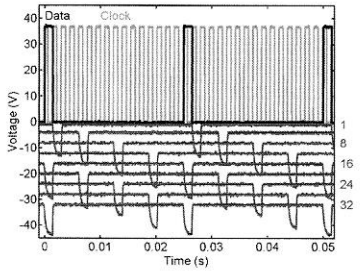
Organic thin-film transistors offer the potential to manufacture low-cost electronics on large surfaces, ideally on flexible substrates. We have manufactured functional 32-bit shift registers, each one containing up to 1888 transistors, the highest integration level reported for organic electronics. Shift registers are general-purpose circuits that can be used in a large range of applications, such as row drivers in active-matrix displays and RF identification tags.

A big step in organic electronics: *Fabrication of large ICs*

The aim of organic electronics is to realize ICs based on organic semiconductors instead of silicon. The advantages are ease of processing (from solution) and mechanical flexibility of the circuits. The Organic Electronics project at the Nat.Lab. (with input from the groups of Gerjan van de Walle, Hans Hofstraat, Frank Dirne, Leo Warmerdam, Mark Overwijk and Toon Holtslag) is a frontrunner in this relatively new field of research. Routinely, we make organic transistors with a performance approaching that of amorphous-silicon transistors. Last year, it was decided to fabricate organic ICs containing more than 1000 transistors. The reason is that this level of complexity is needed for any possible commercial application of organic electronics, but has not yet been achieved by any group active in this field of research.



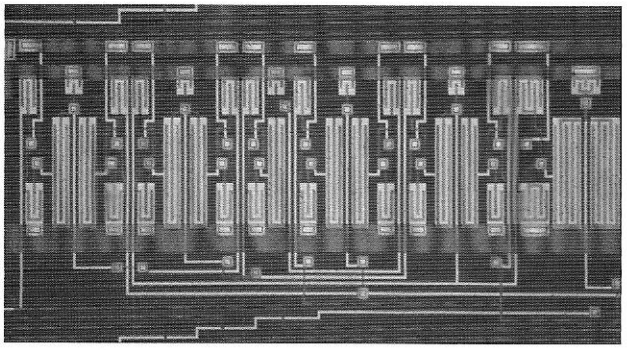
Input data pulses (black), clock (light grey), and buffered output (dark grey) at different stages of a 32-bit shift register. The clock frequency is 640 Hz, but the circuit works up to 5 kHz. The output correspond to stages 1, 4, 8, 12, 16, 20, 24, 28 and 32.

Shift registers

A shift register is an ideal demonstrator: its structure is extremely repetitive, the location of a potential fault can readily be found, and it is easy to characterize. It consists of identical 1-bit memory elements ('flip-flops') connected in series, so that the bit stored in each flip-flop can be transferred to the next one at a rate given by a clock pulse.

First-time-right design

Four 32-bit shift registers using different logic styles were designed and manufactured on 6-inch wafers. The design showing best performance contains 1888 transistors, more than twice as much as the largest organic circuit reported to date. It works at a speed of up to 5 kHz, ten times the maximum speed reached up to now in an organic shift register, and can be manufactured with a reasonable yield of 30%. Shift registers based on slower architectures show a yield as high as 90%. The design proved to be first-time-right, showing that the degree of reproducibility of the technology and the transistor modelling used in circuit simulation have made significant progress.



Detail of an organic flip-flop.

Application areas

A very promising application of organic electronics is to build flexible, eventually rollable, displays with an organic active-matrix backplane and an E-ink frontplane. An organic shift register can be used directly as a row driver to address this display line-by-line. Integrating part of the driving circuitry on the flexible display reduces the number of interconnect lines and the footprint of the display, i.e. reduces the manufacturing complexity and ultimately the cost. Organic shift registers can also be used to generate a sequential code from a set of memorized bits in an RF identification tag. These circuits can be read from any direction, contrary to traditional optical barcodes, and can therefore be used with great advantage in logistics, wholesale, etc.

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on behalf of the Organic Electronics project