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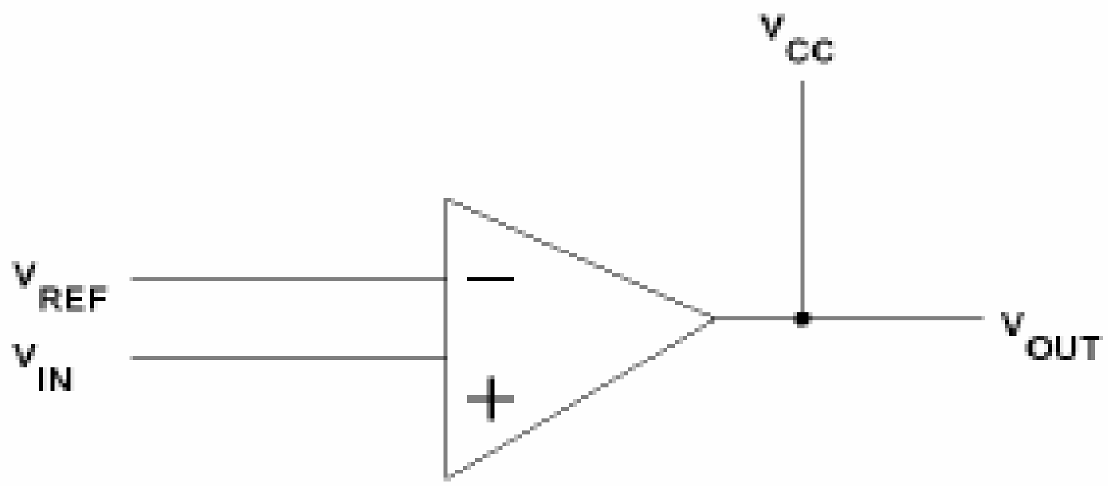
# Flash (Parallel) Converter

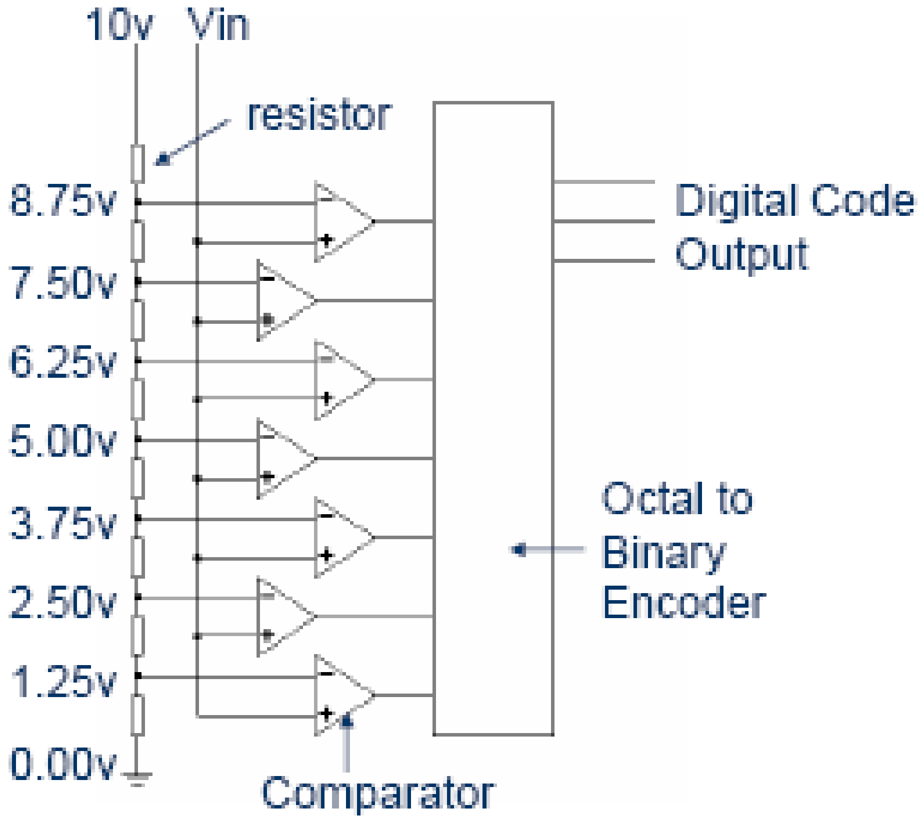



If Vin > Vref then Vout = Vcc (Logic high)

If Vin < Vref then Vout = 0 (Logic low)

An n-bit flash converter uses $2^n-1$ comparators

# Flash (Parallel) Converter




Example-

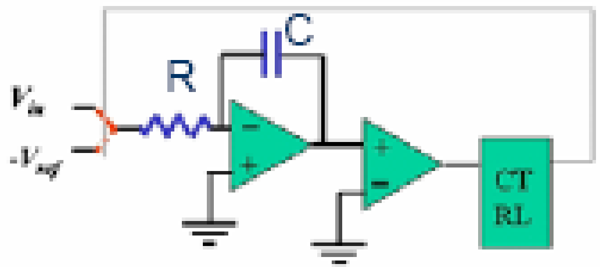
If Vin = 6.00v, then the first 4 comparators from the bottom will return a logic high signal while the top three will return a low signal.

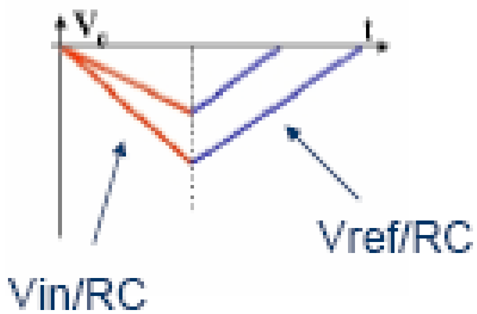
Octal 4 = Binary 100

# Flash (Parallel) Converter

- Advantages
  - Very Fast
- Disadvantages
  - Lower resolution (many comparators are required for higher resolution: 8 bit = 255 comparators)
  - Higher cost

# Dual-Slope Converter




CTRL allows capacitor (C) to charge with rate given by Vin/RC for time $T_0$ ($N_0$ clock cycles). Then CTRL switched and allows capacitor to discharge for to time $T_1$ ($N_1$ clock cycles) at a rate given by Vref/RC.

$Vref/N_1 = Vin/N_0$

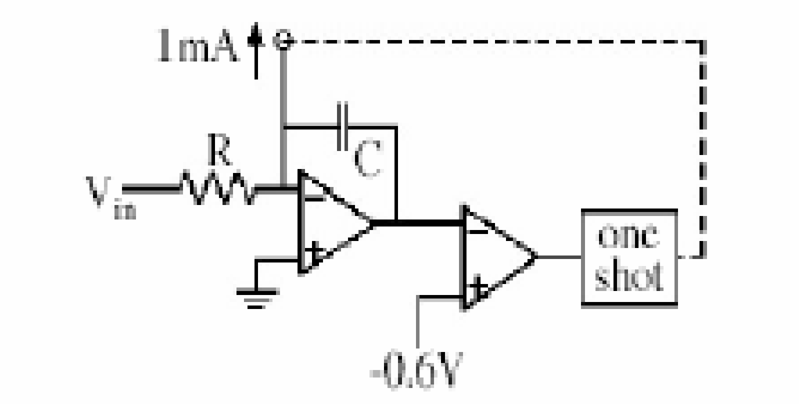
Vref and $N_0$ are known and $N_1$ is measured, so:

$Vin = (N_1/N_0)Vref$

# Dual-Slope Converter

- Advantages
  - Higher resolution
  - Higher accuracy
  - Lower cost
  - Good noise immunity
- Disadvantages
  - Slow

# Voltage-to-Frequency Converters



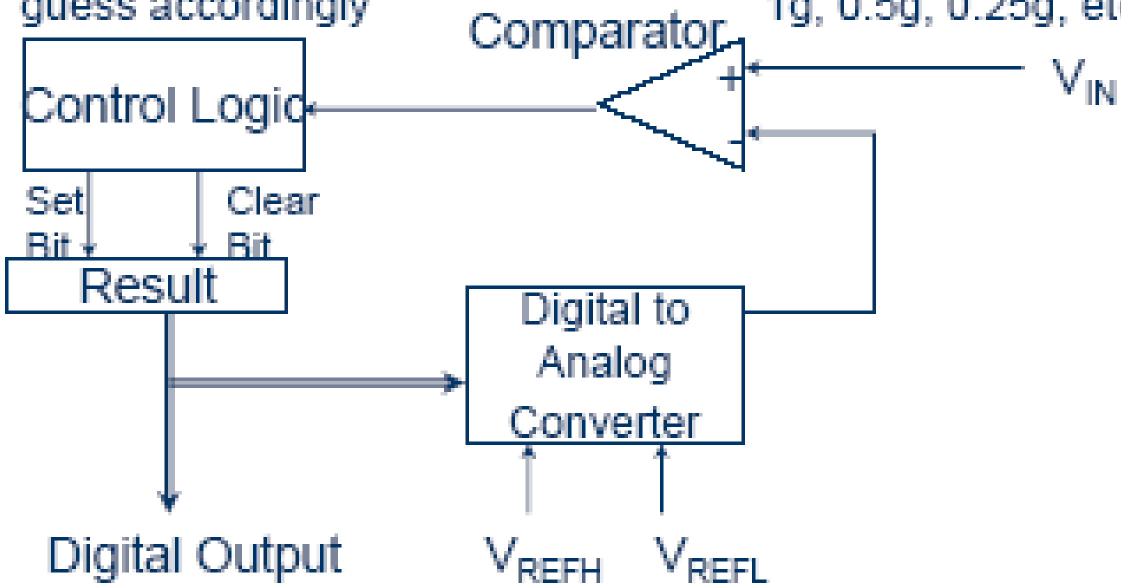

Converter takes in a voltage (Vin) and returns a series of pulses. Frequency of pulses is proportional to Vin.

# Voltage-to-Frequency Converters

- Advantages
  - Excellent noise reduction
- Disadvantages
  - Slow
  - Generally limited to 10bits or less

# Successive Approximation Converter

- Guess the answer, use a D/A to convert it to an analog voltage and compare it to the voltage being measured – adjust your guess accordingly
- Similar to the ordering weighing (on a scale) of an unknown quantity on a precision balance, using a set of weights, such as 1g, 0.5g, 0.25g, etc.



# Successive Approximation Converter

- Reliable
- Capable of high speed
- Conversion time is clock rate times number of bits.
  - Example with 8-bit, 2-MHz clock rate:
    - Conversion time= (clock period) x (#bits being converted)
    - Conversion time= (0.5 micro-sec) x (8-bits) = 4μs

# Successive Approximation Example

- 10-bit resolution or 0.0009765625V of $V_{ref}$
- $V_{in}$ =0.6V
- $V_{ref}$ =1V
- Find the digital value of $V_{in}$

| Bit | Voltage |
|---|---|
| 1 | .5 |
| 2 | .25 |
| 3 | .125 |
| 4 | .0625 |
| 5 | .03125 |
| 6 | .015625 |
| 7 | .0078125 |
| 8 | .00390625 |
| 9 | .001952125 |
| 10 | .0009765625 |

# Successive Approximation Example (cont.)

- MSB (bit 1)
  - Divide $V_{ref}$ by 2 = .5V
  - Compare $V_{ref}$ /2 with $V_{in}$
  - If $V_{in}$ is greater, turn MSB* ON
  - If $V_{in}$ is less than $V_{ref}$ /2, turn MSB off

  - Compare $V_{in}$=0.6V and V= 0.5V
  - Since 0.6 > 0.5 $\rightarrow$ MSB =1 (turned on)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |

# Successive Approximation Example (cont.)

- Calculate the state of MSB-1 (bit 2)
  - Compare $V_{in}$ =0.6V and $V=V_{ref}/2 + V_{ref}/4 = 0.5+0.25 = 0.75V$
  - Since $0.6 < 0.75 \rightarrow$ MSB-1 =0 (turned off)

- Calculate the state of MSB-2 (bit 3)
  - Go back to the last voltage value that caused it to be turned on (in this case 0.5V) and add $V_{ref}/8$ to it and compare with $V_{in}$.
  - Compare $V_{in}$ and $(0.5 + (V_{ref}/8)=0.625)$
  - Since $0.6 < 0.625 \rightarrow$ MSB-2 =0 (turned off)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | | | | | | | |

# Successive Approximation Example (cont.)

- Calculate the state of MSB-3 (bit 4)
  - Go back to the last voltage value that caused it to be turned on (in this case 0.5V) and add $V_{ref}/16$ to it and compare with $V_{in}$.
  - Compare $V_{in}$ and $(0.5 + (V_{ref}/16)=0.5625)$
  - Since 0.6 > 0.5625 → MSB-3 =1 (turned on)

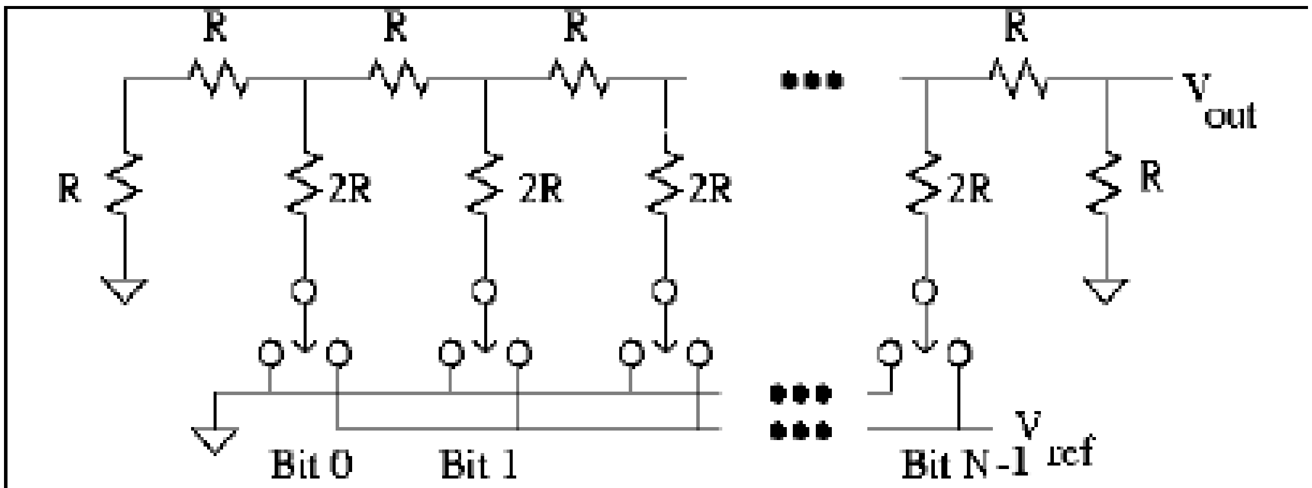
| MSB | MSB-1 | MSB-2 | MSB-3 | ... | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | | | | | | |

# Successive Approximation Example (cont.)

- Digital Results:

| MSB | MSB-1 | MSB-2 | MSB-3 | ... | | | | | LSB |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |

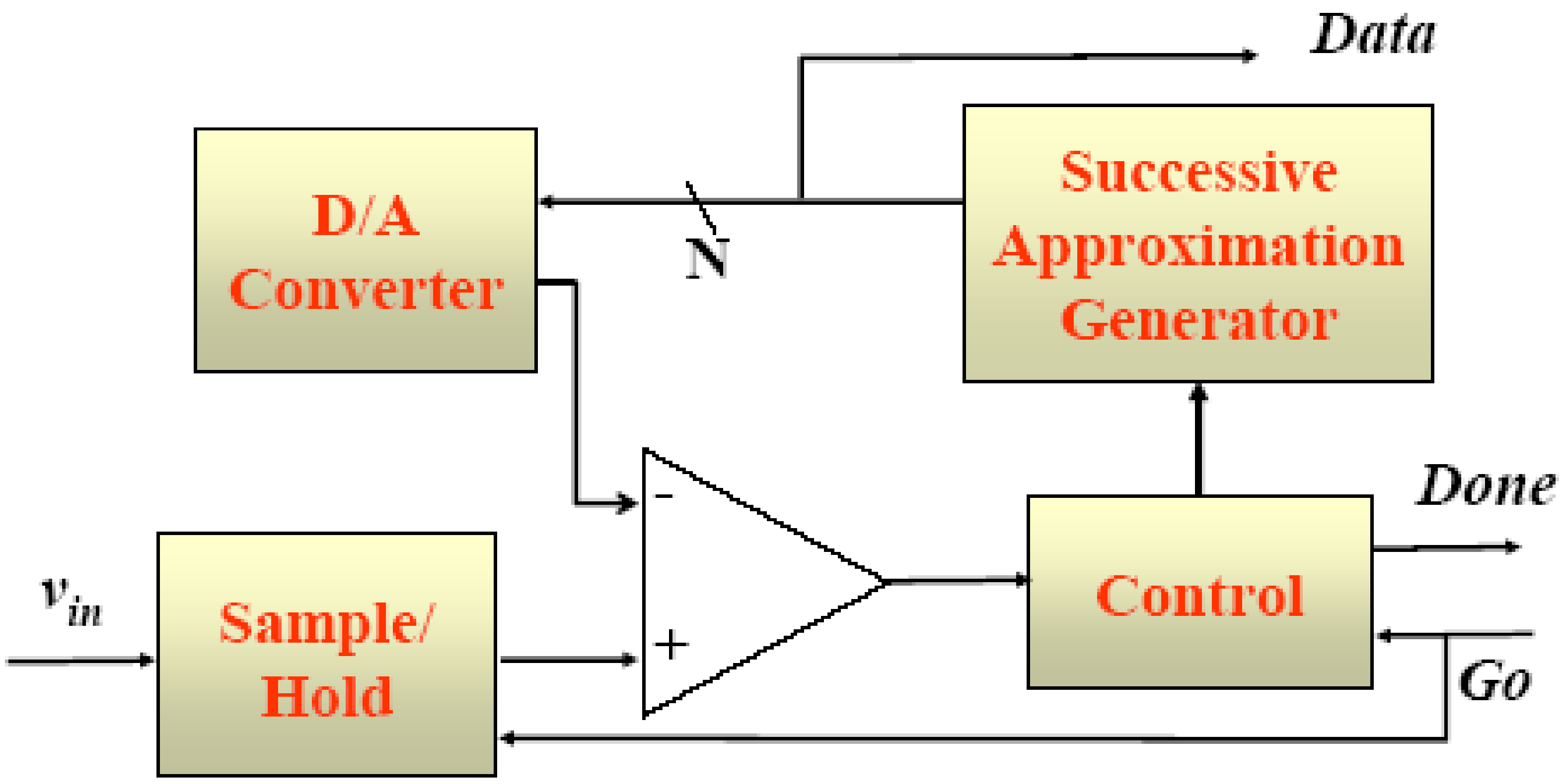
- Results = $\frac{1}{2}+\frac{1}{16}+\frac{1}{32}+\frac{1}{256}+\frac{1}{512}=.599609375 \quad V$



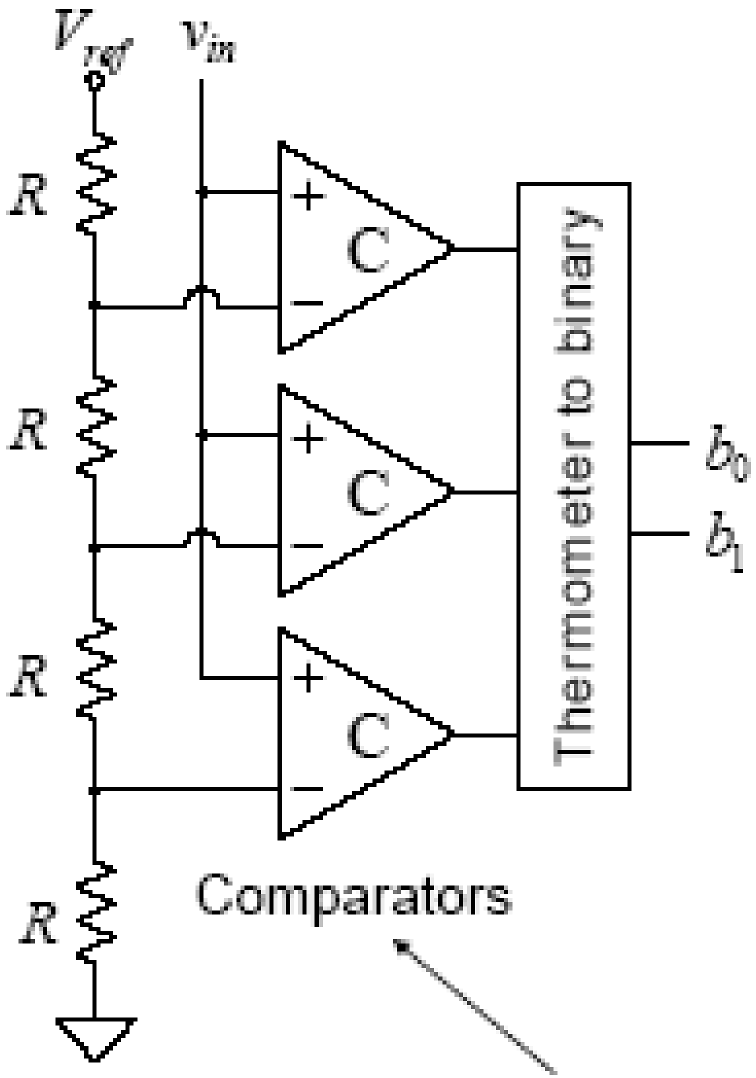

$$V_{out} = \frac{1}{6} V_{ref} \left[ B_7 + \frac{1}{2} B_6 + \frac{1}{4} B_5 + \cdots + \frac{1}{128} B_0 \right]$$

- Note that the driving point impedance (resistance) is the same for each cell.
- R-2R Ladder achieves large current division ratios with only two resistor values

# Successive-Approximation A/D



# Flash A/D Converter




**Brute-force A/D conversion**

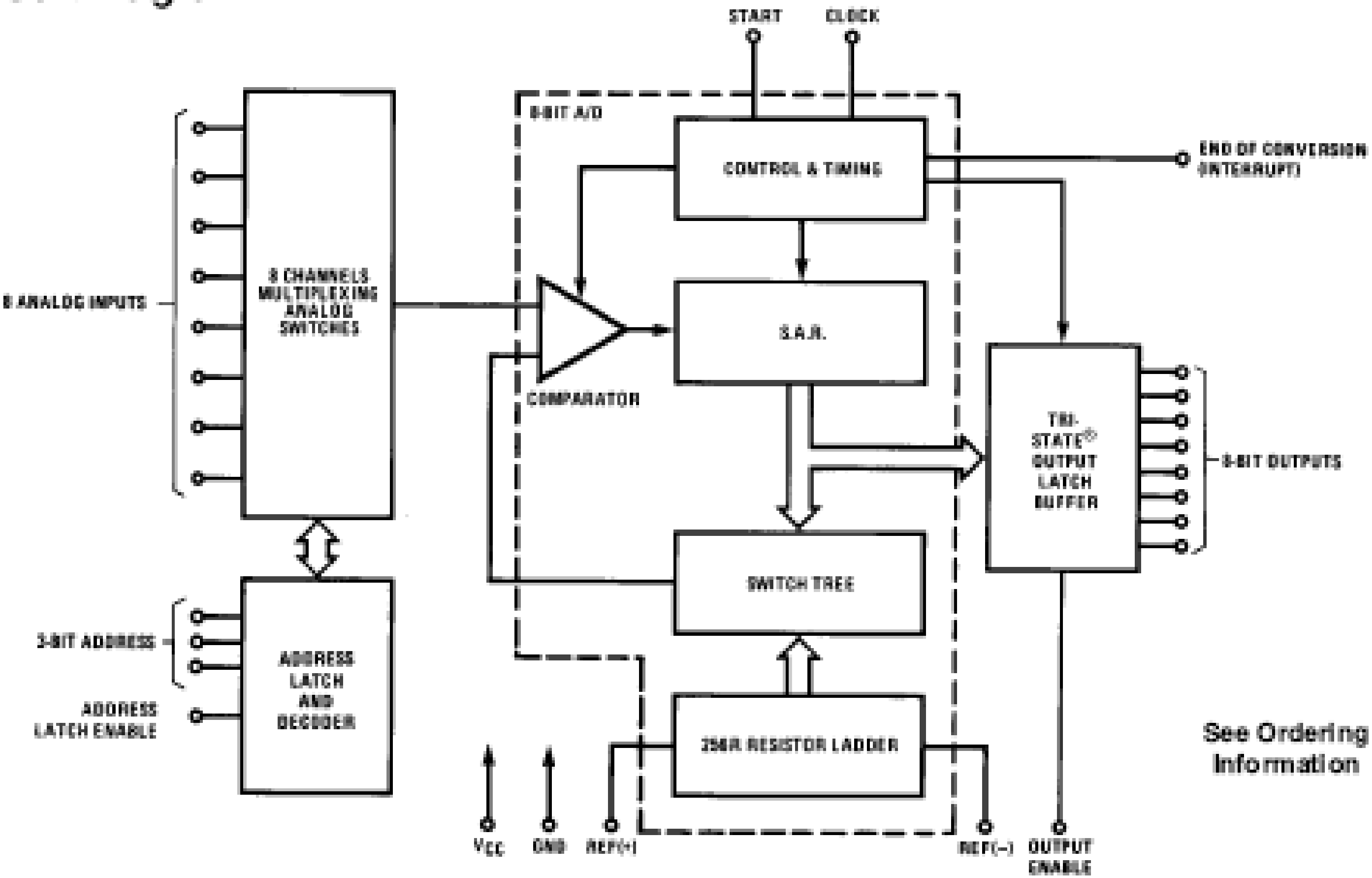
**Simultaneously compare the analog value with every possible reference value**

**Fastest method of A/D conversion**

**ize scales exponentially with precision**
**(requires 2N comparators)**

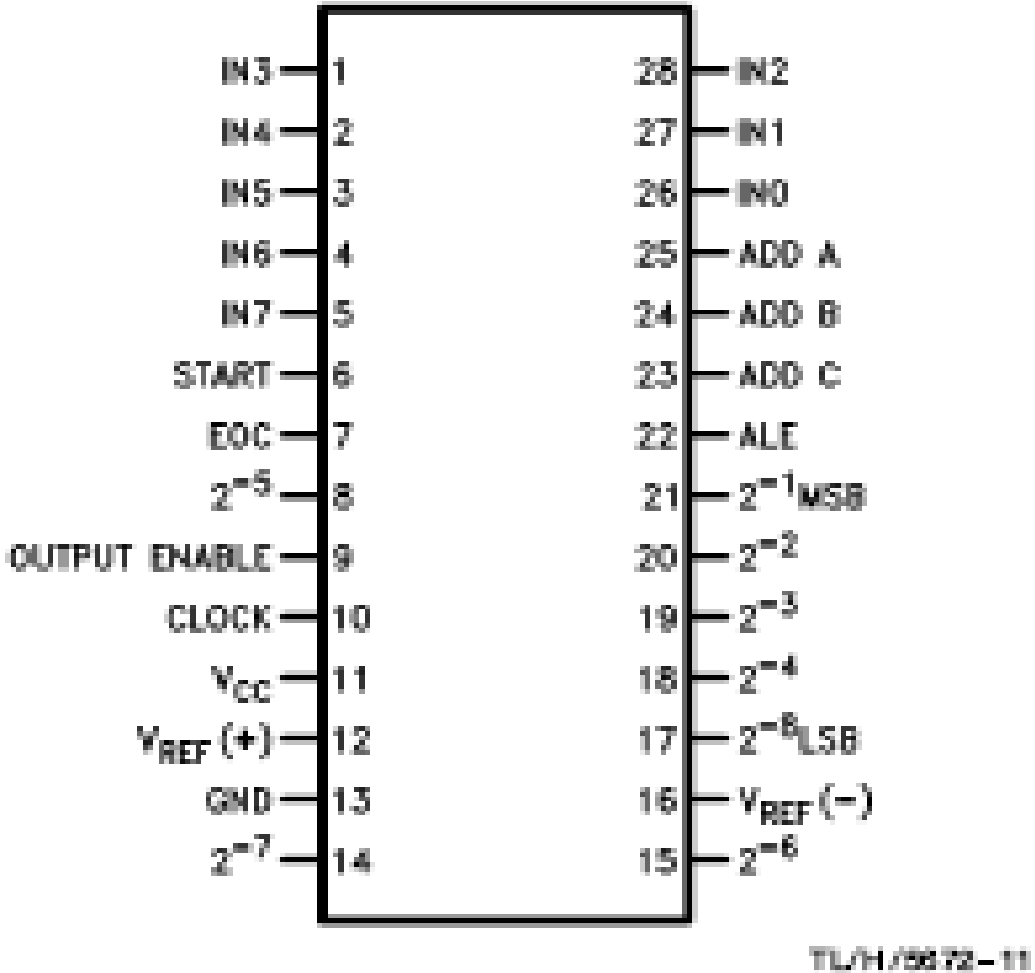
# ADC 0809

## Block Diagram



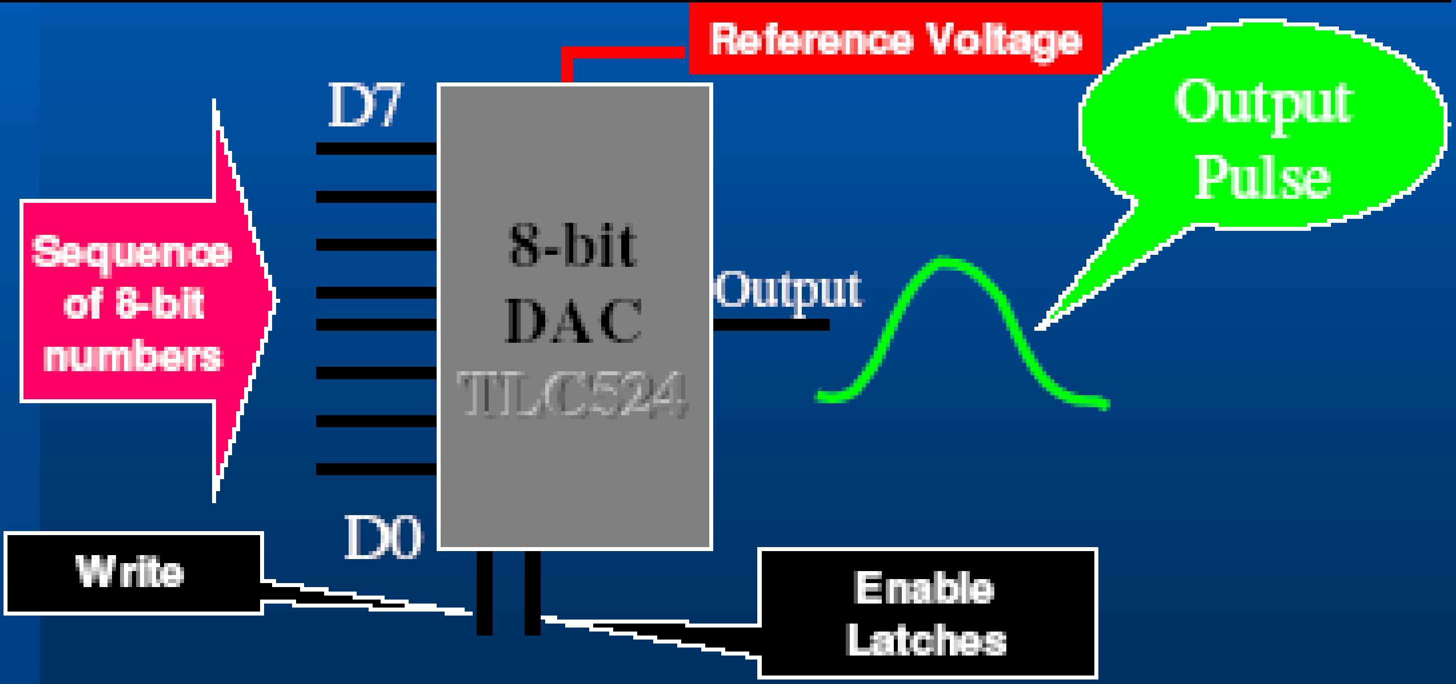

See Ordering Information

## Dual-In-Line Package

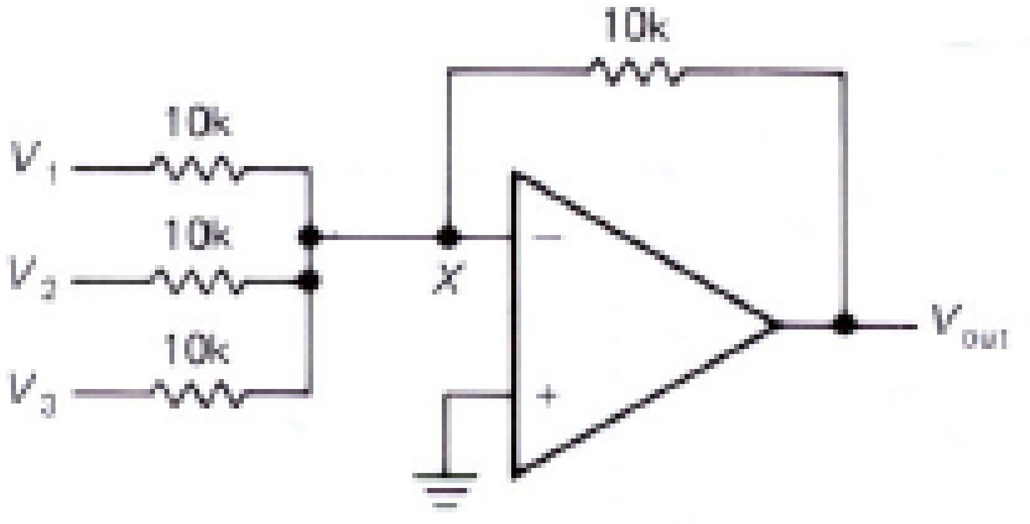



**Order Number ADC0808CCN, ADC0809CCN, ADC0808CCJ or ADC0808CJ**
**See NS Package J28A or N28A**

The DIGITAL to ANALOG CONVERTERS (DAC) are devices that convert digital to analog signals:

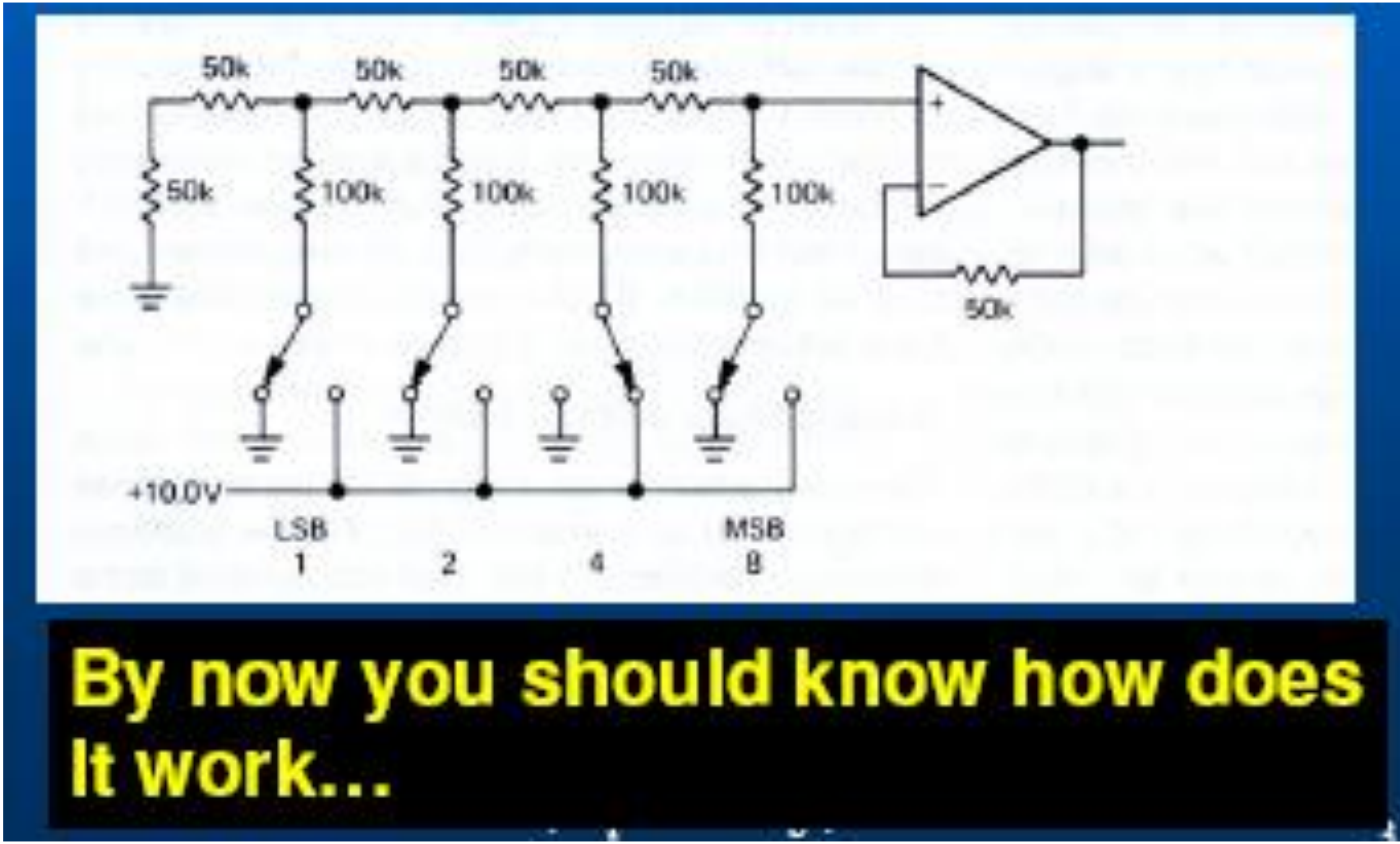


# Summing Amplifier

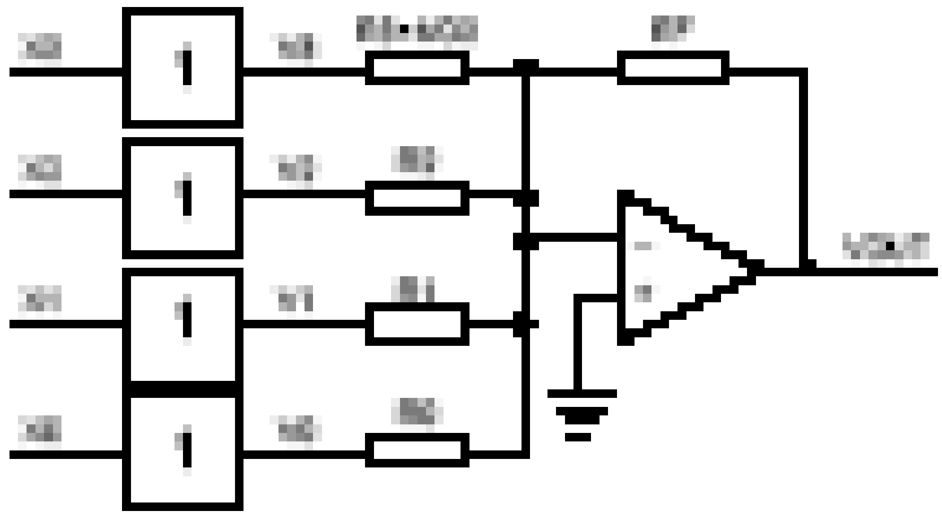



**Exercise : Show that $V_{out} = -(V1+V2+V3)$**

# R-2R Network to convert Digital to Analog



# Output Op-Amp




$$V_{OUT} = \frac{-R_F}{R_{Thévenin}} \times V_{Thévenin} = -R_F\left(V_3G_3 + V_2G_2 + V_1G_1 + V_0G_0\right)$$