NCP5332ADEMO/D

Demonstration Note for NCP5332A and NTB85N03

Power Solution for the Intel Pentium® 4 Processor

ON Semiconductor®

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DEMONSTRATION NOTE

Description

This solution is designed to power the Intel 478–Pin Pentium 4 Processor. This design meets Intel's transient requirements and features ON Semiconductor's NCP5332A Two–Phase Controller together with ON Semiconductor's NTB85N03 Power MOSFETs.

Features

- 2–Phase Architecture
- 200 kHz Constant Frequency Design
- Lossless Adaptive Positioning
- Internal Gate Drivers to Minimize Board Space
- 5–Bit DAC with 1% Tolerance
- Compatible with the 478–Pin Intel Voltage Transient Test (VTT) Tool
- Hiccup Mode Current Limit
- Power Good Output with Internal Delay
- VRM 9.0 Compliance Meets Transient Requirements for the Intel Pentium 4 Processor in the 478–Pin Package

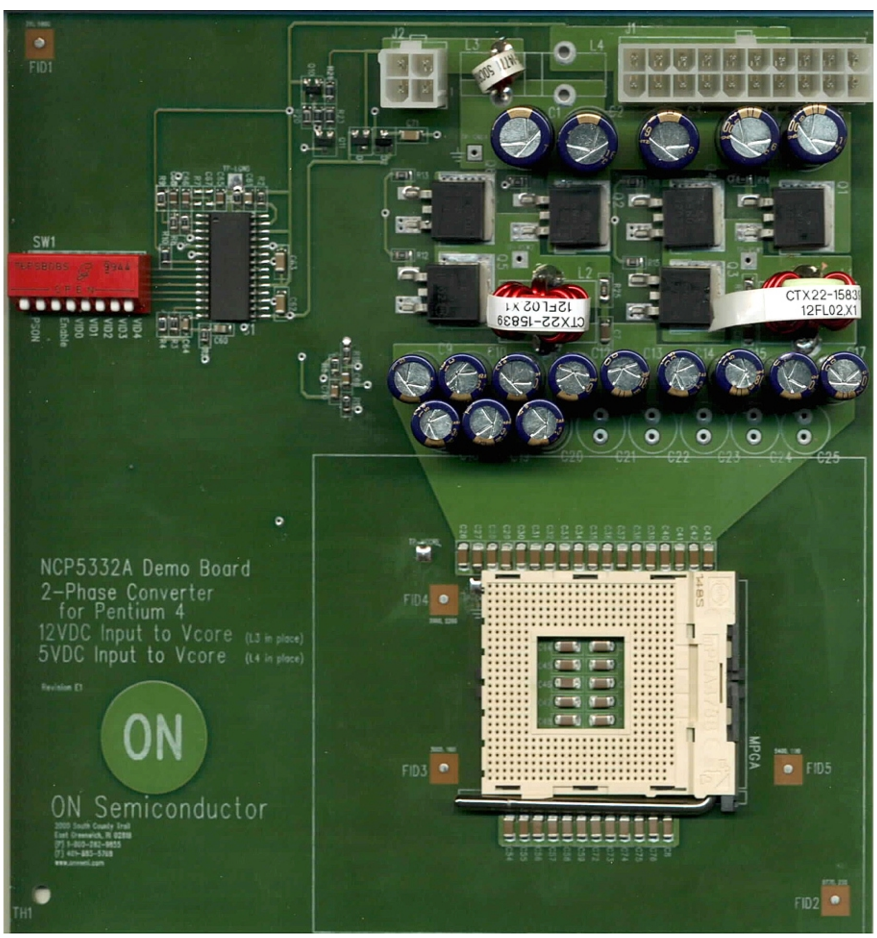

Figure 1. NCP5332A Demonstration Board

Introduction

The ON Semiconductor NCP5332A is a 2–phase integrated circuit buck controller that incorporates internal MOSFET gate drivers thereby providing a compact solution targeted at the high–current Pentium 4 microprocessor.

Input Power

Connect to J1 the main output connector of an ATX 'silver–box' computer power supply. The ATX power supply needs to be able to source a minimum of 8 A at 12 V in order to supply the maximum voltage (1.85 V) and current (~40 A). J2 should be used to connect to the ATX12V connector of the power supply. This demo board will only work if the ATX12V connector is used. No power is provided through the 12 V J1 connection. Lastly, most ATX power supplies require a minimum load of 2 A on the 5 V supply in order to properly regulate the 12V. This 'pre–load' will need to be externally supplied.

Alternatively, a low–power 5 V and a high–power 12 V bench–top power supply may be used instead of a 'silver–box' supply. The 12 V supply should then be connected to J2 while the 5 V supply should be connected to any or all of J1 pins 4, 6, 9 and 20. *Note: only a small amount of current (< 0.5 A) is required from the 5 V supply. Pins 4, 6, 9 and 20 are all connected together on the demo board.*

Output Load

The mPGA478 ZIF socket provides a connection for the Intel transient test tool. This tool is the preferred test method as it has the means to provide the proper slew rate for transient load testing. Alternately an electronic or resistive load may be used, but a suitable interconnect will have to be devised.

SW1 Jumper Settings

The 8–position DIP switch SW1 is used to set the demo board output voltage. Choose the desired Vcore voltage by setting the VID jumper code corresponding to the values listed in Table 1. Note: the switch in the 'Ground' position corresponds to a logic '0'. Ensure the Enable jumper SW1–11 is in the '1' position, and the PSON jumper SW1–9 is in the '0' position.

Provisional Capacitors

There are several optional board locations where additional output capacitors may be added to reduce ripple, improve transient response or investigate the use of other capacitor types than the ones supplied. These locations are provided at positions C21 through C25.

Table 1. Vcore DAC Settings

V_{ID} Setting					
V_{ID4}	V_{ID3}	V_{ID2}	V_{ID1}	V_{ID0}	Nominal Vcore
1	1	1	1	1	No Output
1	1	1	1	0	1.075
1	1	1	0	1	1.100
1	1	1	0	0	1.125
1	1	0	1	1	1.150
1	1	0	1	0	1.175
1	1	0	0	1	1.200
1	1	0	0	0	1.225
1	0	1	1	1	1.250
1	0	1	1	0	1.275
1	0	1	0	1	1.300
1	0	1	0	0	1.325
1	0	0	1	1	1.350
1	0	0	1	0	1.375
1	0	0	0	1	1.400
1	0	0	0	0	1.425
0	1	1	1	1	1.450
0	1	1	1	0	1.475
0	1	1	0	1	1.500
0	1	1	0	0	1.525
0	1	0	1	1	1.550
0	1	0	1	0	1.575
0	1	0	0	1	1.600
0	1	0	0	0	1.625
0	0	1	1	1	1.650
0	0	1	1	0	1.675
0	0	1	0	1	1.700
0	0	1	0	0	1.725
0	0	0	1	1	1.750
0	0	0	1	0	1.775
0	0	0	0	1	1.800
0	0	0	0	0	1.825

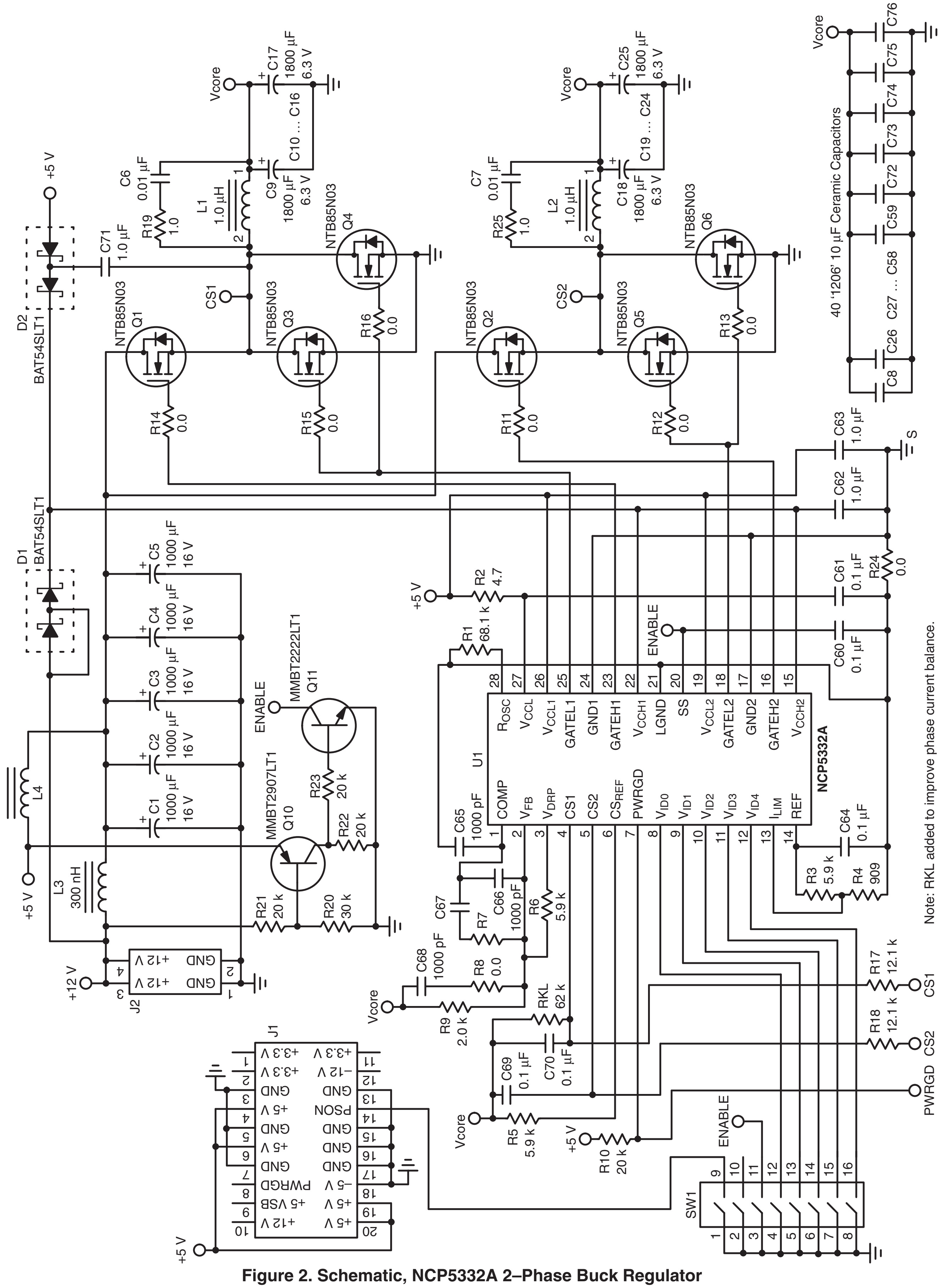

Figure 2. Schematic, NCP5332A 2−Phase Buck Regulator

Table 2. Demo Board Specifications

Parameter	Conditions	Min	Typ	Max	Unit
5 V Maximum Input	–	–	16	–	V
5 V UVLO Start	–	4.05	4.30	4.50	V
5 V UVLO Stop	–	3.75	4.10	4.35	V
5 V UVLO Hysteresis	–	100	200	300	mV
12 V Maximum Input	–	–	20	–	V
12 V UVLO Start	–	8.70	9.20	9.70	V
12 V UVLO Stop	–	6.90	7.40	7.90	V
12 V UVLO Hysteresis	–	1500	1800	2100	mV
Power Good Lower Threshold	% of Nominal VID Setting	–18	–14	–11	%
Power Good Upper Threshold	–	2.00	2.08	2.15	V
Power Good Fault Delay	–	60	120	140	μs
Output Current Limit	–	–	58	–	A
Vcore Tolerance	Deviation from Nominal VID Setting	–0.025	–	0.025	–
Switching Frequency	–	–	200	–	kHz

TYPICAL PERFORMANCE

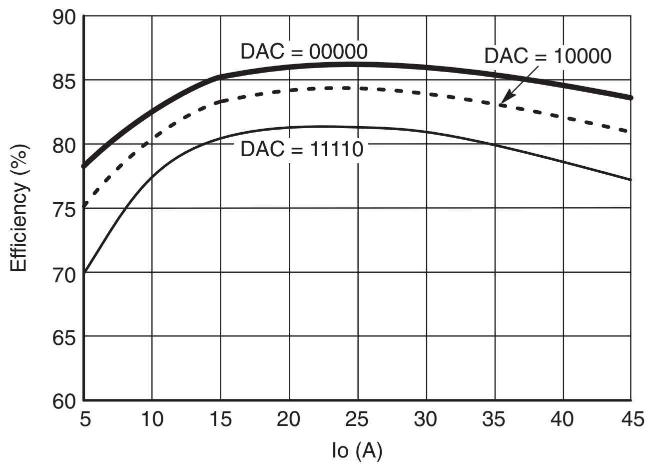

Figure 3. Efficiency vs Io

Table 3. Efficiency vs Io

DAC	**00000**									
Vin	12.064	11.941	11.878	11.825	11.773	11.718	11.667	11.613	11.558	11.501
Iin	0.176	0.944	1.825	2.663	3.529	4.416	5.316	6.265	7.251	8.258
Pin	2.526	11.675	22.080	31.893	41.949	52.149	62.424	73.158	84.210	95.378
Vcore	1.8248	1.8192	1.8131	1.8059	1.7944	1.7927	1.7859	1.7805	1.7747	1.7682
Io	0.000	5.012	10.035	15.012	20.078	25.065	30.031	35.071	40.073	45.013
Po	0.000	9.118	18.195	27.110	36.028	44.934	53.632	62.445	71.116	79.592
η	0.00%	78.10%	82.40%	85.00%	85.89%	86.16%	85.92%	85.36%	84.45%	83.45%
DAC	**10000**									
Vin	12.082	11.960	11.904	11.859	11.817	11.775	11.732	11.689	11.644	11.599
Iin	0.135	0.770	1.449	2.109	2.783	3.482	4.195	4.941	5.734	6.535
Pin	2.034	9.612	17.651	25.413	33.289	41.403	49.618	58.158	67.169	76.202
Vcore	1.4234	1.4186	1.4127	1.4057	1.3993	1.3927	1.3861	1.3798	1.3744	1.3675
Io	0.000	5.067	10.050	15.045	20.038	25.063	30.036	35.045	40.073	45.018
Po	0.000	7.188	14.197	21.148	28.038	34.904	41.631	48.356	55.078	61.561
η	0.00%	74.78%	80.43%	83.22%	84.23%	84.30%	83.90%	83.15%	82.00%	80.79%
DAC	**11110**									
Vin	12.091	11.985	11.929	11.892	11.857	11.824	11.790	11.756	11.985	11.683
Iin	0.097	0.609	1.120	1.622	2.144	2.673	3.220	3.800	0.609	5.052
Pin	1.575	7.701	13.763	19.691	25.824	32.008	38.366	45.075	7.701	59.425
Vcore	1.0715	1.0660	1.0598	1.0533	1.0469	1.0404	1.0340	1.0278	1.0660	1.0154
Io	0.000	5.017	10.082	15.011	20.078	25.017	30.022	35.010	5.017	45.084
Po	0.000	5.348	10.685	15.811	21.020	26.028	31.043	35.983	5.348	45.778
η	0.00%	69.45%	77.63%	80.29%	81.40%	81.32%	80.91%	79.83%	69.45%	77.04%

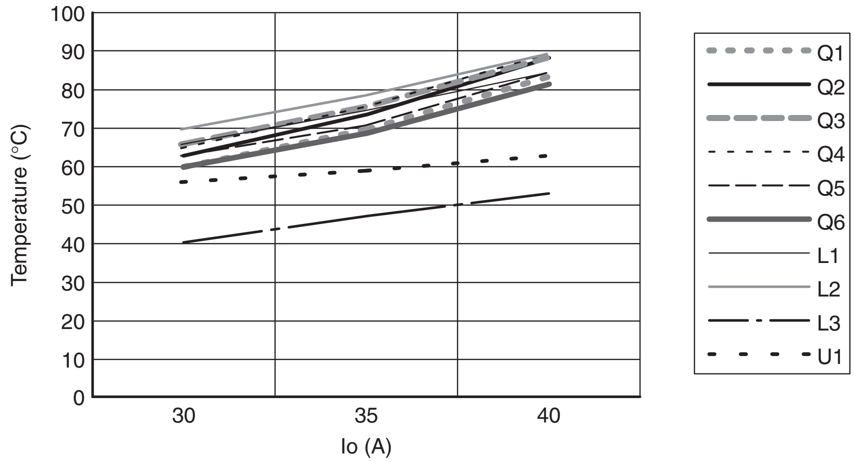

Figure 4. Component Temperature vs Io (DAC = 10000)

Table 4. Component Temperatures (°C)

	DAC = 00000				DAC = 10000				DAC = 11110			
Vin	11.65	11.59	11.62	12.09	11.72	11.67	11.63	12.09	11.78	11.75	11.71	12.09
Iin	5.33	6.28	6.27	0.98	4.21	4.98	5.78	0.99	3.25	3.83	4.46	0.99
Vo	1.788	1.781	1.774	0	1.389	1.382	1.374	0	1.036	1.029	1.022	0
Io	30.0	35.0	40.0	S/C	30.0	35.0	40.0	S/C	30.0	35.0	40.0	S/C
Q1	65	75	88	29	60	70	83	28	59	70	76	20
Q2	69	76	93	30	63	74	88	28	63	73	81	29
Q3	69	77	90	30	65	75	87	30	65	77	82	30
Q4	68	77	93	30	64	75	88	29	66	76	82	30
Q5	64	68	86	30	62	70	83	30	61	70	77	30
Q6	62	68	85	30	60	69	81	30	60	70	76	30
L1	77	82	92	30	65	74	83	29	64	71	74	30
L2	80	84	98	30	69	77	88	30	66	73	77	30
L3	44	47	52	26	40	47	53	26	42	48	47	26
U1	55	56	62	32	55	58	62	32	57	56	60	32
Ambient	25	25	25	25	25	25	25	25	25	25	25	25

S/C = Output Short Circuit

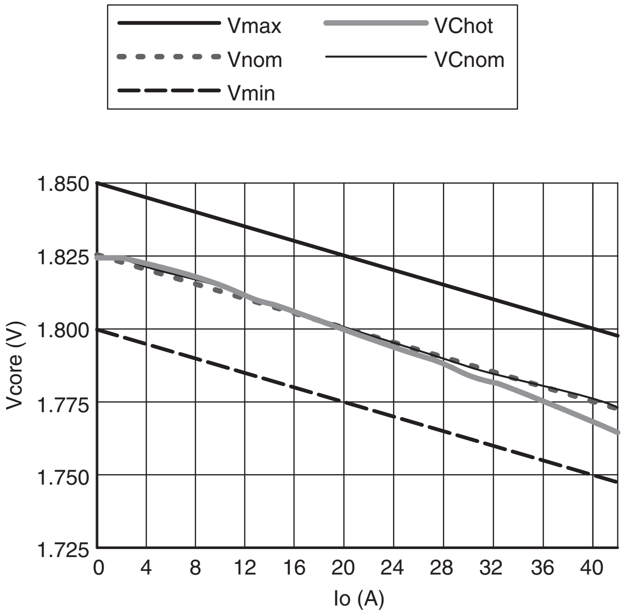

Figure 5. Load Regulation, Vcore vs Io, DAC = 00000

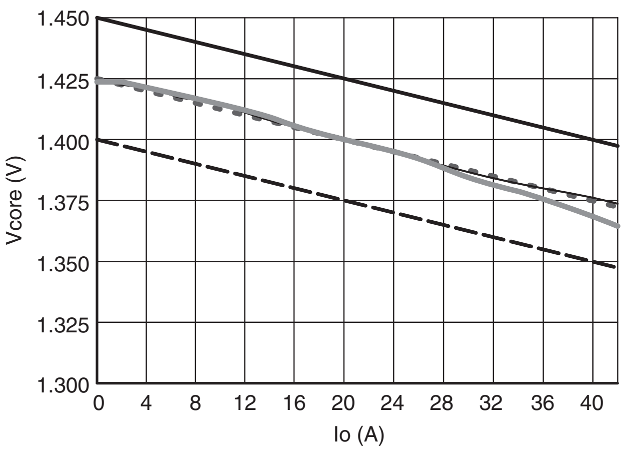

Figure 6. Load Regulation, Vcore vs Io, DAC = 10000

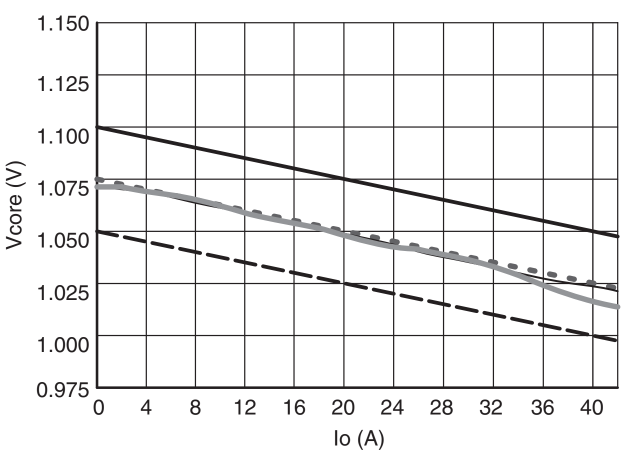

Figure 7. Load Regulation, Vcore vs Io, DAC = 11110

Table 5. Vcore vs Io

	DAC = 00000		DAC = 10000		DAC = 11110	
Io	**VCnom**	**VChot**	**VCnom**	**VChot**	**VCnom**	**VChot**
0	1.82489	1.82480	1.42369	1.42389	1.07179	1.07175
2	1.82416	1.82453	1.42288	1.42334	1.07051	1.07096
4	1.82133	1.82210	1.42068	1.42154	1.06845	1.06917
6	1.81897	1.81975	1.41836	1.41915	1.06568	1.06688
8	1.81696	1.81763	1.41626	1.41702	1.06348	1.06448
10	1.81425	1.81495	1.41384	1.41451	1.06103	1.06190
12	1.81125	1.81200	1.41114	1.41191	1.05853	1.05930
14	1.80844	1.80873	1.40830	1.40891	1.05593	1.05653
16	1.80575	1.80597	1.40557	1.40591	1.05329	1.05359
18	1.80294	1.80294	1.40283	1.40302	1.05077	1.05077
20	1.80057	1.79994	1.40054	1.40013	1.04830	1.04796
22	1.79779	1.79697	1.39780	1.39735	1.04564	1.04503
24	1.79536	1.79386	1.39526	1.39432	1.04321	1.04277
26	1.79264	1.79079	1.39276	1.39154	1.04053	1.04234
28	1.78979	1.78763	1.38999	1.38795	1.03793	1.03950
30	1.78707	1.78429	1.38725	1.38485	1.03530	1.03576
32	1.78457	1.78113	1.38448	1.38181	1.03261	1.03228
34	1.78254	1.77813	1.38205	1.37870	1.03013	1.02826
36	1.78055	1.77490	1.37982	1.37558	1.02766	1.02391
38	1.77846	1.77168	1.37786	1.37215	1.02524	1.02009
40	1.77616	1.76811	1.37566	1.36892	1.02325	1.01685
42	1.77357	1.76437	1.37331	1.36458	1.02107	1.01323

VChot data is taken after component temperatures have stabilized at each Io. VCnom data is taken by allowing component temperatures to stabilize at Io = 20 A, and then varying Io between minimum and maximum values.

TYPICAL WAVEFORMS

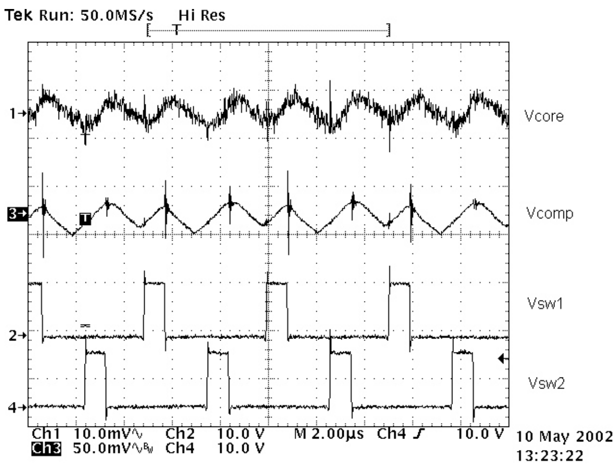

Figure 8. Output Ripple vs 1 Switch Node at 40 A Load

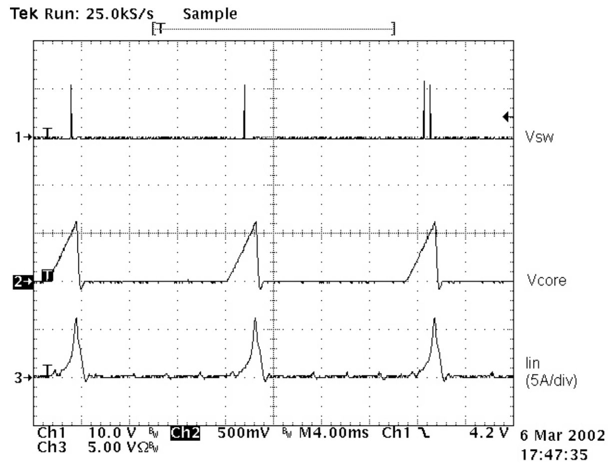

Figure 9. Hiccup Mode (Output Shorted)

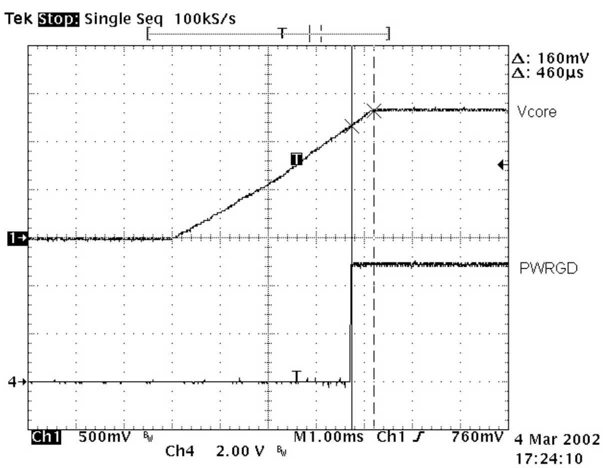

Figure 10. Power Good at Turn–On at 40 A Load

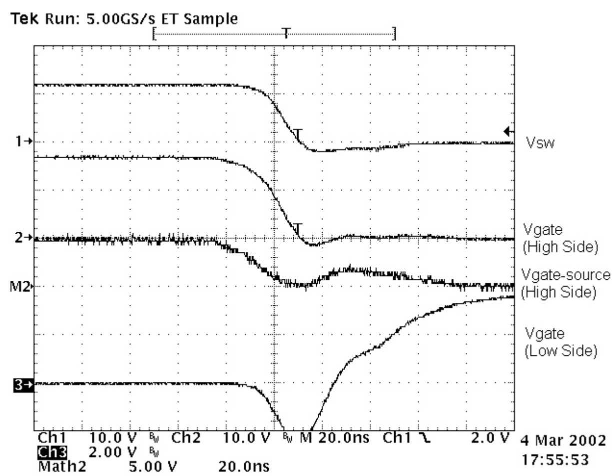

Figure 11. Switch Turn–Off at 40 A Load

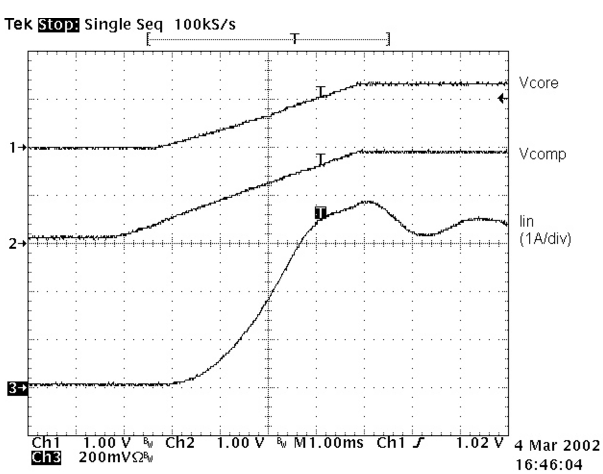

Figure 12. Turn–On at 40 A Load

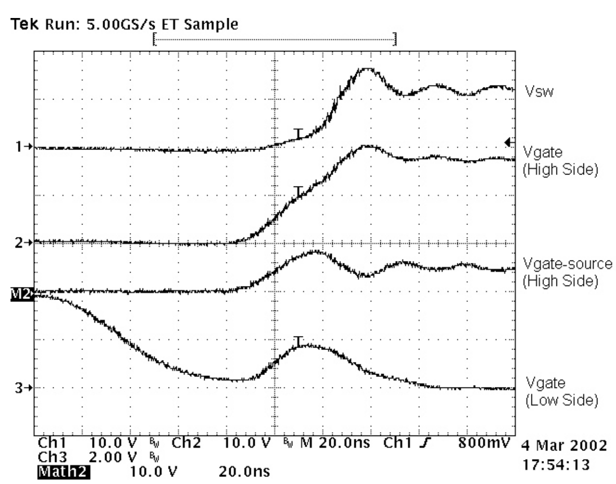

Figure 13. Switch Turn–On at 40 A Load

TRANSIENT RESPONSE WAVEFORMS

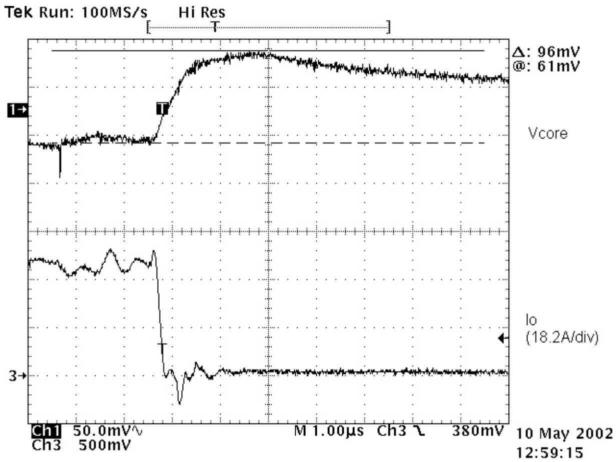

Figure 14. Transient Response (40 A to 0 A at 350 A/μs)

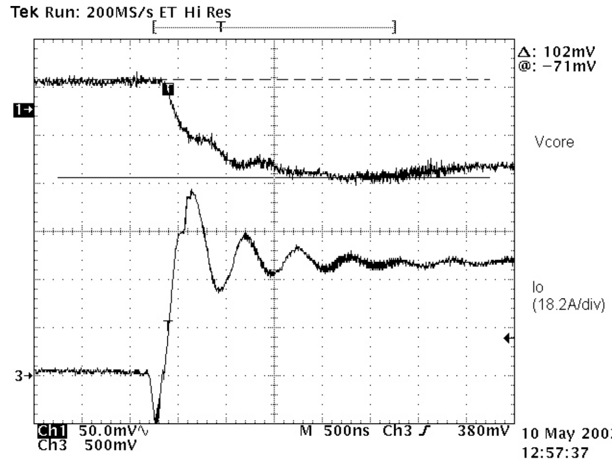

Figure 15. Transient Response (0 A to 40 A at 350 A/μs)

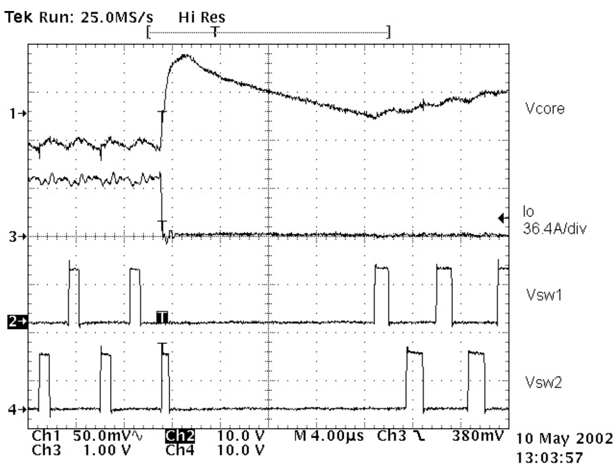

Figure 16. Transient Response (40 A to 0 A at 350 A/μs)

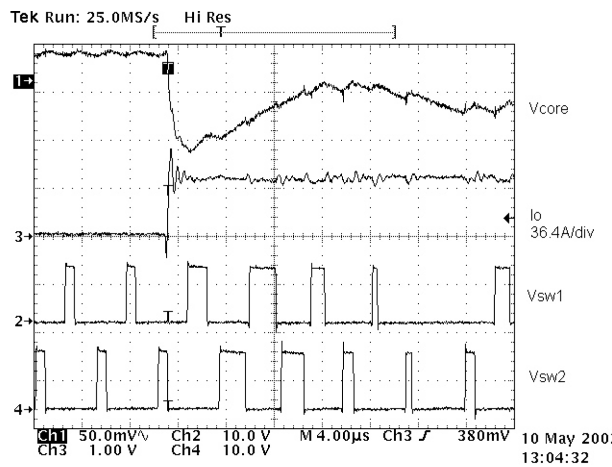

Figure 17. Transient Response (0 A to 40 A at 350 A/μs)

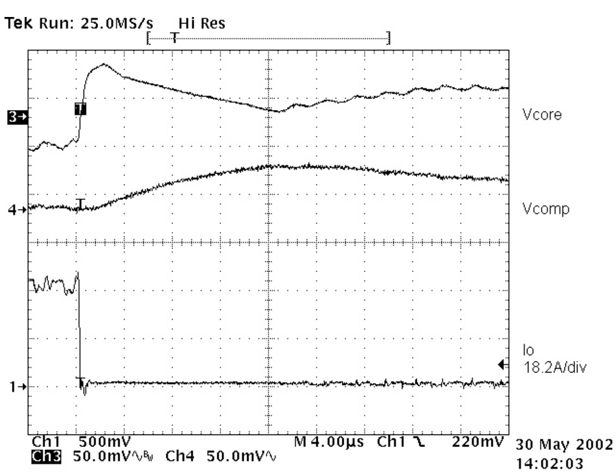

Figure 18. Transient Response (40 A to 0 A at 350 A/μs)

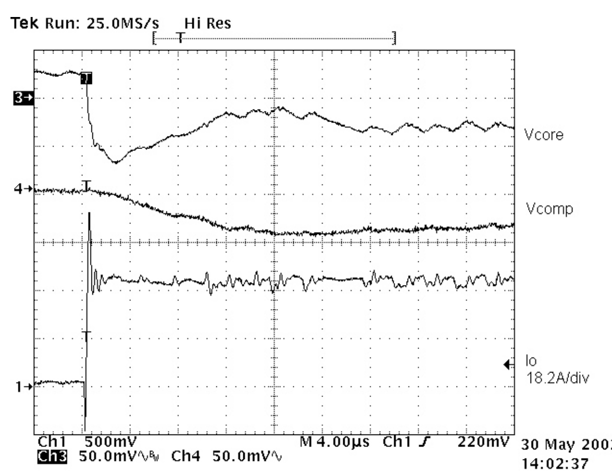

Figure 19. Transient Response (0 A to 350 A at 40 A/μs)

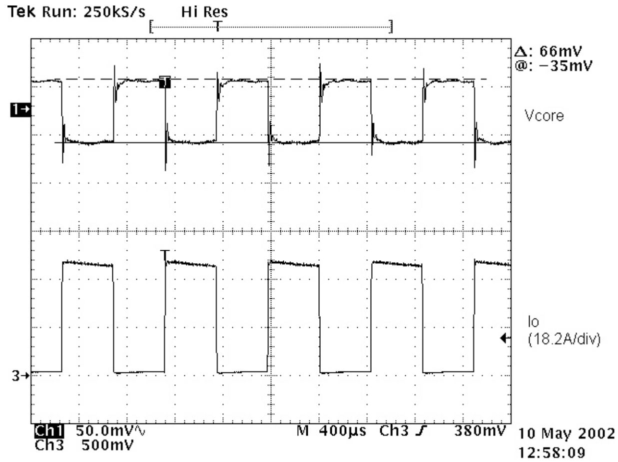

Figure 20. Transient Response 0 A to 40 A (Fs = 1.15 kHz)

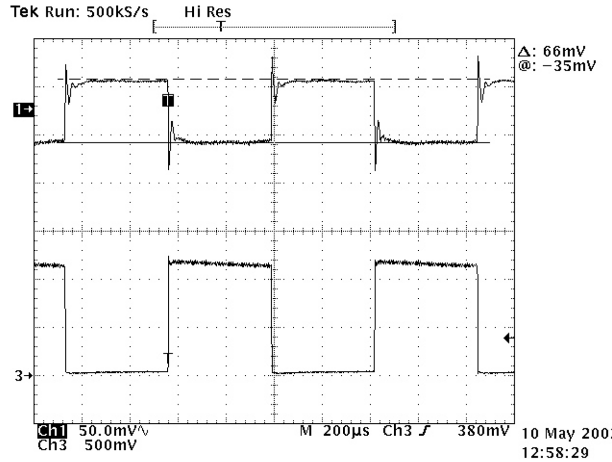

Figure 21. Transient Response 0 A to 40 A (Fs = 1.15 kHz)

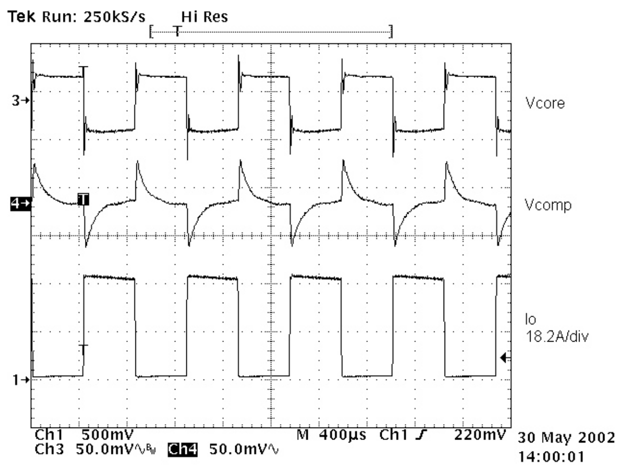

Figure 22. Transient Response 0 A to 40 A (Fs = 1.15 kHz)

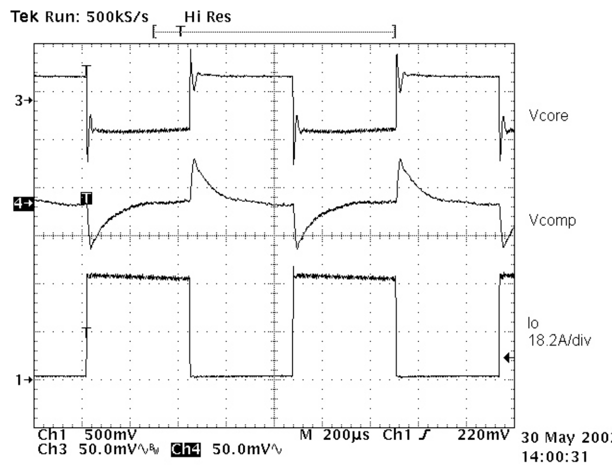

Figure 23. Transient Response 0 A to 40 A (Fs = 1.15 kHz)

PHASE CURRENT WAVEFORMS

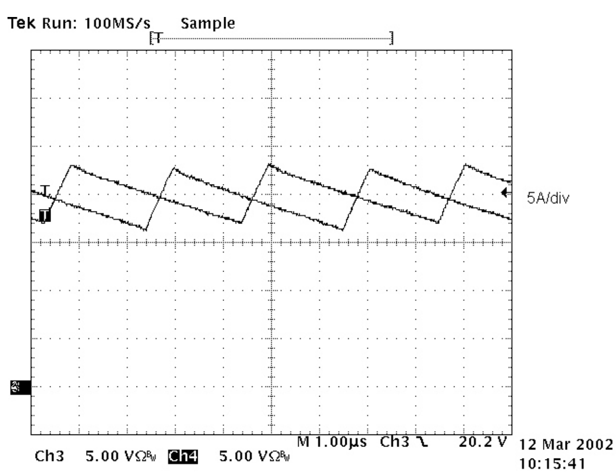

Figure 24. L2 and L3 Inductor Current at 40 A Load

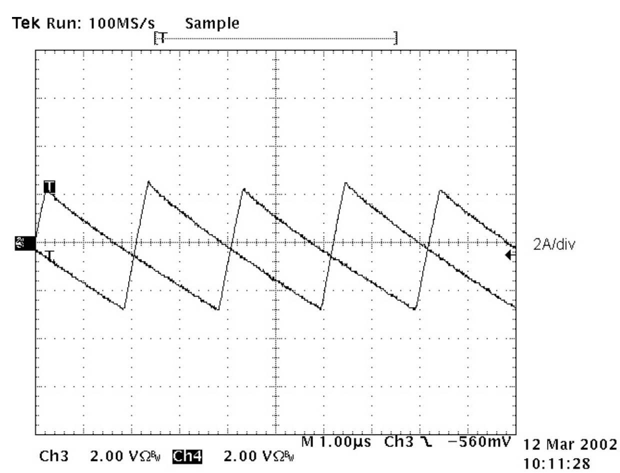

Figure 25. L2 and L3 Inductor Current at No Load

Note: Resistor RKL is added across C70 on the NCP5332A demo board in order to decrease the current in that phase (L1) and achieve better phase current balance. This resistor makes up for imbalances due to the different parasitic resistance each phase will see and the value is therefore dependent on the layout of the printed circuit board.

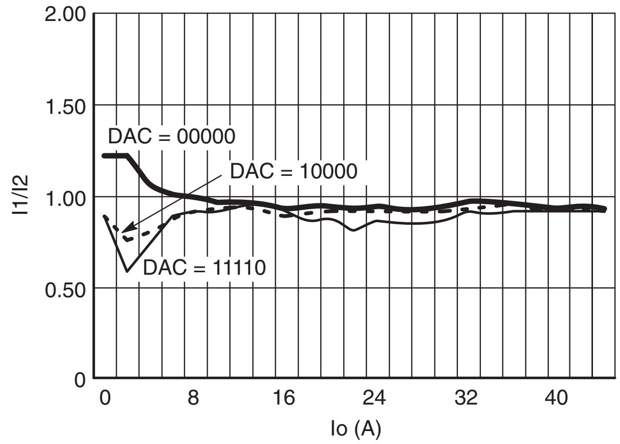

Figure 26. Phase Current Balance vs Io

Table 6. Phase Current Balance

	DAC = 00000			DAC = 10000			DAC = 11110		
Io	I1	I2	IA/IB	I1	I2	IA/IB	I1	I2	IA/IB
0	0.11	–0.09	1.22	–0.52	0.59	0.89	–0.38	0.43	0.89
2	1.27	1.04	1.22	1.01	1.33	0.76	0.99	1.68	0.59
4	2.34	2.21	1.06	2.16	2.74	0.79	2.23	3.01	0.74
6	3.36	3.32	1.01	3.12	3.57	0.87	3.09	3.48	0.89
8	4.45	4.48	0.99	4.26	4.63	0.92	4.17	4.58	0.91
10	5.47	5.65	0.97	5.31	5.74	0.92	5.26	5.74	0.92
12	6.62	6.88	0.96	6.37	6.82	0.93	6.36	6.77	0.94
14	7.66	7.98	0.96	7.40	8.06	0.92	7.49	7.87	0.95
16	8.48	9.14	0.93	8.17	9.20	0.89	7.33	8.06	0.91
18	9.44	10.09	0.94	9.18	10.17	0.90	8.28	9.65	0.86
20	10.57	11.22	0.94	10.22	11.25	0.91	9.38	10.68	0.88
22	11.43	12.28	0.93	11.28	12.40	0.91	10.47	12.91	0.81
24	12.52	13.37	0.94	12.23	13.36	0.92	11.75	13.60	0.86
26	13.53	14.59	0.93	13.13	14.38	0.91	12.59	14.76	0.85
28	14.31	15.46	0.93	14.09	15.45	0.91	13.41	15.86	0.85
30	15.31	16.24	0.94	14.97	16.28	0.92	14.29	16.57	0.86
32	16.36	17.03	0.96	16.01	17.27	0.93	15.63	17.19	0.91
34	17.39	18.07	0.96	16.90	18.05	0.94	16.49	18.25	0.90
36	18.12	19.08	0.95	17.92	18.91	0.95	17.41	19.14	0.91
38	19.04	20.38	0.93	18.77	20.22	0.93	18.13	19.97	0.91
40	19.84	21.29	0.93	19.27	20.90	0.92	19.11	20.88	0.92
42	20.87	22.26	0.94	20.16	21.80	0.92	19.84	21.60	0.92
44	21.31	22.99	0.93	20.94	22.85	0.92	20.59	22.56	0.91

Table 7. Converter Bill of Materials

Item	Qty	Reference	Part	Mfg. & P/N	Distributor & Phone No.
1	1	U1	**NCP5332A Controller 2–Phase with Integrated Drivers**	**ON Semiconductor – NCP5332A**	–
2	6	Q1–Q6	**MOSFET, D2PAK 28 V, 85 A, 6.1 m**	**ON Semiconductor – NTB85N03**	–
3	12	C9–C20	Capacitor, Electrolytic 1800 μF, 6.3 V, 8 × 20 mm	Rubycon – 6.3MBZ1800M8X20	Masline 716–546–5373
4	5	C1–C5	Capacitor, Electrolytic 1000 μF, 16 V, 10 × 16 mm	Rubycon – 16MBZ1000M10X16	Masline 716–546–5373
5	1	L3	Inductor, 300 nH	T44–26 Core w/ 6T of #16 AWG	Coiltronics 561–241–7876
6	2	L1, L2	Inductor, 1.0 μH, 20 A	T50–18B Core w/ 5T of #16 AWG Bifilar	Coiltronics 561–241–7876
7	1	C65, C66, C68	Capacitor, X7R ceramic 1000 pF, 10%, 50 V, 0805	Panasonic – ECJ–2VB1H102K Digikey – PCC102BNCT–ND	Digi–Key
8	2	C6, C7	Capacitor, X7R ceramic 0.01 μF, 10%, 50 V, 1206	Panasonic – ECU–V1H103KBM Digikey – PCC103BCT–ND	Digi–Key
9	5	C60, C61, C64, C69, C70	Capacitor, X7R ceramic 0.1 μF, 25 V, 0805	Panasonic – ECJ–2VB1E104K Digikey – PCC1828CT–ND	Digi–Key
10	3	C62, C63, C71	Capacitor, X7R ceramic 1.0 μF, 10%, 25 V, 1206	Panasonic – ECJ–3YB1E105K Digikey – PCC1893CT–ND	Digi–Key
11	40	C8, C26–C59, C72–C76	Capacitor, X5R ceramic 10 μF, 10%, 6.3 V, 1206	Panasonic – ECJ–3YB0J106K Digikey – PCC1940CT–ND	Digi–Key
12	1	Q10	**Transistor, PNP General Purpose –40 V, SOT23**	**ON Semiconductor – MMBT2907LT1**	–
13	1	Q11	**Transistor, NPN General Purpose 30 V, SOT23**	**ON Semiconductor – MMBT2222LT1**	–
14	2	D1, D2	**Diode, Schottky Dual Series 30 V, SOT23**	**ON Semiconductor – BAT54SLT1**	–
15	8	R8, R11–R16, R24	Resistor, 0 Ω, 5%, 0.10 W, 0805	Phycomp – 9C08052A0.0JLHFT Digikey – 3110.0ACT–ND	Digi–Key
16	1	R2	Resistor, 4.7, 5%, 0.10 W, 0805	Panasonic – ERJ–6GEYJ4.7V Digikey – P4.7ACT–ND	Digi–Key
17	2	R19, R25	Resistor, 1.0, 5%, 0.125 W, 1206	Panasonic – ERJ–8GEYJ1.0V Digikey – P1.0ETR–ND	Digi–Key
18	2	R4	Resistor, 909 Ω, 1%, 0.10 W, 0805	Panasonic – ERJ–6ENF9090V Digikey – P909CCT–ND	Digi–Key
19	2	R9	Resistor, 2.0 k, 1%, 0.10 W, 0805	Panasonic – ERJ–6ENF2001V Digikey – P2.00KCCT–ND	Digi–Key
20	1	R3, R5, R6	Resistor, 5.90 k, 1%, 0.10 W, 0805	Panasonic – ERJ–6ENF5901V Digikey – P5.90KCCT–ND	Digi–Key
21	4	R17, R18	Resistor, 12.1 k, 1%, 0.10 W, 0805	Panasonic – ERJ–6ENF1212V Digikey – P12.1KCCT–ND	Digi–Key
22	4	R10, R21, R22, R23	Resistor, 20 k, 5%, 0.10 W, 0805	Panasonic – ERJ–6GEYJ203V Digikey – P20KACT–ND	Digi–Key
23	4	R20	Resistor, 30 k, 5%, 0.10 W, 0805	Panasonic – ERJ–6GEYJ303V Digikey – P30KACT–ND	Digi–Key
24	1	R1	Resistor, 68.1 k, 1%, 0.10 W, 0805	Panasonic – ERJ–6ENF6812V Digikey – P68.1KCCT–ND	Digi–Key
25	1	J1	ATX Connector	Molex, 039281203	Many
26	1	J2	ATX 12 V Connector	Molex, 03928143	Many

Table 7. Converter Bill of Materials (continued)

Item	Qty	Reference	Part	Mfg. & P/N	Distributor & Phone No.
27	1	SW1	8–Pos DIP Switch	Amp, 435640–5	Many
28	1	PCB	Printed Circuit Board	ON Semiconductor, 5332 REV E1	CGI Circuits, Inc.
29	1	MPGA	mPGA478B Socket	Tyco, 1364990–1	Many

PCB ARTWORK

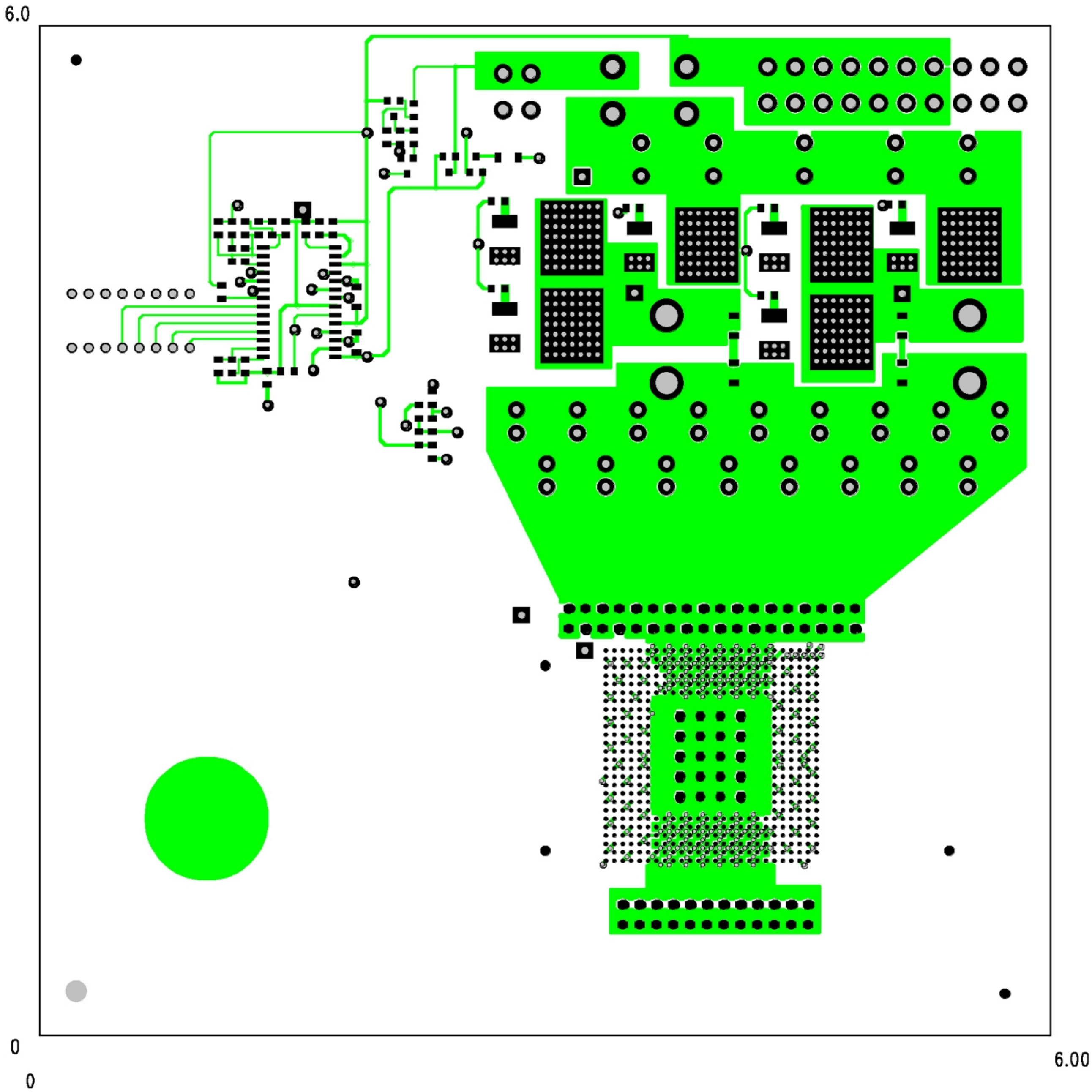

Figure 27. PCB Top Layer

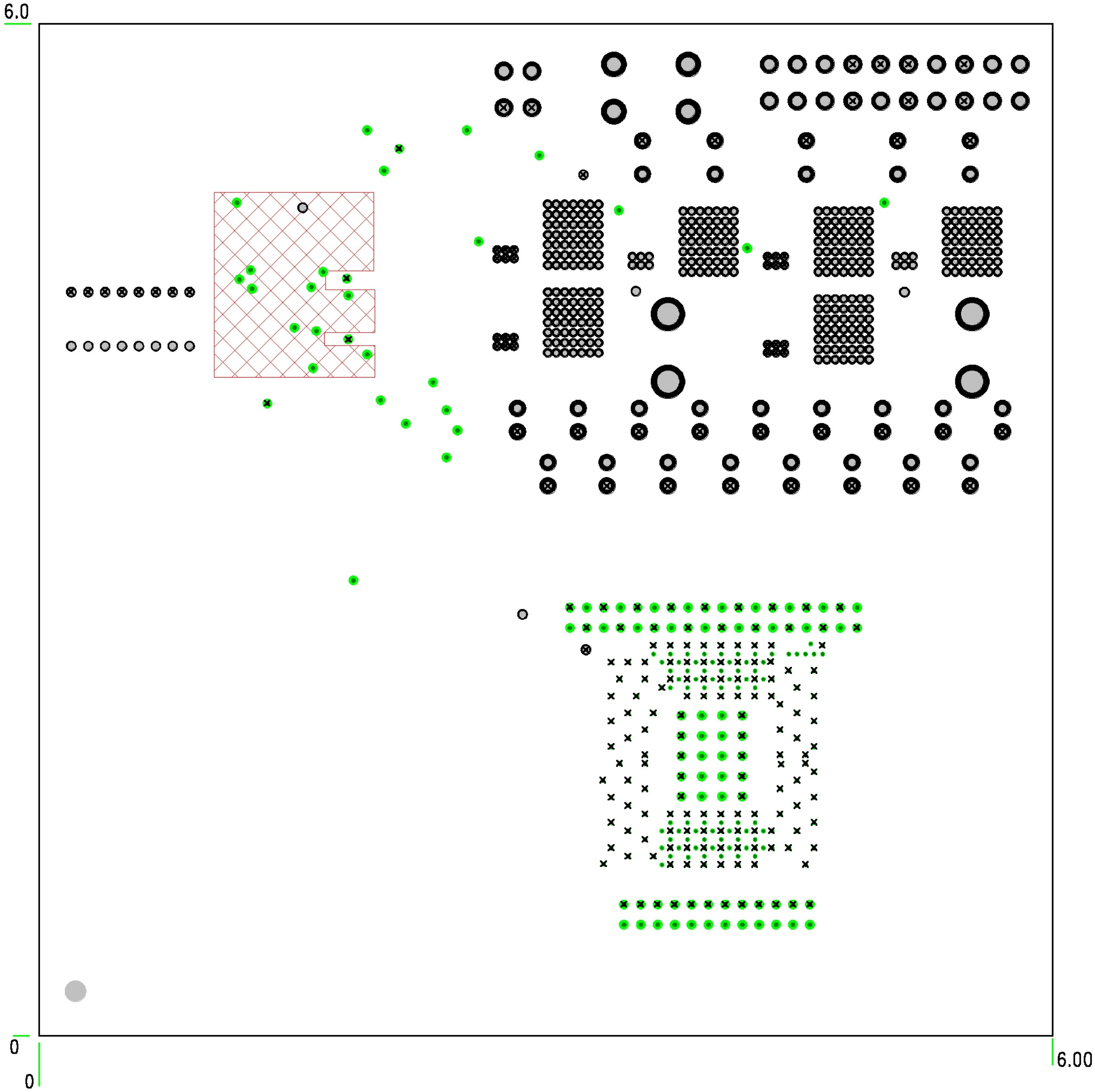

Figure 28. PCB Ground Plane

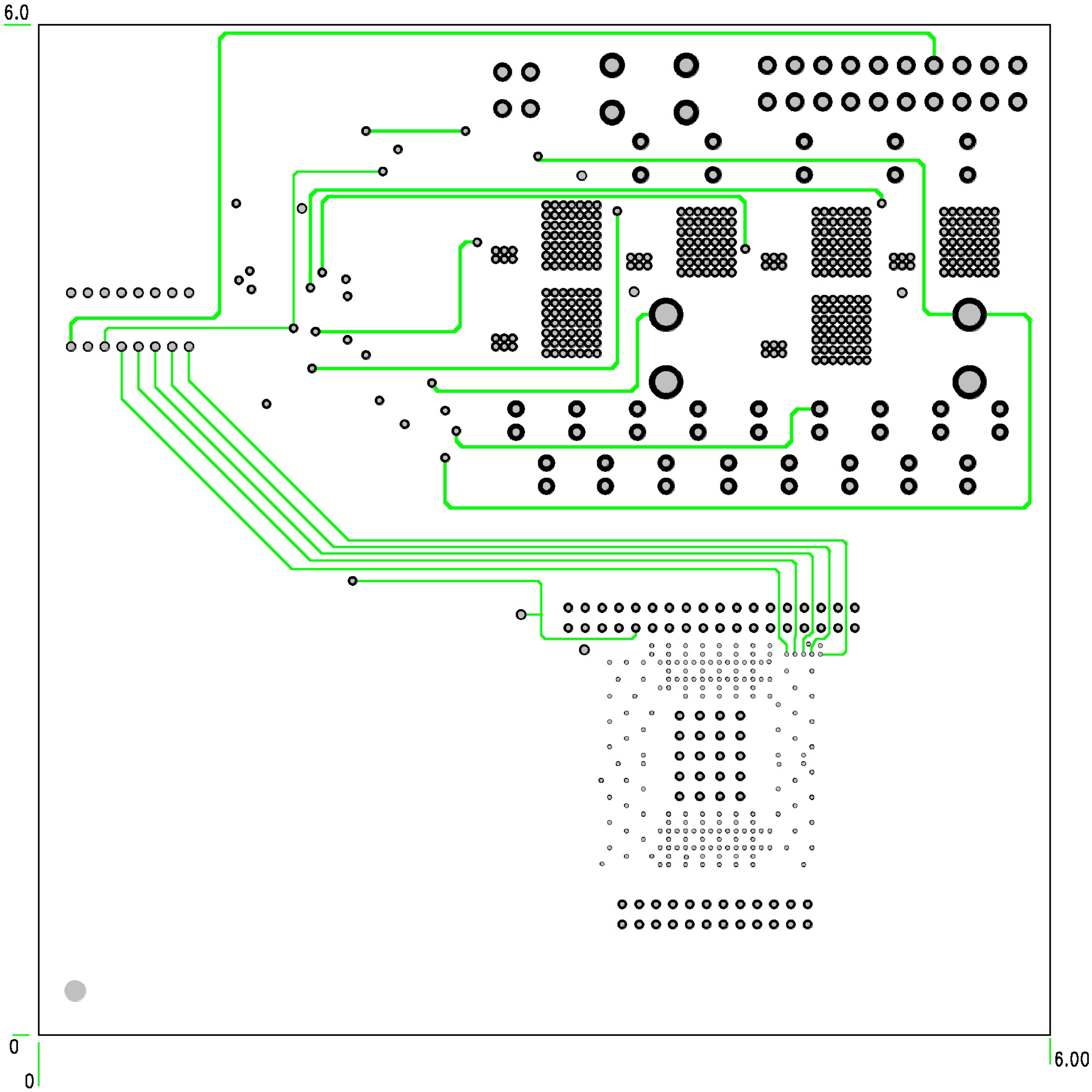

Figure 29. PCB Mid Layer

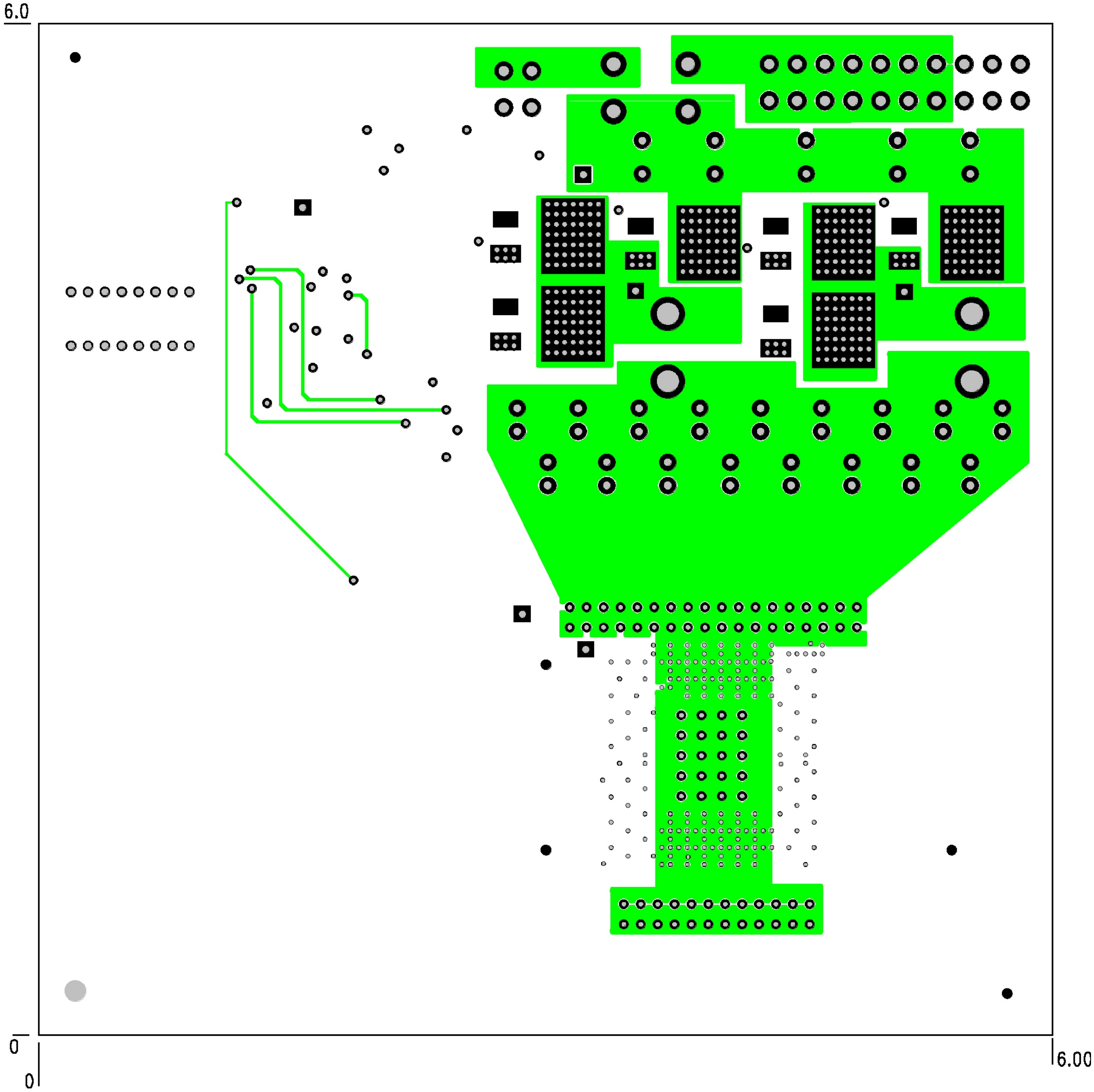

Figure 30. PCB Bottom Layer

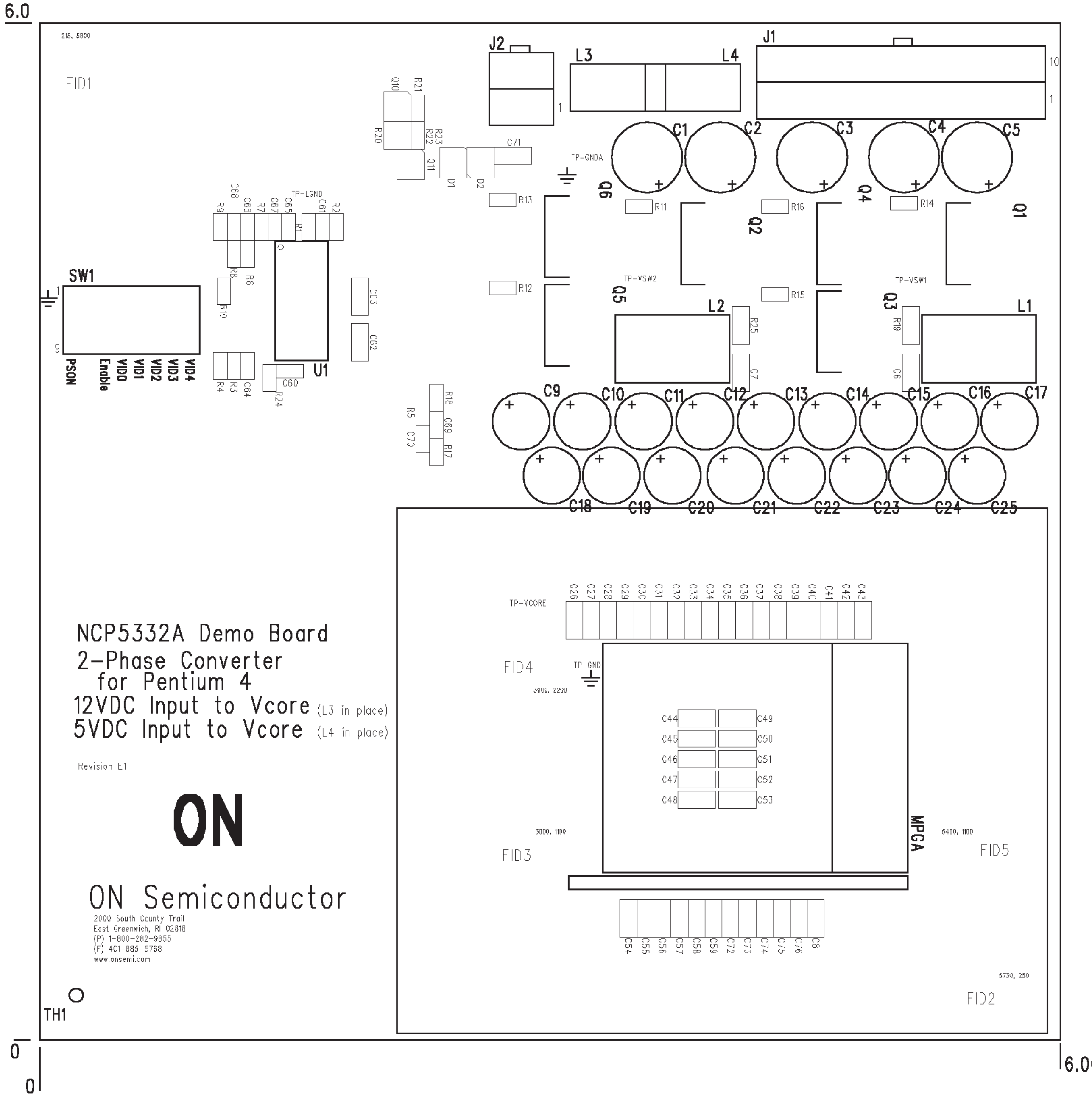

Figure 31. PCB Component Map and Silkscreen

Notes

Notes

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