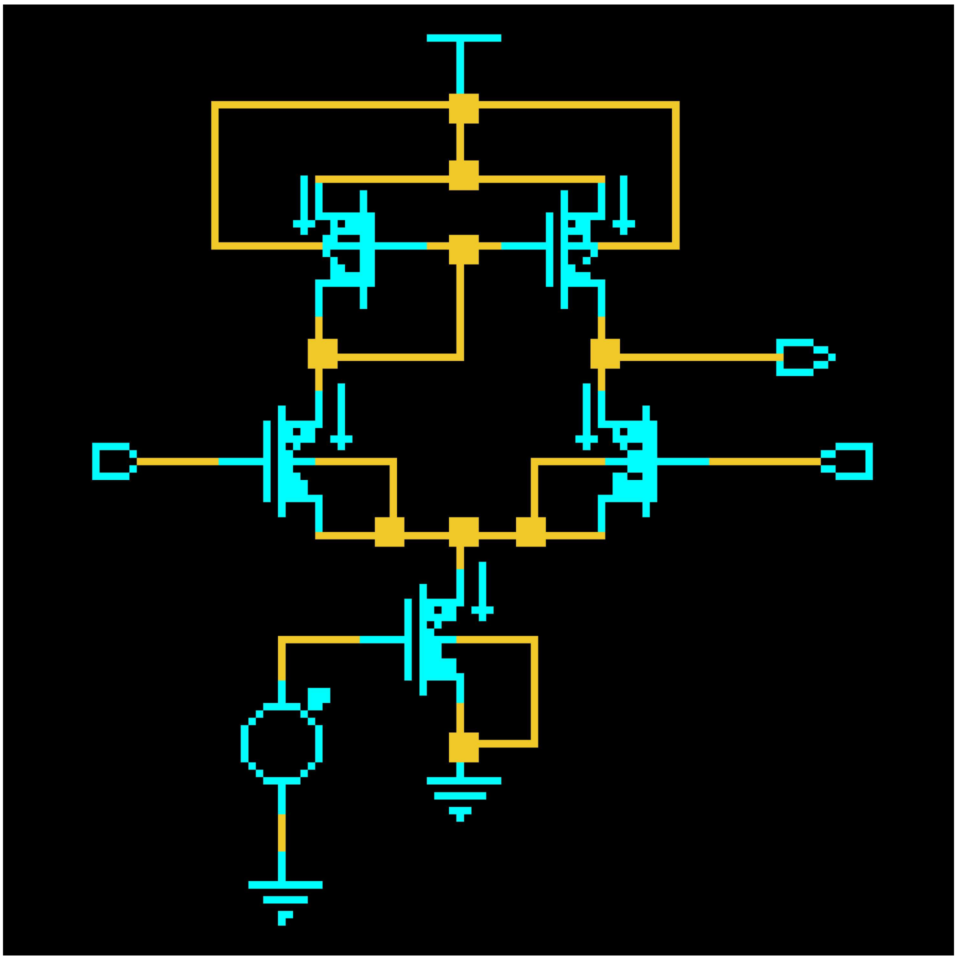
CIRCUIT DIAGRAM



Differential Amplifier

Theory:

the gain of this differential amplifier is

$$\text{Gain} = V_{OUT}/(V_1 - V_2). \text{ --------------- (1)}$$

We can find the expression of VOUT in term of V1 and V2 by using superposition theorem:

$$V_{OUT} = [R_3/(R_1+R_3)]\,[(R_4 + R_2)/R_2]\,\mathbf{V_1} - [R_4/R_2]\,\mathbf{V_2} \text{ -------------- (2)}$$

However, we will not be able to re-arrange this expression in the form of eqn (1) to find the gain of the amplifier (except in the special case of R1 = R2 and R3 = R4).

Instead of applying superposition theorem with V_1 and V_2 separately, a better way is to first combined V_1 and V_2 in a different format, viz. (V_1-V_2). This is known as the differential mode input - V_d. Associated with this differential mode component will be the common mode input - V_{cm}., which is equal to the average value of V_1 and V_2.

Differential mode component : $V_d = (V_1-V_2)$

Common mode component : $V_{cm} = (V_1+V_2)/2$

By using these alternate representation of the input components (V_d and V_{cm}) instead of the original components (V_1 and V_2), we can re-express eqn (2) in terms of V_d and V_{cm} as follows.

$V_{cm} = (V_1+V_2)/2 \quad \Rightarrow \quad 2V_{cm} = V_1 + V_2$ ---- (3)

Since $\quad V_d = V_1 - V_2$ ---- (4)

Therefore

(3) + (4) $\quad \Rightarrow \quad V_1 = V_{cm} + V_d/2$ ---- (5)

and (3) - (4) $\quad \Rightarrow \quad V2 = Vcm - Vd/2$ ---- (6)

Substitute eqns (5) & (6) into eqn (2) :

$$\mathbf{V_{OUT}} = 1/2[R_3/(R_1+R_3)]\,[(R_4+ R_2)/R_2+ R_4/R_2]\mathbf{V_d}+[R_3/(R_1+R_3)]\,[(R_4+ R_2)/R_2- R_4/R_2]\mathbf{V_{cm}} \text{ -------------- (7)}$$

From this expression, we can find the gain of the differential amplifier

Gain $= V_{OUT}/(V_1-V_2)$

$= V_{OUT}/V_d$

$= 1/2[R_3/(R_1+R_3)]\ [(R_4 + R_2)/R_2 + R_4/R_2]$

This gain is known as the **Differential Gain**(Ad) as it is based on the differential input alone, i.e.

$$\mathbf{A_d = 1/2[R_3/(R_1+R_3)]\ [(R_4+ R_2)/R_2+ R_4/R_2]}$$

As there is another component in V_{OUT} due to the common-mode component V_{cm} of the input, we define another gain for the differential amplifier, the **Common Mode Gain** ($A_{cm}=V_{OUT}/ V_{cm}$). From eqn (7), this is

$$\mathbf{A_{cm} = [R_3/(R_1+R_3)]\ [(R_4 + R_2)/R_2 - R_4/R_2]}$$

So although a differential amplifier is supposed to amplify the differential component of the input signals, the common component of the input signals (which is the average value of the two input voltages) will also appear at the output. In practice, this common mode component will cause an error in the measurement of the signals.

To eliminate the effect of the common mode component, we can either

(i)make the input common mode component equal to zero, i.e. make $V_2= -V_1$ such that the average value of the two input signals equal to zero

or

(ii) choose the resistor values of R_1 to R_4 in such a way that A_{cm} is zero.

(i) is usually not possible in practice due to the constraint of the measuring circuitry used to produce V1 and V2 (e.g. the Bridge circuit).

(ii) can be achieved <u>theoretically</u> by making $R_1 = R_2$ and $R_3 = R_4$. However, this is not feasible in practice due to the tolerance of the resistors used.

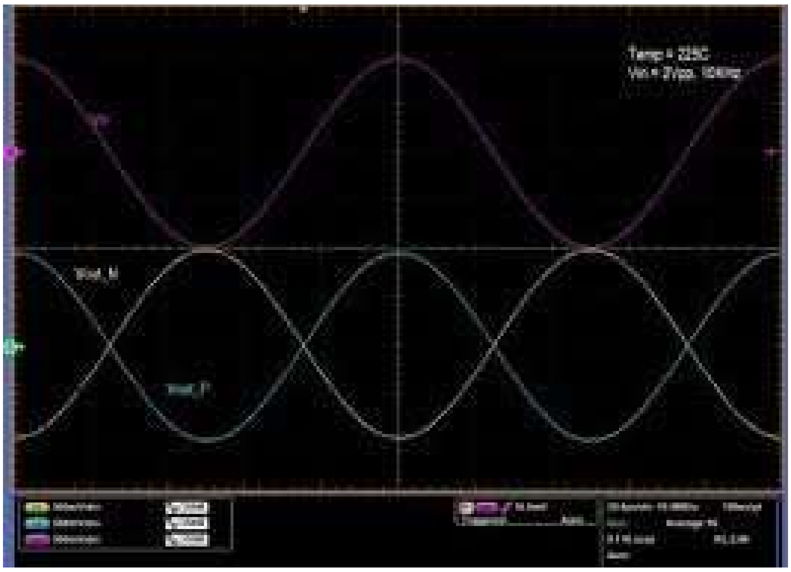
Because of this imperfection, a figure of merit used to describe differential amplifier is the **Common Mode Rejection Ratio (CMRR)**, which is defined as

$$\mathbf{CMRR = 20 \log (A_d/A_{cm})}$$

For a <u>perfect</u> differential amplifier, the CMRR is equal to ∞, as A_{cm} is zero.

In practice, a CMRR in excess of 80dB to 100dB will be needed for high accuracy measuring system (e.g. a microcomputer data acquisition system). This is very difficult to achieve if the differential amplifier uses discrete resistors for R_1 to R_4.

Output:



Gain

-----------------------------XXXXXXXXXXXXX-----------------------------