AuE 8200: Machine Perception and Intelligence

Homework 1

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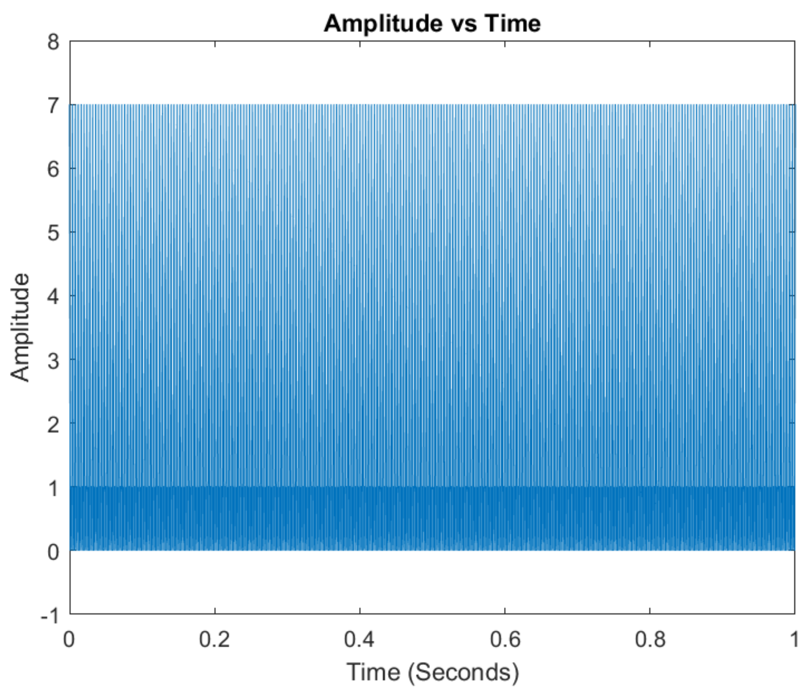
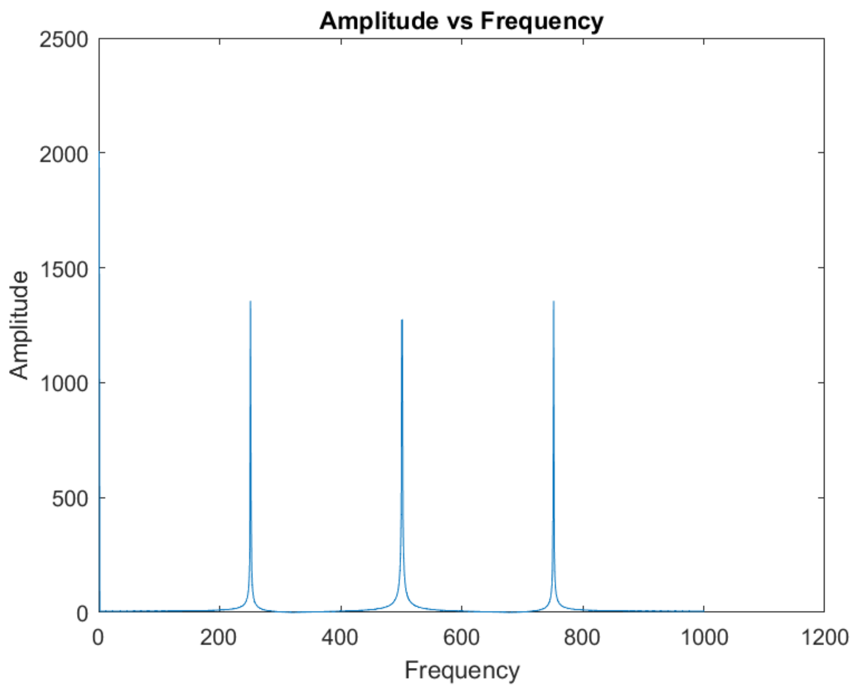
1. a) Visualize continuous period signal x(t) = 2 + 3*cos(500*pi*t) + 2*cos(1000*pi*t) + 3*sin(2000*pi*t) in time-domain (axis: Amplitude and t) (5 points)

```
fs = 1000;
t = 0:1/fs:1;
x = 2 + 3*cos(500*pi*t) + 2*cos(1000*pi*t) + 3*sin(2000*pi*t);
plot(t,x)
xlabel('Time (Seconds)')
ylabel('Amplitude')
title('Amplitude vs Time')
```



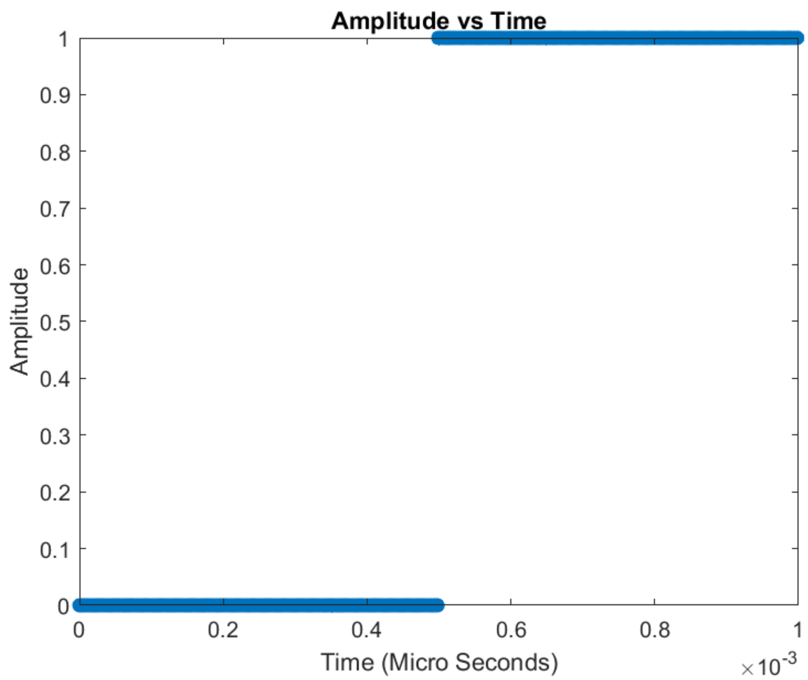
1. b) visualize its digital Fast Fourier transform (axis: Amplitude and f). Given Sampling frequency as 1K HZ. (5 points)

```
X = fft(x);
X_mag = abs(X);
plot(X_mag)
xlabel('Frequency')
ylabel('Amplitude')
title('Amplitude vs Frequency')
```



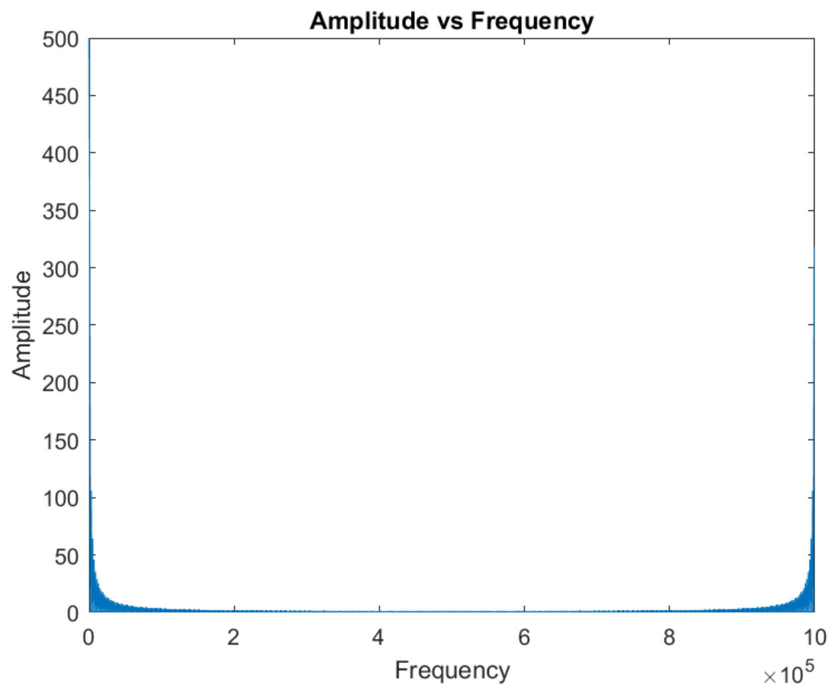
2. a) Visualize the discrete signal x(k) = 0 for k $\in$ [0 499] & x(k) = 1 for k $\in$ [500 1000) μs (sampling frequency as 1M HZ) in time-domain (Amplitude and t) (5 points);

```
fs = 1000000;

for t = [0:499]
    x = zeros(1,499);
end
for t = [500:999]
    x(end+1) = ones(1,1);
end

L = length(x);
T = (0:L-1)*1/fs;

figure
stem (T,x, "LineStyle", "none");
xlabel('Time (Micro Seconds)')
ylabel('Amplitude')
title('Amplitude vs Time')
ylabel('Amplitude')
title('Amplitude vs Time')
```

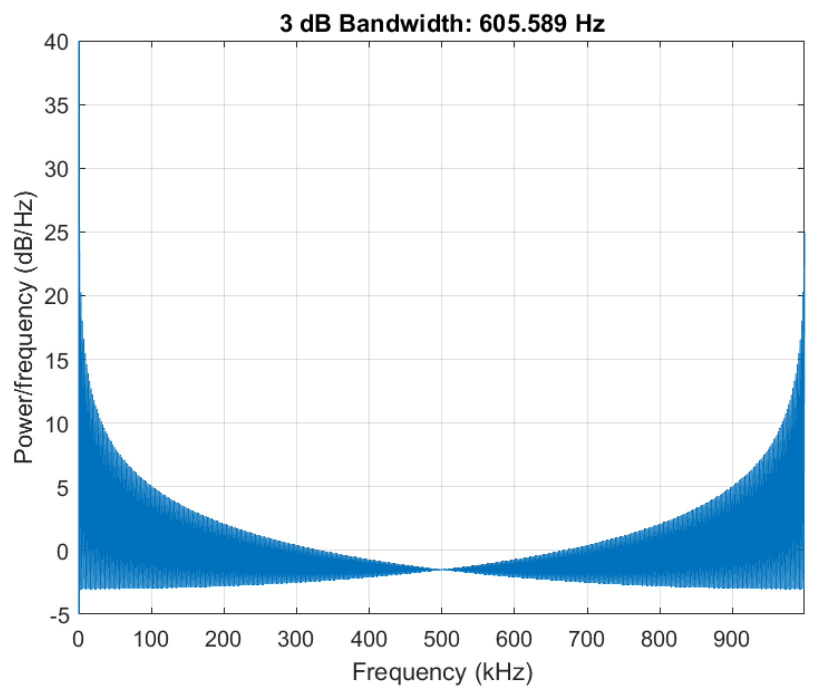


2. b) Visualize its digital Fast Fourier transform (Amplitude and f), find its -3dB (called half-power) bandwidth frequencies (f_low, f_high) in frequency spectrum. (15 points)

```
fs = 1000000;

for t = [0:499]
    x = zeros(1,499);
end
for t = [500:999]
    x(end+1) = ones(1,1);
end

y = abs(fft(x));
F = fs*(0:(L-1))/L;

figure
plot(F, y);
xlabel('Frequency')
ylabel('Amplitude')
title('Amplitude vs Frequency')
```




```
figure
powerbw(y, F);
```



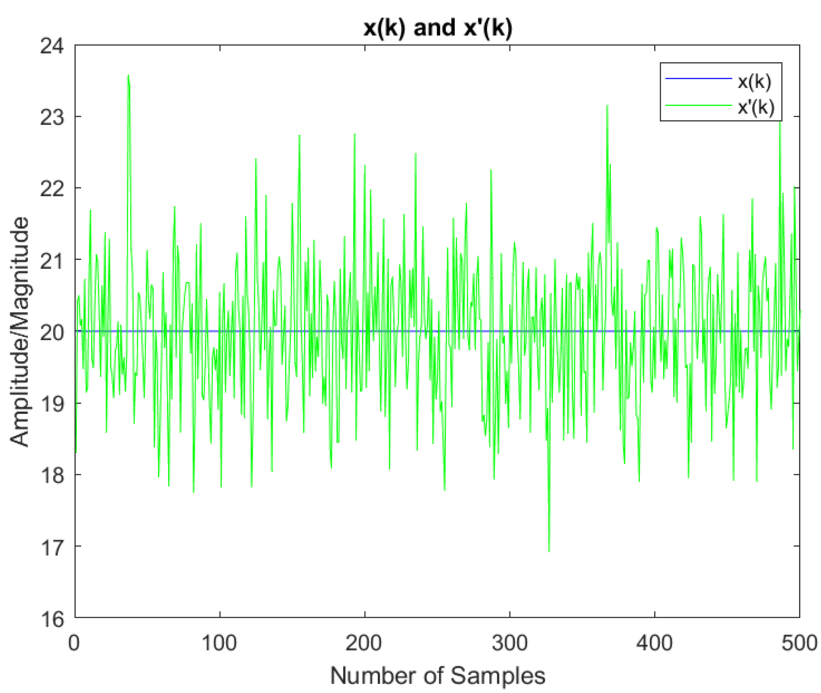

```
[bw,f_low,f_high,poweAr] = powerbw(y, F)
```

```
bw = 605.5886
f_low = 0
f_high = 605.5886
poweAr = 5.3392e+05
```

3. For discrete signal x(k) = 20 for k ∈[0 499], add a normally distributed random noise n(k) (mean 0, variance 1) to the signal, and get x′(k) = x(k) + n(k). Then, apply a normalized (mean 0, standard deviation 1) Gaussian kernel (windows size 3 and 11 respectively as a low pass filter, then rescale all elements to make sure the sum is 1) to perform convolution y(k) = x′(k) * h(k) (h presents the impulse response, and in this case it's the filter) by using basic arithmetic operations only. (Implement the convolution without using library API)

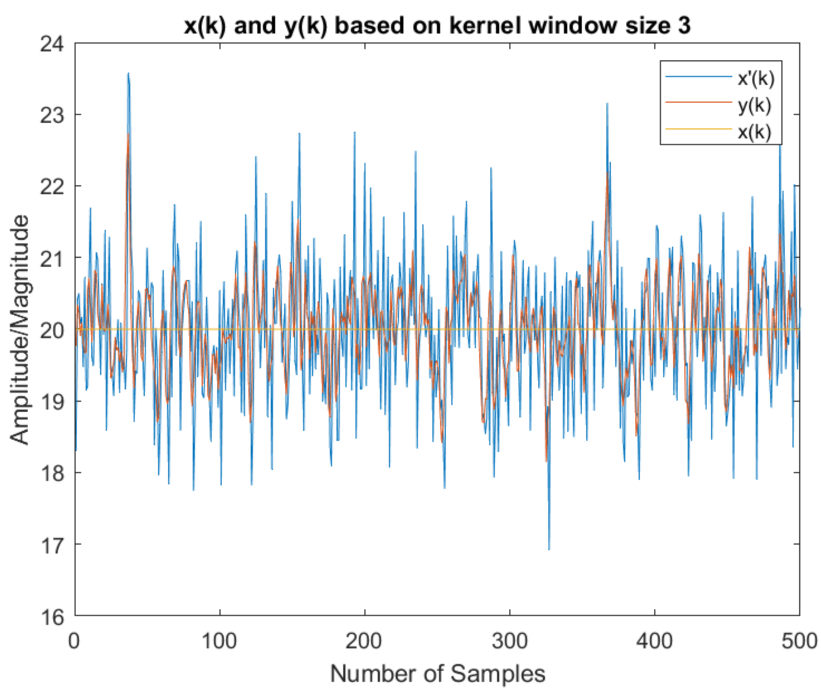
a) Visualize both x(k) and x′(k) in one figure (10 points)

```
x_k = [];

for t = [0:499]
    x_k(end+1) = 20;
end

noise = normrnd(0, 1, 1, 500);
noisy_x = x_k + noise;

plot(x_k, "Color", "blue")
hold on
plot(noisy_x, "Color", "Green")
legend("x(k)", "x'(k)")
title("x(k) and x'(k)")
xlabel("Number of Samples")
ylabel("Amplitude/Magnitude")
hold off
```



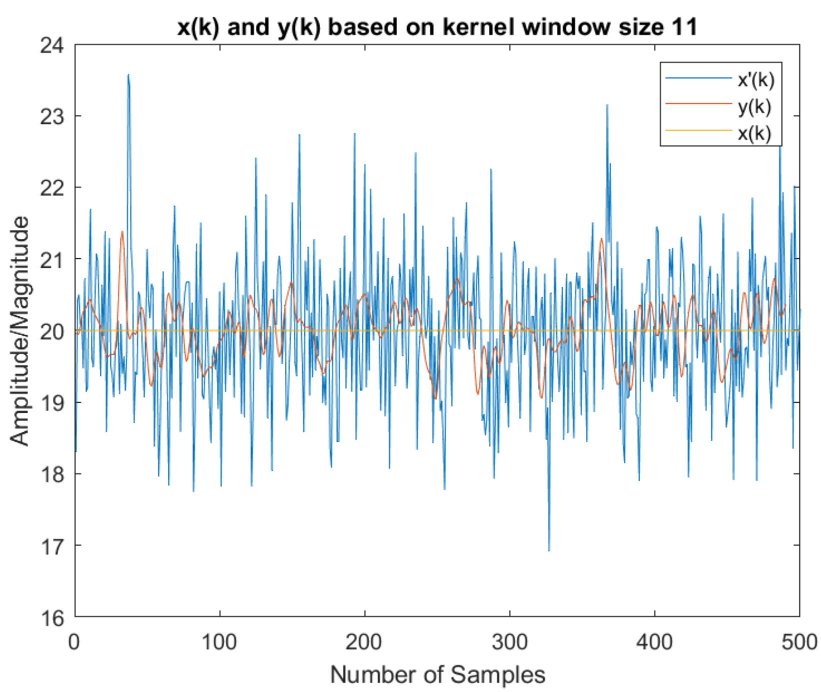
3. b) Visualize both x(k), and y(k) based on kernel window size 3 in one figure (15 points)

```
h_k = [0.31946576033846985, 0.3610684793230603, 0.31946576033846985];

i = 0;
n = 1;
new_array= [0];
y_k = [0];

for i = [0:1:497]
    P = noisy_x(1+i:3+i).*h_k;
    Q(1+i:3+i) = P;
    y_k(n) = sum(Q(1, 1+i:3+i));
    n = n+1;
end

figure
plot(noisy_x)
hold on
plot(y_k)
plot(x_k)
title("x(k) and y(k) based on kernel window size 3")
legend("x'(k)", "y(k)", "x(k)")
xlabel("Number of Samples")
ylabel("Amplitude/Magnitude")
```



3. c) Visualize both x(k), and y(k) based on kernel window size 11 in one figure (5 points)

```
 h_k = [0.009300040045324049, 0.028001560233780885, 0.06598396774984912,0.12170274650962626,
0.17571363439579307, 0.19859610213125314, 0.17571363439579307, 0.12170274650962626,
0.06598396774984912, 0.028001560233780885, 0.009300040045324049];

 i = 0;
 n = 1;
 new_array= [0];
 y_k = [0];

 for i = [0:1:489]
     P = noisy_x(1+i:11+i).*h_k;
     Q(1+i:11+i) = P;
     y_k(n) = sum(Q(1, 1+i:11+i));
     n = n+1;
 end

 figure
 plot(noisy_x)
 hold on
 plot(y_k)
 plot(x_k)
 title("x(k) and y(k) based on kernel window size 11")
 legend("x'(k)", "y(k)", "x(k)");
 xlabel("Number of Samples")
 ylabel("Amplitude/Magnitude")
```



Question4: Survey

Sensing and Measuring Vibrations in Automobiles

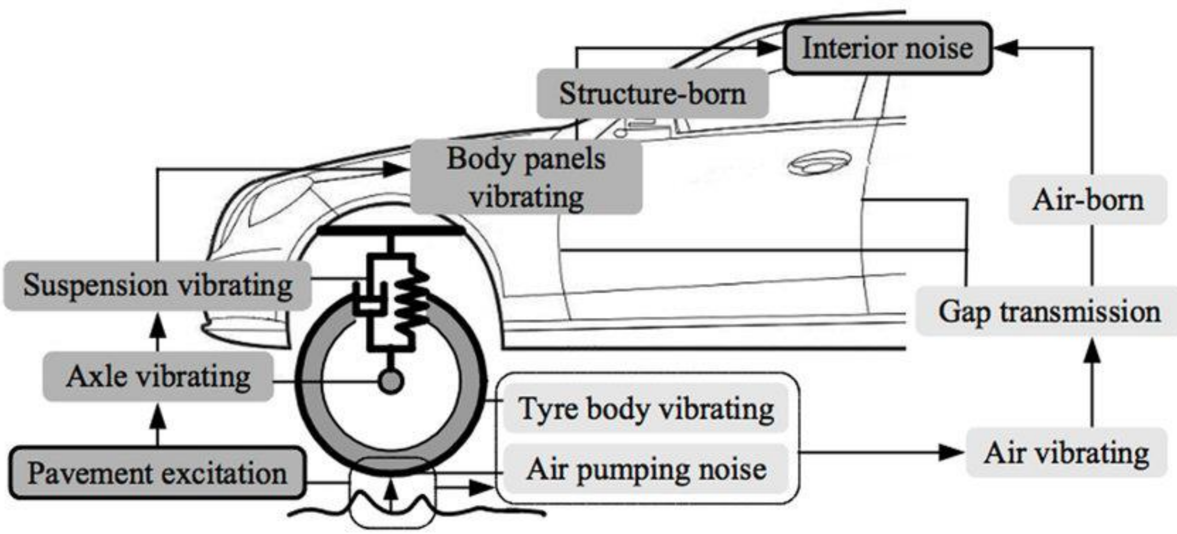
What is Vibration?

The movement or oscillation about the equilibrium position of a part, component, or assembly is termed as 'vibration.' It can be random, such as the movement of the tire on a road surface, or periodic like the motion of a pendulum. Typically, vibration is expressed in metric units (m/s^2).
Any object or component can vibrate in two manners: forced and free vibration.
Free vibration happens when an object is displaced and oscillates naturally without any external force. On the other hand, forced vibration occurs when an external force is repeatedly applied to the object. Forced vibration is often dangerous as normal environmental vibrations can match the component's natural frequency, resulting in more violent vibrations and premature failures.

Importance of Measuring Vibrations

Vibration affects the reliability and durability of components in an automobile. Over a while, undesirable vibrations can cause problems like reduced functioning capability, damage, or even failure of the affected parts.

In automobiles, vibration is normal, which results from rotating and moving parts, often triggered by usual manufacturing and assembly tolerances leading to clearances between mating components or inequities in rotating components. Although, usual wear can cause vibration to rise over time. However, a sudden rise in vibration indicates the components are being subjected to increased forces. Therefore, it is essential to measure vibration in the assembly and components of an automobile.

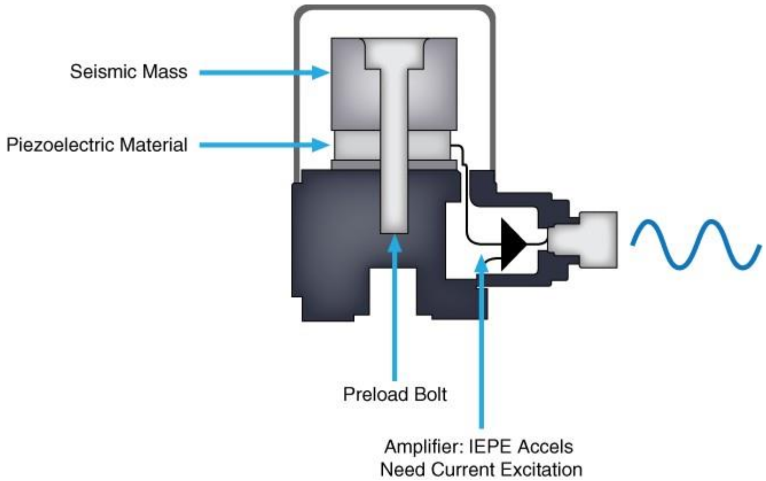


Source: https://www.researchgate.net/

Existing Approaches of Measuring Vibrations

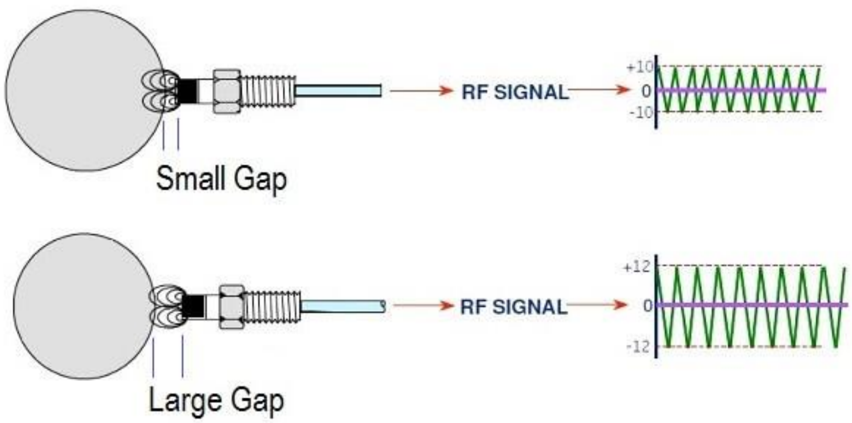
Vibration is commonly measured using an accelerometer (or a piezoelectric sensor) or proximity probe.

An accelerometer measures the dynamic acceleration of a physical device in the form of voltage. Typically, accelerometers are contact transducers mounted straight on high-frequency components such as gearboxes, rolling-element bearings, or spinning blades. Moreover, these sensors can also be employed to measure shocks and low-frequency vibrations. The benefit of using an accelerometer includes linearity over an extended dynamic range and wide frequency range.



Source: https://ni.scene7.com/is/image/ni/accelerometer_cross_section?scl=1

Another sensor used to sense and measure vibration is the proximity probe. Unlike accelerometers, which determine vibration using acceleration, proximity probes measure the distance to a target being a non-contacting transducer. Proximity sensors are exclusively used in rotating assemblies to sense the vibration of the rotating shaft.



Source: https://instrumentationtools.com/proximity-transducer-system-operation/

Vibration Frequency

Frequency depicts the number of times a component vibrates, or oscillates, per unit of time and is either expressed in cycler per minute (CPM) or cycles per second (Hertz or Hz). Frequency is the most fundamental parameter to analyze any kind of vibration. It helps narrow down the vibration causes, as every component vibrates at a distinct frequency or range.

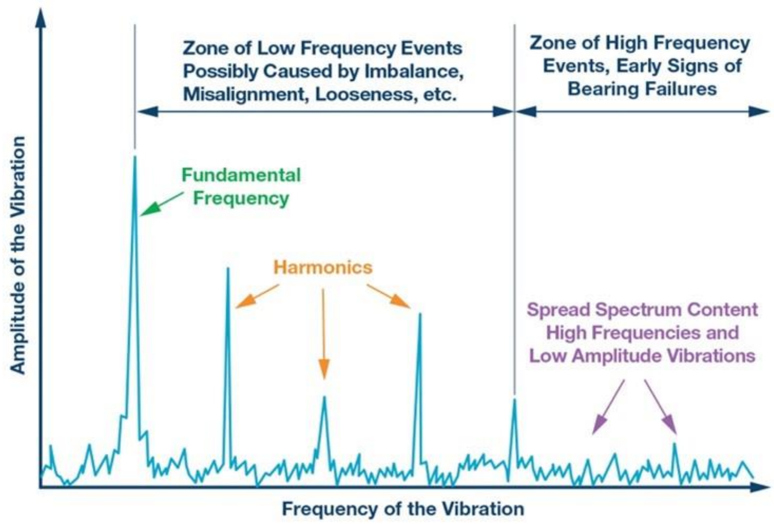
Vibration Amplitude

Amplitude depicts the magnitude of the oscillation and is used to find the severity of the vibration. Oscillations with significant amplitude show that the vibrations are large, forceful, or fast, causing more stress on the components and assemblies. Amplitude, in general, can be specified for three characteristics of oscillation, displacement, velocity, and acceleration.
Displacement amplitude: It measures the distance the vibrating component can travel in a single direction from a reference position during oscillations.
Velocity amplitude: It measures the speed of the oscillations, and it takes into account both vibration frequency and displacement.
Acceleration amplitude: It is directly related to the force conveyed by the vibration and helps assess the component's chances of fracture and failure.

Existing Problems of These Existing Approaches

There are certain problems in the existing approaches when it comes to sensing and measuring vibration.

For one, the main axis of the accelerometer should coincide with the desired measuring direction to avoid any erratic measurements. Secondly, accelerometers are sensitive to vibrations in the transverse direction and high-frequency noises.
Furthermore, most of the time, the vibration sensors fail to measure static signals and possess an inherent noise leading to inaccurate measurements.



Source: https://www.ien.eu/uploads/tx_etim/RO1_01.jpg

References

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2. https://www.motioncontroltips.com/how-is-machine-vibration-defined/
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