ECEN 4013
Design of Engineering Systems

Agenda

Project 1 Questions
4024 Materials
New Sprint
Schmitt Triggers

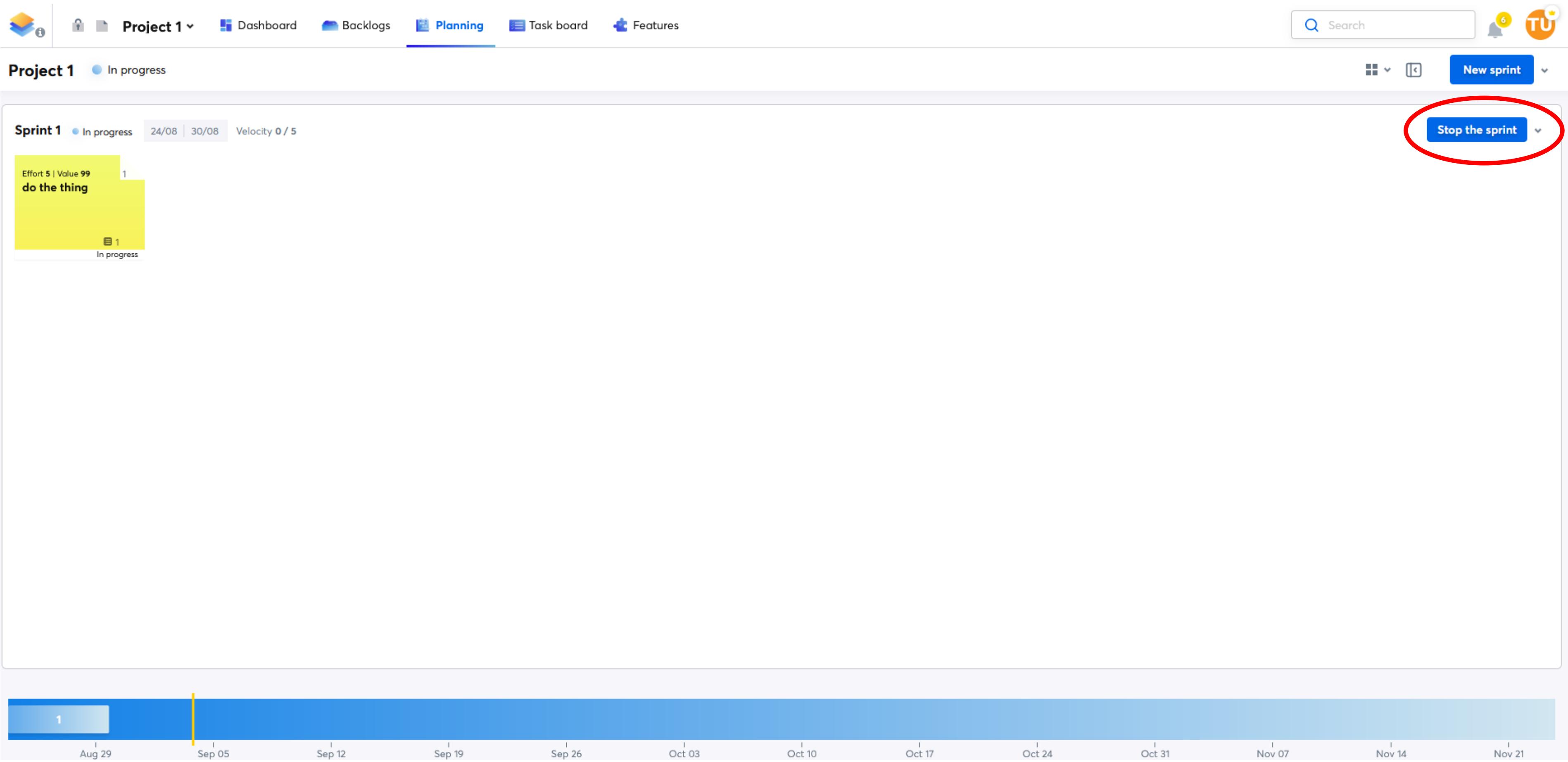
Project 1

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

ECEN 4024 Materials

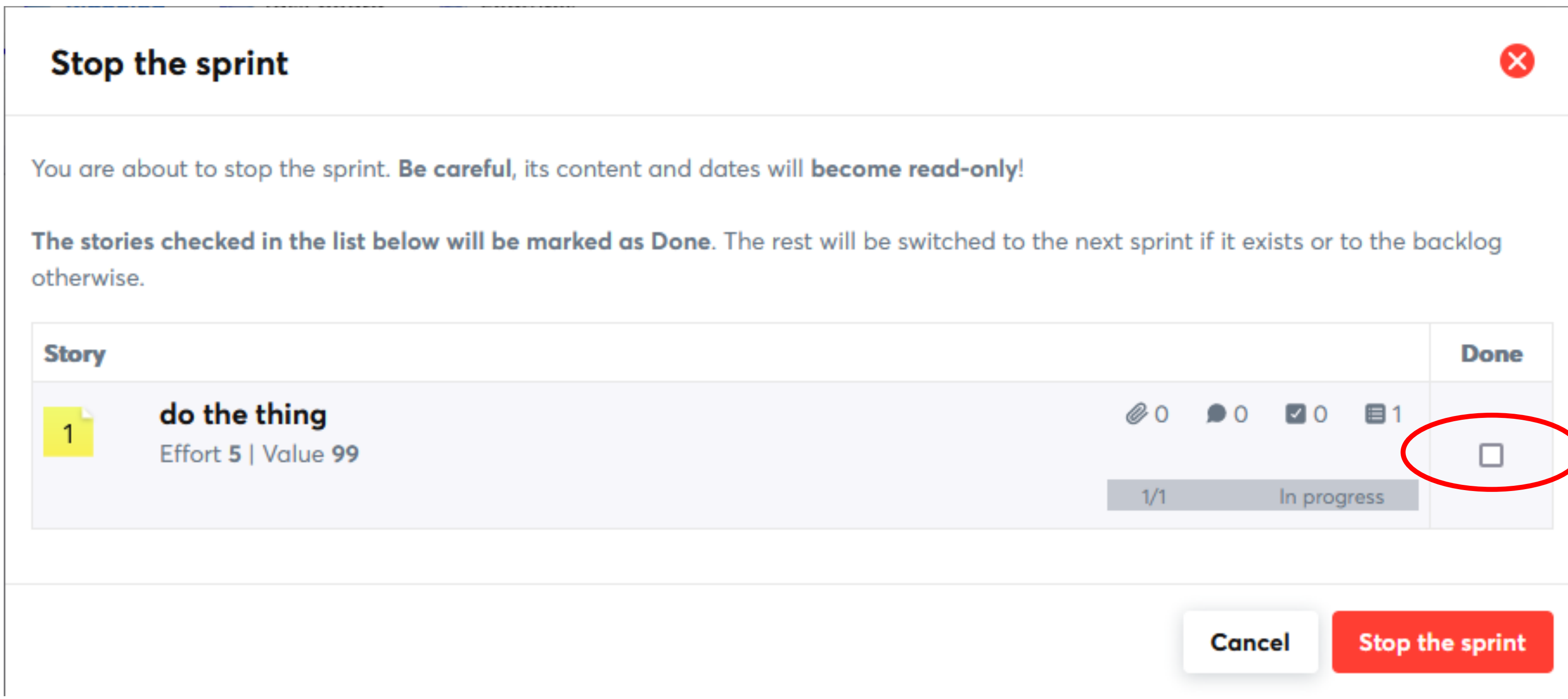
Throughout the semester I will provide presentation videos and slides for teams in 4024 so that you can get a feel for what is expected of you. Also, it helps to have knowledge of the projects because some of them are multi-semester, and you might find yourself

New Sprint



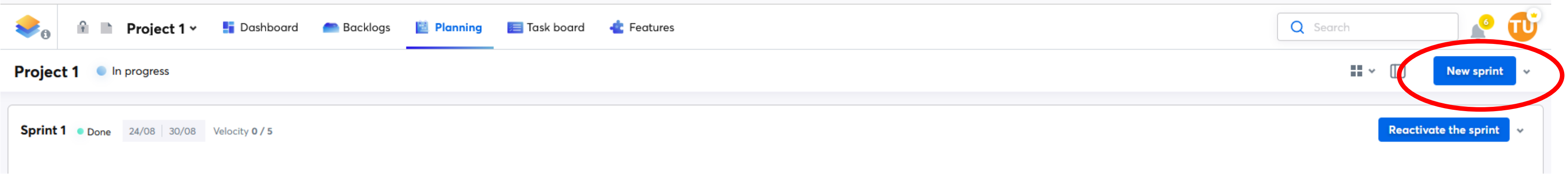
Project 1
Dashboard
Backlogs
Planning
Task board
Features
Search
Project 1
In progress
New sprint
Sprint 1
In progress
24/08
30/08
Velocity 0 / 5
Stop the sprint
Effort 5 | Value 99
do the thing
In progress
Aug 29
Sep 05
Sep 12
Sep 19
Sep 26
Oct 03
Oct 10
Oct 17
Oct 24
Oct 31
Nov 07
Nov 14
Nov 21

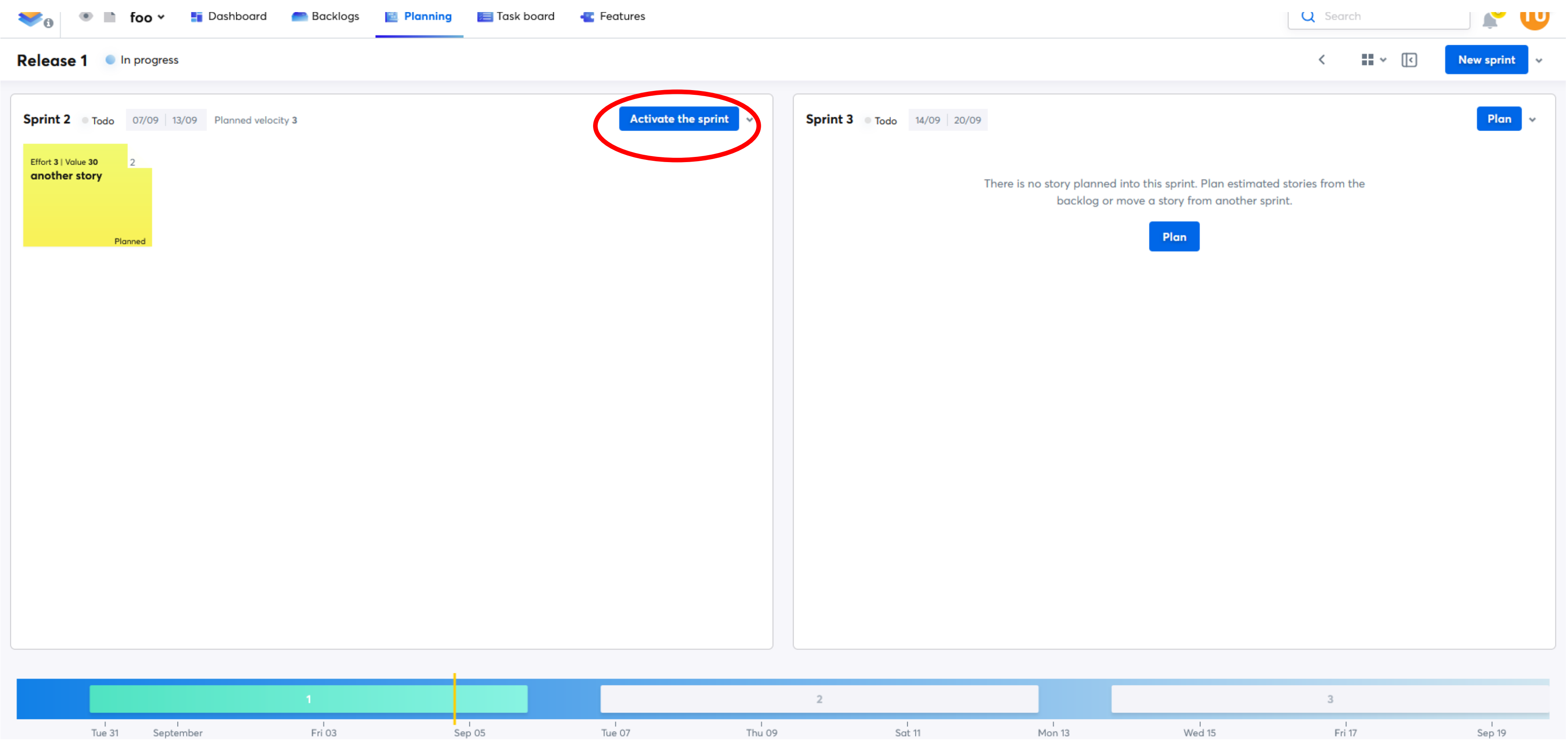
New Sprint



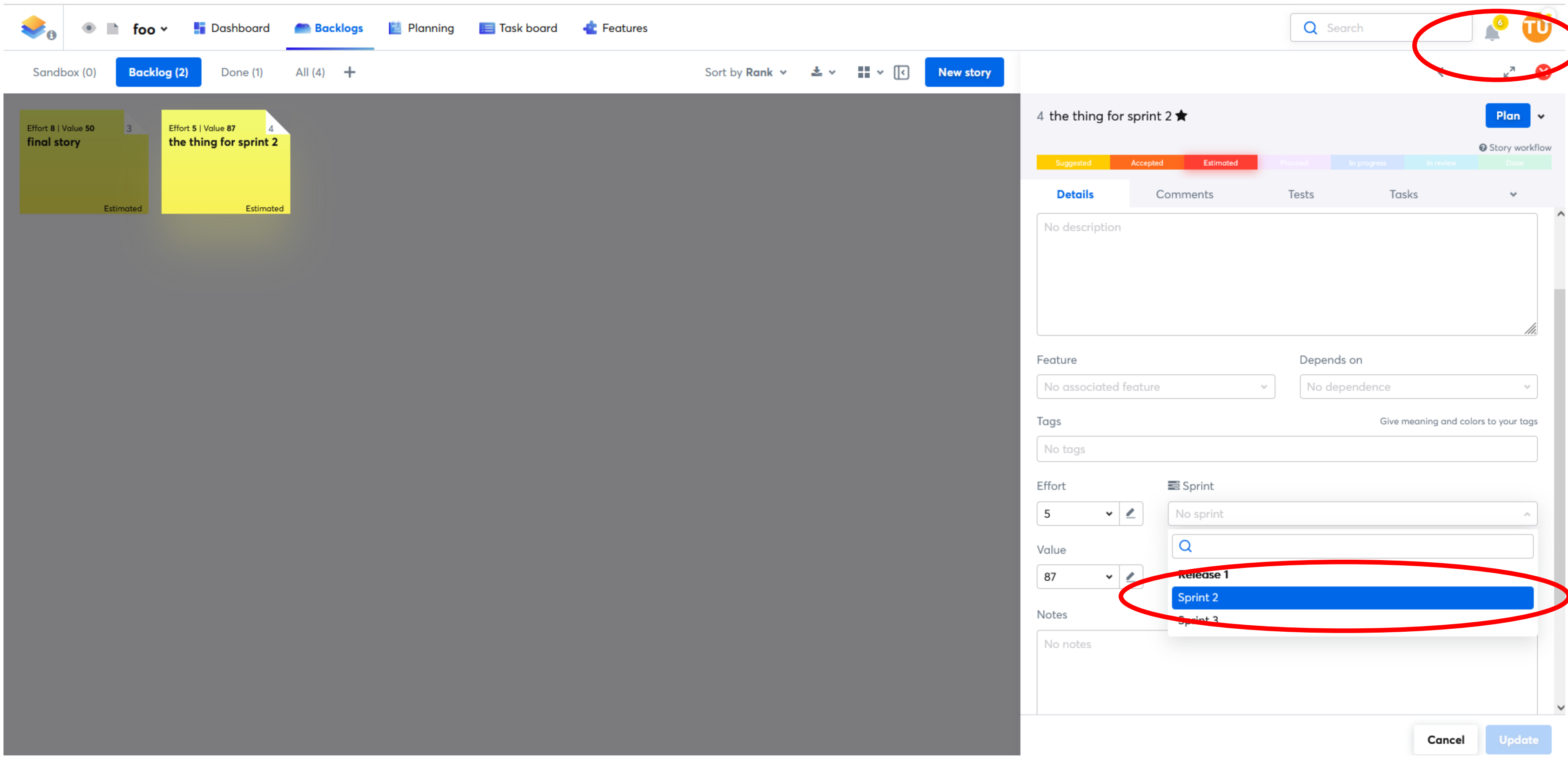
All completed stories will be moved to the "done" section of the backlog. Stories not finished will be moved to the next sprint.

New Sprint


Project 1
Dashboard
Backlogs
Planning
Task board
Features
Search
TU
Project 1
In progress
New sprint
Sprint 1
Done
24/08
30/08
Velocity 0 / 5
Reactivate the sprint


foo
Dashboard
Backlogs
Planning
Task board
Features
Search
Release 1
In progress
New sprint
Sprint 2
Todo
07/09
13/09
Planned velocity 3
Activate the sprint
Effort 3 | Value 30
2
another story
Planned
Sprint 3
Todo
14/09
20/09
Plan
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

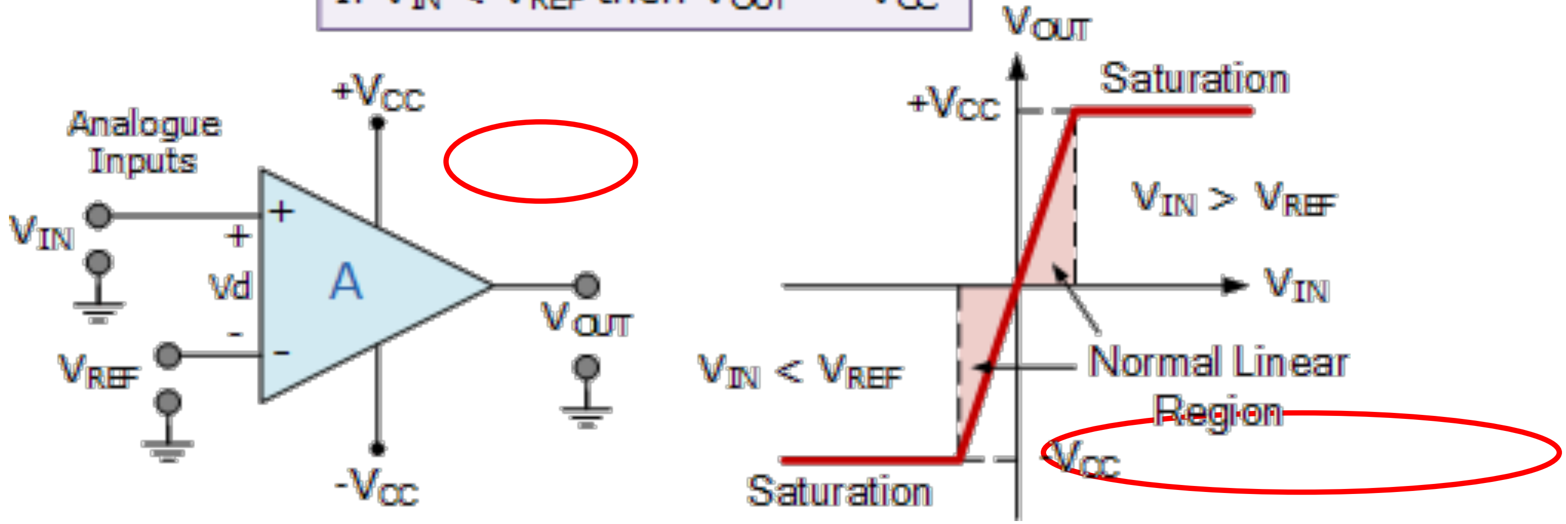
New Sprint


foo
Dashboard
Backlogs
Planning
Task board
Features
Search
TU
Sandbox (0)
Backlog (2)
Done (1)
All (4)
Sort by Rank
New story
Effort 8 | Value 50
final story
Estimated
Effort 5 | Value 87
the thing for sprint 2
Estimated
4 the thing for sprint 2
Plan
Story workflow
Suggested
Accepted
Estimated
Details
Comments
Tests
Tasks
No description
Feature
No associated feature
Depends on
No dependence
Tags
Give meaning and colors to your tags
No tags
Effort
5
Sprint
No sprint
Value
87
Release 1
Sprint 2
Sprint 3
Notes
No notes
Cancel
Update

Schmitt Trigger

Basic Op amp Comparator

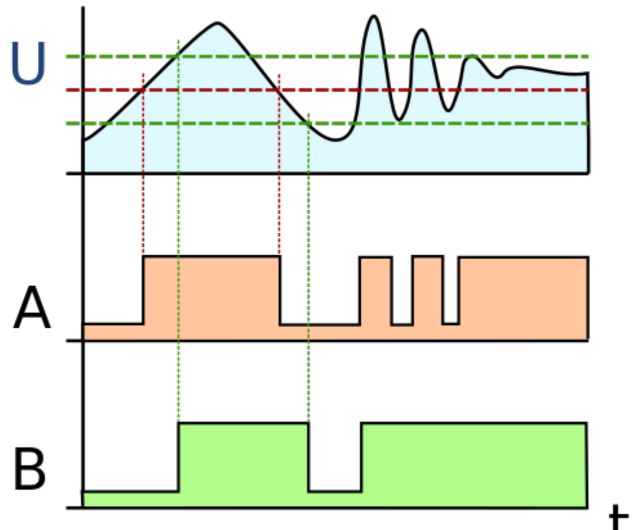
If $V_{IN} > V_{REF}$ then $V_{OUT} = +V_{CC}$
If $V_{IN} < V_{REF}$ then $V_{OUT} = -V_{CC}$



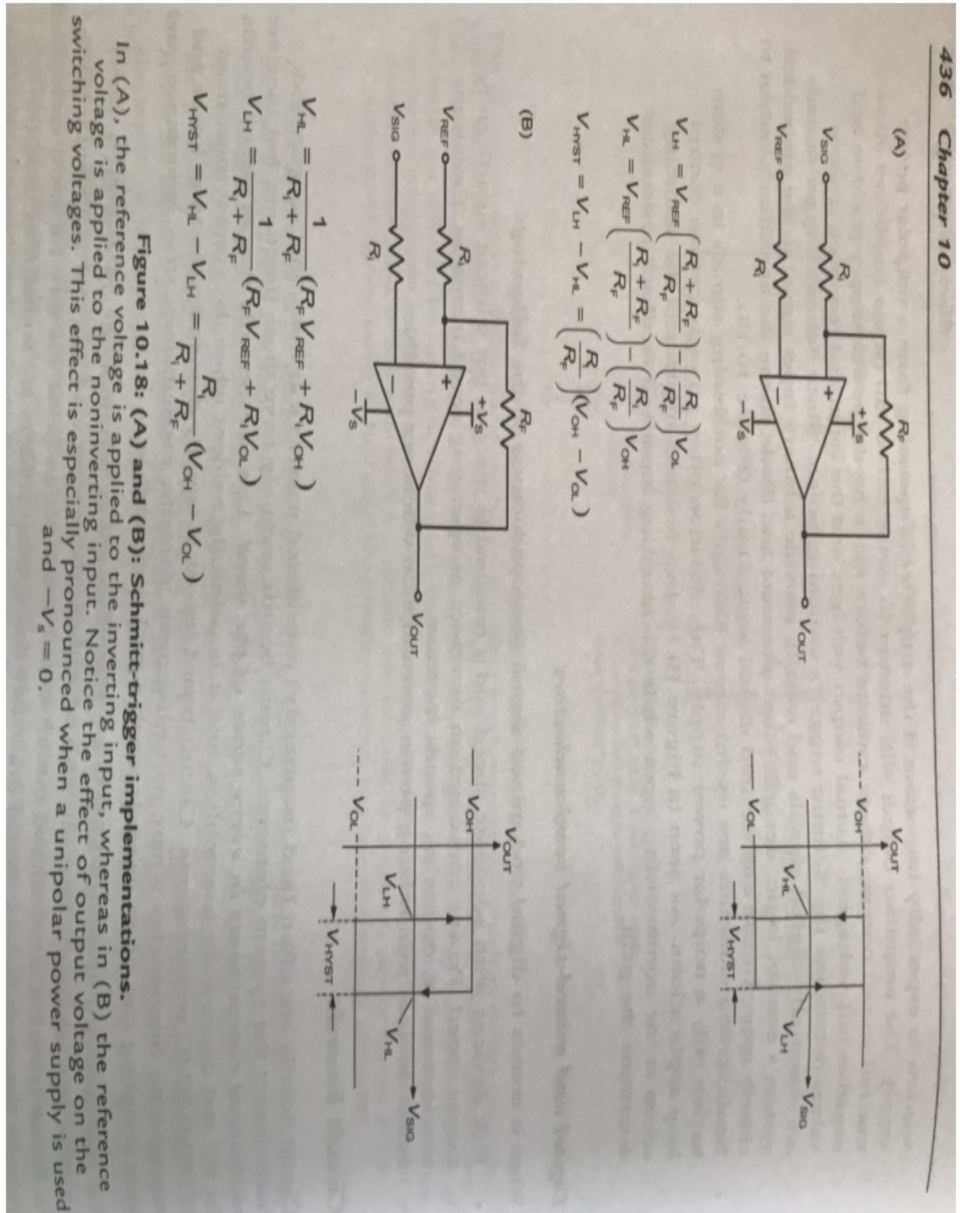
What happens at the decision boundary?

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 inverting input, whereas in (B) the reference voltage is applied to the noninverting 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.

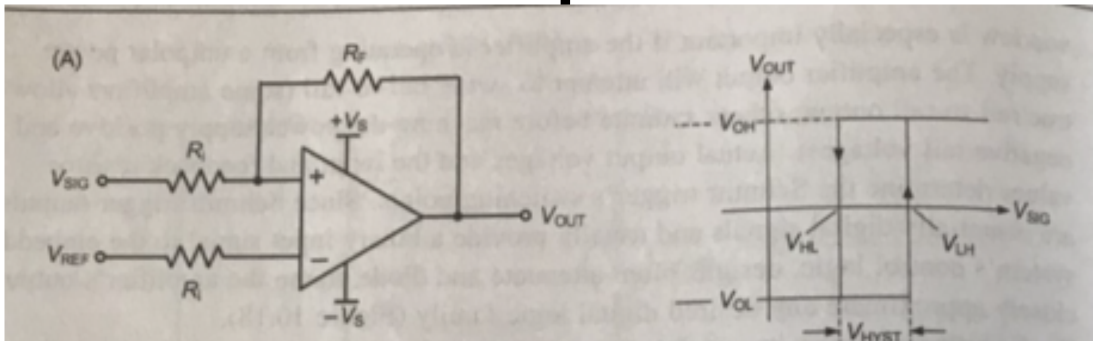
Derivation of Schmitt trigger relationships – form A

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



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

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

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

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

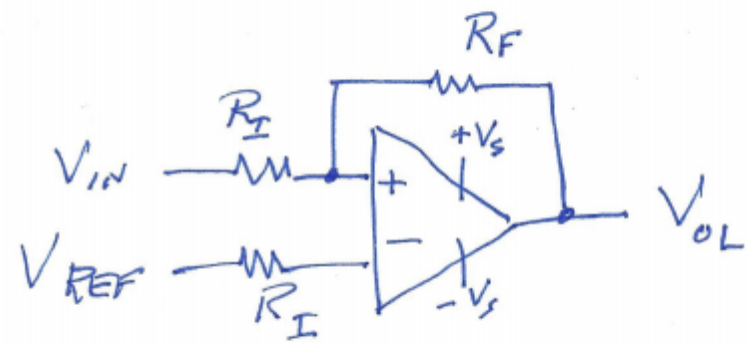
Derivation of Schmitt trigger relationships – form A

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.



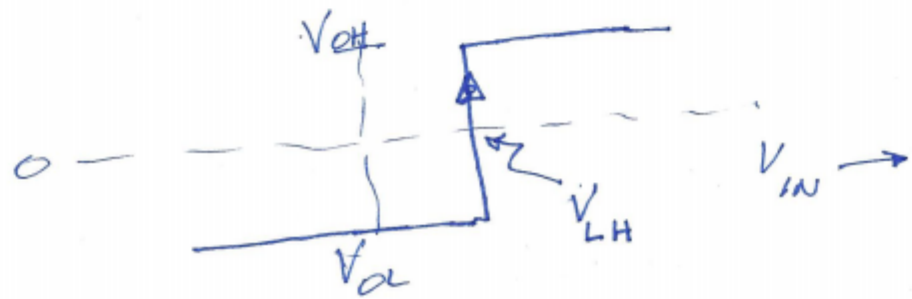
ASSUME

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

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

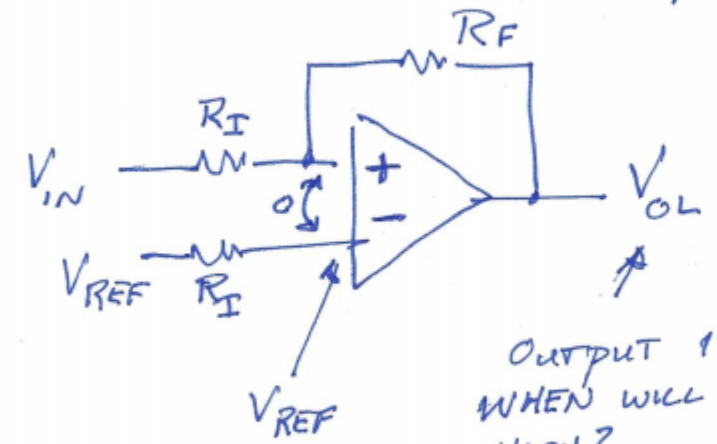
(2) WE INCREASE V_{IN} UNTIL THE AMPLIFIER OUTPUT SATURATES HIGH AT $V_{OH} \simeq +V_S$.

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

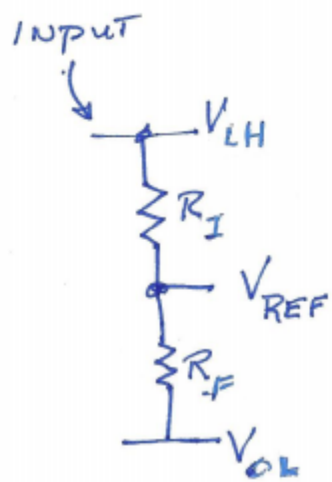


Schmitt trigger – form A

USE VOLTAGE DIVIDER AT NON-INVERTING INPUT



OUTPUT IS LOW –
WHEN WILL IT GO HIGH?
THAT IS V'_{LH}?



WHEN + INPUT
EQUALS V_{REF}

Schmitt trigger – form A

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

$$= V_{OL}\left(1 - \frac{R_F}{R_I + R_F}\right) + \left(\frac{R_F}{R_I + R_F}\right) V_{LH}$$

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

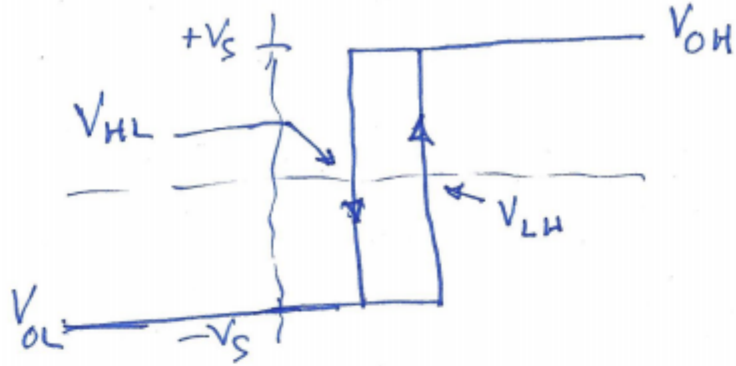
$$V_{LH} = \left(\frac{R_I + R_F}{R_F}\right)\left[V_{REF} - \left(\frac{R_I}{R_I + R_F}\right) V_{OL}\right]$$

Schmitt trigger – form A

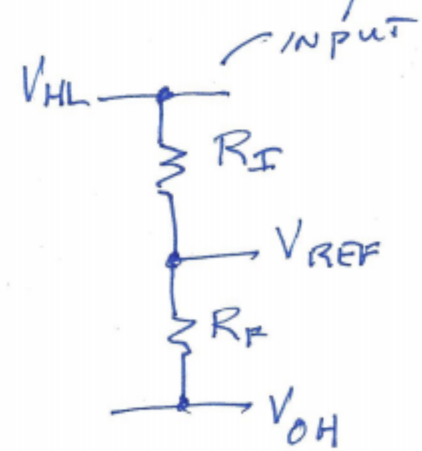
SOLVE FOR V_{LH}:

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

NOW FIND HIGH-LOW TRANSITION LEVEL V_{HL} when OUTPUT IS HIGH (V_{OH}) AND V_{IN} IS DECREASING



USE SAME VOLTAGE DIVIDER ANALYSIS



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

Schmitt trigger – form A

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

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

SOLVE FOR V_{HL} AS BEFORE!

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

NOW FIND HYSTERESIS:

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

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

$$- \underbrace{\left[\left(\frac{R_I + R_F}{R_F}\right)V_{REF} - \left(\frac{R_F}{R_I}\right)V_{OH}\right]}_{V_{HL}}$$

$$\boxed{V_{HYST} = \frac{R_I}{R_F}\left(V_{OH} - V_{OL}\right)}$$

Schmitt trigger – form A

Things to notice:

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

If RI = 10 K and RF = 10 M, the hysteresis is 0.1% of the voltage difference between VOH and VOL.

Schmitt trigger – form A

VOH and VOL 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 VOH and VOL 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 VOH and VOL are equal in magnitude and opposite in sign.

Schmitt trigger – form A

Suggestions:

1) Assume outputs
2) Set Vref at anticipated midpoint of the hysteresis window.
3) Select RI and RF based on anticipated output voltages and desired hysteresis window
4) Vary Vref 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?