# Variable Frequency AC Source

Functional Description and Complete System Block Diagram

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**Introduction:**
Variable frequency drives (VFDs) are commonly used in systems with AC motors requiring speed control (e.g., conveyor belts, pumps, pulleys). VFDs are generally comprised of the following four subsystems:
- AC to DC Rectifier
- DC Signal Conditioner (low pass filter)
- Inverter
- PWM Generator

The four subsystems work in combination to modify the frequency of the standard US 60[Hz] power signal for use in various system applications involving AC induction motors. VFDs are also used to maintain the constant volts/hertz ratio needed to limit motor current and provide the required torque on the load as the speed is varied. Without a constant volts/hertz ratio, the motor current would increase at lower frequencies (i.e., less than 60[Hz]), potentially decreasing motor reliability.

Variable frequency drives are often used in three phase power systems in industrial settings, but can also be found in single phase and DC input applications. Because of their versatility, VFDs have grown in popularity in recent years. This popularity increase has forced the manufacturers of VFDs to create smarter and more efficient VFDs.

**Project:**
The goal of this project is to design and construct a Variable Frequency AC Source (VFACS) that can be used as a platform for the development of a Variable Frequency Drive. The system will initially be developed for a single phase source, but will be extended to a three phase source if time permits. Our subsystem goals for this project are as follows:
- Development of the PWM Generation Controller with LabVIEW
- Design and Implementation of Gate Drive Circuitry
- Design and Implementation of the Inverter with Gate Drive Circuitry
- Closed-loop control for voltage

The overall goal for the project is to produce a Variable Frequency AC Source with these subsystems that will be able to drive a single phase load. Again, if time permits, a three phase VFACS will be attempted.

**High Level Block Diagram:**
Our system will be comprised of four main subsystems. The overall block diagram of the VFACS system can be seen in figure 1 on page 3. The first subsystem will be the PWM Generation Controller. This controller will be implemented in LabVIEW and will be responsible for the PWM signal generation. The inputs for the PWM Generation Controller will be a user input of the desired output frequency and a voltage feedback signal from the inverter output.
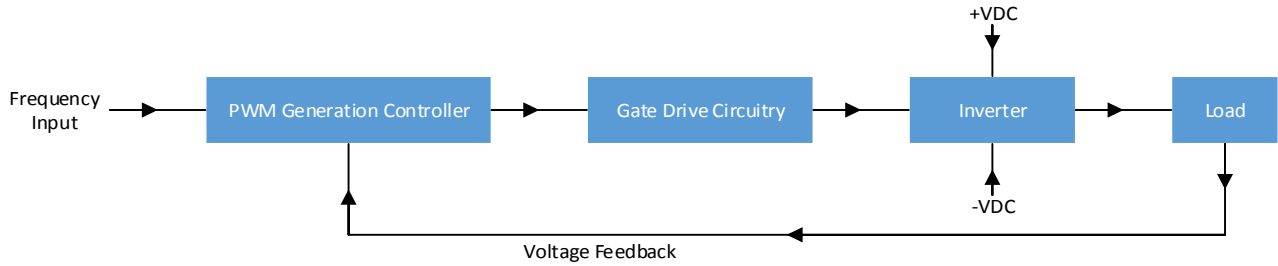
*Figure 1: Overall VFACS System Block Diagram*

The second portion of the system will be the Gate Drive Circuitry. The Gate Drive Circuitry will accept a PWM input from the PWM Generation Controller and amplify the PWM signal for use with the Inverter. The Inverter is the third portion of the system and will be comprised of IGBT pairs accepting the amplified PWM input from the Gate Drive Circuitry. It will use both positive and negative DC rail voltages to create a source signal for a load. The final component of the system will be a load. Ideally, our load will be a motor with voltage feedback signal. This signal will be used as an input to the PWM Generation Controller for increased system performance.

**PWM Generation Controller**

The general block diagram for our PWM Generation Controller can be seen in figure 2. This block diagram shows the inputs, output, and subsystems of the PWM Generation controller.
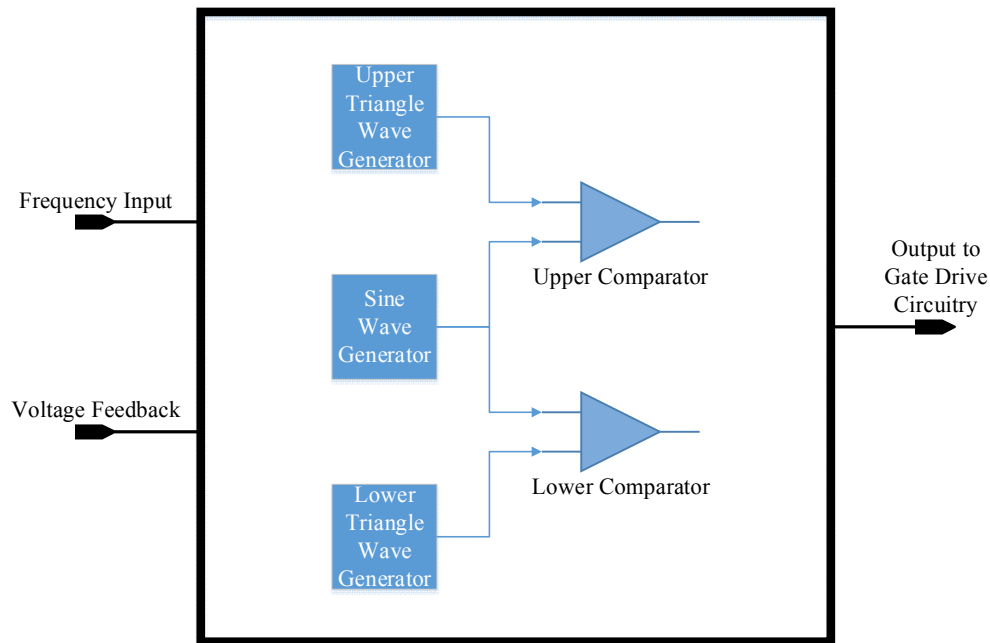


Block Diagram of LabVIEW Program

*Figure 2: PWM Generation Controller (LabVIEW Block Diagram)*

The PWM Generation Controller will accept an input from the user for a desired output frequency. The desired frequency input will be entered into LabVIEW where software will then generate the PWM signal output for the Gate Drive Circuitry. This subsystem will also accept feedback signal from the inverter output. The voltage feedback signal will be used to ensure the PWM Generation Controller can adapt to variations in load. From the voltage feedback signal, a frequency signal will be derived to ensure that the system is operating at the correct frequency. If the desired output frequency is not met, then a system error report will be generated. This subsystem will initially be designed with one PWM output signal (upper and lower halves) to test on a single phase load. Time permitting, two additional phases will be added as outputs (upper and lower halves) via phase shifting the original PWM output signal by 120° and 240°, respectively.

To create the PWM signal, the PWM Generation Controller will use a comparison between a triangle wave and sine wave. Both the triangle wave and sine wave will be generated in LabVIEW. These two signals will then be compared as follows:
- If the amplitude of the triangle wave is greater than the amplitude of the sine wave, then the PWM will be "off" [3].
- If the amplitude of the triangle wave is less than the amplitude of the sine wave, then the PWM will be "on" [3].

There will be two comparisons used (and hence two triangle waves used), one for the positive half of the sine wave and one for the negative half of the sin wave. This technique is shown in figure 3.
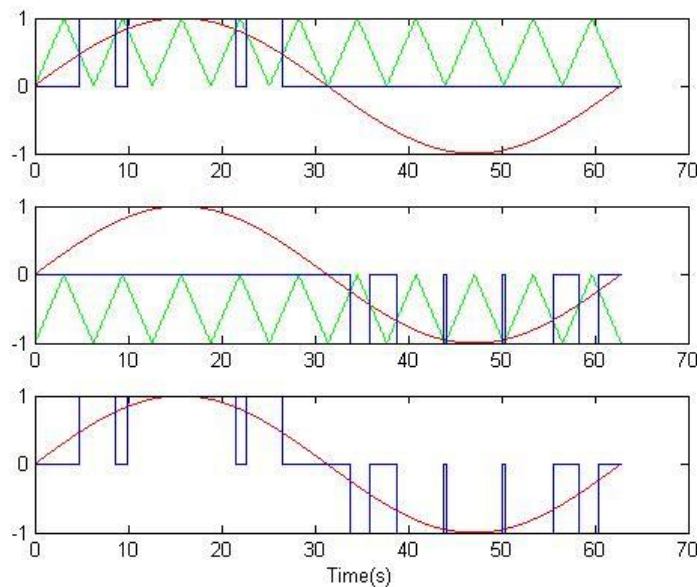


*Figure 3: Triangle Sine Wave Comparison*

Figure 3 demonstrates the fundamentals of the technique to be used for the generation of a PWM signal representative of a sine wave of varying frequency. The generation of the PWM must also

account for a constant volts/hertz ratio. The PWM Generation controller is an essential part of the overall system because it will generate a PWM equivalent representation of a sine wave that can be used for driving an Inverter.

**Gate Drive Circuitry**

The Gate Drive Circuitry will consist of three inputs and one output. Its inputs will be the two output signals from the PWM Generation Controller and biasing voltages for the amplification of the PWM signal. The output of this subsystem will be an amplified PWM signal that will be used to drive the Inverter. Again, this subsystem will be initially designed for a single phase and, time permitting, extended to three phases.

This subsystem is essential because of the power required to drive an Inverter. The generated signal from the PWM Generation Controller will not have the power needed to drive the Inverter. Therefore, we will need this power amplification system as an intermediate step from the controller to the Inverter.

**Inverter**

The Inverter will be used to produce a usable output for a load, whether resistive or electromechanical. The system will initially be designed for a single phase, as shown in figure 4, and will be extended to three phases, considering time constraints, as shown in figure 5 on page 6.
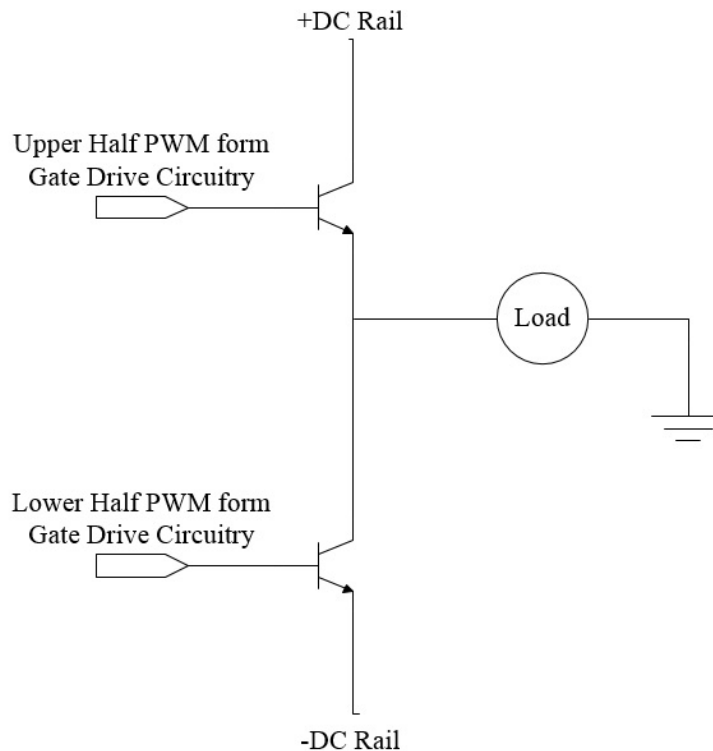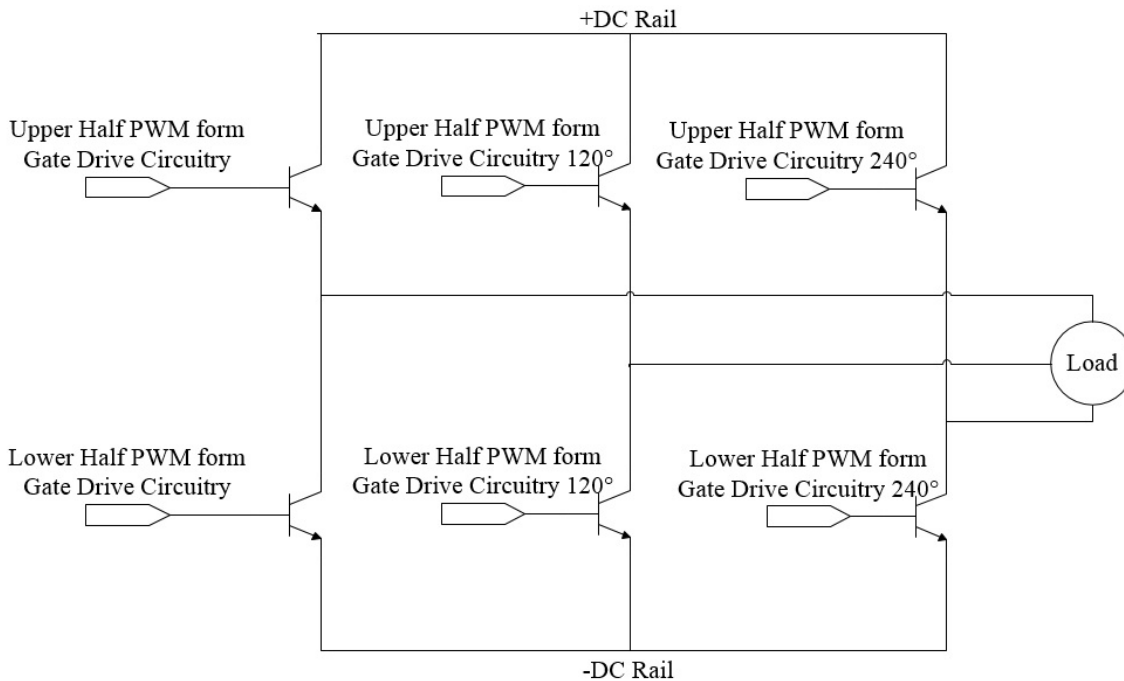


*Figure 4: Single Phase Inverter*

The Single Phase Inverter will consist of four inputs and one output. The inputs will be the amplified Upper/Lower Half PWM from the Gate Drive circuitry and Positive/Negative DC Rail Voltages. The output will be a single phase power signal that will drive either a resistive or electromechanical load (dependent on testing). If attempted, the three phase Inverter will contain similar inputs with the addition of Upper/Lower Half PWM signals with both a 120° and 240° phase shift. This extended bridge will also have two additional outputs for the two additional phases of a three phase load as indicated in figure 5.



*Figure 5: Three Phase Inverter*

The Inverter is a standard component of all variable frequency drives. It will be essential to build and test this component of the drive to verify the overall system design.

**Load**
The load will be the final component in our system. During initial single phase testing (and possibly initial three phase testing) the load will be resistive, but ultimately the system will be tested using an induction motor as the load.

**Conclusion**
The design of this VFACS will be divided into four subsystems as follows; PWM Generation Controller, Gate Drive Circuitry, Inverter, Load. The PWM Generation Controller will be a software based design using LabVIEW. The controller will be used to fabricate a PWM signal used by the Gate Drive Circuitry and Inverter. The Gate Drive Circuitry and Inverter will amplify this PWM signal which will then be used to drive the Load.

**References**

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[2]  C. Edwards, E. Smith, "Design of Simulink-Based 2-DOF Robot Arm Control Workstation" October 2006.

[3]  (June 2000) AC Drives Using PWM Techniques. [Online] Available: http://literature.rockwellautomation.com/idc/groups/literature/documents/wp/drives-wp002_-en-p.pdf

[4]  K. Gavelek, V. Panek, C. Smith, "Closed Loop Control of Halbach Array Magnetic Levitation System Height (CLCML)" October 2012.