Chaos_In_OTA_Filters

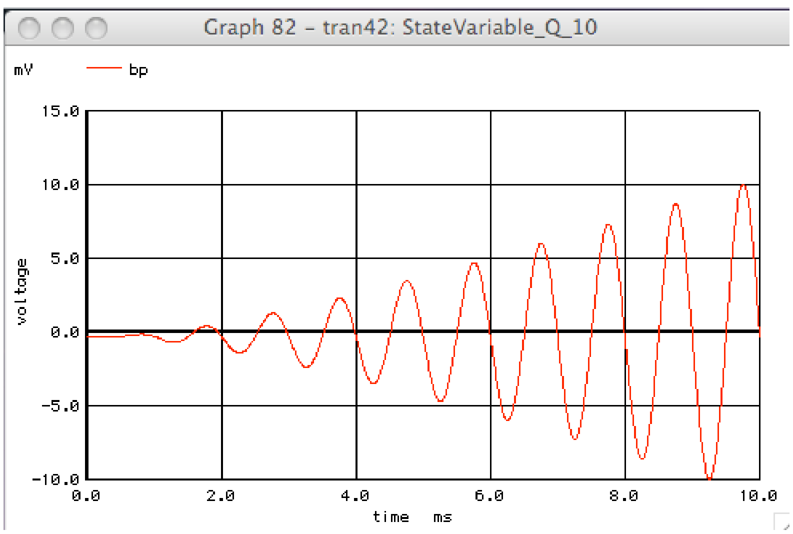
```
 *    dsauersanjose@aol.com
 *    www.idea2ic.com                                          R3 = 1/A0
 *    4/15/08                    ____________________________/\  /\  /\___
 *                              |                               \/  \/     |
 *                              |                       R2 = 1/A1          |
 *                              |______________/\  /\  /\_                 |
 *                              |                \/  \/   |                |
 *                              |        R1 = 1           |BP              |LP
 *                              |_/\  /\  /\_ HP          |                |
 *             R0 = 1/A0        |   \/  \/   |            |                |
 *      ___                     |\           |  XOTA_S1   |  XOTA_S2       |
 *     |IN |_/\  /\  /\_____|_|-\          |  _______   |  _______       |  ___
 *     |___|   \/  \/  SUMN  |   \_________|_|       |_|_|       |______|_|OUT|
 *      _|_                  |   /           |  1/s  |   |  1/s  |        |___|
 *     /VIN\              ___|+/ OPA1        |_______|   |_______|
 *     \___/               | |/
 *       |                _|_             H(s) = 1/(s^2 +s*A1    + A0)
 *      _|_               ///             H(s) = 1/(s^2 +s*w0/Q + w0^2)
 *      ///
 *               Set  A0 = 1 and scale s to 1KHz
 *               Then R2 = Q and  s = 2*PI*1KHz
```

```
.OPTIONS  GMIN=1p     METHOD=euler  ABSTOL=1n  TEMP=27 srcsteps = 100  gminsteps = 10 ITL1=400
.OPTIONS RELTOL=.001  ABSTOL=1p     VNTOL=1p      ITL4=500
*======== ====== ====== ====== ====== ====== ====== ====== ======
VT        Vtime   0      PWL    ( 0 0 1 1 )
VF        VF      0      DC     1k
VF2       VF2     0      PWL    ( 0 2K 1 0 )
V_IN      VIN     0      DC     0     SIN( 0 .1 .7k 1p )
*BIN      BIN     0      v =    1.2*v(Vtime)*(sin(6.28319*v(VF)*v(Vtime))+.3*sin(6.28319*v(VF)*v(Vtime)*2))
BIN       BIN     0      v =    0.2*v(Vtime)*(sin(6.28319*v(VF)*v(Vtime)))
R0        BIN     SUMN   10k
R1        SUMN    HP     10k
R2        SUMN    BP     100k
R3        SUMN    LP     10k
XOPA1     SUMN    0      HP     OPA
XOTAS1    HP      BP            OTA_S
XOTAS2    BP      LP            OTA_S

*==OTAs_Can_Perform_The_Exact_Same_Function====
.control
tran    .1m    .01     0
plot  bp  title  StateVariable_Q_10
plot bp vs bin
plot lp vs bin
plot hp vs bin
.endc

.SUBCKT OTA_S IN     OUT
QN1        VC1     IN     VE1    NPNP
QN2        VC2     0      VE1    NPNP
QP1        VC1     VC1    VCC    PNPP
QP2        VC2     VC1    VCC    PNPP
IB         VE1     0             5.2u
VCC        VCC     0             DC     2
EGN2       OUT     0      VC2    0      +1
C1         VC2     0            .01592u
.ends
```

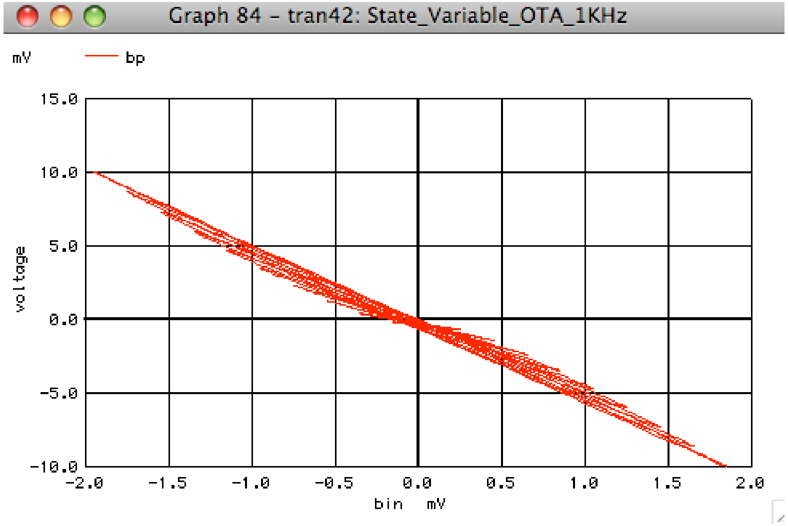
```
*
*              _|_________________
*        _|_       VCC             |
*       /VCC\   |                  |       C1
*       \___/   |    ->         <-  |    _||_
*         |     QP1`|___|'QP2     _| ||  |      ______  ___
*        _|_       _   '|  |`    |      _|_   |      |OUT|
*        ///       |    |VC1  VC2 |    ///  _|_   |___|
*                  |    |_________|______|___ /   \      .SUBCKT   OTA_S  IN   OUT
*         ___     _|__VC1__        |       | | Egn2|  ---->  ___   _________   ___
*        |IN |___|'QN1     QN2`|___    _|  +1  |  ----> |IN |_|        |_|OUT|
*        |___|   |`->  VE1   <-'|  |   | \___/          |___| |  1/s   | |___|
*                   |_____________|   _|_  |_____|                |________|
*                         |           ///    _|_
*                        _|_                 ///           s   = jw0     s = 2*PI*Freq
*                       /   \IB                            @s  = jw0     R = 1/sC
*                       \/ \/
*                       /\_/\        IOUT = IB*TANH( VIN/52mV) =>VIN*IB/52mV
*                       \___/
*                         |
*                        _|_
*                        ///
```

```
.SUBCKT OPA    INP    INN    OUT
EGN1           O1     0      INP    INN    -1
EGN2           OUT    0      IP     0      -1000000
R1             O1     IP     10k
C1             OUT    IP     3p
.ends

*
*  http://www.idea2ic.com/PlayWithJavascript/R_C_Freq.html
*
*               O1         C1 10pF          .SUBCKT  OPA INP INN OUT
*    ____                          ____
*   |INP|_       _____     | _||_______|OUT|
*   |___|  |    _|_   |  R1 |   ||  _|_   |___|       |\
*          |_ /    \  |_/\ _|__   /   \          ____ |-\
*            | EGN1 | 10K\/  IP| EGN2 |  ---->  |INP|__|   \__|OUT|
*    ____    |  -1  |           _| 90dB |  ---->  |___|  |   /   |___|
*   |INN|____|      |        IP |  \___/          ____ |+/
*   |___|     \____/            |____|            |INN|__|/ OPA
*               |                    |            |___|
*              _|_                  _|_
*              ///                  ///

.model    NPNP   NPN(   BF=2100 VAF=216 )
.model    PNPP   PNP(   BF=2100 VAF=210)

.end

======================END_OF_SPICE=======================
```

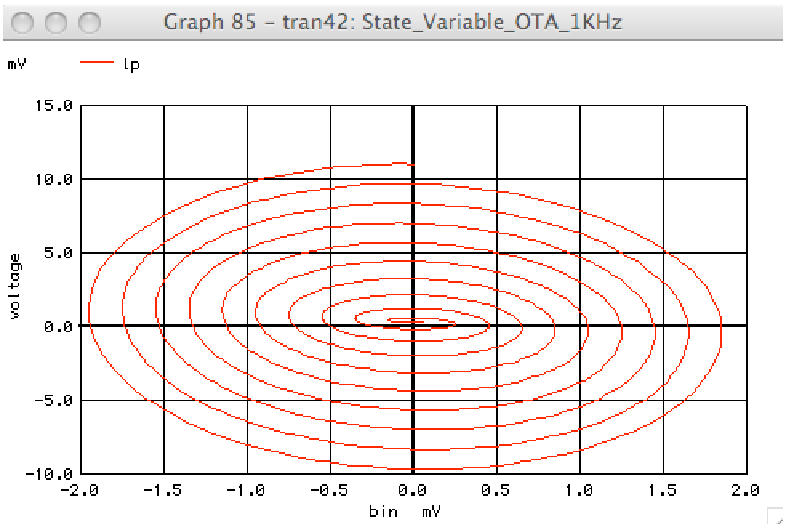
The methods used to observe chaos may provide a better way to view a filter as to whether is operating properly.



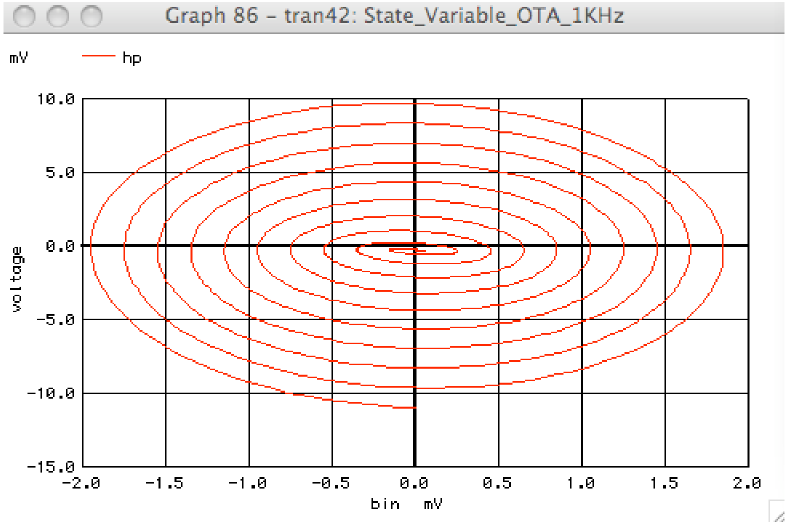
The waveform above is at the exact resonance frequency of a two pole LM3080 type filter. The input signal is ramped up from 0 to 20mV.



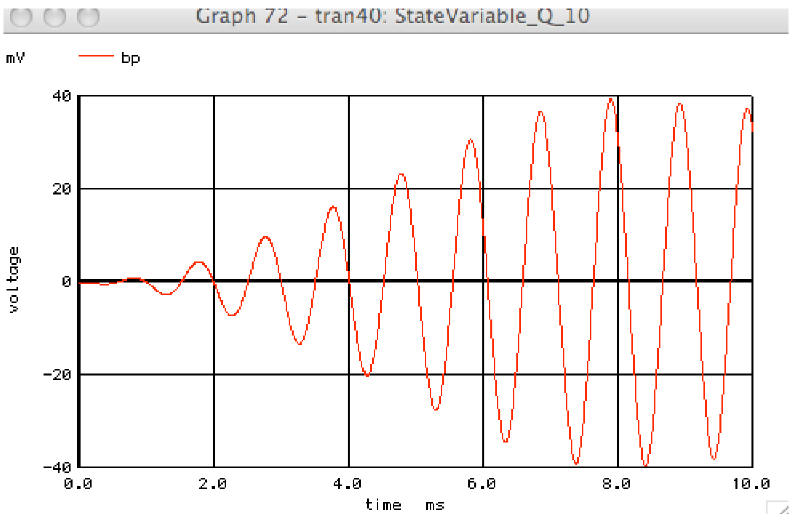
Using the chaos technique of plotting Output versus input, the plot at the Bandpass output is a straight line similar to a resistor. As the input signal increases, the line essentially widens.



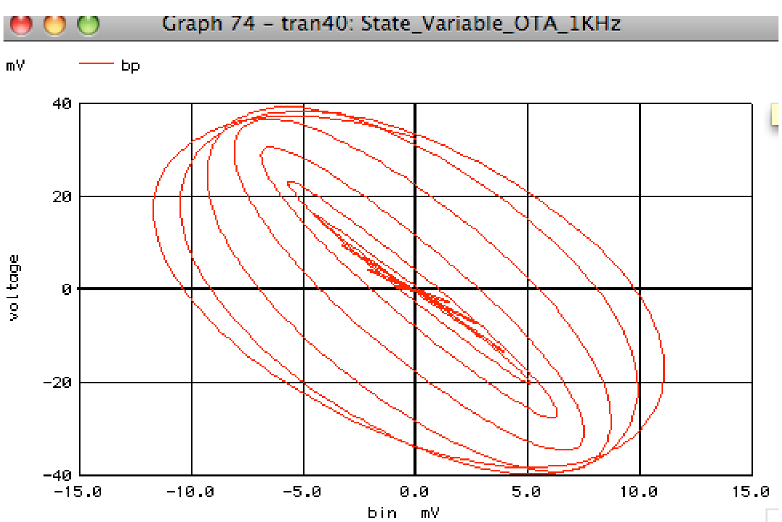
But the LowPass and HighPass outputs are phase shifted by 90degrees. As the input signal increases in magnitude, the shapes at all output increase in size but don't change in shape.



Since the LowPass and HighPass are at different phases, their rotations are opposite.

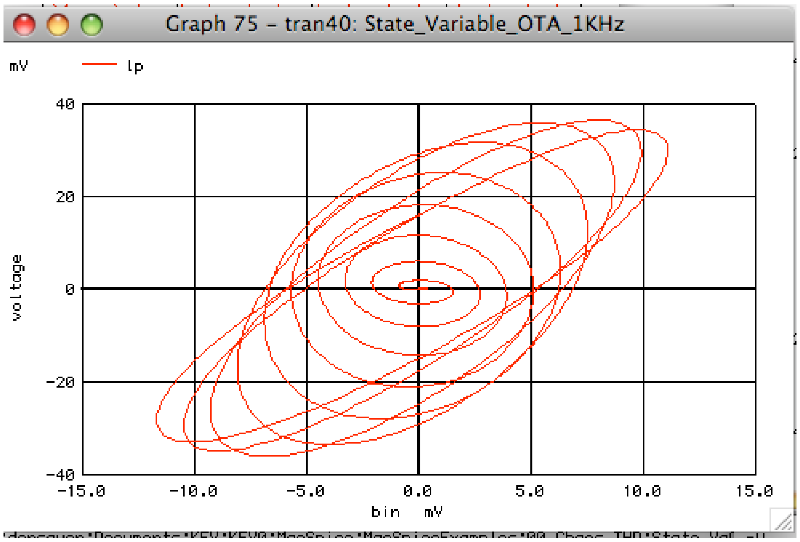


Now when the input signal is made larger, the output at the Bandpass is beginning to act a little different.

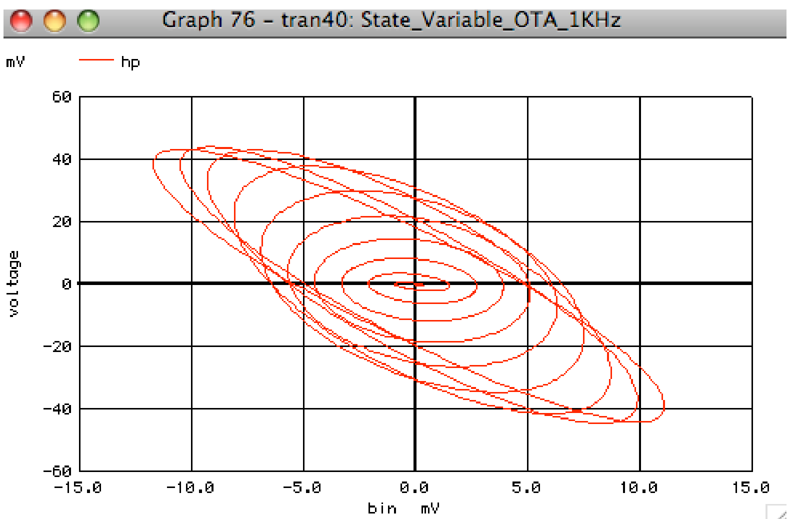


But the plotting of the Bandpass output versus the input makes it easy to see when the transfer function is no longer a straight

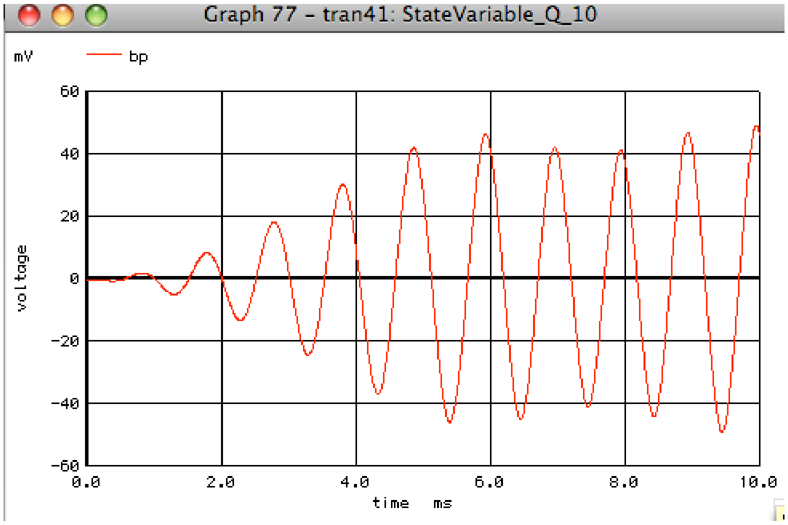
line. This looks like a good way to test whether or not a filter is behaving properly.



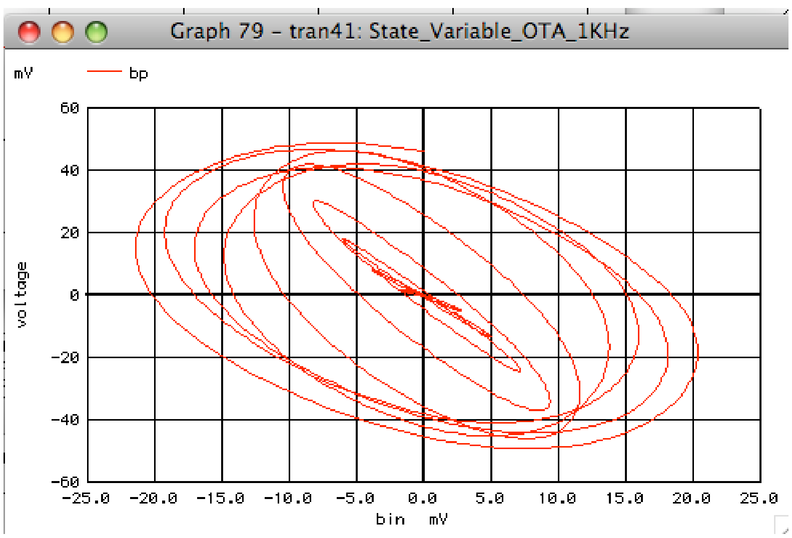
The wave forms at both the LowPass and HighPass output also change shape. What is happening is that the inputs to the OTA are distorting enough that the assumption of linearity are obviously no longer valid.



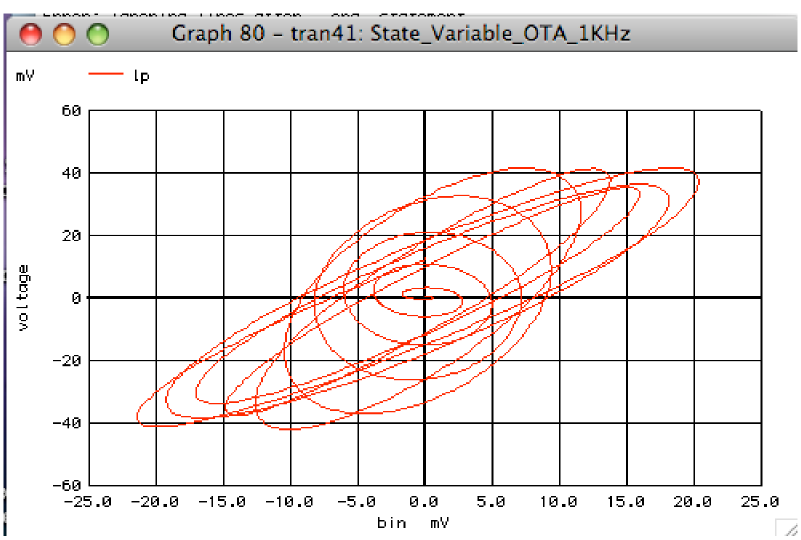
This perhaps answers a question of how low must the THD be in an OTA based filter? The answers is when does the filter begin to effectively operate in another mode?



When the input signal is increased further, now we are begining to generate chaos curves.

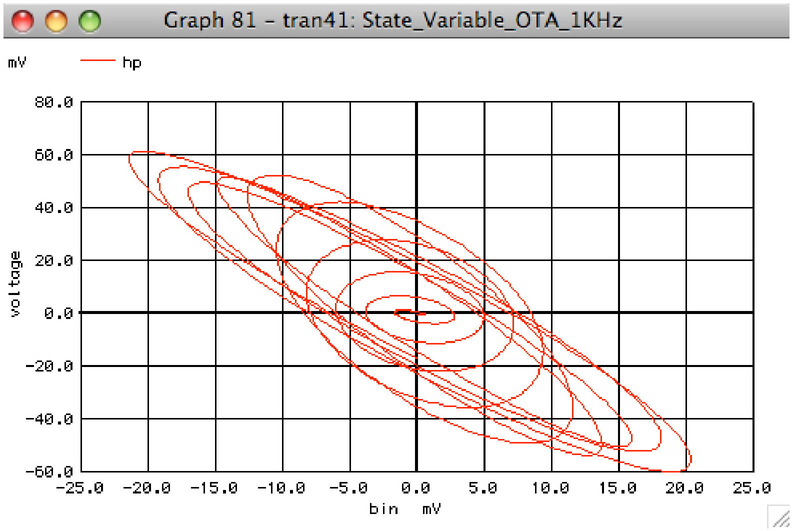


Some key elements to a Chaos circuit appear to be feedback and nonlinearity.



The nonlinear feedback may allow input signal

to be interpedated in more than one way.



Perhaps the multiple states can result from the output distorted signal having multiple ways to regenerate its own input signal.