M-S Motor X25

Description
The Miniature Stepper Motor M-S X25 series was developed primarily as an indicator drive for dashboard instrumentation and other indicator equipment. The inherent properties of torque, current consumption, robust construction, etc. extend its use also to a number of other applications. The motor can operate directly from a numerical, i.e. digital, driving signal to move and position a pointer to visualise any parameter required. A fine analogue representation of its value and its changes is made without the need for a digital to analogue conversion.

The miniature stepper motor consists of a motor and gear train with a reduction ratio of 1:180. It is produced with the advanced wide range technologies of the SWATCH GROUP. These technologies assure a high quality product as proven by the success of the famous SWATCH watch. The motor is robust and simple in construction without concessions to versatility or longevity.

Each half revolution of the rotor, defined as a full step, is converted to a one degree rotation of the pointer shaft. The full step itself again is divided into three partial steps, i.e. a 360 degree rotation of the pointer shaft consists of 1080 partial steps. Full steps can be carried out up to 600 Hz resulting in a 600 °/s angular speed. Such characteristics allow a large dynamic range for indicator applications.

Features
- 1/3° resolution per step
- low current consumption
- small dimensions: Ø 30 x 9 mm
- can be directly driven by a µ-controller
- large temperature range: -40°C ÷ 105°C
- high speed: >600 °/s
- qualified for automotive applications

Motor versions
This specification applies only to the following motor versions.


For more details on the differences between those motors, please refer to the buyer's guide.

Typical Application

![Typical Application Diagram](image URL)

An Analogue/Digital Instrument Cluster Concept

**Fig. 1**
**Pin Connection**

![Pin Connection Diagram](image)

**Absolute Maximum Ratings**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving voltage</td>
<td>$U_b$</td>
<td>10 V</td>
</tr>
<tr>
<td>ESD tolerance (MIL 883)</td>
<td>$U_{ESD}$</td>
<td>10'000 V</td>
</tr>
<tr>
<td>EMI tolerance (1 kHz; AM 80%; 100 kHz - 2 GHz)</td>
<td>$E$</td>
<td>80 V/m</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>$T_{stg}$</td>
<td>95 °C</td>
</tr>
<tr>
<td>Solder temperature (10 sec)</td>
<td>$T_s$</td>
<td>260 °C</td>
</tr>
<tr>
<td>Solder temperature (5 sec)</td>
<td>$T_s$</td>
<td>270 °C</td>
</tr>
</tbody>
</table>

Table 1

Stresses beyond these listed maximum ratings may cause permanent damage to the M-S X25. Exposure to conditions beyond specified operating conditions may affect the M-S X25 reliability or cause malfunction.

**Electrical and Mechanical Characteristics**

$T_{amb} = 25°C$ and $U_b = 5 V$; unless otherwise specified.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Type</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td>$T_a$</td>
<td></td>
<td>-40</td>
<td>260</td>
<td>105</td>
<td>°C</td>
</tr>
<tr>
<td>Coil resistance</td>
<td>$R_b$</td>
<td>$f_z = 200 Hz$</td>
<td>290</td>
<td>320</td>
<td>15</td>
<td>mA</td>
</tr>
<tr>
<td>Operating current</td>
<td>$I_{m}$</td>
<td>$f_z = 200 Hz$</td>
<td>15</td>
<td>20</td>
<td>9</td>
<td>V</td>
</tr>
<tr>
<td>Magnetic saturation voltage</td>
<td>$U_{bs}$</td>
<td>$J_L = 0.2x10^{-6}$kgm²</td>
<td>9</td>
<td>200</td>
<td>0.35</td>
<td>Hz</td>
</tr>
<tr>
<td>Start-Stop Frequency</td>
<td>$f_{ss}$</td>
<td>$J_L = 0.2x10^{-6}$kgm²</td>
<td>600</td>
<td></td>
<td>600</td>
<td>Hz</td>
</tr>
<tr>
<td>Maximum driving frequency</td>
<td>$f_m$</td>
<td>$f_z = 200 Hz$</td>
<td>1.0</td>
<td>1.3</td>
<td>1.3</td>
<td>mNm</td>
</tr>
<tr>
<td>Dynamic torque</td>
<td>$M_{200}$</td>
<td>$f_z = 200 Hz$</td>
<td>1.0</td>
<td>1.3</td>
<td>1.3</td>
<td>mNm</td>
</tr>
<tr>
<td>Static torque</td>
<td>$M_{600}$</td>
<td>$f_z = 600 Hz$</td>
<td>0.35</td>
<td>600</td>
<td>0.35</td>
<td>mNm</td>
</tr>
<tr>
<td>Gear play</td>
<td>$M_s$</td>
<td>$U_b = 5 V$</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
<td>mNm</td>
</tr>
<tr>
<td>Axial push on force</td>
<td>$F_A$</td>
<td></td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>Degree</td>
</tr>
<tr>
<td>Axial pull off force</td>
<td>$F_Q$</td>
<td></td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>N</td>
</tr>
<tr>
<td>Perpendicular force</td>
<td>$P$</td>
<td></td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>N</td>
</tr>
<tr>
<td>Imposed acceleration</td>
<td>$\alpha_p$</td>
<td>see p. 5</td>
<td>1'000</td>
<td>1'000</td>
<td>1'000</td>
<td>rad/s²</td>
</tr>
<tr>
<td>Noise level</td>
<td>SPL</td>
<td>(conditions : see p. 11)</td>
<td>45</td>
<td>50</td>
<td>50</td>
<td>dBA</td>
</tr>
<tr>
<td>Angle of rotation of motors</td>
<td>$\beta$</td>
<td>MS w/o stop: Unlimited rotation</td>
<td>315</td>
<td>315</td>
<td>315</td>
<td>Degree</td>
</tr>
</tbody>
</table>

Table 2
Typical Performance Characteristics

Dynamic Torque \( M_d = f(\omega) \)

![Figure 3a](dynamic_torque_w.png)

Dynamic Torque \( M_d = f(U_b) \)

![Figure 3b](dynamic_torque_ub.png)

Dynamic Torque \( M_d = f(T_a) \)

![Figure 3c](dynamic_torque_ta.png)
# Product Identification

## Coding for production date

Each motor is marked with the product number and its manufacturing date.

<table>
<thead>
<tr>
<th>Hour</th>
<th>Day</th>
<th>Manufact. place</th>
<th>Week</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>1</td>
<td>Line 1 - Zhuhai</td>
<td>01</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>7</td>
<td>\ = Special trace.</td>
<td>52</td>
<td>9</td>
</tr>
</tbody>
</table>

- Line 2 - Zhuhai
  - \ = Normal prod.
  - \ = Special trace.

- Line 3 - Zhuhai
  - \ = Normal prod.
  - \ = Special trace.

## Coding for prototypes

The coding for prototypes and special motor types is printed above or below the production date.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Variant</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Z</td>
<td>9</td>
</tr>
</tbody>
</table>

Example:

A1

145>10.6  14th hour (14:00 - 14:59), Friday, Line 1 Zhuhai, normal production, week 10, 2006

## Patents

- US PAT 4371821

OTHER PATENTS IN:
- DE, GB, FR, JP, CH, HK
Installation and Dimensions

Motor Mounting

The Miniature Stepper Motors can be secured in place by a variety of methods. For all automotive applications even when the motor is exposed to very strong vibrations, the soldering of the contact pins is sufficient provided the versions with mounting pegs are used. The mounting pegs have been developed to allow screw-free fixing in ALL applications.

As a general rule, screws are unnecessary and should be avoided as much as possible, both for cost and process capability reasons. The motor has a robust design but normal care should be taken that excessive forces do not deform the housing.

For further details, refer to the application note “Mounting the M-S/ACC Motor” X15.002.02.AN.E.

Examples for Motor Mounting

![Diagram of Motor Mounting](image)

Mounting Load on Pointer Shaft

The load mounting on the pointer shaft, such as a pointer, gear, etc. is usually done in a pressing operation. When using this technique, care should be taken that the forces (F_A and F_Q) do not exceed those given in the specifications (table 2).

Caution

Care should be taken not to impose excessive acceleration onto the pointer shaft. A kick on the mounted pointer might damage the gear and cause permanent damage to the M-S motor!

Forces on the Pointer Shaft

![Diagram of Forces on Pointer Shaft](image)
Functional Description

General

The M-S series consist of a "Lavet" type stepper motor and a gear train. The integrated two step gear train reduces the rotation by a factor of 180 whereby a full step driving pulse results in a one degree rotation of the pointer shaft.

As mentioned earlier, the motor rotor makes one half revolution for each full step with each full step again divided into three partial steps. The steps are carried out according to the applied pulse sequence and driving diagram shown in fig. 8 and 9 respectively.

The bit map (fig. 8) shows the logic levels at the contacts 1÷4 (fig. 7) and the corresponding coil voltage pulses. The direction of rotation is determined by the bit map sequence chosen. The rotation can immediately and at any point be reversed up to the maximum start-stop frequency fss without losing a step. The frequency fss is dependent on the mechanical load applied and can be calculated using the formulae given below.

The driving diagram (fig. 9) shows how the M-S can be driven using standard logic components capable of supplying 20 mA output current at Vdd of 5 volts. For applications where very little current is available, such as for battery powered devices, the motors can be supplied with an optional current less static torque (see p.4). Here the full step positions 1 and 4 provide a static torque even in the absence of the coil current ib.

Rotor Positions

<table>
<thead>
<tr>
<th>Pulse Sequence:</th>
<th>Rotor Position:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor position</td>
<td>clockwise</td>
</tr>
<tr>
<td>Coil Voltage Ub1</td>
<td></td>
</tr>
<tr>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>- -</td>
<td></td>
</tr>
<tr>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>- -</td>
<td></td>
</tr>
<tr>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>- -</td>
<td></td>
</tr>
<tr>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>- -</td>
<td></td>
</tr>
<tr>
<td>+ +</td>
<td></td>
</tr>
<tr>
<td>- -</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rotor Position:</th>
<th>clockwise</th>
</tr>
</thead>
<tbody>
<tr>
<td>partial step</td>
<td></td>
</tr>
<tr>
<td>full step</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact</th>
<th>clockwise</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2,3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit Map:</th>
<th>clockwise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact 1</td>
<td></td>
</tr>
<tr>
<td>Contact 2,3</td>
<td></td>
</tr>
<tr>
<td>Contact 4</td>
<td></td>
</tr>
</tbody>
</table>
Driving Diagram

Start-Stop-Frequency \( f_{SS} \)

As is normally the case for stepper motors, a shift register type driver supplies the clock frequency which determines the rotational speed of the motor. Up to the start-stop frequency \( f_{SS} \) a reverse rotation and a full stop is possible without missing, i.e., failing to carry out a driving step. The dynamic behaviour of the system (i.e., \( f_{SS} \)) is influenced by the inertia of the load. The \( f_{SS} \) of the M-S X25 loaded with an inertial mass of 200 gmm\(^2\) is approximately 200 Hz. The following example shows how the \( f_{SS} \) of a motor can be calculated.

The parameters needed are:
- dependence of torque on the frequency (fig. 3)
- motor gear inertia \( J_{M-S} \)
- load inertia \( J_L \)
- number of steps \( z \) in 360°
- full step frequency \( f_z \)

The angular velocity is \( \omega \):

\[
1°) \quad \omega = f_z \frac{2\pi}{z} = f_z \frac{\pi}{180}
\]

The acceleration torque \( M_\alpha \) needed to move the sum of the inertial masses \( J_{M-S} + J_L = J \) with the angular acceleration \( \alpha \) is:

\[
2°) \quad M_\alpha = J \cdot \alpha
\]

Also for acceleration from zero to the applied velocity, i.e., the applied full step frequency \( f_z \), the acceleration torque \( M_\alpha \) is equal to the effective dynamic torque \( M_d \) at this angular velocity:

\[
3°) \quad M_\alpha = M_d
\]

The value of \( M_d \) as a function of the full step frequency \( f_z \) is determined by measurements directly on the motor. The acceleration torque \( M_\alpha \) must also be determined as a function of \( f_z \). The angular acceleration \( \alpha \) is:

\[
4°) \quad \alpha = \frac{\omega}{f_z} = \omega \cdot f_z
\]

\[
5°) \quad M_\alpha = J \cdot f_z^2 \cdot \frac{\pi}{180} \quad (J = J_{M-S} + J_L)
\]

The start-stop frequency \( f_{SS} \) is given by the intersection of the plot of these two curves as shown in fig. 10. The calculation of \( f_{SS} \) using the indicator norm mass results:

\[
J_{M-S} = 480 \times 10^{-9} \quad \text{kgm}^2
\]
\[
J_L = 200 \times 10^{-9} \quad \text{kgm}^2
\]
\[
J = 680 \times 10^{-9} \quad \text{kgm}^2
\]
\[
M_{\alpha100} = 0.118 \quad \text{mNm}
\]
\[
M_{\alpha200} = 0.475 \quad \text{mNm}
\]
\[
M_{\alpha300} = 1.068 \quad \text{mNm}
\]

Then, from fig. 10 \( \Rightarrow f_{SS} = 235 \text{ Hz} \)
Graphic Determination of \( f_{ss} \)

\[
\begin{align*}
\text{(mNm)} & \quad (\text{Hz}) \\
M_\alpha 300 & \quad 1.0 \\
M_\alpha 200 & \quad 0.75 \\
M_\alpha 100 & \quad 0.50 \\
1/2 \text{ Torque } M_d = f(\ fraction) \\
\end{align*}
\]

Full step frequency \( f_z \)

**Acceleration to Frequencies > \( f_{ss} \)**

In order to determine the maximum acceleration step \( \Delta f \), the same type of calculation can be made as for \( f_{ss} \). The difference is that instead of the angular velocity \( \omega \), the change in the angular velocity \( \Delta \omega \) is used in the calculation. The intersection of the two curves is again used to determine the next higher step frequency \( f_i \).

\[
6^\circ) \quad \Delta \omega = \omega_i - \omega_{i-1} = \frac{(f_i - f_{i-1}) \cdot \pi}{180} = \frac{\Delta f_i \cdot \pi}{180}
\]

Using the acceleration time

\[
7^\circ) \quad t_\alpha = \frac{1}{f_i}
\]

and the angular acceleration

\[
8^\circ) \quad \alpha = \frac{\Delta \omega}{t_\alpha} = \frac{(f_i - f_{i-1}) \cdot f_i \cdot \pi}{180}
\]

the acceleration torque \( M_\alpha \) needed to accelerate \( J \) to \( f_i \) can be calculated.

\[
9^\circ) \quad M_\alpha = J \cdot \alpha = \frac{J \cdot (f_i - f_{i-1}) \cdot f_i \cdot \pi}{180} = \frac{J \cdot f_i \cdot \Delta f_i \cdot \pi}{180}
\]

The intersection of the curves gives the maximum driving frequency or the shortest period which is needed to drive the motor with a maximum acceleration.

**Determination of the Acceleration Steps**

\[
\begin{align*}
\text{(mNm)} & \quad (\text{Hz}) \\
M_\alpha 300 & \quad 1.0 \\
M_\alpha 200 & \quad 0.75 \\
M_\alpha 100 & \quad 0.50 \\
1/2 \text{ Torque } M_d = f(\ fraction) \\
\end{align*}
\]

Full step frequency \( f_z \)

**Fig. 10**

**Fig. 11**
Control Circuits

M-S Quad Driver X12.017

The M-S Quad Driver X12.017 is a monolithic CMOS device intended to be used as an interface circuit to ease the use of the Miniature Stepping Motors X25. The circuit allows the user to drive four motors as it contains four identical drivers on the same chip.

M-S Dual Driver X12.014

Manufactured with the same technologies and using the identical drivers as the M-S Quad Driver X12.017, the M-S Dual Driver X12.014 allows the user to drive two motors which require a smooth and appealing movement of the pointer (i.e major gauges such as speed and RPM). Minor gauges such as fuel or temperature which move only from time to time may be driven in the partial steps mode directly by the micro-processor (refer to example fig. 13b).

Microstepping Mode of Operation

The M-S Quad/Dual Driver converts a pulse train into a current level sequence sent to the two motor coils of the M-S. This sequence of 24 current levels per rotor revolution is used to produce the microstepping movement of the rotor.

A microstep is an angular rotation of 1/12° of the M-S shaft or 15° on the rotor shaft.

A partial step is an angular rotation of 1/3° of the M-S shaft or 60° on the rotor shaft. The microstepping allows for a continuous smooth movement of a pointer if the M-S is used as pointer drive. It is not intended as a precise positioning. The precision of the angular position is given by the resolution of the partial step.
Tests Description and Conditions

174 PCS
START

1. INITIAL CHARACTERISTICS EVALUATION
   (Without print)
   - Noise, VJ, coil resistance, Torque, static and dynamic detent

2. MECHANISM ATTACHMENT
   (Hand soldering)

3. FIRST INTERMEDIATE CHARACTERISTICS EVALUATION
   (On print)
   - Noise, VJ, coil resistance, kick back

4. INDICATOR MANUAL INSERTION

5. 24 PCS
   TEST LEG A
   - POWER TEMPERATURE CYCLING
     (1000 h)
   - OPERATING LIFE
     (1000 h)

6. 24 PCS
   TEST LEG B
   - STORAGE LIFE EVALUATION
     (100 h)

7. 24 PCS
   TEST LEG C
   - CYCLE TEMPERATURE AND HUMIDITY
     (1000 h)

8. 24 PCS
   TEST LEG D
   - MECHANICAL SHOCKS
   - AMBIANT TEMP. LIFE EVALUATION
     (1000 h)

9. 24 PCS
   TEST LEG E
   - THERMAL SHOCK CONDITIONING
   - POWER THERMAL SHOCKS
     (500 h)
   - VIBRATIONS
     - RANDOM (12 PCS)
     - SINUS (12 PCS)

10. 24 PCS
    TEST LEG F
    - FINAL CHARACTERISTICS EVALUATION
      (Without print)
      - Noise, VJ, Torque, Analysis + photos

Validation Plan Overview

11. 30 PCS
    TEST LEG G
    - MOTORS CHARACTERISATION
    - Coil resistance, Noise (16 speeds), VJ, Torque – dynamic (16 speeds), static, detent and friction, pointer movement (3 speeds), angular play, kick back, coupling flux, axial & radial load

12. FINAL REPORT
    - INTERMEDIATE CHARACTERISTICS EVALUATION
      (On print at 48, 250, 500, 750 & 1000h; Leg F 48, 160, 320 & 500h)
      - Noise, VJ, coil resistance, kick back
General Conditions

Initial preconditioning

After the initial characteristics evaluation, the M-S Motors are mounted on a board and soldered with a gap of 0.5 mm. When soldered, an axial force (FA) of 150 N and a radial force (FQ) of 12 N must be applied on the shaft of all the tested M-S motors. The radial force is applied at 8.5 mm of the top of the cover.

Indicator Norm Load

- mass \( m \) : 2.5 g
- inertia \( J_L \) : 0.2 \( \cdot 10^{-6} \) kgm\(^2\)
- unbalance \( M_u \) : 0.01 mNm

Driving Cycles

The Driving Cycle consists of the following sequential movements in loop for the M-S Motors. Before the first cycle, the motors with internal stop are driven continuously in the same direction to hit the stop at 150°/s and then return 5°. The motor is zeroing at this position.

Type of driving speed used:

<table>
<thead>
<tr>
<th></th>
<th>( \omega_1 )</th>
<th>( \omega_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving cycle at high speed:</td>
<td>200°/s</td>
<td>600°/s</td>
</tr>
<tr>
<td>Driving cycle at low speed:</td>
<td>100°/s</td>
<td>300°/s</td>
</tr>
</tbody>
</table>

1) Driving from 0° to 60° at \( \omega_1 \) and wait 1 s.
2) Five cycles consisting each of a driving from 60° to 120° at \( \omega_1 \) and back to 60° at \( \omega_2 \), Waiting during 2 s after each cycle.
3) Back to 0° at \( \omega_1 \).
4) **Variant A**: The motor is driven freely without hitting the stop. Driven at \( \omega_2 \) to reach 300° (360° for motors w/o stop) and back again of 0° at \( \omega_1 \).

**Variant B**: The motor is driven against the stop on versions so fitted in order to increase the shocks and stresses. They drive at \( \omega_2 \) to reach 360° and back again of 360° at \( \omega_1 \).

The motor is driven about 25% of the time with driving cycle at high speed and 40% at low speed. During the waiting period, the recommended voltage is applied on both coils.

For the ACC-Motor the driving cycle consist of one minute step each 0.5 s.

Specific Test Conditions

Test Leg A: Power Temperature Cycling

Defect free functioning after passing 1000 h in Temperature Cycling Test. The temperature cycle consists of \( \frac{1}{2} \) h at 105°C, \( \frac{1}{2} \) h to cool down to -40°C, \( \frac{1}{2} \) h at -40°C and \( \frac{1}{2} \) h to return to 105°C. The time of each cycle is 2 h. The motors drive during the first 500 h in variant A and during the last 500 h in variant B.

Test Leg B: Storage and operating life evaluation

Defect free functioning after passing 100 h in Storage Life Evaluation and after 1000 h in Operating Life. The storage life evaluation consists to place the motors without rotation at -40°C during 100 h. After this time all the motors must start correctly without step loss.

The operating life consists of a permanent temperature at 105°C during which the motors drive. The motors drive during the first 500 h in variant A and during the last 500 h in variant B.
Test Leg C: Cycle Temperature and Humidity

Defect free functioning after passing 1000 h in Cycle Temperature and Humidity Test. The cycle temperature and humidity test consists of 2 h to ascend the temperature from 25°C to 65°C and the relative humidity from 50% to 95%. The temperature and the humidity are maintained during 4 h then they are descending to the start values 25°C and 50% of relative humidity. The time of each cycle is 8 h.

The motors drive during the first 500 h in variant A and during the last 500 h in variant B.

Test Leg D: Shocks and Vibrations Test

Defect free functioning after being subjected Shocks and Vibrations Tests.

Thermal shock conditioning

First, the motors are placed without rotation to be conditioned in a thermal shock test which consists of 16 thermal shocks between 85°C and -40°C in 10 s. The extreme temperatures are maintained ½ h. The time of each cycle is 1 h.

Mechanical shocks

The motors are subjected to shocks 5 times in 3 axes on the vibration machine. Each shock consists of a half-sine waveform pulse with an acceleration peak of 20 g during 11 ms. The motors drive in variant A during this test.

Random vibrations

Previously subjected to thermal/mechanical shocks, ½ of the motors are subjected to the random vibrations test in each 3 axes. Vibrations are applied for 10 minutes at a level of 1.8 grms between 10 and 1000 Hz during which no step loss shall be evident. Then the motors are vibrated 20 h at a level of 4.5 grms without mechanical damage and then, they are again vibrated 10 minutes at the level of 1.8 grms. During this last step, no step loss shall be evident. The motors drive in variant A during this test.

Sinus vibrations

Previously subjected to thermal/mechanical shocks, ½ of the motors are subjected to the sinus vibrations test in each 3 axes. Vibrations are applied for 8 h with an acceleration of 6 gp-p, but maximum 10 mm of amplitude in the frequency range of 5 to 250 Hz with a sweep of 1 octave / minute. The motors drive in variant A during this test.

Test Leg E: Ambient Temperature Life Evaluation

Defect free functioning after passing 1000 h in Ambient Temperature Life Evaluation. The motors drive during the first 500 h in variant A and during the last 500 h in variant B. Comparison is then made between motors subjected to this test, and those of the other legs in order to evaluate the evolution of the motors under different conditions.

Test Leg F: Power Thermal Shocks

Defect free functioning after passing the test. The Power Thermal Shocks test consists of continuous sequential thermal shocks between 110°C and -50°C every 15 min during 500 h. During this test, the motors drive like the CCP test (see doc no : CCP-002-e-A M-S Motors CCP Plan). That means 300° at high speed (600°/s), then 60° at a speed under the start stop frequency (150°/s) to assure a kick back and the same to the another direction.
Acoustic Measurements

Test Configuration

1. reflection free room
2. microphone 1/2” omni-directional Larson-Davis, Typ. 2541
3. sonometer Larson-Davis Typ. 800B
4. motor under test
5. reflection free cube
6. M-S control unit in µ-stepping mode (1/12° / step)

Test Conditions

- temperature \( T_{\text{amb}} : 25 \) °C
- measurement distance \( L_m : 4 \) cm
- measurement range : 20 ÷ 20k Hz
- measurement time \( t_m : 4 \) s
- angular speed max \( \omega : 600 \) °/s
- ambient noise max : 20 dBA
- motor without load.

Instrument Parameters

The noise level SPL was determined using the instrument settings (Larson-Davis Typ. 800B):

- weighting : " A "
- integration time : " Slow "
- detection : " RMS "

...
## Parameter Definitions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>EMI tolerance</td>
<td>V/m</td>
</tr>
<tr>
<td>FA</td>
<td>axial force on the pointer shaft</td>
<td>N</td>
</tr>
<tr>
<td>FQ</td>
<td>perpendicular force on the pointer shaft</td>
<td>N</td>
</tr>
<tr>
<td>fAM</td>
<td>amplitude modulated carrier frequency</td>
<td>Hz</td>
</tr>
<tr>
<td>fm</td>
<td>maximum driving frequency</td>
<td>Hz</td>
</tr>
<tr>
<td>fss</td>
<td>start-stop frequency</td>
<td>Hz</td>
</tr>
<tr>
<td>fz</td>
<td>full step frequency</td>
<td>Hz</td>
</tr>
<tr>
<td>Gnd</td>
<td>ground</td>
<td>-</td>
</tr>
<tr>
<td>Ib</td>
<td>coil current</td>
<td>A</td>
</tr>
<tr>
<td>Im</td>
<td>M-S ac-current</td>
<td>A</td>
</tr>
<tr>
<td>J</td>
<td>total inertia ( = J_{M-S} + J_L )</td>
<td>kgm²</td>
</tr>
<tr>
<td>JL</td>
<td>inertia of the load</td>
<td>kgm²</td>
</tr>
<tr>
<td>J_{M-S}</td>
<td>inertia of the M-S</td>
<td>kgm²</td>
</tr>
<tr>
<td>Lm</td>
<td>noise measurement distance</td>
<td>cm</td>
</tr>
<tr>
<td>m</td>
<td>mass of the driven load</td>
<td>g</td>
</tr>
<tr>
<td>Mα</td>
<td>acceleration torque</td>
<td>mNm</td>
</tr>
<tr>
<td>M200</td>
<td>dynamic torque at 200 Hz full step frequency</td>
<td>mNm</td>
</tr>
<tr>
<td>Md</td>
<td>dynamic torque</td>
<td>mNm</td>
</tr>
<tr>
<td>M0</td>
<td>static torque at ( U_B = 0 ) V</td>
<td>mNm</td>
</tr>
<tr>
<td>Ms</td>
<td>static torque at ( U_B &gt; 0 ) V</td>
<td>mNm</td>
</tr>
<tr>
<td>Mu</td>
<td>unbalance of the load</td>
<td>mNm</td>
</tr>
<tr>
<td>Rb</td>
<td>coil resistance</td>
<td>Ω</td>
</tr>
<tr>
<td>SPL</td>
<td>noise level of the motor (sound pressure level)</td>
<td>dB</td>
</tr>
<tr>
<td>Ta</td>
<td>temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Tamb</td>
<td>ambient temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Ts</td>
<td>solder temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Tstg</td>
<td>storage temperature</td>
<td>°C</td>
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<tr>
<td>tα</td>
<td>acceleration time</td>
<td>s</td>
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<tr>
<td>t(\text{m})</td>
<td>noise measurement time</td>
<td>s</td>
</tr>
<tr>
<td>Ub</td>
<td>coil voltage</td>
<td>V</td>
</tr>
<tr>
<td>Ubs</td>
<td>magnetic saturation voltage</td>
<td>V</td>
</tr>
<tr>
<td>UESD</td>
<td>Electro Static Discharge tolerance</td>
<td>V</td>
</tr>
<tr>
<td>Vdd</td>
<td>operating voltage</td>
<td>V</td>
</tr>
<tr>
<td>z</td>
<td>number of full steps per revolution (=360)</td>
<td>-</td>
</tr>
<tr>
<td>α</td>
<td>angular acceleration (( = M_\alpha/I ))</td>
<td>rad/s²</td>
</tr>
<tr>
<td>α(p)</td>
<td>angular acceleration imposed to the pointer shaft</td>
<td>rad/s²</td>
</tr>
<tr>
<td>β</td>
<td>possible angle of rotation of the internal stop version</td>
<td>degrees</td>
</tr>
<tr>
<td>ω</td>
<td>angular speed</td>
<td>rad/s (rad/s)</td>
</tr>
<tr>
<td></td>
<td>random vibration unit</td>
<td>grms</td>
</tr>
<tr>
<td></td>
<td>sinus vibration unit (g peak to peak)</td>
<td>gp-p</td>
</tr>
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