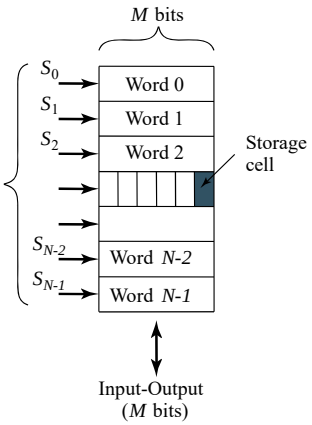
Digitalna elektronika
RAM memorije

RWM Read-Write Memory		**Non-Volatile Read-Write Memory**	**ROM** Read-Only Memory
Random Access	**Non-Random Access**	EPROM E^2PROM FLASH	Mask-Programmed Programmable (PROM)
SRAM DRAM	FIFO LIFO Shift Register CAM		

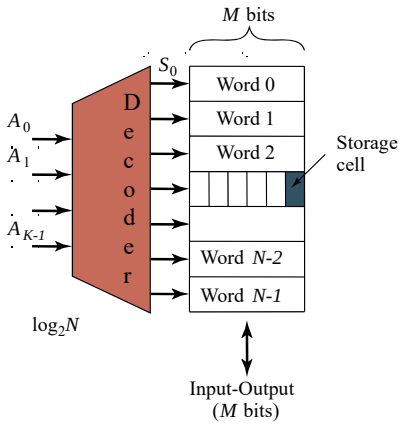
NV RWM = NV RAM

Ne gube sadržaj kada se isključi napajanje

Digitalna elektronika
RAM memorije



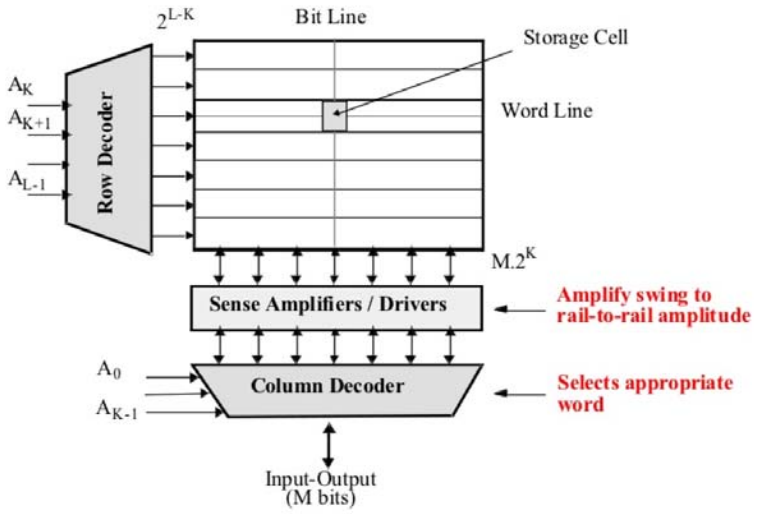
N x M memorija
N reči == N selekcionih signala



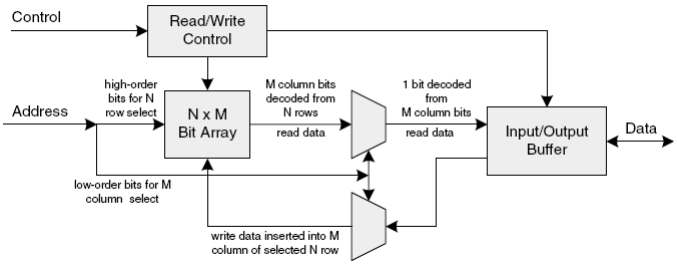
Dekoder smanjuje broj selekcionih signala
K = log $_2$N

Digitalna elektronika
RAM memorije

Problem: broj reči >> broja bita po reči



Digitalna elektronika
RAM memorije

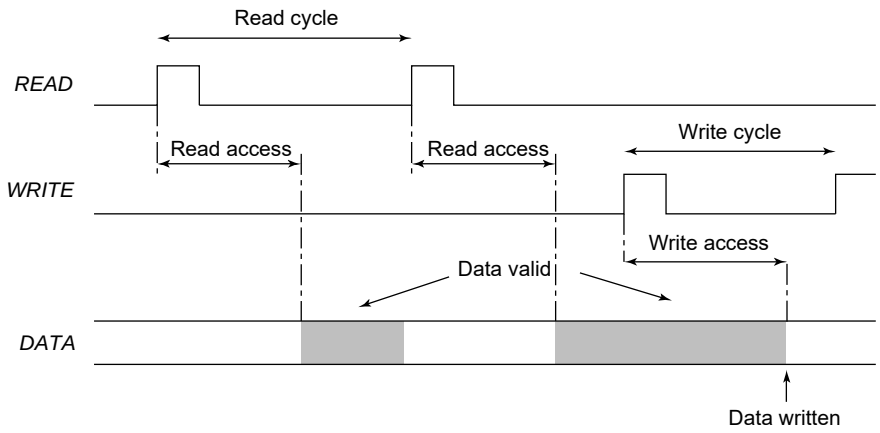


Adresa

Podatak

Kontrolni signali

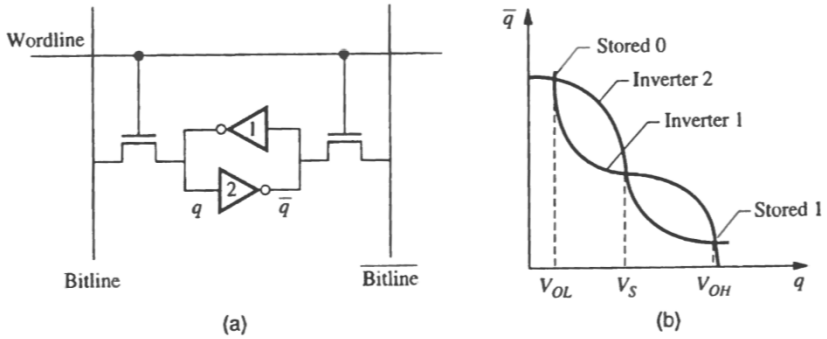
Digitalna elektronika
RAM memorije



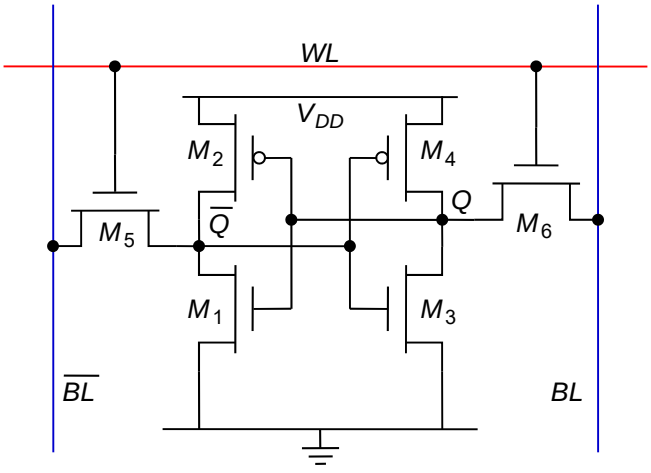
Digitalna elektronika
RAM memorije

- **STATIC (SRAM)**
  - **Podaci se pamte dok postoji napajanje**
  - **Velika memorijska ćelija – 6 tranzistora**
  - **Brze**
  - **Memorijska ćelija ima diferencijalni izlaz**
- **DYNAMIC (DRAM)**
  - **Da bi podatak ostao sačuvan potrebno ”osvežavanje”**
  - **Mala memorijska ćelija – 1 do 3 tranzistora**
  - **Sporije**
  - **Memorijska ćelija ima jednostruki izlaz**

Digitalna elektronika
RAM memorije - SRAM

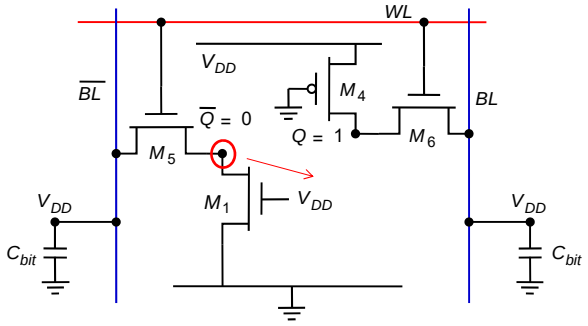


Digitalna elektronika
RAM memorije – 6T SRAM



Da bi ovo radilo moraju biti precizno izabrane veličine tranzistora

Digitalna elektronika
RAM memorije – 6T SRAM - Read



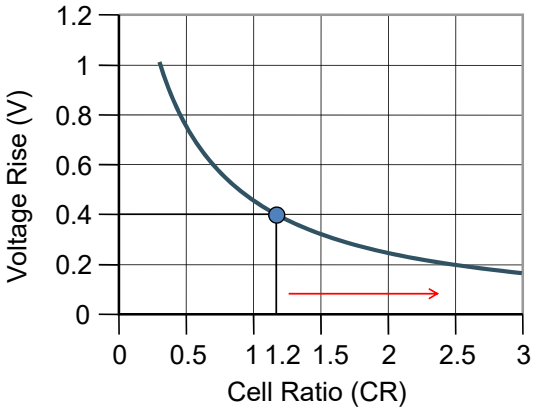
Pre aktiviranja čitanja, bitske linije na V_{DD}
V_{DS1} ne sme da uključi M3, V_{GS3}

$$I_{D5} = \frac{B_5}{2}(V_{GS5} - V_{Tn})^2 = I_{D1} = \frac{B_1}{2}\left(2V_{DS1}(V_{GS1} - V_{Tn}) - V_{DS1}^2\right)$$

$$(V_{DD} - V_{DS1} - V_{Tn})^2 = \frac{B_1}{B_5}\left(2V_{DS1}(V_{DD} - V_{Tn}) - V_{DS1}^2\right)$$

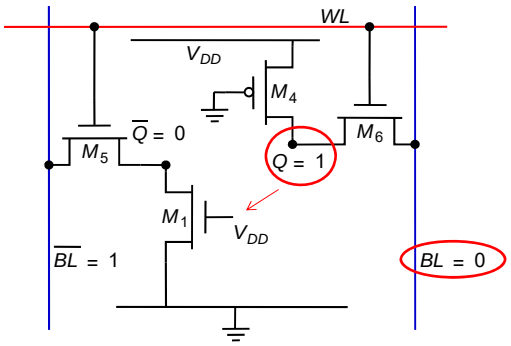
$$V_{DS1} = (V_{DD} - V_{Tn}) - \sqrt{(V_{DD} - V_{Tn})^2 - \frac{(V_{DD} - V_{Tn})^2}{(1 + CR)}}$$

Digitalna elektronika
RAM memorije – 6T SRAM - Read



$$CR = \frac{W_1/L_1}{W_5/L_5}$$

Digitalna elektronika
RAM memorije – 6T SRAM - Write

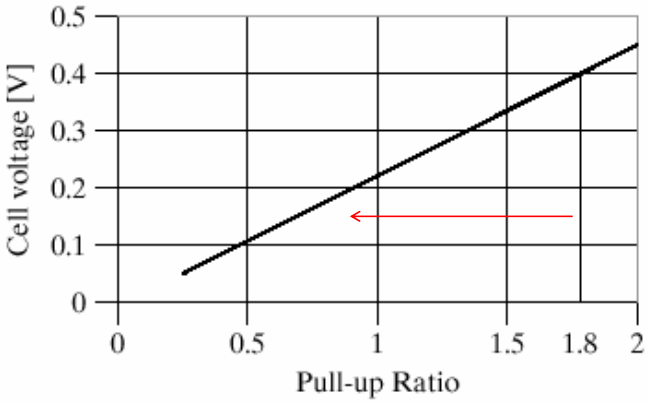


$$I_{D4} = \frac{B_4}{2}\left(V_{GS4} - V_{Tp}\right)^2 = I_{D6} = \frac{B_6}{2}\left(2V_{DS6}\left(V_{GS6} - V_{Tn}\right) - V_{DS6}^2\right)$$

$$\left(-V_{DD} - V_{TP}\right)^2 = \frac{B_6}{B_4}\left(2V_{DS6}\left(V_{DD} - V_{Tn}\right) - V_{DS6}^2\right)$$

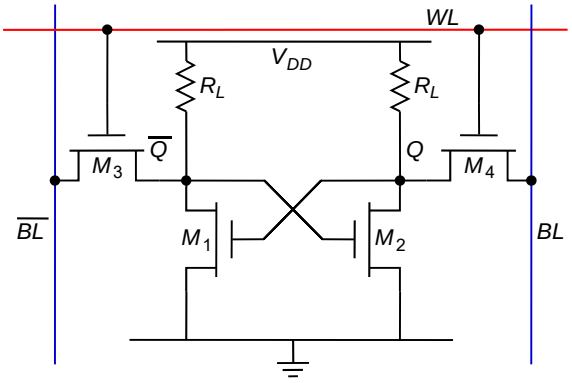
$$V_{DS6} = \left(V_{DD} - V_{Tn}\right) - \sqrt{\left(V_{DD} - V_{Tn}\right)^2 - \frac{\mu_p}{\mu_n} PU\left(-V_{DD} - V_{Tp}\right)^2}$$

Digitalna elektronika
RAM memorije – 6T SRAM - Write



$$PU = \frac{W_4 / L_4}{W_6 / L_6}$$

Digitalna elektronika
RAM memorije – Resistance load SRAM



R_L veliko da bi se smanjila struja u statičkom režimu

Koliko veliko?

Digitalna elektronika
RAM memorije – TFT load SRAM

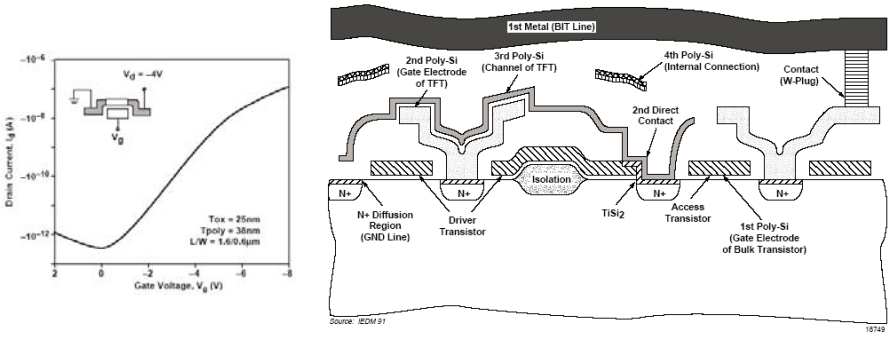


Figure 8-7. Cross Section of TFT SRAM Cell

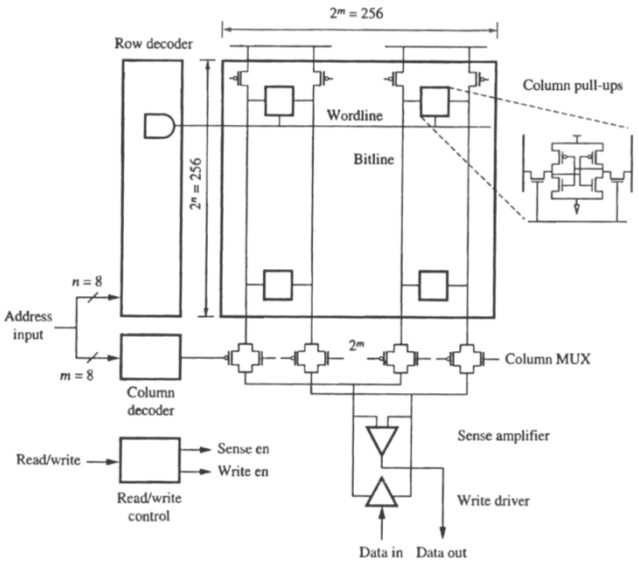
TFT - Thin Film Transistors - kao opterećenje

Digitalna elektronika
RAM memorije – SRAM

Table 12-2 Comparison of CMOS SRAM cells used in 1-Mbit memory (from [Takada91])

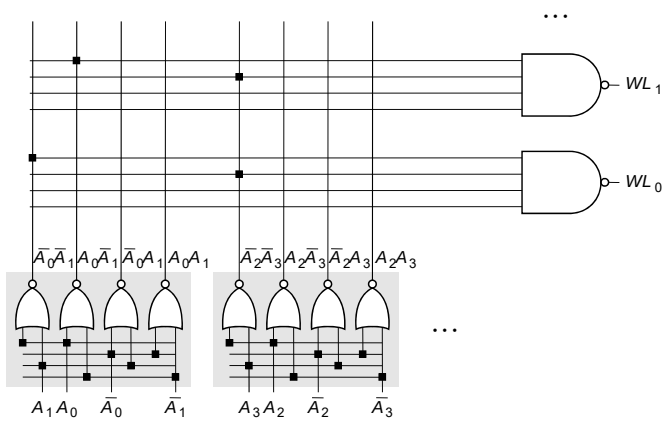
	Complementary CMOS	Resistive Load	TFT Cell
Number of transistors	6	4	4 (+2 TFT)
Cell size	58.2 μm^2 (0.7-µm rule)	40.8 μm^2 (0.7-µm rule)	41.1 μm^2 (0.8-µm rule)
Standby current (per cell)	10^{-15} A	10^{-12} A	10^{-13} A

Digitalna elektronika
RAM memorije – SRAM

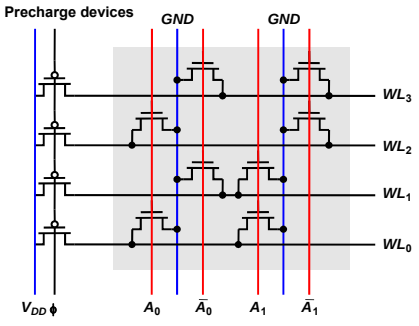


Digitalna elektronika
RAM memorije – SRAM - dekoderi

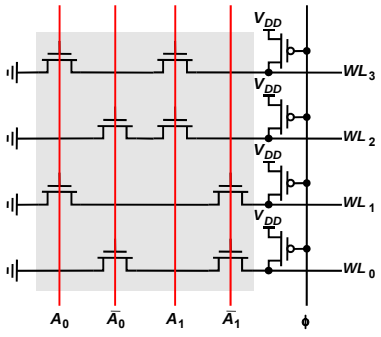
U više nivoa



Digitalna elektronika
RAM memorije – SRAM - dekoderi

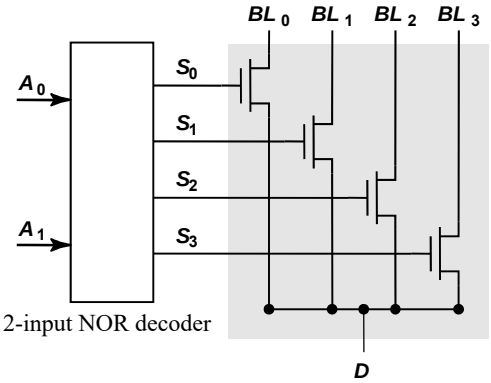


2-input NOR decoder



2-input NAND decoder

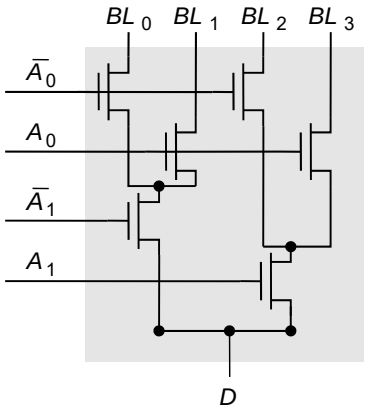
Digitalna elektronika
RAM memorije – SRAM - dekoderi



Prednost: brzina - samo jedan tranzistor na putanji podatka

Mana: Veliki broj tranzistora

Digitalna elektronika
RAM memorije – SRAM - dekoderi



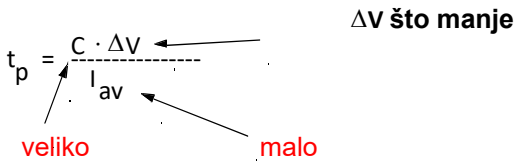
Stablo

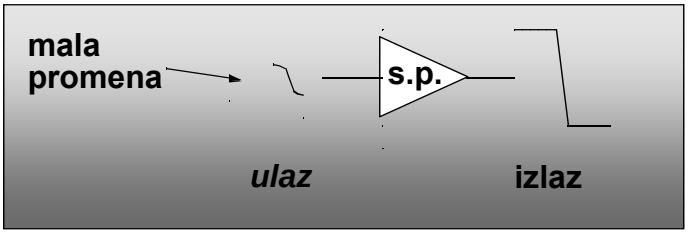
tree

Broj tranzistora znatno manji, ali raste vreme propagacije

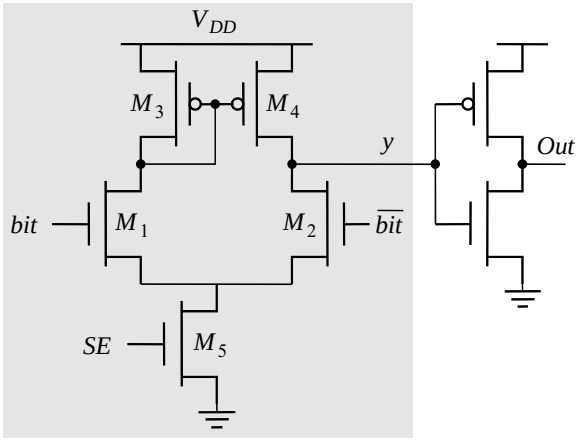
Rešenje je kombinacija prethodnih slučajeva, arhitektura memorije, baferi

Digitalna elektronika
RAM memorije – SRAM – senzorski pojačavači

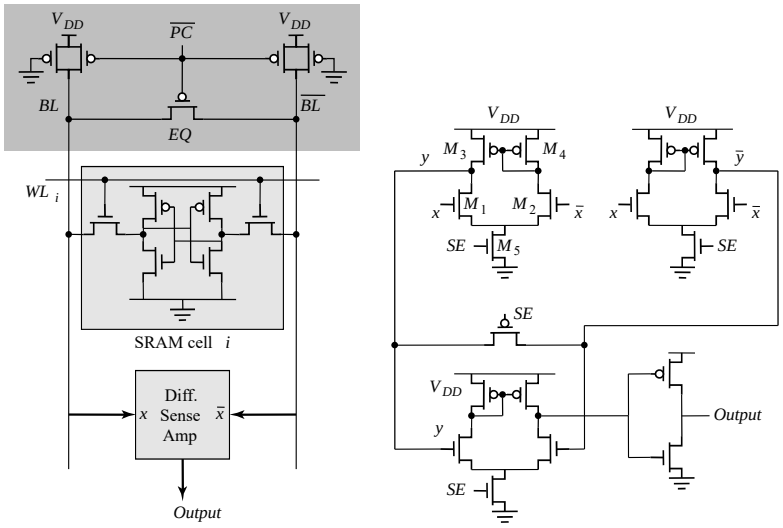




Digitalna elektronika
RAM memorije – SRAM – senzorski pojačavači

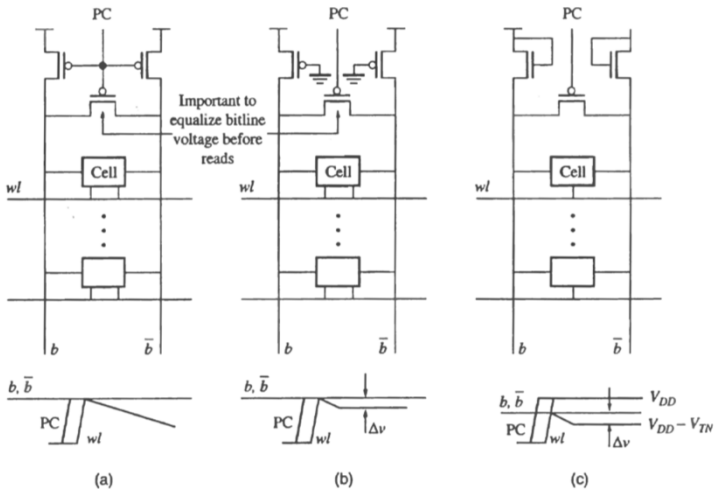


Digitalna elektronika
RAM memorije – SRAM – senzorski pojačavači



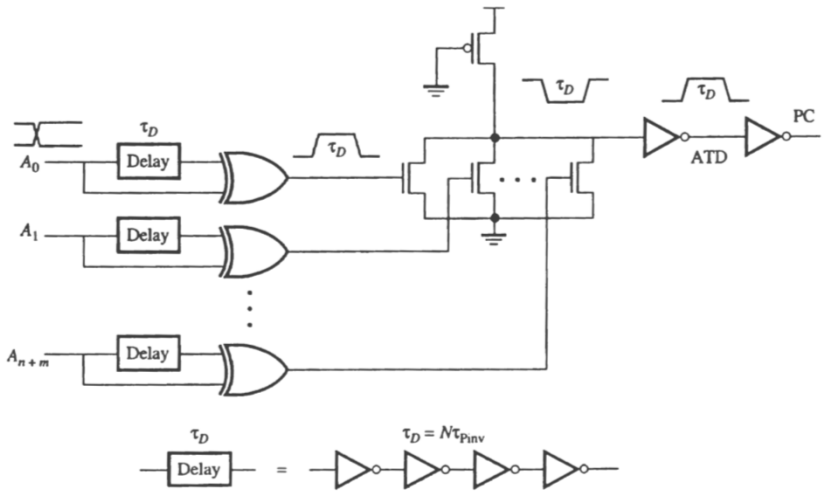
(a) SRAM sensing scheme (b) two stage differential amplifier

Digitalna elektronika
RAM memorije – SRAM – precharge



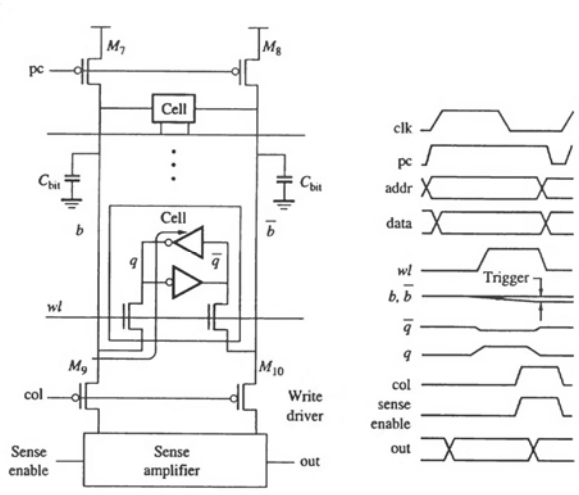
(a) (b) (c)

Digitalna elektronika
RAM memorije – SRAM – precharge

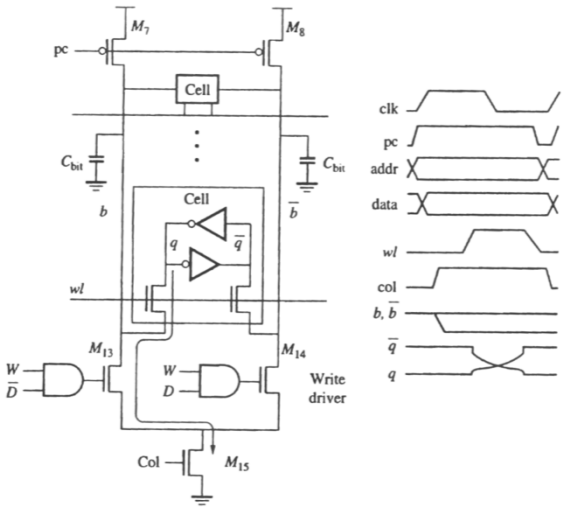


Detekcija promene adrese

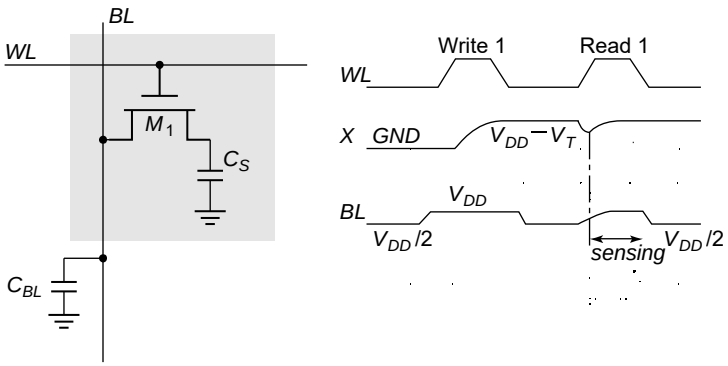
Digitalna elektronika
RAM memorije – SRAM – Read



Digitalna elektronika
RAM memorije – SRAM – Write



Digitalna elektronika
RAM memorije – 1T DRAM



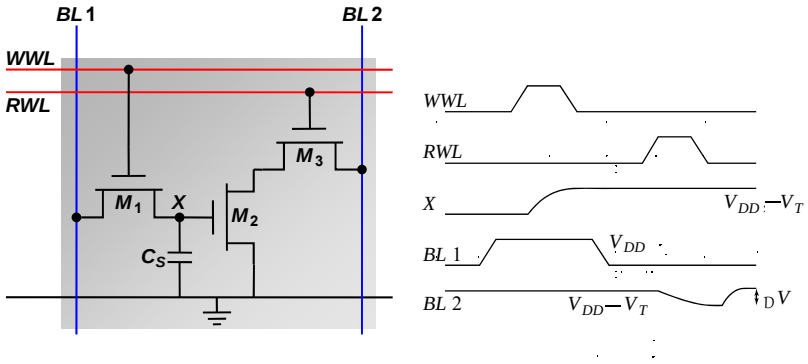
Write: C_S se puni i prazni aktiviranjem WL and BL.
Read: razmena naelektrisanja Cs i Cbl

$$\Delta V = V_{BL} - V_{PRE} = (V_{BIT} - V_{PRE})\frac{C_S}{C_S + C_{BL}}$$

Promena napona 250 mV.

Destruktivno!!!

Digitalna elektronika
RAM memorije – 3T DRAM

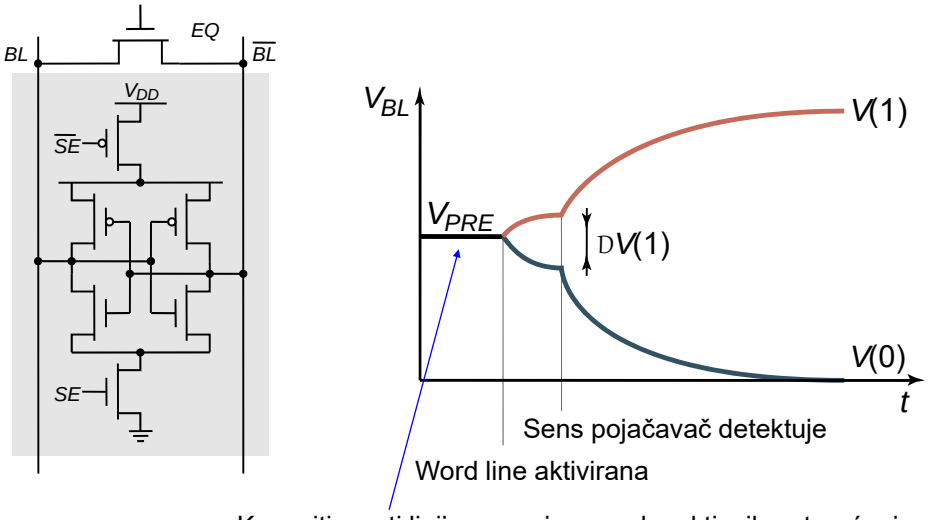


NEDestruktivno!!!

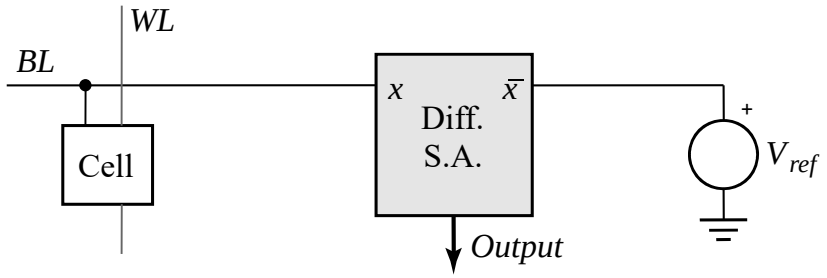
Digitalna elektronika
RAM memorije – DRAM

- 1T DRAM zahteva senzorski pojačavač
- DRAM memorijska ćelija je sa jednostrukim izlazom - single ended.
- SRAM ćelija je sa diferencijalnim izlazom.
- Čitanje 1T DRAM ćelije je destruktivno; čitanje odnosno osvežavanje je neophodno.
- Za razliku od 3T ćelije, 1T ćelija zahteva dodatnu kapacitivnost.
- Kada se upisuje "1" u DRAM ćeliju napona na kondenzatoru je manji za napon praga MOS tranzistora, manje naelektrisanja, Vwl >*VDD*

Digitalna elektronika
RAM memorije - DRAM

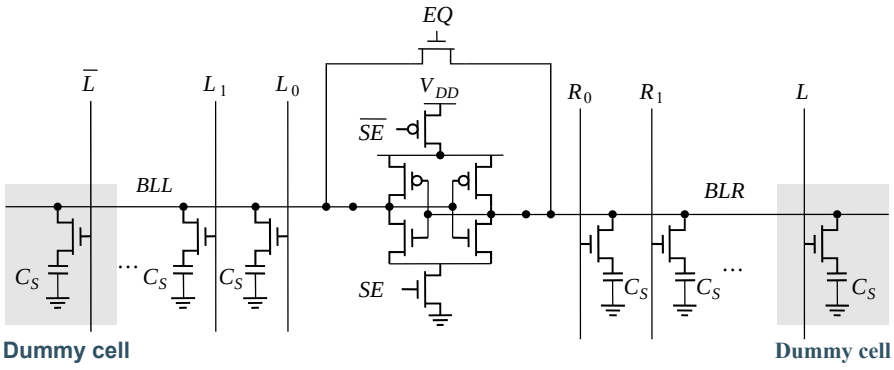


Digitalna elektronika
RAM memorije - DRAM

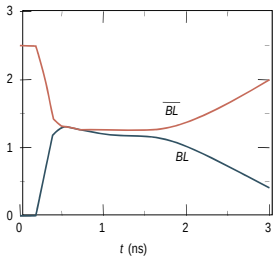


Koliko dobro V_{ref}?

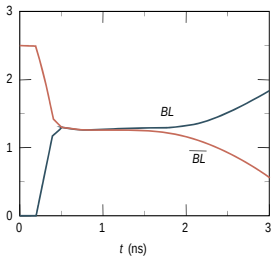
Digitalna elektronika
RAM memorije – DRAM – open bitline



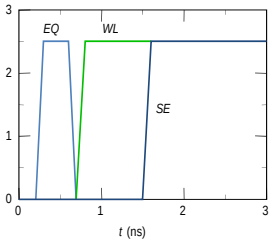
Digitalna elektronika
RAM memorije – DRAM – open bitline



reading 0

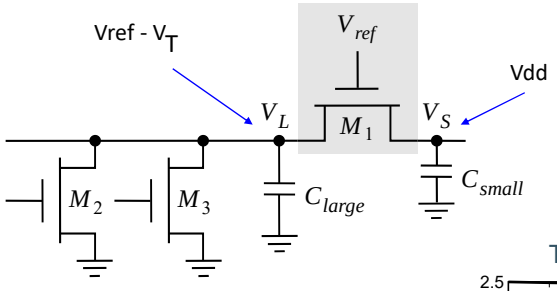


reading 1

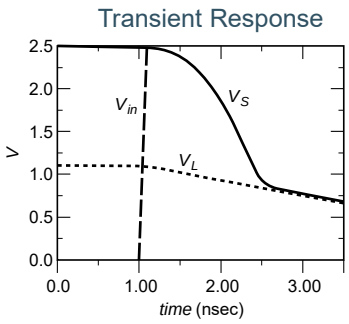


control signals

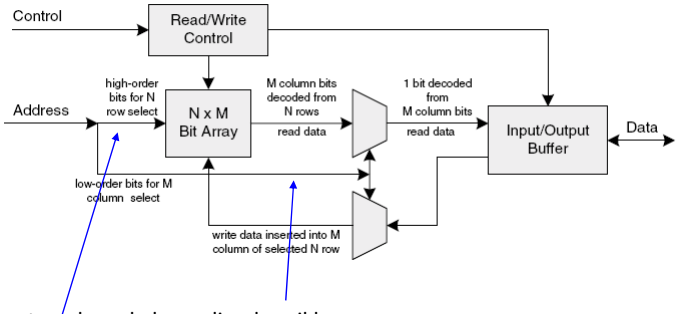
Digitalna elektronika
RAM memorije – DRAM – charge redistribution



Concept



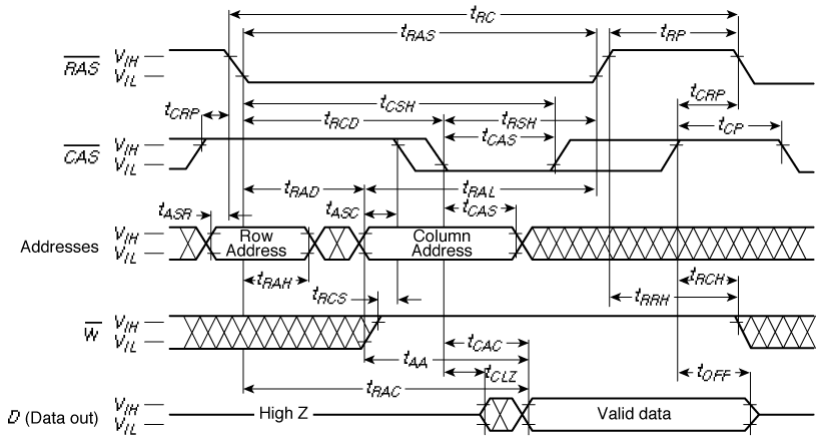
Digitalna elektronika
RAM memorije – DRAM



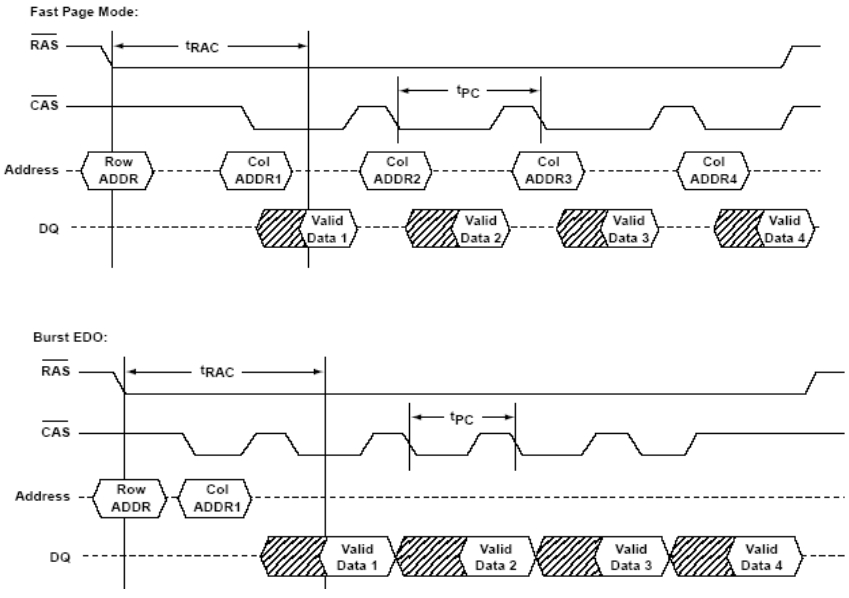
Adresa vrste, adresa kolone ali u dva ciklusa

RAS i CAS kontrolni signali

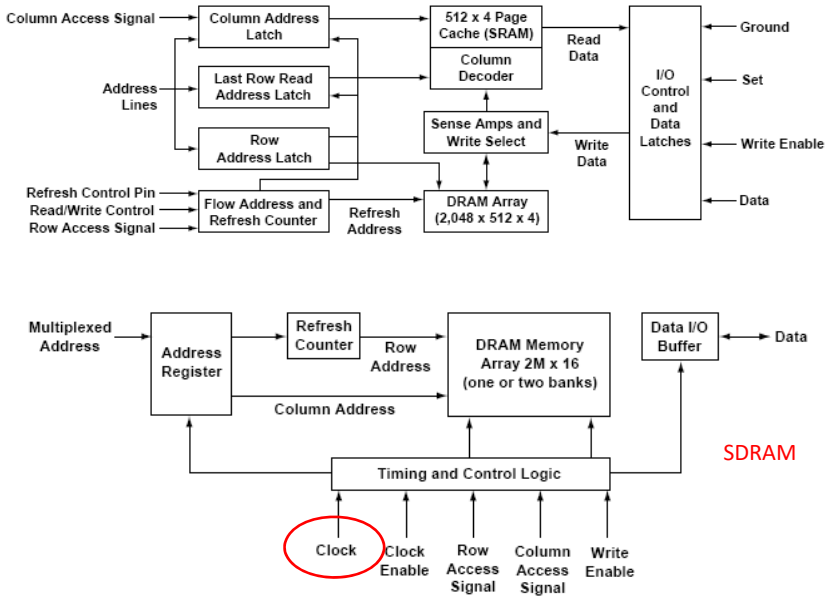
Digitalna elektronika
RAM memorije – DRAM



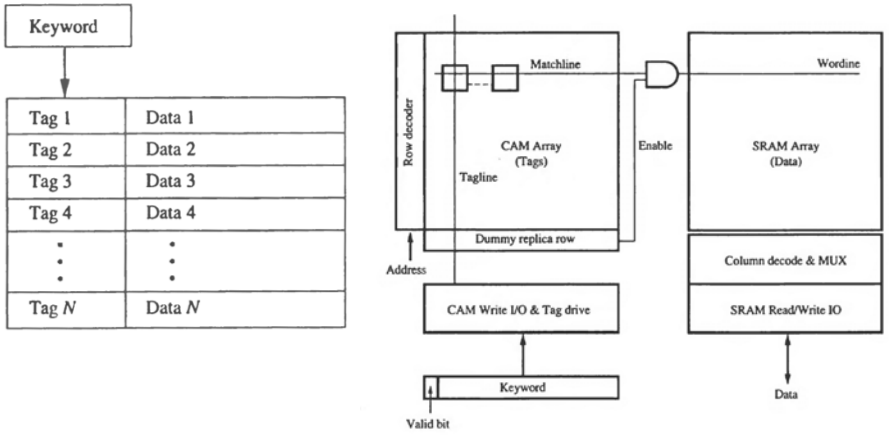
Digitalna elektronika
RAM memorije – DRAM



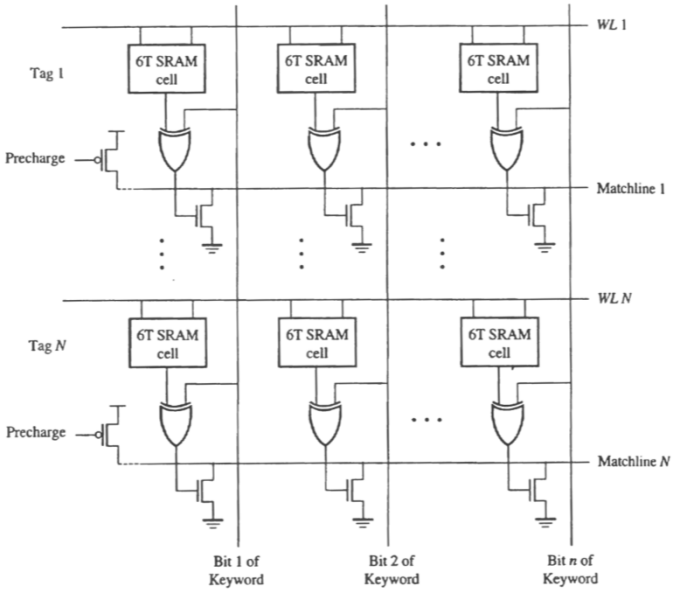
Digitalna elektronika
RAM memorije – DRAM



Digitalna elektronika
RAM memorije – CAM Content Addressable Memories – Asocijativne memorije



Digitalna elektronika
RAM memorije – CAM Content Addressable Memories – Asocijativne memorije



Digitalna elektronika
RAM memorije – CAM Content Addressable Memories – Asocijativne memorije