CS-215: Experiment 6B

Soumen Pradhan – 1912176

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1. Total Harmonic Distortion

Aim

To compute the Total Harmonic Distortion (THD) of a clipped sine wave.

Theoretical Background

Any Periodic Signal can be approximated by sum of sinusoidal signals. As the shape of signal departs from a pure sinusoid, higher frequencies get added into the approximation. This addition of higher frequencies is known as Harmonic Distortion.

THD can be thought of as a measure of contribution of the fundamental harmonic in the signal. The higher it is, the lower the contribution.

Methodology

- The ideal signal is generated and all values > 7 or < -7 are replaced.
- The ideal, real signals and their difference are plotted.
- The fundamental frequency is found using Fourier Transform.
- 2 new copies of Fourier Transform are made, one containing only fundamental Harmonics and another containing everything else.
- Inverse Fourier are applied and the 2 resulting time domain signals are plotted.
- Power of the signals are computed using the NORM function, i.e. $\frac{\text{NORM}(x)^2}{\text{LENGTH}(x)}$

Code

```
close all
clc

sampleRate = 1e-6;
timeRange = [0: sampleRate: 1e-3];
idealOut = 10 * sin(2*pi * 8000 * timeRange);

```

```
resPlt = subplot(2, 1, 1);
hold on
plot(timeRange, idealOut);

realOut = idealOut;
realOut(realOut > 7) = 7;
realOut(realOut < -7) = -7;

plot(timeRange, realOut);
plot(timeRange, realOut - idealOut);

legend('Ideal Response', 'Real Response', 'Error', ...
    'Location', 'northoutside', ...
    'Orientation', 'horizontal');
legend('boxoff');

pbaspect([4, 1, 1]);
set(gca , ...
    'Box'        ,'off'            , ...
    'TickDir'    ,'out'            , ...
    'YGrid'      ,'on'             , ...
    'YTick'      ,[-10: 5: 10]     );

hold off


ft = fft(realOut);
len = int32(length(ft) / 2);

fundFT = ft;
fundFT(fundFT < max(ft)) = 0;
fundHarm = ifft(fundFT, 'symmetric');

harmPlt = subplot(2, 1, 2);
hold on
plot(timeRange, fundHarm);

otherFT = ft;
otherFT(otherFT >= max(ft)) = 0;
otherHarm = ifft(otherFT, 'symmetric');

plot(timeRange, otherHarm);

legend('Fundamental Harmonic', 'Higher Harmonics', ...
    'Location', 'northoutside', ...
    "Orientation","horizontal");
legend('boxoff');
```

```
pbaspect([4, 1, 1]);
set(gca, ...
    'Box'       ,'off'          , ...
    'TickDir'   ,'out'          , ...
    'YGrid'     ,'on'           , ...
    'YTick'     ,[-10: 5: 10]   );

hold off
print('harmonics.eps', '-depsc');


fs = 1 / sampleRate;
freqRange = (-len+1: len-1) * fs / (2 * len);
freqRange = round(double(freqRange), 2, 'significant');

subplot(1, 1, 1);
ftPlt = plot(freqRange, abs( fftshift(ft) ));

freqData = zeros(len, 2);
freqData(:, 1) = abs(ft(1: len))';
freqData(:, 2) = freqRange(len: end)';
freqData = sortrows(freqData, 'descend');
freqData(freqData(:, 1) < freqData(4, 1), :) = [];

text(freqData(:, 2), freqData(:, 1), ...
    num2cell(freqData(:, 2)'), ...
    'VerticalAlignment','bottom');

pbaspect([2, 1, 1]);
set(gca, ...
    'Box'       ,'off'  , ...
    'TickDir'   ,'out'  , ...
    'YGrid'     ,'on'   );
axis([0, freqRange(end) / 6, -500, 4500]);

print('ft.eps', '-depsc');
```

Input Description

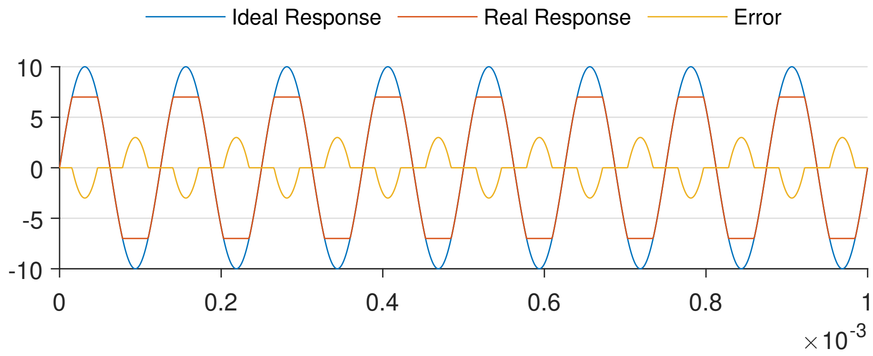
The ideal response is:

$$10 \cdot \sin\left(2\pi \cdot 8000t\right)$$

Saturation Voltage $= \pm 7$ volts

The sampling is 10^{-6} s or 1 Mhz;

Result



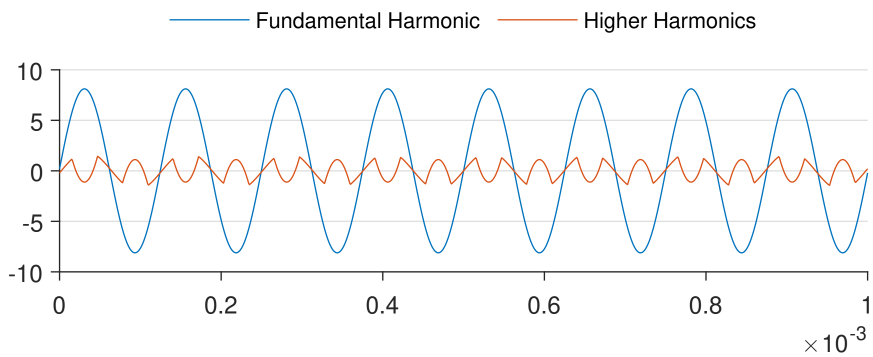


Figure 1.1: *Signal and the decomposition into Harmonics*

Power of

Ideal Signal $= 49.95$

Real Signal $= 33.54$

Fundamental Harmonic $= 32.92$

Other Harmonics $= 0.62$

Since,

$$\text{THD} = \frac{\text{power of higher harmonics}}{\text{power of fundamental harmonic}} = \frac{0.6247}{32.9239} \cdot 100\% = 1.89\%$$

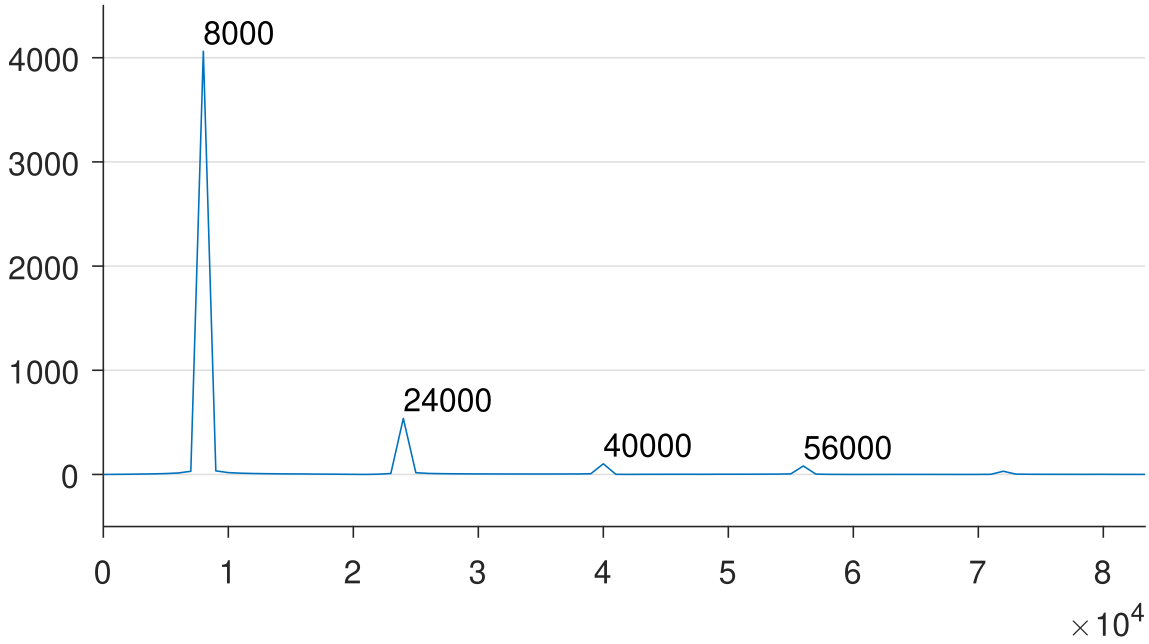


Figure 1.2: *Fourier Transform.*

Note: Frequencies of spikes are in Hz and amplitude is real absolute value of complex fourier transform.

All higher spike frequencies are odd multiple of fundamental frequency (8000 Hz). Also, since signal is real, the transform is conjugate symmetric and only half the graph is shown.

Conclusion

The fundamental harmonic contains most of the power of the real response. The amplitude in Fourier Transform can be interpreted as the power contained by that frequency.