A Dynamic Ferroelectric Capacitance Model for Circuit Simulators

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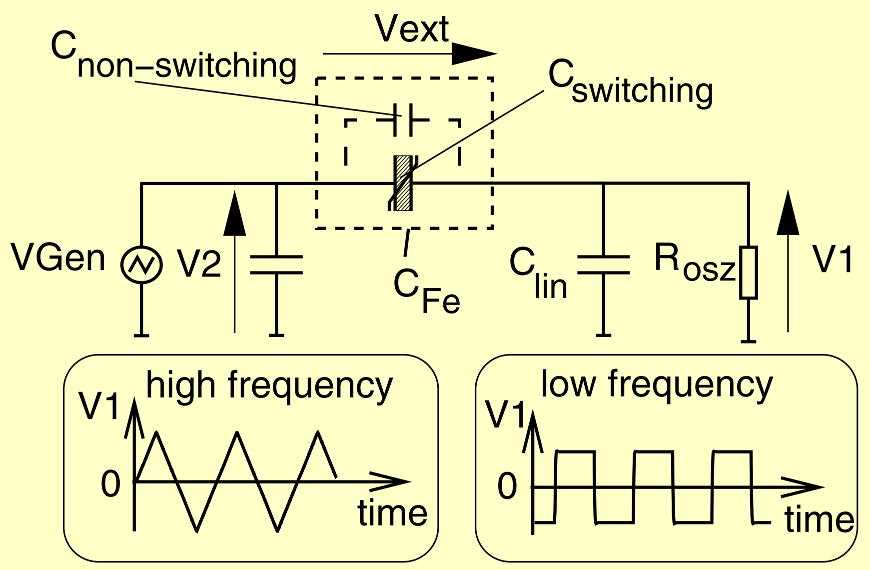
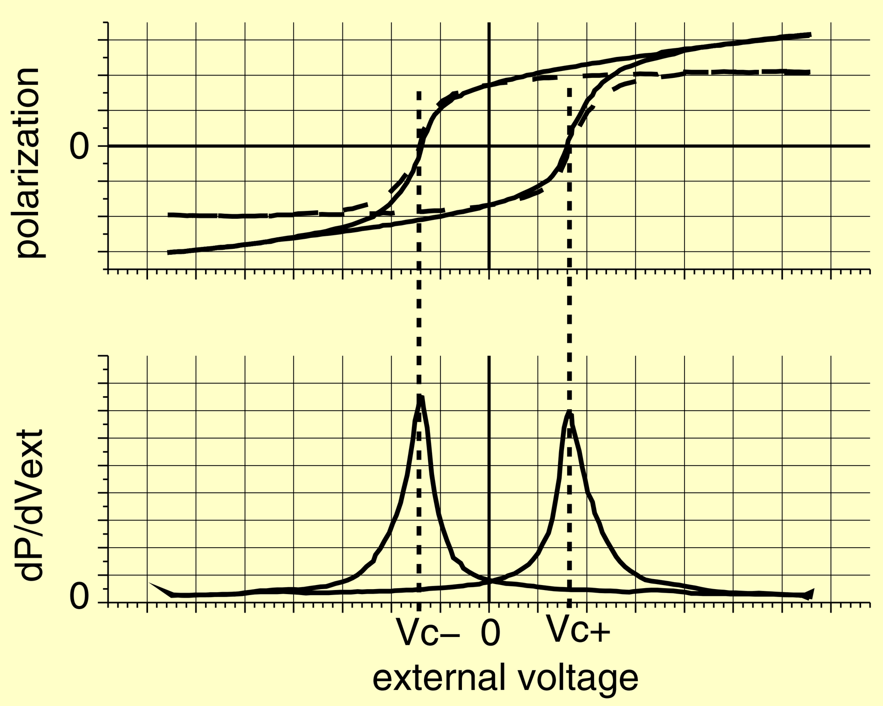
Measurement

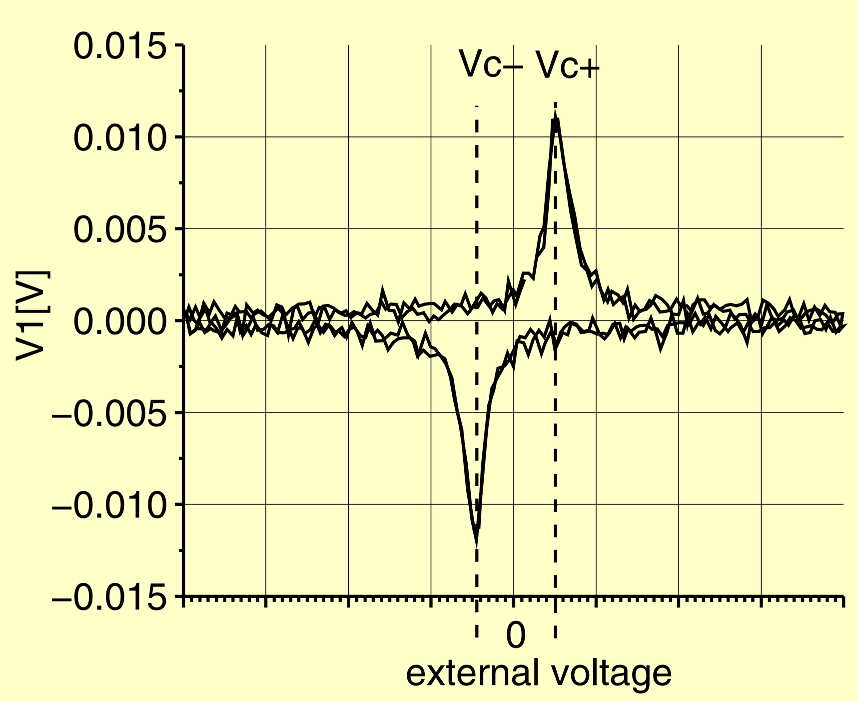
A symmetrical measurement circuit provides reliable data up to 3MHz.



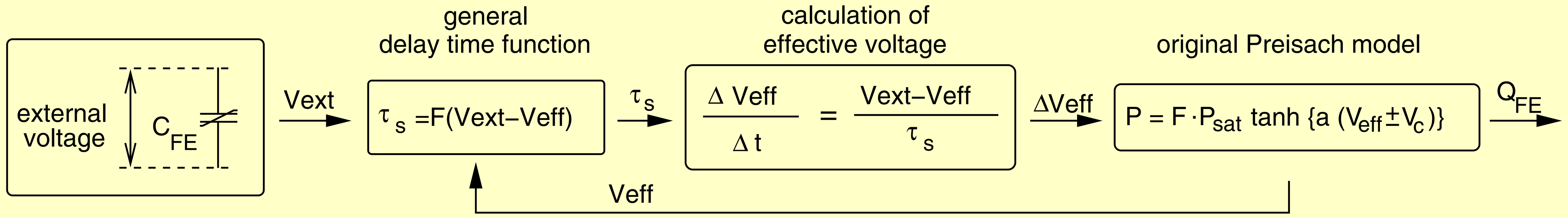
For high frequencies (1kHz–3MHz) $V_C(f)$ is determined by the maximum of the derivative of the polarization curve.



For low frequencies the maximum of V_1 indicates the current maximum and thus $V_C(f)$.



New Dynamic Model for Ferroelectric Capacitances



Extraction of Parameters

At the coercive voltage $V_C(f)$ the polarization charge equals zero:

$$V_{ext}=V_C(f) \Leftrightarrow Q(V_{eff})=0$$
$$\Leftrightarrow V_{eff}=V_{C\pm}$$

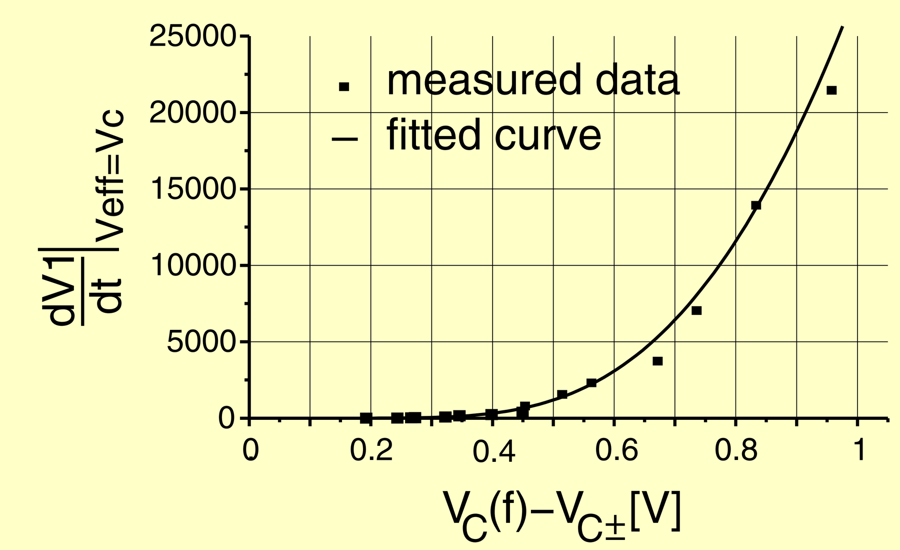
With $\Delta V=V_{ext}-V_{eff}$ the time derivative of V_{eff} reads:

$$\left.\frac{dV_{eff}}{dt}\right|_{V_{eff}=V_{C\pm}}=\frac{V_{ext}-V_{eff}}{F(V_{ext}-V_{eff})}=\frac{\Delta V}{F(\Delta V)}$$

The time derivative of the voltage V_1 across the linear capacitor is:

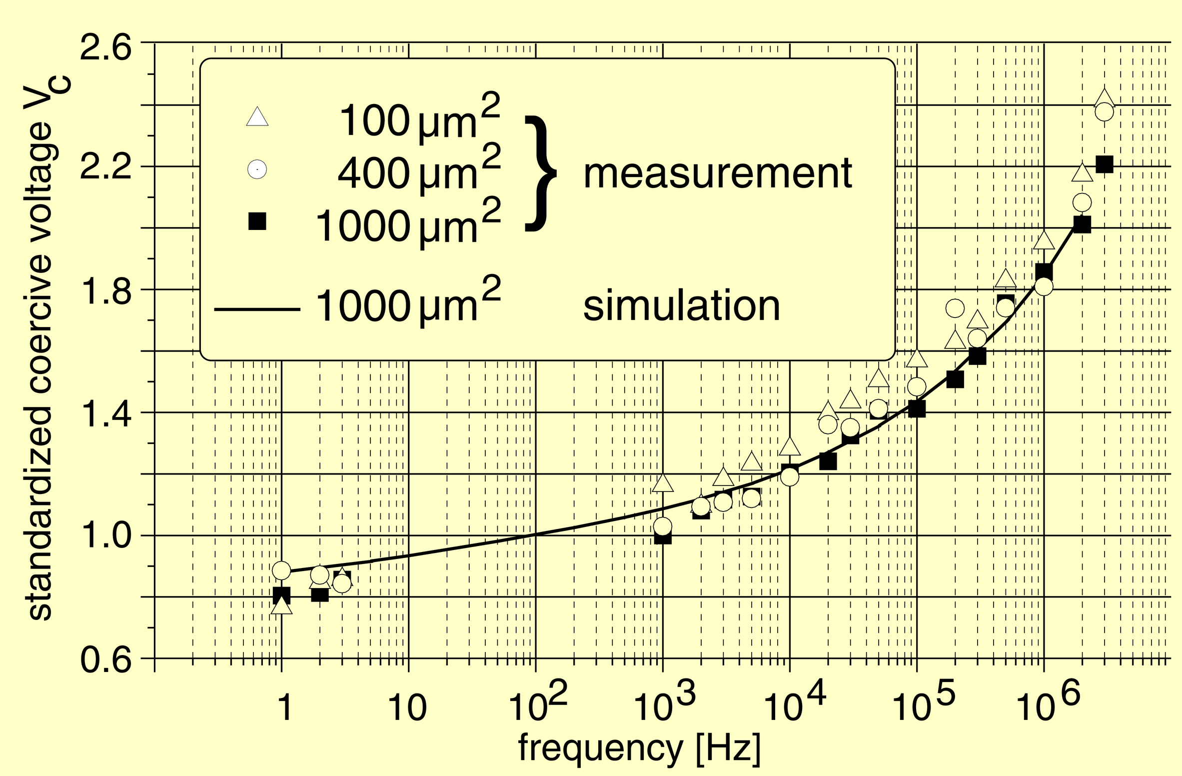
$$\frac{dV_1}{dt}=\frac{Q_0}{C_{lin}}\cdot\frac{a}{\cosh^2\{a(V_{eff}-V_{C\pm})\}}\cdot\frac{dV_{eff}}{dt} \Rightarrow \left.\frac{dV}{dt}\right|_{V_{eff}=V_{C\pm}}=\frac{Q_0\,a}{C_{lin}}\cdot\frac{\Delta V}{F(\Delta V)}$$

The function $\tau_s = F(V_{ext} - V_{eff})$ is determined by the measured voltage gradient dV_1/dt vs. $\Delta V=V_{ext}-V_{eff}$.

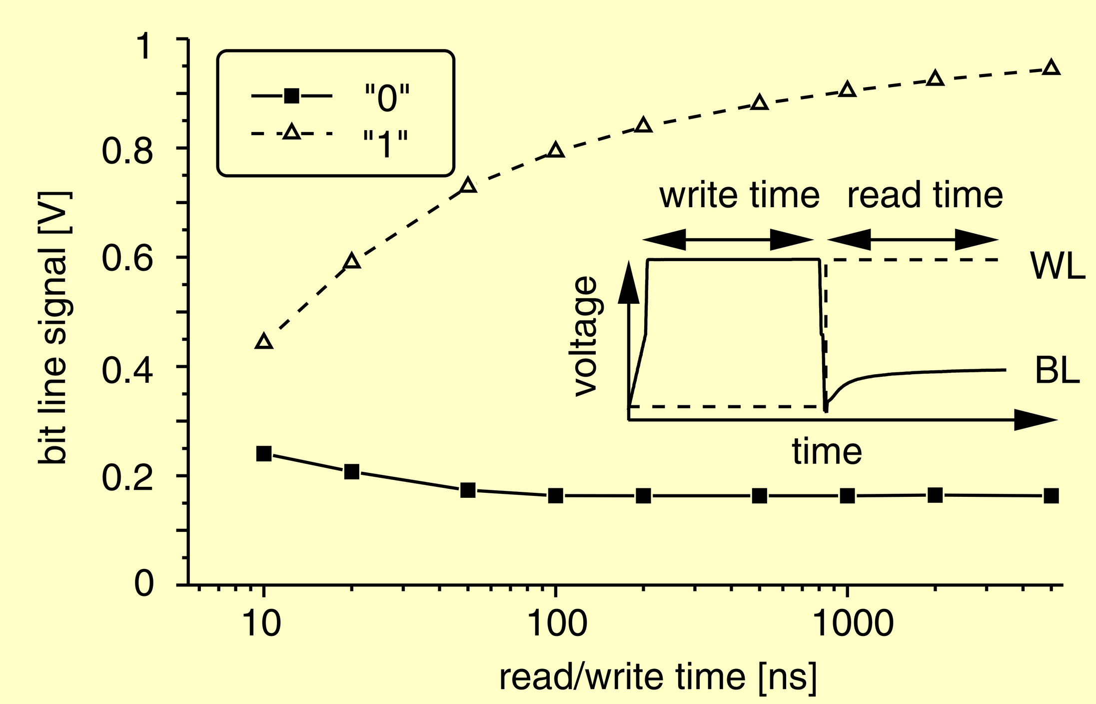


$\tau_s=\tau_\infty \exp\{\alpha/\Delta V\}$ fits the measured data best.

Measurement and simulation

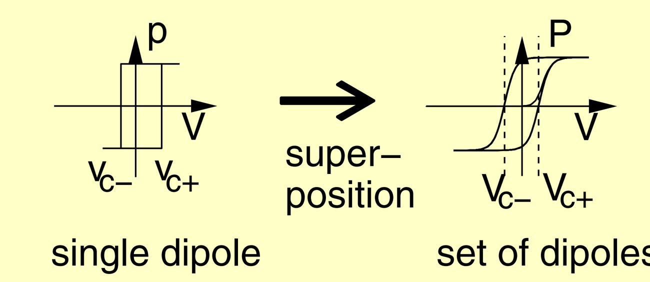


FeRAM Simulation

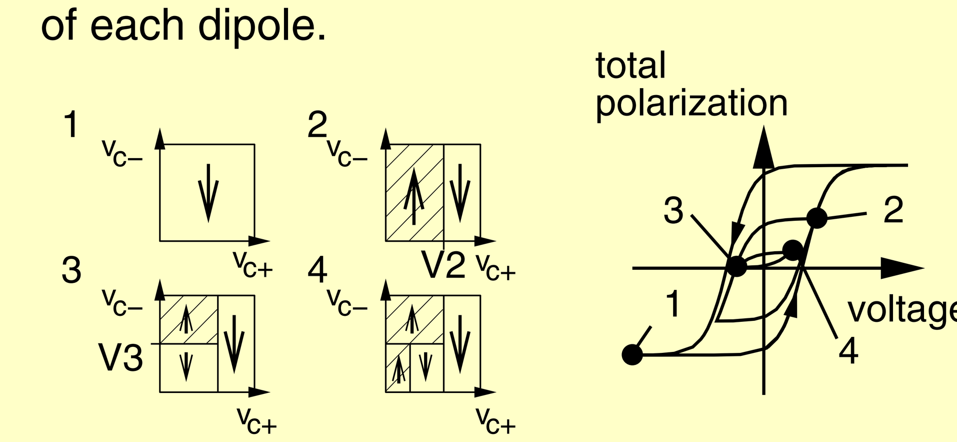


Original Preisach Modell

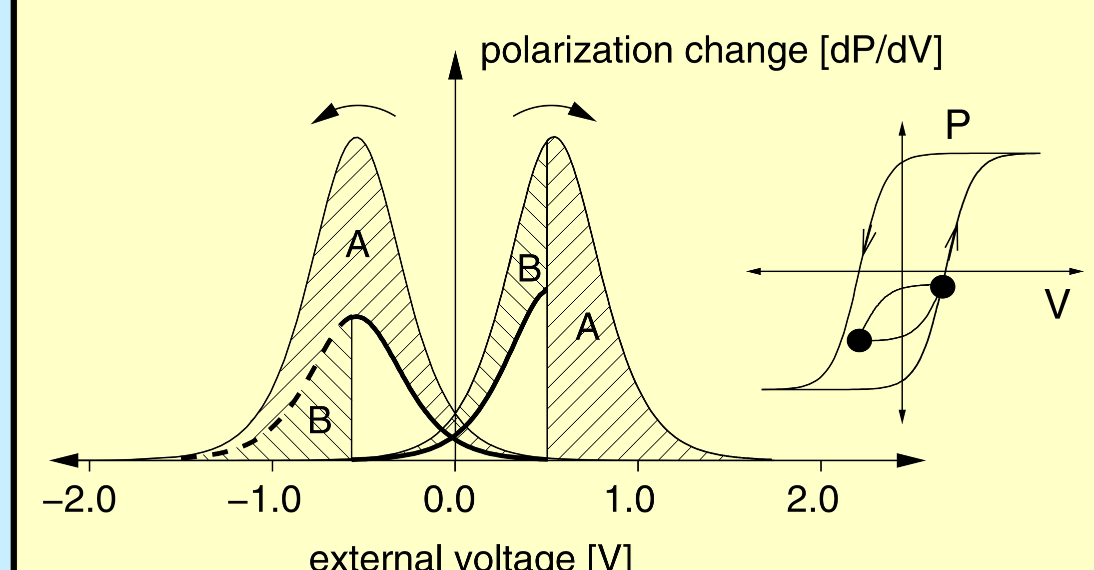
The macroscopic hysteresis loop is seen as the superposition of the hystersis curves of the single dipoles.



The dipoles are classified by (v_{C+}, v_{C-}). The history of external voltage determines the state of each dipole.



The proportion F of dipoles that take part in the switching process of the non–saturated loop is calculated by storing the turning points of the external voltage.



Conclusion

The observed increase of the coercive voltage can be explained by our dynamic model.

It is a development of the Preisach model including a switching time delay.

Dynamic modeling is imperative for accurate prediction of FeRAM–performance.