Study and Control of a DC Motor for a Line Tracking Robot

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Abstract

On this Project we proposed to study and control a motor for further uses on a line tracking robot, having by final goal the CRUO's competition (Robot's competition in Oviedo's university). We will also study other aspects apart from the motor, as batteries and how to power them.

Objetivos

Como meta para este trabajo se proponían dos objetivos principales:

-Elegir un motor que pudiera ser implementado en un robot sigue-líneas para competir en la competición de robótica de la universidad de Oviedo, realizando, por un lado, el estudio de los componentes y estructuras físicos más adecuados para el montaje, y por otro, la búsqueda del software necesario, con la intención de controlar tanto la velocidad como el sentido de giro de dicho motor.

-Entender el funcionamiento de las baterías de litio, elegir unas adecuadas para el proyecto y estudiar y diseñar la topología de potencia necesaria para cargar dichas baterías en el menor tiempo posible y sin dañar ningún componente.

Keywords

DC motor, Stepper motor, Brushed DC, Full Bridge, H bridge, CRUO, flyback, PWM, EPWM, LIPO batteries, driver, heatsink, PCB.

THE COMPETITION

Figure 1.- Last year's CRUO's logo

This competition is an annual event held by the Oviedo's University for the last four years. There are several categories: sumo, line tracking (one more accurate, ecobot and the fast one). Each one of the line tracking robots are different but are intended for the same thing: following a line.

Our project will be based on its power, control and motor selection for the last one, the fastest.

MAKING DECISIONS – THE SHAPE

When you start a project like this, one of the first decisions you have to make is the shape of the robot itself, because this will lead us to choose the rest of the components, as motor, semiconductors, sensors and electronic in general.

The final decision was the typical line tracking's shape, with a large body in which you can notice two main parts, back part (the main part of the robot, all on top of a PCB) and forward (just a ball caster with some optical sensors so the robot can "see" where it is going. Everything will be controlled with a microchip's pic.

MOTOR ELECTION

Once the shape is decided, we need to choose a motor. There are three main types where we can use DC power: step by step, brushed DC or brushless DC. To reach a decision it will be necessary to study how it is and works each one of it.

Stepper motor

It is a device capable of converting a series of electrical impulses into angular displacement: unlike conventional brushed DC, which rotates in a continuous way, this one can advance a serial of degrees each time it receives an impulse (from 1.8º to 90º). This property makes it ideal when it comes to high precision mechanisms, and can make it stay still in a desired position.

Figure 2.- Stepper motor

How it works: it is formed by a fixed part, known as stator, and a moving part known as rotor.

The stator held the coils, and when a current flows through them, they create the north-south poles needed for the rotor's movement (permanent magnet).

The movement is generated due to changes of excitation coils, creating a rotating magnetic field that causes the motor to rotate according to its direction of rotation.

When a change in these coils is produced, a magnetic field is generated, and that is how we control it.
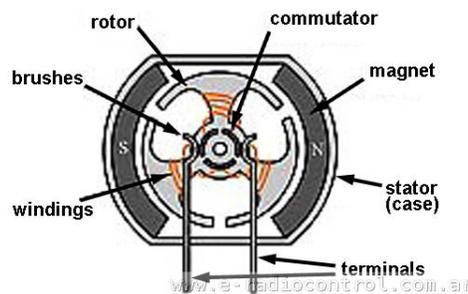
Brushed DC

Figure 3.- Typical brushed motor in cross-section

DC motors are based on repulsion that exert the magnetic poles on a permanent electromagnet when, in accordance to Lorenz's law, interact with the magnetic poles of an electromagnet that is mounted on a shaft. This electromagnet is called "rotor" and its shaft allows it to rotate freely between north and south permanent electromagnet's poles, held into the motor's body, also known as stator.

This type of motors are difficult to build and have low reliability due to the progressive wear of the brushes, and its efficiency is worse than brushless'. On the other hand, they are easy to control, even in open loop, and they are cheaper than other types of motor. Their power range between a few watts to thousands, and they can reach up to 20000rpm.

How to control them: the best way to control the way it rotates, in addition to its speed, is the use of what is known as H bridge, powered by PWM (pulse width modulation).

Brushless motor (BLDC)

Electronically commutated DC motors (brushless DC) are special because of its great torque conditions, high performance, wide speed range and long life service.

They have no mechanical commutation (no brushes), what leads them to a soft turn, no holding torque in rotation, but force them to dispose of external electronics (or integrated) to make the switching. On the other hand, their life and speed are longer, and its efficiency up to 90%, so they generate less heat and reduce the size (when needed) of heat sinks.

They are based on the grouping of three coils, electrically placed at 120° to generate the rotating magnetic field of the motor.

How to control it: control and power stages differ completely from a brushed DC motor. It must include electronic control for its operation. Sequential switching of the coils is based on rotor position signals, generated by the Hall sensors or when the current comes to zero (for simple applications, abrupt start).

Conclusion

Each motor could be, in a way, good for the project. We finally decided to use a brushed motor. The reason for not taking a step by step motor is because it can, sometimes, skip an impulse, and this could cause the robot to lose control. Another reason, not so important, is that step by step motors can't normally reach the speed that we are looking for, even though we could find one.

The reason to discard a brushless motor is that we believe that the same speed that we look for, can be easily reached both by brushless and brushed, and it's easier to control this last one.

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CHOSEN MOTOR

</div>

After we made the decision on wich type of motor is the best, we needed to chose one. The place to look for it was *http://www.maxonmotor.es,* with a huge DC motors catalog.

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Figure 4.- Maxon DC motor

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We looked for a motor that could provide at least 4000rpm, and found one that matched our expectation (118683).

HOW TO CONTROL A DC MOTOR –H BRIDGE

If you want to make a motor move, it can't be connected directly to the PIC, because it can only give around 20mA. To solve this problem, a current amplifier is needed. The easier way is to use transistors.
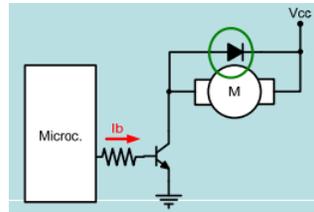

Figure 5.- Motor control with only a transistor

With this arrangement, the PIC will provide the necessary current to force the transistor to start driving and giving the motor the necessary current for its operation.

Thus, the motor can rotate in only one direction. A way to allow rotation in both directions is by interchanging supply terminals, which is carried out using a device known as H Bridge.

Transistors here work as interrupts, so it is only important their operation in cut-off and saturation region. It is really important not to make two transistors in the same part of the bridge being "closed" at the same time, because this will end up causing a short circuit. The way to avoid this is by using *Dead-band delays*, switching them according to the time it takes them to switch from one state to the other.

This configuration has a problem, and it's the appearance of a floating voltage in the intermediate part between the two transistors on each side. To avoid this, some sort of system will be needed to be implement.

HOW DOES PWM AND EPW WORK?

PWM consists on an electronic control, in which voltage isn't supplied in continuous mode, it's supplied in pulses than can be regulated (pulse width modulation).

Keeping a constant frequency and varying the time the signal remains high, the average voltage to the motor is changed.

The duty cycle is the percentage of time the signal remains in active status above the total time considered (pulse width / pulse period), so changing the pulse width changes the average voltage received by the motor.
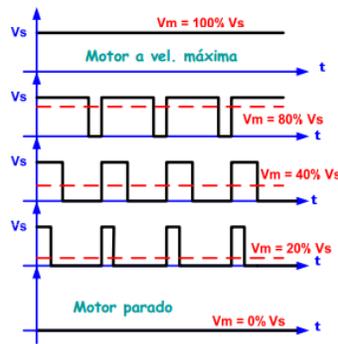
Figure 6.- Response to different duty values

PWM on the PIC:

A lot of PICs own hardware modules which allows the PWM generation on a simple mode, where you can chose how much time the signal will be "one" and the total time or frequency.
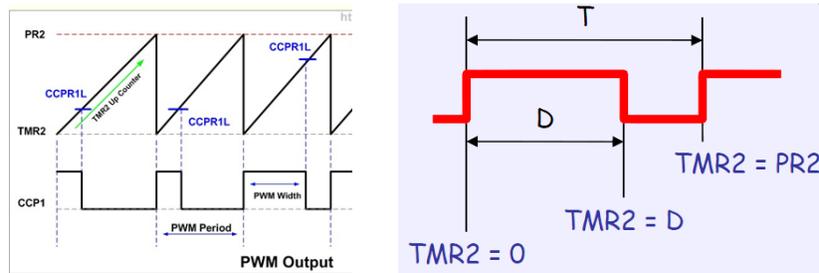

Figure 7.- Values to be considered using PWM control

This function is normally integrated in a CCP module (Capture/ Compare/ PWM). Depending on the PIC we have, it can have on or more of this modules, all working at the same frequency but each one working with a different duty if needed. Associated with this module there is a non configurable pin and a timer. The count this timer makes is compared with a pair of registers: with one (PR2) we decide the moment where the output signal switch to one and with the other (CCPRxL together with two bits in CCPXCON to make it up to 10 bits) the time when it switch back to zero. This registers are related with some equations:

$$T = (PR2 + 1) * 4 * Tosc * PrescalerTMR2$$
$$T_{on} = (CCPRxL: CCPxON < 5: 4 >) * Tosc * PrescalerTMR2$$

EPWM on the PIC:

This module comes with more output pins and allows the PIC to work on half or full bridge, and some other options. The equations are the same as PWM's.

Full bridge mode is intended for bidirectional motors or power converters control. Depending on the type of mosfets that we use (channel N or P) it will be necessary to set one option or other. One change in a bit will cause the module to change direction in the next PWM cycle. To avoid short circuits due to slow switching, this module, unlike PWM, allows the user to set some *Dead-band delays*.
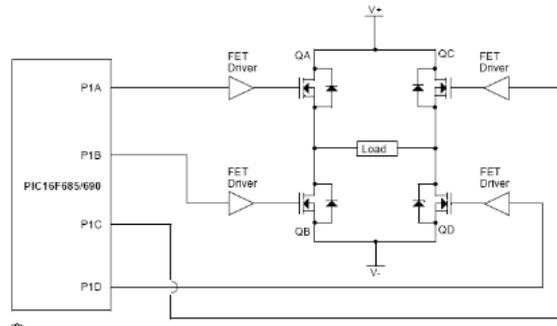

Figure 8.- Typical application using full bridge mode

HOW TO AVOID FLOATING VOLTAGE

To avoid this problem we will use an integrated circuit base on a bootstrap circuit. The one we chose is IR2110. It is a high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 500 or 600 volts.

Bootstrap circuit is based on a capacitor (outside of the integrated) which stores energy when the low side transistor is on, and then this energy is used to switch the upper transistor. It will also be necessary to use a diode between V_B and V_{CC}.
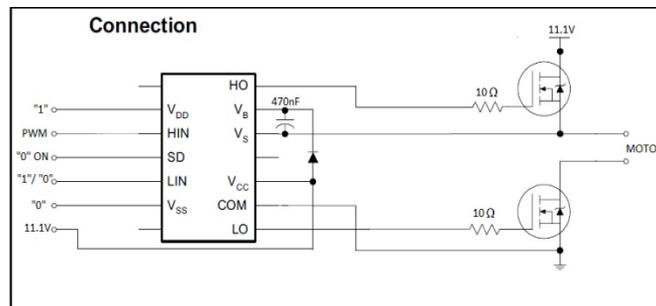

Figure 9.- IR2110 connection and components values

V_{DD} will be 5 volts because we are connecting it to a PIC. SD will always be "0" unless we want to turn it off. HIN is what we want to get to the upper size mosfet and LIN to the low size mosfet. One of these two signals can be an square PWM wave form. To properly work, we need to provide V_{CC} with at least 10 volts, and 20 volts will be the maximum. The wave forms that will finally reach the mosfets will be HO y LO, and COM will be connected to the ground. Vs provides the necessary floating voltage needed by the load to reach the desired tension.

Values for its components were obtained thanks to some application notes.

COMPONENTS

In this section we choose components to build our H bridge. We need 4 N channel mosfets, with their 4 protecting diodes, one decoupling capacitor against noises coming from the motor and a little resistor to protect the motor against surges.

IRFB33N15D mosfet

This is an N cannel mosfet (International Rectifier). Its high switching frequency makes it ideal for our application with PWM. The package selected will be TO-220AB.

Figure 10.- IRFB33N15D, TO-220 package

1N4148 diode

It will be used as a protection in parallel with mosfets in the h bridge. It is also suitable for working as bootstrap's diode in the IR2110 (fast switching, so it reduces the amount of charge given back to grid by the capacitor). It is also good at high temperatures, important in case of needing the capacitor to maintain the load for a long time.

Decoupling capacitor - 100nF

It will be placed in parallel with the motor, to reduce inductive noises coming from it.

Resistor

The last component will be a very small resistor ($0,1\Omega$ or less). Its purpose will be to measure the amount of current that will reach the motor. If this current is bigger than the one asked normally by the motor, supply must be cut down, so we are making a software control.

Our motor will ask, at most, 0.711A, the voltage drop in the resistance would be 0.0711V. We will need to make sure that in case of exceeding this value, we would interrupt the power supply.
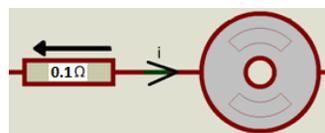

Figure 11.- Resistors connection

PIC16F690

Microchip's 20 pins pic, available in different packages. It allows EPWM module use in full-bridge, very useful for our application. Other modules that will also be needed are: timers, 10 bit A/D converter, interruptions and comparator modules (where the 0,1Ω resistor will be connected).

MOSFET HEATSINK

This section is dedicated to know if the selected mosfet will need an additional heatsink. We know from its datasheet:

P_D (@ T_A=25ºC)=3.8W $\qquad$ T_{Jmax}=175ºC

R_{JC}=0.9ºC/W $\qquad$ R_{JA}=62ºC/W

R_{DS}=0.056Ω $\qquad$ T_{on}=13 ns $\qquad$ T_{off}=23 ns

Knowing that the motor will ask for a maximum current of 0.711A, that the mosfet will be powered up with a maximum value of 11.1V and that the working frequency is 20kHz we can calculate the power losses when it is switching:

$$P_{com} = \frac{1}{2} * V_s * I_s * f_s * (t_{on} + t_{off}) = \frac{1}{2} * 11.1 * 0.711 * 20 * 10^3 * (13 + 23) * 10^{-9} = 0.057W$$

And the power dissipated in conduction, assuming duty=0.5:

$$P_{cond} = R_{DS} * I_{rms}^2 = 0.056 * \left(0.711\sqrt{0.5}\right)^2 = 0.0142W$$

The total power losses will be:

$$P_T = 0.057 + 0.0142 = 0.0712W$$

We know the maximum power dissipation allowed by this component is 3.8W, so we don't need a heat sink.

POWER SUPPLY - BATTERIES

For this project, we will use Lithium batteries (LiPo) consisting of connected cells in serial or parallel, each one with a voltage up to 3.7V. Their main parameters are:

Capacity: It indicates how much energy the battery can hold, measured in Ah.

Serial connection: It allows increasing the supplied voltage without increasing the maximum capacity.

Parallel connection: It allows increasing the supplied capacity without increasing the maximum voltage.

Name: Batteries formed by more than a cell come with a number, which indicates the number of cells, and a letter: S for serial and P for parallel.

Discharge speed: How fast the battery can be discharged without damaging it. It's expressed as a number followed by letter C. This factor limits the maximum current that we can demand during a time space. It is calculated as:

$$Time(\min) = \frac{Battery's\ capacity(A*min)}{Maximum\ current\ (A)}$$

This is a theoretical time, it's not common to ask the maximum current all the time, and there will be power losses due to different causes. Also, it is not recommended to let them discharge completely, because this can damage the battery.

To know which battery to use, we must take on account how much current our motor asks, and the power supply demanded by different elements of the circuit (PIC, IR, etc), in addition to a safety margin.

Figure 12.- LiPo battery

The chosen battery will have 300 mAh, 3.7V, 1S, 25C, 8 grams. We'll place three serial batteries to reach 11,1V and this way we can supply the IR2110, which is the one that demands more supply (at least 10V). The rest of the components will need to have its supply reduced.

The maximum current we can demand is 0.3*25=7.5A in $\frac{0.3*60}{7.5} = 2.4\ min$. We have two motors; we will need 1.4A, so the battery will last $\frac{0.3*60}{1.4} = 13min$, enough to finish a race.

Notice that, because we are using 11.1V batteries, but our motor only asks for 4.8V, it is not recommended to reach that level, so we can improve our motor's life. We will work with 50% duty as a maximum value, this way we'll make sure that only 5.5V reach the motor at most.

CHARGING BATTERIES - FLYBACK

Once the batteries are chosen, we need a way to charge them. At first, we thought about buck converters, reducing 325 rectified volts to 3.7V, but we find out that the duty needed is extremely small and difficult to implement in a real design. This problem can be solved using a transformer, which will adapt the voltage working at high frequencies to reduce size and power losses. Another advantage is that it provides galvanic isolation, protecting this way against short circuits in case of failure. Switching a power mosfet will result in the required duty. This semiconductor will need to stand up to 325volts.

Considering the following information, the design process can begin:

$$V_e = 325V \qquad V_{load} = 3.7V \qquad I_{load} = 5A \qquad f = 50kHz$$

325volts come from an AC/DC converter connected to the network. Even though we will get a DC level with ripple, it doesn't mind because it will all happen in the high side part. 5A come from the maximum current that we want to give to our batteries. Actually, this value is 7.5A, but it's not recommended to charge the battery to its maximum permissible current. 3.7V are the voltage on each battery, and we will charge them separately. 50 kHz are chosen in a way they are out from audible frequencies.

We will take R_{load} as $\frac{3.7}{5} = 0.74\Omega$. Assuming 0.5 as initial duty, we can calculate transformer's winding turns ratio.

$$U_s = U_e * \frac{N_2}{N_1} * \frac{d}{1-d} \rightarrow 3.7 = 325 * \frac{N_2}{N_1} * \frac{0.5}{1-0.5} \rightarrow \frac{N_2}{N_1} = \frac{1}{87.84}$$

Rounding this value up to 90, the needed duty will be:

$$3.7 = 325 * \frac{1}{90} * \frac{d}{1-d} \rightarrow d = 0.494$$

Knowing that he average current through the load must be equal to the average current through the diode, and knowing that we want 5A to reach the load, admitting a 10% current ripple, we can estimate the coils' value:

$$I_{load} = \frac{1}{2} * \frac{N_1}{N_2} * \frac{U_e}{L_1} * d * T * (1-d)$$

$$0.5A = \frac{1}{2} * 90 * \frac{325}{L_1} * 0.494 * \frac{1}{50 * 10^3} * (1 - 0.494)$$

$$L_1 = 0.146\ H = 146mH$$

$$\left(\frac{N_1}{N_2}\right)^2 = \frac{L_1}{L_2} \rightarrow L_2 = \frac{0.146}{90^2} = 18 * 10^{-6}\ H = 18\ \mu H$$

As we made with the current ripple, in terms of calculating the capacitor's value we'll admit a 10% voltage ripple:

$$\Delta U_c = \frac{I_{load} * d * T}{C} \rightarrow C = \frac{5 * 0.494 * \frac{1}{50 * 10^3}}{0.37}$$

$$C = 1.33 * 10^{-4} F = 134 \mu F \rightarrow \boldsymbol{470\ \mu F}\ \text{(standard value, less voltage ripple)}$$
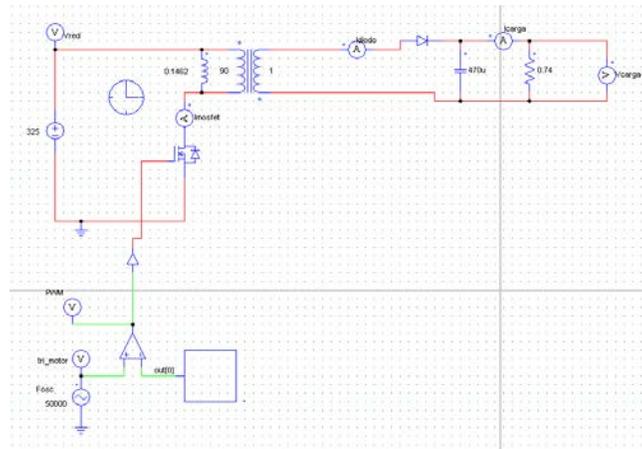
Simulating all of these data with PSIM we have the following circuit:
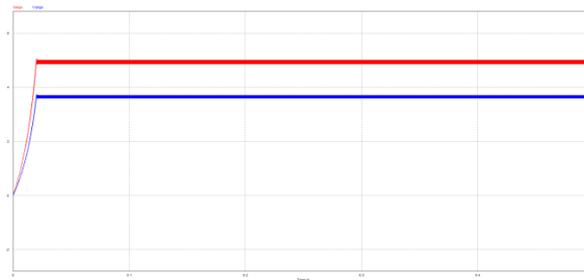

Figure 13.- PSIM design

Representing voltage and current through load:

Figure 14.- Voltage (down) and current (up) through load

As you can see, current's average value is 5.00A (up) and voltage's average value is 3.70volts (down), both equal to calculated values. Current and voltage peak at startup is avoided by an algorithm that is changing the duty gradually to reach the steady state smoothly.

If we feedback the current to the PIC using a "shunt" resistor, we could determinate whether the current that reaches the load is the one expected and, otherwise, change the duty to adapt it to the required value.

This resistance will be chosen in the same manner as the motor's one, a small value (about 0.1 Ω) that does not affect the circuit.

COMPONENTS

A power mosfet and a diode is needed, and a transformer's design.

Mosfet IRFR825

This N cannel mosfet (international rectifier) can handle up to 500volts and will be switched from the PIC using PWM.

BY229 diode

Power diode (philips semiconductors) in his TO-220 package. It can handle up to 150volts (average voltage).

Figure 15.- BY229 diode in TO-220 package

Transformer design

We know that L_1=146mH, and its current will be more or less 100mA. The remaining values are a part of the design.

Material: using Siemens' N27 material, it is necessary to avoid the region near the elbow, to reduce big losses, but not too far away, because that will increase the size of the design. Considering this we'll take 300mT as a maximum value.

It is necessary to look for a core that allows a correct winding, having a bigger window's area than the one needed, also knowing that we won't take advantage of all the space (more or less 50%).

Using E32 core, we'll have A_e=83 mm^2 and window's area $11.2 * 2 * \frac{22.7-9.5}{2} = 147.84 mm^2$.

Using simplified formulas, the unknown values are g and N:

$$L = \frac{B_{max} * A_e * N}{i_{max}} \rightarrow 0.146 = \frac{0.3 * 147.84 * 10^{-6} * N}{0.1} = 329.18 \rightarrow \boldsymbol{N = 329}$$

$$B_{max} = \frac{\mu_o * N}{g} * i_{max} \rightarrow 0.3 = \frac{4\pi * 10^{-7} * 329.18}{g} * 0.1 \rightarrow g = 1.38 * 10^{-4}m \rightarrow \boldsymbol{g = 0.138mm}$$

Now we have to check if the chosen core is suitable, assuming a 0.5mm wire diameter:

$$N * \pi * \left(\frac{\emptyset_{hilo}}{2}\right)^2 = 329.18 * \pi * \left(\frac{0.5mm}{2}\right)^2 = 64.63mm^2$$

Because we won't take advantage of all the space, we'll need at least 64.63*2=129.27mm² <147.84 mm²: the chosen core matches our design.

To reach this result, several cores have been tested, with the intention of optimizing both the space and weight.

Having 329.18 windings in L_1, N_2 would be 329.18/90=3.66 → **4**

The last step in this design is to know the power losses in both coils. To calculate this we'll need L_m knowing all data from design's measures:

$$L_m = \left(\left(\frac{22.7 - 9.5}{2} + 9.5\right) * 2 + 9.5 * 2\right) * 329.18 = 16854.016mm$$

$$P_{cu} = \rho_{cu} \frac{L_m * N}{\pi * \left(\frac{D_{wire}}{2}\right)^2} * i_{rms}^2$$

High side:

$$P_{cu1} = 2.07 * 10^{-8} * \frac{16.85 * 329}{\pi * \left(\frac{0.5 * 10^{-3}}{2}\right)^2} * \left(0.1 * \sqrt{2}\right)^2 = \mathbf{11.69W}$$

Low side:

$$P_{cu2} = 2.07 * 10^{-8} * \frac{1,24 * 3.66}{\pi * \left(\frac{0.5 * 10^{-3}}{2}\right)^2} * (6.5)^2 = \mathbf{20.21W}$$

HEATSINK

The same way as the H Bridge's mosfet, we'll need to know if the designed flyback needs a heat sink.
From its datasheet we know:

T_{Jmax}=150ºC	R_{DS}=1.05Ω	
R_{JC}=1.05ºC/W	R_{JA}=50ºC /W	T_{on}=8.5 ns	T_{off}=30 ns

Knowing these values we can estimate the power losses due to switching process, assuming 100 mA:

$$P_{com} = \frac{1}{2} * V_s * I_s * f_s * \left(t_{on} + t_{off}\right) = \frac{1}{2} * 325 * 0.1 * 50 * 10^3 * (8.5 + 30) * 10^{-9} = 0.0313W$$

The power losses in conduction:

$$P_{cond} = R_{DS} * I_{rms}^2 = 1.05 * \left(0.1 * \sqrt{0.494}\right)^2 = 0.0052W$$

So the total power losses will be:

$$P_T = 0.0313 + 0.0052 = 0.0365W$$

Assuming ambient temperature as 50ºC, the temperature reached on junction will be:

$$T_j = 50 + 0.0365 * 50 = 51.825ºC < 150ºC$$

As you can see, the maximum temperature is not bigger than the maximum admissible temperature, son it doesn't need a heat sink.

Repeating the same steps to the diode, we know:

$$T_{Jmax}=150ºC \qquad R_{JA}=20ºC \ /W \qquad R_{JC}=2ºC/W \qquad V_D = 1.4V \qquad R_D = \frac{0.1}{4} = 0.025\Omega$$

So we can calculate power losses due to conduction:

$$P_D = R_D * I_{rms}^2 + V_D * I_{D(med)} = 0.025 * \left(5 * \sqrt{0.494}\right)^2 + 1.4 * 5 = 7.3W$$

Assuming ambient temperature as 50ºC, the temperature reached on junction will be:

$$T_j = T_A + P_D * R_{JA} = 50 + 7.3 * 20 = 196ºC > 150ºC$$

It is clear that a heat sink is needed.

Heatsink calculation

Choosing a heat sink for a TO220 with direct contact and no mica, we have R_{cs}=0.8 ºC/W. The thermal resistor is negligible compared to the others, because it is quite bigger. So, having again 50ºC as ambient temperature and the maximum allowable temperature, we have everything to get R_{sa}:

$$R_{SA} = \frac{150 - 50}{7.3} - (2 + 0.8) = 10.9 \frac{^oC}{W}$$

This value is the maximum value allowed so that there is a good power evacuation. Lower values of thermal resistance will be better, because this way the component will not reach the maximum junction temperature under any circumstances.
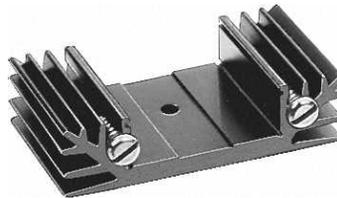

Figure 16.- TO-220 Heatsink

In RS we find this black model (black is better because it favors heat dissipation) for TO220. Its thermal resistance is 6.8ºC/W, so we have enough dissipation:

$$T_j = 50 + 7.3 * (6.8 + 0.8 + 2) = 120^oC < 150^oC$$

POWERING ELECTRONIC COMPONENTS – VOLTAGE ADAPTATION

As we wrote above, our batteries will give us 11.1volts, but our electronic circuitry, such as the PIC, needs to be fed up to 5volts. We need something that allows us to lower this voltage, so we get something accepted by the components. To perform this task, there are several options: a resistive divider, a small integrated circuit or a buck converter. We won't use this last one because we need to make a reduction in order to feed low power integrated circuits, and there are simpler solutions.

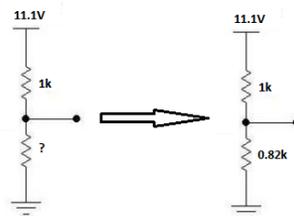**Resistive divider:** It consists on putting two resistors in series.

Figure 17.- Resistor divider calculation

At the union of the two we will have the voltage desired. To calculate this, we will randomly give a value to one resistor and calculate the other knowing what voltage we do want. Choosing this value as 1k, the other will be:

$$I = \frac{11.1 - 5}{1000} = 6.1 * 10^{-3} A \rightarrow 6.1 * 10^{-3} * R_2 = 5 \rightarrow R_2 = 820 \, \Omega$$

Integrated circuit LM7805: it makes the conversion between any input voltage (up to 24volts) to 5volts. It includes short circuit protection. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current (so it is not suitable for high power conversions).

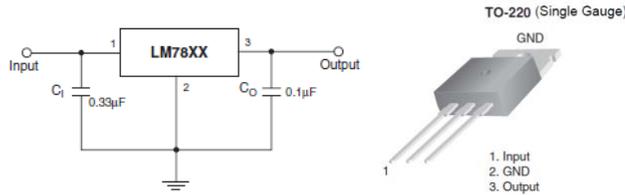Two capacitors must be added in the circuit: 0.33µF in the input and 0.1µF in the output.

Figure 18.- LM7805

LM7805'S heat sink:

In order to know if we need a heat sink here, we will operate in the same way as in the other cases. We know from its datasheet:

$$T_{Jmax}=125° \, C \, R_{JC}=5°C/W \, R_{JA}=65°C/W$$

We don't know exactly how much current our electronic components demand, but we can assume that it won't be more than 200mA, because all of them are low power components. We do know that we'll have 11.1volts on the input pin, and 5volts on the output one, so the power losses are:

$$P = 0.2A * (11.1 - 5)V = 1.22W$$

And assuming 25ºC as the ambient temperature, the temperature in the junction will be:

$$T_j = 25 + 1.22 * (5 + 65) = 110.4°C < 125°C$$

We see that we don't need a heat sink.

H BRIDGE SIMULATION

Using PSIM simulation program we'll check the motor's operation using the parameters provided by the manufacturer. The program will consist of a power part:
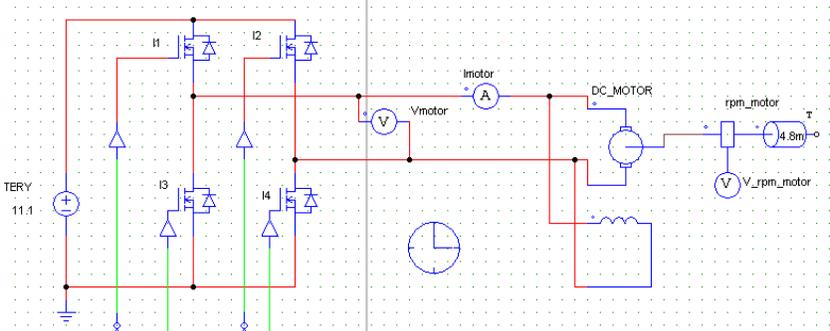

Figure 19.- H bridge simulation using PSIM
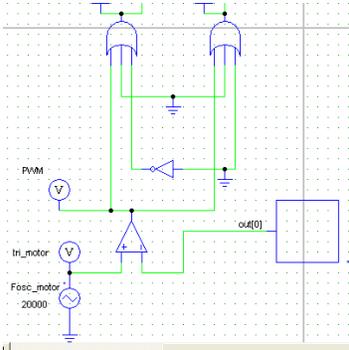
and a control part that simulates the PWM:

Figure 20.- H bridge control

Representing its speed when a 0.35 duty value is applied it reaches 2938rpm, and the expected value is 2966rpm:
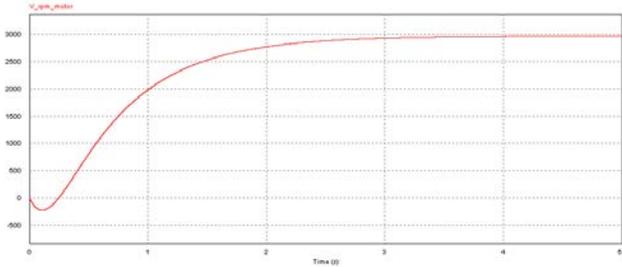

Figure 21.- Speed response

PCB DESIGN WITH DESIGNSPARK

In order to finish this Project, a PCB design program has been used. On it, we've represented the H bridge with all the components that we have been mentioning throughout the article, including status indicator LEDs, switches and capacitors associated with each integrated, and a large electrolytic capacitor in parallel with the power supply.
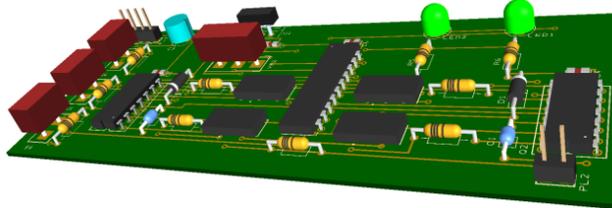

Figure 22.- PCB final design

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