Offset Cancellation Overview

- Two main ideas/approaches
  - Modulate and/or filter offset so that it is outside of signal band
    - CDS (auto-zeroing)
    - Chopping (synch. detection, DEM)
  - Inject a DC signal that opposes the offset
    - Trimming
    - Often digitally controlled (especially for comparators)

Filtering/Modulating Offset

- General idea:
  - Put elements around the amplifier that treat offset differently than signal
- CDS:
  - Configure amplifier so that offset is (approx.) differentiated
- Chopping:
  - Modulate offset to frequencies beyond signal band, then filter it out

CDS #1: Output Offset Cancellation

- Relatively insensitive to switch errors
- Storing amplified offset
- But, what happens if gain is large?

\[ V'_c = -AV'_m \]
\[ \begin{align*}
  V'_m &= AD(V'_c - V'_o) - V'_c \\
  &= ADV'_c
\end{align*} \]

CDS #2: Input Offset Cancellation

Multistage Cancellation

- Open switches left to right
- Errors from \( S_1 \) ... \( S_{n-1} \) cancelled by final stage
- Application: continuous time comparators
**Auxiliary Amplifier Offset Cancellation**

**CDS and Flicker Noise**

**Aux. Amplifier Example**

**Flicker Noise Analysis**

**Aux. Amplifier Implementation**

**Flicker Noise Frequency Response**

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\( V_{in} = V_{in} - V_{out} \)

Laplace Transform

\[ V_{in}(s) = \frac{F(s) + V_{in}(s) - V_{out}(s) \cdot s - \frac{1}{2}}{s} \]

Delay by \( t_d \) \( \rightarrow e^{-\frac{s}{t_d}} \)

\[ V_{out}(s) = V_{in}(s) \left( 1 - e^{-\frac{s}{t_d}} \right) \]

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\( H(s) = 1 - e^{-\frac{s}{2}} \)

\( H(s) = 1 - e^{-\frac{s}{2}} \)

\( H(s) = 1 - \cos \frac{\pi s}{2} + j \sin \frac{\pi s}{2} \)

\( H(s) = 1 - 2 \cos \frac{\pi s}{2} + \cos^2 \frac{\pi s}{2} + \sin^2 \frac{\pi s}{2} \)

\( H(s) = 2 \left( 1 - \cos \frac{\pi s}{2} \right) \)

\( H(s) = 2 \sin^2 \frac{\pi s}{2} \)

\( H(s) = 2 \sin \frac{\pi s}{2} \cdot \frac{\pi s}{T} \)
Flicker Noise Spectrum

- Flicker noise is differentiated
- As is thermal noise
- Noise removed at low freq.
- But amplified at “high” freq.
- Noise above f_s/2 folds to baseband

Offset Trimming

Chopping

- Inner chopper at high freq. to remove 1/f noise
- Outer chopper at low frequency to minimize “spiking” and remove residual offset from inner chopper.

Digital Trimming

Nested Chopper Amplifier

Comparator Trimming
Trim Implementation Issues

- Infinite number of ways to introduce digitally controlled offset
  - People have tried just about all of them

- Key issues:
  - Power overhead
  - Circuit Imbalance
  - Effective resolution
  - Area overhead

Comparator Trim Schemes

Pre-Amp Trim