This is a non-inverting amplifier with a gain of \( G = 1 + \frac{519}{1.16} = 448.4 \). With such a large gain, it will saturate when \( V_i = \pm 10 V/G = \pm 0.022 V \).

Times when \( |V_i| < 0.022, V \), are

\[
T_1 = \pm \frac{0.1-0.022}{5 V/100 ms} = \pm 1.560 ms.
\]

\[
T_2 = \pm \frac{0.1+0.022}{5 V/100 ms} = \pm 2.440 ms.
\]

- Sketch \( V_o \).
- At what times does \( V_o \) reach \( \pm 10 V \)?
  1) From start to \(-2.440 ms, V_o = -10 V\)
  2) From \(-2.440 ms \) to \(-1.560 ms, V_o = \) transitions from \(-10 V \) to \(+10 V\)
  3) From \(-1.560 ms \) to \(0 ms, V_o = +10 V\)
  4) From \(0 ms\) to \(+1.560 ms, V_o = -10 V\)
  5) From \(+1.560 ms \) to \(+2.440 ms, V_o = \) transitions from \(-10 V \) to \(+10 V\)
  6) From \(+2.440 ms\) to end, \( V_o = +10 V\)
- Does this circuit suffer from multiple transitions?
  Yes
Sketch $V_o$.

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

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)

Thresholds at $\pm \frac{1.73\ k\Omega}{356+1.73\ k\Omega} \times 10\ V = \pm 0.048\ V$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\ V$ and $V_+ = +0.048\ V$.
2) If $V_i > V_+ \implies V_o = -10\ V$ and $V_+ = -0.048\ V$.

Sketch $V_o$.

1) Initially, $V_o = +10$ and $V_+ = +0.048\ V$
2) when $V_i$ crosses $+0.048\ V$, then $V_o = -10$ and $V_+ = -0.048\ V$
3) when $V_i$ crosses $-0.048\ V$, then $V_o = +10$ and $V_+ = +0.048\ V$
4) when $V_i$ crosses $+0.048\ V$, then $V_o = -10$ and $V_+ = -0.048\ V$

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

Transitions at $\pm \frac{0.1-0.048}{5\ V/100\ ms} = \pm 1.04\ ms$.
1) Beginning until $-1.04\ ms \implies V_o = +10\ V$.
2) $-1.04\ ms$ until $0\ ms \implies V_o = -10\ V$.
3) $0\ ms$ until $+2.96\ ms \implies V_o = +10\ V$.
4) $+2.96\ ms$ 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 \( G = \frac{-527 \text{k}\Omega}{12.0 \text{k}\Omega} = -43.92 \).

With such a large gain, it will saturate when \( V_i = \pm 10 \text{V} / G = \pm 0.228 \text{V} \).

The time constant is \( \tau = 527 \text{k}\Omega \times 349 \text{nF} = 183.9 \text{ms} \).

- At what times does \( V_o \) reach \( \pm 10 \text{V} \)?
  - Transitions at \( \pm \frac{0.1+0.228}{5 \text{V}/100 \text{ms}} = \pm 6.6 \text{ms} \).
  - Thus: 1) Beginning until \(-6.6 \text{ms} \implies V_o = +10 \text{V} \).
  - 2) +6.6 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 \(-6.6 \text{ms} \implies V_o = +10 \text{V} \). Then, from +6.6 ms until \(-6.6 \text{ms} \) 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 +6.6 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 \( RC = 183.9 \text{ms} \). 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.