DEMO MANUAL DC106

DESIGN-READY SWITCHERS

LTC1439/LTC1539
Constant-Frequency Synchronous 4-Output DC/DC Converter

DESCRIPTION

Demonstration circuit board DC106 provides a constant frequency, 4-output, low noise switching regulator. The outputs include: 5V/3A, 3.3V/3A, 12V/200mA and 2.9V/3A. Refer to the LTC®1438/LTC1439 and LTC1538-AUX/LTC1539 data sheets for other possible configurations. The 5V and 3.3V outputs are complete synchronous buck switching regulators. The 12V is derived from a secondary winding and is regulated irrespective of the load on the primary 5V output using a secondary feedback control input to the first controller. The 2.9V output is derived from the 3.3V output using an internal linear regulator controller. The transient response and peak current rating of 3A is consistent with Intel P54LM requirements. The controllers operate at a constant frequency of 200kHz, thereby providing low noise operation. This constant frequency prevents any unpredictable or audible radiation. The controller can operate at a 99% duty cycle for very low dropout conditions. Internal power-on reset and a second uncommitted comparator are included to facilitate a complete system power solution. The demonstration board operates on an input supply of from 5.2V to 28V, however, 12V output power is limited at low input voltages. **Gerber files for this circuit board are available. Call the LTC factory.**

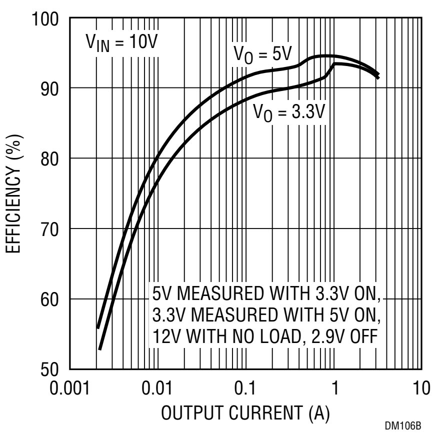
PERFORMANCE SUMMARY (continued on page 2) Operating Temperature Range 0°C to 50°C.

Input Voltage/Current Range	Input Voltage Limited by External MOSFET Drive and Breakdown Requirements	5.2V to 28V	8A Max
Output	Output Voltage, Controller 1 (J11-J12)	5V ± 0.1V	3A
	Output Voltage, Controller 2 (J7-J8)	3.3V ± 0.08V	3A
	Output Voltage, Auxiliary Regulator (J2-J5)	2.9V ± 0.10V	3A
	Output Voltage, Controller 1 Synchronous Secondary (J10-J9); V_{IN} > = 7V	12V ± 0.60V	0.2A

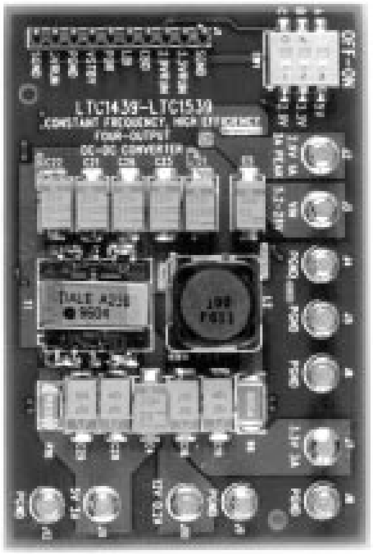
Specifications on this data sheet are preliminary only, and subject to change without notice.
Contact the manufacturer before finalizing a design using this part.

TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTOS

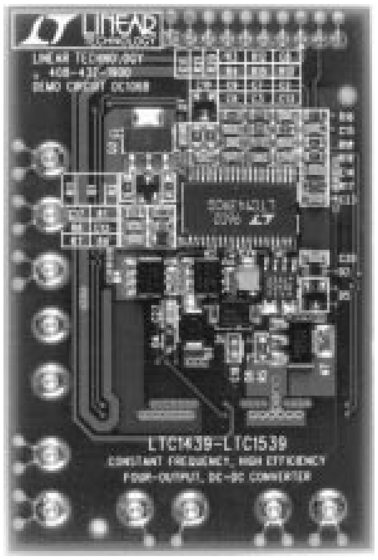
Efficiency vs Load Current



Front



Back



PERFORMANCE SUMMARY (continued from page 1) Operating Temperature Range 0°C to 50°C.

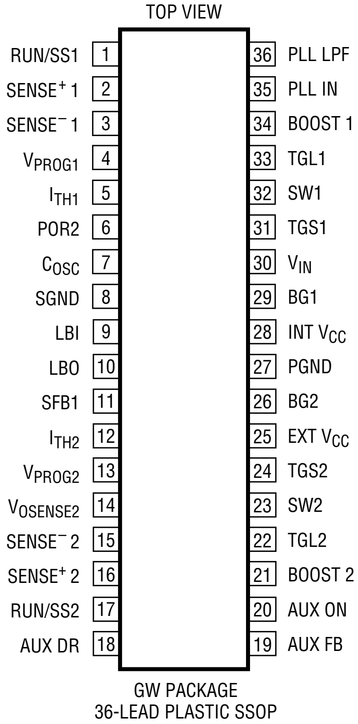
PARAMETER	CONDITIONS	OUTPUT 1	OUTPUT 2	OUTPUT 3	OUTPUT 4	UNITS
Output Voltage		5V ± 0.1	3.3V ± 0.08	12V ± 0.6	2.9V ± 0.05	V
Output Rated Current		3	3	0.2	3	A
Line Regulation	Measured at Rated Current	0.013	0.002	0.16	0.007	%/V
Load Regulation	10% to 100% of Rated Current	0.65	0.52	3.3	0.14	%
Short-Circuit Current		1.1	2.9	N/A	N/A	A
Ripple Voltage at Rated Current	Measured at Rated Current	40	40	100*	20	mV
Transient Response						
Load Step Settling Time	10% to 100% load	100	50	150	10	µs
	100% to 10% load	200	100	150	80	µs
Load Step Undershoot Transient	10% to 100% load	3.6	2.5	1.3	1.0	%
Load Step Overshoot Transient	100% to 10% load	4	4.2	1.2	2.7	%

General

PARAMETER	CONDITIONS	TYPICAL	UNITS
V_{IN} Range	All Outputs in Regulation	7 to 28	V
Supply Current in Shutdown	All Outputs Shut Down, V_{IN} = 15V (LTC1439) All Outputs Shut Down, V_{IN} = 15V (LTC1539)	16 70	µA µA
Supply Current	All Outputs On, V_{IN} = 15V All Outputs On, V_{IN} = 28V	450 280	µA µA
Operating Frequency		200	kHz

*5V output loaded with 1A

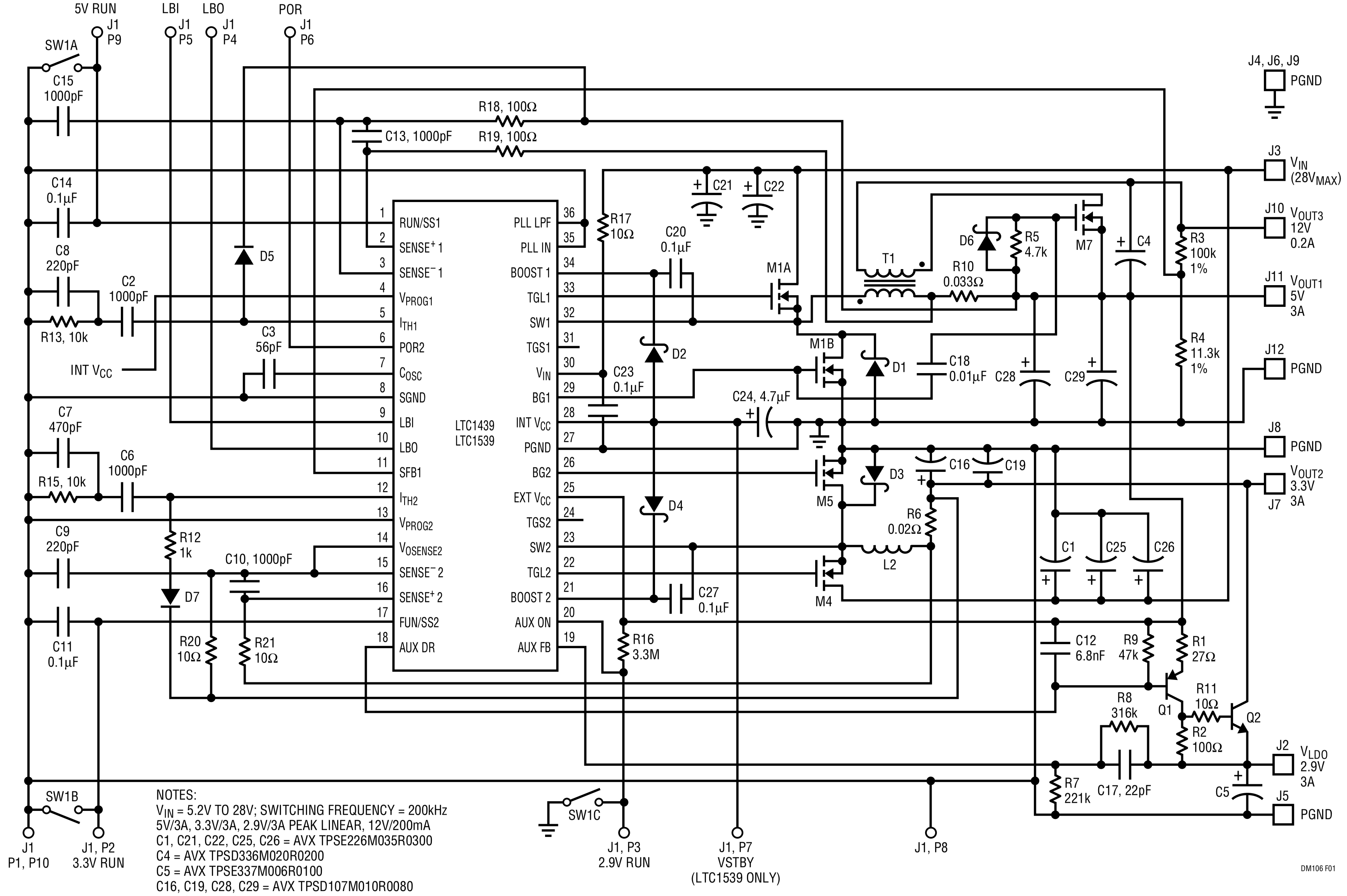
PACKAGE DIAGRAM



LTC1439CGW
LTC1539CGW

LTC1439/LTC1539 Pinout

SCHEMATIC DIAGRAM



NOTES:
V_{IN} = 5.2V TO 28V; SWITCHING FREQUENCY = 200kHz
5V/3A, 3.3V/3A, 2.9V/3A PEAK LINEAR, 12V/200mA
C1, C21, C22, C25, C26 = AVX TPSE226M035R0300
C4 = AVX TPSD336M020R0200
C5 = AVX TPSE337M006R0100
C16, C19, C28, C29 = AVX TPSD107M010R0080
L2 = SUMIDA CDRH127-100MC
M1 = SILICONIX Si4936; M4, M5 = SILICONIX Si4412DY
Q1 = 2N2907A; Q2 = ZETEX ZTX849
T1 = DALE LPE-6562-A236

Figure 1. Constant Frequency, 4-Output, Low Noise Switching Regulator

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR
C1, C21, C22, C25, C26	5	TPSE226M035R0300	22μF 35V 20% Tantalum Capacitor	AVX
C2, C6, C10, C13, C15	5	08055A102MAT1A	1000pF 50V 20% NPO Capacitor	AVX
C3	1	08055A560KAT1A	56pF 50V 10% NPO Capacitor	AVX
C4	1	TPSD336M020R0200	33μF 20V 20% Tantalum Capacitor	AVX
C5	1	TPSE337M006R0100	330μF 6.3V 20% Tantalum Capacitor	AVX
C7	1	08055A471KAT1A	470pF 50V 10% NPO Capacitor	AVX
C8, C9	2	08055A221KAT1A	220pF 50V 10% NPO Capacitor	AVX
C11, C14, C20, C23, C27	5	08055C104MAT1A	0.1μF 50V 20% X7R Capacitor	AVX
C12	1	08055C682MAT1A	6800pF 50V 20% X7R Capacitor	AVX
C16, C19, C28, C29	4	TPSD107M010R0080	100μF 10V 20% Tantalum Capacitor	AVX
C17	1	08055A220KAT1A	22pF 50V 10% NPO Capacitor	AVX
C18	1	08055C103MAT1A	0.01μF 50V 20% X7R Capacitor	AVX
C24	1	TAJB475M016R	4.7μF 16V 20% Tantalum Capacitor	AVX
D1, D3	2	MBRS140T3	40V 1A Schottky Diode	Motorola
D2, D4, D6	3	CMDSH-3TR	30V 0.1A Schottky Diode	Central
D5, D7	2	MMBD914LT1	100V General Diode	Motorola
L2	1	CDRH127-100MC	10μH 20% 7A Inductor	Sumida
M1	1	Si9436DY	Dual N-Channel MOSFET	Siliconix
M4, M5	2	Si4412DY	N-Channel MOSFET	Siliconix
M7	1	IRLL014TR	N-Channel MOSFET	IR
Q1	1	MMBT2907ALT1	2907A PNP Transistor	Motorola
Q2	1	FZT849TA	FZT849TA NPN Transistor	Zetex
R1	1	CR21-270J-T	27Ω 1/10W 5% Chip Resistor	AVX
R2, R18, R19	3	CR21-101J-T	100Ω 1/10W 5% Chip Resistor	AVX
R3	1	CR21-1003F-T	100k 1/10W 1% Chip Resistor	AVX
R4	1	CR21-1132F-T	11.3k 1/10W 1% Chip Resistor	AVX
R5	1	CR21-472J-T	4.7k 1/10W 5% Chip Resistor	AVX
R6	1	LR2512-01-R020-F	0.02Ω 1W 1% Chip Resistor	IRC
R7	1	CR21-2213F-T	221k 1/10W 1% Chip Resistor	AVX
R8	1	CR21-3163F-T	316k 1/10W 1% Chip Resistor	AVX
R9	1	CR21-473J-T	47k 1/10W 5% Chip Resistor	AVX
R10	1	LR2010-01-R033-F	0.033Ω 1/2W 1% Chip Resistor	IRC
R11, R17, R20, R21	4	CR21-100J-T	10Ω 1/10W 5% Chip Resistor	AVX
R12	1	CR21-102J-T	1k 1/10W 5% Chip Resistor	AVX
R13, R15	2	CR21-103J-T	10k 1/10W 5% Chip Resistor	AVX
R16	1	CR21-335J-T	3.3M 1/10W 5% Chip Resistor	AVX
T1	1	LPE-6562-A236; Gapped SMT E-Core	9.5μH 3.5A 1:1.42 Inductor	Dale
T1 (Alternate Supplier)		501-0655; Gapped SMT Toroid	9.5μH 3.5A 1:1.41 Inductor	BH Electronics
U1	1	LTC1439CGW/LTC1539CGW	LTC1439/LTC1539 36-Pin SSOP IC	LTC

MANUFACTURER TELEPHONE DIRECTORY

MANUFACTURER	USA	EUROPE	JAPAN	HONG KONG	SINGAPORE	TAIWAN
AVX	(207) 282-5111	(0252) 336868		3633303		
BH Electronics	(612) 894-9590					
Central	(516) 435-1110	49 8161 43963				822 268 9795
Dale	(605) 665-9301	49 9287 71434			65 747 2767	
IR	(310) 322-3331	44 8837 13215		(852) 803 7380		
IRC	(512) 992-7900					
Siliconix (TEMIC)	(408) 970-5700	49 07131 67-0		(852) 23-789-789		
LTC	(408) 432-1900					
Motorola	(602) 244-5768	49 8992 1030		(852) 480 8333		
Sprague	(207) 324-4140	33 4754 0575		(852) 797 9893	65 475 1826	886 277 19582
Sumida	(708) 956-0666		03-3607-5111	880 6688	296 33 88	02-726-2177-9
Zetex	(516) 543-7100	44 61 627 5105				

QUICK START GUIDE

This demonstration board is easily set up to evaluate the performance of the LTC1439 or LTC1539. Please follow the procedure outlined below for proper operation.

- Refer to Figure 2 below for board orientation and proper measurement equipment setup.
- Set the three DIP switches, (SW1A, B, and C) to the left position (switches closed).
- Connect the desired loads between the V_{OUT1}, V_{OUT2}, V_{OUT3}, V_{OUT4} and their closest PGND terminals on the board. The loads can be up to 3A for V_{OUT1}, V_{OUT2}, and V_{OUT4}; and 200mA for V_{OUT3}. Soldered wires should be used when the load current exceeds 1A in order to achieve proper testing results.
- Connect the input power supply to the V_{IN} and the adjacent PGND terminals at the top of the board. It is safest to start with a voltage less than 6V to verify all of the connections without inadvertently forcing too much voltage on one of the tantalum output capacitors. Once the output voltage and loading conditions have been verified, it will be safe to increase the input supply to the maximum allowed value of 28V. **Do NOT increase V_{IN} over 28V or the MOSFETs MAY BE DAMAGED.**
- Switch the desired output(s) on by moving SW1 A, B, or C to the right position (5V, 3.3V, and 2.9V respectively). The 12V output will be properly generated when the 5V output is turned on and when the input supply voltage is a minimum of 7V. The 2.9V output can only be produced when the 5V, 3.3V, *and* 2.9V output switches are turned on due to this particular demonstration board design.
- Measure V_{OUT1}, V_{OUT2} and V_{OUT4} to verify output voltages of 5V ± 0.1V, 3.3V ± 0.08V and 2.9V ± 0.05V respectively at load currents of 1A each.
- Verify the input supply voltage is at a minimum of 7V. Measure V_{OUT3} to verify the output voltage of 12V ± 0.6V over the allowed load current range of 0mA to 200mA.

OPERATION

The circuit shown in the Schematic Diagram generates 5V, 3.3V, 12V and 2.9V. It provides 5V at currents up to 3A. The 2.9V output is derived from the 3.3V output using a low dropout linear regulator using the on-chip auxiliary controller. The total current available at the 2.9V and 3.3V outputs combined is 6A with a maximum of 3A for the 2.9V output. The 12V output can deliver up to several hundred milliamps. Figure 2 illustrates the correct measurement setup in order to verify the typical numbers found in the Performance Summary table. The use of small spring-clip leads is very convenient for small-signal bench testing but should not be used at the current and impedance levels associated with this switching regulator. Soldered wire connections are required to properly evaluate the performance of this demonstration board.

In addition to the input and output pins, a 10-pin male connector, J1, allows the user to examine other functions included on the LTC1439/LTC1539 system demonstration board. Three pins, 5V RUN (J1-Pin 9), 3.3V RUN (J1-Pin 2) and 2.9V RUN (J1-Pin 3) operate in parallel with the manual switches on the board to allow electronic ON/OFF switching of the voltage outputs.

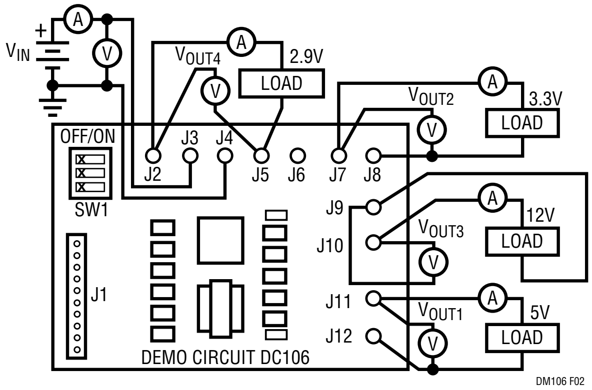


Figure 2. Proper Measurement Setup

A power-on reset (POR, J1-Pin 6) output can be externally pulled up to an external supply of less than 12V. The LTC1439 keeps the POR output low in shutdown and for 65536 oscillator clock periods after the first controller's output is within 5% of its final value. The LTC1539 has the

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same POR functionality with the exception that the second controller's output is monitored rather than the first.

The Low-Battery Input, (LBI, J1-Pin 5) and the Low-Battery Output, (LBO, J1-Pin 4) are available as connections to a separate comparator. LBI is tied to the noninverting input of the comparator whose other input is tied to the internal 1.19V, 1% accurate voltage reference. The comparator is active in shutdown (5V RUN and 3.3V RUN inputs low) on the LTC1539 but is shut down on the LTC1439.

The 5V Standby (J1-Pin 7) is also active in shutdown on the LTC1539 but inactive for the LTC1439. This 5V, 4% accurate standby supply can be very useful in an application which requires power for a "wake-up" function such as a keyboard controller. The cost of leaving these functions alive in the LTC1539 is a typical shutdown current of 70µA, an increase of 50µA over the LTC1439. The LTC1439 turns off all internal functionality (except for holding POR low) to minimize supply current in shutdown.

The first controller generates the 5V and 12V outputs using a 9µH primary and a secondary winding with a turns ratio of 1:1.42. The technique used to generate the 12V is superior to using a simple rectifying diode in terms of regulation accuracy and efficiency. Synchronous MOSFETs M1B and M7 are driven in parallel. The primary output voltage storage capacitor is used to provide power during the synchronous MOSFET's active period by transforming the well-controlled 5V output by the turns ratio and stacking this output on top of the 5V output. A well-coupled transformer and low $R_{DS(ON)}$ MOSFETs provide an output which is controlled to within ±5% over all primary and secondary loading conditions. A 12V secondary output load current is normally limited to an amount less than that which is being drawn from the primary winding. This is not the case with the design here! A secondary feedback input to the first controller senses the 12V output voltage via a resistive divider, compares this to the internal 1.19V reference, and forces synchronous MOSFET operation on the primary 5V controller as required to maintain a minimum output voltage. The resistive divider is set for a value of less than 12V to guarantee that synchronous operation will only be forced as required by the 12V load when the primary is unloaded. The demonstration board design sets this value to be 11.7V—comfortably below the 12.2V which is generated during continuous inductor current operation. The secondary winding approach also requires that the synchronous switch have adequate on-time duration as set by the V_{IN}/V_{OUT} voltage ratio for the primary regulator. This particular design requires approximately 7V minimum input voltage to properly generate the 12V at its maximum rated load. A secondary winding from a 3.3V output would work down to 5.4V input but would be slightly less efficient and accurate. The design does not use the Adaptive Power™ mode to prevent a higher secondary output voltage generated due to the increased voltage across the primary when the Schottky rectifier, D1, is conducting. Foldback current limit is provided by D5 to protect the bottom MOSFET from overheating during short-circuit conditions.

The 3.3V output uses a 10µH inductor and a 0.02Ω sense resistor to provide up to 6A for the combined 3.3V and 2.9V loads. R20, R21, C10 and C9 provide HF decoupling from the output for the current and voltage sensing of the output. The loop compensation components have been optimized for the higher current output level and the transient response performance. A slightly larger inductor can be substituted in order to reduce the ripple current requirements on the input and output capacitors. Foldback current limit is provided by D7 and R12 to protect the bottom MOSFET from overheating during short-circuit conditions.

The 2.9V output is generated from the 3.3V output using an internal auxiliary regulator controller. The significant base current required by the output NPN pass device, Q2, is taken from the 5V switcher output. This approach provides a reasonably efficient, high performance linear regulator solution for Intel P54LM applications. The output accuracy is set by the internal, 1% accurate reference and an external resistive divider. The external divider allows flexibility in output voltage as well as remote voltage sensing, a requirement in high current applications. While additional low ESR capacitance is required at the load in order to capitalize on the full performance potential of the regulator, care must be taken to make sure that the overall loop is stable. Additional suggestions for stability include: a resistor in series with C12 to provide a

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zero in the forward response to reduce phase shift at high frequencies (50Ω to 500Ω); changing the value of feedforward capacitor, C17(5pF to 50pF), to minimize any peaking in the fed-back response; and increasing R1 (20Ω to 100Ω) to reduce the open-loop gain of the amplifier (making sure Q1 can still provide enough base current for Q2). 500µF of low ESR tantalum capacitance is recommended for CPU power applications. Extremely low ESR ceramic capacitors are not recommended due to the particular NPN emitter follower output stage design.

The power to drive the output power MOSFETs is taken from the IC's INT V_{CC} pin. The voltage at this pin is normally derived from the V_{IN} supply using an internal, low dropout linear regulator. The power MOSFET's gate currents alone can be in the range of 0mA to 50mA depending upon the oscillator frequency, the MOSFETs used and the particular output loading condition. The "gate charge" current times the voltage drop between V_{IN} and the INT V_{CC} output voltage can result in significant power loss and thermal demands upon the IC. It is for this reason that an additional input pin, EXT V_{CC}, is provided. When the voltage applied to the EXT V_{CC} pin is greater than 4.8V the internal regulator is turned off and an internal switch is closed between the INT V_{CC} and EXT V_{CC} pins. The current normally delivered by the INT V_{CC} supply is now provided by the voltage source applied to the EXT V_{CC} pin. Efficiency and thermal dissipation are improved significantly. The 5V output of the IC's switching controller or another external supply of 5V to 9V can be used to provide the EXT V_{CC} power. Connecting the EXT V_{CC} pin to the 5V switcher output takes full advantage of the high efficiency of the DC/DC converter and reduces the IC's required thermal dissipation, truly a win-win situation! At high input voltage using large output MOSFETs, this may be the only way to stay within the worst-case IC package power dissipation limits.

An uncommitted comparator referenced to 1.19V is available at terminals J1-P4 and J1-P5, and an open-drain power-on reset output for channel 2 for the LTC1439 (channel 1 for the LTC1539) is available at terminal J1-P6. Refer to the LTC1439 and LTC1539 data sheets for further information on these functions.

LTC1439 AND LTC1539 EFFICIENCY MEASUREMENT

The measurement of efficiency depends upon the operating conditions of all four regulators so care and thought must be given when doing so. Efficiency figures ideally should be taken with only the minimum required circuitry operating on an individual regulator. Since there is much common circuitry operating when more than one regulator is running, overall efficiency numbers will actually increase when the two switching regulators are active. The increase is not significant at high output currents, but can become very significant at low output currents when the IC supply current becomes an appreciable part of the total system supply current.

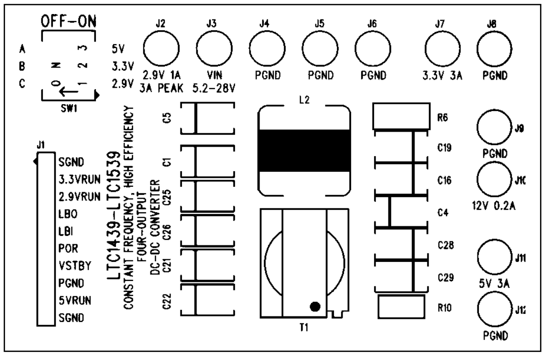
IC FUNCTIONAL DESCRIPTION

The LTC1439/LTC1539 switching regulators accomplish high efficiency DC/DC voltage conversion while maintaining constant frequency using a current mode architecture. The externally adjustable free-running oscillator frequency can be phase-locked to an external input, or it can be logically switched using the PLL FLTR pin. High efficiency, maintained at lower currents even when operating at constant frequency, is made possible by using a new Adaptive Power architecture employing two automatically switched output stages. The high current output stage uses a better-than-90% efficient synchronous regulator with the ability to disable the synchronous MOSFET during each period if the current in the output inductor (transformer) reverses. The low current output stage uses a constant frequency nonsynchronous switch technique using a second, smaller switching MOSFET. Adaptive Power operation is featured in demonstration circuit DC096B.

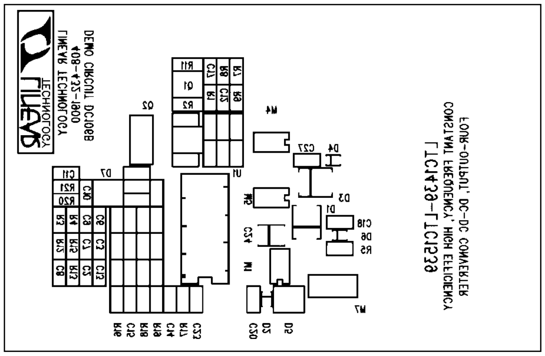
Adaptive Power operation is not employed in the DC106B circuit, rather, the smaller MOSFET is eliminated, resulting in Burst Mode™ operation. Subharmonics of the oscillator switching frequency will be present at low current levels, and an assessment needs to be made as to any potential interference problems.

Burst Mode is a trademark of Linear Technology Corporation.

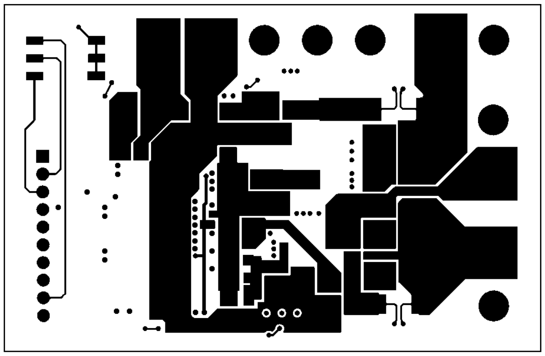
PCB LAYOUT AND FILM **All as viewed from topside.**



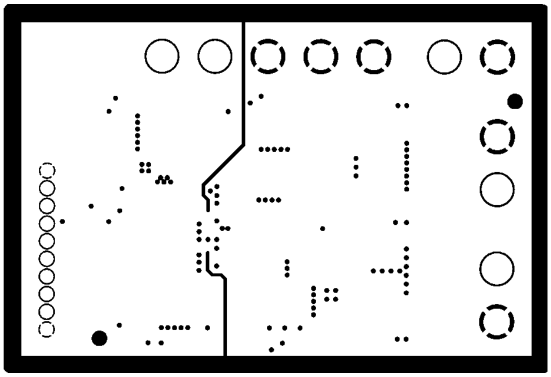
Top Silkscreen



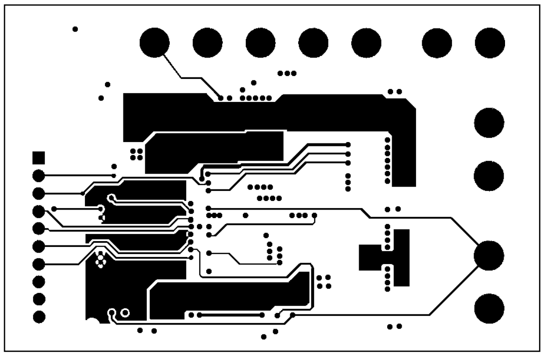
Bottom Silkscreen



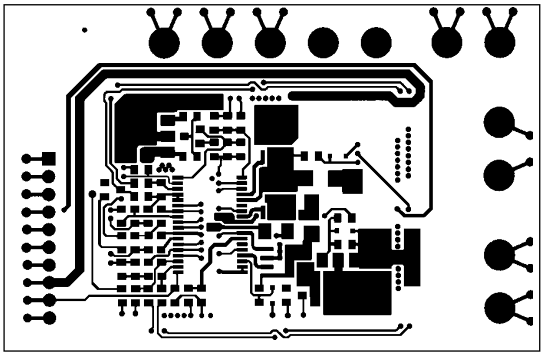
Top Copper Layer



PGND-SGND Ground Plane



Third Copper Layer



Bottom Copper Layer

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