MEMS mirror

S12237-03P

Ultra-miniature, high performance Electromagnetically driven laser scanning MEMS mirror

The S12237-03P is an electromagnetically driven mirror that incorporates our unique MEMS (micro-electro-mechanical systems) technology. We achieved an ultra-miniature scale by mounting the magnet beneath the mirror. Within a magnetic field generated by the magnet, electrical current flowing in the coil surrounding the mirror produces a Lorentz force based on Fleming’s rule that drives the mirror. Hamamatsu MEMS mirrors offer a wide optical deflection angle and high mirror reflectivity as well as low power consumption.

Features
- Low current operation
- Ultra-miniature size
- Wide optical deflection angle

Applications
- Laser scanner unit
- Light switch

Structure and principle

In a MEMS mirror, a metallic coil is formed on a single-crystal silicon, a mirror is formed inside the coil through MEMS processing, and a magnet is arranged beneath the mirror. Within a magnetic field generated by the magnet, electrical current flowing in the coil surrounding the mirror produces a Lorentz force based on Fleming’s rule that drives the mirror tilt angle in one dimension. The path of the laser light incident on the mirror surface is varied in this way to scan and project. Compared to the electrostatic or piezoelectric driven mirrors, electromagnetically driven MEMS mirrors are smaller, lower voltage driven, and lower power consuming.

Structure diagram

![Structure diagram](KOTHC0058EB)

Absolute maximum ratings (Tcase=25 °C unless otherwise noted)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive current</td>
<td>Is max</td>
<td></td>
<td>±20</td>
<td>mA</td>
</tr>
<tr>
<td>Optical deflection angle^1</td>
<td>Bs max</td>
<td></td>
<td>±18</td>
<td>°</td>
</tr>
<tr>
<td>Operating temperature^2</td>
<td>Tcase</td>
<td>No dew condensation^3</td>
<td>-40 to 80</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>Tstg</td>
<td>No dew condensation^3</td>
<td>-40 to 85</td>
<td>°C</td>
</tr>
<tr>
<td>Soldering conditions</td>
<td></td>
<td>Using a soldering iron^4</td>
<td>260 °C max, within 10 s</td>
<td>-</td>
</tr>
</tbody>
</table>

^1: Angle at which the mirror makes contact with the magnet, damaging the mirror. The optical deflection angle is twice the mechanical deflection angle.
^2: Case temperature (temperature of the metal frame on back side of case)
^3: When there is a temperature difference between a product and the surrounding area in high humidity environments, dew condensation may occur on the product surface. Dew condensation on the product may cause deterioration in characteristics and reliability.
^4: The magnetic force of the mirror built into this product degrades if the mirror is exposed to high temperature. Do not use reflow soldering on this product.

Note: Exceeding the absolute maximum ratings even momentarily may cause a drop in product quality. Always be sure to use the product within the absolute maximum ratings.

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### Structure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror size</td>
<td>ϕ2.59</td>
<td>ϕ2.60</td>
<td>ϕ2.61</td>
<td>mm</td>
</tr>
<tr>
<td>Mirror material</td>
<td>Aluminum alloy</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Window material</td>
<td>None</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Operation mode</td>
<td>Linear mode</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Note: As there is no window material on the S12237-03P, be sure to take measures to prevent dust adhesion and measures against moisture.

### Recommended operating conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature*5</td>
<td>Tcase</td>
<td>No dew condensation</td>
<td>-20</td>
<td>+25</td>
<td>+70</td>
<td>°C</td>
</tr>
<tr>
<td>Optical deflection angle*6</td>
<td>θs</td>
<td></td>
<td>-15</td>
<td>-</td>
<td>+15</td>
<td>°</td>
</tr>
<tr>
<td>Drive frequency*7</td>
<td>fs</td>
<td>DC*8</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>Hz</td>
</tr>
<tr>
<td>Drive method*9</td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

*5: Case temperature  
*6: If a drive current is not applied, the optical deflection angle is defined to be 0°.  
*7: It is recommended to drive at a frequency of 100 Hz or less. Using in the resonance frequency band results in a high gain, and the maximum optical deflection angle may be exceeded even if a small drive current is applied. It is also recommended to insert a low-pass filter to attenuate high-frequency components above 100 Hz in the drive current signal.  
*8: Using the mirror with only one side (positive or negative) of the optical deflection angle is not recommended, as it can shorten the service life.  
*9: Voltage drive is not available.

### Electrical and optical characteristics (recommended operating conditions unless otherwise noted, Tcase=25 °C)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive current</td>
<td>Is</td>
<td>fs=0.1 Hz, arbitrary waveform</td>
<td>-17</td>
<td>-15</td>
<td>-13</td>
<td>mA</td>
</tr>
<tr>
<td>Optical deflection angle accuracy*10</td>
<td>dgs</td>
<td>Ac=15°</td>
<td>-0.3</td>
<td>-</td>
<td>+0.3</td>
<td>°</td>
</tr>
<tr>
<td>Temperature coefficient of optical deflection angle*11</td>
<td>α</td>
<td>I0: Reference current (Tcase=25 °C, θ=±15°)</td>
<td>-0.105</td>
<td>-0.095</td>
<td>-0.085</td>
<td>%/°C</td>
</tr>
<tr>
<td>Resonant frequency</td>
<td>fs-R</td>
<td>Is=0.6 mA, 1 atm</td>
<td>500</td>
<td>530</td>
<td>560</td>
<td>Hz</td>
</tr>
<tr>
<td>Quality factor</td>
<td>Q</td>
<td>Is=0.6 mA, 1 atm</td>
<td>30</td>
<td>34</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Coil resistance</td>
<td>Rs</td>
<td>Is=0.1 mA</td>
<td>135</td>
<td>165</td>
<td>195</td>
<td>Ω</td>
</tr>
</tbody>
</table>

*10: Deviation between specified optical deflection angle θc(t) and actual optical deflection angle θs(Is(t)) [equation (1)]  
\[dθs=θs(Is(t))-θc(t) \ldots (1)\]  
θc(t): optical deflection angle of sine wave for drive frequency fs and amplitude Ac [equation (2)]  
\[θs(Is(t)): \text{actual optical deflection angle for drive current } Is(t) \text{ calculated from equation (3)}\]  
\[θc(t)=Ac \cdot \sin(2πfs \cdot t) \ldots (2)\]  
\[Is(t)=\sum_{m,n}a(m,n) \cdot \left\{Ac \cdot \left[1-\left(\frac{fs}{Ts-R}\right)^2\right] \sin(2πfs \cdot t+ϕ)\right\} \ldots (3)\]  
a(m, n): correction factor, where m is the order. The correction factor is indicated on the final inspection sheet.  
ϕ: Phase deviation [equation (4)]  
\[ϕ=\tan^{-1}\left[\frac{fs}{Ts-R} \cdot \left[\frac{fs}{Ts-R}\right]^2\right] \ldots (4)\]  

*11: Temperature dependency of optical deflection angle when the drive current is constant [equation (5)]  
\[α=\frac{θs(I0, T2) - θs(I0, T1)}{θs(I0, T0)} \times \frac{1}{(T2 - T1)} \times 100 \ldots (5)\]  
T0: Reference temperature (Tcase=25 °C)  
T1, T2: Any temperature in the operating temperature range  
I0: Reference current (Tcase=25 °C, θ=±15°)  
θs(I0, Tx): Optical deflection angle for drive current I0, and temperature Tx (x=0 to 2)
### Optical deflection angle vs. drive current

**Optical deflection angle vs. drive current**

(Typ. Tcase=25 °C)

Drive current (mA) vs. Optical deflection angle (°)

- Drive current (mA): -20 to 20
- Optical deflection angle (°): -20 to 20

### Frequency response

**Frequency response**

(Typ. Tcase=25 °C, Is=0.6 mA p-p, 1 atm, input waveform: sine wave)

Frequency (Hz) vs. Optical deflection angle (°)

- Frequency (Hz): 0 to 800
- Optical deflection angle (°): 0 to 12

Solid line range recommended.
Quality factor vs. case temperature

(Typ. Is=0.6 mA p-p, 1 atm)

Temperature characteristics of optical deflection angle

(Typ. I=I0: Reference current at Tcase=25 °C, θ=+15°)

Dimensional outline (unit: mm)

Index

Mirror
(ϕ2.60 ± 0.01)

2.55 ± 0.2

8.0 ± 0.2

8.4 ± 0.1

9.0

10.9

12.3

14.3 ± 0.1

3.85 ± 0.1

6.8

10.16 ± 0.1

6.6 ± 0.5

6.9 ± 0.05

70 °C

40 °C

25 °C

0 °C

-20 °C

Drive current vs. ambient temperature

(Typ. Is=10 mA: Reference current at Tcase=25 °C, θ=+15°)

Quality factor

Optical deflection angle (°)

Case temperature (°C)

Drive frequency (Hz)

Temperature characteristics of optical deflection angle

(Typ. I=I0: Reference current at Tcase=25 °C, θ=+15°)

Drive frequency (Hz)

Quality factor

Optical deflection angle (°)

Case temperature (°C)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

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Mirror
(ϕ2.60 ± 0.01)

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10.9

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14.3 ± 0.1

3.85 ± 0.1

6.8

10.16 ± 0.1

6.6 ± 0.5

6.9 ± 0.05

70 °C

40 °C

25 °C

0 °C

-20 °C

Drive current vs. ambient temperature

(Typ. Is=10 mA: Reference current at Tcase=25 °C, θ=+15°)

Quality factor

Optical deflection angle (°)

Case temperature (°C)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

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8.4 ± 0.1

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12.3

14.3 ± 0.1

3.85 ± 0.1

6.8

10.16 ± 0.1

6.6 ± 0.5

6.9 ± 0.05

70 °C

40 °C

25 °C

0 °C

-20 °C

Drive current vs. ambient temperature

(Typ. Is=10 mA: Reference current at Tcase=25 °C, θ=+15°)

Quality factor

Optical deflection angle (°)

Case temperature (°C)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Optical deflection angle (°)

Drive frequency (Hz)

Index

Mirror
(ϕ2.60 ± 0.01)

2.55 ± 0.2

8.0 ± 0.2

8.4 ± 0.1

9.0

10.9

12.3

14.3 ± 0.1

3.85 ± 0.1

6.8

10.16 ± 0.1

6.6 ± 0.5

6.9 ± 0.05

70 °C

40 °C

25 °C

0 °C

-20 °C

Drive current vs. ambient temperature

(Typ. Is=10 mA: Reference current at Tcase=25 °C, θ=+15°)

Quality factor

Optical deflection angle (°)

Case temperature (°C)

Drive frequency (Hz)


**Mechanical deflection direction of mirror due to drive current**

The direction of the mirror’s mechanical deflection varies depending on the direction of the drive current flowing through ①Coil1 and ②Coil2.

![Diagram showing mechanical deflection direction of mirror due to drive current]

**Test result (reference)**

(1) Operating conditions: Input waveform: sine, optical deflection angle: ±15°, continuous operation
(2) Ambient environment: Case temperature: 23 °C, humidity: 45%, clean room cleanliness: ISO class 7

For (1) and (2), it has been confirmed that characteristics do not change after 12 billion times operations. Note that this data is for reference. It does not guarantee the reliability.

**Precautions**

### Handling
- MEMS mirrors (hereafter called “the product”) are unsealed products. Use the product in an environment where dust and blemish do not adhere to it. The inside of the product is prone to damage. As such, do not apply air blower or wipe the product even if dust or blemish adheres to it.
- A powerful magnet is inside the product. Do not bring metallic items (screws, screwdrivers, etc.) near the product. Doing so may damage the mirror area.
- Do not use the product in a strong magnetic field environment. The operating characteristics of the product may degrade due to the magnetic field.
- When carrying several products together, prevent each product from making contact with each other due to the attraction force of magnets, such as by fixing the products in place with space between them inside the container.
- Bringing the product near a person with electronic medical equipment (e.g., pacemaker) is dangerous. Never do so.
- Do not bring the product near magnetic tapes, prepaid cards, and the like. They may become unusable, or the magnetic recording may be corrupted.
- Bringing the product near electronic control equipment may affect instrument boards or control boards and may lead to failures or accidents. If you want to use the product with electronic control equipment, check that the equipment does not fail or cause accidents due to the magnet inside the product.
- The product may fail due to the damage that it receives when it is mounted. Be sure to inspect the product after mounting, and check that the product is working properly.
- Do not apply excessive vibration or shock. It may damage the mirror part and cause a malfunction.

### Soldering
- Do not use reflow soldering on this product. Exceeding the absolute maximum temperature rating will cause the product’s characteristics to change.
Related product

Evaluation circuit for MEMS mirror C15087 (sold separately)

The C15087 is a circuit board designed to simply evaluate linear mode MEMS mirror (1D: S12237-03P, 2D: S13124-01). First axis or second axis (linear mode) is driven with the selection from triangular wave, sine wave, or any chosen wave. A USB 2.0 interface is used to set the driving conditions of the MEMS mirror from the PC. This product can be driven with USB bus power.

The MEMS mirror circuit A14110 is attached for mounting the S1223-03P and connection to the C15087.

Absolute maximum ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td>No dew condensation</td>
<td>-20 to +70</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>No dew condensation</td>
<td>-40 to +85</td>
<td>°C</td>
</tr>
<tr>
<td>Supply voltage</td>
<td></td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>Current consumption</td>
<td></td>
<td>0.5</td>
<td>A</td>
</tr>
</tbody>
</table>

*12: When there is a temperature difference between a product and the surrounding area in high humidity environment, dew condensation may occur on the product surface. Dew condensation on the product may cause deterioration in characteristics and reliability.

Note: Exceeding the absolute maximum ratings even momentarily may cause a drop in product quality. Always be sure to use the product within the absolute maximum ratings.

Electrical specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typ,</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output waveform</td>
<td>Triangular wave, sine wave, or arbitrary waveform</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Operation Mode</td>
<td>Linear mode</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Frequency</td>
<td>1D linear mirror</td>
<td>DC*14</td>
<td>100</td>
<td>Hz</td>
</tr>
<tr>
<td></td>
<td>2D linear mirror*13</td>
<td>DC*14</td>
<td>90</td>
<td>Hz</td>
</tr>
<tr>
<td>Output current</td>
<td>-25</td>
<td>-</td>
<td>25</td>
<td>mA</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>4</td>
<td>5</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Current consumption</td>
<td>-</td>
<td>-</td>
<td>0.4</td>
<td>A</td>
</tr>
<tr>
<td>Interface</td>
<td>USB 2.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*13: We recommend that the frequency of the first axis be greater than or equal to the frequency of the second axis.

*14: Using a mirror on only one side (positive or negative) of the optical deflection angle is not recommended as it may shorten its life.

Related information

www.hamamatsu.com/sp/ssd/doc_en.html

- Precautions
  - Disclaimer
  - Unsealed products

- Technical note
  - MEMS mirrors
Information described in this material is current as of January 2023.

Product specifications are subject to change without prior notice due to improvements or other reasons. This document has been carefully prepared and the information contained is believed to be accurate. In rare cases, however, there may be inaccuracies such as text errors. Before using these products, always contact us for the delivery specification sheet to check the latest specifications.

The product warranty is valid for one year after delivery and is limited to product repair or replacement for defects discovered and reported to us within that one year period. However, even if within the warranty period we accept absolutely no liability for any loss caused by natural disasters or improper product use. Copying or reprinting the contents described in this material in whole or in part is prohibited without our prior permission.