ece341_lab1

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January 19, 2016

Part I

Frequency domain measurements

This lab measures an interesting opamp circuit and explores the frequency-domain measurements available on the `MSOX-2004A` oscilloscopes.

1 Procedure

1.1 Switch-hitter

Construct the circuit of Figure 1. The `LM324N` IC includes four opamps with a common power supply. The 3 unused amplifiers should be connected as shown in Figure 2 to avoid floating inputs.

Apply an input sinusoid of $1\,\mathrm{V_{peak}}$ at $1\,\mathrm{kHz}$. Measure the amplifier's gain, $A_v = v_o/v_i$, for varying positions of the potentiometer, including each end of rotation. Display both the input and output to also be able to measure the transfer function's phase.

Analyze this circuit and express the circuit's gain as a function of potentiometer rotation $x \in [0, 1]$. Use Figure 3 as the model of a potentiometer for circuit analysis.

Leave this circuit setup for use with the next part.

1.2 Oscilloscope FFT function

Connect the function generator directly to a 'scope input and turn off all other inputs. Set the function generator to output a sinusoid of $2\,\mathrm{V_{p-p}}$ at $1\,\mathrm{MHz}$ with no offset. Display the waveform with a horizontal time scale of $5\,\mu\mathrm{s/div}$. Press the "Math" button and set the operator to "FFT". Set the FFT frequency settings to a span of $10\,\mathrm{MHz}$ and center of $5\,\mathrm{MHz}$. Also, ensure the vertical units setting in the "More FFT" menu is set to "V RMS" instead of decibels. Adjust the scale and position knobs next to the Math button to show all of the spectrum (place the input sinusoid waveform small and at the bottom).

The purple display should show a single spike at the first horizontal division from the left.

Use the cursors to measure the maximum amplitude and frequency of the spike. Ensure the cursors are in the "Track Waveform" mode.

Switch the waveform to "square" with 50% duty cycle and measure the frequencies and amplitudes of the spikes in the spectrum.

- Compare these amplitudes with those calculated by the Fourier series of a $1\,\mathrm{MHz}$, $1\,\mathrm{V_p}$ square wave.

Switch the FFT amplitude setting to display in decibels. The scope uses units of dBV which are decibels referenced to $1\,\mathrm{V_{RMS}}$, or $x\,\mathrm{dBV} = 20\log_{10}\left(\frac{x\,\mathrm{V_{RMS}}}{1\,\mathrm{V_{RMS}}}\right)$. Convert the measured and predicted square wave harmonic amplitudes from linear to dBV units and compare.

Change the amplitude units back to $\mathrm{V_{RMS}}$.

Switch the waveform to "pulse" and set the pulse width to $500\,\mathrm{ns}$. Isn't this just a 50% duty cycle square wave? Slowly decrease the pulse width to its minimum setting and observe the spectrum. Notice how the even harmonics are completely gone *only* when the waveform is symmetric, as predicted by Fourie'r analysis.

- From the spectrum plot for the minimum pulse width, can you predict what the time-domain waveform should be? (You may want to change the FFT scale.) Change the time-domain display to zoom into the function generator output to confirm and correlate your observations.

Switch the waveform back to a sinusoid and the spectrum amplitude to dBV. From the "Acquire" button, turn on averaging and notice the spikes which appear in the spectrum. These spikes are periodic and not noise (whose amplitude is lowered by the averaging). The spikes are harmonic distortion from the signal generator. Measure the decibel difference in amplitude between the fundamental frequency and the amplitude of the largest harmonic. This difference is in units of dBc or "decibels relative to the carrier (the fundamental)". It should be somewhere around $-40\,\mathrm{dBc}$. Cross-reference this measurement with the oscilloscope datasheet's claim about the WaveGen's output sinusoid's purity from the table at the end of the document. %

Finally, attach the signal generator to the input of the switch-hitter circuit and probe both the input and output. Set the switch-hitter gain to the +1 setting. Set the signal generator to a $40\,\mathrm{kHz}$ square wave and setup the FFT display to show in decibels.

Measure the amplitude (in dBV) of the first 5 harmonics of the input signal and also the first 5 harmonics of the output signal in dB.

- Use this information to calculate the gain of the opamp circuit at each of these frequencies.

2 Report

Write-up your report according to the format guide.