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Bipolar Modelling for ESD Circuits Design

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a leap ahead

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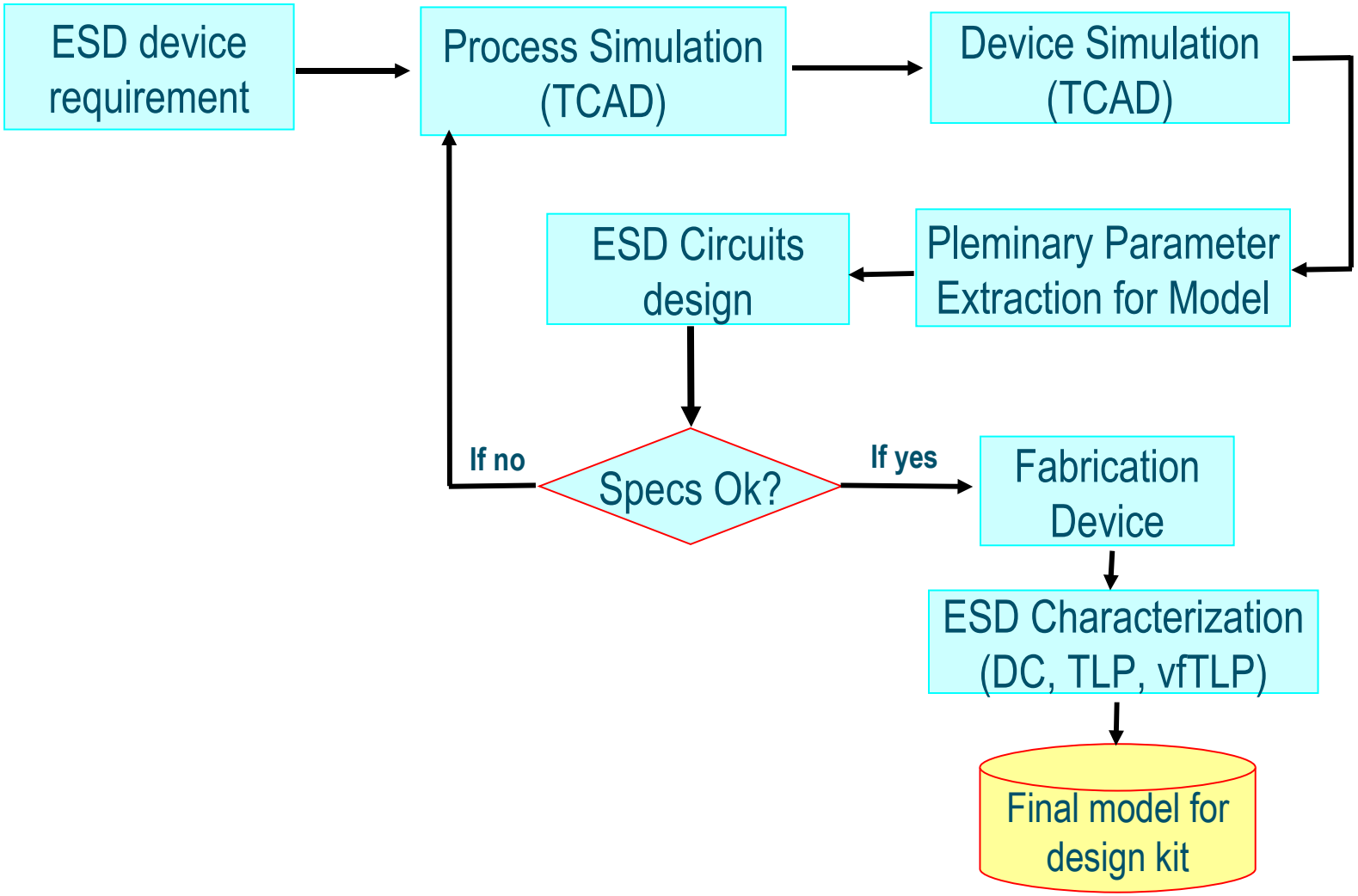
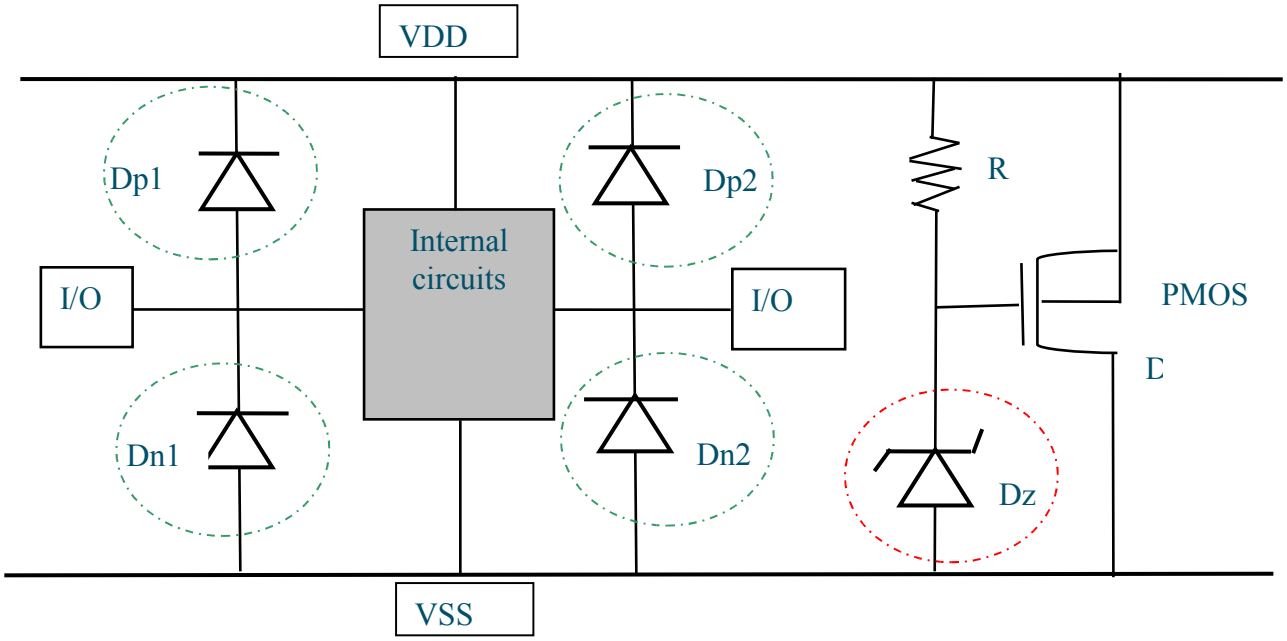
Outline

- Flow of ESD device optimization and modelling
- Diode/Bipolar used as ESD Protection Device
- Diode Overshoot Measurements
- Bipolar B-E Breakdown Model
- Snapback phenomena of NMOS MOSFETs
- Summary

Flow of ESD Device Optimization and Modelling

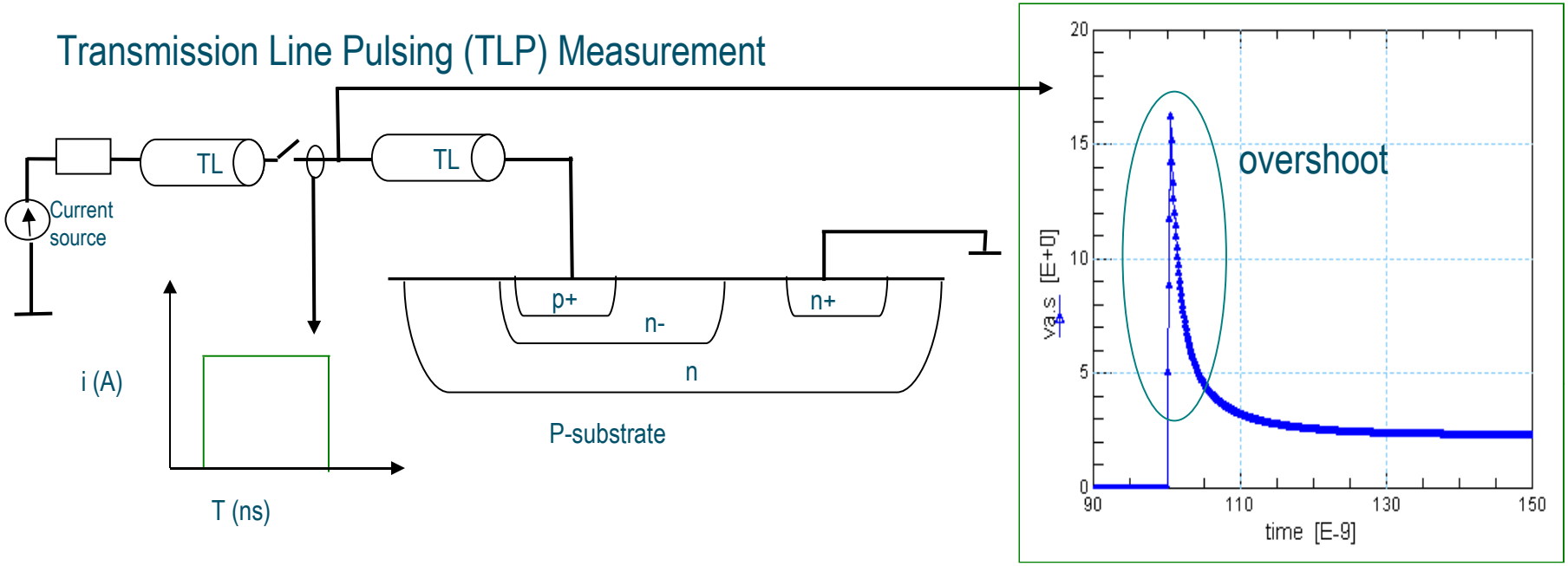


Diode or Bipolar Used in ESD Protection Circuits



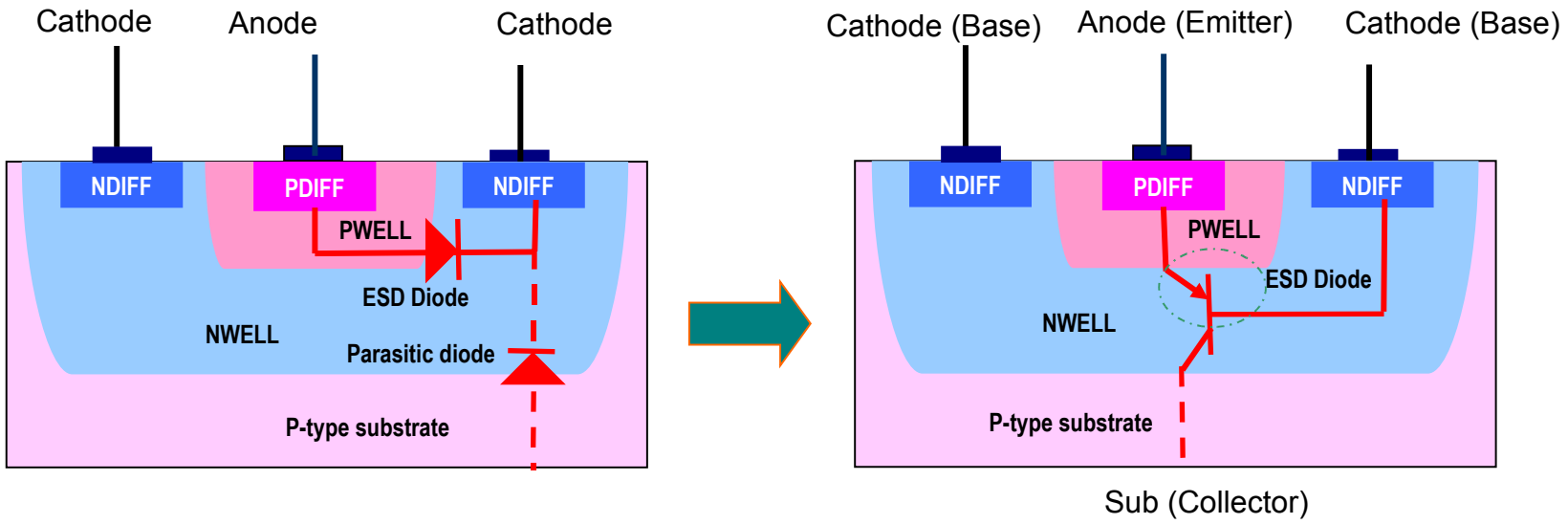
- Diode Dp1,Dn1 and Dp2, Dn2 are used as ESD protection, and used in the forward operation
- Diode Dz is used as trigger device for MOSFETs for ESD protection, and used in reverse operation

Forward Diode Measurement



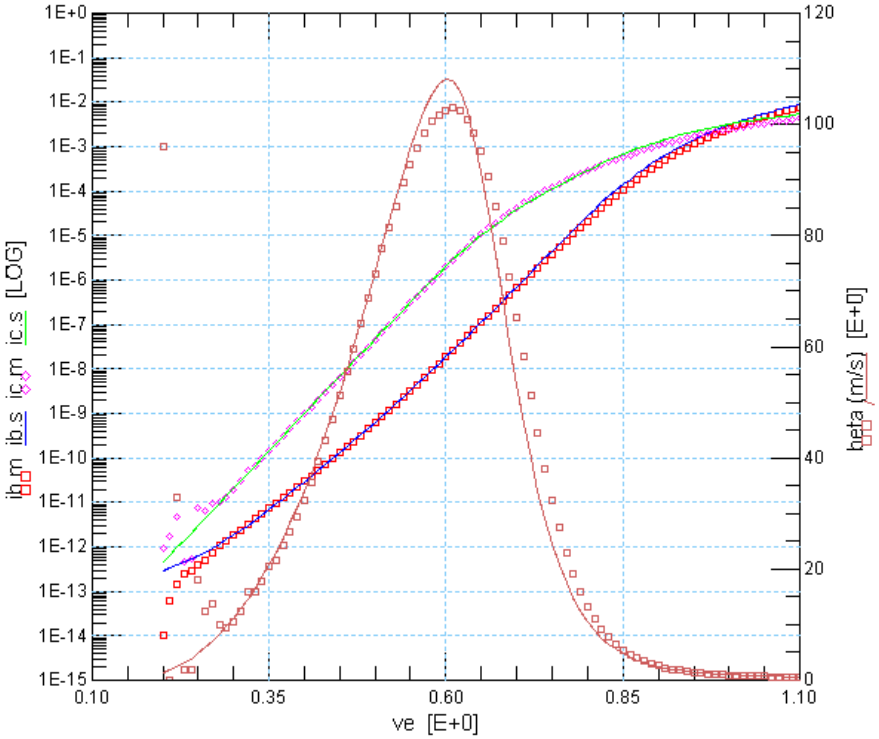
- Forward diode measurement in TLP instrument
- Measurement accuracy for Overshoot ?
- How to calibrate the systems ?
- How to get a precise fast current ramp ?

Modeling Reverse Diode, Dz



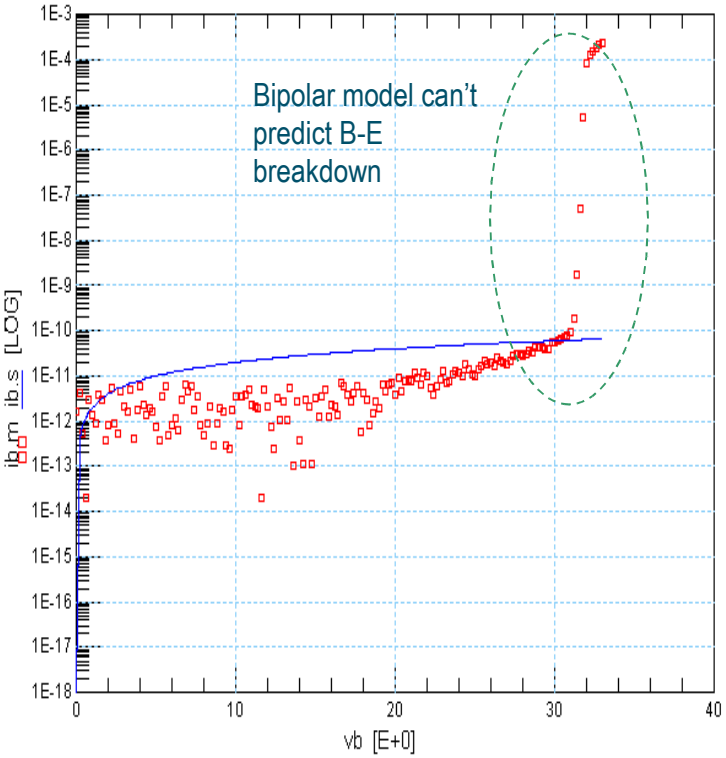
- Device cross section shows a actual diode and a parasitic diode at substrate
- Consider as a bipolar device to model both actual diode and parasitic diode

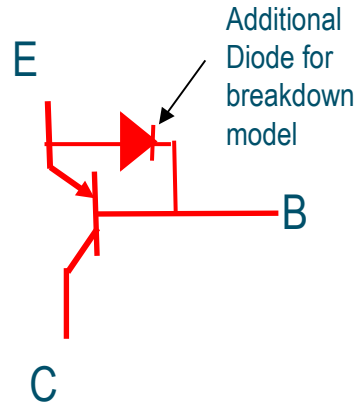
Forward Model



- Forward characteristics shows very good Bipolar action instead of diode.
- Measurement data has very good fit with a Bipolar Model

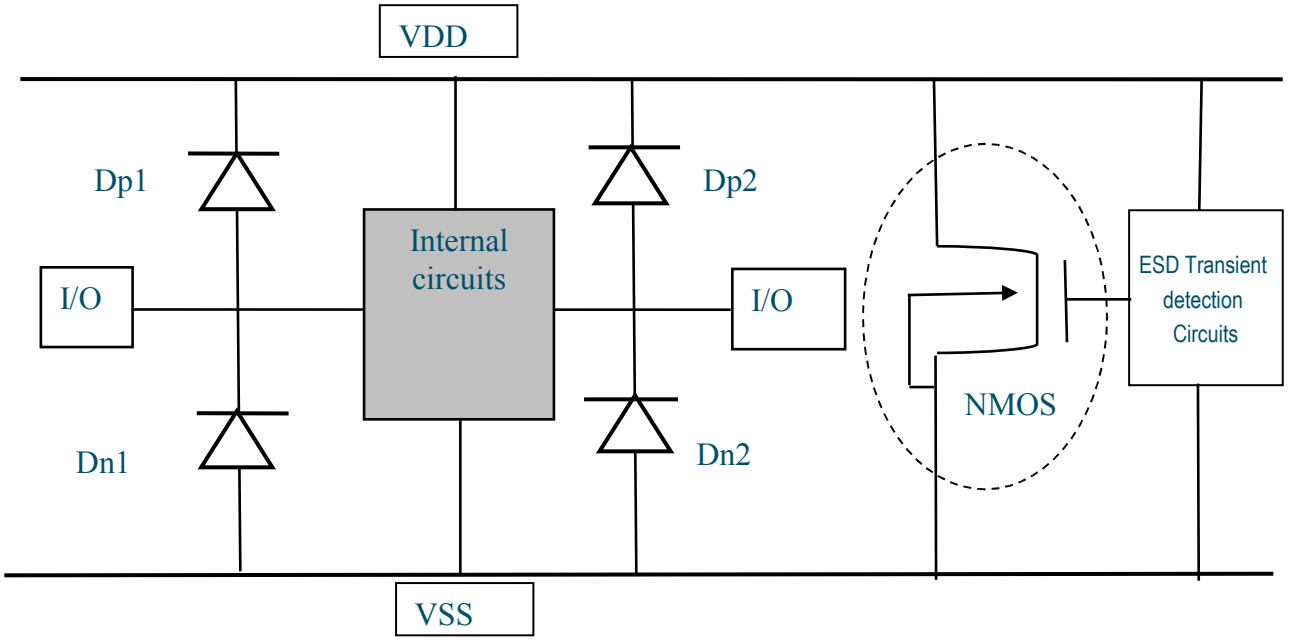
Base-Emitter Breakdown Modelling





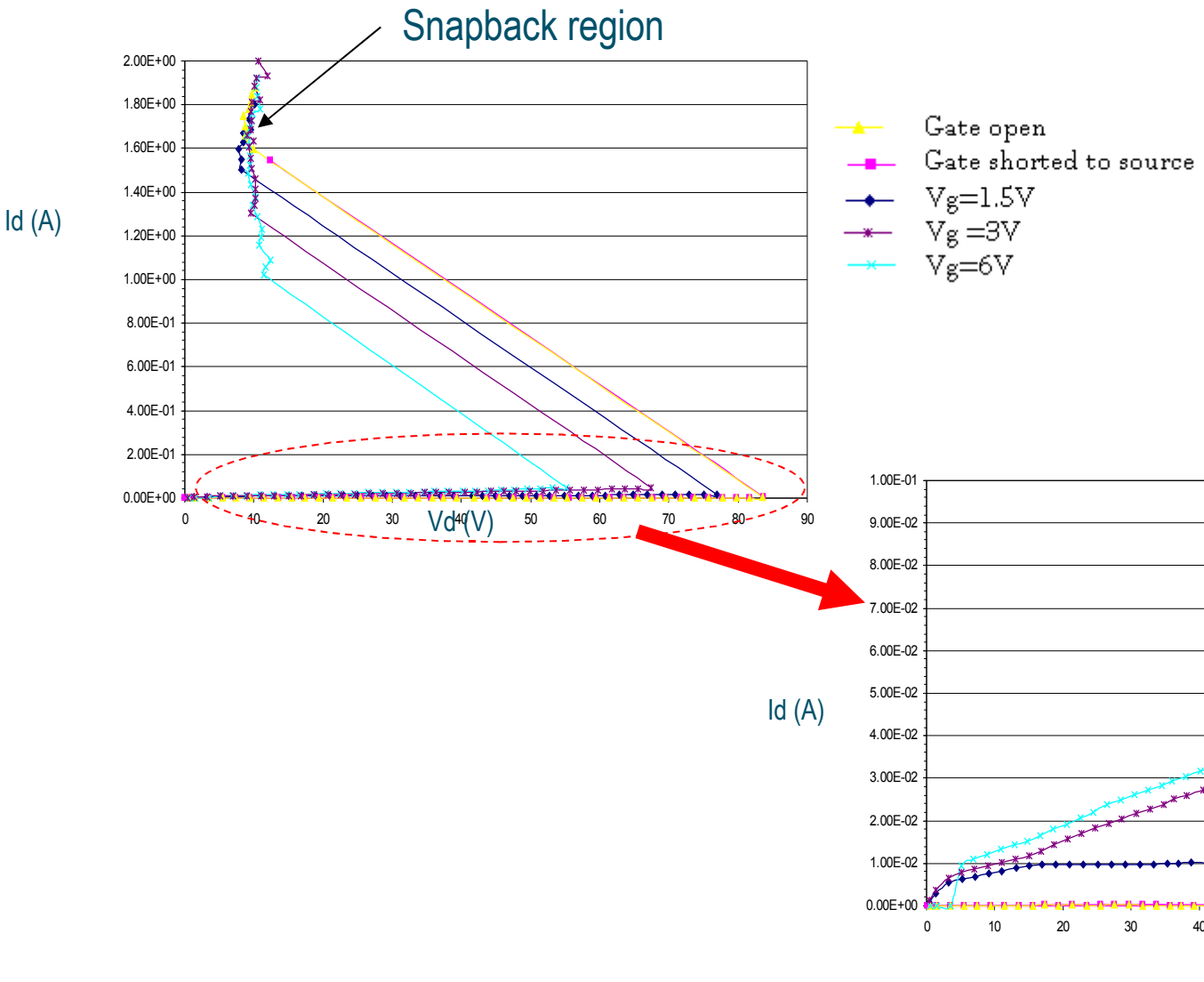
- Bipolar model is not suitable for B-E breakdown model required for ESD Model
- Required B-E avalanche effect inside the Bipolar Model
- Alternatively, an extra diode in parallel between B-E may necessary to model breakdown

MOSFET Used in ESD Protection

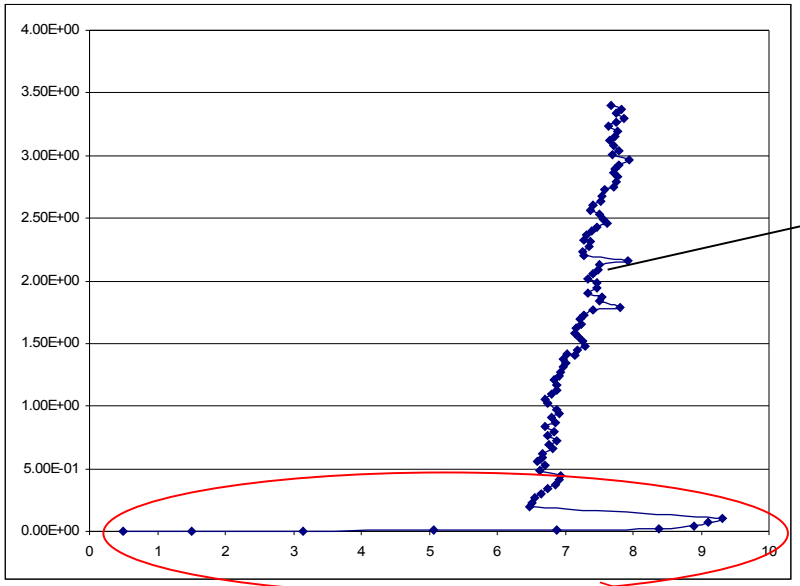


- MOSFET used as central clamp ESD protection
- Parasitic Bipolar in MOSFET play the role during ESD event

Snapback Drain Current in HVNMOS50T

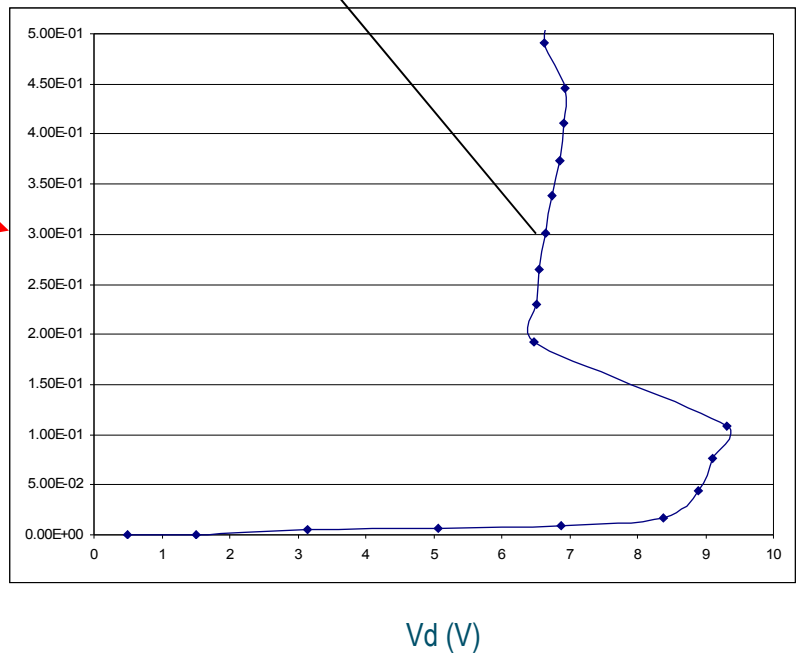


Snapback Drain Current in NMOS5

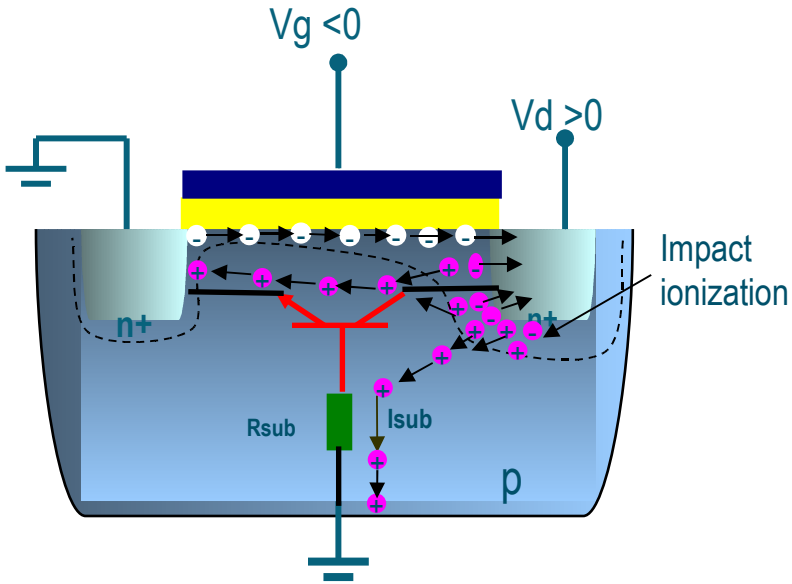


Vg=1V

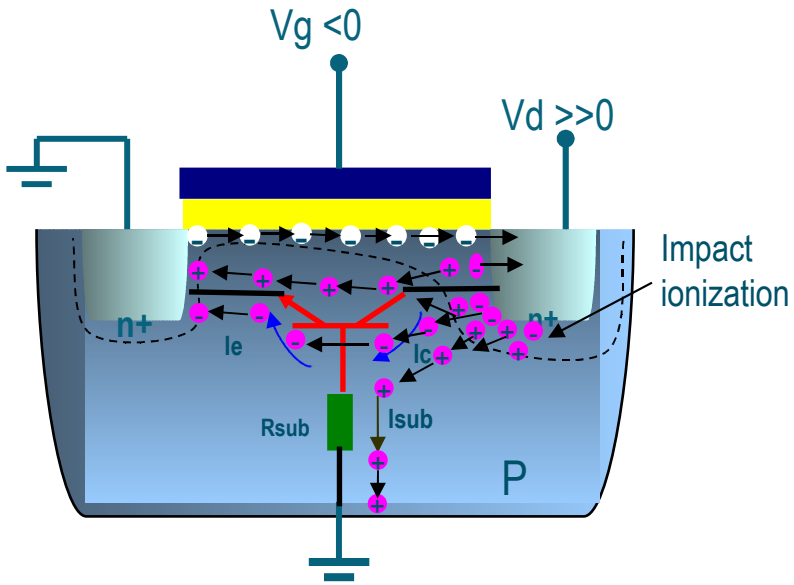
Snapback



Why Snapback ?



Parasitic NPN transistor turns off

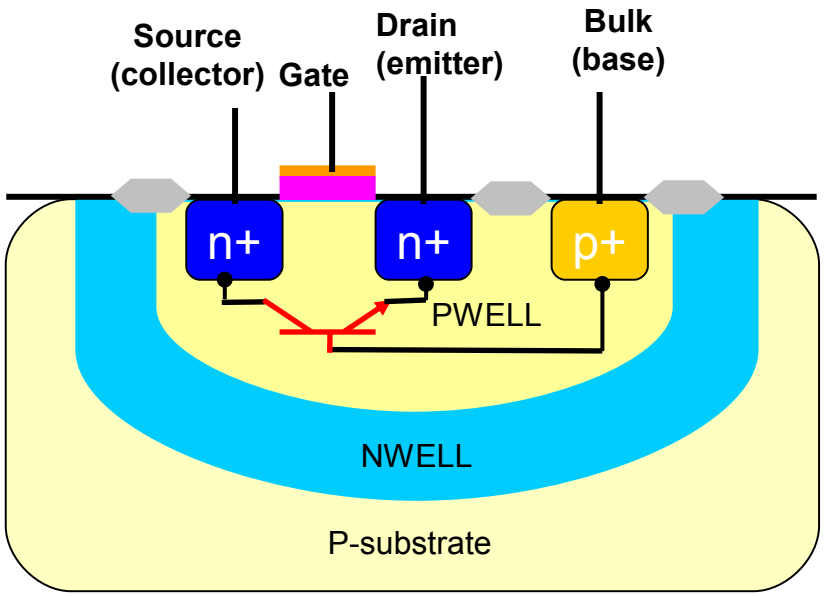


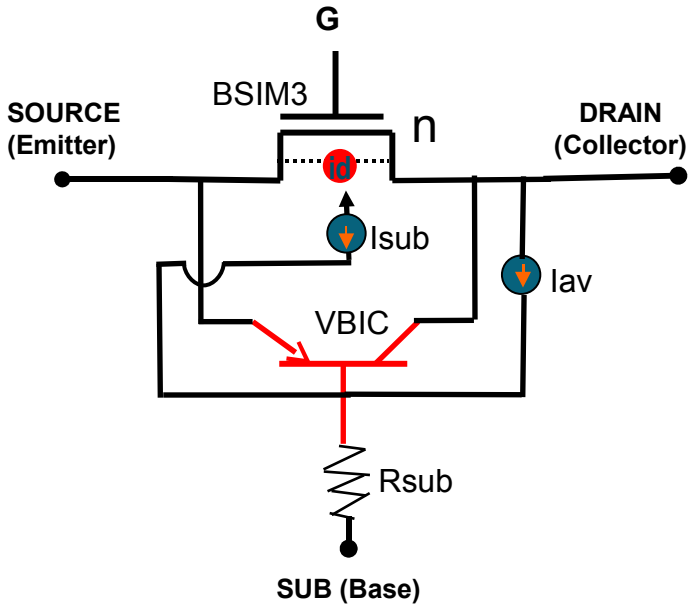
Parasitic NPN transistor turns on

- Holes created by Impact Ionization in Drain-to-Bulk depletion layer are injected into substrate

- Parasitic NPN transistor turns on when the voltage drop cross Rsub (Isub x Rsub) reaches ~0.7V
- Electrons emitted when S-B junction is forward biased

Composite Model NMOSFET and Lateral Bipolar





BSIM:

$$Isub = \left[alpha1 + \frac{alpha0}{L_{eff}} \right] * \left[Vds - V_{dseff} \right] \exp\left(- \frac{beta0}{vds - V_{dseff}} \right) * Id$$

VBIC:

$$Iav = Ic * AVC1 * \left(PC - Vbci \right) * \exp^{- AVC2 \left(PC - Vbci \right) \left(MC - 1 \right)}$$

Summary

- Details flow of ESD device to model generation
- Basic application of Diode and Bipolar used in ESD circuits
- Forward overshoot measurement problem
- Forward diode needs a B-E avalanche breakdown model
- Snapback results of MOSFETs in ESD events