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?

\[ V_C = -AV_{os} \]

Phase 1:

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

\[ T = \frac{1}{f_n} \]
Flicker Noise Analysis

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

Laplace Transform

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

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

Flicker Noise Frequency Response

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

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

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

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