SolarMagic SM73201 DC Arc Detection Evaluation Board

National Semiconductor
Application Note 2154
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Introduction

The SolarMagic™ reference design kit RD-195 includes the SM73201-ARC-EV PCB which is a UL1699B compliant Photo-Voltaic Arc Detect System with a minimal footprint of less than 50mm x 30mm. The reference design utilizes National Semiconductor's advanced Analog technology along with an innovative dynamic filtering technique to effectively detect the signature of Arcing conductors in the presence of highly noisy real world environments. Implemented with National Semiconductor's PowerWise® technology, the Analog path requires less than 50mW of power to implement the active filtering. The operation range of the device covers the industrial temperature range of -40°C to +125°C. SolarMagic™ technology is an overall solution that works in existing and new installations, residential, commercial, and utility scale projects. National Semiconductor's 50 years of experience in the electronics industry delivers unsurpassed manufacturing, design, and development technology.

Features

- 1,000V isolation
- Maximum DC string current=15A
- Simple LED arc detection flag
- Industrial Temperature Range (-40°C to +125°C)
- Small PCB footprint of less than 50mm x 30mm.
- Low power requirement <400mW

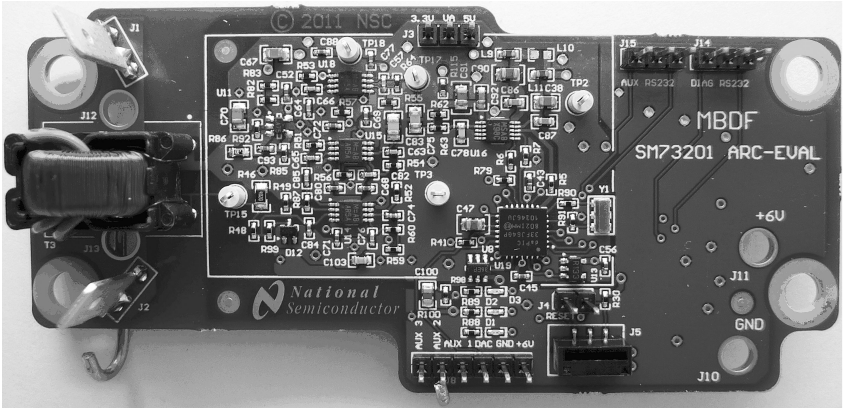

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FIGURE 1. Evaluation board

PowerWise® is a registered trademark of National Semiconductor.

Connection

The multiple connections on the Eval Board are labeled. Refer to the table below for a description of their usage.

Connection	Usage
J1	String Current A. J1 is a Flag connector
J2	String Current B. J2 is a Flag connector
J3	VA connection: a jumper between 5V and VA must be present for operation.
J4	Reset: momentarily short these pins to reset the system
J11/J8p6	Positive supply. Provide 5.4V< Vin <12.5V, with >90mA. J11 can use a banana plug.
J10/J8p5	Ground. J10 can be connected with a banana plug.
J15	RS232 interface; {Pin1:Txout, Pin2:Gnd, Pin3:Rxin}.

Quick Setup Procedure

Step 1: Connect 6V power supply positive to +6V pin of J8 (J8p6) and negative to GND pin of J8 (J8p5). Alternatively connect positive terminal to J11 and and negative terminal to J10.

Step 2: Verify proper LED pattern: GREEN LED is on, YELLOW LED is blinking, RED LED is off.

LED functionality

Upon power-up, the green LED will turn on. While the board searches for an arc, the yellow LED will blink continuously. When an arc is detected the red LED will turn on and the yellow LED will stop blinking.

As shipped, a detected Arc is automatically cleared after 4 seconds and the board will resume looking for arcs.

RS232 Interface Option

The Eval Board can output its arc detection status via an RS232 interface located at connector J15. It will periodically issue a message stating “No Arc Detected” or “Arc Detected” as appropriate.

A custom interface cable is required for this functionality; refer to the table below for pinouts

Pin Number	Function
1	TX (out)
2	GND
3	RX (in)

The port settings for the RS232 link must be set to 115200 bauds, 8 Data Bits, No Parity, 1 Stop Bit and No Flow Control on the computer or device communicating with the arc detection evaluation board.

Theory of Operation

Arcing present in a PV system creates random noise current in the cabling used for the PV string. The current noise of the arc itself has a Gaussian distribution with a spectrum extending to several MHz. Because of the geometry of the cabling in a typical PV system, the noise current density above 200 kHz, varies significantly with frequency. The inverters used in PV systems usually use switch mode controllers to regulate the incoming DC voltage. These switching regulators usually operate in the kHz range, generally below 50kHz, and cause a high noise level on the PV string wiring at the switching frequency. For these reasons, noise in the band of frequencies between 40 kHz and 100 kHz was selected for arc detection. The point in the PV string in which the arc detection system is used may be at a potential of as high as 1000 VDC. The current monitored by the system may have a DC component as high as 10Amps DC. To isolate the high DC voltage and current from the arc monitoring circuit, an isolation transformer is used. A reasonably sized transformer meeting these requirements has relatively low magnetization inductance. Because of this, the noise signal at the secondary of the transformer is relatively low.

The 50 to 100 KHz spectrum is used by services such as maritime radio navigation, and standard time services. The large loop area of a standard PV cabling system may intercept these low frequency signals and create line current many times that of the noise signals caused by arcing. In addition, the harmonics from the inverter or other electronics present on the PV systems may also create noise sources at this frequency. An effective way to eliminate these signals is by digitally processing these signals after A/D conversion. However, in order to eliminate unwanted signals digitally, the signal chain including the A/D converter must have the dynamic range to process the high level CW signals while detecting the low level noise signal created by the arc. This drives the selection of a 16-bit ADC which has a dynamic range of 96dB. This enables the signal path to handle CW signals 93 dB greater than the noise that needs to be measured for arc detection purposes. *Figure 2* shows the spectrum (10kHz-130kHz) in dB of the sensed current (after filtering and sampling) with arc and no arc condition. The arc is occuring in a PV string with a DC current of 12A.

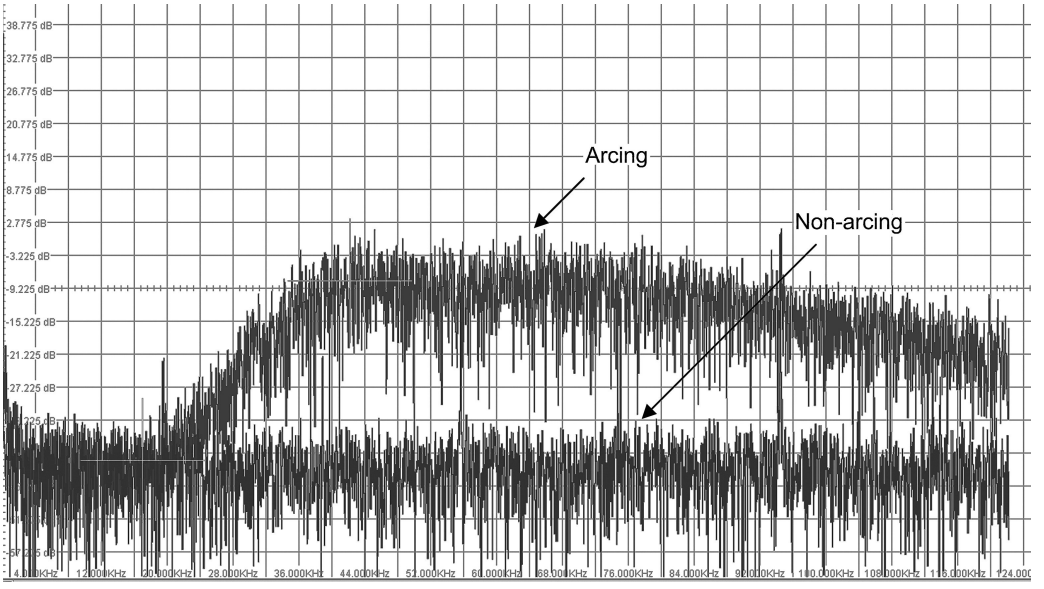

FIGURE 2. Spectrum of Digitized Current on SM73201

System Implementation

The arc detection board is comprised of a transformer, where the string current flows through the primary and that reacts to AC noise present on the string line. The signal appearing on the secondary is amplified and filtered to be fed to an A/D converter. The signal is then fed to a microcontroller for signal processing and arc detection.

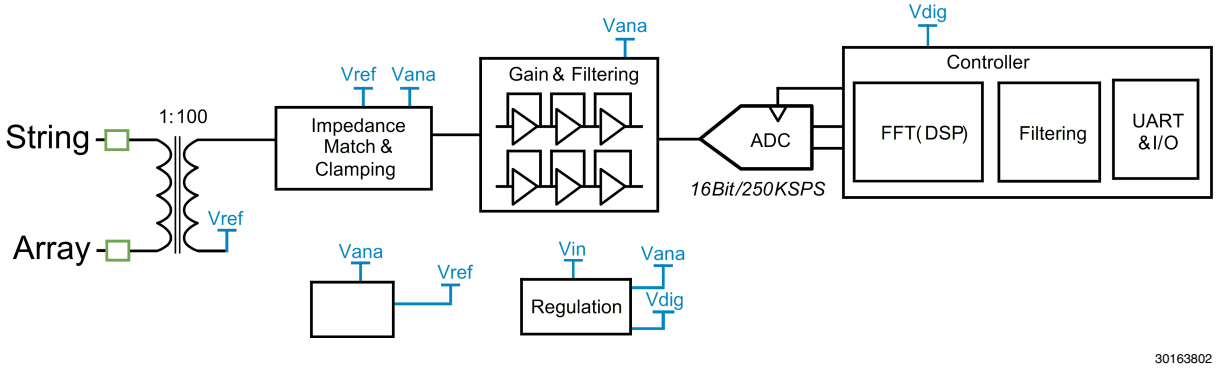

FIGURE 3. System Diagram

The board is designed to fit in a single string configuration as shown in *Figure 4*. The board connects on the negative side of the string. Arrays containing multiple PV strings can be serviced by connecting one arc detection board per string.

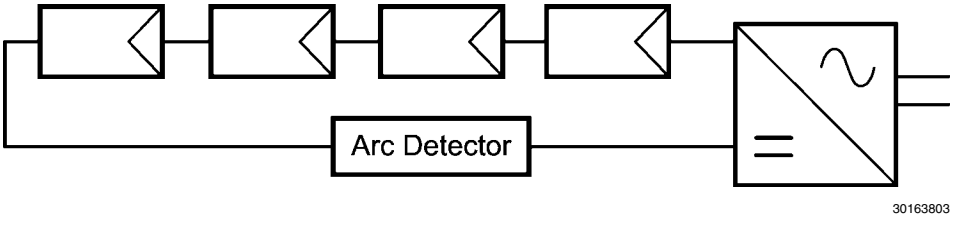

FIGURE 4. System Insertion

The board has a 1000V isolation capability. Therefore, the board could be connected at mid-string or on the positive side of the string if the voltage does not exceed 1000V. However, this is not recommended due to safety concerns regarding handling. The 6V power supply used to power the board is fed through J10 and J11. The current carrying the string current connects through J1 and J2 or J12 an J13. See *Figure 5*.

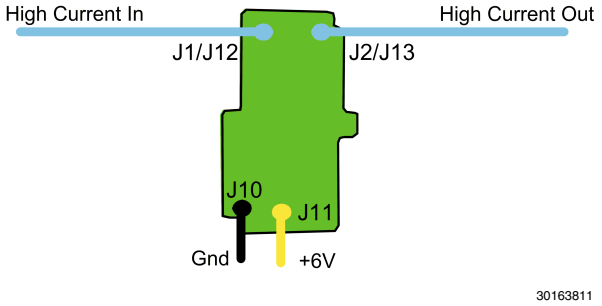

FIGURE 5. Board Connection

Design Description

The analog signal path is shown in *Figure 7*. The current is sensed through T1. U15A and U18A form a 4 pole Butterworth high pass filter, while U14B, U15B, and U18B form a 5 pole low pass filter. U18B and U14A add gain to the system with low noise floor operational amplifiers. The output of U18B is the input to the A/D conversion circuit. The filter has a cutting frequency of 40kHz for the low limit and 100kHz for the high limit. This bandwidth is necessary for the proper operation of the software programmed in the microcontroller.

The op-amps are powered from a 3.3V rail provided by a linear regulator. The op-amps inputs are biased using a reference voltage derived from another op-amp circuit shown in *Figure 6*.

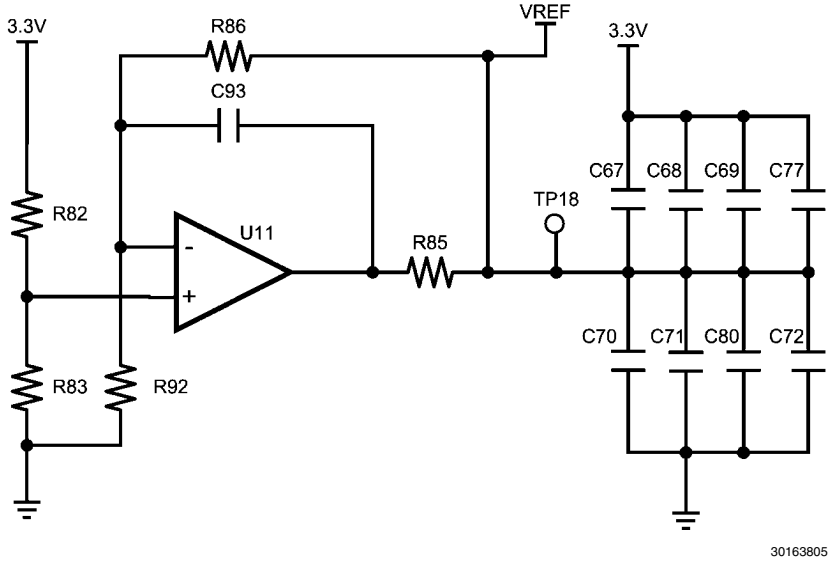

FIGURE 6. Reference voltage

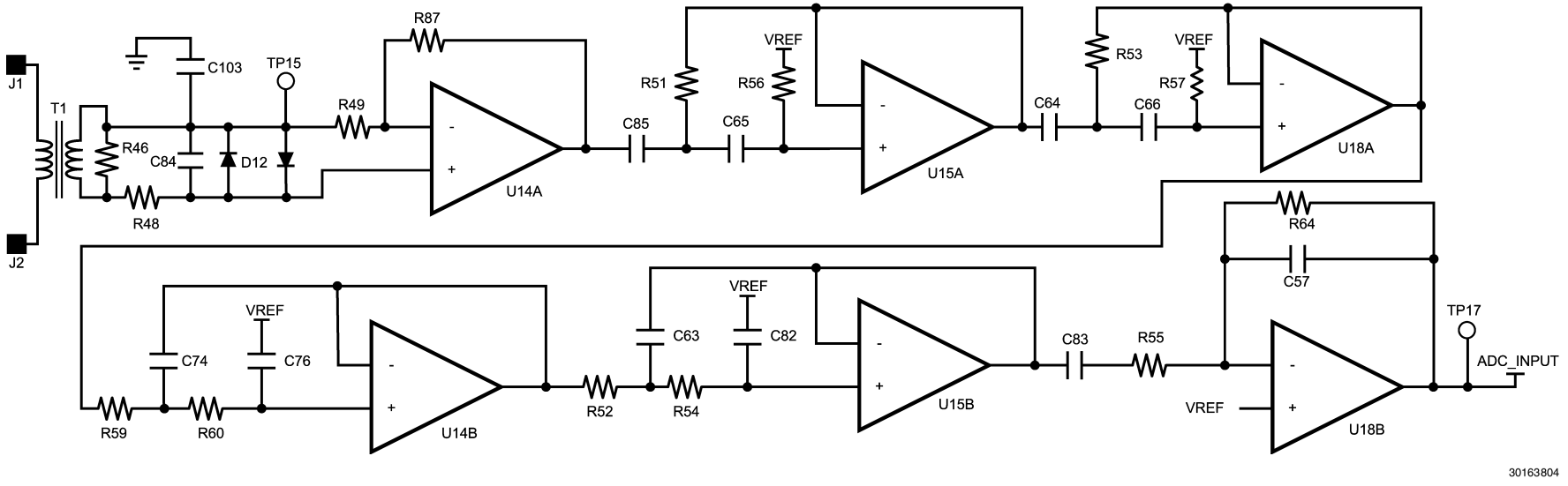

FIGURE 7. Analog Front End

The A/D converter is a 16bit converter operating at approximately 250kS/s. The high resolution translates to a high dynamic range for the sensed signal, thereby allowing the arc signature to be sensed properly without clipping due to the potentially higher amplitude of interference signals from the inverter. The converter sampling rate is controlled by the microcontroller. The connection is shown in *Figure 8*.

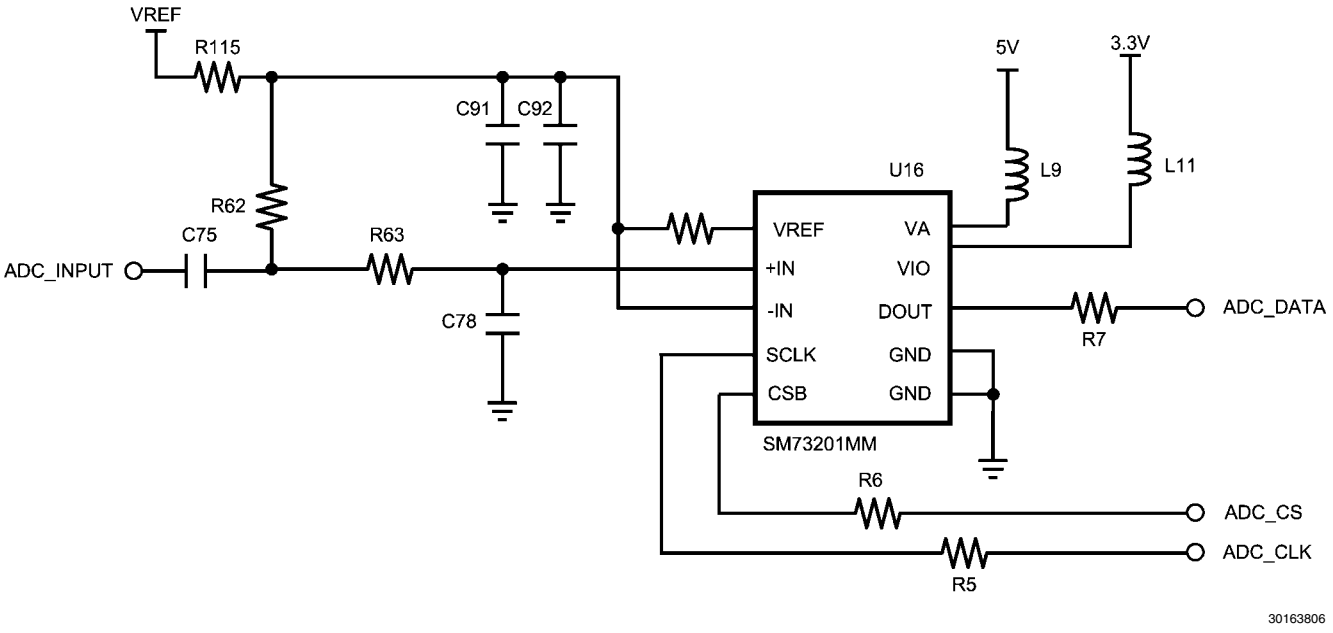

FIGURE 8. A/D Converter

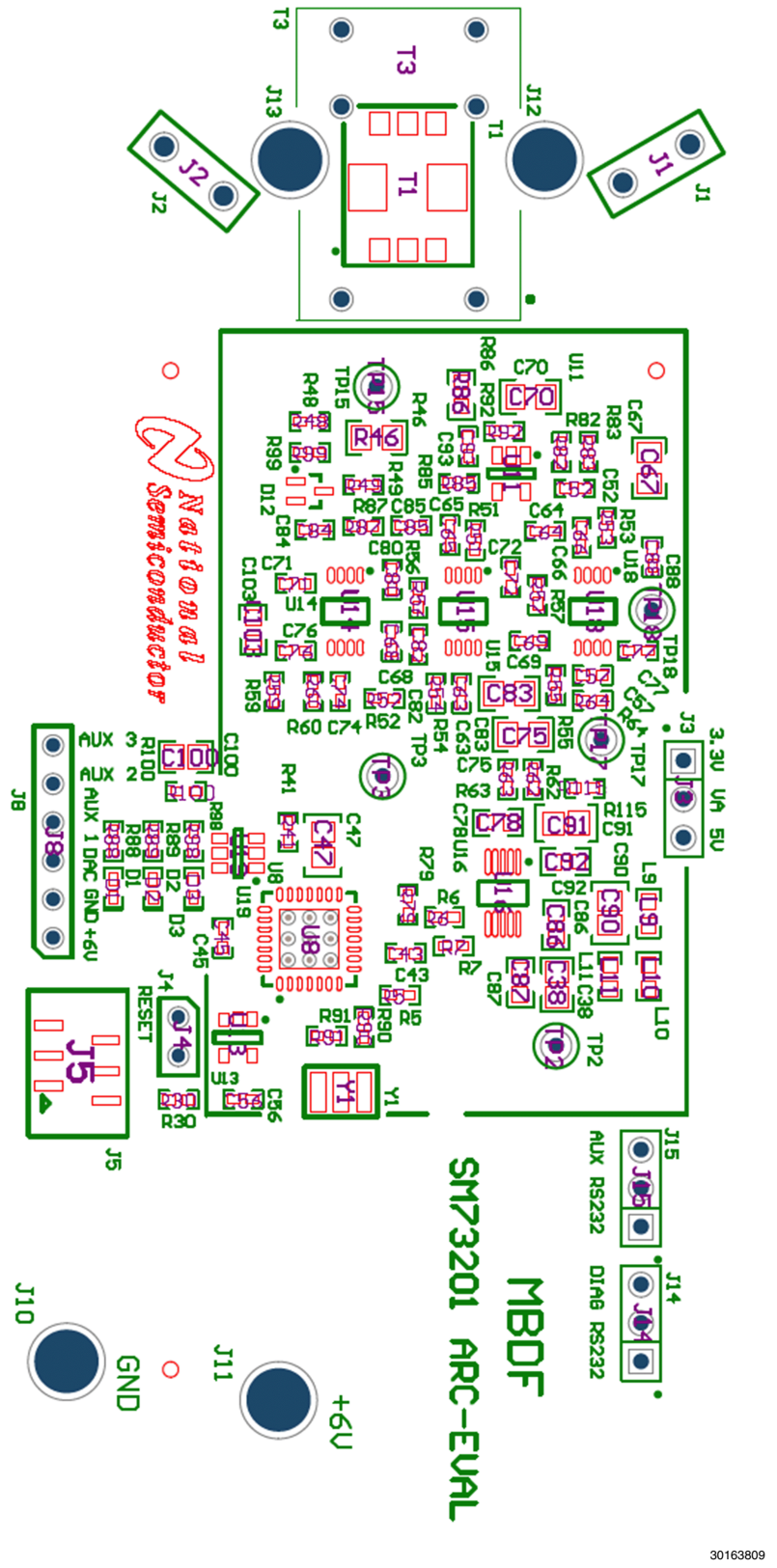

FIGURE 9. Board Assembly TOP

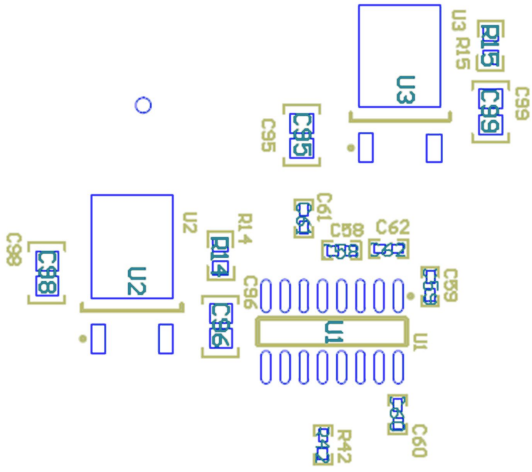

FIGURE 10. Board Assembly BOTTOM

Bill of Materials

Designator	Description	Manufacturer	Part Number	Quantity
C38, C47, C90, C91, C95, C98, C100	CAP, CERM, 1uF, 16V, +/-10%, X7R, 0805	Taiyo Yuden	EMK212B7105KG-T	7
C43, C45, C52, C56, C58, C59, C60, C61, C62, C68, C69, C71, C72, C77, C80, C88	CAP CER .10UF 16V X7R AUTO 0402	TDK	CGA2B1X7R1C104K	16
C57, C63, C64, C65, C66, C76, C85	CAP CER 1000PF 50V 5% C0G 0402	Murata	GRM1555C1H102JA01D	7
C67, C70	CAP, CERM, 4.7uF, 10V, +/-10%, X5R, 0805	MuRata	GRM219R61A475KE34	2
C74	CAP CER 1500PF 25V 5% C0G 0402	Murata	C0402C152K3GACTU	1
C75, C83	CAP, CERM, 0.033uF, 25V, +/-5%, C0G/NP0, 0805	TDK	C2012C0G1E333J	2
C78	CAP CER 1000PF 50V 5% C0G 060	Murata	GRM1885C1H102JA01D	1
C82	CAP CER 91PF 50V 5% C0G 0402	TDK	C1005C0G1H910J	1
C84	CAP CER 2200PF 25V 5% C0G 0402	Kemet	C0402C222J3GACTU	1
C86, C87, C92	CAP, CERM, 0.1uF, 25V, +/-10%, X7R, 0603	MuRata	GRM188R71E104KA01D	3
C93	CAP CER 10PF 50V C0G 0402	Mutata	GCM1555C1H100JZ13D	1
C96, C99	CAP, CERM, 2.2uF, 16V, +/-10%, X7R, 0805	Taiyo Yuden	EMK212B7225KG-T	2
C103	CAP, CERM, 2200pF, 50V, +/-5%, C0G/NP0, 0603	TDK	C1608C0G1H222J	1
D1	LED RED RECTANGLE SMD 0402	Panasonic	LNJ247W82RA	1
D2, D3	LED GREEN RECTANGLE SMD 0402	Panasonic	LNJ347W83RA	2
D12	DIODE SW DUAL 75V 200MW SC70-3	Micro Commercial	BAV99W-7-F	1
FID1, FID2, FID3, FID4, FID5, FID6, J10, J11, J12, J13	200 mill pad with 165 mill hole, Fiducial mark. There is nothing to buy or mount.	N/A	N/A	10
J1, J2	TERM QF .032"DIA .250" STURDY MT	Keystone	1289-ST	2
J3, J14, J15	Header, TH, 100mil, 3x1, Gold plated, 230 mil above insulator	Samtec Inc.	TSW-103-07-G-S	3
J4	CONN HEADER 2POS .100" T/H GOLD	Samtec	HTSW-102-07-L-S	1
J5	CONN FPC/FFC 6POS 1MM VERT SMD	FCI	HFW6S-2STE1LF	1
J8	CONN HEADER 6POS VERT .100 GOLD	Tyco	644884-6	1
L9, L11	FERRITE CHIP 330 OHM 1200MA 0603	Murata	BLM18PG331SN1D	3
R5	RES, 64.9 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040264R9FKED	1
R6, R7, R49, R55	RES, 1.00k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K00FKED	4
R14, R15, R86	RES, 0.33 ohm, 1%, 0.1W, 0603	Panasonic	ERJ-3RQFR33V	3
R30	RES, 60.4k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040260K4FKED	1
R41, R42, R62, R79, R82, R83	RES, 10.0k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040210K0FKED	6
R46	RES, 402 ohm, 1%, 0.125W, 0805	Vishay-Dale	CRCW0805402RFKEA	1
R48, R100	RES, 100 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW0402100RFKED	2
R51	RES, 2.61k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04022K61FKED	1
R52, R54	RES, 5.11k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04025K11FKED	2
R53	RES, 1.78k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K78FKED	1
R56	RES, 3.92k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04023K92FKED	1
R57	RES, 10.5k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040210K5FKED	1
R59, R60	RES, 1.27k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K27FKED	2

Designator	Description	Manufacturer	Part Number	Quantity
R63, R99	RES, 49.9 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040249R9FKED	2
R64	RES, 1.65k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K65FKED	1
R85, R115	RES, 1.00 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021R00FNED	2
R87	RES, 2.05k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04022K05FKED	1
R88, R89, R98	RES, 330 ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW0402330RJNED	3
R90	RES, 681 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW0402681RFKED	1
R91, R92	RES, 1.00Meg ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021M00FKED	2
T3	XFRMR CURR SENSE 76MH 200:1:1 TH	Pulse	P0581NL	1
TP2, TP3, TP15, TP17, TP18	Test Point, TH, Miniature, White	Keystone Electronics	5002	5
U1	15KV ESD Rated, 5V Single Supply TIA/EIA-232 Dual Transceivers	National Semiconductor	LMS202EIM	1
U2	IC REG VOLT MICROPWR 3.3V TO-252	National Semiconductor	SM72238TD-3.3	1
U3	IC REG VOLT MICROPWR 5V TO-252	National Semiconductor	SM72238TD-5.0	1
U8	IC DSPIC MCU/DSP 64K 28-QFN-S	Microchip Technology	DSPIC33FJ64GP802-I/MM	1
U11	IC OPAMP LOW OFFSET RRO SC70-5	National Semiconductor	SM73308MG	1
U13	5-Pin Microprocessor Reset Circuit 3.08V	National Semiconductor	SM72240MF-3.08	1
U14, U15, U18	1.8V Precison, Dual Low Noise CMOS Input Op Amp	National Semiconductor	SM73307MM	3
U16	IC ADC 16BIT 50/250KSPS 10-MSOP	National Semiconductor	SM73201IMM	1
U19	IC EEPROM 4KBIT 10MHZ SOT23-6	Microchip Technology	25LC040AT-E/OT	1
Y1	CER RESONATOR 6.00MHZ SMD	Murata	CSTCR6M00G53-R0	1
T1	Current sense and ARC detect transformer	Pulse	PA1005.100NLT	1

Notes

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Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Applications & Markets	www.national.com/solutions
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