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Temperature Controller for Multizone Hot Runner in Injection Moulding Machine

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Abstract: Injection moulding is the process of manufacturing of plastic products in which the molten plastic is filled into the mould. It can be performed with a host of materials including metals, glasses, confections, and commonly thermoplastic and thermosetting polymers. Material for the part is fed into a heated barrel, mixed using a helical shaped screw and injected into a mould cavity, where it cools and hardens to the configuration of the cavity. Injection moulding is the most common modern method of manufacturing plastic parts; it is ideal for producing high volumes of the same object. A hot runner controller is a temperature controller used to control the temperature in the hot runner. It is available in Indian market are expensive to purchase and operate; they are lack of modularity and features that will support the user friendly experience. This paper aims on developing a hot runner controller which is cost-effective, modular and user-friendly. Microcontroller is used for providing efficient design of hot runner controller used in the plastic moulding industries. The use of integrated display makes monitoring and control easy. Auto-check functionality is used to predict the faults in connections of the sensors to avoid the damage before the controller turns ON the heaters.

*Keywords —**mould, controller, modularity, heater, moulding, auto-check.***

I. INTRODUCTION

The injection moulds [7] have been designed to the customer's specifications and the presses pre-programmed, the actual moulding process is very quick compared to other methods of moulding. Plastic injection moulding process hardly takes times and this allows more parts to be manufactured from a single mould. The high production output rate makes plastic injection moulding more cost effective and efficient. Typically, hot-runner injection mould systems produce parts with more consistent quality and do so with faster cycle times, but it's not as easy to change colors nor can hot runners accommodate some heat-sensitive polymers

The hot runner controller requires accurate control of temperature to maintain the quality of the polymers and ensure the quality of the end component. The user needs to specify the temperature through the control panel which has display and input buttons. The hot runners use the heaters that have power rating above 700 W with the temperature sensors in it. The hot runners [8] uses dedicated heaters and thermocouples for each zone to sense and control the temperature as given by the user or machine operator for the specific plastic material. Hot runner controllers are used to improve the efficiency of the process by the precise temperature controlling methods.

The existing model of the multi-zone hot runner controllers lags certain functionalities which has impact on the user experience (UX) and cost. The industries are in demand of the hot runner controller system which has options to select the predefined set of temperature values to initialize in the single click, to enhance the troubleshooting efficiency with improved modularity, stand-by mode to keep the quality of the plastic material without degradation by maintaining the temperature at specific level for prolonged period during the troubleshooting time. The Injection moulding industries are in need of controller which can save the initialization time by pre-programmed settings and user friendly display and input functionalities which is economic than the existing system.

II. LITERATURE REVIEW

A.L.Amoo et.al [1] proposed "Design and implementation of room temperature control system: Microcontroller-Based" in which the design considered the flexibility of using a microcontroller, PIC16F876A along with other peripheral devices such as LM35 temperature sensor, LCD display unit to form all encompassing single system. In this work the microcontroller was programmed using MP LAB

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IDE. It accepts inputs from a simple four-key keypad providing users with ease of adaptability and flexibility in selecting desired temperature range of choice. The microcontroller compares the measured room temperature with the reference input. The output from the controller was used to drive a relay through an Opto-coupler which switches between AC and Room Heater according to the control decision. The result obtained was adequate within the scope of the work with 95% accuracy index. The design could be improved upon by making use of silicon controlled switches that are not noisy in operation rather than the electromagnetic relays used as actuator in construction of the prototype automatic room temperature reconditioning device.

Gungor BAL et.al [2] proposed "Design and Implementation of Microcontroller Based Temperature Measurement and Control System" in which the microcontroller based temperature controlling technique is used to keep the devices in the required temperature. The microcontroller used in this design is PIC16F628 which has ability to read the input from the temperature sensor and control the connected devices accordingly. The temperature sensors are mostly thermocouples of J/ K type. The connected loads will be heaters and exhaust systems. Measurement of temperature value is carried out by the ADC of the microcontroller which is of the resolution 10 bits. The measured temperature value is compared with the reference input from the user and the loads are controlled by the controller accordingly.

N.ChandraSekhar et.al [3] proposed "Implementation of low cost MEMS based temperature measurement and control system using Lab VIEW and Microcontroller which aim to implement low-cost MicroElectroMechanical Systems based real time temperature measuring, monitoring and control system which uses a monolithic temperature sensor that provides a pulse width modulated digital output signal corresponding to its input temperature. Two different platforms are chosen to implement the MEMS based temperature control system. First one is using real time controlling software NI LabVIEW and another is using PIC microcontroller. As the implemented system uses advance technologies i.e. MEMS and LabVIEW, results in compactness, low cost, high level of accuracy and wide range of temperature measurement

Radhaprasanna Merugu et.al [4] proposed "Microcontroller based temperature and luminosity control system using CAN bus" which was developed to support applications like real time temperature control system. It is ideally suited for many rugged applications like automotive and industrial applications. The model implements the master slave communication to achieve the desired result. The system is designed with one master and two slaves, where the master sets the parameter values of both the slaves and the slave set its respective parameters accordingly. At the slave side there is control action module to maintain the set value. The communication between the master and the slave takes place via CAN bus.

III. METHODS AND MATERIALS

A. Existing system

Hot runner controllers are used to eliminate the problem of overheating of molten plastic granules and polymers. If the polymers are overheated, they may get burned or lose their property which in turn may affect the quality of the end component or product. Hot runner controller ensures the temperature of the molten plastic inside the conducting tract and to fill in the mould. They use temperature sensor to sense the temperature of the molten plastic. The temperature sensor can be thermocouples of J or K type.

In the existing temperature control system for the hot runner control has dedicated heater, temperature sensor and control panel to maintain the temperature of the molten plastic granules. The temperature control, monitoring and user input are difficult to done by the user.

The hardware components like SSR, DC power supply and HRC fuses are kept in the cabin. When there is any problem in the controller, the troubleshooting person needs to shut down the whole system and then troubleshoot the problem. They lack modularity which can be used to trouble shoot the whole system without shutting down the whole controller.

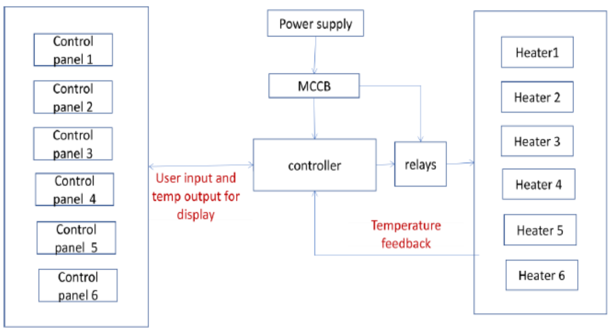

Figure 1 Block diagram of the existing system

The industries are in the need of temperature control system which can be troubleshoot using the method of removing the particular module which is under problem and the other modules will be working fine as expected. Whenever the problem is resolved the troubleshooting person needs to shut down and install the repaired or serviced module. The industries are also searching for the system which can be used to avoid this problem. Figure 1 shows the existing system used for temperature controlling and monitoring in plastic injection moulding industries.

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B. Proposed system

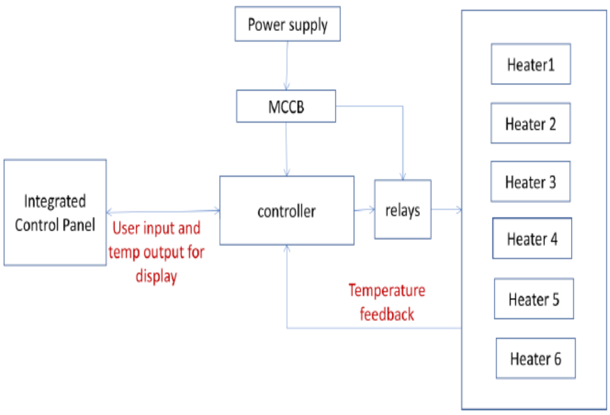

Figure 2 Blocking diagram of the proposed system

Figure 2 shows the proposed system for control and monitoring the temperature of the heaters used in plastic injection moulding machines.

C. Integrated display

Existing System uses dedicated display at zones. Which make control and monitoring difficult, the proposed system overcome these problems by integrating the controls of the zones to a single controller from which is capable of controlling and monitoring the zones. The centralized controller consists of a LCD display integrated with a keypad to navigate between zones, programs and set temperature values and modes by user.

D. Temperature control

The temperature sensor (LM35) is used to sense the temperature of the hot runner and the sensor output is connected as input to the microcontroller's analog input channels. The voltage value (analog signal) is converted into temperature values (digital signals) with the help of ADC (Analog to Digital Convertor) of the microcontroller which has 10 bit resolution. The heater is turned OFF when the required temperature is achieved. The controller continuously checks the sensor value with its initialized value and controls the heater accordingly.

Figure 3 shows the working of automatic temperature control system in the proposed model. The user needs to input the reference temperature and the sensor will continuously monitor the temperature of the heater. If the temperature of the heater reaches the reference temperature or more than that, the relay with controls the heater will be turned OFF and when the temperature is below the reference temperature the relay will be turned ON.

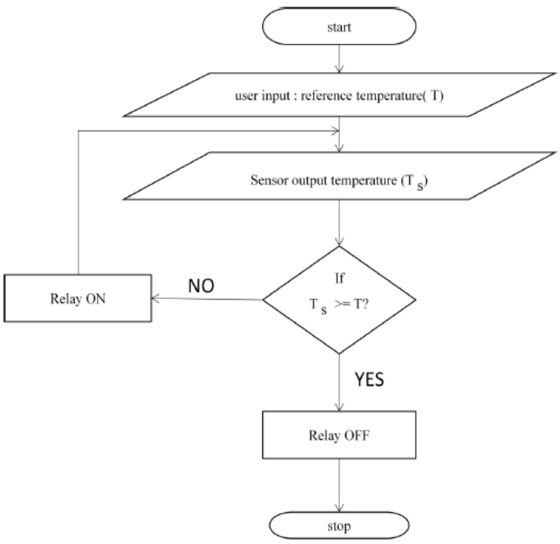

Figure 3 Flow chart demonstration of temperature control

E. Program selection

The initialization of the temperature takes time and difficult to configure of each zone separately. But in this proposed model the initialization can be avoided if the user is choosing the program which is saved already in the microcontroller's EEPROM. When the user is starting the controller, User doesn't need to involve in the process of initializing temperature for each zone instead of that user can select the program which is already defined.

This program selection functionality enables the user to create multiple programs for various components and materials, whereas the existing temperature controller system will not allow the user to do the same function. In the existing temperature controller system, the user needs to input temperature for each zone and when the user needs to change the process for different material or products which is produced by the process. This process will take lot of time and user will not be able to able to use the configured temperature for the future usage.

Program selection process is carried out every time when the program is started, which prompts the user to select the required program. The programs can be stored with different names consists of alphabets, alphanumeric characters. The program data will be stored as array in the memory (EEPROM) of the PIC16F877A microcontroller with the program name. All the programs which are stored in the EEPROM will be displayed during the prompt screen allows the user to select the required program and execute the same.

The user will also be able to configure the values of the each zone in the selected program during the runtime of the program. The user will also be able to change the temperature for the particular zone. It allows the user to change the temperature of the program which is not currently running. The following are the advantages of the program selection functionality,

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- Reduces initialization time
- Configure the temperatures in the program during the runtime of the program
- Configure the temperature of the zone during the run time
- Improves the user experience in initialization

F. Sensor auto-check functionality

Sensor auto-check functionality is used to verify the sensors are connected properly to the sensor ports. The main objective of this functionality to check that the sensors are properly connected to input ports of the controller and with the output ports of the relay. If the sensors are connected to the output port of the relay, the sensor will be supplied with high voltage and it will get damaged. This may lead to the loss of temperature control function and lead to overheating, which may damage the plastic material. This problem also increases the production time and decreases the production efficiency. The system will not be functioning as expected in case of sensors are connected to the system. This functionality will also detect the loose connections and wire breakage. This key feature is used to avoid the damage in the production and saves time in routing the problems related to the sensor. Figure 4 shows the flow chart which demonstrates the working of sensor auto-check functionality. This functionality checks whether the sensors are properly connected to the sensors input ports. This function checks for the input from each sensor when the program is started. This function is performed every time during the controller is powered ON. When the sensor output is equal to zero, which indicates that there is a problem. The problem may be caused due to the following reasons,

- Wire breakage
- Wrong connections
- Damaged sensors
- Use of inappropriate senor

Whenever there is an error in the sensor input, the error message will be displayed in the display with the respective zone number and it will prompt the user to continue or stop the program. When the user opts for the continue option, then the controller will power up all the heaters except the zone which has error. When there is no error, the display will show the message as “No error detected” and it will prompt the user to continue or stop the process

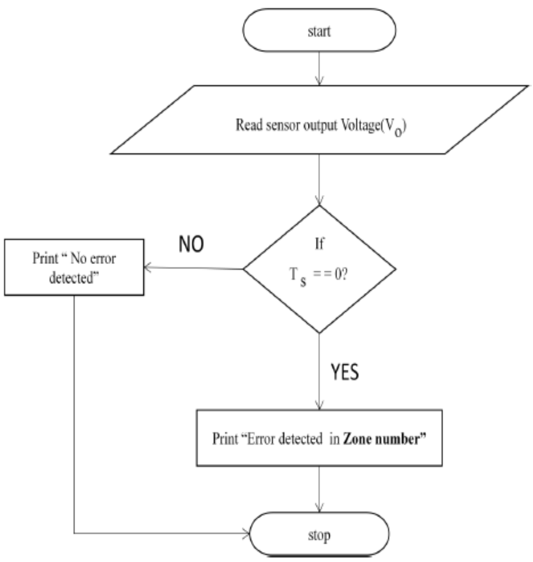

Figure 4 Flow chart to demonstration of Sensor auto-check functionality

IV. DATA AND RESULTS

The program used for controlling the heaters used in the hot runner controller is developed with the help of MPLAB IDE.

Simulation of 6 zone hot runner controller is carried out by Proteus ISIS and its parameters are studied with the output of the simulation.

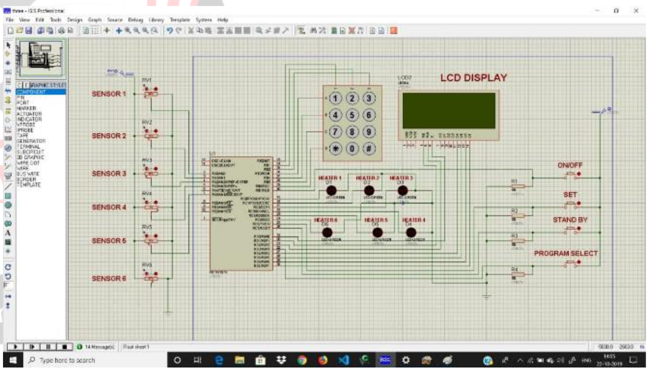

Figure 5 Simulink model of 6 zone hot runner controller

Figure 5 shows the Simulink model of 6 zone hot runner controller of the proposed system.

The splash screen in the simulation is shown in figure 6. The Controller used in this simulation is PIC16F877A. The temperature inputs are given by the potentiometers in the simulation to get the various voltage inputs like the real time sensor. The LED’s are used to indicate the output. The LED’s and potentiometers are connected to the GPIO pins of the different ports of the PIC16F877A microcontroller. In order to give additional functionalities, push buttons connected to the controller. The inputs are received by the controller and the desired actions are performed as per the program. Figure 6 shows the overall view of the six zone hot runner controller

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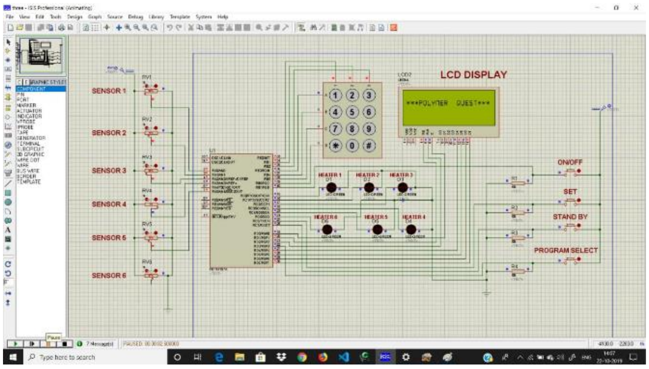

Figure 6 Splash screen of the controller

G. Simulation Outputs

The proposed system is simulated in the Proteus ISIS software to verify the functionalities are performed as expected. The simulation is performed with the help of Proteus ISIS software for the proposed model. The program is loaded in the PIC16F877A microcontroller used in the simulation. The performance of the proposed system is observed with the help of 16x2 LCD display used in the simulation. User inputs are given using the keypad and it is executed by the controller. The display will display the current temperature of all the heaters connected to it. LEDs are used to indicate the heater in the developed prototype model. The simulation results are achieved as per the objectives and the hardware prototype is designed for the same. The simulation has be done for the various scenarios such as,

1. Program selection
2. Temperature configuration for particular zone
3. Temperature configuration for selected zone
4. Sensor auto check functionality (with errors)
5. Sensor auto check functionality (without errors)
6. Stand-by mode
7. Working mode

The simulation outputs of the proposed system are obtained as shown in the below figures,

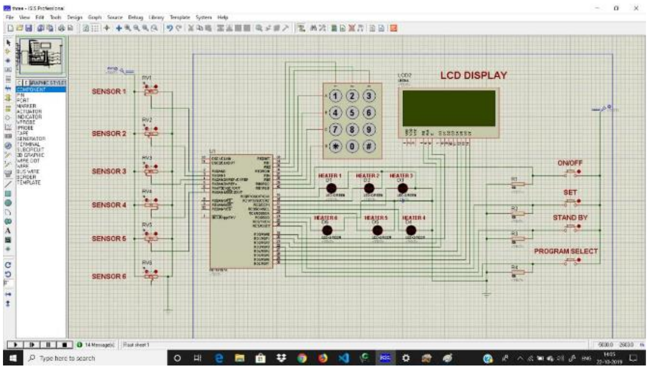

Figure 7 Schematic in OFF state

Figure 7 shows the output when the power supply is OFF (before turning ON) in which the hot runner controller is under power OFF condition.

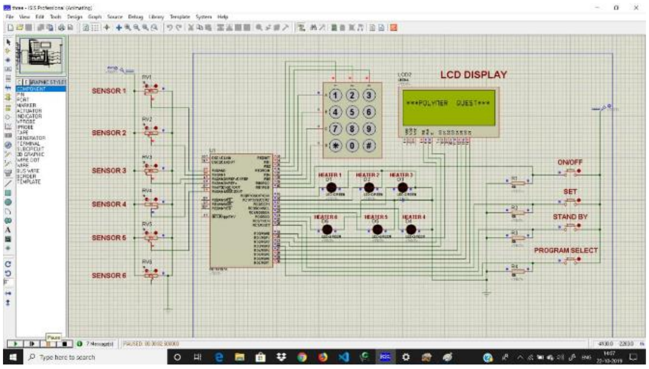

Figure 8 Splash Screen

Figure 8 shows the splash screen of the proposed system which displays the brand name of the prototype.

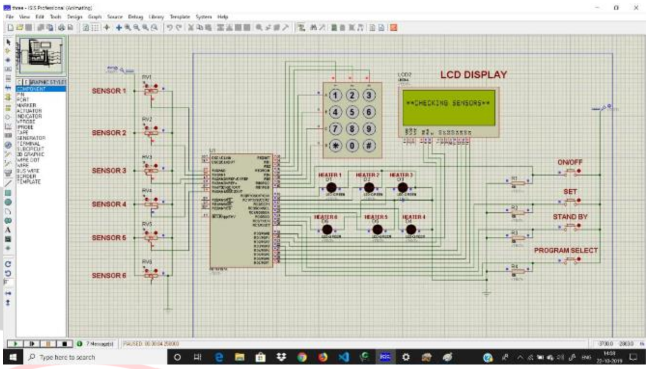

Figure 9 Sensor Auto-check function

Figure 9 shows the implementation of the automatic sensor checking functionality which will work during the every start of the hot runner controller.

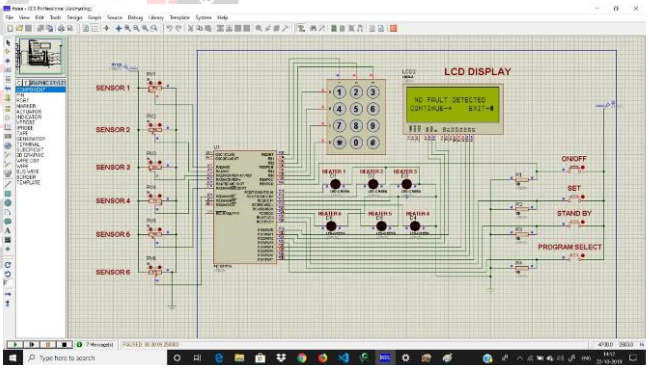

Figure 10 Sensor check results with no error

Figure 10 shows the results of the sensor check functionality when no error is detected.

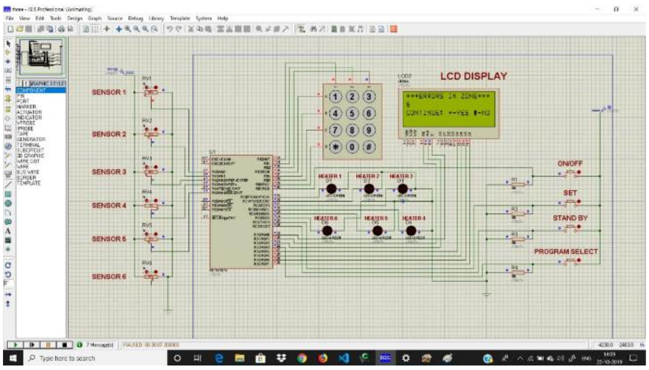

Figure 11 Sensor Auto check results with errors

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Figure 11 shows the results of the sensor Auto check functionality with errors detected.

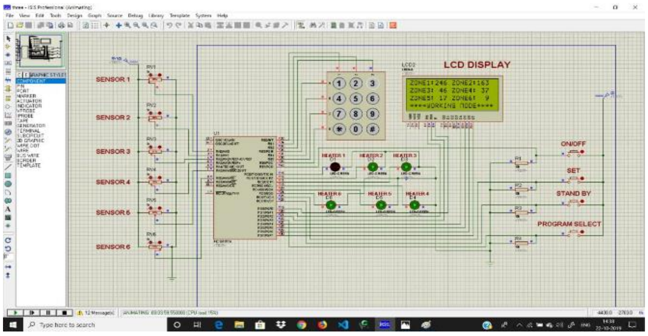

Figure 12 Working mode

Figure 12 shows the function of proposed system with the working mode.

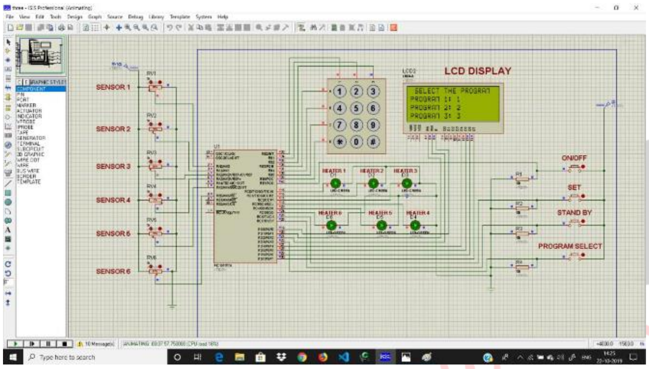

Figure 13 Program select functionality

Figure 13 shows the functionality of the proposed system when program select button is pressed.

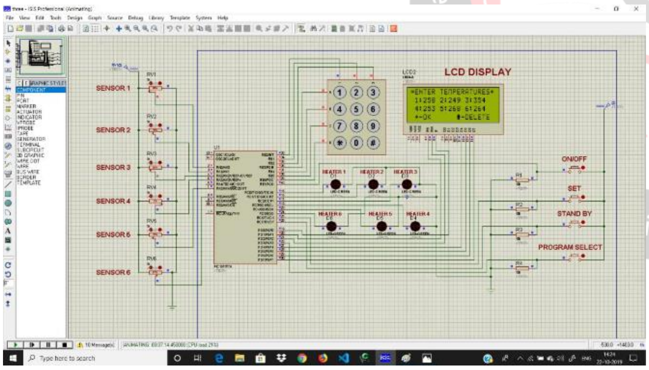

Figure 14 Temperature configurations for the selected program

Figure 14 shows the screen prompting for the configuration temperature for each zone in the selected program.

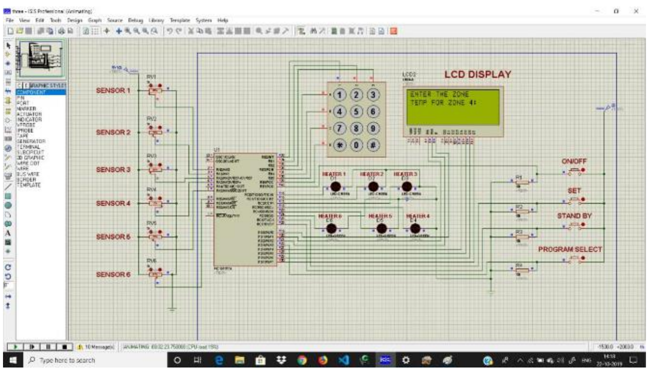

Figure 15 Temperature configurations for the particular zone

Figure 15 shows the temperature configuration for the particular selected zone among the available zones.

H. Hardware test run results

The hardware circuit is fabricated as per the requirement and it tested for various scenarios. The hardware implantation of the proposed system is done using PIC16F877A microcontroller. The hardware is operated in the various scenarios such as,

1. Program selection
2. Sensor auto-check with errors
3. Sensor auto-check without errors
4. Temperature configuration for the selected program
5. Temperature configuration for the selected zone
6. Working mode
7. Standby mode

The figures below shows the outputs obtained with the developed hardware prototype.

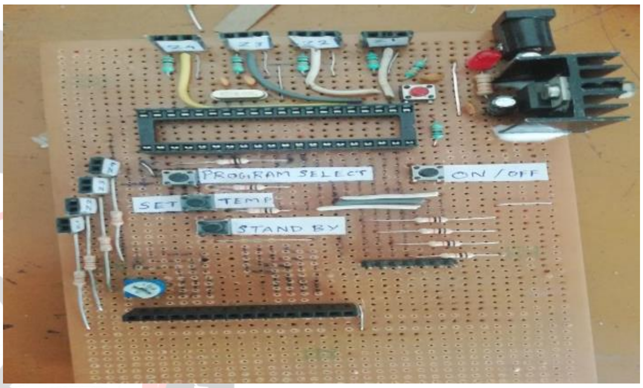

Figure 16 Hardware circuit

Figure 17 shows the custom made circuit designed for temperature control and monitoring

Figure 17 Splash Screen

Figure 18 shows the 16x 2 LCD display showing the splash screen with brand name in it

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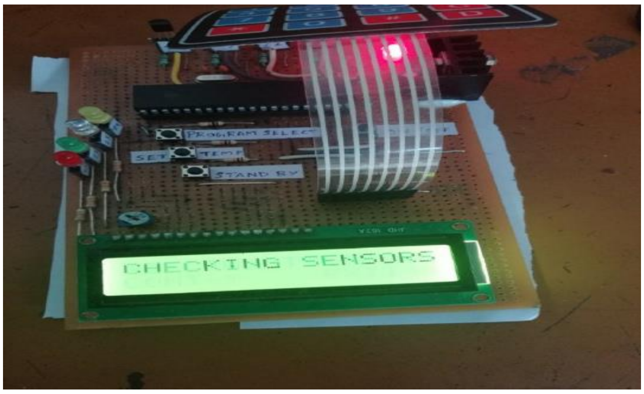

Figure 18 Sensor auto check function

Figure 19 shows the Sensor auto-check functionality performed by the proposed hot runner controller system.

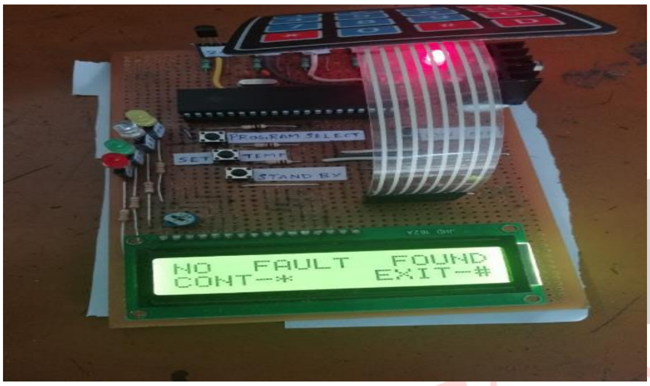

Figure 19 Sensor auto check results

Figure 20 shows the results of the sensor auto check functionality with no error detected in the connections.

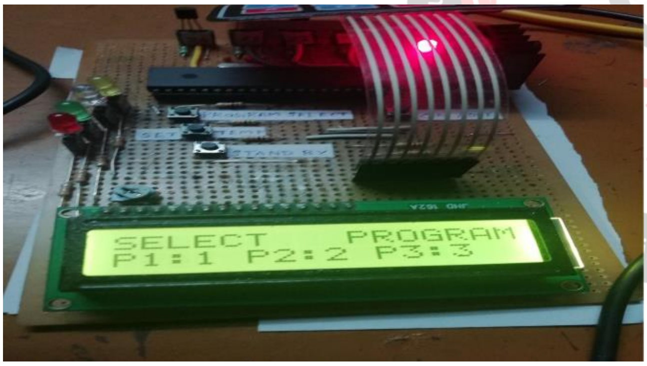

Figure 20 Program selection prompting

Figure 21 shows the prompting menu for selecting the program to be executed after the sensor auto check functionality is performed

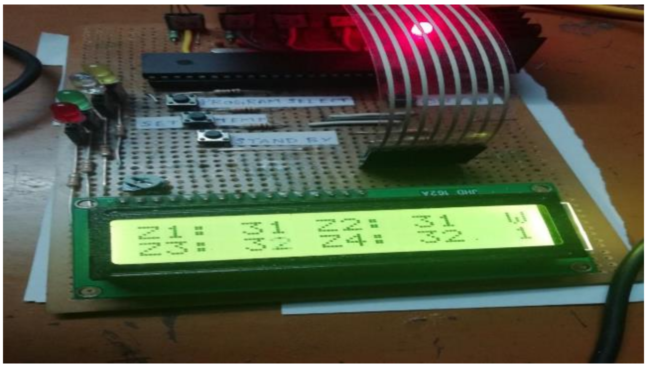

Figure 21 Working mode

Figure 22 shows the working mode of the controller with temperature of each zone.

Figure 22 Standby mode

Figure 23 shows the temperature of each zone in standby mode. In Standby mode the temperature value is maintained as the predefined input configured by the user.

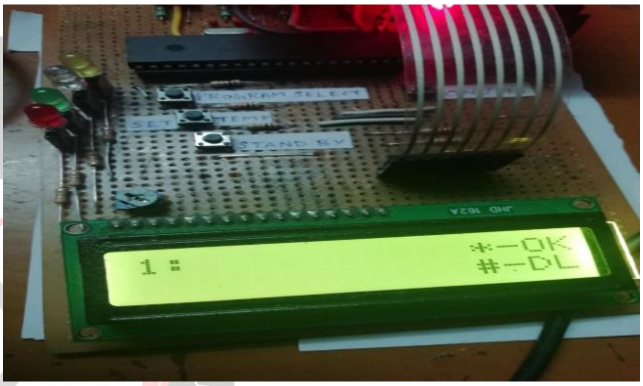

Figure 23 Temperature configuration screen

Figure 24 shows the screen which is for changing the temperature of the zone in the program.

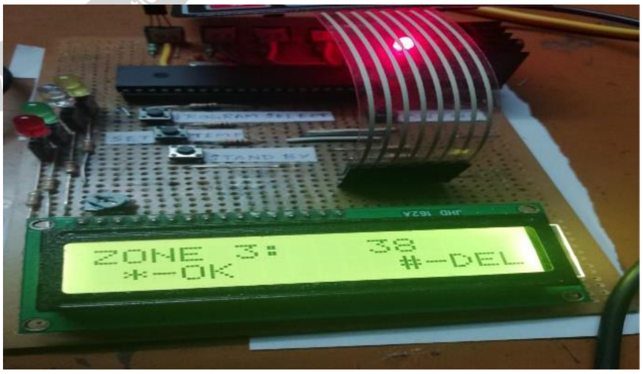

Figure 24 Post configuration screen

Figure 25 shows the temperature of all the zones after the configuration of temperature for all the zones.

The prototype was tested for its performance with two programs for 6 zones (12 control parameters), 2 modes of operation (working mode and stand-by mode) and program configuration with single integrated control panel. The test results of hardware prototype shows appreciable results and lead to implement in real time application.

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V. Conclusion

The prototype of the temperature controller for Multizone hot runner was developed to achieve improved user experience functionalities such as stand-by mode, program selection, auto check functionality and integrated display. It can handle six hot runner zones with integrated control panel. Connection checking for sensors and hot runners, stand-by, program select, error handling are the new functionalities added to the prototype which were not available in the existing system. This prototype is PIC16F877A microcontroller based controlling system. This project is capable of handling zones more than 6 in number. Since 6 zones are standard for the small injection moulding machines, the operation can be performed with multiple numbers of controllers integrated together which gives modularity to troubleshoot without affecting the other zones and their operation. Extension of number of zones and their controllers is possible since the implementation is module oriented. In future, master-slave implementation can be used with integrated control panel having touch screen as user interface; soft starting implementation with the help of Solid State Relays (SSR) and more number of heaters can be controlled. This system is designed in low cost with high speed performance and capability of controlling more zones; it was possible through sensor and microcontroller with high-performance computational capabilities. The temperature control tests in three different zones, the pressure control and position control, show good results. Implementation of the proposed system can be retrofitted in industrial machinery.

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