Indian Institute of Technology Gandhinagar

6 Step Geneva Wheel Mechanism

ME 352 : Mechanical Engineering Lab 2

Lab Report - Experiment 8

Group - 8

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Authors

Pavidhar Jain - 20110136

Priya Gupta - 20110147

Rahul R Pai - 20110155

Raj Krish Dipakkumar - 20110160

Under The Guidance Of

Prof. Jayaprakash

1. OBJECTIVE :

Obtain a physical model which rotates the indexing wheel with 6 steps and an index and dwell time of 10 s and 20 s, respectively using Geneva Wheel mechanism.

2. EXPERIMENTAL DESIGN :

2.1 Geneva wheel and driver wheel

We had to design a Geneva wheel with 6 steps such that it gives one full 360-degree rotation by 360/6 = 6 rotations of the constantly rotating disk called the driver. This is achieved by the Geneva disk with 6 slots and cutouts for the driver to rotate.

The driver has a pin responsible for rotating the geneva wheel and also a concentric shoulder to lock the wheel during the rest periods. We designed slots in the driver to fix the motor shaft in and rotate the driver.

A box was designed to support the mechanism and house the motor, arduino, and the motor driver.

2.2 Electrical connection

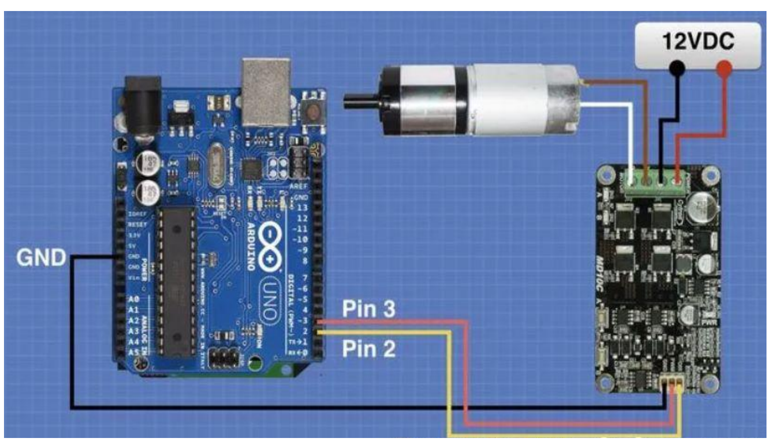


Figure 1 : Electrical circuit

The electric connections are made as shown in the diagram above. The md10c r3 motor driver can be used to control the speed and direction of the high torque motor.

An SMPS is used to convert 220V AC current into the desired 12V DC voltage.

Arduino Code:

```
// Pin Definition
// PWM is connected to pin 3.
const int pinPwm = 3;
// DIR is connected to pin 2.
const int pinDir = 2;

// The setup routine runs once when you press reset.
void setup() {
  // Initialize the PWM and DIR pins as outputs.
  pinMode(pinPwm, OUTPUT);
  pinMode(pinDir, OUTPUT);
}

// The loop routine runs over and over again forever.
void loop() {
  analogWrite(pinPwm, 51);
}
```

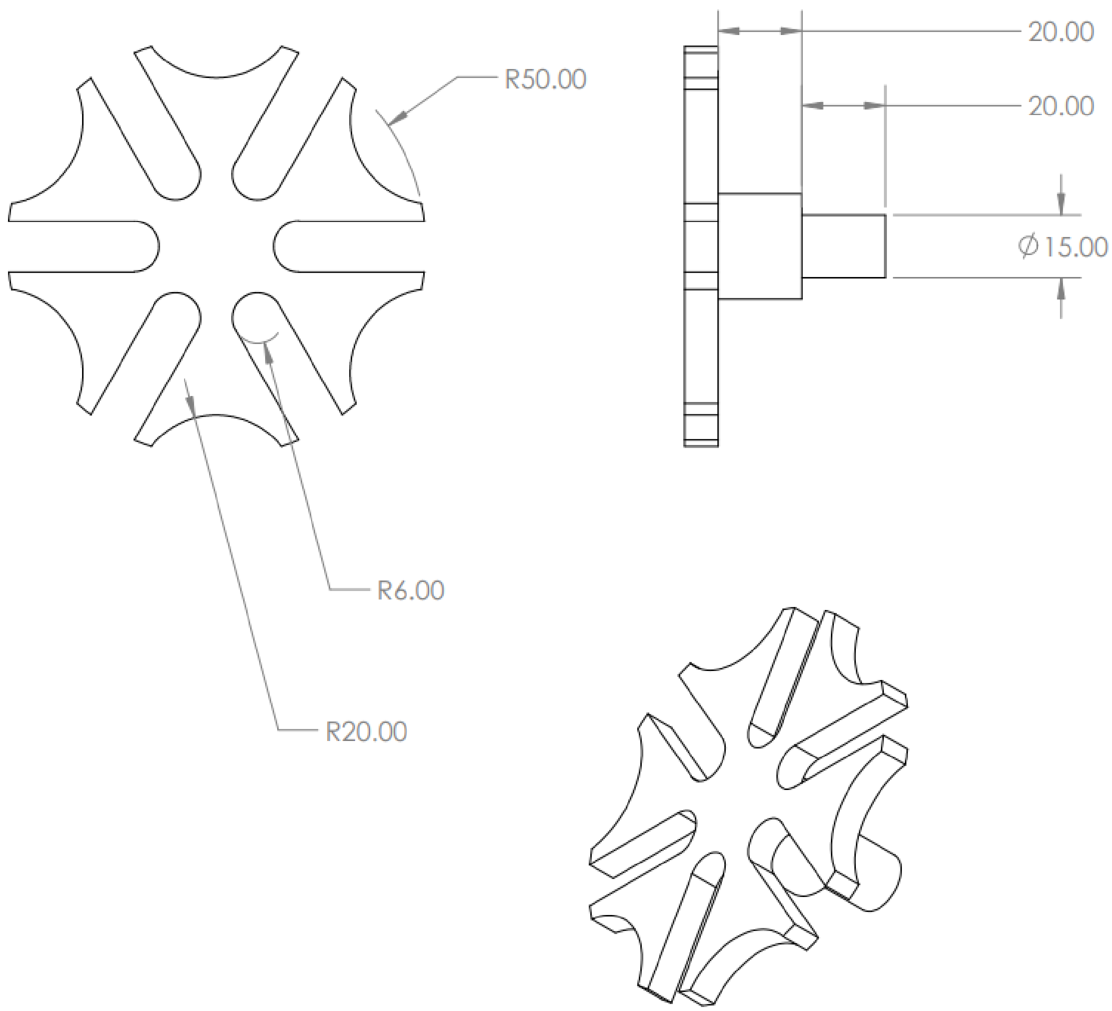
The PWM pin controls the speed of the motor while the DIR pin controls the direction. We can have any direction here, so we've left it at low.

The PWM pin can vary the power from 0 to 255 where 0 corresponds to 0% power and 255 corresponds to 100% power.

Since we have used a 12V 10 RPM motor, the motor works at 10 RPM at 255 pin power.

3. FABRICATION DETAILS

- **Geneva wheel and driver:** A 3-D model was created in Solidworks with appropriate dimensions. Then, we used 3-D printing for fabrication.
- **Box for holding electrical circuit:** A 3-D model was created with appropriate dimensions to hold the Geneva wheel, driver wheel and electrical circuit propeerly as shown in figure. We used laser cutting of acrylic and MDF sheets to get the desired box.



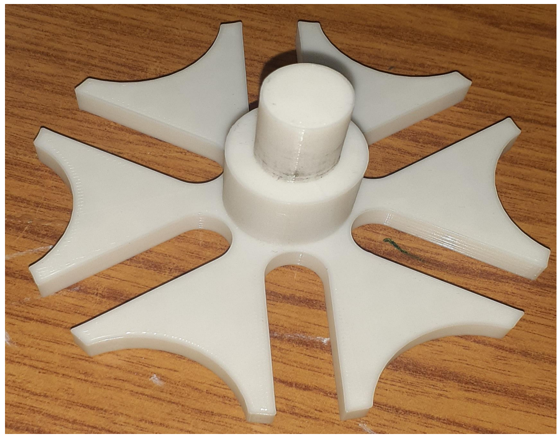


Figure 2 : 3-D printed Geneva wheel

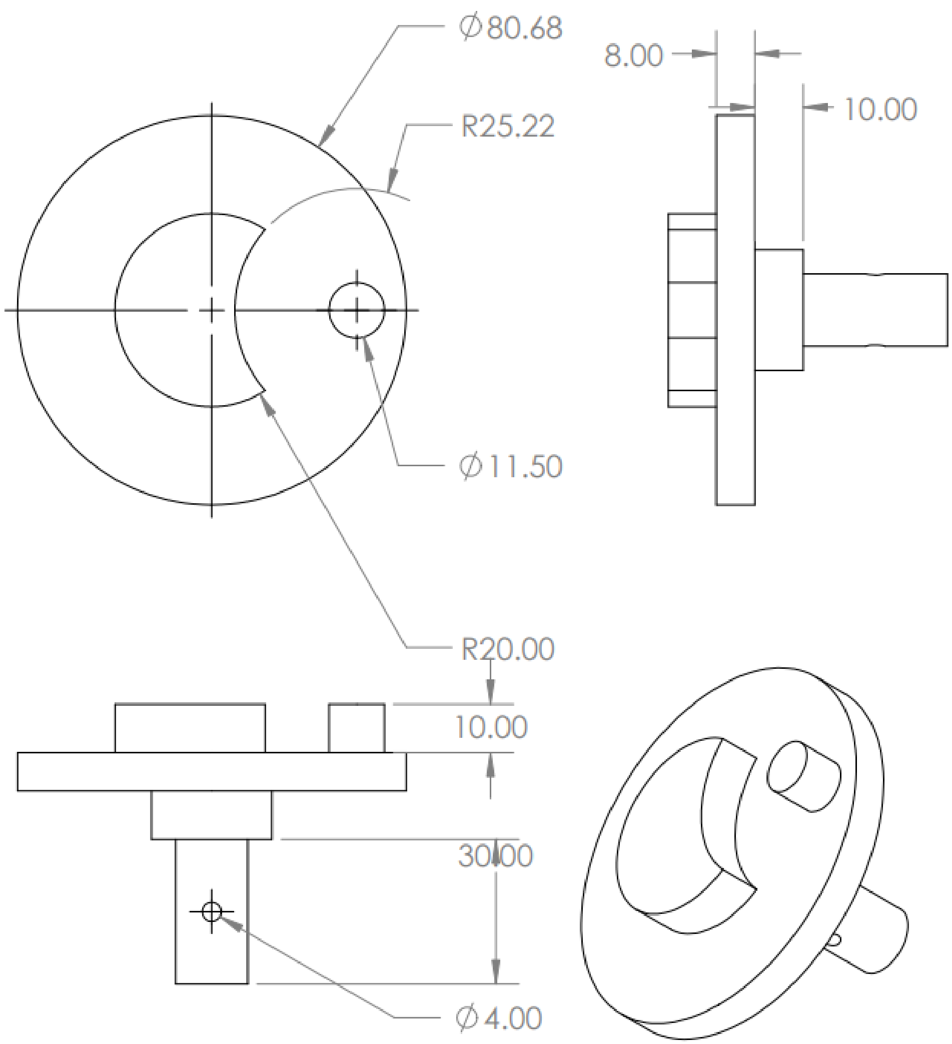


Figure 3 : 3-D printed driven wheel

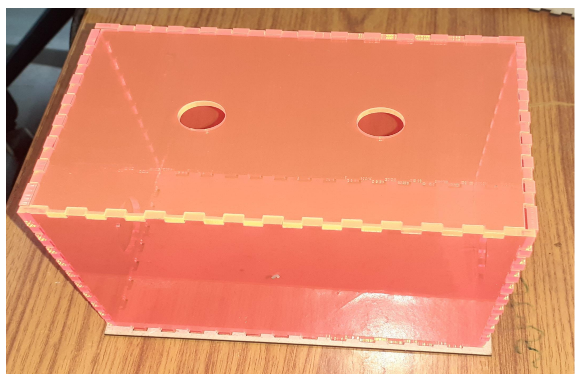


Figure 4 : Box made with acrylic and MDF sheets

4. MATHEMATICAL MODELLING AND ANALYSIS

It is a gear mechanism that translates a continuous rotation into an intermittent rotary motion. The mechanism comprises a single wheel driver with concentric shoulder and a driven component with a specific number of "equally" spaced slots. The driven member has slots engaged by a pin on the driving member. The driver pin can enter and exit the driven component "tangentially" due to the mechanism's special design. The concentric shoulder plate's function is to restrain the driven member's rotational motions, releasing it only when the driven member and the driver make contact. The parts of a standard six-step external Geneva mechanism are shown in figures.

The driver must rotate n times for each full rotation of the driven wheel, where n is the number of slots on the driven member. As a result, in an indexing procedure, the number of slots matches the number of stations. The minimum number of slots is three, while there is no limit on the highest number. However, Genevas, with more than 18 stations, is rarely deployed due to dimensional restrictions. Only a dwell period of more than 180° can be produced using conventional external Geneva procedures.

4.1 Index and Dwell period

The rotational orientation of the driven wheel is always "opposite" to the driver.

The "indexing" period begins when the driver pin first engages with one of the driven wheel's slots. When the pin completely disengages from the slot, this phase is over. The "dwell" period begins at the end of the index period and ends precisely with the driver pin's initial interaction with the "next" slot. The driven part can only spin during the index period when the driver is in constant angular motion.

The equation for index and dwell time in minutes can be expressed as:

$$\textbf{Index time,} \quad T_i = \frac{180 - (360/n)}{360 * N} \tag{1}$$

$$\textbf{Dwell time,} \quad T_d = \frac{180 + (360/n)}{360 * N} \tag{2}$$

where, n = number of slots

N = revolution per minute

In this report, 6 slot Geneva mechanism is described with index and dwell time of 10 seconds and 20 seconds respectively.

Here, n = 6

T_i = 10 s = ⅙ min

T_d = 20 s = ⅓ min

Using equation (1), we get N as:

$$10 = \frac{180 - (360/6)}{360 * N} \Rightarrow N = \frac{180 - (360/6)}{360\ (1/6)} = 2\ rpm$$

Using equation (2), we get dwell time at 2 rpm as:

$T_d = \frac{180 + (360/6)}{360\ (2)} = 1/3\ min$ which satisfied the given condition.

So, we need to rotate the driver at **2 rev/min (RPM)** to get the desired index and dwell time.

So as mentioned above, we need to control the power to the motor to get 2 RPM.

As the maximum speed of the motor is 10 RPM,

Required Pin Power $= \frac{2}{10} * 255 = 51.$

4.2 Nomenclature

O_1 = center of the driver

O_2 = center of the driven wheel

n = number of slots = 6

β_o = initial angular orientation of the driven wheel where the driver's pin start moving along the slot(always same for the considered case)

$= \frac{360^o}{2n} = 30^o$

α_o = initial angular orientation of the driver where the driver's pin start moving along the slot(always same for the considered case)

β = general angular orientation of the driven wheel

α = general angular orientation of the driver

$C = O_1O_2$ = distance between center of driver and driven wheel

R_{gw} = radius of the driven wheel

R_{drv} = radius of the driver

R_p = radius of the driving pin

r = active length of the radius of the driven wheel

γ = locking angle of driver $= \frac{180^o(6+2)}{6} = 240^o$

R_l = radius of the locking disc $= R_{drv} - 2\,R_p$

4.3 Mathematical modelling of Geneva wheel motion

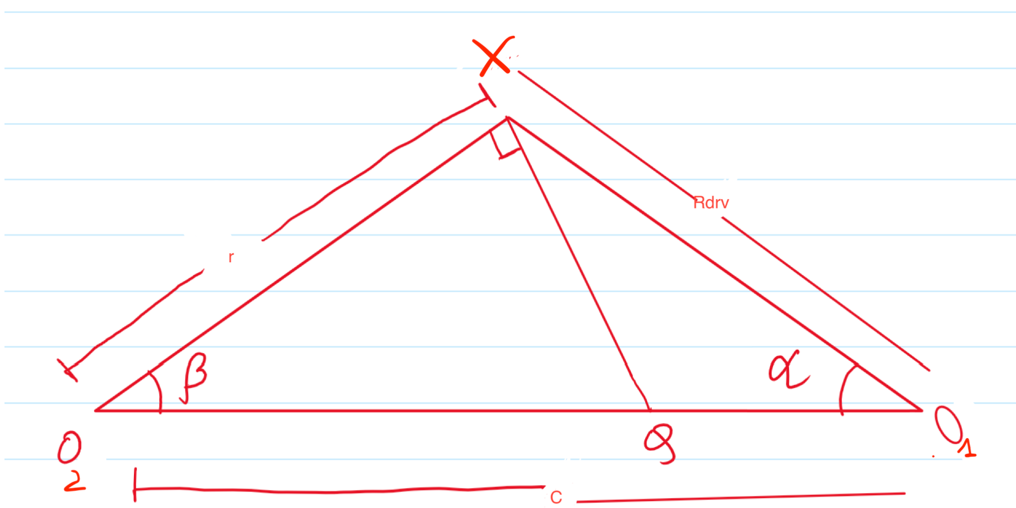


Figure 5 : Intermediate position of driver and driven wheel

Let ω_1 = angular velocity of the driver and ω_2 = angular velocity of the driven wheel. The angular displacement of driven wheel(β) changes in a non-uniform way when α changes uniformly.

Figure shows an arbitrary position of the driver and driven wheel of an external Geneva mechanism. Here, XQ represents a general position of the common normal intersected with O_1O_2.

From figure 5, we have:

$$\frac{sin\beta}{R_{drv}} = \frac{sin\alpha}{r} \Rightarrow sin\beta = \frac{R_{drv} \cdot sin\alpha}{r} \quad (4)$$

$$r = (C^2 + R_{drv}^2 - 2CR_{drv}.cos\alpha)^{1/2} \quad (5)$$

Also, $1 + cot^2\beta = cosec^2\beta$

$$\Rightarrow \frac{1}{tan^2\beta} = \frac{1}{sin^2\beta} - 1 \quad (6)$$

$$sin^2\alpha + cos^2\alpha = 1 \quad (7)$$

Using equation (4) and (5), we get:

$$\frac{1}{tan^2\beta} = \frac{r^2}{R_{drv}^2 sin^2\alpha} - 1 \Rightarrow \frac{r^2 - R_{drv}^2 sin^2\alpha}{R_{drv}^2 sin^2\alpha}$$

$$\Rightarrow tan^2\beta = \frac{R_{drv}^2 sin^2\alpha}{r^2 - R_{drv}^2 sin^2\alpha} \quad (8)$$

Using equation (5) and (8), we get:

$$tan^2\beta = \frac{R_{drv}^2 sin^2\alpha}{C^2 + R_{drv}^2 - 2CR_{drv}.cos\alpha - R_{drv}^2 sin^2\alpha}$$

$$\Rightarrow tan^2\beta = \frac{R_{drv}^2 sin^2\alpha}{C^2 - 2CR_{drv}.cos\alpha + R_{drv}^2 - R_{drv}^2 sin^2\alpha} = \frac{R_{drv}^2 sin^2\alpha}{C^2 - 2CR_{drv}.cos\alpha + R_{drv}^2(1 - sin^2\alpha)} \quad (9)$$

Using equation (7) and (9), we get:

$$tan^2\beta = \frac{R_{drv}^2 sin^2\alpha}{C^2 - 2CR_{drv}.cos\alpha + R_{drv}^2 - R_{drv}^2 sin^2\alpha} = \frac{R_{drv}^2 sin^2\alpha}{C^2 - 2CR_{drv}.cos\alpha + R_{drv}^2 cos^2\alpha} = \frac{R_{drv}^2 sin^2\alpha}{\left(C - R_{drv}.cos\alpha\right)^2}$$

$$\Rightarrow tan\beta = \frac{R_{drv} sin\alpha}{C - R_{drv} cos\alpha}$$

$$\Rightarrow \beta = tan^{-1}\left(\frac{R_{drv} sin\alpha}{C - R_{drv} cos\alpha}\right) \tag{10}$$

On differentiating equation (10) and manipulating it, we get:

$$\frac{d\beta}{dt} = \frac{\left(C/R_{drv}\right)cos\alpha - 1}{1 + \left(C/R_{drv}\right)^2 - 2\left(C/R_{drv}\right)cos\alpha} \cdot \frac{d\alpha}{dt}$$

$$\Rightarrow \omega_2 = \frac{\left(C/R_{drv}\right)cos\alpha - 1}{1 + \left(C/R_{drv}\right)^2 - 2\left(C/R_{drv}\right)cos\alpha}. \omega_1 \tag{11}$$

When the crank angle is zero($\alpha = 0$), the Geneva wheel is at its maximum speed, which is equal to:

$$\omega_2 = \frac{\left(C/R_{drv}\right) - 1}{1 + \left(C/R_{drv}\right)^2 - 2\left(C/R_{drv}\right)}. \omega_1 = \frac{R_{drv}}{C - R_{drv}}. \omega_1 \tag{12}$$

On differentiating equation (11) and manipulating it, we get:

$$\frac{d_2\beta}{dt^2} = \frac{\left(C/R_{drv}\right)sin\alpha\left(1 - \left(C/R_{drv}\right)^2\right)}{\left(1 + \left(C/R_{drv}\right)^2 - 2\left(C/R_{drv}\right)cos\alpha\right)^2}. \omega_1$$

$$\Rightarrow \alpha_2 = \frac{\left(C/R_{drv}\right)sin\alpha\left(1 - \left(C/R_{drv}\right)^2\right)}{\left(1 + \left(C/R_{drv}\right)^2 - 2\left(C/R_{drv}\right)cos\alpha\right)^2}. \omega_1 \tag{13}$$

5. COMPARISON OF EXPERIMENTAL AND THEORETICAL RESULTS

Rpm	Total Rotation of Geneva Driver	Theoretical Time (s)	Experimental Time (s)	Error (%)
2	10	300	297	1
2	20	600	593	1.167

6. RESULTS AND DISCUSSIONS:

The geneva wheel with the required dwell and index time of 20 seconds and 10 seconds was manufactured, within a reasonable error limit.

Figure 6 : Final set-up

7. **REASONS FOR MISMATCHING**:

- Human error (Error in time measurement)
- Dimensional inaccuracy
- Friction
- Inaccuracy in code
- Improper fit
- Material

8. FUTURE SCOPE

- Multiple operation in single stroke
- Small industry as it is easily available in small sizes and less expensive
- Geneva operator roller conveyor

9. REFERENCES

- https://iiste.org/Journals/index.php/ISDE/article/viewFile/28790/29553
- https://www.festi.info/boxes.py/BasedBox
- Geneva Mechanism Animation - YouTube
- https://digitalcommons.njit.edu/cgi/viewcontent.cgi?article=2239&context=theses

10. ACKNOWLEDGEMENT

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