

## General Description

The AOZ2297QI-03 is a high-efficiency, easy-to-use DC/DC buck regulator that targeted for system-power supply solution. It provides 3.3V LDO. The devices are capable of supplying 18A of continuous output current with 3.3V output voltage.

The AOZ2297QI-03 integrates an internal linear regulator to generate 3.3V VREG3P3 from input. If input voltage is lower than 3.3V, the linear regulator operates at low drop output mode, which allows the VREG3P3 voltage is equal to input voltage minus the drop-output voltage of the internal linear regulator.

A proprietary constant on-time PWM control with input feed-forward results in ultra-fast transient response while maintaining relatively constant switching frequency over the entire input voltage range.

The device features multiple protection functions such as LDO under-voltage lockout, cycle-by-cycle current limit, output over-voltage protection, short-circuit protection, and thermal shutdown.

The AOZ2297QI-03 is available in a 4mm×4mm QFN-31L package and is rated over a -40°C to +85°C ambient temperature range

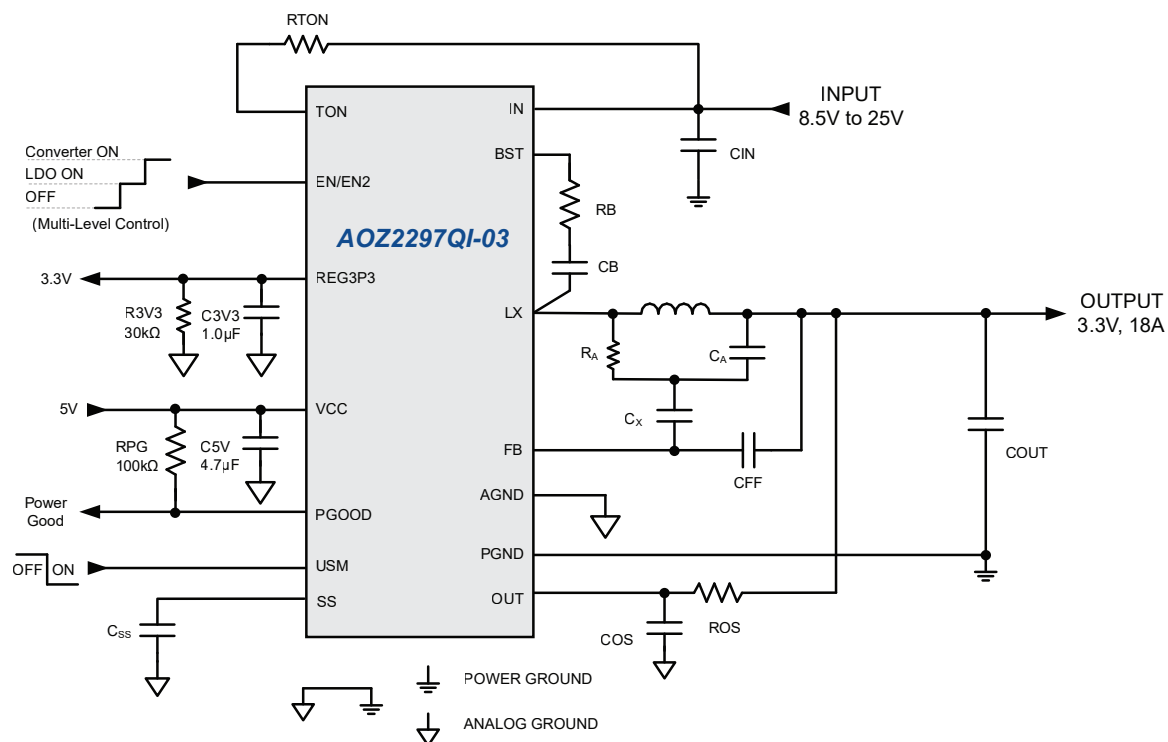
## Features

- Wide input voltage range
  - 8.5V to 25V
- 18A continuous output current
- Output voltage: 3.3V ±1.0%
- Low RDS(ON) internal NFETs
  - 8mΩ high-side
  - 1.6mΩ low-side
- 3.3V LDO Output controlled by multi-level
- Constant On-Time with input feed-forward
- Ripple Reduction at light load
- Ton Extension Mode
- Ultrasonic Mode
- Ceramic capacitor stable
- Adjustable soft start
- Power Good output
- Integrated bootstrap diode
- Cycle-by-cycle current limit
- Short-circuit protection
- Thermal shutdown
- Thermally enhanced 31-pin 4mm× 4mm QFN

## Applications

- Notebook computers
- Tablet computers





Part	Value
CIN	20uF
COUT	1760uF
RTON	270kΩ
RPG	100kΩ
C5V	4.7uF
R3V3	30kΩ
C3V3	1.0uF
CSS	10nF
CFF	47pF
RB	3.3Ω
CB	100nF
RA	100kΩ
CA	3.3nF
CX	680pF
L1	0.68uH
ROS	0Ω
COS	100nF

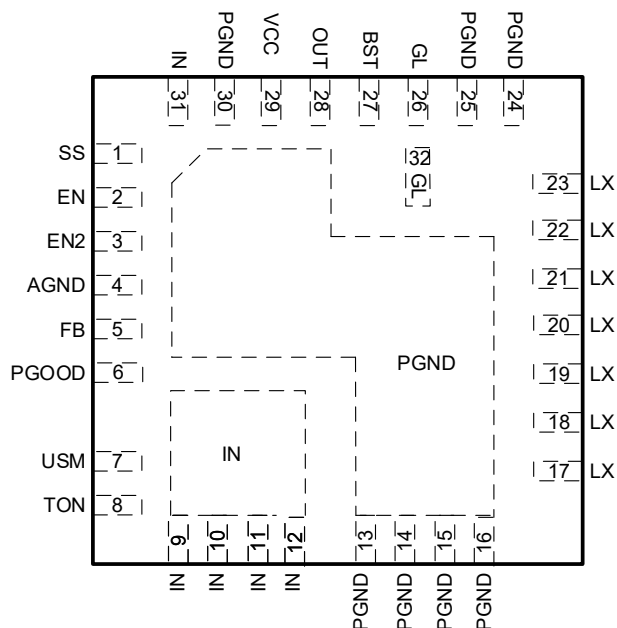
## Ordering Information

Part Number	Temperature Range	Package	Environmental
AOZ2297QI-03	-40°C to +85°C	31-Pin 4mm × 4mm QFN	Green



AOS products are offered in packages with Pb-free plating and compliant to RoHS standards.  
Please visit <https://aosmd.com/sites/default/files/media/AOSGreenPolicy.pdf> for additional information.

## Pin Configuration



**AOZ2297QI-03**  
**31-Pin 4mm x 4mm QFN**

## Pin Description

Pin Number	Pin Name	Pin Function
1, 9, 10, 11, 12	IN	Supply Input. IN is the regulator input. All IN pins must be connected together.
2	SS	Soft-Start Time Setting Pin. Connect a capacitor between SS and AGND to set the soft-start time.
3	EN/EN2	Multi-level Enable Input for 3.3V LDO & Converter.
4	AGND	Analog Ground.
5	FB	Feedback Input. Adjust the output voltage with a resistive voltage-divider between the regulator's output and AGND.
6	PGOOD	Power Good Signal Output. PGOOD is an open-drain output used to indicate the status of the output voltage. It is internally pulled low when the output voltage is 10% lower than the nominal regulation voltage or 20% higher than the nominal regulation voltage. PGOOD is pulled low during soft-start and shut down.
7	USM	Ultrasonic mode selection. Pull this pin low to enable ultrasonic mode.
8	TON	On-Time Setting Input. Connect a resistor between VIN and TON to set the on time.
13, 14, 15, 16, 24, 25, 30	PGND	Power Ground.
17, 18, 19, 20, 21, 22, 23	LX	Switching Node.
26, 32	GL	Low-Side MOSFET Gate connection. This is for test purposes only.
27	BST	Bootstrap Capacitor Connection. The device includes an internal bootstrap diode. Connect an external capacitor between BST and LX.
28	OUT	Output Voltage Input.
29	VCC	Supply Input for analog functions. Bypass VCC to AGND with a 4.7 $\mu$ F~10 $\mu$ F ceramic capacitor. Place the capacitor close to VCC pin.
31	REG3P3	3.3V LDO & output switching-over output. A 30k $\Omega$ bypass resistor is required for this pin.

## Absolute Maximum Ratings

Exceeding the Absolute Maximum ratings may damage the device.

Parameter	Rating
IN, TON to AGND	-0.3V to 27V
LX to AGND <sup>(1)</sup>	-0.7V to 27V
BST to AGND	-0.3V to 33V
PGND to AGND	-0.3V to +0.3V
Other Pins to AGND	-0.3V to 6V
Junction Temperature (T <sub>J</sub> )	+150°C
Storage Temperature (T <sub>S</sub> )	-65°C to +150°C
ESD Rating-HBM <sup>(2)</sup>	2kV
ESD Rating-CDM	1kV

### Notes:

- LX to PGND Transient (t<20ns) ----- -7V to Vin+7V.
- Devices are inherently ESD sensitive, handling precautions are required.  
Human body model rating: 1.5KΩ in series with 100pF.

## Maximum Operating Ratings

The device is not guaranteed to operate beyond the Maximum Operating Ratings.

Parameter	Rating
Supply Voltage (V <sub>IN</sub> )	8.5V to 25V
Ambient Temperature (T <sub>A</sub> )	-40°C to +85°C
Package Thermal Resistance (θ <sub>JA</sub> ) (θ <sub>JC</sub> )	32°C/W 4°C/W

## Electrical Characteristics

T<sub>A</sub> = 25°C, V<sub>IN</sub> = 12V, EN = 5V, unless otherwise specified. Specifications in **BOLD** indicate a temperature range of -40°C to +85°C.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V <sub>IN</sub>	IN Supply Voltage		8.5		25	V
V <sub>UVLO</sub>	Under-Voltage Lockout Threshold of V <sub>CC</sub>	V <sub>CC</sub> rising V <sub>CC</sub> falling	3.4	4.2 3.9	4.7	V
I <sub>q</sub>	Quiescent Supply Current of V <sub>CC</sub>	I <sub>OUT</sub> = 0A, V <sub>EN</sub> > 2V, PFM mode		180		μA
I <sub>OFF</sub>	Shutdown Supply Current of V <sub>IN</sub>	V <sub>EN</sub> = 0V, V <sub>EN2</sub> = 0V		10		μA
V <sub>FB</sub>	Reference Voltage			2.00		V
V <sub>OUT</sub>	Output Voltage	C <sub>OUT</sub> = 88μF	3.201	3.300	3.399	V
<b>Enable</b>						
V <sub>EN</sub>	LDO Enable Threshold	Off threshold On threshold	1.3		0.5	V
V <sub>EN_HYS</sub>	LDO Enable Hysteresis			300		mV
V <sub>EN2</sub>	Converter Enable Threshold	Off threshold On threshold	2.5		1.9	V
V <sub>EN2_HYS</sub>	Converter Enable Hysteresis			50		mV
<b>Ultrasonic Mode</b>						
V <sub>USM</sub>	USM Input Threshold	Off threshold On threshold	1.6		0.5	V
V <sub>USM_HYS</sub>	USM Input Hysteresis			300		mV
T <sub>USM</sub>	Switching Period at Ultrasonic Mode	USM pin = L		35		μs
V <sub>USM_OUT</sub>	Threshold for Exit Ultrasonic Mode	USM pin = L, FB falling		1.96		V

## Electrical Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$ ,  $V_{EN} = 5\text{V}$ , unless otherwise specified. Specifications in **BOLD** indicate a temperature range of  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ .

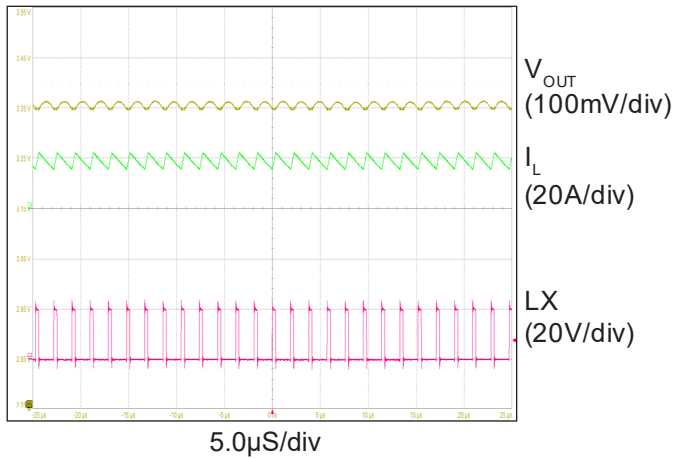
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Modulator						
T <sub>ON_MIN</sub>	Minimum On Time			100		ns
T <sub>ON_MAX</sub>	Maximum On Time			5000		ns
T <sub>OFF_MIN</sub>	Minimum Off Time			300		ns
Soft-Start						
I <sub>SS_OUT</sub>	SS Source Current	V <sub>SS</sub> = 0, C <sub>SS</sub> = 0.001μF to 0.1μF	7	10	13	μs
Power Good Signal						
V <sub>PG_LOW</sub>	PGOOD Low Voltage	I <sub>OL</sub> = 500μA			0.5	V
	PGOOD Leakage Current				±1	μs
V <sub>PGH</sub>	PGOOD Threshold (Low level to High level)	FB rising		95		%
V <sub>PGL</sub>	PGOOD Threshold (High level to Low level)	FB rising FB falling		120 90		
Under Voltage and Over Voltage Protection						
V <sub>PL</sub>	Under Voltage Threshold	FB falling		50		%
V <sub>PH</sub>	Over Voltage Threshold	FB rising		120		%
Power Stage Output						
R <sub>DS(ON)</sub>	High-Side NFET On-Resistance	V <sub>IN</sub> = 12V, V <sub>CC</sub> = 5V		7		mΩ
	High-Side NFET Leakage	V <sub>EN</sub> = 0V, V <sub>LX</sub> = 0			10	μA
R <sub>DS(ON)</sub>	Low-Side NFET On-Resistance	V <sub>LX</sub> = 12V, V <sub>CC</sub> = 5V		1.6		mΩ
	Low-Side NFET Leakage	V <sub>EN</sub> = 0V			10	μA
Over-current and Thermal Protection						
I <sub>LIM</sub>	Current Limit	V <sub>OUT</sub> = 3.3V	27			A
	Thermal Shutdown Threshold	T <sub>J</sub> rising T <sub>J</sub> falling		150 100		°C
LDO Output						
V <sub>REG3P3</sub>	LDO Output Voltage	EN/EN2 = 5V, V <sub>CC</sub> = 5V, I <sub>CC</sub> < 35mA	3.15	3.30	3.50	V
I <sub>REG3G3P3</sub>	LDO Current Limit	V <sub>OUT</sub> = 0V, V <sub>CC</sub> = 5V		50		mA
Output Discharge						
R <sub>DIS</sub>	Discharge Resistance	V <sub>EN</sub> = 0V, V <sub>LX</sub> = 0.1V,		100		Ω



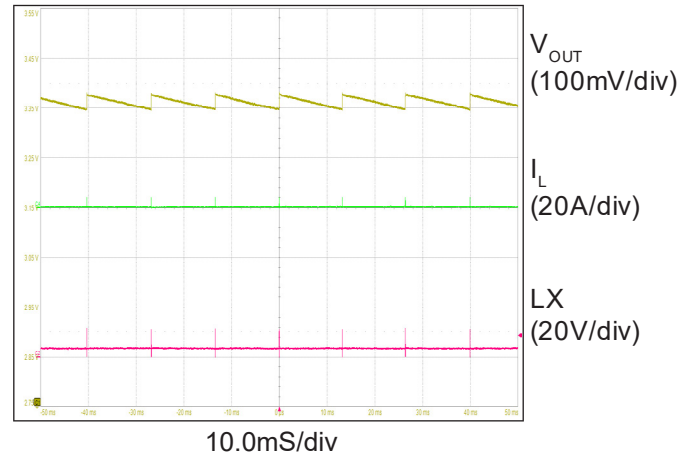
## Typical Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{IN} = 9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $V_{OUT} = 3.3\text{V}$ ,  $V_{CC} = 5\text{V}$ ,  $f_s = 500\text{kHz}$ ,  $L = 0.68\mu\text{H}$ ,  $C_{OUT} = 22\mu\text{F} \times 8$ , unless otherwise specified.

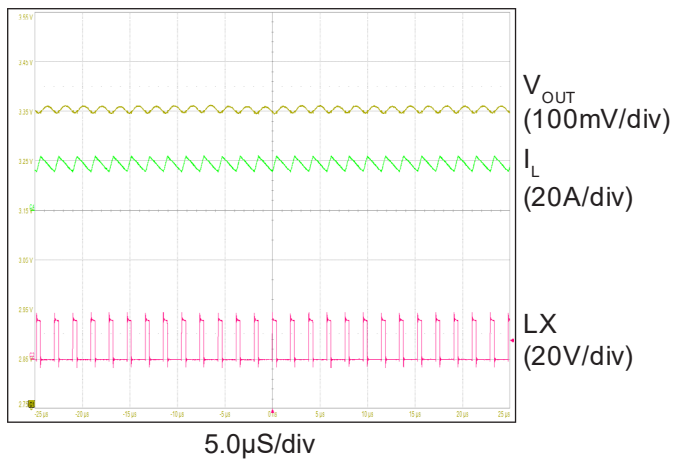
**Normal Operation**  
( $V_{IN} = 20\text{V}$ ,  $I_{OUT} = 18\text{A}$ )



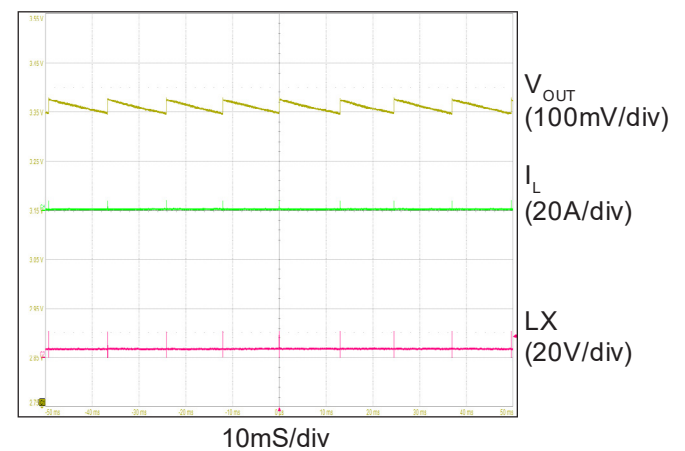
**Normal Operation**  
( $V_{IN} = 20\text{V}$ ,  $I_{OUT} = 0\text{A}$ )



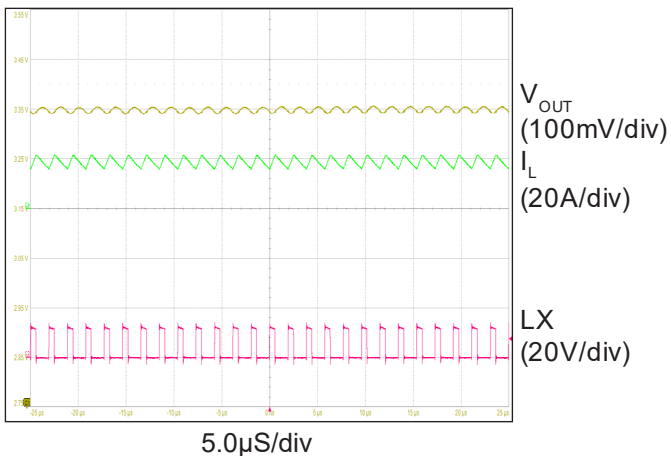
**Normal Operation**  
( $V_{IN} = 16\text{V}$ ,  $I_{OUT} = 18\text{A}$ )



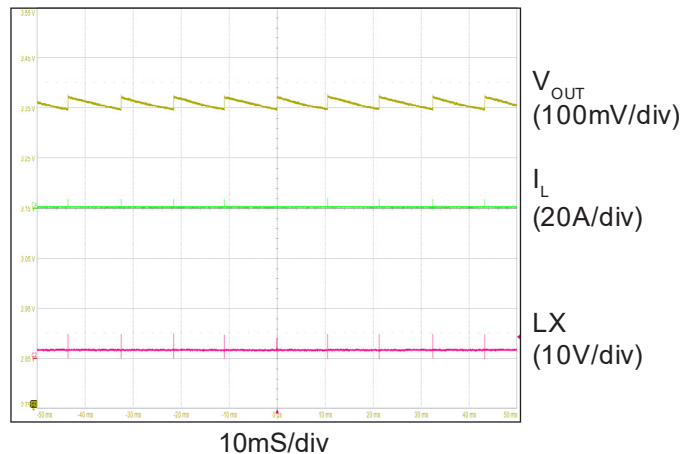
**Normal Operation**  
( $V_{IN} = 16\text{V}$ ,  $I_{OUT} = 0\text{A}$ )



**Normal Operation**  
( $V_{IN} = 12\text{V}$ ,  $I_{OUT} = 18\text{A}$ )



**Normal Operation**  
( $V_{IN} = 12\text{V}$ ,  $I_{OUT} = 0\text{A}$ )

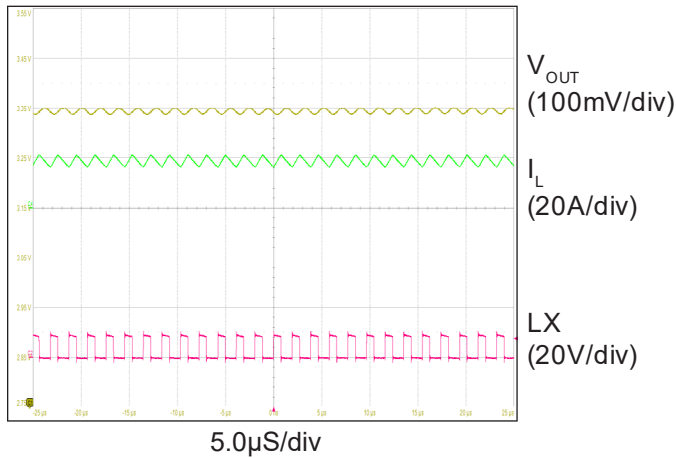




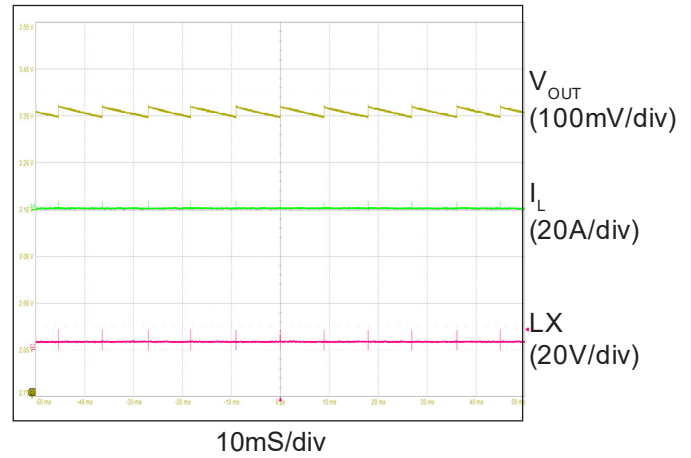
## Typical Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{IN} = 9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $V_{OUT} = 3.3\text{V}$ ,  $V_{CC} = 5\text{V}$ ,  $f_s = 500\text{kHz}$ ,  $L = 0.68\mu\text{H}$ ,  $C_{OUT} = 22\mu\text{F} \times 8$ , unless otherwise specified.

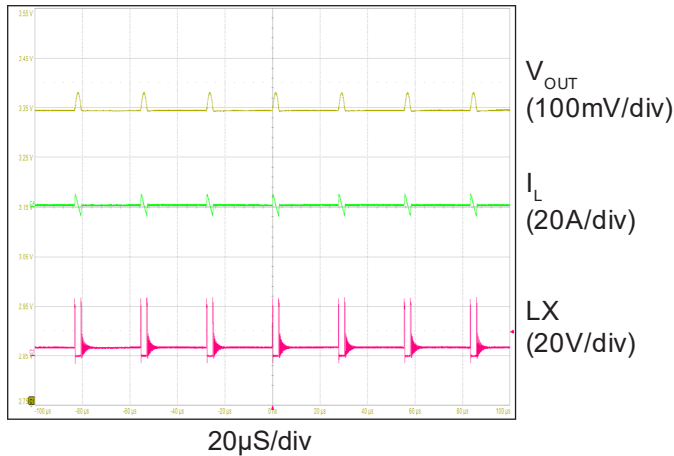
**Normal Operation**  
( $V_{IN} = 9\text{V}$ ,  $I_{OUT} = 18\text{A}$ )



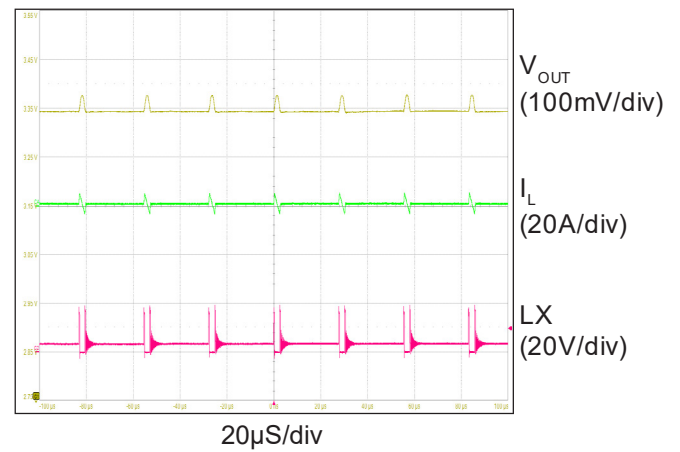
**Normal Operation**  
( $V_{IN} = 9\text{V}$ ,  $I_{OUT} = 0\text{A}$ )



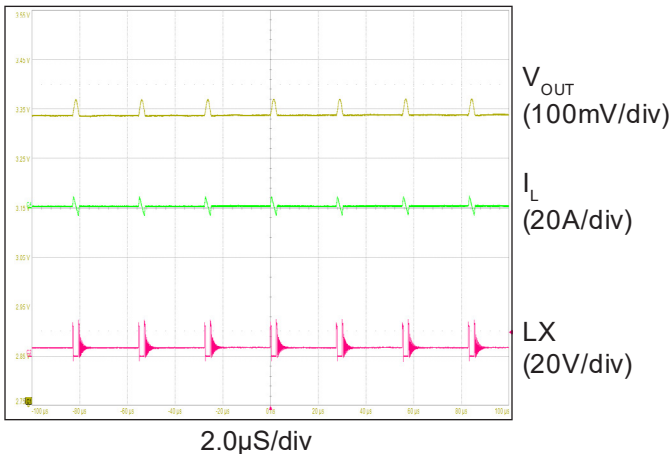
**Ultrasonic Mode**  
( $V_{IN} = 20\text{V}$ ,  $I_{OUT} = 0\text{A}$ )



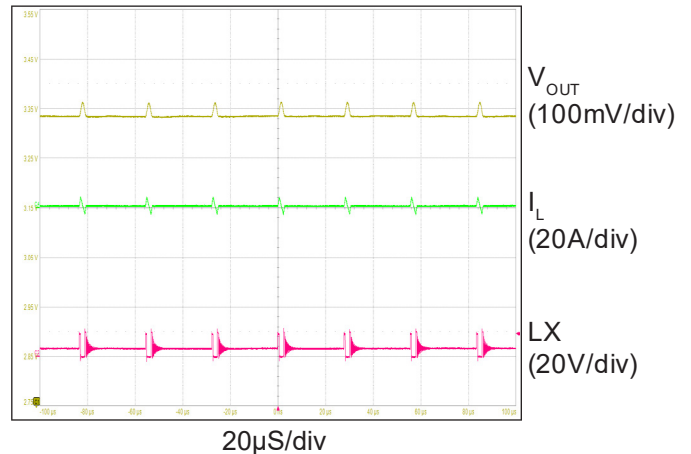
**Ultrasonic Mode**  
( $V_{IN} = 16\text{V}$ ,  $I_{OUT} = 0\text{A}$ )



**Ultrasonic Mode**  
( $V_{IN} = 12\text{V}$ ,  $I_{OUT} = 0\text{A}$ )



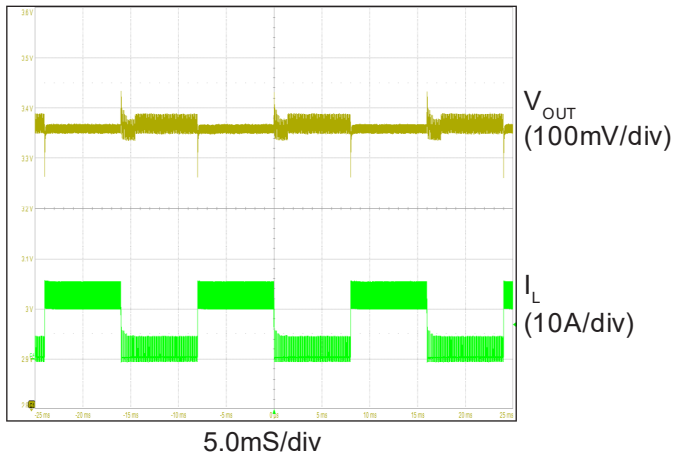
**Ultrasonic Mode**  
( $V_{IN} = 9\text{V}$ ,  $I_{OUT} = 0\text{A}$ )



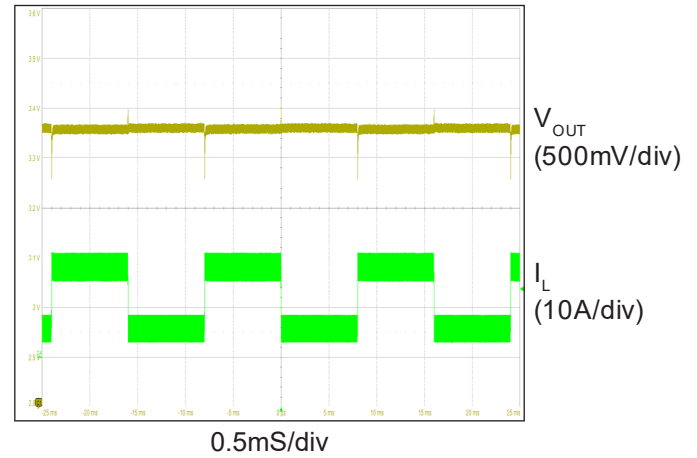
## Typical Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{IN} = 9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $V_{OUT} = 3.3\text{V}$ ,  $V_{CC} = 5\text{V}$ ,  $f_s = 500\text{kHz}$ ,  $L = 0.68\mu\text{H}$ ,  $C_{OUT} = 22\mu\text{F} \times 8$ , unless otherwise specified.

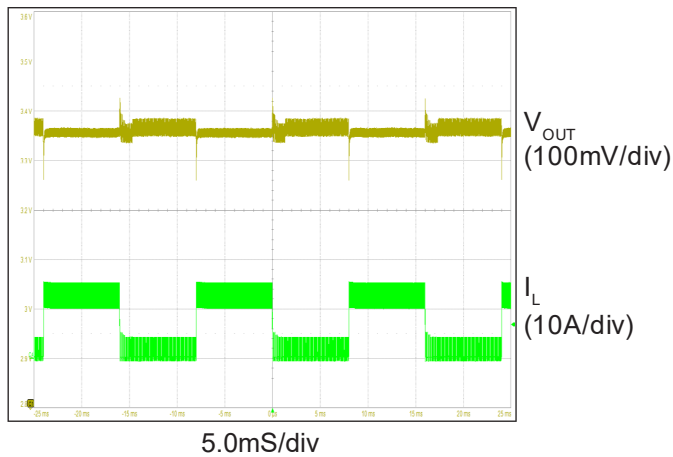
**Load Transient**  
( $V_{IN} = 20\text{V}$ ,  $I_{OUT} = 0\text{A} \sim 12.6\text{A}$  @ $\text{SR}=2.5\text{A}/\mu\text{S}$ )



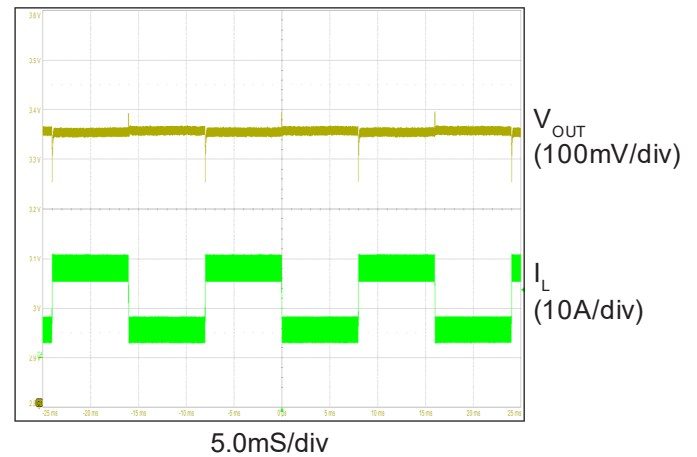
**Load Transient**  
( $V_{IN} = 20\text{V}$ ,  $I_{OUT} = 5.4\text{A} \sim 18\text{A}$  @ $\text{SR}=2.5\text{A}/\mu\text{S}$ )



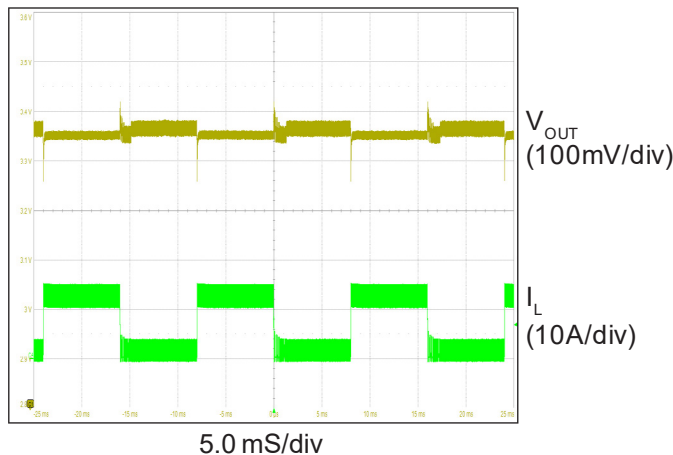
**Load Transient**  
( $V_{IN} = 16\text{V}$ ,  $I_{OUT} = 0\text{A} \sim 12.6\text{A}$  @ $\text{SR}=2.5\text{A}/\mu\text{S}$ )



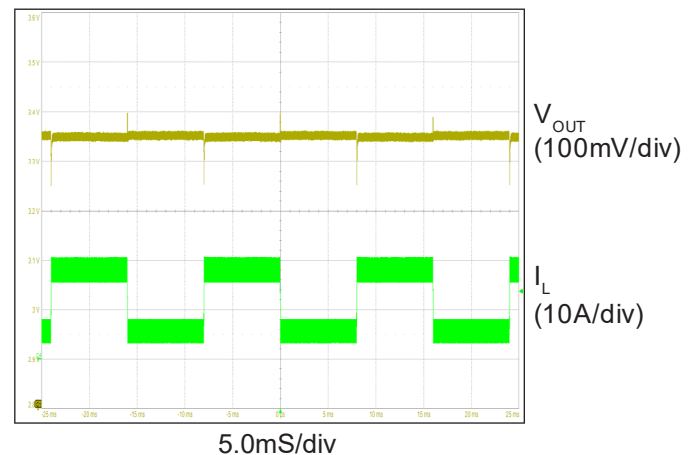
**Load Transient**  
( $V_{IN} = 16\text{V}$ ,  $I_{OUT} = 5.4\text{A} \sim 18\text{A}$  @ $\text{SR}=2.5\text{A}/\mu\text{S}$ )



**Load Transient**  
( $V_{IN} = 12\text{V}$ ,  $I_{OUT} = 0\text{A} \sim 12.6\text{A}$  @ $\text{SR}=2.5\text{A}/\mu\text{S}$ )

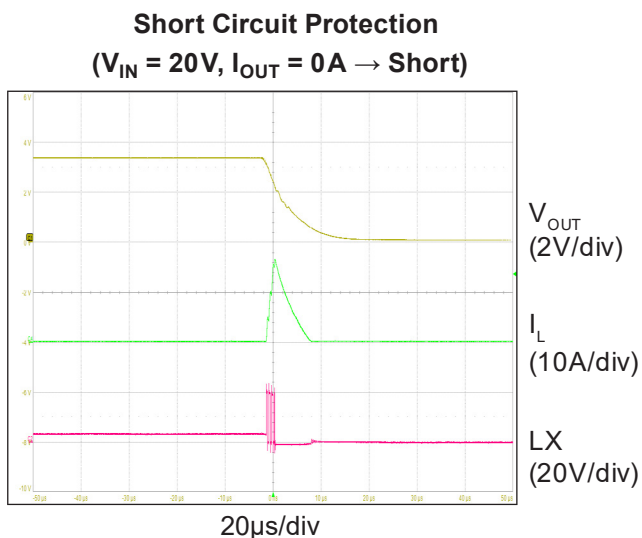
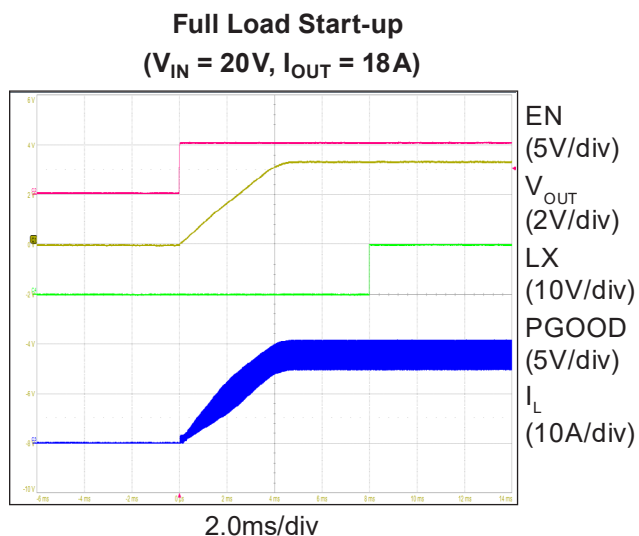
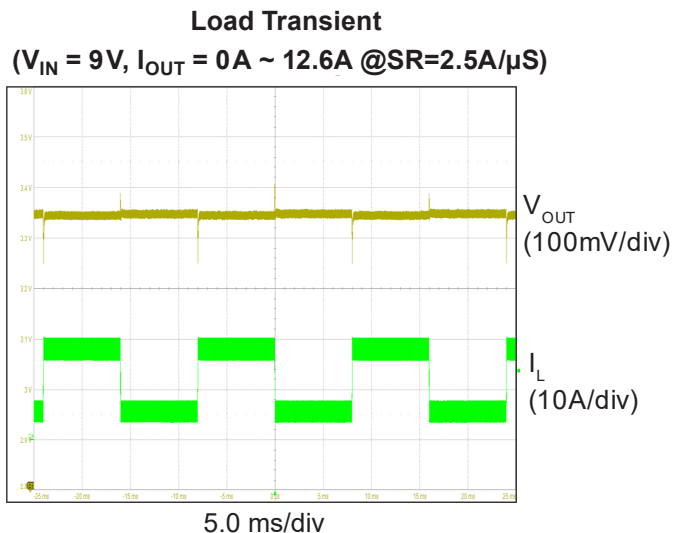
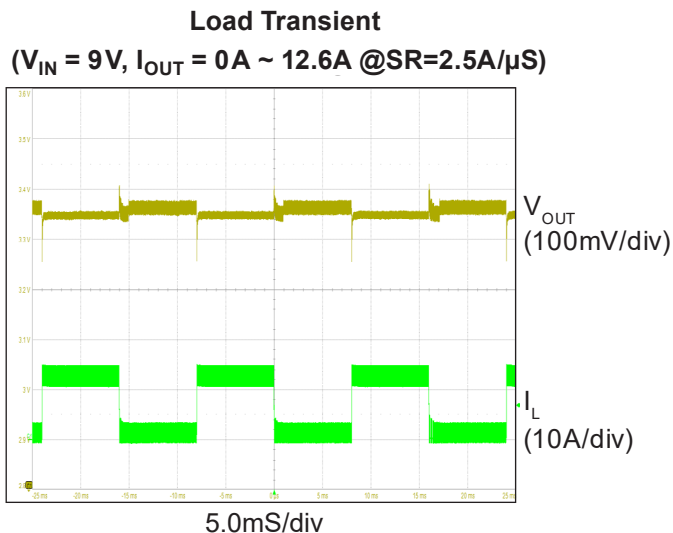


**Load Transient**  
( $V_{IN} = 12\text{V}$ ,  $I_{OUT} = 5.4\text{A} \sim 18\text{A}$  @ $\text{SR}=2.5\text{A}/\mu\text{S}$ )



## Typical Characteristics

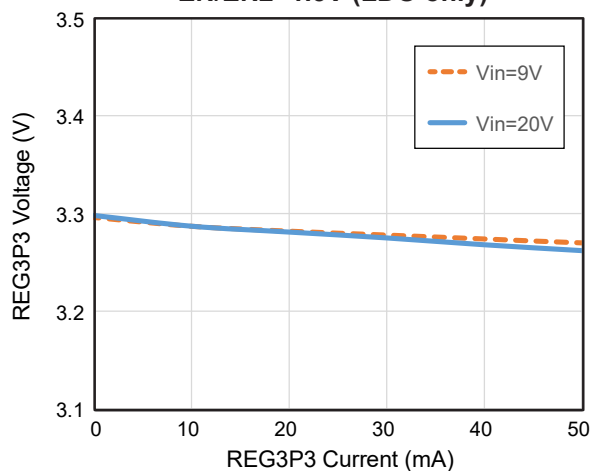
$T_A = 25^\circ\text{C}$ ,  $V_{IN} = 9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $V_{OUT} = 3.3\text{V}$ ,  $V_{CC} = 5\text{V}$ ,  $f_s = 500\text{kHz}$ ,  $L = 0.68\mu\text{H}$ ,  $C_{OUT} = 22\mu\text{F} \times 8$ , unless otherwise specified.



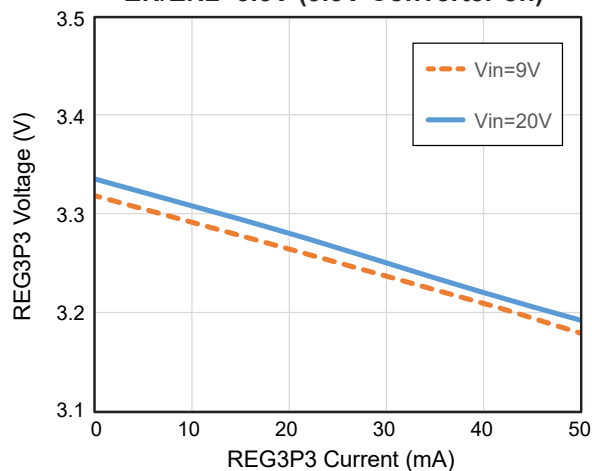
## Typical Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{IN} = 9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $V_{OUT} = 3.3\text{V}$ ,  $V_{CC} = 5\text{V}$ ,  $f_s = 500\text{kHz}$ ,  $L = 9.68\mu\text{H}$ ,  $C_{OUT} = 22\mu\text{F} \times 8$ , unless otherwise specified.

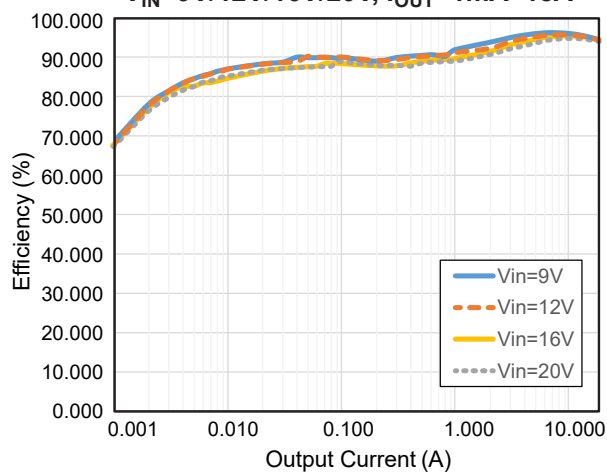
**REG3P3 Voltage vs. Current**  
**EN/EN2=1.5V (LDO only)**



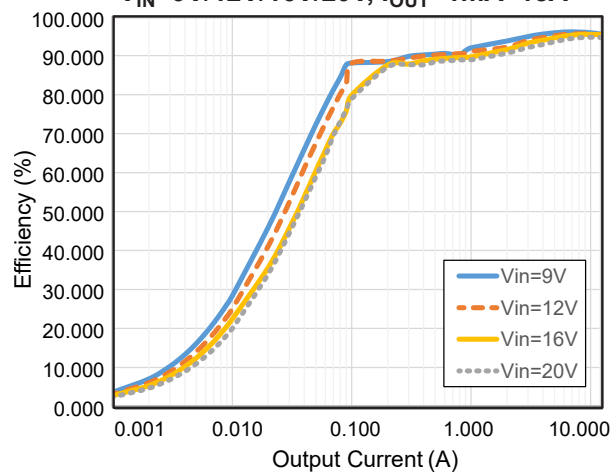
**REG3P3 Voltage vs. Current**  
**EN/EN2=3.3V (3.3V Converter on)**



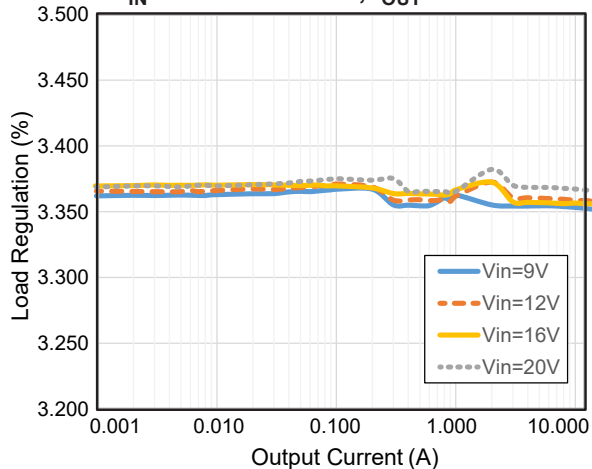
**Efficiency**  
 **$V_{IN}=9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $I_{OUT}=1\text{mA}\sim 18\text{A}$**



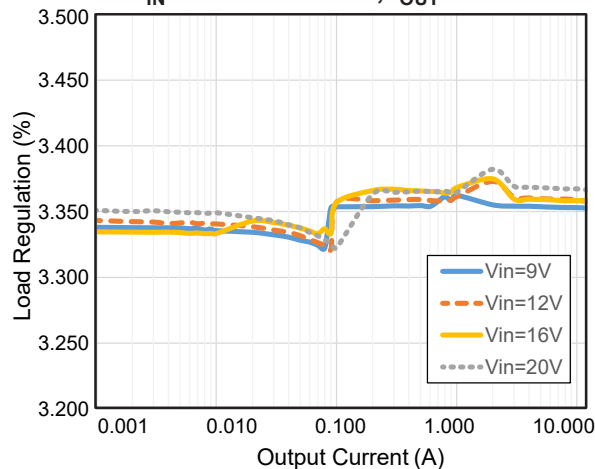
**Efficiency (USM)**  
 **$V_{IN}=9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $I_{OUT}=1\text{mA}\sim 18\text{A}$**



**Load Regulation**  
 **$V_{IN}=9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $I_{OUT}=1\text{mA}\sim 18\text{A}$**



**Load Regulation (USM)**  
 **$V_{IN}=9\text{V}/12\text{V}/16\text{V}/20\text{V}$ ,  $I_{OUT}=1\text{mA}\sim 18\text{A}$**



## Detailed Description

The AOZ2297QI-03 is a high-efficiency, easy-to-use DC/DC buck regulator that targeted for system-power supply solution. It provides an independent 3.3V LDO with multi-level control. The devices are capable of supplying 18A of continuous output current with 3.3V output voltage.

The input voltage of AOZ2297QI-03 can be as low as 8.5V. The highest input voltage of AOZ2297QI-03 can be 25V. Constant on-time PWM with input feed-forward control scheme results in ultra-fast transient response while maintaining relatively constant switching frequency over the entire input range. True AC current mode control scheme guarantees the regulators can be stable with ceramics output capacitor. The AOZ2297QI-03 also has switch over function. When the output voltage ready and PGOOD signal is pulled high, the internal LDO is turned off, and then the power of AOZ2297QI-03 internal control circuit is supplied by output terminal to reduce the LDO power loss. Protection features include LDO under-voltage lockout, cycle-by-cycle current limit, output over voltage and under voltage protection, short-circuit protection, and thermal shutdown.

The AOZ2297QI-03 is available in 31-pin 4mm×4mm QFN package.

### Enable and Soft Start

The AOZ2297QI-03 has external soft start feature to limit in-rush current and ensure the output voltage ramps up smoothly to regulate voltage. A soft start process begins when  $V_{CC}$  rises to over than UVLO threshold and the EN pin voltage is HIGH. An internal current source charges the external soft-start capacitor; the FB voltage follows the voltage of soft-start pin ( $V_{SS}$ ) when it is lower than 2V. When  $V_{SS}$  is higher than 2V, the FB voltage is regulated by internal precise band-gap voltage (2V). When  $V_{SS}$  is higher than 3.8V, the PGOOD signal is pulled high. The soft-start time for PGOOD can be calculated by the following formula:

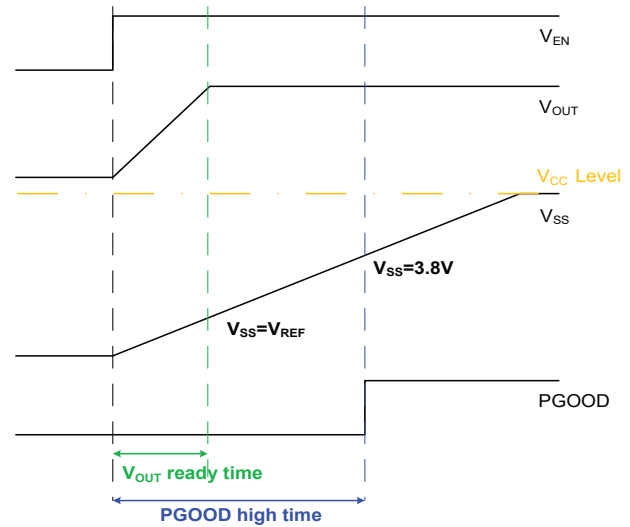
$$T_{SS}(\mu s) = 420 * C_{SS}(nF)$$

If  $C_{SS}$  is 1nF, the PGOOD high time will be 420μ seconds;  
if  $C_{SS}$  is 10nF, the PGOOD high time will be 4.2m seconds.

The soft-start time for VOUT ready can be calculated by the following formula:

$$T_{SS}(\mu s) = 220 * C_{SS}(nF)$$

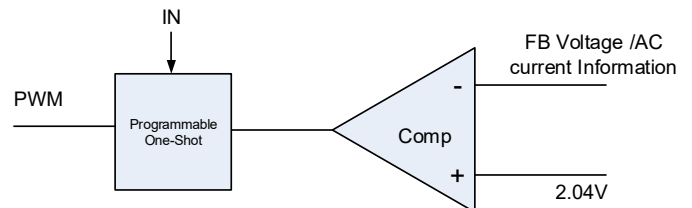
If  $C_{SS}$  is 1nF, the VOUT ready time will be 220μ second;  
if  $C_{SS}$  is 10nF, the VOUT ready time will be 2.2m second.



**Figure 5. Soft Start Sequence of AOZ2297QI-03**

### Constant-On-Time PWM Control with Input Feed-Forward

The control algorithm of AOZ2297QI-03 is constant-on-time PWM control with input feed-forward. The simplified control schematic is shown in Figure 6. The high-side switch on-time is determined solely by a one-shot whose pulse width is inversely proportional to input voltage (IN). The one-shot is triggered when the internal 2V is higher than the combined information of FB voltage and the AC current information of inductor, which is processed and obtained through the sensed low-side MOSFET current once it turns-on. The added AC current information can help the stability of constant-on time control even with pure ceramic output capacitors, which have very low ESR. The AC current information has no DC offset, which does not cause offset with output load change, which is fundamentally different from other  $V^2$  constant-on time control schemes.



**Figure 6. Simplified Control Schematic of AOZ2297QI-03**

The constant-on-time PWM control architecture is a pseudo-fixed frequency with input voltage feed-forward. The internal circuit of AOZ2297QI-03 sets the on-time of high-side switch inversely proportional to the IN.

$$T_{on} \propto \frac{R_{ton}(\Omega)}{V_{in}(V)}$$

To achieve the flux balance of inductor, the buck converter has the equation:

$$F_{sw} = \frac{V_{out}}{V_{in} * T_{on}}$$

Once the product of  $V_{in} * T_{on}$  is constant, the switching frequency keeps constant and is independent with input voltage.

An external resistor between the IN and TON pin sets the switching on-time according to the following equation:

$$T_{on}(ns) = \frac{R_{TON}(k\Omega)}{V_{in}(V)} \cdot 25$$

A further simplified equation will be:

$$F_{sw}(KHz) = \frac{V_{out}}{V_{in} * T_{on}(ns)} \cdot 10^6 = \frac{V_{out}(V)}{R_{TON}(k\Omega)} \cdot 4 \cdot 10^4$$

If  $V_{OUT}$  is 3.3V, and set  $F_{SW}=500kHz$ . According to the above equation, we can find out  $R_{TON}$  is 264k $\Omega$ . Notice that the frequency would be slightly increased due to the voltage dropping at the resistance of power trace.

This algorithm results in a nearly constant switching frequency despite the lack of a fixed-frequency clock generator.

### True Current Mode Control

The constant-on-time control scheme is intrinsically unstable if output capacitor's ESR is not large enough as an effective current-sense resistor. Ceramic capacitors usually cannot be used as output capacitor. The AOZ2297QI-03 senses the low-side MOSFET current and processes it into DC current and AC current information using AOS proprietary technique. The AC current information is decoded and added on the FB pin on phase. With AC current information, the stability of constant-on-time control is significantly improved even without the help of output capacitor's ESR; and thus the pure ceramic capacitor solution can be applicant. The pure ceramic capacitor solution can significantly reduce the output ripple (no ESR caused overshoot and undershoot) and less board area design.

### Current-Limit Setting

The AOZ2297QI-03 has the current-limit protection by using  $R_{dson}$  of the low-side MOSFET to be as current sensing. To detect real current information, a minimum constant off time (300ns typical) is implemented after a constant-on time. If the current exceeds the current-limit threshold, the PWM controller is not allowed to initiate a new cycle. The actual peak current is greater than the current-limit threshold by

an amount equal to the inductor ripple current. Therefore, the exact current-limit characteristic and maximum load capability are a function of the inductor value and input and output voltages. The current limit will keep the low-side MOSFET on and will not allow another high-side on-time, until the current in the low-side MOSFET reduces below the current limit.

After 64 switching cycles, the AOZ2297QI-03 considers this is a true failed condition and thus turns-off both high-side and low-side MOSFET and latches off. Only when triggered, the enable can restart the AOZ2297QI-03 again.

### Output Voltage Under-voltage Protection

If the output voltage is lower than 50% by over-current or short circuit, AOZ2297QI-03 will turns-off both high-side and low-side MOSFET immediately then latches off. Only when triggered, the enable can restart the AOZ2297QI-03 again.

### Output Voltage Over-voltage Protection

The threshold of OVP is set 20% higher than 2V. When the VFB voltage exceeds the OVP threshold, high-side MOSFET is turned-off and low-side MOSFETs is turned-on 1 $\mu$ s, then latch-off.

### Power Good Output

The power good (PGOOD) output, which is an open drain output, requires the pull-up resistor. When the output voltage is 10% below than the nominal regulation voltage for, the PGOOD is pulled low. When the output voltage is 20% higher than the nominal regulation voltage, the PGOOD is also pulled low. When combined with the under-voltage protection circuit, this current-limit method is effective in almost every circumstance

### PFM Mode Operation

The AOZ2297QI-03 enables pulse-frequency modulation (PFM) mode when the inductor current decreases to be across zero. In PFM operation, the conduction period of low-side MOSFET is ended at the moment that inductor current approaches zero. The output voltage slowly decreases without the low-side MOSFET discharge path until FB voltage reaches  $V_{REF}$ . As a result, the switching frequency is decreased along with the load current decreases. PFM mode increases output voltage ripple but reduces switching loss to improve efficiency for light-load.

### Ripple Reduction

When switching frequency at PFM mode is down to 50% of the original setting, AOZ2297QI-03 actively decreases on-time pulse width to reduce inductor current ripple and output voltage ripple. On-time pulse width can shrink to 70% of origin after this mechanism executes 3 times at most.



## Ultrasonic Mode

In PFM mode operation, the switching frequency is possibly in the audible range (20Hz~20kHz) at an extreme low load current. The AOZ2297QI-03 provides ultrasonic mode to prevent audible noise problem. When USM pin is pulled low, the AOZ2297QI-03 allows to enable ultrasonic mode when the switching frequency of PFM mode decreased to be closed to audible range. The judgments and actions of this mode are described as below:

1. PFM mode: Once the switching period is detected to be over than 40μs, the mode moves to ultrasonic mode from next cycle.
2. Ultrasonic mode: Disable FB judgment in this mode. The controller is forced to enter next switching cycle once the switching period reaches 30μs. Meanwhile, the conduction time of low-side MOSFET is also increased to release excessive energy. When output voltage drops to  $V_{USM\_OUT}$  because of load current rising, the operating mode moves to PFM mode immediately.

## Application Information

The basic AOZ2297QI-03 application circuit is shown in Typical Application section. Component selection is explained below.

### Input Capacitor

The input capacitor must be connected to the IN pins and PGND pin of the AOZ2297QI-03 to maintain steady input voltage and filter out the pulsing input current. A small decoupling capacitor, usually 4.7μF, should be connected to the  $V_{CC}$  pin and AGND pin for stable operation of the AOZ2297QI-03. The voltage rating of input capacitor must be greater than maximum input voltage plus ripple voltage.

The input ripple voltage can be approximated by equation below:

$$\Delta V_{IN} = \frac{I_{OUT}}{f \times C_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \frac{V_{OUT}}{V_{IN}}$$

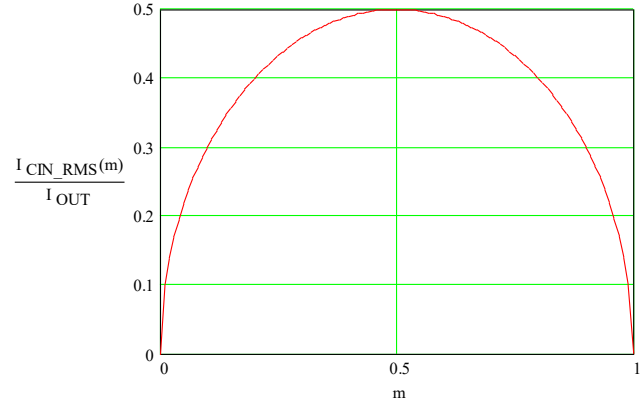
Since the input current is discontinuous in a buck converter, the current stress on the input capacitor is another concern when selecting the capacitor. For a buck circuit, the RMS value of input capacitor current can be calculated by:

$$I_{CIN\_RMS} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

if let  $m$  equal the conversion ratio:

$$\frac{V_{OUT}}{V_{IN}} = m$$

The relation between the input capacitor RMS current and voltage conversion ratio is calculated and shown in Figure. 7. It can be seen that when  $V_{OUT}$  is half of  $V_{IN}$ ,  $C_{IN}$  is under the worst current stress. The worst current stress on  $C_{IN}$  is  $0.5 \cdot I_{OUT}$ .



**Figure 7.  $I_{CIN}$  vs. Voltage Conversion Ratio**

For reliable operation and best performance, the input capacitors must have current rating higher than  $I_{CIN\_RMS}$  at worst operating conditions. Ceramic capacitors are preferred for input capacitors because of their low ESR and high ripple current rating. Depending on the application circuits, other low ESR tantalum capacitor or aluminum electrolytic capacitor may also be used. When selecting ceramic capacitors, X5R or X7R type dielectric ceramic capacitors are preferred for their better temperature and voltage characteristics. Note that the ripple current rating from capacitor manufactures is based on certain amount of life time. Further de-rating may be necessary for practical design requirement.

### Inductor

The inductor is used to supply constant current to output when it is driven by a switching voltage. For given input and output voltage, inductance and switching frequency together decide the inductor ripple current, which is,

$$\Delta I_L = \frac{V_{OUT}}{f \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

The peak inductor current is:

$$I_{L\_peak} = I_{OUT} + \frac{\Delta I_L}{2}$$

High inductance gives low inductor ripple current but requires larger size inductor to avoid saturation. Low ripple current reduces inductor core losses. It also reduces RMS current through inductor and switches, which results in less conduction loss. Usually, peak to peak ripple current on inductor is designed to be 30% to 50% of output current.

When selecting the inductor, make sure it is able to handle the peak current without saturation even at the highest operating temperature.

The inductor takes the highest current in a buck circuit. The conduction loss on inductor needs to be checked for thermal and efficiency requirements.

Surface mount inductors in different shape and styles are available from Coilcraft, Elytone and Murata. Shielded inductors are small and radiate less EMI noise. But they cost more than unshielded inductors. The choice depends on EMI requirement, price and size.

### Output Capacitor

The output capacitor is selected based on the DC output voltage rating, output ripple voltage specification and ripple current rating.

The selected output capacitor must have a higher rated voltage specification than the maximum desired output voltage including ripple. De-rating needs to be considered for long term reliability.

Output ripple voltage specification is another important factor for selecting the output capacitor. In a buck converter circuit, output ripple voltage is determined by inductor value, switching frequency, output capacitor value and ESR. It can be calculated by the equation below:

$$\Delta V_{OUT} = \Delta I_L \times (ESR_{COUT} + \frac{1}{8 \times f \times C_{OUT}})$$

where  $C_{OUT}$  is output capacitor value and  $ESR_{COUT}$  is the Equivalent Series Resistor of output capacitor.

When low ESR ceramic capacitor is used as output capacitor, the impedance of the capacitor at the switching frequency dominates. Output ripple is mainly caused by capacitor value and inductor ripple current. The output ripple voltage calculation can be simplified to:

$$\Delta V_{OUT} = \Delta I_L \times \frac{1}{8 \times f \times C_{OUT}}$$

If the impedance of ESR at switching frequency dominates, the output ripple voltage is mainly decided by capacitor ESR and inductor ripple current. The output ripple voltage calculation can be further simplified to:

$$\Delta V_{OUT} = \Delta I_L \times ESR_{COUT}$$

For lower output ripple voltage across the entire operating temperature range, X5R or X7R dielectric type of ceramic, or other low ESR tantalum are recommended to be used as output capacitors.

In a buck converter, output capacitor current is continuous. The RMS current of output capacitor is decided by the peak to peak inductor ripple current. It can be calculated by:

$$I_{COUT\_RMS} = \frac{\Delta I_L}{\sqrt{12}}$$

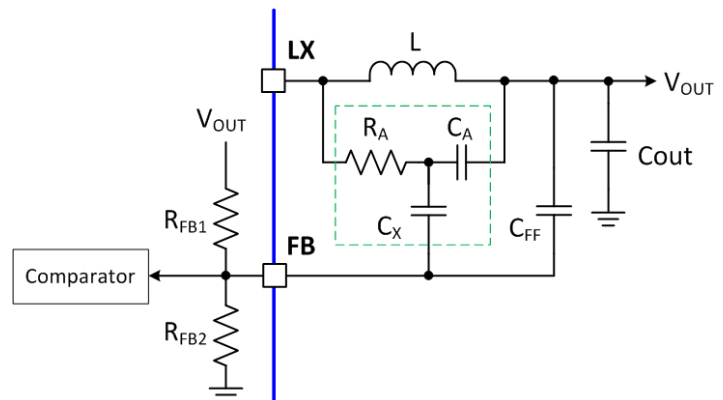
Usually, the ripple current rating of the output capacitor is a smaller issue because of the low current stress. When the buck inductor is selected to be very small and inductor ripple current is high, output capacitor could be overstressed.

### Feed-forward Capacitor (CFF)

A feed-forward capacitor is able to be placed between output node and FB node to achieve better output performance. The feed-forward capacitor can proportionally couple the high frequency component of output voltage to the FB node. With this coupling, the FB ripple can be increased to improve noise immunity. The dynamic response can also be improved due to the phase-leading of the FB signal. In the typical application circuit of the AOZ2297QI-03, a 47pF CFF is required for optimization.

### RCC Ripple Injection

In ultrasonic mode, it is suggested to add a RCC circuit as shown in Figure 8. The network uses an RC filter consisting of  $R_A$  and  $C_A$  to generate an approximated triangle ripple. The ripple is fed to FB node by a coupling capacitor  $C_B$  to be as a slope compensation for suppressing subharmonic phenomenon.



**Figure 8. RCC Ripple Injection Circuit**



Approximated formulas for calculating these parameters is shown as below:

$$C_A \geq \frac{k}{2\pi \cdot f_{sw} \cdot R_{FB\_Paralle\ 1}}$$

$$C_X \geq \frac{m}{2\pi \cdot f_{sw} \cdot R_{FB\_Paralle\ 1}}$$

$$R_A = \frac{V_{IN} - V_{OUT}}{V_{RCC,peak} \cdot C_A \cdot f_{sw}} \cdot \frac{V_{OUT}}{V_{IN}}$$

Where:

$$R_{FB\_Paralle\ 1} = \frac{R_{FB1} \cdot R_{FB2}}{\sqrt{(R_{FB1} + R_{FB2})^2 + (2\pi \cdot f_{sw} \cdot C_{FF} \cdot R_{FB1} \cdot R_{FB2})^2}}$$

The k, m represents the impedance ratio between CA, CX and the equivalent resistance of FB circuit RFB\_Parallel. The VRCC,peak represents the peak value of generated triangle ripple of RA, CA node. The built-in FB resistors RFB1 is 13kΩ and RFB2 is 20kΩ. For a proper design, the ratio k can be chosen as 50, the ratio m can be chosen as 10 and the VRCC,peak can be chosen as 15mV. The recommended design value of RCC circuit is listed in page 2.

### Thermal Management and Layout Consideration

In the AOZ2297QI-03 buck regulator circuit, high pulsing current flows through two circuit loops. The first loop starts from the input capacitors, to the IN pin, to the LX pins, to the filter inductor, to the output capacitor and load, and then return to the input capacitor through ground. Current flows in the first loop when the high side switch is on. The second loop starts from inductor, to the output capacitors and load, to the low side switch. Current flows in the second loop when the low side low side switch is on.

In PCB layout, minimizing the two loops area reduces the noise of this circuit and improves efficiency. A ground plane is strongly recommended to connect input capacitor, output capacitor, and PGND pin of the AOZ2297QI-03.

In the AOZ2297QI-03 buck regulator circuit, the major power dissipating components are the AOZ2297QI-03 and the output inductor. The total power dissipation of converter circuit can be measured by input power minus output power.

$$P_{total\_loss} = V_{IN} \cdot I_{IN} - V_{OUT} \cdot I_{OUT}$$

The power dissipation of inductor can be approximately calculated by DCR of inductor and output current.

$$P_{inductor\_loss} = I_{OUT}^2 \cdot R_{inductor} \cdot l.l$$

The actual junction temperature can be calculated with power dissipation in the AOZ2297QI-03 and thermal impedance from junction to ambient.

$$T_{junction} = (P_{total\_loss} - P_{inductor\_loss}) \cdot \theta_{JA} + T_A$$

The maximum junction temperature of AOZ2297QI-03 is 150°C, which limits the maximum load current capability.

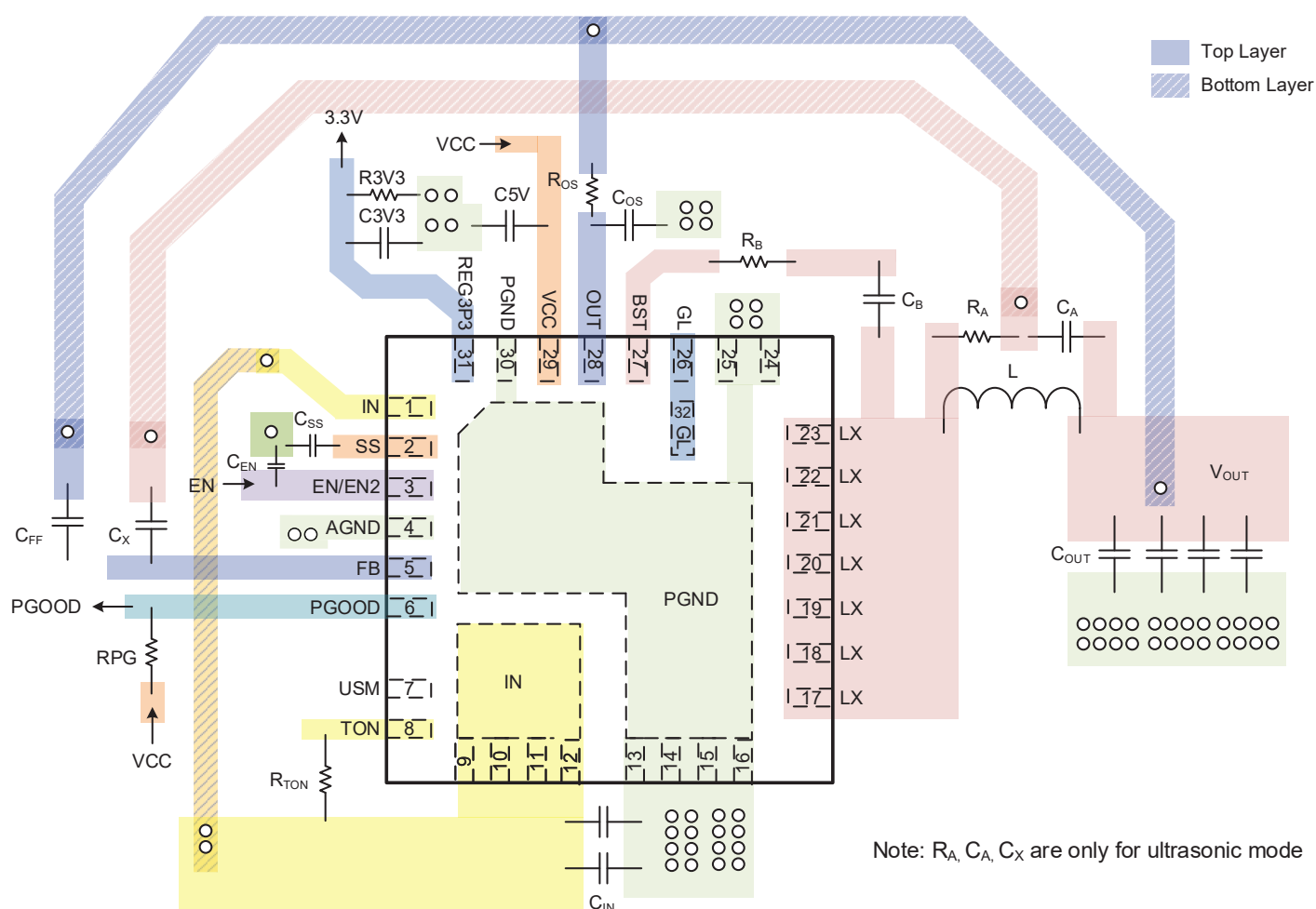
When AOZ2297QI-03 operates at the ambient temperature -40°C condition, the external components must cover the -40°C temperature condition. For example: the capacitor must use X-series type components to cover -40°C temperature condition, which can avoid the system unstable by capacitance reduction.

The thermal performance of the AOZ2297QI-03 is strongly affected by the PCB layout. Extra care should be taken by users during design process to ensure that the IC will operate under the recommended environmental conditions

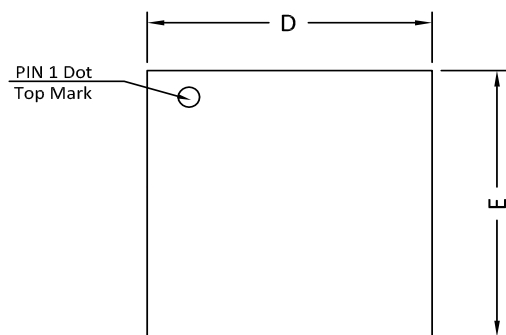
Several layout tips are listed below for the best electric and thermal performance.

1. Several layout tips are listed below for the best electric and thermal performance.
2. Connected a small copper plane to LX pin to have lower noise interference area.
3. The IN pins and pad are connected to internal high side switch drain. They are also low resistance thermal conduction path. Connected a large copper plane to IN pins to help thermal dissipation.
4. Input capacitors should be connected to the IN pin and the PGND pin as close as possible to reduce the switching spikes.

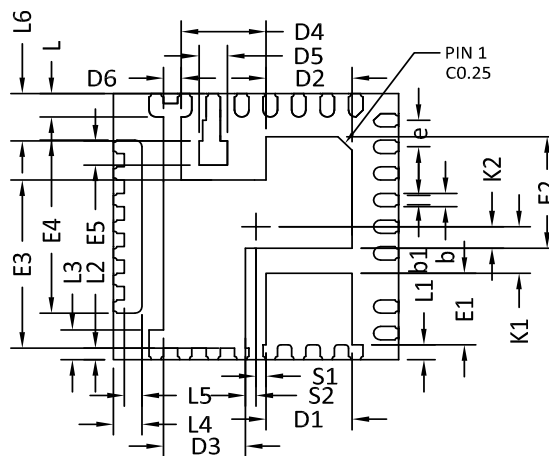
5. Decoupling capacitor C5V should be connected to VCC and AGND as close as possible.
6. A large ground plane is preferred.
7. Keep sensitive signal traces such as feedback trace far away from the LX pins.
8. Pour copper plane on all unused board area and connect it to stable DC nodes, like VIN, GND or VOUT.
9. Place via to connect AGND pin and ground layer, the via must be placed as close as possible to AGND pin. Place via as close as possible to PGND pins and the ground side of output capacitor, too.



## Package Dimensions, QFN4x4-31L



TOP VIEW

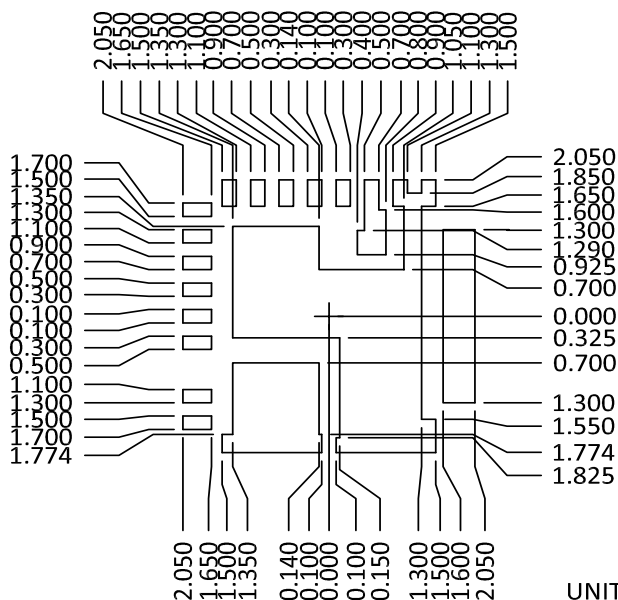


BOTTOM VIEW



SIDE VIEW

### RECOMMENDED LAND PATTERN



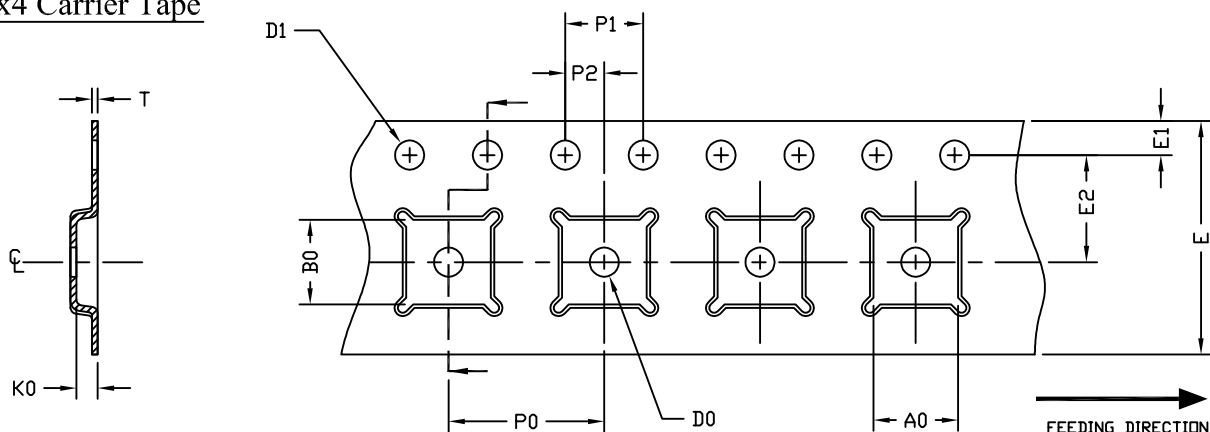
UNIT: mm

SYMBOLS	DIMENSION IN MM			DIMENSION IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	0.80	0.90	1.00	0.031	0.035	0.039
A1	0.00	-	0.05	0.000	-	0.002
A2	0.20REF			0.008REF		
D	3.90	4.00	4.10	0.154	0.157	0.161
E	3.90	4.00	4.10	0.154	0.157	0.161
D1	1.16	1.21	1.26	0.046	0.048	0.050
D2	1.16	1.21	1.26	0.046	0.048	0.050
D3	1.10	1.15	1.20	0.043	0.045	0.047
D4	1.14	1.19	1.24	0.045	0.047	0.049
D5	0.35	0.40	0.45	0.014	0.016	0.018
D6	0.20	0.25	0.30	0.008	0.010	0.012
E1	1.02	1.07	1.12	0.040	0.042	0.044
E2	1.63	1.68	1.73	0.064	0.066	0.068
E3	2.48	2.53	2.58	0.097	0.099	0.101
E4	2.55	2.60	2.65	0.100	0.102	0.104
E5	0.32	0.37	0.42	0.012	0.014	0.016
K1	0.65	0.70	0.75	0.026	0.028	0.030
K2	0.28	0.33	0.38	0.011	0.013	0.015
S1	0.09	0.14	0.19	0.004	0.006	0.007
S2	0.10	0.15	0.20	0.004	0.006	0.008
L	0.30	0.35	0.40	0.012	0.014	0.016
L1	0.18	0.23	0.28	0.007	0.009	0.011
L2	0.13	0.18	0.23	0.005	0.007	0.009
L3	0.40	0.45	0.50	0.016	0.018	0.020
L4	0.35	0.40	0.45	0.014	0.016	0.018
L5	0.20	0.25	0.30	0.008	0.010	0.012
L6	0.66	0.71	0.76	0.026	0.028	0.030
b	0.15	0.20	0.25	0.006	0.008	0.010
b1	0.09	0.14	0.19	0.004	0.006	0.007
e	0.40BSC			0.016BSC		

NOTE:  
CONTROLLING DIMENSION IS MILLIMETER.  
CONVERTED INCH DIMENSIONS ARE NOT NECESSARILY EXACT.

## Tape and Reel Dimensions, QFN4x4-31L

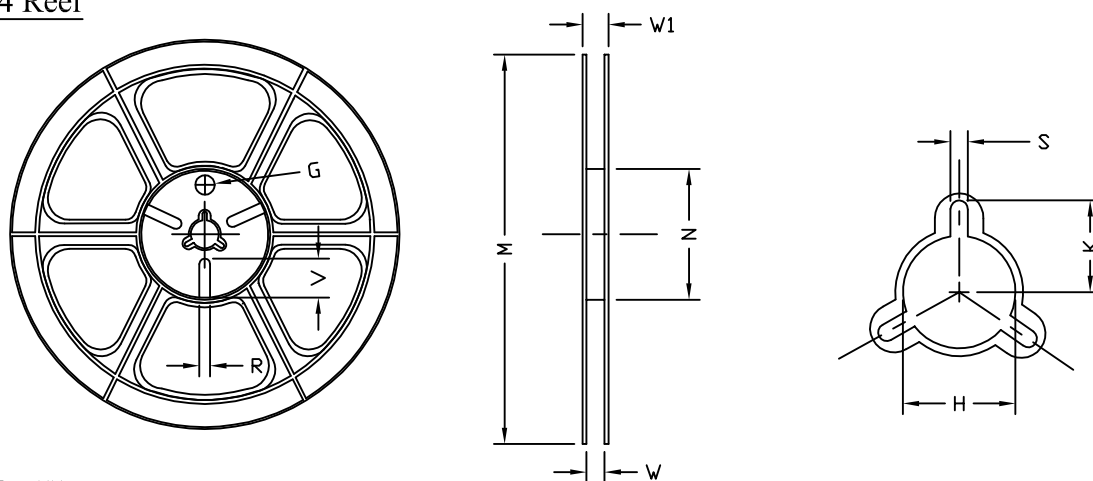
### QFN4x4 Carrier Tape



UNIT: MM

PACKAGE	A0	B0	K0	D0	D1	E	E1	E2	P0	P1	P2	T
QFN4x4 (12 mm)	4.35 ±0.10	4.35 ±0.10	1.10 ±0.10	1.50 MIN.	1.50 +0.1 -0.0	12.0 ±0.3	1.75 ±0.10	5.50 ±0.05	8.00 ±0.10	4.00 ±0.10	2.00 ±0.05	0.30 ±0.05

### QFN4x4 Reel



UNIT: MM

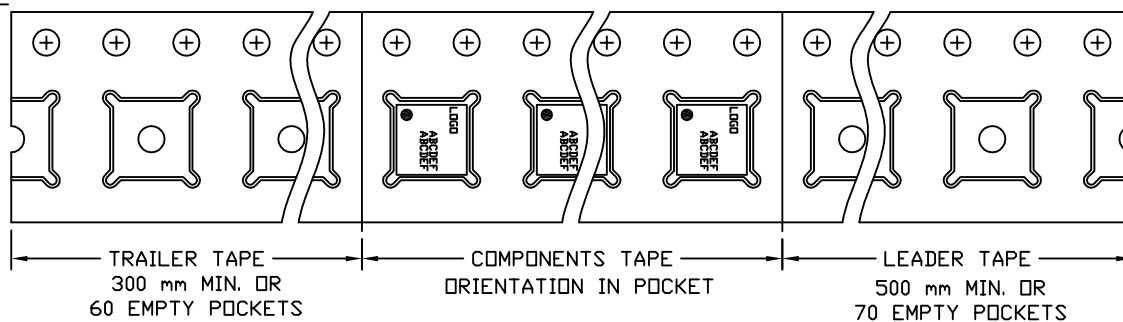
TAPE SIZE	REEL SIZE	M	N	W	W1	H	K	S	G	R	V
12 mm	ø330	ø330.0 ±2.0	ø79.0 ±1.0	12.4 +2.0 -0.0	17.0 +2.6 -1.2	ø13.0 ±0.5	10.5 ±0.2	2.0 ±0.5	---	---	---

### QFN4x4 Tape

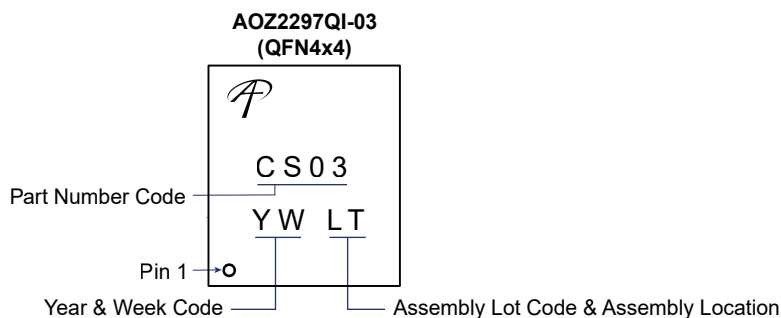
Leader / Trailer  
& Orientation

Normal

Unit Per Reel:  
3000pcs



## Part Marking



## LEGAL DISCLAIMER

Applications or uses as critical components in life support devices or systems are not authorized. Alpha and Omega Semiconductor does not assume any liability arising out of such applications or uses of its products. AOS reserves the right to make changes to product specifications without notice. It is the responsibility of the customer to evaluate suitability of the product for their intended application. Customer shall comply with applicable legal requirements, including all applicable export control rules, regulations and limitations.

AOS's products are provided subject to AOS's terms and conditions of sale which are set forth at:

[http://www.aosmd.com/terms\\_and\\_conditions\\_of\\_sale](http://www.aosmd.com/terms_and_conditions_of_sale)

## LIFE SUPPORT POLICY

ALPHA AND OMEGA SEMICONDUCTOR PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS.

As used herein:

1. Life support devices or systems are devices or systems 2. A critical component in any component of a life support, which, (a) are intended for surgical implant into the body or device, or system whose failure to perform can be reasonably (b) support or sustain life, and (c) whose failure to perform expected to cause the failure of the life support device or when properly used in accordance with instructions for use system, or to affect its safety or effectiveness. provided in the labeling, can be reasonably expected to result in a significant injury of the user.