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FCXO : A Fuzzy Compensated Crystal Oscillator

Mario Reyes de los Mozos*, Elena Valderrama*, Javier Arguelles**

* C.N.M.(C.S.I.C.)-Departamento de Informatica,Universitat Autonoma de Barcelona, 08193 Bellaterra,SPAIN
** Facultad de Ciencias, Universidad de Cantabria, Avda. Los Castros, 39005 Santander,

0. ABSTRACT

We present a F.L.C. (*Fuzzy Logic Controler*) to control of the oscillation frequency of a V.C.X.O. (*Voltage Controled Crystal Oscillator*). This F.C.X.O. maintains stable its oscillation frequency inside a range of 1 ppm (*one part per millon*), with temperature between -55° C to +75° C.

1. INTRODUCCION

There are a lot of applications with crystal oscillators that need a larger stability, over the operation temperature rank, than the stability that they can to reach with one uncompesated crystal on ambient temperature. In this kind of applications is very interesting to overcome the problems derived from the crystal dependence in relation to temperature. Nowadays there are some compensation techniques, *(analogical & digital)*, that achieve to solve the objection commented before, reaching one error close to 1ppm into the operation temperature rank, *(from -55 ℃ to +75 ℃)*. The common problem of these techniques is the absolute necessity to know the performance graphs of the cuartz crystal depending on the temperature, forcing the crystal maker to realize a sequence of measurement over several conditions, and a sequence of mathematical calculations that increase the final price of the component, losing competitiveness in the market.

This paper presents a controller based in fuzzy logic that realizes the control of the frequency supplied by a V.C.X.O. *(Voltage Controlled Crystal Oscillator)*, behaving the complete system as a T.C.X.O. *(Temperature Compensated Crystal Oscillator)*. This new family of TCXO contributes with the fact that doesn't need the performance graphs commented before, reducing the final price of the component. Our goal is to hold up the same features that the known techniques *(1ppm // from -55 ℃ to +75 ℃)*.

2. F.L.C.

The FLC proposed has the network structure showed in the figure 1. With this design, the system has a high parallelism degree, reducing the response time. This network is made up of a finite number of process units, distributed by four layers. The nodes in these layers are connected with nodes of the adjacent layers.

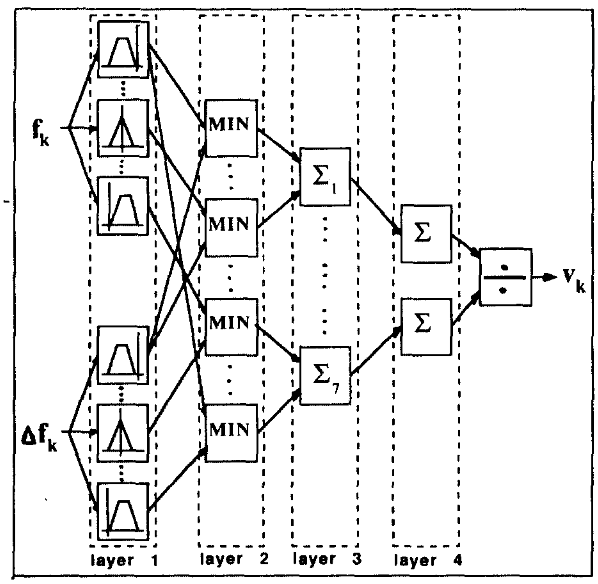


Figure 1. Structure of the F.L.C.

The nodes of the first layer realize the quantification process for every fuzzy set defined into every universe of condition,

$$O_{ij} = f_{ij}(I_i) \qquad i = 1,2 \; ; \; j = 1,\dots,7 \qquad (1)$$

where f_{ij} is the function that characterizes the *ith* fuzzy set defined into the *jth* universe of condition. The figure 2 shows the function model for these fuzzy sets.

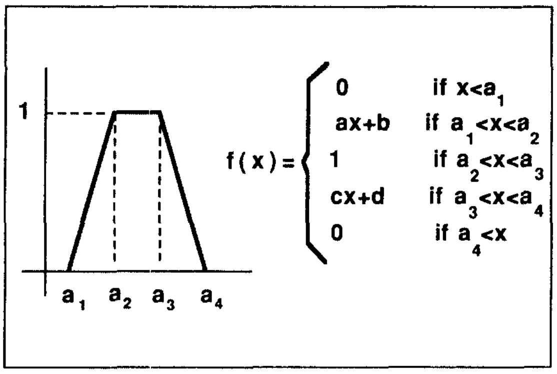


Figure 2. Function model of the fuzzy sets of the condition universes.

The nodes of the second layer evaluate the performance degree of every rule that makes up the knowledge base of the FLC,

$$O_l = \min(i_1, i_2) \qquad (2)$$

where i_1 and i_2 are two output from the first layer, being the membership degree appropriate to the frequencial error and diferential frequencial error.

The third layer has exactly seven nodes, where everyone of them evaluates the activity degree of a fuzzy set of the consequent universe,

$$O_j = \sum_{i=1}^{N} (w_{ij} * h_i), \qquad (3)$$

where w_{ij} is the weight assigned to every joint between the nodes of the second and third layers. The weight corresponds with the importance given to each of the rules, in the present case the weights are initiated to 0 or 1, remaining constants.

The last layer only has two nodes, both of of them are characterized by the equation 4,

$$O_i = \sum_{j=1}^{7} (w_{ij} * h_j), \qquad (4)$$

where the joint weights are shown in equation 5,

$$w_{1j} = y_j J_p \qquad w_{2j} = J_p \qquad (5)$$

where y_j is the median of the *jth* fuzzy set of the consequent universe, and J_j is the result of the integral given in equation 6,

$$J_j = \int_{a_{j1}}^{a_{j2}} f_j(x)dx \qquad (6)$$

where f_j is the function that characterizes the *jth* fuzzy set of the consequent universe. The figure 3 shows the function model adopted for these fuzzy sets.

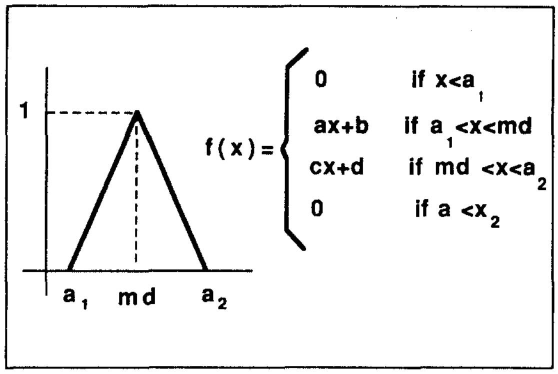
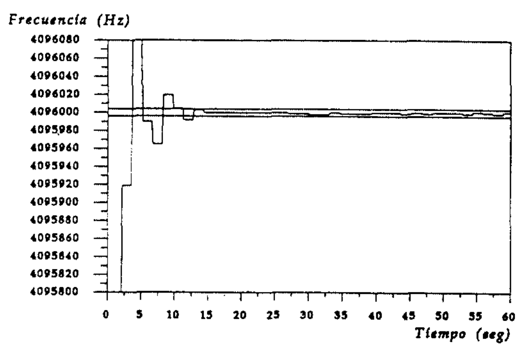


Figure 3. Function model of the fuzzy sets of the consequent universe.

3.PHYSICAL IMPLEMENTATION OF THE F.L.C. AND RESULTS

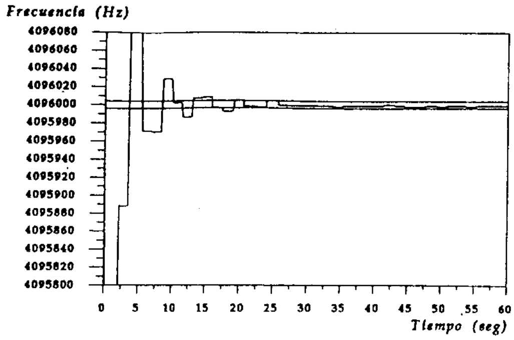
In a first version we have implemented the complete system by three blocks: V.C.X.O., frequencier, and F.L.C. , where the FLC has been implemented by software using a PC-AT. The measure of the actual frequency is nowadays realized by means of conventional frequencimeter.

We have done several experiments with it. In a first experiment we used the two condition uiverses defined before (*frequencial error & diferential frequencial error*). In this experiment we saw what the second universe had no effect in the results obtained.



Curve 1. VCXO oscillation frequency for T=27°C.

In subsequent experiments we used only the first condition universe, in which we have obtained a sort of results. The curves 1 and 2 show a sample of these.



Curve 2. VCXO oscillation frequency for T=70°C.

These results obtained with our first version reach the objectives marked in the beginning : 1 ppm.

5. CONCLUSIONS AND FUTURE WORK

We have presented a FLC for the control of the crystal oscillator frequency. The present version implements the FLC via software. A second version will include the VLSI implementation of booth the FLC and measure unit. This will lead to a sensitive time reduction and, consequently, to a more accurate control. For this new version the FLC inputs might not being the same that we have presented in this paper. In a VLSI implementation we can't measure the VCXO frequency because it is necessary another quartz crystal, a quartz crystal with a very stable oscillation frequency. So we are studing how to obtain sufficient information for knowing the crystal oscillation frequency as well as the work temperature. For this goal we take advantage of the different behaviours of the relation f:f/T of the quartz crystal in different overtones and different modes.

We are also studing how to add neural-based characteritics (learning) to defining better the fuzzy rules and the fuzzy sets.

6. REFERENCES

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