Lecture 30

EC103

Multivibrators

- In the design of electronic circuits, we frequently need signals of specified waveforms, e.g., sinusoidal, square, triangular, pulse etc.
- You have already studied a family of `linear’ oscillators which generate sinusoidal of a predetermined frequency and amplitude using some kind of resonance phenomenon.
- Multivibrators are circuits which are used in another type of waveform generators (nonlinear oscillators / function generators) which can generate square, triangular waveforms. Triangular waveforms are then `shaped’ into sinusoidal waveforms.

Three types of `Multivibrators':

1. Bistable: Two stable states.

2. Astable: No stable states.

3. Monostable: A single stable state.

Bistable Multivibrators

- The circuit can be at any of the two stable states for infinite duration, and goes to the other stable state only if a triggering signal is appropriately applied.

The Feedback Loop

- Bistability can be obtained by connecting a dc amplifier in a positive-feedback loop having a loop gain greater than unity.

- Such a feedback loop consists of an op amp and a resistive voltage divider in the positive-feedback path.

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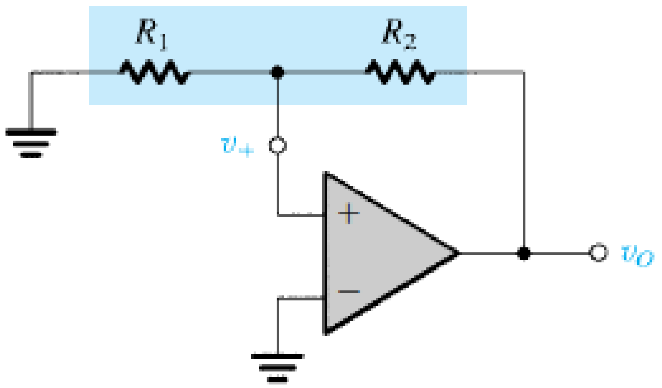
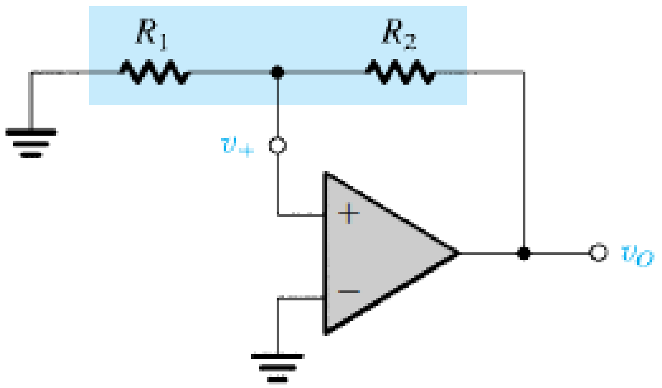


The Feedback Loop

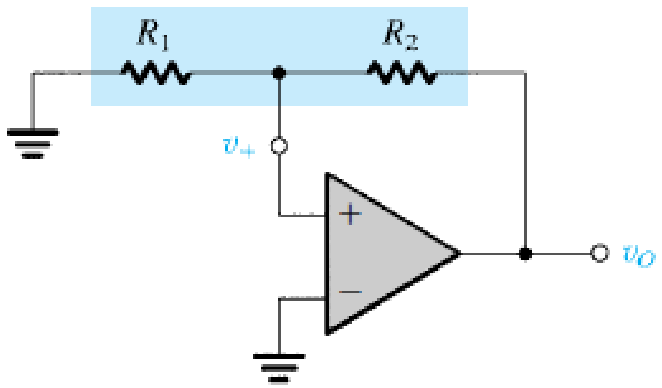
- To see how bistability is obtained, consider operation with the positive-input terminal of the op amp near ground potential.
- This is a reasonable starting point, since the circuit has no external excitation.



The Feedback Loop

- Assume that the electrical noise that is inevitably present in every electronic circuit causes a small positive increment in the voltage v_+. This incremental signal will be amplified by the large open-loop gain *A* of the op amp, with the result that a much greater signal will appear in the op amp's output voltage v_O.

- The voltage divider (*R*1, *R*2) will feed a fraction of the output signal $\beta = R_1/(R_1 + R_2)$ back to the positive-input terminal of the op amp. If *A*β is greater than unity, as is usually the case, the fed-back signal will be greater than the original increment in v_+.



- This *regenerative* process continues until eventually the op amp saturates with its output voltage at the positive-saturation level, L_+. When this happens, the voltage at the positive-input terminal, v_+, becomes βL_+, which is positive and thus keeps the op amp in positive saturation.

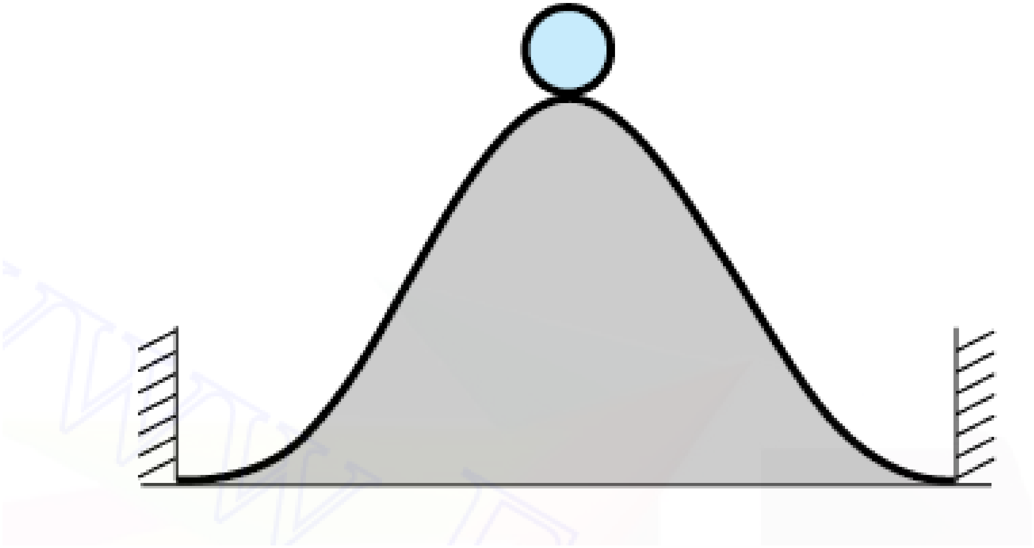
The Feedback Loop

- This is one of the two stable states of the circuit.

- We assumed that when v_+ was near zero volts, a positive increment occurred in v_+. Had we assumed the equally probable situation of a negative increment, the op amp would have ended up saturated in the negative direction with $v_O = L_-$ and v_+=βL_-.
- This is the other stable state.

- We thus conclude that the circuit has two stable states, one with the op amp in positive saturation and the other with the op amp in negative saturation.
- The circuit can exist in either of these two states indefinitely.
- We also note that the circuit cannot exist in the state for which $v_+ = 0$ and $v_O = 0$ for any length of time. This is a state of *unstable equilibrium* (also known as a **metastable state**); any disturbance, such as that caused by electrical noise, causes the bistable circuit to switch to one of its two stable states.

A Physical Analogy

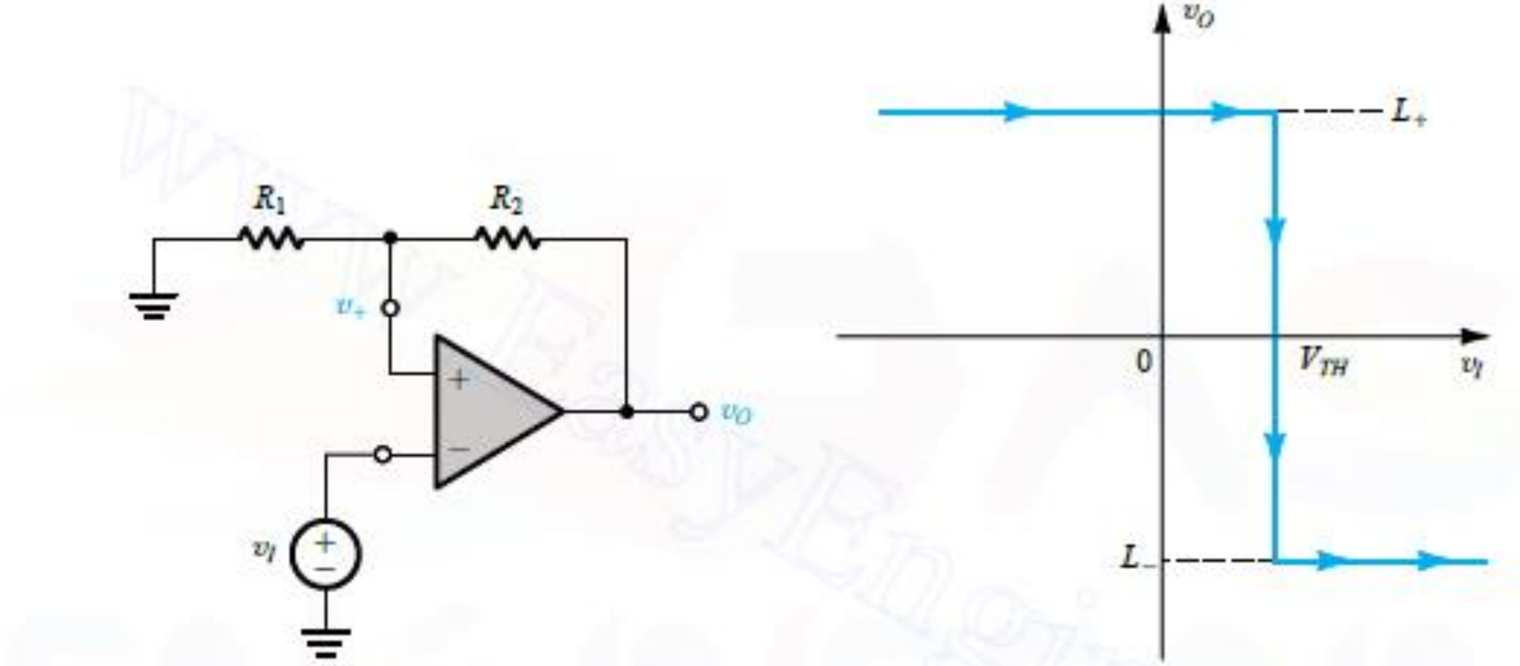


Transfer Characteristics

- The question naturally arises as to how we can make the bistable circuit change state. To help answer this crucial question, we derive the transfer characteristics of the bistable.

- Either of the two circuit nodes that are connected to ground can serve as an input terminal. We investigate both possibilities.

Transfer Characteristics



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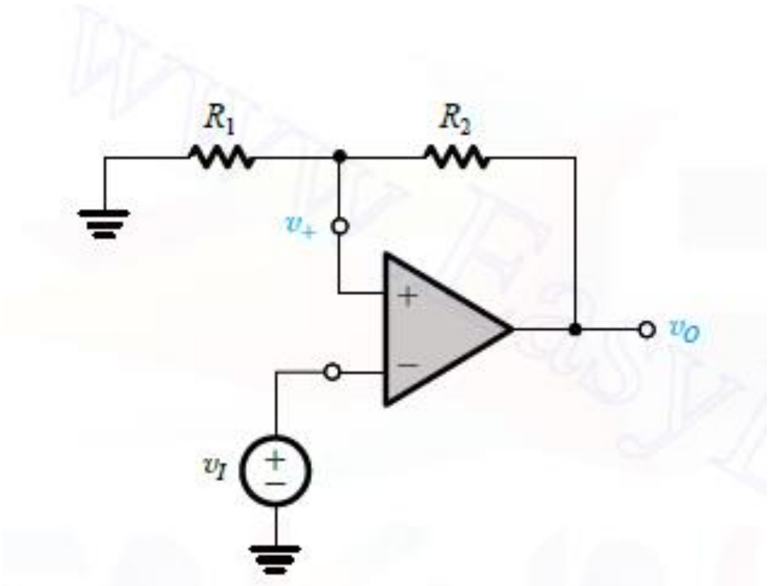
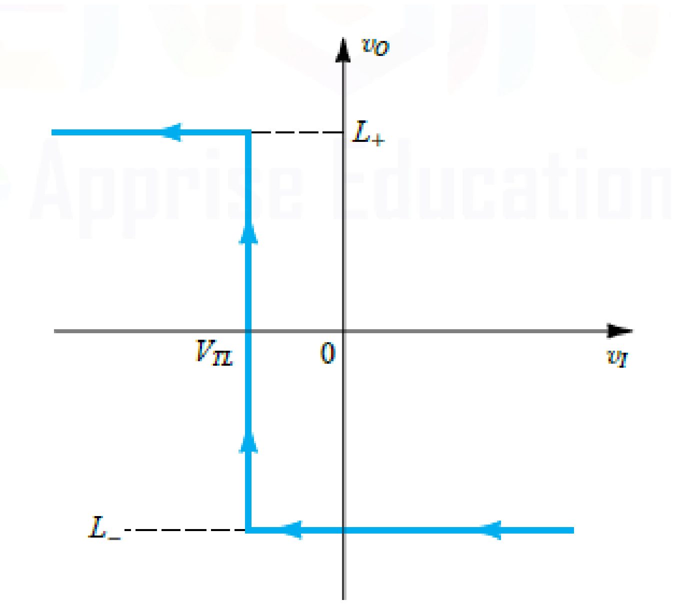
EC103

Transfer Characteristics

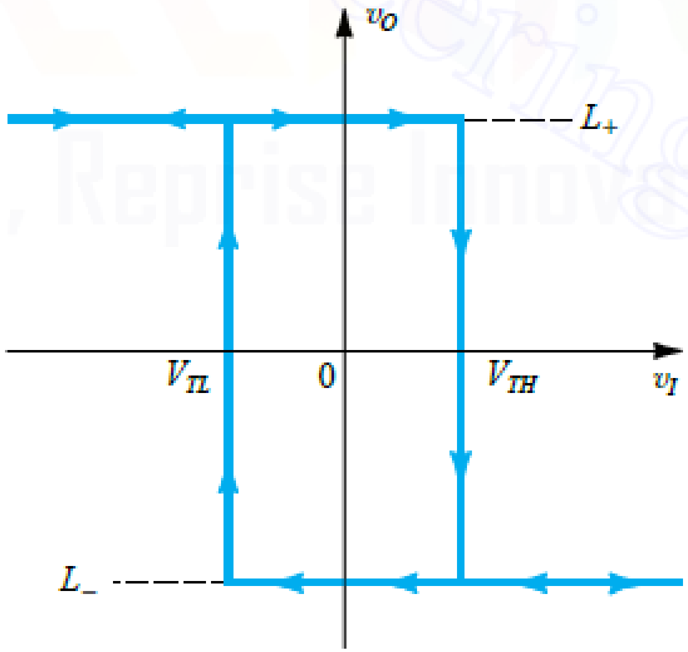




Transfer Characteristics

- `Hyesteresis’

- `Inverting Characteristics’:
As the circuit goes to positive state to negative state with increasing input voltage.



- Bistable circuit is also known as a **Schmitt trigger.**

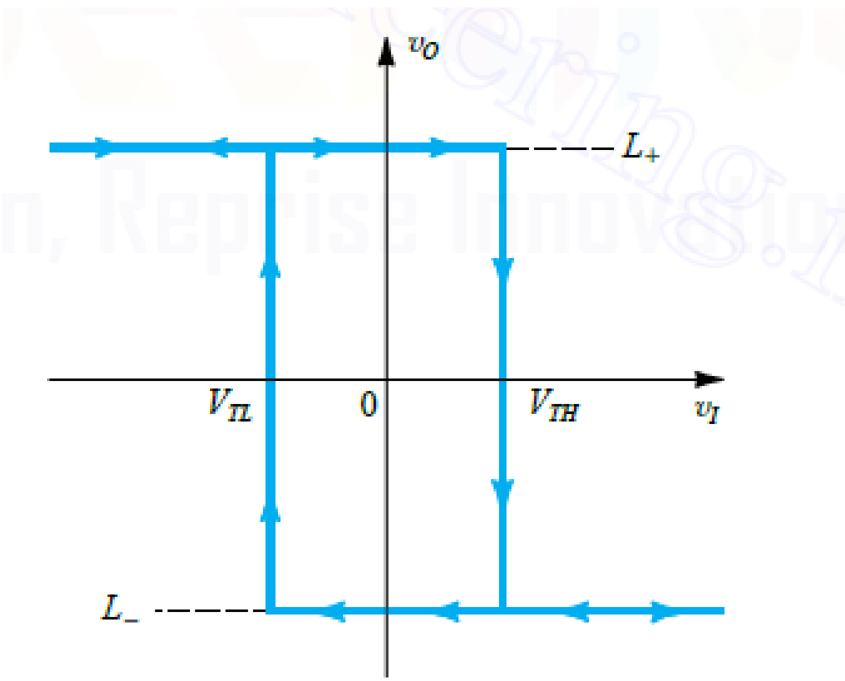
Triggering the Bistable circuit

- Returning now to the question of how to make the bistable circuit change state, we observe from the transfer characteristics if the circuit is in the *positive* state it can be switched to the *negative* state by applying an input of value greater than βL_+.

- Such an input causes a net negative voltage to appear between the input terminals of the op amp, which initiates the regenerative cycle that culminates in the circuit switching to the *negative* stable state.
- Here it is important to note that the input merely initiates or *triggers* regeneration.

- Thus we can remove with no effect on the regeneration process. In other words, *the input* can be simply a pulse of short duration. The input signal is thus referred to as a **trigger signal**, or simply a **trigger**.

Triggering the Bistable circuit



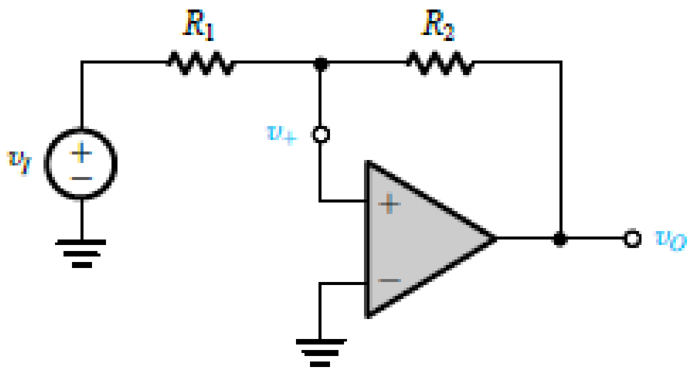
- The characteristics indicate also that the bistable circuit can be switched to the positive state by applying a negative trigger signal of magnitude greater than that of the negative threshold.

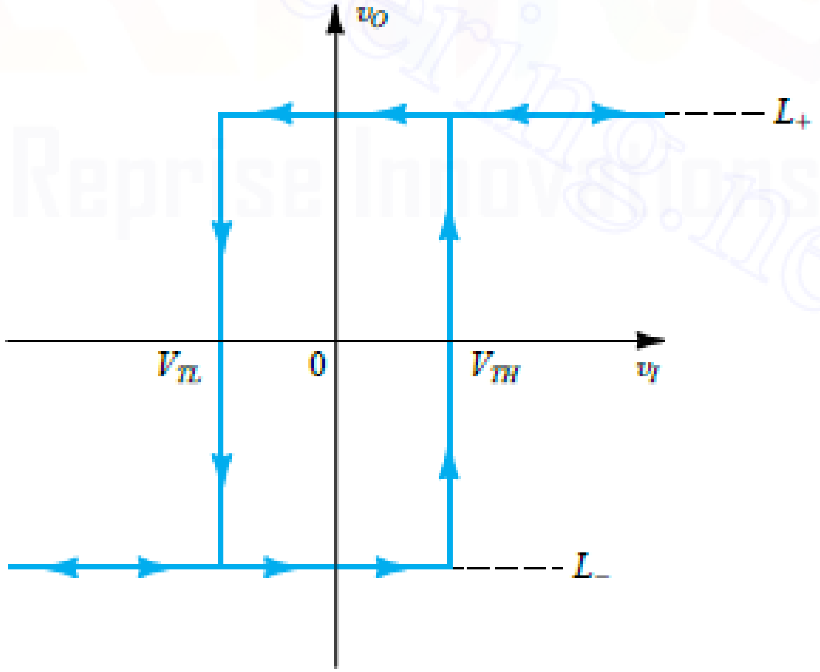
The Bistable Circuit As A Memory Element

- For an input within the range between the two thresholds, the circuit can be in either *of the two stable states*.
- Thus, for this input range, the output is determined by the *previous* value of the trigger signal (the trigger signal that caused the circuit to be in its current state). Thus the circuit exhibits *memory*.
- Indeed, the bistable multivibrator is the basic memory element of digital systems.

Non-inverting Transfer Characteristics

- $$v_+ = v_I \frac{R_2}{R_1 + R_2} + v_O \frac{R_1}{R_1 + R_2}$$





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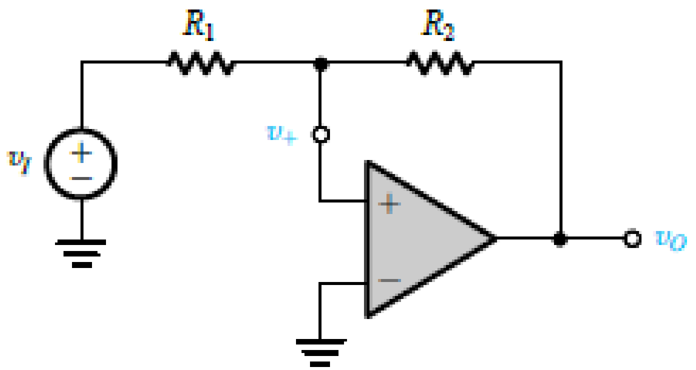

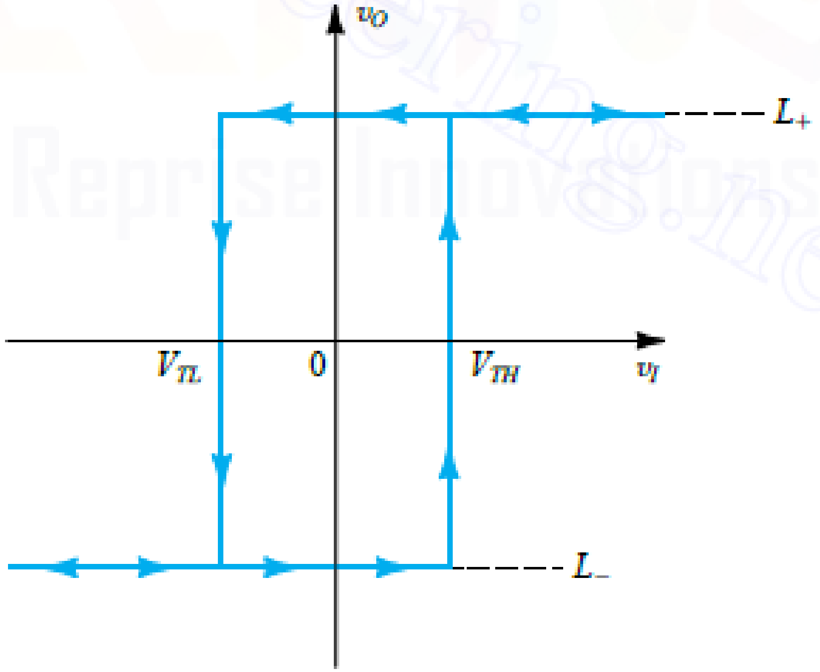

Find out the threshold values.

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- $V_{TL} = -L_{+}\left(\frac{R_1}{R_2}\right)$

Find out the threshold values?

- $V_{TL} = -L_{+}\left(\frac{R_1}{R_2}\right)$
- $V_{TH} = -L_{-}\left(\frac{R_1}{R_2}\right)$

Find out the threshold values?

- $V_{TL} = -L_+ \left(\frac{R_1}{R_2}\right)$
- $V_{TH} = -L_- \left(\frac{R_1}{R_2}\right)$

- Compare them with the thresholds of inverting mode
- $V_{TL(inv)} = L_- \left(\frac{R_1}{R_1+R_2}\right)$
- $V_{TH(inv)} = L_+ \left(\frac{R_1}{R_1+R_2}\right)$

Application of a Bistable Circuit as A Comparator and Usefulness of Adding Hysteresis

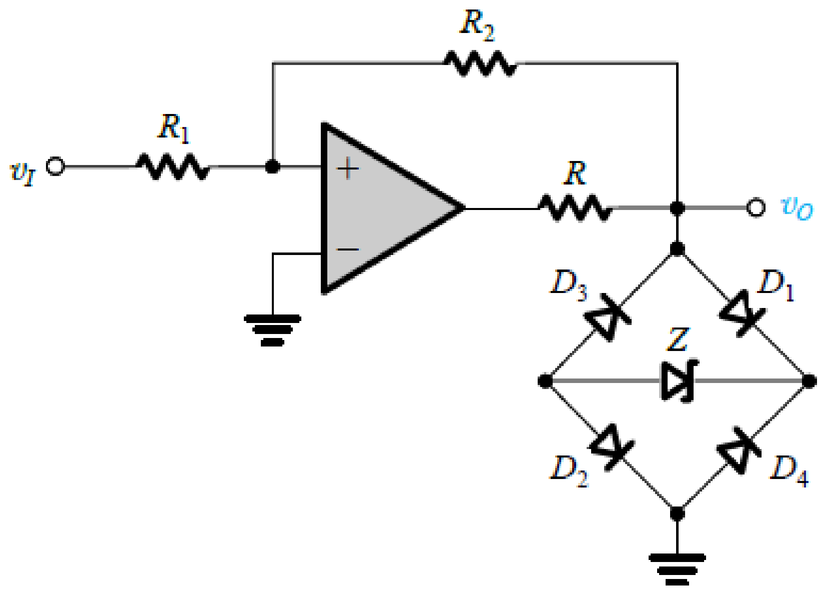
- *Already studied.* ☺

Making the Output Levels More precise

- Limiter circuits: *Already studied.* ☺

Making the Output Levels More precise

- Limiter circuits: *Already studied.* ☺
- Determine the positive and negative saturation levels of the output voltage for the following circuit:



Astable Multivibrators

- No stable states.

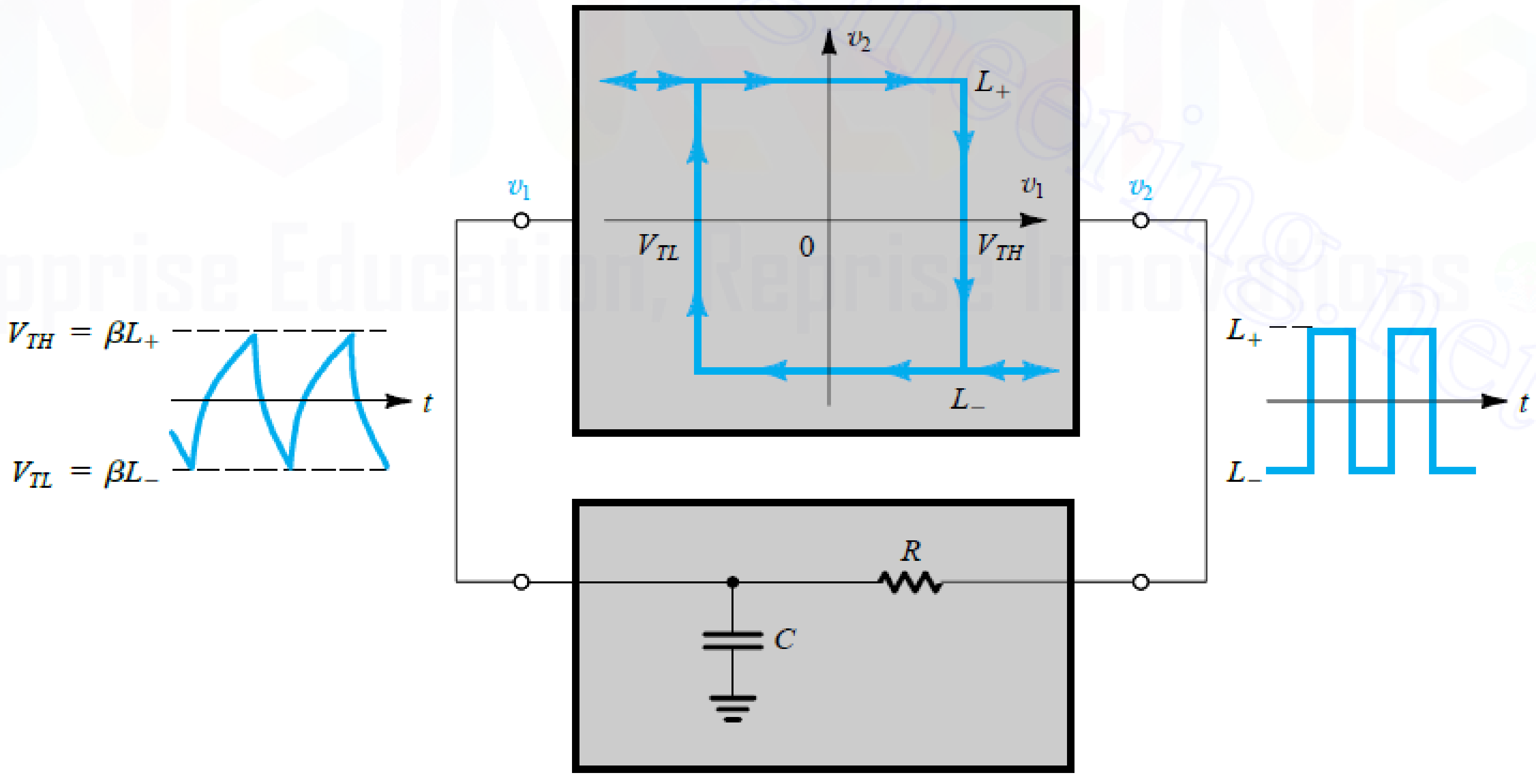
Generation of Square Waveforms using Astable Multivibrators

- A square waveform can be generated by arranging for a bistable multivibrator switch states periodically.

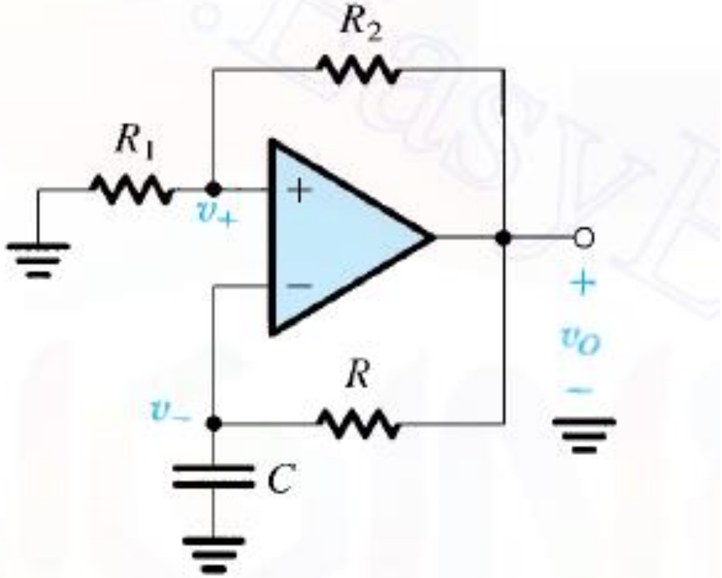
- This can be done by connecting a bistable multivibrator with an RC circuit in a feedback loop.

- The circuit has no stable state.

Generation of Square Waveforms using Astable Multivibrators



Generation of Square Waveforms using Astable Multivibrators



Operation of the Astable Multivibrators

- An important relationship to be recalled:

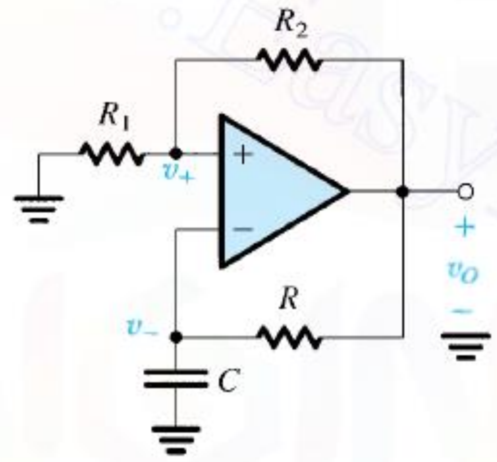
- A capacitor C that is charging and discharging through the resistor R toward a final voltage V_∞ has a voltage $v(t)$,

$$v(t) = V_\infty - (V_\infty - V_{0+})\, e^{-t/\tau}$$

where V_{0+} is the voltage at $t = 0+$ and $\tau = CR$ is the time constant.

Operation of the Astable Multivibrators

- To see how the astable multivibrator operates, assume that its output is at one of its two possible levels, say L_+.



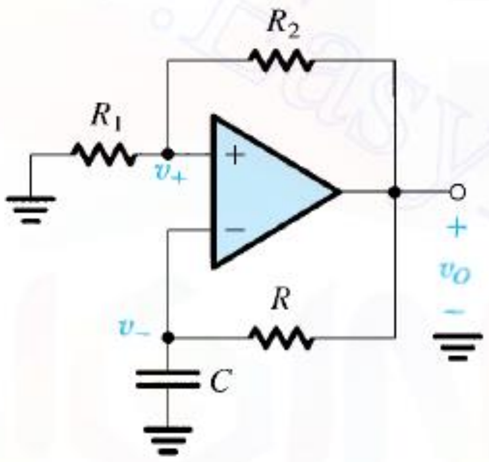
- Capacitor C will charge toward this level through the resistor R.

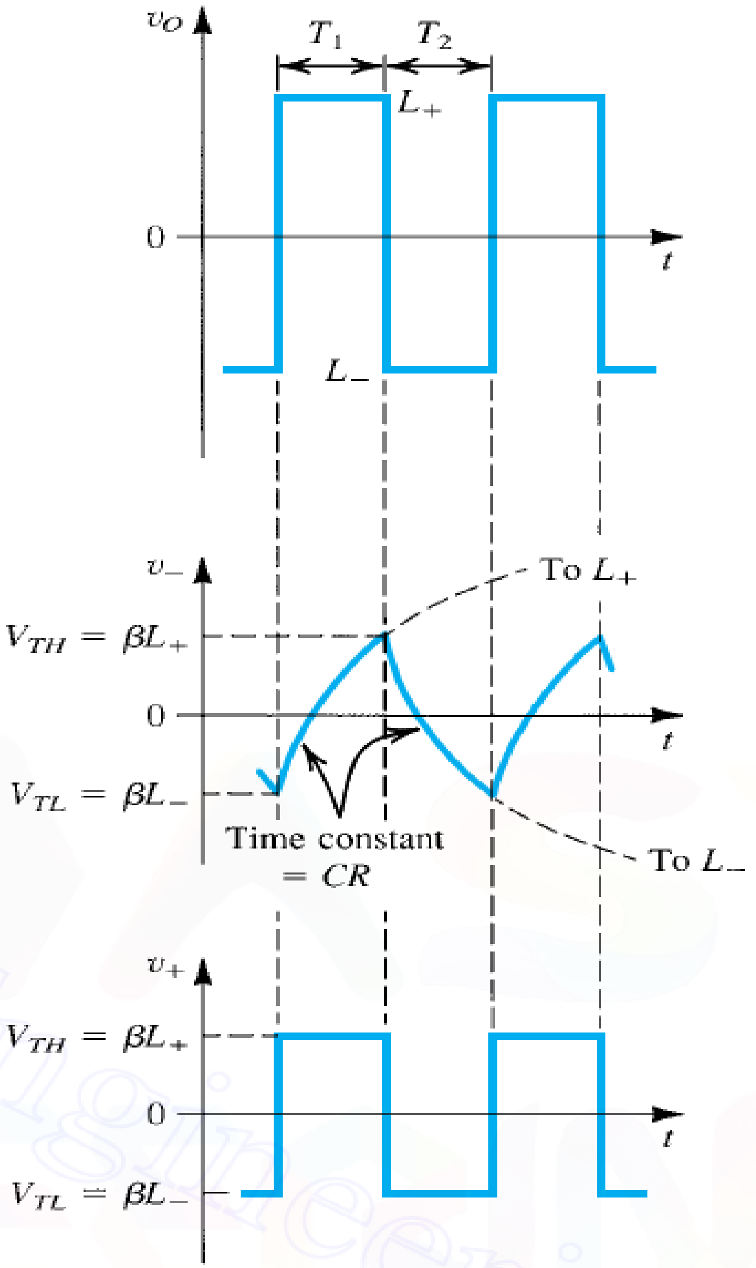
- The voltage across C $(denoted\ by\ v_-)$ will rise exponentially toward L_+ with a time constant $\tau = CR$.

- Meanwhile, $v_+ = \beta L_+$
- The situation will continue until the capacitor

voltage reaches the positive threshold $V_{TH} = \beta L_+$, at which point the bistable multivibrator switch to the other stable state, in which $v_o = L_-$ and $v_+ = \beta L_-$

- The capacitor will then start discharging, and v_- will decrease exponentially toward L_-



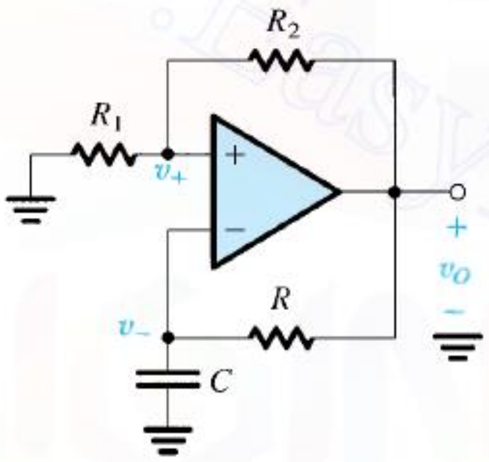


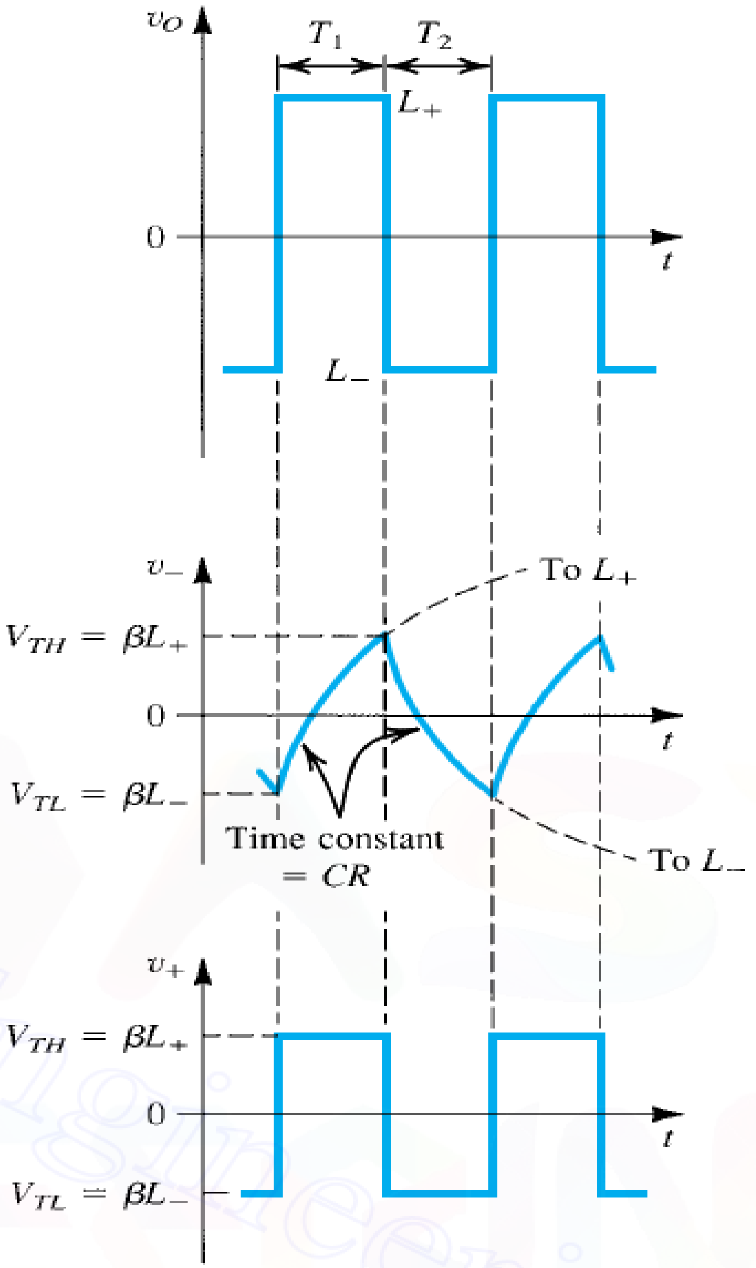
- This new state will prevail until v_- reaches the negative threshold $V_{TL} = \beta L_-$, at which point the bistable multivibrator switch to the positive output state, in which $v_o = L_+$ and $v_+ = \beta L_+$.

- The capacitor begins to charge, and ***the cycle repeats itself.***

- So, we see that the astable circuit oscillates and produces a square waveform at the output of the op amp.

- This waveform, and the waveforms at the two input terminals of the op amp, are displayed here.





<u>Home Assignment:</u>

- Derive a closed form expression for the time period of the oscillation of the astable multivibrator we studied today.
- Please write down all the steps with associated equations and figures on a paper, scan the answer sheets, and convert them into a single pdf file.
- Please send the pdf file to bijit.iiitg@gmail.com with subject

`HA: EC103: *<your roll number>*’ by 4th July, 2021 (11:55 PM). Name the pdf file ***<your roll number>*.pdf**