EE 240B – Spring 2018

Advanced Analog Integrated Circuits

Lecture 10: Settling-Limited Amplifier Design Methodology

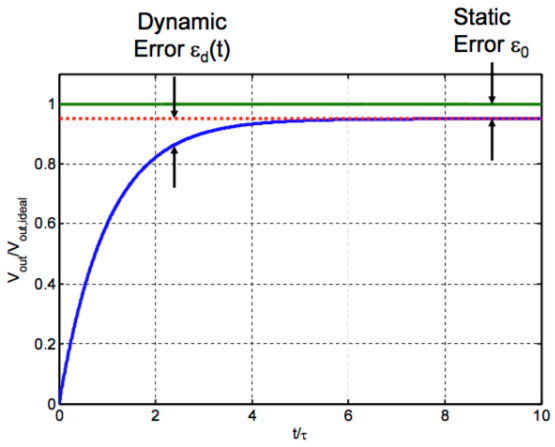
Elad Alon

Dept. of EECS

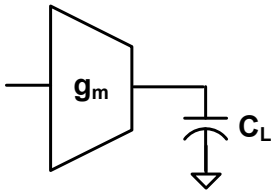
Why "Settling"?

- **Really (time-domain) waveform fidelity that is of interest**
  - Often important not just in oscilloscopes
- **Step-response used as a means to characterize this**
  - Sometimes actually dealing with "inputs" that actually look like steps (e.g., switched-capacitor circuits – more later)

Step Response: Error Breakdown



Simple Settling Limited Amplifier Design Methodology



- **Input specifications:**
  - Supply voltage V_{dd}
  - Minimum small signal gain A_v
  - Maximum relative dynamic settling error ε_{dyn}
- **Goal: minimize power**

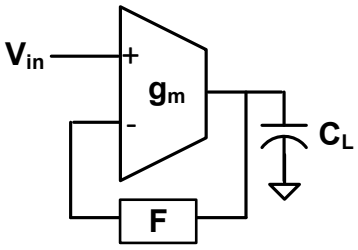
Dynamic Settling Error: Single Pole System

Dynamic Settling Error

ε_d	T_{settle}/τ
1%	4.6
0.1%	6.9
0.01%	9.2
10^{-6}	13.8

Methodology Implication

Settling Limited Amplifier Design Methodology (w/Feedback)



- **Input specifications:**
  - Supply voltage V_{dd}
  - Known "feedback factor" F
  - Maximum relative static settling error ε_{stat}
  - Maximum relative dynamic settling error ε_{dyn}
- **Goal: minimize power**

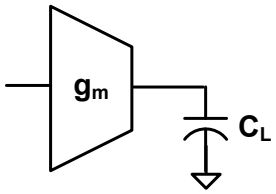
Step Response

Static Error

Side Note

Dynamic Error

Simple Settling Limited Amplifier Design Methodology



- **Input specifications:**
  - Supply voltage V_{dd}
  - Minimum small signal gain A_v
  - Total settling error $\varepsilon_{dyn} + \varepsilon_{stat}$
- **Goal: minimize power**

- **How to allocate between static and dynamic errors?**

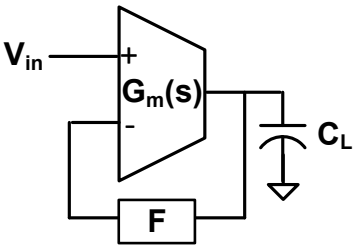
Patching Some Things Up

- **Basic methodology doesn't really change**
  - Just that dynamic settling in particular will be affected by things like zeros and additional poles in the OTA
- **Look at these effects next**
  - Good news: (linear) dynamic settling still basically set by OTA g_m – just get some extra scale factors
  - (Slewing is a little different – will look at that too)

Feedforward Zero

Feedforward Example

Second-Order OTA (Cascode)



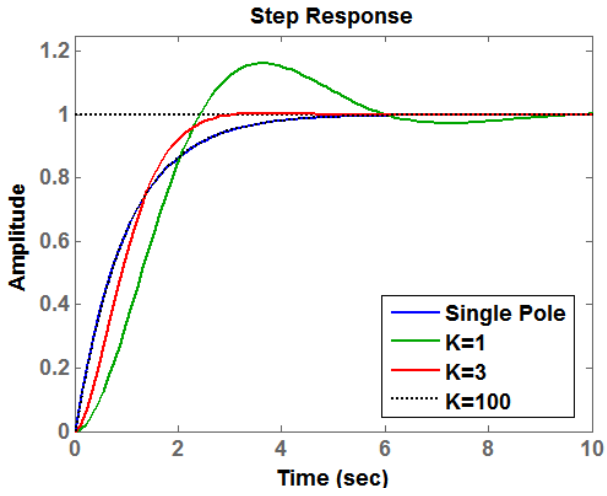
- **Model with:**

$$G_m(s) = \frac{g_m}{1 + s/\omega_{p2}}$$

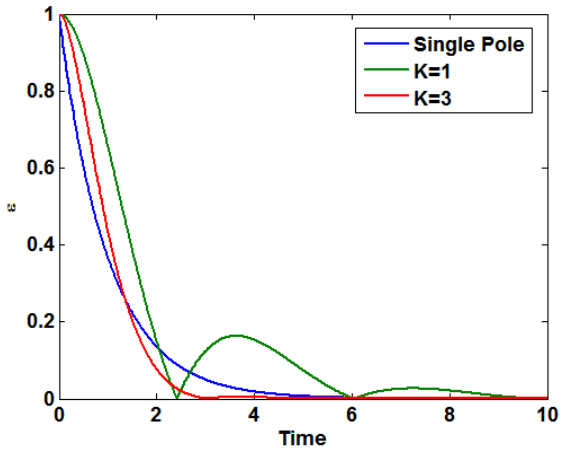
$$\omega_{p2} = K\omega_u$$

ω_u is unity gain bandwidth of $T(s)$

Step Response

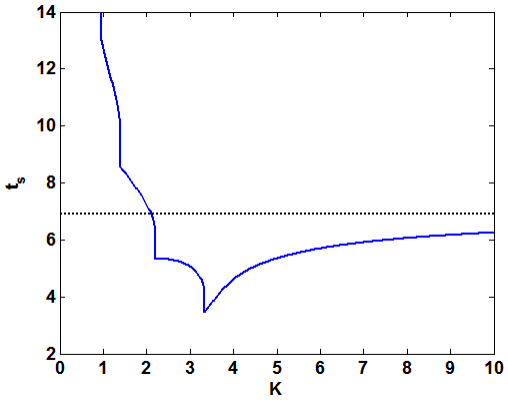


Dynamic Error



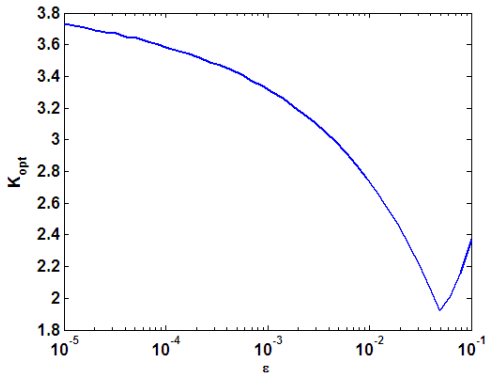
Settling Time

$$\varepsilon_{dyn} = 10^{-3}$$



- **Optimum at K=3.3**

Optimal K



- Optimum K depends on required accuracy
- But always want to avoid K<~2

Side Note: Pole-Zero Doublets

Feedback and Slewing

- **Use of feedback allows you to decouple V* from overall "amplifier" linearity**
  - Often intentionally want low V* for the g_m (for current efficiency)
- **When first apply an input step, actual input to OTA may exceed V***
  - This is the source of slewing

Slewing Model

Settling Time with Slewing

Putting It All Together

Methodology