Positive Feedback, Relaxation Oscillators and Chaotic Circuits

Lecture 1 – Positive Feedback

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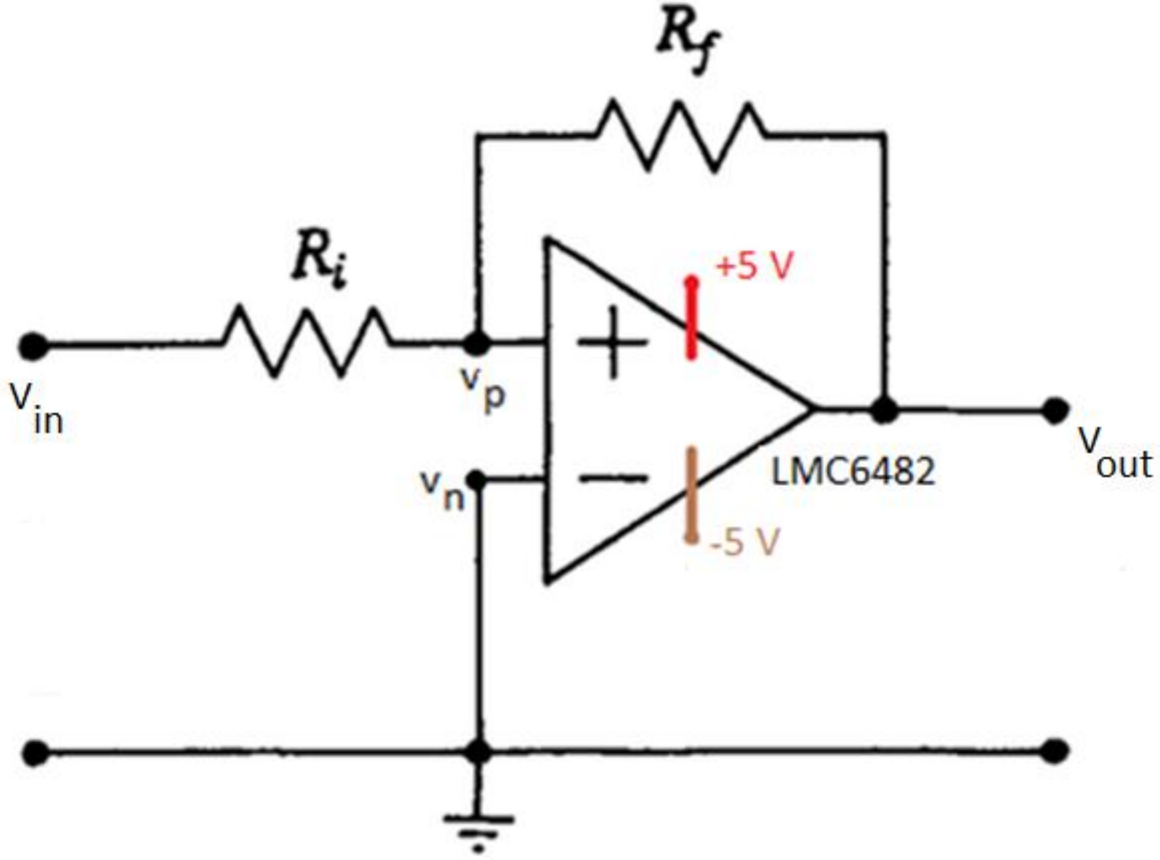
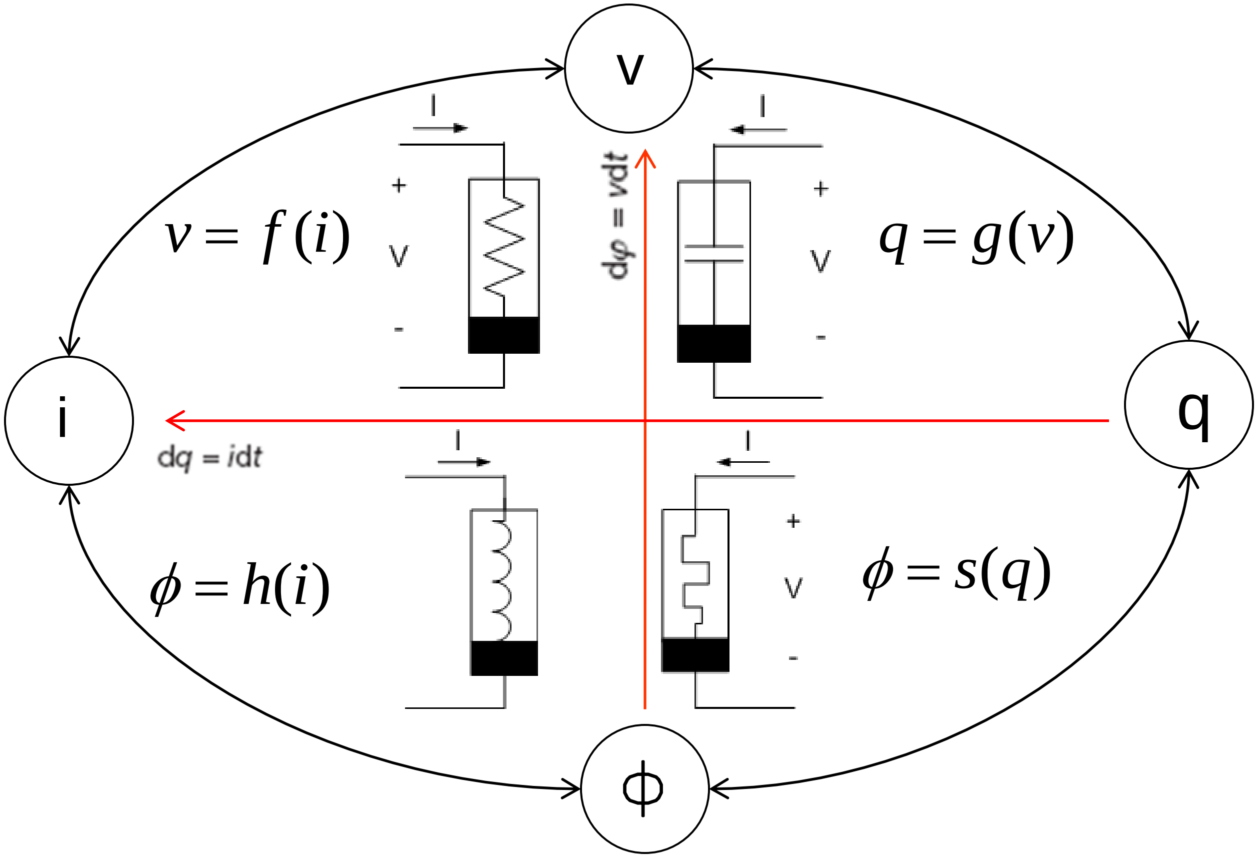
Goal of Lecture 1

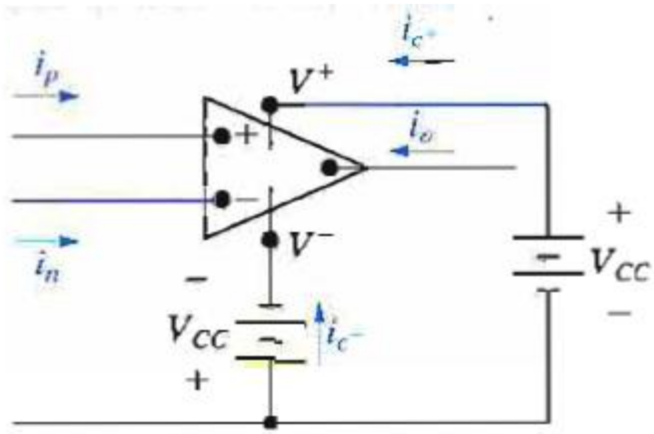
Sketch V_{out} vs V_{in} for the circuit below. Verify your analysis experimentally. Explain any discrepancies between your analysis and experimental results.

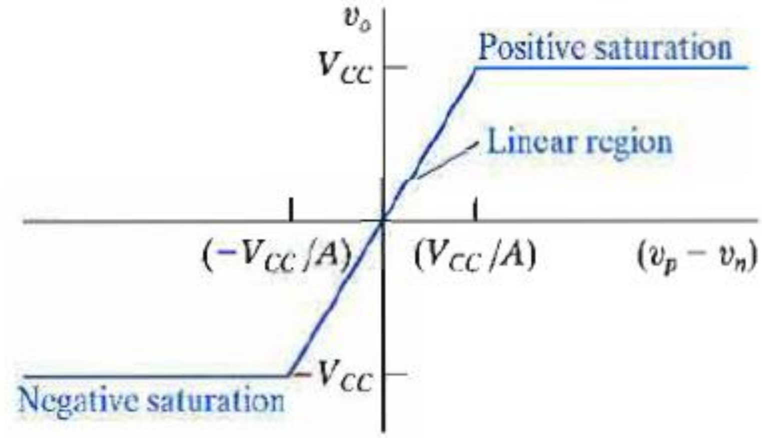


"Review" : The Fundamental Circuit Elements



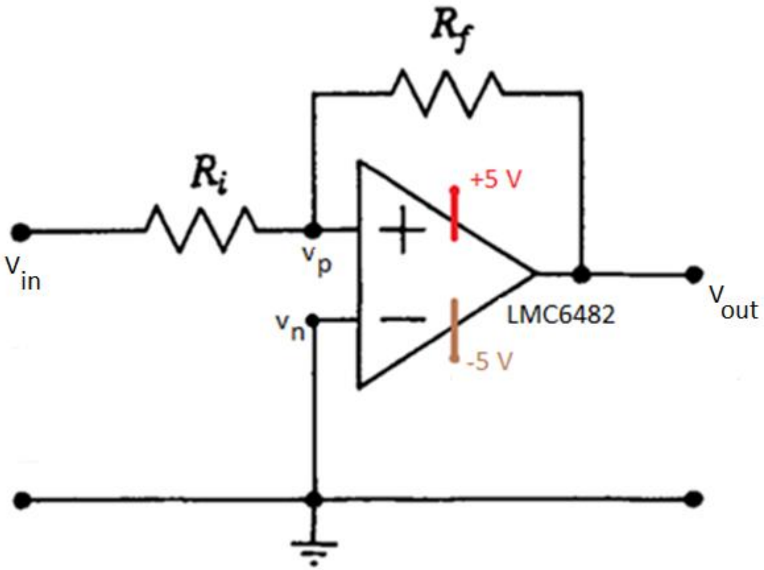
“Review” : The Operational Amplifier





$$v_o = \begin{cases} -V_{CC} & A(v_p - v_n) < -V_{CC}, \\ A(v_p - v_n) & -V_{CC} \leq A(v_p - v_n) \leq +V_{CC}, \\ +V_{CC} & A(v_p - v_n) > +V_{CC}. \end{cases}$$

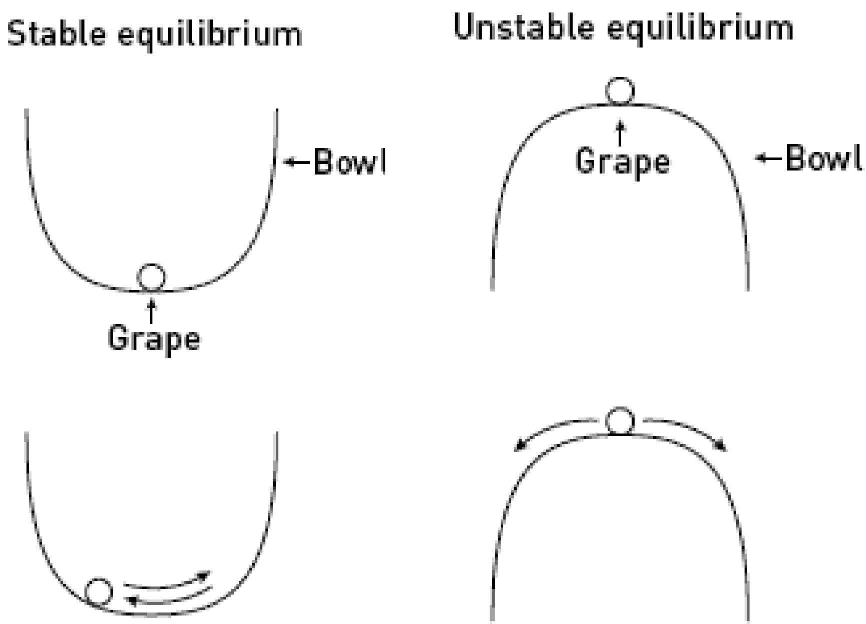
Step 1: Understand Problem



This circuit (system) is non-dynamical!

Equilibrium Points are:

Reference : http://www.learner.org/courses/mathilluminated/units/13/textbook/03.php



Step 2: Devise a Plan

1. Derive V_{out} vs V_{in} using op-amp golden rules

2. Interpret the results

3. Devise an experiment to confirm our derivation (theory)

Step 3 (a): Carry out the plan – Derive V_{out} vs V_{in} (linear region)

Assuming op-amp is in the linear region: $v_p = v_n$

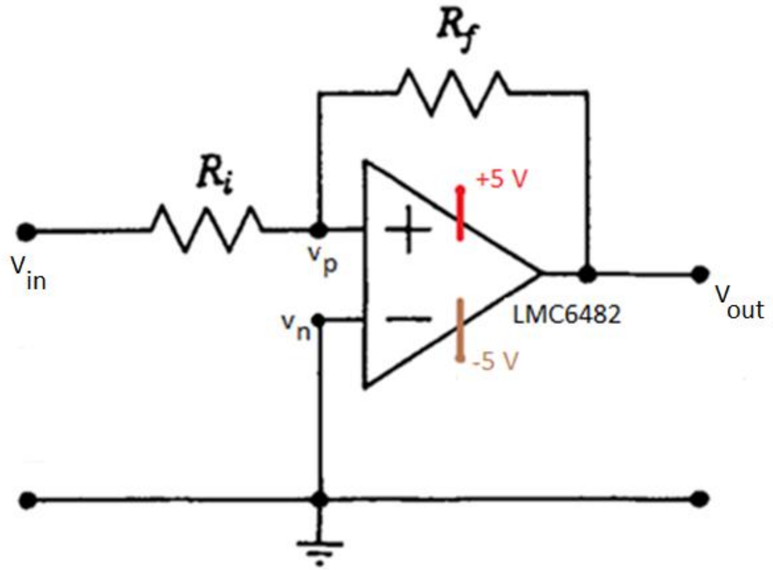
Applying KCL and Ohm's law at v_p :

$$\frac{v_{in} - v_p}{R_i} = \frac{v_p - v_{out}}{R_f}$$

$$\Rightarrow \quad \frac{v_{in} - v_n}{R_i} = \frac{v_p - v_{out}}{R_f}$$

$$\Rightarrow \quad \frac{v_{in}}{R_i} = \frac{-v_{out}}{R_f}$$

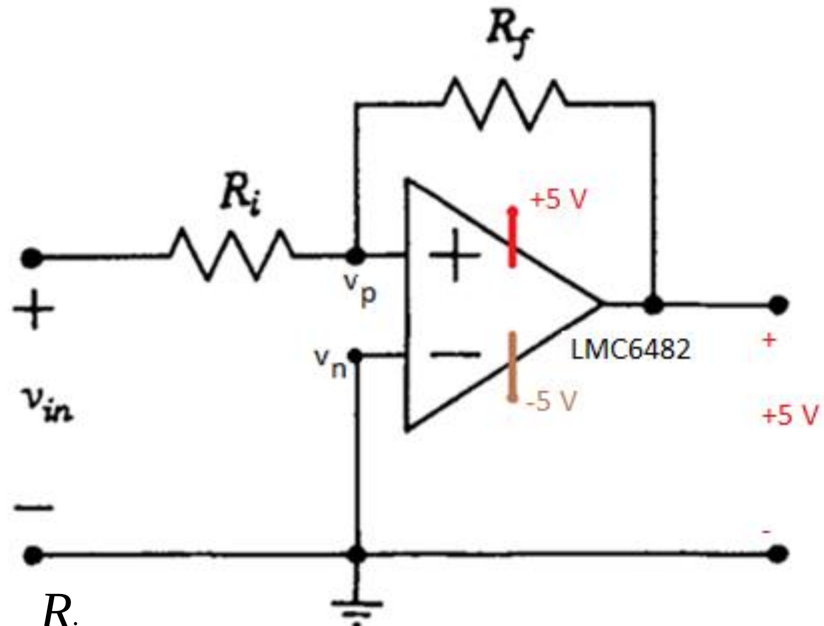
Hence $v_{out} = -2v_{in}$



Step 3 (b): Carry out the plan – Derive V_{out} vs V_{in} (positive saturation region)

Since op-amp is assumed to be in positive saturation: $v_{out} = +v_{CC}$, $v_p \geq v_n$

Applying KCL and Ohm's law at v_p :



$$\frac{v_{in} - v_p}{R_i} = \frac{v_p - v_{out}}{R_f}$$

$$\Rightarrow \quad v_p = \frac{v_{in} + \frac{R_i}{R_f} v_{CC}}{1 + \frac{R_i}{R_f}}$$

Now, $v_{out} = +v_{CC}$ if $v_p \geq v_n \Rightarrow v_{out} = +v_{CC}$ if $\dfrac{v_{in} + \frac{R_i}{R_f} v_{CC}}{1 + \frac{R_i}{R_f}} \geq 0$

Hence: $v_{out} = 5$ if $v_{in} \geq -2.5$ V

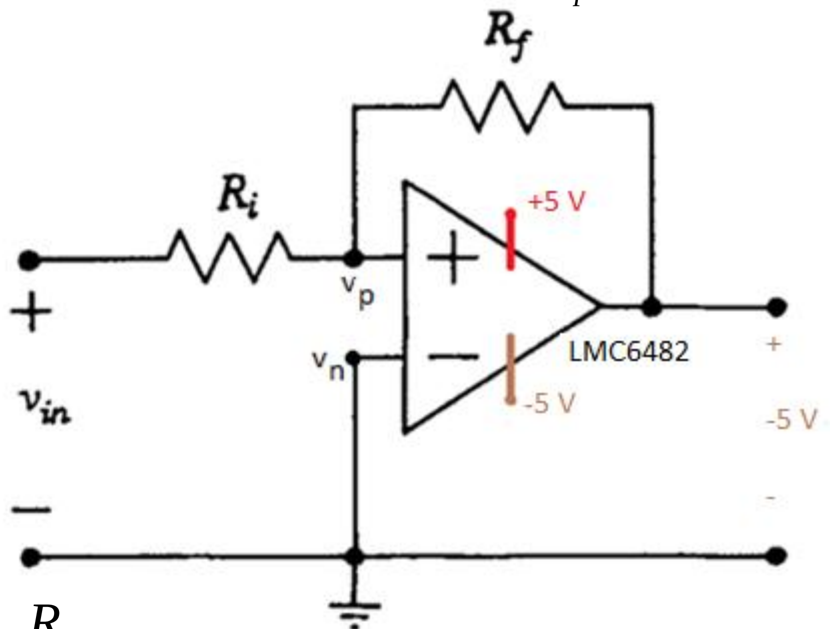
Step 3 (c): Carry out the plan – Derive V_{out} vs V_{in} (negative saturation region)

Since op-amp is assumed to be in negative saturation ($v_{CC}>0$) : $v_{out} = -v_{CC}$, $v_p \le v_n$

Applying KCL and Ohm's law at v_p :

$$\frac{v_{in} - v_p}{R_i} = \frac{v_p - v_{out}}{R_f}$$

$$\Rightarrow \quad v_p = \frac{v_{in} - \frac{R_i}{R_f} v_{CC}}{1 + \frac{R_i}{R_f}}$$

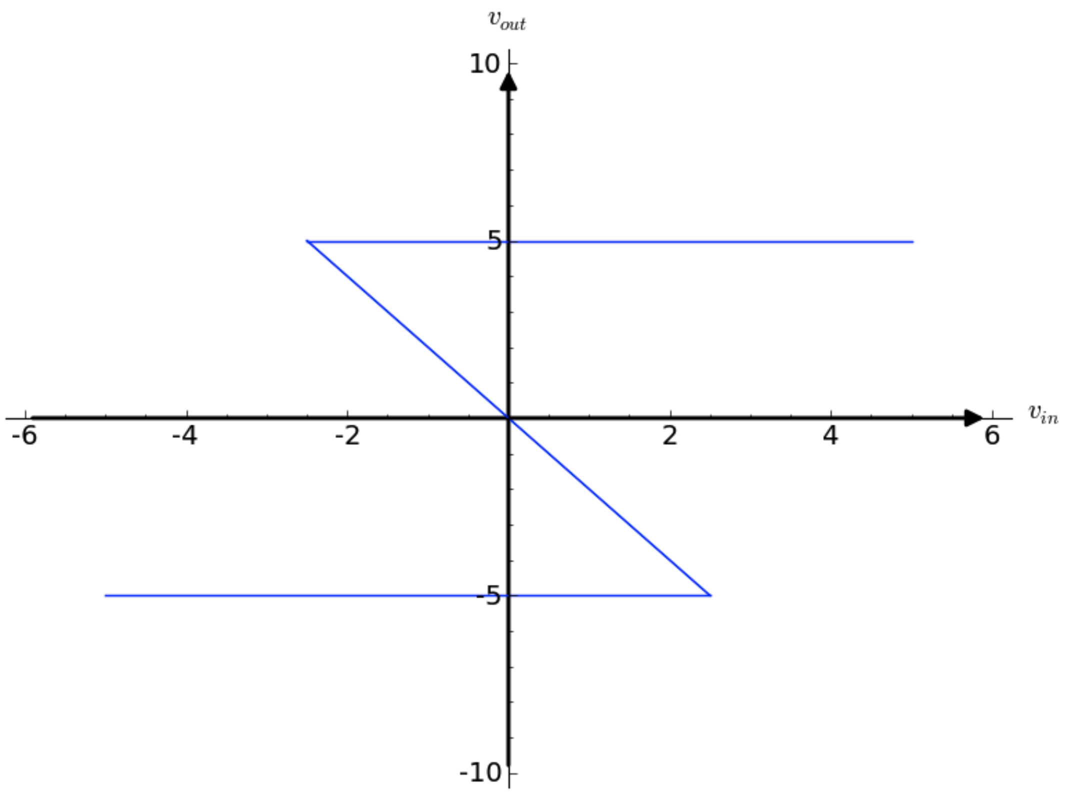


Now, $v_{out} = -v_{CC}$ if $v_p \le v_n \Rightarrow v_{out} = -v_{CC}$ if $\dfrac{v_{in} - \frac{R_i}{R_f} v_{CC}}{1 + \frac{R_i}{R_f}} \le 0$

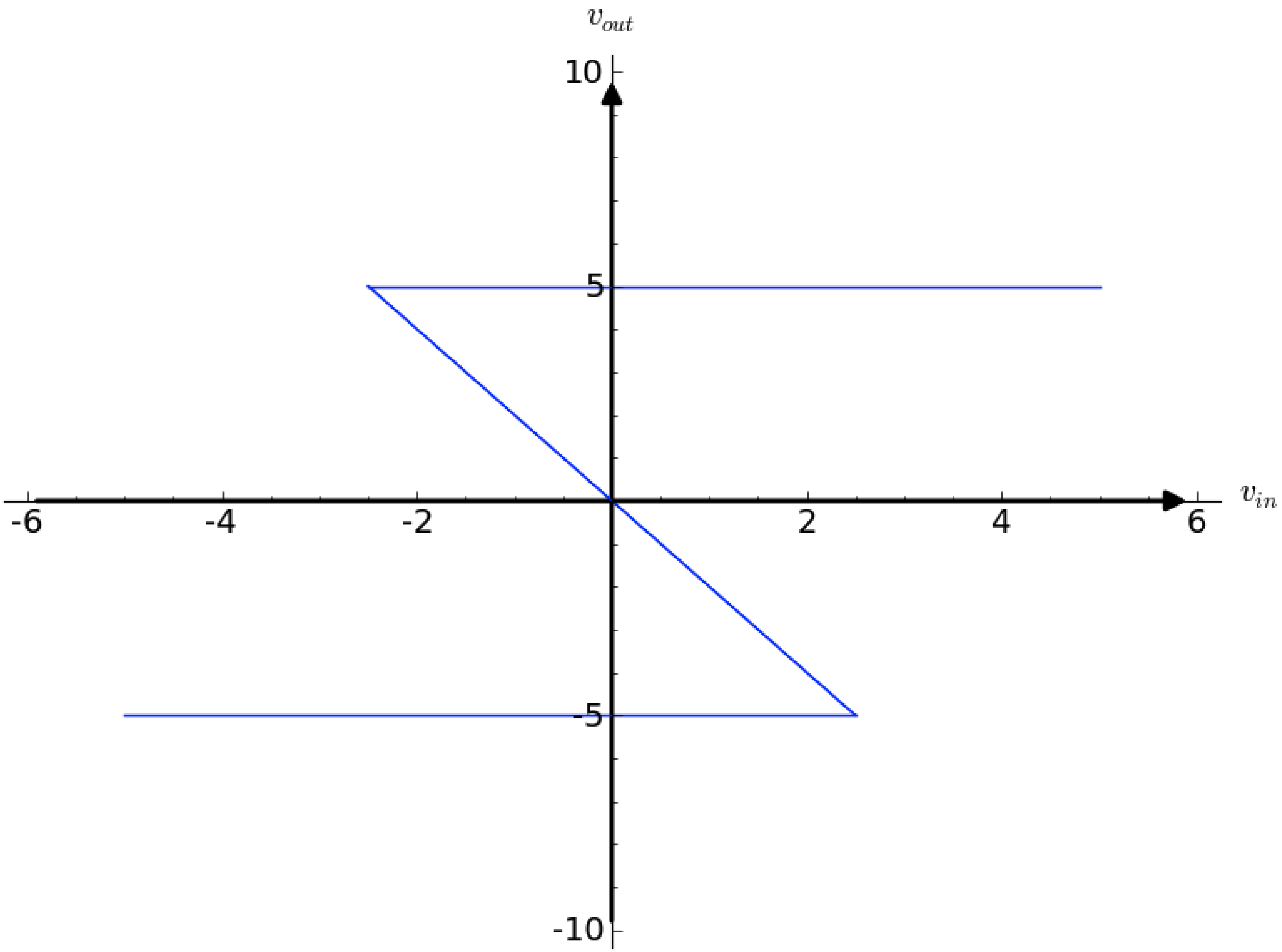
Hence: $v_{out} = -5$ if $v_{in} \le 2.5$ V

Step 3 (d): Sketch V_{out} vs V_{in}

$$v_{out} = \begin{cases} 5\text{ V if } v_{in} \geq -2.5\text{ V} \\ -2v_{in} \text{ if } -2.5 < v_{in} < 2.5 \\ -5\text{ V if } v_{in} \leq 2.5\text{ V} \end{cases}$$

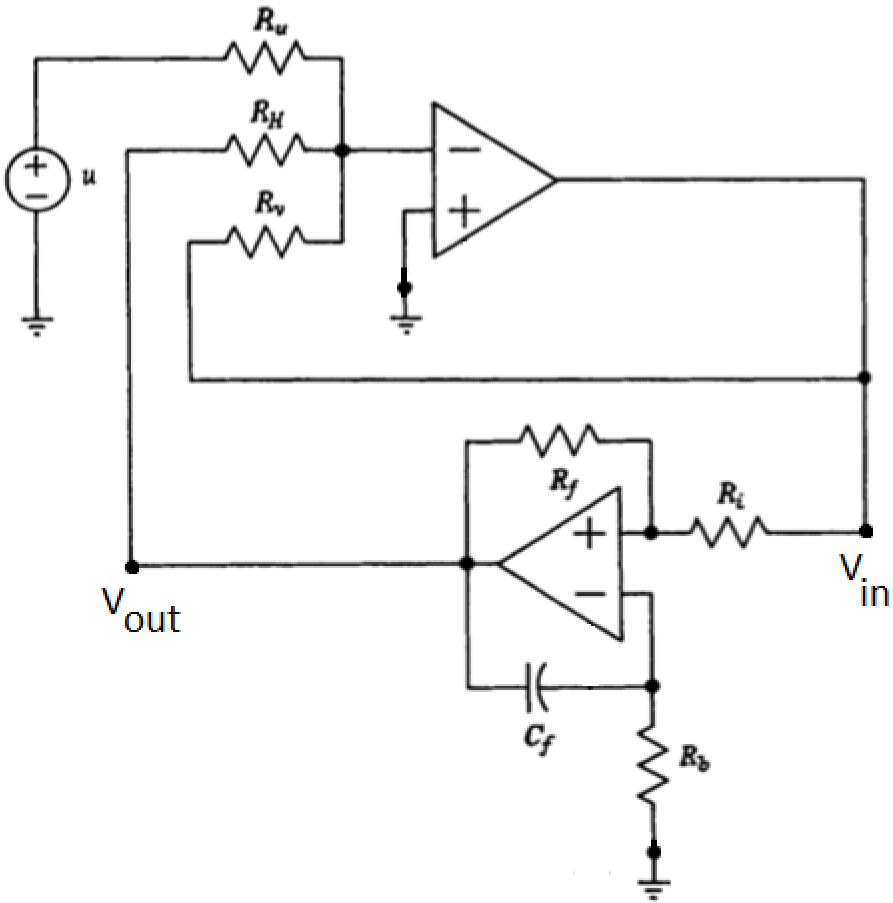


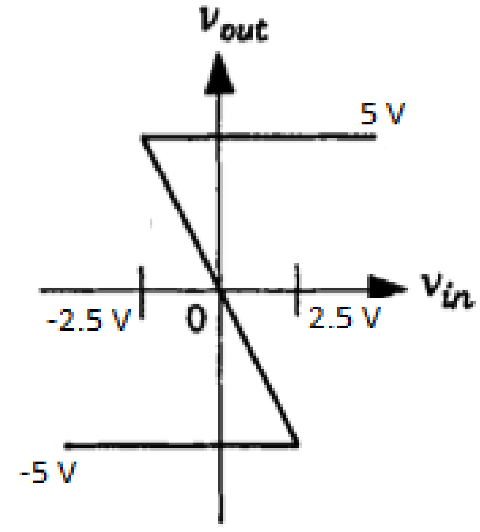
Step 3 : Carry out the plan – Interpret the results



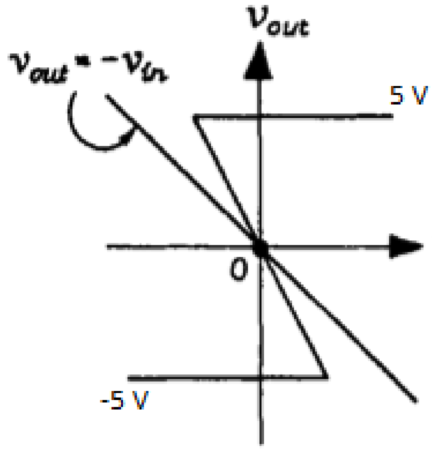
Step 4 : Check your answer

Test Circuit $u + v_{out} + v_{in} = 0$

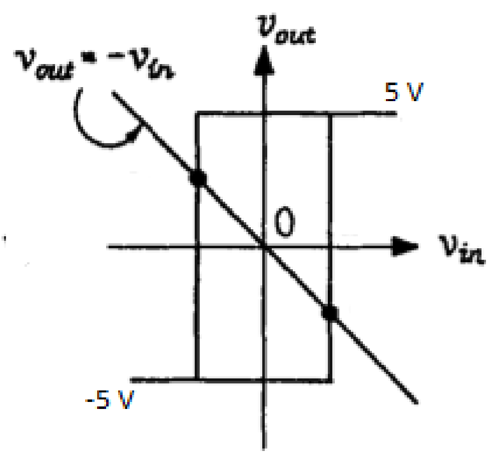




(a)

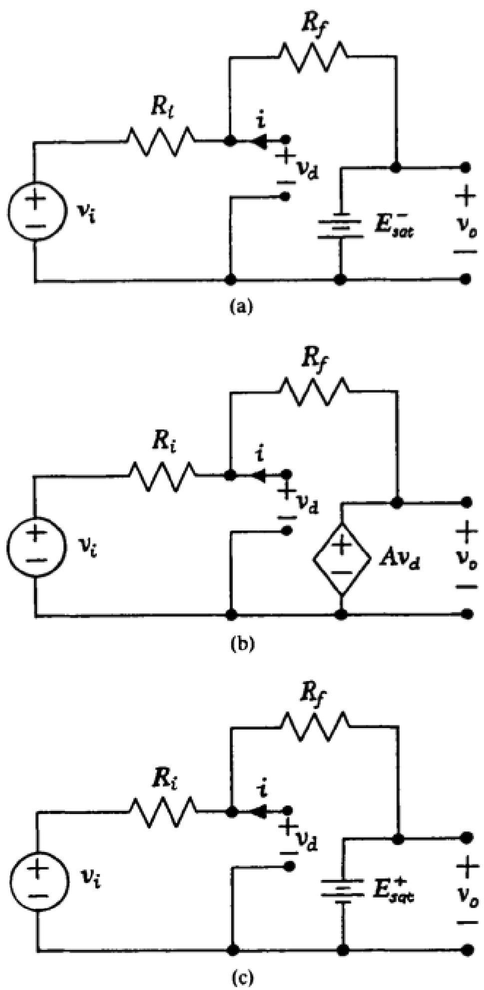


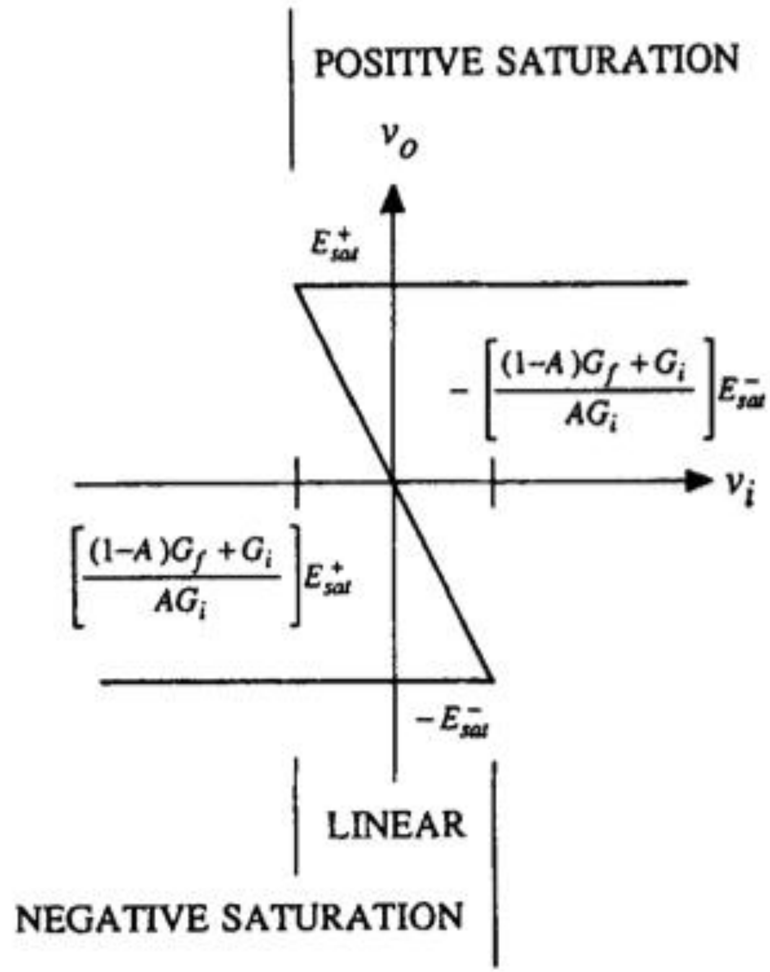
(b)



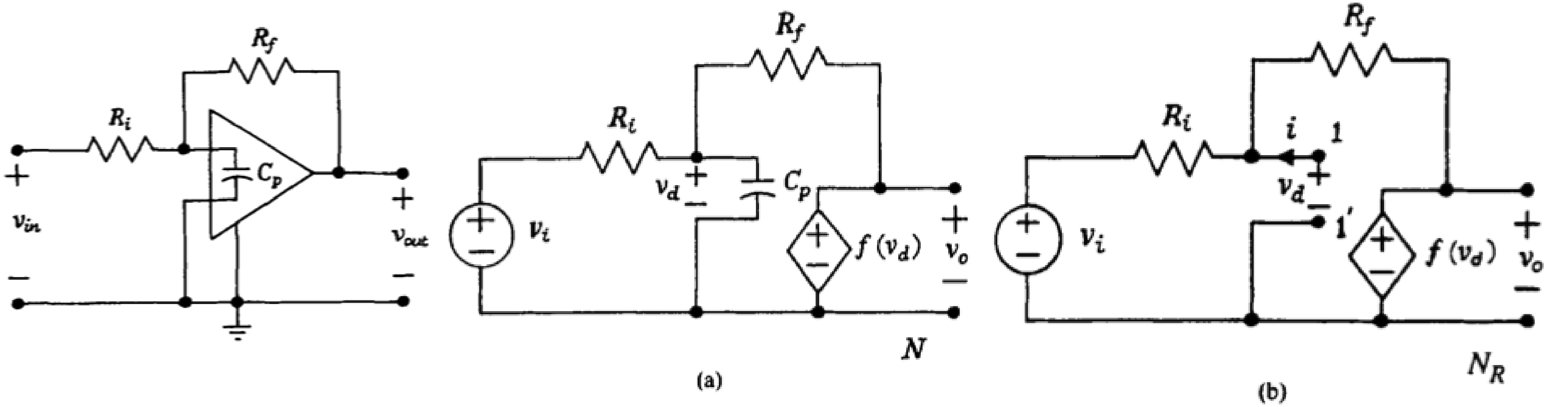
(c)

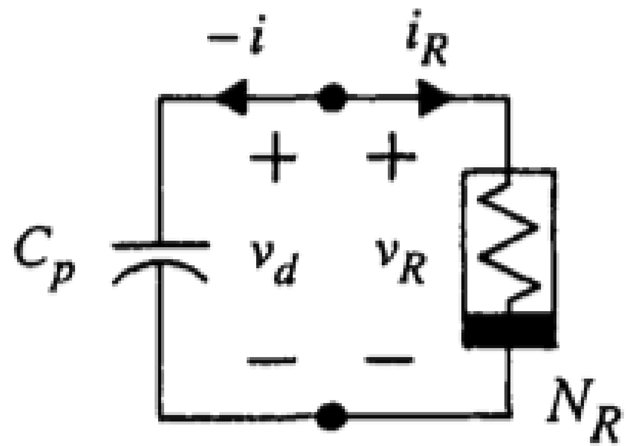
Step 4 : Check your answer (contd.)



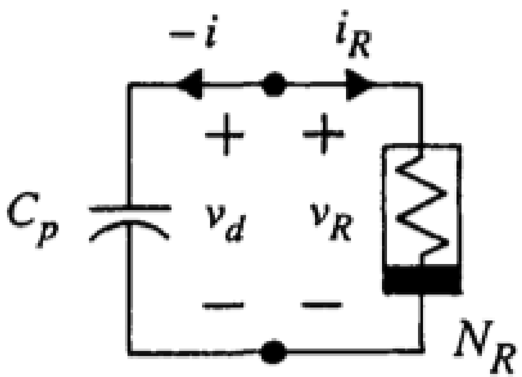


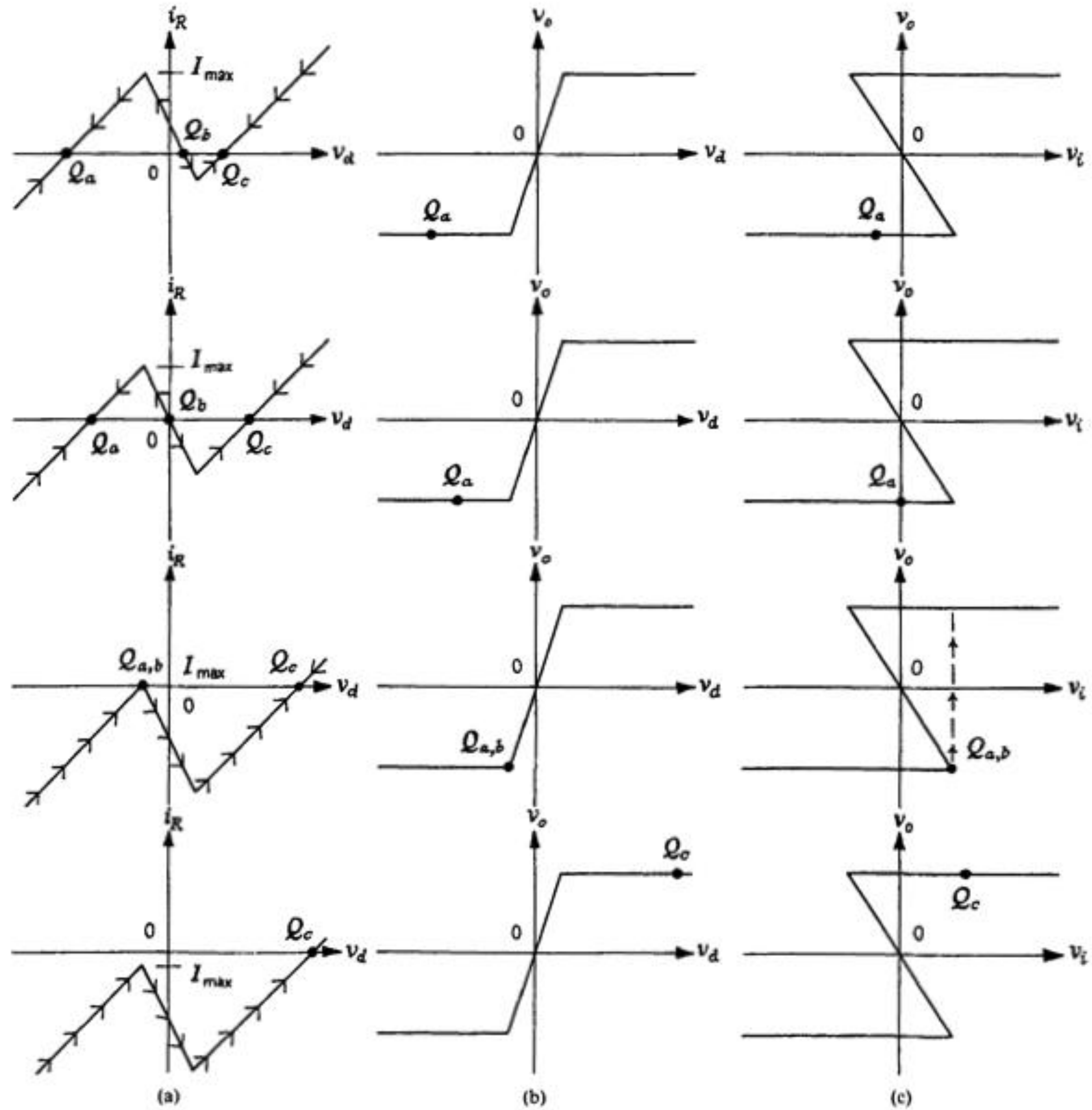
Concept of Parasitic Capacitance





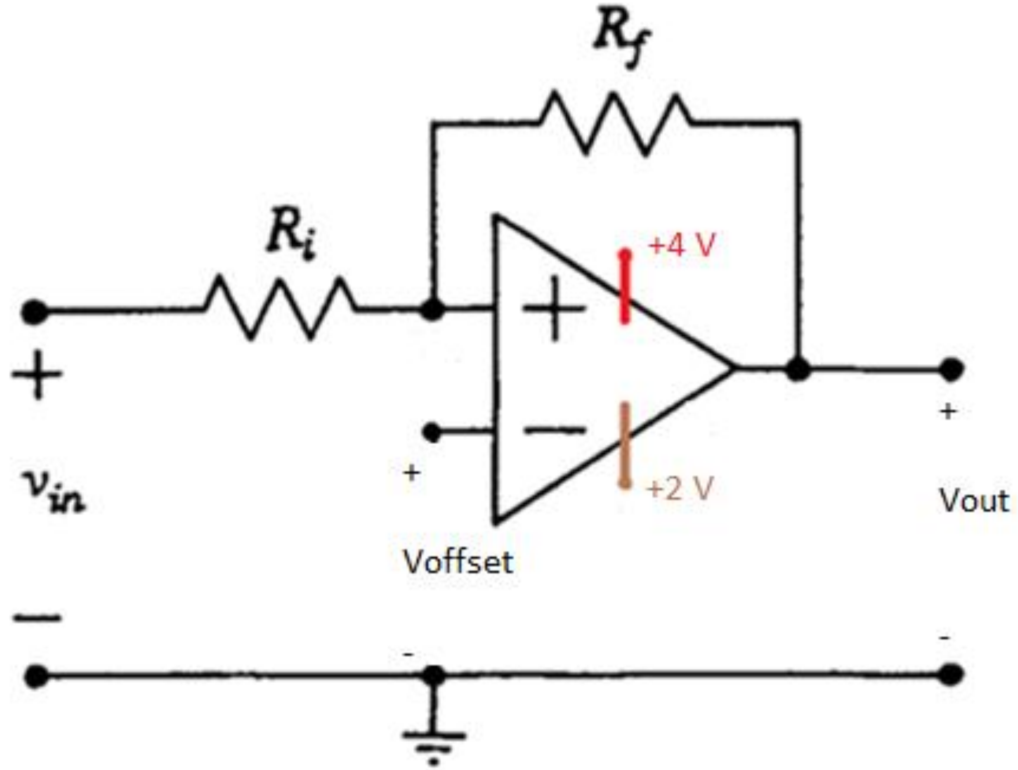
Concept of Parasitic Capacitance (contd.)





Conclusion

Sketch V_{out} vs V_{in} for the circuit below, for a constant V_{offset}.



Questions??