ACTUADOR SERVO DEVICES WITH TEMPERATURE AND POSITION INFORMATION TO UNMANNED AERIAL VEHICLES (UAV)

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Abstract. *Servos actuator devices are of great importance in the control of unmanned aerial vehicles (UAV) and other mechanisms. In applications in UAV are used to control the aircraft's control surfaces. The performance and stability of the vehicle depends, among other factors, the adequate modeling of servo-systems, their physical and particularly the feedback of the correct position of the actuator to the driver or the test system in flight. This work shows the development of an electronic small enough to be inserted inside the servo (internal circuit) without the need for external mechanical changes, able to provide the following information: a) internal temperature of the servo motor (to detect overheating in abnormal operation and b) the position of the arm of the servo actuator, allowing the feedback of position for testing in flight, or the algorithm used to UAV control. The position signal provided by the servomotors to the inner board has high coupling impedance and conditioning capable of protecting the internal electronics of the control of any short-circuiting the terminals of the signal or the external noise that could damage the position of the servo control and consequently the loss of control of the aircraft. The changes implemented to: a) feeding stabilized internal circuitry needed to ensure the accuracy of the position signal provided even considering the low and high voltages of polarization noise caused by high current servants of the high performance and b) provide the signals of temperature and filtered position enough and with great immunity to electromagnetic interference in the UAV large. The study reports a range of tests performed in laboratories and test flights, which demonstrated the effectiveness in implementation and monitoring facility for controlled surfaces.*

***Keywords**: Servo actuator; Unmanned Aerial Vehicles (UAV); feedback of the position; immunity to noise*

1. INTRODUCTION

Servo actuator devices are of great importance in the control of unmanned aerial vehicles (UAV) and other mechanisms. In applications in UAVs are used to control the aircraft's control surfaces. The performance and stability of the vehicle depends, among other factors, the modeling of appropriate servo-systems, their physical and particularly the feedback of the correct position of the actuator to the driver or the test system in flight. This work shows the development of an electronic small enough to be inserted inside the servo (internal circuit) without the need for external mechanical changes, able to provide the following information: a) internal temperature of the servo motor (to detect overheating in abnormal operation and b) the position of the arm of the servo actuator, allowing the feedback of position for testing in flight, or the control algorithm used in UAV. The position signal provided by the internal adapter to servomotors has high coupling impedance and conditioning capable of protecting the internal electronics of the control of any short-circuits the terminals of the signal or the external noise that could jeopardize the position of the servo control and consequently, the loss of control of the aircraft. The changes implemented yet allow: a) feeding stabilized internal circuitry needed to ensure the accuracy of the position signal provided, even considering the low and high voltages of polarization noise caused by high current servos in high performance and b) provide the signals temperature and position enough filtered and great immunity to electromagnetic interference in the large UAV. The paper describes a range of tests performed in laboratories and in flight tests that demonstrated the effectiveness in implementation and monitoring facility to the areas controlled.

2. THE VECTOR-P

The Vector-P is a unmanned aerial vehicles manufactured by Intellitech Microsystems (USA) in composite material, the Figure 1 shows the Vector-P in the test in a test flight. Originally the Vector-P has a link data for tracking by the ground station, this link allows the scheduling of flight (for the case of autonomous flights), as well as monitoring of variables related to flight or status of the system such as: data the GPS (Time, Longitude, Latitude, Speed, Altitude), the inertial data (Pitch, Roll, Yaw), data of Pitot (Air Speed), making static (altitude), ADs (the main battery voltage and battery of servos), the throttle position, among others.

The Vector-P was purchased by the Department of Mechanical Engineering of Aeronautics-ITA to serve as a testing platform for their academic development: development of controllers and a model of aircraft through flight tests in (aerodynamic model, derived from stability, moments of inertia, etc.).

Figure 1. Unmanned aerial vehicles on a test flight test

2.1 Specifications

The main specifications of the Vector-P are presented in Table 1.

Table 1. Main specifications of the Vector-P.

Wingspan	101 inches (2.57 meters)
Fuselage Length	5 feet (1.524 meters)
Max Speed	100 knots (185 km/hr)
Cruise Speed	70 knots (129 km/hr)
Landing Speed	~40 knots (74 km/hr)
Engine	75cc, 7.5 hp 3W 2-stroke reverse rotation gasoline engine. Options range from 62 to 100cc, quoted on request.
Propeller	Biela 24x10
Max Range	280 miles (519 km), depending on fuel on board.
Max Altitude	10,000 ft. (3 km) MSL
Max Takeoff Weight	75 lbs (34 kg)
Empty Weight	43.5 lbs. (19.7 kg)

3. ICASIM

The Vector-P was fitted with a monitoring system for flight Icasim Flight Test Equipment (IFTE) TRM/916 that provides more accurate data from the flight because it uses inertial sensors, anemometer and more accurate GPS system compared to the original Vector-P. The Icasim also allows the data to monitor the positioning of control surfaces, as has four channels of ADs of 03 reserved for reading the control surfaces (aileron, rudder and profundor) and reading of rotation of the engine or throttle.

3.1 Technical Data

The TRM/916 is a small computer running a Linux system, an interface control panel directly in which it has a display of 320x240.

The TRM/916 has a LAN Ethernet interface for communication and has a compact flash memory card of 256MB memory and mass storage where the recorded data of the units coupled to it. Figure 2 shows (1) The TRM/916 has external connections with: (2) Module AD (PotiAMP) for reading potentiometers for sensing the surface of control, (3) inertial unit (Crossbow AHRS400), (4) GPS Receiver 1Hz, (5) Anemometric probe of evidence and the power cord from the system.

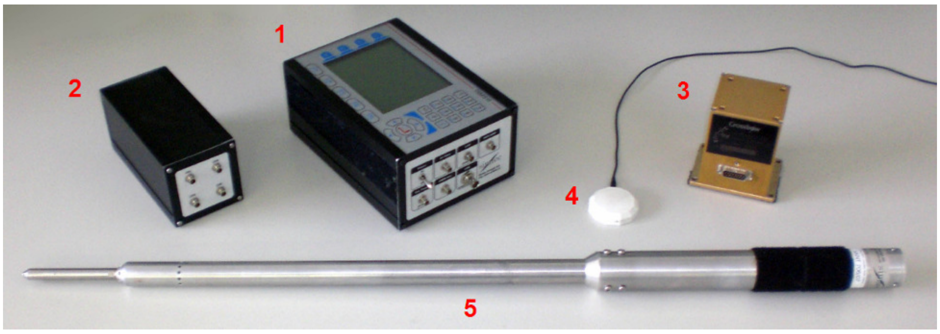

Figura 2. (1) TRM/916, (2) PotiAMP, (3) Crossbow AHRS400, (4) Antena GPS e (5) Ponta de prova anemométrica.

3.2 Operation

The TRM/916 as shown in Figure 3 has buttons that allow the interface to start and stop recording, switch between the modes of display where you can verify the data from each sensor (see Fig 4 which shows the screen for the recording of data from the sensors to the control surface), but can also start the process of shutting down Icasim.

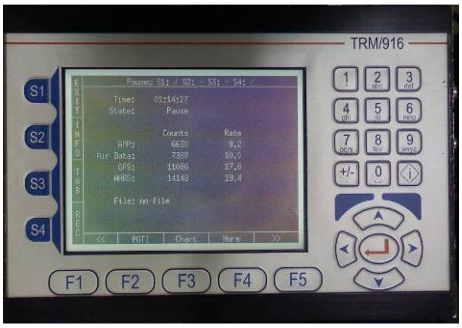

Figure 3. TRM/916 highlighting the buttons to control S1 to S4, the F1 and F4 and directional keypad on the right

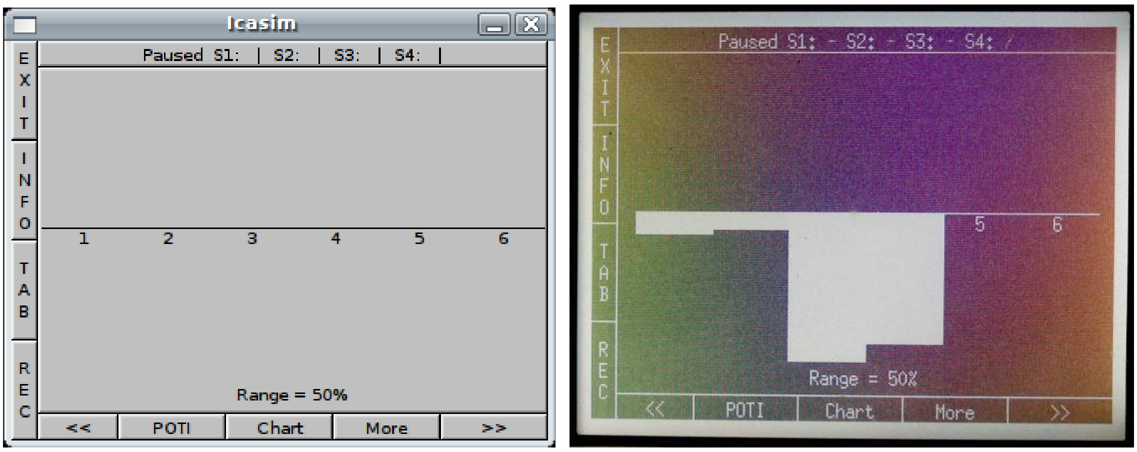

Figure. 4: Panel of the bar graph from the PotiAMP (left layout, right photo).

Figure 4 contains information from the PotiAMP displayed in bar such as: the values for the channels (Ch 1, Ch 2, Ch 3, Ch 4, Ch 5 and Ch 6). The channels Ch 5 and Ch 6 are not used in the Vector-P, you can change the range shown in the panel through the Up and Down buttons on the control panel of Icasim.

3.3 The Sensors

The Icasim have in your system a range of sensors such as inertial unit (as of attitude), tip of anemometer probe (data anemometer and air temperature), GPS (positioning, speed and altitude) and also has a module for reading AD of analogue signals (PotiAMP).

3.4 PotiAMP

The system has a module of Icasim ADs external (PotiAMP) with 4 analog channels from 1.25 to 3.75V with 24 bits that communicates via RS-485 with TRM/916. The PotiAMP read the signs of the position of the control surfaces (aileron, rudder and profundor) and the rotation of the engine.

4. MODIFICATIONS IN VECTOR-P

For the platform flight (Vector-P) was equipped with Icasim, some changes were needed on the aircraft such as the addition of a pack of batteries from 24V to supply the TRM/916, addition of TRM/916, the tip of anemometer test of conditioning and a board reading of RPM to connect with PotiAMP that the fuselage was set.

5. MODIFICATIONS IN SERVO ACTUATOR

The servo actuator was modified with the addition of an internal circuit (placed inside the servo actuator) and an external circuit (power cord plugged in the servo) as Fig.5.

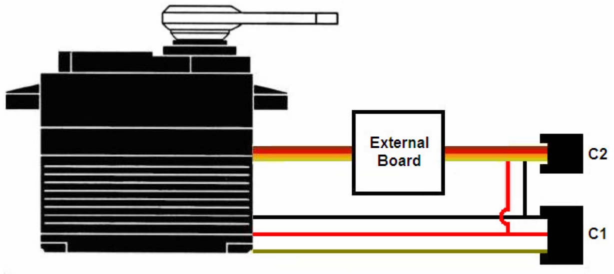

Figure 5. Illustration of the servo with the external adapter and connections after the modification

4.1 Internal board (Internal circuit)

To facilitate the reading of the position of the surfaces was chosen to add a card electronic servos actuators small enough to be inserted inside the servo (internal circuit) without the need for external mechanical significant changes. The Fig. 6 illustrates the installation of the inner board accommodated within the servo.

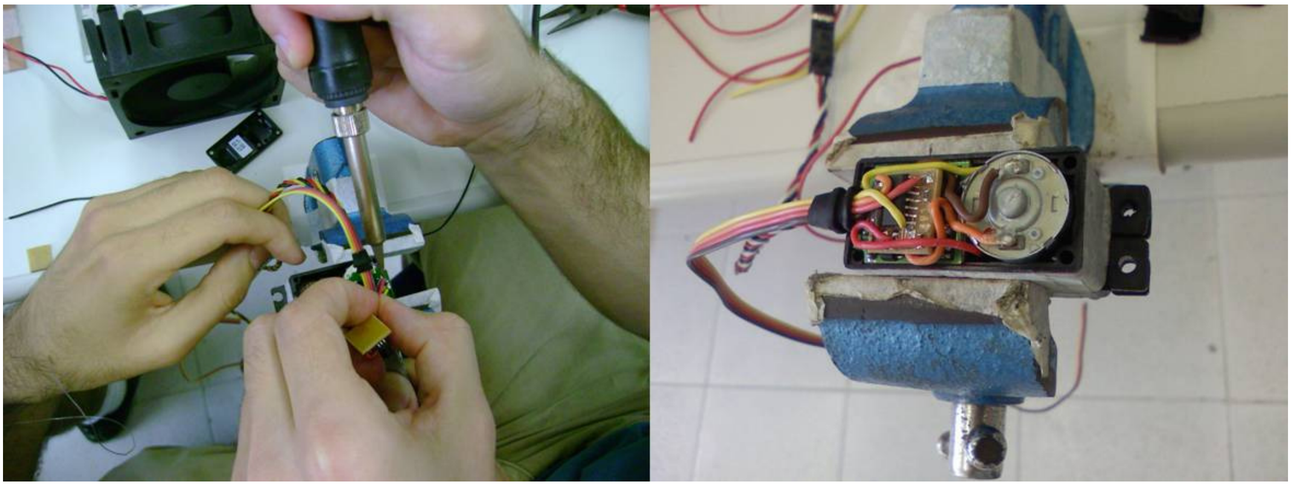

Figure 6. Left picture of the modification of the servo, the right shows the internal adapter already installed on the servo.

It is noteworthy that the inner board was supplied with only 3.3V, which makes use of temperature sensors of small dimensions, but also to restrict amount of available channels that meet the operational requirements of low voltage, single supply, rail-to-rail, industrial temperature, and the smaller package. Were originally developed to test board manufactured "craftsmen" to validate the first prototypes for both were developed 03 versions of the inner board, the last version where the card was manufactured industrially and components used meet the industrial specifications to ensure greater safety of operation before the high temperature environment of the inner board may be exposed. Can be viewed in Fig. 3 versions of the inner board.

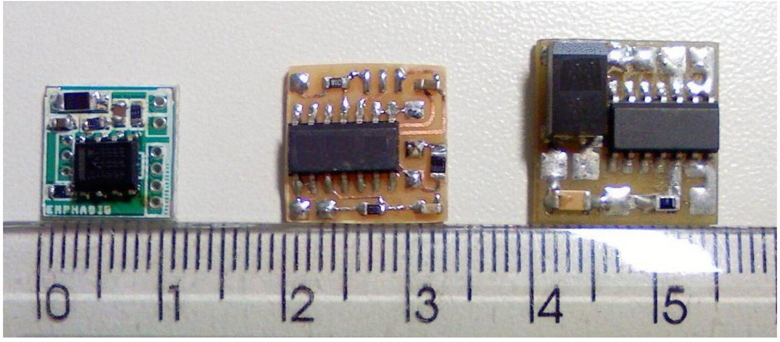

Figure 7. Versions of the inner board, left to right is in the versions (2.0, 1.1 and 1.0), the scale is in centimeters.

The internal circuit is shown in Fig. 8, can monitor the internal temperature of the servo motor (to detect overheating in abnormal operation, track and especially the position of the arm of the servo actuator, allowing the feedback of position for testing in flight, or for the control algorithm used in UAVs or other, the position signal provided by the internal adapter to servomotors has a coupling of high impedance, passive filter "Fp" (see Fig. 8 below) and conditioning capable of protecting the electronic control internal short-circuit any of the terminals of the signal or the external noise that could jeopardize the position of the servo control and the consequent loss of control of the aircraft.

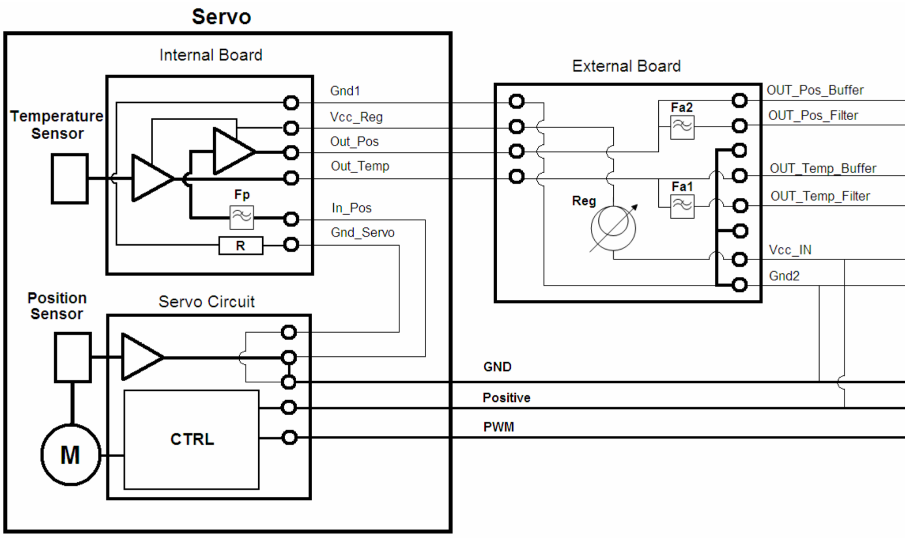

Figure 8. The block diagram of the modification of the servo actuator, with the inner board (internal circuit) and external adapter (external circuit).

The coupling between the supplies of reference of the servo and the inner board (from external adapter) is done through the resistor "R" as seen in Fig. 8 above, the value is calculated in the same way as if the reference to cable the servo power is broken by the current resistor is limited to values supported by the same tracks and the internal circuit. Using this resistor allows you to maintain a constant less noisy for the internal circuit, since the high current drained by the servo motor noise pollution with the internal circuit to control the servo.

4.1 External Board (External circuit)

The external circuit (external board) is connected to the power cord and contains the servo electronics that allows power stabilized internal circuitry needed to ensure the accuracy of the position signal provided even considering the low and high voltages of polarization noise caused by high current in high performance servos see "Reg" in Fig. 8 where the voltage supplied to the internal adapter is 3.3V.

The external board can also provide the signals of temperature and position enough filtered (through the active filters "Fa1" and "Fa2" as shown in Fig. 8) with high immunity to electromagnetic interference common in the large UAVs. Figure 9 shows the internal and external board in the final version.

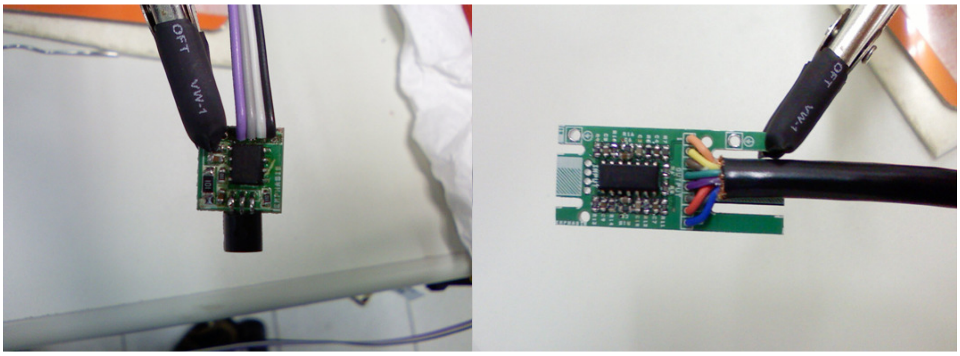

Figure 9. Final version of the left inner board and outer board of the right.

4.1.1 Active filter "Fa1"

The active filter "Fa1" (shown in Fig. 8) is a low pass filter sallen-key with 4 poles and cutoff frequency of 10Hz. Figure 10 shows the response of "Fa1", highlighting the injected signal and the filtered signal.

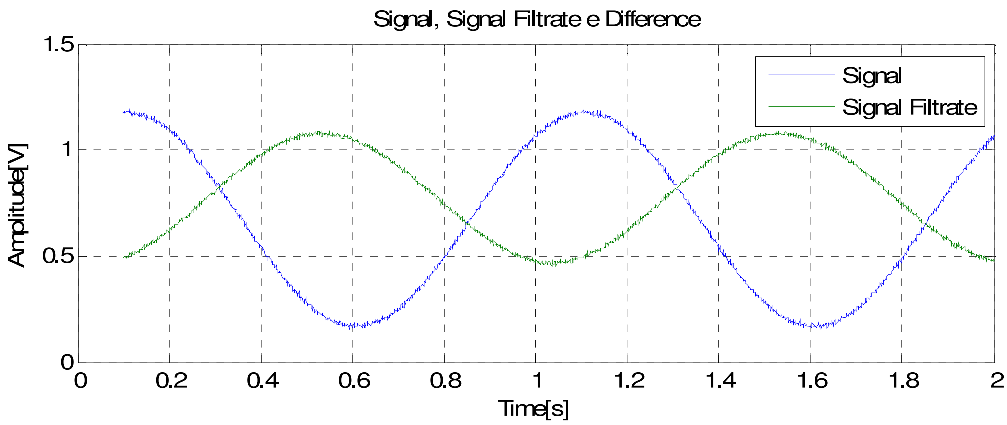

Figure 10. Shows the injected signal and filtered signal (test of the response of the filter).

The dynamics of temperature is slow so that could be used an even lower cut-off frequency, however, low frequency filter with cut-off requires an array of passive components with RC large size, which prevented the small size of the circuit, it was necessary to remodeling in the laboratory the filters because of the active ingredients work with the bias current out of specification (see Fig. 11), thus achieved by using passive components of reduced size and still obtain the correct information allowing the filtered signal.

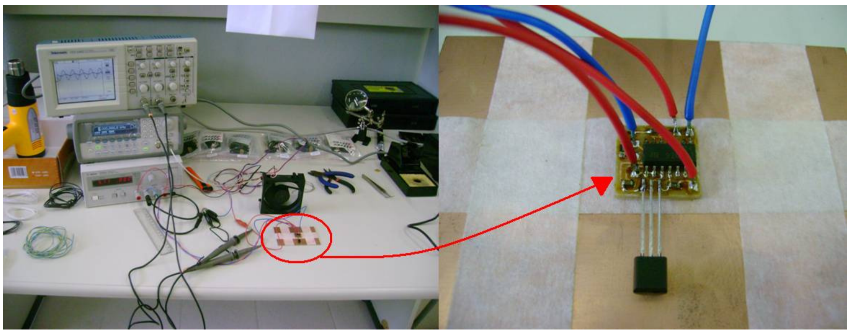

Figure 11. Left photo of laboratory tests in aeronautical systems from ITA (ITA-LSA), the right emphasis on the inner board that is being tested.

Figure 12 shows the signals that pass through the filter of 10Hz used in the output of the sensor of temperature, with the input signal, the filtered signal and the difference between these signals, (Diference Div = division, Diference Sub = subtraction) so it can is to understand the nonlinearity in the amplitude of the output signal.

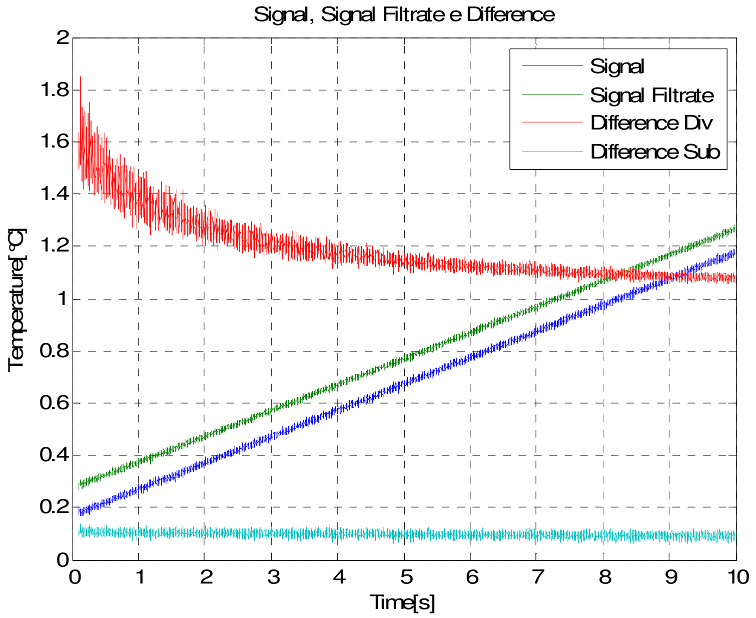

Figure 12. Signals that pass through the filter of 10Hz used in the output of the sensor of temperature, with the input signal, the filtered signal and the difference between these signals.

In Figure 13, it is the filtered signal of the sensor temperature (in volts) and is also the figure in temperature (in ° C). By fitting the MATLAB tool you can get to the final equation Eq. (1) that includes non-linearity of the filter as well as conversion of the voltage sensor to temperature.

$$T = (Vof - 0.10523) * 160.04 - 67.858 \tag{1}$$

Where: T is the temperature in ° C
Vof is the voltage output of the filter temperature (filtered signal of the sensor temperature)

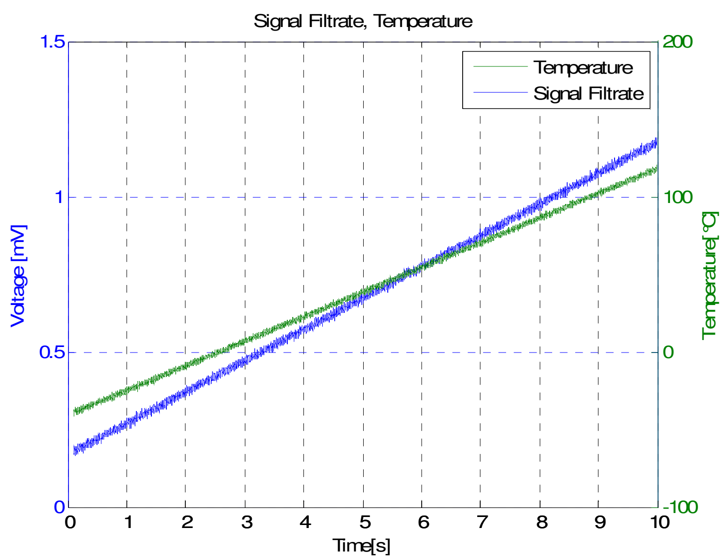

Figure 13. Showing the output signal (unfiltered) from the temperature sensor signal and the equivalent temperature in ° C

4.1.2 Active filter "Fa2"

The active filter "Fa2" (see Fig. 8) is a low pass filter sallen-key with 4 poles and cutoff frequency of 200Hz. The cut-off frequency was set according positioning dynamic of the servo arm. As active filter "Fa1", passed through this filter in laboratory tests.

4.1.3 Test of servos using the program in LabVIEW

Was developed in a LabVIEW routine tests that run the servos with specific positions and varying speeds, so analyzing the response of tests you can check the functioning of the internal and external adapter, but also confirm that there was no damage during the modification the servo. Figure 14 shows the test result of the positioning servo and Figure 15 shows the test result of measuring the temperature of the servo operation.

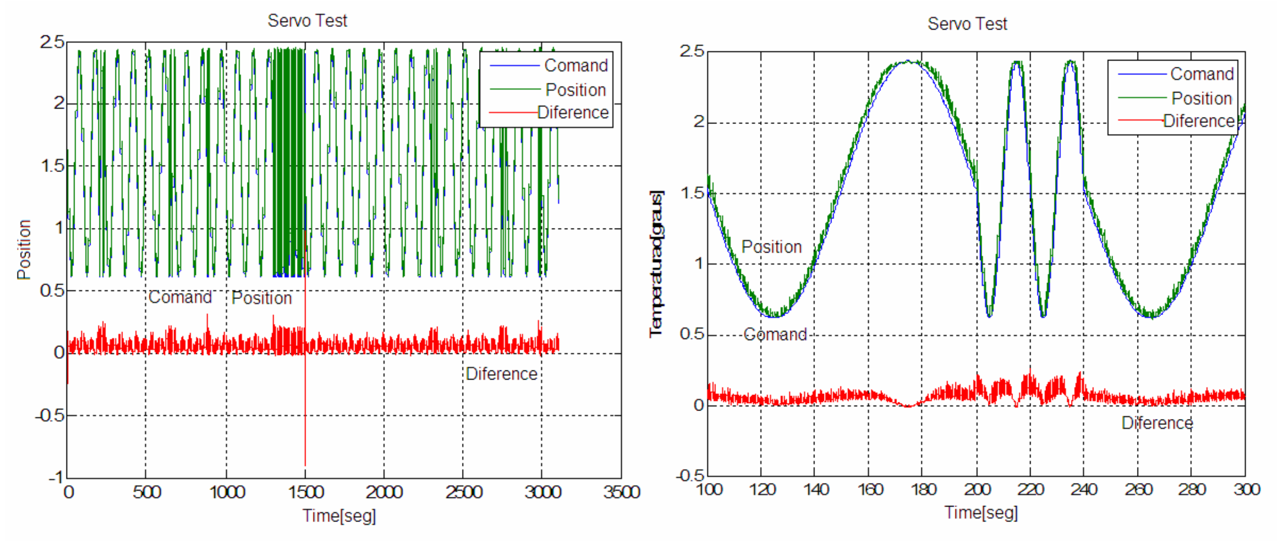

Figure 14. Sign of control, and position error (between control and position): a test of the left and right 3500 seconds in a zoom window of 5 minutes of test

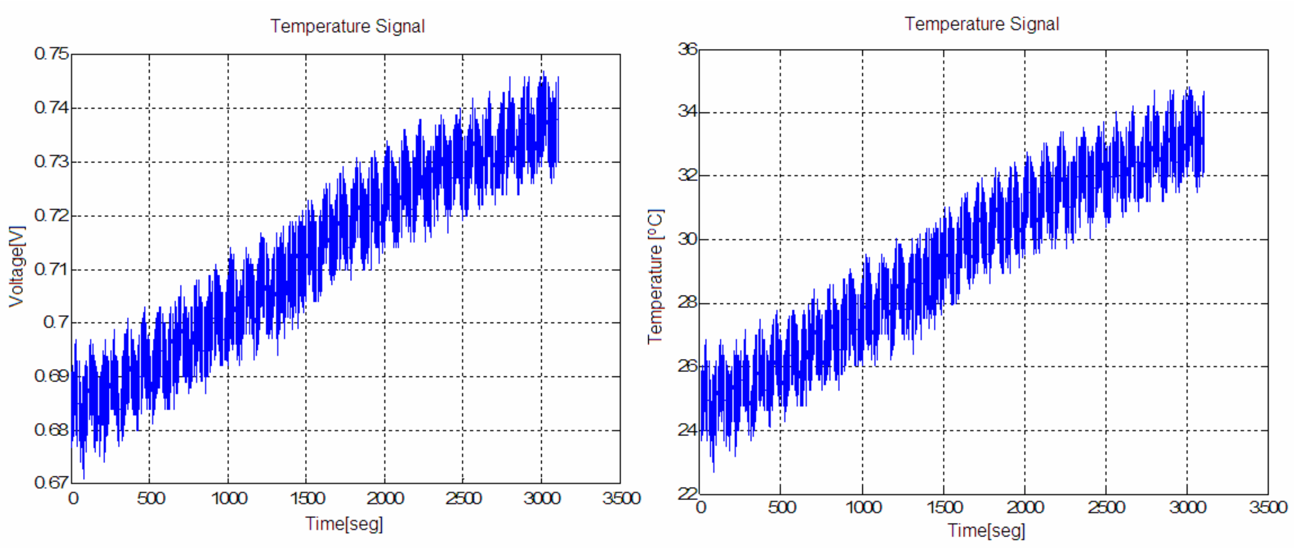

Figura 15. Sinal de Temperatura em mV à esquerda e em °C a direta.

5. RESULTS OF FLIGHT

On May 14, 2009 was the first flight of Vector-P with Icasim already integrated with the system as shown in Fig. 16, which shows the modified servo is already installed on the aircraft. Data for control of aerodynamic surfaces are shown in Figure 17. Data from this flight will be analyzed and used to identify the parameters of the model of the aircraft.

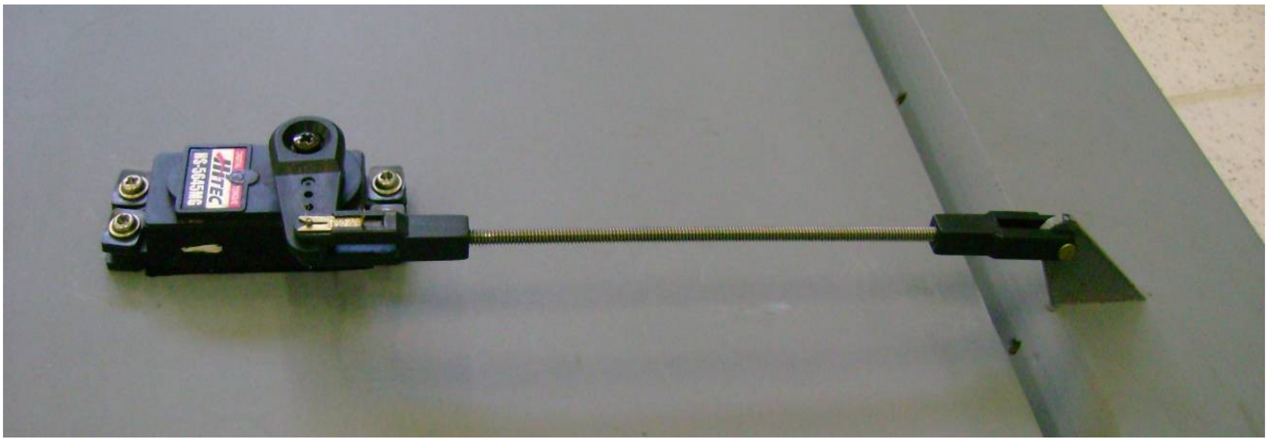

Figure 16. Servo modified at the surface of aerodynamic control.

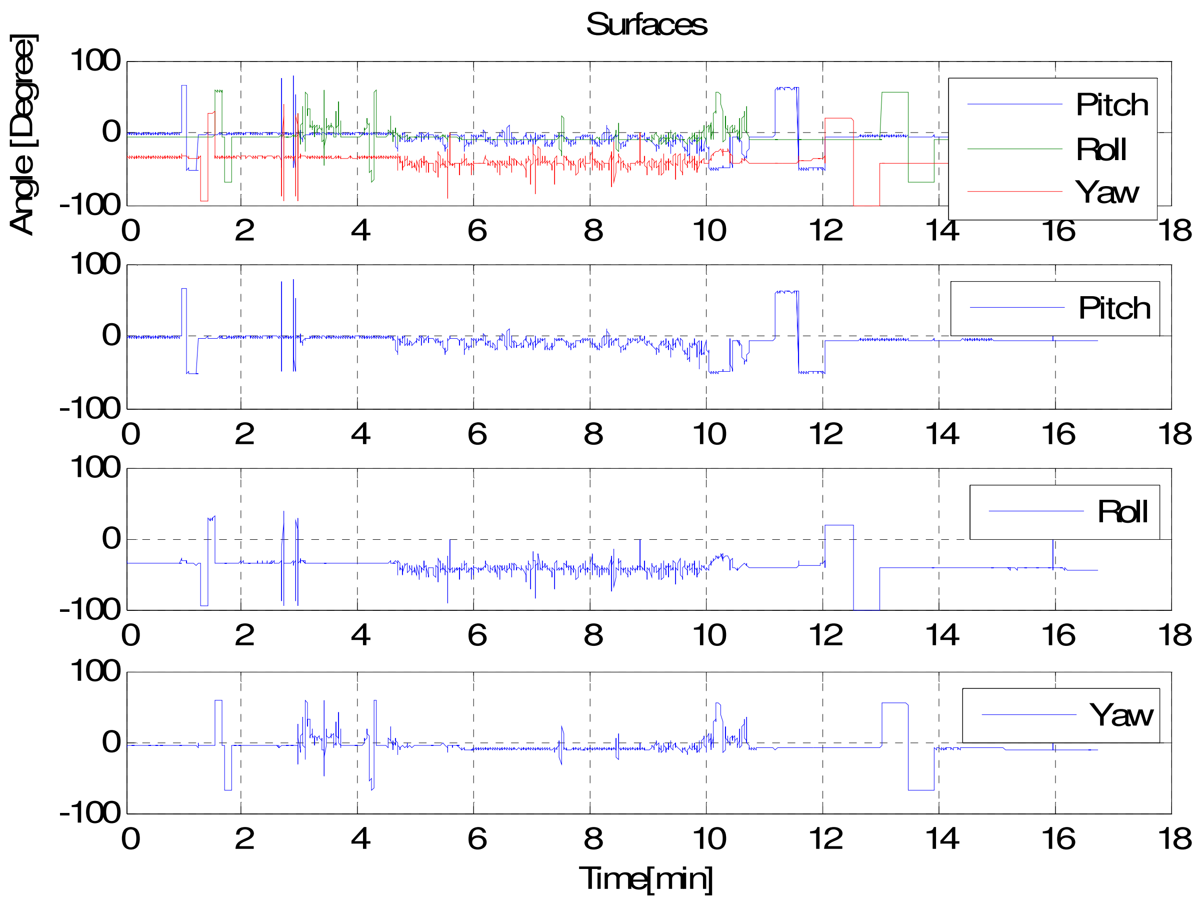

Figure 17. Graph with the deflections of control surfaces on the flight of the day May 14, 2009.

6. CONCLUSIONS

After tests in ground in the laboratory and in flight test it was found that the modification of the servos to the system in flight testing that has been integrated with Vector-P meets the needs of providing data for the aerodynamic modeling technique based on test flight. Thus, you can create an automated tool for identifying type of flight test, which will facilitate the gathering of new model parameters associated with the Vector-P for academic studies in the ITA, or even, for the removal of new parameters the model of Vector-P if it change with the objective of changing the dynamics of the flight.

7. REFERENCES

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8. RESPONSIBILITY NOTICE