Temperature dependences

Threshold voltage, \( TC_F(V_t) \approx -3000 \text{ ppm/}^\circ\text{C} \)

Resistors
  Positive and negative TC resistors are available
  Example 0.35u CMOS process: -400ppm/\(^\circ\text{C}\) and +830ppm/\(^\circ\text{C}\)

Mobility, and MOSFET conductance parameter \( TC_F(\mu C_{ox}) \approx -5000 \text{ ppm/}^\circ\text{C}\)

Forward biased pn-junction \((V_{EB}, V_{BE} \text{ or } V_D), \approx -2\text{mV/}^\circ\text{C}\)

Thermal voltage \( V_T = kT/q = 26\text{mV at 300}^\circ\text{K},\)
  \(+3300\text{ppm/}^\circ\text{C at room temperature}\)
Temperature coefficient: simple examples
Introduction to bandgap references

Idea: a combination of forward-biased pn junction voltage and a voltage proportional to the thermal voltage $V_T = kT/q$ can result in ideally zero temperature coefficient at one temperature.
pn-junction in an n-well process
How to obtain voltage proportional to $V_T$?
A bandgap reference circuit example
A bandgap reference circuit example
Bandgap reference: temperature dependence*

Bandgap reference: temperature dependence