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
  • Feedback-based
  • 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?

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 $S_1 \ldots S_{N-1}$ cancelled by final stage
- Application: continuous time comparators
CDS and Flicker Noise

Flicker Noise Analysis

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

Laplace Transform

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

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

\[ \text{Ref. input error} \]
Flicker Noise Frequency Response

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

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

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

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

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

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.
Auxiliary Amplifier Offset Cancellation

Aux. Amplifier Implementation
Aside: Switched Cap. Resistor

Aside: Switched Cap Low-Pass Filter
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
Pre-Amp Trim