SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

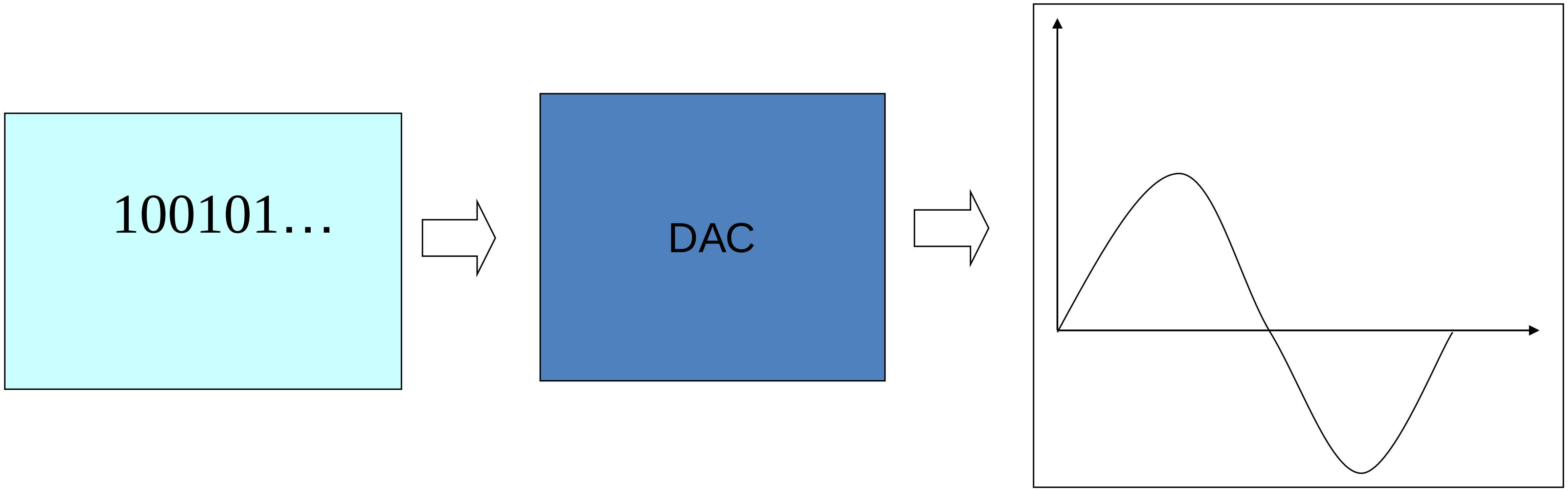
19ECB204 – LINEAR AND DIGITAL CIRCUITS

II YEAR/ III SEMESTER

UNIT 2 – **COMPARATORS AND SPECIAL FUNCTION IC's**

TOPIC 6 – D/A converter – Types

WHAT IS A DAC?



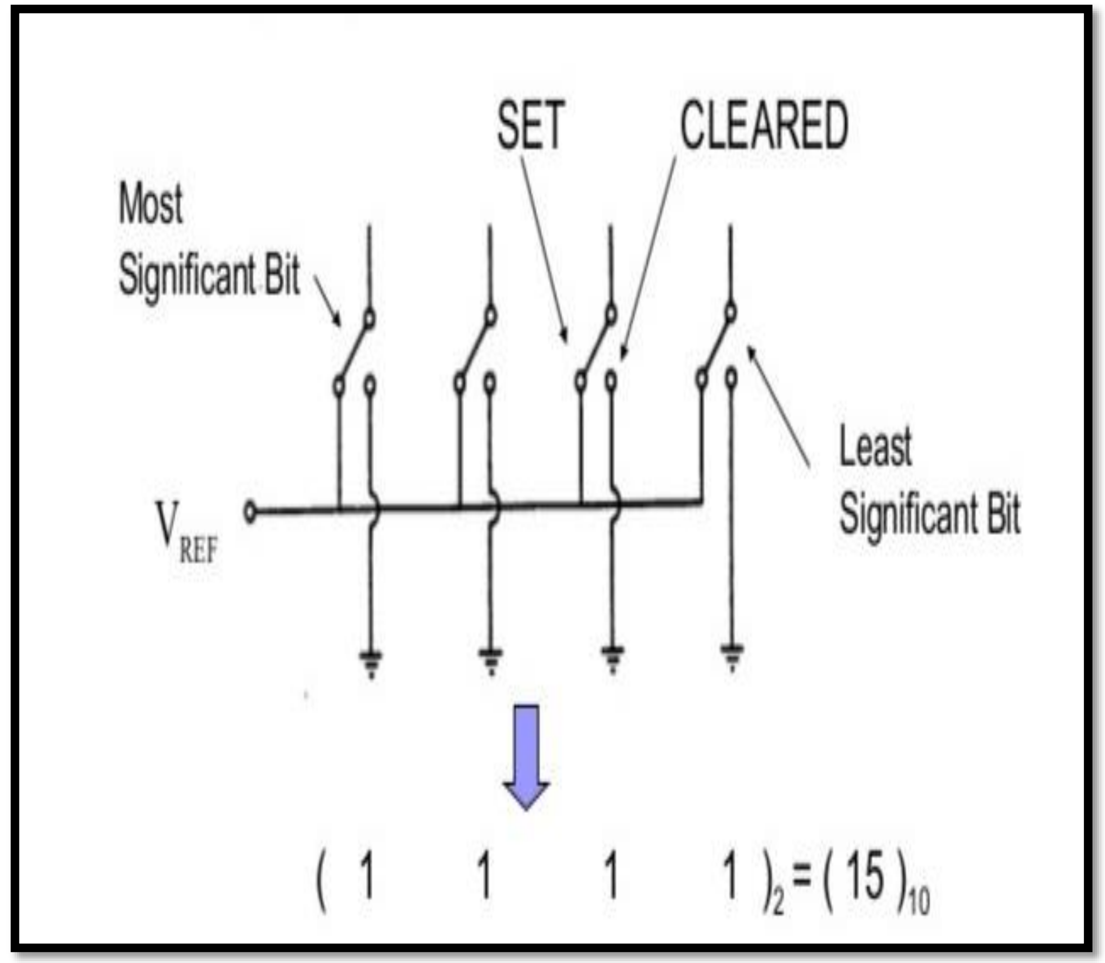
- A Digital-to-analog converter(DAC) takes a digital code as its input and produce an analog voltage or current as its output
- This analog output is proportional to the digital input

TYPES OF DACS

- Many types of DACs available.
- Usually switches, resistors, and op-amps used to implement conversion
- Two Types:
  - Binary Weighted Resistor
  - R-2R Ladder

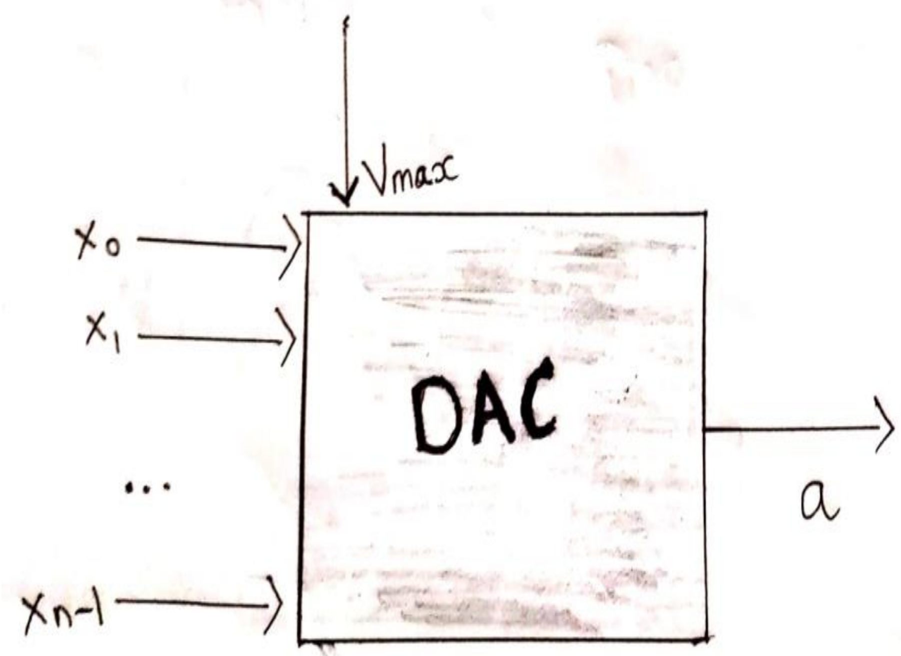
BINARY WEIGHTED RESISTOR

- Utilizes a summing op-amp circuit
- Weighted resistors are used to distinguish each bit from the most significant to the least significant
- Transistors are used to switch between V_{ref} and ground (bit high or low)

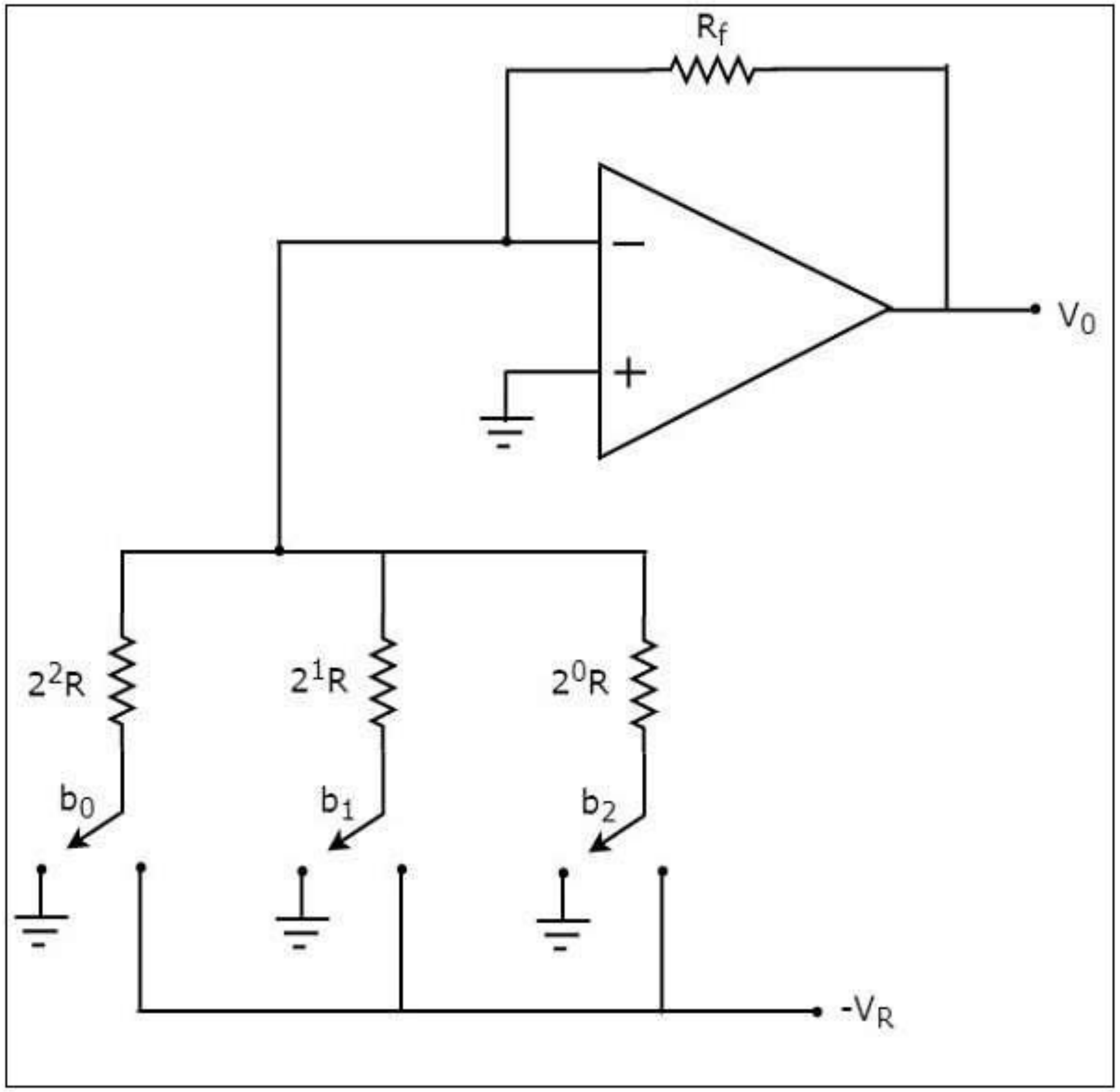


BINARY WEIGHTED RESISTOR

- Smallest analog increment corresponding to 1 LSB change
- An N-bit resolution can resolve 2^N distinct analog levels
- Common DAC has a 8-16 bit resolution



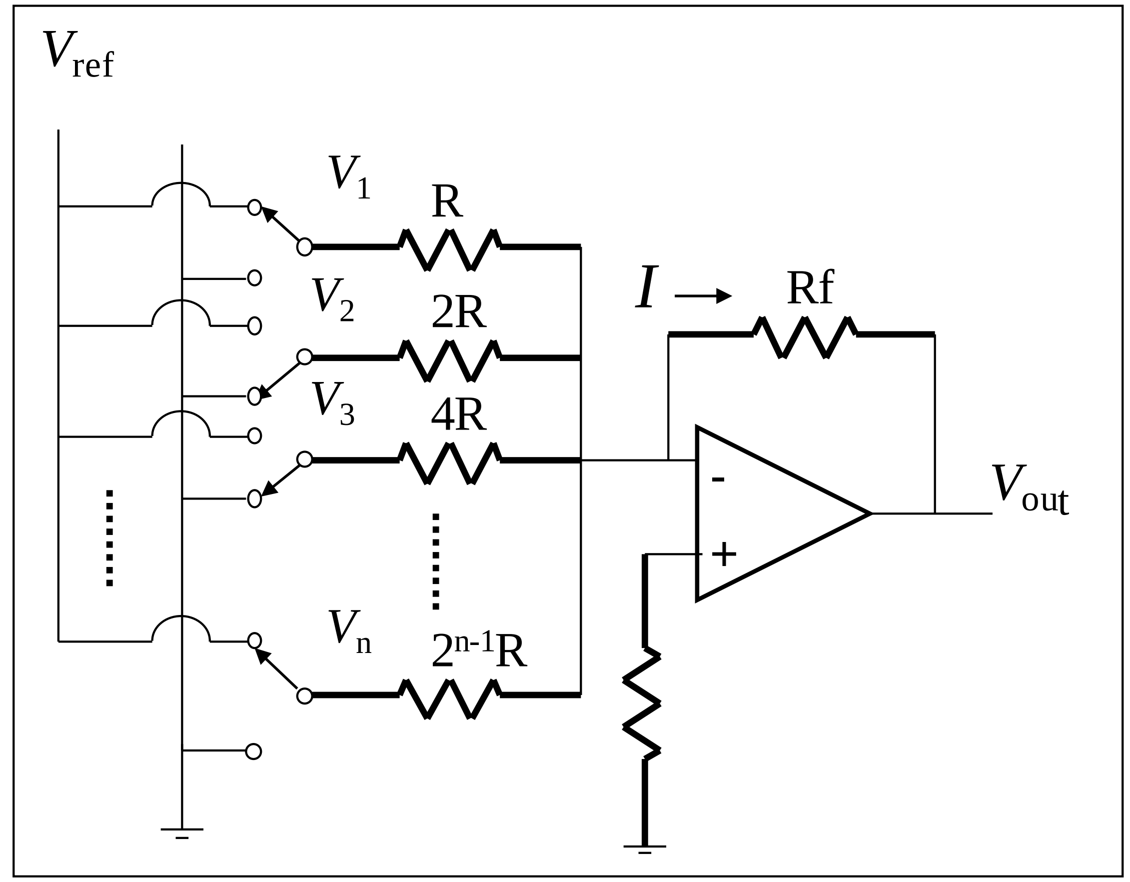
BINARY WEIGHTED RESISTOR



- Assume Ideal Op-amp
- No current into op-amp
- Utilizes a inverting weighted OP-AMP circuit.
- Weighted resistors are used to distinguish each bit from the MSB to the LSB.
- Virtual ground at inverting input
- $V_{out} = -IR_f$

BINARY WEIGHTED RESISTOR

- Voltages V_1 through V_n are V_{ref} if corresponding bit is high
- Voltages V_1 through V_n are Ground if corresponding bit is low
- V_1 is most significant bit
- V_n is least significant bit



MSB

LSB

$$V_{out} = -IR_f = -R_f\left(\frac{V_1}{R} + \frac{V_2}{2R} + \frac{V_3}{4R} + \cdots \frac{V_n}{2^{n-1}R}\right)$$

BINARY WEIGHTED RESISTOR

If $R_f = R/2$

$$V_{out} = -IR_f = -\left(\frac{V_1}{2} + \frac{V_2}{4} + \frac{V_3}{8} + \cdots \frac{V_n}{2^n}\right)$$

For example, a 4-Bit converter yields

$$V_{out} = -V_{ref}\left(b_3\frac{1}{2} + b_2\frac{1}{4} + b_1\frac{1}{8} + b_0\frac{1}{16}\right)$$

Where b_3 corresponds to Bit-3, b_2 to Bit-2, etc.

ADVANTAGES

- Advantages
  - Simple Construction/Analysis
  - Fast Conversion

DISADVANTAGES

- Disadvantages
  - Requires large range of resistors (2000:1 for 12-bit DAC) with necessary high precision for low resistors
  - Requires low switch resistances in transistors
  - Can be expensive. Therefore, usually limited to 8-bit resolution.

Activity

Odd or Even?

Name: ____________________

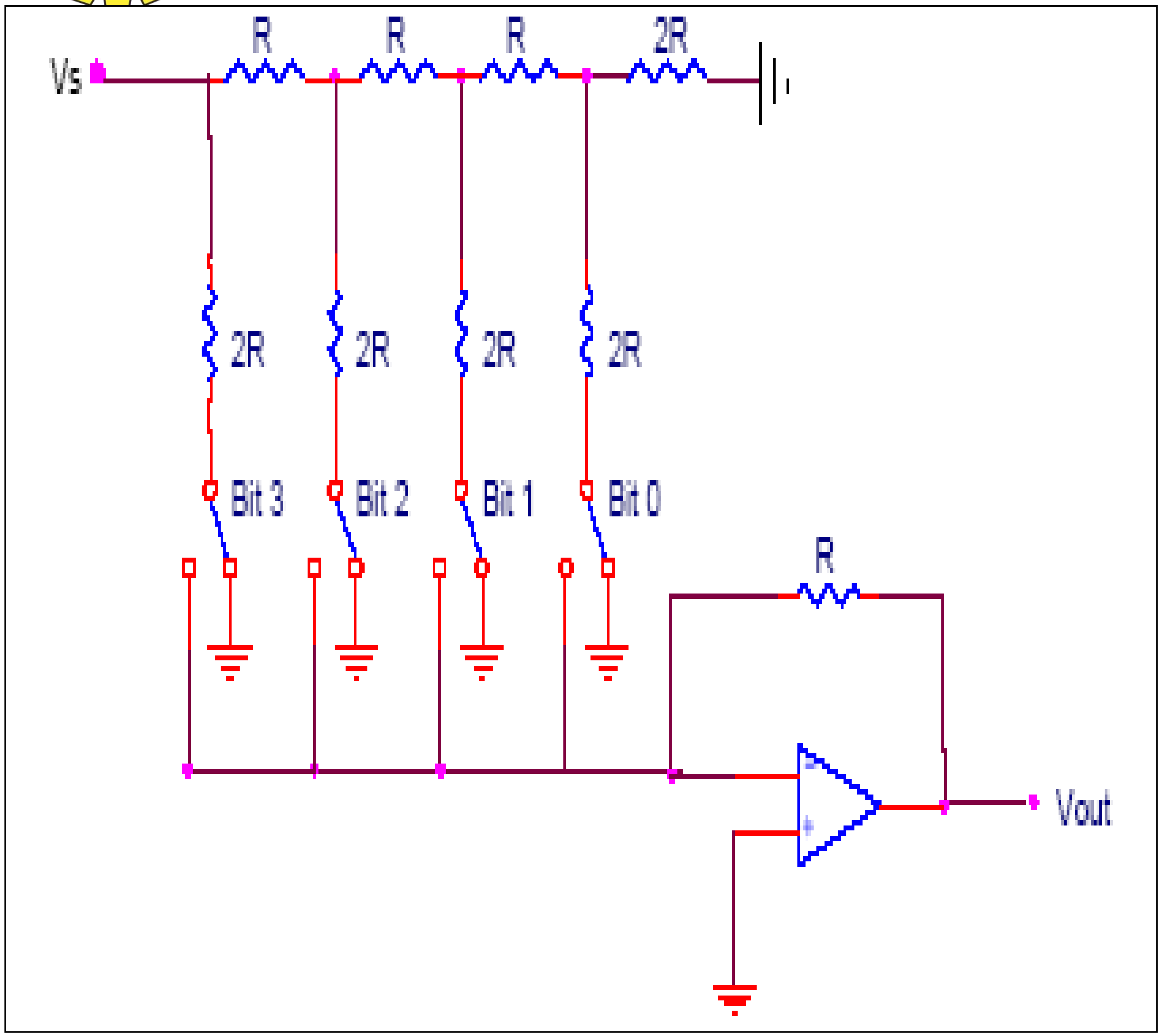
Directions: Cut out numbers. Sort them into even or odd. Glue in the correct box.

Odd	Even

© First Grade Brain

7	54	28	53	16	42	105	75
11	38	91	100	89	64	33	86

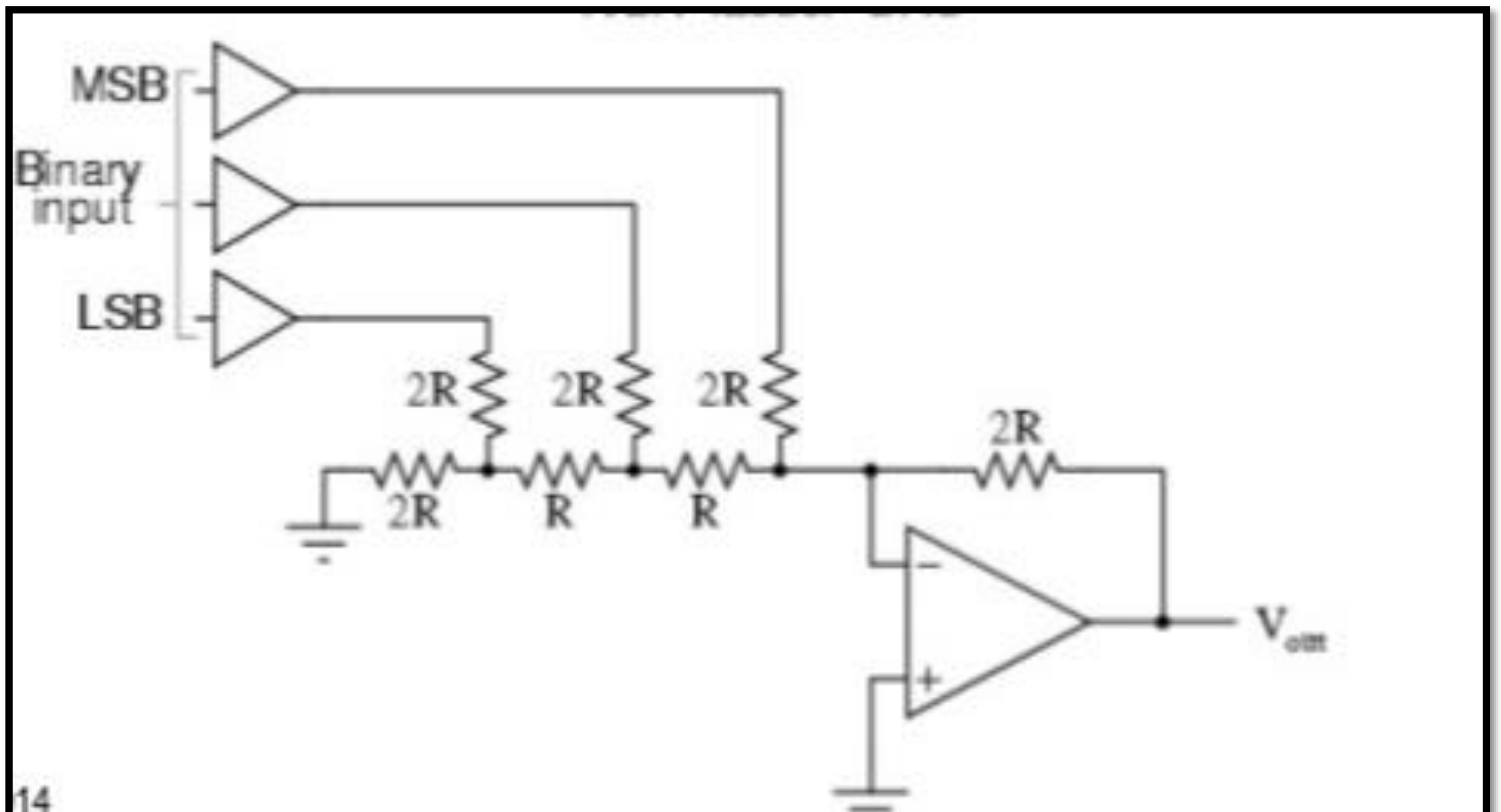
R-2R LADDER



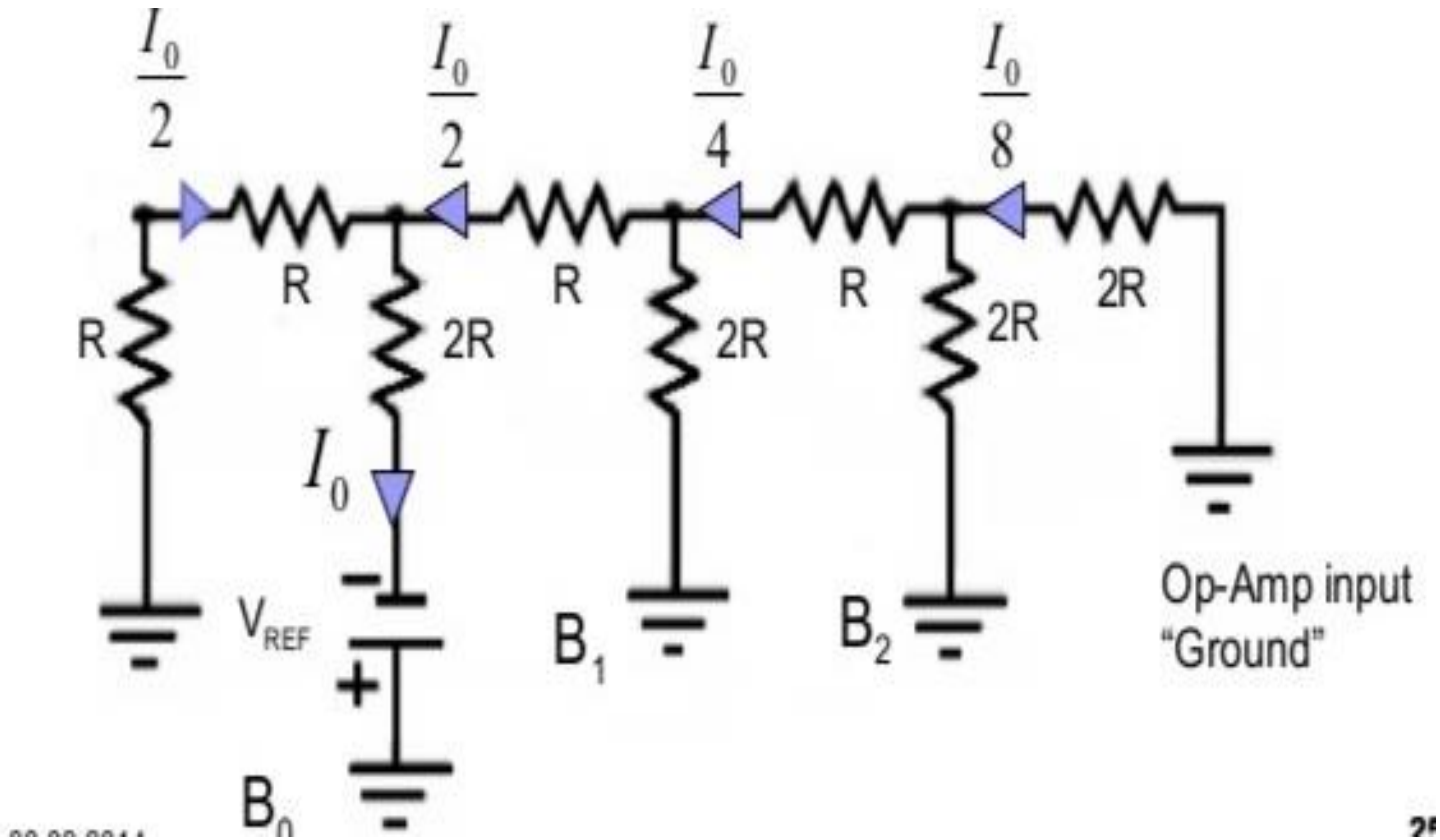
- ➢Each bit corresponds to a switch:
- ➢If the bit is high, the corresponding switch is connected to the inverting input of the op-amp.
- ➢If the bit is low, the corresponding switch is connected to ground.

R-2R LADDER

- Current Dependent on bits position.
- The current is divided by a factor of 2 at each node.

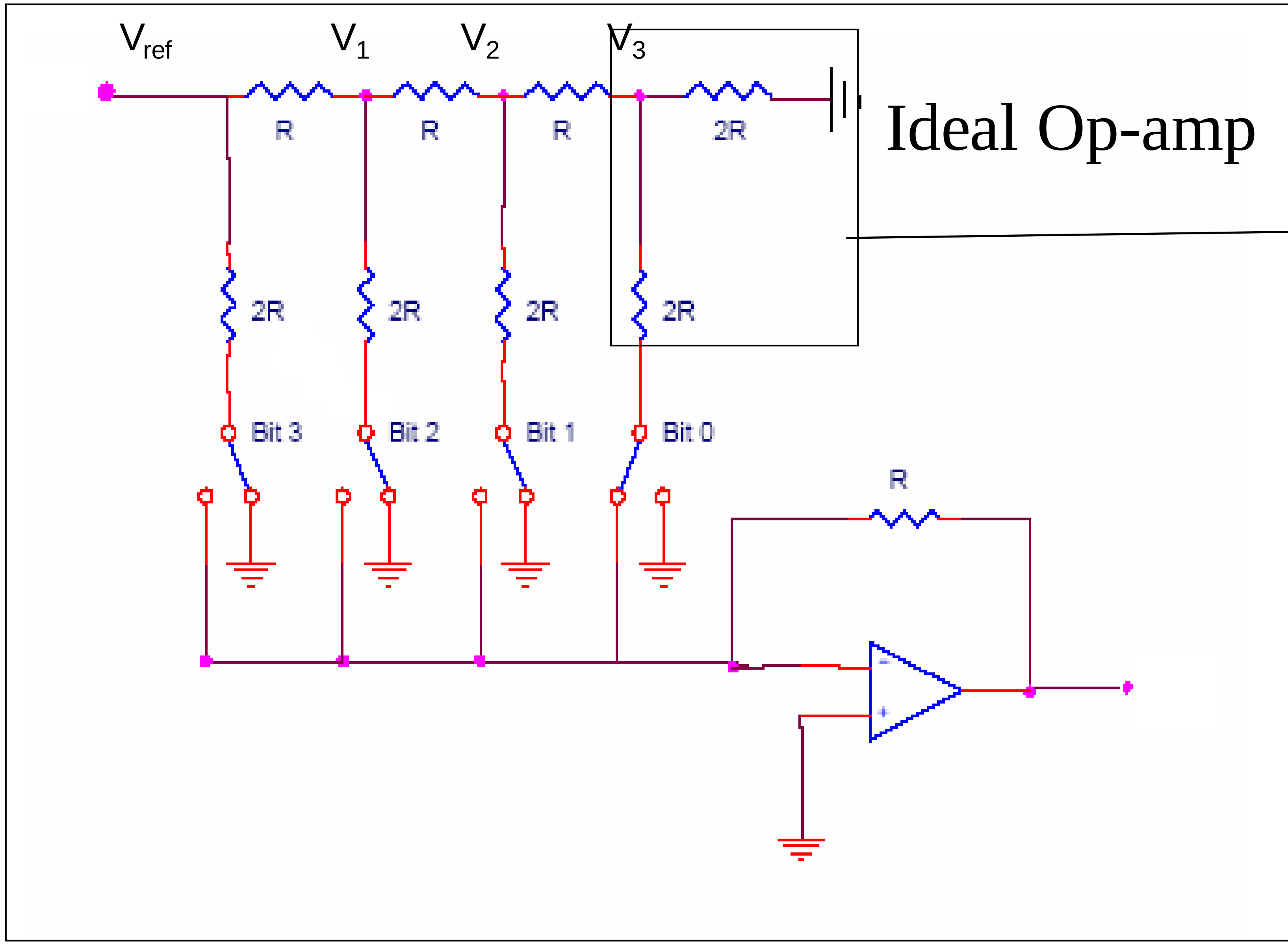


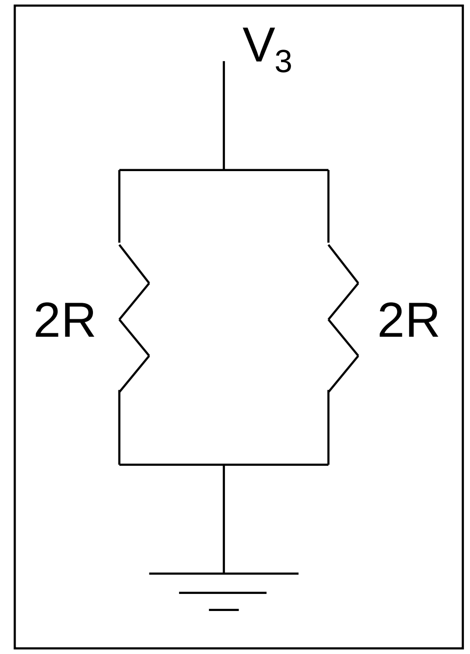
R-2R LADDER



$\frac{I_0}{2}$
$\frac{I_0}{2}$
$\frac{I_0}{4}$
$\frac{I_0}{8}$
R
R
R
2R
R
2R
2R
2R
I_0
V_{REF}
B_1
B_2
B_0
Op-Amp input
"Ground"

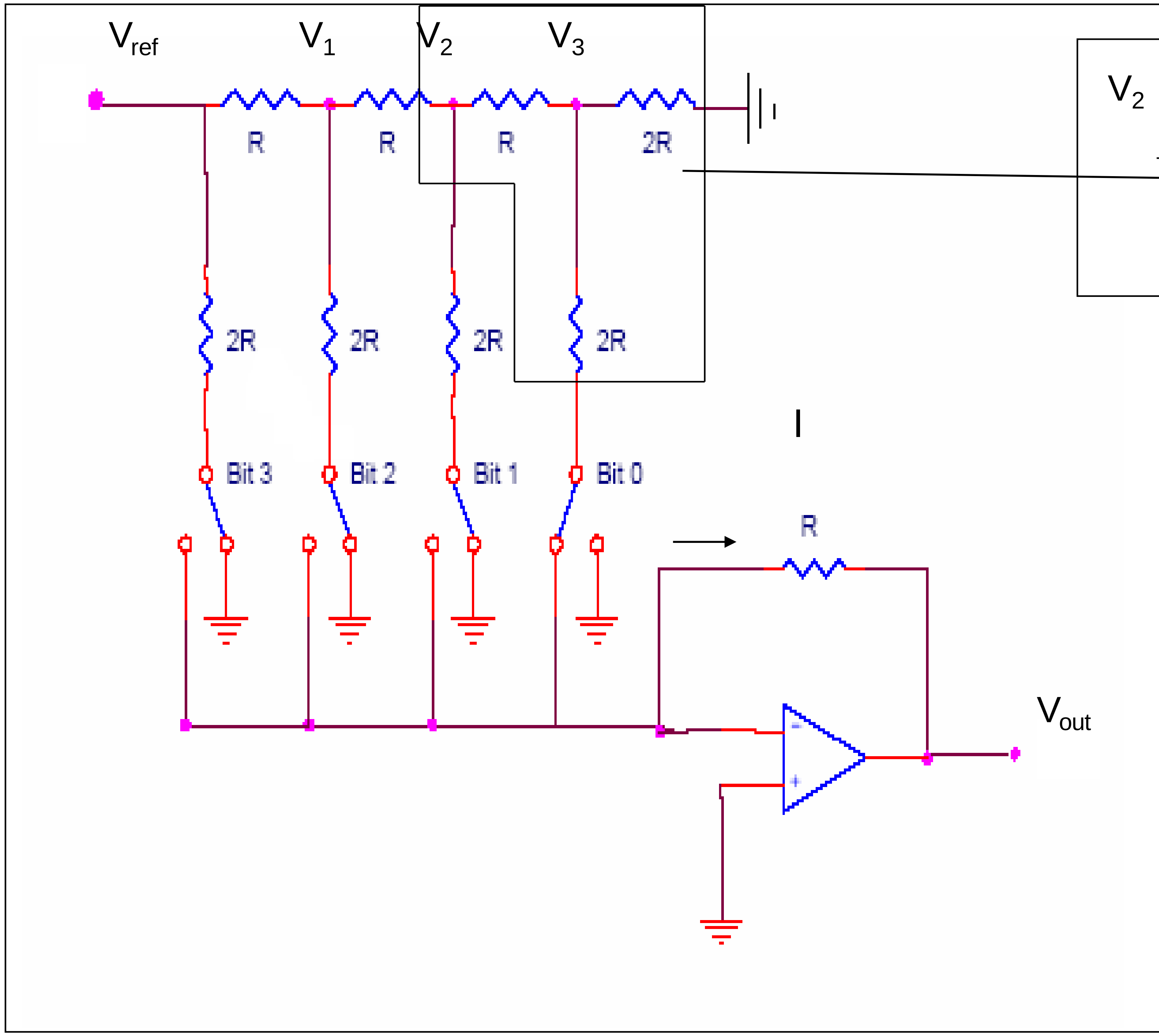
R-2R LADDER

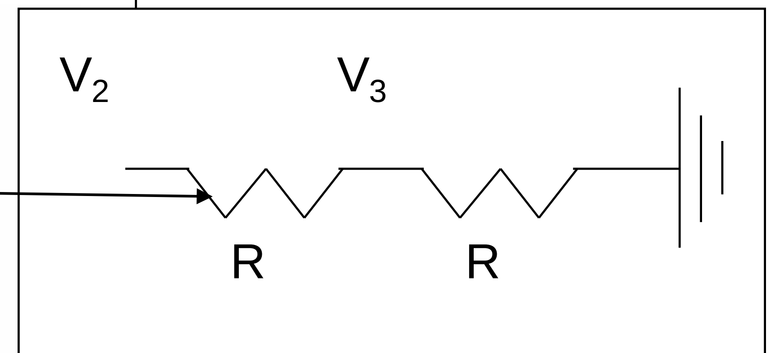




$$R_{eq} = \frac{(2R)(2R)}{(2R+2R)} = R$$

R-2R LADDER





Likewise,

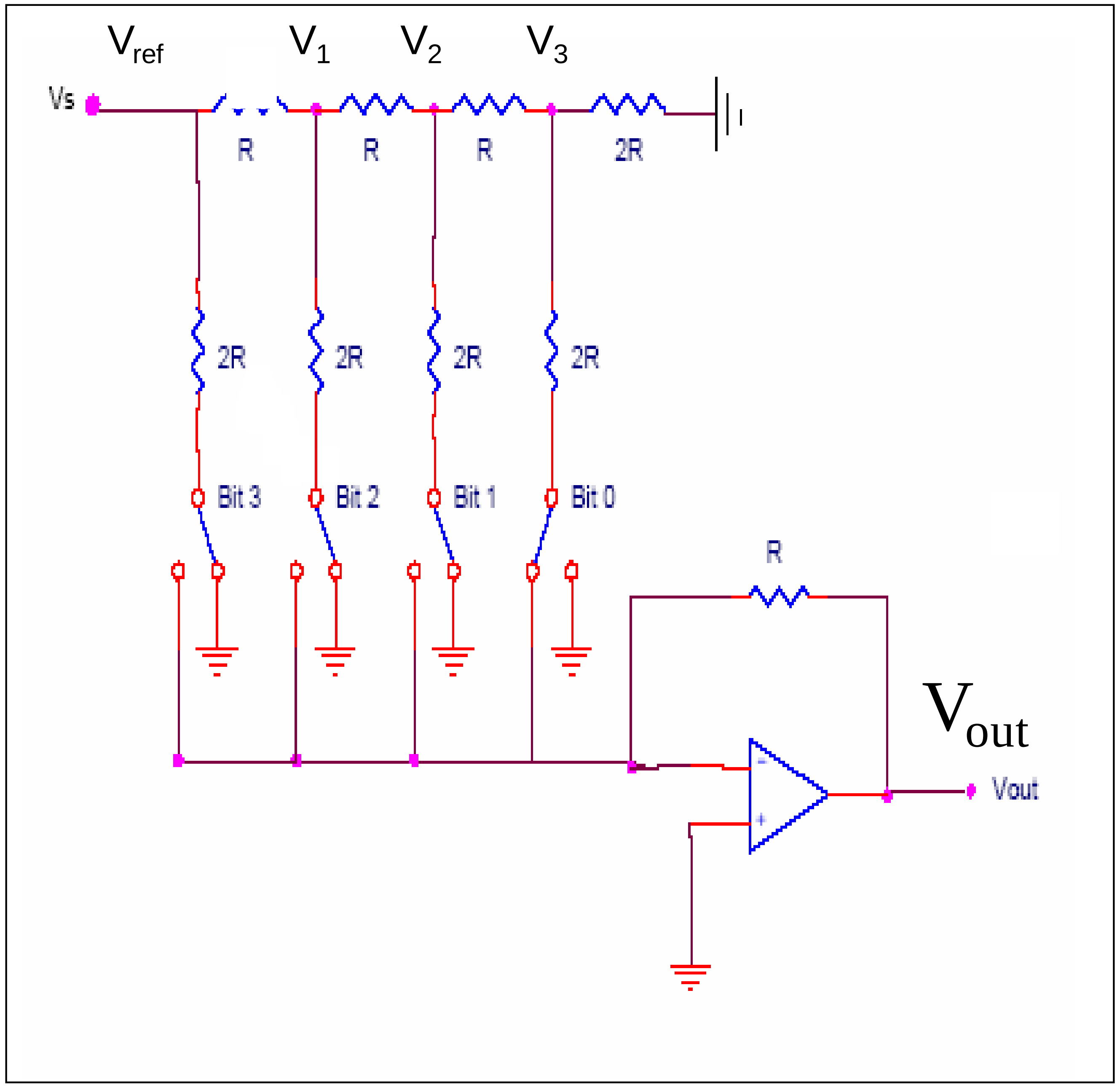
$$V_3 = \left(\frac{R}{R+R}\right)V_2 = \frac{1}{2}V_2$$

$$V_2 = \frac{1}{2}V_1$$

$$V_1 = \frac{1}{2}V_{\text{ref}}$$

$$V_{\text{out}} = -IR$$

R-2R LADDER



$$V_3 = \frac{1}{8}V_{ref},\ V_2 = \frac{1}{4}V_{ref},\ V_1 = \frac{1}{2}V_{ref}$$

$$V_{out} = -R\left(b_3\frac{V_{ref}}{2R} + b_2\frac{V_{ref}}{4R} + b_1\frac{V_{ref}}{8R} + b_0\frac{V_{ref}}{16R}\right)$$

Where b_3 corresponds to bit 3, b_2 to bit 2, etc.

If bit n is set, b_n=1

If bit n is clear, b_n=0

R-2R LADDER

For a 4-Bit R-2R Ladder

$$V_{out} = -V_{ref}\left(b_3 \frac{1}{2} + b_2 \frac{1}{4} + b_1 \frac{1}{8} + b_0 \frac{1}{16}\right)$$

For general n-Bit R-2R Ladder or Binary Weighted Resister DAC

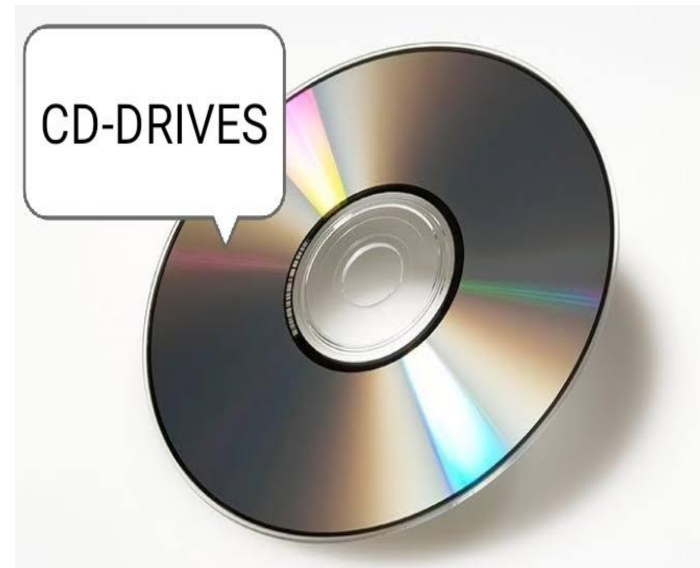
$$V_{out} = -V_{ref} \sum_{i=1}^{n} b_{n-i} \frac{1}{2^i}$$

R-2R LADDER

- Advantages
  - Only two resistor values (R and 2R)
  - Does not require high precision resistors
- Disadvantage
  - Lower conversion speed than binary weighted DAC

APPLICATIONS

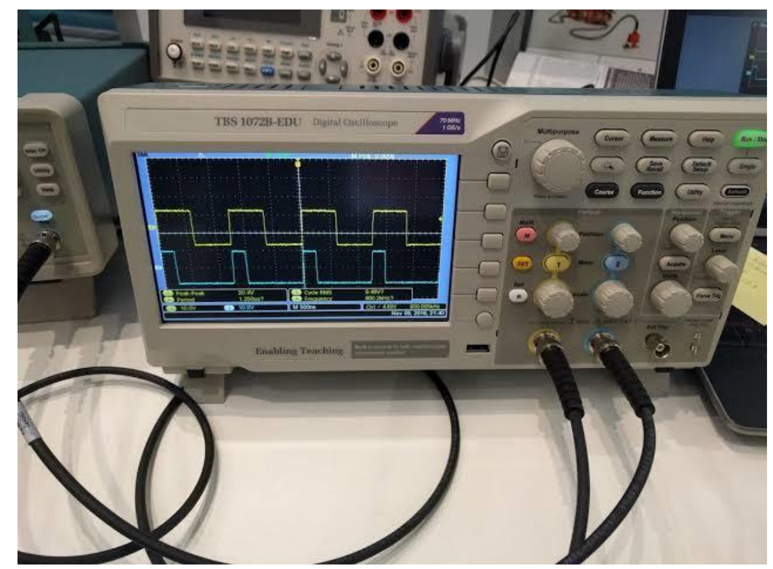
- Digital Motor Control
- Computer Printers
- Sound Equipment (e.g. CD/MP3 Players, etc.)



APPLICATIONS

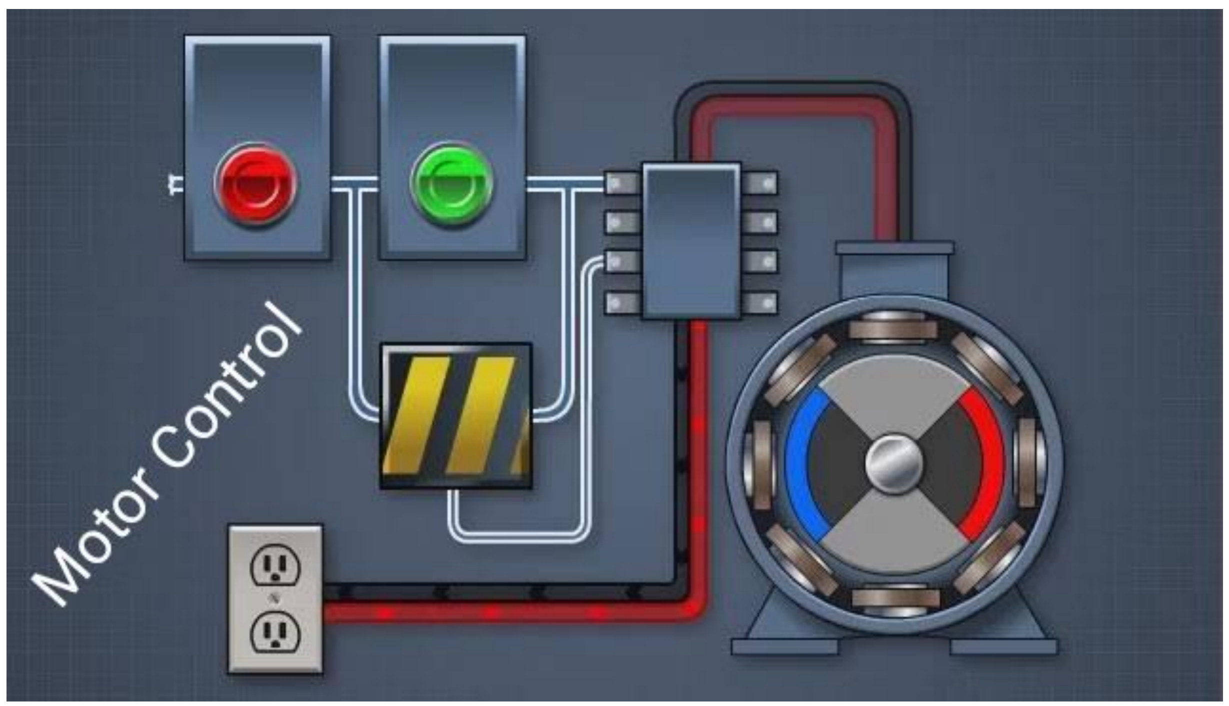
- Digital Oscilloscopes

- Signal Generators



APPLICATIONS

- Motor controllers



Assessment

1. A type of resistor network known as an R-2R ladder is often used in digital-to-analog conversion circuits: why?
2. The output voltage magnitude stands independent of the number of bits(sections) in the R-2R ladder network because-------

THANK YOU