ESSENTIAL IDEAS IN ELECTRONICS:
Voltage (Part 1)

As you are no doubt aware, teaching electronics can raise many a tricky question! With this in mind, *Electronics Education* aims to assist beleaguered teachers by offering some guidance with a series of 'building block' articles. In the first of our series of 'Essential Ideas' **Torben Steeg** explains the fundamentals of voltage, or, as it should be known 'potential difference'.
Look out for Part Two in the Summer issue of Electronics Education.

PREFACE

Like many essential ideas in electronics, voltage is a slippery customer; it's easy to think you have a grip on it only to find that, when you think a bit harder about it, you don't after all. However all is not lost; you can do a lot of useful things in electronics without holding a fully formed theory of voltage. And as your experience with electronics develops you can allow your understanding of voltage to develop at the same time (along with other essential concepts that will follow in later articles).

So, this pair of articles starts with a broad, easily understandable description of voltage. This description is very general and non-mathematical. Note, though, that it is still a correct description, just one that can only be used in rather general and imprecise ways. By way of various analogies and models, the articles will gently move to more tightly defined, and more mathematical, descriptions of voltage that can be used in a wider range of situations. As you will see, voltage turns out to be a very abstract idea, even though the presence of voltage can have very concrete effects, and you'll find out why physicists don't like the term 'voltage' at all.

If you find that the articles are leading you into water that is too deep for you, stop reading while you →

Illustration: Melvyn Evans

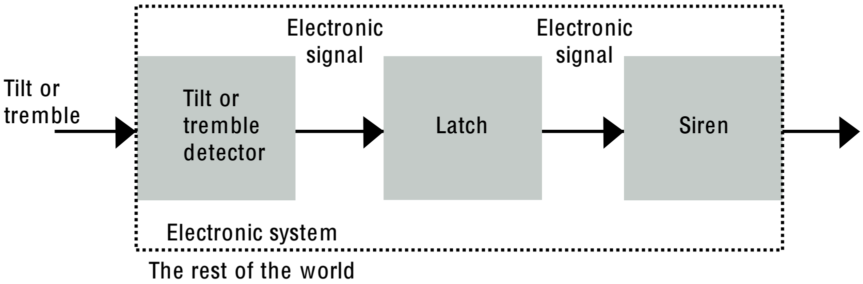


Fig 1

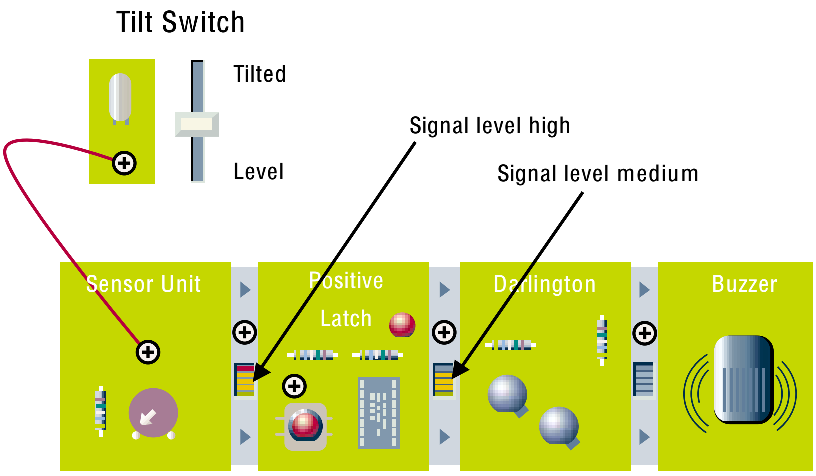


Fig 2

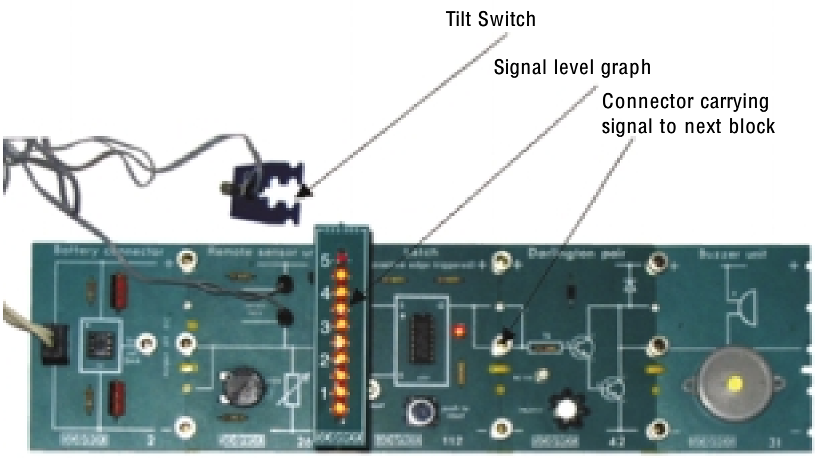


Fig 3

still understand what they are saying; you can always come back to the harder stuff another time.

VOLTAGE IN SYSTEMS

Fig 1 shows a typical system diagram, in this case it could be for a bag alarm that sounds when it senses movement and, thanks to the latch, keeps the siren going after the movement has stopped.

In this system diagram the arrows represent real physical signals. Some signals pass information across the system boundary (the dotted line in Fig 1) either from 'the rest of the world' into the system or out of the system into the world. Other signals pass information from one block to another within the system. For example the arrow pointing across the system boundary out of the system represents the sound signal that you hear when the alarm is triggered. You'll see that inside the system the signals are labelled as 'electronic' signals. Each of these electronic signals is actually a varying voltage.

So, one very straightforward way to think about voltage is as a signal in a circuit; let's explore this a bit further.

Fig 2 shows the circuit blocks that you could use to make up the circuit. If you have access to Control Studio , you can try this circuit out yourself.

Each connector has a coloured bar graph that shows the level of the signal, or voltage, between each pair of blocks.

Fig 3 shows the same circuit made up with System Alpha boards; again, if you have access to Alpha boards, you can try this circuit out as well.

In fig 3 an electronic bar graph is showing the signal level and giving a rough idea of the voltage.

As fig 4 shows, instead of using the bar graph you can attach a voltmeter to any of the signal connectors to get a more precise reading of voltage.

Notice that, in fig 4, the voltmeter has two connections; one to the signal connection and one to the connection marked with a minus sign. You'll see why two connections are needed later in this article.

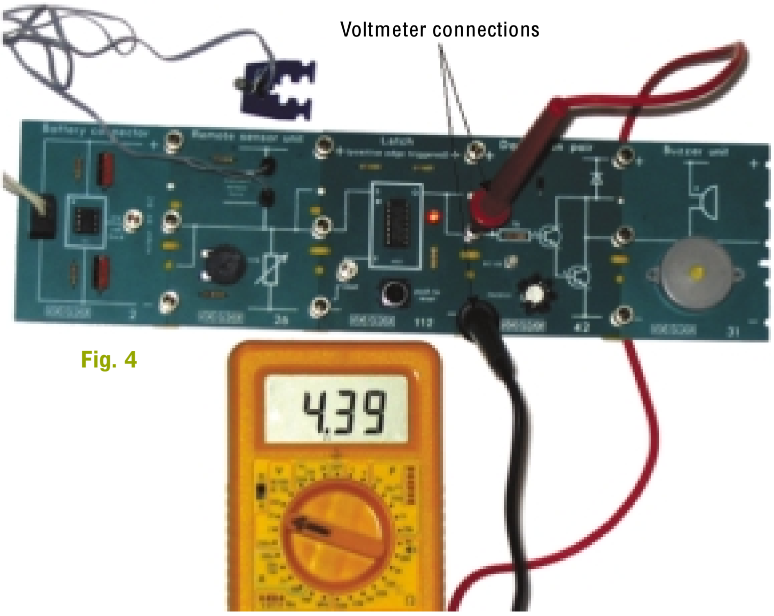


Fig. 4

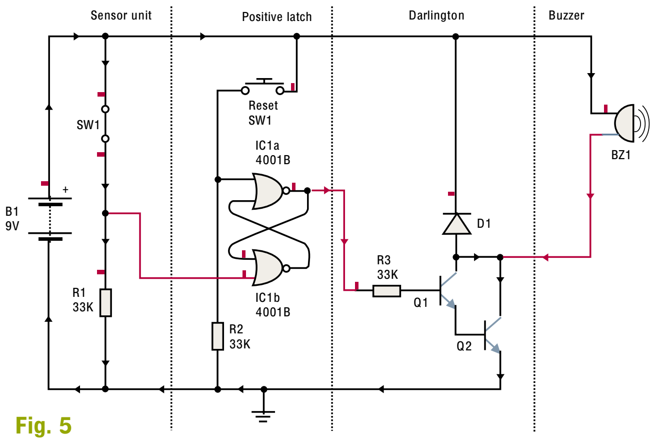


Fig. 5

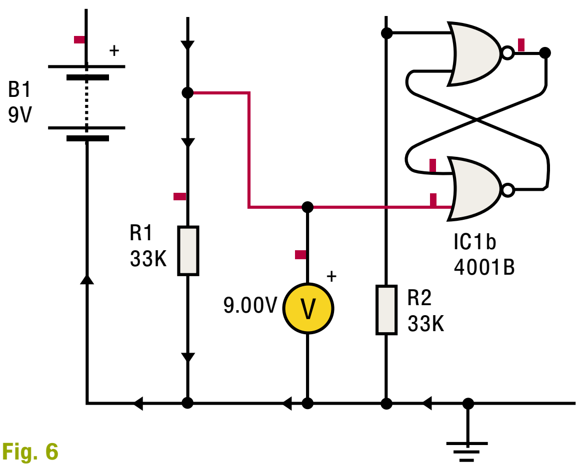


Fig. 6

> "Like many essential ideas in electronics, voltage is a slippery customer; it's easy to think you have a grip on it only to find that, when you think a bit harder about it, you don't after all"

In summary, the signals in an electronic system are actually voltages and they can be measured with a voltmeter.

VOLTAGE IN CIRCUITS

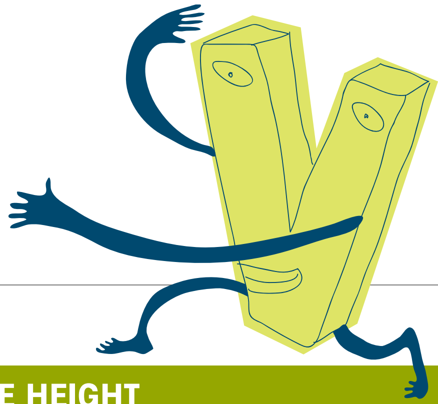
Fig 5 shows a possible circuit to provide the system blocks of figs 2 and 3. In this circuit the wires that carry the signals between blocks are shown in red.

If you want to measure the 'level of the voltage on' these signal wires (you'll see later why I've put this expression in quote marks), you need to use the arrangement shown in fig 6 where the highlighted symbol with a 'V' represents the voltmeter:

The important thing to notice about diagram 6 is that the voltmeter, like the one in fig 4, is connected to both the signal line and the wire attached to the negative side of the battery.

This is because a voltmeter measures the difference in something called the electrical potential between the two places it is attached to. This difference is expressed in volts. Electrical potential is also measured in volts. You'll find out what electrical potential actually is in part 2 of this article; for now you can start to use the proper phrase.

So, voltage is a measurement of difference; in fig 6 you are not measuring the voltage 'on a wire', rather you are measuring the difference, expressed in volts, between the electrical potential on the signal wire and the electrical potential on the zero volt side of the circuit (that's why quote marks were used earlier). In fig 6 this difference is shown as 9.00V – which means the electrical potential of the signal wire is 9 volts greater than the →



VOLTAGE IS QUITE A LOT LIKE HEIGHT

	Voltage	Height
It's a measurement of difference	The difference is in electrical potential between two places in a circuit	The difference is in vertical distance between two physical places
The unit of measurement represents this difference	The unit is the volt	The unit is the metre
It's measured from a reference point	The fixed place is usually 0V	The fixed place depends on what you are measuring: > The floor if you are measuring heights of people > The ground if you are measuring heights of buildings > Sea level if you are measuring heights of mountains

electrical potential on the other wire which, following a common convention, we will agree to call zero volts or 0V.

There is one other thing you should notice about the voltmeters in figs 4 and 6. The positive side of the voltmeter (the red wire in fig 4 and the '+' symbol in fig 6) is always connected to the signal line. The other side of the voltmeter (called the negative side) is connected to 0V.

You can, if you wish, measure voltage between any two wires in a circuit. However, as a general rule, it is only useful to take measurements that can be compared sensibly to other voltage measurements. Because of this, the negative side of the voltmeter is always attached to the 0V side of the circuit and voltage measurements are always relative to this point of the circuit.

This is a good place to bring in a useful analogy for voltage: Voltage is quite a lot like height (see table above).

You'll see more use of this analogy in Part 2 of this article.

To finish this first part of the article, there is one more important thing you should know. The word 'voltage' is not a proper scientific term. It's a bit like using the word 'metreage' instead of 'height', as in "what metreage are you?". The correct term is potential difference because it is the measurement of the difference in electrical potentials (in the same way you might ask the question 'what's the height difference?' about two mountains). Because the word 'voltage' is in such common use, these articles will continue to use it – but you have been warned; don't let a physicist catch you using the wrong term!

Part 2 of this article, in the next edition of *Electronics Education*, will explore what an electric potential actually is and how a voltage (potential difference) can be created. ■

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