Intermediate Bus Converter Demo Board Using SiP11205 or SiP11206

INTRODUCTION

Both SiP11205 and SiP11206 are controllers for half-bridge intermediate bus converters. The difference between SiP11205 and SiP11206 is that SiP11205 has built-in feed-forward circuitry and SiP11206 does not. The feed-forward circuitry adjusts duty cycle when input voltage changes. The duty cycle increases with the decrease of input voltage and the duty cycle decreases while input voltage increases. This feed-forward feature allows an IBC to be semi-regulated. While SiP11206 allows better efficiency throughout the whole range of input voltage, since its duty cycle can be set to an optimized value for the whole range of input voltage. Therefore SiP11205 is more suited for point of load applications that require tighter range of input voltage, which is the output of an SiP11205 controlled IBC, and SiP11206 is better for applications that efficiency is a key for whole input voltage range.

This demo board is an eighth-brick IBC power converter, which plugs into a baseboard. The IBC board has the following specifications and options:

- Narrow input voltage range (42 to 55 V) with SiP11205 or SiP11206 controller IC
- Wide input voltage range (36 to 75 V) with SiP11205 controller IC
- Nominal 12 V output, nominal load current 15 A
- PolarPAK SO-8 or PowerPAK SO-8 options for primary and secondary power MOSFETs

The baseboard contains input fuse, input, output, and remote enable connectors, enable switch, input bulk capacitance and output voltage measurement SMC connector. The cutout in the baseboard allows for probing of both sides of the IBC board. Photos are shown in Figure 1.

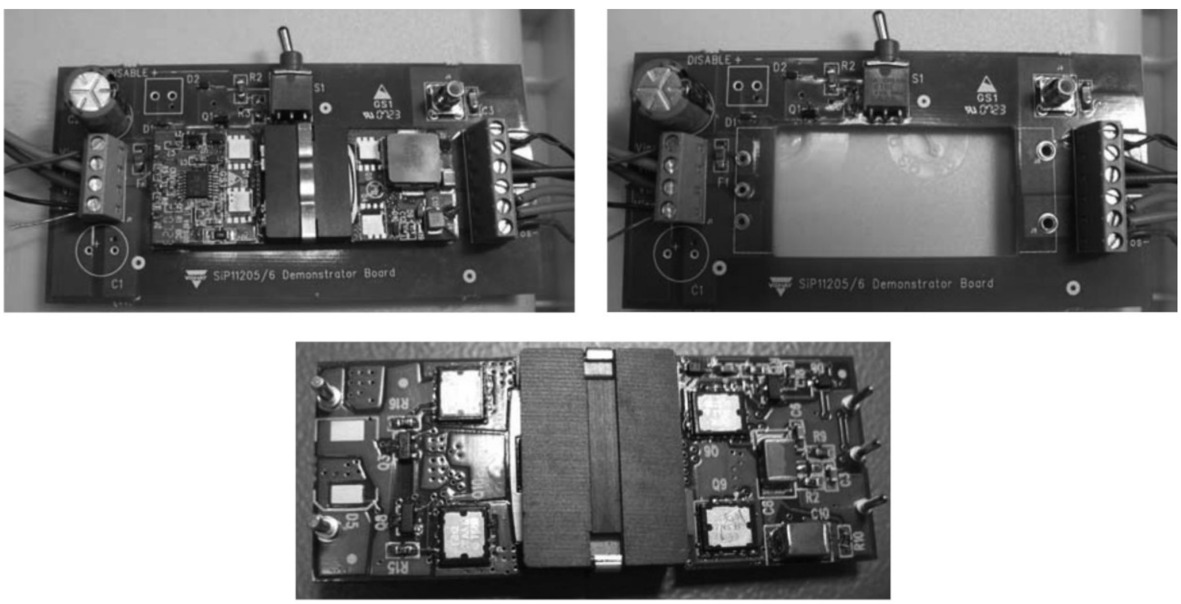


Figure 1. Photos of Demo Board with PolarPAK MOSFET Options

This document details the following of the demo board:

1. Set up
2. Operation
3. Waveforms and Performance curves
4. Schematic and BOM
5. Board Layout

SET UP

The connection diagram for the demo board is depicted in Figure 2. Power and sense connections are provided at the input and output for the main current path and for voltage sensing for efficiency monitoring. Wire rated at 5 A should be used for the input connections and 2 x 8 A rated wire should be used for the output lines. The board can be enabled/ disabled manually by using the on-board switch S1 or by connecting a 0 V/5 V logic signal in the disable connector. 5 V represents ‘Disable’.

Wiring lengths should be kept as short as possible, especially at the output in order to avoid excessive voltage drop across the cable length. If the input cables are less than 1 meter long, connection of one bulk capacitor on the baseboard is sufficient. However if longer lengths are utilized, both capacitors should be connected. It should be noted that with long cable lengths, the input voltage might be quite oscillatory on power up, potentially leading to under-voltage or the converter cycling in and out of operation until the voltage becomes steady.

A small fan should be placed so that cooling air is blown over the demo board in the direction shown. If the temperature of the board exceeds 105 °C, the board will be disabled by the over temperature shutdown mechanism.

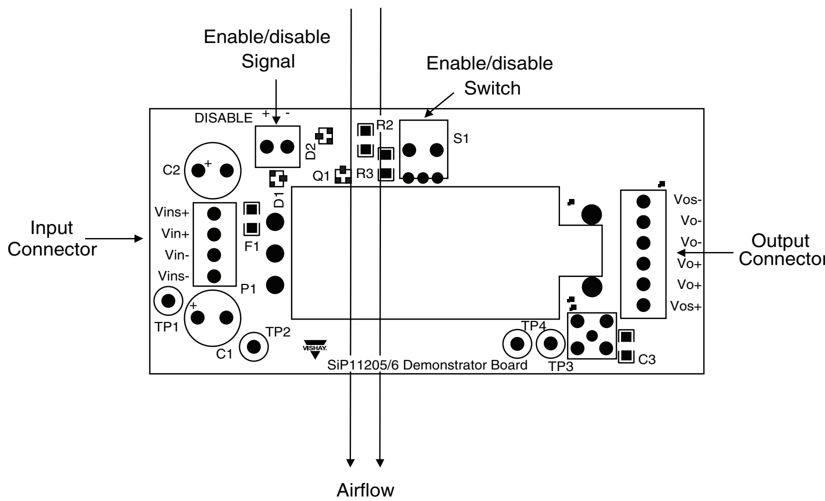


Figure 2. Connection Diagram

OPERATION AND TEST RESULTS

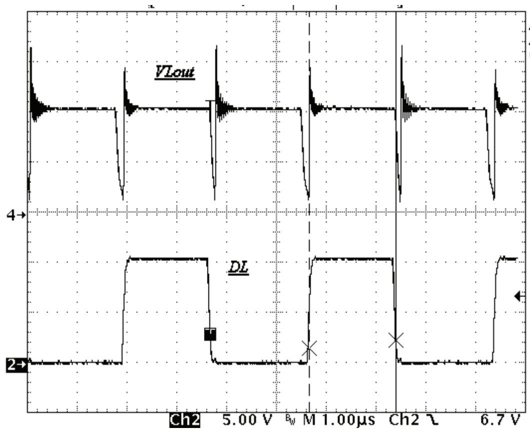
The power circuit is a half-bridge converter controlled by the SiP11205/6 IC. In the SiP11206 version, the converter duty cycle is fixed and is set by R_2. It is typically set to a value close to 50 % for maximum efficiency. The output voltage is then determined by the input voltage variation and the transformer turns ratio. In this demo board, the transformer turns ratio is 2:1. In the SiP11205 version, the maximum duty cycle is set at the minimum input voltage. The duty cycle will then decrease as the input voltage increases, in a feed-forward manner, resulting in a much smaller variation in output voltage over the line voltage range.

The controller IC is powered at startup by its own internal 9.5 V pre-regulator, which is driven from the line voltage. Once converter switching commences, a separate 10.3 V V_{CC} supply is supplied from an auxiliary transformer winding, and linear regulator R_{18}, Q_7, D_8.

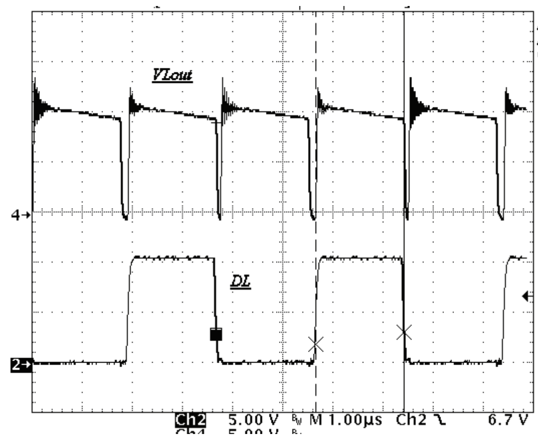
The secondary side synchronous rectifiers are self-driven, but with a controlled gate voltage that does not vary with input voltage. This results in improved efficiency and safer drive voltages. A local 10 V bias supply is generated on the secondary side through D_9, R_{19}, C_{12} and D_{10}. MOSFETs Q_8 and Q_3 are triggered by the opposite transformer node, and the 10 V is coupled to the synchronous rectifier gate less a threshold voltage drop.

In the feed-forward version, a Schottky diode is connected across the output filter. There are longer dead times in the feedforward version due to the smaller duty cycle at higher line voltages. During this dead time, the synchronous rectifiers are off as there is no transformer voltage available to turn them on. Hence, without the Schottky diode present, the inductor current will flow through the two body diodes of the synchronous rectifiers. The Schottky diode has a smaller on voltage drop than the body diodes, and so will enhance efficiency. Some typical converter waveforms are shown in Figure 3 to 10.

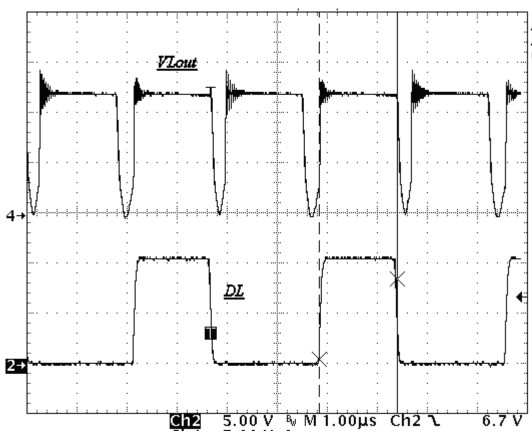
This demo board is laid out in such a way that Vishay Siliconix's PowerPAK and PolarPAK MOSFETs can both be used as long as they satisfy voltage and current requirements for primary and secondary. Therefore system performance may be slightly different when different MOSFETs with different footprints are used. Figure 11 to 14 illustrate typical system efficiency and line and load regulation curves when the PolarPAK MOSFETs SiE818DF and SiE812DF are used respectively for primary and secondary.



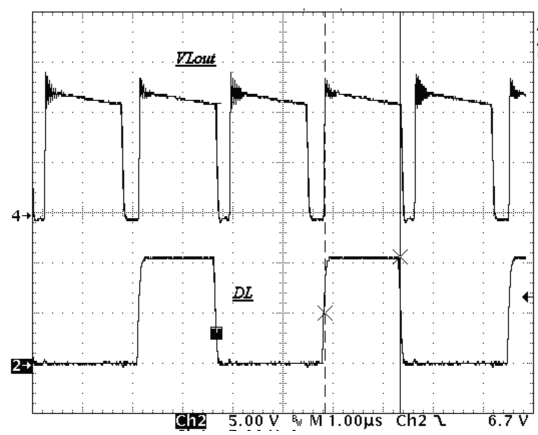
(a) 42 V with 0.5 A load



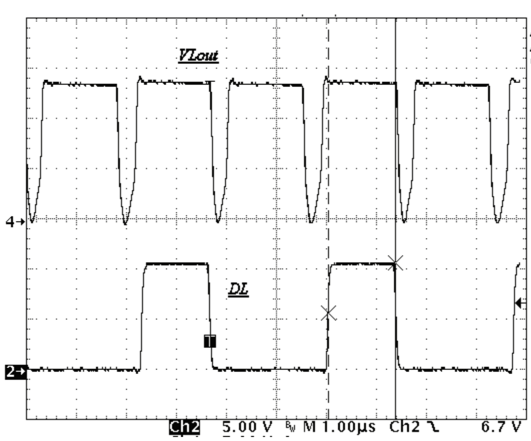
(b) 42 V with 15 A load



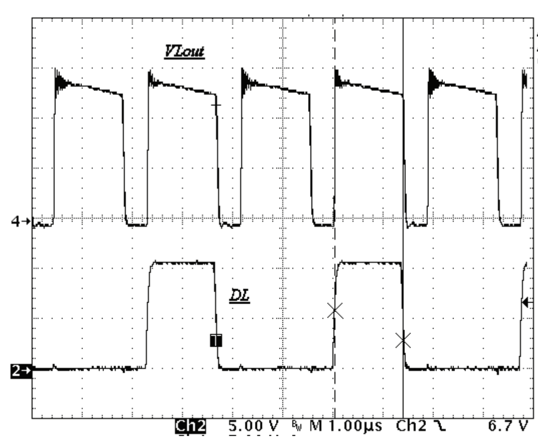
(c) 48 V with 0.5 A Load



(d) 48 V with 15 A Load

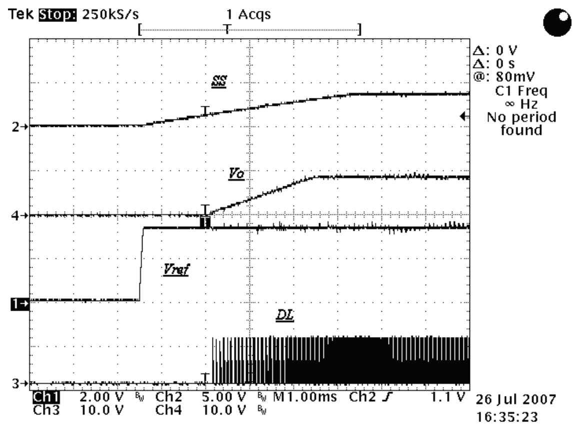


(e) 55 V with 0.5 A Load



(f) 55 V with 15 A Load

Figure 3. SiP11205 Driving Signal and Inductor Voltage



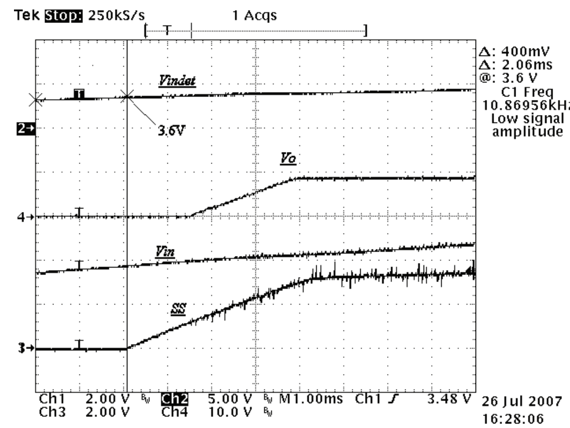
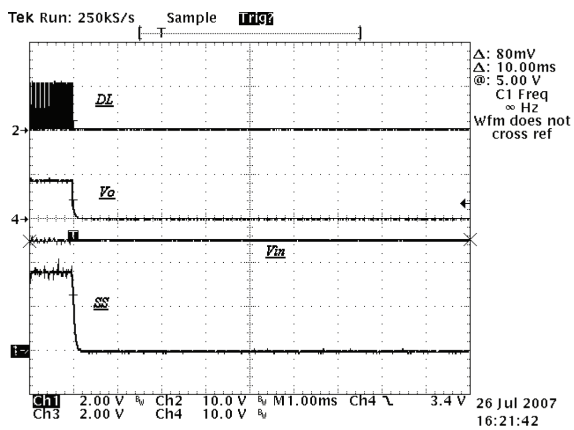


Figure 4. SiP11205 Startup Waveforms



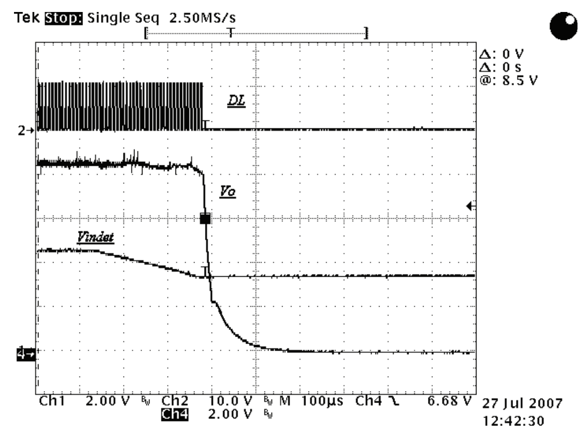


Figure 5. SiP11205 Shutdown Waveforms

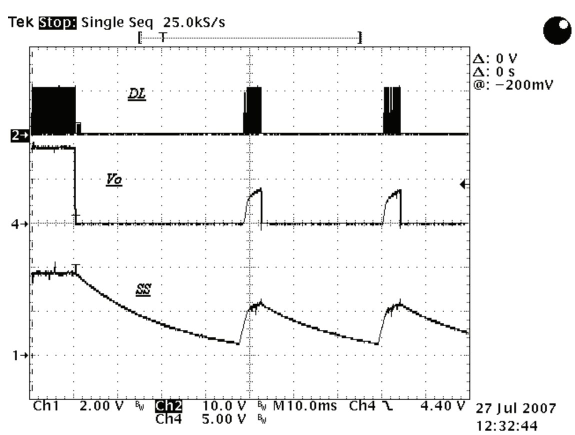


Figure 6. SiP11205 Hiccup Waveforms when Output is Shorted

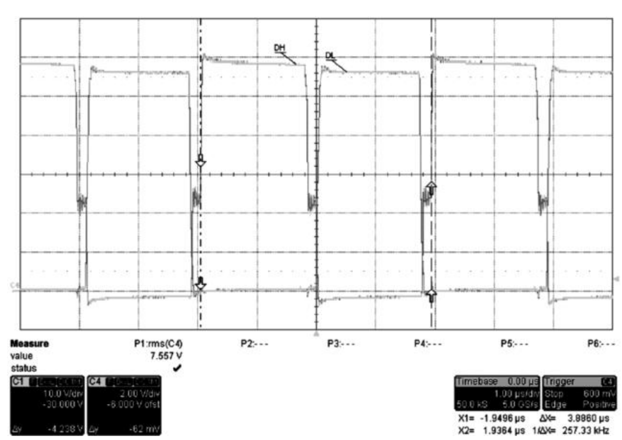


Figure 7. SiP11206 Switching Waveforms

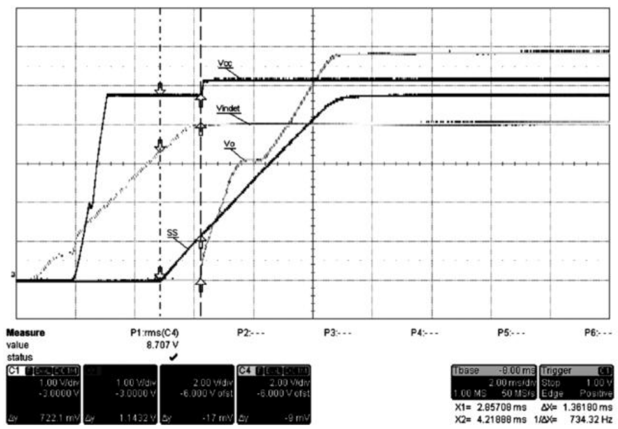


Figure 8. SiP11206 Startup Waveforms

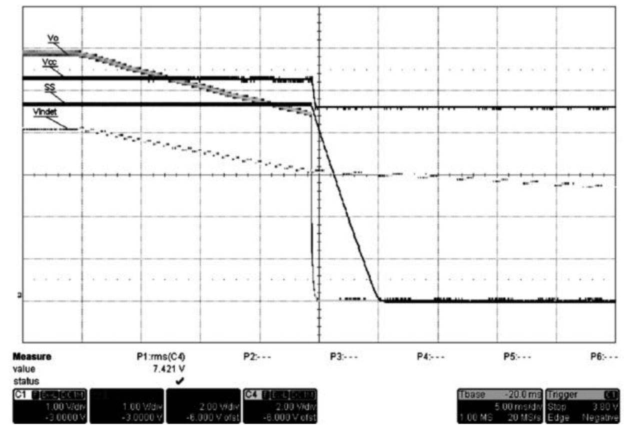


Figure 9. SiP11206 Shutdown Waveforms

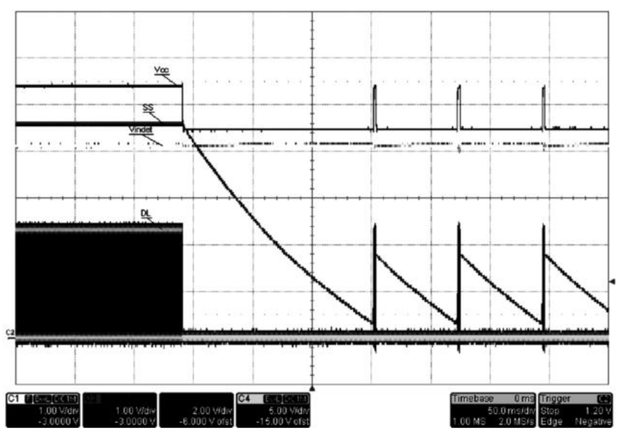


Figure 10. SiP11206 Hiccup Waveforms when Output is Shorted

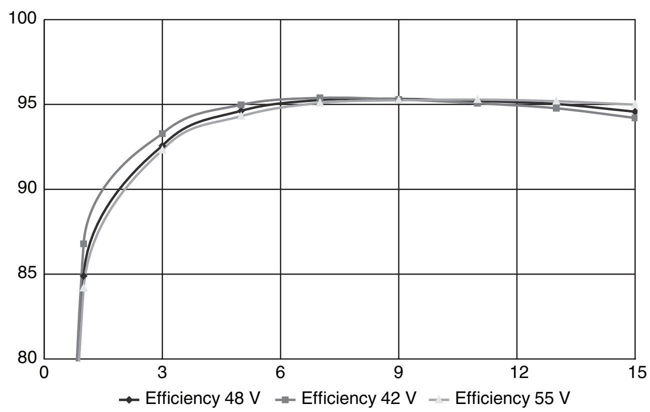
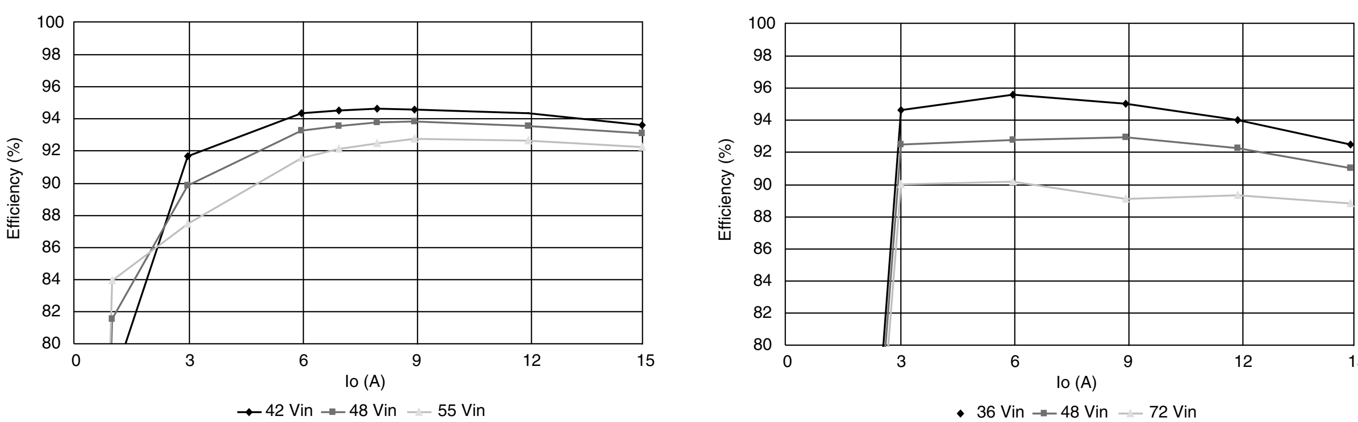


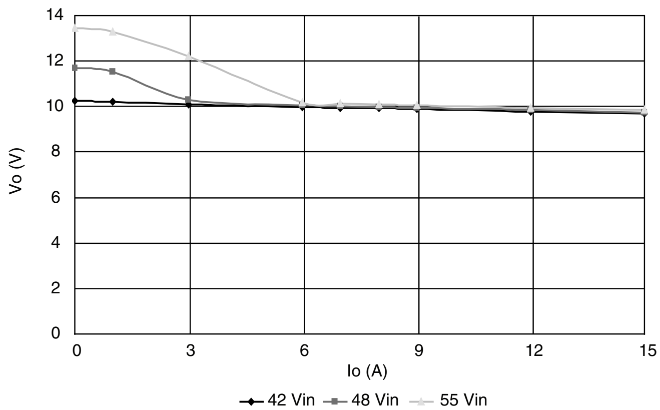
Figure 11. SiP11206 Efficiency at f_{SW} = 135 kHz



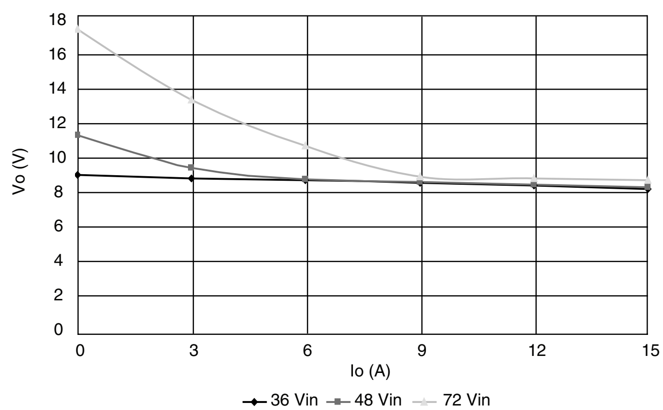
a) 42 to 55 V Input Range

b) 36 to 72 V Input Range

Figure 12. SiP11205 Efficiency



a) 42 to 55 V Input Range



b) 36 to 72 V Input Range

Figure 13. SiP11205 Line and Load Regulation at f_{SW} = 135 kHz

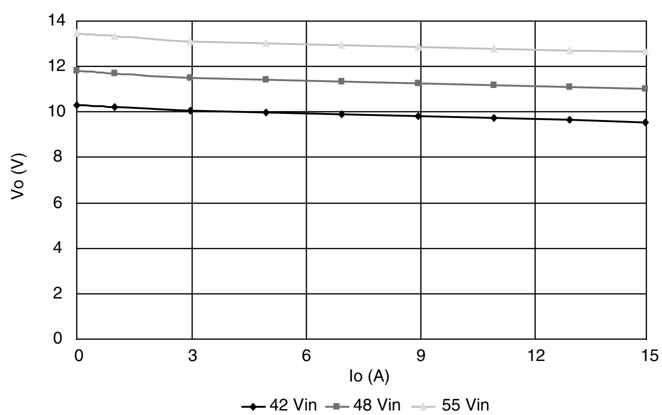


Figure 14. SiP11206 Line and Load Regulation at f_{SW} = 135 kHz

PCB LAYOUT

The demo board is an 8 layer board in the eighth-brick form factor, manufactured with 3 oz copper on the outer layers and 4 oz copper on the inner layers. The circuit schematics for the demo board are illustrated in Figure 17 to 19.

The transformer is a planar magnetic component with an E22/6/16 core. The primary winding has 4 turns, located on layers 2 and 7, with 2 turns per layer. Each secondary winding has 2 turns, located on layers 3, 4, 5, and 6, with 1 turn per layer. The auxiliary winding has 3 turns, consisting of 2 turns on the top layer and 1 turn on the bottom layer. The PCB layout plots are shown in Figure 14 to 16.

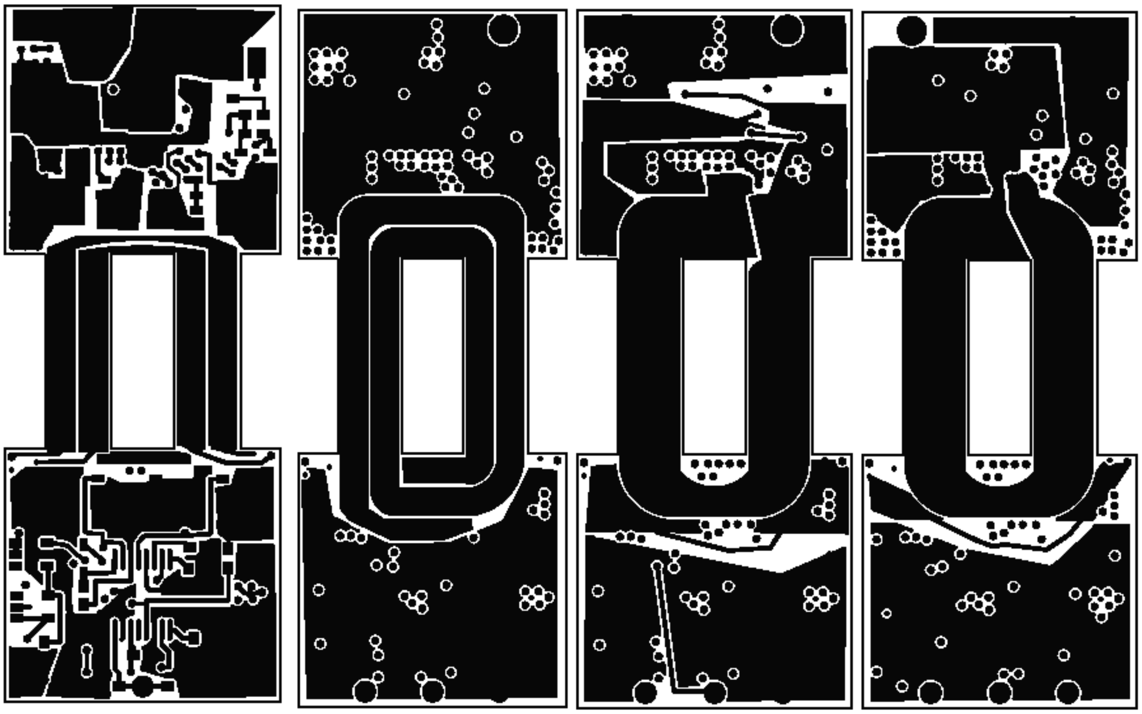


Figure 15. Layers 1 to 4 of PCB (l - r)

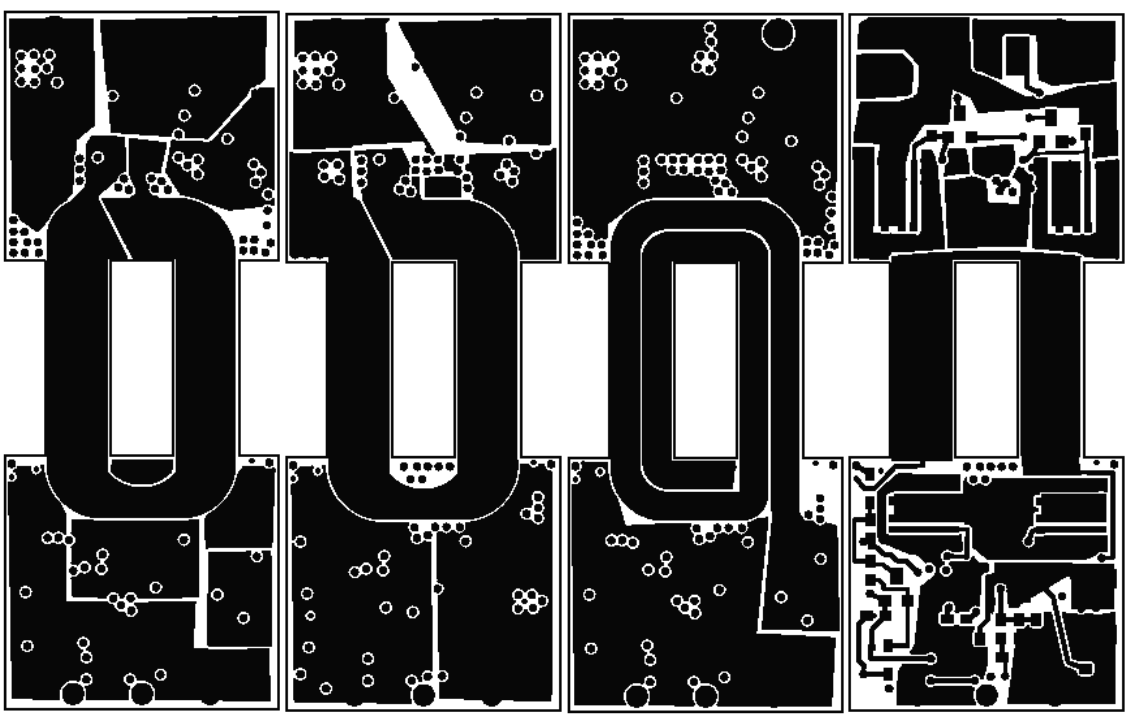


Figure 16. Layers 5 to 8 of PCB (l - r)

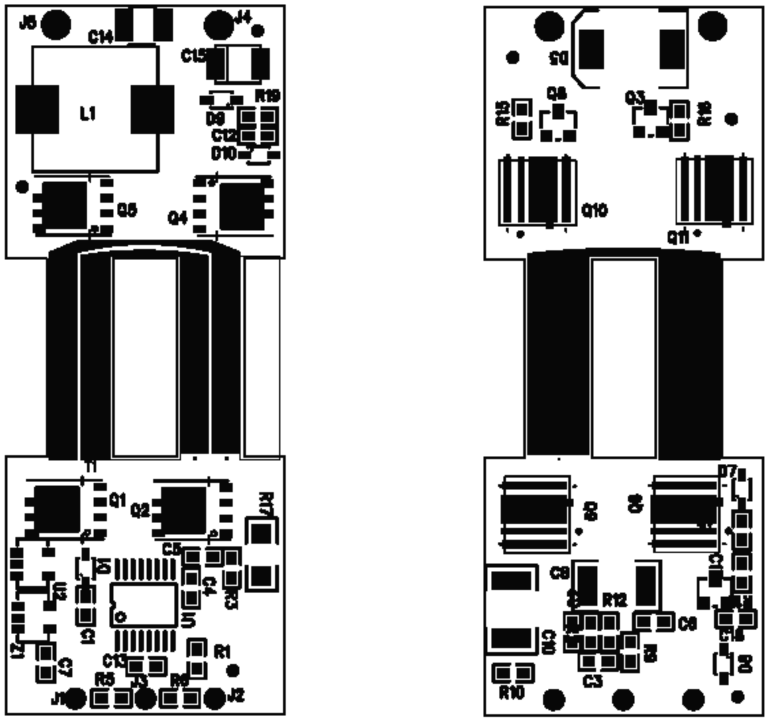


Figure 17. Top and Bottom PCB Component Placement (l - r)

The schematics are shown in Figure 18 to 20, and parts list are shown in table 1 and 2.

TABLE 1 - IBC PARTS LIST

Item	Ref.	Description	Part Number	Value	Footprint	Manufacturer
1	C1	Capacitor		100 nF, 50 V	0603	
2	C2	Capacitor		3.3 nF, 10 V	0603	
3	C3	Capacitor		1 µF, 25 V	0603	
4	C4	Capacitor		100 pF, 10 V (270 kHz)	0603	
				220 pF, 10 V (135 kHz)	0603	
5	C5	Capacitor		22 nF, 10 V	0603	
6	C6	Capacitor		220 pF, 10 V	0603	
7	C7	Capacitor		22 nF, 10 V	0603	
8	C8	Capacitor	C4532X7R1H475M	4.7 µF, 50 V	1812	TDK
9	C10	Capacitor		4.7 µF, 50 V	1812	TDK
10	C12	Capacitor	C4532X7R1H475M	100 nF, 50 V	0603	
11	C13	Capacitor		1 µF, 25 V	0603	
12	C14	Capacitor	GRM32ER61C226KE20L	22 µF, 16 V	1210	Murata
13	C15	Capacitor (Tantalum)	TAJB226K016R	22 µF, 16 V	Case B	AVX
14	C17	Capacitor		100 nF, 50 V	0603	
15	C18	Capacitor		1 µF, 25 V	0603	
16	D1	Small Signal switching diode	BAV19WS-V	0.2 A, 100 V	SOD323	Vishay
17	D5	SSC54 Schottky Diode		5 A, 40 V	SMC	Vishay
18	D7	Schottky Diode	BAS170WS	70 V, 70 mA	SOD323	Vishay
19	D8	Zener Diode	BZX384B11-V	11 V, 2 %	SOD323	Vishay

TABLE 1 - IBC PARTS LIST						
Item	Ref.	Description	Part Number	Value	Footprint	Manufacturer
20	D9	Schottky Diode	BAS170WS	70 V, 70 mA	SOD323	Vishay
21	D10	Zener Diode	BZX384B11-V	11 V, 2 %	SOD323	Vishay
22	J1	1.02 mm Pin	3102-3-00-xx-00-00-08-0			Mill-Max
23	J2	1.02 mm Pin	3102-3-00-xx-00-00-08-0			Mill-Max
24	J3	1.02 mm Pin	3102-3-00-xx-00-00-08-0			Mill-Max
25	J4	1.58 mm Pin	3144-3-00-xx-00-00-08-0			Mill-Max
26	J5	1.58 mm Pin	3144-3-00-xx-00-00-08-0			Mill-Max
27	L1	Inductor	IHLP4040DZ-01	1 µH (3.3 µH)[b]	4040	Vishay
28	Q1	Power MOSFET	Si7852DP[b]	80 V[b]	PowerPAK SO8	Vishay
			Si7138DP	60 V	PowerPAK SO8	Vishay
29	Q2	Power MOSFET	Si7852DP[b]	80 V[b]	PowerPAK SO8	Vishay
			Si7138DP	60 V[b]	PowerPAK SO8	Vishay
30	Q3	MOSFET	Si2308	60 V, 2 A	SOT23	Vishay
31	Q4	Synch MOSFET	Si7156DP	40 V	PowerPAK SO8	Vishay
			Si7138DP[b]	60 V[b]	PowerPAK SO8	Vishay
32	Q5	Synch MOSFET	Si7156DP	40 V	PowerPAK SO8	Vishay
			Si7138DP[b]	60 V[b]	PowerPAK SO8	Vishay
33	Q6	Power MOSFET	SiE818DF	75 V	PolarPAK	Vishay
34	Q7	Small signal npn BJT	ZXTN2031F	50 V, 3 A	SOT23	Zetex
35	Q8	MOSFET	Si2308	60 V, 2 A	SOT23	Vishay
36	Q9	Power MOSFET	SiE818DF	75 V	PolarPAK	Vishay
37	Q10	Synch MOSFET	SiE812DF	40 V	PolarPAK	Vishay
38	Q11	Synch MOSFET	SiE812DF	40 V	PolarPAK	Vishay
39	R1	Resistor		82k 1%	0603	
40	R2	Resistor		82k, (82k)[a], (80k6)[b], 1 %	0603	
41	R3	Resistor		220 R, 1 %	0603	
42	R5	Resistor		36k, (36k)[a], (33k)[b], 1 %	0603	
43	R6	Resistor		3k6, 1 %	0603	
44	R9	Resistor		100k, 1 %	0603	
45	R10	Resistor		100k, 1 %	0603	
46	R12	Resistor		NC (75k)[a], (82k)[b]	0603	
47	R15	Resistor		10k, 1 %	0603	
48	R16	Resistor		10k, 1 %	0603	
49	R17	Current Sense Resistor	WSLP1206R01000DEA	0R01	1206	Vishay
50	R18	Resistor		1k5, 1 %	0603	
51	R19	Resistor		1k5, 1 %	0603	
52	T1	Power Transformer		4:2:2 + 3 (Aux)	E22/6/16+I	
53	U1	IBC Control IC	SiP11205/11206		TSSOP-16	Vishay
54	U2	Temperature Sensor	LM26CIMM			
55	Z1	Micropower Voltage Reference	LM4120	3.3 V, 0.2 %	SOT23-5	National Semi

Notes:
a. Part values are for narrow input feed-forward version
b. Part values are for wide input feed-forward version

TABLE 2 - BASE BOARD PARTS LIST			
Item	**Designator**	**Part Number**	**Manufacturer**
1	C1	EEUED2C470	Panasonic
2	C2	EEUED2C470	Panasonic
3	C3	2238 911 15649	Phycomp
4	D1	BAS16	Philips
5	D2	BAS16	Philips
6	F1	3216FF5-R	Bussmann
7	J1	1727036	Phoenix Contact
8	J2	1727010	Phoenix Contact
9	J3	1727052	Phoenix Contact
10	J4	R112426000	Radiall
11	J5	H3183-05	Harwin
12	J6	H3183-05	Harwin
13	J7	H3183-05	Harwin
14	J8	0364-0-15-01-13-27-10-0	Mill-Max
15	J9	0364-0-15-01-13-27-10-0	Mill-Max
16	Q1	MMUN2213LT1G	ON Semi
17	R2	16K 1206	
18	R3	1K5 1206	
19	S1	ET01MD1ABE	C&K
20	TP1	20-313137	Vero
21	TP2	20-2137	Vero
22	TP3	20-313137	Vero
23	TP4	20-2137	Vero

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S-72177-Rev. A, 22-Oct-07

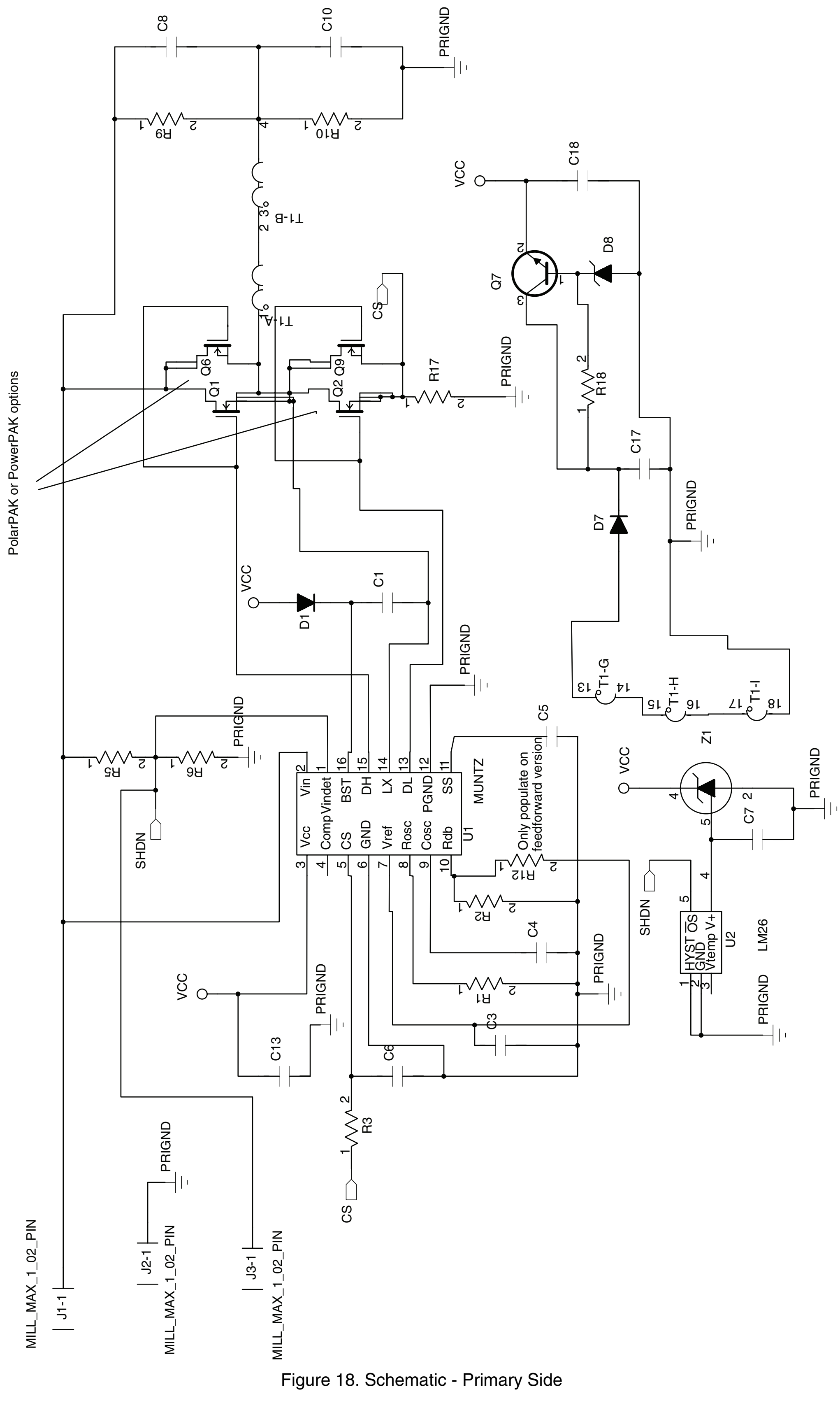

Figure 18. Schematic - Primary Side

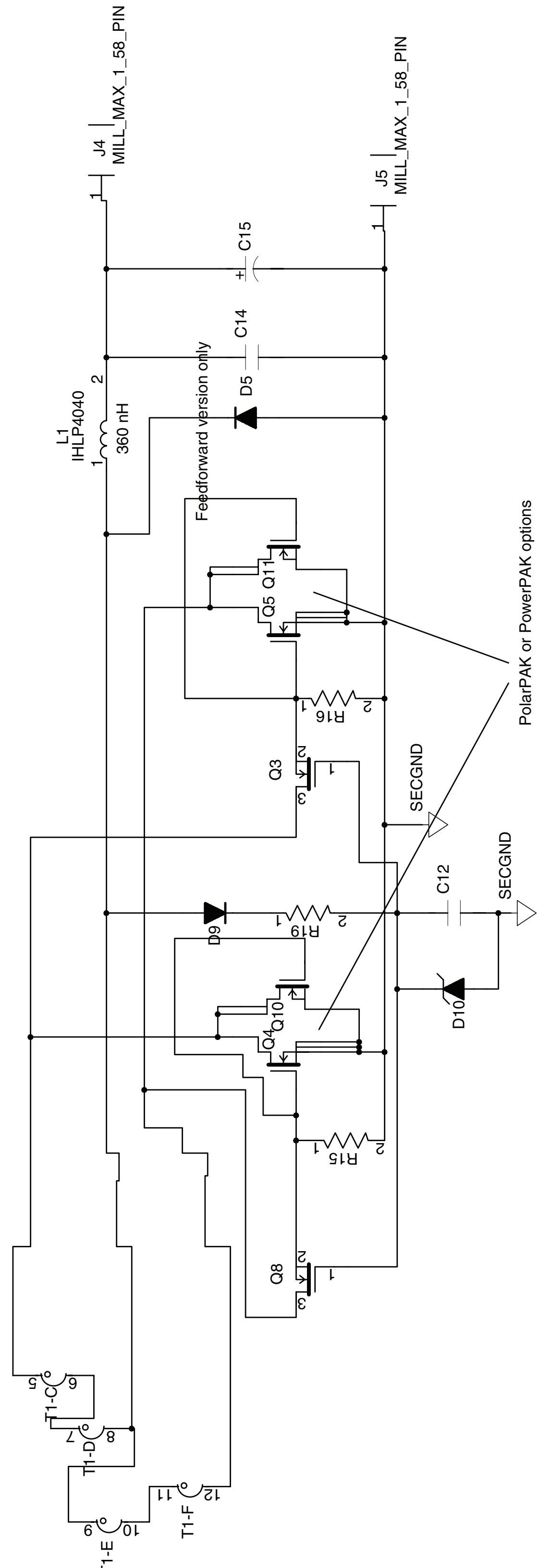

Figure 19. Schematic - Secondary Side

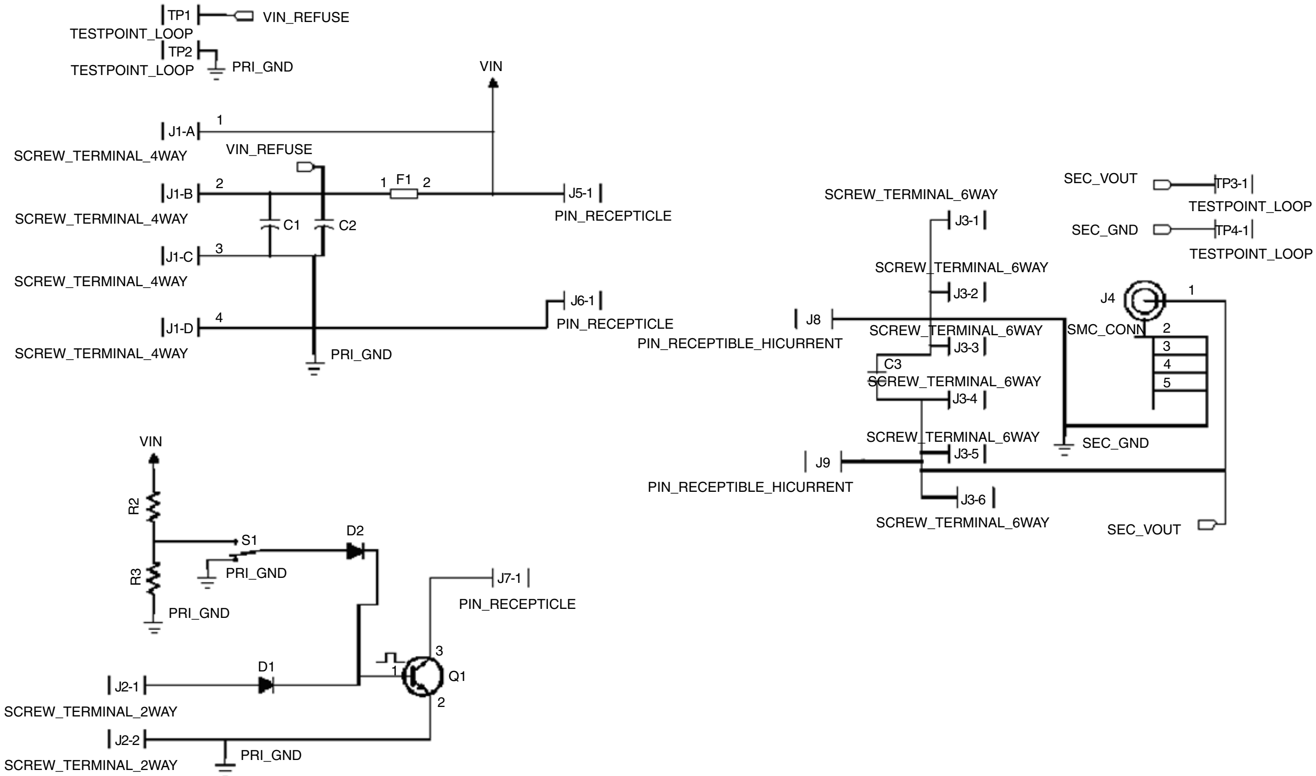

Figure 20. Schematic - Base Board

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