This is a non-inverting amplifier with a gain of \( G = 1 + \frac{364}{1.85} = 197.8 \). With such a large gain, it will saturate when \( V_i = \pm 10 V / G = \pm 0.051 V \).

Times when \( |V_i| < 0.051 V \), are
\[
T_1 = \pm \frac{0.1 - 0.051}{5 V/100 \text{ms}} = \pm 0.980 \text{ ms}. \\
T_2 = \pm \frac{0.1 + 0.051}{5 V/100 \text{ms}} = \pm 3.020 \text{ ms}. 
\]

- Sketch \( V_o \).
  1) From start to \(-3.020 \text{ ms}, V_o = -10 V \)
  2) From \(-3.020 \text{ ms} \) to \(-0.980 \text{ ms}, V_o = \) transitions from \(-10 V \) to \(+10 V \)
  3) From \(-0.980 \text{ ms} \) to \(0 \text{ ms}, V_o = +10 V \)
  4) From \(0 \text{ ms} \) to \(+0.980 \text{ ms}, V_o = -10 V \)
  5) From \(+0.980 \text{ ms} \) to \(+3.020 \text{ ms}, V_o = \) transitions from \(-10 V \) to \(+10 V \)
  6) From \(+3.020 \text{ ms} \) to end, \( V_o = +10 V \)

- At what times does \( V_o \) reach \( \pm 10 V \)?
  1) From start to \(-3.020 \text{ ms}, V_o = -10 V \)
  3) From \(-0.980 \text{ ms} \) to \(0 \text{ ms}, V_o = +10 V \)
  4) From \(0 \text{ ms} \) to \(+0.980 \text{ ms}, V_o = -10 V \)
  6) From \(+3.020 \text{ ms} \) to end, \( V_o = +10 V \)

- Does this circuit suffer from multiple transitions?
  [Yes]
• Sketch $V_o$.

• At what times does $V_o$ reach ±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 $\pm \frac{1.21 \text{ k}\Omega}{458} \times 10 V = \pm 0.026 V$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10 V$ and $V_+ = +0.026 V$.
2) If $V_i > V_+ \implies V_o = -10 V$ and $V_+ = -0.026 V$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.026 V$
  2) when $V_i$ crosses $+0.026 V$, then $V_o = -10$ and $V_+ = -0.026 V$
  3) when $V_i$ crosses $-0.026 V$, then $V_o = +10$ and $V_+ = +0.026 V$
  4) when $V_i$ crosses $+0.026 V$, then $V_o = -10$ and $V_+ = -0.026 V$

• At what times does $V_o$ reach ±10 V?
  Transitions at $\pm \frac{0.1 - 0.026}{5 V/100 ms} = \pm 1.48 ms$.
  1) Beginning until $-1.48 ms \implies V_o = +10 V$.
  2) $-1.48 ms$ until $0 ms \implies V_o = -10 V$.
  3) $0 ms$ until $+2.52 ms \implies V_o = +10 V$.
  4) $+2.52 ms$ 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 $G = \frac{-556 \, \text{k}\Omega}{17.4 \, \text{k}\Omega} = -31.95$.
With such a large gain, it will saturate when $V_i = \pm 10 \, \text{V} / G = \pm 0.313 \, \text{V}$.
The time constant is $\tau = 556 \, \text{k}\Omega \times 556 \, \text{nF} = 309.1 \, \text{ms}$.

• At what times does $V_o$ reach $\pm 10 \, \text{V}$?
  Transitions at $\pm 0.1 + 0.313 \frac{5 \, \text{V}}{100 \, \text{ms}} = \pm 8.3 \, \text{ms}$.
  Thus: 1) Beginning until $-8.3 \, \text{ms} \Rightarrow V_o = +10 \, \text{V}$.
  2) $+8.3 \, \text{ms}$ until end $\Rightarrow V_o = -10 \, \text{V}$.

• Sketch $V_o$ (this is difficult because of the exponential – indicate the main features of the curve)
  Begining until $-8.3 \, \text{ms} \Rightarrow V_o = +10 \, \text{V}$. Then, from $+8.3 \, \text{ms}$ until $-8.3 \, \text{ms}$ 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 $+8.3 \, \text{ms}$ until end $\Rightarrow V_o = -10 \, \text{V}$.

• 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 $RC = 309.1 \, \text{ms}$. 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.