Electron Tunneling and its applications in flash memory

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Outline

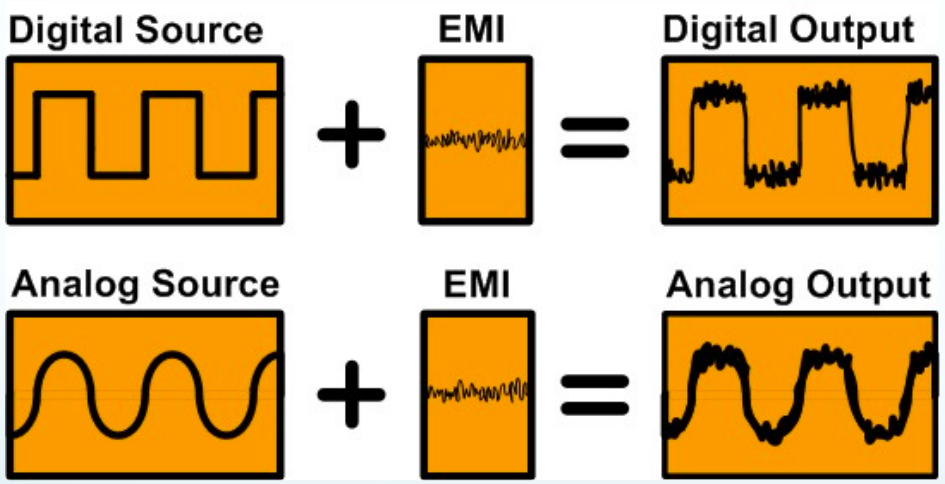
- Electron tunneling
- Data
- Flash Memory
- Flash Memory's Drawbacks and dependency on electron tunneling

Electron Tunneling Overview

- Electron tunneling is the quantum phenomena where an electron tunnels through a barrier that it could not pass through with classical mechanics.
- Related to the Heisenberg uncertainty principal and wave-particle nature of matter.

Overview of data

- Digital data is binary, it is either on or off (1 or 0)
- Digital data maintains its integrity even when distorted with noise

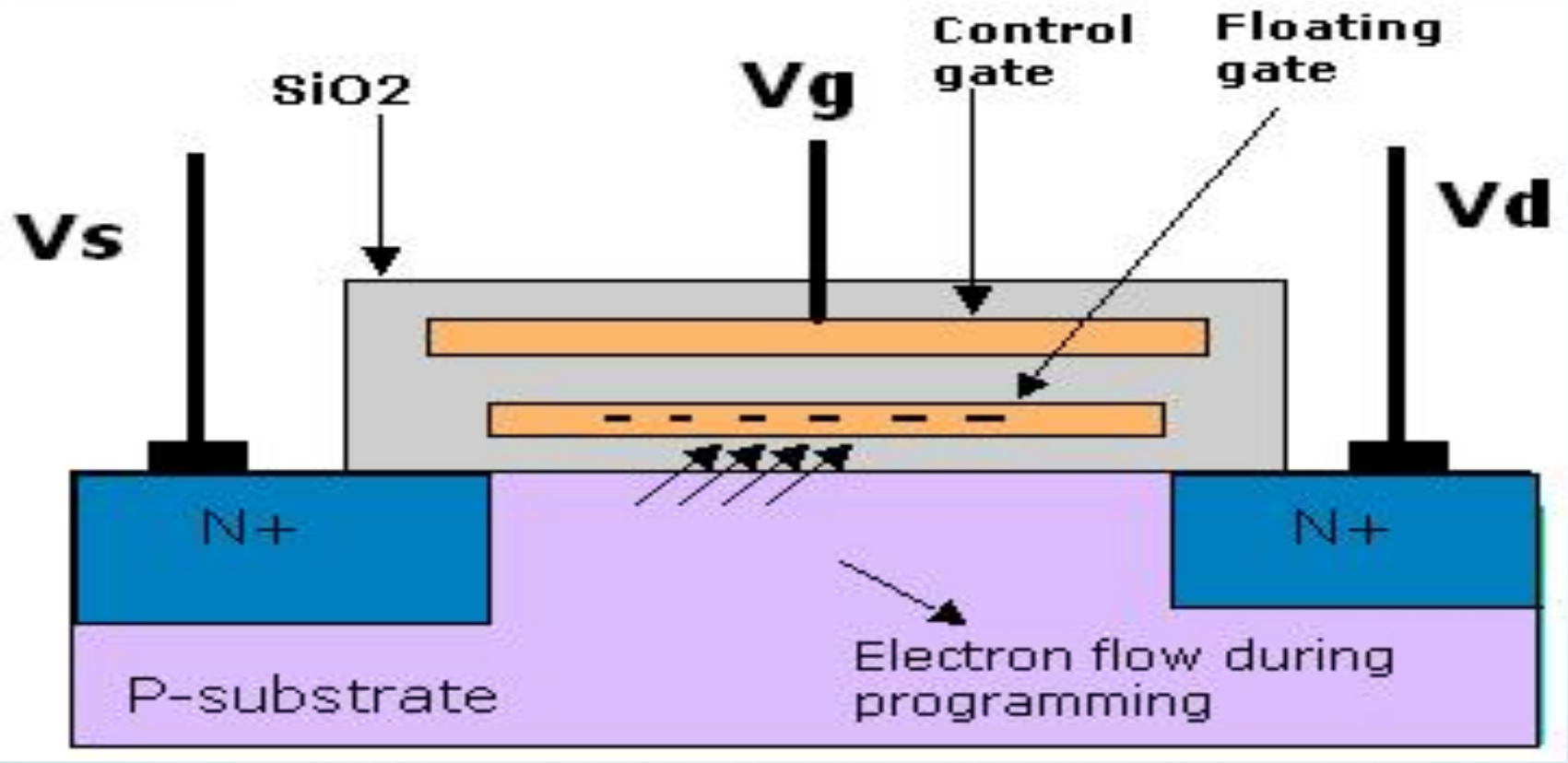


http://www.hometheaternetwork.com/pics/EMI_cables_Analog_digital.jpg

Flash Memory

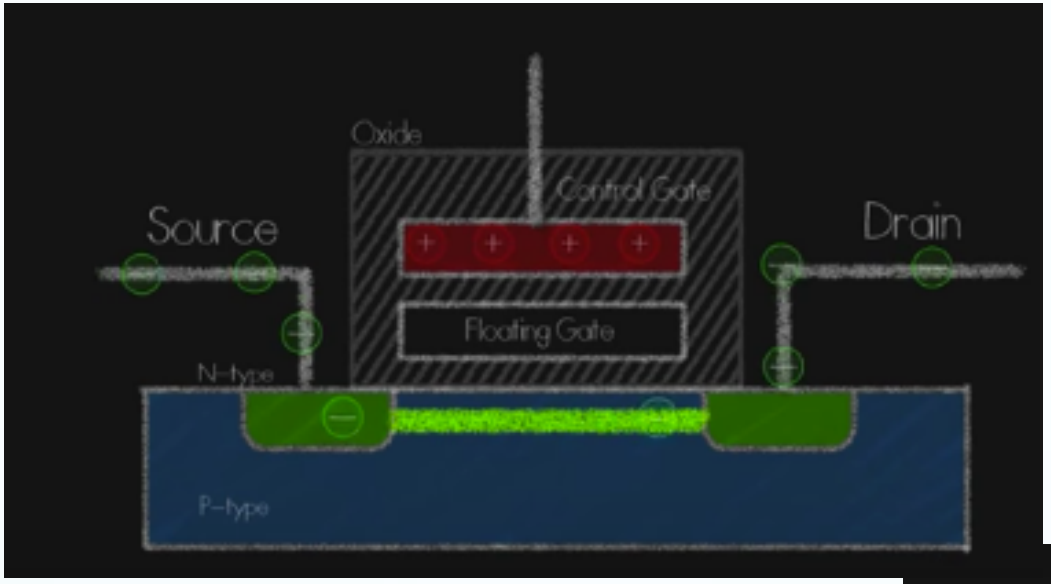
- Developed in 1984 by Dr. Fujio Masuoka
- Used every day by millions of people
- Has virtually replaced non-volatile HDD storage in modern portable computing
- No mechanical parts make for a more robust system
- Stores bits of data as 1s and 0s by storing electrons

Diagram of Flash Memory



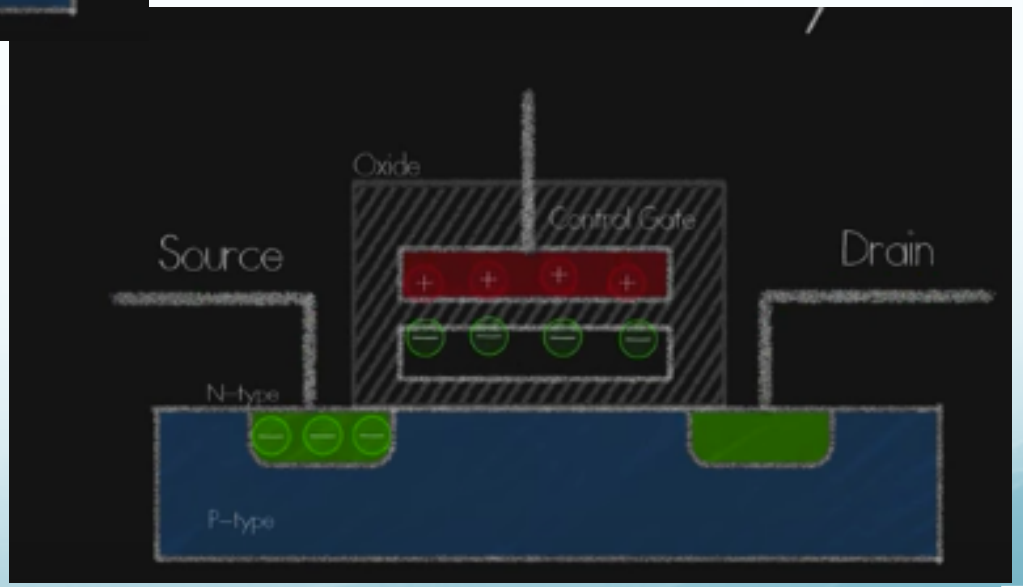
http://www.eeherald.com/section/design-guide/esmod16.html

How flash memory is read



Left: a positive voltage is applied to the control gate, facilitating the transfer of electrons through the electric field from the source to the drain

Right: in this case, electrons in the floating gate cancel out the positive voltage and prevent electron transfer from the source to the drain.



http://filmmakeriq.com/2015/10/a-bit-of-history-on-data-a-filmmakeriq-lesson/

How data is written to flash memory

- Data is written to flash memory in one of two ways:
  - By applying a large voltage to the gate, a large number of electrons are moved through the substrate, with some tunneling through to be trapped in the floating gate.
  - Hot electron injection increases the kinetic energy of the electrons so that they may classically overcome the barrier between the substrate and the floating gate. (This does not rely on quantum physics)

Current storage of bits

- 0s and 1s are stored as a charge on the floating gate
- Since the charge is hard to measure accurately, it is truncated as >50% for 1 and <50% for 0

Advancements in Flash Memory

- Ferroelectric tunnel junctions
  - Advancements in FTJs have led to a new system of polarizing layers with different tunneling electroresistances when exposed to UV light, resulting in 4 states, left and right charge, and light and dark. Offering 00, 01, 10, and 11 states, effectively doubling data density.
- Multi-level Cells (MLC)
- Accuracy in charge readings

Drawbacks to Electron Tunneling in Flash Memory

- Layer breakdown
  - Due to the effects of hot electron injection, materials in the floating gate eventually break down, allowing electrons to leak from their proper space
- Breakdown in the nonconductive oxide layer or defects in manufacturing can lead to electrons leaking out of the floating gate.
- Multiple write failure: write-erase cycles degrade the insulation, and lead to cell failure.

Questions?

Sources

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