**SOLUTION**

Graphical user interface, application

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First of all, the LC filter at the output of the buck converter will not be used because the DC motor has a very large inductance that can filter the current in the square waveform. In other words, the DC machine will be driven with the square wave.

Secondly, transient current must be diminished to obtain a soft start operation. There are two ways: designing a controller (closed-loop operation) or designing a gate driver circuit such that the duty cycle starts from very low values and rises up to the maximum limit manually (open-loop operation). At first, a closed-loop PI controller is tried via TL494 IC; however, it is not ended with success. Therefore, due to lack of time, the open-loop operation is selected, and the following gate-driver circuit is designed.

Finally, the input voltage is desired according to the limited maximum duty cycle, which is 0.65. The duty cycle is limited in order to decrease the conduction loss, and the switching frequency is limited to 1 kHz to reduce the switching loss. So, the required input voltage for obtaining 180 V output voltage is calculated as

**Gate Driver Circuit**

As previously mentioned, the open-loop operation with soft start is aimed. The PWM is generated via 555 timer. So, after brief research, the following gate driver circuit is designed. The numbers represent the ports of the timer in pin diagram. The pin diagram and appearance of the 555 timer is also presented below.

A picture containing electronics, circuit

Description automatically generatedDiagram, schematic

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Diagram

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According to this topology, the duty cycle can be expressed as . Furthermore, the switching frequency is calculated as . Then, in order to achieve the desired duty cycle and switching frequency, resistor and capacitor parameters are tuned as , , and . RA will be composed of two series potentiometers in order to change the duty cycle. Specifically speaking, RA will be consisting of 100 kΩ and 10 kΩ resistors, which are series. The soft-start operation is achieved via 10 kΩ POT while the 100 kΩ POT is set as zero. After the start, duty cycle is adjusted via 100 kΩ POT.

After the 555 timer, the optocoupler is needed to isolate the gate driver circuit, i.e., prevent the gate driver circuit. For that purpose, the internal schematic of a typical optocoupler is presented to illustrate its working principle.

Diagram, engineering drawing, schematic

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The optocoupler utilizes the light to isolate one side from another, that’s what their name comes from. The picture above is the inside of the optocoupler. So, a 1 kΩ resistor will be placed to the pin 2 in order to limit the LED current in the input side of the optocoupler. Also, the PWM signal generated by the timer circuit is also connected to the second pin. Then, at the 6th or 7th pin, the same PWM signal will also be obtained. The 5th pin will be connected to the switch’s low voltage pin, which is the emitter.

Also, according to the datasheet of the switch (for reasoning of component selection please refer to the preceding simulation results and component selection sections), there must be at least a 10 Ω resistor placed in the gate of the IGBT. However, this value is for nearly perfect applications. Since it is not possible to design such a circuit, a 50 Ω resistor is used to increase the opening time of the switch, i.e., it is used to decrease the switching speed. There is also a 20 kΩ resistor for discharging the junction of the switch when it is turning of. Final version of the gate driver circuit including the IGBT is presented below.

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**Buck Converter**

Buck converter is a basic step-down converter, and it will be utilized to drop the DC link voltage to the at most 180 V depending on the duty cycle. The basic buck converter topology is presented below.

Diagram

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It can be easily seen that whenever switch is on, the output voltage is equal to DC link voltage, and whenever the diode is conducting, output voltage will be zero. Mathematically speaking

If the mean value of the output voltage is calculated, it can be seen that it is equal to 180 V at the maximum duty cycle which is the desired output voltage according to the project definition. In more detail,

In the preceding section, this solution procedure will be implemented in Simulink environment except the gate driver circuit because the components in gate driver circuit are not available in Simulink. So, gate driver topology will be implemented and simulated in LTSpice environment.

**SIMULATION RESULTS**

The desired topology is simulated via Simulink environment. The Simulink model can be seen below. According to the model, steady state switch current and voltage, diode current and voltage, and output voltage and current are as follows.

Chart

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A picture containing text, antenna

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Chart

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However, during transient, current flows through the circuit is extremely high that has capability of damaging the components, which can also be seen from the figures below.

Chart, bar chart

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Chart, histogram

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Chart

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The inrush current in transient part will be eliminated with the help of the gate designed gate driver circuit.

The simulation result of the gate driver circuit is presented below, excluding the optocoupler because it has no effect on the output of the gate driver circuit.

Background pattern

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**COMPONENT SELECTION**

According to the simulation results and calculations, the components are decided as follows.

* As a rectifier, a 50 Hz three-phase rectifier module is chosen. The specific model of this rectifier is IXYS VUO36-16NO8. It is bought from a local electronic store in Ankara.
* The DC link capacitor must withstand at least 276.75 V. Also, in the simulation model, various capacitor values are tried and according to price and performance, two 330 μF 400 V electrolytic capacitors are chosen. It is bought from *“direnc.net”*. Its specific model and datasheet are not available on the seller’s site.
* At first, the switch is thought of as MOSFET whereas due to global chip shortage, MOSFETs with higher voltage ratings were too expensive, even are not in stock. So, IGBT present in the laboratory is chosen since it meets the requirements, which are withstanding around 300 V and must carry a 10 A in average, and gives a safety margin. The specific model of the IGBT is IXGH24N60C4D1.
* Freewheeling diode is chosen as MUR3060PT because it satisfies the values obtained from the simulation, which should carry around 10 A in average, and it is available in a local electronic store in Ankara.
* TLP250 optocoupler is chosen since it is available in the laboratory.

Datasheets of all the components can be seen in [GitHub Repository.](https://github.com/sametyakut/EE463-TERM-PROJECT)