Lecture 6 FIR Filter Implementations

Objectives:

- Understand basics of FIR filter design using MATLAB
- Understand C67x implementations
- Understand circular buffer usage

FIR Filter Basics

- The transfer function of a M^{th} order FIR filter is:

$$H(z) = b_0 + b_1 z^{-1} + \cdots + b_M z^{-M}$$

- The difference equation is:

$$y(n) = b_0 x(n) + b_1 x(n-1) + \cdots + b_M x(n-M)$$

- For linear phase FIR filters, the coefficients are real & symmetrical
- FIR filters are easy to implement in either hardware or DSP software
- FIR filters are inherently stable

FIR Filter Design in MATLAB

- MATLAB provides a large variety of routines for designing FIR filters. We will concentrate on Parks-McClellan's algorithm.

FIR Filter Design	Description
cremez	Complex and nonlinear-phase equiripple FIR filter design
fir1	Design a window-based finite impulse response filter
fir2	Design a frequency sampling-based finite impulse response filter
fircls	Constrained least square FIR filter design for multiband filters
fircls1	Constrained least square filter design for lowpass and highpass linear phase FIR filters
firls	Least square linear-phase FIR filter design
firrcos	Raised cosine FIR filter design
intfilt	Interpolation FIR filter design
kaiserord	Estimate parameters for an FIR filter design with Kaiser window
remez	Compute the Parks-McClellan optimal FIR filter design
remezord	Parks-McClellan optimal FIR filter order estimation
sgolay	Savitzky-Golay filter design

REMEZORD & REMEZ functions

- **[N,Fo,Mo,W] = REMEZORD(F,M,DEV,Fs)**
  - finds the approximate order N, normalized frequency band edges Fo, frequency band magnitudes Mo and weights W to be used by the REMEZ function as follows:

  B = REMEZ(N,Fo,Mo,W)
- The resulting filter will approximately meet the specifications given by the input parameters **F, M**, and **DEV**.
- **F** is a vector of cut-off frequencies in Hz, in ascending order between 0 and half the sampling frequency **Fs**.
- **M** is a vector specifying the desired function's amplitude on the bands defined by **F**.
- The length of **F** is twice the length of **M**, minus 2 (it must therefore be even).
- The first frequency band always starts at zero, and the last always ends at **Fs/2**.
- **DEV** is a vector of maximum deviations or ripples allowable for each band.

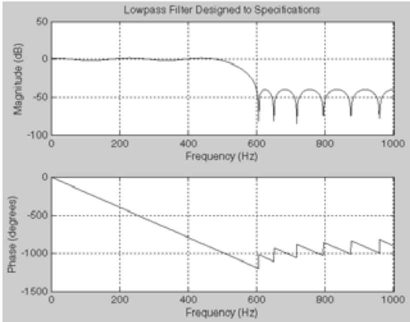
A Design Example

- Lowpass filter spec:
  - 500 Hz passband cutoff frequency, less than 3 dB passband ripple
  - 600 Hz stopband cutoff frequency, with at least 40 dB attenuation
  - sampling frequency of 2000 Hz

```
rp = 3;              % Passband ripple
rs = 40;             % Stopband ripple
fs = 2000;           % Sampling frequency
f = [500 600];       % Cutoff frequencies
a = [1 0];           % Desired amplitudes

% Compute deviations
dev = [(10^(rp/20)-1)/(10^(rp/20)+1)  10^(-rs/20)];

[n,fo,ao,w] = remezord(f,a,dev,fs);
b = remez(n,fo,ao,w);
freqz(b,1,1024,fs);
title('Lowpass Filter Designed to Specifications');
```



FIR Implementation on C6711

- Must declare buffer arrays to store input samples x(n), and coefficients b(n), for n = 0 to M

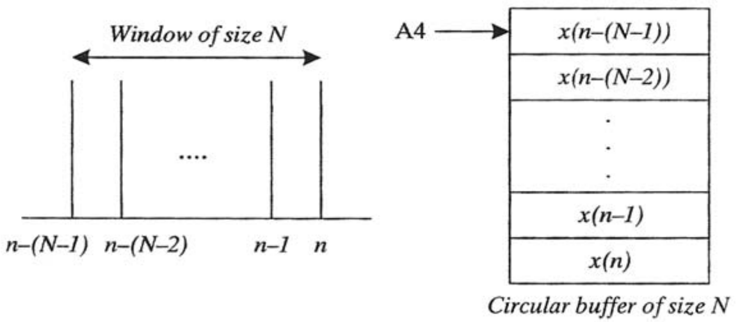
```
#define  M          12
// FIR filter coefficients
float  b[ ] = {1.0,  0.2356,  -0.03987,
                 …….           };
float  x[M];
```

- Require to implement delay operator by shifting all previous M-1 samples and insert current input sample in x[0]:

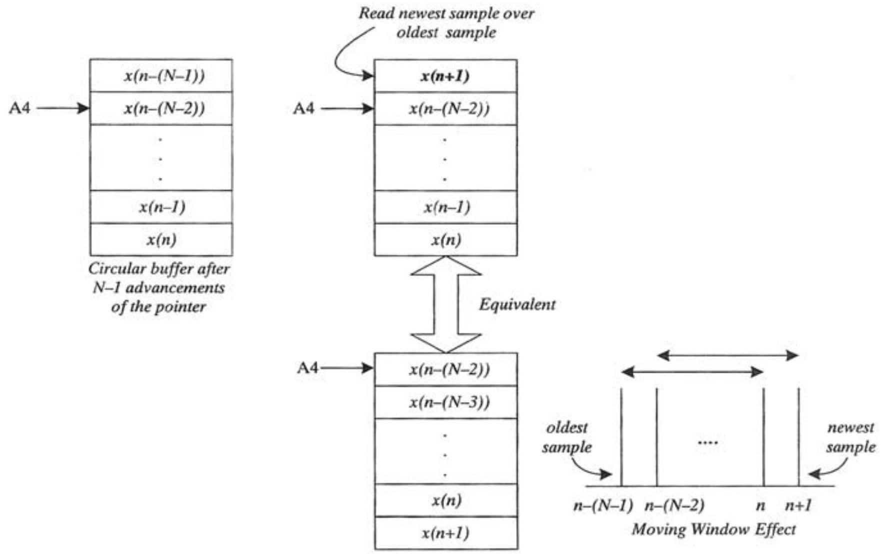
```
// Z-1 delay operator
for (i=M-2; i>=0; i--)  x[i+1] = x[i];
x[0] = input_sample;
```


Circular Buffers

- Shifting data this way is a form of circular buffer - inefficient
- Far better to implement this circular buffer using fixed memory (without moving data) and a moving pointer
- After N accesses, A4 returns to the same place

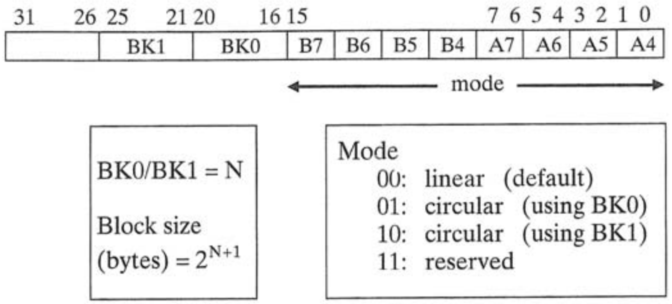


Circular buffer with sliding window



C6x Support for circular buffers

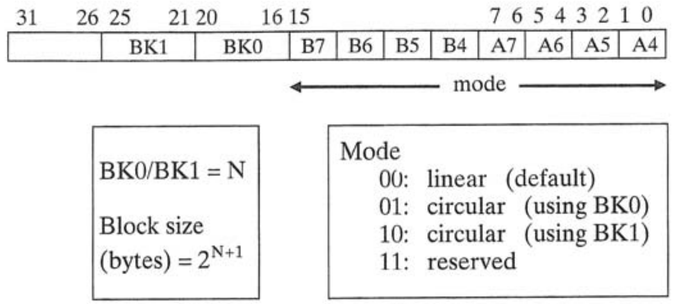
- Program Address Mode Register AMR according to:



- BK0 and BK1 defines the block size of the buffer as $2^{(N+1)}$ bytes
- C6x allows two independent circular buffer sizes in powers of 2
- Choose which 8 registers (A4-7, B4-7) as circular buffer pointers

C6x Support for circular buffers setup

- Example: A4 as a pointer for buffer size of 256 bytes




```
asm (“MVK.S2     0001h,B2”);     // A4 used as pointer
asm (“MVKLH.S2   0007h,B2”);     // use BK0, size is 256
asm(“MVC.S2      B2,AMR”);       // setup AMR
```