Unit 1

We are ready to investigate the behavior of basic electric circuits in this unit. Two simple laws, Kirchhoff's current law and Kirchhoff's voltage law, form the foundation for circuit analysis procedures.

Section A Basic Laws of Electrical Networks

1. Nodes, Paths, Loops, and Branches

We are now ready to determine the current-voltage relationship in simple networks of two or more circuit elements. The elements will be connected together by wires, which have zero resistance. **Since the network then appears as a number of simple elements and a set of connecting leads, it is called a lumped-parameter network.**[1]

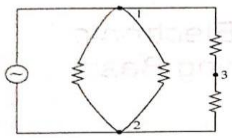


Fig. 1-A-1 A circuit containing three nodes and five branches.

A point at which two or more elements have a common connection is called a node. For example, Fig. 1-A-1 shows a circuit containing three nodes. **We must necessarily consider all of the perfectly conducting leads or portions of leads attached to the node as part of the node.**[2] Note also that every element has a node at each of its ends.

Suppose that we start at one node in a network and move through a simple element to the node at the other end. We then continue from that node through a different element to the next node, and continue this movement until we have gone through as many elements as we wish. If no node was encountered more than once, then the set of nodes and elements that we have passed through is defined as a path. If the node at which we started is the same as the node on which we ended, then the path is, by definition, a closed path or a loop.

Another term whose use will prove convenient is branch. We define a branch as a single path in a network, composed of one simple element and the node at each end of that element. Thus, a path is a particular collection of branches.

2. Kirchhoff's Current Law

We are now ready to consider the first of the two laws named for Gustav Robert Kirchhoff, a German university professor who was born about the time Ohm was doing his experimental work. This axiomatic law is called Kirchhoff's current law (abbreviated KCL), and it simply states that:

The algebraic sum of the currents entering any node is zero.

This law represents a mathematical statement of the fact that charge cannot accumulate at a node. **A node is not a circuit element, and it certainly cannot store, destroy, or generate charge.**[3] Hence, the currents must sum to zero. A hydraulic analogy is sometimes useful here: for example, consider three water pipes joined in the shape of a Y. We define three "current" as

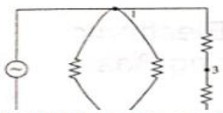
单元 1

我们准备在这个单元中研究hasic电路的行为。基尔霍夫特电流定律和基尔霍夫特电压定律是进行电路分析的步骤

一个节 电力网的基本定律

1. 节点、路径、循环和分支

我们现在准备在两个或两个以上电路元件的简单网络中探测电流-电压关系。这些元件将用导线连接在一起，导线的电阻为零。由于网络是以许多简单的元件和一组连接导线的形式出现的，所以它被称为集总参数网络



两个或两个以上的元素具有公共性的点

连接称为节点。例如，图1-A-1所示为a

包含三个节点的电路。我们必须考虑

完全导通导线的!!或部分导通导线

附加到节点作为节点的一部分，还请注意

每个元素的两端都有一个节点

假设我们从网络中的一个节点开始，通过一个简单的元素将包含三个节点的图I-A-I a sircuit移动到另一端的节点。然后,我们

节点和五个分支。从该节点通过一个不同的元素继续移动到下一个节点，并继续移动，直到我们遍历了尽可能多的元素为止。如果没有遇到节点超过一次。然后，我们通过的节点和元素集被定义为路径。如果我们开始的节点与结束的节点相同，那么根据定义，路径就是闭合路径或循环。

另一个方便使用的术语是branch。我们将分支定义为网络中的单一路径，由一个简单元素和该元素两端的节点组成。

因此，路径是分支的特定集合

2. 基尔霍夫电流定律

我们现在准备考虑以古斯塔夫·罗赫特·基尔霍夫命名的两个定律中的第一个，一位德国大学教授，他出生的时候欧姆正在做他的实验工作。这个公理定律被称为基尔霍夫电流定律(缩写为KCL)，它简单地说明了这一点。

进入amy节点的电流的aleebraic和为zeo

这个定律是电荷不能在一个节点上积聚这一事实的数学表述。节点不是电路元件，它当然不能存储、破坏或产生电荷。因此，电流之和必须为零。在这里，一个水力类比有时是有用的:例如，考虑三条y形连接的水管，我们定义了三条美国“当代”

flowing into each of the three pipes. If we insist that water is always flowing, then obviously we cannot have three positive water currents, or the pipes would burst. This is a result of our define currents independent of the direction that water is actually flowing. Therefore, the value of either one or two of the currents as defined must be negative.

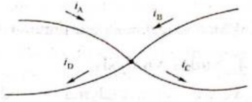


Fig. 1-A-2 Example node to illustrate the application of Kirchhoff's current law.

Consider the node shown in Fig. 1-A-2. The algebraic sum of the four currents entering the node must be zero,

$$i_A + i_B(-i_C) + (-i_D) = 0 \qquad (1\text{-A-}1)$$

It is evident that the law could be equally well applied to the algebraic sum of the currents leaving the nod

$$(-i_A) + (-i_B) + i_C + i_D = 0 \qquad (1\text{-A-}2)$$

A compact expression for Kirchhoff's current law is

$$\sum_{n=1}^{N} i_n = 0 \qquad (1\text{-A-}3)$$

3. Kirchhoff's Voltage Law

We now turn to Kirchhoff's voltage law (abbreviated KVL). This law states that

The algebraic sum of the voltage *around any closed path is zero.*

Current is related to the charge flowing through a circuit element, whereas voltage is a measure of potential energy difference across the element.[4] There is a single unique value for voltage in circuit theory. Thus the energy required to move a unit charge from point A to point B in a circuit must have a value that is independent of the path taken from A to B.

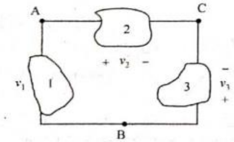


Fig. 1-A-3 The potential difference between point A and B is independent of the path select.

In Fig. 1-A-3, if we carry a charge of 1 C from A to B through element 1, the reference polarity signs for v_1 show that we do v_1 joules of work. Now if, instead, we choose to proceed from A to B via node C, then we expend v_2−v_3 joules of energy. The work done, however, is independent of the path in a circuit, and these values must be equal. Any route must lead to the same value for the voltage. Thus,

$$v_1 = v_2 - v_3 \qquad (1\text{-A-}4)$$

It follows that if we trace out a closed path, the algebraic sum of the voltages across the individual elements around it must be zero. Thus, we may write

$$\sum_{n=1}^{N} v_n = 0 \qquad (1\text{-A-}5)$$

We may apply KVL to a circuit in several different ways. One method that leads to fewer equation-writing errors than others consists of moving mentally around the closed path in a

流入三根管子中的每一根。如果我们坚持水总是流动的，那么很明显我们不能有三个正的水流，否则管道会破裂。这是我们定义的独立于水流方向的水流的结果。因此，定义的onc或两个currenis的值必须是当前的

考虑fi1 - a -2中的节点。的进入节点的四个电流的代数和必须是零。

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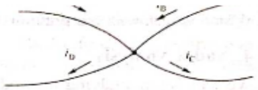


显然，该定律同样适用于图1-A-2示例《基尔霍夫库尔特法》的颁布。

1
o
d 基尔霍夫定律的一个简洁表达式是

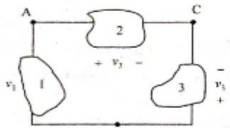
(l)+ (-ig)+ic + =0 (1-A-2)

2 = （
no

3.基尔霍夫电压定律

现在我们转到基尔霍夫电压定律(缩写为KVL)。这项法律规定任何闭合路径周围电压的代数和为零

电流与流经电路元件的电荷有关，而电压则是测量元件之间的位能差。[]在电路理论中，电压只有一个唯一的值。因此，将一个单位电荷从a点移动到B点所需要的能量，必须与从a点到B点的路径无关



在图1-A-3。如果电荷是1c从A到B，通过元素1，引用极性符号表示我们做了多少次工作。现在，如果我们选择从A通过节点C到B，然后消耗vz-vs焦耳能量。然而，所做的功是独立的，这些值必须是图1-A-3，点与点之间的可能的差值，每条Anv路由必须导致相同的值

B与路径选择无关。的电压。 “因此。

y，\w，-ri (1-A-4

因此，如果我们追踪一条闭合路径，它周围各个元件上的电压之和必然为零。因此，我们可以这样写

$\sum$ = 0，（

我们可以用几种不同的方法将KVL应用于电路。一种比其他方法更能减少等式书写错误的方法是在a中的封闭路径上进行思想上的移动

clockwise direction and writing down directly the voltage of each element whose (+) terminal is entered, and writing down the negative of every voltage first met at the (−) sign. Applying this to the single loop of Fig. 1-A-3, we have

$$-v_1 + v_2 - v_3 = 0 \qquad (1\text{-A-}6)$$

Which agrees with our previous result, Eq. (1-A-4).

4. Nodal Analysis

We will begin studying methods of simplifying circuit analysis by considering a powerful general method, that of nodal analysis.

In the previous chapter we considered the analysis of a simple circuit containing only two nodes. We will now let the number of nodes increase, and corresponding provide one additional unknown quantity and one additional equation for each added node. Thus, a three-node circuit should have two unknown voltages and two equations; an N-node circuit will need $(N-1)$ voltages and $(N-1)$ equations.

We consider the mechanics of node analysis in this section. As an example, let us consider the three-node circuit shown in Fig. 1-A-4(a).

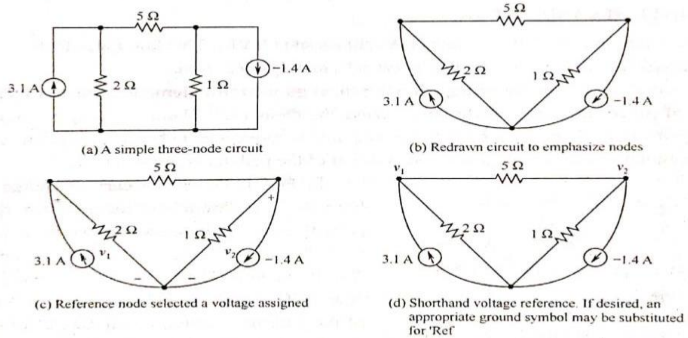


Fig. 1-A-4 The mechanics of node analysis.

As a first step, we redraw the circuit as in Figure1-A-4(b) to emphasize the fact that there are only three nodes. We now associate a voltage with each node, but we must remember that a voltage has to be defined as existing between two nodes in a network. We thus select one node as a reference node and then define a voltage between each remaining node and the reference node. Hence, we note again that there will be only $(N-1)$ voltage defined in an N-node circuit.

A little simplification in the resultant equations is obtained if the node connected to the greatest number of branches is identified as the reference node. **If there is a ground node, it is usually most convenient to select it as the reference node; more often than not, the ground**

按顺时针方向，并直接记下每个(+)端子的电压，并写下在(-)符号处第一次遇到的每个伏特的电流。将此应用于Fip. 1-A-3的单回路。我们也还

-V, + v.-V= 0 (1-A-6)

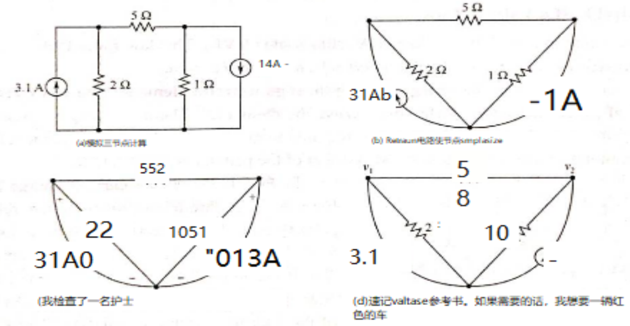
这与我们之前的结果Ea. (1-A-4)一致。

4. 节点分析

我们将通过考虑一个强大的通用方法，即节点分析，来开始研究简化电路分析的方法。

在前面的讨论中，我们考虑了只包含两个节点的简单电路的分析。我们现在让节点的数目增加，相应的为每个增加的节点提供一个额外的未知量和一个额外的方程。因此，一个三节点电路应该有两个未知电压和两个方程式:一个n节点电路将需要(N-1)电压和(N-1)方程式

我们将在本节中讨论节点分析的机制。作为一个例子。让我们考虑图1-A-4(a)所示的三节点电路。



作为第一步，我们在fieurela -4(b)中重新绘制电路，以强调只有三个节点的事实。我们现在为每个节点规定一个电压，但我们必须记住，一个电压必须定义为网络中两个节点之间的电压。因此，我们选择一个节点作为参考节点，然后在每个剩余节点和参考节点之间定义一个电压。

因此，我们再次注意到，只有(N-1)电压定义在一个n节点电路

如果将连接到最大分支节点的节点确定为参考节点，则得到的结果方程得到了一些简化。如果有一个地面节点，通常选择它作为参考节点是最方便的:通常是pround

node appears as a common lead across the bottom of a circuit diagram.[5] For this example, we choose node 3 as the reference node.

The voltage of node 1 relative to the reference node as v_1, and v_2 is defined as the voltage of node 2 with respect to the reference node. These two voltages are sufficient, as the voltage between any other pair of nodes may be found in terms of them. For example, the voltage of node 1 with respect to node 2 is (v_1-v_2). The voltage v_1 and v_2 their reference signs are shown in Fig. 1-A-4(c). It is common practice once a reference node has been labeled to omit the reference signs for the sake of clarity; the node labeled with the voltage is taken to be the positive terminal (Fig. 1-A-4(d)). This is understood to be a type of shorthand voltage notation. We now apply KCL to nodes 1 and 2. We do this by equating the total current leaving the node through the several resistors to the total source current entering the node. Thus,

$$\frac{v_1}{2}+\frac{v_1-v_2}{5}=3.1 \tag{1-A-7}$$

or

$$0.7v_1-0.2v_2=3.1 \tag{1-A-8}$$

At node 2 we obtain

$$\frac{v_2}{1}+\frac{v_2-v_1}{5}=-(-1.4)a \tag{1-A-9}$$

or

$$-0.2v_1+1.2v_2=1.4 \tag{1-A-10}$$

Eqs (1-A-8) and (1-A-10) are the desired two equations in two unknowns, and they may be solved easily. The results are $v_1=5$ V and $v_2=2$ V.

From this, it is straight forward to determine the voltage across the 5-Ω resistor: $v_{5\Omega}=v_1-v_2=3$ V. The currents and absorbed powers may also be computed in one step.

New Words

investigate [in'vestigeit] *v.* 调查，研究
assemble [ə'sembəl] *v.* 集合，聚集，装配
resistance [ri'zistəns] *n.* 电阻，阻力
significant [sig'nifikənt] *adj.* 重要的，相当数量的，有意义的
node [nəud] *n.* 节点，结节
portion ['pɔ:ʃən] *n.* 部分，份，命运；*v.* 将……分配，分配
term [tə:m] *n.* 术语，名词，学期，期限；*v.* 称，呼
branch [brɑ:ntʃ] *n.* 分支，支线；支路
axiomatic *adj.* 公理的；格言的，自明的
algebraic [ældʒi'breiik] *adj.* 代数的；算术运算中的数目有限的
accumulate [ə'kju:mjuleit] *v.* 积聚，堆积
hydraulic [hai'drɔ:lik] *adj.* 水力的，水压的
analogy [ə'nælədʒi] *n.* 相似，类似
polarity [pəu'læriti] *n.* 有两极，磁性引力，极性；两极分化，极端性
joule [dʒu:l] *n.* 〈物〉焦耳（米千克秒制中热量、能量和功的单位）

节点作为公共引线出现在电路图上。在本例中，我们选择节点3作为rcference节点

节点I相对于参考节点的电压为v' ，vz定义为节点2相对于参考节点的电压。这两个电压是足够的，因为任何其他对节点之间的电压可以用它们来表示。例如，电压或节点I相对于节点2为()。电压vy和vz的参考符号如图1-A-4(c)所示。通常的做法是，一旦一个refcrence节点被选中，为了清晰起见，省略参考符号:标记有电压的节点被认为是正端子(图1-A-4(d))。这是理解为一种速记电压符号。现在我们把KCL应用到节点I和节点2上。我们这样做，通过几个电阻的总电流离开节点的总电源电流进入节点。因此

4-31 (

'n

0.7 - 0.2 - y = (

在节点2处，
我们得到

乌- 4 - 1)a (

'n

-0.2 y, y = 1.4 + 1.2 (

Egs (1-A-8)和(1-A-10)是两个未知数中的两个方程，它们很容易求解。结果是vn- 5v和- 2v。

从这，它是直接确定电压通过5-2电阻。
"3 o =电流-电压= 3 v。电流和吸收功率也可以一步计算出来。

新单词

The investigate (in 'vestigeil] v.
Assemble the I 'semball v. collection,
To hold (ristons] n. Resistance,
Significan Ssignifikont] aub. Importantly, a significant number of,
[noudj n. node, the node
Portion [' posfan] n.,, fate, v., matchs outside will be allocated
Term (t: m] n, terminology, noun, semester, deadline: v.
Branch/bra: nt/n. outside, feeder; branch
Axiomatic adi. Axiom: maxim.
Algebraic (eldsibreik) AD. Algebra; Limited number of arithmetic operations in the accumulate [akju: njuleig)
Hiydraulic [haidr: lik) adj. Hydraulic and
Analogy [o 'naeladsil n
Polariy [parlariti) m. poles, magnetic attraction, polarity: polarization, extreme joule [d3a: 1 n. (" joule (MKS system

mentally ['mentli]　*adv.* 精神上，在内心，智力上
nodal ['nəudl]　*adj.* 节点的，节的
corresponding [ˌkɔris'pɔndiŋ]　*adj.* 符合的，一致的，相同的，相应的，相当的
mechanics [mi'kæniks]　*n.* 结构，构成法，技巧，机械学，力学
equation [i'kwei ʃən]　*n.*（数）方程式，等式
convenient [kən'vi:njənt]　*adj.* 方便的，便利的
sufficient [sə'fiʃənt]　*adj.* 足够的，充分的

Phrases

circuit analysis　电路分析
lumped-parameter　集总参数
apply … to …　将应用于……
consist of …　由……组成
lead to　导致，引起，通向
compact expression　简介表达式
be related to　与……相关
associate … with …　把……与……联系起来
be identified as　被定义为
in terms of　依据，按照，在……方面，以……措辞
for the sake of　为了，为了……的利益

Abbreviations

KVL (Kirchhoff's Voltage Law)　基尔霍夫电压定律
KCL (Kirchhoff's Current Law)　基尔霍夫电流定律

Notes

1. Since the network then appears as a number of simple elements and a set of connecting leads, it is called a lumped-parameter network.
由于接下来的网络是以一系列简单的元件和连线出现的，因此被称为集总参数网络。

2. We must necessarily consider all of the perfectly conducting leads or portions of leads attached to the node as part of the node.
我们必须把连线本身或者与元件相连的连线部分作为该节点的一部分。

3. A node is not a circuit element, and it certainly cannot store, destroy, or generate charge.
节点不是电路元件，显然不能存储、消灭或产生电荷。

4. Current is related to the charge flowing through a circuit element, whereas voltage is a measure of potential energy difference across the element.
电流与电路元件中的电荷有关，而电压是元件两端电势能量的度量。

5. If there is a ground node, it is usually most convenient to select it as the reference node; more often than not, the ground node appears as a common lead across the bottom of a circuit diagram.
如果电路中包含接地节点，通常将该节点选择为参考节点，但是很多人喜欢将电路最下端的节点作为参考节点。

Mentally [mentlil AD: mentally, in the heart, 1 of
Nodal I oudl adi nodes.
Coriesponding [karispandin] adj. Meet., for the same, the corresponding, considerable mechanics [mikeniks] n. structure, method, skill, mechanics, mechanics equation [ikwei. Jan] n, the number of) equations, the equation
Work [kan 'vinjant] adj. Convenient, convenient
Sulficent fs. 'fifont adi enough, enough

短语
Circuit analysis
lumped circuit analysis

Consist of. Bv
Lead to lead to,
Compact expression
Be related to. Related
The associate with.. connect
Be identified as was
In terms of the basis, in accordance with, in aspect, in the phrase for the sake of in order to,

缩写
KVI. (Kirchhoff 's Voltage Law) Kirchhoff's Voltage Law KCL (KirchhofT' s Current Law)

笔记 i
由于网络是由许多简单的元件和一组连接导线构成的，所以称为lunped-parameter网络

By the hand the next network has emerged as a series of simple components
2. 我们必须把连接到节点上的所有完全导通的引线或引线的一部分作为节点的一部分来考虑

We must get the attachment itself or connected with yuan f
3.节点不是电路元件，它当然不能存储、破坏或产生电荷
Node is not a circuit element,
4. Cutrent与流经电路元件的电荷有关，而电压则是整个电路中电位能差的量度。

I flow associated with the charge circuit
5. 如果有一个地面节点，通常选择它作为参考节点是最方便的;更常见的情况是，接地节点作为一个普通的导线出现在电路图的底部
If the circuit grounding nodes, usually will choose for the reference node, the node but a
点作为 The reference node