International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 24 (2017) pp. 14019-14025

Design And Construction of an Electrocardiogram with Visualization of Data in an App

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Abstract

This article explains in detail the design process of a mobile application, for the data visualization of an electrocardiogram. All the steps are explained, from the construction of a low cost data electrocardiogram adquisition signal device, to the design of the application, developing it to be able to visualize the data anywere in real time, in this way, the person can act faster before any cardiac problem occurs. This system is development using an smartphone to display the data using the Bluetooth to receive the informacion from processing device. The operative system select in this article is Android for its facility and easy sharing of information with the bluetooth devices.

Objective: Develop a device which can measure the electrical activity of the heart during a period of time and this signal can be observed and processed by a mobile application to be able to have information on the structure and function of the heart.

THEORETICAL FRAMEWORK

The history of how was the development of the Electrocardiograph through time.

- Seventeenth century: Begin studies of electricity with the tissues of animals and humans, experimenting on frogs, dogs, among others. To which, according to time and studies, it is possible to detect and perform cardiac treatments such as electrocardiographs.
- 1842: The physicist Carlo Matteucci, experimenting that by means of a nerve extracted from a frog's legs, which he used as an electrical sensor, shows that when the muscle contracted an electrical activity was observed, that is, that each heartbeat is accompanied by an electric current[1].
- 1856: Koelliker and Muller apply a galvanometer (Instrument used to determine the intensity and direction of an electric current by the deviation it produces in a magnetic needle at the base and apex of an exposed ventricle, making a test similar to Matteucci's, they could observe a small convulsion of the muscle just before the ventricular systole and a much smaller one after the systole, which are caused by the electric currents, which in the electrocardiogram appear as QRS complex and t-waves [2].
- 1872: An electrocardiogram is recorded, which is connected to wires on a wrist by the electronic engineer Alexander Muishead [3].
- 1872: John Burdon Sanderson demonstrates that there are two phases in the electric current: QRS y T [4].
- 1880: By the end of the 19th century the first human electrocardiogram was recorded by Auguste Waller [5].
- 1895: Five waves are differentiated in the improved voltmeter, which are called P, Q, R, S and T by Mr. Willem Einthoven.
- 1901: The first article by scientist Einthoven is published with the experience of a new galvanometer.
- 1906: Through the article "Telecardiogramme" describes "various cardiovascular disorders such as left and right ventricular and atrial hypertrophy, the U wave (reviewed for the first time), QRS dents, ventricular premature beats, ventricular bigeminy, atrial flutter and blockage full. This publication was the one that established the bases for the future reports that were developed on the electrocardiograms" [6].
- 1928: The first portable electrocardiograph with a weight of 25 kg was produced which operated with a 6V battery.

An electrocardiogram (ECG) is a test used to record heart rhythm. The ECG is used to study the activity of the heart through electrodes placed on the chest, wrists and ankles. This activity is measured in several points of the heart, called derivations, and is recorded as a curve for each of them. Normally, 12 leads are registered, although they can be extended to 18 in certain circumstances. The electrocardiogram is performed by suspecting a heart disease, a chest pain for example that makes us suspect a myocardial infarction, to control the progress of a disease or to guarantee the absence of abnormality. The test is quick and painless. The ECG can discover problems of cardiac arrhythmias, alterations in cardiac conduction, signs of heart suffering [7].

A mobile application, is a computer application designed to be executed on smartphones, tablets and other mobile devices and allows the user to perform a specific task of any professional type, leisure, educational, access to services, et, facilitating the efforts or activities to develop [8].

The AD8232 is a small chip used to measure the electrical activity of the heart. This electrical activity can be plotted as an ECG or electrocardiogram [9].

ELECTRIC ACTIVITIES OF THE HEART

The generation of the heartbeat is through a succession of ordered steps: contraction of the atrium followed by the ventricles, and during diastole, the atria and ventricles relax [10]. The signal of the electrocardiogram is due to the contraction of the ventriloquies and atria.

The atria (or atria) are the two upper secular cavities, right and left, separated by a septum (the interatrial septum) and located above the respective ventricles, with which they communicate through two atrioventricular orifices equipped with valves and the right ventricle and left ventricle. The left atrium communicates with the left ventricle through the mitral valve and the right atrium communicates with the right ventricle through the tricuspid valve. Each ventricle receives blood from the atrium on its same side and drives it to an artery: the pulmonary arteries, in the case of the right ventricle and the aorta, in the case of the left ventricle. The ventricles are separated from each other by the interventricular septum [5].

The difference between these two parts of the heart is that the atria reach the arterial blood and the ventricles the venous blood, that is, the arteries reach the atria and the ventricles reach the veins. In Fig. 1, is shown how the conformation of the wave depends on the movement of the heart.

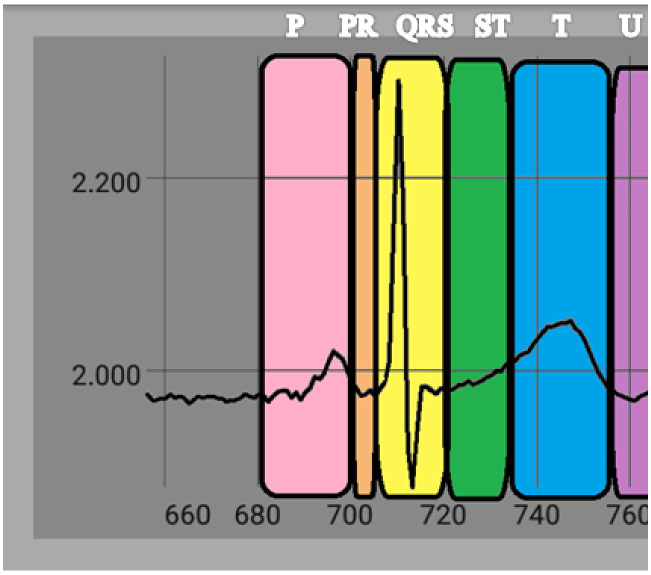

Figure 1: Electrocardiogram signal

Where:

Wave P: corresponds to atrial contraction. It is also composed of two waves that are equivalent to the contraction of both atria that in certain circumstances can be separated and clearly distinguished from each other. Its value is 2.5 mm in height and 2.5 mm in width as maximums. When these measures are exceeded we have left or left atrial enlargements (width greater than 2.5 mm) or enlargement of the right atrium (height greater than 2.5 mm) [11].

Interval P-R: it is measured from the beginning of the P wave to the beginning of the QRS complex (sometimes it is called PQ, since its measurement reaches to the beginning of the QRS complex) [11].

QRS Complex: It is also composed of a Q wave that is the first negative wave of the QRS complex, the R wave that is the first positive wave of the complex and the S wave that is the second negative wave of the same. It is measured from the first wave that appears in the complex until the end of them until where the ST segment begins. There may be different morphologies of QRS complexes that are conventionally referred to as uppercase or lowercase letters [11].

Segment S-T: It is not measured usually. It is interesting to know if it is above or below the level of unevenness or descending with respect to the electric line [11].

Q-T interval: it is measured from the beginning of the Q wave to the end of the T wave. It must be corrected according to the heart rate [11].

Intrinsicide deflexion: a bisector is drawn from the apex of the R wave to the isoelectric line and the space between the beginning of the QRS and the foot of this line is called intrinsicide deflection [11].

Wave U: it is an inconstant wave. It is found after the T wave. As in all things, the correct and complete reading of an electrocardiographic tracing is the best guarantee that the correct diagnosis can be made. For this we recommend always follow a basic order consisting of the following [11].

STEPS FOR THE READING OF THE ELECTROCARDIOGRAM:

1- Rhythm: Sinus or not.

2- Heart rate:

1. Applying the formula where FC = 300 / N, knowing that N = the number of large squares between two QRS complexes.

3- Determination of the electric axis: using the perpendicular or higher voltage method.

4- Value the P wave: Height and width.

5- Measure the P-R interval: From the beginning of the P Until the beginning of the QRS.

6- Value the QRS complex: Width and characteristics.

7- Valuing the S-TSi segment is above or below level.

8- Value the T wave: if it is positive or negative.

9- Measure the Q-T: Especially know if it is long or short by measuring the corrected QT according to the frequency.

10- Value the u wave: It has little value, but it can be useful in cardiopathic disease.

Table I: Wave interval segments

Waves	Normal duration (s)		Event
	Average	Boundaries	
PR	0.18	0.12-0.20	AV conduction
QRS	0.08	To 0.1	Ventricular depolarization
QT	0.4	To 0.43	Ventricular depolarization with ventricular depolarization
ST	0.32	Not defined	Ventricular depolarization

The Table I. shows the intervals of the waves and segments that make up the electrocardiogram and the cardiac events that occur during these intervals [10].

ANALYSIS OF THE ELECTROCARDIOGRAM SIGNAL.

PROCESSING OF THE SIGNAL

The signal of the electrocardiogram is accompanied by a series of interferences which must be taken into account to dictate a diagnosis of the electrocardiogram, these factors are noise, interference of the network and variations of the line [9].

- Noise can be caused by the electronic equipment used or by the movement of the muscles that intervenes at the time of the data collection by the ECG.
- The interference of the network can be an effect that appears relatively frequently in electrocardiographic signals and in general, in any biomedical signal, it is the superposition of an interference due to the signal of the network, which in this case is high frequency.
- Variations of baseline can be caused by the patient's breathing or the movement of this and finally by the impedance presented by the electrodes.

Discrete Fourier Transform (DFT) and Fast Fourier (FFT).

It is a method that assigns a description about the distribution of energy of the signal with respect to its frequency content. His mathematical expression is defined as [12].

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot W^{nk} \; k = 0,1,2,\dots,N-1$$

$$X(n) = \frac{1}{N}\sum_{n=0}^{N-1} x(n) \cdot W^{-nk} \; k = 0,1,2,\dots,N-1$$

The Fast Fourier Transform is basically defined as a mathematical algorithm, which captures digitized samples in the time domain and in turn calculates its representation in the frequency domain.

Discrete Cosine Transform (DCT).

This transform has a good property of energy compaction, which produces incorrect coefficients, with the difference that the base vectors of the DCT depend only on the order of the selected transformation, and not on the statistical properties of the input data. Its mathematical expression is defined as [12]:

$$g(u,v) = a_u \cdot a_v \frac{2}{N} \cdot \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y) \cdot cos\left(\frac{(2x+1)\cdot u \cdot \pi}{2N}\right) \cdot cos\left(\frac{(2y+1)\cdot v \cdot \pi}{2N}\right)$$

Wavelet Discrete Transform (DWT).

Known for the implementation of signals to detect their noise and possible decompositions of each of the ECG signals, used to design a QRS detector. Its mathematical expression is defined in how [12].

$$s(2^i, 2^i \cdot n) = \frac{1}{\sqrt{2^i}} \cdot \sum_k \Psi \cdot \left(\frac{k}{2i} - n\right) \cdot s(k)$$

As shown in the previous image it is observed that the Wavelet transform helps us to mitigate the noise of the signal.

ELECTRONIC DESIGN:

This segment shows the design that was made to manufacture the device to measure or read in the same way as an electrocardiogram, for this a series of steps were established which are the following:

1- Which elements will be used.
2- Join the required hardware.
3- Perform tests using a bluetooth module to send data to the computer.

4- Perform tests using a Wifi module to send data to the computer.
5- Design an APP for the electrocardiogram.

The chosen elements were.

- Atmega16A microcontroller.
- HC-05 Bluetooth module.
- AD8232 Sensor.
- LM1117t voltage regulator.
- Android phone.

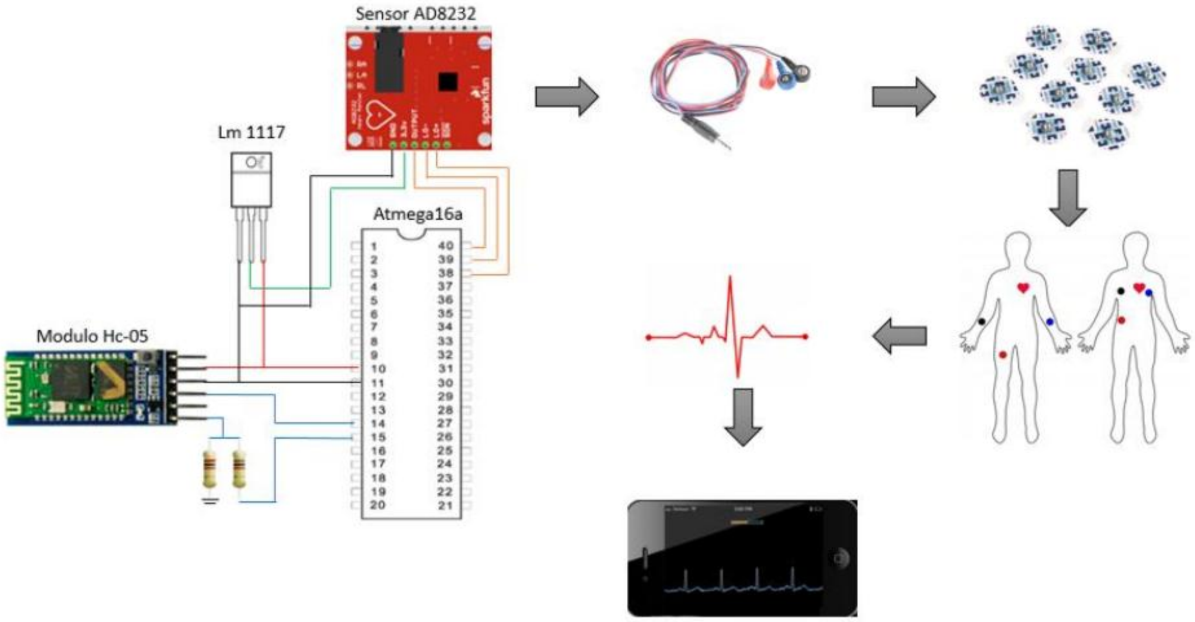

Figure 3: Connection of data acquisition system components

CLASS DIAGRAM

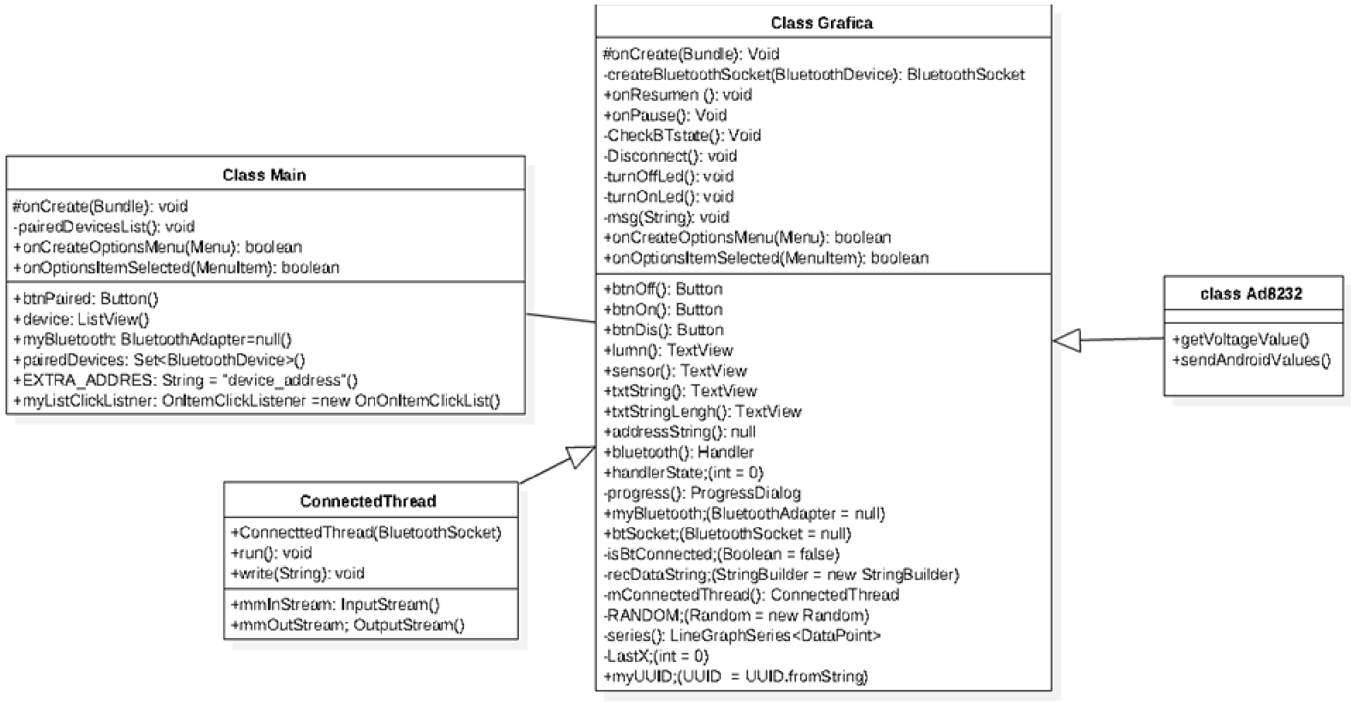

Figure 4: Class Diagram

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 24 (2017) pp. 14019-14025

After pressing the button previously allow this will start the activation of the bluetooth module.

The next step is to find out which Bluetooth devices the cell phone is linked to, by clicking on the "SEARCH DEVICE" button

When pressing the button will show all the devices linked to the cell phone and its respective MAC., The next step is to press the device to which we want to connect in this case would be the "HC-05"

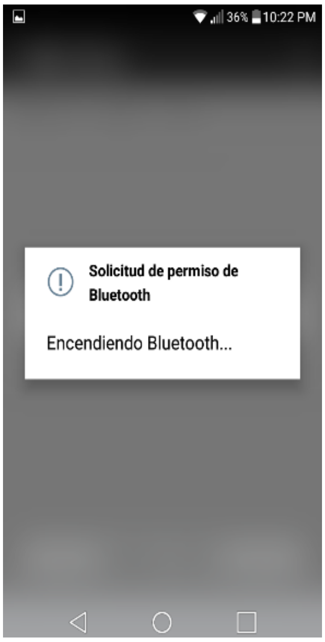

Figure 5: Application start

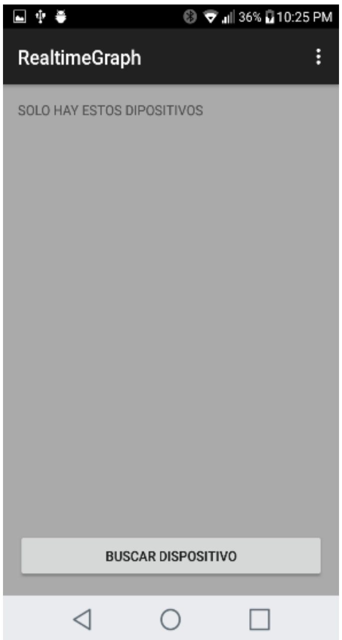

Figure 6: Device search

Figure 7: List of linked devices

When you start sending data from the Atmega16 to the cell phone via Bluetooth, the graph will be generated, and you can see it in the graphical interface and in the same way you can send data from the cell phone to atmega16, in case you need to take any action or measure, you will also find the button to disconnect when the task of observing the electrocardiogram data is finished.

Satisfactory results were obtained by being able to use the database [13] that gives the possibility of comparing the graph of the ECG signal in the mobile. The monitoring of a single derivative was performed, obtaining the accuracy and precision required, compared with the signals of real patients. A delay has been noticed when converting the signal, passing it to the mobile and plotting it, which is in the order of 10ms. The purpose of the development of this project is didactic, however it is expected that in the future you could have a data acquisition card with higher speed and less delay in the transmission.

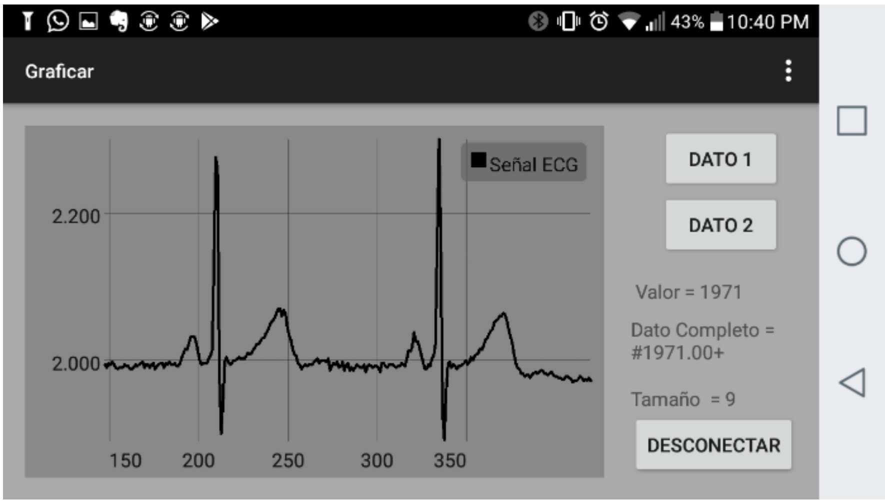

Figure 8: Signal received from micro controller

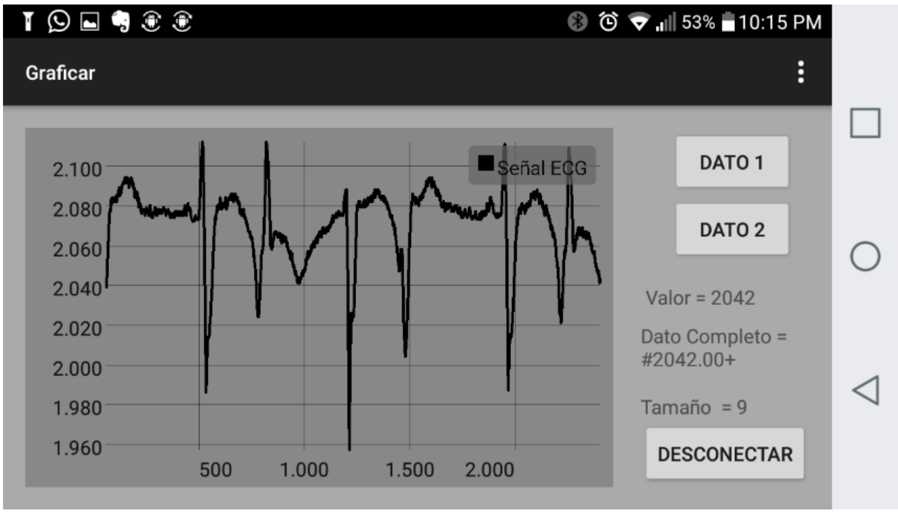

Figure 9: Heart attack

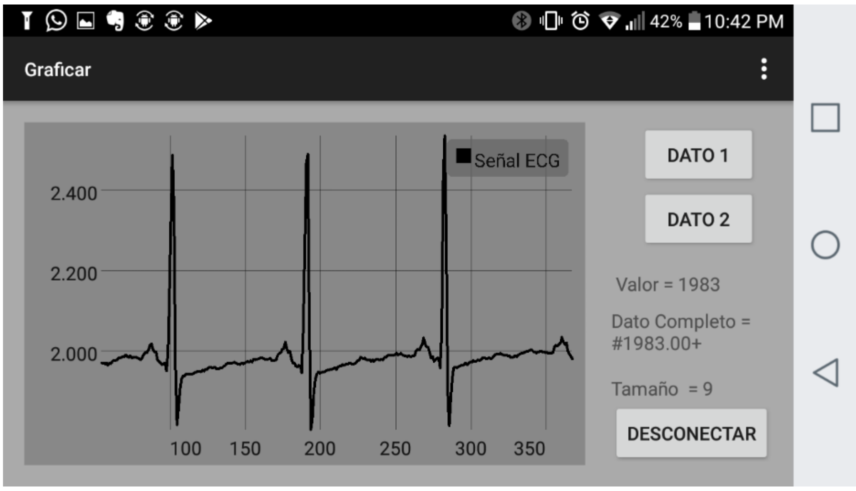

Figure 10: Signal of a normal heart rhythm

CONCLUSIONS

The AD8232 sensor allowed to measure the electrical activity of the heart in the first derivative. This electrical activity was traced as an electrocardiogram and transmitted to Bluetooth, obtaining in relation to the data patterns of [13]a briefly noisy output. In the case of this article, the AD8232 acted as a heart rate monitor when integrating a signal conditioning block for biopotential measurement applications.

The implemented ECG prototype can be enabled for personal use, since its electrocardiography signal display tool is low cost compared to commercial electrocardiographs.

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