Offset propagation through Gilbert-based integrated mixer e.g. AD534

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1. Mixer offset model

Analog mixer/multiplier $X \cdot Y$ offset model: $m=(X+o_x)(Y+o_y)+o_z$

X and Y inputs of mixer fed with harmonic signal $A\sin\omega t$:

$$(X\sin\omega t+o_x)(Y\sin\omega t+o_y)+o_z=XY\sin^2\omega t+(X o_y+Y o_x)\sin\omega t+o_x o_y+o_z$$

$$...=-\frac{XY}{2}\cos^2 2\omega t+(X o_y+Y o_x)\sin\omega t+(o_x o_y+o_z+\frac{XY}{2})$$

After low-pass filter, any harmonic signal is removed:

$$m=o_x o_y+o_z+\frac{XY}{2}=\frac{XY}{2}+o_t$$

2. Mixer offset cancellation by reference polarity chopping

While reference signal comes from local generator with high amplitude thus parasitic charge injection from analog switch will be much lower than chopping of measured signal.

Mixer is fed with the reference $V_R=R\sin\omega t$ signal for N consecutive periods:

$$m_p=(X+o_x)(V_R+o_y)+o_z \quad \text{and} \quad m_n=(X+o_x)(-V_R+o_y)+o_z$$

and average (DC) product of the mixer with total offset o_t :

$$m_{pAV}=X\frac{V_R}{2}+o_t \quad \text{and} \quad m_{nAV}=-X\frac{V_R}{2}+o_t$$

Substraction $m_{pAV}-m_{nAV}$ we obtain signal with offset removed:

$$m_{AV}=X\,V_R$$

Note that this technique assumes ideal linear mixer model, while real analog mixer exhibits nonlineraity typically 0,2-3 %. As described below this nonlinearity causes non-zero propagation of the o_x, o_y offsets with highly reduced amplitude.

3. Simultaneous hall cell and mixer offset cancellation by chopping

Mixer is fed with the reference $V_R=R\sin\omega t$ signal for N consecutive periods:

$$m_p=((V_h+o_h)+o_x)(V_R+o_y)+o_z \quad \text{and} \quad m_n=((V_h-o_h)+o_x)(-V_R+o_y)+o_z$$

o_h is offset of hall cell demodulated by mixer:

$$m_{pAV}=\frac{V_R}{2}(V_h+o_h)+o_t \quad \text{and} \quad m_{nAV}=-\frac{V_R}{2}(V_h-o_h)+o_t$$

Substraction $m_{pAV}-m_{nAV}$ we obtain hall voltage scaled V_h with reference signal V_R :

$$m_{AV}=V_R V_h$$

This shows simultaneous hall cell offset cancelation and mixer offset cancellation possible.

While hall voltage is propotinal to current through hall cell and induction B :

$$V_h=A_f k_h B I_h$$

and $I_h=gV_R$ where g is transconductance of voltage-to-current source, overall product from our amplifier is

$$m_{AV}=A_f g k_h B V_R^2$$

A_f is total forward amplification of input instrumentation amplifier, mixer and differential amplifier.

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4. Nonlinear mixer offset model

If second-order nonlinerity of mixer is assumed $m=XY+q(XY)^2$
there is evidence of one square-root product:

$$(X o_y+Y o_x)^2 \sin^2 \omega t=\frac{(X o_y+Y o_x)^2}{2}-\frac{(X o_y+Y o_x)^2}{2}\cos^2 \omega t$$

and propagation of offset voltage o_x, o_y at inputs that cannot be removed by multiplier chopping.

While normalized $q \ll 0.01$ propagation of offset product should be very low. TBD.

5. Charge injection from analog switch

Second issue is charge injection from analog switch in range 0,5 - 5pC. While low pass filter is the R-C network with cut-off frequency 1 Hz (7.2 k - 22 uF), charge injection at multiplier output causes dV = dQ/C = 0,5pC/22uF =max.+/-0,05uV at 2Hz chopping frequency (DG636: 0,5 pC, 100 pA leakage).