ME (Embedded Systems)

DIGITAL SIGNAL PROCESSING

Lab Assignment 1

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1. Write a Matlab function "linearconv.m" to perform linear convolution of two sequences. Use this function to verify following properties of Linear Convolution.

a. Commutative Property

b. Associative Property

c. Distributive Property

Code :

linearconv.m

```
function [output]= linearconv(a,b)
l1=length(a);
l2=length(b);
lo=l1+l2-1;
output=zeros(1,lo); %initialise output vector to m+n-1 zeros
for n=1:lo
 sum=0;
 for k=1:l1
 if(n-k+1>0 && n-k+1<=l2)
 sum=sum+a(k)*b(n-k+1);
 end
 end
 output(n)=sum;
end
```

verify.m

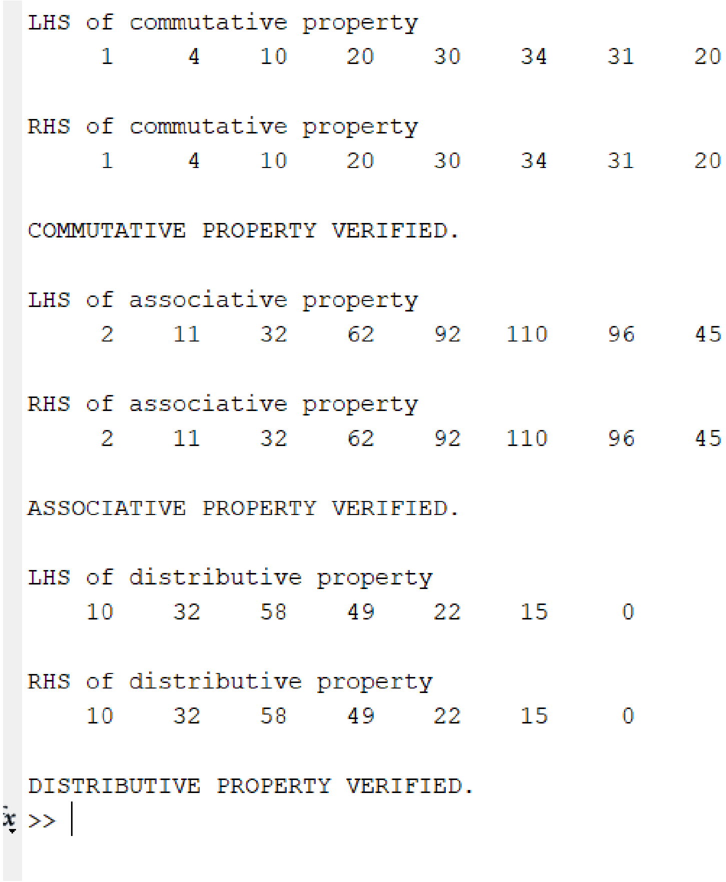
```
clc;
%test commutative property
% c=a*b d=b*a
a=[1,2,3,4,5];
b=[1,2,3,4];
c=linearconv(a,b);
d=linearconv(b,a);
```

```
disp('LHS of commutative property');
disp(c);
disp('RHS of commutative property');
disp(d);
disp('COMMUTATIVE PROPERTY VERIFIED.');
disp(' ')

%test associative property
a=[1,2,3,4,5];
b=[1,2,3];
c=[2,3];
%find (a*b)*c where d=a*b
d=linearconv(a,b);
e=linearconv(d,c);
%find a*(b*c) where f=b*c
f=linearconv(b,c);
g=linearconv(a,f);
disp('LHS of associative property');
disp(e);
disp('RHS of associative property');
disp(g);
disp('ASSOCIATIVE PROPERTY VERIFIED.');
disp(' ')

%test distributive property
a=[1,2,3];
x1=[2,3,4,5];
x2=[8,9];
com_length=max([length(a),length(x1),length(x2)]);
a=[a zeros(1,com_length-length(a))];
x1=[x1 zeros(1,com_length-length(x1))];
x2=[x2 zeros(1,com_length-length(x2))];
lhs=linearconv(a,x1)+linearconv(a,x2);
rhs=linearconv(a,x1+x2);
disp('LHS of distributive property');
disp(lhs);
disp('RHS of distributive property');
disp(rhs);
disp('DISTRIBUTIVE PROPERTY VERIFIED.');
```

Output:



```
LHS of commutative property
     1     4    10    20    30    34    31    20

RHS of commutative property
     1     4    10    20    30    34    31    20

COMMUTATIVE PROPERTY VERIFIED.

LHS of associative property
     2    11    32    62    92   110    96    45

RHS of associative property
     2    11    32    62    92   110    96    45

ASSOCIATIVE PROPERTY VERIFIED.

LHS of distributive property
    10    32    58    49    22    15     0

RHS of distributive property
    10    32    58    49    22    15     0

DISTRIBUTIVE PROPERTY VERIFIED.
>>
```

2. Write a Matlab function “dft.m” to find DFT of a sequence. Use this function to find the convolution of two sequences.

Code :

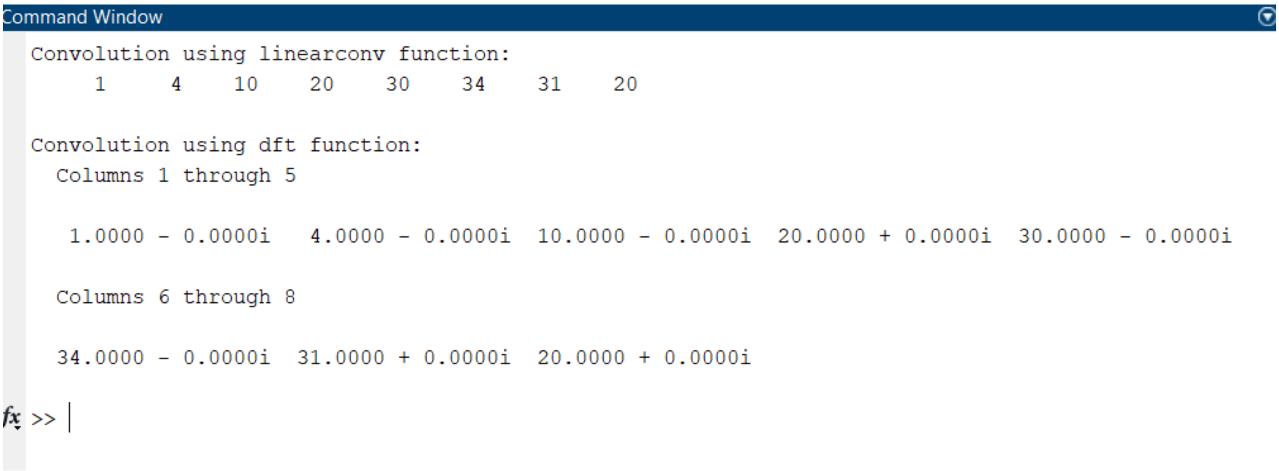
dft.m

```
function [output]=dft(x,N)
%initialise ouput vector to N zeros
output= zeros(1,N);
%constant factor in dft equation pre-computed
b= -1i*2*pi/N;
lx=length(x);
for k=1:N
 output(k)=0;
 for n=0:lx-1
 output(k)=output(k)+x(n+1)*exp(b*(k-1)*n);
 end
end
```

verifydft.m

```
%find convolution using dft function
clc;
N=8;
% a and b are two vectors whose convolution is to be computed
a=[1,2,3,4,5];
b=[1,2,3,4];
%convolution using user defined function
c=linearconv(a,b);
Ak=dft(a,N);
Bk=dft(b,N);
Ck=Ak.*Bk;
%convolution by idft of pointwise multiplied DFT sequences
conSeq=(1/N).*(conj(dft(conj(Ck),N)));
disp('Convolution using linearconv function:');
disp(c);
disp('Convolution using dft function:');
disp(conSeq);
```

Output:



```
Convolution using linearconv function:
     1     4    10    20    30    34    31    20

Convolution using dft function:
  Columns 1 through 5

   1.0000 - 0.0000i   4.0000 - 0.0000i  10.0000 - 0.0000i  20.0000 + 0.0000i  30.0000 - 0.0000i

  Columns 6 through 8

  34.0000 - 0.0000i  31.0000 + 0.0000i  20.0000 + 0.0000i

fx >> |
```

3. Write a Matlab program to find DFT of a sequence using DIF-FFT.

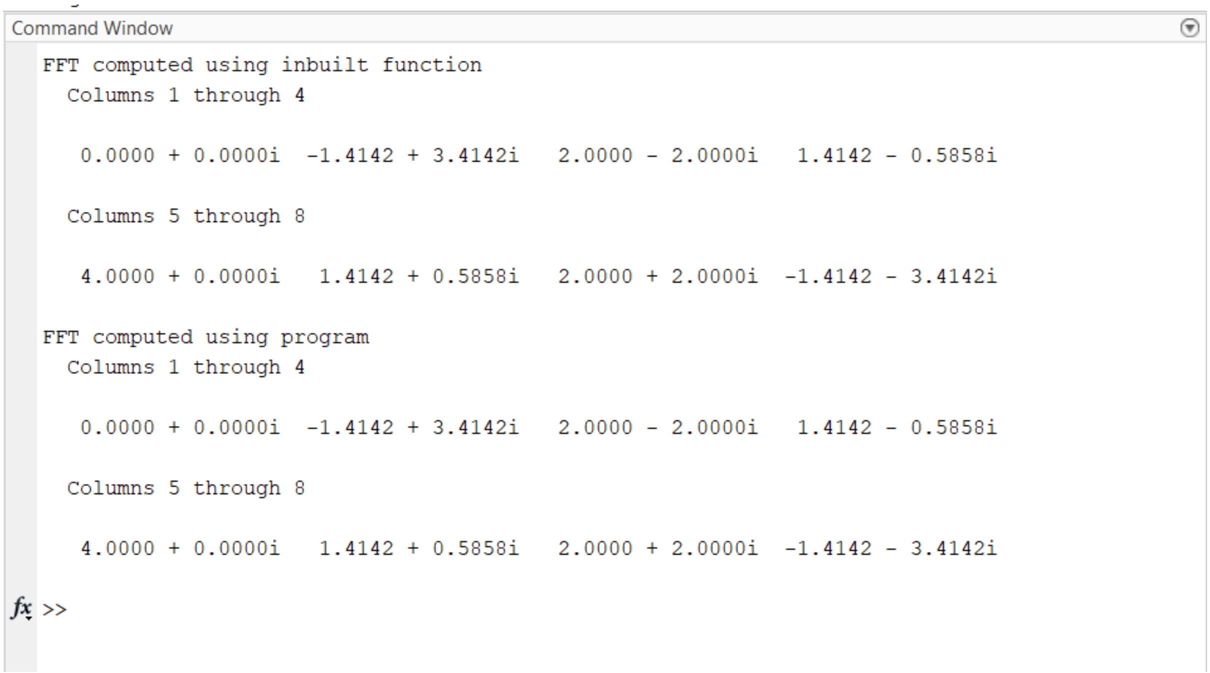
Code :

dif_fft.m

```
%dft using DIF-FFT
clc;
x =[1,-1,-1,-1,1,1,1,-1];
N =8;
Xk=fft(x);
p=log2(N);
```

```
Half=N/2;
for stage=1:p %process input vector stage by stage and write
back to it
 for index=0:(N/(2^(stage-1))):(N-1)
 for n=0:(Half-1)
 pos=n+index+1;
 pow=(2^(stage-1))*n;
 w=exp((-1i)*(2*pi)*pow/N); %twiddle factors
 a=x(pos)+x(pos+Half); %butterfly addition
 b=(x(pos)-x(pos+Half)).*w; %butterfly subtraction
 x(pos)=a;
 x(pos+Half)=b;
 end
 end
Half=Half/2;
end
y=bitrevorder(x); %inbuilt function to bit reverse the indices
disp('FFT computed using inbuilt function');
disp(Xk);
disp('FFT computed using program');
disp(y);
```

Output:



```
FFT computed using inbuilt function
  Columns 1 through 4

   0.0000 + 0.0000i  -1.4142 + 3.4142i   2.0000 - 2.0000i   1.4142 - 0.5858i

  Columns 5 through 8

   4.0000 + 0.0000i   1.4142 + 0.5858i   2.0000 + 2.0000i  -1.4142 - 3.4142i

FFT computed using program
  Columns 1 through 4

   0.0000 + 0.0000i  -1.4142 + 3.4142i   2.0000 - 2.0000i   1.4142 - 0.5858i

  Columns 5 through 8

   4.0000 + 0.0000i   1.4142 + 0.5858i   2.0000 + 2.0000i  -1.4142 - 3.4142i

fx >>
```