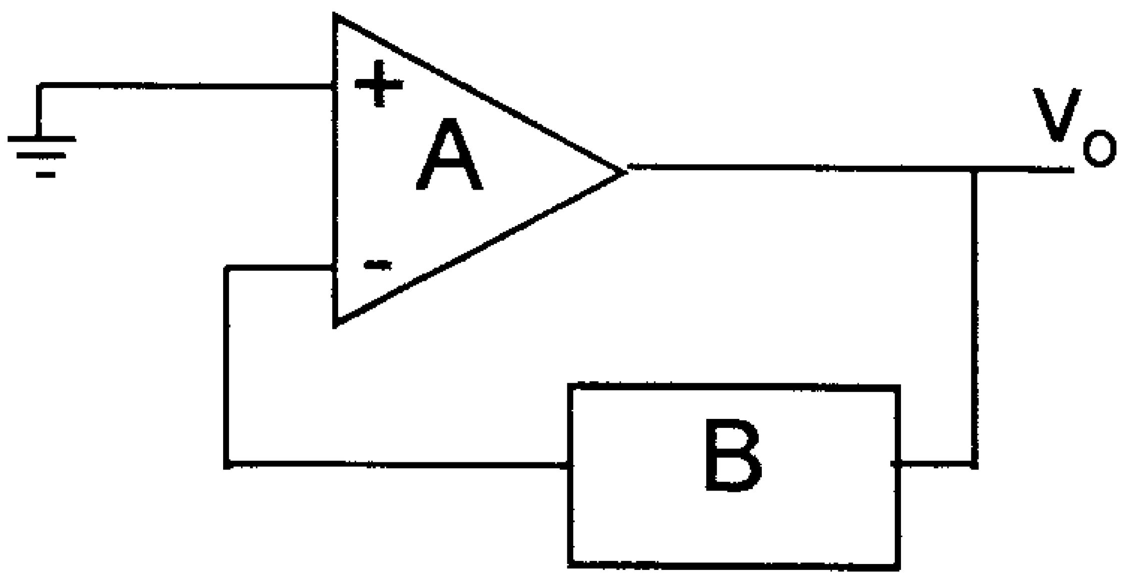
# Positive Feedback (Oscillators)

$$G = A / (1+AB)$$

For oscillation AB = -1 i.e. 180° phase shift and subtraction becomes addition.
Consider

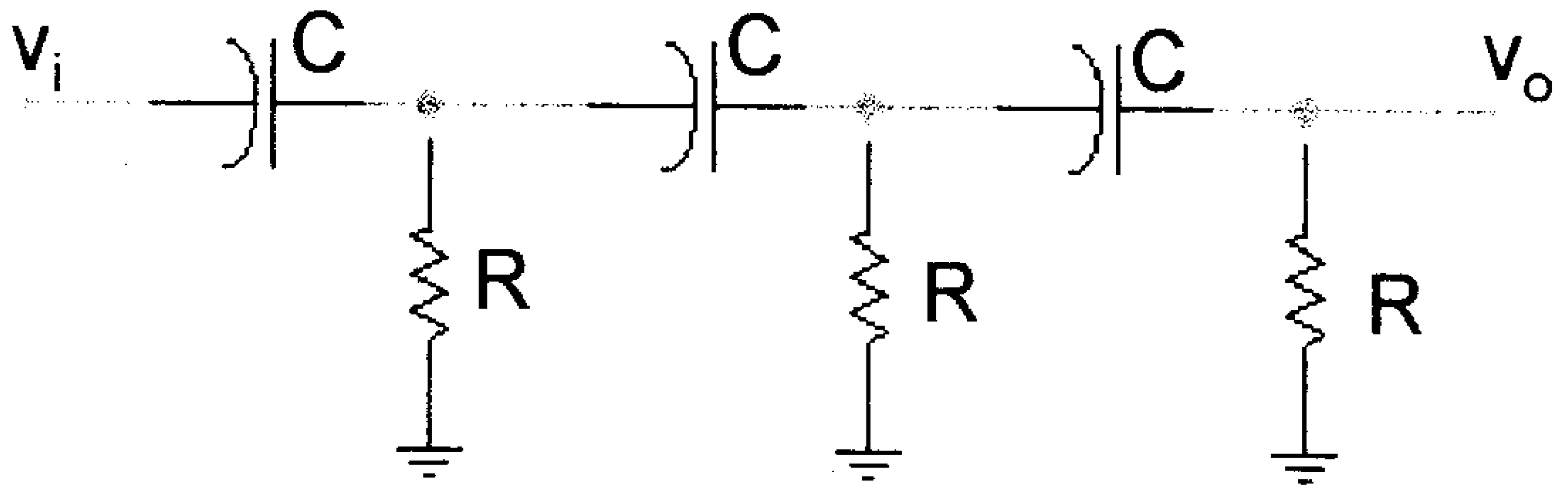



If B = -1 / A, then system stays in whatever state it was at turn on. This is impractical since A is a function of temperature i.e. loop gain will be too low and the output signal will die away or too high and the output will go to the rail. Easier to arrange for AB = -1 at a particular frequency and the circuit will oscillate at that frequency.

# RC Oscillator

RC Oscillator:

Max phase shift from a single RC is 90° at $\omega = \infty$ , therefore to produce a 180° phase shift require a minimum of 3 RC's. Consider a ladder network with 3 identical RC stages



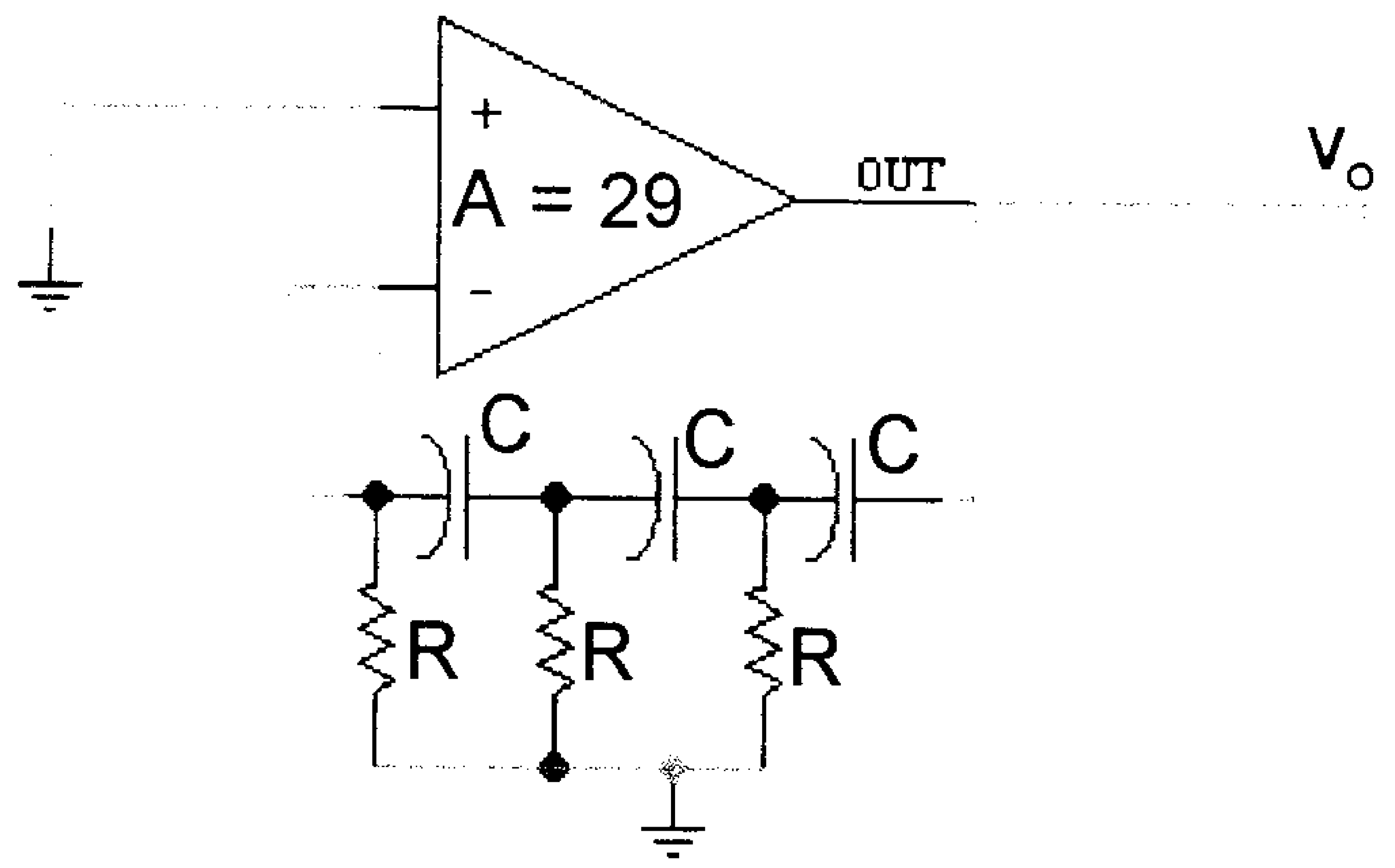

$$\frac{V_o}{V_i} = \frac{1}{1 - \frac{5}{(\omega CR)^2} - j\left(\frac{6}{\omega CR} - \frac{1}{(\omega CR)^3}\right)}$$

Want $\omega$ such that phase shift is 180° i.e. gain is real and negative - imaginary part is zero.

i.e. $\frac{6}{\omega CR} = \frac{1}{(\omega CR)^2}$ i.e. $\omega = \frac{1}{CR\sqrt{6}}$ and $f = \frac{1}{2\pi CR\sqrt{6}}$

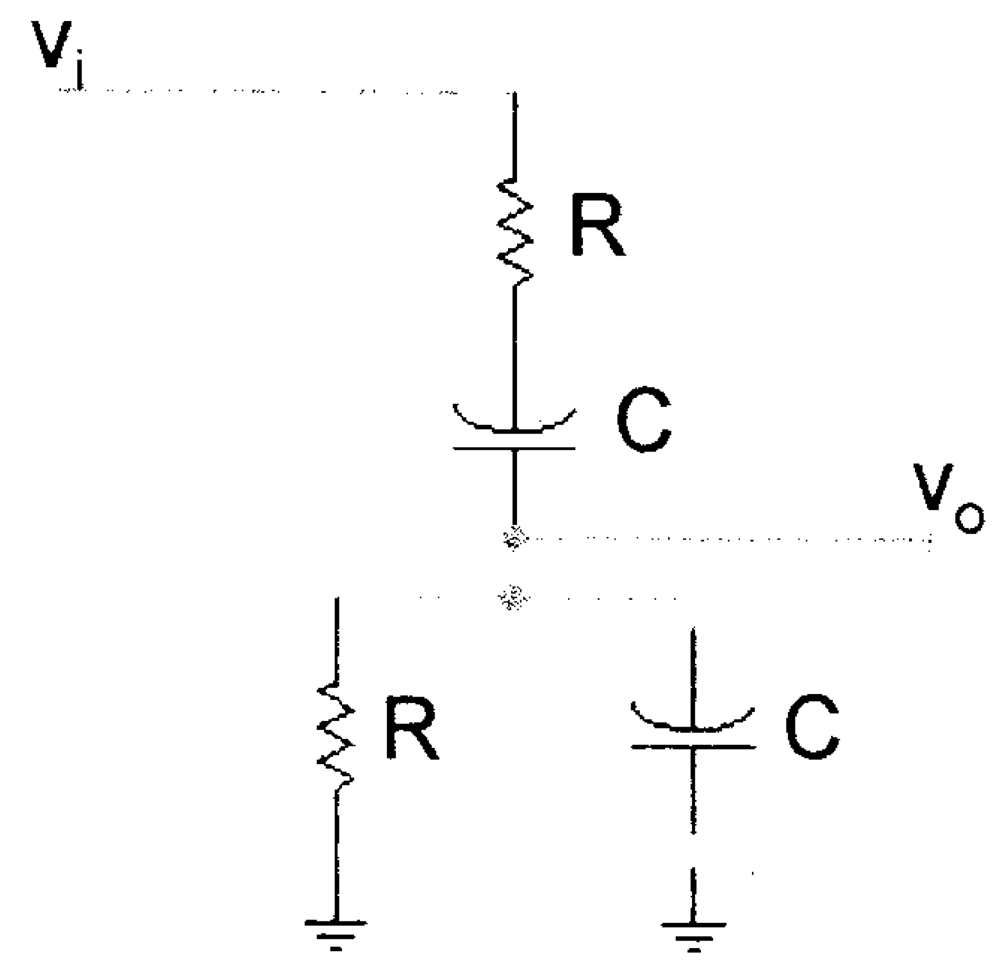
$$\Rightarrow V_o/V_i = -1/29$$

i.e. B = -1 / 29 if RC ladder network used as the feedback network and AB = -1 if A = 29.



# Wien-Bridge Oscillator

Consider




$$\frac{V_o}{V_i} = \frac{Z_2}{Z_1 + Z_2} \quad \text{where } Z_1 = R\text{-}C \text{ and } Z_2 = R\,//\,C$$

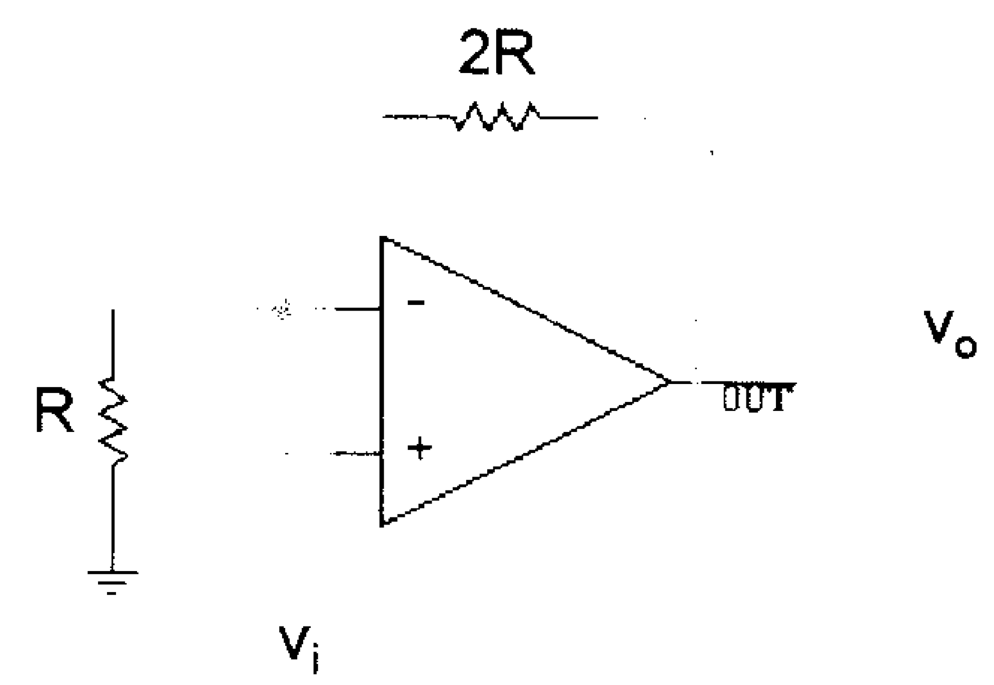
$$\text{i.e. } Z_1 = R + \frac{1}{j\omega C} \text{ and } Z_2 = \frac{1}{\frac{1}{R} + j\omega C}$$

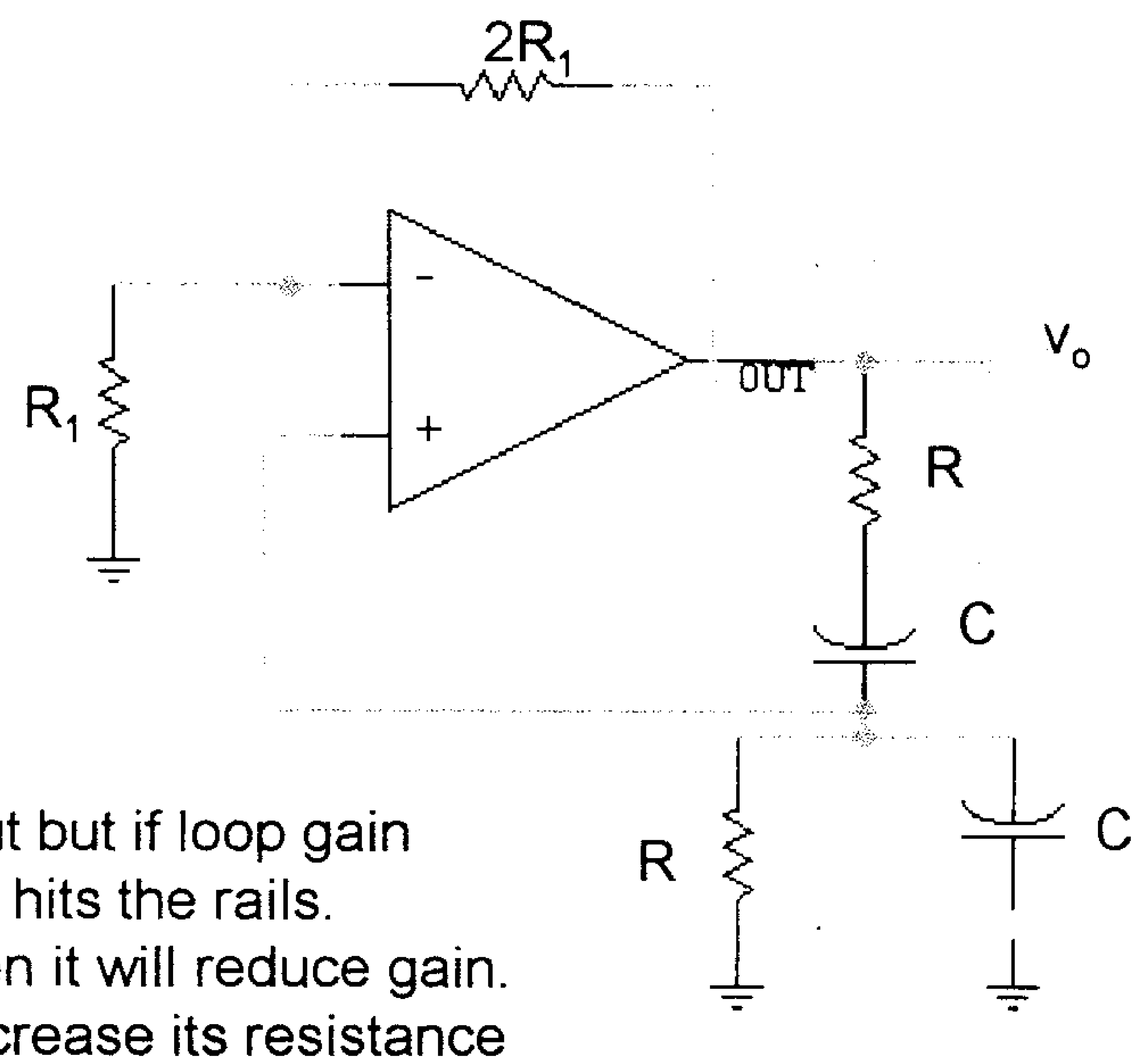
$$\therefore \frac{V_o}{V_i} = \frac{\frac{1}{\frac{1}{R} + j\omega C}}{R + \frac{1}{j\omega C} + \frac{1}{\frac{1}{R} + j\omega C}} = \frac{1}{3 + j\left(\omega CR - \frac{1}{\omega CR}\right)}$$

i.e. phase shift = 0 when $(\omega CR)^2 = 1$ i.e. $\omega = \frac{1}{CR}$

At $\omega = \frac{1}{CR}$ $\frac{V_o}{V_i} = \frac{1}{3}$ (also the maximum value and $\therefore$ the resonant freq.

To make an oscillator, this has to be combined with a non-inverting amplifier with a gain of 3 i.e.

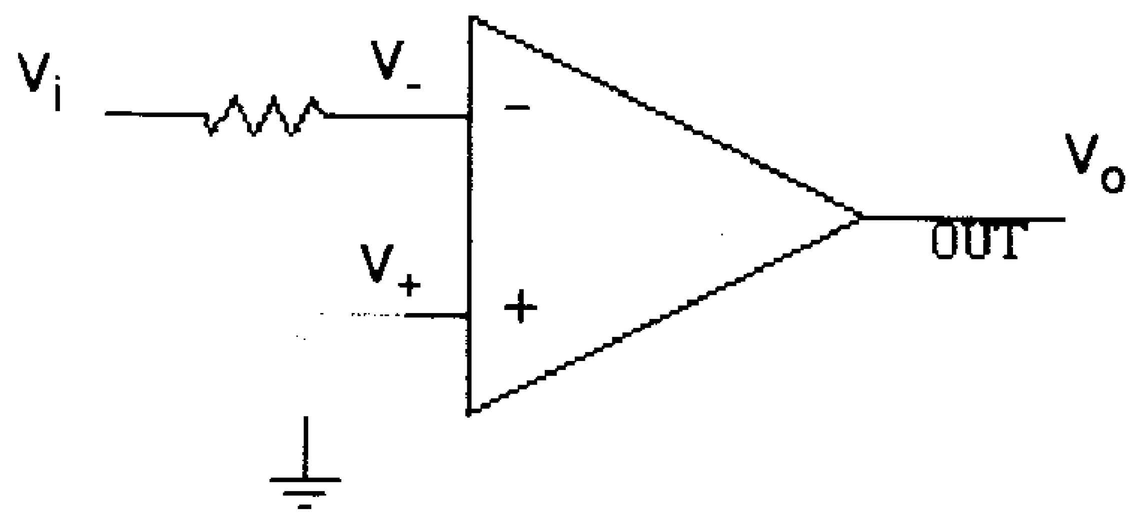



If loop gain too low then oscillations will die out but if loop gain too high then oscillations will grow until output hits the rails.
Need something that when gain grows > 1 then it will reduce gain.
Could replace $2R_1$ with something that will decrease its resistance when power goes up i.e. something with a negative temp. coefficient e.g. a thermistor.
Alternatively, replace $R_1$ with something whose R increases with temp e.g. a lamp.
(There are more elegant solutions that use FET's)

# Comparators

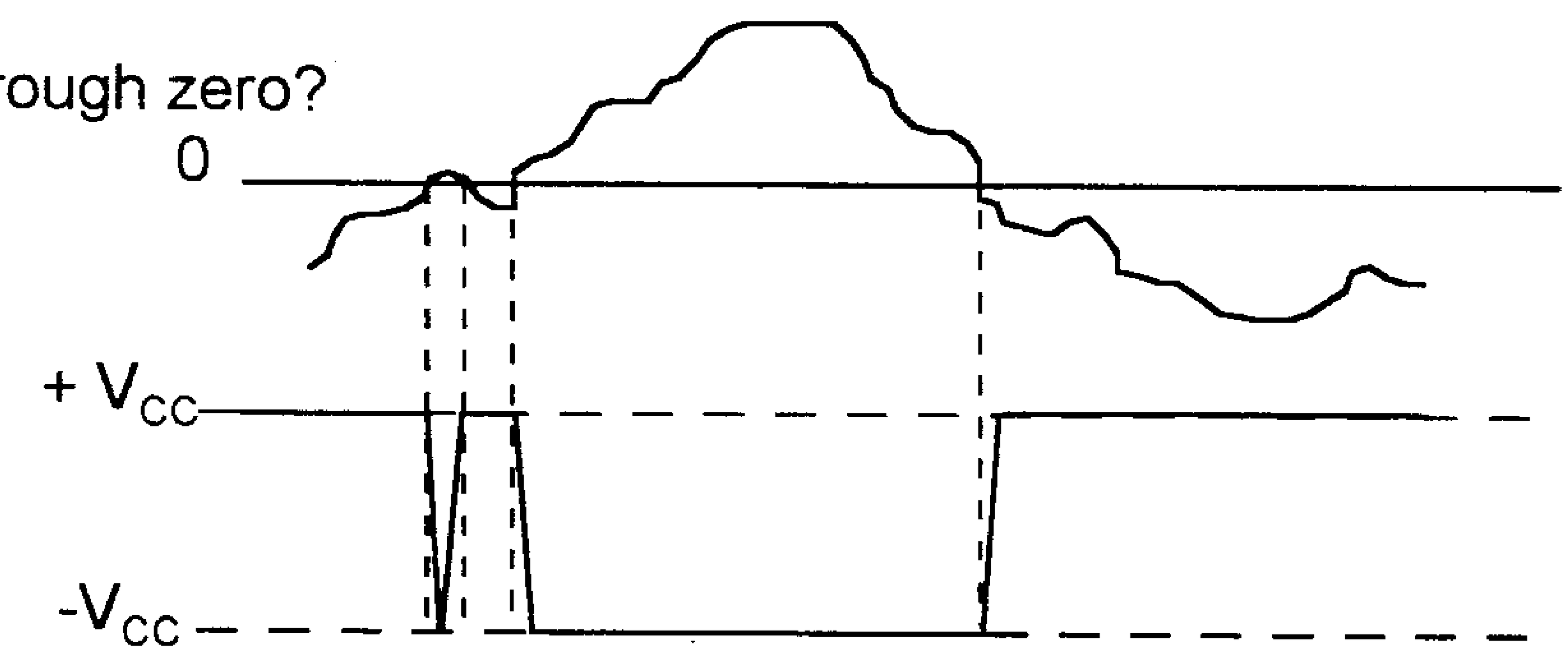
Positive feedback helps make a circuit more decisive - forces output to extremes
A comparator is a circuit that compares its 2 inputs and goes to 1 of 2 extremes depending on which of the 2 inputs is more positive i.e. just a high gain differential amplifier - could be an operational amplifier with no feedback.




If $v_i > 0$ then $v_o \rightarrow (-V_{CC})$
If $v_i > 0$ then $v_o \rightarrow (+V_{CC})$

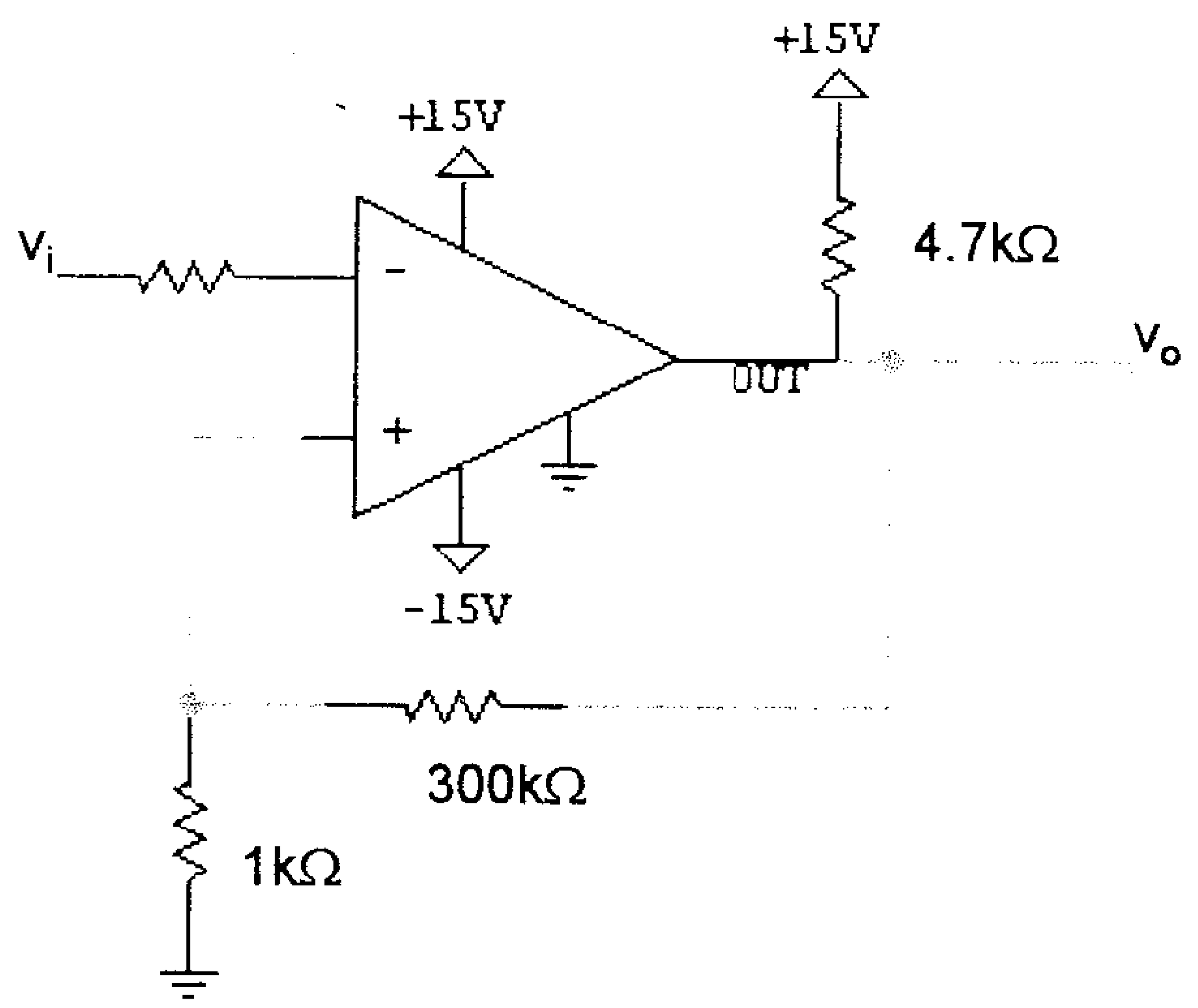
Problem: what about noise as $v_i$ goes through zero?

Want to avoid the multiple switching due to noise as $v_i$ passes thro' 0.
The angles on the output as it switches are because an op-amp is a fairly slow device - can overcome this by using special IC's called comparators.




To avoid switching on noise do 2 things : (1) displace the switching thresholds slightly from 0 e.g. - 0.1V on way down and + 0.1V on the way up i.e. build in hysteresis; and (2) add in positive feedback to confirm what the comparator wants to do.
Example:

This comparator output switches between 0 and 301/305.7 x 15V.
When output goes from 15V and 0 which occurs when $v_- > v_+$ i.e. when $v_- > 1/301 \times v_o$ = approx 0.2V
Lower threshold will still be 0 since when $v_o = 0$ then $v_+ = 0$




Such a circuit, a comparator with positive feedback to build in hysteresis is called a <u>Schmitt Trigger</u>.

(How much hysteresis? - enough so that noise doesn't bother you)