General Description

The AOZ2263BQI-28 is a high-efficiency, easy-to-use DC/DC synchronous buck regulator that operates up to 28 V. The device is capable of supplying 12 A of continuous output current with an output voltage adjustable down to 0.8 V ±1%.

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 on time can be externally programmed up to 3.3 μs.

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

The AOZ2263BQI-28 is available in a 4 mm × 4 mm QFN-23L package and is rated over a -40°C to +85°C ambient temperature range.

Features

- Wide input voltage range
  - 10 V to 28 V
- 12A continuous output current
- Output voltage adjustable from 0.8 V ±1.0%
- Low RDS(ON) internal NFETs
  - 11 mΩ high-side
  - 8 mΩ low-side
- Constant On-Time with input feed-forward
- Programmable on-time up to 3.3 μs
- Selectable PFM/PWM Mode
- Ceramic capacitor stable
- Adjustable soft start
- Ripple Reduction
- Power Good output
- Integrated bootstrap diode
- Cycle-by-cycle current limit
- Short-circuit protection
- Over voltage protection
- Thermal shutdown
- Thermally enhanced 23-pin 4 mm × 4 mm QFN

Applications

- Portable computers
- Compact desktop PCs
- Servers
- Graphics cards
- Set top boxes
- LCD TVs
- Cable modems
- Point of load dc/dc converters
- Telecom/Networking/Datacom equipment
Typical Application

![Typical Application Diagram]

- **VCC**: Power supply input
- **BST**: Bootstrap capacitor
- **L1**: Inductor
- **C4**: Capacitor
- **C2**: Output capacitor
- **R3**: Resistor
- **C5**: Feedback capacitor
- **R1**: Feedback resistor
- **R2**: Feedback resistor
- **R_TON**: TON resistor
- **AGND**: Analog ground
- **PGND**: Power ground
- **INPUT**: 10V to 28V
- **OUTPUT**: 1.05V, 12A
- **SS**: Synchronization input
- **EN**: Enable input
- **PFM**: PFM input
- **FB**: Feedback input
- **TON IN**: Input voltage range: 10V to 28V
- **OFF**: Power good off
- **ON**: Power good on
- **C3**: Output capacitor

**Note:** The diagram shows the typical application circuit for the AOZ2263BQI-28 power management IC, illustrating connections and component values.
### Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Temperature Range</th>
<th>Package</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOZ2263BQI-28</td>
<td>-40°C to +85°C</td>
<td>23-Pin 4 mm × 4 mm QFN</td>
<td>Green</td>
</tr>
</tbody>
</table>

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](https://aosmd.com/sites/default/files/media/AOSGreenPolicy.pdf) for additional information.

### Pin Configuration

- **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 or 20% higher than the nominal regulation voltage. PGOOD is pulled low during soft-start and shut down.
- **EN**: Enable Input. The AOZ2263BQI-28 is enabled when EN is pulled high. The device shuts down when EN is pulled low. Assert EN to high for power-up after IN and VCC are well supplied.
- **PFM**: PFM Selection Input. Connect PFM pin to VCC for forced PWM operation. Connect PFM pin to ground for PFM operation to improve light load efficiency.
- **AGND**: Analog Ground.
- **FB**: Feedback Input. Adjust the output voltage with a resistive voltage-divider between the regulator’s output and AGND.
- **TON**: On-Time Setting Input. Connect a resistor between VIN and TON to set the on-time.
- **IN**: Supply Input. IN is the regulator input. All IN pins must be connected together.
- **PGND**: Power Ground.
- **LX**: Switching Node.
- **BST**: Bootstrap Capacitor Connection. The AOZ2263BQI-28 includes an internal bootstrap diode. Connect an external capacitor between BST and LX as shown in a typical application.
- **VCC**: Supply Input for analog functions. Bypass VCC to AGND with a 4.7 µF~10 µF ceramic capacitor. Place the capacitor close to VCC pin.
- **SS**: Soft-Start Time Setting Pin. Connect a capacitor between SS and AGND to set the soft-start time.

### Pin Description

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Pin Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PGOOD</td>
<td>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 or 20% higher than the nominal regulation voltage. PGOOD is pulled low during soft-start and shut down.</td>
</tr>
<tr>
<td>2</td>
<td>EN</td>
<td>Enable Input. The AOZ2263BQI-28 is enabled when EN is pulled high. The device shuts down when EN is pulled low. Assert EN to high for power-up after IN and VCC are well supplied.</td>
</tr>
<tr>
<td>3</td>
<td>PFM</td>
<td>PFM Selection Input. Connect PFM pin to VCC for forced PWM operation. Connect PFM pin to ground for PFM operation to improve light load efficiency.</td>
</tr>
<tr>
<td>4</td>
<td>AGND</td>
<td>Analog Ground.</td>
</tr>
<tr>
<td>5</td>
<td>FB</td>
<td>Feedback Input. Adjust the output voltage with a resistive voltage-divider between the regulator’s output and AGND.</td>
</tr>
<tr>
<td>6</td>
<td>TON</td>
<td>On-Time Setting Input. Connect a resistor between VIN and TON to set the on-time.</td>
</tr>
<tr>
<td>7, 8, 9, 22</td>
<td>IN</td>
<td>Supply Input. IN is the regulator input. All IN pins must be connected together.</td>
</tr>
<tr>
<td>12, 13, 14, 15, 19</td>
<td>PGND</td>
<td>Power Ground.</td>
</tr>
<tr>
<td>10, 11, 16, 17, 18</td>
<td>LX</td>
<td>Switching Node.</td>
</tr>
<tr>
<td>20</td>
<td>BST</td>
<td>Bootstrap Capacitor Connection. The AOZ2263BQI-28 includes an internal bootstrap diode. Connect an external capacitor between BST and LX as shown in a typical application.</td>
</tr>
<tr>
<td>21</td>
<td>VCC</td>
<td>Supply Input for analog functions. Bypass VCC to AGND with a 4.7 µF~10 µF ceramic capacitor. Place the capacitor close to VCC pin.</td>
</tr>
<tr>
<td>23</td>
<td>SS</td>
<td>Soft-Start Time Setting Pin. Connect a capacitor between SS and AGND to set the soft-start time.</td>
</tr>
</tbody>
</table>
### Absolute Maximum Ratings
*Exceeding the Absolute Maximum ratings may damage the device.*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN, TON to AGND</td>
<td>-0.3 V to 30 V</td>
</tr>
<tr>
<td>LX to AGND(^{(1)})</td>
<td>-0.7 V to 30 V</td>
</tr>
<tr>
<td>BST to AGND</td>
<td>-0.3 V to 36 V</td>
</tr>
<tr>
<td>PGND to AGND</td>
<td>-0.3 V to +0.3 V</td>
</tr>
<tr>
<td>Other Pins to AGND</td>
<td>-0.3 V to 6 V</td>
</tr>
<tr>
<td>Junction Temperature (T(_J))</td>
<td>+150°C</td>
</tr>
<tr>
<td>Storage Temperature (T(_S))</td>
<td>-65°C to +150°C</td>
</tr>
<tr>
<td>ESD Rating-HBM(^{(2)})</td>
<td>2 kV</td>
</tr>
<tr>
<td>ESD Rating-CDM</td>
<td>1 kV</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage (V(_\text{IN}))</td>
<td>10 V to 28 V</td>
</tr>
<tr>
<td>Output Voltage Range</td>
<td>0.8 V to 5 V</td>
</tr>
<tr>
<td>Ambient Temperature (T(_A))</td>
<td>-40°C to +85°C</td>
</tr>
<tr>
<td>Package Thermal Resistance ((\theta_{JA}))</td>
<td>32°C/W</td>
</tr>
<tr>
<td></td>
<td>((\theta_{JC}))</td>
</tr>
</tbody>
</table>

### Notes:
1. LX to PGND Transient (t<20ns) ----- -7V to V\(_\text{IN}\)+7V.
2. Devices are inherently ESD sensitive, handling precautions are required.
   Human body model rating: 1.5kΩ in series with 100pF.

### Electrical Characteristics
\(T_A = 25°C, V_{\text{IN}}=12V, \text{ EN} = 5V\), unless otherwise specified. Specifications in BOLD indicate a temperature range of -40°C to +85°C.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(_\text{IN})</td>
<td>IN Supply Voltage</td>
<td></td>
<td>10</td>
<td>28</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>V(_\text{UVLO})</td>
<td>Under-Voltage Lockout Threshold of V(_\text{CC})</td>
<td>V(<em>\text{CC}) rising, V(</em>\text{CC}) falling</td>
<td>3.5</td>
<td>4.2</td>
<td>4.5</td>
<td>V</td>
</tr>
<tr>
<td>I(_q)</td>
<td>Quiescent Supply Current of V(_\text{CC})</td>
<td>I(<em>\text{OUT}) = 0A, V(</em>\text{EN}) &gt; 2V, PFM mode</td>
<td>0.17</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>I(_\text{OFF})</td>
<td>Shutdown Supply Current</td>
<td>V(_\text{EN}) = 0 V</td>
<td>1</td>
<td>2</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>V(_\text{FB})</td>
<td>Feedback Voltage</td>
<td>T(_A) = 25°C, T(_A) = 0°C to 85°C</td>
<td>0.792</td>
<td>0.788</td>
<td>0.808</td>
<td>V</td>
</tr>
<tr>
<td>I(_\text{FB})</td>
<td>FB Input Bias Current</td>
<td></td>
<td>200</td>
<td></td>
<td></td>
<td>nA</td>
</tr>
</tbody>
</table>

### Enable

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(_\text{EN})</td>
<td>EN Input Threshold</td>
<td>Off threshold, On threshold</td>
<td>1.6</td>
<td>0.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>V(_\text{EN_HYS})</td>
<td>EN Input Hysteresis</td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
</tbody>
</table>

### PFM Control

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(_\text{PFM})</td>
<td>PFM Input Threshold</td>
<td>PFM Mode threshold, Force PWM threshold</td>
<td>2.5</td>
<td>0.5</td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

### Modulator

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>T(_\text{ON_MIN})</td>
<td>Minimum On-Time</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>T(_\text{ON_MAX})</td>
<td>Maximum On-Time</td>
<td></td>
<td>3.3</td>
<td></td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td>T(_\text{OFF_MIN})</td>
<td>Minimum Off-Time</td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>
## Electrical Characteristics

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_{SS.OUT} )</td>
<td>SS Source Current</td>
<td>( V_{SS} = 0, \ C_{SS} = 0.001 \mu\text{F} ) to ( 0.1 \mu\text{F} )</td>
<td>7</td>
<td>11</td>
<td>15</td>
<td>\mu\text{A}</td>
</tr>
<tr>
<td><strong>Power Good Signal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{PG_LOW} )</td>
<td>PGOOD Low Voltage</td>
<td>( I_{OL} = 1 \text{mA} )</td>
<td></td>
<td></td>
<td>0.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PGOOD Leakage Current</td>
<td></td>
<td></td>
<td>1</td>
<td>\mu\text{s}</td>
</tr>
<tr>
<td>( V_{PGH} )</td>
<td>PGOOD Threshold (Low level to High level)</td>
<td>FB rising</td>
<td></td>
<td></td>
<td>90</td>
<td>%</td>
</tr>
<tr>
<td>( V_{PGL} )</td>
<td>PGOOD Threshold (High level to Low level)</td>
<td>FB rising, FB falling</td>
<td></td>
<td>120</td>
<td>85</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PGOOD Threshold Hysteresis</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Under Voltage and Over Voltage Protection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{PL} )</td>
<td>Under Voltage threshold</td>
<td>FB falling</td>
<td></td>
<td></td>
<td>50</td>
<td>%</td>
</tr>
<tr>
<td>( V_{PH} )</td>
<td>Over Voltage Threshold</td>
<td>FB rising</td>
<td></td>
<td></td>
<td>120</td>
<td>%</td>
</tr>
<tr>
<td><strong>Power Stage Output</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R_{DS(ON)} )</td>
<td>High-Side NFET On- Resistance</td>
<td>( V_{IN} = 12 \text{V}, \ V_{CC} = 5 \text{V} )</td>
<td>11</td>
<td></td>
<td></td>
<td>m\Omega</td>
</tr>
<tr>
<td></td>
<td>High-Side NFET Leakage</td>
<td>( V_{EN} = 0 \text{V}, \ V_{LX} = 0 )</td>
<td>10</td>
<td></td>
<td></td>
<td>\mu\text{A}</td>
</tr>
<tr>
<td>( R_{DS(ON)} )</td>
<td>Low-Side NFET On- Resistance</td>
<td>( V_{LX} = 12 \text{V}, \ V_{CC} = 5 \text{V} )</td>
<td>8</td>
<td></td>
<td></td>
<td>m\Omega</td>
</tr>
<tr>
<td></td>
<td>Low-Side NFET Leakage</td>
<td>( V_{EN} = 0 \text{V} )</td>
<td>10</td>
<td></td>
<td></td>
<td>\mu\text{A}</td>
</tr>
<tr>
<td><strong>Over-Current and Thermal Protection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{LIM} )</td>
<td>Current Limit</td>
<td></td>
<td></td>
<td></td>
<td>18</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Thermal Shutdown Threshold</td>
<td>( T_J ) rising, ( T_J ) falling</td>
<td>150</td>
<td>100</td>
<td></td>
<td>\degree\text{C}</td>
</tr>
</tbody>
</table>
Functional Block Diagram
Typical Characteristics

Circuit of Typical Application. \( T_A = 25 \, ^\circ\text{C}, \ V_{\text{IN}} = 19\, \text{V}, \ V_{\text{OUT}} = 1\, \text{V}, \) unless otherwise specified.

**Normal Operation**

- **ILX** (5A/div)
- **V_{\text{OUT}}\text{ ripple}** (50mV/div)
- **VLX** (20V/div)

(20\(\mu\text{s}/\text{div})

**Load Transient 0A to 12A**

- **ILX** (10A/div)
- **V_{\text{OUT}}\text{ ripple}** (50mV/div)

(5ms/div)

**Full Load Start-up**

- **EN** (5V/div)
- **ILX** (10A/div)
- **V_{\text{OUT}}** (500mV/div)
- **VLX** (20V/div)

(1ms/div)

**Short Circuit Protection**

- **ILX** (10A/div)
- **VLX** (20V/div)
- **V_{\text{OUT}}** (500mV/div)

(50\(\mu\text{s}/\text{div})

**Efficiency vs. Load Current**

- **VIN = 12V**
- **VIN = 19V**
- **VIN = 24V**

Output Current (A) vs. Efficiency (%) graph

\( V_{\text{OUT}} = 1\, \text{V} \)
**Detailed Description**

The AOZ2263BQI-28 is a high-efficiency, easy-to-use, synchronous buck regulator optimized for notebook computers. The regulator is capable of supplying 12 A of continuous output current with an output voltage adjustable down to 0.8 V. The programmable on-time from 100 ns to 3.3 μs enables optimizing the configuration for PCB area and efficiency.

The input voltage of AOZ2263BQI-28 can be as low as 10 V. The highest input voltage of AOZ2263BQI-28 can be 28 V. 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. The switching frequency can be externally programmed. Protection features include VCC under-voltage lockout, cycle-by-cycle current limit, output over voltage and under voltage protection, short-circuit protection, and thermal shutdown.

The AOZ2263BQI-28 is available in 23-Pin 4 mm × 4 mm QFN package.

**Enable and Soft Start**

The AOZ2263BQI-28 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 VCC rises to 4.5 V 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 (VSS) when it is lower than 0.8 V. When VSS is higher than 0.8 V, the FB voltage is regulated by internal precise band-gap voltage (0.8 V). The soft-start time for FB voltage can be calculated by the following formula:

\[ T_{SS}(\mu s) = 330 \times C_{SS}(nF) \]

If \( C_{SS} \) is 1 nF, the soft-start time will be 330 μs; if \( C_{SS} \) is 10 nF, the soft-start time will be 3.3 ms.

![Figure 1. Soft Start Sequence of AOZ2263BQI-28](image)

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

The control algorithm of AOZ2263BQI-28 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 (IN). The one-shot is triggered when the internal 0.8 V 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 AOZ2263BQI-28](image)

The constant-on-time PWM control architecture is a pseudo-fixed frequency with input voltage feed-forward. The internal circuit of AOZ2263BQI-28 sets the on-time of high-side switch inversely proportional to the IN.

\[ T_{ON} \propto \frac{R_{TON}(k\Omega)}{V_{IN}(V)} \]  

(1)

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

\[ F_{SW} = \frac{V_{OUT}}{V_{IN} \times T_{ON}} \]  

(2)

Once the product of Vin*Ton is constant, the switching frequency keeps constant and is independent of input voltage.

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

\[ T_{ON}(ns) = \frac{R_{TON}(k\Omega)}{V_{IN}(V)} \times 25 \]  

(3)
A further simplified equation will be:

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

If \( V_{OUT} \) is 1.05 V, \( V_{IN} \) is 19 V, and set \( F_S = 500 \text{kHz} \). According to the equation above, \( T_{ON} = 110 \text{ns} \) is needed. Finally, use the \( T_{ON} \) to \( R_{TON} \) curve, we can find out \( R_{TON} \) is 82 kΩ.

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 AOZ2263BQI-28 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 AOZ2263BQI-28 has the current-limit protection by using \( R_{ds(on)} \) of the low-side MOSFET to be as current sensing. To detect real current information, a minimum constant off time (300 ns 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 AOZ2263BQI-28 considers this a true failed condition and thus turns-off both high-side and low-side MOSFETs and latches off. Only when triggered, the enable can restart the AOZ2263BQI-28 again.

**Output Voltage Under-voltage Protection**

If the output voltage is lower than 50% by over-current or short circuit, AOZ2263BQI-28 turns-off both high-side and low-side MOSFET and latches off. Only trigger the enable again can restart the AOZ2263BQI-28.

**Output Voltage Over-voltage Protection**

The threshold of OVP is set 20% higher than 0.8 V. When the VFB voltage exceeds the OVP threshold, high-side MOSFET is turn-off and low-side MOSFET is turn-on 1 μs, then shuts down. Only when triggered, the enable can restart the AOZ2263BQI-28 again.

**Power Good Output**

The power good (PGOOD) output, which is an open drain output, requires the pull-up resistor. When the output voltage is 15% 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 pull low.

When combined with the under-voltage-protection circuit, this current-limit method is effective in almost every circumstance.

**PFM/PWM Mode Selection**

The AOZ2263BQI-28 has the selectable PFM (pulse-frequency modulation) and PWM (pulse-width modulation) modes operation by PFM pin setting. When the PFM setting voltage is lower than 0.5 V, the AOZ2263BQI-28 operates at PFM mode. When PFM setting voltage is higher than 2.5 V, the AOZ2263BQI-28 operates at PWM mode.

**Application Information**

The basic AOZ2263BQI-28 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 AOZ2263BQI-28 to maintain steady input voltage and filter out the pulsing input current. A small decoupling capacitor, usually 4.7 μF, should be connected to the \( V_{CC} \) pin and AGND pin for stable operation of the AOZ2263BQI-28. 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:

\[ I_{CIN,RMS} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (6) \]
if let $m$ equal the conversion ratio:

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

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 $V_{\text{OUT}}$ is half of $V_{\text{IN}}$, $C_{\text{IN}}$ is under the worst current stress. The worst current stress on $C_{\text{IN}}$ is $0.5 \cdot I_o$.

![Figure 3. $I_{\text{CIN}}$ vs. Voltage Conversion Ratio](image)

For reliable operation and best performance, the input capacitors must have current rating higher than $I_{\text{CIN-RMS}}$ 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:

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

The peak inductor current is:

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

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:

$$\Delta V_{\text{out}} = \Delta I_L \times \left( \frac{\text{ESR}_{\text{CO}}}{8 \times f \times C_{\text{O}}} + \frac{1}{8 \times f \times C_{\text{O}}} \right) \quad (10)$$

where $C_{\text{O}}$ is output capacitor value and ESR$_{\text{CO}}$ 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:

$$\Delta V_{\text{out}} = \Delta I_L \times \frac{1}{8 \times f \times C_{\text{O}}} \quad (11)$$

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:

\[ \Delta V_{\text{out}} = \Delta I_L \times ESR_{C_o} \]  \hspace{1cm} (12)

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:

\[ I_{C_{O,RMS}} = \frac{\Delta I_L}{\sqrt{12}} \]  \hspace{1cm} (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 AOZ2263BQI-28 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 AOZ2263BQI-28.

In the AOZ2263BQI-28 buck regulator circuit, the major power dissipating components are the AOZ2263BQI-28 and the output inductor. The total power dissipation of converter circuit can be measured by input power minus output power.

\[ P_{\text{total_loss}} = V_{\text{IN}} \times I_{\text{IN}} - V_{\text{OUT}} \times I_{\text{OUT}} \]  \hspace{1cm} (14)

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

\[ P_{\text{inductor_loss}} = I_{\text{OUT}}^2 \times R_{\text{inductor}} \times 1.1 \]  \hspace{1cm} (15)

The actual junction temperature can be calculated with power dissipation in the AOZ2263BQI-28 and thermal impedance from junction to ambient.

\[ T_{\text{junction}} = (P_{\text{total_loss}} - P_{\text{total_loss}}) \times \theta_{JA} + T_A \]  \hspace{1cm} (16)

The maximum junction temperature of AOZ2263BQI-28 is 150°C, which limits the maximum load current capability. The thermal performance of the AOZ2263BQI-28 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.
Layout Considerations

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

1. The LX pins and pad are connected to internal low side switch drain. They are low resistance thermal conduction path and most noisy switching node. Connected a large copper plane to LX pin to help thermal dissipation.

2. 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.

3. Input capacitors should be connected to the IN pin and the PGND pin as close as possible to reduce the switching spikes.

4. Decoupling capacitor CVCC should be connected to VCC and AGND as close as possible.

5. Voltage divider R1 and R2 should be placed as close as possible to FB and AGND.

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, QFN4x4-23L

RECOMMENDED LAND PATTERN

Option 1

Option 2

UNIT: mm

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.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DIMENSIONS IN MILLIMETERS</th>
<th>DIMENSIONS IN INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.80, 0.90, 1.00</td>
<td>0.031, 0.035, 0.039</td>
</tr>
<tr>
<td>A1</td>
<td>0.60</td>
<td>0.000, 0.002</td>
</tr>
<tr>
<td>A2</td>
<td>0.2 REF</td>
<td>0.008 REF</td>
</tr>
<tr>
<td>E</td>
<td>3.90, 4.00, 4.10</td>
<td>0.153, 0.157, 0.161</td>
</tr>
<tr>
<td>E1</td>
<td>2.95, 3.05, 3.15</td>
<td>0.116, 0.120, 0.124</td>
</tr>
<tr>
<td>E2</td>
<td>1.65, 1.75, 1.85</td>
<td>0.066, 0.069, 0.073</td>
</tr>
<tr>
<td>E3</td>
<td>2.95, 3.05, 3.15</td>
<td>0.116, 0.120, 0.124</td>
</tr>
<tr>
<td>D</td>
<td>3.90, 4.00, 4.10</td>
<td>0.153, 0.157, 0.161</td>
</tr>
<tr>
<td>D1</td>
<td>0.65, 0.75, 0.85</td>
<td>0.026, 0.030, 0.034</td>
</tr>
<tr>
<td>D2</td>
<td>0.85, 0.95, 1.06</td>
<td>0.033, 0.037, 0.041</td>
</tr>
<tr>
<td>D3</td>
<td>1.24, 1.34, 1.44</td>
<td>0.049, 0.053, 0.057</td>
</tr>
<tr>
<td>L</td>
<td>0.35, 0.40, 0.45</td>
<td>0.014, 0.016, 0.018</td>
</tr>
<tr>
<td>L1</td>
<td>0.57, 0.62, 0.67</td>
<td>0.022, 0.024, 0.026</td>
</tr>
<tr>
<td>L2</td>
<td>0.23, 0.28, 0.33</td>
<td>0.009, 0.011, 0.013</td>
</tr>
<tr>
<td>L3</td>
<td>0.57, 0.62, 0.67</td>
<td>0.022, 0.024, 0.026</td>
</tr>
<tr>
<td>L4</td>
<td>0.30, 0.35, 0.40</td>
<td>0.012, 0.014, 0.016</td>
</tr>
<tr>
<td>b</td>
<td>0.20, 0.25, 0.30</td>
<td>0.008, 0.010, 0.012</td>
</tr>
<tr>
<td>c</td>
<td>0.50 RSC</td>
<td>0.020 RSC</td>
</tr>
</tbody>
</table>
Tape and Reel Dimensions, QFN4x4-23L

QFN4x4 Carrier Tape

UNIT: MM

<table>
<thead>
<tr>
<th>PACKAGE</th>
<th>A0</th>
<th>B0</th>
<th>K0</th>
<th>D0</th>
<th>D1</th>
<th>E</th>
<th>E1</th>
<th>E2</th>
<th>P0</th>
<th>P1</th>
<th>P2</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>QFN4x4</td>
<td>4.35</td>
<td>4.35</td>
<td>1.10</td>
<td>1.50</td>
<td>1.50</td>
<td>1.75</td>
<td>5.50</td>
<td>4.00</td>
<td>4.00</td>
<td>2.00</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>(12 mm)</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.05</td>
<td>±0.05</td>
<td>±0.05</td>
<td>±0.05</td>
<td>±0.05</td>
<td>±0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

QFN4x4 Reel

UNIT: MM

<table>
<thead>
<tr>
<th>TAPE SIZE</th>
<th>REEL SIZE</th>
<th>M</th>
<th>N</th>
<th>W</th>
<th>W1</th>
<th>H</th>
<th>K</th>
<th>S</th>
<th>G</th>
<th>R</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 mm</td>
<td>Ø33.0</td>
<td>±2.0</td>
<td>Ø79.0</td>
<td>±1.0</td>
<td>12.4</td>
<td>17.0</td>
<td>Ø13.0</td>
<td>10.5</td>
<td>2.0</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

QFN4x4 Tape

Leader / Trailer & Orientation

Normal

Unit Per Reel: 3000pcs

TRAILER TAPE 300 mm MIN. OR 60 EMPTY POCKETS
COMPONENTS TAPE ORIENTATION IN POCKET
LEADER TAPE 500 mm MIN. OR 70 EMPTY POCKET
Part Marking

AOZ2263BQI-28 (QFN4x4)

- Part Number Code
- Option Code
- Special Code
- Date & Week Code
- Assembly Lot Code and Assembly Location

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

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 which, (a) are intended for surgical implant into the body or device, or system whose failure to perform can be reasonably expected to result in a significant injury of the user.

   2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness 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.