Rethinking Transistor Operation for Oscillating and Spiking Behavior

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A metal-oxide-semiconductor field-effect transistor (MOSFET) typically operates by receiving an input voltage (I_{in}) and delivering an output current (V_{out}). However, when a floating body is present within the MOSFET, applying Iin to the drain terminal initiates a series of internal processes: (i) electron-hole pairs are generated through impact ionization, (ii) the generated holes temporarily accumulate in the floating body, reducing the built-in potential barrier (V_{bi,S_FB}) between the source and the floating body, (iii) this reduction allows more electrons to be injected into the floating body, and (iv) the resulting increase in carrier injection further enhances impact ionization, leading to additional hole accumulation. This sequence forms a positive feedback loop, referred to as the charging process. The positive feedback results in a phenomenon known as the single transistor latch (STL). Once the floating body becomes fully charged and V_{bi,S_FB} is flattened, the output voltage (V_D = V_{out}) is rapidly generated at the drain terminal, while a spike shaped output current (I_S = I_{out}) is abruptly discharged through the source terminal. This discharging event completes the cycle. The interplay of gradual charging and abrupt discharging produces a sawtooth shaped oscillation in V_{out}, which persists as long as I_{in} is applied.

Owing to its inherent leakage current, charge accumulation capability, and sudden discharge behavior, the MOSFET exhibits leaky, integrate, and fire characteristics, respectively. These attributes enable the device to operate in a leaky-integrate-fire (LIF) mode, making it suitable for implementation as an artificial neuron. The LIF behavior has been experimentally demonstrated in MOSFETs fabricated not only on silicon on insulator (SOI) substrates featuring a floating body, but also on bulk silicon substrates, where both spiking and oscillatory behaviors have been observed.

Furthermore, when a charge trapping nitride layer, such as an ONO stack, is employed as the gate dielectric, the MOSFET functions not only as an artificial neuron but also as an artificial synapse. This is due to its multi-level memory characteristics, which enable the modulation and retention of synaptic weights. Since artificial neurons and synapses share an identical physical structure and differ only in their mode of operation, they have been co-integrated on a single plane. This unified platform has been utilized to implement character and pattern recognition tasks using a spiking neural network (SNN).

These MOSFET devices, capable of mimicking brain-inspired signal processing, are not only effective as artificial neurons and synapses but also responsive to external stimuli, making them suitable for use as sensory neurons in in-sensor computing applications. This paper presents experimental results that demonstrate the multifunctionality of this homotypic MOSFET structure through a reexamination of its operating principles.