A Generalized Approach to Kirchhoff's Current Law

Arushi Golia,[1] Shaunak Lunawat[2], Parmeshwari Aland[3]

AJEENKYA D Y PATIL UNIVERSITY, CHAROLI PUNE

Abstract

When we turn on the light switch, the light glows immediately, right? Have you ever imagined why does that happen? What's exactly going inside the wires? What happens within seconds that results in glowing of the light?

There are two basic concepts behind every electric circuit, that is:

1. **Current-** It is the flow of electrons inside a circuit.
2. **Voltage-** It is the difference in electric potential between two points.

Kirchhoff's current law deals with the conservation of charge entering and leaving a junction and also helps us analyse complex circuits. It states that for a parallel path the total current entering a circuit junction is exactly equal to the total current leaving the same junction.

Keywords

Current, Junction Law, Circuit, Charge Conservation, Ohm's Law

Introduction

Electric current is defined as the rate at which an electrical charge passes through a point. It is the flow of positive charges. The higher the rate of flow of electrons, the higher is the current in the circuit. The flow of current is due to potential difference between two points.

There are two laws that Gustav Kirchhoff proposed. First is Kirchhoff's current law and second is Kirchhoff's voltage law. Kirchhoff's current law states that the total current entering into a node or a junction is equal to total current flowing outside the junction. This is a consequence of charge conservation. Gustav Kirchhoff's current law is one of the fundamental law used for circuit analysis.

As we know by ohm's law V=IR where V is the potential difference between two points, I is the current flowing inside the circuit and R is the resistance present in the circuit.

Implementation System

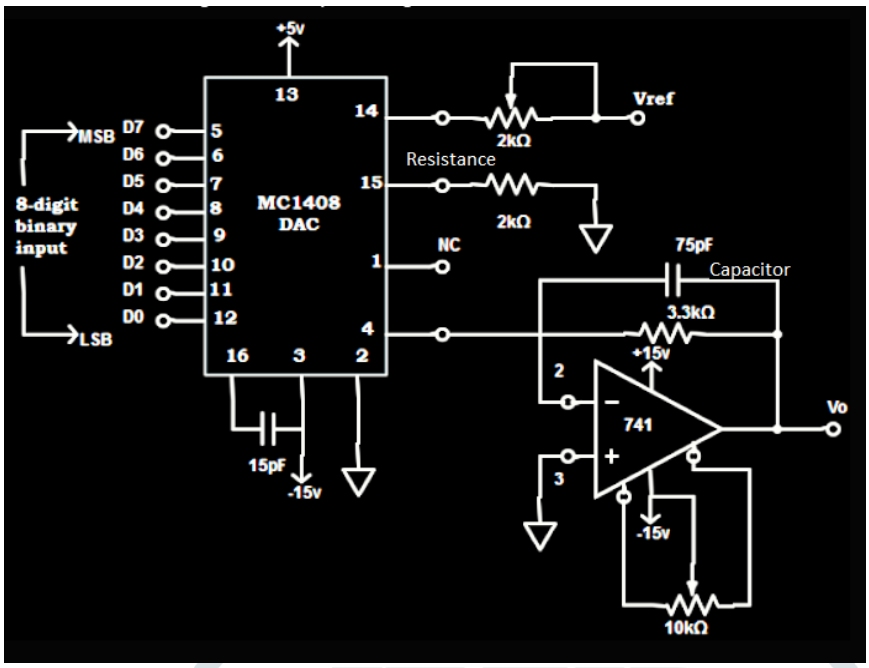


Fig. 1-Diagram of Thermistor

If all the binary input, D0 through D7 are 0, then current I0=0.

Therefore, minimum value of V0=0 volts.

If all the inputs are in logic 1,

$I0= \left(\frac{VRef}{R1}\right) \text{ x } \left(\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\frac{1}{32}+\frac{1}{64}+\frac{1}{128}+\frac{1}{256}\right)$

$= \left(\frac{3}{2}k\Omega\right) \text{ x } (0.996)$

= 1.494 mA

Hence, maximum voltage is V0=I0.RF

V=1.494X3.3

=4.93 V

If all the inputs are at logic 2,

$I0= \left(\frac{V0}{R2}\right) X \left(\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\frac{1}{32}+\frac{1}{64}+\frac{1}{128}+\frac{1}{256}\right)$

$= \left(\frac{15}{3.3}\right) k\Omega \text{ X } (0.996)$

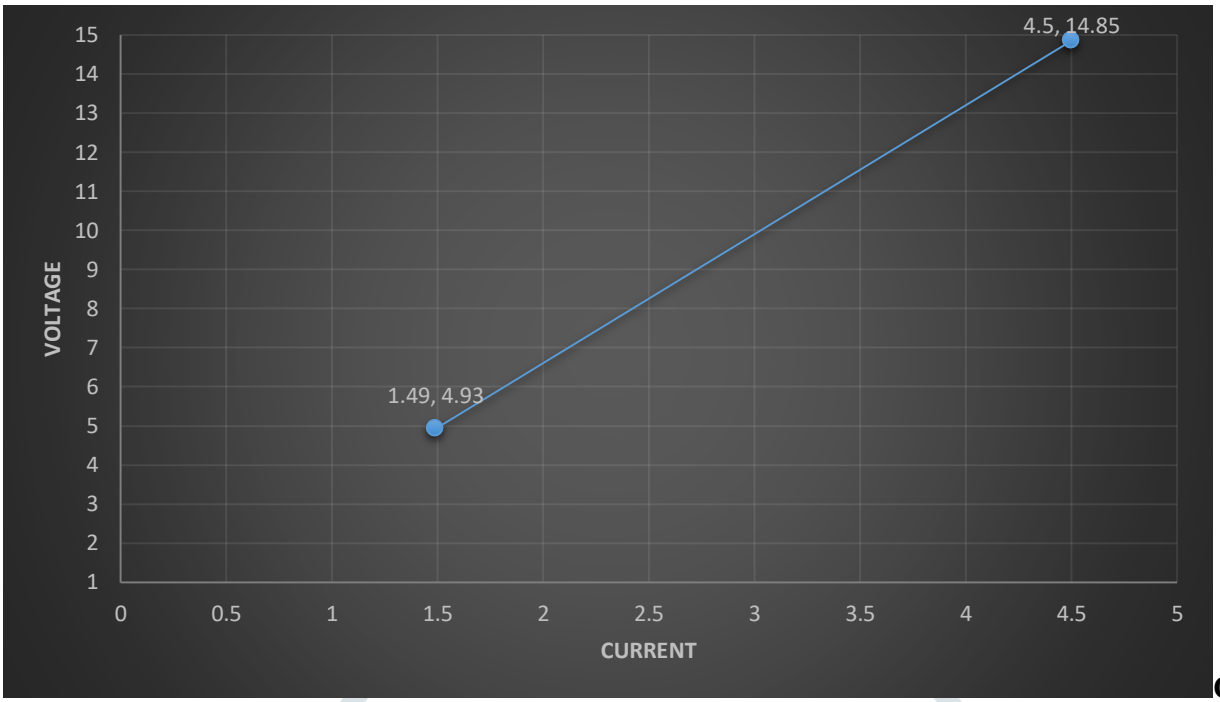
= 4.5mA

Hence, maximum voltage is V0= I0 RF

= 4.5x3.3

= 14.85 V

Therefore, the output voltage range is from 0 to 14.85.



Graph of Voltage v/s Current

(This tells us that V is directly proportional to I (By Ohm's Law).)

Observations

Applications- The practical application of Kirchhoff's current law is to determine the amount of current and voltage flowing through an individual electronic component in a circuit. Using this law we can manipulate current to the component by controlling resistance to it.

Advantages- Calculations of unknown currents becomes easy. Simplification and analysis of complex closed loop circuits becomes manageable. It helps in understanding the transfer of energy through an electrical circuit.

Literature Survey

The sum of the currents entering a particular point must be zero.

Mathematically, Kirchhoff's Current Law is given by $\sum_n i_n = 0$

For reference, this law is sometimes called Kirchhoff's First Law, Kirchhoff's Junction Rule, Kirchhoff's Point Rule and Kirchhoff's First Rule.

Four currents are entering the junction as shown in the fig. as shown, two currents are positive (entering the junction) and remaining two are negative (leaving the junction). By solving the equation, we can get the values of currents. Doing so allow us to write Kirchhoff's law for this example:

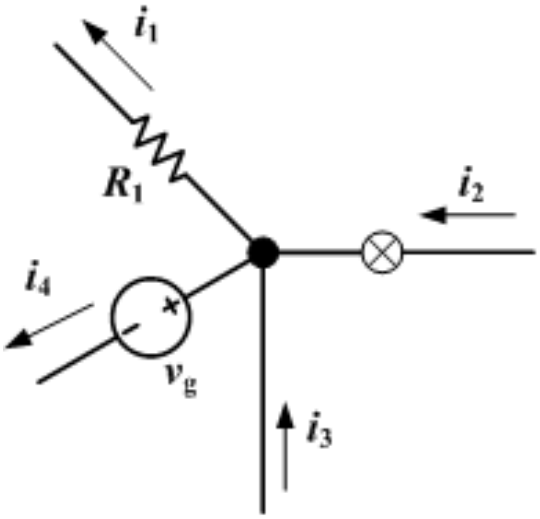


Fig. 2- Junction Rule

$$\sum_n i_n = -i_1 + i_2 + i_3 - i_4 = 0$$

$$\sum_n i_n = i_2 + i_3 = i_1 + i_4$$

Kirchhoff's laws and some linear algebra can be used to calculate the resistance of any such network, but most of the circuits you'll work with don't need this level of math. The resistance can always be found through more explicit use of Kirchhoff's laws

Conclusion

The above project relies on the principles of Kirchhoff's current law and helps in understanding the application of KCL in day to day life. They quantify how current flows through a circuit and how voltage varies around a loop in a circuit. We get an account on the amount of current that flows through a circuit and understanding of complex circuits become easier and manageable.

References

[1] J. Gabelli, G. Fève, J.-M. Berroir, B. Plaçais, A. Cavanna, B. Etienne, et. al., "Violation of Kirchhoff's Laws for a Coherent RC Circuit."

[2] P. Feldmann, R.A. Rohrer, "Proof of the number of independent Kirchhoff's equation in an electrical circuit."

[3] Kirchhoff G. ¨Uber den Zusammenhang zwischen Emission und Absorption von Licht und. W¨arme. Monatsberichte der Akademie der Wissenschaften zu Berlin, sessions of Dec. 1859, 1860, 783–787

[4] Yong Wang, D. Gope, V. Jandhyala, C. –J, R. Shi, "Generalized Kirchoff's current and Voltage law formulation for coupled circuitelectromagnetic Simulation with surface Integral equations," Microwave Theory and Techniques, IEEE Transactions on , vol.52, no.7, pp. 1673- 1682, July 2004.

[5] F. R. Quintela, R. C. Redondo, N. R. Melchor, M. Redondo, "A General Approach to Kirchhoff's Laws," Education, IEEE Transactions on , vol.52, no.2, pp.273 - 278, May 2009.

[6] A. H. Zemanian, "Nonstandard electrical networks and the resurrection of Kirchhoff's laws," Circuits and Systems I: Fundamental Theory and Applications, IEEE Transactions on, vol.44, no.3, pp.221,233, Mar 1997

[7] Variational alternatives to Kirchoff's loop theorem in dc circuits.Van Baak, D.A.. American journal of physics, 1999, vol. 67, no. 1, pp. 36, Ingenta