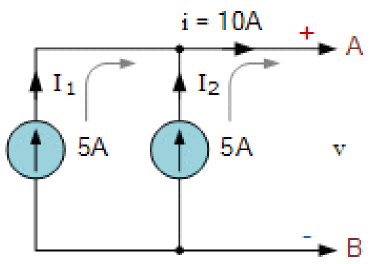


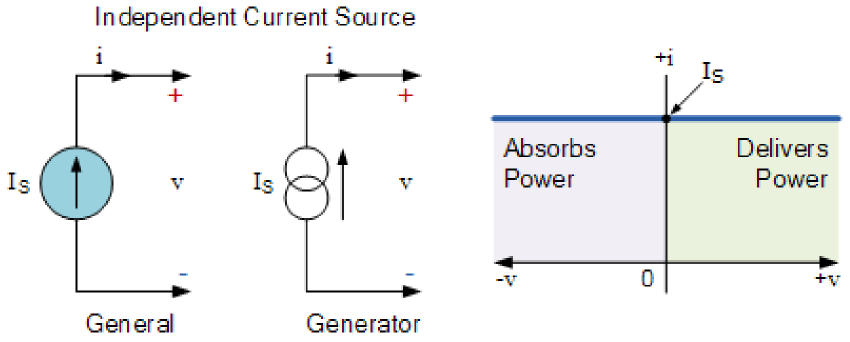
Current Sources

A **Current Source** is an active circuit element that is capable of supplying a constant current flow to a circuit regardless of the voltage developed across its terminals

As its name implies, a *current source* is a circuit element that maintains a constant current flow regardless of the voltage developed across its terminals as this voltage is determined by other circuit elements. That is, an ideal constant current source continually provides a specified amount of current regardless of the impedance that it is driving and as such, an ideal current source could, in theory, supply an infinite amount of energy. So just as a voltage source may be rated, for example, as 5 volts or 10 volts, etc, a current source will also have a current rating, for example, 3 amperes or 15 amperes, etc.

Ideal constant current sources are represented in a similar manner to voltage sources, but this time the current source symbol is that of a circle with an arrow inside to indicates the direction of the flow of the current. The direction of the current will correspond to the polarity of the corresponding voltage, flowing out from the positive terminal. The letter "i" is used to indicate that it is a current source as shown.

Ideal Current Source



Then an ideal current source is called a "constant current source" as it provides a constant steady state current independent of the load connected to it producing an I-V characteristic represented by a straight line. As with voltage sources, the current source can be either independent (ideal) or dependent (controlled) by a voltage or current elsewhere in the circuit, which itself can be constant or time-varying.

Ideal independent current sources are typically used to solve circuit theorems and for circuit analysis techniques for circuits that containing real active elements. The simplest form of a current source is a resistor in series with a voltage source creating currents ranging from a few milli-amperes to many hundreds of amperes. Remember that a zero-value current source is an open circuit as R = 0.

The concept of a current source is that of a two-terminal element that allows the flow of current indicated by the direction of the arrow. Then a current source has a value, i, in units of amperes, (A) which are typically abbreviated to amps. The physical relationship between a current source and voltage variables around a network is given by Ohm's law as these voltage and current variables will have specified values.

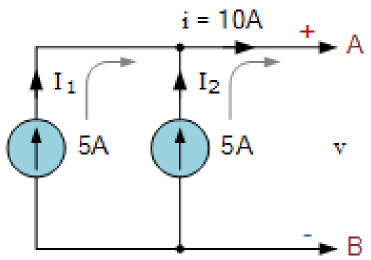
It may be difficult to specify the magnitude and polarity of voltage of an ideal current source as a function of the current especially if there are other voltage or current sources in the connected circuit. Then we may know the current supplied by the current source but not the voltage across it unless the power supplied by the current source is given, as P = V*I.

However, if the current source is the only source within the circuit, then the polarity of voltage across the source will be easier to establish. If however there is more than one source, then the terminal voltage will be dependent upon the network in which the source is connected.

Connecting Current Sources Together

Just like voltage sources, ideal current sources can also be connected together to increase (or decrease) the available current. But there are rules on how two or more independent current sources with different values can be connected, either in series or parallel.

Current Source in Parallel

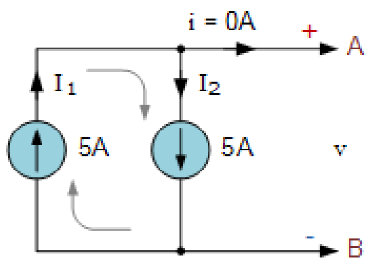


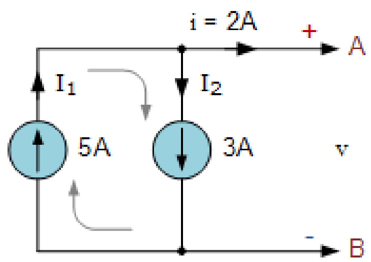
Connecting two or more current sources in parallel is equivalent to one current source whose total current output is given as the algebraic addition of the individual source currents. Here in this example, two 5 amp current sources are combined to produce 10 amps as $I_T = I_1 + I_2$.

Current sources of different values may be connected together in parallel. For example, one of 5 amps and one of 3 amps would combined to give a single current source of 8 amperes as the arrows representing the current source both point in the same direction. Then as the two currents add together, their connection is said to be: parallel-aiding.

While not best practice for circuit analysis, parallel-opposing connections use current sources that are connected in opposite directions to form a single current source whose value is the algebraic subtraction of the individual sources.

Parallel Opposing Current Sources

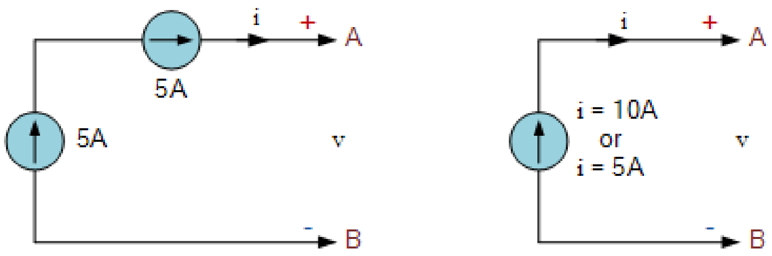




Here, as the two current sources are connected in opposite directions (indicated by their arrows), the two currents subtract from each other as the two provide a closed-loop path for a circulating current complying with Kirchoff's Current Law, KCL. So for example, two current sources of 5 amps each would result in zero output as 5A -5A = 0A. Likewise, if the two currents are of different values, 5A and 3A, then the output will be the subtracted value with the smaller current subtracted from the larger current. Resulting in a I_T of 5 - 3 = 2A.

We have seen that ideal current sources can be connected together in parallel to form parallel-aiding or parallel-opposing current sources. What is not allowed or is not best practice for circuit analysis, is connecting together ideal current sources in series combinations.

Current Sources in Series

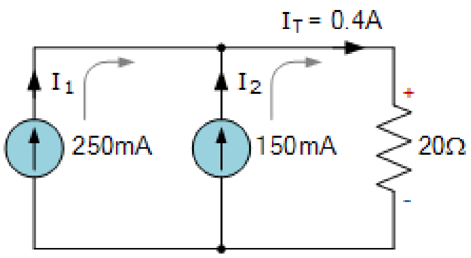


Current sources are not allowed to be connected together in series, either of the same value or ones with different values. Here in this example, two current sources of 5 amps each are connected together in series, but what is the resulting current value. Is it equal to one source of 5 amps, or is it equal to the addition of the two sources, that is 10 amps. Then series connected current sources add an unknown factor into circuit analysis, which is not good.

Also, another reason why series connected sources are not allowed for circuit analysis techniques is that they may not supply the same current in the same direction. Series-aiding or series-opposing currents do not exist for ideal current sources.

Current Source Example No1

Two current sources of 250 milli-amps and 150 milli-amps respectively are connected together in a parallel-aiding configuration to supply a connected load of 20 ohms. Calculate the voltage drop across the load and the power dissipated. Draw the circuit.



$I_T = I_1 + I_2 = 0.25 + 0.15 = 0.4A$

$V_R = I_T \times R = 0.4 \times 20 = 8V$

$P_R = I_T^2 \times R = 0.4^2 \times 20 = 3.2W$

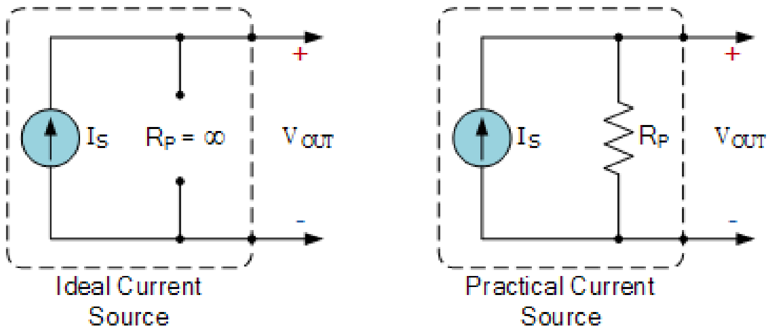
Then, I_T = 0.4A or 400mA, V_R = 8V, and P_R = 3.2W

Practical Current Source

We have seen that an ideal constant current source can supply the same amount of current indefinitely regardless of the voltage across its terminals, thus making it an independent source. This therefore implies that the current source has an infinite internal resistance, (R = ∞). This idea works well for circuit analysis techniques, but in the real world current sources behave a little differently as practical current sources always have an internal resistance, no matter how large (usually in the mega-ohms range), causing the generated source to vary somewhat with the load.

A practical or non-ideal current source can be represented as an ideal source with an internal resistance connected across it. The internal resistance (R_P) produces the same effect as a resistance connected in parallel (shunt) with the current source as shown. Remember that circuit elements in parallel have exactly the same voltage drop across them.

Ideal and Practical Current Source



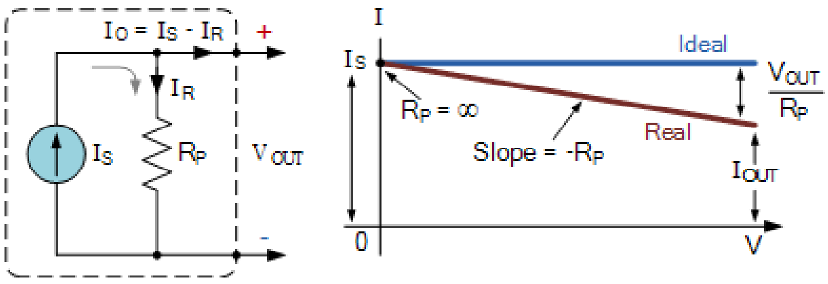
You may have noticed that a practical current source closely resembles that of a Norton's equivalent circuit as Norton's theorem states that "any linear dc network can be replaced by an equivalent circuit consisting of a constant-current source, I_S in parallel with a resistor, R_P". Note that if this parallel resistance is very low, $R_P = 0$, the current source is short-circuited. When the parallel resistance is very high or infinite, $R_P \approx \infty$, the current source can be modelled as ideal.

An ideal current source plots a horizontal line on the I-V characteristic as shown previously above. However as practical current sources have an internal source resistance, this takes some of the current so the characteristic of this practical source is not flat and horizontal but will reduce as the current is now splitting into two parts, with one part of the current flowing into the parallel resistance, R_P and the other part of the current flowing straight to the output terminals.

Ohms law tells us that when a current, (i) flows through a resistance, (R) a voltage drop is produce across the same resistance. The value of this voltage drop will be given as $i*R_P$. Then V_{OUT} will be equal to the voltage drop across the resistor with no load attached. We remember that for an ideal source current, R_P is infinite as there is no internal resistance, therefore the terminal voltage will be zero as there is no voltage drop.

The sum of the current around the loop given by Kirchoff's current law, KCL is: $I_{OUT} = I_S - V_S/R_P$. This equation can be plotted to give the I-V characteristics of the output current. It is given as a straight line with a slope $-R_P$ which intersects the vertical voltage axis at the same point as $I_S$when the source is ideal as shown.

Practical Current Source Characteristics

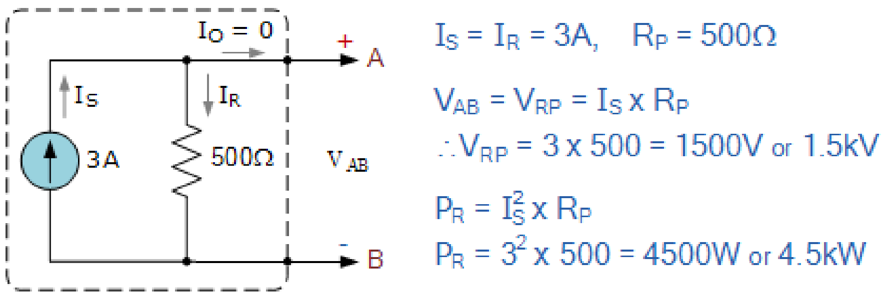


Therefore, all ideal current sources will have a straight line I-V characteristic but non-ideal or real practical current sources will have an I-V characteristic that is slightly angled down by an amount equal to V_{OUT}/R_P where R_P is the internal source resistance.

Current Source Example No2

A practical current source consists of a 3A ideal current source which has an internal resistance of 500 Ohms. With no-load attached, calculate the current sources open-circuit terminal voltage and the no-load power absorbed by the internal resistor.

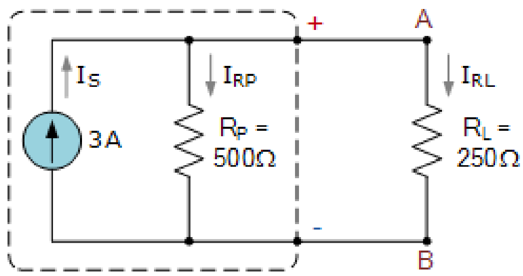
1. No-load values:



Then the open circuit voltage across the internal source resistance and terminals A and B (V_{AB}) is calculated at 1500 volts.

Part 2: If a 250 Ohm load resistor is connected to the terminals of the same practical current source, calculate the current through each resistance, the power absorbed by each resistance and the voltage drop across the load resistor. Draw the circuit.

2. Data given with load connected: I_S = 3A, R_P = 500Ω and R_L = 250Ω



2a. To find the currents in each resistive branch, we can use the current-division rule.

$$I_{RP} = \frac{R_L}{R_P + R_L} \times I_S = \frac{250}{500 + 250} \times 3 = 1A$$

$$I_{RL} = \frac{R_P}{R_L + R_P} \times I_S = \frac{500}{250 + 500} \times 3 = 2A$$

$$\therefore I_{RP} + I_{RL} = 1 + 2 = 3A = I_S$$

2b. The power absorbed by each resistor is given as:

$$P_{RP} = I_{RP}^2 \times R_P = 1^2 \times 500 = 500W$$

$$P_{RL} = I_{RL}^2 \times R_L = 2^2 \times 250 = 1000W$$

2c. Then the voltage drop across the load resistor, R_L is given as:

$$V_{AB} = I_S \times R_T$$

$$R_T = \frac{R_P \times R_L}{R_P + R_L} = \frac{500 \times 250}{500 + 250} = 166.7\Omega$$

$$\therefore V_{AB} = 3 \times 166.7 = 500V$$

We can see that the terminal voltage of an open-circuited practical current source can be very high it will produce whatever voltage is needed, 1500 volts in this example, to supply the specified current. In theory, this terminal voltage can be infinite as the source attempts to deliver the rated current.

Connecting a load across its terminals will reduce the voltage, 500 volts in this example, as now the current has somewhere to go and for a constant current source, the terminal voltage is directly proportional to the load resistance.

In the case of non-ideal current sources that each have an internal resistance, the total internal resistance (or impedance) will be the result of combining them together in parallel, exactly the same as for resistors in parallel.

Dependent Current Source

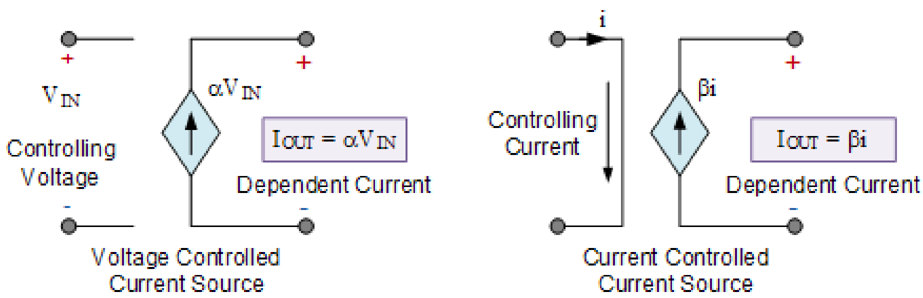
We now know that an ideal current source provides a specified amount of current completely independent of the voltage across it and as such will produce whatever voltage is necessary to maintain the required current. This then makes it completely independent of the circuit to which it is connected to resulting in it being called an *ideal independent current source*.

A controlled or dependent current source on the other hand changes its available current depending upon the voltage across, or the current through, some other element connected to the circuit. In other words, the output of a dependent current source is controlled by another voltage or current.

Dependent current sources behave similar to the current sources we have looked at so far, both ideal (independent) and practical. The difference this time is that a dependent current source can be controlled by an input voltage or current. A current source that depends on a voltage input is generally referred to as a **Voltage Controlled Current Source** or **VCCS**. A current source that depends on a current input is generally referred too as a **Current Controlled Current Source** or **CCCS**.

Generally, an ideal current dependent source, either voltage or current controlled is designated by a diamond-shaped symbol where an arrow indicates the direction of the current, i as shown.

Dependent Current Source Symbols



An ideal dependent voltage-controlled current source, VCCS, maintains an output current, I_{OUT}that is proportional to the controlling input voltage, V_{IN}. In other words, the output current "depends" on the value of input voltage making it a dependent current source.

Then the VCCS output current is defined by the following equation: $I_{OUT} = \alpha V_{IN}$. This multiplying constant *α* (alpha) has the SI units of mhos, ℧ (an inverted Ohms sign) because $\alpha = I_{OUT}/V_{IN}$, and its units will therefore be amperes/volt.

An ideal dependent current-controlled current source, CCCS, maintains an output current that is proportional to a controlling input current. Then the output current "depends" on the value of the input current, again making it a dependent current source.

As a controlling current, I_{IN} determines the magnitude of the output current, I_{OUT} times the magnification constant β (beta), the output current for a CCCS element is determined by the following equation: $I_{OUT} = \beta I_{IN}$. Note that the multiplying constant *β* is a dimensionless scaling factor as $\beta = I_{OUT}/I_{IN}$, so therefore its units would be amperes/amperes.

Current Source Summary

We have seen in this tutorial about **Current Sources**, that an ideal current source, (R = ∞) is an active element that provides a constant current which is totally independent of the voltage across it as a result of the load connected to it producing an I-V characteristic represented by a straight line.

Ideal independent current sources can be connected together in parallel for circuit analysis techniques as either parallel-aiding or parallel-opposing configurations, but they can not be connected together in series. Also for solving circuit analysis and theorems, current sources become open-circuited sources to make their current equal to zero. Note also that current sources are capable of either delivering or absorbing power.

In the case of non-ideal or practical current sources, they can be modelled as an equivalent ideal current source and an internal parallel (shunt) connected resistance which is not infinite but of a value that is very high as $R \approx \infty$ producing an I-V characteristic which is not straight but slopes down as the load decreases.

We have also seen here that current sources can be dependent or independent. A dependent source is one whose value depends on some other circuit variable. Voltage-controlled current source, VCCS, and current-controlled current source, CCCS, are types of dependent current sources.

Constant current sources with very high internal resistances find numerous applications in electronic circuits and analysis and can be built using bipolar transistors, diodes, zeners and FETs as well as a combination of these solid-state devices.