NUEVA GRANADA MILITARY UNIVERSITY

SERVOMOTORS

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1. RESUMEN:

En el siguiente informe se mostrará el trabajo de un servomotor de corriente alterna mediante un servopack que proporciona control de velocidad y control de posición.

2. PALABRAS CLAVES:

- Velocidad nominal
- Tren de pulsos
- Parámetros
- Funciones auxiliares

3. ABSTRACT

The following report will show the work of a AC servomotor using a servopack that provides speed control and position control. Using PWM module of microcontroller and a optocouplers to protect the embedded device.

4. KEY WORDS

- Rated speed
- Pulse train
- Settings
- Auxiliary Functions

5. INTRODUCTION:

A servo motor is an electric motor that can be controlled by factors, such as steering and speed, within its operating range.

Because of this they are very useful because they allow any type of movement, preserving strength, speed and low inertia. This device will be controlled by a driver, capable of mastering the different variables of the engine.

6. OBJECTIVES:

GENERAL OBJECTIVE:

- Reconocer los elementos a implementar, tales como los terminales y el tablero de usuario.

SPECIFIC OBJECTIVES:

- Implement the JOG mode in the servomotor.
- Control by means of a microcontroller the internal speeds as automatic changes of the servomotor.
- Optimally develop the acceleration and deceleration time control of the device.
- Optimally develop the control of the pulse train of the device.
- Check the effect of the different position control gains.

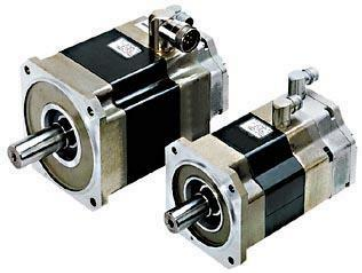
7. THEORETICAL FRAMEWORK

➢ Servomotors:

"Servo motors are used in the most varied industrial applications where high dynamics, torque control, speed accuracy and positioning are decisive factors for increasing quality and productivity. They have all these characteristics allied to a low cost, high performance and robustness.

The servo motor is designed to provide precise control and "performance". For example, transporting a load and positioning it faster. However, what allows the servo motor to do this, what makes the servo motor different from other motors? The answer lies in the diameter of the servo motor and the use of a feedback device" [1].

Any servo motor operates with electromagnetically induced forces and are employed to directly produce linear motions and angular motions, from small fractions of a radian to a full spin. They are also used to provide limited linear or angular motions limited by relatively large forces [3].

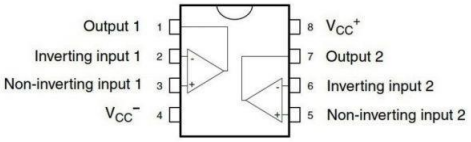


Graph 1. Industrial servomotors [6]

➢ Operational amplifier LF353:

The operational amplifier is a device that has the ability to handle a signal, is coupled in high gain direct current, which has two inputs and one output. This device is capable of being configured according to the objective to be developed.

For the speed control, the LF353 amplifier will be implemented, which has the following configuration.

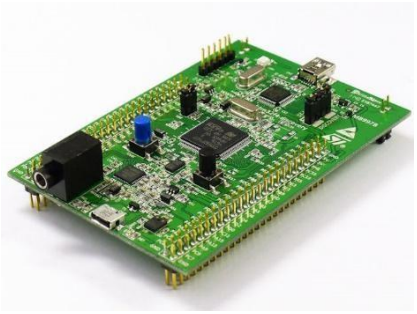


Graph 2. Op Amp integrated circuit JFET LF353 [4]

➢ Microcontroller:

A microcontroller is the main integrated circuit of a computer system, developing instructions for the entire environment, processing is performed by logical and arithmetic operations by means of arithmetic units (ALU) or logical units (UL). This consists of mathematical coprocessor, cache memory, encapsulated, heat sink, registers, memory, processing units and a control unit that is the one that sends the orders to each of these.

In this case, the STM32F4 Discovery card will be used as a development microcontroller.



Graph 3. Embedded system STM32F4 Discovery [5]

- **Pulses of YASKAWA servomotor:**

The inputs of the nominal pulses, reference code and zeroing inputs are implemented for the position reference. Having this signal must set the appropriate nominal input for the created design.

Positioning is controlled by introducing a nominal impulse of motion.

As the servo motor only rotates at an angle proportional to the input pulse, the nominal pulse format input is set on the servo pack from the main controller, and subsequently set one of the formats based on the specifications of the main controller, using the following configurations.

Constante de usuario Pn200.0	Formato de impulso nominal	Multiplicador de impulsos de entrada	Operador lógico	Valor nominal de rotación a derechas	Valor nominal de rotación a izquierdas
0	Secuencia de impulsos signo +	–	Operador lógico positivo	PULS (CN1-7) SIGN (CN1-11) Nivel alto	PULS (CN1-7) SIGN (CN1-11) Nivel bajo
1	Impulso en el sentido del reloj + impulso en el sentido opuesto al reloj	–		PULS (CN1-7) Nivel bajo SIGN (CN1-11)	PULS (CN1-7) SIGN (CN1-11) Nivel bajo
2	Secuencia de impulsos bifásica con diferencial de fase 90°	×1		90° PULS (CN1-7) SIGN (CN1-11)	90° PULS (CN1-7) SIGN (CN1-11)
3		×2			
4		×4			
5	Secuencia de impulsos signo +	–	Operador lógico negativo	PULS (CN1-7) SIGN (CN1-11) Nivel bajo	PULS (CN1-7) SIGN (CN1-11) Nivel alto
6	Impulso en el sentido del reloj + impulso en el sentido opuesto al reloj	–		PULS (CN1-7) Nivel alto SIGN (CN1-11)	PULS (CN1-7) SIGN (CN1-11) Nivel alto
7	Secuencia de impulsos bifásica con diferencial de fase 90°	×1		90° PULS (CN1-7) SIGN (CN1-11)	90° PULS (CN1-7) SIGN (CN1-11)
8		×2			
9		×4			

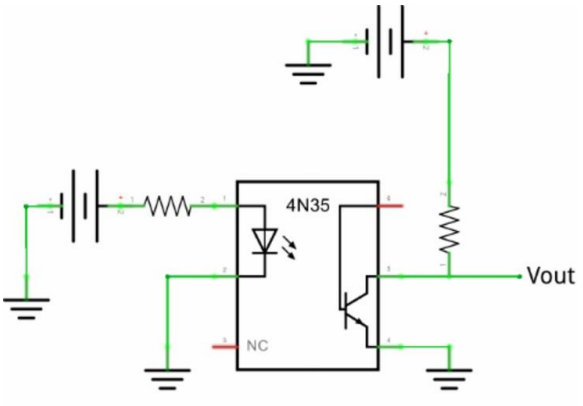
Graph 4. Nominal pulses of servomotor SIGMA II Yaskawa [2]

- **Optocoupler:**

It is a basic integrated circuit composed of an LED and a phototransistor coupled in such a way that when circulating a sufficient current through the LED to emit light, this light is received by the phototransistor remaining in the saturation zone.

As it is an integrated circuit, it is not affected by physical factors such as dust, and external lights. It is used as an interface of two optically joined circuits functioning as a method of protection. That is, an optocoupler represents an open circuit, an infinite impedance resistor.

You can regulate the voltage drop that the LED receives, which would affect the behavior of the phototransistor, that is, "take advantage of the gain provided by the phototransistor and use it to amplify the signal" [7].



Graph 5. Internal structure of optocoupler 4N35 and usual connection [7].

8. MATERIALS:

To carry out the practice, the following materials are used:

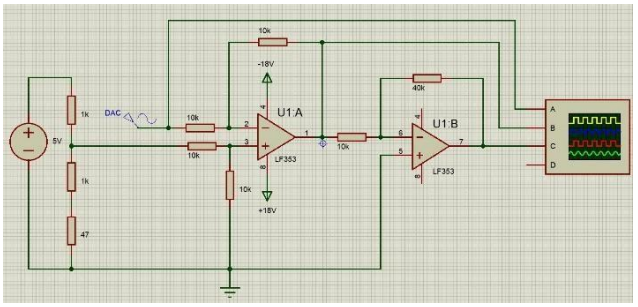
- Industrial servomotor
- Manual
- Driver
- Connecting wires
- Power board
- Resistors
- Bakelite
- Welding
- Cautin
- OP AMP LF353N
- Oscilloscope
- STM32F4
- Mini cable USB
- Optocouplers

9. METHODOLOGY

For the speed control of a servo motor, a design will be carried out to perform the control by means of a micro controller that changes

Control of speed and position of servomotors both its internal speeds and the analog reference.

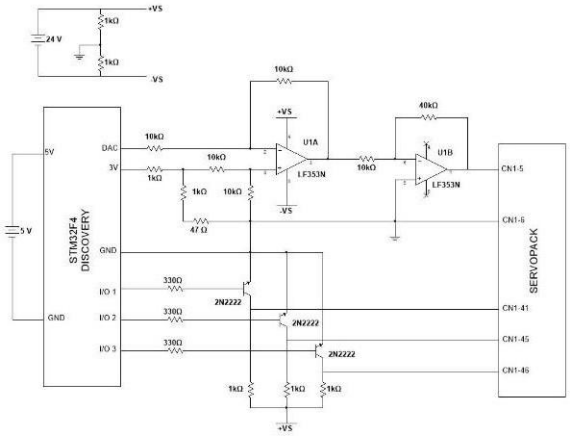
To perform this control using the analog reference it is necessary to implement an analog digital signal converter (DAC). A micro controller gives an always positive analog signal, usually from 0 to 5 volts. Therefore, it is necessary to configure that signal so that it gives negative values and in a wider range. Simply put, subtract and amplify:



Graph 6. DAC Digital Analog Control

El The servopack has features that allow the servo motor not to work. Exactly they are terminals that can be configured for external enablement, always enabled or always disabled, and these are: S-ON (servo motor enablement), P-OT (forward rotation enablement), N-OT (reverse rotation enablement). In addition, internal speeds are also chosen by enabling and disabling the P-CON (direction reference), P-CL and N-CL (internal speeds selection) terminals. Ideally when they are controlled by external signals, it is better to use dry contacts such as buttons or switches, and to be electronically controlled relays, but transistors can also be used as switches ensuring that the current in collector in case it is BJT or the voltage drop in the door if it is JFET are sufficient to control the 24 volts that feed the servopack terminals.

The structure that will be implemented for the development of the control of servo motor speed variables will be as follows:

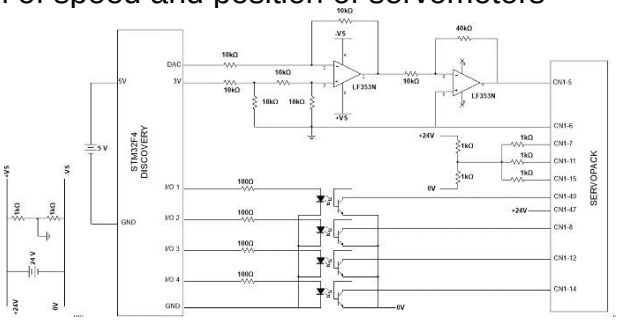


*Graph 7. Circuit for **speed** control of servomotor.*

As a square signal of 0 to 24 volts [2] is needed in the position control, it will be handled in an open collector way using the switching of a phototransistor belonging to an optocoupler. The optocoupler not only allows high switching, but also an invisible coupling that separates the power circuit from the control circuit.

The structure that will be implemented for the development of the control of position variables of the servo motor will be as follows:

Control of speed and position of servomotors



*Graph 8. Circuit for **position** control of servomotor*

10. PROCESS

The first steps are performed for any procedure, and should be at the beginning. These are as follows:

- The driver and servo terminals are recognized.
- By means of the configuration and auxiliary functions the servo motor is placed in factory mode, auxiliary function Fn005.

The first procedure is to place the servo motor in JOG mode:

- The direction of rotation, parameter Pn000.0, is configured and then configured in the auxiliary function of the JOG mode, Fn002, which has the servopack by means of the user control that has attached.
- The servo motor is enabled and tested to rotate in both directions.
- It is disabled to be able to change the speed set in JOG mode in the Pn304 parameter and the previous step is repeated.

The next step is the configuration to have the servo motor in speed control:

- An input voltage is determined to the driver which will control the speed, this voltage being the nominal speed configured in the Pn300 parameter.
- Then the 3 internal speeds of the servo will be controlled, which are variable with the programming of the driver in the parameters Pn301, Pn302 and Pn303 for speeds 1, 2 and 3 respectively.
- In the Pn305 and Pn306 parameters, the soft start time will be set for acceleration and deceleration respectively. It will be in units of time.
- With the Un000 monitor the current speed of the motor will be displayed, in rev/min units.
- The values of the parameters pn100 and pn101 are changed by alternating the values between them of major, less or equal and the previous step is repeated.

The last procedure is to place the servo motor in position contro:

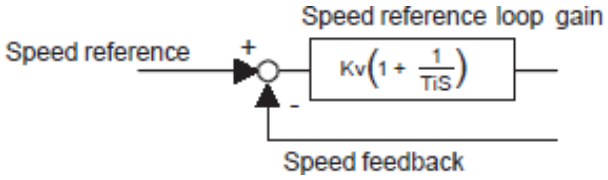
- It is determined in the parameter Pn200.0 what the position control mode will be, for this the pulse trains are taken into account, along with the logic either positive or negative, and the shape of the reference pulses.
- Then 3 signals will be connected to the puls inputs, (pulse input reference), SIGN (sign reference) and CLR (counter error erasure). It has to be done for reference of pulse train plus sign in and pulse train with pulse train out of phase 90°.
- The gain for position control will be configured, in the Pn102 parameter. This seeks to know and distinguish the changes that this gain makes in the movement of the servo.
- Finally with the Un004 monitor the current position of the motor measured at angles will be displayed, and the number of pulses that the servopack receives on the UN003 monitor.

11. ANALYSIS OF RESULTS

The servopack has programmed the JOG mode for two purposes: the first is to give an introduction or tutorial to the user of how to work with the digital operator of the servopack by configuring the auxiliary function of the JOG mode and changing its speed in the Pn304 parameter, and the second is to test if the servo motor is in good condition until it is brought up to its nominal speed. Once you have mastered the mode of configuration of functions, parameter and checked the servo motor rotate at its nominal speed in both directions, you can continue to the control modes.

Speed control has a ramp-like behavior, where it goes from one speed to another speed to another. When controlled with contactors, the slopes of the ramps are subject to acceleration and deceleration times (parameters Pn305 and Pn306 respectively), and when controlled by analog reference the behaviors of the slopes depend on the speed at which the value of the input voltage changes.

Keep in mind that the servo motor is subject to mechanical imperfections, that is, the speed of the servo motor that is desired is not the one at which it is rotating, so the servopack has a closed loop control:



Graph 9. Gain adjustment of servo [2].

The operation is as follows: the reference speed is the one that one selects either by contactors or analog reference, the feedback speed is the information provided by the encoder, then the reference speed is subtracted from the feedback speed and the result stops by a reference speed gain loop. This modifies the speed of the motor and the response of both the control and the mechanical structure.

To look at the behavior, it will be analyzed in a single stable and continuous speed as it is one of the internal velocities, and the constants of the reference speed gain loop will be changed: speed gain loop (K_v) and integral time constant loop of speed (Ti). The SGHD Sigma II servo motor to be used has a nominal speed of 3000, and with that speed the behavior of the constants will be analyzed. the speeds displayed on the un001 monitor are as follows:

Speed in encoder (rpm)	Loop gain of speed (K_v)	Constant of integral time of speed (Ti).
2999	40	2000
2999	200	3000
2992 – 3003	500	500
2801 – 3138	1000	500
2995 – 3010	100	1500

Table 1. Velocities vs. Velocity Gain Loop Constant.

To these data is due additional physical responses that were presented when raising the loop of constant of integral time of speed (Ti), the engine emitted noise from vibrations produced in the rotor. Additional the velocity is neither stable nor continuous, and begins to oscillate between speed ranges, and the size of the ranges is subject to the value of the speed gain loop (K_v), the larger the velocity oscillation range.

Position control is done with a pulse train, which also implies a specific frequency of the pulse train. That frequency represents the speed at which you will go from one position to another. So, when doing position control, you also do speed control and reference speed gain loop constants.

The number of pulses indicates how many degrees the servo motor will rotate and depends on the resolution of the servo motor encoder. The SGHD Sigma II servo motor to use has an encoder resolution of 2048 pulses per revolution, so if you want to move 90 degrees, the number of pulses to be introduced is:

$$2048\frac{pulsos}{rev}x\frac{rev}{360°}=5{,}689\frac{pulsos}{grado} \qquad (1)$$

$$\frac{5{,}698 pulsos\ x\ 90°}{1°}=512 pulsos \qquad (2)$$

With 512 pulses the servo motor will rotate 90°.

That signal is placed in the PULS terminal, and in SIGN a digital signal will be placed that will change between high state and infinite impedance if the position control is sign plus pulse, or another train of pulses equal to the first out of phase signal +90° or -90°. For it to move from 90° to 90°, it is necessary for the CLR terminal to erase the internal count of received pulses, otherwise it would add the number of pulses previously introduced with the pulses to be introduced.

12. CONCLUSIONS

Servos are of great importance within the industry, because you have control in factors such as torque, speed and position providing a wide range of applications, for their accuracy and optimal operation. Likewise, the driver provides the configuration and manipulation of the different control systems granting this precision.

Servo manipulation needs to implement twisted pair cables so that they are not affected in the signals and interference occurs.

13. BIBLIOGRAPHY

[1] Electrónica industrial. Modelos y especificaciones de servo motores. (2016, Agosto) Disponible en: http://www.electronicaindustrial.cl/index.php/productos/servo-motores

Control of speed and position of servomotors

[2] Σ-II Series SGMBH Servomotor/SGDH Servopack User's Manual, Manual N° SIES800-32.4, YASKAWA Electric Corporation, Kurosakishiroishi, Japan.

[3] McGraw-Hill. (1964) Servomecanismos, Servomotores (impulsadores), Servomotores eléctricos. Enciclopedia Salvat Ciencia y Tecnología [versión impresa]. Barcelona, ES: Salvat Editores.

[4] Electrónicos caldas. Amplificador LF353N. [En línea]. Available: http://www.electronicoscaldas.com/amplificadores-operacionales/352-amplificador-operacional-lf353.html

[5] STM32F4 Discovery. ST life augmented. [En línea]. Available:

http://www.st.com/content/st_com/en/products/evaluation-tools/product-evaluation-tools/mcu-eval-tools/stm32-mcu-eval-tools/stm32-mcu-discovery-kits/stm32f4discovery.html

[6] Servomotores. Grup Dap. {} Automatización industrial. [En línea]. Available: http://www.grupdap.es/dataesp/prod-familiasdetalle.asp?idFamilia=37

[7] Optoacoplador, ¿Qué es y cómo funciona? EducaChip. [En línea]. Available: http://www.educachip.com/optoacoplador-que-es-y-como-utilizarlo/