A Textile Based Capacitive Pressure Sensor

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Background. As interest on wearable computing [1] increases, researchers are looking for new materials to use as a support for electronics. A fabric substrate is very appealing: it is elastic and extensible [2], supported by a well known technology and produced at low-cost.

State of the art. Some smart pressure-sensors interfacing with a flexible substrate have been developed, but they are either based on electro-optical fabric ([3]) which is not suitable for the low cost market, or they need expensive and cumbersome PCB electronics ([4]).

Our contribution. This paper introduces an approach for decoding the pressure information exerted over a broad piece of fabric by means of capacitive sensing. The system is composed of a distributed passive array of capacitors (i.e. an array where no active elements like transistors are involved), whose capacitance varies according to the pressure exerted over a surface, as well as an electronic system that collects and computes the subsequent capacitance variations. Capacitors can be realized in different ways, though, in our demonstrator they have been implemented between rows and columns of conductive fibers patterned on the two opposite sides of an elastic synthetic foam. When the dielectric layer between a given row and column electrodes is squeezed, as a pressure is exerted over the corresponding fabric area, the coupling capacitance between the two is increased. The principle of sensing the capacitor array is displayed in Fig.1.

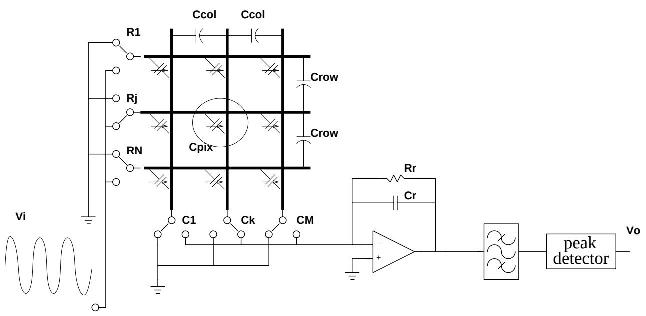

Fig. 1. AC sensing scheme

In this arrangement, a sinusoidal wave is applied onto the vertical line of the corresponding pixel so that the charge variation on the horizontal one is read-out by means of a charge amplifier. The peak-to-peak output sine wave encodes the value of the capacitance of the addressed node. It should be noted that the charge injected on the virtual ground node of the opamp should depend only on the pixel capacitance. Thus injection by large parasitic capacitances due to neighboring columns (C_{col}) should be ruled out, as well as injection by pixels in the same column. Since the virtual ground node is at a fixed voltage level, grounding all columns but the selected one allows us to avoid injection from the neighboring columns by way of C_{col}, while grounding all rows but the selected one allows us to avoid injection from pixels in the same column.

The emphasis in this solution is on detection of small pressures (e.g. light stroking) being applied over a relatively wide area. The architecture proposed enables us to measure a coupling capacitance variation of about 100 fF induced by a light pressure exerted over a 1 m^2 fabric surface. Furthermore, the use of a simple capacitive sensing scheme results in a robust sensor even if exposed to strong mechanical stresses (impacts, compression) that are incompatible with the working conditions required by more sophisticated sensors, based, for example, on piezoelectric materials.

Results. A prototype 24 × 16 pixels sensor with a readout board has been implemented to validate the design. The pixel pitch is $8mm$, which is about the same as the tactile resolution of human back skin. The electrodes are implemented as strips of conductive fabric thermally soldered to the two opposite sides of a foam layer, and are connected to the board by non-shielded wiring.

The board uses conventional MOS switches and an operational amplifier and has been implemented on a wire-wrap board. The output of the charge amplifier is digitized by an A/D converter, then data are collected by a general purpose digital acquisition board and the images are displayed in real time at about 3 F/s on a PC monitor.

Examples of images acquired by the board are illustrated in the figure below.

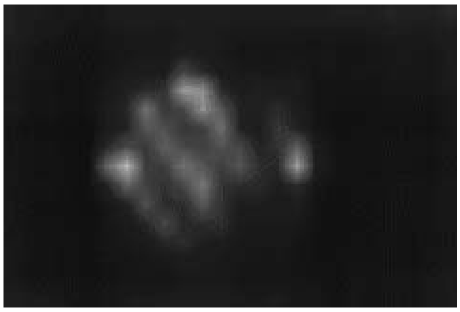

Fig. 2. Image of a fist acquired by prototype board. A simple smoothing algorithm has been applied.

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References

[1] Post, E.R.; Orth, M. *Smart fabric, or "wearable clothing"*. Digest of Papers. First International Symposium on, 1997.
[2] V. J. Lumelsky; M. S. Shur; S. Wagner. *Sensitive Skin*. IEEE Sensors Journal. VOL. 1, NO. 1, June 2001.
[3] S. Jayaraman *et al.* Full-fashioned weaving process for production of a woven garment with intelligence capability. US Patent 6,145,551.
[4] P. Wellman *et al.* System generating a pressure profile across a pressure sensitive membrane. US Patent 5,983,727.