

Research Migration Project

<https://esim.fossee.in/research-migration-project>



The Research Migration Project is an initiative of FOSSEE, IIT Bombay that promotes the use of eSim for reproducing published research circuits originally implemented using proprietary simulation tools. The objective is to migrate these validated designs to eSim to build an open source resource database.

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Title of the circuit : Op-Amp based analog computer that solves second-order damped harmonic differential equations.

Theory/Description :

Theoretical background: A second-order linear differential equation representing a mechanical spring-mass-damper system with a forcing function is defined as:

$$a \frac{d^2 x(t)}{dt^2} + b \frac{dx(t)}{dt} + cx(t) = f(t)$$

By feeding the acceleration term into successive integrator circuits made of op-amps, the circuit continuously evaluates the velocity and position of the system in real time.

Key components: Op-Amps, Capacitor, Resistor

how the circuit functions:

The circuit initializes when an external excitation voltage representing the forcing function is applied to the input. The Op-Amps instantaneously compute the algebraic sum of the system forces at the summing node. As current flows through the feedback capacitors of the integrator stages, the circuit outputs a continuous, time-varying analog voltage.

Varying the resistor values changes the differential equation's coefficients (a,b,c) and alters its feedback loop dynamics. The resulting transient response cleanly displays on an oscilloscope or simulation plot, capturing how the system transitions and approaches equilibrium.

Reason to reproduce with eSim :

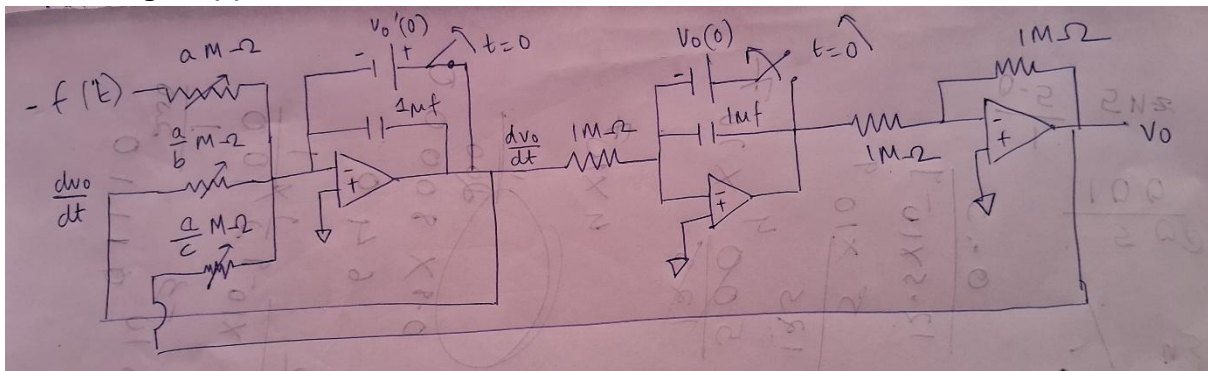
- **Educational value:** This circuit offers great educational value because second-order damped harmonic differential equations are standard equations that most engineering students are familiar with. Operational amplifiers are also very fundamental, so this circuit combines the two, merging two essential subjects into an application that is easy

to understand by a wide audience. Additionally, it gives a glimpse into how computing might have looked earlier in history, before digital systems became more robust.

- **Why suitable for eSim:** This circuit is suitable for eSim because it utilizes standard cells and relies entirely on the built-in transient analysis features. Since eSim provides all the necessary simulation tools out of the box, users can easily gain a basic understanding of the circuit without needing external plugins. Furthermore, because eSim is open-source, the entire project remains accessible and free for everyone to use

Expected Outcome/outputs : Measurable outputs are $dv(t)/dt$ and $v(t)$. The transient analysis of $v(t)$ directly reveals the graphical solution of the differential equation. To verify the correctness of the circuit, one can solve the differential equation independently using an external mathematical tool and then compare that theoretical plot with the transient analysis graph obtained from the simulation.

Circuit Diagram(s) :



Block Diagram (s)

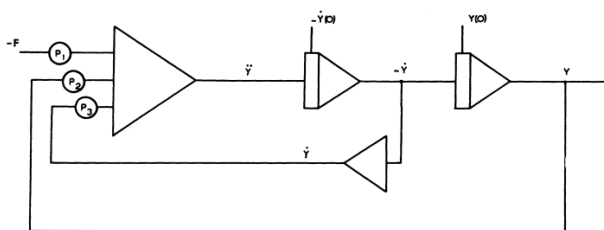
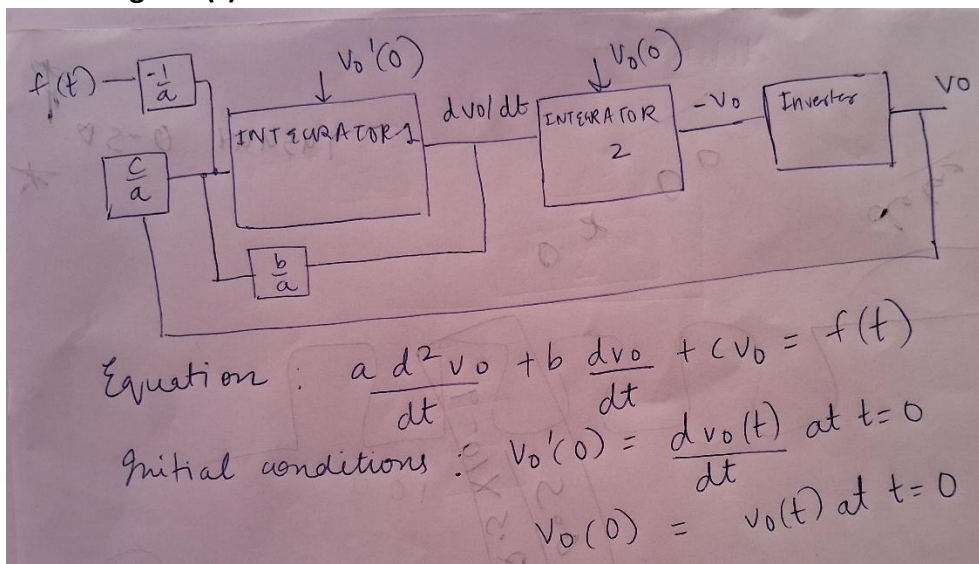


Fig. 2. Computer circuit for solving the equation $m\ddot{y} + n\dot{y} + ky = F$. Potentiometer settings: $P_1 = 1/m$; $P_2 = k/m$; $P_3 = n/m$.

Expected Results (Input, Output waveforms and/or Multimeter readings) : The transient analysis of the output voltage should yield the same graph as the solution of the differential equation

Research Paper/Journal/etc. :

Title : " A Study of the Applications of Analog Computers | IEEE Journals & Magazine "

Author : V.P. Kodali

Link : <https://share.google/QRrcpP2SYmCddJU7k>

Source/Reference(s) : Fundamentals of electric circuits by Sadiku and Alexander
