PROJECT REPORT

ON

ELECTRONIC ANALOG COMPUTER

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COURSE: EEE 208: Electronics Circuits II Laboratory

GROUP NO. 2, Level-3 Term-1

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OBJECTIVE

The electronic analog computer that we have designed using PSPICE uses op-amps as its fundamental building blocks. The circuit electrically solves and simulates the output of a second order differential equation of the form:

$$\boxed{\frac{d^2v}{dt^2} + K_1\frac{dv}{dt} + K_2v - K_3v_1(t) = 0}$$

where $v_1(t)$ is a given function of time, and K_1 and K_2 are real positive constants. This indicates it can solve **second order differential equations of all types**, including ones which require **separation of variables** to obtain solution.

The **initial conditions** $\frac{dv(0)}{dt}$ and $v\ (0)$ are also accounted for.

The linear integrated op-amp circuit designed is an **electrical analog to the differential equation model of an RLC circuit** which arises in numerous applications, particularly in control and communication systems such as resonant circuits, filters and oscillators.

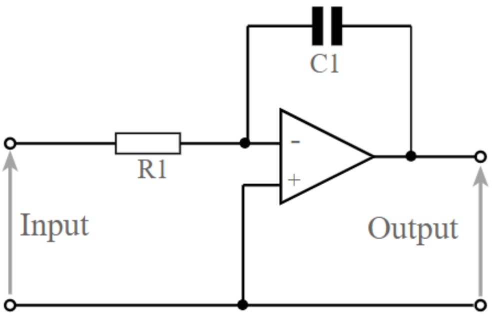
The circuit employs integrator circuits instead of differentiator circuits to obtain for **stability** in the output waveform.

EQUIPMENTS NEEDED

1. uA741 op-amps
2. DC power source
3. AC power source with sinusoidal waveform
4. Switches
5. Resistors
6. Capacitors
7. Connecting wires

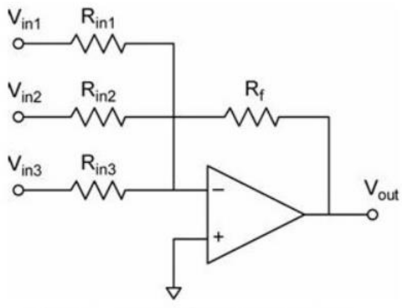
Calculation

Inverting integrator:



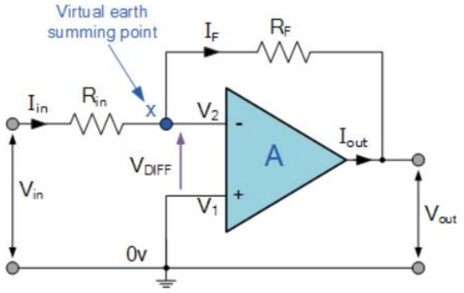
$$V_{out} = -\int_0^t \frac{V_{in}}{RC}\,dt + c$$

Inverting adder:



$$V_{out} = -\left(\frac{R_f}{R_{in1}}V_{in1} + \frac{R_f}{R_{in2}}V_{in2} + \frac{R_f}{R_{in3}}V_{in3}\right)$$

Inverter:



$$V_{out} = -\frac{R_f}{R_{in}}V_{in}$$

CIRCUIT DESIGN: SCHEMATIC

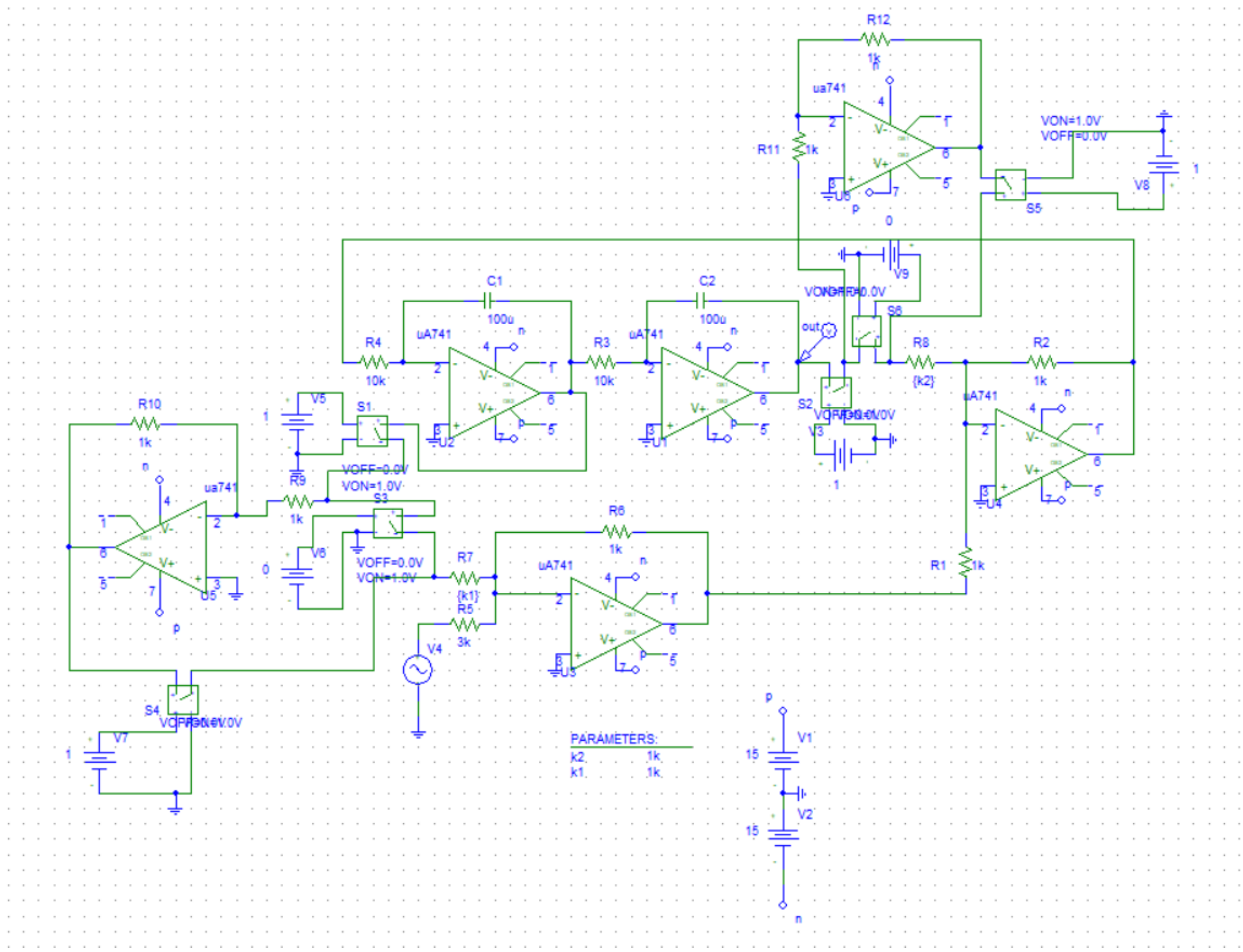


Fig.1 Schematic of the analog computer.

PROCEDURE

Input:

1.User calculates ratio $1k/K_1$ and inserts it in parameter k1 and ratio $1k/K_2$ and inserts it in parameter k2. In case of K_1 and/or K_2 equals zero, any arbitrary value can be used.
2. User adjusts initial conditions of capacitors with IC of C1= $\frac{dv(0)}{dt}$ and IC of C2= $-v(0)$.
3. User adjusts the switch settings as required. The settings are summarized below.

Table of summary of settings required for the various cases:

K1				K2			
	0	**positive**	**negative**		**0**	**positive**	**negative**
S1	open	close	close	**S2**	open	close	close
V5	0	1	1	**V3**	0	1	1
S3	-	close	open	**S5**	-	open	close
V6	-	1	0	**V8**	-	0	1
S4	-	open	close	**S6**	-	close	open
V7	-	0	1	**V9**	-	1	0

Block diagram:

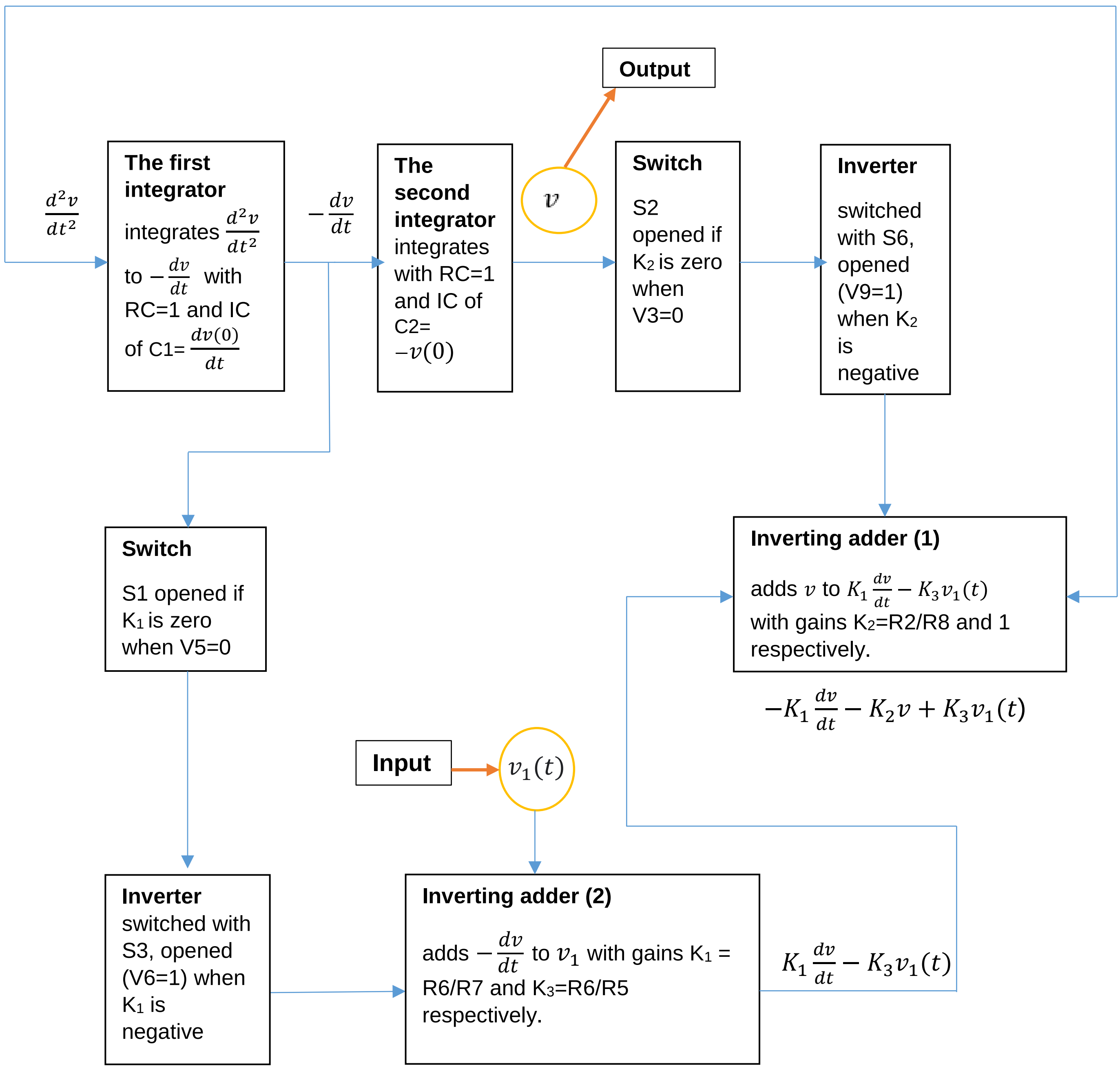


Fig.2 Block diagram explaining the circuit design.

Simulation Results

We simulate various cases solving different forms of a second order differential equation.

Case 1

K_1=positive,K_2=positive, Dy(0)=1, y(0)=2

$$\frac{d^2v}{dt^2} + 3\frac{dv}{dt} + 4v - \sin(2x) = 0$$

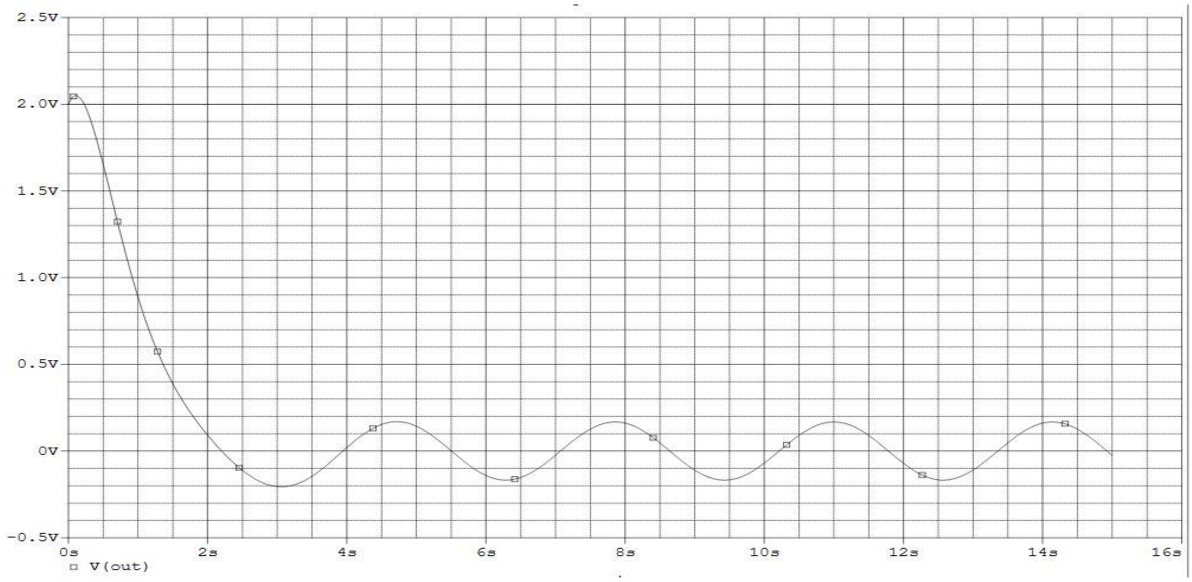


Fig.3a Pspice solution of case 2, output voltage v against time

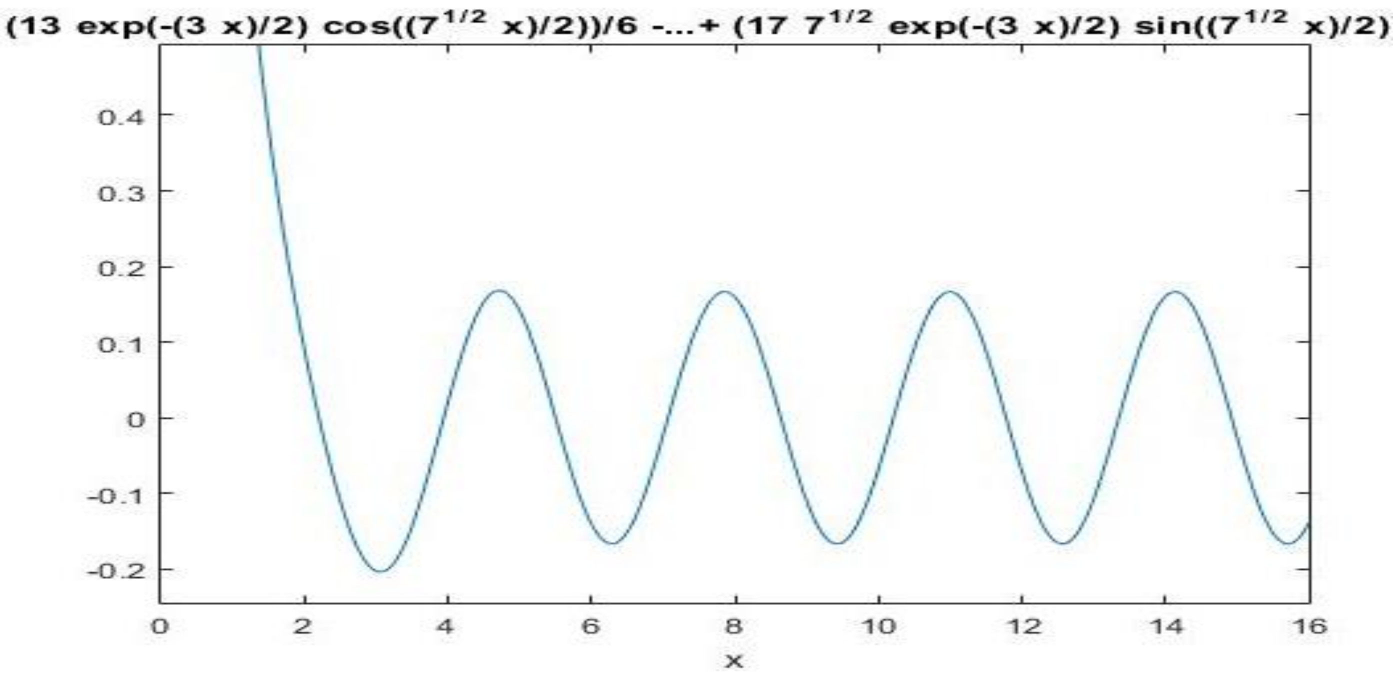


Fig.3b MATLAB solution of case 2, output voltage v against time

Case 2

K_1=positive, K_2=negative, Dy(0)=0, y(0)=0

$$\frac{d^2v}{dt^2} + \frac{dv}{dt} - v - \sin(2x) = 0$$

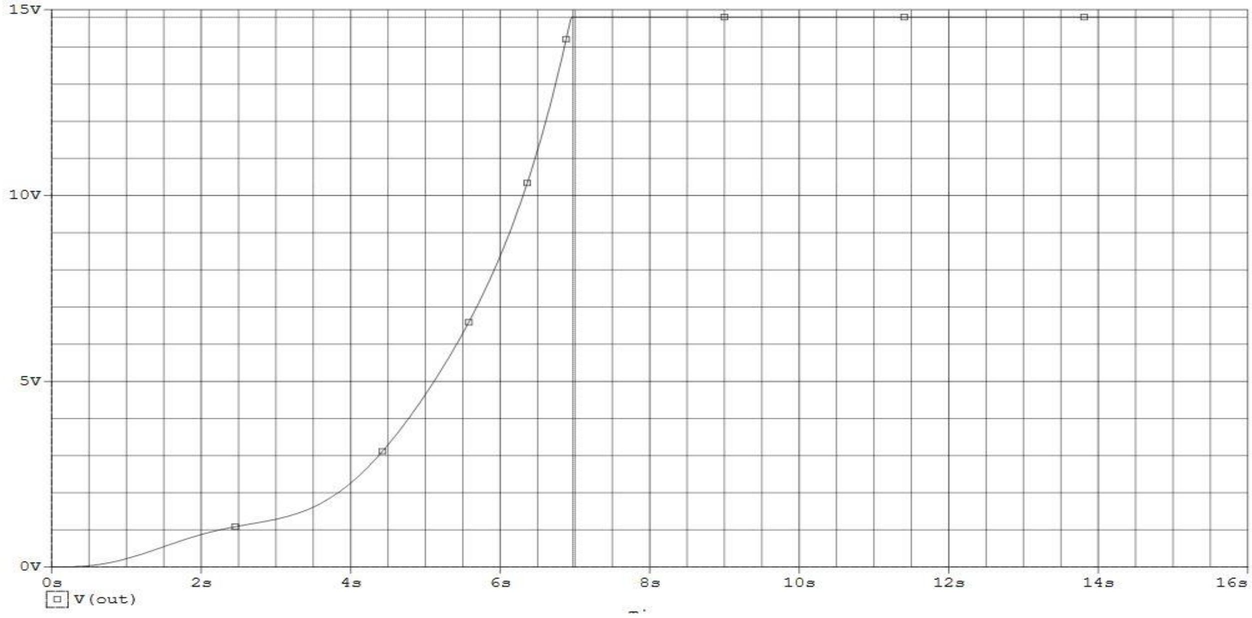


Fig.4a Pspice solution of case 7, output voltage v against time

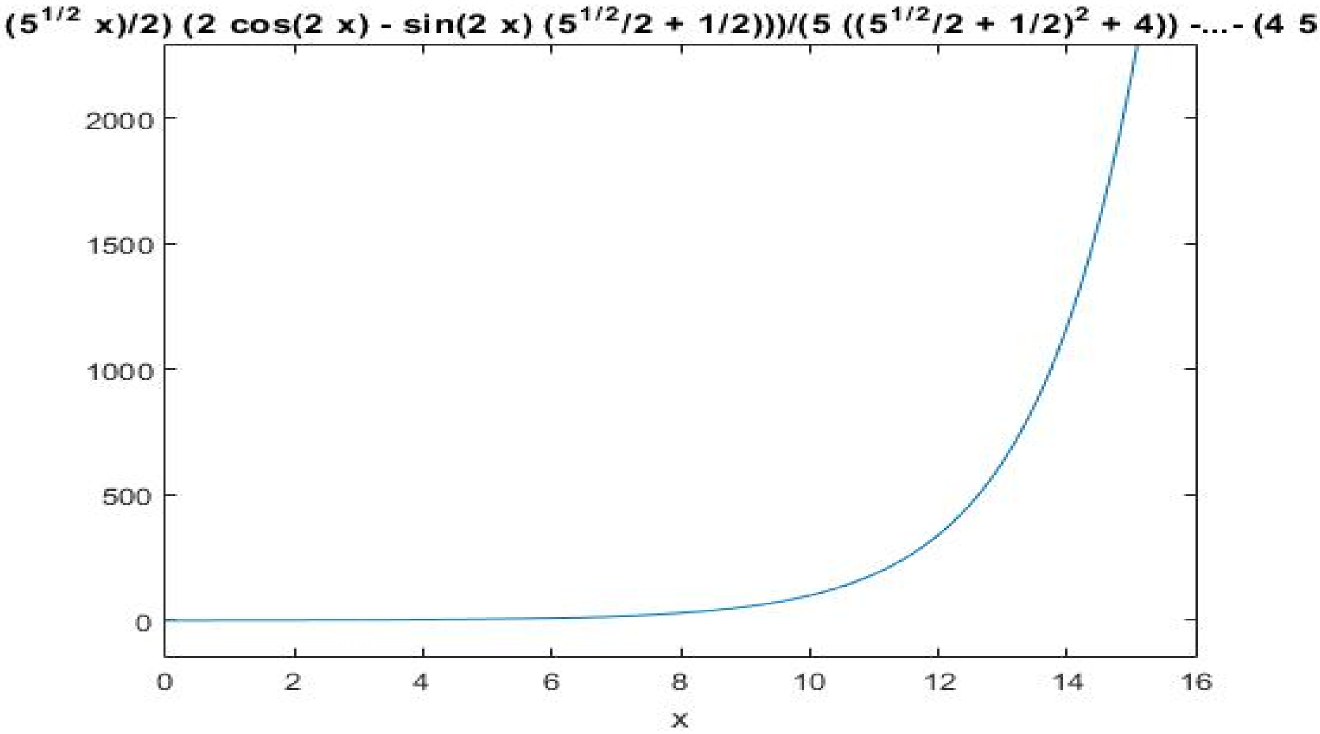


Fig.4b MATLAB solution of case 7, output voltage v against time

Case 3

$K_1=0, K_2=0, Dy(0)=0, y(0)=0$

$$\frac{d^2v}{dt^2} - \sin(2x) = 0$$

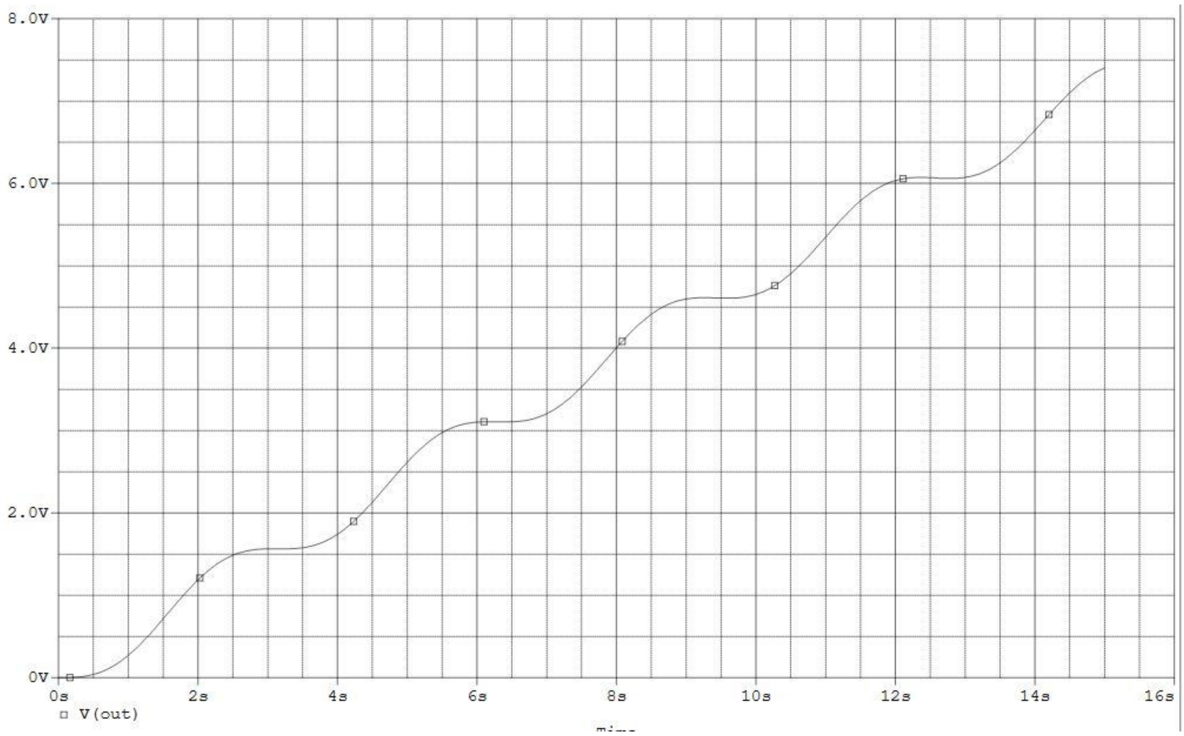


Fig.5a Pspice solution of case 5, output voltage v against time

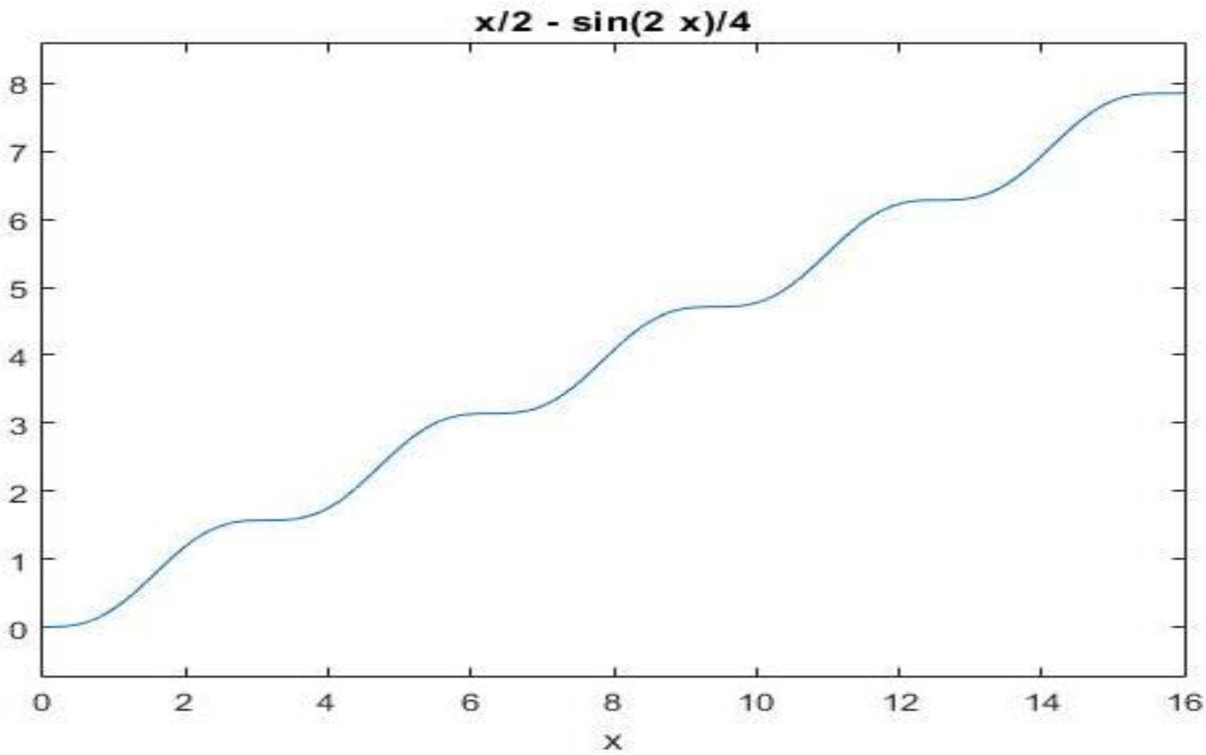


Fig.5b MATLAB solution of case 5, output voltage v against time

Case 4

K_1=negative, K_2=negative, Dy(0)=0, y(0)=0

$$\frac{d^2v}{dt^2} - \frac{dv}{dt} - v - \sin(2x) = 0$$

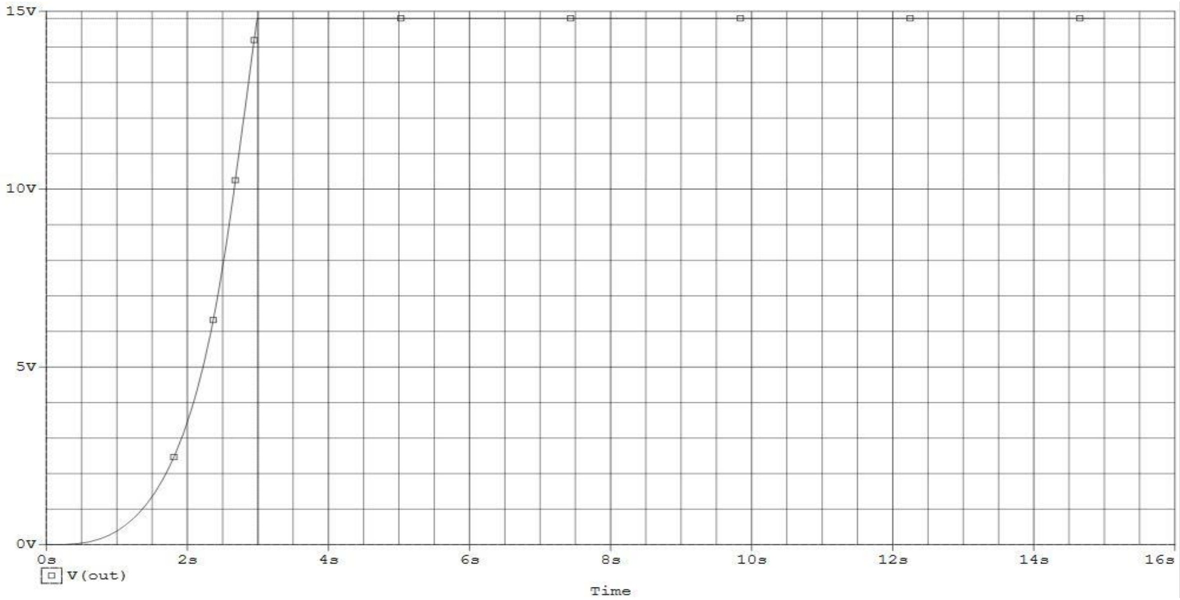


Fig.6a Pspice solution of case 8, output voltage v against time

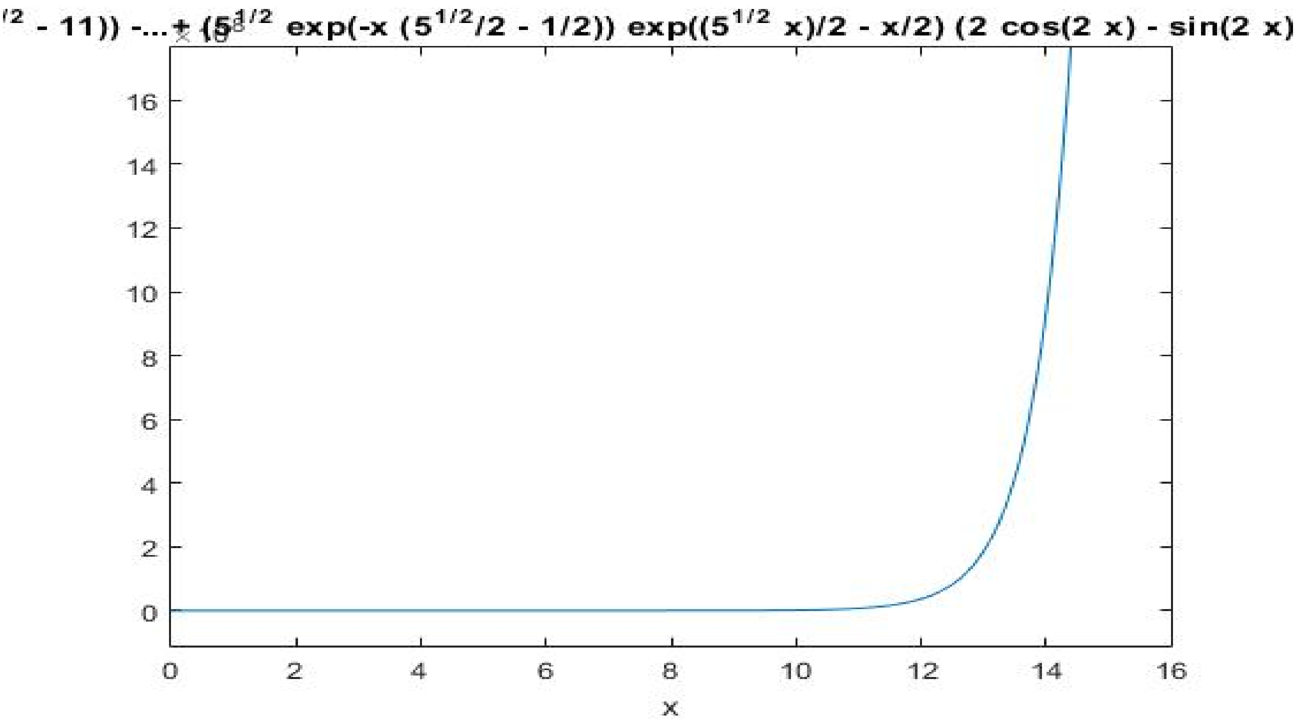


Fig.6b MATLAB solution of case 8, output voltage v against time

CONCLUSION

The results above show that our design for electronic analog computer has successfully solved a second order differential equation as verified by the more accurate MATLAB results. The small discrepancies between the two arises in values of voltage due to slew rate. In this project we have used uA741 op-amp which has the maximum slew rate of 0.5V/us. This means that the output voltage can change a maximum of 1/2V in 1us. The slowest slew rate occurs at unity gain. In this project we have used several unity gain uA741 op amp that is why output frequency is slight less than that of MATLAB.

In order to avoid distortion due to transient response of capacitors, time of charging of capacitors was kept less than time period of the input signal used.

The solution can also be obtained with a computer which contains differentiators instead of integrators. However, integrators are almost invariably preferred over differentiators in analog computer applications, for the following reasons: since the gain of an integrator decreases with frequency whereas the gain of a differentiator increases nominally linearly with frequency, it is easier to stabilize the former than the latter with respect to spurious oscillations. As a result of its limited bandwidth, an integrator is less sensitive to noise voltages than a differentiator. Further, if the input waveform changes rapidly, the amplifier of a differentiator may overload. Finally, as a matter of practice, it is convenient to introduce initial conditions in an integrator.

The biggest drawback in this design however, is that very high frequency signals cannot be used as input signal as they result in high gains due to which the output signals often get clipped off. Furthermore, if the output voltage is such that it increases with time, it will get clipped off at the saturation voltages too (as shown by cases 6-8 in our report).

When it comes to switches, voltage-controlled switches are used instead of time dependant transient switches as a specific differential equation is modelled by a specific circuit model which does not vary with time. Hence, the voltage controlled switches help increase convenience. Two additional switches S5 and S4 are used to avoid voltage drops across the inverters due to bias currents when S6 and S3 are shorted respectively.

Overall, op-amps are fundamental components for designing analog computers and more often provide an accurate solution for real life input signals, which are then observed in indicators like cathode-ray tube (with a triggered sweep) or a recorder or, for qualitative analysis with slowly varying quantities, a high-impedance voltmeter, etc.