- Similarly, when a ***large positive signal*** is applied at the ***base*** of Q_1 (w.r.t. the base of Q_2), Q_2-Q_4 branch would ***instantly turn off***

  $\Rightarrow$ ***Entire bias current*** I_{C8} would ***flow*** through the Q_1-Q_3 ***branch***, ***pushing the same current*** through Q_5

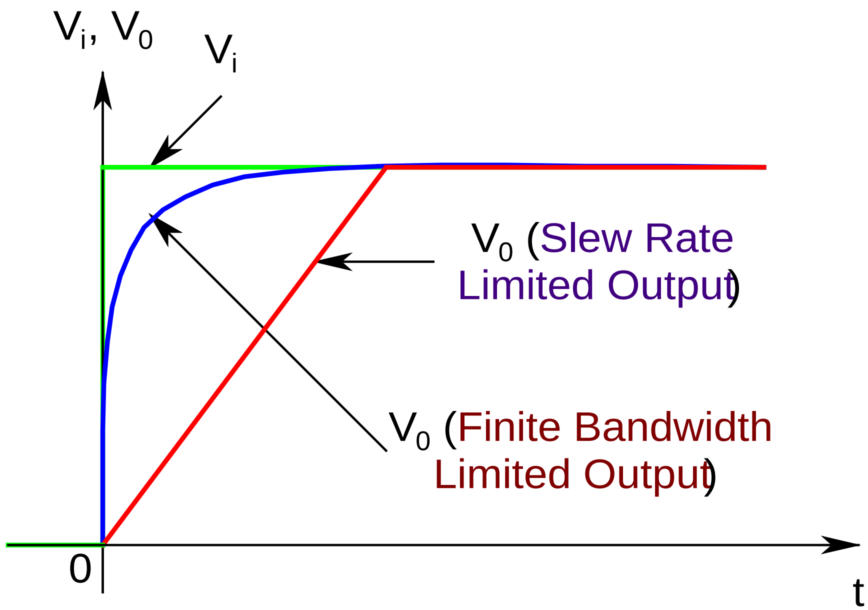
  $\Rightarrow$ Q_6 would ***carry the same current*** (***mirror*** with Q_5)

- This ***current*** would ***flow*** from the ***output node*** through C_C to Q_6

  $\Rightarrow$ C_C would ***start to discharge***, and V_0 would ***start to fall***, going into its ***negative swing***

- Since the ***same current*** (I_{C8}) is used to ***discharge*** the ***output node***:

  $SR^+ = SR^- = 1.52\ V/\mu sec$



Slew Rate Limitation of Op-Amps

- Situation becomes ***more dramatic*** if a ***sinusoidal signal*** is applied at the ***non-inverting input*** of the op-amp, connected in a ***voltage-follower*** configuration
- Let ***input signal*** $V_i = V_M \sin(\omega t)$, with ***large*** V_M

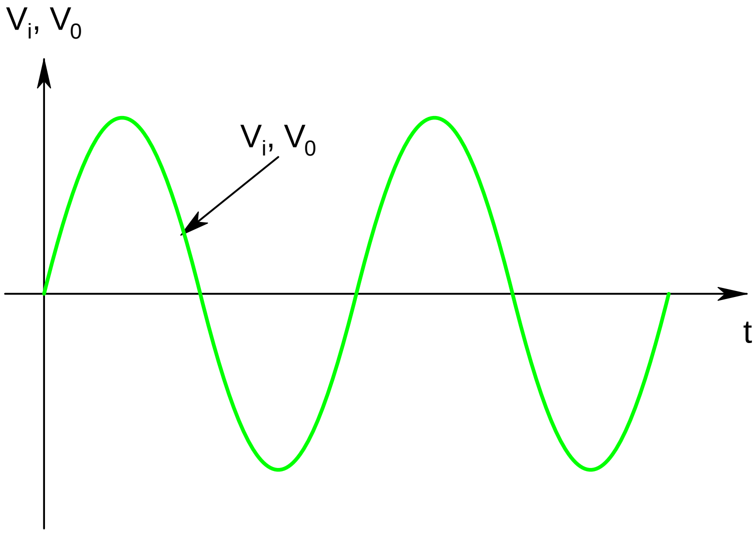
  $\Rightarrow$ ***Transistors*** in the ***differential input stage*** act as ***switches***
- Under ***unity feedback***, V_0 would ***follow*** V_i

  $\Rightarrow dV_0/dt = dV_i/dt = V_M \omega \cos(\omega t)$
- The ***maximum value*** of this ***derivative*** occurs when $\omega t = n\pi$ $(n = 0, 1, 2, \ldots)$

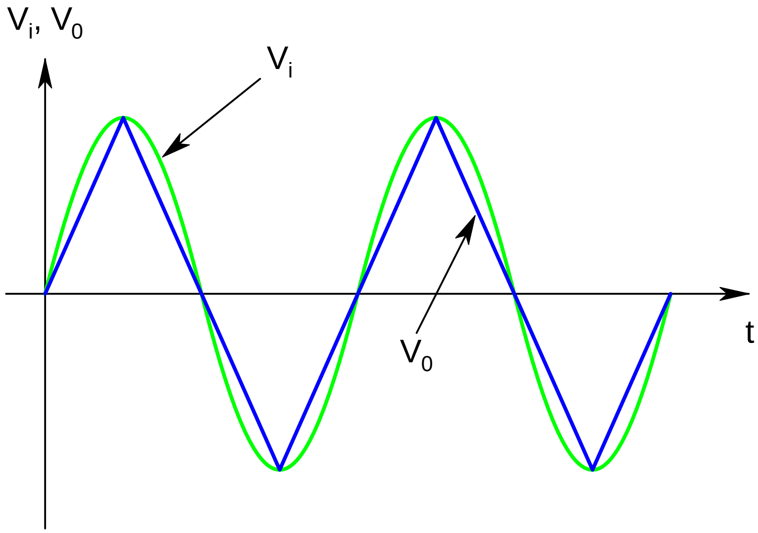
  $\Rightarrow$ It occurs when the ***signal crosses zero***
- So long as ***this rate*** remains ***smaller*** than SR, V_0 would ***follow*** V_i with ***fidelity***

- However, as soon as ***dV_0/dt becomes $\geq$ SR***, V_0 ***won't be able to follow*** V_i anymore – rather, it would ***start to become triangular***
- ***Note***: $dV_0/dt\uparrow$ with an ***increase*** of ***either V_M or ω or both***

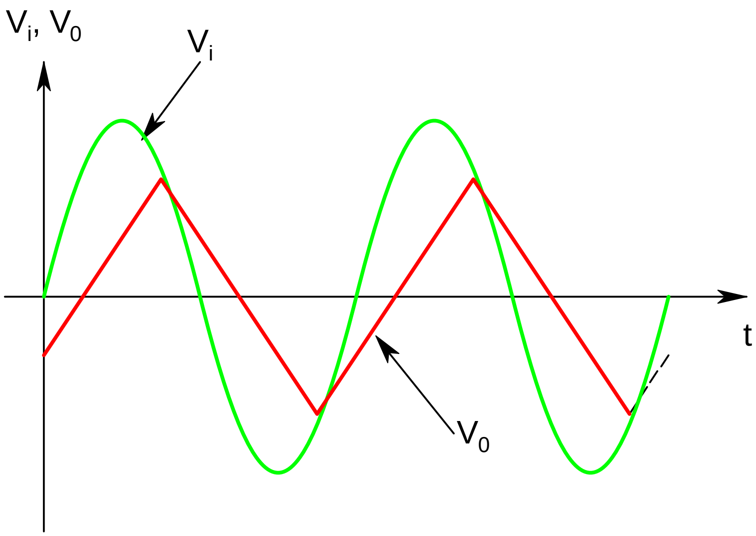
  $\Rightarrow$ ***What essentially matters is the product $V_M\omega$***
- If this ***product*** keeps on ***increasing*** beyond the SR, then V_0 remains ***triangular***, however, ***two major observations*** become apparent:
  - ❖ The ***zero crossings*** of V_0 ***do not quite coincide*** with those of V_i
  - ❖ The ***peak-to-peak swing*** of V_0 starts to become ***smaller*** than that of V_i due to V_0 ***not getting enough time*** to ***reach its maximum possible value***



Normal Behavior



Onset of Slew Rate Limitation



Severely Slew Rate Limited

- If $V_M\omega$ becomes ***very large***, then there ***may not be any output at all***

  $\Rightarrow$ V_0 would ***become zero***, implying that the op-amp is ***not able to keep up with the variation*** of V_i at all!

- ***Mathematical Description***:
  - Let the ***gain*** of the op-amp = A

    $\Rightarrow$ $(dV_0/dt)_{max} = AV_M\omega$
  - This must be ***less*** than the SR of the op-amp to get a ***distortion-free output***
  - ***Maximum possible value*** of $AV_M = V_{SAT}$

    $\Rightarrow$ The ***maximum allowed value*** of ω ($= \omega_M$) of V_i for V_0 to be ***without any distortion*** due to ***slew rate limitation***:

    $$\omega_M = SR/V_{SAT}$$

- This is an ***extremely important relation***, and ω_M is referred to as the ***full-power bandwidth***
- It is a ***constant*** for a given op-amp
- This ***derivation*** is for V_0 ***swinging*** between $\pm V_{SAT}$
- If the ***swing*** of V_0 is ***less*** than this, then ω can be ***increased*** beyond ω_M, following the ***relation***:

$$SR = \omega_M V_{SAT} = \omega_0 V_0 = \omega_0 A V_i$$

ω_0: ***Frequency till which V_0 won't have any slew rate limited distortion***

$\Rightarrow$ ***Maximum amplitude*** of V_i (of ***frequency*** ω_0), beyond which ***slew rate limited distortion*** would ***set in at the output***:

$$V_{i,max} = \omega_M V_{SAT}/(\omega_0 A)$$


"That's all Folks!"