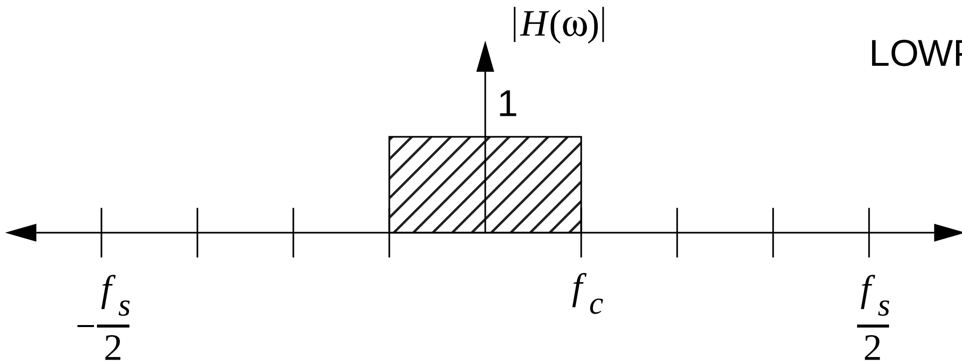
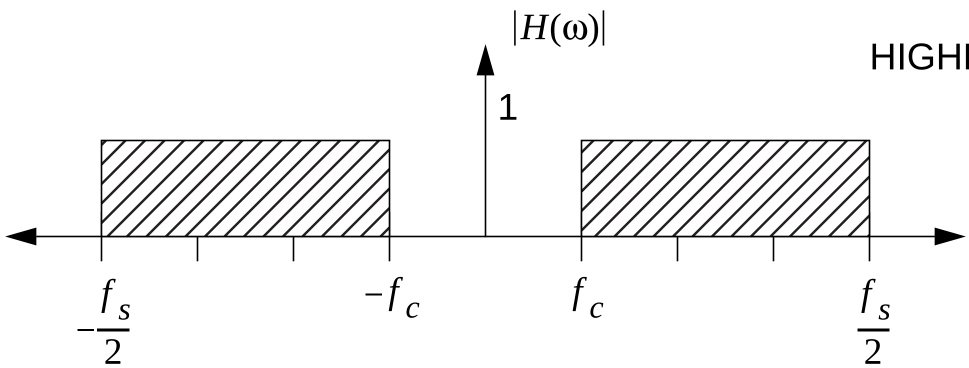
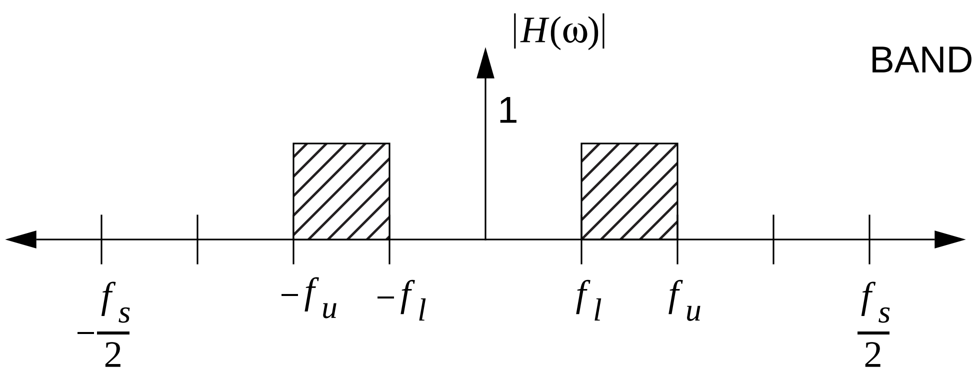
Ideal Filter Characteristics



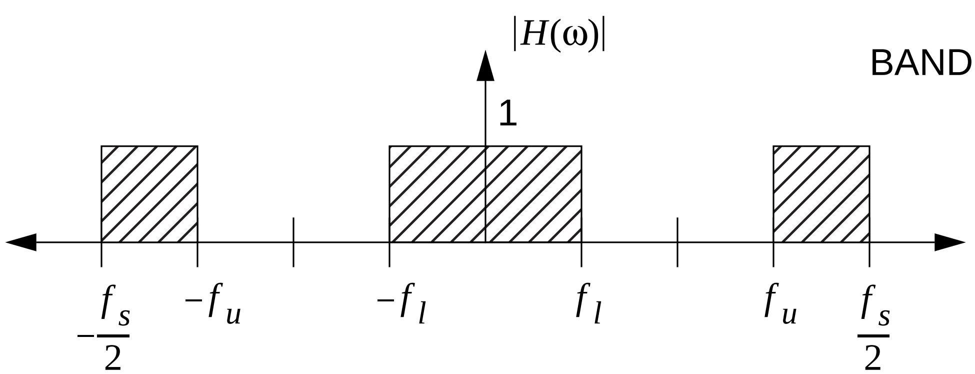
LOWPASS



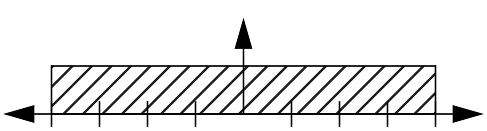
HIGHPASS



BANDPASS



BANDSTOP



ALL-PASS

Ideal Filter Have A Linear Phase Response: Why?

$$H(\omega) = \begin{cases} Ce^{-j\omega n_0}, & \omega_1 < \omega < \omega_2 \\ 0, & otherwise \end{cases}$$

$$\begin{aligned} Y(\omega) &= X(\omega)H(\omega) \\ &= CX(\omega)e^{-j\omega n_0} \qquad \omega_1 < \omega < \omega_2 \end{aligned}$$

from the inverse Fourier transform:

$$y(n) = Cx(n - n_0)$$

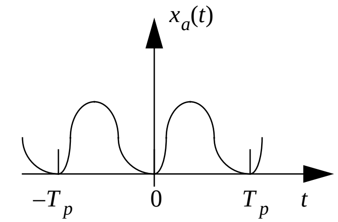
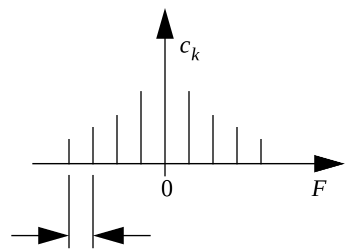
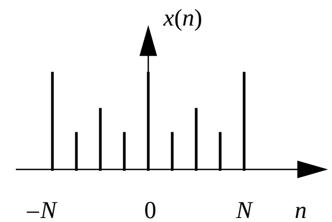
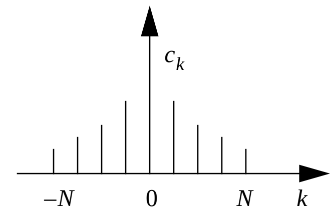
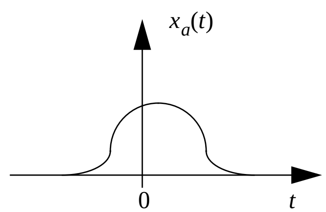
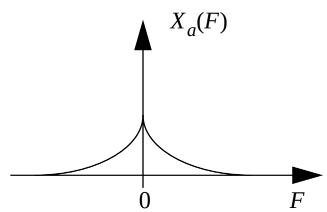
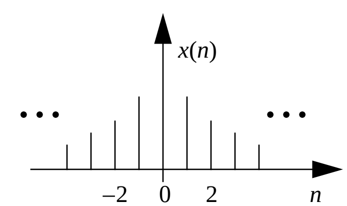
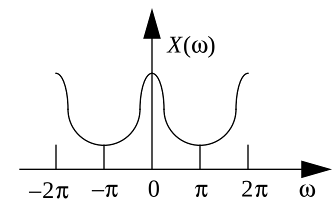
linear phase implies a time delay.

the phase of the Fourier transform of the filter is given by:

$$\Theta(\omega) = -\omega n_0$$

the derivative with respect to frequency is the envelope (or group) delay:

$$\begin{aligned} \tau_g(\omega) &= -\frac{d}{d\omega}\Theta(\omega) \\ &= n_0 \end{aligned}$$

		CONTINUOUS -TIME SIGNALS		DISCRETE -TIME SIGNALS	
		TIME-DOMAIN	FREQUENCY-DOMAIN	TIME-DOMAIN	FREQUENCY-DOMAIN
PERIODIC SIGNALS	FOURIER SERIES	 $c_k = \frac{1}{T_p}\int_{T_p} x_a(t) e^{-j2\pi k F_0 t} dt$	 $F_0 = \frac{1}{T_p}$; $x_a(t) = \sum_{k=-\infty}^{\infty} c_k e^{-j2\pi k F_0 t}$	 $c_k = \frac{1}{N}\sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi}{N}kn}$	 $x(n) = \sum_{k=0}^{N-1} c_k e^{-j\frac{2\pi}{N}kn}$
		CONTINUOUS AND PERIODIC	DISCRETE AND APERIODIC	DISCRETE AND PERIODIC	DISCRETE AND PERIODIC
APERIODIC SIGNALS	FOURIER TRANSFORMS	 $X_a(F) = \int_{-\infty}^{\infty} x_a(t) e^{-j2\pi F t} dt$	 $x_a(t) = \int_{-\infty}^{\infty} X_a(F) e^{j2\pi F t} dF$	 $X(\omega) = \sum_{n=-\infty}^{\infty} x(n) e^{-j\omega n}$	 $x(n) = \frac{1}{2\pi}\int_{2\pi} X(\omega) e^{j\omega n} d\omega$
		CONTINUOUS AND APERIODIC	CONTINUOUS AND APERIODIC	DISCRETE AND APERIODIC	CONTINUOUS AND PERIODIC

The Concept of Bandwidth

power (or energy) concentrated at low frequencies:

low-frequency signal

power (or energy) concentrated at high frequencies:

high-frequency signal

power (or energy) concentrated at mid frequencies:

narrowband signal if $F_2 - F_1 < 10\%((F_1 + F_2)/2)$
otherwise, wideband

no signal can be time-limited and bandlimited!

Effective Bandwith:

How much is enough?

3 dB point?

SNR of system? (-80 dB)

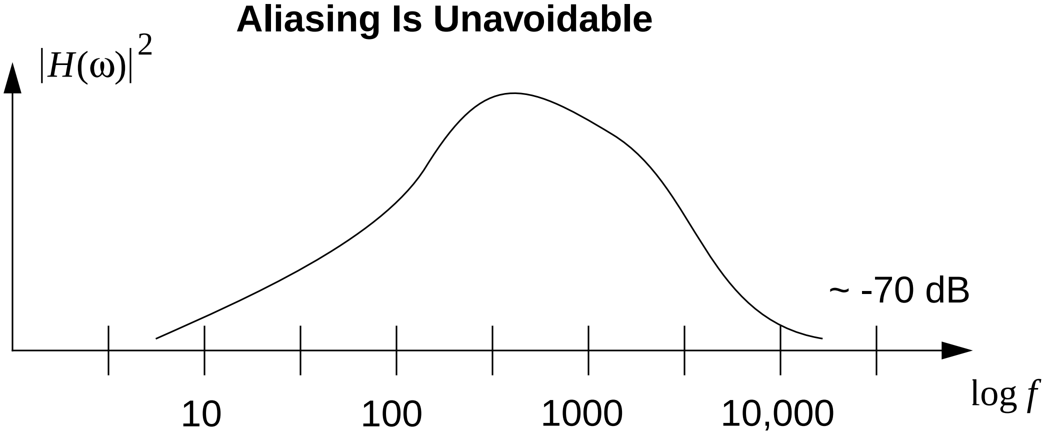
% of power/energy covered in the range $[0, f_s/2]$?

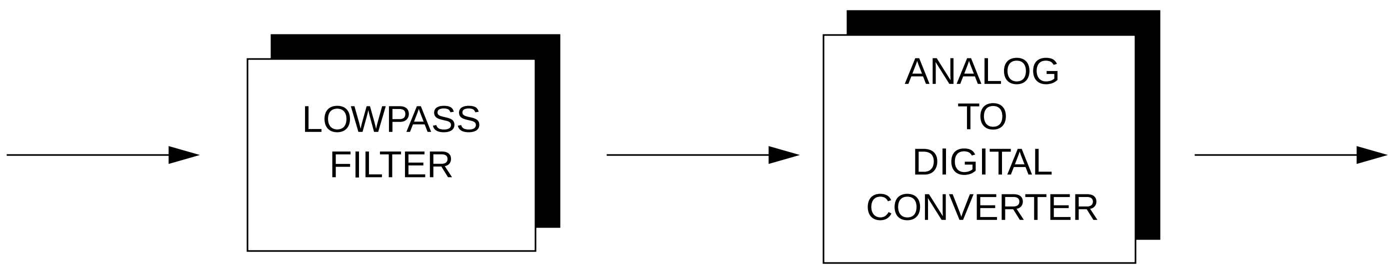
RMS Bandwidth:

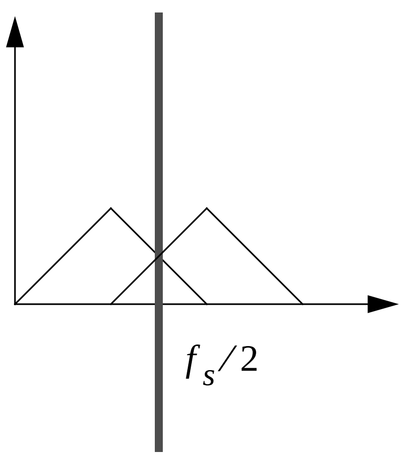
$$B \equiv \left[\frac{\int_0^{f_s} f^2 |H(f)|^2 df}{\int_0^{f_s} |H(f)|^2 df} \right]^{\frac{1}{2}}$$

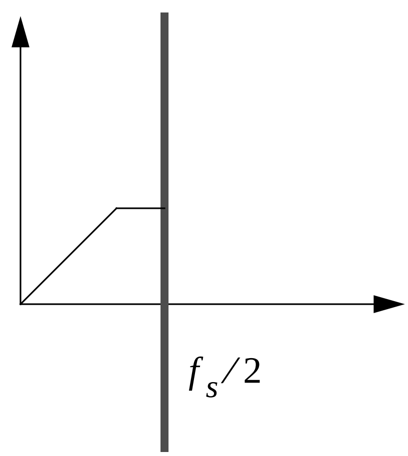
Lowpass Filtering Is Essential To Any DSP System

Aliasing Is Unavoidable









The Frequency Ranges of Natural Signals

Type of Signal	Frequency Range
Electroretinogram	0-20
Electronystagmogram	0-20
Pneumogram	0-40
Electrocardiogram	0-100
Electroencephalogram	10-200
Electromyogram	10-200
Sphygmomanogram	0-200
Speech	100-4000
Music	10-25000
NTSC Video	$0\text{-}6 \times 10^6$
HDTV	???

Type of Signal	Frequency Range
Radio Broadcast	3×10^4 - 3×10^6
Shortwave Radio Signals	3×10^6 - 3×10^{10}
Radar	3×10^8 - 3×10^{10}
Infrared	3×10^{11} - 3×10^{14}
Visible Light	3.7×10^{14} - 7.7×10^{14}
Ultraviolet	3×10^{15} - 3×10^{16}
Gamma rays and x-rays	3×10^{17} - 3×10^{18}