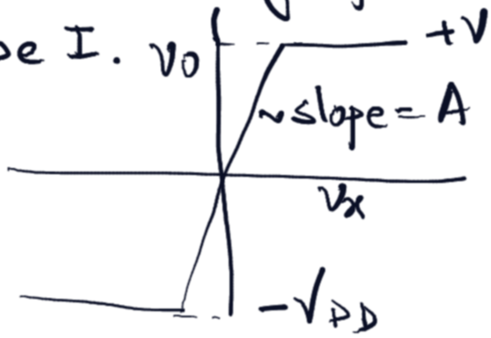
$v_0 = A v_x$

$$v_0 = -v_{in}\frac{R_2}{R_1}\left[\frac{1}{1-\frac{1}{A}(1+R_2/R_1)}\right]$$

We will consider one non-idality at a time and understand the meaning of an ideal OPAMP.

Case I.



The OPAMP is driven by a finite voltage $\pm V_{DD}$ and gain A is finite.

$|v_x| \leqslant \frac{V_{DD}}{A}$ for linearity.

$$v_0 = A v_x = -v_{in}\frac{R_2}{R_1}\left[\frac{1}{1-\frac{1}{A}(1+R_2/R_1)}\right] \text{ -- Eq. 1}$$

$$\Rightarrow |v_x| = \left| -\frac{v_{in}}{A}\frac{R_2}{R_1}\left[\frac{1}{1-\frac{1}{A}(1+R_2/R_1)}\right]\right| \leqslant \frac{V_{DD}}{A}$$

$$\Rightarrow |V_{in}| \leqslant V_{DD}\frac{R_1}{R_2}\left[1-\frac{1}{A}\left(1+\frac{R_2}{R_1}\right)\right]$$

Condition I for ideality $A \to \infty$.

$|V_{in}| \leqslant V_{DD} R_1/R_2$

What happens if $|V_{in}| > V_{DD} R_1/R_2$, i.e. $|V_{in}| = a|V_{DD} R_1/R_2|$, $a > 1$

Eqn. (1) suggests that,

$$|V_0| = \left| aV_{DD}\left[\frac{1}{1-\frac{1}{A}(1+R_2/R_1)}\right]\right|$$

But, $A \to \infty$ from condition I; so

$$|V_0| = aV_{DD} > V_{DD}$$

But we started with the assumption that V_{DD} is finite and maximum available voltage.

Condition II for ideality, $V_{DD} \to \infty$

Case II

So far we have assumed that the signal is all DC in the circuit. Let us bring in a non-ideality that the amplifiers are usually a single pole amplifier.

$$A = \frac{A_0}{1+s/\omega_0}$$, where ω_0 is the corner freq, A_0 is the low frequency gain.

$$v_0 = -v_{in}\frac{R_2}{R_1}\left[\frac{1}{1-\frac{1}{A}\left(1+\frac{R_2}{R_1}\right)}\right]$$

$$= -v_{in}\frac{R_2}{R_1}\left[\frac{1}{1-\frac{1+S/W_0}{A_0}\left(1+R_2/R_1\right)}\right]$$

$$v_0(s) = -v_{in}(s)\frac{R_2}{R_1}\,\frac{A_0}{A_0-(1+S/W_0)(1+R_2/R_1)}$$

$$= -v_{in}(s)\frac{R_2}{R_1}\,\frac{A_0}{\left[A_0-(1+R_2/R_1)\right]-\frac{S}{W_0}(1+R_2/R_1)}$$

$$= -v_{in}(s)\frac{R_2}{R_1}\,\frac{A_0W_0/(1+R_2/R_1)}{W_0\left(\frac{A_0}{1+\frac{R_2}{R_1}}-1\right)-S}$$

$$= v_{in}(s)\frac{R_2}{R_1}\,\frac{A_0W_0/(1+R_2/R_1)}{S-\left(\frac{A_0}{1+R_2/R_1}-1\right)W_0} \quad \text{-- Eqn(2)}$$

Please note it may appear that we can now take limit $A_0 \to \infty$ and $v_0(s) = -v_{in}(s)(R_2/R_1)$ but S (frequency) can be very large also, hence such operation is mathematically wrong.

Independent of the form of $v_{in}(s)$, the output will always have a time dependent signal

$$v_0(t) = v_0'(t) + K_1 e^{\left(\frac{A_0}{1+R_2/R_1}-1\right)W_0 t}$$

This can make the signal grow out of bound. So we need to make sure pole remains on the left half s plane i.e.

$$W_0\left(\frac{A_0}{1+R_2/R_1}-1\right) < 0$$

$$\Rightarrow A_0 < (1+R_2/R_1)$$

But we also need $A_0 \to \infty$. Hence this condition can never be met with finite S. However, if we start with the assumption that $S \to 0$ [DC condition only] then Eqn (2) will boil down to $v_0(s) = -\frac{R_2}{R_1}v_{in}(s)$ when $A_0 \to \infty$

However there is always noise in the ckt which will have all sorts of frequency components.

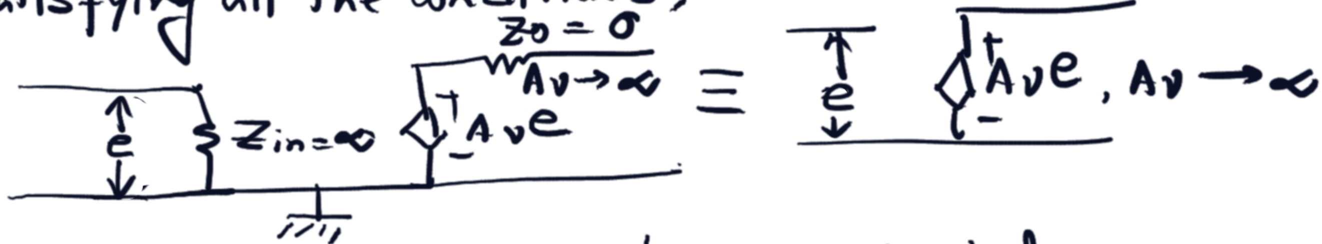
<u>Condition III</u> The OPAMP is noiseless and no time varying signal is present.

Equivalently speaking, $A = A_0 / (1 + S/\omega_0) \simeq A_0$ i.e $\omega_0 \to \infty$ in comparison $S (= j\omega)$. So the operating frequency is always small w.r.t the bandwidth of OPAMP.

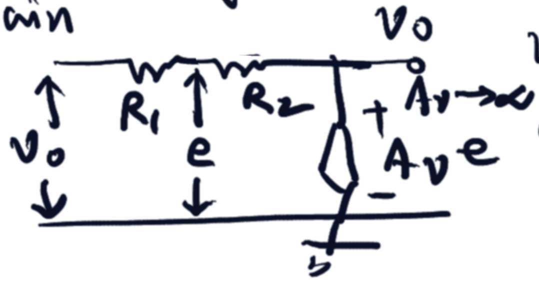
<u>Condition IV</u> $\omega_0 \to \infty$, OPAMP has infinite bandwidth.

Case - III

So, what is the equivalent ckt of an ideal opAMP satisfying all the conditions,



As long as the OPAMP can be approximated as an ideal voltage controlled voltage source only with infinite gain



$V_0 = - V_{in}\left(\frac{R_2}{R_1}\right)$. This matches with your result.

[Please note I have not considered input and output bias currents, resistances and capacitances elsewhere. In the ideal condition they have all been assumed to be zero.]