The genesis of the Wheatstone bridge

by Stig Ekelöf

In the paper in the Philosophical Transactions of the Royal Society *in which Wheatstone described the DC bridge that now bears his name, he attributes the idea of the bridge to S. H. Christie. French and German translations published the following year and possibly prepared from a preprint of the paper do not carry this attribution and this may explain why the bridge does not bear Christie's name.*

Wheatstone

The Royal Society's Bakerian Lecture for 1843 was given by Charles Wheatstone. Its title was: 'An account of several new instruments and processes for determining the constants of a voltaic circuit'[1]. The paper was published the same year in the *Philosophical Transactions*. It is a beautiful paper—clear, easy to read, nearly modern in form. To a great deal this is due to the fact that Wheatstone was one of the first scientists to understand and make practical use of Ohm's law, at that time already seventeen years old[2]. He mastered the circuit concept and the ideas of voltage, current and resistance.

The paper is a foundation stone of DC measurements. Towards its end (pp.323–325) Wheatstone describes his 'differential resistance measurer', which we call today a DC Wheatstone bridge. Wheatstone used a balanced bridge with the ratio 1:1. Indirectly one can see from his text that he was fully aware of one great advantage of his null method—it is independent of variations in the current source.

On page 325 Wheatstone has an interesting note. In it he says:

> 'Mr. CHRISTIE, in his "Experimental determination of the laws of magnetoelectric induction" printed in the *Philosophical Transactions* for 1833, has described a differential arrangement of which the principle is the same as that on which the instruments described in this section have been devised. To Mr. CHRISTIE must, therefore, be attributed the first idea of this useful and accurate method of measuring resistances.'

Christie*

An account of Wheatstone's paper was given by H. J. J. Winter in the *Philosophical Magazine* for 1943[3]. About Christie's paper very little seems to have been written. It is the printed version of his Bakerian lecture for 1833 and its complete title is: 'Experimental determination of the laws of magneto-electric induction in different masses of the same metal, and of its intensity in different metals'[4]. It is a long paper, nearly 50 pages, and—let it be said at once—it is somewhat tedious and not easy to read. One cause is obvious: Christie did not know Ohm's law, and he had very confused ideas about voltage, current, resistance and circuits.

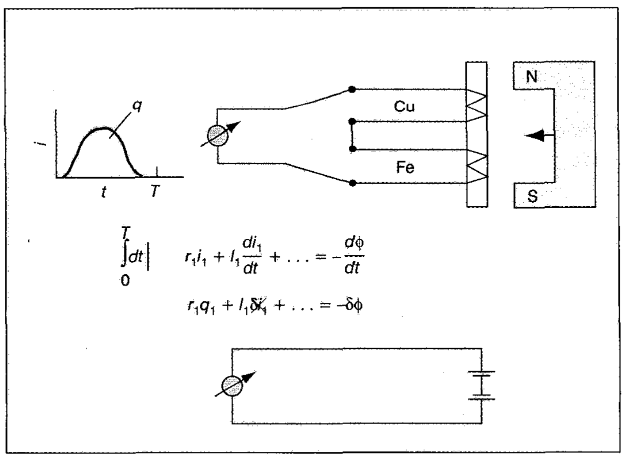

Fig. 1 One of Christie's early experiments

This becomes clear if we look a little at one of his first experiments (Fig. 1). Christie does not use constant currents, he works with current pulses, obtained through magnetoelectric induction—the great discovery announced by Faraday only 15 months earlier. Now, the charges in a pulsed network with resistances and inductances but no capacitances can be computed from an equivalent DC circuit in which the currents represent the charges and the EMFs the total

*Samuel Hunter Christie was the only son of James Christie, founder of the famous auction galleries. From 1837 to 1854 he served as secretary of the Royal Society.

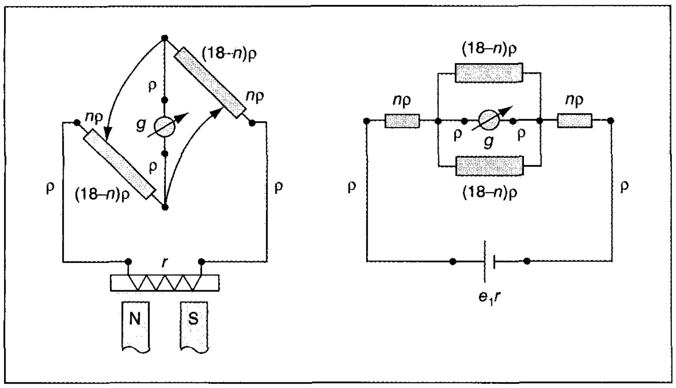

Fig. 2 One of Christie's circuits for determining the influence of the length of the wire

It is evident that Christie has no idea of a current running around a closed circuit. He thinks that currents are created independently in the different parts of the circuit. Gradually (pp.112, 125) it dawns upon him, however, that the galvanometer—but not the induction coil—might have some influence. But Christie's measurements are quite good. Fig. 2 shows a circuit he used for determining the influence of the length of the wire. From data given in the paper I have been able to calculate the galvanometer deflections (Fig. 3). I find the agreement with the deflections, measured by Christie, quite satisfactory. (Christie's data only gave me the sum $r+g$, not r and g separately. In Fig. 3 these values have been chosen so as to give for $n=0$ a calculated value equal to the measured one.)

flux changes. In Christie's case, we obtain two equal and opposite EMFs in series, which of course make the current zero.

Now let us see what Christie has to say. If you find that he talks nonsense, you have understood him correctly! But don't judge him too hard—perhaps, with *his* background and *his* knowledge, you wouldn't have done it better yourself! Christie writes (Ref. 4, pp.98, 99):

> 'As the copper and iron helices were, as nearly as possible, subjected to the same inductive force, and that force was of the most powerful description, this experiment shows very clearly that however the intensity of the current excited in the copper helix might exceed that in the iron, this excess was very accurately counterbalanced by the greater difficulty of transmission offered by the iron wire to the stronger current of the copper wire, and the greater facility offered by the copper wire to the transmission of the weaker current of the iron wire: or, in other words, that the intensities of the currents excited in the two wires were very accurately proportional to their conducting powers.'

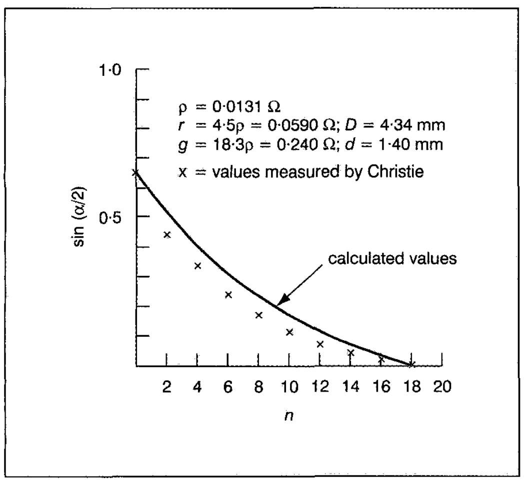

Fig. 3 Galvanometer deflections for the circuit of Fig. 2 as measured by Christie and calculated by the author

By and by (p.99) Christie arrives at the bridge principle (Fig. 4). He writes:

> '...a more accurate method of determining both the relative intensities of the currents excited in different metals under precisely the same circumstances, and their conducting power, presented itself... It affords a very accurate measure of the difference of the intensities of two currents... The general nature of the arrangement, to which the term differential arrangement may with great propriety be applied, will be fully understood by the following experiment...'

Christie explains his arrangement (p.107) through the superposition of two galvanometer currents, a 'direct' current copper-galvanometer-copper, and a 'reverse' current iron-galvanometer-iron, the direct and reverse currents having opposite directions through the galvanometer. Alas, were circuit theory that simple!

Christie also balances his bridge, for instance in order to determine how the conducting power of a metal wire depends upon its cross-section (pp.120 ff.). In comparing two wires, No. 11 and No. 16 (Fig. 5), he starts with two equal lengths of both. He knows that the conducting power is inversely proportional to the length. He shortens the two wires No. 16 until the bridge is balanced, and finds correctly that the conducting power is proportional to the cross-sectional area.

Christie versus Wheatstone

Let us now compare the results of Christie and Wheatstone. Christie works with current pulses, Wheatstone with constant currents. Both scientists balance the bridge and they both only use the ratio 1:1. Christie always employs four equal bridge arms, Wheatstone arrives at the more general case of two unequal resistance pairs. Wheatstone seems to have understood better than Christie the advantage of a null method. Finally, Wheatstone is in command of Ohm's law and understands well what he's doing, Christie is

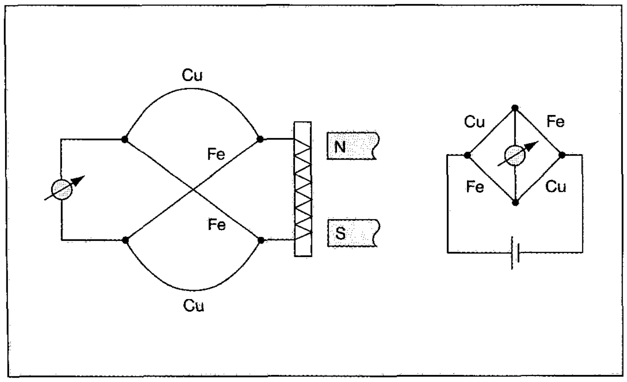

Fig. 4 The bridge principle as arrived at by Christie

not always clear about his own methods. A parallel reading of the two papers gives a strong impression of the overwhelming importance of Ohm's work, neglected for so many years.

Why Wheatstone's and not Christie's bridge?

Why is the arrangement known today as 'Wheatstone's bridge' in spite of what one author[5] describes as Wheatstone's 'generous and unqualified ascription to Christie of what today would be termed the "bridge principle"'? The answer has generally been: 'In spite of the famous note, the bridge became connected with the name of Wheatstone because at the time of Wheatstone's paper his name was on everybody's lips—he was one of Britain's foremost scientists'. I want to show you that this is not the whole truth, perhaps not even the most important part of the truth.

In my library of the history of electricity, or, rather, my university's library, I have a reprint of Wheatstone's paper. The pagination, beginning with page 303, is the same as in the *Philosophical Transactions* but the reprint has a special cover where Wheatstone has written a dedication to the French Professor Dumas. There is, however, another and more important difference: *the reprint lacks the note about Christie.* And this is no mishap! If we make the natural assumption that the note has been introduced into and not taken away from an already composed page, we find that space has been obtained for it on page 325 by moving the last four lines of the main text on this page to page 326, and from page 326 four lines to the last page, 327.

How can this be explained? I can only see one solution: Wheatstone got his reprints *before* the final printing in the *Transactions* and gave them to colleagues and friends. Then one—or several—of the recipients must have said to him: 'But haven't you seen Christie's paper?' or 'But shouldn't you mention Christie?' And so Wheatstone put in the note in the final printing for the *Transactions.*

But there is more to this. Wheatstone's paper was immediately translated into French and German. In 1844, the year after the Bakerian lecture and the printing in the *Transactions*, it appeared in the French *Annales de Chimie et de Physique*[6]. It appeared without the note! In 1844 it was also published in German in the *Annalen der Physik*[7], also without the note. Following the title, Poggendorff, the German publisher, has inserted a short notice: 'Aus den *Philosoph. Transact.* f. 1843, pt.II, in einem besonderen Abzuge mitgeteilt vom Hrn. Verfasser'—communicated by the author in a special copy. Hence, Wheatstone must have sent his reprint to Poggendorff, and most probably to the French publisher also.

Wheatstone's handling of scientific matter has always given rise to discussions. In this connection the facts reported above add some further questions. Is it possible that Wheatstone did not know of Christie's paper? Or had he forgotten it? Or was he so filled with his own ideas that he did not see the close connection with his own work?

I will not try to give an answer. Let me only observe that Wheatstone was famous for his enormous bibliographical knowledge and that, judging from circumstances, he must have known Christie quite well. In fact, Christie and Wheatstone were both members of the Royal Society, Christie since 1826 and Wheatstone, 18 years younger, since 1836; and in 1843 Christie had already been the Society's secretary for six years! A final question: Why did not Wheatstone send his note about Christie to the French and German publishers or translators? There seems to have been plenty of time for this.

How did the arrangement become known as 'Wheatstone's bridge'? In trying to answer this question, it should be borne in mind that in the 1840s English was not the habitual language of science as it is today. Most scientists on the continent—and in my country also—knew German and French well, quite often also Italian, but few of them knew English; and still fewer knew it well. So in most of Europe Wheatstone's paper must have been read in the French

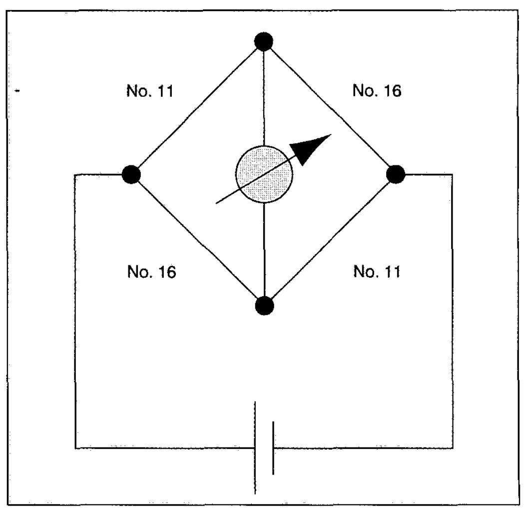

Fig. 5 Christie's balanced bridge

or German translation—and neither of them mentions Christie!

The denomination 'Wheatstone's bridge' obtained an early and widespread use on the continent. It possibly arose there. In 1861 William Thomson wrote a paper in which he introduced what is known today as the Kelvin bridge[8]. About Wheatstone's arrangement he makes the following remark:

> 'I have given this name [Thomson uses the name Wheatstone's Balance] to the beautiful arrangement first invented by Professor Wheatstone, and called by himself a "differential resistance measurer". It is frequently called "Wheatstone's bridge", especially by German writers.'

Is it too daring to assume that, if the note about Christie had been included in the French and German translations of Wheatstone's paper, we should not speak today of Wheatstone's bridge but of Christie's bridge, or, why not, as Oliver Heaviside did[9] in later years, call it a 'Christie'?

I am not going to recommend a change. But I seek consolation in the fact that fame, if not priority, generally goes to those who have been most influential in forming the world. So we remember Columbus before the old Viking Leif Erikson, we remember Marconi before the Russian Popoff—and we will probably go on remembering Wheatstone before Christie!

References

1 WHEATSTONE, C.: 'An account of several new instruments and processes for determining the constants of a voltaic circuit', *Philos. Trans. R. Soc.*, 1843, Pt.II, pp.303–327; Pl. XVI, XVII.

2 OHM, G. S. *in* Schweigger's *J. für Chemie und Physik*, 1826, **46**, pp.137–166

3 WINTER, H. J. J.: 'The significance of the Bakerian Lecture of 1848', *Philos. Mag.*, 1943, **34**, pp.700–711

4 CHRISTIE, S. H.: 'Experimental determination of the laws of magneto-electric induction in different masses of the same metal, and of its intensity in different metals', *Philos. Trans. R. Soc.*, 1833, Pt. I, pp.95–142; Pl. III, IV

5 APPLEYARD. R.: 'Pioneers of electrical communication' (Macmillan, London, 1930), p.96

6 *Annales de Chimie et de Physique*, 1844, **10**, pp.257–293; Pl. III (translation of Ref. 1)

7 Poggendorf's *Annalen der Physik und Chemie*, 1844, **62**, pp.499–543 (translation of Ref. 1). The plates were missing in the copy available to the author.

8 THOMSON, W.: 'On the measurement of electric resistance', *Philos. Mag.*, 1862, **24**, pp.149–162

9 HEAVISIDE, O.: 'Electrical papers, Vol. 2' (London, 1892), pp.102–106, Sect. XXXVII (from *The Electrician*, 11th March 1887, p.390 ff.)

The late Professor Ekelöf was formerly Head of the Institute for the History of Electricity, Chalmers University, Göteborg, Sweden. He presented this paper at the weekend meeting on 'The history of electrical engineering' organised by IEE Professional Group Committee S7 and held in Cardiff, 1st–3rd July 1977.

INTERNATIONAL SYMPOSIUM REPORT

Engineering education:

innovations in teaching, learning and assessment

The symposium on engineering education held at Savoy Place on 4th and 5th January this year was a very successful meeting attended by approximately 85 UK and international delegates. It covered a wide range of topics, including engineering mathematics, electronic and electrical engineering, international perspectives, project management, computing, and teaching and learning.

Innovation in education takes place in response to both new opportunities and threats. In this context the former include the development of new technologies, which changes both the subjects to be taught and the means of teaching them. The changes in the experience and knowledge of students entering universities and the resource and other pressures on these institutions form the main threats. This symposium provided an excellent forum for delegates to discuss the ways in which they and their colleagues attempt to deal with these shared issues. Most of the novel solutions include the use of computers connected to an intranet and some also to the Internet.

There was great interest in exploiting the potential of the Internet and a fair amount of 'crystal gazing' in trying to predict the short- and medium-term future of its applications. Internet-based globalisation was generally seen as an opportunity rather than a threat. The need for human input to the educational process, particularly at the undergraduate level, was emphasised and contrasted with the delivery of CPD to practising professionals.

Several of the speakers described projects that could be extremely useful to other academics if only they could be made aware of the existence of the work. This raised the need for a single focus, a 'one stop shop' that could act as the gateway to the resources made available by all these projects.

The symposium provided a timely and valuable snapshot of current developments and good practice in teaching, learning and assessment. An impressive range of papers was presented whilst still ensuring time for some debate and discussion. This was considered a very valuable conference.

The IEE is at present looking into organising a symposium on international education in January 2002. The main theme will be 'Training in education: professional scenarios'. If you are interested in contributing or would like further information please contact Ann Miskin (Head of Professional Networks Department), *E-mail* Amiskin@iee.org.uk.