



ECEN 4013
Design of Engineering Systems

Agenda

Project 1 Questions
4024 Materials
New Sprint
Schmitt Triggers



Project 1

- Questions?
- It is now the first week of Sprint 2.

ECEN 4024 Materials


Throughout the semester I will provide presentation videos and slides for teams in 4024 so that you can get a feel for what is expected of you. Also, it helps to have knowledge of the projects because some of them are multi-semester, and you might find yourself

New Sprint

Project 1  In progress

  **New sprint** 


Sprint 1  In progress 24/08 30/08 Velocity 0 / 5

Stop the sprint 

Effort 5 | Value 99 1
do the thing
 1
In progress







New Sprint

Stop the sprint 

You are about to stop the sprint. **Be careful**, its content and dates will **become read-only**!

The stories checked in the list below will be marked as **Done**. The rest will be switched to the next sprint if it exists or to the backlog otherwise.

Story	Done
<div><div>1</div><div>do the thing</div><div>Effort 5 Value 99</div></div> <div> 0  0  0  1</div> <div>1/1 In progress</div>	<input type="checkbox"/>

Cancel

Stop the sprint

All completed stories will be moved to the "done" section of the backlog. Stories not finished will be moved to the next sprint.

New Sprint

This screenshot shows the Jira interface for 'Project 1' in the 'Planning' tab. The top navigation bar includes 'Project 1', 'Dashboard', 'Backlogs', 'Planning', 'Task board', and 'Features'. A search bar and user avatars are on the right. Below the navigation bar, 'Project 1' is shown as 'In progress'. A 'New sprint' button is circled in red. Below this, 'Sprint 1' is listed as 'Done' with dates '24/08' and '30/08' and a velocity of '0 / 5'. A 'Reactivate the sprint' button is visible on the right.

Project 1 In progress

Sprint 1 Done 24/08 30/08 Velocity 0 / 5

New sprint

Reactivate the sprint

This screenshot shows the Jira interface for 'Release 1' in the 'Planning' tab. The top navigation bar is similar to the previous one. Below, 'Release 1' is shown as 'In progress'. Two sprint cards are visible. 'Sprint 2' is 'Todo' with dates '07/09' and '13/09' and a planned velocity of 3. It contains a yellow story card labeled 'another story' with 'Effort 3 | Value 30' and 'Planned'. The 'Activate the sprint' button is circled in red. 'Sprint 3' is also 'Todo' with dates '14/09' and '20/09'. It contains a message: 'There is no story planned into this sprint. Plan estimated stories from the backlog or move a story from another sprint.' and a 'Plan' button. At the bottom, a timeline shows dates from 'Tue 31' to 'Sep 19' with three numbered segments (1, 2, 3) representing different periods.

Release 1 In progress

Sprint 2 Todo 07/09 13/09 Planned velocity 3

Effort 3 | Value 30
another story
Planned

Activate the sprint

Sprint 3 Todo 14/09 20/09

There is no story planned into this sprint. Plan estimated stories from the backlog or move a story from another sprint.

Plan

1 2 3

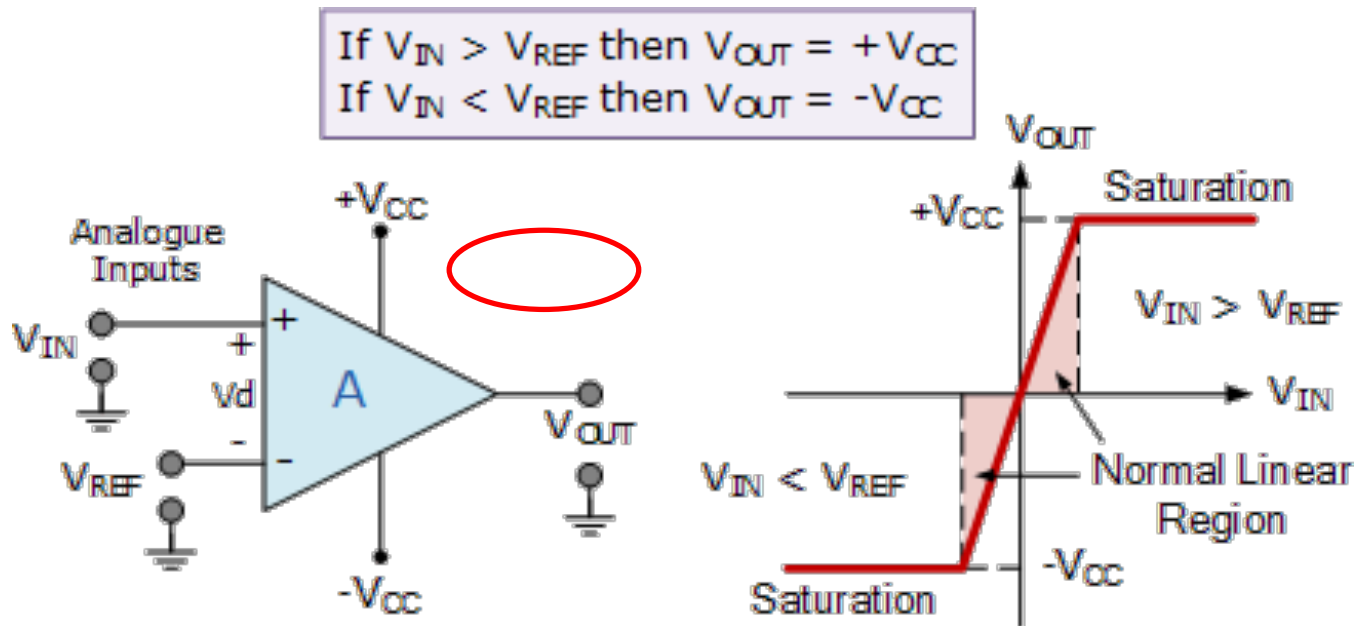
Tue 31 September Fri 03 Sep 05 Tue 07 Thu 09 Sat 11 Mon 13 Wed 15 Fri 17 Sep 19

New Sprint

The screenshot displays the Jira web interface. At the top, the navigation bar includes 'Dashboard', 'Backlogs', 'Planning', 'Task board', and 'Features'. The 'Backlogs' tab is active, showing a backlog with two items: 'final story' (Effort 8, Value 50) and 'the thing for sprint 2' (Effort 5, Value 87). The 'the thing for sprint 2' item is highlighted. On the right, the 'New story' modal is open for the selected item. The modal has tabs for 'Details', 'Comments', 'Tests', and 'Tasks'. The 'Details' tab is active, showing a description field, 'Feature' dropdown (No associated feature), 'Depends on' dropdown (No dependence), 'Tags' field (No tags), 'Effort' dropdown (5), 'Value' dropdown (87), and 'Notes' field (No notes). The 'Sprint' dropdown menu is open, showing 'No sprint', 'release 1', 'Sprint 2' (highlighted), and 'Sprint 3'. The 'Sprint 2' option is circled in red. At the bottom right of the modal are 'Cancel' and 'Update' buttons. In the top right corner of the Jira interface, there is a search bar and a user profile icon (TU) circled in red.

Schmitt Trigger

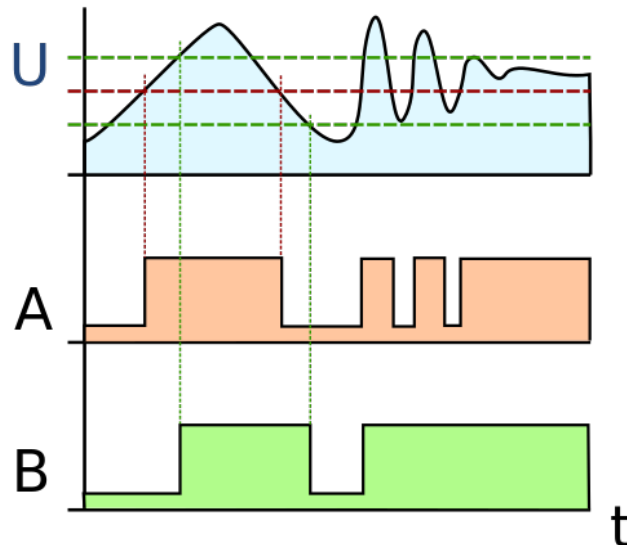
Basic Op amp Comparator



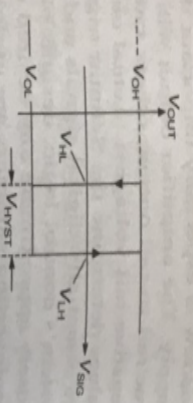
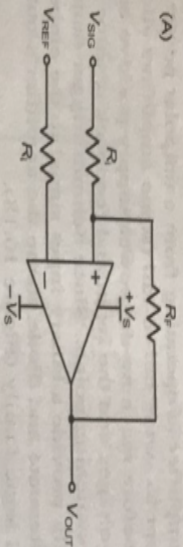
What happens at the decision boundary?

Schmitt Trigger

- Why are Schmitt Triggers used?
 - The hysteresis loop is beneficial. There are two thresholds, a low to high and a high to low. This effectively reduces noise in the stage where you are very close to your decision line



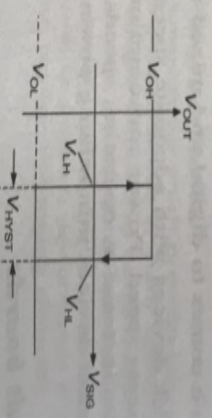
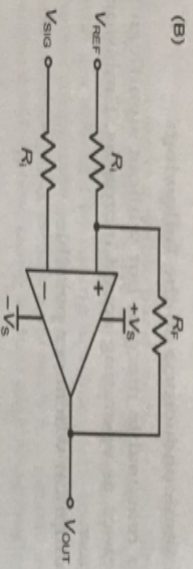
Schmitt Trigger



$$V_{LH} = V_{REF} \left(\frac{R_i + R_F}{R_F} \right) - \left(\frac{R_i}{R_F} \right) V_{OL}$$

$$V_{HL} = V_{REF} \left(\frac{R_i + R_F}{R_F} \right) - \left(\frac{R_i}{R_F} \right) V_{OH}$$

$$V_{HYST} = V_{LH} - V_{HL} = \left(\frac{R_i}{R_F} \right) (V_{OH} - V_{OL})$$



$$V_{HL} = \frac{1}{R_i + R_F} (R_F V_{REF} + R_i V_{OH})$$

$$V_{LH} = \frac{1}{R_i + R_F} (R_F V_{REF} + R_i V_{OL})$$

$$V_{HYST} = V_{HL} - V_{LH} = \frac{R_i}{R_i + R_F} (V_{OH} - V_{OL})$$

Figure 10.18: (A) and (B): Schmitt-trigger implementations.
 In (A), the reference voltage is applied to the noninverting input, whereas in (B) the reference voltage is applied to the inverting input. Notice the effect of output voltage on the switching voltages. This effect is especially pronounced when a unipolar power supply is used and $-V_S = 0$.

Derivation of Schmitt trigger relationships – form A

A Schmitt trigger has two possible output states and two switching points – one when the input signal is low and going high, the other when the input signal is high and going low.

The circuit is clearly nonlinear, but analysis can be done using techniques of conventional linear op amp analysis.

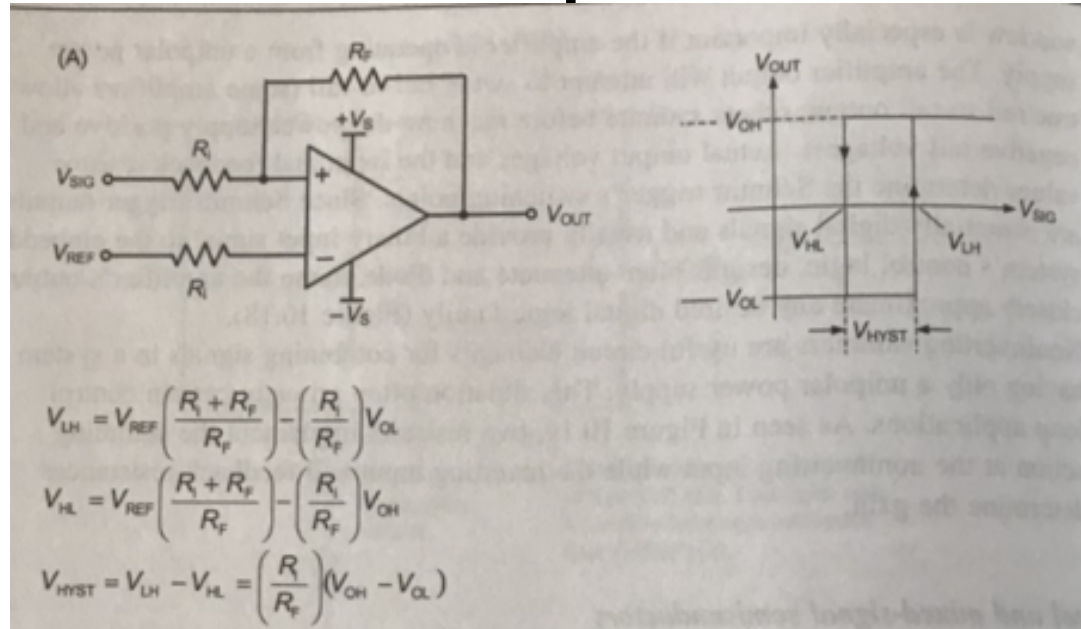
Derivation of Schmitt trigger relationships – form A

There are two inputs: the signal input and a voltage reference input.

The voltage reference is the approximate middle of the switching hysteresis loop.

*** The reference voltage will be the center of the loop if using a bipolar supply and an amplifier with rail-to-rail outputs.

Derivation of Schmitt trigger relationships – form A



The input signal is assumed to be approaching the threshold from the left – that is, negative and going positive.

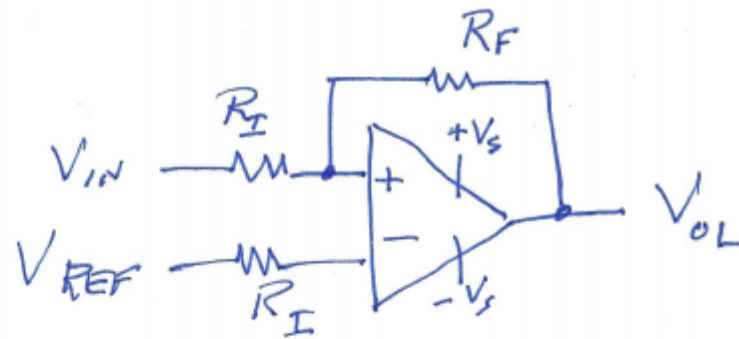
Derivation of Schmitt trigger relationships – form A

The amplifier will saturate positive when the noninverting input voltage exceeds the reference voltage present at the inverting input.

The amplifier will saturate negative when the reference voltage at the inverting input exceeds the voltage at the noninverting input.

Derivation of Schmitt trigger relationships – form A

Analysis of the two conditions and input node voltages are how we obtain the equations defining the switching points and the hysteresis window.



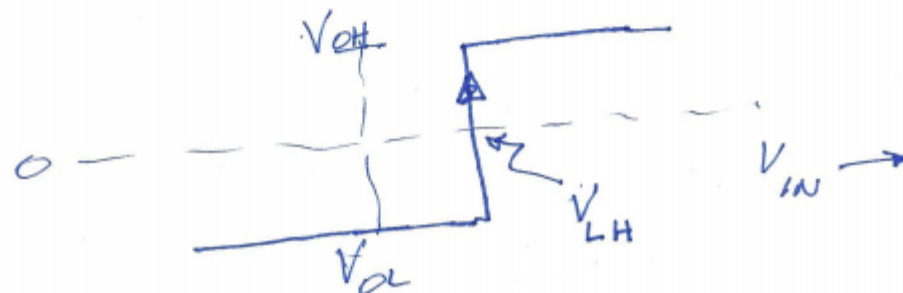
ASSUME

- (1) $V_{IN} \ll V_{REF}$, SO THE AMPLIFIER OUTPUT IS SATURATED LOW AT V_{OL} .

$$V_{OL} \approx -V_S$$

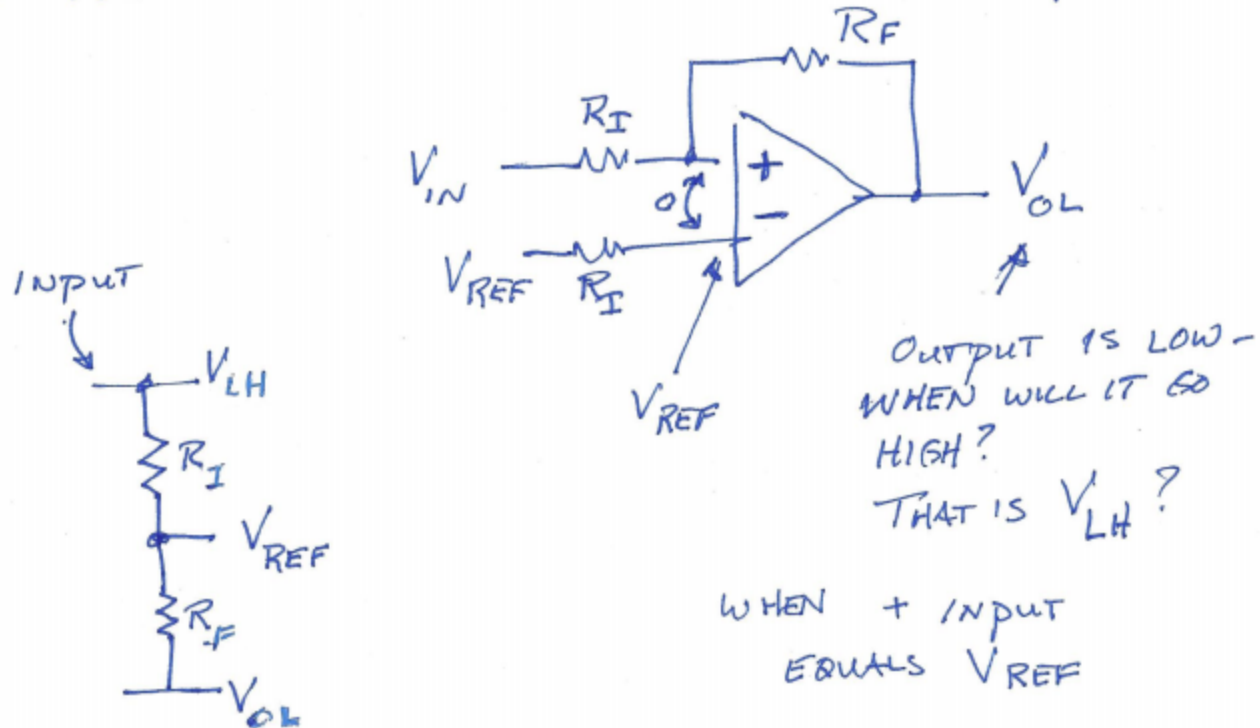
- (2) WE INCREASE V_{IN} UNTIL THE AMPLIFIER OUTPUT SATURATES HIGH AT $V_{OH} \approx +V_S$.

- (3) WHAT IS THE LOW-HIGH TRANSITION VOLTAGE V_{LH} ?



Schmitt trigger – form A

USE VOLTAGE DIVIDER AT NON-INVERTING INPUT



Schmitt trigger – form A

$$\begin{aligned} V_{REF} &= V_{OL} + \left(\frac{R_F}{R_I + R_F} \right) (V_{LH} - V_{OL}) \\ &= V_{OL} \left(1 - \frac{R_F}{R_I + R_F} \right) + \left(\frac{R_F}{R_I + R_F} \right) V_{LH} \\ &= \left(\frac{R_I}{R_I + R_F} \right) V_{OL} + \left(\frac{R_F}{R_I + R_F} \right) V_{LH} \end{aligned}$$

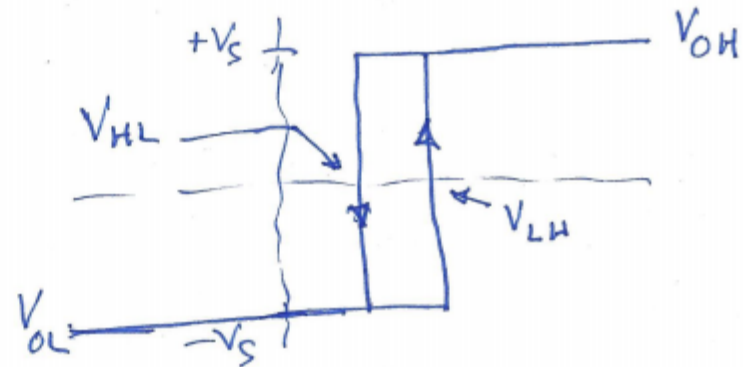
$$V_{LH} = \left(\frac{R_I + R_F}{R_F} \right) \left[V_{REF} - \left(\frac{R_I}{R_I + R_F} \right) V_{OL} \right]$$

Schmitt trigger – form A

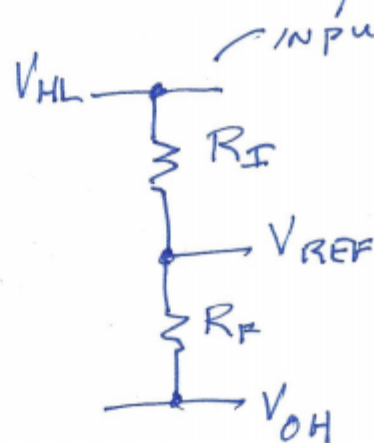
SOLVE FOR V_{LH} :

$$V_{LH} = \left(\frac{R_I + R_F}{R_F} \right) V_{REF} - \left(\frac{R_I}{R_F} \right) V_{OL}$$

Now FIND HIGH-LOW TRANSITION LEVEL V_{HL}
 when output is HIGH (V_{OH}) AND V_{IN} IS
 DECREASING



USE SAME VOLTAGE DIVIDER ANALYSIS



$$V_{REF} = V_{OH} + \frac{R_F}{R_I + R_F} (V_{HL} - V_{OH})$$

Schmitt trigger – form A

$$\begin{aligned} V_{REF} &= V_{OH} \left(1 - \frac{R_F}{R_I + R_F} \right) + V_{HL} \left(\frac{R_F}{R_I + R_F} \right) \\ &= \left(\frac{R_I}{R_I + R_F} \right) V_{OH} + \left(\frac{R_F}{R_I + R_F} \right) V_{HL} \end{aligned}$$

SOLVE FOR V_{HL} AS BEFORE!

$$V_{HL} = \left(\frac{R_I + R_F}{R_F} \right) V_{REF} - \left(\frac{R_I}{R_F} \right) V_{OH}$$

NOW FIND HYSTERESIS:

$$\text{LET } V_{\text{HYST}} = V_{\text{LH}} - V_{\text{HL}}$$

$$V_{\text{HYST}} = \left[\left(\frac{R_I + R_F}{R_F} \right) V_{\text{REF}} - \left(\frac{R_F}{R_I} \right) V_{\text{OL}} \right] \\ - \left[\left(\frac{R_I + R_F}{R_F} \right) V_{\text{REF}} - \left(\frac{R_F}{R_I} \right) V_{\text{OH}} \right]$$

↙ V_{LH}

↙ V_{HL}

$$V_{\text{HYST}} = \frac{R_I}{R_F} (V_{\text{OH}} - V_{\text{OL}})$$

Schmitt trigger – form A

Things to notice:

Resistor ratio of R_I to R_F is a large part of the hysteresis, but not all of it.

If $R_I = 10\text{ K}$ and $R_F = 10\text{ M}$, the hysteresis is 0.1% of the voltage difference between V_{OH} and V_{OL} .

Schmitt trigger – form A

V_{OH} and V_{OL} will equal the supply voltages only if the amplifier has rail-to-rail output. If not, you must use specified amplifier saturated output voltages.

Schmitt trigger – form A

These results are perfectly general. If the amplifier has a unipolar supply, then V_{OH} and V_{OL} will equal the positive supply voltage and zero Volts, respectively (if rail-to-rail output).

The reference voltage will be in the center of the hysteresis window only if V_{OH} and V_{OL} are equal in magnitude and opposite in sign.

Schmitt trigger – form A

Suggestions:

- 1) Assume outputs
- 2) Set V_{ref} at anticipated midpoint of the hysteresis window.
- 3) Select R_I and R_F based on anticipated output voltages and desired hysteresis window
- 4) Vary V_{ref} slightly to position the hysteresis window where you want it.

Derivation of Schmitt trigger relationships – form B

Reversing the input and reference voltages in the same structure gives the designer the flexibility to change the output switching and possibly eliminate the need for an additional inverter.

The analytical process is the same. The results are deceptively similar, but the two results are not the same.

Questions?