DEMO MANUAL DC156
NO DESIGN SWITCHER

No Design, Low Cost, High Current Switcher

DESCRIPTION

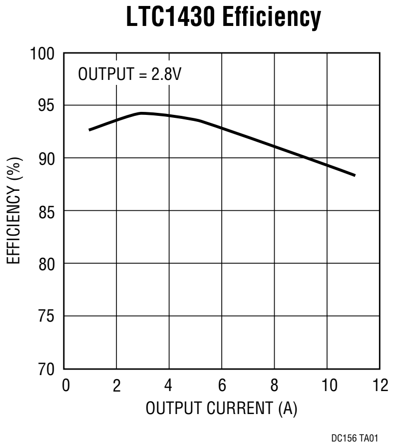
Demo Board DC156 is a synchronous buck regulator designed to provide a low voltage, high current output for high performance microprocessors and other digital systems. The heart of the design is the 8-pin LTC1430CS8 synchronous buck regulator controller. This IC is a low cost version of the 16-pin LTC1430CS. The loss of eight pins naturally requires the sacrifice of several functions. The 8-pin IC gives up soft start, current limit and the ability to adjust the operating frequency. It also gives up the fixed 3.3V output capability and is only available as an adjustable output device. Both the power and signal grounds are combined into a single pin, as are the low-side gate supply voltage and the V_{CC} supply for the IC's control circuits.

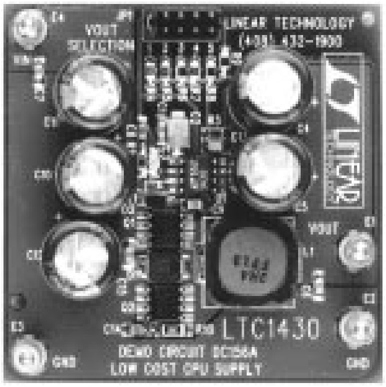
The demo board uses aluminum electrolytic input and output capacitors for the lowest possible cost. The inductor is a small, low cost, surface mount design, although an iron powder toroidal design, which may be slightly less costly, will also work satisfactorily. The output voltage is jumper-programmable to popular processor core voltages. If a different voltage is desired, a single resistor change should be all that's required. Details are provided in the section on operation.

PERFORMANCE SUMMARY

SYMBOL	PARAMETER	CONDITIONS	VALUE
V_{IN}	Input Voltage		5V ±5%
V_{OUT}	Output Voltage	Jumper Select for 2.5V, 2.8V, 2.9V, 3.1V, 3.3V and 3.5V	
	Output Accuracy		±1% Typ
I_{OUT}	Output Current		8A Steady State,10A Peak for <5s
	Output Ripple	24-1µF Ceramic Capacitors at Load	$<50mV_{P-P}$
	Transient Response	5A Load Step (1A to 6A)	<100mV
	Efficiency		>90% at 6A

TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO





PACKAGE AND SCHEMATIC DIAGRAMS

JUMPER SHORT	OUTPUT VOLTAGE
JP1-1	3.5V
JP1-2	3.3V
JP1-3	3.1V
JP1-4	2.9V
JP1-5	2.8V
NONE	2.5V

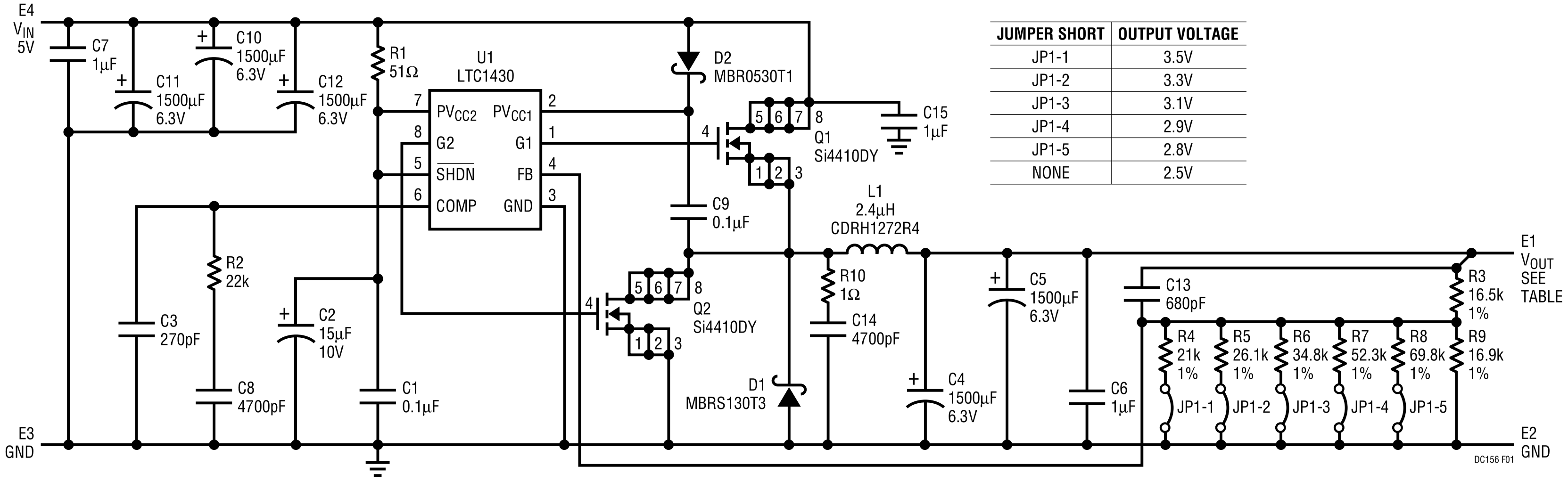
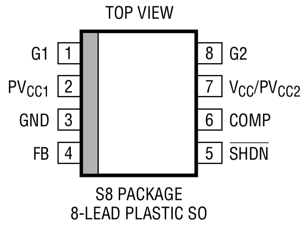


Figure 1. DC156 Schematic



LTC1430CS8

DESCRIPTION

In many applications, the smaller size and lower cost of the 8-pin version of the LTC1430 more than offset the loss of the features available in the 16-pin version. Although current limit will ensure that the power MOSFETs won't be damaged in an overcurrent fault, there is no reason for an overcurrent condition to exist if the rest of the board is functioning correctly. If a component fails, resulting in a short circuit, the board is probably going to be scrapped due to the failed component. Therefore, preventing collateral damage is of little or no concern. Also, most of the off-line supplies used in desktop computer systems have a feature that latches the supply off after a few milliseconds of operation into a short circuit. There is a high probability that the power MOSFET switches will survive a short circuit of this duration.

The lack of soft start shouldn't result in any adverse conditions. The large off-line supplies used in the intended applications can supply the required inrush currents. Transient response and reference accuracy are the same as those of the higher-pin-count LTC1430CS design.

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
C1, C9	2	08055C104MAT1A	0.1µF 50V 20% X7R Chip Capacitor	AVX	(803) 946-0362
C2	1	TAJB156M010	15µF 10V 20% Tantalum Capacitor	AVX	(207) 282-5111
C3	1	08055A271KAT1A	270pF 50V 10% NPO Chip Capacitor	AVX	(803) 946-0362
C4, C5, C10 to C12	5	6MV1500GX	1500µF 6.3V 20% Electrolytic Capacitor	Sanyo	(619) 661-6835
C6, C7, C15	3	0805ZC105KAT1A	1µF 10V 10% X7R Chip Capacitor	AVX	(803) 946-0362
C8, C14	2	08055C472KAT1A	4700pF 50V 10% X7R Chip Capacitor	AVX	(803) 946-0362
C13	1	08055A681KAT1A	680pF 50V 10% NPO Chip Capacitor	AVX	(803) 946-0362
D1	1	MBRS130T3	Schottky Diode	Motorola	(602) 244-3576
D2	1	MBR0530T1	Schottky Diode	Motorola	(602) 244-3576
E1 to E4	4	2804-2	Turret Terminal	Mill Max	(516) 922-6000
JP1	1	2202S-10-G2	Pin Header Connector	Comm Con	(818) 301-4200
L1	1	CDRH127-2R4	2.4µH Inductor	Sumida	(847) 956-0666
Q1, Q2	2	Si4410DY	N-Channel MOSFET	Siliconix	(408) 970-5700
R1	1	CR21-510J-T	51Ω 0.1W 5% 0805 Chip Resistor	AVX	(803) 946-0524
R2	1	CR21-223J-T	22k 0.1W 5% 0805 Chip Resistor	AVX	(803) 946-0524
R3	1	CR21-1652F-T	16.5k 0.1W 1% 0805 Chip Resistor	AVX	(803) 946-0524
R4	1	CR21-2102F-T	21k 0.1W 1% 0805 Chip Resistor	TAD	(800) 508-1521
R5	1	CR21-2612F-T	26.1k 0.1W 1% 0805 Chip Resistor	TAD	(800) 508-1521
R6	1	CR21-3482F-T	34.8k 0.1W 1% 0805 Chip Resistor	AVX	(803) 946-0524
R7	1	CR21-5232F-T	52.3k 0.1W 1% 0805 Chip Resistor	TAD	(800) 508-1521
R8	1	CR21-6982F-T	69.8k 0.1W 1% 0805 Chip Resistor	AVX	(803) 946-0524
R9	1	CR21-1692F-T	16.9k 0.1W 1% 0805 Chip Resistor	AVX	(803) 946-0524
R10	1	CR32-1R0J-T	1Ω 0.125W 5% 1206 Chip Resistor	AVX	(803) 946-0524
U1	1	LTC1430CS8	IC	LTC	(408) 432-1900
	1	CCIJ2mm-138-G	Shunt Jumper	Comm Con	(818) 301-4200

OPERATION

The circuit is a fairly conventional synchronous buck regulator. See the schematic in Figure 1 for details. The LTC1430 controller uses voltage mode control, and therefore does not require any load current information for pulse-by-pulse control of the power path. This eliminates the need to incorporate a current sense resistor, resulting in additional cost savings, as well as a marked improvement in efficiency. With voltage mode control, the output of the error amplifier (COMP pin) is compared to a ramp waveform generated by an on-chip oscillator (200kHz for the LTC1430). The higher the error voltage, the longer the high-side switch on-time. The comparator output controls the complimentary MOSFET drivers, G1 and G2, which, in turn, control the power FETs. The output of this chopper is then filtered by the LC filter formed by inductor L1 and capacitors C4 and C5. The DC output voltage is compared to an internal 1.265V reference and the resulting error voltage is amplified by the error amplifier. Frequency compensation is connected between the COMP pin and ground to stabilize the loop.

This board uses a charge pump consisting of C9 and D2 to develop the required gate drive for the high-side switch. An alternative is to connect Pin 2 to a 12V supply. If a 12V supply is used, eliminate D2 and connect C9 from Pin 2 to ground. D1 may be eliminated for cost savings but there will be a slight decrease in efficiency and possibly an increase in conducted EMI (electromagnetic interference).

Measured Performance

Figure 2 shows the measured efficiency of the board over a load current range of 1A to 10A. Figure 3 is the output voltage transient response to a 5A load step. The load used for this test had 24 1µF 0805 case ceramic capacitors with X7R dielectric material. If further reduction in response amplitude is required, either install additional capacitors at the regulator output or replace the existing capacitors with lower ESR devices. Figure 4 shows the output ripple voltage with a steady-state 8A load applied.

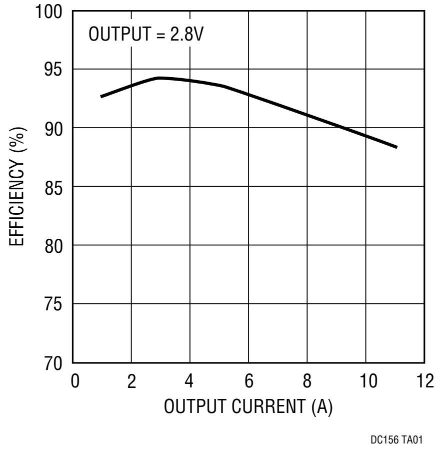


Figure 2. LTC1430 Efficiency

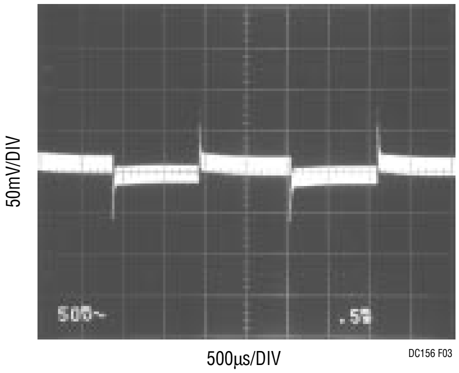


Figure 3. Transient Response

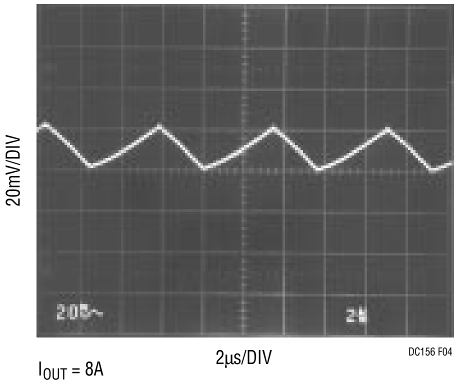


Figure 4. Output Ripple

OPERATION

When measuring output ripple, be sure to connect the oscilloscope probe directly across an output capacitor with a zero-length ground lead. If a standard ground pigtail is used, a large amount of switching noise will be picked up on this lead. Care must be used to obtain accurate results. Note that both of these photos were taken with the scope probe located at the load. These results will not be duplicated if measurements are made on the demo board's output terminals.

Capacitor Considerations

Input and output capacitors are Sanyo MV-GX type. The input capacitors must be rated for the RMS input ripple. A good rule of thumb is that the input ripple current will be 50% of the output current. It isn't necessary to design for the worst-case peak output current. The capacitors can easily handle short excursions to higher loads. Only the sustained average load current need be considered. For an 8A output, the ripple current rating of the input capacitors should be 4A. The capacitors chosen are rated at 1.25A each, so an additional 0.25A of ripple current capability is assumed to exist on the motherboard as part of the existing 5V supply bypass.

Output capacitors need to have a ripple current rating high enough for the inductor ripple current rating. This is a function of the operating frequency and inductor value, as well as input and output voltages. Because the ripple current is relatively small, the controlling parameter is generally the capacitor's ESR (equivalent series resistance). Low ESR is essential if good transient response is to be obtained. When an instantaneous load change occurs, the output voltage immediately droops by an amount equal to $(\Delta I)(ESR)$. As an example, for a 5A load step and an allowable 50mV droop, the ESR must be less than 0.01Ω. In general, if the ESR is low enough for the ripple voltage and transient requirements, the capacitors will have more than adequate ripple current capability.

One caution is that electrolytic capacitors have a finite life expectancy. As they age, their electrolyte evaporates. This tends to raise a capacitor's ESR and lower its capacitance. Most manufacturers specify the life of the capacitor as the point in time when the ESR has *doubled*. As such, if a circuit is expected to operate for the stated lifetime at rated temperature, the circuit must still work correctly with half of the capacitors removed when new. Capacitor life expectancy can be expected to approximately double with each 10°C reduction in temperature from the rated maximum temperature.

As an example, consider a capacitor that is specified for 1,000 hours life at 85°C. If it is operated at 65°C, the life expectancy will be $2^{(20°C/10°C)} \bullet 1000 \text{ hours} = 4{,}000 \text{ hours}$. At this time, ESR will have doubled. Using a 105°C capacitor increases this to 16,000 hours, or slightly less than two years of continuous operation. Clearly, if a board is produced with small design margins, the life expectancies above will not be realized.

Inductor Selection

Inductor selection is not extremely critical. The inductor used here was chosen for low cost and ready availability. The main concerns in choosing an appropriate inductor are the inductance value required, saturation current and the temperature rise. Most manufacturers specify a DC current rating that produces a temperature rise of 40°C. If a design will not see high ambient temperatures, a larger temperature rise can be tolerated. Another maximum current specification is related to core saturation. A manufacturer may specify that maximum rated current is the point at which inductance is down by 10% (some specify 25%). Since most core materials will produce a gentle, controlled roll off of inductance with DC bias, there is no magical point where the inductor is no longer useful. Look at what the inductance will be at the maximum load current expected and determine if the output ripple will remain within specified limits. If it will, the inductor will most likely work correctly. Ripple current is generally designed for between 10% and 40% of output current. See the LTC1430 data sheet for design equations.

OPERATION

Transient Response

This circuit exhibits excellent load transient response for a low cost design. When using large value aluminum electrolytic capacitors, as is done on this demo board, the transient droop is dominated by the capacitors' ESR. The voltage perturbation consists mainly of two components. One is the droop that is equal to the ESR multiplied by the load-current delta. This appears essentially instantaneously for very fast load steps. Regulator performance and loop dynamics do not affect the amplitude of this droop. Only capacitor ESR reductions can yield improvements. The other component involved in output voltage perturbations is the droop caused by current flowing out of (or into) the output capacitors. The droop rate, $\Delta V/\Delta t$, is equal to I/C, but because the capacitor values are large, this slope is quite small. For example, with 3000µF and a 5A load step, $\Delta V/\Delta t = 5/3000\mu F = 1.7mV/\mu s$. Clearly, the ESR will dominate the design.

Inductor selection also affects the transient response of the system. The smaller the inductance, and therefore the larger the ripple current, the faster the regulator can respond to load transients. Switching frequency is not a major factor in determining the large-signal transient dynamics of the regulator. The ultimate limit in the rate of rise of current through the regulator is determined by the inductor. A low value inductor results in a high current slew rate and a relatively large output ripple voltage. There will also be a slight reduction in efficiency due to the DC losses associated with the higher peak currents and greater core losses caused by higher AC flux swing in the inductor core material. These effects will likely be small.

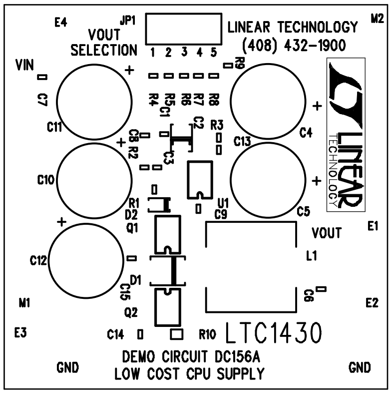
Selecting Different Outputs

If an output voltage other than the jumper selectable options is desired, the feedback divider resistors may be chosen by the following formula:

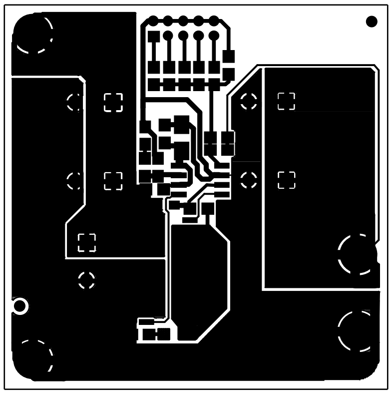
$$R9 = \frac{(1.265V)(R3)}{V_{OUT} - 1.265V}$$

It is recommended that R3 remain 16.5k as it currently exists on the demo board and R9 be altered as required. For a 5V input, the maximum practical output voltage will be approximately 3.9V and the low limit equals the 1.265V reference voltage.

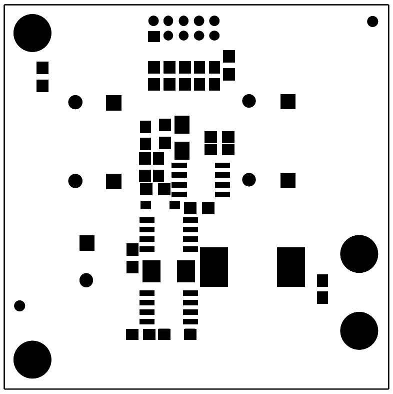
PCB LAYOUT AND FILM



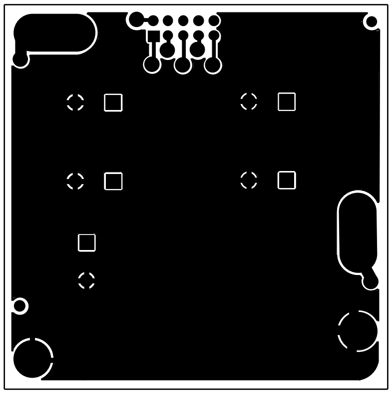
Component Side Silkscreen



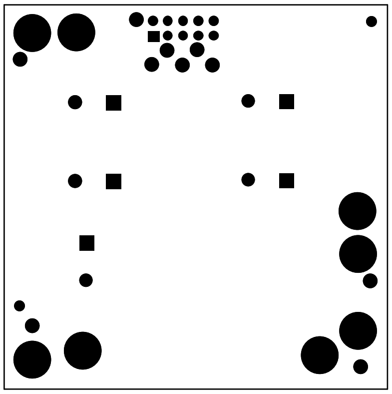
Component Side



Component Side Solder Mask

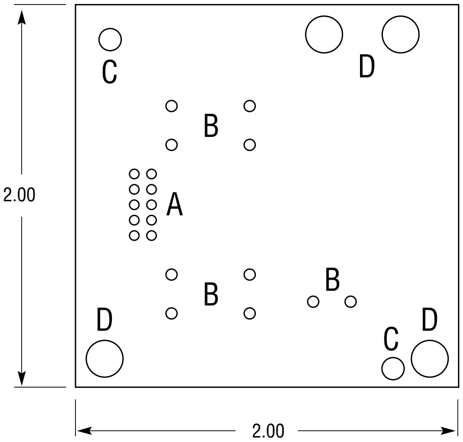


Solder Side



Solder Side Solder Mask

PC FAB DRAWING



SYMBOL	DIAMETER	NUMBER OF HOLES
A	0.030	10
B	0.035	10
C	0.070	2
D	0.116	4
	TOTAL HOLES	26

DC114B FAB

NOTES:
1. ALL DIMENSIONS ARE IN INCHES ±0.005
2. ALL HOLE SIZES AFTER PLATING +0.003/–0
3. MATERIAL IS FR4, 0.062" THICK WITH 2 OZ COPPER
4. PCB WILL BE DOUBLE SIDED WITH PLATED THROUGH HOLES
5. PLATED THROUGH HOLE: WALL THICKNESS MIN 0.0014" (1 OZ)
6. SOLDER MASK BOTH SIDES
7. SILKSCREEN COMPONENT SIDE. USE WHITE, NONCONDUCTIVE INK

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dc156f LT/TP 0797 500 • PRINTED IN USA