Click here to ask an associate for production status of specific part numbers.

MAX18002

500mV to 5.5V Input, Ultrasonic Boost Converter with Short-Circuit Protection and True Shutdown

General Description

The MAX18002 is an ultrasonic, high-performance boost converter with an input voltage range of 0.5V to 5.5V and a switching current limit of 3.6A. The IC operates in ultrasonic mode (USM) (F_{SW} at 29kHz typ) at low loads and transitions into skip mode and continuous conduction mode (CCM) of operation at higher load currents. The MAX18002 can operate in pass-through mode when the input voltage is higher than the output voltage.

The output voltage can be varied between 2.5V and 5.5V (USM disabled for V_{OUT} > 5V) using a single RSEL resistor.

The MAX18002 features a True Shutdown™ mode which disconnects V_{IN} and V_{OUT} when the EN pin is pulled low. It also features a short-circuit protection circuitry that limits the current to 700mA when V_{OUT} < 0.5V and automatically restarts the part when the fault is removed. The thermal-shutdown protection disables the part when the junction temperature crosses +165˚C (typ).

The MAX18002 is available in 1.07mm x 1.57mm, 6-bump, wafer-level package (WLP).

True Shutdown is a trademark of Maxim Integrated Products, Inc.

Benefits and Features

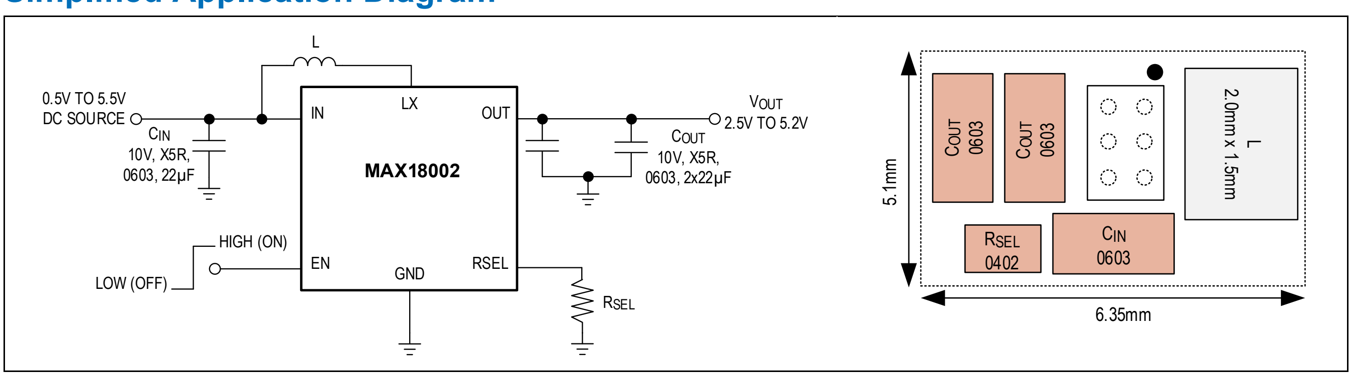
- 0.5V to 5.5V Input Voltage
- 1.8V Minimum Start-Up Voltage
- 2.5V to 5.5V (in 100mV Steps) Output Voltage
- 3.6A Cycle-by-Cycle Inductor Current Limit
- Automatic Pass-Through Mode when V_{IN} > V_{OUT}
- Ultrasonic Mode (F_{SW} at 29kHz typ) to Alleviate Acoustic Audible Interference for Light-Load Operation
- True-Shutdown Mode
  - 7nA Shutdown Current
  - Output Disconnects from Input Without Forward or Reverse Current
- Output Short-Circuit Protection
- Thermal-Shutdown Protection
- 95% Peak Efficiency (3.6V_{IN}, 5V_{OUT})
- 1.07mm x 1.57mm, 0.5mm Pitch, 6-Bump WLP
- -40°C to +125°C Operating Temperature Range

Key Applications

- Wearable Applications
- IoT Applications
- Battery-Powered Applications
- Portable Devices
- Metering Applications

***Ordering Information* appears at end of data sheet.**

Simplified Application Diagram



19-101623; Rev 0; 1/23

Absolute Maximum Ratings

IN, EN, OUT, RSEL to GND ....-0.3V to +6V

PGND to GND ....-0.3V to +0.3V

LX RMS current..................................-2.4A_{RMS} to +2.4A_{RMS}

LX to GND (Note 1) ....-0.3V to V_{OUT} + 0.3V

Output Short-Circuit Duration ....Continuous

Continuous Power Dissipation (T_A = +70°C (derate 12.34mW/°C above +70°C))...................................... 980mW

Operating Temperature Range ....-40˚C to +125˚C

Maximum Junction Temperature................................. +150˚C

Storage Temperature Range ....-65˚C to +150˚C

Lead Temperature (soldering, 10 seconds)................. +300˚C

Soldering Temperature (reflow).................................. +260˚C

Note 1: LX pin has internal clamps to GND and OUT. These diodes may be forward biased during switching transitions. During these transitions, the max LX current should be within the maximum RMS current rating for safe operation.

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.

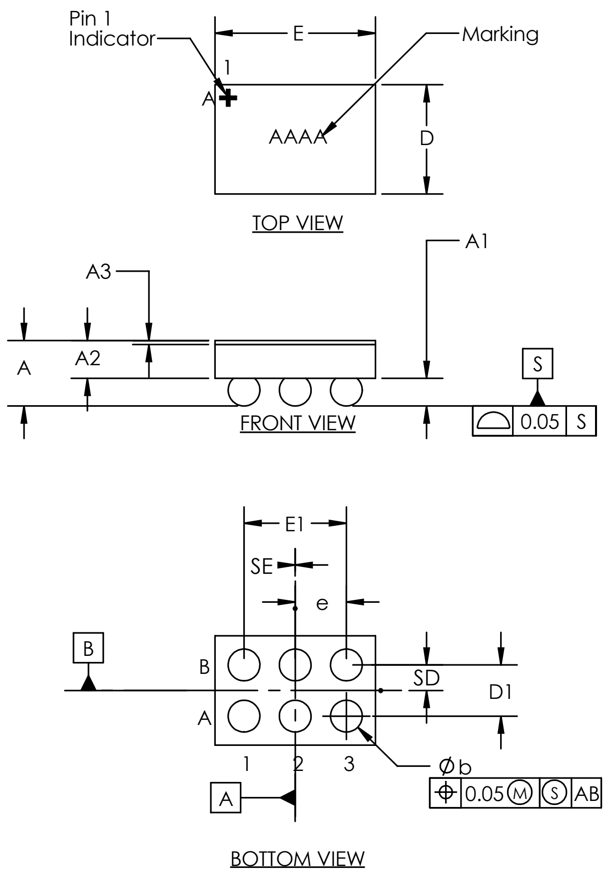
Recommended Operating Conditions

PARAMETER	SYMBOL	TYPICAL RANGE
Input Voltage Range	V_{IN}	0.5V to 5.5V
Switching Current Limit	I_{PEAK_LX}	0A to 3.6A
Operating Junction Temperature	T_J	-40˚C to +125˚C

Package Information

WLP

Package Code	W61M1Z+1
Outline Number	21-100570
Land Pattern Number	Refer to Application Note 1891
Thermal Resistance, Four Layer Board:	
Junction-to-Ambient (θ_{JA})	81.03°C/W
Junction-to-Case Thermal Resistance (θ_{JC})	NA



COMMON DIMENSIONS	
A	0.64 ±0.05
A1	0.27 ±0.03
A2	0.37 REF
A3	0.04 BASIC
b	Ø 0.31 ±0.03
D	1.068 ±0.025
E	1.568 ±0.025
D1	0.50 BASIC
E1	1.00 BASIC
e	0.50 BASIC
SD	0.25 BASIC
SE	0.00 BASIC
DEPOPULATED BUMPS: NONE	

NOTES:
1. Terminal pitch is defined by terminal center to center value.
2. Outer dimension is defined by center lines between scribe lines.
3. All dimensions in millimeter.
4. Marking shown is for package orientation reference only.
5. Tolerance is ± 0.02 unless specified otherwise.
6. All dimensions apply to PbFree (+) package codes only.
7. Front - side finish can be either Black or Clear.

maxim integrated™

TITLE: PACKAGE OUTLINE 6 BUMPS WLP PKG. 0.5 mm PITCH, W61M1Z+1

APPROVAL | DOCUMENT CONTROL NO. 21-100570 | REV. A | 1/1

- DRAWING NOT TO SCALE -

Electrical Characteristics

(V_{IN} = 3V, V_{OUT} = 3.3V, EN = high, T_J = -40ºC to +125ºC, unless otherwise specified. See Note 2.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}	Input range after start-up	0.5		5.5	V
Input Voltage UVLO	V_{IN_UVLO}	V_{IN} rising, when V_{OUT} is 1V or below	1.75	1.8	1.85	V
		V_{IN} falling, when V_{OUT} is 1V or below	1.65	1.7	1.75	
Supply Current Into OUT	I_{Q_OUT}	V_{EN} = V_{IN}, not switching, T_J = +25°C, RSEL = 191kΩ (Note 3)		150	1600	µA
Supply Current Into IN	I_{Q_IN}	V_{EN} = V_{IN}, not switching, T_J = +25°C, RSEL = 191kΩ (Note 3)	-3	-1	1	µA
Input Shutdown Current	I_{SD_IN}	V_{EN} = 0V, V_{OUT} = 0V, T_J = +25°C		7	36	nA
LX Maximum Duty Cycle	DC_USM	T_J = +25°C (Note 4)		85		%
POWER SWITCHES						
High-Side R_{DSON}	R_{DS_H}			60	90	mΩ
Low-Side R_{DSON}	R_{DS_L}			30	60	mΩ
OUTPUT VOLTAGE						
Output-Voltage Range	V_{OUT}	(Note 5)	2.5		5.5	V
Output Accuracy	V_{OUT_ACC}	Measured when the part exits USM and is in skip mode (Note 6)	-1		+1	%
DC Load Regulation	ACC_{LOAD}	Load from 20mA to IOUT at 80% of peak inductor current		-1		%
DC Line Regulation	ACC_{LINE}	Duty cycle varied from 25% to maximum		-1		%
LX SWITCHING WAVEFORMS						
Switching Frequency	F_{SW}	V_{IN} = 3.3V, V_{OUT} - V_{IN} > 0.25V, T_J = +25°C		2		MHz
LX T_{ON}	$T_{ON\_3.3V}$	V_{IN} = 3.3V, V_{OUT} = 5V	136	170	204	ns
	$T_{ON\_1.8V}$	V_{IN} = 1.8V, V_{OUT} = 5V	256	320	384	
LX Minimum T_{ON}	T_{ONMIN}	V_{IN} = 3V, V_{OUT} = 3.3V	50	60	70	ns
LX Minimum T_{OFF}	T_{OFFMIN}	V_{IN} = 3V, V_{OUT} = 3.3V	50	60	70	ns
LIGHT LOAD CONDITION						
Ultrasonic Mode Minimum Switching Frequency	F_{USM}	V_{IN} = 3.3V, V_{OUT} - V_{IN} > 0.25V	22	29	35	kHz
Zero Crossing Threshold	I_{ZX_LX}	(Note 7)	75	150	225	mA
STARTUP						
Soft-Start Time	t_{SS_LINEAR}	Target V_{IN} = V_{OUT} = 3.6V, linear mode, C_{OUTEFF} = 22µF, T_J = +25°C		350		µs
Soft-Start Rate	dV/dt	V_{IN} = 3.6V, V_{OUT} from 3.3V to 5V, boost mode, C_{OUTEFF} = 22µF, T_J = +25°C		3		V/ms
ENABLE, RSEL, ACTIVE DISCHARGE						
Required Select Resistor Accuracy	ACC_{RSEL}	Use the resistor from the RSEL selection table		±1		%
Select Resistor Detection Time	t_{RSEL}	C_{RSEL} < 2pF (Note 8)		600	1320	µs
Active Discharge Resistance	R_{DIS}	Between OUT and GND when EN = low, T_J = +25°C		100		Ω

(V_{IN} = 3V, V_{OUT} = 3.3V, EN = high, T_J = -40ºC to +125ºC, unless otherwise specified. See Note 2.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Enable Input Leakage	I_{LEAK_EN}	T_J = +25°C, V_{EN} = 5.5V		0.3	100	nA
Enable Voltage High Threshold	V_{IH}	V_{EN} rising, LX begins switching		0.8	1.2	V
Enable Voltage Low Threshold	V_{IL}	V_{EN} falling, LX stops switching	0.4			V
PROTECTION						
Inductor Peak Current Limit	I_{PEAK_LX}	V_{OUT} = 3.3V (Note 7)	3	3.6	4	A
Short-Circuit Current Limit	I_{SC}	V_{IN} = V_{EN} = 2.5V, V_{OUT} < 0.5V, V_{OUT} hysteresis = 100mV	400	700	1000	mA
Short-Circuit Detection Time	t_{SC}	V_{IN} - V_{OUT} = 0.7V		100		ns
Thermal-Shutdown Threshold	T_{SHUT_R}	T_J rising		165		˚C
	T_{SHUT_F}	T_J falling		150		

Note 2: Limits over the specified operating temperature and supply voltage range are guaranteed by design and characterization and production tested at room temperature only.

Note 3: This measurement was taken in test mode.

Note 4: Guaranteed by measuring LX frequency and duty cycle. Maximum duty cycle is a function of input voltage since LX on time varies with V_{IN}.

Note 5: The ultrasonic function is disabled when OUT regulation is set above 5V.

Note 6: This does not account for ripple, load regulation, and line regulation.

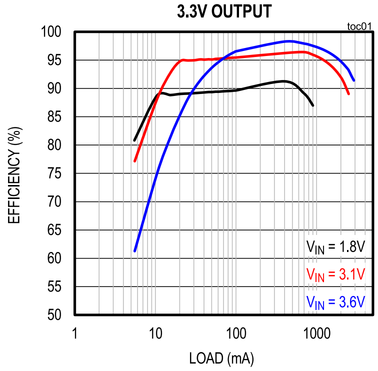
Note 7: This is a static measurement. The actual peak current limit and zero crossing threshold depend on V_{IN} and L due to propagation delays.

Note 8: This is the time required to determine the RSEL value. This time adds to the start-up time.

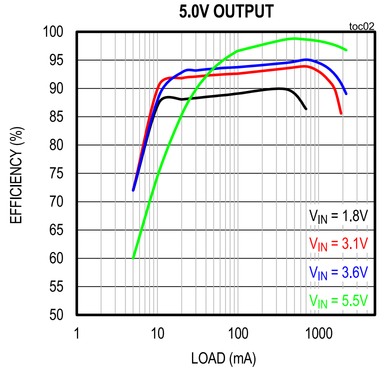
Typical Operating Characteristics

(V_{IN} = 3.6V, V_{OUT} = 5V, L = 470nH (DFE201612E-R47M for V_{OUT} = 5V) and 330nH (DFE201612E-R33M for V_{OUT} = 3.3V), C_{OUT} = 2 x 22µF (C1608X5R1A226M080AC), T_A = +25°C unless otherwise noted. Measurement limited by switching the current limit. Actual maximum output current depends on system thermal performance.)

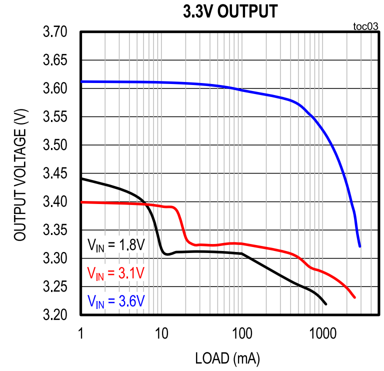
EFFICIENCY vs. LOAD
3.3V OUTPUT



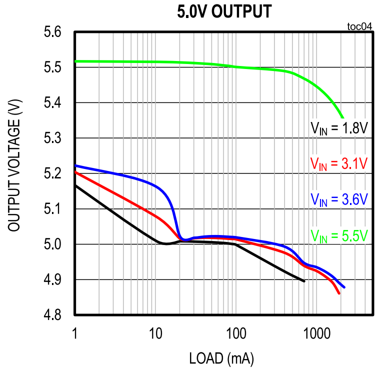
EFFICIENCY vs. LOAD
5.0V OUTPUT



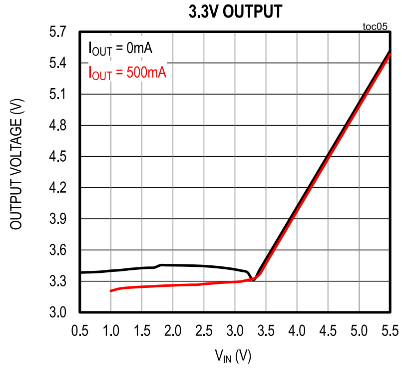
LOAD REGULATION
3.3V OUTPUT



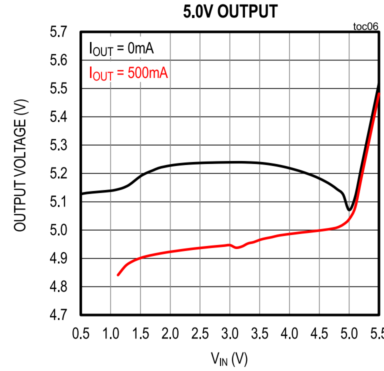
LOAD REGULATION
5.0V OUTPUT



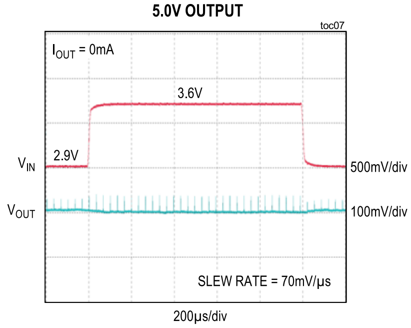
LINE REGULATION
3.3V OUTPUT



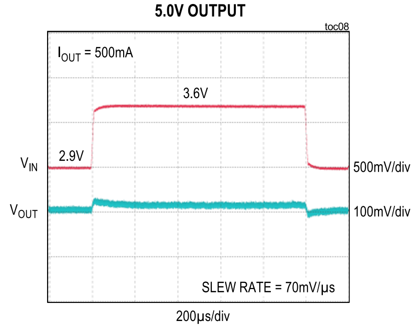
LINE REGULATION
5.0V OUTPUT



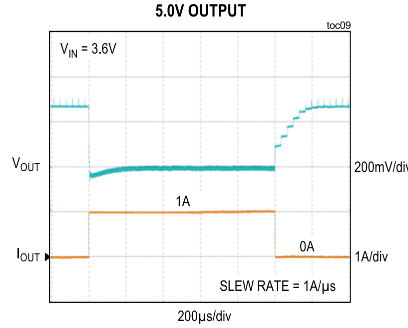
LINE TRANSIENT RESPONSE
5.0V OUTPUT



LINE TRANSIENT RESPONSE
5.0V OUTPUT

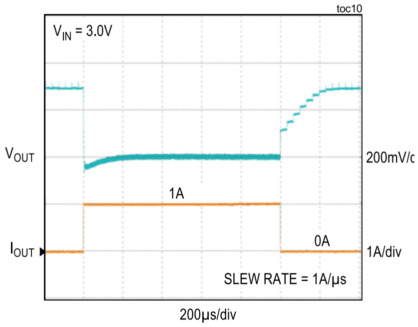


LOAD TRANSIENT RESPONSE
5.0V OUTPUT

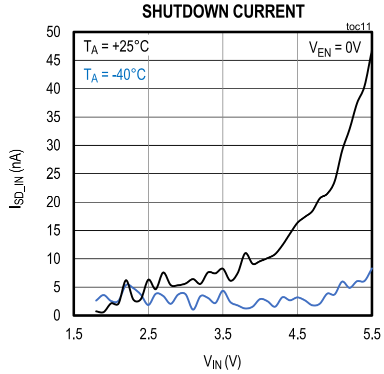


(V_{IN} = 3.6V, V_{OUT} = 5V, L = 470nH (DFE201612E-R47M for V_{OUT} = 5V) and 330nH (DFE201612E-R33M for V_{OUT} = 3.3V), C_{OUT} = 2 x 22µF (C1608X5R1A226M080AC), T_A = +25̊C unless otherwise noted. Measurement limited by switching the current limit. Actual maximum output current depends on system thermal performance.)

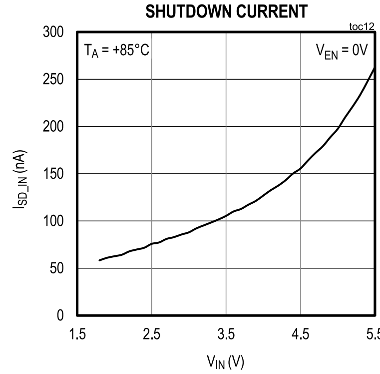
LOAD TRANSIENT RESPONSE
5.0V OUTPUT



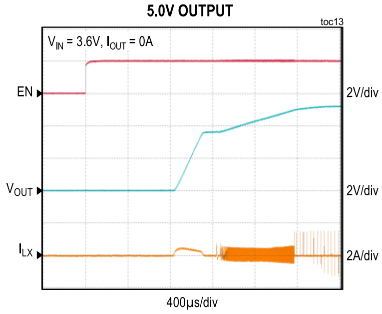
SHUTDOWN CURRENT



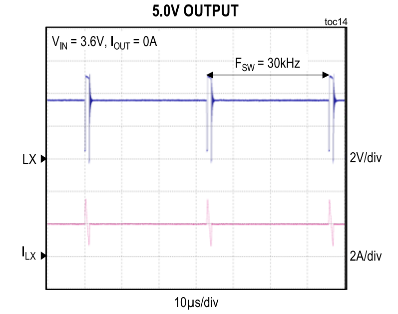
SHUTDOWN CURRENT



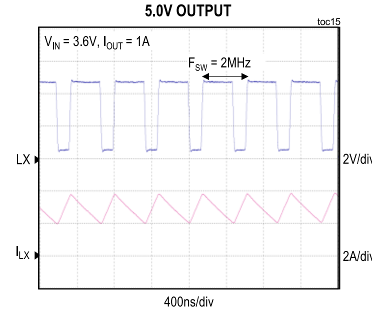
SOFT-START WAVEFORM
5.0V OUTPUT



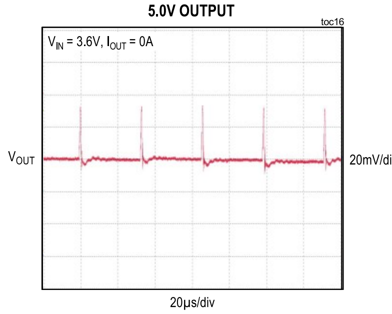
SWITCHING WAVEFORM
5.0V OUTPUT



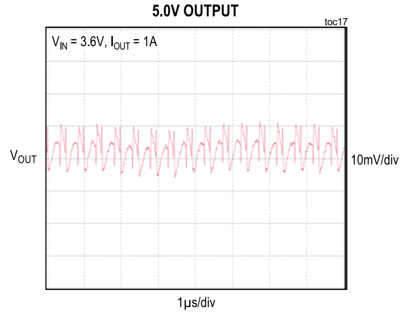
SWITCHING WAVEFORM
5.0V OUTPUT



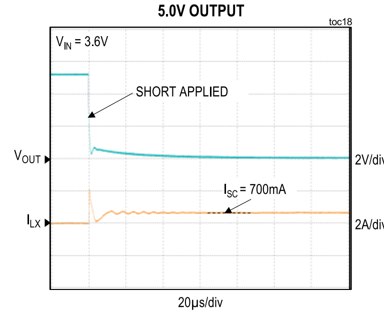
OUTPUT RIPPLE WAVEFORM
5.0V OUTPUT



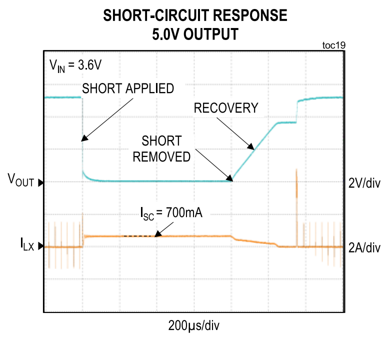
OUTPUT RIPPLE WAVEFORM
5.0V OUTPUT

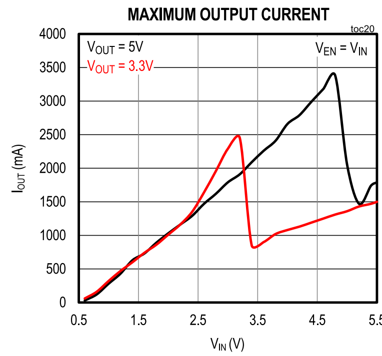


SHORT-CIRCUIT RESPONSE
5.0V OUTPUT

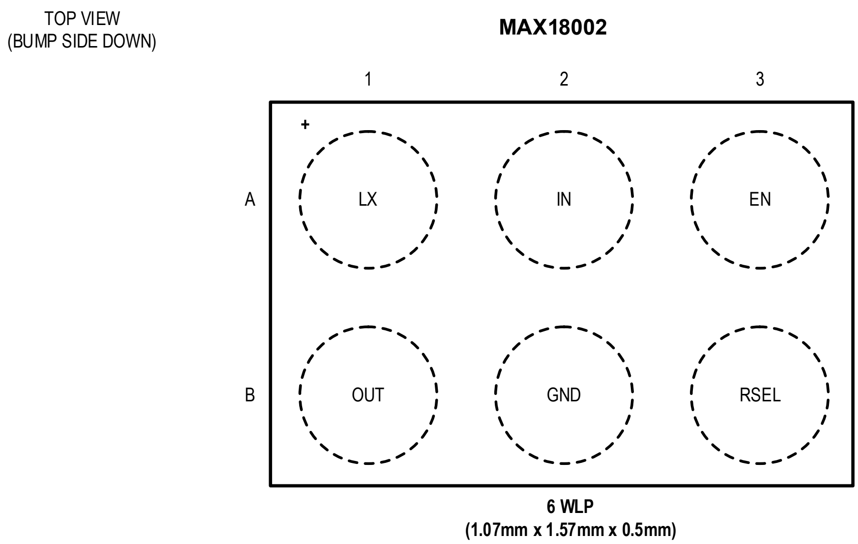


(V_{IN} = 3.6V, V_{OUT} = 5V, L = 470nH (DFE201612E-R47M for V_{OUT} = 5V) and 330nH (DFE201612E-R33M for V_{OUT} = 3.3V), C_{OUT} = 2 x 22μF (C1608X5R1A226M080AC), T_A = +25°C unless otherwise noted. Measurement limited by switching the current limit. Actual maximum output current depends on system thermal performance.)





Pin Configuration



Pin Description

PIN	NAME	FUNCTION	Type
A1	LX	Switching Node. Connect the inductor (See the *Inductor Selection* section for more information) from LX to IN.	Power
A2	IN	Input Pin. Connect a 22µF X7R ceramic capacitor from IN to ground. Depending on the specific application requirements, more capacitance may be needed.	Power
A3	EN	Enable Input Pin. Force this pin to higher than 1.2V to enable the boost converter. Force this pin below 0.4V to disable the part and enter True Shutdown mode.	Digital
B1	OUT	Output Pin. Connect a 2 x 22µF X7R ceramic capacitor from OUT to GND.	Power
B2	PGND	Power Ground. Connect to System GND	Ground
B3	RSEL	Output Voltage Select Pin. Connect a resistor from RSEL to GND based on the desired output voltages. See *Table 1* for more information. RSEL floats in shutdown. Care must be taken that the total capacitance on this pin should be less than 2pF.	Analog

Functional Diagram

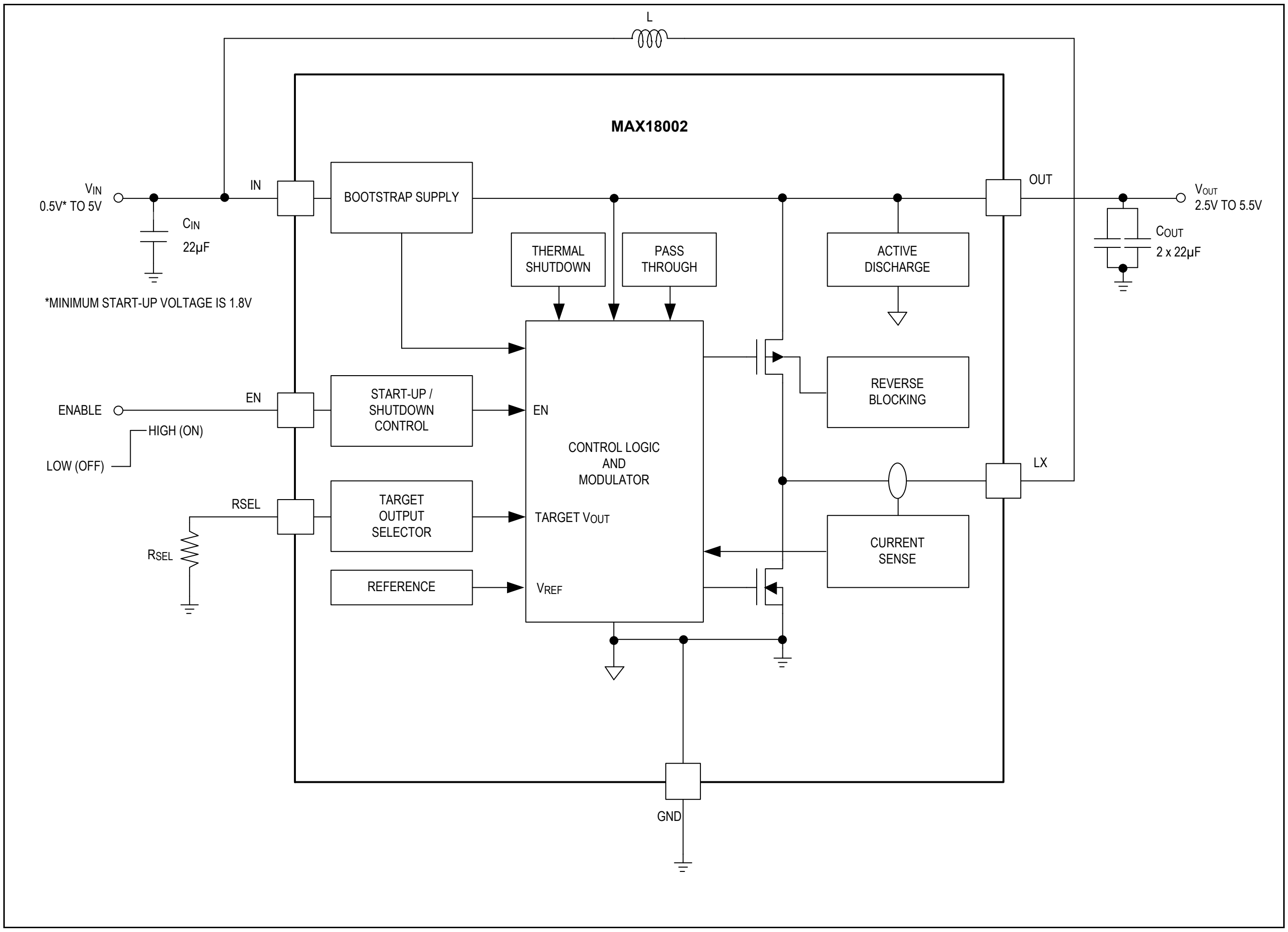


Figure 1. MAX180002 Simplified Block Diagram

Detailed Description

The MAX18002 is an ultrasonic boost converter with an input voltage range of 500mV to 5.5V ideal for IoT and wearable applications. The start-up voltage required for the IC is about 1.8V (typical). The output voltage is adjustable between 2.5V and 5.5V (in steps of 100mV) using a single external resistor connected between RSEL and GND.

The MAX18002 operates in three modes; ultrasonic mode (USM), skip mode, and continuous conduction mode (CCM) according to the load current. In USM, the switching frequency of the IC is kept above 22kHz even at light loads to stay away from the audible frequency range. When $V_{IN} > V_{OUT}$, the part goes into pass-through mode where it regulates to the V_{IN} level and operates with a switching frequency of 29kHz (typical).

The part is equipped with a cycle-to-cycle switch current limit, thermal shutdown, and short-circuit protection to protect the system and the device itself.

Output-Voltage Selection

The MAX18002 has a unique single resistor output selection method where the resistor connected between RSEL and GND is used to select different output voltages from 2.5V to 5.5V (USM disabled for V_{OUT} > 5V) in 100mV steps as shown in Table 1. The advantages of using a single RSEL for output-voltage selection are as follows:

- Lower cost and smaller size, since only one resistor is needed versus the two resistor strings needed in typical feedback connections.
- No power loss through feedback resistors during operation leading to higher efficiency.
- Allows customers to stock just one part in their inventory system and use it in multiple projects with different output voltages just by changing a single standard 1% resistor.

Table 1. RSEL Selection Table

OUTPUT VOLTAGE (V)	RSEL (kΩ)**
2.5	768
2.6	634
2.7	536
2.8	452
2.9	383
3.0	324
3.1	267
3.2	226
3.3	191
3.4	162
3.5	133
3.6	113
3.7	95.3
3.8	80.6
3.9	66.5
4.0	56.2
4.1	47.5
4.2	40.2
4.3	34
4.4	28
4.5	23.7
4.6	20
4.7	16.9

4.8	14
4.9	11.8
5.0	10.0
5.1*	8.45
5.2*	7.15
5.3*	5.9
5.4*	4.99
5.5*	Short to Ground

*USM disabled for V_{OUT} > 5V.
**Use a standard 1% resistor at the RSEL pin.

Soft-Start

When the EN logic goes high and $V_{IN} > V_{IN\_UVLO}$, the MAX18002 starts up by turning on the bias circuitry after which the resistance value at the RSEL pin is read to set the V_{OUT} target voltage level. The MAX18002 addresses the issue of high inrush current during start-up by having the high-side PMOS operate in linear mode (PMOS slew) until $V_{OUT} = V_{IN}$. The PMOS slew phase typically takes about 350µs.

After the PMOS slew is complete, the high-side PMOS turns off and the IC enters a boost-slew mode. In the boost slew mode of operation, the part switches and the output voltage ramps up with a slew rate of 3V/ms (typical) until the regulation target.

If the MAX18002 sees an output voltage level of less than 0.5V after the PMOS slew timer expires (350µs typical), it enters short-circuit protection mode. In short-circuit protection mode, the IC stops switching and the PMOS current is limited to 700mA (typical).

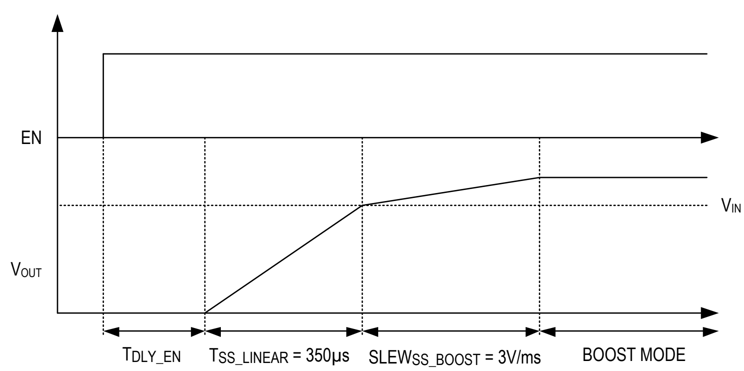


Figure 2. Soft-Start Behavior

Boost Control Scheme

The MAX18002 operates based on an adaptive on-time current mode control. Adaptive on-time is used to get a fast transient response and better efficiency across the product operation range. In both continuous conduction mode (CCM) and discontinuous conduction mode (DCM), the on-time is adjusted depending on the input voltage and target output voltage.

Automatic Pass-Through

Automatic pass-through mode is activated whenever $V_{IN} > V_{OUT}$. During the pass-through mode of operation, the MAX18002 follows the V_{IN} level and operates at a switching frequency of 29kHz (typical) in USM to stay away from acoustic audible range.

Ultrasonic Mode (USM)

The MAX18002 features a USM in which the converter seamlessly operates at a switching frequency of 29kHz (typical) to stay away from acoustic audible noise interference while operating at light loads. The USM circuit operates by clamping the minimum switching frequency.

When the load current reduces, the switching frequency goes down until it reaches 29kHz (typical). USM is turned on at this stage. In USM, the MAX18002 switches at 29kHz (typical) until the output voltage reaches 2% above the output voltage target. The device then switches at about 29kHz (typical) and keeps the boost discharge cycle on even after the inductor current crosses 0A resulting in the output capacitor discharging to the input. This extra cycle is necessary to prevent the output voltage from ramping up. The MAX18002 overregulates to 5% above the output voltage target when the part operates in no load.

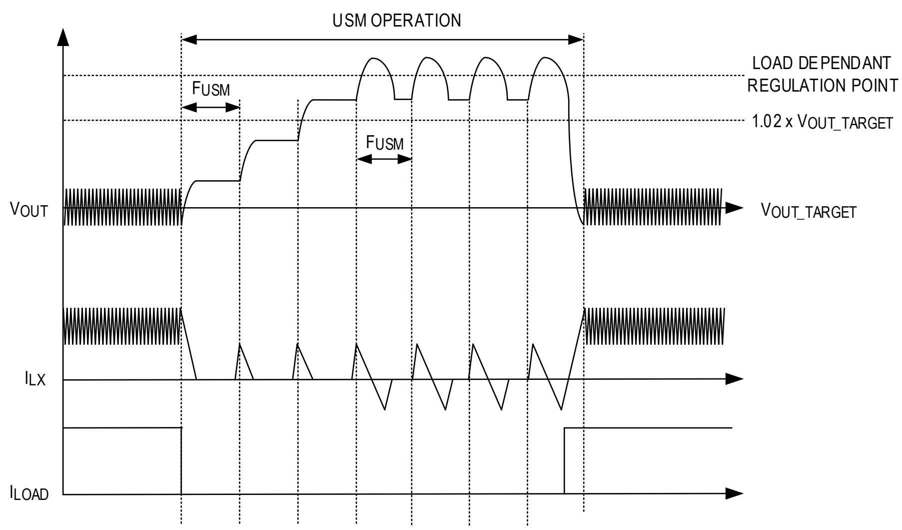


Figure 3. USM Operation

Thermal Shutdown

When the junction temperature exceeds T_{SHUT_R} (+165°C typical), the converter is turned off until the temperature drops to T_{SHUT_F} (+150°C typical) after which the part starts up again. If the fault condition persists, power is cycled on and off until the fault is cleared.

Over-Current Protection

The MAX18002 features a cycle-to-cycle peak current limit of 3.6A (typical) to protect the IC and the system from overload conditions. When the IC is in boost mode and the inductor current hits the current limit, the pMOS is turned on to start a discharge cycle and bring the inductor current down.

When the IC hits current limit in pass-through mode, the pMOS turns off to protect the part causing the inductor current to fall to zero. The part then goes into pMOS slew mode gradually causing the inductor current to rise and bring output back to the V_{IN} level.

Short-Circuit Protection

When the MAX18002 is hard shorted and the output voltage falls below 0.5V, it enters hard-short state. In the hard-short condition, the MAX18002 stops switching and pMOS switch limits short-circuit current from the input to 0.7A (typical).

If the fault persists, the heat generated in the pMOS switch due to the short-circuit current may cause the part to enter thermal shutdown.

When the fault is removed, the MAX18002 goes into pMOS slew until V_{IN} = V_{OUT}. After the pMOS slew is complete, the MAX18002 skips the boost slew phase (that is observed during start-up) and enters the boost mode of operation. This operation could lead to an overshoot in output voltage of about 10% (typical) when V_{IN} and V_{OUT} are close to each other.

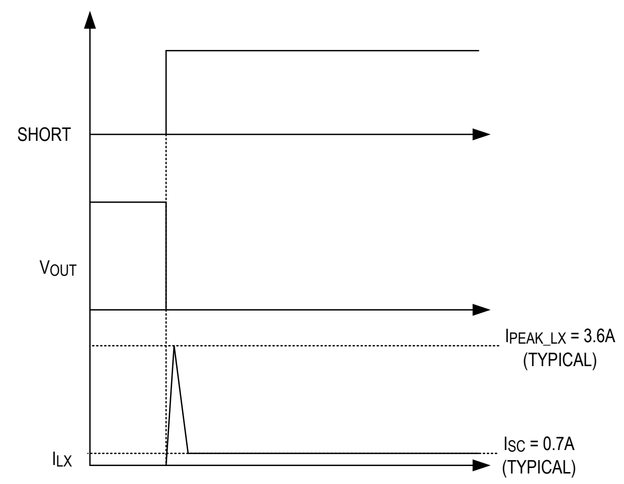


Figure 4. Short-Circuit Operation

Applications Information

Inductor Selection

Select an inductor with a saturation current rating (I_{SAT}) greater than or equal to the maximum high-side switching current limit threshold (I_{LIM}) setting. In general, inductors with lower saturation current and higher DC resistance (DCR) ratings are physically small. Higher values of DCR reduce converter efficiency. Choose RMS current rating (I_{RMS}) of the inductor (the current at which the temperature rises appreciably) based on the expected load current.

The chosen inductor value should ensure that the peak-inductor ripple current (I_{PEAK}) is below the I_{LIM} setting so that the converter can maintain regulation. The inductors recommended for different ranges of output voltages are shown in *Table 2*.

Table 2. Inductor and Output Capacitance Values vs Output Voltage

OUTPUT VOLTAGE (V)	RECOMMENDED INDUCTOR (nH)	EFFECTIVE OUTPUT CAPACITANCE (µF)*
5	470	9
3.3–5	330	20
2.5–3.3	220	20

*The effective capacitance for all voltage levels can be achieved using 2 x 22µF, X5R, 0603 capacitors.

Table 3. Recommended Inductors

VENDOR	PART NUMBER	NOMINAL INDUCTANCE (nH)	TYPICAL DCR (mΩ)	I_{SAT} (A)	I_{RMS} (A)	DIMENSIONS (L x W x H (mm))	OUTPUT VOLTAGE (V)
Murata	DFE201612E-R47M	470	26	5.5	4.5	2.0 x 1.6 x 1.2	5
Taiyo Yuden	MEKK2016HR47M	470	26	6.1	4.7	2.0 x 1.6 x 1.0	5
Murata	DFE201612E-R33M	330	21	6.3	4.8	2.0 x 1.6 x 1.2	3.3
Bourns	SRP2010TMA-R33M	330	29	5.0	3.8	2.0 x 1.6 x 1.0	3.3
Vishay	IHHP0806ABERR22M01	220	13	5.8	5.3	2.0 x 1.6 x 1.2	2.5
Taiyo Yuden	MAKK2016HR22M	220	26	5.8	4	2.0 x 1.6 x 1.0	2.5

Input-Capacitor Selection

For most applications, bypass the IN pin with a 10V 22µF nominal ceramic input capacitors (C_{IN}) that maintains 5µF or higher effective capacitance at its working voltage. Effective C_{IN} is the actual capacitance value seen from the converter input during operation. Larger values improve decoupling for the converter but increase inrush current from voltage supply when connected. C_{IN} reduces the current peaks drawn from the input power source and reduces switching noise in the system. The ESR/ESL of C_{IN} and its series PCB trace should be very low (i.e., < 15mΩ + < 2nH) for frequencies up to the converter's switching frequency.

Pay special attention to the capacitor's voltage rating, initial tolerance, variation with temperature, and DC bias characteristic when selecting C_{IN}. Ceramic capacitors with X7R dielectrics are highly recommended due to their small size, low ESR, and small temperature coefficients. All ceramic capacitors derate with DC bias voltage (effective capacitance goes down as DC bias goes up). Generally, smaller case-size capacitors derate more heavily compared to larger case sizes (0603 case size performs better than 0402). Consider the effective capacitance value carefully by consulting the manufacturer's data sheet. Refer to *Tutorial 5527* for more information.

Output-Capacitor Selection

Sufficient output capacitance (C_{OUT}) is required for stable operation of the converter. The minimum effective output capacitance for different output voltage targets are shown in *Table 2*. Effective C_{OUT} is the actual capacitance value seen by the converter output during operation. Larger values (above the required effective minimum) improve load transient performance but increase input surge currents during soft-start and output-voltage changes. To meet output ripple and load transient requirements, the output filter capacitor must have low enough ESR for frequencies up to the converter's switching frequency. The output capacitance must be high enough to absorb the inductor energy while transitioning from full load to no-load conditions. For most applications, 2 x 22µF capacitors ($10V_{DC}$) is recommended for C_{OUT}.

Pay special attention to capacitor's voltage rating, initial tolerance, variation with temperature, and DC bias characteristic when selecting C_{OUT}. Ceramic capacitors with X7R dielectrics are highly recommended due to their small size, low ESR, and small temperature coefficients. All ceramic capacitors derate with DC bias voltage (effective capacitance goes down as DC bias goes up). Generally, smaller case-size capacitors derate more heavily compared to larger case sizes (0603 case size performs better than 0402). Consider the effective capacitance value carefully by consulting the manufacturer's data sheet. Refer to *Tutorial 5527* for more information.

Other Required Component Selection

The resistor between the RSEL pins and GND should have a tolerance of ±1% for the internal ADC to read the value accurately.

PCB Layout Guidelines

Careful circuit board layout is critical to achieve low switching power loss and clean, stable operation.

When designing the PCB, follow these guidelines:

- Place the input capacitors (C_{IN}) and output capacitors (C_{OUT}) immediately next to the IN pin and OUT pin of the IC, respectively. Since the IC operates at a high switching frequency with fast LX edges, this placement is critical for minimizing parasitic inductance within the input and output current loops, which can cause high voltage spikes and can damage the internal switching MOSFETs.
- Place the inductor next to the LX bumps (as close as possible) and make the traces between the LX bumps and the inductor short and wide to minimize PCB trace impedance. Excessive PCB impedance reduces converter efficiency.
- When routing LX traces on a separate layer, make sure to include enough vias to minimize trace impedance. Routing LX traces on multiple layers is recommended to further reduce trace impedance. Furthermore, do not make LX traces take up an excessive amount of area. The voltage on this node switches very quickly and additional area creates more radiated emissions.
- Connect the inner GND bumps to the low-impedance ground plane on the PCB with vias placed next to the bumps. Do not create GND islands, as GND islands risk interrupting the hot loops.
- Keep the power traces and load connections short and wide. This is essential for high converter efficiency.
- Do not neglect ceramic capacitor DC voltage derating. Choose capacitor values and case sizes carefully. See *Output-Capacitor Selection* section and refer to *Tutorial 5527* for more information.

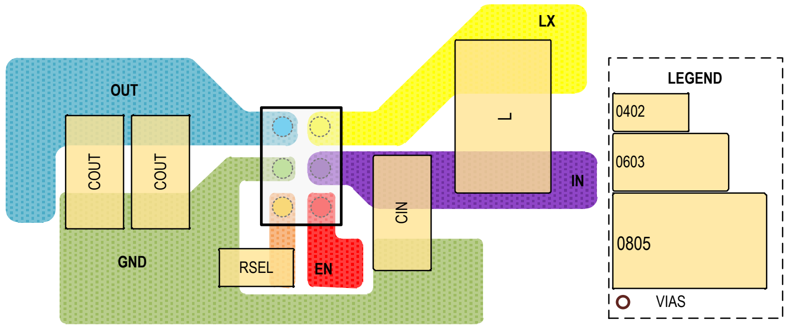
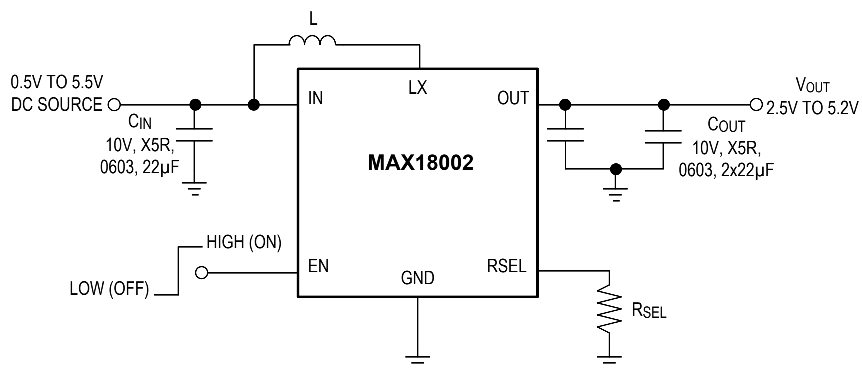


Figure 5. PCB Layout Recommendation for WLP Package

Typical Application Diagram



Ordering Information

PART NUMBER	TEMPERATURE RANGE	PIN-PACKAGE	FEATURES
MAX18002AWT+T	-40°C to +125°C	6-Bump WLP, 1.05mm x 1.55mm	3.6A IPK, Ultrasonic Mode (> 20kHz), > 0% Duty Cycle, True Shutdown/Active Discharge

+Denotes lead(Pb)-free/RoHS packaging.

T = Tape and reel.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	1/23	Release for Market Intro	—