Effective number of bits (ENOB)

1. Introduction to effective number of bits (ENOB):

Effective Number of Bits(ENOB) is an indicator used to evaluate the performance of an ADC. It provides a measure of the ADC's actual resolution or the quality of its output in terms of the number of ideal bits it effectively represents. In other words, ENOB reflects the accuracy of the ADC, indicating how many bits in the output digital code truly contain meaningful information.

2. ENOB Measurement Process

2-1 Hspice test bench

HSPICE code is shown in Fig. 1., you only need to modify the highlighted sections.

final_tb2.sp

```
.title ssAD and band gap reference
.protect
.lib "~/spice_model/cic018.l"tt
.unprotect
.temp 25
.option
+ post                         $output waveform to user
+ acout=0 runlvl=6      $increase simulation accuracy
+ captable                     $list every node capacitance

.include "./bgr2.spi"
.include './ssAD.spi'


.param VSS=0
.param Fs=20k
.param sampling_duty_cycle=0.2
.param cnt_freq=1.594x
.param NFIN=511
.param NSAMPLE=1024

.param cnt_period='1/cnt_freq'
.param Ts='1/Fs'

****************** you can modify start**********************
.param VDD=1.8                  $ you could only have three type of VDD(1.62V, 1.8V 1.98V)
                                        $ There is no spec when supply voltage=1.62V and 1.98V
                                        $ just for you to observe the performance change of ssAD

.param Vb=0.5                   $ comparator biasing voltage

.param ramp_max = 1.3   $ ramping signal maximum value
.param ramp_min = 0.35  $ ramping signal minimum value

.param VCM = 0.825              $ common mode of input sine wave
.param amplitude = 474m $ amplitude of input sine wave
****************** you can modify end**************************


************define voltage source*************
Vdd vdd gnd dc=VDD
Vss vss gnd dc=VSS
Vb Vb GND Vb

Vramp_in ramp_in vss dc=0 pulse(ramp_min ramp_max 'Ts/2 + sampling_duty_cycle * Ts + 5n' 'Ts - sampling_duty_cycle * Ts - 5n - 0.01 * Ts' 0.1n 5n Ts)
Vinput input gnd sin(VCM 474m 'Fs*NFIN/NSAMPLE')

```

Fig. 1. HSPICE code

2-2 Export CSV Table from Waveview

Step1 : Select the waveform of b5~b0(output bits).

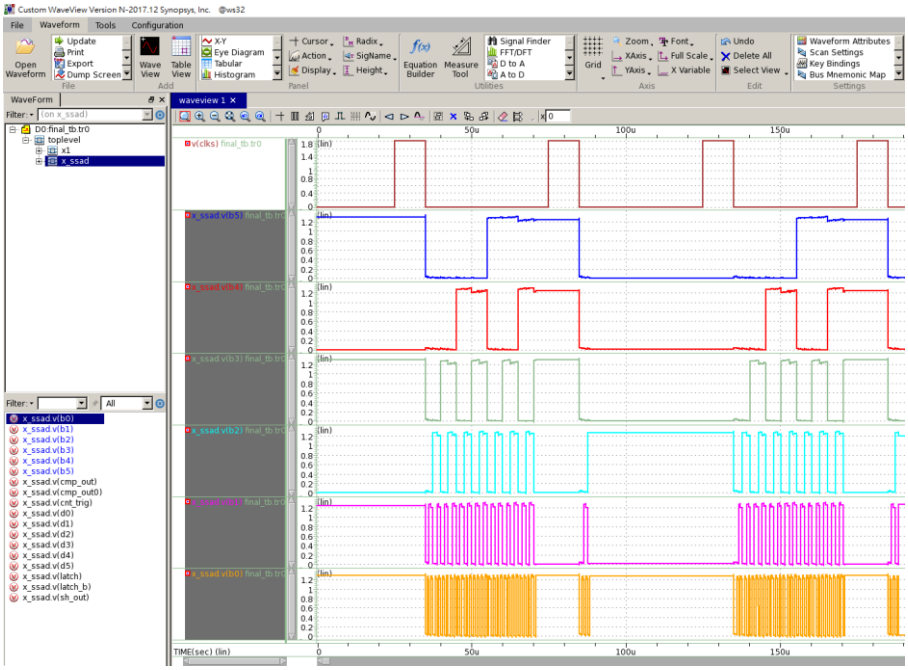


Fig. 2. Select the waveform

Step2 : Select “Export” according to Fig. 3. The output path for the output file can be filled in manually.

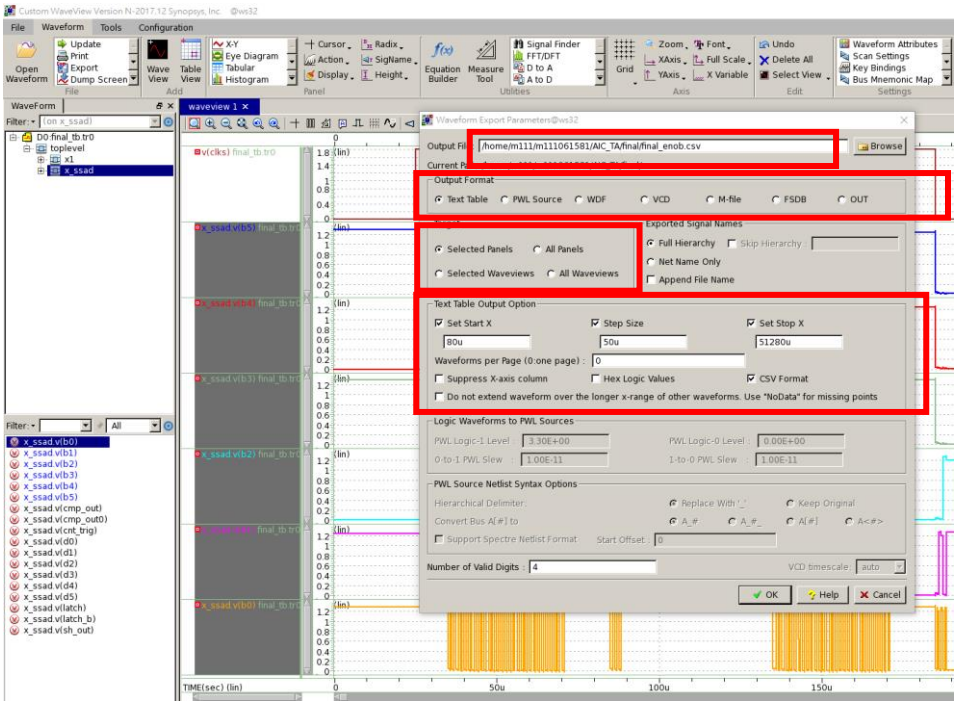
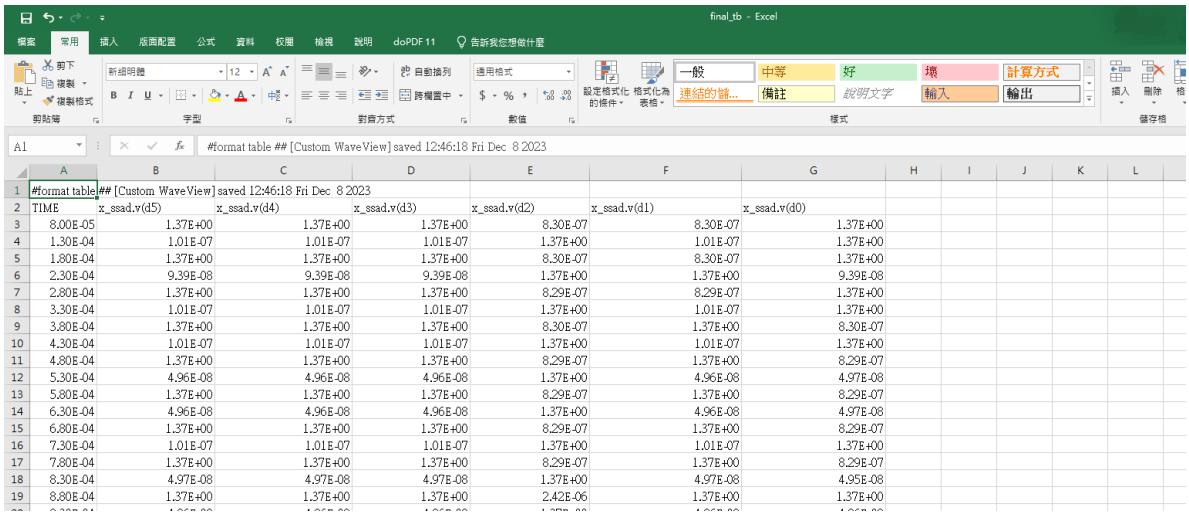


Fig. 3 Select Export settings

Step3 : Check if the number of data points in the output CSV file is larger than 1024.



final_tb - Excel

A1: #format table ## [Custom WaveView] saved 12:46:18 Fri Dec 8 2023

	A	B	C	D	E	F	G
1	#format table	## [Custom WaveView] saved 12:46:18 Fri Dec 8 2023					
2	TIME	x_ssad.v(d5)	x_ssad.v(d4)	x_ssad.v(d3)	x_ssad.v(d2)	x_ssad.v(d1)	x_ssad.v(d0)
3	8.00E-05	1.37E+00	1.37E+00	1.37E+00	8.30E-07	8.30E-07	1.37E+00
4	1.30E-04	1.01E-07	1.01E-07	1.01E-07	1.37E+00	1.01E-07	1.37E+00
5	1.80E-04	1.37E+00	1.37E+00	1.37E+00	8.30E-07	8.30E-07	1.37E+00
6	2.30E-04	9.39E-08	9.39E-08	9.39E-08	1.37E+00	1.37E+00	9.39E-08
7	2.80E-04	1.37E+00	1.37E+00	1.37E+00	8.29E-07	8.29E-07	1.37E+00
8	3.30E-04	1.01E-07	1.01E-07	1.01E-07	1.37E+00	1.01E-07	1.37E+00
9	3.80E-04	1.37E+00	1.37E+00	1.37E+00	8.30E-07	1.37E+00	8.30E-07
10	4.30E-04	1.01E-07	1.01E-07	1.01E-07	1.37E+00	1.01E-07	1.37E+00
11	4.80E-04	1.37E+00	1.37E+00	1.37E+00	8.29E-07	1.37E+00	8.29E-07
12	5.30E-04	4.96E-08	4.96E-08	4.96E-08	1.37E+00	4.96E-08	4.97E-08
13	5.80E-04	1.37E+00	1.37E+00	1.37E+00	8.29E-07	1.37E+00	8.29E-07
14	6.30E-04	4.96E-08	4.96E-08	4.96E-08	1.37E+00	4.96E-08	4.97E-08
15	6.80E-04	1.37E+00	1.37E+00	1.37E+00	8.29E-07	1.37E+00	8.29E-07
16	7.30E-04	1.01E-07	1.01E-07	1.01E-07	1.37E+00	1.01E-07	1.37E+00
17	7.80E-04	1.37E+00	1.37E+00	1.37E+00	8.29E-07	1.37E+00	8.29E-07
18	8.30E-04	4.97E-08	4.97E-08	4.97E-08	1.37E+00	4.97E-08	4.95E-08
19	8.80E-04	1.37E+00	1.37E+00	1.37E+00	2.42E-06	1.37E+00	1.37E+00

Fig. 4 Export csv

2-3 Matlab Code

Place the output CSV file and the MATLAB code in the same folder.

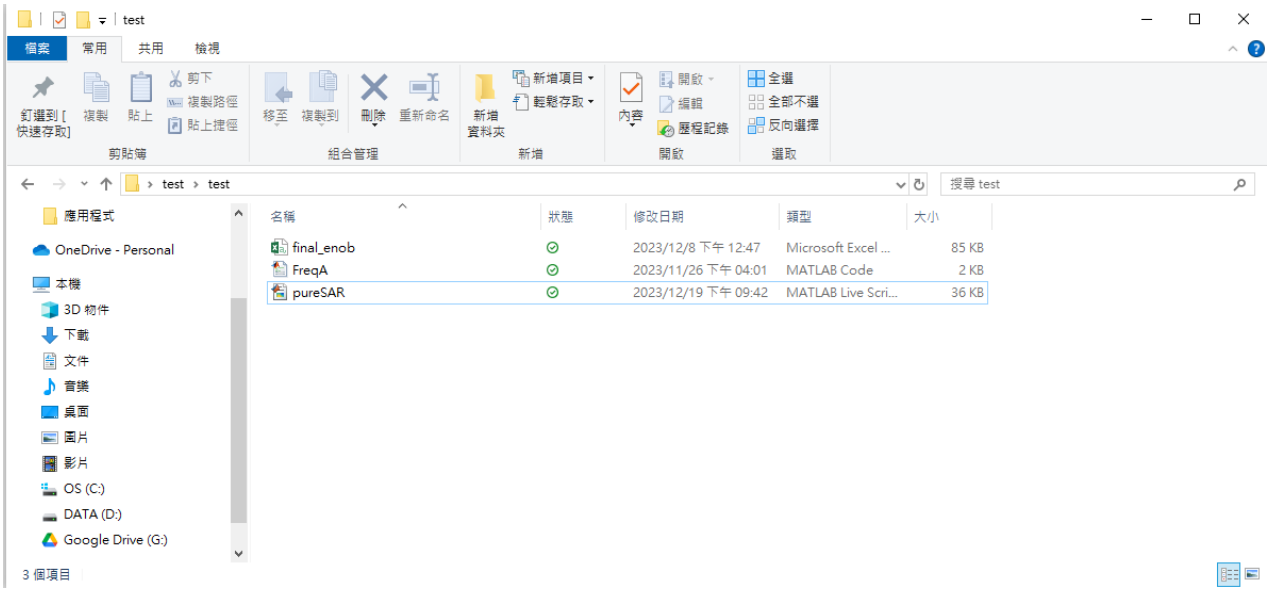


Fig. 5 file arrangement

Check if the CSV file being read is correct.

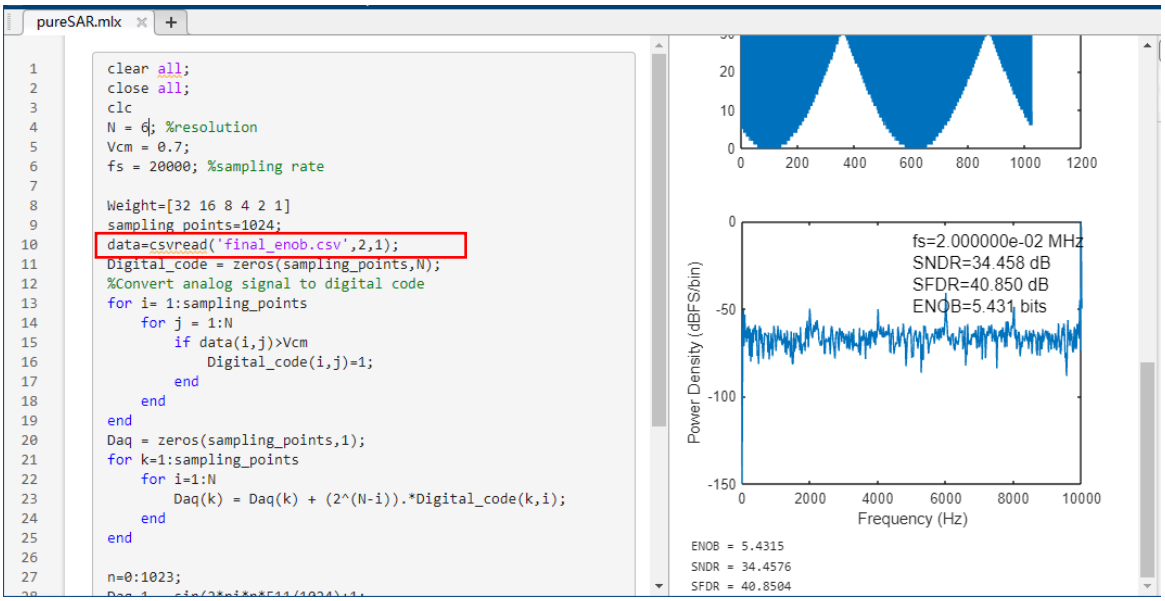


Fig. 6 matlab code