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19-0177; Rev 1; 8/98

MAXIM

3.3V-Input to Regulated 5V-Output Charge Pumps

General Description

The MAX682/MAX683/MAX684 charge-pump regulators generate 5V from a 2.7V to 5.5V input. They are specifically designed to serve as high-efficiency auxiliary supplies in applications that demand a compact design. The MAX682, MAX683, and MAX684 deliver 250mA, 100mA, and 50mA output current, respectively.

These complete 5V regulators require only one resistor and three external capacitors—no inductors are needed. High switching frequencies (externally adjustable up to 2MHz) and a unique regulation scheme allow the use of capacitors as small as 1µF per 100mA of output current. The MAX683/MAX684 are offered in a space-saving 8-pin µMAX package that is only 1.1mm high, while the MAX682 is available in an 8-pin SO.

Features

- **Ultra-Small: 1µF Capacitors per 100mA of Output Current**
- **No Inductors Required**
- **1.1mm Height in µMAX Package (MAX683/MAX684)**
- **Up to 250mA Output Current (MAX682)**
- **Regulated ±4% Output Voltage**
- **50kHz to 2MHz Adjustable Switching Frequency**
- **2.7V to 5.5V Input Voltage**
- **100µA Quiescent Current in Pulse-Skipping Mode**
- **0.1µA Shutdown Current**

Applications

Flash Memory Supplies

Battery-Powered Applications

Miniature Equipment

PCMCIA Cards

3.3V to 5V Local Conversion Applications

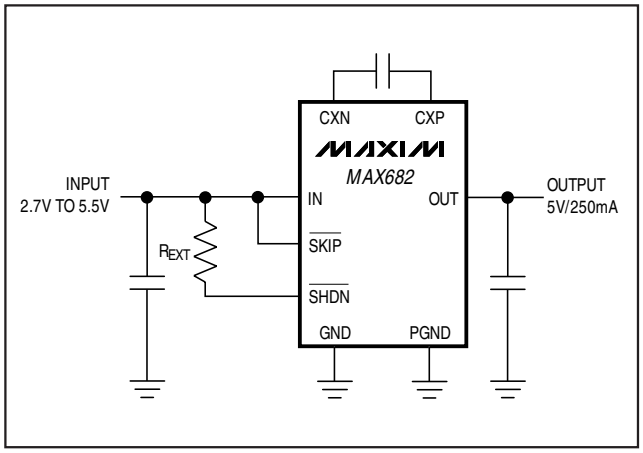
Backup-Battery Boost Converters

3V to 5V GSM SIMM Cards

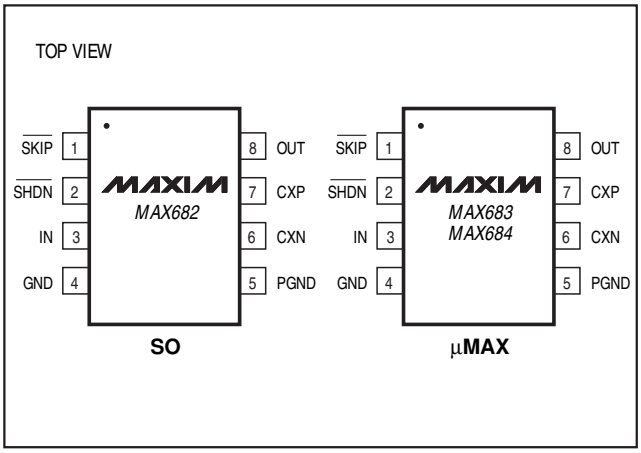
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX682ESA	-40°C to +85°C	8 SO
MAX683EUA	-40°C to +85°C	8 µMAX
MAX684EUA	-40°C to +85°C	8 µMAX

Typical Operating Circuit



Pin Configurations



3.3V-Input to Regulated 5V-Output Charge Pumps

ABSOLUTE MAXIMUM RATINGS

IN, OUT, $\overline{SHDN}$, $\overline{SKIP}$ to GND .....-0.3V to +6V
PGND to GND .....±0.3V
CXN to GND .....-0.3V to (V_{IN} + 0.3V)
CXP to GND .....-0.3V to (V_{OUT} + 0.3V)
Continuous Output Current
MAX682 .....300mA
MAX683 .....150mA
MAX684 .....75mA
Output Short-Circuit Duration 5sec

Continuous Power Dissipation (T_A = +70°C)
8-Pin SO (derate 5.9mW/°C above +70°C) 471mW
8-Pin µMAX (derate 4.1mW/°C above +70°C) 330mW
Operating Temperature Range
MAX68_E_A .....-40°C to +85°C
Junction Temperature .....+150°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

(V_{IN} = 3V, $V_{\overline{SKIP}}$ = 0V, C_{IN} = 1µF, C_X = 0.47µF, C_{OUT} = 2µF, $I_{\overline{SHDN}}$ = 22µA; I_{MAX} = 250mA for MAX682, I_{MAX} = 100mA for MAX683, I_{MAX} = 50mA for MAX684; T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}	Regulation with V_{IN} > 3.6V requires $\overline{SKIP}$ = high		2.7		5.5	V
Input Undervoltage Lockout Threshold				2.0	2.35	2.6	V
Input Undervoltage Lockout Hysteresis					100		mV
Output Voltage	V_{OUT}	0 < I_{LOAD} ≤ I_{MAX}; 3.0V ≤ IN ≤ 3.6V for $\overline{SKIP}$ = 0, 3.0V ≤ IN ≤ 5.5V for $\overline{SKIP}$ = IN		4.80	5.05	5.20	V
Maximum Output Current	I_{MAX}	MAX682		250			mA
		MAX683		100			
		MAX684		50			
No-Load Input Current	I_Q	$\overline{SKIP}$ = 0, V_{IN} = 3.6V			0.1	0.18	mA
		$\overline{SKIP}$ = V_{IN} = 3.6V	MAX682		7.5		
			MAX683		2.5		
			MAX684		1.7		
Load Regulation	ΔV_{LDR}	$\overline{SKIP}$ = high, 0 ≤ I_{LOAD} ≤ I_{MAX}			-3		%
$\overline{SHDN}$ Logic Low Input	$V_{INL, \overline{SHDN}}$					0.35	V
$\overline{SHDN}$ On Bias Voltage	$V_{ON, \overline{SHDN}}$	T_A = +25°C		630	690	750	mV
$\overline{SHDN}$ Input Current Range	$I_{\overline{SHDN}}$	(Note 2)		1		50	µA
Switching Frequency (Note 2)		$I_{\overline{SHDN}}$ = 22µA	0°C < T_A < +85°C	850	1000	1200	kHz
			-40°C < T_A < +85°C	750	1000	1300	
		$I_{\overline{SHDN}}$ =4.4µA	0°C < T_A < +85°C	160	200	250	
			-40°C < T_A < +85°C	150	200	270	
Shutdown Supply Current	$I_{Q, \overline{SHDN}}$	$\overline{SHDN}$ = 0, V_{IN} = 5.5V, V_{OUT} = 0			0.1	5	µA
Shutdown Exit Time	t_{START}	R_L = 5V/I_{MAX}			50		µs

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3V, $V_{\overline{SKIP}}$ = 0V, C_{IN} = 1µF, C_X = 0.47µF, C_{OUT} = 2µF, $I_{\overline{SHDN}}$ = 22µA; I_{MAX} = 250mA for MAX682, I_{MAX} = 100mA for MAX683, I_{MAX} = 50mA for MAX684; T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
$\overline{SKIP}$ Input Voltage Low	$V_{INL, \overline{SKIP}}$				0.8	V
$\overline{SKIP}$ Input Voltage High	$V_{INH, \overline{SKIP}}$	V_{IN} = 5.5V	2.4			
$\overline{SKIP}$ Input Leakage Current	$I_{\overline{SKIP}}$	V_{IN} = 5.5V, $V_{\overline{SKIP}}$ = 0V or 5.5V	-1		1	µA

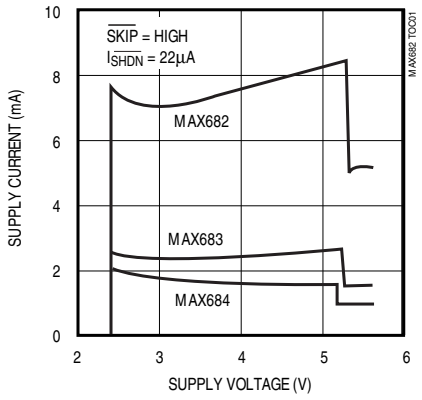
Note 1: Specifications to -40°C are guaranteed by design and not production tested.

Note 2: Current into $\overline{SHDN}$ determines oscillator frequency: R_{EXT} (kΩ) = 45000 (V_{IN} - 0.69V) / f_{OSC} (kHz)

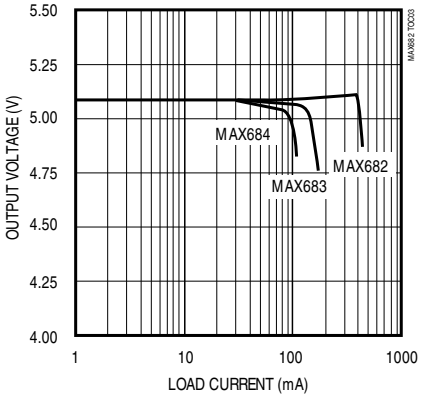
Typical Operating Characteristics

(Circuit of Figure 5, V_{IN} = 3.3V, component values from Tables 2 and 3, T_A = +25°C, unless otherwise noted.)

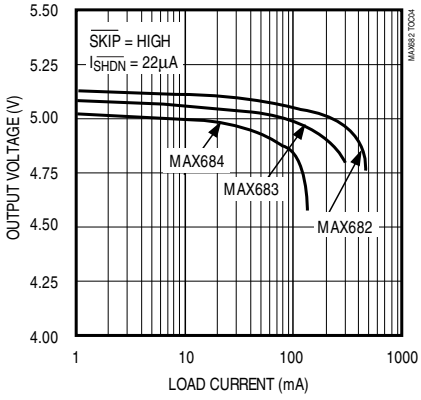
NO-LOAD SUPPLY CURRENT vs. SUPPLY VOLTAGE



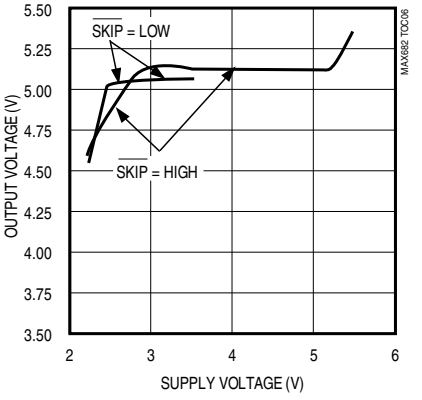
OUTPUT VOLTAGE vs. LOAD CURRENT (SKIP = LOW)



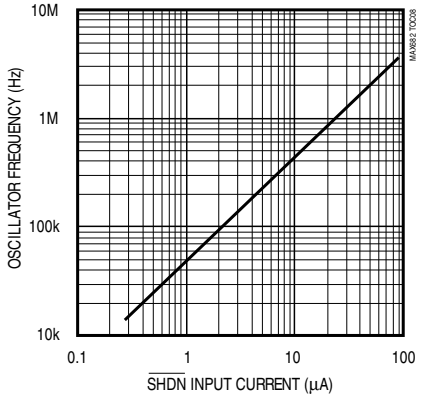
OUTPUT VOLTAGE vs. LOAD CURRENT (SKIP = HIGH)



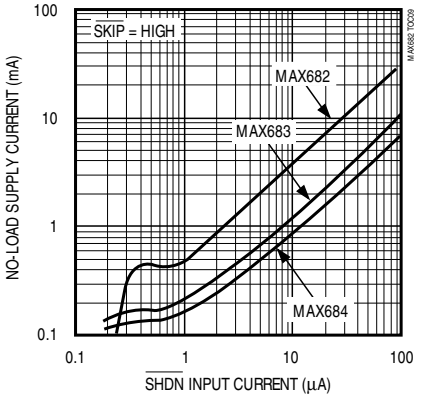
OUTPUT VOLTAGE vs. SUPPLY VOLTAGE



OSCILLATOR FREQUENCY vs. SHUTDOWN PIN INPUT CURRENT



NO-LOAD SUPPLY CURRENT vs. SHUTDOWN PIN INPUT CURRENT

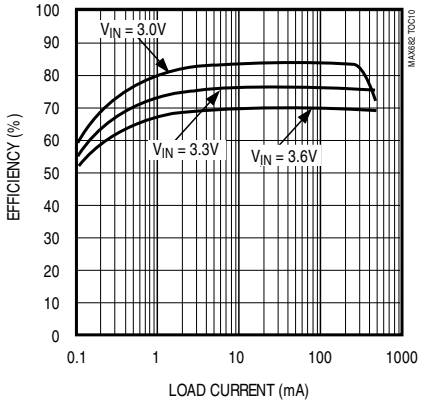


3.3V-Input to Regulated 5V-Output Charge Pumps

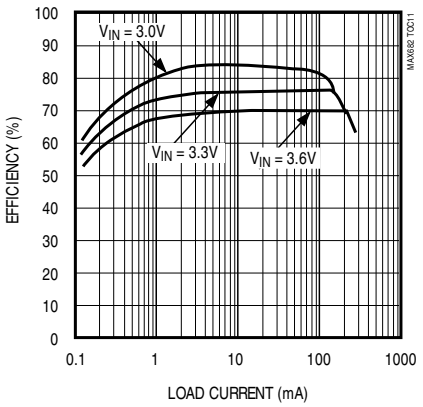
Typical Operating Characteristics (continued)

(Circuit of Figure 5, V_{IN} = 3.3V, component values from Tables 2 and 3, T_A = +25°C, unless otherwise noted.)

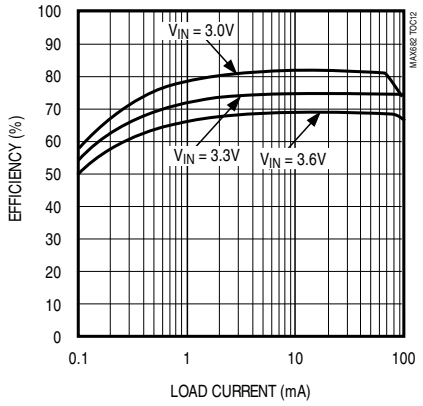
MAX682 EFFICIENCY vs. LOAD CURRENT ($\overline{SKIP}$ = LOW)



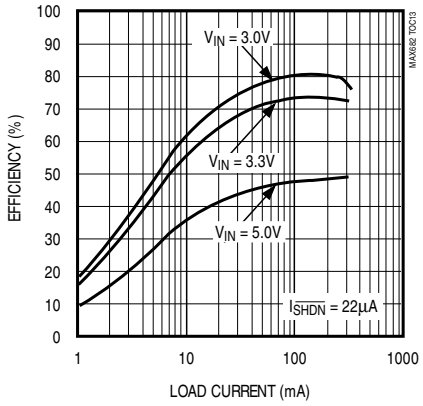
MAX683 EFFICIENCY vs. LOAD CURRENT ($\overline{SKIP}$ = LOW)



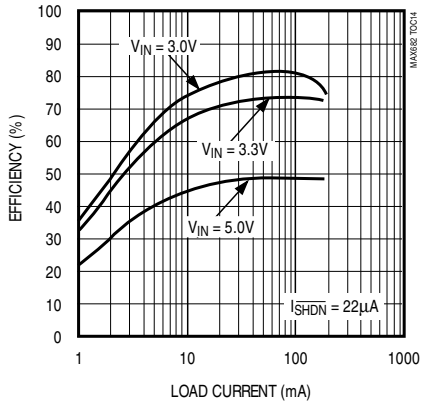
MAX684 EFFICIENCY vs. LOAD CURRENT ($\overline{SKIP}$ = LOW)



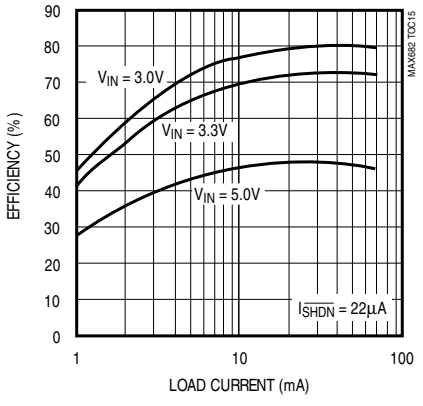
MAX682 EFFICIENCY vs. LOAD CURRENT ($\overline{SKIP}$ = HIGH)



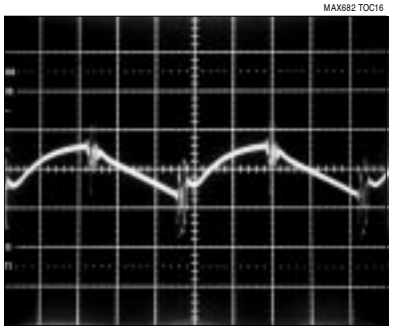
MAX683 EFFICIENCY vs. LOAD CURRENT ($\overline{SKIP}$ = HIGH)



MAX684 EFFICIENCY vs. LOAD CURRENT ($\overline{SKIP}$ = HIGH)

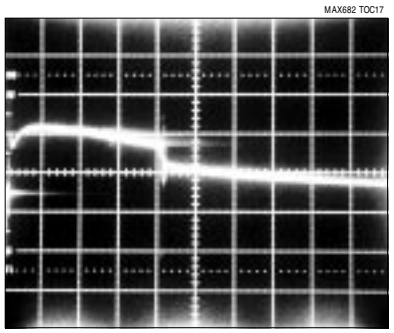


OUTPUT WAVEFORM ($\overline{SKIP}$ = HIGH)



$\overline{SKIP}$ = HIGH, $I_{\overline{SHDN}}$ = 22µA, I_{LOAD} = 250mA, MAX682

OUTPUT WAVEFORM ($\overline{SKIP}$ = LOW)

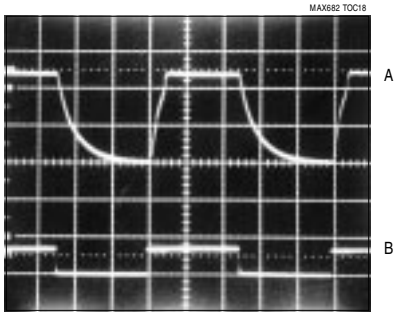


$\overline{SKIP}$ = LOW, I_{LOAD} = 250mA, MAX682

Typical Operating Characteristics (continued)

(Circuit of Figure 5, V_{IN} = 3.3V, component values from Tables 2 and 3, T_A = +25°C, unless otherwise noted.)

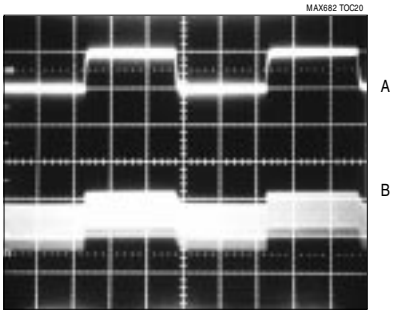
SHUTDOWN TIMING



100µs/div

A: OUTPUT VOLTAGE: $\overline{SKIP}$ = HIGH, R_L = 5V / I_{MAX}, 2V/div
B: $\overline{SHDN}$ VOLTAGE: 1V/div

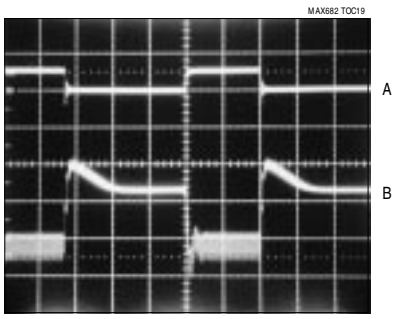
LINE-TRANSIENT RESPONSE



2ms/div

A: INPUT VOLTAGE: V_{IN} = 3.1V TO 3.6V, 500mV/div
B: OUTPUT VOLTAGE: $\overline{SKIP}$ = HIGH, $I_{\overline{SHDN}}$ = 22µA, I_{LOAD} = 250mA, 50mV/div, MAX682

LOAD-TRANSIENT RESPONSE



2ms/div

A: LOAD CURRENT: I_{LOAD} = 5mA TO 250mA, 500mA/div
B: OUTPUT VOLTAGE: $\overline{SKIP}$ = HIGH, $I_{\overline{SHDN}}$ = 22µA, 100mV/div, MAX682

Pin Description

PIN	NAME	FUNCTION
1	$\overline{SKIP}$	When $\overline{SKIP}$ = low, the regulator operates in low-quiescent-current skip mode. When $\overline{SKIP}$ = high, the regulator operates in constant-frequency mode, minimizing output ripple and noise. $\overline{SKIP}$ must be tied high for input voltages above 3.6V.
2	$\overline{SHDN}$	Shutdown Input. Drive $\overline{SHDN}$ through an external resistor. When $\overline{SHDN}$ = low, the device turns off. When current is sourced into $\overline{SHDN}$ through R_{EXT}, the device activates, and the $\overline{SHDN}$ pin input current sets the oscillator's switching frequency. R_{EXT} (kΩ) = 45000 (V_{IN} - 0.69V) / f_{OSC} (kHz).
3	IN	Input Supply Pin. Can range from 2.7V to 5.5V for $\overline{SKIP}$ = high, and 2.7V to 3.6V for $\overline{SKIP}$ = low. Bypass to PGND with a suitable value capacitor (see *Capacitor Selection* section).
4	GND	Ground Pin. Connect to PGND through a short trace.
5	PGND	Power Ground Pin
6	CXN	Negative Terminal of the Charge-Pump Transfer Capacitor
7	CXP	Positive Terminal of the Charge-Pump Transfer Capacitor
8	OUT	Fixed 5V Power Output. Bypass to PGND with output filter capacitor.

3.3V-Input to Regulated 5V-Output Charge Pumps

Detailed Description

The MAX682/MAX683/MAX684 charge pumps provide a regulated 5V output from a 2.7V to 5.5V input. They deliver a maximum of 250mA, 100mA, or 50mA load current, respectively. Designed specifically for compact applications, a complete regulator circuit requires only three small external capacitors and one resistor. An externally adjustable switching frequency and innovative control scheme allow the circuit to be optimized for efficiency, size, or output noise. The devices also contain a shutdown feature.

The MAX682/MAX683/MAX684 consist of an error amplifier, a 1.23V bandgap reference, an internal resistive feedback network, an oscillator, high-current MOSFET switches, and shutdown and control logic (Figure 1). Figure 2 shows an idealized unregulated charge-pump voltage doubler. The oscillator runs at a 50% duty cycle. During one half of the period, the transfer capacitor (C_X) charges to the input voltage. During the other half, the doubler stacks the voltage across C_X and the input voltage, and transfers the sum of the two voltages to the output filter capacitor (C_{OUT}). Rather than simply doubling the input voltage, the MAX682/MAX683/MAX684 provide a regulated fixed output voltage (5V) using either skip mode or constant-frequency mode. Skip mode and constant-frequency mode are externally selected via the $\overline{SKIP}$ input pin.

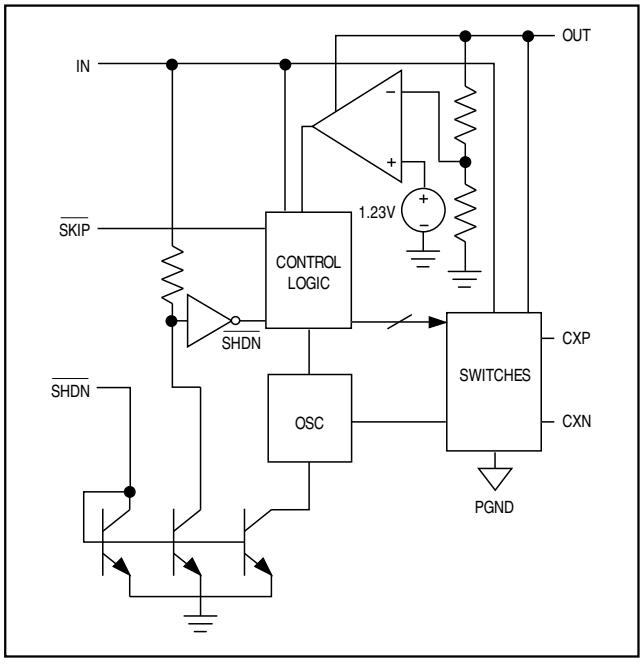


Figure 1. Functional Block Diagram

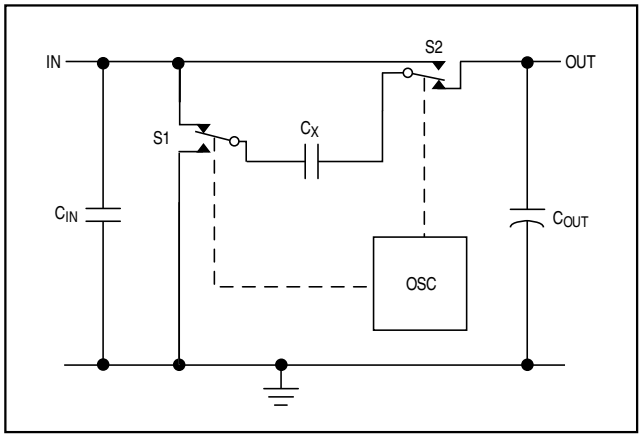


Figure 2. Unregulated Voltage Doubler

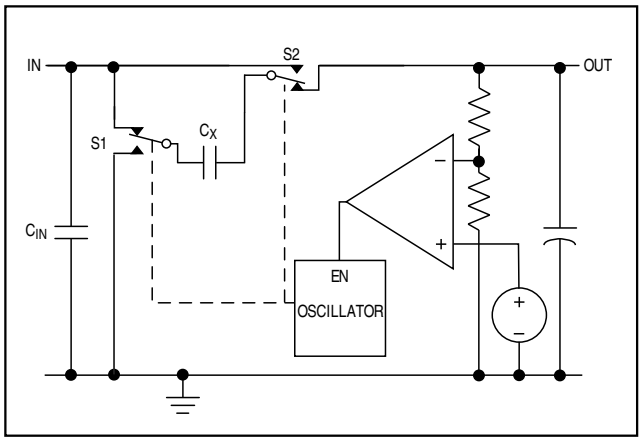


Figure 3. Skip-Mode Regulation

Skip Mode

In skip mode ($\overline{SKIP}$ = low), the error amplifier disables switching when it detects an output higher than 5V. The device then skips switching cycles until the output voltage drops. Then the error amplifier reactivates the oscillator. Figure 3 illustrates the regulation scheme. This regulation method minimizes operating current because the device does not switch continuously. $\overline{SKIP}$ is a logic input and should not remain floating.

Constant-Frequency Mode

When $\overline{SKIP}$ is high, the charge pump runs continuously at the selected frequency. Figure 4 shows a block diagram of the device in constant-frequency mode. The error amplifier controls the charge on C_X by driving the gate of the N-channel FET. When the output voltage falls, the gate drive increases, resulting in a larger voltage across C_X. This regulation scheme minimizes output ripple. Since the device switches continuously, the

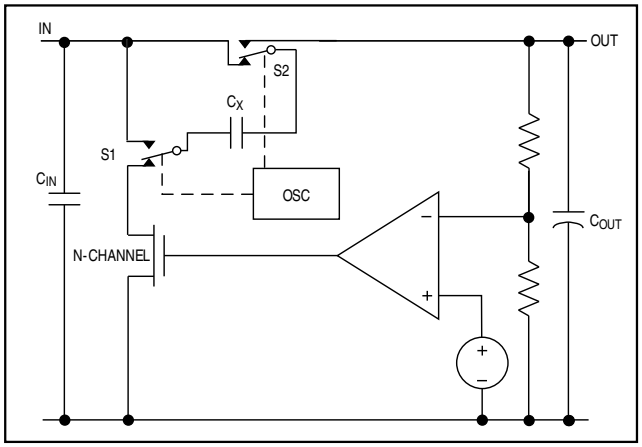


Figure 4. Constant-Frequency-Mode Regulation

Table 1. Tradeoffs Between Operating Modes

FEATURE	SKIP MODE (SKIP = LOW)	CONSTANT-FREQUENCY MODE (SKIP = HIGH)
Best Light-Load Efficiency	✔	
Smallest External Component Size		✔
Output Ripple Amplitude and Frequency	Relatively large amplitude, variable frequency	Relatively small amplitude, constant frequency
Load Regulation	Very Good	Good

output noise contains well-defined frequency components, and the circuit requires much smaller external capacitors for a given output ripple. However, constant-frequency mode, due to higher operating current, is less efficient at light loads than skip mode. Note: For input voltages above 3.6V, the devices must operate in constant-frequency mode. Table 1 summarizes the tradeoffs between the two operating modes.

Frequency Selection and Shutdown

The SHDN pin on the MAX682/MAX683/MAX684 performs a dual function: it shuts down the device and determines the oscillator frequency. The SHDN input looks like a diode to ground and should be driven through a resistor.

Driving SHDN low places the device in shutdown mode. This disables all switches, the oscillator, and control logic. The device typically draws 0.1µA (5µA max) of supply current in this mode and the output presents a 50kΩ impedance to ground. The device exits shutdown once SHDN is forward biased (minimum of 1µA of current). The typical no-load shutdown exit time is 50µs.

When SHDN is pulled high through an external resistor to V_{IN}, the bias current into SHDN determines the charge-pump frequency. To select the frequency, calculate the external resistor value, R_{EXT}, using the following formula:

$$R_{EXT} = 45000\ (V_{IN} - 0.69V) / f_{OSC}$$

where R_{EXT} is in kΩ and f_{OSC} is in kHz. Program the frequency in the 50kHz to 2MHz range. This frequency range corresponds to SHDN input currents between 1µA and 50µA. Proper operation of the oscillator is not guaranteed beyond these limits. Currents lower than 1µA may shut down the device. The forward-biased diode voltage from the SHDN input to GND has a temperature coefficient of -2mV/°C.

Undervoltage Lockout

The MAX682/MAX683/MAX684 have an undervoltage-lockout feature that deactivates the devices when the input voltage falls below 2.25V. Regulation at low input voltages cannot be maintained. This safety feature ensures that the device shuts down before the output voltage falls out of regulation by a considerable amount (typically 10% with no load). Once deactivated, hysteresis holds the device in shutdown until the input voltage rises 100mV above the lockout threshold.

Applications Information

Capacitor Selection

The MAX682/MAX683/MAX684 require only three external capacitors (Figure 5). Their values are closely linked to the output current capacity, oscillator frequency, output noise content, and mode of operation.

Generally, the transfer capacitor (C_X) will be the smallest, and the input capacitor (C_{IN}) is twice as large as C_X. Higher switching frequencies allow the use of smaller C_X and C_{IN}. The output capacitor (C_{OUT}) can be anywhere from 5-times to 50-times larger than C_X, depending on the mode of operation and ripple tolerance. In continuous switching mode, smaller output ripple allows smaller C_{OUT}. In skip mode, a larger C_{OUT} is required to maintain low output ripple. Tables 2 and 3 show capacitor values recommended for lowest supply-current operation (skip mode) and smallest size operation (constant-frequency mode), respectively.

3.3V-Input to Regulated 5V-Output Charge Pumps

Table 2. Recommended Capacitor Values for Quiescent Current (Skip Mode)

PART	OUTPUT (mA)	C_{IN} (µF)	C_X (µF)	C_{OUT} (µF)		V_{OUT} RIPPLE (mV)
				TANTALUM	CERAMIC	
MAX682	250	2.2	1	47	10	100
MAX683	100	1	0.47	22	4.7	100
MAX684	50	0.47	0.22	10	2.2	100

Table 3. Recommended Capacitor Values for Smallest Size (Constant-Frequency Mode, $I_{\overline{SHDN}}$ = 22µA, 1MHz)

PART	OUTPUT (mA)	C_{IN} (µF)	C_X (µF)	CERAMIC C_{OUT} (µF)	V_{OUT} RIPPLE (mV)
MAX682	250	1	0.47	2.2	80
MAX683	100	0.47	0.22	1	80
MAX684	50	0.22	0.1	0.47	80

Table 4. Recommended Capacitor Manufacturers

VALUE	DESCRIPTION	MANUFACTURER	PHONE NUMBER
47µF to 10µF	595D-series tantalum surface mount	Sprague	(603) 224-1961
47µF to 10µF	TPS-series surface mount	AVX	(803) 946-0690
0.1µF to 2.2µF	Ceramic surface mount	TDK	(847) 390-4373

In addition, the following two equations approximate output ripple for each mode. In skip mode, output ripple is dominated by ESR, and is approximately:

$$V_{RIPPLE(SKIP)} \cong (2V_{IN} - V_{OUT})ESR_{COUT} / R_{TX}$$

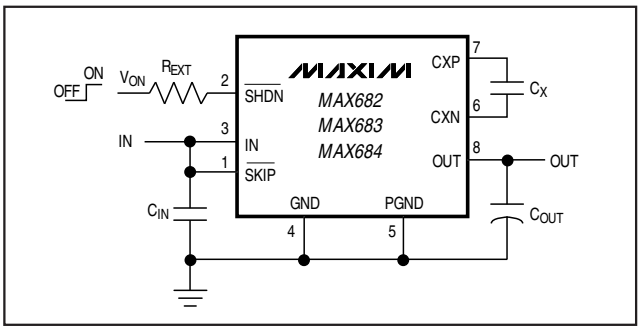


Figure 5. Standard Operating Circuit

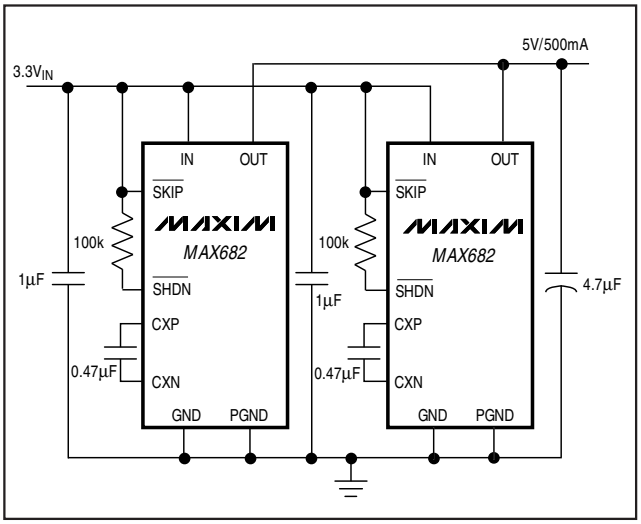


Figure 6. Paralleling Two MAX682s

where ESR_{COUT} is the ESR of the output filter capacitance, and R_{TX} is the open-loop output transfer resistance of the IC. R_{TX} is typically 0.8Ω for the MAX682, 1.6Ω for the MAX683, and 3Ω for the MAX684. In constant-frequency mode, output ripple is dominated by C_{OUT} and is approximately:

$$V_{RIPPLE(const\text{-}freq)} \cong I_{OUT} / (2 \times f_{OSC} \times C_{OUT})$$

All capacitors must maintain a low (<100mΩ) equivalent series resistance (ESR). Table 4 lists the manufacturers of recommended capacitors. Surface-mount tantalum capacitors will work well for most applications. Ceramic capacitors will provide the lowest ripple due to their typically lower ESR.

If the source impedance or inductance of the input supply is large, additional input bypassing (2.2µF to 22µF) may be needed. This additional capacitance need not be a low-ESR type.

Power Dissipation

The power dissipated in the MAX682/MAX683/MAX684 depends on output current and is accurately described by:

$$P_{DISS} = I_{OUT} (2V_{IN} - V_{OUT})$$

P_{DISS} must be less than that allowed by the package rating. See the *Absolute Maximum Ratings* for 8-pin µMAX (MAX683/MAX684) and SO (MAX682) power-dissipation limits and deratings.

Layout Considerations

All capacitors should be soldered in close proximity to the IC. Connect ground and power ground through a short, low-impedance trace. If a high-value resistor is driving the shutdown input and is picking up noise (i.e., frequency jitter at CXP and CXN), bypass $\overline{SHDN}$ to GND with a small capacitor (0.01µF).

Paralleling Devices

The MAX682/MAX683/MAX684 can be paralleled to yield higher load currents. The circuit of Figure 6 can deliver 500mA at 5V. It uses two MAX682s in parallel. The devices can share the output capacitors, but each one requires its own transfer capacitor (C_X) and input capacitor. For best performance, the paralleled devices should operate in the same mode (skip or constant frequency).

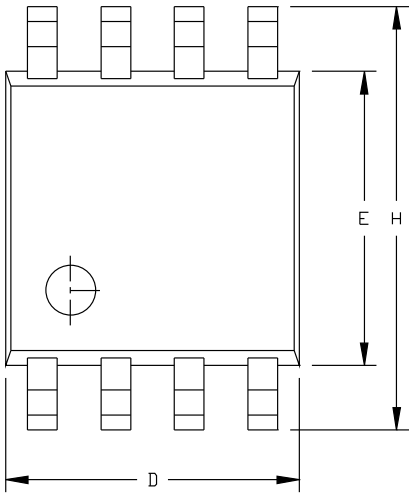
Chip Information

TRANSISTOR COUNT: 659

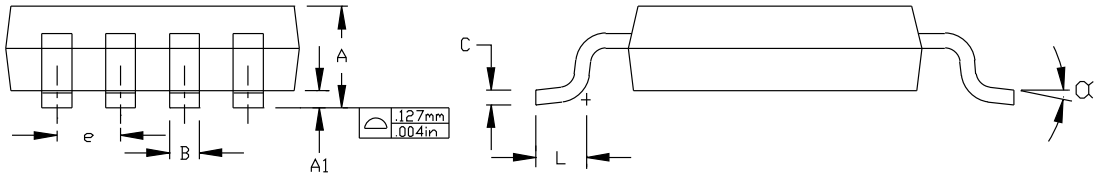
SUBSTRATE CONNECTED TO GND

Package Information

8LUMAXD.EPS



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.036	0.044	0.91	1.11
A1	0.004	0.008	0.10	0.20
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		0.65	
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°	6°	0°	6°



NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm(.006").
3. CONTROLLING DIMENSION: INCHES

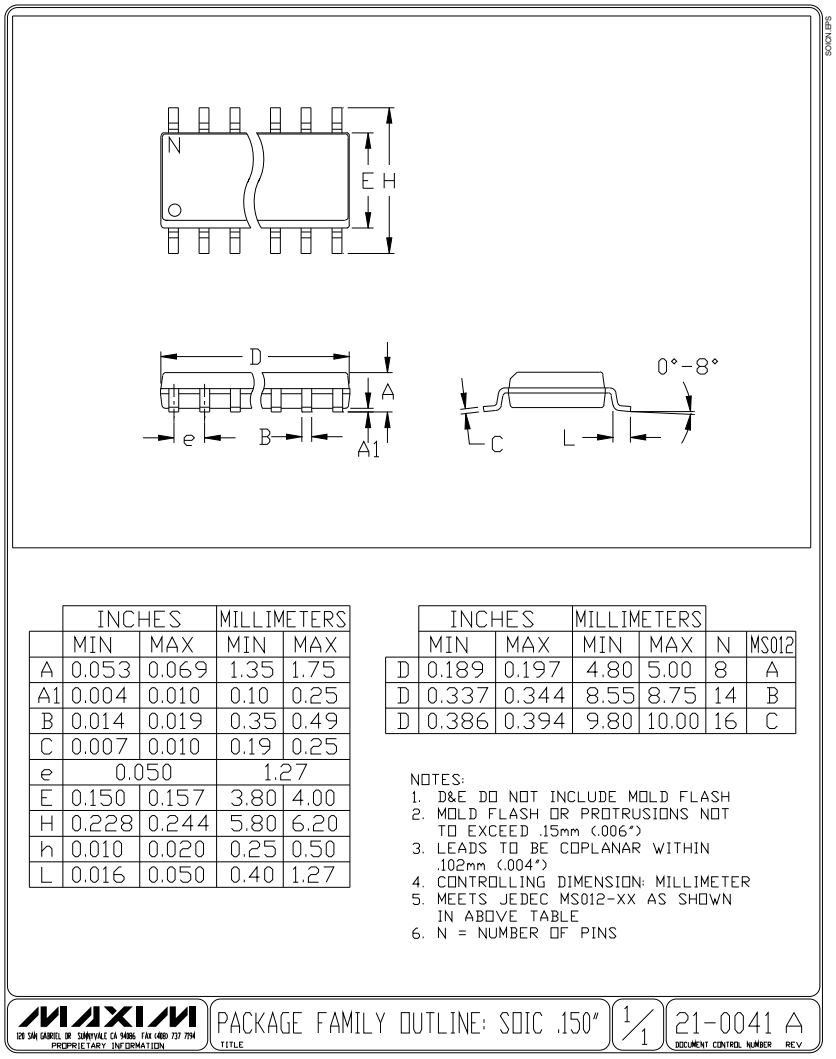
MAXIM
PROPRIETARY INFORMATION

TITLE:
8LD µMAX PACKAGE OUTLINE DWG.

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0036	D	1/1

3.3V-Input to Regulated 5V-Output Charge Pumps

Package Information



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
B	0.014	0.019	0.35	0.49
C	0.007	0.010	0.19	0.25
e	0.050		1.27	
E	0.150	0.157	3.80	4.00
H	0.228	0.244	5.80	6.20
h	0.010	0.020	0.25	0.50
L	0.016	0.050	0.40	1.27

	INCHES		MILLIMETERS			
	MIN	MAX	MIN	MAX	N	MS012
D	0.189	0.197	4.80	5.00	8	A
D	0.337	0.344	8.55	8.75	14	B
D	0.386	0.394	9.80	10.00	16	C

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
3. LEADS TO BE COPLANAR WITHIN .102mm (.004")
4. CONTROLLING DIMENSION: MILLIMETER
5. MEETS JEDEC MS012-XX AS SHOWN IN ABOVE TABLE
6. N = NUMBER OF PINS

MAXIM — 120 SAN GABRIEL DR SUNNYVALE CA 94086 FAX (408) 737 7194 — PROPRIETARY INFORMATION

PACKAGE FAMILY OUTLINE: SOIC .150" — TITLE

1/1

21-0041 A — DOCUMENT CONTROL NUMBER — REV

NOTES

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