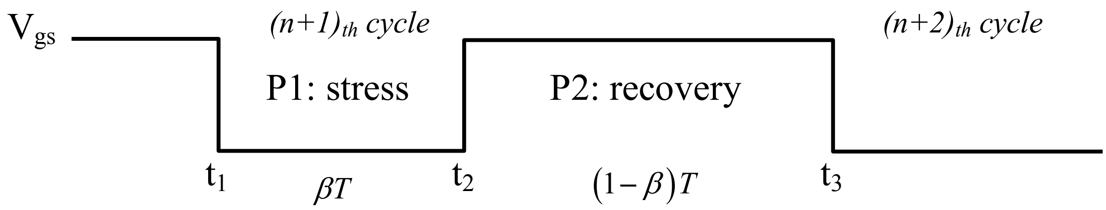
Predictive Model for NBTI (Beta Version)

Negative-Bias-Temperature-Instability (NBTI) manifests itself as an increase in the amount of the threshold voltage (V_{th}), especially for the PMOS transistor.

Stress and Recovery (Cycle-to-cycle predictions)

The following analytical models describe the dependence of NBTI on process and design parameters, during either static or dynamic operation. It is based on the reaction-diffusion mechanism, assuming H is the diffusing species.



Phase 1: Stress; t= (t1, t2):

$$\Delta V_{th} = \sqrt{K_v^{\,2} \cdot (t - t_0)^{0.5} + \Delta V_{th1}^{\,2}} + \delta_v$$

Phase 2: Recovery; t= (t2, t3):

$$\Delta V_{th} = (\Delta V_{th2} - \delta_v) \cdot \left[1 - \sqrt{\eta (t - t_0)/t}\,\right]$$

where $K_v = A \cdot T_{ox} \cdot \sqrt{C_{ox}(V_{gs} - V_{th})} \cdot \exp\left(\frac{E_{ox}}{E_0}\right) \cdot \left[1 - \frac{V_{ds}}{\alpha(V_{gs} - V_{th})}\right] \cdot \exp\left(-\frac{E_a}{kT}\right)$,

and $E_{ox} = (V_{gs} - V_{th})/T_{ox}$.

Multiple-cycle predictions

For the long term degradation, the following equations describe the V_{th} change after n cycles of stress and recovery. β is the duty cycle and T is the clock period.

$$\Delta V_{th} = K_v \cdot \beta^{0.25} \cdot T^{0.25} \cdot \left[\frac{1 - \left(1 - \sqrt{\eta(1-\beta)/n}\right)^{2n}}{1 - \left(1 - \sqrt{\eta(1-\beta)/n}\right)^{2}}\right]^{0.5} + \delta_v$$

Default values of model coefficients:

A ($mV/nm/C^{0.5}$)	1.8	α	1.3
E_0 (MV/cm)	2.0	η	0.35
E_a (eV)	0.13	**δ_v (mV)**	5.0

Technology extrapolations:

Technology Node(nm)	250	180	130	90	65	45	32
V_{DD} (V)	1.8	1.5	1.3	1.2	1.1	1.0	0.9
V_{th} (V)	0.29	0.22	0.20	0.20	0.20	0.20	0.20
T_{oxe} (nm)	4.8	3.0	2.25	2.05	1.85	1.75	1.65