A 100V-IC FOR THE REMOTE POWERING AND CONTROL OF A MICROROBOT USING AN ELECTROSTATIC CILIARY MOTION SYSTEM

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ABSTRACT

For the first time a high-voltage IC, specially dedicated to the remote powering and the control by inductive coupling of electrostatic actuators, has been designed and successfully tested. Four actuators can be controlled simultaneously with a maximum actuation voltage of 100 V. As a preliminary test, a capacitive load of 220 pF has been driven at a frequency of 100 Hz with an output voltage of 30 V and a distance of 2.5 cm between emitter and receiver antennas. To avoid the electrostatic stiction of mobile parts, the IC alternates the polarity of the actuation voltage. The possibility to control 4 highly capacitive actuators independently makes this circuit suitable for the remote control of a two degrees of freedom electrostatic Ciliary Motion System (CMS). The chip has been fabricated using European multi-chip service (EUROPRACTICE) in the Alcatel-Mietec I2T100 technology. Its dimensions are 5*3 mm^2.

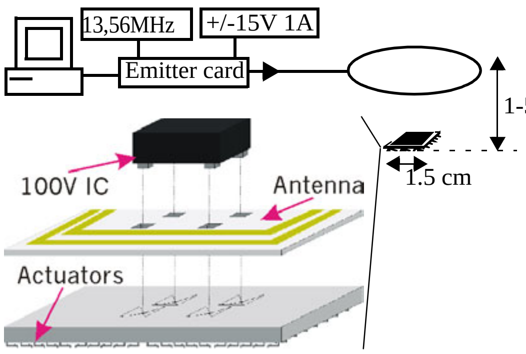

Figure 1 : Autonomous microrobot project overview. The emitter card provides a 1A/15V current, modulated in amplitude by the PC, through the emitter antenna. The power is transmitted by inductive coupling thanks to a light received antenna, carried out on an epoxy substrate. It feeds a high voltage control circuit, allowing the electrostatic actuation of two CMS.

INTRODUCTION

The realization of microrobots is one of the first exploration fields of the research in microsystems. Many applications are expected, particularly in the field of the microassembly and the test of circuits in confined environement [1]. Several devices have been imagined since ten years using various kinds of actuation such as piezoelectricity [2], thermal expansion [3], or electrostatic actuation [4][5]. In 1999, T. Ebefors *et al.* presented the first microrobot able to support a significant load, and in 2003 Hollard *et al.* the first remote powering microrobot, using a photocell.

In this paper a high-voltage IC is described, making it possible to power but also to remote control by magnetic coupling a double electrostatic Ciliary Motion System (CMS) [6], allowing a two degrees of freedom displacement. Voltages up to 100V can be used. This

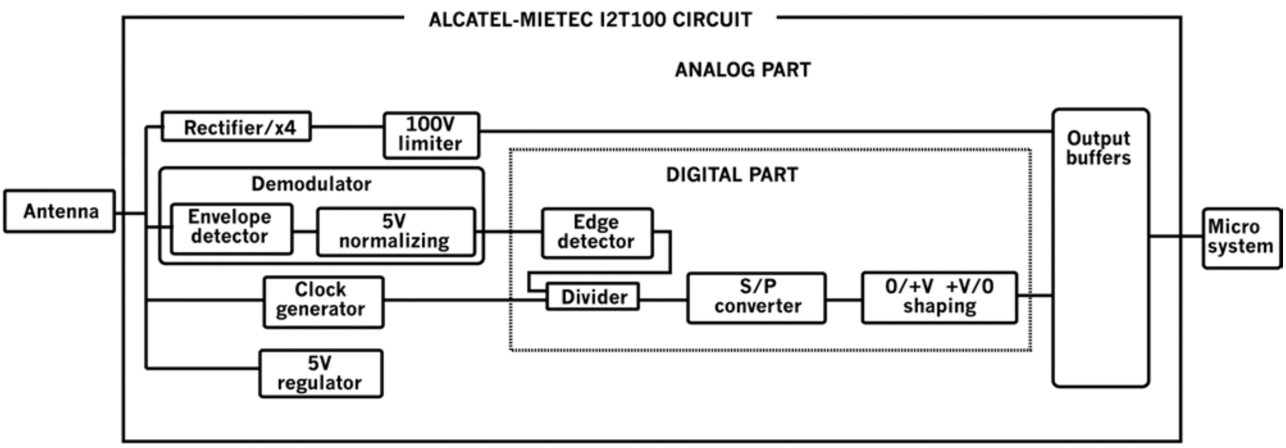

Figure 2 : Block diagram of the 100V-telemetry IC.

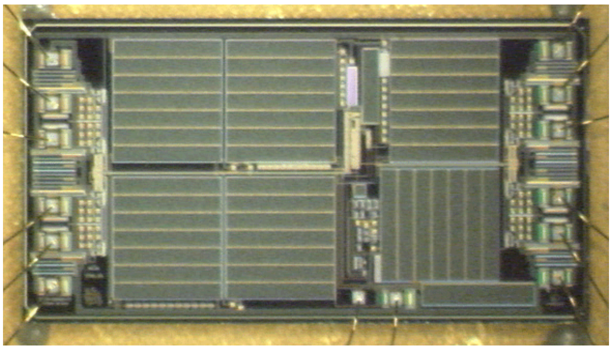

Figure 3 : Microphotograph of the chip (2*3 mm^2). The huge capacities are needed for driving capacitive loads higher than 200 pf.

circuit is to be assembled with a large stepwise motion electrostatic actuator [7] and a light antenna on an epoxy substrate [8]. These three components will be used in the near future for the realization of a completely autonomous microrobot (cf. figure 1).

DESIGN OF THE CIRCUIT

The chip (cf. figure 3) has been fabricated using European multi-chip service (EUROPRACTICE) in the Alcatel-Mietec I2T100 technology. Voltages up to 100 V are supported thanks to the use of DMOS transistors. Its dimensions are 5*3 mm^2. Large areas are used for the capacitances in order to drive high capacitive loads. The block diagram of figure 2 shows its main functionalities.

Analog part

The signal received by the antenna is a 13.56 MHz amplitude modulated sinewave and must be between 20 and 50 V peak. The actuation voltage of the microsystems is obtained from a Cockcroft-Walton rectifier/quadruplor. As a precaution, a device limiting the voltage to 100 V is implemented. A 5 V regulator and a clock generator at the carrier frequency allow the operation of the digital block. The amplitude modulation is betwen 10 and 25 % of the full scale voltage in order to continuously power the circuit. Its frequency is 10 kHz

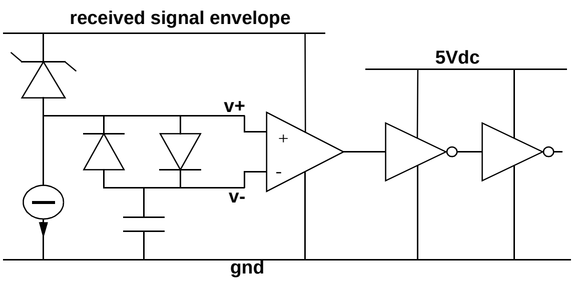

Figure 4 : Simplified schematic of the demodulator. The signal envelope is applied to the positive output of a differential pair and compared to a voltage ranging between the peak and bottom level.

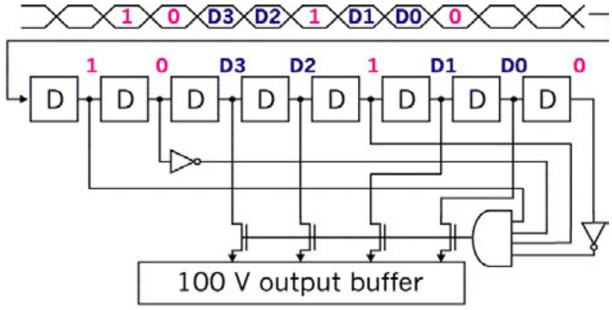

Figure 5 : Simplified schematic of the serial/parallel converter.The data are encapsulated to be transmitted to the output buffer only when the shift register is correctly filled.

and the signal is recovered using an envelope detector. It is then converted to 5 V by a differential pair comparing the envelope with an average voltage ranging between the peak and bottom levels of the signal as shown in figure 4. Four outputs can be driven simultaneously. The description of the output buffer can be obtained in [9].

Digital part

A frequency divider converts the clock of 13.56 MHz to 10 kHz. A reset of the divider occurs at each front detection of the signal in order to constantly synchronize the data with the clock. The serial/parallel conversion of the data is carried out according to the principle of a very simplified UART. The actuation of the robot requires 4 (two by CMS) simultaneous bits of information. Those are encapsulated in a simple 8 bits of protocol and are continuously sent into a shift register. At each clock period the protocol bits are checked. If they are recognized as being valid, the data are read (figure 5).

During the charging of the capacitive load, the received voltage drops due to the high current consumption. To avoid misinterpretation of the input code, the data transmission from the analog to the digital circuit is disabled for that time.

In order to avoid the stiction of the actuators to the substrate because of charge accumulation in the device

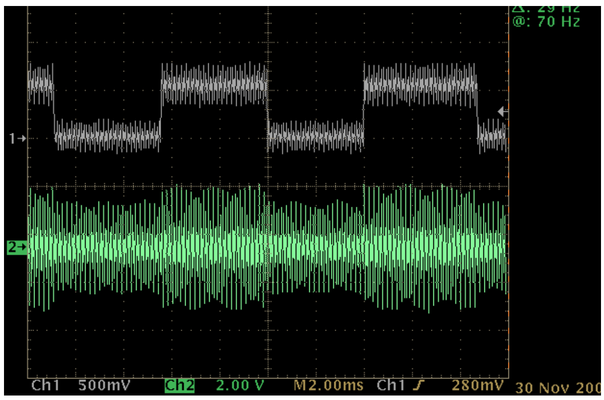

Figure 6 : Received signal and demodulator output. The amplitude modulation of the carrier is correctly transposed to a 0/5V pulse. (*10 probe measurement).

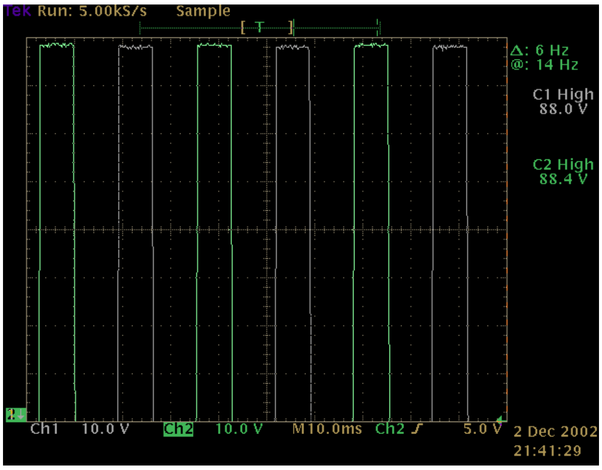

Figure 7 : High-voltage signal on the two electrodes of one output for a pulse input. The polarity is inverted periodically.

[10], a last block inverts periodically the polarity of the output voltage.

EXPERIMENTAL RESULTS

The preliminary tests of the circuit were carried out using an electronic card able to provide a sinewave of 13.56 MHz of strong intensity in the emitter antenna. This antenna is composed of 4 windings of 7 cm in diameter each. The conductor is a copper wire with a section of 1 mm. The sinewave is modulated at 10 Khz by a PC. The receiver antenna is a copper hollow square coil, 30 µm in thickness and 2 cm in diameter. It has an inductive value of 2 µH and a loss resistance in DC of 3 Ω.

With a distance of 2,5 cm betwen the antennas, the received voltage is 16 V_{peak}. On the rectifier, the output voltage is 30 V, that is half of that predicted. This is probably due to unpredictible leakage currents in the substrate. A modulation higher than 15 % is necessary to correctly recover the 0/5 V pulse of the transmitted signal, as it is shown on the figure 6. A capacitive load of 220 pF was applied to the outputs without affecting the signal. Using a high-voltage generator, the circuit was successfully tested upto 100 V. The figure 7 shows the signal on the two electrodes of the same output for a pulse entry. The polarity is alternatively applied to each electrode in order to avoid the electrostatic stiction of the microsystem actuators.

CONCLUSION

We have presented a new circuit specially dedicated to the remote actuation of electrostatic microsystems. Thanks to the independant control of 4 outputs, this circuit can be used for a wireless double CMS, making now possible the realisation of an autonomous microrobot using this principle of displacement.

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