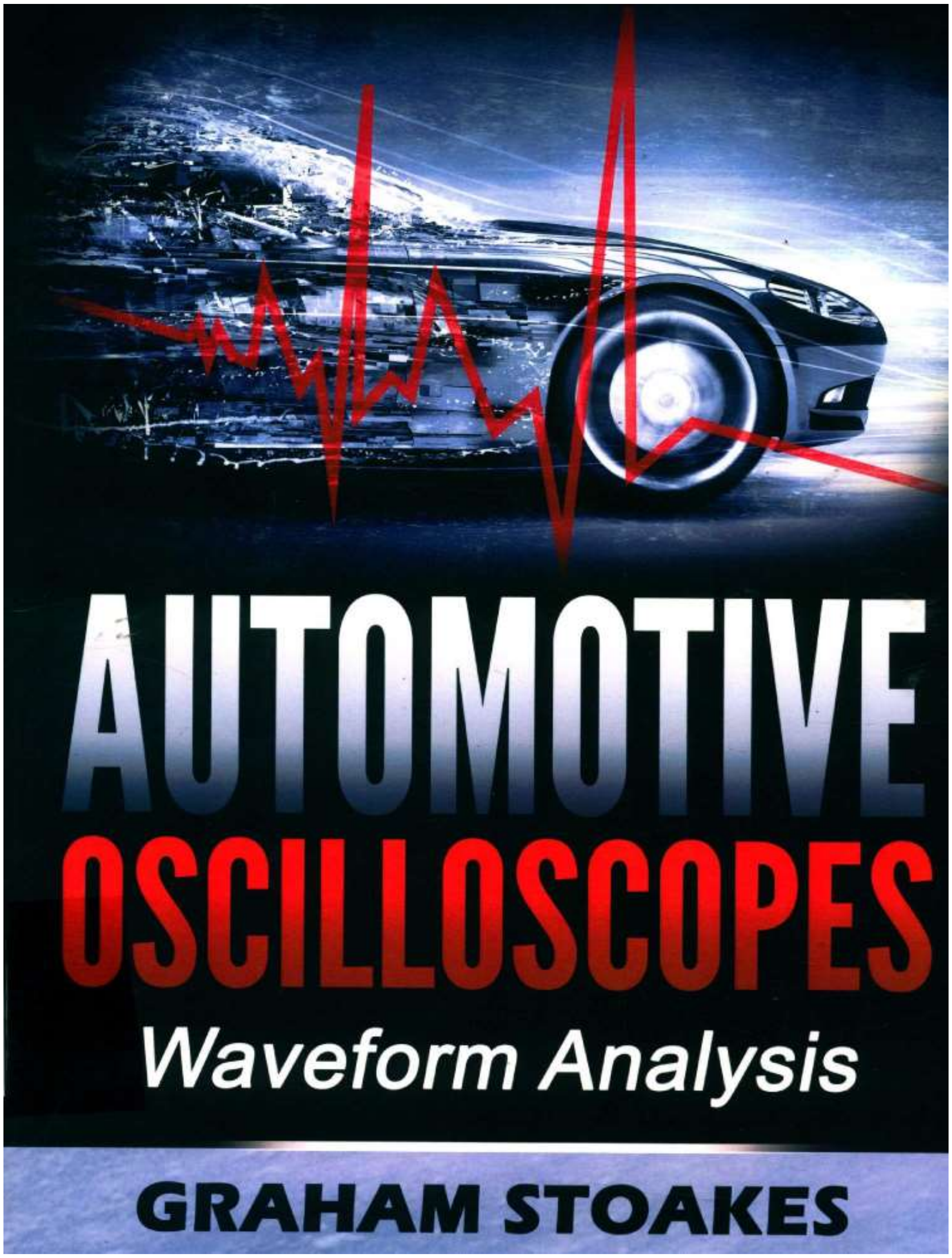
AUTOMOTIVE
OSCILLOSCOPES
Waveform Analysis
GRAHAM STOAKES

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Some of the waveforms and analysis contained in this book are based around the automotive tests included with PicoScope, the most popular Automotive Oscilloscope.
More information and some really useful additonal resources can be found on the Pico Technology website www.picoauto.com.

Introduction

How to use this book

Could you spot if someone tried to badly fake your signature?

Are the curves in the wrong place?

Do letters slope upwards instead of downwards?

Are there letters missing completely?

If so, then you can use an oscilloscope for automotive electronic diagnosis.

Every electrical and electronic component found on a car has its own signature, and once you can identify the forgery, you're on your way to discovering the problem. The oscilloscope allows you to have a viewing window on the normally hidden worlds of current, voltage and pressure. Once you have become familiar with the function and operation of automotive electrical circuits, and what the components do, you'll be able to analyse a representation of their signatures and spot the fake.

This book has been fully illustrated to help give you information about the waveforms produced and procedures used when conducting diagnosis with an oscilloscope. Unlike many publications or training manuals, it has been written with an aim to help technicians become confident in the use and set-up of automotive scopes.

Due to the wide range of circuits, components and operating faults possible on a vehicle, this publication tries to remain generic, allowing you the flexibility to adapt the content to your diagnostic needs without tying you down to specific settings or figures. It concentrates more on the shape of the waveforms and what different parts mean.

Throughout this book, you will find features that aim to support and enhance your understanding and use, including:

Information in these boxes will help indicate safety features that you should consider when conducting work on vehicles and electrical circuits.
They are designed to reduce the possibility of injury, or damage to vehicles or equipment.
Even if no specific safety advice is given, you must always assess the potential risks in any activity or diagnostic routine.

Information provided in these boxes is designed to support the use of oscilloscopes in automotive diagnostics.
They give material which will help understanding and reinforce knowledge on systems, components and testing.

Information in these boxes describe key terms related to the subject of automotive diagnostic testing.
If technical vocabulary is understood and used in the correct context, it provides a basis for good practice when undertaking repairs.
Within the text, words highlighted in **bold** will have a definition described by this feature.

Information in these boxes provide handy diagnostic tips when working on specific systems or components.
Although they may not all be relevant to the vehicle or task you are conducting at the time, they will help give you ideas that you can adapt and use within your systematic diagnostic routines.

Electronic and electrical safety procedures

Working with any electrical system has its hazards and you must take safety seriously. When you are working with light vehicle electrical and electronic systems, the main hazard is the possible risk of electric shock. Although most systems operate with low voltages of around 12V, an accidental electrical discharge caused by incorrect circuit connection can be enough to cause severe burns. Where possible, isolate electrical systems before repairing or replacing components.

If working on hybrid or fully electric vehicles, take care not to disturb the high voltage system. The high voltage system can normally be identified by its reinforced insulation and shielding, which is often coloured bright orange. These systems carry voltages that can cause severe injury or death.

Always use the correct tools and equipment. Damage to components, tools or personal injury could occur if the wrong tool is used or misused. Check tools and equipment before each use.

If you are using electrical measuring equipment, you should check that it is accurate and calibrated before you take any readings.

If you need to replace any electrical or electronic components, always check that the quality meets the original equipment manufacturer (OEM) specifications. (If the vehicle is under warranty, inferior parts or deliberate modification might make the warranty invalid. Also, if parts of an inferior quality are fitted, it might affect vehicle performance and safety). You should only carry out the replacement of electrical components if the parts comply with the legal requirements for road use and environmental protection.

Although oscilloscopes can be used for testing the high voltage systems of hybrid and electric vehicles, you should not attempt diagnosis and repair of these vehicle types unless you have had specific training.

Provision and Use of Work Equipment Regulations 1998 (PUWER)

The equipment used in your workshop needs to be:

- Safe to use.
- Maintained correctly.
- Inspected regularly.
- Only used by people who have received appropriate training.

The Provision and Use of Work Equipment Regulations 1998 (PUWER) place the responsibility for the safety of workplace equipment on anyone who has control over the use of work equipment, including your employer, you and your colleagues.

Personal Protective Equipment (PPE) at Work Regulations 1992

This regulation requires that employers provide appropriate personal protective clothing and equipment for their employees. It is your duty to use PPE if required.





When selecting PPE, make sure that the equipment:

- Is the right PPE for the job – ask for advice if you are not sure.
- Fits correctly – it needs to be adjustable so it fits you properly.
- Is properly looked after.
- Prevents or controls the risk for the job you are doing.
- Does not create a new risk, e.g. Overheating.
- Is comfortable enough to wear for the length of time you need it.
- Does not impair your sight, communication or movement.
- Is compatible with other PPE worn.
- Does not interfere with the job you are doing.

Vehicle Protective Equipment (VPE)

To reduce the possibility of damage to the car, always use the appropriate vehicle protection equipment (VPE):


Wing covers


Seat covers


Steering wheel covers


Floor mats

Quick Set-up

Quick set-up guide

An oscilloscope is a piece of electrical test equipment designed to act like a voltmeter or an ammeter.
A multimeters' measurement display can't change fast enough to deal with modern electronic systems on motor vehicles – the numbers on the screen can't keep up. The answer to this is to use an oscilloscope.
Unlike a voltmeter, oscilloscopes not only show volts or amps but also time.
Instead of a digital readout, the results are shown as a graph of volts or amps against time on a screen (as shown in Figure 0.1).

- A point on the display screen shows the measurement taken from the circuit and then moves across the screen left to right. It leaves behind it a trace, showing a history of its journey and this is known as the **waveform**. When the trace reaches the right-hand side of the display, it resets to the left-hand side and starts over again. (This is known as **triggering**).
- The graph normally shows voltage or amperage at the side of the screen (on the Y-axis) – this axis is often called **amplitude**. Use the scale setting switch in a similar way to the dial on a manual multimeter to choose the amount of volts or amps that are shown on the screen.
- The graph normally shows time across the bottom of the screen (on the X-axis). This axis is often called **frequency** or sweep. Use the timescale switch in a similar way to the dial that is used to choose the amount of volts on a multimeter.

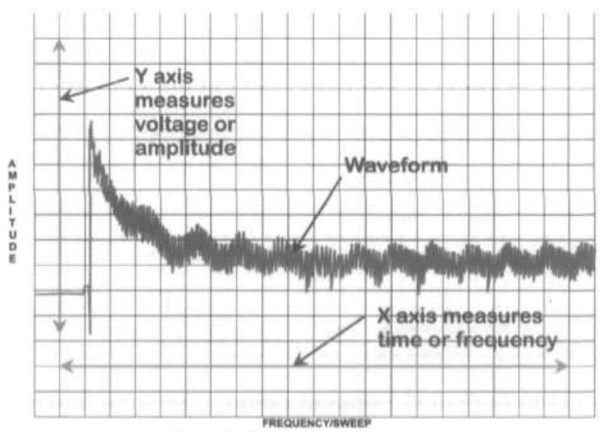


Figure 0.1 An Oscilloscope screen

An easy way to remember which axis is which on a graph is to say 'X is across' (a cross).

Quick Set-up

If you are unsure of the most appropriate voltage or timescale to use for a particular test, simply select a value somewhere in the middle and then move up and down the scales until the pattern is displayed to your satisfaction.

Lots of people are put off using oscilloscopes by the large box containing many wires and connectors. They feel that it will be complicated and time consuming to set up, so they don't bother.
However, to use an oscilloscope for simple electrical testing, you only need two probes – a common and voltage wire – just like a multimeter.
To measure amperage, you may need an inductive clamp and HT ignition systems will require a secondary probe. Most of the diagnostic sockets found on oscilloscopes are colour-coded, so after a quick check of the manufacturer's instructions, it should be fairly easy to know where to plug these probes in.

Waveform – the line traced on the screen of an oscilloscope as measurements are taken.

Amplitude – the height of a waveform, measured in volts or amps.

Frequency – the time scale of a waveform (how often something happens).

Triggering – the point on an oscilloscope display when the waveform refreshes and starts again.

4 step guide to connecting an oscilloscope

How to:

Note: The oscilloscope probes may come in different colours, but for the sake of simplicity we will call them red and black here.

Step 1
- Connect the tip of the black lead to a good source of earth, such as the battery terminal, metal bodywork or engine. This will then only leave you with the red wire to worry about.

Step 2
- Now connect the red probe to the circuit to be tested.

Step 3
- Adjust the scales until you see an image on the screen.

Step 4
- After some practice, you will become familiar with the patterns and waveforms created by different vehicle systems.

Chapter 1 Electrical Fundamentals

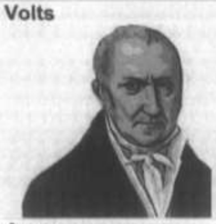
This chapter will help you develop an understanding of fundamental electrical principles used in automotive engineering. It also introduces the basic operating theories of electricity and electrical systems that will aid you when undertaking maintenance and repairs. Remember to work safely at all times and observe the relevant health and safety regulations; while developing diagnostic routines that are systematic and effective.

Contents

Electrical and electronic units

In cars, electrical energy is created by a chemical reaction (in a battery for example) or by the disruption of magnetic fields near electrical conductors (in an alternator for example). A description of the main electrical units is shown in Table 1.1.

Table 1.1 Electrical units

Volts 	Voltage is electrical pressure. Voltage is the potential force in any part of an electrical circuit, and is named after Alessandro Volta. Two main types of voltage occur in electrical circuits: **Electromotive force (EMF)** is potential pressure, and is usually considered to be the open circuit voltage when all electrical consumers are switched off and no current is flowing. **Potential difference (Pd)** is the voltage drop caused by flowing electricity when the circuit is switched on.
Amps 	Amps are the units used to measure the amount of electricity in any part of an electrical circuit and are named after André-Marie Ampère. Amps is measured when electricity is allowed to flow in an electrical circuit – this is known as **current**. There are two main types of electrical current: Direct current (DC) is electricity that flows in one direction only. Alternating current (AC) is electricity that moves backwards and forwards in an electric circuit. Amperage is the same wherever you measure it in the circuit (at the beginning in the middle or at the end).

Ohms

Ohms are the units used to measure the resistance to electrical flow and are named after Georg Ohm.

Resistance has a direct effect on the operation of any electrical circuit as it tries to slow down the flow of electricity.

As resistance rises in a circuit, current and voltage fall, which can restrict the operation of electrical components. In some electrical circuits, resistance can be used as a method of control for electrical components, but in most circumstances a high resistance is undesirable.

Watts

Watts are the units used to measure electrical power made or consumed and are named after James Watt.

Power is defined as the rate at which work is done. When referring to electrical components, the higher the wattage, the more powerful the component will be and the more electrical energy it will use.

Electromotive force (EMF) – the open circuit voltage when everything is switched off.

Potential difference (Pd) – the voltage drop in an electric circuit when it is switched on.

Current – flowing or moving electricity, measured in amps.

What is electricity?

Every substance known to man is made of molecules. The molecules of a substance are made up from atoms. For example, if the substance is water, the molecule is H2O. This means that the molecule is made up of two hydrogen (H) atoms joined to one oxygen (O) atom.

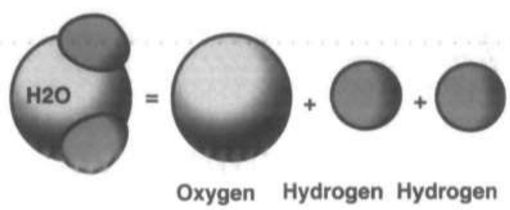
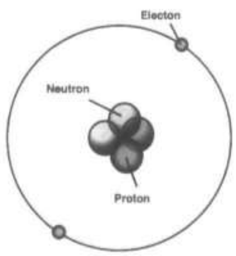


Figure 1.2 The atoms in water



The reason why it can be difficult to understand electricity is because it is contained within atoms. Atoms are very small and hard to imagine.
The easiest way to imagine an atom is like a miniature solar system, with a sun in the middle and planets orbiting around the outside.
In the case of an atom, the nucleus represents the sun. The nucleus is made of positively charged particles known as protons. It also contains particles with no charge known as neutrons.
Orbiting around this nucleus (in a similar way to the planets) are negatively charged particles known as electrons. As the name suggests, it is the electrons that produce electric current.

Figure 1.3 A helium atom

Different atoms have different numbers of protons and electrons, as shown in the periodic table – a chart with the known elements laid out in order of atomic weight (or the number of protons in their nucleus.

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Figure 1.4 The periodic table of elements

Movement of electrons

To make the electric current, you need to move electrons from one atom to the next. To do this they need to be given a push by an external force or pressure.
The pressure used to move electrons can be created by:
- magnets
- a chemical reaction