

# Oven for dry cleaning of graphene

## 1 Construction

Required electronic parts:

- Arduino Uno R3 Board
- HNP15-USB 5V 2,5A USB power supply 12,5W (+ B-Type USB cable)
- Power Supply 30 V/8 A (RS 705-9838)
- iTeed Arduino 1602 LCD Keypad Shield
- 4 Channel MOSFET Switch IRF540
- Thermocouple to digital converter MAX31855 breakout board
- K-Type Thermocouple (RS 621-2170)
- Nichrome Wire 24 SWG (Brimal Components)

The oven itself is made from an YTONG brick. A 30 ml glass beaker (borosilicate glass) is used as the sample container. The nichrome resistance wire is coiled helically around the beaker. To obtain a total resistance of about  $4\Omega$ , one needs about 2m of wire. To ensure good contact with the beaker, the wire is first coiled around a smaller beaker and subsequently transferred to the 30 ml beaker. The resistance of the coil is now adjusted to the required value by trimming of the wire. Finally, it is placed inside a hole in the brick.

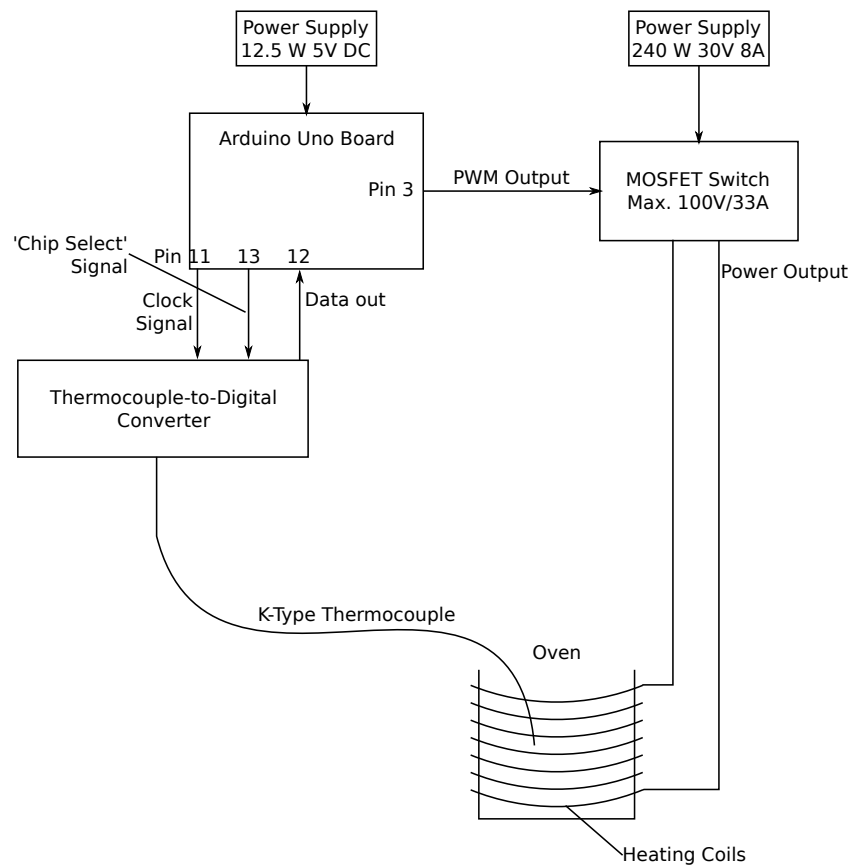


Figure 1: Sketch of the oven setup.

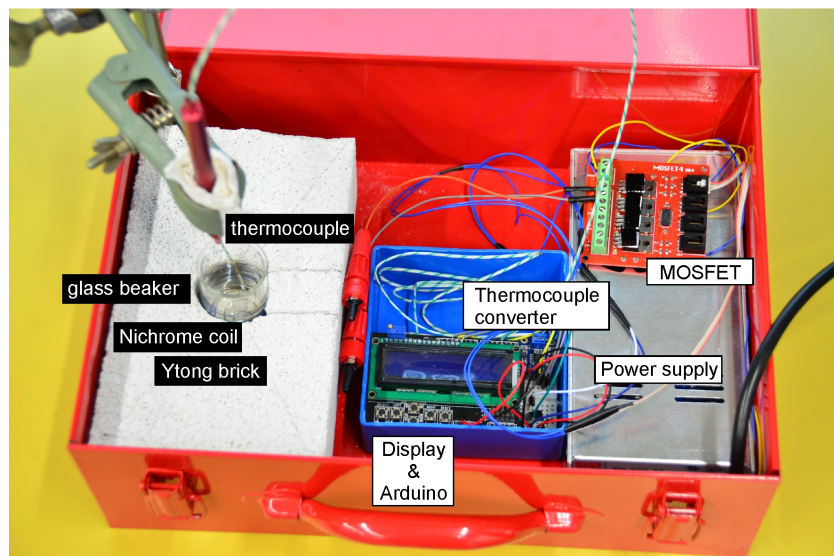


Figure 2: Photo of the oven setup.

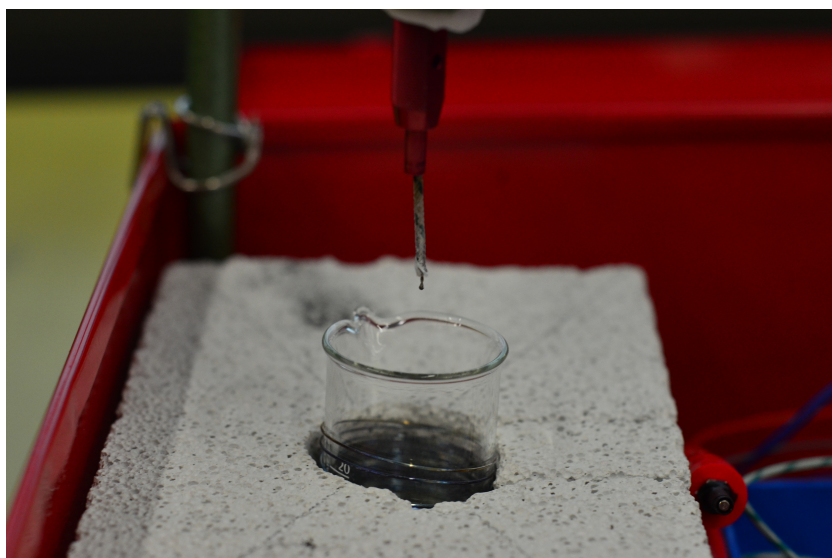


Figure 3: Photo of the glass beaker.



Figure 4: Photo of the glass beaker.

## 2 Source code

The Source code includes two external libraries:

<https://github.com/adafruit/Adafruit-MAX31855-library> (for the thermocouple amplifier)

[http://sainsmart.com/zen/documents/20-011-901/keypad\\_lcd.zip](http://sainsmart.com/zen/documents/20-011-901/keypad_lcd.zip) (for the keypad shield)

The source code of the program, which makes use of a simple PID algorithm, can be found on our web page.

## 3 Operating Instructions

First, the Arduino unit has to be connected to the power supply using a USB cable. The display should now show an initialization screen for several seconds before it shows the current temperatures of the thermocouple as well as the internal sensor. At this point, the oven is ready to be programmed as follows:

- Press the “select” button to start.
- Use the “up” and “down” buttons to select the required target temperature (in °C), confirm with “select”.
- Use the “up” and “down” buttons to select the required heating rate (in °C per minute), confirm with “select”.
- Use the “up” and “down” buttons to select the required annealing time (in minutes), confirm with “select”.
- Use the “up” and “down” buttons to select the required cooling rate (in °C per minute). If no controlled cooling is required, press the “down” button until “off” is displayed. This will cause the oven to power off directly after the annealing process. Confirm with “select”.
- The heating process will now start.
- After the program has finished, the system returns to its original state and displays the current temperatures. It can now be reprogrammed using the same procedure as above.

### 3.1 Temperature protocol

A detailed protocol of the measured temperatures can be obtained from the serial output via USB. For example, the built-in serial monitor of the Arduino IDE software can be used. The baudrate is set to 115200. The first line in the resulting list contains the following information: Timecode (ms), temperature, set temperature. The next line contains Information about the output power: Output value (0-255), followed by the composition from the PID terms.

## 4 Troubleshooting

- “Error! Thermocouple”: If this is displayed, the thermocouple controller has failed to get a correct reading from the sensor. Check the connection of the thermocouple on the board and make sure that the wire is tightly connected. Also check for mechanical damage of the thermocouple wire. Once the problem is resolved, press the “reset” button to restart the system.
- “Error! Overheated”: If this is displayed, the thermocouple has measured a temperature exceeding 600 °C. Make sure that there are no flammable materials present. If necessary, reduce the target temperature. Once the problem is resolved, press the “reset” button to restart the system.
- “Error! Overload”: If this is displayed, the output power of the oven has reached its maximum for a total of 120 seconds. Make sure that the thermocouple is in good contact with the sample. If necessary, reduce the mass of the sample or use a lower heating rate. Once the problem is resolved, press the “reset” button to restart the system.