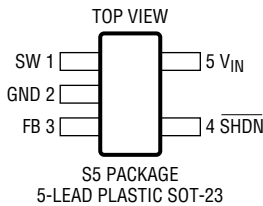


ABSOLUTE MAXIMUM RATINGS

(Note 1)

| | |
|--------------------------------------|-----------------|
| V_{IN} Voltage | 10V |
| SW Voltage | −0.4V to 36V |
| FB Voltage | $V_{IN} + 0.3V$ |
| Current into FB Pin | ±1mA |
| SHDN Voltage | 10V |
| Maximum Junction Temperature | 125°C |
| Operating Temperature Range | |
| Commercial | 0°C to 70°C |
| Extended Commercial (Note 2) | −40°C to 85°C |
| Storage Temperature Range | −65°C to 150°C |
| Lead Temperature (Soldering, 10 sec) | 300°C |

PACKAGE/ORDER INFORMATION

| | |
|--|-------------------|
|  | ORDER PART NUMBER |
| | LT1613CS5 |
| | S5 PART MARKING |
| | LTED |

Consult factory for Industrial and Military grade parts.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. Commercial grade 0°C to 70°C, $V_{IN} = 1.5V$, $V_{SHDN} = V_{IN}$ unless otherwise noted. (Note 2)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|-------------------------------|---------------------------------|---------|------|-------|-------|
| Minimum Operating Voltage | | | 0.9 | 1.1 | V |
| Maximum Operating Voltage | | | | 10 | V |
| Feedback Voltage | | ● 1.205 | 1.23 | 1.255 | V |
| FB Pin Bias Current | | ● | 27 | 80 | nA |
| Quiescent Current | $V_{SHDN} = 1.5V$ | | 3 | 4.5 | mA |
| Quiescent Current in Shutdown | $V_{SHDN} = 0V$, $V_{IN} = 2V$ | | 0.01 | 0.5 | μA |
| | $V_{SHDN} = 0V$, $V_{IN} = 5V$ | | 0.01 | 1.0 | μA |
| Reference Line Regulation | $1.5V \leq V_{IN} \leq 10V$ | | 0.02 | 0.2 | %/V |
| Switching Frequency | | ● 1.0 | 1.4 | 1.8 | MHz |
| Maximum Duty Cycle | | ● 82 | 86 | | % |
| Switch Current Limit | (Note 3) | 550 | 800 | | mA |
| Switch V_{CESAT} | $I_{SW} = 300mA$ | | 300 | 350 | mV |
| Switch Leakage Current | $V_{SW} = 5V$ | | 0.01 | 1 | μA |
| SHDN Input Voltage High | | 1 | | | V |
| SHDN Input Voltage Low | | | | 0.3 | V |
| SHDN Pin Bias Current | $V_{SHDN} = 3V$ | | 25 | 50 | μA |
| | $V_{SHDN} = 0V$ | | 0.01 | 0.1 | μA |

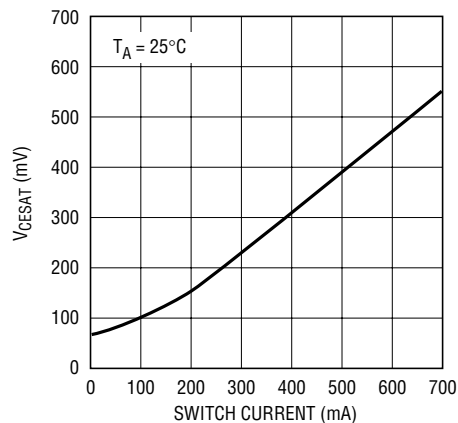
Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: The LT1613C is guaranteed to meet performance specifications from 0°C to 70°C. Specifications over the −40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

Note 3: Current limit guaranteed by design and/or correlation to static test.

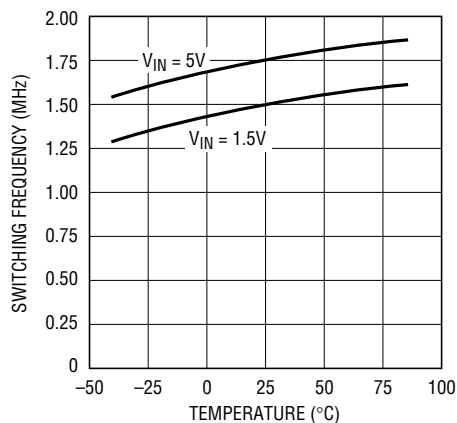
TYPICAL PERFORMANCE CHARACTERISTICS

Switch V_{CESAT} vs Switch Current



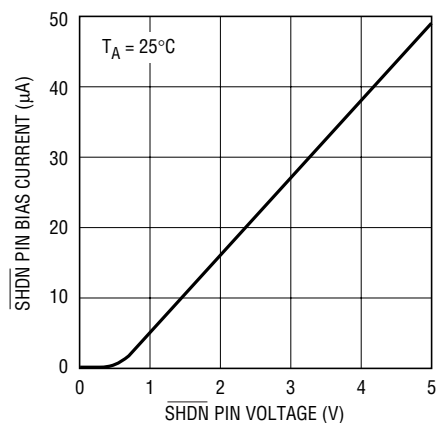
1613 G01

Oscillator Frequency vs Temperature



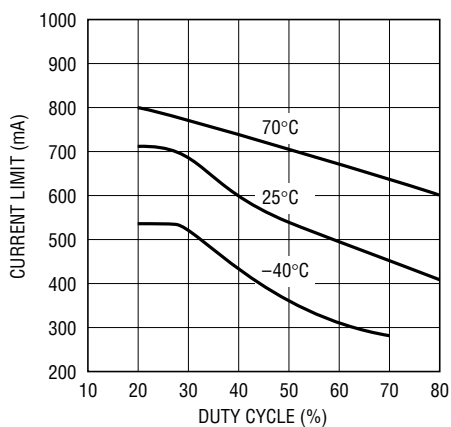
1613 G02

$\overline{\text{SHDN}}$ Pin Current vs $V_{\overline{\text{SHDN}}}$



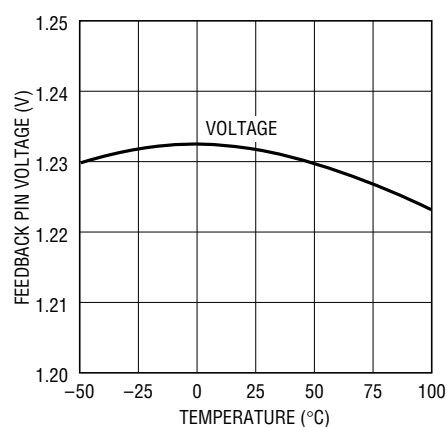
1613 G03

Current Limit vs Duty Cycle



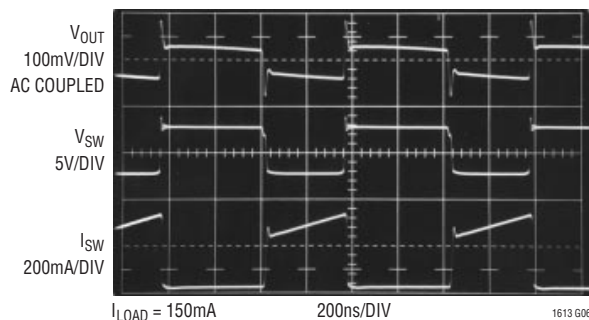
1613 G04

Feedback Pin Voltage



1613 G05

Switching Waveforms, Circuit of Figure 1



1613 G06

PIN FUNCTIONS

SW (Pin 1): Switch Pin. Connect inductor/diode here. Minimize trace area at this pin to keep EMI down.

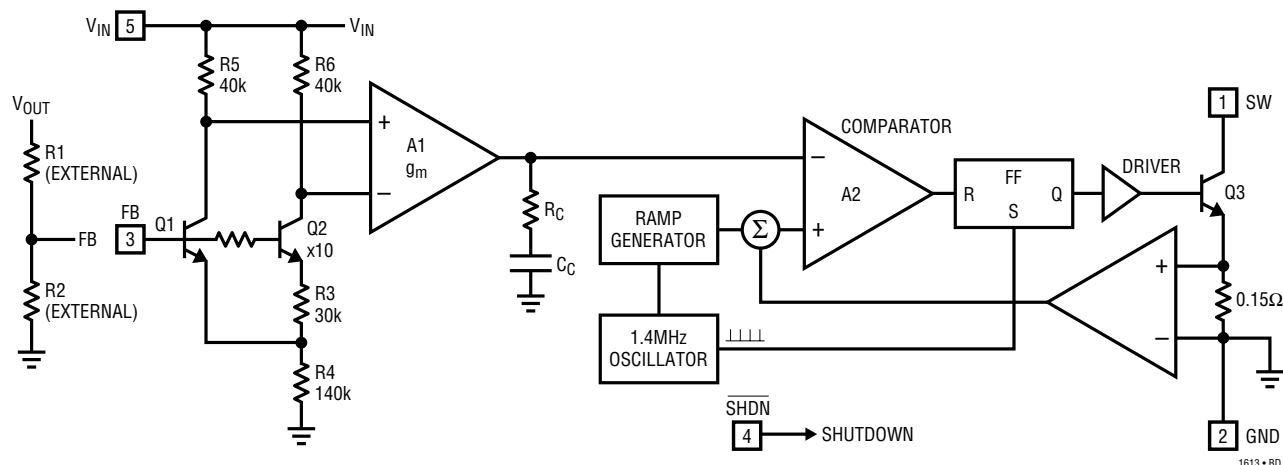
GND (Pin 2): Ground. Tie directly to local ground plane.

FB (Pin 3): Feedback Pin. Reference voltage is 1.23V. Connect resistive divider tap here. Minimize trace area at FB. Set V_{OUT} according to $V_{OUT} = 1.23V(1 + R1/R2)$.

SHDN (Pin 4): Shutdown Pin. Tie to 1V or more to enable device. Ground to shut down.

V_{IN} (Pin 5): Input Supply Pin. Must be locally bypassed.

BLOCK DIAGRAM



OPERATION

LAYOUT

The LT1613 switches current at high speed, mandating careful attention to layout for proper performance. *You will not get advertised performance with careless layouts.* Figure 2 shows recommended component placement for a boost (step-up) converter. Follow this closely in your PCB layout. Note the direct path of the switching loops. Input capacitor C1 *must* be placed close ($< 5\text{mm}$) to the IC package. As little as 10mm of wire or PC trace from C_{IN} to V_{IN} will cause problems such as inability to regulate or oscillation.

The ground terminal of output capacitor C2 should tie close to Pin 2 of the LT1613. Doing this reduces di/dt in the ground copper which keeps high frequency spikes to a minimum. The DC/DC converter ground should tie to the PC board ground plane at one place only, to avoid introducing di/dt in the ground plane.

A SEPIC (single-ended primary inductance converter) schematic is shown in Figure 3. This converter topology produces a regulated output voltage that spans (i.e., can be higher or lower than) the output. Recommended component placement for a SEPIC is shown in Figure 4.

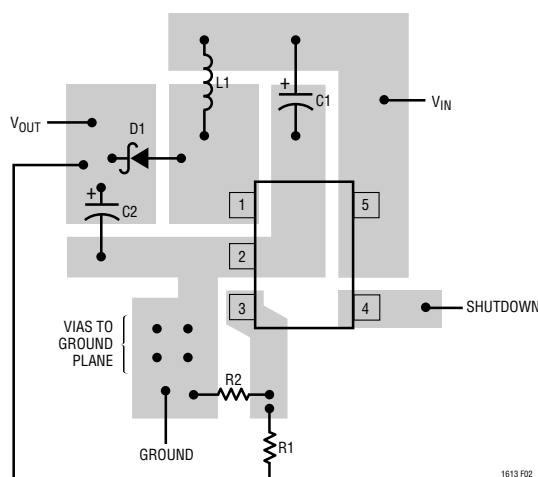


Figure 2. Recommended Component Placement for Boost Converter. Note Direct High Current Paths Using Wide PCB Traces. Minimize Area at Pin 3 (FB). Use Vias to Tie Local Ground Into System Ground Plane. Use Vias at Location Shown to Avoid Introducing Switching Currents Into Ground Plane

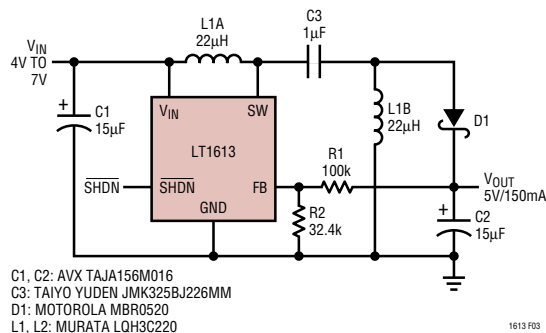


Figure 3. Single-Ended Primary Inductance Converter (SEPIC) Generates 5V from An Input Voltage Above or Below 5V

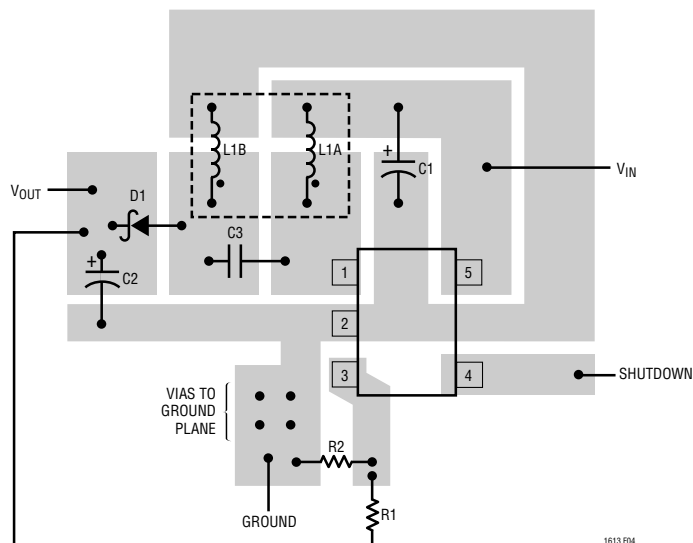


Figure 4. Recommended Component Placement for SEPIC

COMPONENT SELECTION

Inductors

Inductors used with the LT1613 should have a saturation current rating (where inductance is approximately 70% of zero current inductance) of approximately 0.5A or greater. DCR of the inductors should be 0.5Ω or less. For boost converters, inductance should be 4.7μH for input voltage less than 3.3V and 10μH for inputs above 3.3V. When using the device as a SEPIC, either a coupled inductor or two separate inductors can be used. If using separate inductors, 22μH units are recommended for input voltage above 3.3V. Coupled inductors have a beneficial mutual inductance, so a 10μH coupled inductor results in the same ripple current as two 20μH uncoupled units.

OPERATION

Table 1 lists several inductors that will work with the LT1613, although this is not an exhaustive list. There are many magnetics vendors whose components are suitable for use.

Diodes

A Schottky diode is recommended for use with the LT1613. The Motorola MBR0520 is a very good choice. Where the input to output voltage differential exceeds 20V, use the MBR0530 (a 30V diode). If cost is more important than efficiency, the 1N4148 can be used, but only at low current loads.

Capacitors

The input bypass capacitor must be placed physically close to the input pin. ESR is not critical and in most cases an inexpensive tantalum is appropriate.

The choice of output capacitor is far more important. The quality of this capacitor is the greatest determinant of the output voltage ripple. The output capacitor must have enough capacitance to satisfy the load under transient conditions and it must shunt the switched component of current coming through the diode. Output voltage ripple results when this switched current passes through the finite output impedance of the output capacitor. The capacitor should have low impedance at the 1.4MHz switching frequency of the LT1613. At this frequency, the impedance is usually dominated by the capacitor's equivalent series resistance (ESR). Choosing a capacitor with

lower ESR will result in lower output ripple.

Ceramic capacitors can be used with the LT1613 provided loop stability is considered. A tantalum capacitor has some ESR and this causes an "ESR zero" in the regulator loop. This zero is beneficial to loop stability. The internally compensated LT1613 does not have an accessible compensation node, but other circuit techniques can be employed to counteract the loss of the ESR zero, as detailed in the next section.

Some capacitor types appropriate for use with the LT1613 are listed in Table 2.

OPERATION WITH CERAMIC CAPACITORS

Because the LT1613 is internally compensated, loop stability must be carefully considered when choosing an output capacitor. Small, low cost tantalum capacitors have some ESR, which aids stability. However, ceramic capacitors are becoming more popular, having attractive characteristics such as near-zero ESR, small size and reasonable cost. Simply replacing a tantalum output capacitor with a ceramic unit will decrease the phase margin, in some cases to unacceptable levels. With the addition of a phase lead capacitor (C_{PL}) and isolating resistor (R_3), the LT1613 can be used successfully with ceramic output capacitors as described in the following figures.

A boost converter, stepping up 2.5V to 5V, is shown in Figure 5. Tantalum capacitors are used for the input and output (the input capacitor is not critical and has little

Table 1. Inductor Vendors

| VENDOR | PHONE | URL | PART | COMMENT |
|-------------|----------------|---------------------|-------------------------------------|-----------------------------------|
| Sumida | (847) 956-0666 | www.sumida.com | CLS62-22022 CD43-220 | 22μH Coupled 22μH |
| Murata | (404) 436-1300 | www.murata.com | LQH3C-220 LQH3C-100 LQH3C-4R7 | 22μH, 2mm Height 10μH 4.7μH |
| Coiltronics | (407) 241-7876 | www.coiltronics.com | CTX20-1 | 20μH Coupled, Low DCR |

Table 2. Capacitor Vendors

| VENDOR | PHONE | URL | PART | COMMENT |
|-------------|----------------|-----------------|-------------------------------|----------------|
| Taiyo Yuden | (408) 573-4150 | www.t-yuden.com | Ceramic Caps | X5R Dielectric |
| AVX | (803) 448-9411 | www.avxcorp.com | Ceramic Caps Tantalum Caps | |
| Murata | (404) 436-1300 | www.murata.com | Ceramic Caps | |

OPERATION

effect on loop stability, as long as minimum capacitance requirements are met). The transient response to a load step of 50mA to 100mA is pictured in Figure 6. Note the “double trace,” due to the ESR of C2. The loop is stable and settles in less than 100 μ s. In Figure 7, C2 is replaced by a 10 μ F ceramic unit. Phase margin decreases drastically,

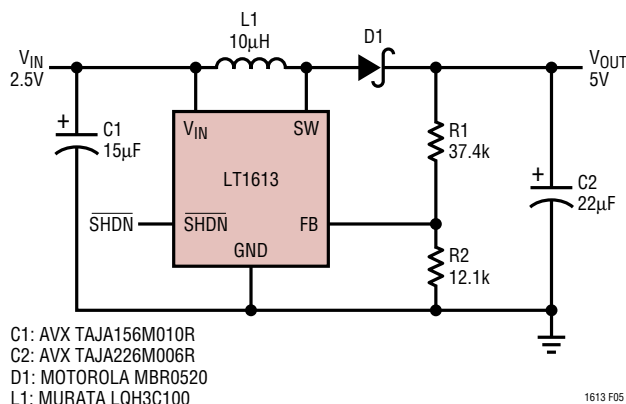


Figure 5. 2.5V to 5V Boost Converter with “A” Case Size Tantalum Input and Output Capacitors

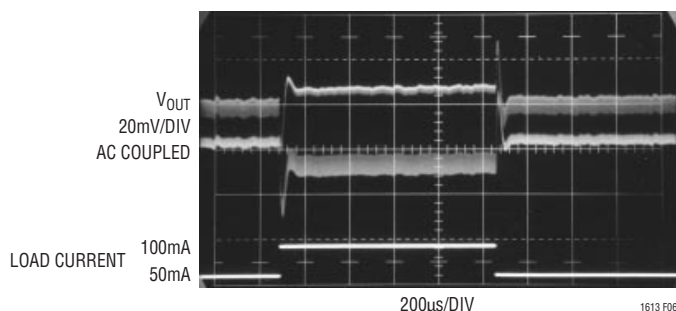


Figure 6. 2.5V to 5V Boost Converter Transient Response with 22 μ F Tantalum Output Capacitor. Apparent Double Trace on V_{OUT} Is Due to Switching Frequency Ripple Current Across Capacitor ESR

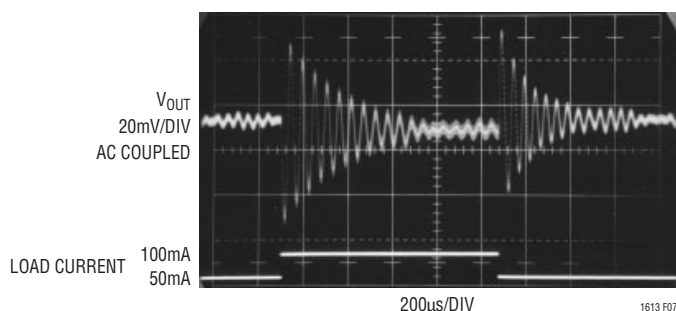


Figure 7. 2.5V to 5V Boost Converter with 10 μ F Ceramic Output Capacitor, No C_{PL}

resulting in a severely underdamped response. By adding R3 and C_{PL} as detailed in Figure 8’s schematic, phase margin is restored, and transient response to the same load step is pictured in Figure 9. R3 isolates the device FB pin from fast edges on the V_{OUT} node due to parasitic PC trace inductance.

Figure 10’s circuit details a 5V to 12V boost converter, delivering up to 130mA. The transient response to a load step of 10mA to 130mA, without C_{PL} , is pictured in Figure 11. Although the ringing is less than that of the previous example, the response is still underdamped and can be improved. After adding R3 and C_{PL} , the improved transient response is detailed in Figure 12.

Figure 13 shows a SEPIC design, converting a 3V to 10V input to a 5V output. The transient response to a load step of 20mA to 120mA, without C_{PL} and R3, is pictured in Figure 14. After adding these two components, the improved response is shown in Figure 15.

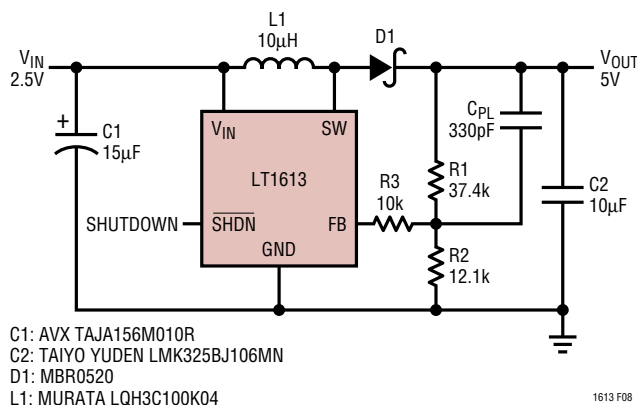


Figure 8. 2.5V to 5V Boost Converter with Ceramic Output Capacitor. C_{PL} Added to Increase Phase Margin, R3 Isolates FB Pin from Fast Edges

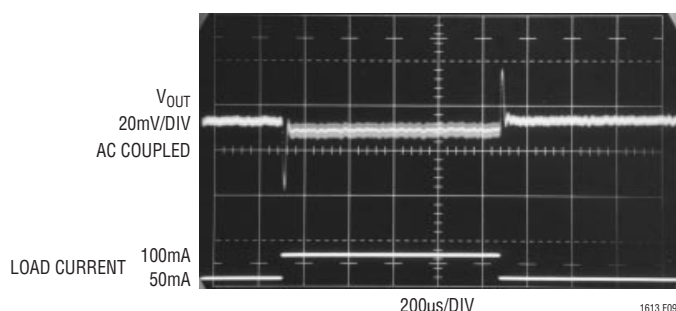


Figure 9. 2.5V to 5V Boost Converter with 10 μ F Ceramic Output Capacitor, 330pF C_{PL} and 10k in Series with FB Pin

OPERATION

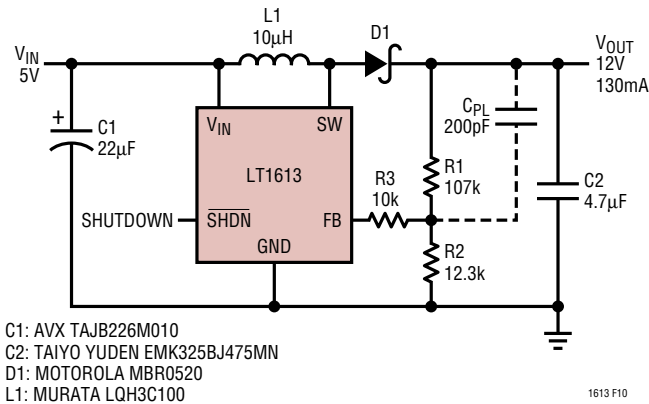


Figure 10. 5V to 12V Boost Converter with 4.7µF Ceramic Output Capacitor, C_{PL} Added to Increase Phase Margin

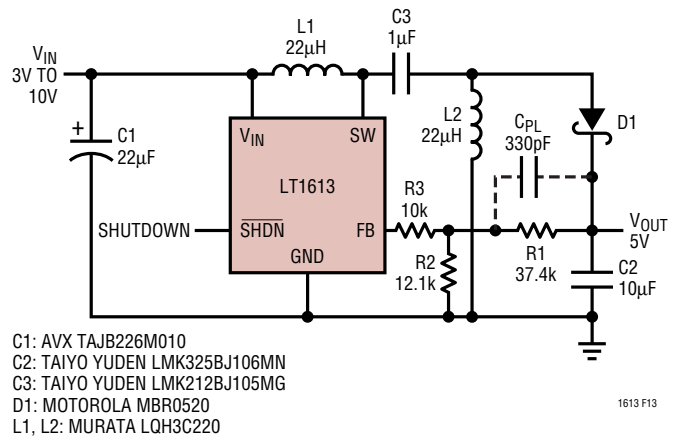


Figure 13. 5V Output SEPIC with Ceramic Output Capacitor. C_{PL} Adds Phase Margin

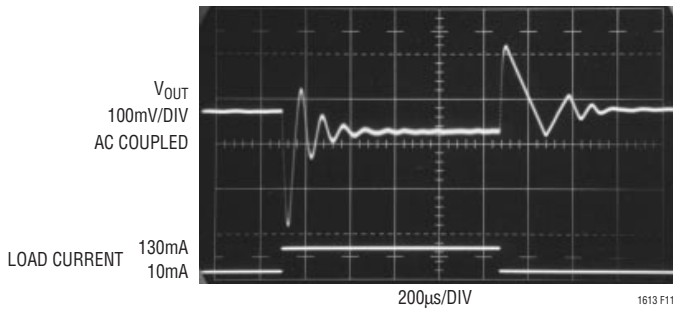


Figure 11. 5V to 12V Boost Converter with 4.7µF Ceramic Output Capacitor

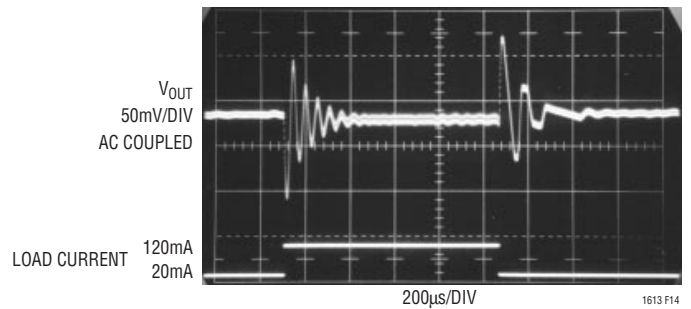


Figure 14. 5V Output SEPIC with 10µF Ceramic Output Capacitor. No C_{PL} . $V_{IN} = 4V$

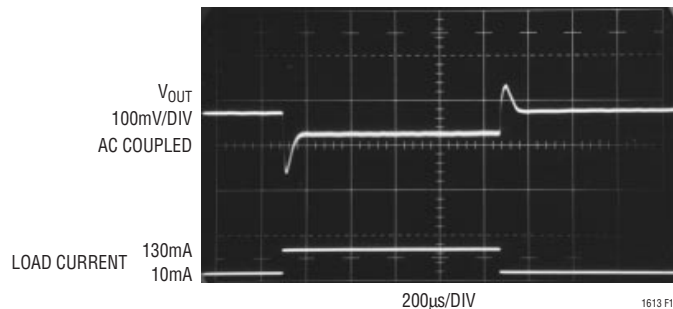


Figure 12. 5V to 12V Boost Converter with 4.7µF Ceramic Output Capacitor and 200pF Phase-Lead Capacitor C_{PL} and 10k in Series with FB Pin

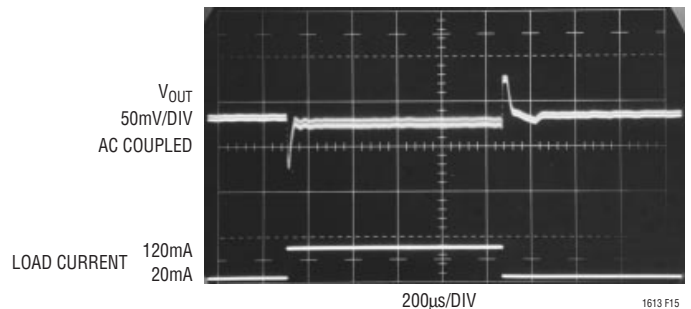


Figure 15. 5V Output SEPIC with 10µF Ceramic Output Capacitor, 330pF C_{PL} and 10k in Series with FB Pin

OPERATION

START-UP/SOFT-START

When the LT1613 $\overline{\text{SHDN}}$ pin voltage goes high, the device rapidly increases the switch current until internal current limit is reached. Input current stays at this level until the output capacitor is charged to final output voltage. Switch current can exceed 1A. Figure 16's oscillograph details start-up waveforms of Figure 17's SEPIC into a 50Ω load without any soft-start. The output voltage reaches final value in approximately $200\mu\text{s}$, while input current reaches 400mA. Switch current in a SEPIC is 2x the input current, so the switch is conducting approximately 800mA peak.

Soft-start reduces the inrush current by taking more time to reach final output voltage. A soft-start circuit consisting of Q1, R_{S1} , R_{S2} and C_{S1} as shown in Figure 17 can be used to limit inrush current to a lower value. Figure 18 pictures V_{OUT} and input current with R_{S2} of 33k Ω and C_S of 10nF. Input current is limited to a peak value of 200mA as the

time required to reach final value increases to 1.7ms. In Figure 19, C_S is increased to 33nF. Input current does not exceed the steady-state current the device uses to supply power to the 50Ω load. Start-up time increases to 4.3ms. C_S can be increased further for an even slower ramp, if desired.

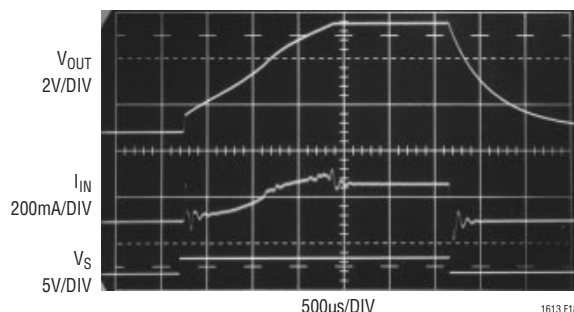


Figure 18. Soft-Start Components in Figure 17's SEPIC Reduces Inrush Current. $C_{SS} = 10\text{nF}$, $R_{\text{LOAD}} = 50\Omega$

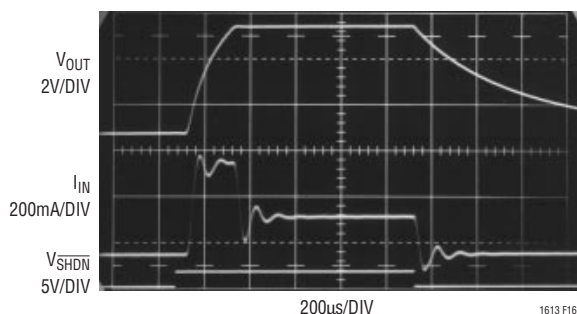


Figure 16. Start-Up Waveforms of Figure 17's SEPIC Into 50Ω Load

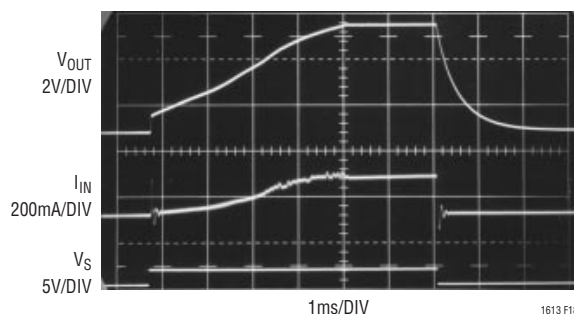


Figure 19. Increasing C_S to 33nF Further Reduces Inrush Current. $R_{\text{LOAD}} = 50\Omega$

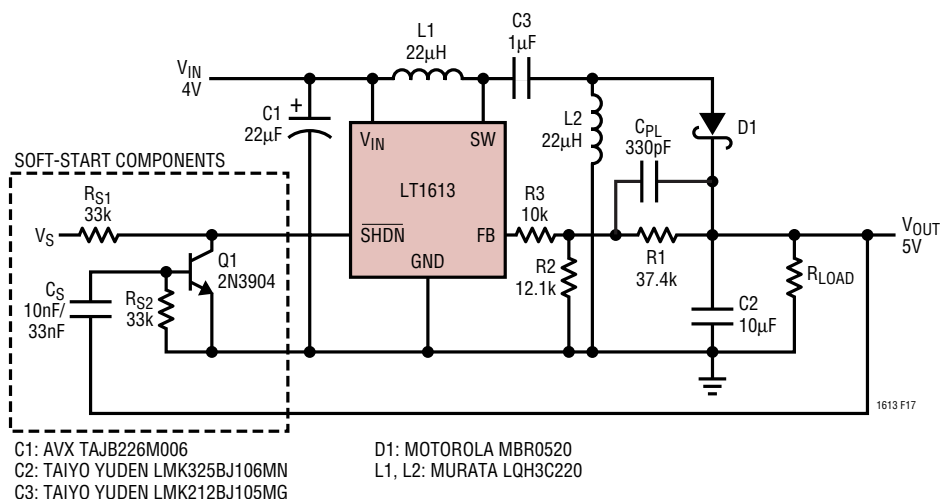
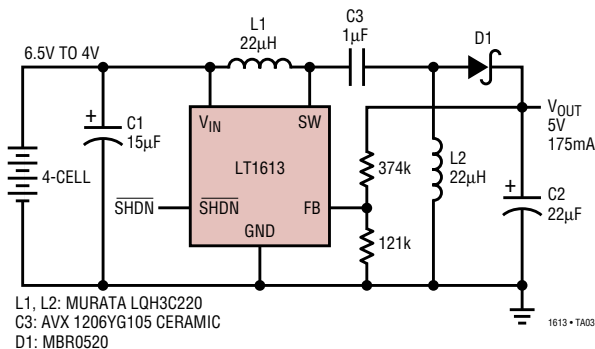


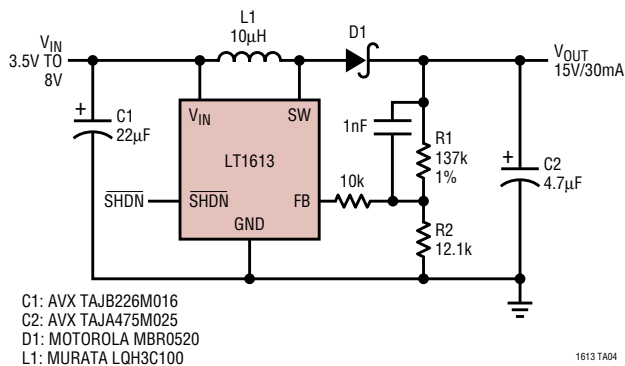
Figure 17. 5V SEPIC with Soft-Start Components

TYPICAL APPLICATIONS

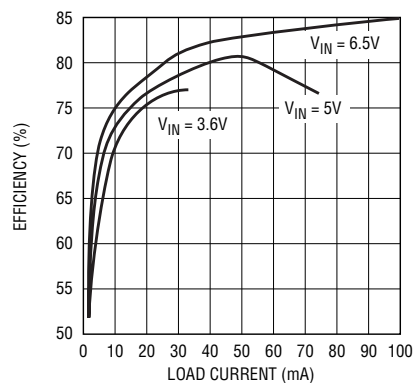
4-Cell to 5V SEPIC DC/DC Converter



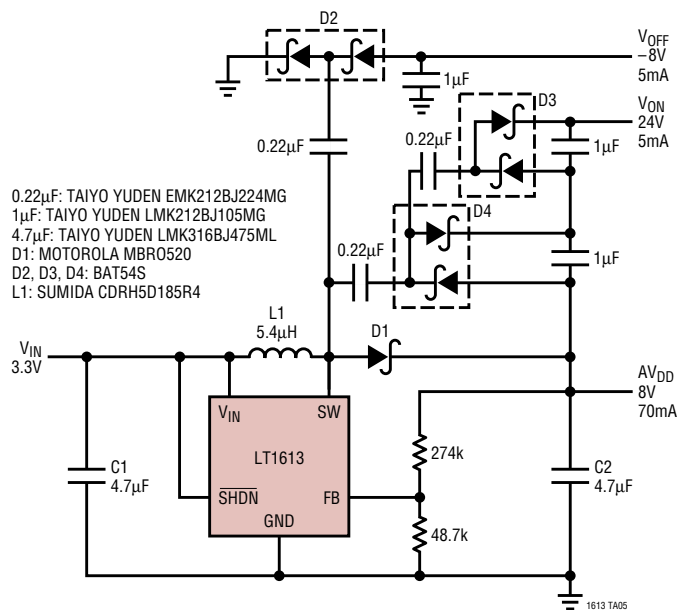
4-Cell to 15V/30mA DC/DC Converter



Efficiency

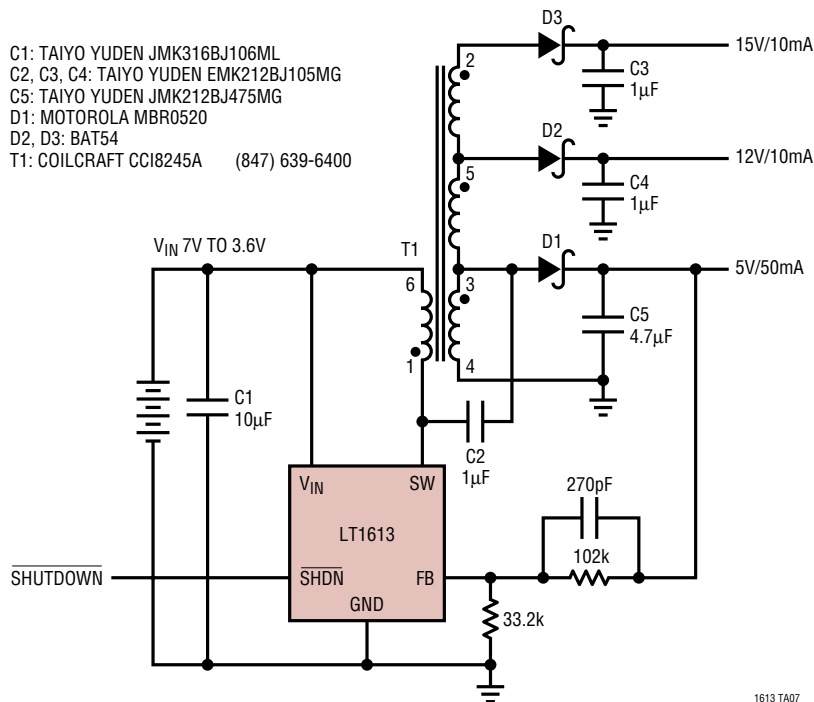


3.3V to 8V/70mA, -8V/5mA, 24V/5mA TFT LCD Bias Supply Uses All Ceramic Capacitors

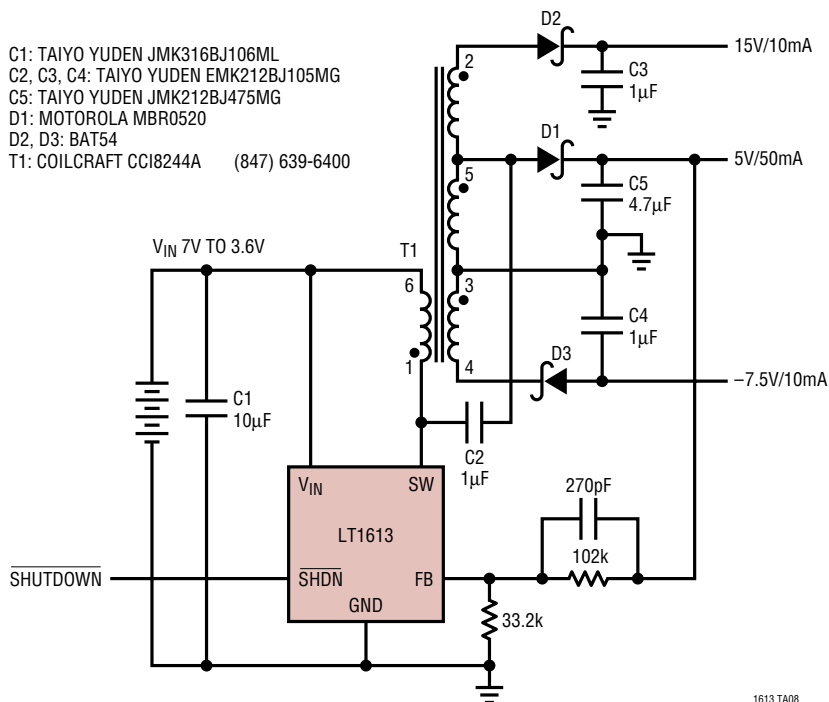


TYPICAL APPLICATIONS

4-Cell to 5V/50mA, 12V/10mA, 15V/10mA Digital Camera Power Supply

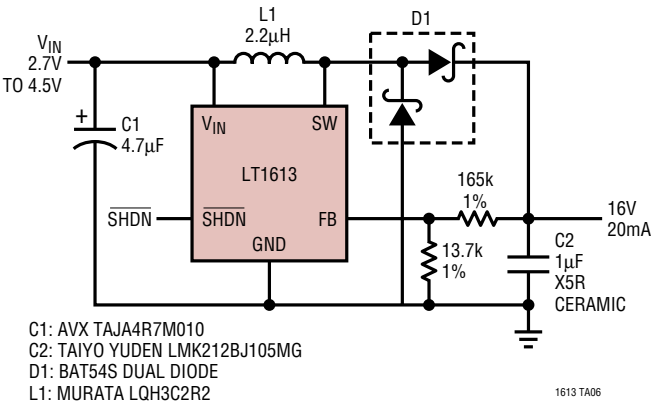


4-Cell to 5V/50mA, 15V/10mA, -7.5V/10mA Digital Camera Power Supply



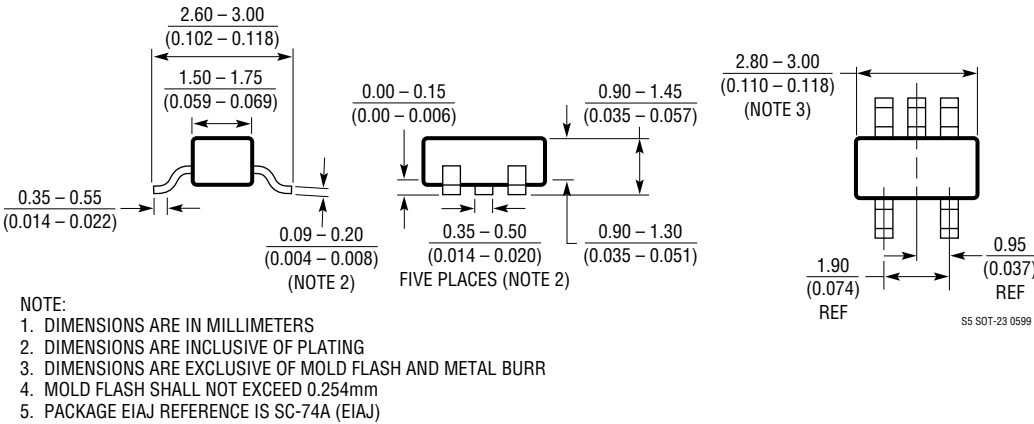
TYPICAL APPLICATIONS

Li-Ion to 16V/20mA Step-Up DC/DC Converter



PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

S5 Package
5-Lead Plastic SOT-23
(LTC DWG # 05-08-1633)



RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|-----------------|--|---|
| LT1307 | Single Cell Micropower DC/DC | 3.3V/75mA From 1V; 600kHz Fixed Frequency |
| LT1317 | 2-Cell Micropower DC/DC | 3.3V/200mA From Two Cells; 600kHz Fixed Frequency |
| LTC1474 | Low Quiescent Current, High Efficiency Step-Down Converter | 94% Efficiency, 10µA I _Q , 9V to 5V at 250µA |
| LT1521 | 300mA Low Dropout Regulator with Micropower Quiescent Current and Shutdown | 500mV Dropout, 300mA Output Current, 12µA I _Q |
| LTC1517-5 | Micropower, Regulated Charge Pump | 3-Cells to 5V at 20mA, SOT-23 Package, 6µA I _Q |
| LT1610 | 1.7MHz Single Cell Micropower DC/DC Converter | 30µA I _Q , MSOP Package, Internal Compensation |
| LT1611 | Inverting 1.4MHz Switching Regulator | 5V to -5V at 150mA, Low Output Noise |
| LT1615/LT1615-1 | Micropower DC/DC Converter in 5-Lead SOT-23 | 20V at 12mA from 2.5V Input, Tiny SOT-23 Package |