

Development of a Microcontroller Based Tray Dryer Machine

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Abstract: This paper presented a microcontroller based tray dryer machine which is useful to dry different types of materials such as fruits, seedlings to mention a few. The drying process and its functions are selectable by user to obtain a multi dryer system application. The Microcontroller base that enables simultaneous monitoring was utilized. Two types of sensors were used as inputs into the system which are temperature and humidity. The output of sensors continuously was monitored with the main processor given functions based on fruit types being executed. Meanwhile, the selected fruits were put on trays in batches into the dryer. In this research, the amount of heat is controlled automatically without human intervention. The controller monitors the temperature continuously and compare it with a pre-determined value and take decision whether to continue heating or to put the heater off autonomously. However, the operation of this oven is based on microcontroller and temperature sensor. This sensor can only measure temperature up to 150o C.

1. PREAMBLE

Drying has been used centuries as a method for food preservation. Fluid extraction in material is known as drying whereby water is removed from solids to a certain level with different techniques. Hence drying is moisture migration from material within a specific period of time. During drying process, high energy levels are consumed due to moisture removal from the body.

Drying characteristics of fruits depends on various factors such as sorption equilibrium, density and thermal properties. Design of any kind of heating process required knowledge about the materials density and thermal attributes. This culminates into changes in shape and size of the final product due to mass moisture transfer and dielectric properties.

To obtain higher quality products, reliable controller is one of the significant requirement. There are several types of controllers which are utilized in industrial automations. The common controllers are Programmable Logic Controller (PLC). The total cost of PLC-based automation is very expensive and does not allow using in small systems. However, Microcontroller is the other processor component which is very low-cost processor. It is being employed in many semi-industrial projects and small factories. Meanwhile in this research, ATMEGA-16L microcontroller that is high performance and low-cost component was used and the systems block diagram is described below (Fig. 1).

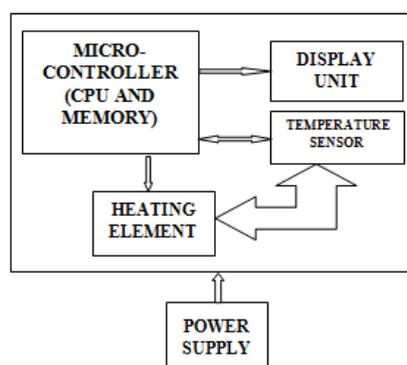


Figure1. System Block Diagram

The temperature sensor read the temperature of the surrounding, the temperature is converted into digital format by the controller. After the conversion, the controller compares the converted value with the inputted value. If inputted value is greater than the value read by the controller, the heater is left connected to power supply that is, it keeps heating otherwise, it is disconnected from the supply. The inputted value is display in a 7-segment visual display unit. A power supply unit (PSU) provides a clean 5 volts DC to the circuit. Meanwhile, all controller action is based on software programmed into the controller. This software is a set of controller instructions and these are executed by the controller using clock pulses provided by a crystal oscillator – the clock source.

2. COMPONENTS REVIEW

2.1. Microcontroller Unit

Microcontroller is a dedicated computer on a single chip unlike a general purpose computer such as the PDA, laptop and desktops with powerful processors which are very versatile and powerful, a microcontroller in slower and in most cases performed single control system in its lifetime. The controls has its own internal memory-EEPROM & RAM and input and output ports for communication with the outside world. The controller used in this research is ATMEGA16L (Fig. 2) because it has its own in-built analogue to digital converter which is necessary for converting the temperature sensor analogue output to digital format.

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1MIPS per MHz allowing the system designed to optimize power consumption versus processing speed.

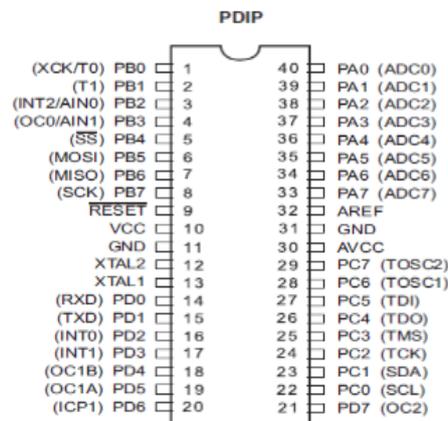


Figure2. Pinout of the ATMEGA16

2.3. Temperature Sensor

The temperature sensor used in LM35, the sensor measure the surrounding temperature and output 10mv per each degree rise in temperature. For instance, if the temperature is 30°C, the transducer output will be 30MV. It can measure temperature from zero degree to 150°C. In voltage, the output has a minimum value of zero mill volts and a maximum of one thousand five hundred mill volts.

2.4. Visual Display Unit

The visual display unit comprises 7 segment display and shift register, the bit pattern of the character to display is latch into the shift register internal memory (Fig. 4).

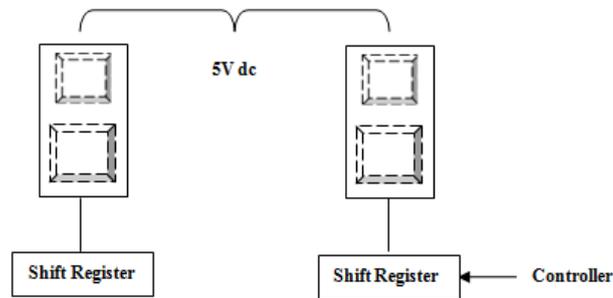


Figure4. Visual Display Unit

2.5. Heater

A heating element rated at 300 watt 220Vac is used as a source of heat. AC is applied across the terminal of the A.C supply, electrical energy is converted to heat energy which result in production of heat. The turning ON and OFF of this heater is automatically under the influence of the microcontroller

2.6. IC Regulator (LM7805)

This is a voltage regulator that has three (3) terminals (input, output and ground) and is factory-trimmed to provide a fixed output. This in general produces a fixed dc voltage (for LM 7805-5Vdc).IC regulators are available in plastic or metal power packages. It can provide up to 1A load current and has an on-chip circuitry to prevent damage. In event of overheating or excessive load current, the chip simply shuts down rather than blowing out.

3. PRINCIPLE OF OPERATIONAL DESIGN

Microcontroller based tray dryer is designed in such a way that electrical energy is being converted to heat. The material intended to dry is placed in an enclosed vacuum of the dryer and the sensor senses the temperature of material as the enclosure temperature. The inputs which are digital buttons connected to the controller are pressed down to make contact; thereby responding appropriately via Controller software when the button is pressed by increasing the preset temperature by 5 or 1.

3.1. Operational Algorithm

The Algorithmic procedure is as stated below:

Step 1: Start

Step 2: Set preset temperature

Step 3: Compare preset temperature with enclosure temperature.

Step 4: If preset temperature is lesser to the enclosure temperature then nothing happens in the system, it start all over again by setting a preset temperature.

Step 5: If the preset temperature is greater, then it turns on the heater.

Step 6: Compare preset temperature with the enclosure temperature, if both are equal it turns off heater to start it all over again.

Step 7: End

3.2. Operational Flow

The flowchart (Fig. 5) representing the operational dimensions of the system is represented below

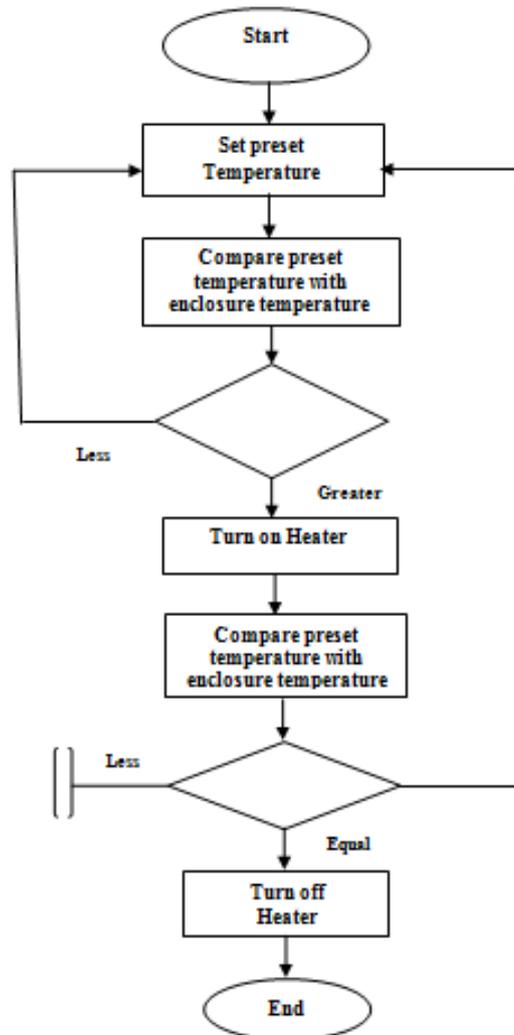


Figure5. Flowchart for Operation

4. CIRCUITRY DESIGN AND ANALYSIS

These reveals the design and the associate calculation carried out to achieve the desired results. The entire circuit is divided into three main units: Power Supply Unit (PSU), ATMEGA16L circuit Unit and Display units (Display Unit already discussed in II – D above). Each of these units consist of various electronic components wired together to form a sub-circuit which enable the main unit to function as required.

4.1. Power Supply Unit

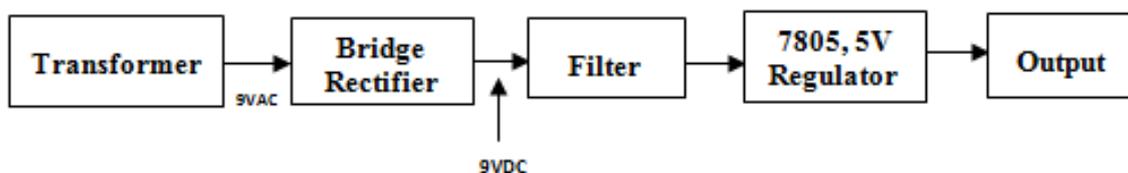


Figure6. Block Diagram of Power Supply Unit

9V alternating current (AC) signal is obtained from secondary terminal of the transformer. The voltage is rectified to give 9V direct current (D.C) signal by mean of diode bridge rectifier. The DC voltage obtained from the rectifier is routed to a capacitor filter which removes pulsating and fluctuating components called ripples from the signal. At this point, 9V unregulated DC voltage is

now available. A 5V regulator, LM7805 is used to regulate the voltage to a 5VDC which is required by the micro-controller. The direct 9V is used to the transistors and relays in the circuit. Transformation of 220V AC to 9V AC done by transformer is based on the faraday principle of electromagnetic induction. The A.C voltage output of a transformer is determine by the transformer ratio.

$$E_s / E_p = N_s / N_p$$

Where

E_s = Voltage at secondary side of the transformer

E_p = Voltage at primary side of the transformer (220 Vac)

N_s = Number of turns of coil at secondary

N_p = Number of turns of coil at primary.

Normally **N_s** and **N_p** are given by the manufacturer while **E_p** is in the voltage supply from the domestic socket outlet which is 220 Vac in Nigeria and Uk.

Since the major supply of power is the 240vac, there is need for this voltage value to be stepped by transformation mean to smaller value of 12v. The transformer used for this purpose is a twelve volts transformer and the output is fed to the rectification section. A regulation IC is used to obtain the desired 5Vdc at this section. The 7805 is a regulator IC that regulates for 5V output at 1A with its input varying between 6.5V and 18V. The circuitry representation of the power supply unit is represented below (Fig, 8).

Shown below is the full circuit of the power supply.

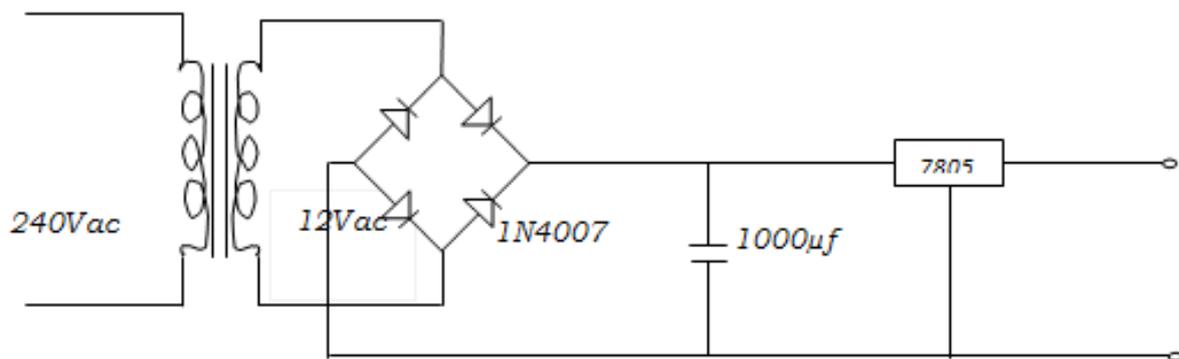


Figure7. Circuit diagram of the Power Supply

4.2. Atmega16l Microcontroller Unit

The ATMEGA16L is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the industry-standard 80C51 instruction set and pin-out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel ATMEGA16L is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. The ATMEGA16L provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the ATMEGA16L is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes (Fig, 8). The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM con-tents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

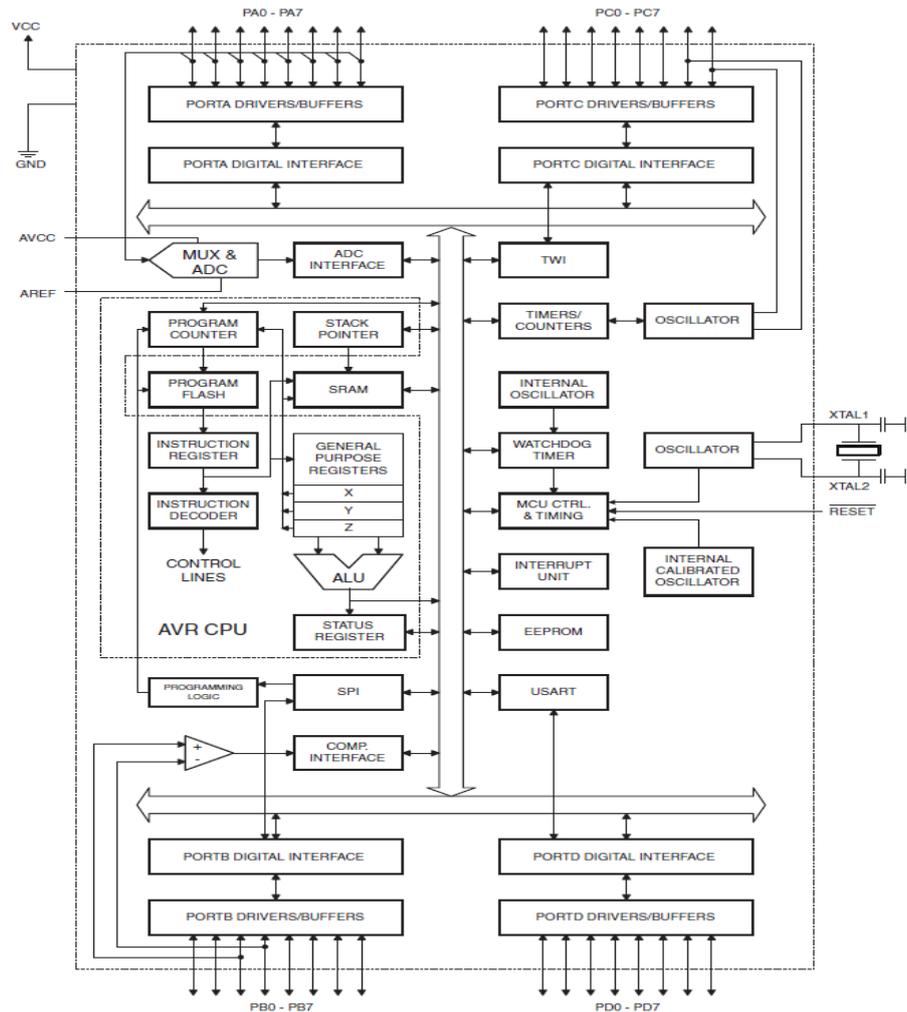


Figure8. Schematic Diagram of ATMEGA 16L

However, the controller needs three basic things to function properly; these are: Power supply, Clock circuit and Software. The microcontroller receives 5V dc from the power supply stage. The clock to the system is provided by a 16MHz crystal oscillator as shown below (Fig. 9):

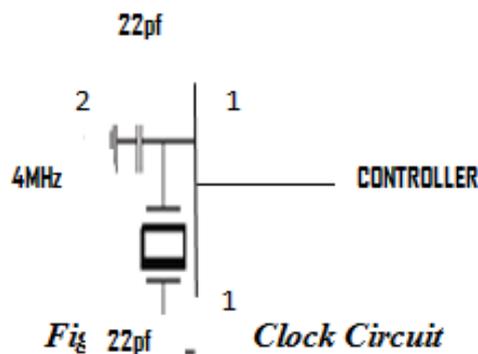


Figure9. Clock Circuit

In terms of the Software, machine language is used which comprises of set of zeros and ones which are understandable by the hardware components to form the instructions needed by the machine to make decision. This machine language is programmed into the controller. The language of choice in this research is the C-language because of its flexibility and ease of use. Therefore, the source code written in C-language is compiled by a compiler to generate the required machine code for the ATMEGA 16L unit.

Finally, the complete circuit diagram for the dryer machine is shown below (Fig. 10).

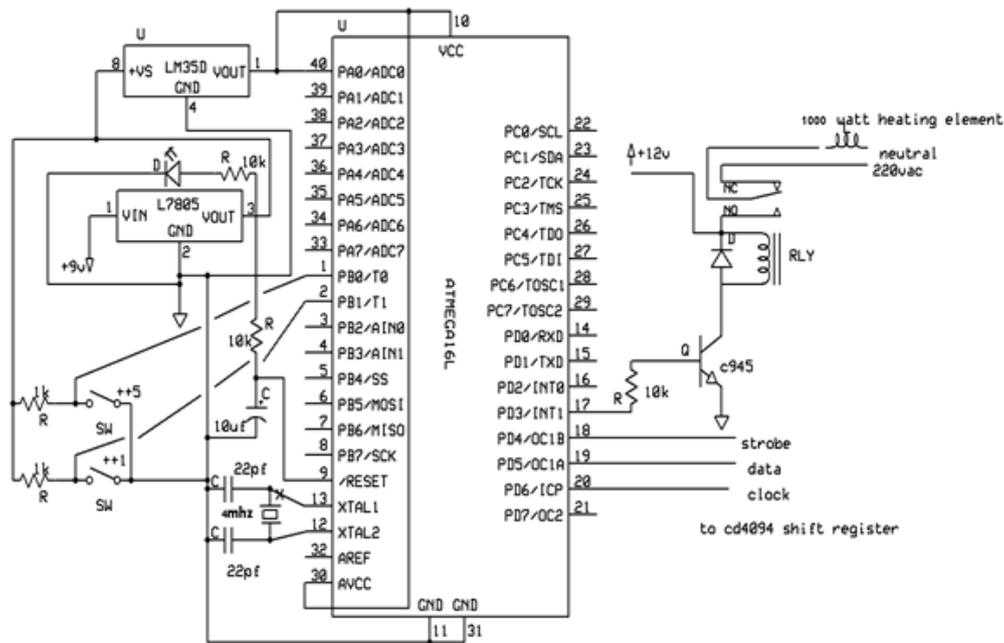


Figure10. Complete Circuit Diagram

The internal part of the designed machine shows the physical connection of the systems components (Fig. 11) and the enclosed vacuum (Fig. 12) is hereby shown below.



Figure11. Pictorial representation of the Internal part of the machine



Figure12. Interior part of the Project (Enclosed Vacuum)

Therefore, the final designed product of this research is shown below (Fig. 13)



Figure13. Complete picture of the Drying Machine

5. TEST AND CONTROL

5.1. For Apple Fruit

The apples were dried at 75°C in the tray batch fruit dryer. The thickness of the measured samples was around 10mm. The initial moisture content of the apples was 4 ± 0.1 kg water/kg dry matter and the equilibrium moisture content was approximately 0.06 kg water/kg dry matter (these results were obtained where there was no more change in the weight). The moisture ratio versus drying time for apple at 75°C is shown in Table 1 below. The drying time to reach the equilibrium moisture content for the fresh apple slices were at over 30 min at 75°C. The curve indicates that the moisture ratio decreases through the drying process (Figure 14), furthermore analysis of the drying curves showed that there was no constant drying rate. Interestingly, to remove the last half of the moisture it took about two third of the whole drying process time. This can be due to reduce of speed in the diffusion process.

Table1. Moisture ratio with Time slice for Apple

Moisture ratio	1	0.9	0.7	0.5	0.3	0.2
Time (min)	0	5	10	15	20	25

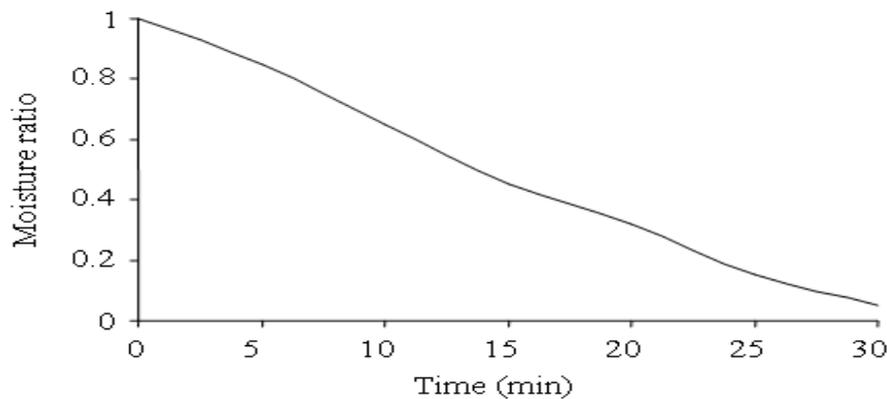


Figure14. Moisture profile of Apple during drying at 75°C

5.2. For Banana

The experiment was conducted at 60°C to conduct the drying characteristics of banana figs. The thickness of the specimens was 35 mm. The experiments were done to determine the equilibrium moisture content of banana. The results indicated that the moisture content of banana was around 80%, this was measured by measuring the bone-dry mass which was approximately 20%. The moisture ratio versus drying time for banana at 60°C is shown in below (Table 2). From the drying curves it is apparent that the moisture content ratio decreases continuously (Fig. 12) during the drying process moreover there is no constant drying rate period observed.

Table2. Moisture ratio with Time slice for Banana

Moisture ratio	1	0.37	0.30	0.20	0.15	0.10
Time (min)	0	10	20	30	40	50

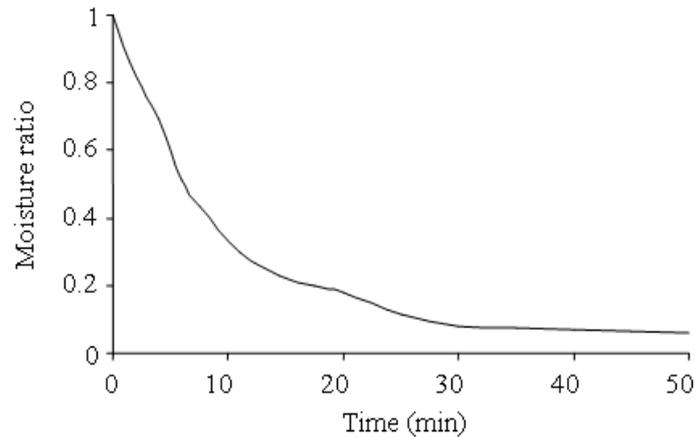


Figure15. Moisture profile of Banana during drying at 60°C

6. CONCLUSION

This research has reviewed and explored the fundamentals and applications of various electronic components. It has demonstrated that home appliances and industrial systems can be fully automated without human intervention as automated system are accurate and require no human intervention to work. This will not only eliminate cost but also leads to efficiency.

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