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

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CDS #1: Output Offset Cancellation

- Relatively insensitive to switch errors
  - Storing amplified offset

- But, what happens if gain is large?

Phase 1:
\[ V_C = -AV_{os} \]

Phase 2:
\[ V_{out} = A(V_{in} - V_{os}) - V_C = AV_{in} \]
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


Aux. Amplifier Example
Aux. Amplifier Implementation

CDS and Flicker Noise
Flicker Noise Analysis

\[ V_e(kT) = A \left( V_s(kT) + V_{1/f}(kT) - V_{1/f}(kT - T/2) \right) \]

Laplace Transform

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

\[ V_{eq}(s) = V_{1/f}(s) \left( 1 - e^{-sT/2} \right) \]

Flicker Noise Frequency Response

\[ H_n(s) = 1 - e^{-sT/2} \]

\[ |H_n(s)|_{s \rightarrow \omega} = \left| 1 - \cos \frac{\omega T}{2} + j \sin \frac{\omega T}{2} \right| 
= 1 - 2 \cos \left( \frac{\omega T}{2} \right) + \cos \left( \frac{\omega T}{2} \right) + \sin \left( \frac{\omega T}{2} \right)^2
= 2 \left( 1 - \cos \frac{\omega T}{2} \right)
= 4 \sin^2 \frac{\omega T}{4} \]

\[ |H_n(s)|_{s \rightarrow \omega} = \left| 2 \sin \frac{\omega T}{4} \right| = \left| 2 \sin \frac{\pi f}{2 f_s} \right| \]
**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

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**Chopping**
Nested Chopper Amplifier

- 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.

Offset Trimming
Digital Trimming

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