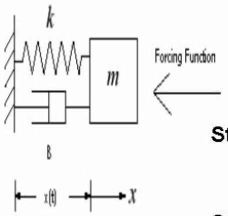
Modeling Spring/Mass System:



By Neil Warren and James Johnston

Step 1: Write Differential Equation -

$$m*d^2[x(t)]/dt^2 = k*x(t) + B*dx/dt + force(t)$$

Step 2: Define Initial Conditions - x(0) = 0 & d[x(0)]/dt = 0

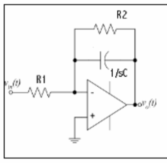
Step 3: Apply Laplace Transform $f^{(n)}(t) = s^{n}F(s) - s^{(n-1)}f(0) - s^{(n-2)}f'(0) - \ldots - f^{(n-1)}(0)$

Which yields: $s^2*m*X(s) = force(s) + B*s*X(s) + k*X(s)$

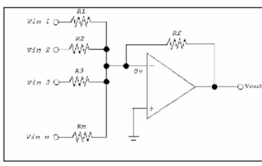
Step 4: Solve for Laplace Transform of Solution:

$$X(s) = (s^2*m)^{-1}*force(s) + B*(s*m)^{-1}*X(s) + k*(s^2*m)^{-1}*X(s)$$

Step 5: Identify Circuit Building Blocks:



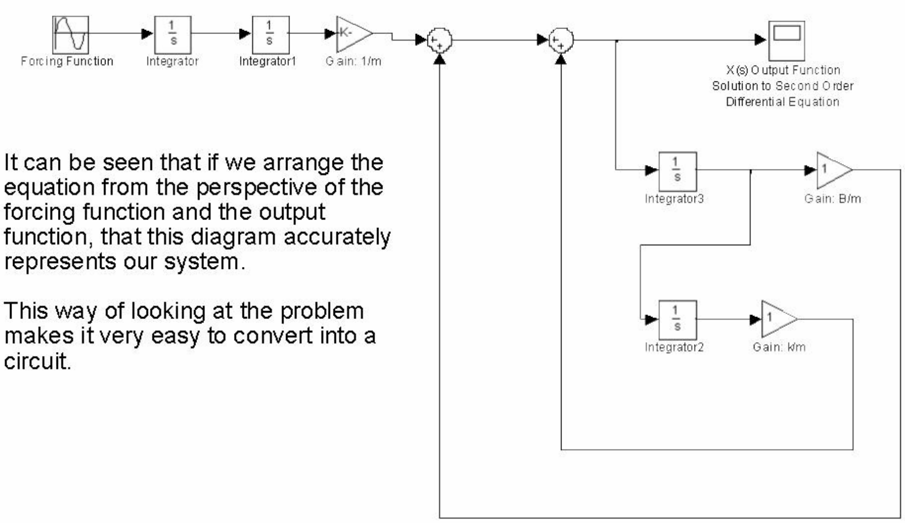
This circuit acts as our -1/s operator when appropriate R and C values added.



This circuit acts as both our addition and multiplication operator

Another Way Of Looking At The Problem:

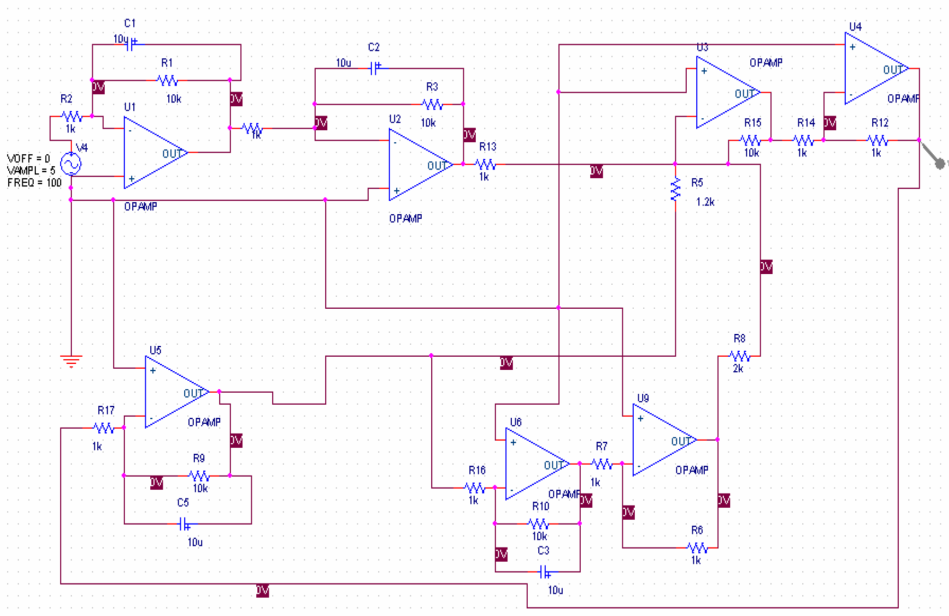
To further simplify the problem of modelling the equation using circuitry, we convert the equation into a system representation. This provides an intermediate step between the circuitry and the differential equation.



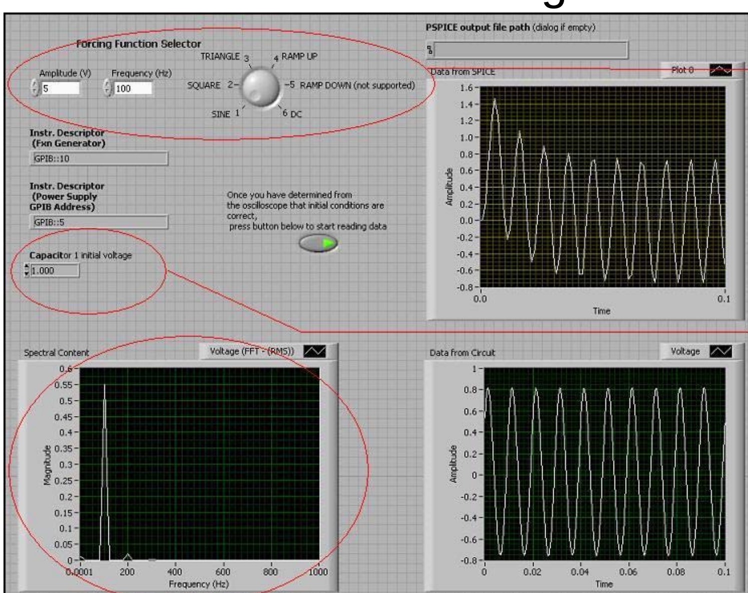
It can be seen that if we arrange the equation from the perspective of the forcing function and the output function, that this diagram accurately represents our system.

This way of looking at the problem makes it very easy to convert into a circuit.

Our Circuit



LabVIEW integration



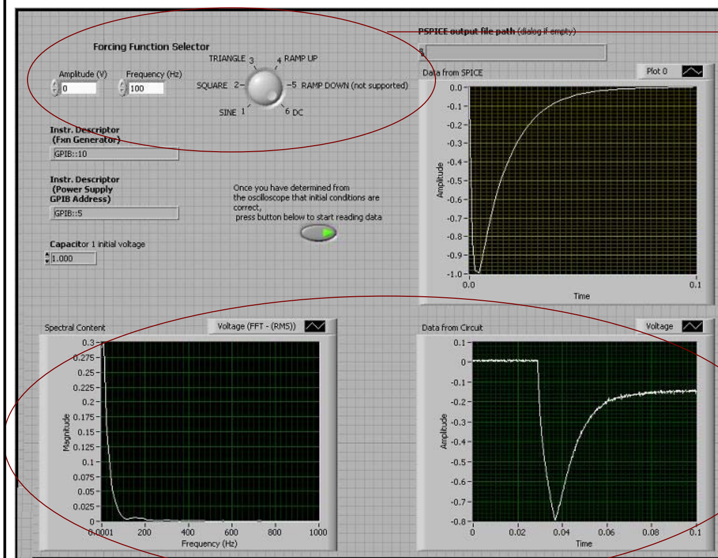
Forcing function type selector with user defined amplitude and frequency adjustments

Initial capacitor voltage simulates spring being pulled to an initial displacement

Frequnecy Analysis (Fourier Transform) of circuit output.

Response Without Forcing function

Models spring being pulled to an initial displacement in the absence of an external force.



Turned forcing function selector to DC and set amplitude to 0v.

In the absence of a forcing function spring simply moves back to neutral position. Spectral content is very low frequency due to non-oscillatory motion.