matsar

Matlab script for performing LMSE calibration/nonlinearity measurements. There are two versions of matsar.

- **matsar_auto.m**: *automatically calculates required input frequency for coherent sampling [2]. It also calculates minimum samples needed for measuring DNL and INL correctly [1]. Use this if you don't know how to change parameters in the script. The run time of this script is slow due to large number of samples needed.*
- **matsar_manual.m**: *this script does not calculate input frequency to guarantee coherent sampling. It allows users to specify simulation end time (tend) to allow faster convergence. Use this when you are doing layouts to validate redundancies.*

Useful Input Parameters

Symbol	Default Value	Full Name
F	1MHz	Input Sine Wave Frequency
Fs	200MHz	ADC Sampling Frequency
FullScale	1.2V	Full Scale Input Voltage
N	10	10-bits ADC
M	12	12 steps for redundancy.
Cmin	1fF	Unit capacitance
C_mask	[array]	Used to toggle capacitors
Cpar_mult	[array]	Apply multiplicative factor to each capacitor.
Cpar_add	[array]	Apply additive factor to each capacitor.
Carray	[array]	SAR capacitor array.
mu	1e-4	LMSE training rate. Not applicable for 'AdaDelta'.
mode	'AdaDelta'	LMSE SGD method. Valid values are 'AdaDelta','AdaGrad' and 'Constant'.
Gamma	0.7	Tuning parameter for AdaDelta.

Useful Output Parameters

Availabe in Workspace after running the script.

Symbol	Default Value	Full Name
F	999928Hz	Input Sine Wave Frequency
Ts	5ns	Sampling interval = 1/Fs.
tend	10.5ms	Input Sine Wave end time.
Input	[array]	Input waveform.
nsampmin	1070679	Number of samples required for DNL/INL measurements. See Doernberg [1].
numsamp	999928	Number of samples required for DNL/INL measurements.
W	[matrix]	Trained weights.

codes_ideal	[array]	Ideally converted codes.
codes_precal	[array]	Converted codes with mismatch.
codes_cal	[array]	Calibrated codes with mismatch.
Rdn	[array]	Redundancy at each conversion step.
Regs	[matrix]	Ideal register values. The nth row is the register for sample n. Each register is a M-element row vector.
Regs_mis	[matrix]	Mismatched register values. The nth row is the register for sample n. Each register is a M-element row vector.
sndrIdeal	[scalar]	Ideally converted SNDR.
sfdrIdeal	[scalar]	Ideally converted SFDR.
enobIdeal	[scalar]	Ideally converted SNDR.
sndrPrecal	[scalar]	SNDR of converted code with capacitative mismatch (pre-calibration).
sfdrPrecal	[scalar]	SFDR of converted code with capacitative mismatch (pre-calibration).
enobPrecal	[scalar]	ENOB of converted code with capacitative mismatch (pre-calibration).
sndrPrecal	[scalar]	SNDR of converted code with capacitative mismatch (calibrated).
sfdrPrecal	[scalar]	SFDR of converted code with capacitative mismatch (calibrated).
enobPrecal	[scalar]	ENOB of converted code with capacitative mismatch (calibrated).

Plot Controls

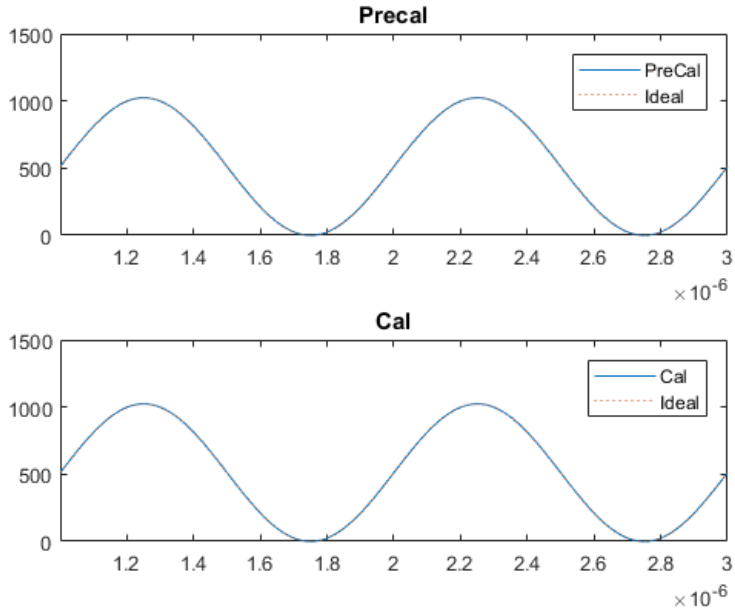
Symbol	Default Value	Full Name
Windowing	1	1: Blackman window. 0: Rect window.
ShowWeights	1	Show weights convergence over time.
ShowError	1	Show error over time.
ShowSE	1	Show squared error over time.
ShowWave	1	Show time domain waveform
ShowSpectrum	1	Show frequency spectrum
ShowHistogram	1	Show normalized code histogram.
ShowSNDR	1	Show Signal-to-Noise-and-Distortion ratio.
ShowSFDR	1	Show Spurious Free Dynamic Range.
ShowENOB	1	Show effective number of bits.
ShowDNL	1	Show Differential Non-Linearity.
ShowINL	1	Show Integral Non-Linearity.

Sample Output

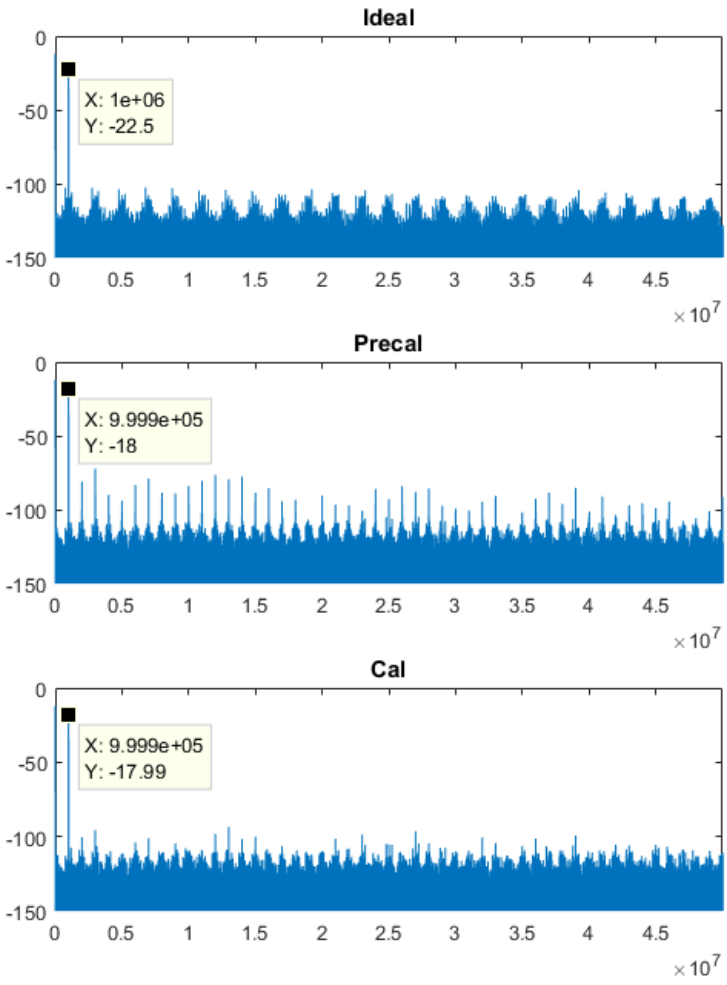
This sample output is the result of simulating a 12 steps 10-bit SAR ADC (default parameters) using "matsar_auto.m". Default parasitics are extracted from TSMC 65nm into the 'Cpar_add' array.

```
Calculated input frequency is F=999928(Hz)
SNDR(Ideal) = 61.911478
SFDR(Ideal) = 84.559386
ENOB(Ideal) = 9.991940
SNDR(Precal) = 48.861151
SFDR(Precal) = 54.278683
ENOB(Precal) = 7.824111
SNDR(Cal) = 60.772993
SFDR(Cal) = 75.439158
ENOB(Cal) = 9.802823
```

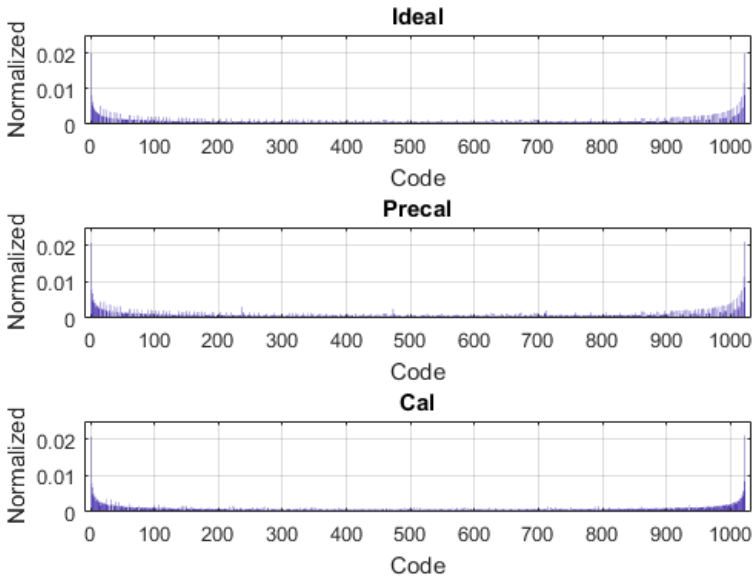
Time Domain Waveforms



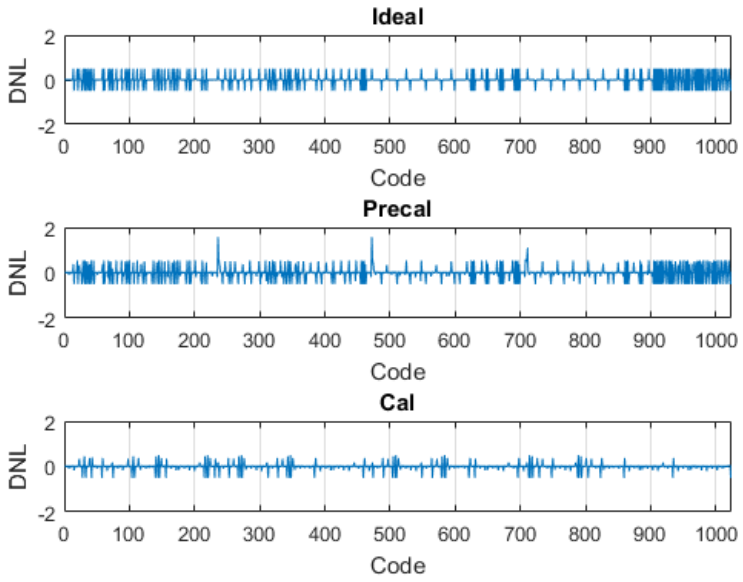
FFT Spectrum



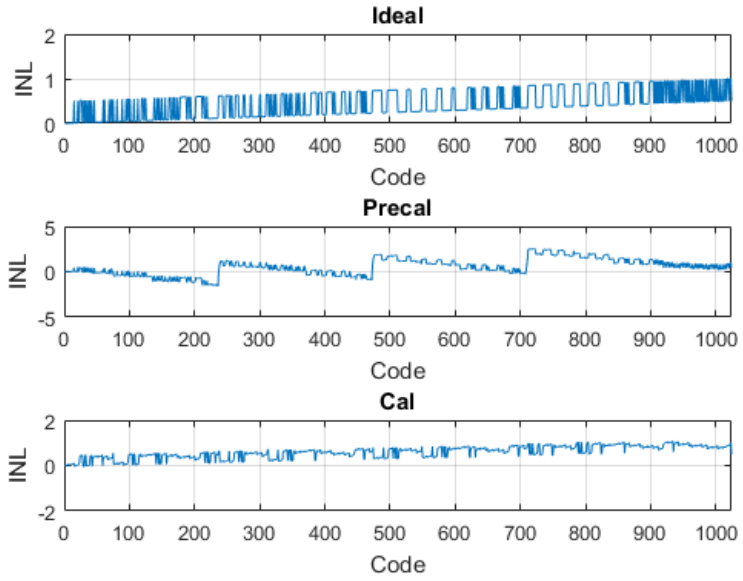
Histogram



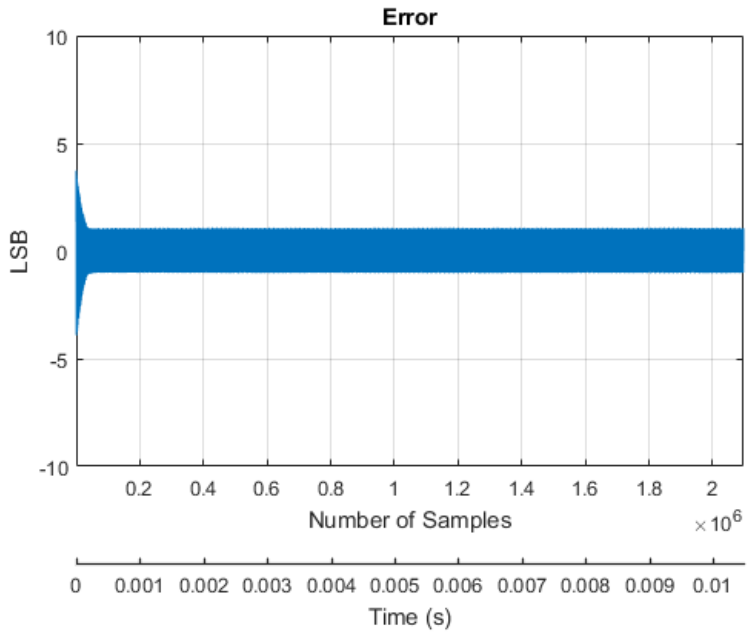
Differential Non-linearity (DNL)



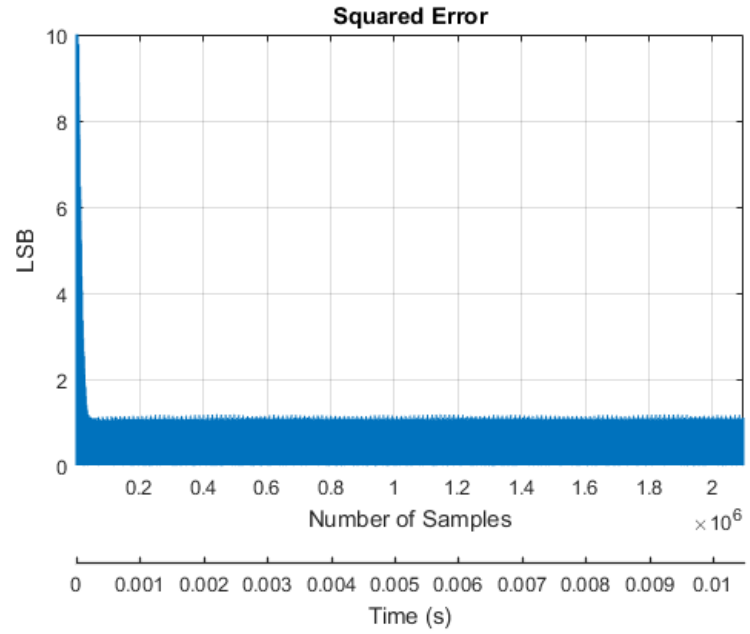
Integral Non-linearity (INL)



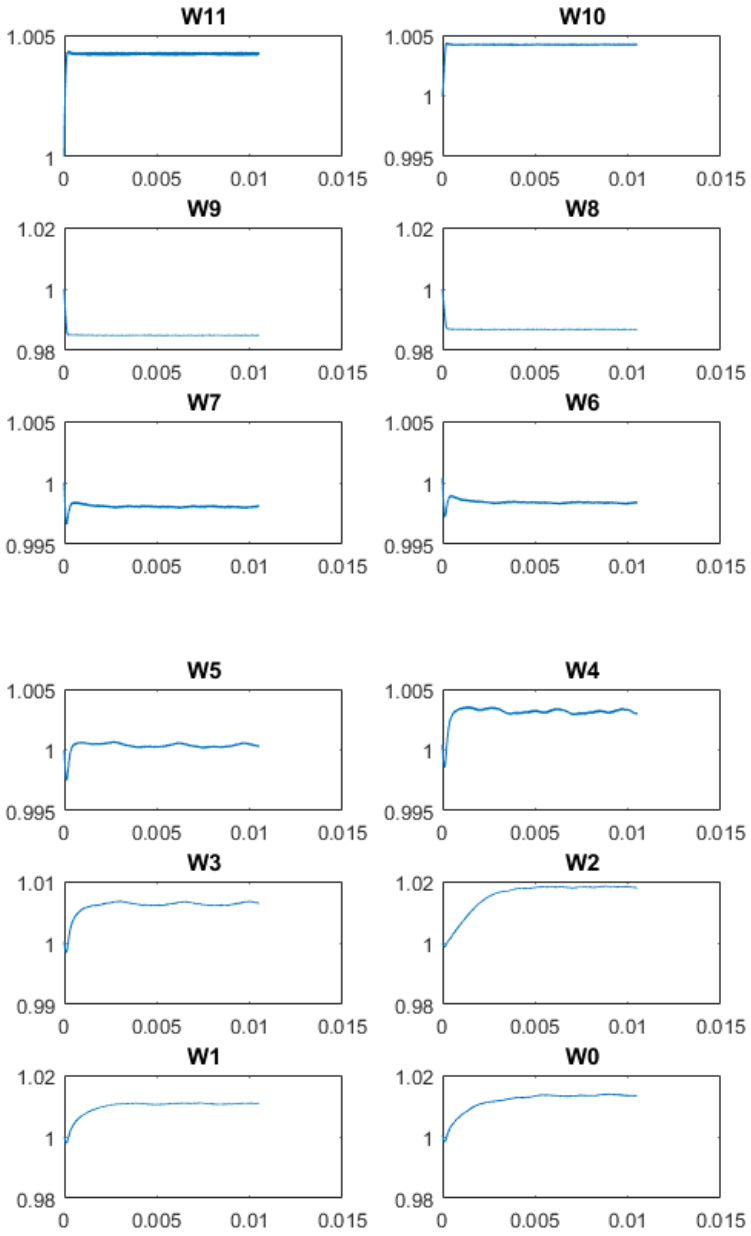
Error



Squared Error



LMSE Trained Weights



References

[1] J. Doernberg, H. -. Lee and D. A. Hodges, "Full-speed testing of A/D converters," in IEEE Journal of Solid-State Circuits, vol. 19, no. 6, pp. 820-827, Dec. 1984.

[2] Wikipedia contributors. "Coherent sampling." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 2 Jul. 2015. Web. 2 Mar. 2020.