# Filter Comparison

This document shows a case study about the comparison of all possible filter solutions for the same requirements

The filter requirements are:

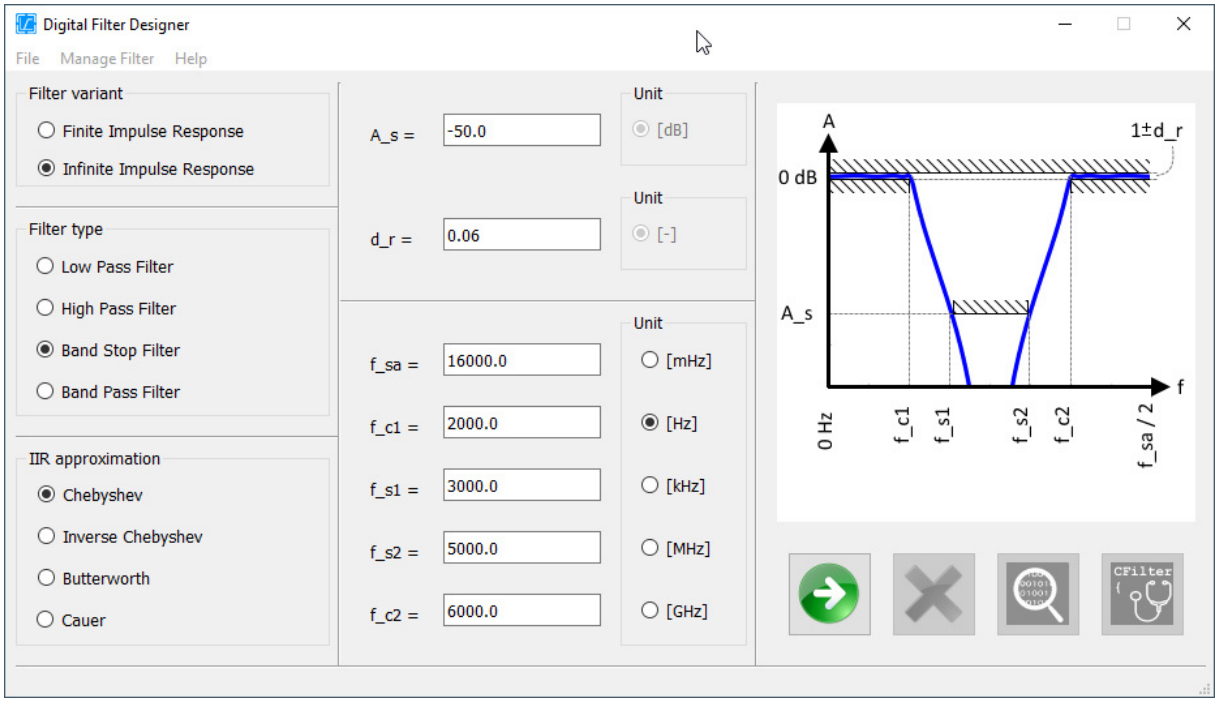


FIGURE 1: REQUIREMENTS OF THE EXAMPLE

## 1. FIR Filter

Number of stages: 49

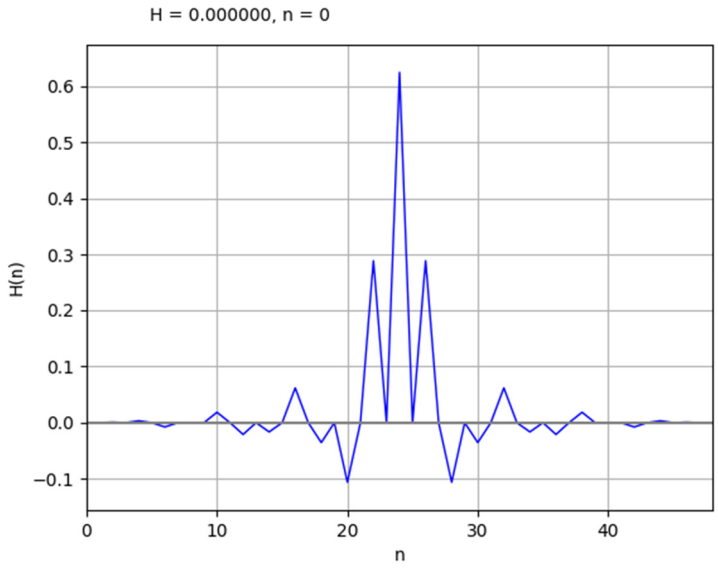


FIGURE 2: EXPECTED IMPULSE RESPONSE OF THE FIR FILTER

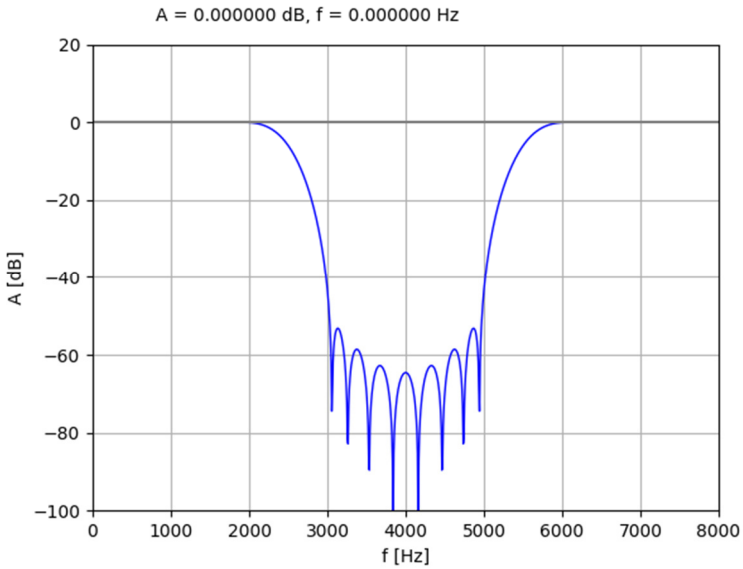


FIGURE 3: EXPECTED FREQUENCY RESPONSE OF THE FIR FILTER

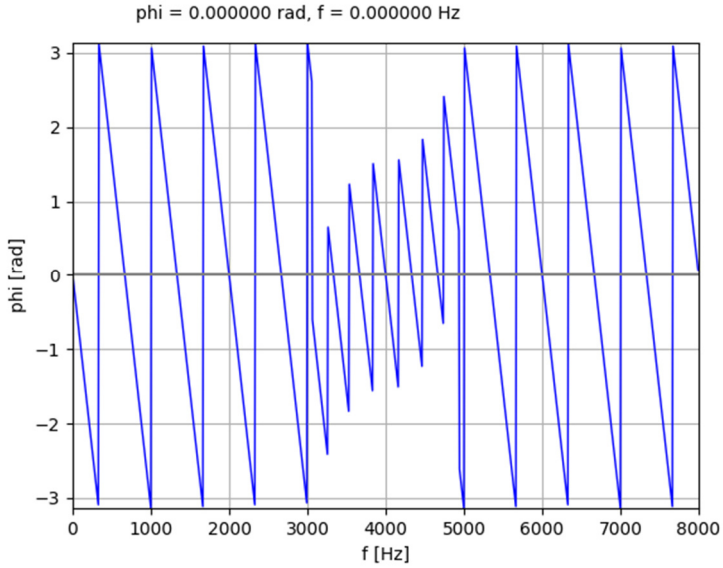


FIGURE 4: EXPECTED PHASE ANGLE CHARACTERISTIC OF THE FIR FILTER

## 2. IIR Filter Chebyshev Approximation

Number of stages: 6

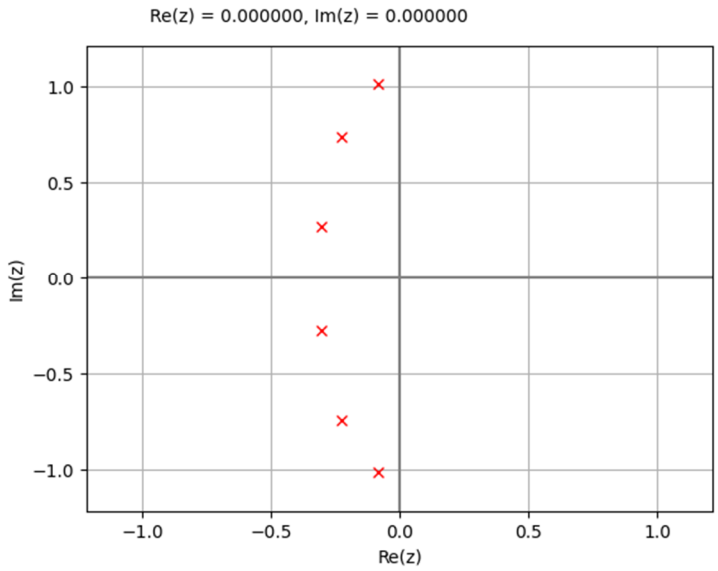


FIGURE 5: ANALOG POLE-ZERO DIAGRAM OF THE IIR CHEBYSHEV FILTER

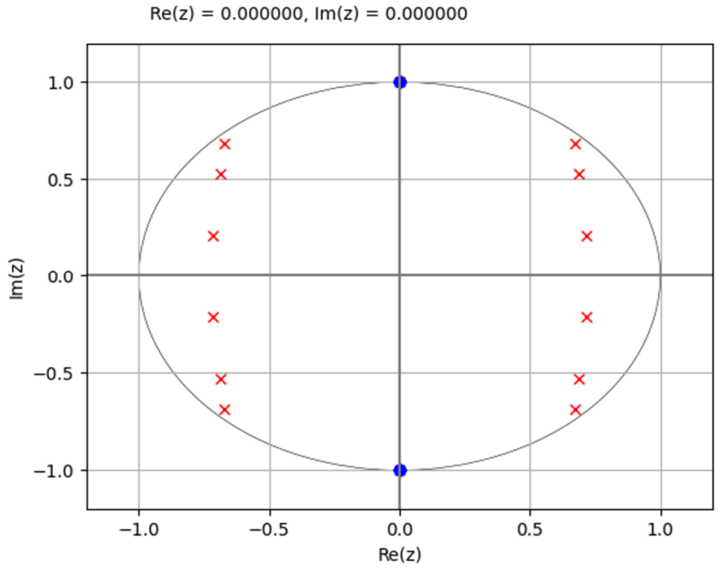


FIGURE 6: DIGITAL POLE-ZERO DIAGRAM OF THE IIR CHEBYSHEV FILTER

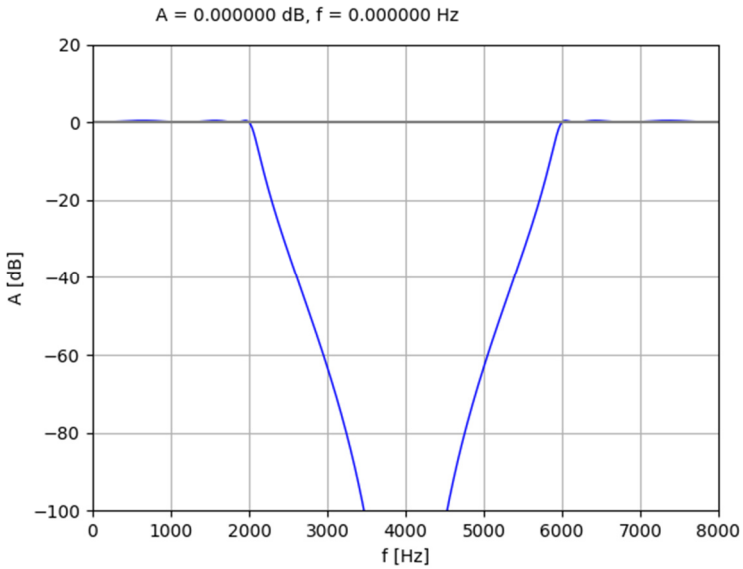


FIGURE 7: EXPECTED FREQUENCY RESPONSE OF THE IIR CHEBYSHEV FILTER

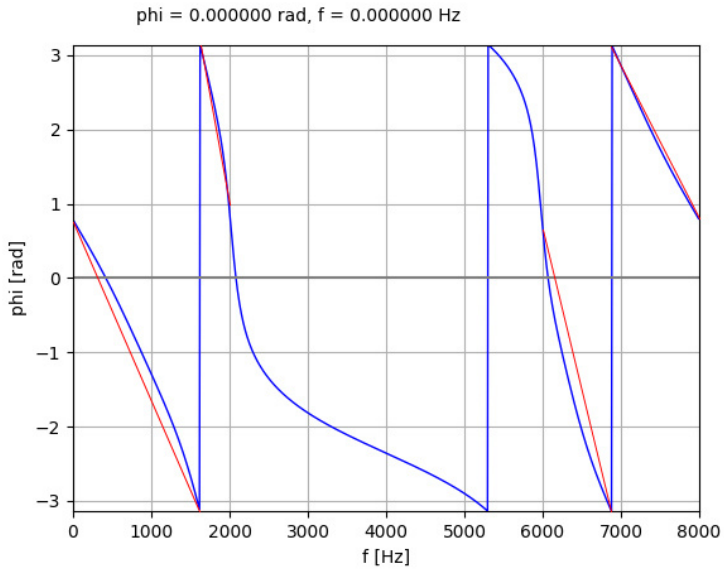


FIGURE 8: EXPECTED PHASE ANGLE CHARACTERISTIC OF THE IIR CHEBYSHEV FILTER, WITH RED LINES THE IDEAL "LINEAR" CASE IN PASS-BAND

## 3. IIR Filter Inverse Chebyshev Approximation

Number of stages: 6

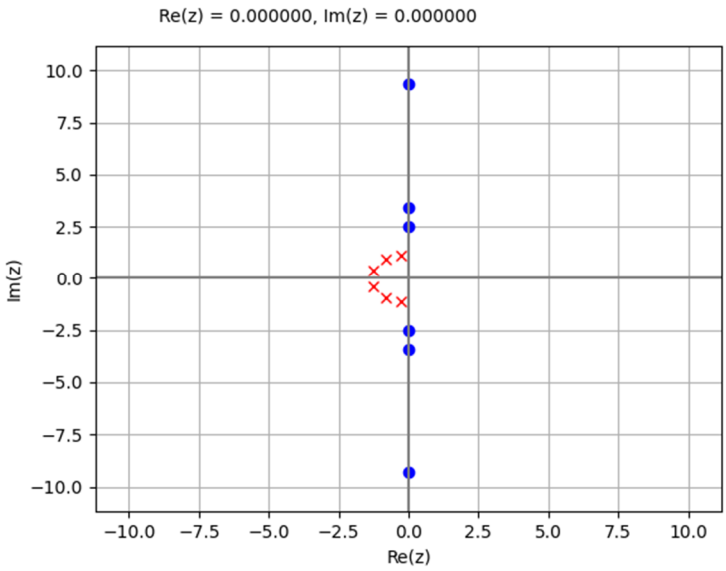


FIGURE 9: ANALOG POLE-ZERO DIAGRAM OF THE IIR INVERSE CHEBYSHEV FILTER

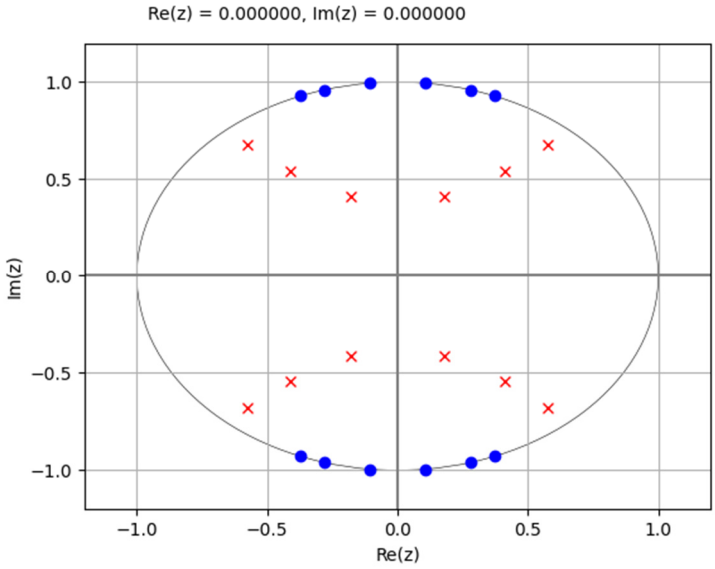


FIGURE 10: DIGITAL POLE-ZERO DIAGRAM OF THE IIR INVERSE CHEBYSHEV FILTER

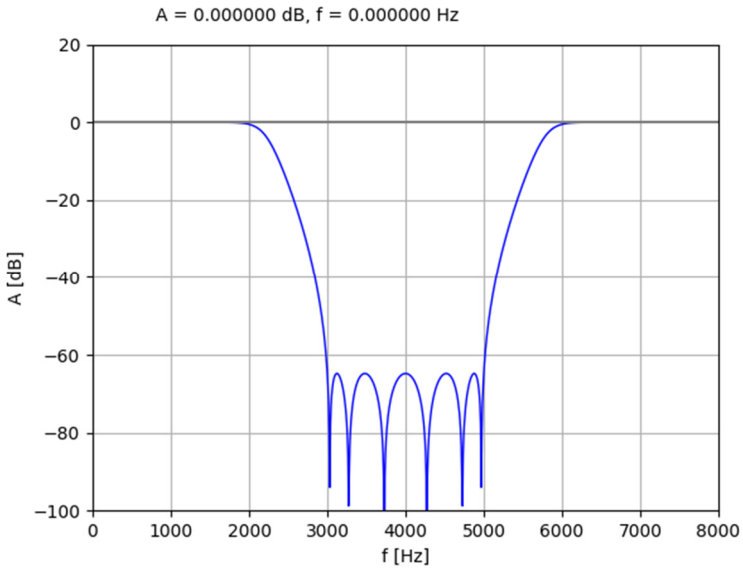


FIGURE 11: EXPECTED FREQUENCY RESPONSE OF THE IIR INVERSE CHEBYSHEV FILTER

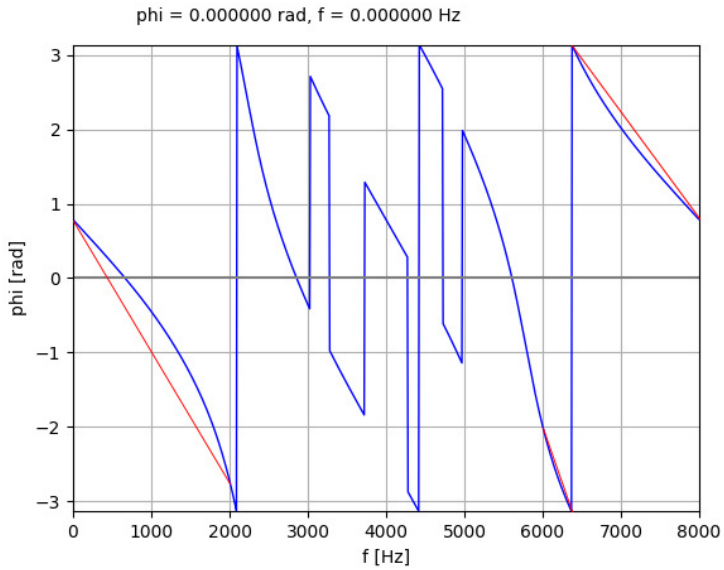


FIGURE 12: EXPECTED PHASE ANGLE CHARACTERISTIC OF THE IIR INVERSE CHEBYSHEV FILTER, WITH RED LINES THE IDEAL "LINEAR" CASE IN PASS-BAND

# 4. IIR Filter Butterworth Approximation

Number of stages: 8

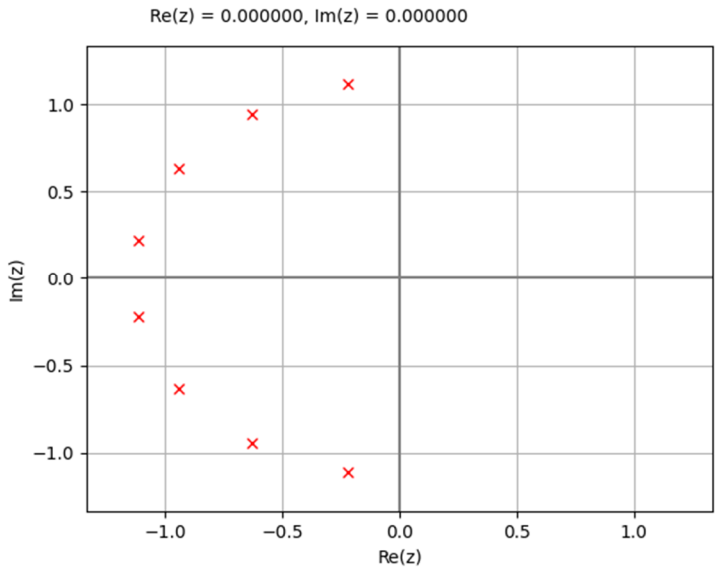


FIGURE 13: ANALOG POLE-ZERO DIAGRAM OF THE IIR BUTTERWORTH FILTER

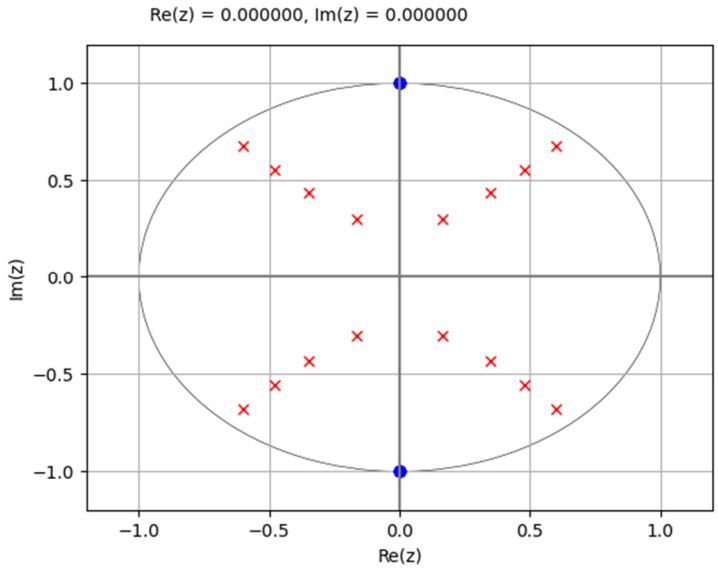


FIGURE 14: DIGITAL POLE-ZERO DIAGRAM OF THE IIR BUTTERWORTH FILTER

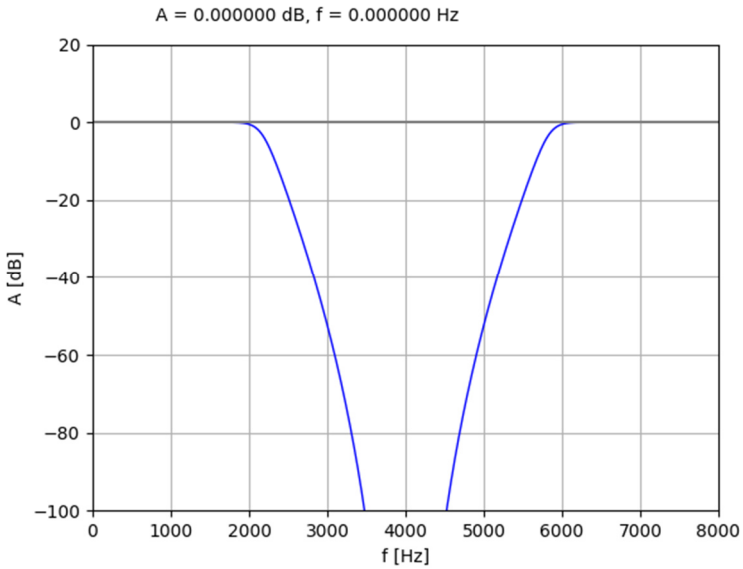


FIGURE 15: EXPECTED FREQUENCY RESPONSE OF THE IIR BUTTERWORTH FILTER

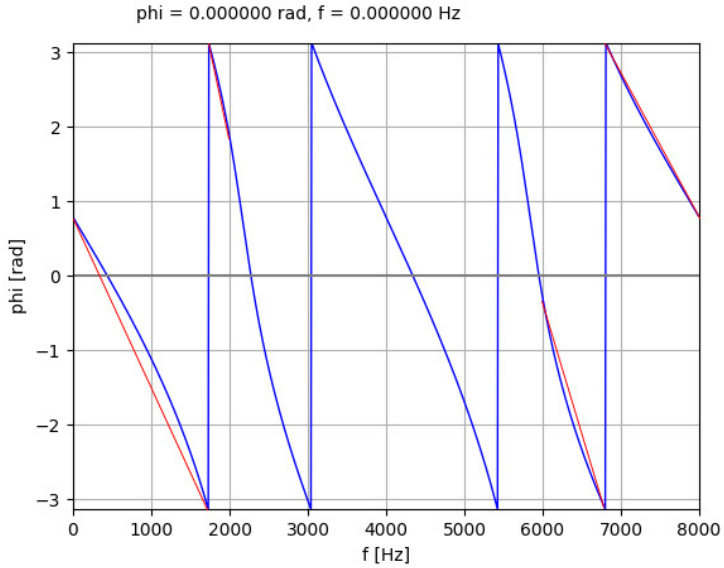


FIGURE 16: EXPECTED PHASE ANGLE CHARACTERISTIC OF THE IIR BUTTERWORTH FILTER, WITH RED LINES THE IDEAL "LINEAR" CASE IN PASS-BAND

## 5. IIR Filter Cauer Approximation

Number of stages: 4

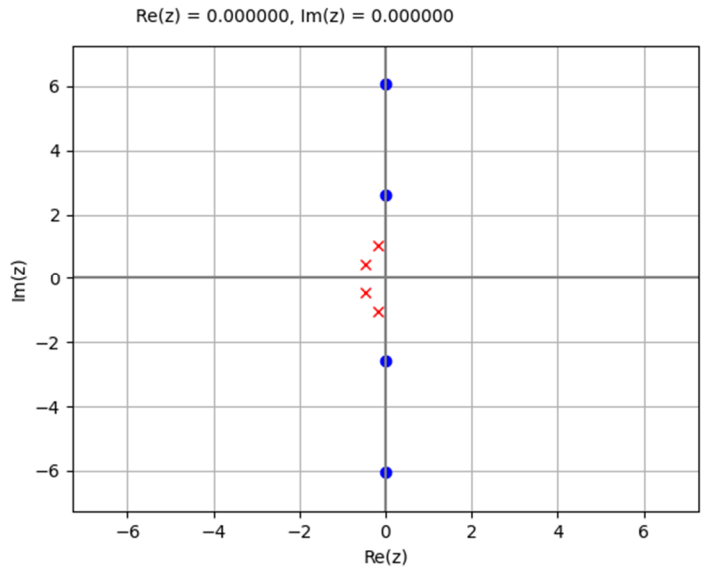


FIGURE 17: ANALOG POLE-ZERO DIAGRAM OF THE IIR CAUER FILTER

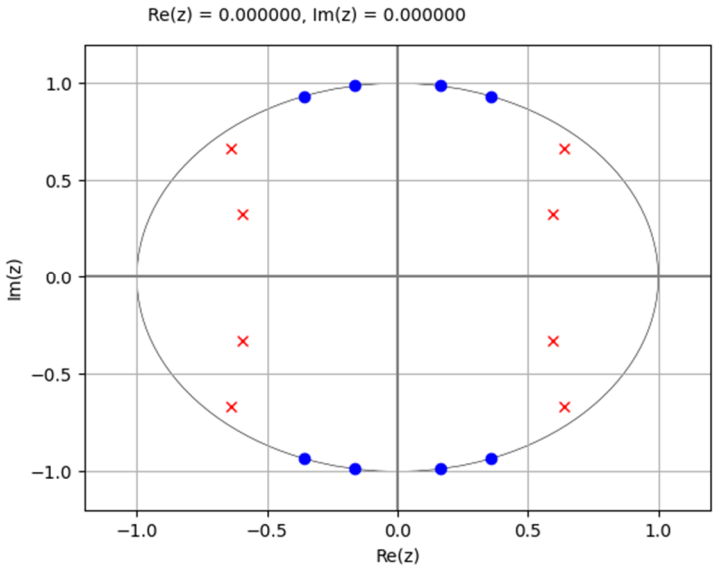


FIGURE 18: DIGITAL POLE-ZERO DIAGRAM OF THE IIR CAUER FILTER

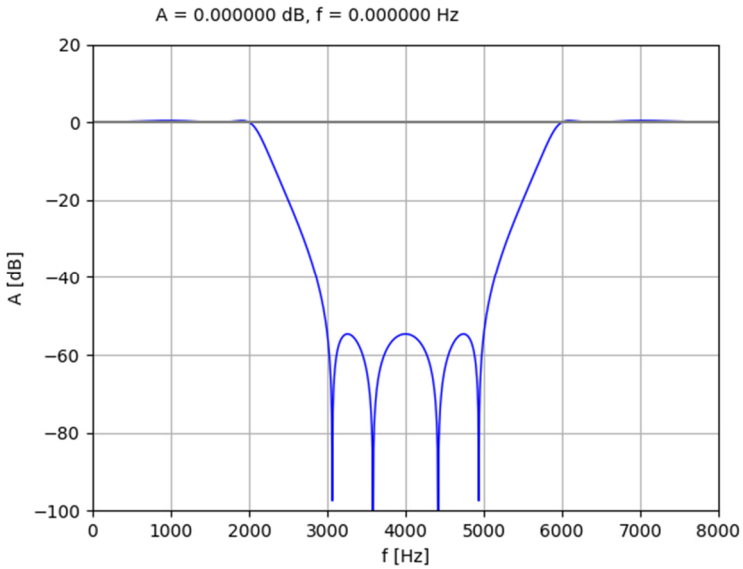


FIGURE 19: EXPECTED FREQUENCY RESPONSE OF THE IIR CAUER FILTER

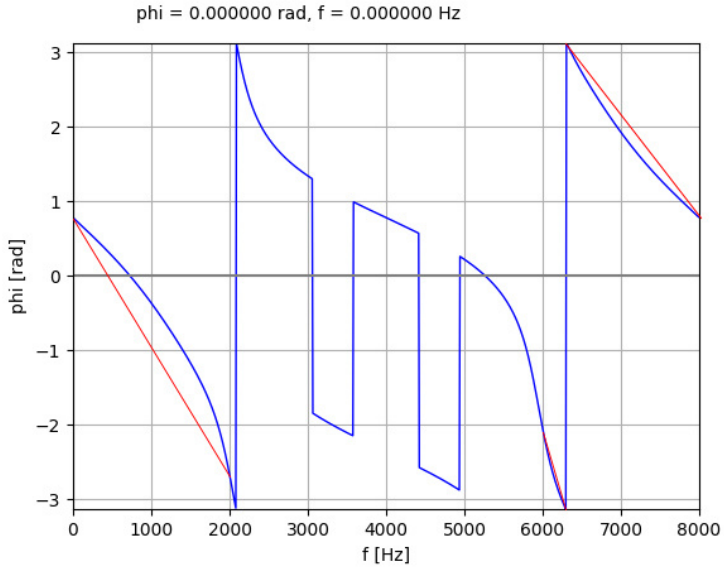


FIGURE 20: EXPECTED PHASE ANGLE CHARACTERISTIC OF THE IIR CAUER FILTER, WITH RED LINES THE IDEAL "LINEAR" CASE IN PASS-BAND

## 6. Comparison and summary

The evaluation criteria of the particular filter implementation are the following:

1. Operational speed: the less the number of the stages is, the faster filtering operation can be expected.
2. Pass-band attenuation: in ideal case the attenuation of the filter is 0 dB for the whole pass-band. Any ripple within the pass-band would cause worse evaluation results.
3. Pass-band phase angle linearity: in ideal case the phase angle must be linear within the pass-band, thus distortion can be avoided. The linear case for the pass-band is visualised on all the IIR phase angle diagrams with the red lines. The less the deviation to the phase angle data plot, the higher linearity can be expected.
4. Instability: due to the feedback loop within the structure of the IIR implementation, a stable operation for IIR cannot be guaranteed. A stability analysis of the IIR filters is not discussed in this document.

| | **Number of stages[1]** | **Ripple of pass-band attenuation [dB][2]** | **Phase angle non-linearity** |
|---|---|---|---|
| **FIR** | 49 | 0.101301553 | LINEAR |
| **IIR Chebyshev** | 6 | 0.41976554 | MEDIUM |
| **IIR Inv. Chebyshev** | 6 | 0.682272115 | MEDIUM |
| **IIR Butterworth** | 8 | 0.608130839 | WEAK |
| **IIR Cauer** | 4 | 0.41831452 | VERY STRONG |

TABLE 1: EVALUATION OF THE FILTER IMPLEMENTATIONS

Table 1 shows the evaluation of the filter implementations according to the above discussed criteria. This is only a use case example, and does not mean any reference to any concrete application. Further evaluation of the filter approximations is not the subject of this document.

**These results are based solely on diverse simulation calculations! These simulations do not substitute the necessary testing steps on your target device!**

[1] Due to the different filter structure, the numerical complexity of the FIR and IIR filters cannot be compared directly, although with effective alogrithm, one stage of a IIR block can be executed as fast as the execution of a FIR filter stage

[2] The evaluation of this criterion was done by the Digital Filter Validator, as filter with double precision was validated to each approximation