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
PTAT Reference

CMOS PTAT Reference
**Startup Circuit**

![Startup Circuit Diagram](image)

**Conceptual Band-Gap**

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

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