New Way To Use Kirchhoff's Current Law Simplifies Circuit Analysis

ANSHI CHEN
STANFORD RESEARCH SYSTEMS, SUNNYVALE, CALIF.
achen@thinksrs.com

ED ONLINE 18896

The well-known Kirchhoff's current law is often used in linear circuit analysis. It's also called Kirchhoff's first law, Kirchhoff's point rule, Kirchhoff's junction rule, and Kirchhoff's first rule. The law says that at any point in an electric circuit, the sum of currents flowing toward the point is equal to the sum of currents flowing away from the point. That is, the net current flow into the point is always zero.

This article describes a new way of using Kirchhoff's current law to make circuit analysis clearer and simpler. For example, using the very simple example circuit in Figure 1, the current law says:

$$\frac{V1-\phi}{R1}+\frac{V2-\phi}{R2}+I1=0 \qquad (1)$$

We can write the above equation as:

$$\frac{V1}{R1}-\frac{\phi}{R1}+\frac{V2}{R2}-\frac{\phi}{R2}+I1=0 \qquad (2)$$

and rearrange it to:

$$\phi\left(\frac{1}{R1}+\frac{1}{R2}\right)=\frac{V1}{R1}+\frac{V2}{R2}+I1 \qquad (3)$$

Equation 3 is equivalent to Equation 1, but it could have different meanings. The left side of Equation 3 means currents flowing away from the point through resistors as if V1 and V2 are grounded. The right side means all currents flowing into the point as if the middle point is grounded. It's much easier to write equations in this way.

Another example involves equations for a differential amplifier *(Fig. 2)*. Using the new method, we have:

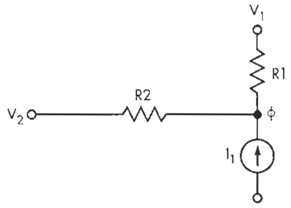
$$\phi\left(\frac{1}{R1}+\frac{1}{R2}\right)=\frac{V1}{R1}+\frac{Vo}{R2} \qquad (4)$$

$$\phi\left(\frac{1}{R3}+\frac{1}{R4}\right)=\frac{V2}{R3}+\frac{0}{R4} \qquad (5)$$

Solving the above equations:

$$Vo=\frac{V2\times R4(R1+R2)}{R1(R3+R4)}-V1\left(\frac{R2}{R1}\right) \qquad (6)$$

Extending this technique to a more complicated circuit *(Fig. 3)* leads to four equations for the four nodes:

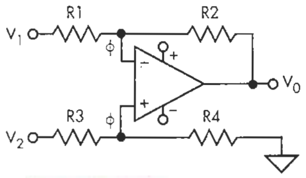


1. This simple circuit can be used to show how to employ Kirchhoff's current law in a new way.

$$\phi1\left(\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R7}+\frac{1}{R11}\right)=$$
$$\frac{V1}{R1}+\frac{\phi2}{R2}+\frac{V8}{R7}+\frac{\phi3}{R11}-I2 \qquad (7)$$

$$\phi2\left(\frac{1}{R2}+\frac{1}{R3}+\frac{1}{R8}+\frac{1}{R12}\right)=$$
$$\frac{\phi1}{R2}+\frac{V6}{R3}+\frac{V7}{R8}+\frac{\phi4}{R12}-I1 \qquad (8)$$

$$\phi3\left(\frac{1}{R4}+\frac{1}{R5}+\frac{1}{R11}+\frac{1}{R9}\right)=$$
$$\frac{V2}{R4}+\frac{\phi4}{R5}+\frac{\phi1}{R11}+\frac{V3}{R9}+I1 \qquad (9)$$



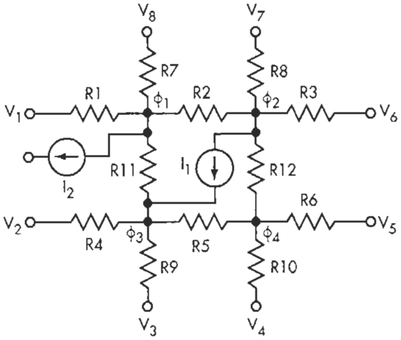
2. A differential amplifier circuit with two nodes offers another example of how to use the new technique.

ANSHI CHEN, senior design engineer, received a BS from Changchun University of Science and Technology, China, and an MS and PhD from Beijing Institute of Technology, China.

$$\phi 4\left(\frac{1}{R5}+\frac{1}{R6}+\frac{1}{R12}+\frac{1}{R10}\right)=$$

$$\frac{\phi 3}{R5}+\frac{V5}{R6}+\frac{\phi 2}{R12}+\frac{V4}{R10} \qquad (10)$$

Thus, the new technique for using Kirchoff's law generates equations that are simple and easy to use.



3. Even for this relatively complex circuit, the new method of using Kirchhoff's current law allows designers a simple way to create analysis equations.