DC BLOCKING FILTERS

DC offset often exists in the microphone output. This can be removed with a DC blocking filter to provide clean audio for downstream signal processing. This document describes a relatively simple implementation that can be used to block DC offset in many applications. It also includes an example fixed point implementation.

DESIGN

The common design of a DC blocking filter is with one pole and one zero. Its transfer function, \( H(z) \), is defined as:

\[
H(z) = \frac{1 - z^{-1}}{1 - a \cdot z^{-1}}
\]

The coefficient “\( a \)” determines the cut off frequency depending on the system sample rate.

Larger “\( a \)” coefficients produce a slower DC blocking response but with less attenuation at lower frequencies. Conversely, smaller “\( a \)” coefficients achieve a faster DC blocking response but with more low-frequency attenuation. Choosing the best coefficient value is always a trade-off in applications.

Some applications require both during the startup stage. That is, the filter must have a quick DC blocking response while having minimal attenuation at the lower frequencies during normal operation. In this scenario, the goal can be achieved by choosing a smaller DC blocking filter coefficient at startup and switching to a larger coefficient once the filter is blocking all or most of the DC offset. An audible glitch could occur during the switch, so muting the audio output may be necessary during the transition of coefficients.

Typically, designers have flexibility in choosing coefficients. Implementation may also limit this flexibility. For example, in a floating point implementation, coefficients of \((1-2^{-11}) = 0.99951171875\) or \((1-2^{-12}) = 0.999755859375\) may work for a typical DC Blocking filter. However, filter parameters chosen for optimal precision in a fixed-point implementation typically utilize filter coefficients less than 0.999 (eg. \( a \leq (1-2^{-9}) = 0.998046875\)).

For faster startup time, choose a smaller coefficient tailored to the application.

For a coefficient of 0.99951171875, Table 1 shows the -3 dB cut off frequency (Low Frequency Roll Off or LFRO) for various sample rates.

<table>
<thead>
<tr>
<th>Sample Rate (Hz)</th>
<th>-3 dB Cutoff Frequency (Hz)</th>
<th>20 Hz Attenuation (db)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8000</td>
<td>.625</td>
<td>-0.0042</td>
</tr>
<tr>
<td>16000</td>
<td>1.250</td>
<td>-0.0169</td>
</tr>
<tr>
<td>24000</td>
<td>1.875</td>
<td>-0.0380</td>
</tr>
<tr>
<td>32000</td>
<td>2.500</td>
<td>-0.0673</td>
</tr>
<tr>
<td>48000</td>
<td>3.750</td>
<td>-0.1501</td>
</tr>
</tbody>
</table>

Similarly, Table 2 shows the cut off frequency for various sample rates for a coefficient of 0.998046875.

<table>
<thead>
<tr>
<th>Sample Rate (Hz)</th>
<th>-3 dB Cutoff Frequency (Hz)</th>
<th>20 Hz Attenuation (db)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8000</td>
<td>2.500</td>
<td>-0.0673</td>
</tr>
<tr>
<td>16000</td>
<td>5.000</td>
<td>-0.2633</td>
</tr>
<tr>
<td>24000</td>
<td>7.500</td>
<td>-0.5714</td>
</tr>
<tr>
<td>32000</td>
<td>10.000</td>
<td>-0.9691</td>
</tr>
<tr>
<td>48000</td>
<td>15.000</td>
<td>-1.9382</td>
</tr>
</tbody>
</table>

The filter’s frequency response for a sampling rate (\( F_s \)) of 48 kHz for various filter coefficients is shown in Figure 1.
Figure 1: Filter Frequency Response, Fs=48kHz

Also important to filter performance is DC blocking time. As described earlier, smaller coefficients will provide faster blocking times, but have more low-frequency attenuation. Figure 2 below shows blocking time for various coefficients.

Figure 2: Filter DC Blocking Time, Fs=48kHz

A fixed-point C reference code example is:

```
void dc_filter(Uint16 *pcmIn)
{
    Int16 sampleIn, delta_x, sampleOut;
    Int32 a1_y_prev;
    sampleIn = (Int16)*pcmIn;
    delta_x = sampleIn-x_prev;
    a1_y_prev = A1*y_prev/MAX_SIGN_POS_PCMBIT_SIZE;
    sampleOut = delta_x+(Int16)a1_y_prev;
    x_prev = sampleIn;
    y_prev = (Int32)sampleOut;
    *pcmIn = (Uint16)sampleOut;
}
```

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