3.3V, Step-Down, Current-Mode PWM DC-DC Converters

ABSOLUTE MAXIMUM RATINGS

Pin Voltages:
- V+ (MAX748A) ..... +17V, -0.3V
- V+ (MAX763A) ..... +12V, -0.3V
- LX (MAX748A) ..... (V+ - 21V) to (V+ + 0.3V)
- LX (MAX763A) ..... (V+ - 12V) to (V+ + 0.3V)
- OUT ..... ±25V
- SS, CC, $\overline{SHDN}$ ..... -0.3V to (V+ + 0.3V)

Peak Switch Current (I_{LX}) 2.0A
Reference Current (I_{REF}) 2.5mA
Continuous Power Dissipation (T_A = +70°C)
- 8-Pin Plastic DIP (derate 6.90mW/°C above +70°C) ... 552mW
- 8-Pin SO (derate 5.88mW/°C above +70°C) 471mW
- 16-Pin Wide SO (derate 9.52mW/°C above +70°C) 762mW
- 8-Pin CERDIP (derate 8.00mW/°C above +70°C) 640mW

Operating Temperature Ranges:
- MAX7__AC__ ..... 0°C to +70°C
- MAX7__AE__ ..... -40°C to +85°C
- MAX7__AMJA__ ..... -55°C to +125°C

Junction Temperatures:
- MAX7__AC/E ..... +150°C
- MAX7__AM ..... +175°C

Storage Temperature Range ..... -65°C to +160°C
Lead Temperature (soldering, 10sec) ..... +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 3, V+ = 5V, I_{LOAD} = 0mA, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	CONDITIONS	MAX748A			MAX763A			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Voltage Range		3.3		16.0	3.3		11.0	V
Output Voltage	C/E temp. ranges, V+ = 4.0V to 16V, 0mA < I_{LOAD} < 300mA	3.135	3.3	3.465				V
	M temp. range, V+ = 4.0V to 16V, 0mA < I_{LOAD} < 250mA	3.135	3.3	3.465				
	C/E temp. ranges, V+ = 4.75V to 16V, 0mA < I_{LOAD} < 500mA	3.135	3.3	3.465				
	M temp. range, V+ = 4.75V to 16V, 0mA < I_{LOAD} < 400mA	3.135	3.3	3.465				
	C/E temp. ranges, V+ = 4.0V to 11V, 0mA < I_{LOAD} < 300mA				3.135	3.3	3.465	
	M temp. range, V+ = 4.0V to 11V, 0mA < I_{LOAD} < 250mA				3.135	3.3	3.465	
	C/E temp. ranges, V+ = 4.75V to 11V, 0mA < I_{LOAD} < 500mA				3.135	3.3	3.465	
	M temp. range, V+ = 4.75V to 11V, 0mA < I_{LOAD} < 400mA				3.135	3.3	3.465	
Line Regulation			0.13			0.13		%/V
Load Regulation	I_{LOAD} = 0mA to 500mA		0.001			0.001		%/mA

ELECTRICAL CHARACTERISTICS (continued)

(Circuit of Figure 3, V+ = 5V, I_{LOAD} = 0mA, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

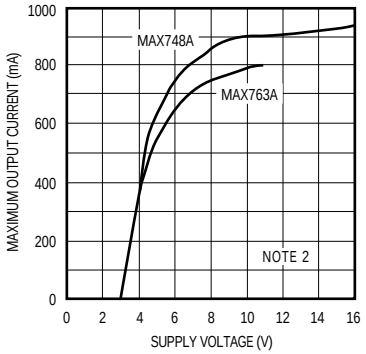
PARAMETER	CONDITIONS		MAX748A MIN	MAX748A TYP	MAX748A MAX	MAX763A MIN	MAX763A TYP	MAX763A MAX	UNITS
Efficiency	V+ = 5V	I_{LOAD} = 300mA		88			88		%
		I_{LOAD} = 100mA		90			90		
Supply Current	Includes switch current			1.7	3.0		1.4	2.5	mA
Shutdown Current	$\overline{SHDN}$ = 0V (Note 1)			0.2	100.0		0.2	100.0	µA
Shutdown Input Threshold	V_{IH}		2.0			2.0			V
	V_{IL}				0.25			0.25	
Shutdown Input Leakage Current					1.0			1.0	µA
Short-Circuit Current				1.2			1.2		A
Undervoltage Lockout	V+ falling			2.7	3.0		2.7	3.0	V
LX On Resistance	I_{LX} = 500mA			1.0			1.0		Ω
LX Leakage Current	V+ = 12V, LX = 0			10			10		nA
Reference Voltage	T_A = +25°C		1.15	1.22	1.30	1.15	1.22	1.30	V
Reference Drift	T_A = T_{MIN} to T_{MAX}			50			50		ppm/°C
Oscillator Frequency			159	180	212.5	159	200	212.5	kHz
Compensation Pin Impedance				7500			7500		Ω

Note 1: The standby current typically settles to 10µA (over temperature) within 2 seconds; however, to decrease test time, the part is guaranteed at a 100µA maximum value.

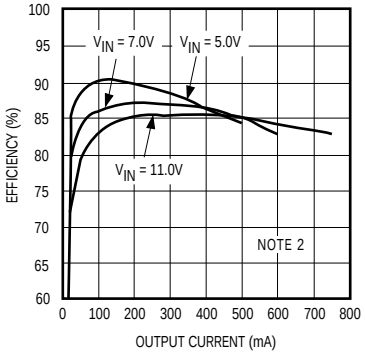
Typical Operating Characteristics

(Circuit of Figure 3, T_A = +25°C, V_{OUT} = 3.3V, unless otherwise noted.)

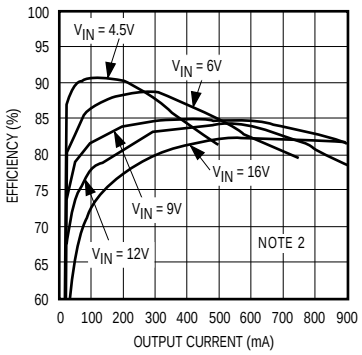
MAXIMUM OUTPUT CURRENT vs. SUPPLY VOLTAGE



MAX763A EFFICIENCY vs. OUTPUT CURRENT



MAX748A EFFICIENCY vs. OUTPUT CURRENT

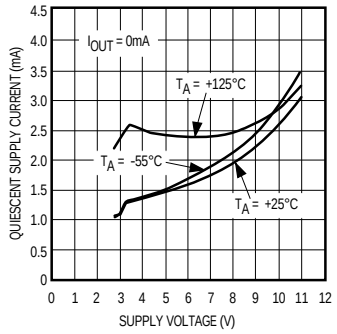


3.3V, Step-Down, Current-Mode PWM DC-DC Converters

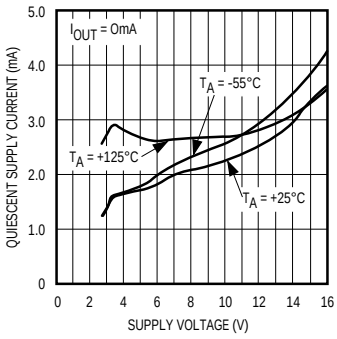
Typical Operating Characteristics (continued)

(Circuit of Figure 3, T_A = +25°C, V_{OUT} = 3.3V, unless otherwise noted.)

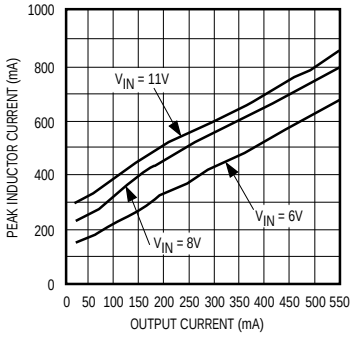
MAX763A QUIESCENT SUPPLY CURRENT vs. SUPPLY VOLTAGE



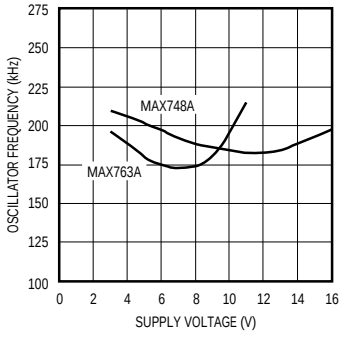
MAX748A QUIESCENT SUPPLY CURRENT vs. SUPPLY VOLTAGE



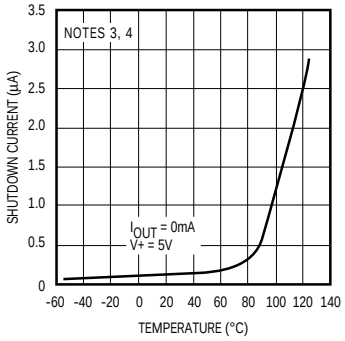
PEAK INDUCTOR CURRENT vs. OUTPUT CURRENT



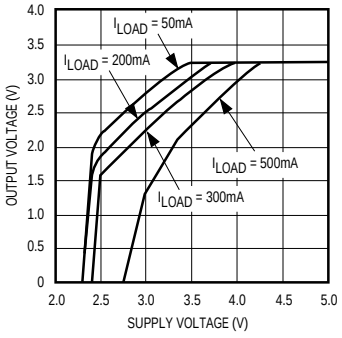
OSCILLATOR FREQUENCY vs. SUPPLY VOLTAGE



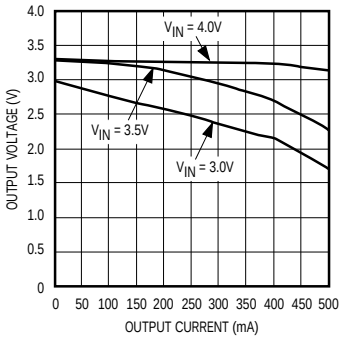
SHUTDOWN CURRENT vs. TEMPERATURE



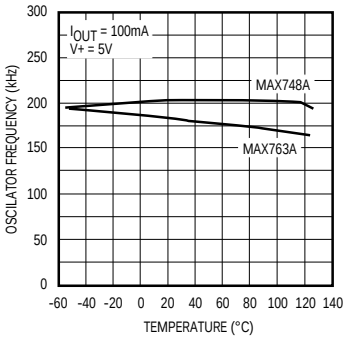
OUTPUT VOLTAGE vs. SUPPLY VOLTAGE



OUTPUT VOLTAGE vs. OUTPUT CURRENT



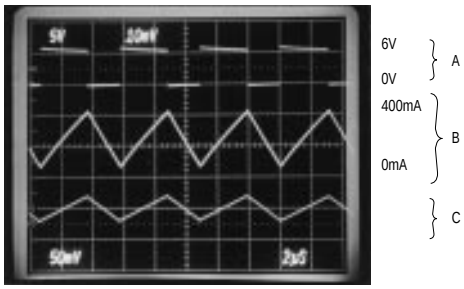
OSCILLATOR FREQUENCY vs. TEMPERATURE



Typical Operating Characteristics (continued)

(Circuit of Figure 3, T_A = +25°C, V_{OUT} = 3.3V, unless otherwise noted.)

SWITCHING WAVEFORMS, CONTINUOUS CONDUCTION

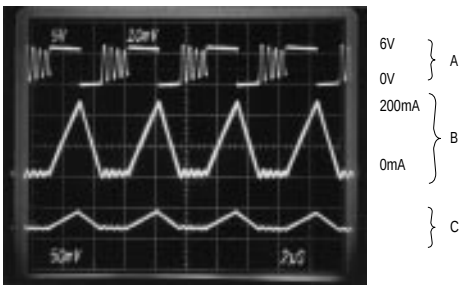


2µs/div

A: SWITCH VOLTAGE (LX PIN), 5V/div, 0V TO +6V
B: INDUCTOR CURRENT, 200mA/div
C: OUTPUT VOLTAGE RIPPLE, 50mV/div

V+ = 6V, I_{OUT} = 250mA

SWITCHING WAVEFORMS, DISCONTINUOUS CONDUCTION

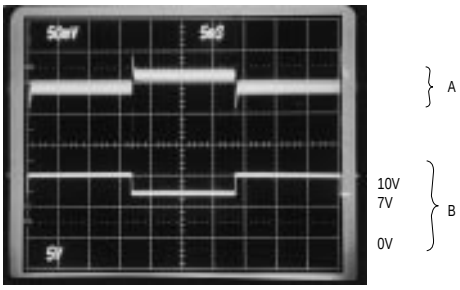


2µs/div

A: SWITCH VOLTAGE (LX PIN), 5V/div, 0V TO +6V
B: INDUCTOR CURRENT, 100mA/div
C: OUTPUT VOLTAGE RIPPLE, 50mV/div

V+ = 6V, I_{OUT} = 75mA

LINE-TRANSIENT RESPONSE

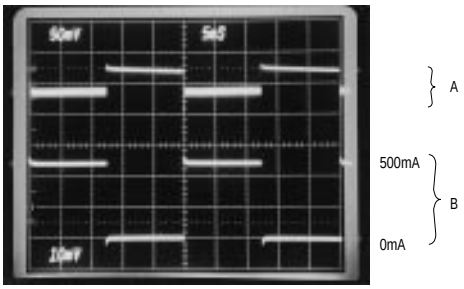


5ms/div

A: V_{OUT}, 50mV/div
B: V+, 5V/div, 7.0V TO 10.0V

I_{OUT} = 350mA

LOAD-TRANSIENT RESPONSE



5ms/div

A: V_{OUT}, 50mV/div
B: I_{OUT}, 200mA/div, 0mA TO 500mA

V+ = 6V

Note 2: Operation beyond the specifications listed in the *Electrical Characteristics* may exceed the power dissipation ratings of the device.
Note 3: Wide temperature range circuit of Figure 5 using Sprague surface-mount capacitors.
Note 4: Standby current includes all external component leakage currents. Capacitor leakage currents dominate at T_A = +85°C.

Pin Description

PIN #		NAME	FUNCTION
8-PIN DIP/SO	16-PIN WIDE SO (MAX748A)		
1	2	$\overline{SHDN}$	Shutdown—active low. Connect to ground to power down chip; tie to V+ for normal operation. Output voltage falls to 0V when $\overline{SHDN}$ is low.
2	3	REF	Reference Voltage Output (+1.23V) supplies up to 100µA for external loads. Bypass to GND with a 0.047µF capacitor.
3	7	SS	Soft-Start. Capacitor between SS and GND provides soft-start and short-circuit protection.
4	8	CC	Compensation Capacitor Input externally compensates the outer (voltage) feedback loop. Connect to OUT with a 330pF capacitor.
5	9	OUT	Output-Voltage Sense Input provides regulation feedback sensing. Connect to +3.3V output.
6	10, 11	GND	Ground*
7	12, 13, 14	LX	Drain of internal P-channel power MOSFET*
8	1,15,16	V+	Supply Voltage Input. Bypass to GND with 1µF ceramic and large-value electrolytic capacitor in parallel. The 1µF capacitor must be as close to the GND and V+ pins as possible.*
	4, 5, 6	N.C.	No Connect—no internal connections to these pins.

**16-pin wide SO package: All pins sharing the same name must be connected together externally.*

Detailed Description

The MAX748A/MAX763A switch-mode regulators use a current-mode pulse-width-modulation (PWM) control system in a step-down (buck) regulator topography. They convert an unregulated DC input voltage from 4V to 11V (MAX763A) or from 4V to 16V (MAX748A) to a regulated 3.3V output at 300mA. For loads less than 300mA, V+ may be less than 4.0V (see the Output Voltage vs. Supply Voltage graph in the *Typical Operating Characteristics*). The current-mode PWM architecture provides cycle-by-cycle current limiting, improved load-transient response, and simpler outerloop design.

The controller consists of two feedback loops: an inner (current) loop that monitors the switch current via the current-sense resistor and amplifier, and an outer (voltage) loop that monitors the output voltage through the error amplifier (Figure 1). The inner loop performs cycle-by-cycle current limiting, truncating the power transistor on-time when the switch current reaches a predetermined threshold. This threshold is determined by the outer loop. For example, a sagging output voltage produces an error signal that raises the threshold, allowing the circuit to store and transfer more energy during each cycle.

Programmable Soft-Start

Figure 2 shows a capacitor connected to the soft-start (SS) pin to ensure orderly power-up. A typical value is 0.047µF. SS controls both the SS timing and the maximum output current that can be delivered while maintaining regulation.

The charging capacitor slowly raises the clamp on the error-amplifier output voltage, limiting surge currents at power-up by slowly increasing the cycle-by-cycle current-limit threshold. Table 1 lists timing characteristics for selected capacitor values and circuit conditions.

The overcurrent comparator trips when the load exceeds approximately 1.2A. When either an undervoltage or overcurrent fault condition is detected, an SS cycle is actively initiated, which triggers an internal transistor to discharge the SS capacitor to ground. An SS cycle is also enabled at power-up and when coming out of shutdown mode.

Overcurrent Limiting

The overcurrent comparator triggers when the load current exceeds approximately 1.2A. On each clock cycle, the output FET turns on and attempts to deliver current until cycle-by-cycle or overcurrent limits are exceeded. Note that the SS capacitor must be greater than 0.01µF for overcurrent protection to function properly. A typical value is 0.047µF.

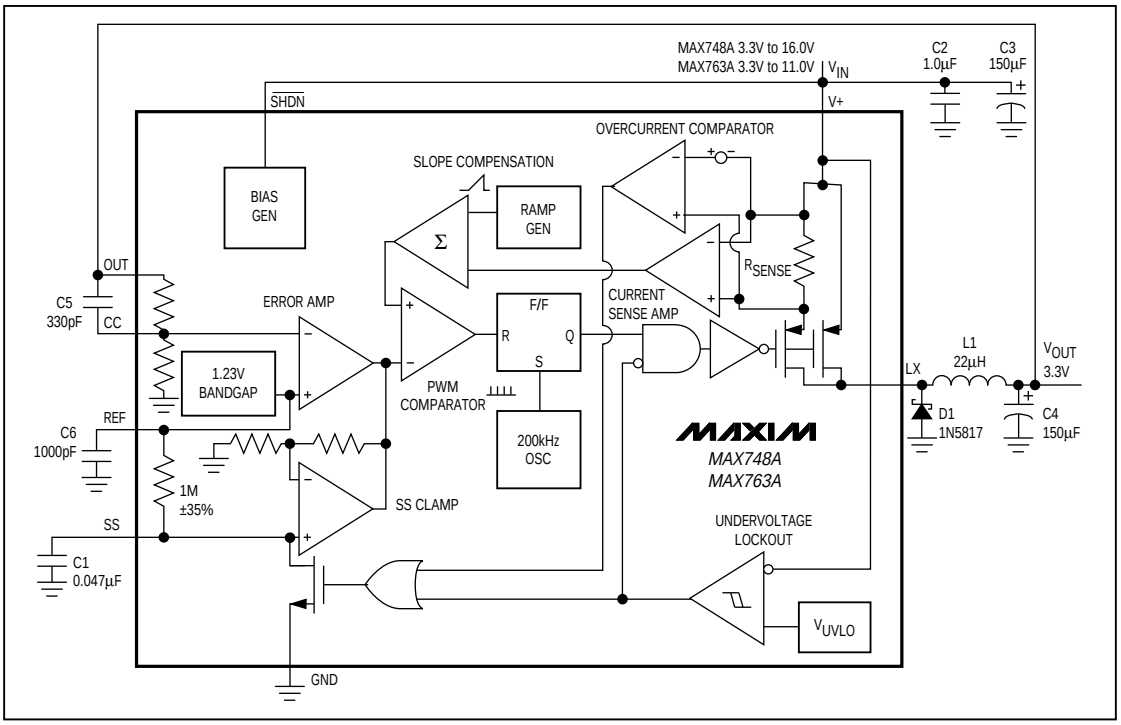


Figure 1. Detailed Block Diagram with External Components

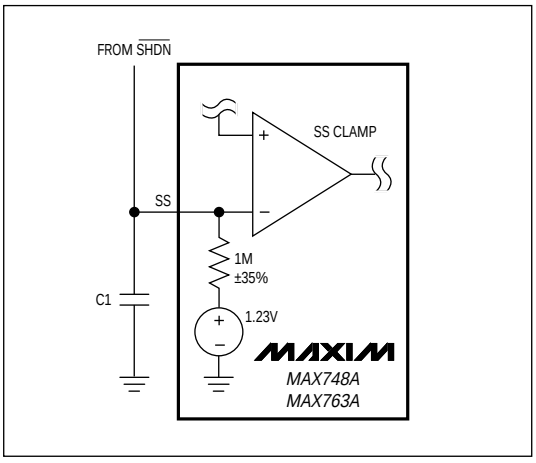


Figure 2. Soft-Start Circuitry Block Diagram

Table 1. Typical Soft-Start Times

(Circuit of Figure 3, C4 = 150µF)

Circuit Cond.		Soft-Start Time (ms) vs. C1 (µF)			
V+ (V)	I_{OUT} (mA)	C1 = 0.01	C1 = 0.047	C1 = 0.1	C1 = 0.47
8	0	1	4	7	12
12*	0	1	2	3	6
8	200	10	33	50	200
12*	200	7	17	20	80
8	300	13	44	65	325
12*	300	8	25	35	140

** MAX748A only*

Table 3. External Component Suppliers

Production Method	Inductors	Capacitors
Surface Mount	Sumida CD105 series Coiltronics CTX series Coilcraft DT series	Matsuo 267 series Sprague 595D/293D series
High Performance/ Miniature Through-Hole	Sumida RCH895 series	Sanyo OS-CON series (very low ESR)
Through-Hole	Renco RL1284 series	Nichicon PL series (low ESR)

Phone and FAX Numbers:

Coilcraft	USA:	(708) 639-6400, FAX: (708) 639-1469	Renco	USA:	(516) 586-5566, FAX: (516) 586-5562
Coiltronics	USA:	(305) 781-8900, FAX: (305) 782-4163	Sanyo	USA:	(0720) 70-1005, FAX: (0720) 70-1174
Matsuo	USA:	(714) 969-2491, FAX: (714) 960-6492	Sprague Elec. Co.	USA:	(603) 224-1961, FAX: (603) 224-1430
	Japan:	(06) 332-0871	Sumida	USA:	(708) 956-0666, FAX: (708) 956-0702
Nichicon	USA:	(708) 843-7500, FAX: (708) 843-2798			
	Japan:	(03) 3607-5111, FAX: (03) 3607-5428			

Undervoltage Lockout

The undervoltage lockout feature monitors the supply voltage at V+ and allows operation to start when V+ rises above 2.95V. When V+ falls, operation continues until the supply voltage falls below 2.7V (typ). When an undervoltage condition is detected, control logic turns off the output power FET and discharges the SS capacitor to ground. This prevents partial turn-on of the power MOSFET and avoids excessive power dissipation. The control logic holds the output power FET off until the supply voltage rises above approximately 2.95V, at which time an SS cycle begins. When the input voltage exceeds the undervoltage lockout threshold, switching action will occur, but the output will not be regulated until the input voltage exceeds 3.3V (no load). The exact input voltage required for regulation depends on load conditions (see the Output Voltage vs. Supply Voltage graph in the *Typical Operating Characteristics*).

Shutdown Mode

The MAX748A/MAX763A are held in shutdown mode by keeping $\overline{SHDN}$ at ground. In shutdown mode, the output drops to 0V and the output power FET is held in an off state. The internal reference also turns off, which causes the SS capacitor to discharge. Typical supply current in shutdown mode is 0.2µA. The actual design limit for shutdown current is much less than the 100µA specified in the *Electrical Characteristics*. However, testing to tighter limits is prohibitive because the current takes several seconds to settle to a final value. For normal operation, connect $\overline{SHDN}$ to V+. Coming out of shutdown mode initiates an SS cycle.

Continuous-/Discontinuous-Conduction Modes

The input voltage, output voltage, load current, and inductor value determine whether the IC operates in continuous or discontinuous mode. As the inductor value or load current decreases, or the input voltage increases, the MAX748A/MAX763A tend to operate in discontinuous-conduction mode (DCM). In DCM, the inductor current slope is steep enough so it decays to zero before the end of the transistor off-time. In continuous-conduction mode (CCM), the inductor current never decays to zero, which is typically more efficient than DCM. CCM allows the MAX748A/MAX763A to deliver maximum load current, and is also slightly less noisy than DCM, because it doesn't exhibit the ringing that occurs when the inductor current reaches zero.

Internal Reference

The +1.23V bandgap reference supplies up to 100µA at REF. A 1000pF bypass capacitor from REF to GND is required.

Oscillator

The MAX748A/MAX763A's internal oscillator is guaranteed to operate in the 159kHz to 212.5 kHz range over temperature for V+ = 5V. Temperature stability over the military temperature range is about 0.04%/°C.

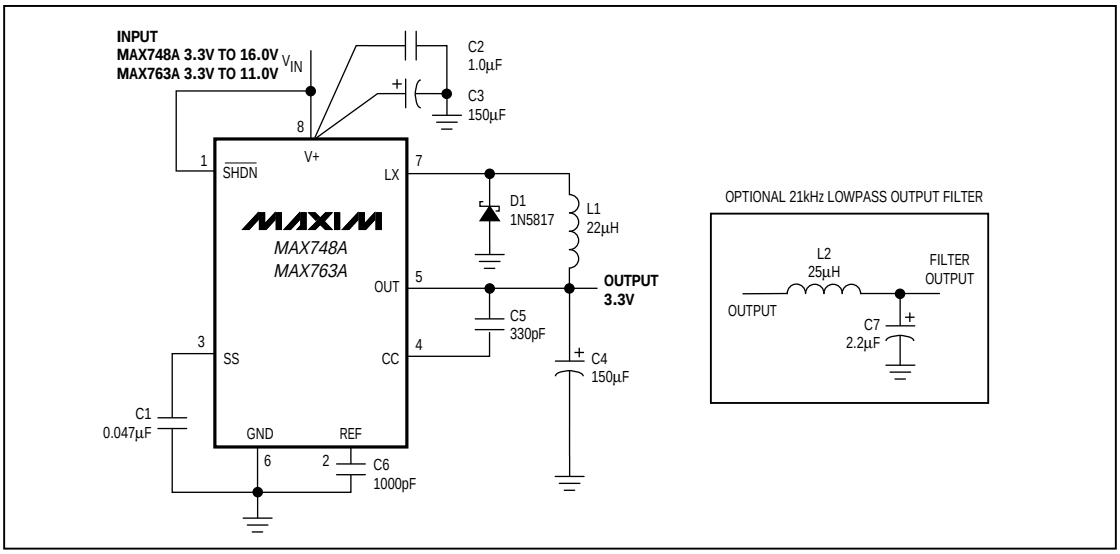


Figure 3. Standard 3.3V Step-Down Application Circuit Using Through-Hole Components (commercial temperture range)

Table 2. Component Table for Wide Temperature Applications

	C1(µF)	C2(µF)	C3(µF)	C4(µF)	C5(pF)	C6(pF)	L1(µH)
Through-Hole	0.047	1.0	150*	220*	330	1000	22
SO	0.047	1.0	68**	100***	330	1000	22

** Sanyo OS-CON Series (very low ESR)*

*** 16V or greater maximum voltage rating.*

**** 6.3V or greater maximum voltage rating.*

Applications Information

Fixed +3.3V Step-Down Converter Application

Figure 3 shows the standard 3.3V step-down circuit with components shown for commercial temperature range applications. Figures 4, 5, and Table 2 suggest external component values for both SO and through-hole wide temperature range applications. These circuits are useful in systems that require high current and high efficiency and are powered by an unregulated supply, such as a battery or wall-plug AC-DC adapter.

The MAX748A delivers a guaranteed 300mA for input voltages of 4V to 16V, and a guaranteed 500mA for input voltages of 4.75V to 16V with 800mA typical output currents. The MAX763A delivers a guaranteed 300mA for input voltages of 4V to 11V, a guaranteed 500mA for input voltages of 4.75V to 11V, and has 700mA typical output currents. The MAX748A/MAX763A operate from an input down to 3V (the upper limit of undervoltage lockout), but with some reduction in output voltage and maximum output current.

Inductor Selection

The MAX748A/MAX763A require no inductor design because they are tested in-circuit, and are guaranteed to deliver the power specified in the *Electrical Characteristics* with high efficiency using a single 22µH inductor. The 22µH inductor's incremental saturation current rating should be greater than 1A for 500mA load operation. Table 3 lists inductor types and suppliers for various applications. The surface-mount inductors have nearly equivalent efficiencies to the larger through-hole inductors.

Output Filter Capacitor Selection

The primary criterion for selecting the output filter capacitor is low effective series resistance (ESR). The product of the inductor-current variation and the output capacitor's ESR determines the amplitude of the sawtooth ripple seen on the output voltage. Minimize the output filter capacitor's ESR to maintain AC stability.

3.3V, Step-Down, Current-Mode PWM DC-DC Converters

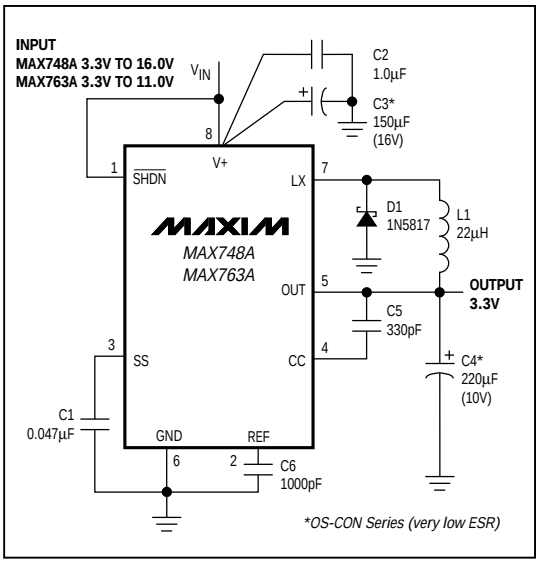


Figure 4. Standard 3.3V Step-Down Application Circuit Using Through-Hole Components (all temperature ranges)

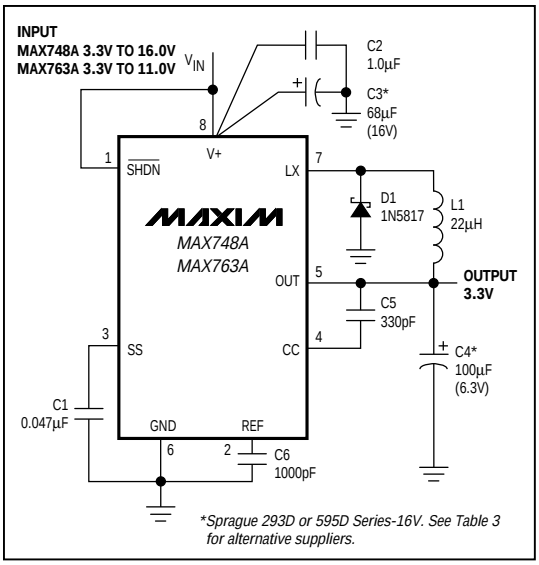


Figure 5. Standard 3.3V Step-Down Application Circuit Using Surface-Mount Components (Commercial and Extended Industrial Temperature Ranges)

The capacitor's ESR should be less than 0.25Ω to keep the output ripple less than 50mV$_{P-P}$ over the entire current range (using a 22µH inductor). Capacitor ESR usually rises at low temperatures, but OS-CON capacitors provide very low ESR below 0°C. Table 3 lists capacitor suppliers.

Other Components

The catch diode should be a Schottky or high-speed silicon rectifier with a peak current rating of at least 1.0A for full-load (500mA) operation. The 1N5817 is a good choice. The 330pF outer-loop compensation capacitor provides the widest input voltage range and best transient characteristics.

Printed Circuit Layouts

A good layout is essential for stable, low-noise operation. The layouts and component placement diagrams in Figures 6-9 have been tested successfully over a wide range of operating conditions. **The 1µF input bypass capacitor must be positioned as close to the V+ and GND pins as possible.** Also, place the output capacitor as close to the OUT and GND pins as possible. The traces connecting ground to the input and output filter capacitors and to the catch diode must be short to reduce inductance. Use an uninterrupted ground plane if possible.

Output-Ripple Filtering

A simple lowpass pi-filter (Figure 3) can be added to the output to reduce output ripple to about 5mV$_{P-P}$. The cutoff frequency shown is 21kHz. Since the filter inductor is in series with the circuit output, minimize the filter inductor's resistance so the voltage drop across it is not excessive.

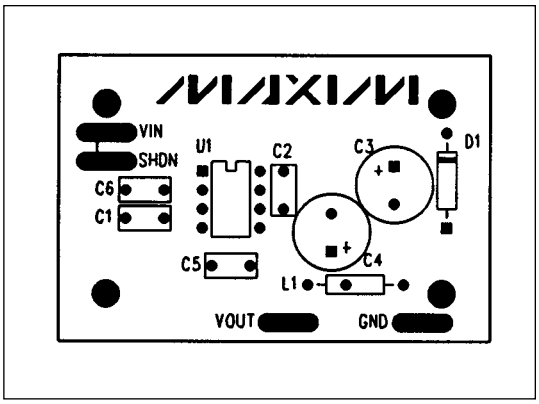


Figure 6. DIP PC Layout, Through-Hole Component Placement Diagram (1X Scale)

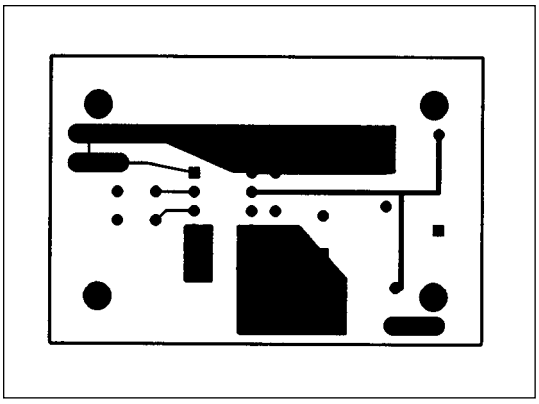


Figure 7. DIP PC Layout, Component Side (1X Scale)

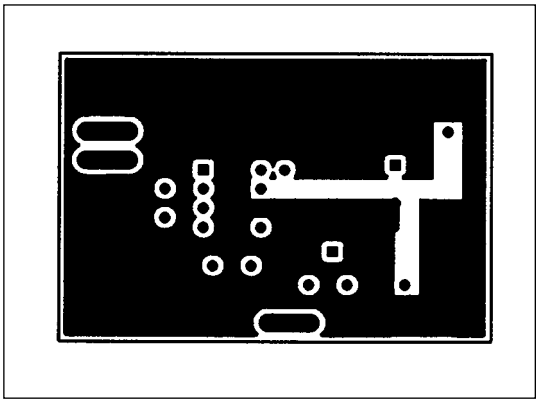


Figure 8. DIP PC Layout, Solder Side (1X Scale)

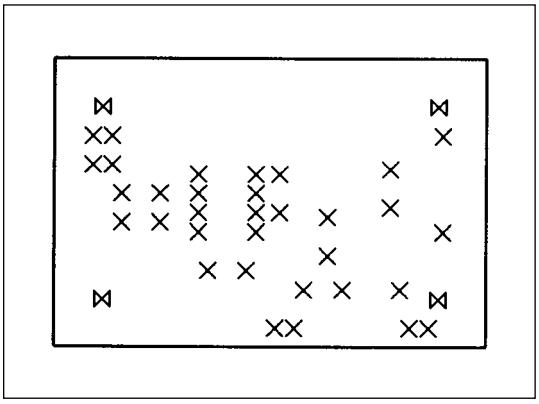
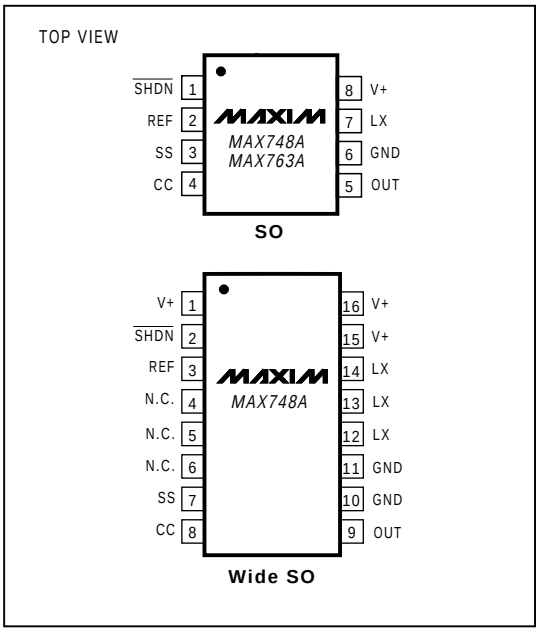


Figure 9. DIP PC Layout, Drill Guide (1X Scale)

3.3V, Step-Down, Current-Mode PWM DC-DC Converters

Pin Configurations (continued)

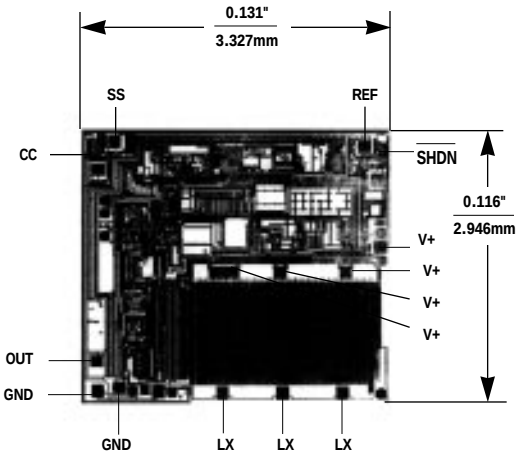


Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE
MAX763ACPA	0°C to +70°C	8 Plastic DIP
MAX763ACSA	0°C to +70°C	8 SO
MAX763AC/D	0°C to +70°C	Dice*
MAX763AEPA	-40°C to +85°C	8 Plastic DIP
MAX763AESA	-40°C to +85°C	8 SO
MAX763AMJA	-55°C to +125°C	8 CERDIP

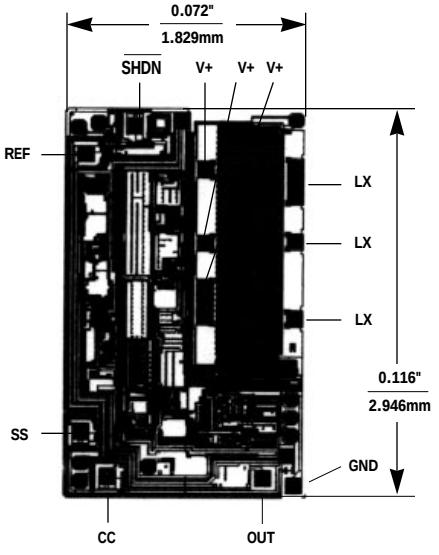
** Contact factory for dice specifications.*

Chip Topographies



MAX748A

TRANSISTOR COUNT: 298
SUBSTRATE CONNECTION: V+



MAX763A

TRANSISTOR COUNT: 281
SUBSTRATE CONNECTION: V+