

## The Four-Gate Transistor

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### Abstract

*The four-gate transistor or  $G^4$ -FET combines MOSFET and JFET principles in a single SOI device. Experimental results reveal that each gate can modulate the drain current. Numerical simulations are presented to clarify the mechanisms of operation. The new device shows enhanced functionality, due to the combinatorial action of the four gates, and opens rather revolutionary applications.*

### 1. Introduction

MOS transistors with two gates are attractive in terms of improved performance and extended scalability [1,2]. Multiple-gate MOSFETs can also be useful for signal mixing and more complex (non-binary) logic functions. The innovative 4-gate transistor ( $G^4$ -FET) presented in this paper has the *maximum* number of gates which can be achieved. The body of the device (Fig. 1) is surrounded by a top MOS gate ( $V_{PG}$ ), a bottom substrate gate ( $V_{SUB}$ ), and two side junction gates ( $V_{JG1,2}$ ). Section 2 shows that the architecture and processing of the 4-gate transistor takes advantage of the isolation capabilities of the SOI technology. Experimental data are described in section 3 and explained in section 4 using detailed numerical simulations.

### 2. Device description

An n-channel  $G^4$ -FET is formed from a normal partially-depleted SOI MOSFET with p-channel. The N-type body is provided with two independent  $N^+$  body contacts, on each side of the channel, which act as source

and drain (Fig. 1). The former source and drain of the original p-channel MOSFET are  $P^+$  doped and play the role of *lateral junction gates*. These gates control the channel cross-section. With the possibility to bias the substrate as a *back gate* and the poly-Si as a *top gate*, the new device is indeed a four-gate transistor with narrow channel and accumulation-mode operation.

It is worth noting the differences between the  $G^4$ -FET and the original MOSFET. In a  $G^4$ -FET, the drain current is composed of majority carriers and flows in a direction perpendicular to that in the original inversion-mode MOSFET. The gate length of the MOSFET defines the channel width  $W$  of the  $G^4$ -FET and vice-versa.

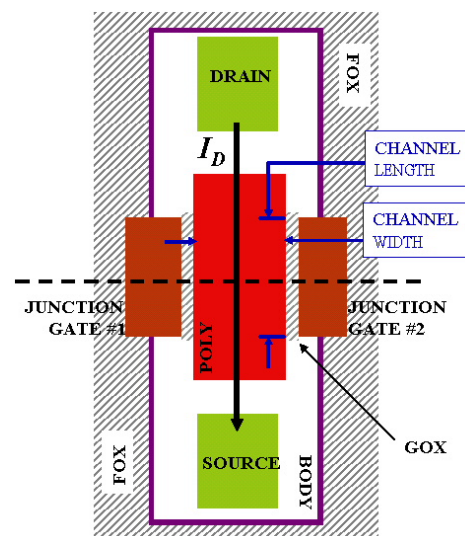


Figure 1. Top view of the  $G^4$ -FET structure.