

## The Delta-Sigma Toolbox

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- Matlab functions for the design, simulation and realization of delta-sigma modulators.
- Developed at OSU by Dr. Schreier
- Download sites:  

```
ftp://ftp.mathworks.com/pub/contrib/v5/control/delsig.zip
```

```
http://www.mathworks.com/matlabcentral/fileexchange/Files.jsp?fileId=19
```
- Documentation is in file DelSig.pdf

1

## Installation

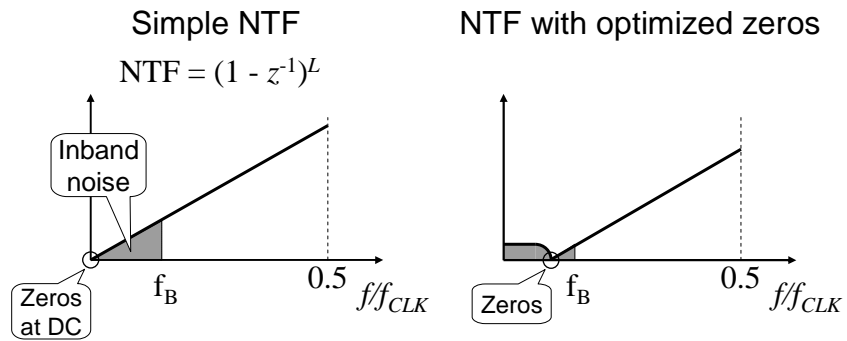
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- Unzip file to ~/delsig
- In non-existent, create directory ~/matlab
- Copy file mexopts.sh into ~/matlab
- Edit file ~/matlab/startup.m to include:  

```
path(path, '<full-path-to-home>/delsig');
```
- Compile C functions using `mex file.c`
- Start matlab.

2

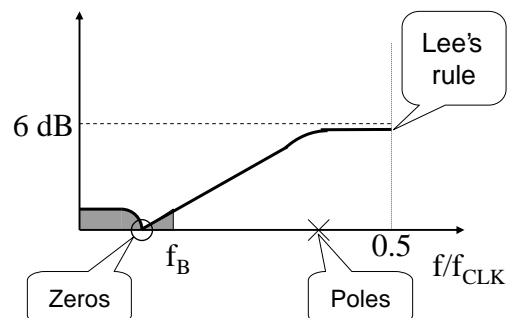
## Noise Transfer Function



3

## Even better

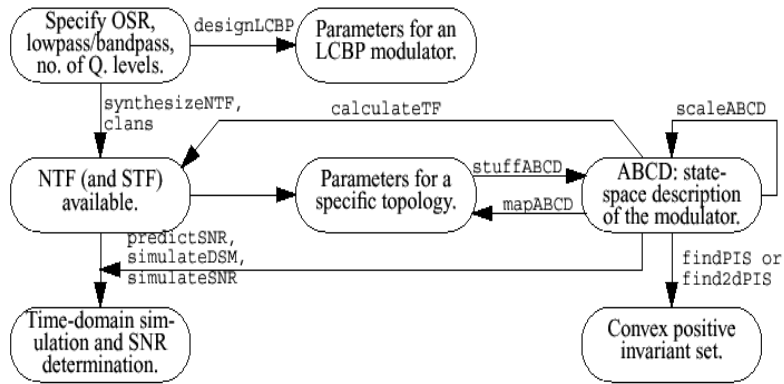
- Less in-band noise (optimized zeros)
- Meets stability requirements (Lee's rule)



4

## Design Flow

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5

## Key Functions (1)

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- Modulator synthesis and simulation
  - `synthesizeNTF` Noise transfer function (NTF) synthesis.
  - `clans` Closed-loop analysis of noise shapers (NTF synthesis for multi-bit modulators).
  - `simulateDSM` Simulate a delta-sigma modulator using either its NTF or its state-space description.
  - `simulateSNR` Use `simulateDSM` to simulate a DSM with sine wave inputs of varying amplitudes and then determine the SNR for each.
  - `predictSNR` SNR prediction for binary modulators (Ardalan & Paulos method)

6

## Key Functions (2)

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- Modulator Realization:

- `realizeNTF` Compute coefficients for a particular modulator topology.
- `stuffABCD` Create state-space description of a modulator given the coefficients for a particular topology.
- `mapABCD` Convert state-space description back to coefficients.
- `scaleABCD` Perform dynamic-range scaling.

7

## Key Functions (3)

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- Demonstrations and Examples:

- `dsdemo1` Synthesize 5th-order lowpass and 8th-order bandpass NTF.
- `dsdemo2` Time-domain simulation and SNR calculation.
- `dsdemo3` Modulator realization and dynamic range scaling.
- `dsdemo4` Continuous-time bandpass modulator design using LC tanks.
- `dsdemo5` Find positively-invariant sets for second and third-order modulators.
- `dsdemo6` Simulate element selection logic of mismatch-shaping DAC.
- `dsdemo7` Design hardware-efficient halfband filter.
- `dsexample1` Discrete-time lowpass modulator.
- `dsexample2` Discrete-time bandpass modulator.

8

## Design Example

- Delta-sigma ADC for digital audio applications:
  - SNR > 98 dB (16-bit resolution)
  - Output data rate: 44.1 KS/s
  - Use 1-bit quantizer
  - Second-order noise transfer function (NTF)
- Quick lookup shows that oversampling ratio needs to be > 128.
  - => Select OSR = 256 , and check later.
- Start code with:

```
order = 2; OSR = 256; nlev = 2;
```

9

## Synthesize Noise Transfer Function

```
>> ntf = synthesizeNTF(order,OSR,opt)
```

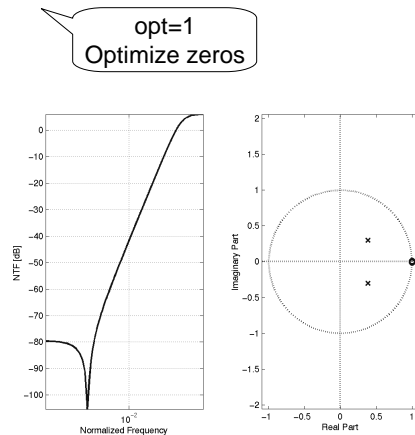
Zero/pole/gain:

```
(z^2 - 2z + 1)
```

```
-----  
(z^2 - 0.7639z + 0.2361)
```

```
>> [NUM,DEN] = tfdata(ntf,'v')
```

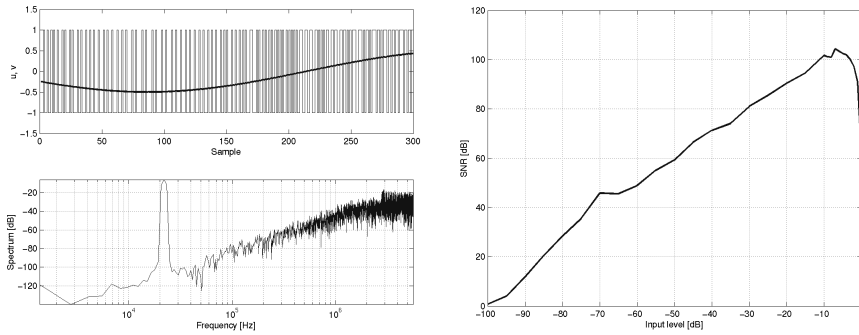
```
NUM =  
 1.0000  -1.9999  1.0000  
DEN =  
 1.0000  -0.7639  0.2361
```



10

# Modulator Simulation

```
N=8192; f=N/(2*OSR); u=0.5*sin(2*pi*f*[0:N-1]/N);  
[v,xn,xmax,y]=simulateDSM(u,ntf,nlev);  
fB = 1/(8*OSR); Au = [-100:5:-10 -9:1:0];  
[snr,Au] = simulateSNR(ntf,OSR,Au,0,nlev,fB,14);
```

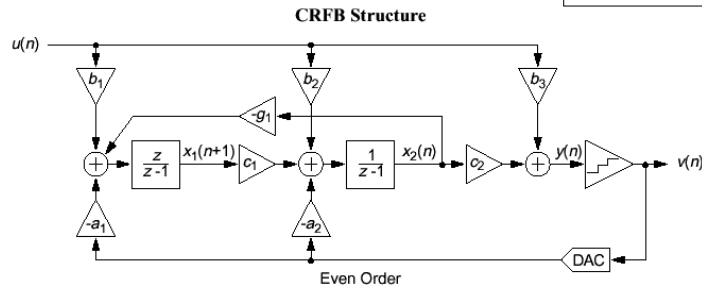


11

# Calculate Coefficients

```
>> form = 'CRFB'; [a,g,b,c] = realizeNTF(ntf,form,1)  
a = 0.4721    0.7639  
g = 5.0199e-05  
b = 0.4721    0.7639    1.0000  
c = 1        1
```

Other forms:  
CRFF  
CIFB  
CIFF, etc



12

# Scaling

- Scale coefficients for optimum dynamic range:

`ABCD = stuffABCD(a,g,b,c,form)`

`[ABCDs,umax]=scaleABCD(ABCD,nlev,0,1,7)`

`umax = 0.9000`

ABCDs =	1.0000	-0.0003	0.7286	-0.7286
	0.1530	0.9999	0.2919	-0.2919
	0	4.2349	1.0000	0

threshold for judging stability

signal limit

`[a,g,b,c] = mapABCD(ABCDs,form)`

`a = 0.7286 0.1804`

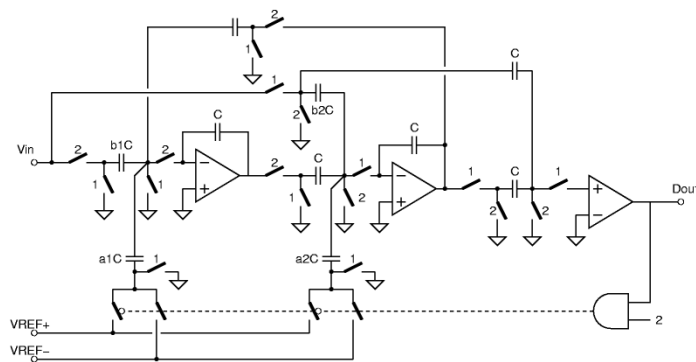
`g = 3.2808e-04`

`b = 0.7286 0.1804 1.0000`

`c = 0.1530 4.2349`

13

# Circuit Level Implementation



$$f_{CLK} = 2 \times f_B \times OSR = 11.29 \text{ MHz}$$

14