Homework #2 Solution Set

(23 points - 1 per problem)

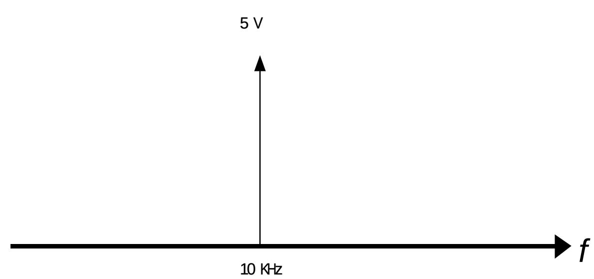
1. *What is the frequency domain?*

   The <u>frequency domain</u> is a way of representing signals. In this representation, the individual frequencies that make up the signals are shown. The strength of each individual component frequency is also shown, usually in RMS units.

2. *What are the units on the horizontal axis of a spectrum analyzer?*

   The horizontal axis of a spectrum analyzer is calibrated in <u>frequency (Hz)</u>.

3. *Draw a 10 KHz, 5 V RMS sine wave as it would be seen on the display of a spectrum analyzer.*



   The figure above shows a 10 KHz, 5 V RMS sine wave as it would appear on the display of an ideal spectrum analyzer.

4. *What is the only "pure" waveform?*

   The only "pure" waveform is the sine wave, because a sine wave has only one frequency.

5. *A square wave has a period of 2 mS. What is its fundamental frequency?*

   The frequency can be calculated as follows:

$$f = \frac{1}{T} = \frac{1}{2mS} = \underline{\underline{500Hz}}$$

6. *If a non-sinusoidal waveform has a frequency of 3 KHz, what are the frequencies of its 2^{nd}, 3^{rd}, and 4^{th} harmonics?*

   The 2^{nd} harmonic is at (2)(3 KHz) or <u>6 KHz</u>.
   The 3^{rd} harmonic is at (3)(3 KHz) or <u>9 KHz</u>.
   The 4^{th} harmonic is at (4)(3 KHz) or <u>12 KHz</u>.

7. *What approximate (practical) bandwidth would be needed to reproduce a square wave with a frequency of 10 KHz, ignoring the DC level?*

Since the DC level is being ignored, the approximate bandwidth will be the difference between the 13th harmonic (130 KHz) and the fundamental (10 KHz), which is the same as *12 times the fundamental frequency***, or 120 KHz.**

8. *What type of waveform is being displayed below in figure 2-26?*

The waveform being displayed is a pure sine wave; there is only one frequency present.

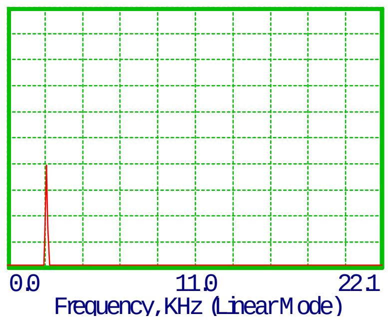


Figure 2-26: A Display for Analysis (Vertical, 5 Volts/Division)

9. *What is the period and peak voltage of the waveform being displayed above in figure 2-26?*

To find the period, the frequency must be determined. The horizontal scale is from DC to 22.1 KHz, which is also 10 divisions. Therefore, the frequency scale is (22.1 KHz - 0 Hz)/(10 Divisions) or *2.21 KHz/Division***. The energy appears at the first division, therefore it is at approximately 2.21 KHz.**

The period is:

$$T = \frac{1}{f} = \frac{1}{2.21KHz} \approx \underline{\underline{450mS}}$$

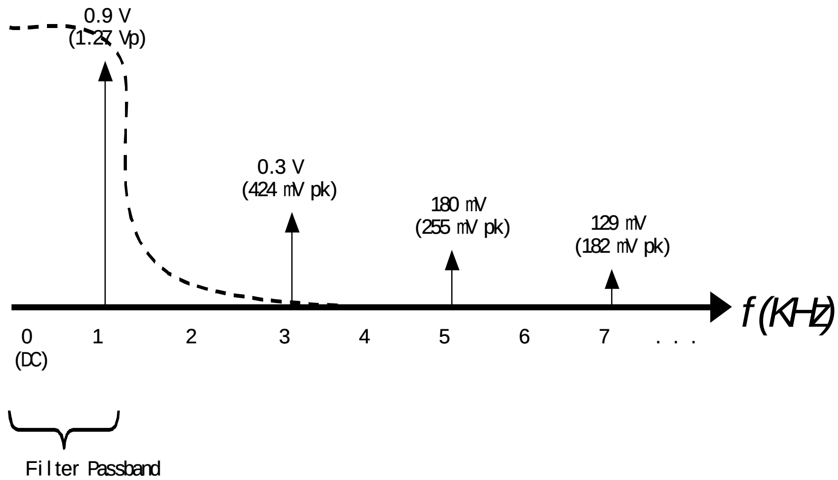
The peak voltage is calculated by reading the RMS voltage from the graph. The 2.2 KHz energy has an RMS voltage of (4 Divisions)(5 Volts/Division) = 20 V RMS. The peak voltage is:

$$V_{pk} = \sqrt{2} \times V_{RMS} = \underline{\underline{28.3Vpk}}$$

10. *How many frequencies are present in a perfect square wave?*

A perfect (ideal) square wave contains an infinite number of frequencies.

11. *If the signal of figure 2-8 is fed into an ideal low-pass filter with a cutoff frequency of 1 KHz, what will the filter's output signal be if viewed on an oscilloscope?*



The filter's output will be a <u>1 KHz sine wave</u>, because the low-pass filter will reject all frequencies except for the 1 KHz fundamental.

12. *List and explain at least two external noise sources.*

a) <u>Cosmic Noise</u> - Radiated energy from the sun and other stars.
b) <u>Atmospheric Noise</u> - Radiated interference from lightning, wind friction, etc.
c) <u>Man Made Noise</u> - Electrical noise from machinery and electronic equipment.

13. *What factors control the Voltage of a Johnson noise source?*

The three factors are the <u>temperature</u>, the <u>bandwidth</u>, and the <u>noise resistance</u>.

14. *What noise Voltage will be generated across a 10KW resistor under the following conditions? (a) T = 20 °C, fmin = 1 MHz, fmax = 4 MHz ; (b) T = 112 °F, fmin = 100 Hz, fmax = 10 KHz ; (c) T = 100 °C, bandwidth = 1 MHz*

a) T = 20°C = 293 °K, BW = (4 MHz - 1 MHz) = 3 MHz.

$$Vn = \sqrt{4\,k\,T\;BW\;\mathrm{R}} = \sqrt{(4)(1.38\mathrm{x}10^{-23})(293)(3MHz)(10K\Omega)} = \underline{\underline{22mV}}$$

b) T = 112 °F = 317.6 °K, BW = (10 KHz - 100 Hz) = 9.9 KHz.

$$Vn = \sqrt{4\,k\,T\;BW\;\mathrm{R}} = \sqrt{(4)(1.38\mathrm{x}10^{-23})(317.6)(9.9KHz)(10K\Omega)} = \underline{\underline{1.3mV}}$$

c) T = 100 °C = 373 °K, BW = 1 MHz (given).

$$Vn = \sqrt{4\,k\,T\;BW\;\mathrm{R}} = \sqrt{(4)(1.38\mathrm{x}10^{-23})(373)(1MHz)(10K\Omega)} = \underline{\underline{14.3mV}}$$

15. *If a certain amplifier has an input noise power of 1mW and an input signal power of 1 mW, what is the resulting SNR power ratio?*

The SNR power ratio is:

$$SNR = \frac{Ps}{Pn} = \frac{1mW}{1mW} = \underline{\underline{1000:1}}$$

16. *What is the decibel S/N ratio for the amplifier of problem 15?*

$$SNR(dB) = 10\log\left(\frac{Ps}{Pn}\right) = 10\log\left(\frac{1mW}{1mW}\right) = \underline{\underline{30dB}}$$

17. *A certain amplifier has 1 mV of input noise, and 10 mV of input signal.*
(a) What is the SNR power ratio? ; (b) What is the SNR ratio in decibels?

a) $SNR = \left(\frac{Vs}{Vn}\right)^2 = \left(\frac{10mV}{1mV}\right)^2 = \underline{\underline{100:1}}$

b) $SNR(dB) = 20\log\left(\frac{Vs}{Vn}\right) = 20\log\left(\frac{10mV}{1mV}\right) = \underline{\underline{20dB}}$

18. *If the signal voltage in an amplifier is fixed at 1 Volt, what is the maximum noise voltage that can be present while maintaining a 25 dB (or better) S/N ratio?*

This result can be obtained by solving equation (2-7) for Vn, the voltage of the noise:

(2-7) $SNR(dB) = 20\log\left(\frac{Vs}{Vn}\right)$

$$Vn \le \frac{Vs}{10^{(dB/20)}} \le \frac{1V}{10^{(1.25)}} \le \underline{\underline{56.2mV}}$$

19. *What is the noise figure of an amplifier?*

The <u>noise figure</u> is a measurement of the amount of noise introduced by an amplifier or other electronic system. It is calculated by subtracting the input and output decibel S/N ratios.

20. *If an amplifier has a noise figure of 5 dB, and the input S/N is 50 dB, what will the resulting S/N at the output be*?

The output S/N will be 5 dB worse than the input, or 45 dB.

21. *A certain amplifier is rated with a noise figure of 1.5 dB. A technician measured a S/N of 30 dB at the input, and 27 dB at the output. Does the amplifier meet its specification? Why or why not*?

The technician measured a NF of (30 dB - 27 dB) or 3 dB. The amplifier does not meet specifications; it is out of tolerance by 1.5 dB.

22. *What are three measures that are used to reduce the pickup of external noise*?

a) Metal shielding around sensitive circuit areas
b) Directional antennas that point away from known noise sources
c) Use of shielded cable and connectors, to prevent accidental signal leakage
d) Use of the minimum bandwidth necessary for communications

23. *What are three circuit construction techniques that reduce internal noise*?

a) The use of low-noise resistors (typically carbon-film or wire-wound).
b) The application of low-noise semiconductors (such as GaSFETs).
c) Using the lowest possible resistor values in sensitive circuits.
d) Special component layout techniques to reduce unwanted circuit interactions.
e) Reducing forward-bias currents in diodes and transistors to the minimum practical values, in order to reduce shot noise.
f) Refrigeration (an expensive and generally impractical/exotic method.)