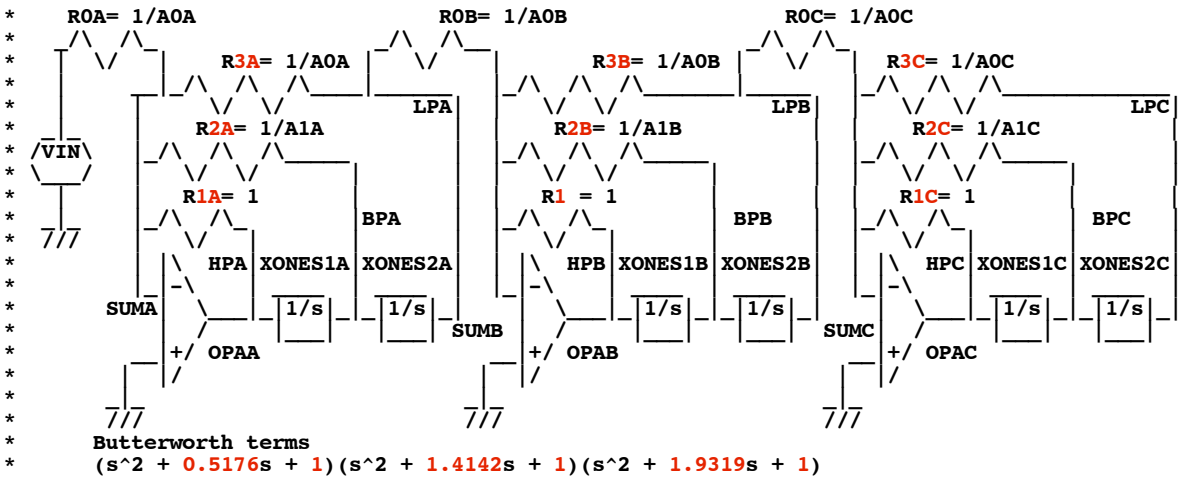
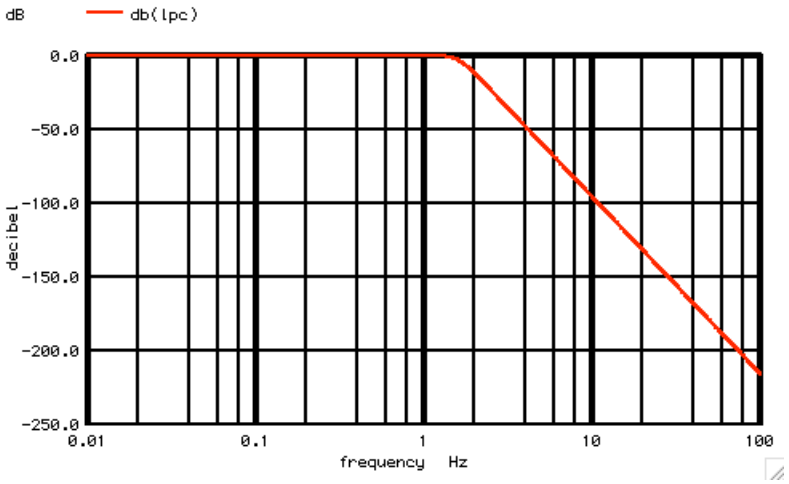
=====Analog_Brickwall_filters=====

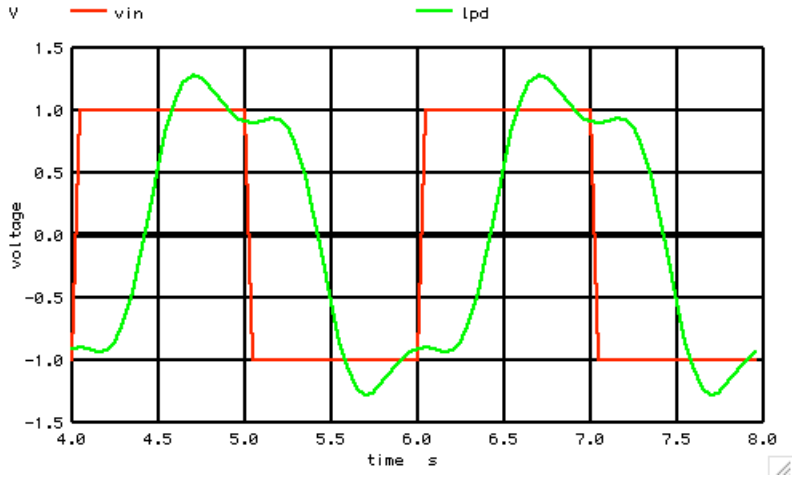
Better_Butterworth_6P_State_Variable



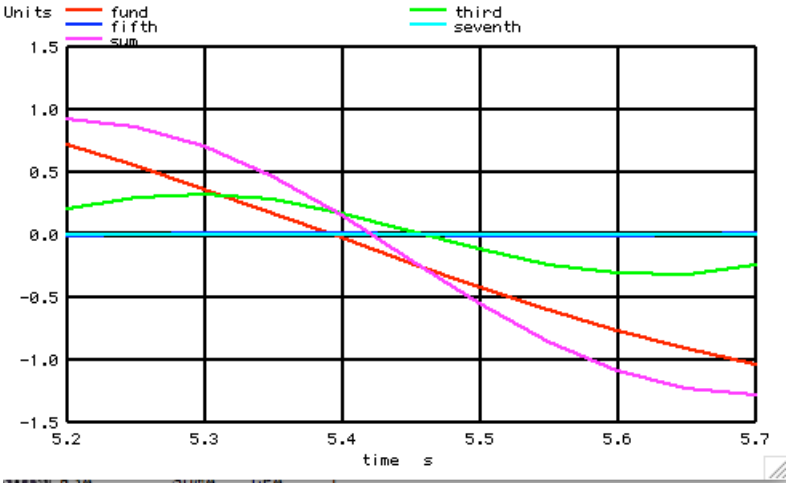
Building Filters that come close to being perfect is a little more involved than simply adding more stages. The Butterworth filter above has be optimize for ideal gain response.



But looking at the transient output for a butterworth reveals a bit of a distorted output wave form.



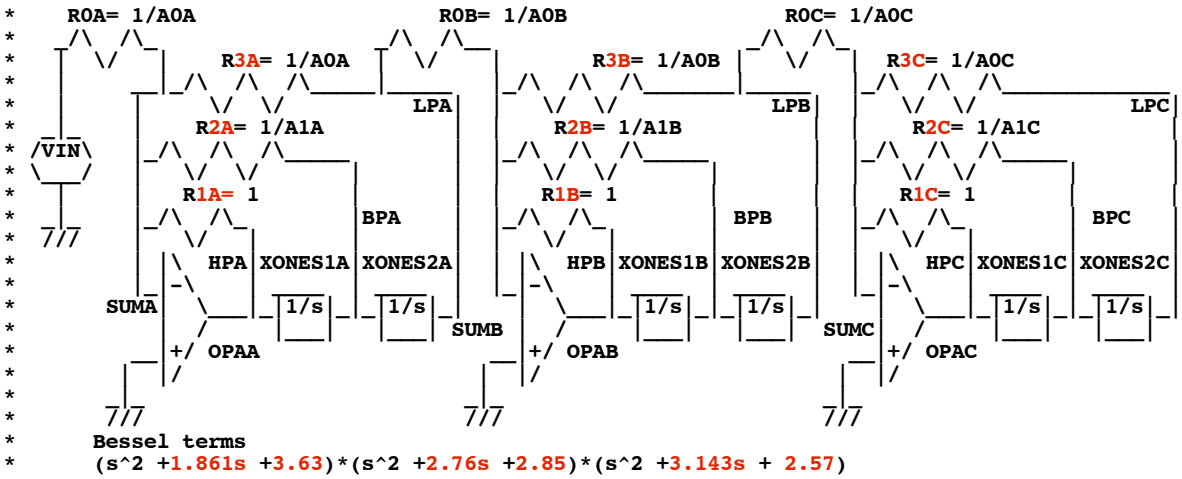
When a outputs square wave's harmonic are broken down, this butterworth will have removed any harmonics above the third.



But when the fundamental and third are plotted together, it is apparent that the third has a different time delay than the fundamental.

==========

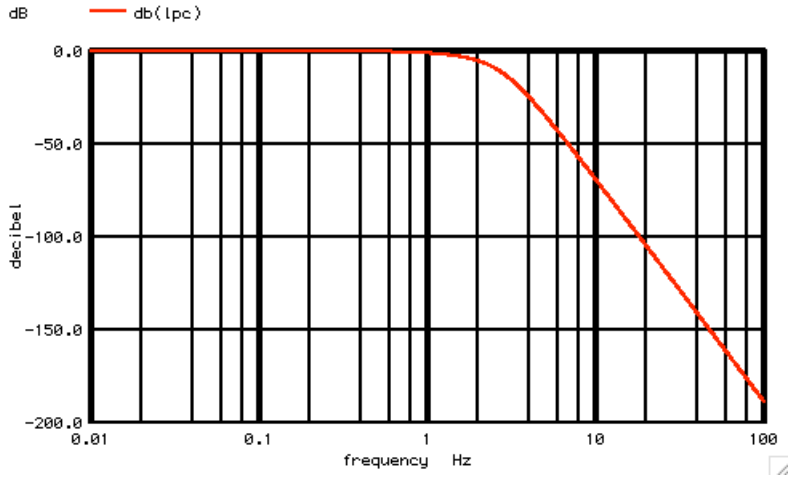
Better_Bessel_6P_State_Variable



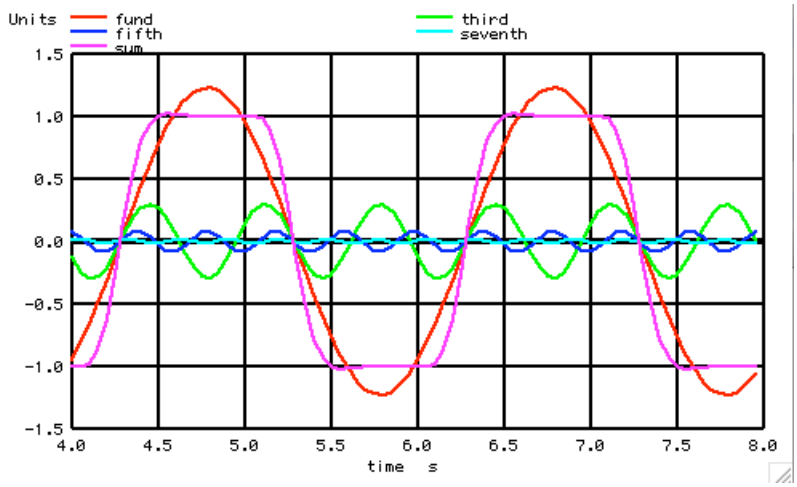
Bessel terms

(s^2 +1.861s +3.63)*(s^2 +2.76s +2.85)*(s^2 +3.143s + 2.57)

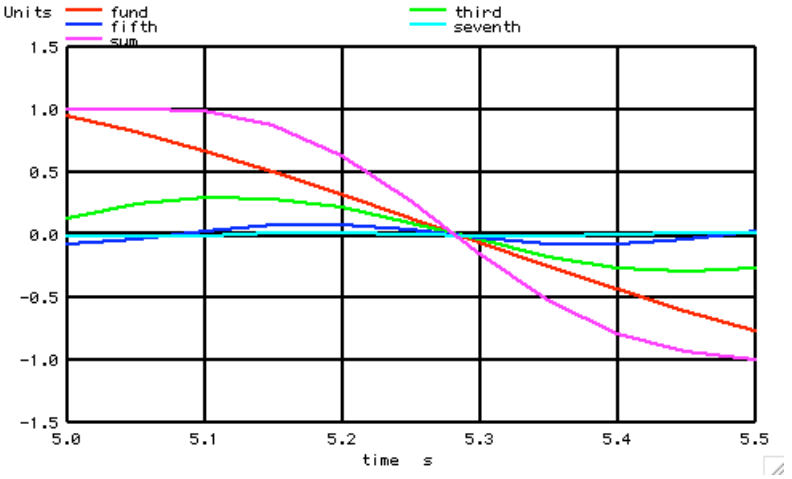
The Bessel is an alternative with much different poles.



The Bessel is not as good as a Butterworth in terms of magnitude.



**But a Bessel does not distort the output like a Butterworth.
In this case harmonics below the seventh have gotten through.**



Plotting all the harmonics on the same plot shows that everything has the exact same time delay. This allows the Bessel to do a better job of rounding off the edges of a square wave without changing its shape.

So building an ideal filter involves not only ideal magnitude response, but also ideal timing or phase response.

```
===========Full_Netlist_For_Copy_Paste========================
Better_Butterworth_6P_State_Variable
*  dsauersanjose@aol.com
*  www.idea2ic.com
*  8.13.10_10.02AM
*
*    R0A= 1/A0A                  R0B= 1/A0B                R0C= 1/A0C
*   _/\  /\_                  _/\  /\__                 _/\  /\_
*   |  \/   |     R3A= 1/A0A  |  \/    |      R3B= 1/A0B |  \/   |  R3C= 1/A0C
*   |      __|_/\  /\  /\_____|_____   |_/\  /\  /\______|_____  |_/\  /\  /\____________
*   |      |    \/  \/           LPA|  |  \/  \/            LPB| |  \/  \/             LPC|
*  _|_     |    R2A= 1/A1A          |  |  R2B= 1/A1B           | |  R2C= 1/A1C            |
* /VIN\    |_/\  /\  /\_____        |  |_/\  /\  /\_____       | |_/\  /\  /\_____        |
* \___/    |  \/  \/        |       |  |  \/  \/        |      | |  \/  \/        |       |
*   |      |   R1A= 1       |       |  |   R1 = 1       |      | |   R1C= 1       |       |
*  _|_     |_/\  /\_        |BPA    |  |_/\  /\_        |BPB   | |_/\  /\_        |BPC    |
*  ///     |  \/    |       |       |  |  \/    |       |      | |  \/    |       |       |
*          | |\  HPA|XONES1A|XONES2A|  | |\  HPB|XONES1B|XONES2B| | |\  HPC|XONES1C|XONES2C|
*          |_|-\    |  ____ |  ____ |  |_|-\    |  ____ |  ____| |_|-\    |  ____ |  ____ |
*       SUMA|   \___|_|1/s|_|_|1/s|_|  |   \___|_|1/s|_|_|1/s|_| |   \___|_|1/s|_|_|1/s|_|
*           |   /     |____|  |____| SUMB  /     |____|  |____| SUMC  /    |____|  |____|
*         __|+/ OPAA                   __|+/ OPAB                  __|+/ OPAC
*        |  |/                        |  |/                       |  |/
*       _|_                          _|_                         _|_
*       ///                          ///                         ///
*      Butterworth terms
*      (s^2 + 0.5176s + 1)(s^2 + 1.4142s + 1)(s^2 + 1.9319s + 1)
.OPTIONS  GMIN=1e-18    METHOD=euler  srcsteps = 1  gminsteps = 1
*======== ====== ====== ====== ====== ====== ====== ====== ======
*V_PULSE# NODE_P NODE_N DC     VALUE  PULSE( VINIT  VPULSE TDELAY TRISE  TFALL  PWIDTH PERIOD )
V_IN      VIN    0      DC     0      PULSE( -1      1      100u   100u   100u  1      2 ) AC = 1
R0A       VIN    SUMA   1
R1A       SUMA   HPA    1
R2A       SUMA   BPA    1.9319
R3A       SUMA   LPA    1
BOPA1A    HPA    0      V =    5*tanh(tanh((-v(SUMA))*100)*100)
XONES1A   HPA    BPA    ONE_S
XONES2A   BPA    LPA    ONE_S
R0B       LPA    SUMB   1
R1B       SUMB   HPB    1
R2B       SUMB   BPB    .707
R3B       SUMB   LPB    1
BOPA1B    HPB    0      V =    5*tanh(tanh((-v(SUMB))*100)*100)
XONES1B   HPB    BPB    ONE_S
XONES2B   BPB    LPB    ONE_S
R0C       LPB    SUMC   1
R1C       SUMC   HPC    1
R2C       SUMC   BPC    .5176
R3C       SUMC   LPC    1
BOPA1C    HPC    0      V =    5*tanh(tanh((-v(SUMC))*100)*100)
XONES1C   HPC    BPC    ONE_S
XONES2C   BPC    LPC    ONE_S
Binv      LPD    0      V =    -V(LPC)

*===========Integrator_Cell===============================================
*            C1 .1F                  ____
*            _||______ OUT1  _____|OUT|
*   ___     R1 |  ||  _|_  |    _|_   |___|     .SUBCKT   ONE_S  IN   OUT
*  |IN |_/\  _|__ /   \ |__ /   \
*  |___|  \/ISUM| BOP1|    |BINV1|    ---->  |IN |_|_______|__|OUT|
*        1     _| 80dB|  _|  -1  |    ---->  |___| |  1/s  |  |___|
*             |  \___/  |  \___/                   |_______|
*             |_____|   |_____|
*                _|_       _|_       R = 1 = 1/sC   s = 1 =  2*PI*Freq
*                ///       ///
*
.SUBCKT     ONE_S    IN     OUT
R1          IN       ISUM   1
C1          ISUM     OUT1   .1
BOP1        OUT1     0      V =    5*tanh(tanh((-v(ISUM))*100)*100)
BINV1       OUT      0      V =    -v(OUT1)
.ends


*=========A_Bessel_is_Best_for_Low_Phase_Distortion====
.control
ac         dec    500     .01   100
plot       db(lpc)
*TRAN      TSTEP  TSTOP  TSTART TMAX
tran      50m    7.95   4      50m
```

```
linearize
plot      vin    lpd
let       numb2   = length(vin)
print     numb2
let       t_indx2 = vector($&numb2)
let       ac      = lpd +j(0)
let       ac_fft  = fft(ac)
plot      real(ac_fft) imag(ac_fft) vs t_indx2

let       funbin = 2
let       unvect                = unitvec($&numb2)
let       fundspec              = unvect*0 +j(0)
let       fundspec[2]           = real(ac_fft[2])        +j(imag(ac_fft[2] ))
let       fundspec[numb2-2]     = real(ac_fft[numb2-2])  +j(imag(ac_fft[numb2-2] ))
let       fund                  =  ifft(fundspec)
let       thirdspec             = unvect*0 +j(0)
let       thirdspec[6]          = real(ac_fft[6])        +j(imag(ac_fft[6] ))
let       thirdspec[numb2-6]    = real(ac_fft[numb2-6])  +j(imag(ac_fft[numb2-6] ))
let       third                 = ifft(thirdspec)
let       fifthspec             = unvect*0 +j(0)
let       fifthspec[10]         = real(ac_fft[10])        +j(imag(ac_fft[10] ))
let       fifthspec[numb2-10]   = real(ac_fft[numb2-10])  +j(imag(ac_fft[numb2-10] ))
let       fifth                 = ifft(fifthspec)
let       seventhspec           = unvect*0 +j(0)
let       seventhspec[14]       = real(ac_fft[14])        +j(imag(ac_fft[14] ))
let       seventhspec[numb2-14] = real(ac_fft[numb2-14])  +j(imag(ac_fft[numb2-14] ))
let       seventh               = ifft(seventhspec)
let       sum  = fund + third + fifth + seventh
set       scale  time
plot      fund  third fifth seventh  sum

plot      fund  third fifth seventh  sum xlimit 5.2 5.7
.endc



.end


Better_Bessel_6P_State_Variable
*  dsauersanjose@aol.com
*  www.idea2ic.com
*  8.13.10_10.02AM
*
*    R0A= 1/A0A                    R0B= 1/A0B                    R0C= 1/A0C
*     /\  /\_                       /\  /\__                      /\  /\_
*    \  \/   |     R3A= 1/A0A      \  \/   |       R3B= 1/A0B     \  \/   |   R3C= 1/A0C
*     |  /\  /\  /\_____|_____      |  /\  /\  /\_____|_____      |  /\  /\  /\_____________
*     |     \/  \/          LPA     |     \/  \/          LPB     |     \/  \/              LPC
*    _|_    |    R2A= 1/A1A         |    R2B= 1/A1B               |    R2C= 1/A1C
* /VIN\     |  /\  /\  /\_____      |  /\  /\  /\_____            |  /\  /\  /\_____
* \___/     |     \/  \/            |     \/  \/                  |     \/  \/
*    |      |    R1A= 1             |    R1 = 1                   |    R1C= 1
*   _|_     |  /\  /\_        BPA   |  /\  /\_          BPB      |  /\  /\_          BPC
*   ///     |     \/          |     |     \/          |           |     \/          |
*           |  |\  HPA|XONES1A|XONES2A|  |\  HPB|XONES1B|XONES2B|  |\  HPC|XONES1C|XONES2C|
*           |  -\     |_1/s_|_1/s_|     |  -\     |_1/s_|_1/s_|     |  -\     |_1/s_|_1/s_|
*      SUMA |    \____|_1/s_|_1/s_|SUMB |    \____|_1/s_|_1/s_|SUMC |    \____|_1/s_|_1/s_|
*           |    /    |___|   |___|     |    /    |___|   |___|     |    /    |___|   |___|
*           |  +/ OPAA                  |  +/ OPAB                  |  +/ OPAC
*           |  /                        |  /                        |  /
*           |                           |                           |
*          ///                         ///                         ///
*      Bessel terms
*      (s^2 +1.861s +3.63)*(s^2 +2.76s +2.85)*(s^2 +3.143s + 2.57)
.OPTIONS  GMIN=1e-18    METHOD=euler  srcsteps = 1  gminsteps = 1
*======== ====== ====== ====== ====== ====== ====== ====== ======
*V_PULSE# NODE_P NODE_N DC     VALUE  PULSE( VINIT  VPULSE TDELAY TRISE  TFALL  PWIDTH PERIOD )
V_IN      VIN    0      DC     0      PULSE( -1      1      100u   100u   100u  1      2 ) AC = 1
R0A       VIN    SUMA   .333
R1A       SUMA   HPA    1
R2A       SUMA   BPA    .54
R3A       SUMA   LPA    .333
BOPA1A    HPA    0      V =    5*tanh(tanh((-v(SUMA))*100)*100)
XONES1A   HPA    BPA    ONE_S
XONES2A   BPA    LPA    ONE_S
R0B       LPA    SUMB   .35
R1B       SUMB   HPB    1
R2B       SUMB   BPB    .362
R3B       SUMB   LPB    .35
BOPA1B    HPB    0      V =    5*tanh(tanh((-v(SUMB))*100)*100)
XONES1B   HPB    BPB    ONE_S
```

```
XONES2B   BPB    LPB    ONE_S
R0C       LPB    SUMC   .389
R1C       SUMC   HPC    1
R2C       SUMC   BPC    .318
R3C       SUMC   LPC    .389
BOPA1C    HPC    0      V =    5*tanh(tanh((-v(SUMC))*100)*100)
XONES1C   HPC    BPC    ONE_S
XONES2C   BPC    LPC    ONE_S
Binv      LPD    0      V =    -V(LPC)
*==========Integrator_Cell==================================================
*             C1 .1F               ___
*             _||______ OUT1 _____|OUT|
*  ___    R1 |  || _|_  |    _|_  |___|     .SUBCKT   ONE_S  IN   OUT
* |IN |_/\  _|__ /   \ |__ /   \             ___  _______  ___
* |___|   \/ISUM| BOP1|   |BINV1|   ---->   |IN |_|       |__|OUT|
*        1     _| 80dB|  _|  -1 |   ---->   |___| |  1/s  |  |___|
*             |  \___/  |  \___/                  |_______|
*             |____|    |____|
*                 _|_       _|_       R = 1 = 1/sC   s = 1 =  2*PI*Freq
*                 ///       ///
*
.SUBCKT     ONE_S    IN     OUT
R1          IN       ISUM   1
C1          ISUM     OUT1   .1
BOP1        OUT1     0      V =    5*tanh(tanh((-v(ISUM))*100)*100)
BINV1       OUT      0      V =    -v(OUT1)
.ends


*=========A_Bessel_is_Best_for_Low_Phase_Distortion====
.control
ac         dec    500     .01   100
plot       db(lpc)
*TRAN     TSTEP  TSTOP  TSTART TMAX
tran      50m    7.95   4      50m


linearize
plot      vin    lpd
let       numb2 = length(vin)
print     numb2
let       t_indx2 = vector($&numb2)

let       ac = lpd +j(0)
let       ac_fft=fft(ac)
plot      real(ac_fft) imag(ac_fft) vs t_indx2

let       funbin = 2
let       unvect               = unitvec($&numb2)
let       fundspec             = unvect*0 +j(0)
let       fundspec[2]          = real(ac_fft[2])        +j(imag(ac_fft[2] ))
let       fundspec[numb2-2]    = real(ac_fft[numb2-2])  +j(imag(ac_fft[numb2-2] ))
let       fund                 =  ifft(fundspec)
let       thirdspec            = unvect*0 +j(0)
let       thirdspec[6]         = real(ac_fft[6])        +j(imag(ac_fft[6] ))
let       thirdspec[numb2-6]   = real(ac_fft[numb2-6])  +j(imag(ac_fft[numb2-6] ))
let       third                = ifft(thirdspec)
let       fifthspec            = unvect*0 +j(0)
let       fifthspec[10]        = real(ac_fft[10])        +j(imag(ac_fft[10] ))
let       fifthspec[numb2-10] = real(ac_fft[numb2-10])  +j(imag(ac_fft[numb2-10] ))
let       fifth                = ifft(fifthspec)
let       seventhspec            = unvect*0 +j(0)
let       seventhspec[14]        = real(ac_fft[14])        +j(imag(ac_fft[14] ))
let       seventhspec[numb2-14] = real(ac_fft[numb2-14])  +j(imag(ac_fft[numb2-14] ))
let       seventh                = ifft(seventhspec)
let       sum  = fund + third + fifth + seventh
set       scale  time
plot      fund  third fifth seventh  sum

plot      fund  third fifth seventh  sum xlimit 5 5.5
.endc



.end
```