Reference Circuits

• External bias current not always available
  • May need to generate reference internally

• Tons of “constant X” reference circuits in the literature
  • Important considerations include power, accuracy, PSRR, output impedance, etc.

• Most important question: what do you really want to be constant?
Constant Current Bias?

Constant Gain Example
Supply “Independent” Biasing

Improved $V_{GS}$ Reference
CMOS PTAT Reference

- p⁺ substrate
- p⁺ diffusion
- n⁻ well
- n⁺ diffusion

Diagram:
- Transistors (M1, M2, M3, M4)
- Resistors (R)
- Voltage sources (V1, V2)

- Gate (G)
- Source (S)
- Drain (D)

- Connections (C, E, B)
**Startup Circuit**

- $V_{BE}$ has a tempco of roughly $-2 \text{ mV/}^\circ\text{C}$
- Add $V_{BE}$ to PTAT voltage (with right M) $\rightarrow V_{bg}$ independent of $T$
- Reference derived from band-gap of Si ($1.205\text{V}$)

**Conceptual Band-Gap**

\[
V_{bg} = V_{G0} + V_T(\gamma - \alpha) \left(1 + \ln\left(\frac{T_0}{T}\right)\right)
\]
Constant $g_m$ Reference