RUPRECHT-KARLS-
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References

(only some very basic things)

P. Fischer, Heidelberg University

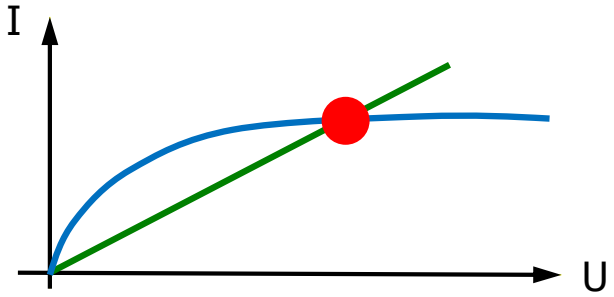
Goal

- To bias chips, we need a reference voltage or current
- This should be 'constant', i.e. mostly independent of
  - **P**rocess variations (Thresholds, resistor values,..)
  - Power Supply **V**oltage
  - **T**emperature
- 'PVT independent'

- To asses quality, study
  - Power supply rejection (rel. change of V_{REF} / rel. change of VDD)
  - Temperature Rejection (rel. change of V_{REF} per degree K)

Implementation

- Common principle:
  - Look for two different I(U) dependencies and find the intersection



- There are normally several (2) intersections!
  → Need **startup circuit** to avoid wrong operation point

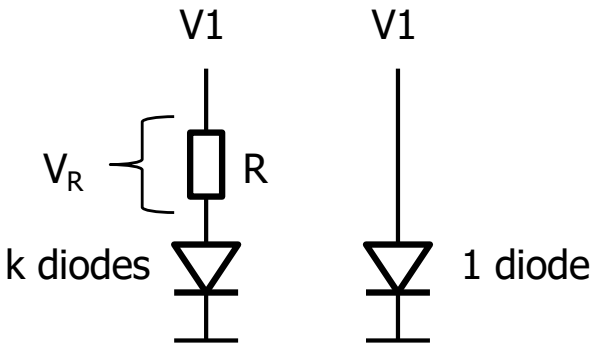
Getting rid of Temperature Dependence

- Most component properties depend on temperature

- To obtain temperature independence, add two quantities with opposite temperature dependency
  - PTAT = Proportional To Absolute Temp.
  - NTAT = Negative To ..

Simple Example

- Diode current $I_D \sim I_S \, Exp(V_D/U_{th})$ $\rightarrow V_D = U_{th} \ln(I_D/I_S)$
  - $U_{TH} = kT/q \sim 25mV$ @ RT
  - I_S depends on diode geometry etc. I_S also depends on temperature!
- Consider circuit shown right. Assume V1 is identical left/right



- $V_R + U_{th} \ln(I_D/\mathbf{k}\, I_S) = V1 = U_{th} \ln(I_D/I_S)$
- $\rightarrow V_R = U_{th} \ln(I_D/I_S) - U_{th} \ln(I_D/k\, I_S)$
  $= U_{th} [\ln(I_D/I_S) + \ln(k\, I_S/I_D)]$

- $V_R = U_{th} \ln(k)$ independent of diode parameters!

- BUT: U_{th} depends on temperature…

Implementation

- Vref = R2/R1 U_{th} ln(k) + U_{th} ln(ID/IS)
  PTAT NTAT