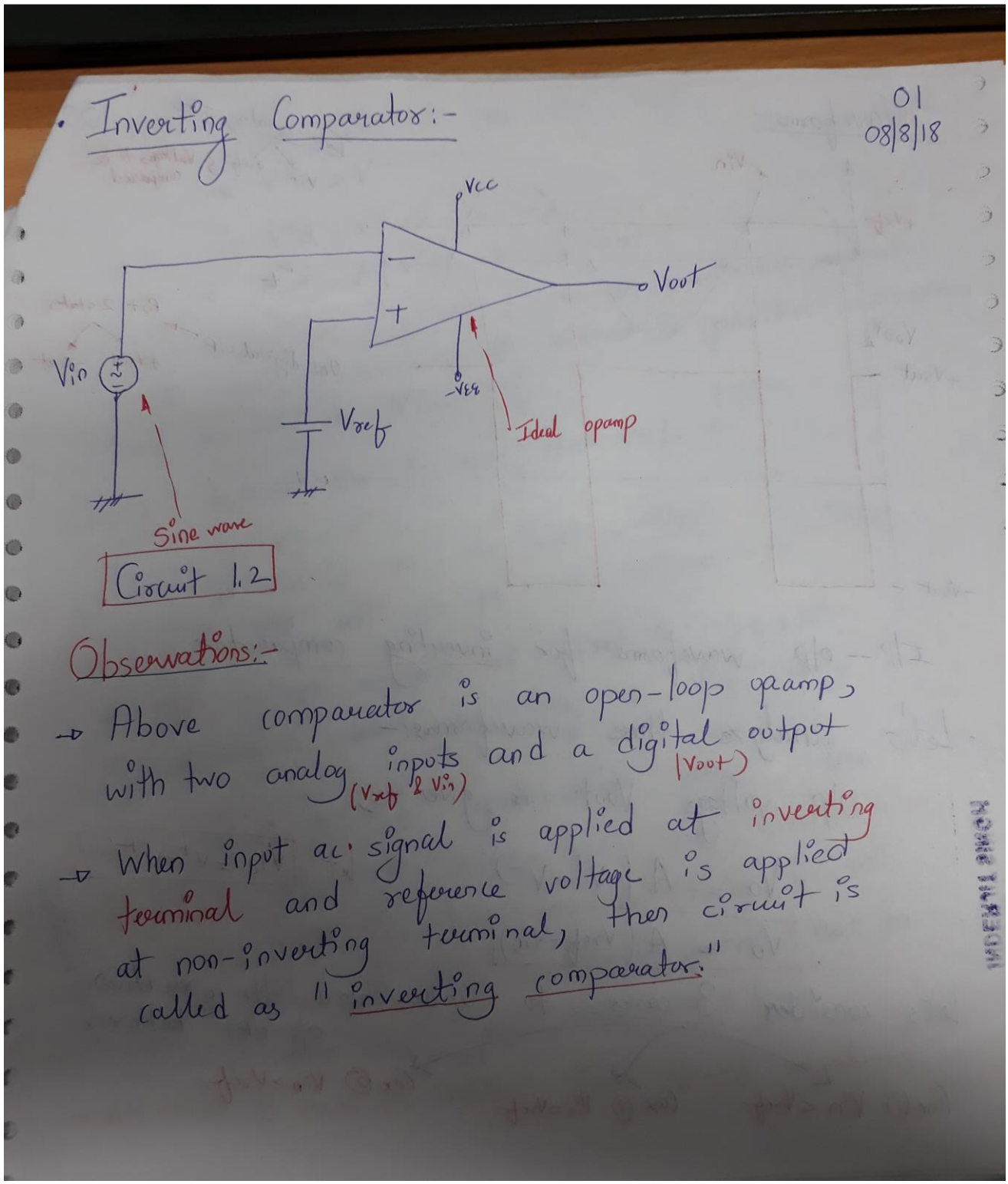
LICD lecture 13 dated 07-08-2018

Topics Covered: Inverting comparator: working + input-output waveforms + transfer characteristics, a look at practical comparator circuit, comparator bounded output using zener, Negative Vs Positive feedback, Analogy of a bowl and a marble, Application of a Comparator: Zero crossing Detector (ZCD), Limitation of ZCD



• Inverting Comparator:-

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Circuit 1.2

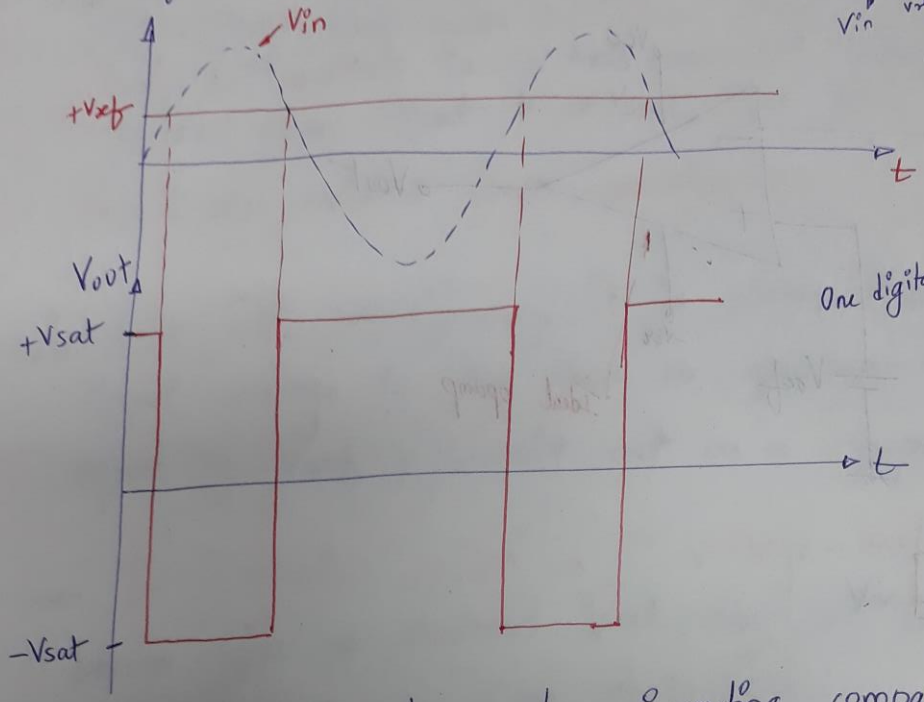
Observations:-

→ Above comparator is an open-loop opamp, with two analog inputs (Vref & Vin) and a digital output (Vout)

→ When input ac signal is applied at inverting terminal and reference voltage is applied at non-inverting terminal, then circuit is called as "inverting comparator."

Waveforms:-

Two analog I/ps: V_{in}, V_{ref} } Voltages to be compared



But 2 states

One digital o/p → +Vsat, -Vsat

I/P – o/p waveforms for inverting comparator

- Let's analyze these waveforms:-

o/p voltage Vout is given as,

let $V_{id} = V^+ - V^-$

$$V_o = A(V^+ - V^-)$$

$$V_o = A(V_{ref} - V_{in})$$

Let's consider 3 cases, to understand the operation of ckt better.

Case ① $V_{in} < V_{ref}$

Case ② $V_{in} > V_{ref}$

Case ③ $V_{in} \approx V_{ref}$

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Case ①:- When V_{in} is less than V_{ref},

ie $V^+ > V^-$

ie $V_{id} = V^+ - V^- \approx +ve$

ie $V_{out} = A(V_{id}) \rightarrow +V_{sat}$.

ie $\boxed{V_{out} = +V_{sat}}$ → o/p goes to +ve saturation

→ o/p voltage remains at $+V_{sat}$ ie positive saturation level as long as $V_{in} < V_{ref}$.

Case ②: When V_{in} is more than V_{ref},

ie $V^+ < V^-$

ie V_{id} is -ve ⇒ $\boxed{V_{out} = -V_{sat}}$

ie o/p will go to +ve saturation.

→ o/p voltage remains at $-V_{sat}$ ie negative saturation level as long as $V_{in} > V_{ref}$

Case ③:- When V_{in} is approaching very close to V_{ref}, then the o/p voltage V_{out} ⇒ switches from one saturation level to another ie in this case the o/p V_{out} switches from $+V_{sat}$ to $-V_{sat}$ and then from $-V_{sat}$ to $+V_{sat}$.

→ All these 3 cases are evident from I/P-O/P waveforms

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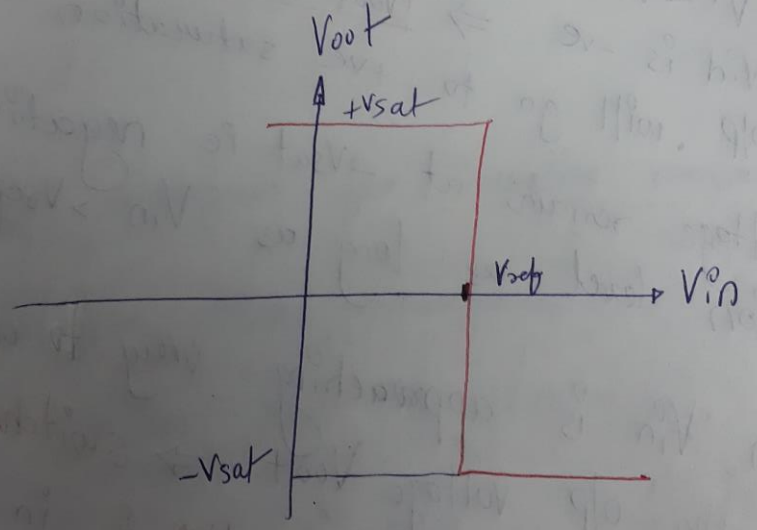
∴ from o/p waveforms, it is clear that, whether input is less than or greater than or equal to V_{ref}, circuit act as a comparator.

→ It is also called as "Voltage-level detector", because for a desired level of V_{ref}, the voltage level of V_{in} can be detected.

• Let's draw the transfer characteristics



VTC curve for ideal inverting comparator

Let's walk through a Practical Comparator ckt:-

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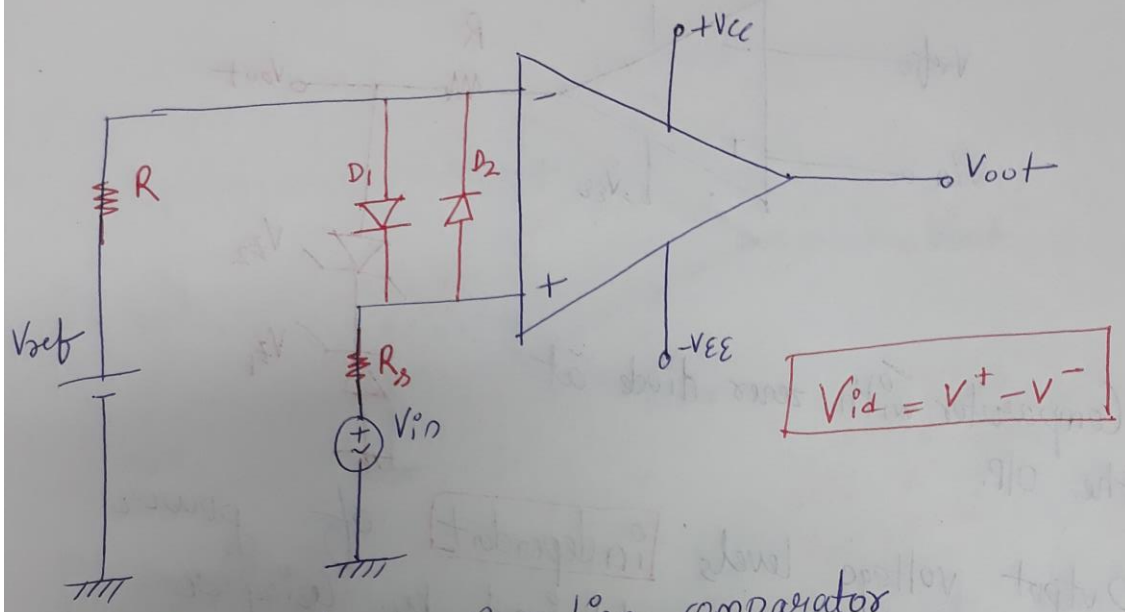


Circuit: Practical non-inverting comparator

- Diodes D_1 and D_2 and resistance R & R_s are used to protect the input terminal of opamp.
- Due to diode D_1 & D_2, the terminal of opamp will be at the most of $\pm 0.7V$ ie $V_{id} = \pm 0.7V$, whatever the value of input voltage.
- The excess input voltage appears across resistance R_s and R.
- Resistor R is also used to reduce the offset problem.

* Comparator bounded o/p using zener diodes:-

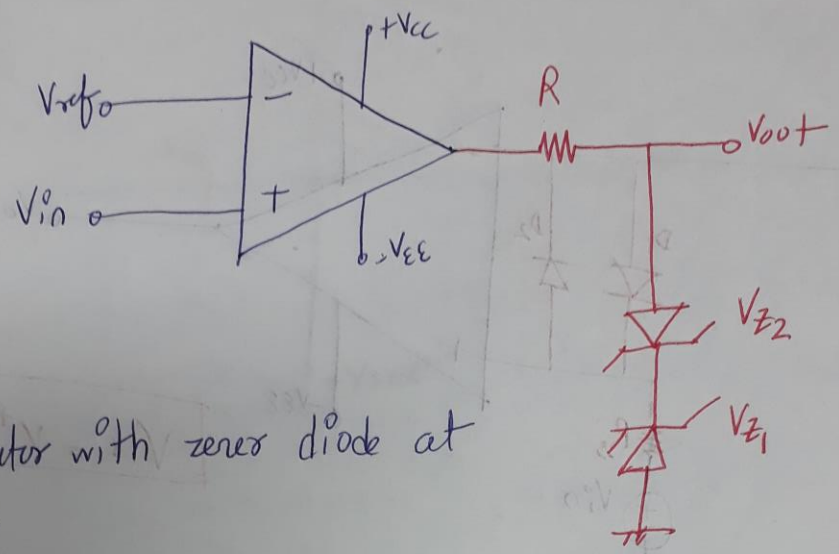


fig:- Comparator with zener diode at the o/p.

→ Output voltage levels independent of power supply can also be obtained by using a resistor R and two back to back zener diodes at the output of opamp.

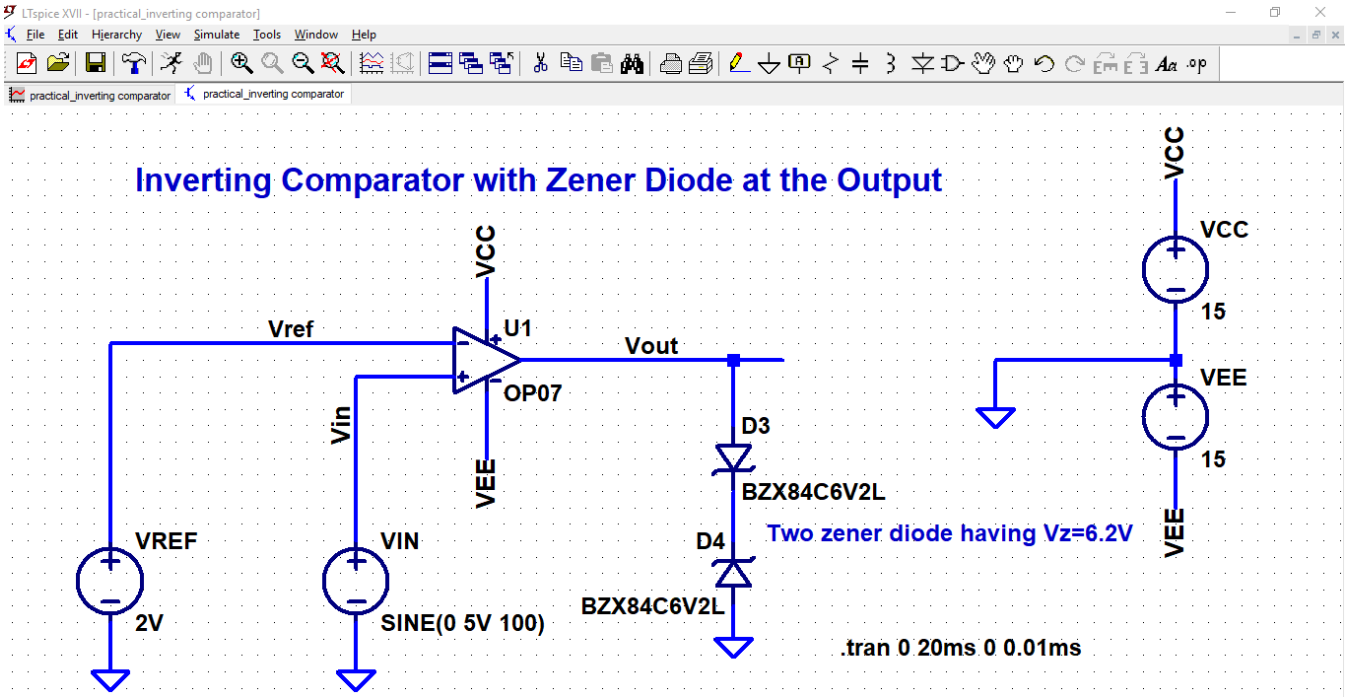
→ Value of R is chosen so that zener-diode operate at the recommended current.

→ It can be seen that the limiting voltages of Vout are $(V_{Z_1}+V_D)$ and $-(V_{Z_2}+V_D)$ where, V_D (~0.7V) is the diode forward voltage.

Simulation was carried out in LT Spice and simulation results were NOT discussed in class

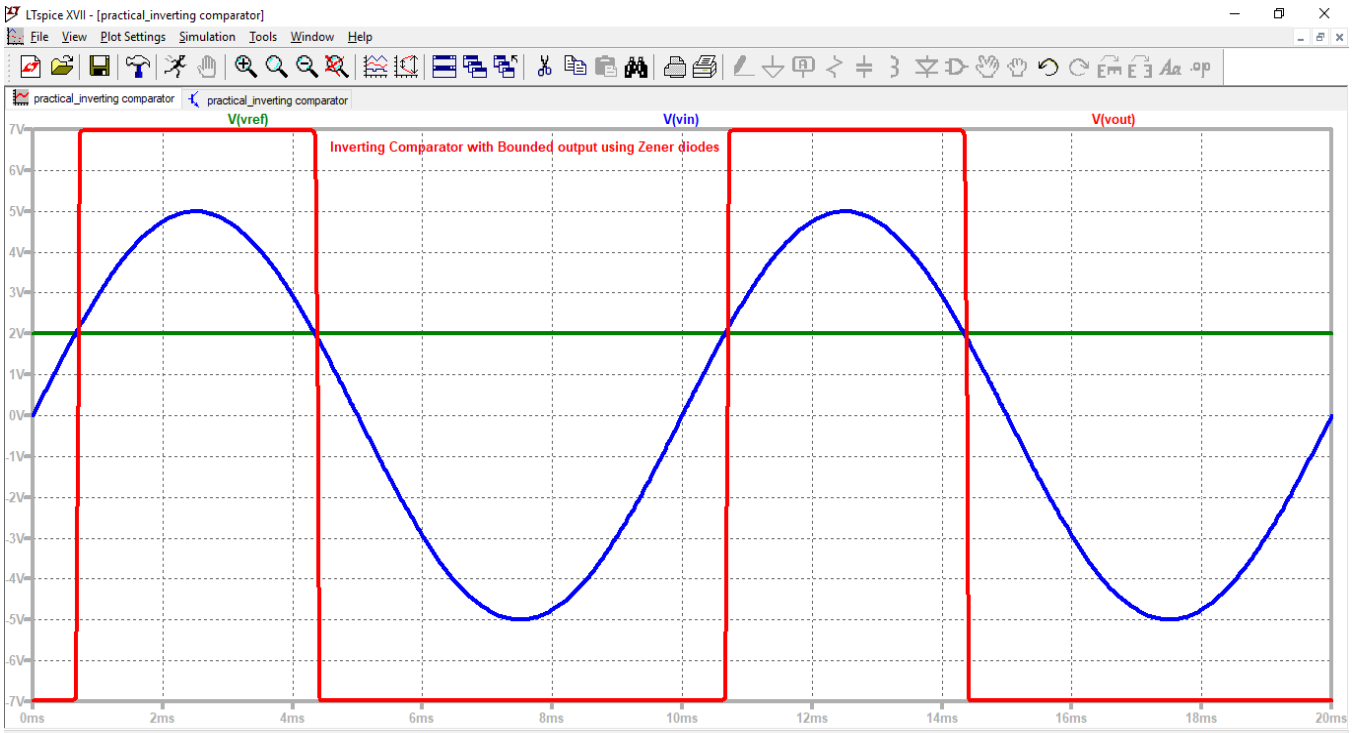
Topics: Inverting Comparator using Opamp with Vref= 2V and Vin is a sine wave of 5V peak, 100Hz and with bounded output:

For bounded outputs, two zener having 6.2V rating are used

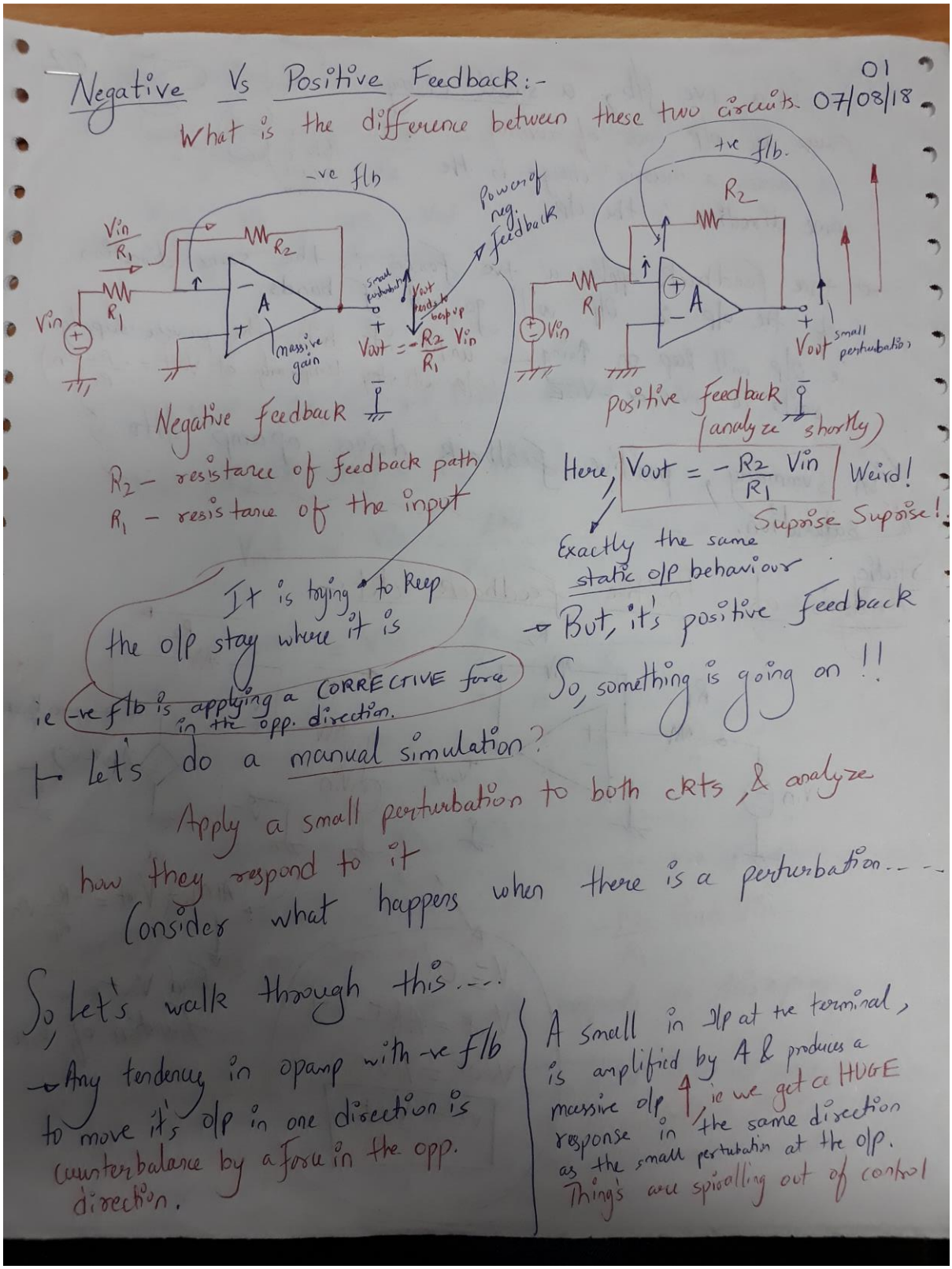


Vout is having positive max (6.2V + 0.7V) and negative max of – (6.2V + 0.7V)

Output waveforms are bounded between +7V and -7V



Negative Vs Positive Feedback



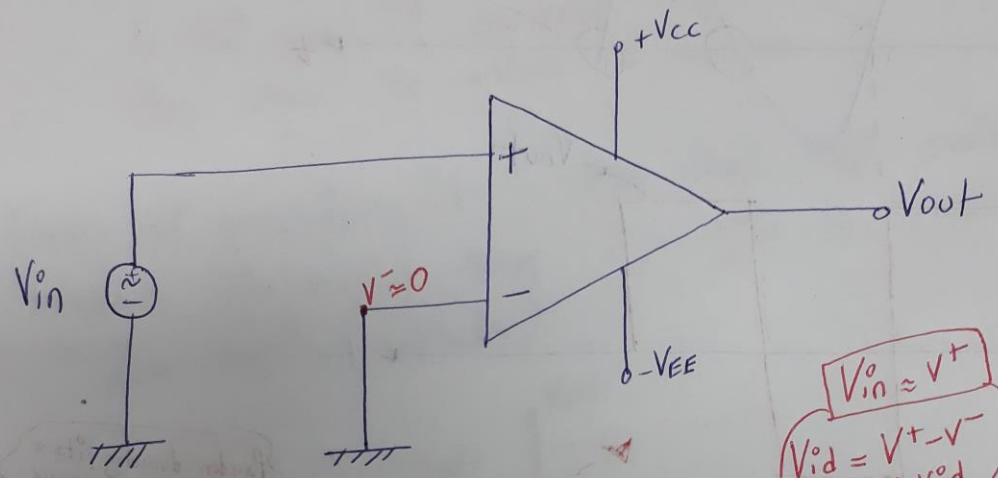
- So in a +ve f/b, a small change cause the o/p out-of-control → (like a spiral storm)
  ie causes a massive change in the same direction in the o/p.

→ +ve feedback applies a +ve force in the same direction of the o/p ie o/p will go out of bonds.
ie o/p will keep on ↑sing → until it hits the power supply rails ie +Vcc or -VEE (o/p will stay temporarily at $V_{out} = -\frac{R_2}{R_1} V_{in}$)

In summary, positive feedback drives opamp into saturation.

• Comparator Applications :-

↳ Zero Crossing Detector



$V_{in} \approx V^+$

$V_{id} = V^+ - V^-$

$V_{out} = A\,V_{id}$

Observations:-

1. V_{in} ie input voltage is applied at the non-inv^r terminal and inverting terminal is grounded.
2. o/p voltage V_{out} is given as,

$$V_{out} = A V_{id}$$
$$= A(V^+ - V^-)$$
$$\therefore V_{out} = A[V_{in} - 0] = A V_{in}$$

let's consider the 3 case to explain the operation of this circuit :-

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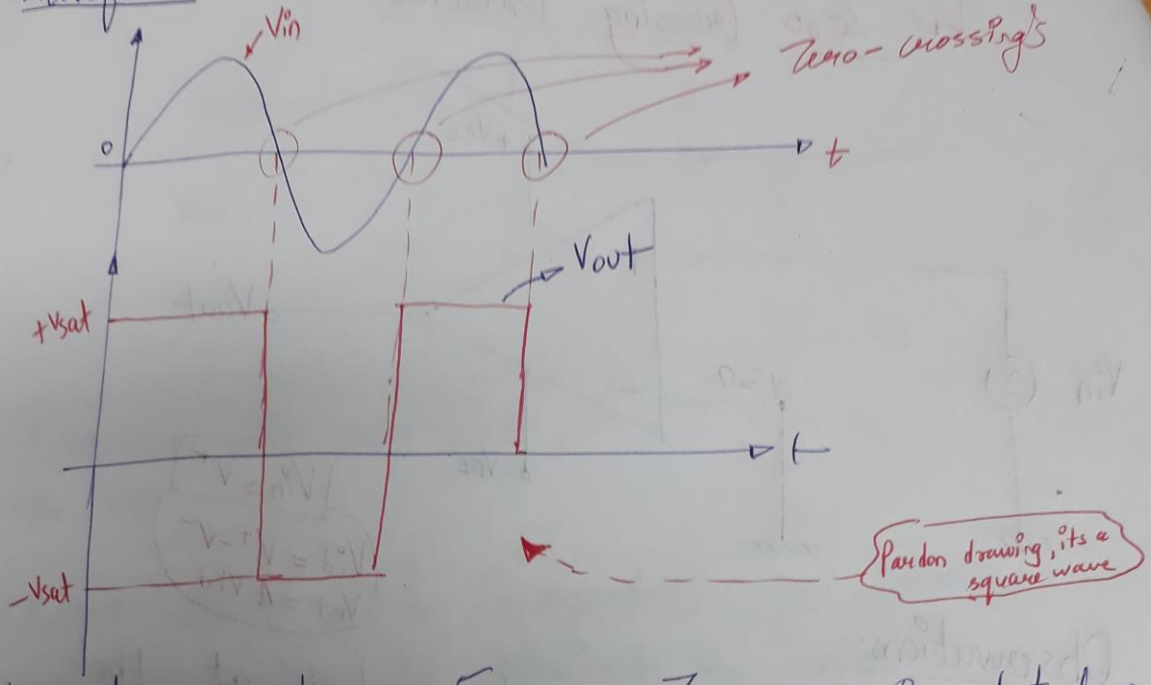
Waveforms:-



I/p - o/p waveforms for a Zero-crossing detector

Case ①:- When V_{in} is more than zero, then $V_{id} > 0$, ie $V^+ > V^-$.

∴ o/p voltage V_{out} is at positive saturation level

ie $\boxed{V_{out} = +V_{sat}}$

Case ②:- When V_{in} is less than zero, then $V_{id} < 0$, ie $V^+ < V^-$

∴ o/p voltage V_{out} is at negative saturation level.

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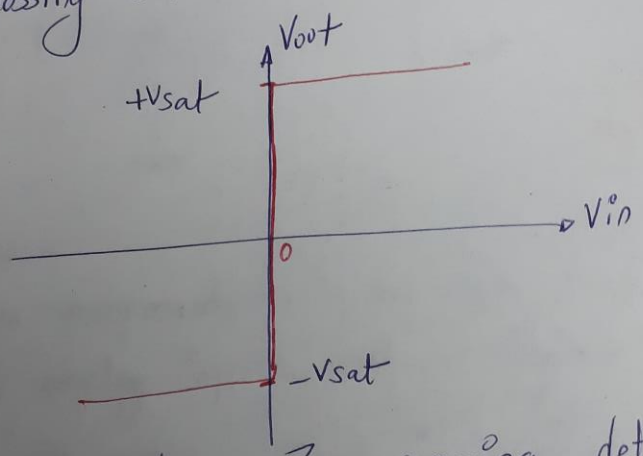
Case 3:- When Vin is equal to zero, then o/p switches from one saturation level to another. in this case, it switches from +Vsat to -Vsat & then -Vsat to +Vsat & so on

From o/p waveforms, it is clear that o/p switches wherever Vin crosses zero. ∴ It is called as "Zero-crossing detector."



Transfer curve for Zero-crossing detector.

Applications:-

1. It is used for converting a sine wave to a square wave
2. It is used to detect whether input voltage is less than or greater than zero.

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• Response to small disturbance to V_o (noise)

) Stable situation (equilibrium) (like in a negative f/b)

Move marble → it will graviate back to stable state.

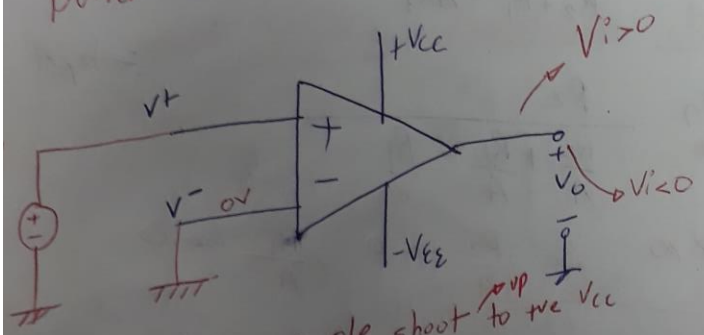
) Unstable situation (equilibrium) (like in a +ve f/b)

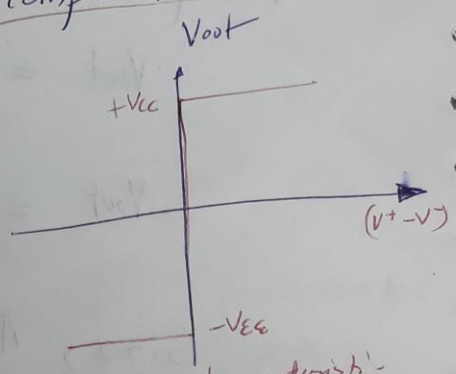
marble sitting up here → No noise/disturbance, marble will sit at the tip forever (stay)

marble will be going either to left-hand side or Right hand side.

Opamp: One use for instability: –

Build on the basic opamp as a comparator



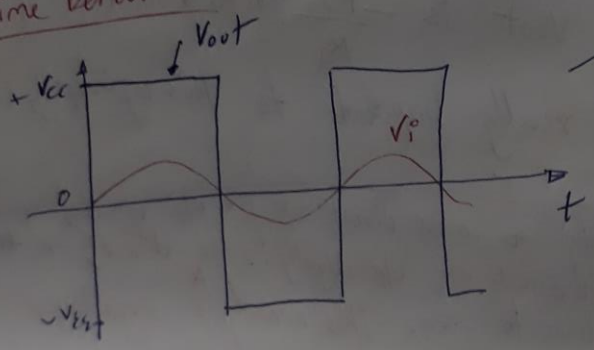


Transfer characteristic

$V_i = V^+ > 0 \Rightarrow$ o/p shoot up to +ve Vcc

$V_i = V^+ < 0 \Rightarrow$ o/p shoot down to -ve VEE

Time behavior:-



oh that's a comparator.

Lots of uses

1) It tells us whether i/p is +ve or -ve.

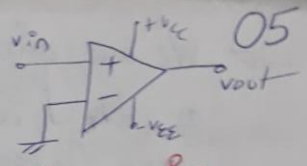
2) It is also used to take an analog & turn that into 1bit digital value

3) Act as Zero-crossing detector.

Limitation of Zero-crossing Detector (Comparator)

Opamp Comparator:- 05

Issues with a comparator like this is that

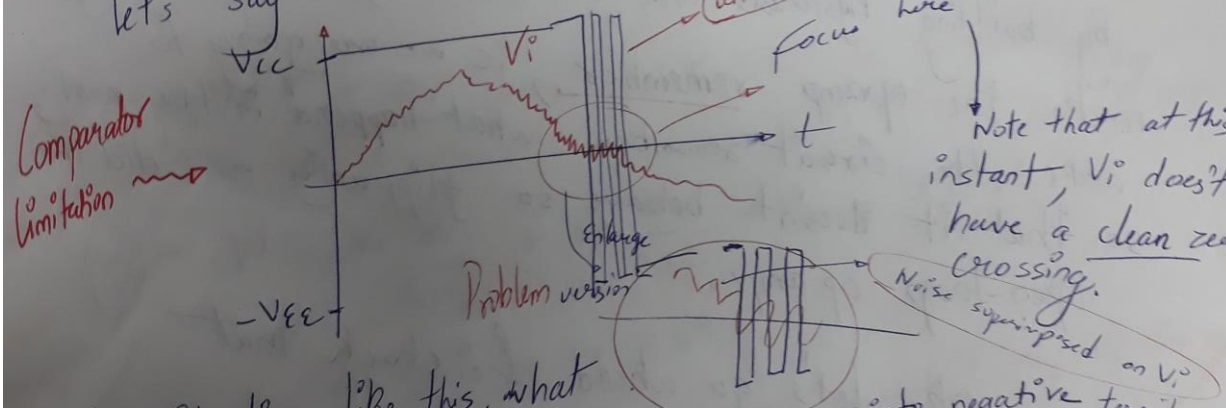


Zero-crossing detector

It has the unfortunate property that small perturbations, or small noise imposed at the input, can cause weird, unexpected behavior, which don't want.

This is NOT good
It's a problem

let's say the I/p looks as follows



Note that at this instant, Vi doesn't have a clean zero crossing.

· In situations like this, what really happens?

As we make the crossing into negative territory, Vout is going down to -Vee, But then, becoz of noise, my input crossed back up, I'm going to have a bounce back up to +Vcc in the o/p. & then, becoz it crossed back down, & bounced back up & then finally, its settle's at -Vee (-Vsat)

So, the part where the signal is crossing the zero line, the o/p is going to go bouncing back and forth, becoz of all those crossings