

## General Description

The AOZ2223QI is a high-efficiency, easy-to-use DC/DC synchronous buck regulator that operates up to 36V. The device is capable of supplying 8A of continuous output current with an output voltage adjustable from 0.8V to 16V.

The AOZ2223QI integrates an internal linear regulator to generate 5.3V ( $\pm 5\%$ ) VCC from input power or external bias power. If bias voltage is higher than 4.8V, the input voltage of linear regulator switches to the bias for power saving. When the input voltage of linear regulator is lower than 5.3V, the linear regulator operates at low drop-output mode; the VCC voltage is equal to input voltage minus the drop-output voltage of 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  $V_{CC}$  under-voltage lockout, cycle-by-cycle current limit, output over-voltage protection, short-circuit protection, and thermal shutdown.

The AOZ2223QI is available in a 4mm×4mm QFN-23L package and is rated over a  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  ambient temperature range.

## Features

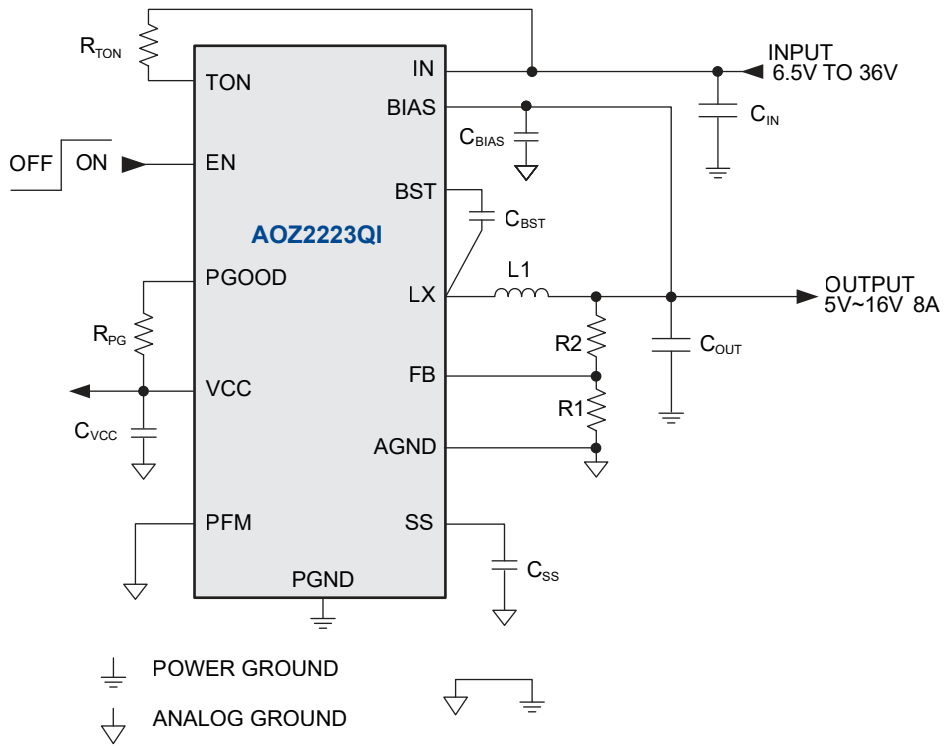
- Wide input voltage range
  - 4.8V to 36V Connect BIAS to an external bias ( $>5\text{V}$ )
  - 6.5V to 36V (Connect BIAS to  $V_{OUT}$  if  $V_{OUT}>5\text{V}$ )
- 8A continuous output current
- Output voltage adjustable from 0.8V to 16V.
- Low RDS(ON) internal NFETs
  - 20m $\Omega$  high-side
  - 10m $\Omega$  low-side
- Constant On-Time with input feed-forward
- Ceramic capacitor stable
- Adjustable soft start
- Integrated bootstrap diode
- Cycle-by-cycle current limit
- Short-circuit protection
- Thermal shutdown
- Thermally enhanced 4mm x 4mm QFN-23L package

## Applications

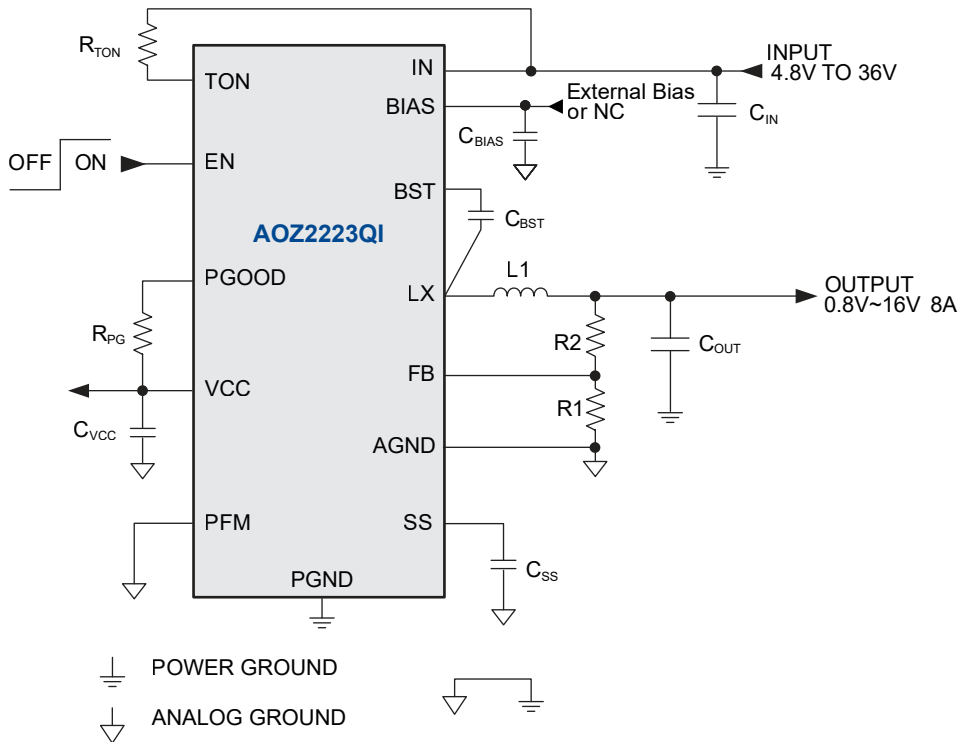
- General-purpose wide VIN applications
- Industrial distributed power applications
- 12-V and 24-V Industrial and communications power systems
- USB dedicated charging ports and battery chargers
- Industrial automation and motor control
- Point of load dc/dc converters
- USB type-C
- Test and measurement



Typical Application (a). Output > 5V, connect output to BIAS



Typical Application (b). Connect to external BIAS or NC



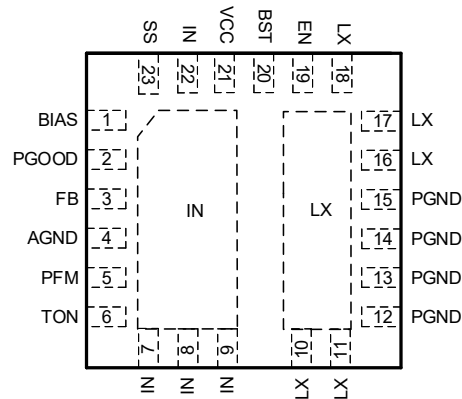
## Ordering Information

| Part Number | Temperature Range | Package        | Environmental |
|-------------|-------------------|----------------|---------------|
| AOZ2223QI   | -40°C to +85°C    | 23-Pin 4x4 QFN | Green         |



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## Pin Configuration



**AOZ2223QI**  
23-pin 4mm x 4mm QFN

## Pin Description

| Pin Number         | Pin Name | Pin Function  |
|--------------------|----------|---|
| 1                  | BIAS     | LDO switching-over input. Connect this pin to output when $V_{OUT} \geq 5V$ , or connect this pin to external 5V power supply for saving LDO power loss. Bypass BIAS to AGND with a 1 $\mu$ F ceramic capacitor. Place the capacitor close to BIAS pin.   |
| 2                  | 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 15% lower than the nominal regulation voltage for or 20% higher than the nominal regulation voltage. PGOOD is pulled low during soft-start and shut down. |
| 3                  | FB       | Feedback Input. Adjust the output voltage with a resistive voltage-divider between the regulator's output and AGND.   |
| 4                  | AGND     | Analog Ground.  |
| 5                  | PFM      | PFM/PWM Mode Selection pin.   |
| 6                  | TON      | On-time Setting Input. Connect a resistor between VIN and TON to set the on-time.   |
| 7, 8, 9, 22        | IN       | Supply Input. IN is the regulator input. All IN pins must be connected together.  |
| 10, 11, 16, 17, 18 | LX       | Switching Node.   |
| 12, 13, 14, 15     | PGND     | Power Ground.   |
| 19                 | EN       | Enable Input. The AOZ2223QI is enabled when EN is pulled high. The device shuts down when EN is pulled low.   |
| 20                 | BST      | Bootstrap Capacitor Connection. The AOZ2223QI includes an internal bootstrap diode. Connect an external capacitor between BST and LX as shown in Typical Application diagram.   |
| 21                 | 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.  |
| 23                 | SS       | Soft-Start Time Setting Pin. Connect a capacitor between SS and AGND to set the soft-start time.  |

## Absolute Maximum Ratings

Exceeding the Absolute Maximum ratings may damage the device.

| Parameter                                | Rating          |
|--|-----------------|
| IN to AGND                               | -0.3V to 42V    |
| BIAS, TON, EN, LX to AGND <sup>(1)</sup> | -0.3V to 40V    |
| BST to AGND                              | -0.3V to 46V    |
| SS, PGOOD, FB, VCC, PFM to AGND          | -0.3V to 6V     |
| PGND to AGND                             | -0.3V to +0.3V  |
| Junction Temperature (T <sub>J</sub> )   | +150°C          |
| Storage Temperature (T <sub>S</sub> )    | -65°C to +150°C |
| ESD Rating <sup>(2)</sup>                | 2kV             |

### Notes:

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

## Recommended Operating Conditions

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

| Parameter  | Rating          |
|--|-----------------|
| Supply Voltage (VIN)   | 4.8V to 36V     |
| External BIAS  | 5V to 36V       |
| Output Voltage Range   | 0.8V to 16V     |
| Ambient Temperature (TA)   | -40°C to +85°C  |
| Package Thermal Resistance<br>(θ <sub>JA</sub> )<br>(θ <sub>JC</sub> ) | 32°C/W<br>4°C/W |

## Electrical Characteristics

T<sub>A</sub> = 25°C, V<sub>IN</sub> = 24V, EN = 5V, unless otherwise specified. Specifications in **BOLD** indicate a temperature range of -40°C to +85°C.

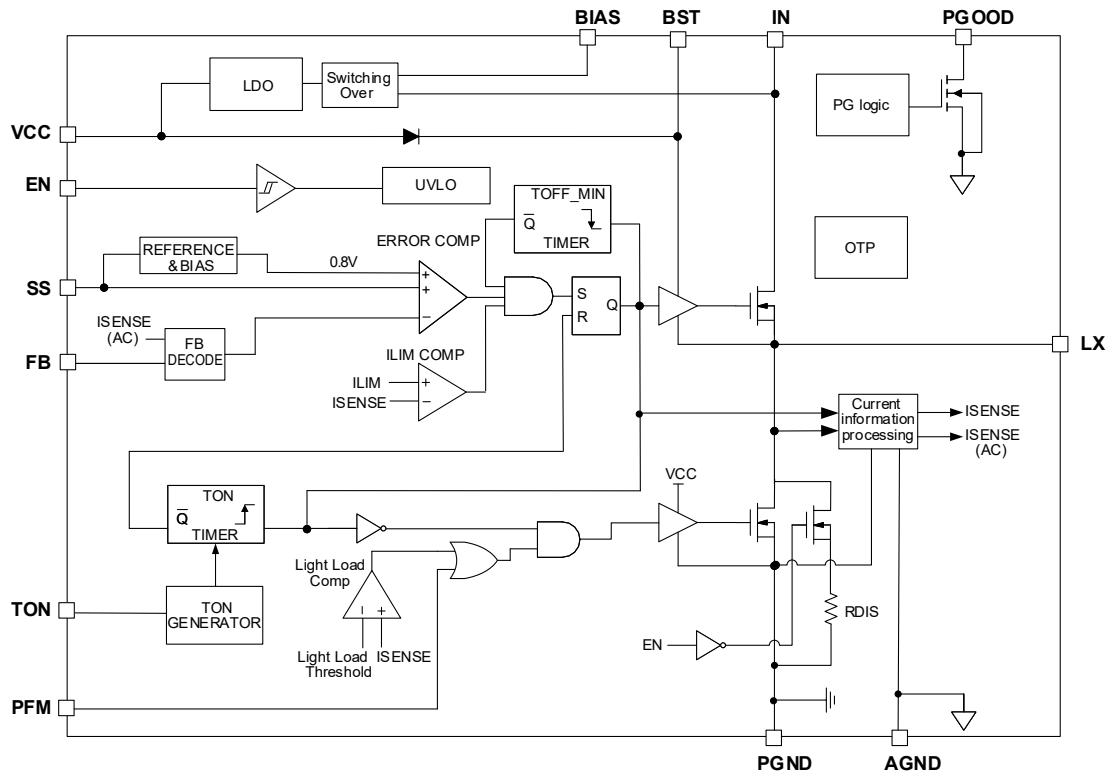
| Symbol               | Parameter                              | Conditions   | Min                      | Typ                        | Max            | Units |
|----------------------|--|--|--------------------------|----------------------------|----------------|-------|
| V <sub>IN</sub>      | IN Supply Voltage                      | BIAS>5V<br>BIAS=NC   | <b>4.8</b><br><b>6.5</b> |                            | <b>36</b>      | V     |
| V <sub>UVLO</sub>    | Under-Voltage Lockout Threshold of VCC | V <sub>CC</sub> rising<br>V <sub>CC</sub> falling                              | <b>3.2</b>               | <b>4.0</b><br><b>3.7</b>   | <b>4.4</b>     | V     |
| I <sub>q</sub>       | Quiescent Supply Current of IN         | PFM Mode, V <sub>OUT</sub> =BIAS=5V<br>PFM Mode, V <sub>OUT</sub> =5V, BIAS=NC |                          | <b>0.14</b><br><b>0.32</b> |                | mA    |
| I <sub>OFF</sub>     | Shutdown Supply Current                | V <sub>IN</sub> = 28V, V <sub>EN</sub> = 0V                                    |                          | <b>45</b>                  |                | μA    |
| V <sub>FB</sub>      | Feedback Voltage                       | T <sub>A</sub> = 25°C<br>T <sub>A</sub> = 0°C to 85°C                          | 0.792<br>0.788           | 0.800<br>0.800             | 0.808<br>0.812 | V     |
| I <sub>FB</sub>      | FB Input Bias Current                  |  |                          | 200                        |                | nA    |
| <b>Enable</b>        |  |  |                          |                            |                |       |
| V <sub>EN</sub>      | EN Input Threshold                     | Off threshold<br>On threshold  | 1.6                      |                            | 0.5            | V     |
| V <sub>EN_HYS</sub>  | EN Input Hysteresis                    |  |                          | 300                        |                | mV    |
| <b>Modulator</b>     |  |  |                          |                            |                |       |
| T <sub>ON_MIN</sub>  | Minimum On Time                        |  |                          | 100                        |                | ns    |
| T <sub>ON_MAX</sub>  | Maximum On Time                        |  |                          | 4.5                        |                | μs    |
| T <sub>OFF_MIN</sub> | Minimum Off Time                       |  |                          | 300                        |                | ns    |

## Electrical Characteristics

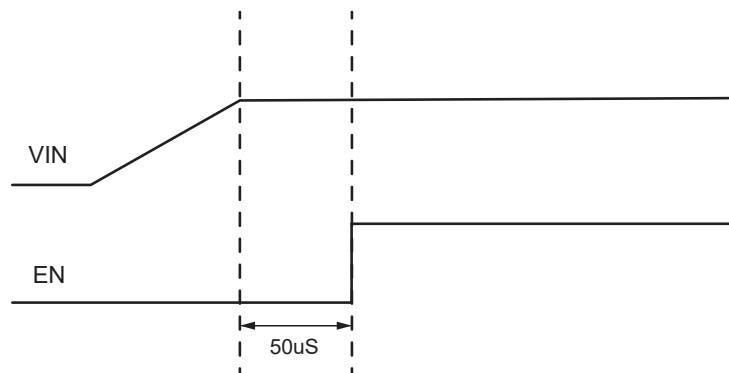
$T_A = 25^\circ\text{C}$ ,  $V_{IN} = 24\text{V}$ ,  $V_{EN} = 5\text{V}$ , unless otherwise specified. Specifications in **BOLD** indicate a temperature range of  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ .

| Symbol   | Parameter   | Conditions   | Min  | Typ        | Max     | Units            |
|--|---|--|------|------------|---------|------------------|
| <b>Soft-Start</b>                                |   |  |      |            |         |                  |
| $I_{SS\_OUT}$                                    | SS Source Current   | $V_{SS} = 0$ , $C_{SS} = 0.001\mu\text{F}$ to $0.1\mu\text{F}$ | 7    | 11         | 15      | $\mu\text{A}$    |
| <b>PFM Control</b>                               |   |  |      |            |         |                  |
| $V_{\overline{\text{PFM}}}$                      | $\overline{\text{PFM}}$ Input Threshold                     | PFM Mode threshold<br>Force PWM threshold                      | 2.5  |            | 0.5     | V                |
| $V_{\overline{\text{PFM}}\_HYS}$                 | $\overline{\text{PFM}}$ Input Hysteresis                    |  |      | 300        |         | mV               |
| <b>BIAS Switching-Over</b>                       |   |  |      |            |         |                  |
| $V_{SVOV}$                                       | Linear Regulator Input Switching-over Threshold of BIAS pin | Switching-over to $V_{IN}$<br>Switching-over to BIAS           | 4.8  |            | 4.5     | V                |
| $V_{SVOV\_HYS}$                                  | Linear Regulator Input Switching-over Hysteresis            |  |      | 300        |         | mV               |
| <b>Under Voltage and Over Voltage Protection</b> |   |  |      |            |         |                  |
| $V_{PL}$   | Under Voltage threshold                                     | FB falling   |      | 70         |         | %                |
| $T_{PL}$   | Under Voltage Delay Time                                    |  |      | 32         |         | $\mu\text{s}$    |
| $V_{PH}$   | Over Voltage Threshold                                      | FB rising  |      | 120        |         | %                |
| <b>Power Good Signal</b>                         |   |  |      |            |         |                  |
| $V_{PG\_LOW}$                                    | PGOOD Low Voltage   | $I_{OL} = 1\text{mA}$  |      |            | 0.5     | V                |
|  | PGOOD Leakage Current                                       |  |      |            | $\pm 1$ | $\mu\text{s}$    |
| $V_{PGH}$  | PGOOD Threshold (Low level to High level)                   | FB rising  |      | 90         |         | %                |
| $V_{PGL}$  | PGOOD Threshold (High level to Low level)                   | FB rising<br>FB falling  |      | 120<br>85  |         |                  |
|  | PGOOD Threshold Hysteresis                                  |  |      | 5          |         |                  |
| <b>Power Stage Output</b>                        |   |  |      |            |         |                  |
| $R_{DS(ON)}$                                     | High-Side NFET On- Resistance                               | $V_{IN} = 12\text{V}$  |      | 20         |         | $\text{m}\Omega$ |
|  | High-Side NFET Leakage                                      | $V_{EN} = 0\text{V}$ , $V_{LX} = 0$                            |      |            | 10      | $\mu\text{A}$    |
| $R_{DS(ON)}$                                     | Low-Side NFET On- Resistance                                | $V_{LX} = 12\text{V}$  |      | 10         |         | $\text{m}\Omega$ |
|  | Low-Side NFET Leakage                                       | $V_{EN} = 0\text{V}$   |      |            | 10      | $\mu\text{A}$    |
| <b>Over-Current and Thermal Protection</b>       |   |  |      |            |         |                  |
| $I_{LIM}$  | Current Limit   |  | 12   |            |         | A                |
|  | Thermal Shutdown Threshold                                  | $T_J$ rising<br>$T_J$ falling                                  |      | 150<br>100 |         | $^\circ\text{C}$ |
| <b>LDO Output</b>                                |   |  |      |            |         |                  |
| $V_{CC}$   | LDO Output Voltage  | $V_{IN} > 4.8\text{V}$ , $V_{EN} = 0\text{V}$                  | 5.10 | 5.30       | 5.50    | V                |
| $I_{CC\_LIM}$                                    | LDO Current Limit   | $V_{IN} > 24\text{V}$ , $V_{OUT} = 5\text{V}$ , BIAS = NC      |      |            | 120     | mA               |
| $I_{CC\_LIM\_SVOV}$                              | LDO Current Limit (switching-over)                          | $V_{IN} > 24\text{V}$ , $V_{OUT} = \text{BIAS} = 5\text{V}$    |      |            | 25      | mA               |
| <b>Output Discharge</b>                          |   |  |      |            |         |                  |
| RDIS   | Discharge Resistance  | $V_{EN} = 0\text{V}$ , $V_{LX} = 0.1\text{V}$                  |      | 35         |         | $\Omega$         |

## Functional Block Diagram



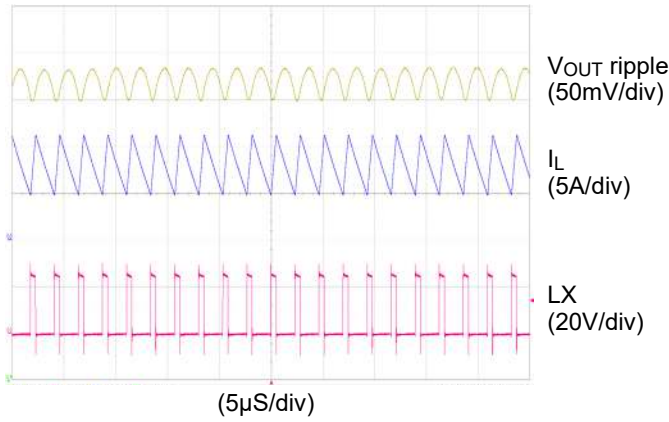
## Recommended Start-up Sequence



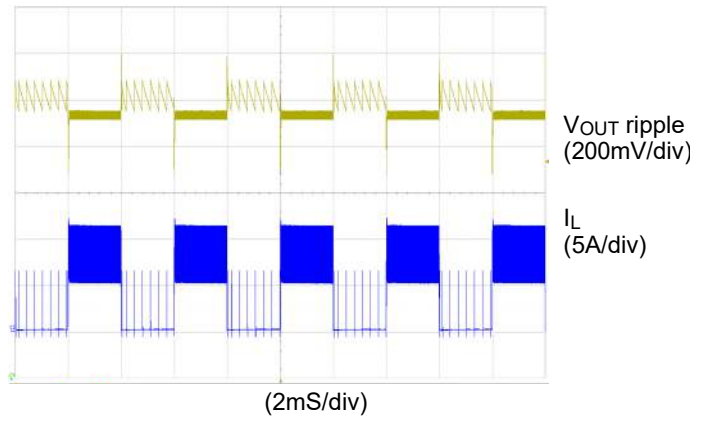
## Typical Characteristics

$T_A = 25\text{ }^\circ\text{C}$ ,  $V_{IN} = 24\text{V}$ ,  $V_{OUT} = 5\text{V}$ ,  $f_s = 400\text{kHz}$ ,  $L = 2.2\mu\text{H}$ ,  $C_{OUT} = 88\mu\text{F}$  unless otherwise specified.

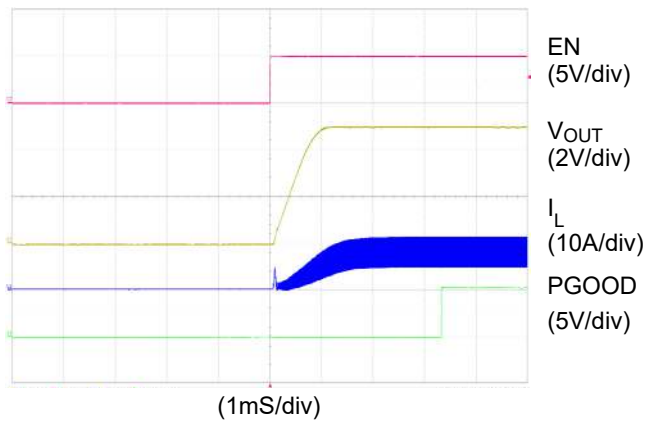
Normal Operation



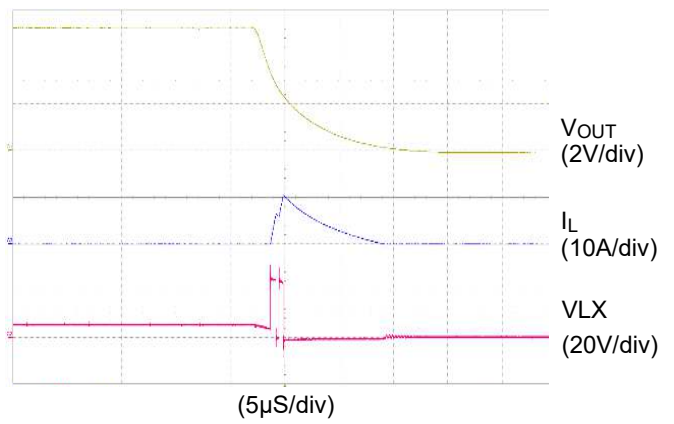
Load Transient 0A to 8A



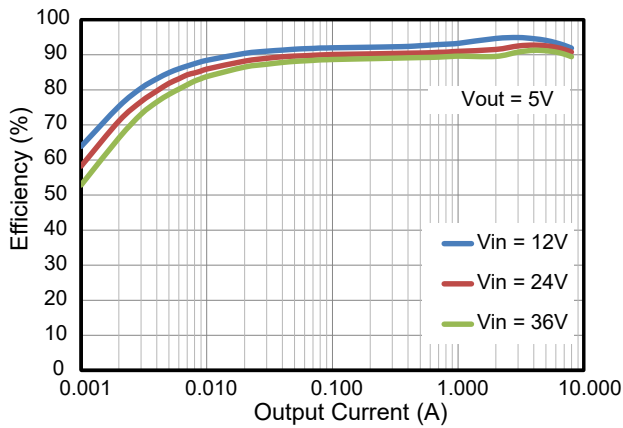
Full Load Start-up



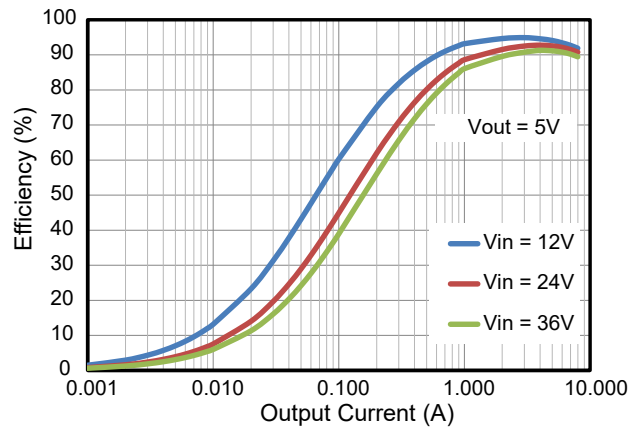
Short Circuit Protection



Efficiency (PFM Mode)



Efficiency (Force PWM Mode)



## Detailed Description

The AOZ2223QI is a high-efficiency, easy-to-use, synchronous buck regulator. The regulator is capable of supplying 8A of continuous output current with an output voltage adjustable from 0.8V to 16V.

The input voltage of AOZ2223QI can be as low as 4.8V. The highest input voltage of AOZ2223QI can be 36V. 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 regulator can be stable with ceramics output capacitor. Protection features include  $V_{CC}$  under-voltage lockout, cycle-by-cycle current limit, output over voltage and under voltage protection, short-circuit protection, and thermal shutdown.

The AOZ2223QI is available in 23-pin 4mm×4mm QFN package.

### Input Power Architecture

The AOZ2223QI integrates an internal linear regulator to generate 5.3V ( $\pm 5\%$ )  $V_{CC}$  from input power or external bias power. If bias voltage is higher than 4.8V, the input voltage of linear regulator switches to the bias for power saving. When the input voltage of linear regulator is lower than 5.3V, the linear regulator operates at low drop-output mode; the  $V_{CC}$  voltage is equal to input voltage minus the drop-output voltage of internal linear regulator.

### Enable and Soft Start

The AOZ2223QI 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 4.5V and voltage on EN pin 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 0.8V. When  $V_{SS}$  is higher than 0.8V, the FB voltage is regulated by internal precise band-gap voltage (0.8V). The soft-start time for FB voltage can be calculated by the following formula:

$$T_{SS}(\mu s) = 330 * C_{SS}(\text{nF})$$

If  $C_{SS}$  is 10nF, the soft-start time will be 3300u seconds.

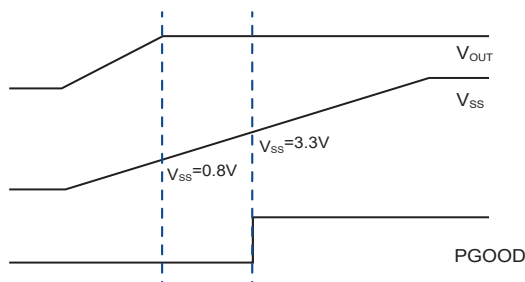


Figure 1. Soft-Start Sequence of AOZ2223QI

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

The control algorithm of AOZ2223QI is constant-on-time PWM control with input feed-forward.

The simplified control schematic is shown in Figure.2. The high-side switch on-time is determined solely by an one-shot whose pulse width is inversely proportional to input voltage ( $I_N$ ). The one-shot is triggered when the internal 0.8V 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.

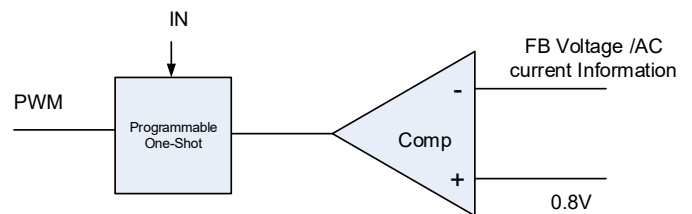


Figure 2. Simplified Control Schematic of AOZ2223QI

The constant-on-time PWM control architecture is a pseudo-fixed frequency with input voltage feed-forward. The internal circuit of AOZ2223QI sets the on-time of high-side switch inversely proportional to the  $I_N$ .

$$T_{ON} \propto \frac{R_{TON}(\text{k}\Omega)}{V_{IN}(\text{V})} \quad (1)$$

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

$$F_{SW} = \frac{V_{OUT}}{V_{IN} \times T_{ON}} \quad (2)$$

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



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

$$T_{ON}(ns) = \frac{R_{TON}(k\Omega)}{V_{IN}(V)} \times 25 \quad (3)$$

Then, the switching frequency can be estimated by:

$$F_{SW}(kHz) = \frac{V_{OUT}}{V_{IN} * T_{ON}(ns)} \times 10^6 = \frac{V_{OUT}}{R_{TON}(k\Omega)} \times 4 \times 10^4 \quad (4)$$

If  $V_{OUT}$  is 3.3V, and set  $F_s=500kHz$ . 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 AOZ2223QI 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 Protection

The AOZ2223QI 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.

### Output Voltage Under-voltage Protection

If the output voltage is lower than 70% by over-current or short circuit, AOZ2223QI will wait for 32 $\mu$ s (typical) and turns-off both high-side and low-side MOSFET and shuts down. Only when triggered, the enable can restart the AOZ2223QI again.

### Output Voltage Over-voltage Protection

The threshold of OVP is set 20% higher than 0.8V. When the VFB voltage exceeds the OVP threshold, high-side MOSFET is turn-off and low-side MOSFET is turn-on 1 $\mu$ s, then shuts down. Only when triggered, the enable can restart the AOZ2223QI again.

## Application Information

The basic AOZ2223QI application circuit is shown in previous page. Component selection is explained below.

### Input Capacitor

The input capacitor must be connected to the IN pins and PGND pin of the AOZ2223QI to maintain steady input voltage and filter out the pulsing input current. A small decoupling capacitor, usually 4.7uF, should be connected to the VCC pin and AGND pin for stable operation of the AOZ2223QI. 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:

$$\Delta V_{IN} = \frac{I_{OUT}}{f \times C_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \frac{V_{OUT}}{V_{IN}} \quad (5)$$

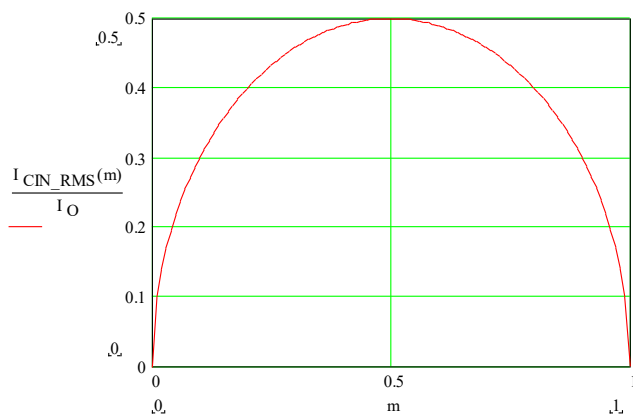
Since the input current is discontinuous in a buck converter, the current stress on the input capacitor is another concern when selecting the capacitor. For a buck circuit, the RMS value of input capacitor current can be calculated by:ww

$$I_{CIN\_RMS} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (6)$$

if let m equal the conversion ratio:

$$\frac{V_{OUT}}{V_{IN}} = m \quad (7)$$

The relation between the input capacitor RMS current and voltage conversion ratio is calculated and shown in Figure. 3. It can be seen that when  $V_O$  is half of  $V_{IN}$ ,  $C_{IN}$  is under the worst current stress. The worst current stress on  $C_{IN}$  is  $0.5 \cdot I_O$ .



**Figure 3. ICIN vs. Voltage Conversion Ratio**

For reliable operation and best performance, the input capacitors must have current rating higher than ICIN-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,

$$\Delta I_L = \frac{V_{OUT}}{f \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (8)$$

The peak inductor current is:

$$I_{Lpeak} = I_{OUT} + \frac{\Delta I_L}{2} \quad (9)$$

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:

$$\Delta V_{OUT} = \Delta I_L \times \left( ESR_{C_o} + \frac{1}{8 \times f \times C_o} \right) \quad (10)$$

where CO is output capacitor value and ESR<sub>CO</sub> is the Equivalent Series Resistor of output capacitor.

$$\Delta V_{OUT} = \Delta I_L \times \frac{1}{8 \times f \times C_o} \quad (11)$$

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:

$$\Delta V_{OUT} = \Delta I_L \times ESR_{C_o} \quad (12)$$

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:

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:

$$I_{CO\_RMS} = \frac{\Delta I_L}{\sqrt{12}} \quad (13)$$

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.

## Thermal Management and Layout Consideration

In the AOZ2223QI buck regulator circuit, high pulsing current flows through two circuit loops. The first loop starts from the input capacitors, to the VIN 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 AOZ2223QI.

In the AOZ2223QI buck regulator circuit, the major power dissipating components are the AOZ2223QI and the output inductor. The total power dissipation of converter circuit can be measured by input power minus output power.

$$P_{total\_loss} = V_{IN} \times I_{IN} - V_{OUT} \times I_{OUT} \quad (14)$$

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

$$P_{inductor\_loss} = I_{OUT}^2 \times R_{inductor} \times 1.1 \quad (15)$$

The actual junction temperature can be calculated with power dissipation in the AOZ2223QI and thermal impedance from junction to ambient.

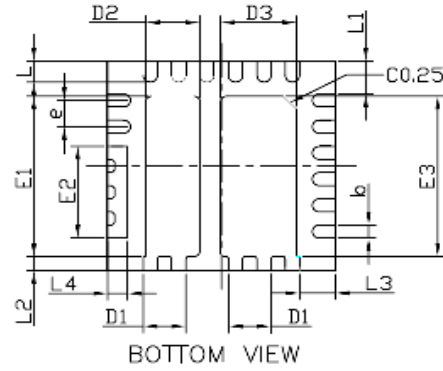
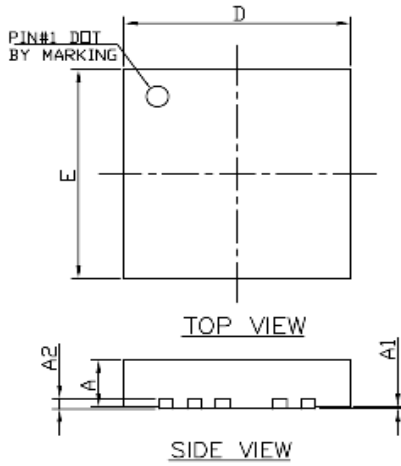
$$T_{junction} = (P_{total\_loss} - P_{total\_loss}) \times \theta_{JA} + T_A \quad (16)$$

The maximum junction temperature of AOZ2223QI is 150°C, which limits the maximum load current capability.

The thermal performance of the AOZ2223QI 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.

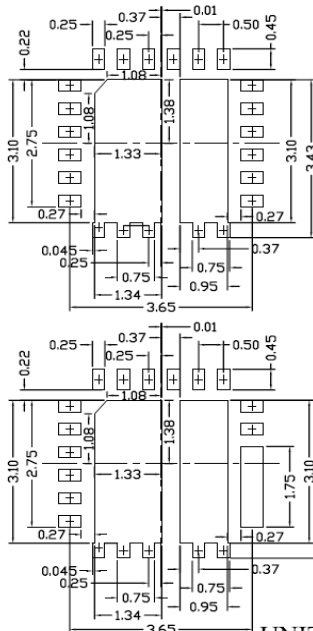


Package Dimensions, QFN4x4-23L

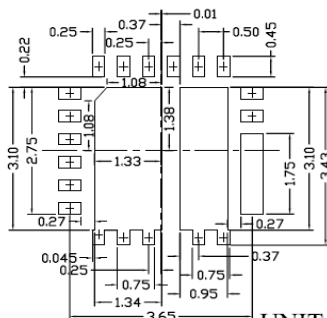


RECOMMENDED LAND PATTERN

Option 1



Option 2



UNIT: mm

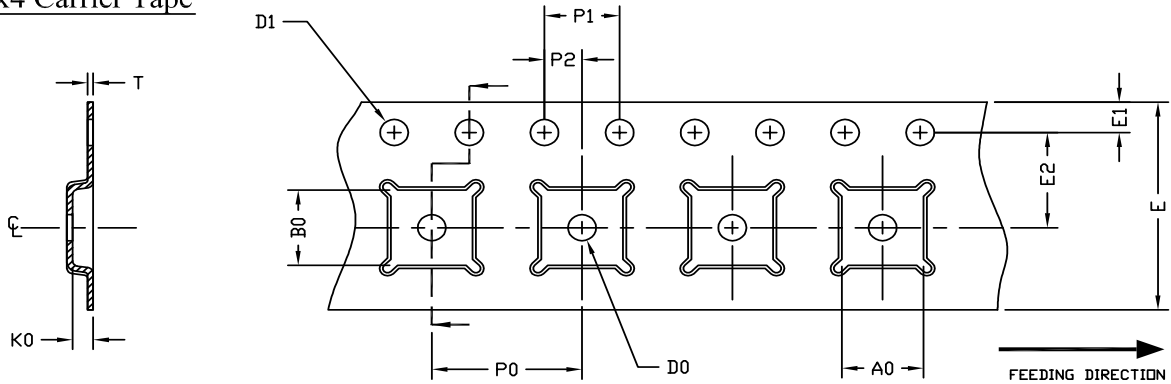
| SYMBOLS | DIMENSIONS IN MILLIMETERS |      |      | DIMENSIONS IN INCHES |       |       |
|---------|---------------------------|------|------|----------------------|-------|-------|
|         | MIN                       | NOM  | MAX  | MIN                  | NOM   | MAX   |
| A       | 0.80                      | 0.90 | 1.00 | 0.031                | 0.035 | 0.039 |
| A1      | 0.00                      | —    | 0.05 | 0.000                | —     | 0.002 |
| A2      | 0.2 REF                   |      |      | 0.008 REF            |       |       |
| E       | 3.90                      | 4.00 | 4.10 | 0.153                | 0.157 | 0.161 |
| E1      | 2.95                      | 3.05 | 3.15 | 0.116                | 0.120 | 0.124 |
| E2      | 1.65                      | 1.75 | 1.85 | 0.065                | 0.069 | 0.073 |
| E3      | 2.95                      | 3.05 | 3.15 | 0.116                | 0.120 | 0.124 |
| D       | 3.90                      | 4.00 | 4.10 | 0.153                | 0.157 | 0.161 |
| D1      | 0.65                      | 0.75 | 0.85 | 0.026                | 0.030 | 0.034 |
| D2      | 0.85                      | 0.95 | 1.05 | 0.033                | 0.037 | 0.041 |
| D3      | 1.24                      | 1.34 | 1.44 | 0.049                | 0.053 | 0.057 |
| L       | 0.35                      | 0.40 | 0.45 | 0.014                | 0.016 | 0.018 |
| L1      | 0.57                      | 0.62 | 0.67 | 0.022                | 0.024 | 0.026 |
| L2      | 0.23                      | 0.28 | 0.33 | 0.009                | 0.011 | 0.013 |
| L3      | 0.57                      | 0.62 | 0.67 | 0.022                | 0.024 | 0.026 |
| L4      | 0.30                      | 0.35 | 0.40 | 0.012                | 0.014 | 0.016 |
| b       | 0.20                      | 0.25 | 0.30 | 0.008                | 0.010 | 0.012 |
| e       | 0.50 BSC                  |      |      | 0.020 BSC            |       |       |

NOTE

1. CONTROLLING DIMENSION IS MILLIMETER.  
CONVERTED INCH DIMENSIONS ARE NOT NECESSARILY EXACT.
2. TOLERANCE :±0.05 UNLESS OTHERWISE SPECIFIED.
3. RADIUS ON ALL CORNER ARE 0.152 MAX., UNLESS OTHERWISE SPECIFIED.
4. PACKAGE WARPAGE: 0.012 MAX.
5. NO ANY PLASTIC FLASH ALLOWED ON THE TOP AND BOTTOM LEAD SURFACE.
6. PAD PLANARITY: ±0.102
7. CRACK BETWEEN PLASTIC BODY AND LEAD IS NOT ALLOWED.

## Tape and Reel Dimensions, QFN4x4-23L

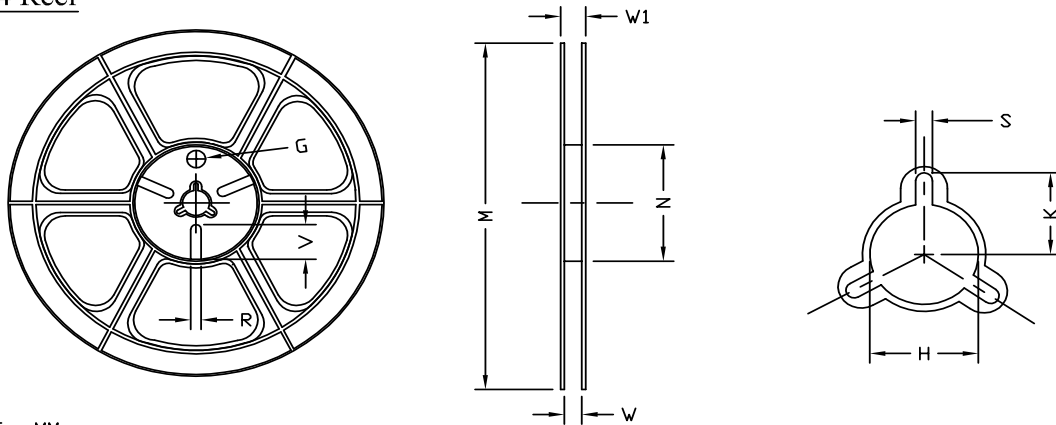
### QFN4x4 Carrier Tape



UNIT: MM

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

### QFN4x4 Reel



UNIT: MM

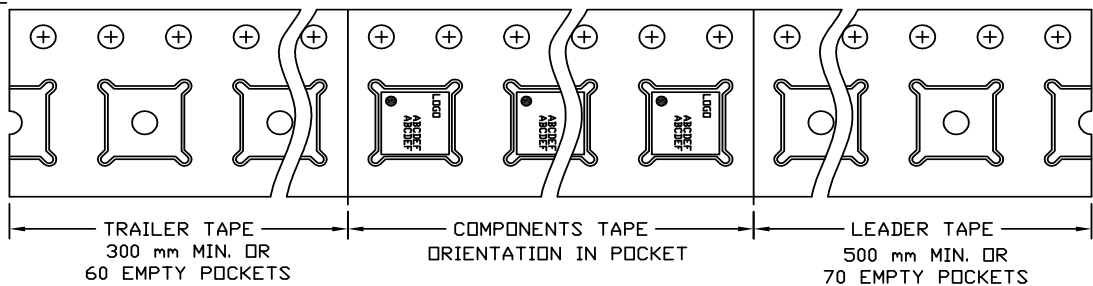
| TAPE SIZE | REEL SIZE | M              | N             | W            | W1           | H             | K            | S           | G   | R   | V   |
|-----------|-----------|----------------|---------------|--------------|--------------|---------------|--------------|-------------|-----|-----|-----|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

### QFN4x4 Tape

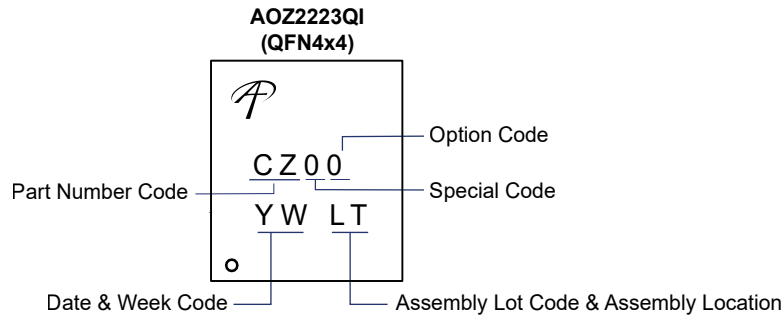
Leader / Trailer  
& Orientation

Normal

Unit Per Reel:  
3000pcs



**Part Marking**



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