

Low-Noise Step-Up DC-DC Converters

General Description

The MAX1790/MAX8715 boost converters incorporate high-performance (at 1.2MHz), current-mode, fixed-frequency, pulse-width modulation (PWM) circuitry with a built-in 0.21Ω/0.15Ω n-channel MOSFET to provide a highly efficient regulator with fast response.

High switching frequency (640kHz or 1.2MHz selectable) allows easy filtering and faster loop performance. An external compensation pin provides the user flexibility in determining loop dynamics, allowing the use of small, low equivalent-series-resistance (ESR) ceramic output capacitors. The device can produce an output voltage as high as 12V from an input as low as 2.6V.

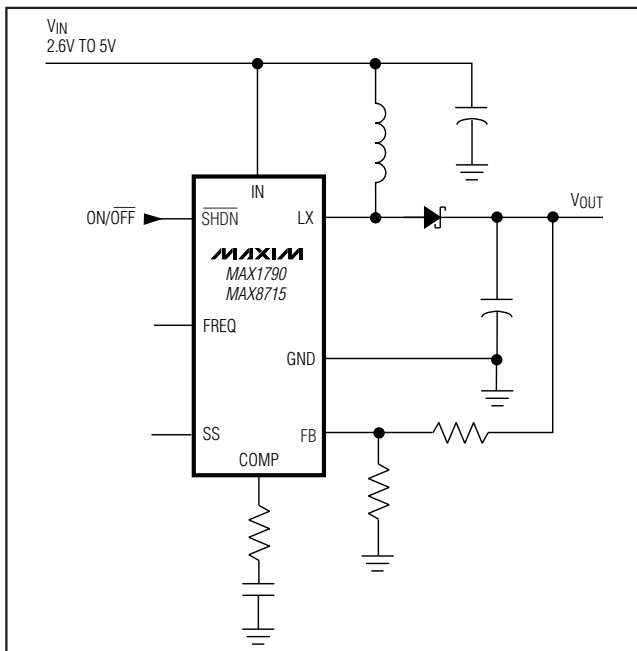
Soft-start is programmed with an external capacitor, which sets the input-current ramp rate. In shutdown mode, current consumption is reduced to 0.1μA. The MAX1790/MAX8715 are available in a space-saving 8-pin μMAX® package. The ultra-small package and high switching frequency allow the total solution to be less than 1.1mm high.

μMAX is a registered trademark of Maxim Integrated Products, Inc.

Applications

LCD Displays
PCMCIA Cards
Portable Applications
Hand-Held Devices

Typical Operating Circuit



Features

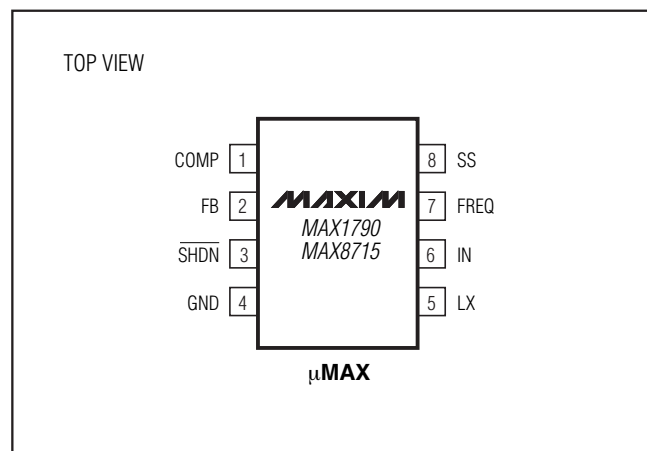
- ◆ 90% Efficiency
- ◆ Adjustable Output from V_{IN} to 12V
- ◆ 1.6A, 0.21Ω, 14V Power MOSFET (MAX1790)
- ◆ 2.4A, 0.15Ω, 14V Power MOSFET (MAX8715)
- ◆ +2.6V to +5.5V Input Range
- ◆ Pin-Selectable 640kHz or 1.2MHz Switching Frequency
- ◆ 0.1μA Shutdown Current
- ◆ Programmable Soft-Start
- ◆ Small 8-Pin μMAX Package

Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE |
|-------------|----------------|-------------|
| MAX1790EUA | -40°C to +85°C | 8 μMAX |
| MAX1790EUA+ | -40°C to +85°C | 8 μMAX |
| MAX8715EUA | -40°C to +85°C | 8 μMAX |
| MAX8715EUA+ | -40°C to +85°C | 8 μMAX |

+ Denotes lead-free package.

Pin Configuration



Low-Noise Step-Up DC-DC Converters

ABSOLUTE MAXIMUM RATINGS

| | |
|---|-----------------------------------|
| LX to GND | -0.3V to +14V |
| IN, SHDN, FREQ, FB to GND | -0.3V to +6.2V |
| SS, COMP to GND | -0.3V to (V _{IN} + 0.3V) |
| RMS LX Pin Current | 1.2A |
| Continuous Power Dissipation (T _A = +70°C) | |
| 8-Pin μMAX (derate 4.1mW/°C above +70°C) | 330mW |

| | |
|---|-----------------|
| Operating Temperature Range | |
| MAX1790EUA/MAX8715EUA | -40°C to +85°C |
| Junction Temperature | +150°C |
| Storage Temperature Range | -65°C to +150°C |
| Lead Temperature (soldering, 10s) | +300°C |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = SHDN = 3V, FREQ = GND, T_A = 0°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|--------------------------------------|--------------------|---|---------------------------------------|------|-------|-------|----|
| Input Supply Range | V _{IN} | | 2.6 | | 5.5 | V | |
| V _{IN} Undervoltage Lockout | UVLO | V _{IN} rising, typical hysteresis is 40mV, LX remains off below this level | 2.25 | 2.38 | 2.52 | V | |
| Quiescent Current | I _{IN} | MAX1790 | V _{FB} = 1.3V, not switching | 0.18 | 0.35 | mA | |
| | | | V _{FB} = 1.0V, switching | 2 | 5 | | |
| | | MAX8715 | V _{FB} = 1.3V, not switching | 0.21 | 0.35 | | |
| | | | V _{FB} = 1.0V, switching | 2.5 | 5.0 | | |
| Shutdown Supply Current | I _{IN} | SHDN = GND | | 0.1 | 10 | μA | |
| ERROR AMPLIFIER | | | | | | | |
| Feedback Voltage | V _{FB} | Level to produce V _{COMP} = 1.24V | 1.222 | 1.24 | 1.258 | V | |
| FB Input Bias Current | I _{FB} | V _{FB} = 1.24V | MAX1790 | 0 | 40 | nA | |
| | | | MAX8715 | 125 | 190 | | |
| Feedback-Voltage Line Regulation | | Level to produce V _{COMP} = 1.24V, 2.6V < V _{IN} < 5.5V | | 0.05 | 0.15 | %/V | |
| Transconductance | g _m | ΔI = 5μA | MAX1790 | 70 | 140 | 240 | μS |
| | | | MAX8715 | 70 | 160 | 240 | |
| Voltage Gain | A _V | | | 700 | | V/V | |
| OSCILLATOR | | | | | | | |
| Frequency | f _{OSC} | FREQ = GND | 540 | 640 | 740 | kHz | |
| | | FREQ = IN | 1000 | 1220 | 1500 | | |
| Maximum Duty Cycle | DC | FREQ = GND | 79 | 85 | 92 | % | |
| | | FREQ = IN | | 84 | | | |
| N-CHANNEL SWITCH | | | | | | | |
| Current Limit | I _{LIM} | V _{FB} = 1V, duty cycle = 65% (Note 1) | MAX1790 | 1.2 | 1.6 | 2.3 | A |
| | | | MAX8715 | 1.8 | 2.4 | 3.4 | |
| On-Resistance | R _{ON} | MAX1790 | | 0.21 | 0.5 | Ω | |
| | | MAX8715 | | 0.15 | 0.35 | | |
| Leakage Current | I _{LXOFF} | V _{LX} = 12V | MAX1790 | 0.01 | 20 | μA | |
| | | | MAX8715 | 5 | 30 | | |

Low-Noise Step-Up DC-DC Converters

MAX1790/MAX8715

ELECTRICAL CHARACTERISTICS (continued)

($V_{IN} = \overline{SHDN} = 3V$, $FREQ = GND$, $T_A = 0^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted. Typical values are at $T_A = +25^{\circ}C$.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---------------------------------|------------|----------------------------|---------------------|-------|------|----------|
| Current-Sense Transresistance | R_{CS} | MAX1790 | 0.30 | 0.45 | 0.65 | V/A |
| | | MAX8715 | 0.20 | 0.30 | 0.43 | |
| SOFT-START | | | | | | |
| Reset Switch Resistance | | | | | 100 | Ω |
| Charge Current | | $V_{SS} = 1.2V$ | 1.5 | 4 | 7.0 | μA |
| CONTROL INPUTS | | | | | | |
| Input Low Voltage | V_{IL} | \overline{SHDN} , $FREQ$ | $0.3 \times V_{IN}$ | | | V |
| Input High Voltage | V_{IH} | \overline{SHDN} , $FREQ$ | $0.7 \times V_{IN}$ | | | V |
| Hysteresis | | \overline{SHDN} , $FREQ$ | $0.1 \times V_{IN}$ | | | V |
| FREQ Pulldown Current | I_{FREQ} | | 1.8 | 5 | 9.0 | μA |
| \overline{SHDN} Input Current | I_{SHDN} | | | 0.001 | 1 | μA |

ELECTRICAL CHARACTERISTICS

($V_{IN} = \overline{SHDN} = 3V$, $FREQ = GND$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|----------------------------------|-----------|--|---------------------------------|------|-------|---------|
| Input Supply Range | V_{IN} | | 2.6 | | 5.5 | V |
| V_{IN} Undervoltage Lockout | UVLO | V_{IN} rising, typical hysteresis is 40mV, LX remains off below this level | 2.25 | | 2.52 | V |
| Quiescent Current | I_{IN} | MAX1790 | $V_{FB} = 1.3V$, not switching | | 0.35 | mA |
| | | | $V_{FB} = 1.0V$, switching | | 5 | |
| | | MAX8715 | $V_{FB} = 1.3V$, not switching | | 0.35 | |
| | | | $V_{FB} = 1.0V$, switching | | 5 | |
| Shutdown Supply Current | I_{IN} | $\overline{SHDN} = GND$ | | | 10 | μA |
| ERROR AMPLIFIER | | | | | | |
| Feedback Voltage | V_{FB} | Level to produce $V_{COMP} = 1.24V$ | 1.215 | 1.24 | 1.260 | V |
| FB Input Bias Current | I_{FB} | $V_{FB} = 1.24V$ | MAX1790 | | 40 | nA |
| | | | MAX8715 | | 190 | |
| Feedback-Voltage Line Regulation | | Level to produce $V_{COMP} = 1.24V$, $2.6V < V_{IN} < 5.5V$ | | | 0.15 | %/V |
| Transconductance | g_m | $\Delta I = 5\mu A$ | MAX1790 | 70 | 260 | μS |
| | | | MAX8715 | 70 | 260 | |
| OSCILLATOR | | | | | | |
| Frequency | f_{OSC} | $FREQ = GND$ | 490 | | 770 | kHz |
| | | $FREQ = IN$ | 900 | | 1500 | |
| Maximum Duty Cycle | DC | $FREQ = GND$ | 78 | | 92 | % |

Low-Noise Step-Up DC-DC Converters

ELECTRICAL CHARACTERISTICS (continued)

($V_{IN} = \overline{SHDN} = 3V$, $FREQ = GND$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|-------------------------------|-----------|---|---------|---------------------|-----|---------------------|----------|
| N-CHANNEL SWITCH | | | | | | | |
| Current Limit | I_{LIM} | $V_{FB} = 1V$, duty cycle = 65% (Note 1) | MAX1790 | 1.2 | | 2.3 | A |
| | | | MAX8715 | 1.8 | | 3.0 | |
| On-Resistance | R_{ON} | MAX1790 | | | | 0.5 | Ω |
| | | MAX8715 | | | | 0.35 | |
| Current-Sense Transresistance | R_{CS} | MAX1790 | | 0.30 | | 0.65 | V/A |
| | | MAX8715 | | 0.20 | | 0.43 | |
| CONTROL INPUTS | | | | | | | |
| Input Low Voltage | V_{IL} | \overline{SHDN} , FREQ | | | | $0.3 \times V_{IN}$ | V |
| Input High Voltage | V_{IH} | \overline{SHDN} , FREQ | | $0.7 \times V_{IN}$ | | | V |

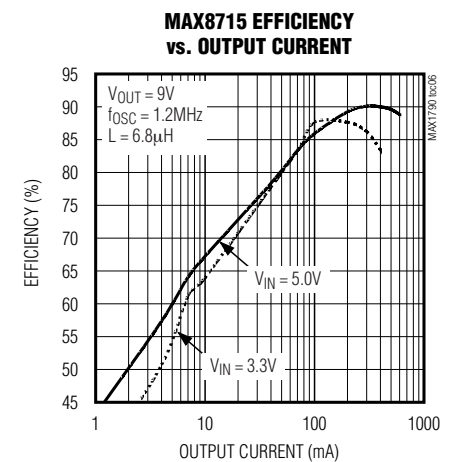
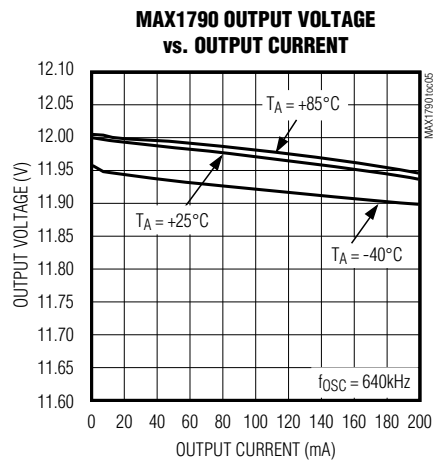
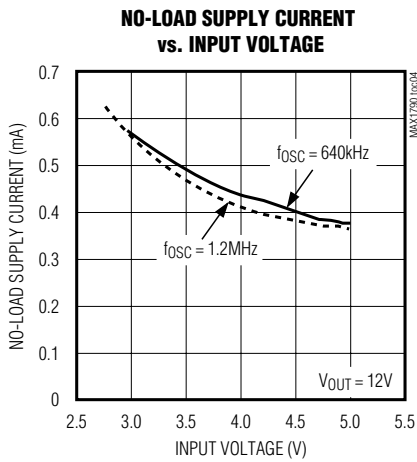
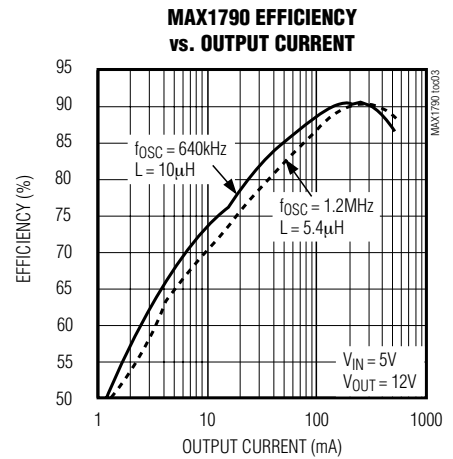
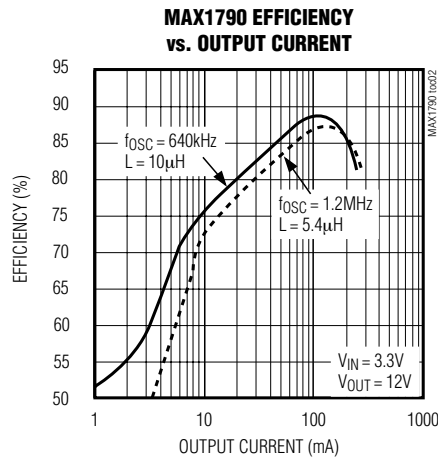
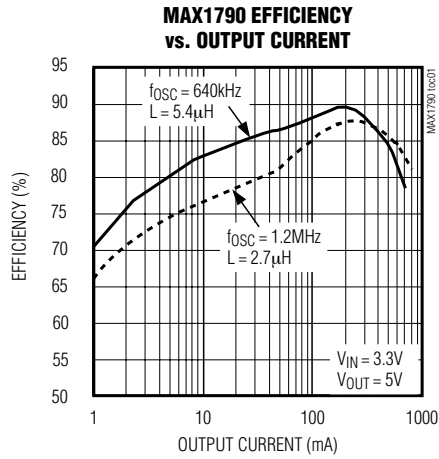
Note 1: Current limit varies with duty cycle due to slope compensation. See the *Output-Current Capability* section.

Note 2: Specifications to $-40^{\circ}C$ are guaranteed by design and not production tested.

Low-Noise Step-Up DC-DC Converters

Typical Operating Characteristics

(Circuit of Figure 1, $V_{IN} = 3.3V$, $f_{OSC} = 640kHz$, $T_A = +25^\circ C$, unless otherwise noted.)



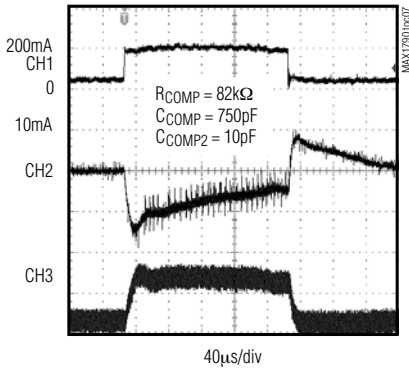
MAX1790/MAX8715

Low-Noise Step-Up DC-DC Converters

Typical Operating Characteristics (continued)

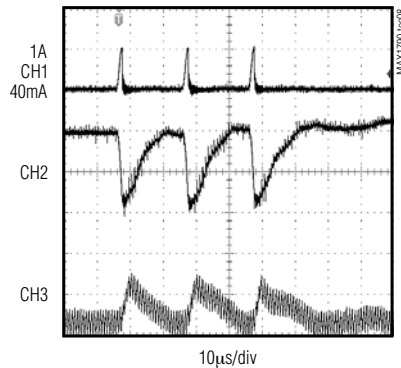
(Circuit of Figure 1, $V_{IN} = 3.3V$, $f_{OSC} = 640kHz$, $T_A = +25^\circ C$, unless otherwise noted.)

MAX8715 LOAD-TRANSIENT RESPONSE



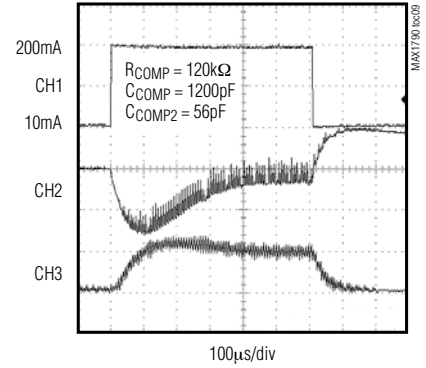
CH1 = LOAD CURRENT, 200mA/div
 CH2 = OUTPUT VOLTAGE, AC-COUPLED, 100mV/div
 CH3 = INDUCTOR CURRENT, 500mA/div
 $V_{IN} = 3.3V$, $V_{OUT} = 9.0V$
 $f_{OSC} = 1.2MHz$, $L = 6.8\mu H$, $C_{OUT} = 3 \times 3.3\mu F$

MAX8715 PULSED LOAD-TRANSIENT RESPONSE



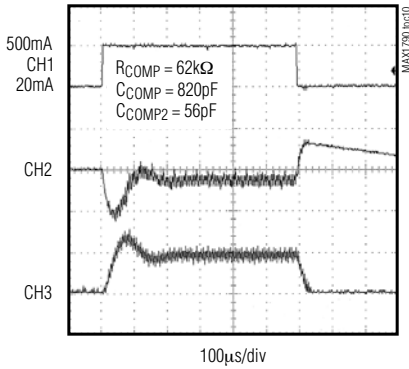
CH1 = LOAD CURRENT, 1A/div
 CH2 = OUTPUT VOLTAGE, AC-COUPLED, 100mV/div
 CH3 = INDUCTOR CURRENT, 500mA/div
 $V_{IN} = 3.3V$, $V_{OUT} = 9.0V$
 $f_{OSC} = 1.2MHz$, $L = 6.8\mu H$, $C_{OUT} = 3 \times 3.3\mu F$

MAX1790 LOAD-TRANSIENT RESPONSE



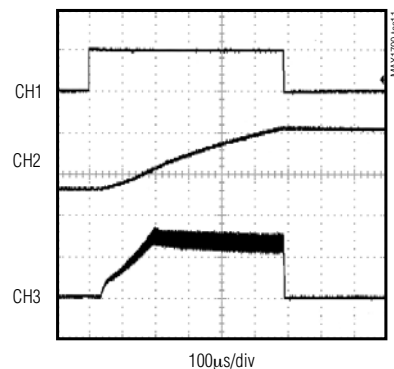
CH1 = LOAD CURRENT, 100mA/div
 CH2 = OUTPUT VOLTAGE, AC-COUPLED, 200mV/div
 CH3 = INDUCTOR CURRENT, 1A/div
 $V_{IN} = 3V$
 $V_{OUT} = 12V$, $f_{OSC} = 640kHz$, $C_{OUT} = 33\mu F + 0.1\mu F$

MAX1790 LOAD-TRANSIENT RESPONSE



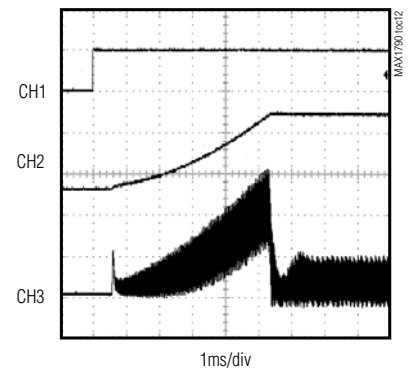
CH1 = LOAD CURRENT, 500mA/div
 CH2 = OUTPUT VOLTAGE, AC-COUPLED, 200mV/div
 CH3 = INDUCTOR CURRENT, 1A/div
 $V_{OUT} = 5V$, $f_{OSC} = 640kHz$, $C_{OUT} = 47\mu F + 0.1\mu F$

MAX1790 STARTUP WAVEFORM WITHOUT SOFT-START



CH1 = \overline{SHDN} , 5V/div
 CH2 = OUTPUT VOLTAGE, 5V/div
 CH3 = INDUCTOR CURRENT, 1A/div
 $V_{IN} = 3.3V$, $V_{OUT} = 12V$, $I_{OUT} = 10mA$, $f_{OSC} = 640kHz$
 NO SOFT-START CAPACITOR, $C_{OUT} = 33\mu F$

STARTUP WAVEFORM WITH SOFT-START



CH1 = \overline{SHDN} , 5V/div
 CH2 = OUTPUT VOLTAGE, 5V/div
 CH3 = INDUCTOR CURRENT, 200mA/div
 $V_{OUT} = 12V$, $I_{OUT} = 10mA$, $f_{OSC} = 640kHz$,
 $C_{SS} = 0.027\mu F$, $C_{OUT} = 33\mu F$

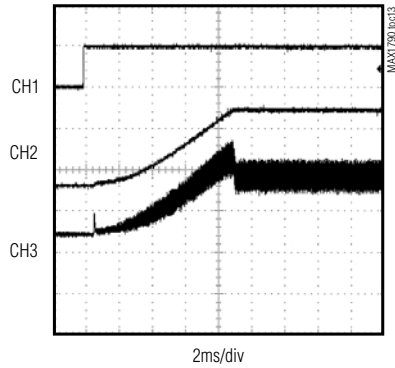
Low-Noise Step-Up DC-DC Converters

Typical Operating Characteristics (continued)

(Circuit of Figure 1, $V_{IN} = 3.3V$, $f_{OSC} = 640kHz$, $T_A = +25^\circ C$, unless otherwise noted.)

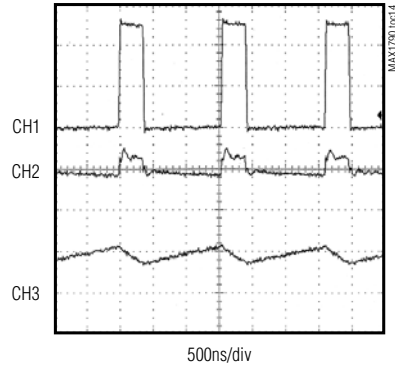
MAX1790/MAX8715

STARTUP WAVEFORM WITH SOFT-START



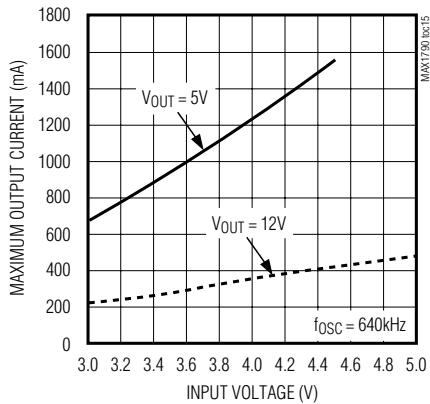
CH1 = \overline{SHDN} , 5V/div
 CH2 = V_{OUT} , 5V/div
 CH3 = INDUCTOR CURRENT, 500mA/div
 $V_{OUT} = 12V$, $I_{OUT} = 200mA$, $f_{OSC} = 640kHz$,
 $C_{SS} = 0.027\mu F$

SWITCHING WAVEFORM

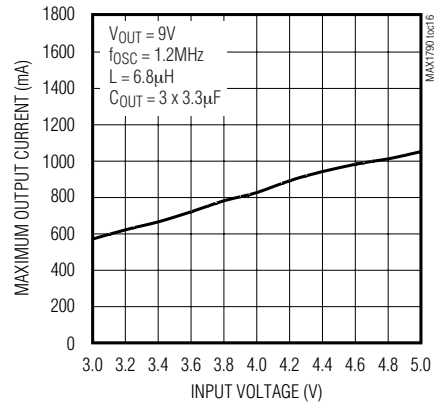


CH1 = LX SWITCHING WAVEFORM, 5V/div
 CH2 = OUTPUT VOLTAGE, AC-COUPLED, 200mV/div
 CH3 = INDUCTOR CURRENT, 1A/div
 $V_{OUT} = 12V$, $I_{OUT} = 200mA$, $f_{OSC} = 640kHz$, $L = 10\mu H$;
 $C_{OUT} = 33\mu F + 0.1\mu F$

MAX1790 MAXIMUM OUTPUT CURRENT vs. INPUT VOLTAGE



MAX8715 MAXIMUM OUTPUT CURRENT vs. INPUT VOLTAGE



Low-Noise Step-Up DC-DC Converters

Pin Description

| PIN | NAME | FUNCTION |
|-----|-------------------|---|
| 1 | COMP | Compensation Pin for Error Amplifier. Connect a series RC from COMP to ground. See the <i>Loop Compensation</i> section for component selection guidelines. |
| 2 | FB | Feedback Pin. Reference voltage is 1.24V nominal. Connect an external resistor-divider tap to FB and minimize the trace area. Set V_{OUT} according to: $V_{OUT} = 1.24V (1 + R1 / R2)$. See Figure 1. |
| 3 | \overline{SHDN} | Shutdown Control Input. Drive \overline{SHDN} low to turn off the MAX1790/MAX8715. |
| 4 | GND | Ground |
| 5 | LX | Switch Pin. Connect the inductor/catch diode to LX and minimize the trace area for lowest EMI. |
| 6 | IN | Supply Pin. Bypass IN with at least a 1 μ F ceramic capacitor directly to GND. |
| 7 | FREQ | Frequency Select Input. When FREQ is low, the oscillator frequency is set to 640kHz. When FREQ is high, the frequency is 1.2MHz. This input has a 5 μ A pulldown current. |
| 8 | SS | Soft-Start Control Pin. Connect a soft-start capacitor (C_{SS}) to this pin. Leave open for no soft-start. The soft-start capacitor is charged with a constant current of 4 μ A. Full current limit is reached after $t = 2.5 \times 10^5 C_{SS}$. The soft-start capacitor is discharged to ground when \overline{SHDN} is low. When \overline{SHDN} goes high, the soft-start capacitor is charged to 0.5V, after which soft-start begins. |

Detailed Description

The MAX1790/MAX8715 are highly efficient power supplies that employ a current-mode, fixed-frequency PWM architecture for fast transient response and low-noise operation. The device regulates the output voltage through a combination of an error amplifier, two comparators, and several signal generators (Figure 2). The error amplifier compares the signal at FB to 1.24V and varies the COMP output. The voltage at COMP determines the current trip point each time the internal MOSFET turns on. As the load varies, the error amplifier sources or sinks current to the COMP output accordingly to produce the inductor peak current necessary to service the load. To maintain stability at high duty cycle, a slope-compensation signal is summed with the current-sense signal.

At light loads, this architecture allows the ICs to “skip” cycles to prevent overcharging the output voltage. In this region of operation, the inductor ramps up to a fixed peak value (approximately 50mA, MAX1790 or 75mA, MAX8715), discharges to the output, and waits until another pulse is needed again.

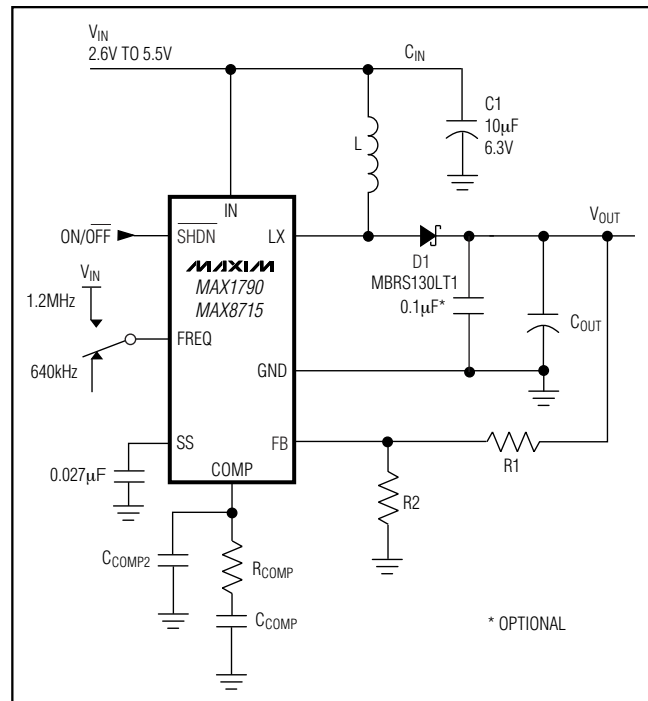


Figure 1. Typical Application Circuit

Low-Noise Step-Up DC-DC Converters

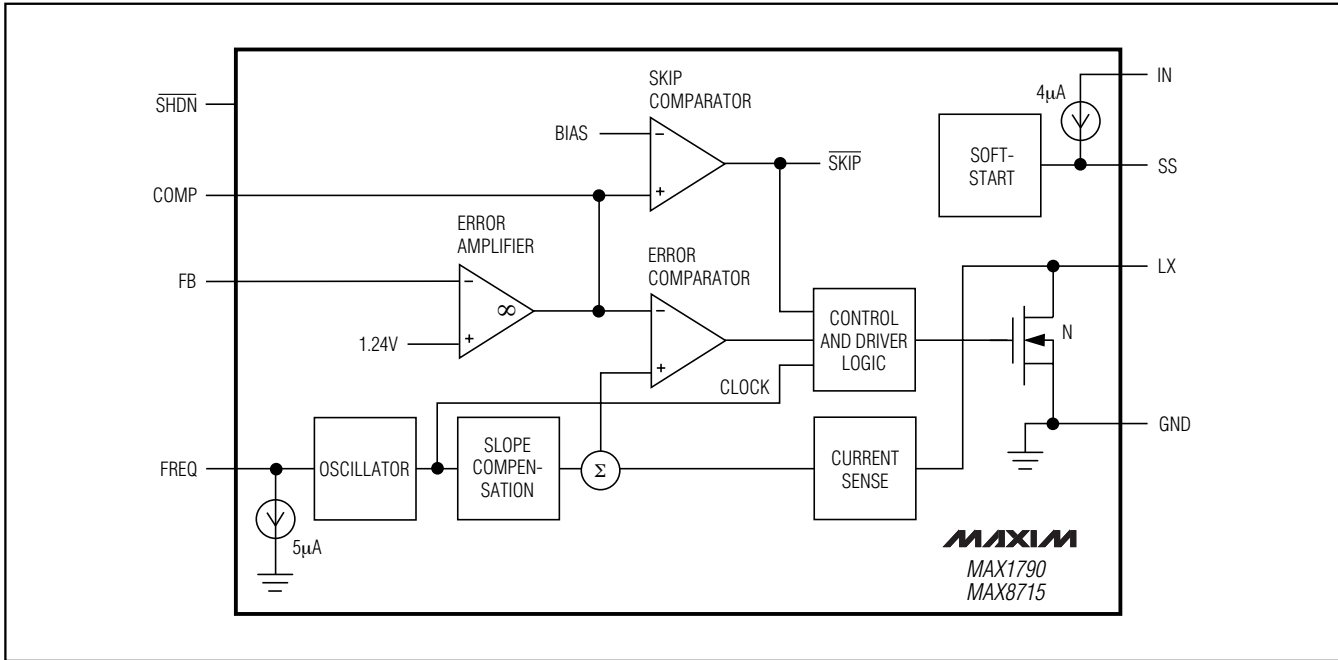


Figure 2. Functional Diagram

Output-Current Capability

The output-current capability of the MAX1790/MAX8715 is a function of current limit, input voltage, operating frequency, and inductor value. Because of the slope compensation used to stabilize the feedback loop, the duty cycle affects the current limit. The output-current capability is governed by the following equation:

$$I_{OUT(MAX)} = [I_{LIM} \times (1.26 - 0.4 \times \text{Duty}) - 0.5 \times \text{Duty} \times V_{IN} / (f_{OSC} \times L)] \times \eta \times V_{IN} / V_{OUT}$$

where:

I_{LIM} = current limit specified at 65% (see the *Electrical Characteristics*)

$$\text{Duty} = \text{duty cycle} = (V_{OUT} - V_{IN} + V_{DIODE}) / (V_{OUT} - I_{LIM} \times R_{ON} + V_{DIODE})$$

V_{DIODE} = catch diode forward voltage at I_{LIM}

η = conversion efficiency, 85% nominal

Soft-Start

The MAX1790/MAX8715 can be programmed for soft-start upon power-up with an external capacitor. When the shutdown pin is taken high, the soft-start capacitor (C_{SS}) is immediately charged to 0.5V. Then the capacitor is charged at a constant current of 4µA (typ). During this time, the SS voltage directly controls the peak inductor current, allowing 0A at $V_{SS} = 0.5V$ to the full current limit at $V_{SS} = 1.5V$. The maximum load current is available

after the soft-start cycle is completed. When the shutdown pin is taken low, the soft-start capacitor is discharged to ground.

Frequency Selection

The MAX1790/MAX8715s' frequency can be user selected to operate at either 640kHz or 1.2MHz. Connect FREQ to GND for 640kHz operation. For a 1.2MHz switching frequency, connect FREQ to IN. This allows the use of small, minimum-height external components while maintaining low output noise. FREQ has an internal pulldown, allowing the user the option of leaving FREQ unconnected for 640kHz operation.

Shutdown

The MAX1790/MAX8715 are shut down to reduce the supply current to 0.1µA when $\overline{\text{SHDN}}$ is low. In this mode, the internal reference, error amplifier, comparators, and biasing circuitry turn off while the n-channel MOSFET is turned off. The boost converter's output is connected to IN by the external inductor and catch diode.

Applications Information

Boost DC-DC converters using the MAX1790/MAX8715 can be designed by performing simple calculations for a first iteration. All designs should be prototyped and tested prior to production. Table 1 provides a list of

Low-Noise Step-Up DC-DC Converters

Table 1. Component Selection

| V _{IN} (V) | V _{OUT} (V) | f _{osc} (Hz) | L (μH) | C _{OUT} (μF) | R _{COMP} (kΩ) | C _{COMP} (pF) | C _{COMP2} (pF) | I _{OUT(MAX)} (mA) |
|---------------------|----------------------|-----------------------|-----------------------------|---|------------------------|------------------------|-------------------------|----------------------------|
| MAX1790 | | | | | | | | |
| 3.3 | 12 | 640k | 10 (Sumida CDRH5D18-100NC) | 33 tantalum (AVX TPSD336020R0200) | 120 | 1200 | 22 | 250 |
| 3.3 | 12 | 1.2M | 5.4 (Sumida CDRH5D18-5R4NC) | 33 tantalum (AVX TPSD336020R0200) | 180 | 650 | 20 | 250 |
| 3.3 | 5 | 640k | 5.4 (Sumida CDRH5D18-5R4NC) | 47 tantalum (6TPA47M) | 62 | 820 | 56 | 800 |
| 3.3 | 5 | 1.2M | 2.7 (Sumida CDRH4D18-2R7) | 47 tantalum (6TPA47M) | 91 | 390 | 33 | 800 |
| MAX8715 | | | | | | | | |
| 3.3 | 9 | 1.2M | 6.8 (Sumida CLQ4D10-6R8) | 3 x 3.3 ceramic (Taiyo Yuden LMK325BJ335MD) | 82 | 750 | 10 | 150 |

Table 2. Component Suppliers

| SUPPLIER | PHONE | FAX |
|-------------------------|--------------|--------------|
| Inductors | | |
| Coilcraft | 847-639-6400 | 847-639-1469 |
| Coiltronics | 561-241-7876 | 561-241-9339 |
| Sumida USA | 847-956-0666 | 847-956-0702 |
| TOKO | 847-297-0070 | 847-699-1194 |
| Capacitors | | |
| AVX | 803-946-0690 | 803-626-3123 |
| Kemet | 408-986-0424 | 408-986-1442 |
| Sanyo | 619-661-6835 | 619-661-1055 |
| Taiyo Yuden | 408-573-4150 | 408-573-4159 |
| Diodes | | |
| Central Semiconductor | 516-435-1110 | 516-435-1824 |
| International Rectifier | 310-322-3331 | 310-322-3332 |
| Motorola | 602-303-5454 | 602-994-6430 |
| Nihon | 847-843-7500 | 847-843-2798 |
| Zetex | 516-543-7100 | 516-864-7630 |

components for a range of standard applications. Table 2 lists component suppliers.

External component value choice is primarily dictated by the output voltage and the maximum load current,

as well as maximum and minimum input voltages. Begin by selecting an inductor value. Once L is known, choose the diode and capacitors.

Inductor Selection

The minimum inductance value, peak current rating, and series resistance are factors to consider when selecting the inductor. These factors influence the converter's efficiency, maximum output load capability, transient-response time, and output voltage ripple. Physical size and cost are also important factors to be considered.

The maximum output current, input voltage, output voltage, and switching frequency determine the inductor value. Very high inductance values minimize the current ripple and therefore reduce the peak current, which decreases core losses in the inductor and I^2R losses in the entire power path. However, large inductor values also require more energy storage and more turns of wire, which increase physical size and can increase I^2R losses in the inductor. Low inductance values decrease the physical size but increase the current ripple and peak current. Finding the best inductor involves choosing the best compromise between circuit efficiency, inductor size, and cost.

The equations used here include a constant LIR, which is the ratio of the inductor peak-to-peak ripple current to the average DC inductor current at the full load current. The best trade-off between inductor size and circuit efficiency for step-up regulators generally has an LIR between 0.3 and 0.5. However, depending on the AC characteristics of the inductor core material and the

Low-Noise Step-Up DC-DC Converters

ratio of inductor resistance to other power path resistances, the best LIR can shift up or down. If the inductor resistance is relatively high, more ripple can be accepted to reduce the number of turns required and increase the wire diameter. If the inductor resistance is relatively low, increasing inductance to lower the peak current can decrease losses throughout the power path. If extremely thin high-resistance inductors are used, as is common for LCD-panel applications, the best LIR can increase to between 0.5 and 1.0.

Once a physical inductor is chosen, higher and lower values of the inductor should be evaluated for efficiency improvements in typical operating regions.

Calculate the approximate inductor value using the typical input voltage (V_{IN}), the maximum output current ($I_{MAIN(MAX)}$), the expected efficiency (η_{TYP}) taken from an appropriate curve in the *Typical Operating Characteristics*, and an estimate of LIR based on the above discussion:

$$L = \left(\frac{V_{IN}}{V_{MAIN}} \right)^2 \left(\frac{V_{MAIN} - V_{IN}}{I_{MAIN(MAX)} \times f_{OSC}} \right) \left(\frac{\eta_{TYP}}{LIR} \right)$$

Choose an available inductor value from an appropriate inductor family. Calculate the maximum DC input current at the minimum input voltage $V_{IN(MIN)}$ using conservation of energy and the expected efficiency at that operating point (η_{MIN}) taken from an appropriate curve in the *Typical Operating Characteristics*:

$$I_{IN(DC,MAX)} = \frac{I_{MAIN(MAX)} \times V_{MAIN}}{V_{IN(MIN)} \times \eta_{MIN}}$$

Calculate the ripple current at that operating point and the peak current required for the inductor:

$$I_{RIPPLE} = \frac{V_{IN(MIN)} \times (V_{MAIN} - V_{IN(MIN)})}{L \times V_{MAIN} \times f_{OSC}}$$

$$I_{PEAK} = I_{IN(DC,MAX)} + \frac{I_{RIPPLE}}{2}$$

The inductor's saturation current rating and the MAX1790/MAX8715s' LX current limit (I_{LIM}) should exceed I_{PEAK} and the inductor's DC current rating should exceed $I_{IN(DC,MAX)}$. For good efficiency, choose an inductor with less than 0.1Ω series resistance.

Considering the application circuit in Figure 4, the maximum load current ($I_{MAIN(MAX)}$) is 150mA with a 9V output and a typical input voltage of 3.3V. Choosing an LIR of 0.5 and estimating efficiency of 85% at this operating point:

$$L = \left(\frac{3.3V}{9V} \right)^2 \left(\frac{9V - 3.3V}{0.15A \times 1.2MHz} \right) \left(\frac{0.85}{0.5} \right) \approx 6.8\mu H$$

Using the circuit's minimum input voltage (3V) and estimating efficiency of 80% at that operating point:

$$I_{IN(DC,MAX)} = \frac{0.15A \times 9V}{3V \times 0.8} \approx 0.6A$$

The ripple current and the peak current are:

$$I_{RIPPLE} = \frac{3V \times (9V - 3V)}{6.8\mu H \times 9V \times 1.2MHz} \approx 0.25A$$

$$I_{PEAK} = 0.6A + \frac{0.25A}{2} \approx 0.725A$$

Diode Selection

The output diode should be rated to handle the output voltage and the peak switch current. Make sure that the diode's peak current rating is at least I_{PK} and that its breakdown voltage exceeds V_{OUT} . Schottky diodes are recommended.

Input and Output Capacitor Selection

Low-ESR capacitors are recommended for input bypassing and output filtering. Low-ESR tantalum capacitors are a good compromise between cost and performance. Ceramic capacitors are also a good choice. Avoid standard aluminum electrolytic capacitors. A simple equation to estimate input and output-capacitor values for a given voltage ripple is as follows:

$$C \geq \frac{0.5 \times L \times (I_{PK}^2)}{V_{RIPPLE} \times V_{OUT}}$$

where V_{RIPPLE} is the peak-to-peak ripple voltage on the capacitor.

Output Voltage

The MAX1790/MAX8715 operate with an adjustable output from V_{IN} to 13V. Connect a resistor voltage-divider to FB (see the *Typical Operating Circuit*) from the output to GND. Select the resistor values as follows:

$$R1 = R2 \left(\frac{V_{OUT}}{V_{FB}} - 1 \right)$$

where V_{FB} , the boost-regulator feedback set point, is 1.24V. Since the input bias current into FB is typically 0,

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R2 can have a value up to 100kΩ without sacrificing accuracy. Connect the resistor-divider as close to the IC as possible.

Loop Compensation

The voltage feedback loop needs proper compensation to prevent excessive output ripple and poor efficiency caused by instability. This is done by connecting a resistor (R_{COMP}) and capacitor (C_{COMP}) in series from COMP to GND, and another capacitor (C_{COMP2}) from COMP to GND. R_{COMP} is chosen to set the high-frequency integrator gain for fast transient response, while C_{COMP} is chosen to set the integrator zero to maintain loop stability. The second capacitor, C_{COMP2}, is chosen to cancel the zero introduced by output-capacitance ESR. For optimal performance, choose the components using the following equations:

$$R_{COMP} \cong (200\Omega / A^2) \times V_{OUT}^2 \times C_{OUT} / L \quad (\text{MAX1790})$$

$$R_{COMP} \cong (274\Omega / A) \times V_{IN} \times V_{OUT} \times C_{OUT} / (L \times I_{OUT}) \quad (\text{MAX8715})$$

$$C_{COMP} \cong (0.4 \times 10^{-3} A/\Omega) \times L / V_{IN} \quad (\text{MAX1790})$$

$$C_{COMP} \cong (0.36 \times 10^{-3} A/\Omega) \times L / V_{IN} \quad (\text{MAX8715})$$

$$C_{COMP2} \cong (0.005 A^2/\Omega) \times RESR \times L / V_{OUT}^2 \quad (\text{MAX1790})$$

$$C_{COMP2} \cong (0.0036 A/\Omega) \times RESR \times L \times I_{OUT} / (V_{IN} \times V_{OUT}) \quad (\text{MAX8715})$$

For the ceramic output capacitor, where ESR is small, C_{COMP2} is optional. Table 1 shows experimentally verified external component values for several applications. The best gauge of correct loop compensation is by inspecting the transient response of the MAX1790/MAX8715. Adjust R_{COMP} and C_{COMP} as necessary to obtain optimal transient performance.

Soft-Start Capacitor

The soft-start capacitor should be large enough that it does not reach final value before the output has reached regulation. Calculate C_{SS} to be:

$$C_{SS} > 21 \times 10^{-6} \times C_{OUT} \left(\frac{V_{OUT}^2 - V_{IN} \times V_{OUT}}{V_{IN} \times I_{NRUSH} - I_{OUT} \times V_{OUT}} \right)$$

where:

C_{OUT} = total output capacitance including any bypass capacitor on the output bus

V_{OUT} = maximum output voltage

I_{NRUSH} = peak inrush current allowed

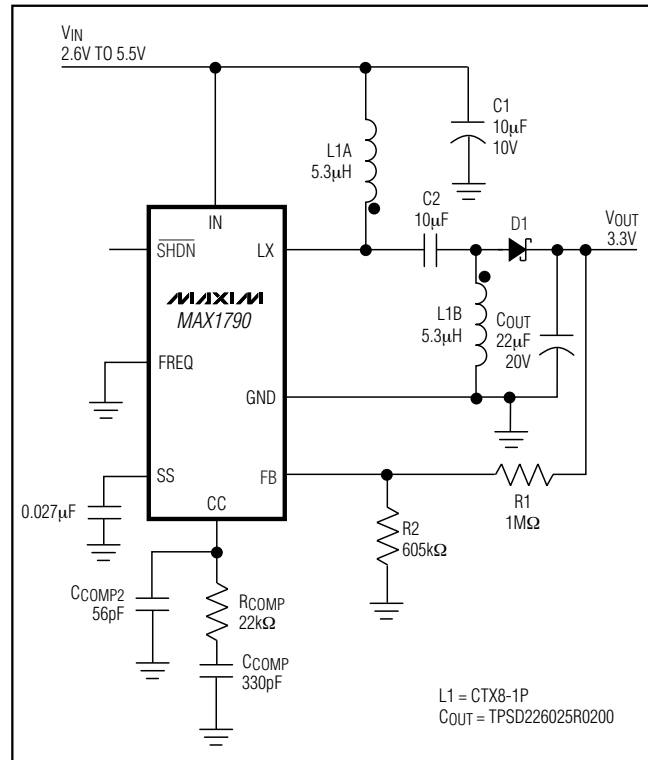


Figure 3. MAX1790 in a SEPIC Configuration

I_{OUT} = maximum output current during power-up stage

V_{IN} = minimum input voltage

The load must wait for the soft-start cycle to finish before drawing a significant amount of load current. The duration after which the load can begin to draw maximum load current is:

$$t_{MAX} = 6.77 \times 10^5 C_{SS}$$

Application Circuits

1-Cell to 3.3V SEPIC Power Supply

Figure 3 shows the MAX1790 in a single-ended primary inductance converter (SEPIC) topology. This topology is useful when the input voltage can be either higher or lower than the output voltage, such as when converting a single lithium-ion (Li+) cell to a 3.3V output. L1A and L1B are two windings on a single inductor. The coupling capacitor between these two windings must be a low-ESR type to achieve maximum efficiency, and must also be able to handle high ripple currents. Ceramic capacitors are best for this application. The circuit in Figure 3 provides 400mA output current at 3.3V output when operating with an input voltage from +2.6V to +5.5V.

Low-Noise Step-Up DC-DC Converters

MAX1790/MAX8715

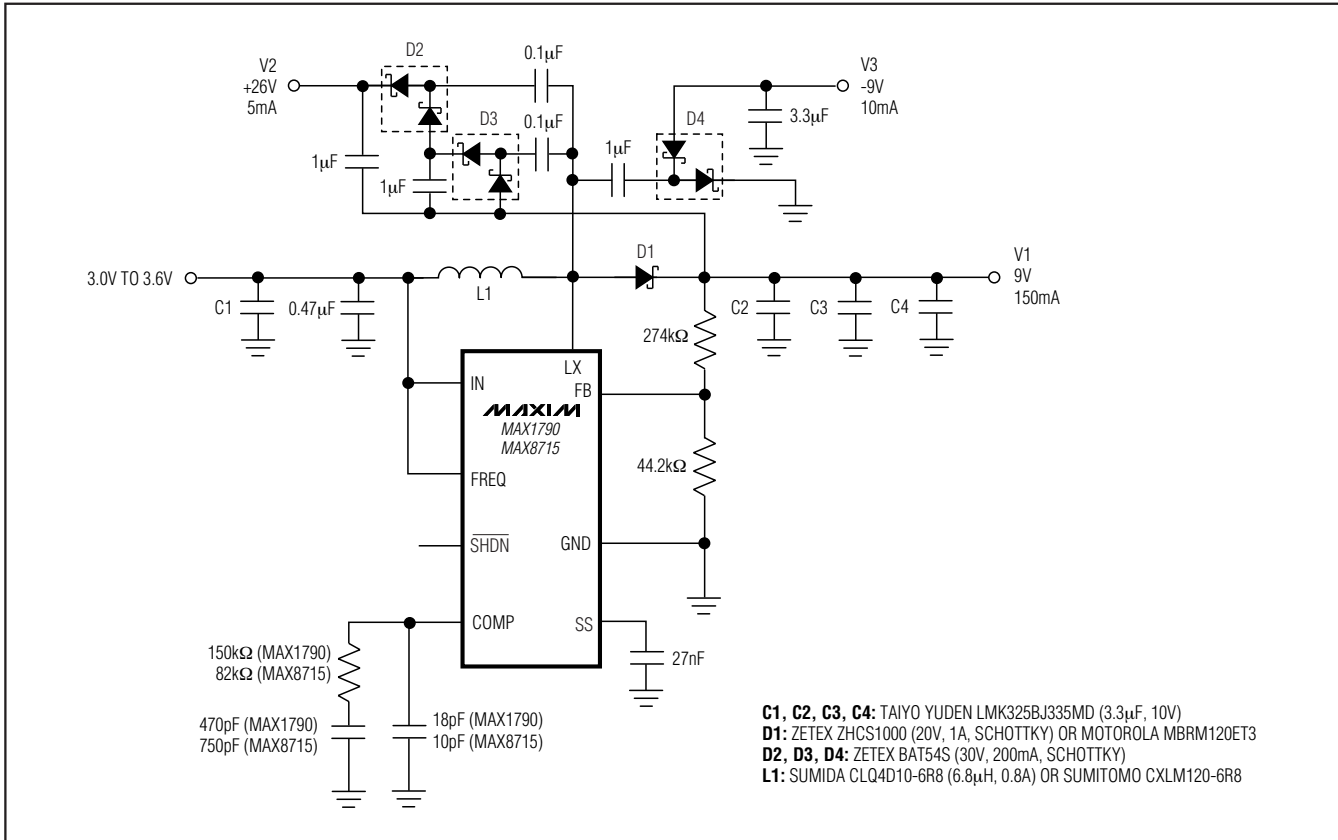


Figure 4. Multiple-Output, Low-Profile (1.2mm max) TFT-LCD Power Supply

AMLCD Application

Figure 4 shows a power supply for active matrix (TFT-LCD) flat-panel displays. Output-voltage transient performance is a function of the load characteristic. Add or remove output capacitance (and recalculate compensation-network component values) as necessary to meet transient performance. Regulation performance for secondary outputs (V2 and V3) depends on the load characteristics of all three outputs.

Layout Procedure

Good PC board layout and routing are required in high-frequency switching power supplies to achieve good reg-

ulation, high efficiency, and stability. It is strongly recommended that the evaluation kit PC board layouts be followed as closely as possible. Place power components as close together as possible, keeping their traces short, direct, and wide. Avoid interconnecting the ground pins of the power components using vias through an internal ground plane. Instead, keep the power components close together and route them in a star ground configuration using component-side copper, then connect the star ground to internal ground using multiple vias.

Chip Information

TRANSISTOR COUNT: 1012

Low-Noise Step-Up DC-DC Converters

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)

| DIM | INCHES | | MILLIMETERS | |
|----------|-------------|-------------|-------------|-------------|
| | MIN | MAX | MIN | MAX |
| A | - | 0.043 | - | 1.10 |
| A1 | 0.002 | 0.006 | 0.05 | 0.15 |
| A2 | 0.030 | 0.037 | 0.75 | 0.95 |
| b | 0.010 | 0.014 | 0.25 | 0.36 |
| c | 0.005 | 0.007 | 0.13 | 0.18 |
| D | 0.116 | 0.120 | 2.95 | 3.05 |
| e | 0.0256 BSC | | 0.65 BSC | |
| E | 0.116 | 0.120 | 2.95 | 3.05 |
| H | 0.188 | 0.198 | 4.78 | 5.03 |
| L | 0.016 | 0.026 | 0.41 | 0.66 |
| α | 0 $^\infty$ | 6 $^\infty$ | 0 $^\infty$ | 6 $^\infty$ |
| S | 0.0207 BSC | | 0.5250 BSC | |

NOTES:
 1. D&E DO NOT INCLUDE MOLD FLASH.
 2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15MM (.006").
 3. CONTROLLING DIMENSION: MILLIMETERS.
 4. MEETS JEDEC MO-187C-AA.

DALLAS SEMICONDUCTOR **MAXIM**
 PROPRIETARY INFORMATION
 TITLE: PACKAGE OUTLINE, 8L uMAX/uSOP
 APPROVAL: DOCUMENT CONTROL NO. 21-0036 REV. J 1/1

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