Mechatronics Lab. Gearboxes and transmissions Report

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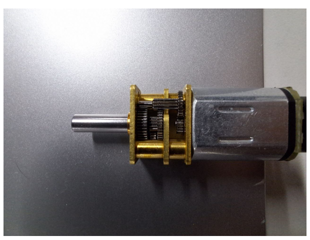
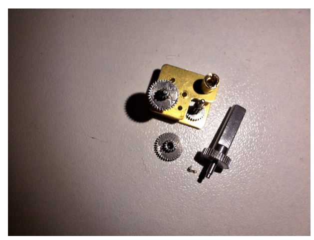
Objective of this lab: learn how to determine gear ratio of the motor by 3 different way.

0.1 Analytical solution

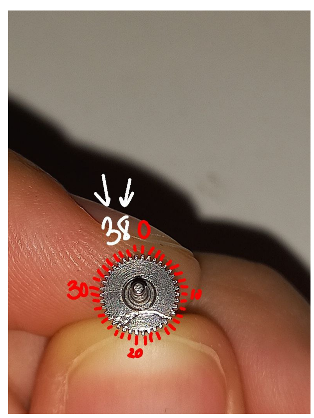


(a) Motor disassembly 1



(b) Motor disassembly 2

(c) Motor disassembly 3



(d) Teeth calculations approach

Figure 1: Overview of motor disassembly and teeth calculations

Method: We disassembled the motor and calculated the number of teeth in each gear.

The gearbox diagram looks like this:

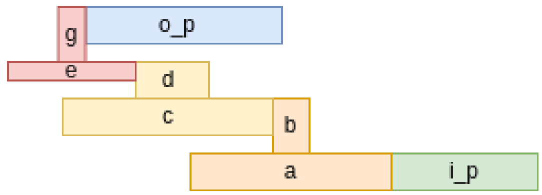


Figure 2: Gearboxes diagram

with the corresponding number of teeth for each gear:

$$i_p = 20, \quad a = 27, \quad b = 10, \quad c = 37, \quad d = 13, \quad e = 35, \quad f = 10, \quad o_p = 38$$

Considering that

$$GR = \frac{\text{num\_teeth\_driver}}{\text{num\_teeth\_follower}},$$

we can calculate the final gear ratio for our gear mechanism:

$$\frac{i_p}{a} \cdot \frac{b}{c} \cdot \frac{d}{e} \cdot \frac{f}{o_p} = \frac{20}{27} \cdot \frac{10}{37} \cdot \frac{13}{35} \cdot \frac{10}{38} \approx 0.01957$$

or approximately 1 : 50.

0.2 Experimental solution

Via this approach, we will rotate the motor, calculate the rotor's velocity, end-effector's velocity (found with the use of encoder) and define the gear ratio as the ratio of these values.

0.2.1 Experimental Setup

For the experiment we made a stand, which consisted of the following components:

- magnetic encoder AS5600
- Arduino Nano
- DC motor with Hall sensor
- self-made fixator for motor and enocoder

The assembly looks like this.

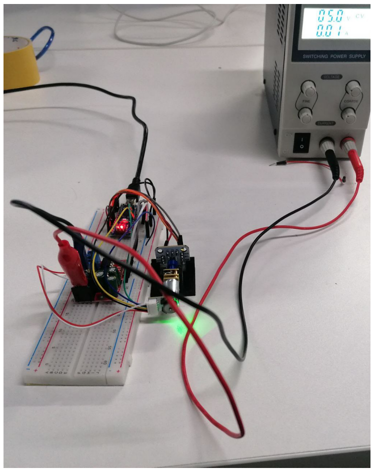


Figure 3: Motor connection scheme

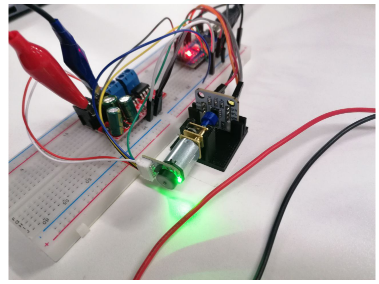


Figure 4: Motor connection scheme

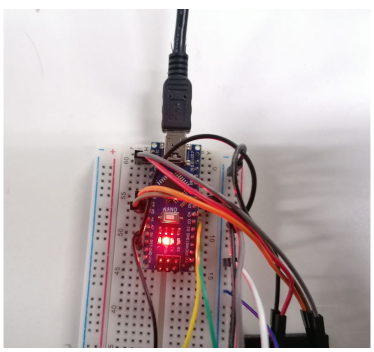


Figure 5: Motor connection scheme

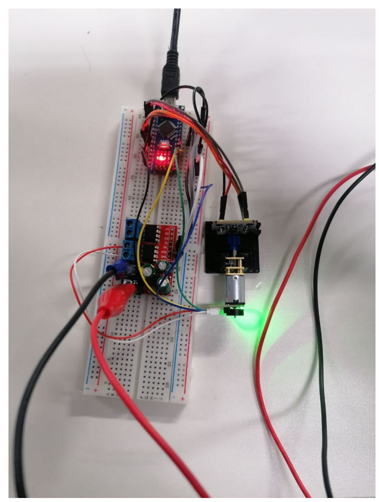


Figure 6: Motor connection scheme

The idea behind the motor fixation mechanism is the following: the magnetic encoder is attached to the stand with the motor fixed in front of it. This setup ensures that as the rotor rotates, it affects the magnetic chip of the encoder.

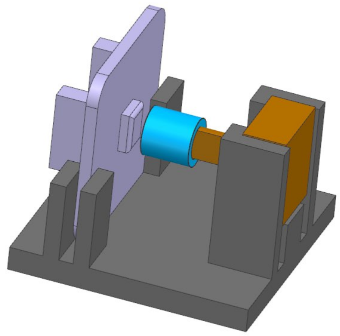


Figure 7: Motor fixation. View 1

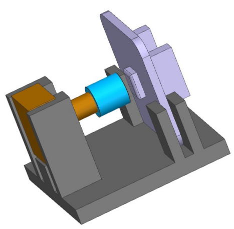


Figure 8: Motor fixation. View 2

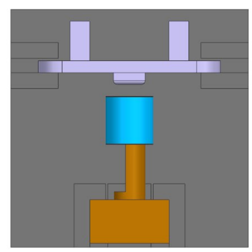


Figure 9: Motor fixation. View 3

0.2.2 Code

We used Arduino Nano as a hardware component, and we used Arduino IDE for coding.

We used this open-source library (click) for reading data from the encoder AS5600.

You can find our code in our repository (click).

The idea was to calculate the velocity of the motor's rotor and the velocity of the end-effector. The ratio between these values will give us the gear ratio.

Rotor's velocity calculation

We calculate the motor's rotor position with the following function.

```
void updateEncoder() {
    int MSB = digitalRead(C1); // MSB = most significant bit
    int LSB = digitalRead(C2); // LSB = least significant bit
```

```
    int encoded = (MSB << 1) | LSB; // converting the 2 pin value to a single number
    int sum = (lastEncoded << 2) | encoded; // adding it to the previous encoded value

    if (sum == 0b1101 || sum == 0b0100 || sum == 0b0010 || sum == 0b1011) encoderValue--;
    if (sum == 0b1110 || sum == 0b0111 || sum == 0b0001 || sum == 0b1000) encoderValue++;

    lastEncoded = encoded; // store this value for next time
}
```

To calculate the rotor's velocity, we divide the change in position by the time difference.

The plot of encoder's position for a random time interval looks like this.

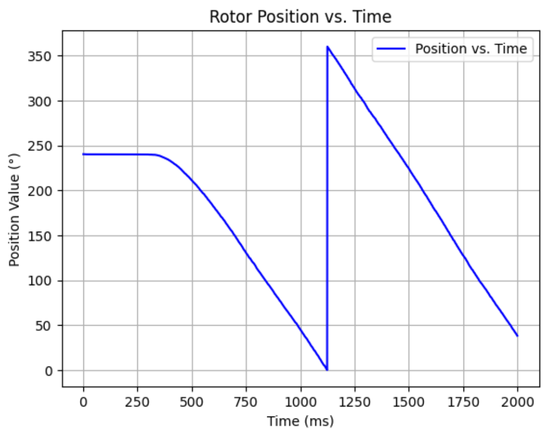


Figure 10: Motor characteristics

End-effector's velocity calculation

To find the end-effector velocity, we can read the values from the magnetic encoder and divide the change in values by the time difference.

We read the raw data from the encoder with the use of the library mentioned above.

To calculate the position, we used this formula:

$$\text{angle\_val\_pos} = \frac{\text{raw\_angle\_val} \times 360}{\text{CPR}}$$

This corresponds to the following function in our code.

```
float convertRotorRawAngleToDegrees(long newAngle)
{
  float retVal = newAngle * 360 / 28;
  return retVal;
}
```

The CPR (Counts Per Revolution) reflects the total number of discrete steps for a full 360-degree rotation.

$$\text{CPR} = 7\,\text{PPR} \times 4\,\text{phases} = 28\,\text{counts per revolution}$$

We found PPR (7) in the documentation, and the factor of 4 comes from using a 4-phase encoder.

Gear ratio calculation

We calculate both velocities in the Arduino program, calculate the velocities and their ratio (gear ratio) and display them in the terminal in Arduino IDE.

The example of output looks like this:

```
Angle Rot: 4547.99  Delta Rot: -3.78 degrees,  Velocity Rot: -0.25 degrees/second
Angle out: 326.51   Delta out: -33.69 degrees, Velocity out: -12.78 degrees/second, Gear rat

Angle Rot: 4544.21  Delta Rot: -3.78 degrees,  Velocity Rot: -0.25 degrees/second
Angle out: 314.65   Delta out: -33.87 degrees, Velocity out: -12.79 degrees/second,
Gear ratio: 51.16

Angle Rot: 4540.43  Delta Rot: -3.78 degrees,  Velocity Rot: -0.27 degrees/second
Angle out: 302.87   Delta out: -33.78 degrees, Velocity out: -12.84 degrees/second,
Gear ratio: 47.56
```

0.2.3 Results

As a result of our experiments, we got the gear ratio ≈ 50, the same as we calculated analytically (1:50).

0.3 Determining the gear ratio from the documentation

We do not know the exact parameters of the motor, except for the voltage, which is $V = 12\,\text{V}$.

For this type of motor, we can analyze its characteristics:

DC 12V								
Reduction ratio	10	30	50	100	150	210	298	380
No load current (MA)	≤75	≤75	≤75	≤75	≤75	≤75	≤75	≤75
No load speed (RPM)	3000	1000	600	300	200	140	100	78
Rated torque (g.cm)	0.2	0.6	1.0	200	3.0	340	3.0	3.0
Rated speed (RPM)	2300	770	460	230	150	100	77	160
Rated current(A)	≤0.3	≤0.3	≤0.3	≤0.3	≤0.3	≤0.3	≤0.3	≤0.3
Maximum torque(kg.cm)	0.2	0.48	0.8	1.6	2.4	3.4	3.4	3.4
Stall current(A)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Figure 11: Motor characteristics

Additionally, we can see that there is a gear ratio that we calculated (50), which suggests that our calculation is likely correct.

1 Results

For this lab, we used three different methods to calculate the gear ratio of the given motor. Although the official documentation did not provide this information directly, we conducted experiments with the motor and disassembled it to complete the task. Both analytical and experimental approaches yielded approximately the same result. We then compared this result with the possible values from the datasheet.

Thus, the gear ratio is 1:50.