Multistage Amplifiers

In practice, we need amplifier which can amplify a signal from a very weak source such as a microphone, to a level which is suitable for the operation of another transducer suchas loudspeaker. This is achieved by cascading number of amplifier stages, known as multistage amplifier

Need for Cascading

For faithful amplification amplifier should have desired voltage gain, current gain and it should match its input impedance with the source and output impedance with the load. Many times these primary requirements of the amplifier cannot be achieved with single stage amplifier, because of the limitation of the transistor/FET parameters. In such situations more than one amplifier stages are cascaded such that input and output stages provide impedance matching requirements with some amplification and remaining middle stages provide most of the amplification.

We can say that,

- When the amplification of a single stage amplifier is not sufficient,

Or

- When the input or output impedance is not of the correct magnitude, for a particular application two or more amplifier stages are connected, in cascade. Such amplifier, with two or more stages is also known as multistage amplifier.

- Two Stage Cascaded Amplifier

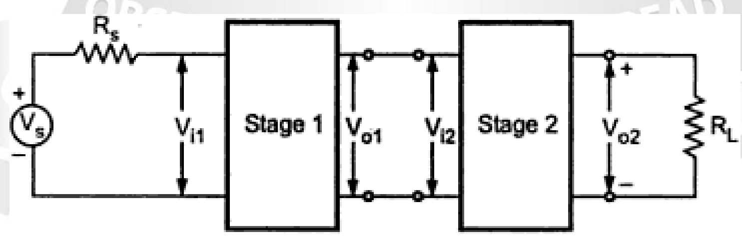

Figure: 1 Two Stage Cascaded Amplifier

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 140]

- Vi1 is the input of the first stage and Vo2 is the output of second stage. So, Vo2/Vi1 is the overall voltage gain of two stage amplifier.

N-Stage Cascaded Amplifier

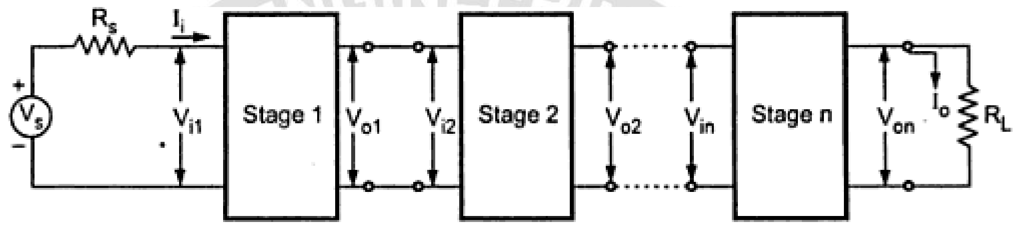

Figure: 2 N-Stage Cascaded Amplifier

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 140]

Voltage gain:

The resultant voltage gain of the multistage amplifier is the product of voltage gains ofthe various stages.

Av = Avl Av2 ... Avn Gain in Decibels

In many situations it is found very convenient to compare two powers on logarithmic scale rather than on a linear scale. The unit of this logarithmic scale is called decibel (abbreviated dB). The number N decibels by which a power P2 exceeds the power P1 isdefined by Decibel, dB denotes power ratio. Negative values of number of dB means that the power P2 is less than the reference power P1 and positive value of number of dB meansthe power P2 is greater than the reference power P1.For an amplifier, P1 may represent input power, and P2 may represent output power.Both can be given as. Where Ri and Ro are the input and output impedances of the amplifier respectively. Then,If the input and output impedances of the amplifier are equal i.e. Ri = Ro= R, thenGain of Multistage Amplifier in dB.

The gain of a multistage amplifier can be easily calculated if the gains of the individual stages are known in dB, as shown below

20 log10 Av = 20 log10 Avl + 20 log10Av2 +… + 20 log10 Avn

Thus, the overall voltage gain in dB of a multistage amplifier is the decibel voltage Gains of the individual stages. It can be given as

$$A_{v\,dB} = A_{v1\,dB} + A_{v2\,dB} + ... + A_{vn\,dB}$$

Advantages of Representation of Gain in Decibels

- Logarithmic scale is preferred over linear scale to represent voltage and power gains because of the following reasons:
- In multistage amplifiers, it permits to add individual gains of the stages to calculate overall gain.
- It allows us to denote, both very small as well as very large quantities of linear, scale by considerably small figures.
- For example, voltage gain of 0.0000001 can be represented as -140 dB and voltage gain of 1, 00,000 can be represented as 100 db.
- Many times output of the amplifier is fed to loudspeakers to produce sound which is received by the human ear. It is important to note that the ear responds to the sound intensities on a proportional or logarithmic scale rather than linear scale. Thus use of dB unit is more appropriate for representation of amplifier gains.

Methods of coupling Multistage Amplifiers

In multistage amplifier, the output signal of preceding stage is to be coupled to the input circuit of succeeding stage. For this inter stage coupling, different types of coupling elements can be employed.

RC coupling

Figure shows RC coupled amplifier using transistors. The output signal of first stage is coupled to the input of the next stage through coupling capacitor and resistive load atthe output terminal of first stage

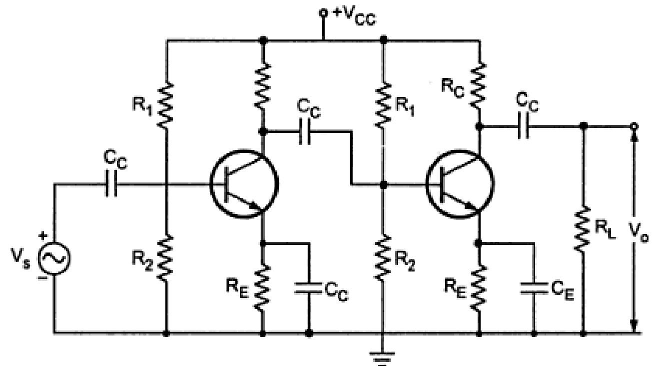

Figure: 3 RC coupling

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain]

The coupling does not affect the quiescent point of the next stage since the coupling capacitor Cc blocks the d.c. voltage of the first stage from reaching the base of the second stage. The RC network is broadband in nature. Therefore, it gives a wideband frequency response without peak at any frequency and hence used to cover a complete A.F amplifier bands. However its frequency response drops off at very low frequencies due to coupling capacitors and also at high frequencies due to shunt capacitors such as stray capacitance.

Transformer Coupling

Figure shows transformer coupled amplifier using transistors. The output signal of first stage is coupled to the input of the next stage through an impedance matching

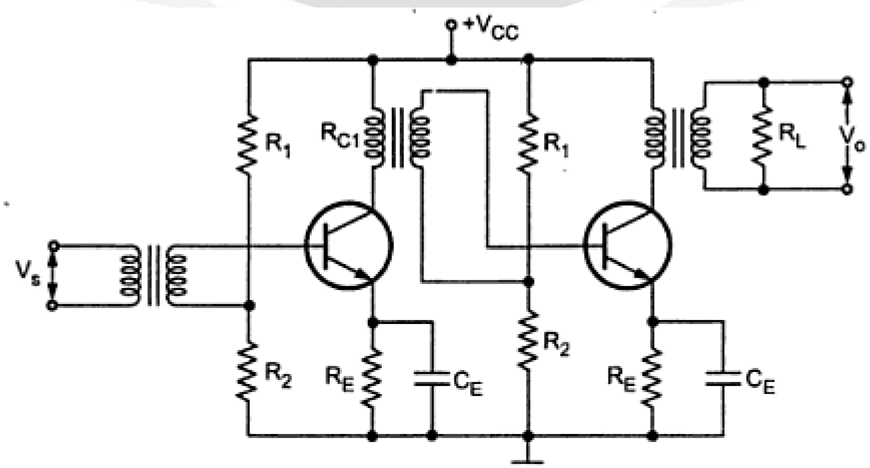

Figure: 4. Transformer Coupling

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain]

This type of coupling is used to match the impedance between outputs an input cascadedstage. Usually, it is used to match the larger output resistance of AF power amplifier to a low impedance load like loudspeaker. As we know, transformer blocks are providing d.c isolation between the two stages. Therefore, transformer coupling does not affect the quiescent point of the next stage.

Frequency response of transformer coupled amplifier is poor in comparison with that an RC coupled amplifier. Its leakage inductance and inter winding capacitances does not allow amplifier to amplify the signals of different frequencies equally well. Inter winding capacitance of the transformer coupled may give rise resonance at certain frequency which makes amplifier to give very high gain at that frequency. By putting shunting capacitors across each winding of the transformer, we can get resonance at any desired RF frequency. Such amplifiers are called tuned voltage amplifiers. Theseprovide high gain at the desired of frequency, i.e. they amplify selective frequencies. For this reason, the transformer-coupled amplifiers are used in radio and TV receivers for amplifying RF signals.

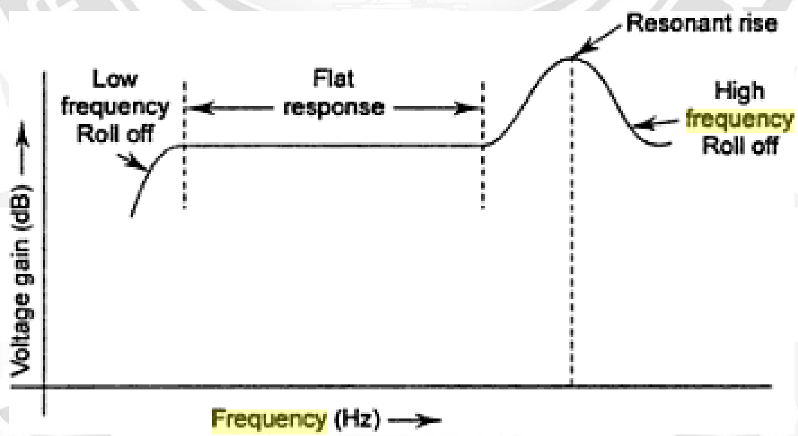

Figure: 5 Frequency response of transformer coupled amplifier
[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain]

Direct Coupling

Figure shows direct coupled amplifier using transistors. The output signal of first stage is directly connected to the input of the next stage. This direct coupling allows the quiescent d.c. collector current of first stage to pass through base of the next stage, affecting its biasing conditions.

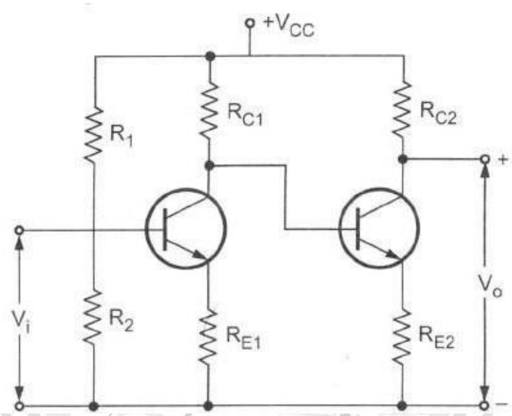

Figure: 6 Direct Coupling

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain]

Due to absence of RC components, frequency response is good but at higher frequencies shunting capacitors such as stray capacitances reduce gain of the amplifier. The transistor parameters such as VBE and β change with temperature causing the collector current and voltage to change. Because of direct coupling these changes appear at the base of next stage, and hence in the output. Such an unwanted change in the output is called drift and it is serious problem in the direct coupled amplifiers.

Cascode amplifier

The cascode amplifier is combination of common-emitter and common-base amplifier. While the C-B amplifier is known for wider bandwidth than the C-E configuration, the low input impedance (10s of Ω) of C-B is a limitation for many applications. The solution is to precede the C-B stage by a low gain C-E stage which has moderately high input impedance (kΩs).

- A common-base configuration is not subject to the Miller effect because the grounded base shields the collector signal from being fed back to the emitter input. Thus, a C-B amplifier has better high frequency response.

- The way to reduce the common-emitter gain is to reduce the load resistance. The gain of a C-E amplifier is approximately RC/re.
- The collector load RC is the resistance of the emitter of the C-B stage loading the C-E stage.
- CE gain amplifier gain is approximately Av = RC/re=1. This Miller capacitance is
    - Cmiller = Ccbo(1-Av) = Ccbo (1-(-1)=2Ccbo.

- We now have a moderately high input impedance C-E stage without suffering the Miller effect,

  but no C-E stage voltage gain.
- The C-B stage provides a high voltage gain.
- The total current gain of cascode is β as current gain of the C-E stage is 1 for the C-B is β.
- A cascode amplifier has a high gain, moderately high input impedance, a high output impedance, and a high bandwidth.