This is a non-inverting amplifier with a gain of $G = 1 + \frac{548}{1.92} = 286.4$. With such a large gain, it will saturate when $V_i = \pm 10 V / G = \pm \frac{10}{286.4} V$.

Times when $|V_i| < 0.035$ V, are

$T_1 = \pm \frac{0.1 - 0.035}{5 V/100 \text{ms}} = \pm 1.300 \text{ ms}$.
$T_2 = \pm \frac{0.1 + 0.035}{5 V/100 \text{ms}} = \pm 2.700 \text{ ms}$.

- Sketch $V_o$.
  1) From start to $-2.700 \text{ ms}$, $V_o = -10 \text{ V}$
  2) From $-2.700 \text{ ms}$ to $-1.300 \text{ ms}$, $V_o = \text{ transitions from } -10 \text{ V to } +10 \text{ V}$
  3) From $-1.300 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 \text{ V}$
  4) From $0 \text{ ms}$ to $+1.300 \text{ ms}$, $V_o = -10 \text{ V}$
  5) From $+1.300 \text{ ms}$ to $+2.700 \text{ ms}$, $V_o = \text{ transitions from } -10 \text{ V to } +10 \text{ V}$
  6) From $+2.700 \text{ ms}$ to end, $V_o = +10 \text{ V}$

- At what times does $V_o$ reach $\pm 10 \text{ V}$?
  1) From start to $-2.700 \text{ ms}$, $V_o = -10 \text{ V}$
  3) From $-1.300 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 \text{ V}$
  4) From $0 \text{ ms}$ to $+1.300 \text{ ms}$, $V_o = -10 \text{ V}$
  6) From $+2.700 \text{ ms}$ to end, $V_o = +10 \text{ V}$

- Does this circuit suffer from multiple transitions?
  Yes
• 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)

\[
\frac{1.83 \, \text{k}\Omega}{425 \, \text{k}\Omega} \times 10 \, \text{V} = \pm 0.043 \, \text{V}.
\]

Conditions:
1) If $V_i < V_+$ $\implies$ $V_o = +10$ V and $V_+ = +0.043$ V.
2) If $V_i > V_+$ $\implies$ $V_o = -10$ V and $V_+ = -0.043$ V.

• Sketch $V_o$.

1) Initially, $V_o = +10$ and $V_+ = +0.043$ V
2) when $V_i$ crosses +0.043 V, then $V_o = -10$ and $V_+ = -0.043$ V
3) when $V_i$ crosses -0.043 V, then $V_o = +10$ and $V_+ = +0.043$ V
4) when $V_i$ crosses +0.043 V, then $V_o = -10$ and $V_+ = -0.043$ V

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

Transitions at $\pm \frac{0.1-0.043}{5\text{V}/100\text{ms}} = \pm 1.14$ ms.
1) Beginning until $-1.14$ ms $\implies$ $V_o = +10$ V.
2) $-1.14$ ms until 0 ms $\implies$ $V_o = -10$ V.
3) 0 ms until $+2.86$ ms $\implies$ $V_o = +10$ V.
4) $+2.86$ 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 \( G = \frac{519 \, \text{k}\Omega}{16.6 \, \text{k}\Omega} = -31.27 \).
With such a large gain, it will saturate when \( V_i = \pm 10 \, \text{V} / G = \pm 0.320 \, \text{V} \).
The time constant is \( \tau = 519 \, \text{k}\Omega \times 576 \, \text{nF} = 298.9 \, \text{ms} \).

- At what times does \( V_o \) reach \( \pm 10 \, \text{V} \)?
  Transitions at \( \pm \frac{0.1+0.320}{5 \, \text{V} / 100 \, \text{ms}} = \pm 8.4 \, \text{ms} \).
  Thus: 1) Beginning until \( -8.4 \, \text{ms} \implies V_o = +10 \, \text{V} \).
    2) \(+8.4 \, \text{ms} \) 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)
  Beginning until \( -8.4 \, \text{ms} \implies V_o = +10 \, \text{V} \). Then, from \(+8.4 \, \text{ms} \) until \( -8.4 \, \text{ms} \) 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 \(+8.4 \, \text{ms} \) until end \( \implies V_o = -10 \, \text{V} \).

- Does this circuit suffer from multiple transitions?
  \[ \text{No} \]

\textit{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 \( RC = 298.9 \, \text{ms} \). 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.