Development of an ATTiny1614-Based Heater Controller and a Silicone-Based Heating Element for a Tissue Processor

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Intisari* – Tissue Processor merupakan salah satu alat yang memiliki peran penting dalam menyiapkan tissue untuk observasi. Meskipun tingkat kebutuhannya tinggi, produk serupa belum dikembangkan secara lokal. Untuk itu peneliti mengupayakan pengembangan alat serupa melalui metode reverse engineering. Salah satu komponen penting dari tissue processor adalah automatic heater yang terdiri dari heater controller dan heater element. Dengan menggunakan ATTiny1614 dan silicon pad, kedua komponen tersebut telah dikembangkan mengikuti cara kerja yang sama. Berdasarkan pengujian, heater controller berhasil mengalirkan arus bolak-balik ke heater element berdasarkan suhu maksimum yang diberikan. Pengujian heater element menunjukkan spesifikasi impedansi sebesar 418,9 Ω dan hanya membutuhkan waktu sekitar 1 menit 37 detik baginya mencapai suhu 100^{0}C. Dengan demikian, purwarupa yang dihasilkan telah memenuhi kriteria sebagai automatic heater untuk tissue processor.

***Kata kunci* – ATTiny1614, heater controller, heater element, silicon, nikelin**

Abstract – The tissue processor is an essential device for preparing tissue samples for observation. Despite the high demand, no similar products have been developed locally. Therefore, the researchers have undertaken the development of a comparable device through reverse engineering. One of the key components of a tissue processor is the automatic heater, which consists of a heater controller and a heating element. Utilizing an ATTiny1614 microcontroller and a silicone pad, both components were developed to operate with the same functionality as the original. Based on the tests, the heater controller successfully supplied alternating current to the heating element according to the specified maximum temperature. The heating element test showed an impedance specification of 418.9 Ω and required only approximately 1 minute and 37 seconds to reach a temperature of 100 °C. Therefore, the resulting prototype meets the criteria for an automatic heater for a tissue processor.

Keywords – *ATTiny1614, heater controller, heater element, silicon, nichrome*

I. INTRODUCTION

Histology is the study of body tissues that constitute an organ [1], [2]. In the field of histology, microscopic observation requires tissues in proper condition that have undergone a series of preparatory treatments. These treatments can be carried out manually or with the aid of specialized equipment. One such device is the tissue processor, which is equipped with at least twelve vessels containing chemical solutions. Among these vessels, there are at least three independent heaters controlled by a microcontroller [3].

The heating vessel is typically filled with chunks of paraffin, which are melted by the heater at a temperature between 50–80 °C. A limit switch sensor is usually installed alongside the tissue chamber to detect any paraffin chunks that have not yet melted [4], [5], and [6]. Once the tissue has passed through this stage, the preparation process is considered complete, allowing the tissue to be utilized for subsequent purposes, such as microscopic observation.

Advanced tissue processors typically operate automatically after being programmed through an interface such as a Human Machine Interface (HMI). Consequently, these devices greatly facilitate the critical task of preparing observation specimens in the field of histology. In general, tissue preparation requires more than two hours; therefore, manual processing is highly discouraged [7].

Based on the information gathered, tissue processors remain predominantly imported products, which contributes to higher purchase and maintenance costs. Therefore, similar devices hold significant potential for local development through reverse engineering techniques [8] and [9]. The engineering process in this context does not involve fully replicating the components used, but rather reconstructing the device based on its features and operational principles.

This study focuses on the development of a prototype heater controller and heater element specifically designed for a rotational-type tissue processor, model KD TS6A [10]. Although this model is now obsolete due to discontinued production, it remains widely used because it occupies less space compared to the linear movement type [3].

Although reverse engineering techniques are implemented in this study, the development of circuits, component selection, PCB (printed circuit board) routing, nichrome wire selection, and other aspects are carried out independently, without replicating the original form of the components used in the KD TS6A tissue processor.

II. METHODOLOGY

A. Microcontroller ATTiny1614

The ATTiny1614 microcontroller belongs to the tinyAVR 1-series family manufactured by Microchip. This type is built with an 8-bit processor and a maximum master clock of 20 MHz. This frequency is generated by an in-built crystal, thus eliminating the need for an external oscillator component. Maximum processing speed can be achieved by supplying a voltage of 5 V.

With an internal flash memory capable of storing programs up to 16 KB, this 14-pin microcontroller can be programmed via the UPDI (Unified Program and Debug Interface) communication protocol, specifically on pin 10 [11]. An illustration of this microcontroller is shown in Figure 1. This microcontroller was selected due to its compatibility with the Arduino IDE environment, its number of pins, and its in-built crystal with a relatively high frequency.

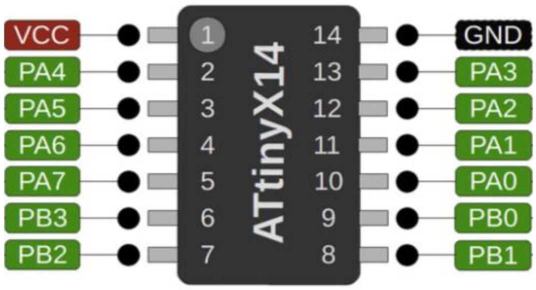


Figure 1. Illustration of the ATTiny1614 microcontroller

B. *Unified Program and Debug Interface*

The Unified Program and Debug Interface (UPDI) protocol is an interface for programming and debugging based on a 1-wire, UART-based half-duplex communication method [12]. A developed program can be uploaded to the target microcontroller either through a dedicated pin or the reset pin. In this study, an ATMega328 microcontroller is used as a chain to enable the uploading of the compiled binary file to the ATTiny1614, with the circuit configuration shown in Figure 2.

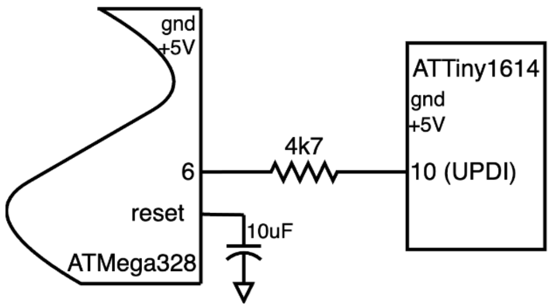


Figure 2. Circuit for programming the ATTiny1614

C. *Heater Element*

The heating element is designed based on the characteristics of a conductor that converts electrical energy into thermal energy. The greater the electrical power supplied per second, the higher the heat generated by the conductor. The conductor material used is nichrome wire with a diameter of 0.2 mm. The nichrome wire is arranged in a spiral pattern at the center of silicone rubber, as shown in Figure 3.

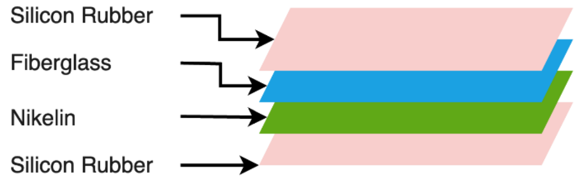


Figure 3. Arrangement of the heating element

The resistance of the nichrome wire is R = $46{,}5\ \Omega/m$. Therefore, the total resistance, R_{total} (1).

$$R_{total} = l * R \quad \Omega \tag{1}$$

where *l* represents the length of the nichrome wire. The power source for the heating element is an alternating voltage of 220 V or 110 V.

D. *Temperature Sensor*

The temperature sensor used is a Dallas DS18B20 digital temperature sensor, which measures the temperature of the heating vessel. This sensor operates using the 1-wire protocol, requiring only one pin from the microcontroller for transmitting the measurement data [13]. It is selected due to its wide measurement range, from −55 °C to +125 °C, with an accuracy of ±0.5 °C for temperatures below 85 °C. In addition, the sensor's resolution can be configured between 9 and 12 bits [11] and [14]. This sensor can output relatively stable temperature time to time; therefore, implementation of filters is not needed as in [15], [16], and [17].

The purpose of using this temperature sensor is to provide feedback to the heater controller for switching the alternating current supply to the heating element on and off. The operating temperature of the heater controller is below 85 °C, as expressed in equation (2).

$$HEATER = \begin{cases} ON & T \leq 85 \\ OFF & T > 85 \end{cases} \tag{2}$$

where *T* represents the measured temperature. To obtain the temperature reading from the Dallas DS18B20, the microcontroller first sends a request. Once communication is established, the temperature can be read. Both processes are illustrated in the program snippets shown in Figures 4 and 5.

```
Request:
DS18B20.Reset();
DS18B20.Select();
DS18B20.Write(0x44);
```

Figure 4. Program snippet for DS18B20 request

```
DS18B20.Reset();
DS18B20.Select();
DS18B20.Write(0xBE);
while (true){
        data = DS18B20.Read();
        temp = (data[1] << 8) + data[0];
        temp = temp / 16
}
```

Figure 5. Program snippet for DS18B20 temperature data reading

E. *System Operation*

The overall operation of the heating system is illustrated in the flowchart shown in Figure 6. First, chunks of paraffin are placed into the heating vessel. The heater is then activated independently for a certain period, depending on the user, as shown in Figure 6. Subsequently, the device is operated in accordance with the general standard operating procedures as in tissue processor machines. During the operation of the machine, the heater remains ON to prevent the melted paraffin from solidifying due to a decrease in temperature.

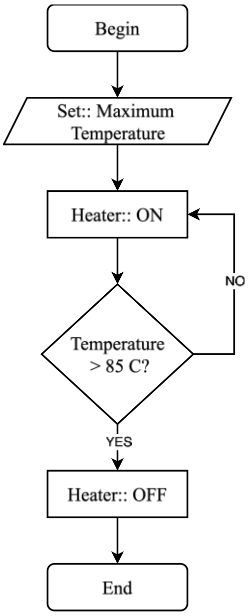


Figure 6. *Flowchart* for *heater controller*

III. RESULTS AND DISCUSSION

The developed prototype was tested on a KD TS6A-type tissue processor. Two components of the heater were tested, namely the heater controller and the heating element.

A. *Heater Controller*

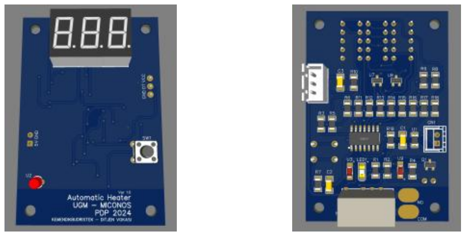
The heater controller section was implemented using an ATTiny1614 microcontroller. The main components included in this circuit are listed in Table 1.

In this article, the complete circuit schematic cannot be presented due to copyright restrictions. Only the 3D view of the PCB routing, implemented on a two-layer PCB, is shown in Figure 7. Figure 8 presents the testing of temperature measurement by the Dallas sensor and the ON/OFF switching of the relay.

Inside the ATTiny1614, a program has been embedded to control the heating element according to the predetermined temperature limit. The set temperature and the measured temperature are alternately displayed on a 3-digit seven-segment display. The connectors used in this controller module are industry-standard JST connectors, utilized for the Dallas DS18B20 sensor and the 5V/1A supply from a buck converter.

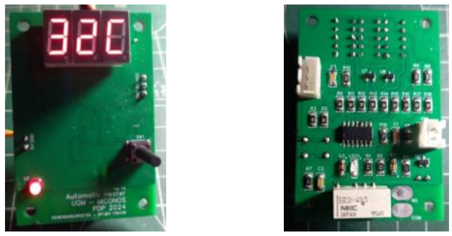
Table 1. Main components used in the *heater controller*

No.	Component	Quantity	Specifications
1	ATTiny1614	1	8-bit MCU
2	Seven Segment	3	*Common Cathode*
3	JST Connector	1	3 Pin *Male*
4	JST Connector	1	2 Pin *Male*
5	Relay	1	EE2-4N3 2A
6	*Tactical Switch*	1	4 Pin 12mm
7	LED	1	Red
8	Dallas DS18B20	1	Temperature sensor



(a) (b)

Figure 7. 3D View of PCB routing: (a) Top view, (b) Bottom view



(a) (b)

Figure 8. Implementation and testing: (a) Top view, (b) Bottom view

A light emitting diode is used as an indicator for 5V voltage, while a tactical switch is used to change the temperature value as the maximum limit when the heater is OFF. A relay with a small dimension is used as an automatic switch to turn the heater off and on. This relay can only pass a continuous current of up to 2A.

The display consists of a 3-digit seven-segment type 2381AS, which indicates that it is a Common Cathode type with a dimension of 0.28 inch. By optimizing the microcontroller pins, a scanning technique is used to display each digit alternately. This technique is very effective for limited power resources, utilizing the human eye's slower perception speed compared to the display frequency of the seven-segment. Each digit is controlled by an NPN-type bipolar junction transistor. To reduce the brightness of the display, a current limiting resistor of 1 kΩ is used. With these components, the automatic heater can operate according to the needs. Since there are three automatic heaters, each of them can work independently.

Table 2. Functional testing results of the heater controller

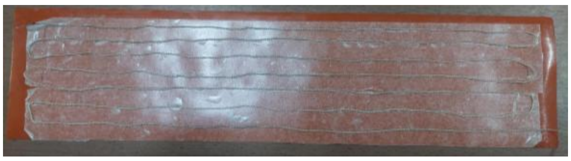
No.	Activities	Temp. Actual (^{0}C)	Max Temp. (^{0}C)	Relay Status	Remarks
1	Heater controller switched ON	25	50	OFF	2-second delay, 7-segment animation
2	Press the button once	25	*50*	ON	Displays the maximum temperature value (set point)
3	Press the button once	27	51	ON	Set point increases by 1
4	Long press the button	30	60	ON	Set point increases rapidly
5	Temperature rises to 40 °C	40	60	ON	Relay active
6	Temperature rises to 58 °C	58	60	ON	Relay remains active
7	Temperature rises to 61 °C	61	60	OFF	Relay inactive

More than 90% of the components used in this automatic heater control module are surface-mount components, aiming to provide greater heat dissipation space between components, thereby reducing potential thermal noise, considering that this heater control module is mounted directly on the heating glass.

Subsequently, the functionality test of the heater controller, as illustrated in Figure 8, is presented in Table 2. In this test, the evaluation was conducted sequentially from number 1 to 7. Based on the results, the developed heater controller was able to replicate the operation of the heater controller in the KD TS6A-type tissue processor.

B. Heater Element

The components of the fabricated heating element are shown in Figure 9. This work was carried out manually, resulting in a spiral shape that is not yet consistent, as depicted in Figure 9(a). Nevertheless, the heating element has been tested at a certified National Central Laboratory.



(a)

(b)

Figure 9. (a) Inner layer, (b) Complete heating element

The measuring instrument used in the initial measurement, a multimeter, indicated total resistance of 225 Ω. However, this instrument had not been calibrated, and the measurement did not represent a pure impedance component, considering that the nichrome wire used still contains capacitance and inductance. Testing at the certified Central Laboratory was conducted under environmental conditions of 25 °C temperature, 51% humidity, and a supply voltage of 220V AC/1A.

Table 3. Results of specification testing at a certified central laboratory

No.	Parameters	Our test result	Certified lab test result
1	Frequency	50 Hz	50 Hz
2	Power Dissipation	220 W	219,3 W
3	Length	37 cm	37,2 cm
4	Width	9 cm	9,1 cm
5	Thick	-	3,214 mm
6	Impedance	225 Ω	418,9 Ω

The heat or thermal distribution over time on the surface of the heating element was measured at five different points. This test was conducted to observe the time required to reach a temperature of 100 °C and to identify any damage to the element's surface when exposed to high temperatures. If damage such as burn marks were observed, the heating element was deemed to have failed the test for use in the tissue processor. The test results, obtained at a certified Central Laboratory, are presented in Table 4, with only the four highest temperatures displayed. The time is shown in minutes: second format, starting from minute 0:27.

Based on the test results presented in Table 4, the measured surface temperature of the heating element reached 100 °C in only 1 minute and 37 seconds, indicating that the melting of paraffin chunks can be accomplished rapidly. Furthermore, the test results demonstrated that heat was distributed relatively evenly across the silicone surface, with no visible signs of damage to the heating element.

Table 4. Results of heat resistance testing at a certified central laboratory

Time	**Point 1**	**Point 2**	**Point 3**	**Point 4**	**Point 5**
1:37	100.14	105.77	101.44	100.67	89.28
1:39	101.10	106.97	103.34	101.70	90.65
1:41	102.38	108.16	103.12	102.88	92.28
1:43	103.60	109.49	105.37	103.97	98.39
1:45	104.86	109.51	105.40	105.07	101.15

IV. CONCLUSION

Prototype heater controllers and heating elements have been developed in this study. The test results indicate that the heater controller can supply alternating current to the heating element in accordance with the specified maximum temperature or set point. Based on the heating element test conducted at a certified Central Laboratory, the total impedance was measured at 418.9 Ω, and it required only approximately 1 minute and 37 seconds for the silicone surface temperature to reach 100 °C. Therefore, this prototype can be utilized as a replacement for existing devices, with a higher Domestic Component Level.

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