IIR Filter Implementation Approaches

1. Fixed Q Format:

- Approach: Use a fixed Q format with enough integer bits (based on the largest denominator coefficient) for both numerator and denominator coefficients.
- Advantages:
  - Simplicity: Easier to implement because all coefficients are treated with the same Q format.
  - Prevents overflow: The integer part can accommodate larger coefficients in the denominator.
- Disadvantages:
  - Reduced precision: Using more integer bits reduces the number of fractional bits, which can affect the precision of smaller coefficients.

2. Q Format with 1 Integer Bit (Normalization):

- Approach: Use a Q format with 1 integer bit and normalize all coefficients except the leading 1 in the denominator.
- Advantages:
  - More fractional bits: Maximizes the precision for smaller coefficients by using more fractional bits.
  - Simpler Q format: Treating all coefficients except the leading one with the same Q format simplifies the fixed-point operations.
- Disadvantages:
  - Frequency response alteration: The normalization will affect the filter's amplitude and frequency response, so this method may require careful evaluation to see if the performance meets your requirements.
  - Instability risk: If the denominator coefficients are significantly altered, it may affect the stability of the IIR filter.

3. Specific Q Format for Each Coefficient (Highest Precision):

- Approach: Assign a specific Q format to each coefficient based on its range. Use the greatest Q format for operations (e.g., Q10.14 for multiplication) and then scale results to the respective Q format for each coefficient.

- Advantages:

  - Maximum precision: You can optimize the precision for each coefficient individually, ensuring the best possible performance.

  - Prevents overflow: Carefully chosen Q formats for each coefficient ensure that the filter is stable while maintaining precision.

- Disadvantages:

  - Complexity: This is the most complex implementation. You will need to handle different Q formats for each coefficient and ensure that the operations and results are properly scaled.

  - Possible need for fixed-point libraries: Implementing this method might require specialized fixed-point libraries or extensive scaling logic to handle different formats correctly.

Comparison of Results:

- Filter frequency response: Compare the amplitude and phase response of the filter for each method to see how the frequency characteristics are affected.

- Precision of coefficients: Assess the impact on precision, especially for coefficients with small values.

- Stability: Ensure that the filter remains stable, particularly for the normalized implementation.

- Implementation complexity: Weigh the complexity of each approach against the precision and stability benefits.

- Next Steps: After comparing the results, you can decide which implementation strikes the best balance between complexity, precision, and stability for your specific application.