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# PROJECT EXERCISE 04 REPORT

## SELECTION OF A STEPPER MOTOR TO WORK IN THE PULL-IN RANGE

HARSHIT VERMA
WARSAW UNIVERSITY OF TECHNOLOGY
Faculty of Mechatronics

# 1. Introduction

**Electric stepping motors, crucial electromechanical energy converters, are explored in this report for their role in converting control pulses into precise angular displacements. The report covers operational principles, design variants, characteristics, and a mathematical model of stepping motors. These motors find application in positioning systems with open position feedback loops, allowing accurate control over angular movements. Controlled by electronic systems called drivers, stepping motors exhibit various operational characteristics, such as static, quasi-static, kinematic, and dynamic work. Design variations, including permanent magnet, reluctance, and hybrid stepping motors, are discussed. The mathematical model provides insights into torque and rotor dynamics. This report aims to offer a comprehensive understanding of electric stepping motors and their applications.**

# 2. Aim

**The aim of the exercise is to learn the rules of selecting stepping motors to work in the pull-in range and to acquire the ability to independently carry out such a selection.**

# 3. My data

| **No. of data set** | $J_{mech}\ [gcm\text{^}2]$ | $M_{Fst}\ [Nmm]$ | $n\ [1]$ | $T_p\ [ms]$ |
|---|---|---|---|---|
| **14** | **100** | **150** | **5** | **240** |

$J_{mech}$ – table mass moment of inertia

$M_{Fst}$ – constant torque loading the motor

$n$ – current commutation step number

$T_p$ – length of the positioning cycle

## A. Checking the possibility of implementation of direct drive:

### A.1. Calculation of the stepping rate:

$$\Delta\Upsilon_{mech} = 360^0/5 = 72\,° \qquad \ldots 1$$

$$f_t = \Delta\Upsilon_{mech}/\theta \cdot 1/T_p = 72°/1.8° \cdot 1/0.24 = 166.66\ Hz \qquad \ldots 2$$

$f_t$ – stepping rate in the direct drive [Hz]

$\Delta\Upsilon_{mech}$ – required angular displacement of the mechanism [°]

$\theta$ – step of motor [°]

$T_p$ – required time to complete the movement [s]

## A.2. Selecting a motor with sufficient torque:

Our required torque is 150 Nmm, in other terms, it should be 1.52 Kg-F cm.

We selected Stepper Motor Series SST58D, since it lies in the required sector, our selected motor is **SST58D1830.**

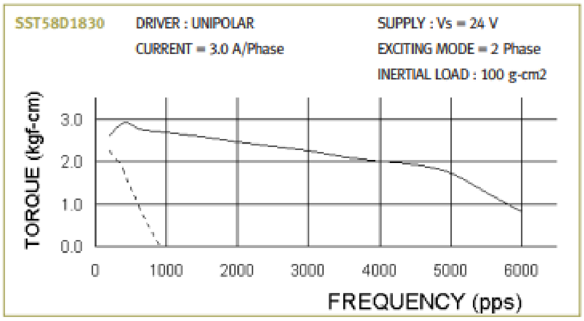



FIGURE A.2-A-1 GRAPH COMPARING TORQUE VS FREQUENCY OF THE MOTOR SERIES SST58D.

**Specifications**

| MODEL | | STEP ANGLE | VOLTAGE | CURRENT | RESISTANCE | INDUCTANCE | HOLDING TORQUE | ROTOR INERTIA | NUMBER OF LEADS | WEIGHT | DIMENSION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SINGLE SHAFT | DOUBLE SHAFT | DEG. | V | A/Phase | Ω/Phase | mH/Phase | kg-cm | g-cm² | LEAD | kg | L |
| SST58D1810 | SST58D1811 | 1.8 | 5.0 | 1.0 | 5.0 | 5.4 | 3.7 | 135 | 8 | 0.49 | 42 |
| SST58D1820 | SST58D1821 | 1.8 | 2.4 | 2.0 | 1.2 | 1.3 | 3.7 | 135 | 8 | 0.49 | 42 |
| SST58D1830 | SST58D1831 | 1.8 | 1.5 | 3.0 | 0.5 | 0.54 | 3.7 | 135 | 8 | 0.49 | 42 |
| SST58D2810 | SST58D2811 | 1.8 | 6.2 | 1.0 | 6.2 | 9.7 | 6.4 | 230 | 8 | 0.6 | 49 |
| SST58D2820 | SST58D2821 | 1.8 | 3.0 | 2.0 | 1.5 | 2.6 | 6.4 | 230 | 8 | 0.6 | 49 |
| SST58D2830 | SST58D2831 | 1.8 | 2.2 | 3.0 | 0.73 | 1.1 | 6.4 | 230 | 8 | 0.6 | 49 |
| SST58D3810 | SST58D3811 | 1.8 | 6.9 | 1.0 | 6.9 | 14.0 | 7.3 | 290 | 8 | 0.71 | 54 |
| SST58D3820 | SST58D3821 | 1.8 | 3.4 | 2.0 | 1.7 | 3.6 | 7.3 | 290 | 8 | 0.71 | 54 |
| SST58D3830 | SST58D3831 | 1.8 | 2.1 | 3.0 | 0.7 | 1.3 | 7.3 | 290 | 8 | 0.71 | 54 |
| SST58D4810 | SST58D4811 | 1.8 | 7.2 | 1.0 | 7.2 | 12.0 | 9.2 | 330 | 8 | 0.86 | 65 |
| SST58D4820 | SST58D4821 | 1.8 | 3.6 | 2.0 | 1.8 | 3.0 | 9.2 | 330 | 8 | 0.86 | 65 |
| SST58D4830 | SST58D4831 | 1.8 | 2.4 | 3.0 | 0.8 | 1.3 1 | 9.2 | 330 | 8 | 0.86 | 65 |
| SST58D5810 | SST58D5811 | 1.8 | 8.8 | 1.0 | 8.8 | 19.0 | 11.7 | 430 | 8 | 1.1 | 77 |
| SST58D5820 | SST58D5821 | 1.8 | 4.8 | 2.0 | 2.4 | 5.1 | 11.7 | 430 | 8 | 1.1 | 77 |
| SST58D5830 | SST58D5831 | 1.8 | 3.0 | 3.0 | 1.0 | 2.62 | 11.7 | 430 | 8 | 1.1 | 77 |

RoHS compliant

FIGURE A-2-2 SPECIFICATION CHART FOR THE MOTOR SERIES SST58D HIGHLIGHTING THE SELECTED MODEL SST58D1830.

Now,

$$J_{pom} = 100 \text{ g cm}^2$$

$$J_m = 135 \text{ g cm}^2$$

## A.3. Calculation of the pull-in stepping rate:

$$f_{gm} = f_{gp} \cdot \sqrt{\left((J_m + J_{pom})/(J_m + J_{mech})\right)} \quad \ldots 3$$

$$= 500 \cdot \sqrt{\left((135 + 100)/(135 + 100)\right)} = 500\ Hz$$

$f_{gm}$ – maximum pull-in stepping rate of the motor loaded with the mass moment of inertia $J_{mech}$ [Hz]

$f_{gp}$ – maximum pull-in stepping rate of the motor loaded with the mass moment of inertia equal to $J_{pom}$ [Hz]

$J_m$ – mass moment of inertia of rotor [$kgm^2$]

$J_{pom}$ – Inertial load [$gcm^2$]

$J_{mech}$ – mass moment of inertia of load [$kgm^2$]

## A.4. Checking the stepping rate condition:

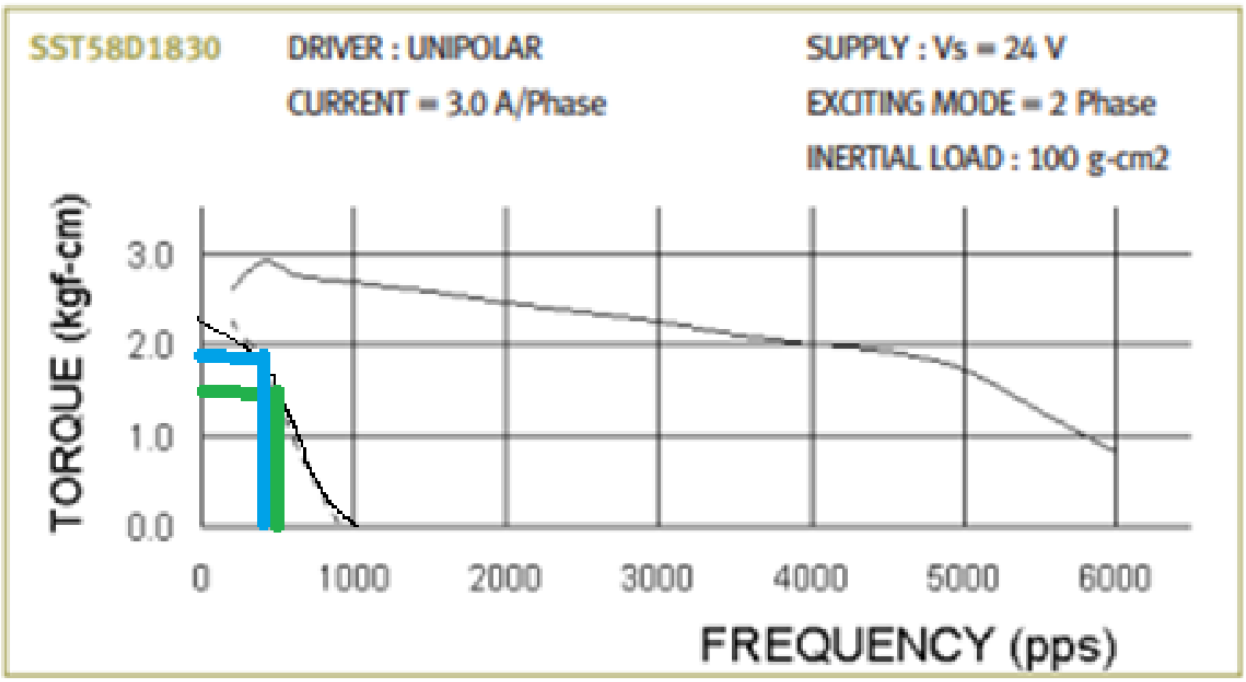



FIGURE A.4-1 CHECKING CONDITIONS OF KINEMATIC WORK ACCORDING TO (3).

It looks OK, so we move on towards the next steps.

# B. Selection of the gear system:

## A.2. Calculation of the gear ratio:

The gear ratio $i_{pobl}$ is calculated formula,

$$i_{pobl} = \sqrt{((J_{mech})/(J_m))} \qquad \ldots 4$$

$$= \sqrt{((100)/(135))} = 0.86$$

$i_{pobl}$ – *gear ratio*[1]

$J_{mech}$ – *mass moment of inertia of the driven elements of the mechanism*

$J_m$ – mass moment of inertia of the motor rotor

## A.3. Calculation of the stepping rate:

$$i_p \approx i_{pobl} \quad \ldots 5$$

Condition, in order for the drive system to execute the assumed motion with full motor strokes, the gear ratio must meet the additional condition that the number of Z strokes is an integer,

$$\begin{aligned}\Delta\Upsilon/\Theta &= \Delta\Upsilon_{mech} \cdot i_p/\theta \\ &= 72\,° \cdot 0.86/1.8° = 34.47\end{aligned} \quad \ldots 6$$

$\Delta\Upsilon$ – required angular displacement of the rotor [rad]

$\Delta\Upsilon_{mech}$ – required angular displacement of the mechanism [rad]

$i_p$ – required angular displacement of the mechanism [rad]

$i_{pobl}$ – calculated gear ratio [1]

## A.4. Calculation of the stepping rate for a geared drive

Stepping rate,

$$\begin{aligned}f_t &= \Delta\Upsilon/(\theta \cdot T_p) \\ &= 61.92/(1.8 \cdot 0.25) = 137.6\,Hz\end{aligned} \quad \ldots 7$$

Condition,

$$\begin{aligned}\Delta\Upsilon &= \Delta\Upsilon_{mech} \cdot i_p \\ &= 72 \cdot 0.86 = 61.92\,s\end{aligned} \quad \ldots 8$$

$\Delta\Upsilon$ – required time to complete the movement [s]

$T_p$ – required angular displacement of the rotor [°]

$\theta$ – the step of the motor [°]

$f_t$ – stepping rate for a geared drive [Hz]

## A.5. Calculation of the reduced loading torque:

$$\begin{aligned}M_{red} &= M_{mech}/(\eta_p \cdot i_p) \\ &= 150/(0.9 \cdot 0.86) = 87.71\,Nmm\end{aligned} \quad \ldots 9$$

$M_{mech}$ – torque needed to drive the mechanism [N mm]

$M_{red}$ – reduced load torque [N mm]

$i_p$ – gear ratio [1]

$\eta_p$ – gear efficiency [1]

## A.6. Calculation of the maximum pull-in stepping rate of the driven system:

$$f_{gm} = f_{gp}\sqrt{\left((J_m + J_{pom})/(J_m + J_m)\right)}$$ ...10

$$= 900\sqrt{\left((81 + 14)/(104)\right)} = 859.95 \approx 860\ Hz$$

$f_{gp}$ – maximum pull-in stepping rate of the motor loaded with the mass moment of inertia equal to $J_{pom}$ [Hz]

$f_{gm}$ – maximum pull-in stepping rate of the motor loaded with the mass moment of inertia $J_{mech}$ [Hz]

$J_m$ – mass moment of inertia of rotor [$kgm^2$]

$J_{pom}$ – mass moment of inertia loading motor during measurements [$kgm^2$]

**Size 23**

# 6.Conclusions:

- The method used to select the stepper motor that meets specific requirements.
- The selected stepper motor meets the specific requirements.
- The stepper motor has a lower torque but higher efficiency.

# 7.Literature:


a. MDR_2022 - Proj_Ex_4 – Instruction by J. Wierciak.
b. MDR_2022 - Proj_Ex_3 – Shinano Kenshi catalogue


# 8.Attachments:

Catalogue card of the selected stepper motor – **Stepper Motor Series SST58D.**

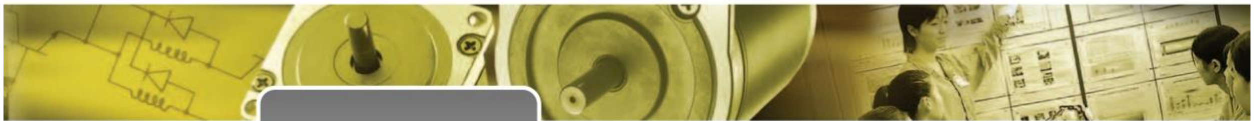
## Declaration of Work

I, Harshit Verma, confirm that the work for the following term paper with the title: "PROJECT EXERCISE 04 Report - Selection of the stepping motor for operation in the pull-in range " was solely undertaken by myself and that no help was provided from other sources as those allowed. All sections of the paper that use quotes or describe an argument or concept developed by another author have been referenced, including all secondary literature used, to show that this material has been adopted to support my thesis.

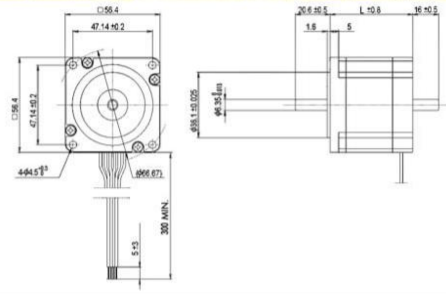
Harshit Verma Warsaw,Poland
302601 17/01/24

# Stepper Motor Series SST58D

## Size 23



**8 Lead Wire**
**42mm, 49mm, 54mm, 65mm, 77mmL**
**$1.8^{o}$ step**

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RoHS compliant

## Typical Performance

Refer to page 41 for Driver Information

— Pull Out - - - Pull In