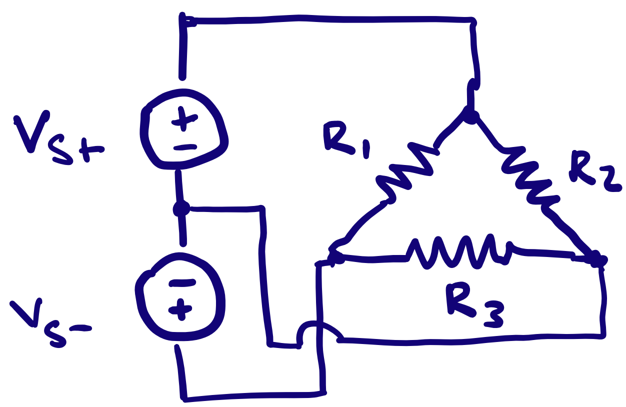
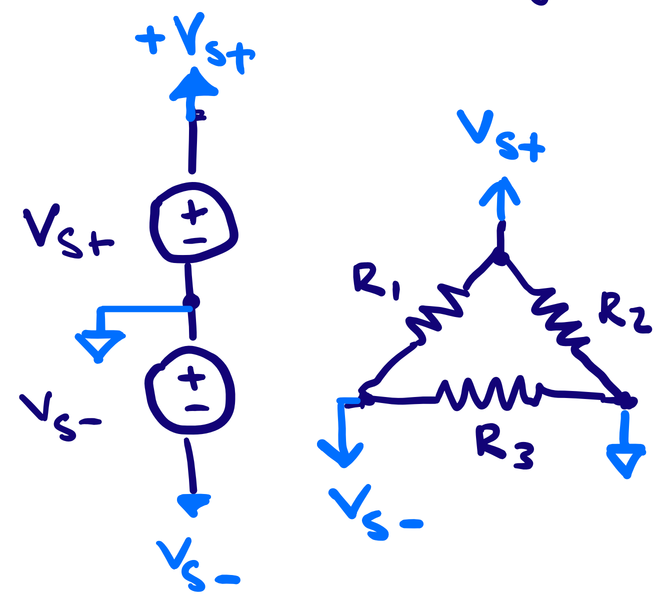
Op Amp Comparator, Oscillator

Aside / Reminder: Voltage Bus Notation

We often introduce symbols to convey node connections without explicitly drawing them. This often simplifies diagrams (esp. for power, gnd, etc.) but does not change circuit rules in any way.

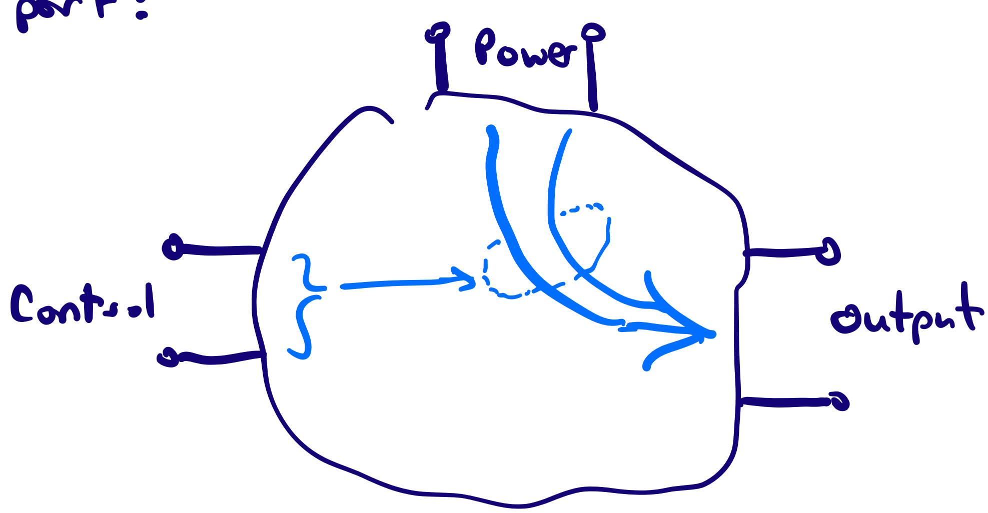
e.g.





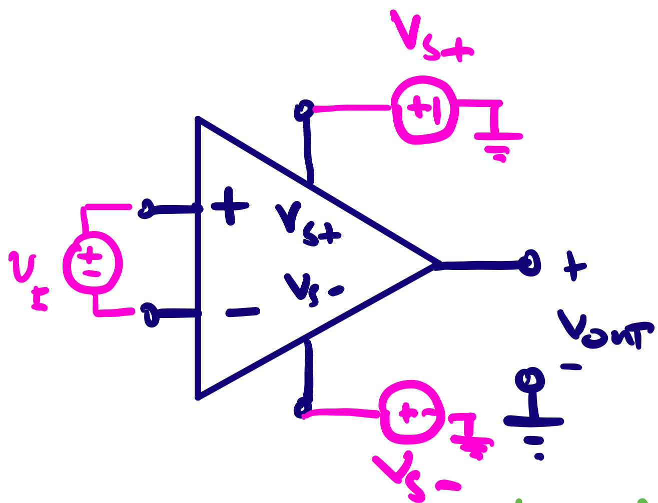
Amplifiers are a type of device that serves an important need in circuits and has many applications. They may be thought of as three-port devices with a control port, a power port and an output port

Amplifiers use a small quantity (voltage, current, power) at the control port to deliver a large quantity from a power port to the output port:

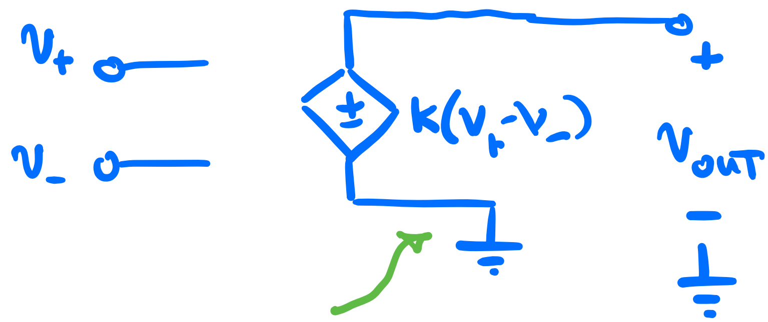


The need for amplification is so common that engineers have developed a class of electronic building blocks that realize this function: The <u>Operational Amplifier</u>, or Op-Amp

The symbol for an op-amp:



model As:



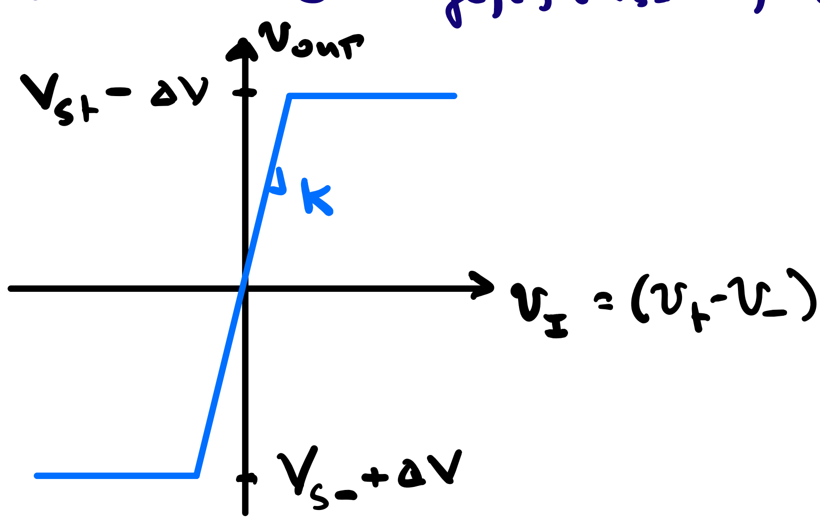
In reality, dependent source may be referenced to V_{S-}, but this doesn't change the result significantly because K is <u>BIG</u> (ideally $K \to \infty$)

- A practical op amp has an "open-loop gain" K that is very large: $10^5 - 10^6$ in practice. Ideally we treat as $K \to \infty$
- In practice, the output voltage V_{OUT} is constrained to remain within the range of the power supply, i.e. between (V_{S-}, V_{S+}) or an even narrower range, e.g. $(V_{S-} - \Delta V, V_{S+} + \Delta V)$

e.g., if

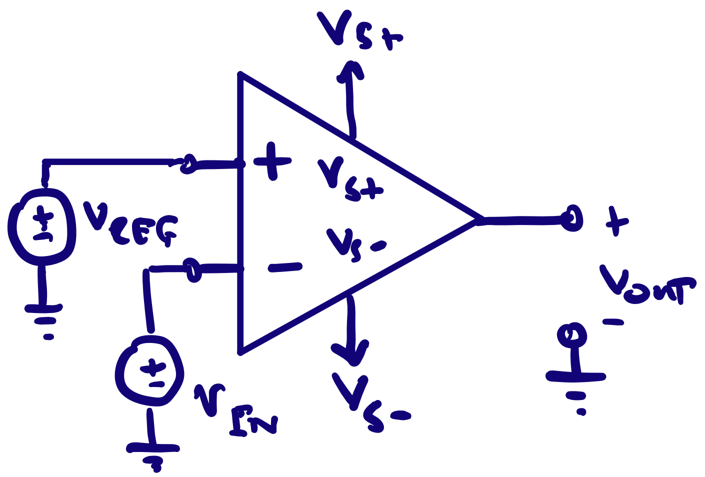
$V_{S+} = +15\,V$
$V_{S-} = -15\,V$
$\Delta V = 3\,V$

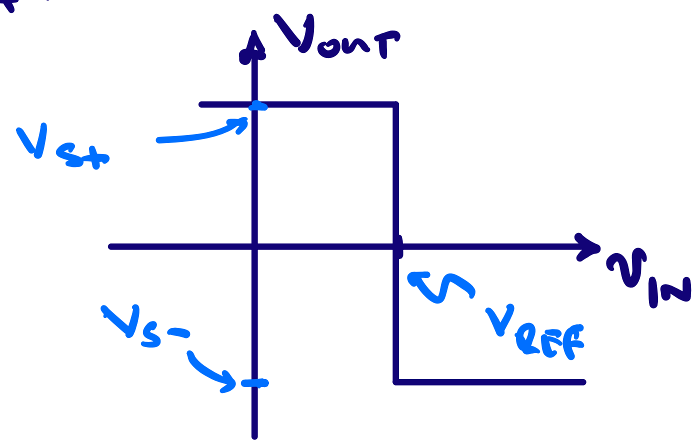
V_{out} in $(-12, 12)\,V$ range



One way we can use an op-amp is as a comparator. (there are special versions designed specifically for use as comparators, though we can do this function with most op amps).

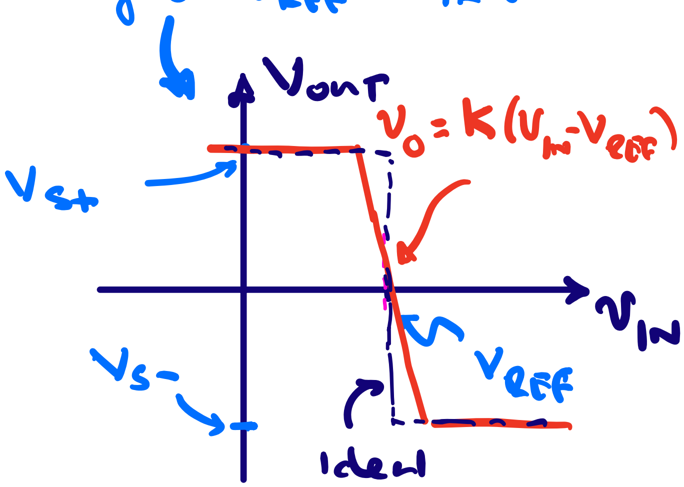
Suppose we want to compare some "input" voltage V_{IN} to a "reference" voltage V_{ref}:

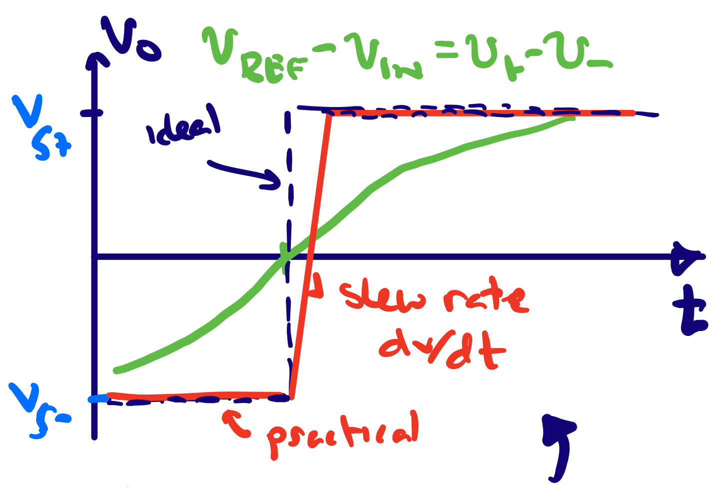




Our comparator can tell us whether or not our input signal is greater than or less than the reference voltage.

In reality the output transitions over a small but nonzero range of $V_{REF} - V_{IN}$ (but k is big so transition range is small)

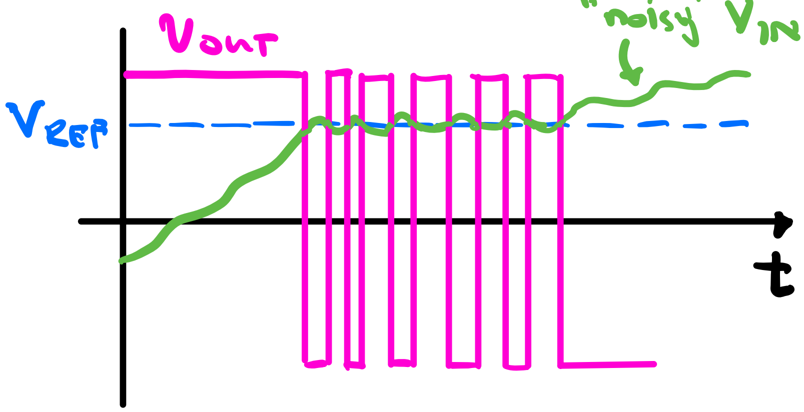


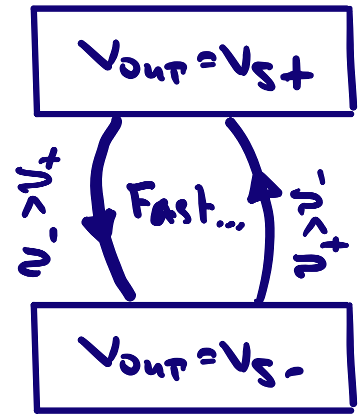


In reality, the speed with which the output can switch is finite, with a limiting "slew rate" in output voltage that depends on the difference between V_+, V_- up to a practical maximum that depends on the device.

Op Amp Comparator Oscillator

A problem with comparator circuits is that the output can "chatter" back and forth for input voltages near the reference voltage (such that v_+ is very close to v_-), especially in the presence of noise:

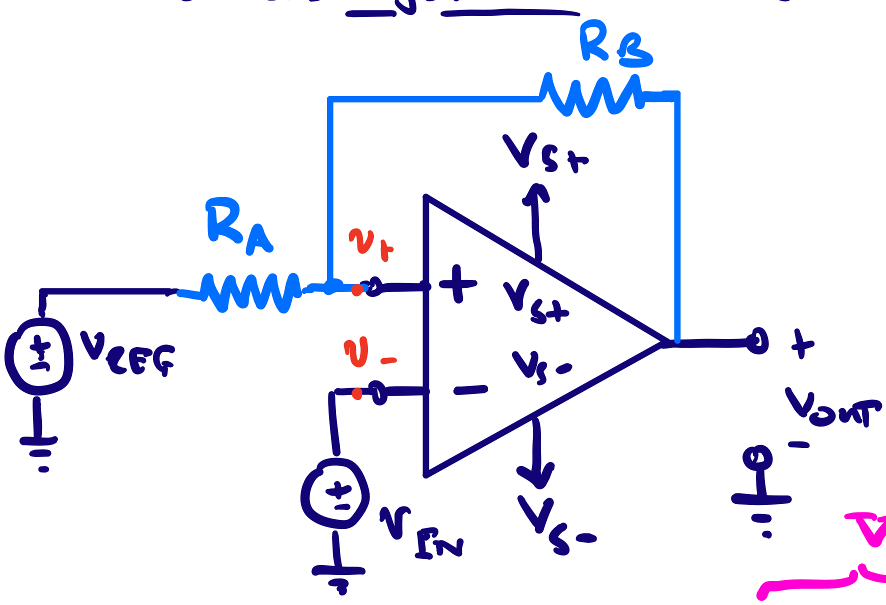




Such chatter can cause problems for circuits that try to use V_{out}.

We can fix the chattering problem with "positive feedback" that causes hysteresis in the switching.

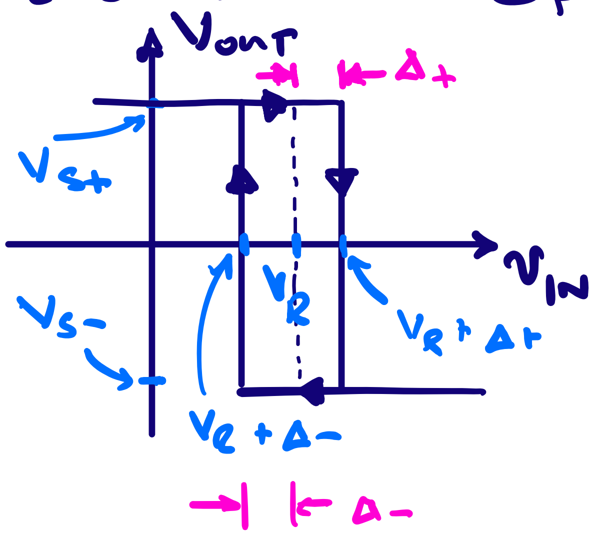
See demo

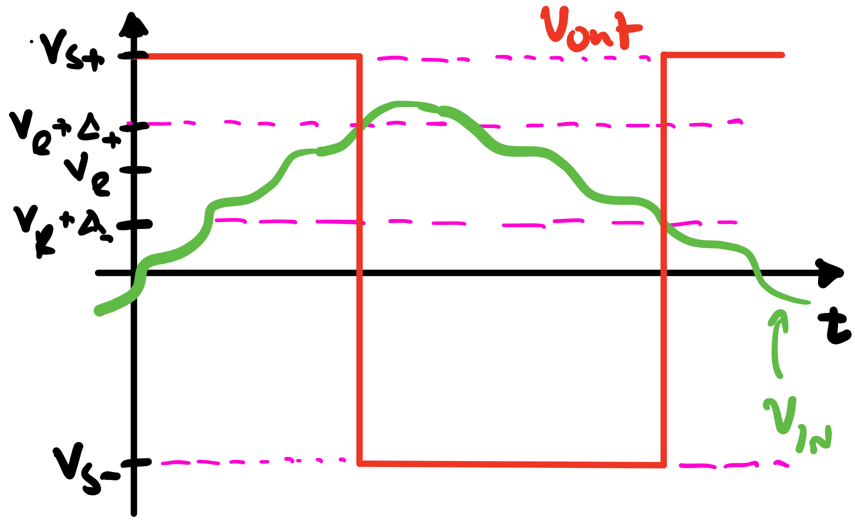


$$\text{If } V_{OUT} = V_{S+} \longleftrightarrow V_{IN} < \underbrace{V_{REF} \cdot \frac{R_B}{R_A + R_B}}_{V_R} + \underbrace{V_{S+} \cdot \frac{R_A}{R_A + R_B}}_{\Delta_+}$$

$$\text{If } V_{OUT} = V_{S-} \longleftrightarrow V_{IN} > \underbrace{V_{REF} \cdot \frac{R_B}{R_A + R_B}}_{V_R} + \underbrace{V_{S-} \cdot \frac{R_A}{R_A + R_B}}_{\Delta_-}$$

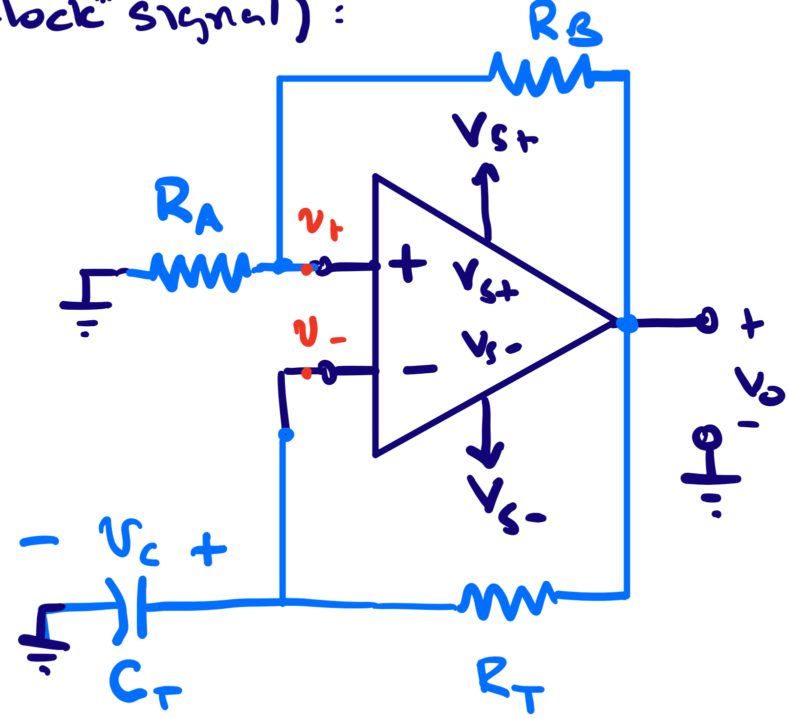
Op Amp Comparator Oscillator





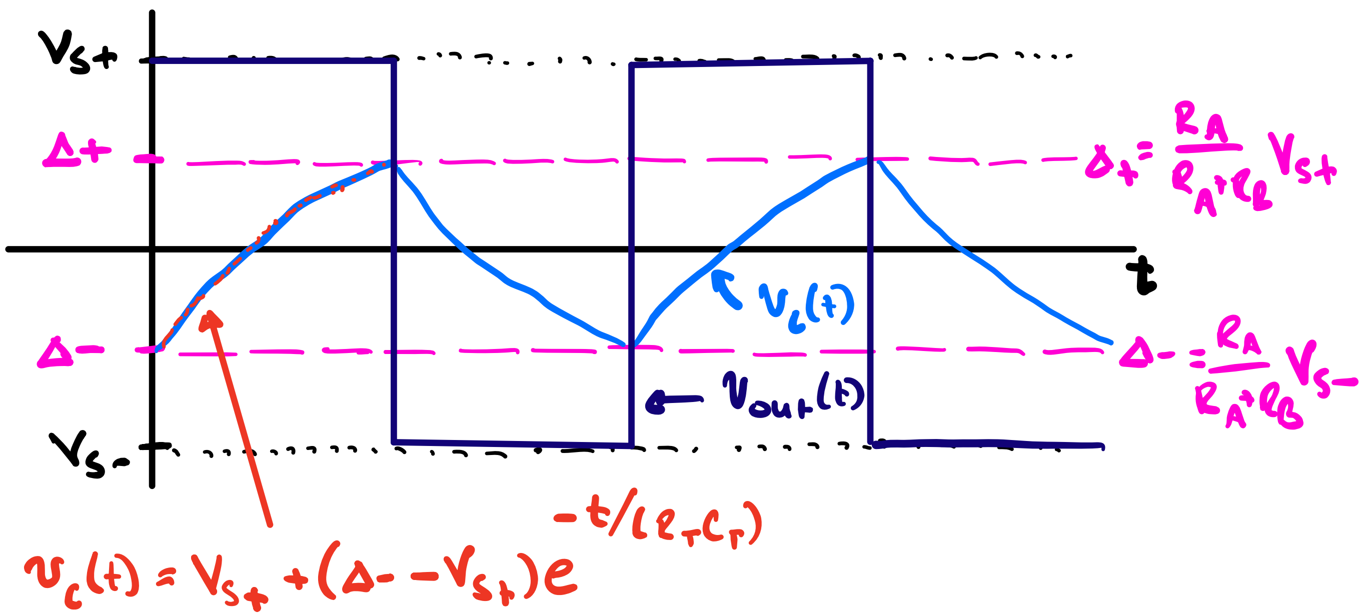
The transition threshold is <u>different</u> for positive- and negative-going transitions, so we do not get chattering at the boundary! (Positive feedback provides hysteresis.)

We can also use hysteresis (with both +ve and -ve feedback) to build an <u>oscillator</u>. (e.g. to generate a "clock" signal):



Consider V_o, V_c as a function of time

Op Amp Comparator Oscillator



The oscillation period is related to the output saturation voltages (here V_{S+}, V_{S-}), hysteresis band size $\Delta+ - \Delta-$ (determined by R_A, R_B) and the time constant $R_T C_T$