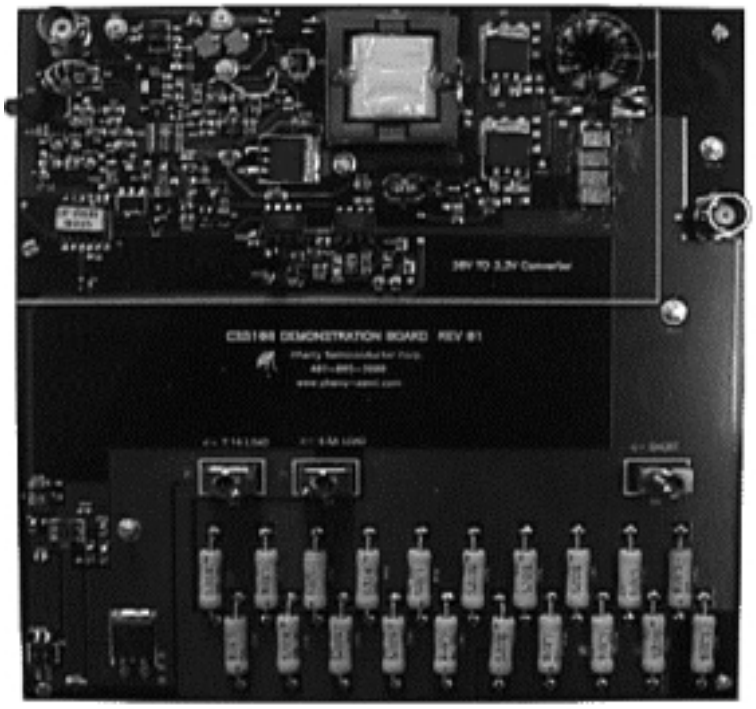
48V to 3.3V, 12A Converter With 12V, 75mA Auxiliary Output

a CS5106 Demonstration Manual



January, 2000 - Rev. 2
CS5106DM

ON Semiconductor

Description

The CS5106 Demonstration Board displays the integrated protection and performance-enhancing features of the CS5106 Controller. The demonstration board accomplishes bootstrapping, input under / overvoltage protection, two-level input over-current protection with hiccup mode, output undervoltage protection, master / slave syncing capability with frequency range protection using a minimal number of discrete components.

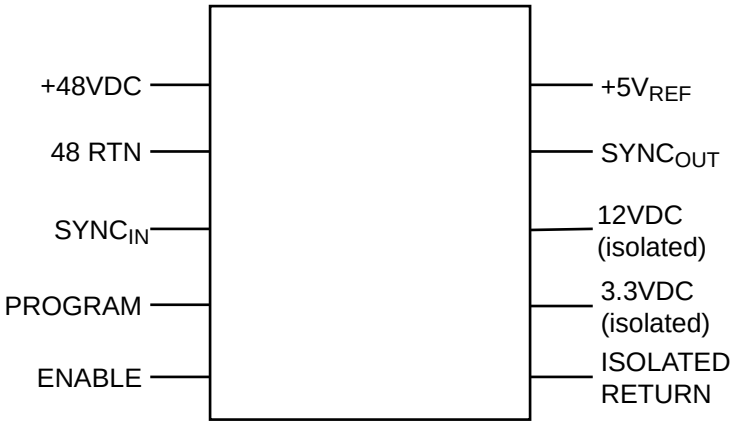
The circuit is a fixed frequency, high efficiency, isolated, fully protected, synchronous forward converter that converts 48VDC to 3.3VDC and 12VDC. High efficiency over a wide input voltage range is accomplished by bootstrapping the CS5106 Controller using the integrated 12V controller. The flyback transformer for the bootstrap supply also provides an isolated housekeeping supply. The main supply uses synchronous rectification to achieve high efficiency for the 3.3V output. The board can function as a master or slave in synchronized operation and is protected from incorrect SYNC frequencies. Short circuit, overload, under / overvoltage protection are all accomplished by integrated CS5106 circuitry.

The demo board contains circuitry to test the converter under various pulsed and continuous load conditions including a shorted output.

Features

- Up to 84 % Efficiency
- 36 to 72VDC Input Voltage Range
- Master / Slave Clock Syncing Capability
- Sync Frequency Range Detection
- Input Under and Overvoltage Shutdown
- Output Overcurrent Protection with Timer
- Controlled Hiccup Mode
- Programmable Enable Input
- 5V, 20mA Reference
- Isolated 3.3V, 12A Output
- Isolated 12V, 75mA Output
- Power-Good Indicator
- Integrated Pulsed / Continuous Load Circuit

Applications Diagram



Absolute Maximum Ratings

Absolute Maximum Ratings @ 25°C			
Input/Output Name	**Minimum**	**Maximum**	**Units**
+48VDC	–1	100	Volts
3.3 V Output Current (Derate at 0.12A / °C between 40 and 70°C.)	–	16	Amps
$SYNC_{IN}$	–0.3	6	Volts
PROGRAM	–0.3	16	Volts
ENABLE	–0.3	16	Volts
$SYNC_{OUT}$ (source)	–	50	mA
$SYNC_{OUT}$ (sink)	–	100	mA
Isolated Return	–500	+500	VDC

Electrical Characteristics

Performance Specifications @ 25°C					
Parameter	**Test Conditions**	**Minimum**	**Typical**	**Maximum**	**Units**
3.3V Output Voltage	$2A < I_{OUT} < 12A$	3.25	3.30	3.35	Volts
3.3V Load Reg.	$2A < I_{OUT} < 12A$ $36V < V_{IN} < 72V$		0.1	0.2	%
3.3V Line Reg.	$2A < I_{OUT} < 12A$ $36V < V_{IN} < 72V$		0.05	0.20	%
3.3V Transient Regulation & Recovery Time	Step between 50% and 75% di / dt < 2A / µs		120 200	200 400	mV µs
3.3V Ripple and Noise	$72V_{IN}$ @ Full Load (20MHz BW)		70	100	mV_{pk-pk} mV_{rms}
Overall Efficiency	12A Out 8A Out		81 83		% %
3.3V Power-up / S.S. Time	Full Load		10		ms
12V Output Voltage	$0 < I_{OUT} < 75mA$ $36 < V_{IN} < 72V$	11.0	12.2	13.5	Volts
12V Ripple and Noise	$72V_{IN}$, 75mA (20MHz BW)		150		mV
Undervoltage Lockout (Turn-off)			34	36	Volts
Undervoltage Lockout (Turn-on)			33	35	Volts
Overvoltage Lockout		75	78		Volts
Output Undervoltage Response Time to Short Circuit			50		ms
3.3V Over Current Shutdown Threshold			16		A
Oscillator Frequency			245		kHz
SYNC Input Range	(Referenced to free running frequency)	0.9		1.1	

Operating Instructions

Input Power and Grounding Requirements

The demo board is designed to operate with an input voltage between 36VDC and 72VDC. It will operate at higher or lower voltages, but will shutdown when the over or under-voltage thresholds are exceeded. Approximately 1.5A of input current is required at full load with a 36V input.

There are two ground connections for the demo board: one labeled “36V RETURN” and one labeled “ISOLATED RTN”. Normally both returns should be separately connected to Earth Ground.

PROGRAM and ENABLE Inputs

The PROGRAM and ENABLE pins must be EXCLUSIVE-ORed to enable the power supply. Normally the PROGRAM pin, tied high or low, will determine the polarity of the ENABLE pin. S1-1 controls the ENABLE input. S1-2 controls the PROGRAM input. These inputs are high when their respective switches are open and low when the switches are closed. IF S1-1 is left open, the Enable pin can be driven from a pulse generator.

SYNC Input and Output

The switching frequency of several demo boards can be synchronized by connecting the $SYNC_{OUT}$ pin of one board to the $SYNC_{IN}$ pins of the boards to be synchronized. For more detail about synchronization refer to the CS5106 Data Sheet.

Resetting Fault Conditions

If a fault condition in either output causes the output under-voltage delay timer to trip, the power supply must be reset by toggling the PROGRAM or ENABLE pins, or by cycling the power supply. See the CS5106 Data Sheet for more detail about fault conditions and restart.

Operating the Load Circuit

CAUTION: If the ISOLATED RTN is referenced to a potential other than Earth Ground, SW3-5 will also be raised to that potential. Caution: The LOAD RESISTOR temperature may reach 180°C during full load operation.

The load circuit for the main output provides a minimum load of 2A and a maximum load of 12.4A (It should be noted that these values slightly exceed the minimum and maximum rated load conditions.) S2 and S3 switch the load resistors between the ISOLATED RTN and the pulse circuit. If the pulsing circuit is off, the total load is the sum of the 2A minimum load plus the additional loads switched by S2 and S3. When the pulse circuit is on, the load is switched between 12.4A and the value selected by S2 and S3. The table below lists the available load conditions.

Load Circuit Switch Positions			
S2 Pulser	**S3**	**S4**	**Nominal Load**
X	Left / Gnd	Left / Gnd	12.4A, 100% Duty Cycle
Off / Open	Right / Pulse	Left / Gnd	5.9A, 100% Duty Cycle
Off / Open	Left / Gnd	Right / Pulse	8.5A, 100% Duty Cycle
Off / Open	Right / Pulse	Right / Pulse	2A, 100% Duty Cycle
On / Gnd	Right / Pulse	Left / Gnd	5.9A / 12.4A 50% Duty Cycle
On / Gnd	Left / Gnd	Right / Pulse	8.5A / 12.4A 50% Duty Cycle
On / Gnd	Right / Pulse	Right / Pulse	2A / 12.4A 50% Duty Cycle

Theory of Operation

Circuit Description

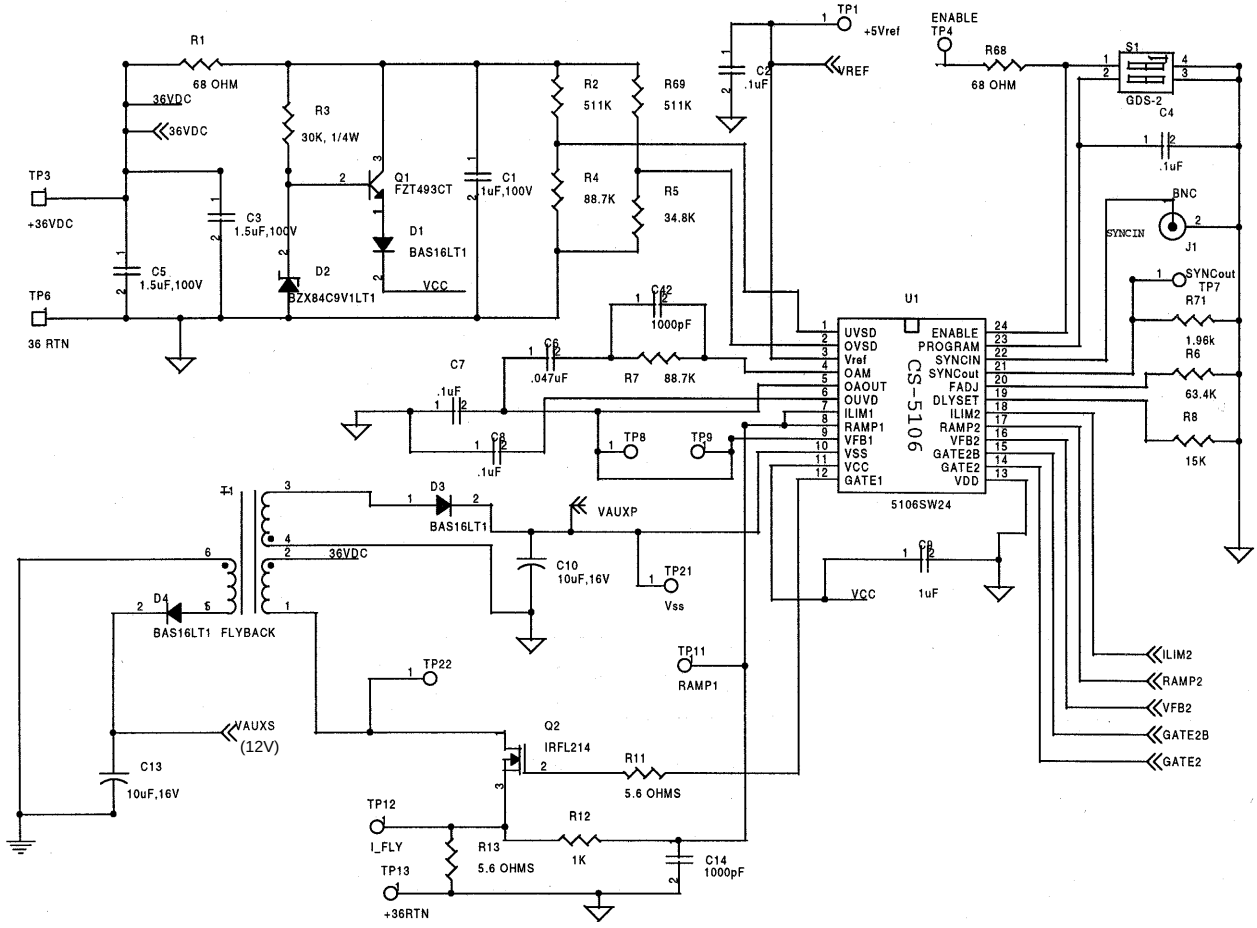
Bootstrapping & Control

When power is initially applied to the circuit, V_{CC} is regulated at about 8V by Q1, the 5V reference turns on and when the UVLO pin exceeds 5V, Gate 1 begins driving the flyback circuit. V_{SS} begins to rise at the rate determined by Soft Start capacitor C7. When V_{SS} exceeds V_{CC} the controller is powered through D3 and sufficient voltage is available to power isolated housekeeping circuitry from the isolated flyback winding and D4.

C8 selects the delay time for the Output Undervoltage Delay Timer (OUVDELAY). The OUVDELAY Timer monitors the feedback from the bootstrap and main supplies. If the feedback for either control loop exceeds 4.1V (indicating a low output) for longer than the selected delay time, the timer will shut down both supplies. To restart V_{SS} must bleed down to less than 1.4V and the ENABLE / PROGRAM must be toggled or the power supply cycled.

R2 and R4 set the threshold for input undervoltage protection. R5 and R69 set the threshold for input overvoltage protection. R6 sets the oscillator frequency. R8 sets the non-overlap delay for the synchronous rectifiers of the main supply. S1 enables the controller. S1-1 enables the PWM sections of the controller. S1-2 chooses the logic level to enable the controller. S1-1 and S1-2 must be X-Ored to enable the controller.

Circuit Schematic – Bootstrapping & Control

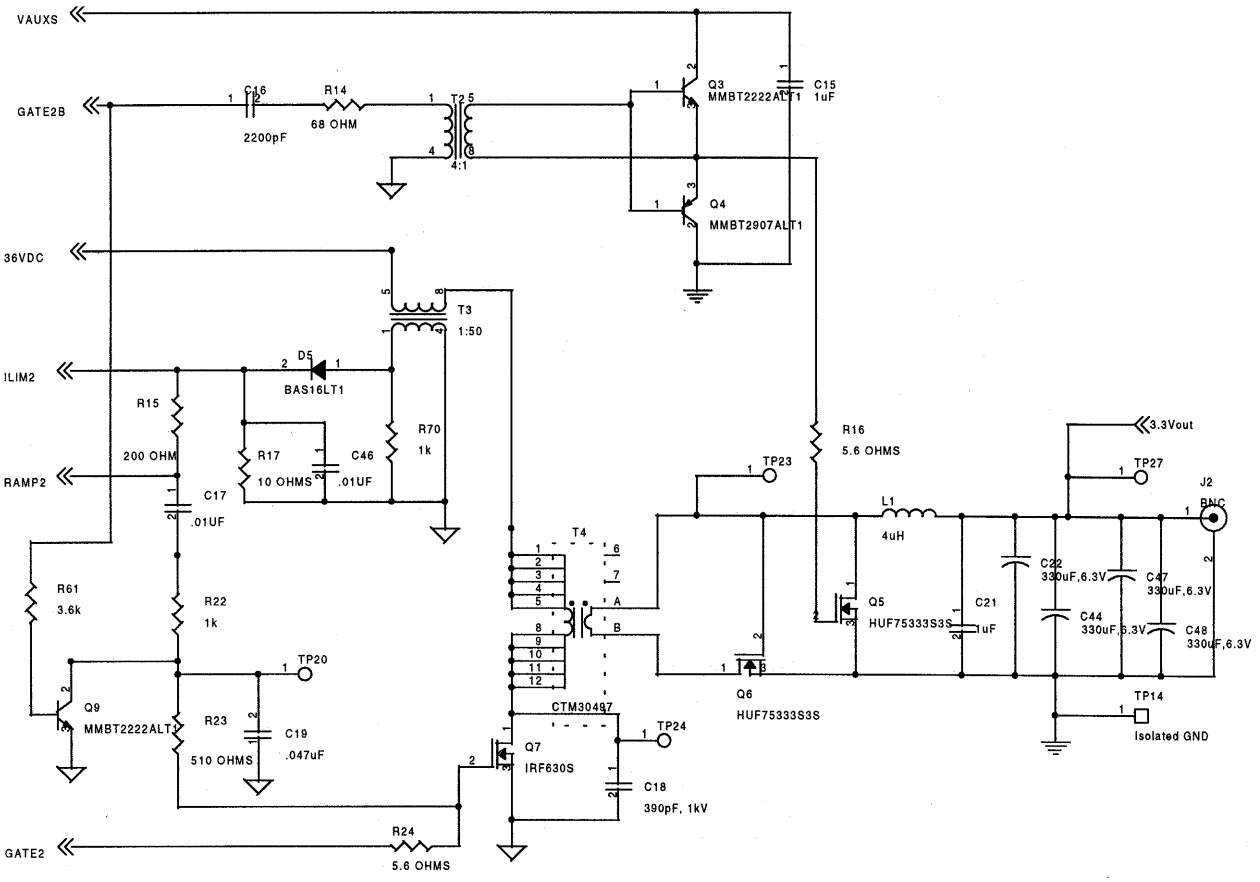


Main Power Stage and Slope Compensation

Power conversion for the main output is accomplished through main power switch Q7, forward transformer T4 and synchronous rectifiers Q5 & Q6. Q6 is driven directly by T4. Q5 is driven from GATE2B through isolation transformer T2 and buffered by Q3 & Q4.

Slope compensation is generated by the block of circuits in the lower left section of the schematic. C19 is charged through R23 when GATE2 goes high and discharged through Q9 when GATE2 goes low to form the slope compensation ramp. R15 and R22 determine the amount of ramp signal coupled to the RAMP2 pin. C17 provides AC coupling of the slope compensation.

Circuit Schematic – Main Power Stage



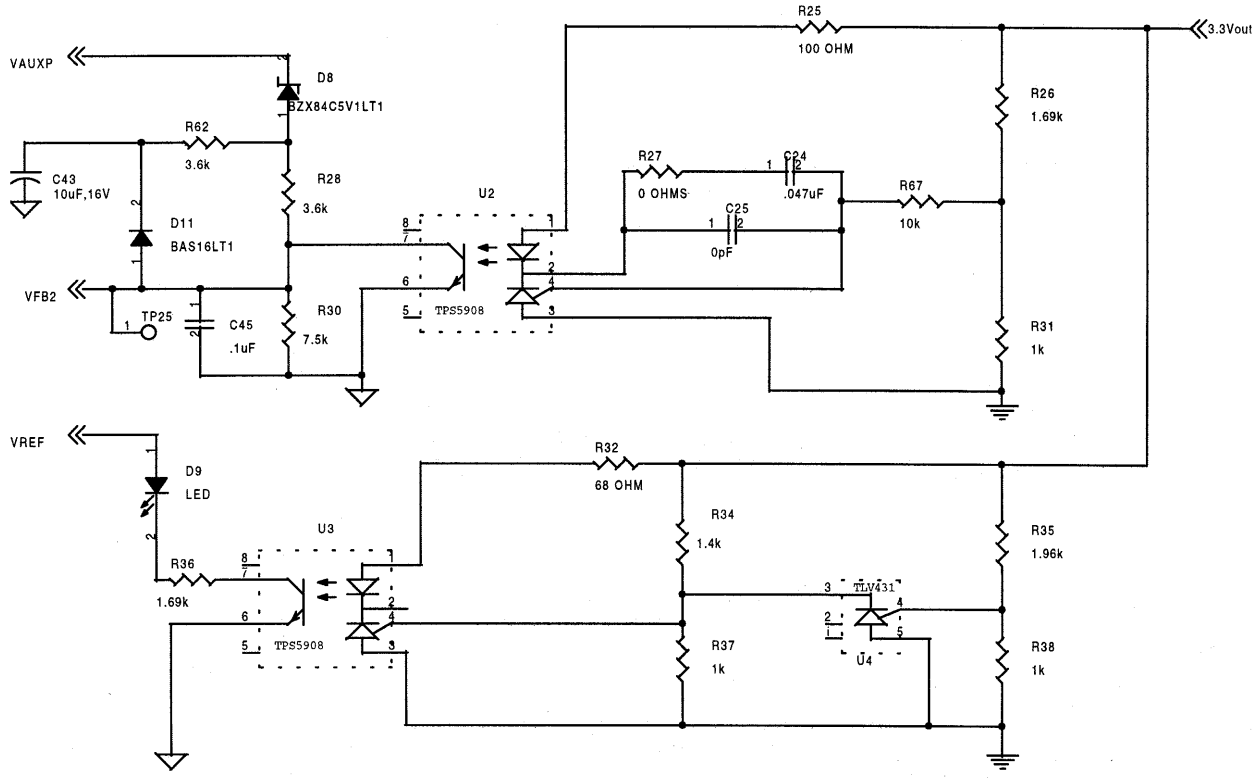
Feedback, Soft Start & Power-Good

The upper section of the circuit provides isolated feedback from the main output. R26 & R31 form a divider with an output of 1.24V when the main supply is at 3.3V. Components R67and C24 set the low frequency gain of optoisolator U2. R25 sets the high frequency gain and the maximum current through the photodiode. R28 and R30 set the maximum voltage across the phototransistor to about 4.6V and must have a high enough Thevenin resistance to prevent the photo-transistor of U2 from being saturated during light load. C45 compensates the high-frequency gain of the circuit.

R28, R62 and C43 determine the Soft Start time. After Soft Start is accomplished, C43 charges up to about 7V and is disconnected from the control loop by D11.

The lower section of the circuit provides the Power-Good function. D9 is on to indicate a good main output when it is within 10% of nominal. When the main output is less than 89% of nominal, the outputs of U3 and U4 do not sink current and D9 is off. When the main output is within 10% of nominal, the output of U3 draws current and D9 is on. When the output is more than 111% of nominal, U4 draws current and turns U3 and D9 off.

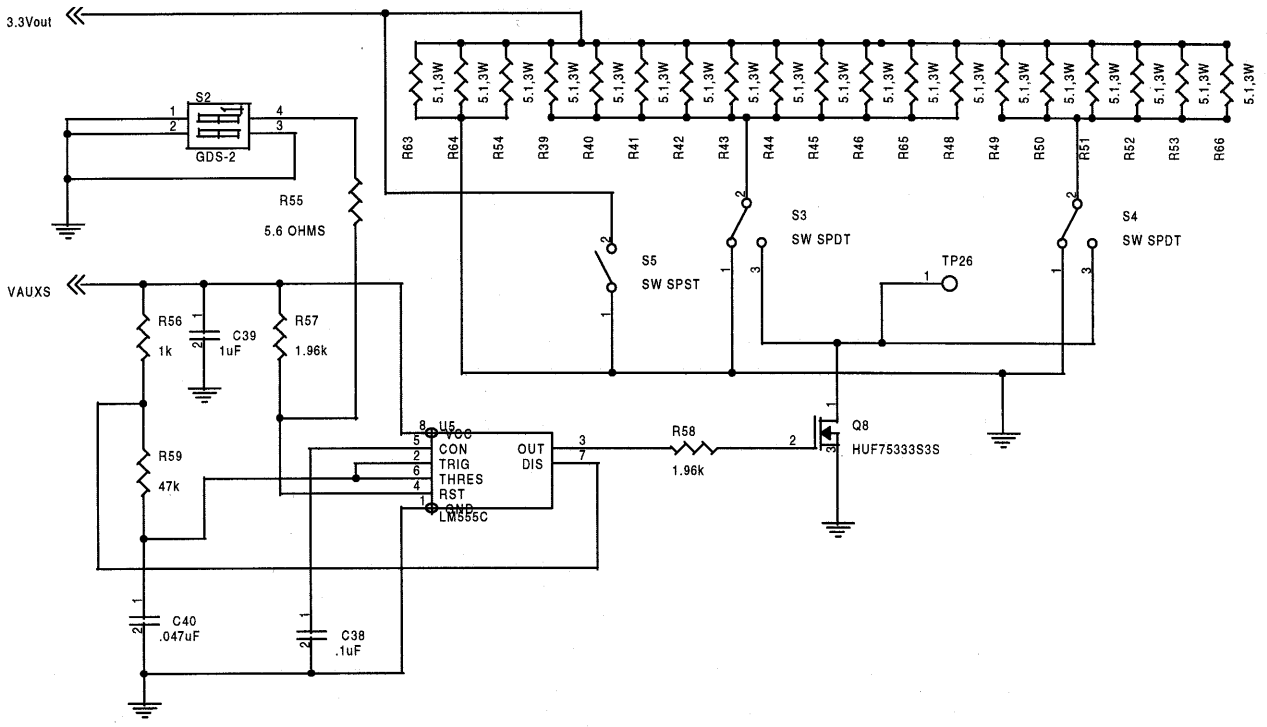
Circuit Schematic – Main Feedback & Power-Good



Load Circuit

The load circuit has provisions for various DC and pulsed loads (400kHz, 50% duty cycle) and short circuit testing. A minimum load of 2A is provided by R63, R54 and R64. S3 controls an additional 6.4A nominal load and S4 controls additional 3.8A load. S2 turns the 555 timer circuit on and off for pulsed loading. The loads provided by various switch combinations are listed in the Load Circuit Switch Positions table on page 4. S5 shorts the 3.3V output to isolated Gnd.

Load Circuit Schematic



Typical Performance Characteristics

The figures below show the typical performance of the CS5106 Demo Board. Input current waveforms were taken with a 5µH inductor in series with the source. All waveforms were taken with the 20MHz filter option selected on the oscilloscope. Input current and apparent converter efficiency may vary due to the 5% tolerance on the load resistors.

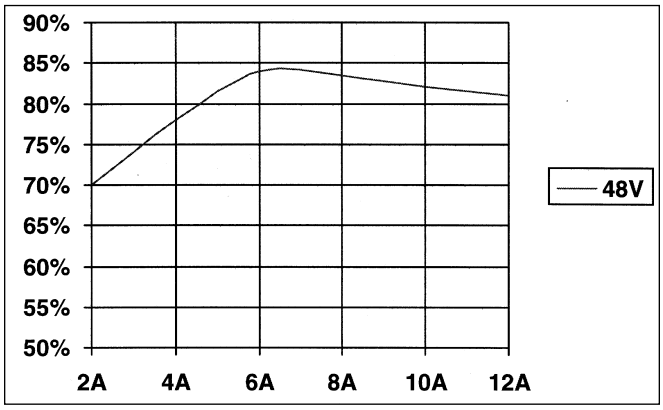


Figure 1: Typical Output Efficiency at 48 V_{IN}.

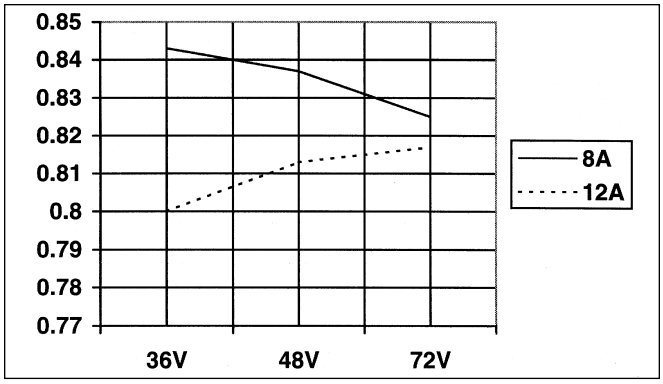


Figure 2: Typical Output Efficiency at 8A and 12A Out.

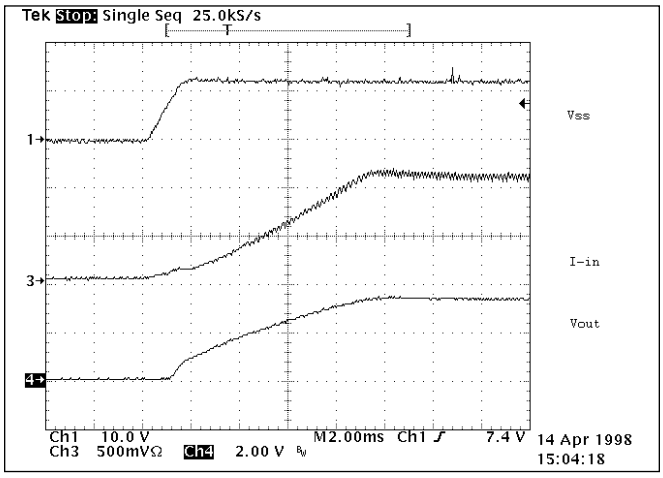


Figure 3: Startup Waveforms, V_{SS}, I_{IN} and V_{OUT}, 48V @ Full Load.

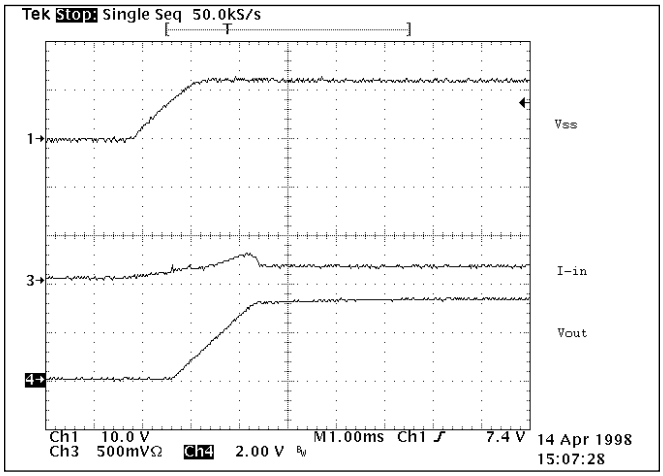


Figure 4: Startup Waveforms, V_{SS}, I_{IN} and V_{OUT}, 48V @ 1.3A Load.

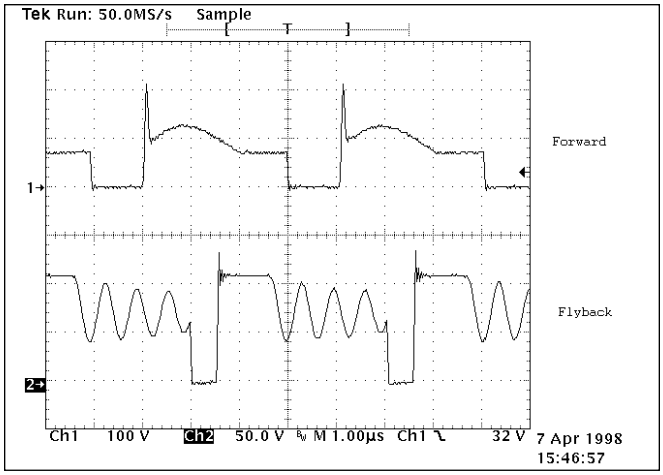


Figure 5: Forward and Flyback Primaries at 72V_{IN} and Full Load.

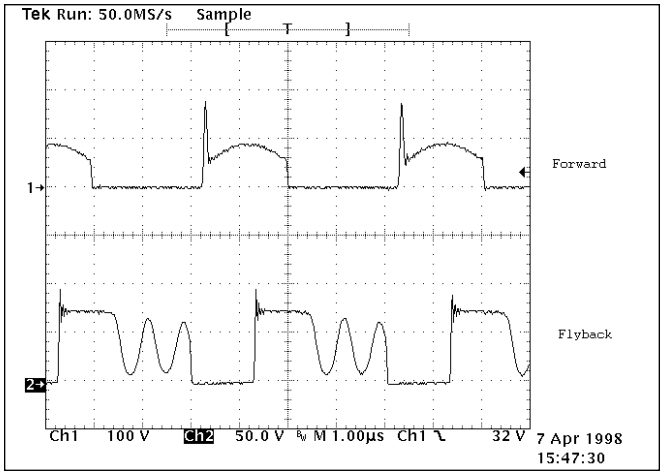


Figure 6: Forward and Flyback Primaries at 36V_{IN} and Full Load.

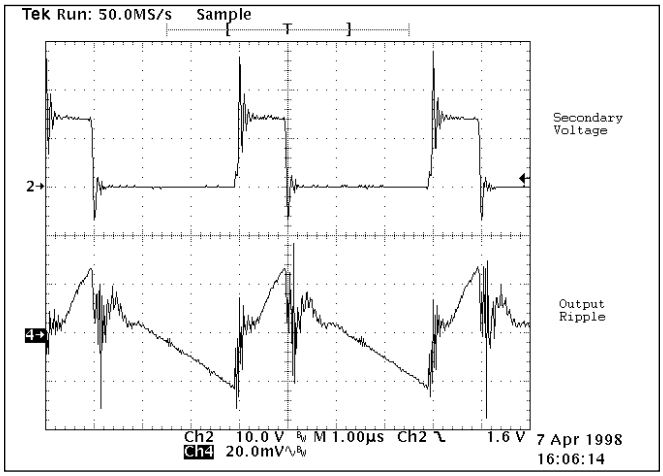


Figure 7: Secondary Voltage, Output Ripple, Full Load, 72V_{IN}.

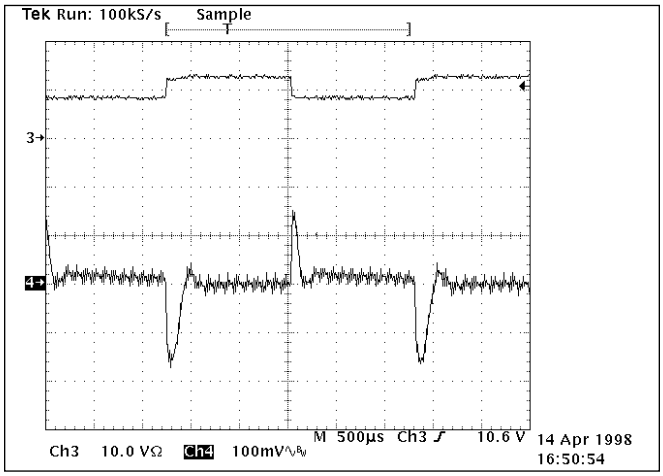


Figure 10: Transient Response 8.2A to 12.7A Step.

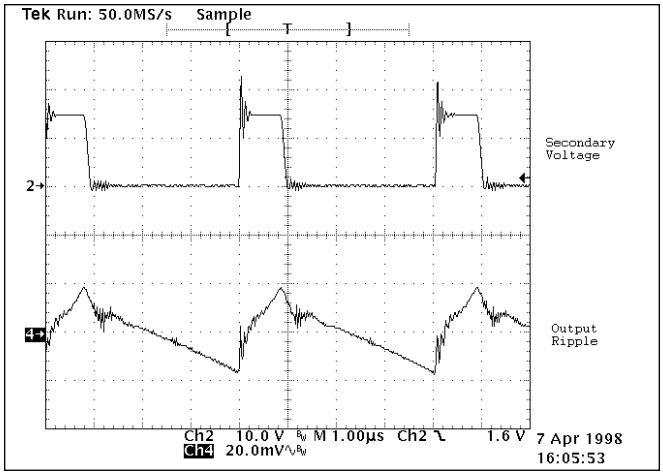


Figure 8: Secondary Voltage, Output Ripple, 1.2A Load, 72V_{IN}.

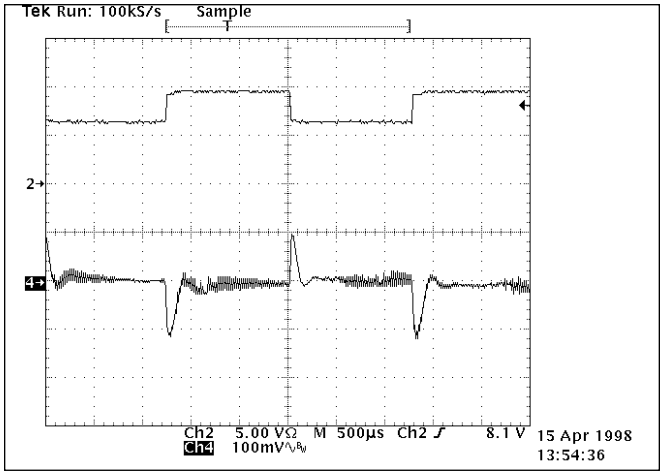


Figure 11: Transient Response 6A to 10A Step.

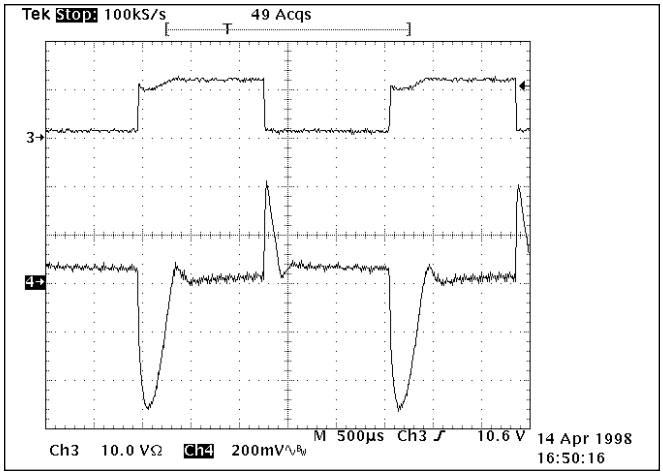


Figure 9: Transient Response 1.3A to 12.7A Step.

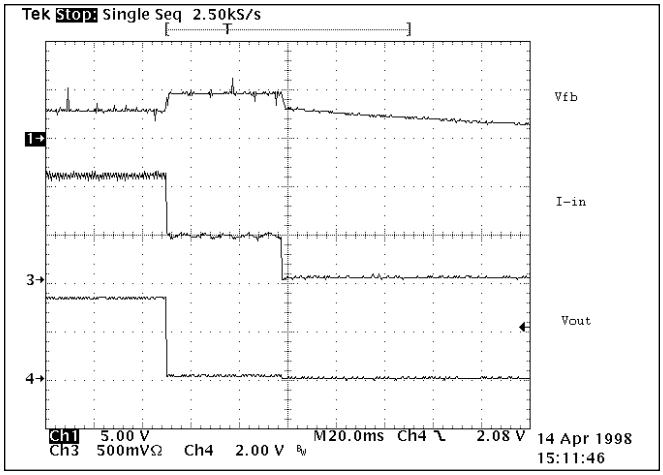


Figure 12: OUVDELAY Timer Response to Short Circuit.

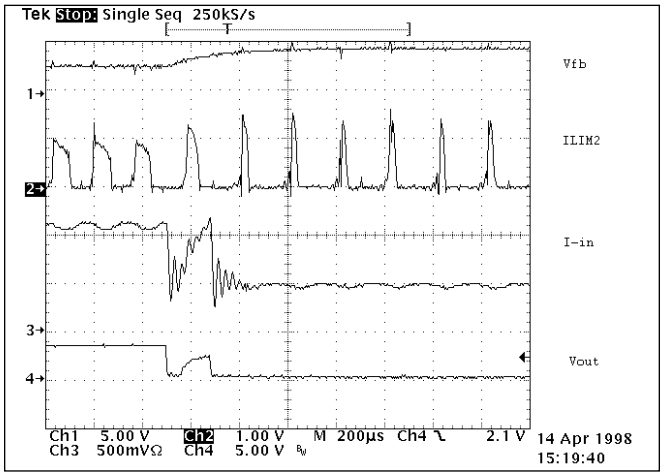


Figure 13: OUVDELAY Timer Response to Short Circuit.

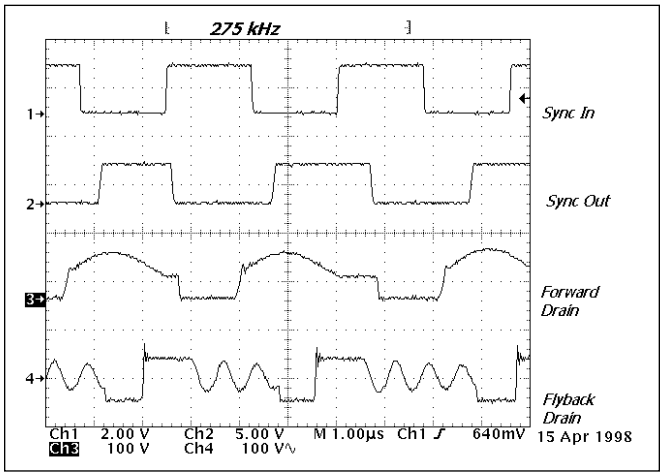


Figure 16: Synchronized Operation at 275kHz.

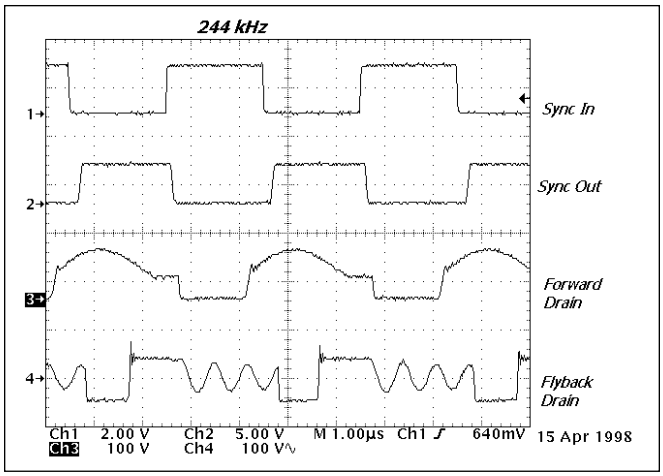


Figure 14: Synchronized Operation at 244kHz.

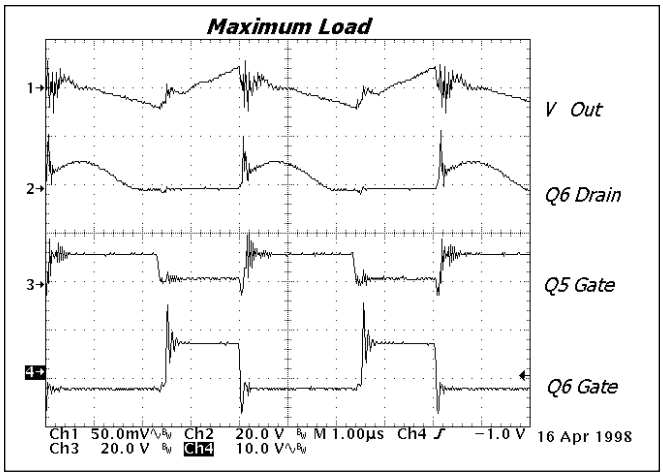


Figure 17: Synchronous Rectifiers – Max Load.

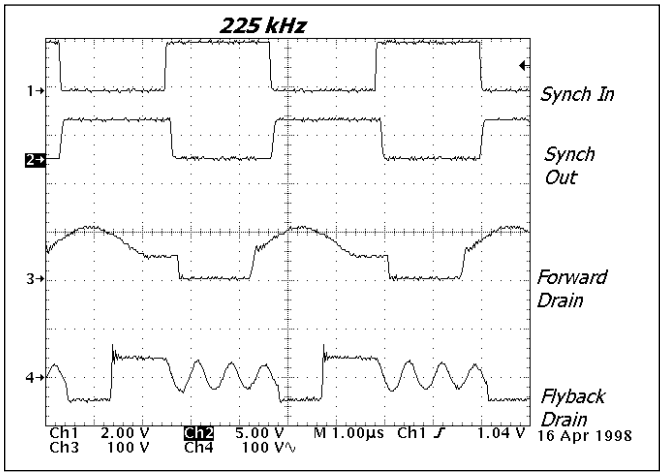


Figure 15: Synchronized Operation at 225kHz.

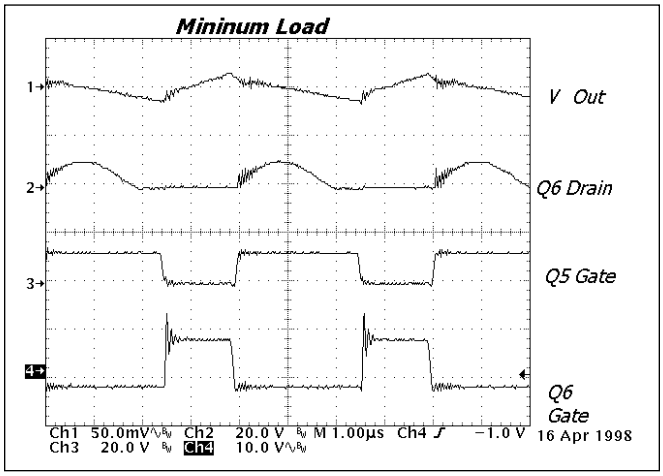


Figure 18: Synchronous Rectifiers – Min Load.

Bill of Materials

Power Supply Bill of Material					
Item	**Qty**	**Reference**	**Part**	**Mfg.& P/N**	**Distributor**
1	1	C1	cer, 0.1µF, 100V	Kemet C1206C104M5UAC	Newark 800-463-9275
2	5	C2,C4,C7,C8,C45	cer, 0.1µF, 50V	PANASONIC ECO-V1H104KBW	Digi-Key
3	2	C3,C5	cer, 1.5µF, 100V	TDK C5750XR72A155K	TDK 603-886-6600
4	3	C6,C19,C24	cer, .047µF, 50V	PANASONIC ECU-V1H473KBW	Digi-Key 800-344-4539
5	3	C9,C15,C21	cer, 1µF,25V	AVX-KYOCERA	Farnell 800-718-1997
6	3	C10,C13,C43	tant, 10µF,16V	PANASONIC ECS-H1CC106R	Digi-Key
7	2	C14,C42	cer, 1000pF, 50V	PANASONIC ECU-V1H102KBM	Digi-Key
8	1	C16	cer, 2200pF, 50V	PANASONIC ECU-V1H222KBM	Digi-Key
9	2	C17,C46	cer, .01µF, 25V	PANASONIC ECU-V1H103KBM	Digi-Key
10	1	C18	cer, 680pF, 1kV	PANASONIC ECKD3A681KBN	Digi-Key
11	4	C22,C44,C47,C48	330µF, 6.3V	AVX TPSE337M006R0100	Hamilton-Hallmark 800-354-1616
12	5	D1,D3,D4,D5,D11	diode	Motorola BAS16LT1	Newark
13	1	D2	zener, 9.1V	Motorola BZX84C9V1LT1	Newark
14	1	D8	zener, 5.1V	Motorola BZX84C5V1LT1	Newark
15	1	L1	4µH	Micrometals T68-52A with 8 turns of #16 bifilar wire	E. Comp 781-271-9953
16	1	Q1	NPN, 120V	Zetex FZT493CT	Digi-Key
17	1	Q2	MOSFET, 250V, .79A	I.R. IRFL214	Newark
18	2	Q3,Q9	NPN	Motorola MMBT2222ALT1	Newark 800-463-9275
19	1	Q4	PNP	Motorola MMBT2907ALT1	Newark 800-463-9275
20	2	Q5,Q6	MOSFET, 55V, 55A	Harris HUF75333S3S	Gerber 617-769-6000
21	1	Q7	MOSFET, 200V, 9A	I.R. IRF630S	Hamilton-Hallmark
22	2	R26,R36	1.69k, 1%, 0805	PANASONIC ERJ-6ENF1691	Digi-Key
23	1	R27	0Ω, 0805	PANASONIC ERJ-6GE0R00	Digi-Key
24	3	R28,R61,R62	3.6k, 5%, 0805	PANASONIC ERJ-6GEYJ362	Digi-Key

Bill of Materials continued

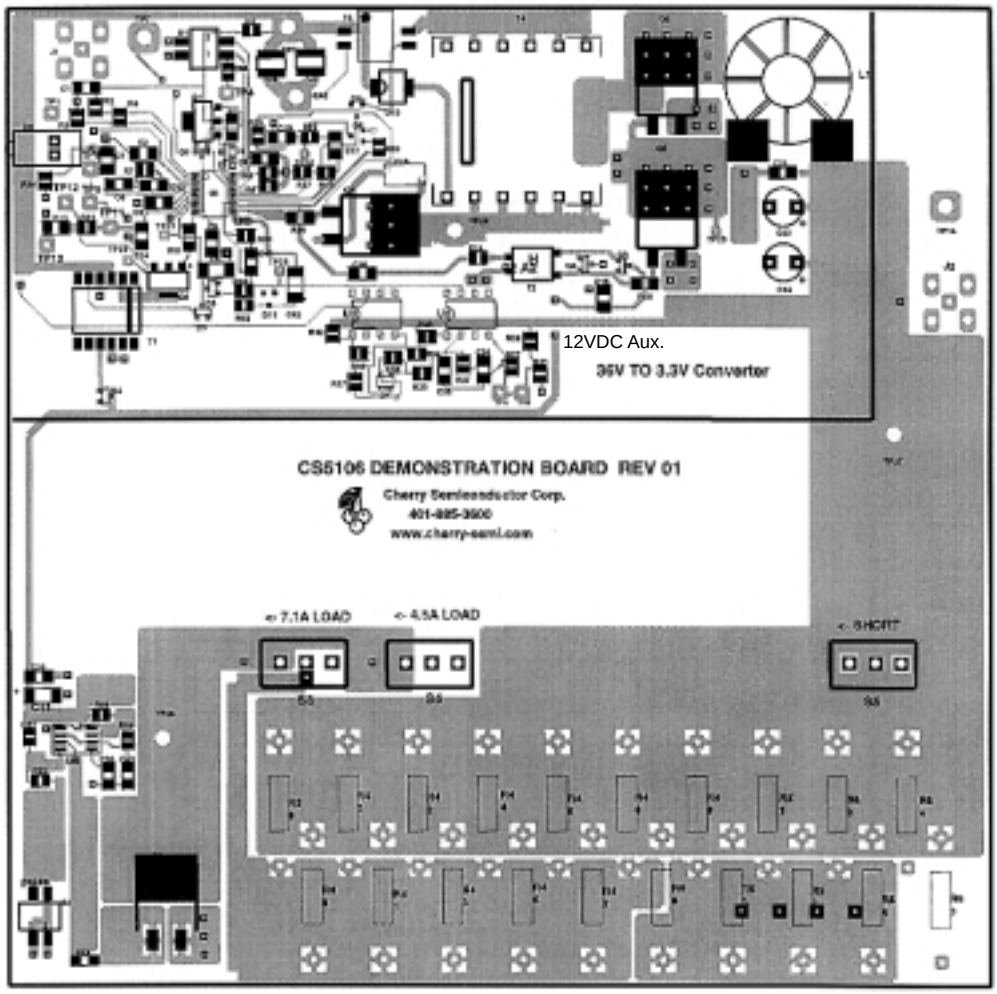
Power Supply Bill of Material					
Item	**Qty**	**Reference**	**Part**	**Mfg.& P/N**	**Distributor**
25	1	R30	7.5k, 5%, 0805	PANASONIC ERJ-6GEYJ752	Digi-Key
26	1	R34	1.4k, 1%, 0805	PANASONIC ERJ-6ENF1401	Digi-Key
27	2	R35,R71	1.96k, 1%, 0805	PANASONIC ERJ-6ENF1961	Digi-Key
28	1	R23	511Ω,1%, 0805	PANASONIC ERJ-6ENF5110	Digi-Key
29	2	R2,R69	511k, 1%, 0805	PANASONIC ERJ-6ENF5113	Digi-Key
30	4	R1,R14,R32,R68	68Ω,5%, 0805	PANASONIC ERJ-6GEYJ680	Digi-Key
31	1	R15	200Ω, 5%, 0805	PANASONIC ERJ-6GEYJ201	Digi-Key
32	4	R11,R13,R16,R24	5.6Ω,5%, 1206	PANASONIC ERJ-8GEYJ5R6	Digi-Key
33	1	R25	100 ,5%, 0805	PANASONIC ERJ-6GEYJ101	Digi-Key
34	6	R12,R22,R31, R37,R38,R70	1k, 1%, 0805	PANASONIC ERJ-6ENF1001	Digi-Key
35	1	R3	30k, 5%, 1206, .25W	Philips 9C12063A-JL	Allied 80-433-5700
36	2	R4,R7	88.7k, 1%, 0805	PANASONIC ERJ-6ENF8872	Digi-Key
37	1	R5	34.8k, 1%, 0805	PANASONIC ERJ-6ENF3482y	Digi-Key
38	1	R6	63.4k, 1%, 0805	PANASONIC ERJ-6ENF6342	Digi-Key
39	1	R17	18Ω, 5%, 0805	PANASONIC ERJ-6GEYJ180	Digi-Key
40	1	R67	10k, 5%, 0805	PANASONIC ERJ-6GEYJ103	Digi-Key
41	1	R8	20k, 5%, 0805	PANASONIC ERJ-6GEYJ203	Digi-Key
42	1	T1	Flyback Transformer	Coiltronics CTX15-14132	Coiltronics 561-241-7876
43	1	T2	Pulse Transformer	GB International 3738-G	GB International 607-785-0938
44	1	T3	Current Transformer	GB International 3554-G	GB International 607-785-0938
45	1	T4	Forward Transformer	CTM Magnetics CTM30497	CTM Magnetics 602-967-9447
46	1	U1		ON Semiconductor CS5106SW24	ON Semiconductor 401-885-3600
47	2	U2,U3	Opto-isolator	T.I. TPS5908	WYLE 781-271-9953
49	1	U4	Regulator	T.I. TLV431	WYLE 781-271-9953

Bill of Materials continued

Load & Test Circuit Bill of Material					
Item	**Qty**	**Reference**	**Part**	**Mfg.& P/N**	**Distributor**
1	1	C38	cer, 0.1µF, 50V	PANASONIC ECU-V1H104KBW	Digi-Key 800-344-4539
2	1	C40	cer, .047µF, 50V	PANASONIC ECU-V1H473KBW	Digi-Key
3	1	C39	cer, 1µF,25V	AVX-KYOCERA 800-718-1997	Farnell
4	1	D9	LED	Lumex SSF-LXH100RD	Digi-Key
5	2	J1,J2	BNC, PCB Socket	Multicomp	Farnell
6	1	Q8	MOSFET, 55V, 55A	Harris HUF75333S3S	Gerber 617-769-6000
7	1	R55	5.6Ω, 5%, 1206	PANASONIC ERJ-8GEYJ5R6	Digi-Key
8	1	R56	1k, 1%, 0805	PANASONIC ERJ-6ENF1001	Digi-Key
9	1	R57	1.96k, 1%, 0805	PANASONIC ERJ-6ENF1961	Digi-Key
10	1	R59	47k, 5%, 0805	PANASONIC ERJ-6GEYJ473	Digi-Key
11	19	R39,R40,R41,R42,R43 R44,R45,R46,R48,R49 R50,R51,R52,R53,R54 R63,R64,R65,R66	5.1Ω, 5%, 3W	Digi-key P5.1W-3TR-ND	Digi-key
12	2	S1,S2	SW, 2 Position	Augat GDS02	Newark
13	3	S3,S4,S5	SW SPDT	C&K CKN1004	Digi-Key
14	1	U5		National LM555C	Newark 800-463-9275

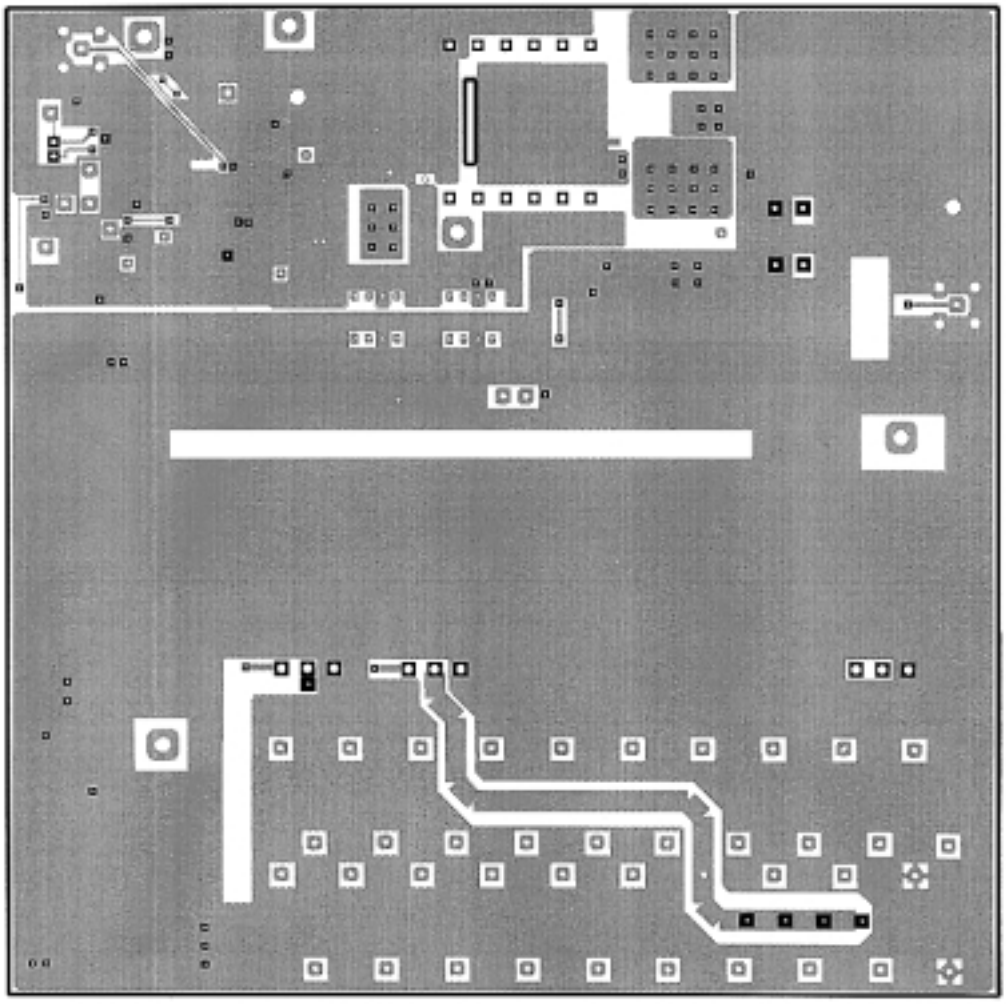
PCB Layout

Top Copper and Component Layer



PCB Layout

Bottom (Solder) Layer



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