Simulation # 6

Fourier analysis of waveforms

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Aim: **Fourier analysis of waveforms**

Objective:

a. Understanding the concept of Fourier analysis of output waveforms
b. Fourier analysis of a triangular waveform
c. Extending the study to compare output of two square waveform generators based on Fourier analysis

Theory:

Fourier analysis is a method of analysing complex periodic waveforms. It permits any nonsinusoidal period function to be resolved into sine or cosine waves, possibly an infinite number, and a DC component. This permits further analysis and allows you to determine the effect of combining the waveform with other signals.

Given the mathematical theorem of a Fourier series, the period function f(t) can be written as follows:

$$f(t) = A_0 + A_1\cos\omega t + A_2\cos 2\omega t + \ldots + B_1\sin\omega t + B_2\sin 2\omega t + \ldots$$

Where:

A_0 = The DC component of the original wave.
$A_1\cos\omega t + B_1\sin\omega t$ = the fundamental component (has the same frequency and period as the original wave).
$A_n\cos n\omega t + B_n\sin n\omega t$ = the nth harmonic of the function.
A, B = the coefficients.

Each frequency component (or term) of the response is produced by the corresponding harmonic of the periodic waveform. Each term is considered a separate source. According to the principle of superposition, the total response is the sum of the responses produced by each term. Note that the amplitude of the harmonics decreases progressively as the order of the harmonics increases. This indicates that comparatively few terms yield a good approximation.

When Multisim performs Discrete Fourier Transform (DFT) calculations, only the second cycle of the fundamental component of a time-domain or transient response (extracted at the output node) is used. The first cycle is discarded for the settling time. The coefficient of each harmonic is calculated from the data gathered in the time domain, from the beginning of the cycle to time point t. That is set automatically and is a function of the fundamental frequency. This analysis requires a fundamental frequency matching the frequency of the AC source or the lowest common factor of multiple AC sources.

Fourier analysis produces a graph of Fourier voltage component magnitudes and, optionally, phase components versus frequency. By default, the magnitude plot is a bar graph but may be displayed as a line graph. The analysis also calculates Total Harmonic Distortion (THD) as a percentage. The THD is generated by notching out the fundamental frequency, taking the square root of the sum of the squares of each of the n harmonics, and then dividing this number by the magnitude of the notched out fundamental frequency:

$$THD = [(S_{i=2} Vi^2)/V_1] \text{ x } 100\%$$

Where V_i is the magnitude of the i^{th} harmonics.

Table 1 describes the **Analysis Parameters** tab in detail.

Table 1 Parameters used in Fourier analysis

Parameter	Meaning
Frequency resolution (Fundamental frequency)	Sets the frequency of an AC source in your circuit. If you have several AC sources, use the lowest common factor of frequencies. Click the **Estimate** button to have the fundamental frequency estimated.
Number of harmonics	Sets the number of harmonics of the fundamental frequency that are calculated.
Stop time for sampling (TSTOP)	Sets the amount of time during which sampling should occur. You can specify this value to avoid unwanted transient results prior to the circuit reaching steady-state operation.
Edit transient analysis	Displays the **Analysis Parameters** tab of the **Transient Analysis** window. The analysis will use either the **Maximum time step (TMAX)** and **Set initial time step (TSTEP)** values that you enter in this tab, or an automatically calculated minimum value that is based on the value in the **Frequency resolution (Fundamental frequency)** field in the **Analysis Parameters** tab of the **Fourier Analysis** window—whichever offers a higher sampling rate (resulting in a more accurate simulation).
Display phase	Displays phase results.
Display as bar graph	Displays results as bar graph. If not enabled, results are displayed as line graph.
Normalize graphs	Normalizes graphs against the 1st harmonic.
Display	Choose a display option: **Chart**, **Graph**, or **Chart and Graph**.
Vertical Scale	Choose a vertical scale: **Linear**, **Logarithmic**, **Decibel**, or **Octave**.
Degree of polynomial for interpolation	Enable to enter degree to be used when interpolating between points on simulation. The higher the degree of polynomial the greater the accuracy of the results.
Sampling frequency	Specifies a sampling frequency. This value should be equal to the frequency resolution (the number of harmonics plus one) multiplied by at least 10.

Procedure:

1. Figure 1 shows a circuit which generates a triangular waveform with a frequency of about 1 kHz.

2. Open the **Oscilloscope** front panel and run the simulation. Observe the output of the circuit.

3. Select **Simulate » Analyses » Fourier analysis**. The **Fourier analysis** window opens.

4. Configure the **Analysis Parameters** as per Figure 2**.**

5. Click the **Edit transient analysis** button and configure the **Transient Analysis parameters.**

6. Select the **Output** tab. Select the **Variables in circuit** list, select **Static Probes** from the drop-down list, and then highlight **V(Probe1)** from the list. Click the **Add** button to move the variable to the right side under **selected variables for analysis.**

7. Click **Simulate**.

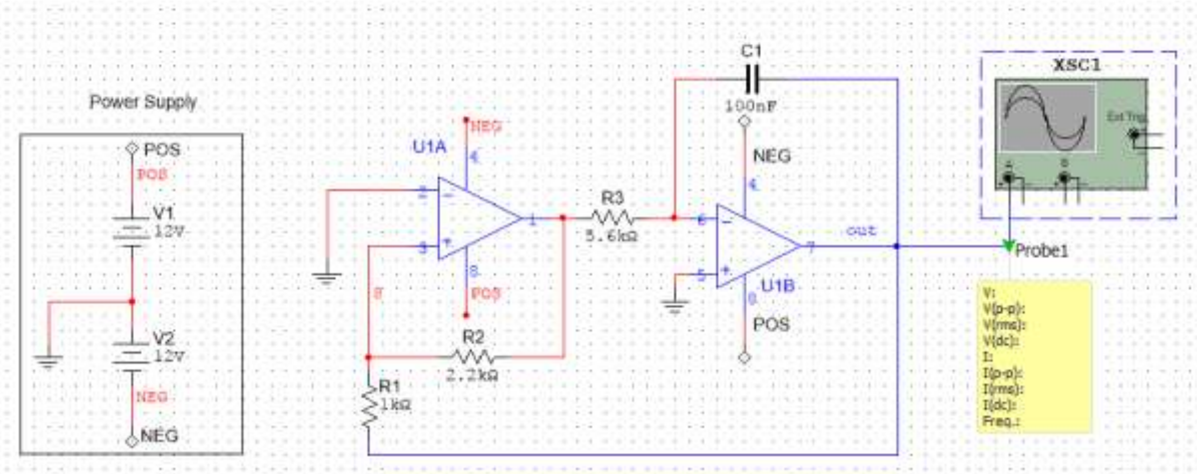

Figure 1 Triangular wave generator

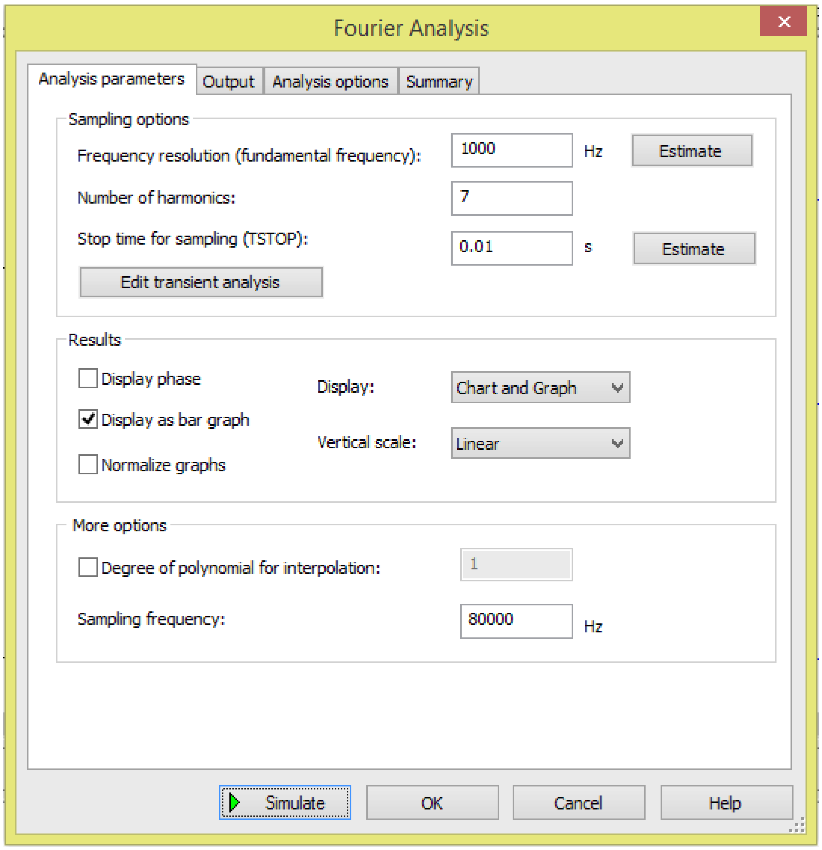

Figure 2 Parameters setting for Fourier analysis

Questions:

1. For any two square wave generating analog circuit, perform the Fourier analysis and compare the result.
2. Compare the harmonic content of a triangular and a square waveform.
3. Is it possible to build a square waveform using multiple undistorted sinusoidal waveforms?