PSEC3 Ongoing Timing Calibration

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Data samples

• Old PSEC3 data from Eric:
  – 10 GSa/s
  – CH3 (256 sample cells)
  – 100 events each of:
    • 40 MHz
    • 120 MHz

• New PSEC3 data from Eric:
  – 5 GSa/s
  – CH3 (256 sample cells)
  – 1200 events of:
    • 100 MHz
Qualitative Features of New Data

- Sampling rate slipped in events ~400-600:
Qualitative Features of New Data

• Some gain variation between cells?
  – Manifests as rotation of ellipse.

All waveforms except events 400-600

⇒ If so, very small... not incorporating the effect into fit at this time.
Example Fit

Data and fit

Residuals in x, y

Improved first guess procedure, relatively robust.
Still some fit failures due to outliers... need to implement outlier removal.
Distributions of $\Delta t_{i,i+10}$ and $\Delta t_{i,i+9}$

- Number of entries $\neq 256$, (still) due to some failed / bad fits.
- Width of distributions ($\sim 5\%$ of mean, compared to $\sim 15\%$ last time):
  - Previous calibration was definitely statistics limited.
Some structure overall with respect to sample cell.
Corresponding fit shown at right.
  - Appears to have multiple sampling rates.
Derived Distribution of $\Delta t_{i,i+1}$

$\text{dt1-dt2 } \{\text{status1 == 0 && status2 == 0}\}$

<table>
<thead>
<tr>
<th>htemp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>RMS</td>
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</tbody>
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$\Rightarrow$ Mean is reasonable for 5 GSa/s, no more negative time intervals.
Still lots of potential improvements...

• Better combinations of $\Delta t_{i,j}$ values to get $\Delta t_{i,i+1}$.
  – Can utilize significant overconstraints of system by fitting for many (or all) feasible i,j pairs.

• Increase fit robustness:
  – Add outlier rejection.

• Apply $\Delta t$ values from one dataset to another dataset (or compare from independent datasets).
  – Ellipse fits with $\Delta t$ values fixed, fit for $f_{\text{input}}$.
  – Sine wave fits to 40 MHz data.

• Modify fitter to get meaningful errors.

• More next week...
BACKUP
Timing Calibration w/ Correlations

- Plot correlations between pairs of samples:
  - To determine $\Delta t_{ij}$, plot $V_i - V_j$ versus $V_i + V_j$

Input signals given by:

$V_i = A \sin(\omega t_i + \phi)$

$V_j = A \sin(\omega t_j + \phi)$

Effectively rotate by $45^\circ$:

$-x := V_i + V_j$

$-y := V_i - V_j$

$\Rightarrow \frac{x^2}{4A^2 \cos^2(\omega \delta t/2)} + \frac{y^2}{4A^2 \sin^2(\omega \delta t/2)} = 1$

i and j can be adjacent (or not), but should not be $> 1$ period apart.

*Method and results from Andres-Romero Wolf and myself, with data from LAB3. Planning as TIPP submission(?)
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Timing Calibration w/ Correlations

• Ellipse features:

1) Different $\Delta t$ (for known sampling frequency) give different major/minor radii.
2) Noise makes ellipse “fuzzy”
3) Nonzero pedestals shift origin
4) Difference in gain between two cells causes a rotation.

➤ We have written an ellipse fitter to perform this method.
➤ Even without fitting, it provides nice qualitative check on results.

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