Simultaneous in vitro recording of electrode position and electrograms

A.C. Linnenbank[12], D.G. Kistemaker[1], V.M. Meijborg[3], A.C.G. van Ginneken[1], C. Kools[1], C.N. Belterman[1], J.M.T. de Bakker[12], C.E. Conrath[3]

[1] Exp. Cardiololgy section, Heart Failure Research Center, AMC, Amsterdam, Netherlands
[2] Interuniversity Cardiology Institute Netherlands, Utrecht, Netherlands
[3] Dept. of Cardiology, AMC, Amsterdam, Netherlands

***Abstract*— A method was developed to localize measurement electrodes within a beating heart in a Langendorff setup. A prototype printed circuit board was build. First results show that it is possible to follow the electrodes during the contraction although the coordinates are distorted.**

***Keywords*— 3D Localization , LocaLisa, Langendorff,**

Introduction

The movement of the heart during the heart cycle influences local electrograms and body surface electrocardiograms. It is known that contraction, which follows activation, influences the activation of cardiac myocytes by electro-mechanical feedback. Contraction also leads to changes in the volume conductor e.g. by diminishing the volume of blood in the ventricles and rotation of the heart in the thorax. How much the total effect is of these factors and their interaction is not known.

Tagged MRI's can be used to investigate movement of the heart, but then it is not possible to change the activation sequence of the heart while recording with multiple electrodes. In an in vivo or in vitro animal experiment, different activation sequences can easily be induces, but recording the movement of the heart is difficult especially during simultaneous recording of epi/endo and intramural electrograms. In addition, it would be practical to use the same electrodes for recording and estimation of movement. Therefore, we used an isolated, Langendorff-perfused pig heart submerged in a blood/tyrode mixture-filled container which had 60 electrodes on its inside wall to record pseudo surface leads (figure 1).

To determine the position of the recording (needle) electrodes various methods are available (e.g. CT, echo, video, Carto), but none of them is able to do this in real time in a blood filled container. The best suited method thus far seemed to be the LocaLisa approach. The Localisa system is a pseudo GPS system that allows real-time imaging of the position of the tip of a catheter in the heart[1]. It does this by recording the voltage on regular intracardiac electrodes inside an electric field that defines a coordinate system. The electric field is made by three orthogonally placed alternating current sources with frequencies outside the recording bandwidth (30 kHz). Each channel requires special electronics to extract these position signals. However, for sufficient spatial resolution to detect heart movement, the position of about 100 electrodes has to be determined. This would add a significant amount of hardware to the setup.

I. Methods

For our application we used three signals with a frequency within the bandwidth of our (mapping) amplifier, but outside the frequency range of our physiological signals; a sine and cosine wave of 896 Hz and a cosine wave of 1024 Hz. The amplifier has a sampling frequency of 2048 Hz with a lowpass filter that leads to about 15 and 20dB attenuation at 896 and 1024 Hz. (Active2 system, BioSemi Amsterdam). The recording system generates a clock signal synchronous with the sampling clock. A phase locked loop (PLL) was used to generate another clock signal with a multiple of that sampling frequency (figure 2). Four electrodes were added to the container at the top level of the blood at 90 degrees intervals. The 896 Hz sine wave currents flowed between two opposite electrodes, the other two electrodes were used for the cosines (figure 1). This provides an X-Y quadrature signal system with the zero in the top middle of the container. This is also the position where the heart is suspended from the aorta and where the reference electrode of the recording system is positioned. An electrode at the center of the bottom of the container was used for the 1024Hz cosine signal to obtain the Z-position. The combination of the four electrodes that provide the X and Y directions was used as the negative pole.

The frequencies were chosen in such a way that after 16 samples the “localizing signals” repeated. A digital input of the system was used to indicate the first sample of each sequence.

To extract the X,Y and Z components, the recorded signals were multiplied by a sine/cosine of the appropriate frequency and integrated over 16 samples. This is in fact a Fourier analysis of only the frequencies that are needed.

The conducting fluid acts as a variable potentiometer setup. Any point in the central axis of the container is equally distant from the X and Y electrodes and will consequently have zero amplitude for both directions. Displacements from the axis lower in the container, i.e. further away from the X and Y axis generating electrodes, will change the relative distances to the electrodes less than the same displacement higher in the container. The shape of the container also plays a role, resistance is larger when an electrode is closer to the wall of the container than in the middle. The system is therefore nonlinear and the resolution at the apex of the heart is less than more close to the base of the heart.

II. Discussion

Although we have developed a system where we can measure the position of many electrodes simultaneously, the X, Y, and Z coordinates are distorted (figure 3). However, they are reproducible and the distortion should be computable from standard volume conduction theory. Within a needle the distance between the electrodes are known. This could also be used to define a local coordinate transformation.

III. Conclusions

Using a standard data acquisition system and only a few extra components, we were able to record simultaneously the position of the heart and electrograms at the endo- and epicardium and intramurally.

References

1. Wittkampf FHM, Wever EFD et al. (1999) LocalLisa: a New Technique for Real-Time 3-Dimensional Localization of Regular Intracardiac Electrodes, Circulation 99;1312-1217

Author: A.C. Linnenbank
Institute: Academic Medical Center
Street: Meibergdreef 15
City: Amsterdam
Country: Netherlands
Email: a.c.linnenbank@amc.uva.nl

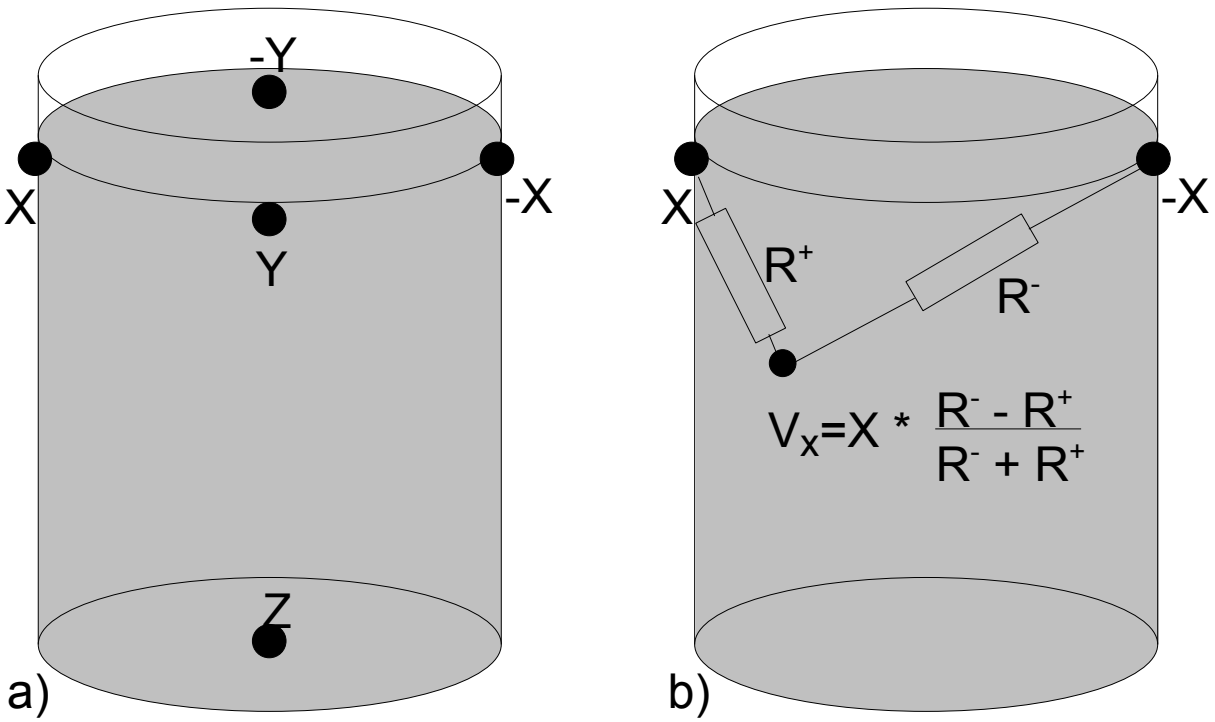

Figure 1: a) positions of the electrodes that inject the current in the fluid (grey) filled container. b) the amplitude of the signal depends on the relative distances to the current injecting electrodes. Lower in the container the resistances are more similar and the amplitude of the recorded signal increases less with the distance from the center.

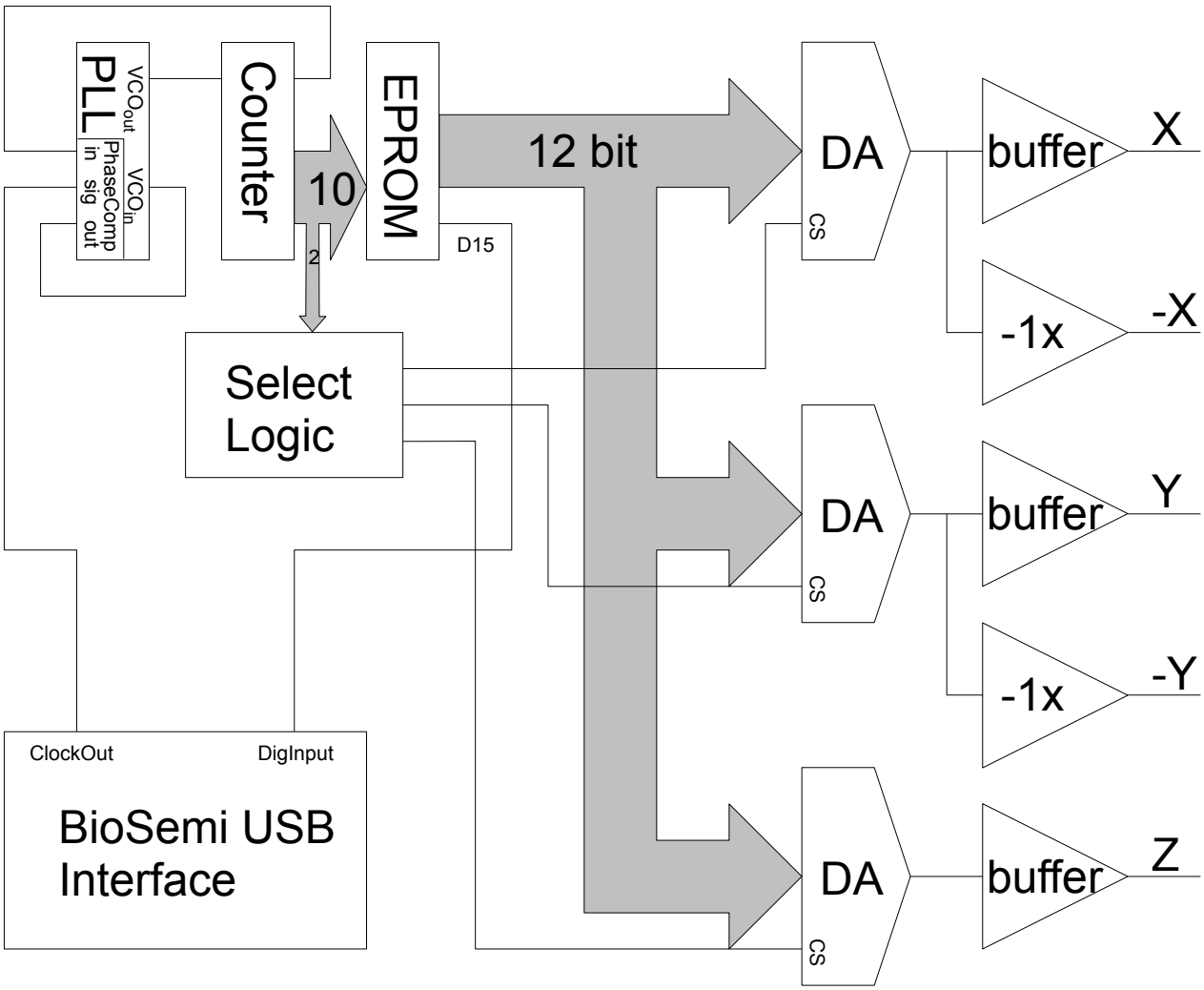

Figure 2: Simplified schematics of the hardware. The ClockOut line on the USB interface is used to derive a clock signal that is synchronous with the sampling. This signal clocks a counter that scans an EPROM. Data from the EPROM is fed into DA converters. Buffered outputs from the DAC's are connected to the current injecting electrodes. The highest bit (D15) of the first sample is set to indicate the start of a sequence of samples. This bit is inserted synchronous in the digitized analog data stream.

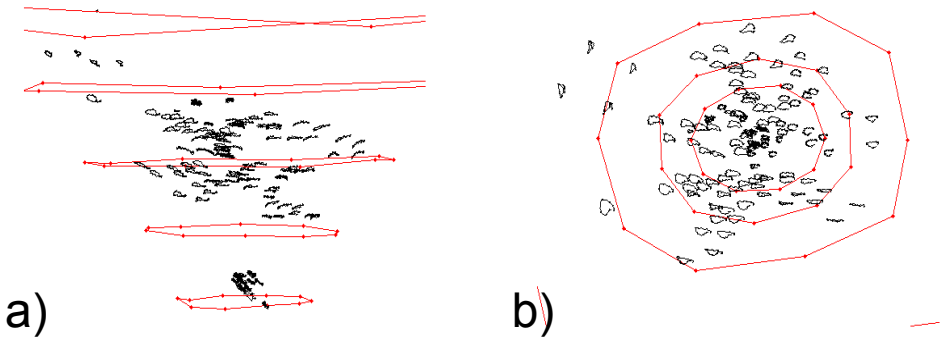

Figure 3: a) front view of the electrodes. In red and drawn lines the electrodes on the inside of the container. In black the needle electrodes moving during one heartbeat. Note that the container appears distorted with the radius of the container ('surface') electrodes near the bottom much smaller than those at the top rows. b) top view.