University of Technology Sydney

Faculty of Engineering and IT

Smart Sensing Glove for Hand Pose Estimation using Inertial Measurement Units

A 12-credit-point Capstone Project submitted in partial fulfilment of the requirements for the degree of

Bachelor of Engineering (Honours) in Mechatronic Engineering Bachelor of Medical Science

By

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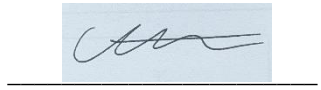
Abstract

Patient outcomes in post-stroke rehabilitation can be improved by the use of robotic-assisted mirror therapy. The UTS Rapido Exoglove project aims to develop a system to mirror the fine motor movements of one hand to the other, primarily for use in clinical rehabilitation purposes. This capstone project focuses on integrating a Data Glove, which tracks hand movements using inertial measurement units (IMUs), with a Power Glove, which replicates these movements through motor actuation. The project aimed to optimise the system for low latency, accuracy, and overall reliability. The completed system was tested and exhibited these attributes, showing extremely low latency. The accuracy of the system was unable to be tested as the Power Glove fingers were not available, but a methodology was proposed to that end for when the test should become possible. Reliability testing showed the Data Glove thumb produced unreliable data due to the positioning and securing of the IMUs on the glove. Addressing this sensor issue is crucial for the system's further development and practical application in a clinical environment. The system could also benefit from improvements in hardware integration by developing connectors for communication and power on the Data Glove as currently jumper wires are being used.

Statement of Originality

I, **Charkrit Atherton**, hereby declare that the work contained in this report, other than that specifically attributed to another source, is mine and has not been previously submitted, in whole or in part, to this or any other institution. I understand that should this declaration be found to be false, disciplinary action could be taken and penalties imposed in accordance with university policy and rules.

Date: 27 May, 2024



Acknowledgements

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I would also like to thank the students who have contributed to UTS Rapido's Exoglove Project up to this point, particularly Ren Nguyen and Julian Taffa, who were instrumental in providing support for the Data Glove and Power Glove.

Table of Contents

1 Introduction

1.1 Background

Stroke has a major impact on society, with 39 500 cases across Australia in the year of 2020 (AIHW, 2023), the equivalent of one stroke every 13 minutes. One common effect of stroke is impaired muscle movement and coordination, such as weakness (paresis) or paralysis (plegia) of an arm or hand (NINDS, 2023). Of patients with a paretic arm caused by stroke, 38% regain some coordination, and only 11.6% regain complete function (Kwakkel et al., 2003). These outcomes are poor and underscore the need for improved rehabilitation strategies.

Certain physical therapies have been shown to increase the chance and degree of limb mobility recovery after stroke. Studies have supported the treatment potential of robotically augmenting that physical therapy. Beom et al. (2016) used robotics to mirror the movements of the healthy arm to the paretic arm and found a significant improvement when using robotic augmentation. Schrader et al. (2022) conducted a similar study focused on hand and finger movement, though the improvement found was less clinically significant. Tran et al. (2016) proposed further avenues of research to take full advantage of neuroplasticity during rehabilitation by combining dopaminergic drugs with robotically augmented physical therapy.

This situation creates a demand for tools to facilitate research and practice of robotics-assisted rehabilitative physical therapy. This capstone aims to address this demand as part of UTS Rapido's Exoglove project, which proposes a system to mirror the fine motor movements of a subject's hand to the other hand. The system is proposed to consist of a 'Data Glove' with the ability to track the pose and position of a subject's hand and a 'Power Glove' with the ability to manipulate a subject's hand into various poses. My contribution focuses on the integration of these gloves and the performance of the complete system, aiming to achieve seamless and accurate mirroring of hand movements.

1.2 Problem Statement

The critical challenge of the Exoglove project is achieving seamless and accurate integration of the Data Glove and Power Glove to ensure precise and synchronised mirroring of fine motor hand movements for use in rehabilitation for improved outcomes.

1.3 Research Question

What are the critical factors influencing the successful integration of the Data Glove and Power Glove in the Exoglove system?

2 Project Scope

2.1 Project Aims and Objectives

This capstone work forms a part of UTS Rapido's Exoglove project. At this stage, the project has produced a Power Glove (PG) and a Data Glove (DG). The PG uses 5 motors to actuate the fingers on a wearer's hand. The DG uses 15 IMUs to track the position of the wearer's hand and calculate joint angles along the fingers. The aim of my contribution through this capstone is to complete the integration of the PG and DG to demonstrate the ability of the PG to reflect the movement and position of the DG.

To achieve this, I will:

1. Identify and address the critical factors influencing the successful integration of the Data Glove and Power Glove.
2. Develop and implement algorithms for real-time data transmission and processing between the gloves.
3. Evaluate the system's performance in terms of accuracy, responsiveness, and usability.
4. Optimize the integration to ensure seamless and synchronised operation of the gloves.

By addressing these objectives, the project aims to create a reliable and effective system for mirroring fine motor movements, contributing to the broader goal of improving robotics-assisted rehabilitative physical therapy.

2.2 Identifying Critical Factors

The success of the integration of the Exoglove system should be measured against several critical factors. These factors are:

- **Synchronisation and Low Latency:** Movements made by the DG must occur in the PG without a noticeable delay. Therefore, the system must achieve as close to real-time data transmission and processing as possible. This will involve optimising communication protocols and minimising processing time.
- **Accuracy:** The system must reproduce accurate and recognisable representations of hand poses. Accurate replication of hand movements ensures the system is effective for clinical use. This requires robust algorithms for data processing.
- **Reliability:** The system must consistently produce hand poses under varying conditions. This would involve both hardware durability and software stability and requires thorough testing to ensure reliability over time.
- **Usability:** All components, including all hardware and software, should integrate seamlessly. The overall system should be intuitive to set up and use. A user-friendly interface and straightforward setup process are essential for practical use. This necessitates including simple connectors and wiring diagrams.

The following methodology should proceed with these factors in mind when tackling the original problem of mirroring fine motor movements of the human hand. Understanding and focusing on these factors will create a robust and effective system and enhance the overall functionality and usability of the Exoglove.

3 Literature Review

3.1 Hand Pose Tracking

Current approaches to hand pose estimation conform to two methodologies: video motion capture (Cerveri et al., 2007) or sensors placed on the hand (Kortier et al., 2014; Mohammadi et al., 2016; Lin et al., 2020). The raw data collected from those methods is then processed to generate a suitable kinematic model of the hand.

All motion capture methods have notable disadvantages. They often have a lengthy calibration process and require a dedicated, often irremovable, space. Another drawback of the use of video capture is that the hand may become obscured from view, interrupting the system's ability to function continuously (Li et al., 2019). Some applications of this technology use multi-camera arrays (Cerveri et al., 2007), though this further complicates calibration and solidifies the need for a dedicated space. Therefore, sensor gloves are used much more commonly.

Several types of sensors have been used in sensor gloves for hand pose estimation. The most common sensors used are flex sensors (Li et al., 2018) and inertial measurement units (IMU) (Lin et al., 2020). Flex sensors generate much greater errors than IMU-based gloves. The mean absolute error of the flex-sensor-based glove used by Li et al. (2018) was 6.35 ± 0.92°, while that of the IMU-based glove used by Kortier et al. (2014) was <2° ± 0.6°. Considering that a <5° error is required to be considered acceptable for clinical use (Kim et al., 2016; Simone & Kamper, 2005), only IMU-based sensorised gloves are suitable.

3.2 Hand-Actuating Gloves

There are a wide variety of gloves designed to manipulate the hand into various poses. Each is adapted to a specific use case with unique compromises between power, efficiency, weight, precision, and degrees of freedom. The designs could be categorised by the method of actuation used, which includes motorised systems, pneumatics, hydraulics, and passive unpowered systems. A very few examples of this very varied sector are represented here.

Popov et al. (2017) and Gerez et al. (2019) present two examples of soft glove, tendon driven exogloves. These gloves support the wearer's grip strength and hand movements by tensioning cables attached to the soft glove. They generally provide very high forces with a very low mass glove. The glove developed by Gerez et al. (2019) could develop a peak of 48N while only weighing 335g. This however comes at the compromise of degrees of freedom, either affecting fewer fingers or sacrificing or only supporting flexion and not extension.

Two direct linear-actuator-based gloves are exemplified by Hu et al. (2013) which developed an electric motor driven glove and Ryu et al. (2008) which developed a hydraulicly driven glove. These gloves provide much greater control and accuracy while sacrificing weight. Both gloves also sacrifice freedom of movement for the wearer's wrist to mount the actuators. These factors lead to these gloves being much more cumbersome than other options.

Passive unpowered systems have also been trialled in this space. Zhang et al. (2019) and Zhao et al. (2022) produced gloves which exemplify this. Using the body's own movement, mechanics, and kinetic energy. Both published works show an improvement in efficiency in the joints and movements studies.

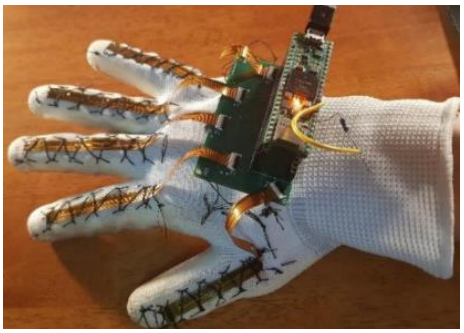
4 Methodology

4.1 Hardware Integration

4.1.1 Existing Hardware Description

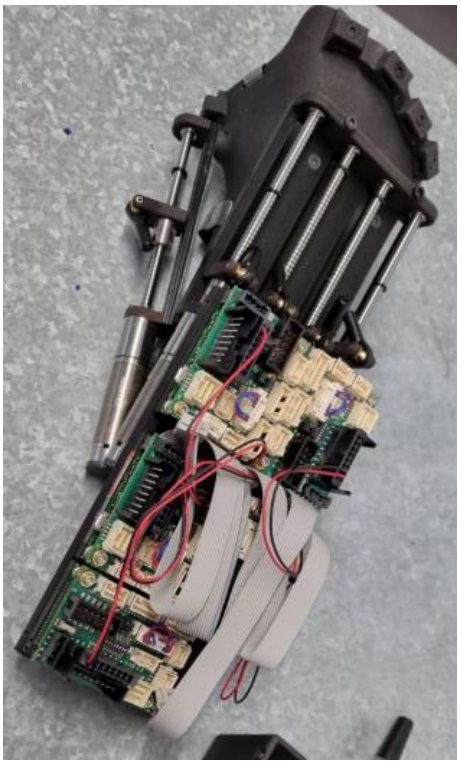
The current hardware consists of the Data Glove (DG), which is capable of measuring joint angles, and a Power Glove (PG), which is capable of actuating fingers to different positions. The following describes the state of the two gloves as of the beginning of this project to establish a baseline, which can be referenced later to understand the modifications and additions made.

The DG consists of a soft fabric glove, the top surface of which is affixed with control electronics and sensors. The electronics include a mainboard mounted on the back of the glove. Five flexible PCBs run from the mainboard out along the back of each of the five fingers. The flex PCBs are connected to the mainboard via surface-mount FPC connectors. All of the PCBs are affixed to the glove with stitching through holes in the PCB. A total of sixteen *LSM6DSV16XTR* 6-axis IMU sensors are positioned across the glove; the mainboard has one to track the position of the palm, and the flex PCBs have three each to track the inter-phalangeal joint angles. The mainboard contains a socket for an installed *Teensy 4.1* microcontroller. All of the IMUs are connected to the Teensy via SPI using traces along the PCBs. Note that a 62-ohm resistor has been externally added in series to the SPI clock line which reportedly aids communication stability (Nguyen R, 2023).

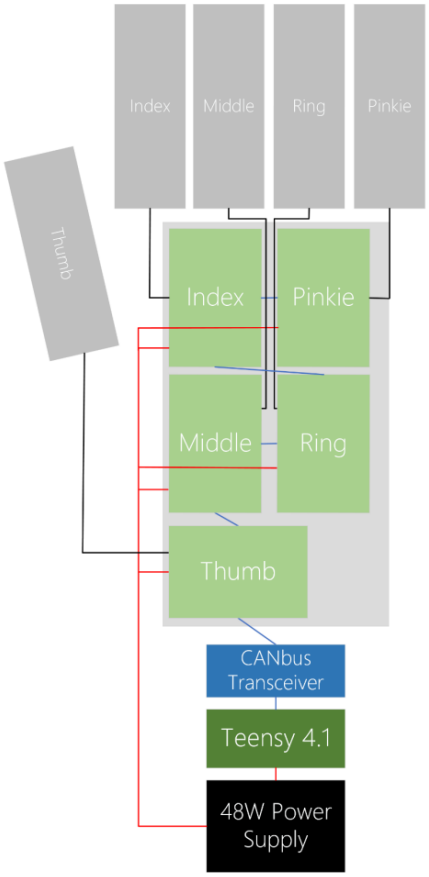


(Fig.1) DG as of the start of this Project.

The PG consists of a 3D-printed gauntlet with foam padding and 4elcro straps. Positioned on the gauntlet are five *Maxon DCX16L GB KL 36V* motors equipped with *Maxon ENX16 EASY 1024IMP* encoders with *Maxon GP 16 S* lead screw drives. The motor assemblies are wired to five *Maxon EPOS4 Compact 24/1.5 CAN* motor controllers within an enclosure at the base of the gauntlet. The motor controllers are daisy-chained to a single CAN network, which terminates at a break-out board with an *SN65HVD230* CAN transceiver. This CAN breakout board is connected to a *Teensy 4.1* microcontroller.



(Fig.2) PG as of the start of this project.



(Fig.3) PG hardware component block diagram. (Taffa J, 2023)

4.1.2 Modifications and Additions

Controller

A microcontroller will be required in the integrated system to communicate with the various components and perform data processing. The standalone DG and PG both currently use their own *Teensy 4.1* development boards. Given that the Teensy controllers have been demonstrated to work with both gloves, the integration will proceed with using the same microcontroller. This aims to enhance the efficiency of system integration and streamline the process by using the existing and proven components.

To streamline the hardware architecture, the decision was made to eliminate the Teensy dedicated to the PG and retain the Teensy on the DG. The Teensy on the DG was kept as it is a key component of the DG mainboard. It is also better positioned to maintain shorter SPI traces to the IMUs while leveraging the longer range of CAN communication to the PG. This consolidation simplifies the hardware architecture, allowing easier synchronisation and lower latency.

Communication with DG (SPI)

There were no changes to the hardware architecture of the communication with the DG IMUs. There was no need to change as we are retaining the Teensy 4.1 microcontroller in the DG's mainboard socket. The system will continue to use the SPI bus on the DG mainboard and flex PCBs. The SPI bus uses the MOSI and MISO pins 11 and 12 on the teensy, respectively. Further, pin 13 will be used for the serial clock to synchronise communications.

All of these connections are made through the DG mainboard socket to traces on the mainboard PCB and flex PCBs.

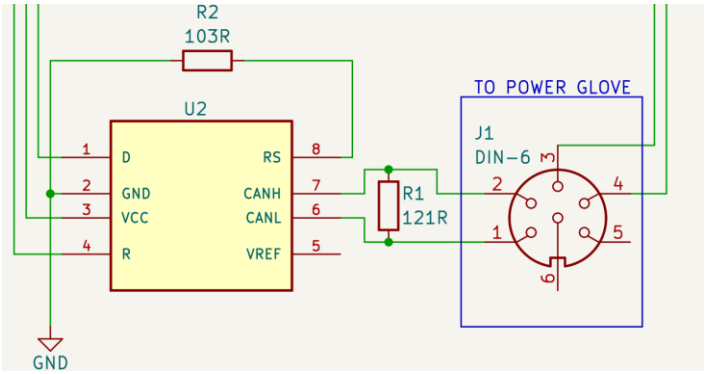
Item	Pin
MOSI	11
MISO	12
Clock	13
Chip Select	0, 2, 3, 4, 8, 9, 10, 16, 17, 18, 27, 28, 29, 36, 37, 38

(Fig.4) All teensy 4.1 pins utilised by the SPI bus.

Communication with PG (CAN)

The *SN65HVD230* CAN transceiver previously included as part of the PG standalone system was coopted for use in the integrated Exoglove system. This CAN transceiver was used to develop software to control the motors and has already demonstrated functionality. Retaining the same components will make integration much more streamlined. This transceiver was connected to the teensy via the 3.3V output and GND pins for power and pins 22 and 23 for communication.

These connections are made from the teensy to the PG via a set of temporary jumper wires to a circular DIN-6 connector. It is recommended, in future, to modify the DG mainboard by finding and fitting a more permanent solution on the DG mainboard.



(Fig.5) The power glove is connected to the rest of the system via a DIN-6 circular connector. The CAN lines run from the transceiver to this connector as seen in the extract from the wiring diagram (Appendix B).

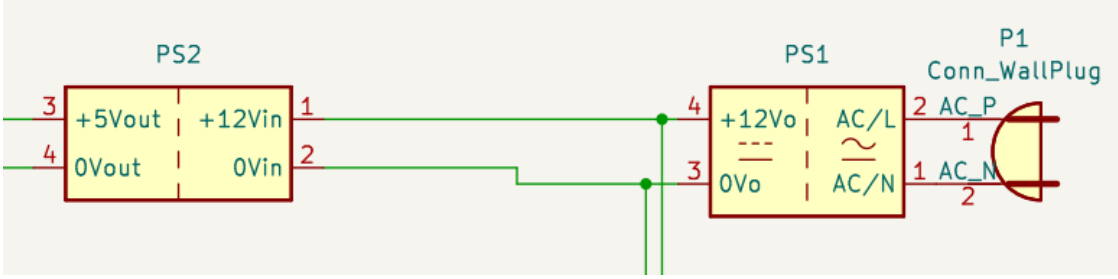
Power

All electrical components require power to operate. These system components have a variety of power requirements.

Item	Part Number	Qty	Rated Voltage (V)	Nominal Current (mA)
Motor	DCL16L GB KL 36V	5	12	1240
Motor Controller	EPOS4 Compact 12/1.5	5	12	n/a
Encoder	ENX16 EASY 1012IMP	5	12	23
Teensy 4.1	Teensy 4.1	1	5	100
CAN Transceiver	SN65HVD230	1	3.3	0.6
IMU	LSM6DSV16X	16	3.3	0.015

(Fig.6) All electrical components of the Exoglove system and their nominal power requirements.

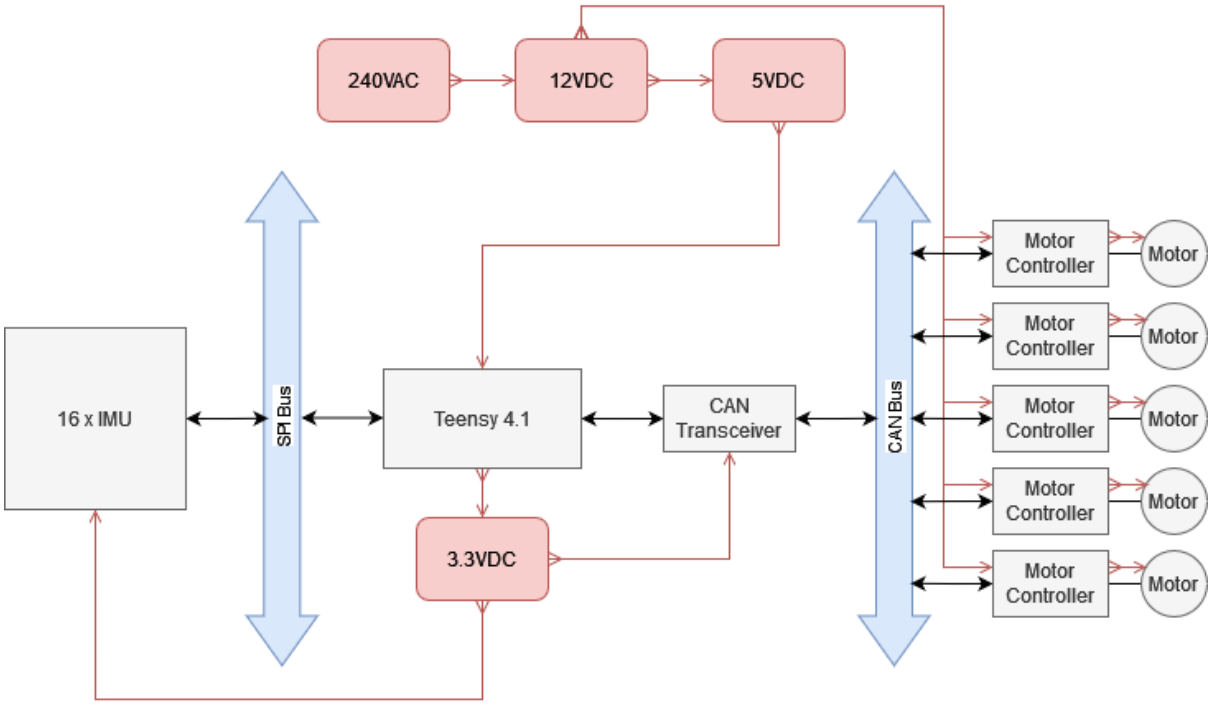
The 12V devices will be supplied by a 240VAC 1.5A to 12VDC 4A power supply model number A481-1204000S for standard Australian wall sockets. The 12V power supply will then be stepped down to 5V using an automotive voltage regulator and used to power the Teensy 4.1 via the Vin and GND pins. However, throughout development, this 5V supply is disconnected in favour of supplying power to the Teensy via USB. This reduces the risk of PC and USB bus damage while developing and testing software. Finally, power to the 3.3V devices is supplied by the Teensy 4.1 using its onboard 3.3V output pins. This last step utilises the Teensy's onboard voltage regulator.



(Fig.7) Extract from the wiring diagram (Appendix B) showing power stepping down from 240VAC to 12VDC and then to 5VDC.

4.1.3 Overall Integrated Exoglove Hardware Architecture

The following block diagram (Fig. 8) illustrates the overall hardware architecture of the integrated Exoglove system derived from the existing Data Glove and Power Glove. The figure shows the control electronics (i.e. the teensy 4.1 and CAN transceiver), and the various connections to the electronics components.



(Fig.8) Block diagram of Exoglove integrated hardware architecture. The lines in red are connections for power, and the lines in black are connections for communication and data.

4.2 Software Integration

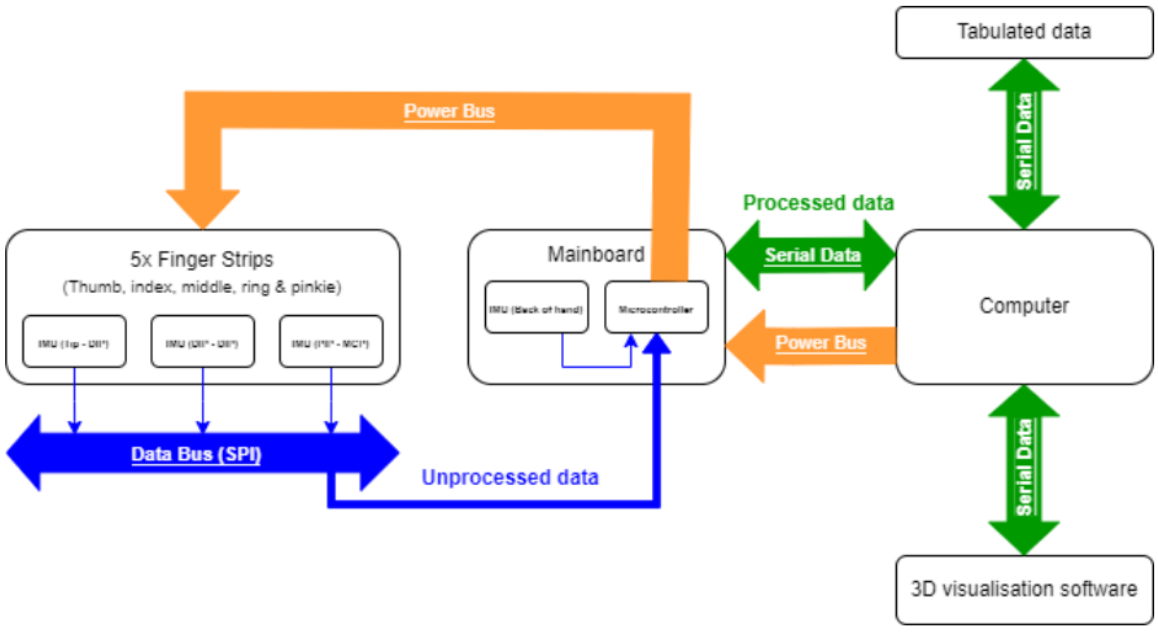
4.2.1 Existing Software Description

The DG and PG both have custom software programs written for them intended to run on the Teensy 4.1 controllers. Both gloves and their software are currently functional in demonstrating the intended capabilities. The following describes the state of the software of the gloves as separate standalone systems to establish a baseline to understand the steps made for integration.

The DG software is written in C++ in a Platform IO development environment. It utilises SPI communication to calibrate and collect data from the 16 IMUs. It then processes this data to produce the current pose of the palm and the angles of all metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints.

Two algorithms exist for processing IMU data into the hand pose and joint angle results. The first is the currently active algorithm using a quaternion representation of the pose of the IMU. A second inactive and effectively obsolete algorithm uses the IMU's gravity vector. (Nguyen R, 2023)

This joint angle data is temporarily stored in an array to be sent via a USB serial connection to a computer, which can receive the data and run applications to visualise the results. Two such visualisation applications currently exist, written in the Processing programming language. The first simply displays the angle values on the screen. The second draws a full kinematic model of the hand as a representation of the result from the DG.



(Fig.9) DG high-level system diagram. (Nguyen R, 2023)

The PG software is written in C++ in the Arduino IDE development environment. It utilises CAN communication to issue commands to the motor controllers. The program initialises the motors and then performs a homing procedure. The program then enters a demonstration mode, moving each motor back and forth between the limits of travel without hitting any physical stops in a sweeping/cyclone pattern. This demonstrates the simultaneous movement of all five motors across their entire range and the success of the homing procedure.

To achieve this, there are functions that issue a variety of commands to the motor controllers. The most relevant function for the integration of the exoglove system is a function that issues commands to move the motor to a specified encoder position.

4.2.2 Initial Integration

Firstly, the PG code was ported to the Platform IO environment from the Arduino IDE. This allows for much more flexibility in how the code is organised compared to the Arduino IDE's simplified but rigid structure. This also allowed for the DG and PG code to be merged into a single Platform IO project so that the code could be compiled and uploaded to a single Teensy controller as required by the hardware architecture.

Next, the code from the two gloves was reorganised into two libraries. One library retained all of the DG functions, while the other retained the PG functions. While this was primarily done to improve readability and maintainability, it was also the easiest way to separate variables with identical names into separate scopes, which would have otherwise caused compilation errors.

At this point in the integration, the two gloves demonstrated the same functional behaviour as before the integration, except now the entire system was being coordinated by the single Teensy 4.1 microcontroller. This demonstrated the success of the chosen integrated hardware architecture and validated the steps taken in software development thus far.

Steps can be taken at this point to take the measured joint angles from the DG and convert them to commands to move the PG.

4.2.3 Processing Joint Angle to Motor Position

Approach

Algorithms were required to process the joint angle data provided by the DG into motor position commands to be sent to the PG. The following reasoning explains the approach taken to do this.

It can be observed that the finger position is mainly dependent on the pose of two joints, the MCP and PIP. The DIP has much less effect, and most people cannot move this joint independently of the others. Therefore, only the MCP and PIP are considered.

Four different methods of using these angles are available:

1. Use only the MCP joint.
2. Use only the PIP joint.
3. Average the MCP and PIP joints.
4. Take the larger of the MCP and PIP joints.

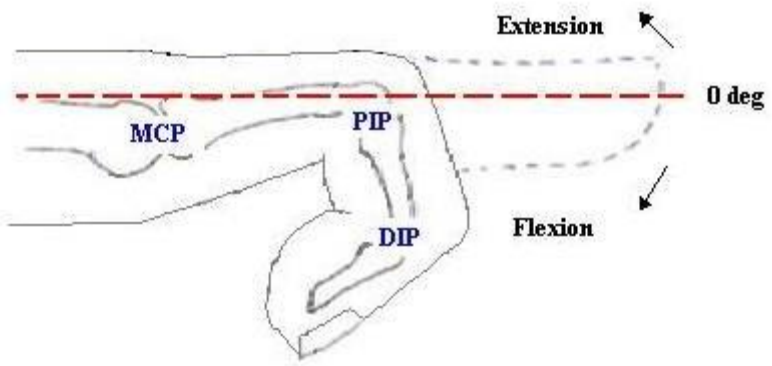
All four methods remain available for experimentation and demonstration to determine later which produces the most representative and accurate motion from the PG. However, the second method was chosen for this project as the PIP joint was considered the most consequential to finger position.

This processed finger joint angle data can then be used to formulate a command to send to the corresponding PG motor. The finger is converted to a ratio, with 0 being the maximum extension and 1 being the maximum flexion. The motor is then commanded to move to the same ratio of total travel.

This process aims to be implemented in software to run on the Teensy 4.1 microcontroller to reflect the pose of the DG to the PG.

Normalising Finger Angle Data

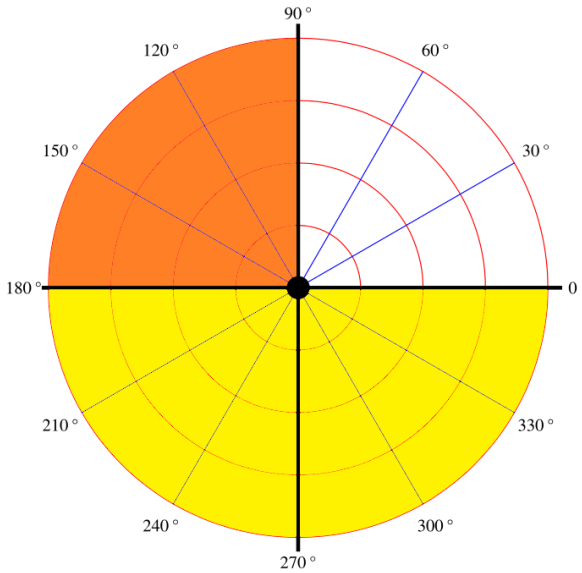
The DG produces values between 0° and 360°, with 0° corresponding to a straight finger and the positive direction being in the direction of finger flexion.



(Fig.10) Finger joint coordinate system example with the PIP joint.

However, the theoretical range of motion of a finger joint is generally from 0° to 90° (Jimon G, 2014). This can be confirmed through some observations of the human hand. Also, the normal operational range of motion for the data glove was measured from 0° to 90°. Therefore, joint angles are first normalised to these values to prevent invalid values and simplify processing.

Any value 90° < angle < 180° is changed to 90°. Any value 0° < angle ≤ 180° is changed to 0°.



(Fig.11) The Range coloured in orange is normalised to 90°, and the range coloured in yellow is normalised to 0°. The uncoloured range includes all valid values that are unmodified

```
void normaliseJointAngle(float &angle) {
  if(angle > 180) {
    angle = 0;
  }
  else if(angle > 90) {
    angle = 90;
  }
}
```

(Fig.12) An excerpt of the code shows the function of normalising finger joint data.

Only the MCP and PIP joints undergo this process as they are the only joints being considered here. This process ensures that there are no invalid values and that the data is predictable from this point forward.

Move To Percentage Function

A new function was written to move the motor to a ratio of its total travel using an existing function, which drove the motor to a defined number of encoder steps.

It takes a motor node ID (**nodeID**) and a percentage (**percent**) as inputs. The function performs the following steps:

1. Validates that the percentage is within the range [0.0, 1.0]. If not, it returns false.
2. Calculates the target position (**pos**) by offsetting the motor's zero point by a proportion of its total travel distance (**motorTravel**), corresponding to the given percentage.
3. Calls **moveToPosition** with the calculated position to move the motor to the desired location.
4. Returns the result of the moveToPosition function, indicating the success of the movement.

```
bool PowerGlove::moveToPercentage(uint8_t nodeID, double percent) {
  if(percent < 0.0 || percent > 1.0) {
    return false;
  }
  int32_t pos = motorZeroPoint[nodeID] - static_cast<int32_t>(motorTravel * percent);
  bool r = moveToPosition(nodeID, pos);
  return r;
}
```

(Fig.13) An excerpt of the code shows the function written to move to the motor a ratio of the total travel.

Illustrative Case

Using the method of taking only the PIP joint. If the PIP joint is at 65°, this results in a flexion ratio of 0.7222. Therefore, the motor is sent to 0.7222 of the total travel. With the motor travel set to 135000 steps, the motor would be sent to 97 497 steps away from the zero point.

4.2.4 Smoothing and Filtering

The movement that results from this process can be unstable and jittery. The motor exhibits movement even when the DG is completely stationary on the desk. To alleviate this, a smoothing algorithm was introduced. Two algorithms were implemented: a simple moving average filter and an exponential moving average filter. The filters are applied to the finger angle ratio before it is used to calculate the motor position and send a command. Both filters remain implemented for further testing.

Simple Moving Average

A Simple Moving Average (SMA) filter is used to smooth short-term fluctuations and follow long-term trends in the data. It calculates the average of a specified range of past values. The SMA is uncomplicated and easy to implement. However, the Teensy platform has limited memory and limits the size of the window of values that can be used. Also, it may cause higher latency in the movement of the motor as it may lag behind the data due to the averaging.

$$SMA_k = \frac{1}{k} \sum_{i=n-k+1}^{n-1} x_i$$

(Fig.14) Simple Moving Average filter formula.

```cpp
double MovingAverage::next(double value) {
    if(isnan(value) || isinf(value)) {
        return value;
    }
    sum += value;
    window.push(value);
    if (window.size() > period) {
        sum -= window.front();
        window.pop();
    }
    return sum / (window.size() > 0 ? window.size() : 1);
}
```

(Fig.15) An excerpt of the code showing the implementation of the Simple Moving Average Filter.

Exponential Moving Average

An Exponential Moving Average (EMA) filter smooths short-term fluctuations while giving more weight to recent data points. The EMA applies a weighting to the most recent data point, which exponentially decreases as the data point gets older. The advantage of the EMA is that it is able to react faster to changes than the SMA filter. This should allow for a PG movement reacting to the DG with lower latency.

$\boldsymbol{EMA_t = \alpha * D_t + (1 - \alpha) * EMA_{t-1}}$	EMA_t = EMA at the current period D_t = most recent data point EMA_{t-1} = EMA at the previous period α = smoothing factor, can be estimated as $\alpha = \frac{2}{n+1}$ where n is the number of periods over which the EMA is calculated

(Fig.16) Exponential Moving Average filter formula.

```cpp
double ExponentialMovingAverage::next(double value) {
    if(isnan(value) || isinf(value)) {
        return value;
    }
    if(!init) {
        ema = value;
        init = true;
    } else {
        ema = alpha * value + (1-alpha) * ema;
    }
    return ;
}
```

(Fig.17) An excerpt of the code showing an implementation of the Exponential Moving Average Filter.

4.3 Methods for Testing and Validation

The following describes the processes used to test the integrated Exoglove implementation against the original aims for the system as outlined in the project scope; to demonstrate the ability of the PG to reflect the movement and position of the DG. The tests adhere to assessing the following critical factors defined in the project scope:

- **Synchronisation and Low Latency**
- **Accuracy**
- **Reliability**

4.3.1 Latency Testing

To test latency, we must consider the time between the initial input and the final output. In this case, the input is the joint angle of the finger measured by the DG in degrees, and the output is the final position of the PG motor measured in encoder pulses. Therefore, the test recorded these variables simultaneously over time. This data was plotted, and that plot was used to analyse the time difference between the input and the desired output.

4.3.2 Accuracy Testing

Accuracy refers to the accuracy and recognisability of the pose of the DG reflected in the PG. As of this project, the PG fingers are still being designed and developed. Hence, the PG cannot be observed to understand the accuracy of the system. However, the following method is proposed to test this accuracy when the fingers are fitted to the PG. Set the finger joints on the DG to a static angle and record this angle. Then, measure the corresponding finger angle on the PG. The difference between these angles can be used to analyse the accuracy of the Exoglove system.

4.3.3 Reliability Testing

The complete integrated system was powered on, and then each finger moved through the entire range of motion. The system was observed through this process and then powered off again. This process was repeated 5 times. The following functional criteria were assessed at each test to investigate the reliability of the system.

Item	Criteria
1	PG initialisation and homeseek process complete.
2	DG initialisation complete and data sent through USB Serial comms.
3	The motors on each PG finger move through the entire range of motion as the DG fingers are flexed and extended.
4	All motors on the PG move simultaneously through their entire range of motion as the DG makes a fist.

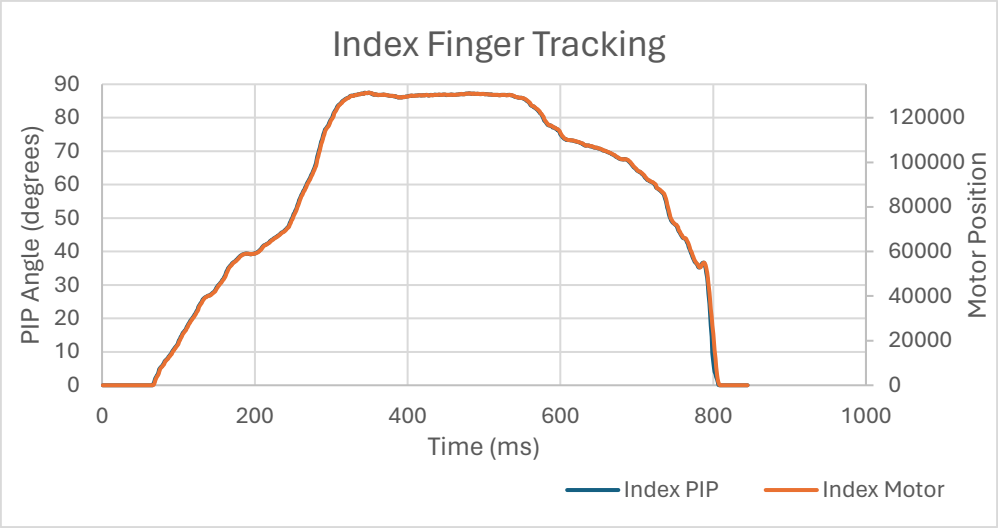
(Fig.18) Functional testing criteria used to assess the reliability of the Exoglove System.

5 Results

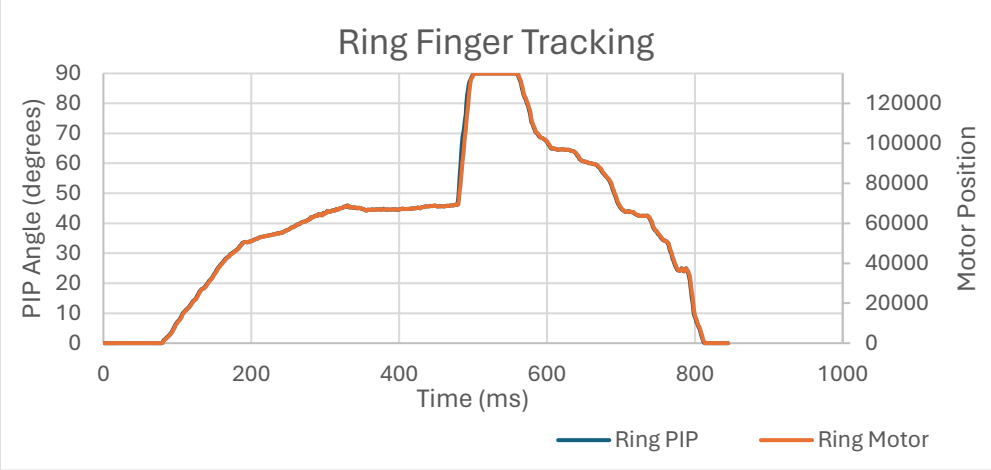
5.1 Latency

The output of the system, being the position of the PG motor, closely matched the input of the system, the position of the DG PIP finger joint across all fingers. The plots of the variables overlapped consistently, showing that there is very little latency and that the movements of the DG and PG are well synchronised (see Figure 19). There was a slight lag when the DG joint was moved at a faster rate; however, this latency was less than 50 ms (see Figure 20).

The Thumb was excluded from these results as the poor reliability of the values calculated by the DG made it impossible to achieve consistent results with this finger.



(Fig.19) Index finger latency test results. Note the lines overlap for the entire test for all movements.



(Fig.20) Ring finger latency test results. Note the steep section around 550 ms where the PG lags behind the DG very slightly.

See Appendix C and Appendix D for full results.

5.2 Accuracy

This test was not conducted as the PG fingers had not been completed at the time of writing, making this test impossible.

5.3 Reliability

The Exoglove system passed criteria 1 across all trials. The PG homeseek process is extremely robust and functional. Criteria 2 provided inconsistent results for the DG thumb, which occasionally produced “NaN” or other invalid values. Criteria 3 results were similar to Criteria 2 in that the thumb was often exhibiting invalid values. Hence, the motor would move unexpectedly towards the extremes and would not move smoothly between these extremes, while the other fingers exhibited normal movement. Criteria 4 was similar to Criteria 3, with identical thumb unreliability while the other fingers passed.

See Appendix E for full results.

6 Discussion

6.1 Latency

The results demonstrate a high level of synchronization between the DG and PG across most fingers, indicating effective system integration and minimal latency. The position of the PG motor closely matches the input from the DG PIP finger joints, as evidenced by the consistent overlap of the plotted variables (Appendix C). This suggests that the system can accurately mirror the fine motor movements of the user's hand with negligible delay.

The observed latency, which is less than 50 ms, is particularly notable for its minimal impact on the performance. This slight lag occurs primarily when the DG joint is moved at a faster rate, as seen in the steep section around 550 ms for the ring finger (Figure 20). Despite this minor delay, the system's response time remains within acceptable limits for real-time applications, ensuring that the movements of the PG and DG are well synchronized for practical clinical purposes.

The exclusion of the thumb from the results highlights an area for potential improvement. The unreliable values calculated by the DG for the thumb joint impede consistent performance for this finger. Future work should focus on enhancing the accuracy and reliability of the thumb's position data, which is crucial for achieving comprehensive hand movement replication.

In summary, the system's ability to synchronize the movements of the PG with the DG's input effectively demonstrates its potential for rehabilitative applications. The minor latency observed under rapid movements does not significantly detract from the overall performance. Further refinement, particularly regarding the thumb's data accuracy, will enhance the system's robustness and utility in real-world scenarios.

6.2 Accuracy

This test was not conducted as the PG fingers had not been completed at the time of writing, making this test impossible.

6.3 Reliability

The reliability testing of the integrated Exoglove system provided valuable insights into its performance and areas requiring improvement. The testing involved five trials, each consisting of powering on the system, moving each finger through its full range of motion, observing the system's behaviour, and then powering off. Four specific functional criteria were assessed during these trials to gauge the reliability of the system.

Criteria 1: PG Initialisation and Homeseek Process

The Exoglove system consistently passed the first criterion across all trials. This indicates that the Power Glove (PG) initialisation and homeseek process is highly robust and functional. The reliable completion of this process ensures that the system can correctly identify the starting positions of the motors, providing a stable foundation for subsequent movements.

Criteria 2: DG Initialisation and Data Transmission

The second criterion revealed inconsistencies in the Data Glove (DG) initialization and data transmission. Specifically, the DG thumb occasionally produced "NaN" (Not a Number) or other invalid values. This inconsistency suggests potential issues with the thumb sensor or its calibration. Since the rest of the DG fingers transmitted data correctly, it indicates that the problem is localized to the thumb. The position of the thumb IMUs seemed to affect this. The Proximal IMU was often not secured in the correct orientation on the glove, holding this IMU at the appropriate position and pose against the thumb alleviated this problem but was not always a reliable fix. Addressing this issue will be crucial for ensuring reliable and accurate data transmission from all DG sensors.

Criteria 3: PG Finger Movements in Response to DG Flexion and Extension

For the third criterion, the motors on each PG finger generally moved through their full range of motion in response to the flexion and extension of the corresponding DG fingers. However, the thumb again exhibited unreliable behaviour, often producing invalid values. This resulted in erratic movements, where the thumb motor would move unexpectedly towards its extreme positions rather than transitioning smoothly between them. This is caused by the unreliable data from thumb joints generated by the DG.

Criteria 4: PG Simultaneous Finger Movements During DG Fist Formation

The fourth criterion assessed the simultaneous movement of all PG fingers as the DG made a fist. Similar to the previous criteria, the thumb's unreliability persisted while the other fingers performed as expected. The thumb's erratic behaviour during fist formation is particularly concerning, as it impacts the system's ability to replicate natural hand movements accurately. Again, this defect of the thumb movement was caused by unreliable data from the DG.

Summary

The reliability testing of the integrated Exoglove system has provided critical insights into its performance and highlighted areas for improvement. The system consistently passed the initialisation and homeseek process, demonstrating a robust foundation for the PG. However, inconsistencies in the DG data, particularly with the thumb, revealed issues with sensor positioning. Addressing the thumb sensor's reliability is crucial for enhancing the overall system performance and achieving accurate replication of natural hand movements.

7 Conclusion

This project successfully integrated the DG and PG components of the Exoglove system, achieving a high degree of synchronisation and minimal latency in mirroring hand movements. The system's performance demonstrated the potential for practical applications in rehabilitative therapy, where accurate and timely replication of fine motor movements is essential. However, the reliability testing highlighted persistent issues with the DG thumb sensor, resulting in occasional data inaccuracies and erratic movements of the PG thumb. These inconsistencies underscore the need for further refinement in the sensor placement for the DG thumb. Addressing this will enhance the system’s effectiveness and reliability. Further, improvements could be made in the hardware integration between the DG and PG. The primary recommendation is to develop connectors for the DG for communication with the PG, replacing the current jumper wires to improve the system's usability.

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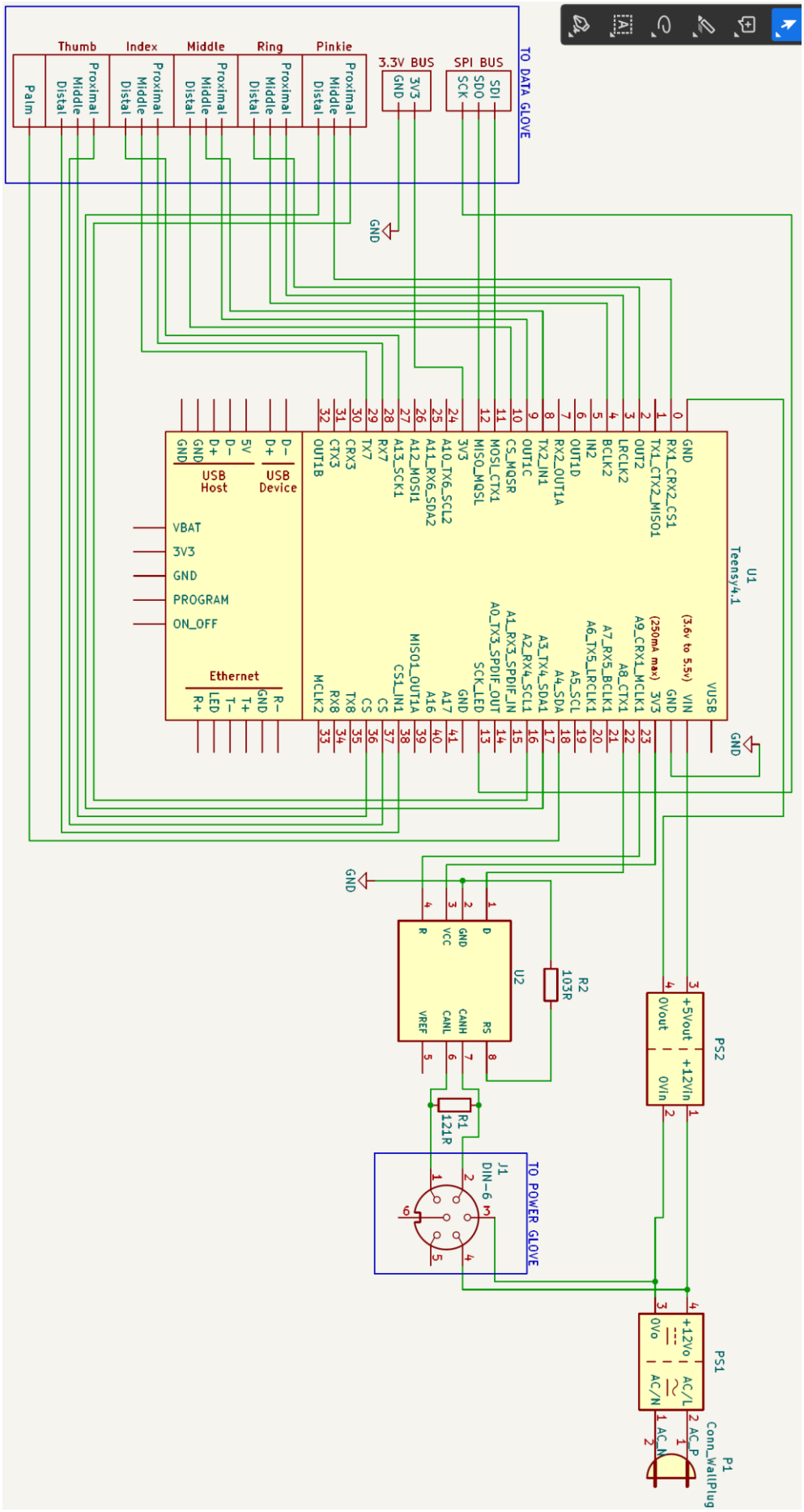
Appendices

A. Communication Log

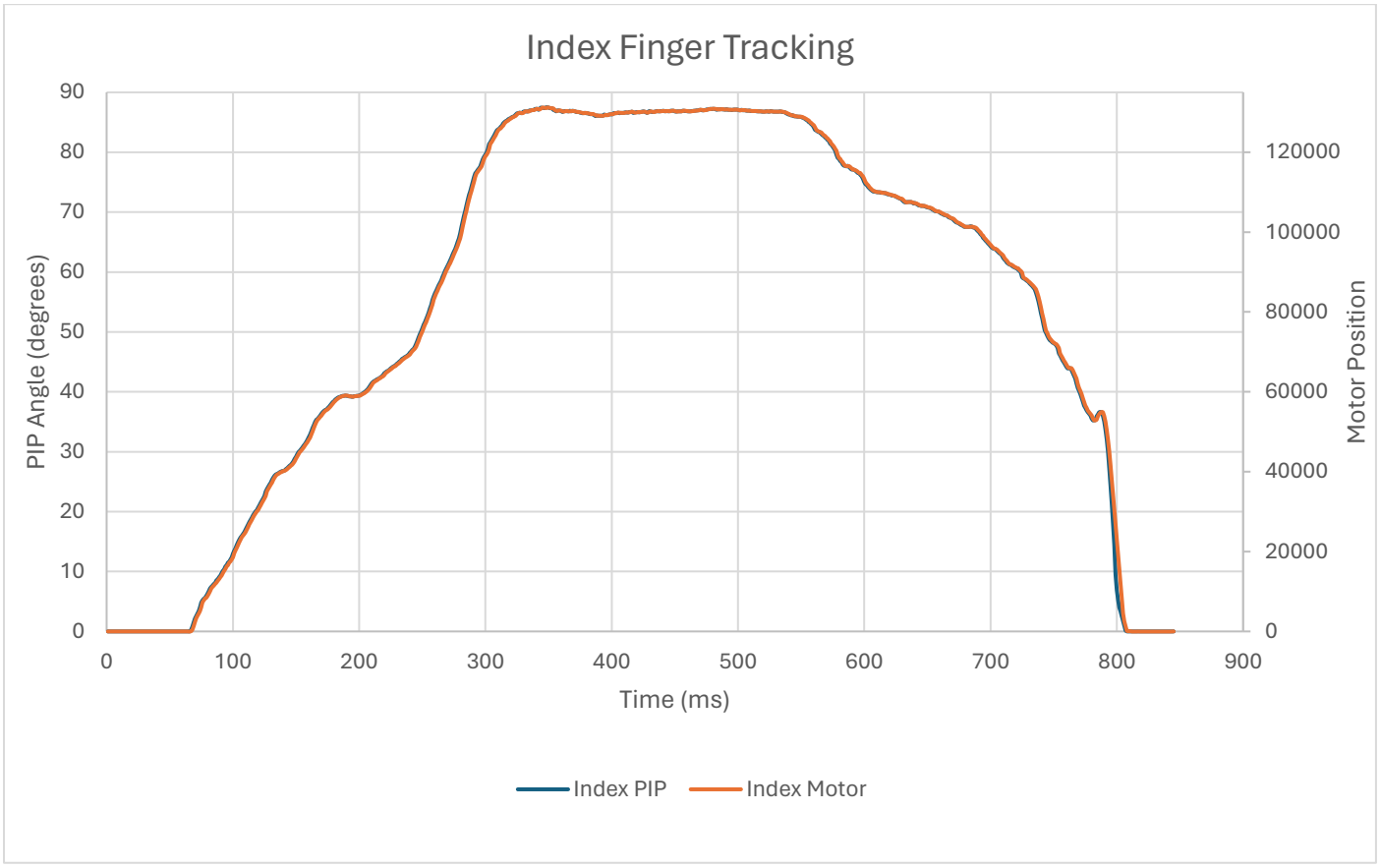
Project Title:	Smart sensing glove for hand pose estimation using IMUs		
Student Name:	Charkrit Atherton	**Supervisor Name:**	Dr Michael Behrens

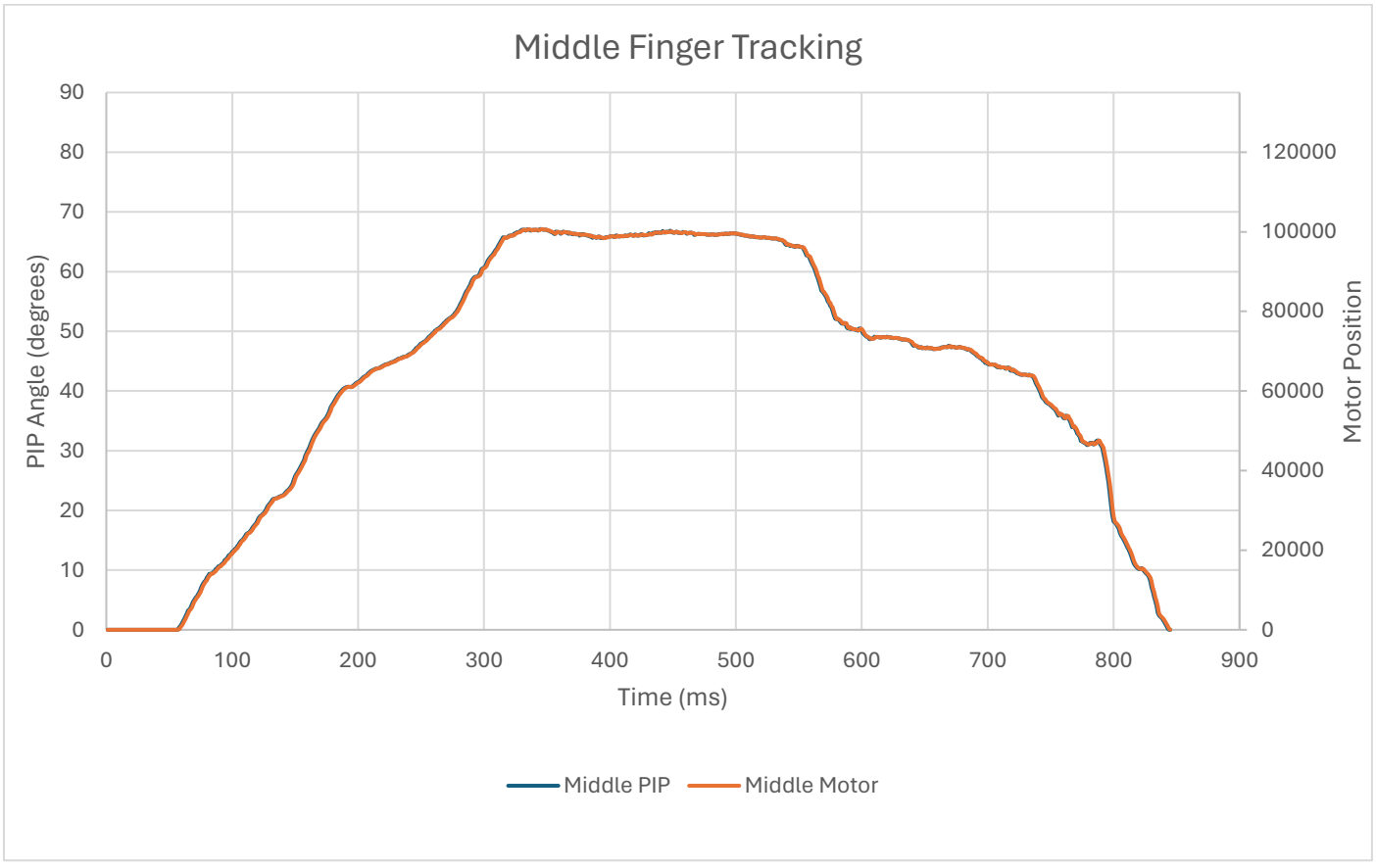
Date	**Event**	**Topic of Communication**	**Outcome**
01/01/2023	Face-to-face	Project Introduction.	Full introduction to the project.
15/03/2023	Face-to-face	Review of the project plan, ethics, and safety submissions	We agreed on an overall skeleton for the project. Advise was given for the ethics and safety submissions.
03/04/2023	Email	Delivered ethics and safety submissions for review.	Michael returned digitally signed copies via email.
11/04/2023	Email	Notification of virtual attendance at next meeting.	Email sent.
12/04/2023	Online Meeting	Scheduled meeting with supervisor.	Supervisor updated on the progress of research review. Feedback was received.
26/04/2023	Face-to-face	Project update.	Supervisor updated on recent research.
03/05/2023	Teams	Meeting Schedule.	Cancelled meeting on the 10/05/2023.
04/03/2024	Scheduled Update	Project Rebrief and start of capstone unit	Pick up IMU glove and power glove on 06/03/24.
16/03/2024	Teams	Attempt troubleshoot IMU glove with Ren online.	IMU glove to be transferred to Ren for troubleshooting.
18/03/2024	Teams	Regular Project update.	Supervisor directed further debugging of data glove.
15/04/2024	Teams	Regular Project Update	Update on state of the data glove and continued debugging.
29/04/2024	Email	Regular Project Update	Update on project developments after missed in person meeting. Advice provided on procuring cable to ensure proper current rating.
13/05/2024	Teams	Regular Project Update	Demonstrated current PG ability to track DG movement. Final regular meeting before project handover. Handover date TBC after report submission.

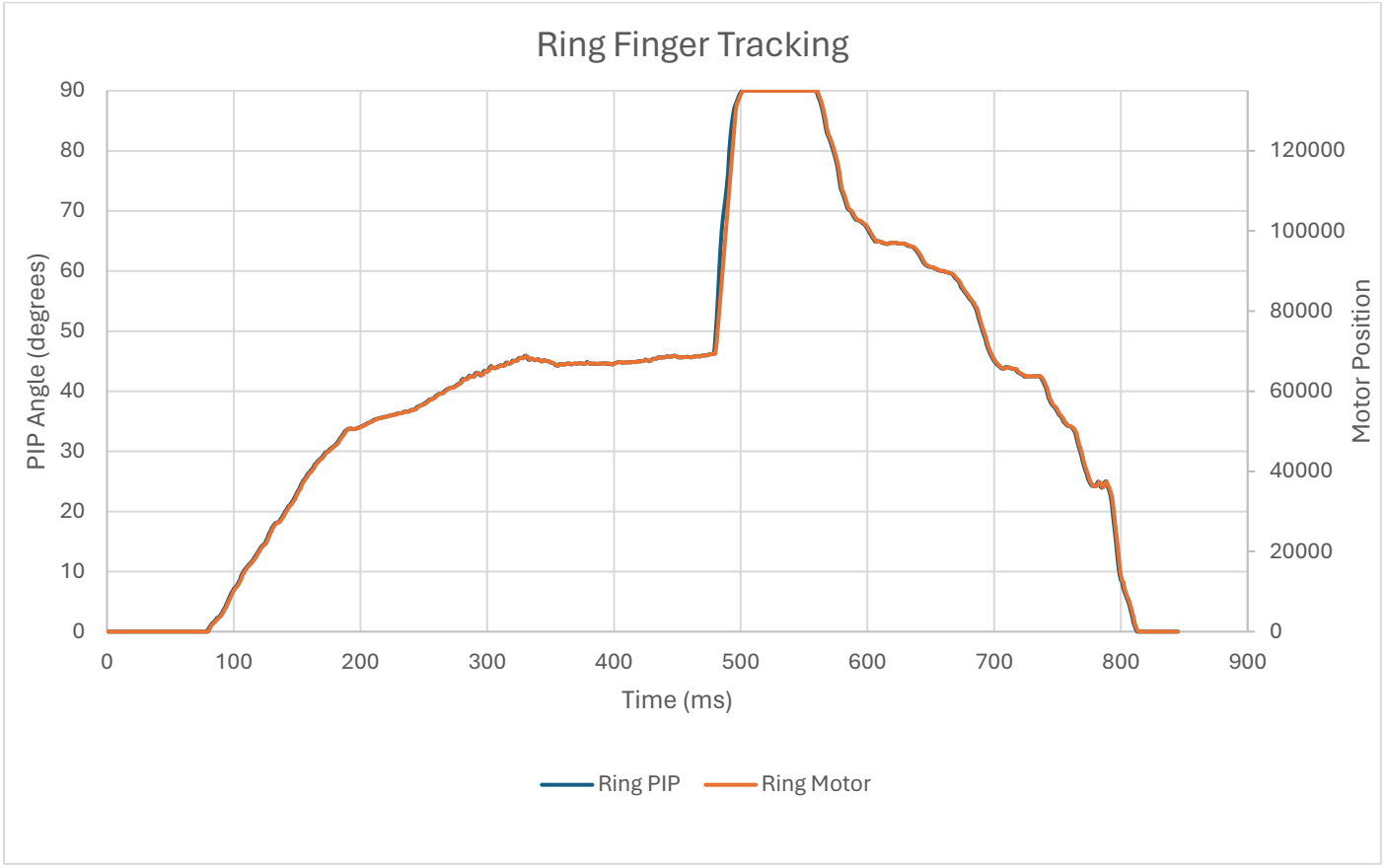
B. Wiring Diagram

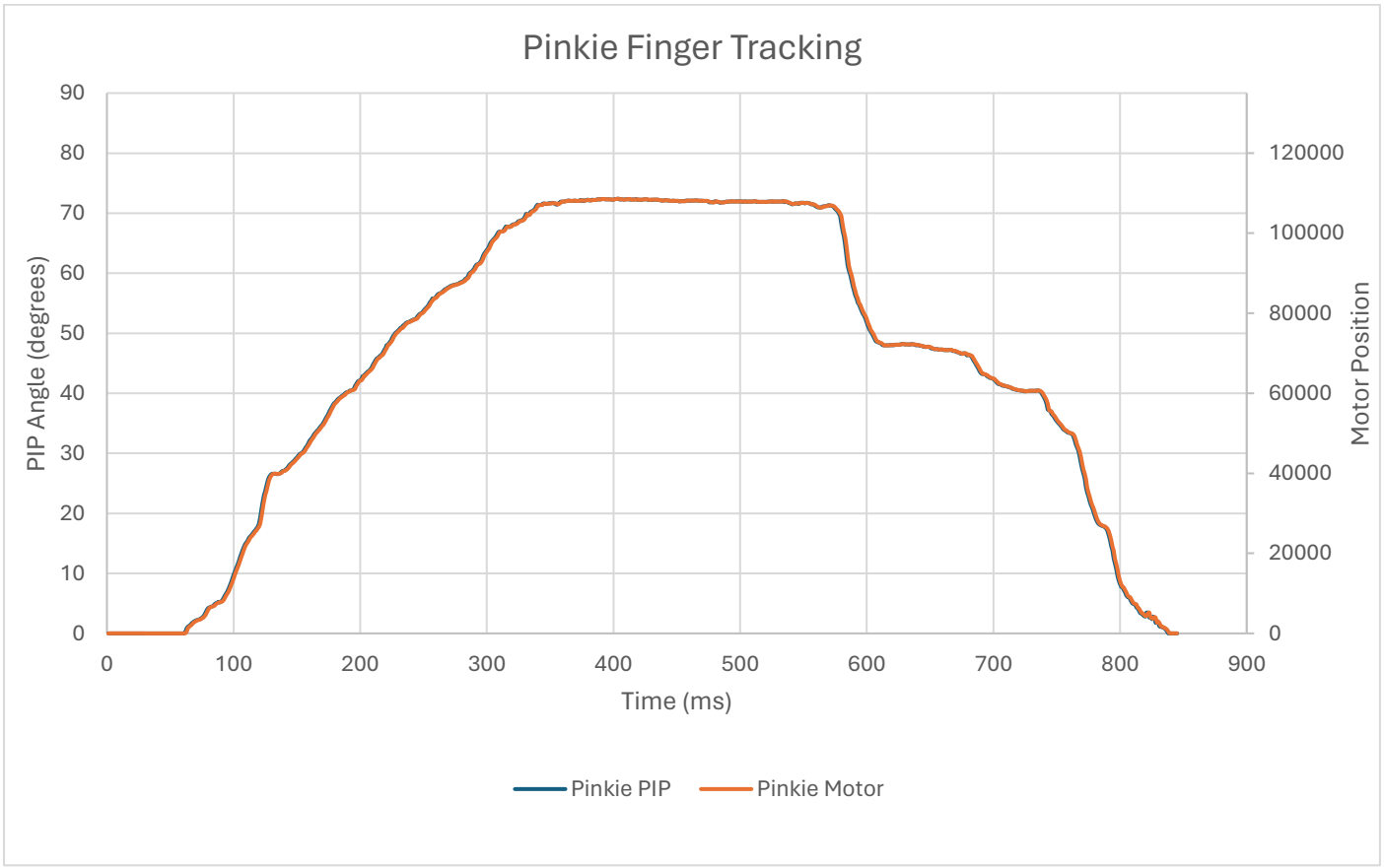


C. Latency Test Graphed Results






Ring Finger Tracking
PIP Angle (degrees)
Motor Position
Time (ms)
0
10
20
30
40
50
60
70
80
90
0
20000
40000
60000
80000
100000
120000
0
100
200
300
400
500
600
700
800
900
Ring PIP
Ring Motor


Pinkie Finger Tracking
PIP Angle (degrees)
Motor Position
Time (ms)
0
10
20
30
40
50
60
70
80
90
0
20000
40000
60000
80000
100000
120000
0
100
200
300
400
500
600
700
800
900
Pinkie PIP
Pinkie Motor

D. Latency Test Full Results

Time (ms)	Index PIP	Index Motor	Middle PIP	Middle Motor	Ring PIP	Ring Motor	Pinkie PIP	Pinkie Motor
0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	1
40	0	0	0	0	0	0	0	1
60	0	0	0	0	0	0	0	1
80	0	0	0	0	0	0	0	1
100	0	0	0	0	0	0	0	1
120	0	0	0	0	0	0	0	1
140	0	0	0	0	0	0	0	1
160	0	0	0	0	0	0	0	1
180	0	0	0	0	0	0	0	1
200	0	0	0	0	0	0	0	1
220	0	0	0	0	0	0	0	1
240	0	0	0	0	0	0	0	1
260	0	0	0	0	0	0	0	1
280	0	0	0	0	0	1	0	1
300	0	0	0	0	0	1	0	1
320	0	0	0	0	0	1	0	1
340	0	0	0	0	0	1	0	1
360	0	0	0	0	0	1	0	1
380	0	0	0	0	0	1	0	1
400	0	0	0	0	0	1	0	1
420	0	0	0	0	0	1	0	1
440	0	0	0	0	0	1	0	1
460	0	0	0	0	0	1	0	1
480	0	0	0	0	0	1	0	1
500	0	0	0	0	0	1	0	1
520	0	0	0	0	0	1	0	1
540	0	0	0	0	0	2	0	1
560	0	0	0	0	0	2	0	0
580	0	0	0	0	0	2	0	0
600	0	0	0	0	0	2	0	0
620	0	0	0	0	0	2	0	0
640	0	0	0	0	0	2	0	0
660	0	0	0	0	0	2	0	0
680	0	0	0	0	0	2	0	0
700	0	0	0	0	0	2	0	0
720	0	0	0	0	0	2	0	0
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760	0	0	0	0	0	2	0	0
780	0	0	0	0	0	2	0	0
800	0	0	0	0	0	2	0	0
820	0	0	0	0	0	2	0	0
840	0	0	0	0	0	2	0	0

860	0	0	0	0	0	2	0	0
880	0	0	0	0	0	2	0	0
900	0	0	0	0	0	2	0	0
920	0	0	0	0	0	2	0	0
940	0	0	0	0	0	2	0	0
960	0	0	0	0	0	2	0	0
980	0	0	0	0	0	2	0	0
1000	0	0	0	0	0	2	0	0
1020	0	0	0	0	0	2	0	0
1040	0	0	0	0	0	2	0	0
1060	0	0	0	0	0	2	0	0
1080	0	0	0	0	0	2	0	0
1100	0	0	0.060379	20	0	2	0	0
1120	0	0	0.47406	134	0	2	0	0
1140	0	0	0.665695	693	0	2	0	0
1160	0	0	1.054489	1003	0	2	0	0
1180	0	0	1.454727	1575	0	2	0.005432	2
1200	0	0	1.814377	2183	0	2	0.259521	57
1220	0	0	2.27121	2722	0	2	0.850647	391
1240	0	0	2.713058	3415	0	1	1.115784	1286
1260	0	1	3.219971	4075	0	1	1.283813	1700
1280	0	1	3.375992	4833	0	1	1.424149	1947
1300	0.301498	53	3.724091	5082	0	0	1.685837	2158
1320	0.835724	461	4.212326	5582	0	0	1.868652	2533
1340	1.515762	1279	4.691559	6318	0	0	2.010834	2819
1360	2.142319	2316	5.002106	7044	0	0	2.111526	3045
1380	2.574661	3258	5.408859	7502	0	0	2.211136	3189
1400	2.983994	3885	5.605087	8109	0	0	2.28862	3331
1420	3.390472	4496	5.95166	8415	0	0	2.314713	3433
1440	4.017838	5101	6.325165	8919	0	0	2.486145	3522
1460	4.810425	6072	6.863708	9483	0	0	2.58168	3741
1480	5.17511	7280	7.391479	10304	0	0	2.784546	3904
1500	5.470337	7784	7.769379	11093	0	0	3.036942	4185
1520	5.602081	8214	8.095734	11660	0	0	3.475906	4556
1540	5.912445	8427	8.273987	12140	0	0	3.886597	5218
1560	6.262497	8874	8.751648	12416	0.38855	49	4.207458	5838
1580	6.706146	9402	9.030945	13128	0.772079	592	4.343048	6317
1600	7.165161	10077	9.382462	13547	1.086075	1181	4.435989	6523
1620	7.415237	10771	9.338959	14012	1.353882	1636	4.505859	6664
1640	7.658554	11138	9.433975	14059	1.501129	2027	4.567368	6771
1660	7.892548	11499	9.666336	14197	1.732773	2276	4.853348	6895
1680	8.088074	11851	9.807358	14495	2.006699	2603	4.990189	7285
1700	8.486313	12148	10.18964	14721	2.274231	3018	5.10556	7505
1720	8.732361	12743	10.37535	15275	2.428635	3418	5.244019	7684
1740	9.058853	13107	10.6364	15571	2.657257	3667	5.185257	7822
1760	9.319839	13597	10.63088	15908	2.922607	3999	5.297928	7815
1780	9.742401	13986	10.88959	16006	3.310394	4394	5.506882	7984

1800	10.1122	14622	11.05753	16335	3.702286	4965	5.906204	8266
1820	10.40479	15185	11.25584	16592	4.068253	5584	6.33049	8859
1840	10.83879	15625	11.67285	16885	4.547302	6106	6.625641	9499
1860	11.07886	16278	11.78322	17503	4.973724	6851	7.023834	9943
1880	11.47961	16633	12.04169	17702	5.49762	7478	7.46225	10542
1900	11.66547	17229	12.40851	18053	5.968765	8281	8.0186	11204
1920	12.01827	17515	12.56888	18607	6.427109	8970	8.514099	12047
1940	12.35469	18032	12.73605	18863	6.762817	9672	9.132584	12786
1960	13.03056	18543	13.10425	19113	7.147049	10154	9.767822	13723
1980	13.50243	19609	13.21588	19652	7.387665	10732	10.33254	14679
2000	13.90677	20275	13.53124	19850	7.598831	11087	10.86502	15522
2020	14.42806	20903	13.63127	20287	7.926117	11416	11.41051	16325
2040	14.87871	21668	13.99126	20477	8.339233	11893	12.01581	17141
2060	15.32826	22339	14.26352	20979	8.731628	12534	12.66298	18037
2080	15.70947	23014	14.64476	21396	9.43956	13108	13.23366	19033
2100	15.97183	23584	14.90675	21969	9.745911	14209	13.82913	19874
2120	16.26721	23974	15.05911	22357	10.13254	14634	14.37192	20776
2140	16.58896	24433	15.33705	22596	10.39899	15221	14.84256	21577
2160	16.99811	24892	15.6427	22998	10.69354	15610	15.13863	22276
2180	17.42751	25514	15.99533	23457	10.95357	16065	15.43199	22713
2200	17.86314	26156	16.18417	23993	11.19087	16440	15.89116	23153
2220	18.25385	26837	16.23978	24263	11.36237	16818	16.15884	23850
2240	18.61871	27401	16.49672	24403	11.63818	17064	16.35017	24245
2260	19.02286	27965	16.7437	24740	11.86742	17488	16.63318	24537
2280	19.40028	28557	17.133	25115	12.21144	17810	16.90799	24947
2300	19.71365	29114	17.36597	25700	12.5471	18339	17.1181	25365
2320	20.03575	29578	17.63376	26050	12.89652	18829	17.4388	25684
2340	20.27402	30085	17.86021	26443	13.22455	19370	17.72847	26155
2360	20.67865	30418	18.31973	26786	13.57971	19848	18.22994	26594
2380	21.02782	31047	18.71365	27482	13.90401	20393	19.30518	27360
2400	21.47217	31560	18.98134	28074	14.19414	20866	20.68199	29045
2420	21.83225	32232	19.17725	28470	14.39536	21319	21.9099	31103
2440	22.18225	32764	19.36185	28769	14.5634	21607	23.00012	32940
2460	22.61339	33306	19.54933	29043	14.83318	21880	23.69142	34554
2480	23.34493	33935	19.82004	29326	15.37022	22254	24.58267	35577
2500	23.79292	35110	20.23483	29723	15.84457	23074	25.45956	36940
2520	24.15575	35706	20.69949	30349	16.33957	23776	26.00812	38243
2540	24.48969	36251	20.93794	31060	16.69203	24547	26.33788	39028
2560	24.83069	36749	21.18935	31410	17.2551	25051	26.57057	39513
2580	25.28537	37280	21.45502	31782	17.5804	25916	26.62022	39840
2600	25.6729	37948	21.82556	32185	17.82503	26377	26.57817	39916
2620	25.97351	38544	21.9599	32734	18.07559	26770	26.6143	39880
2640	26.1844	38971	21.98557	32924	18.14047	27109	26.54948	39900
2660	26.28967	39282	22.0394	32998	18.1667	27229	26.56812	39830
2680	26.41962	39465	22.12129	33088	18.34865	27309	26.61905	39868
2700	26.55551	39675	22.23489	33213	18.70087	27566	26.72653	39973
2720	26.66838	39856	22.34618	33376	18.95554	28057	26.96451	40130

2740	26.76663	40030	22.42	33525	19.41393	28461	27.07831	40450
2760	26.78551	40146	22.52605	33661	19.724	29136	27.09699	40603
2780	26.89658	40218	22.65135	33812	20.11375	29606	27.27473	40702
2800	27.07015	40382	22.88561	33999	20.40302	30178	27.41815	40924
2820	27.26851	40644	23.13185	34321	20.84074	30633	27.72543	41146
2840	27.4599	40913	23.35425	34697	21.00192	31270	28.00047	41585
2860	27.66356	41222	23.52754	35026	21.23494	31547	28.20226	42007
2880	27.84308	41503	23.76225	35296	21.59773	31871	28.39117	42309
2900	28.07985	41776	24.07791	35641	21.87735	32397	28.58267	42599
2920	28.39146	42127	24.50263	36112	22.28769	32822	28.80623	42883
2940	28.81053	42617	25.17354	36751	22.73338	33460	29.06268	43218
2960	29.16414	43229	25.74362	37784	23.1461	34113	29.28513	43601
2980	29.56307	43782	26.0984	38633	23.51968	34749	29.53311	43934
3000	29.9052	44365	26.41025	39146	23.83174	35293	29.77658	44301
3020	30.14162	44870	26.77246	39610	24.4027	35751	29.94548	44674
3040	30.39063	45222	27.1355	40159	24.77216	36625	30.07278	44930
3060	30.65851	45609	27.54851	40701	25.13239	37189	30.28674	45134
3080	30.97243	45997	27.98155	41325	25.40149	37704	30.5876	45432
3100	31.26225	46470	28.34682	41973	25.6975	38129	30.95058	45882
3120	31.55859	46903	29.08646	42519	26.08099	38554	31.2023	46421
3140	31.92712	47343	29.53862	43675	26.39806	39130	31.60681	46805
3160	32.32851	47902	29.99814	44308	26.5139	39605	32.04738	47419
3180	32.86267	48519	30.50198	45000	26.9008	39826	32.38666	48083
3200	33.3782	49325	31.09978	45760	27.12605	40361	32.64055	48584
3220	33.95659	50102	31.6178	46666	27.49748	40716	32.98993	48964
3240	34.4588	50985	32.10817	47438	27.90141	41256	33.30327	49485
3260	34.96199	51715	32.48288	48169	28.02916	41856	33.55125	49955
3280	35.32108	52491	32.85611	48726	28.33008	42077	33.80867	50328
3300	35.5217	52999	33.16766	49285	28.51579	42496	34.02042	50713
3320	35.78006	53314	33.51099	49752	28.74326	42790	34.33806	51040
3340	36.01869	53683	33.83641	50265	28.83725	43120	34.56369	51507
3360	36.354	54035	34.26656	50748	29.1889	43319	34.79578	51850
3380	36.59699	54537	34.65057	51404	29.45027	43790	35.15959	52203
3400	36.79396	54904	34.91165	51973	29.74458	44185	35.53249	52743
3420	36.96126	55213	35.14346	52367	29.89452	44621	35.96193	53301
3440	37.0356	55437	35.36781	52715	29.9455	44839	36.24916	53960
3460	37.26749	55613	35.73296	53050	30.17494	44968	36.67983	54380
3480	37.50369	55933	36.15366	53598	30.43329	45270	37.16232	55022
3500	37.7408	56263	36.58159	54232	30.53481	45656	37.52585	55758
3520	38.03532	56640	37.22815	54875	30.75563	45843	37.91762	56298
3540	38.2704	57064	37.59105	55887	30.87425	46140	38.24512	56888
3560	38.44307	57434	37.89104	56391	31.05452	46344	38.4912	57374
3580	38.6919	57700	38.30348	56835	31.27248	46594	38.65907	57741
3600	38.84679	58045	38.66341	57451	31.52426	46919	38.92874	57996
3620	38.99591	58286	38.99822	57996	31.89873	47299	39.1422	58394
3640	39.13684	58525	39.33612	58497	32.23686	47853	39.28523	58719
3660	39.17528	58692	39.59908	58997	32.46593	48367	39.48463	58941

3680	39.26721	58804	39.87718	59400	32.77121	48710	39.61641	59232
3700	39.31865	58917	40.13649	59810	33.08595	49166	39.7309	59439
3720	39.35657	58988	40.31996	60201	33.44515	49637	39.98837	59620
3740	39.39679	59048	40.48052	60485	33.55751	50171	40.1666	59987
3760	39.35417	59075	40.59851	60726	33.67345	50371	40.2056	60230
3780	39.3376	59022	40.68007	60902	33.80927	50544	40.33202	60353
3800	39.23612	58953	40.72212	61021	33.81206	50695	40.45242	60524
3820	39.26202	58872	40.70364	61073	33.77199	50703	40.47362	60668
3840	39.1788	58861	40.65836	61037	33.67941	50616	40.556	60742
3860	39.17746	58781	40.7034	60998	33.69057	50525	40.70467	60873
3880	39.26997	58814	40.88838	61109	33.74675	50546	41.23001	61078
3900	39.26906	58899	41.08411	61340	33.84406	50664	41.57434	61858
3920	39.31357	58928	41.28668	61628	33.92191	50798	41.95869	62364
3940	39.34583	58987	41.41495	61928	34.01543	50917	42.07886	62938
3960	39.36795	59027	41.47748	62111	34.02412	51020	42.11073	63109
3980	39.49579	59098	41.64478	62255	34.20125	51089	42.42461	63214
4000	39.60706	59285	41.84506	62472	34.28864	51313	42.8862	63634
4020	39.73236	59437	42.05893	62766	34.35155	51443	42.85782	64300
4040	39.8871	59641	42.25777	63082	34.48868	51580	43.17458	64375
4060	40.05533	59871	42.43031	63386	34.65073	51764	43.41893	64761
4080	40.26358	60100	42.54448	63643	34.72217	51977	43.61217	65139
4100	40.47363	60410	42.6937	63834	34.80896	52115	43.73764	65428
4120	40.78024	60744	42.93887	64050	34.87381	52234	44.00539	65627
4140	41.11578	61185	43.11227	64404	34.99635	52356	44.26744	66013
4160	41.44772	61703	43.31447	64671	35.17232	52532	44.72076	66402
4180	41.65636	62206	43.43835	64975	35.28377	52775	45.10698	67086
4200	41.79033	62497	43.53954	65168	35.34482	52933	45.47592	67671
4220	41.89844	62699	43.63471	65329	35.38887	53035	45.76679	68223
4240	42.04825	62874	43.76357	65501	35.49054	53126	45.87373	68656
4260	42.18294	63107	43.76761	65621	35.50877	53237	46.07436	68844
4280	42.29176	63306	43.81119	65668	35.52983	53271	46.32504	69122
4300	42.43749	63466	43.8994	65763	35.61777	53326	46.38281	69469
4320	42.5948	63695	43.96895	65866	35.69013	53471	46.79689	69622
4340	42.81372	63913	44.17427	65997	35.73538	53556	47.21016	70191
4360	43.10809	64230	44.24181	66244	35.7641	53621	47.51814	70814
4380	43.25293	64672	44.35255	66411	35.79776	53660	48.02068	71281
4400	43.41707	64922	44.4742	66554	35.8562	53729	48.07177	72020
4420	43.55644	65146	44.47018	66687	35.92798	53817	48.39794	72191
4440	43.711	65378	44.58369	66747	35.9726	53919	48.64155	72593
4460	43.89644	65592	44.64664	66885	36.06566	54001	49.08405	72968
4480	44.08324	65851	44.7757	67006	36.02943	54084	49.50415	73637
4500	44.20866	66132	44.86469	67188	36.11374	54075	49.77494	74266
4520	44.33112	66351	44.90434	67297	36.15393	54180	50.06256	74665
4540	44.48167	66522	45.01126	67391	36.24323	54267	50.22524	75096
4560	44.66502	66759	45.14317	67545	36.34923	54408	50.46648	75350
4580	44.84436	67006	45.23439	67722	36.32826	54514	50.67878	75701
4600	45.03461	67291	45.43134	67878	36.34003	54501	50.92851	76027

4620	45.22699	67565	45.42633	68110	36.40334	54528	50.88939	76341
4640	45.48106	67870	45.52274	68178	36.50165	54648	51.28561	76390
4660	45.64317	68229	45.633	68331	36.60786	54791	51.46621	76932
4680	45.79727	68483	45.72861	68485	36.65503	54922	51.71777	77212
4700	45.87256	68696	45.7338	68581	36.55328	54949	51.79761	77570
4720	46.04103	68849	45.8042	68637	36.63403	54855	51.82338	77699
4740	46.22443	69081	45.9442	68749	36.78606	55002	51.95721	77789
4760	46.51148	69351	46.12531	68934	36.90126	55202	52.05767	77956
4780	46.76054	69792	46.23496	69193	36.89383	55334	52.18243	78115
4800	46.97516	70151	46.33138	69385	36.95039	55361	52.27168	78287
4820	47.18013	70475	46.43162	69521	36.93924	55427	52.29294	78400
4840	47.51727	70779	46.70664	69692	37.23604	55471	52.44627	78488
4860	48.00874	71282	46.88785	70070	37.41093	55854	52.76047	78688
4880	48.50862	72039	47.19067	70329	37.54378	56131	53.01348	79137
4900	49.12782	72796	47.3222	70782	37.6304	56333	53.23879	79529
4920	49.61429	73761	47.508	70999	37.66	56450	53.30079	79843
4940	50.09793	74446	47.78523	71267	37.77924	56539	53.48712	80000
4960	50.65164	75170	47.9903	71672	37.87145	56698	53.7687	80244
4980	51.19815	76016	48.00713	71959	38.05641	56850	54.00105	80657
5000	51.62033	76841	48.26845	72086	38.20366	57099	54.23547	81010
5020	52.15552	77456	48.33953	72395	38.35443	57327	54.43768	81352
5040	52.6897	78268	48.54738	72550	38.57866	57550	54.7616	81662
5060	53.26012	79067	48.81164	72841	38.66478	57872	55.15945	82139
5080	53.92365	79929	49.04282	73216	38.69377	58007	55.38074	82748
5100	54.52202	80941	49.20464	73560	38.73567	58068	55.81474	83074
5120	55.33225	81828	49.41413	73830	38.91324	58162	55.73084	83649
5140	55.91682	83078	49.65547	74142	39.15637	58392	55.8672	83674
5160	56.4324	83909	49.78266	74495	39.33653	58735	56.12779	83850
5180	56.86391	84676	50.08874	74716	39.4815	59025	56.42823	84193
5200	57.3694	85320	50.22932	75148	39.56097	59229	56.59058	84647
5220	57.81393	86082	50.39138	75357	39.61881	59354	56.65854	84881
5240	58.19453	86745	50.44946	75573	39.60325	59428	56.77355	85025
5260	58.62778	87307	50.66335	75733	39.76984	59467	56.94143	85192
5280	59.18274	87965	50.90314	76014	39.93793	59681	57.13792	85423
5300	59.676	88809	51.09237	76373	40.16137	59925	57.32639	85716
5320	60.19801	89542	51.35942	76664	40.30283	60249	57.38448	85974
5340	60.61218	90334	51.49925	77054	40.35593	60453	57.60836	86118
5360	61.051	90940	51.80353	77267	40.49369	60583	57.66286	86394
5380	61.42812	91598	51.94099	77696	40.55167	60750	57.84399	86535
5400	61.904	92154	52.12054	77939	40.57021	60833	57.87093	86744
5420	62.37267	92886	52.25549	78193	40.65578	60886	58.02067	86852
5440	62.91653	93586	52.34032	78398	40.70941	61012	57.99579	86997
5460	63.37028	94412	52.55665	78558	40.87911	61118	58.0937	87029
5480	63.83701	95076	52.78546	78851	41.04503	61343	58.11742	87137
5500	64.37225	95785	53.0736	79179	41.2035	61588	58.24566	87223
5520	65.0127	96591	53.32462	79608	41.27142	61809	58.29232	87368
5540	65.58655	97564	53.68118	79983	41.35922	61938	58.46523	87485

5560	66.4314	98414	54.05436	80513	41.93686	62089	58.47859	87671
5580	67.48282	99726	54.49886	81104	42.10489	62918	58.63204	87766
5600	68.43878	101315	54.88408	81771	42.00018	63098	58.76092	87967
5620	69.39041	102740	55.32357	82349	41.98902	62998	59.0602	88163
5640	70.19492	104171	55.75919	82988	42.0838	63018	59.10299	88566
5660	71.13238	105344	56.30523	83660	42.33302	63173	59.45095	88709
5680	72.0092	106792	56.74248	84470	42.55345	63507	59.90728	89181
5700	72.83244	108078	57.00896	85122	42.4911	63777	60.10126	89873
5720	73.50591	109313	57.40726	85535	42.40925	63708	60.20055	90155
5740	74.26647	110311	57.76676	86109	42.39629	63607	60.48915	90333
5760	75.03468	111466	58.33511	86646	42.70374	63637	60.76682	90729
5780	75.82455	112614	58.73531	87547	43.05277	64056	61.17864	91156
5800	76.45167	113811	58.97337	88126	43.10188	64562	61.43349	91774
5820	76.72826	114719	59.12618	88460	42.94729	64618	61.53592	92152
5840	77.05592	115112	59.1354	88659	42.76511	64391	61.5957	92317
5860	77.30182	115591	59.2198	88734	42.62475	64132	61.88901	92443
5880	77.6075	115961	59.37376	88870	42.75628	64008	62.29496	92835
5900	78.25527	116421	59.81802	89076	43.19141	64183	62.83145	93449
5920	78.85578	117424	60.40141	89715	43.47929	64792	63.24634	94273
5940	79.27271	118330	60.5784	90625	43.31562	65123	63.53588	94881
5960	79.59363	118931	60.64547	90864	43.2365	64960	63.83588	95309
5980	79.91658	119400	60.88326	91010	43.48496	64920	64.09044	95754
6000	80.49857	119883	61.32378	91323	43.91665	65233	64.55956	96141
6020	81.37147	120807	61.79807	91981	44.1825	65882	65.031	96851
6040	81.65592	122131	62.15358	92702	43.91044	66178	65.34104	97561
6060	82.03839	122504	62.37502	93231	43.86731	65886	65.59012	98018
6080	82.42013	123062	62.6638	93568	43.80511	65776	65.77818	98386
6100	82.79792	123650	62.89164	93991	43.89294	65738	66.04199	98675
6120	83.29943	124211	63.29588	94336	44.07116	65894	66.47515	99067
6140	83.64719	124991	63.59349	94933	44.20556	66128	66.81965	99714
6160	83.85015	125485	63.89227	95389	44.31184	66328	66.94289	100238
6180	83.99965	125788	64.264	95828	44.29841	66449	66.94464	100393
6200	84.23747	126018	64.64151	96396	44.26721	66439	66.94897	100419
6220	84.45715	126366	65.00947	96962	44.23864	66384	67.11604	100473
6240	84.80231	126699	65.40324	97517	44.57621	66406	67.47513	100693
6260	85.04161	127212	65.73968	98103	44.75556	66874	67.77016	101213
6280	85.18407	127564	65.70493	98561	44.75903	67112	67.72266	101602
6300	85.29647	127790	65.63668	98548	44.55853	67094	67.7087	101591
6320	85.49198	127971	65.7138	98497	44.63882	66891	67.70527	101571
6340	85.63521	128245	65.88284	98618	44.84861	67015	67.90105	101618
6360	85.74548	128462	66.02477	98831	45.07632	67284	68.07504	101865
6380	85.87293	128660	66.08389	99029	45.074	67579	68.13477	102101
6400	85.95658	128817	65.99757	99084	45.04558	67605	68.17234	102207
6420	86.092	128966	66.12903	99050	45.03017	67565	68.20146	102267
6440	86.31958	129162	66.36588	99222	45.36066	67602	68.47846	102357
6460	86.51119	129491	66.4375	99531	45.49691	68043	68.69824	102713
6480	86.51151	129739	66.57752	99691	45.58347	68258	68.66434	102993

6500	86.58926	129808	66.62286	99855	45.51499	68348	68.82522	103046
6520	86.53442	129868	66.64304	99932	45.45992	68244	68.77993	103193
6540	86.53831	129800	66.84169	100016	45.75313	68235	69.03667	103217
6560	86.7584	129854	67.00078	100266	45.94704	68640	69.41057	103556
6580	86.80724	130122	67.01557	100467	45.82672	68847	69.89838	104115
6600	86.81993	130215	66.99965	100516	45.41782	68688	69.6663	104758
6620	86.76284	130217	66.88104	100454	45.17034	68122	69.67605	104541
6640	86.88178	130182	67.06885	100393	45.31989	67844	70.10342	104569
6660	86.98324	130350	67.09302	100580	45.43125	68007	70.32083	105158
6680	86.99791	130469	67.04194	100618	45.35081	68102	70.30661	105444
6700	87.03695	130516	66.88092	100509	45.19894	67969	70.5034	105519
6720	87.02602	130556	66.95212	100379	45.13905	67799	70.7305	105769
6740	87.19514	130618	67.00751	100455	45.25924	67754	71.14446	106107
6760	87.24748	130788	66.9704	100499	45.33296	67912	71.39488	106721
6780	87.22981	130864	67.0043	100462	45.17102	67947	71.32643	107031
6800	87.09059	130799	66.98826	100503	45.01076	67733	71.37503	107012
6820	87.30853	130711	66.87105	100437	44.94192	67516	71.34777	107059
6840	87.44943	130978	67.05233	100379	45.07814	67463	71.57969	107075
6860	87.42817	131146	67.14945	100586	45.19238	67654	71.63937	107353
6880	87.42506	131144	67.06634	100672	45.0926	67739	71.58289	107432
6900	87.33575	131109	67.03175	100586	44.96302	67591	71.52004	107350
6920	87.4959	131053	67.0026	100534	45.02531	67479	71.54604	107290
6940	87.48463	131221	67.04432	100515	44.9083	67505	71.65865	107362
6960	87.45368	131218	66.95452	100537	44.78664	67326	71.60266	107459
6980	87.33405	131133	66.8549	100401	44.70897	67160	71.66169	107423
7000	87.3364	131014	66.79698	100273	44.66684	67048	71.70285	107507
7020	87.31324	130997	66.67393	100160	44.56696	66960	71.63202	107530
7040	87.01902	130917	66.63026	100014	44.31325	66802	71.63406	107451
7060	86.96312	130543	66.4631	99902	44.2489	66474	71.41763	107394
7080	86.80364	130395	66.28845	99682	44.24291	66371	71.47385	107184
7100	86.97593	130287	66.68074	99526	44.51122	66413	71.6663	107266
7120	87.00098	130451	66.64684	99957	44.57236	66751	71.89236	107513
7140	86.91537	130479	66.63617	99980	44.48569	66832	71.93581	107819
7160	86.86626	130355	66.52419	99922	44.43223	66706	71.95135	107907
7180	86.7433	130251	66.35113	99755	44.43375	66643	71.94138	107928
7200	86.84728	130164	66.59882	99629	44.51431	66673	72.01481	107940
7220	86.85043	130269	66.71568	99909	44.62043	66821	72.03999	108027
7240	86.86764	130285	66.61104	100010	44.60626	66923	72.09984	108083
7260	86.80504	130281	66.5211	99888	44.59242	66918	72.08084	108143
7280	86.81927	130210	66.59602	99823	44.45549	66840	72.02239	108101
7300	86.91306	130254	66.35477	99842	44.52042	66719	72.04938	108039
7320	86.84268	130348	66.5406	99633	44.58107	66811	72.05751	108075
7340	86.90819	130298	66.32861	99723	44.63231	66899	72.11533	108105
7360	86.86382	130350	66.36888	99546	44.63312	66953	72.03045	108148
7380	86.80353	130270	66.23366	99512	44.54703	66921	72.02812	108053
7400	86.71482	130171	66.36807	99420	44.59612	66833	72.0448	108046
7420	86.71182	130075	66.24641	99492	44.6433	66916	72.03703	108067

7440	86.70409	130063	66.29144	99397	44.69533	66991	72.17749	108110
7460	86.60777	130012	66.27008	99436	44.53828	66999	72.05597	108202
7480	86.57492	129902	66.0311	99353	44.57845	66834	72.12585	108115
7500	86.50174	129828	66.27263	99151	44.5628	66862	72.03441	108154
7520	86.5439	129771	66.15378	99329	44.65308	66881	72.16746	108106
7540	86.5556	129821	66.25973	99277	44.85431	67032	72.17919	108240
7560	86.49825	129816	66.18557	99356	44.68066	67197	72.25039	108298
7580	86.48465	129742	66.15055	99267	44.57427	66993	72.08727	108318
7600	86.42923	129707	65.99968	99172	44.60421	66880	72.15303	108176
7620	86.34869	129610	66.09067	99064	44.56741	66892	72.23187	108260
7640	86.39875	129539	65.87112	99084	44.61524	66867	72.1814	108327
7660	86.29081	129571	65.99613	98890	44.55533	66914	72.20008	108273
7680	86.211	129415	65.67548	98929	44.55102	66829	72.22515	108306
7700	86.06041	129255	65.84444	98613	44.52672	66818	72.28511	108365
7720	86.15067	129142	65.82897	98732	44.60754	66819	72.30089	108436
7740	86.06271	129195	65.67612	98690	44.57221	66902	72.24899	108439
7760	86.08874	129108	65.77539	98576	44.60748	66868	72.3426	108404
7780	86.10958	129138	65.94003	98706	44.64466	66928	72.35059	108511
7800	86.10097	129167	65.66567	98820	44.63892	66970	72.33491	108524
7820	86.08625	129155	65.62285	98522	44.56194	66938	72.32726	108500
7840	86.28059	129180	65.66354	98454	44.64485	66864	72.31905	108488
7860	86.18025	129355	65.59324	98473	44.52758	66923	72.2986	108471
7880	86.19709	129276	65.68064	98427	44.62613	66828	72.30417	108439
7900	86.26845	129314	65.77715	98550	44.53626	66907	72.30631	108444
7920	86.32177	129433	65.77132	98648	44.46438	66772	72.24012	108430
7940	86.37424	129513	65.82635	98675	44.47887	66697	72.26389	108372
7960	86.30953	129544	65.92216	98771	44.62791	66764	72.24477	108394
7980	86.44725	129509	65.93955	98874	44.68491	66945	72.37551	108437
8000	86.56752	129716	65.91839	98903	44.77734	67062	72.36429	108548
8020	86.51049	129815	65.82724	98838	44.80595	67171	72.38654	108556
8040	86.58035	129791	65.7967	98737	44.90543	67247	72.41019	108589
8060	86.61214	129885	66.0649	98745	44.84301	67338	72.26317	108566
8080	86.5327	129896	65.94826	99005	44.76819	67232	72.30506	108428
8100	86.54155	129803	65.85548	98900	44.73771	67139	72.27976	108453
8120	86.54887	129807	65.9269	98826	44.79909	67122	72.25903	108412
8140	86.555	129816	65.98717	98915	44.78798	67201	72.30713	108402
8160	86.59083	129842	65.91364	98953	44.82121	67201	72.28751	108456
8180	86.67819	129934	65.91396	98872	44.77522	67215	72.3226	108442
8200	86.60323	129988	66.0786	98916	44.82765	67174	72.37045	108500
8220	86.63732	129915	65.95208	99039	44.79264	67236	72.26908	108521
8240	86.69817	129986	66.04397	98969	44.87804	67215	72.27666	108412
8260	86.73627	130064	66.07221	99070	44.86469	67313	72.28125	108411
8280	86.75404	130119	66.253	99164	44.81905	67293	72.25847	108410
8300	86.58534	130082	66.11742	99296	44.88812	67238	72.30136	108402
8320	86.6266	129919	65.99484	99139	44.94174	67351	72.3373	108469
8340	86.68106	129959	66.00819	99025	44.91951	67410	72.19565	108439
8360	86.70377	130039	66.22197	99066	45.01683	67424	72.22794	108318

8380	86.65179	130043	66.08276	99239	44.97621	67506	72.27344	108354
8400	86.68832	129989	66.00026	99104	45.01026	67469	72.22273	108399
8420	86.70864	130042	66.06964	99041	45.06015	67532	72.27097	108350
8440	86.78644	130101	66.164	99146	45.11417	67615	72.30206	108421
8460	86.81089	130192	66.27071	99274	45.28705	67728	72.30992	108462
8480	86.74561	130193	66.08649	99335	45.14115	67855	72.31247	108466
8500	86.6466	130079	66.09908	99165	45.09071	67699	72.26276	108443
8520	86.58732	129946	66.09836	99150	44.99022	67595	72.20018	108368
8540	86.7516	129930	66.12546	99159	45.16708	67544	72.22323	108311
8560	86.86269	130162	66.19285	99216	45.27633	67774	72.24492	108341
8580	86.78871	130257	66.42729	99331	45.42027	67946	72.2204	108363
8600	86.71925	130143	66.20805	99540	45.41951	68110	72.2758	108350
8620	86.7086	130070	66.22115	99353	45.42557	68130	72.26669	108412
8640	86.78925	130096	66.46932	99380	45.47779	68153	72.26683	108408
8660	86.8286	130200	66.50298	99677	45.66322	68271	72.23328	108387
8680	86.8812	130275	66.59621	99789	45.65726	68471	72.18926	108322
8700	86.81533	130301	66.41608	99828	45.58527	68460	72.13453	108248
8720	86.80134	130212	66.61487	99711	45.64124	68393	72.11147	108193
8740	86.85269	130216	66.48499	99840	45.59245	68452	72.09756	108158
8760	86.86357	130285	66.53064	99751	45.6598	68410	72.16692	108168
8780	86.91313	130312	66.51277	99793	45.71034	68511	72.15064	108242
8800	86.84637	130344	66.79097	99822	45.8471	68622	72.15247	108229
8820	86.85401	130272	66.55135	100071	45.78979	68739	72.10505	108206
8840	86.86592	130277	66.53519	99859	45.7398	68660	72.06984	108137
8860	86.82604	130283	66.69892	99857	45.72406	68591	72.05007	108088
8880	86.88783	130273	66.67647	100014	45.80794	68612	72.04643	108070
8900	86.91682	130345	66.62876	99996	45.89232	68744	72.0964	108094
8920	86.93253	130389	66.84126	99991	45.93111	68854	72.02879	108121
8940	86.93278	130403	66.67641	100160	45.79894	68855	72.05971	108055
8960	86.83604	130354	66.55634	99987	45.69712	68668	72.03398	108082
8980	86.76765	130236	66.50219	99840	45.61277	68521	72.02422	108046
9000	86.8387	130186	66.62309	99807	45.6449	68435	71.95593	108012
9020	86.80553	130252	66.68861	99946	45.60999	68462	71.99653	107950
9040	86.836	130222	66.47202	99971	45.64677	68428	72.01251	108001
9060	86.8417	130256	66.48212	99747	45.65997	68481	72.01722	108022
9080	86.90412	130291	66.44	99706	45.6897	68500	71.97327	108010
9100	86.94856	130373	66.51191	99685	45.72504	68556	72.08481	108016
9120	86.86784	130391	66.62788	99808	45.73296	68595	72.10042	108126
9140	86.88145	130304	66.60411	99914	45.6662	68576	72.11316	108161
9160	86.83368	130290	66.54952	99889	45.67864	68501	72.06649	108155
9180	86.80737	130245	66.32429	99770	45.6275	68493	72.08537	108104
9200	86.80975	130210	66.47932	99583	45.74325	68484	72.09898	108132
9220	86.86902	130231	66.49417	99710	45.77856	68626	72.11035	108153
9240	86.89774	130321	66.53616	99758	45.7977	68684	72.09031	108162
9260	86.91348	130352	66.47456	99780	45.80225	68701	72.14457	108164
9280	86.91866	130372	66.41055	99686	45.80931	68704	72.07082	108193
9300	86.98952	130398	66.13816	99569	45.75755	68690	72.08276	108112

9320	86.98061	130493	66.25747	99295	45.8111	68654	72.03983	108102
9340	87.05704	130507	66.29565	99390	45.92388	68767	72.12083	108101
9360	87.09831	130598	66.35135	99461	45.94982	68898	72.0367	108151
9380	87.04784	130634	66.30507	99506	45.97303	68943	72.02664	108054
9400	87.00088	130543	66.27748	99442	45.92596	68947	72.04118	108040
9420	87.05462	130509	66.30625	99419	45.98274	68902	72.04814	108063
9440	87.02645	130572	66.29412	99458	46.02373	68993	72.02612	108063
9460	87.15054	130585	66.30062	99445	46.13175	69085	71.8899	107970
9480	87.15916	130715	66.22	99419	46.16258	69208	71.80284	107815
9500	87.18919	130750	66.15903	99313	46.1932	69264	71.87524	107750
9520	87.22437	130800	66.15542	99244	46.23443	69303	71.79469	107787
9540	87.21753	130841	66.15614	99233	46.20403	69347	71.80634	107699
9560	87.26497	130856	66.24974	99268	48.8728	69358	72.00266	107757
9580	87.26757	130897	66.24568	99364	51.85074	72005	71.96314	107958
9600	87.20273	130869	66.22686	99365	55.62842	75750	71.90881	107921
9620	87.08857	130760	66.13034	99301	59.89981	79521	71.82912	107830
9640	87.19559	130696	66.20442	99230	63.68589	83387	71.74999	107718
9660	87.11742	130764	66.16315	99289	66.70115	87168	71.75323	107633
9680	87.18336	130708	66.24435	99271	68.9072	91051	71.78167	107638
9700	87.19952	130782	66.27609	99370	70.49303	94836	71.82718	107693
9720	87.14434	130774	66.27358	99414	72.13617	98724	71.84818	107752
9740	87.1553	130716	66.33823	99437	74.05547	102528	71.91823	107813
9760	87.09604	130699	66.25083	99471	76.23038	106417	71.89806	107870
9780	87.18084	130685	66.333	99411	80.04448	110216	71.94309	107870
9800	87.10822	130742	66.37696	99511	82.49043	114108	71.95489	107917
9820	87.10568	130661	66.30616	99538	84.50737	117911	71.97811	107938
9840	87.11149	130656	66.34051	99471	86.02712	121807	71.91589	107948
9860	87.06017	130646	66.35353	99517	87.10866	125608	71.94278	107883
9880	87.08076	130593	66.45886	99570	87.76218	129408	71.91979	107909
9900	87.14629	130642	66.36867	99644	88.23023	131707	71.96371	107894
9920	87.10058	130714	66.37599	99561	88.79435	132354	71.92639	107936
9940	87.11993	130656	66.42323	99578	89.30134	133208	71.97024	107901
9960	87.06884	130655	66.34589	99609	89.67178	133968	71.9521	107950
9980	86.99964	130574	66.32903	99518	89.93587	134522	71.98224	107938
10000	87.01857	130508	66.30254	99482	90	134896	71.90131	107944
10020	87.06936	130545	66.25057	99431	90	135007	71.9436	107871
10040	87.00587	130589	66.11171	99328	90	135011	71.96822	107925
10060	87.02242	130514	66.19127	99222	90	135009	71.89253	107931
10080	86.96323	130506	66.0693	99244	90	135007	71.94316	107859
10100	86.9375	130435	66.00683	99098	90	135004	71.94761	107918
10120	86.91879	130398	66.01047	99022	90	135002	71.95293	107923
10140	86.97032	130393	66.02876	99022	90	135001	71.95602	107925
10160	86.87215	130422	65.94106	99016	90	135001	71.94553	107927
10180	86.86254	130307	65.87135	98895	90	135000	72.00391	107942
10200	86.86682	130288	65.9032	98824	90	135000	72.00391	108010
10220	86.87	130292	65.8683	98847	90	135000	71.89924	107972
10240	86.85801	130295	65.8943	98810	90	135000	71.8829	107851

10260	86.82866	130283	65.81617	98817	90	135000	71.87247	107819
10280	86.82259	130247	65.77924	98719	90	135000	71.87468	107809
10300	86.82605	130242	65.75794	98659	90	135000	71.87116	107809
10320	86.83209	130243	65.73635	98627	90	135000	71.87778	107810
10340	86.759	130220	65.6992	98589	90	135000	71.87778	107813
10360	86.76453	130135	65.72166	98551	90	135000	71.88858	107817
10380	86.76103	130135	65.72281	98585	90	135000	71.88765	107830
10400	86.82008	130164	65.78278	98606	90	135000	71.94972	107852
10420	86.8008	130235	65.74117	98658	90	135000	71.94259	107927
10440	86.78431	130205	65.67694	98585	90	135000	71.91938	107914
10460	86.78032	130175	65.67808	98517	90	135000	71.99981	107902
10480	86.85136	130203	65.63505	98499	90	135000	71.87792	107947
10500	86.80965	130256	65.64292	98452	90	135000	71.95387	107853
10520	86.77997	130196	65.55916	98429	90	135000	71.92915	107922
10540	86.76641	130154	65.52689	98338	90	135000	71.92207	107890
10560	86.77559	130148	65.53388	98293	90	135000	71.9252	107884
10580	86.77875	130155	65.53553	98295	90	135000	71.93731	107888
10600	86.78865	130161	65.5388	98300	90	135000	71.95686	107908
10620	86.79919	130184	65.43228	98269	90	135000	71.95776	107937
10640	86.79421	130203	65.34231	98135	90	135000	72.01643	107957
10660	86.71175	130162	65.31824	98018	90	135000	71.83871	107974
10680	86.70674	130067	65.29791	97969	90	135000	71.94846	107820
10700	86.64223	130036	65.1736	97898	90	135000	71.874	107890
10720	86.51524	129898	65.00361	97731	90	135000	71.74111	107762
10740	86.42232	129753	64.63829	97500	90	135000	71.65929	107601
10760	86.28924	129597	64.45637	96967	90	135000	71.56789	107464
10780	86.22074	129418	64.59702	96771	90	135000	71.47687	107334
10800	86.12583	129289	64.51521	96848	90	135000	71.51895	107243
10820	86.17515	129212	64.28507	96722	90	135000	71.61272	107317
10840	86.061	129231	64.39157	96505	90	135000	71.62548	107416
10860	85.99093	129067	64.23743	96528	90	135000	71.6373	107445
10880	85.96938	128985	64.27367	96393	90	135000	71.54159	107420
10900	85.94819	128943	64.12682	96364	90	135000	71.71083	107378
10920	85.95377	128919	64.28016	96269	90	135001	71.73789	107553
10940	85.9232	128915	64.3224	96413	90	135001	71.73732	107603
10960	85.90042	128872	64.19746	96431	90	135001	71.71635	107598
10980	85.79948	128814	64.12377	96282	90	135001	71.63012	107537
11000	85.7271	128674	64.11046	96190	90	135001	71.75183	107493
11020	85.57916	128531	64.08624	96155	90	135001	71.70741	107600
11040	85.43052	128353	63.67915	96051	90	135001	71.64869	107536
11060	85.31781	128134	63.24889	95524	90	135001	71.60541	107456
11080	85.02186	127950	62.68778	94875	90	135001	71.46082	107357
11100	84.93099	127527	62.70081	94066	90	135001	71.50686	107231
11120	84.67201	127329	62.51405	93952	90	135001	71.4138	107234
11140	84.50305	126982	61.9764	93761	90	135002	71.24387	107087
11160	84.13004	126735	61.52023	92949	89.84032	134954	71.11929	106854
11180	83.71629	126179	61.05989	92272	89.08609	134735	70.99409	106662

11200	83.6134	125550	60.64399	91580	88.57896	133582	70.94257	106502
11220	83.45818	125336	60.14423	90961	87.96468	132851	70.93824	106420
11240	83.37948	125184	59.44964	90178	87.2028	131922	70.92679	106404
11260	83.34518	125069	58.94089	89111	86.28526	130760	71.12086	106445
11280	83.03589	124967	58.26999	88402	85.21141	129349	71.13659	106653
11300	82.85369	124548	57.54602	87375	83.97994	127753	71.15048	106708
11320	82.73486	124256	56.79292	86289	82.97541	125890	71.2085	106747
11340	82.48911	124056	56.63826	85156	82.47096	124408	71.27112	106832
11360	82.29227	123724	56.27637	84903	81.97115	123685	71.36284	106935
11380	82.02789	123427	55.97874	84416	81.41146	122933	71.27218	106998
11400	81.86903	123031	55.63389	83951	80.72884	122090	71.259	106906
11420	81.41412	122786	54.97955	83459	80.03125	121046	71.18265	106855
11440	81.23384	122094	54.80114	82434	79.34885	120008	71.00233	106730
11460	80.93797	121830	54.2527	82158	78.55813	118975	70.73901	106496
11480	80.60543	121390	54.00214	81354	77.72152	117793	70.52578	106110
11500	80.27067	120893	53.29292	80999	76.43032	116517	70.30302	105784
11520	79.58421	120386	52.61662	79875	74.97585	114568	69.93478	105448
11540	79.05751	119320	52.08458	78894	73.69136	112390	69.50907	104896
11560	78.91293	118552	52.04356	78140	73.15828	110453	68.14082	104244
11580	78.5489	118336	52.0809	78046	72.61208	109721	67.00599	102145
11600	78.3403	117808	51.85366	78023	71.98079	108896	66.08489	100453
11620	77.95958	117491	51.58514	77783	71.29195	107929	64.63374	99062
11640	77.74993	116927	51.29684	77361	70.57605	106902	62.83404	96911
11660	77.71728	116637	51.27832	76973	70.26135	105830	61.24284	94219
11680	77.64239	116545	51.39694	76969	70.123	105377	60.39074	91800
11700	77.71851	116493	51.37062	77064	69.9713	105156	59.76637	90552
11720	77.53179	116520	50.69072	77002	69.57105	104941	58.82724	89613
11740	77.34052	116285	50.4494	75997	69.15389	104352	57.87064	88167
11760	77.09386	115998	50.74512	75796	68.79121	103719	57.08482	86743
11780	77.13007	115683	50.38391	75987	68.54607	103178	56.30383	85597
11800	77.02699	115659	50.3932	75630	68.55142	102852	55.82766	84404
11820	76.93207	115513	50.40277	75578	68.44055	102781	55.06203	83723
11840	76.72025	115363	50.38081	75581	68.33597	102627	54.77512	82546
11860	76.51893	115067	50.28153	75516	68.18651	102465	54.20727	82153
11880	76.53898	114817	50.20354	75406	68.00227	102259	53.69901	81291
11900	76.21659	114758	50.09154	75277	67.82098	101982	53.25927	80525
11920	75.98748	114299	50.49046	75212	67.69431	101716	52.93571	79873
11940	75.57826	113973	50.44499	75664	67.44006	101514	52.43882	79395
11960	75.06312	113340	50.13899	75605	67.06801	101157	51.79665	78646
11980	74.68971	112559	49.66766	75222	66.66335	100592	51.21542	77653
12000	74.4761	112013	49.39682	74474	66.23473	99983	50.59509	76806
12020	74.15385	111697	49.18359	74077	65.91014	99338	50.31354	75864
12040	73.94313	111217	49.05878	73761	65.5161	98850	49.90256	75462
12060	73.7319	110899	48.94322	73555	65.224	98270	49.4905	74848
12080	73.60542	110589	48.7003	73388	64.89591	97822	49.05855	74227
12100	73.45163	110386	48.6942	73090	64.89616	97376	48.66559	73578
12120	73.47915	110210	48.79849	73093	64.98006	97360	48.55183	72999

12140	73.36861	110170	48.76875	73178	64.92548	97445	48.47578	72814
12160	73.33997	110045	49.11995	73203	64.90811	97375	48.43658	72707
12180	73.3213	110001	49.06877	73601	64.7341	97305	48.29726	72604
12200	73.31503	109978	49.06584	73612	64.70078	97111	48.08186	72423
12220	73.23802	109950	49.06798	73610	64.59654	97011	48.0051	72129
12240	73.24686	109855	48.95078	73546	64.56319	96891	47.98183	72009
12260	73.23624	109857	48.9716	73442	64.49239	96816	47.96239	71962
12280	73.16915	109833	49.01497	73474	64.52655	96749	47.96153	71941
12300	73.14526	109746	49.03172	73534	64.6317	96833	47.96276	71941
12320	73.00945	109671	49.01971	73548	64.64735	96955	48.0378	71968
12340	72.97917	109514	48.9864	73515	64.68291	96990	48.00403	72044
12360	72.93028	109444	49.08191	73524	64.66437	97026	48.05634	72022
12380	72.87197	109376	49.04495	73596	64.66342	96999	48.00121	72065
12400	72.75851	109265	48.95845	73517	64.68123	97003	48.07562	72024
12420	72.77751	109153	48.99394	73458	64.68169	97015	48.07059	72108
12440	72.6786	109127	48.88974	73437	64.57712	96978	48.06878	72108
12460	72.57738	108991	48.86002	73329	64.57901	96876	48.07442	72108
12480	72.46931	108838	48.91304	73316	64.52492	96851	48.09557	72116
12500	72.35183	108674	48.86789	73351	64.56079	96796	48.19584	72178
12520	72.27194	108518	48.87042	73302	64.57959	96851	48.17188	72276
12540	72.23461	108403	48.80322	73267	64.52525	96854	48.1723	72259
12560	72.02562	108299	48.77786	73193	64.43781	96754	48.14614	72251
12580	71.78534	108026	48.68221	73115	64.33534	96623	48.13826	72211
12600	71.65764	107674	48.60197	72989	64.18153	96462	48.13608	72203
12620	71.63703	107500	48.62224	72921	64.166	96284	48.12866	72201
12640	71.71598	107476	48.63182	72935	64.13176	96234	48.10759	72188
12660	71.69395	107565	48.59157	72929	64.0735	96173	48.17493	72179
12680	71.69109	107544	48.55685	72871	63.98984	96071	48.16997	72253
12700	71.67043	107534	48.47958	72795	63.74507	95929	48.14541	72246
12720	71.57227	107465	48.35098	72655	63.5389	95599	48.10674	72200
12740	71.44341	107317	48.22505	72497	63.26331	95294	48.00146	72117
12760	71.53957	107216	47.91925	72318	62.94511	94883	48.03064	72021
12780	71.38684	107258	47.60187	71879	62.64366	94415	47.98493	72030
12800	71.3294	107079	47.65396	71465	62.25893	93956	47.9505	71965
12820	71.11894	106949	47.55791	71432	61.86664	93378	47.90684	71907
12840	71.13251	106712	47.4653	71301	61.46108	92786	47.83981	71831
12860	71.00201	106650	47.25946	71143	61.1731	92180	47.75372	71727
12880	71.04382	106528	47.2529	70926	60.99471	91746	47.736	71633
12900	71.01384	106558	47.34673	70910	60.86653	91474	47.74355	71602
12920	70.99999	106518	47.18639	70959	60.73802	91267	47.75212	71612
12940	70.87674	106456	47.2079	70813	60.6872	91099	47.74229	71625
12960	70.7812	106285	47.19089	70807	60.63596	91011	47.61736	71574
12980	70.74849	106167	47.16356	70777	60.6191	90947	47.47247	71389
13000	70.718	106111	47.34081	70794	60.55104	90907	47.45409	71225
13020	70.59403	106032	47.14848	70922	60.42212	90772	47.33575	71136
13040	70.44626	105854	47.17203	70764	60.38825	90632	47.32671	71014
13060	70.30716	105647	47.22592	70782	60.2424	90532	47.33221	70990

13080	70.17896	105434	47.09975	70774	60.09509	90335	47.3322	70994
13100	70.1517	105276	46.99861	70628	60.06107	90147	47.23512	70960
13120	70.10773	105204	47.03563	70526	60.02597	90077	47.32229	70898
13140	70.05861	105143	47.06703	70569	60.00798	90031	47.32244	70982
13160	69.90179	105036	47.08781	70616	60.01874	90016	47.2208	70951
13180	69.75897	104831	47.11397	70645	59.88541	89978	47.19894	70833
13200	69.70912	104645	47.13028	70679	59.80034	89807	47.19492	70793
13220	69.55608	104517	47.24416	70739	59.77855	89697	47.18236	70787
13240	69.50104	104339	47.31274	70874	59.70725	89639	47.20544	70781
13260	69.45239	104240	47.36287	70978	59.65155	89539	47.2147	70812
13280	69.3116	104126	47.39462	71049	59.58081	89445	47.26598	70846
13300	69.12303	103943	47.38542	71089	59.45985	89320	47.18644	70871
13320	69.04311	103685	47.33629	71055	59.23434	89149	47.02515	70707
13340	68.95776	103532	47.56317	71051	58.90732	88843	47.08576	70590
13360	68.87323	103414	47.52467	71290	58.71005	88352	46.99616	70601
13380	68.62499	103272	47.31772	71235	58.50853	88047	46.89429	70469
13400	68.44478	102933	47.34557	71021	58.25459	87747	46.80461	70322
13420	68.27983	102651	47.40363	71040	57.83104	87373	46.74895	70193
13440	68.21222	102420	47.30397	71066	57.28365	86734	46.60026	70080
13460	68.06294	102256	47.19943	70927	56.95833	85916	46.55927	69904
13480	67.9138	102072	47.30356	70869	56.63796	85420	46.64523	69874
13500	67.81271	101856	47.35233	70975	56.407	84950	46.66953	69975
13520	67.68318	101687	47.37805	71040	56.1152	84598	46.58167	69963
13540	67.55319	101496	47.24162	70998	55.81755	84166	46.30847	69828
13560	67.54862	101344	47.22867	70879	55.51473	83714	46.42881	69566
13580	67.53722	101317	47.20494	70834	55.2462	83238	46.33467	69598
13600	67.53033	101307	47.11961	70773	55.00084	82860	46.26219	69465
13620	67.52998	101303	47.02658	70638	54.69614	82486	45.90891	69344
13640	67.63466	101351	46.87462	70505	54.26018	82040	45.5368	68845
13660	67.58432	101419	46.9921	70404	53.95822	81378	45.17812	68301
13680	67.45807	101318	46.83812	70410	53.46886	80926	44.82141	67742
13700	67.45781	101192	46.62856	70234	52.65855	80189	44.46329	67208
13720	67.28008	101128	46.46483	69924	51.8876	78940	44.08844	66692
13740	67.00435	100897	46.33516	69690	51.15997	77783	43.69704	66113
13760	66.80548	100499	46.21269	69484	50.537	76710	43.34831	65540
13780	66.61105	100195	45.93744	69294	49.86601	75774	43.1946	64999
13800	66.2589	99903	45.78865	68893	49.24052	74772	43.19475	64818
13820	66.10265	99378	45.66589	68648	48.64711	73834	43.12872	64766
13840	65.69815	99133	45.49272	68475	47.77754	72945	43.04617	64651
13860	65.50667	98540	45.52132	68282	47.15692	71612	42.85223	64526
13880	65.22836	98244	45.10007	68229	46.62349	70713	42.74103	64253
13900	65.04259	97827	45.04274	67678	46.14401	69908	42.57886	64062
13920	64.76659	97544	44.68791	67504	45.70921	69204	42.51253	63864
13940	64.57263	97114	44.89897	67166	45.35309	68552	42.48377	63760
13960	64.26959	96839	44.5491	67233	45.00777	68017	42.37949	63669
13980	64.09135	96395	44.41327	66826	44.70746	67504	42.12526	63524
14000	63.91386	96122	44.44746	66658	44.46443	67045	41.94302	63162

14020	63.85617	95880	44.45584	66675	44.30063	66681	41.69537	62900
14040	63.82686	95781	44.41818	66672	44.12219	66426	41.54295	62520
14060	63.55589	95666	44.37553	66614	43.9464	66165	41.52535	62332
14080	63.33817	95328	44.3533	66558	43.77896	65903	41.3969	62240
14100	63.1326	95002	44.07295	66480	43.71613	65668	41.27342	62051
14120	63.0014	94689	43.96384	66113	43.81529	65612	41.30295	61940
14140	62.75206	94473	44.11173	66022	44.01373	65776	41.22701	61916
14160	62.34796	94125	43.89626	66093	43.97244	65978	41.13547	61798
14180	62.07755	93505	43.94165	65896	43.9973	65964	41.14891	61719
14200	61.87317	93100	43.96878	65925	43.89842	65957	41.0186	61655
14220	61.55292	92794	43.94653	65952	43.84866	65833	40.98975	61527
14240	61.37933	92319	43.72566	65867	43.72766	65727	40.87051	61441
14260	61.24634	92055	43.75041	65637	43.7273	65603	40.73166	61273
14280	61.22627	91883	43.95967	65681	43.71852	65591	40.73058	61127
14300	61.0242	91789	43.83669	65854	43.6292	65553	40.61835	61039
14320	60.88767	91528	43.44955	65714	43.28946	65389	40.58435	60921
14340	60.78601	91316	43.38097	65191	43.10593	64926	40.51227	60851
14360	60.67342	91155	43.59033	65121	43.01265	64647	40.49765	60767
14380	60.62146	91012	43.27846	65292	42.87869	64477	40.46864	60731
14400	60.35739	90892	43.28038	64960	42.78043	64296	40.42816	60679
14420	60.19646	90530	43.03548	64862	42.61644	64129	40.40077	60624
14440	59.92545	90274	42.92879	64553	42.40674	63901	40.38728	60593
14460	59.14099	89879	42.87993	64394	42.52977	63684	40.3297	60558
14480	58.92642	88651	42.73555	64274	42.463	63774	40.34502	60496
14500	58.85219	88378	42.69611	64111	42.44409	63682	40.33716	60509
14520	58.65501	88228	42.74854	64067	42.48888	63677	40.41473	60547
14540	58.4922	87971	42.74884	64126	42.44156	63725	40.41899	60622
14560	58.33015	87720	42.72589	64119	42.48108	63672	40.42023	60632
14580	58.07025	87482	42.67969	64069	42.51354	63736	40.40543	60628
14600	57.88275	87099	42.57065	63974	42.45738	63758	40.40514	60607
14620	57.65872	86816	42.72772	63921	42.47276	63686	40.36961	60589
14640	57.41547	86479	42.60887	64025	42.50378	63711	40.45738	60579
14660	57.15257	86091	42.61278	63921	42.53795	63776	40.4577	60680
14680	56.5746	85716	42.38673	63862	42.49025	63804	40.42903	60674
14700	55.89238	84829	41.9932	63580	42.23811	63680	40.30742	60594
14720	55.06683	83781	41.41962	63001	41.86287	63345	40.06203	60424
14740	54.15215	82534	41.02814	62114	41.46933	62790	39.66264	60067
14760	53.08546	81148	40.65253	61538	40.95166	62195	39.32591	59460
14780	52.25795	79542	40.19751	60976	40.59338	61409	38.91246	58958
14800	51.2207	78334	39.71576	60296	39.71474	60873	38.28009	58344
14820	50.28183	76735	39.08507	59564	38.87274	59519	37.27193	57378
14840	49.83569	75345	38.74985	58602	38.48674	58264	37.1348	55835
14860	49.34985	74741	38.617	58124	37.98608	57712	37.07831	55576
14880	48.95416	73998	38.24626	57910	37.66959	56970	36.54157	55502
14900	48.62317	73417	38.01375	57382	37.49382	56495	36.29176	54782
14920	48.40123	72922	37.87091	57013	37.1924	56217	35.9686	54407
14940	48.20868	72581	37.74805	56792	36.84581	55781	35.60497	53931

14960	48.07901	72297	37.54538	56601	36.45027	55261	35.29321	53406
14980	47.93813	72094	37.32311	56315	36.07694	54664	35.05959	52941
15000	47.71831	71882	37.15169	55985	35.91463	54109	34.87033	52571
15020	47.31227	71550	37.0062	55698	35.627	53828	34.5753	52288
15040	46.43463	70957	36.63255	55492	35.23241	53436	34.29506	51862
15060	46.03053	69573	36.29013	54955	34.80721	52841	34.0044	51416
15080	45.63167	69025	35.87798	54440	34.6593	52205	33.85045	50977
15100	45.23747	68429	36.25017	53921	34.37532	51965	33.76411	50750
15120	44.91902	67839	36.07889	54263	34.21783	51554	33.51578	50604
15140	44.51555	67345	35.90799	54090	34.23219	51349	33.42435	50262
15160	44.16306	66759	35.49039	53855	34.15814	51320	33.39787	50133
15180	43.91882	66225	35.40633	53244	33.9445	51185	33.33728	50072
15200	43.96178	65924	35.85996	53156	33.81265	50896	33.21916	49965
15220	43.97025	65945	35.83202	53739	33.41913	50684	32.87268	49779
15240	43.61789	65899	35.41046	53725	33.01312	50123	32.23851	49294
15260	43.16721	65422	35.07436	53126	32.09126	49504	31.50903	48344
15280	42.71323	64731	34.53445	52615	31.24643	48087	30.9406	47198
15300	42.2336	64039	33.90288	51799	30.55356	46825	30.40848	46370
15320	41.38796	63322	34.16711	50937	29.92641	45798	29.50923	45572
15340	40.6689	62009	33.79216	51137	29.04767	44869	28.40344	44208
15360	40.18831	60952	33.429	50701	28.10017	43509	27.40846	42524
15380	39.66699	60252	32.886	50151	27.45	42096	26.6601	41032
15400	39.01068	59471	32.64475	49314	26.75884	41142	25.80051	39938
15420	38.36224	58459	32.32817	48965	26.23482	40109	24.32417	38648
15440	37.72263	57503	31.61853	48495	25.45013	39335	23.44486	36443
15460	37.32571	56540	31.61501	47444	24.97786	38137	22.7945	35134
15480	36.90414	55964	31.38742	47303	24.62605	37447	21.98853	34147
15500	36.62051	55314	31.31458	47086	24.27396	36927	21.35559	32939
15520	36.33865	54925	31.15906	46943	24.23705	36431	20.88692	32010
15540	36.08391	54497	30.9514	46722	24.20766	36323	20.25829	31291
15560	35.56201	54113	31.08667	46515	24.18855	36287	19.57219	30344
15580	35.22652	53316	31.31227	46663	24.6149	36326	18.9708	29301
15600	35.21956	52864	31.20659	46886	24.9751	36925	18.56839	28437
15620	35.30434	52840	31.35584	46867	24.79623	37367	18.23854	27848
15640	35.89716	52999	31.03056	46948	24.13361	37168	18.10765	27336
15660	36.2544	53871	31.176	46650	23.92709	36187	17.9949	27124
15680	36.57382	54397	31.53549	46794	24.50348	35979	17.85634	26939
15700	36.66278	54856	31.68864	47290	24.78827	36759	17.88313	26811
15720	36.62224	54980	31.69043	47499	25.00929	37191	17.65746	26768
15740	35.96954	54890	31.20201	47483	24.23514	37423	17.5079	26472
15760	35.07156	53915	30.8961	46817	23.98206	36328	17.06369	26221
15780	33.68907	52518	30.51271	46344	23.27596	35955	16.42073	25575
15800	32.09045	50452	29.46942	45774	22.46465	34882	15.59665	24611
15820	30.02081	48064	28.46985	44145	21.00185	33651	14.56981	23339
15840	27.27588	45205	27.30194	42645	18.92159	31469	13.8212	21786
15860	24.41185	41702	25.93549	40877	17.10286	28489	12.4825	20704
15880	21.34236	38029	24.60817	38834	15.28619	25620	11.63156	18647

15900	18.01256	34324	22.7361	36847	13.11617	22929	10.7318	17407
15920	14.48454	30609	20.83885	34191	10.96893	19856	9.598312	16018
15940	9.495987	26886	19.15872	31215	9.516785	16548	8.767136	14325
15960	6.907791	23155	18.1815	28681	8.553162	14210	8.18811	13114
15980	5.305969	19429	17.93317	27235	8.271545	12777	7.732925	12265
16000	3.982635	15709	17.7179	26884	7.205048	12392	7.696045	11624
16020	3.368057	11966	17.3929	26569	6.568207	10729	7.205963	11444
16040	2.490845	8228	17.0067	26101	5.932556	9830	6.825821	10809
16060	1.725983	4496	16.27945	25517	5.436218	8879	6.327866	10231
16080	0.932846	2523	15.78676	24384	4.878845	8144	6.071167	9485
16100	0.146393	1335	15.46964	23675	4.196838	7300	6.108734	9154
16120	0	156	15.138	23204	3.338531	6260	5.665131	9078
16140	0	63	14.70377	22705	2.545929	4952	5.244446	8501
16160	0	53	14.25147	22057	1.492645	3778	4.965179	7869
16180	0	23	13.813	21381	0.888062	2162	4.922256	7469
16200	0	9	13.4377	20712	0.348663	1317	4.871597	7357
16220	0	5	12.955	20158	0	501	4.323959	7246
16240	0	3	12.40176	19437	0	34	4.188232	6473
16260	0	2	11.73538	18585	0	20	3.775665	6247
16280	0	1	11.16484	17582	0	19	3.395447	5658
16300	0	0	10.81392	16737	0	15	3.396515	5132
16320	0	1	10.56267	16225	0	7	3.137512	5019
16340	0	1	10.34007	15847	0	2	2.925598	4706
16360	0	1	10.19365	15509	0	1	2.81189	4384
16380	0	1	10.1581	15306	0	2	3.470673	4324
16400	0	1	10.34847	15291	0	3	3.471283	5170
16420	0	1	10.13846	15434	0	3	2.647583	5194
16440	0	2	9.86113	15196	0	3	2.677368	3996
16460	0	2	9.596298	14796	0	4	2.379211	3878
16480	0	2	9.364914	14397	0	4	2.821777	3682
16500	0	2	9.151382	14049	0	4	2.639618	4123
16520	0	2	8.802795	13721	0	4	1.753723	3935
16540	0	2	8.168503	13214	0	4	2.093964	2680
16560	0	2	7.13324	12235	0	4	1.749115	3024
16580	0	2	6.441711	10623	0	4	1.194519	2623
16600	0	2	5.525726	9652	0	4	1.235931	1830
16620	0	2	4.829163	8234	0	4	1.007935	1750
16640	0	2	4.02829	7217	0	4	0.988403	1537
16660	0	2	2.811432	5996	0	3	0.843445	1431
16680	0	2	2.388733	4134	0	3	0.663849	1236
16700	0	2	2.167603	3580	0	3	0.311218	978
16720	0	2	1.95639	3248	0	2	0	469
16740	0	2	1.691711	2931	0	2	0	44
16760	0	2	1.362274	2540	0	2	0	15
16780	0	2	0.989868	2047	0	2	0	15
16800	0	2	0.597137	1491	0	2	0	11
16820	0	1	0.210785	899	0	2	0	5

16840	0	0	0	318	0	1	0	0
16860	0	0	0	41	0	1	0	2

E. Reliability Test Results

An X marking indicates that the testing criterion was met. No mark indicates that the criterion was not met.

TRIAL	CRITERIA 1	CRITERIA 2	CRITERIA 3	CRITERIA 4
1	X			
2	X	X	X	X
3	X			
4	X			
5	X			