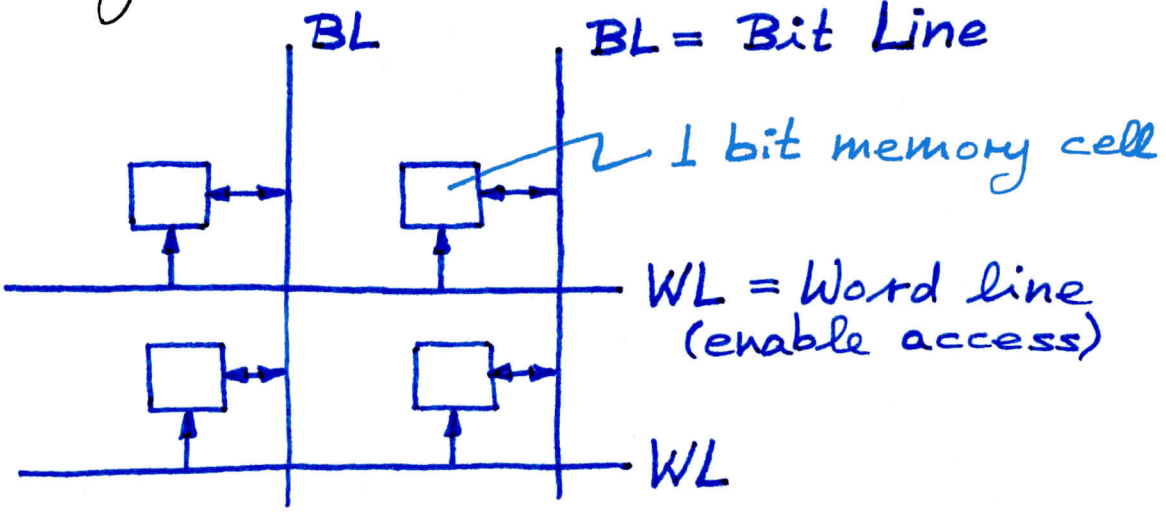
Iconic circuits

Memory circuits

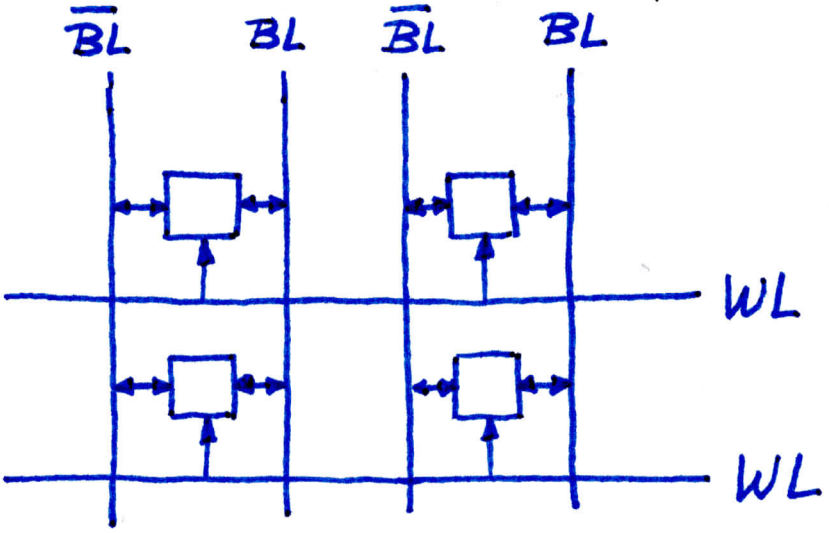
Memory is organized in bits and words

(e.g. one word is 1 byte = 8 bit)

Memory organization



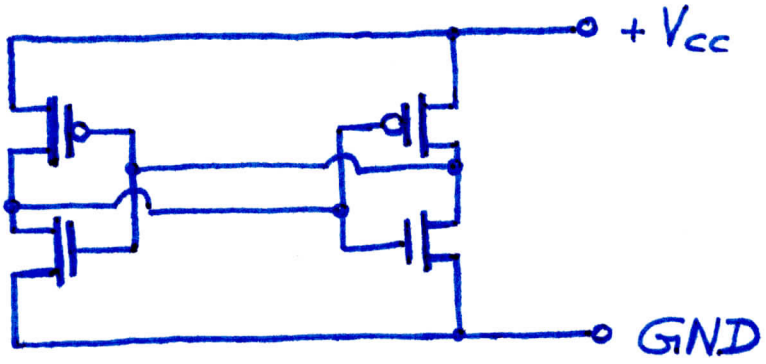
Sometimes there are two Bit Lines per bit



Q: Why 2 BLs?

WL enables memory cell to communicate with BL

Flip-flop circuit (bistable)



Convince yourself that this is a bistable circuit.

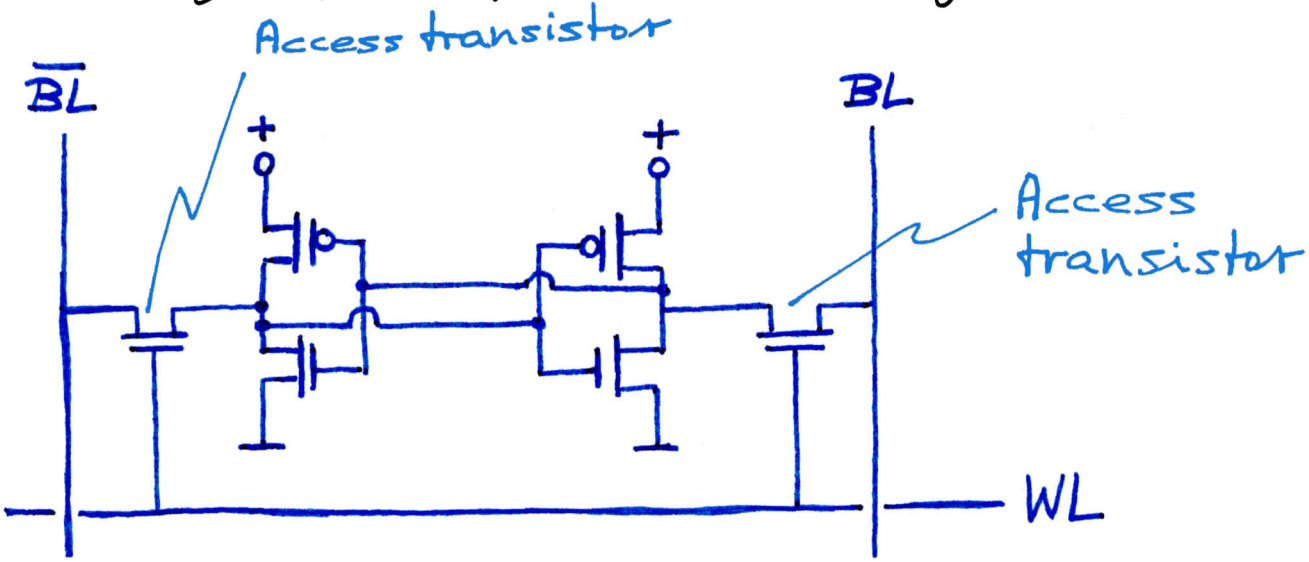
Q: How many transistors ? ⇒ 4 FETs

SRAM circuit

RAM = Random Access Memory

SRAM = Static RAM

⇒ Using flip-flop as memory



Q: Static power consumption ? ⇒ Zero

Q: How many transistors ? ⇒ Six

Q: Which regime does Access Transistor operate in ? Ohmic (ON) and Saturation (OFF)

Q: Advantage of SRAM ? ⇒ Fast

Q: Disadvantage of SRAM ? ⇒ 6 transistors

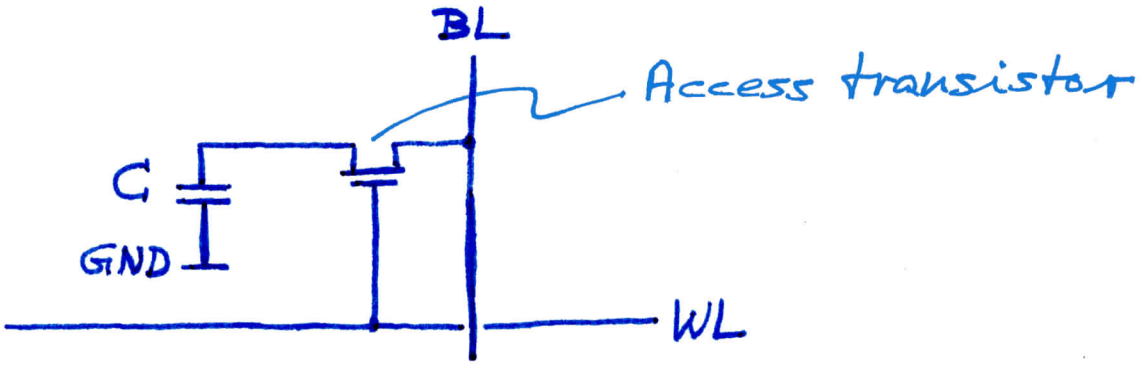
Q: SRAM volatile or non-volatile ? ⇒ Volatile

DRAM circuit

DRAM = Dynamic RAM

Storage element is capacitor C ⇒ Discharges over time ⇒ Needs to be recharged ⇒ "Dynamic"

1 transistor 1 capacitor ⇒ 1T 1C



C is a bit leaky ⇒ C self-discharges ⇒ Information needs to be "refreshed".

Q: Refresh time ? ⇒ 64 ms

Q: As an engineer, do you prefer SRAM or DRAM ?

Q: As an economist, do you prefer SRAM (6T) or DRAM (1T 1C) ?

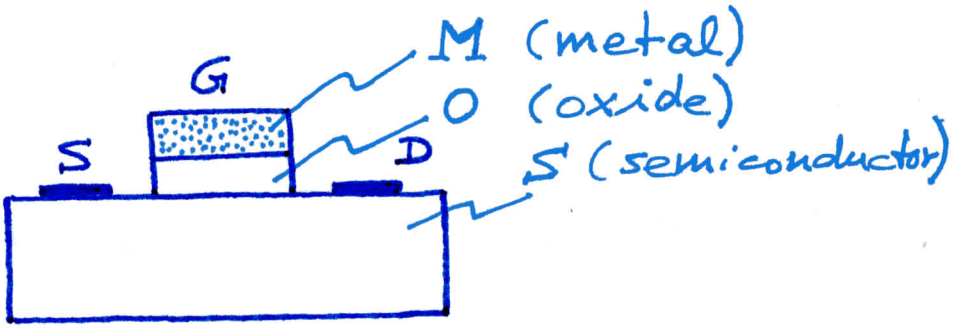
Q: Is SRAM a volatile memory?

Q: Is DRAM a volatile memory?

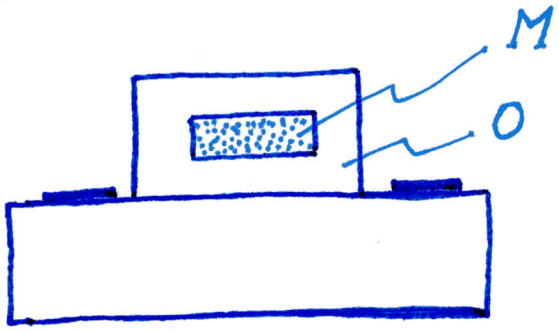
Flash memory

Flash memory = Non-volatile memory

Regular FET

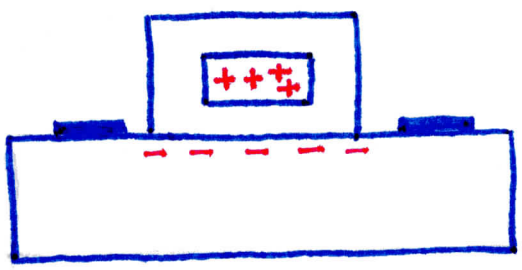


Flash memory FET

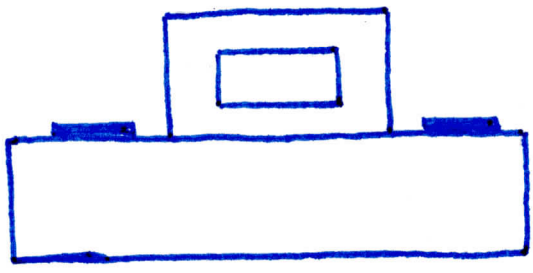


Gate metal is completely surrounded by oxide (SiO_2 insulator) so that the charge on the gate is kept for 10 ~ 20 years.

Gate charge:



ON



OFF

Due to the permanent (10~20 years) charge on the Gate, the FET is "frozen" in its ON or OFF state.

How do we change the Gate charge?
We need a high-energy pulse ("flash") to transfer charge (through the insulator) to the gate.
What is the "flash"? ⇒ A very high voltage pulse between S and D. During the pulse some charge end up on the G.

Q: Is flash memory volatile? No.

Q: Name some examples where flash memory is used.