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FPGA Based Motorize Cooling

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Abstract: ***The aim of this paper is to control the speed of dc motor based on room temperature using pulse width Modulation technique with FPGA. To get rid of the problem of Obscurity to control temperature in industries and for the requirement of increasing flexibility and overall automation in the high systems performance, a FPGA is used as a controller. A temperature sensor built with thermistor along with series resistance which indicates the change in the voltage as the temperature changes and according to the change in voltage, speed of the motor is varied using pulse width modulation technique. The duty cycle is varied from 0% to 100% depending upon the variation in the room temperature. Smooth and efficient control of DC motor is obtained at 25% to 100%. It is easier, reliable and energy efficient. Hardware implementation is also done. The result of the research and output form has been investigated. Various design criteria, performance characteristics, comparison with different parameters have been plotted in MATLAB software system and other simulation results have been discussed in detail in this paper. The Proteus software 8.6 is used for circuit designing and ISIM Xilinx software is used to observe the variation in PWM.***

Keywords: FPGA Spartan 6 (XC6SLX9-TQG144), Temperature Sensor, Analog to digital converter (MCP3202), DC Motor, Pulse width modulation and speed control.

1. Introduction

Nowadays to make a difference in the market, new intelligent control systems have to be highly performing, flexible and reliable with real time monitoring. For high demanding task in modern industries FPGAs have been favored due to high efficiency provided by their architectural flexibility (parallelism, on-chip memory etc.), re-configurability and superb performance in development of algorithms with better software development tools. FPGAs have its advantage to reprogram itself thus changing the hardware capability of whole system as per our requirement. Since the circuit arrangement is formed by the interconnection of gates its processing speed seems to be very faster.

The idea behind this paper is to control the speed of DC motor using FPGAs based on variation in temperature using PWM. Temperature control is the process in which the transfer of heat takes place from one object to another under supervision. In FPGA there is generation of High resolution PWM for controlling of motor speed which leads to low power consumption with better payback period. This paper presents the interfacing of temperature sensor (NTC thermistor) with FPGA by means of analog to digital converter. Variation in duty cycle controls the speed of dc motor according to variation in temperature.

2. Literature Survey

2.1 FPGAs

Field Programmable Gate Arrays (FPGAs) are semiconductor devices that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects. FPGAs can be reprogrammed to desired application or functionality requirements after manufacturing. In FPGAs other than any other microcontroller or microprocessor there is no CPU which checks and intercepts the commands and executes it.

Whenever the command is given, it executes it with the formation of interconnection of gates which makes the system really faster. Microcontroller or microprocessors have the dedicated pin for a different port like UART, Serial, I2C where else in FPGA any pin can be redesign for any port with the help of programing. FPGAs allows us to have better control over hardware and have faster real-time operating system

FPGA Spartan6 Development Board (XC6SLX9-TQ144)
The Spartan6 FPGA Project Board (XC6SLX9-TQ144) is a digital system development board which features Xilinx Spartan6 FPGA, 4Mb of external non-volatile memory and enough I/O devices and external connector to interface variety of digital applications.

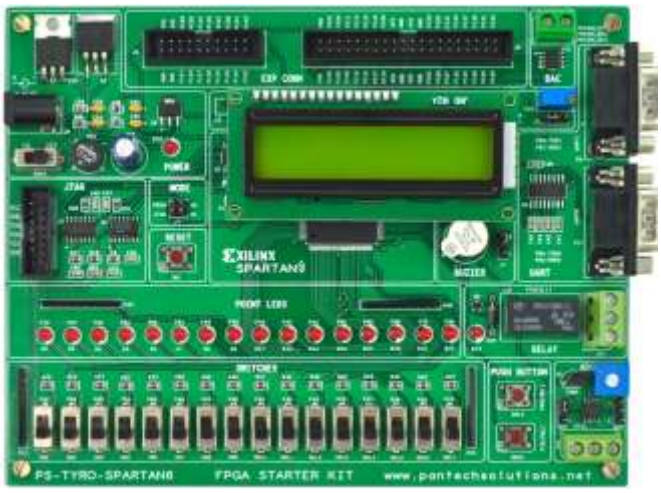

Figure 1: FPGA SPARTAN 6 Development board

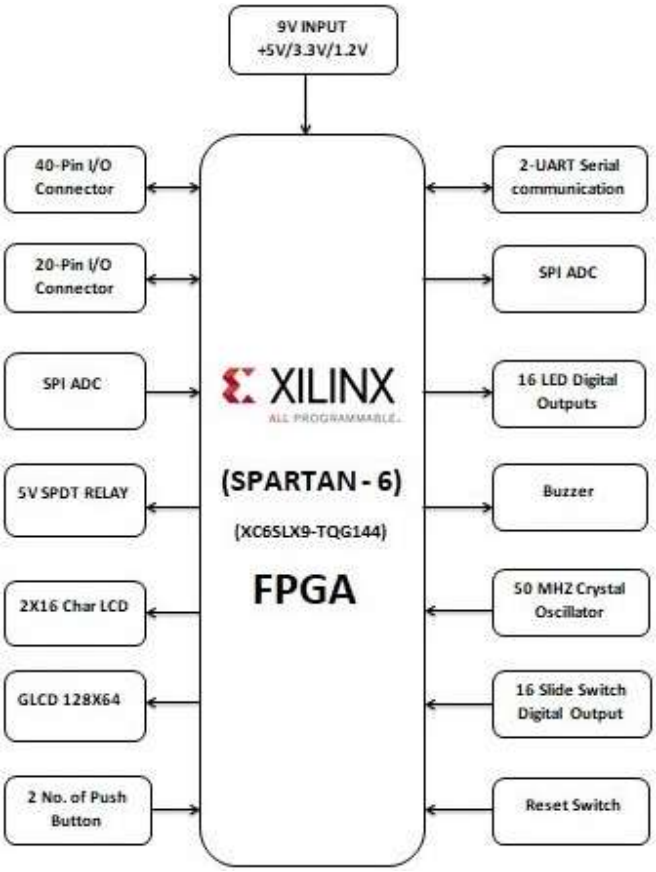

Figure 2: FPGA Block Diagram

2.2 Dc motor

A DC motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. DC motors are widely used in industrial applications, robot manipulators and home appliances, because of their high reliability, flexibility and low cost, where speed and position control of motor are required.

- Speed control over a wide range both above and below the rated speed.
- High starting torque.
- Quick starting, stopping, reversing and acceleration
- The speed torque characteristics of DC motors are much more superior to that of AC motors
- DC motors provide excellent control of speed for deceleration and acceleration.

2.3 Speed control of Dc Motor

Speed control means intentional change of the drive speed to a value required for performing the specific work process. The EMF equation of DC motor is given by -

$$E = \frac{NP\varphi Z}{60A}$$

$$N = \frac{60AE}{P\varphi Z}$$

$$N = \frac{E}{K\varphi} \quad \text{Where,} \quad K = \frac{PZ}{60A}$$

$$N = \frac{V - I_a R_a}{\varphi} \quad \text{As,} \quad E = V - I_a R_a$$

Where,
E= EMF induced
V= armature terminal voltage
I_a= armature current;
R_a= equivalent resistance of armature circuit
φ = each level of magnetic flux
K = machine constant
So, speed varies by changing -

- Terminal voltage of the armature V.
- External a**rter)**

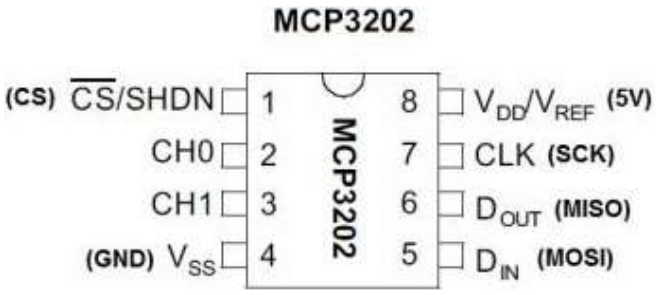

Figure 4: MCP3202 IC Pin Diagram

The Analog to digital converter (ADC) is used to convert analog signal into digital signal. MCP3202 is successive approximation 12-bit Analog to Digital (A/D) Converter with on-board sample and hold circuitry. The MCP3202 device operates over a broad voltage range (2.7-5.5V). To process the analog signal onto digital devices, like as FPGAs which should be converted as digital form. The analog form means such as voltage or current. After the signal conversion, data is processed using FPGA. It contains two channels channel one, channel zero and it's a 12bit parallel ADC.

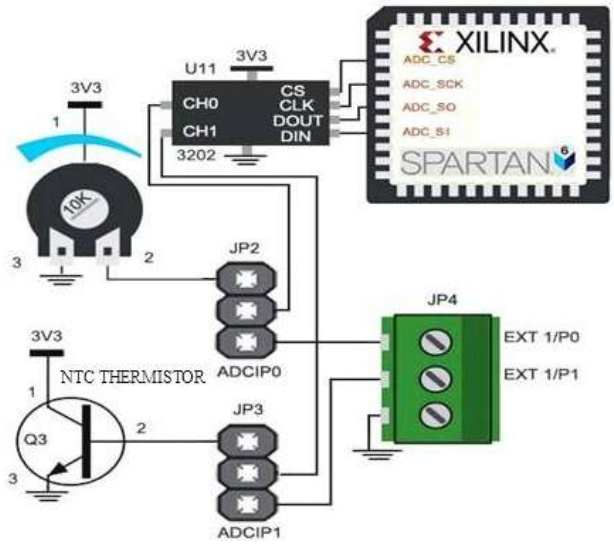

Figure 5: Interfacing SPI ADC with FPGA Board

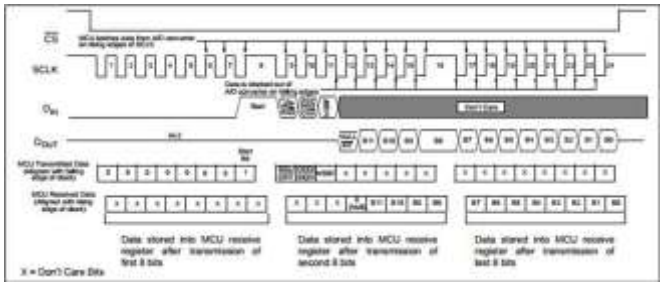

Figure 6: Timing Diagram of ADC

CS control register activates the ADC when CS=0 that means during this time FPGA will communicate with ADC.SCLK clock indicates that how the data processing speed will take place. Din contains four bits indicating odd/even, channel selector and MOST significant bit/least significant bit. When the falling edge of SCLK clock will come the ADC will send the data out and since it is a 12-bit ADC it will send a parallel 12-bit data out

2.6 Negative Temperature Coefficient Thermistor

The Thermistor is a solid-state temperature sensing device that acts a bit like an electrical resistor but is temperature sensitive. They have non-linear with temperature as the temperature increase, resistance of material decreases. This is because it creates a change in its electrical properties due to a physical change in heat. A thermistor is basically a two-terminal solid state thermally sensitive transducer made from sensitive semiconductor based on metal oxides with metalized leads onto a ceramic disc or bead. This allows it to change its resistive value in proportion to small changes in temperature. Small changes in resistance are reflected very fast. They are known to have fast responses, high sensitivity and exhibit large predicate and precision change in resistance. They can operate at very high temperature up to 200℃.

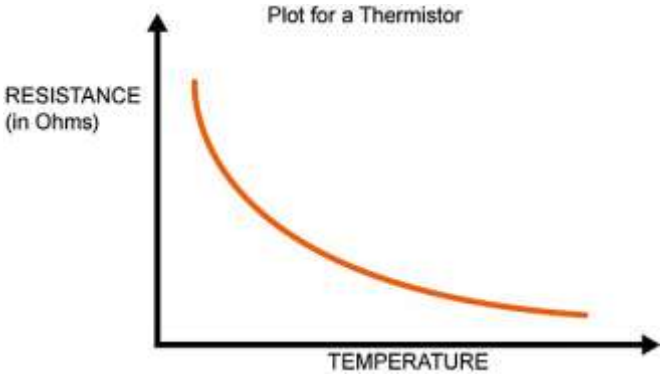

Figure 7: Nature of Temperature with respect to resistance

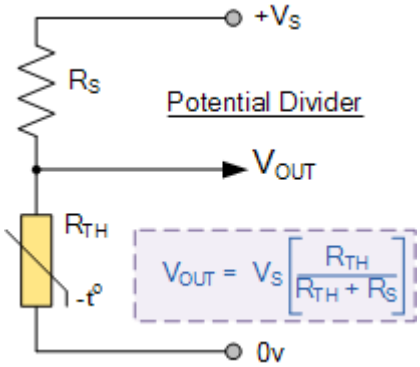

Figure 8: Circuit Diagram of Sensor

In the sensor circuit, a series resistance is used along with the thermistor. Total potential of 3.3v is given to the circuit. When the temperature increase resistance of the thermistor decreases thereby the potential is increased at another resistance which is given to analog to digital converter.

2.7 Pulse Width Modulation

This paper specifies the generation of PWM signals for variable duty cycles using VHDL. Pulse Width Modulation found in large number of applications as a voltage controller. It is used in controlling output voltage of inverter in most of the applications. PWM has a fixed frequency and a variable voltage. The advantage of this method is that it is used to generate High-frequency variable duty cycle PWM output.
Field Programmable Gate Arrays (FPGA) provides very good hardware design flexibility. The VHDL code is written and synthesized using Xilinx ISE. Results are verified by downloading the code into SPARTAN6 FPGA.

Pulse Width Modulation (PWM) is an integral part of almost all embedded systems. It is widely used as a control technique in most of the power electronic applications like DC/DC, DC/AC, etc. The PWM is widely used for motion control. PWM signal is generated by comparing an adjustable reference voltage, V_{ref} with a triangular wave of constant amplitude and frequency. The DC output voltage is regulated to the desired value by adjusting the reference voltage value, thus modifying the PWM signal duty cycle, as follows.

$$V_o = D.V_{in} = \frac{t_{on}}{T_s}.V_{in}$$

Where, V_{in} is the DC input voltage, D the PWM signal duty cycle ($0 < D < 1$), ton is the PWM signal ON time, T_s is switching time period.

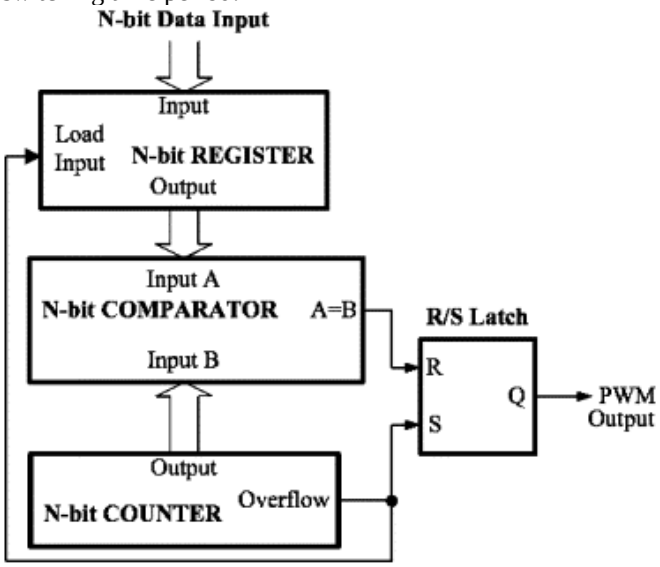

Figure 9: Block diagram of PWM

3. Flow Chart

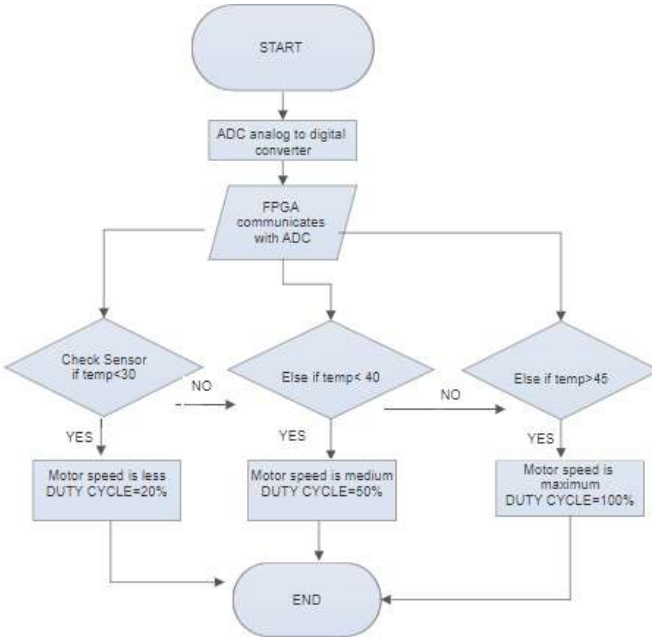

Figure 10: Flow chart

The logical representation of software code has been represented in flowchart form. Fig 10 represented the logical implemented in the modelled system.

- When temperature is less than 30 degrees Celsius, the motor speed is SLOW.
- When temperature is greater than 30 and less than 40 degrees Celsius, the motor speed is MEDIUM.
- When temperature is greater than 45, the motor speed is FAST.

Until and unless temperature is less than 30-degree Celsius, motor will be off and will not operate.

4. Hardware Implementation

4.1 Circuit Diagram

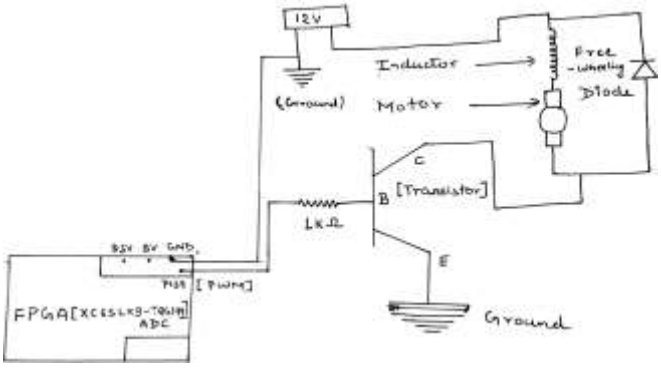

Figure 11: Circuit of speed control of motor

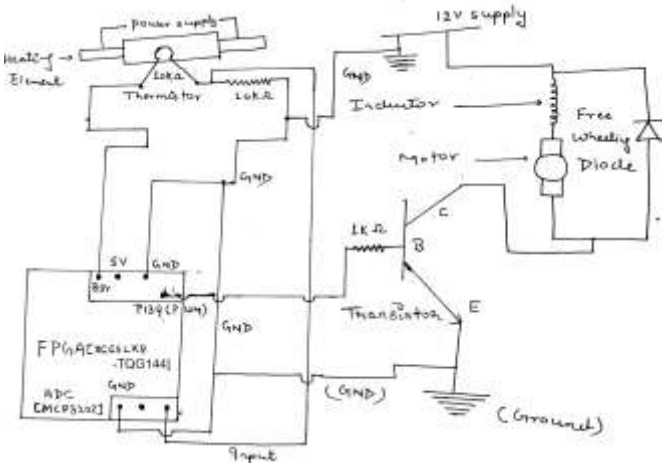

Figure 12: Circuit Diagram

4.2 Block Diagram of system

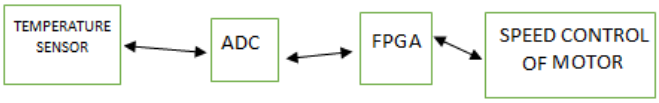

Figure 13: Block diagram

5. Results and Discussion

The speed of the motor has been controlled using PWM technique according to the room temperature. The simulation of the system has been done on ISE Design Suite 14.5 software packages and it is running in good agreement. The logic used in the system is verified and shown in the flowchart form. The duty cycle has been varied according to room temperature and speed of the motor was controlled accordingly. The graphs showing the relationship between temperature and the room temperature are plotted in MATLAB and accuracy of the system was validated. The design of the system presented in this paper is appropriate according to the modern technology and it has a very significant role in upcoming modern industries

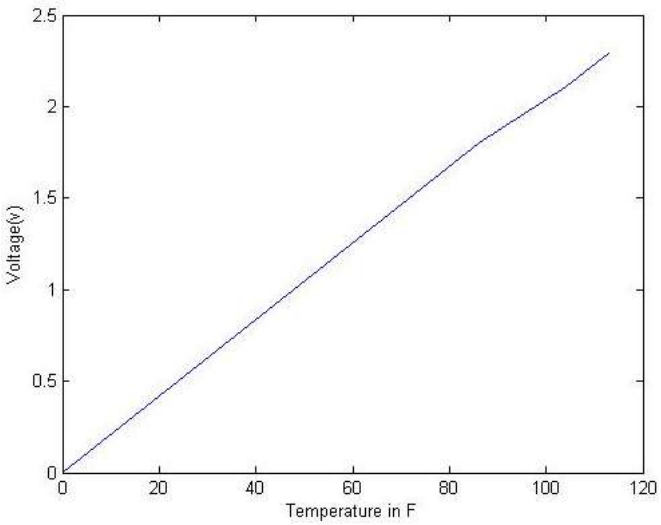

Figure 14: Graph between Voltage and Temperature

Table 1: Temperature and voltage

SR NO.	*Temperature (in ℃)*	*Voltage*
1	0	0
2	30	1.804
3	40	2.110
4	45	2.290

Table 2: Variation in speed according to Duty cycle

SR NO.	*Temperature (in ℃)*	*Duty Cycle (in %)*	*Speed (rpm)*
1	0	0	0 (zero)
2	30	20	105(slow)
3	40	50	223 (fast)
4	45	100	295 (very fast)

5.1 Simulation

Figure 15: PWM Generation 20% using ISE Design Suite

Figure 16: PWM Generation 50% using ISE Design Suite

Figure 17: PWM Generation 1O0% using ISE Design Suite

Table 3: Duty cycle vs ADC Output

SR NO.	*Duty Cycle (in %)*	*ADC Output*
1	0	000000000000
2	20	001110000101
3	50	010000011110
4	100	111111111111

6. Future Aspects

FPGA have been significant been used for past decades in consumer electronics, defense, Test Measurement and Medical etc. Telecom is the largest application segment for FPGA. Other applications include automobile, consumer electronics, industrial, data processing, military and aerospace, and medical industries. The automobile market continues to witness a proliferation of electronic content due to governmental guidelines on pollution, security and safety regulations, and the ongoing oil crisis. Moreover, rising fuel prices in the global market have resulted in demand for electric and hybrid vehicles, which in turn is expected to drive FPGA content in automobiles. In the field of AI based data center major companies like Microsoft are shifting towards FPGA. Furthermore, increasing luxury features in automobiles require efficient solutions, thereby boosting demand in the FPGA market.

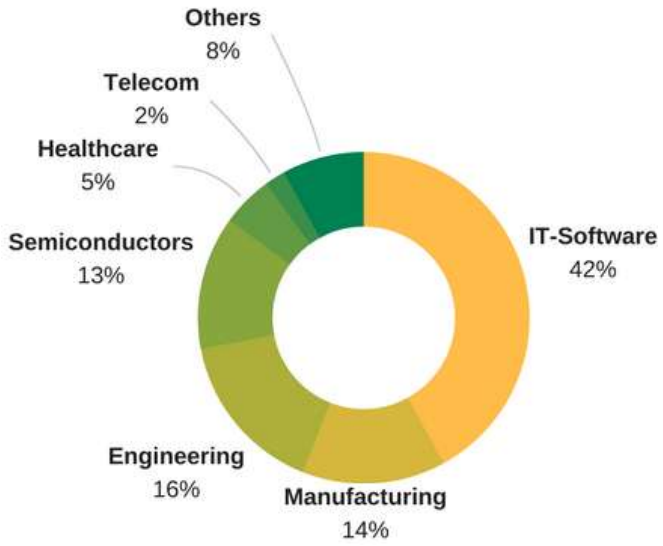

Figure 17: Graphical Representation of future aspect

7. Conclusion

The FPGA based automatic speed control of motor based on room temperature using PWM technique has been proposed in this paper. The simulation of the system is working properly and the design is appropriate according to the modern needs and technology. The speed of motor depends on the room temperature and there is no need for regulating the speed manually. Various graphs have been plotted to show the varying relationships between different parameters. PWM technique is found to be appropriate for controlling motor speed according to room temperature. After comparing duty cycle and speed of DC motor according to temperature variation in software and hardware we have observed approximately same result. Since FPGA is used in the system it is one of the fast and efficient systems as compare to any microcontroller or microprocessor.

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