Amplifier
Lecture 11

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Class B Push Pull Amplifier:

The power output of amplifier can be enhanced by connecting two transistor in parallel or using the push pull connection. The two transistor are so connected that the collector current in one transistor falls while that in the other transistor raises.

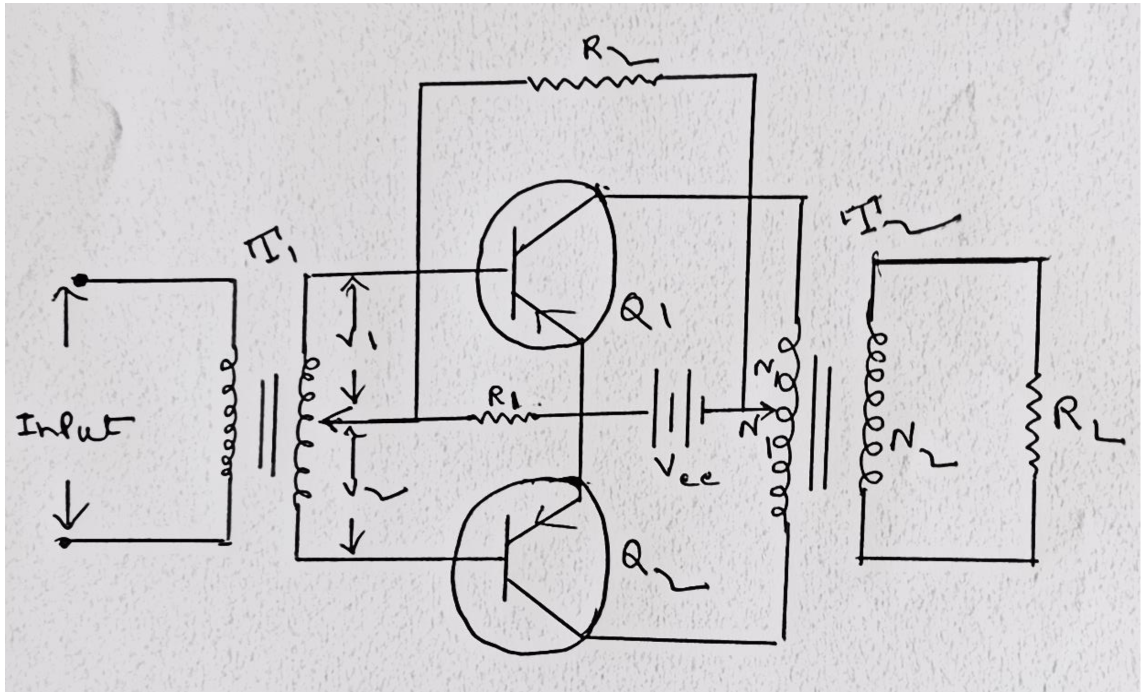

Fig 1

The advantage of push pull operation over parallel connection is that the symmetry of the circuit eliminates the even order harmonic distortion. Push pull connection can be form for $Class\ A, Class\ B, Class\ AB\ or\ Class\ C$.

In push pull $Class\ B$ circuit the base and collectors of two transistors $Q_1\ and\ Q_2$ are connected to two ends of the centre taped input and output transformers $T_1\ and\ T_2$ respectively. In absence of any input signal voltage, both the transistors are cut off which ensures $Class\ B$ operation.

In one half cycle of input signal voltage v_s, the top ends of the input transformer (T_1) , the secondary coil attains $(+)$ polarity with respect to CT point while bottom ends attains $(-)$ polarity.

For the other half cycle bottom ends becomes $(+)$ and top ends becomes $(-)$ with respect to CT point. For first cycle Q_1 conducts and Q_2 is in cut off. In the next cycle Q_1 is cut off and Q_2 conducts. The collector current are i_{c_1} and i_{c_2} for Q_1 and Q_2 . As collector current of each transistor flows through each half of primary of output transformer T_2 , the total load current i_L is a full sine wave. Resistance of primary of T_2 is

$$R_{L_2} = n^2 R_L$$

The load resistance for each transistor operating between one end of primary of T_2 and CT point is

$$R_{L_1} = \left(\frac{n}{2}\right)^2 R_L = \frac{n^2 R_L}{4}$$

For Class B operation, voltage across each transistor is $v_c = v_{cc}$, when collector current $i_c = 0$ for that transistor. When $v_c = 0$ we have $i_c = \frac{v_{cc}}{R_{L_1}}$. RMS collector voltage and RMS current are

$$v_{cc} = \frac{v_{cm}}{2} \text{ and } i_{cc} = \frac{i_{cm}}{2}$$

Where v_{cm} *and* i_{cm} are peak collector voltage and current. The AC power output from one transistor is

$$P_{AC} = v_{cc}\, i_{cc} = \frac{v_{cm} i_{cm}}{4}$$

The total AC power output for two transistor is

$$(P_{AC})_{total} = 2P_{AC} = \frac{v_{cm} i_{cm}}{2}$$

Maximum collector voltage swings has $v_{cm} = v_{cc}$ gives maximum output power

$$(P_{AC})_{toatl} = \frac{v_{cc} i_{cm}}{2} = \frac{v_{cc}^2}{2R_L}$$

The DC power supplied by source for each transistor is

$$P_S = v_{cc} i_0$$

Where $i_0 = \frac{i_{cm}}{\pi}$ is the average value of half sinusoidal collector current. The total DC power supplied by source for two transistor is

$$(P_S)_{total} = 2P_S = 2v_{cc}\ \frac{i_{cm}}{\pi} = \frac{2v_{cc}^2}{\pi R_{L_1}}$$

The maximum collector dissipation in two transistor is

$$(P_S)_{total} - (P_{AC})_{total}$$

The maximum efficiency is found to be

$$\eta = \frac{(P_{AC})_{total}}{(P_S)_{total}} = \frac{\pi}{4} = 0.785$$

Principle of Feedback :

Feedback is a process in which a fraction of output energy is combined to input. Depending on feedback aids and oppose the input signal there are two basic types of feedback, first one is positive feedback and the second one is negative feedback.

When feedback voltage or current is applied and increase the input voltage or current it is in phase with input and known as positive or regenerative or direct feedback. It increase the gain of amplifier. When feedback voltage or current is so applied that it decrease the input voltage or current , it is out of phase with the input and it is known as negative or degenerative or inverse feedback. It reduces the gain of the amplifier.

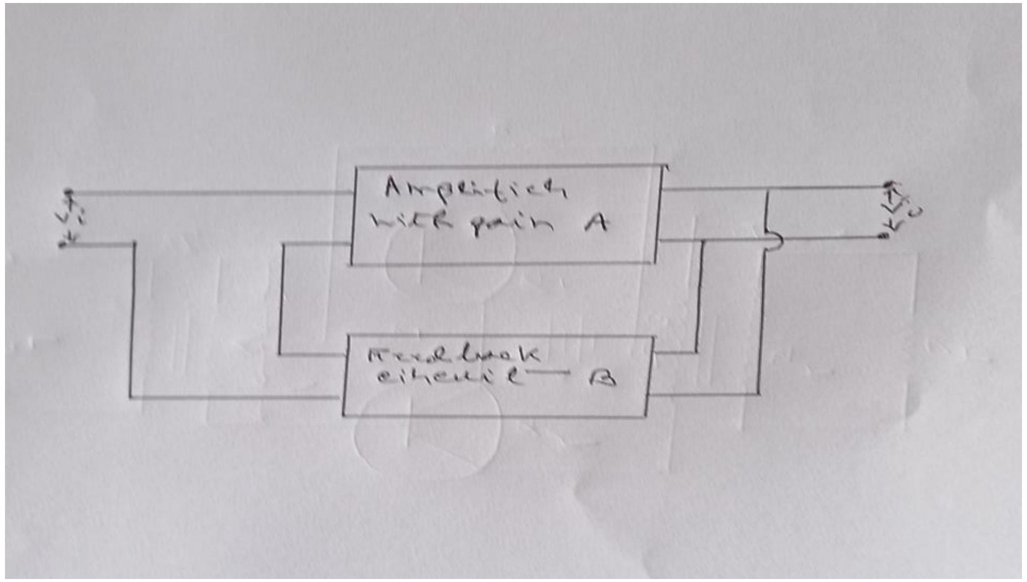

Fig 2

Disadvantage of positive feedback is , it increases distortion and instability. If positive feedback is sufficiently large it leads to oscillation. Advantage of negative feedback is, it reduce distortion, stability in gain and increased the band width.

For an ordinary amplifier without feedback v_0 and v_i are output and input voltage and A be the voltage gain. Then

$$A = \frac{v_0}{v_i}$$

Now if amplifier with feedback , let v_0' be the output voltage and a factor B of this voltage is applied to input voltage. Now input voltage becomes $(v_i \pm Bv_0')$ depending whether feedback is positive or negative. This voltage is amplified A times by the amplifier.

Considering positive feedback, we have

$$A(v_i + Bv_0') = v_0'$$

$$Av_i + ABv_0' = v_0'$$

$$Av_i = v_0'(1 - AB)$$

$$\frac{v_0'}{v_i} = \frac{A}{1 - AB}$$

Where $A' = \frac{A}{1-AB}$ represent amplifier gain with feedback for positive feedback.

Again for negative feedback

$$A' = \frac{A}{1-(-AB)} = \frac{A}{1+AB}$$

Here AB is called feedback factor and B is known as feedback ratio. Again $(1 \pm AB)$ is known as loop gain.

Advantage of Negative feedback :

(A) Increased Stability

The gain with negative feedback is given by $A' = \frac{A}{1+AB}$

For negative feedback the factor (AB) should be much greater than 1. Therefore

$$A' \cong \frac{A}{AB} \cong \frac{1}{B}$$

Thus A' only on B. As feedback is usually a voltage divider and resistor can be selected very precessiously with almost zero temperature co-efficient of resistance, so gain is unaffected by changes in temperature, variation of transistor parameter and frequency. Hence gain of amplifier is extremely stable.

(B) Reduction in Non Linear Distortion :

A large signal stage has non linear distortion because its voltage gain changes at various points in cycle. The use of negative feedback is large signal amplifier reduces non linear distortion.

Let D be the distortion voltage generated in amplifier without feedback and D' is distortion voltage generated in amplifier with feedback, then

$$D' = xD$$

Now fraction of output distorted voltage feedback to input is

$$BD' = BxD$$

This voltage is amplified by amplifier. The amplifier distorted voltage will be $BxDA$. So new distorted voltage D' which appears in output is

$$D' = D - BxDA$$

Therefore

$$xD = D - BxDA$$

$$x(1 + AB) = 1$$

$$x = \frac{1}{(1 + AB)}$$

Therefore

$$D' = \frac{D}{(1 + AB)}$$

$$D' < D$$

So negative feedback reduces the amplifier distortion by a factor $(1 + AB)$

(C) Increased Band Width:

In general gain falls off at low and high frequencies. At low frequencies the series frequencies can no longer be taken as short circuited and hence gain falls off. At high frequencies the shunt capacitance can not be considered as open circuited as at mid frequencies and hence due to the reactance of shunt capacitances the gain falls off. Let us consider $f_1\ and\ f_2$ be lower $3dB$ and upper $3dB$ frequencies respectively without feedback. Then Band Width of the amplifier will be $(f_2 - f_1)$. If A be gain of amplifier, the Gain Band Width Product will be

$$A \times B\,W$$

When feedback is applied, the gain of amplifier is decreased but gain band width remains same. This indicates that the $B\ W$ must increase to compensate the decrease in gain. It can be shown that with negative feedback, the lower and upper $3dB$ frequencies expressed as

$$f_1' = \frac{f_1}{(1 + AB)}$$

$$f_2' = \frac{f_2}{(1 + AB)}$$

From these expression it is clear that when f_1' decreases, f_2' increases.

Thus $B\ W$ increase, of course Gain $B\ W$ Product remains the same i.e.

$$A(f_2 - f_1) = A'(f_2' - f_1')$$

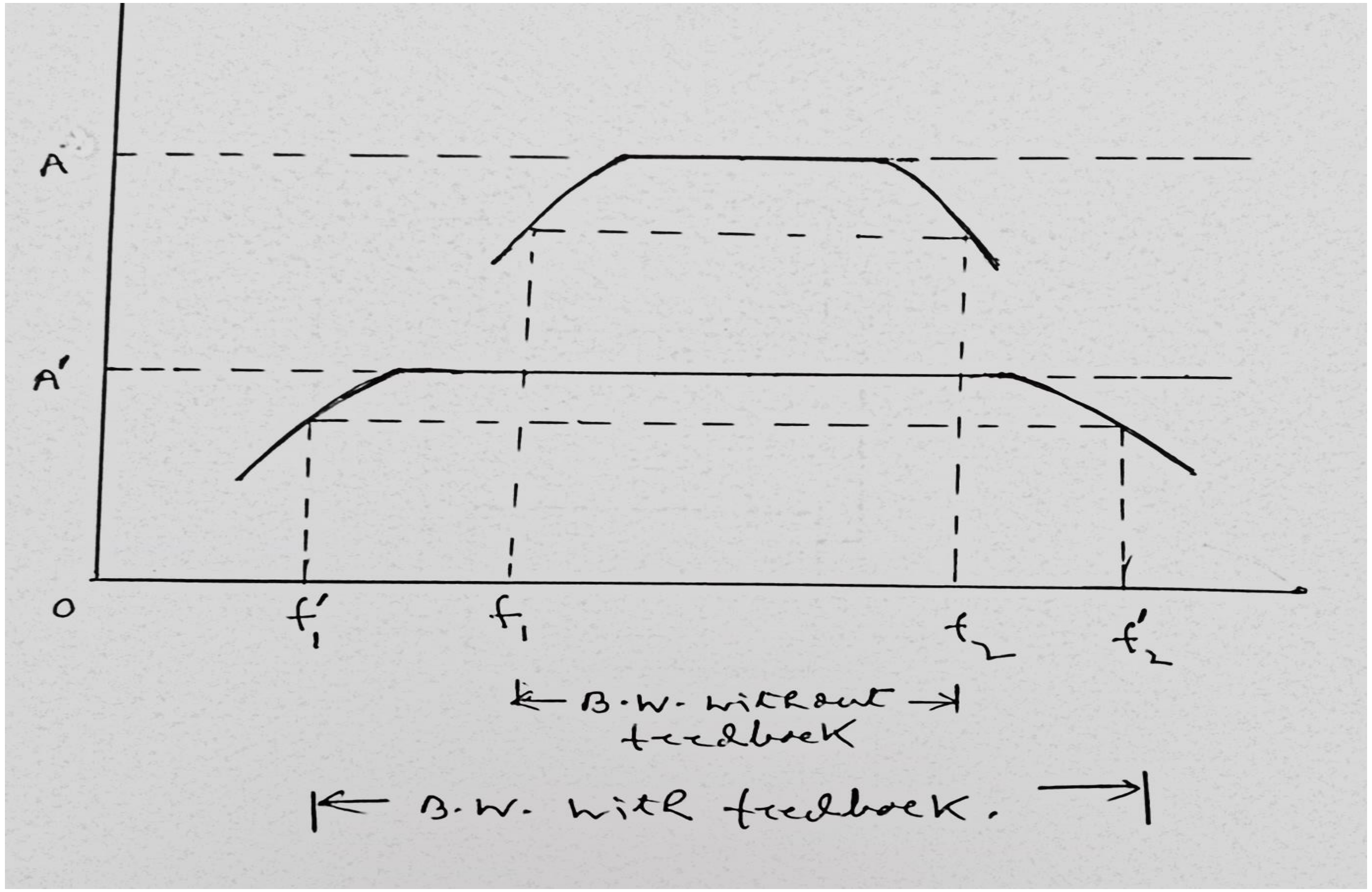

Fig 3

(D) Effect on input impedance of a transistor amplifier:

Let A is the normal gain of amplifier without feedback. BV_0 is the fraction of output voltage which is feedback to input.

Without feedback the input impedance is

$$Z_i = \frac{e_1}{i_1} = \frac{V_i}{i_1}$$

With feedback the input impedance Z_{if} is given by

$$Z_{if} = \frac{e_1 - BV_0}{i_1} = \frac{e_1 - B \times Ae_1}{i_1}$$

$$Z_{if} = \frac{e_1}{i_1} [1 - AB]$$

$$Z_{if} = Z_i[1 - AB]$$

In negative feedback $(1 - AB)$ is greater than unity and consequently Z_{if} is greater than Z_i i.e. due to negative feedback input impedance of a transistor amplifier increases.

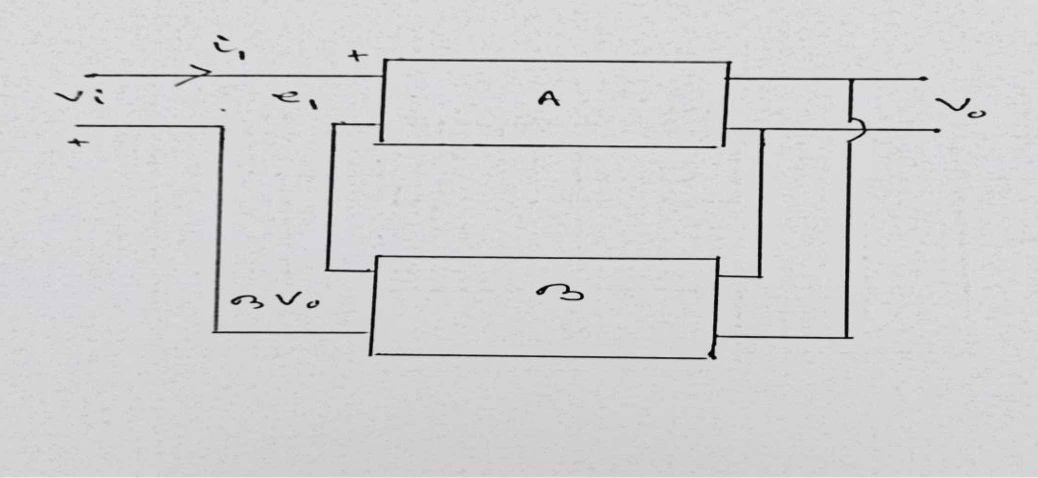

Fig 4

(E) Effect of output impedance of a transistor amplifier:

The output impedance of without feedback is given by

$$Z_0 = \frac{V_0}{i_0}$$

With BV_0 as voltage feedback the output loop current i_0' (after the feedback loop is closed) is given by

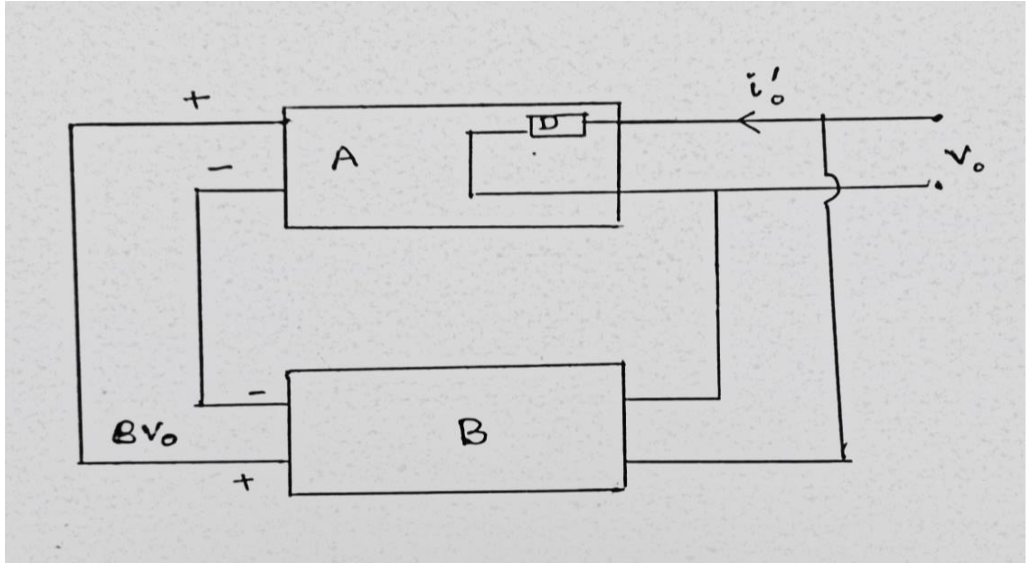

Fig 5

$$i_0' = V_0 - \frac{ABV_0}{Z_0} = \frac{V_0}{Z_0}(1 - AB)$$

So output impedance is

$$Z_{of} = \frac{V_0}{i_0'} = \frac{Z_0}{(1 - AB)}$$

Since the negative feedback $(1 - AB) > 1, Z_{of}$ is less than Z_0 i.e. output impedance decreases due to negative feedback.