

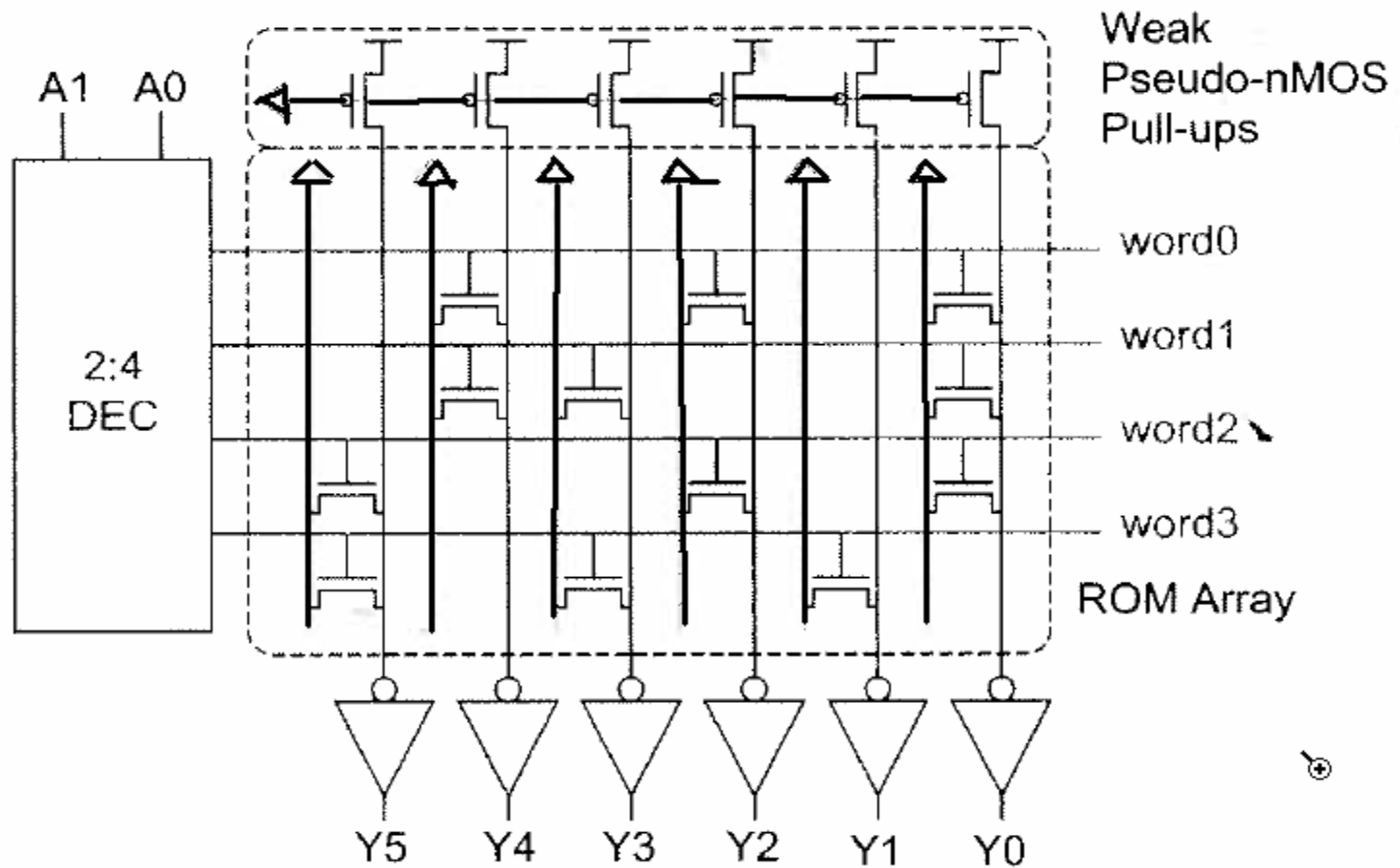
FPGA INTEGRATED CIRCUIT DESIGN

NON VOLATILE MEMORY

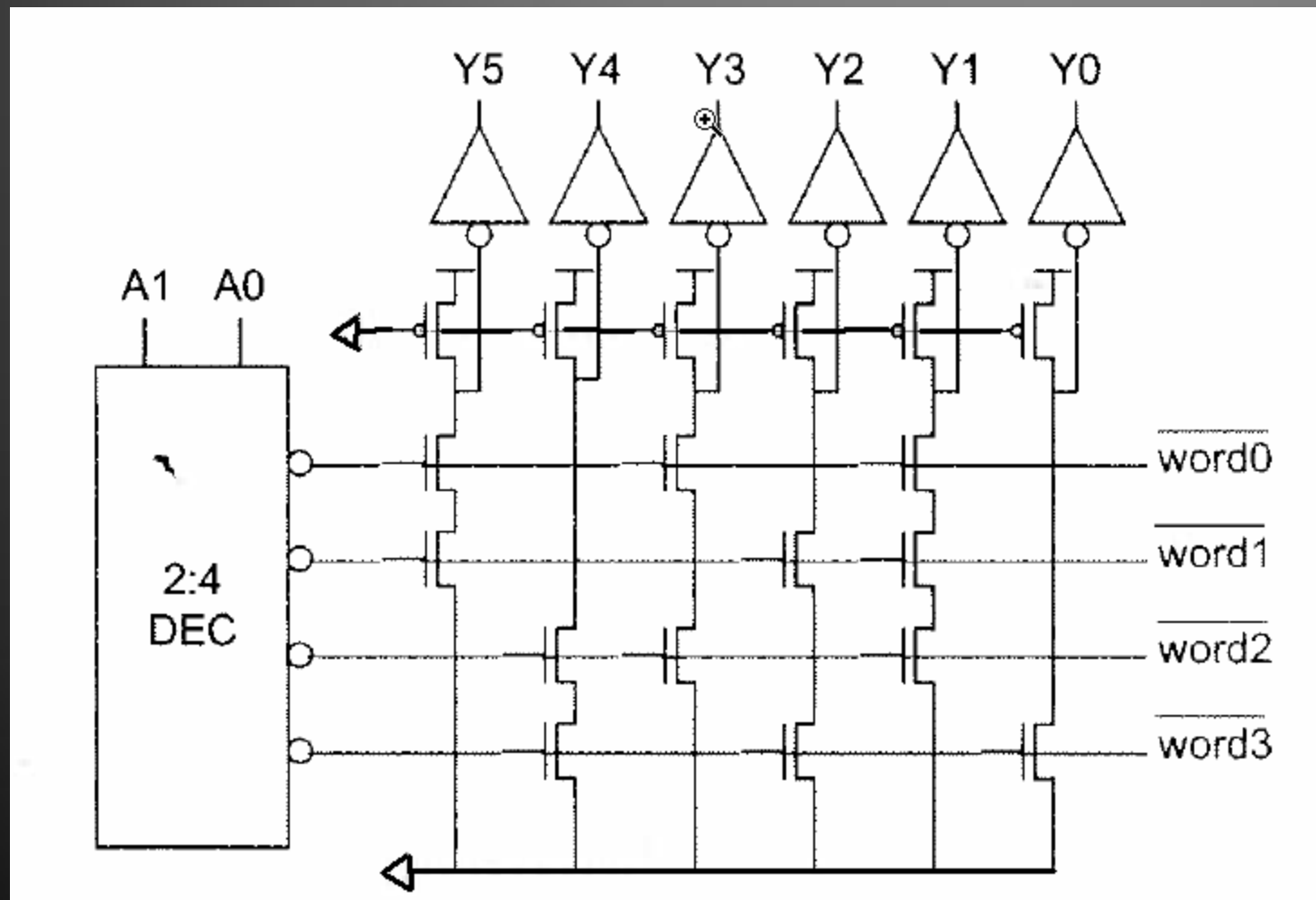
Non-volatile Memory

- ▶ EEPROM – electrically erasable memory, a general-term
 - this is a historical term to differentiate from an older type of memory that used UV-light to for eraser
- ▶ “Flash” memory is the dominant type currently
 - NOR flash
 - NAND flash
- ▶ A relatively recent new type of non-volatile Memory is MRAM – Magnetoresistive Random Access Memory (MRAM)

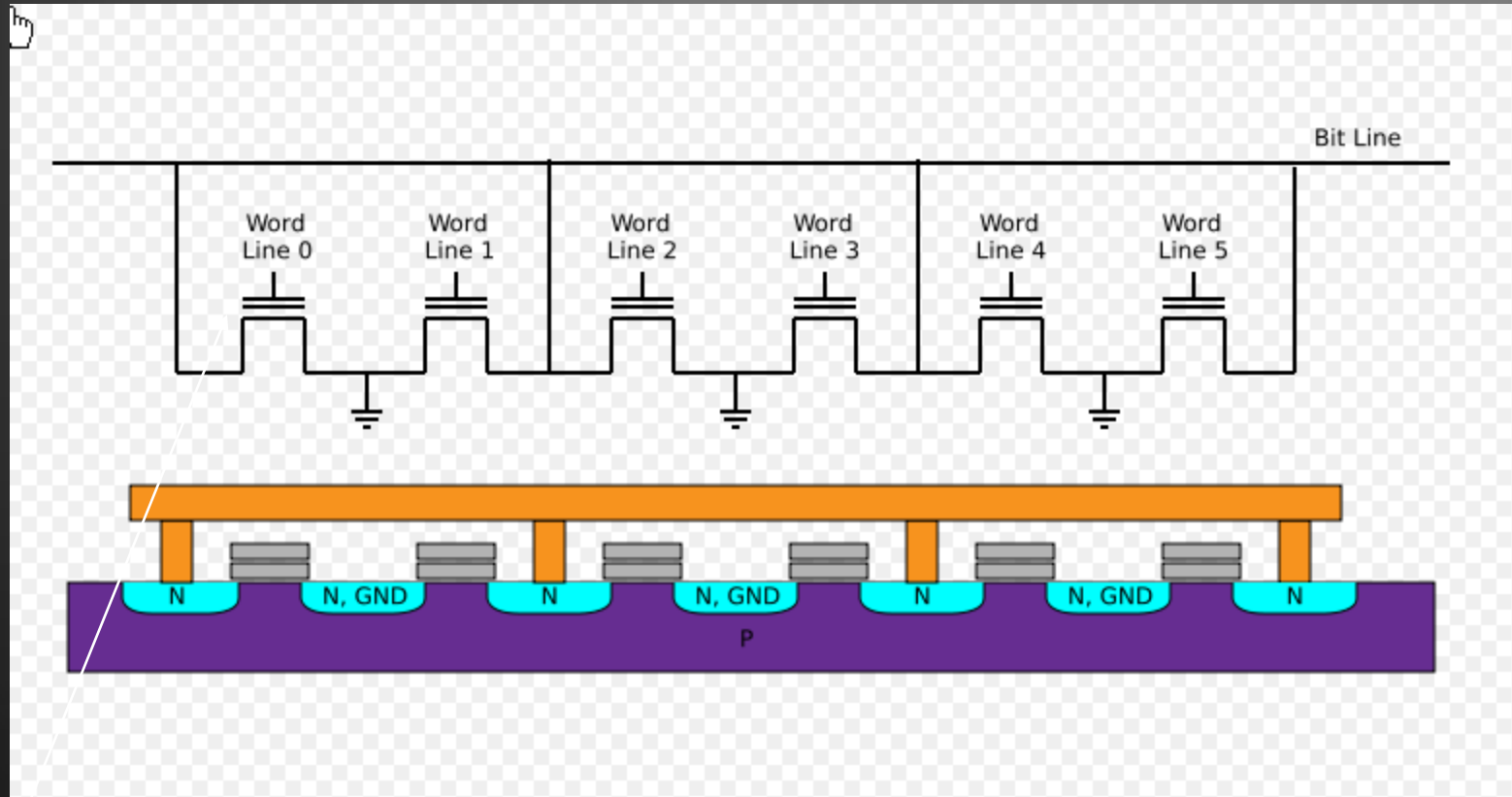
NOR Rom



NAND ROM



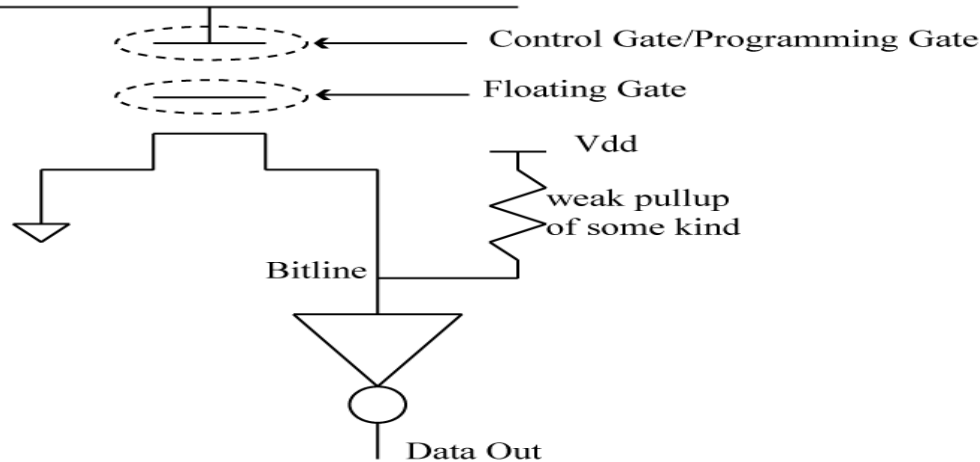
NOR Flash



Floating gate

Floating Gate Operation

Word Line



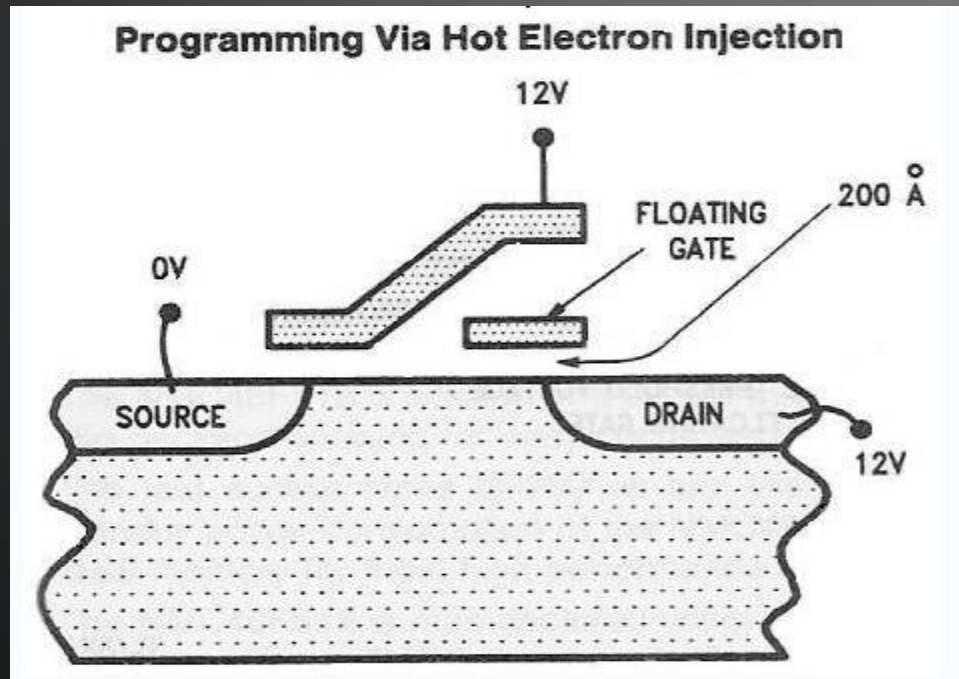
When Floating Gate has no electrons trapped on it (unprogrammed), then WL = '1' turns on transistor, pulling Bitline low, and Data Out = '1'

Unprogrammed $\rightarrow$ WL=1 $\rightarrow$ transistor on $\rightarrow$ Bitline = 0 $\rightarrow$ Data Out = 1
as floating gate has no effect

When Floating gate has electrons trapped on it (negative charge), this increases the V_t of the transistor, so now transistor remains off when WL is 1.

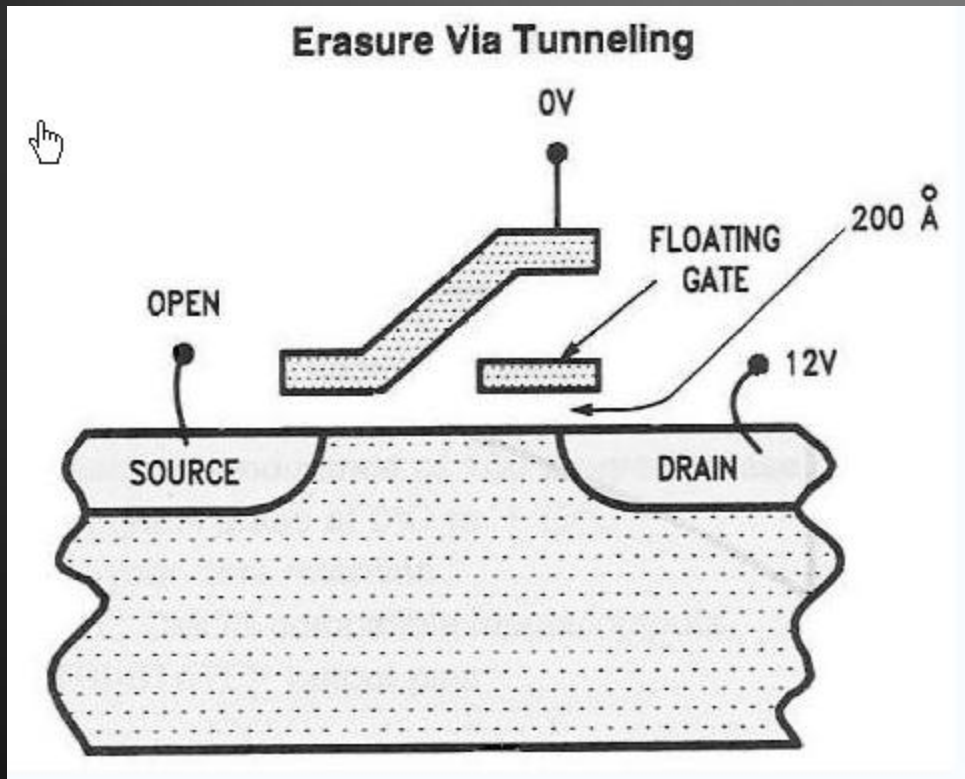
Programmed $\rightarrow$ WL=1 $\rightarrow$ transistor off $\rightarrow$ Bitline = 1 $\rightarrow$ Data Out = 0
as negative charge on floating gate raises V_t

Floating Gate for NOR Flash : Programming



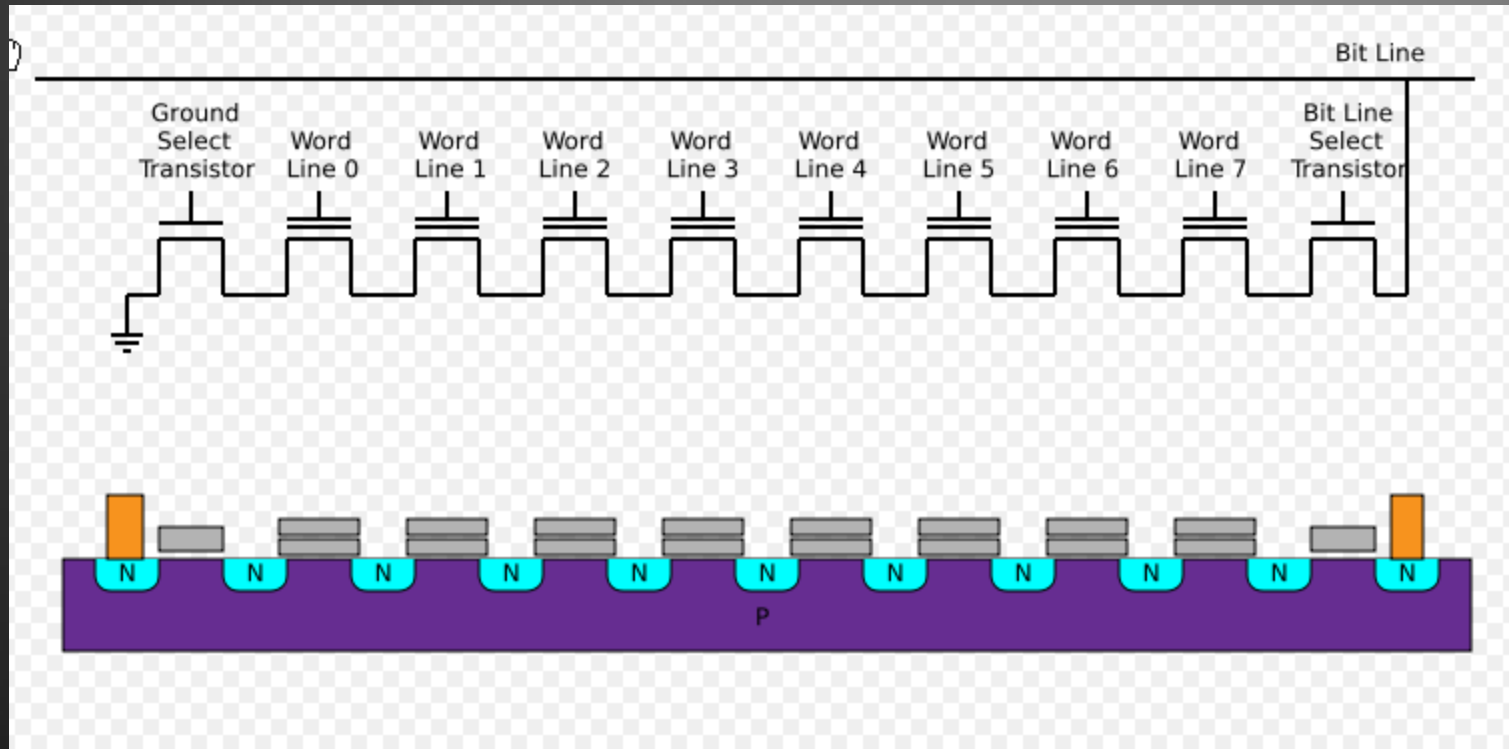
Electrons flowing in channel from drain to source attracted to +12v on the programming gate, become trapped on floating gate, giving it a negative charge.

Floating Gate for NOR Flash : Erase



+12v on drain attracts trapped charge on floating gate and removes the electrons.

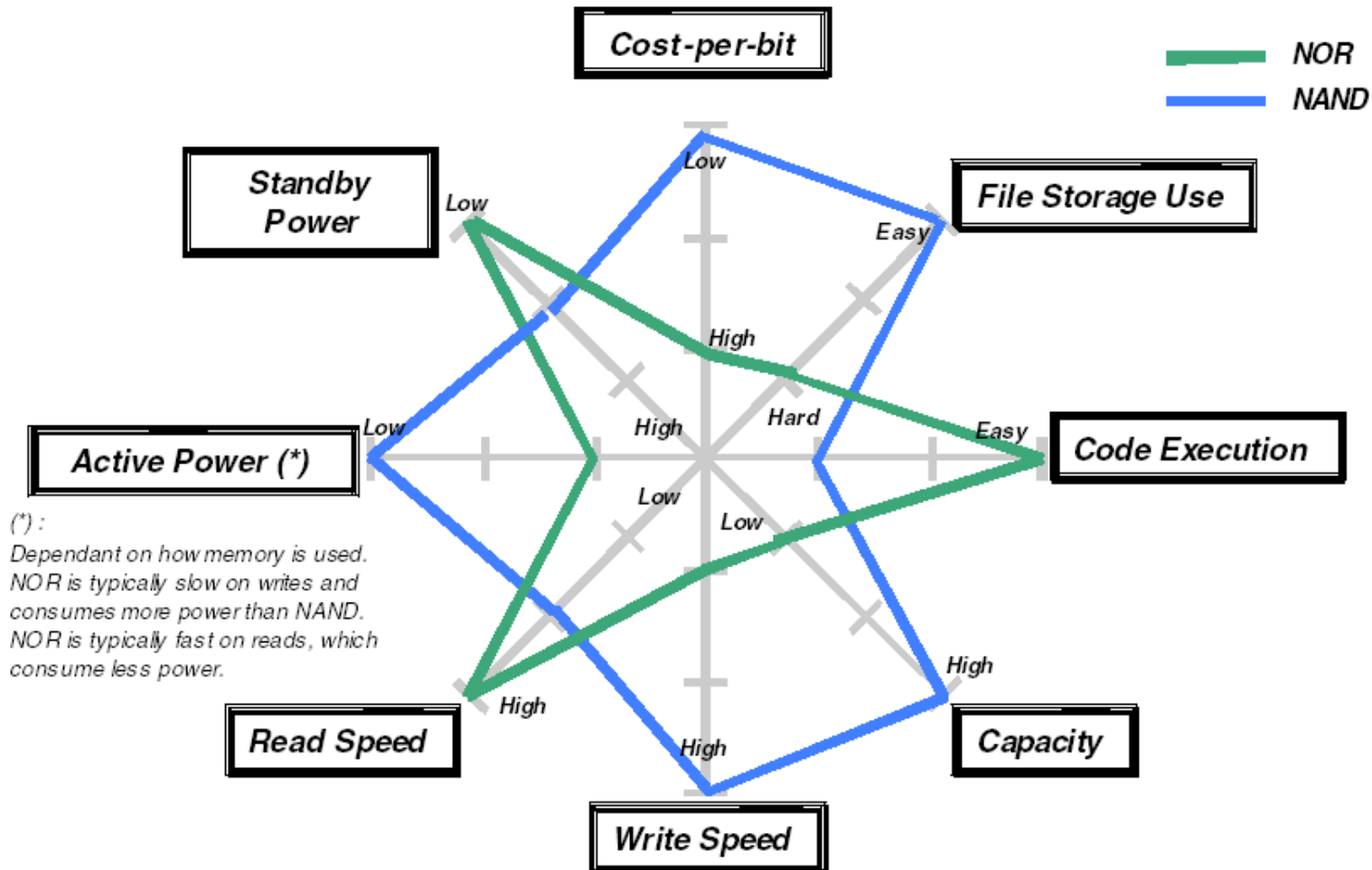
NAND Flash



Standard NAND flash has 8 transistors in parallel.

NAND vs NOR Flash

Fig. 1 Comparison of NOR and NAND Flash



NAND vs. NOR Flash

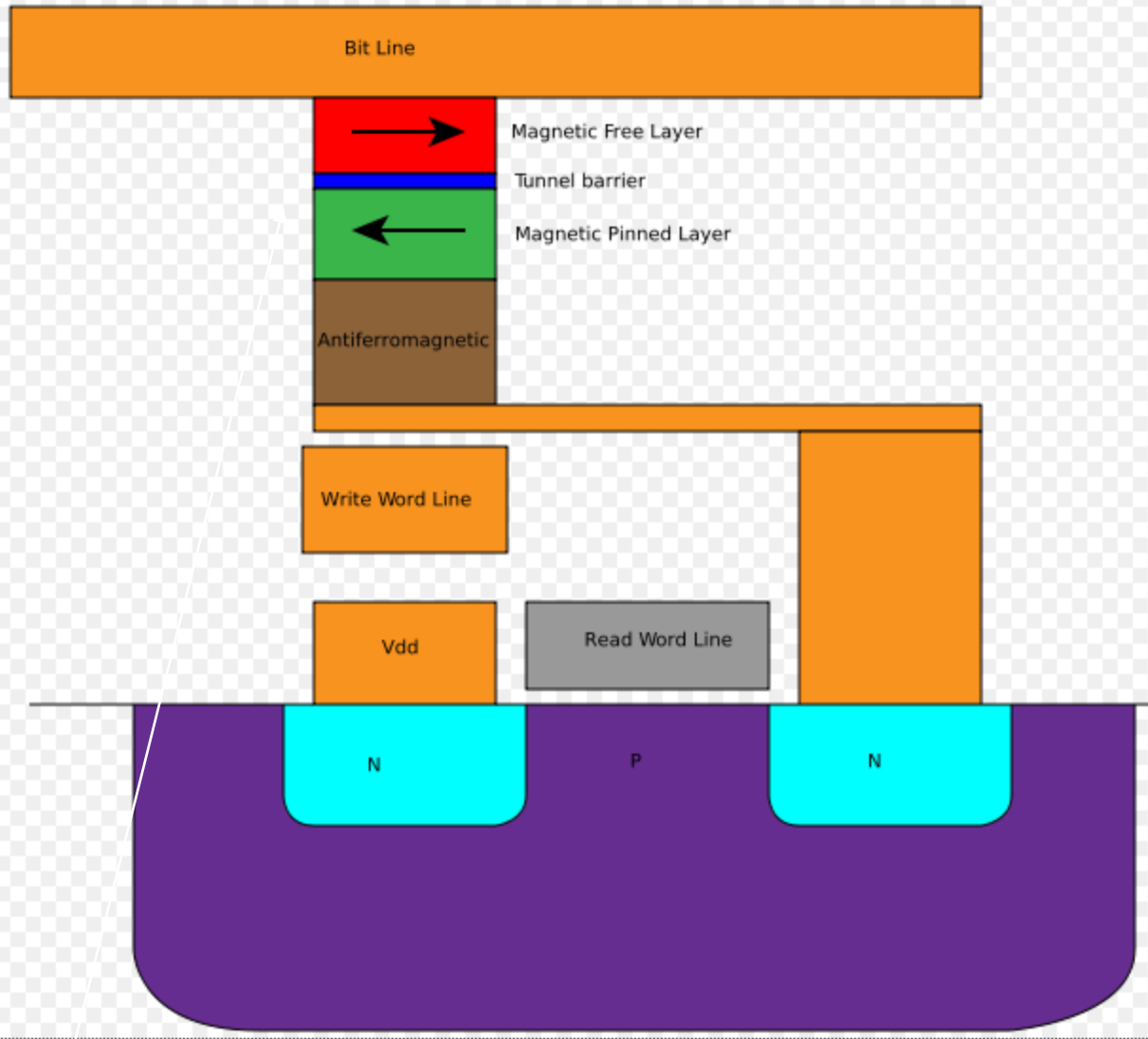
- ▶ NAND denser than NOR because of smaller cell size
 - preferred for data memory storage (flash drives)
 - NAND is about 2x denser than NOR because of layout efficiencies due to series transistors (less metal contacts)
- ▶ NAND slower read time because of stacked cell arrangement
 - NOR preferred as program memory storage for microcontrollers because of faster access time
- ▶ NAND is always block read/block write; NOR allows read of individual memory locations
- ▶ NAND programming/erase is faster than NOR programming/erase

NAND/NOR Flash Limitations

- ▶ Both NAND/NOR memory has limited number of programming/erasure cycles
- ▶ About 100,000 cycles is a typical number, even though cells with higher cycle numbers can be designed
 - The Data memory EEPROM cells (100K minimum cycles, 1M max) in the PIC microprocessors are designed to have about 10X the maximum number of programming/erase cycles as the program memory EEPROM cells (10K minimum cycles, 100K max)

MRAM – Magnetoresistive Random Access Memory

- ▶ Semiconductor memory that uses magnetic storage elements
- ▶ Advantages
 - Non-volatile
 - Fast Read/Write (nanoseconds)
 - Random access
 - Unlimited read/write (does not degrade with usage like Flash)
 - Radiation hard (military applications)
- ▶ Disadvantages
 - Tough to scale down, IBM believes that scaling past 65 nanometer is impractical
 - Stray magnetic fields can impact them, but packaging by Vendors gives more than adequate protection from typical stray encountered fields
- ▶ Uses
 - Proponents believe will replace flash memory on microcontrollers since these are not usually fab'ed with the most aggressive technologies, and some applications can benefit from the fast write times, and unlimited writes
 - Could also replace SRAM/DRAM use in embedded systems.



Essentially a resistor with two different resistances depending on if the magnetic fields of the two plates are in the same direction or opposite directions

Magnetic Tunnel Junctions (MTJ)

MRAM Cell (Freescale)

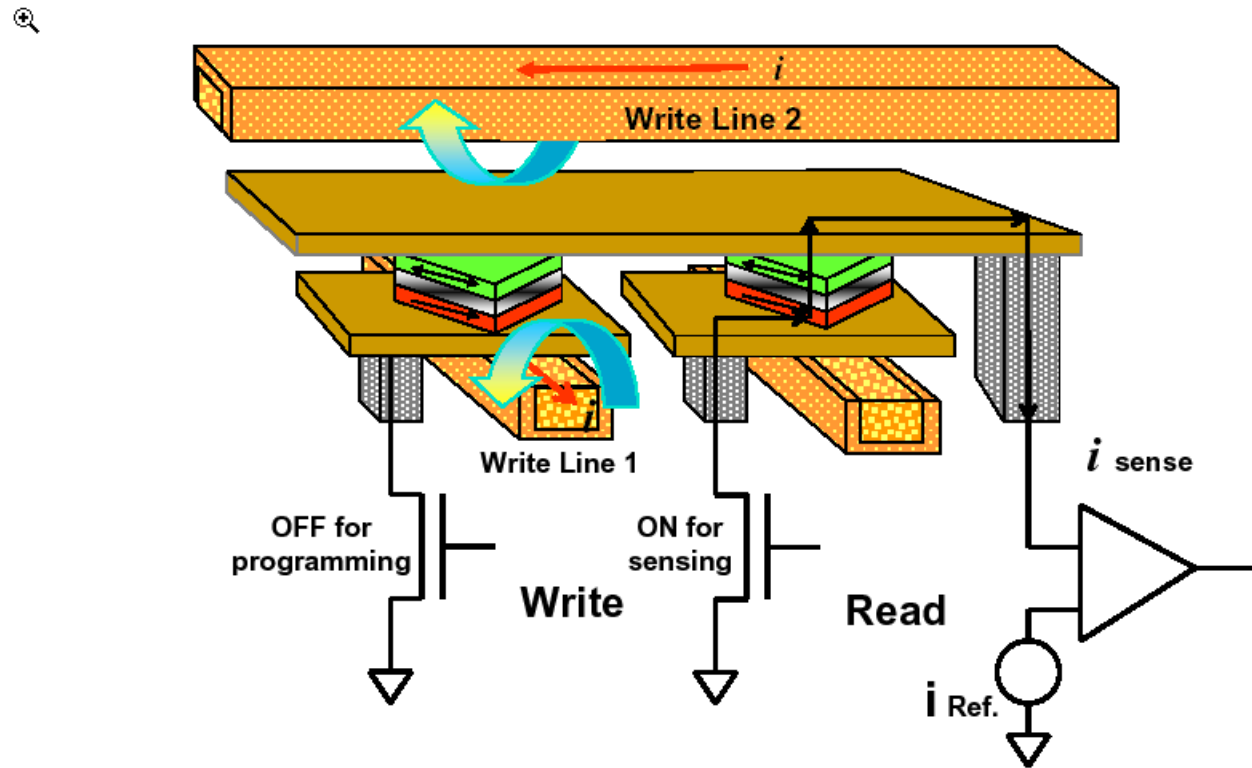


Figure 1 Bit cell is represented by the red and green layers; being the fixed and free layer respectively.

Resistance of Magnetic Tunnel Junctions (MTJ) is high when oppositely aligned, low when aligned.

MRAM Operation

- ▶ Two thin-film ferromagnetic films are used
 - magnetic polarization of one film is fixed, the other is free to be changed to aligned to be the same or opposite of fixed field
- ▶ Electrons have two spins, 'up' and 'down', about 50% distributed and this changes as electrons move
- ▶ When electrons pass through ferromagnet, spins become spin-polarized
 - parallel with magnetic field ('up'), majority carrier
 - anti-parallel with magnetic field ('down'), minority carrier
 - 'down' spin electrons are scattered, 'up' spin electrons are not
- ▶ Electrons passing through two thin plates with same aligned fields means that only type of electron spin is scattered (looks like low resistance, more electrons get through)
- ▶ Electrons passing through two thin plates with opposite-aligned fields means that both types of spin is scattered (looks like high resistance, less electrons get through).

MRAM Device (Freescall)

**256K x 16-Bit 3.3-V
Asynchronous
Magnetoresistive RAM**

MR2A16A



44-TSOP
Case 924A-02

Introduction

Features

Features

- Single 3.3-V power supply
- Commercial temperature range (0°C to 70°C), Industrial temperature range (-40°C to 85°C) and Extended temperature range (-40°C to 105°C)
- Symmetrical high-speed read and write with fast access time (35 ns)
- Flexible data bus control — 8 bit or 16 bit access
- Equal address and chip-enable access times
- Automatic data protection with low-voltage inhibit circuitry to prevent writes on power loss
- All inputs and outputs are transistor-transistor logic (TTL) compatible
- Fully static operation
- Full nonvolatile operation with 20 years minimum data retention

0.18u technology