

LTC3774EUHE

4-Phase High Current Step-Down Converter with Very Low DCR Inductor

DESCRIPTION

Demonstration circuit DC2111A features the [LTC®3774](#) in a 4-phase, high output current step-down converter with sub-mΩ DCR sensing. This high performance converter operates at a switching frequency of 400kHz over an input voltage range of 10V to 14V. The 5mm × 5mm DrMOS and 0.33μH/0.325mΩ inductor provide high efficiency while supplying 30A per phase. The board comes in two assembly types. The –A assembly provides a 1.2V/90A converter with N+1 MOSFET failure protection and the –B assembly provides a high efficiency 1.2V/120A converter.

1.2V/90A Converter with N+1 MOSFET Failure Protection

The –A assembly is intended for high reliability applications which have a very low tolerance for down-time or which operate in rugged environments. Each phase of the 1.2V/90A converter is protected by its own LTC4226-1 hot swap circuit on the input and an LTC4352 ideal diode on its output. If an internal DrMOS MOSFET fails, then that phase will be isolated from the rest of the circuit and the converter will continue to operate with only a small perturbation on the output and will provide the full rated 90A load. Once a fault is detected, the PWM signal for that phase will be floated. This in turn will signal the DrMOS to pull its TG and BG signals low. Examples of the converter's response to MOSFET failures can be seen in Figure 2 and Figure 3. Further protection is provided by a dedicated 5V bias supply for each phase. If the 5V bias for a given phase is pulled down due to a DrMOS failure or other fault, the 5V bias for the other phases will not be affected.

In case of an overvoltage event, an external overvoltage protection circuit will pull down the output. The LTC3774 does have its own crowbar type overvoltage protection,

but the ideal diodes will prevent the bottom FETs from pulling down the output once an overvoltage is detected. The external OVP comparator will also provide overvoltage protection in case the voltage sense lines are shorted or reversed.

For a 12V input, the –A assembly provides a full load efficiency of 89.3% and a peak efficiency of 90.6% which occurs around 50% load.

1.2V/120A High Efficiency Converter

The –B assembly is a high efficiency 1.2V/120A 4-phase converter. Given that it does not have the MOSFET failure protection and redundancy of the –A assembly, it provides higher efficiency and more output current. For a 12V input it provides a full load efficiency of 90.6% and a peak efficiency of 93.1% which occurs at 55% load.

More Features

Both assembly types provide many features. These include:

- Remote sensing
- CLKIN and CLKOUT pins
- PGOOD, RUN and TRACK/SS pins
- Dynamic load circuit
- Optional phase shedding circuit

The LTC3774 data sheet provide a complete description of the IC operation and application information. The data sheet must be read in conjunction with the quick start guide.

Design files for this circuit board are available at <http://www.linear.com/demo/DC2111A-A-B>

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DEMO MANUAL

DC2111A-A/-B

PERFORMANCE SUMMARY

Specifications are at $T_A = 25^\circ\text{C}$

Table 1. A Converter ($T_A = 25^\circ\text{C}$, No Airflow)

PARAMETER	CONDITION	VALUE
Minimum Input Voltage		10V
Maximum Input Voltage		14V
Output Voltage V_{OUT}	$I_{OUT} = 0\text{A to } 90\text{A}$, $V_{IN} = 10\text{V to } 14\text{V}$	$1.2\text{V} \pm 1.5\%$
$I_{OUT(MAX)}$	$V_{IN} = 10\text{V to } 14\text{V}$	90A
Nominal Switching Frequency		400kHz
Efficiency, See Figure 6	$V_{OUT} = 1.2\text{V}$, $I_{OUT} = 90\text{A}$, $V_{IN} = 12\text{V}$	89.3% Typical

Table 2. B Converter ($T_A = 25^\circ\text{C}$, No Airflow)

PARAMETER	CONDITION	VALUE
Minimum Input Voltage		10V
Maximum Input Voltage		14V
Output Voltage V_{OUT}	$I_{OUT} = 0\text{A to } 120\text{A}$, $V_{IN} = 10\text{V to } 14\text{V}$	$1.2\text{V} \pm 1.5\%$
$I_{OUT(MAX)}$	$V_{IN} = 10\text{V to } 14\text{V}$	120A
Nominal Switching Frequency		400kHz
Efficiency, See Figure 7	$V_{OUT} = 1.2\text{V}$, $I_{OUT} = 120\text{A}$, $V_{IN} = 12\text{V}$	90.6% Typical

QUICK START PROCEDURE

The evaluation setup for demonstration circuit 2111A is shown in Figure 1. To test the board, follow the procedure below:

- 1) With power off, connect the input supply, load and meters as shown in the setup drawings. Preset the load to 0A and V_{IN} supply to be 0V.
- 2) Place the jumpers in the following positions:

JP1	RUN	ON	
JP2	MODE	CCM	
JP5	IDEAL DIODE MODE	DIODE	A ONLY

- 3) Set the input voltage to 12V.
- 4) Check the output voltage. The output voltage should be within the regulation limits shown in the Performance Summary table.
- 5) Next, apply full load and re-measure V_{OUT} . Check the output voltage again to make sure it is within the regulation limits.
- 6) Adjust the input voltage and load current to the desired levels within their limits and observe the regulation, output ripple, load step response, efficiency and other parameters.

Note 1. To monitor the output voltage ripple, use the BNC connectors labeled V_{OUT} .

Note 2. Do not connect load between the VOS+ and VOS– turrets. This could damage the converter. Only apply load across the VOUT+ and VOUT– stud connectors on the edge of the board.

Note 3. For loads less than 5A, some low level noise may appear on the output of the –A assembly. This is due to the normal operation of the ideal diodes and the slight current sharing discrepancy between the phases. To avoid this, place the DIODE jumper in the REV I ALLOWED setting. This will allow reverse current to flow through the diodes for clean output voltage ripple. However, the output will not be protected from faults which short the switch node to ground.

Dynamic Load Circuit (Optional)

Demonstration circuit 2111A provides a simple dynamic load circuit consisting of a MOSFET and sense resistor. To use the circuit, follow the steps below:

1. Connect the output of the pulse generator between PULSE GEN and GND.
2. Connect the BNC labeled LOAD STEP to an oscilloscope.
3. Connect the BNC labeled V_{OUT} to an oscilloscope.
4. Preset the amplitude of a pulse generator to 0V and the duty cycle to 5% or less.
5. With the converter running, slowly increase the amplitude of the pulse generator output to provide the desired load step pulse height. The scaling for the load step signal is 2mV/A.

DEMO MANUAL

DC2111A-A/-B

QUICK START PROCEDURE

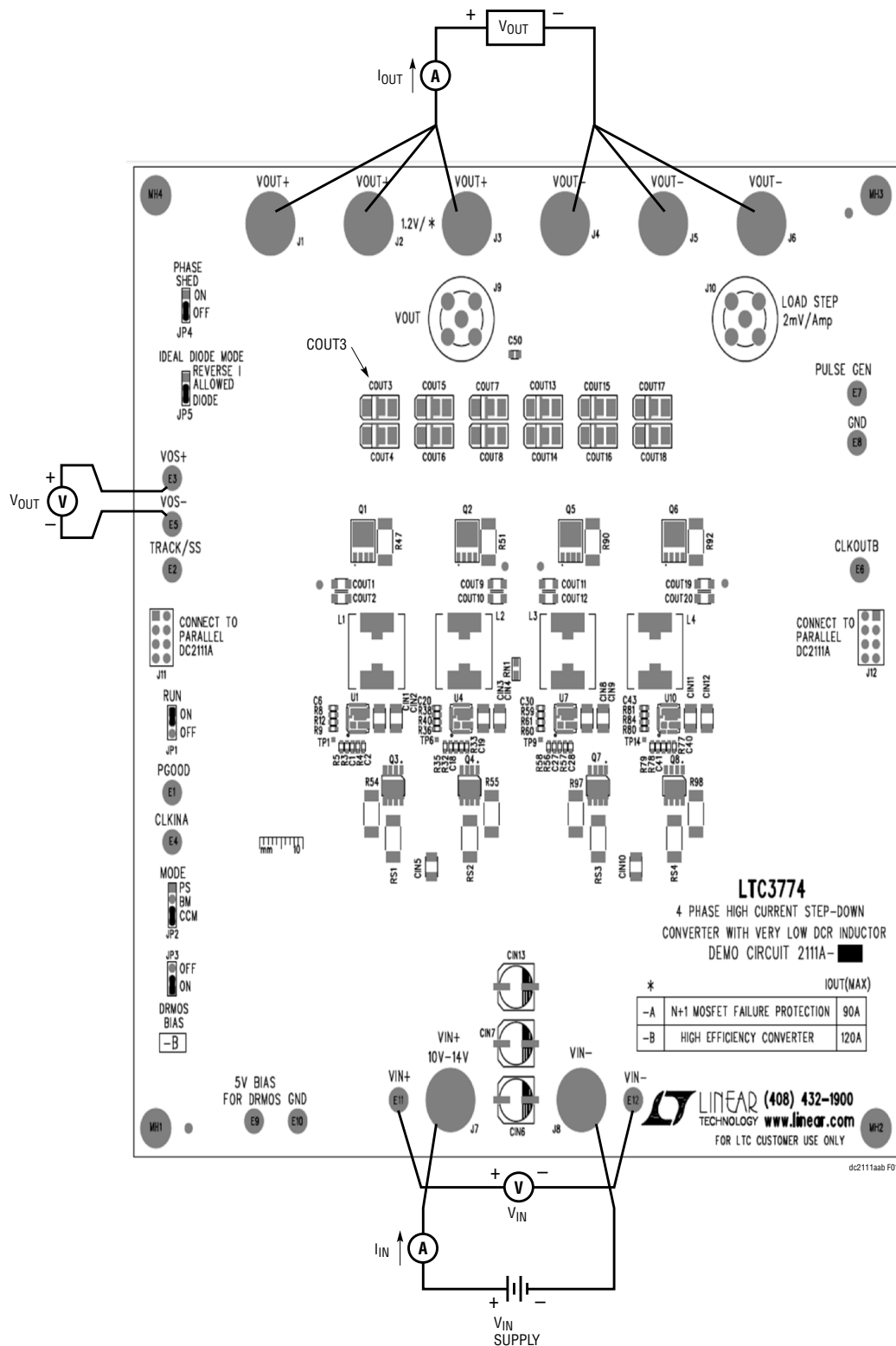


Figure 1. Proper Measurement Equipment Setup for DC2111A-A/-B

dc2111aabf

QUICK START PROCEDURE

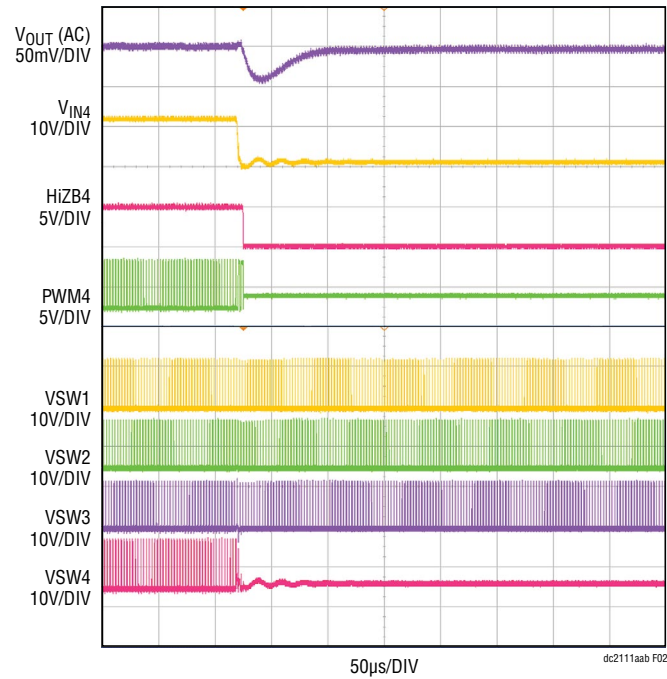


Figure 2. 1.2V/90A Converter with N+1 MOSFET Failure Protection. Top MOSFET of Phase 4 Shorted Drain to Source with Full Load on the Output and a 12V Input. The Output Continues to Regulate with Only a small Perturbation on the Output.

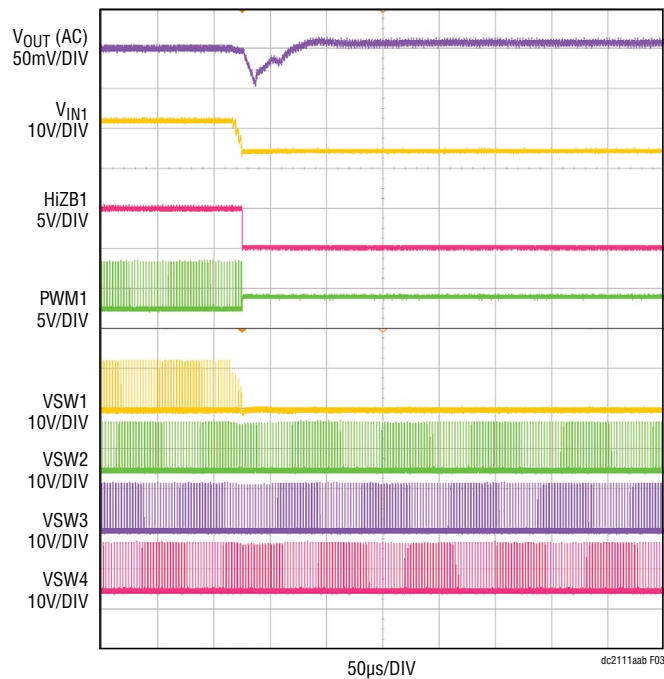


Figure 3. 1.2V/90A Converter with N+1 MOSFET Failure Protection. Bottom MOSFET of Phase 1 Shorted Drain to Source with Full Load on the Output and a 12V input. The Output Continues to Regulate with Only a Small Perturbation on the Output.

QUICK START PROCEDURE

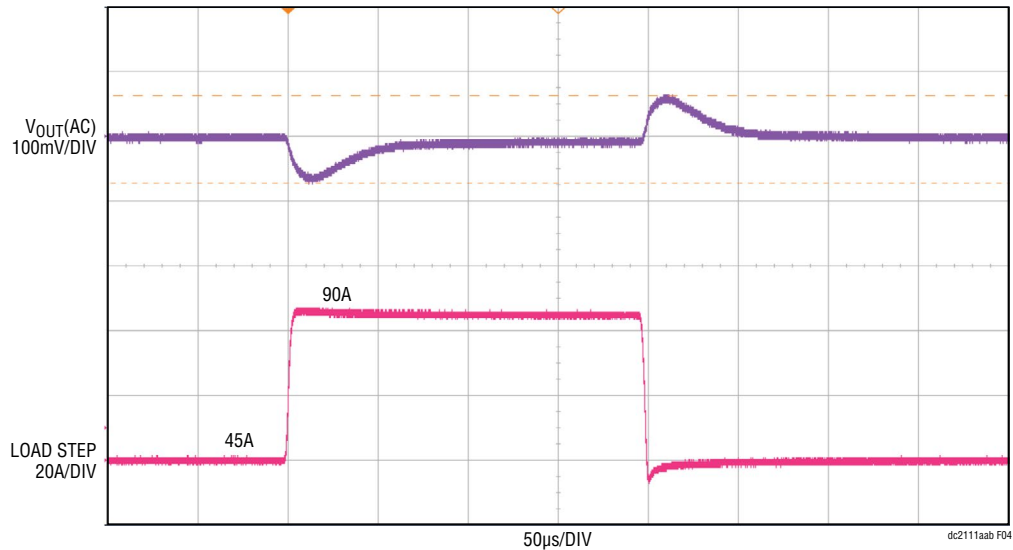


Figure 4. 45A to 90A Load Step Response of the 1.2V/90A Converter with N+1 MOSFET Failure Protection Circuit. $V_{IN} = 12V$.

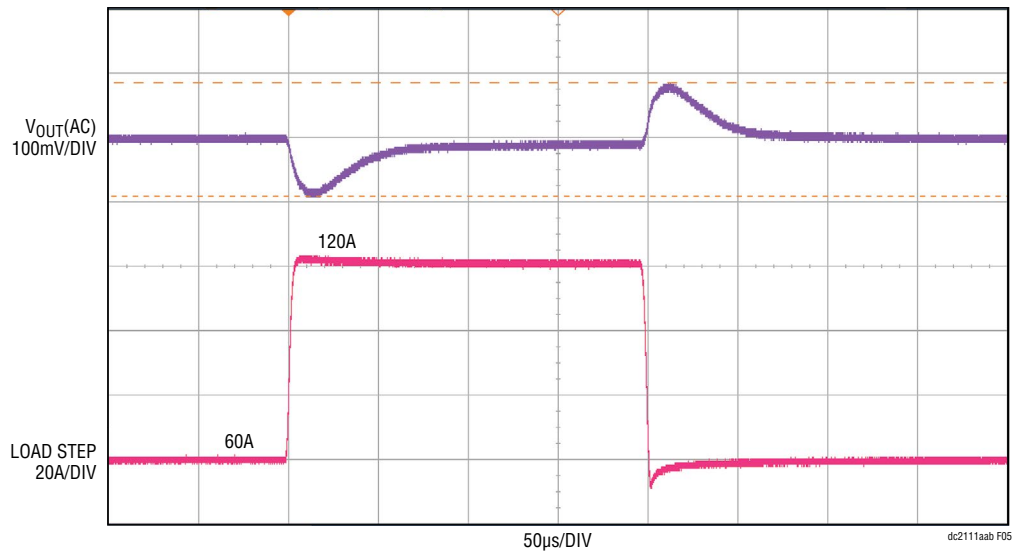


Figure 5. 60A to 120A Load Step Response of the 1.2V/120A High Efficiency Converter. $V_{IN} = 12V$.

QUICK START PROCEDURE

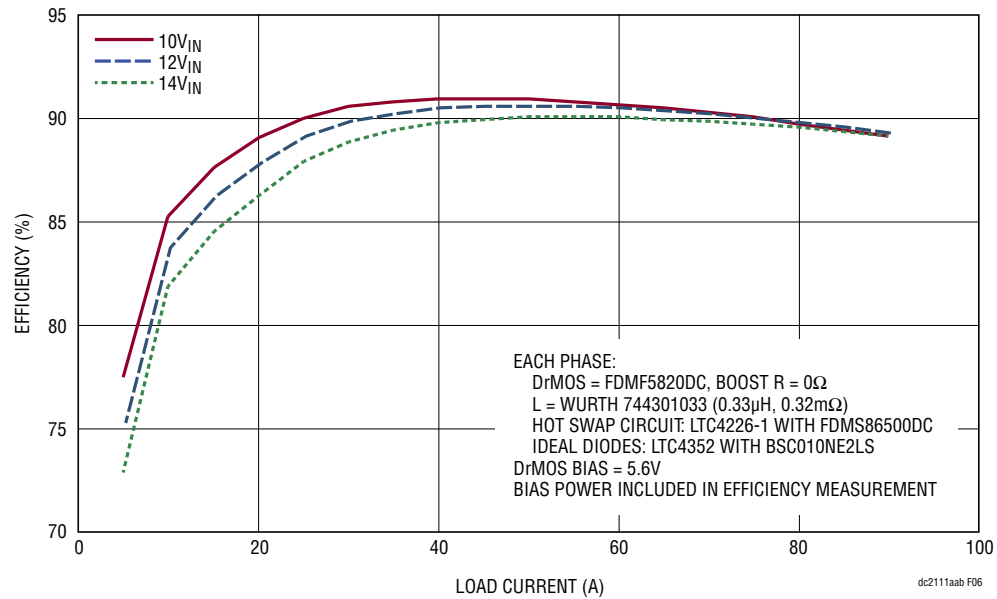


Figure 6. Efficiency Curves for the 1.2V/90A Converter with N+1 MOSFET Failure Protection. No Airflow.

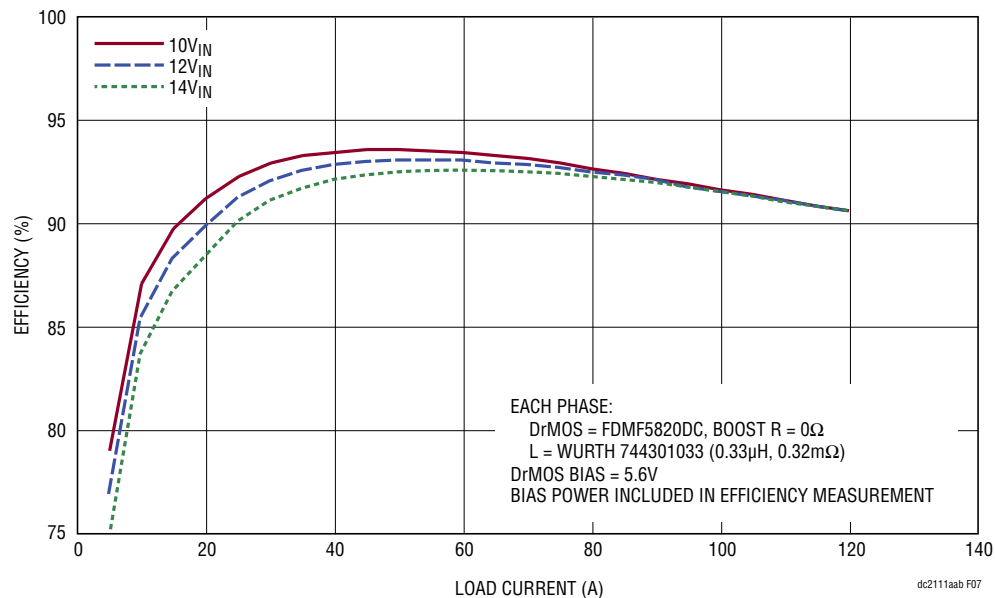


Figure 7. Efficiency Curves for the 1.2V/120A High Efficiency Converter. No Airflow.

QUICK START PROCEDURE

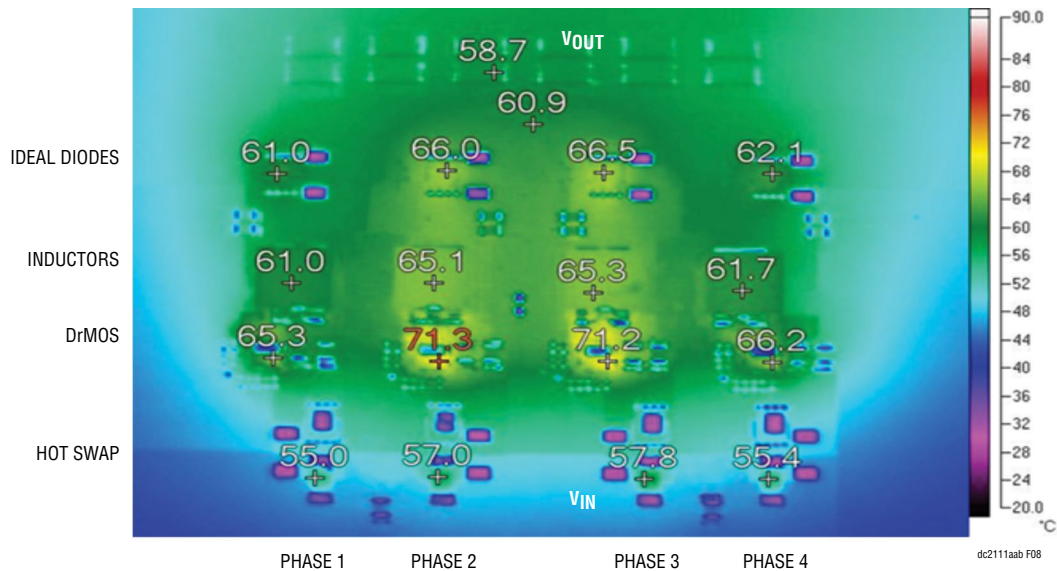


Figure 8. Thermal Image of the 1.2V/90A Converter with N+1 MOSFET Failure Protection. Measured with Full Load and an Input Voltage of 12V. $T_{AMB} = 21^{\circ}\text{C}$. Hot Spot is the DrMOS of Phases 2 with a Rise Over Ambient of 50°C .

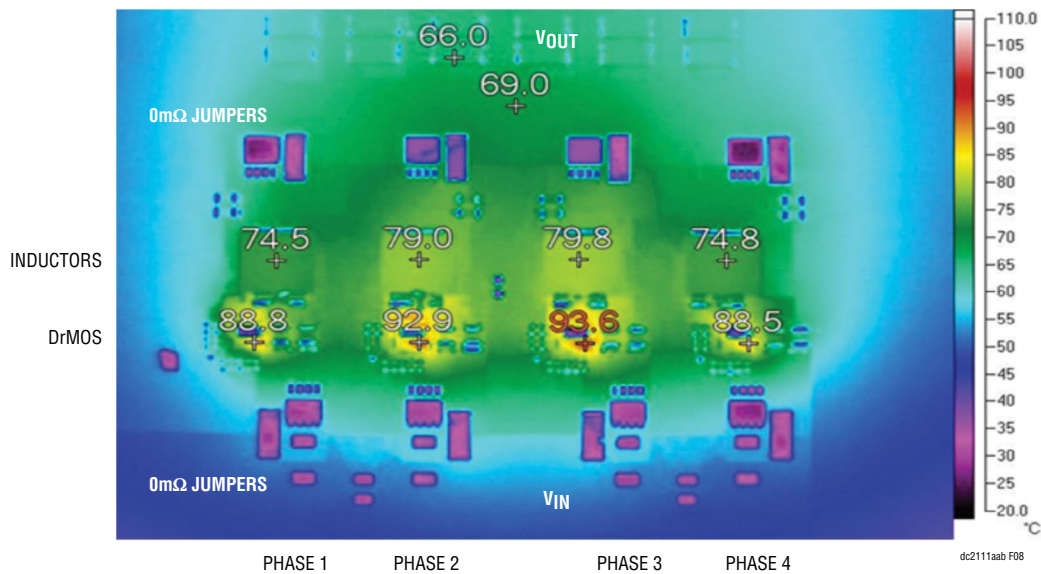


Figure 9. Thermal Image of the 1.2V/90A Converter with N+1 MOSFET Failure Protection. Measured with Full Load and an Input Voltage of 12V. $T_{AMB} = 21^{\circ}\text{C}$. Hot Spot is the DrMOS of Phases 2 with a Rise Over Ambient of 50°C .

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	9	C1, C6, C18, C20, C27, C30, C41, C43, C66	CAP, 2.2μF 10% 16V X5R 0603	MURATA, GRM188R61C225KE15D
2	1	C10	CAP, 4.7nF, 5%, 25V, X7R 0603	AVX, 06033C472JAT2A
3	4	C11, C24, C33, C45	CAP, 1μF 20% 25V X5R 0603	AVX, 06033D105MAT2A
4	2	C15, C37	CAP, 4.7μF 20% 10V X5R 0805	AVX, 0805ZD475MAT2A
5	2	C17, C39	CAP, 1μF 20% 25V X5R 0603	AVX, 06033D105MAT2A
6	12	C2, C12, C13, C14, C16, C19, C28, C34, C35, C36, C38, C40	CAP, 0.22μF 10% 25V X7R 0603	AVX, 06033C224KAT2A
7	4	C23, C25, C46, C47	CAP, 100pF 10% 25V NPO 0603	AVX, 06033A101KAT2A
8	1	C4	CAP, 47pF 5% 50V NPO 0603	AVX, 06035A470JAT2A
9	4	C5, C21, C29, C42	CAP, 0.1μF 10% 25V X7R 0603	AVX, 06033C104KAT2A
10	1	C50	CAP, 10μF 20% 6.3V X5R 0805	AVX, 08056D106MAT2A
11	1	C73	CAP, 0.1μF 10% 25V X7R 0603	AVX, 06033C104KAT2A
12	2	C8, C32	CAP, 330pF 10% 25V NPO 0603	AVX, 06033A331KAT2A
13	1	C9	CAP, 0.01μF 10% 25V X7R 0603	AVX, 06033C103KAT2A
14	8	CIN1, CIN2, CIN3, CIN4, CIN8, CIN9, CIN11, CIN12	CAP, 22μF, 10%, 16V, X5R, 1210	MURATA, GRM32ER61C226KE20L
15	2	CIN5, CIN10	CAP, 22μF 10% 16V X5R 1210	MURATA, GRM32ER61C226KE20L
16	2	CIN6, CIN7	CAP, 150μF, 25%, 25V, ALUM	CORPORATION, 25HVVH150M
17	8	COUT1, COUT2, COUT9, COUT10, COUT11, COUT12, COUT19, COUT20	CAP, 100μF 20% 6.3V X5R 1206	MURATA, GRM31CR60J107ME39L
18	12	COUT3, COUT4, COUT5, COUT6, COUT7, COUT8, COUT13, COUT14, COUT15, COUT16, COUT17, COUT18	CAP, 330μF 20% 2.5V POSCAP 7343	PANASONIC, 2R5TPE330M9
19	9	D1, D2, D3, D4, D6, D8, D11, D13, D18	DIODE, 1N4448HWT SOD523	DIODES INC, 1N4448HWT-7
20	2	D5, D10	DIODE, CMHZ4701 SOD123	CENTRAL SEMI, CMHZ4701
21	2	D7, D12	DIODE, CMHZ4683 SOD123	CENTRAL SEMI, CMHZ4683
22	1	D9	DIODE, SMAJ17A SMA-DIODE	DIODE INC, SMAJ17A-13-F
23	4	L1, L2, L3, L4	IND, 0.33μH 20%	WURTH ELEKTRONIK 744301033
24	4	Q1, Q2, Q5, Q6	MOSFET, BSC010NE2LS LFPK	INFINEON, BSC010NE2LS
25	4	Q3, Q4, Q7, Q8	MOSFET, FDMS86500DC POWER56	FAIRCHILD, FDMS86500DC
26	1	R1	RES, 100k 1% 1/10W 0603	VISHAY, CRCW0603100KFKEA
27	4	R12, R40, R61, R84	RES, 24.9k 1% 1/10W 0603	VISHAY, CRCW060324K9FKEA
28	10	R13, R42, R45, R62, R86, R91, R112, R180, R181, R182	RES, 0Ω JUMPER 0603	VISHAY, CRCW06030000Z0EA
29	1	R154	RES, 2k 5% 1/4W 1206	VISHAY, CRCW12062K00JNEA
30	1	R16	RES, 1.69k 1% 1/10W 0603	VISHAY, CRCW06031K69FKEA
31	4	R18, R29, R65, R72	RES, 4.64k 1% 1/10W 0603	VISHAY, CRCW06034K64FKEA
32	4	R183, R184, R185, R186	RES, 100Ω 1% 1/16W 0603	VISHAY, CRCW0603100RFKEA
33	1	R187	RES, 100Ω 1% 1/10W 0805	VISHAY, CRCW0805100RFKEA
34	1	R19	RES, 30.1k 1% 1/10W 0603	VISHAY, CRCW060330K1FKEA
35	1	R2	RES, 56.2k 1% 1/10W 0603	VISHAY, CRCW060356K2FKEA
36	4	R20, R27, R66, R73	RES, 931Ω 1% 1/10W 0603	VISHAY, CRCW0603931RFKEA

DEMO MANUAL

DC2111A-A/-B

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
37	2	R23, R69	RES, 37.4k 1% 1/10W 0603	VISHAY, CRCW060337K4FKEA
38	2	R24, R34	RES, 10 Ω 1% 1/10W 0603	VISHAY, CRCW060310R0FKEA
39	4	R3, R32, R56, R78	RES, 1 Ω 1% 1/10W 0603	VISHAY, CRCW06031R00FKEA
40	2	R30, R75	RES, 2.2 Ω 1% 1/10W 0603	VISHAY, CRCW06032R20FKEA
41	2	R37, R82	RES, 30.1k 1% 1/10W 0603	VISHAY, CRCW060330K1FKEA
42	2	R39, R83	RES, 2.4M 1% 1/10W 0603	VISHAY, CRCW06032M40FKEA
43	18	R4, R10, R15, R21, R28, R31, R33, R48, R50, R57, R63, R67, R68, R74, R76, R77, R93, R95	RES, 0 Ω JUMPER 0603	VISHAY, CRCW06030000Z0EA
44	2	R41, R85	RES, 38.3k 1% 1/10W 0603	VISHAY, CRCW060338K3FKEA
45	2	R44, R88	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
46	18	R5, R6, R7, R9, R11, R17, R22, R35, R36, R46, R52, R58, R60, R79, R80, R89, R96, R104	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
47	1	R64	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
48	4	RS1, RS2, RS3, RS4	RES, 0.007 Ω , 1% 1W 2512	VISHAY, WSL25127L000FEA
49	4	U1, U4, U7, U10	MOSFET, DrMOS DC-DC 2MHz QFN-5X5-31	FAIRCHILD, FDMF5820DC
50	4	U2, U5, U8, U11	IC, LTC4352CDD DFN12DD	LINEAR TECHNOLOGY, LTC4352CDD#PBF
51	2	U3, U9	IC, LTC3774EUHE UHE-5X6-36P+1	LINEAR TECHNOLOGY, LTC3774EUHE#PBF
52	2	U6, U12	IC, LTC4226CUD-1 QFN16UD-3X3	LINEAR TECHNOLOGY, LTC4226CUD-1#PBF

Bias Supplies

1	1	C66	CAP, 2.2 μ F 10% 16V X5R 0603	MURATA, GRM188R61C225KE15D
2	2	C52, C57	CAP, 1 μ F 10% 25V X5R 0805	AVX, 08053D105KAT2A
3	4	C53, C54, C61, C64	CAP, 10 μ F 20% 6.3V X5R 0805	AVX, 08056D106MAT2A
4	4	C55, C56, C62, C63	CAP, 0.01 μ F 10% 25V NPO 0603	AVX, 06033C103KAT2A
5	4	R114, R115, R127, R128	RES, 0 Ω JUMPER 0603	VISHAY, CRCW06030000Z0EA
6	4	R116, R117, R130, R131	RES, 1M 5% 1/16W 0603	VISHAY, CRCW06031M00JNEA
7	4	R122, R123, R133, R134	RES, 255k 1% 1/10W 0603	VISHAY, CRCW0603255KFKEA
8	4	R125, R126, R137, R138	RES, 73.2k 1% 1/10W 0603	VISHAY, CRCW060373K2FKEA
9	2	U15, U16	IC, LT3027EDD DFN10DD	LINEAR TECHNOLOGY, LT3027EDD#PBF

Overvoltage Comparator

1	1	R129	RES, 0 Ω JUMPER 0603	VISHAY, CRCW06030000Z0EA
2	2	C58, C59	CAP, 1 μ F 20% 25V X5R 0603	AVX, 06033D105MAT2A
3	1	U17	IC, LT6656BIS6-25 SOT6	LINEAR TECHNOLOGY, LT6656BIS6-2.5#PBF
4	1	R136	RES, 931k 1% 1/10W 0603	VISHAY, CRCW06039K31FKEA
5	1	R140	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
6	1	R132	RES, 1k 1% 1/10W 0603	VISHAY, CRCW06031K0FKEA
7	1	R135	RES, 100k 1% 1/10W 0603	VISHAY, CRCW0603100KFKEA
8	1	R178	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
9	1	C65	CAP, 1 μ F 20% 25V X5R 0603	AVX, 06033D105MAT2A

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
10	1	R147	RES, 11k 1% 1/10W 0603	VISHAY, CRCW060311K0FKEA
11	1	R149	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
12	1	R145	RES, 25.5k 1% 1/10W 0603	VISHAY, CRCW060325K5FKEA
13	1	R146	RES, 100k 1% 1/10W 0603	VISHAY, CRCW0603100KFKEA
14	2	R151, R152	RES, 1k 1% 1/10W 0603	VISHAY, CRCW06031K0FKEA
15	1	R150	RES, 100Ω 1% 1/16W 0603	VISHAY, CRCW0603100RFKEA
16	1	Q11	MOSFET, BSC010NE2LS LPAK	INFINEON, BSC010NE2LS
17	1	Q12	TRANSISTOR, NPN, MMBT3904L SOT23	ON SEMI, MMBT3904LT1G
18	1	R148	RES, 0.1Ω 1% 1W 2512	VISHAY, WSL2512R1000FEA
19	1	U14	IC, LTC6702IDC DFN8DC	LINEAR TECHNOLOGY, LTC6702IDC#PBF

Dynamic Load Circuit

1	1	Q10	MOSFET, FDB8832 TO263AB	FAIRCHILD, FDB8832
2	1	R104	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
3	1	R109	RES, 0.002Ω 1% 1W 2512	VISHAY, WSL25122L000FEA

Additional Demo Board Circuit Components

1	0	C3	CAP, OPT 0805	OPT
2	1	C31	CAP, 1μF 10% 25V X7R 0603	AVX, 06033C104KAT2A
3	0	C69, C74	CAP, OPT 1206	OPT
4	0	C7, C22, C26, C44, C48, C49, C51, C60, C67, C68	CAP, OPT 0603	OPT
5	0	C70	CAP, OPT 0402	OPT
6	0	C71	CAP, OPT 0805	OPT
7	0	C72	CAP, OPT 0603	OPT
8	0	CIN13	CAP, OPT 25V OSCON	OPT
9	0	COUT21 TO COUT28	CAP, OPT POSCAP 7343	OPT
10	0	D14, D15, D16, D17	DIODE, OPT SOD523	OPT
11	0	D19, D20	DIODE, OPT SOD523	OPT
12	1	D21	DIODE, CMHZ4701 SOD123	CENTRAL SEMI, CMHZ4701
13	4	D22, D23, D24, D25	DIODE, 1N4448HWT SOD523	DIODES INC, 1N4448HWT-7
14	0	JP3	HEADER, OPT 3 PIN 0079 SINGLE	OPT
15	0	L5	IND, OPT	OPT
16	0	Q9	MOSFET, FDB8832 TO263AB	OPT
17	1	R140	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA
18	0	R141, R142, R143, R144	RES, OPT 1206	OPT
19	0	R153, R174, R175	CAP, OPT 0603	OPT
20	0	R169, R170, R171, R172, R173	RES, OPT 0402	OPT
21	1	R176	RES, 75k 1% 1/10W 0603	VISHAY, CRCW060375K0FKEA
22	1	R177	RES, 10k 1% 1/10W 0603	VISHAY, CRCW060310K0FKEA

DEMO MANUAL

DC2111A-A/-B

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
23	1	R179	RES, 2k 5% 1/4W 1206	VISHAY, CRCW12062K00JNEA
24	0	R47, R51, R54, R55, R90, R92, R97, R98	RES, OPT 2512	OPT
25	0	R8, R14, R25, R26, R38, R43, R49, R53, R59, R70, R71, R81, R87, R94, R99, R100, R101, R102, R103, R105, R106, R107, R108, R110, R111, R113, R118, R119, R120, R121, R139, R155, R156, R157, R158, R159, R160, R161, R162, R163, R164, R165, R166, R167, R168, R188, R189, R190, R191	RES, OPT 0603	OPT
26	0	RN1	NTC, OPT 0603 / 0805	OPT
27	0	U13	IC, OPT DFN8DC	OPT
28	0	U18	IC, OPT SOT23-5	OPT
29	1	U20	IC, LT6703IDC-3 DFN3DC	LINEAR TECHNOLOGY, LT6703IDC-3#PBF

Hardware: For Demo Board Only

1	12	E1 TO E12	TESTPOINT, TURRET, 0.095"	MILL MAX, 2501-2-00-80-00-00-07-0
2	1	JP1	HEADER, 3 PIN 0.079 SINGLE ROW	WURTH ELEKTRONIK 62000311121
3	1	JP2	HEADER, 4 PIN 0.079 SINGLE ROW	WURTH ELEKTRONIK 62000411121
4	2	XJP1, XJP2	SHUNT, 0.079" CENTER	WURTH ELEKTRONIK 60800213421
5	8	J1, J2, J3, J4, J5, J6, J7, J8	STUD, TEST PIN	PEM, KFH-032-10
6	16	J1, J2, J3, J4, J5, J6, J7, J8 (x2)	NUT, BRASS PL # 10-32	ANY, #10-32M/S
7	8	J1, J2, J3, J4, J5, J6, J7, J8	RING, LUG # 10	KEYSTONE, 8205
8	8	J1, J2, J3, J4, J5, J6, J7, J8	WASHER, TIN, PLATED BRASS	#10EXT BZ TN
9	2	J9, J10	CON, BNC, 5 PINS	CONNEX, 112404
10	1	J11	HEADER, DBL ROW, RT ANGLE, 2X4, 8PIN	MILL-MAX, 802-10-008-20-001000
11	1	J12	SOCKET, DBL ROW, RT ANGLE, 2X4, 8PIN	MILL-MAX, 803-43-008-20-001000
12	4	MTGS AT 4 CORNERS	STAND-OFF, NYLON 0.5"	KEYSTONE, 8833 (SNAP ON)
13	1	JP5	HEADER, 3 PIN 0.079 SINGLE ROW	WURTH ELEKTRONIK, 62000311121
14	1	XJP5	SHUNT, 0.079" CENTER	WURTH ELEKTRONIK 60800213421

DEMO MANUAL

DC2111A-A/-B

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