A

Seminar Report On

" DC MOTOR CONTROLLER USING FPGA WITH INTERFACING OF VGA"

Submitted in the partial fulfillment of the

Requirement for the Award of Degree

Of

Electrical Engineering

(Lovely Professional

University)

LOVELY PROFESSIONAL UNIVERSITY

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INTRODUCTION

The DC Motor Controller project leveraging Field-Programmable Gate Array (FPGA) technology, coupled with VGA interfacing, represents a cutting-edge fusion of hardware and software to achieve precise motor control and visual feedback. This innovative system is designed to offer a flexible and efficient solution for controlling DC motors in diverse applications, ranging from robotics to automation.

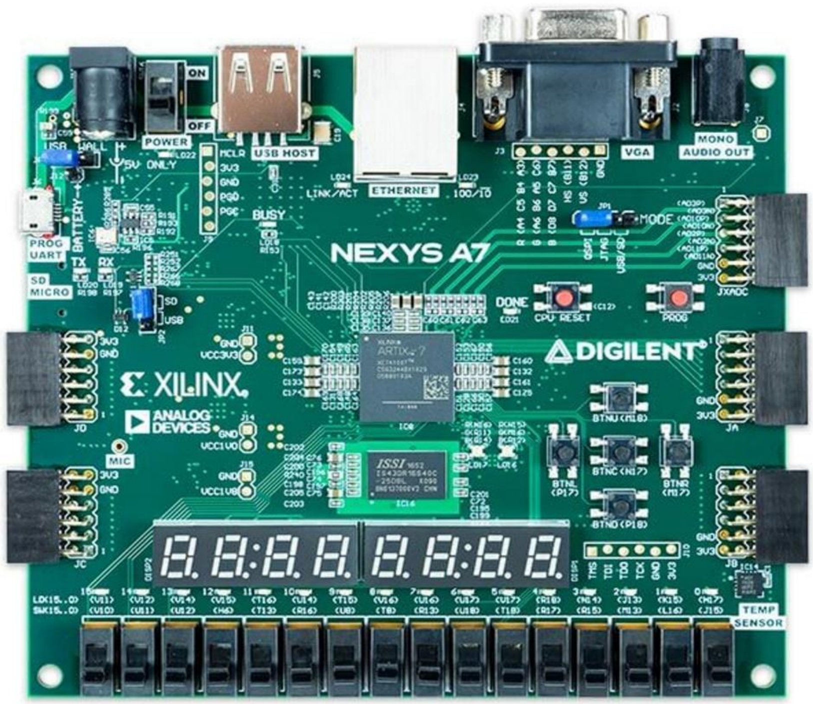
The FPGA serves as the heart of the project, providing reconfigurable logic that enables real-time control and customization of motor parameters. This adaptability is crucial for accommodating various motor types and responding dynamically to changing operational requirements. The FPGA's parallel processing capabilities ensure swift and accurate motor control, enhancing overall system responsiveness.

The incorporation of VGA interfacing adds a visual dimension to the project, allowing users to monitor motor behavior in real-time through a standard display. This graphical feedback provides a user-friendly interface for adjusting motor settings and observing performance metrics, contributing to a more intuitive and interactive user experience.

By combining FPGA technology with VGA interfacing, this project aims to deliver a robust and versatile DC motor control system, capable of meeting the demands of diverse applications while providing a seamless and visually informative user interface. This integration of hardware and visual feedback showcases the potential for FPGA-based solutions to drive innovation in the field of motor control and beyond.

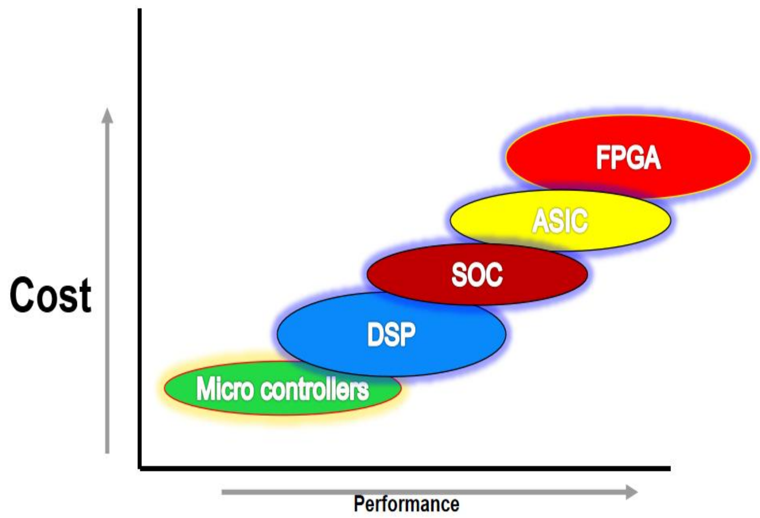
Field-Programmable Gate Array (FPGA)

A field-programmable gate array (FPGA) is an integrated circuit designed to be configured by a customer or a designer after manufacturing – hence "field-programmable". The FPGA configuration is generally specified using a hard ware description language (HDL), similar to that used for an application-specific integrated circuit (ASIC) (circuit diagrams were previously used to specify the configuration, as they were for ASICs, but this is increasingly rare).



Contemporary FPGAs have large resources of logic gates and RAM blocks to implement complex digital computations. As FPGA designs employ very fast T/O s and bidirectional data buses it becomes a challenge to verify correct timing of valid data within setup time and hold time. Floor planning enables resources allocation within FPGA to meet these time constraints. FPGAs can be used to implement any logical function that an ASIC could perfurm. The ability to update the functionality after shipping, partial re-configuration of a portion of the design and the low non-recurring engineering costs relative to an ASIC design (not withstanding the generally higher (cost), ofter advantages for many applications.

FPGAs contain programmable logic components called "logic blocks", and a hierarchy of reconfigurable interconnects that allow the blocks to be "wired together" – somewhat like many (changeable) logic gates that can be inter-wired in (many) different configurations. Logic blocks can be configured to perform complex combinational functions, or merely simple logic gates like AND and XOR In 100st FPGAs, the logic blocks also include memory elements, which may be simple flip-flops or imre complete blocks of memory.

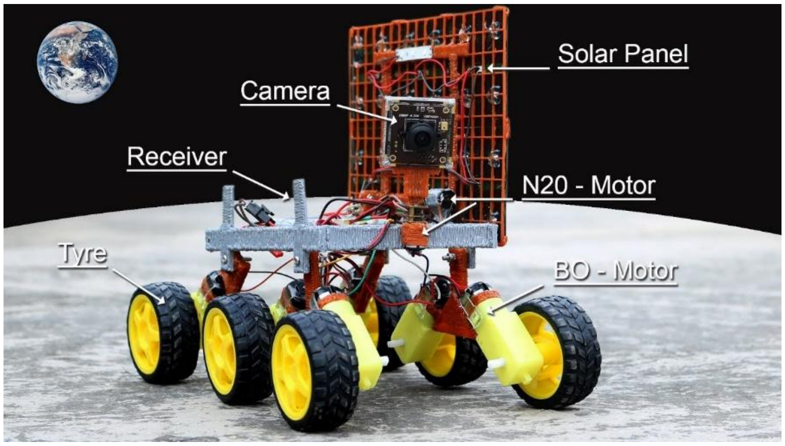


DC MOTOR

Direct Current (DC) motors find extensive applications across various industries due to their reliability, simplicity, and ease of control. Their versatile nature makes them indispensable in a wide range of systems and devices. When combined with Field-Programmable Gate Array (FPGA) technology for precise control, DC motors become even more powerful and adaptable. Here, we explore the myriad uses of DC motors and delve into how FPGA-based control enhances their functionality.

1.Industrial Automation
DC motors play a pivotal role in industrial automation processes. From conveyor systems to robotic arms, DC motors provide the necessary torque and speed control essential for efficient and precise movements. FPGA-based control ensures real-time adjustments, allowing for seamless integration into automated production lines.
In robotics, DC motors are the go-to choice for actuation. They power joints and limbs, offering the required precision for intricate movements. FPGA control facilitates sophisticated motion control algorithms, enabling robots to perform tasks with accuracy and agility. This combination is crucial for applications such as robotic surgery, manufacturing, and exploration in hostile environments.

2.Electric Vehicles
The automotive industry has embraced DC motors for electric and hybrid vehicles. These motors efficiently convert electrical energy into mechanical motion, providing the necessary propulsion. FPGA control allows for optimized motor control algorithms, enhancing energy efficiency and extending the range of electric vehicles.
From electric toothbrushes to power tools, DC motors are ubiquitous in consumer electronics. Their compact size, high efficiency, and controllable speed make them ideal for applications like disk drives, cooling fans, and vibrational devices. FPGA control ensures precise speed regulation and responsiveness in these consumer-oriented devices.



3.In Aerospace
In aerospace applications, where weight and space constraints are critical, DC motors find application in various systems. They power actuators for flight control surfaces, adjust wing flaps, and drive fuel pumps. FPGA-based control ensures that these systems operate with optimal efficiency and respond rapidly to changing flight conditions.

4.Home Appliances

DC motors are integral components in numerous home appliances, including washing machines, vacuum cleaners, and kitchen appliances. The ability to control speed and direction makes them suitable for tasks ranging from agitating clothes to powering blenders. FPGA-based control allows for intelligent and adaptive motor behavior, enhancing the performance of these appliances.

In the medical field, DC motors contribute to the precision required in various devices. They power infusion pumps, ventilators, and prosthetic limbs. FPGA control ensures that these devices can be finely tuned to meet the specific needs of individual patients, providing a high degree of customization and accuracy.

DC motors are utilized in renewable energy systems, such as wind turbines and solar tracking systems. They play a crucial role in adjusting the orientation of solar panels or controlling the pitch of wind turbine blades. FPGA-based control allows for efficient tracking and optimization of energy capture, contributing to the overall effectiveness of these systems.

In heating, ventilation, and air conditioning (HVAC) systems, DC motors drive fans and pumps. The ability to control the speed of these motors based on real-time requirements ensures energy-efficient operation. FPGA-based control enables dynamic adjustments, responding to changing temperature and airflow demands in different environments.

5.Scientific Instruments

In laboratories and research facilities, DC motors are employed in scientific instruments like spectrometers, microscopes, and centrifuges. FPGA-based control enhances the precision and repeatability of experiments by allowing researchers to finely tune motor parameters and motion profiles.

Incorporating FPGA technology for the control of DC motors brings a new level of sophistication and adaptability to these already versatile devices. FPGA-based control allows for real-time adjustments, rapid response to changing conditions, and the implementation of complex algorithms, making DC motors even more powerful tools across various industries. Whether it's for intricate robotic movements, energy-efficient transportation, or precise medical applications, the combination of DC motors and FPGA control represents a synergy that continues to drive innovation across diverse fields.

MOTOR DRIVER

Motor drivers play a crucial role in the precise and efficient control of electric motors, serving as the intermediary between a microcontroller or a control system and the motor itself. These specialized electronic circuits are designed to handle the unique characteristics and requirements of electric motors, ensuring reliable operation and optimal performance. Here are some key uses and functions of motor drivers:

1.Current Regulation

Motor drivers regulate the flow of electrical current to the motor windings. This is essential for preventing the motor from drawing excessive current, which could lead to overheating and damage. Current regulation is particularly important during motor startup and under varying load conditions.

2.Voltage Regulation

Motor drivers control the voltage supplied to the motor, ensuring that it operates within its specified voltage range. This regulation is critical for preventing overvoltage, which could damage the motor, and for maintaining consistent motor performance.

3.Direction Control

Motor drivers facilitate the control of motor direction. By managing the sequence and polarity of the electrical signals sent to the motor windings, motor drivers enable precise control over the rotational direction of the motor shaft.

4.Speed Control

One of the primary functions of motor drivers is to regulate the speed of the motor. This is achieved by adjusting the frequency of the electrical signals supplied to the motor. Speed control is crucial in applications where varying speeds are required, such as in industrial automation or robotics.

5.Efficiency Optimization

Motor drivers help optimize the efficiency of motor operation by controlling the energy consumption and minimizing losses. This is particularly important in applications where energy efficiency is a priority, such as in electric vehicles or battery-powered devices.

6.Protection Mechanisms

Motor drivers incorporate protection features to safeguard the motor from potential issues. These may include overcurrent protection, overtemperature protection, and short-circuit protection. These mechanisms enhance the reliability and longevity of the motor.

7.Microstepping (for Stepper Motors)

In the case of stepper motors, motor drivers enable microstepping, which allows for smoother motion and finer positioning control. Microstepping divides each step of the motor into smaller increments, reducing vibration and improving precision.

8.Compatibility with Control Systems

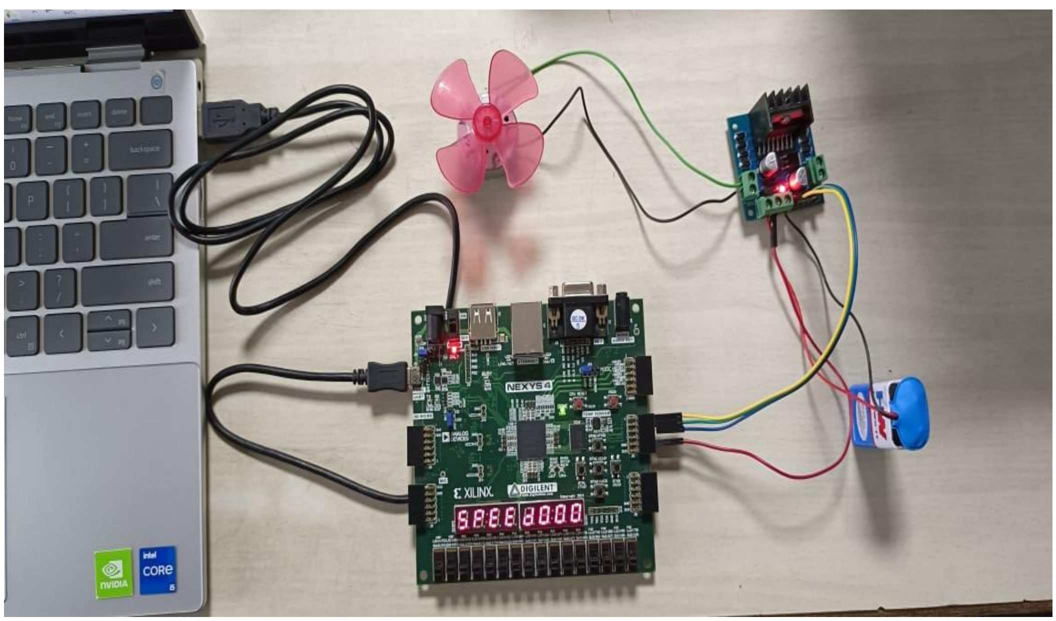
Motor drivers ensure seamless integration with control systems, microcontrollers, or programmable logic controllers (PLCs). This compatibility enables easy implementation of various control algorithms and facilitates communication between the motor and the broader system.

9.Motor drivers are indispensable components in the realm of motor control, providing the necessary intelligence and control capabilities to ensure the reliable and efficient operation of electric motors in a wide range of applications, from simple household appliances to complex industrial systems. Their ability to regulate current, voltage, direction, and speed makes them essential for achieving precise and tailored motor performance.

<u>PROJECT</u>

A DC Motor Controller utilizing a Field-Programmable Gate Array (FPGA) with VGA interfacing represents an innovative integration of hardware and software technologies for advanced motor control and visualization. The project involves leveraging the reconfigurable logic of an FPGA to achieve real-time, customizable control over a DC motor, while VGA interfacing provides a graphical user interface for monitoring and adjusting motor parameters.

- Block Diagram:-



- FPGA-Based Control:

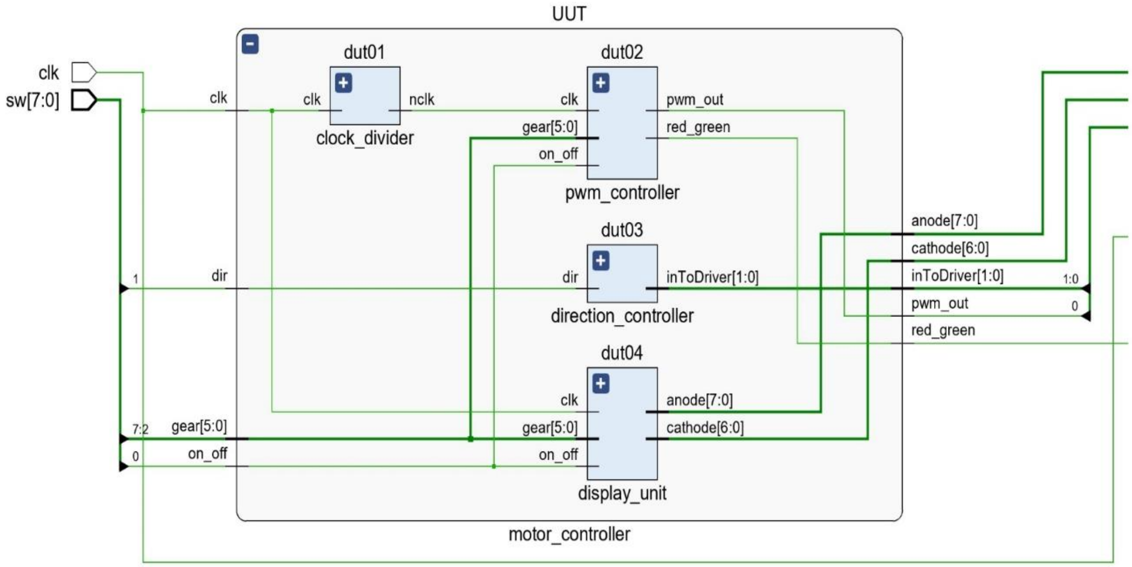
1.Reconfigurable Logic:
The FPGA's reconfigurable logic allows for the implementation of custom control algorithms tailored to specific motor requirements. This adaptability is crucial for accommodating various motor types and responding dynamically to changing operational needs.

2.Parallel Processing:

FPGA's parallel processing capabilities enable rapid and simultaneous execution of control tasks. This is particularly advantageous for applications demanding swift adjustments in motor speed, torque, or direction.

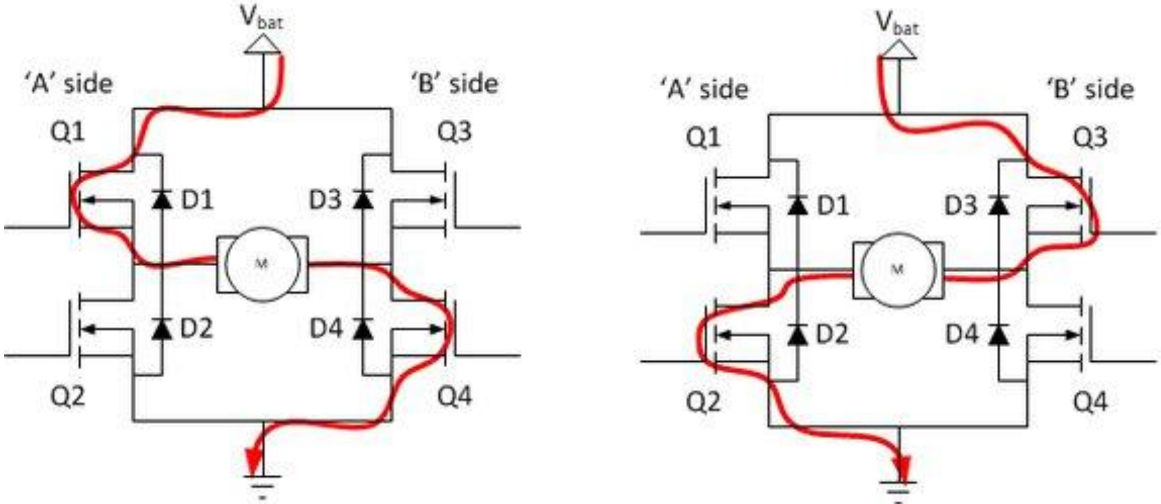
3.Real-time Control:

FPGA facilitates real-time control, ensuring that the motor responds promptly to input signals. This is essential in applications where precise and immediate control over the motor's behavior is critical.



- H-Bridge logic for controlling the motor direction:-

H-bridge logic is a fundamental circuit configuration employed in motor control systems to manage the direction of DC motors. Consisting of four switches arranged in the shape of an "H," the H-bridge allows for the control of current flow through the motor in both directions. This versatile configuration enables bidirectional control, crucial for applications where reversible motion is necessary.

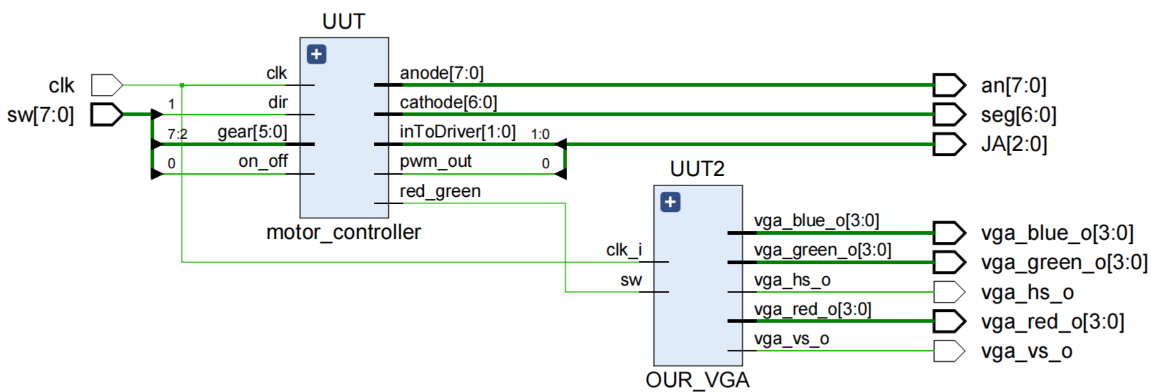


In one operational mode, the top two switches are closed, allowing current to flow from the power supply to one side of the motor, initiating motion in one direction.

Conversely, closing the bottom two switches reverses the current flow, causing the motor to rotate in the opposite direction. By selectively activating or deactivating specific switches, the H-bridge circuit achieves precise control over the motor's speed, torque, and direction.

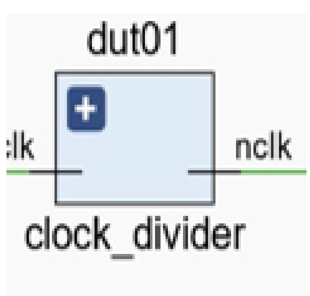
The H-bridge logic is a cornerstone in robotics, automotive systems, and various industrial applications due to its simplicity, efficiency, and ability to facilitate bidirectional motor control. Its role in changing the polarity of the applied voltage to the motor terminals showcases its significance in enabling versatile and dynamic motion control in electromechanical systems.

- Block Diagram:-



<u>**Implementation in “Verilog” HDL Language...**</u>

<u>1.Clock divider:-</u>



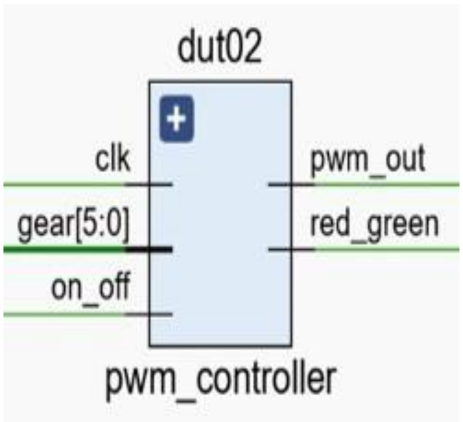
```
module clock_divider(nclk,clk);
```

```
output reg nclk;
input clk;
reg [31:0]cnt=32'd0;
always@(posedge clk)
begin
cnt=cnt+1;
nclk=cnt[16];
end
endmodule
```

2.PWM Controller:-

```
pwm_controller(pwm_out,red_green,clk,on_off,g
ear);
output reg pwm_out=0;
output reg red_green=0;
input clk,on_off;
input [5:0]gear;
reg [7:0]cnt=8'd0;
always@(posedge clk)
cnt<=(cnt<255)?(cnt+1):7'd0;

always@(posedge clk)
begin
if(on_off==0)
begin
     pwm_out<=0;
     red_green<=0;
end
else
begin
     case(gear)
     6'b0000_01: begin
                     pwm_out
<=(cnt<1)?1:0;
                     red_green    <=1;
                 end
```

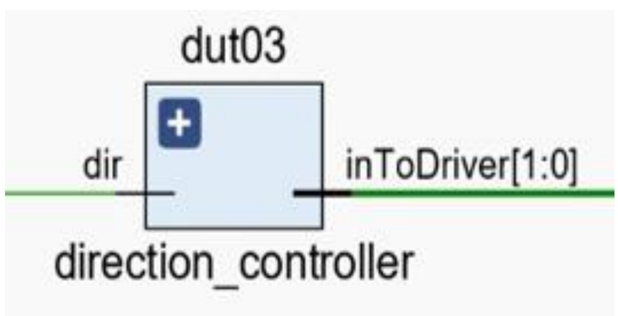



```
6'b0000_11: begin
                pwm_out<=(cnt<2)?1:0;
                red_green    <=1;
            end

6'b0001_11: begin
                pwm_out<=(cnt<3)?1:0;
                red_green    <=1;
            end
6'b0011_11: begin
                pwm_out<=(cnt<4)?1:0;
                red_green    <=1;
            end

6'b0111_11: begin
                pwm_out<=(cnt<5)?1:0;
                red_green    <=1;
            end
6'b1111_11: begin
                pwm_out<=(cnt<95)?1:0;
                red_green    <=1;
            end
default:    begin
                pwm_out<=0;
                red_green    <=0;
```

3.Direction Controller:-



```
module direction_controller(inToDriver,dir);
```

```
output reg [1:0]inToDriver=2'b0;
input dir;
always@(dir)
begin
    case(dir)
        1'b0:inToDriver=2'b10;
        1'b1:inToDriver=2'b01;
        default: inToDriver=2'b00;
    endcase
end
endmodule
```

4.Motor controller Instantiations with the display:-

```
module

motor_controller(pwm_out,red_green,inToDriver
,cathode,anode,clk,on_off,dir,gear);
output pwm_out;
output [1:0] inToDriver;
output red_green;
input clk,on_off,dir;
input [5:0]gear;
output [6:0]cathode;
output [7:0]anode;
wire nclk;
clock_divider dut01 (nclk,clk);
pwm_controller dut02
(pwm_out,red_green,nclk,on_off,gear);
direction_controller dut03 (inToDriver,dir);
display_unit dut04
(cathode,anode,clk,on_off,gear);
endmodule
```

- **VGA Interfacing: -**

1.**VGA, or Video Graphics Array**: -is a standard for displaying visual information on computer monitors and screens. It defines the resolution, color depth, and refresh rate of the output, providing a standardized interface between computers and display devices. VGA utilizes an analog signal to transmit information, typically consisting of separate red, green, and blue color channels.

VESA Signal 1280 x 1024 @ 60 Hz timing

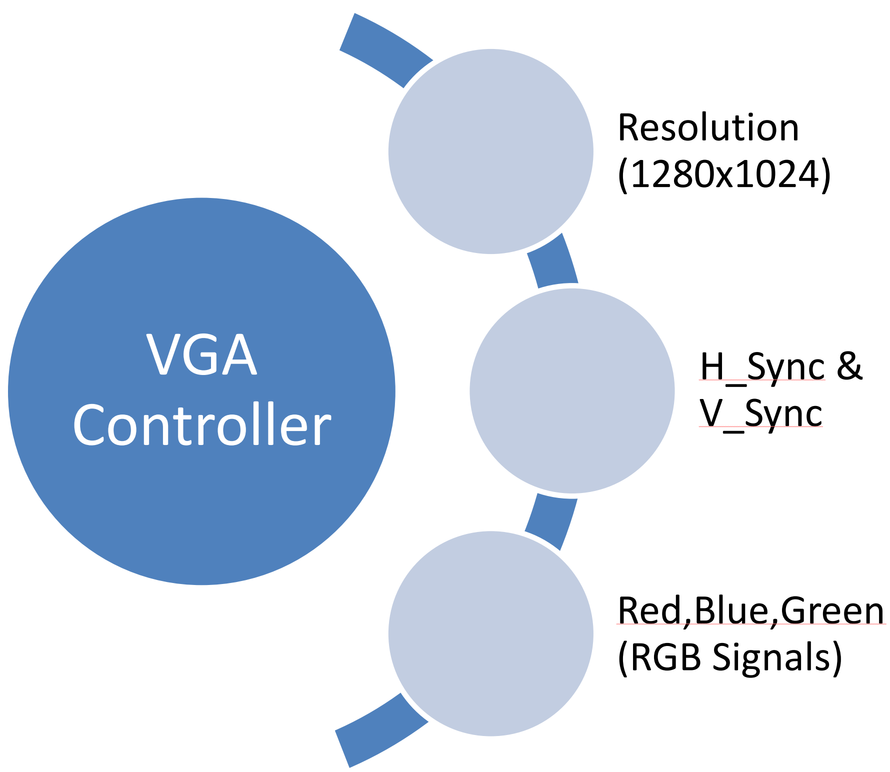
General timing

Screen refresh rate	60 Hz
Vertical refresh	63.981042654028 kHz
Pixel freq.	108.0 MHz

In the context of motor control, VGA can be integrated into a system to provide visual feedback about the motor's status. For instance, when the motor is in an active state, the VGA display can represent this by showing a red color. This visual cue serves as an intuitive indicator that the motor is powered on and ready for operation.

As the motor starts running, a transition to a green color on the VGA display can signify the commencement of motion. This dynamic color change provides immediate and clear visual information about the motor's operational status. Integrating VGA into motor control systems not only adds a user-friendly interface but also enhances situational awareness, allowing operators to quickly ascertain the state of the motor at a glance.

VGA is a standard for visual display, and its integration into motor control systems can be leveraged to offer real-time, color-coded feedback on the motor's status. The use of red to indicate the motor being on and a transition to green upon activation provides an intuitive and visually impactful means of representing the dynamic states of the motor, contributing to efficient monitoring and control in various applications.



1.Graphical User Interface (GUI):
The integration of VGA interfacing introduces a graphical user interface, allowing users to interact with the system through a display. This GUI provides a visual representation of the motor's performance, enhancing user experience and ease of operation.

2.Real-time Visualization:
VGA interfacing enables real-time visualization of motor parameters, such as speed,

direction, and torque. Users can monitor these parameters graphically, facilitating quick assessment and adjustment during operation.

3.User-Friendly Interaction:

The graphical interface offers a user-friendly platform for adjusting motor settings and observing performance metrics. This enhances the accessibility of the system, making it more intuitive for users without extensive technical expertise.

4.Versatility in Motor Control:

The project's integration of FPGA and VGA technologies enhances the versatility of DC motor control. It accommodates a wide range of applications, from industrial automation to educational platforms, by offering a customizable and user-friendly control system.

5.Innovation in Automation:

The project exemplifies innovation in automation, showcasing the potential of FPGA-based solutions to drive advancements in motor control technology. The real-time control and graphical visualization contribute to the evolution of smart and efficient automation systems.

6.Educational Application:

The project holds educational value by providing a practical platform for learning about FPGA-based control systems, motor control principles, and the integration of graphical interfaces in engineering applications.

7.The DC Motor Controller using FPGA with VGA interfacing combines the power of FPGA-based control with the visual feedback capabilities of VGA interfacing. This integration not only advances the state-of-the-art in motor control technology but also opens up new possibilities for interactive and user-friendly control systems across a spectrum of applications.

Implementation in “Verilog” HDL Language:

Horizontal timing (line)

Polarity of horizontal sync pulse is positive.

Scanline part	Pixels	Time [µs]
Visible area	1280	11.851851851852
Front porch	48	0.44444444444444
Sync pulse	112	1.037037037037
Back porch	248	2.2962962962963
Whole line	1688	15.62962962963

Vertical timing (frame)

Polarity of vertical sync pulse is positive.

Frame part	Lines	Time [ms]
Visible area	1024	16.004740740741
Front porch	1	0.01562962962963
Sync pulse	3	0.046888888888889
Back porch	38	0.59392592592593
Whole frame	1066	16.661185185185

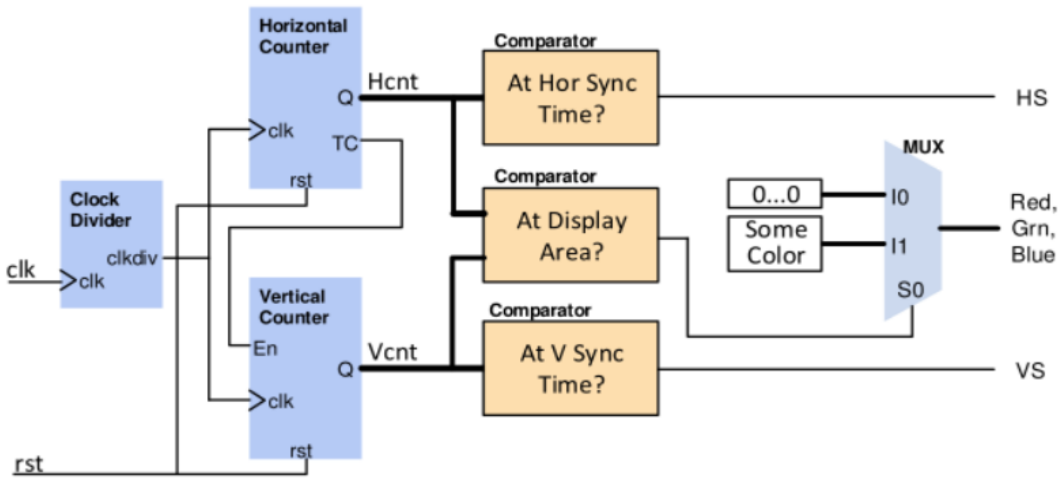
```
parameter reg [10:0]   FRAME_WIDTH = 11'd1280,
                       FRAME_HEIGHT= 11'd1024,

                       H_FP        = 11'd48,
                       H_PW        = 11'd112,
                       H_MAX       = 11'd1688,

                       V_FP        = 11'd1,
                       V_PW        = 11'd3,
                       V_MAX       = 11'd1066,

 parameter reg         H_POL       = 1,
                       V_POL       = 1
```

➢ Motor Controller Block Diagram:-




```
if(h_cntr_reg == (H_MAX-1))
    h_cntr_reg <= 11'd0;
else
    h_cntr_reg <= h_cntr_reg+1;
```

```
if((h_cntr_reg == (H_MAX-1)) &&
(v_cntr_reg == (V_MAX - 1)))
    v_cntr_reg <= 11'd0;
else if(h_cntr_reg == (H_MAX-1))
    v_cntr_reg <= v_cntr_reg+1;
```

```
if ((h_cntr_reg >= (H_FP +
FRAME_WIDTH -1)) && (h_cntr_reg < (H_FP +
FRAME_WIDTH + H_PW-1)))
    h_sync_reg <= H_POL;
else
    h_sync_reg <= ~H_POL;
```

```
reg temp1=0;
reg temp2=0;

reg temp1_dly;
reg temp2_dly;

always@(h_cntr_reg_dly,v_cntr_reg_dly )
begin
    if(h_cntr_reg_dly < FRAME_WIDTH)
temp1<=1;
    if(v_cntr_reg_dly < FRAME_HEIGHT)
temp2<=1;
end
```

```
always@(posedge pxl_clk)
begin
    temp1_dly <= temp1;
    temp2_dly <= temp2;
end

assign active = (temp1_dly && temp2_dly)?
1:0;

vga_red_gen      <=4'b1111;
vga_green_gen    <=4'b0000;
vga_blue_gen     <=4'b0000;


assign vga_red_cmb      =(active)?
vga_red:4'd0;
assign vga_green_cmb    =(active)?
vga_green:4'd0;
assign vga_blue_cmb     =(active)?
vga_blue:4'd0;
```

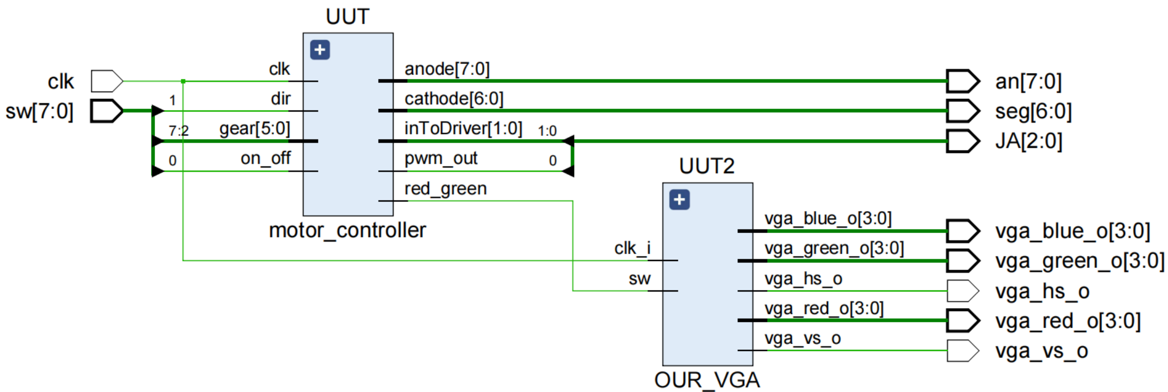
PIPELINING

```
always@(posedge pxl_clk)
begin
//     if(pxl_clk)
//          begin
                v_sync_reg_dly <= v_sync_reg;
                h_sync_reg_dly <= h_sync_reg;
                vga_red_reg    <= vga_red_cmb;
                vga_green_reg  <= vga_green_cmb;
                vga_blue_reg   <= vga_blue_cmb;
//          end
end
```

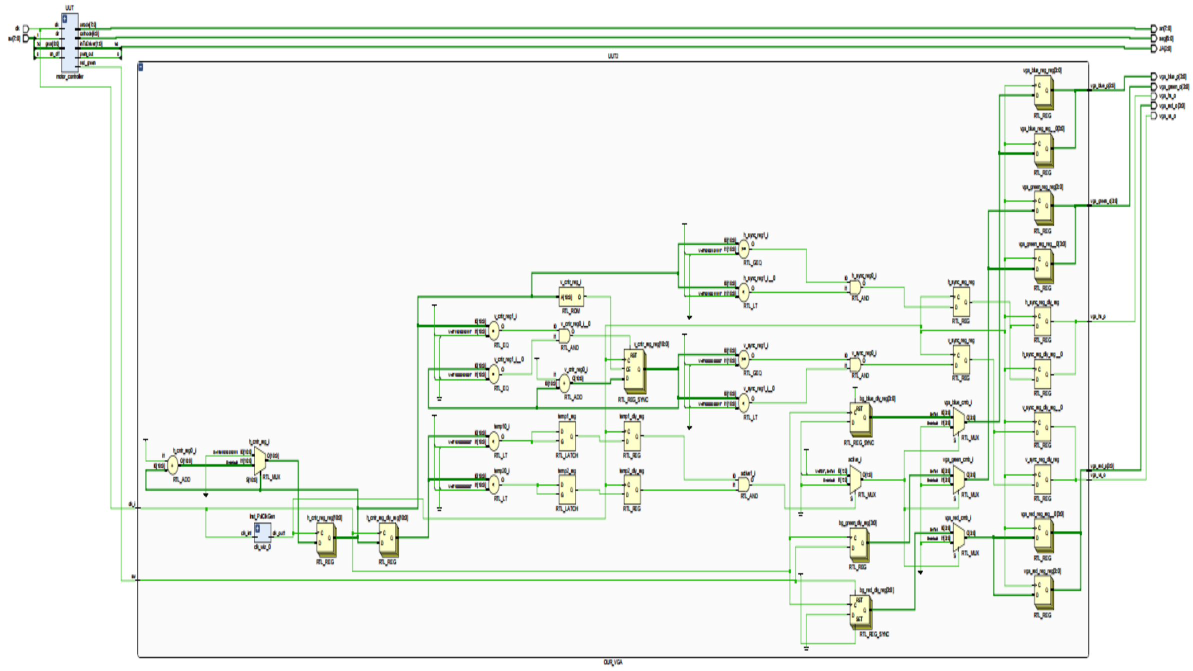
```
assign vga_hs_o      = h_sync_reg_dly;
assign vga_vs_o      = v_sync_reg_dly;
assign vga_red_o     = vga_red_reg;
assign vga_green_o   = vga_green_reg;
assign vga_blue_o    = vga_blue_reg;



endmodule
```



- Overall Block Diagram:-



- **APPLICATIONS:-**

1. Industrial Automation Systems:
Employing the FPGA-based DC motor controller in industrial automation allows for precise control of conveyor belts, robotic arms, and other manufacturing processes. The VGA interfacing provides real-time visual feedback for monitoring and optimizing these systems.

2. Robotic Platforms:
Robotics applications benefit from the FPGA's real-time processing and the precise control offered by the DC motor controller. The VGA interface enables users to visually program and monitor the movements of robotic platforms in industries ranging from logistics to healthcare.

3. CNC Machines:
In Computer Numerical Control (CNC) machining, the FPGA-controlled DC motor system ensures accurate and responsive control of the tool's movements. VGA interfacing allows operators to monitor machining processes in real-time, enhancing precision and efficiency.

4. Automated Guided Vehicles (AGVs):
AGVs used for material handling and logistics can leverage FPGA-based DC motor control for optimal navigation and speed adjustments. VGA interfacing provides a user-friendly interface for configuring AGV routes and monitoring their movements.

5. Solar Tracking Systems:
The FPGA-controlled DC motor system is well-suited for solar tracking applications. It ensures efficient orientation of solar panels towards the sun for maximum energy harvesting. VGA interfacing allows for real-time visualization of solar panel positions.

6. Educational Robotics:
In educational settings, the FPGA-based DC motor controller with VGA interfacing serves as an excellent platform for teaching robotics. Students can program and visualize the movements of robotic systems, fostering hands-on learning in STEM education.

7. 3D Printers:
Precision is crucial in 3D printing, and the FPGA-controlled DC motor system excels in providing accurate control over the printing mechanisms. VGA interfacing allows users to monitor the printing process and make real-time adjustments.

8. Medical Equipment:
Applications in the medical field, such as automated drug delivery systems or robotic surgery platforms, can benefit from the FPGA-controlled DC motor system. The VGA interface enhances user interaction and monitoring in these critical applications.

9. Automated Testing Equipment (ATE):
FPGA-based DC motor control is valuable in ATE for positioning and controlling test probes or components. The VGA interface aids in monitoring the testing process and identifying potential issues.

10. Electric Scooters and Bikes:
In electric vehicles, particularly scooters and bikes, the FPGA-controlled DC motor system ensures efficient speed control and responsiveness. VGA interfacing can provide riders with a dashboard display for monitoring battery status and speed.

CONCLUSION

The DC Motor Controller project leveraging FPGA technology with VGA interfacing represents a successful integration of hardware and software for precise motor control and visual feedback. The FPGA's programmable logic allowed for adaptable motor control, demonstrating versatility in accommodating various applications. The addition of VGA interfacing enhanced user interaction, providing a real-time graphical display for monitoring and adjusting motor parameters. This fusion of FPGA and VGA technologies showcased the potential for innovative solutions in the field of motor control. The project's success underscores the importance of programmable logic in achieving dynamic control, while the visual interface contributes to a user-friendly experience. This endeavor signifies a significant stride in advancing motor control systems, offering a blueprint for future developments in FPGA-based applications with enhanced user interfaces.

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