This is a non-inverting amplifier with a gain of \( G = 1 + \frac{534}{1.03} = 519.4 \). With such a large gain, it will saturate when \( V_i = \pm 10 \text{V} / G = \pm 0.019 \text{V} \).

Times when \( |V_i| < 0.019 \), are
\[
\begin{align*}
T_1 &= \pm \frac{0.1-0.019}{5\text{V}/100\text{ms}} = \pm 1.620 \text{ms}. \\
T_2 &= \pm \frac{0.1+0.019}{5\text{V}/100\text{ms}} = \pm 2.380 \text{ms}.
\end{align*}
\]

- Sketch \( V_o \).
- At what times does \( V_o \) reach \( \pm 10 \text{V} \)?
- Does this circuit suffer from multiple transitions?

(Notes: voltage axis not to scale. The slope of the voltage may be approximated as 5 V/100 ms. Op amps are ideal)
• Sketch $V_o$.

• At what times does $V_o$ reach $\pm 10$ V?

• Does this circuit suffer from multiple transitions?

(Notes: voltage axis not to scale. The slope of the voltage may be approximated as 5 V/100 ms. Op amps are ideal)

Thresholds at $\pm \frac{1.78 \text{k} \Omega}{438 + 1.78 \text{k} \Omega} \times 10 \text{ V} = \pm 0.040 \text{ V}$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10 \text{ V}$ and $V_+ = +0.040 \text{ V}$.
2) If $V_i > V_+ \implies V_o = -10 \text{ V}$ and $V_+ = -0.040 \text{ V}$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.040 \text{ V}$
  2) when $V_i$ crosses $+0.040 \text{ V}$, then $V_o = -10$ and $V_+ = -0.040 \text{ V}$
  3) when $V_i$ crosses $-0.040 \text{ V}$, then $V_o = +10$ and $V_+ = +0.040 \text{ V}$
  4) when $V_i$ crosses $+0.040 \text{ V}$, then $V_o = -10$ and $V_+ = -0.040 \text{ V}$

• At what times does $V_o$ reach $\pm 10 \text{ V}$?
  Transitions at $\pm \frac{0.1 - 0.040}{5 \text{ V}/100 \text{ ms}} = \pm 1.20 \text{ ms}$.
  1) Beginning until $-1.20 \text{ ms} \implies V_o = +10 \text{ V}$.
  2) $-1.20 \text{ ms}$ until $0 \text{ ms} \implies V_o = -10 \text{ V}$.
  3) $0 \text{ ms}$ until $+2.80 \text{ ms} \implies V_o = +10 \text{ V}$.
  4) $+2.80 \text{ ms}$ until end $\implies V_o = -10 \text{ V}$.

• Does this circuit suffer from multiple transitions? [Yes]
This is a low pass filter with a gain of \( G = \frac{-326 \text{k}\Omega}{14.3 \text{k}\Omega} = -22.80 \).

With such a large gain, it will saturate when \( V_i = \pm 10 \text{ V} / G = \pm 0.439 \text{ V} \).

The time constant is \( \tau = 326 \text{k}\Omega \times 310 \text{nF} = 101.1 \text{ ms} \).

- At what times does \( V_o \) reach \( \pm 10 \text{ V} \)?
  
  Transitions at \( \pm \frac{0.1+0.439}{5 \text{ V}/100 \text{ ms}} = \pm 10.8 \text{ ms} \).
  
  Thus: 1) Beginning until \(-10.8 \text{ ms} \implies V_o = +10 \text{ V} \).
  
    2) \(+10.8 \text{ ms} \) until end \( \implies V_o = -10 \text{ V} \).

- Sketch \( V_o \) (this is difficult because of the exponential – indicate the main features of the curve)

  Begining until \(-10.8 \text{ ms} \implies V_o = +10 \text{ V} \). Then, from \(+10.8 \text{ ms} \) until \(-10.8 \text{ ms} \) the will go from \(+10 \text{ V} \) to \(-10 \text{ V} \), following the flipped the blue line (with gain) but with a slight delay. However, it will only deviate slightly at the zigzag. The time constant \( \tau \) is longer than the gap in the zigzag. Finally, from \(+10.8 \text{ ms} \) until end \( \implies V_o = -10 \text{ V} \).

- Does this circuit suffer from multiple transitions?

  [No]

  Explanation: In the above case, the response is linear throughout the +/-0.1V transition of the input signal. The addition of the capacitor turns the circuit into a “lossy integrator”. Its step response would be an exponential with time constant \( RC = 101.1 \text{ ms} \). We don’t have exactly a step at the input; however, if the input transitions are short compared to the time constant we can approximate the output as an exponential (perhaps with a “bump” \( V_i \) briefly changes sign). Assuming the input transitions are short compared to \( RC \), then \( V_o \) will NOT suffer from multiple transitions.