QRS Detection by Fuzzy Controller

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Abstract—**This paper describes a QRS detector system to be implemented using 0.35µm CMOS technology which is used in biomedical applications. The proposed system uses fuzzy logic controller and several analog circuits for detecting QRS complexes and separating these parts from the rest of ECG signal. Simulation results using HSPICE that verify the functionality of system are presented.**

Keywords—QRS Detection Algorithm, Fuzzy Logic Controller and Classifier

I. INTRODUCTION

The electrocardiogram (ECG) is one of the most relatively inexpensive and easily accessible investigational tools for the rapid diagnosis of arrhythmias. A typical waveform from an electrocardiogram (ECG) is shown in Fig. 1. It consists of several complexes, the P-complex, the QRS-complex, the T-complex and the U-complex.

The dominant component of the ECG is the QRS complex, which indicates the electrical depolarization of the muscles in the ventricle of the heart [1]. Several clinical applications including ECG monitoring system in intensive care unit, operating room and implantable defibrillator require accurate QRS detection algorithms while The QRS is easily recognized by a human observer. Previous automated algorithm detects QRS complexes when the ECG amplitude exceeds a threshold level [2]. Various types of automated algorithms were proposed in the literature for modifying QRS detection. This algorithms use multiple features of the EGG including RR internal, pulse duration and amplitude, to detect QRS complexes (Fig. 2).

By processing several features, it is less likely that large amplitude but short duration noise would be mistaken for a QRS. Similarly, it is more likely that a true QRS with low amplitude, but normal width and RR internal would be correctly detected.

Fuzzy inference systems are well-suited for this application (Fig. 3), since detection in this system based on a few amounts of uncertainly which is very similar to the medical reasoning process. Moreover the decision process is extremely easy to understand by human; consequently such easy interpretability allows external changes by experts on the decision process [3].

In this paper, we have used a fuzzy inference system to identify QRS complexes and designed a new circuit which is used in bio-medical applications. The block diagram of system is presented in section II and the method of system for detecting QRS complexes is discussed. Section III describes the circuits which are used in this system. Several simulation results are also presented in this section. Conclusion will be presented in section IV.

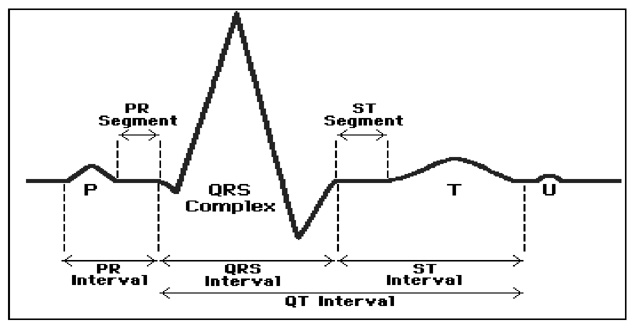

Fig. 1: A typical wave form of an ECG

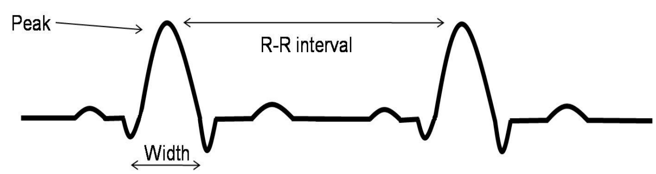

Fig. 2: Features of the ECG

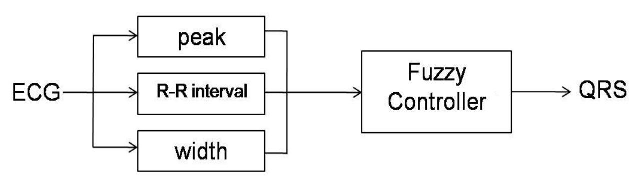

Fig. 3: using fuzzy controller for detecting QRS complexes

II. SYSTEM DESCRIPTION

The proposed chip consists of 2 main parts:

- QRS detector circuit
- Extracting QRS from an ECG circuit

First these parts will be explained separately and then the block diagram of the chip will be presented.

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A. QRS Detector Circuit

In this system QRS complex will be detected provided that a square wave synchronizes with them, consequently we use a fuzzy controller to adjust this square wave with QRS complexes. R-R internal, pulse duration and amplitude are features of ECG which are measured by specific circuits. The measured features are entered to a controller as inputs parameter. Fuzzy controller evaluates these features and adjusts the output pulse of VCO to be synchronized with QRS complexes (Fig. 4).

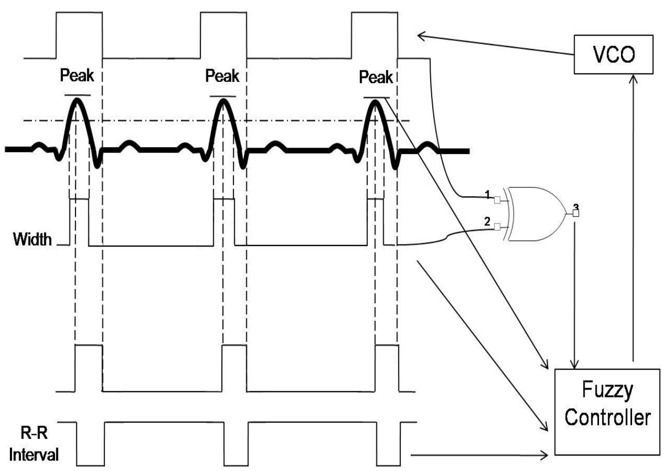

Fig. 4: The proposed QRS detector algorithm

A feedback is used to correct the synchronization process. This feedback is produced by error between the output pulse of VCO and the pulse that shows the width of QRS complex and is done by XOR logical gate. This feedback is also enter to controller and processed by fuzzy controller. Finally, the output of fuzzy controller goes to VCO circuit and makes the output pulse of VCO to be synchronized with QRS complex.

B. Extracting QRS from an ECG circuit

To separate QRS complexes, we passed ECG signals and synchronize VCO with the same DC voltage level trough an analog median filter (Fig. 5). Median Filter pass the median part of the input signals which, in this case, is QRS complexes.

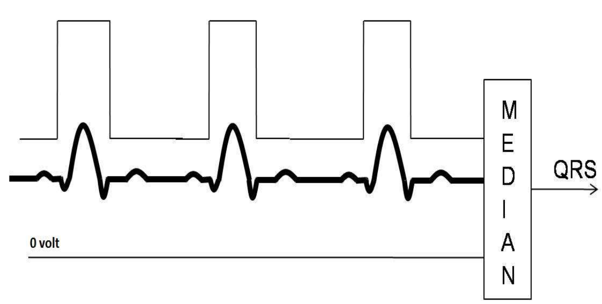

Fig. 5: Extracting QRS from an ECG

C. The proposed QRS detector chip

The block diagram of proposed system is presented in Fig. 6.

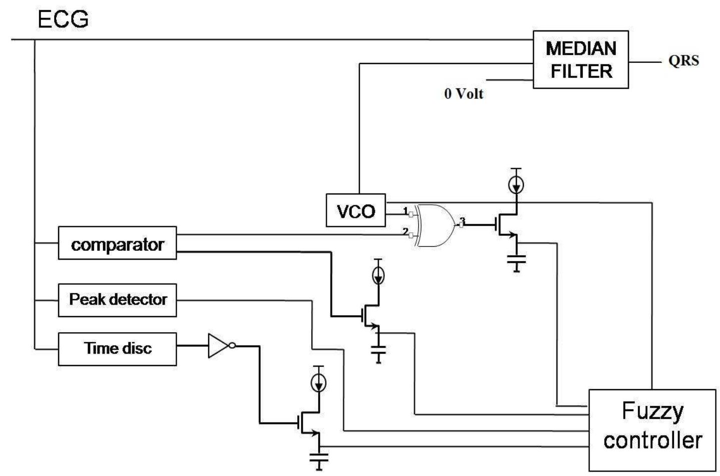

Fig. 6: The proposed QRS detector system

III. CIRCUIT DESCRIPTION

In this section the Fuzzy controller which is used in the system will be discussed and simulation results of the controller by MATLAB software which verified the functionality of the circuit are demonstrated. Finally, the simulation result for the system will be presented.

A. Fuzzy Controller

A 4 voltage inputs 1 voltage output Takagi-Sugeno (TS0) fuzzy controller is used in this work (Fig. 7).

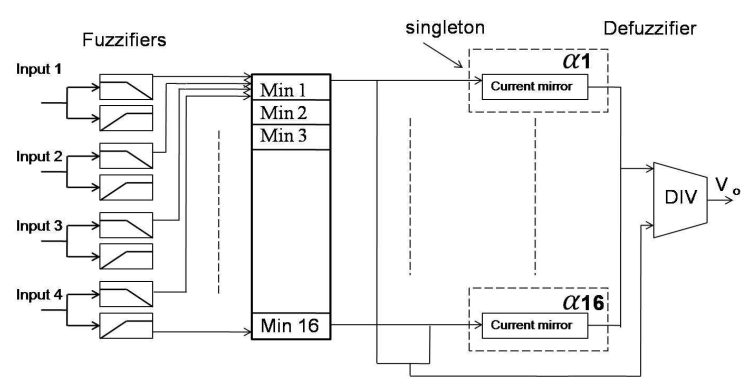

Fig. 7: Takagi-sugeno (TS0) fuzzy controller

Each input variables has two membership function; ‘small’ (Sm) and ‘large’ (Lg).

And each membership function is replaced by two trapezoids. Fig. 8 shows the structure of fuzzy controller which is used in MATLAB software for simulating the system.

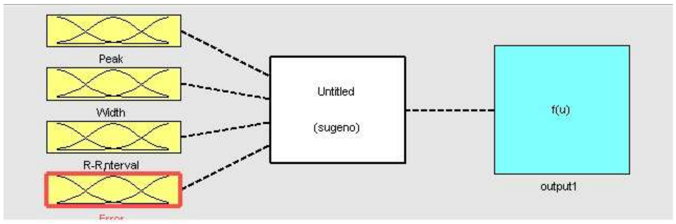

Fig. 8: The structure of fuzzy controller

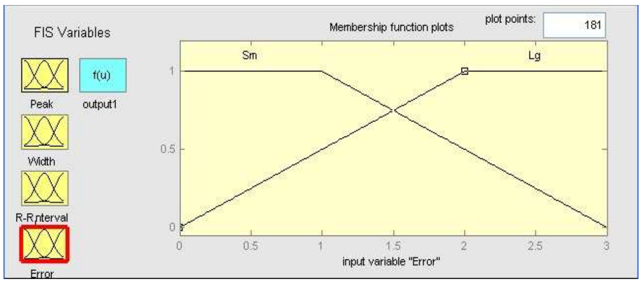

Fig. 9: Membership function

Since the TK0 fuzzy controller is used in this work, we have selected 5 language terms for the controller which is shown in Fig. 10.

Low-Normal (Norm)-Big-Very big (Vbig)-Very Very big (VVbig):

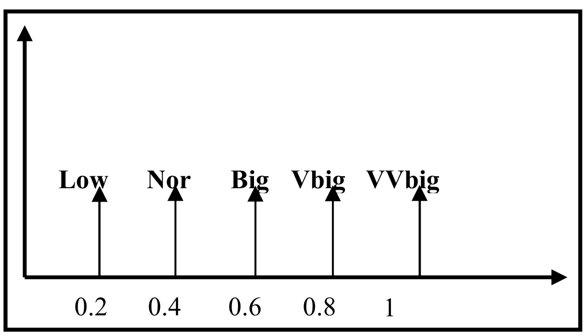

Fig. 10: Language terms

The fuzzy controller is simulated by MATLAB software and systematic control surfaces are obtained. Since there were 4 inputs and 1 output in our controller, the system control surface would have 5 dimensions. Consequently, we were selecting 2 inputs and 1 output and simulating controller. Fig. 11, Fig. 12 and Fig. 13 show the control surface of controller.

The Table I present the rules of fuzzy controller:

IV. SIMULATION RESULT

The output voltage of fuzzy controller is applied to VCO for synchronizing the output of VCO with QRS complexes.

Simulation result for the system is shown in Fig. 14.

Table I: Input and Output rules of fuzzy controller

Error	Width	R-R Interval	Peak	Output
S_m	S_m	S_m	S_m	Norm
S_m	S_m	S_m	L_g	Vbig
S_m	S_m	L_g	S_m	big
S_m	S_m	L_g	L_g	big
S_m	L_g	S_m	S_m	Norm
S_m	L_g	S_m	L_g	Norm
S_m	L_g	L_g	S_m	Norm
S_m	L_g	L_g	L_g	big
L_g	S_m	S_m	S_m	big
L_g	S_m	S_m	L_g	Vbig
L_g	S_m	L_g	S_m	Vbig
L_g	S_m	L_g	L_g	VVbig
L_g	L_g	S_m	S_m	big
L_g	L_g	S_m	L_g	big
L_g	L_g	L_g	S_m	Low
L_g	L_g	L_g	L_g	Low

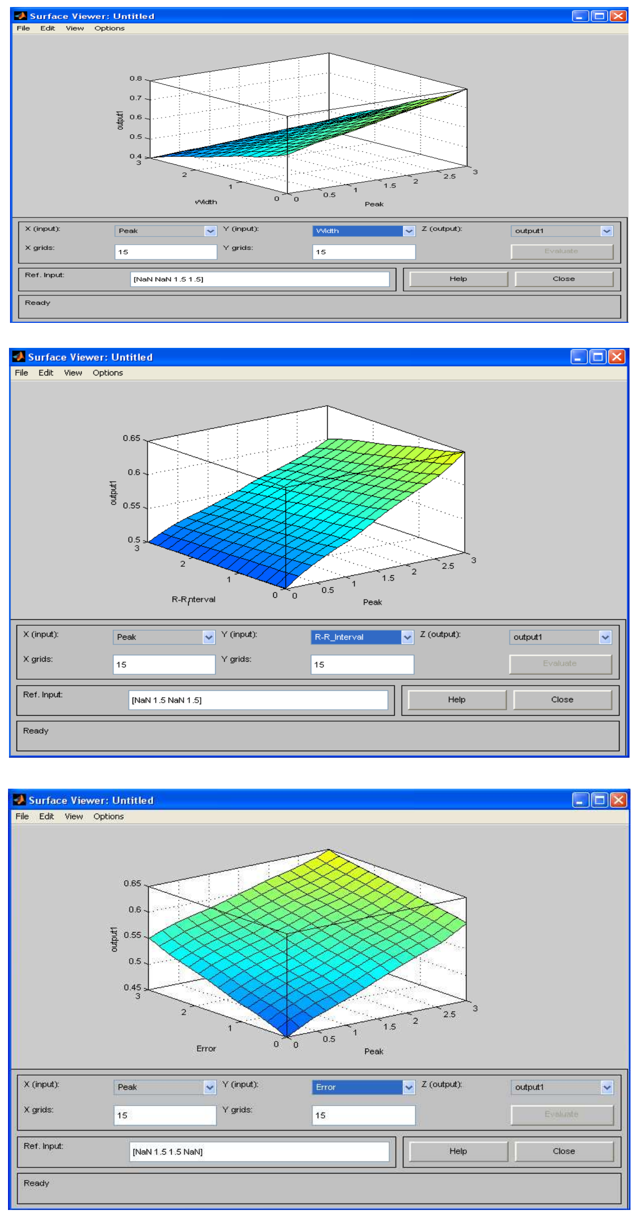

Fig. 9: Control surface

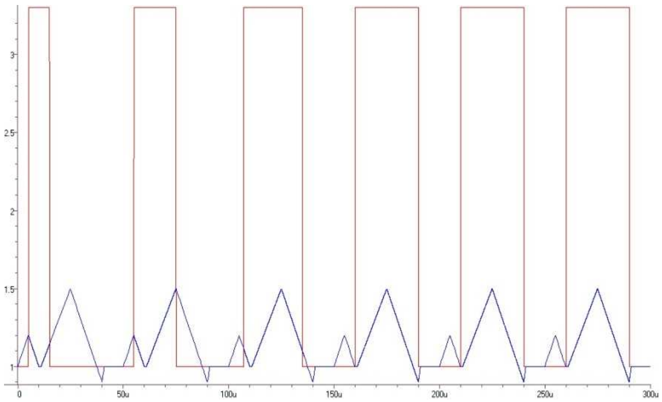

Fig. 14: Simulation result of the system

The VCO pulses are synchronized with QRS complexes by receiving a voltage from fuzzy controller. This synchronization process will be done after at most 5 cycles of ECG.

As mentioned above, if the VCO pulses and ECG are applied to a median filter QRS complexes will separate from the rest of ECG.

V. CONCLUSION

In this paper a QRS detector circuit is presented. Since the proposed system uses analog circuits, no need for A/D converter between the ECG and the detector circuit. The system could be used in several biomedical applications.

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