RMS error is the average error (in engineering units), also called the **standard deviation**.

$$e_{rms} = \sqrt{\left(\frac{1}{N}\right)^2 \sum_{i-1}^{N} (m_i - \overline{m})^2}$$

ε_{rms} = rms error [eng. units]
N = number of samples
m_i = sample [eng. units]
$\overline{m}$ = mean value (avg. value) [eng. units]

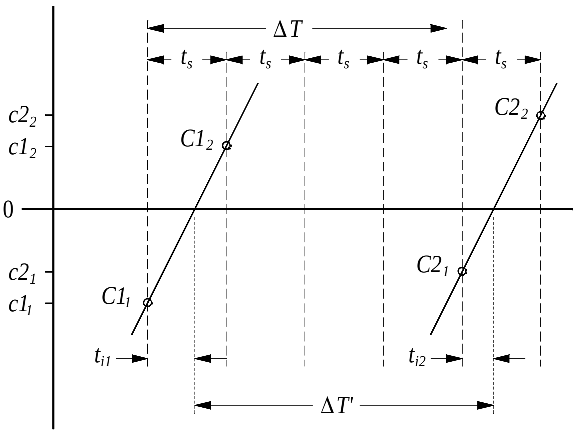
MEASURING PHASE SHIFT:

Finding the **phase shift** on the scope:

$$\phi = \frac{\Delta t}{T} \times 360 \text{ degrees}$$

ϕ = phase shift [degrees]
Δt = difference in time of the zero-crossings of two waveforms [seconds]
T = period [seconds]

Finding **phase shift** by **interpolation**:



where:

- t_s = the sample period of the scope [seconds]
- t_{i1} = the horizontal distance from cursor position $C1_1$ to the zero crossing of the first wave [seconds]
- t_{i2} = the horizontal distance from cursor position $C2_1$ to the zero crossing of the second wave [seconds]
- $\Delta T'$ = the actual offset of the two waves [seconds]
- ΔT = the offset of the two waves as measured by the first-selected cursor positions [seconds]
- $C1_1$ = the first-selected position of Cursor 1
- $C2_1$ = the first-selected position of Cursor 2
- $C1_2$ = the second-selected position of Cursor 1
- $C2_2$ = the second-selected position of Cursor 2
- $c1_1$ = the vertical dimension of the first-selected position of Cursor 1 [volts]
- $c2_1$ = the vertical dimension of the first-selected position of Cursor 2 [volts]
- $c1_2$ = the vertical dimension of the second-selected position of Cursor 1 [volts]
- $c2_2$ = the vertical dimension of the second-selected position of Cursor 2 [volts]

$$t_{i1} = \frac{|c1_1|}{|c1_1| + |c2_1|} t_s \qquad t_{i2} = \frac{|c2_1|}{|c2_1| + |c2_2|} t_s$$

$$dT' = dT - t_{i1} + t_{i2}$$

DETERMINING THE TIME CONSTANT τ:

Method 1: Where the voltage can be observed reaching the steady state value:

1) Place cursor C2 where the voltage appears to have reached the steady state. It remains here.
2) Place cursor C1 at another point on the curve.
3) Record ΔV_1 and ΔT_1.
4) Move C1 to another position along the curve.
5) Record ΔV_2 and ΔT_2.
6) Solve for **τ**

$$\ln \frac{\Delta V_2}{\Delta V_1} = \frac{-|\Delta T_1 - \Delta T_2|}{\tau}$$

Method 2: This method can be used even when the steady state voltage value is not visible:

1) Place cursor C2 on the curve near its midpoint relative to the *x*-axis. It remains here.
2) Choose a value for ΔT such that cursor C1 may be placed this distance from C2 on either side.
3) Using C1, determine values ΔV_1 and ΔV_2 found by placing C1 ΔT from the left and ΔT from the right of C2.
4) ΔV_1 and ΔV_2 are interchangeable, affecting only the sign of the result. Use the formula to find **τ**:

$$\ln \frac{\Delta V_2}{\Delta V_1} = \frac{-\Delta T}{\tau}$$

GRAPHING TERMINOLOGY

With *x* being the horizontal axis and *y* the vertical, we have a graph of ***y* versus *x*** or ***y* as a function of *x***. The *x*-axis represents the **independent variable** and the *y*-axis represents the **dependent variable**, so that when a graph is used to illustrate data, the data of regular interval (often this is time) is plotted on the *x*-axis and the corresponding data is dependent on those values and is plotted on the *y*-axis.

PSPICE ABBREVIATIONS

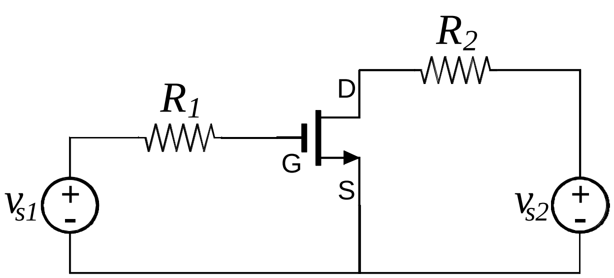
AC voltage used for AC sweep simulation
DF (large value) from e^(-DF(T)/2)
TD Time Delay before start
TR Time to Rise
TRAN the source voltage for a transient analysis
TF Time to Fall
PW Pulse Width
PER Period
T1, T2, T3, etc. elapsed time from zero
V1 bottom voltage level
V2 top or next voltage level
VAMPL voltage amplitude
VOFF voltage offset

% ERROR in measurement.

$$\frac{\text{value of one division}}{\text{value of measurement}} \times 100 = \text{percent error}$$

$$\frac{1}{\text{quantity counted}} \times 100 = \text{percent error}$$

SETUP FOR PLOTTING CHARACTERISTIC CURVES



In Pspice, select Analysis / Setup / DC Sweep / Linear / Nested / Voltage Source / Values. Set values for V_{s1} such as 0,-1,-2,-3,-4. Sweep V_{s2} over a range of voltages. Plot drain current versus drain-to-source voltage.

DIGITAL SIGNAL ANALYZER (DSA)

The **sample rate** must be at least two times the frequency. The sample rate is the number of samples taken per second or **frame size / total sample time** .

The **frame size** is required by the software to be some power of two. This is the number of segments that the sample is broken into.

The **total sample time** must be some multiple of the period (no fractions of a period).

$$\text{total sample time} = \frac{\text{frame size}}{\text{sample rate}}$$

$$\text{total sample time} = \frac{1}{\text{frequency}} \times \text{number of periods}$$

$$\boxed{\frac{\text{frame size}}{\text{sample rate}} = \frac{\text{number of periods}}{\text{frequency}}}$$