Lecture 6 – Thevenin Theorem

Dr. Aftab M. Hussain,

Associate Professor, PATRIoT Lab, CVEST

The Thevenin Theorem

- Named after Léon Charles Thévenin, a French engineer working in telegraphy who published the theorem in 1883
- The theorem, at that time, was an interesting new way of simplifying electronic circuits
- A note with English translation of the full text, was published as: ["On a New Theorem in Dynamic Electricity"](), *The Telegraphic Journal and Electrical Review.* ***XIV*** *(819). London: H. Alabaster, Gatehouse & Co.: 11 5 January 1884*
- One source states that the theorem was "originally enunciated by Helmholtz and should more correctly be called Helmholtz's theorem."

"Extension de la loi d’Ohm aux circuits électromoteurs complexes" [Extension of Ohm’s law to complex electromotive circuits], *Annales Télégraphiques* (Troisieme série), vol. 10, pages 222–224.

there used. If one of the 850 windows or 230 doors is opened, a bell rings, and an electric annunciator shows to an attendant at the main office which window or door it is. This system is soon to be applied to every case of specimens.
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This rule, which hitherto does not seem to have been pointed out, is very useful in certain theoretical calculations. Practically, it enables us to ascertain immediately, by means of two data easily obtained by experiment, the intensity of the current which will traverse a branch to be joined on to any network of conductors, without it being necessary to enter otherwise into the constitution of this net.

To demonstrate the theorem, let us suppose that we introduce into the conductor, A, B, A′, an electromotive force, − E, equal and opposite to the difference of potential, V − V′. It is clear that no current will traverse the conductor, A, B, A′. Thus the system of electromotive forces, − E, E_1, E_2 . . . . . . E_n, gives rise to a distribution of currents among which that traversing the conductor, A, B, A′, is null.

Suppose now, we introduce into this same conductor, conjointly with the former, a second electro-

motive force, + E, equal to the difference of potential, V − V′, and in the same direction. In virtue of the principle of the independence of simultaneous electromotive forces, the force, + E, gives rise to a new
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Bull's Power Company, Limited.—The Registered Office of this company is removed to 1, Hackins Hey, Liverpool.

Eastern Electric Light and Power Company, Limited.—The annual return of this company, made up to the 14th ult., was filed on the 31st ult. The nominal capital is £250,000, in 50,000 shares of £5 each. 29,900 shares have been taken up and the full amount has been called thereon. The calls paid (including £400 received on forfeited shares) amount to £148,820 10s.; the calls unpaid (including £100 unpaid on forfeited shares) amount to £1,179 10s. The paid up capital of the company is £25,775 10s. in excess of the amount recorded in last year's return. Registered Office 19, Great Winchester Street.

The Theorem

- *Given a system of connected linear conductors, including the electromotive forces El, E2, … En randomly distributed, consider two points A and A' belonging to the system and having potentials V and V".*
- *If points A and A' are joined by a wire ABA' of resistance* ***r*** *containing no electromotive force, the potentials of points A and A' are changed from V and V', but the current* ***i*** *which flows in the wire is given by the formula:*

$$i = \frac{V - V'}{r + R}$$

- *Where* ***R*** *is the resistance of the original system, measured between the points A and A' considered the electrodes.*

- In modern parlance, we call $V - V' = V_{oc}$ and $R = R_{th}$

The Theorem

- *Thus Ohm's formula is applicable not only to simple circuits containing sources with well-defined poles such as a battery or generator, but also to any network of conductors, which can then be considered as generators with arbitrary poles, and having an electromotive force, in each case, equal to the difference of potential previously existing at the two points chosen as poles.*
- *This rule, which doesn't seem to have previously appeared in the journal, is very useful in certain theoretical calculations. From a practical point of view, it permits immediate calculation, given two values which are easily determined experimentally, the value of current which will flow through a branch added to a network of conductors, without the necessity of dealing with the internal components of the network.*

The Proof

- *To demonstrate the theorem, suppose one introduces in the wire ABA' an electromotive force -E, equal and opposite to the potential difference V- V'. No current will flow in conductor ABA'. Therefore, the system of electromotive forces -E, El, E2,…, En, causes a distribution of currents, among which the one in conductor ABA' is zero.*
- *Suppose now that, in the same conductor, one introduces, joined to the first, a second electromotive force +E, equal to the potential difference V- V', and of the same polarity. The force +E causes a new current distribution, which is simply superimposed on the previous one. Among these new currents, that which flows in conductor ABA' is precisely the current **i**, since the effects of the forces +E and -E, equal and opposite, cancel one another. The current i being due only to the force +E= V- V', in the branch **r**, one is able, by calling **R** a certain resistance, to write, that according to Ohm's formula,*

$$i = \frac{V - V'}{r + R}$$

The Proof

- *Moreover, the significance of the quantity* $\mathcal{R}$ *is immediately apparent; it is the resistance of a wire which may replace the original network of conductors between A and A', so that the proper output of a constant source of electric current in branch* $\boldsymbol{r}$ *is not changed. The quantity* $\mathcal{R}$ *now has a precise physical meaning, and it can be called the resistance of the original network measured between the points A and A' considered as electrodes. The statement of the theorem follows immediately from this definition.*

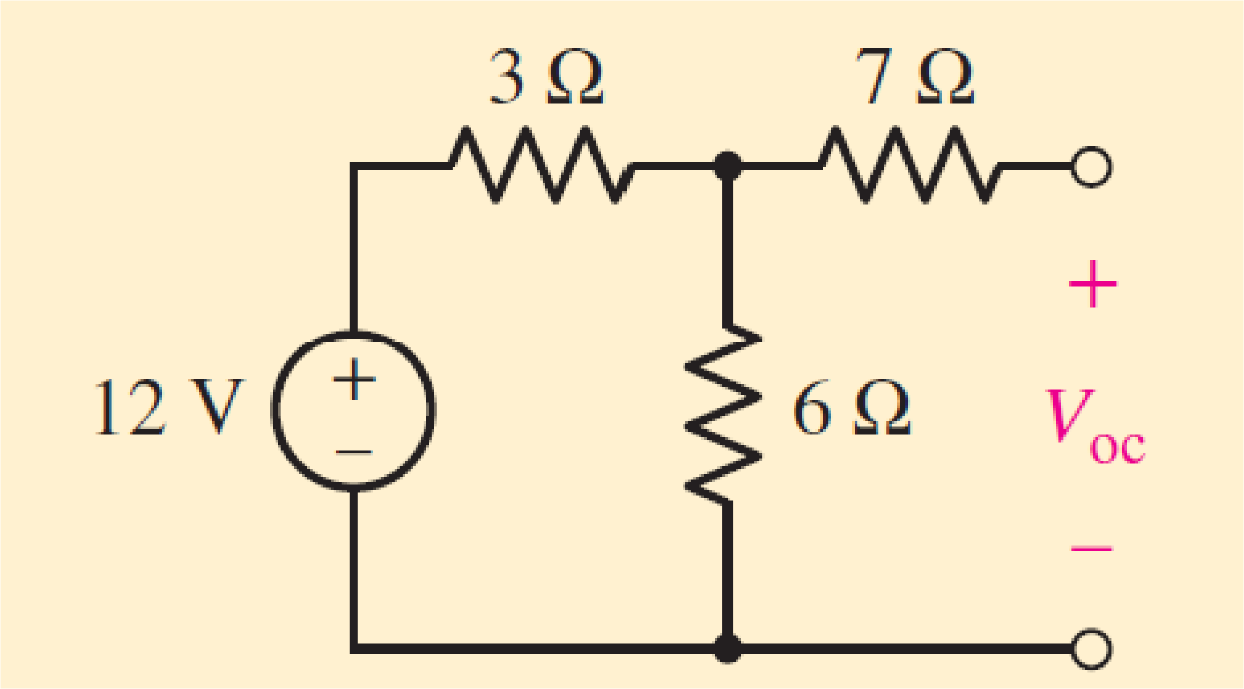
- This theorem, only 1 page long, is one of the most important in electronics history.
- Unfortunately, did not receive the level of attention it deserved, neither did Thevenin

The Algorithm

1. Determine the circuit to be converted and identify its two terminals
2. Keep the terminals open circuit and calculate the voltage across it (call it V_{oc})
3. Make the circuit inactive by replacing the sources in the circuit:
    1. Short circuit for a voltage source
    2. Open circuit for a current source
4. Calculate the resistance across the terminal for this configuration (call it R_{th})
5. Connect V_{oc} and R_{th} in series with the two terminals. This is the equivalent circuit for the circuit under consideration

- Note: We can also short the terminals and calculate the current through it (call it I_{sc}). It will be seen that $V_{oc} = R_{th} I_{sc}$

Examples



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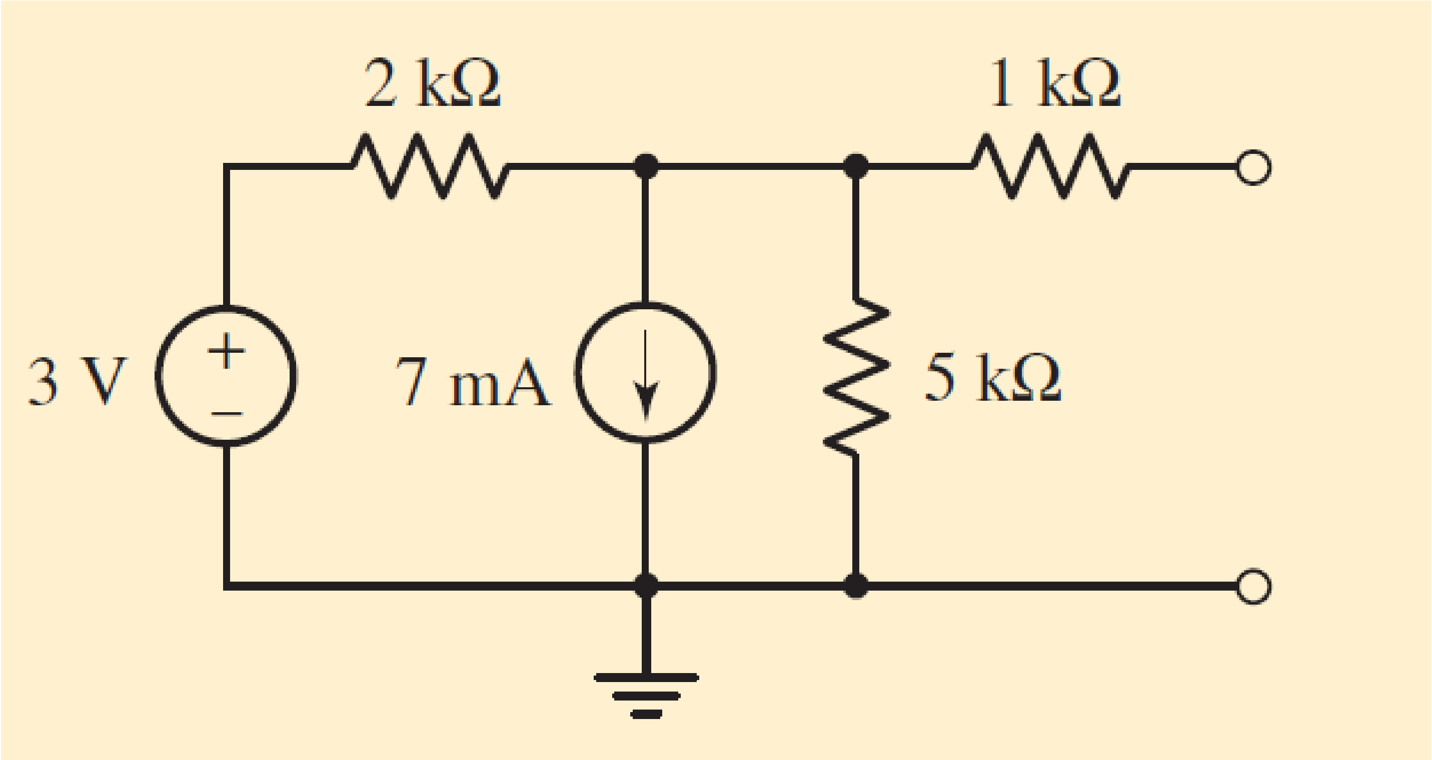
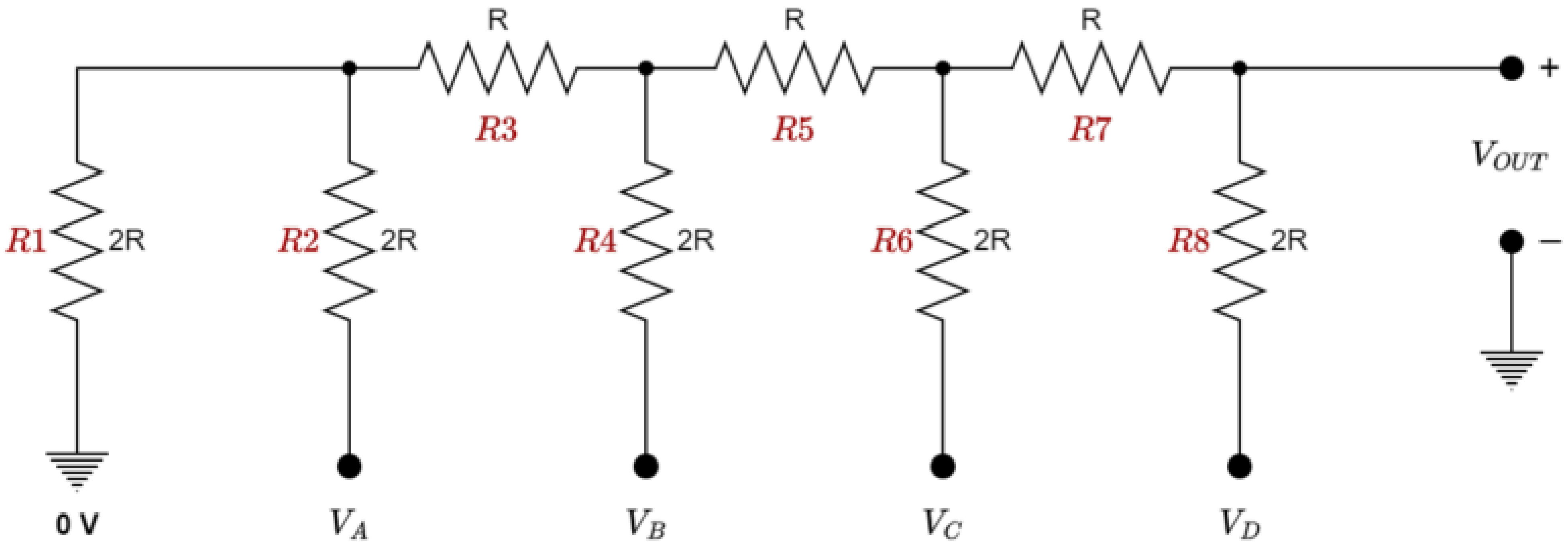


V = -7.857 V; R = 2.429 kOhm

Examples



This is the famous R-2R ladder. More about this in CCIoT course, UG2!