Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

MAX742

General Description

The MAX742 DC-DC converter is a controller for dual-output power supplies in the 3W to 60W range. Relying on simple two-terminal inductors rather than transformers, the MAX742 regulates both outputs independently to within ±4% over all conditions of line voltage, temperature, and load current.

The MAX742 has high efficiency (up to 92%) over a wide range of output loading. Two independent PWM current-mode feedback loops provide tight regulation and operation free from subharmonic noise. The MAX742 can operate at 100kHz or 200kHz, so it can be used with small and lightweight external components. Also, ripple and noise are easy to filter. The MAX742 provides a regulated output for inputs ranging from 4.2V to 10V (and higher with additional components).

External power MOSFETs driven directly from the MAX742 are protected by cycle-by-cycle overcurrent sensing. The MAX742 also features undervoltage lock-out, thermal shutdown, and programmable soft-start.

Inductors and capacitors to complement the MAX742 can be ordered directly from Maxim in production quantities (see Ordering Information). Refer to the MAXL001 and MAXC001 data sheets for detailed product specifications. If 3W of load power or less is needed, refer to the MAX743 data sheet for a device with internal power MOSFETS.

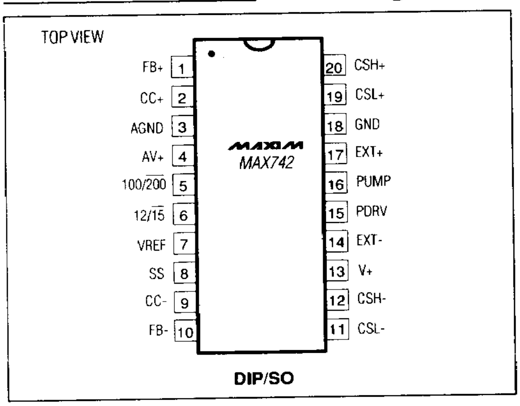
Applications

DC-DC Converter Module Replacement

Distributed Power Systems

Computer Peripherals

Pin Configuration



Features

- ◆ Specs Guaranteed for In-Circuit Performance
- ◆ Load Currents to ±2A
- ◆ 4.2V to 10V Input-Voltage Range
- ◆ Switches From ±15V to ±12V Under Logic Control
- ◆ ±4% Output Tolerance Max Over Temp, Line, and Load
- ◆ 90% Typ Efficiency
- ◆ Low-Noise, Current-Mode Feedback
- ◆ Cycle-by-Cycle Current Limiting
- ◆ Undervoltage Lock-Out and Soft-Start
- ◆ 100kHz or 200kHz Operation

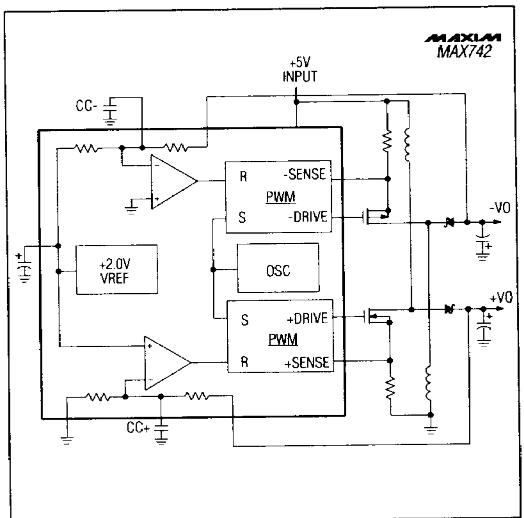
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX742CPP	0°C to +70°C	20 Plastic DIP
MAX742CWP	0°C to +70°C	20 Wide SO
MAX742C/D	0°C to +70°C	Dice
MAX742EPP	-40°C to +85°C	20 Plastic DIP
MAX742EWP	-40°C to +85°C	20 Wide SO
MAX742MJP	-55°C to +125°C	20 CERDIP

Ordering Information continued on page 15.

4

Simplified Block Diagram



Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

ABSOLUTE MAXIMUM RATINGS

V+, AV+ to AGND, GND ....-0.3V to +12V
PDRV to V+ ....+0.3V to -17V
FB+, FB- to GND ....±25V
Input Voltage to GND
(CC+, CC-, CSH+, CSL+, CSH-, CSL-,
SS, 100/$\overline{200}$K, 12/$\overline{15}$V) ....-0.3V to (V+)+0.3V
Output Voltage to GND
(EXT+, PUMP) ....-0.3V to (V+)+0.3V
EXT- to PDRV ....-0.3V to (V+)+0.3V

Power Dissipation (any Package) to +75°C 500mW
Derates Above +75°C by .... 10mw/°C
Operating Temperature Ranges
MAX742C_ _ ....0°C to +70°C
MAX742E_ _ ....-40°C to +85°C
MAX742MJP ....-55°C to +125°C
Storage Temperature Range ....-65°C to +160°C
Lead Temperature (Soldering, 10 sec.) .... +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

(Circuit of Figure 2, +4.5V < V+ < +5.5V.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage, ±15V Mode (Notes 1, 2)		0 < I_L < 100mA, 12/$\overline{15}$V = 0V T_A = 25°C T_A = T_{MIN} to T_{MAX}	 14.55 14.40		 15.45 15.60	V
Output Voltage, ±12V Mode (Notes 1, 2)		0 < I_L < 125mA, 12/$\overline{15}$V = V+ T_A = 25°C T_A = T_{MIN} to T_{MAX}	 11.64 11.52		 12.36 12.48	V

ELECTRICAL CHARACTERISTICS

(Circuit of Figure 2, V+ = +5V, 100/$\overline{200}$K = 12/$\overline{15}$ = 0V; T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Line Regulation		V+ = 4.5V to 5.5V, PDRV from PUMP		0.01	0.05	%/%
Load Regulation (Note 2)		I_{LOAD} = 0 to 100mA		30	100	mV
No-Load Supply Current		No EXT+, EXT- or PUMP Load, FB+ = FB- = open circuit; V+ = +5V V+ = +10V			3 10	mA
Undervoltage Lock-Out	UVLO		3.8		4.2	V
Undervoltage Lock-Out Hysteresis				0.2		V
Reference Output Voltage				2.0		V
Oscillator Frequency	f_{OSC}	100/$\overline{200}$K = 0V 100/$\overline{200}$K = V+	170 75	200 100	230 125	kHz
PUMP Frequency				$f_{OSC}/2$		
Duty-Cycle Limit (Note 3)		EXT+ or EXT-	85	90		%
Positive Current-Limit Threshold (CSH+ to CSL+)		CSL+ = 0V, FB+ = open circuit	150	225	300	mV
Negative Current-Limit Threshold (CSH- to CSL-)		CSH- = V+, FB- = open circuit	150	225	300	mV

ELECTRICAL CHARACTERISTICS (Continued)

(Circuit of Figure 2, V+ = +5V, 100/$\overline{200}$K = 12/$\overline{15}$V = 0V; T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage High	V_{OH}	EXT+, EXT-, IL = 1mA, V+ = 4.5V, PDRV = -3V		4.3			V
Output Voltage Low	V_{OL}	EXT+, EXT-, IL = -1mA, V+ = 4.5V, PDRV = -3V				-2.8	V
Output Sink Current		V+ = 4.5V, PDRV = -3V, T_A = 25°C	EXT+ = 4.5V EXT- = 4.5V	100 200	200 350		mA
Output Source Current		V+ = 4.5V, PDRV = -3V, T_A = 25°C	EXT+ = 0V EXT- = -3V		-200 -350	-100 -200	mA
Output Rise/Fall Time		EXT+, C_{LOAD} = 2nF EXT-, C_{LOAD} = 4nF, PDRV = -3V			70 100		ns
PUMP Output Voltage (Note 4)		V+ = 4.5V, IL = -5mA, T_A = 25°C				-3	V
Compensation Pin Impedance		CC+, CC-			10		kΩ
Thermal-Shutdown Threshold					190		°C
Soft-Start Source Current		SS = 0V		3		7	µA
Soft-Start Sink Current		V+ = 3.8V, SS = 2V			-2	-0.5	mA

Note 1: Devices are 100% tested to these limits under 0mA to 100mA and to 125mA load conditions using automatic test equipment. The ability to drive loads up to 1A is guaranteed by the current-limit threshold, output swing, and the output current source/sink tests. See Figures 2 and 3.

Note 2: Actual load capability of the circuit of Figure 2 is ±200mA in ±15V mode and ±250mA in ±12V mode. Load regulation is tested at lower limits due to test equipment limitations.

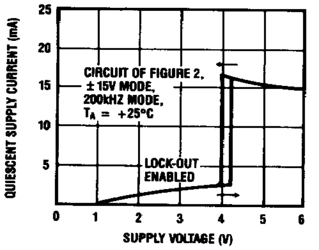
Note 3: Guaranteed by design.

Note 4: Measured at Point A, circuit of Figure 2, with PDRV disconnected.

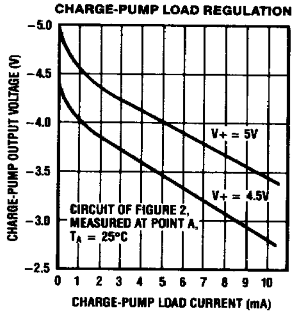
Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

Typical Operating Characteristics

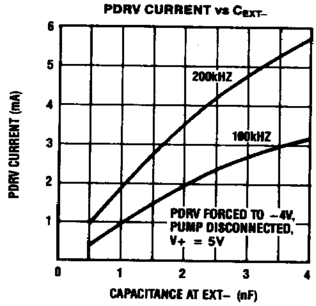
UNDERVOLTAGE LOCK-OUT HYSTERESIS



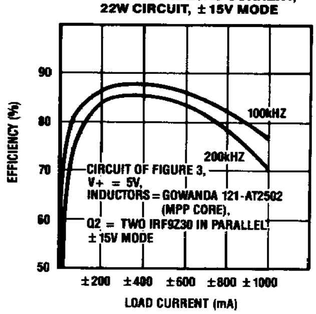
CHARGE-PUMP LOAD REGULATION



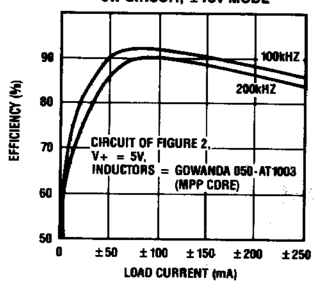
PDRV CURRENT vs C_{EXT-}



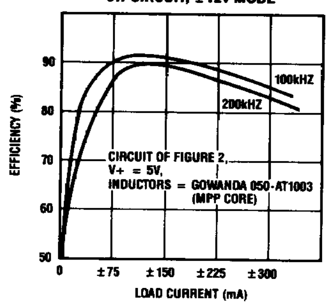
EFFICIENCY vs LOAD CURRENT, 22W CIRCUIT, ±15V MODE



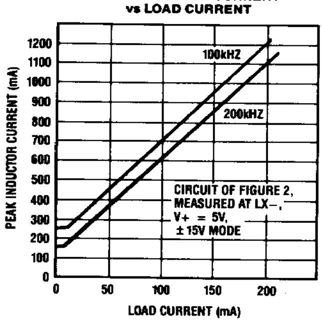
EFFICIENCY vs LOAD CURRENT, 6W CIRCUIT, ±15V MODE



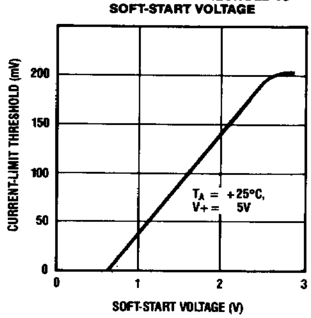
EFFICIENCY vs LOAD CURRENT, 6W CIRCUIT, ±12V MODE



PEAK INDUCTOR CURRENT vs LOAD CURRENT

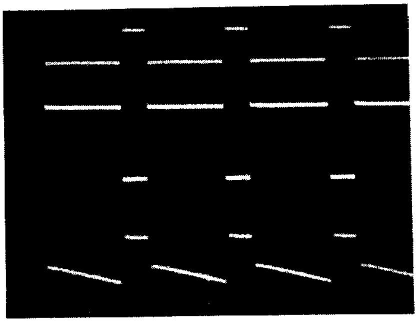


CURRENT-LIMIT THRESHOLD vs SOFT-START VOLTAGE



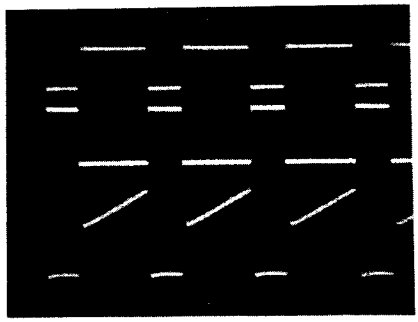
Typical Operating Characteristics (continued)

SWITCHING WAVEFORMS Inverting Section



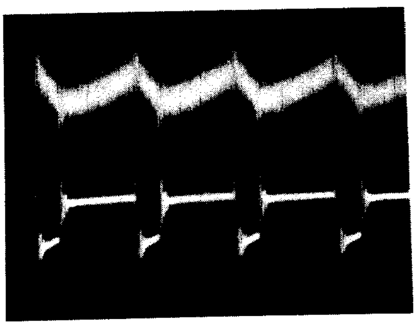
A = Gate Drive, 5V/div
B = Switch Voltage, 10V/div
C = Switch Current, 0.2A/div
Horizontal = 2μs/div
I_{LOAD} = 100mA
Circuit of Figure 2

SWITCHING WAVEFORMS Step-up Section



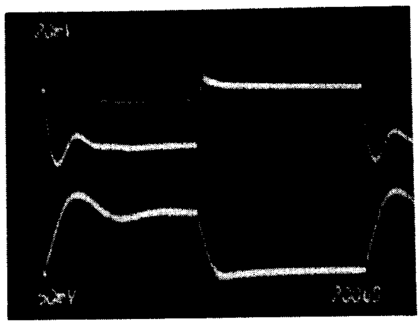
A = Gate Drive, 5V/div
B = Switch Voltage, 10V/div
C = Switch Current, 0.2A/div
Horizontal = 2μs/div
I_{LOAD} = 100mA
Circuit of Figure 2

OUTPUT-VOLTAGE NOISE, FILTERED AND UNFILTERED



A = Noise with PI Filter, 1mV/div
B = Noise without Filter, 20mV/div
Horizontal = 2μs/div
Measured at $-V_{OUT}$
I_{LOAD} = 100mA
V+ = 5V
BW = 5MHz
Circuit of Figure 2

LOAD TRANSIENT RESPONSE



A = +VO, 20mV/div
B = −VO, 50mV/div
Horizontal = 200μs/div
I_{LOAD} = 0 to ± 100mA
Circuit of Figure 2

Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

Pin Description

PIN	NAME	FUNCTION
1	FB+	Step-Up Feedback Input
2	CC+	Step-Up Compensation Capacitor
3	AGND	Analog Ground
4	AV+	Analog Supply Voltage Input (+5V)
5	$100/\overline{200}$	Selects Osc Frequency. Ground for 200kHz, or tie to V+ for 100kHz.
6	$12/\overline{15}$	Selects V_{OUT}. Ground for ±15V, or tie to V+ for ±12V.
7	VREF	Reference Voltage Output (+2.00V) (force to GND or V+ to disable chip).
8	SS	Soft-Start Timing Capacitor (sources 5µA)
9	CC-	Inverting Compensation Capacitor
10	FB-	Inverting Section Feedback Input
11	CSL-	Current Sense Low (Inverting Section)
12	CSH-	Current Sense High (Inverting Section)
13	V+	High-Current Supply Voltage Input (+5V)
14	EXT-	Push-Pull Output - drives external P-channel MOSFET.
15	PDRV	Voltage Input - negative supply for P-channel MOSFET driver.
16	PUMP	Charge-Pump Driver - clock output at 1/2 Oscillator Frequency.
17	EXT+	Push-Pull Output - drives external logic-level N-channel MOSFET.
18	GND	High-Current Ground
19	CSL+	Current Sense Low (Step-Up Section)
20	CSH+	Current Sense High (Step-Up Section)

Operating Principle

Each current-mode controller consists of a summing amplifier that adds three signals: the current waveform from the power switch FET, an output-voltage error signal, and a ramp signal for AC compensation generated by the oscillator. The output of the summing amplifier resets a flip-flop, which in turn activates the power FET driver stage (Figure 1).

Both external transistor switches are synchronized to the oscillator and turn on simultaneously when the flip-flop is set. The switches turn off individually when their source currents reach a trip threshold determined by the output-voltage error signal. This creates a duty-cycle modulated pulse train at the oscillator frequency, where the on time is proportional to both the output-voltage error signal and the peak inductor current. Low peak currents or high output-voltage error signals result in a high duty cycle (up to 90% maximum).

AC stability is enhanced by the internal ramp signal applied to the error amplifier. This scheme eliminates regenerative "staircasing" of the inductor current, otherwise a problem when in continuous current mode and >50% duty cycle. Note that the slope of the ramp signal generated by the current-sense resistor must always be proportional to this internal ramp signal. Lower sense-resistor values necessitate lower inductor values in order to maintain the correct slope. As a rough guide for selecting an inductor value based on the value of the sense resistor, multiply by 0.001:

$L \text{ (Henries)} = R_{SENSE} \text{ (Ohms)} \times 0.001$

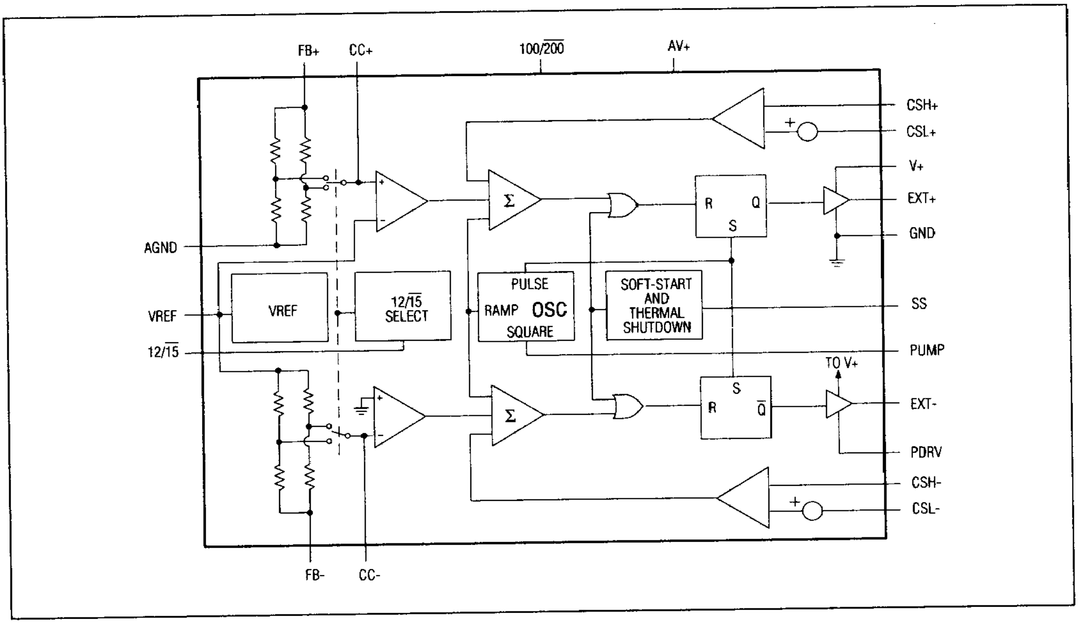


Figure 1. MAX742 Detailed Block Diagram

Detailed Description

100kHz/200kHz Oscillator

The MAX742 oscillator frequency is generated without external components and can be set at 100kHz or 200kHz by pin strapping. Operating the device at 100kHz results in lower supply current and improved efficiency, particularly with light loads. However, component stresses are increased and noise becomes more difficult to filter. For a given inductor value, the lower operating frequency results in slightly higher peak currents in the inductor and switch transistor (see Typical Operating Characteristics, Peak Inductor Current vs. Load Current graph). When the lower frequency is used in conjunction with a LC-type output filter (optional components in Figure 2), larger component values are required for equivalent filtering.

Charge-Pump Voltage Inverter

The charge-pump (PUMP) output is a rail-to-rail square wave at half the oscillator frequency. The square wave drives an external diode-capacitor circuit to generate a negative DC voltage (Point A in Figure 2), which in turn biases the inverting-output drive stage via PDRV. The charge pump thus increases the gate-source voltage applied to the external P-channel FET. The low on resistance resulting from increased gate drive ensures high efficiency and guarantees start-up under heavy loads. If a -5V to -10V supply is already available, it can be tied directly to PDRV and all of the charge-pump components removed. For input voltages greater than 8V, ground PDRV to prevent overvoltage. Observe PDRV Absolute Maximum Ratings.

Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

Supply-Voltage Range

Although designed for operation from a +5V logic supply, the MAX742 works well from 4.2V (the upper limit of the undervoltage lock-out threshold) to +10V (absolute maximum rating plus a safety margin). The upper limit can be further increased by limiting the voltage at V+ with a zener shunt or series regulator (see MAX742/MAX743 Application Notes). To ensure AC stability, the inductor value should be scaled linearly with the nominal input voltage. For example, if the application circuit of Figure 3 is powered from a nominal 9V source, the inductor value should be increased to 40µH or 50µH. At high input voltages (>8V), the charge pump can cause overvoltage at PDRV. If the input can exceed 8V, ground PDRV and remove the capacitors and diodes associated with the charge pump.

In-Circuit Testing for Guaranteed Performance

The circuit in Figure 2 has been tested at all extremes of line, load, and temperature. Refer to the Electrical Characteristics table for guaranteed in-circuit specifications. Successful use of this circuit requires no component calculations.

For designs that differ significantly from the basic applications, or for those who have an academic interest in the MAX742, design and component information is covered in detail in UM-3, MAX742/MAX743 Application Notes.

Standard 6W Application

The 6W supply (Figure 2) generates ±200mA at ±15V, or ±250mA at ±12V. By heatsinking the power FETs, using cores with higher current capability (such as Gowanda #050AT1003), and using higher filter capacitance, output capability is increased to 10W or more.

Ferrite and MPP inductor cores optimize efficiency and size. Iron-powder toroids designed for high frequencies (such as MAXL001) are economical, but are larger. Efficiency with MAXL001 inductors is about 80% at full load.

With MAXL001 inductors and MAXC001 or equivalent output filter capacitors, output-voltage ripple at full load is about 100mVp-p at the oscillator frequency (200kHz). Ripple is directly proportional to filter capacitor equivalent series resistance (ESR). In addition, about 250mV transient noise occurs at the LX switch transitions. A very short scope probe ground lead or a shielded enclosure is needed for making accurate measurements of transient noise. Extra filtering, as shown in Figure 2, reduces both noise components.

High-Power 22W Application

The 22W application circuit (Figure 3) generates ±15V at ±750mA or ±12V at ±950mA. Noninductive wire-wound resistors with Kelvin current-sensing connections replace the metal-film resistors of the previous (6W) circuit. Gate drive for the P-channel FET is bootstrapped from the negative supply via diode D6. The 2.7V zener (D5) is required in 15V mode to prevent overvoltage. The charge pump (D3, D4, and C6) may not be necessary if the circuit is lightly loaded (<100mA) on start-up. AIE part #415-0963 is a ferrite pot-core inductor that can be used in place of the smaller, more expensive Gowanda molypermalloy toroid inductor (L1, L2). Higher efficiencies can be achieved by adding extra MOSFETs in parallel. Load levels above 10W make it necessary to add heatsinks, especially to the P-channel FET.

Printed Circuit Layouts

A good layout is essential to clean, stable operation. Use the layouts and component placement diagrams given in Figures 4 through 7. Other construction methods may result in marginal performance. In particular, avoid plastic plug-in protoboards.

Grounding is especially important for low-noise operation. Connect output loads directly across the output filter caps. A top-side ground plane will reduce switching noise and interaction between sections. The short analog ground strip on the pin 1 side of the IC should be connected to ground only by way of pin 2 (AGND). A short connection between this strip and AGND minimizes noise injected into the reference and compensation capacitors. Do not leave $12/\overline{15}$, $100/\overline{200}$, or FB floating.

Component suppliers for the two standard applications are listed at the end of this data sheet.

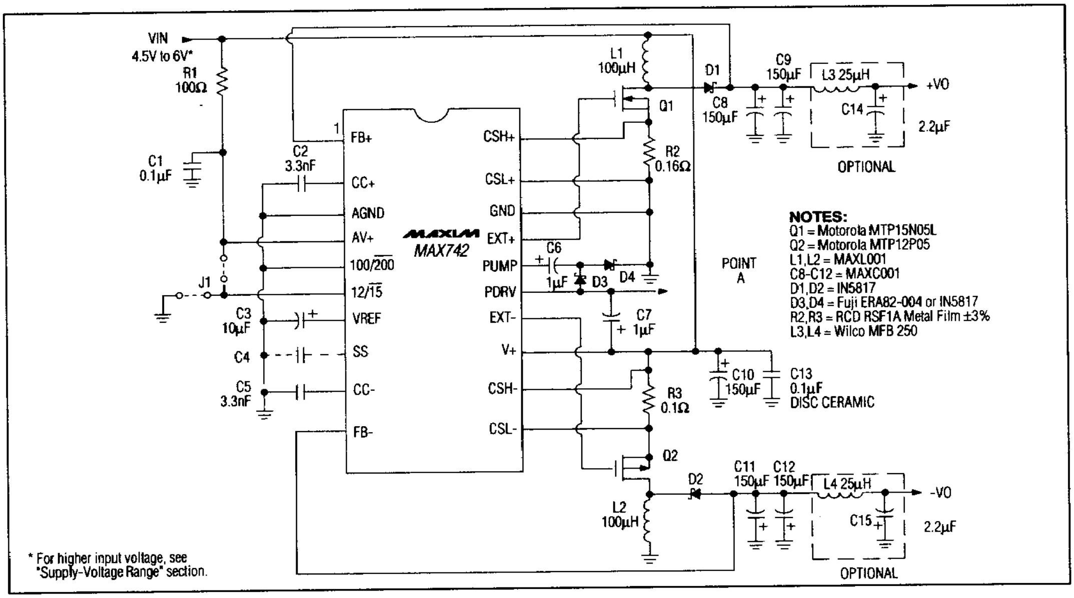


Figure 2. Standard 6W Application Circuit

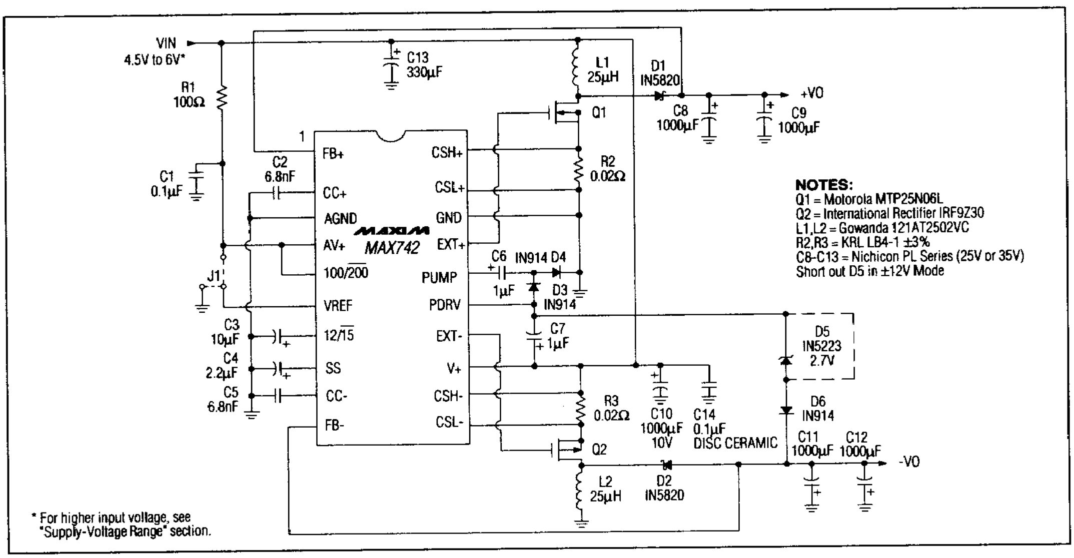


Figure 3. 22W Application Circuit

Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

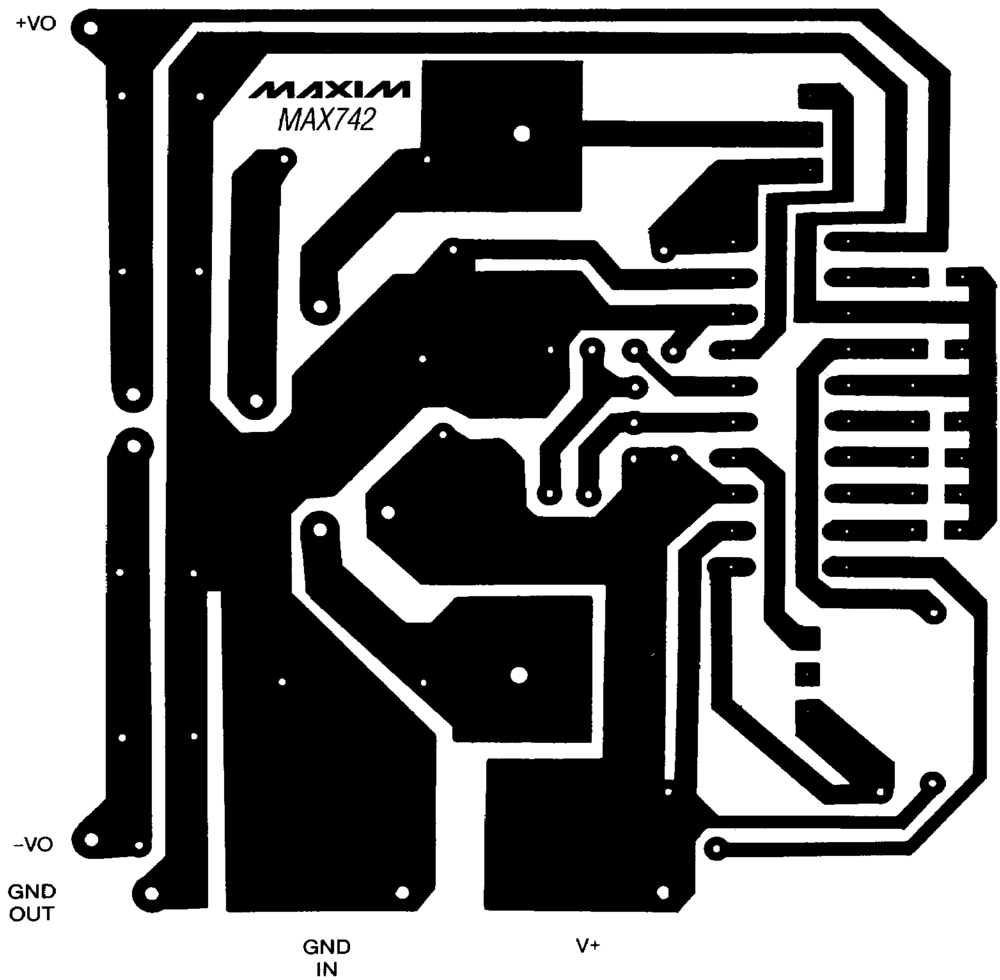


Figure 4. PC Layout for Standard 6W Application (2X Scale, Trace Side View)

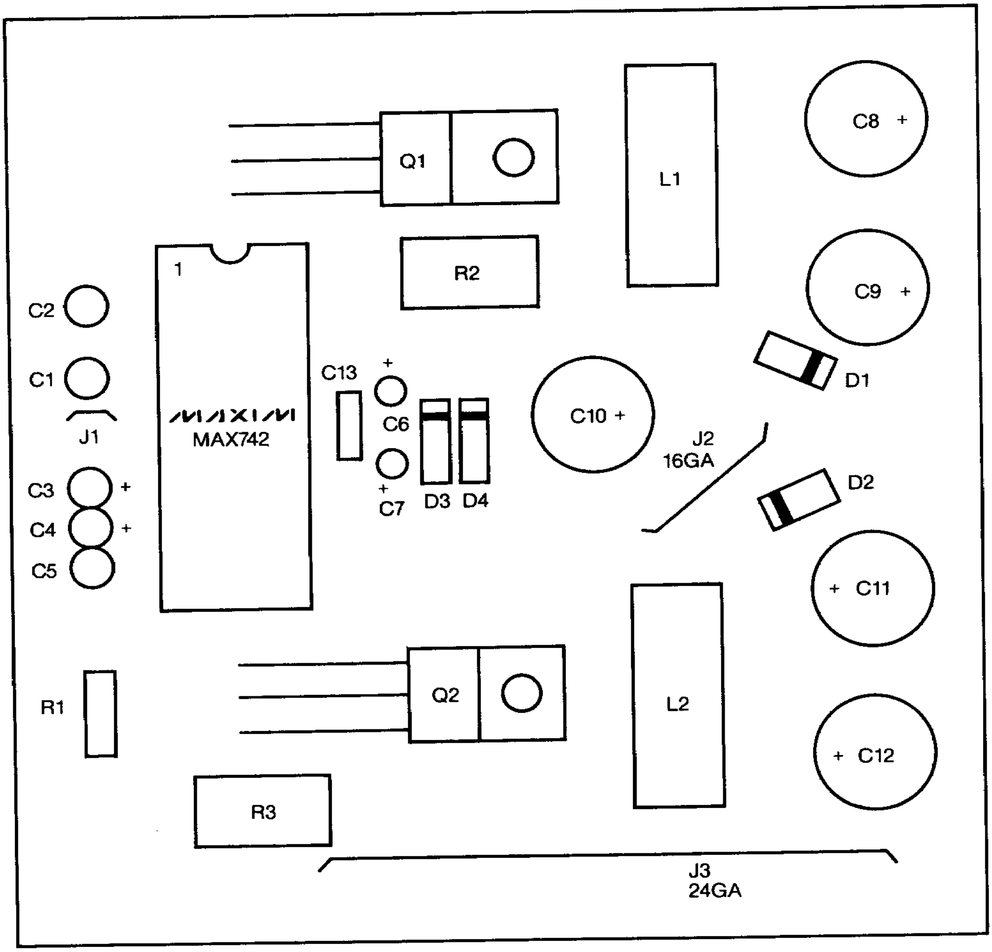


Figure 5. Component Placement for 6W Layout (Top View)

Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

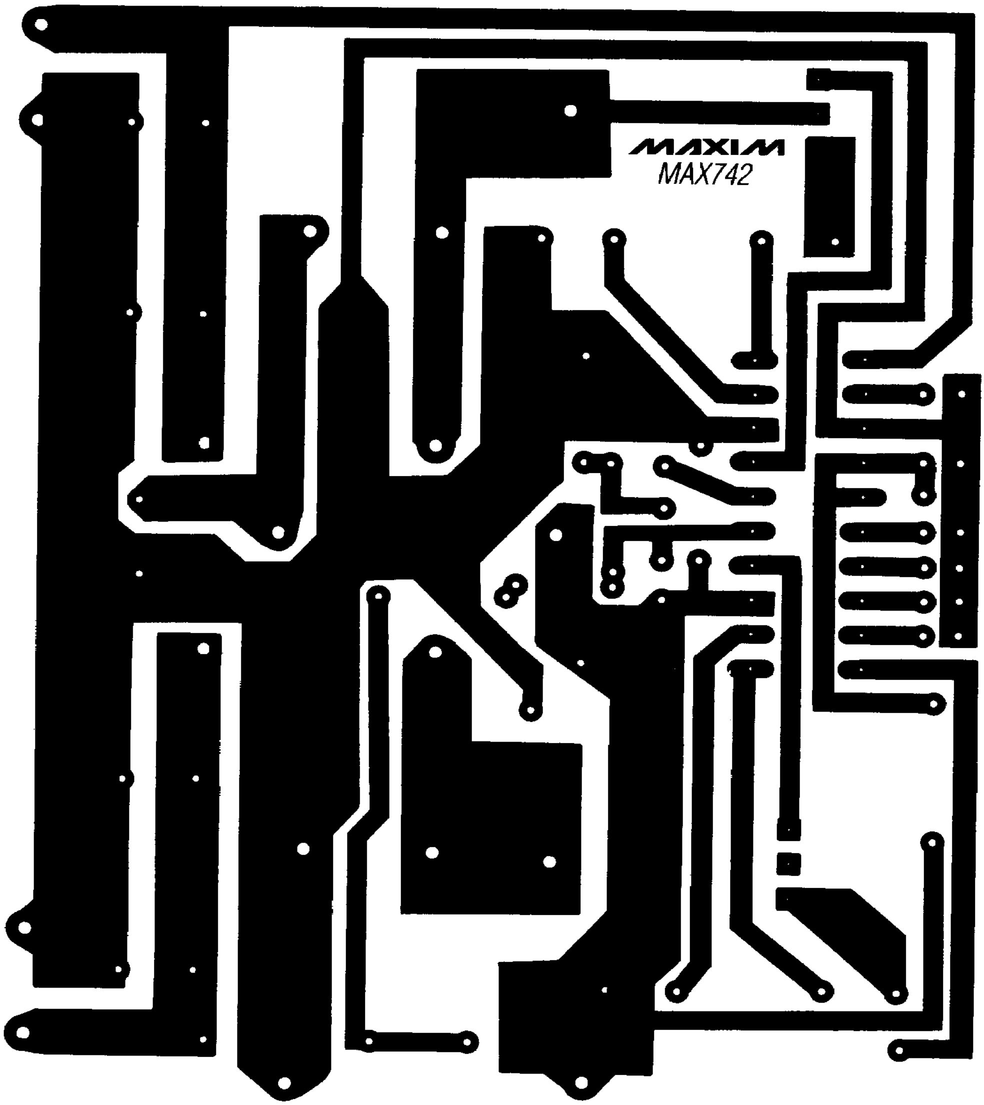


Figure 6. PC Layout for 22W Application (2X Scale, Trace Side View)

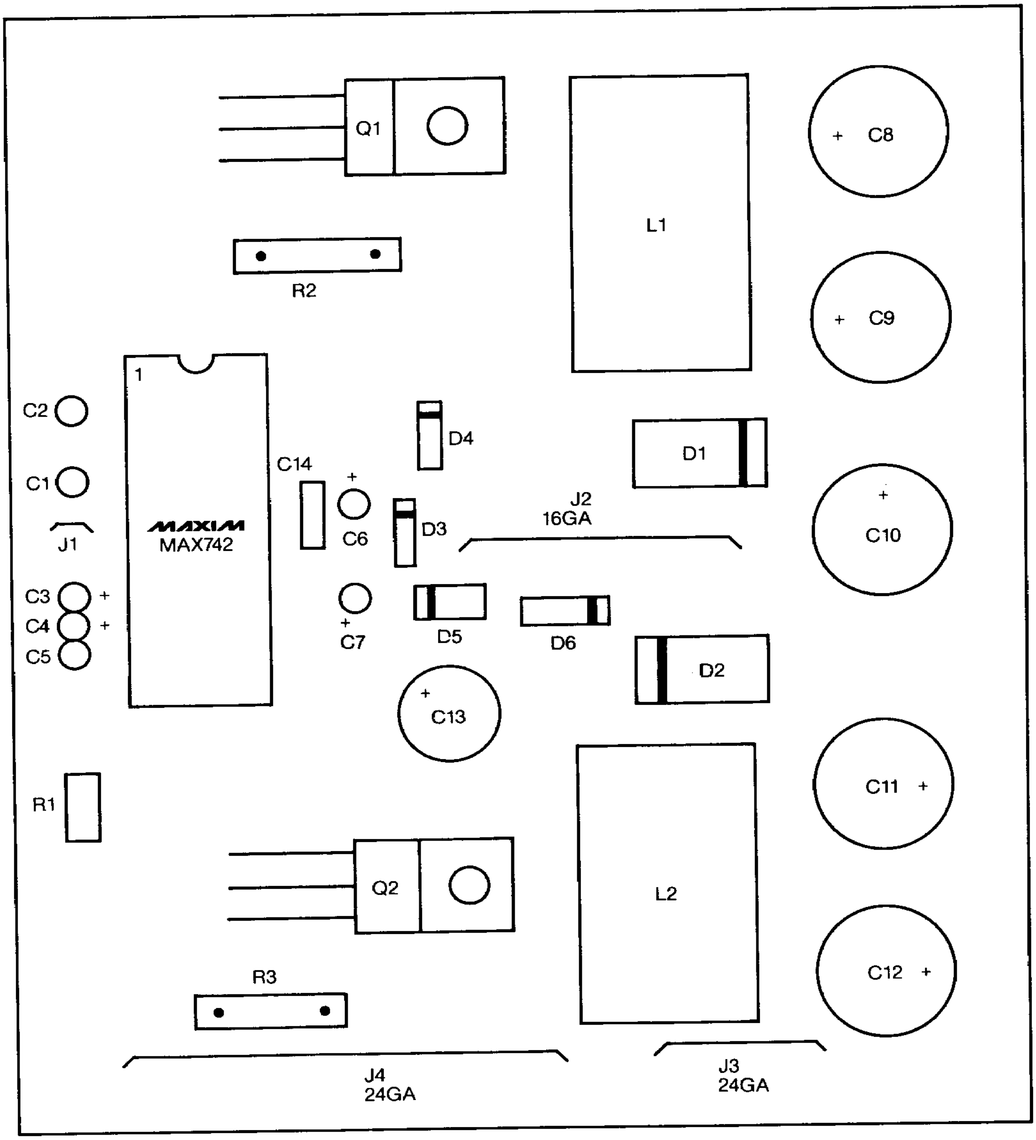


Figure 7. Component Palcement for 22W Layout

Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

Soft-Start

A capacitor connected between Soft-Start (SS) and ground limits surge currents at power-up. As shown under Typical Operating Characteristics, the peak switch current limit is a function of the voltage at SS. SS is internally connected to a 5µA current source and is diode-clamped to 2.6V (Figure 8). Soft-start timing is therefore set by the SS capacitor value. As the SS voltage ramps up, peak inductor currents rise until they reach normal operating levels. Typical values for the SS capacitor, when it is required at all, are in the range of 1µF to 10µF.

Fault Conditions Enabling SS Reset

In addition to power-up, the soft-start function is enabled by a variety of fault conditions. Any of the following conditions will cause an internal pull-down transistor to discharge the SS capacitor, triggering a soft-start cycle:

Undervoltage lock-out
Thermal shutdown
VREF shorted to ground or supply
VREF losing regulation

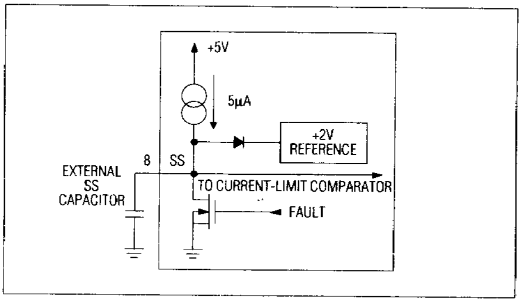


Figure 8. Soft-Start Equivalent Circuit

Table 1. Trouble Shooting Chart

SYMPTOM	CORRECTION
Unstable Output. Noise or jitter on output ripple waveform. Scope may not trigger correctly.	Loop stability problem. A. CC+ or CC- disconnected. B. EMI: Move inductor away from IC or use shielded inductors. Keep noise sources away from CC- and CC+. C. Grounding: Tie AGND directly to the filter capacitor ground lead. Ensure that current spikes from GND do not cause noise at AGND or compensation capacitor or reference bypass ground leads. Use wide PC traces or a ground plane. D. Bypass: Tie 10µF or larger between AGND and VREF. Use 150µF to bypass the input right at AV+. If there is high source resistance, 1000µF or more may be required. E. Current Limiting: Reduce load currents. Ensure that inductors are not saturating. F. Slope Compensation: Inductor value not matched to sense resistor.
Noisy Output. Switching is steady, but large inductive spikes are seen at the outputs.	A. Ground noise: Probe ground is picking up switching EMI. Reduce probe ground lead length (use probe tip shield) or put circuit in shielded enclosure. B. Poor HF response: Add ceramic or tantalum capacitors in parallel with output filter capacitors.
Self-destruction. Transistors or IC die on power-up.	A. Input overvoltage: Never apply more than +12V. B. FB+ or FB- disconnected or shorted. This causes runaway and output overvoltage. C. CC+ or CC- shorted. D. Output filter capacitor disconnected.
Poor Efficiency. Supply current is high. Output will not drive heavy loads.	A. Inductor saturation: Peak currents exceed coil ratings. B. MOSFET on resistance too high. C. Switching losses: Diode is slow or has high forward voltage. Inductor has high DC resistance. Excess capacitance at LX nodes. D. Inductor core losses: Hysteresis losses cause self-heating in some core materials. E. Loop instability: See **Unstable Output** above.
No Output. +VO = 5V or less, -VO = 0V.	A. Check connections. VREF should be +2V. B. When input voltage is less than +4.2V, undervoltage lock-out is enabled.
No Switching. ±VO are correct, but no waveform is seen at LX+ or LX-.	Output is unloaded. Apply ±30mA or greater load to observe waveform.

Dual-Output, Switch-Mode Regulator (+5V to ±12V or ±15V)

Component Suppliers

AIE Magnetics
2801 72nd Street N.
St. Petersburg, FL 33710
(813) 347-2181

Collmer Semiconductor (Fuji)
14368 Proton Street
Dallas, TX 75244
(800) 527-0251

Gowanda Electronics
1 Industrial Place
Gowanda, NY 14070
(716) 532-2234

International Rectifier
233 Kansas Street
El Segundo, CA 90245
(213) 772-2000

KRL-Bantry Components
160 Bouchard Street
Manchester, NH 03103
(603) 668-3210

Motorola Semiconductor
P.O. Box 20912
Phoenix, AZ 85036
(602) 244-6900

Nichicon America
927 East State Parkway
Schaumberg, IL 60173
(708) 843-2798

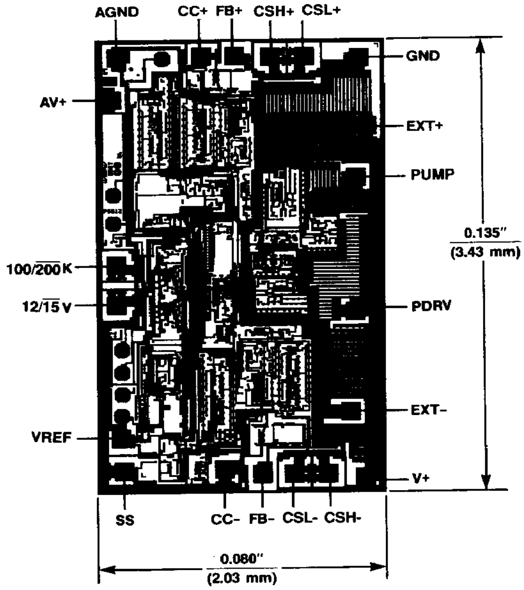
RCD Components
520 E. Industrial Park
Manchester, NH 03103
(603) 669-5455

Wilco Corporation
6451 Saguaro Court
Indianapolis, IN 46268
(317) 293-9300

External Component Ordering Information

PART	DESCRIPTION
MAXL001	100µH Toroid Inductor
MAXC001	150µF Aluminum Electrolytic Capacitor

Chip Topography



NOTE: SUBSTRATE IS CONNECTED TO V+