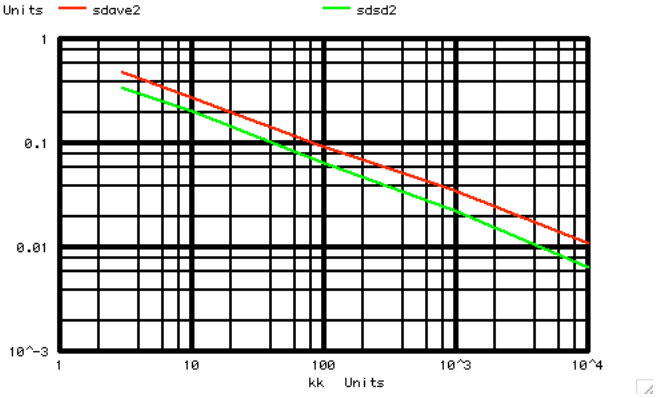
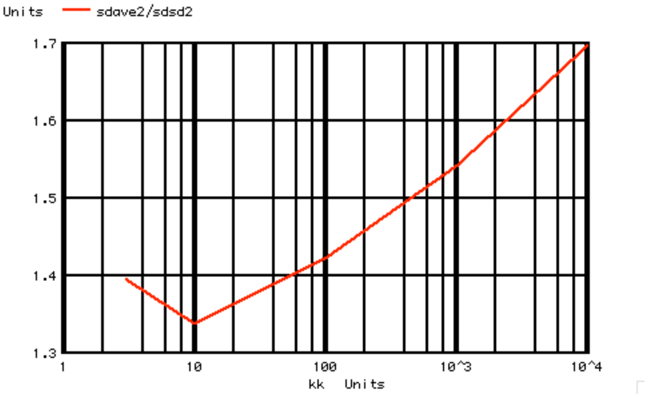
=====================How_Well_Does_N_samples_Work=====================================

1) Standard_deviation is the RMS_AC of the samples where the average is removed
2) For N samples   Ave   = Ave_real   +/- RMS_AC_real/sqrt(N)
                        RMS_AC = RMS_AC_real +/- RMS_AC_real/sqrt(N*(2->3))

When one takes N samples, how well can one trust the calculated average and standard deviation results? Both the average and the standard deviations will have +/- errors with ther own standard deviations.

This spice example tests and plots accuracy as a function of samples.





When N is one, then..

average_one_point = real_average +/- real_standard_deviation.

When adding more data points, random signal adds with the power

average_N_point   = real_average +/- real_standard_deviation/sqrt(N)

The standard deviation appears to start off with sqrt(2) less of a value.
Note that a binary square wave has a sqrt(2) more energy than a sine wave. Something like that would add a 3dB improvement in signal to noise for the standard deviation error.

standard_deviation _N_point = real_standard_deviation +/- real_standard_deviation/(sqrt(N)* sqrt(2->3)

For larger number of samples, there appears to be more of a sqrt(3) or 4.77dB improvement.
That resembles more the power ratio of a sine wave to a triangle wave when the signal is the sine wave and the triangle wave is the randomness.

===================MacSpiceCode===

```
Standard_Deviation_Tests
*================Need_A_voltage_Source_to_alter====================="
V1              V1      0       0    dc
.control
set             pensize = 2

*echo           "==================k_tests===================="
unlet           aveave2
unlet           sdave2
unlet           avesd2
unlet           sdsd2
unlet           kk
let aveave2 =   vector(5)
let sdave2 =    vector(5)
let avesd2 =    vector(5)
let sdsd2 =     vector(5)
let kk =        vector(5)

*echo           "==================j_tests===================="
unlet           sd
unlet           ave
unlet           jj
let sd =        vector(50)
let ave =       vector(50)
let jj =        vector(50)

*echo           "==================create_number_points===================="
let n =         3
unlet           noise
unlet           noisAC
unlet           ii
let noise =     vector($&n)
let ii =        vector($&n)
let noisAC =    vector($&n)
*echo           "=================loop_j==================="
let j =         0
```

```
repeat           50
*echo            "===================create_noise_array====================="
let index =      0
repeat           $&n
let              ii[index] = index
let              noise[index] = 1.0*(rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)-507.5)/102.879 +.04
let index =      index + 1
end
*plot            noise  vs ii
*echo            "===================Find_Ave_Rms====================================="
let averVal =    mean(noise)
let noisAC =     noise - averVal
let RmsVal =     sqrt(mean(noisAC* noisAC))
*echo            "number Points      $&n"
*echo            "Average level      $&averVal"
*echo            "RMS level          $&RmsVal"
let              jj[j]  = j
let              sd[j]  = RmsVal
let              ave[j] = averVal
let j =          j + 1
endrepeat
plot             sd ave vs jj
echo             "===================Find_Ave_SD_for_N====================================="
let k            = 0
let aveave       = mean(ave)
unlet            noisave
let noisave =    ave - mean(ave)
let sdave =      sqrt(mean(noisave* noisave))
let avesd =      mean(sd)
unlet            noissd
let noissd =     sd - mean(sd)
let sdsd  =      sqrt(mean(noissd* noissd))
echo             "NumPoint  $&n  "
echo             "Average   $&aveave  +/- $&sdave  "
echo             "StanDev   $&avesd   +/- $&sdsd  "
let aveave2[0] = aveave
let sdave2[0] =  sdave
let avesd2[0] =  avesd
let sdsd2[0] =   sdsd
let kk[0] =      n
*echo            "===================create_number_points====================="
let n =          10
unlet            noise
unlet            noisAC
unlet            ii
let noise =      vector($&n)
let ii =         vector($&n)
let noisAC =     vector($&n)
*echo            "===================loop_j====================="
let j =          0
repeat           50
*echo            "===================create_noise_array====================="
let index =      0
repeat           $&n
let              ii[index] = index
let              noise[index] = 1.0*(rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)-507.5)/102.879 +.04
let index =      index + 1
end
*plot            noise  vs ii
*echo            "===================Find_Ave_Rms====================================="
let averVal =    mean(noise)
let noisAC =     noise - averVal
let RmsVal =     sqrt(mean(noisAC* noisAC))
*echo            "number Points      $&n"
*echo            "Average level      $&averVal"
*echo            "RMS level          $&RmsVal"
let              jj[j]  = j
let              sd[j]  = RmsVal
let              ave[j] = averVal
let j =          j + 1
endrepeat
plot             sd ave vs jj
echo             "===================Find_Ave_SD_for_N====================================="
let k =          1
let aveave =     mean(ave)
unlet            noisave
let noisave =    ave - mean(ave)
let sdave =      sqrt(mean(noisave* noisave))
let avesd =      mean(sd)
unlet            noissd
let noissd =     sd - mean(sd)
let sdsd  =      sqrt(mean(noissd* noissd))
echo             "NumPoint  $&n  "
echo             "Average   $&aveave  +/- $&sdave  "
echo             "StanDev   $&avesd   +/- $&sdsd  "
let aveave2[1] = aveave
let sdave2[1] =  sdave
let avesd2[1] =  avesd
let sdsd2[1] =   sdsd
let kk[1] =      n
*echo            "===================create_number_points===================="
let n =          100
unlet            noise
unlet            noisAC
unlet            ii
let noise =      vector($&n)
let ii =         vector($&n)
let noisAC =     vector($&n)
*echo            "===================loop_j====================="
let j =          0
repeat           50
*echo            "===================create_noise_array====================="
```

```
let index =      0
repeat           $&n
let              ii[index] = index
let              noise[index] = 1.0*(rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)-507.5)/102.879 +.04
let index =      index + 1
end
*plot            noise  vs ii
*echo            "===================Find_Ave_Rms====================================="
let averVal =    mean(noise)
let noisAC =     noise - averVal
let RmsVal =     sqrt(mean(noisAC* noisAC))
*echo            "number Points      $&n"
*echo            "Average level      $&averVal"
*echo            "RMS level          $&RmsVal"
let              jj[j]  = j
let              sd[j]  = RmsVal
let              ave[j] = averVal
let j =          j + 1
endrepeat
plot             sd ave vs jj
echo             "===================Find_Ave_SD_for_N====================================="
let k =          2
let aveave =     mean(ave)
unlet            noisave
let noisave =    ave - mean(ave)

let sdave =      sqrt(mean(noisave* noisave))
let avesd =      mean(sd)
unlet            noissd
let noissd =     sd - mean(sd)
let sdsd  =      sqrt(mean(noissd* noissd))
echo             "NumPoint  $&n  "
echo             "Average   $&aveave  +/- $&sdave  "
echo             "StanDev   $&avesd   +/- $&sdsd  "
let aveave2[2] = aveave
let sdave2[2] =  sdave
let avesd2[2] =  avesd
let sdsd2[2] =   sdsd
let kk[2] =      n
*echo            "===================create_number_points====================="
let n =          1000
unlet            noise
unlet            noisAC
unlet            ii
let noise =      vector($&n)
let ii =         vector($&n)
let noisAC =     vector($&n)
*echo            "===================loop_j====================="
let j =          0
repeat           50
*echo            "===================create_noise_array====================="
let index =      0
repeat           $&n
let              ii[index] = index
let              noise[index] = 1.0*(rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)-507.5)/102.879 +.04
let index =      index + 1
end
*plot            noise  vs ii
*echo            "===================Find_Ave_Rms====================================="
let averVal =    mean(noise)
let noisAC =     noise - averVal
let RmsVal =     sqrt(mean(noisAC* noisAC))
*echo            "number Points      $&n"
*echo            "Average level      $&averVal"
*echo            "RMS level          $&RmsVal"
let              jj[j]  = j
let              sd[j]  = RmsVal
let              ave[j] = averVal
let j =          j + 1
endrepeat
plot             sd ave vs jj
echo             "===================Find_Ave_SD_for_N====================================="
let k =          3
let aveave =     mean(ave)
unlet            noisave
let noisave =    ave - mean(ave)
let sdave =      sqrt(mean(noisave* noisave))
let avesd =      mean(sd)
unlet            noissd
let noissd =     sd - mean(sd)
let sdsd  =      sqrt(mean(noissd* noissd))
echo             "NumPoint  $&n  "
echo             "Average   $&aveave  +/- $&sdave  "
echo             "StanDev   $&avesd   +/- $&sdsd  "
let aveave2[3] = aveave
let sdave2[3] =  sdave
let avesd2[3] =  avesd
let sdsd2[3] =   sdsd
let kk[3] =      n
*echo            "===================create_number_points====================="
let n =          10000
unlet            noise
unlet            noisAC
unlet            ii
let noise =      vector($&n)
let ii =         vector($&n)
let noisAC =     vector($&n)
*echo            "===================loop_j====================="
let j =          0
repeat           50
*echo            "===================create_noise_array====================="
let index =      0
```

```
repeat           $&n
let              ii[index] = index
let              noise[index] = 1.0*(rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)+rnd(127)-507.5)/102.879 +.04
let index =      index + 1
end
*plot            noise  vs ii
*echo            "===================Find_Ave_Rms=====================================" 
let averVal =    mean(noise)
let noisAC =     noise - averVal
let RmsVal =     sqrt(mean(noisAC* noisAC))
*echo            "number Points      $&n"
*echo            "Average level      $&averVal"
*echo            "RMS level          $&RmsVal"
let              jj[j]  = j
let              sd[j]  = RmsVal
let              ave[j] = averVal
let j =          j + 1
endrepeat
plot             sd ave vs jj
echo             "===================Find_Ave_SD_for_N=====================================" 
let k =          4
let aveave =     mean(ave)
unlet            noisave
let noisave =    ave - mean(ave)
let sdave =      sqrt(mean(noisave* noisave))
let avesd =      mean(sd)
unlet            noissd
let noissd =     sd - mean(sd)
let sdsd  =      sqrt(mean(noissd* noissd))
echo             "NumPoint  $&n  "
echo             "Average   $&aveave  +/- $&sdave  "
echo             "StanDev   $&avesd   +/- $&sdsd  "
let aveave2[4] = aveave
let sdave2[4] =  sdave
let avesd2[4] =  avesd
let sdsd2[4] =   sdsd
let kk[4] =      n
plot             sdave2 sdsd2 vs kk  loglog
plot             sdave2/sdsd2 vs kk  xlog
plot             sdave2/sdsd2 vs kk  xlog ylimit 0 2

.endc
.end
```

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