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Design & Implementation of Intelligent Digital Home Thermostat using NXP Low Power 32bits LPC2148 Microcontroller

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ABSTRACT:
The goal of this design is to build a digital home thermostat using NXP Low Power LPC series microcontroller. The present design includes sensors for providing a signal representing the actual temperature within a space and ambient Humidity in air to monitor indoor air quality. LPC Microcontroller is coupled to the sensors and generates output signals in response to the temperature signal. A thermistor is read using the slope A/D technique. The microcontroller is connected to the power supply as a sole power source. A Latching relay is coupled to the microcontroller and temperature-affecting equipment such as a heating or cooling system.

The relay actuates the equipment in response to output signals from the microcontroller. This thermostat includes improved user interface like touch-screen, system failure warning messages. A voltage detection circuit is provided for signaling a low voltage condition. This thermostat is programmable by entering input through a large-format touch-screen display. The touch-screen display displays different sets of icons depending on the mode of the thermostat to work. Displaying several sets of icons at once allows a user to quickly and intuitively operate the thermostat, which in turn facilitates using energy saving functions of the thermostat.

I. INTRODUCTION

When building a microcontroller based thermostat, some of the important goals include small size, low power, low cost, high reliability and easy manufacturability. One of the ways to reach these goals is to use a highly-integrated microcontroller that supports features directly applicable to building a thermostat. As environment-friendly equipment becomes ever more important this becomes the trump card in slashing power consumption. In this design LPC2148 is used as Power Management Controller, the configurable Sleep, Deep-sleep, and Deep power-down modes allow designers to fine tune their systems power consumption to the minimum making the products we use more energy efficient. A thermostat regulates the temperature of a system, room, or building, keeping the temperature at a desired level. There are different ways to get the temperature measurement in an electronic system, for example the use of a thermistor, thermocouples, and in some cases integrated circuits. To control the temperature a digital thermostat is typically connected to an HVAC unit. The thermostat provides voltage to the heater, venting, and air conditioning (HVAC) terminals indicating to the HVAC system, what should be turned on based on the current system temperature. Humidity concentration measurement is important factor in determining air conditions in the office and at home. Too high humidity to feelings of tiredness, disturbs concentration, and causes headaches. The Humidity described here makes it easy to determine the concentration of suspended particles in the air.

II. DESIGN PROCEDURE

We are going to create an intelligent thermostat that takes humidity into account in order to maintain an environment that "feels like" the temperature the user desires. In the summer, a heat index is used to explain how a high relative humidity increases the apparent temperature. With cooler air, low humidity has an opposite effect, making dry air feel even colder. Our thermostat will manipulate existing heating and cooling systems to maintain a constant “comfort index” indoors.

Heat-index background:

Everyone is familiar with the weatherman’s heat index on hot summer days. When the “apparent” or “feels-like” temperature is given, it is not just estimated; there is a complicated formula used that is based on the relative humidity and the temperature. This formula, in use for over 30 years, is as follows:

$$HI = -42.379 + 2.04901523T + 10.14333127H - 0.22475541TH - 6.83783x10^{-3}T^2 - 5.481717x10^{-2}H^2 + 1.22874x10^{-3}T^2H + 8.5282x10^{-4}TH^2 - 1.99x10^{-6}T^2H^2$$

It is formulated specifically for lightly windy and shady conditions outdoors, and takes into account a multitude of other biological factors from skin coverage to perspiration efficiency to core body temperature. Furthermore, this equation is only valid for temperatures 80°F and above. Many of these factors, along with the basic assumptions made about the environment, render this equation ineffective for our indoor, low-temperature purposes.

The comfort-index and model:

Instead of using the traditional heat-index equation, we found data for an indoor comfort-index. The mean difference between the given and predicted apparent temperatures is .608°F and the max difference is 1.98°F. Given the fact that the original data was already rounded to the nearest integer, this additional error is negligible.

The extrapolated equation is:

$$CI = 1.058957219T + 0.0925H - 10.43983957$$

III. TECHNIQUES USED FOR REDUCING POWER

Consumption:

When optimizing a design for battery-powered applications where minimum power consumption is an important goal, there are many factors to consider. Since power increases with Vcc ($I = V^2f$; where I is current and f is frequency), we can reduce power consumption without limiting the maximum operating frequency by reducing voltage of the device. For example, running at 4.5V instead of 5.0V for a 16MHz device, drops power by almost 20% without compromising the device's performance. Reducing clock frequency also plays an important role in power savings. If we can optimize code to run at 10MHz instead of 16MHz, current consumption is reduced by 30%-40%. Furthermore, if we manage to get down to 8MHz, we can change to a low voltage device and reduce Vcc to 3V – the resulting power consumption will be 75% lower than what we started with at 16MHz. A voltage sensing circuit for signalling a low battery voltage condition is provided for alerting the user when replacement will soon be required and includes a transistor for periodically coupling the battery positive point to a high voltage reference terminal at the microcontroller which divides the difference between the normal 3Vdc voltage at terminal and that voltage at terminal into 1024 reference levels (10 bit A\D conversion).For extremely low power application such as the thermostat where two AA Batteries have to last years, very low frequencies between 32 kHz and 1 MHz are often used. Many maintenance tasks, such as the sampling of a Temperature sensor can be accomplished at these low frequency levels. Alternatively, these same tasks can be handled at higher frequency levels, taking advantage of LPC2148 sleep modes during idle cycles. In other words, it would be appropriate to run the LPC2148 at high speed for a short period of time and then put it back in the very low power consumption sleep mode for the bulk of the time. This may yield an average power consumption that is much lower than the low frequency operation in active mode would give. The optimum frequency and duty cycle must be determined for each part of your application.

NXP LPC2148 series microcontroller also includes a 10-bit analog-to-digital converter, internal analog reference,512kbytes flash memory, 32+8kbyte SRAM a . In this design LPC2148 is used as POWER MANAGEMENT CONTROLLER by using configurable Sleep, Deep-sleep, and Deep power-down modes allows to fine tune the system power consumption to the minimum. The high integration level of LPC2148 simplifies system design, helps to lower power consumption and significantly reduces board space.

IV. TEMPERATURE MEASUREMENT

To measure temperature, the thermostat uses a thermistor and the ADC. Program provides functions to start an ADC conversion for any channel, stops the ADC, declares the interrupt vector to read the last ADC conversion, and stores it in a buffer. To measure temperature, the thermostat can use either Celsius or Fahrenheit. The process is to get the average of eight ADC conversions to reduce noise and then convert the ADC value to a temperature value by using a lookup table.

A temperature sensor used in the design is a variable temperature dependent resistor. A [redacted]

voltage divider. This design uses a 100 k temperature sensor. At 25 °C (77 °F) the temperature sensor coefficient is "1". Therefore, the voltage in the resistor divider network is 1.486 V. The temperature sensor manufacturer provides a list of values for the RT coefficient, it is possible to calculate the resistance and in this case the voltage present for each temperature.

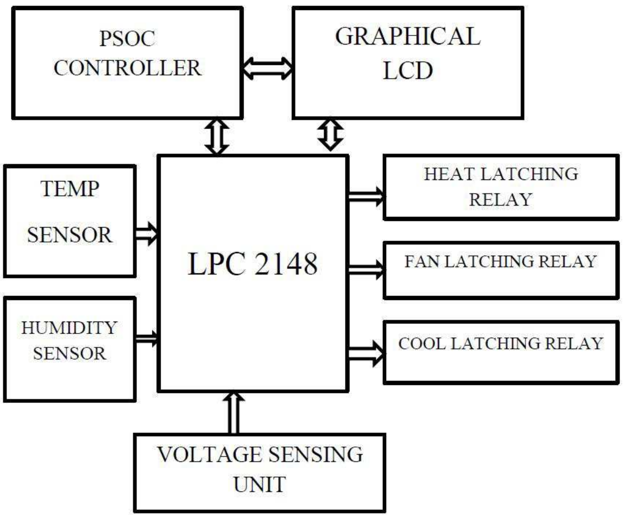

Figure. Block Diagram Thermostat.

V. TOUCH-SCREEN DISPLAY

A touch panel is a thin, self-adhesive transparent panel placed over the screen of a graphic LCD. It is very sensitive to pressure so that even a soft touch causes some changes on output signal. The software consists of writing a menu on graphic LCD, turning the circuit for touch panel control on/off (driving touch panel) and reading the values of A/D converter which actually represent the X and Y coordinates of the point The microcontroller connects appropriate contacts of the touch panel to ground and the power supply in order to determine the X and Y coordinates. The on-chip 10-bit Analog-to-Digital converter provides an interface for resistive touch screen displays. Touch screen display eliminate specialized keyboards bringing simplicity to the user and an opportunity for the designers to further differentiate the end product from the competition.

VI. TESTING PROCEDURES

Sensor Calibration –

To calibrate our sensors, we will use a commercial thermometer and hygrometer in various environments with which to compare our sensor outputs.

Behavioral Testing – To test our Intelligent thermostat, we plan to bring the device into a variety. of environments with varying temperature and humidity. These environments may include the outdoors, a greenhouse, or other campus buildings. We can also take measurements at the same location on different days, different times of the same day, and varying weather conditions. The purpose of these experimental measurements will be to analyze the behavior of the Intelligent Thermostat to different and extreme surroundings. Two main procedures will be used:

Non-equilibrium testing –

We will set the thermostat to a comfort-index inconsistent with the surroundings and observe its output.

Equilibrium testing –

We will set the thermostat to a comfort-index consistent with the surroundings and observe its output

VII. CONCLUSION

In this case of a thermostat application, the LPC2148 is able to read the external sensor, update and store a set point in permanent memory, maintain a real-time clock, determine if any action is required based on the temperature, and display all the information on an LCD. This design concept could be expanded to include upper and lower set points and different set points for different times of the day or from day to day.In a world where pollution is increasing, a simple everyday product that can be used to monitor compound levels is, valuable. Eventually this designed product can be built using less expensive components thus making it an affordable alternative for consumers. It is a simple upgrade to an existing standard product and it has endless expansion possibilities. In particular, such thermostats enable the user to program the device to maintain a lower, energy conserving temperature within the space during those hours or days when the occupants are absent or sleeping and a higher , more comfortable temperature at other times.

The power consumption by ARM7TDMI based LPC2148 core is 0.6 mW per MHz and it suppot speeds up to 100 MHz at 2.5V which save resulting power consumption will be 75% lower than any other microcontroller

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