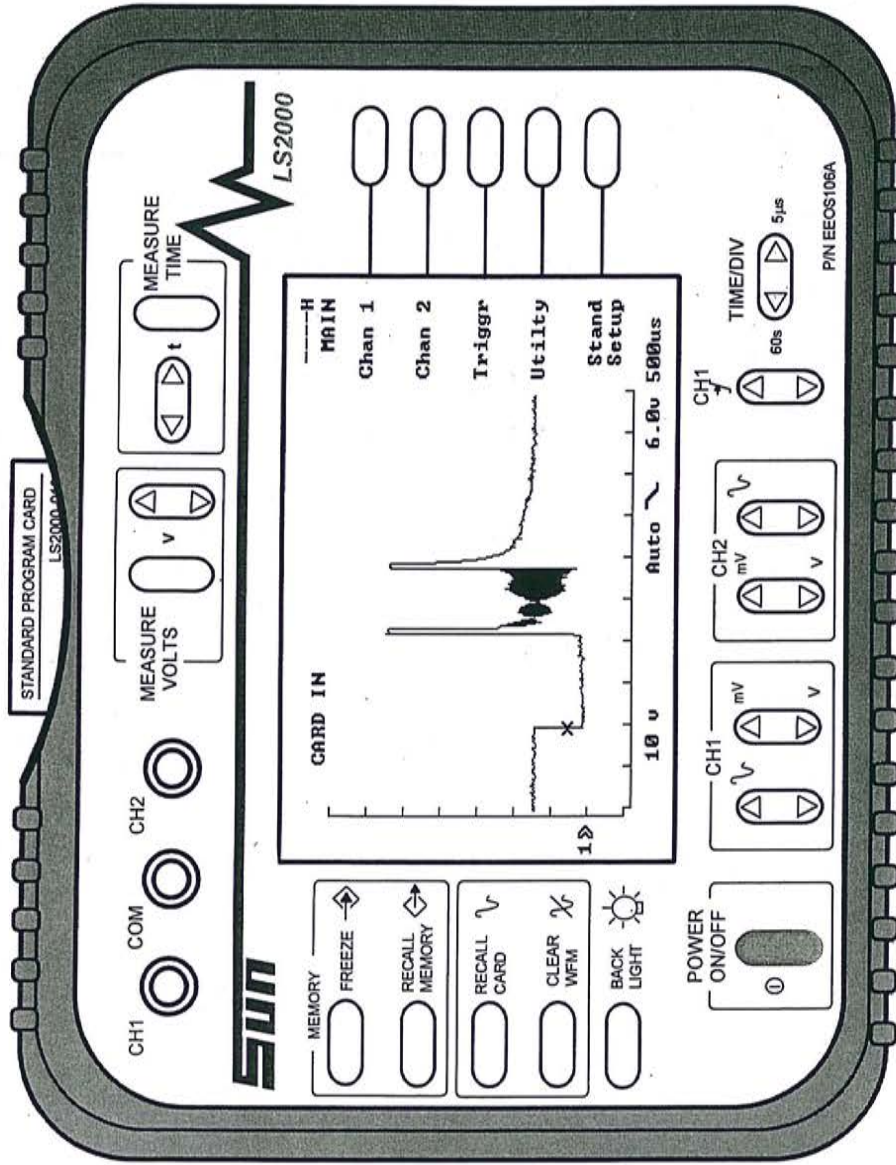


# LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS



***Safety Warnings & Cautions*** - Read this user's guide completely before using the LS2000.

1. Unless instructed otherwise, the parking brake should be applied and the gear selector in neutral (standard transmission) or park (automatic) and the drive wheels blocked before performing a test with the engine running. The ignition or fuel system must be disabled when performing starting system tests.
2. Always wear safety goggles when working near batteries. If considerable time is spent handling/servicing batteries, wear protective clothing. Avoid making an accidental connection between battery terminals with tools, jumper leads, etc. Use a suitable battery carrier when transporting batteries.
3. Keep yourself, clothing and test equipment clear of all moving or hot engine parts.
4. Do not smoke or allow open flames or sparks in the work area. Gasoline fumes and gases produced by batteries are highly explosive.
5. Exhaust gas contains deadly poison. When testing a vehicle with the engine running, test in a well-ventilated area or route exhaust gas outside.
6. On marine applications with inboard or inboard/outboard engines, make sure work area is well ventilated. Operate bilge blower for at least four minutes before starting engine or making test lead connections.
7. Be sure ignition is in the OFF position, headlights and other accessories are off, and doors are closed before disconnecting battery cables. This also helps to prevent damage to on-board computer systems.
8. Always disconnect the ground connections on all batteries before servicing the electrical system. Be sure all test leads are connected as instructed before proceeding with a test.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### Table of Contents

Introduction
Chapter 1 - Fundamentals of Automotive Electronics
Chapter 2 - Comparing DMM's, Scan Tools & Scopes
Chapter 3 - Oscilloscope Basics
Chapter 4 - LS2000 Features and Functions
Chapter 5 - Automotive Diagnostics & Applications
Chapter 6 - Safety Tips and Precautions

### LS2000 Specifications

### Glossary

### List of Illustrations

Figure 1-A	Typical Basic Circuit
Figure 1-B	Ohm's Law Circle
Figure 1-C	Simple Series Circuit
Figure 1-D	Simple Parallel Circuit
Figure 1-E	Simple Series-Parallel Circuit
Figure 1-F	Simple Open Circuit
Figure 1-G	Simple Short Circuit
Figure 2-A	Normal ABS Signal
Figure 2-B	Faulty ABS Signal
Figure 2-C	House Current Displayed on a Voltmeter
Figure 2-D	House Current Displayed on a Scope
Figure 2-E	Waveform Frequency and Period
Figure 2-F	Battery Voltage
Figure 2-G	Analog Throttle Position Sensor
Figure 2-H	Digital Mass Air Flow Sensor Output
Figure 2-I	Idle Speed Control Signal
Figure 2-J	Park/Neutral Switch
Figure 2-K	ABS Sensor Output
Figure 3-A	Phase of a Sine Wave in Degrees
Figure 3-B	Phase Shift

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### List of Illustrations (cont.)

Figure 4-A	Getting Started	Figure 5-C	DIS Power Spark
Figure 4-B	Front Panel Controls and Soft Keys	Figure 5-D	DIS Power and Waste Spark
Figure 4-C	Oscilloscope Display Layout	Figure 5-E	Idle Speed Control
Figure 4-D	Main Menu	Figure 5-F	Knock Sensor
Figure 4-E	Channel 1 Menu	Figure 5-G	Magnetic Crankshaft Reference
Figure 4-F	Time Base Warning Message	Figure 5-H	Magnetic Crankshaft Sensor
Figure 4-G	Channel 2 Menu	Figure 5-I	Mixture Control Solenoid
Figure 4-H	Trigger Menu	Figure 5-J	O <sub>2</sub> Sensor Output
Figure 4-I	Freeze Menu	Figure 5-K	Optical Crankshaft Sensor
Figure 4-J	Recall Memory Menu	Figure 5-L	Port Fuel Injector
Figure 4-K	Recall Card Menu	Figure 5-M	Throttle Body Injector
Figure 4-L	Utility Menu	Figure 5-N	Throttle Position Sensor
Figure 4-M	Graticule Display		
Figure 4-N	Time Cursors		
Figure 4-O	Voltage Cursors		
Figure 4-P	Changing Volts/Div and Position		
Figure 4-Q	Changing Time/Div		
Figure 4-R	Changing Trigger Level		
Figure 5-A	ABS Wheel Speed Sensor		
Figure 5-B	Digital Mass Air Flow		



## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### Introduction to the Oscilloscope

This guide should be used to get you started in troubleshooting electrical problems using the LS2000. Your real learning can best be accomplished through experience. As you become more proficient in using the oscilloscope to troubleshoot, you will learn very quickly how certain electrical symptoms can relate to various driveability problems.

Automotive electrical problems can be divided into several categories, that we will discuss later in this guide. Depending on the system in the vehicle causing the trouble, the real problem may exist in one system, while the symptoms you are testing appear in another. An oscilloscope can help you to isolate the real cause of a particular problem.

Oscilloscopes should be thought of as any other tool in the technician's or mechanic's tool box - just like another wrench or scan tool or multimeter. It will not solve all of your problems. It was only designed to give you some information about electrical activity (or lack of) occurring in components, sensors and wires of the vehicle's electronics.

For many years oscilloscopes have been used in the world of electronics. At first, they were (and still are) used in the design phase of many electronic systems. Then, their usefulness became even more important for diagnosing and repairing electronic devices (especially out in the field, far from the resources of factories and personnel). Once the oscilloscopes became smaller, lighter, battery powered and more portable, almost every electronic technician was required to have a scope as an essential diagnostic tool.

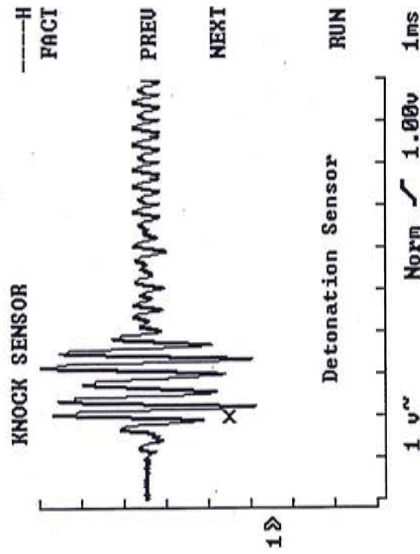
Electronic technicians realized early on, that trying to troubleshoot many automotive electronic systems without oscilloscopes was equivalent to trying to drive a car with your eyes covered. Your other senses could detect the fact that events were occurring, however, it is difficult to determine exactly what those events are. Oscilloscopes have been used by technicians to repair many types of electronic devices like TV's, VCR's, computers and copiers.

The oscilloscope is not limited to the electronics world. With the appropriate transducer, an oscilloscope can measure almost any kind of physical phenomena.

(i)

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

A transducer is a device that produces electrical energy in response to some kind of physical energy. As an example, a detonation or "knock" sensor on an engine is a transducer. A typical knock sensor contains a piezoelectric crystal that produces an electrical signal when it is subjected to mechanical stress, i.e. - the engine knocking (shown below).



For years "Ignition Scopes" were used to display secondary ignition patterns from conventional ignition systems. You can still view secondary ignition patterns on today's oscilloscopes. However, it is extremely important to realize that there are many other patterns, signals and sensor outputs that need to be checked on the vehicles being built today. The only way to determine if many of these circuits are performing properly is to use an oscilloscope.

As you progress through this guide, the benefits of using an oscilloscope will become very obvious. The job of troubleshooting difficult electrical problems will become easier, as you become more familiar with the functions and features incorporated into the LS2000.

(ii)

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### Chapter 1 - Fundamentals of Automotive Electronics

Troubleshooting electrical systems uses the same skills you have already developed as an automotive technician. It is important to use a logical process of deductive reasoning to solve any problem you might encounter in a vehicle. This process is important, since you can not see inside or listen to electrical components to tell if they are functioning properly, (like you can with mechanical devices). Thinking through the process in a logical and organized way should help you determine the source of the problem the first time.

There are typically four basic elements that make up a complete electric circuit. They are the energy source, the conductor or circuit wiring, the circuit load or device and the control (which, can be optional). In a complete circuit, all of the current that leaves a power source also returns back to the power source.

Current represents the movement of electrons through an electric circuit. The amount of electrical current flow is measured in Amperes (usually shortened to Amps). The symbol for Amperes or Amps is the letter "I".

Many vehicle electronic circuits use only milliamps of current to operate. (A milli-Amp is 1/1000th of an Ampere.) The symbol for milliamp is "mA"

Another term that is important to understand is Resistance, which is the opposition or restriction to current flow in a circuit. Electrical resistance is measured in terms of "Ohms". Every part of any electrical circuit has resistance, including the wiring to and from that circuit. Lights, relays and electronic devices in a circuit are often referred to as the "Load" and all have some resistance, called the "Load Resistance".

Resistance in a wire can be affected by a number of things including the wire length and diameter, wire type, the temperature and condition of the wire. You should always check the condition of the circuit wiring before replacing any suspected bad components.

The reason that current flows from the battery, through the circuit, and back is because of a force called the "Electromotive Force", or "emf".

The total amount of electromotive force, or difference in potential, that is present is measured in terms of "Volts" or "Voltage" using the symbol "E". A typical vehicle battery has a difference in potential electromotive force between the positive and negative terminals of just over twelve volts. A battery provides this voltage by a chemical reaction that takes place inside the battery. In contrast, an alternator needs mechanical movement of a wire through a magnetic field in order to produce this voltage.

A vehicle battery supplies what is called "Direct Current" or "DC", and current flows in one direction. Conventional theory - used by the automotive industry - says current flows from the positive terminal, through the circuit, to the negative terminal.

On the other hand, there is "Alternating Current" or "AC" which first flows in one direction, then "alternates" and flows in the opposite direction. This happens continuously many times per second. The electricity supplied to your home from the electric company is "AC", (it alternates at a rate of sixty times per second or 60 Hz).

In vehicles, the alternator supplies AC or alternating current which is converted or rectified to DC or direct current that is supplied by the battery for use in most of the electrical circuits in the vehicle.

A very important physical law governing electricity is called Ohm's Law. This law states that Voltage, Current and Resistance are all related to each other. According to Ohm's Law, one volt in a circuit with a resistance of one ohm will cause a current flow of one ampere.

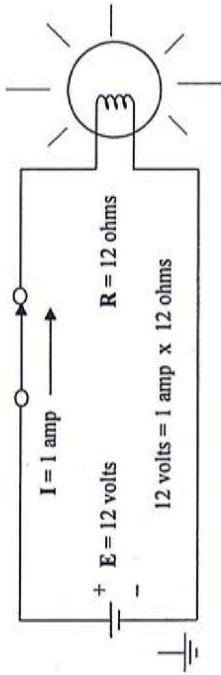


Figure 1-A: Typical Basic Circuit

(1-2)



## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

Voltage, current, and resistance in any electrical circuit can be calculated by using Ohm's Law, which states "the voltage in a circuit is equal to the current multiplied by the resistance". If any two values in the formula are known, the third can be determined.

### Ohm's Law States:

$$\text{Amperes} = \text{Volts} \div \text{Ohms}$$

$$\text{Ohms} = \text{Volts} \div \text{Amperes}$$

$$\text{Volts} = \text{Amperes} \times \text{Ohms}$$

According to Ohm's Law, if the resistance in a circuit stays constant, a change in voltage will cause a similar change in current. If the voltage stays constant, a change in resistance will cause an opposite change in current.

Below is a simple example which illustrates how to use Ohm's law to solve for an unknown voltage, current or resistance in a simple circuit.

To solve for E:      To solve for I:      To solve for R:

$$E = I \times R$$

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

$$E = 1 \text{ amp} \times 12 \Omega$$

$$I = \frac{12 \text{ volts}}{12 \Omega}$$

$$R = \frac{12 \text{ volts}}{1 \text{ amp}}$$

$$E = 12 \text{ volts}$$

$$I = 1 \text{ amp}$$

$$R = 12 \Omega$$

*(Note: In the above example "—" means "divide by" and "x" means "multiply by".)*

Ohm's Law explains the relationship between voltage, current and resistance. The next graphic shows you how to quickly solve for the unknown value. Put your finger over the value you want to find, then multiply the remaining values if they are side-by-side or divide them if one is over the other.

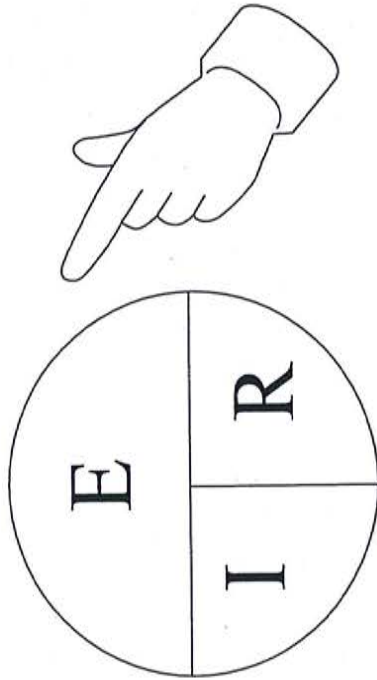


Figure 1-B: Ohm's Law Circle

In vehicles there are three types of automotive circuits that exist. The circuits are Series, Parallel and Series-Parallel circuits.

In a Series circuit - there is a power source, wiring to and from the power source, one or more loads with a single current path and an optional control.

The current flowing in a series circuit is the same at any point in the circuit. Let's look at a simple series circuit:

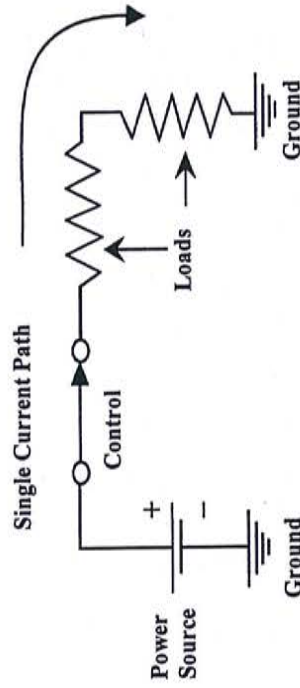


Figure 1-C: Simple Series Circuit

(1-4)

In a Parallel circuit - there is a power source, wiring to and from the power source, more than one load (connected to produce multiple current paths) and an optional control.

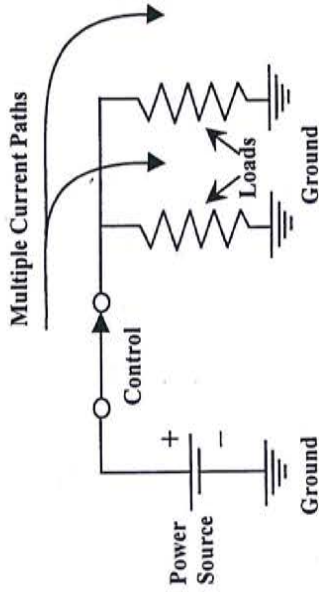


Figure 1-D: Simple Parallel Circuit

The current flowing in a parallel circuit divides among the separate branches. The total circuit current is equal to the sum of the individual branches. The current through each branch is determined by the load resistance in that branch.

In a Series-Parallel circuit - there is a power source, wiring to and from the power source, more than two loads connected (in series and parallel) to produce multiple current paths and an optional control. A Series-Parallel circuit can be a series circuit wired with two or more loads in parallel. It can also be a parallel circuit with the loads of one or more branches wired in series.

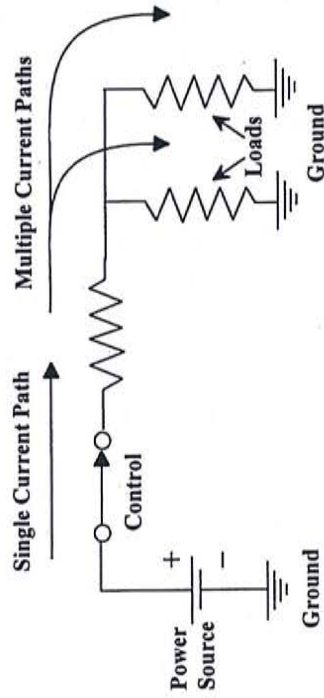


Figure 1-E: Simple Series-Parallel Circuit

There are two very common types of problems or faults that can exist in a circuit. They are known as an "Open Circuit", commonly called an "Open" and a "Short Circuit", commonly called a "Short".

A short circuit can exist between components, or directly to ground, causing a "Grounded Circuit". An open circuit has a complete break in the current path at some point causing one or more circuit loads or devices to not work.

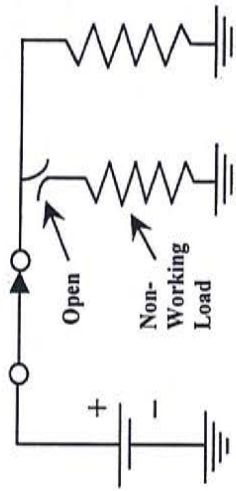


Figure 1-F: Simple Open Circuit

Since electricity will always take the path of least resistance, a short across a load will by-pass that load either through a

lower resistance or directly to ground. This will cause the shorted load and other components in the same circuit to malfunction or not work at all.

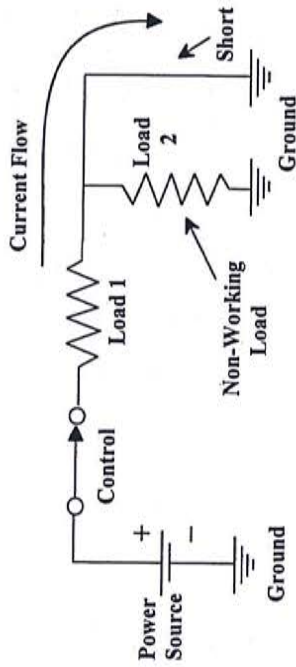


Figure 1-G: Simple Short Circuit

*(Note: It is important to realize that the loads or components may be operational, yet not working properly because of the short in the system.)*

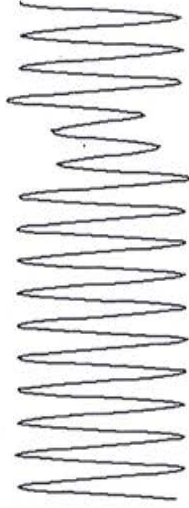
## Chapter 2 - Comparing DMM's, Scan Tools & Scopes

All of these tools have unique capabilities, and today's vehicles demand that technicians are able to use all three tools to correctly diagnose many of the problems that exist. Oscilloscopes alone can not replace voltmeters or scan tools. By the same token, voltmeters or scan tools can not replace oscilloscopes. Take for instance, a wheel speed sensor - a customer with anti-lock brakes comes into your shop and complains that the brakes on his car are sometimes erratic. You road test his vehicle and confirm the problem. During the road test you notice that the ABS light does not come on. When you get back to the shop, you plug in your scan tool and find no trouble codes. Well you still have your voltmeter - you follow the manufacturer's instructions and you look at the output voltage from each of the wheel speed sensors. They all appear to be in tolerance, and the manufacturer's fault tree informs you the next step is to replace the ABS computer. Unfortunately, the ABS computer on this vehicle is embedded in the master cylinder, so you must replace everything. The worst part is after you complete all of the work the problem still exists.



**Figure 2-A: Normal ABS Signal**

Most of the signal shown in figure 2-A is visible to voltmeters, scan tools and scopes



**Figure 2-B: Faulty ABS Signal**

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

However, the faults shown in figure 2-B are not visible to voltmeters and scan tools. They are only visible to scopes.

If you had a scope, you could look at the output signal from each of the wheel speed sensors. From this you would have discovered that the right rear wheel speed sensor had some very fast aberrations that caused the ABS computer to act strange. You replace the right rear wheel speed sensor and cure the problem. The scan tool missed this problem because no trouble codes were set and the computer communications bus was too slow to pick up the spikes. The voltmeter missed this problem because it averaged the sensor signals and could not see the fast aberrations.

Scan tools and DMMs sample very slow when compared to scopes. Scan tools are limited to sampling less than 100 times per second and many only sample at 10 times per second. The fastest handheld digital multimeters only sample at 1,000 times per a second and digital multimeters also average the value of the signal you are viewing. Digital oscilloscopes sample at more than 1,000,000 times per second.

This means digital oscilloscopes are typically more than 100,000 times faster than scan tools and more than 1,000 times faster than DMMs.

There are many examples of vehicle signals that voltmeters and scan tools are unable to see. There are many vehicle problems that can occur that really require a scope to diagnose accurately. Trying to solve these problems with just voltmeters and scan tools would be like trying to diagnose a problem wearing a blindfold, you simply could not see.

Voltmeters average many samples together to display a composite value of the signal, and on AC signals they typically display what is referred to as the **RMS (Root Mean Square)** value of the signal.

A brief definition of RMS for a sine wave is - "the peak voltage of the sine wave multiplied by 0.707", this gives the equivalent DC voltage value that would be required to produce the same power through a fixed resistor.

(2-2)



Scan tools rely on what the vehicle computer sees - it too samples very slow (much slower than a voltmeter).

The vehicle computer uses a slow communication bus to talk to the scan tool, this further reduces it's ability to see glitches or transient events. Yet, a digital scope can typically sample signals at more than 1,000,000 times per second, or 1,000 times faster than a fast voltmeter. A scope can display the actual waveform being produced by a sensor or sent by a device.

Let's look at a simple example of electrical signal the power company sends to your home and the difference between what you would see on a voltmeter and a scope.

117 Volts

Figure 2-C: House Current Displayed on a Voltmeter

In the previous example, the voltmeter has taken the peak value of 165 volts and multiplied it by 0.707 to display 117 volts.

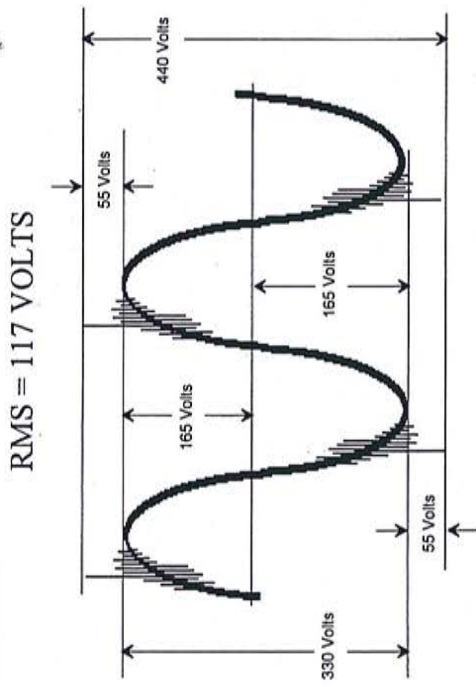


Figure 2-D: House Current Displayed on a Scope

As you can clearly see, the scope shows you a great deal more information than the voltmeter (notice the spikes).

The scope you buy today will work with past, present and future vehicle electronics. A typical signal from a fuel injector on a 1970 Volkswagen looks very similar to a 1990 Oldsmobile or 1993 Cummings diesel.

There are typically five types of signals you will find in vehicles. They are:

1. "**Fast repetitive signals**" - such as the signal output by a digital mass air flow sensor.
2. "**Slow repetitive signals**" - such as the control signal for a fuel injector.
3. "**AC signals riding on top of a DC voltage**" - such as the output of a vehicle speed sensor.
4. "**Slow changing voltage**" - such as the output voltage from an analog throttle position sensor.
5. "**Single shot or transient signal**" - such as those found on a park/neutral switch.

Once you become familiar with basic vehicle waveforms it will not matter how new or old the vehicle is, or even who manufactured the vehicle. You will be able to recognize signals that do not look right.

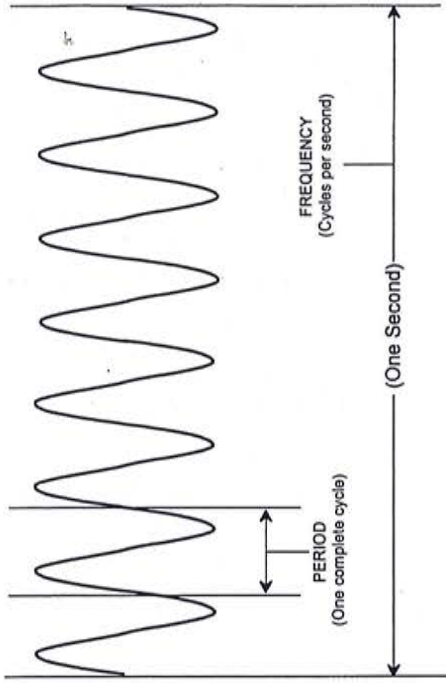
Waveforms are graphical representations of a voltage or current level moving up and down on a vertical or Y axis and displayed over time, from left to right, on a horizontal or X axis. Waveforms allow us to see exactly what is happening to a voltage or current level at a particular moment in time.

A straight diagonal line pointing up from left to right would indicate an increasing voltage or current, where as a straight diagonal line pointing down from left to right would indicate a decreasing voltage or current. This is the type of signal you would expect to see if you placed your scope leads across the terminals of an analog throttle position sensor. As you opened the throttle you would see the voltage increase, and as you closed the throttle you would see the voltage decrease. If you see a sharp angle up or down this would indicate a sudden change in current or voltage.



This is the type of signal you would expect to see if you placed your scope leads across the primary ignition terminals going into a coil. As the coil voltage is cycled on and off you would see sharp edges that would indicate sudden changes in current and voltage.

Waveforms represent a voltage or current level, which is referred to as amplitude, moving up and down on a vertical axis and displayed over time, from left to right, on a horizontal axis. If a waveform is repetitive, like a sine wave, we can measure its frequency and period. The frequency, which is measured in **Hertz (Hz)** or **Cycles Per Second (CPS)**, refers to the number of times a signal repeats itself in one second. The period is measured in time and refers to the amount of time it takes for a waveform to complete one cycle. As an example, in the United States, the power company supplies power to your home that has a frequency of 60 Hz. This means that the waveform repeats itself sixty times per second. The period of this waveform would be  $1/60$  of a second or 16.7 milliseconds or 0.0167 seconds, this is the amount of time it takes to complete one cycle.



**Figure 2-E: Waveform Frequency and Period**

*(Note: The LS2000 will automatically display the frequency of any signal on channel one that is properly triggered and has at least one complete cycle being displayed on the scope. To calculate the period of the signal displayed you can take the reciprocal of the frequency or use the time cursors provided on the LS2000 and measure one complete cycle.)*

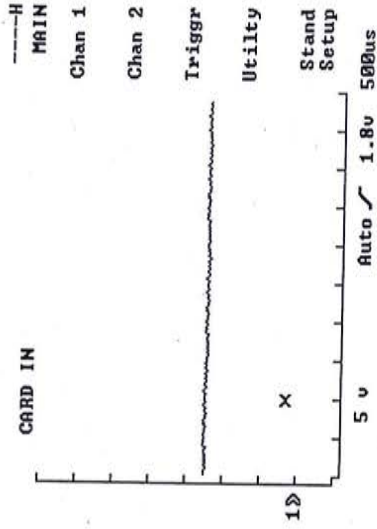
## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

In the next few pages, we will review several of the most common types of waveforms you are likely to encounter in today's vehicles. Such as constant voltage waveforms, slow changing waveforms, square waves, pulse width modulated waveforms, step waveforms and sine waves.

Waveforms that are produced by the various sensors and monitored by the vehicle's on-board computer must stay within certain boundaries or have certain characteristics that it will recognize to allow the automobile to function as designed. Waveforms that go outside these boundaries can confuse the vehicle's computer and cause drivability problems or basic malfunction of certain systems.

On a **D**igital **S**torage **O**scilloscope (**DSO**) a constant DC voltage will appear as a flat horizontal line displayed across the screen. The amplitude of the DC voltage can be measured with a DSO by selecting GND (ground) coupling, setting the displayed trace to one of the lower horizontal graticule lines and then selecting DC coupling. At a vertical volts/division setting of 5 volts per division, a 12 volt DC signal will move approximately 2 1/2 divisions up above the selected GND (ground) reference line on screen.

*(Note: On the LS2000 you can use the voltage cursors to easily measure the voltage level of a constant DC voltage.)*



**Figure 2-F: Battery Voltage**

Most constant DC voltage waveforms found in automobile systems are used as the main power supply to electronic control modules and sensors. In order for these components to perform correctly they must have a supply voltage (typically 12-15 volts) and a good return path (ground).

A DSO can be used to monitor the DC supply voltage or ground connections while looking for any intermittent shorts or open circuits.

Slowly changing DC voltage waveforms are found in analog (continuous) output sensors and components. These sensors and components produce a slowly changing voltage in response to some stimulus (heat, air flow, throttle movement, exhaust oxygen content, engine vacuum etc.). **Manifold Absolute Pressure (MAP)** sensors, **Throttle Position Sensors (TPS)**, **Oxygen (O<sub>2</sub>)** sensors, analog **Mass Air Flow (MAF)** sensors (vane type and some hot wire), **Coolant Temperature Sensors (CTS)** are all examples of sensors that output a slowly changing DC voltage.

The DSO can be used at slower horizontal time base settings (0.1 seconds or slower) to view these slowly changing DC waveforms. When viewing slowly changing waveforms the most important characteristic is it's vertical amplitude or voltage and whether the voltage changes within certain boundaries.

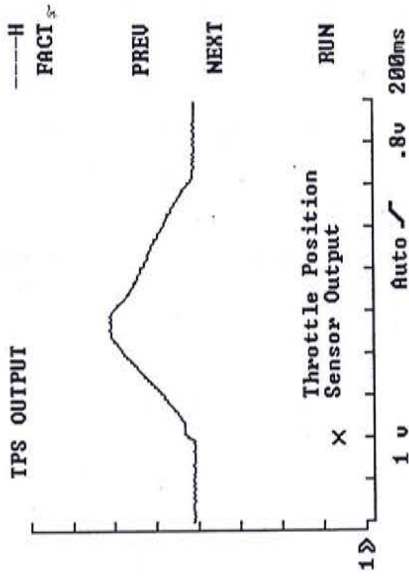


Figure 2-G: Analog Throttle Position Sensor

Square waveforms are produced by an electronic circuit that repeatedly turns a DC voltage on and off. The percentage of "On-time" and the "Off-time" remains the same even as the frequency changes.

Digital MAF sensors, Hall effect and optical crankshaft and camshaft position sensors, ignition reference waveforms, are all examples of square waveforms. These sensors output square waveforms that typically increase in frequency as the engine RPM or load increases.

Some important characteristics of square waveforms are their on and off vertical voltage amplitude, how many on and off cycles occur per second (frequency in Hertz), and their shape (clean and symmetrical).

Some square waves modulated pulse widths and are called **Pulse Width Modulated** or (**PWM**) waveforms. These waveforms have changing or modulated pulse widths.

Examples of PWM square waveforms can be found in mixture control solenoids, canister purge solenoids, idle air control solenoids, fuel injector waveforms, Electronic Spark Timing (**EST**) waveforms, blower motor speed control waveforms, transmission shift control solenoids, ignition coil primary waveforms, and even some electric fuel pump control waveforms.

Some important characteristics of a PWM waveform are it's vertical voltage amplitude, on-time and off-time (duty cycle), shape and whether the duty cycle changes as required by changing engine loads or speed.

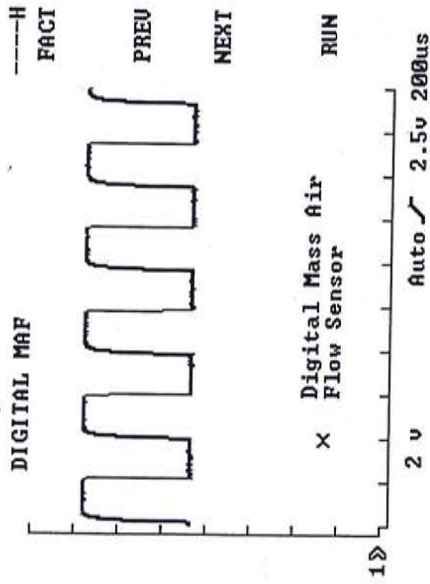


Figure 2-H: Digital Mass Air Flow Sensor Output

# LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

PWM waveforms have on and off times that change frequently to regulate the average amount of voltage to a device.

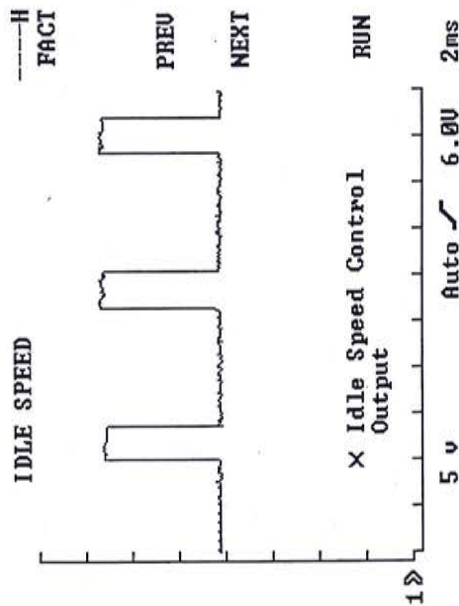


Figure 2-I: Idle Speed Control Signal

Step voltage waveforms can be found at the park/neutral switch as the selector is changed from park to drive or reverse.

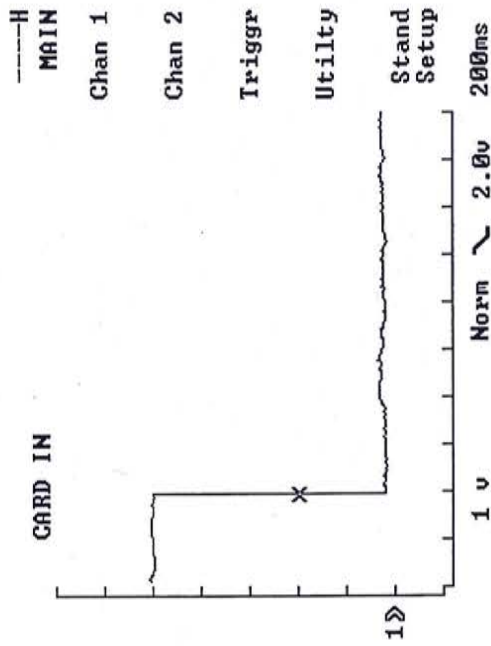


Figure 2-J: Park/Neutral Switch

Sine waves are AC voltage waveforms that have voltage levels above and below a DC voltage reference level. When displaying sine waves, set the DC GND (ground) reference line to the center horizontal graticule line. Then set the AC input coupling to block out the DC voltage and view the signal above and below the reference line.

Some important characteristics of the sine waves are their peak-to-peak voltage amplitude, the time duration of the signal (period or frequency) and the appearance or shape of the waveform.

*(Note: The LS2000 voltage cursors are especially useful when measuring a peak-to-peak voltage amplitude. Place one voltage cursor on the top of the waveform and the other at the bottom of the waveform, the readout in the upper right corner of the display will show the peak-to-peak voltage.)*

Sine waves are produced by Anti-Lock Brake System (ABS) magnetic wheel speed sensors, magnetic vehicle speed sensors, and by the charging system alternator.

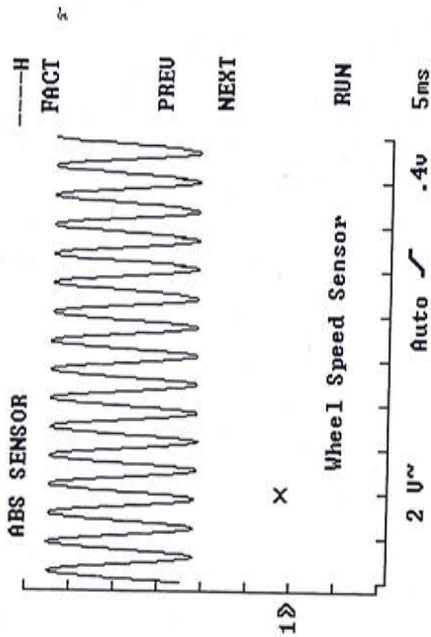


Figure 2-K: ABS Sensor Output

**Chapter 3 - Oscilloscope Basics**

The oscilloscope is basically a graph-displaying device, that draws a graph of an electrical signal. In most applications the graph shows how signals change over time: the vertical axis represents voltage and the horizontal axis represents time. This simple graph can tell you many things about a signal. Here are just a few:

- You can find out how much of a signal is direct current (DC) or alternating current (AC).
- You can tell how much of the signal is noise and whether the noise is changing with time.
- You can compare known "Good" waveforms with "Live" waveforms.

- You can determine the time and voltage values of a signal.
- You can calculate the frequency of an oscillating signal.
- You can see the "moving parts" of a circuit represented by the signal.
- You can tell if a malfunctioning component is distorting the signal.

**Analog and Digital Oscilloscopes**

Oscilloscopes can be divided into two types: analog and digital. Analog oscilloscopes directly display continuously variable signals, while digital oscilloscopes convert these signals to discrete binary data that digitally represent the signal being acquired. An example of this is, a conventional phonograph turntable is an analog device, directly converting the record grooves into sound, on the other hand a compact disc player is a digital device, that takes discrete binary data and converts it to sound.

An analog oscilloscope works by directly applying a voltage being measured to an electron beam moving across the oscilloscope screen. The voltage deflects the beam up and down proportionally, tracing the waveform on the screen. In contrast, a digital oscilloscope samples the waveform and uses an Analog-to-Digital Converter (ADC) to convert the voltage being measured into digital information. It then uses this digital information to reconstruct the waveform on the screen.

Each type of oscilloscope does possess some unique characteristics making it more or less suitable for specific tasks. For instance, analog oscilloscopes can display rapidly varying signals in "real time" (or as they occur). However, they can not capture and store signals for analysis and comparison, like digital oscilloscopes.

Digital oscilloscopes even allow you to capture and view events that may happen only once. Also, they can process the digital waveform data and display it or send the data to a computer for processing.

Since they can store the digital waveform data in memory or on a computer this allows viewing and printing at a later time, next week or even next year.

To better understand the oscilloscope controls, you need to know a little more about how oscilloscopes display a signal. Analog oscilloscopes work somewhat differently than digital oscilloscopes. However, several of the internal systems are similar. Analog oscilloscopes are somewhat simpler in concept.

When you connect an oscilloscope probe to a circuit, the voltage signal travels through the probe to the vertical system of the oscilloscope. Depending on how you set the vertical scale (volts/div control), an attenuator reduces the signal voltage or an amplifier increases the signal voltage.

Next, the signal travels directly to the vertical deflection plates of the Cathode Ray Tube (CRT). Voltage applied to these deflection plates causes a glowing dot to move. (An electron beam hitting phosphor inside the CRT creates the glowing dot.)





## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

A positive voltage causes the dot to move up while a negative voltage causes the dot to move down.

The signal also travels to the trigger system to start or trigger a "horizontal sweep." Horizontal sweep is a term referring to the action of the horizontal system causing the glowing dot to move across the screen. Triggering the horizontal system causes the horizontal time base to move the glowing dot across the screen from left to right within a specific time interval. Many sweeps in rapid sequence cause the movement of the glowing dot to blend into a solid line. At higher speeds, the dot may sweep across the screen up to 500,000 times each second.

Together, the horizontal sweeping action and the vertical deflection action traces a graph of the signal on the screen. The trigger is necessary to stabilize a repeating signal. It ensures that the sweep begins at the same point of a repeating signal, resulting in a clear picture.

In order to use an analog or digital oscilloscope, you need to adjust three basic settings to accommodate an incoming signal:

- 1) The attenuation or amplification of the signal. Use the volts/div control to adjust the amplitude of the signal before it is displayed on the screen.
- 2) The time base. Use the sec/div control to set the amount of time per division represented horizontally across the screen.
- 3) The triggering of the oscilloscope. Use the trigger level to stabilize a repeating signal, as well as triggering on a single event.

Also, adjusting the focus and intensity controls will help you to create a sharp, visible display on analog scopes

Digital oscilloscopes contain additional data processing and acquisition systems, not available on analog scopes. The digital oscilloscope first collects data for the entire waveform and then displays it.

When you connect a probe to a circuit, the vertical system adjusts the amplitude of the signal, just as in the analog oscilloscope.

Next, the ADC in the acquisition system samples the signal at discrete points in time and converts the signal's voltage at these points to digital values called "sample points". The horizontal system's sample clock determines how often the ADC takes a sample. The rate at which the clock "ticks" is called the "sample rate" and is measured in "samples per second". Then the sample points from the ADC are stored in memory as waveform points.

Together, the sampled points make up one waveform record. The number of waveform points used to make a waveform record is called the "record length".

*(Note: The LS2000 runs at a sample rate of up to 5 million samples per second. In most cases, more than one sample point will make up one waveform point. The LS2000 stores the highest and lowest sampled point. This prevents signal aliasing.)*

The trigger system determines the starting point of the record. The display receives these record points after being stored in memory.

As a reminder, on both digital and analog oscilloscopes, you need to adjust the vertical, horizontal and trigger settings to properly display a waveform.

#### Signal Probing with an Oscilloscope

The engine compartment of a running vehicle is a very unfriendly environment for automotive signals to live. Temperature extremes, dirt and corrosion, and electrical leaks, or "noise" from the high voltage pulses from a typical ignition system can produce interference that can contribute significantly to the cause of many driveability complaints.



Have you ever found that a car phone was the cause of a driveability complaint?

When you are probing components, sensors and circuits, be aware that the electrical "noise" from today's high output ignition systems can produce an **RF (Radio Frequency)** energy that is similar to a radio station. Since oscilloscopes are so sensitive, this interference can actually override the signals you are trying to capture and give you a false reading on the display.

To minimize this possible interference with the oscilloscope, try to remember these tips and suggestions:

- ◆ Most interference will be picked up by the oscilloscope test leads.
- A. Route the test leads away from all ignition wires and components whenever possible.

- B. With the potential for RF interference in the engine compartment, if possible, use the vehicle chassis as ground when connecting the oscilloscope test leads. In some cases the engine block can actually act as an antenna for the RF signals.
- C. Use the shortest test leads possible, since other test leads may act as an antenna and increase the potential for interference, especially at higher frequency levels that are found when probing near the vehicle's on-board computer.
- D. The test leads are a very important part of any oscilloscope. The test leads supplied with your LS2000 are designed to operate with signals up to 500 kHz, which is the rated bandwidth of the oscilloscope. Substituting other leads in both length and capability may alter the signals on your display.

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- ◆ Like the test leads, the oscilloscope can also pick up interference.

A. Because the circuits of an oscilloscope are so sensitive, and therefore powerful, do not place the oscilloscope directly on ignition wires or near high energy ignition components, like coil packs.

B. If you are using the AC or DC charger/adaptor to power the LS2000, keep the external power leads as far away from the engine and ignition as possible.

Learning a new skill often involves learning a new vocabulary. This idea holds true for learning how to use an oscilloscope. There are many terms to describe the types of measurements you can make with your oscilloscope. The following describes some of the most common measurement terms.

### Frequency and Period

If a signal repeats, it has a frequency. The frequency is measured in Hertz (Hz) and equals the number of times the signal repeats itself in one second (the cycles per second).

A repeating signal also has a period - this is the amount of time it takes the signal to complete one cycle. Frequency and period are reciprocals of each other, so that  $1/\text{period}$  equals the frequency and  $1/\text{frequency}$  equals the period. So, for example, if a certain sine wave has a frequency of 3 Hz, it will have a period of  $1/3$  second.

### Voltage

Voltage is the amount of electric potential (a kind of signal strength) between two points in a circuit. Usually one of these points is ground (zero volts) but not always. You may want to measure the voltage from the maximum peak to the minimum peak of a waveform, referred to as the peak-to-peak voltage. The word amplitude commonly refers to the maximum voltage of a signal measured from ground or zero volts.

### Phase

Phase is best explained by looking at a sine wave. Sine waves are based on circular motion and a circle has  $360^\circ$ . One cycle of a sine wave has  $360^\circ$ .

Using degrees, you can refer to the phase angle of a sine wave when you want to describe how much of the period has elapsed.

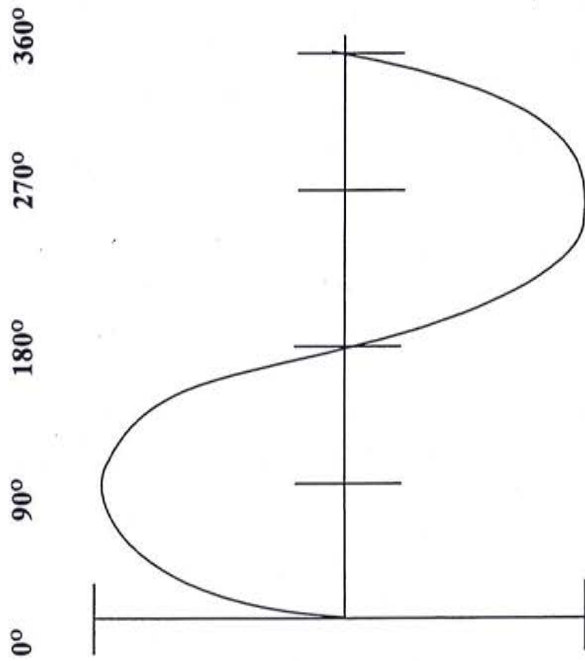


Figure 3-A: Phase of a Sine Wave in Degrees

**Phase Shift**

Phase shift describes the difference in timing between two otherwise similar signals, as shown below.

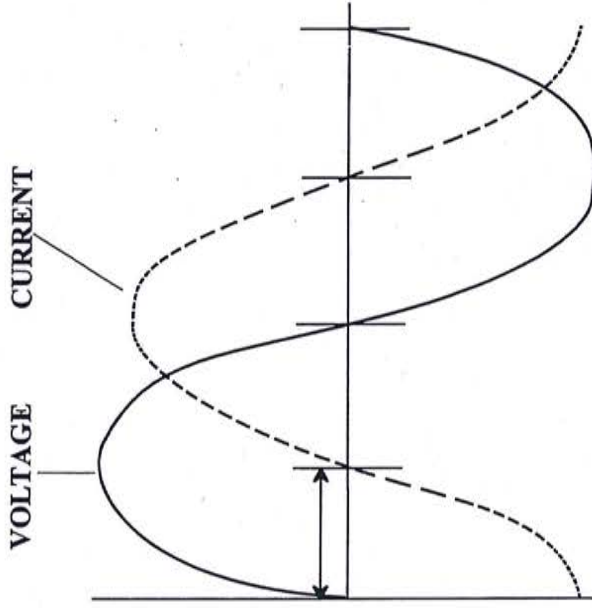


Figure 3-B: Phase Shift

(3-7)

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

For example, using a sine wave from a standard AC outlet, the "current" waveform is said to be  $90^\circ$  out of phase with the "voltage" waveform, since the sine waves reach similar points in their cycles exactly  $1/4$  of a cycle apart ( $360^\circ/4 = 90^\circ$ ). The voltage and current waveforms are said to have a  $90^\circ$  phase shift. Phase shifts are very common in electronics.

### Aliasing

Aliasing occurs when a digital oscilloscope does not take enough samples on a particular signal. After the oscilloscope reconstructs and displays the waveform you can be "fooled" into seeing a false waveform. The LS2000 uses Min/Max acquisition at all sweep speeds, this prevents the scope from aliasing a waveform. Aliasing can be a problem when viewing signals on oscilloscopes, since you never know when it is occurring, you can be "fooled" into seeing a false waveform.

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## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### Chapter 4 - LS2000 Features and Functions

#### Product Description

The LS2000 is a portable two channel digital oscilloscope designed expressly for use in the automotive service market. The main purpose of the LS2000 is to provide advanced troubleshooting capabilities for automotive service technicians in an easy to operate format. The LS2000 is capable of providing both amplitude and timing information on signals up to 500 kHz at a sampling rate of up to 5 megasamples per second.

An interchangeable memory card is provided for comparison to stored known good waveforms. Individual settings are also stored in the plug-in card along with waveform information. This way a technician can look up a known pattern in the card memory and have the scope set itself up for the measurement and at the same time display the good signal to compare. Easy to use cursors are available for making more precise voltage and timing measurements.

Power is supplied via an internal lead acid battery as well as an external adapter/charger.

An optional RS-232 adapter is also available for interfacing to a computer for mass waveform storage and to print the LS2000 display to a printer.

All automotive features are accessed by soft push buttons. In most cases, changes are indicated on the LCD screen in a position adjacent to the control.

To assist the operator there is a factory standard setup that always defaults to channel 1 only positioned to the center of the screen with DC coupling, auto-trigger with a trigger level of 2.5 volts, vertical set to 5 volts/division, horizontal set to 5 milliseconds/division and cursors turned off. All menus are only one level deep to avoid confusion during operation.

#### Theory of Operation

Two separate channels with a common ground are used for signal input. Signal conditioning consists of two attenuators with a bandwidth exceeding 500 kHz. The attenuators use an exclusive design that limits the number of mechanical relays to one per channel.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

The oscilloscope is controlled by a single M68HC11 microprocessor. The processor handles all of the internal housekeeping and display functions. The analog inputs are digitized at a rate of up to 5 megasamples per second and directed to a DSP-2105 digital signal processor which handles all signal processing and math manipulation. The Min/Max acquisition is used at all sweep speeds, this prevents the scope from aliasing a waveform.

Aliasing can be a problem when viewing signals on other digital oscilloscopes, since you never know when it is occurring, you can be "fooled" into seeing a false waveform, as mentioned earlier.

*(Note: Since the LS2000 was designed to be used by a wide variety of users, it was important to incorporate a design that would prevent aliasing. The LS2000 uses a digital sampling method call "Min/Max", this prevents aliasing from ever occurring.)*

The LCD display unit incorporates it's own internal display drivers and an electroluminescent backlight.

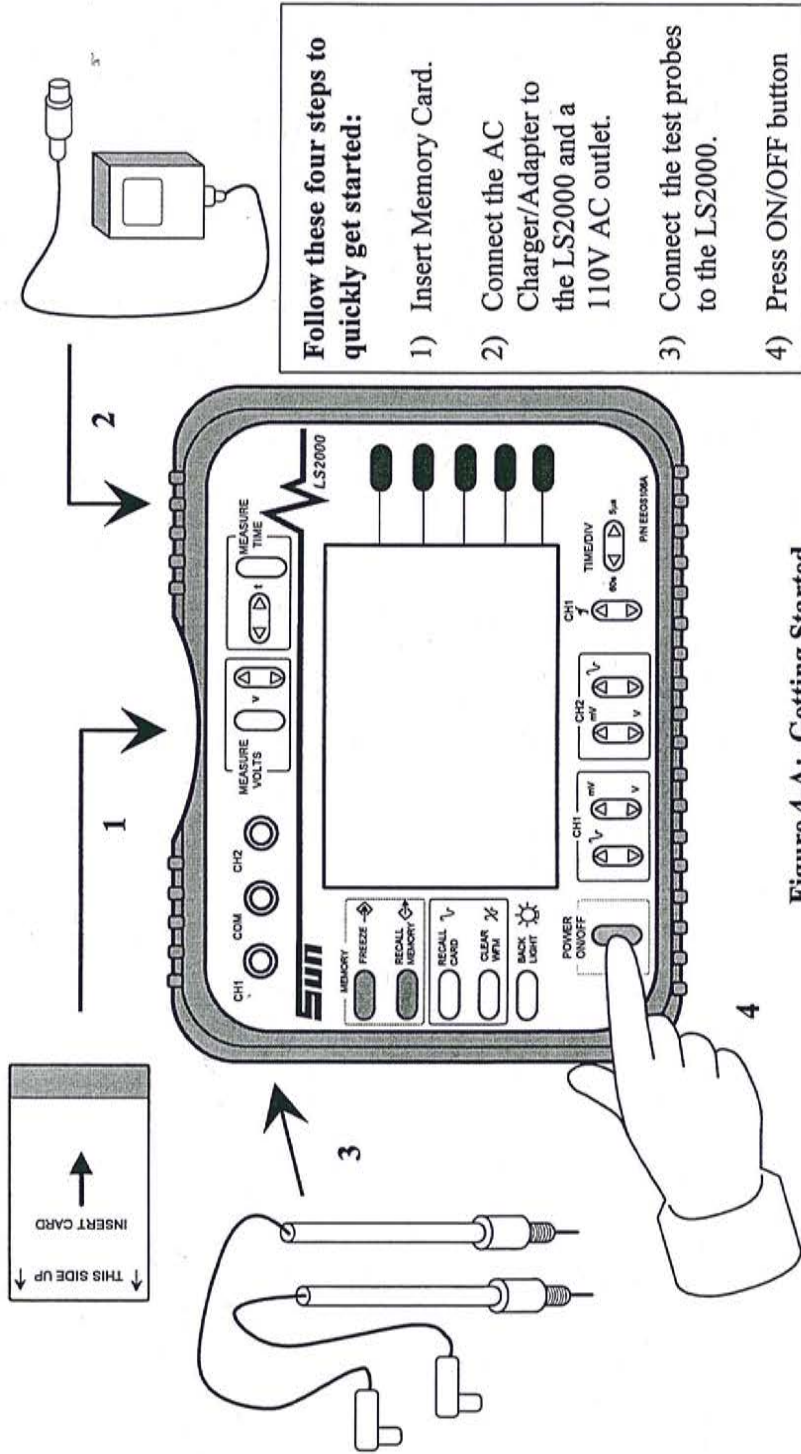
The operating system resides on an OTP (One Time Programmable) 128K memory plug-in card. On power-up, the processor checks the version of software that is resident on the card, if a later version is present, the oscilloscope will automatically be up-dated.

*(Note: Once the operating system is loaded from the card to internal memory the LS2000 will operate without the card as long as the internal battery is charged or connected to the external adapter. Attempting to recall a waveform from the card when it is not installed may also affect the operating system in memory.)*

**CAUTION - To be safe, you should always operate the scope with the card installed.**







Follow these four steps to quickly get started:

- 1) Insert Memory Card.
- 2) Connect the AC Charger/Adapter to the LS2000 and a 110V AC outlet.
- 3) Connect the test probes to the LS2000.
- 4) Press ON/OFF button

Figure 4-A: Getting Started

(4-3)

# LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

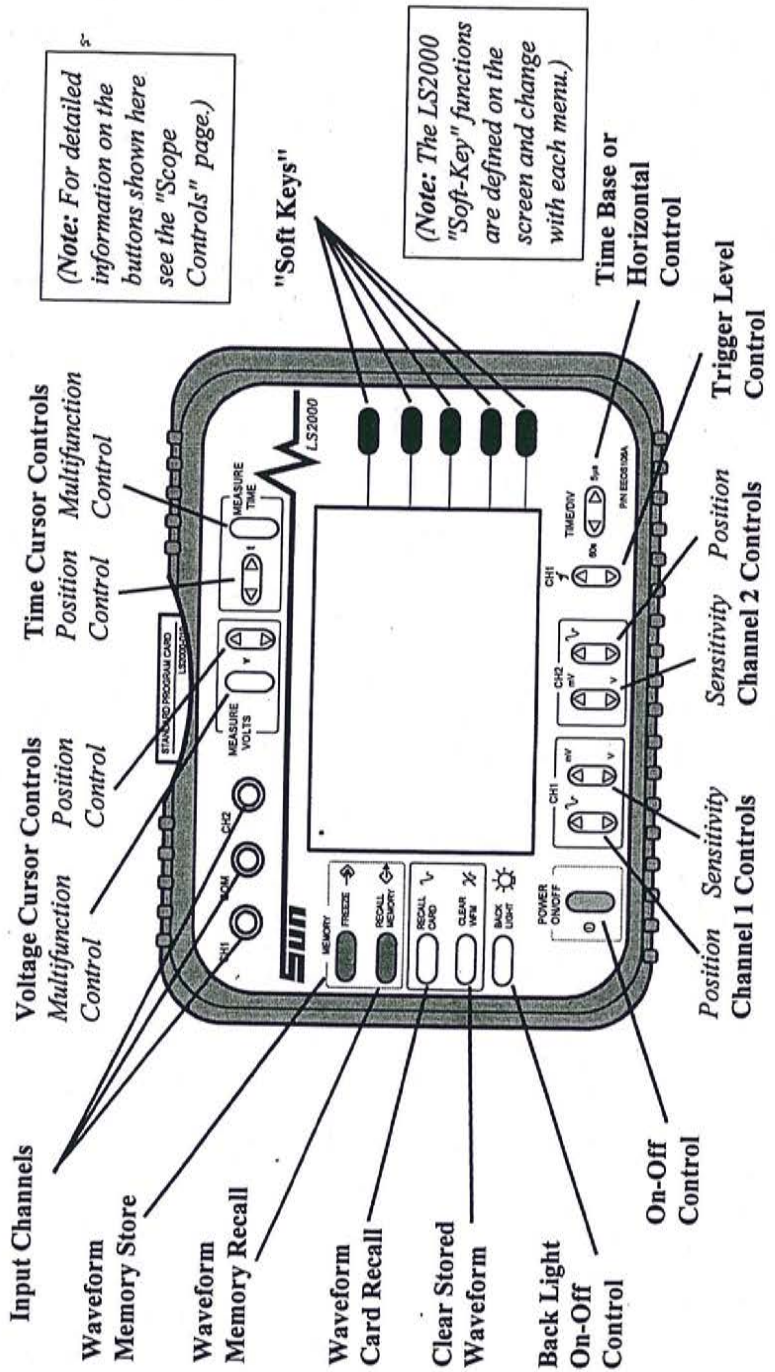


Figure 4-B: Front Panel Controls and Soft Keys

**SCOPE CONTROLS:**

**On-Off Control** - Green instrument power on-off button. Instrument goes through a self-test when first powered on, if no problems are found, the oscilloscope will power up in the last setup used.

**Channel 1 Controls**

**Sensitivity** - Controls the volts per division setting on channel one. Up increases sensitivity and down decreases.

**Position** - Controls the vertical position of the channel one trace on the display.

**Channel 2 Controls**

**Sensitivity** - Controls the volts per division setting on channel two. Up increases sensitivity and down decreases.

**Position** - Controls the vertical position of the channel two trace on the display.

**Trigger Level Control** - Sets the trigger level on channel one only.

**Time Base or Horizontal Control** - Sets the horizontal sweep speed from 60 seconds per division to 5 microseconds per division.

**Voltage Cursor Controls**

**Multifunction Control** - Turns the voltage cursors on and off and toggles to each cursor.

**Position Control** - Controls the vertical position of the voltage cursors on the display.

**Time Cursor Controls**

**Multifunction Control** - Turns the time cursors on and off and toggles to each cursor.

**Position Control** - Controls the horizontal position of the time cursors on the display.

**Input Channels** - The red inputs for channel one and two are the high inputs and the black input is the common or low input for both channels.

**SCOPE CONTROLS (continued):**

*(Note: Since this scope is considered to be "floating" - that is, it is not connected to a ground - in order to properly make measurements that are referenced to ground, you must physically connect the common input to ground.)*

**Waveform Memory Store** - Captures live waveforms on the screen for storage in one of four locations.

**Waveform Memory Recall** - Recalls stored waveforms and front panel setups from one of four locations.

**Waveform Card Recall** - Recalls waveforms and front panel setups stored on the memory card.

**Clear Stored Waveform** - Removes the stored waveform from the display and returns the scope to normal operation.

**Back Light On-Off Control** - Toggles the backlight on and off for use in low level or difficult lighting conditions.

*(Note: Turning on the backlight increases battery power consumption to a very high level. If the LS2000 is going to be used for more than 30 minutes at a time, external power is recommended.)*

**Frequency Readout** - The frequency of channel one is always displayed in the upper right corner of the display.

*(Note: The frequency will only be displayed if at least one complete cycle is displayed on the screen and the scope is properly triggered. The signal must be less than 500 kHz. If the frequency is not available, -----H will appear on the display.)*

**"Soft Keys"** - These keys are menu driven. The functions of these keys are determined by the menu selected and are defined on the right side of the screen.



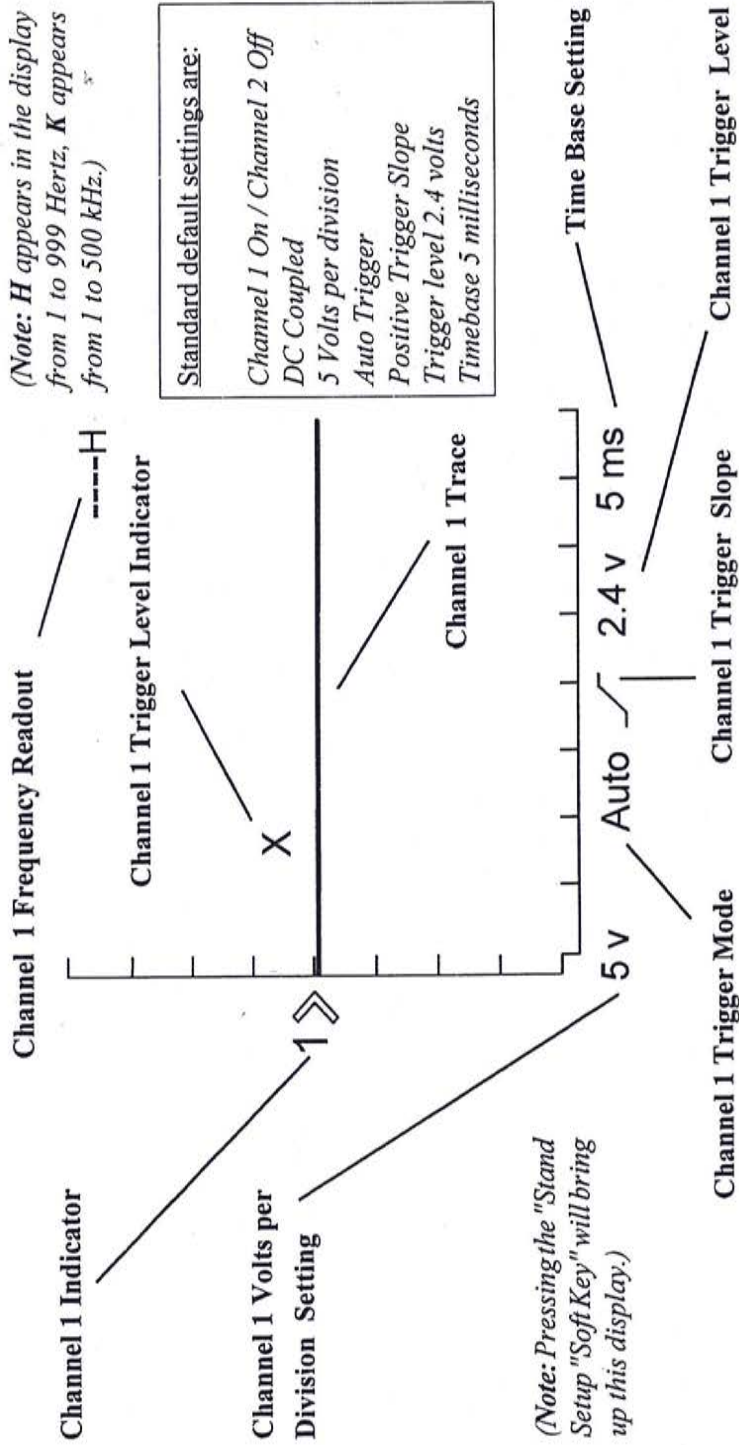


Figure 4-C: Oscilloscope Display Layout

(4-7)

LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

**MAIN - Main menu.**  
**Chan 1 - Selects input signal coupling for Channel 1.**  
**Chan 2 - Turns ON or OFF Channel 2 and selects input signal coupling.**  
**Triggr - Selects trigger mode and slope.**  
**Utility - Allows access to contrast control and interface functions for printer and computer.**  
**Stand Setup - Returns the oscilloscope to a setup that is predetermined.**

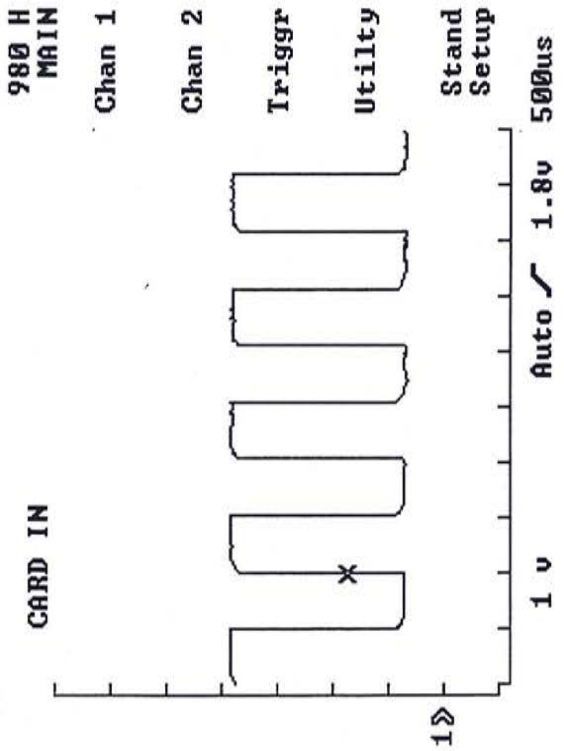
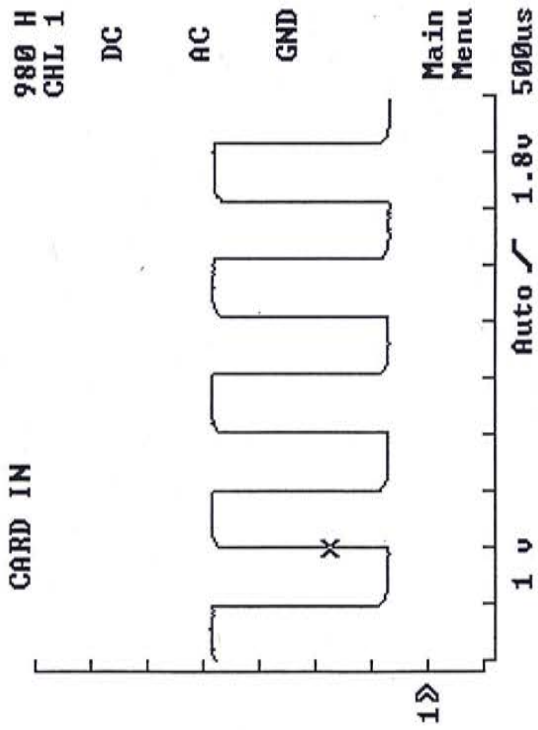


Figure 4-D Main Menu

(4-8)





**CHL 1 - Channel 1 menu.**

**DC - DC coupling allows the DC component of the signal to be included on the oscilloscope display.**

**AC - AC coupling removes the DC component of the input signal.**

**GND - Grounds the input of the scope internally.**

**Main Menu - Returns oscilloscope to the Main Menu.**

Figure 4-E: Channel 1 Menu

(4-9)

LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

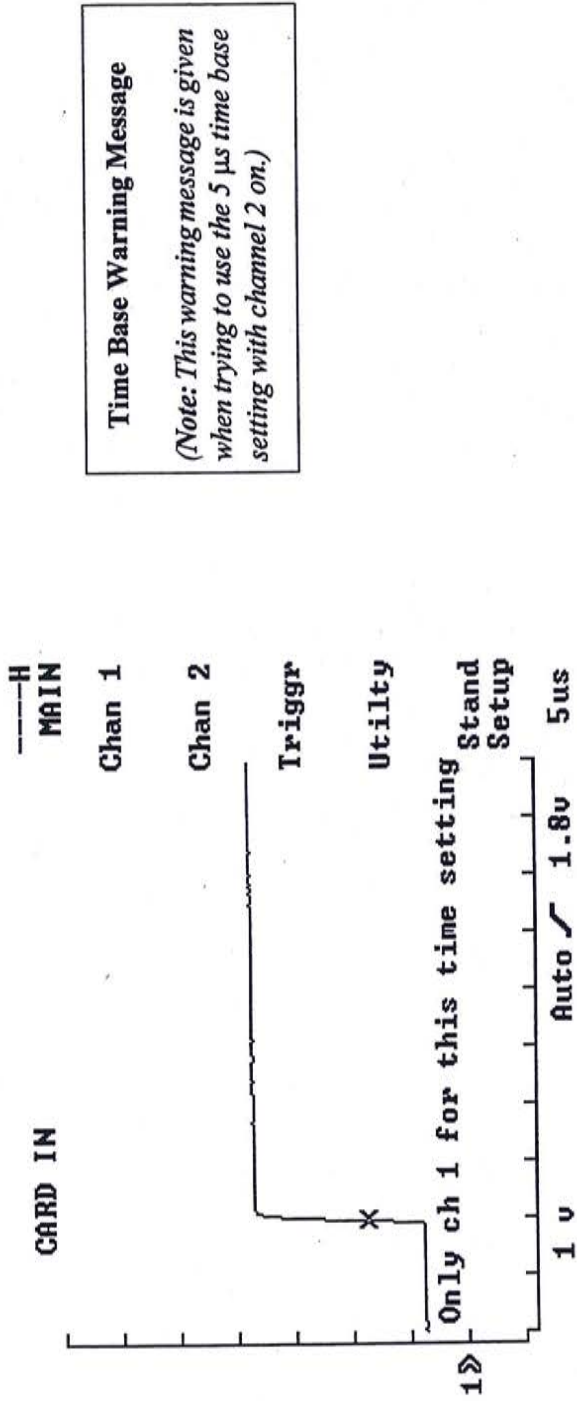


Figure 4-F: Time Base Warning Message

(4-10)



CHL 2 - Channel 2 menu.  
 DC - DC coupling allows the DC component of the signal to be included on the oscilloscope display.  
 AC - AC coupling removes the DC component of the input signal.  
 GND - Grounds the input of the scope internally.  
 OFF - Turns off only channel 2.  
 Main Menu - Returns oscilloscope to the Main Menu.

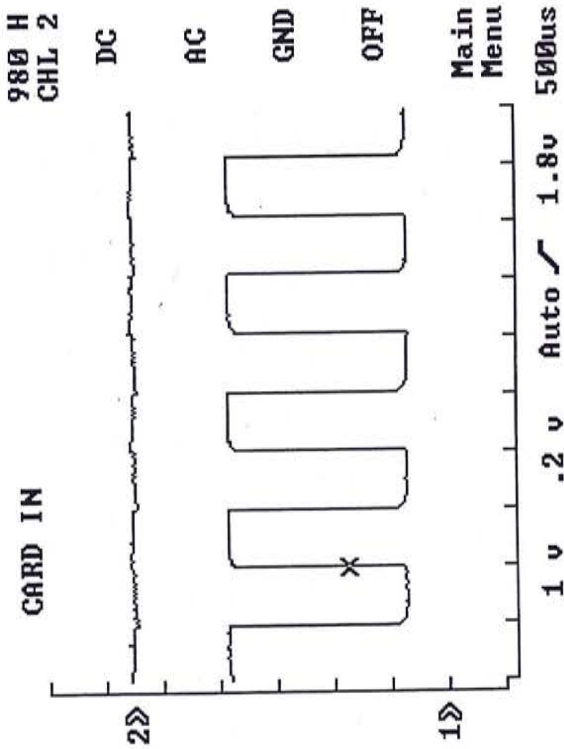
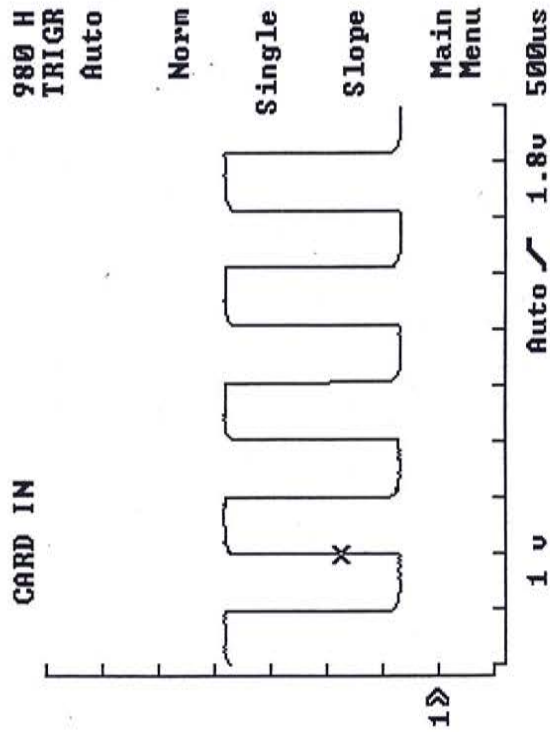


Figure 4-G: Channel 2 Menu

(4-11)

LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS



**TRIGR** - Trigger menu.

**Auto** - Looks for a trigger signal, if one is not present the oscilloscope will free run.

**Norm** - In this trigger mode the oscilloscope will not display a trace until a trigger occurs.

*(Note: The horizontal trigger position is fixed at two divisions from the left. The vertical trigger level can be adjusted using the CHI trigger level button.)*

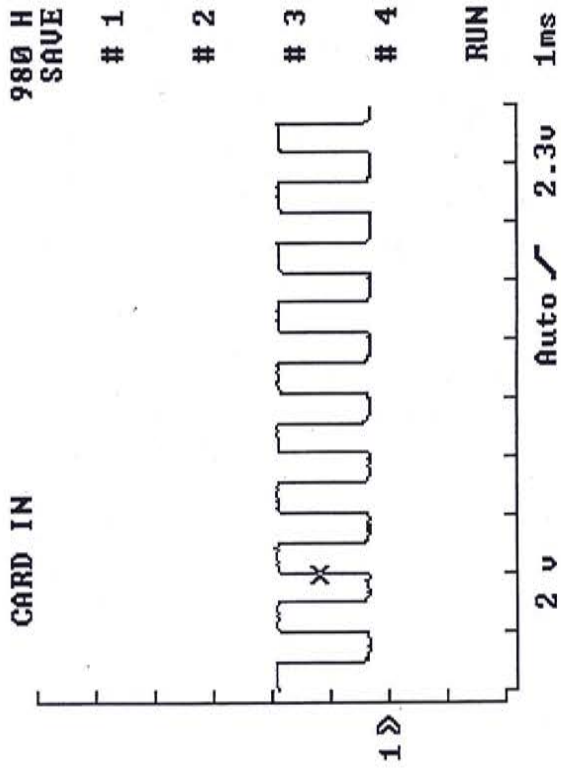
**Single** - Triggers the oscilloscope once each time it is pressed.

**Slope** - Changes the trigger from the positive  $\nearrow$  to the negative  $\searrow$  slope of the signal. Pressing it again, toggles it back.

**Main Menu** - Returns oscilloscope to the main menu.

Figure 4-H: Trigger Menu

(4-12)



**SAVE - Freeze menu.**

**#1 to # 4 - Allows you to store a waveform in memory locations 1 to 4.**

**(Note: The LS2000 also stores the front panel setup with the waveform. To clear a stored location, you can write over the location with another waveform and front panel settings.)**

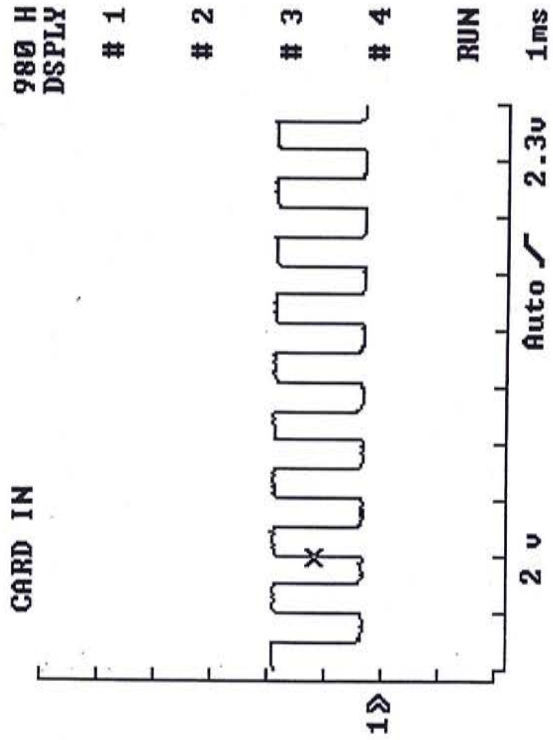
**RUN - Returns the oscilloscope to the Main Menu.**

**(Note: Freezing a waveform will not store the frequency value. However, you can calculate the frequency by using the time cursors and calculating the reciprocal.)**

Figure 4-1: Freeze Menu

(4-13)

LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS



DSPLY - Recall memory menu.

#1 to # 4 - Allows you to recall a stored waveform from memory location 1 to 4.

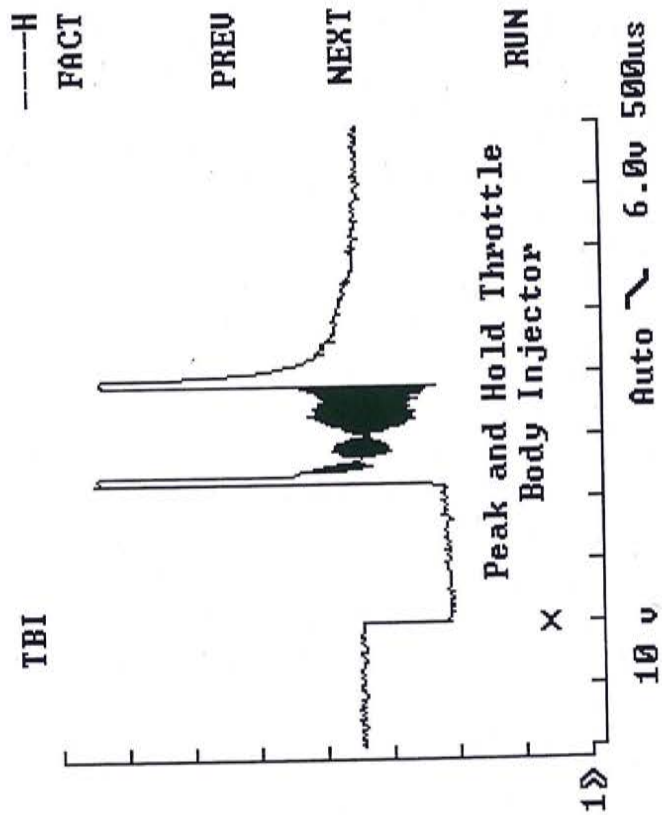
(Note: The LS2000 also recalls the front panel setup that was stored with the waveform.)

RUN - Returns the oscilloscope to the Main Menu and continues to display the stored waveform for comparison to a live waveform.

Figure 4-J: Recall Memory Menu

(4-14)





**FACT** - Factory stored waveform menu.

**PREV** - Recalls the previous reference waveform stored on the memory card. Repeatedly pressing this button scrolls to each previous consecutive stored waveform.

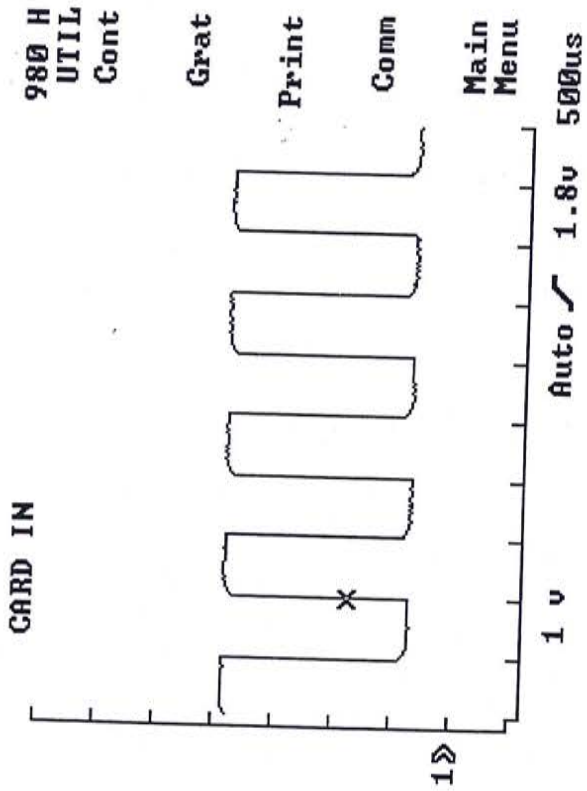
**NEXT** - Advances to the next reference waveform stored on the memory card. Repeatedly pressing this button scrolls to each next consecutive stored waveform.

**RUN** - Returns the oscilloscope to the Main Menu and continues to display the stored waveform for comparison to a live waveform.

Figure 4-K: Recall Card Menu

(4-15)

LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS



UTIL - Utility menu.

Cont - The contrast control scrolls through several levels of adjustment to compensate for glare or varying levels of light.

Grat - Displays a dot type graticule.

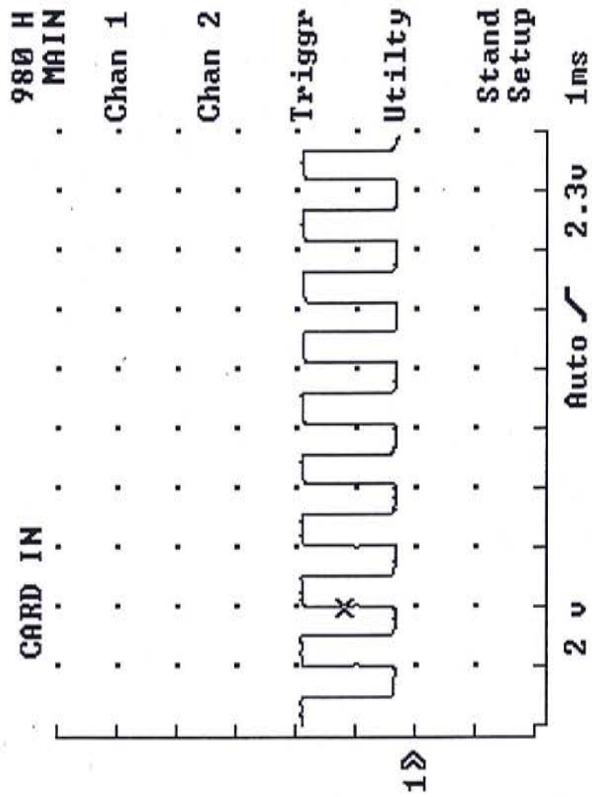
Print - Allows you to print the display directly to any Epson compatible printer. (Note: This requires an optional RS-232 interconnect cable and software.)

Comm - Begins communication with a computer via the RS-232 interface. (Note: This requires an optional RS-232 interconnect cable and software.)

Main Menu - Returns oscilloscope to the Main Menu.

Figure 4-L: Utility Menu

(4-16)

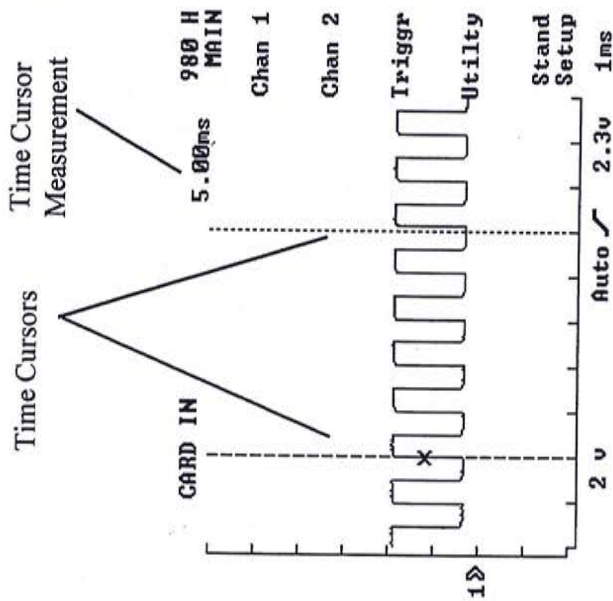


Shown to the left, is the display graticule that is accessed through the Utility menu. The "Grat" button displays a dot type graticule to assist in making visual voltage and timing measurements. The distance between adjacent dots is one division.

The graticule also allows you to easily compare waveforms between channel 1 and channel 2 and stored waveforms for timing and voltage differences.

Figure 4-M: Graticule Display

(4-17)



### Using the Time Cursors

When a signal is displayed, follow these steps to make a timing measurement:

1. Press the cursor toggle button to turn on the time cursors.
2. Press the cursor movement button to position the first reference line.
3. Press the cursor toggle button to select the other reference line.
4. Press the cursor movement button to position the other reference line.
5. Read the time between the cursors in the upper right corner.
6. Press the cursor toggle button again to turn off the cursors.

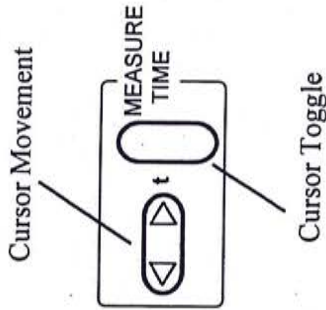
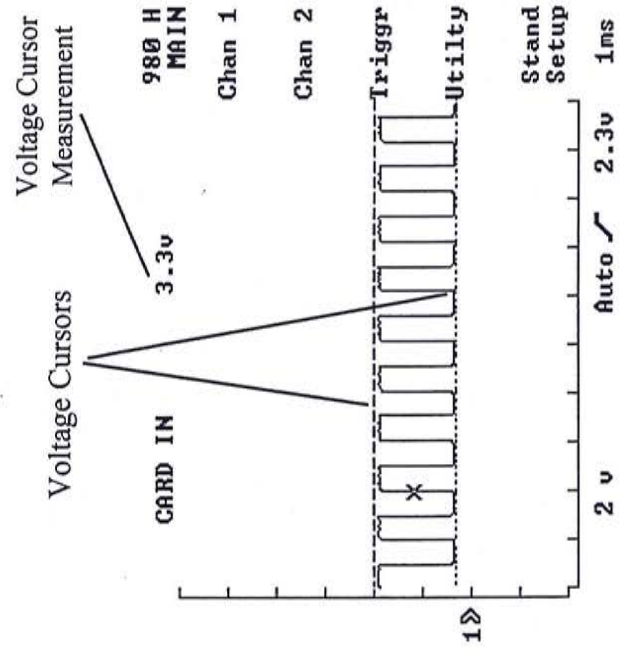


Figure 4-N: Time Cursors

(4-18)

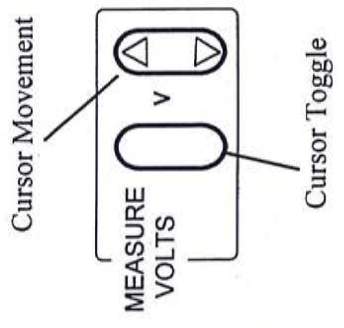




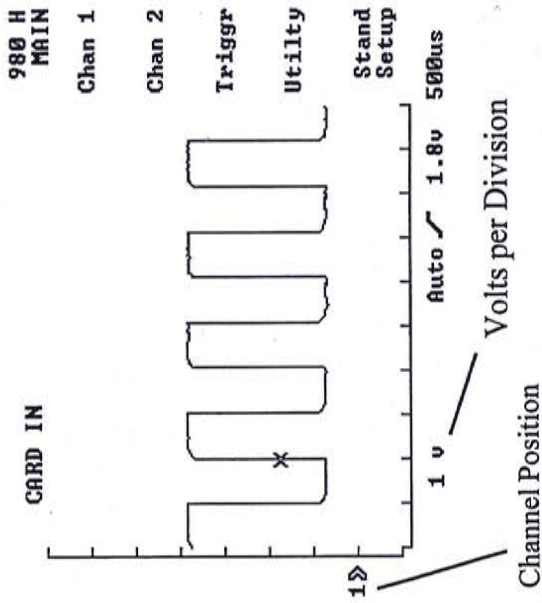
**Using the Voltage Cursors**

When a signal is displayed, follow these steps to make a voltage measurement:

1. Press the cursor toggle button to turn on the time cursors.
2. Press the cursor movement button to position the first reference line.
3. Press the cursor toggle button to select the other reference line.
4. Press the cursor movement button to position the other reference line.
5. Read the volts between the cursors in the upper right corner.
6. Press the cursor toggle button again to turn off the cursors.



**Figure 4-0: Voltage Cursors**  
(4-19)



(Note: Increasing the volts/div on the display makes the signal appear smaller, decreasing the volts/div on the display makes the signal appear larger.)

**Changing Volts/Div & Position**

Follow these steps to change the volts/div and the position, using a live, repetitive waveform:

1. To increase the volts/div on channel 1 press the bottom of the volts/div button.
2. To decrease the volts/div on channel 1 press the top of the volts/div button.
3. To position the channel 1 waveform up on the screen, press the top of the channel 1 position button.

4. To position the channel 1 waveform down on the screen, press the bottom of the channel 1 position button.

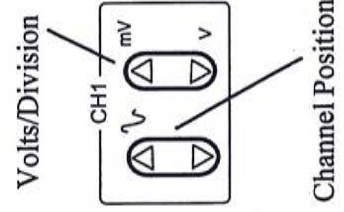
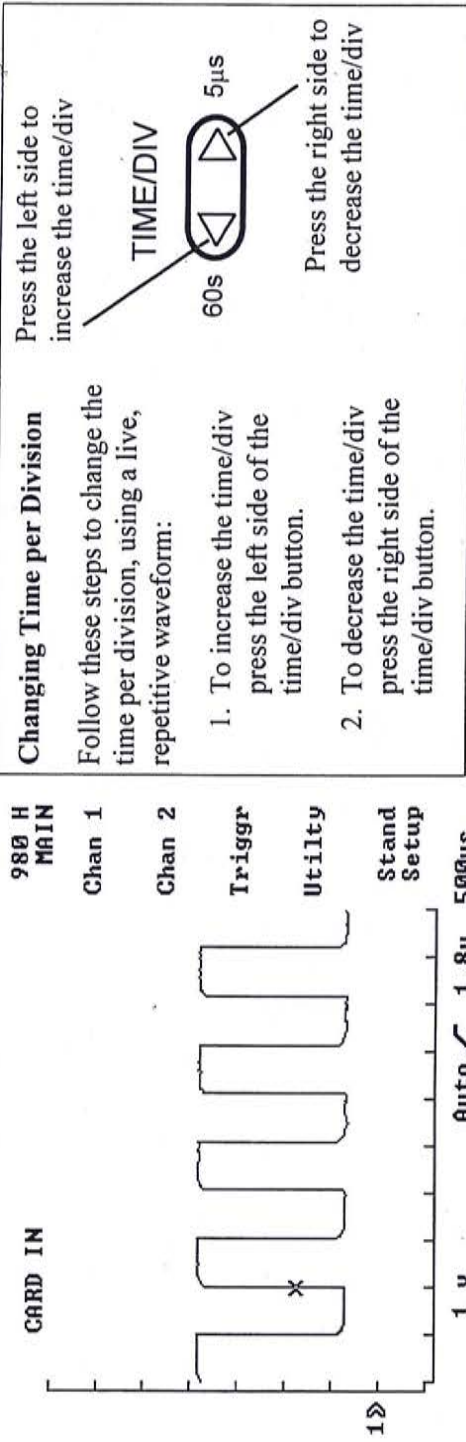


Figure 4-P: Changing Volts/Div and Position

(4-20)

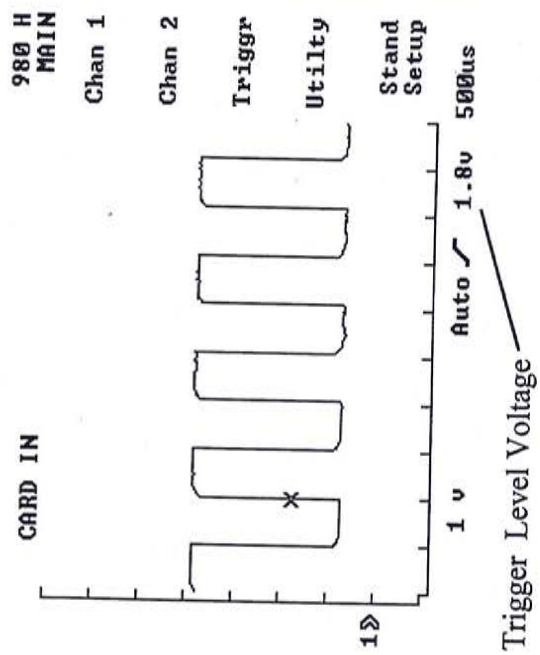




*(Note: Increasing the time per division will appear to compress the displayed waveform on the screen, decreasing the time per division will appear to expand the displayed waveform on the screen.)*

**Figure 4-Q: Changing Time/Div**

(4-21)



**Changing the Trigger**

Follow these steps to change the trigger level, using a live, repetitive waveform:

1. To increase the trigger level, press the top of the trigger level button.
2. To decrease the trigger level, press the bottom of the trigger level button.

Press the top to increase the Trigger Level

CH1

Press the bottom to decrease the Trigger Level

Figure 4-R: Changing Trigger Level

(4-22)



## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### Chapter 5 - Automotive Diagnostics & Applications

How and where you hook up to sensors and signals in the vehicle is important. You should never pierce any wire insulation, strip insulation away or break a weather pack seal. The best way to view vehicle signals is to use a recommended or approved breakout box. The next best approach is to use an old wiring harness to make your own breakout leads. Once you have made a good connection, it is important to check that all leads and cables are away from hot surfaces, belts, fans, moving parts and secondary ignition wires. Remember that connections can move around after the engine is started. A poor signal or one that disappears, could be bad due to a poor connection.

It is important that you only use probes that are recommended as an option or supplied with your LS2000. Using probes that are not recommended for use could seriously distort the measurement you are making and may even damage the LS2000 or the circuit or sensor that is connected. When probing certain sensors, like an O<sub>2</sub> sensor, you should never short the output of the O<sub>2</sub> sensor or load them down.

In this next section we will explore a number of common waveform shapes from various vehicle manufacturers with oscilloscope set-ups. These waveforms represent typical signals from actual automotive outputs.

Signals that you acquire from similar vehicles may appear different. These waveform shapes and oscilloscope set-ups will give you a quick working knowledge of how to set-up your LS2000 for various automotive signal types you will encounter.

The good news is that all of these waveforms and front panel control settings are pre-programmed into the memory card on the LS2000. This makes the LS2000 extremely easy to use for diagnosing the most common driveability problems.

On the following pages you will find an easy to follow format for using these pre-programmed waveforms.

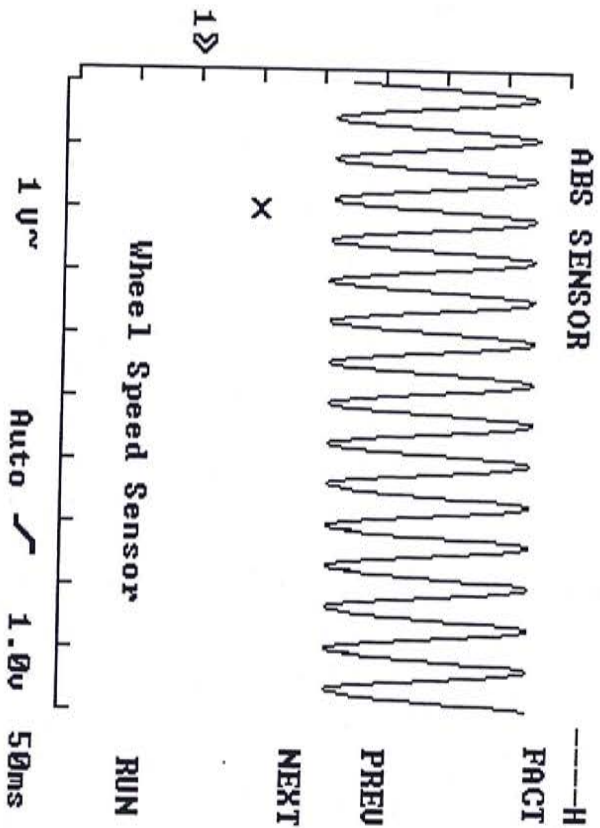


Figure 5-A: ABS Wheel Speed Sensor

(5-2)

**Testing a Wheel Speed Sensor**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red and Black test leads to the output of a wheel speed sensor.
5. Press the Recall Card button on the LS2000.
6. Scroll through the stored waveforms by pressing the Next button until you find the ABS waveform.
7. Press the Run button and the LS2000 is ready to start displaying a signal.

*(Note: You can road test the vehicle with someone else driving while you observe the scope display; or you can put the vehicle up on a floor jack and spin the wheel by hand, with out the engine running.)*

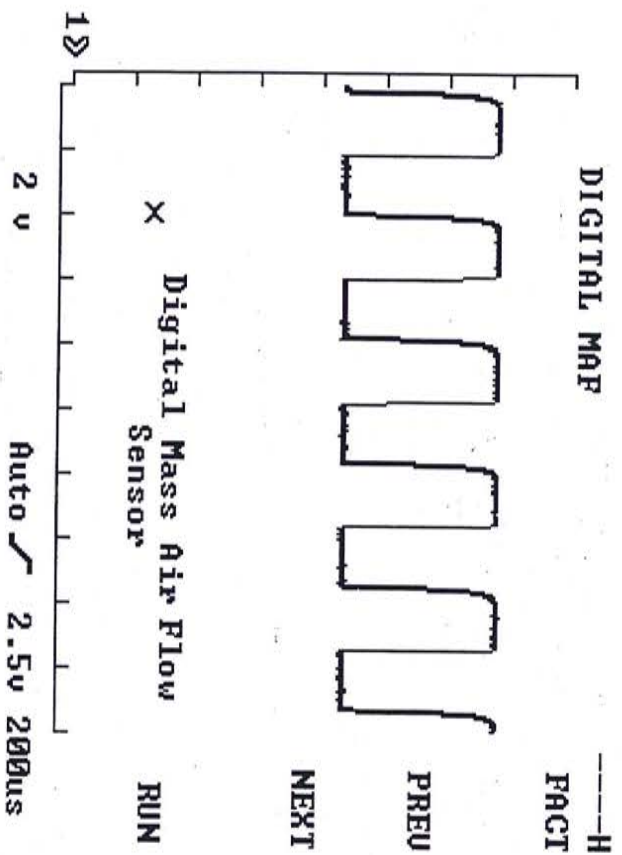


Figure 5-B: Digital Mass Air Flow Sensor

(5-3)

**Testing a Digital Mass Air Flow Sensor**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel I input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of a mass air flow sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the digital MAF waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and observe the display.

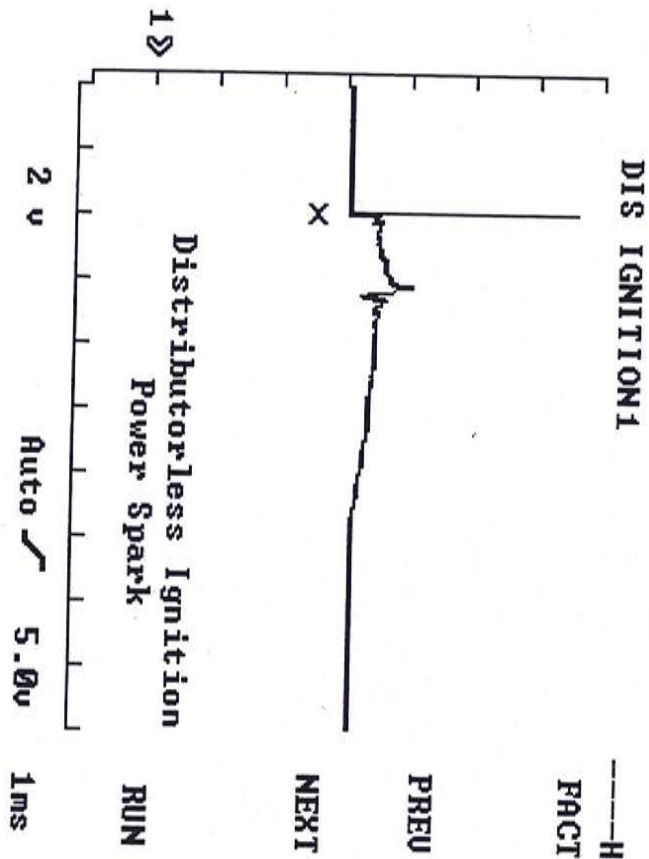


Figure 5-C: DIS Power Spark

(5-4)

**Testing a Distributorless Ignition Output**

1. Turn on the LS2000.
2. Connect the optional capacitive probe to the channel 1 and common inputs.
3. Connect the capacitive probe around the output of any coil pack.
4. Connect the Black test lead to a good ground on the engine.
5. Press the Recall Card button on the LS2000.
6. Scroll through the stored waveforms by pressing the Next button until you find the Distributorless Ignition Power Spark waveform.
7. Press the Run button and the LS2000 is ready to start displaying a signal.
8. Start the engine and observe the display.

*(Note: To perform this test requires an optional capacitive probe.)*



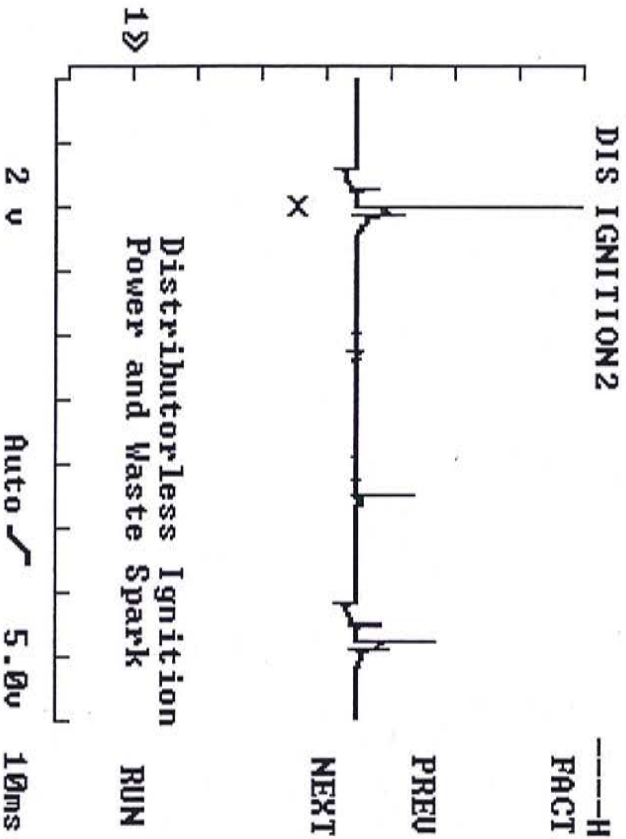


Figure 5-D: DIS Power and Waste Spark

(5-5)

**Testing a Distributorless Ignition Output**

1. Turn on the LS2000.
2. Connect the optional capacitive probe to the channel 1 and common inputs.
3. Connect the capacitive probe around the output of any coil pack.
4. Connect the Black test lead to a good ground on the engine.
5. Press the Recall Card button on the LS2000.
6. Scroll through the stored waveforms by pressing the Next button until you find the Distributorless Ignition Power and Waste Spark.
7. Press the Run button and the LS2000 is ready to start displaying a signal.
8. Start the engine and observe the display.

*(Note: To perform this test requires an optional capacitive probe.)*

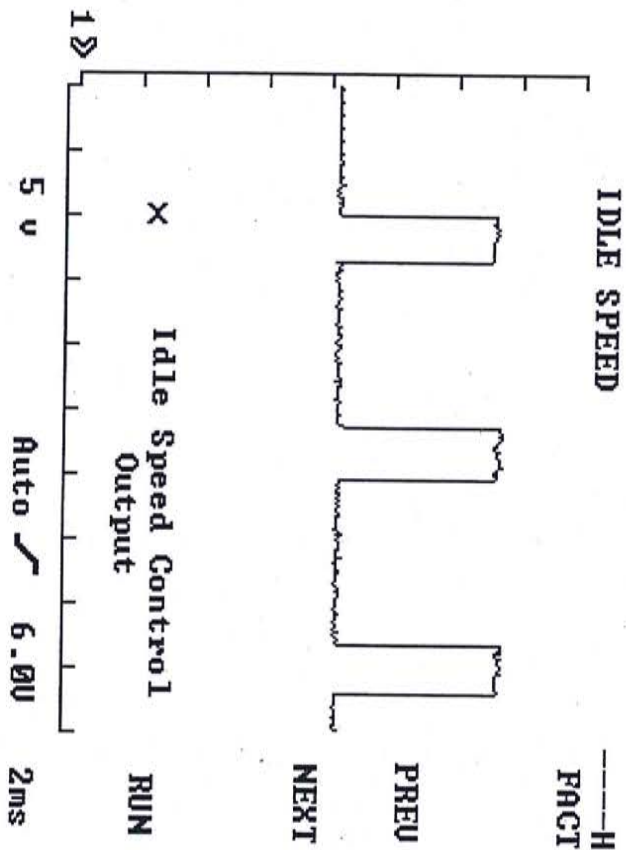


Figure 5-E: Idle Speed Control

(5-6)

**Testing an Idle Speed Control Output**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Idle Speed Control.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the Idle Speed waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and observe the display.

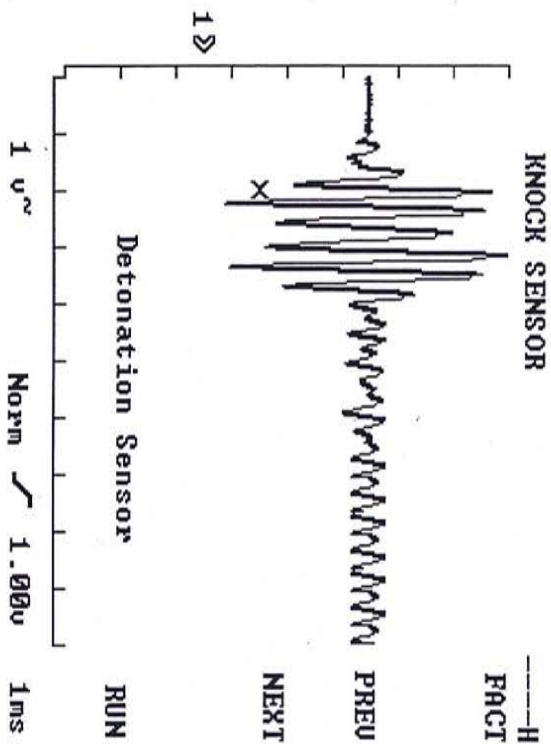


Figure 5-F: Knock Sensor

(5-7)

**Testing a Knock Sensor Output**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of a Knock Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the Knock Sensor waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Gently tap the engine with a tool near the sensor and observe the display.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

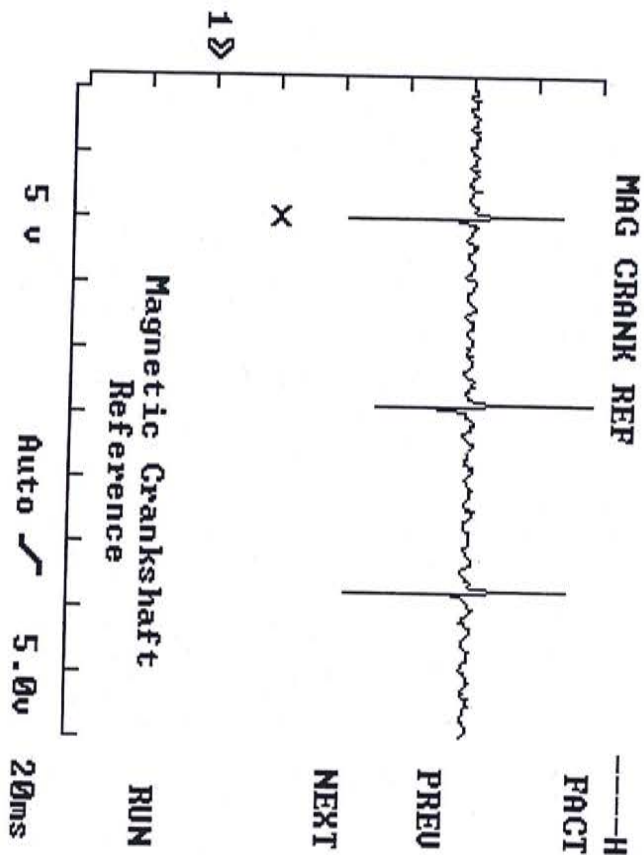


Figure 5-G: Magnetic Crankshaft Reference

(5-8)

### Testing a Magnetic Crank Reference

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Magnetic Crank Reference.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the Mag Crank Ref waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and observe the display.

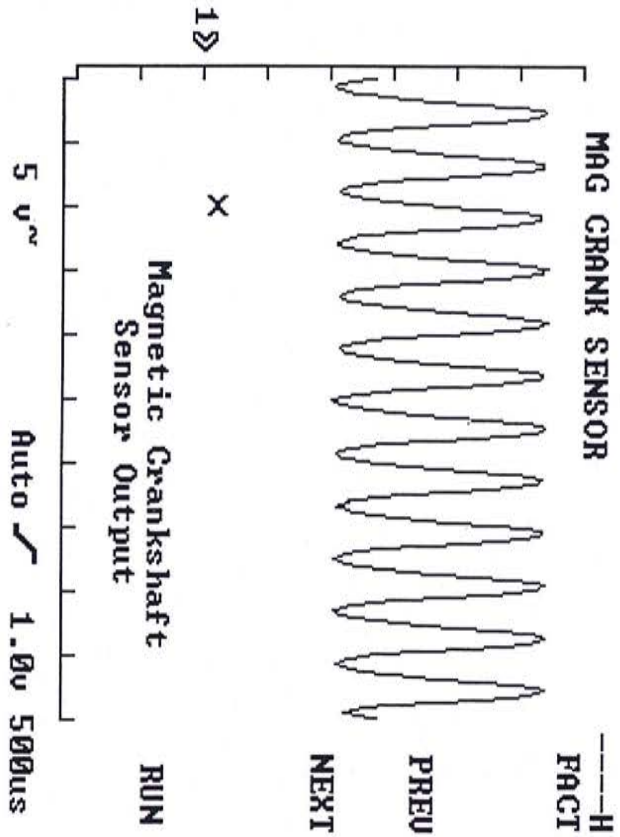


Figure 5-H: Magnetic Crankshaft Sensor

(5-9)

**Testing a Magnetic Crankshaft Sensor**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red and Black test leads to the output of a magnetic crank sensor.
5. Press the Recall Card button on the LS2000.
6. Scroll through the stored waveforms by pressing the Next button until you find the MAG Crank Sensor waveform.
7. Press the Run button and the LS2000 is ready to start displaying a signal.
8. Start the engine and observe the display.

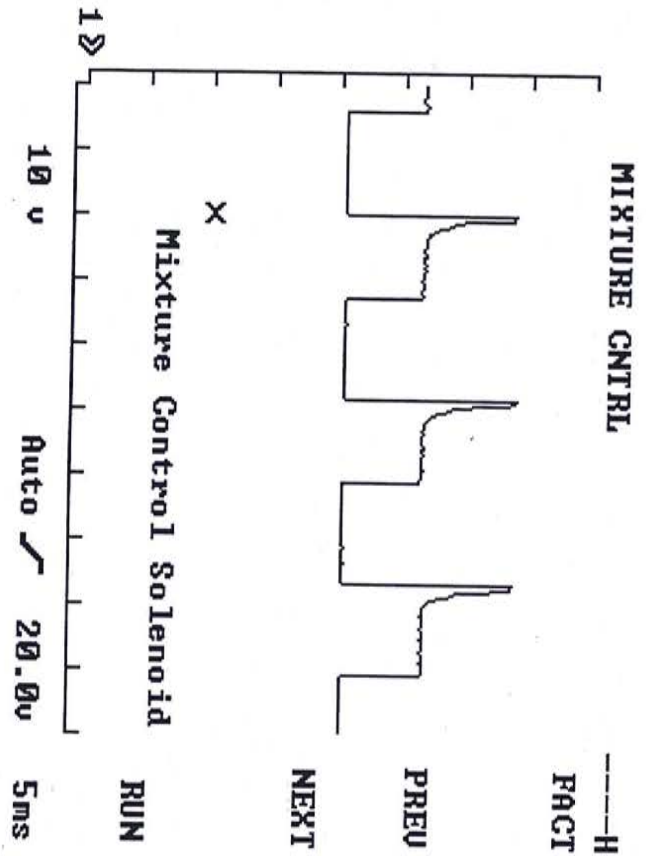


Figure 5-1: Mixture Control Solenoid

(5-10)

**Testing the Mixture Control Output**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Mixture Control.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the Mixture Control Solenoid waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and observe the display.

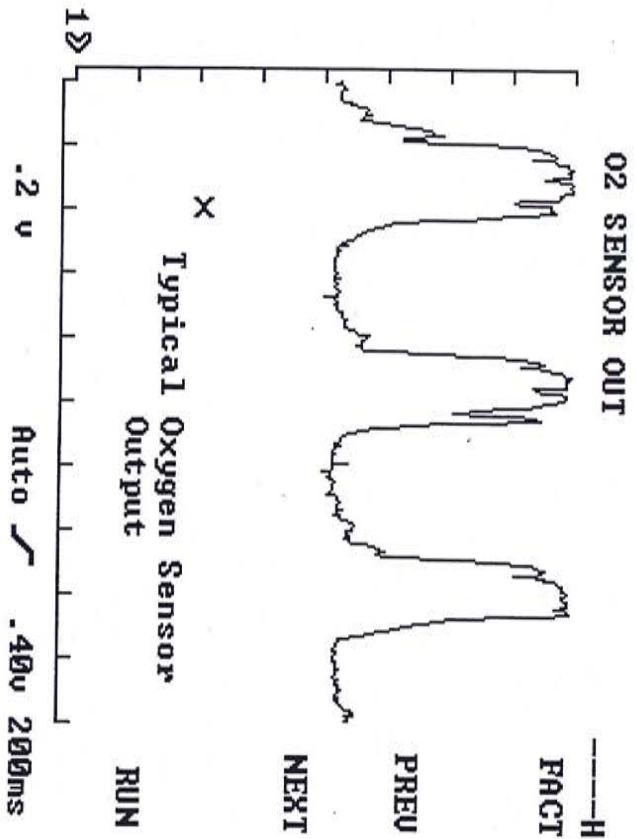


Figure 5-J: O<sub>2</sub> Sensor Output

(5-11)

**Testing an O<sub>2</sub> Sensor Output**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the O<sub>2</sub> Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the O<sub>2</sub> Sensor waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and let it warm up. The O<sub>2</sub> sensor must be warm to operate properly then, observe the display.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

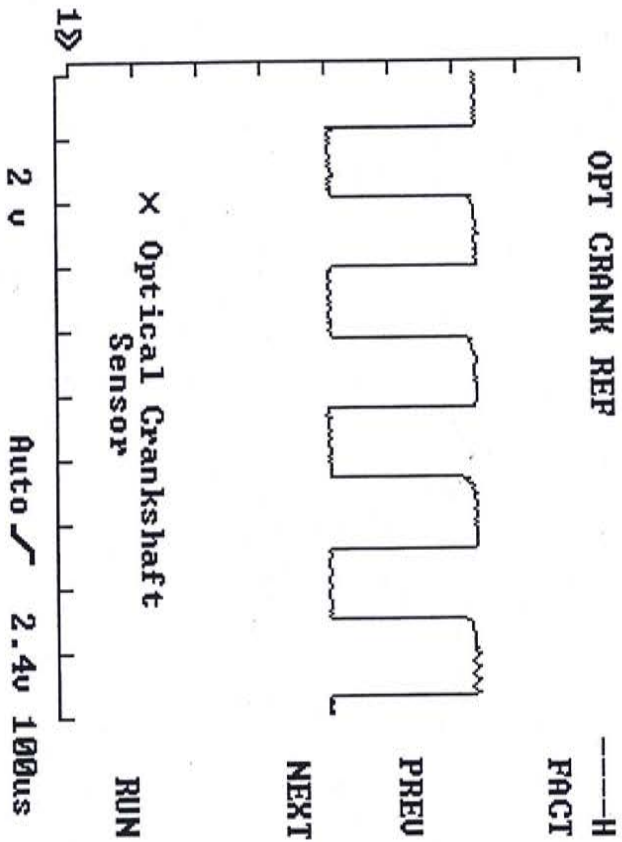


Figure 5-K: Optical Crankshaft Sensor

(5-12)

### Testing an Optical Crank Reference

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Optical Crank Ref.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the Optical Crank Reference waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and observe the display.



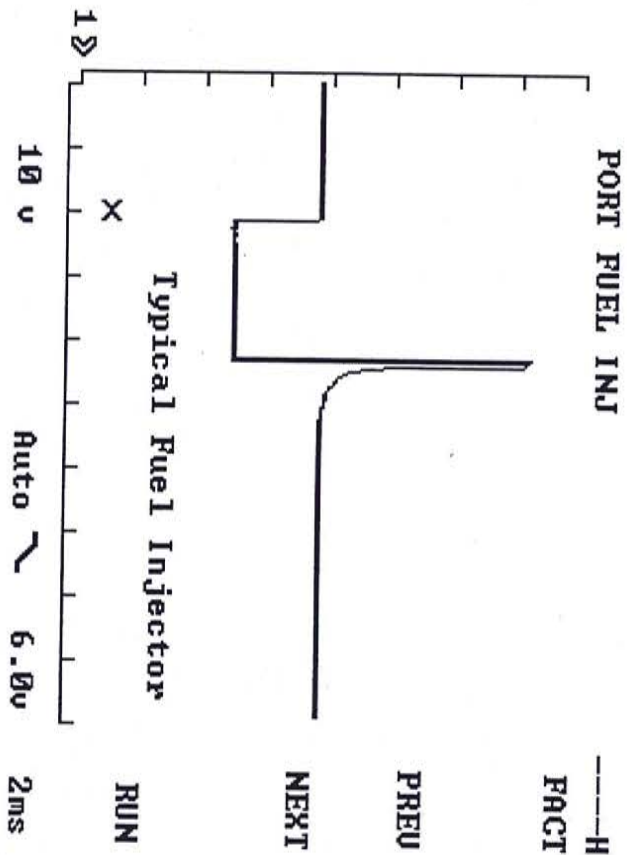


Figure 5-1: Port Fuel Injector

(5-13)

#### Testing a Port Fuel Injector

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the injector.
5. Connect the Black test lead to a good ground, close to the injector.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the Port Fuel Injector waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and observe the display.

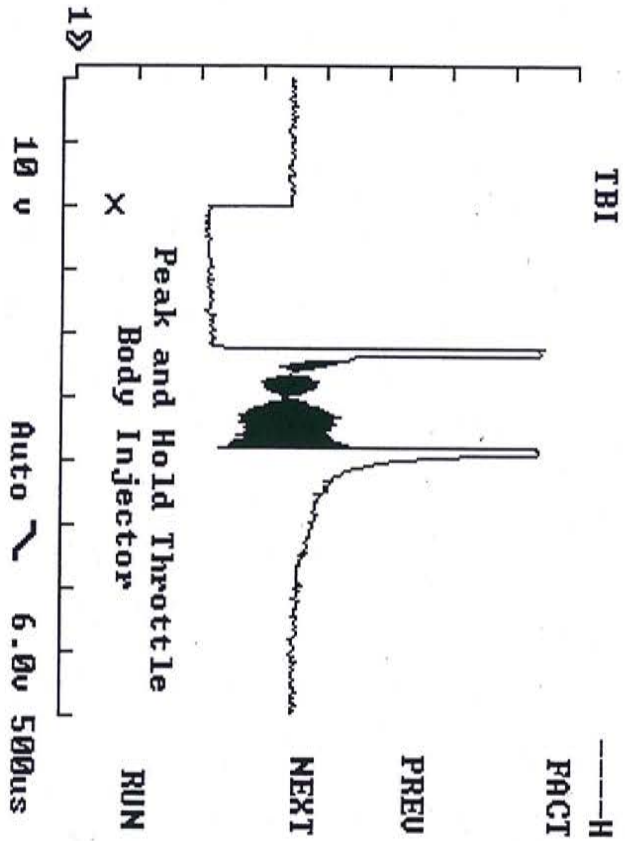


Figure 5-M: Throttle Body Injector

(5-14)

**Testing a Throttle Body Injector**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the injector.
5. Connect the Black test lead to a good ground, close to the injector.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the Throttle Body Injector waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Start the engine and observe the display.

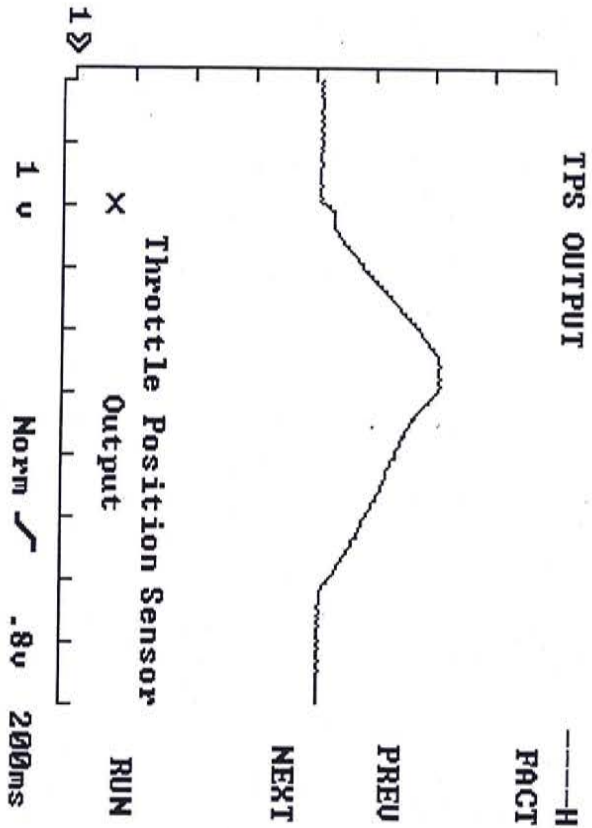


Figure 5-N: Throttle Position Sensor

(5-15)

**Testing a Throttle Position Sensor**

1. Turn on the LS2000.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the throttle position sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the LS2000.
7. Scroll through the stored waveforms by pressing the Next button until you find the TBS output waveform.
8. Press the Run button and the LS2000 is ready to start displaying a signal.
9. Do not start the engine, turn the key on.
10. Rotate the throttle open and closed and observe the display.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### Chapter 6 - Safety Tips and Precautions

#### Oscilloscope Safety

Making measurements safely begins with following good measurement procedures. Regularly check your scope for correct operation and signs of wear. Be very careful in high voltage or high current situations.

This is very important to remember - **SAFETY IS YOUR RESPONSIBILITY** - none of us should depend on our employer to provide a completely safe work environment. You have much more control over your activities than anyone else. You should always exercise caution around electricity. You are encouraged to always use common sense and follow general safety precautions. Always read and follow instructions that are specific to the circuits or equipment you will be working with. Listed below you will find general safety guidelines.

#### Safety Guidelines:

*Turn off power before working on electrical or electronic circuits, except when it is absolutely necessary.*

*Always apply the emergency brake and block the drive wheels, if the vehicle is running. The gear selection should be set to neutral, in a standard transmission or park in an automatic. If the vehicle has an automatic parking brake release, disconnect the release mechanism before performing any test.*

*Consider all wiring and terminals to be "live" until proven otherwise by a safe test method.*

*When connecting power leads to a vehicle's battery, connect the positive lead (red) to the positive terminal and then the negative lead (black) to the negative terminal. When disconnecting, remove the negative lead first, then the positive lead.*

*Keep cigarettes, sparks and open flames away from the vehicle's battery at all times.*

*Testing should always be done in a well-ventilated area.*

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

*Turn off power and unplug equipment before checking or replacing fuses.*

*Be sure all electronic test equipment is operating properly before you use it.*

*Be sure test leads are properly connected to the scope before proceeding with a test.*

**Electrical shock from secondary ignition system components can be very dangerous (especially from electronic and distributorless ignition systems). Use extreme care when working near these components, and observe the following:**

*Turn off the engine and attach the GROUND (black) lead prior to connecting to capacitive pickup or adapter.*

*Never use any test lead, pickup or adapter, other than those that are intended to be connected to the NO. 1 PLUG or SECONDARY lead for testing in the secondary ignition circuit.*

*Always use extreme care when working around high voltage spark plug wires and coil terminals.*

*Never puncture an ignition wire in order to connect test equipment.*

*It is a good practice to treat all circuits as if high voltage or high current is present.*

*Always remove metal jewelry, watches, rings, chains, etc., before working on any electrical circuits or equipment.*

*Do not place test equipment on a vehicle fender or other location from where it could slip or fall into electrical circuitry or moving parts.*

*Avoid making accidental connections between battery terminals through tools, jumper leads, or any other object that will conduct electricity.*

*Before replacing a fuse or resetting a tripped circuit breaker, locate and correct the cause of the problem.*

(6-2)



## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

*Engine exhaust contains deadly carbon monoxide gas. When performing a test with the engine running, test in a well-ventilated area or route the exhaust out-of-doors.*

*Always replace defective wires and connectors that are frayed, cracked or loose.*

*Always check the electrical ratings of the equipment you are using, and never exceed those ratings.*

*Do not rely on erratic, questionable, or obviously erroneous test results or information. Misdiagnosis may lead to incorrect or improper repair and/or adjustment. Improper repair and/or adjustment may cause damage to the vehicle or equipment, or make them unsafe to operate.*

*If test information or results are erratic, questionable, or obviously erroneous, make sure that lead connections are correct, and the test procedure was performed correctly. If test information or results are still suspicious, do not use them for diagnosis; contact your Snap-on/Sun representative.*

### **The Effects of Electric Shock:**

The importance of being cautious around electrical and electronic circuits can not be overemphasized. The following is a list of things that could happen as a result of Electric Shock. Please be careful!

*Current above a certain current level can produce involuntary movement and cause a serious accident.*

*Continuous current levels, above a person's let-go current, passing through the chest can produce collapse, unconsciousness, asphyxia and death.*

*An alternating current of 20 mA can produce ventricular fibrillation, if injected directly into the human heart.*

*When milliamps of current flow through the portion of the nervous system which controls breathing, even after the current has been turned off, respiratory arrest can continue for an extended period of time.*

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

*Cardiac arrest can be caused by even relatively low currents flowing in the region of the heart.*

*Amperes of current can produce fatal damage to the central nervous system.*

*Electric currents can produce deep burns and raise one's body temperature sufficiently to cause immediate death.*

*Delayed death can occur from serious burns or other complications.*

**REMEMBER: SAFETY IS YOUR RESPONSIBILITY**

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(6-4)



## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### LS2000 Specifications

#### Vertical Deflection

Sampling Rate	5 megasamples/second
Bandwidth	DC: DC to 500 kHz
	AC: 10 Hz to 500 kHz
Resolution	8 bits
Deflection	50 mV/Div to 10 V/Div (in a 1, 2, 5 sequence)
Input Impedance	10 MΩ ± 2%, 25 pf ± 5%
Accuracy	± 5%
Coupling	DC (default), AC
Maximum Input Voltage	500 V (DC + AC P-P)
Input Surge Protection	30 KV

#### Horizontal Deflection

Resolution	8 Bits, 320 Pixels
Sweep Rate	5 μS/div to 60 S/div (in a 1, 2, 5 sequence)
	Scan Mode below
	100 mS/div

#### Trigger System

Triggering Mode	Auto DC (50% point) with selectable AC, Normal and Single
Pre-Trigger Mode	Fixed at 2 divisions (20%)
Source	Internal only, Channel 1
Slope	+ or - (default to +)

#### Acquisition

Mode	Min/Max
Frequency	4 digit resolution to 500 kHz

#### Interface

Format	RS232C, Talk/Listen with optional adaptor
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#### Display

Total Area	LCD 240 X 320 Matrix
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(S-1)



## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

**Memory**  
Capacity  
Format  
Content

**Operation**

**Power**  
Internal Source  
External Source

*4 Waveforms at 250 points each  
Plug-in Card  
Each card contains up to  
20 waveforms, character  
descriptions and oscilloscope  
settings  
Scroll through*

*Lead acid sealed battery  
9 volt DC, 500 mA*

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(S-2)

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### Glossary

**AC (Alternating Current)**

A signal in which the current and voltage vary in a repeating pattern over time.

**ADC (Analog-to-Digital Converter)**

A digital electronic component that converts an electrical signal into discrete binary values.

**Aliasing**

Aliasing occurs when a digital oscilloscope does not take enough samples on a particular signal. After the oscilloscope reconstructs and displays the waveform you can be "fooled" into seeing a false waveform. The LS2000 uses Min/Max acquisition at all sweep speeds, this prevents the scope from aliasing a waveform.

**Amplitude**

The magnitude of a quantity or strength of a signal. In electronics, amplitude usually refers to either voltage or current.

**Attenuation**

A decrease in signal voltage during its transmission from one point to another.

**Averaging**

A processing technique used by digital oscilloscopes to minimize noise in a signal.

**Bandwidth**

A frequency range.

**CRT (Cathode-Ray Tube)**

An electron-beam tube in which the beam can be focused on a luminescent screen and varied in both position and intensity to produce a visible pattern. A television picture tube is a CRT.

**Circuit Loading**

The unintentional interaction of the probe and oscilloscope with the circuit being tested, distorting the signal.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### **Coupling**

The method of connecting two circuits together. Circuits connected with a wire are directly coupled; circuits connected through a capacitor or a transformer are indirectly (or AC) coupled.

### **DC (Direct Current)**

A signal with a constant voltage and current.

### **Display**

The surface of the oscilloscope upon which the visible pattern is produced in the display area.

### **Division**

Measurement markings on the display graticule of the oscilloscope.

### **Earth Ground**

A conductor that will dissipate large electrical currents into the Earth.

### **Focus**

The oscilloscope control that adjusts the CRT electron beams to control the sharpness of the display.

### **Frequency**

The number of times a signal repeats in one second, measured in Hertz (cycles per second). The frequency equals 1/period.

### **Glitch**

An intermittent error in a circuit.

### **Graticule**

The grid lines on a display for measuring oscilloscope traces.

### **Ground**

1. A conducting connection by which an electric circuit or equipment is connected to the earth to establish and maintain a reference voltage level.
2. The voltage reference point in a circuit.

(G-2)

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### **Hertz (Hz)**

One cycle per second; the unit of frequency.

### **Kilohertz (kHz)**

1000 Hertz; a unit of frequency.

### **Megahertz (MHz)**

1,000,000 Hertz; a unit of frequency.

### **Megasamples per second (MS/s)**

A sample rate unit equal to 1,000,000 samples every second.

### **Microsecond ( $\mu$ s)**

A unit of time equivalent to 0.000001 seconds.

### **Millisecond (ms)**

A unit of time equivalent to 0.001 seconds.

### **Noise**

An unwanted voltage or current in an electrical circuit.

### **Oscilloscope**

An instrument used to make voltage changes visible over time. The word oscilloscope comes from "oscillate," since oscilloscopes are often used to measure oscillating voltages.

### **Peak (Vp)**

The maximum voltage level measured from a zero reference point.

### **Peak-to-peak (Vp-p)**

The voltage measured from the maximum point of a signal to its minimum point, usually twice the Vp level.

### **Period**

The amount of time it takes a wave to complete one cycle. The period equals 1/frequency.

### **Phase**

The amount of time that passes from the beginning of a cycle to the beginning of the next cycle, measured in degrees. One complete cycle represents 360°.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### **Probe**

An oscilloscope input device, usually having a pointed metal tip for making electrical contact with a circuit element and a flexible cable for transmitting the signal to the oscilloscope.

### **Pulse**

A common waveform shape that has a fast rising edge, a width, and a fast falling edge.

### **RMS (Root Mean Square)**

For a sine wave, RMS is the peak voltage multiplied by 0.707 this gives the equivalent DC voltage value that would be required to produce the same amount of power through a fixed resistor.

### **Real-time Sampling**

A sampling mode in which the oscilloscope collects as many samples as it can as the signal occurs.

### **Record Length**

The number of waveform points used to create a record of a signal.

### **Rise Time**

The time taken for the leading edge of a pulse to rise from its minimum to its maximum values (typically measured from 10% to 90% of these values).

### **Sample Point**

The raw data from an ADC used to calculate waveform points.

### **Screen**

The surface of the oscilloscope upon which the visible pattern is produced in the display area.

### **Signal Generator**

A test device for injecting a signal into a circuit input; the circuit's output is then read by an oscilloscope.

### **Sine Wave**

A common curved wave shape that is mathematically defined.

(G-4)



## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### **Single Shot**

A signal measured by an oscilloscope that only occurs once (also called a transient event).

### **Slope**

On an oscilloscope display, the ratio of a vertical distance to a horizontal distance. A positive slope increases from left to right, while a negative slope decreases from left to right.

### **Square Wave**

A common wave shape consisting of repeating square pulses.

### **Sweep**

One horizontal pass of an oscilloscope's trace from left to right across the display.

### **Sweep Speed**

Same as the time base.

### **Time Base**

Oscilloscope circuitry that controls the timing of the sweep. The time base is set by the seconds/division control.

### **Trace**

The visible shapes drawn on an oscilloscope display.

### **Transducer**

A device that converts a specific physical quantity such as sound, pressure or light intensity into an electrical signal.

### **Transient**

A signal measured by an oscilloscope that only occurs once (also called a single-shot event).

### **Trigger**

The circuit that initiates a horizontal sweep on an oscilloscope and determines the beginning point of the waveform.

### **Trigger Level**

The voltage level that a trigger source signal must reach before the trigger circuit initiates a sweep.

### **Volt**

The unit of electric potential difference.

## LS2000 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

### **Voltage**

The difference in electric potential, expressed in volts, between two points.

### **Waveform**

A graphic representation of a voltage varying over time.

### **Waveform Point**

A digital value that represents the voltage of a signal at a specific point in time. Waveform points are calculated from sample points and stored in memory.

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(G-6)



**COMPANION PRODUCT**

**MT586 MULTI-MATE**

Automotive Digital Multimeter

**Measures:**

AC/DC Volts

AC/DC Amps

Ohms

Temperature

Frequency

RPM

% Duty Cycle

Dwell

Pulse Width

Diode Check

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