Application of Electronic Circuits in Mechatronics

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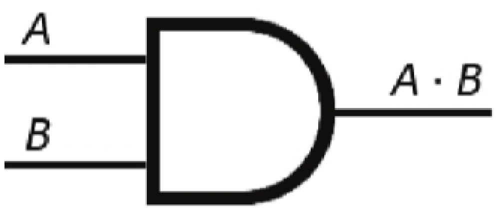
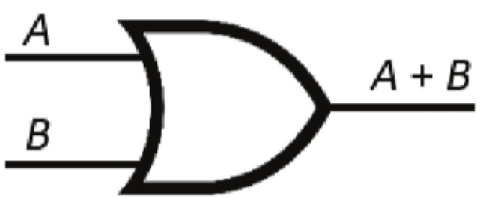
COMBINATIONAL CIRCUITS

- Combinational circuits are logic circuits in which the output depends only on the current values of the inputs, regardless of the previous states of the system.

- The simplest combinational circuits are AND or OR circuits.



AND Logic Circuit



OR Logic Circuit

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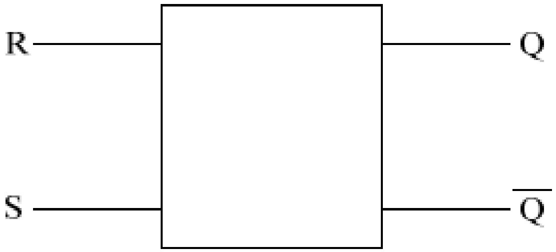
SEQUENTIAL CIRCUITS

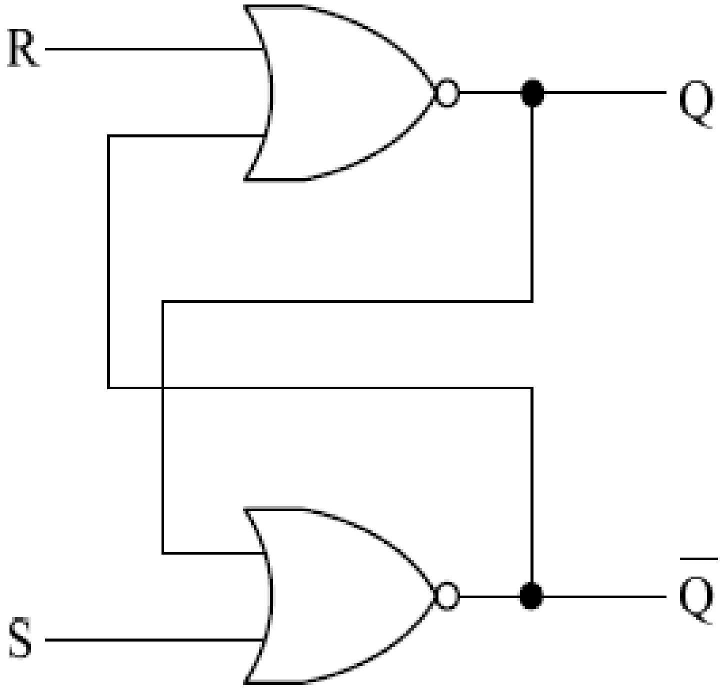
- **Sequential circuits** are logic circuits in which the output depends on the current inputs and the previous states of the system.

- Sequential circuits use memory elements (flip-flops, registers, etc.) that allow for the storage of the previous state.



RS-Flip-Flop circuit

- The basic RS flip-flop can be realized by cross-coupling two NAND gates or two NOR gates.



RS flip-flop in implementation with NOR logic gates

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EXAMPLE OF USING COMBINATIONAL CIRCUITS IN AN ELECTRIC CAR

- **Control of Lighting and Signaling Systems**

Based on current inputs, such as pressing a button or turning the steering wheel, it enables the control of lights, turn signals, brake lights, etc.

- **Interface Control**

Control panels, buttons, and screens use combinational circuits to generate responses to current user commands, such as turning on the seat heater, adjusting the temperature, etc.

COMBINATIONAL CIRCUITS IN ENGINE CONTROL SYSTEM

- **Vehicle Speed Control**

- Through logical operations, the current inputs are analyzed, such as:

- **Accelerator pedal pressure** (input)
- **Vehicle speed** (feedback from sensors)
- **Driving mode** (e.g., economy, sport, or standard mode)

EXAMPLE OF USING SEQUENTIAL CIRCUITS IN AN ELECTRIC CAR

- **Regenerative Braking Systems**

This system allows energy to be returned to the battery during braking.
The output of the system depends on the current inputs (brake pressure) and previous states (e.g., vehicle speed and battery status).

- **Autonomous Driving Systems**

These systems use previous states (e.g., vehicle speed, distance to obstacles) and current inputs (e.g., signaling, prediction of other vehicle movements) to make the right decision in real-time.

INTERCONNECTION OF COMBINATIONAL AND SEQUENTIAL CIRCUITS (ELECTRIC CAR)

- Combinational circuits provide immediate decisions, while sequential circuits store the system's state and use that memory for further operation.

- Combinational circuits can activate sequential circuits, which detect input changes and store the appropriate state for later use.

Example:
The start-stop system can use combinational circuits to recognize when the engine is in idle mode, while sequential circuits store the vehicle's state (whether the engine is truly off or if the vehicle is ready to start).

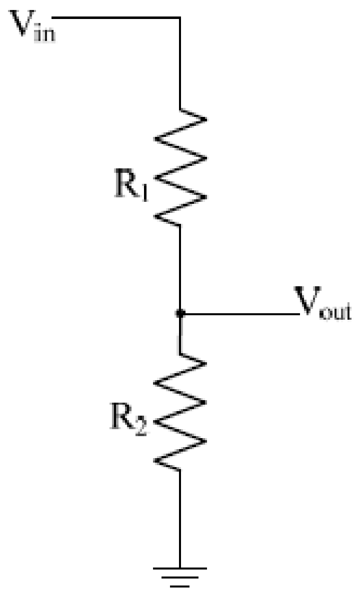
INTEGRATION OF COMBINATIONAL AND SEQUENTIAL CIRCUITS (ELECTRIC CAR)

Integration of Key Functions in Electric Vehicles:

- Powering the system on and off
- Power control
- Energy modes
- Safety mechanisms

VOLTAGE DIVIDER

A voltage divider consists of two resistors connected in series, with a voltage input V_{in} applied across them.



Schematic of a Simple Voltage Divider

- The voltages across the resistors of a voltage divider are directly proportional to the values of their resistances.

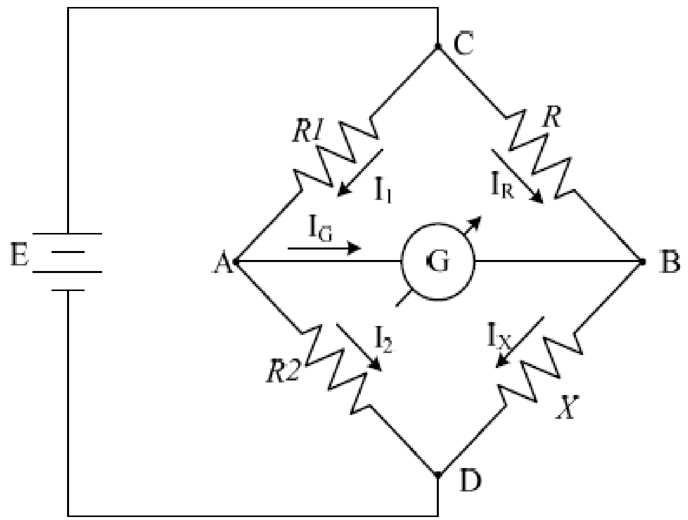
- The voltage across the i-th resistor is:

$$\frac{U_i}{U} = \frac{R_i}{R_1 + R_2 + \cdots + R_i + \cdots + R_n} = \frac{R_i}{\sum_{k=1}^{n} R_k}$$

- The application of the voltage divider rule directly gives the voltage across the desired component in the circuit, without the need for prior calculation of the current.

MEASURING BRIDGES

- Measuring bridges are often used for highly precise measurements.
- The value of an unknown resistance is compared with a known, precise resistance (standard).



Wheatstone Bridge

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SIGNAL AMPLIFIERS

- An amplifier increases the signal strength using an external power supply voltage.
- The signal levels of certain components in a mechatronic system must be properly adjusted to achieve satisfactory performance.
- Many types of sensors produce weak signals that need to be amplified before being sent to the data processor, controller, etc

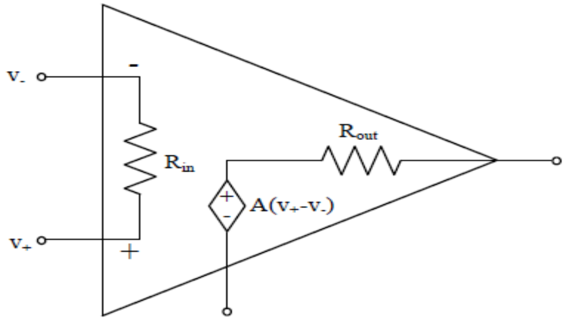
OPERATIONAL AMPLIFIER

- An operational amplifier is an integrated linear amplifier circuit that has two inputs (inverting and non-inverting) and one output.

- The output voltage is proportional to the difference between the voltages at its inputs (positive and negative).

- $V_{out} = A \cdot (V_{+} - V_{-})$

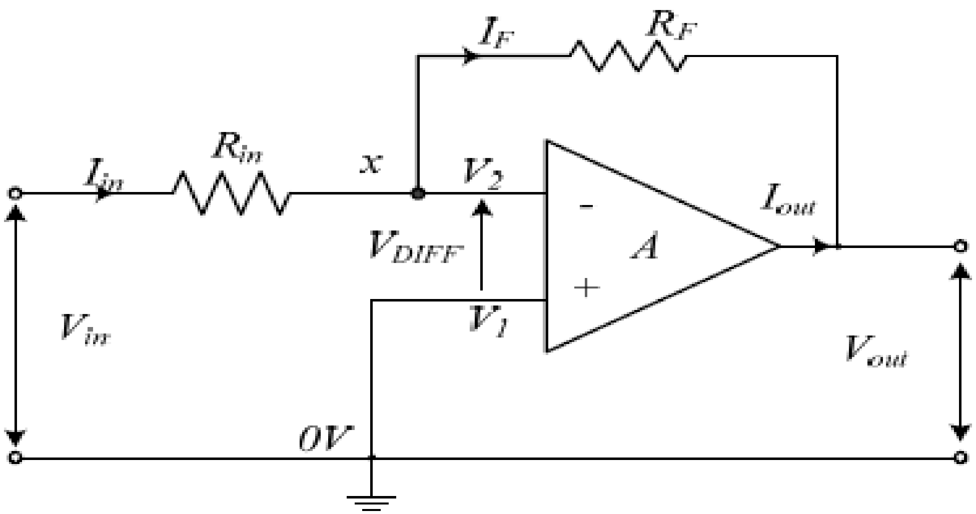
A - The gain of an operational amplifier



Operational Amplifier - Schematic

INVERTING AMPLIFIER

$$A_v = \frac{V_{out}}{v_{in}} = -\frac{R_F}{R_{in}}$$



Inverting amplifier - Schematic

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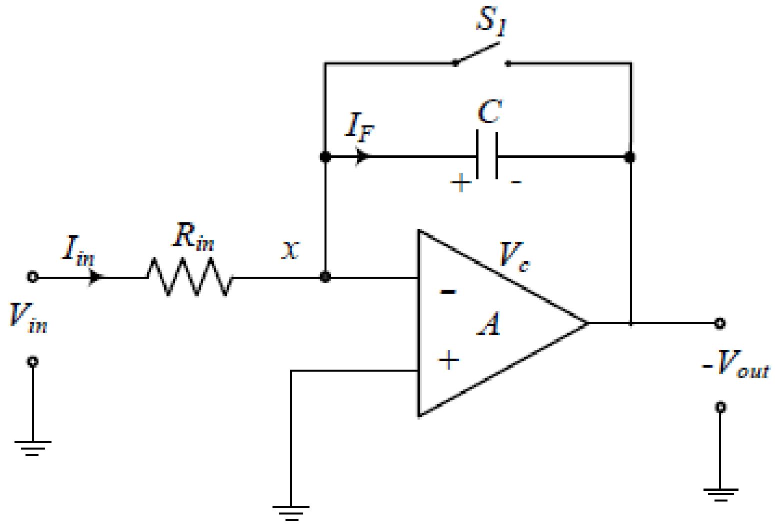
INTEGRATOR

$$V_{out} = -\frac{1}{R_{in}C}\int_0^T V_{in}dt$$



Integrator - Schematic

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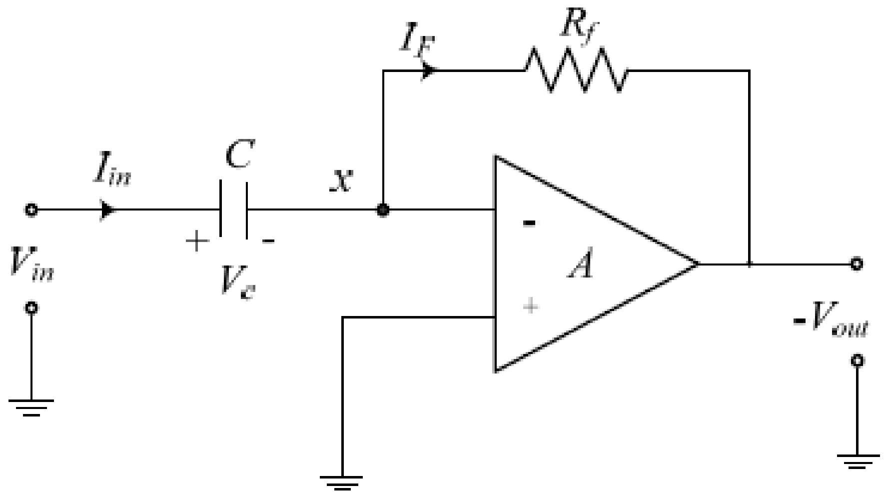
INVERTING DIFFERENTIATOR

$$V_{out} = -R_f C \frac{dV_{in}(t)}{dt}$$



Inverting Differentiator - Schematic

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