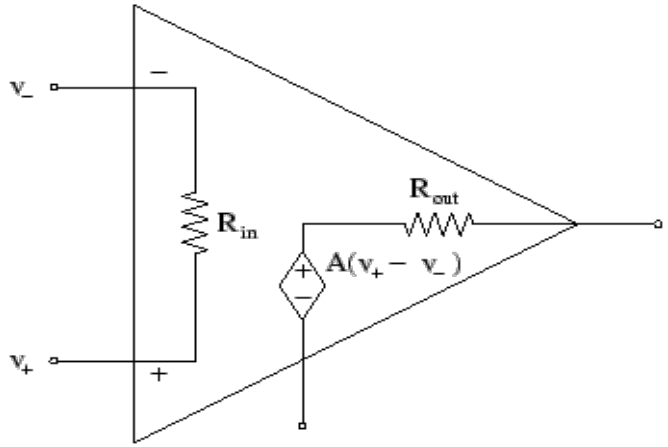
CG1111: Engineering Principles and Practice I

Comparators and Filters

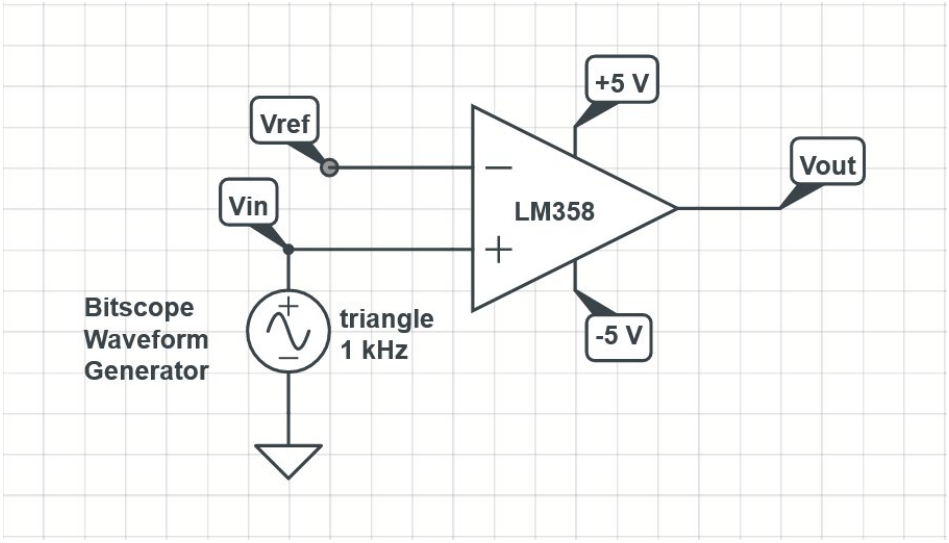
Op-Amp Equivalent Circuit



- R_i is the input impedance & R_{out} is the output impedance
- A is the open loop voltage gain
  - The open-loop gain, *A*, is very large, approaching infinity

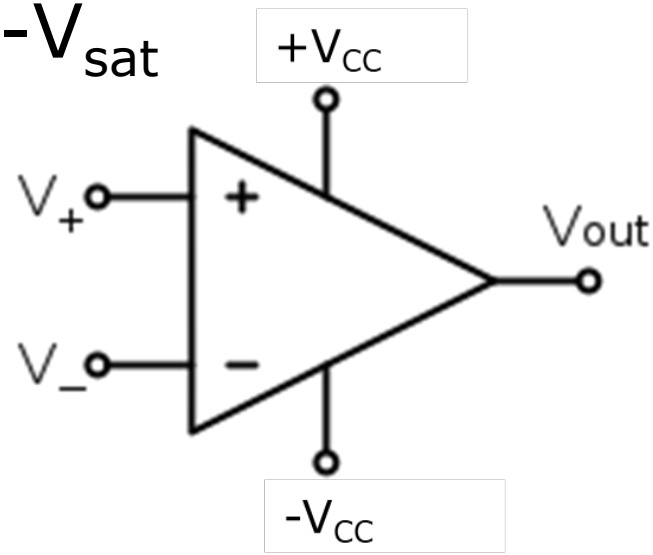
Comparator

- The comparator is an electronic decision-making circuit that makes use of an operational amplifier's very high gain in its open-loop state, that is, there is no feedback resistor
- The comparator is ideal to convert analog signals to digital signals at certain threshold values



Analysis of a Comparator

- The difference between the two inputs is amplified as '$A(V_+ - V_-)$' at the output
- The open loop voltage gain ('*A*') of the op-amp is very high (ideally ∞)
- Even if there is a very small difference between the inputs, the high 'A' will pull the output to either $+V_{sat}$ or $-V_{sat}$
- If $V_+ > V_- \rightarrow V_{out} = +V_{sat}/+V_{cc}$
- If $V_+ < V_- \rightarrow V_{out} = -V_{sat}/-V_{cc}$



Filter

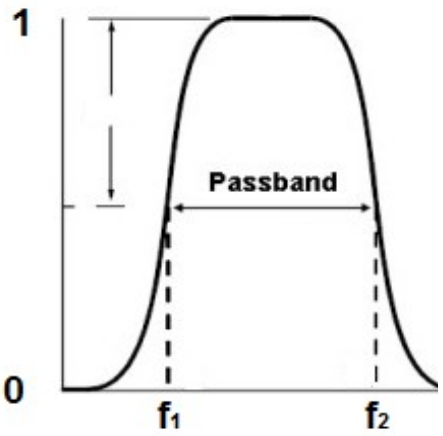
- A filter is a device or process that removes some unwanted components or features from a signal
- (eg) Removing the noise from measured ECG signal using a filter to help a doctor understand the heart better

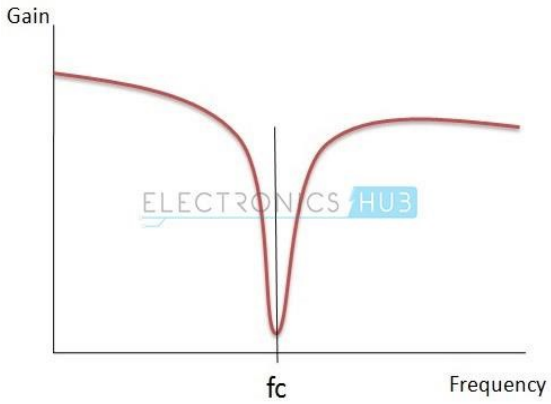
- Removing some frequencies or frequency bands which are unwanted in the signal

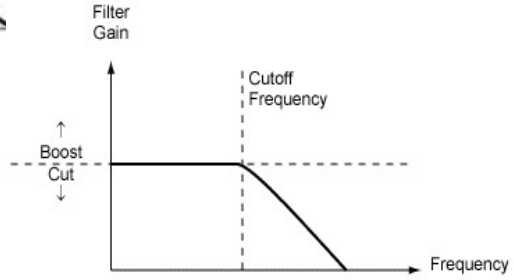
Types of Filters

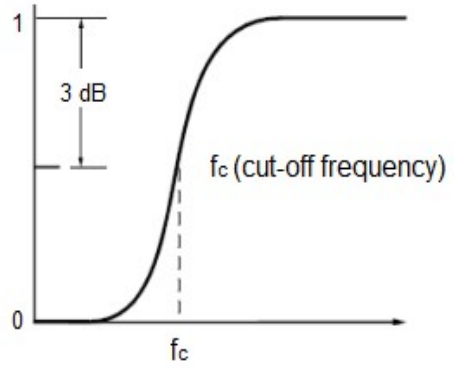
- Low-Pass Filters: The filter passes low frequencies and cuts off high frequencies
- High Pass Filters: The filter passes high frequencies and cuts off low frequencies
- Band Pass Filters: The filter passes frequencies in a certain band
- Band Stop Filters: The filter stops frequencies in a certain band
- Notch Filter: The filter stops just one specific frequency

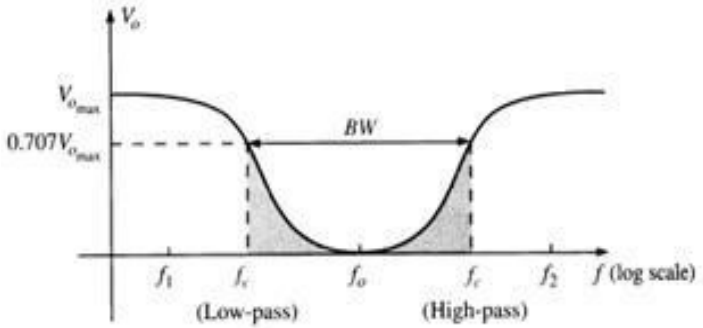
Identify the following filters!!





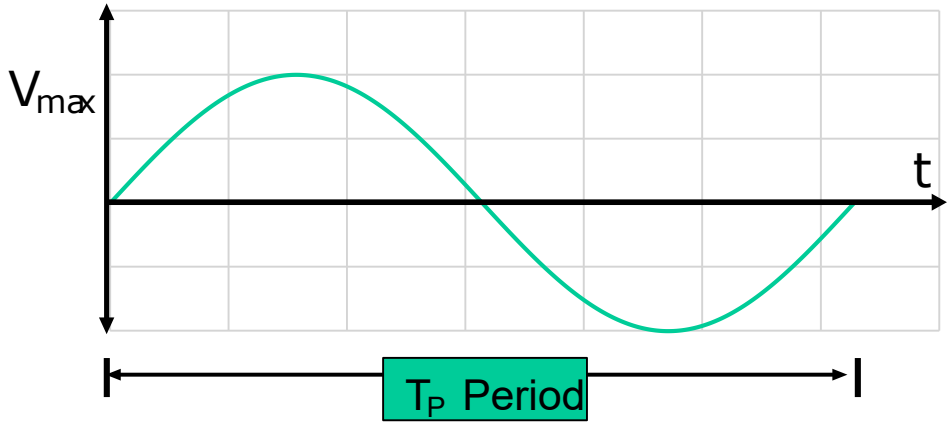




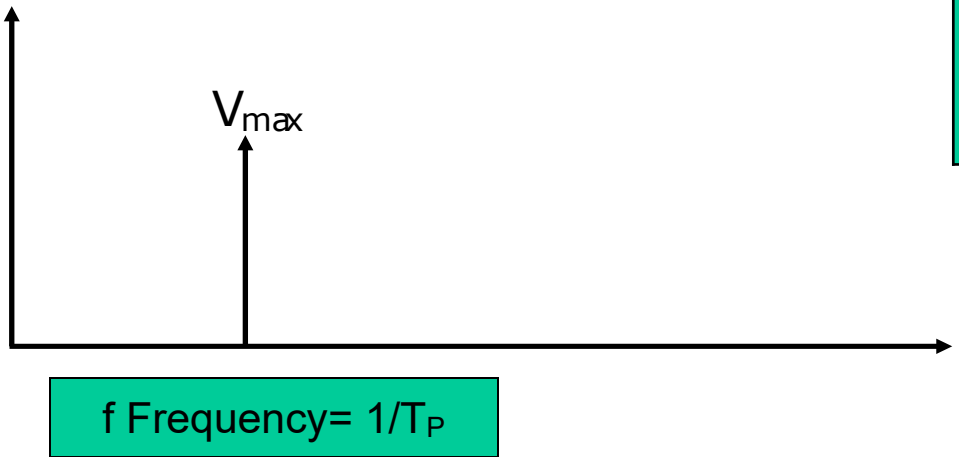


Time vs Frequency

- Time Domain



- Frequency Domain



We can represent a waveform in time domain as a line in the frequency axis with corresponding magnitude

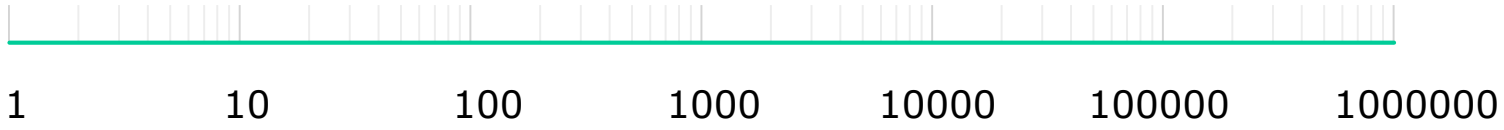
Frequency Response

- Frequency response is the quantitative measure of the output spectrum of a system or device in response to a stimulus, and is used to characterize the dynamics of the system
- It is a measure of magnitude and phase of the output as a function of frequency, in comparison to the input
- The graphs you identified for type of filters were the magnitude-frequency plots for different filters

Logarithmic Scale

- Response curves normally use a logarithmic scale of frequency, plotted along the horizontal x-axis
- This allows for a wider range of frequency to be accommodated than if a linear scale were used
- Linear frequency scale from 0-200Hz

- Logarithmic frequency scale from 1-1000000Hz



Power Gain in decibels (dB)

- The Voltage Amplification (Av) or Gain of a voltage amplifier/filter is given by:

$$A_V = \frac{V_{out}}{V_{in}}$$

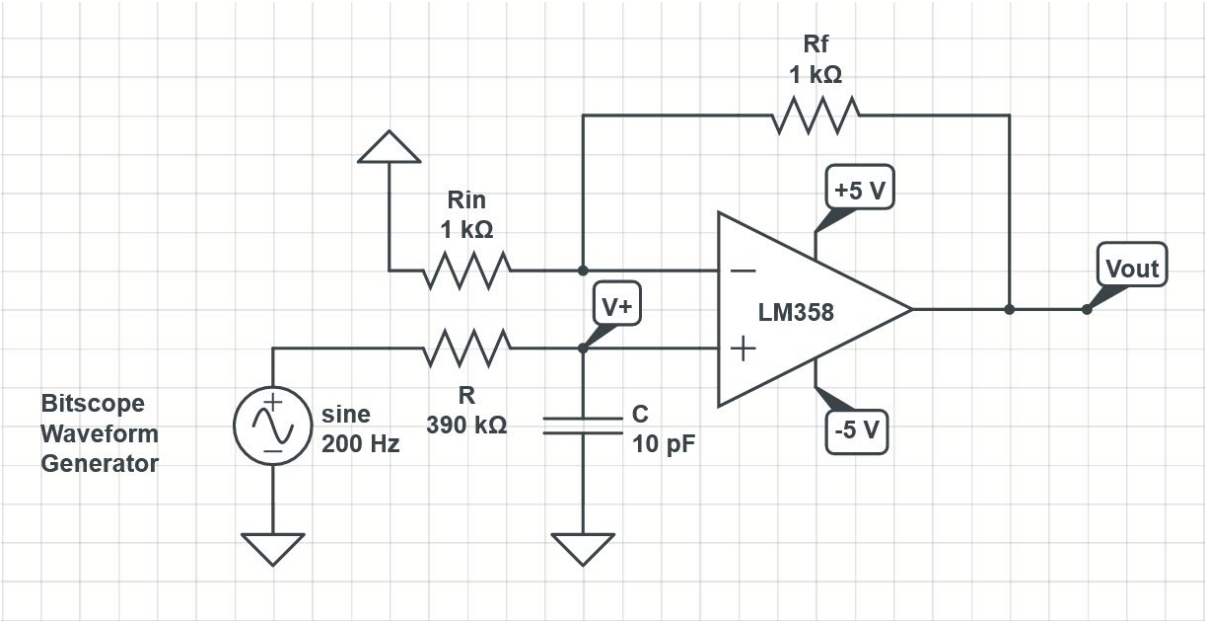
- To describe a change in output power over the whole frequency range of the amplifier/filter, a response curve, plotted in decibels is used to show variations in output

$$Power\ (dB) = 20log_{10}\frac{V_{out}}{V_{in}}$$

Low Pass Filter using Op-Amp

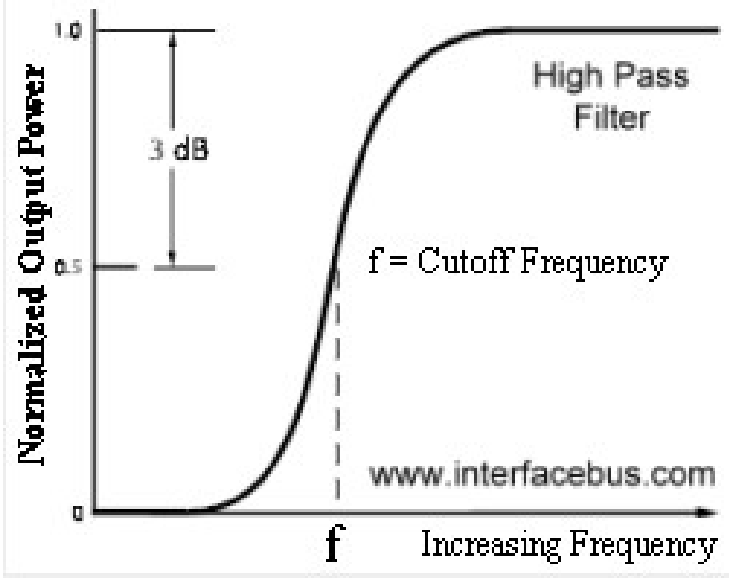
- The cut-off frequency of a low pass filter is given by

$$f_c = \frac{1}{2\pi RC}$$



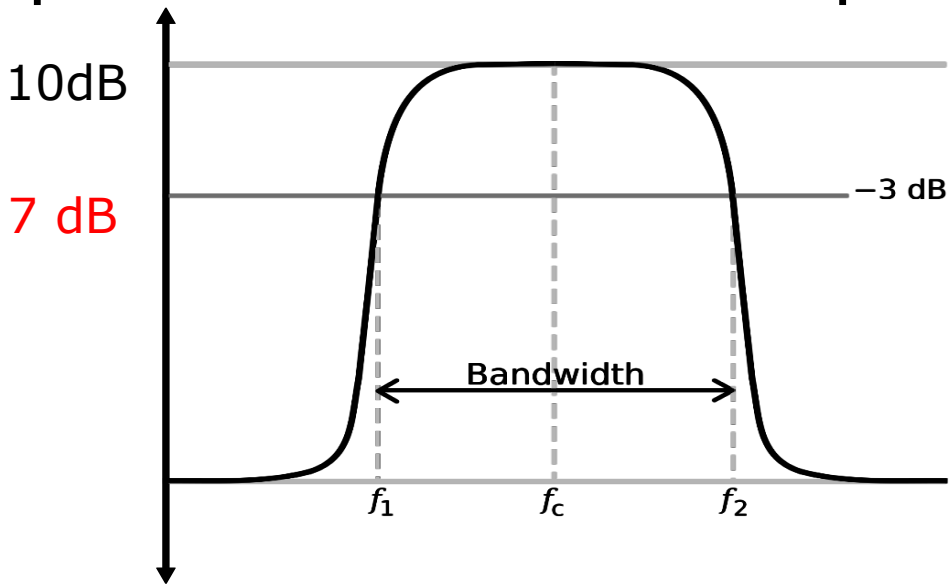
Cut-off Frequency

- In filters the cutoff frequency applies to an edge in a lowpass, high pass, bandpass, or band-stop characteristic – a frequency characterizing a boundary between a passband and a stopband
- It is taken to be the point in the filter response where a transition band and passband meet, as defined by a half-power point
- The cut-off frequency is taken as the frequency for which the output of the circuit is −3 dB of the nominal passband value



-3dB Point for Cut-off Frequency

- Find the pass band gain from the magnitude vs frequency plot
- Subtract 3db from the pass band gain and draw a line on the plot
- The points where this line cuts the plot corresponds to the cut- frequency(s)



THANK YOU