SIGNAL
AND
SYSTEMS

LINEAR
OR
NON-LINEAR SYSTEMS

Date *- 16th August 2019*

Name *- Shivam Malviya*

Roll no. *- 18EC01044*

THEORY

A signal is a function that conveys information about a phenomenon (or) A signal is an electrical or electromagnetic current that is used for carrying data from one device or network to another.

A signal may also be defined as an observable change in a quantity.

In ECE, it refers to any time varying voltage, current.

What is a system?

A system is something which performs some mathematical operations on Input signals to convert to the output signal. An output signal is always produced from a system for a set of given known inputs.

So, the systems are classified into four sub-categories: -

- ➢ *MIMO SYSTEMS (multiple input and multiple output).*
- ➢ *SISO SYSTEMS (single input and single output).*
- ➢ *MISO SYSTEMS (multiple inputs and single output).*
- ➢ *SIMO SYSTEMS (single input and multiple output).*

Most of them are based on the operation of filtering of a signal.

Filtering is the operation of retaining the desired sources and removing the unwanted sources.

Systems can be classified into many categories.

But, for this experiment we have considered only one of them.

That systems is :

Linear and Nonlinear.

Discussion

LINEAR AND NONLINEAR SYSTEMS

A linear system follows the laws of superposition. This law is necessary and sufficient condition to prove the linearity of the system. Apart from this, the system is a combination of two types of laws −

- *Law of additivity*
- *Law of homogeneity*

y(t) = a1y1(t) + a2y2(t) = T[a1x1(t) + a2x2(t)].

There are some other conditions to check whether the system is linear or not.

The conditions are :

- *Zero input – zero output property must satisfy. This property is necessary for a system to be linear, but not a sufficient property for a system to be linear.*
- *There should not be any non-linear operator present in the system.*
- *There is again a special case: Incrementally linear system.*

If any system that doesn’t agree with the superposition principle. Then, it is a nonlinear system.

Examples of non-linear operators are: -

(a) ***Trigonometric operators -*** *Sin, Cos, Tan, Cot, Sec, Cosec etc.*

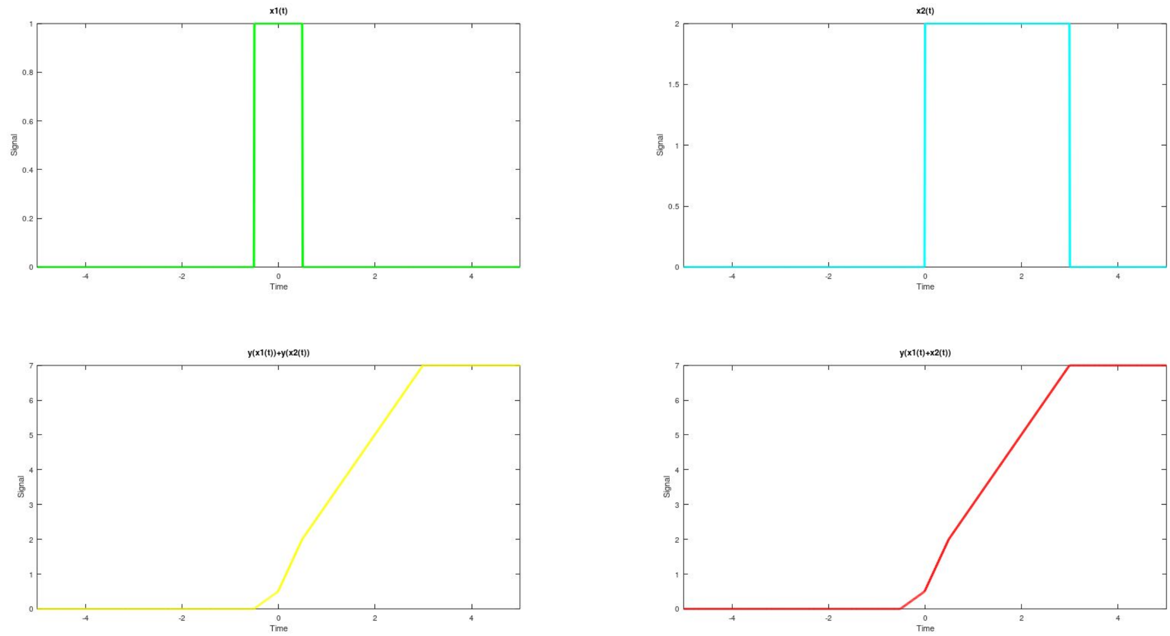
(b) Exponential, logarithmic, modulus, square, Cube etc.

(c) Saw (I /p), Sqn (I /p) etc.

RESULTS

1.

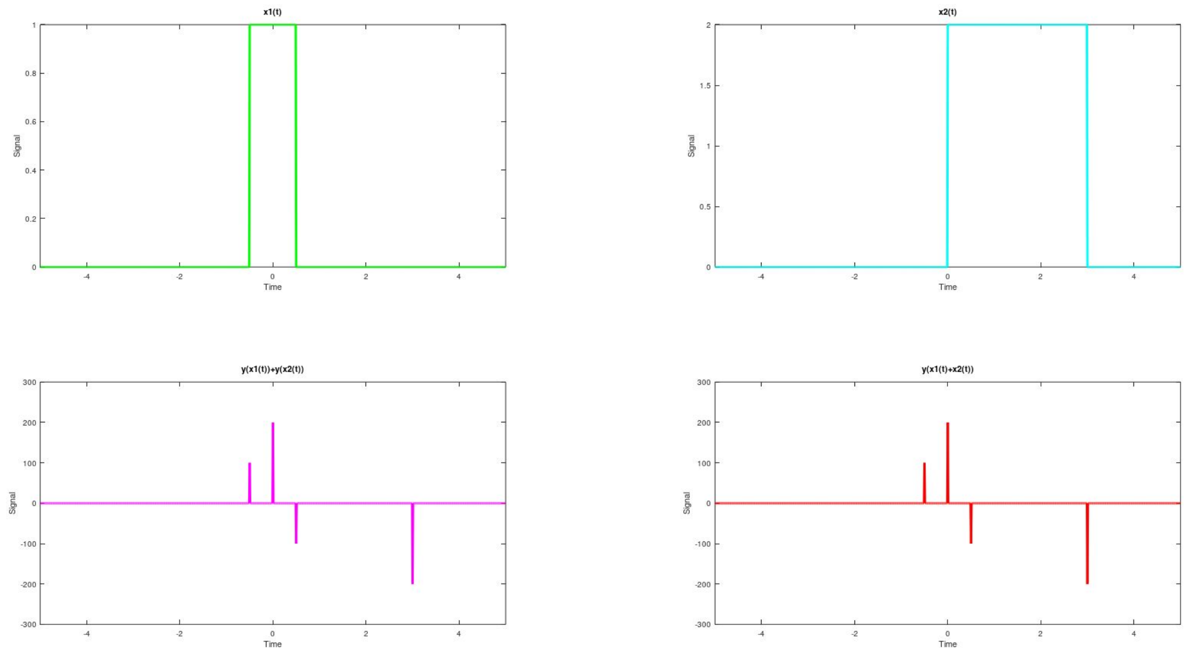
$$y(t) = \int_{-\infty}^{t} x(t)$$



The given system is Linear.

2.

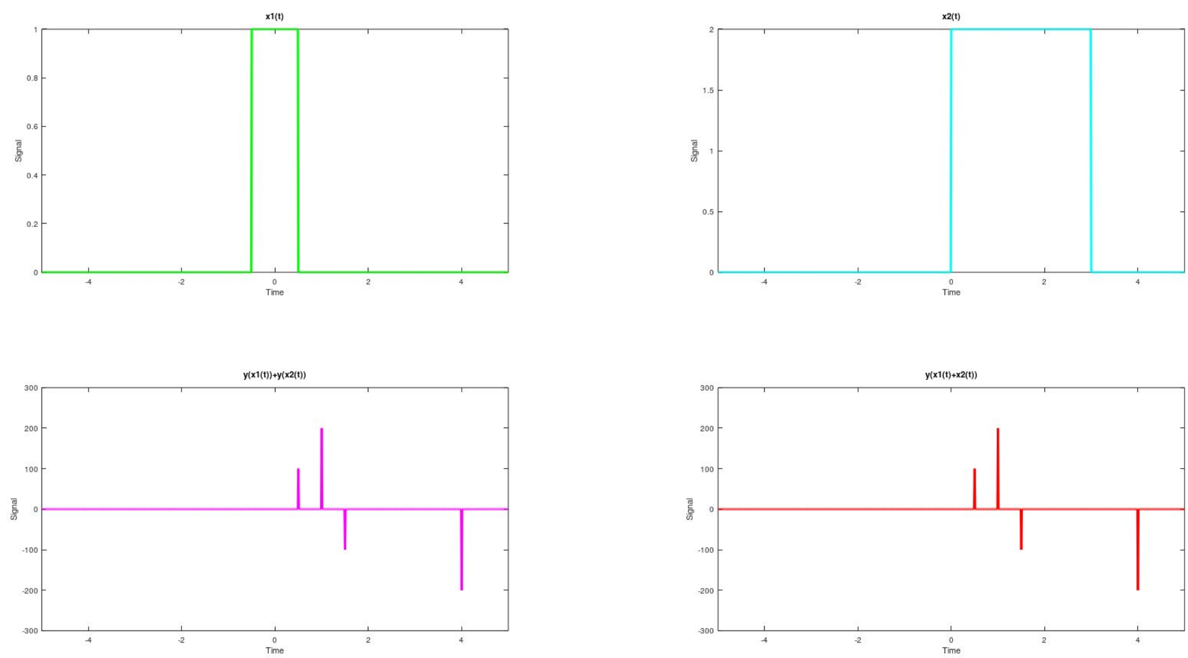
$$y(t) = \frac{\mathrm{d}}{\mathrm{d}t}(x(t))$$



The given system is Linear.

3.

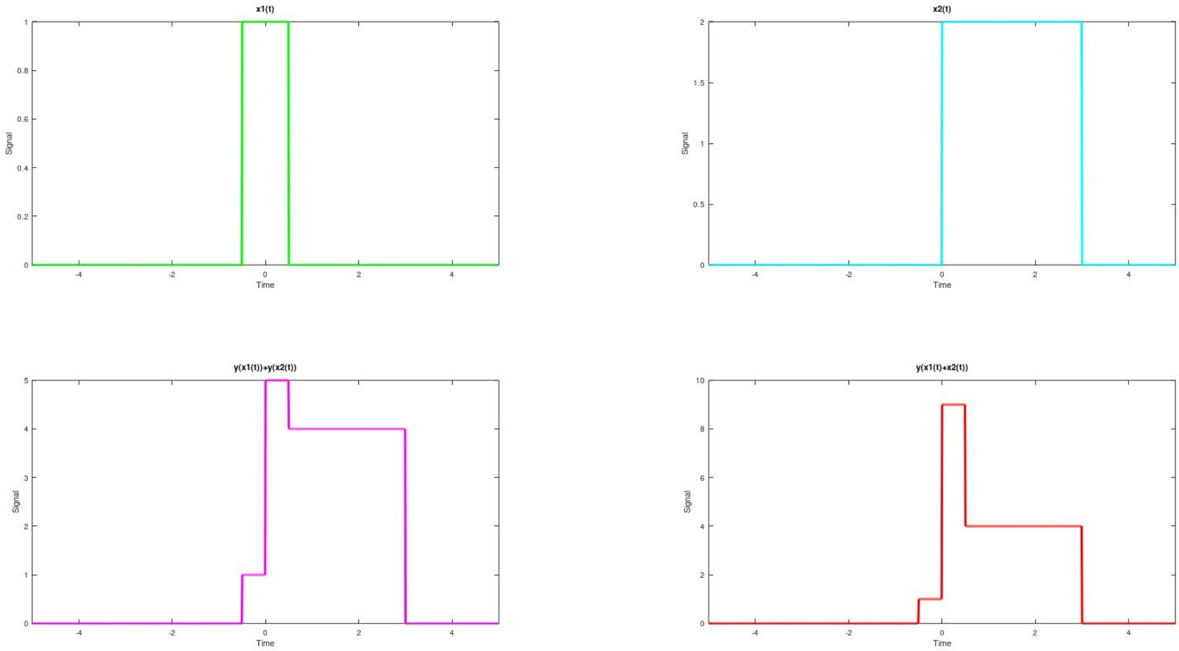
$$y(t) = \frac{d}{dx}(x(t-1))$$



The given system is Linear.

4.

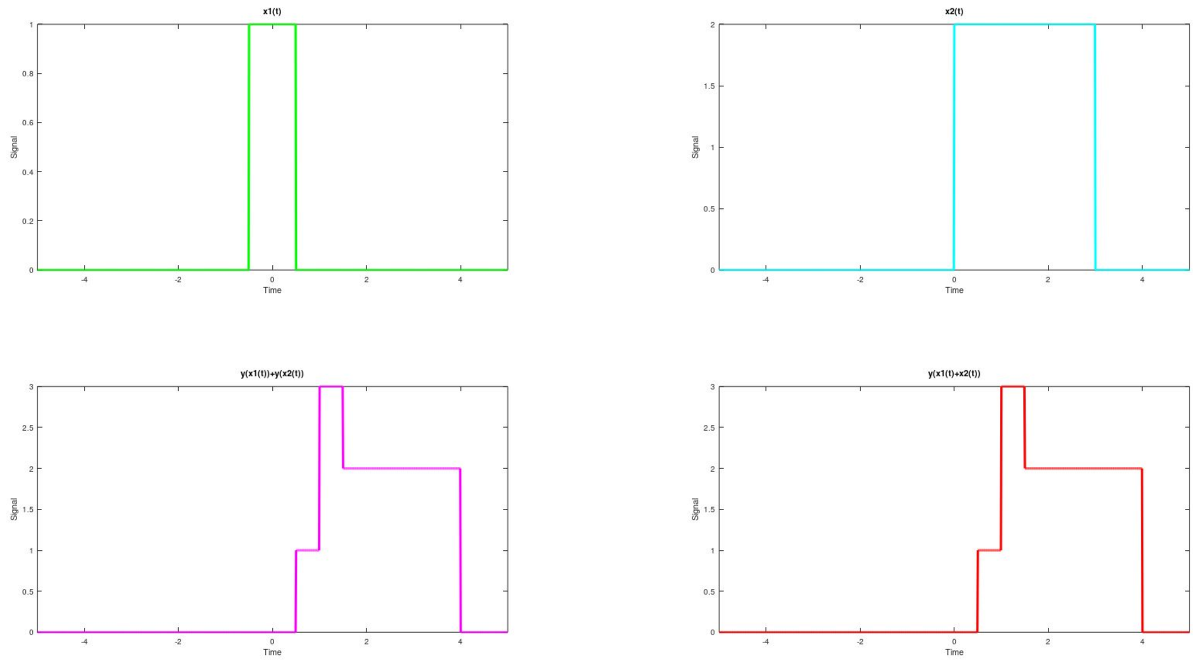
$$y(t) = x(t)^2$$



The given system is Nonlinear.

5.

$$y(t) = x(t-1)$$



The given system is Linear.

CONCLUSION

Linear system

- *They strictly follows the Superposition and Homogeneous principle.*
- *Linear control system have one operating point at a time.*
- *Output can change its magnitude but its baseline form never changes with respect to input. A sinusoidal input will always give a sinusoidal output.*
- *Stability of these systems do not depend upon on initial conditions.*

Nonlinear system

- *They don't follow superposition and homogeneous theorem, at a time.*
- *They have multiple operating points with indefinite response.*
- *Output change all its parameter from magnitude to phase and frequency. Input form are no where realizable.*
- *Stability depends upon both real time output and the input.*
- *They can be analyzed as piecewise linear.*

APPENDIX

1. x1

```
function y = x1(t)

    y = heaviside(t+0.5, 1) - heaviside(t-0.5, 1);
```

2. x2

```
function y = x2(t)

    y = 2*(heaviside(t, 1) - heaviside(t-3, 1));
```

3. Function 1

```
function y = fun1(f, t)

    n = length(t);
    y = zeros(1, n);
    d = t(2) - t(1);

    for i = 2:n
```

```
  y(i) = y(i-1) + f(t(i))*d;
end
```

4. Function 2

```
function y = fun2(f, t)

    n = length(t);
    y = zeros(1, n);
    d = t(2) - t(1);

    y(1) = (f(t(2)) - f(t(1)))/d;
    for i = 2:n
      y(i) = (f(t(i)) - f(t(i-1)))/d;
    end
```

5. Function 3

```
function y = fun3(f, t)

    f = @(t) f(t-1);
    y = fun2(f, t);
```

6. Function 4

```
function y = fun4(f, t)

    y = (f(t)).^2;
```

7. Function 5

```
function y = fun5(f, t)

    f = @(x) f(x-1);
    y = f(t);
```

8. Check

```
function check(fun, tmin, tmax)

    tol = 0.001;
    t = tmin:0.01:tmax;
    xran = [tmin tmax];

    f = @(t) (x1(t));
```

```
f1 = fun(f, t);

f = @(t) (x2(t));
f2 = fun(f, t);

f = @(t) (x1(t) + x2(t));
f3 = fun(f, t);

subplot(2, 2, 1)
plot(t, x1(t), '-g', 'LineWidth', 3);
xlabel('Time');
ylabel('Signal');
title('x1(t)');
xlim(xran);

subplot(2, 2, 2)
plot(t, x2(t), '-c', 'LineWidth', 3);
xlabel('Time');
ylabel('Signal');
title('x2(t)');
xlim(xran);
```

```
subplot(2, 2, 3)
plot(t, f1+f2, '-m', 'LineWidth', 3);
xlabel('Time');
ylabel('Signal');
title('y(x1(t))+y(x2(t))');
xlim(xran);

subplot(2, 2, 4)
plot(t, f3, '-r', 'LineWidth', 3);
xlabel('Time');
ylabel('Signal');
title('y(x1(t)+x2(t))');
xlim(xran);

error = abs(f3 - (f1+f2));
error = find( error > tol);
if (sum(error) == 0)
   fprintf('\nThe given system is Linear.\n');

else
```

```
    fprintf('\nThe given system is Nonlinear.\n');
end
```