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CZ-381x Application Note (rev.2)
0. Overview

This document is an application note to help use AKM’s current sensor CZ-381x series effectively.

This document consists of three sections;
1. Electric characteristics of the current sensor
2. Board design guideline
3. Useful tips

0.1. CZ-381x

**Part number**  
CZ-381x (x : 3~5)

**Features**  
High Accuracy Small-sized Coreless Current Sensor  
supporting operating temperatures up to 125 °C

**Applications**  
AC Motors, DC Motors, UPS, Power Conditioners, Air Conditioners  
Best fit for the applications that need isolation, low heat and small size.

**Market trend**  
The market has been recently demanding smaller sized systems, dustproof, and waterproof structures. Small bodies, lower heat generation and high temperature operation range is required for current sensors.  
The CZ-381x series has a miniaturized body while maintaining a low-heat generation characteristic, supporting up to 125°C operation temperature. It is suitable for systems having difficulty in heat suppressing design and applications that use large current.

CZ-381x Application Note (rev.2)
Details of Features

1. Supporting 125°C and 40 Arms

The CZ-381x series supports up to 125 °C operation temperature by suppressing heat generation with an originally developed AKM package. This enables 40 Arms continuous current, making the CZ-381x usable even in the current range where conventional current sensors with a core are required. Therefore, downsizing for existing systems is possible.

2. High Accuracy

The CZ-381x series is a highly accurate coreless current sensor with 0.7% F.S. (Typical). This will contribute to improving system efficiency and precise control in a wide range of applications.

3. Small Size

The CZ-381x series achieves this size using a coreless structure AKM’s developed original package. The package size is 11.5 x 8.3 x 2.0 (mm), which is about 1/20 of the volume of conventional products.

Table 1. CZ-381x series

<table>
<thead>
<tr>
<th>Part #</th>
<th>Operating Ambient Temperature (°C)</th>
<th>Linear Sensing Range (A)</th>
<th>Sensitivity (mV/A)</th>
<th>Temperature Drift of Sensitivity (%)&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Temperature Drift of Zero-current Output Voltage (mV)&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Total Accuracy (%F.S.)&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CZ-3813</td>
<td>-40°C~125°C</td>
<td>±33</td>
<td>60</td>
<td>±0.9</td>
<td>±3</td>
<td>0.7</td>
</tr>
<tr>
<td>CZ-3814</td>
<td>-40°C~125°C</td>
<td>±50</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CZ-3815</td>
<td>±60</td>
<td>33.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Defined as the average value ±1σ of the actual measurement results within a certain lot at T<sub>a</sub>=-40~125°C.
1. Electrical Characteristics of the current sensor

1.1. Temperature Drift of Sensitivity

Temperature Drift of Sensitivity \((V_{h-d} \%)\) is defined as the change rate of Sensitivity \((V_{h} \text{ [mV/A]})\) when Operating Ambient Temperature \((T_a \text{ [°C]})\) changes from 25°C to \(T_{a1}(-40°C \leq T_{a1} \leq 125°C)\);

\[
V_{h-d} = 100 \times \left( \frac{V_h(T_a = T_{a1})}{V_h(Typical\,\,value\,\,at\,\,T_a = 25°C)} - 1 \right)
\]

![Figure 1. Temperature Drift of Sensitivity](image)

Figure 1 shows “Average” and “Average ±3σ” of the actual result in a certain lot. This temperature characteristic is the same in all CZ-381x series.

Please be noted that there is a difference between the definition of “Average” and that of “Typical” in the datasheet. “Typical” in the datasheet equals “Average” ±1σ.

1.2. Temperature Drift of Zero-current Output

Temperature Drift of Zero-current Output \((V_{of-d} \text{ [mV]})\) is defined as the change of Zero-current Output \((V_{of} \text{ [V]})\) when Operating Ambient Temperature \((T_a \text{ [°C]})\) changes from 25°C to \(T_{a1}(-40°C \leq T_{a1} \leq 125°C)\);

\[
V_{of-d} = V_{of}(T_a = T_{a1}) - V_{of}(T_a = 25°C)
\]
Figure 2. Temperature Drift of Zero-current Output

Figure 2. shows “Average” and “Average ±3σ” of the actual result in a certain lot. Please note that there is a difference between the definition of “Average” and that of “Typical” in the datasheet. “Typical” in the datasheet equals “Average” ±1σ.

1.3. Temperature dependency of Total Accuracy
Total Accuracy ($E_{total}$) is defined as follows;

$$E_{total} = 100 \times \frac{V_{err}}{F.S.}$$

$$V_{err} = \left| V_{o-f-d, meas} \right| + \left| I_{NS} \right| \times V_h \times \left| \frac{V_{h-d, meas}}{100} \right| + \left| \frac{\rho_{meas}}{100} \right| \times F.S.$$

- $V_{o-f-d, meas}$: Measured Drift of Zero-current Output [mV]
- $V_{h-d, meas}$: Measured Sensitivity [mV/A]
- $V_h$: Typical Sensitivity [mV/A]
- $\rho_{meas}$: Measured Linearity Error [%F.S.]
Figure 3. Temperature dependency of Total Accuracy

Figure 3. shows “Average” and “Average ±3σ” of the actual results within a certain lot. Please note that there is a difference between the definition of “Average” and that of “Typical” in the datasheet. “Typical” in the datasheet equals “Average” ±1σ.

1.4. Resolution of measured current (Output Noise)

Output noise affects the resolution of the measured current. It is possible to reduce the output noise by filter and to increase the resolution depending on the filter characteristic.

<table>
<thead>
<tr>
<th>Part #</th>
<th>Sensitivity [mV/A]</th>
<th>Linear sensing range [A]</th>
<th>Output Noise [mV_{pp}]</th>
<th>Output Noise [mV_{rms}]</th>
<th>Input Current Equivalent Noise [mA_{rms}]</th>
<th>ENOB [Bits]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CZ-3813</td>
<td>60</td>
<td>±33</td>
<td>20</td>
<td>3</td>
<td>50</td>
<td>8.6</td>
</tr>
<tr>
<td>CZ-3814</td>
<td>40</td>
<td>±50</td>
<td></td>
<td></td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>CZ-3815</td>
<td>33.3</td>
<td>±60</td>
<td></td>
<td></td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Example of Current Resolution and Filter Characteristics (CZ-3813, actual result of N=1)

<table>
<thead>
<tr>
<th>C_{f}[nF]</th>
<th>R_{f}[kΩ]</th>
<th>Bandwidth [kHz]</th>
<th>Output Noise [mV_{pp}]</th>
<th>Output Noise [mV_{rms}]</th>
<th>Input Current Equivalent Noise [mA_{rms}]</th>
<th>ENOB [Bits]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without filter</td>
<td>210</td>
<td>9.7</td>
<td>1.6</td>
<td>26.7</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>4.7</td>
<td>1</td>
<td>34</td>
<td>4.5</td>
<td>0.7</td>
<td>11.7</td>
<td>10.7</td>
</tr>
<tr>
<td>4.7</td>
<td>10</td>
<td>3.4</td>
<td>1.5</td>
<td>0.3</td>
<td>5</td>
<td>11.9</td>
</tr>
</tbody>
</table>
Figure 4. External Circuits Example

(a) 1μF bypass capacitor should be placed near by the VDD pin and VSS pin of CZ-381x.

(b) CZ-381x has the ratiometric output. By making the supply voltage of CZ-381x and the reference voltage of A/D converter common, the A/D conversion error caused by the fluctuation of supply voltage is decreased. Voltage dividers (R1 and R2) are required if the reference voltage of A/D converter is less than +5V.

ex.) If the reference voltage of A/D converter is +3.3V which is its supply voltage level, R1 = 20kΩ, R2 = 39kΩ are recommended. If the reference voltage of A/D converter is different from its supply voltage level, one more voltage divider is required.

(c) Add a low-pass filter if it is necessary.

1.5. Voltage Noise Rejection Ratio
The Voltage Noise Rejection Ratio of the Primary Conductor was calculated by measuring the output while a high frequency sine wave voltage was applied as the input noise to the primary conductor. Table 4 shows the CZ-381x series having a strong voltage noise rejection ratio. Figure 5. shows the frequency dependency of the voltage noise rejection ratio.

Table 4. Voltage Noise Rejection Ratio when high frequency sine wave voltage (20V_{pp}) is applied

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Vout (mV_{pp})</th>
<th>Noise Rejection (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>-72.9</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>-61.0</td>
</tr>
<tr>
<td>15</td>
<td>42</td>
<td>-53.6</td>
</tr>
<tr>
<td>20</td>
<td>61</td>
<td>-50.3</td>
</tr>
</tbody>
</table>
1.6. Temperature Drift of the Primary Conductor Resistance

Figure 6. shows the temperature drift of the primary conductor resistance of CZ-381x. (reference)
1.7. Thermal Resistance
The thermal resistance ($\theta_{ja}$) of CZ-381x is 41.7°C/W when using the board shown in Figure 7.

<table>
<thead>
<tr>
<th>Table 5. Thermal Resistance measurement board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board size</td>
</tr>
<tr>
<td>Number of layer</td>
</tr>
<tr>
<td>Copper layer thickness</td>
</tr>
<tr>
<td>Board thickness</td>
</tr>
</tbody>
</table>

- Face (1st layer)
- Inner (2nd/3rd layer: VSS)
- Tail (4th layer)

![Figure 7. Thermal Resistance measurement board](image)

1.8. Response Time
Figure 8. shows the actual performance of the typical pulse response waveform. The part used was CZ-3813 ($V_h=60mV/A$), Input current $I_{in}=33A$. Rise and fall response time is about 0.8μs.

![Figure 8. Rise response waveform (left), fall response waveform (right).](image)
1.9. \( \frac{dV}{dt} \) Noise, \( \frac{dI}{dt} \) Noise

Figure 9 shows the \( \frac{dV}{dt} \) noise property of CZ-381x output voltage (\( V_{\text{OUT}} \)), when 1kV is applied to the primary conductor at the rise time of 1\( \mu \)s. The yellow line shows the input voltage waveform and the green line shows the output voltage waveform. The convergence time is as short as 4\( \mu \)s. Please avoid this noise by adjusting the capture timing.

![Figure 9. \( \frac{dV}{dt} \) noise waveform (left: rise waveform, right: fall waveform)](image)

Figure 9. \( \frac{dV}{dt} \) noise waveform (left: rise waveform, right: fall waveform)

Figure 10. shows the output voltage (\( V_{\text{OUT}} \)) of CZ-381x, when a 25A pulse is applied to the primary conductor with a pulse width of 1\( \mu \)s. The yellow line shows the input current waveform and the green line shows the output voltage waveform. The convergence time is as short as 1\( \mu \)s.

![Figure 10. \( \frac{dI}{dt} \) noise waveform](image)

Figure 10. \( \frac{dI}{dt} \) noise waveform
2. Board Design Guidelines

![Diagram of CZ-381x]

1. Primary Conductors
2. Signal Paths

Figure 11. Board layout names in this section

2.1. External Circuits Example

In this subsection, we show three examples of the external circuit when using CZ-381x. These are just examples and there are other possible circuits. Please evaluate your external circuit by yourself.

Case 1) Connecting a 5V A/D converter in the subsequent stage
Case 2) Connecting a 3.3V A/D converter in the subsequent stage
Case 3) Connecting an amplifier to change the reference voltage of the output or to change the sensitivity
Case1) CZ-381x + ADC(5V)

(a) 1μF bypass capacitor should be placed near by the VDD pin and VSS pin of CZ-381x.
(b) Add a low-pass filter to VOUT pin if it is necessary. The $R_F$ and $C_F$ values should be fixed in consideration of the time constant.

Case2) CZ-381x + ADC(3.3V)

(a) 1μF bypass capacitor should be placed near by the VDD pin and VSS pin of CZ-381x.
(b) Add a low-pass filter to VOUT pin if it is necessary. The $R_1$ and $R_2$ values should be fixed in consideration of the resistive divider ratio.

ex.) If the reference voltage of A/D converter is +3.3V which is its supply voltage level, $R_1 = 20k\Omega$, $R_2 = 39k\Omega$ are recommended. If the reference voltage of A/D converter...
is different from its supply voltage level, one more voltage divider is required.

(c) Add a low-pass filter to VOUT pin if it is necessary. The $R_F$ and $C_F$ values should be fixed in consideration of the time constant.

Case3) CZ-381x + Amplifier

![External Circuit Example 3](image)

**Figure 14. External Circuit Example 3**

(a) 1μF bypass capacitor should be placed near by the VDD pin and VSS pin of CZ-381x.
(b) R1 and R2 are resistors that decides the gain. The R0 value should be fixed in consideration of the load condition. The R1 and R2 values should be fixed in consideration of the gain.
2.2. Trace of the Primary Current

2.2.1. Width and Length of the Primary Current Trace
Please design the trace of the primary current for CZ-381x wider in the width and shorter in the length to make the trace resistance small and to prevent overheating.
Please refer to Figure15. and Table 6. for the recommended footprint.

![Figure 15. CZ-381x recommended footprint](image)

Table 6. CZ-381x recommended footprint dimensions

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>1.42</td>
</tr>
<tr>
<td>E</td>
<td>10.58</td>
</tr>
<tr>
<td>W1</td>
<td>3.3</td>
</tr>
<tr>
<td>W2</td>
<td>0.54</td>
</tr>
<tr>
<td>C</td>
<td>0.66</td>
</tr>
<tr>
<td>P</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Unit : mm

2.2.2. The Configuration of the Trace
We recommend extending straight to right and left as shown in the Figure 16(a). If this is not possible due to board layout limitations, we recommend extending away from the signal paths as shown in the Figure 16(b). The sensitivity may differ 1% at maximum between these two traces. Please evaluate the trace design in the actual environment in order to achieve the highest possible accuracy.
We do not recommend extending toward the signal paths as shown in the Figure 16(c).
It may degrade the withstand voltage as stated in section 2.3.4.
We also do not recommend running current-carrying traces beneath the current sensor. The output may fluctuate due to stray magnetic fields. Refer to section 2.5. Please evaluate carefully if this is not avoidable.

![Diagram with CZ-381x components]

(a) Straight (Recommended)  
(b) Away from the signal paths (Recommended)  
(c) Toward the signal paths (Not recommended)

**Figure 16. How to trace the primary conductor of CZ-381x**

### 2.2.3. Direction of the primary current

The user needs to know the direction of the current flow in the primary conductor to detect the correct output. In case of the trace shown in the Figure 17, the output of the CZ-381x decreases as current flows from right to left, and increases from left to right.

![Diagram with CZ-381x components and current directions]

(a) $V_{OUT} < \frac{1}{2} \times V_{DD}$  
(b) $V_{OUT} > \frac{1}{2} \times V_{DD}$

**Figure 17. The relationship between the output of CZ-381x and the direction of the primary current**
2.3 Trace of the signal paths
Please refer to the followings for pin names of CZ-381x.

![Pin Configuration Diagram]

**Figure 18. CZ-381x Pin configuration**

**Table 7. Pin functions of CZ-381x**

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Pin Name</th>
<th>I/O</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VSS</td>
<td>GND</td>
<td>Power</td>
<td>Ground pin (GND)</td>
</tr>
<tr>
<td>2</td>
<td>OCD</td>
<td>O</td>
<td>Digital</td>
<td>Overcurrent detection pin. Normal output: “L”, Over current detection: “H”. Overcurrent detection function is initially off, and OCD pin is high-impedance when shipped.</td>
</tr>
<tr>
<td>3</td>
<td>VDD</td>
<td>PWR</td>
<td>Power</td>
<td>Power supply pin (5V)</td>
</tr>
<tr>
<td>4</td>
<td>CS (Note1)</td>
<td>I</td>
<td>Digital</td>
<td>Chip select input pin for EEPROM access</td>
</tr>
<tr>
<td>5</td>
<td>VOUT</td>
<td>O</td>
<td>Analog</td>
<td>Sensor output pin</td>
</tr>
<tr>
<td>6</td>
<td>DIO (Note1)</td>
<td>I</td>
<td>Digital</td>
<td>Data input/output pin for EEPROM access</td>
</tr>
<tr>
<td>7</td>
<td>SCLK (Note1)</td>
<td>I</td>
<td>Digital</td>
<td>Clock input pin for EEPROM access</td>
</tr>
<tr>
<td>8</td>
<td>VSS</td>
<td>GND</td>
<td>Power</td>
<td>Ground pin (GND)</td>
</tr>
<tr>
<td>9</td>
<td>IN</td>
<td>I</td>
<td>–</td>
<td>Primary conductor pin (-)</td>
</tr>
<tr>
<td>10</td>
<td>IP</td>
<td>I</td>
<td>–</td>
<td>Primary conductor pin (+)</td>
</tr>
</tbody>
</table>

Note1. Recommended to open when not using the programming function.
2.3.1. Length and width of the signal paths
We recommend making the traces of VDD and VOUT signals as wide and short as possible to avoid electrical noise from external capacitive coupling.

2.3.2. Noise filtering
In order to reduce the noise superimposed on the power line, we recommend placing a 1µF by-pass capacitor between VDD and VSS pins as close to those pins as possible. By adding an electrolytic capacitor with larger capacitance in parallel, it will reduce the effect of the instant voltage drop of the power supply.
In case that large noise is superimposed on the output, adding a low pass filter to the VOUT pin may provide improvement. When adding a low pass filter, please consider the time constant to meet the required response time.

2.3.3. Connection to GND
Generally, in an inverter circuit board, GND of power line and that of signal line are isolated from each other in order to avoid malfunction of the MCU due to noise. Please connect the VSS pin of CZ-381x to the GND of signal line.

2.3.4. Insulation design
The clearance and creepage of CZ-381x between the primary conductor and the signal paths is more than 7.2mm. The Comparative Tracking Index (CTI) of the CZ-381x package resin is 600V, and the Material Group is I. Table 8 shows the Working Voltage of CZ-381x.
In order to maximize the insulation withstanding voltage of CZ-381x, please keep enough distance between traces of the primary conductor and the signal paths. In case that there is a specific standard required for the system, please design the clearance and creepage to meet that requirement.
If the creepage is shorter than the requirement, it is possible to increase the creepage by adding a slit in the board as shown in Figure 19.

<table>
<thead>
<tr>
<th></th>
<th>Pollution Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Basic Isolation</td>
<td>1937</td>
</tr>
</tbody>
</table>
| Reinforced Isolation    | 1100 | 715  | 285   | (Vrms)
2.4 Thermal design
The CZ-381x is capable of 40A\textsubscript{rms} continuous current, even larger current in case of transitional. When CZ-381x is used under conditions compliant with the safety standard, please ensure the case temperature (T\textsubscript{c}) is kept lower than 130\textdegree C from heating by the primary current. Please refer to the Figure 20. for the position to measure T\textsubscript{c}.

If the heat dissipation is not enough, using “pad on vias” at the primary conductor pads may help. These can increase heat dissipation without increasing the trace area by thermally connecting the primary conductors to an inner and outer layers directly.

2.5. Stray Magnetic Field Reduction Function
There are two Hall elements inside CZ-381x connected in a differential manner. By detecting the difference of these two Hall elements’ outputs, CZ-381x reduces the effects of stray magnetic fields as a built-in common-mode rejection function. When the same magnetic field is applied to both Hall elements, this magnetic field is deemed to be the stray and is reduced from the output of CZ-381x by the ratio of Stray Magnetic Field Reduction (E\textsubscript{bc}: 0.01A/mT Typ.).

Example: When a stray magnetic field of 1mT is applied to the CZ-381x, the output will have additional error of 0.01A=10mA equivalent.
- CZ-3813: Sensitivity=60mV/A, Error=10mA → Output error=0.6mV
- CZ-3815: Sensitivity=33.3mV/A, Error=10mA → Output error=0.33mV
On the other hand, when different magnetic fields are applied to each Hall element, this will appear as output error. For example, a current carrying trace that runs close the CZ-381x may cause this. The extent of the error will depend on the layout of the current trace, actual current, distance from the CZ-381x, and the part number (sensitivity). Figure 22 shows some simulated examples of output error by the nearby current.

![Figure 21. Examples of nearby current lines](image1)

![Figure 22. Output Error by nearby current](image2)
3. Useful Tips

3.1 Supply Voltage
The CZ-381x has a ratiometric output. This means that the output of the current sensor changes proportionally to the supply power voltage. A ratiometric output is suitable for applications where the output is converted to digital using an A/D converter and where fluctuation of the power supply voltage causes reference error of the A/D converter. Figure 12 shows an example of the external circuit where a 5V A/D converter is connected. Figure 13 shows the case where a 3.3V A/D converter is used. The supply voltage of the CZ-381x and the reference voltage of the A/D converter fluctuate at the same ratio. This will avoid the effects of the fluctuation of the power supply to the A/D converter output. Figure 23 shows the output voltage of the CZ-3813 (Sensitivity $V_h=60\text{mV/A}$) as an example ratiometric output.

![Figure 23. Output voltage of the CZ-3813 vs Input Current with different VDD.](image)

3.2 Calibration of Zero-Current Output in initialization
The Zero-Current Output of the CZ-381x may drift over time within the values defined in datasheet Section 14. Therefore, in order to minimize this drift, we strongly recommend calibrating the Zero-Current Output by software after the power-up time of the system when the measured current is zero.
3.3 Power up
Figure 24. shows a recommended example of the power up sequence. In the power up sequence, if the time to VDD=5V is less than 0.4msec, the output will be stabilized after 35msec(max) from the time VDD=4.5V. If it takes 0.4msec or more, it may take longer to stabilize the output. Please check the time needed to stabilize the output in that case.

![Figure 24. Recommended example of the power up sequence](image)

3.4 Magnetic parts around
The CZ-381x output can be affected by magnetic devices (mechanical relays, transformers, etc.) that are nearby. In the case where magnetic devices must be placed close to the CZ-381x, please check the effect on sensitivity or other characteristics and make sure any effects are understood and mitigated as much as possible.

3.5 Storage Environment
CZ-381x is the condition of MSL3 (JEDEC J-STD-020). Please store under the following conditions.
[Storage term]
Within 1 year after delivery (Before and after unpacking the moisture-proof packing.)
[Before unpacking the moisture-proof packing]
5~40°C, less than 90%RH
[After unpacking the moisture-proof packing]
5~30°C, 60%RH or less, less than 168hours (1week).

3.6 Sensitivity and Zero-Current Output Drift by Reflow
Solder reflow can cause the Sensitivity and Zero-Current Output of CZ-381x to drift. Section 9 of the datasheet shows the variation of the shipment test results by AKM. The reflow process can induce drift within the values defined in Section 14 of the datasheet. Regarding Zero-Current Output drift, we recommend calibrating according to Section 3.2 CZ-381x Application Note (rev.2)
Figure 25. and Table 10 show the recommended reflow temperature profile. AKM recommends subjecting the CZ-381x to a reflow process a maximum of three (3) times.

Table 9 Reflow Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tmin</th>
<th>Tmax</th>
<th>Tmin to Tmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preheat/Soak</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquidus Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ramp-up Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Package Body Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ramp-down Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 25°C to Peak Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 25. Reflow profile

3.7 Maximum Primary Current and Linear Sensing Range

Maximum Primary Current ($I_{\text{RMSmax}}$) is the maximum current that can be flowed through the primary conductor continuously. It depends on the cross-sectional area of the primary conductor. CZ-381x can be damaged if it is used in conditions where the DC current or the root-mean-square value of AC current exceeds $I_{\text{RMSmax}}$ for an extended period of time.

In the case of pulsed current, it is possible to apply currents larger than $I_{\text{RMSmax}}$.

Linear Sensing Range ($I_{\text{NS}}$) is the current range where we guarantee the linearity of CZ-381x.
CZ-381x output. If the primary current is beyond $I_{NS}$, the output will saturate. However, it will return to normal once the primary current is back within $I_{NS}$.

3.8 Safety Standard
CZ-381x is certified as IEC/UL-62368, UL-1577 by the international certification organization.

- IEC/UL 62368-1, 2nd Ed, 2014-12-01 (Audio/video, information and communication technology equipment Part 1: Safety requirements) (File No. E359197)
- CAN/CSA C22.2 No. 62368-1-14, 2nd Ed-(Audio/video, information and communication technology equipment Part 1: Safety requirements) (File No. E359197)
- CSA Component Acceptance Service No. 5A – Component Acceptance Service for Optocouplers and Related Devices (File No. E499004)

3.9 Overcurrent detection function
CZ-381x has the Overcurrent detection function. Overcurrent detection function is initially off and OCD pin is high-impedance when shipped. When the overcurrent detection is ON, the OCD pin outputs “L”. When input current exceeds the set overcurrent detection threshold, OCD output changes from “L” to “H”. The ON/OFF switching of the overcurrent detection function and setting the overcurrent detection threshold can be changed using the internal EEPROM. Please refer to Appendix for ON/OFF switching overcurrent detection function and setting overcurrent detection threshold.

3.10 Other information
Please check our website akm.com for datasheets, selection guide, and more.
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CZ-381x uses the 3-wire synchronous serial interface with SCLK, DIO and CS to write to or to read from EEPROM data. When the serial interface circuit waits for input, and CS detects “High”, CZ-381x reads the input signal via DIO at the rising edge of SCLK. Communication signal consists of 7bits INSTRUCTION ([I[6:0])], 7bits ADDRESS ([A[6:0]) and 16bits DATA ([D[15:0]). Upper 2bits of INSTRUCTION ([I[6:5])], upper 5bits of ADDRESS ([A[6:2]) and upper 8bits of DATA ([D[15:8]) should be “0”. The order of communication signal is [I[6] → I[5] → … → I[0] → A[6] → A[5] → … → A[0] → D[15] → D[14] → … → D[0]. As for write command, data bits should be entered right-justified. As for read command, the data bits are output right-justified. READ data are output at the falling edge of SCLK.

### 1. Digital Interface Timing Chart

**[READ]**

<table>
<thead>
<tr>
<th>CS</th>
<th>SCLK</th>
<th>DIO(input)</th>
<th>DIO(output)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>[I[6]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[I[0]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[A[0]</td>
<td></td>
</tr>
</tbody>
</table>

**[WRITE]**

<table>
<thead>
<tr>
<th>CS</th>
<th>SCLK</th>
<th>DIO(input)</th>
<th>DIO(output)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>[I[6]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[I[0]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[A[0]</td>
<td></td>
</tr>
</tbody>
</table>

CZ-381x Application Note (rev.2)
2. Detailed Timing

[WRITE]

Parameter | Symbol | Min. | Typ. | Max. | Units
---|---|---|---|---|---
Write time (EEPROM) | $t_{wr}$ | 18 | 36 | ms
CS setup time | $t_{cs}$ | 100 |  | ns
DIO input setup time | $t_d$ | 100 |  | ns
DIO input hold time | $t_h$ | 100 |  | ns
SCLK high time | $t_{veh}$ | 900 | 1000 | ns
SCLK low time | $t_{vle}$ | 900 | 1000 | ns
DIO output setup time | $t_{lod}$ | 200 |  | ns
SCLK→DIO delay time | $t_d$ | 200 |  | ns
CS Idle time | $t_i$ | 100 |  | ns
SCLK rising time (Note1) | $t_r$ | 100 |  | ns
SCLK falling time (Note1) | $t_f$ | 100 |  | ns

DIO pin CL=100pF, IL=0μA

Note1) These parameters are not tested.
3. Instruction

One of the following commands is specified by the INSTRUCTION (I [4: 0]). Instructions which are not described are prohibited.

<table>
<thead>
<tr>
<th>[4:0]</th>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>02h</td>
<td>EEPROM READ</td>
<td>Read the EEPROM data of the specified ADDRESS.</td>
</tr>
<tr>
<td>04h</td>
<td>EEPROM WRITE_EN</td>
<td>Enable mode to write to the EEPROM.</td>
</tr>
<tr>
<td>05h</td>
<td>EEPROM WRITE</td>
<td>Write data to the EEPROM of the specified ADDRESS. This command is valid just after EEPROM WRITE_EN command. This command to the ELOCK address (03h) is not allowed. When ELOCK[1:0]=2, this command is not allowed. When ELOCK[1:0]=3, this command to the ADDRESS(01h~02h) are allowed.</td>
</tr>
<tr>
<td>09h</td>
<td>LOCK</td>
<td>You can switch the setting of LOCK function. EEPROM WRITE_EN Command is not required. Write data to ELOCK address (03h); D[15:0] = 16’h0002 (lock EEPROM) or D[15:0] = 16’h0003 (unlock EEPROM). When writing data to the EEPROM, unlock EEPROM first using this command.</td>
</tr>
</tbody>
</table>

How to write data to the EEPROM
1. Unlock EEPROM by writing “3” to ELOCK (ADDRESS 03h).
2. Enable mode to write to the EEPROM using EEPROM WRITE_EN command. (ADDRESS (A [6: 0]) and DATA (D [15: 0]) inputs are arbitrarily selected.)
3. Input EEPROM WRITE command to write data to the specified address.
4. Lock EEPROM by writing “2” to ELOCK (address 03h).
4. Command Summary

EEPROM READ command
When the command is recognized, Ack and 16 bits data are output from DIO pin. Data for one address of EEPROM memory array can be read by the EEPROM READ command. When the EEPROM READ command with unused address executes, the data of "0" is output.

Waveform example: INSTRUCTION:02h ADDRESS=01h DATA=0080h

For VOUT and OCD outputs, recovery time from Hi-Z or Low to Normal is 10μs at maximum.
**EEPROM WRITE_EN command**

After instruction, you should input 7 bits ADDRESS data and 16 bits DATA. When CZ-381x receives this command, CZ-381x switches to enable mode to write to the EEPROM, and Ack bit is output from DIO pin. (00h is recommended for ADDRESS and DATA.) Since write enable mode is released when CS is low, input the EEPROM WRITE command with CS high.

During lock mode, Ack is not output and the state does not switch to the write enable mode even if you input this command.

If you would like to use EEPROM WRITE continuously, you need to input the EEPROM WRITE_EN command before every EEPROM WRITE command.

Waveform example: INSTRUCTION:04h ADDRESS:00h DATA:0000h
EEPROM WRITE command
After instruction, you should input 7 bits ADDRESS data and 16 bits DATA.
If the EEPROM WRITE_EN command has not been executed, writing to the EEPROM can not be performed.
After CZ-381x receives this command, EEPROM write operation is performed, and the Ack bit is output from the DIO pin. Please do not make CS low during t_wr. If the recommended operating conditions (see data sheet) are exceeded during the write operation, this operation can not be guaranteed. You need to write again. After this operation, please return to the normal mode by setting CS low.

Waveform example: INSTRUCTION:05h ADDRESS:01h DATA:0080h

For VOUT and OCD outputs, recovery time from Hi-Z or Low to Normal is 10μs at maximum.
**LOCK command**

After instruction, you should input 7 bits ADDRESS data and 16 bits DATA. After CZ-381x receives this command, EEPROM write operation is performed, and the Ack bit is output from the DIO pin. Please do not make CS low during $t_{wr}$. If the recommended operating conditions (see data sheet) are exceeded during the write operation, this operation can not be guaranteed. You need to write again.

The LOCK command is valid only for the ELOCK address. After this operation, please return to the normal mode by setting CS low. Data of all addresses can be read regardless of the mode of the LOCK function.

Waveform example: INSTRUCTION:09h ADDRESS:03h DATA:0003h

For VOUT and OCD outputs, recovery time from Hi-Z or Low to Normal is 10μs at maximum.
## 5. Memory Function

### EEPROM memory map

<table>
<thead>
<tr>
<th>Item</th>
<th>Content</th>
<th>ADDRESS (hex)</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOCD</td>
<td>Overcurrent detection function</td>
<td>01</td>
<td>D7 D6 D5 D4 D3 D2 D1 D0</td>
</tr>
<tr>
<td></td>
<td>ON/OFF and Threshold setting</td>
<td></td>
<td>- - EOCDOFF EOC[4:0]</td>
</tr>
<tr>
<td>DUM</td>
<td>Dummy</td>
<td>02</td>
<td>DUM DUM DUM DUM DUM DUM DUM DUM</td>
</tr>
<tr>
<td>ELOCK</td>
<td>Lock function</td>
<td>03</td>
<td>- - - - 0 0 0 0 0 0 ELOCK[1:0]</td>
</tr>
</tbody>
</table>

The lower Shade area is the initial value when shipped.
Access to "—" is prohibited.
"DUM" can be used freely by users. Both reading and writing are possible.

### ADDRESS 01h(EOCD_OFF, EOCD)

**EOCD_OFF**

Overcurrent detection function ON/OFF setting.

<table>
<thead>
<tr>
<th>Overcurrent detection function</th>
<th>EOCD_OFF</th>
<th>OCD pin output state</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>0h</td>
<td>Normal : OCD=L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At overcurrent detection : OCD=H</td>
</tr>
<tr>
<td>OFF</td>
<td>1h</td>
<td>Hi-z</td>
</tr>
</tbody>
</table>

The lower Shade area is the initial value when shipped.
EOCD
You can set the overcurrent detection threshold. At the same time, the overcurrent recovery threshold can be also set.
When the overcurrent detection function is ON, OCD pin outputs “L” during normal operation, and OCD pin outputs “H” when measured current value exceeds overcurrent detection threshold.

Conditions: VDD=5.0V, R.T.

<table>
<thead>
<tr>
<th>EOCD[4:0]</th>
<th>Overcurrent detection threshold [% of I_{NS}]</th>
<th>EOCD[4:0]</th>
<th>Overcurrent detection threshold [% of I_{NS}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>76</td>
<td>10h</td>
<td>116</td>
</tr>
<tr>
<td>01h</td>
<td>78</td>
<td>11h</td>
<td>119</td>
</tr>
<tr>
<td>02h</td>
<td>81</td>
<td>12h</td>
<td>121</td>
</tr>
<tr>
<td>03h</td>
<td>83</td>
<td>13h</td>
<td>124</td>
</tr>
<tr>
<td>04h</td>
<td>86</td>
<td>14h</td>
<td>126</td>
</tr>
<tr>
<td>05h</td>
<td>88</td>
<td>15h</td>
<td>129</td>
</tr>
<tr>
<td>06h</td>
<td>91</td>
<td>16h</td>
<td>131</td>
</tr>
<tr>
<td>07h</td>
<td>93</td>
<td>17h</td>
<td>134</td>
</tr>
<tr>
<td>08h</td>
<td>96</td>
<td>18h</td>
<td>136</td>
</tr>
<tr>
<td>09h</td>
<td>98</td>
<td>19h</td>
<td>139</td>
</tr>
<tr>
<td>0Ah</td>
<td>101</td>
<td>1Ah</td>
<td>141</td>
</tr>
<tr>
<td>0Bh</td>
<td>104</td>
<td>1Bh</td>
<td>144</td>
</tr>
<tr>
<td>0Ch</td>
<td>106</td>
<td>1Ch</td>
<td>146</td>
</tr>
<tr>
<td>0Dh</td>
<td>109</td>
<td>1Dh</td>
<td>149</td>
</tr>
<tr>
<td>0 Eh</td>
<td>111</td>
<td>1 Eh</td>
<td>152</td>
</tr>
<tr>
<td>0Fh</td>
<td>114</td>
<td>1Fh</td>
<td>154</td>
</tr>
</tbody>
</table>

In the factory setting, 1Fh is set for EOCD[4:0] when the overcurrent detection function is turned ON.

ADDRESS02h
This address can be used freely by users.
ADDRESS03h(ELOCK)

ELOCK
You can set the access mode to the EEPROM.

Access mode table

<table>
<thead>
<tr>
<th>ELOCK[1:0]</th>
<th>Modes</th>
<th>Read</th>
<th>Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>LOCK</td>
<td>Available</td>
<td>N/A</td>
</tr>
<tr>
<td>11</td>
<td>UNLOCK</td>
<td>Available</td>
<td>Available</td>
</tr>
</tbody>
</table>

The upper shade area is the initial value when shipped.
Inputting other data described to ELOCK [1: 0] is prohibited.
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