Unit 4
Multirate Digital signal processing

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Multirate Digital Signal Processing

- Systems that employ multiple sampling rates in the processing of digital signals are called Multirate digital signal processing systems.
- Multirate systems are sometimes used for sampling-rate conversion
- In most applications multirate systems are used to improve the performance, or for increased computational efficiency.

Multirate Digital Signal Processing

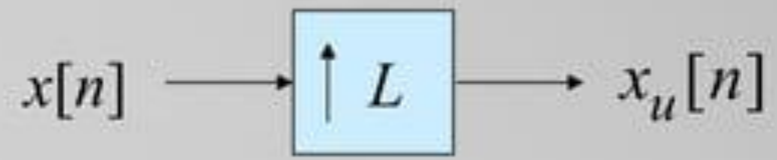
Basic Sampling Rate Alteration Devices:

Up-sampler - Used to increase the sampling rate by an integer factor
Down-sampler - Used to decrease the sampling rate by an integer factor

Up-Sampler

Time-Domain Characterization:

An up-sampler with an up-sampling factor L, where L is a positive integer, develops an output sequence $x_u[n]$ with a sampling rate that is L times larger than that of the input sequence x[n]
Block-diagram representation

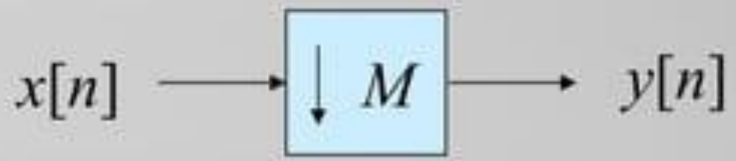


Down-Sampler

Time-Domain Characterization:

An down-sampler with a down-sampling factor M, where M is a positive integer, develops an output sequence y[n] with a sampling rate that is (1/M)-th of that of the input sequence x[n]

Block-diagram representation



Sampling Rate Reduction by Integer Factor D

In decimation, the sampling rate is reduced from F_x to F_x/D by discarding D– 1 samples for every D samples in the original sequence

$$H_{D}= \begin{cases} 1, & W \leq \pi/D \\ 0 & otherwise \end{cases}$$

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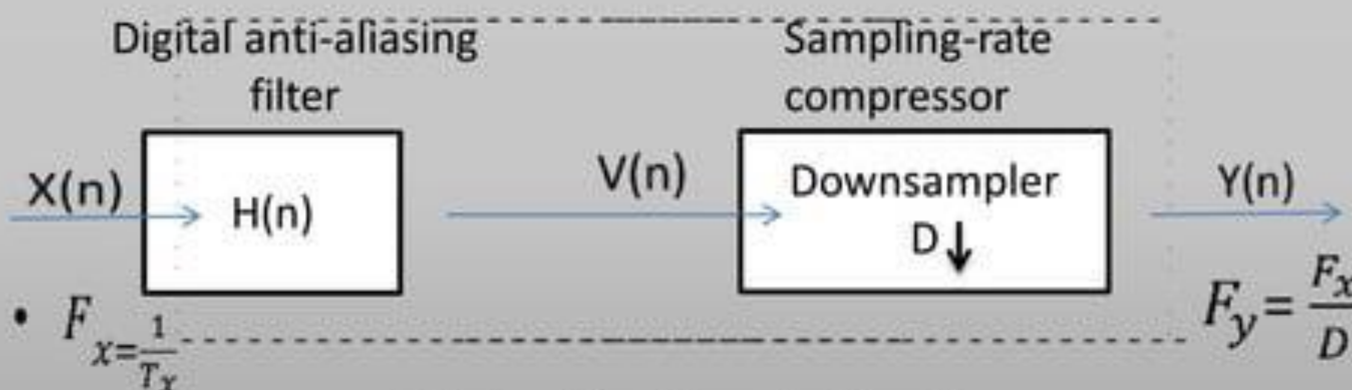


Decimation by a factor *D*

Sampling Rate Reduction by Integer Factor D

- Decimation by a factor of D, where D is a positive integer, can be performed as a two-step process, consisting of an anti-aliasing filtering followed by an operation known as down sampling.

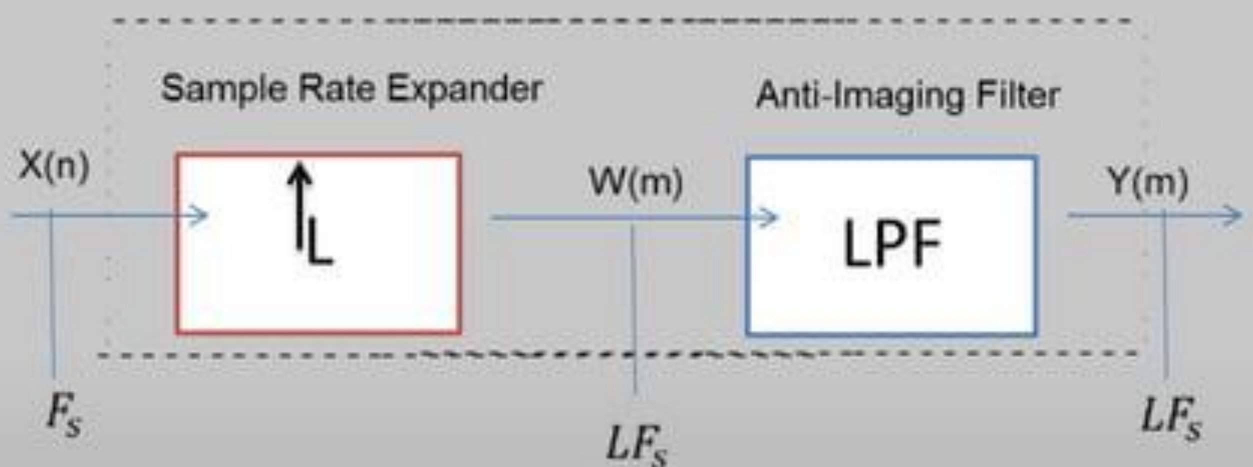
$$Y(n) = v nD$$

$$= \sum_{k=0}^{\infty} h(k) x(nD - k)$$

$$v(n) = \sum_{-\infty}^{\infty} h(k)\, x(n-k)$$

Sampling Rate Reduction by Integer Factor D

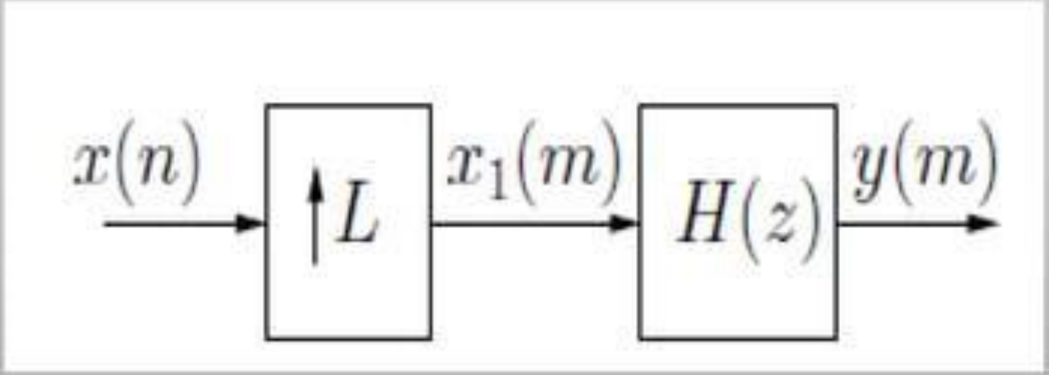
- Interpolation by a factor of L, where L is a positive integer, can be realized as a two-step process of upsampling followed by an anti-imaging filtering.



Sampling Rate Increase by Integer Factor D

- An upsampling operation to a discrete-time signal x(n) produces an upsampled signal y(m) according to

$$y(m) = \begin{cases} x\left(\frac{n}{L}\right), & n = 0, \pm L, \pm 2L, \dots, \\ 0, & otherwise \end{cases}$$



Multirate systems are used in a CD player when the music signal is converted from digital into analogue (DAC). Digital data (16-bit words) are read from the disk at a sampling rate of 44.1 kHz. If this data were converted directly into an analogue signal, image frequency bands centred on multiples of the sampling-rate would occur, causing amplifier overload, and distortion in the music signal. To protect against this, a common technique called oversampling is often implemented nowadays in all CD players and in most digital processing systems of music signals

Applications of Multirate DSP

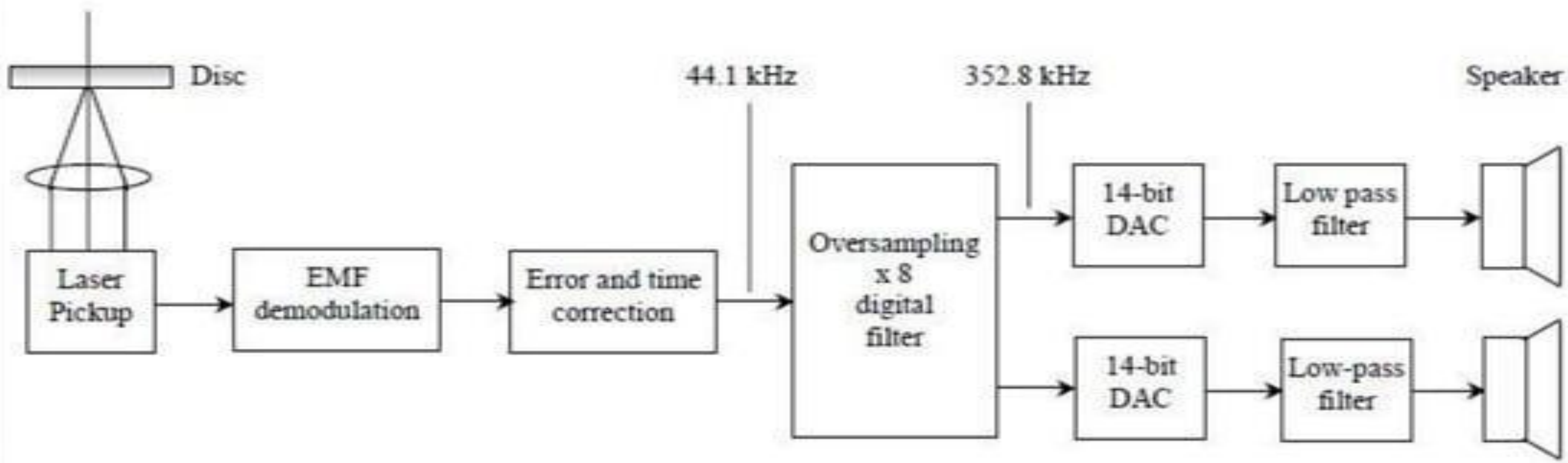


Figure 9.11: Digital to analogue conversion for a CD player using x8 oversampling.

Applications of Multirate DSP

- ❑ The effect of oversampling also has some other desirable features:
- Firstly, it causes the image frequencies to be much higher and therefore easier to filter out.
- Secondly reducing the noise power spectral density, by spreading the noise power over a larger bandwidth.

$$Noise\ \ power\ \ spectral\ \ density = \frac{Total\ \ power}{Bandwidth}$$

THANK YOU