This is a non-inverting amplifier with a gain of $G = 1 + \frac{409}{1.19} = 344.7$. With such a large gain, it will saturate when $V_i = \pm 10 V/G = \pm 0.029 V$.

Times when $|V_i| < 0.029$, V, are:

- $T_1 = \pm \frac{0.1 - 0.029}{5 V/100\text{ms}} = \pm 1.420 \text{ms}$.
- $T_2 = \pm \frac{0.1 + 0.029}{5 V/100\text{ms}} = \pm 2.580 \text{ms}$.

### 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)

- Sketch $V_o$.
  1) From start to $-2.580 \text{ ms}$, $V_o = -10 V$
  2) From $-2.580 \text{ ms}$ to $-1.420 \text{ ms}$, $V_o = \text{transitions from} -10 V \text{ to} +10 V$
  3) From $-1.420 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 V$
  4) From $0 \text{ ms}$ to $+1.420 \text{ ms}$, $V_o = -10 V$
  5) From $+1.420 \text{ ms}$ to $+2.580 \text{ ms}$, $V_o = \text{transitions from} -10 V \text{ to} +10 V$
  6) From $+2.580 \text{ ms}$ to end, $V_o = +10 V$

- At what times does $V_o$ reach $\pm 10 V$?
  1) From start to $-2.580 \text{ ms}$, $V_o = -10 V$
  3) From $-1.420 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 V$
  4) From $0 \text{ ms}$ to $+1.420 \text{ ms}$, $V_o = -10 V$
  6) From $+2.580 \text{ ms}$ to end, $V_o = +10 V$

- Does this circuit suffer from multiple transitions?
  Yes
1. Sketch $V_o$.

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

3. 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 $\pm \frac{1.36\, k\Omega}{423+1.36\, k\Omega} \times 10\, V = \pm 0.032\, V$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\, V$ and $V_+ = +0.032\, V$.
2) If $V_i > V_+ \implies V_o = -10\, V$ and $V_+ = -0.032\, V$.

1) Initially, $V_o = +10$ and $V_+ = +0.032\, V$
2) when $V_i$ crosses $+0.032\, V$, then $V_o = -10$ and $V_+ = -0.032\, V$
3) when $V_i$ crosses $-0.032\, V$, then $V_o = +10$ and $V_+ = +0.032\, V$
4) when $V_i$ crosses $+0.032\, V$, then $V_o = -10$ and $V_+ = -0.032\, V$

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

Transitions at $\pm \frac{0.1-0.032}{5\, V/100\, ms} = \pm 1.36\, ms$.
1) Beginning until $-1.36\, ms \implies V_o = +10\, V$.
2) $-1.36\, ms$ until $0\, ms \implies V_o = -10\, V$.
3) $0\, ms$ until $+2.64\, ms \implies V_o = +10\, V$.
4) $+2.64\, ms$ 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 $G = -\frac{596 \, \text{k}\Omega}{18.8 \, \text{k}\Omega} = -31.70$.
With such a large gain, it will saturate when $V_i = \pm 10 \, \text{V} / G = \pm 0.315 \, \text{V}$.
The time constant is $\tau = 596 \, \text{k}\Omega \times 356 \, \text{nF} = 212.2 \, \text{ms}$.

- At what times does $V_o$ reach $\pm 10 \, \text{V}$?
  Transitions at $\pm \frac{0.1 + 0.315}{5 \, \text{V}/100 \, \text{ms}} = \pm 8.3 \, \text{ms}$.
  Thus: 1) Beginning until $-8.3 \, \text{ms} \implies V_o = +10 \, \text{V}$.
  2) $+8.3 \, \text{ms}$ 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)

- Does this circuit suffer from multiple transitions?
  No

Explanation: In the above case, the response is linear throughout the $\pm 0.1 \, \text{V}$ 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 $RC = 212.2 \, \text{ms}$. 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.