**Unit-IV**

**Design of Digital Filters**

**Session-1 Date: 16.09.13 , 5th hour, Time: 1.30 pm- 2.20 pm**

**Recap: Discrete In Frequency (DIF)**

**Suggested Activity: Quiz**

1. **Definition of DFT:**

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1. **Pass Loop:** An *N* (=2*p* ) point transform will perform *p* 'passes', indexed by *P*=0..*p*-1. p/
2. **Block Loop:** Pass will *P* operate on *BP* (=2*P* ) sub-blocks, each of size *NP* (=*N*/*BP*=2*p*-*P*), indexed by b=0..*BP*-1
3. **Butterfly Loop:** Each sub-block operation will perform *N*'*P* (=*NP*/2=2*p*-*P-1*) butterflies, indexed by n=0..*N*'*P*-1.

**Content: Introduction to Digital Filters**

**Suggested Activity: Match the following**

 **Column A Column B**

1. Low Pass Filter Ω p(s2+ Ω1 Ωu / s(Ωu- Ω1) **4**
2. High Pass Filter Ω p(s(Ωu- Ωc) / s2+Ωu Ωc) **3**
3. Band Pass Filter (Ω p Ω’p / s) **2**
4. Band Stop Filter (Ω p / Ω’p) s **1**

**Conclusion: Introduction to Digital Filters**

**Suggested Activity:** One word Answer

1. Give an example for Low pass filter.

**Butterworth filter**

1. State any one transformation used in filter design.

**Bilinear transformation**

1. **Frequency transformation** is used to convert one filter design to another design.

**Ref:** <http://www.freewebs.com/angsuman/dsp%20filter%20design.pdf>

**Session-2 Date: 16.09.13 , 6th hour, Time: 2.20 pm- 3.10 pm**

**Recap: Introduction to Digital Filters**

**Suggested Activity: Remembering**

Typical characteristics of ideal filter

1) Constant-gain in pass band (unity gain)

 2) Zero gain in stop band

3) Linear phase response

**Content: FIR & IIR filter realization**

**Suggested Activity:** Brain Storming

1. The impulse response of an ideal low pass filter with frequency characteristics

is given by



1. The impulse response of the above filter is





**Conclusion: FIR & IIR filter realization**

**Suggested Activity:** Questions & Answers

1. Give the expression for frequency response of an ideal filter.

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1. Expression for the impulse response

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**Ref :** <http://content.lib.utah.edu/utils/getfile/collection/uspace/id/545/filename/4199.pdf>

**Session-3 Date: 17.09.13 , 1st hour, Time: 9.15 am- 10.05 am**

**Recap: FIR & IIR filter realization**

**Suggested Activity: Quiz**

1. Bilinear transformation is used to **design Low pass, High pass, Band pass and Band stop**.
2. A stable analog filter gives a **stable digital filter.**
3. **The maxima and minima of the amplitude response** in the analog filter are preserved in the digital filter.

**Content: Parallel & cascade forms**

**Suggested Activity:** Group Activity

The entire class is divided into totally five groups. Each group is assigned a specific topic and asked to discuss about various points involved in that topic.

**Group-1: Parallel forms**

The first group is asked to discuss about **Parallel forms.**

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**Group-2: Cascade forms**

The second group is asked to discuss about **Cascade forms.**

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**Conclusion: Parallel & cascade forms**

**Suggested Activity:** Rapid fire

DESIGN OF IIR FILTERS FROM ANALOG FILTERS

1. Map the desired digital filter specifications into those for an equivalent analog filter
2. Derive the analog transfer function for the analog prototype
3. Transform the transfer function of the analog prototype into an equivalent digital filter transfer function

**Ref :** <https://blog.mozilla.org/blog/2012/05/09/windows-on-arm-users-need-browser-choice-too/>

**Session-4 Date: 17.09.13 , 2nd hour, Time: 10.05 am- 10.55 am**

**Recap: Parallel & Cascade forms**

**Suggested Activity: Brainstorming**

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**Content: FIR design-Windowing Techniques**

**Suggested Activity:** Match the following

Rectangular Window:

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**Conclusion: FIR design-Windowing Techniques**

**Suggested Activity:** Show & Tell Activity

Various shapes of Windowing techniques

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**Ref:**[https://courseware.ee.calpoly.edu/~fdepiero/fdepiero\_dsp\_notes/notes%20&%20materials/DSP%20Linear%20Phase.pdf](https://courseware.ee.calpoly.edu/~fdepiero/fdepiero_dsp_notes/notes%20%26%20materials/DSP%20Linear%20Phase.pdf)

**Session-5 Date: 19.09.13 , 7th hour, Time: 3.20 pm- 4.00 pm**

**Recap: FIR design-Windowing Techniques**

**Suggested Activity: Quiz**

Low pass filter designed with rectangular window

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**Content: Need and choice of windows**

**Suggested Activity:** Tit for Tat



**Conclusion: Need and choice of windows**

**Suggested Activity:** Unspoken word

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Ref: [www.personal.rdg.ac.uk/~stsgrimb/teaching/filters.pdf](http://www.personal.rdg.ac.uk/~stsgrimb/teaching/filters.pdf)

**Session-6 Date: 20.09.13 , 8th hour, Time: 4.10 pm- 5.00 pm**

**Recap: Need and choice of windows**

**Suggested Activity: Recall by keywords**

1. Bilinear Transformation
2. Impulse Invariant transformation
3. Butterworth filter design
4. Chebyshev filter design

**Content: Linear phase characteristics**

**Suggested Activity:** Group Discussion

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The students were asked to discuss about the linear phase characteristics of various filters.



**Conclusion: Linear phase characteristics**

**Suggested Activity:** Questions & Answers

1. Phase of filter is given by < H(F)
2. Group delay is defined as 1/2π- d{< H(F)}/dF
3. A constant group delay implies:
* Linear phase variation
* Constant delay, for any frequency
* No dispersion. Hence no change in overall signal
* Shape due to non-linear phase shifts.

Ref:[https://courseware.ee.calpoly.edu/~fdepiero/fdepiero\_dsp\_notes/notes%20&%20materials/DSP%20Linear%20Phase.pdf](https://courseware.ee.calpoly.edu/~fdepiero/fdepiero_dsp_notes/notes%20%26%20materials/DSP%20Linear%20Phase.pdf)

**Session-7 Date: 21.09.13 , 7th hour, Time: 3.20 pm- 4.10 pm**

**Recap: Linear phase characteristics**

**Suggested Activity: Pick & Answer**

1. Linear phase shift results in pure delay
2. Cos function is shifted in proportion to frequency
3. A constant group delay implies: Linear phase variation
4. Constant delay, for any frequency.Useful when filters are included in timing applications, for example. Filter delay is same, irrespective of signal input.
5. No dispersion, so no change in overall signal shape.Useful when trying to recognize wave shape, or find peak of a wave shape (for example) in time domain.

**Content:**  **IIR design-Analog filter design**

**Suggested Activity:** Group Discussion

The entire class is divided into totally two groups. Each group is assigned a specific topic and asked to discuss about various points involved in that topic.





**Conclusion: IIR design-Analog filter design**

**Suggested Activity:** Questions & Answers

1. The transition of the frequency response from pass band to the stop band defines the transition band or transition region of the filter.
2. The width of the transition band is ω1 - ωp and this is called the bandwidth of the filter.
3. Some desirable characteristics of window:

1) The central lobe of the frequency response of the window should contain most of the energy and should be narrow

2) The highest side lobe level of the frequency response should be small

3) The side lobes of the frequency response should decrease in energy as w tends to PI.

4) The width of the transition band ( on either side of discontinuity ) depends on the width of the main lobe . Ripples are coming from the side lobes of window response which produces error.

Ref: [www.personal.rdg.ac.uk/~stsgrimb/teaching/filters.pdf](http://www.personal.rdg.ac.uk/~stsgrimb/teaching/filters.pdf)

**Session-8 Date: 25.09.13 , 3rd hour, Time: 11.10 am-12.00 pm**

**Recap: IIR design-Analog filter design**

**Suggested Activity: Remembering**

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**Content: Warping, prewarping**

**Suggested Activity:** Board Activity

1. **Warping Effect:** Distortion is introduced in the frequency scale of the digital filter relative to that of the analog filter.
2. **Digital frequency,** ω = 2/T tan ( ΩT/2)

**Conclusion: Warping, prewarping**

**Suggested Activity:** One word answer

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**Ref:** <http://www.ece.ucsb.edu/~roy/classnotes/147b/lecture4_small.pdf>

**Session-9 Date: 25.09.13 , 4th hour, Time: 12.00 pm- 12.50 pm**

**Recap: Warping, prewarping**

**Suggested Activity:** Quiz

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This transformation is a one –to -one mapping from the s-domain to the z-domain. i.e it is a mapping that transforms the jΩ axis into the unit circle in the z plane only once. Also it presents in a stable digital filter as all the poles in the LHP of S-plane are mapped into points inside the unit circle of the z-domain.

**FIR filters are particularly useful for applications where exact linear phase response is required.**

The FIR filter is generally implemented in a non-recursive way which guarantees a stable filter.

FIR filter design essentially consists of two parts

(i) approximation problem

(ii) realization problem

**Content: Frequency transformation**

**Suggested Activity:** Board Activity

**Merits of frequency sampling technique**

(i) Unlike the window method, this technique can be used for any given magnitude response.

(ii) This method is useful for the design of non-prototype filters where the desired magnitude

response can take any irregular shape.

There are some disadvantages with this method i.e the frequency response obtained by

interpolation is equal to the desired frequency response only at the sampled points. At the other

points, there will be a finite error present.

**Optimal Filter Design Methods**

Many methods are present under this category. The basic idea in each method is to design the

filter coefficients again and again until a particular error is minimized. The various methods are

as follows:

(i) Least squared error frequency domain design

(ii) Weighted Chebyshev approximation

(iii) Nonlinear equation solution for maximal ripple FIR filters

(iv) Polynomial interpolation solution for maximal ripple FIR filters

**Conclusion: Frequency transformation**

**Suggested Activity:** Questions & Answers

*Hd*(*w*) = the desired (real) frequency response of the filter

*H*(*w*)= the frequency response of the designed filter

*W*(*w*)= the frequency response of the weighting function

The weighting function enables the designer to choose the relative size of the error in different

frequency bands.

**Ref:** <http://www.electronics.dit.ie/staff/ptobin/3chapt05.pdf>

**Session-10 Date: 26.09.13 , 1st hour, Time: 9.15 am- 10.05 am**

**Content: Tutorial: Butterworth and Chebyshev approximations**

**Suggested Activity:** Board Activity- Problem Solving

**Ref:**<http://paginas.fisica.uson.mx/horacio.munguia/aula_virtual/Cursos/Instrumentacion%20II/Documentos/Tutorial%20Filtros.pdf>

**Session-11 Date: 27.09.13 , 6th hour, Time: 2.20 pm-3.10 pm**

**Content: Tutorial: Digital design using bilinear transformation**

**Suggested Activity:** Board Activity- Problem Solving

**Ref:** <http://www.ece.uvic.ca/~andreas/ISCASTutorial/Part%203-IIR%20Filters-Bilinear%20Transformation%20Method.pdf>

**Session-12 Date: 28.09.13 , 6th hour, Time: 2.20 pm-3.10 pm**

**Content: Tutorial: Digital design using impulse invariant**

**Suggested Activity:** Board Activity- Problem Solving

**Ref:**[https://courseware.ee.calpoly.edu/~fdepiero/fdepiero\_dsp\_notes/notes%20&%20materials/DSP%20Linear%20Phase.pdf](https://courseware.ee.calpoly.edu/~fdepiero/fdepiero_dsp_notes/notes%20%26%20materials/DSP%20Linear%20Phase.pdf)