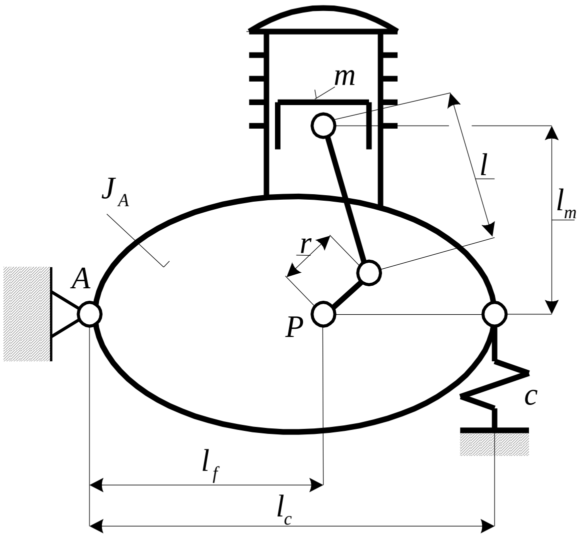
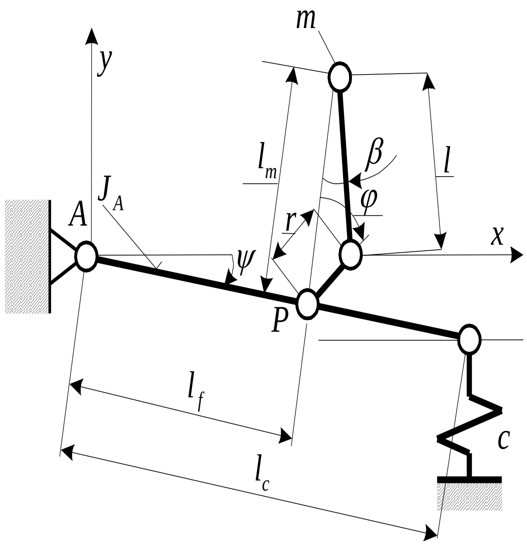
Dynamics of Machines Week 8 – Exercise

Vibrations of a Single Cylinder Engine with Elastic Mounting



Single Cylinder Engine



Mechanical Model

Equation of motion:

$$\underbrace{\left[J_{Az}+m\left(l_f^2+l^2+\frac{r^2}{2}\right)\right]}_{J_{red}}\ddot{\psi}+\frac{l_c^2\psi}{c}=-ml_f r\Omega^2\cos\Omega t\ ,\qquad \psi=\frac{y_p}{l_f},\ \ \ddot{\psi}=\frac{\ddot{y}_p}{l_f}$$

Rearrangement:

$$\ddot{y}_P=-\underbrace{\frac{l_c^2}{c\,J_{red}}}_{\alpha^2}y_P-\frac{ml_f^2 r}{J_{red}}\Omega^2\cos\Omega t$$

If we take into account damping: $\ddot{y}_P=-2\alpha\xi\dot{y}_P-\alpha^2 y_P-\frac{ml_f^2 r}{J_{red}}\Omega^2\cos\Omega t$

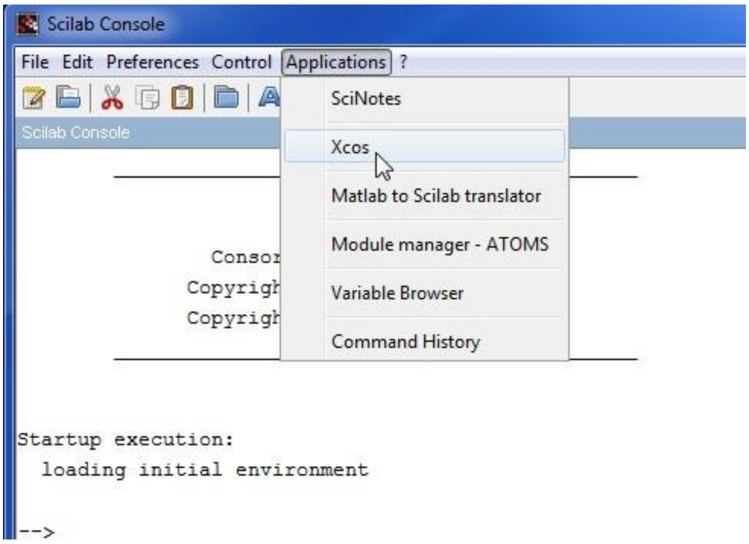
(where $\xi=0{,}1$ is the material damping)

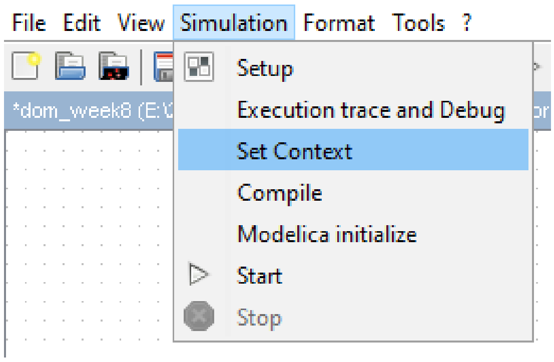
Idle speed of the engine is $n_{\min} = 1000\,rev/min$, maximum engine speed is $n_{\max} = 5000\ rev/min$. Determine the spring constant $c(m/N)$ of the engine mount that the vertical displacement of point P must stay in the $\pm\ 1\ mm$ range in both maximum and minimum engine speed!

There are two spring constants that are the results of previous calculation.

$c_1 = 0{,}00281\ m/N$ (soft spring) and $c_2 = 0{,}000102\ m/N$ (stiffer spring)

Determine which spring is suitable for the engine to fulfill the requirement (±1mm)!

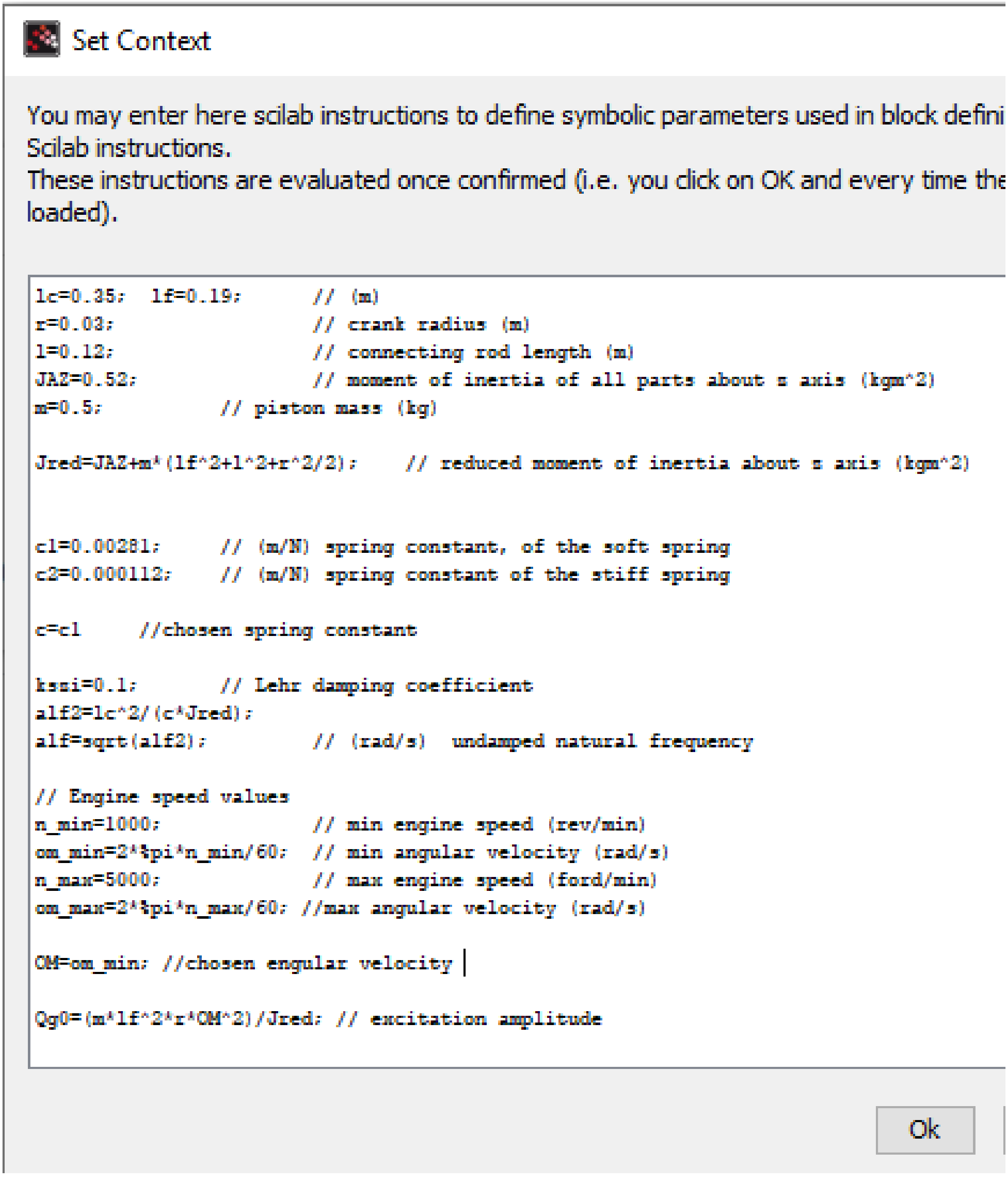


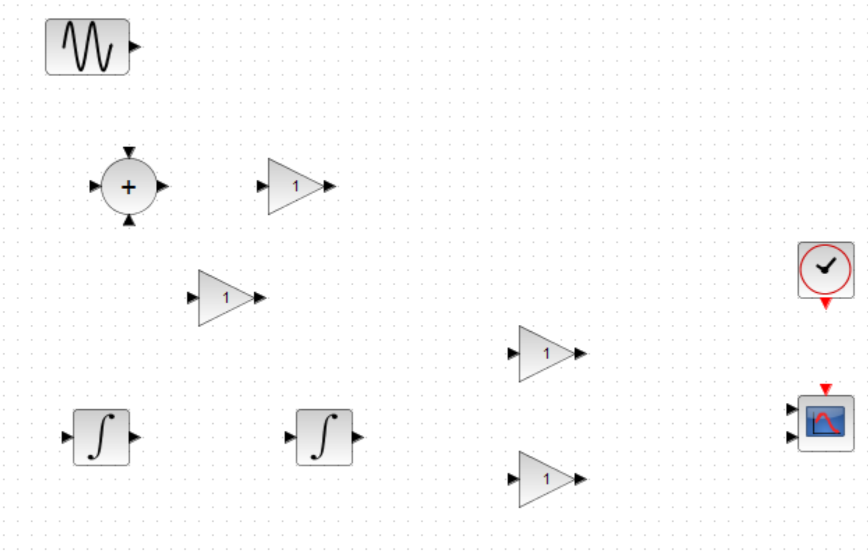


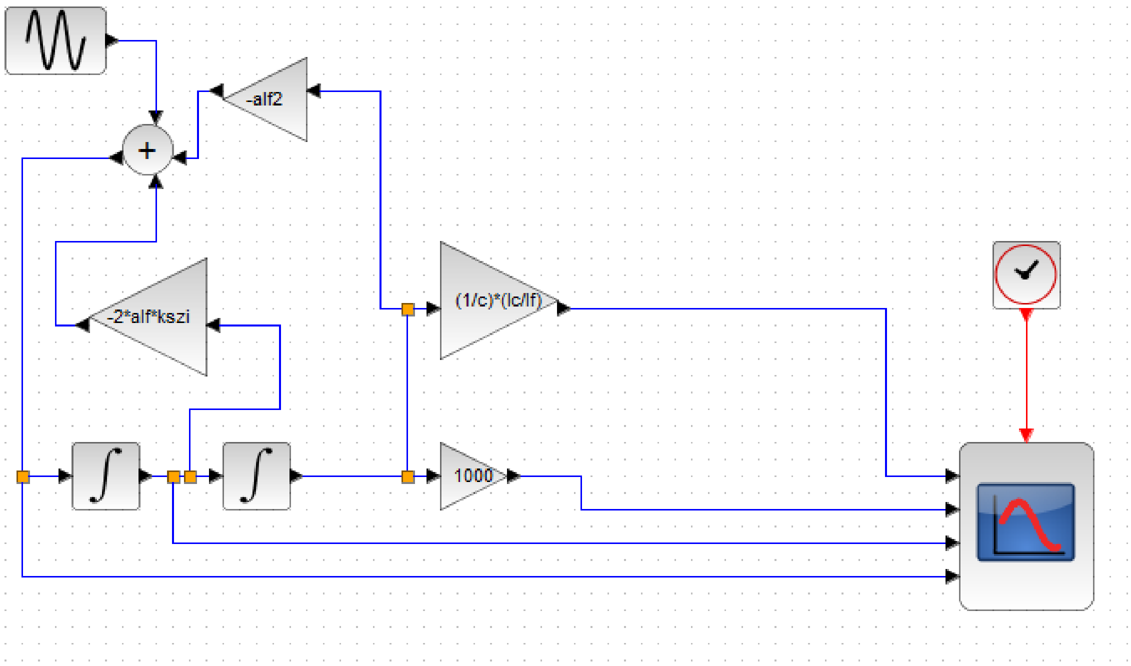
Set Context:

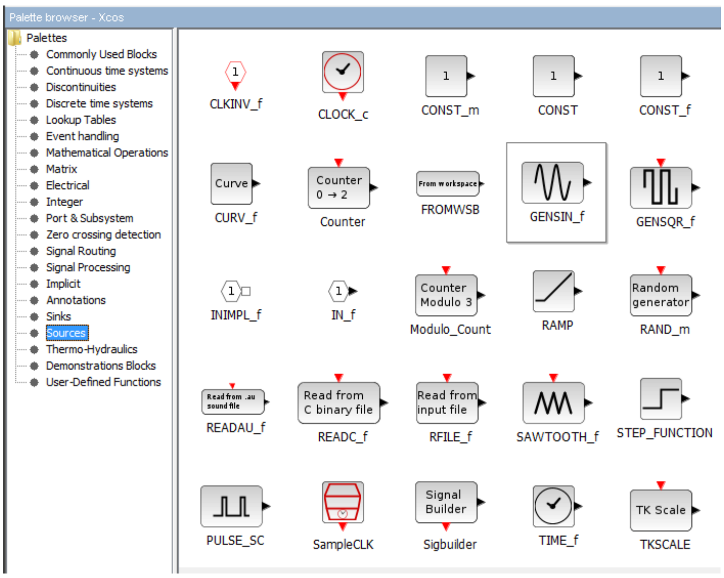
```
lc=0.35;  lf=0.19;        // (m)
r=0.03;                   // crank radius (m)
l=0.12;                   // connecting rod length (m)
JAZ=0.52;                 // moment of inertia of all parts about z axis (kgm^2)
m=0.5;                    // piston mass (kg)

Jred=JAZ+m*(lf^2+l^2+r^2/2);  // reduced moment of inertia about z axis (kgm^2)

c1=0.00281;               // (m/N) spring constant, of the soft spring
c2=0.000112;              // (m/N) spring constant of the stiff spring

c=c1            //chosen spring constant

kszi=0.1;       // Lehr damping coefficient
alf2=lc^2/(c*Jred);
alf=sqrt(alf2);           // (rad/s)  undamped natural frequency
```

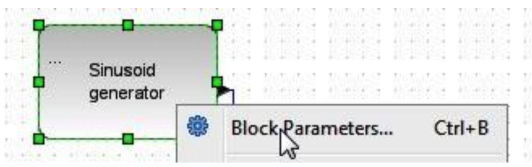
```
// Engine speed values
n_min=1000;                  // min engine speed (rev/min)
om_min=2*%pi*n_min/60;       // min angular velocity (rad/s)
n_max=5000;                  // max engine speed (rev/min)
om_max=2*%pi*n_max/60;       //max angular velocity (rad/s)

OM=om_min;          //chosen engular velocity

Qg0=(m*lf^2*r*OM^2)/Jred;    // excitation amplitude
```

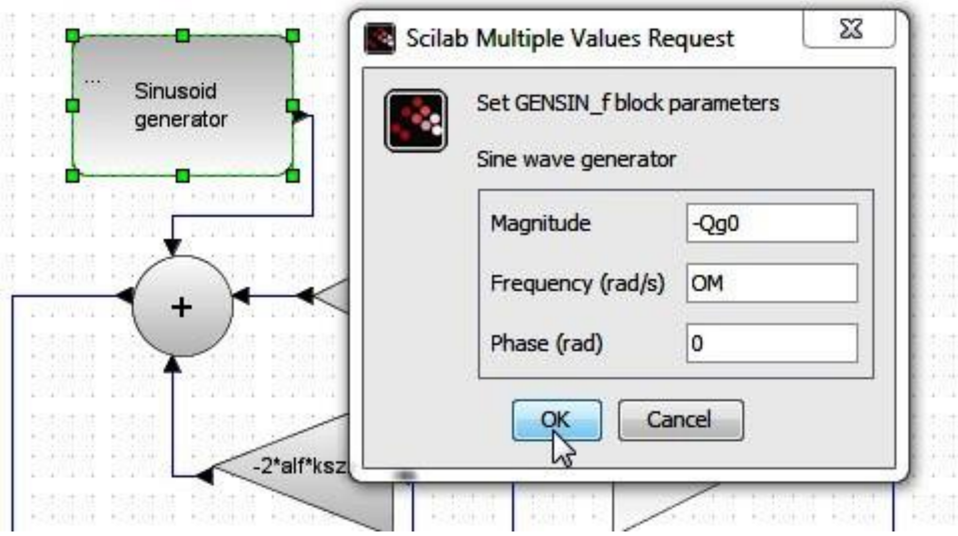


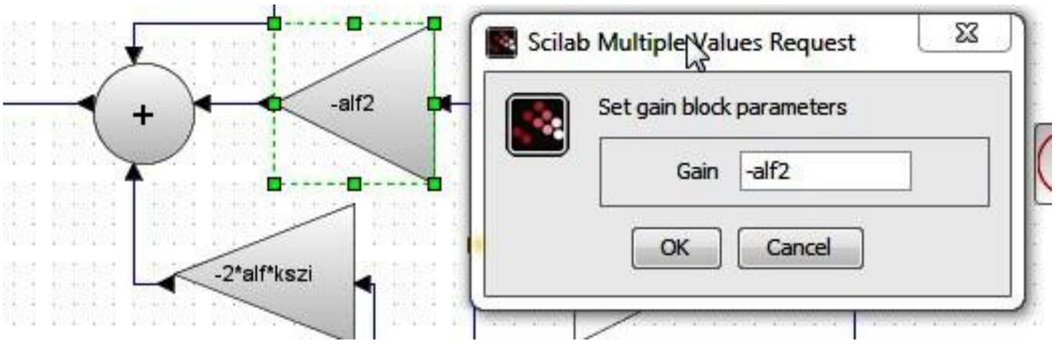

+
1
1
1
1

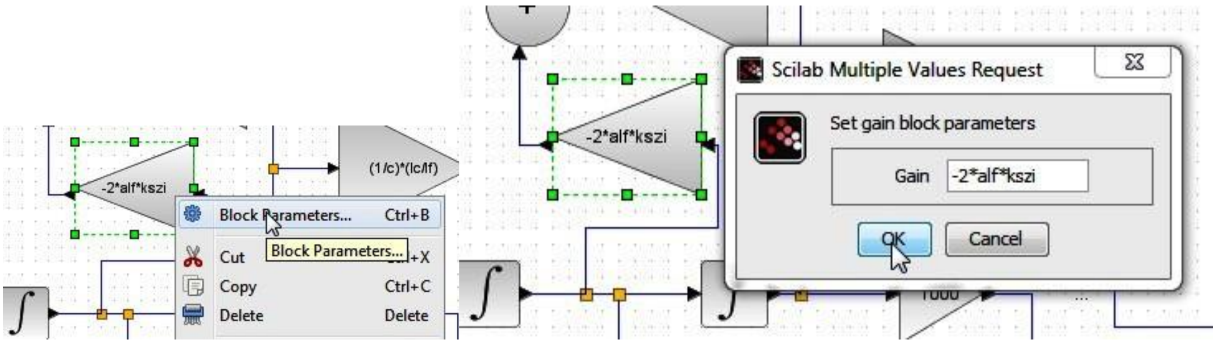

-alf2
+
-2*alf*kszi
(1/c)*(lc/lf)
1000

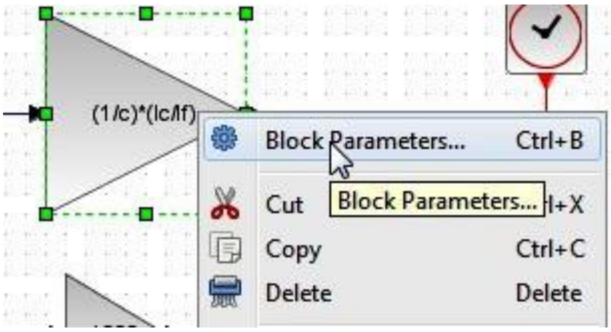

Palette browser - Xcos
Palettes
Commonly Used Blocks
Continuous time systems
Discontinuities
Discrete time systems
Lookup Tables
Event handling
Mathematical Operations
Matrix
Electrical
Integer
Port & Subsystem
Zero crossing detection
Signal Routing
Signal Processing
Implicit
Annotations
Sinks
Sources
Thermo-Hydraulics
Demonstrations Blocks
User-Defined Functions
CLKINV_f
CLOCK_c
CONST_m
CONST
CONST_f
Curve
CURV_f
Counter 0 → 2
Counter
FROMWSB
GENSIN_f
GENSQR_f
INIMPL_f
IN_f
Counter Modulo 3
Modulo_Count
RAMP
Random generator
RAND_m
READAU_f
Read from C binary file
READC_f
Read from input file
RFILE_f
SAWTOOTH_f
STEP_FUNCTION
PULSE_SC
SampleCLK
Signal Builder
Sigbuilder
TIME_f
TK Scale
TKSCALE

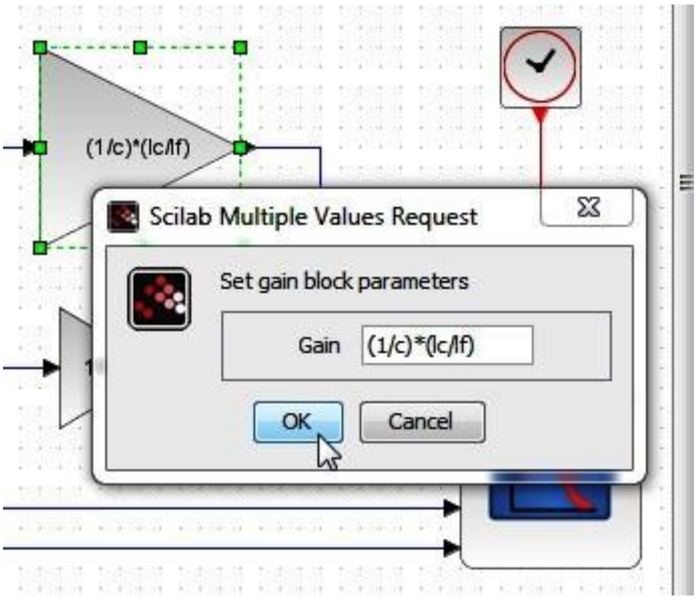

Sinusoid generator
Block Parameters...
Ctrl+B

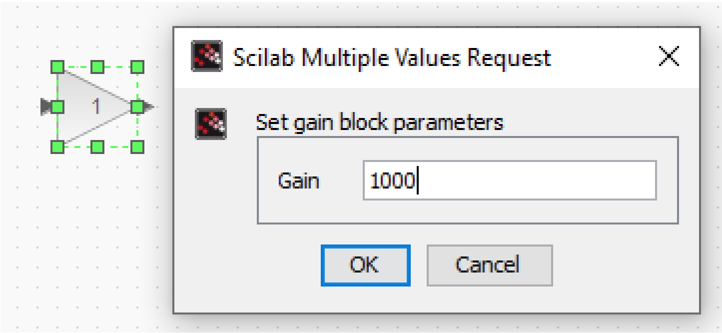

Sinusoid generator
Scilab Multiple Values Request
Set GENSIN_f block parameters
Sine wave generator
Magnitude
-Qg0
Frequency (rad/s)
OM
Phase (rad)
0
OK
Cancel
-2*alf*ksz

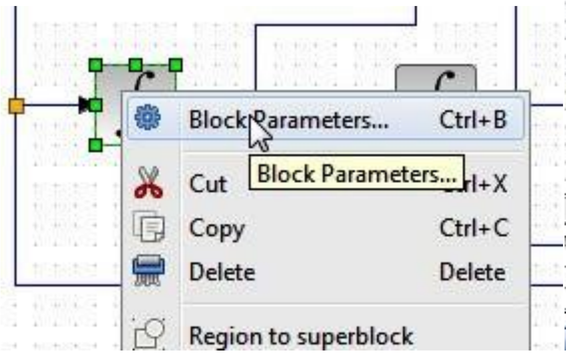

-alf2
-2*alf*kszi
Scilab Multiple Values Request
Set gain block parameters
Gain
-alf2
OK
Cancel

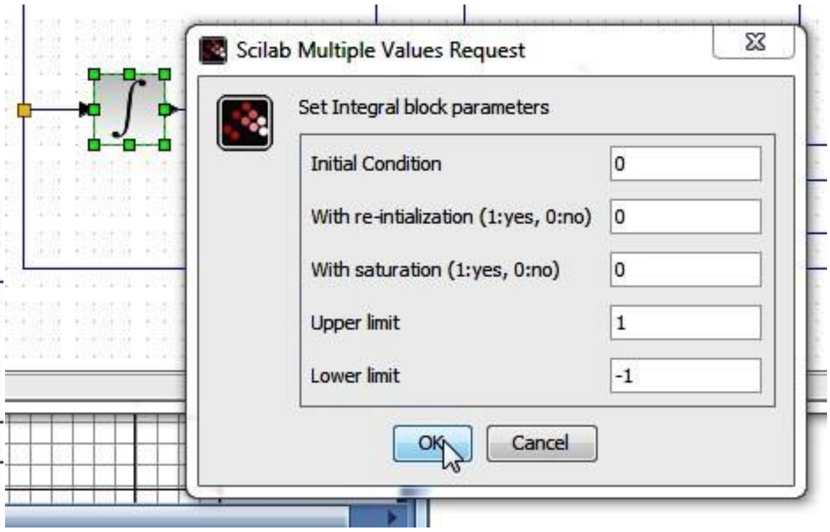

-2*alf*kszi
(1/c)*(lc/lf)
Block Parameters...
Ctrl+B
Cut
Copy
Ctrl+C
Delete
Delete
Block Parameters...
-2*alf*kszi
Scilab Multiple Values Request
Set gain block parameters
Gain
-2*alf*kszi
OK
Cancel

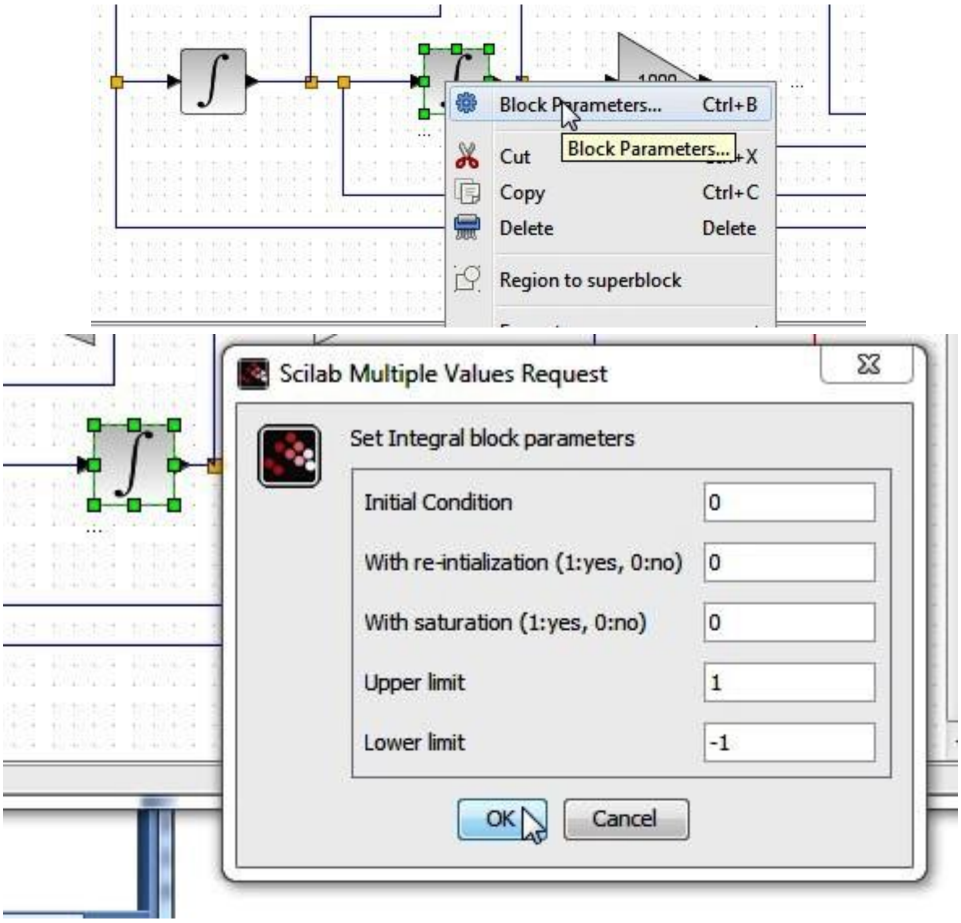

(1/c)*(lc/lf)
Block Parameters... Ctrl+B
Cut
Block Parameters...
Copy Ctrl+C
Delete Delete

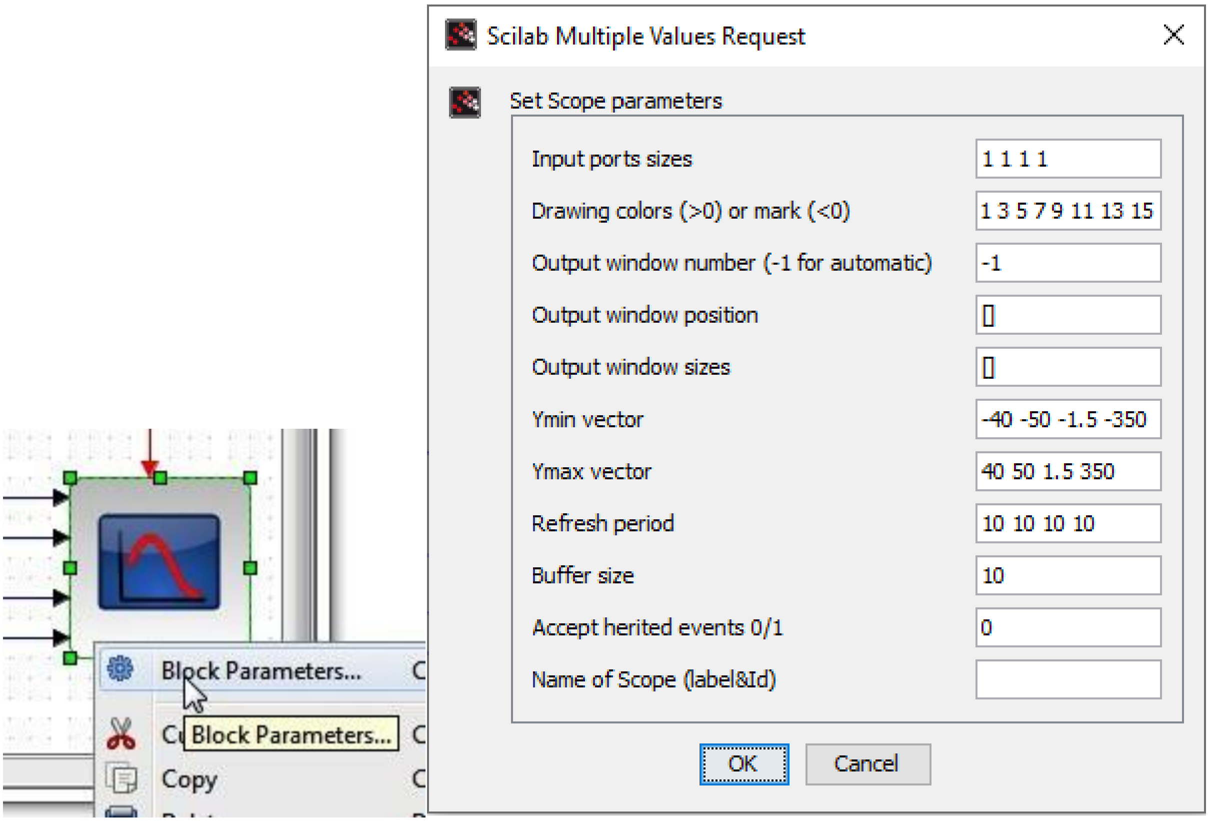

(1/c)*(lc/lf)
Scilab Multiple Values Request
Set gain block parameters
Gain
(1/c)*(lc/lf)
OK
Cancel

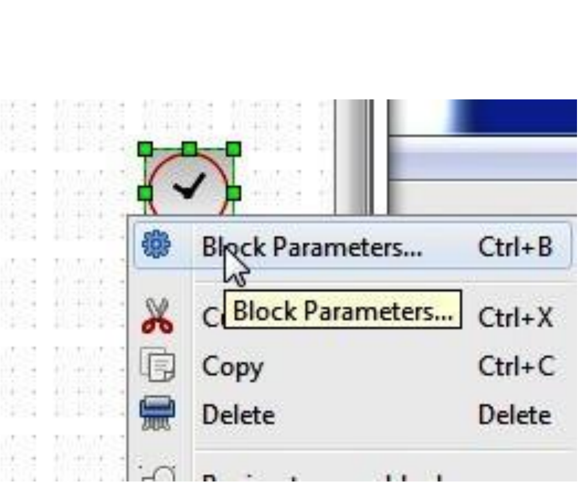

1
Scilab Multiple Values Request
Set gain block parameters
Gain
1000
OK
Cancel

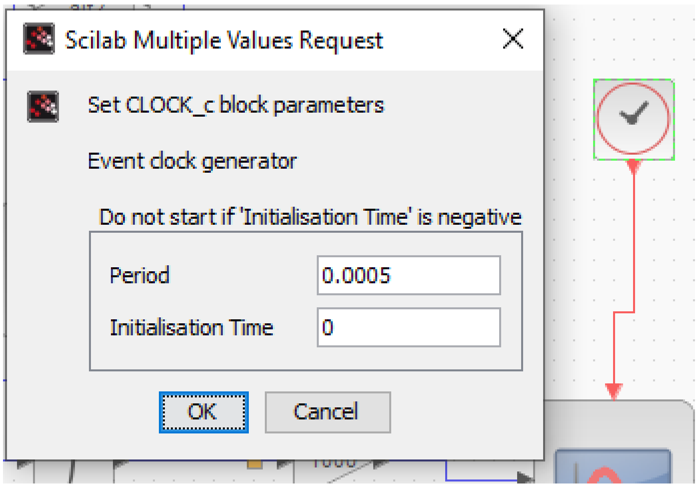

Block Parameters... Ctrl+B
Cut
Block Parameters...
Copy Ctrl+C
Delete Delete
Region to superblock


Scilab Multiple Values Request
Set Integral block parameters
Initial Condition
0
With re-intialization (1:yes, 0:no)
0
With saturation (1:yes, 0:no)
0
Upper limit
1
Lower limit
-1
OK
Cancel

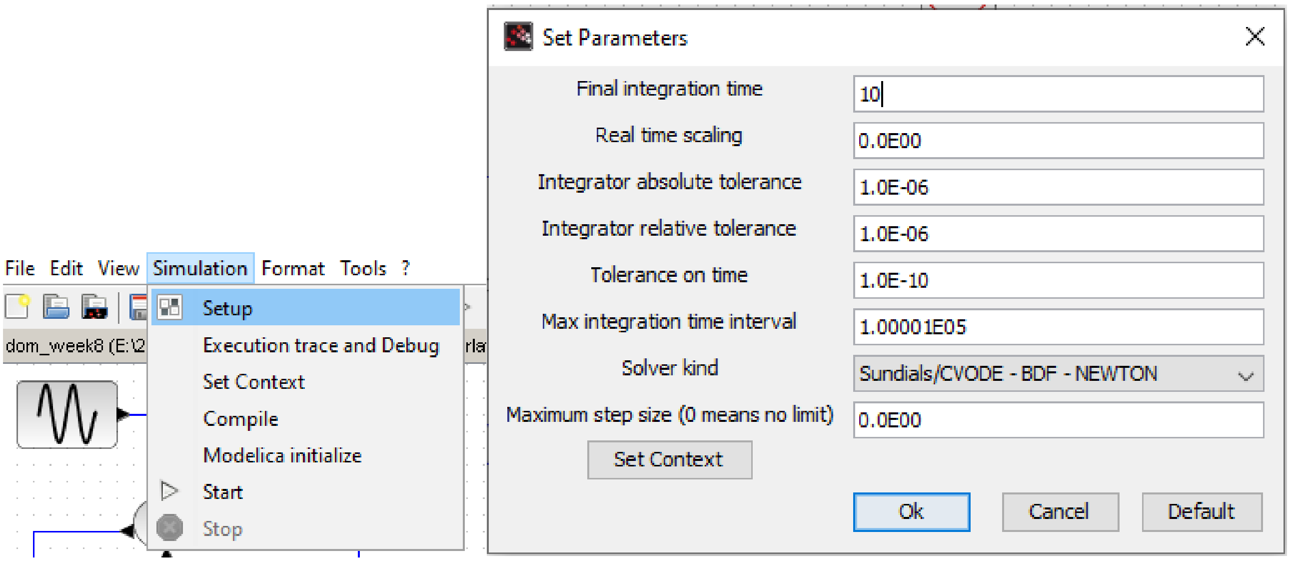

Block Parameters... Ctrl+B
Block Parameters...
Cut
Copy Ctrl+C
Delete Delete
Region to superblock
Scilab Multiple Values Request
Set Integral block parameters
Initial Condition 0
With re-intialization (1:yes, 0:no) 0
With saturation (1:yes, 0:no) 0
Upper limit 1
Lower limit -1
OK
Cancel

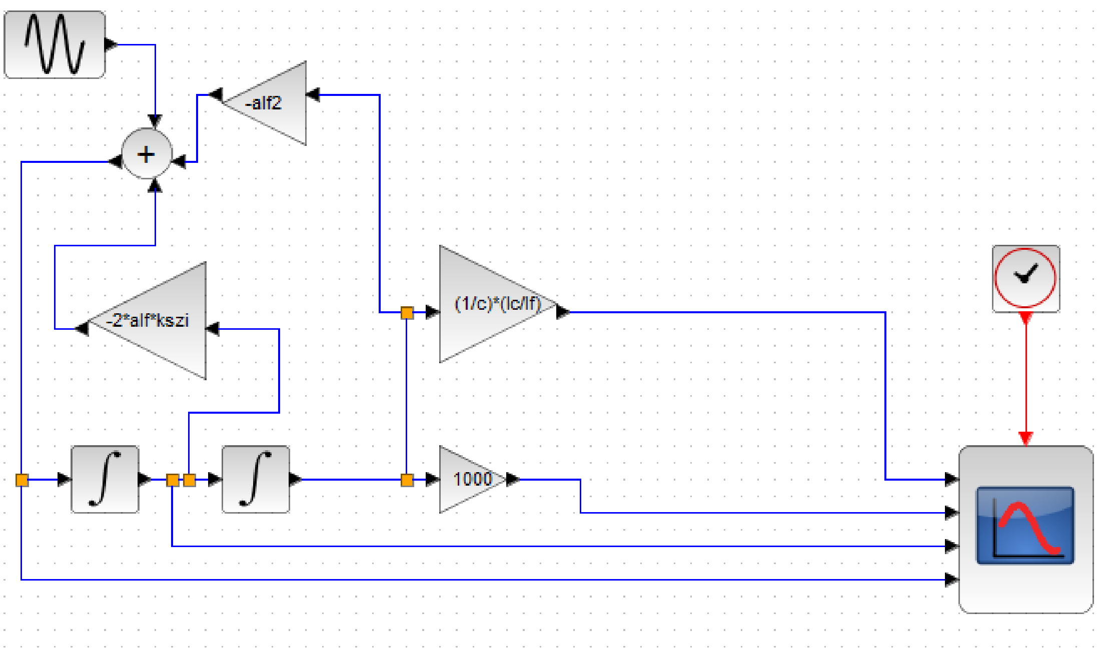

Scilab Multiple Values Request
Set Scope parameters
Input ports sizes 1 1 1 1
Drawing colors (>0) or mark (<0) 1 3 5 7 9 11 13 15
Output window number (-1 for automatic) -1
Output window position []
Output window sizes []
Ymin vector -40 -50 -1.5 -350
Ymax vector 40 50 1.5 350
Refresh period 10 10 10 10
Buffer size 10
Accept herited events 0/1 0
Name of Scope (label&Id)
OK
Cancel
Block Parameters...
Block Parameters...
Copy

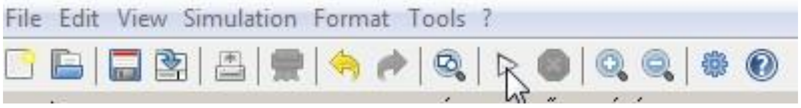




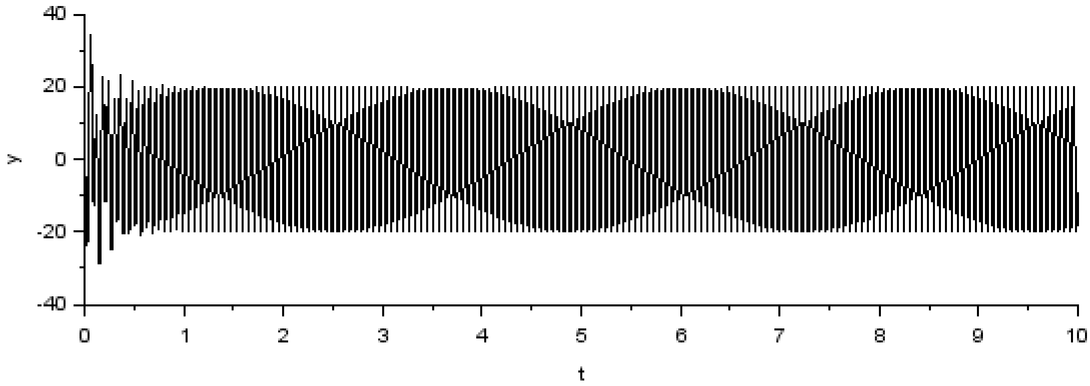
Final intergration time: 10s

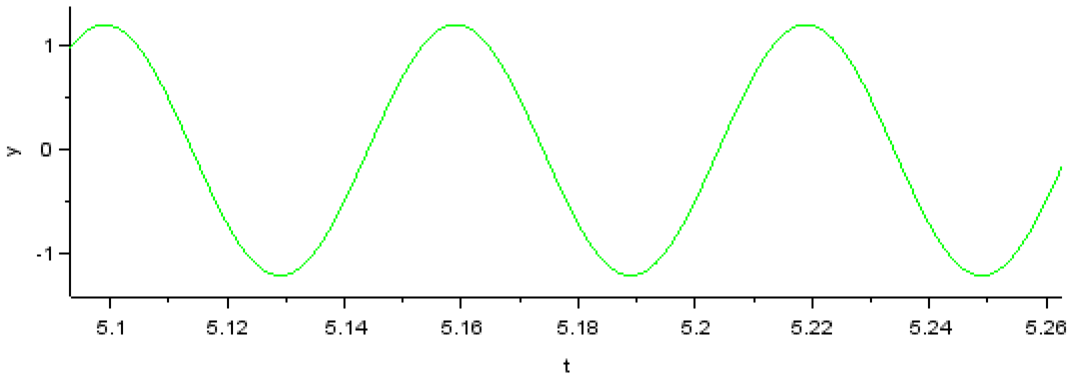


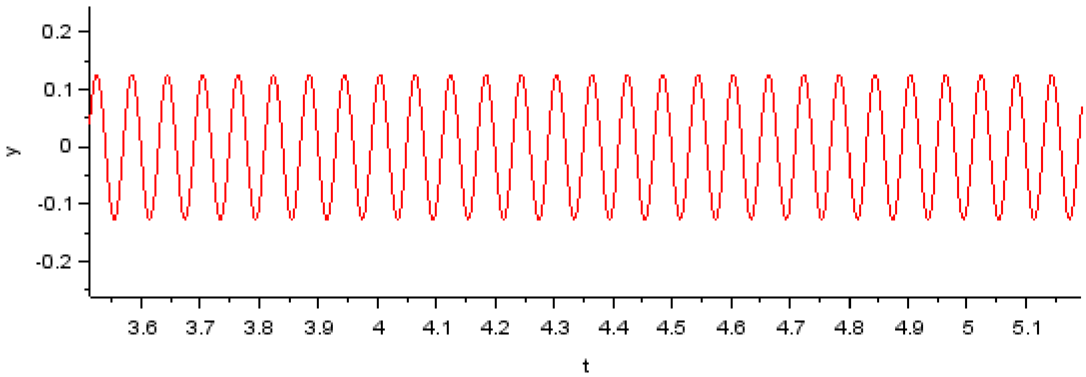


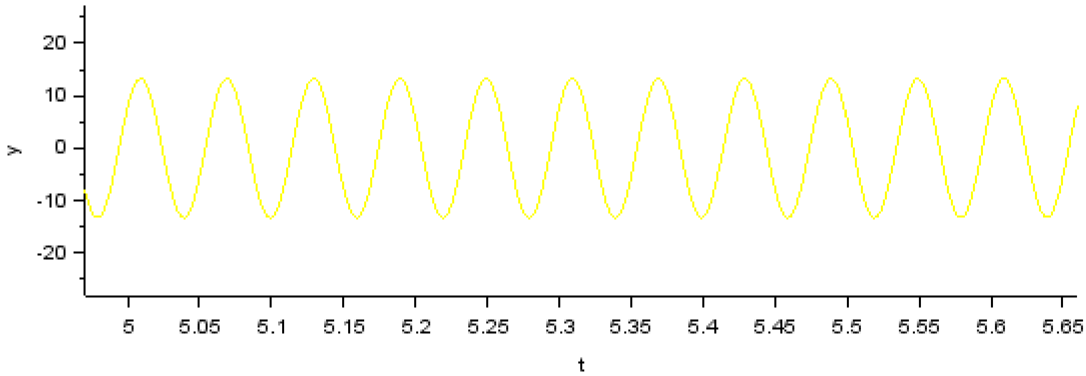


Omega=omega max; c= 0.000112









Omega=omega max; c=0.00281