**Router Lift Test Report**
09/06/2022
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**Report Authors :** Juan, Rainer, Alex
Endurance test of the Nema 23 stepper motor whilst lifting and lowering a weight of 10kg and using a trapezoidal spindle with a 3mm thread

Model of stepper motor: *23HE30-2804S*
*Native resolution: 200 usteps*
*Micro steps used throughout: 4*
*Controller: TI DRV8711*

| ***Speed of motor (usteps/s)*** | ***Spindle Rotations per min (rpm)*** | ***Vertical Speed (mm/s)*** | ***Belt Ratio*** | ***Voltage (V)*** | ***Ampere (A)*** | ***Lifted weight (kg)*** | ***Result*** | ***Notes*** |
|---|---|---|---|---|---|---|---|---|
| *5000* | *187.50* | *9.37* | *2:1* | *32* | *2.0* | *10* | *passed* | *A smooth travel throughout the entire lifting / lowering distance of 100mm was achieved* |
| *5000* | *187.50* | *9.37* | *2:1* | *32* | *2.5* | *10* | *passed* | *A smooth travel throughout the entire lifting / lowering distance of 100mm was achieved* |
| *6000* | *225* | *11,25* | *2:1* | *32* | *2.5* | *10* | *passed* | *A smooth travel throughout the entire lifting / lowering distance of 100mm was achieved* |
| *5000* | *187.50* | *9.37* | *2:1* | *48* | *2.0* | *10* | *failed* | *Motor Controller showing "Predriver Fault"* |
| *5000* | *187.50* | *9.37* | *2:1* | *48* | *2.5* | *10* | *failed* | *Motor Controller showing "Predriver Fault"* |
| *5000* | *375* | *18,75* | *1:1* | *32* | *2* | *10* | *failed* | *Insufficient existing torque of stepper motor!* |
| *2500* | *187.50* | *9.37* | *1:1* | *32* | *2* | *10* | *failed* | *Insufficient existing torque of stepper motor!* |
| *2500* | *187.50* | *9.37* | *1:1* | *32* | *2.5* | *10* | *failed* | *Insufficient existing torque of stepper motor!* |
| *5000* | *375* | *18,75* | *1:1* | *32* | *2.5* | *10* | *failed* | *Insufficient existing torque of stepper motor!* |
| *5000* | *375* | *18,75* | *1:1* | *48* | *2.0* | *10* | *failed* | *Insufficient existing torque of stepper motor!* |
| *5000* | *375* | *18,75* | *1:1* | *48* | *2.5* | *10* | *failed* | *Motor Controller showing "Predriver Fault"* |
| *2500* | *187.50* | *9.37* | *1:1* | *48* | *2.0* | *10* | *failed* | *Insufficient existing torque of stepper motor!* |
| *2500* | *187.50* | *9.37* | *1:1* | *48* | *2.5* | *10* | *failed* | *Motor Controller showing "Predriver Fault"* |

## Testing Summary

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**Electrical Faults**

It has been confirmed that the current NEMA 23 stepper motor is fully capable of smoothly lifting and lowering a weight of 10kg at a vertical speed of max. 11.25mm/s and over a total distance of 100mm, whilst running on 32 V with 2.5 Ampere and using a 2:1 belt ratio.
No significant warming or (over-)heating of the motor was observed.

Increasing the voltage to 48 V caused failure both for applying a speed of 5000 usteps/s and 2500 usteps/s even at a belt ratio of 1.1. In theory the required torque for the stepper motor at a speed of 2500 usteps/s and whilst using a belt ratio of 1:1 should be identical to a torque needed for a stepper motor with a speed of 5000 usteps/s whilst using a belt ratio of 2:1.
The potential reason for the failure is not clear. The motor controller is showing “Predriver Fault” Error which according to the Datasheet could be the following:
*“In PWM mode, if excessive current is detected on the gate drive outputs (which would be indicative of a failed/shorted output FET or PCB fault), the H-bridge experiencing the fault is disabled, the xPDF bit in the STATUS register is set, and the FAULT pin is driven low. The H-bridge will remain off, and the xPDF bit will remain set until it is written to 0 or the device is reset.”*

FET are integrated in the Motor Controller Board, therefore we cannot change anything there. After reading the datasheet not clear what could we change to solve the issue but some possible steps we could try are:

- Measure Stepper Windings with Oscilloscope to see Waveform. Check also with Motor without load
- Try different decay modes
- Try different microsteps to see if error always appear
- Try different Pulse Widths to see if it has an influence
- Check the software calculation of the Current Limit as Rsense resistor from Pololu Driver is not the same as the TI Evaluation Board

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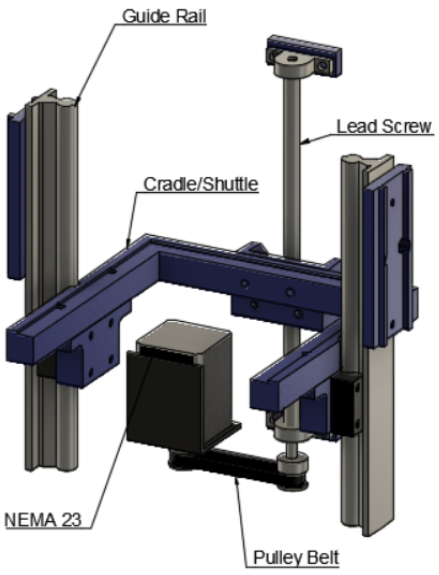
**Mechanical Faults**




- Loose connection between nut housing and cradle
- Grinding of nut material (brass shavings being shed from nut)
- Cradle wobble
- Loose lower screw bearing

## Troubleshooting plan

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### Electrical troubleshooting

In order to find out more about the reasons for the failure a relevant data sheet of the controller would have to be double checked. However, it has been decided that the last successful test result is sufficient to further proceed with the next step of the project.

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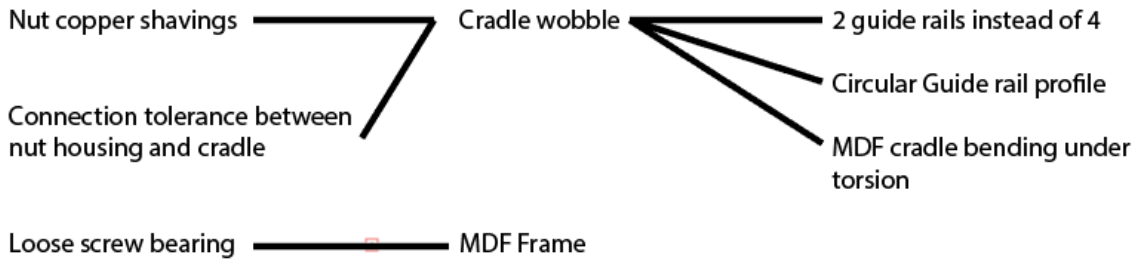
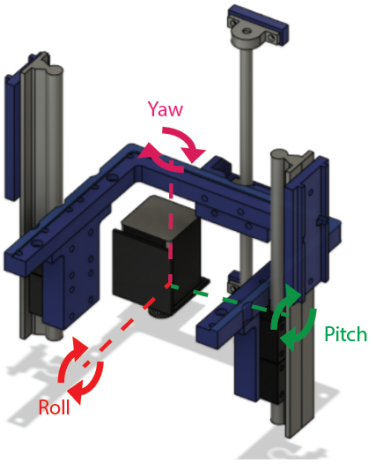
### Mechanical troubleshooting




*Pitch-Yaw-Roll diagram for reference of rotation axes when discussing cradle wobble*

A number of problems are pointed towards cradle wobble, oscillating roll rotation of the cradle is most likely a driver of wear on the nut causing material to be shaved off, furthermore, the loose connection between the nut housing and the cradle may be due to the fact that this wobble (oscillation) may be loosening the screws over time.

There are still a number of solutions that may combat this wobble, firstly, increasing guide rails on either side of the cradle may provide more support and restrict rotation in transit, reducing roll.

The circular profile of the guide rail may also allow for some yaw rotation, so a flat profile guide (like a BR12 flat rail) may provide a more stable transit for the cradle

Finally, the cradle material itself may be the cause of this wobble. MDF may be bending causing the axis of each arm to cyclically not be parallel with the axis of the guid rail. By using a more rigid material, such as milled aluminium. This wobble problem may be resolved.

As for the mentioned lower screw bearing, it was found that repeated stress on the screws holding the bearing to the MDF frame had caused a weakening of the screw's thread gripping onto the MDF. This problem should be resolved when using an aluminium frame with nuts capable of clamping onto a harder material (aluminium).