Contents

1. Assay time for one sample and six samples
2. The hard drive centrifuge recipe
3. The consistence of the CentriDrive speed
4. Rotational speed characterization of CentriDrive at different voltage
5. LAMP reaction results using commercial centrifuge instead of the CentriDrive.
6. A prototype kit with vials in several pouches

Reference
1. Assay time for one sample and six samples

Our lab-in-backpack system can make a maximum of six samples at one time. The difference of assaying one sample and six sample is repeated protocol for adding regents and purifying the nuclei acid. The waiting time for incubation and evaporation and centrifugation are the same.

Table S1. Assay time for one sample and six samples.

| Sample number | Assay time/minute |
|---------------|-------------------|
| 1             | 80                |
| 6             | 90                |

2. The hard drive centrifuge Recipe

The CentriDrive (Fig S1) is a diagnostic 3D-printed hard drive centrifuge, at high rotational speeds of up to 10,000 RPM. Most importantly, at a cost of only $28 (See Appendix), this centrifuge is significantly cheaper than a standard centrifuge.

Fig S1: The CentriDrive

Equipment Needed

Parts:
1x 7,200 RPM Hard drive
1x Breadboard
1x Arduino/Geekcreit Nano with USB upload cable
1x 16x2 LCD
2x 10K potentiometers
1x 10-12V battery
1x 30A ESC
1x Rocker switch
1x Centrifuge rotor
1x Infrared sensor
>35x breadboard wires

**Tools:**
1x T6 Screwdriver
1x Multimeter
1x Soldering Iron

**Software:**
Arduino IDE – Install from: [https://www.arduino.cc/en/main/software](https://www.arduino.cc/en/main/software)
Choose the correct download option for your computer (red arrow Fig S2).

Fig S2. Download Arduino IDE software
Procedure

Step 1: Opening the hard drive

Using the T6 screwdriver, unscrew all T6 screws on the back of the hard drive, including one screw underneath the white label (Fig S3). Once all screws have been removed, use a thin object to remove any glue between the edges. Then remove the back casing to expose the inside of the hard drive.

Step 2: Attaching the rotor

Unscrew the T6 spindle screws located in the centre of the round spindle disk. The platter, spindle disk and actuator arm can now be removed as they are not needed (Fig S4). Screw the 3D-printed centrifuge rotor onto the motor.

Step 3: Connecting the motor to the ESC

This step involves the use of the soldering iron and the multimeter. Remove the green processor chip, revealing the motor with either three or four pins. Four-pin motors have three active pins and one common pin. To identify the common pin, measure the resistance between each pin using the multimeter (switch to the 200 Ω setting). The common pin (usually the far-left pin), will have half the resistance across it compared to the three active pins. Solder the three active pins to the three ESC motor pins.

Step 4: Setting up the CentriDrive

By following the CentriDrive schematic shown in Fig S5, connect all the parts together using the appropriate pins (See Appendix) and breadboard wires. Finally, copy and paste the code provided (See Appendix) into the Arduino IDE software and upload it to the Geekcreit Nano via the USB input. Use the physical set-up in Fig S1 for reference.
Fig S5. Circuit diagram of the CentriDrive. 1. Switch. 2. Power input. 3. LCD. 4. Breadboard. 5. Geekcreit Nano. 6. Infrared sensor. 7. ESC. 8. Potentiometer. 9. Motor. *The Arduino nano is shown in the figure due to the limitation of the software, but the Geekreit Nano was used in the final test.

**Appendix**

**Table S2: Connecting the LCD**

| LCD Pin | Name                  | Connected Pin          |
|---------|-----------------------|------------------------|
| 1       | VSS                   | GND                    |
| 2       | VCC                   | 5V                     |
| 3       | VEE                   | Centre pin of potentiometer |
| 4       | RS (register select)  | Geekcreit Nano pin 8   |
| 5       | RW (read/write)       | GND                    |
| 6       | E (Enable)            | Geekcreit Nano pin 9   |
| 7       | DB0                   | N/A                    |
| 8       | DB1                   | N/A                    |
| 9       | DB2                   | N/A                    |
| 10      | DB3                   | N/A                    |
| 11      | DB4                   | Geekcreit Nanopin 4    |
| 12      | DB5                   | Geekcreit Nano pin 5   |
| 13      | DB6                   | Geekcreit Nano pin 6   |
| 14      | DB7                   | Geekcreit Nano pin 7   |
| 15      | Anode                 | 5V                     |
| 16      | Cathode               | GND                    |
Table S3: Connecting the ESC

| ESC Pin                  | Connected Pin          |
|--------------------------|------------------------|
| Signal Pin (Yellow)      | Geekcreit Nano pin 10  |
| 5V                       | 5V                     |
| GND                      | GND                    |

Table S4: Connecting the potentiometer

| Potentiometer Pin        | Connected Pin          |
|--------------------------|------------------------|
| Signal Pin (Middle)      | Geekcreit Nano pin A0  |
| 5V                       | 5V                     |
| GND                      | GND                    |

Table S5: Connecting the potentiometer

| IR sensor                | Connected Pin          |
|--------------------------|------------------------|
| Signal Pin               | Geekcreit Nano pin 2   |
| 5V                       | 5V                     |
| GND                      | GND                    |

How to use a breadboard:

https://www.youtube.com/watch?v=6WReFkfUIk

How an ESC works:

https://www.youtube.com/watch?v=OZNxbxL7cdc&t=597s

Table S6: Costs of each part

| CentriDrive part                      | Cost ($)               | Availability                                      |
|---------------------------------------|------------------------|---------------------------------------------------|
| 2.85 mm diameter PLA filament         | 20.58/0.5 kg (22 g mass rotor = 0.91) | Ebay - Rast 3D [eBay item number: 362815622512] |
| 11.1v 2200 mAh Lipo rechargeable battery | 9.77                           | HobbyKing – Rhino [SKU: 9952000024-0]             |
| 30 A ESC                              | 4.12                        | Ebay - G-sun [eBay item number: 353142425598]     |
| Geekcreit Nano                        | 5.04                        | Amazon – Geekcreit Nano [ASIN: B072BMYZ18 ]       |
| LCD                                   | 4.18                        | Banggood – Geekcreit [ID: 978160]                 |
| 2X 10 k Potentiometer                 | 1.38                        | Amazon – GAOHOU [ASIN: B00H969CM0]                |
| Switch                                | 0.74                        | CPC Farnell - PRO POWER [catalogue page: CPCC/1490] |
| 35 Wires                              | 1.73                        | CFC Farnell - PRO SIGNAL [catalogue page: CPCC/1561] |
#include <LiquidCrystal.h>  // Includes the LCD library

LiquidCrystal lcd(8, 9, 4, 5, 6, 7);  // LCD pins (RS,E,D4,D5,D6,D7)

#include <Servo.h> // Includes the servo library

Servo esc;  // Stating that esc means Servo

int throttlePin = 0; // Potentiometer (Pot) connected to Pin A0

void setup() {
  esc.attach(10);  // ESC signal pin connected to Pin 10
  lcd.begin(16, 2);  // Set up the LCD's number of columns and rows
  lcd.print("Initialising...");  // Print a message to the LCD.
  delay(4000);  // Delay for 2 seconds
  lcd.clear(); // Clear the screen
  lcd.print(" Developed");
  lcd.setCursor(8,1);
  lcd.print(" by Umar");
  delay(4000);
  lcd.clear();
}
lcd.clear();
Serial.begin(9600);  // Display on Serial Monitor
}
void loop() {
  lcd.clear();
  throttlePin = analogRead(A0);  // Read the input on analog pin 0
  int throttle = analogRead(throttlePin);  // Read value from Pot
  int RPM = (throttlePin*10.23);  // Divide max motor speed by max Pot value
                                 // (10532/1023= 10.23)
  throttle = map(throttle, 0, 1023, 1000, 2000);  // Map Pot onto ESC
  esc.writeMicroseconds(throttle);  // Input Pot values to ESC
  lcd.print("The CentriDrive");  // Print a message to the LCD at (0,0)
  lcd.setCursor(0, 1);  // Position Text on LCD
  lcd.print("Speed:");
  lcd.setCursor(13, 1);
  lcd.print("RPM");
  lcd.setCursor(7, 1);
  lcd.print(RPM);  // Display 'RPM' value on LCD Display
  Serial.println(RPM);  // Display 'RPM' value on Serial Monitor
  delay(1000);
  lcd.clear();
}

**Measurement of the Speed via IR Sensor**

The CentriDrive uses an infrared (IR) sensor which operates as a digital tachometer to LED, onto a piece of metallic tape and receives the reflected light back using a photodiode (IR Receiver), at the frequency of the motor speed (Fig S6).[1] As part of the CentriDrive system, the IR sensor interacts with the Geekcreit Nano to measure the rotor rotation in revolutions per minute (RPM), displaying the speed on an inbuilt LCD. Similar to the way an encoder operates, the Geekcreit Nano records the time between each received IR ray collected by the IR sensor. The Geekcreit Nano then takes the reciprocal of this measure to obtain revolutions per second (RPS) and then multiplies that value by 60 to get RPM.
Speed data was collected by the IR sensor, processed by the Geekcreit Nano and displayed on the LCD. However, the speed of the rotor could also be displayed directly using the Arduinos integrated development environment (IDE). This data could then be exported from the IDE to a spreadsheet (Excel) and filtered to only show speed values at specific intervals.

A 15-minute centrifuge maximum speed test was conducted at least three times to obtain 3 different data sets. Once the centrifuge was turned on, the potentiometer was turned to full and as soon as the centrifuge hits its maximum speed, it was timed for 15 minutes to investigate its consistency. An average was taken across all three data sets to obtain fifteen individual speed values and plotted on a graph of Speed (RPM) against Time (minutes) at 1-minute intervals. The results showed that the centrifuge did not go below its maximum speed during each 15-minute test, hence proving the consistency of the CentriDrive.

3. The consistency of the CentriDrive speed.

![Graph](image)

Fig S7. Relationship between the CentriDrive speed and running time. The tests carried out with an attached rotor containing three water-filled microfuge tubes. Once the centrifuge was turned on, the potentiometer was turned to full and as soon as the centrifuge hits its maximum speed, it was timed for 15 minutes to investigate its consistency. The error bar is within the size of the symbols.
4. Rotational speed characterization of CentriDrive at different voltages.

![Graph showing the relationship between voltage and CentriDrive speed.](image)

Fig S8. Relationship between the voltage and CentriDrive speed (7200 rpm hard drive base).

5. LAMP reaction results using commercial centrifuge instead of the CentriDrive.

| Copies of added virus RNA using nuclease-free water | 0 | 100 | 400 | 2000 |
|---------------------------------------------------|---|-----|-----|------|
| 4 copies/µL                                      |   |     |     |      |

![Image of LAMP reaction results.](image)

Fig S9. LAMP reaction results using commercial centrifuge (SciSpin–Micro, Cat. No:911315410035). After centrifugation, the LAMP protocol can effectively detect synthetic viral RNA down to 4 copies per µL in saliva.

6. A prototype kit with vials in several pouches.
Fig S10. A prototype kit with vials in several pouches for room temperature, 4 °C and –20 °C storage.

Fig S11. The $51 lab-in-a-backpack system pictured in a small backpack, fitting the CentriDrive centrifuge, a 1000 cm³ cooler/freezer box for reagents under the centrifuge, a thermos, digital thermometer, two pipettes, and room for additional storage (ruler for scale).
Reference:

1. Manzoor M. Arduino with Infrared Sensor [cited 2021 Sep 18]. Available from: https://medium.com/illumination/arduino-with-infrared-sensor-48ad4415f320.