European Journal of Computer Science and Information Technology 11 (3), 59-74, 2023
Print ISSN: 2054-0957 (Print),
Online ISSN: 2054-0965 (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Dynamic Control and Performance Evaluation of Microcontroller-Based Smart Industrial Heat Extractor

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doi:https://doi.org/10.37745/ejcsit.2013/vol11n32443 Published June 23 2023

Citation: Essien J. (2023) Dynamic Control and Performance Evaluation of Microcontroller-Based Smart Industrial Heat Extractor, *European Journal of Computer Science and Information Technology* 11 (3), 59-74

ABSTRACT: *Dynamic control and performance evaluation of a microcontroller-based smart industrial heat extractor involves the implementation of control strategies and the assessment of its performance under dynamic operating conditions. Performance evaluation aims to assess the effectiveness and efficiency of the microcontroller-based smart industrial heat extractor under dynamic conditions. Industrial heat extraction systems are often complex, involving multiple components, sensors, actuators, and control algorithms. Understanding and modelling the dynamic behaviour of these systems can be challenging, especially when considering factors like heat transfer rates, thermal delays, and interactions between different system elements. The effectiveness of dynamic control is significantly dependent on precise and dependable measurements from sensors. Sensors deployed in industrial settings may encounter severe environmental conditions, which can result in possible inaccuracies, drift, or even malfunctions. The objective of this research is to propose a simulated methodology for verifying the efficacy of a microcontroller-driven intelligent heat extractor utilised in industrial settings. The execution of experiments or tests within industrial environments can be a costly and time-intensive endeavour, and may entail potential hazards. The efficacy of a smart industrial heat extractor in practical industrial settings can be ascertained through the simulation of its evaluation process, thereby mitigating potential risks. The model designed and simulated in this work utilises an integrated temperature sensor to determine the ambient temperature and transmits a signal to the Arduino UNO microcontroller when the temperature sensor detects variant temperatures ranges. The evaluation is performed by comparing the behaviour and performance of the simulated system with predefined performance metrices.*

KEYWORDS: neural network, cooling system, heat extraction, microcontroller, sensor.

INTRODUCTION

A smart industrial heat extractor based on a microcontroller is an advanced system designed to efficiently manage and control heat extraction in industrial environments. It deploys microcontroller technology in conjunction with a variety of sensors and actuators to monitor and modulate temperature levels, thereby ensuring optimal thermal management. An efficient industrial heat extractor is designed to remove excess heat produced by industrial processes and maintain a safe and comfortable working environment [1]. By intelligently regulating the heat extraction process, these systems prevent equipment from overheating, increase energy efficiency, and boost overall productivity. The microcontroller functions as the central processing unit of the system, tasked with the reception of sensory input, data processing, and the production of control signals for the activation of actuators [2]. It enables real-time monitoring and dynamic control of the heat extraction process based on the fluctuating conditions of the industrial facility. A microcontroller-based intelligent industrial heat extractor relies heavily on its sensors. Microcontrollers have been utilized to measure parameters such as temperature, humidity, ventilation, and pressure, and provide vital feedback on for many environmental conditions [3]. The utilization of this information by microcontrollers enables the implementation of intelligent decision-making processes pertaining to heat extraction and control strategies, rendering it a highly desirable approach. Additionally, microcontrollers have the capability to consistently analyze sensory information, adjusts control variables, and enhances the heat extraction process in real-time [3]. This dynamic control ensures that the system responds quickly to changes, maintaining stable operating temperatures and preventing thermal problems. Consequently, a microcontroller-based intelligent industrial heat extractor offers improved energy efficiency, decreased equipment outage, increased safety, and increased productivity.

Temperature control and stability are essential components of industrial processes because they directly impact cycle durations and output. This has a significant impact on product quality, uniformity, and waste, as well as energy consumption and production costs [4]. Often, manufacturing industries produce numerous distinct products. Various process temperatures are required based on the manufactured product and the employed basic materials [5, 6]. Due to the importance of product consistency and process repeatability in manufacturing, it is crucial to regulate and sustain process temperature throughout the production process [3]. This research aims to design and simulate a microcontroller-based smart industrial heat extractor that can provide a framework for accumulating, collating, evaluating, and producing useful information to promote industry investments in heat extraction technology. The structure of the framework is based on a design method for operational research that has been made available to the industrial management sector [7], and is an expansion of the work presented by Kalker et al. [8]. The smart industrial heat extractor that is based on microcontroller technology is a comprehensive solution that incorporates sensors and actuators to facilitate intelligent and efficient heat extraction in industrial environments. The system offers the capability of monitoring in real-time, as well as dynamic control and optimization, leading to enhanced thermal management and overall performance of industrial processes.

REVIEW OF LITERATURE

Temperature and humidity are crucial environmental factors in numerous industries, including the medical, food, paper mills, textile, metrology, and semiconductors sectors. In recent years, optical fibre sensors have acquired popularity in the sensing and measurement sectors due to their numerous advantages over their conventional electronic counterparts [9, 4]. Using this method and a GSM module to transmit a message displaying the current temperature and humidity levels, the temperature-humidity sensor has also been implemented in tissue culture laboratories [9]. However, if the person in charge is unavailable, such an alerting message may go undetected the majority of the time. This has been countered by logging the data on a remote computer so that it can be tracked [10]. Another endeavour involves implementing an alert system for sensors that measure temperature and humidity [11]. A temperature and humidity rise, followed by an alarm, would go unreported, necessitating the use of a durable device that incorporates an alerting and data recording system to report temperature readings monitored by the sensor via SMS to the user or responsible party [12]. A limited number of manufacturers have integrated microprocessors into their products for the past three decades in order to reduce the number of circuits and, consequently, the price paid by end users [13]. Although microprocessors vastly improved the technology they replaced, they are not a panacea for reducing the price and complexity of product design. The issue has been that a microprocessor must be surrounded by a large number of additional input/output (I/O) and supporting processors in order to execute essential functions. In the 1990s, technological advances in silicon processing and chip fabrication allowed for the integration of more circuits with enhanced capabilities and features onto a single chip [14]. At the time, this device was known as a microcontroller [15]. Microcontrollers are currently an indisputable component of electronic devices. Their use is no longer limited to household and office equipment, instruments, and machinery, but has permeated numerous aspects of daily life [16]. Significant improvements in capability, speed, and cost have facilitated the widespread adoption of microcontrollers. Recently, microcontrollers have been integrated into intelligent sensors and used to modulate product and process operations [1, 16]. Using microcontroller-based devices, the information technology (IT) revolution has enabled a more flexible method of managing household appliances [17]. This revolution occurs because microcontrollers combine flexible programme control with the processing power of computers to solve any problem. The product's incorporated microcontroller functions as an intelligent system. These systems use intelligence to automate the operation of electrical devices including lamps, fans, radios, televisions, air conditioners, and security cameras, among others [4], [9]. They value comfort and energy efficiency more highly [13]. A study by Strenz [18] on the technological evolution of microcontrollers did not include bibliometric analysis of heat extraction [19]. In addition, other studies [6, 9,] investigate the concept of a microcontroller-based system and the measurement and control functions of a microcontroller. Neither of them, however, addressed the issue of intelligent industrial heat extraction. Therefore, it is essential to comprehend how far microcontroller research has advanced over the past five years. The Microcontroller Design Process illustrates that at each stage of the design flow cycle, a variety of design solutions are available to address a particular problem or carry out a particular function [20]. For instance, a task can be completed through the use of software (general purpose processor) or a single purpose processor (pure hardware solution). Based on these facts, the purpose of this study is to design and implement a microcontroller-based intelligent industrial heat extractor using a numerical optimization strategy [21].

Most industrial heating system include a control system. Cooling techniques and heat dissipation have been integral components of the design and operation of the vast majority of electronic components and apparatus. Numerous cooling techniques, including conduction, evaporative cooling, and effective heat extraction technologies such as thermoelectric cooling, have been deployed for use in many industries [4, 5]. Numerous innovative cooling strategies, such as the use of two-phase heat spreaders with enhanced heat transmission on evaporator surfaces [3], synthetic micro jet cooling [6], miniaturized and augmented heat pipes [8] and embedded heat pipes [12] for enhance heat dissipation, have been developed. May researchers affirm that the majority of cooling solutions are designed to increase the efficacy of heat transfer from the surfaces of heat-generating components [1,2]. The integration of power electronic converters is evolving towards the three-dimensional integration of modules containing both active switching devices and integrated electromagnetic power passives [3]. This hybrid technique employs multiple layers of materials with varying heat transfer coefficients and layer-level losses. In addition, heat extraction may result in a significant increase in power density, as the materials may be subjected to increased electrical stress (increased current densities and electromagnetic fields), which can lead to increased loss densities [6]. Chang and Martin [7] conducted research on the thermal and computational analysis of embedding solid state heat extraction in power electronic modules. The study covered several real-world implementation concerns, including actual thermal interface resistances using different materials with heat extractors. According to the research, identifying and analyzing heat extraction solutions within industrial facilities has typically been extremely challenging, especially when the solution with the greatest benefit is selected (e.g., energy savings, return on investment). Given the size and intricacy of many industrial facilities, it is difficult to determine the optimal heat extraction strategy and where to position appropriate sinks [8]. To facilitate relevant industrialized organizations to conduct assessments and drive investment decisions in heat extraction technology, a structured, supported strategy is necessary.

METHODOLOGY FOR CONCEPT ABSTRACTION AND FRAMEWORK

Concept abstraction refers to the process of simplifying complex systems or ideas by identifying and focusing on the essential concepts or components. In the context of a microcontroller-based smart industrial heat extractor, concept abstraction involves distilling the fundamental ideas and functionalities that define the system's operation. This abstraction helps in understanding and designing the system at a higher level, without getting into the specifics of the underlying technologies or implementation details [7]. The architectural framework adopted in this work provides a structured approach for designing and organizing the components, modules, and interactions of a system. In the case of a microcontroller-based smart industrial heat extractor, the architectural framework outlines the high-level structure and relationships between the various components involved in the system. The concept abstraction and architectural framework for the proposed smart industrial heat extractor consist of the sensor module, microcontroller, the actuator module, communication interface, power unit, control algorithm and logic. The Sensor module comprises various sensors, such as temperature sensors, humidity sensors, and airflow sensors, that collect real-time data about the industrial environment. The sensor module is responsible for capturing the necessary information for monitoring and controlling the heat extraction process. The microcontroller serves as the control center of the system. It receives data from the sensor module, processes the information, and generates control signals based on predefined algorithms and logic. The microcontroller acts as the brain of the system, orchestrating the overall operation of the heat extractor. Actuator Module: The actuator module consists of devices such as fans, blowers, or pumps that regulate the airflow and cooling mechanisms in the industrial environment. The microcontroller sends control signals to the actuator module to adjust the speed or operation of these devices, ensuring efficient heat extraction and temperature regulation. The communication interface allows the microcontroller to interact with external systems or interfaces. It may include protocols such as Ethernet, Wi-Fi, or Bluetooth, enabling connectivity with other devices or a central control system. The communication interface facilitates data exchange, remote monitoring, and control of the heat extractor system. The power supply module provides the necessary electrical power to operate the microcontroller, sensors, and actuators. It ensures a stable and reliable power source for the continuous operation of the heat extractor system. The control algorithm and logic define the rules and decision-making processes implemented by the microcontroller. It includes temperature control algorithms, feedback mechanisms, and adaptive control strategies. The control algorithm and logic enable the microcontroller to respond dynamically to changing environmental conditions and optimize the heat extraction process. The proposed concept abstraction and architectural framework provide a high-level overview of the key components and their interactions in a microcontroller-based smart industrial heat extractor. This framework serves as a foundation for the detailed design and implementation of the system, ensuring efficient heat extraction, temperature regulation, and overall thermal management in industrial environments.

Design Partitioning

Partitioning is a critical design instrument when dealing with intricate systems. The design is organized into a number of inherently interconnected activities or abstraction layers. The phases of concept abstraction progress from the most abstract level to the component parts that must be aggregated in order to deliver the highest-level function. For example, digital VLSI design is frequently subdivided into the concurrent processes of architectural design, microarchitecture design, logic design, circuit design, and physical design [3, 6]. This assignment specifies the system's architecture [11]. The x86 microprocessor's architecture describes its instruction set, register set, and memory model [9]. This assignment describes the architecture's partitioning into registers and functional components [12]. The 80386, 80486, multiple Pentium, Celeron, Cyrix

Mu, AMD KS, and Athlon microarchitectures offer distinct performance/transistor count compromises for the 86 architectures [13]. In this implementation, logic design is performed, which involves assembling functional units using circuit design, which is the process of assembling logic using transistors. A carry look-ahead adder is implemented in this proposal with static CMOS circuits, domino circuits, or pass transistors. The circuit is optimized for both excellent performance or minimal power consumption. These designs are inherently interdependent. For example, the number of transistors that can be compressed onto a chip, which is determined by physical design and manufacturing technology, has a significant impact on microarchitecture and logic design decisions. Similarly, an inventive circuit design that reduces a cache access from two cycles to one may have an effect on the optimal microarchitecture. Interactions between microarchitecture and logic, circuit design, and physical design [7] determine the Clock frequency selection. While deeper pipelines facilitate higher frequencies, they also impose greater performance penalties when activities at the beginning of the pipeline depend on those at the end of the pipeline [12]. Multiple functions employ diverse logic and circuit architectures, balancing efficiency against area, power consumption, and design effort.

Optimization Approach

Heat is extracted from the room in either a positive or negative trajectory [3]. The distribution of inserts for heat extraction is homogeneous in all directions. However, end-direction offsets are not always equivalent [10]. First, the geometry of the heat extractor components must be optimized [12] in order to construct a heat extraction system that utilizes as little space as possible while providing sufficient thermal enhancements. By optimizing the cross-sectional shape of a heat extraction insert, it is feasible to reduce the peak temperature within the heat-generating medium while retaining the same heat generation rate, or to increase the heat generation rate while retaining the same maximum operational temperature [13]. The numerical optimization approach generates a large number of models by varying and combining material, geometric, and temperature parameters using an automated procedure [14]. By optimizing for steady-state thermal conditions, similar geometric models can be compared on the basis of their peak temperatures, which may be utilized to characterize the cross-sectional trends of optimal heat extraction inserts. It is crucial to determine which algorithm is the most efficient in terms of execution time and hardware complexity [15], despite the fact that multiple algorithms may accomplish the same objective. In order to obtain an optimal system, the model for a microcontroller-based smart industrial heat extractor optimizes multiple design parameters at each stage of the design process, such as performance, power consumption, and so forth. During the initial stages of the design process, the designer's goal is to determine what is actually achieved at each level [16].

Design Architecture and Algorithm

The rational for the architectural design is to specify the functional components in a manner that restricts their interactions, resulting in a modular framework. Initially, each functional element is specified independently of its hardware and algorithm implementation. After the primary functional aspects have been partitioned into hardware subsystems and software components, the interfaces between them are defined. In this phase, we established the processing technology that will be utilized to perform each subfunction. The proposed system implements this subfunction using a look-up table and an appropriate circuit decoder in hardware. We determined the user-defined software/hardware separation by optimizing an array of design metrics attributes, including execution speed, power consumption, size, memory size, and programme size. The number of layers in the top-down structure is a crucial determinant of how the interfaces between the various components are implemented. System refinement forms the core of the algorithm analysis and continues through the implementation to the lowest level of abstraction. The implementation level of general-purpose processors consists of component algorithms, while that of single-purpose processors consists of a gate-level net list. These metrics are analyzed and optimized at each level of abstraction to guarantee that the end result meets performance and design requirements. On the most abstract levels, algorithms are used to translate functional requirements such as system behavior descriptions into structural requirements. The absolute values of the metrics, such as the number of microseconds variation in processing time or the number of microwatts expended, are irrelevant at this level of abstraction. The primary objective of any algorithm analysis is to estimate the required resources for its implementation. We considered the condition that, when comparing metrics at the system level to those at the instruction level, the analysis can be performed at a much finer granularity. At this level of abstraction, the analysis will be limited to particular devices and small code segments. At a more fundamental level, the objective is to optimize a specific method or determine the upper and lower limits of a sequence via a piece of code. Analytical approaches can provide a high-level or heuristic comprehension of algorithms and software [10]. Analysis of complexity quantifies execution time in time steps or time units while the number of required storage units quantifies the complexity of the components. Each elementary operation is presumed to consist of a single step, and each basic artefact is assumed to inhabit a single memory unit.

SIMULATION AND RESULTS

The proposed system is developed through parallel hardware and software phases, utilizing distinct architecture standards for each. The hardware design process comprises three distinct stages, namely design, simulation, and prototype testing. This section delineates the requisite functions, interfaces, and operational tempo. This facilitates the identification of the testing methodology to be employed for the developed prototype and the corresponding testing variables. Following the identification of the requisite functions that the hardware must execute, the subsequent step involves the selection of the appropriate components. At present, it is imperative to make two pivotal determinations: firstly, the selection of the processor type for the execution of each functional block, and secondly, the choice of integrated circuit technology to be employed for implementation. The technical specifications are determined by taking into account various components such as execution speed, data bus size, and other relevant factors. Nevertheless, non-technical factors are also considered when making these decisions. The illustration presented in

Figure 1 showcases an Arduino-based intelligent industrial heat extractor that has been designed for simulation under multiple settings.

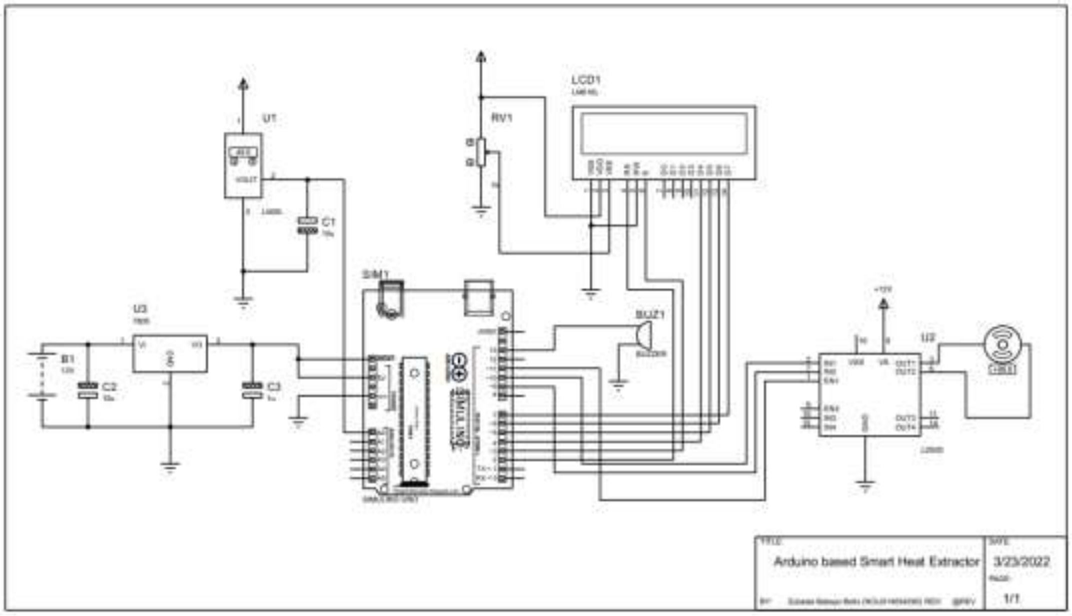


Figure 1 Arduino controlled Smart industrial heat extractor

Simulating the Voltage regulator circuit Section

ARDUINO UNO microcontroller prototyping board controls the algorithm of this work. The device is based on a standalone ATmega328 microcontroller. The clock frequency is 16MHz, and the operating voltage is 5V. It has 14 digital input/output channels, 6 analogue pins, and 6 digital input and output pins dedicated to Pulse Width Modulated Signals, and weighs 25 grammes. The circuit of the intelligent heat extractor is fueled by a 24V dc battery. The 24V source voltage powers the dc motor, while the remainder of the circuit is powered by 5V that has been regulated. The purpose of the circuit's voltage regulator component is to provide a +5V source voltage to the Arduino Microcontroller while allowing the motor to access a higher 24-volt voltage. R1 (330) and R2 (960) are necessary for setting the output voltage of the regulator, which is 5 volts in this case. The addition of the 10uF capacitor improves ripple rejection. Protection diodes provide a low-impedance discharge path to prevent discharge of capacitors into the regulator's output. The formula for the output voltage (Vo) was obtained from the LM317T voltage regulator's datasheet.

$$V_0 = VREF\left(1 + \frac{R2}{R1}\right) + (IADJ \times R2)$$

Where IADJ is typically 50 µA and negligible in most applications and

$$VREF = 1.25V$$

Therefore, Vo = 5V, when R1 = 330 Ω and R2 = 960Ω.

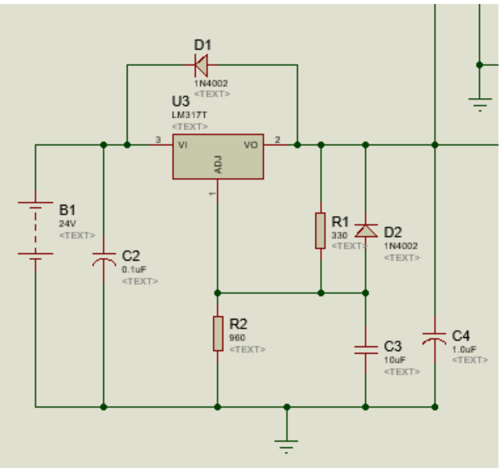


Figure 2: Voltage regulator circuit section

A voltage regulator is an electronic circuit that generates and sustains a consistent output voltage, irrespective of variations in input voltage or load circumstances. Voltage regulators (VRs) are responsible for ensuring that the voltages emanating from a power supply remain within a range that is compatible with other electrical components. The aforementioned is illustrated in Figure 2. Voltage regulators are a crucial component of electronic circuits, ensuring reliability and safety [8]. In industrial settings, high-power voltage regulators utilize power electronics circuits with significant power ratings.

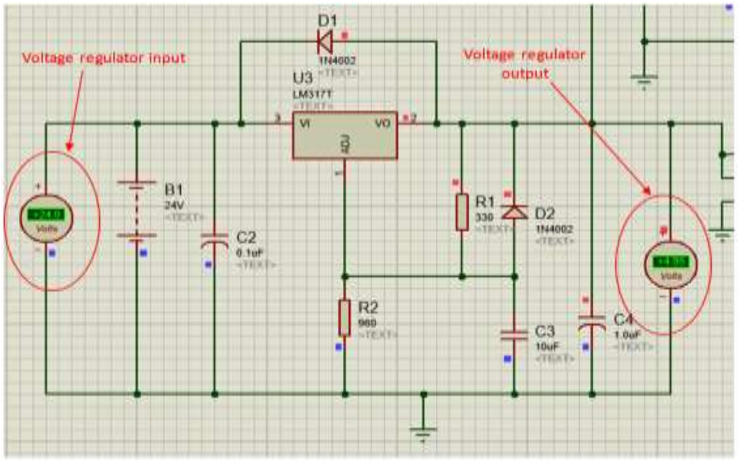


Figure 3: Simulation result for voltage regulator

The sequence simulation and validating the voltage regulator commences with the initialization of the fan motor to the OFF state, which is succeeded by the acquisition of temperature readings. The dispersion of PWM signals is achieved by spanning the temperature range of 25oC to 45oC. Consequently, when the temperature exceeds 45 degrees Celsius, the fan functions at its highest power output. The aim of this particular design is to gradually and systematically return the ambient temperature of the surrounding environment to a level of 25 degrees Celsius. The velocity of the extractor fan gradually diminishes as the temperature decreases, ultimately reaching equilibrium with the ambient temperature of the room. The temperature readings and fan motor speed rate are displayed on a Liquid Crystal Display (LCD) unit, which also features an alarm to indicate the initiation of fan motor rotation. Figure 3 depicts the simulated process model by which the temperature sensor integrated within the device measures the temperature of its immediate surroundings. Upon detecting a temperature exceeding 25 degrees Celsius, the temperature sensor initiates transmission of a signal to the Arduino UNO microcontroller. Subsequently, the microcontroller generates a Pulse Width Modulated (PWM) signal to regulate the speed of the extractor fan motor. The motor's rotational velocity exhibits a gradual increment in tandem with the elevation of temperature and is uniformly dispersed across the entire range of 0 to 100 percent for temperatures spanning from 25 to 45 degrees Celsius.

Simulating the Temperature Sensor Circuit Section

The LM35 temperature sensor performs sensing by converting the measured temperature value to a corresponding electrical output. For every 1oC, the device will send out an analogue output equivalent of 10mV. This output voltage is sent to the Arduino UNO board as an analogue input via the Analog input channel pin A0 as depicted in Figure 3. The sensor's terminals number three. The VCC power pin (pin) is connected to the +5V output of the LM317T voltage regulator circuitry whilst pin 3 is connected to a common ground. The output pin (pin2) of the temperature sensor transmits the temperature values as voltage signals to the Arduino UNO board (see Figure 3). The dissipation of thermal energy from a designated area can be achieved through either a positive or negative process [3]. The uniformity of the heat extraction insert distribution is observed in all directions. However, it is important to acknowledge that the comparison of end-direction offsets may not be universal as observed by Karemore, and Jagtap, [6].

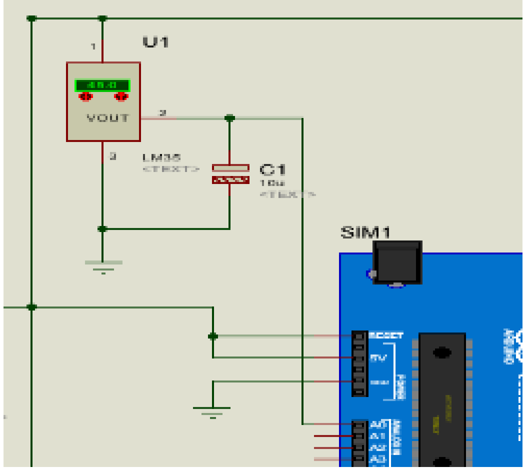


Figure 4: Temperature sensor circuit section

The geometry of the heat extractor components is optimized in order to produce a heat extraction system that occupies minimal space while providing sufficient thermal enhancements. The temperature sensor circuit section was simulated as suggested by many researchers that it is feasible to reduce the uppermost temperature limit of the heat-producing medium without modifying the rate of heat generation. Another simulation involved upholding the identical maximum operational temperature while elevating the heat generation rate by optimizing the cross-sectional configuration of a heat extraction insert. This process of optimization through simulation involved the manipulation and integration of material, geometric, and temperature parameters, resulting in a significant number of models (see Figure 4).

Dynamic Control of the Motor Driver Integrated Circuit

The Arduino UNO microcontroller, like the majority of other microcontrollers, is unable to provide the voltage necessary to drive the 12V DC motor. The Arduino output voltage and current of 5V and 2020mA are insufficient for the DC motor. Therefore, a motor driver integrated circuit (IC) is used to control the motor. The L293D is a four-channel, monolithic, high-current, high-voltage, motor driver IC. It can utilize power supplies of up to 36V and can deliver a maximum of 600mA per channel. For practical purposes the power supply of the L293D (pin 8) will be directly connected to the 24V input supply of the LM317T voltage regulator, thereby bypassing the 5V output used by other components on the circuit. This is to allow the circuit to provide the high startup voltage required for the DC motor (see Figure 5).

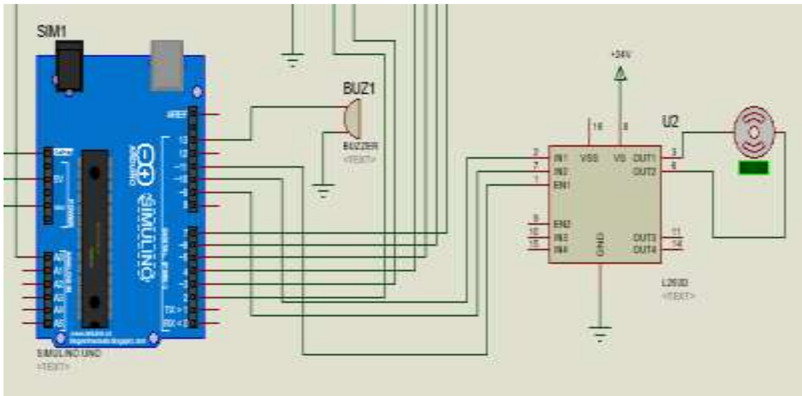


Figure 5: Fan motor control circuit section

The ARDUINO UNO microcontroller employs Pulse Width Modulated (PWM) signals to regulate the speed of the motor through the L293D motor driver Integrated Circuit. Figure 6 illustrates the section of the circuit responsible for controlling the fan motor. The aforementioned process is achieved through the transmission of direct current (DC) voltage pulses to the L293D component, with the modulation of the pulse's on and off states being adjusted accordingly. The duration ratio between the "on" and "off" states is commonly referred to as the duty cycle. The modulation of the duty cycle by adjusting the durations of the "off" and "on" times is the method employed to modify the velocity of a DC motor. The speed of the motor is directly proportional to the duration of the duty cycles "on" pulse. A longer "on" pulse results in a faster rotation, while a shorter "on" pulse leads to slower operation. The simulation output illustrates a range of duty cycles spanning from 5% to 100%, as is apparent.

Performance Evaluation of the Thermal Variants

By optimizing steady-state thermal conditions, it becomes feasible to compare geometric models that exhibit similarities in terms of their maximum temperatures. This is monitored in the model simulated in Figure 6. The LM016L is capable of displaying up to 16 characters across two panels. However, if the displayed information is scrolled using software commands from the ARDUINO UNO microcontroller device, it can exceed 16 characters. Additionally, it should be noted that the LM016L LCD display has its own internal microcontroller. The microcontroller ARDUINO UNO transmits ASCII values to the display controller. The display controller then creates a pattern for the associated dot matrix. The present methodology can be employed to delineate the transverse patterns of optimal heat extraction inserts. The determination of the optimal algorithm with regards to both hardware complexity and execution time is a crucial consideration, as emphasized in [18], even in situations where multiple algorithms are capable of accomplishing the same goal. The optimization of various design parameters, such as performance and power consumption, is a critical component of the design process for a microcontroller-based smart industrial heat extractor. The ultimate goal is to achieve an optimal system that meets the desired specifications.

During the initial stages of the design process, the primary aim of the designer is to determine the specific achievements at each level, as indicated in citation.

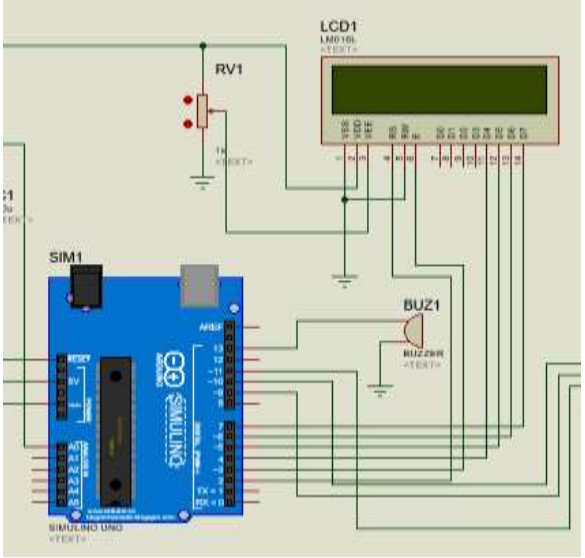
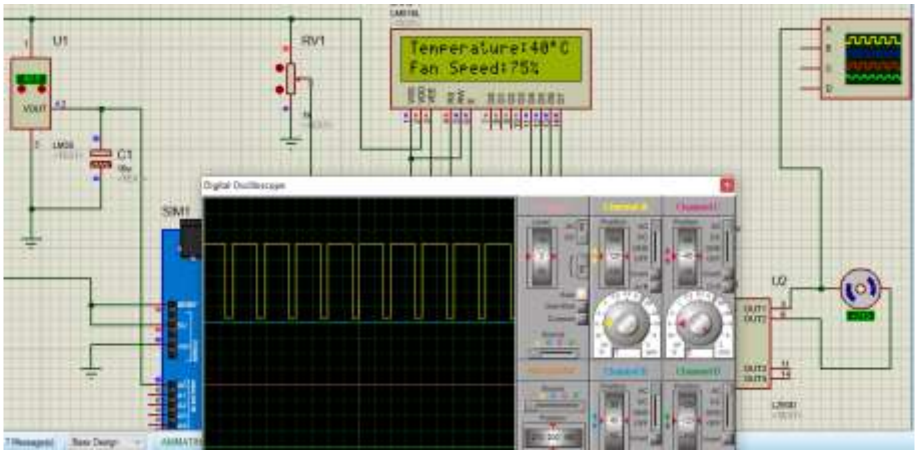


Figure 6: LCD screen circuit section

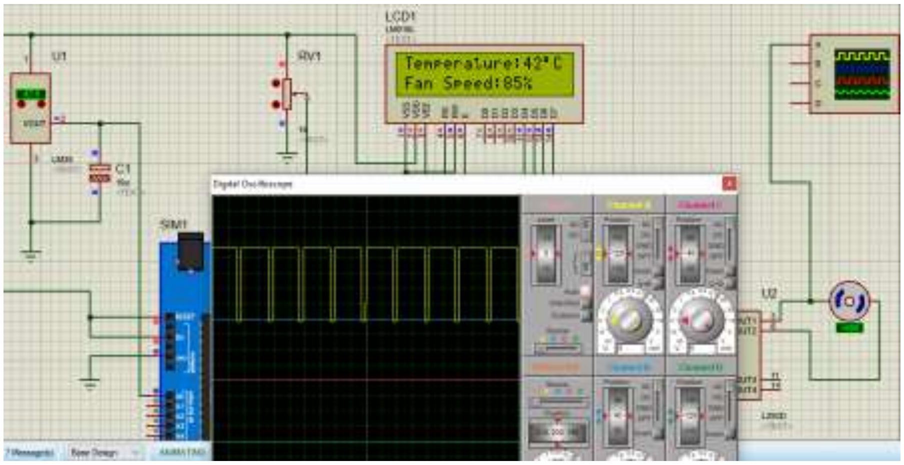
Simulation and Refinement

Through the process of simulation, the model implementation undergoes refinement in order to satisfy the designated design criteria. Upon fulfilment of all requirements, the system, or a preliminary version can be deployed and subjected to evaluation. There exist multiple evaluation methodologies to assess the model during its construction and the gradual integration of the system's distinct components. The procedure for testing the model involves comparing the program's full functionality to the initial functional design specifications. Similar to hardware, there are two distinct approaches to accomplish this task: simulation and emulation. In the process of programme simulation, the utilization of the target microcomputer is not employed. Instead, a comparable model is constructed to emulate the target system. The two primary simulation levels are functional and comprehensive. Figures 7 and 8 illustrate the simulated outcomes of an Extractor Fan motor's performance under different conditions of temperature, duty cycle, and velocity.



Temperature:40°C
Fan Speed:75%

Figure 7: Extractor Fan motor at 40°C, 75% duty cycle and 75% speed



Temperature:42°C
Fan Speed:85%

Figure 8: Extractor Fan motor at 42°C, 85% duty cycle and 85% speed

A functional simulation will utilize the same block interfaces as the actual hardware, but with unique implementations. For instance, if the target hardware contains a keyboard, this can be replicated using a file containing a string of characters. When the programme requests keyboard input, a character from the file is substituted. Even in a functional simulator, the microprocessor's register and memory contents will always be replicated precisely. The internal activities of hardware parts are also meticulously described for comprehensive simulation. This is uncommon because it requires significantly more programming to generate an accurate simulation and does not improve the quality of the results significantly.

CONCLUSION

The aim of this study is to introduce a novel configuration and emulation of a heat dissipation mechanism utilizing the ATmega328 autonomous microcontroller. The proposed solution employs an integrated temperature sensor for the purpose of ascertaining the ambient temperature. Upon detecting a temperature exceeding 25 degrees Celsius, the temperature sensor transmits a signal to the Arduino UNO microcontroller. A low-cost 16-bit microcontroller was utilized in the development of the control system. The microcontroller-based control system was modified to incorporate the numerical optimization technique for the purpose of producing reactive power compensation that achieves a power factor of unity. In order to ascertain the authenticity of the control system, a range of temperatures, duty cycles, and velocities were employed in both experimental and simulated settings. Therefore, a logical deduction can be made that the provided control system is proficient in compensating both balanced and unbalanced single-phase systems. This is supported by the simulated outcomes of an Extractor Fan motor functioning at different temperatures, duty cycles, and speeds. In order to ensure comparability between the results of the experimental and simulation studies, the experimental investigation employed an identical scenario to that of the simulation study. This initiative aims to enhance the ease of monitoring and regulating temperature through the utilization of industrial heat extractors, thereby improving user-friendliness. A potential avenue for further investigation as a continuation of this study is the development of a multisensory system that can be remotely controlled, leveraging internet networks and cloud technology for data storage and thermal monitoring.

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