3.1 LTI SYSTEM

If a system has both the linearity and time invariant properties, then this system is called linear time invariant (LTI) system

This is a linear first order differential equation with constant coefficients (assuming a and b are constants)

$$\frac{d}{dt}y(t) - ay(t) = bx(t)$$

The general nth order linear DE with constant equations is

$$a_0 y(t) + a_1 \frac{d}{dt}y(t) + \ldots + a_{n-1}\frac{d^{n-1}}{dt^{n-1}}y(t) + a_n \frac{d^n}{dt^n}y(t) =$$

$$b_0 x(t) + b_1 \frac{d}{dt}x(t) + \ldots + b_{m-1}\frac{d^{m-1}}{dt^{m-1}}x(t) + b_m \frac{d^m}{dt^m}x(t)$$

which we can write as:

$$\sum_{k=0}^{n} a_k \frac{d^k}{dt^k}y(t) = \sum_{k=0}^{m} b_k \frac{d^k}{dt^k}x(t).$$

3.2.BLOCK DIAGRAM REPRESENTATION

System Realization

There are four types of system realization in continuous time linear time invariant systems. They are

- Direct form I realization
- Direct form II realization
- Cascade form realization
- Parallel form realization

Direct form I realization

It is the direct implementation of differential equation or transfer function describing the system. It uses separate integrators for input and output variables. It provides direct relation between time domain and s-domain equations. In general, this form requires 2N delay elements (for both input and output signals) for a filter of order N. This form is practical for small filters.

Advantages:

- Simplicity
- Most straight forward realization

Disadvantages:

- More number of integrators are used
- Inefficient and impractical (numerically unstable) for complex design

Direct form II realization

It is the direct implementation of differential equation or transfer function describing the system. Instead of using separate integrators for integrating input and output variables separately, an intermediate variable is integrated. It provides direct relation between time domain and s-domain equations.

Advantages:

- It uses minimum number of integrators

- Straight forward realization

Disadvantages:

- It increases the possibility of arithmetic overflow for filters of high Q or resonance

Cascade form

In cascade form realization the given transfer function is expressed as a product of several transfer function and each of these transfer function is realized in direct form II and then all those realized structures are cascaded i.e., is connected in series.

Parallel form realization

The given transfer function is expressed into its partial fractions and each factor is realized in direct form II and all those realized structures are connected in parallel.

Block diagram representations of first-order systems described by differential and difference equations