INTRODUCTION

The process of converting the given rate of a signal into a different rate is called *sampling rate conversion*. Systems that employ multiple sampling rates in the processing of digital signals are called *multirate digital signal processing systems*.

Sample rate conversion is one of the main operations in a multirate system. This chapter focuses on the description of sampling rate conversion in both time and frequency domains.

DECIMATION

The reduction of a sampling rate is called *decimation*, because the original sample set is reduced (decimated).

Decimation consists of two stages: filtering and downsampling, as shown in Figure 1.

We will first consider downsampling and through its description illustrate why it is necessary to apply filtering prior to downsampling.
Downsampling

Downsampling reduces the input sampling rate $f$ by an integer factor $M$, which is known as a downsampling factor. It is customary to use a box with a down-pointing arrow, followed by the downsampling factor, as a symbol to represent downsampling, as shown in Figure 2.

The output signal $y(m)$ is called a downsampled signal and is obtained by taking only every $M$-th sample of the input signal and discarding all others,

$$y(m) = x(mM).$$  

(1)

To model the downsampling process, it is convenient to divide it into two steps. The output of the first step is the signal $x'(n)$, which is obtained by setting all samples whose indices are not integer multiples of $M$ to zero. In the second step, all zeros that were introduced in the preceding step are now discarded, and the downsampled signal is obtained.

The downsampling operation is not invertible because it requires setting some of the samples to zero. In other words, we cannot recover $x(n)$ from $y(m)$ exactly, but can only compute an approximate value.

Step One

We observe that the sampling rate is not altered during the first step, so that the signals $x(n)$ and $x'(n)$ have the same sampling rate. The signal $x'(n)$ can be considered as a multiplication of $x(n)$ with the discrete sampling function $c_M(n)$, where $M$ denotes the downsampling factor,

$$x'(n) = x(n)c_M(n),$$

(2)

where,

$$c_M(n) = \begin{cases} 
  1 & n = mM \\
  0 & \text{otherwise} 
\end{cases}, \quad m = \ldots,-1,0,1,\ldots$$

(3)
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