3B-11 Study on Multi-tone Signals for RF/Analog/Mixed-Signal IC Testing

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1. Research Objective

Analog/Mixed-Signal IC becomes rapidly complicated

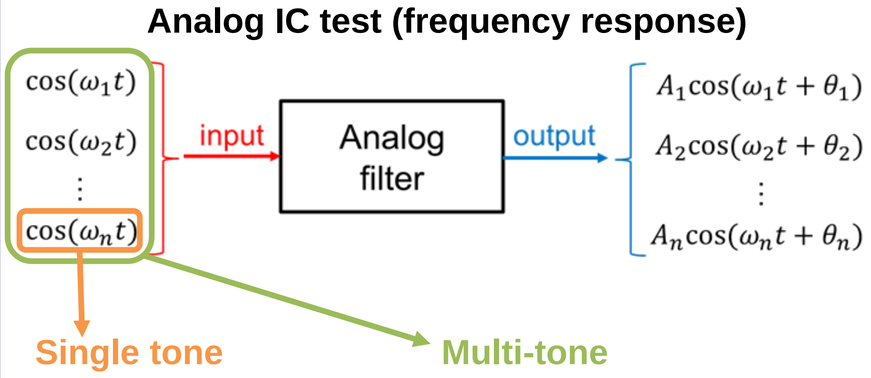
Require :

Quality improvement

Cost reduction by shorting test time

2. Research Background

Analog IC test (frequency response)



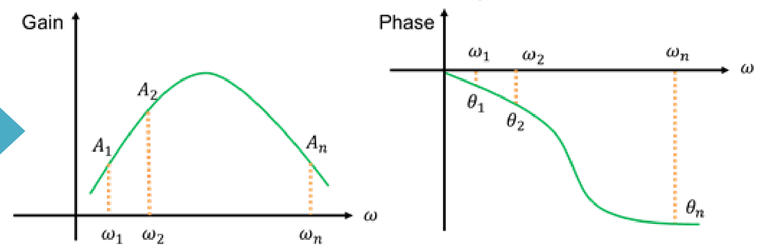
Good SNR

Long testing time

Short testing time

Bad SNR → Low quality test

Bode plot of analog filter



Purpose of this work :

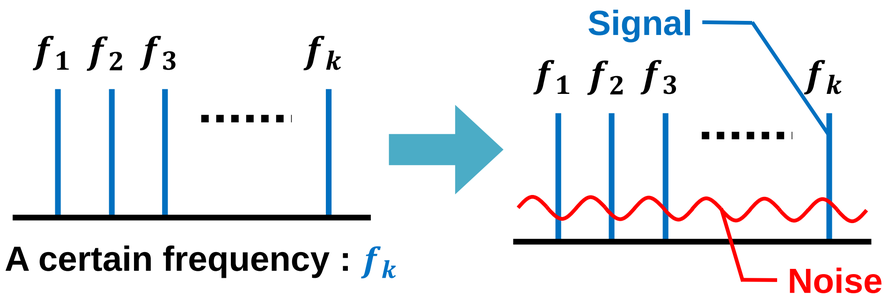
Short-time & high quality testing

for analog IC using multi-tone signal

3.Multi-tone Signal

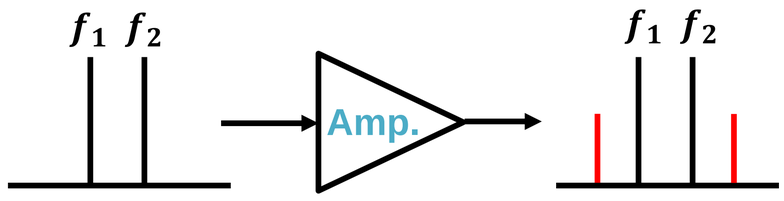
Cause of SNR deterioration:

① Get smaller signal for each frequency component



A certain frequency : f_k

② Occur intermodulation distortion in nonlinear system



Effective measure :

Suppress maximum amplitude

II

Minimize crest factor (CF)

II

Maximize dynamic range (DR)

Using algorithm
to maximize dynamic range
by adjusting phases
of multi-tone signal

4. DR Maximize Algorithm

Basic formula :

$$s(t)=\sum_{n=1}^{m} cos(\frac{2\pi f_k t}{N}+\phi_k)$$

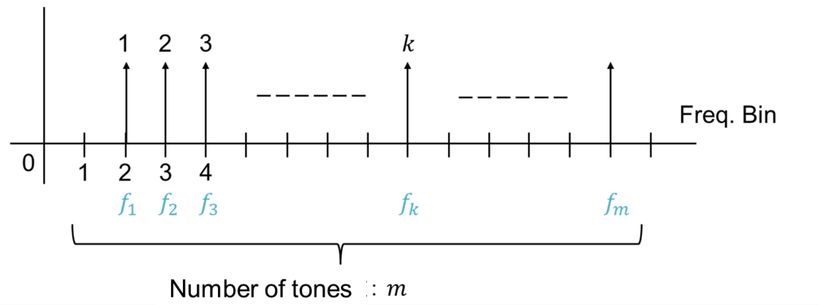
N : 8192

m : a power of 2

Kitayoshi phase : $\phi_k=\frac{\pi}{N}k(k+1)$

Newman phase : $\phi_k=\frac{\pi}{N}(k-1)^2$

Schroeder phase : $\phi_k=-\frac{\pi}{N}k(k-1)$



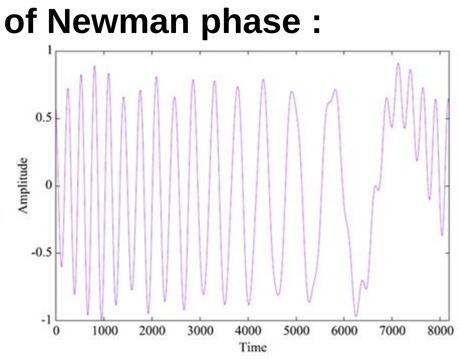
5.Simulation Results

< Dynamic range maximize algorithm >

Waveform of Newman phase :

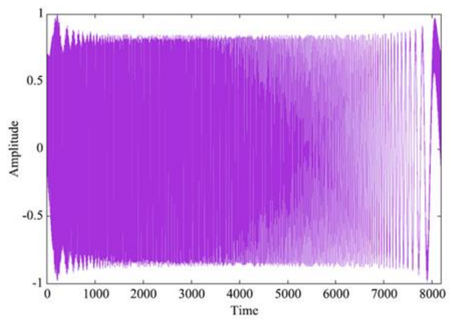
m = 32

(CF = 1.76)

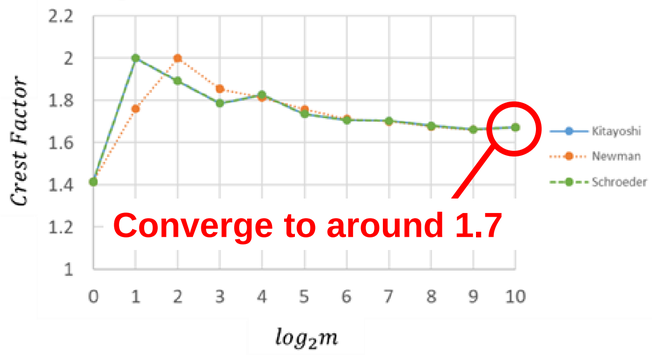


m = 1024

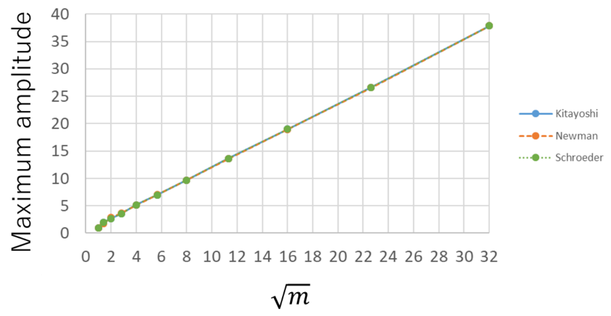
(CF = 1.67)



↓ 3 algorithms : almost consistent

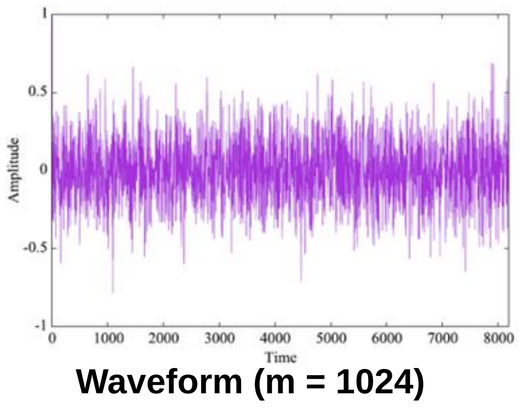


↓ Amplitude : proportional to $\sqrt{m}$

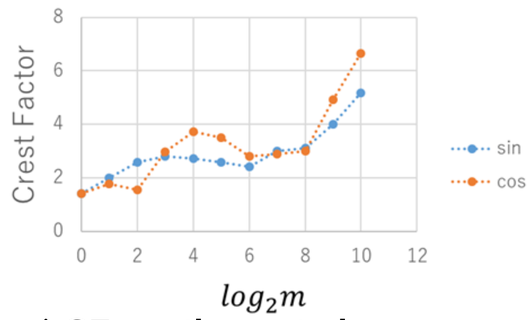


< Random phase >

Phase : random number



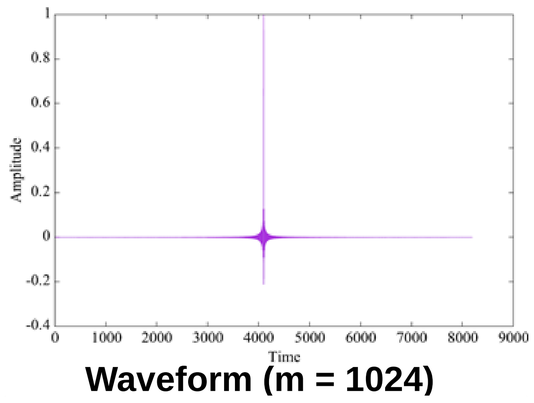
Waveform (m = 1024)



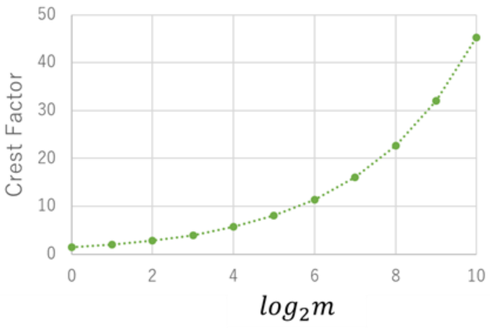
↑ CF continues to increase

< zero initial phase >

Phase : all 0

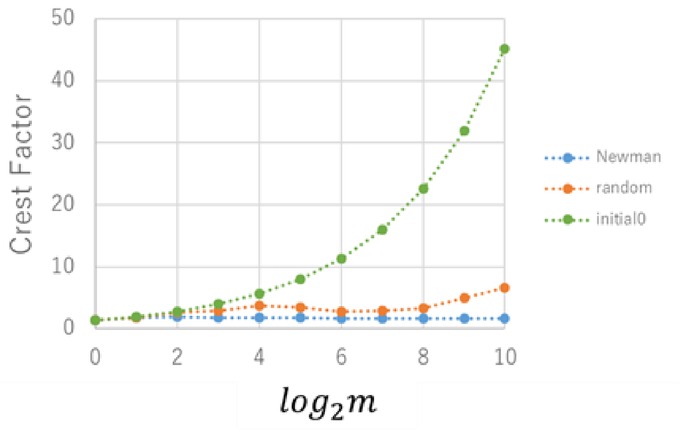


Waveform (m = 1024)



↑ CF continues to increase

6.Comparison



Newman : CF converge to around 1.7

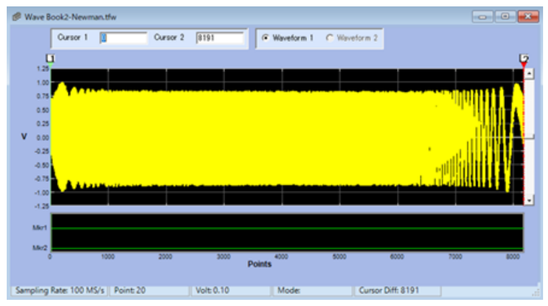
Random : CF increase as m increase

Zero : CF is rapidly increasing as m increase

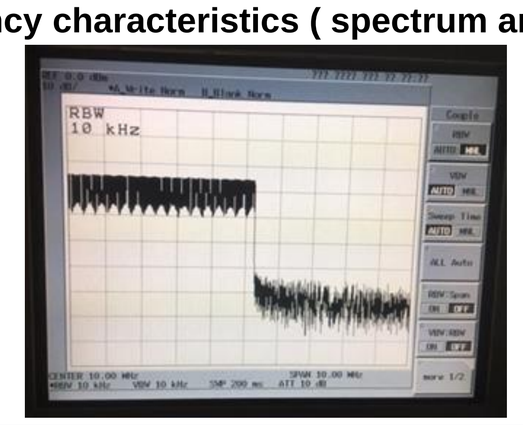
Algorithm properly reduces crest factor

7.Measurement Verification

Kitayoshi algorithm:



Frequency characteristics (spectrum analyzer) :



8.Conclusion

< Multi-tone signal >

Conventional : Bad SNR → Low quality test

Proposed :

Using dynamic range maximize algorithm

for short-time & high quality testing

References

[1]H. Kitayoshi, et. al., "DSP Synthesized Signal Source for Analog Testing Stimulus and New Test Method", IEEE International Test Conference (1985).

[2]D. J. Newman, "An L1 Extremal Problem for Polynomials", American Mathematics Society (Dec.1965).

[3]M. R. Schroeder, "Synthesis of Low-Peak-Factor Signals and Binary Sequences with Low Autocorrelation", IEEE Trans. Information Theory (1970).