Assignment-1

Analog Electronics

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1) a) Generate a square wavefrom (approximate) using sinusoildal waveforms with different frequencies. (start from 5 kHz)
   b) Pass this square wavefrom with an amplifier with a gain A(w) and the following frequency response
      i) (upto 10 kHz A(w) = 1)
      ii) (From 10 kHz to 50 kHz A(w) = 5)
      iii) (From 50 kHz to 200 kHz A(w) = 2)
      iv) (From 200 kHz to 1 MHz A(w) = 1)
      v) (From 1 MHz to 2 MHz A(w) = 0.3)
      vi) (From 2 MHz and above A(w) = 0)
   c) Pass the square waveform generated in (a) with an ideal low-pass filter with cut-off frequenecy = 8 kHz. Get the output waveform.

   Solution: Here the MATLAB to generate the above waveforms

```
% Define time steps and initialize signal arrays
t = 0:0.001:1; % Create a time vector with 0.001s steps from 0 to 1 second
y = zeros(size(t)); % Initialize two empty arrays for storing signals
y1 = zeros(size(t));

% Define constants
k = 2 * pi; % Constant used for calculating sine wave frequencies

% Loop through harmonics (odd multiples of 5)
for i = 1:2:100
    % Define amplitude based on harmonic frequency
    if 5 * i >= 5 && 5 * i < 10
        A = 1; % Amplitude for harmonics between 5 and 10 Hz
    elseif 5 * i >= 10 && 5 * i < 50
        A = 5; % Amplitude for harmonics between 10 and 50 Hz
    elseif 5 * i >= 50 && 5 * i < 200
        A = 2; % Amplitude for harmonics between 50 and 200 Hz
    elseif 5 * i >= 200 && 5 * i < 1000
        A = 1; % Amplitude for harmonics between 200 and 1000 Hz
    elseif 5 * i >= 1000 && 5 * i < 2000
        A = 0.3; % Amplitude for harmonics between 1000 and 2000 Hz
    elseif 5 * i >= 2000
        A = 0; % No contribution for harmonics at or above 2000 Hz
    end

    % Add sine wave component for harmonics within 5 - 100 Hz range
    if 5 * i >= 5 && 5 * i <= 100
```

```
        y = y + (4 / (pi * i)) * sin(k * 5 * i * t); % Add weighted sine wave to original signal
    end

    % Add scaled sine wave component for all harmonics to amplified signal
    y1 = y1 + A * (4 / (pi * i)) * sin(k * 5 * i * t); % Add weighted and scaled sine wave to
        amplified signal
end

% --- Implementing Low-Pass Filter ---

% Get the Fast Fourier Transform of the amplified signal
Y1 = fft(y1);

% Define frequency domain and create filter mask
f = k * (1:length(Y1)) / (2 * pi); % Calculate frequencies from the FFT data
filter_mask = ones(size(f)); % Create a mask with all frequencies initially passed

% Set stopband mask to attenuate frequencies above 8 Hz
filter_mask(f > 8) = 0; % Set all frequencies above 8 Hz to zero in the mask

% Apply filter and inverse transform to get filtered signal
Y2 = filter_mask .* Y1; % Apply the filter mask to the frequency spectrum
y2 = ifft(Y2); % Convert the filtered frequency spectrum back to time domain

% --- Plotting the Signals ---

% Figure 1: Original Signal
figure;
plot(t, y, 'b');
xlabel('Time (s)');
ylabel('Amplitude');
title('Original Signal');
grid on;

% Figure 2: Amplified Signal
figure;
plot(t, y1, 'g');
xlabel('Time (s)');
ylabel('Amplitude');
title('Amplified Signal');
grid on;

% Figure 3: Filtered Signal
figure;
plot(t, y2, 'r');
xlabel('Time (s)');
ylabel('Amplitude');
title('Filtered Signal (Figure 3)');
grid on;
```

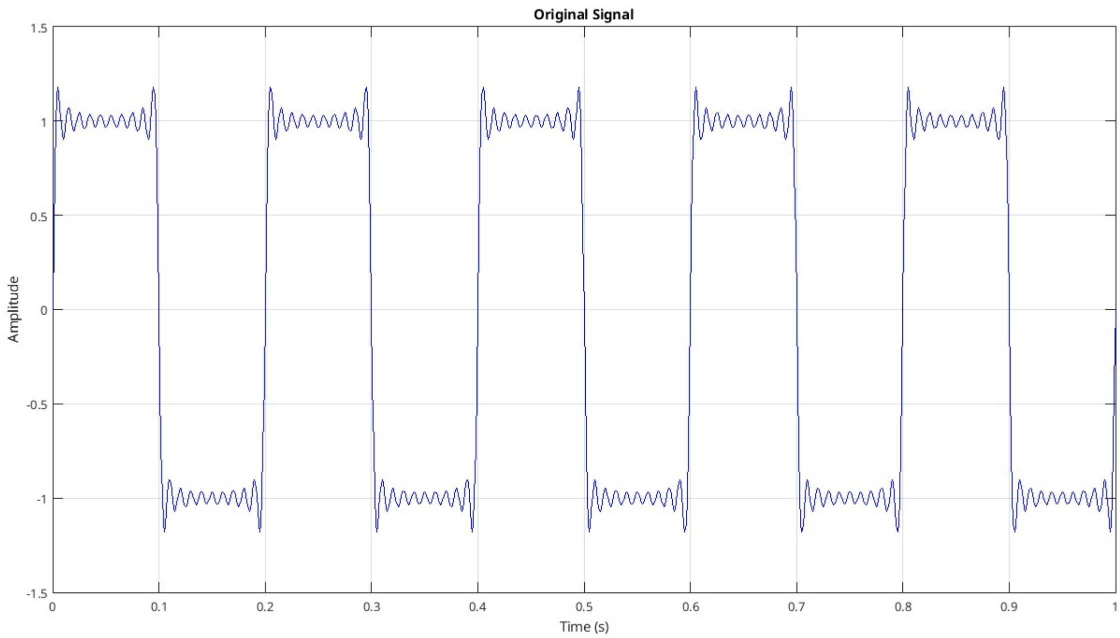

Fig. 1. The i/p signal generated for 100 harmonics,

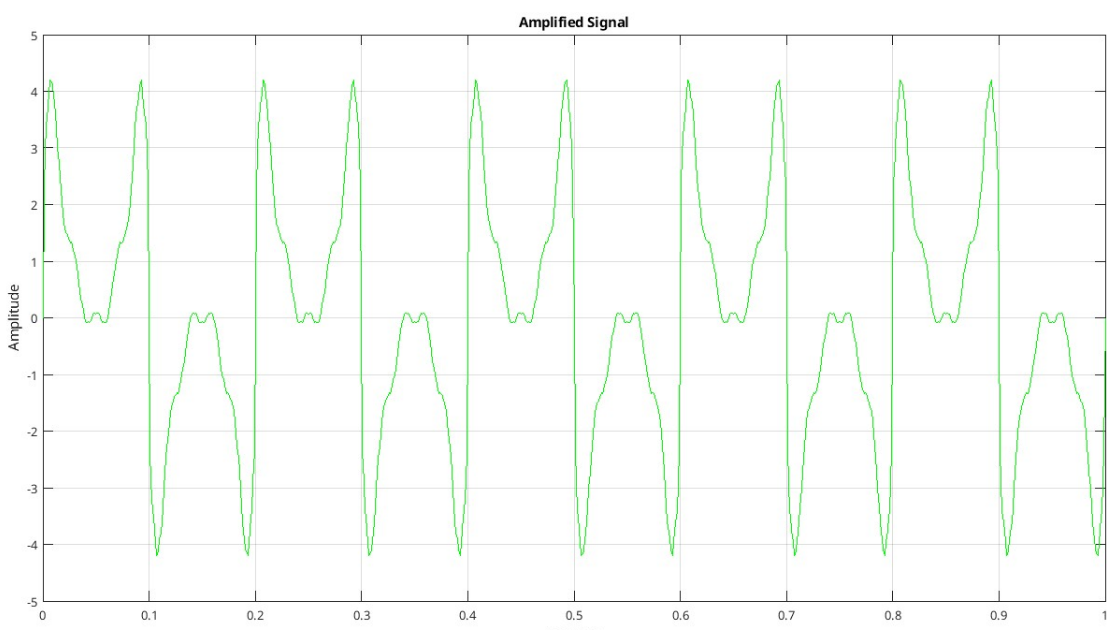

Fig. 1. The amplified i/p signal with variable amplification at different frequencies,

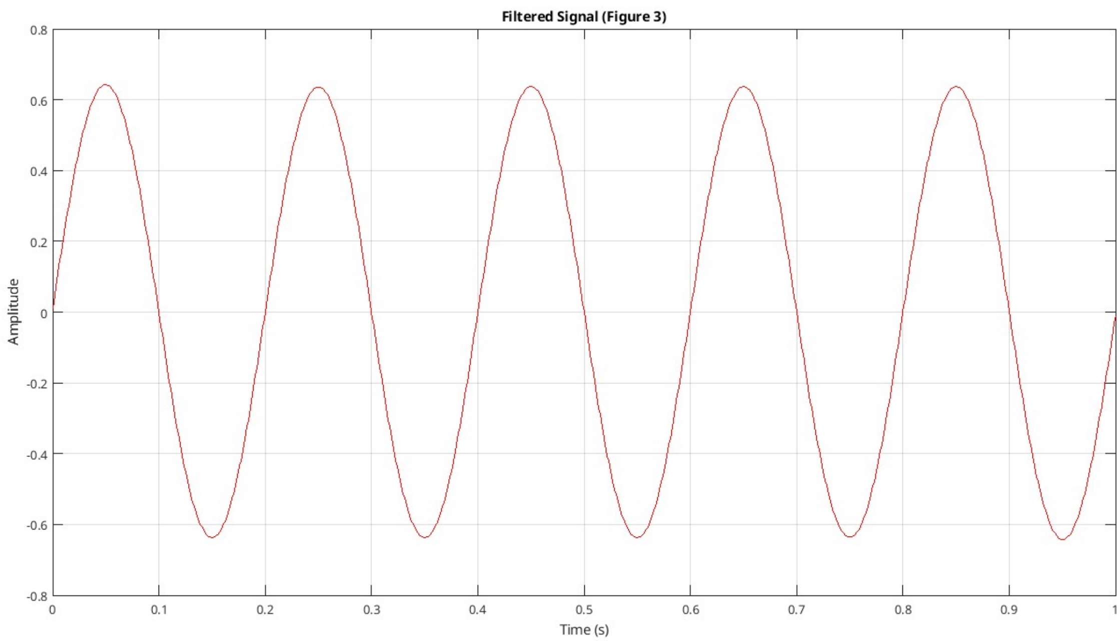

Fig. 1. The filtered ampliplified i/p signal with cutoff at 8khz

Conclusion:

We created a square wave by putting together different sinusoidal waves, starting at 5 kHz. We then ran this square wave through an amplifier that changed how much it boosted or reduced different frequency ranges. After that, we used a filter to keep only the parts of the wave below 8 kHz and cut out the rest. The end result was a modified waveform, showing how amplification and filtering can alter the original square wave.

2) A nonlinear device is with following input/output characteristics:

$$I_{out} = \beta V_{in}^2 \tag{1}$$

Consider β = 10mA/V2 ,and V_{in} = 1V. Find out DC operating point corrospondingly. Find out the range of incremental change in Vin for that the device still considered as a linear one with less than (i) 1%, (ii) 5% non-linearilty.

Solution:

(2) at dc operating point,

$I_{out,dc} = 10\,mA$

$V_{in,dc} = 1\,V$

$I_{out} = \beta V_{in}^2$

$\beta = 10\,mA/V^2$

taking a small change in I_{out} as ΔI_{out},

then, $(I_{out} + \Delta I_{out}) = \beta(V_{in} + \Delta V_{in})^2$

$\Rightarrow I_{out} + \Delta I_{out} = \beta V_{in}^2 + 2\beta V_{in}(\Delta V_{in}) + (\Delta V_{in})^2$

~~$\Delta I_{out} =$~~

Now, $\boxed{\Delta I_{out} = 2\beta(V_{in})(\Delta V_{in}) + (\Delta V_{in})^2}$

Linear component of $\Delta I_{out} = 2\beta(V_{in})(\Delta V_{in})$

at dc point,

(linear) $\Delta I_{out} = 2 \times 10 \times 10^{-3} \times 1 \times \Delta V_{in}$

(linear) $\boxed{\Delta I_{out} = 20(\Delta V_{in}) \times 10^{-3}}$

$$\%\ \text{Non linearity} = \left|\frac{\Delta I_{out} - \Delta I_{out}(\text{linear})}{\Delta I_{out}}\right| \times 100$$

$$= \frac{\pm \beta(\Delta V_{in})^2}{2\beta(V_{in})(\Delta V_{in}) + \beta(\Delta V_{in})^2} \times 100$$

$$\boxed{\%\ NL = \frac{\pm \Delta V_{in}}{2V + \Delta V_{in}} \times 100}$$

i) at tolerance 1%,

$$\pm 0.01 = \frac{\Delta V_{in}}{2V + \Delta V_{in}}$$

$\Rightarrow 0.02V + 0.01\,\Delta V_{in} = \Delta V_{in}$

$\Rightarrow (\Delta V_{in})(0.99) = 0.02 \times 1$

$\Rightarrow \Delta V_{in} = \frac{0.02}{0.99} = +0.0202$ Volts

$\boxed{\Delta V_{in} = +0.0202 \text{ Volts}}$

or, $-0.02V + 0.01\,\Delta V_{in} = \Delta V_{in}$

~~$\Rightarrow -0.01\,\Delta V_{in} =$~~

$\Rightarrow -0.02 \times 1 = 1.01\,\Delta V_{in}$

$\Rightarrow \boxed{\Delta V_{in} = -0.0198 \text{ Volts}}$

$\Delta V_{in,1\%} \in \{-0.0198, +0.0202\}$ V

ii) at tolerance, 5%,

$$\pm 0.05 = \frac{\Delta V_{in}}{2V + \Delta V_{in}} \Rightarrow \pm 0.05 = \frac{\Delta V_{in}}{2 + \Delta V_{in}}$$

solving for ΔV_{in}

~~$\Delta V_{in} = \pm 1.05$~~ $\Delta V_{in} = +0.105$ V

$\Delta V_{in} = -0.0952$ V

$\Delta V_{in,5\%} \in \{-0.0952, +0.105\}$ V