EOS and ESD on ADC
TI Precision Labs – ADCs

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ESD vs. EOS – What’s the Difference?

ESD

- Electrostatic discharge
- Short duration event (1-100ns)
- High voltage (kV)
- Fast edges
- Both “in-circuit” and “out-of-circuit”

EOS

- Electrical overstress
- Longer duration event
  - Milliseconds or more
  - Can be continuous
- Lower voltage
  - May be just beyond absolute maximum ratings
- “In-circuit” event only
EOS from Fault or Overdriven

Fault Conditions

- Harsh electrical environment
- High voltage circuit in the system
- Improper power up sequencing
- Hot-swap connection and disconnection
- Loss of power supply but input signal is applied
- Apply bipolar signal to unipolar input ADC
- Miswiring
- Other conditions violating the absolute maximum specifications
Internal Clamp/Protection on Data Converters

1. Input Steering diodes:

2. Back-to-Back Zener diode:

3. SCR-Based input:

*Bi-directional SCR example
SCR-Based ESD Structure and Latch-up

- **SCR** (silicon controlled rectifier) is a parasitic structure. Overshoot and undershoot outside the normal operating voltage and current levels can cause Latch-up and damage the device.

  - **Trigger Latch-up:**
    - Applied voltage \( V_H \) and applied current \( I_H \)
  - **Terminate Latch-up state:**
    - A latch-up remains even after applied signal has been removed and requires a **power supply shut down** to remove the low impedance path.

Why use SCR-Based ESD protection

- Input Signal Voltage > Power Supply.
- SCR is used as effective input ESD protection element to sustain a higher ESD level within a smaller layout area because:
  - Lower holding voltage
  - Significantly lower power dissipation
  - Robust ESD protection

* Electrostatic Discharge Protection Circuit for High-Speed Mixed-Signal Circuits by Hossein Sarbishaei.
Input Diode to REF/AVDD

- Internal diodes are connected to REF: ADS8860, ADS9110, ADS8900B...
- Internal diodes are connected to AVDD: ADS9224R, ADS8168...
- Absolute Maximum Input Range:
  - Analog input voltage is limited to -0.3V to REF+0.3V (or AVDD+0.3V)
  - Input current is generally limited to -10mA to 10mA
Input ESD Diode turns on and Impacts Voltage Reference

- When input signal is overdriven, a disturbance is found on REF signal (or AVDD) which can degrade the performance if the REF (or AVDD) is shared.
- The higher overdriven signal, the worse disturbance impact.
Input Protection on ADC with AFE

**ADS8588S Input Stage:**

- Typically 5V supply voltage and ±12V input range, so ESD diode to supply will not work.
- Clamp is implemented with back-to-back Zener diodes or SCR input.
  - ABS MAX Input voltage limit: ±15V on ADS8588S, and ±20V on ADS8681/8688
  - ABS MAX Input current Max Limit = ±10mA
Thanks for your time!
Please try the quiz.
Questions: EOS and ESD on ADC

1. For the circuit shown below, what kind of internal ESD structure is **NOT** practical?
   a. Input ESD steering diodes
   b. Back-to-back Zener diodes
   c. SCR type ESD structure
Questions: EOS and ESD on ADC

2. (T/F) The internal ESD protection structures are designed primarily to protect the device during assembly and test (i.e. out of circuit events).
   a. True
   b. False

3. Which type of ESD structure will trigger on and remain on until power is cycled?
   a. Input ESD steering diodes
   b. Back-to-back Zener diodes
   c. SCR type ESD structure
Questions: EOS and ESD on ADC

4. Which of the following does **NOT** apply to ESD?
   a. High voltage (kV)
   b. Fast edges
   c. Long duration event of milliseconds or more.
   d. Both “in-circuit” and “out-of-circuit”

5. For the circuit below, what is the maximum input voltage?
   a. 5.0V
   b. 5.3V
   c. 7V
   d. 12V
Thanks for your time!