This is a non-inverting amplifier with a gain of \( G = 1 + \frac{594}{163} = 365.4 \). With such a large gain, it will saturate when \( V_i = \pm 10 V / G = \pm 0.027 V \).

Times when \( |V_i| < 0.027 \) V are

\[
T_1 = \pm \frac{0.1}{\frac{5 V}{100 \text{ms}}} = \pm 1.460 \text{ ms}.
\]

\[
T_2 = \pm \frac{0.1+0.027}{\frac{5 V}{100 \text{ms}}} = \pm 2.540 \text{ ms}.
\]

Sketch \( V_o \).

At what times does \( V_o \) reach \( \pm 10 V \)?

Does this circuit suffer from multiple transitions?

Yes
• 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 $\pm \frac{1.98 \text{ k}\Omega}{463 + 1.98 \text{ k}\Omega} \times 10 \text{ V} = \pm 0.043 \text{ V}$. 
Conditions:
1) If $V_i < V_+ \implies V_o = +10 \text{ V}$ and $V_+ = +0.043 \text{ V}$.
2) If $V_i > V_+ \implies V_o = -10 \text{ V}$ and $V_+ = -0.043 \text{ V}$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.043 \text{ V}$
  2) when $V_i$ crosses $+0.043 \text{ V}$, then $V_o = -10$ and $V_+ = -0.043 \text{ V}$
  3) when $V_i$ crosses $-0.043 \text{ V}$, then $V_o = +10$ and $V_+ = +0.043 \text{ V}$
  4) when $V_i$ crosses $+0.043 \text{ V}$, then $V_o = -10$ and $V_+ = -0.043 \text{ V}$

• At what times does $V_o$ reach $\pm 10 \text{ V}$?
  Transitions at $\pm \frac{0.1 - 0.043}{5 \text{ V}/100 \text{ ms}} = \pm 1.14 \text{ ms}$.
  1) Beginning until $-1.14 \text{ ms} \implies V_o = +10 \text{ V}$.
  2) $-1.14 \text{ ms}$ until $0 \text{ ms} \implies V_o = -10 \text{ V}$.
  3) $0 \text{ ms}$ until $+2.86 \text{ ms} \implies V_o = +10 \text{ V}$.
  4) $+2.86 \text{ ms}$ 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 \( G = \frac{-554 \text{k}\Omega}{17.7 \text{k}\Omega} = -31.30 \).
With such a large gain, it will saturate when \( V_i = \pm 10 \text{V} \)/\( G = \pm 0.319 \text{V} \).
The time constant is \( \tau = 554 \text{k}\Omega \times 488 \text{nF} = 270.4 \text{ms} \).

- At what times does \( V_o \) reach \( \pm 10 \text{V} \)?
  Transitions at \( \pm \frac{0.319}{5 \text{V}/100 \text{ms}} = \pm 8.4 \text{ms} \).
  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)
  Begining 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?
  \[ \text{No} \]

\[ \text{Explanation:} \] 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 \( RC = 270.4 \text{ ms} \). 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.