This is a non-inverting amplifier with a gain of \( G = 1 + \frac{451}{1.86} = 243.5 \).  
With such a large gain, it will saturate when \( V_i = \pm 10 \text{V} / G = \pm 0.041 \text{V} \).

Times when \(|V_i| < 0.041\), are

\[
T_1 = \pm \frac{0.1 - 0.041}{5/100\text{ms}} = \pm 1.180 \text{ms}.
\]

\[
T_2 = \pm \frac{0.1 + 0.041}{5/100\text{ms}} = \pm 2.820 \text{ms}.
\]

- 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 $\pm 10 \, \text{V}$?

- Does this circuit suffer from multiple transitions?

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

**Thresholds at** $\pm \frac{1.50 \, \text{k}\Omega}{449+1.50 \, \text{k}\Omega} \times 10 \, \text{V} = \pm 0.033 \, \text{V}$.

**Conditions:**
1) If $V_i < V_+ \implies V_o = +10 \, \text{V}$ and $V_+ = +0.033 \, \text{V}$.
2) If $V_i > V_+ \implies V_o = -10 \, \text{V}$ and $V_+ = -0.033 \, \text{V}$.

- Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.033 \, \text{V}$
  2) when $V_i$ crosses $+0.033 \, \text{V}$, then $V_o = -10$ and $V_+ = -0.033 \, \text{V}$
  3) when $V_i$ crosses $-0.033 \, \text{V}$, then $V_o = +10$ and $V_+ = +0.033 \, \text{V}$
  4) when $V_i$ crosses $+0.033 \, \text{V}$, then $V_o = -10$ and $V_+ = -0.033 \, \text{V}$

- At what times does $V_o$ reach $\pm 10 \, \text{V}$?
  Transitions at $\pm \frac{0.1-0.033}{\text{V}/100 \, \text{ms}} = \pm 1.34 \, \text{ms}$.
  1) Beginning until $-1.34 \, \text{ms} \implies V_o = +10 \, \text{V}$.
  2) $-1.34 \, \text{ms}$ until $0 \, \text{ms} \implies V_o = -10 \, \text{V}$.
  3) $0 \, \text{ms}$ until $+2.66 \, \text{ms} \implies V_o = +10 \, \text{V}$.
  4) $+2.66 \, \text{ms}$ until end $\implies V_o = -10 \, \text{V}$.

- Does this circuit suffer from multiple transitions?
  Yes
• Sketch $V_o$ (this is difficult because of the exponential – indicate the main features of the curve)

• 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)

This is a low pass filter with a gain of $G = \frac{-369\, \text{k}\Omega}{18.2\, \text{k}\Omega} = -20.27$. With such a large gain, it will saturate when $V_i = \pm 10$ V/$G = \pm 0.493$ V.

The time constant is $\tau = 369\, \text{k}\Omega \times 558\, \text{nF} = 205.9$ ms.

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

Transitions at $\pm \frac{0.1+0.493}{5\, \text{V}/100\, \text{ms}} = \pm 11.9$ ms.

Thus: 1) Beginning until $-11.9$ ms $\implies V_o = +10$ V.

2) $+11.9$ ms until end $\implies V_o = -10$ V.

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

Beginning until $-11.9$ ms $\implies V_o = +10$ V. Then, from $+11.9$ ms until $-11.9$ ms the will go from $+10$ to $-10$ 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 $+11.9$ ms until end $\implies V_o = -10$ 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 $RC = 205.9$ 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.