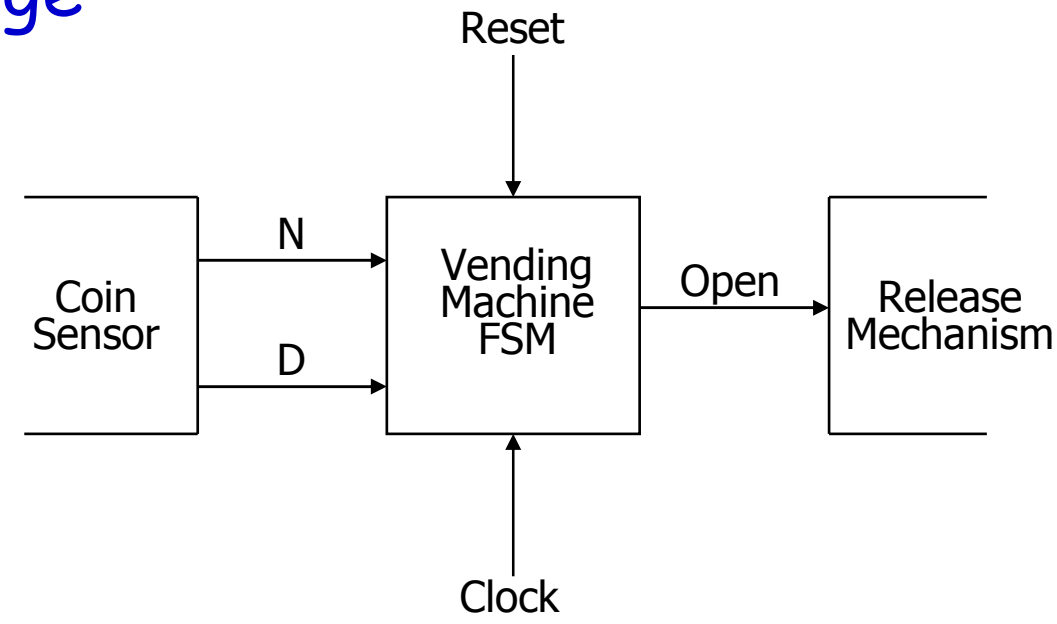
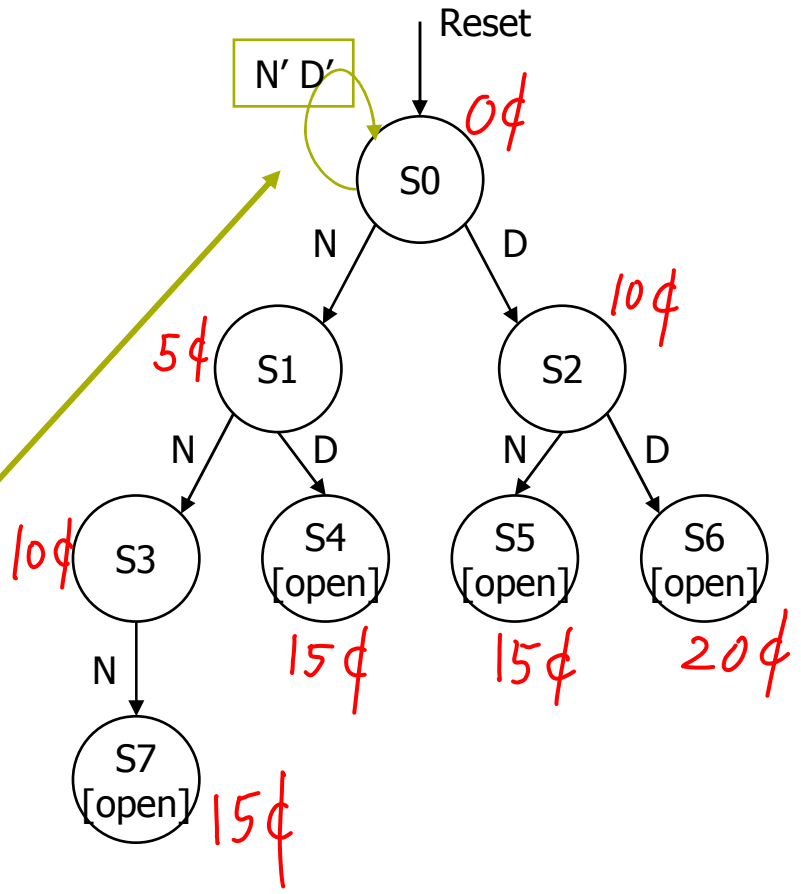
Example: vending machine

- Release item after 15 cents are deposited
- Single coin slot for dimes (10¢), nickels (5¢)
- No change



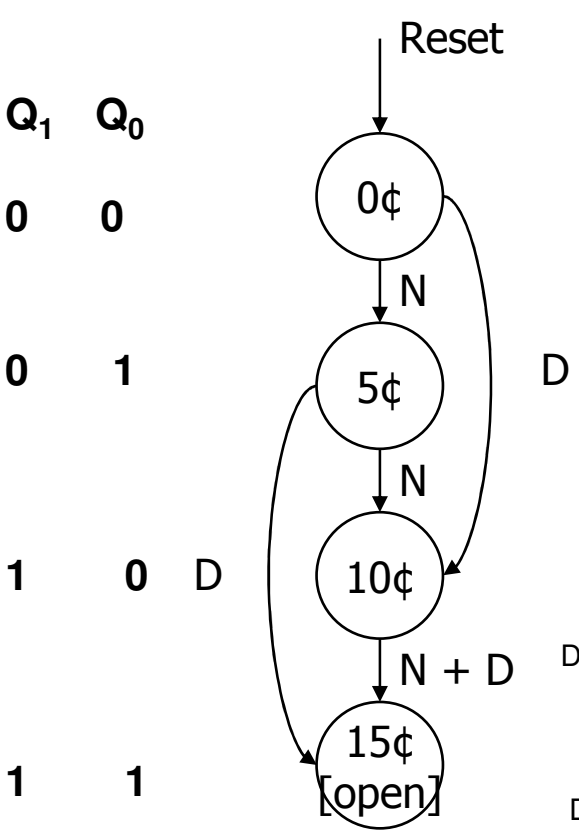
Example: vending machine (cont'd)

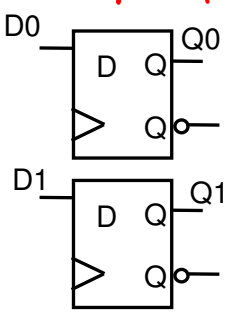
- Suitable abstract representation
  - tabulate typical input sequences:
    - 3 nickels (3 X 5¢ =15¢)
    - nickel, dime (5¢ + 10¢ = 15¢)
    - dime, nickel (10¢ + 5¢ = 15¢)
    - two dimes (2 X 10¢ =20¢)
  - draw state diagram:
    - inputs: N, D, reset
    - output: open chute
  - assumptions:
    - assume N and D asserted for one cycle
    - each state has a self loop for N = D = 0 (no coin)



Example: vending machine (cont'd)

- Minimize number of states - reuse states whenever possible





present state	inputs D	N	next state	output open	D_1	D_0
0¢	0	0	0¢	0	0	0
	0	1	5¢	0	0	1
	1	0	10¢	0	1	0
	1	1	-	-	x	x
5¢	0	0	5¢	0	0	1
	0	1	10¢	0	1	0
	1	0	15¢	1	1	1
	1	1	-	-	X	x
10¢	0	0	10¢	0	1	0
	0	1	15¢	1	1	1
	1	0	15¢	1	•	1
	1	1	-	-	x	x
15¢	–	–	15¢	1		

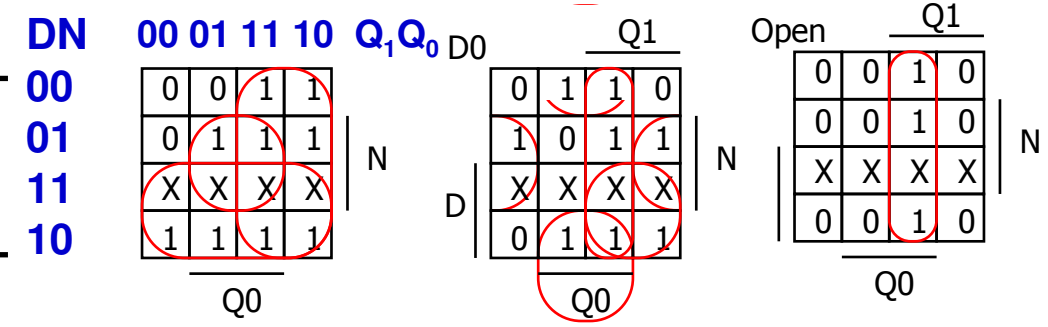
symbolic state table

Use 1 to reset

Example: vending machine (cont'd)

present state Q1	Q0	inputs D	N	next state D1	D0	output open
0	0	0	0	0	0	0
		0	1	0	1	0
		1	0	1	0	0
		1	1	x	x	x
0	1	0	0	0	1	0
		0	1	1	0	0
		1	0	1	1	0
		1	1	x	x	x
1	0	0	0	1	0	0
		0	1	1	1	0
		1	0	1	1	0
		1	1	x	x	x
1	1	–	–	1	1	1

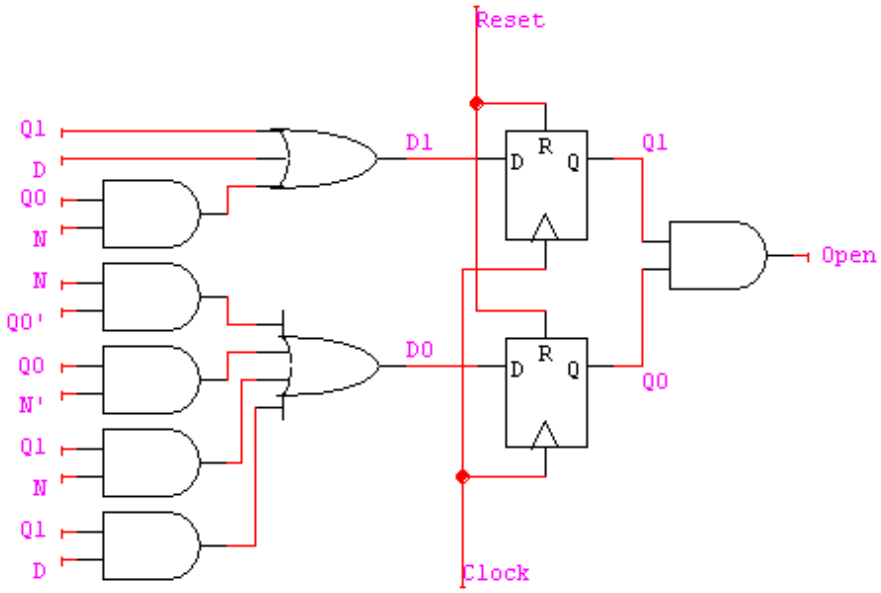
3 more states here



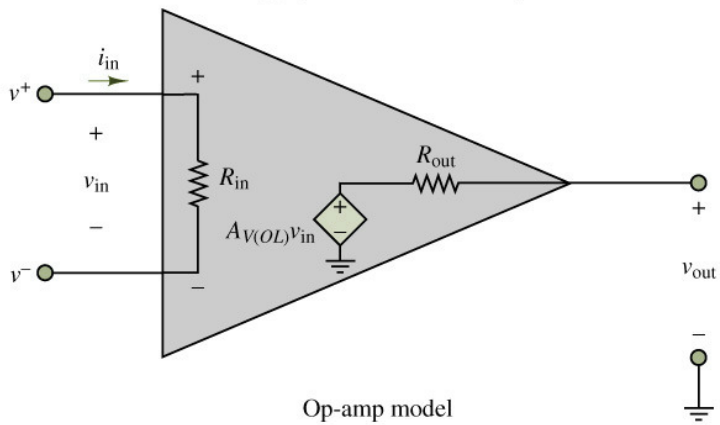
$D1 = Q1 + D + Q0\ N$

$D0 = Q0'\ N + Q0\ N' + Q1\ N + Q1\ D$

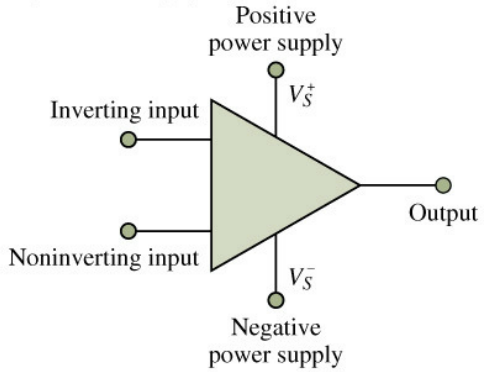
$OPEN = Q1\ Q0$



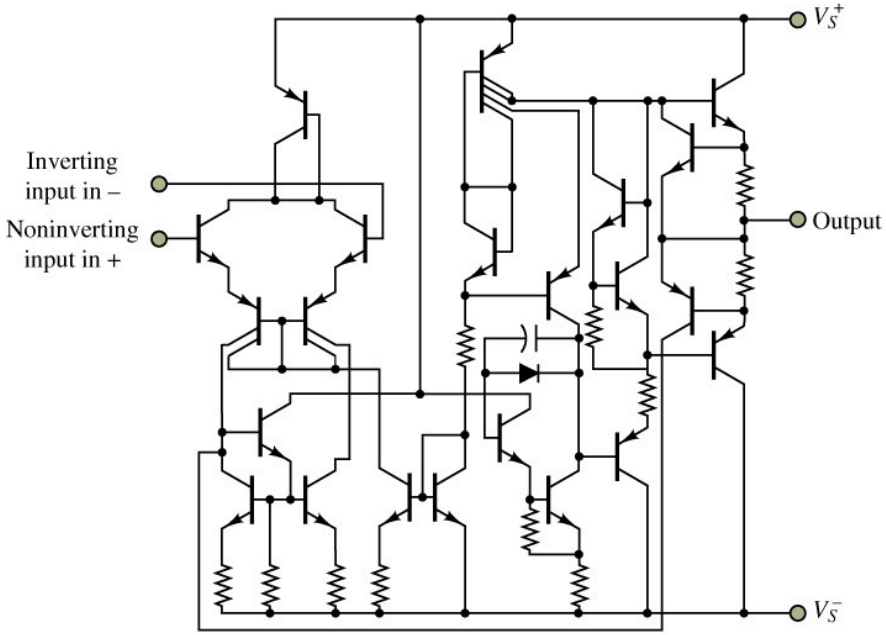
Operational Amplifier



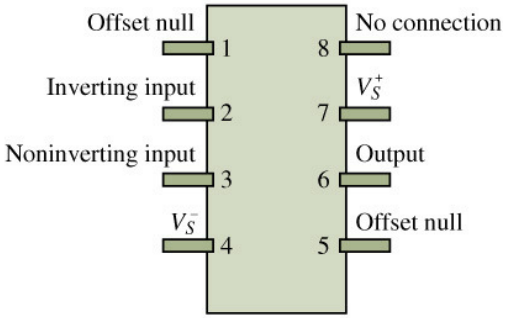
Op-amp model



Simplified circuit symbol

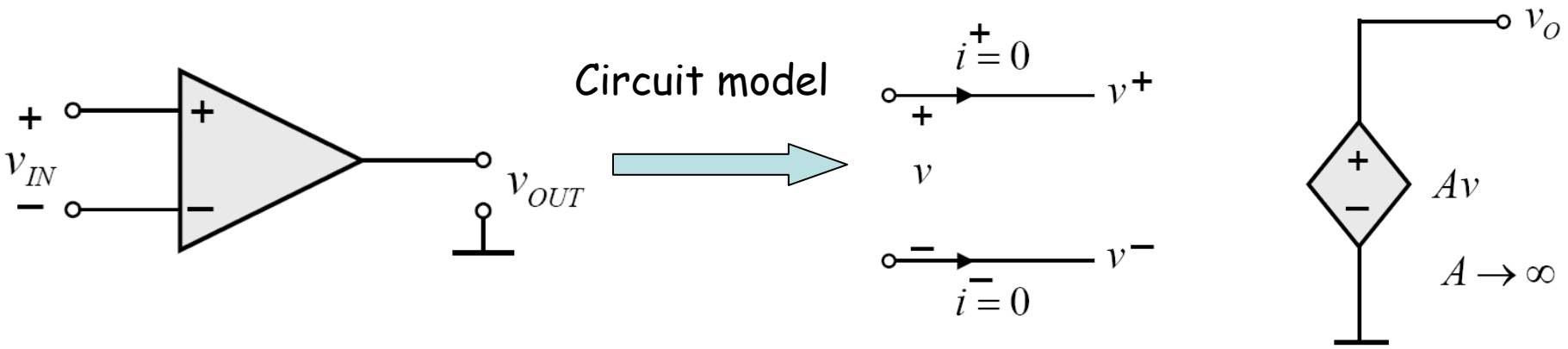


IC op-amp diagram



Integrated-circuit operational
amplifier (IC op-amp)

Ideal OP Amp



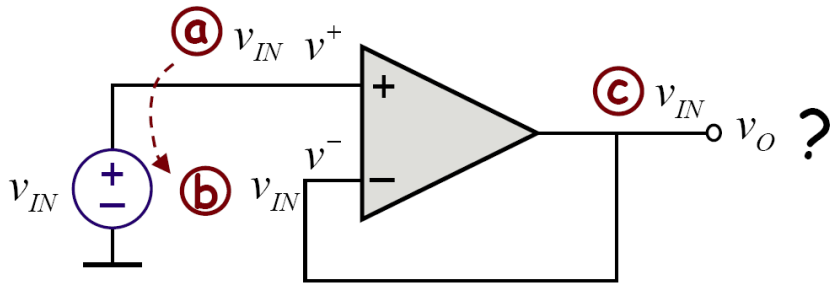
i.e.
- ∞ input resistance
- 0 output resistance
- "A" virtually ∞
- No saturation

1. i_{in}=0, no current flow into op amp.
2. V_+=V_-
   - Typically one end of op amp is connected to ground, therefore, V_+=V_-= 0V, virtual ground. Often V_+ is connected to ground to avoid stability problem.

Applications: building block for analog systems

- Amplifiers
- Adders and Substractors
- Integrators & Differentiators
- Clock generators
- Filters
- Digital-to-analog converters

Example: Voltage follower



$v_O \approx v_{IN}$

Why is this circuit useful?

Buffer

voltage gain = *1*

input impedance = ∞

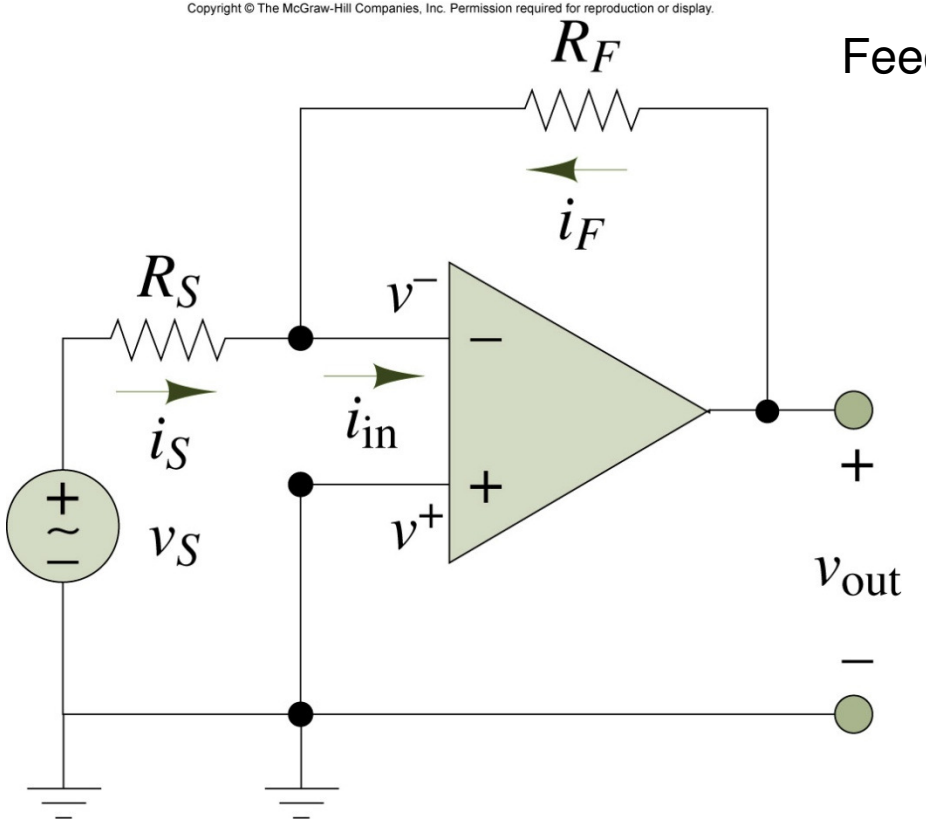
output impedance = *0*

current gain = ∞

power gain = ∞

has minimum effects on previous and next circuit.

Inverting Amplifier



Feedback resistor, always to negative input

$$i_s + i_F = i_{in} = 0$$

$$i_s = -i_F$$

$$\frac{v_S - 0}{R_S} = -\frac{v_{out} - 0}{R_F}$$

$$v_{out} = -\frac{R_F}{R_S} v_S$$

$$Gain = \frac{v_{out}}{v_S} = -\frac{R_F}{R_S}$$