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

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</td>
<td>Condition</td>
<td>±20 mA</td>
<td></td>
</tr>
<tr>
<td>Optical deflection angle*1</td>
<td>θs</td>
<td>Condition</td>
<td>±18 degrees</td>
<td></td>
</tr>
<tr>
<td>Operating temperature*2</td>
<td>Tcase</td>
<td>No dew condensation*3</td>
<td>-40 to +80 °C</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>Tstg</td>
<td>No dew condensation*3</td>
<td>-40 to +85 °C</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
*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 environment, 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: As there is no window material on the S12237-03P, be sure to take measures to prevent dust adhesion and measures against moisture. 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.

www.hamamatsu.com
### 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*</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*</td>
<td>θs</td>
<td>±15</td>
<td>-17</td>
<td>-15</td>
<td>-13</td>
<td>degrees</td>
</tr>
<tr>
<td>Drive frequency</td>
<td>fs</td>
<td>DC*</td>
<td>100</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
</tbody>
</table>

*5: Case temperature
*6: The optical deflection angle is twice the mechanical deflection angle.
*7: If a drive current is not applied, the optical deflection angle is defined to be 0°.
*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.

### Electrical and optical characteristics (recommended operating conditions unless otherwise noted)

<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>Tcase=25 °C, fs=DC, θs=±15°</td>
<td>-17</td>
<td>-15</td>
<td>-13</td>
<td>mA</td>
</tr>
<tr>
<td>Optical deflection angle accuracy*</td>
<td>dθs</td>
<td>Tcase=25 °C, fs≤50 Hz, m=1</td>
<td>-0.8</td>
<td>-</td>
<td>+0.8</td>
<td>degrees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fs≤100 Hz, m=1</td>
<td>-1.0</td>
<td>-</td>
<td>+1.0</td>
<td></td>
</tr>
<tr>
<td>Temperature coefficient of</td>
<td>α</td>
<td>Tcase=-20 to +70 °C, θs=±15°</td>
<td>-0.95</td>
<td>-</td>
<td>-</td>
<td>%/°C</td>
</tr>
<tr>
<td>optical deflection angle*</td>
<td></td>
<td>Tcase=25 °C, Is=0.6 mA p-p</td>
<td>500</td>
<td>530</td>
<td>560</td>
<td>Hz</td>
</tr>
<tr>
<td>Resonant frequency</td>
<td>fs-R</td>
<td>Q Tcase=25 °C, Is=0.6 mA p-p</td>
<td>30</td>
<td>34</td>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>Quality factor</td>
<td>Q</td>
<td>Tcase=25 °C, Is=0.1 mA</td>
<td>135</td>
<td>165</td>
<td>195</td>
<td>Ω</td>
</tr>
</tbody>
</table>

*9: Deviation between specified optical deflection angle θc(t) and actual optical deflection angle θs(Is(t)) [equation (1)]

\[ d\theta_s = \theta_s(Is(t)) - \theta_c(t) \]  
θc(t): optical deflection angle of sine wave for drive frequency fs and amplitude Ac [equation (2)]
θs(Is(t)): actual optical deflection angle for drive current Is(t) calculated from equation (3)

\[ \theta_c(t) = Ac \cdot \sin(2\pi f_s t) \]  
\[ \theta_s(Is(t)) = \sum_{n=0}^{m} a(m,n) \cdot \left[ A_c \left( 1 - \frac{f_s}{f_{S-R}} \right)^2 \sin(2\pi f_s t + \phi) \right] \]  

\[ a(m,n): \text{correction factor, where } m \text{ is the order. The correction factor is indicated on the final inspection sheet.} \]

\[ \phi = \tan^{-1} \left( \frac{1}{Q} \right) \left( 1 - \frac{f_s}{f_{S-R}} \right)^2 \]  

*10: Temperature dependency of optical deflection angle when the drive current is constant [equation (5)]

\[ \alpha = \frac{\theta_s(Is, T_2) - \theta_s(Is, T_1)}{T_2 - T_1} \times 100 \]  
T1, T2: Any temperature in the operating temperature range
θs(Is, T): optical deflection angle for drive current I and temperature T
Optical deflection angle vs. drive current

Optical deflection angle

Optical deflection angle vs. drive current

Drive current (mA)

Optical deflection angle (°)

Frequency response

Frequency (Hz)

Frequency response

Range shown with broken line: not usable

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

Drive current vs. case temperature

Drive current (mA)

Case temperature (°C)

Coil resistance vs. case temperature

Coil resistance (Ω)

Case temperature (°C)

Resonant frequency vs. case temperature

Resonant frequency (Hz)

Case temperature (°C)

Reflectivity vs. wavelength

Reflectivity (%)

Wavelength (nm)

Hamamatsu

Photon is our business
- **Quality factor vs. case temperature**

![Graph showing quality factor vs. case temperature.]

(Typ. Is=0.6 mA p-p)

- **Temperature characteristics of optical deflection angle**

![Graph showing temperature characteristics of optical deflection angle.]

(Typ. AC drive current at T_case=25 °C, θs=15°)

- **Dimensional outline (unit: mm)**

![Dimensional outline diagram.]

- **Mirror**

  - 8.4 ± 0.1
  - 8.0 ± 0.2
  - 6.8
  - 3.85 ± 0.1

- **Index**

  - 2.55 ± 0.2

- **(φ2.60 ± 0.01)**

- **Mirror**

  - 10.9
  - 9.0
  - 12.3 ± 0.1

- **(4 ×) 0.8 ± 0.05

- **(4 ×) 1.1 ± 0.2

- Position accuracy of mirror relative to package center: ±0.15

**Note:**

- Dimensions are given in millimeters (mm).
- The quality factor is shown as a function of case temperature.
- The optical deflection angle is illustrated for different temperatures.
- The dimensional outline includes critical dimensions for the mirror and its surrounding parts.

**Additional Information:**

- The quality factor vs. case temperature graph shows a linear relationship.
- The temperature characteristics of optical deflection angle indicate variations across different temperatures.
- Position accuracy is specified to ±0.15 for the mirror relative to the package center.
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 ① Coil1 and ② Coil2.

<table>
<thead>
<tr>
<th>Mirror</th>
<th>② Coil2</th>
<th>① Coil1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applies negative current to ① Coil1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No drive current</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applies positive current to ① Coil1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test result (reference)

(1) Operating conditions: Input waveform: sine, optical deflection angle: ±15 degrees, continuous operation
(2) Ambient environment: Temperature: 23 °C, humidity: 45%, clean room cleanliness: class 10000

For (1) and (2), it has been confirmed that characteristics do not change after 12,000,000,000 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.

Soldering

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

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

- Precautions
- Disclaimer

Information described in this material is current as of February 2019.

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.

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