Wolfspeed | A CREE COMPANY

(CRD-06600FF10N)

6.6 kW Bi-Directional EV On-Board Charger

OVERVIEW OF CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger

- CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger demo board is based on Cree's 1000 V, 65 mΩ (C3M™) SiC MOSFETs
- This demo board consist of a Bi-Directional Totem-Pole PFC (AC/DC) Stage and an Isolated Bi-Directional DC/DC Stage based on a CLLC topology with a variable DC Link Voltage
- Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger demo board is mainly targeting the EV Charging and the Energy Storage Industries

DESIGN SPECIFICATIONS

- The design specifications of CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger demo board are mentioned in the following table:

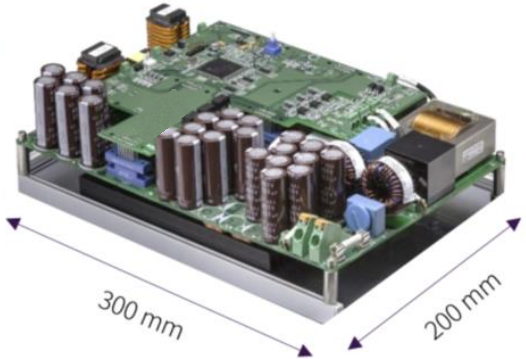
Charging Mode		
Parameters	**Values**	**Notes**
Input voltage range	90VAC-265VAC	Nominal Voltage = 230 VAC Power will be limited when input voltage is below 208 VAC
THD and PF	THD <5% and PF > 0.99	At Rated Power
Output voltage range	250VDC-450VDC	Output current will be limited to 20A when the battery voltage is below 320VDC; Constant Power between 320VDC-430VDC; constant voltage above 430VDC
Input rated power	6.6 kW	
Isolation voltage	> 2.5 kV	
Switching frequency of PFC	67 kHz	
Switching frequency of DC/DC	200 kHz	
Peak Efficiency	> 96%	
Max Ambient Temperature	65 °C	Force Air Cooling

DESIGN SPECIFICATIONS (CONTINUED..)

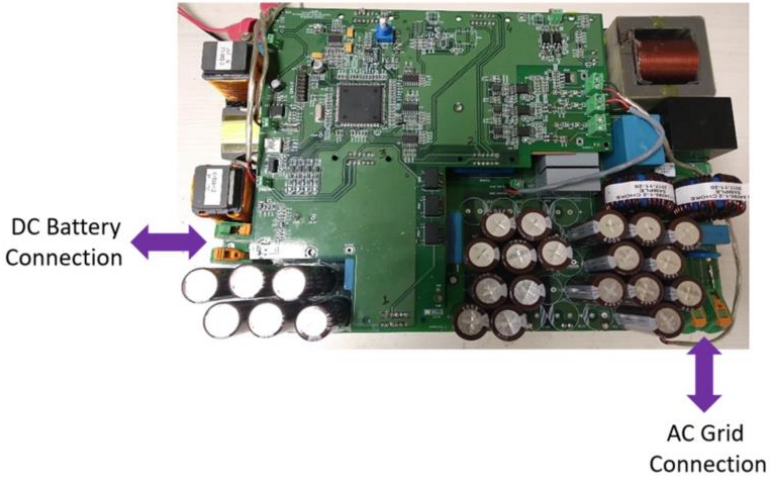
Inversion Mode		
Parameters	**Values**	**Notes**
Input voltage range	250VDC-450VDC	When the battery voltage is below 320VDC, it will stop delivering power
THD and PF	THD <5% and PF > 0.99	At Rated Power
Output voltage range	Grid Voltage: 120 VAC or 230 VAC	Standalone Mode: 230 VAC, 60 Hz
Input rated power	3.3 kW	
Isolation voltage	> 2.5 kV	
Switching frequency of DC/AC	67 kHz	
Switching frequency of DC/DC	200 kHz	
Peak Efficiency	> 96%	
Max Ambient Temperature	65 °C	Forced air cooling for the base plate or the completed PCBA

PHYSICAL DIMENSIONS AND THE PINOUTS OF CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger

- The physical dimensions and the pinouts of CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger demo board are:



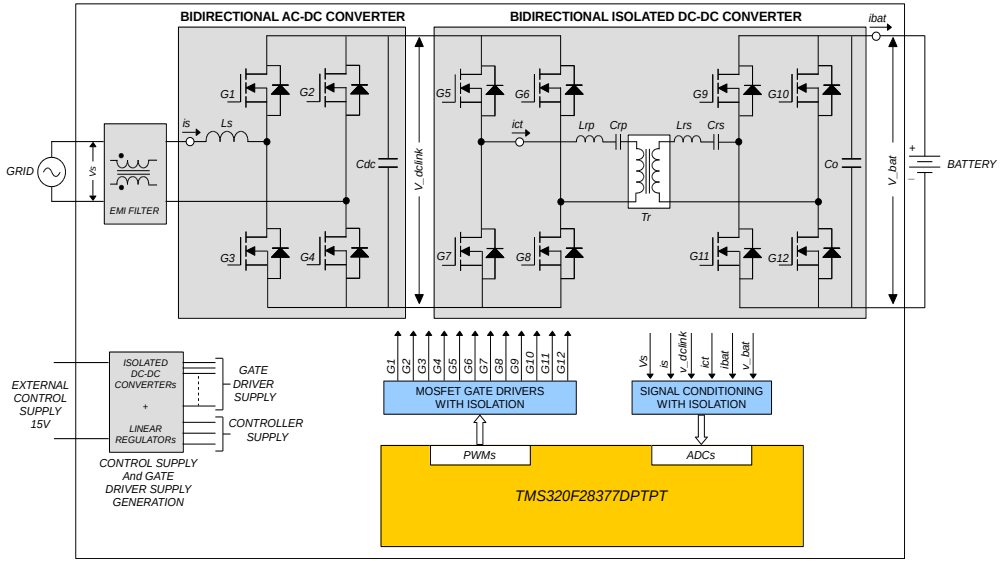
Physical Dimensions



Pinouts

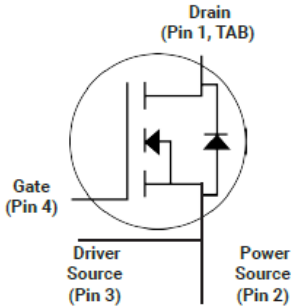
ELECTRICAL OPERATION (OVERVIEW)

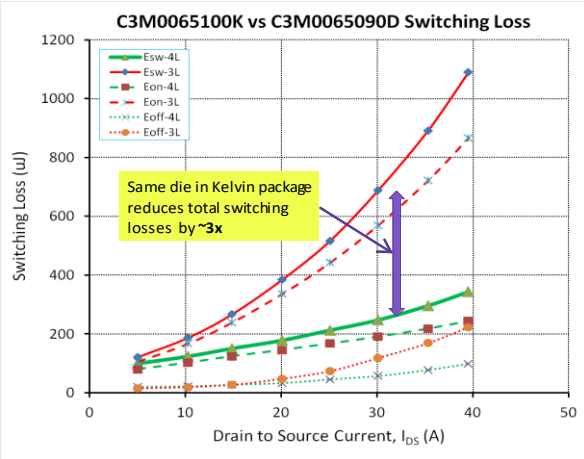
- CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger demo board consist of a Bi-Directional Totem-Pole PFC (AC/DC) stage and an isolated Bi-Directional DC/DC stage based on CLLC topology with a variable DC Link Voltage
- Cree's 1000 V, 65 mΩ (C3M™) SiC MOSFETs have been utilized on both stages of the CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger demo board
- The control system of this demo board is based on Texas Instruments (TI) DSP controller (P/N: TM2320F28377)



ELECTRICAL OPERATION (Cree's 1000 V, 65 mΩ (C3M™) SiC MOSFET)

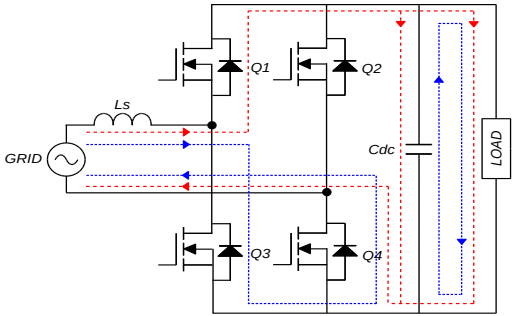
- Cree's 1000 V, 65 mΩ (C3M™) SiC MOSFET (P/N: C3M0065100K) has been utilized in CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board
- C3M0065100K comes in a TO-247-4 Package with a Kelvin source availability
- There is a significant reduction in the source inductance due to the presence of Kelvin source which not only enable faster switching but also play an important role in the reduction of switching losses
- As compared to the TO-247-3 package, the switching losses of TO-247-4 package are 3X lower



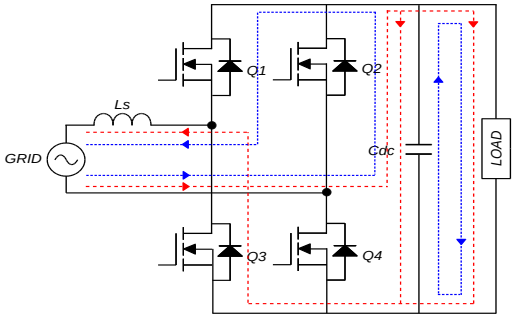


ELECTRICAL OPERATION (AC/DC STAGE)

- In the charging mode, the AC/DC stage is configured as a Totem-Pole PFC Boost converter.
- One leg of the Totem-Pole (AC/DC) PFC stage will switch at high frequency while the other leg operates at low frequency (Grid Frequency)
- Due to the proper switching sequence of SiC MOSFETs in AC/DC stage, the DC Bus remain regulated to the required DC voltage while maintaining the inductor current close to the sinusoidal shape and in phase with the grid voltage
- In the inversion mode, the circuit is configured to work as a grid tie inverter and feed the grid from the available battery energy. The switching scheme remains the same



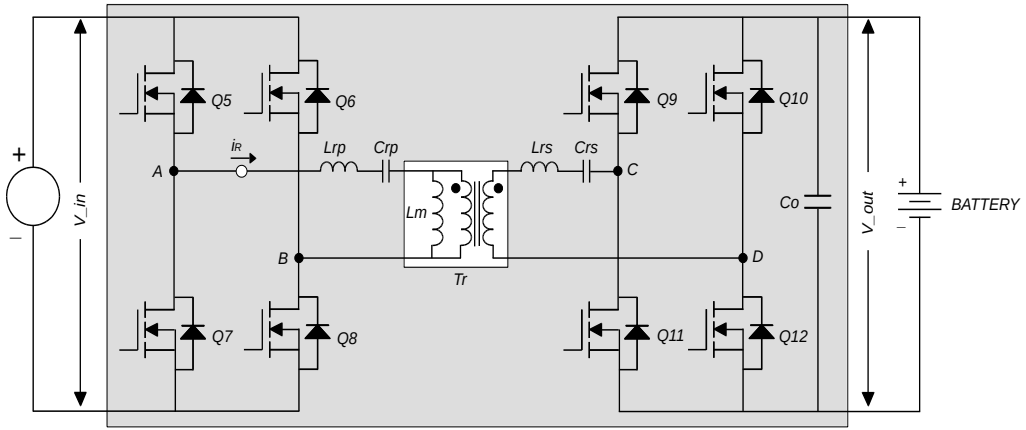
Current path during positive half cycle



Current path during negative half cycle

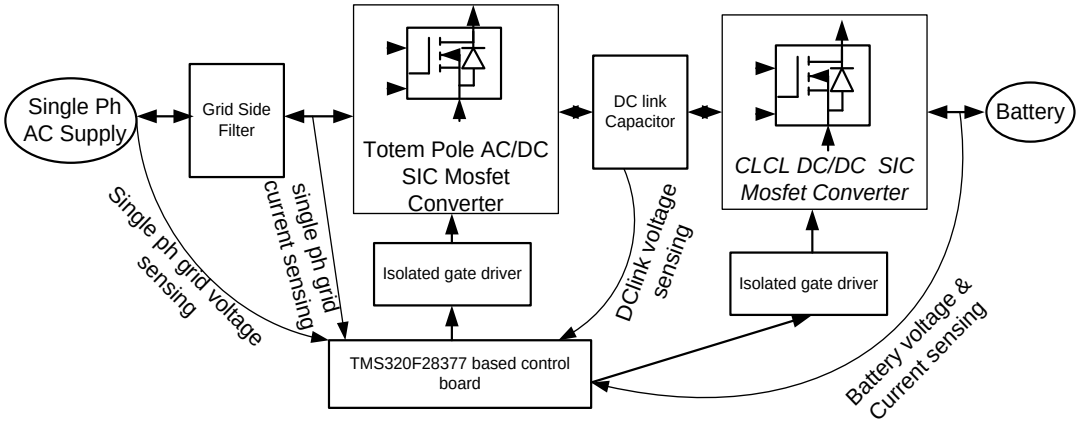
ELECTRICAL OPERATION (DC/DC STAGE)

- The DC-DC Bi-Directional CLLC stage comprises of two identical H-Bridges separated by an isolation transformer.
- Both H-Bridges have dedicated isolated gate drivers with a separate isolated power supply for each SiC MOSFET.
- The construction of CLLC converter is similar to the LLC converter with an addition of LC pair on the secondary side which enable Bi-Directional operation.
- The DC-DC Bi-Directional CLLC stage has been designed to operate at resonance frequency of operation which means that the DC Link voltage will vary in response to the battery voltage and current.



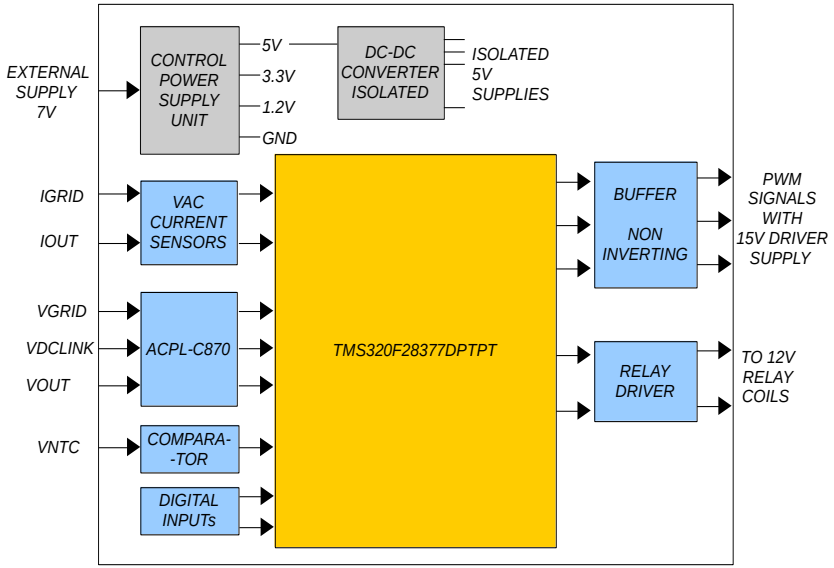
ELECTRICAL OPERATION (CONTROL STRUCTURE)

- Totem-Pole PFC (AC/DC) Stage has a two loop structure, the outer voltage loop controls the DC Link voltage which generates the reference for inner current loop
- The inner current loop maintains a sinusoidal current in phase with the input grid voltage
- The DC-DC Bi-Directional CLLC stage runs at a fixed frequency (resonance) and does not have any kind of closed loop control
- The control algorithm has been implemented on Texas Instruments (P/N: TMS320F28377) Delfino floating point processor



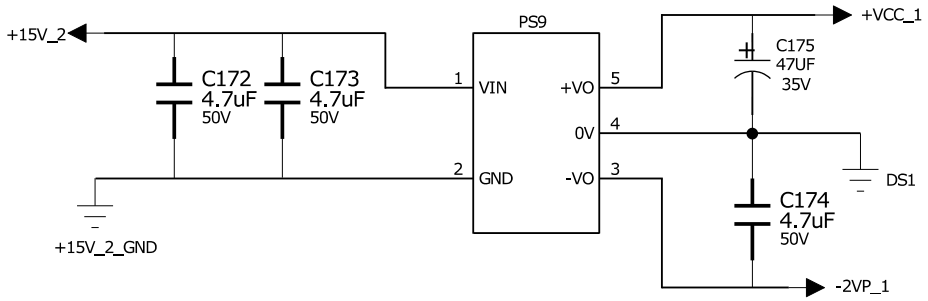
ELECTRICAL OPERATION (CONTROL BOARD)

- In addition to the Texas Instruments (P/N: TMS320F28377) Delfino floating point controller, the control board of CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board consist of further sub-systems as well.
- These sub-systems includes Control Power Supply unit, DC-DC Converter for analog isolation amplifiers, Sensors and Voltage / Current feedback circuitry.



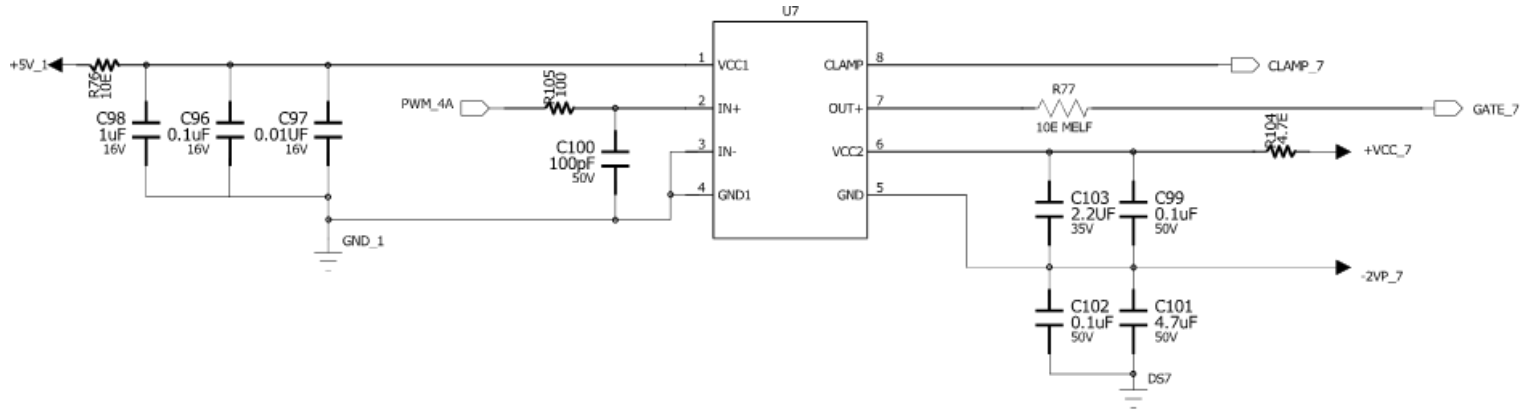
ELECTRICAL OPERATION (GATE DRIVER CIRCUITRY)

- The gate driver circuity is based on isolated gated driver ICs with up to 1200 V isolation on the high voltage side and 3.75 kV isolation on the battery side.
- The isolated dual polarity gate driver supplies for each driver IC is generated from an isolated DC-DC converter module from Mornsun (P/N: QA15115R2) which is powered up by an external 15 V source
- This module generates dual supply of +15 V and -2.5 V with each output capable of handling 100 mA current while the Isolation of the module is up to 3.5 kV



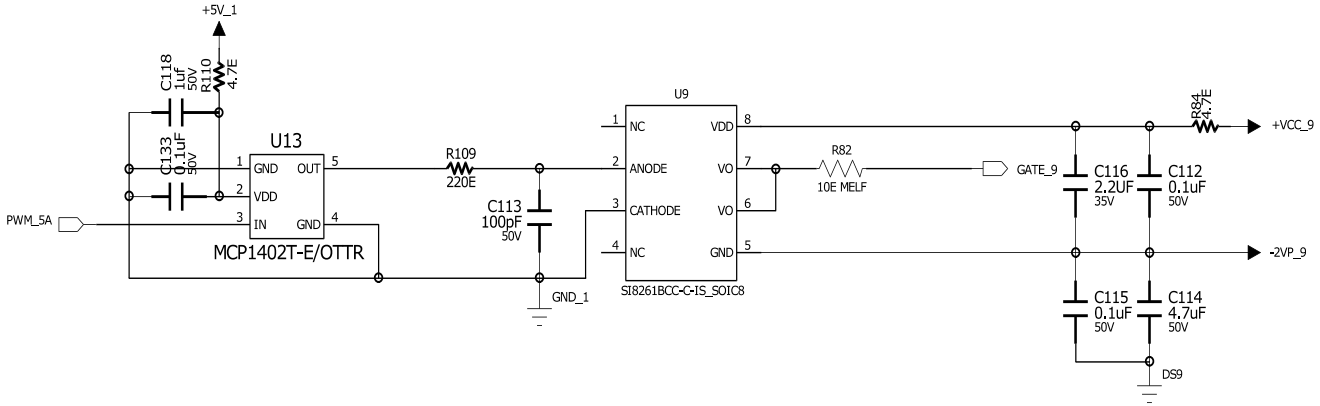
ELECTRICAL OPERATION (GATE DRIVER CIRCUITRY)

- The high voltage side MOSFETs are driven by Infineon gate driver IC (P/N: 1EDI30I12MHXUMA1)
- The driver features 3A peak source and sink current capability, up to 1200 V isolation and active miller clamp for gate which along with the negative supply provides an additional protection against parasitic Turn-On of the MOSFET
- Some additional features of the gate driver includes: under voltage protection, short circuit protection and the low internal voltage drop to ensure the minimal power dissipation



ELECTRICAL OPERATION (GATE DRIVER CIRCUITRY)

- The battery side MOSFETs are driven from an Silicon Labs isolated gate driver IC (P/N: Si8261BCC-C-IS)
- The driver IC is capable of supporting gate current of up to 4A with input to output isolated of about 3.75 kV
- Some additional features of the gate driver includes: under voltage protection and low power dissipation
- Output of the driver follows the input current through the LED at the input side. The current through the LED should > 6 mA to rise the output of the driver
- A non-inverting buffer IC from Microchip (P/N: MCP1402) has been used to provide the adequate level of current (> 6mA) through the LED at the input side



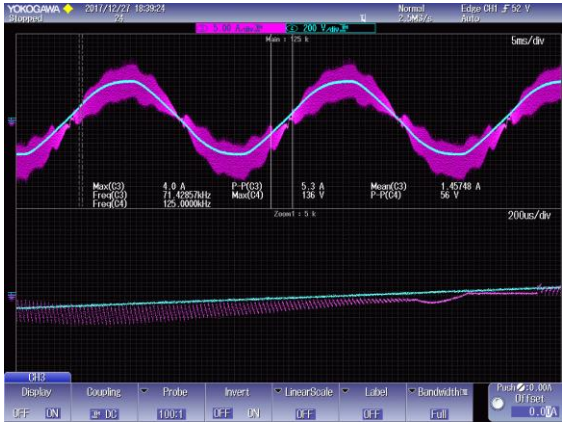
PERFORMANCE DATA

PERFORMANCE DATA (AC/DC STAGE)

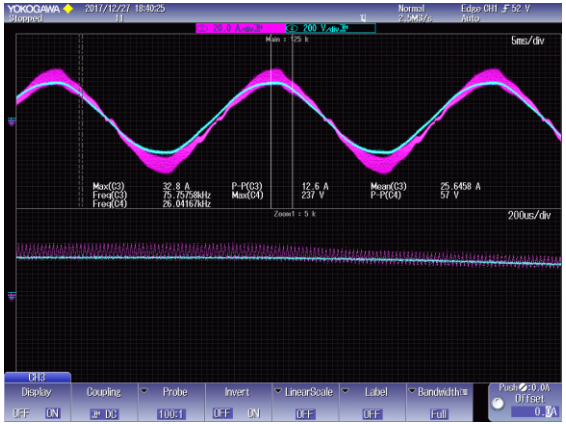
- Performance of the AC/DC stage of Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board can be evaluated by the analysis of drain to source voltage (Green) and the gate to source voltage (Yellow) waveforms, while Switching Frequency of one of the leg is maintained at 67kHz
- There is no ringing or oscillation observed in both drain to source voltage (Green) and gate to source voltage (Yellow) waveforms

PERFORMANCE DATA (AC/DC STAGE)

- Performance of the AC/DC stage can be analyzed by the Inductor current (Pink) and Grid voltage (Blue) waveforms
- Both Inductor current (Pink) and Grid voltage (Blue) waveforms are measured at 1.4 kW and 6.0 kW
- In both loading conditions, the Inductor current (Pink) and Grid voltage (Blue) waveforms remain in phase with each other. At 1.4 kW load, the THD of current waveform is 10.7% while at 6.0 kW load, the THD of current waveform is 6.3%



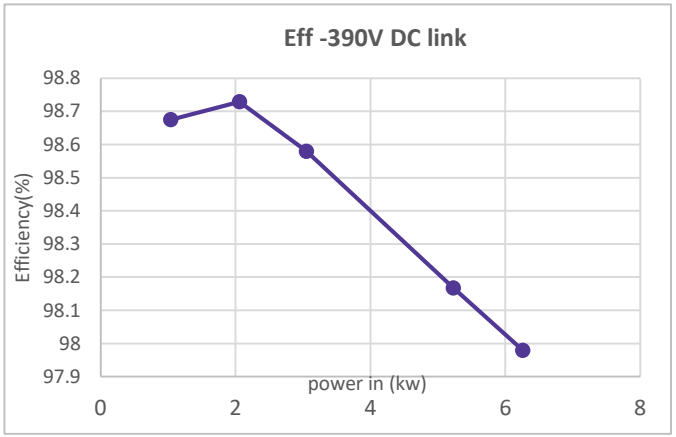
1.4 kW

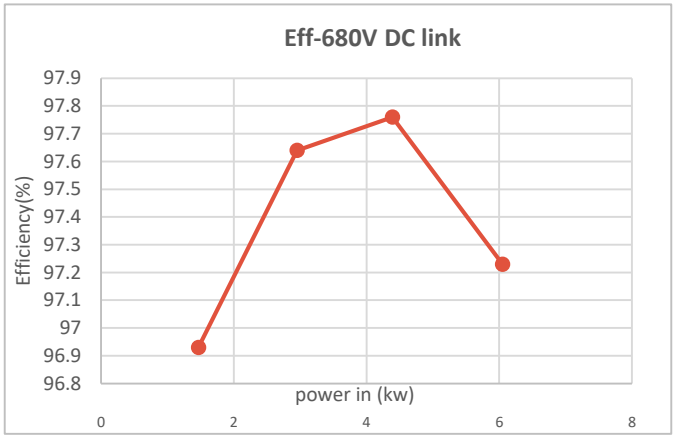


6.0 kW

PERFORMANCE DATA (AC/DC STAGE)

- The efficiency of the AC/DC stage is also measured at various DC Link voltage levels
- AT 390 V DC Link voltage, the efficiency of the AC/DC stage is close to 98 %
- While at 680 V DC Link voltage, the efficiency of the AC/DC stage is close to 97.2 %



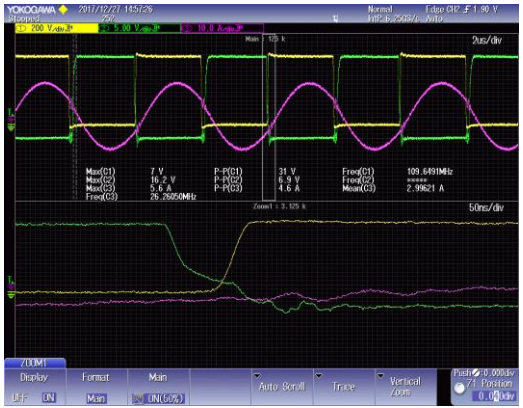


PERFORMANCE DATA (DC/DC STAGE)

- Performance of the DC/DC Stage of Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board can be evaluated by analyzing primary current (Pink), primary MOSFET gate (Green) and drain to source voltage (yellow) waveforms at various input voltages and load conditions
- During no load, 4.5 kW Load (Vin = 280 V) and 6.2 kW Load (Vin = 450 V) conditions, all waveforms remain smooth with negligible ringing during the switching events

No Load

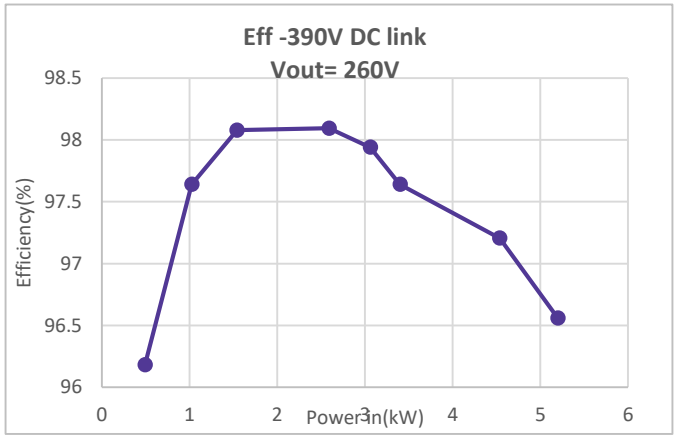
4.5 kW (@ 280 Vin)

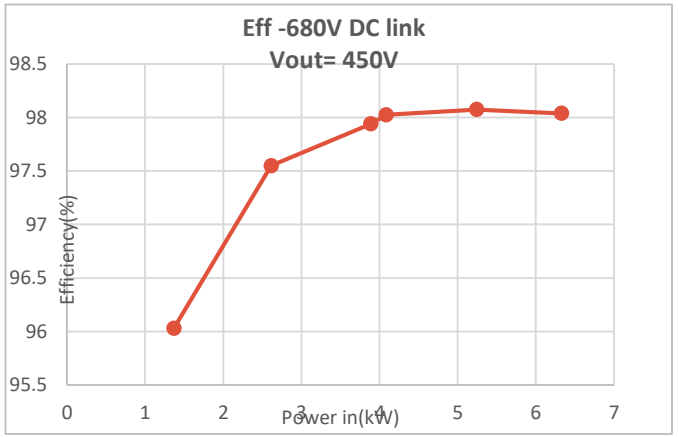


6.2 kW (@ 450 Vin)

PERFORMANCE DATA (DC/DC STAGE)

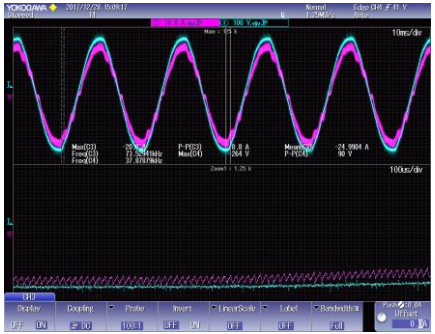
- The efficiency of the DC/DC stage is measured at various DC Link and Output voltage levels
- AT 390 V DC Link voltage and 260 V Output voltage, the efficiency of the DC/DC stage is close to 97 %
- While at 680 V DC Link voltage and 450 V Output voltage, the efficiency of the DC/DC stage is 98 % (approximately)



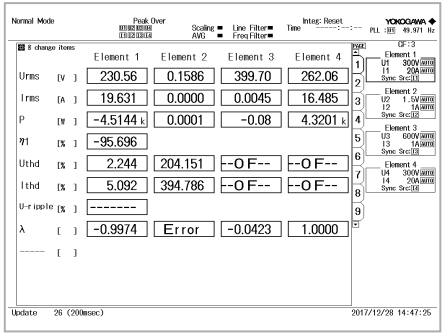


PERFORMANCE DATA (AC/DC STAGE + DC/DC STAGE)

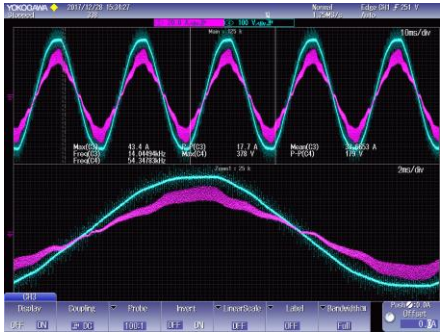
- For the performance evaluation of whole system (AC/DC + DC/DC), Grid Voltage of 230 V is fed into the system and the DC output reference is set at 260 V and 450 V respectively with a loading condition of 4.3 kW.
- The overall efficiency achieved by the whole system during the above mentioned conditions is close to 96 %
- During these conditions, the Inductor current (Pink) and the Grid voltage (Blue) waveforms remain in phase with each other as well



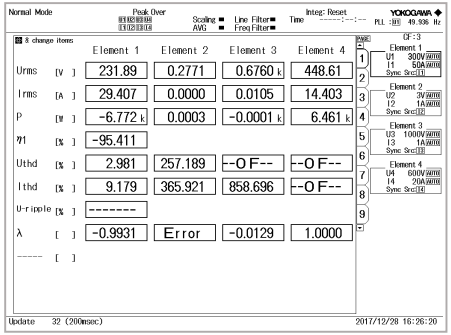
Inductor Current & Grid Voltage at 260 V output



Power Analyzer Measurements at 260 V output



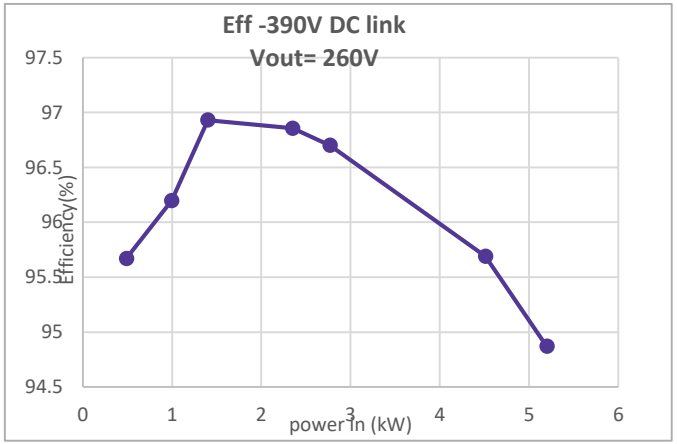
Inductor Current & Grid Voltage at 450 V output

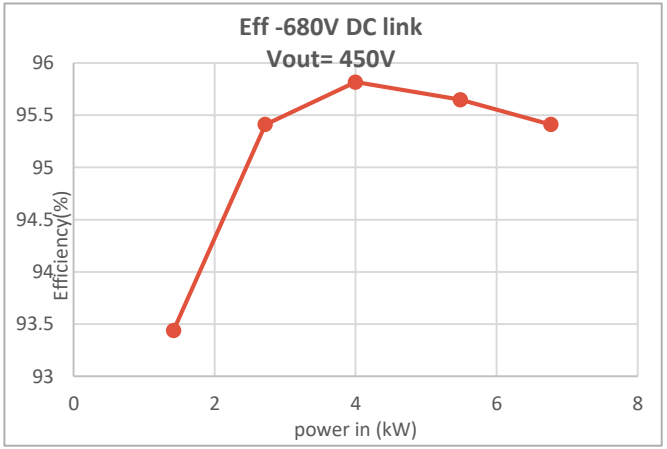


Power Analyzer Measurements at 450 V output

PERFORMANCE DATA (AC/DC STAGE + DC/DC STAGE)

- The overall efficiency achieved by the whole system during the loading condition of 4.3 kW with 260 V Grid Voltage is close to 96 %
- While the overall efficiency at the loading condition of 4.3 kW with 450 V Grid Voltage is close to 96 % as well





SUMMARY

- Demonstration of Cree's 1000 V, 65 mΩ (C3M™) SiC MOSFETs in a 6.6 kW Bi-Directional converter targeting high efficiency and high power density On-Board Charging applications
- Cree's new C3M™ SiC MOSFETs have low switching losses and superior body diode performance, which is ideal for the Bi-Directional Totem-Pole PFC (AC/DC) Stage and for an Isolated Bi-Directional (DC/DC) Stage based on a CLLC topology with a variable DC Link Voltage
- Utilization of the high switching frequency operation allows CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board to be smaller, lighter and overall more cost effective
- Overall efficiency achieved by the 6.6 kW Bi-Directional EV On-Board Charger Demo Board is close of 96% with a THD < 5% under all load conditions

(If user require more information about the detailed operation of Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board please review Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board's Application Note)

(If user have questions about Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board, please contact Cree at sic_power@cree.com)

APPENDIX

- Schematic of Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo board

- Package Contents of Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board

(If user require more information about the detailed operation of Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board please review Cree's CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger Demo Board's Application Note)

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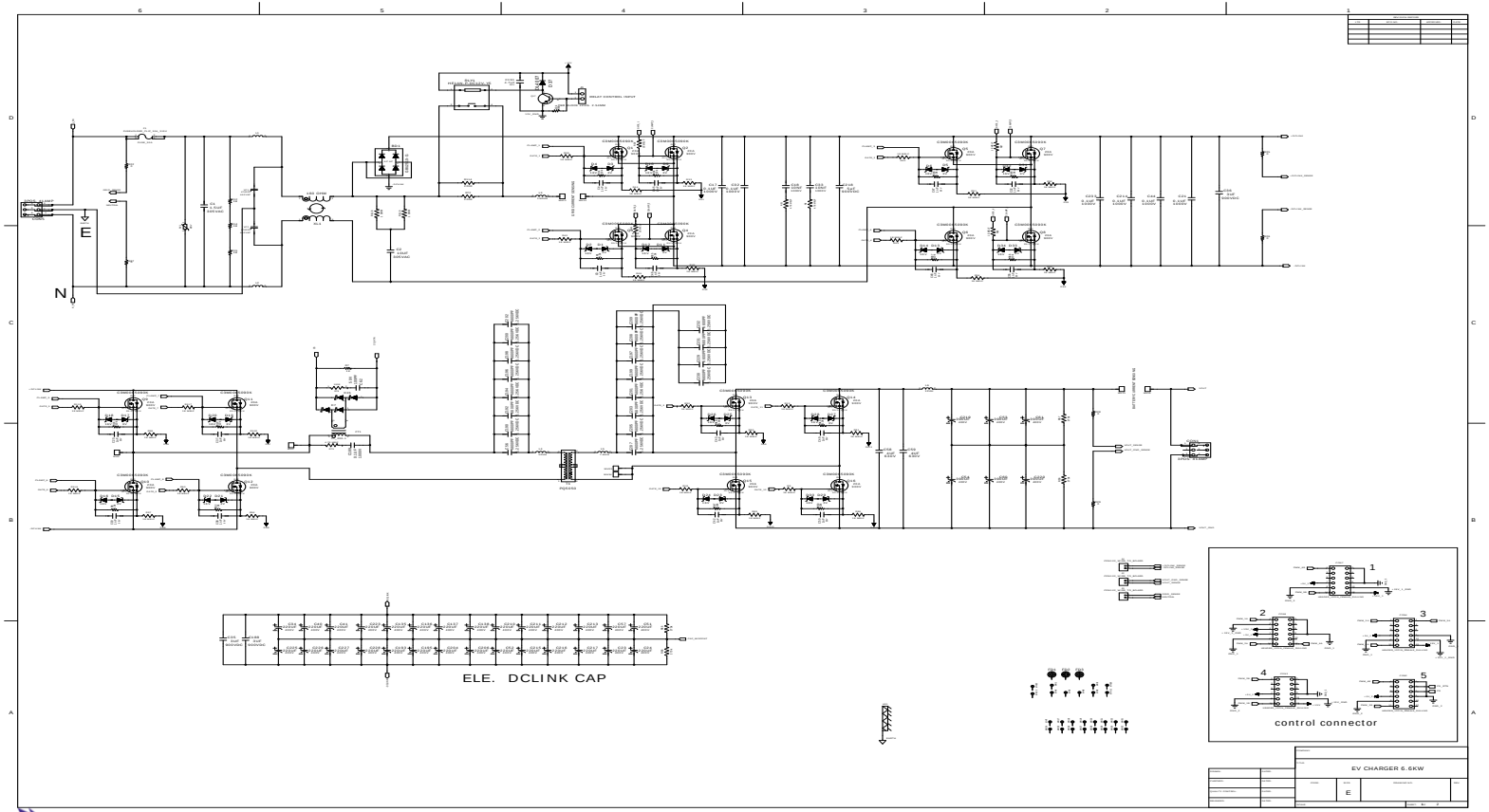
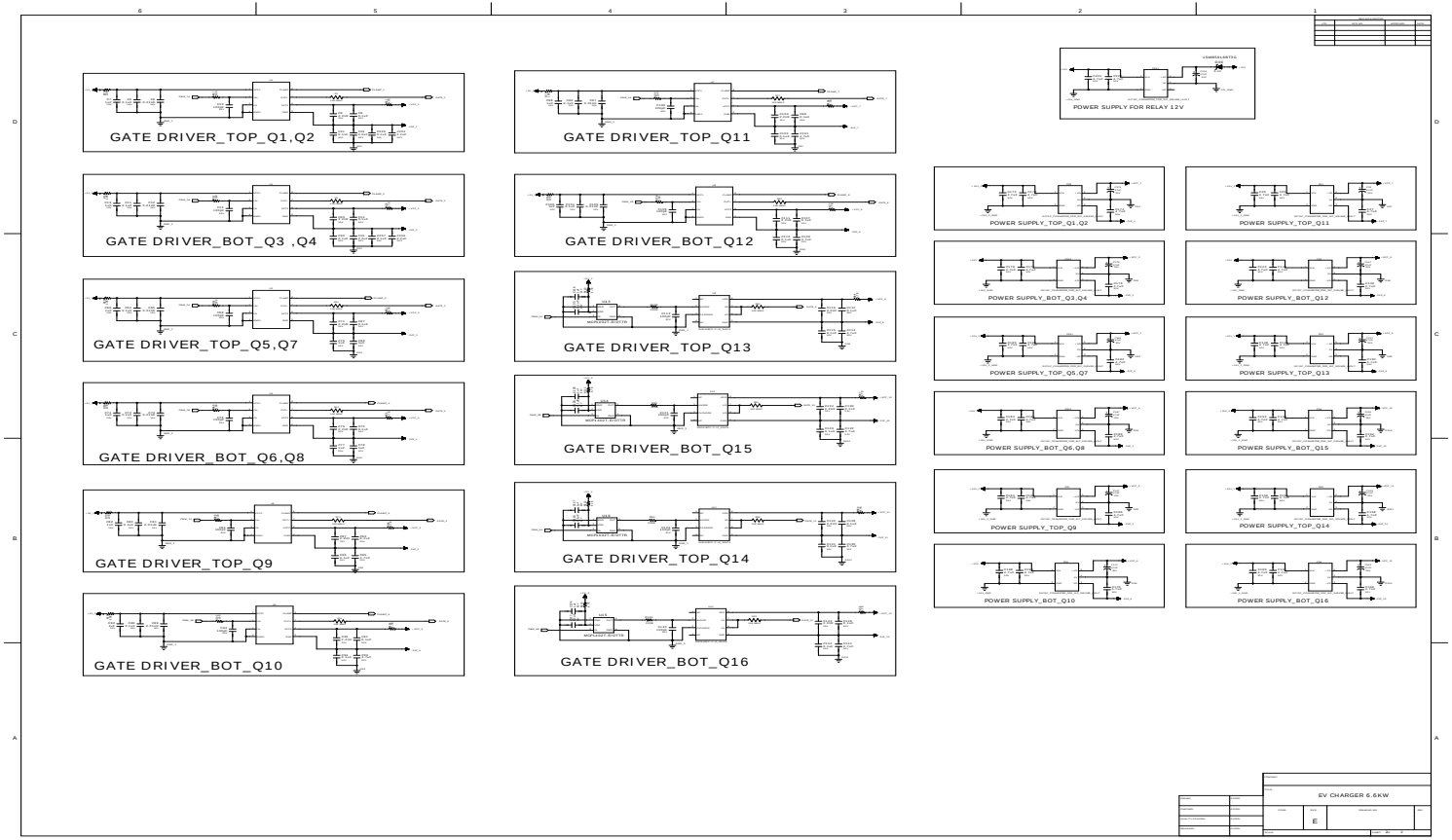
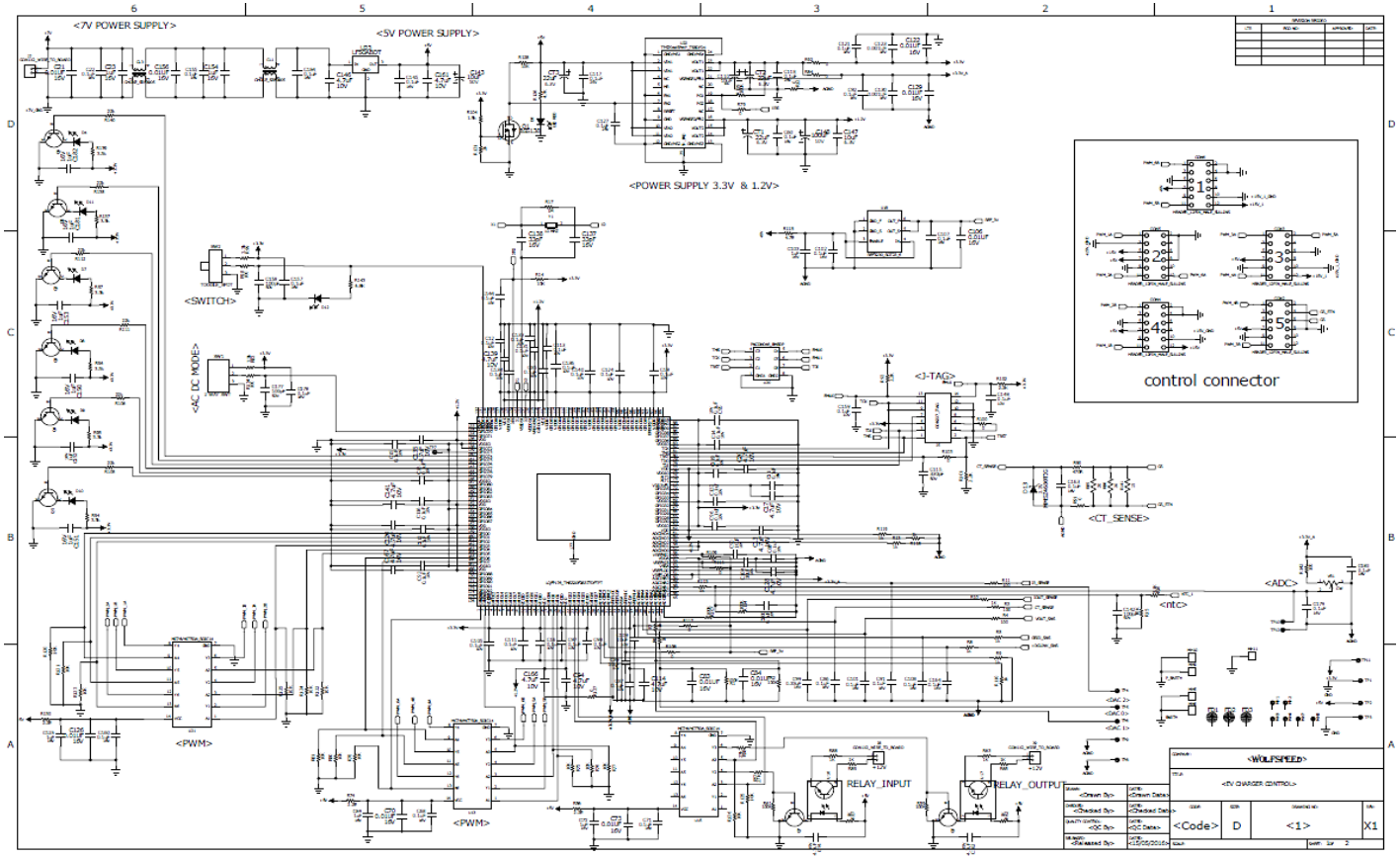
SCHEMATIC OF CRD-06600FF10N, 6.6 kW
Bi-Directional EV On-Board Charger (POWER BOARD SLIDE 1)



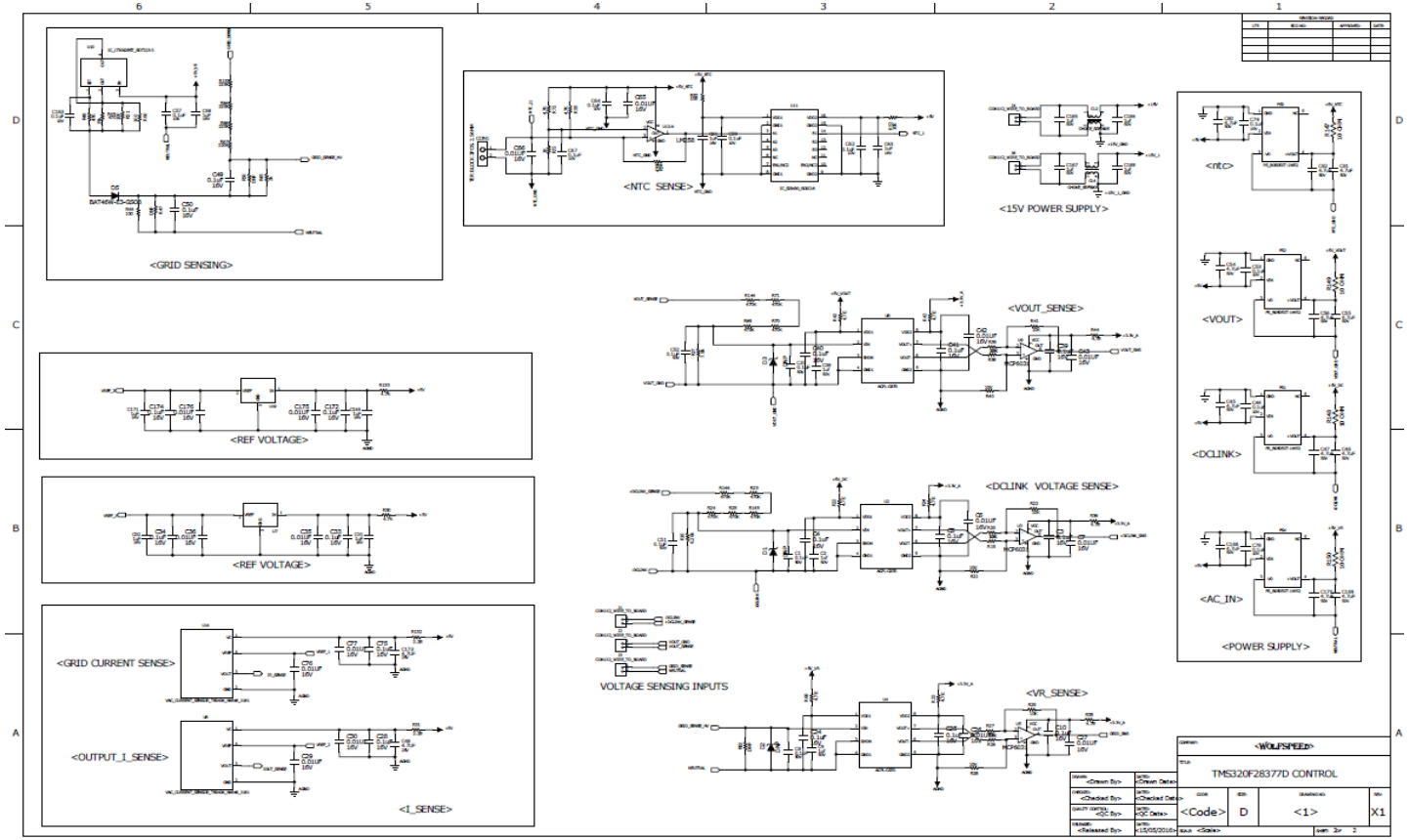
SCHEMATIC OF CRD-06600FF10N, 6.6 kW
Bi-Directional EV On-Board Charger (POWER BOARD SLIDE 2)



SCHEMATIC OF CRD-06600FF10N, 6.6 kW
Bi-Directional EV On-Board Charger (CONTROL BOARD SLIDE 1)



SCHEMATIC OF CRD-06600FF10N, 6.6 kW
Bi-Directional EV On-Board Charger (CONTROL BOARD SLIDE 2)



PACKAGE CONTENTS OF CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger (POWER BOARD)

Item	Qty	Reference	Description	Distributor	Distributor P/N	Manufacturer	Manufacturer P/N	PACKAGE
1	1	BD1	BRIDGERECT SINGLE PHASE 1000V 25A TH	DIGIKEY	641-1374-5_DNP	COMCHIP	GBU2510-G_DNP	TH
2	8	C6 C12 C65 C73 C81 C89 C97 C105	CAP CER 0.01UF 10% 16V X7R 0603	DIGIKEY	445-6855-2-ND	TDK CORP.	C1608X7RIC103K	CAP0603
3	8	C5 C11 C64 C72 C80 C88 C96 C104	CAP 0.1uF 10% 16V X7R 0603	DIGIKEY	399-5344-1-ND	KEMET	C0603X104K4RACTU	CAP0603
4	16	C8 C14 C67 C75 C83 C91 C99 C107 C112 C117 C119-120 C126 C128 C133 C139	CAP CER 0.1uF 10% 50V X7R 0603	DIGIKEY	399-5089-1-ND	KEMET	C0603C104K5RACTU	CAP0603
5	8	C7 C13 C66 C74 C82 C90 C98 C106	CAP CER 1.0uF 10% 16V X5R 0603	DIGIKEY	399-5090-1-ND	KEMET	C0603C105K4PACTU	CAP0603
6	4	C118 C125 C127 C134	CAP CER 1uf 10% 50V X7R 0603	DIGIKEY	1276-1860	PANASONIC	CL10A105KB8NNNC	CAP0603
7	12	C9 C63 C71 C79 C87 C95 C103 C111 C116 C124 C132 C143	CAP0603 2.2UF 35V X5R	DIGIKEY	490-7204	MURATA	GRM188R6YA225KA12D	CAP0603
8	12	C30-31 C86 C94 C102 C110 C115 C123 C131 C142 C226 C228	CAP CER 0.1uF 10% 50V X7R 0805	DIGIKEY	399-736T	TDK	C0805C104K5RAC7410	CAP0805
9	1	C62	CAP0805 100PF 50V	DIGIKEY				CAP0805
10	16	C3-4 C19-20 C22 C37-38 C42-43 C45-50 C55	CAP CER 1nF 10% 50V X7R 0805	DIGIKEY	399-1147	MURATA	C0805C102K5RACTU	CAP0805
11	4	C69-70 C77-78	CAP CER 1uF 10% 50V X7R 0805	DIGIKEY		MURATA		CAP0805
12	4	C16 C29 C225 C227	CAP CER 2.2uF 10% 50V X7R 0805	DIGIKEY		MURATA	GRM32ER71H225KA88L	CAP0805
13	47	C25-27 C34 C40 C85 C93 C101 C109 C114 C122 C130 C141 C144-146 C148-150 C152-154 C156-158 C160-162 C164-166 C168-170 C172-174 C176-178 C180-182 C184-186 C191	CAP CER 4.7uF 10% 50V X7R 0805	DIGIKEY	490-1864-2-ND	MURATA	GRM32ER71H475KA88L	CAP0805
14	2	C18 C33	CAP CER 10000PF 10% 1000V X7R 1206	DIGIKEY	490-12015	MURATA	GRM31CR73A103KW03L	CAP1206
15	4	C17 C32 C51-52	CAP CER 1812 0.01UF 1000V COG/NPO	DIGIKEY	399-14855	KEMET	C1812C103JDGACAUTO	CAP1812
16	1	C189	CAP CER 1812 0.1UF 1000V X7R	DIGIKEY	399-9854-ND	KEMET	C1812C104KDRAC7800	CAP1812
17	2	C21 C44	CAP CER 1812 DNP	DIGIKEY	DNP	KEMET	DNP	CAP1812
18	20	C23-24 C135-138 C193 C195 C204 C210-219 C224	CAP ELECT 220uF 400V DC RADIAL	DIGIKEY	1189-3175	RUBYCON	400BXW220MEFR18X50	DIA-18MM,LEAD SPACE-7.5MM,H-50
19	1	C54	CAP ELECT 390uF 500V DC RADIAL	DIGIKEY	565-3607	united chemicon	VLXS501VSN391MA50S	DIA-35MM, LEAD-10MM,H-52.5MM
20	1	C1	FILM CAPACITOR 1.5UF 305VAC	DIGIKEY	495-1884	EPCOS	B32923C3155M	CAPFILM_26.5X12MM P-22.5MM H-22mm
21	1	C2	FILM CAPACITOR 10UF 20% 305VAC RADIAL	DIGIKEY	495-7023	EPCOS	B32926H3106M	CAPFILM_42MMX28MM P-37.5MM H-42.5mm
22	3	C35-36 C188	CAPFILM 3UF 900VDC 5% RADIAL	DIGIKEY	BC2626	VISHAY BC COMP.	MKP1848530094K2	CAPFILM_ 15MMX32MMX25MM, P-27.5MM
23	30	C39 C53 C56 C60-61 C190 C192 C194 C196-203 C205-209 C220-223 C229-233	CAPFILM 4700pPF 10% 1.25KVDC RADIAL	DIGIKEY	B32651A7472K000	EPCOS	B32651A7472K000	CAPFILM 13MMX5MM P=10MM ,H-11MM
24	2	C58-59	FILM CAPACITOR 4UF 630V	DIGIKEY	495-4133-ND	VISHAY	B32794D2405K	CAPFILM_11/315MM
25	2	YC1-2	CAP CERMIC 4700PF 440VAC RADIAL	DIGIKEY	399-9511-1	KEMET	C947U472MZVDBA7317	DIA 11MM P-7.50MM

PACKAGE CONTENTS OF CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger (POWER BOARD)

Item	Qty	Reference	Description	Distributor	Distributor P/N	Manufacturer	Manufacturer P/N	PACKAGE
26	13	C28 C41 C147 C151 C155 C159 C163 C167 C171 C175 C179 C183 C187	CAP 47UF 35V ELECT PW RADIAL	DIGIKEY	P10417TB	PANASONIC	ECA-1VM470I	5/2.5MM TH
27	1	C57	CAP FILM 5UF 900VDC 5% RADIAL	DIGIKEY	399-7572	KEMET	C4AEOBU4500A11J	CAP_FILM_19X31.5MMx29.2MM P-27.5MM
28	4	J1-4	CONN.TERM BLOCK 2POS. 5MM PCB	DIGIKEY	277-1667	PHOENIX CONTACT	1935161	TH_5MM
29	1	CON5	CONN TER BLOCK 3POS. 7.5MM 41AMP 30DEG	DIGIKEY	277-9887	PHOENIX CONTACT	1792232	3POS. 7.5MM
30	1	CT1	xfrmr current sense 37a 20mh t/h	DIGIKEY		PULSE	PE-67300NL	TH
31	13	PS1-13	DC/DC Converter for SiC Driver low voltage	MORNSON	QA15115R2	MORNSON	QA15115R2	SIP PACK
32	12	C10 C15 C68 C76 C84 C92 C100 C108 C113 C121 C129 C140	CAP CER 100pF 10% 50V X7R 0603	MOUSER	77-VJ0603Y101KXACBC	VISHAY/VITRAMON	VJ0603Y101KXACW1BC	CAP0603
33	16	D2 D4 D6 D10 D12 D14 D16 D18 D20 D22 D24 D26 D28 D30 D32 D34	DIODE BZX-384-C16,115 ZENER 16V	DIGIKEY	568-11172	NXP Semiconductor	BZX384-C16,115	SOD-323
34	16	D1 D3 D5 D9 D11 D13 D15 D17 D19 D21 D23 D25 D27 D29 D31 D33	DIODE BZX-384-C3V0,115 ZENER 3V	DIGIKEY	568-8043-1-ND	NXP SEMI	BZX-384-C3V0,115	SOD-323
35	1	D8	DIODE STANDARD 1000V 1A MELF	DIGIKEY	DL4007-FDITR	DIODES INC.	DL4007-13-	MELF
36	2	D7 D35	DIODE SCHOT BAT754S 30V SOT23	DIGIKEY	BAT754S,215	NEXPERIA USA	BAT754S,215	SOT23
37	1	D36	DIODE ZENER 1W 2.1V SMB	DIGIKEY		ON Semiconductor		SMB
38	1	XL1	LINE COOMON MODE CHOKE TH 160 OHM@100MH	DIGIKEY	240-2488	LAIRD	CM5441Z101B-10	TH
39	1	F2	FUSE 15A LEADED CARTRIDGE	ELEMENT14	0217015.MXEP	LITTLE FUSE	0217015.MXEP	TH
40	1	F1	FUSE HOLDER CLIP 30A 315V	DIGIKEY	0122 0093	LITTLE FUSE	0122 0093	FUSE CLIP
41	5	CON2-4 CON6-7	HEADER 12POS 2.54 pitch DUAL T-HOLE	DIGIKEY	S3296-ND	SULLINS CONN.	EBC06DRXH	CON2X6
42	1	HS1	HEAT SINK 6.6KW	DIGIKEY	COSTUMIZED			
43	8	U1-8	Single Channel IGBT Gate Driver 1200V PG-DSO-	DIGIKEY	1EDI30I12MHXUMA1TR	INFINEON TECH.	1EDI30I12MHXUMA1	PG-DSO-8
44	4	U13-16	IC MOSFET DRIVER 500MA SOT-23-5	DIGIKEY	MCP1402T-E/OTTR	MICROCHIP	MCP1402T-E/OTTR	SOT-23-5
45	1	L3	INDUCTOR 150UH 40AMP	COIL WINDING	EK55246-341M-40AH	COIL WINDING	EK55246-341M-40AH	58MMX58MM, H-35MM
46	1	L4	INDUCTOR FIXED 12UH 19A 4.3 MOHM	DIGIKEY	COSTUMIZED			SMD_35X28.6MM, H-47MM
47	1	L6	INDUCTOR_FIXED_180NH_65A_0.15MOHM_SMD	DIGIKEY	732-11787-1	WURTH ELE.	7443082018A	SMD_10X8MM, H-MM
48	1	L5	INDUCTOR FIXED 7.6UH 20A 3.5 MOHM	DIGIKEY	COSTUMIZED			35MMX28.6MM, H-43MM
49	2	L1-2	INDUCTOR TORRIOD POWER 20UH 40A TH	MICROMETALS	OP-134090-2	MICROMETALS	OP-134090-2	36MM DIA,W-21MM
50	1	Q17	TRANS MMBT2222A GP NPN SOT23	DIGIKEY	MMBT2222AFSCT-ND	FAIRCHILD	MMBT2222A	SOT23
51	16	Q1-16	MOSFET N-CHAN 1000 V, 65 mΩ TO-247-4	DIGIKEY	C3M0065100K	CREE SEMICONDUCTOR	C3M0065100K	TO-247
52	1	VRV1	MOV VERISTOR510V 10KA DISK 20MM	DIGIKEY	495-4658	EPCOS	B72220S2321K101	TH HOLE 20mm dia, 27mm hight 10mm pitch
53	2	CON1 CON8	PCB TERMINAL BLOCK SINGLE POS	DIGIKEY	277-9885-ND	PHOENIX CONTACT	PLA5/1-7 5-1792216	SINGLE POS.
54	2	RV1-2	PTC RESET FUSE 440V 86MA RADIAL	DIGIKEY	495-7219	APCOS	B59751C0120A070	TH_13MMX7.5MM, H-18MM RAD
55	1	RLY1	RELAY GEN PURPOSE 12V 40A SPST	DIGIKEY	PB2352	TE CONN.	T9VV1K15-12S	RELAY12V_TH_40A
56	8	R17 R21 R62 R96 R99 R102 R105 R108	RES 100 Ohm 1% 1/10W 0603	DIGIKEY	541-100HTR-ND	Vishay/Dale	CRCW0603100RFKEA	RES0603
57	8	R3 R10 R23 R63 R70 R73 R76 R79	RES 10.0 OHM 0.1% 1/10W 0603	DIGIKEY	TNP10.0AACT-ND	Vishay/Dale	TNPW060310R0BEEA	RES_0603

PACKAGE CONTENTS OF CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger (POWER BOARD)

Item	Qty	Reference	Description	Distributor	Distributor P/N	Manufacturer	Manufacturer P/N	PACKAGE
58	8	R1 R9 R32 R35 R37 R47 R50 R66	RES 10k 1% 1/10W 0603	DIGIKEY	P10KGCT-ND	PANASONIC	ERJ-3GEYJ103V	RES0603
59	8	R36 R20 R4 R48-49 R34 R65 R16	RES 10k 1% 1/10W 0603	DIGIKEY	P10KGCT-ND	PANASONIC	ERJ-3GEYJ103V	RES0603
60	4	R91 R93 R103 R109	RES0603 220E 1% 1/10W	DIGIKEY	ERJ-3GEYJ221V	PANASONIC	ERJ-3GEYJ221V	RES0603
61	16	R11 R19 R61 R84 R87 R90 R95 R98 R101 R104 R106-107 R110-113	RES 4.7E 1% 1/10W 0603	DIGIKEY	311-4.7GRTR-ND	YAGEO	RC0603JR-074R7L	RES0603
62	1	R78	RES0805 100E 5% SMD	DIGIKEY	P100ACT-ND	PANASONIC	ERJ-6GEYJ101V	RES0805
63	1	R69	RES0805 100E 5% SMD	DIGIKEY	P10.0KACT-ND	PANASONIC	ERJ-6GEYJ103V	RES0805
64	6	R22 R25-29	RES 0.0 OHM 1/10W 5% 1206	DIGIKEY	P0.0ECT-ND	PANASONIC	ERJ-8GEY0R00V	RES1206
65	1	R7	RES1206 1K 1% 1/4W	DIGIKEY	P1.0KECT-ND	PANASONIC	ERJ-8GEYJ102V	RES1206
66	6	R12 R14-15 R57 R59 R114	RES 1.0M 1% 1/4W 1206	DIGIKEY	541-1.00MFTR-ND	VISHAY/DALE	CRCW12061M00FKEA	RES1206
67	12	R2 R5 R24 R64 R71 R74 R77 R80 R82 R85 R88 R92	SURFACE MOUNT RESISTOR 10E MELF	DIGIKEY	MMA-10ACT-ND	YAGEO	MMA02040C1008FB300	3.5X1.4MM
68	31	R8 R13 R18 R30 R33 R39-46 R51-54 R58 R60 R67-68 R81 R83 R86 R89 R94 R97 R100 R115-117	RES SMD 1 OHM 1% 1/4W MELF	DIGIKEY	MMA-1.0ATR-ND	VISHAY	MMA02040C1008FB300	3.5X1.4MM 1206
69	1	R38	RES SMD 1 OHM 1% 1/4W MELF	DIGIKEY	MMA-1.0ATR-ND	VISHAY	MMA02040C1008FB300	3.5X1.4MM 1206
70	3	R6 R31 R75	RES SMD 4.7 OHM 1% 1/4W MELF	ELEMENT	MCFRFTDV4R70	VISHAY	MCFRFTDV4R70	3.5X1.4MM_1206
71	2	R72 R118	RES 1.00 Ohm 5% 2W AXIAL	DIGIKEY	A105939TB	TE CONN.	ROX2SJ1R0	RES_AXIAL_2W
72	2	R55-56	RES 270K Ohm 5% 3W	DIGIKEY	FMP300JR-73-270K-ND	YAGEO CORP.	FMP300JR-73-270K-ND	RES_270K_3W
73	4	U9-12	DGTL ISOLATED GATE DRIVER 3.75KV SOIC8	DIGIKEY	336-2420	SILICON LABS	Si8261BCC-C-IS	SOIC8
74	1	T1	TRANSFORMER PQ5050		COSTUMIZED			50MMX50MM

PACKAGE CONTENTS OF CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger (CONTROL BOARD)

Item	Qty	Reference	Description	Distributor	Distributor P/N	Manufacturer	Manufacturer P/N	PACKAGE
1	3	U2 U4 U8	Precision Optically Isolated Voltage Sensor	DIGIKEY	ACPL-C870	AVAGO TECH	ACPL-C870	SO-8
2	1	Q1	MOSFET N-CH BSS138 220MA SOT23	ELEMENT14	9845330	FAIRCHILD SEMI.	BSS138	SOT23
3	2	C123 C130	CAP CER 0.001UF 10% 16V X7R 0603	DIGIKEY	399-7835-2-ND	KEMET	C0603C102R4RACT	CAP0603
4	26	0 C35-36 C42-43 C65-66 C70 C73 C76-77 C83-84 C106 C122 C1	CAP CER 0.01UF 10% 16V X7R 0603	DIGIKEY	445-6855-2-ND	TDK CORP.	C1608X7RIC103K	CAP0603
5	42	7 C78-79 C85 C87-88 C93 C95-98 C100 C105 C111-113 C116 C1	CAP 0.1uF 10% 10V X7R 0603	DIGIKEY	399-1095-1-ND	KEMET	C0603C104K8RACTU	CAP0603
6	31	C39-41 C49-50 C60 C68 C71 C75 C92 C102 C107 C121 C145 C15	CAP 0.1uF 10% 16V X7R 0603	DIGIKEY	399-5344-1-ND	KEMET	C0603X104K4RACTU	CAP0603
7	4	C101 C179-180 C91	CAP 0.1uF 10% 16V X7R 0603	DIGIKEY	399-5344-1-ND	KEMET	C0603X104K4RACTU	CAP0603
8	5	C86 C99 C108 C163-164	CAP 0.1uF 10% 16V X7R 0603	DIGIKEY	399-5344-1-ND	KEMET	C0603X104K4RACTU	CAP0603
9	3	C117-118 C127	CAP 0.1uF 10% 25V X7R 0603	DIGIKEY	399-5345-1-ND	KEMET	C0603X104K3RACTU	CAP0603
10	5	C1 C8 C37 C51-52	CAP CER 0.1uF 10% 50V X7R 0603	DIGIKEY	399-5089-1-ND	KEMET	C0603C104K5RACTU	CAP0603
11	3	C158 C177 C142	CAP CER 100pF 10% 50V X7R 0603	MOUSER	77-VJ0603Y101KXACBC	VISHAY/VITRAMON	77-VJ0603Y101KXACBC	CAP0603
12	4	C89-90 C104 C109	CAP CER 10uF 10% 10V X5R 0603	DIGIKEY	490-10474-ND	MURATA	GRM188R61A106KE69D	CAP0603
13	19	C153-154 C181-182 C31-32 C58 C61 C63 C69 C72 C103 C125 C	CAP CER 1.0uF 10% 16V X5R 0603	DIGIKEY	399-5090-1-ND	KEMET	C0603C105K4PACTU	CAP0603
14	7	C2 C9 C38 C185-188	CAP CER 1uf 10% 50V X7R 0603	DIGIKEY	CL10B105K8NNNC	PANASONIC	CL10B105K8NNNC	CAP0603
15	1	C115	CAP CER 330pF 10% 50V 0603	DIGIKEY	C1608JB1H331KT000N	TDK	C1608JB1H331KT000N	CAP0603
16	2	C137-138	CAP CER 33pF 10% 16V NPO 0603	DIGIKEY	478-6211-2-ND	AVX CORP	0603YC330JAT2A	CAP0603
17	14	C17 C20 C94 C114 C120 C128 C135 C139 C141 C146 C161 C166	CAP CER 4.7uF 10% 10V X5R 0603	DIGIKEY	445-5170-1-ND	TDK	C1608X5R1A475K	CAP0603
18	2	C74 C162	CAP CER 4.7uF 10% 35V X5R 0603	DIGIKEY	490-7205-2-ND	MURATA	GRM188R6YA475KE15D	CAP0603
19	2	C48 C173	CAP CER 4.7uF 10% 25V 0805	DIGIKEY	490-3335-2-ND	MURATA	GRM21BR61E475KA12L	CAP0805
20	12	C45-47 C54-56 C80-82 C168-170	CAP CER 4.7uF 10% 50V X7R 0805	DIGIKEY	490-1864-2-ND	MURATA	GRM32ER71H475KA88L	CAP0805
21	1	C147	CAP CER 10uF 10% 6.3V X5R 1206	DIGIKEY	1276-1079-2-ND	SAMSUNG	CL31A106KQHNNNE	CAP1206
22	1	C148	CAP ELECT 100uF 20% 10V FK SMD	DIGIKEY	565-2075-2-ND	UNITED CHEMI-CON	EMVA100ADA101MF55G	CAPELEC_ALUM_6.3MM DIA
23	1	C110	CAP ELECT 10uF 20% 50V FK SMD	DIGIKEY	PCE3468CT-ND	PANASONIC	EEV-FK1H100UR	CAPELEC_ALUM_5X5.8MM_FK_SMD
24	1	C143	CAP ELECT 10uF 20% 50V TH RADIAL	DIGIKEY	P997-ND	PANASONIC	ECEA1HKS100	TH
25	3	CT1-3	CAP 22uF TANT 6.3V 10% case size-c/6032-28 SMD	DIGIKEY	399-10521-1-ND	KEMET	T495C226	CAPTANT_T491C
26	4	CL1-4	COMMON MODE FILTER SMD	DIGIKEY	SRF0905-500Y-ND	BOURNS	SRF0905-500Y	SMD
27	1	CON1	TER BLOCK 2POS. 2.54MM PCB	DIGIKEY	ED10561-ND	ON SHORE TECH	OSTVN02A150	TH 2.54MM
28	8	J1-4 J6-9	CONN.TERM BLOCK 2POS. 5MM PCB	DIGIKEY	277-1667	PHONIX CONTACT	1935161	TH_5MM
29	1	J5	J-TAG CONNECTER 14-PIN	DIGIKEY	A104860-ND	TE CONN.	1-1634688-4	14-PIN J-TAG
30	1	Y1	CRYSTAL 10MHZ 18PF 60 OHM	DIGIKEY	CTX919-ND	CTS FREQUENCY CONTROL	ATS100B-E	TH HOLE
31	5	R31 R56 R74 R130 R132	RES 2.2 Ohm 1% 1/10W 0603	ELEMENT14	1799401	YAGEO	RC0603JR-072R2L	RES0603
32	10	R5-9 R13 R110 R113 R118-119	RES 1k 1% 1/10W 0603	DIGIKEY	541-1.00KHTR-ND	Vishay/Dale	CRCW06031K00FKEA	RES0603
33	1	R82	RES 7.5k 1% 1/10W 0603	DIGIKEY	541-7.50KHTR-ND	Vishay/Dale	ERJ-3EKF1202V	RES0603
34	3	R12 R91 R127	RES 0.0 OHM 5% 1/10W 0603	MOUSER	71-CRCW060300000Z0EB	VISHAY/DALE	CRCW060300000Z0EB\	RES0603
35	1	D5	DIODE MBAT46W-V 100V 150MA SOD123	DIGIKEY	BAT46W-E3-08TR-ND	VISHAY SEMI.	BAT46W-E3-GSO8	SOD123
36	1	D13	DIODE ZENER 2.2V 500MW SOD-123	DIGIKEY	MMSZ4680TIGOSTR-ND	ON Semiconductor	MMSZ4680TIG	SOD-123
37	3	D1-3	DIODE ZENER DNP SOD-123	DIGIKEY	DNP		DNP	SOD-123
38	5	CON2-6	CON 12POS 2.54 pitch DUAL T-HOLE	DIGIKEY	S7293-ND	SULLINS CONN.	EBC06MMMD	CON2X6

PACKAGE CONTENTS OF CRD-06600FF10N, 6.6 kW Bi-Directional EV On-Board Charger (CONTROL BOARD)

Item	Qty	Reference	Description	Distributor	Distributor P/N	Manufacturer	Manufacturer P/N	PACKAGE
39	2	U7 U19	IC PRECISION REF 1.5VREF SOT23	Digikey	ISL21010CFH315Z-TK	INTERSIL	ISL21010CFH315Z	SOT23-3
40	1	U10	IC CURRENT SENSOR	DIGIKEY	LT3092EST#PBF-ND	LINEAR TECH.	LT3092EST#PBF	SOT223-3
41	1	U11	IC DIGITAL ISO 3CH TRI-STATE 16SOIC	DIGIKEY	336-1757-5	SI8430	SI8430AB-D-IS1	SOIC16
42	8	D4 D6-12	LED RED 0805 SMD	DIGIKEY	511-1292-2-ND	ROHM	SML-211UTT-86	LED0805
43	1	U23	IC LF50ABDT REG 1.5A 5VOLT DPAK	DIGIKEY	497-8344-1-ND	STMicroelectronics	LF50ABDT	DPAK
44	1	U12	IC LM258 Dual OpAmp SOIC8	Digikey	497-1553-2-ND	ST MICRO	LM258DT	SOIC8
45	1	U1	microcontroller TMS320F28377D	DIGIKEY	TMS320F28377DPTPT-ND	TEXAS INSTRUMENT	TMS320F28377DPTPT	LQFP-176
46	3	U13 U15 U21	IC BUFFER NONINVERTING SOIC14	DIGKEY	MC74VHCT50A-DR2GOSCT-ND	FAIRCHILD SEMICONDUCTOR	MC74VHCT50A	SOIC14
47	3	U3 U5 U9	IC MCP6031 single OpAmp SOIC8	Digikey	MCP6031-E/SN-ND	Microchip	MCP6031-E/SN	SOIC8
48	8	Q2-9	TRANS MMBT2222A GP NPN SOT23	DIGIKEY	MMBT2222AFSCT-ND	FAIRCHILD	MMBT2222A	SOT23
49	2	U16-17	OPTICAL SWITCH, TRANSISTOR OUTPUT 4SMD	DIGIKEY	425-2774	SHARP MICRO ELECTRIC	PC817XNNIP0F	4SMD
50	1	U20	TVS DIODE 5.5VWM 8VC 8MSOP	DIGIKEY	PACDN046MR-ND	ST MICRO	PACDN046MR	8MSOP
51	1	VR1	POT 1K OHM 1/4W PLASTI LINEAR	DIGIKEY	3310Y-001-102L	BOURNS	3310Y-001-102L	TH
52	4	PS1-4	0.25W, FIXED INPUT, ISOLATED & UNREGULATED SINGLE OUTPUT	MORNSON	B0505XT-1WR2	MORNSON	B0505XT-1WR2	SMD
53	1	U18	IC REF3230 SERIES VOLTAGE REFERANCE	DIGIKEY	296-18228-2-ND	TEXAS	REF3230AIDBVT	SOT23-6
54	9	R79 R84 R92 R100 R103 R108-109 R116-117	RES 0.0 OHM 1/10W 5% 0603	DIGIKEY	541-0.0GCT-ND	VISHAY/DALE	CRCW06030000Z0EA	RES0603
55	1	R104	RES 1.5k 1% 1/10W 0603	DIGIKEY	541-1.50KHTR-ND	Vishay/Dale	CRCW06031K50FKEA	RES0603
56	7	R1-2 R59 R61 R107 R114 R129	RES, 100K, 1%. 1/10W, 0603, TF	DIGIKEY	541-100KHTR	Vishay/Dale	CRCW0603100KFKEA	RES0603
57	3	R3 R10 R142	RES 100 Ohm 1% 1/10W 0603	DIGIKEY	541-100HTR-ND	Vishay/Dale	CRCW0603100RFKEA	RES0603
58	7	R11 R46 R51 R60 R98 R134 R4	RES 100 Ohm 1% 1/10W 0603	DIGIKEY	541-100HTR-ND	Vishay/Dale	CRCW0603100RFKEA	RES0603
59	2	R52-53	RES 10.0 OHM 0.1% 1/10W 0603	DIGIKEY	TNP10.0AACT-ND	Vishay/Dale	TNPW060310R0BEEA	RES_0603
60	29	15 R19-22 R26-29 R38-41 R75-78 R80-81 R120-125 R128 R135	RES, 10K, 1%. 1/10W, 0603, TF	DIGIKEY	541-10.0KHCT-ND	Vishay/Dale	CRCW060310K0FKEA	RES0603
61	5	R63 R65 R73 R88-89	RES, 1K, 1%. 1/10W, 0603, TF	DIGIKEY	541-1.00KHCT-ND	Vishay/Dale	CRCW06031K00FKEA	RES0603
62	1	R17	RES 1M 1% 1/10W 0603	DIGIKEY	541-1.00MHCT-ND	VISHAY/DALE	CRCW06031M00FKEA	RES0603
63	3	R93 R101-102	RES, 2.2K, 1%. 1/10W, 0603, TF	DIGIKEY	541-2.20KHCT-ND	Vishay/Dale	CRCW060310K0FKEA	RES0603
64	6	R105-106 R111-112 R138 R140	RES 22K 1% 1/10W 0603	DIGIKEY	P22.0KHCT-ND	PANASONIC-ECG	ERJ-3EKF2202V	RES0603
65	2	R57-58	RES, 27K, 1%. 1/10W, 0603	DIGIKEY	541-27.0KHTR	VISHAY	CRCW060327K0FKEA	RES0603
66	1	R45	RES 2K 1% 1/10W 0603	DIGIKEY	541-2.00KHTR-ND	VISHAY/DALE	ERJ-3EKF1202V	RES0603
67	1	R131	RES 2K 1% 1/10W 0603	DIGIKEY	541-2.00KHTR-ND	VISHAY/DALE	ERJ-3EKF1202V	RES0603
68	8	R83 R94-97 R99 R137 R139	RES 3.3K 1% 1/10W 0603	DIGIKEY	541-3.30KHTR-ND	VISHAY/DALE	CRCW06033K30FKEA	RES0603
69	10	R32-36 R42-44 R68 R115	RES 4.7E 1% 1/10W 0603	DIGIKEY	311-4.7GRTR-ND	YAGEO	RC0603JR-074R7L	RES0603
70	5	R30 R55 R72 R126 R133	RES 4.7 K 1% 1/10W 0603	ELEMENT14	2130911	VISHAY/DALE	MC00063W060314K7	RES0603
71	1	R54	RES 470K 1% 1/10W 0603	ELEMENT14	2059628	PANASONIC	ERJ-3EKF4703V	RES0603
72	1	R49	RES 470 OHM 1% 1/10W 0603	DIGIKEY	541-470HCT-ND	Vishay/Dale	CRCW0603470RFKEA	RES0603
73	1	R90	RES 470 OHM 1% 1/10W 0603	DIGIKEY	541-470HCT-ND	Vishay/Dale	CRCW0603470RFKEA	RES0603
74	1	R48	RES 47K 1% 1/10W 0603	DIGIKEY	CRCW060347K0FKEA	VISHAY/DALE	CRCW060347K0FKEA	RES0603
75	1	R16	RES, 5.1K, 1%. 1/10W, 0603	DIGIKEY	P5.10KHCT	PANASONIC	ERJ-3EKF5101V	RES0603
76	1	R18	RES 6.26K 1% 1/10W 0603	DIGIKEY	P6.26KHCT	PANASONIC	ERJ-3EKF60261V	RES0603
77	1	R143	RES0603 6.8K 5% 1/10W	DIGIKEY	P6.8KGTR	PANASONIC	ERJ-3GEYJ682V	RES0603
78	1	R37	RES 7.8K 1% 1/10W 0603	DIGIKEY	541-7.8KHTR-ND	VISHAY/DALE	CRCW06037K8FKEA	RES0603
79	1	R50	Figure 46. TPS70445 thermal resistance versus dissipation area		DNP		DNP	RES0603
80	1	R47	RES DNP 1% 1/10W 0603	DIGIKEY	DNP	Vishay/Dale	DNP	RES0603
81	4	R147-150	RES2512 10 OHM 5% 1W	DIGIKEY	PT10XTR	PANASONIC	ERJ-1TYJ100U	RES1206
82	2	R62 R87	RES1206 1K 1% 1/4W	DIGIKEY	P1.0KECT-ND	PANASONIC	P1.0KECT	RES1206
83	4	R64 R66-67 R151	RES 220K 1% 1/4W 1206	DIGIKEY	CRCW12061M00FKEA	VISHAY/DALE	CRCW12061M00FKEA	RES1206
84	9	R23-25 R69-71 R144-146	RES1206 470K 1%1/4W	DIGIKEY	P470KFTR	PANASONIC	ERJ-8ENF4703V	RES1206
85	1	R141	RES 15 Ohms 1% 1/4W 1210	DIGIKEY	P15VCT-ND	PANASONIC	ERJ-14YJ150V	RES1210
86	2	R85-86	RES 20 Ohms 1% 1/4W 1210	DIGIKEY	P20VCT-ND	PANASONIC	ERJ-14YJ200V	RES1210
87	1	SW1	SWITCH SLIDE SPDT 300MA 6V	DIGIKEY	EG1270 (EG1847)	E-SWITCH	EG1270	TH_2.54MM
88	1	SW2	SWITCH TOGGLE SPDT 0.4VA	DIGIKEY	360-2614	NKK SERIES	B12AB	SWT_TH SPDT
89	1	U22	IC REG LDO 3.3V/1.2V 24HTSSOP	DIGIKEY	296-8027-5-ND	TEXAS INSTRUMENT	TPS70445PWP	TSSOP24
90	2	U6 U14	VAC CURRENT SENSOR T60404-N4646-X161	DIGIKEY	T60404-N4646-X161	VAC	T60404-N4646-X161	TH_4PIN

THANK YOU