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NEW ANALOGUE SWITCH CIRCUIT HAVING VERY LOW FORWARD RESISTANCE

Indexing terms: Digital circuits, Switching and switching circuits

A new circuit realisation for an analogue switch is reported. The main feature of the proposed design is the low value of the forward resistance as compared with commercial switches. Experimental data confirming the performance of the circuit are also included.

Introduction: The design and implementation of electronic switches have received continued attention from researchers working in the analogue field, the goal being the development of circuits that exhibit a resistance value in the ON state as low as possible.[1] With the advent of integrated chips, reasonable solutions have been proposed and a great number of commercial circuits are in use, mainly in CMOS technology. Values ranging from 300 to 30 Ω are typical for the forward resistance (R_{on}) of these integrated switches.[2,3,6] Nevertheless, it is necessary to lower this resistance value even more, while still preserving the low price that characterises such integrated switches. There are some applications in which R_{on} introduces significant errors, and this fact motivates the search for circuit configurations that can minimise the effects of the ON resistance (see References 1, 4 and 5 for varied examples of those networks).

In this letter we will present a simple circuit realisation of an analogue switch. The design reported herein drastically reduces the switch forward resistance as compared with a typical CMOS integrated switch.

Circuit description: Consider the proposed scheme shown in Fig. 1*a*. Blocks labelled B1 and B2 are a symbolic representation of any three-terminal device, as in the one drawn in Fig. 1*b*. With reference to Fig. 1*b*, the only requirement for these blocks is that they must possess a monotone driving-point characteristic measured between terminals 1 and 2. Preferred candidates are either two MOS transistors or two commercial CMOS switches, although other devices can be used—for instance, two bipolar transistors.

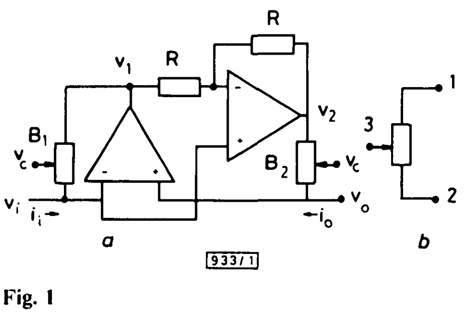

Fig. 1
a Proposed circuit
b Symbolic representation of a three-terminal device

Operation of the circuit is apparent from a first-order analysis which assumes that both operational amplifiers are ideal, each having both infinite differential gain and infinite input impedance. When this is the case, we can determine the circuit behaviour in two different situations:

(*a*) Both three-terminal devices are cutoff. Then $i_i = i_0 = 0$ and the network behaves as an open circuit.

(*b*) Both three-terminal devices are ON. Then, the following equation set applies:

$$\begin{aligned} v_0 &= v_i \\ v_i - v_1 &= f_1(i_i, v_c) \\ v_0 - v_2 &= f_2(i_0, v_c) \\ v_1 - v_i &= v_i - v_2 \end{aligned} \tag{1}$$

where $f_j(. , .)$ $(j = 1, 2)$ represents the above-cited driving-point characteristic of block B_j.

After some manipulations, we get

$$f_1(i_i, v_c) + f_2(i_0, v_c) = 0 \tag{2}$$

which is equivalent to stating

$$i_0 = -i_i \tag{3}$$

since both $f_1(. , .)$ and $f_2(. , .)$ are invertible functions (they have been assumed to be monotone increasing functions).

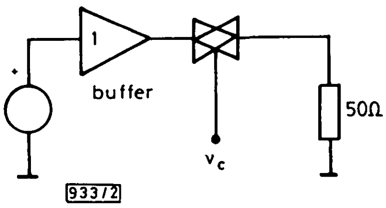

Fig. 2 *Experimental set-up*

Experimental results: In order to check the practical usefulness of the new circuit, we have performed a simple experiment. In the network of Fig. 2 we connected a custom CMOS switch (MC4066) and measured the output voltage v_0. Afterwards, we substituted the switch in Fig. 2 for the circuit in Fig. 1*a* using a pair of MC4066 CMOS switches as blocks B1 and B2. Again, the output voltage v_0 was measured. The voltage source was buffered in order to handle a very low source impedance. The results are compared in the oscillogram in Fig. 3. Here, the superior operation of the new circuit should be clear. The input signal is shown as the second trace starting from the top, the first one being the control voltage v_c. The fourth trace corresponds to the network using the commercial switch, which exhibits an ON resistance comparable to the 50 Ω resistor, thus reducing significantly the signal amplitude. Instead, when we analyse the third trace, which corresponds to the network using the scheme in Fig. 1*a*, we can see that the 50 Ω load is quite large as compared with the ON resistance of the new switch, and hence the output amplitude does not differ appreciably from the input amplitude.

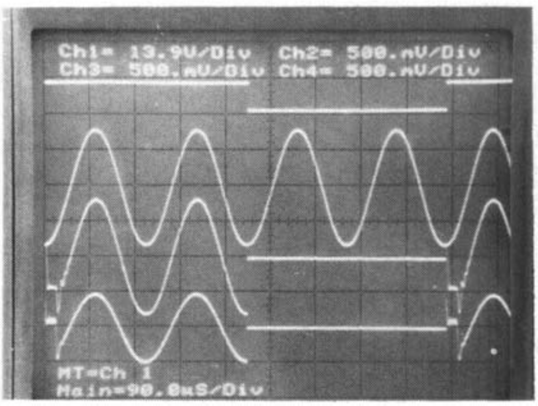

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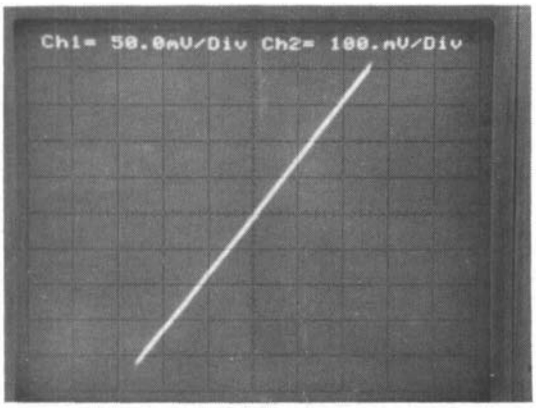
Fig. 3 *Experimental results for circuit in Fig. 2*

Quantitative values for R_{on} can be obtained from the oscillograms in Figs. 4*a* and *b*. The slope *m* of the line in both oscillograms is related to R_{on} through

$$R_{on} = 10 \frac{m}{1 - m} \Omega \tag{4}$$

This means an R_{on} value of approximately 30 Ω for the commercial CMOS switch (Fig. 4*a*) and a much lower value for the new circuit (Fig. 4*b*). Finally, the frequency range for normal operation extends from DC to 30 kHz. However, this range corresponds to a realisation using uA741. By using better amplifiers and/or integrating the whole circuit on a chip, a much more extended frequency range could be expected.



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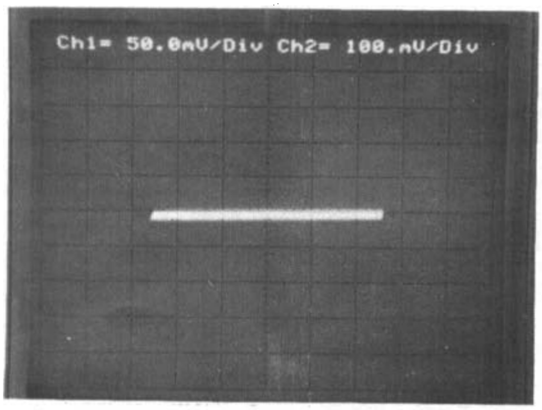

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Fig. 4 *Oscillograms used for determining value of R_{on}*

Discussion: A new circuit realisation for an analogue switch has been reported here, the distinguishing feature being the ultralow resistance the new switch exhibits in its ON state. The circuit is well suited for integration and can be built without resorting to sophisticated components.

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GaP/PHTHALOCYANINE LANGMUIR–BLODGETT FILM ELECTROLUMINESCENT DIODE

Indexing terms: Semiconductor devices and materials, Langmuir–Blodgett films

The electrical and electroluminescent properties of Au/phthalocyanine Langmuir–Blodgett film/GaP diodes are reported. The electroluminescence conversion efficiency is shown to depend on the number of Langmuir–Blodgett layers and is a maximum for a 5·6 nm-thick film. This optimum can be explained in terms of simple tunnel injection theory. A preliminary investigation reveals that the devices are relatively stable and that the maximum power conversion efficiency approaches that of an unencapsulated *p-n* junction diode.

Introduction: In order to obtain electroluminescence (EL) from materials which are efficient phosphors but are poor amphoteric semiconductors (e.g. II-VI compounds) an alternative to the *p-n* junction is required. One possibility is to use a metal-semiconductor (Schottky barrier) structure. In such a device the minority carrier injection ratio is known to be small; however, it has been shown that this can be substantially increased by the incorporation of a thin insulator between the semiconductor and the metal electrode.[1] If commercial metal-insulator-semiconductor (MIS) EL displays are to be produced, a method to deposit high-quality insulating layers over relatively large areas and with a fine control of thickness is required. Furthermore, the insulating layers must adhere well to the semiconductor, be thermally and mechanically stable and, in particular, they must be able to withstand the operating current densities required for EL. In previous publications[2,3] we have reported on the use of the Langmuir–Blodgett (LB) technique to deposit insulating films of cadmium stearate and cadmium 22-tricosenoate onto the surface of epitaxial GaP. In both cases a sharp optimum in the EL power conversion efficiency was found for film thicknesses of approximately 27 nm. Because of their relatively low melting points it is unlikely that these fatty acid LB materials will be useful in a practical device. However, we have recently reported on the deposition and properties of LB films of phthalocyanine,[4,5] a substance well known for its chemical and thermal stability. In this letter we present the results of a preliminary investigation into the properties of MIS EL devices incorporating phthalocyanine LB layers.

Experimental: Epitaxial *n*-type GaP films, grown onto single-crystal substrates, were supplied by the Plessey Company Ltd. The substrates were doped with sulphur to give a carrier concentration of approximately 10^{18} cm^{-3}. The GaP epilayers were grown by vapour-phase epitaxy to a thickness of about 40 μm. These layers were sulphur doped to give carrier concentrations in the range 10^{15}–10^{17} cm^{-3}; additionally the final 10 μm were doped with nitrogen to a concentration of 10^{18}–10^{19} cm^{-3}. Ohmic contacts were made to the GaP substrate by the use of indium, annealed in an inert atmosphere at 500°C for 10 min. Details of the semiconductor surface preparation and the device fabrication have been described previously.[2] The particular phthalocyanine used, CuPc tris ($CH_2NHC_3H_7$-iso), was provided by ICI Ltd. The deposition conditions for this material have been recently described by Baker *et al.*[5] The multilayers were arranged so that a stepped thickness of the LB film was obtained along the length of the GaP substrate.

The EL measurements were made by pulsing (2% duty cycle) the MIS diodes with a maximum current density of 7 A cm^{-2}. The light escaping from the back face of the MIS structure was recorded using a calibrated Si photodiode (5 mm square) positioned approximately 10 mm from the device.

Results and discussion: Under application of a forward bias (> 2·4 V), all of the MIS diodes emitted yellow/green EL from beneath the gold top electrode. The spectrum of this emission was identical to that seen for fatty acid based devices; no additional features were detected as a result of incorporation