4(a) 冲激响应不变法设计Butterworth数字滤波器

（1）Butterworth数字高通滤波器：

```
clear all;
close all;
fs=300;
fp=200;
Fs=1000;
Rp=3;  Rs=30;

wp=2*pi*fp/Fs;
ws=2*pi*fs/Fs;

OmegaP=2*Fs*tan(wp/2);
OmegaS=2*Fs*tan(ws/2);

[N,Wn]=buttord(OmegaP,OmegaS,Rp,Rs,'s');   %选择模拟巴特沃斯低通滤波器的最小阶数
[z,p,k]=buttap(N);              %创建巴特沃斯模拟低通滤波器
[Bp,Ap]=zp2tf(z,p,k)            %由零点、极点、增益确定传输函数的分子与分母的系数
```
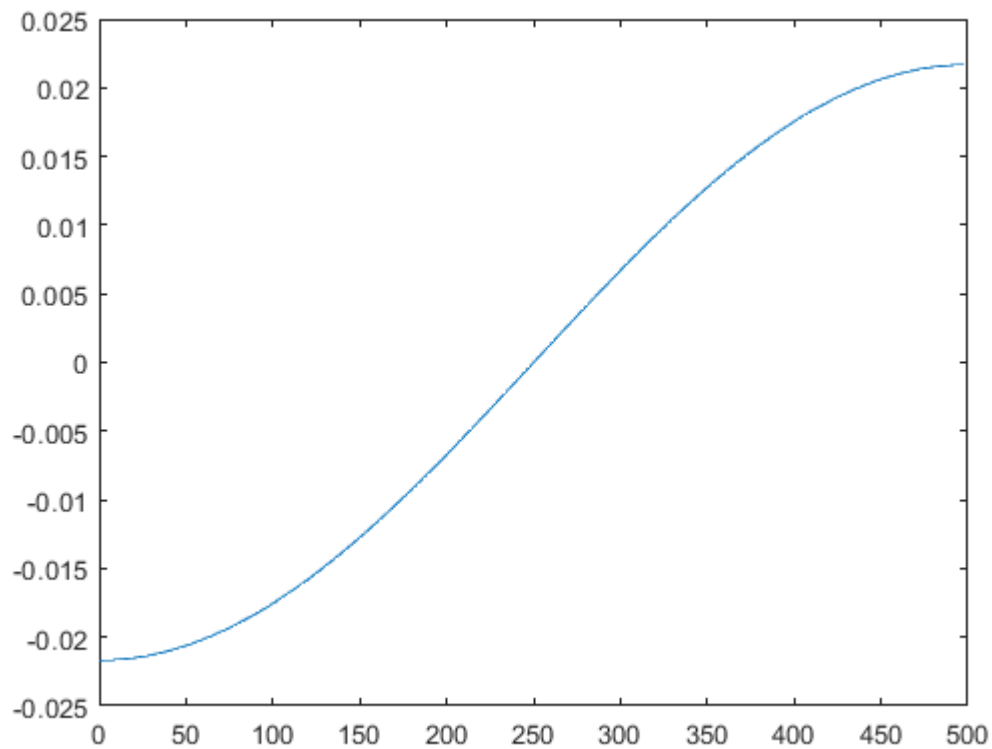
```
Bp = 1×7
     0      0      0      0      0      0      1
Ap = 1×7
   1.0000    3.8637    7.4641    9.1416    7.4641    3.8637    1.0000
```

```
[b,a]=lp2lp(Bp,Ap,Wn)          %模拟低通滤波器到模拟高通滤波器的转换
```

```
b = 1.3767e+19
a = 1×7
10^19 ×
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0034    1.3767
```

```
figure(1);
[h,w]=freqz(b,a,256,Fs);
plot(w,20*log10(abs(h)))
```

（2）Butterworth数字低通滤波器：

```
clear all;
close all;
fp=200;
fs=300;
Fs=1000;
Rp=3;  Rs=30;

wp=2*pi*fp/Fs;
ws=2*pi*fs/Fs;

OmegaP=2*Fs*tan(wp/2);
OmegaS=2*Fs*tan(ws/2);

[N,Wn]=buttord(OmegaP,OmegaS,Rp,Rs,'s');   %选择模拟巴特沃斯低通滤波器的最小阶数
[z,p,k]=buttap(N);              %创建巴特沃斯模拟低通滤波器
[Bp,Ap]=zp2tf(z,p,k)            %由零点、极点、增益确定传输函数的分子与分母的系数
```

```
Bp = 1×7
     0      0      0      0      0      0      1
Ap = 1×7
    1.0000    3.8637    7.4641    9.1416    7.4641    3.8637    1.0000
```
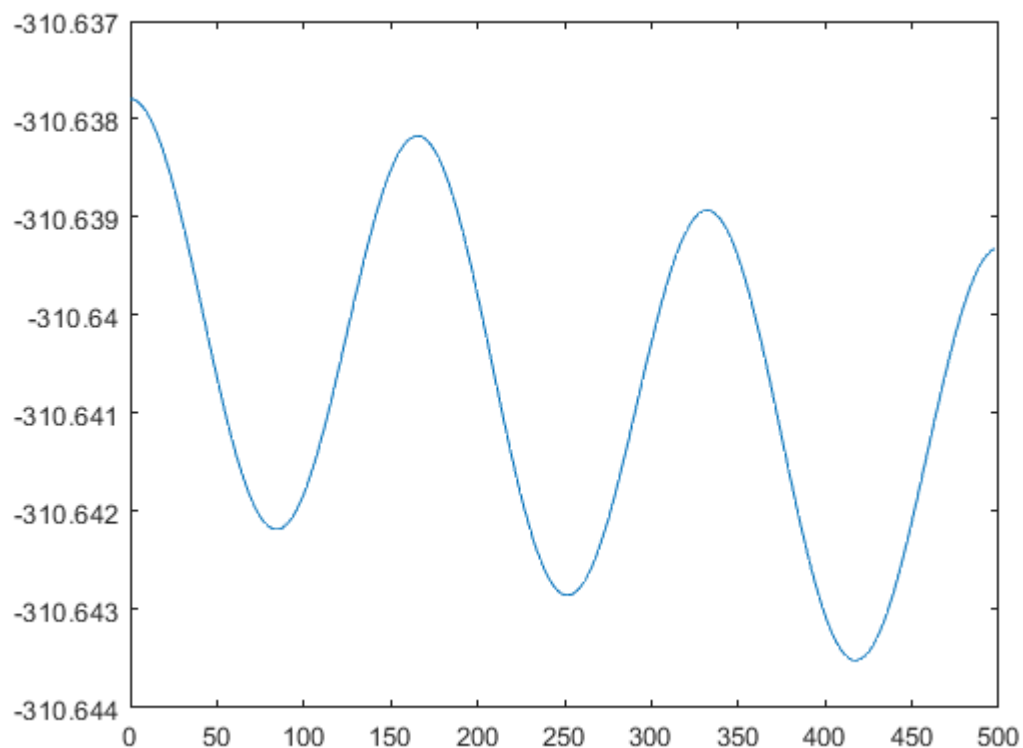
```
[b,a]=lp2hp(Bp,Ap,Wn)           %模拟低通滤波器到模拟高通滤波器的转换
```

```
b = 1×7
10³ ×
    0.0010    0.0000    0.0000    0.0000    0.0000    0.0104    4.0439
a = 1×7
10¹⁹ ×
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0034    1.3767
```

```matlab
figure(1);
[h,w]=freqz(b,a,256,Fs);
plot(w,20*log10(abs(h)))
```


（3）Butterworth数字带通滤波器：

```matlab
clear all;
close all;
fp=[270 330];fs=[200 400];
%wp=[.19*pi 0.21*pi];ws=[.198*pi 0.202*pi];
Fs=1000;
Rp=3;Rs=30;

wp=2.*pi.*fp./Fs;
ws=2.*pi.*fs./Fs;

OmegaP=2*Fs*tan(wp./2);
OmegaS=2*Fs*tan(ws./2);
bw=OmegaP(2)-OmegaP(1)
```

```
w0=sqrt(OmegaP(1)*OmegaP(2))

[N,Wn]=buttord(OmegaP,OmegaS,Rp,Rs,'s');   %选择模拟巴特沃斯低通滤波器的最小阶数
[z,p,k]=buttap(N);               %创建巴特沃斯模拟低通滤波器
[Bp,Ap]=zp2tf(z,p,k)             %由零点、极点、增益确定传输函数的分子与分母的系数
[b,a]=lp2bp(Bp,Ap,Wn,bw)          %模拟低通滤波器到模拟高通滤波器的转换
figure(1);
[h,w]=freqz(b,a,256,Fs);
plot(w,20*log10(abs(h)))
```

（4）Butterworth数字带阻滤波器：

```
clear all;
close all;
fp=[270 330];fs=[200 400];
%wp=[.19*pi 0.21*pi];ws=[.198*pi 0.202*pi];
Fs=1000;
Rp=3;Rs=30;

wp=2.*pi.*fp./Fs;
ws=2.*pi.*fs./Fs;

OmegaP=2*Fs*tan(wp./2);
OmegaS=2*Fs*tan(ws./2);
bw=OmegaP(2)-OmegaP(1)
w0=sqrt(OmegaP(1)*OmegaP(2))

[N,Wn]=buttord(OmegaP,OmegaS,Rp,Rs,'s');   %选择模拟巴特沃斯低通滤波器的最小阶数
[z,p,k]=buttap(N);               %创建巴特沃斯模拟低通滤波器
[Bp,Ap]=zp2tf(z,p,k)             %由零点、极点、增益确定传输函数的分子与分母的系数
[b,a]=lp2bs(Bp,Ap,Wn,bw)          %模拟低通滤波器到模拟高通滤波器的转换
figure(1);
[h,w]=freqz(b,a,256,Fs);
plot(w,20*log10(abs(h)))
```