Controlling Periodic And Aperiodic Real Time Tasks Using Microcontroller

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Abstract
A real-time computer system is required to provide timely responses to external events occurring in its operating environment.
This paper presents an embedded real time digital control system for monitoring and controlling temperature in a smart home. It is a control system based on AT89C51 microcontroller which controls the execution of periodic and aperiodic tasks with real time constraints in smart home. The aim of this paper is to highlight important issues about real-time systems that should be taken into account to implement a digital control system. The system takes in its consideration some constraints like design, multithreading, small size, low cost , low energy consumption, low memory usage and sufficient consumption power for sensory processing in real time.
Keywords: real time, control, periodic, microcontroller, port, embedded.

1. Introduction

A real-time computer system is required to provide timely responses to external events occurring in its operating environment. The performance of such a system is directly related to its ability to adhere to timing constraints placed by these external events and the strictness of these constraints[7,11].

A real-time computer system which is implemented in figure (1), is a class of computer system that the correctness of the computation not only depends upon the logical correctness of the computation, but also upon the time at which the result is produced[5]. Among many types of common computer applications, the most familiar are personal productivity applications or various business applications. There are also high-performance, embedded applications to manage time-critical responses[12]. These are among the most demanding of applications. These applications are not only needed to respond correctly; but to respond also within certain specified time parameters, or in real-time[15].

A real-time system consists of both aperiodic and periodic tasks. Periodic tasks have regular arrival times and hard deadlines. Aperiodic tasks have irregular arrival times and either soft or hard deadlines. The real-time system presents digital control or computer controlled systems as one of its most important practical application field. A real-time system changes its state as a function of physical time, e.g., a chemical reaction continues to change its state even after its controlling computer system has stopped. Based on this a real-time system can be decomposed into a set of subsystems i.e., the controlled object, the real-time computer system and the human operator. A real-time computer system must react to stimuli from the controlled object (or the operator) within time intervals dictated by its environment. The instant at which a result is produced is called a deadline. If the result has utility even after the deadline has passed, the deadline is classified as soft, otherwise it is firm. If a catastrophe could result if a firm deadline is missed, the deadline is hard. Commands and Control systems, Air traffic control systems are examples for hard real-time systems. On-line transaction systems, airline reservation systems are soft real-time systems.[1]

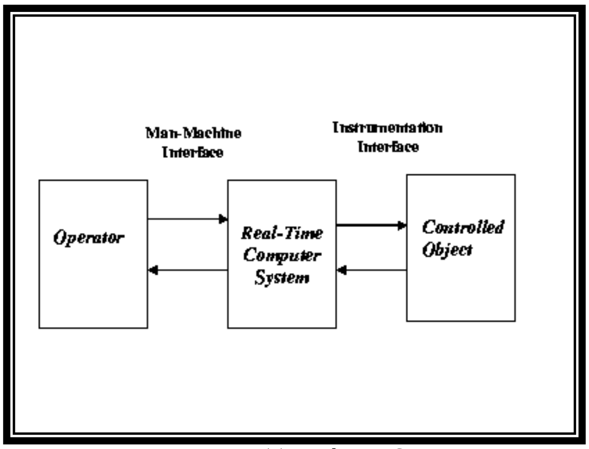


Figure (1): Real Time System

A real-time task is generally placed into one of four categories based upon its arrival pattern and its deadline. If meeting a given task's deadline is critical to the system's operation, then the task's deadline is considered to be *hard*. If it is desirable to meet a task's deadline but occasionally missing the deadline can be tolerated, then the deadline is considered to be *soft [4]*. Tasks with regular arrival times are called *periodic* tasks. A common use of periodic tasks is to process sensor data and update the current state of the real-time system on a regular basis. Periodic tasks, typically used in control and signal processing applications, have hard deadlines. Tasks with irregular arrival times are *aperiodic* tasks. Aperiodic tasks are used to handle the processing

requirements of random events such as operator requests. An aperiodic task typically has a soft deadline. Aperiodic tasks that have hard deadlines are called *sporadic* tasks. We assume that each task has a known worst case execution time.[3]
I consider the problem of real-time system design from a temporal perspective, which is what makes real-time system design inherently different from other forms of system design. That is, real-time system design must explicitly consider the timeliness aspects, it means that the tasks deadlines must be met.

1.2 Related works

-Daniel Simon and Fanny Benattar in 2002 design a Control system using a set of cooperating periodic modules running under control of a real-time operating system. A correct behaviour of the closed-loop controller requires that the system meets timing constraints like periods and latencies, which can be expressed as deadlines. The software uses the fixed priority based preemption service of the operating system. Latencies are controlled through precedence constraints and more or less tight synchronisation between modules. Such a system can be modelled with timed event graphs, and its temporal behaviour can be analysed using the underlying (max,plus) algebra. Examples coming from a uni-processor robot controller are provided.[13]

- Mauro Marinoni , Tullio Facchinetti , Giorgio Buttazzo and Gianluca Franchino in 2006 present a flight control system for autonomus aircraft model. The system runs on an embedded hardware platform, that include the microcontroller, sensors for navigation and monitoring environment, the power management circuit, and communication system.[8]

- Nazlia Omar and Rozli Zulkifli in 2009 present the design and development of a real-time temperature and voltage monitoring system. It is developed for the purpose of monitoring and controlling semiconductor component devices which are very heat sensitive in industry-based applications. This prototype not only involves the development of the software for monitoring purposes but also includes the development of a special electronic hardware designed to interface with the external devices by using the microprocessor parallel port communication[9].

- T. Nandha Kumar, H. A. F. Mohamed, B. A. C. M. Naleem, V. Ganeish in 2010 present a wireless re-programmable real time temperature measurement system designed using the hardware description language and realized in hardware using the field programmable array (FPGA). The proposed system is able to measure the real time temperature of various remote locations with each of them to an accuracy of 0.25 °C. It uses wireless transmission with the data rate of 115 Kbytes/s, to transmit the measured temperatures to the central control system for motioning purpose[6].

- Sadeque Reza Khan, Siddique Reza and Arifa Ferdousi in 2012 present a system called Voltage Temperature Monitoring System or VTMS. It is a Microcontroller based controlling unit which controls the operation of generator and battery when PDB in not available in the BTS room. This system helps companies to develop their own power stations either by using generators or by developing solar plants. Now a days most of the BTS rooms, that the cellular operators are installing with a generator and 48 volt battery backup. So for the synchronisation of the operation of PDB, Generator and battery, the VTMS help them.[10]

1.3 Contributions

1- Designing a digital control system for monitoring temperature based on a microcontroller with timing constraints satisfaction and low cost.
2- Control the scheduling and execution of hybrid task models: periodic and aperiodic in single system.

2. Control system

Most feedback control systems are essentially periodic, where the inputs (reading on sensors) and the outputs (posting on actuators) of the controller are sampled at a fixed rate. While basic digital control theory deals with systems sampled at a single rate, it has been shown, e.g. [14], that the control performance of a non-linear system like a robot can be improved using a multi-rate controller : some parts of the control algorithm, e.g. updating parameters or controlling slow modes, can be executed at a pace slower than the one used for fast modes. In fact, a complex system involves sub-systems with different dynamics which must be further coordinated. Therefore the controller must run in parallel several control laws with different sampling rates inside a hierarchy of more or less tightly coordinated layers.

Digital control systems are often implemented as a set of tasks running on top of an off-the-shelf real-time operating system (RTOS) using fixed-priority and preemption. The performance of the control, e.g measured by the control error, and even more importantly its stability, strongly relies on the respect of the specified sampling rates and computing delays (latencies) [2]. Therefore it is essential to check off-line that the implementation of the controller will respect the specified temporal behaviour.[13]

3. Embedded Computer

An embedded computer is frequently a computer that is implemented for a particular purpose. In contrast, an average PC computer usually serves a number of purposes: checking email, surfing the internet, listening to music, word processing, etc... However, embedded systems usually only have a single task, or a very small number of related tasks that they are programmed to perform. Every home has several examples of embedded computers. Any appliance that has a digital clock, for

instance, has a small embedded microcontroller that performs no other task than to display the clock. Modern cars have embedded computers onboard that control such things as ignition timing and anti-lock brakes using input from a number of different sensors[5].
Embedded computers rarely have a generic interface, however. Even if embedded systems have a keypad and an LCD display, they are rarely capable of using many different types of input or output. An example of an embedded system with I/O capability is a security alarm with an LCD status display, and a keypad for entering a password.
In general, an Embedded System:

- *Is a system built to perform its duty, completely or partially independent of human intervention.*
- *Is specially designed to perform a few tasks in the most efficient way.*
- *Interacts with physical elements in our environment, viz. controlling and driving a motor, sensing temperature, etc.*

An embedded system can be defined as a control system or computer system designed to perform a specific task. Common examples of embedded systems include MP3 players, navigation systems on aircraft and intruder alarm systems. An embedded system can also be defined as a single purpose computer. Most embedded systems are time critical applications meaning that the embedded system is working in an environment where timing is very important: the results of an operation are only relevant if they take place in a specific time frame. An autopilot in an aircraft is a time critical embedded system. If the autopilot detects that the plane for some reason is going into a stall then it should take steps to correct this within milliseconds or there would be catastrophic results. So most embedded systems are also real time systems.[8]

4. SYSTEM DESIGN

The design steps and working scenario principles of the real time system is organized into two different units Hardware unit and Software unit. Hardware unit includes controller unit, power supply part, display part, sensor part, and temperature monitoring system. Software unit includes the embedded program stored in the ROM memory to control the circuit hardware and execution of periodic tasks (monitoring). The software unit also includes the interrupt service routine for controlling the execution of aperiodic (sporadic) task for turning on or off the heater.

4.1 Hardware design

4.1.1 Controller Hardware components

Several components listed below and figure (2) shows the schematic diagram of the designed circuit for temperature real time monitoring:

1. microcontroller (89C51):
   The internal components of this controller are as follows:

   a- Central Processing Unit (CPU) : is used to perform all arithmetic and logic operations via its instruction set. This (CPU) includes number of general and special registers that implemented as follows:

   - (A): Accumulator register: This registers can be used with some instructions that cannot be used with the other registers.
   - (B) Register: Is used for very special purpose with the accumulator in the multiplication and division instructions.
   - (DPTR) Data Pointer register: 16-bit pair register (special purpose) used for addressing purposes for the external RAM or ROM (if necessary). Any half of this register can be used independently like (DPL & DPH).

   b- ROM (Read Only Memory): Is used for storing program codes only and it can't store any type of data because there is no instruction that can manipulates it.

   c- RAM (Random Access Memory): Is used for storing data temporarily. The first (32-bytes) of this memory locations represents the four banks of the internal general and special registers.

   d- Input/Output ports: There are four I/O ports on the previous microcontroller that is used for interchanging data between the inside and outside of the microcontroller.

   e- Frequency divider: There is internal frequency divider inside the microcontroller to divide the external frequency or crystal frequency from 12MHz to 1MHz for internal operations.

2. (74LS541) Tri-state buffers: are used for increasing fan-out, current increasing and other purposes. In this design two of them were used as a multiplexer.

3. (74LS04) Not gates (Inverters).

4. Power supply that supplies two voltages (+5V & +12V).

5. 2SC1815 and 2SA1015 Transistors: General purpose transistors are used as drivers.

6. Relay: used as actuator to control the heater.

7. Multiplexed four (7-segment display).

8. (ADC0804) Analog to Digital Converter: is used to convert from analog to digital signals.

9. Sensor: is the resistance that has heating sensitivity and its variable resistance according to the current temperature (from 1Kohm to 12Kohm).

Figure (2) illustrate the schematic diagram for the hardware components of the designed system.

4.1.2 Circuit Operation

The (ADC) has been connected via Input port (P1) to read and measure the current status of the heater via sensor. The (ADC) can operate as (Free running) (i.e. Operate without using a handshake with the microcontroller by connecting its INTR signal with #WR that represent a SOC: (Start of convert operation).

The multiplexed four digit 7-segment display was connected with the port (P0) to display the current temperature of the furnace.

Connecting two buffers to port (P3) allow to reading the minimum and maximum values of the temperatures as threshold to control the heaters operations. These buffers were used as 8 * 2-1 multiplexer.

The port (P2) was used for the following purposes:

1. <u>(P2.0-P2.3):</u> was used to enable the current column from four columns of the multiplexed 7-segment display. A four PNP transistors was used as drivers because the output signals from this port are active low.

2. <u>(P2.4):</u> was used as indicator of the period (0.5 second) for the real time task.

3. <u>(p2.5):</u> Via this pin the heater operation was controlled (Turning ON or OFF), because of the active low output was used , an inverter is necessary to complement the output signal from this pin and using the output of this gate to saturate the NPN transistor for controlling.

4. <u>(P2.7):</u> was used to control the two inputs of multiplexer that providing the minimum and maximum thresholds of the temperature.

Other pins were not used in this proposed design.

4.2 Software design

The controlling of the operations of microcontroller done by using the embedded program stored into its internal ROM to controlling the external hardware components via the four ports and the implementation of real time issues that guaranties meeting tasks deadlines for the monitoring temperature purpose.

4.2.1 Real time consideration

The controlling program takes into its consideration the mixed execution scenario of periodic and aperiodic tasks which give the power for this system.

***Periodic task*:** time driven, execute critical control activities with hard timing constraint aimed at guarantees regular activation rates.
***Aperiodic task*:** event driven, execute when the event occurred.

The control system consists of a set of periodic real time tasks activated by the scheduler to periodically read the sensor data for the temperature value. This periodic task is used for the monitoring part of the system. The algorithm below shows the steps for the monitoring program. Another task in the system is the aperiodic task which responsible for controlling the turning off and on for the heater and it is implemented by the interrupt service routine. Figure (3) illustrate the flowchart for the interrupt service routine.

<u>Monitoring System Algorithm</u>

1- Select Timer0 (Auto Reload)

2- Enable Interrupt

3- Initialize Flag to UP

4- Initialize counters to 500000

5- Set Look Up Table: Start counter

6- Enable Column 3 of display

7- Get Hundreds value of current temp. from memory then display

8- Enable Column 2 of display

9- Get Tens value of current temp. from memory then display

10-Enable Column 1 of display

11-Get Ones value of current temp. from memory then display

12-Enable Column 0 of display

13-Display 0

14-end

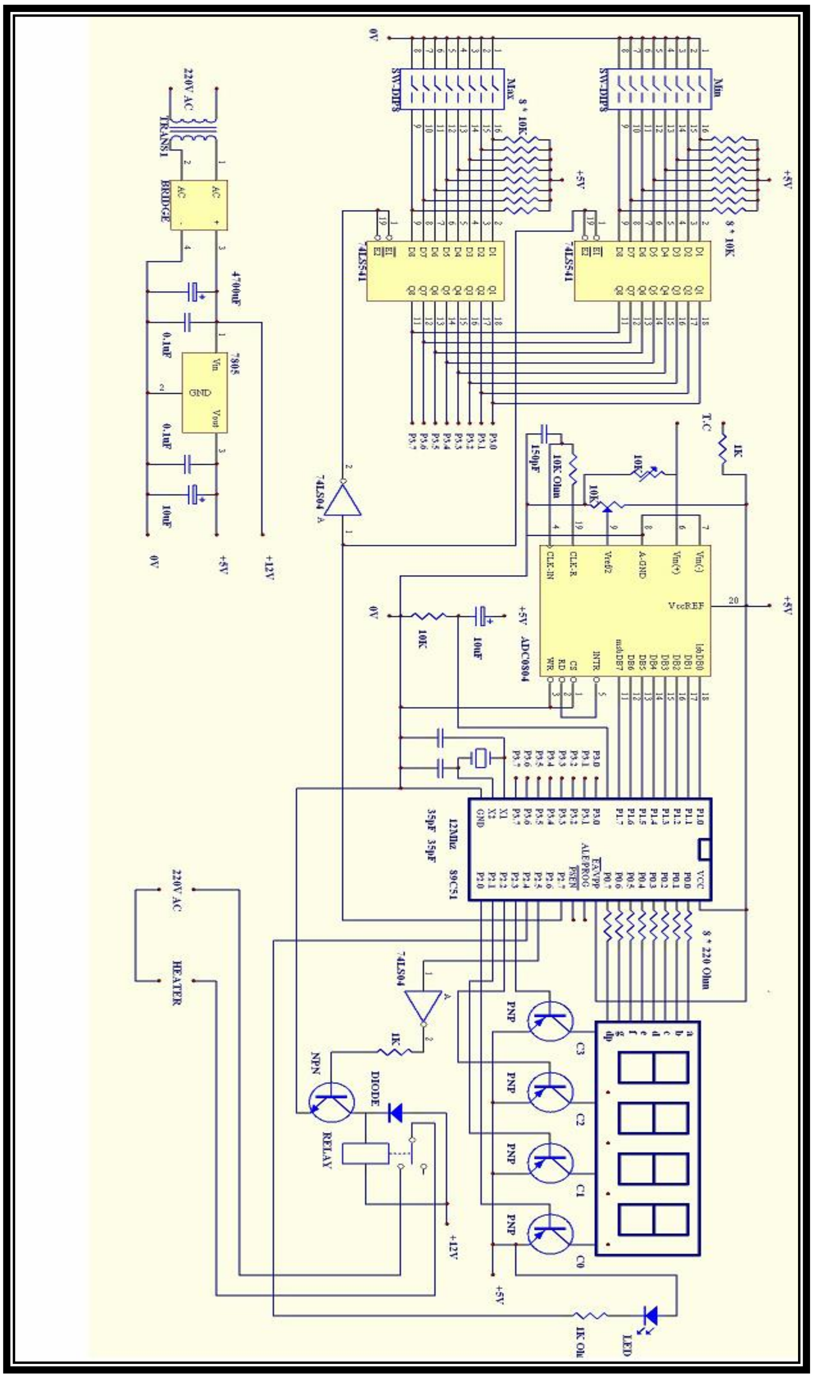
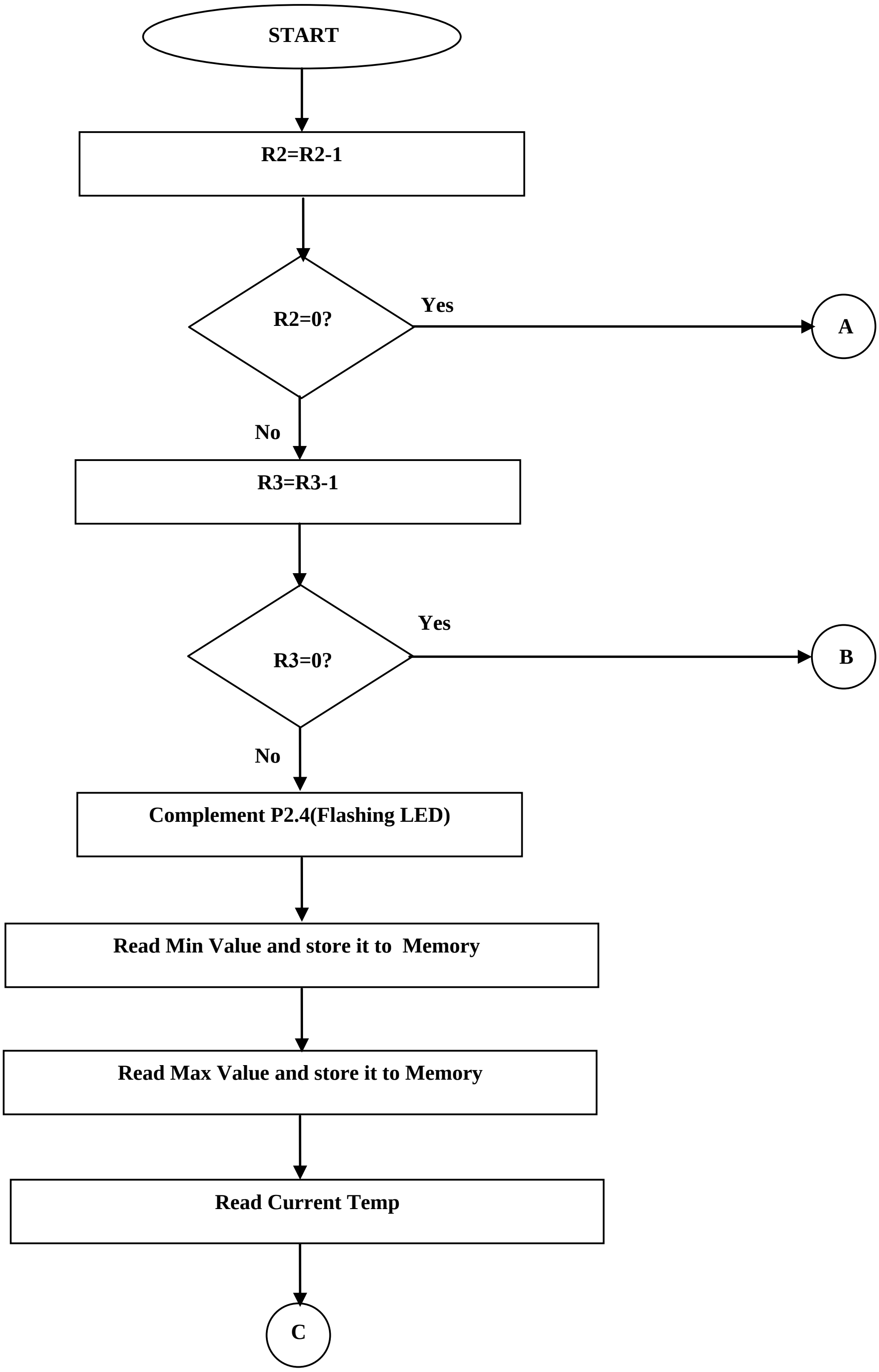
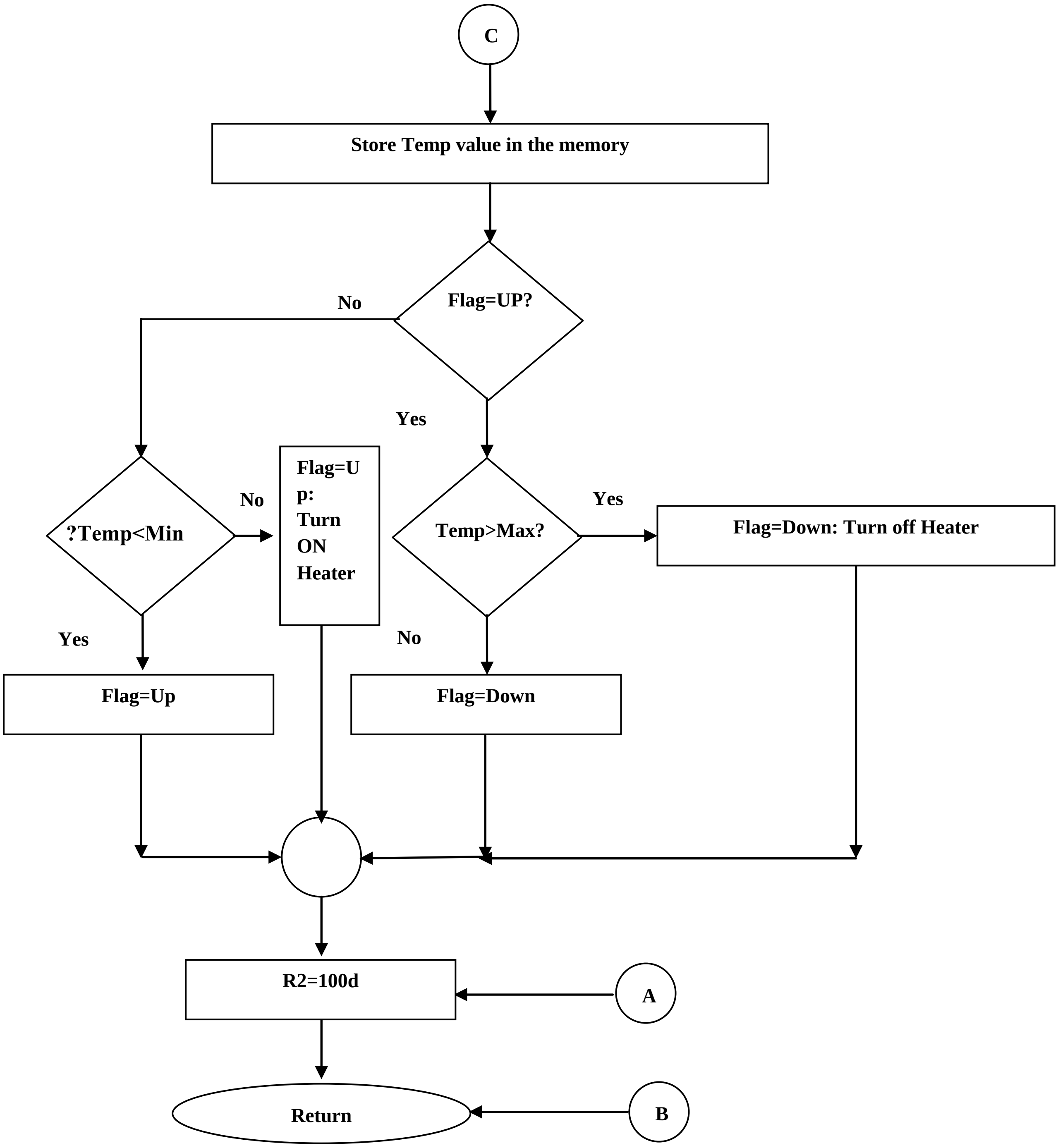


Figure (2): Schematic diagram of the *Real Time* Temperature Monitoring System

ISR:


START
R2=R2-1
R2=0?
Yes
A
No
R3=R3-1
R3=0?
Yes
B
No
Complement P2.4(Flashing LED)
Read Min Value and store it to Memory
Read Max Value and store it to Memory
Read Current Temp
C

ISR Continued..



Figure(3) : The interrupt service routine for the aperiodic task

5. Conclusion

This paper describes a real time digital control system for monitoring the temperature and controlling the heater. The paper points to the hardware requirements and real time issues that implement the software unit. The hardware platform consists of microcontroller, display unit, power management circuit.

The controlling program running in microcontroller guarantees the timing constraint for the application tasks by controlling the interleaved execution of periodic and aperiodic tasks. It is a low cost, low size program reliable and effective. The implementation strategy of this work points to the interleaved execution of periodic and aperiodic tasks in an efficient manner with grantee response time.

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