



Soft Errors in Embedded Applications

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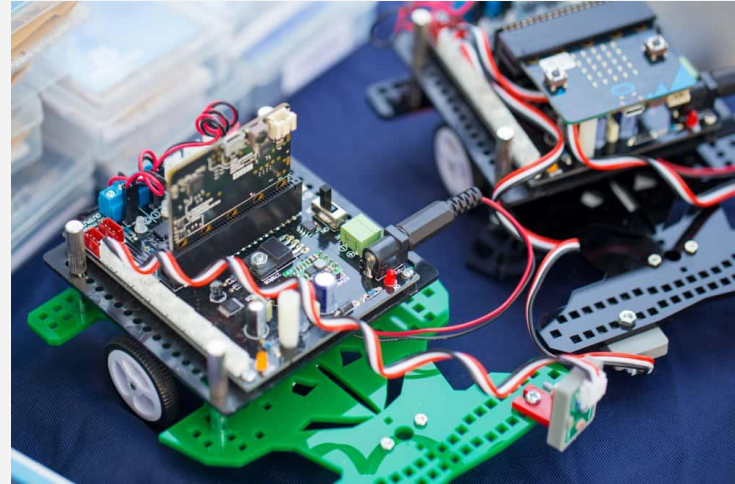
INTRODUCTION

- **Overview of Embedded system**
- **Soft-Errors and Hard-Errors**
- **Importance of addressing Soft-Errors**

Embedded System



[7]



[6]



Types of errors in Embedded Application

- **Hard Errors**

Caused by defect in hardware components

- **Soft Errors**

Caused by external factors



Causes of Soft Errors

- Cosmic Radiation
- Alpha Particles
- Electrical Noise

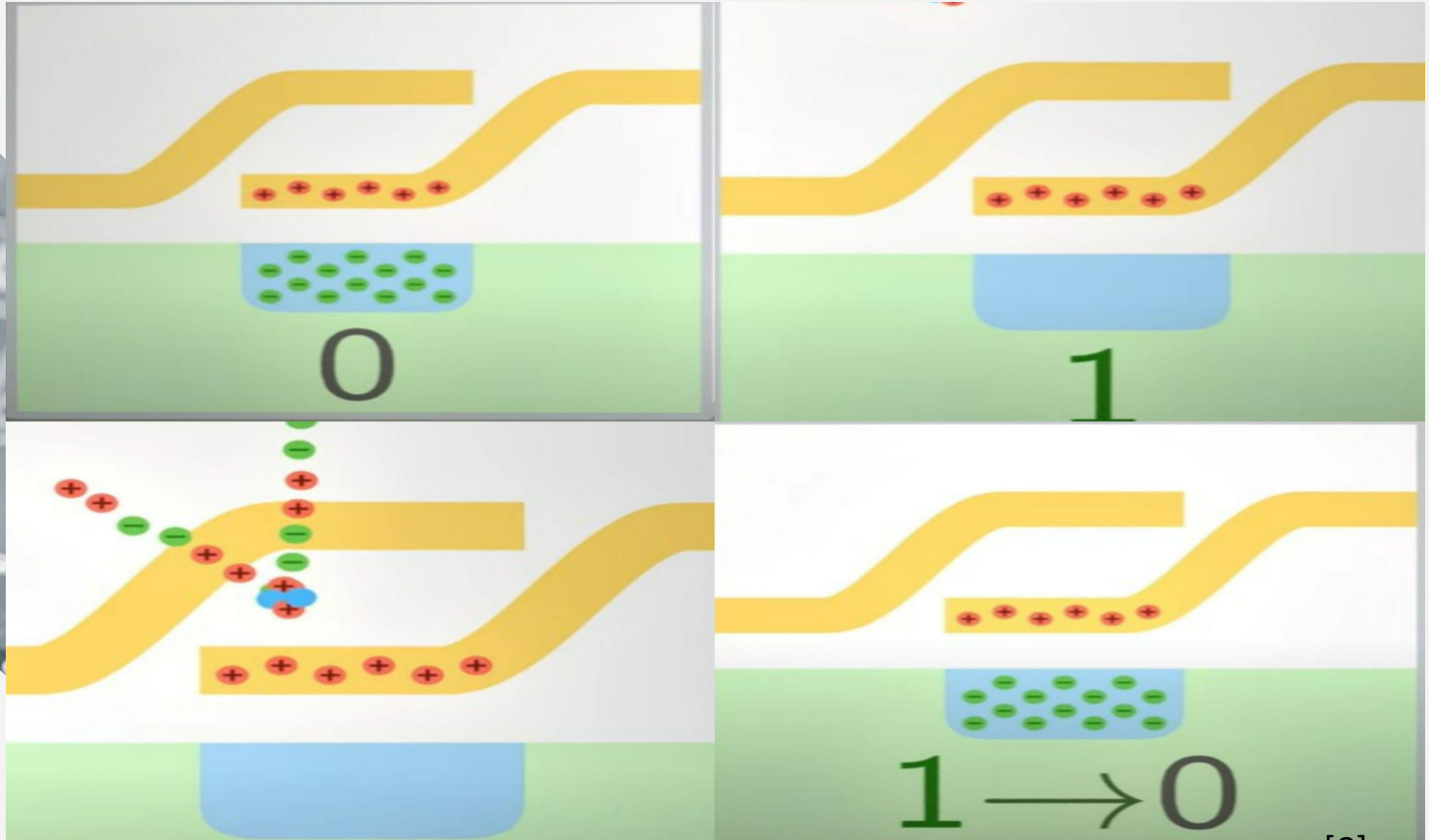


Alpha Particles

- Emission of Alpha Particles
- Effect of Alpha Particles



Effect of alpha particles



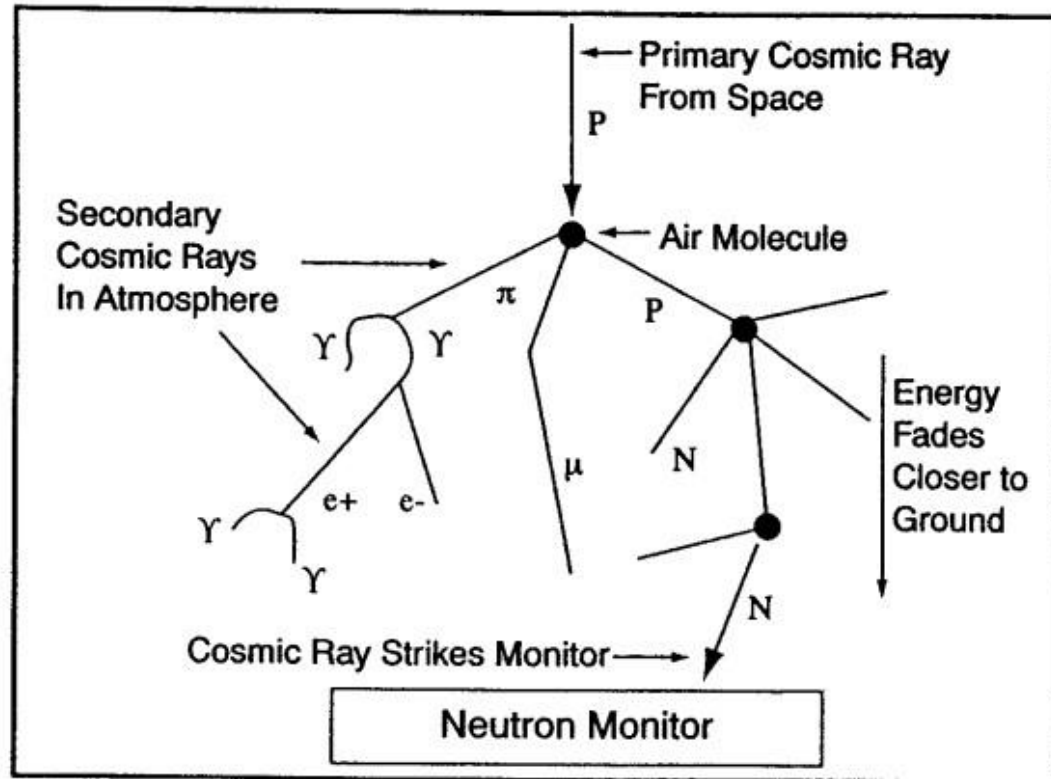


Cosmic Radiation

- Radiation Cause
- Radiation into Earth's Atmosphere
- Effect of Cosmic Radiation

Cosmic Radiation with Atmosphere

N Neutron
P Proton
• Air molecule
 π Pion
 μ Muon
 e^- , e^+ Electron, Positron
 γ Photon



Neutron Reaction with Silicon

REACTION PRODUCTS AND THRESHOLD ENERGIES FOR $n + {}^{28}\text{Si}$ REACTIONS

Reaction Product	Threshold Energy (megaelectron volt)
${}^{25}\text{Mg} + \alpha$	2.75
${}^{28}\text{Al} + p$	4.00
${}^{27}\text{Al} + d$	9.70
${}^{24}\text{Mg} + n + \alpha$	10.34
${}^{27}\text{Al} + n + p$	12.00
${}^{26}\text{Mg} + {}^3\text{He}$	12.58
${}^{21}\text{Ne} + 2\alpha$	12.99


[3]



Electromagnetic Radiation

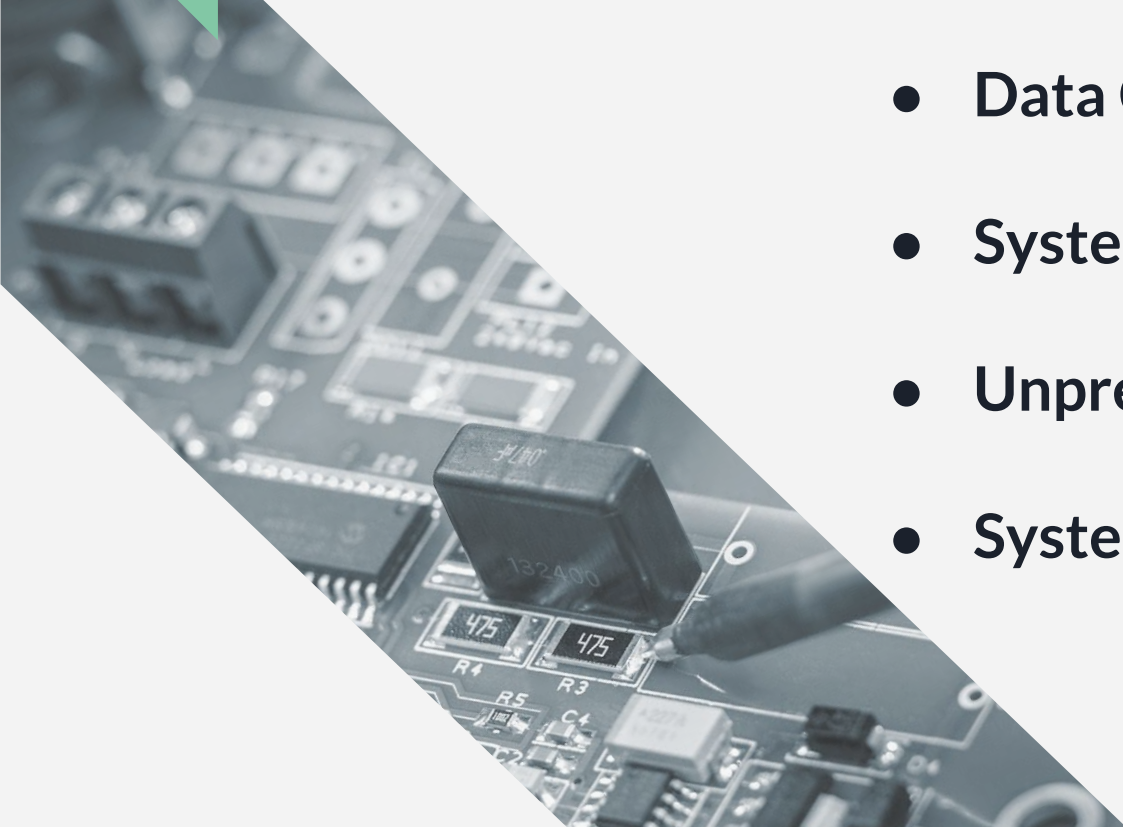
- Cause of EMR
- Effect of EMR on Devices





Impact of Soft Errors in Embedded Applications

- Data Corruption
- System Malfunctions
- Unpredictable Behaviour
- System Crashes





Mitigation Techniques

- Error correcting Code
- Redundancy
- Shielding





Error Correcting Codes

- Hamming Code
- Reed-Solomon Code

Hamming code

(7, 4) Hamming Code



4 Data Bits - D₄ D₃ D₂ D₁

3 Parity Bits - P₃ P₂ P₁

$$P_1 = D_1 \oplus D_2 \oplus D_4$$

$$P_2 = D_1 \oplus D_3 \oplus D_4$$

$$P_3 = D_2 \oplus D_3 \oplus D_4$$

[1]

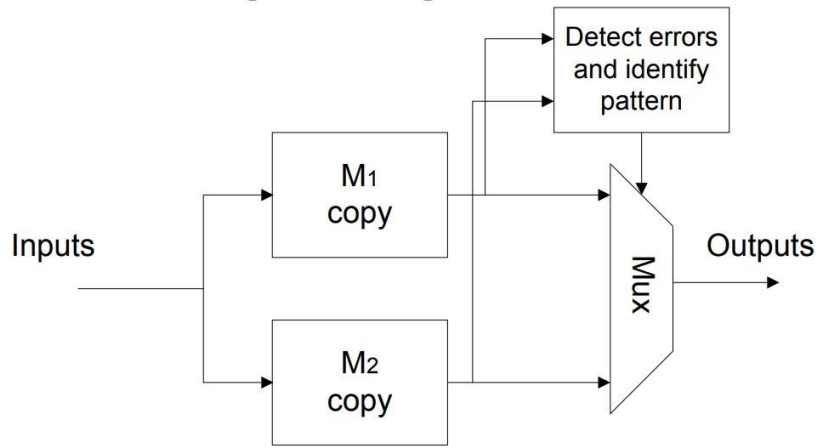


Redundancy

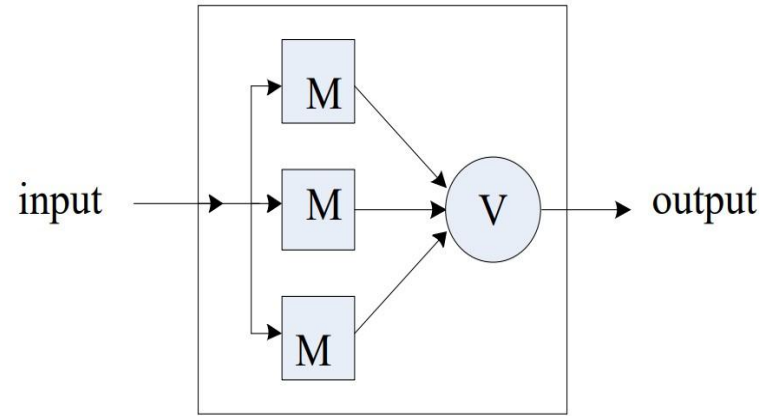
- Double Modular Redundancy
- Triple Modular Redundancy



Redundancy Check



DMR



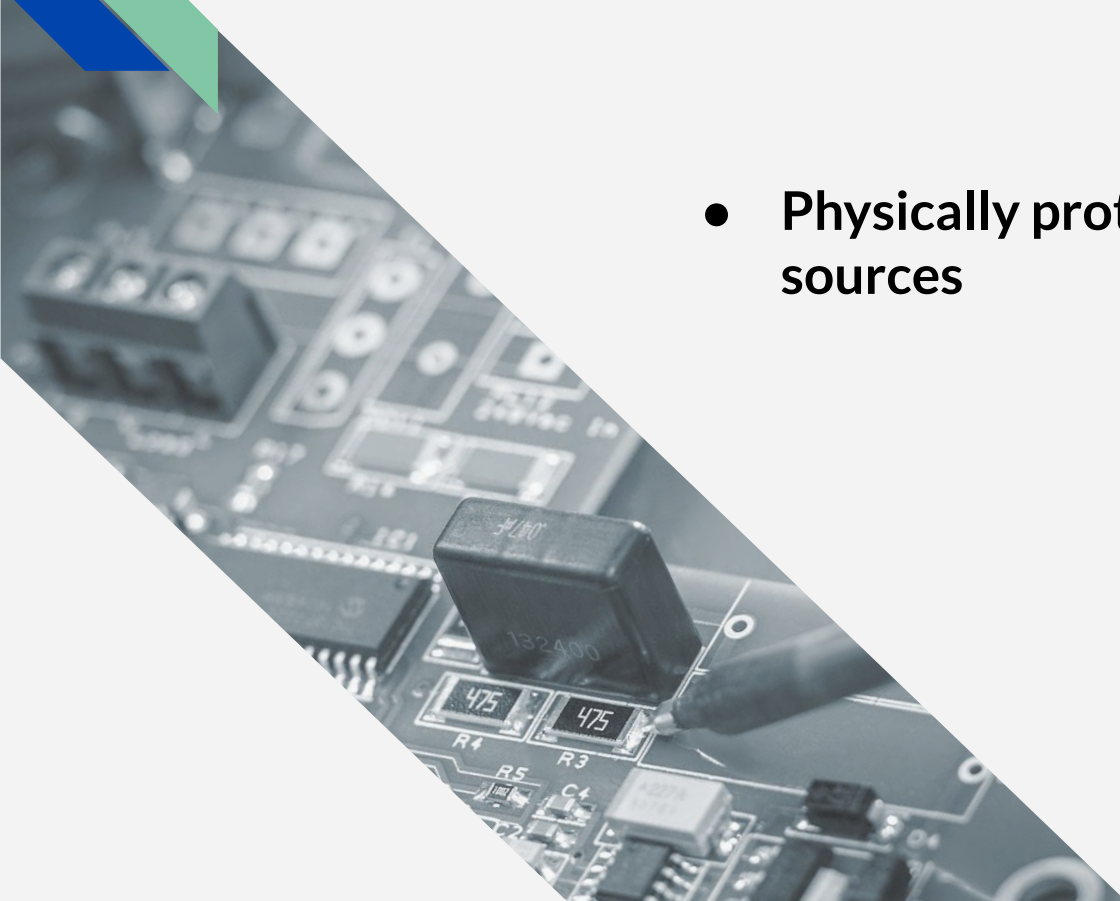
TMR

[4]



Shielding

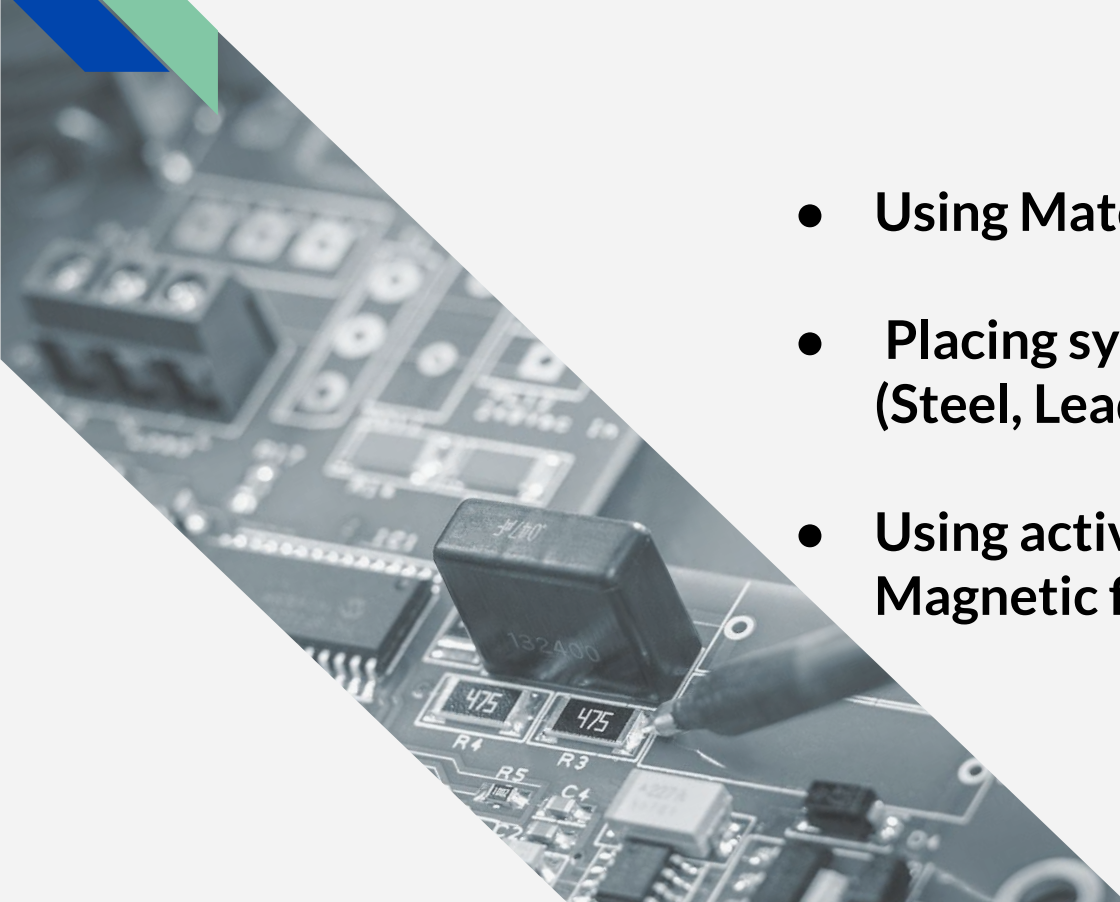
- **Physically protecting the system from the sources**





Shielding Techniques

- Using Materials such as SiC or GaAs
- Placing system in shielded enclosure (Steel, Lead)
- Using active shielding (electric or Magnetic field)





Fault Injection

- **Hardware Fault injection**
- **Software Fault injection**



Future Development

- Enhancing error correction codes (EDCCs) for improved efficiency in detecting and correcting multiple-bit errors.
- Creating radiation-resistant materials to minimize damage
- Exploring AI and machine learning to detect and mitigate soft errors in electronic systems by analyzing data patterns.



Conclusion

As embedded systems become more complex and operate the prevalence of soft errors is expected to rise. Mitigations techniques are introduced to over come this problems.



Reference

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