NUEVA GRANADA MILITARY UNIVERSITY

SPEED VARIATION OF A DC MOTOR USING PWM

Angie Carolaine Ubaque Almanzar
u1802576@unimilitar.edu.co
Jorge Alberto Zorro Sánchez
u1802582@unimilitar.edu.co
David Steven Galvis Arévalo
u1802584@unimilitar.edu.co

1. RESUMEN:

Durante la práctica se usará la modulación por ancho de pulso (PWM), la cual permitirá variar la frecuencia de trabajo, mediante la comunicación con un interfaz conectado con un micro controlador el cual será el encargado de enviar las resoluciones para tener una correcta aplicación, y obtener cambios de velocidad.

2. PALABRAS CLAVE

- Frecuencia
- Ancho de pulso
- Comunicación
- Velocidad
- Control

3. ABSTRACT:

During practice the modulation is used by width of pulse (PWM), it allows to vary the working frequency, by communicating with an interface connected to a micro controller, which will be responsible for sending the resolutions to a proper application, and get speed changes.

4. KEY WORD

- Frequency
- Pulse width
- Communication
- Speed
- Check

5. INTRODUCTION

DC MOTOR:

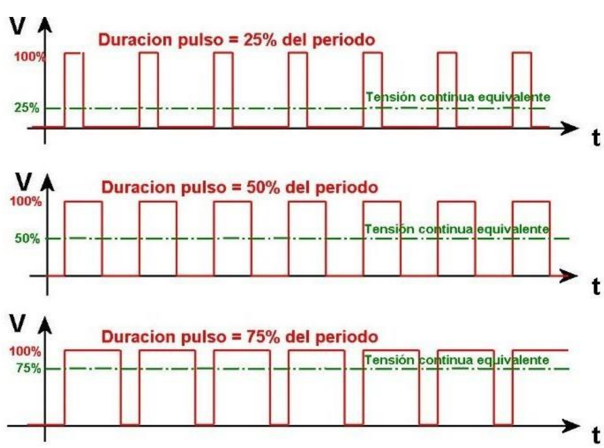
Electric direct current motors are devices capable of transforming electrical energy into mechanical energy, in this case a rotational movement. Its operation is based on the force produced by the presence of a conductive material, such as in the form of a coil, excited with a current intensity within a magnetic field present by a magnet or electromagnet..

PULSE WIDTH MODULATION:

La Pulse duration modulation is the modulation of a pulse-carrying wave, in which the magnitude of each instantaneous scanning value of the modulator wave produces a pulse of duration proportional to that value, varying the position of said of the anterior edge of the impulse, or that of the posterior or both. Pulse duration modulation is also known as pulse-width modulation (PWM)).

It is a type of voltage signal used to send information or to modify the amount of energy that is sent to a charge. This type of signal is widely used in digital circuits that need to emulate an analog signal.

These types of signals are square or sinusoidal in which the relative width is changed with respect to the period of the same, the result of this change is called the work cycle and its units are represented in terms of percentage..



Graph 1. PWM on different duty cycles.

By means of pulse width modulation in a direct current motor the speed will be regulated, it is based on the fact that if the dc supply voltage is cut in the form of a square wave, the energy received by the motor will decrease proportionally to the relationship between the high (enables current) and low (zero current) part of the square wave cycle. Controlling this ratio is able to vary the speed of the engine.

6. OBJECTIVES

GENERAL OBJECTIVE:

- Perform the speed variation of a DC motor.

SPECIFIC OBJECTIVES:

- Check the voltage level obtained from the PWM.
- Determine the relationship between speed and useful frequency of the PWM.
- Relate speed and current as a function of load.

7. METHODOLOGY:

During the practice the design for a motor with the windings connected independently will be carried out. The field winding for being in charge of producing the magnetic field will be fed to a fixed DC source, while the armature winding is connected to a PWM signal, which will be transmitted through a microcontroller.

As pulse width modulation will be used, the following relationship is made:

$$D = \frac{\tau}{T}$$

Where:

D: Duty Cycle

τ: Square signal useful period (pulse width)

T: Function period

8. DESIGN

To design the circuit that is capable of varying the speed depending on the pulse width, we proceed to think of a transistor that works as an electrical switch to be able to carry the signal from 0 to 120v.

As an electronic component, the MOSFET is chosen because it is a good signal switch and allows to control very high currents. It is controlled by potential differential so the current required is ideally 0, special to be able to connect to any digital device. It has a dewind: in the gate terminal the voltage signal that controls the saturation and short (switching) between the drain and source is placed, and can between those terminals can control a maximum current which may not be enough to handle the system; that maximum current depends on the amount of potential differential that excites the gate, the larger the gate, the higher the current the gate and source can support.

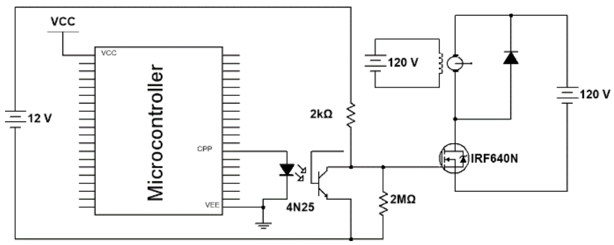
Another important element to use is the integrated circuit of an optocoupler with photo transistor, which works as an insulator between the digital circuit that is controlled with TTL or CMOS technology parameters.

As an integrated circuit, the operation of switching by light emission is completely separated from the disturbances of ambient light.

The MOSFET, because it is working as a switch, saturation or cut are not achieved ideally and the source because it is high voltage may not be fully rectified and / or filtered so it will have a low AC behavior, reverse currents will be formed that the MOSFET does not support and the motor are insignificant but will require more current that MOSFET can not tolerate. In that case, a rectifier diode is placed in reverse to the motor which will protect the engine in case of exhaust of currents in reverse and in that case, the system will not ask for more current than is needed. The characteristic of being a rectifier is that it has a small switching time for the same purpose of rectifying high frequency signals.

The switching time factor is also present in the MOSFET and the optocoupler, so the PWM will have its useful working frequency under the switching time parameters of these elements. Because of this, the signal will never be able to have useful working periods very close to 0, or the motor control signal will not perfectly be a digital signal modulated by pulse width, it could have a sinusoidal behavior.

Taking into account the above, the assembly that will be implemented is as follows:



Graph 2. Electrical drawing.

9. MATERIALS

- Alligator clips
- Three-phase cable
- Tachometer
- Power table
- Multimeter
- Banana- banana connection cable
- DC Motor
- Electrodynamometer
- Distribution strap
- Voltage source
- Embedded microcontroller STM32F4 Discovery
- Transistor MOSFET IRF740B
- Optocoupler 4N25
- Rectifier diode 1N4004

10. PROCESS

1- The parts of the motor, the electro-dynamometer and the power supply are identified to have a proper connection.

2- Perform measurements for supply voltage: 120v for field and a square signal of 1kHz with useful frequency of 100%.

3- Measure the speed of the motor at the load variation.

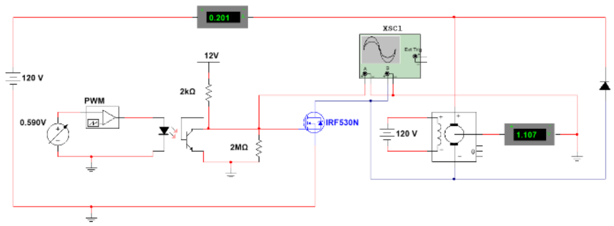
4- Repeat the previous step for different percentages of the useful frequency of the square signal, until it is 0%.

5- With the data obtained, graph speed as a function of the load and speed as a function of the voltage level that gives the useful frequency of the square signal.

11. TEST PLAN

To carry out the procedure mentioned above, it was necessary to carry out simulations that guide the results of the practice. In this way, an approach to the different reactions of the system is sought as the frequency of modulation varies by pulse width.

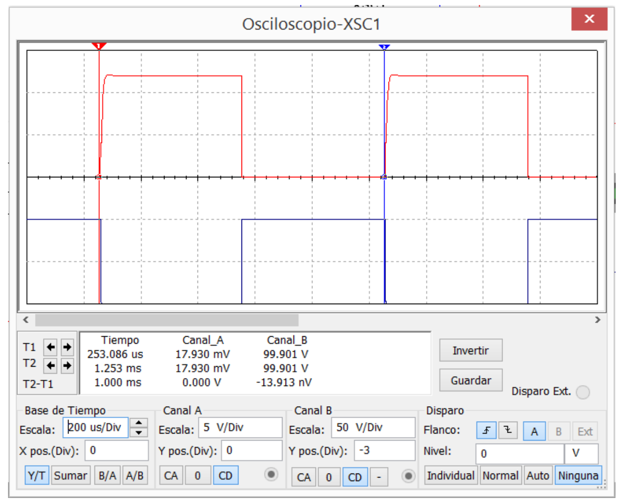
The simulation has the following assembly:



Graph 3: Simulation.

The motor is in an independent connection, where two sources are necessary, one fixed to the field winding that always produces enough field and the other variable to the armature winding to vary the speed. The variation is carried out by switching a 120 V source obtaining a pulse width modulation signal of 120 V amplitude. The switching will be carried out by a MOSFET transistor which allows voltage controlled switching and power handling. As the signal will be produced by means of a direct voltage controlled pulse width modulation source element, the control circuit must be decoupled from the power circuit and for this task is performed by the optocoupler, a photodiode connected to the PWM and a phototransistor connected to the MOSFET transistor. The operation is as follows: the PWM signal will switch the phototransistor of the optocoupler, which will be at 12 V connected, that is, it will produce a PWM signal of 12 V amplitude in a voltage divider; that signal will drive the gate of the MOSFET and switch the 120V source.

The simulator oscilloscope displays the output voltage divider signal by the optocoupler and the 120 V switched signal at the MOSFET drain terminal:



Graph 4: Simulation oscilloscope signals.

The first signal is square with amplitude 12 VPP with offset of 6 V, and the blue signal has the same amplitude as the red but with amplitude of approximately 120 VPP and offset of 60 V, so both are DC signals. They are at 50% useful cycle the set frequency of 1 kHz, one inverse of the other: if the red signal is high, the blue signal is low and vice versa.

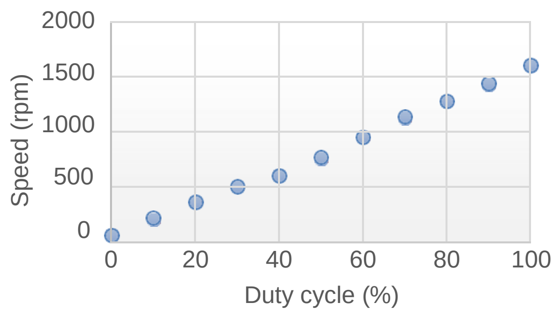
By varying the useful frequency and measuring the speed and speed obtained, the results obtained are as follows:

Duty cycle (%)	Current (A)	Speed (rpm)
0	0,201	60
10	0,302	200
20	0,398	360
30	0,499	500
40	0,598	600

50	0,696	750
60	0,798	950
70	0,899	1120
80	0,998	1275
90	1,097	1425
100	1,199	1600

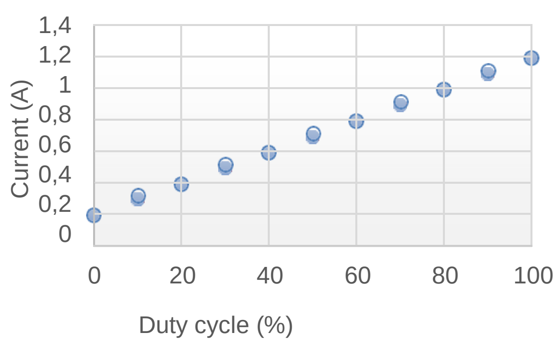
Table 1. Speed and current in function of duty cycle.

Having the data, they are organized in a graph.



Graph 5: Speed in function of duty cycle.

The graph shows the linear behavior of the velocity by varying the pulse width of the square signal. And in the same way the behavior of the current is graphed as a function of the variation of the percentage of pulse width:



Graph 6: Current in function of duty cycle

7. EXPERIMENTAL RESULTS

As the speed variation is made in independent connection, the data obtained vary depending on the DC voltage level of the output PWM signal of the microcontroller, and with the voltage divider, and then repeat it with load on the motor.

Current and speed data are as follows without load:

Voltage (V)	Current (A)	Speed(rpm)
0,15	0	0
1,98	0,038	350
3,94	0,085	695
5,97	0,12	938
8,04	0,14	1095
10,15	0,17	1254
11,2	0,19	1370
12	0,19	1370

Table 2. Experimental data without load.

Now the table of current and voltage data with load:

Voltage (V)	Current(A)	Speed (rpm)
1,99	0,048	226
3,97	0,116	519
5,97	0,180	763
8,05	0,230	970
10,21	0,290	1180
12	0,360	1345

Table 3. Experimental data with load.

From these same data, they can be passed to the domain of the percentage of pulse width, since that DC level represents the percentage of time at which the pulse lasts with respect to the frequency of the PWM signal already defined at 1 kHz. The equation that is needed to calculate the pulse width percentages is as follows:

$$\%PWM = {(V_{GS} * 100\%)}/{12\ V}$$

Applying the equation, the percentages of each DC voltage level in the vacuum and loaded measurements are as follows:

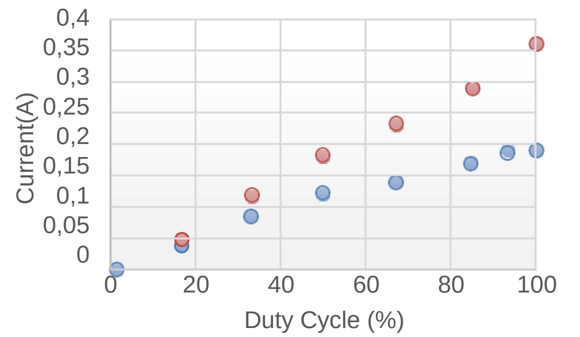
Without load		With load	
Voltage (V)	Duty cycle (%)	Voltage (V)	Duty cycle (%)
0,15	1,25	1,99	16,58
1,98	16,5	3,97	33,08
3,94	32,83	5,97	49,75
5,97	49,75	8,05	67,08
8,04	67	10,21	85,08
10,15	84,58	12	100
11,2	93,33		
12	100		

Table 4. Equivalence of the DC level in percentage of duty cycle..

8. ANALYSIS OF RESULTS

To understand and be able to analyze the behavior of each parameter of which measurement was made regarding the variation of the DC level of the PWM signal that feeds the MOSFET, but the analysis will be carried out with respect to the width of the pulse, the percentage of modulation of the signal.

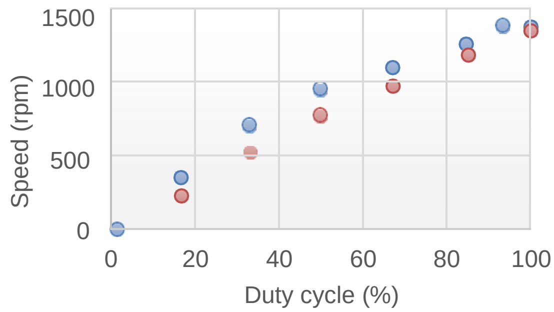
The first graph is that of currents for measurement under vacuum and with fixed load:



Graph 7: Current as function of PWM without load (blue) and with load (red).

By the simple fact of having presence of load, the motor consumes more current that works under vacuum, then like the motor in series or in parallel, the current consumed by the armature winding depends on the load supplied to the motor, because the more load, the force against electromotive increases, regardless of the field exerted by the field winding. In addition the increase in current with load you have to behave more linear and vacuum for the latest measurements you have to stay at a constant value.

The following graph is the velocity value depending on the variation of the pulse width percentage:



Graph 8: Speed as function of PWM with load (red) and without load (blue).

The two behaviors are roughly linear and tend to have the same value in a percentage of PWM. That only implies that it has the characteristic of the motor in parallel: the speed is approximately constant depending on the load, but the speed depends on the supply voltage supplied. That is, the DC level of the PWM signal varies the speed, and at that level, the speed remains constant at different load values.

9. CONCLUSIONS

The relationship between motor speed and pulse width percentage are related in a directly proportional way. By making more accurate control of the motor speed, the PWm voltage is amplified with a transistor.

10. BIBLIOGRAPHY

- Datasheet Transistor MOSFET IRF640N http://www.infineon.com/dgdl/irf640n.pdf?fileId=5546d462533600a4015355e7b76c19eb
- Control de velocidad de un motor DC mediante el uso del PWM. http://robots-argentina.com.ar/MotorCC_ControlAncho.htm

- Enciclopedia Salvat Ciencia y Tecnología, ESCYT. Modulación de impulso: Modulación por duración de impulsos (MDI).

- PWM: Modulación por ancho de pulso. [En línea]. Available: http://www.arduino.utfsm.cl/modulacion-por-ancho-de-pulso-pwm/