Development of Roaster Control System Based on Arduino

Agusto M. H. Kana[1], Folkes E. Laumal[2], Daniel S. Bataona[3], Otnial A. Mone[4], Yohanes Suban Peli[5], Yustinus S. B. Ada[6]
{agusto_kana@gmail.com[1], folkeslaumal76@gmail.com[2], danielbataona@gmail.com[3], oscarmone547@gmail.com[4], jonsubanpeli@gmail.com[5], yustinus_ada@yahoo.co.id[6]}

Politeknik Negeri Kupang, Jalan Adisucipto, Penfui, Kupang – Indonesia[1,2,3,,4,5,6]

Abstract. This research develops roaster control system using Arduino as central to processing data that provides a reference for machine operations. Development of this system as an alternative to use of thermostat as a conventional contactor at roaster that is less detailed, easily damaged, less sensitive and effect to productivity. The research was conducted by the design and implementation method that is by choosing and connecting the appropriate sensor components to Arduino, making algorithm protocol, making programming, doing the installation to roaster machine and test the system. This system works when the thermocouple read and transmits temperature data for processed and used as a reference to execute the machine. Arduino as the central processing for all data input and output. Testing carried out on small-sized roaster after being modified using Arduino control systems. The test results show that under conditions of no load, the control system requires 38 minutes operate until the temperature reaches 450^o Celsius, whereas when given HS coffee, the system requires ± 1-hour with 10-minutes delay until the color of coffee is black and ready for the milling process. Control system of roaster machine with Arduino produces the better black color of coffee, more fragrant and better quality.

Keywords: control system, roaster, Arduino, thermocouple.

1 Introduction

The roaster is one of the appropriate technologies that are used as roasters various types of grains with the frying technique without oil. The grains may include nuts, coffee, corn and soybeans. The roasted method provides several advantages, namely affecting the quality, price and quality of the fried grains [1], helps preservation, provides a distinctive taste of processed products and optimize the treatment process [2],[3].

There are a variety of grainsroasting machines according to user needs. There isroasterfor2 kg, 5 kg, 10 kg, even>50 kg which has been equipped with a thermostat temperature sensor for ON-OFF effect on the switch. The thermostat is a device that can disconnect and reconnect electrical current at the time of detecting changes in temperature. Thermostat divided into two types, there are Mechanical and Electronics. Mechanical

WMA-1 2018, January 20-21, Indonesia

DOI 10.4108/eai.20-1-2018.2281902

Thermostat is a Contact Temperature Sensor, which uses the principle of Electro-Mechanical, while Electronic thermostat using an electronic component to detect temperature changes [4]. Some of the roastershaveimplemented the temperature control system using fuzzy logic concept for reducing the frying time from 1.5-3 hours to ± 35 minutes and use solar reflector concept [1],[3],[5],[6],[7].

Because the thermostat is easily available in the market at a low cost and utilized in roasting machines, it affects the quality of the grain fried processing result, because the thermostat as a conventional contactor works based on the temperature sensor in the roasting tube. The poor sensor quality also provides a less stable of value reading to the thermostat so the contactor also works inaccurately. In addition, the conventional of the thermostat causes the mechanical contactor to be more easily damaged, lead to energy waste and affect the production [8].

In line with the development of electronics technology, starting from the application of analogelectronics, digital and a microprocessor, almost all instrumentation system control uses a microprocessor/microcontroller in their implementation, such as DC/AC motors, liquid level control system and measurements instrumentation of temperature, pH and conductivity. The use of microcontrollers, which are mostly due to the advantages of the electronic components that already have internal memory, the I/O unit, processing bits and bytes and has a command/program is directly related to the I/O. The microcontroller which used in control system applications that are found on ATmega 328 in Arduino.

Arduino is a control board based on ATmega328 microcontroller that has 14 I/O digital pins (6 pins as PWM outputs), 6 analog inputs pins, 16 MHz crystal oscillator with USB connection type to thecomputer. Arduino compatible with electronic/other components sensors through the I/O pins and can be combined to control the behavior/properties of a machine/tool/equipment or natural phenomena that occur around humans, either real-time or delayed. Some applications of Arduino, including for the development of early warning system for earthquakes, combined with the vibrating sensor [9],[10], the indicator of the care and maintenance of the machine [11], the floodgates on farmland in combination with sensors and other applications that are appropriate and practical in people lives [12].

Based on several weaknesses of thermostat utilization above and the development of microprocessor technology, it is necessary to develop another control system in roaster machines which with ATmega 328 microcontrollerin Arduino.

This research has developed a control system of roaster by utilizing Arduino as a central processing and thermocouple as a temperature sensor. This control system also utilizes an LCD display to show the roasting process, buzzer foralarm and a motor driver to controlling the electric motors that move of theroaster.

2 Method

Roaster control system based on Arduino developed by design and implementation method This method is chosen because the corresponding of sensor components are available on the market (including Arduino) andanaverageofcomponents are compatible with Arduino as central processing. The selection of component adjusted to the needs of the voltage and data corresponding to the Arduino. While the adjustment, cooperation and process of data transfer between components is determined by the programming structure created and uploaded to Arduino

The design method is done by 3 stages, namely component selection and interconnects to Arduino, making of protocol algorithm system, making program structure based onanalgorithm, insertingaprogram into Arduino and interconnect system control to roaster machine. While the implementationmethod is done by providing a voltage source to the control system created, run the system to control the frying process simulation and taking the test data to be processed.

The Design of roaster control system is given in Figure 1 as follows:

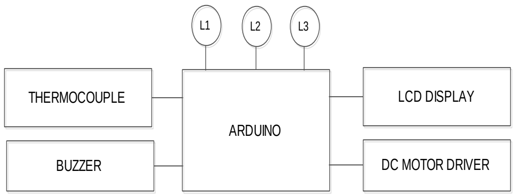

Fig. 1. Design of roaster controlsystems.

Control Systems in Figure 1, consists of a thermocouple, buzzer, LED, LCD displays, motor driver and Arduino asthecentral processing of data. A thermocouple attached to the wall of the tube roaster to read the temperature. Relay as a switch to turn on and off the heating source. Temperature data fromthe thermocoupleis a parameter by Arduino to give the order to turn on and off the relay as the main breaker switch at roaster. Buzzer as the alarm when thermocouple reading the certain temperature value. Led is additional indicator along buzzer that would abuse according to user needs. There are 3 LED used is the L1, L2 and L3 with different roles. Other components used in the control system is that LCD display to show the temperature value. Protocol software from roaster control system designed to work in three phases, namely standby, running and stop. Standby is the phase when the roaster starts the engine bychangesthemain switch to ON position. When the main switch is ON, the control system will perform the initialization of all components connected tothemicrocontroller ports, which then continued by reading the initial temperature of thetube at 0° Celsiuspositions. LCD display at this stage, show the status of preparedness and start reading the temperature from thetube. The algorithmof thecontrol system shown in Figure 2.

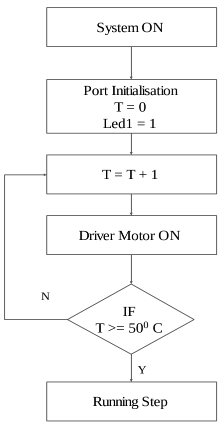

Fig. 2. Algorithm of thecontrolsystem on standby phase.

The control system algorithm in Figure 2 will begin toread theportsinitializing that connected each other when the main switch isturned ON, LED1 will be ON and the LCD displays a certain status that can be seen by theuser. Temperature tube that legible ranging from zero degrees (0° Celsius) in stages according to theheat of the roaster tube and sent by thermocouple to Arduino. The motor driver receives a command to drive an electric motor that connected from the I/O port driver. If the temperature reads50° Celsius valuable, then the tube roaster ready to put the material (grains) and the system switches to the runningphase as the next process. The running phase is given in Figure 3.

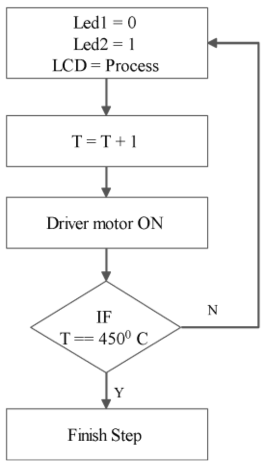

Fig. 3. Algorithm of control systems on running phase.

The frying process(running phase)in Figure 3, will be work when the tube temperature reaches ± 50° Celsius and LED2 is ON. Material that inserted into the tube will experience a stirring roaster according to roaster round tube. Round power supplied by the motor driver depending on motor rotation speed [13], as shownmathematically follows equation (1).

$$N = \frac{V_{to} - I_a . R_a}{K.\emptyset} \quad (1)$$

Equation (1) consist of N is the speed of DC motor rotation, V_{tm} = Voltage Terminal, I_a and R_a are currents and obstacles anchor, K is a constant of the motor, and ∅ is the magnetic flux. Implementation of N on the roaster control system is set up in L298N double H bridge motor driver chip, which works at 5-35 volts voltage and operates at 2 Ampere maximum current. With regulator combination of 7805 and other electronics components, the motor driver module is compatible with Arduino thus setting the rotation motor load connected through L298N drivers can be made through the C programming language on Arduino.

If the temperature of the tube has shown of 450° Celsius, thefried material has matured and the system will move to finish phase. At this phase, the main switch of roaster will be OFF, the flow of current is also OFF and roaster stopped working.

3 Results And Discussion

Interconnection port of Max6675 thermocouple with Arduino using 5 I/O pins as seen in Figure 4 as follows:

Max6675 Thermocouple	Arduino
Vcc	5 Volt
Gnd	Gnd
SO	pin 4
LCK	pin 5
CS	pin 6

Fig. 4. Interconnection max6675 thermocouple module with arduino.

In Figure 4, the voltage source of max6675 thermocouple utilizes 5V voltage from 5-volt pinArduino. SOpin is connected to pin 4 at Arduino,LCK pinconnected to pin 5 Arduino and CS pin is connected to the pin 6 Arduino.Relay serves as a switch to turn ON and OFF a heat source that connected to roaster tube. Temperature data received from max6675 thermocouple becometheparameters to change the relayto ON/OFF.Relay module used in this system is a 2-channel relay to activate the heating source. Buzzer apply twice sound as an indicator of alarm signal, that is when the tube temperature had reached 50° Celsius indicating that the tube roaster ready for charging material and when the temperature had reached 450° Celsius with a 10 minutes delay as an indicator that the frying process has been completed,

LED apply as an indicator additional along thebuzzer.When the temperature reaches 50° Celsius, LED1 will be ON that means that the material is readily inserted into the tube. When the temperature greater than 50° Celsius, indicator LED2 ON that means that the roasting process has occurred with a load of material already inside the tube roaster. Then, when the temperature has reaches 450° Celsius with 10 minutes delay, then frying process has been completed, LED3 ON, LED1 and LED2 will be OFF. A0 pin from Arduino connected to LED1anodepin, A1 pin connected to LED2 anodepin, A2pin connected to LED3 anodepinand output GND of Arduino connected to cathodepin of LED1, LED2 and LED3.

The function of LCD is to display the temperature values that read by thethermocouple. Interconnectionof LCD with Arduinois given in Figure 5 below.

LCD Display	Arduino
6	11
11	2
12	3
13	8
14	9
2, 15	5 volt
1, 16	GND
3	Potensiometer

Fig. 5. Interconnection lcd display module and arduino.

At interconnections like as Figure 5, includes GND pin Arduino connected to pin 1 LCD, 5V pin Arduino connected to pin 2 LCD, 3 pin of LCD connected to the input pin of potentiometer, the positive pin of potentiometer connected to the 5V pin of Arduino, negative pin potentiometer connected to the output GND Arduino, Pin 11 of Arduino connected to pin 6 LCD, pin 2 of Arduino connected to pin 11 on LCD, pin 3 connected to pin 12 LCD, pin 8 connected to pin 13 LCD, pin 9 connected to pin 14 LCD, pin 5V Arduino is connected to pin 15 LCD, GND pin Arduino is connected to pin 16 LCD.

Based on the pattern of interconnection, then the roaster control system developed by Arduinois given in Figure 6.

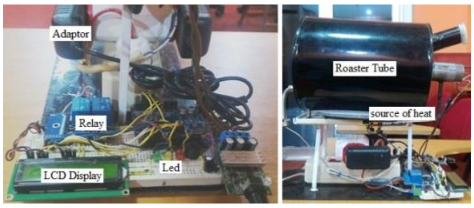

Fig. 6. Result of roasted machine control system.

There are 2 displays in Figure 6, each front view and a side view. From the front, look Arduino microcontrollers with other sensor components that have been integrated into the control system, complete withapower source, while from the side, seen aroasted tube with elements as a source of heat.The next process is making programming system and inserted into ATMega328 microcontroller on Arduino by using theUSB cable.

Programming process on roastercontrol system is built using the C programming language in Arduino version based on logic algorithms have been designed. The reading process of 50° Celsius and 450° Celsius in C programming, as given in the script below.

```
temp_c float;
temp_c = thermocouple.measure (TEMPC);
if (temp_c<= 50)
{  digitalWrite(Led1, LOW);
digitalWrite(Led2, HIGH);
digitalWrite(Led3, HIGH);
 }
```

At temperatures is smaller than 50° Celsius, the system will activate led1 (ON) as a sign that the system has worked, there are heating and the tubes are rotated. But when the temperature exceeds 50° Celsius, led1 will be OFF, led2 will be ON that indicates that the tube has been sufficiently hot and ready to accept the grains (coffee).

```
if (temp_c> = 50)
{digitalWrite (LED1, LOW);
    digitalWrite (LED2, HIGH);
    digitalWrite (LED3, LOW);
digitalWrite (Buzzer, HIGH);
 }
```

The frying process will continue until the tube temperature reaches 450° Celsius. In such conditions, the system will activate led3 and give 10 minutes delay to shut down the system.When led3 ON, led1 and led2 will be OFF, buzzer also gives a sign that the roasting process has been completed.

```
if (temp_c> = 450)
{digitalWrite (LED1, LOW);
digitalWrite (LED2, LOW);
digitalWrite (LED3, HIGH);
BUZZER ();
delay (100000);
digitalWrite (element, LOW);
 }
```

The test of thecontrol system is done in 2 stages. The first stage is activated without grains, while the second stage, by using the grains (the tube filled with coffee)

Performance testing of roaster control system with a Max6675 thermocouple as temperature sensor placed on the roaster tube without grains gets the results as Table 1.

Table 1. Results of temperature testing from thermocouple without grains.

Time required	Temperature
0 seconds	0° Celsius
33 seconds	30° Celsius
1 minute 46 seconds	40° Celsius
2 minutes 32 seconds	50° Celsius
6 minutes 20 seconds	70° Celsius
9 minutes 31 seconds	100° Celsius
15 minutes 10 seconds	140° Celsius
17 minutes 00 seconds	180° Celsius
20 minutes 06 seconds	210° Celsius
23 minutes 45 seconds	260° Celsius
26 minutes 14 seconds	330° Celsius
30 minutes 10 seconds	370° Celsius
33 minutes 07 seconds	400° Celsius
38 minutes 09 seconds	450° Celsius

Table 1 shows the changes in temperature that occur during the heating processwithoutgrains. Temperature changes occur in accordance with the increase in tube heating time. When it starts to heat up the tube, the temperature beginning at 0° Celsius and requires 38 minutes 09 seconds to reach 450° Celsius. When the system is ON, the relay activates heat source and OFF at temperature of 450° Celsiuswith 10 minutes delay. Test results in Table 1 show that in no-load conditions (no grains), the system control reads the change of roasting machine temperature less than 40 minutes until reaches the 450° Celsius. In this test, the rotation of the tube and ignition are considered fixed (unchanged). The control system works well and stables in accordance with the protocols programming created.

Table 2 shows the condition of thealarm system whenrelay turns to ON and OFF. When the system is ON, the relay activates heat source and give effect to LEDs and buzzer. This situation continues after reaching 450° Celsius with 10 minutes delay.

Table 2. Testing alarm system when relay changes.

Temp (celsius)	Led1	Led2	Led3	Buzzer	Conclusion
0°	on	off	off	off	match
40°	on	off	off	off	match
50°	off	on	off	off	match
80°	off	on	off	off	match
100°	off	on	off	off	match
160°	off	on	off	off	match
200°	off	on	off	off	match
240°	off	on	off	off	match
300°	off	on	off	off	match
320°	off	on	off	off	match
370°	off	on	off	off	match
400°	off	on	off	off	match
450°	off	off	off	on	match

For testing with grains, LED1 is ON when the system is ON as designed. Led1 will off and led2 ON when the temperature reaches 50°Celsius.The heating process continues until the temperature reaches 450°Celsius marked by led3 and buzzer ON.The test results in Table 2 show that the control system has worked in accordance with the designed of protocol algorithm in the Arduino. The activity of indicators (led and buzzer) gives a signal to the user that the control system starts to work when Led1 ON until the temperature of the tube roasting machine reaches 49° Celsius. The status of the roasting machine tube is ready to receive the grains when the temperature reaches 50° Celsius and the frying process ends when the temperature reads 450° Celsius.

The next test is to run a system to control the frying coffee process. The grains coffee used in thetestis 1 kg in the form of dried HS coffee. The machine is restarted and the system control works. When given the grains (coffee), the roasting process becomes longer than the no-grains. Increased roasting time due to the load contained in the tube permeates the temperature change of the tube. It took about 10 minutes for a temperature change from 50°Celsius to 140°Celsius. Overall the test results of roaster control system when the roaster is workingare given in Table 3.

Table 3. Result of control system roaster when roaster is working withgrains.

Time	Temp (Celsius)	Specification
0 m	0°	Initial Condition
2.30 m	50°	Before coffee included
3 m – 7 m	41°.	After coffee included
20m -34 m	140° - 200°	Status third
37. 25 m	250°- 300°	Starting delay of
45.07 m	350°- 400°	
58.34 m	420°	Ripe coffee beans
+ 10 m	450°	System off

Table 3 shows the results of tests performed by the system when frying the coffee beans as a sample. When the system is ON, Arduino will be instructed to rotate the tube through DC motor connected. The heat source will be activated and heats the tube that characterized by indicator LED1 active. When the temperature tube reached50° Celsius, indicator LED2 will be active, LED1 will be OFF and the roaster is ready to receive coffee grains asasample. For a few times, the temperature decreases to 41° Celsiusbecause of the heat absorption to the coffee. The heat absorption process takes about 6 - 10 minutes before back to normal. After coffee fried to 90° C, then LED2 will be ON and when the temperature had reached 450° Celsius, the system will give a delay for about 10 minutes before the overall system OFF.Total testing time of 1-kg HS coffee processing to temperature reaches 450 ° Celsius is ± 1 hour.

From the test results in Table 3 illustrates that when frying the HS coffee, the control system works normally to change the coffee beans from brown to black based on the temperature changes that occur in the tube. Although the time required to reach the final temperature (450° Celsius) becomes longer, with steady motor rotation and fire provides a better maturity level of coffee. The black color of coffee is more evenly distributed and the aroma is stronger when compared to the same test using a thermostat roasting machine. The temperature readings are always stable, different than conventional contactor systems. Comparison of coffee processing using microcontrollerroasted with thermostat roasted is shown in Figure 7.

(a) microcontrollerroasted (b) thermostatroasted

Fig. 7. Processed coffee from microcontroller and thermostatroaster.

From Figure 7 there are 2 copies of HS fried with a roaster machine. The coffee in part (a) is fried with a roasting machine based onamicrocontroller, while part (b) is fried using a roasting machine based onathermostat. The amount of coffee is 1 kg of dried HS coffee. The results show that at approximately the same time, with the same engine and fire, coffee (a) produces coffee in a more black and evenly distributed color than coffee (b). In addition, the aroma generated from the two coffee products is also different where coffee (a) is more fragrant than coffee (b).

4 Conclusions

The roaster control system can be developed using Arduino as a central processing withamax6675 thermocouple as a temperature sensor. Activator tube roaster utilizing L298N double H Bridge as a motor driver who works at 2 amperesmaximum current. In the no-load condition, the control system requires ± 38 minutes ofoperation until it reaches 450°Celsius. Meanwhile, in the load condition, the system requires ± 60 minutes with a 10-minute delay to reach the coffee ready to be processed at the milling stage.The control system on the roasting machine works when the engine starts, receives the voltage from thevoltage source and activatethe heat source. The thermocouple sensor placed inside the roasting tube will start reading the temperature and send the data in voltage form to the microcontroller to be processed and displayed to the LCD display as information totheuser. Compare between the microcontroller roaster with thermostat roaster is the microcontroller system has advantages in data resistant, readings and data processing more detail because it uses programming, easier to repair when the disturbance, more easily developed from the hardware and software, the color and aroma of after roasting is better.

References

[1]M. Hadzich, F. Veynandt, J. Delcol, L. M. Hadzich, J. P. Pérez, and S. Vergara, "Design of a Solar Coffee Roaster for Rural Areas," Energy Procedia, vol. 57, pp. 3215–3224, 2014.

[2]K. Y. Ku Madihah, A. H. Zaibunnisa, S. Norashikin, O. Rozita, and J. Misnawi, "Optimization of roasting conditions for high-quality Arabica coffee," Int. Food Res. J., vol. 20, no. 4, pp. 1623–1627, 2013.

[3]N. O. Oliveros, J. A. Hernández, F. Z. Sierra-Espinosa, R. Guardián-Tapia, and R. Pliego-Solórzano, "Experimental study of dynamic porosity and its effects on simulation of the coffee beans roasting," J. Food Eng., vol. 199, pp. 100–112, 2017.

[4]E. J. Pristianto, H. Arisesa, and N. Rahman, "Sistem Pengendali Pemanas Pemanggang Kopi Menggunakan Logika Fuzzy Heater Coffee Roaster Controller System Using Fuzzy Logic," vol. 10, no. 2, pp. 67–74, 2017.

[5]V. J. Davidson, R. B. Brown, and J. J. Landman, "Fuzzy control system for peanut roasting," J. Food Eng., vol. 41, no. 3, pp. 141–146, 1999.

[6]W. F. Godoy, I. N. Da Silva, A. Goedtel, and R. H. C. Palácios, "Fuzzy logic applied at industrial roasters in the temperature control," IFAC Proc. Vol., pp. 450–455, 2013.

[7]L. Virgen-Navarro, E. J. Herrera-López, R. I. Corona-González, E. Arriola-Guevara, and G. M. Guatemala-Morales, "Neuro-fuzzy model based on digital images for the monitoring of coffee bean color during roasting in a spouted bed," Expert Syst. Appl., vol. 54, pp. 162–169, 2016.

[8]M. Pritoni, A. K. Meier, C. Aragon, D. Perry, and T. Peffer, "Energy efficiency and the misuse of programmable thermostats: The effectiveness of crowdsourcing for understanding household behavior," Energy Res. Soc. Sci., vol. 8, pp. 190–197, 2015.

[9]Y. Priyana, F. E. Laumal, and E. Husni, "Development of Earthquake Early Warning System using ADXL335 Accelerometer," in Proceedings of International Conference on Satellite Technology, 2017, pp. 81–85.

[10]F. E. Laumal, Membangun Sistem Peringatan Dini Gempa meggunakan Arduino, 1st ed. Kupang: Samudra Biru, 2017.

[11]F. E. Laumal, "Pengembangan Sensor Getar Adxl335 Sebagai Petunjuk Perawatan Mesin Bubut Horisontal," in Seminar Nasional Science dan Teknologi Fakultas Teknik Universitas Muhammadiyah Jakarta, 2015, vol. 1, no. November, pp. 1–5.

[12]F. E. Laumal, P. H. Edwin, and B. N. N. Kusa, "Pengembangan Pintu Air Irigasi Pintar berbasis Arduino untuk Daerah Irigasi Manikin," J. Rekayasa Elektr., vol. 13, no. 3, pp. 1–7, 2017.

[13]X. mei Guo, Z. chao Zhu, G. ping Shi, and Y. Huang, "Effects of rotational speeds on the performance of a centrifugal pump with a variable-pitch inducer," J. Hydrodyn., vol. 29, no. 5, pp. 854–862, 2017.

.