A Cost-Effective Instrumentation System to Measure Switching Currents of AFLC Displays

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Topics: Electrooptíc Displays.
Key words: Liquid crystal; V-shaped response; switching currents

1.- Introduction

Liquid crystals constitute a form of soft matter possessing higher symmetry than isotropic liquids but lower symmetry than solid crystals. Liquid crystals with a spontaneous electric polarization were discovered in 1975. After that, and five years later, it was realized the first device truly ferroelectric, by using the so-called technique of surface stabilization [1]. The phase where spontaneous polarization appears is the chiral smectic C phase, i.e. a phase which lacks mirror symmetry and where the long molecule axes are inclined with respect to the layer normal. Materials exhibiting this phase are therefore often referred to as ferroelectric liquid crystals (FLCs). It was realized at an early stage that FLCs could be extremely useful in high-speed, high-resolution electrooptic devices. Moreover, an important research in the field of chiral smectics took place in the following years. As a consequence, in 1989 this led to the discovery of antiferroelectric liquid crystals (AFLCs).

AFLCs have focused a great attention from industrial and scientific community. They show interesting electrooptical properties such as tri-state switching, fast response, intrinsic analogue gray scale, wide viewing angle, among others, which are appropriate for high-end video display applications [2].

The performance of the AFLC displays is determined by their electrical and optical behavior [3]. In order to measure some electrical characteristics such as the switching currents and electrical loops (polarization-voltage), a customized instrumentation system has been designed and implemented. It is well known that to carry out measurements of electric current ranged in the pA-nA, a specific and usually expensive equipment should be used. This work presents a cost-effective electronic system which is able to measure with a reasonably precisión low switching currents in AFLC displays.

2.- Design and System Implementation

It is a traditional electronic matter to be able to measure with high precisión low valúes of electric currents in capacitors. There are commercial instrumentation amplifiers, which could perform this kind of measurements, but their cost is usually high. Our prototype is based on the injection/extraction of small pulses of the electric charge (pC) applied to the capacitor that in our case, it is a pixel of the LC display that behaves as a plañe capacitor filled with a non-ideal dielectric. The working principie is the following: if the voltage in the capacitor (Vx) is higher than the reference voltage (Ve), the circuit introduces a pulse of electric charge (+AQ). On the contrary, if Vx is lower than Ve, then the circuit extraets a small amount of the electric charge from the capacitor (-AQ).. A block diagram of the circuit is shown in Figure 1.

Typical valúes for the capacitances associated to individual pixels may range around pF. These very low valúes of capacitances become difficult to measure the electrical currents through the pixels of LCDs by conventional methods, so the need to build a customized electronic system to realize of an appropriate way such measurements.

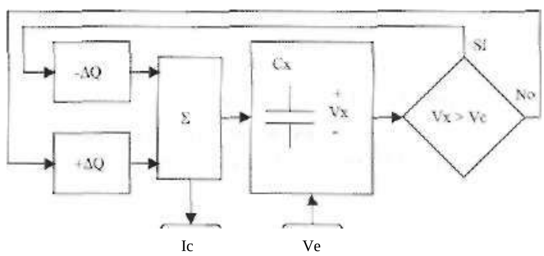

Figure 1. Block diagram ofthe electronic system implemented.

The prototype implemented is formed by the following electronic subsystems:

- an operational amplifier in configuration of transimpedance, which is the responsible for injecting/extracting the charge pulses (AQ).
- A bistable to establish the condition to inject/extract such charge pulses.
- An additional amplifier to genérate the voltage pulses, which reproduce the reference voltage (by following the slope of the applied signal) in the electrodes of the capacitor.
- A low-pass filter to average the voltage pulses in the capacitor.

3. System Calibration

In order to verify the right functioning of the system, a set of preliminary measurements were performed. These measurements are based on the well-established relationship between the voltage and the current across of a linear capacitor:

$$I_x = C_x[dV_x/dt]$$

In this case, when a triangular waveform is applied to the test linear capacitor, the electric current obtained should by a square waveform. If the applied signal is a square waveform, the current should be similar to a train of 8- pulses. In order to reproduce similar characterizing conditions to the pixels of LCDs, we have used a ceramic capacitor of C=100pF. The frequency of the applied signáis was less than 10Hz. The results obtained for different kind of signáis used are shown in Figures 2-5.

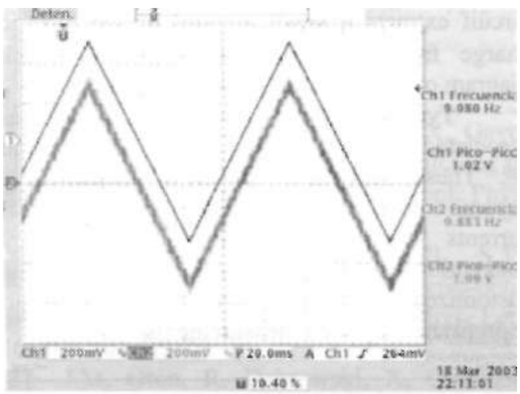

Figure 2.- Triangular waveform: the upper trace corresponds to the reference voltage signal; the lower trace corresponds to the voltage signal measured in the electrodes ofthe capacitor.

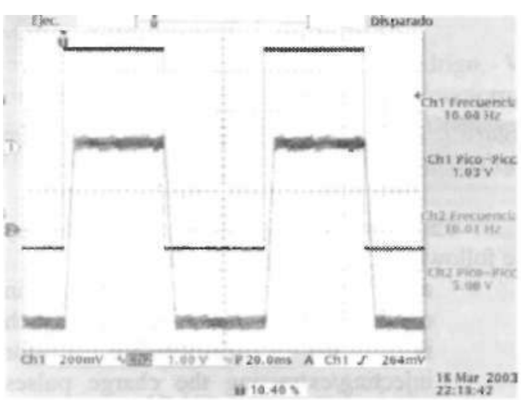

Figure 3.- Square waveform: the upper trace corresponds to the reference voltage signal; the lower trace corresponds to the voltage signal measured in the electrodes ofthe capacitor.

Figures 2 and 3 show how the circuir reproduces the reference voltage signal in the electrodes of the capacitor for triangular and square waveforms, respectively. A small noise appears in both cases due to digital valúes generated in order to follow the slope of the reference signal. However, the whole signal presents similar electric characteristics to the original one.

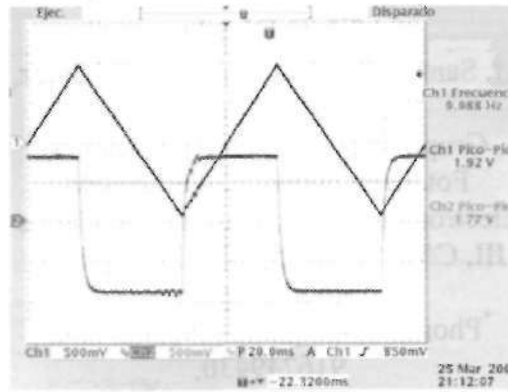

Figure 4.- The upper trace corresponds to the reference voltage signal; the lower trace corresponds to the electric current measured in the electrodes ofthe capacitor.

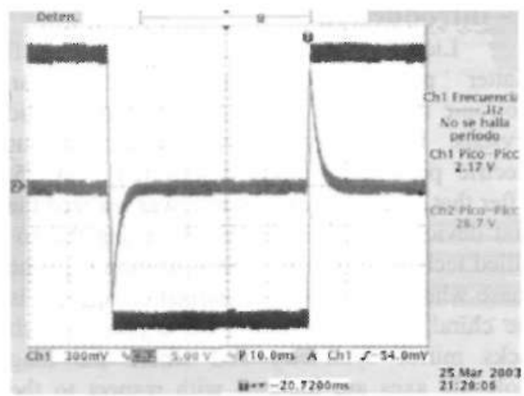

Figure 5.- The upper trace corresponds to the reference voltage signal; the lower trace corresponds to the electric current measured in the electrodes ofthe capacitor.

As it can be seen, experimental and theoretical results agree fairly good. The electrical current measured is approximately the derivative in the temporal domain of the voltage signal in the capacitor.

4.- Results and Discussion.

Once checked the right functioning of our system from the electrical point of view, the next step is to measure the switching currents in AFLC cells (Figures 6-7). This measurement permits to evalúate some important characteristics ofthe AFLC displays:

the electrical loops of the AFLC device can be derived from the current measurement (by integrating in time domain).

The switehing current and complex impedance measurements permit to obtain an electrical equivalent circuit (EEC) for the AFLC cell.

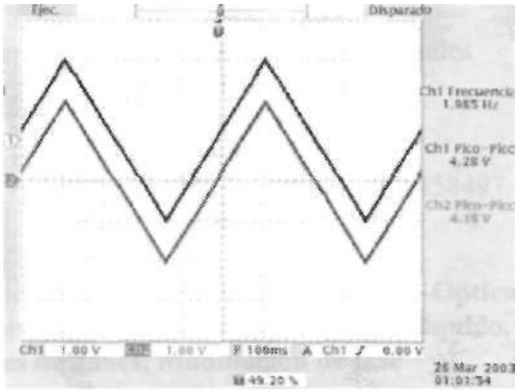

Figure 6.- The upper trace corresponds to the reference voltage signal; the lower trace corresponds to the voltage signal measured in the electrodes ofthe V-shape AFLCpixel.

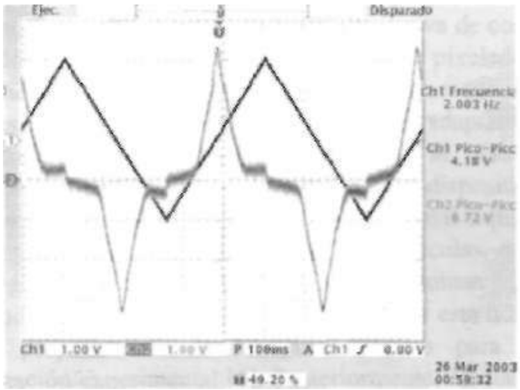

Figure 7.- The upper trace corresponds to the applied voltage signal to a V-shape AFLC pixel; the lower trace corresponds to the switehing current measured in the electrodes of pixel.

Both, electrical hysteresis and EEC, provide useftil information on the electrical behavior ofthe pixel of AFLC display.

The EEC for a V-shape device has been obtained elsewhere [4]. The figure 8 shows the electrical network, including the non-linear elements (Rhx and C_{hx}), that accounts the electrical behavior of the V-shape AFLC pixel.

Each element or combination of elements describes the different aspeets related to the electrooptic response:

(i) The static capacitor C_s, accounts for the nonferroelectric part of the dielectric response (due to instantaneous polarization) of the AFLC pixel.

(ii) The series Rh_xCh_x combination covers the ferroelectric aspect of the dielectric response. Both elements take into account the dielectric relaxation (heat dissipation) and the slow orientation of dipole polarization, respectively.

(iii) The series RsCs combination reflects the influence of the pixel parameters such as resistivity and capacity of ITO layers, insulating and aligning layers. Normally, Cs is very large compared to other capacitances ofthe circuit.

As the EEC that simulates the electrical behavior of the V-shape AFLC pixel is fairly complex, it seems reasonably that when a triangular waveform is applied to the pixel, the shape of the current curve measured could be rather complicated.

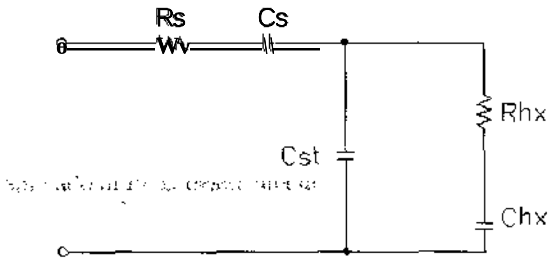

Figure 8. Electrical equivalent circuit ofan AFLC pixel. R^ and C_{hx} show a non-linear dependence with the voltage.

In fact, the plot of the figure 7 shows such the temporal variation. It is remarkable the step in the current curve when the triangular waveform changes the slope.

5.- Conclusions.

A cost-effective instrumentation system has been designed and calibrated to measure electric currents in capacitors, which usually have low valúes of capacitance (pF-nF). The capability ofthe system to measure the switehing currents through pixels of AFLC displays has also been demonstrated. Future work will be orientated to obtain simultaneous measurements of the electrical current and hysteresis. To do that, an additional electronic subsystem should be added to the current prototype. This step is currently under investigation.

6.- Acknowledgements.

This work was partially supported by the Spanish Ministry of Science and Technology, grant no. TIC2000-1594-C02-02. The authors wish to thank to Dr. L. Hernández for his useful suggestions.

7.- References.

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