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Design of a temperature compensator for cool containers in the maritime transport of potato

Carlos Raymundo
Ricardo Palma University
ray36512@hotmail.com

Abstract

A significant part of the production of potatoes is exported to the European Union and the United States. The quality is fundamental for the maintenance and the expansion from this market to others. It also constitutes a trouble at the moment of finalizing business agreements with foreign clients or with theirs intermediaries. During the maritime transport there is a partial deterioration and in some cases total deterioration of the quality, it happens fundamentally because of the wrong way of refrigeration of our Peruvian treasure. This project is about the design of the compensating which could establish an ideal temperature for the conservation of its quality during the transport implemented in a FPGA Virtex II PRO.And the implementation of the filter of Kalman to estimate the temperature.

1. Introduction

The potato, which scientific name is Solanum tuberosum, has an antiquity of eight thousand years. It was domesticated by Peruvians settlers who lived near the Titicaca Lake that is located on the Peruvian Andes in the border with Bolivia.

Specifications:

Common name: Potato

Kind: Solanum

Family: Solánaceas

Species: Solanum tuberosum

Origin :
a) Solanum Tuberosum: Peruvian Andes.
b) Solanum Andigonum: Perú, Colombia and Bolivia.
c) Solanum Gomocalix (papa amarilla): Mountains of Perú.

Potato for exportation:

Nowadays the eyes of the world are put in Peru and mainly in its agricultural products. The potato is our treasure of exportation which has contributed to the improvement of our economy and the world-wide feeding. Nevertheless problems exist in its exportation since the quality of the final product that arrives at the different markets of the world is not the best because the mayority of cool containers do not maintain it in an optimum temperature so that in this way the product can conservate its optimal quality.

2. Objectives

The objectives reached are:

- Modelling of a refrigeration system in variables and equations of state.
- Design of a temperature compensator by Bode and Dead Beat method.
- Implementation of the compensator in simulink in Hadware.
- Implementation of the compensator in a FPGA.
- Implementation of Kalman´s filter in simulink in Hadware.
- Design of the interface for the sensor of temperature and the tests of the sensor in a real system using Labview.

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3. Implementation of the project

a) Stage of state variables modeling

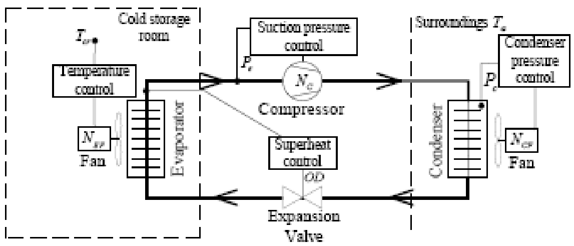

Fig. 1. The block diagram of the refrigeration system

The equations of state of the system

$$C_f\dot{\theta}_f = \frac{1}{R_{e2f}}(\theta_e-\theta_f)+\frac{1}{R_{r2f}}(\theta_r-\theta_f) + \omega\rho\sigma\theta_r - \frac{1}{R_{f2c}}(\theta_f-\theta_c) - \omega\rho\sigma\theta_f$$

$$C_r\dot{\theta}_r = \frac{1}{R_{e2r}}(\theta_e-\theta_r)+\frac{1}{R_{p2r}}(\theta_p-\theta_r) + \omega\rho\sigma\theta_f - \frac{1}{R_{r2f}}(\theta_r-\theta_f) - \omega\rho\sigma\theta_r$$

$$C_p\dot{\theta}_p = -\frac{1}{R_{p2r}}(\theta_p-\theta_r)$$

Fig. 2. Thermodynamic equations of the system

b) Design of the compensator

Development of temperature compensator by Bode method

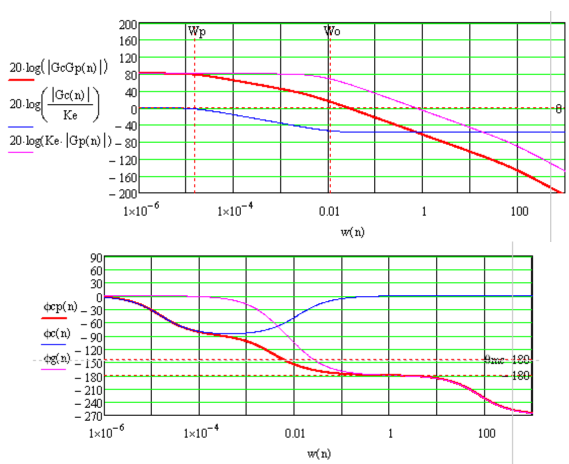

Fig. 3. Diagram of Bode phase and magnitude already compensated

Implementation of a compensator for the temperature by Dead Beat method

For the compensator by Deab beat k1, k2 and k3 are obtained which are going to modify the matrix A in order to obtain the final compensation

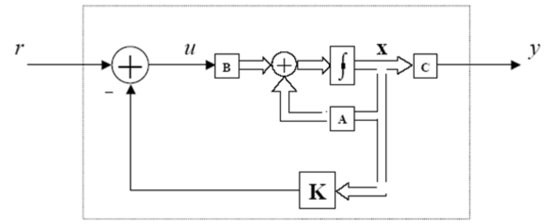

Fig. 4. Diagram of realimentation by state of the matrix A which is modified by K

Then the result of the Gp with the compensator in the time

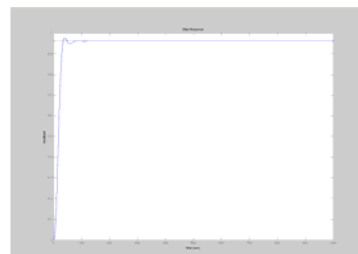

Fig. 5. Diagram of realimentation by state, the matrix A is modified by K

c) Implementation of the compensator in simulink

In simulink, we are considering hardware like a whole system, as if we were using only components like in VHDL

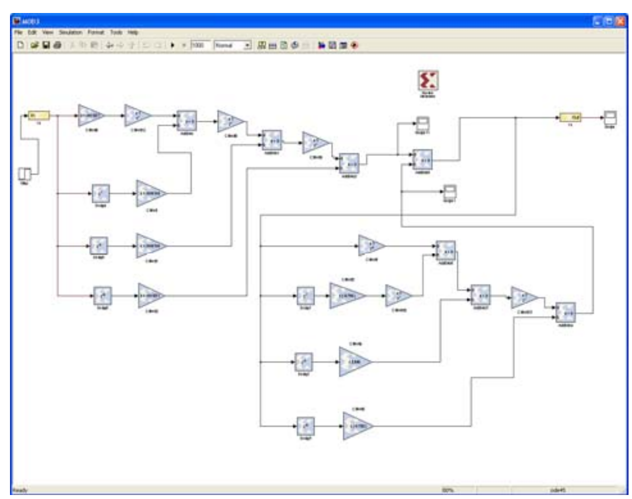

Fig. 6. Hardware diagram in simulink.

Finally, the answer that gives our Compensator is the following one with an entrance of a unitary step:

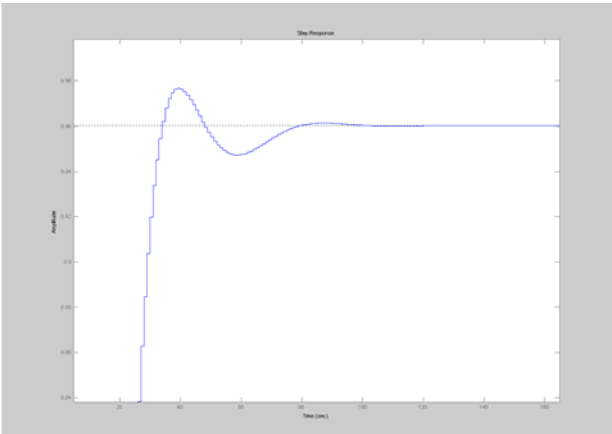

Fig 7. Hardware of the Compensator.

d) Implementation of the compensator in a FPGA

When the hardware is already done, there appears a new library ready to be used in the Co-simulation using the XUP2VP30 of Xilinx, it is shown in figure 8.

Figura 8. Board XUP2VP30 of XILINX.

Then in the System Generator , there is an option that already connects the hadware created to the XILINX Board.

After we create the hardware required, there is an option called ISE where we can see the archives generated by the tool, shown figure 9.

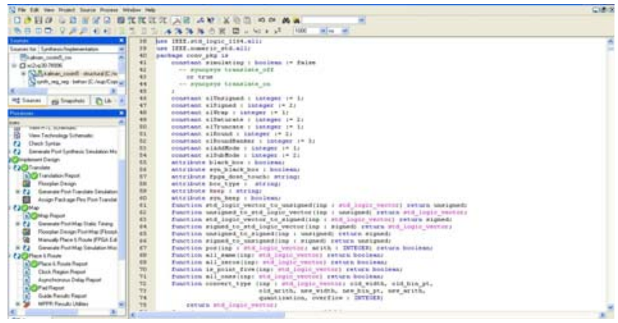

Fig 9. ISE main screen of Xilinx.

e) Implementation of the filter in simulink in Hardware

In a real refrigeration system the noise appears in the measurements. So, a way to manage this problem in order estimate the real value of the temperature sensor is using the optimal estimator of Kalman, which is a robust filter that can gives an excellent response of the temperature signal from the sensor even with noise.

The Kalman filter is an algorithm of optimal recursive data processing. In order to understand this, we are going to define optimal, depending on the selected criteria to evaluate the operation of the algorithm.

An aspect of being OPTIMAL is that the Kalman filter incorporates all the information that we provide to it. So, it processes all the measures availables without worrying its precision, estimates the present value of the variables, with the use of the knowledge of the system and the dynamic sensors, describes inm a statistical way the noises of the system, measures errors of dynamic models, and any information available about the conditions of the variables.

The Kalman filter combines all the data measures, in addition with a previous knowledge about the components to the system, it produces a desirable value of all the variables in a way in which the error is minimized statistically.

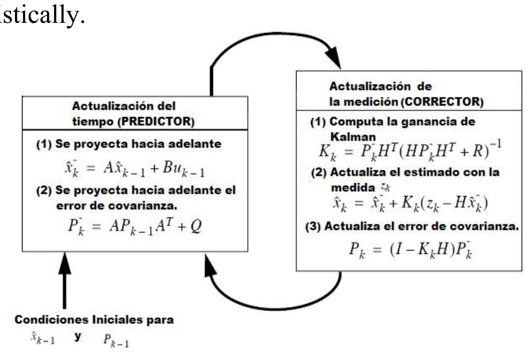

Fig 10. Equations of the Kalman filter.

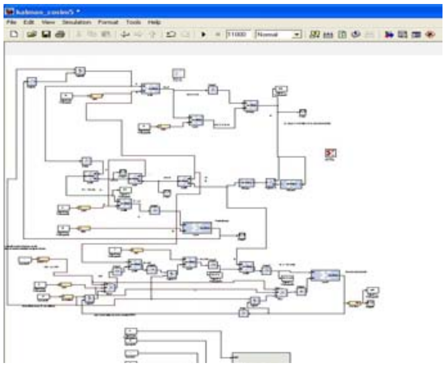

Fig. 11. Hardware Diagram in simulink.

A total of 11000 samples of the variables with noise for the processing with the Kalman filter have been used. Also, the answer considered in hardware that was made in the calculation of the Kalman filter is shown. Finally, is presented the subtraction of the signal with noise and the considered signal. Those answers are showed in figure 12.

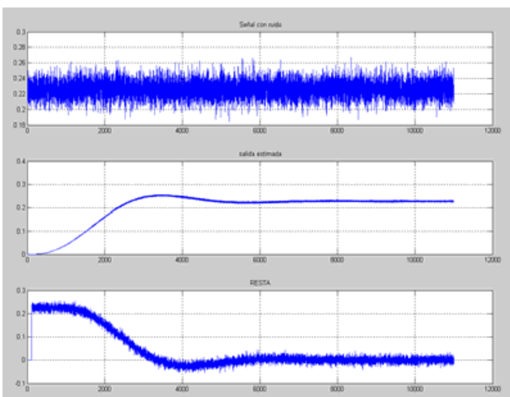

Fig.12. Graphics of the noisy signal, the estimated signal and its subtraction of the noisy and estimated signal.

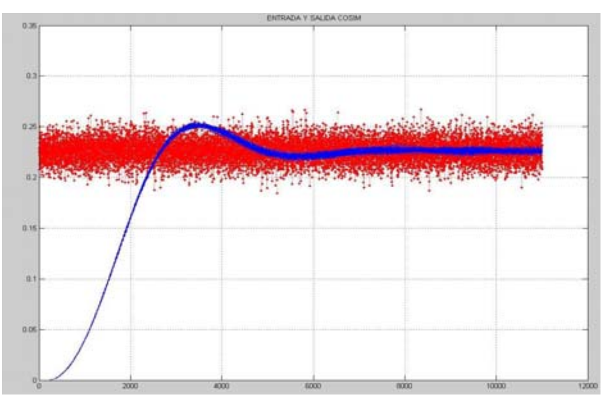

Fig. 13. Noisy and estimated signals

	Noisy signal	Estimated signal	Reduction %
Arithmetic mean (u)	0.2261.	0.2263.	**0.08**
Variance (σ^2)	1.2130e-004	3.9019e-006	**96.78**
Standard deviation (σ)	0.0110.	0.0020	**81.81**

Table 1. Results of comparison.

f) Design of the Interface for the temperature sensor and the tests of the sensor in a real system by Labview.

For this part, it is necessary to know the connections and dimensions of the integrated circuit for the acquisition of data, so we looked in the datasheet, which shows all the required to make the circuit board for the circuit of the conditioning signal and the thermocouple.

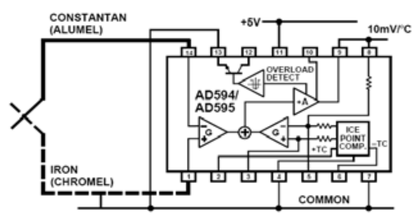

Fig. 14. Basic connection, with a single power supply.

With the diagram showed in the previous figure, the schematic circuit was made, which is in the figure 15, with program ORCAD 9.1, with the ORCAD Capture, for the circuit of signal conditioning AD595 and of the temperature sensor.

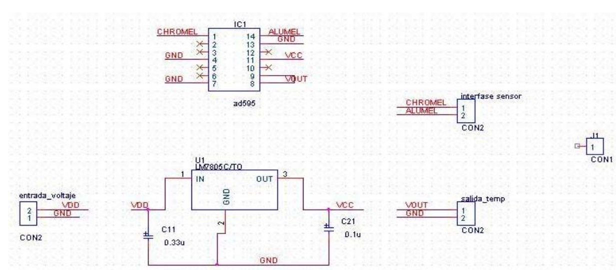

Fig. 15. Schematic circuit of the AD595 and the temperature sensor.

The next step was to import the file created in ORCAD Capture to ORCAD Layout Then, we made the schematic circuit using the footprints of the ORCAD Layout library.

In figure 16 is shown the final circuit and implemented with the AD595 for the temperature conditioner.

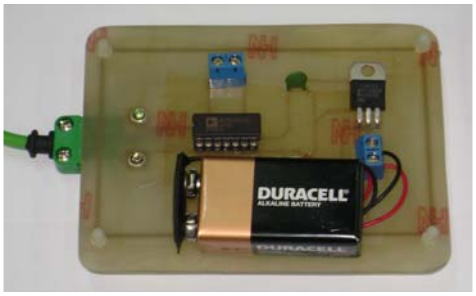

Fig.16. Final circuit of conditioning signal for the thermocouple type K type.

The multimeter shows a value of 218mV , which is the response of the temperature sensor and circuit already donne with the AD595. So, according to the datasheet the sensitivity is about 10mv/°C. Aproximating the value, the average of the thermometer is 21°C with this value gave a certainty measure.

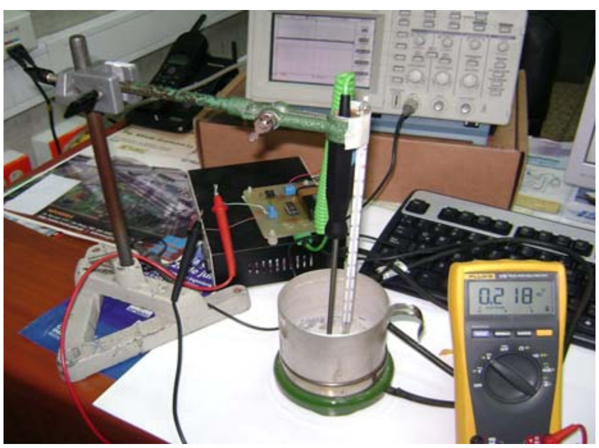

Fig. 17. Thermocouple and Thermometer.

In this part one connects the exits of the circuit of signal conditioning with the thermocouple to the unit DAQ USB-6008, which hass theses characteristics: 8 analogical inputs (12 bit, of up to 10 KS/s), 2 analogical outputs (12bit, 150 S/s), 12 inputs and outputs digital and finally a 32 counter of 32 bits. The connection is in figure 18.

Figure 18. Connection between DAQ and Signal conditioner.

The software national Instruments, labview, was used to visualize the collected data, the acquired values, which were contaminated by noise, this is shown in the main screen of figure 19.

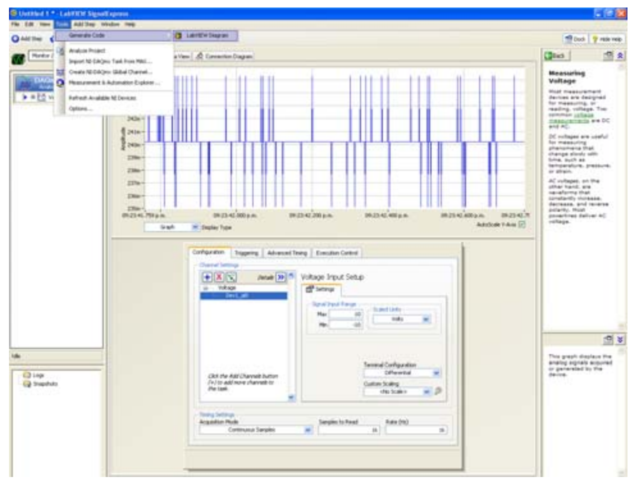

Fig. 19. Main screen of data acquisition from the software of NI.

Later the DAQ USB-6008 export the data collected to Labview. Its block diagram is in figure 20.

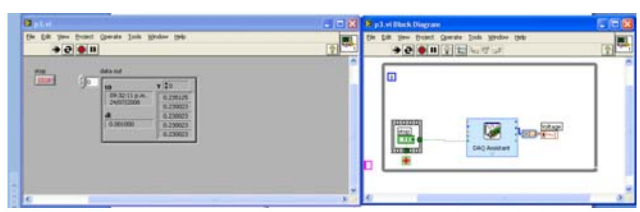

Fig.20. Block diagram exported to Labview.

Fig. 21. Temperature sensor proved in labview.

4. Results

- Modeling of the system in state variables.
- Through the compensators by Bode method and then Dead method beat could be obtained a correct and aproximate output of the system.
- Compensator of low cost.
- Compensator done in simulink.
- Export the compensator code in the simulink to the FPGA Virtex II PRO.
- Implementation of a filter able to estimate the correct and approximate answer.

5. Conclusions

- It is understood that the design of a compensator is theoretical and intuitive. So, when the compesator is tested in a real system there can exist some differences between real signal and theoretical signal.
- The good design of the compensator with state variables from the system refrigeration gives us an excellent response because we can manage the polex and zeros to make it stable system.
- Thanks to the FPGA Virtex II PRO gives the facility of having a real system in which we can prove the compensator obtaining results that can be used in the industry.
- Already realized the previous work, it is possible to be obtained other types of algorithms that can help to improve the input signal of the compensator.

6. Recomendations

- The compensator can be realised in different forms. So, it depends on the answer of the system working in a real situation.
- It is possible to work with other marks of FPGAs from the market. Everything would depend on the facility in the time of the design.
- For proving the design, it is necessary to have a system that is adapted to the equations already modulated from the system.
- No mathematical model is perfect, any model represents. In the other hand, the objective of the modeling is to represent the critical mode or non critical response of the system. So, some parameters are avoided. In fact, the used of models to generate data processors or controller online must be reduced to basic models in order to generate computer algorithms according to our system.

7. References

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