This is a non-inverting amplifier with a gain of \( G = 1 + \frac{397}{160} = 249.1 \).
With such a large gain, it will saturate when \( V_i = \pm 10 \text{ V}/G = \pm 0.040 \text{ V} \).

Times when \( |V_i| < 0.040 \text{ V} \), are
\[
T_1 = \pm \frac{0.1-0.040}{5\text{ V}/100\text{ ms}} = \pm 1.200 \text{ ms},
\]
\[
T_2 = \pm \frac{0.1+0.040}{5\text{ V}/100\text{ ms}} = \pm 2.800 \text{ ms}.
\]

- 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)

- At what times does \( V_o \) reach \( \pm 10 \text{ V} \)?
  1) From start to \(-2.800 \text{ ms} \), \( V_o = -10 \text{ V} \)
  2) From \(-2.800 \text{ ms} \) to \(-1.200 \text{ ms} \), \( V_o \) = transitions from \(-10 \text{ V} \) to \(+10 \text{ V} \)
  3) From \(-1.200 \text{ ms} \) to \(0 \text{ ms} \), \( V_o = +10 \text{ V} \)
  4) From \(0 \text{ ms} \) to \(+1.200 \text{ ms} \), \( V_o = -10 \text{ V} \)
  5) From \(+1.200 \text{ ms} \) to \(+2.800 \text{ ms} \), \( V_o \) = transitions from \(-10 \text{ V} \) to \(+10 \text{ V} \)
  6) From \(+2.800 \text{ ms} \) 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 $5\, \text{V}/100\, \text{ms}$. Op amps are ideal)

Thresholds at $\pm \frac{1.32\, \text{k}\Omega}{319+1.32\, \text{k}\Omega} \times 10\, \text{V} = \pm 0.041\, \text{V}$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\, \text{V} \text{ and } V_+ = +0.041\, \text{V}$.
2) If $V_i > V_+ \implies V_o = -10\, \text{V} \text{ and } V_+ = -0.041\, \text{V}$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.041\, \text{V}$
  2) when $V_i$ crosses $+0.041\, \text{V}$, then $V_o = -10$ and $V_+ = -0.041\, \text{V}$
  3) when $V_i$ crosses $-0.041\, \text{V}$, then $V_o = +10$ and $V_+ = +0.041\, \text{V}$
  4) when $V_i$ crosses $+0.041\, \text{V}$, then $V_o = -10$ and $V_+ = -0.041\, \text{V}$

• At what times does $V_o$ reach $\pm 10\, \text{V}$?
  Transitions at $\pm \frac{0.1-0.041}{5\, \text{V}/100\, \text{ms}} = \pm 1.18\, \text{ms}$.
  1) Beginning until $-1.18\, \text{ms} \implies V_o = +10\, \text{V}$.
  2) $-1.18\, \text{ms}$ until $0\, \text{ms} \implies V_o = -10\, \text{V}$.
  3) $0\, \text{ms}$ until $+2.82\, \text{ms} \implies V_o = +10\, \text{V}$.
  4) $+2.82\, \text{ms}$ 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 ±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 $G = \frac{-394 \text{k}\Omega}{13.6 \text{k}\Omega} = -28.97$.

With such a large gain, it will saturate when $V_i = \pm 10 \text{ V} / G = \pm 0.345 \text{ V}$.

The time constant is $\tau = 394 \text{k}\Omega \times 480 \text{nF} = 189.1 \text{ ms}$.

• At what times does $V_o$ reach ±10 V?
  Transitions at $\pm \frac{0.1+0.345}{5 \text{ V}/100 \text{ ms}} = \pm 8.9 \text{ ms}$.
  Thus:
  1) Begining until $-8.9 \text{ ms} \implies V_o = +10 \text{ V}$.
  2) $+8.9 \text{ ms}$ 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 $-8.9 \text{ ms} \implies V_o = +10 \text{ V}$. Then, from $+8.9 \text{ ms}$ until $-8.9 \text{ ms}$ 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 $+8.9 \text{ ms}$ 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 $RC = 189.1 \text{ ms}$. 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.