PROBLEMS

1) A flipflop is formed by cascading two inverting amplifiers in a manner described before. The circuit diagram is drawn to emphasize the electrical symmetry of the configuration. Note that the connection from the output of one amplifier to the inverting input of the other is through a voltage divider; this is done to reduce the switching threshold voltage. A triggering pulse (pulse waveform) is fed capacitively to one of the amplifier inputs. Circuit element values are as given in the accompanying netlist. Compare the expected voltage at node 2 to the computed result. Describe the overall operation.

Initially $V(1) = 12(3.3)/(10+3.3) \approx 3V$. Then when $V(5)$ is pulled down by 10v $V(1)$ is likewise pulled down by (approx.) 10v. Similarly when $V(5)$ is subsequently pulled up by 10v $V(1)$ is likewise pulled up by (approx.) 10v. Incidentally note that node 1 is not a virtual ground when the OpAmp is saturated.

When $V(1)$ is pulled down it forces each OpAmp to switch regeneratively from its current saturated state into the complementary state. Subsequently, $V(1)$ is pulled up and the saturated states are switched back.
2) A variant Schmitt trigger configuration is drawn to the right; this one is for non-inverting operation. The switching threshold set by the inverting input is fixed. However the voltage at the non-inverting input depends on the amplifier output voltage, and is different for the two saturation voltages.

Assume an idealized opamp and apply superposition to verify that

\[
V_+ = \frac{R_2}{R_2 + R_1} V_{out} + \frac{R_1}{R_2 + R_1} V_{in}
\]

and hence that switching occurs for \( V_{in} = -(R_2/R_1)V_{out} \). Determine the voltage difference between the switching threshold voltages. Design a non-inverting Schmitt trigger for switching at predefined (by you) thresholds. Describe the locus of the operating point on a \( V_{out} - V_{in} \) plane. Compare calculated performance with computed performance.

*Prob#2

**Answer** Set \( R_1 = R_2 = 10\, \text{K}\Omega \) to limit current; assume \( \pm 10 \) volt OpAmp supply voltages. Then estimate the switching thresholds as \( \pm 5\, \text{v} \).
3) An alternate one-shot circuit, introduced previously but not discussed in detail, is the subject of this exercise. A circuit diagram and a sketch of the circuit response to a trigger input is shown below. In addition a netlist for the circuit (including a pulse source not shown in the figure) is provided. Verify qualitatively the circuit response shown. Calculate the timing using the circuit parameters shown. Assume saturation at ±12v. Compare your estimates to the computed performance.

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Answer
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For an approximate analysis assume an idealized OpAmp saturating at $V_{sat}$. In the steady-state the amplified output voltage is $+V_{sat}$, and the capacitor is charged to $V_{sat}/2$. The inverting input voltage is $V_{sat}(3.3/(3.3+6.8)) \approx V_{sat}/3$. When the trigger pulse pulls the non-inverting input voltage below this value the amplifier output switches regeneratively to $-V_{sat}$. Because the capacitor cannot discharge quickly enough this causes $V_+$ to drop by the change in $V_{out}$; this is $V_{sat}/2$. Note that the inverting input voltage drops to $-V_{sat}/3$. The capacitor charges from an initial value of $-V_{sat}/2$ towards the $+V_{sat}/2$. However the amplifier will switch states regeneratively when the voltage crosses $-V_{sat}/3$.

The expression for the non-inverting input voltage is of the form $A + Be^{-t/T}$ where $T$ is the RC time constant. Note that at $t \to \infty$ the voltage approaches $V_{sat}/2$, whereas at $t=0$ it is $-V_{sat}/2$. Assuming a saturation voltage of 12v, estimate this time as 0.46 millisecond.

A PSpice netlist and plot of computed voltages follows.
4) The circuit shown is designed to produce both a square-wave and a triangular output signal. Until switched the non-inverting Schmitt trigger output (left) provides a fixed voltage input to the inverting Miller integrator (right). The integrator then outputs a ramp voltage with a polarity such that eventually the Schmitt trigger will switch. The same situation then obtains, except for the voltage polarity change. Execute a PSpice circuit analysis which verifies the qualitative description of the circuit performance. Calculate the waveform expected (amplitude and timing) and compare to the computed waveform.

**Answer** The Schmitt Trigger will switch (ideally) between saturation limits, and it will do so when $V(4) = \pm 10v$. The integrator output will be a triangular waveform $\pm 10 \times \text{TIME}/0.47$, with time in milliseconds. The period of the waveform will be $4 \times 0.47 = 1.88$ mseconds.

A PSpice netlist is shown to the right and the waveforms plotted below. Note that an initial voltage is placed on the capacitor to initiate the process. In practice this would be an automatic consequence of electrical (thermal) noise.

*Prob#4

| R1 | 4 | 1 | 4.7K |
| R2 | 1 | 2 | 4.7K |
| V+ | 5 | 0 | DC 10 |
| V- | 6 | 0 | DC -10 |
| X1 | 1 | 0 | 5 6 2 UA741 |
| X2 | 0 | 3 | 5 6 4 UA741 |
| R3 | 2 | 3 | 4.7K |
| C1 | 3 | 4 | 0.1U IC=10 |

.PROBE
.END