DUAL INPUT, BALANCED OUTPUT DIFFERENTIAL AMPLIFIER

The circuit shown below is a dual-input balanced-output differential amplifier. Here in this circuit ,the two input signals (dual input), vin1 and vin2, are applied to the bases B1 and B2 of transistors Q1 and Q2.The output vo is measured between the two collectors C1 and C2 which are at the same dc potential. Because of the equal dc potential at the two collectors with respect to ground, the output is referred as a balanced output.

Circuit Diagram:-



***AC Analysis***:-

To perform ac analysis to derive the expression for the voltage gains Ad and input resistance Ri of a differential amplifier:

1) Set the dc voltages +VCC and –VEE at 0

2) Substitute the small signal re equivalent models for the transistors

Figure below shows resulting ac equivalent circuit of the dual input balanced output differential amplifier



AC EQUIVALENT CIRCUIT FOR DUAL-INPUT BALANCED OUTPUT DIFFERETIAL AMPLIFIER

Writing Kirchhoff’s voltage equations for loops 1 and 2 gives us

vin1 – Rin1ib1 – reie1 – RE (ie1+ie2) = 0 (1)

vin2 – Rin2ib2 – reie2 – RE (ie1+ie2) = 0 (2)

Substituting current relations ib1 = ie1/β ac and ib2 = ie2/β ac yields

vin1 – Rin1 ie1/β ac – reie1 – RE (ie1+ie2) = 0 (3)

vin2 – Rin2 ie2/β ac – reie2 – RE (ie1+ie2) = 0 (4)

Generally, Rin1/β ac and Rin2/β ac values are very small therefore we shall neglect them here for simplicity and rearrange these equations as follows:

(re+RE) ie1 + REie2 = vin1 (5)

REie1 + (re+RE) ie2 = vin2 (6)

Eqns (5) and (6) can be solved simultaneously for ie1 and ie2 by using Cramer’s rule:

ie1= $\frac{\left|\begin{matrix}vin1&RE\\vin2&(re+RE)\end{matrix}\right|}{\left|\begin{matrix}(re+RE)&RE\\RE&(re+RE)\end{matrix}\right|}$

ie2= $\frac{\left|\left|\begin{matrix}(re+RE)&vin1\\RE&vin2\end{matrix}\right|\right|}{\left|\begin{matrix}(re+RE)&RE\\RE&(re+RE)\end{matrix}\right|}$

ie1 = [vin1 (re+RE)- vin2RE]/[ (re+RE)2-RE2] (7)

ie2 = [vin2 (re+RE)- vin1RE]/[ re (re+2RE)] (8)

The output voltage is

vo = vc2 – vc1

= -RCic2 – (-RCic1) (9)

= RCic1 – RCic2

=RC (ie1 – ie2) since ic = ie

Substituting current relations ie1 and ie2 in eqn(9), we get

vo = RC[(re+2RE)(vin1 – vin2)/re(re+2RE)]

= (RC/re) (vin1 – vin2)

Thus a differential amplifier amplifies the difference between two input signals .By defining vid as the difference in input voltages, we can write the voltage-gain equation of the dual-input balanced-output differential amplifier as follows:

Ad = vo /vid = RC/re  (10)

***Differential Input Resistance***:-

Differential input resistance is defined as the equivalent resistance that would be measured at either input terminal with the other terminal grounded.

Ri1 = |vin1/ib1|Vin2=0

=|vin/(ie1/βac)|Vin2=0

Substituting the value of ie1, we get

Ri1 = βacvin1/[{(re+RE)vin1 – RE(0)}/{(re+RE)2 – (RE)2}] (11)

=[βac(re2+2reRE)]/(re+RE)

=[βac re(re+2RE)]/(re+RE)

Generally,RE>>re, which implies that (re+2RE) = 2RE and (re+RE) = RE.

Therefore eqn(11) can be rewritten as

Ri1 = βacre(2RE)/RE = 2βacre (12)

Similarly, the input resistance Ri2 seen from the input signal source vin2 is defined as

Ri2 = |vin2/ib2|Vin1=0

=|vin2/(ie2/βac)|Vin1=0

Substituting the value of ie2 from eqn(9b), we get

Ri2 = βacvin2/[{(re+RE)vin2 – RE(0)}/{(re+RE)2 – (RE)2}] (13)

=[βac(re2+2reRE)]/(re+RE)

=[βac re(re+2RE)]/(re+RE)

However, (re+2RE) =2RE and (re+RE) = RE if RE>>re. Therefore eqn(15) can be rewritten as

Ri2 = βacre(2RE)/RE = 2βacre (14)

***Output Resistance***:-

Output resistance is defined as the equivalent resistance that would be measured at either output terminal w.r.t ground.

Ro1 = Ro2 = RC (15)

The current gain of the differential amplifier is undefined; therefore, the current-gain equation will not be derived for any of the four differential amplifier configurations.

***Common mode Gain:-***

A common mode signal is one that drives both inputs of a differential amplifier equally. The common mode signal is interference, static and other kinds of undesirable pickup etc.

The connecting wires on the input bases act like small antennas. If a differential amplifier is operating in an environment with lot of electromagnetic interference, each base picks up an unwanted interference voltage. If both the transistors were matched in all respects then the balanced output would be theoretically zero. This is the important characteristic of a differential amplifier. It discriminates against common mode input signals. In other words, it refuses to amplify the common mode signals.

The practical effectiveness of rejecting the common signal depends on the degree of matching between the two CE stages forming the differential amplifier. In other words, more closely are the currents in the input transistors, the better is the common mode signal rejection. The common mode rejection ratio CMRR is an important parameter of differential amplifier which is equal to Ad/Acm where

 Ad = vo /vid and Acm  = Vocm/vcm is gain when same/common input is applied to both the amplifiers. so ideally Acm  should be equal to zero. So CMRR is infinite for ideal conditions but for practical amplifiers this is not equal to zero because of mismatching of two transistors so CMRR is quite high because of very small common mode gain which makes the circuit capable to reject noise signal which is common to both the inputs.