This is a non-inverting amplifier with a gain of \( G = 1 + \frac{458}{115} = 399.3 \). With such a large gain, it will saturate when \( V_i = \pm 10 V / G = \pm 0.025 V \).

Times when \( |V_i| < 0.025 \), are:

\[
T_1 = \pm \frac{0.1 - 0.025}{5 V/100 \text{ ms}} = \pm 1.500 \text{ ms}.
\]

\[
T_2 = \pm \frac{0.1 + 0.025}{5 V/100 \text{ ms}} = \pm 2.500 \text{ ms}.
\]

• 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)

\[ \begin{align*}
\text{(Notes: voltage axis not to scale. The slope of the voltage may be approximated as 5 V/100 ms. Op amps are ideal)}
\end{align*} \]
• 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 $\pm \frac{1.53\, k\Omega}{415+1.53\, k\Omega} \times 10\, V = \pm 0.037\, V$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\, V$ and $V_+ = +0.037\, V$.
2) If $V_i > V_+ \implies V_o = -10\, V$ and $V_+ = -0.037\, V$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.037\, V$
  2) when $V_i$ crosses $+0.037\, V$, then $V_o = -10$ and $V_+ = -0.037\, V$
  3) when $V_i$ crosses $-0.037\, V$, then $V_o = +10$ and $V_+ = +0.037\, V$
  4) when $V_i$ crosses $+0.037\, V$, then $V_o = -10$ and $V_+ = -0.037\, V$

• At what times does $V_o$ reach $\pm 10\, V$?
  Transitions at $\pm \frac{0.1 - 0.037}{5\, V/100\, ms} = \pm 1.26\, ms$.
  1) Beginning until $-1.26\, ms \implies V_o = +10\, V$.
  2) $-1.26\, ms$ until $0\, ms \implies V_o = -10\, V$.
  3) $0\, ms$ until $+2.74\, ms \implies V_o = +10\, V$.
  4) $+2.74\, ms$ until end $\implies V_o = -10\, V$.

• Does this circuit suffer from multiple transitions? Yes
This is a low pass filter with a gain of $G = \frac{-436 \text{k}\Omega}{10.3 \text{k}\Omega} = -42.33$.
With such a large gain, it will saturate when $V_i = \pm 10 \text{V} / G = \pm 0.236 \text{V}$.
The time constant is $\tau = 436 \text{k}\Omega \times 345 \text{nF} = 150.4 \text{ms}$.

- At what times does $V_o$ reach $\pm 10 \text{V}$?
  Transitions at $\pm \frac{0.1 + 0.236}{3 \text{V}/100 \text{ms}} = \pm 6.7 \text{ms}$.
  Thus: 1) Beginning until $-6.7 \text{ms} \implies V_o = +10 \text{V}$.
    2) $+6.7 \text{ms}$ 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 $-6.7 \text{ms} \implies V_o = +10 \text{V}$. Then, from $+6.7 \text{ms}$ until $-6.7 \text{ms}$ the will go from $+10$ 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 $+6.7 \text{ms}$ 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 $RC = 150.4 \text{ms}$. 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.