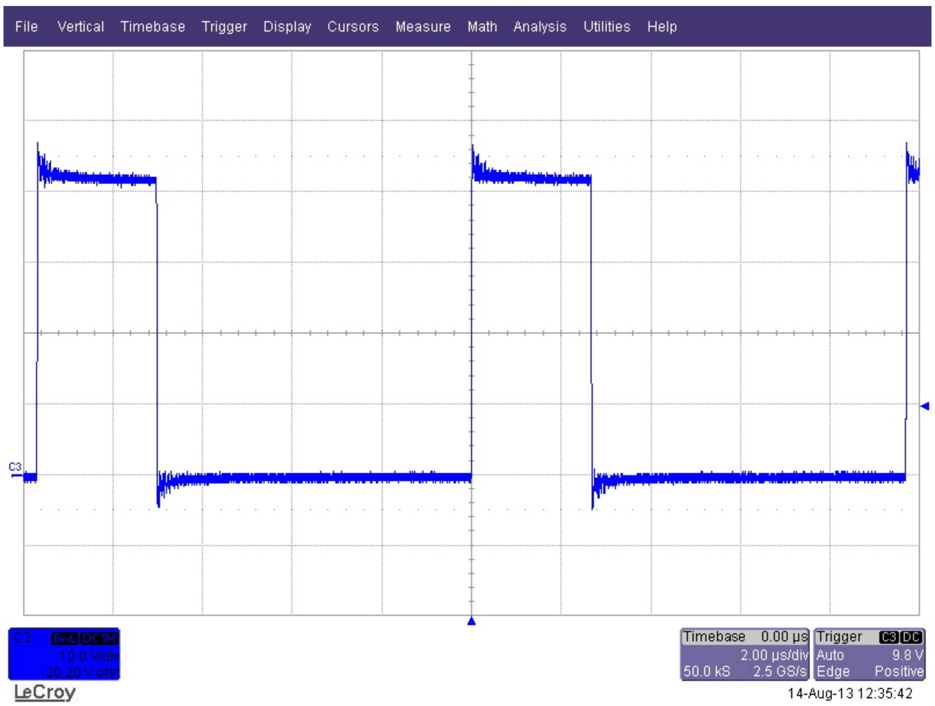
VIII. WAVEFORMS

a. Switching Node Waveforms

MPPT switch node at 10A charging current

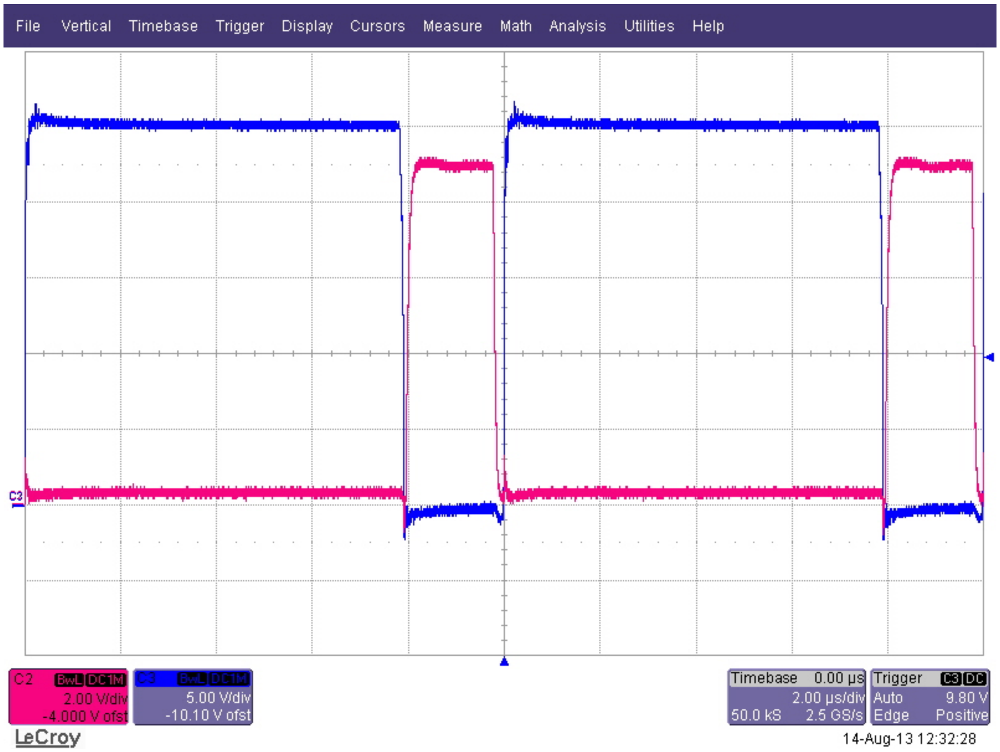


Boost converter switch node at 12LED, 700mA load

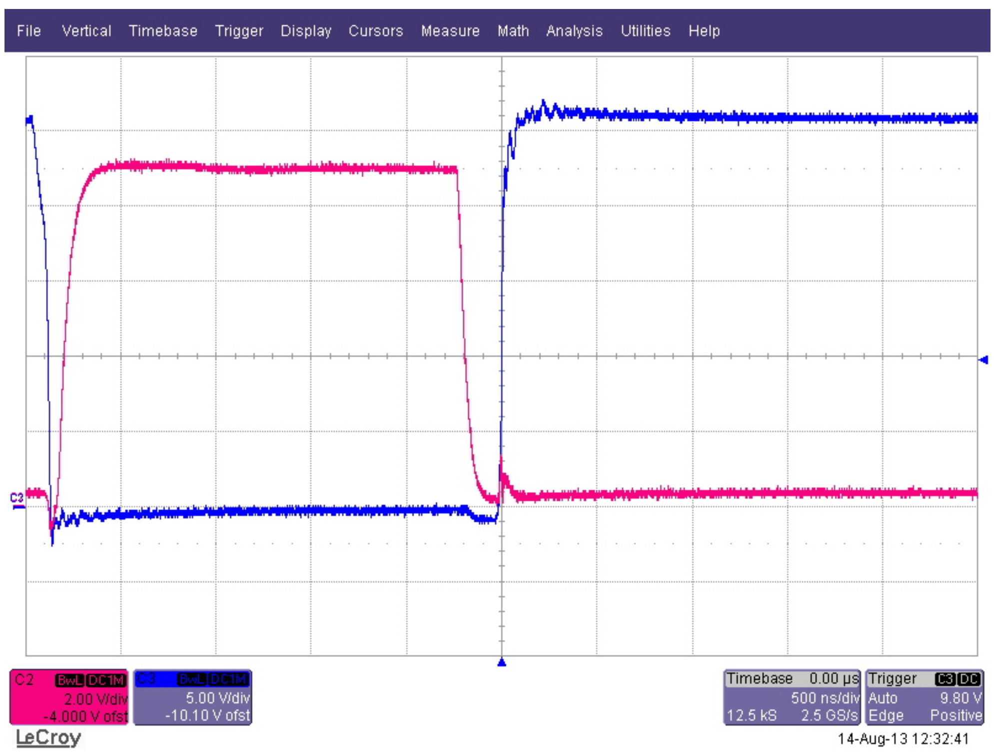


b. Gate waveforms

MPPT gate waveforms at 10A load show dead-time implementation

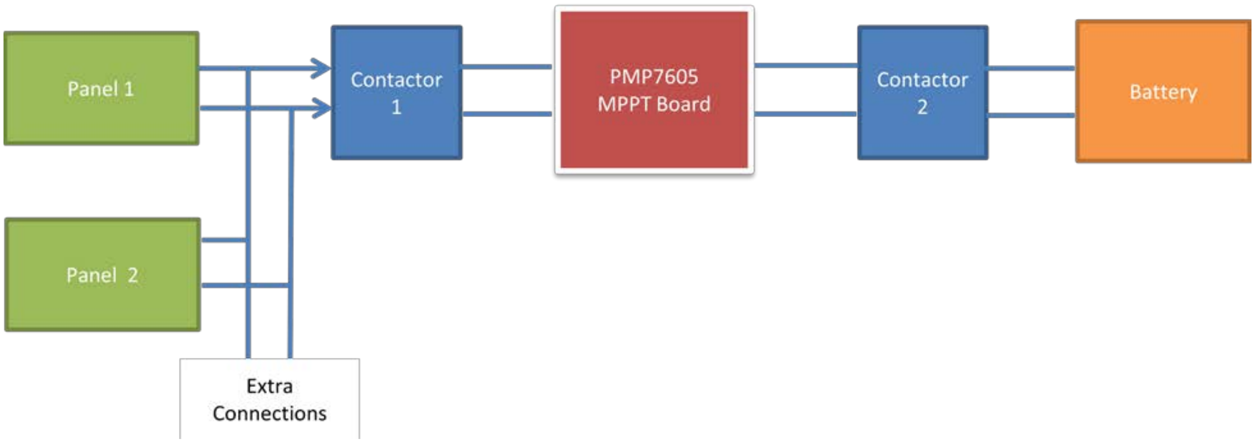


Expanded view



IX. POWER GAIN WITH MPP

a. Test Set-up



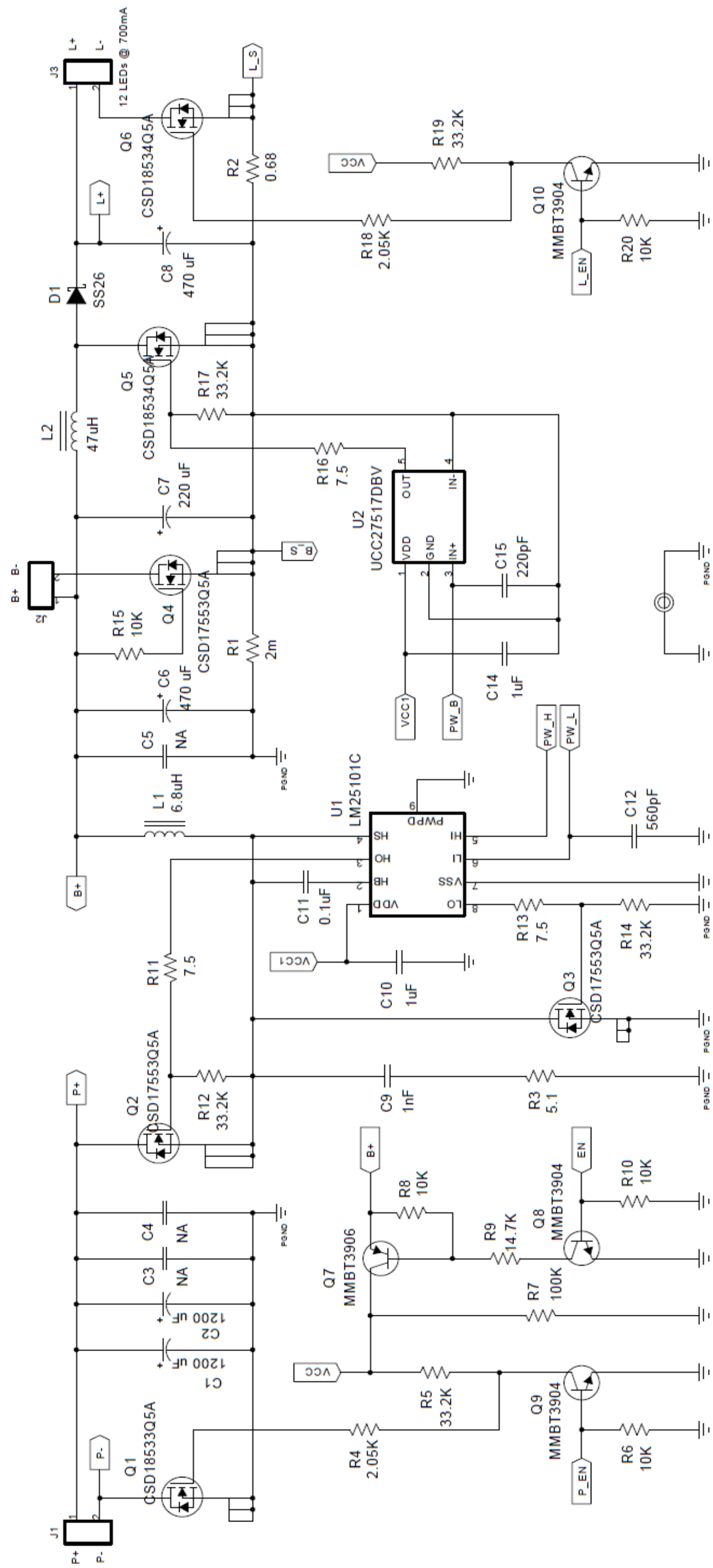
This test was done with an earlier similar design PMP7605.
Setup Explains the Power flow from Panel to Battery during MPPT Operation.
To connect Panel directly to battery, both contactors were opened and Extra connections were connected directly onto the battery.

b. Test Results

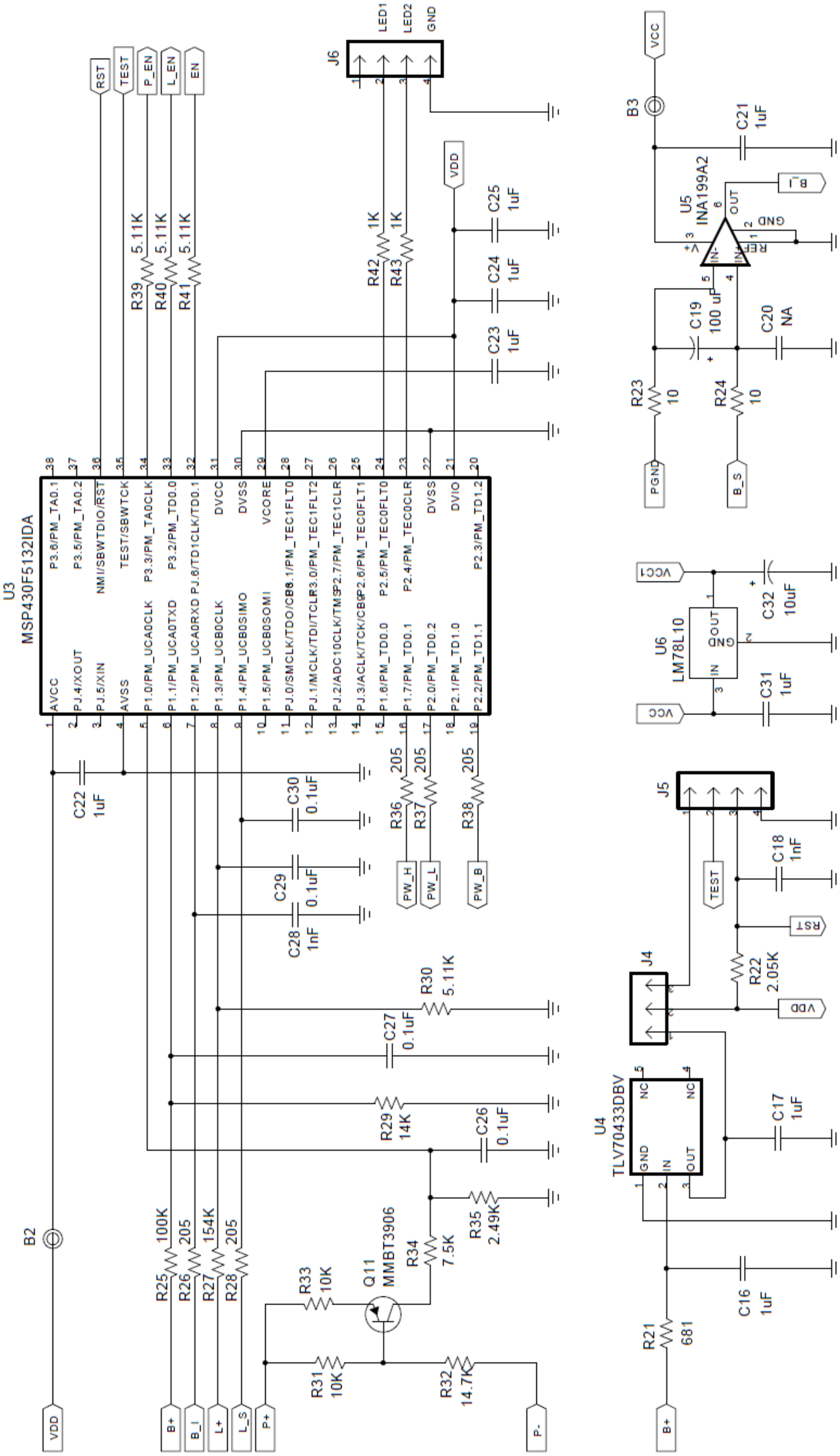
12 V System			
Battery Voltage = 11.96			
Two Panels connected			
Readings Taken approximately every 5-7 mins (@ 3.15 pm) Cloudy Conditions			
Sr No	Charging Currents (A)		**Improvement**
	Panel directly connected to Battery	Charging via MPPT Board	**%**
1	1.794	2.08	**15.94**
2	1.28	1.443	**12.73**
3	0.55	0.6	**9.09**
4	1.15	1.3	**13.04**
5	1.21	1.35	**11.57**
6	2.13	2.5	**17.37**

X. SCHEMATIC

a. Power Stage



b. Controller and Bias Supply



XI. BILL OF MATERIALS

PMP7647 BOM Revision C

Item	Qty	Reference	Value	Description	Part Number	Manufacturer	Size
1	2	B2, B3		Bead, Ferrite, 500mA, 600ohms	7427920415	Wurth Elektronik	805
2	2	C1, C2	1200 uF	Capacitor, Aluminium Electrolytic, Low ESR, 35V	EEU-FM1V122L	Panasonic	12.5 x 30 mm
3	1	C6	470 uF	Capacitor, Aluminium Electrolytic, Low ESR, 35V	EEU-FR1V471L	Panasonic	8 x 22 mm
2	1	C7	220 uF	Capacitor, Aluminium Electrolytic, Low ESR, 35V	UHE1V221MPD6	Nichicon	10 x 12.5 mm
3	1	C8	470 uF	Capacitor, Aluminium Electrolytic, Low ESR, 63V	UPW1J471MHD	Nichicon	12.5 x 25 mm
4	3	C9, C18, C28	1nF	Capacitor, Ceramic, 50V, X7R, 10%	Std	Std	603
5	10	C10, C14, C16, C17, C21, C22, C23, C24, C25, C31	1uF	Capacitor, Ceramic, 25V, X7R, 10%	TMK107B7105KA-T	Taiyo-Yuden	603
6	5	C11, C26, C27, C29, C30	0.1uF	Capacitor, Ceramic, 50V, X7R, 10%	Std	Std	603
7	1	C12	560pF	Capacitor, Ceramic, 50V, NPO, 1%	Std	Std	603
8	1	C15	220pF	Capacitor, Ceramic, 50V, NPO, 1%	Std	Std	603
9	1	C19	100 uF	Capacitor, Aluminium, 10V, 20%	EEU-EB1A101	Panasonic	5 x 11 mm
10	1	C32	10uF	Capacitor, Aluminium, 10V, 20%	50YXM10MEFC5X11	Rubycon	5 x 11 mm
11	1	D1	SS26	Diode, Schottky, 2A, 60V	SS26-TP	MCC Semi	SMA
12	3	J1, J2, J3	OSTTC022162	Terminal Block, 2-pin, 15-A, 5.1mm	OSTTC022162	OST	0.40 x 0.35 inch
13	1	J4	PEC36SAAN	Header, Male 3-pin, 100mil spacing, (36-pin strip)	PEC36SAAN	Sullins	0.100 inch x 3
14	2	J5, J6	PEC36SAAN	Header, Male 4-pin, 100mil spacing, (36-pin strip)	PEC36SAAN	Sullins	0.100 inch x 4
15	1	L1	6.8uH	Inductor, SMT, 18.5-A, 4.1-milliohm	7443556680	Wurth Elektronik	18 x 18 x 9 mm
16	1	L2	47uH	Inductor, SMT, 3.6-A, 60-milliohm	7447709470	Wurth Elektronik	12 x 12 x 10 mm
17	1	Q1	CSD18533Q5A	MOSFET, N-Chan, 60V, 103A, 5.9 mOhm	CSD18533Q5A	TI	QFN-8 POWER
18	2	Q5, Q6	CSD18534Q5A	MOSFET, N-Chan, 60V, 50A, 9.8 mOhm	CSD18534Q5A	TI	QFN-8 POWER
19	3	Q2, Q3, Q4	CSD17553Q5A	MOSFET, N-Chan, 30V, 23.5A, 2.7 mOhm	CSD17553Q5A	TI	QFN-8 POWER
20	2	Q7, Q11	MMBT3906	Trans, PNP, 40-V, 200-mA, 225-mW	MMBT3906LT1G	On Semi	SOT23
21	3	Q8, Q9, Q10	MMBT3904	Trans, NPN, 40-V, 200-mA,225-mW	MMBT3904LT1G	On Semi	SOT23
22	1	R1	2m	Resistor, 2 milliOhm, 3W, 1%	LRMAP2512-R002FT4	TT/Welwyn	2512
23	1	R2	0.68	Resistor, 0.68 Ohm, 2W, 1%	CSRN2512FKR680	Stackpole	2512
24	1	R3	5.1	Resistor, 5.1Ohm, 1W, 5%	Std	Std	2512
25	3	R4, R18, R22	2.05K	Resistor, Chip, 1/16W, 1%	Std	Std	603
26	5	R5, R12, R14, R17, R19	33.2K	Resistor, Chip, 1/16W, 1%	Std	Std	603
27	7	R6, R8, R10, R15, R20, R31, R33	10K	Resistor, Chip, 1/16W, 1%	Std	Std	603
28	1	R7	100K	Resistor, Chip, 1/16W, 1%	Std	Std	603
29	3	R11, R13, R16	7.5	Resistor, Chip, 1/10W, 5%	Std	Std	805
30	1	R21	681	Resistor, Chip, 1/4 watt, ± 5%	Std	Std	1206
31	2	R23, R24	10	Resistor, Chip, 1/16W, 1%	Std	Std	603
32	1	R25	100K	Resistor, Chip, 1/10W, 1%	Std	Std	805
33	5	R26, R28, R36, R37, R38	205	Resistor, Chip, 1/16W, 1%	Std	Std	603
34	1	R27	154K	Resistor, Chip, 1/10W, 1%	Std	Std	805
35	1	R29	14K	Resistor, Chip, 1/16W, 1%	Std	Std	603
36	2	R9, R32	14.7K	Resistor, Chip, 1/16W, 1%	Std	Std	603
37	1	R34	7.5K	Resistor, Chip, 1/16W, 1%	Std	Std	603
38	1	R35	2.49K	Resistor, Chip, 1/16W, 1%	Std	Std	603
39	4	R30, R39, R40, R41	5.11K	Resistor, Chip, 1/16W, 1%	Std	Std	603
40	2	R42, R43	1K	Resistor, Chip, 1/16W, 1%	Std	Std	603
41	1	U1	LM25101C	1A 80V Half-Bridge Gate Driver	LM25101CMAX	TI	SO8
42	1	U2	UCC27517DBV	IC, 4A Single Channel High-Speed Low-Side Gate Drivers	UCC27517DBV	TI	SOT23-5
43	1	U3	MSP430F5132IDA	IC, Mixed Signal Microcontroller	MSP430F5132IDA	TI	MSOP-38
44	1	U4	TLV70433DBV	IC, 24-V Input, 150 mA, Utralow IQ LDO Regulator	TLV70433DBV	TI	SOT-23
45	1	U5	INA199A2	IC, Current shunt monitor, Bi-Directional Zerø-Drift Series	INA199A2DCK	TI	SC-70
46	1	U6	uA78L10A	IC, 3 Pin 100mA Fixed 10V Positive Voltage Regulator	UA78L10ACLPR	TI	TO-92

XII. CONCLUSION

The board is tested for the given specifications and found to meet them. Further optimization of software can be done depending on specific system requirements.

XIII. APPENDIX

EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMER

For Feasibility Evaluation Only, in Laboratory/Development Environments. The EVM is not a complete product. It is intended solely for use for preliminary feasibility evaluation in laboratory / development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical / mechanical components, systems and subsystems. It should not be used as all or part of a production unit.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.

Certain Instructions. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output ranges are maintained at nominal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be indentified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of this agreement. This obligation shall apply whether Claims arise under the law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate TI components for possible use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.