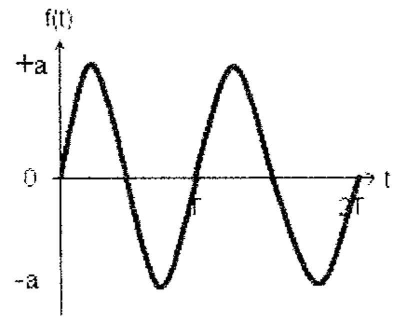
Nevin
Liang

Week 2: Oscilloscopes and Function Generators

RMS of a periodic signal is calculated by first squaring the waveform, then taking its mean over its period, T, then taking the square root. Its definition using the calculus is

$$\text{RMS} = \sqrt{\frac{1}{T}\int_0^T f^2(t)\,dt} \quad .$$

As an example, we will derive the equation for RMS/Vpp for a sine wave. You will be asked to derive the equation for square waves and triangular waves in the pre-lab.



First, $f(t) = a\sin\left(\frac{2\pi t}{T}\right) \rightarrow RMS = \sqrt{\frac{1}{T}\int_0^T \mathrm{a}^2 \sin^2\left(\frac{2\pi t}{T}\right) dt}$

Using the definition of $\sin^2(\theta) = \frac{1-\cos(2\theta)}{2}$, $RMS = \sqrt{\frac{a^2}{T}\int_0^T \frac{1-\cos\left(\frac{4\pi t}{T}\right)}{2} dt}$

Taking the integral, $RMS = \sqrt{\frac{a^2}{T}\left[\frac{1}{2}t - \frac{\frac{1}{2}\mathrm{T}}{4\pi}\sin\left(\frac{4\pi t}{T}\right)\right]_0^T}$

Evaluating, we get $RMS = \sqrt{\frac{a^2}{T}\left[\frac{1}{2}T\right]}$ (Note that at t = 0 and T, $\sin\left(\frac{4\pi t}{T}\right) = 0$)

Therefore, $RMS = \frac{a}{\sqrt{2}}$, and since $Vpp = 2a$, then $\frac{\boldsymbol{RMS}}{\boldsymbol{Vpp}} = \frac{1}{2\sqrt{2}}$

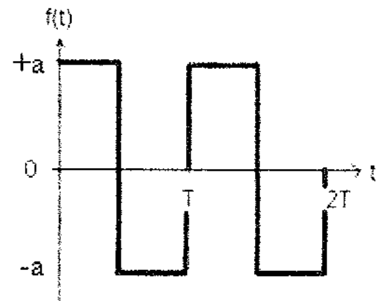
It may for the purposes of your lab helpful to think of RMS in terms of Vpp, like so:

$$RMS = \frac{Vpp}{2\sqrt{2}}$$

Week 2 Prelab

Calculate the ratio RMS/Vpp for the following signals. Show all your work!
Name:

1. Square Wave: RMS / Vpp = ? UID: 705575353



$V_{pp} = 2a$

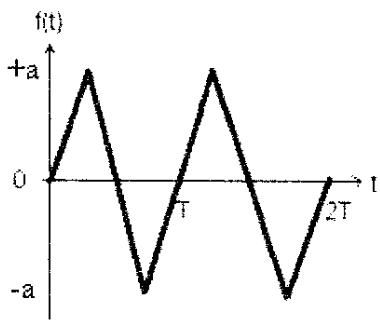
$RMS = \sqrt{\frac{1}{T}\int_0^T f^2(t)\,dt}$

$= \sqrt{\frac{1}{T}\cdot a^2 \cdot T}$

$= a$

$\frac{RMS}{V_{pp}} = \boxed{\frac{1}{2}}$

2. Triangular Wave: RMS / Vpp = ?



$V_{pp} = 2a$

$RMS = \sqrt{\frac{1}{T}\int_0^T f^2(t)\,dt}$

$= \sqrt{\frac{1}{T}\cdot 4 \cdot \int_0^{T/4} \left(t \cdot \frac{4a}{T}\right)^2 dt}$

$RMS = \frac{a}{\sqrt{3}}$ $\boxed{ans = \frac{1}{2\sqrt{3}}}$ $= \sqrt{\cancel{\frac{1}{T}}\cdot\cancel{4}\cdot\frac{16a^2}{\cancel{T^2}}\cdot\frac{1}{3}\cdot\frac{\cancel{T^3}}{\cancel{64}}}$

3. If you see a difference by a factor of 10 between the oscilloscope reading and the function generator setting, where is the first place that you should look? Watch the Probe Setting video (https://youtu.be/dtSuTHIviSo) for the answer.

The first place to look is the probe attenuation and the channel ratio.

4. If you see a difference by a factor of 2 between the oscilloscope reading and the function generator setting, where is the first place that you should look? Watch the Function Generator Output Impedance video (https://youtu.be/-8Dv1oOjD9w) for the answer.

   Look at the utility button → channel 1. There might be internal resistance.

5. Why would you ever want to use AC coupling on an oscilloscope? Watch the AC Coupling video (https://www.youtube.com/watch?v=dtSuTHIviSo&t=6s) for the answer.

   Sometimes square waves look really bad. Using AC coupling lets you increase the sensitivity and see noise and then keep increasing until you see structure.

Week 2 Prelab End

Time Dependent Measurements

This week's experiments will give you the opportunity to learn the basic operations of an oscilloscope and a function generator.

Setting up Function Generator and Oscilloscope

1. Turn on both the function generator (Figure 2-1a) and oscilloscope (Figure 2-2).
2. Connect the function generator's CH1 output to the CH1 input of the oscilloscope.
3. Press the function generator Output button next to the CH1 connector if it is not lit.
4. You will now learn to display the input signal properly by using the three basic functions of the oscilloscope: Horizontal control, Vertical control, and Triggering.
5. [INITIALIZATION]
    a. Press the Save/Recall button in the Measure section of the controls.
    b. Push the Recall soft switch.
    c. Push the "Load from setup_0" soft switch.
    d. Press the "Press to Recall" soft switch. This is your starting point.
6. The display should be similar to that shown in Figure 2-1.

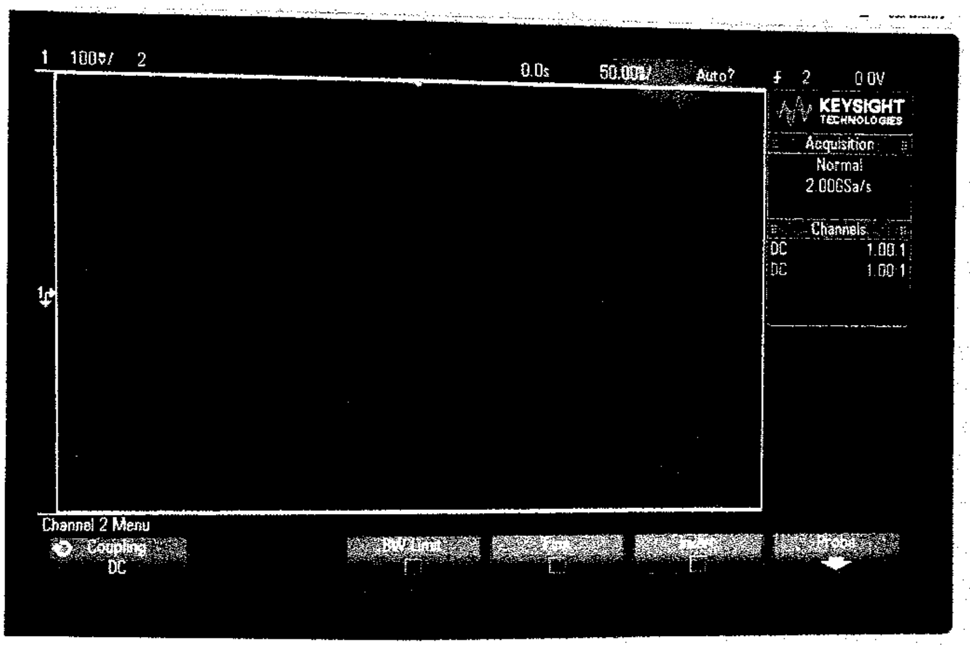


FIGURE 2-1. .Unstabilized, Horizontally and Vertically Incorrect, Sinusoid Display.