c) HW rounding mode #3: Unbiased

- DC bias is unacceptable for 2’s complement
- Logically simple, complex bhw often

- Fix the case:
  1) \( \text{result} \) is negative
  2) \( \text{xxxxxx} | 100000 \)
  - Result form

- Ex Alg. #1
  1) Remove 2 LSB bit
  2) Keep the result when the result is:
     i) neg.
     ii) \( \text{xxxxxx} | 10000 \)
  3) Otherwise, add 2 LSB back in and recalculate
  4) Truncate

- Ex Alg. #3
  Calc. devices:
  i) Rounding bit in
  ii) " " out
  - Select correct answer w/ a max
  \( \text{HW} \leq 2x \)
Drive-thru data processing

Ex: "software thinking"
- init arrays of temp vars
- perform one task at a time
- use lots of buffers
- waste energy on:
  - comm.
  - memories

\[
\begin{align*}
a &= \sin(1:1024); \\
b &= in + a; \\
c &= CertTableMem[addr(1:1024)]; \\
d &= b + c;
\end{align*}
\]

Plan:
- Process data as it flows by
- Store no more data than necessary
- Don't request/generate data until needed

\[
\begin{align*}
\text{Cert Table Addr}
\end{align*}
\]
Complex Arithmetic

\[ j = \sqrt{-1} \quad \text{EE} \]
\[ i = \sqrt{-1} \quad \text{Math} \]

Rectangular: \[ \text{Re} + j \text{Im} \]

Polar: \[ \text{Mag}, \angle \]

\[ \text{Re} = I \text{ in phase} \]
\[ \text{Im} = Q \text{ quadrature} \]

- Keep information needed
  - Drop " not needed

Ex: Signal strength

\[ \text{Rect} \rightarrow \text{Polar, drop Angle} \]
Ex: QPSK receiver

\[
\text{Re} \rightarrow \text{Polar} \quad \text{drop mag}
\]

Complex Add

- Best done in rect

\[
(A + jB) + (C + jD) = (A + C) + j(B + D)
\]

- 2 adds

Complex Mult

- Polar

\[
(A \text{mag}, \theta_A) \times (B_m, \theta_B) = A \times B_m \angle \theta_A + \theta_B
\]

- 1 Mult., 1 Add
Rect \( \text{H1} \)

\[(A + jB) \times (C + jD)\]

\[= AC + j^2 BD + j(AD + BC)\]

\[= AC - BD + j0\]

- 4 Mults, 2 "adds"

Critical path

Mult > Inv > 4:2 > CPA

Rect \( \text{H2} \)

\[\text{Re} = (A-B)D + A(C-D)\]

\[\text{Im} = (A-B)D + B(C+D)\]

- 3 Mults, 5 "adds"
- Two CPA's in critical path

- \( n \times (n+1) \) mults

Complex Rotations

\[ A = B \times C, \quad \text{where } |C| = 1, \quad \text{commonly } |C| \text{ is fixed} \]

- \[ C = \cos \Theta + j \sin \Theta \]

- Change only phase of \( B \)

- Precompute functions of \( \Theta \)
a) Straight forward, same as mult
   - 4 mults, 2 "adds"

b) Golubi method

\[ A_r = (B_r + B_i) (\cos \theta - \sin \theta) + B_r \sin \theta - B_i \cos \theta \]

\[ A_i = B_i \cos \theta + B_r \sin \theta \]

- 3 mults
  + all carry-save outputs

- 5 (4) add/sub

Better: carry-save + CPA for 3-input add