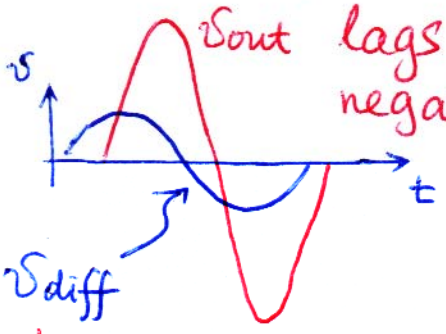
Lecture 5

Op-amp characteristics

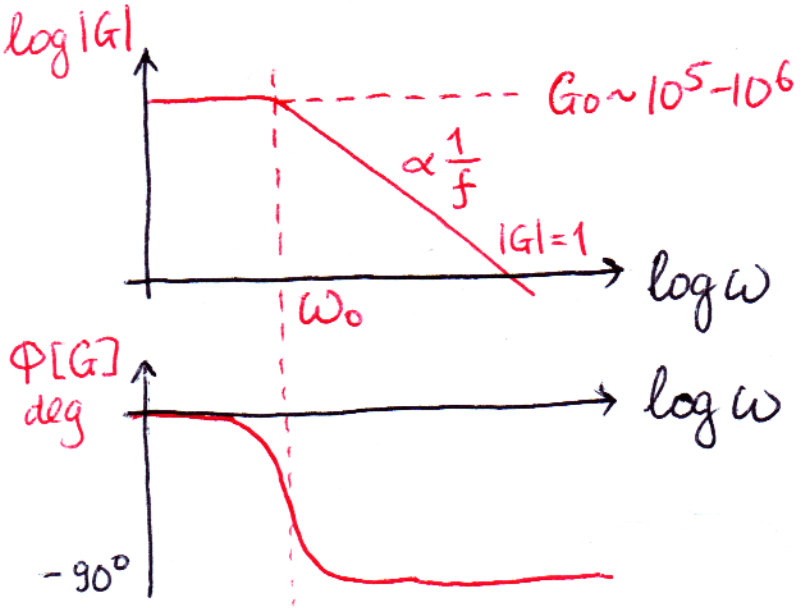
Gain very high DC (10^5–10^6), rolls off at higher f

complex gain : $G = \frac{v_{out}}{v_{diff}}$. AC sine : amplitude & phase



v_{out} lags, => negative phase

$v_{diff} \equiv v_+ - v_-$



Typically

$$G = \frac{G_0}{1 + j\frac{\omega}{\omega_0}}$$

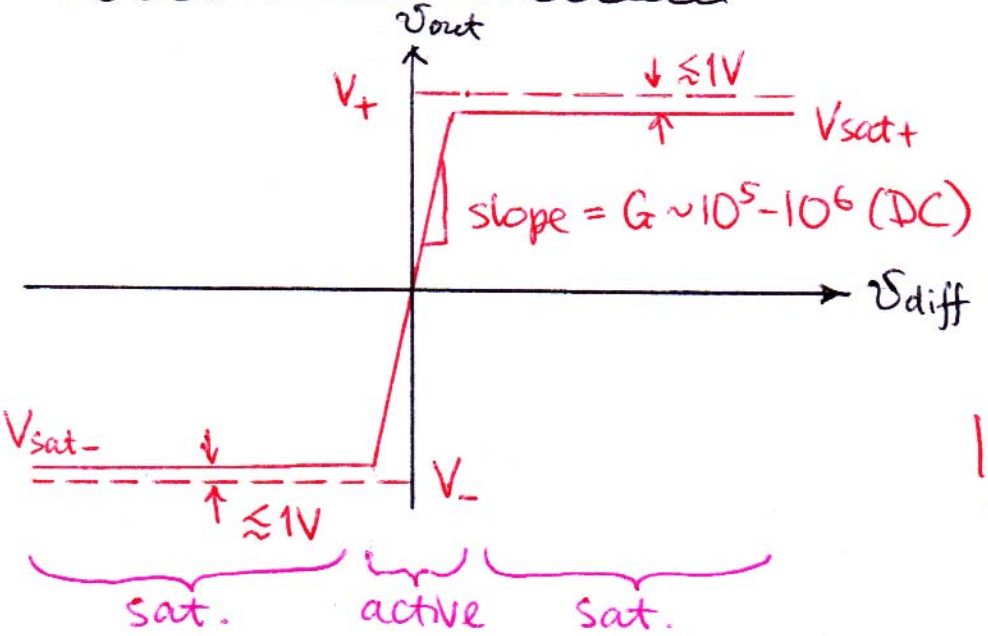
Unity gain bandwidth

$$|G(\omega_{BW})| = 1$$

- 1MHz – 741
- 4.5MHz – 3140

– such 1/f roll-off of gain = internally compensated op-amps, stable behavior with most (not all!) configurations of passive elements connected between output & inputs

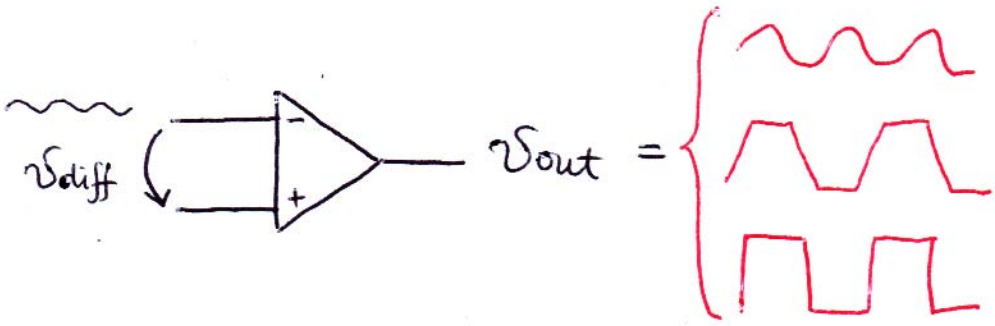
Transfer characteristic



Q: $v_{diff} = 1V$, $v_{out} \sim 1MV$??

A: no, it saturates

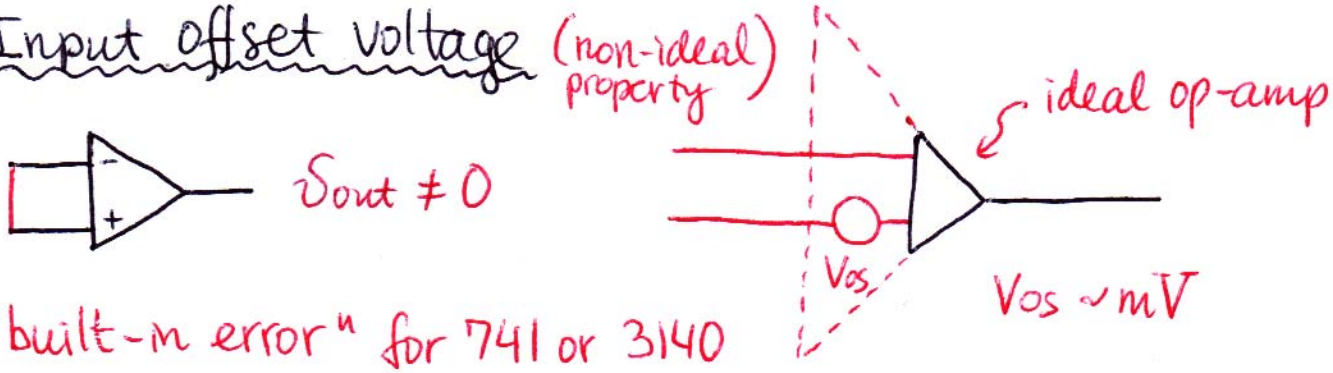
$|V_{sat+,-}| < |V_{+,-}|$ typically by a fraction of 1V



- bare op-amp is a lousy amplifier

  WK4: need negative feedback to build stable amplifier for small voltages

Input offset voltage (non-ideal property)

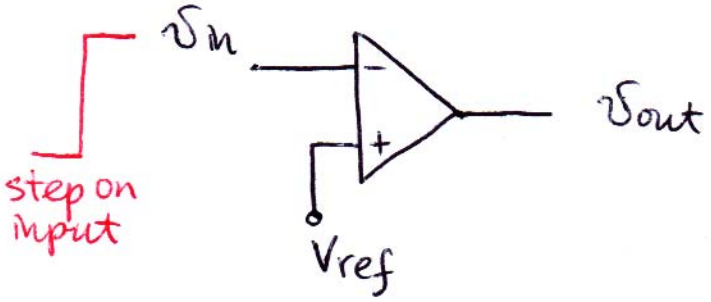


"built-in error" for 741 or 3140

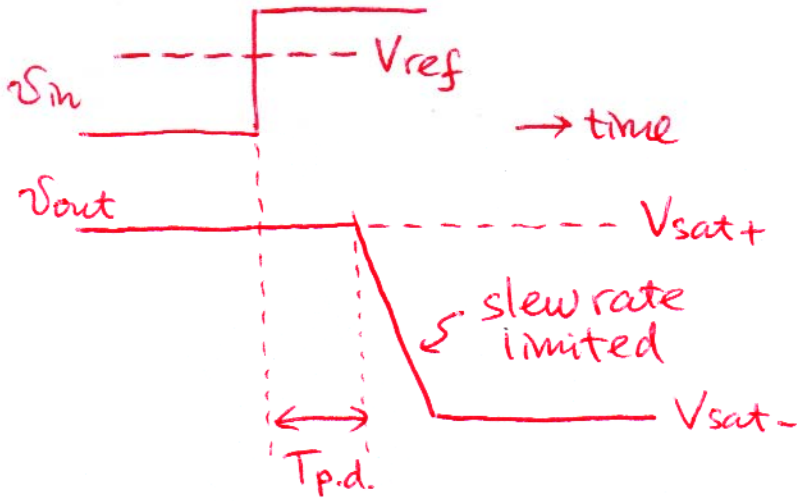
$$v_{out} = G(v_+ + V_{os} - v_-)$$

can be cancelled, see spec. sheets.

Slew rate & propagation delay (more non-ideal properties) ③



$\frac{dv_{out}}{dt}$ = slew rate



typical S.R.

- 0.5 V/μs 741
- 9 V/μs 3140

$T_{p.d.}$ ~ 100 ns or so (?)

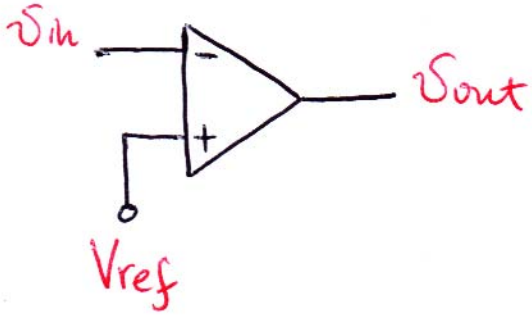
Ideal op-amp (exists in textbooks)

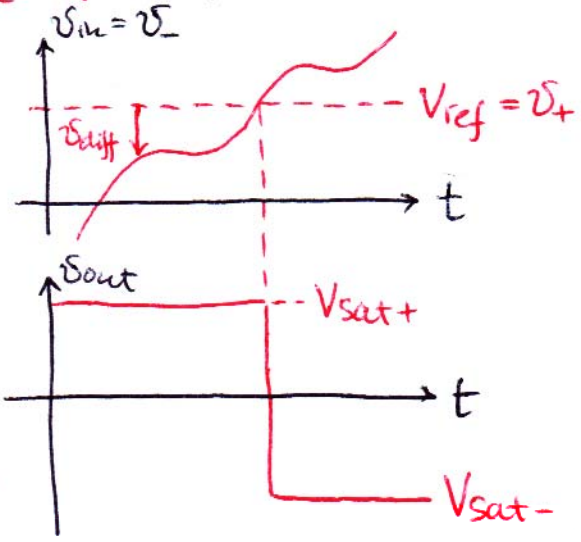
1) input draw no current ($R_{in} \to \infty$) "op-amp current rule"
2) output resistance is 0
3) $V_{sat+} = V_+$, $V_{sat-} = V_-$ } equal to supply rails values
4) $G \sim \infty$
5) $V_{os} \to 0$, S.R. $\to \infty$, $T_{p.d.} \to 0$

- always start with ideal op-amp, then apply non-ideal properties as small perturbations.

Op-amp circuits

Comparator (assume $G \sim \infty$)





$v_{in} < V_{ref}$, $\Rightarrow v_{out} = V_{sat+}$

$v_{in} > V_{ref}$, $\Rightarrow v_{out} = V_{sat-}$

analog signal in = continuously varying v_{in}

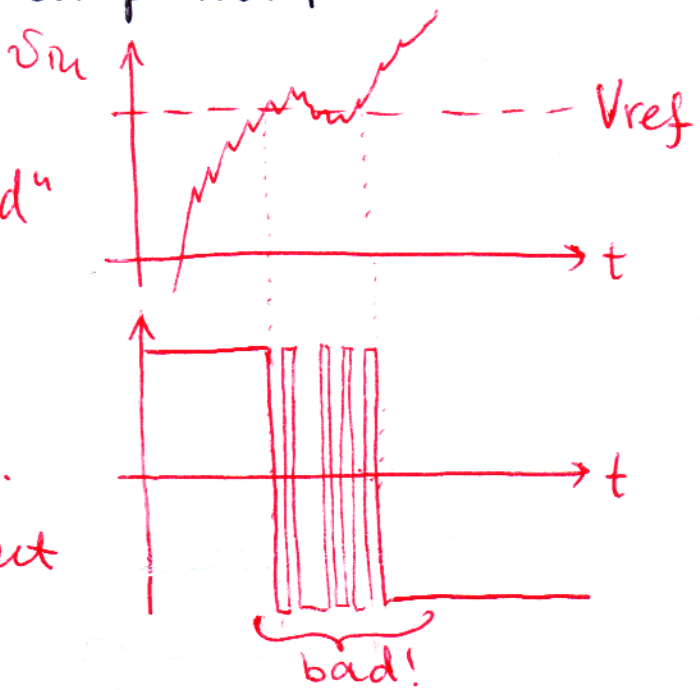
digital signal out = two discrete values only

- comparator = simplest 1-bit ADC

Analog to Digital Converter

(more in Ch. 12)

problems with comparator



simple comp. does not "understand" noise.

soln.: use positive feedback, i.e. change V_{ref} with v_{out}

→ Schmitt trigger