> **read**("DMB.txt")

First Written: Nov. 2021

This is DMB.txt, A Maple package to explore Dynamical models in Biology (both discrete and continuous)
accompanying the class Dynamical Models in Biology, Rutgers University. Taught by Dr. Z. (Doron Zeilbeger)

The most current version is available on WWW at:
http://sites.math.rutgers.edu/~zeilberg/tokhniot/DMB.txt .
Please report all bugs to: DoronZeil at gmail dot com .

For general help, and a list of the MAIN functions,
type "Help();". For specific help type "Help(procedure_name);"

For a list of the supporting functions type: Help1();
For help with any of them type: Help(ProcedureName);

For a list of the functions that give examples of Discrete-time dynamical systems (some famous), type: HelpDDM();
For help with any of them type: Help(ProcedureName);

For a list of the functions continuous-time dynamical systems (some famous) type: HelpCDM();
For help with any of them type: Help(ProcedureName);

------------------------------ **(1)**

> *Help*(*GeneNet*)

GeneNet(a0,a,b,n,m1,m2,m3,p1,p2,p3): The contiuous-time dynamical system, with quantities m1,m2,m3,p1,p2,p3, due to M. Elowitz and S. Leibler
described in the Ellner-Guckenheimer book, Eq. (4.1) (chapter 4, p. 112)
and parameers a0 (called alpha_0 there),a (called alpha there), b (called beta there) and n. Try:
GeneNet(0,0.5,0.2,2,m1,m2,m3,p1,p2,p3); **(2)**

> *GeneNet*(0, 0.5, 0.2, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*);

(3)

$$\left[-m1+\frac{0.5}{p3^2+1},\ -m2+\frac{0.5}{p1^2+1},\ -m3+\frac{0.5}{p2^2+1},\ -0.2\,p1+0.2\,m1,\ -0.2\,p2+0.2\,m2,\ -0.2\,p3+0.2\,m3\right] \quad (3)$$

> *Help*(*TimeSeries*)

TimeSeries(F,x,pt,h,A,i): Inputs a transformation F in the list of variables x

The time-series of x[i] vs. time of the Dynamical system approximating the the autonomous continuous dynamical process

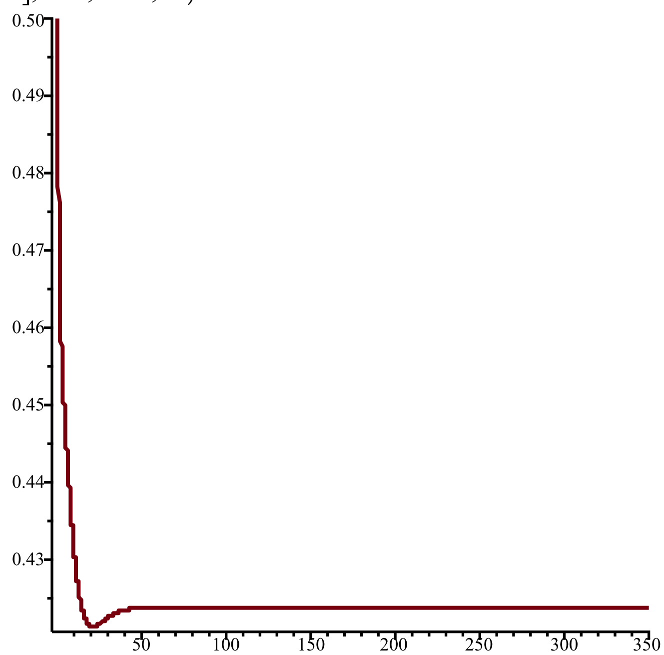
dx/dt=F(x(t)) by a discrete time dynamical system with step-size h from t=0 to t=A

Try:

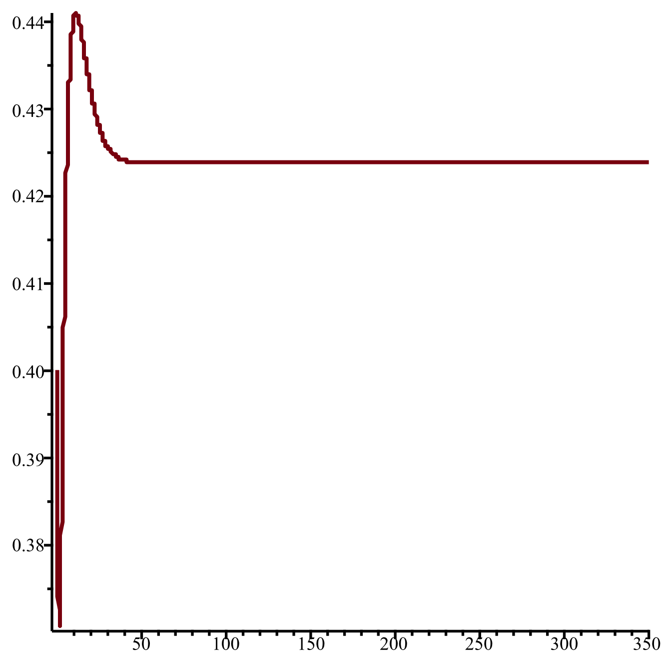
TimeSeries([x(1-y),y*(1-x)],[x,y],[0.5,0.5], 0.01, 10,1);* **(4)**

> *#examples of using TimeSeries using GeneNet as transformation and changing i*

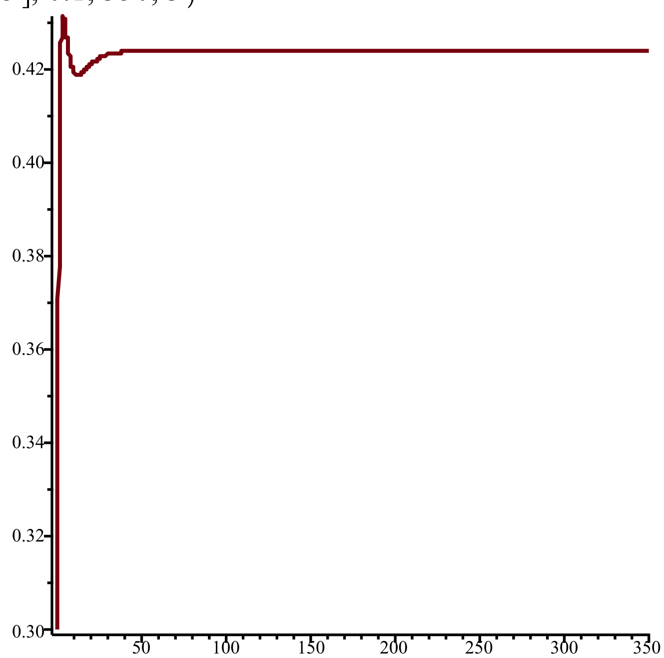
> *TimeSeries*(*GeneNet*(0, 0.5, 0.2, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.2, 0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 6)



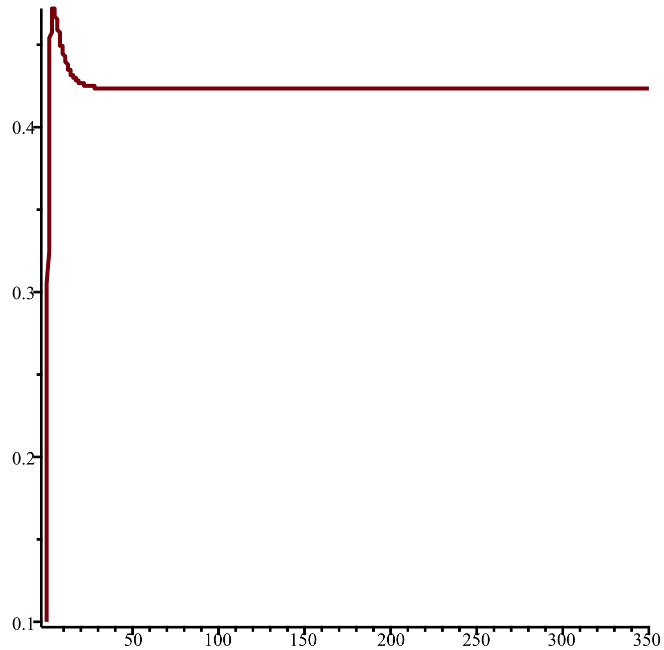
> *TimeSeries*(*GeneNet*(0, 0.5, 0.2, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.2, 0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 5)



> *TimeSeries*(*GeneNet*(0, 0.5, 0.2, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.2, 0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 3)



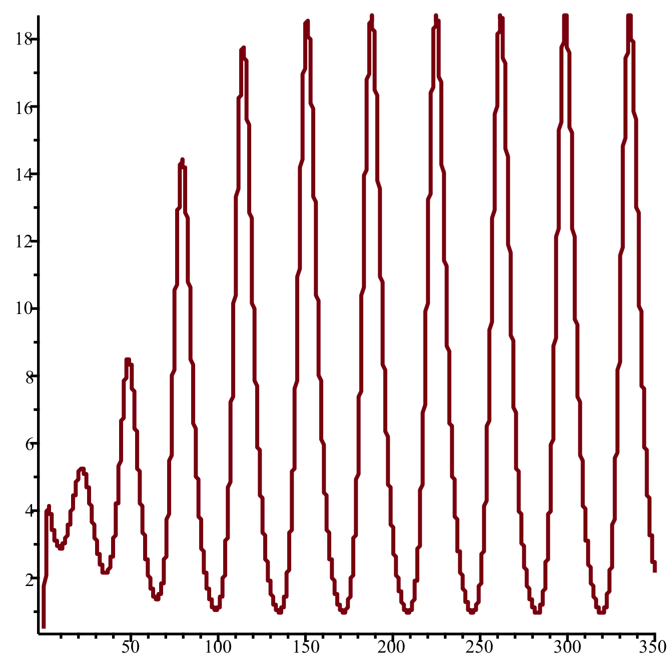
> *TimeSeries*(*GeneNet*(0, 0.5, 0.2, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.2, 0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 2)




```
> #adjusting parameter a0
> a0 := 0;
  for i from 0 to 15
  do
  a0 := a0 + 0.1;
  TimeSeries(GeneNet(a0, 50, 0.2, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.2, 0.1,
      0.3, 0.1, 0.4, 0.5], .1, 350, 6);
  print((a0 , 50, 0.2, 2));
  end do;
```

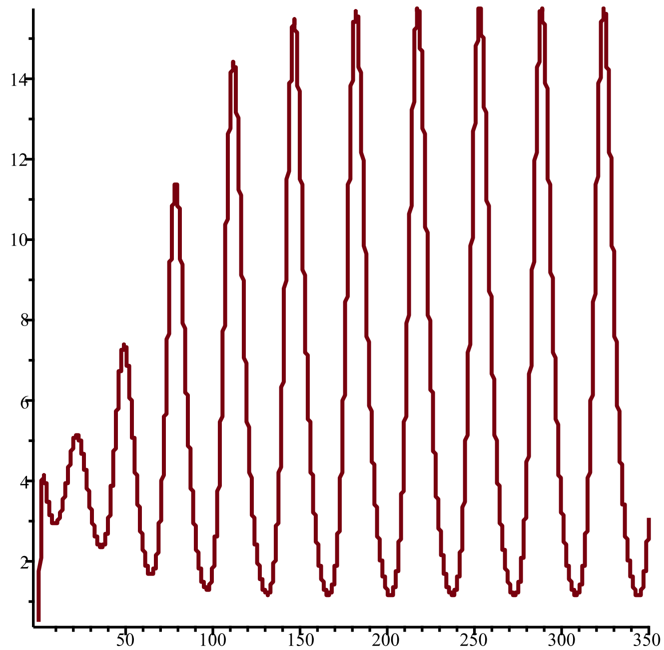
$a0 := 0$

$a0 := 0.1$



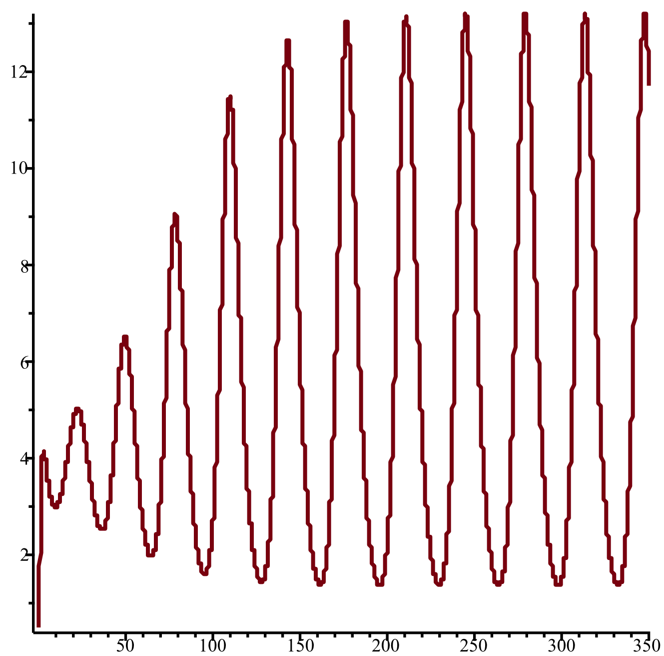
0.1, 50, 0.2, 2

$a0 := 0.2$



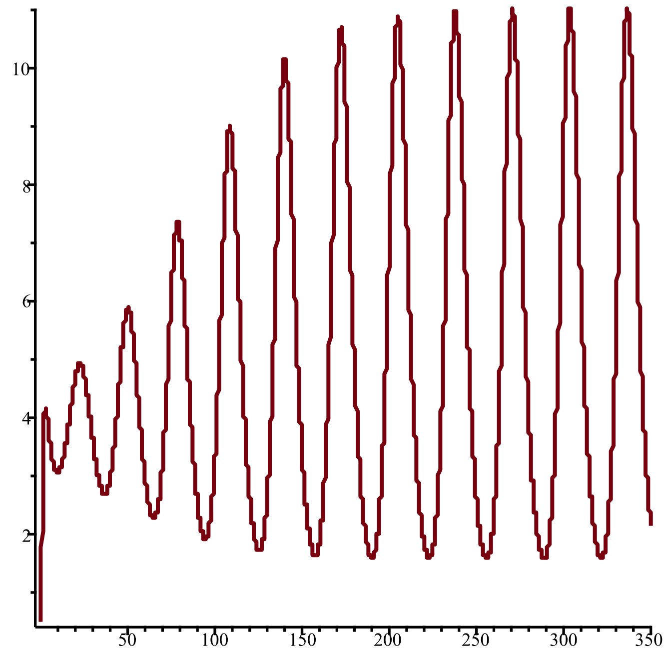
0.2, 50, 0.2, 2

$a0 := 0.3$



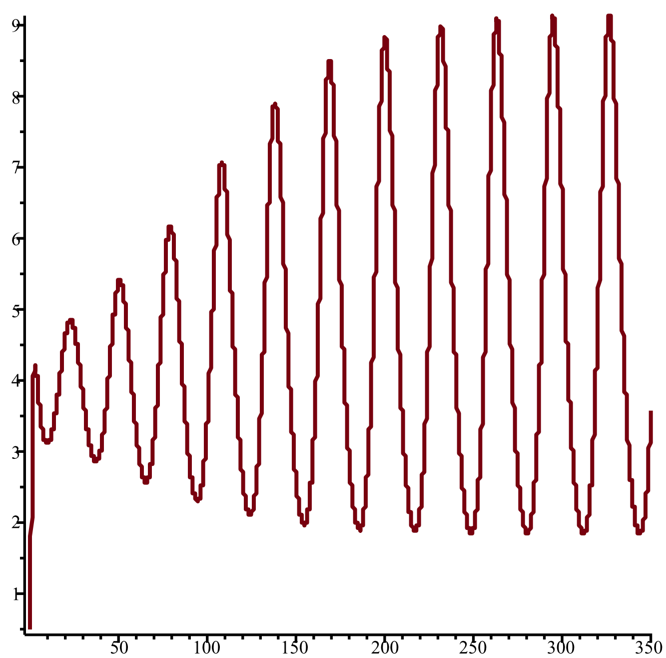
0.3, 50, 0.2, 2

$a0 := 0.4$



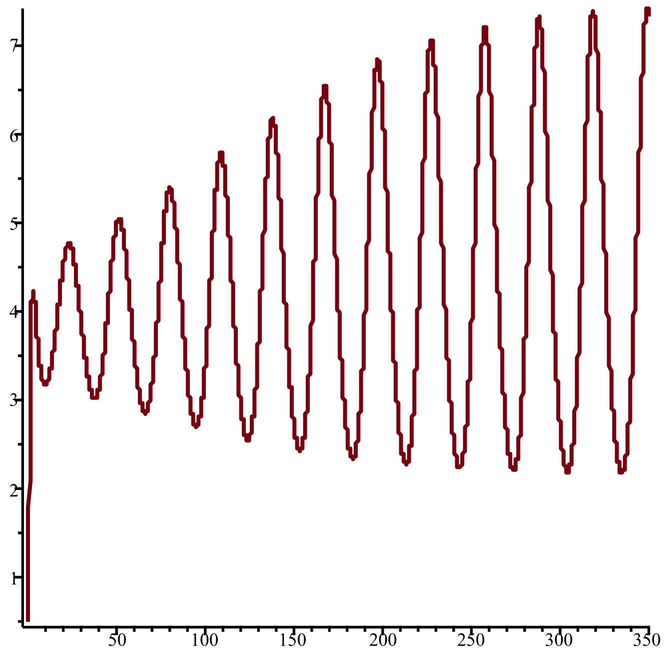
0.4, 50, 0.2, 2

$a0 := 0.5$



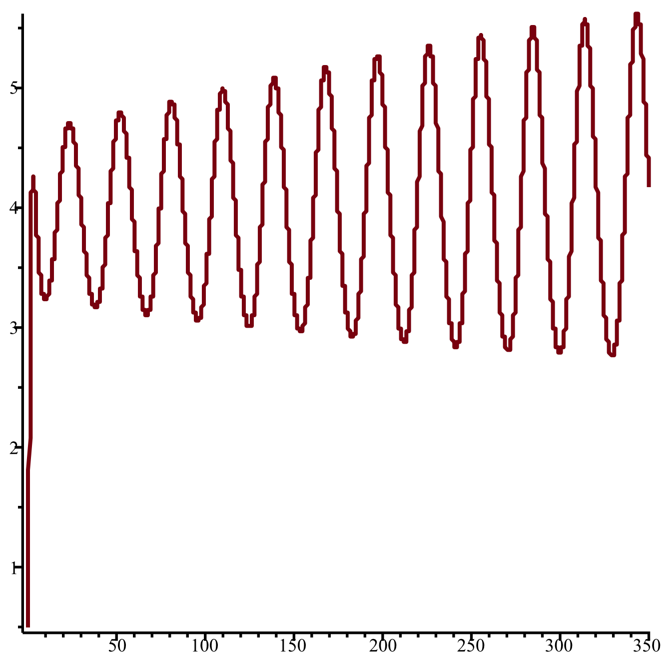
0.5, 50, 0.2, 2

$a0 := 0.6$



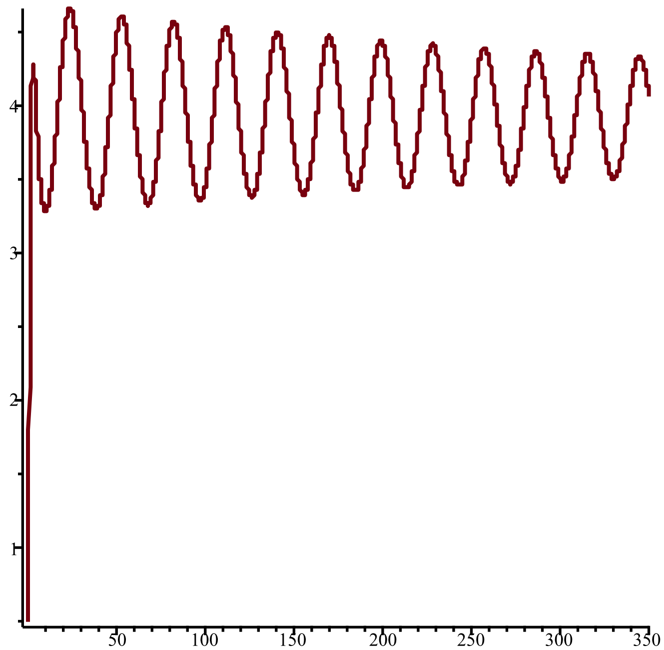
0.6, 50, 0.2, 2

$a0 := 0.7$



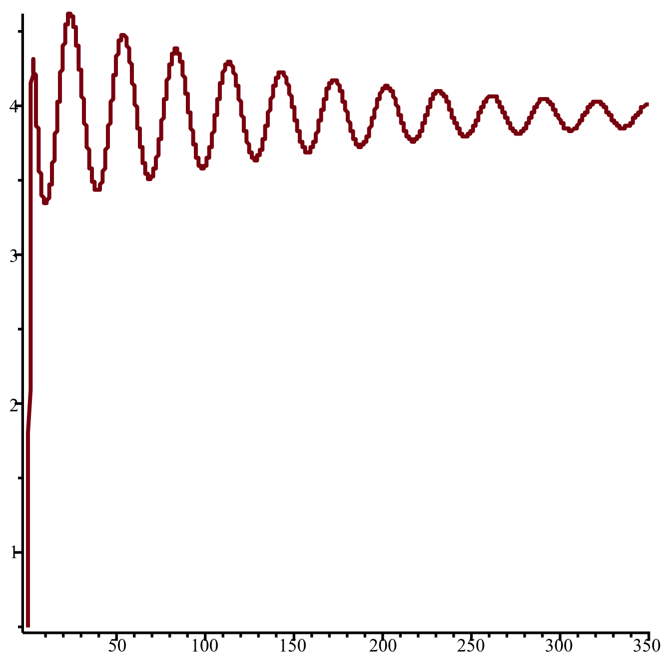
0.7, 50, 0.2, 2

$a0 := 0.8$



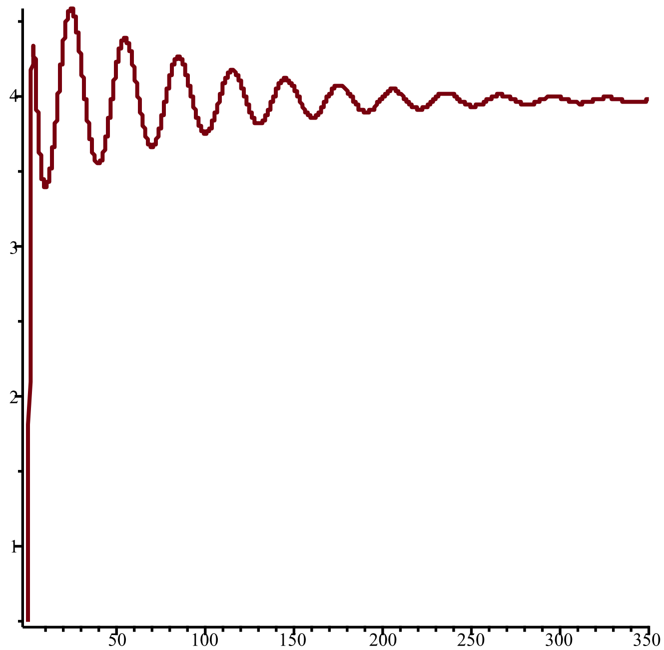
0.8, 50, 0.2, 2

$a0 := 0.9$



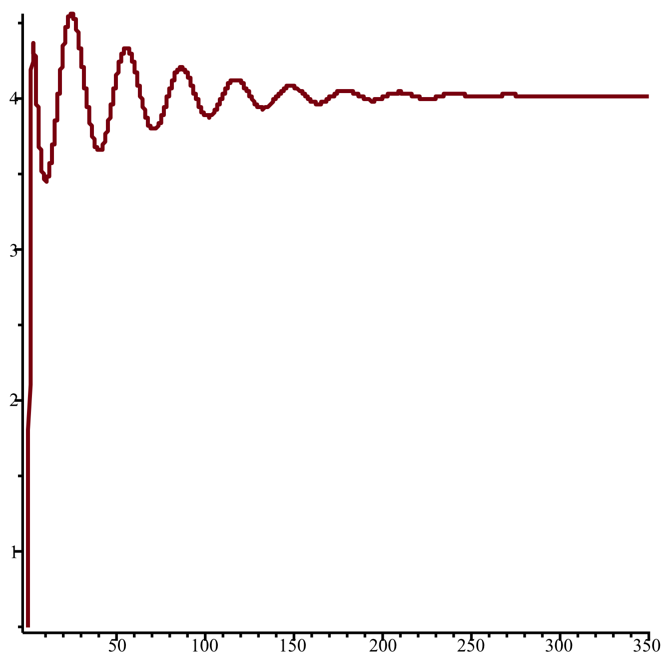
0.9, 50, 0.2, 2

$a0 := 1.0$



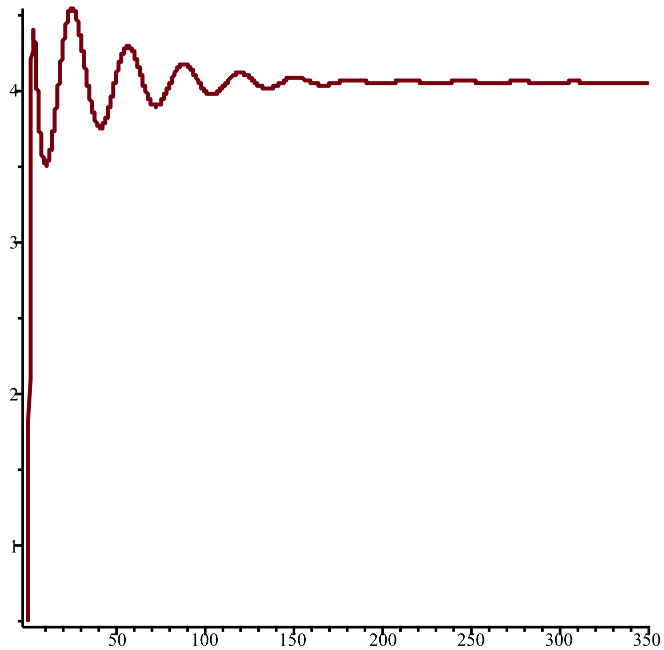
1.0, 50, 0.2, 2

$a0 := 1.1$



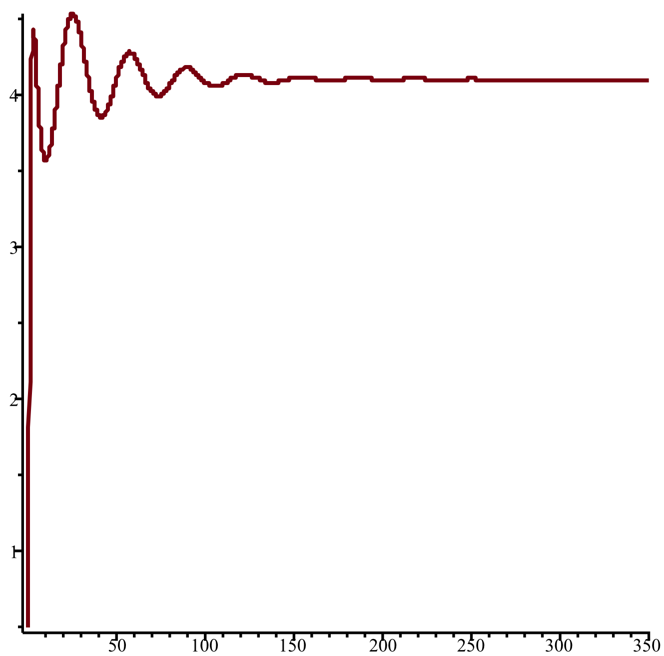
1.1, 50, 0.2, 2

$a0 := 1.2$



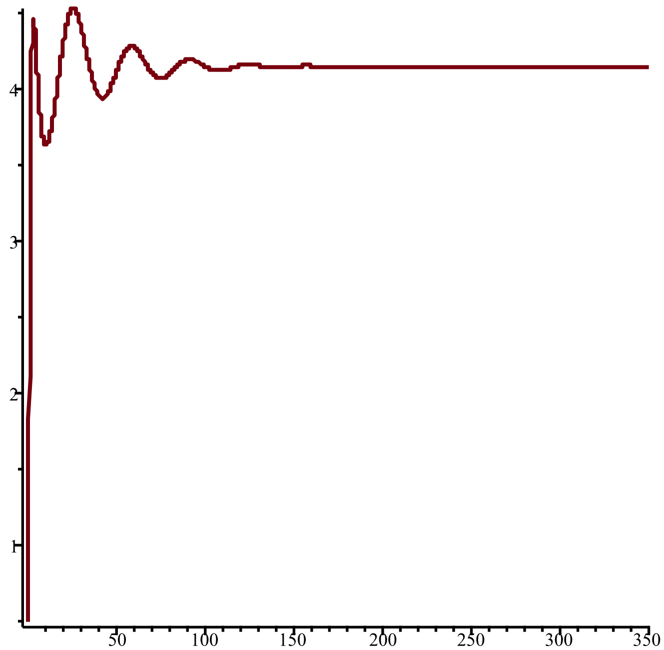
1.2, 50, 0.2, 2

$a0 := 1.3$



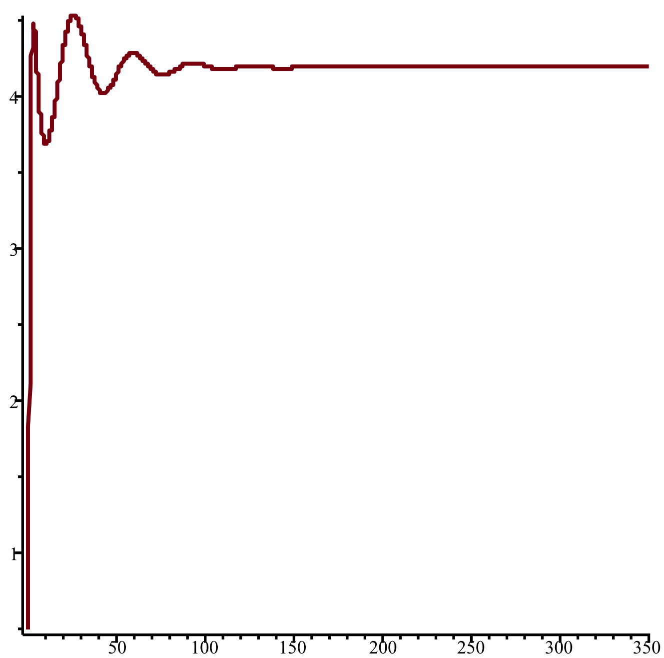
1.3, 50, 0.2, 2

$a0 := 1.4$



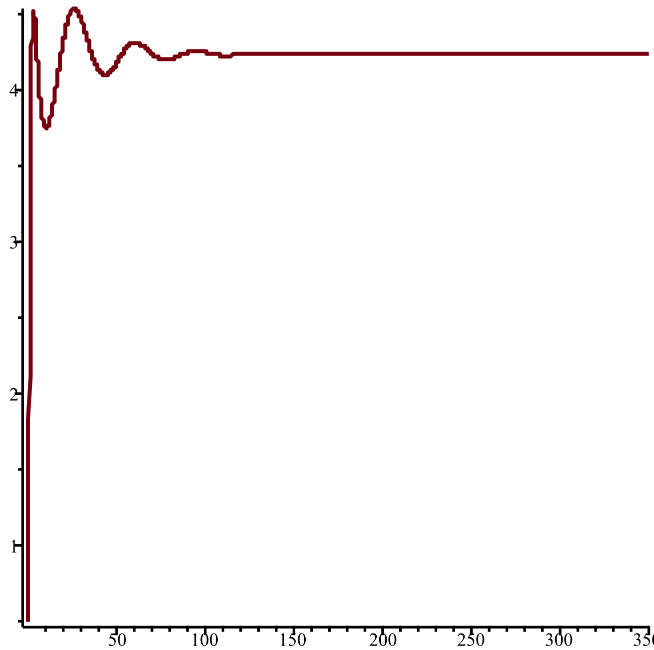
1.4, 50, 0.2, 2

$a0 := 1.5$



1.5, 50, 0.2, 2

$a0 := 1.6$



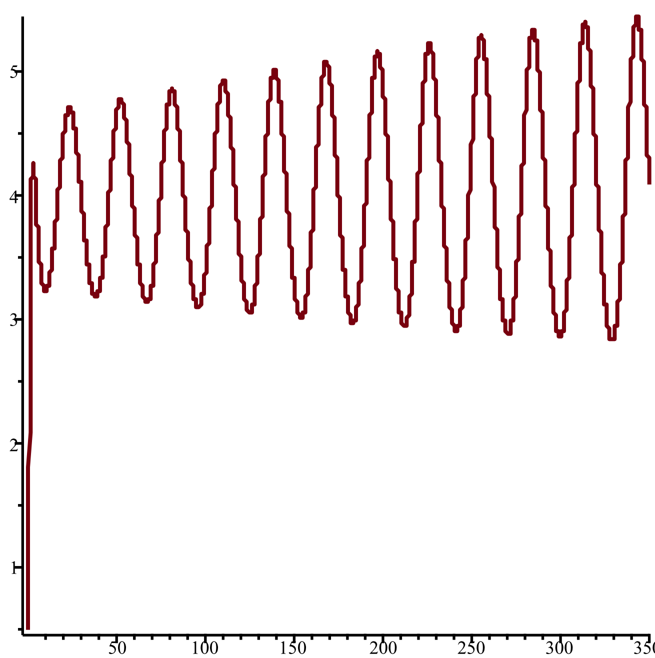
1.6, 50, 0.2, 2 **(5)**

> *# finding exactly where a0 begins to change the long term behavior oscillations to stable*

```
> a0 := 0.70;
  for i from 0 to 8 do
    a0 := a0 + 0.01;
    TimeSeries(GeneNet(a0, 50, 0.2, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.2,
      0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 6);
    print(a0, 50, 0.2, 2);
  end do;
```

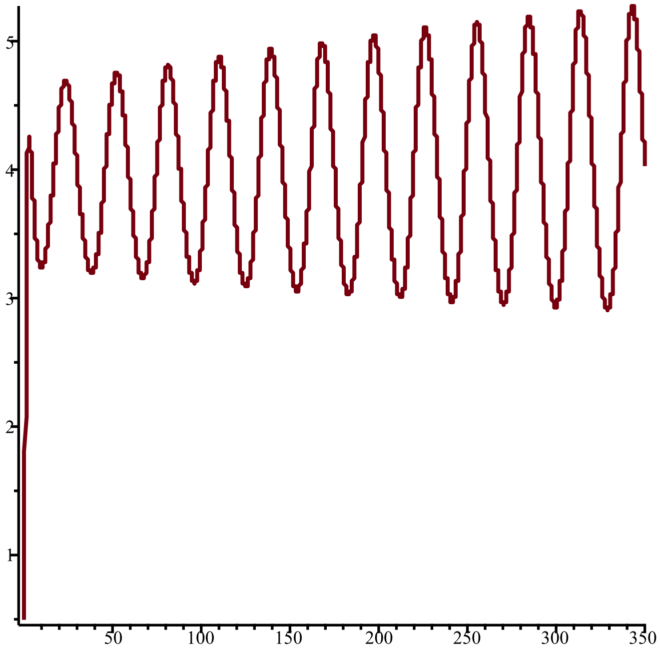
$a0 := 0.70$

$a0 := 0.71$



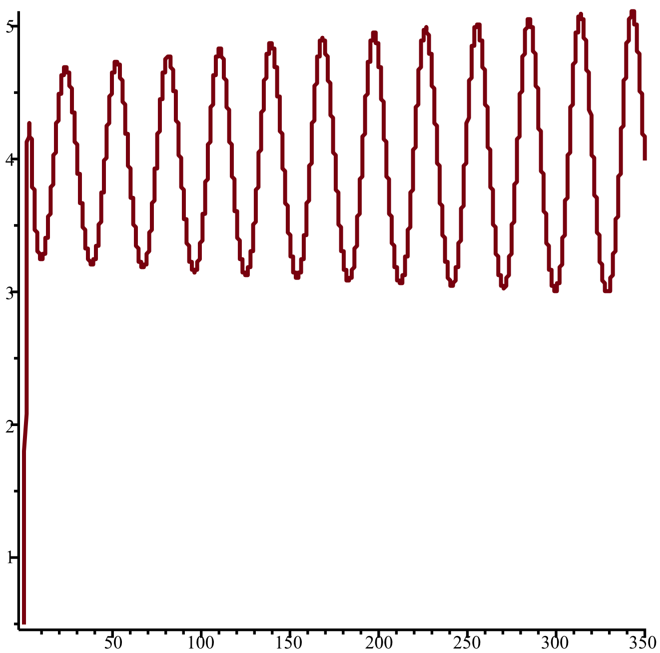
0.71, 50, 0.2, 2

$a0 := 0.72$



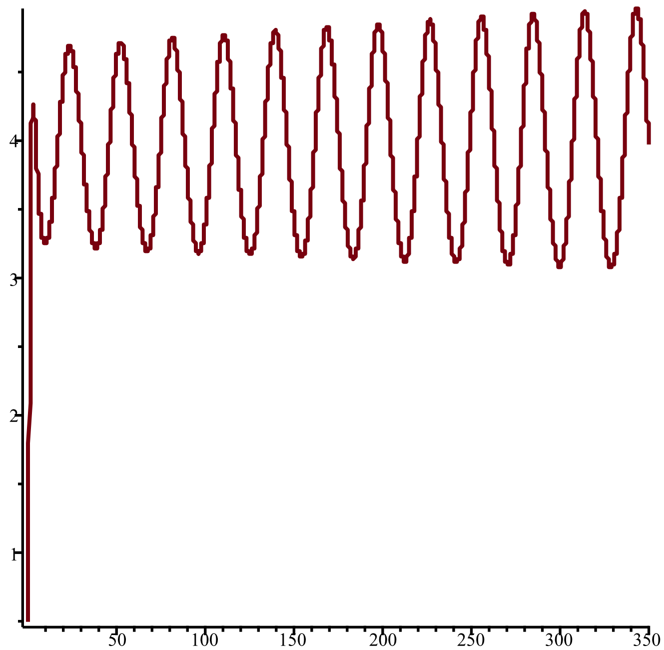
0.72, 50, 0.2, 2

$a0 := 0.73$



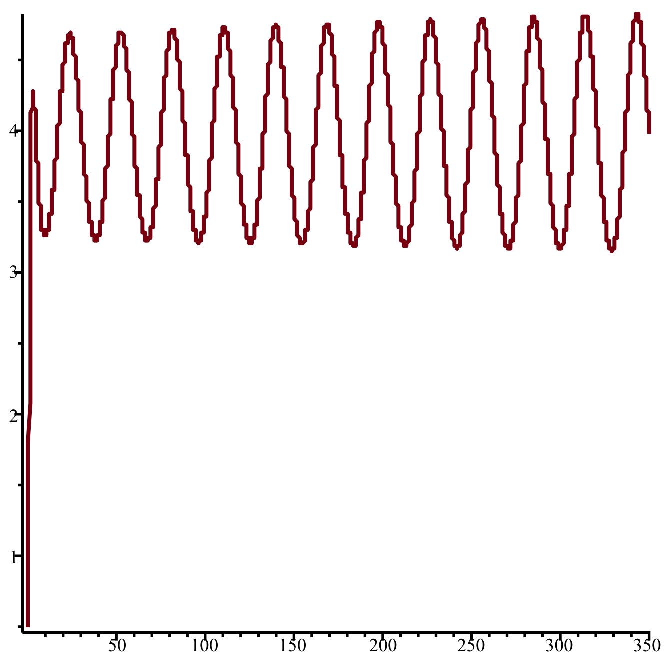
0.73, 50, 0.2, 2

$a0 := 0.74$



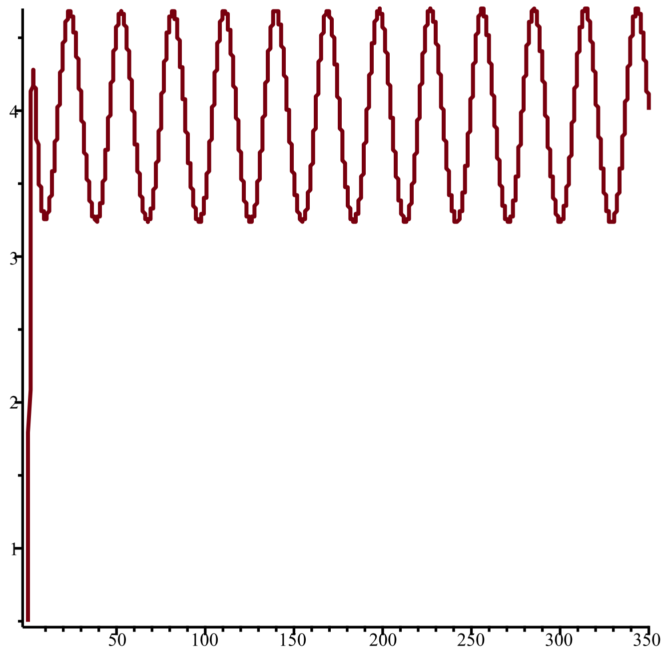
0.74, 50, 0.2, 2

$a0 := 0.75$



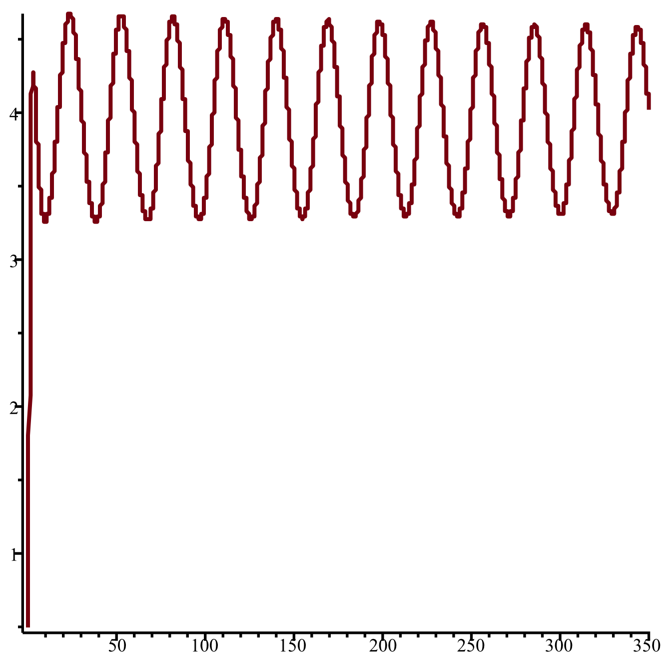
0.75, 50, 0.2, 2

$a0 := 0.76$



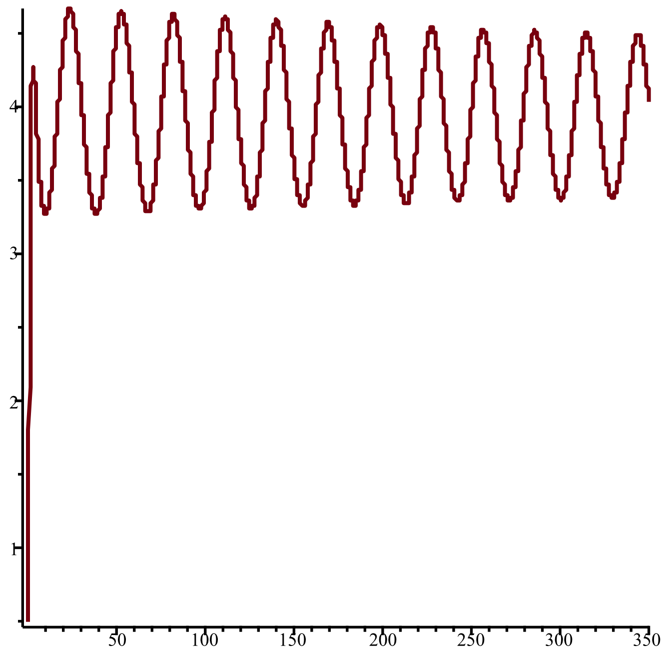
0.76, 50, 0.2, 2

$a0 := 0.77$



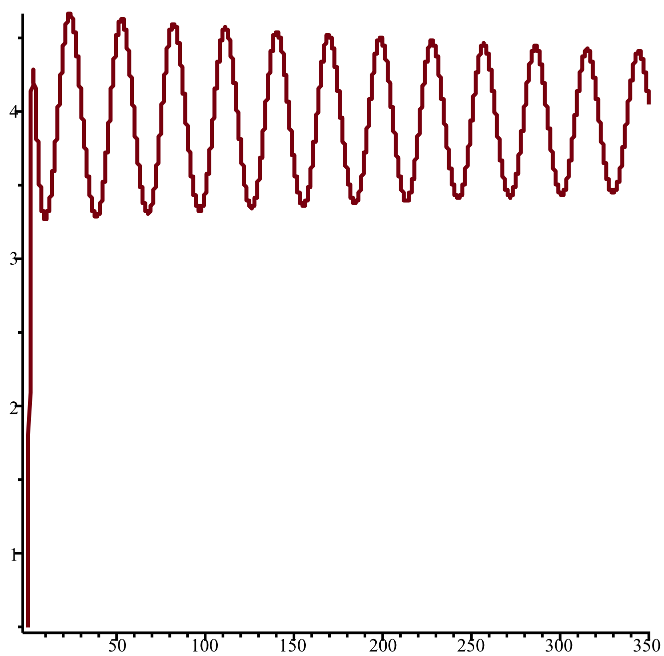
0.77, 50, 0.2, 2

$a0 := 0.78$



0.78, 50, 0.2, 2

$a0 := 0.79$

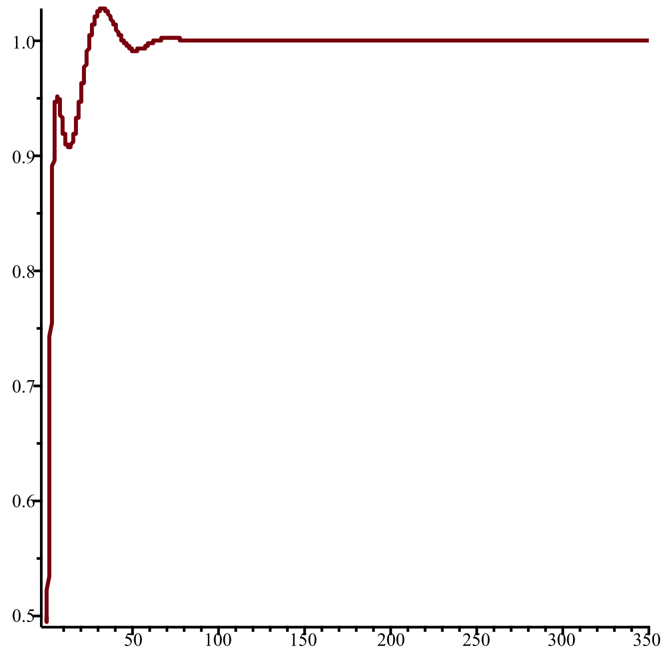


0.79, 50, 0.2, 2 **(6)**

```
> #adjusting parameter a
> a := 0;
  for i from 0 to 10
  do
  a := a + 2;
  TimeSeries(GeneNet(0, a, 0.2, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.2, 0.1,
      0.3, 0.1, 0.4, 0.5], .1, 350, 6);
  print((0, a, 0.2, 2));
  end do;
```

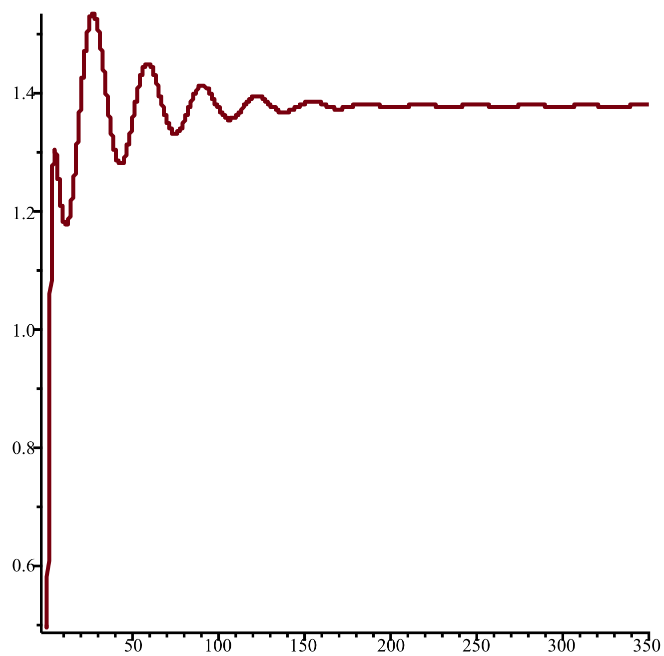
$a := 0$

$a := 2$



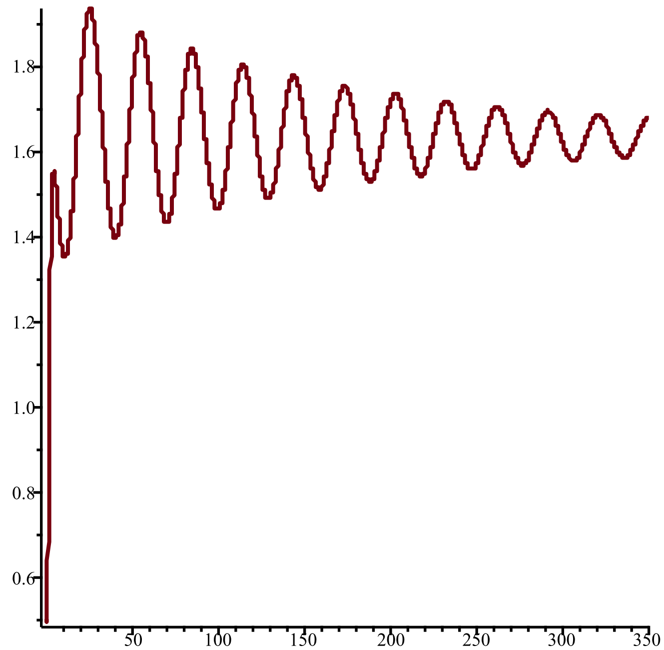
0, 2, 0.2, 2

$a := 4$



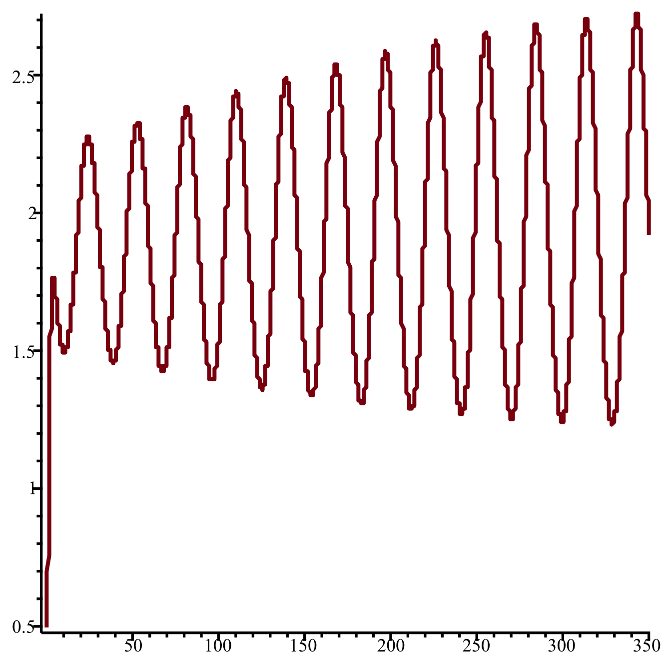
0, 4, 0.2, 2

$a := 6$



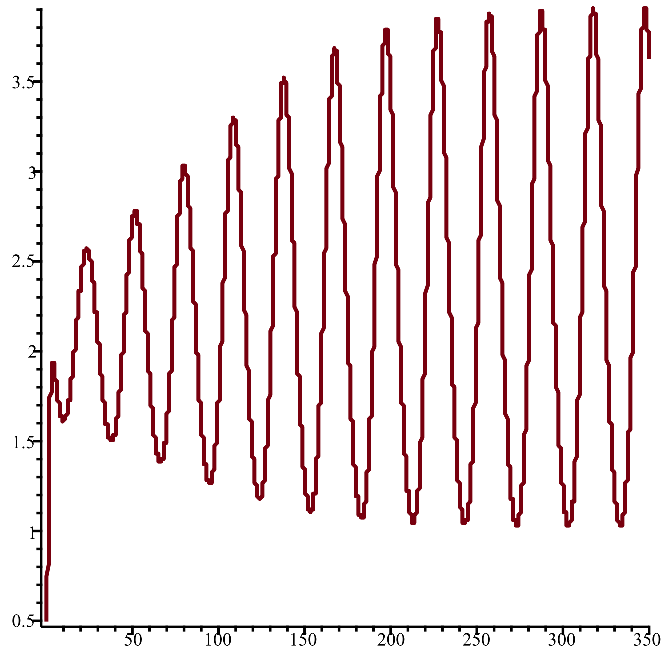
0, 6, 0.2, 2

$a := 8$



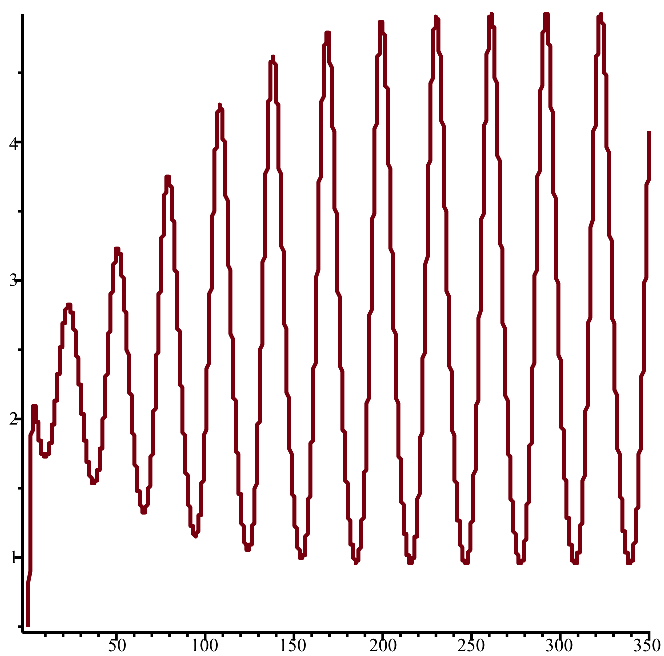
0, 8, 0.2, 2

$a := 10$



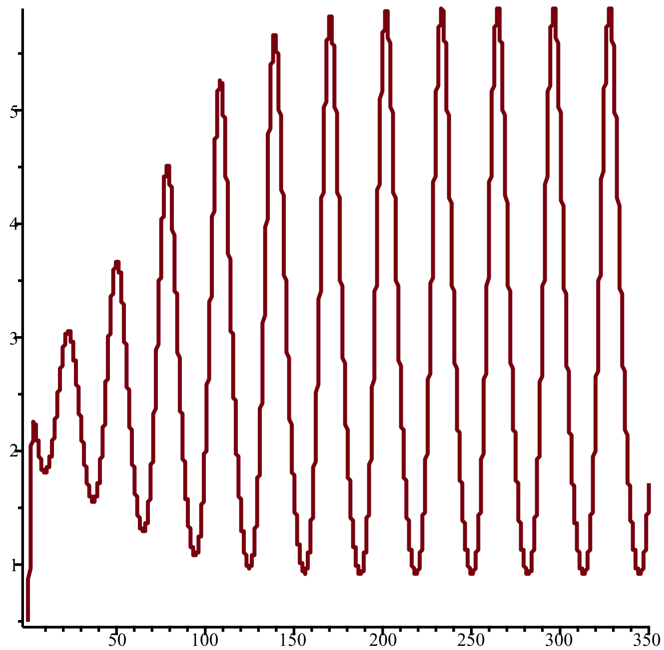
0, 10, 0.2, 2

$a := 12$



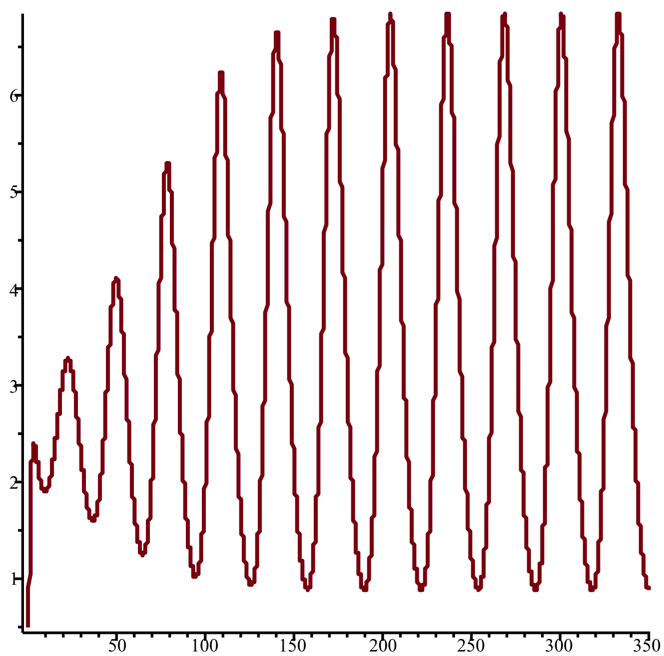
0, 12, 0.2, 2

$a := 14$



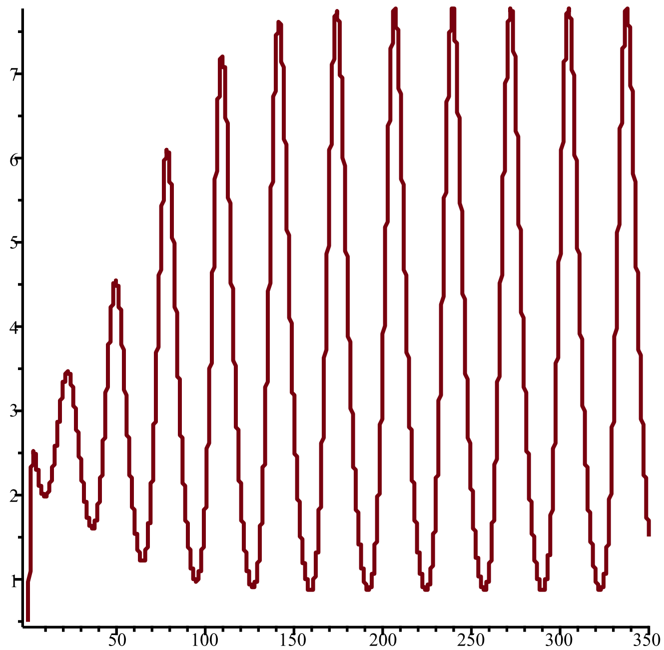
0, 14, 0.2, 2

$a := 16$



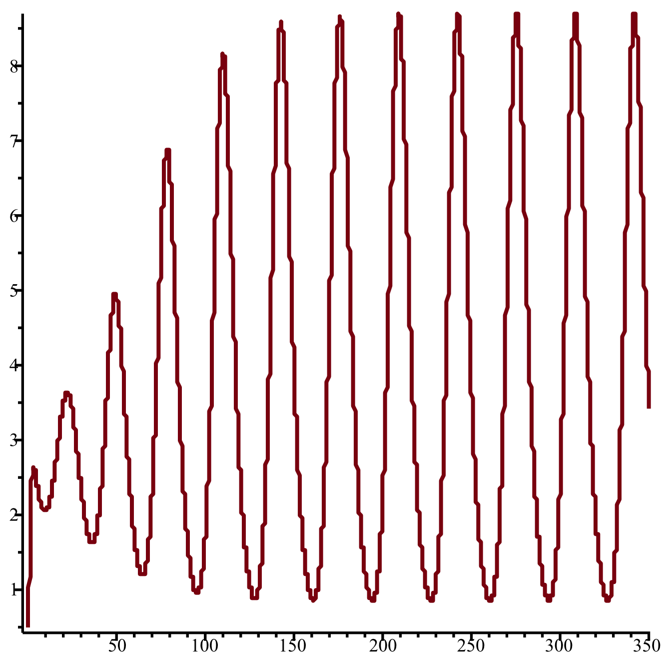
0, 16, 0.2, 2

$a := 18$



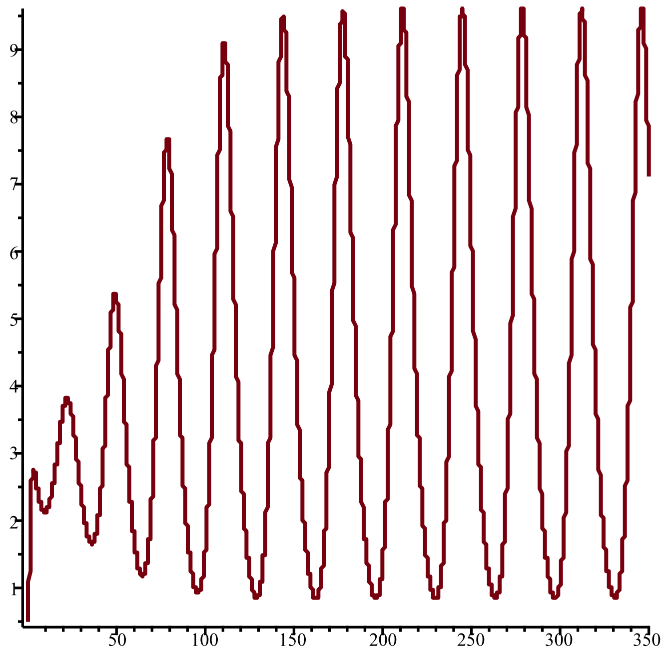
0, 18, 0.2, 2

$a := 20$



0, 20, 0.2, 2

$a := 22$



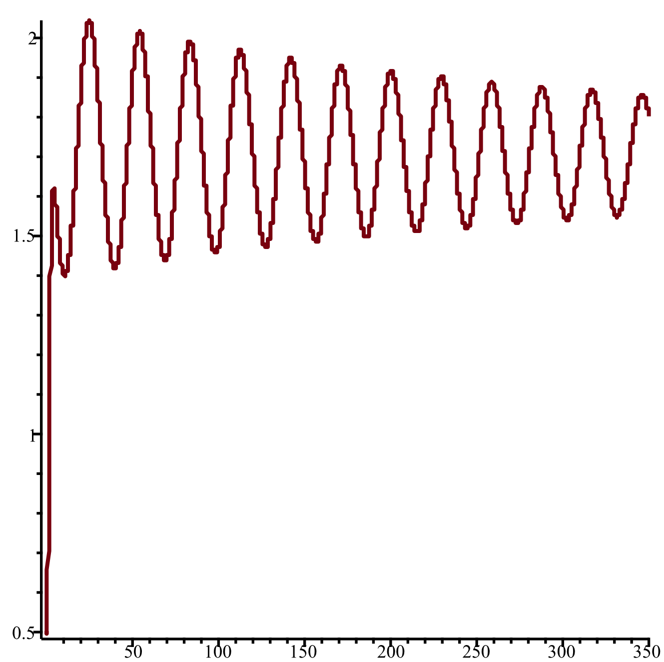
0, 22, 0.2, 2 **(7)**

> *# finding exactly where a begins to change the long term behavior stable equilibria to oscillations*

> $a := 6.5;$
for *i* **from** 0 **to** 12 **do**
$a := a + 0.1;$
TimeSeries(*GeneNet*(0, *a*, 0.2, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.2, 0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 6);
print(0, *a*, 0.2, 2);
end do;

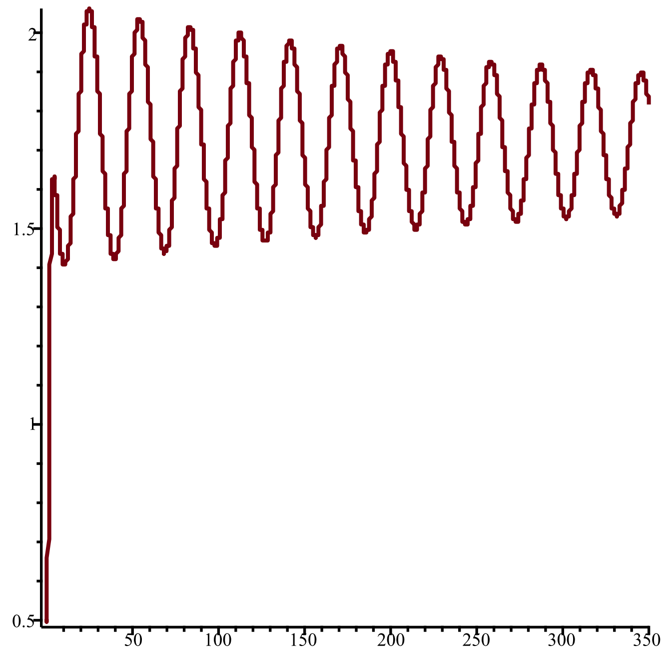
$a := 6.5$

$a := 6.6$



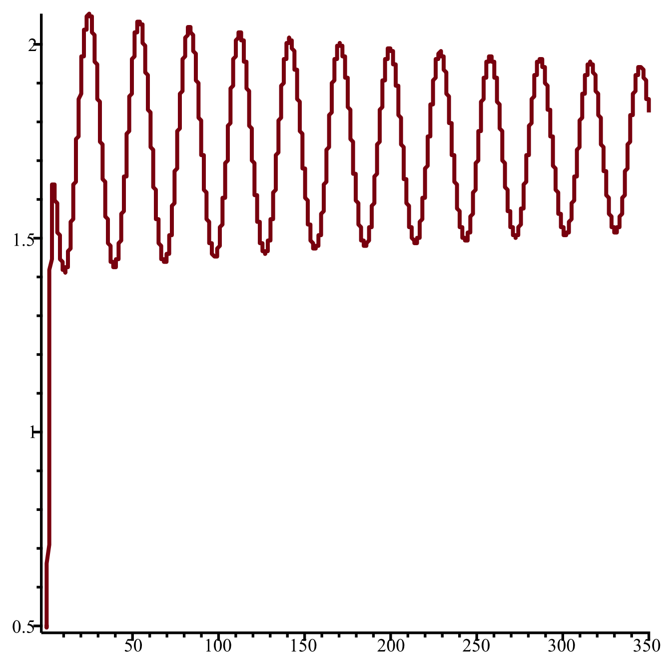
0, 6.6, 0.2, 2

$a := 6.7$



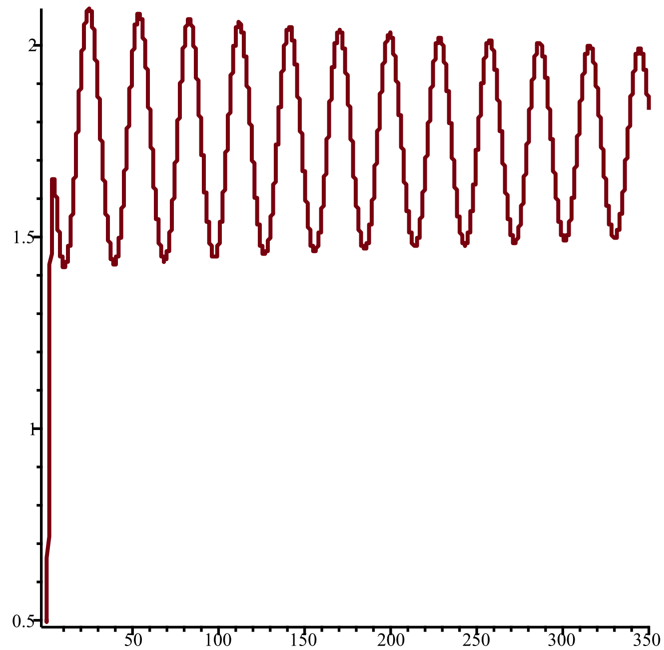
0, 6.7, 0.2, 2

$a := 6.8$



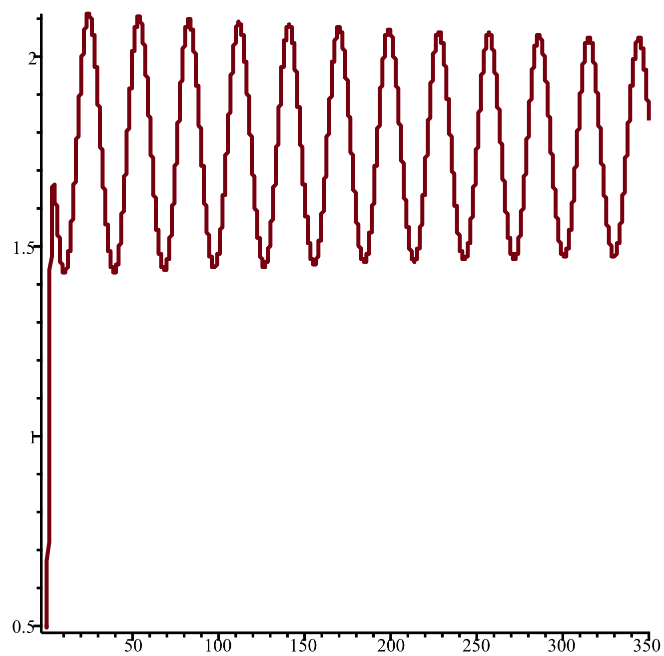
0, 6.8, 0.2, 2

$a := 6.9$



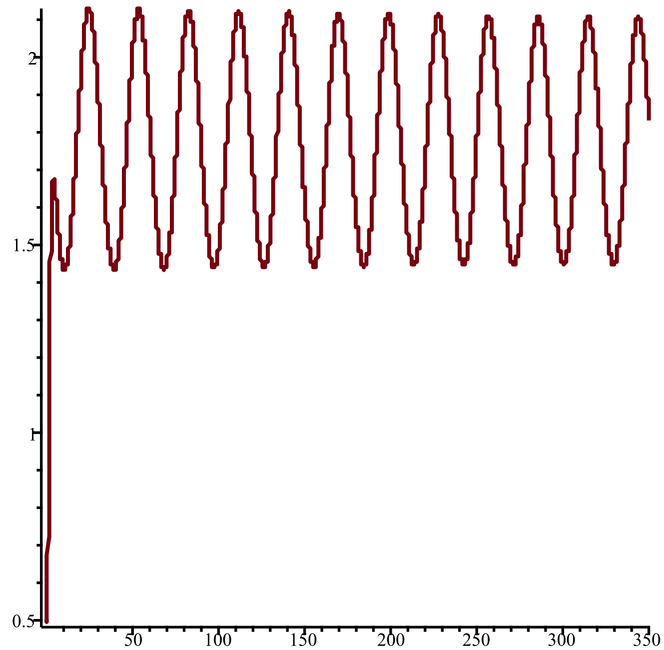
0, 6.9, 0.2, 2

$a := 7.0$



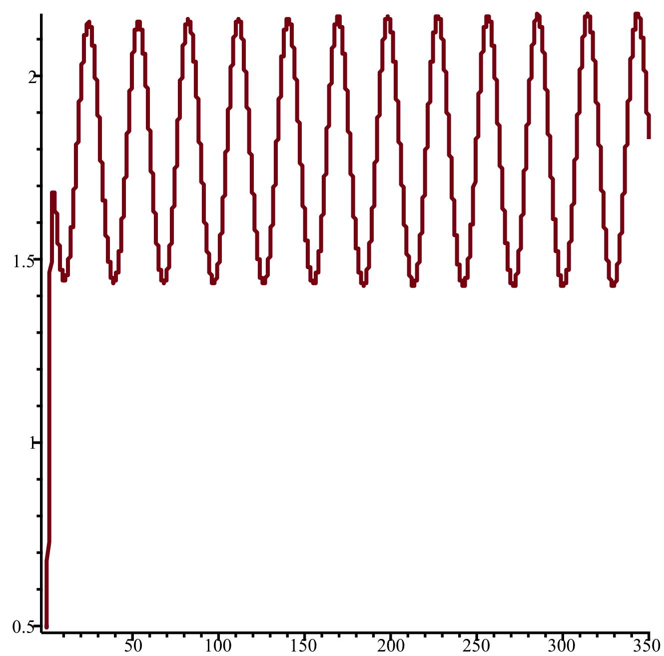
0, 7.0, 0.2, 2

$a := 7.1$



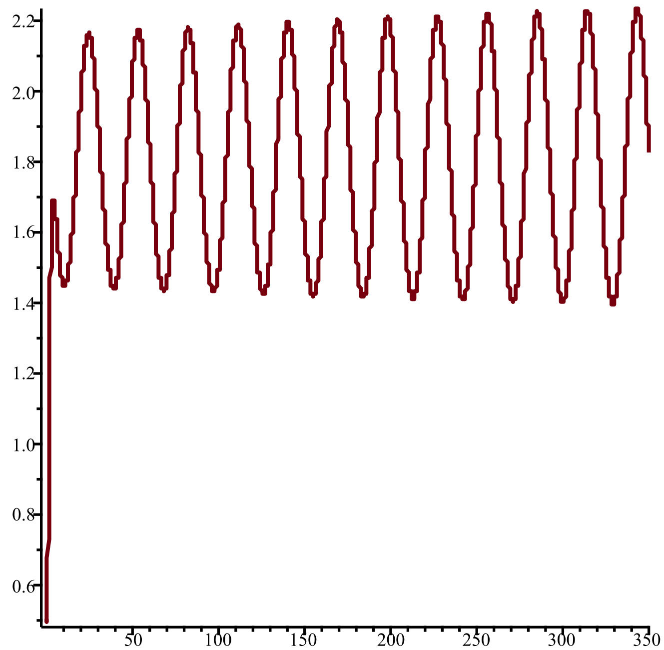
0, 7.1, 0.2, 2

$a := 7.2$



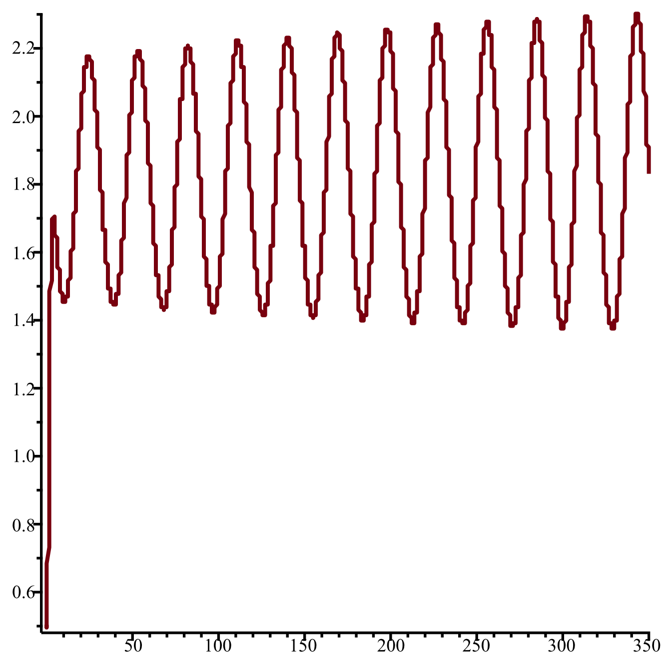
0, 7.2, 0.2, 2

$a := 7.3$



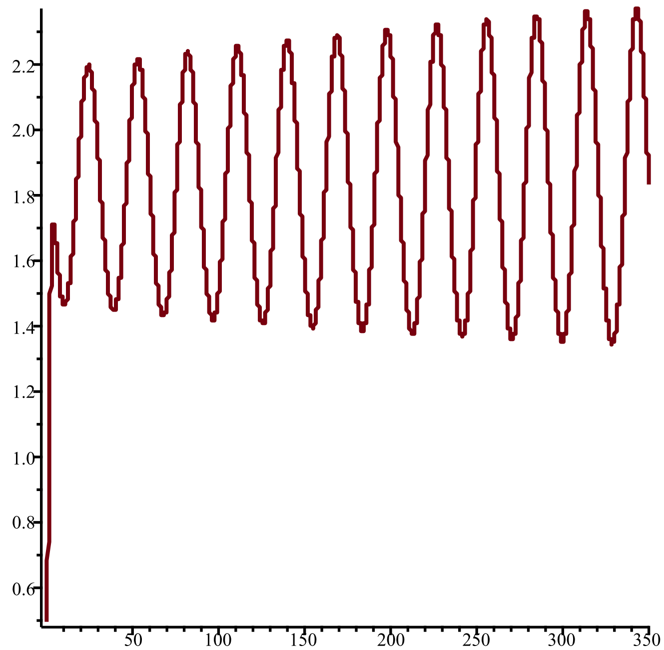
0, 7.3, 0.2, 2

$a := 7.4$



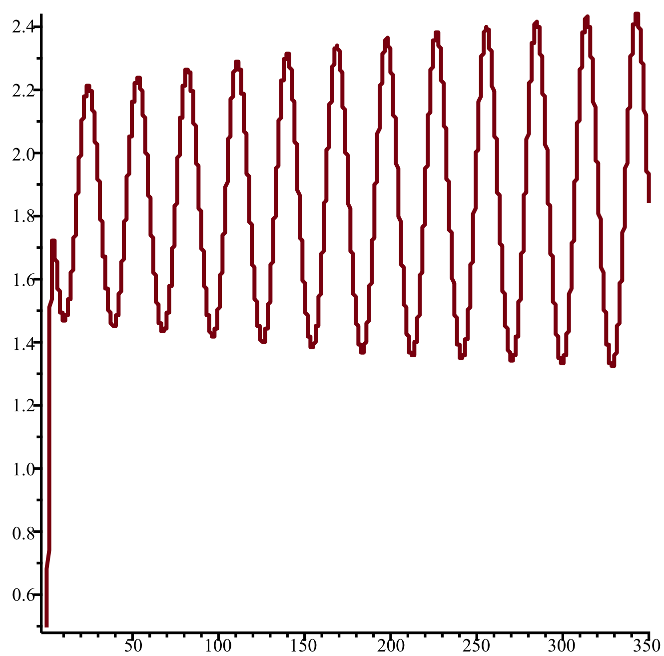
0, 7.4, 0.2, 2

$a := 7.5$



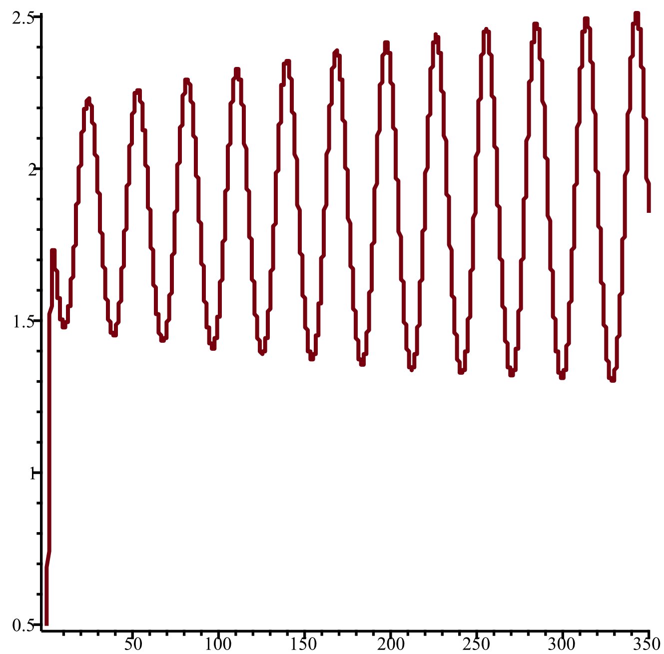
0, 7.5, 0.2, 2

$a := 7.6$



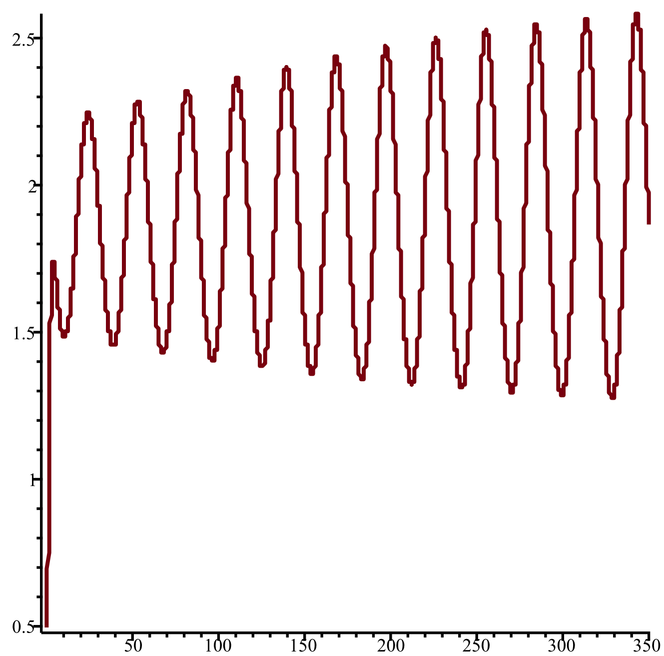
0, 7.6, 0.2, 2

$a := 7.7$



0, 7.7, 0.2, 2

$a := 7.8$



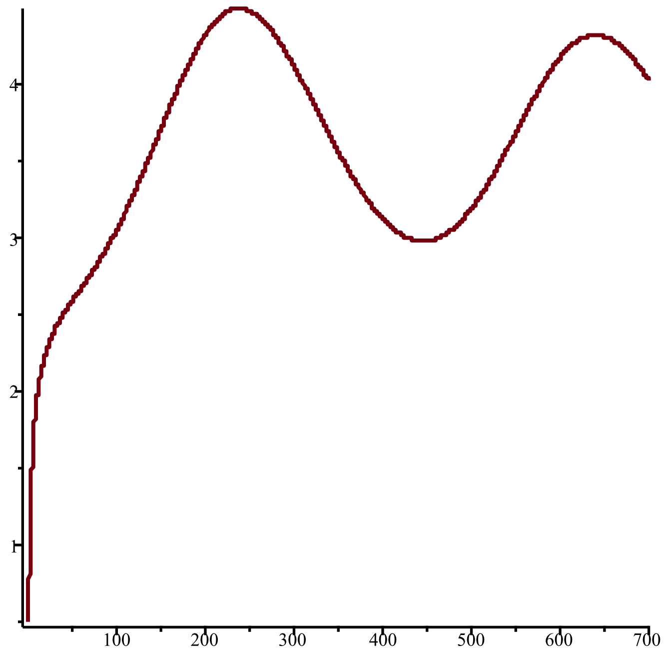
0, 7.8, 0.2, 2 **(8)**

> *#adjusting parameter b*

```
> b := 0;
  for i from 0 to 8 do
    b := b + 0.01;
    TimeSeries(GeneNet(0, 50, b, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.2, 0.1,
      0.3, 0.1, 0.4, 0.5], 0.1, 700, 6);
    print(0, 50, b, 2);
  end do;
```

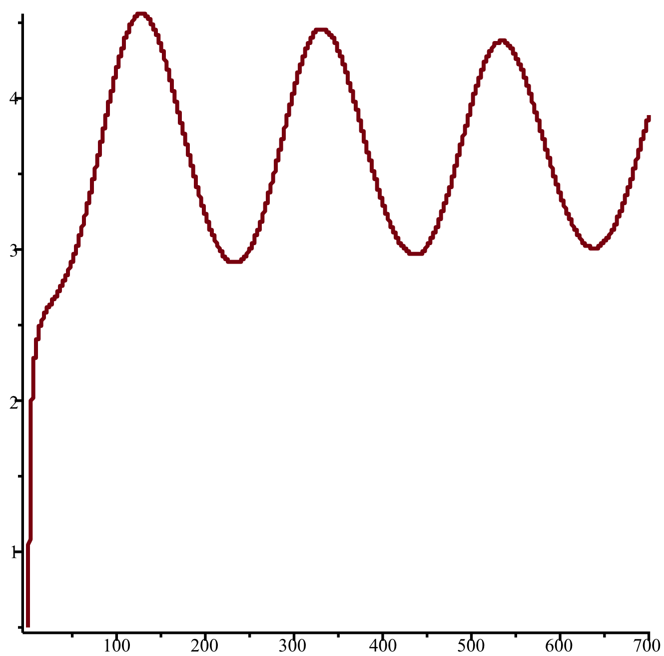
$b := 0$

$b := 0.01$



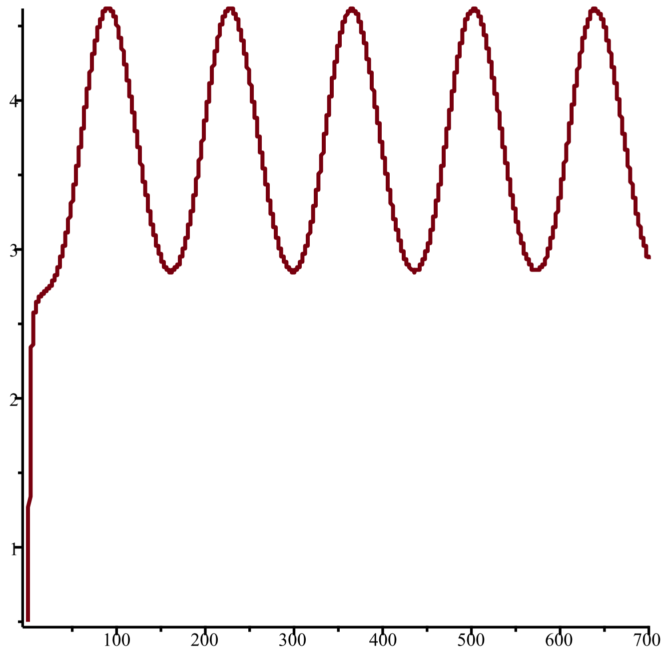
0, 50, 0.01, 2

$b := 0.02$



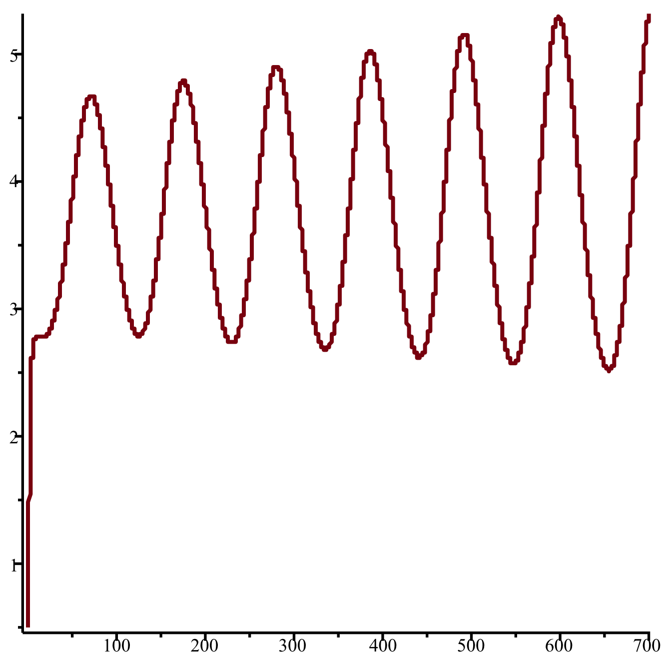
0, 50, 0.02, 2

$b := 0.03$



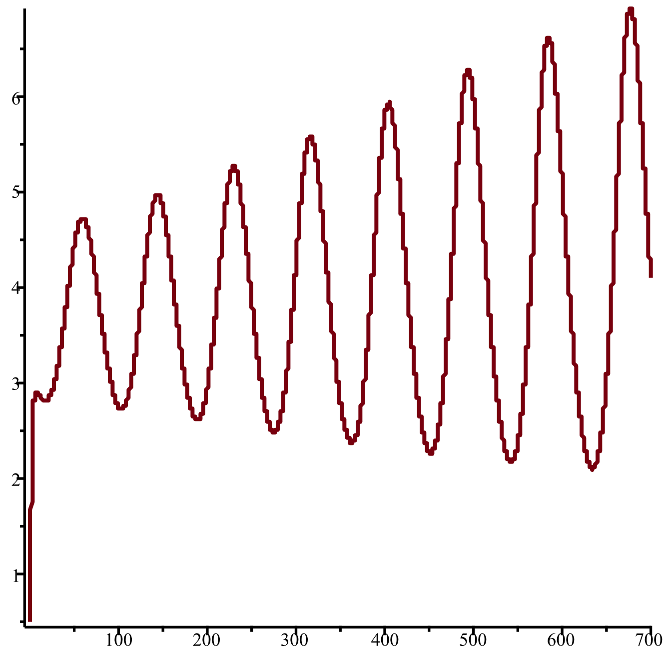
0, 50, 0.03, 2

$b := 0.04$



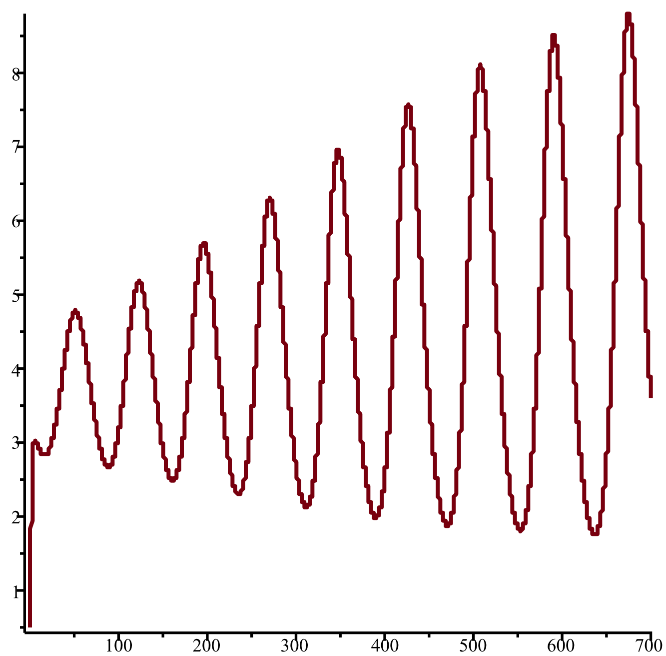
0, 50, 0.04, 2

$b := 0.05$



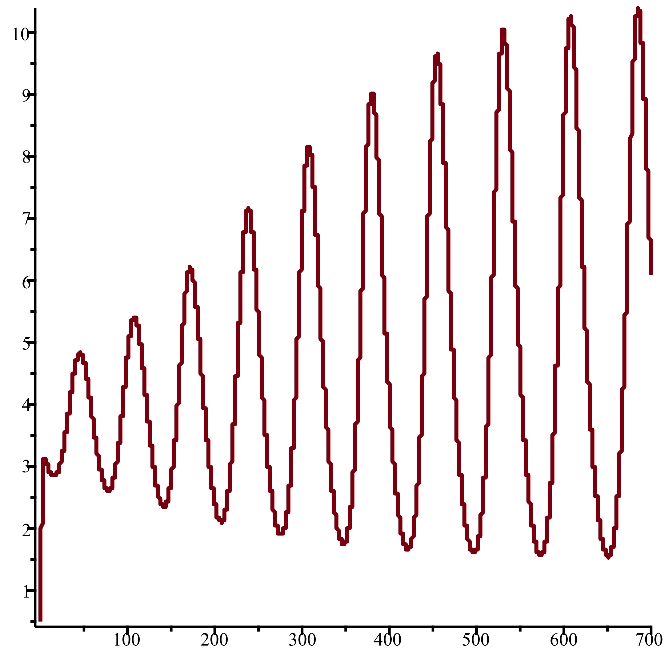
0, 50, 0.05, 2

$b := 0.06$



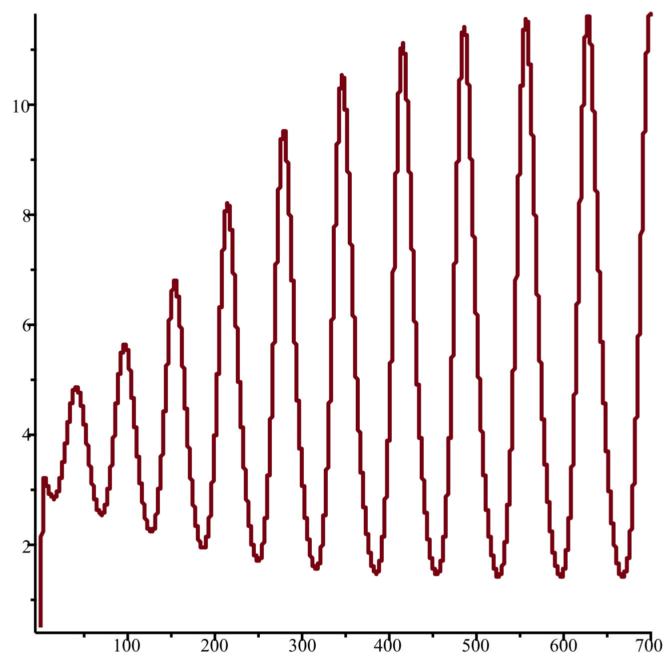
0, 50, 0.06, 2

$b := 0.07$



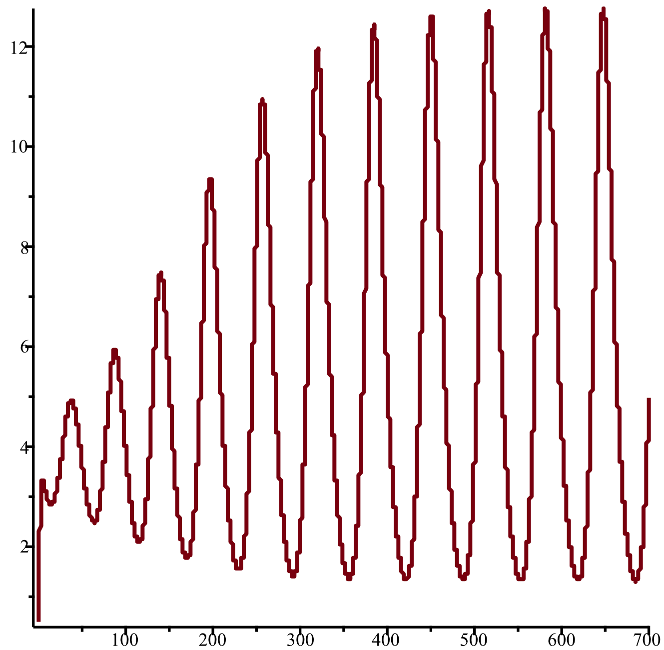
0, 50, 0.07, 2

$b := 0.08$



0, 50, 0.08, 2

$b := 0.09$



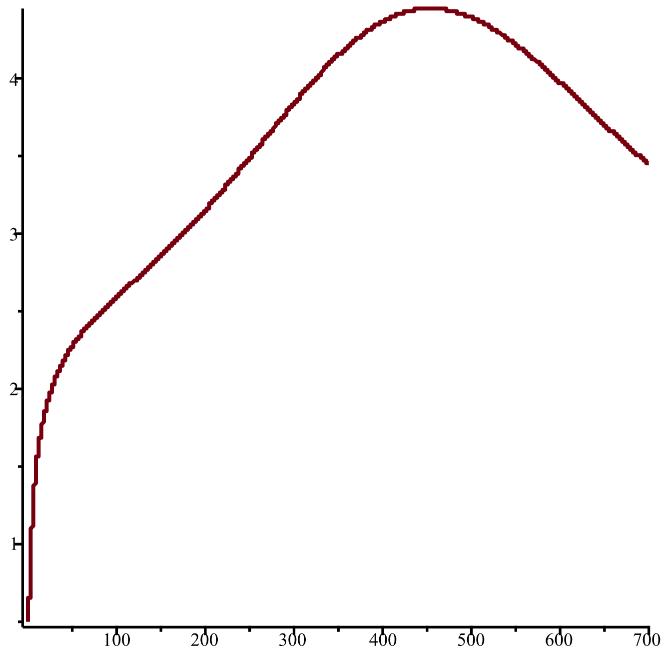
0, 50, 0.09, 2 **(9)**

> *# finding exactly where b begins to change the long term behavior from stable equilibria to oscillations*

```
> b := 0;
  for i from 0 to 8 do
    b := b + 0.005;
    TimeSeries(GeneNet(0, 50, b, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.2, 0.1,
      0.3, 0.1, 0.4, 0.5], 0.1, 700, 6);
    print(0, 50, b, 2);
  end do;
```

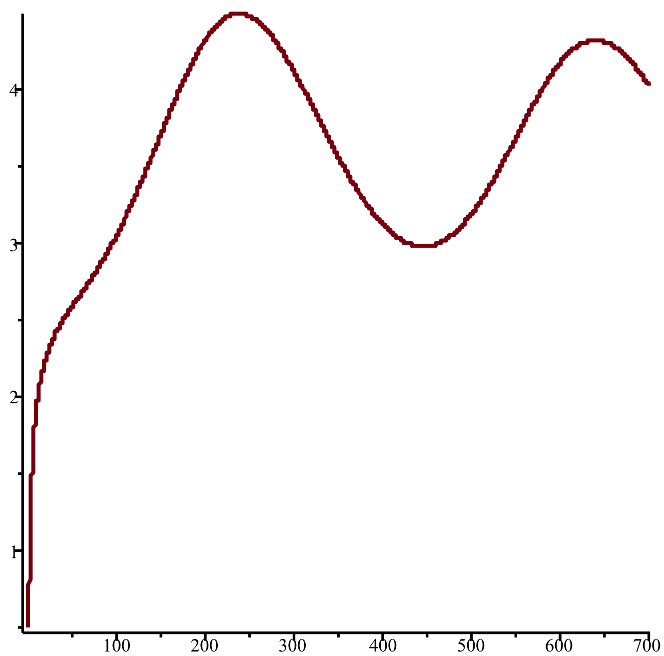
$b := 0$

$b := 0.005$



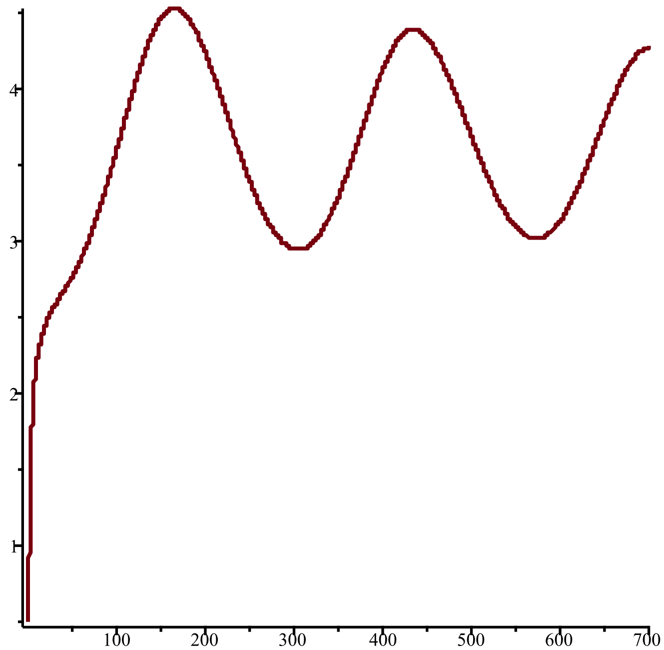
0, 50, 0.005, 2

$b := 0.010$



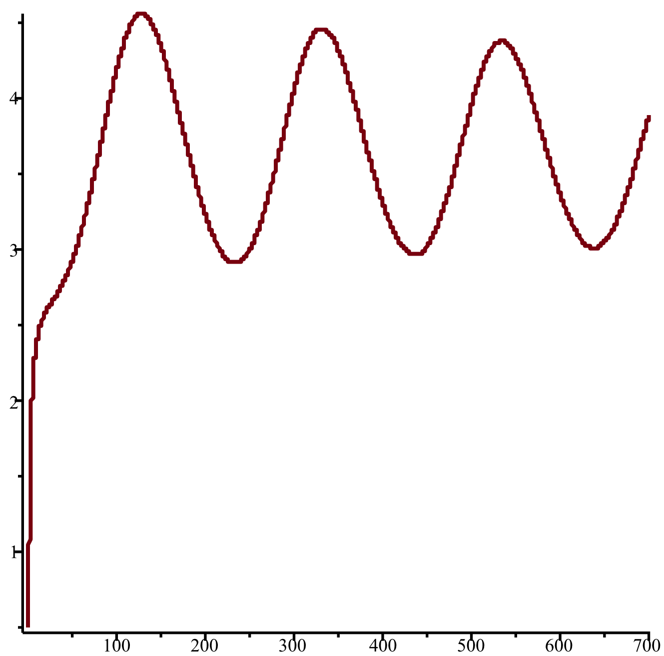
0, 50, 0.010, 2

$b := 0.015$



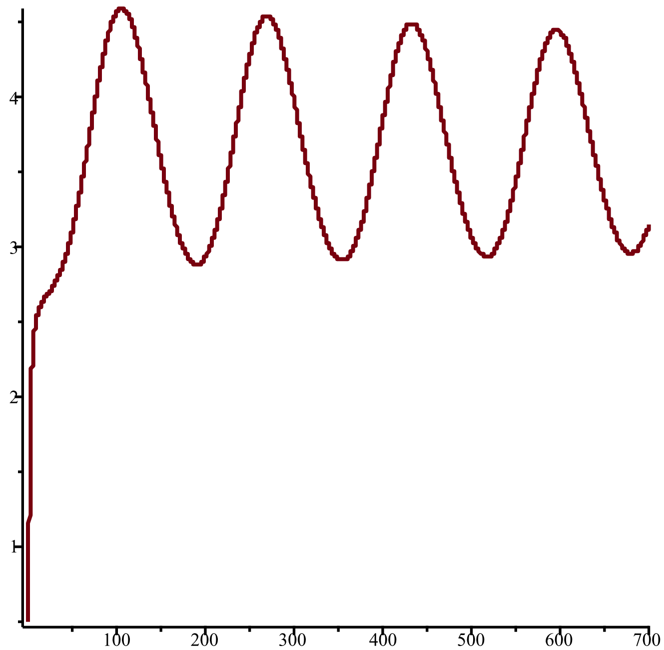
0, 50, 0.015, 2

$b := 0.020$



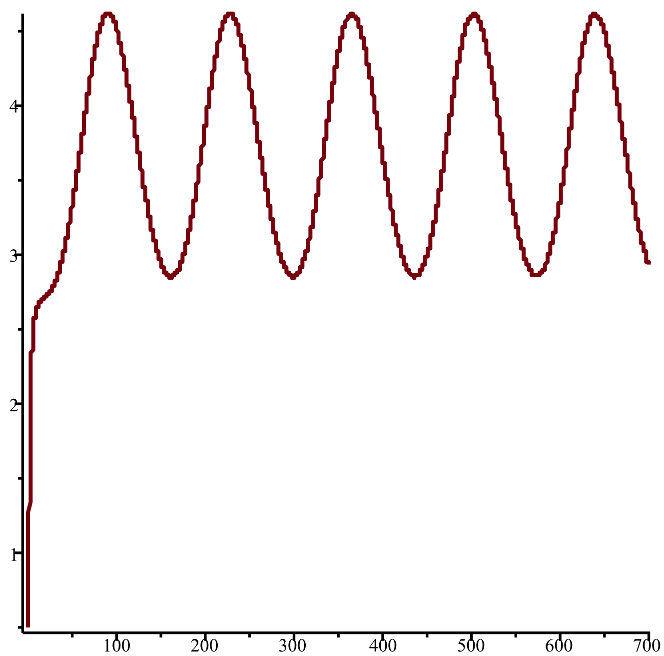
0, 50, 0.020, 2

$b := 0.025$



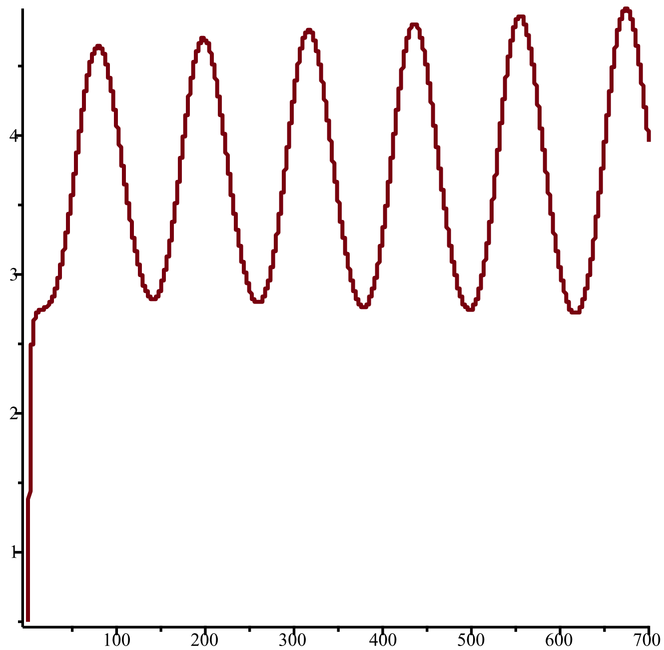
0, 50, 0.025, 2

$b := 0.030$



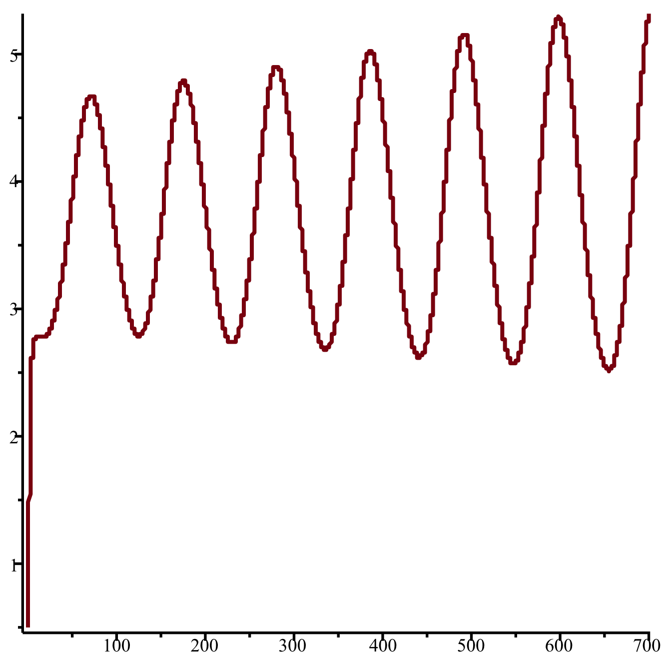
0, 50, 0.030, 2

$b := 0.035$



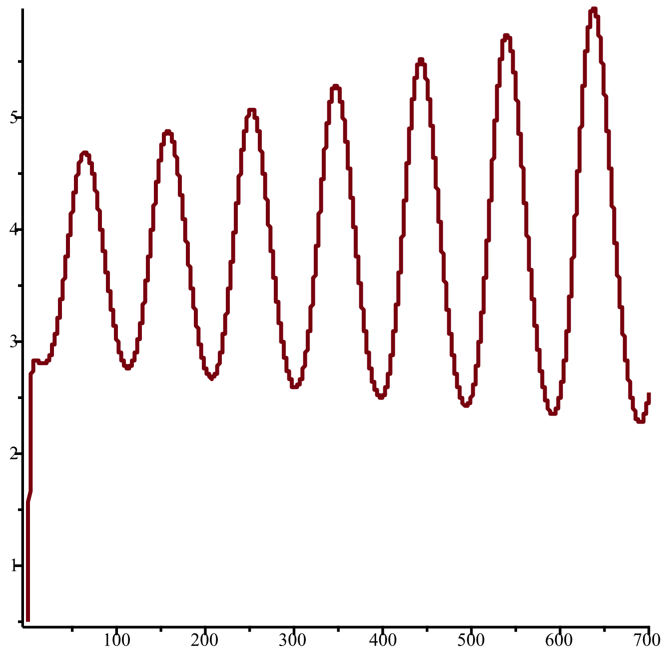
0, 50, 0.035, 2

$b := 0.040$



0, 50, 0.040, 2

$b := 0.045$



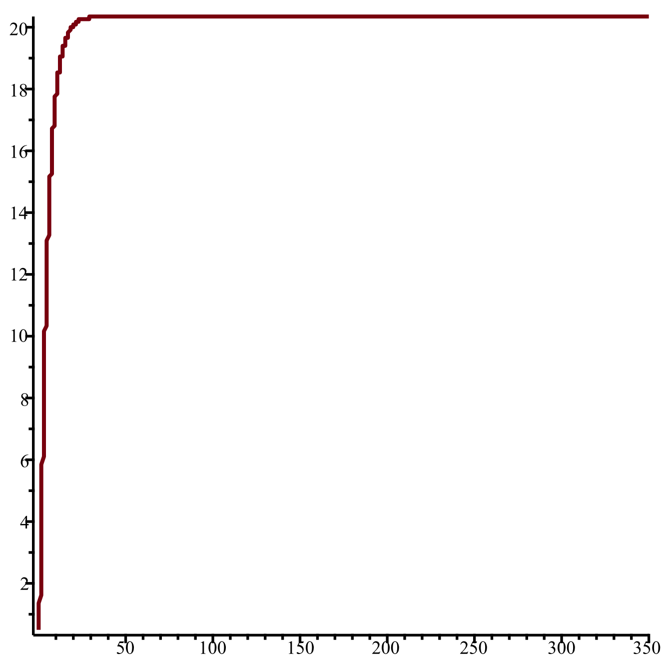
0, 50, 0.045, 2 **(10)**

> *#adjusting parameter n*

```
> n := 0;
  for i from 0 to 15 do
     n := n + 0.125;
    TimeSeries(GeneNet(0, 50, 0.2, n, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.2,
       0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 6);
    print(0, 50, 0.2, n);
  end do;
```

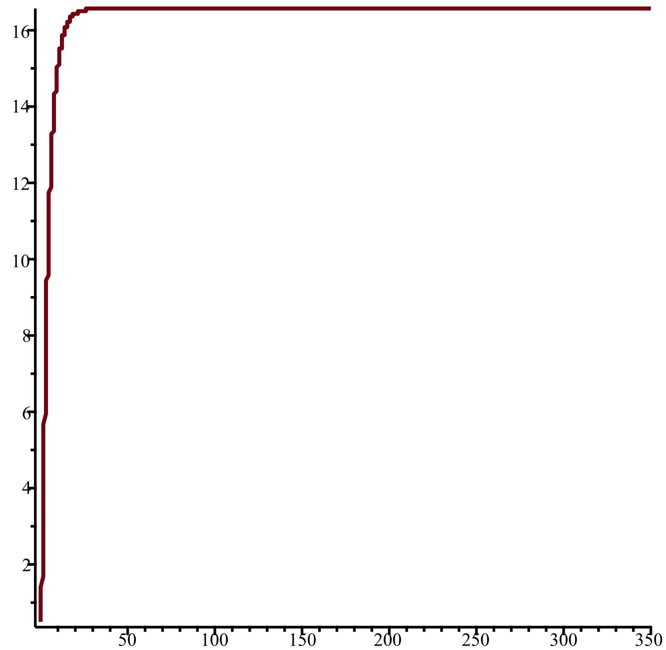
$n := 0$

$n := 0.125$



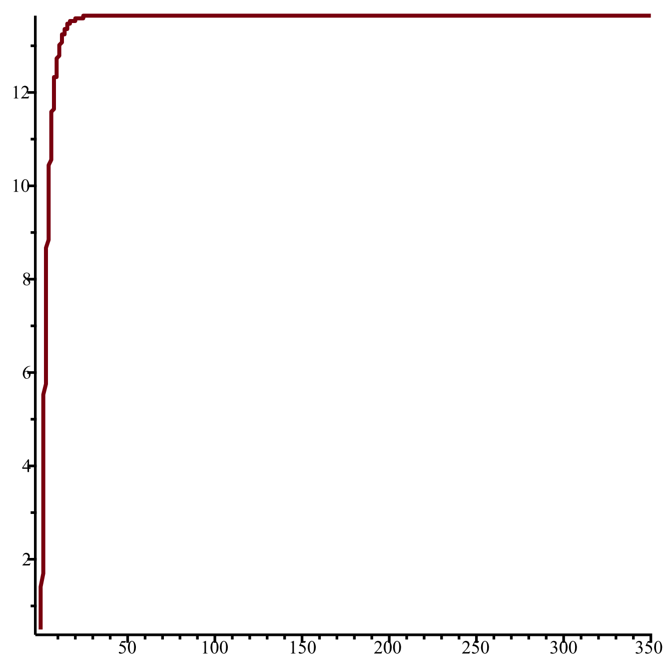
0, 50, 0.2, 0.125

$n := 0.250$



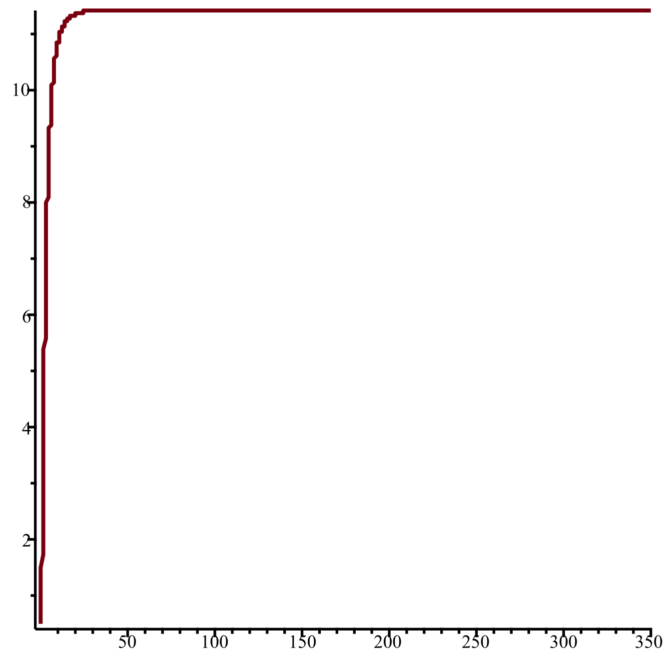
0, 50, 0.2, 0.250

$n := 0.375$



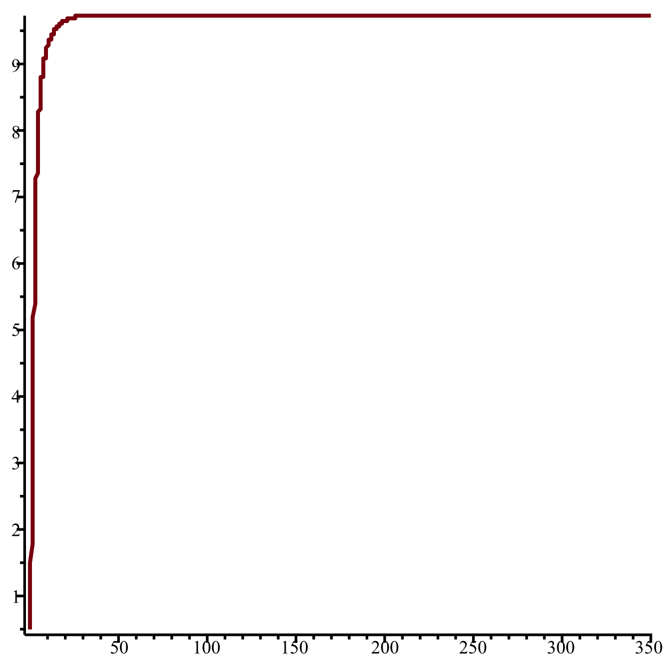
0, 50, 0.2, 0.375

$n := 0.500$



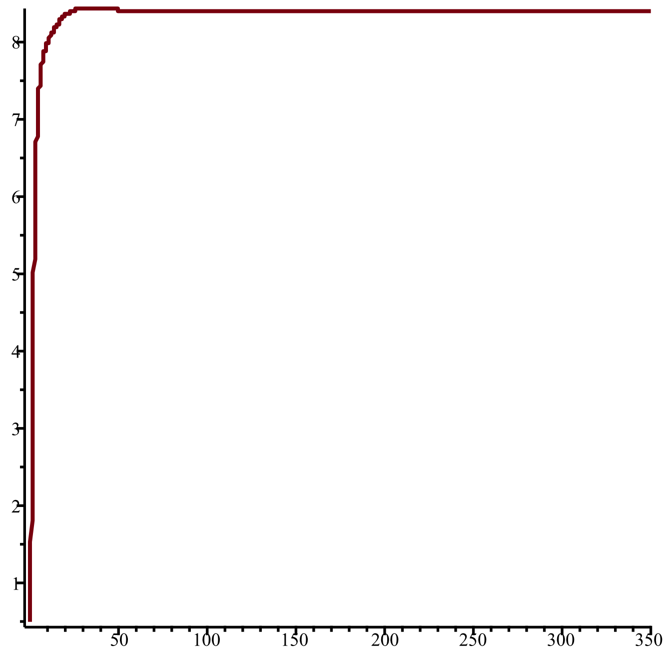
0, 50, 0.2, 0.500

$n := 0.625$



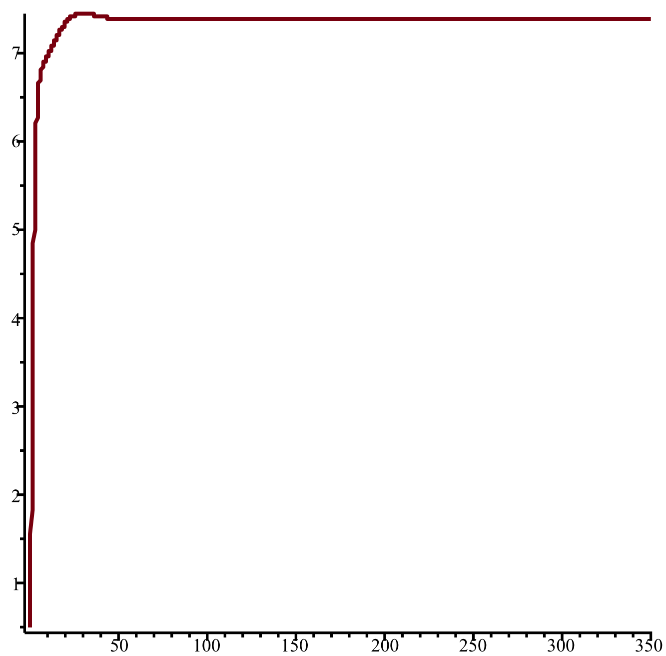
0, 50, 0.2, 0.625

$n := 0.750$



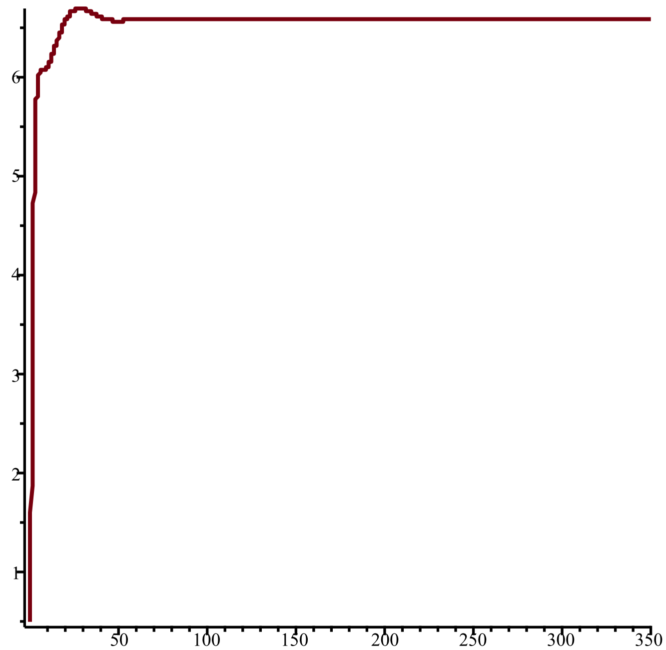
0, 50, 0.2, 0.750

$n := 0.875$



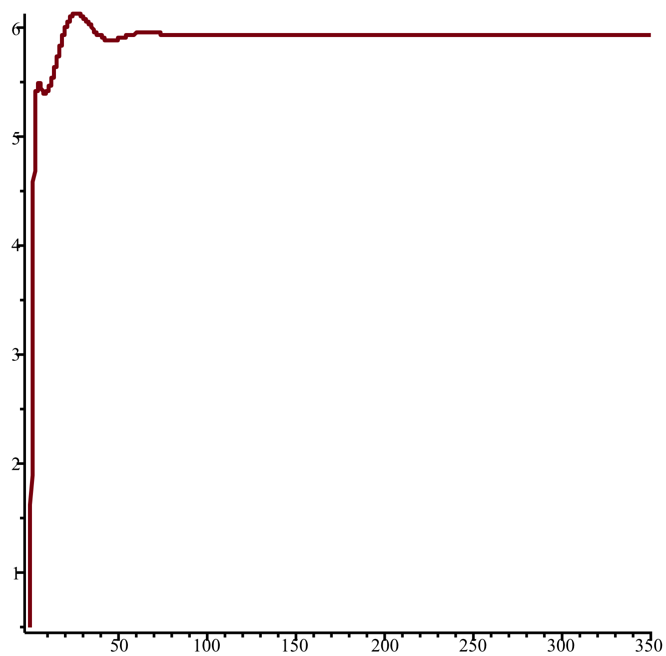
0, 50, 0.2, 0.875

$n := 1.000$



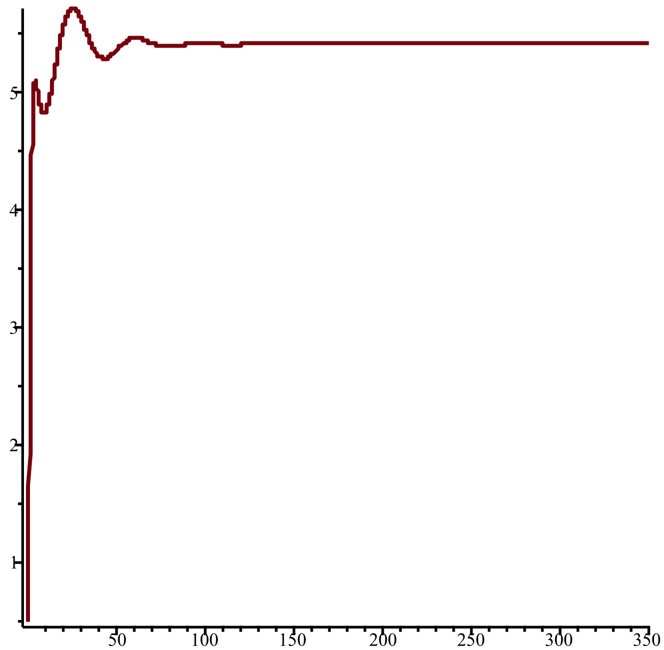
0, 50, 0.2, 1.000

$n := 1.125$



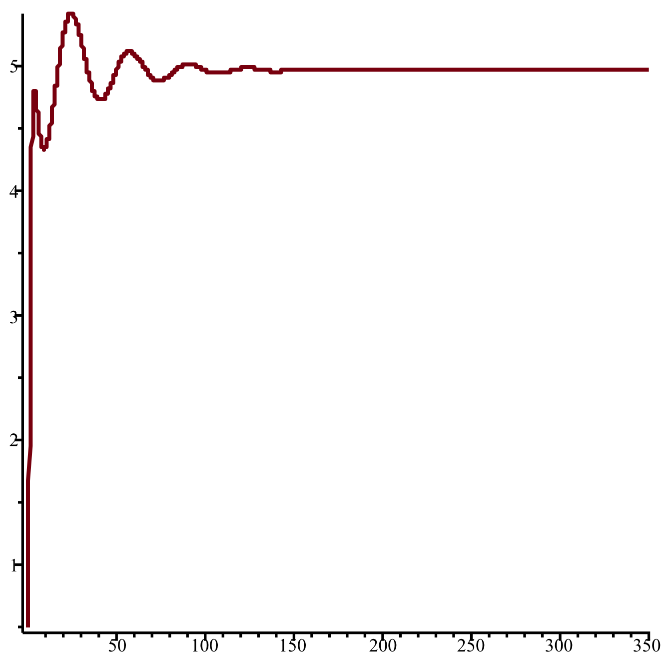
0, 50, 0.2, 1.125

$n := 1.250$



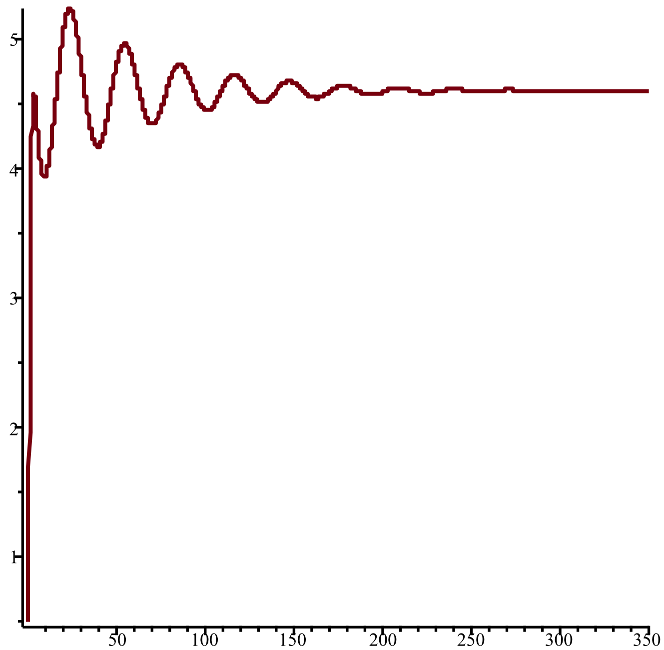
0, 50, 0.2, 1.250

$n := 1.375$



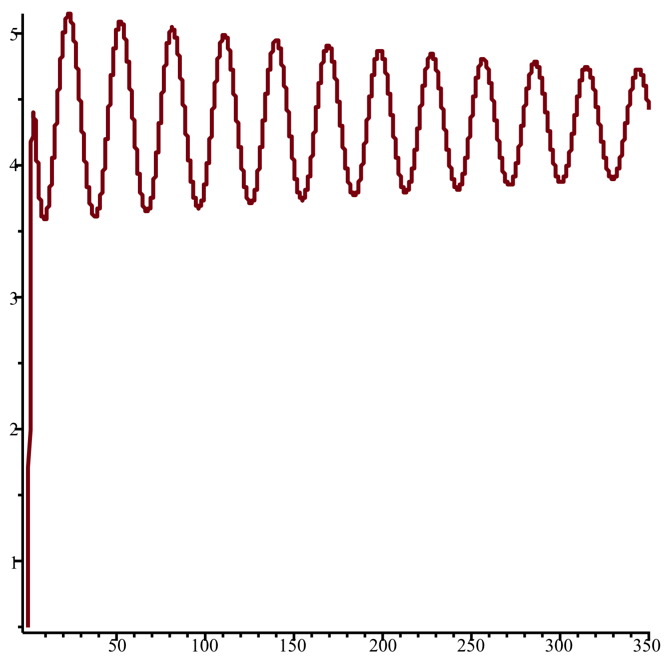
0, 50, 0.2, 1.375

$n := 1.500$



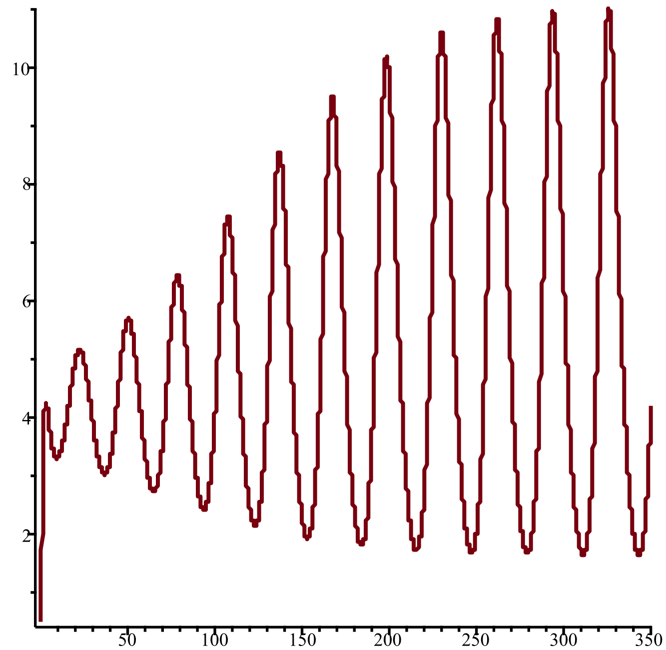
0, 50, 0.2, 1.500

$n := 1.625$



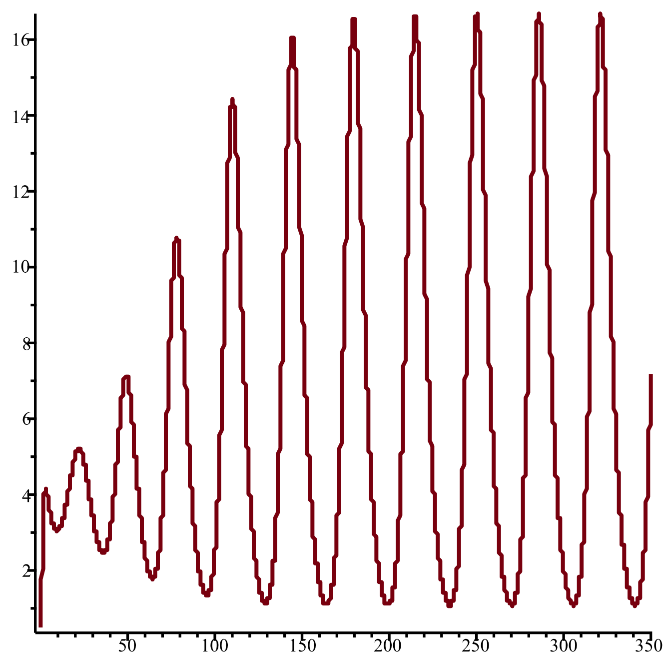
0, 50, 0.2, 1.625

$n := 1.750$



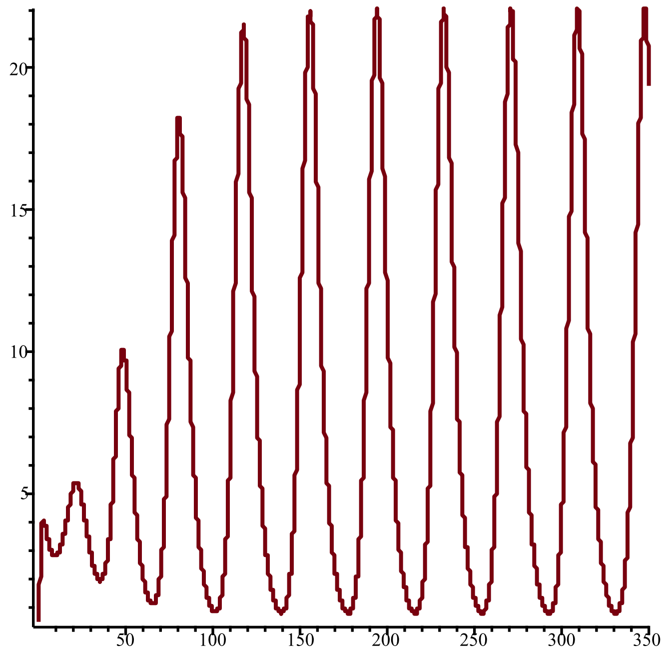
0, 50, 0.2, 1.750

$n := 1.875$



0, 50, 0.2, 1.875

$n := 2.000$



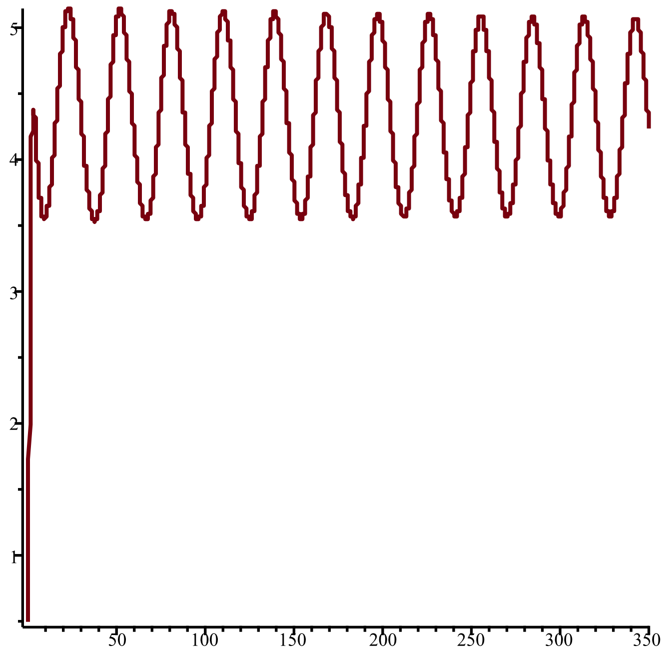
0, 50, 0.2, 2.000 **(11)**

> *# finding exactly where n begins to changes the long term behavior from stable equilibria to oscillations*

```
> n := 1.64;
  for i from 0 to 20 do
    n := n + 0.001;
    TimeSeries(GeneNet(0, 50, 0.2, n, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.2,
      0.1, 0.3, 0.1, 0.4, 0.5], 0.1, 350, 6);
    print(0, 50, 0.2, n);
  end do;
```

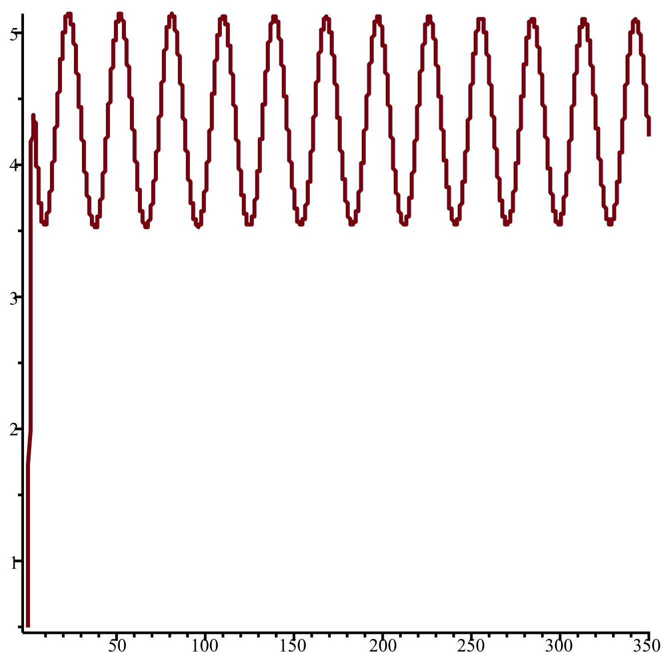
$n := 1.64$

$n := 1.641$



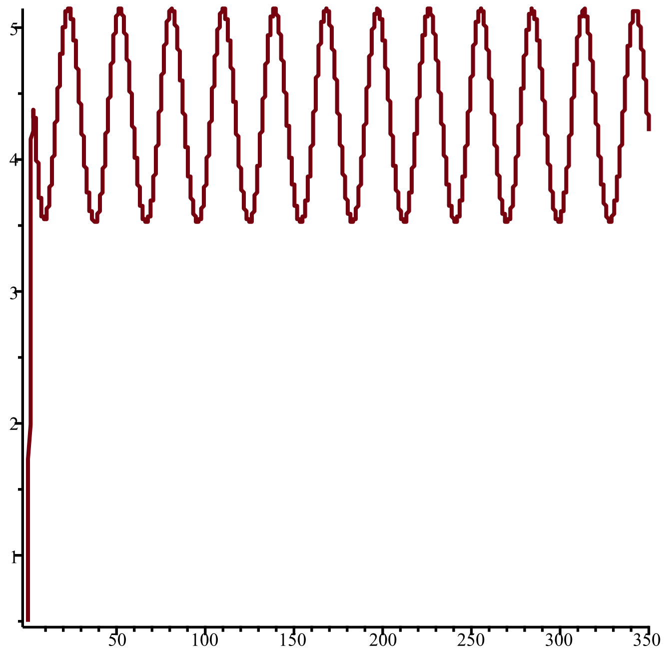
0, 50, 0.2, 1.641

$n := 1.642$



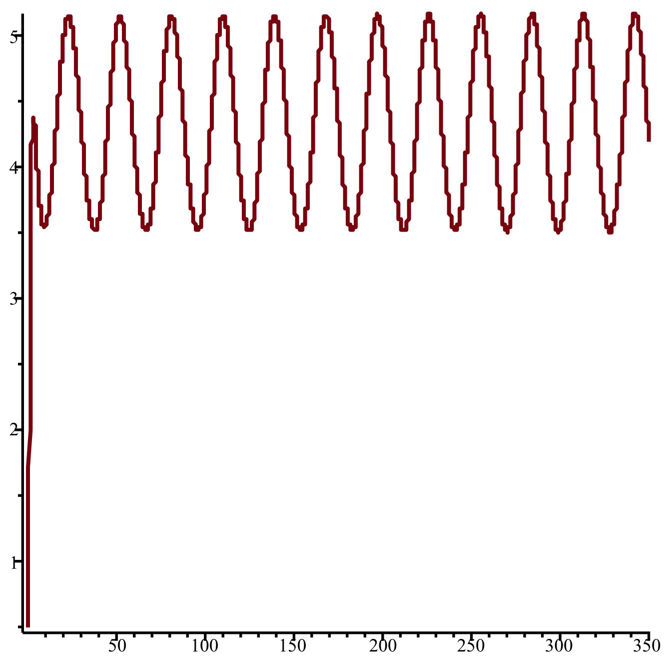
0, 50, 0.2, 1.642

$n := 1.643$



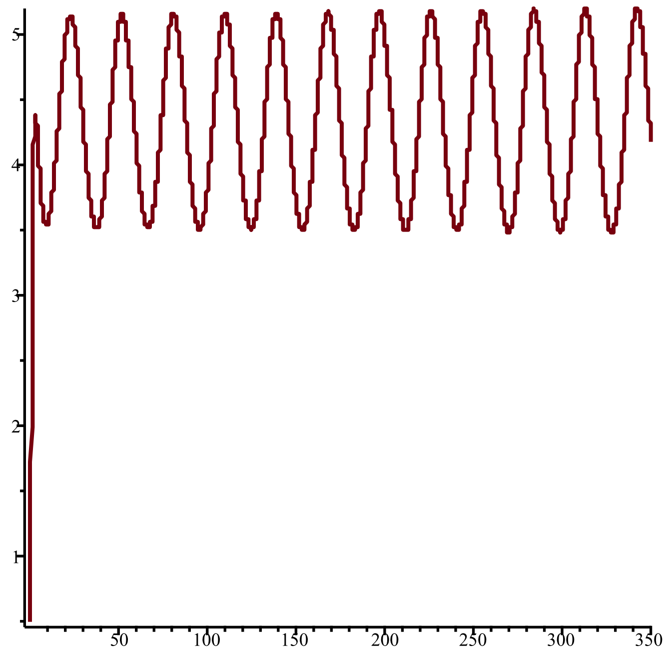
0, 50, 0.2, 1.643

$n := 1.644$



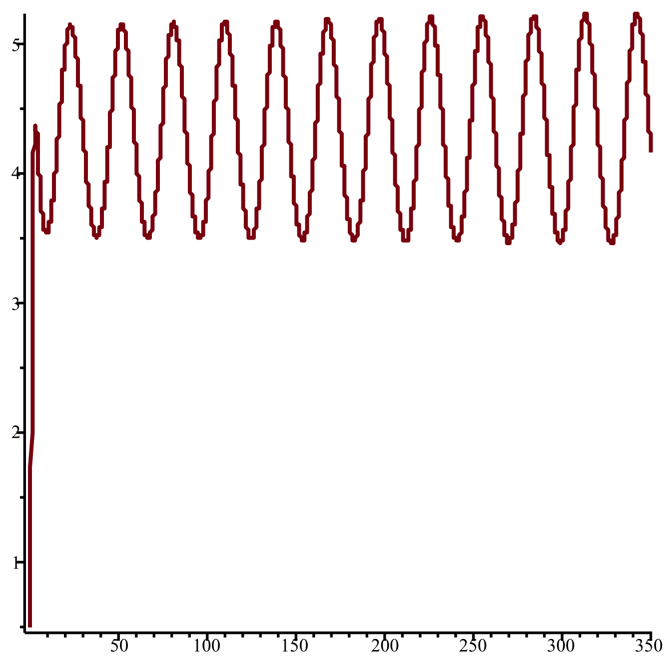
0, 50, 0.2, 1.644

$n := 1.645$



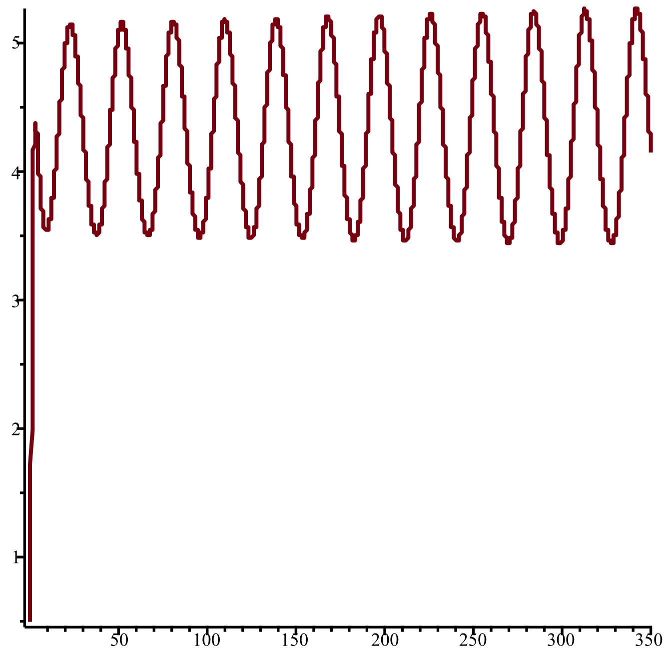
0, 50, 0.2, 1.645

$n := 1.646$



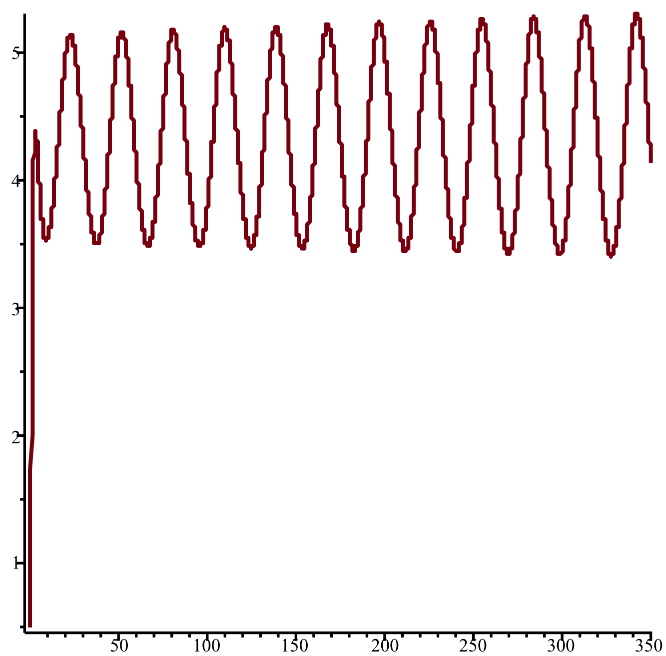
0, 50, 0.2, 1.646

$n := 1.647$



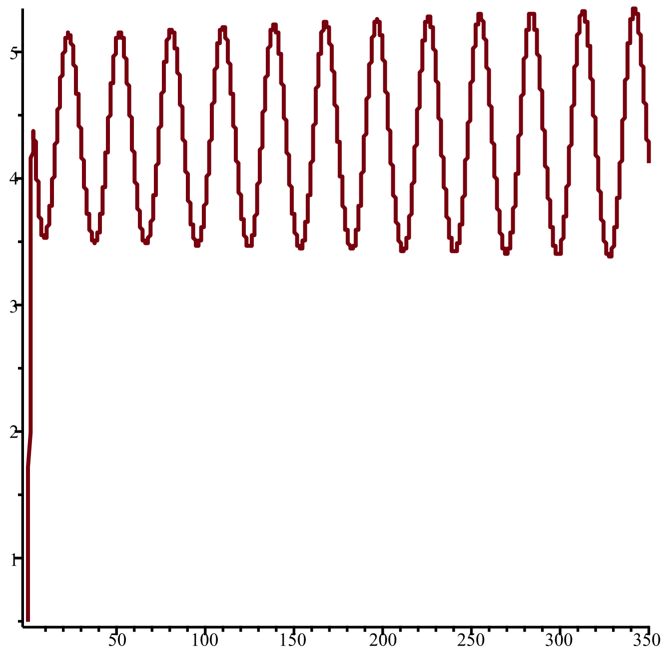
0, 50, 0.2, 1.647

$n := 1.648$



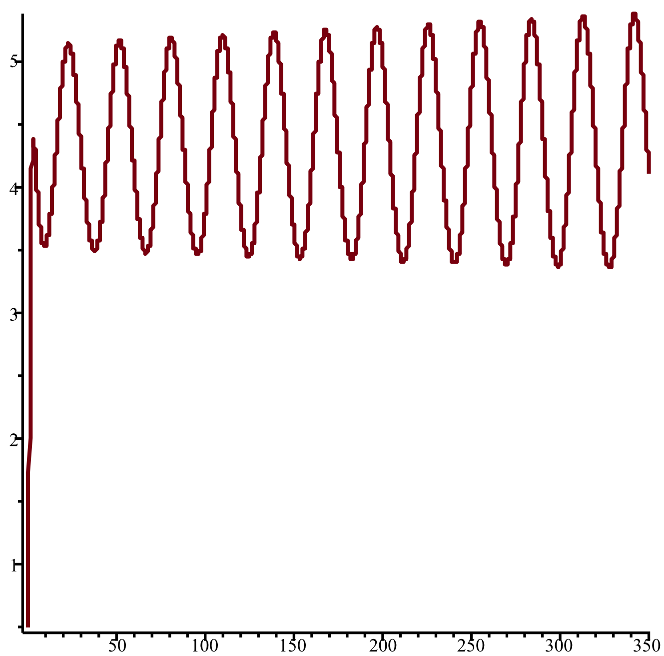
0, 50, 0.2, 1.648

$n := 1.649$



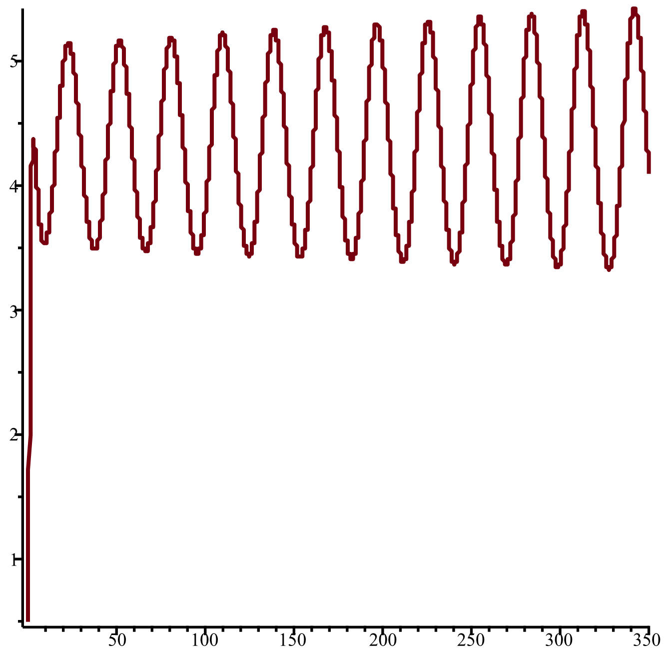
0, 50, 0.2, 1.649

$n := 1.650$



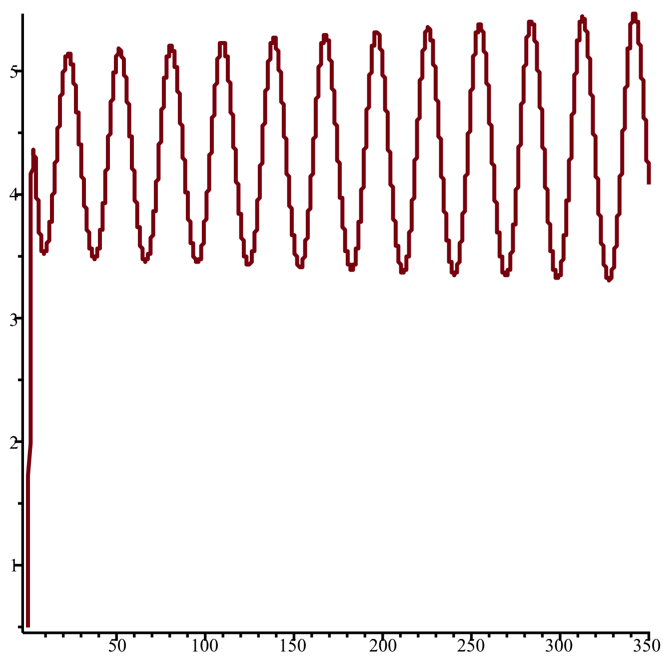
0, 50, 0.2, 1.650

$n := 1.651$



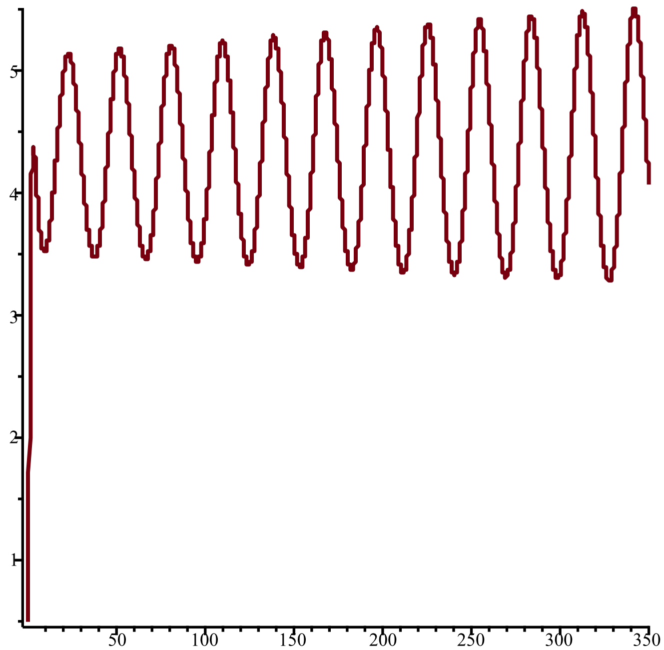
0, 50, 0.2, 1.651

$n := 1.652$



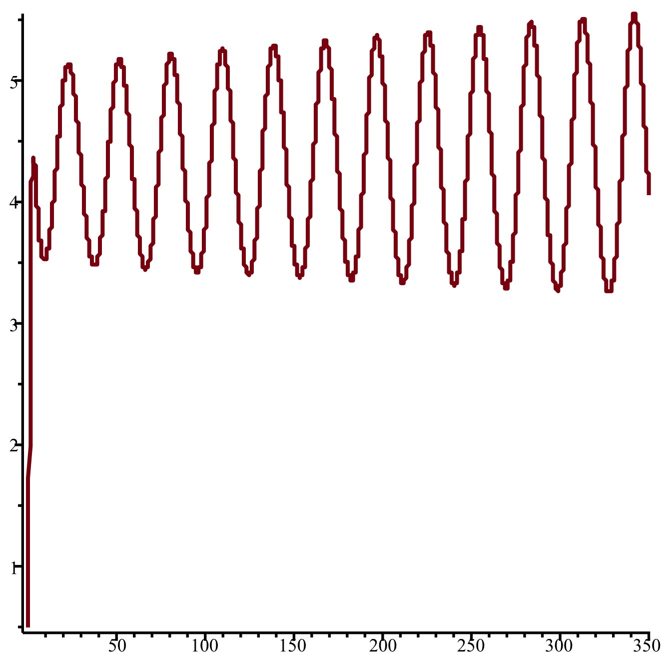
0, 50, 0.2, 1.652

$n := 1.653$



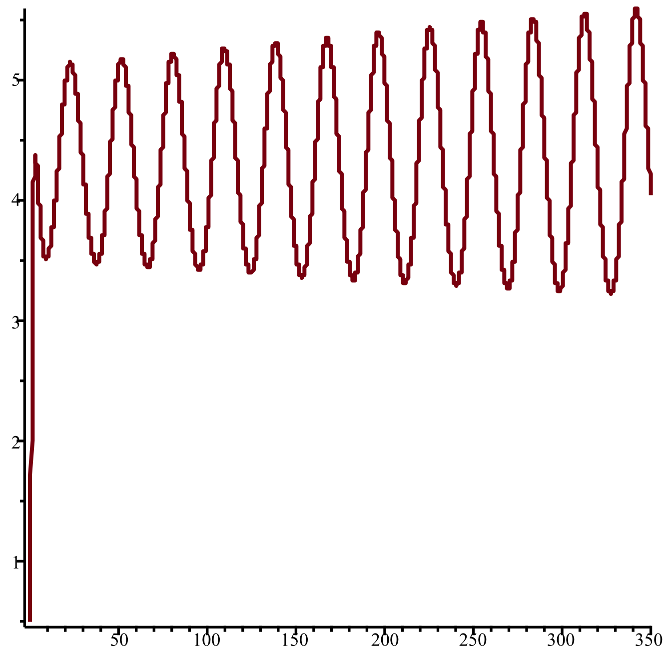
0, 50, 0.2, 1.653

$n := 1.654$



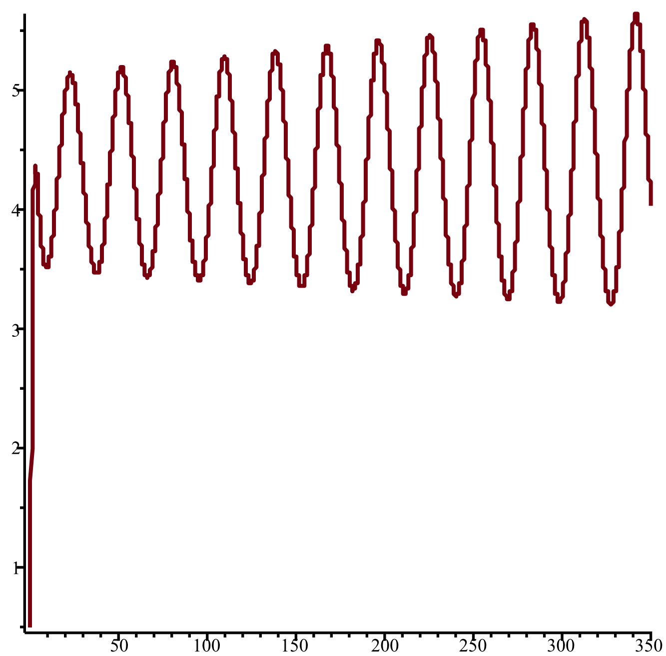
0, 50, 0.2, 1.654

$n := 1.655$



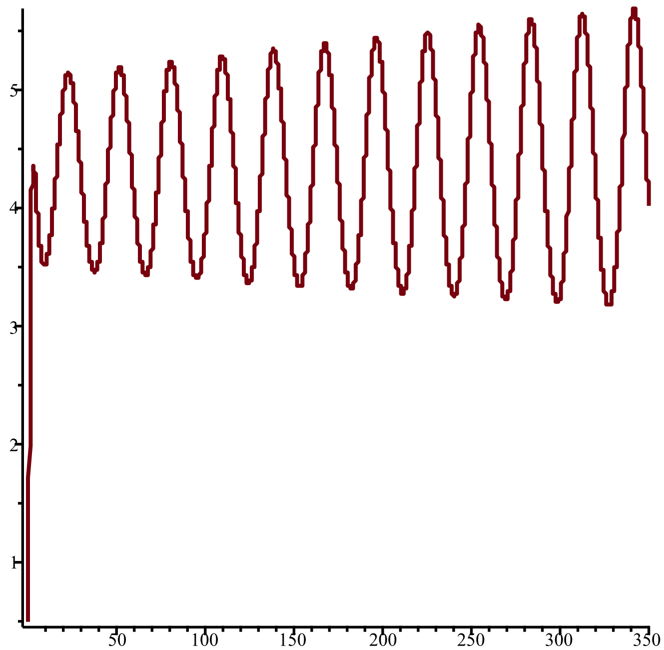
0, 50, 0.2, 1.655

$n := 1.656$



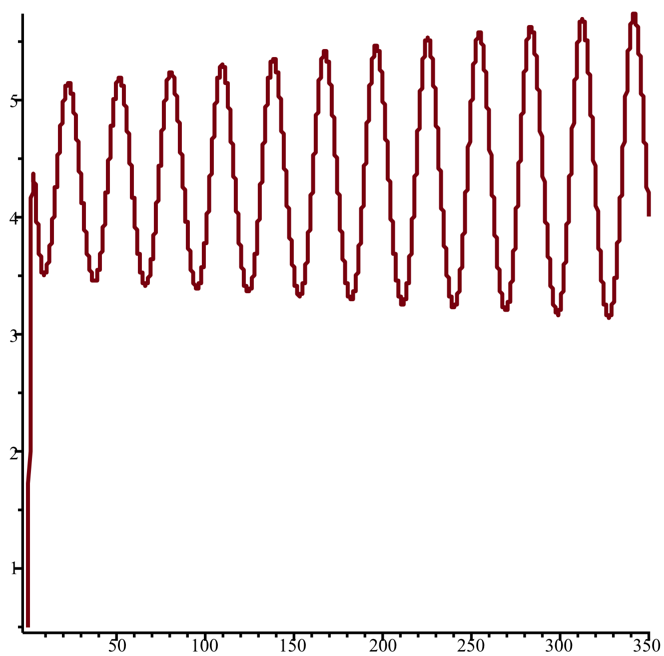
0, 50, 0.2, 1.656

$n := 1.657$



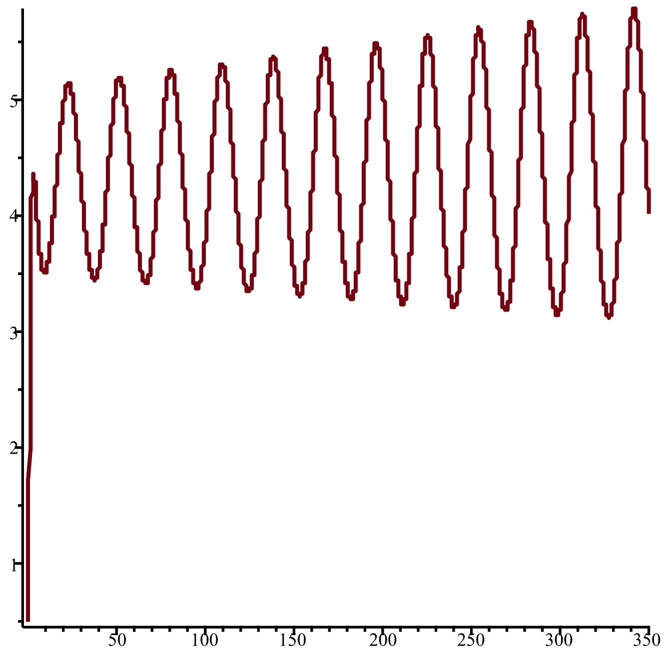
0, 50, 0.2, 1.657

$n := 1.658$



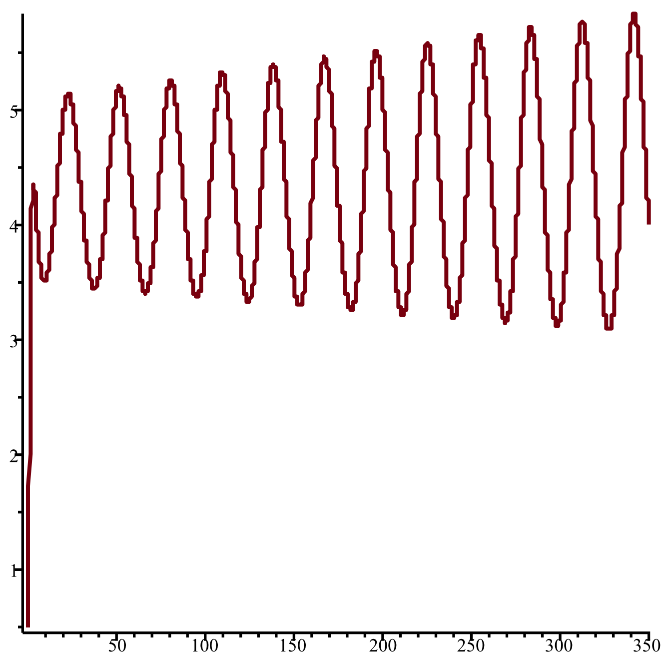
0, 50, 0.2, 1.658

$n := 1.659$



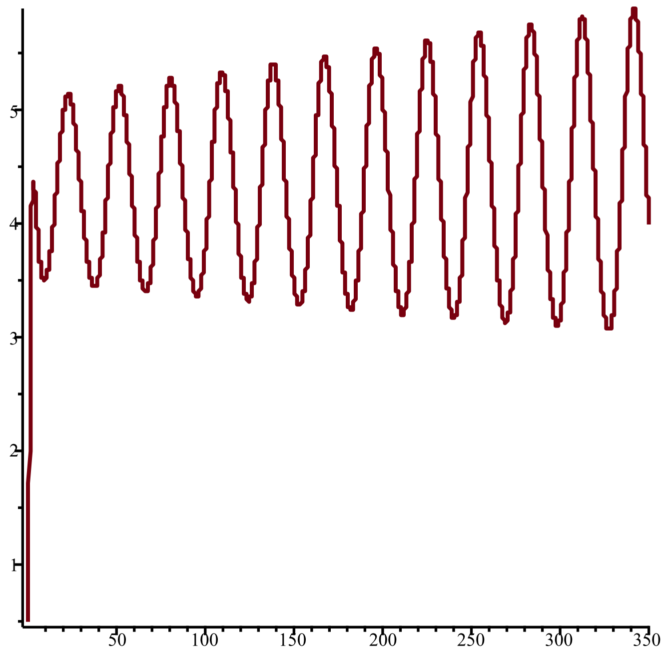
0, 50, 0.2, 1.659

$n := 1.660$



0, 50, 0.2, 1.660

$n := 1.661$



0, 50, 0.2, 1.661 **(12)**

>