Solving Circuits with Dependent Sources

- Dependent sources are often in circuitS
- eg voltage depends on voltage elsewhere in THE circuit
- Common example Op Amps
- With dependent sources write the KVL/KCL as before
- Then replace the source with the dependent equation
- May have to solve algebraically

- Example of a simple circuit, with one dependent source.

$$V_2 = \alpha V_{R1} = 2V_{R1}$$

- Write the mesh equation as before:

$$V_1 = I_1 R_1 + \alpha V_{R1}$$

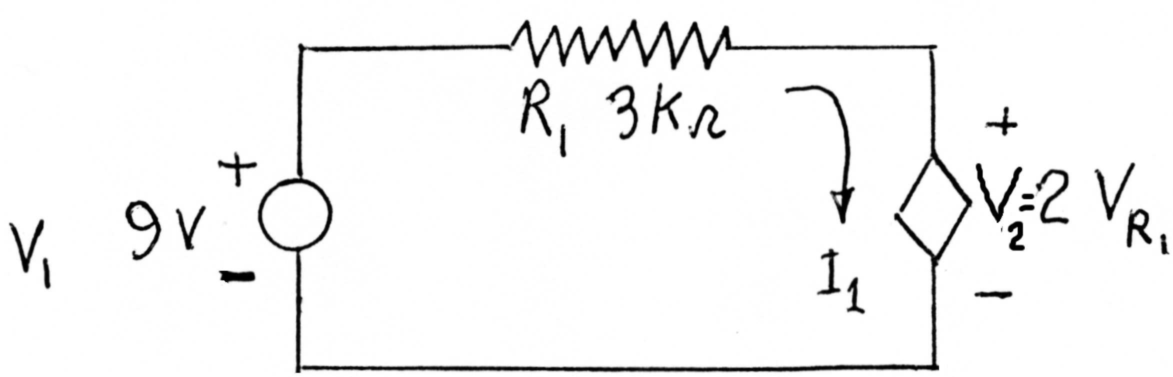
$$V_{R1} = I_1 R_1$$

$$I_1 R_1 = V_1 - \alpha V_{R1} = V_1 - \alpha I_1 R_1$$

- Solving for the unknown current

$$I_1 R_1 (1+\alpha) = V_1$$

$$I_1 = \frac{V_1}{R_1(1+\alpha)} = \frac{9}{3000(1+2)} = 1\ mA$$



Topology in Circuit Analysis (EC 5)

- Many different circuits actually operate the same
- Can reduce a circuit to a "graph"
- Graph only shows the branches, not the devices
- Two circuits are said to have the same topology When the graphs can be made the same

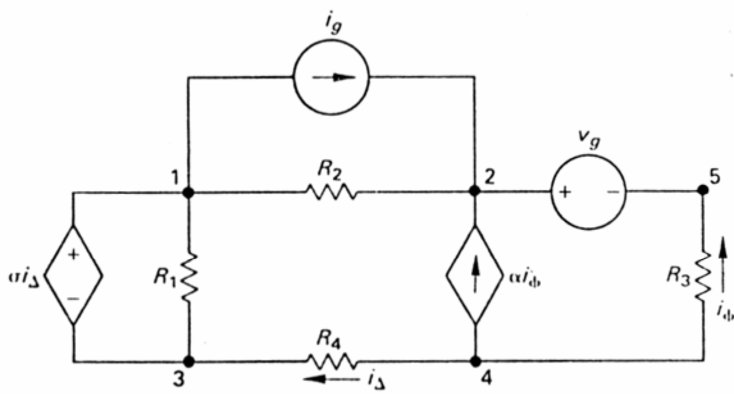


FIGURE 5.3 A circuit that is topologically the same as the circuit shown in Fig. 5.1(a).

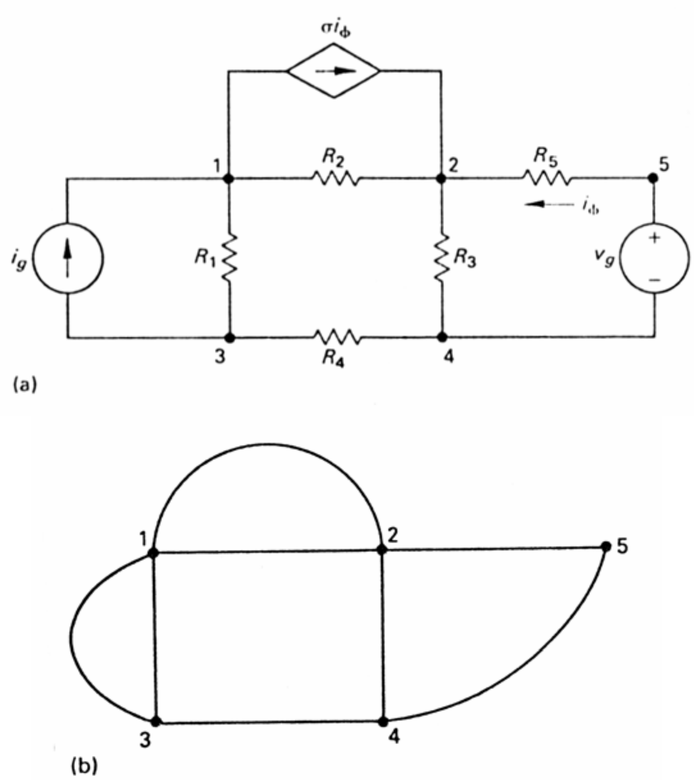


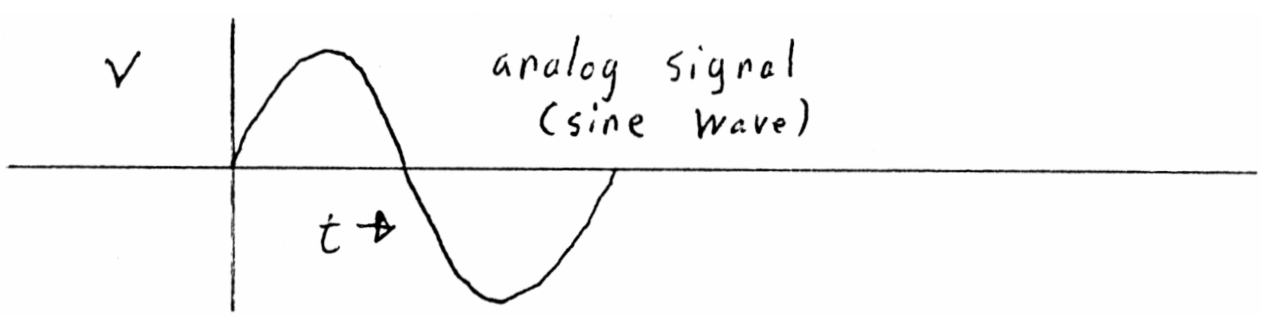
FIGURE 5.1 (a) A circuit; (b) its graph.

Analog and Digital

- Electronics divided into Analog and Digital
- Analog devices: have a continuous range of values
- All real world signals are Analog
- Analog devices: examples
- Amplifiers: increase/decrease signals
- Sensors: measure some variable
- Eg. light intensity, temperature, air flow
- Transducers: convert one energy to another form
- eg: light to electrical or electrical to heat

Analog Advantages:
- Easy representation of real world measurements
- Wide range of values
- Can be very fast reacting circuits

Analog Disadvantages:
- Circuits very tricky to build to operate linearly
- Eg. difficult to keep gain constant in amplifiers
- Thus analog reproduction is inaccurate
- Very sensitive to noise/interference
- Eg Amplification often injects noise in signal
- These combine: thus analog reproduction is inaccurate

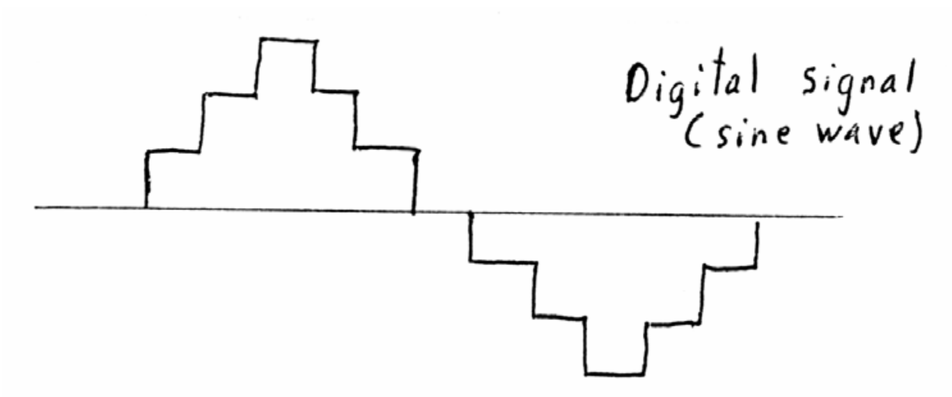


Digital Signals

- Digital: signal can only have discrete values
- Simplest (commonest) Binary
- Binary: only two values: 0 (off or low) or 1 (on or high)
- Almost all digital devices binary at heart
- Effectively all computers digital these days

Digital advantages:
- Very accurate if enough digits
- Noise insensitive, because only discrete values
- Error free coping
- Circuits easy to build

Digital disadvantages:
- Does not reflect continuous real world variables
- Must convert from analog to digital for computer measurement
- Must convert from digital to analog for many applications

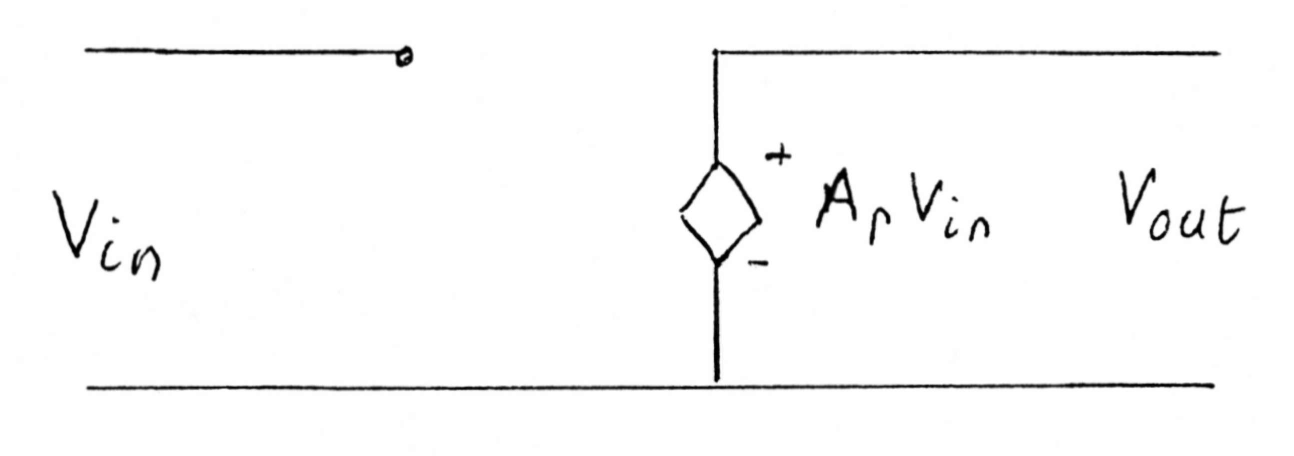


Ideal Operational Amplifier (EC 5)

- Amplification: increase of a signal by a constant factor
- Eg. voltage amplification

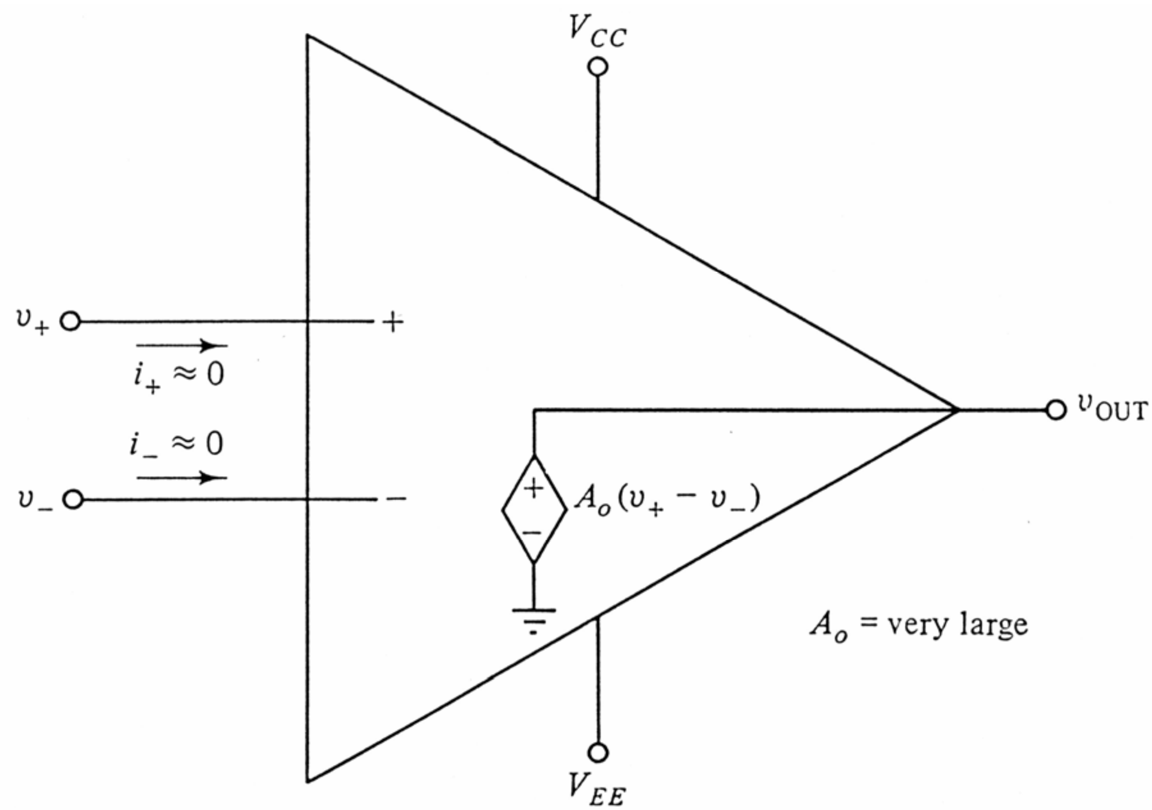
$$A_F = \frac{v_{out}}{V_{in}}$$

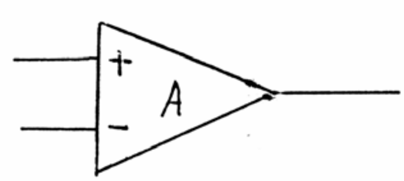
- Amplification is also called the gain G
- Ideal amplifier = ideal voltage controlled voltage source
- An ideal amplifier does not affect the input signal
- Voltage amplifier is ideal voltage controlled voltage source



Ideal Operational Amplifiers

- "Operational Amplifier":
- An approximation to ideal amplifier
- Shorten to "op amp" for common usage
- Originally used in Analog computers during 1940-50's
- "Operational Amplifier" from original function:
- Performance of "mathematical operations"
- Current devices are Integrated Circuits:
- Full amplifier circuit made at once in a single package
- Most common of these called 741 series
- In course treat as a black box:
- Ignore internal operation: only look at outside behaviour





741 Op Amp

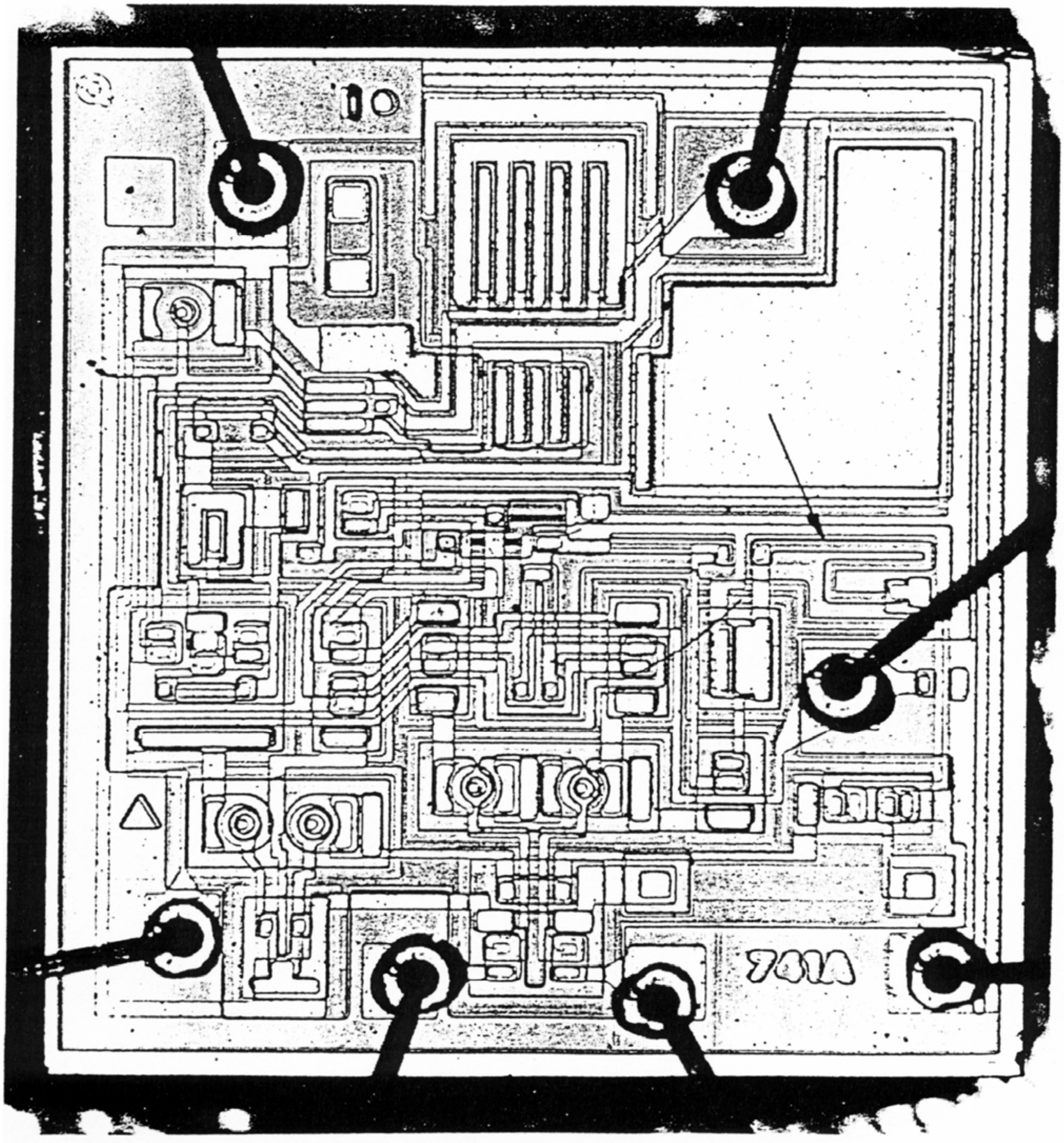
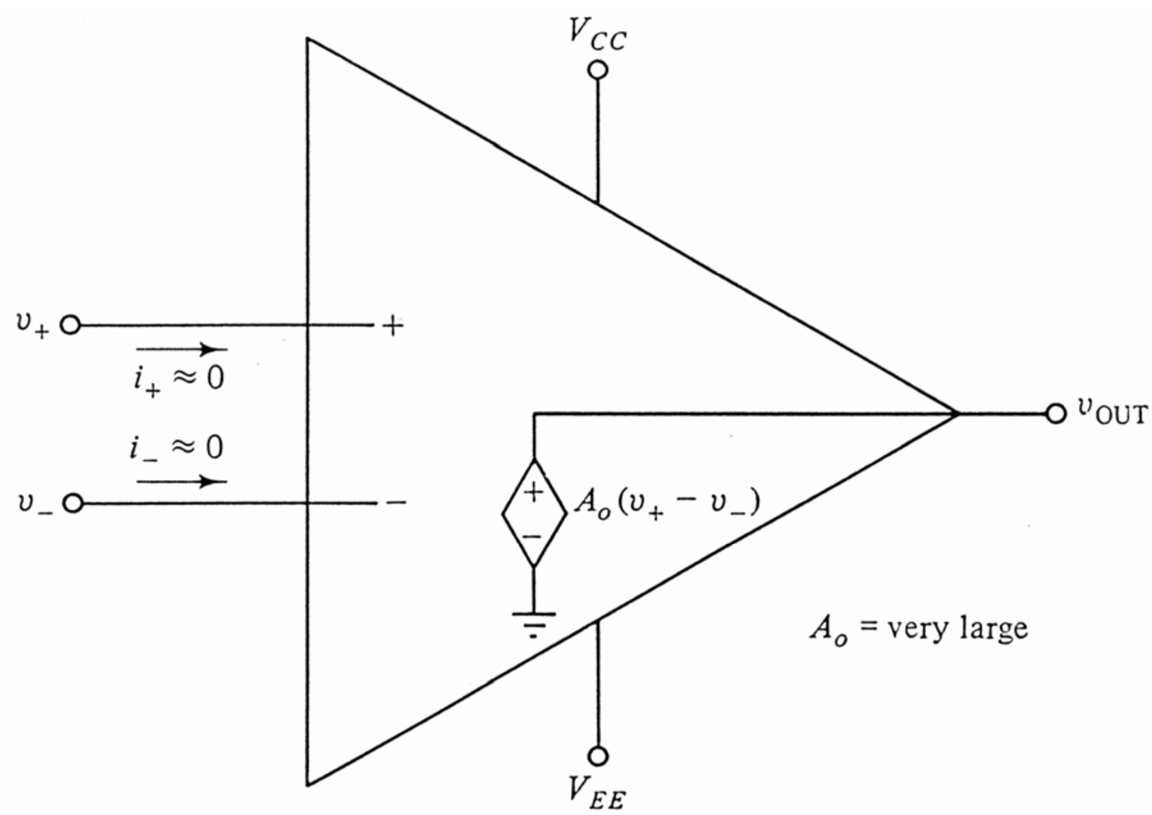
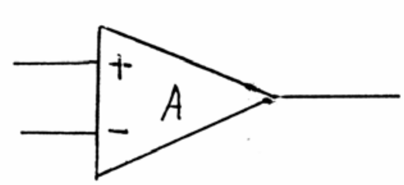


Figure 2.39 Microphotograph of an integrated circuit that makes use of several diffused resistor patters. A 4 kΩ resistor is indicated by the arrow. (*Courtesy Signetics Corp.*)

Ideal Operational Amplifiers

- Op amps act as an ideal amplifier
- But only over limited input range
- Have two signal inputs: v_p and v_n (note often v_+ and v_-)
- Signal is applied between them (differential input)
- Voltage powering device limits operation:
- Positive powering voltage V_{CC}
- Negative powering voltage V_{EE}
- Note often, but not always $V_{EE} = - V_{CC}$
- Text only discusses that condition
- Symbol simple triangle (power input often omitted)





Ideal Operational Amplifiers Behaviour

- Ideal op amp has infinite input resistance
- Thus draws no current from input signal
- Has 3 areas of operation which effect the output v_o

Linear Region

- Output linearly related to input

$$v_o = A_0(v_p - v_n) \quad for \;\; V_{EE} < A_0(v_p - v_n) \,\&\, V_{CC} > A_0(v_p - v_n)$$

Positive Saturation

- Output saturated at positive power V_{CC}

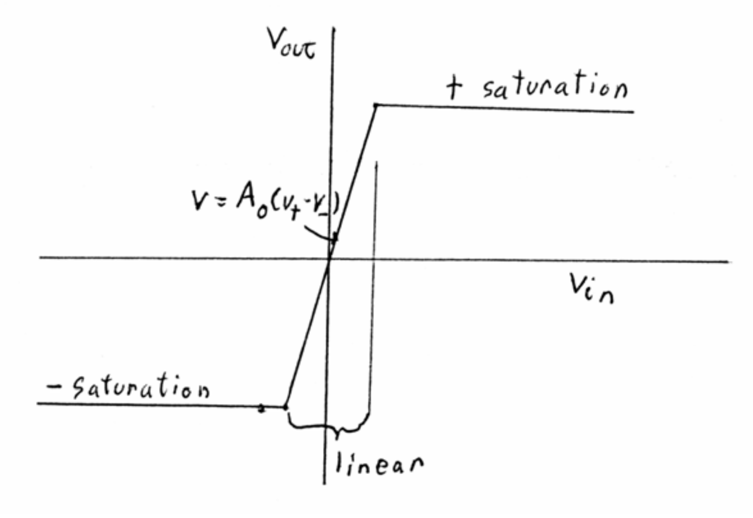
$$v_o = V_{CC} \quad for \;\; A_0(v_p - v_n) > V_{CC}$$

Negative Saturation

- Output saturated at negative power V_{EE}

$$v_o = V_{EE} \quad for \;\; A_0(v_p - v_n) < V_{EE}$$

- Note: output can be both positive and negative
- Typical gain numbers A_0 = 200,000
- Ideal op amp, assume gain nearly infinite
- Thus negligible voltage across input
- In course only consider the linear region



Feedback and Op Amplifiers

- Adding resistors to op amp can control the gain
- Gain controlled by **Feedback**:
  Feeding output back into input
- **Negative Feedback**: output subtracts input signal
- **Positive Feedback**: output adds to input signal
- Note positive feedback generally less stable
- Need to create balance point between output value and op amp v_-
- SP = summing point, where output and input signals sum
- Different op amp circuits use different feedbacks