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?

\[
V_C = -AV_{os}
\]

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 $S_1 \ldots S_{N-1}$ cancelled by final stage
- Application: continuous time comparators
Auxiliary Amplifier Offset Cancellation

Aux. Amplifier Implementation

CDS and Flicker Noise

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

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

Laplace Transform

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

Flicker Noise Frequency Response

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

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

\[ = 1 - 2 \cos \frac{\omega T}{2} + \cos \frac{\omega T}{2} + \sin \frac{\omega T}{2} \]

\[ = 2 \left( 1 - \cos \frac{\omega T}{2} \right) \]

\[ = 4 \sin^2 \frac{\omega T}{4} \]

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