Theory for
Single Board Heater System

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Chapter 1

Block diagram explanation of Single Board Heater System

Figure1.1 shows the block diagram of 'Single Board Heater System'(SBHS). Microcontroller ATmega16 is used at the heart of the setup. The microcontroller can be programmed with the help of an In-system programmer port(ISP) available on the board. The setup can be connected to a computer via two serial communication ports namely RS232 and USB. A particular port can be selected by setting the jumper to its appropriate place. The communication between PC and setup takes place via a serial to TTL interface. The μC operates the Heater and Fan with the help of separate drivers. The driver comprises of a power MOSFET. A temperature sensor is used to sense the temperature and feed to the μC through an Instrumentation Amplifier. Some required parameter values are also displayed along with some LED indications.

1.1 Microcontroller

Some salient features of ATmega16 are listed below:

1. 32 x 8 general purpose registers.

2. 16K Bytes of In-System Self-Programmable flash memory

3. 512 Bytes of EEPROM
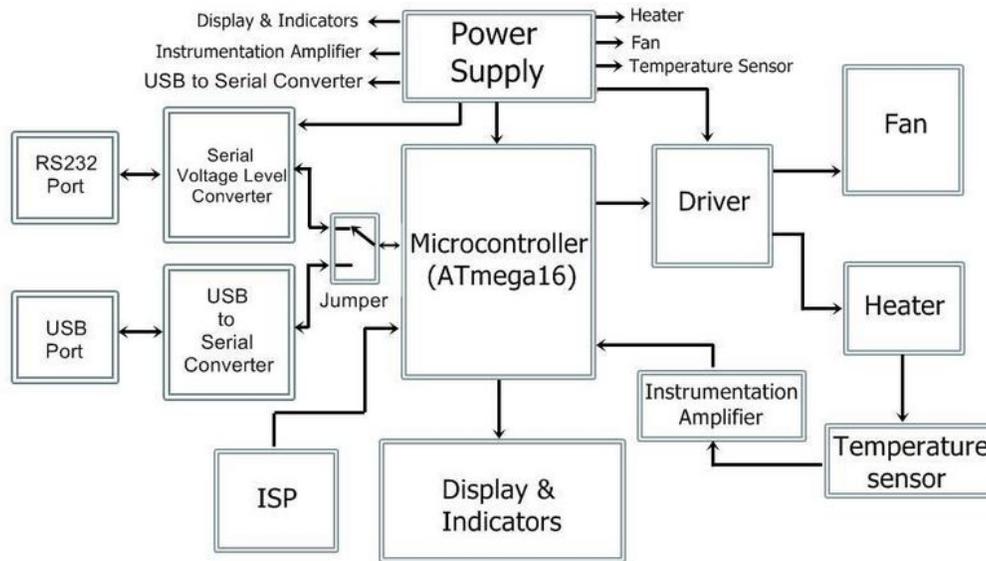
4. 1K Bytes of internal Static RAM (SRAM)

Figure 1.1: Block Diagram

5. Two 8-bit Timer/Counters

6. One 16-bit Timer/Counter

7. Four PWM channels

8. 8-channel,10-bit ADC

9. Programmable Serial USART

10. Up to 16 MIPS throughput at 16 MHz

Microcontroller plays a very important role. It controls every single hardware present on the board, directly or indirectly. It executes various tasks like, setting up communication between PC and the equipment, controlling the amount of current passing through the heater coil, controlling the fan speed, reading the temperature, displaying some relevant parameter values and various other necessary operations.

1.1.1 PWM for heat and speed control

The Single Board Heater System contains a Heater coil and a Fan. The heater assembly consists of an iron plate placed at a distance of about 3.5mm from a
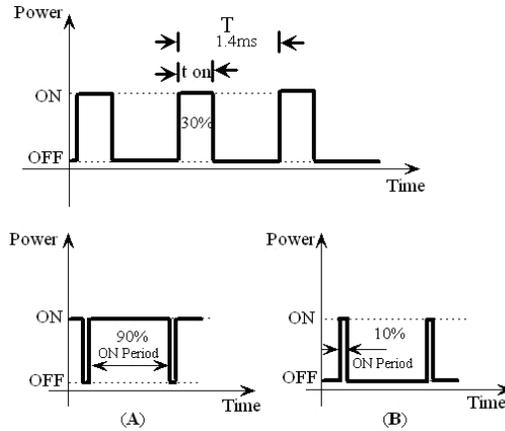
Figure 1.2: Pulse Width Modulation (A): On time is 90% of the total time period, (B): ON time is 10% of total time period

nichrome coil. When current passes through the coil it gets heated and in turn raises the temperature of the iron plate. Altering the heat generated by the coil and also the speed at which the fan is operated, are the objectives of our prime interest. The amount of power delivered to the Fan and Heater can be controlled in various ways. The technique used here is called as PWM (abbreviation of Pulse Width Modulation)technique. PWM is a process in which the duty cycle of the square wave is modulated.

$$\text{Duty cycle} = \frac{T_{ON}}{T} \tag{1.1}$$

Where T_{ON} is the ON time of the wave corresponding to the HIGH state of logic and T is the total time period of the wave. Power delivered to the load is proportional to T_{ON} time of the signal. This is used to control the current flowing through the heating element and also speed of the fan. An internal timer of the microcontroller is used to generate a square wave. The ON time of the square wave depends on a count value set in the internal timer. The pulse width of the waveform can be varied accordingly by varying this count value. Thus, PWM waveform is generated at the appropriate pin of the microcontroller. This generated PWM waveform is used to control the power delivered to the load (Fan and Heater).
A MOSFET is used to switch at the PWM frequency which indirectly controls the power delivered to the load. A separate MOSFET is used to control the power delivered to each of the two loads. The timer is operated at 244Hz.

1.1.2 Analog to Digital conversion

As explained earlier, the heat generated by the heater coil is passed to the iron plate through convection. The temperature of this plate is measured by using a temperature sensor AD590.
Some of the salient features of AD590 include:

1. Linear current output: 1μA/K

2. Wide range: -55°C to +150°C

3. Sensor isolation from the case

4. Low cost

The output of AD590 is then fed to the microcontroller through an Instrumentation Amplifier. The signal obtained at the output of the Instrumentation Amplifier is in analog form. It should be converted in to digital form before feeding as an input to the microcontroller. ATmega16 features an internal 8-channel , 10 bit successive approximation ADC (analog to digital converter) with 0-Vcc(0 to Vcc) input voltage range, which is used for converting the output of Instrumentation Amplifier. An interrupt is generated on completion of analog to digital conversion. Here, ADC is initialize to have 206 μs of conversion time . Digital data thus obtained is sent to the computer via serial port as well as for further processing required for the on-board display.

1.2 Instrumentation amplifier

Instrumentation Amplifiers are often used in temperature measurement circuits in order to boost the output of the temperature sensors. A typical three Op-Amp Instrumentation amplifier is shown in the figure 1.3. The Instrumentation Amplifiers (IAs) are mostly preferred, where the sensor is located at a remote place and therefore is susceptible to signal attenuation, due to their very low DC offsets, high input impedance, very high Common mode rejection ratio (CMRR). The IAs have a very high input impedance and hence do not load the input signal source. IC LM348 is used to construct a 3 Op-Amp IA. IC LM348 contains a set of four Op-Amps. Gain of the amplifier is given by equation 1.2

$$\frac{V_o}{V_2 - V_1} = \left\{ 1 + \frac{2R_f}{R_g} \right\} \frac{R_2}{R_1} \tag{1.2}$$
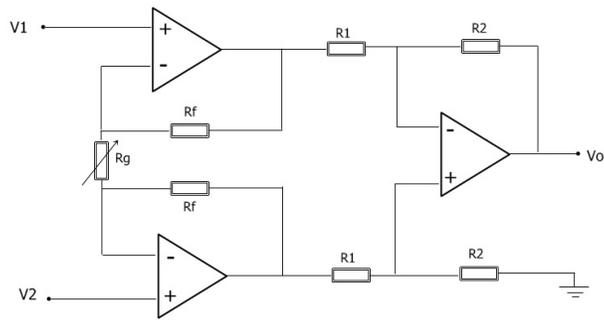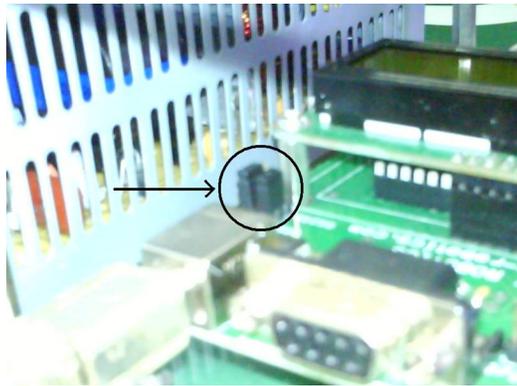
Figure 1.3: 3 Op-Amp Instrumentation Amplifier

Figure 1.4: Jumper arrangement

The value of R_g is kept variable to change the overall gain of the amplifier. The signal generated by AD590 is in μA/°K. It is converted to mV/°K by taking it across a 1 KΩ resistor. The °K to°C conversion is done by subtracting 273 from the °K result. One input of the IA is fed with the mV/°K reading and the other with 273 mV. The resulting output is now in mV/°C. The output of the IA is fed to the microcontroller for further processing.

1.3 Communication

The set up has the facility to use either USB or RS232 for communication with the computer. A jumper is been provided to switch between USB and RS232. The voltages available at the TXD terminal of microcontroller are in TTL (transistor-

Figure 1.5: RS232 cable

transistor logic). However, according to RS232 standard voltage level below -5V is treated as logic 1 and voltage level above +5V is treated as logic 0. This convention is used to ensure error free transmission over long distances. For solving this compatibility issue between RS232 and TTL, an external hardware interface IC MAX202 is used. IC MAX202 is a +5V RS232 transreceiver.

1.3.1 Serial port communication

Serial port is a full duplex device i.e. it can transmit and receive data at the same time. ATmega16 supports a programmable Universal Synchronous and Asynchronous Serial Receiver and Transmitter (USART). Its baud rate is fixed at 9600 bps with character size set to 8 bits and parity bits disabled.

1.3.2 Using USB for Communication

After setting the jumper to USB mode connect the set up to the computer using a USB cable at appropriate ports as shown in the figure 1.8. To make the setup USB compatible, USB to serial conversion is carried out using IC FT232R. Note that proper USB driver should be installed on the computer.

1.4 Display and Resetting the setup

The temperature of the plate, percentage values of Heat and Fan and the machine identification number (MID) are displayed on LCD connected to the microcon-
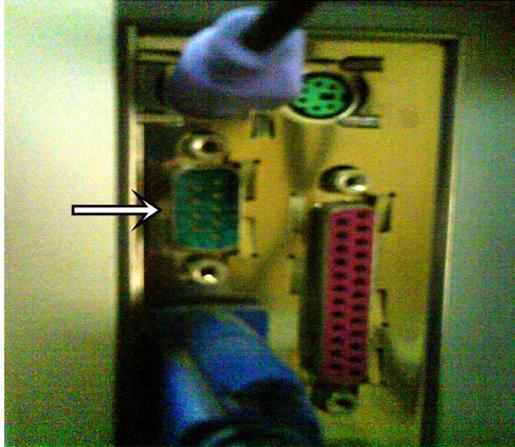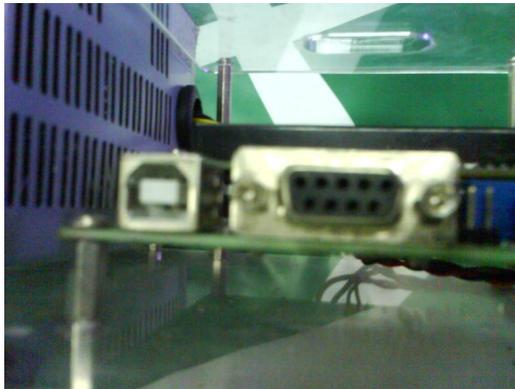
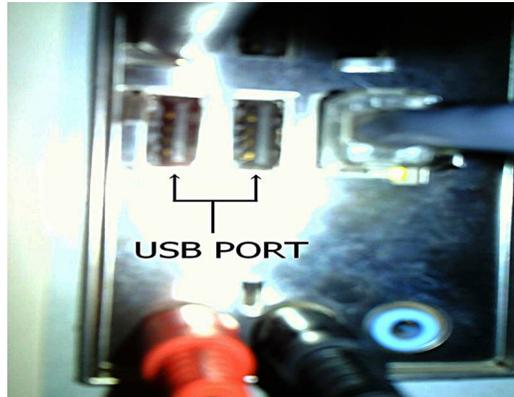Figure 1.6: Serial port

Figure 1.7: USB communication

Figure 1.8: USB PORT

Figure 1.9: Display

troller. As shown in figure 1.9, numerals below TEMP indicate the actual temperature of the heater plate in °C. Numerals below HEA and FAN indicate the respective percentage values at which heater and fan are being operated. Numerals below MID corresponds to the device identification number. The set up could be reset at any time using the reset button shown in figure 1.10. Resetting the setup takes it to the standby mode where the heater current is forced to be zero and fan speed is set to the maximum value. Although these reset values are not displayed on the LCD display these are preloaded to the appropriate units.
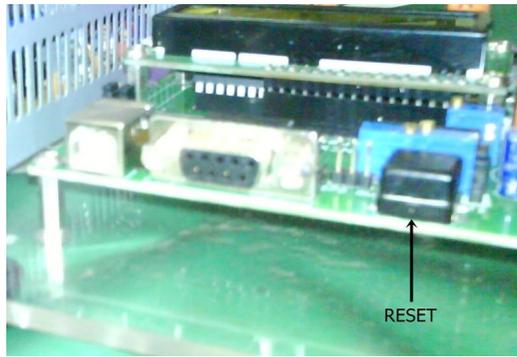
RESET

Figure 1.10: Reset