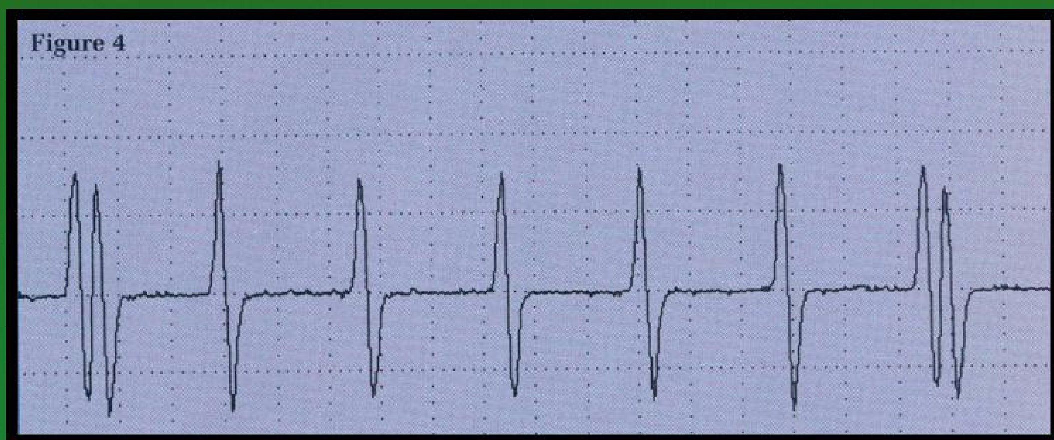
www.aeswave.com

Understanding Waveforms

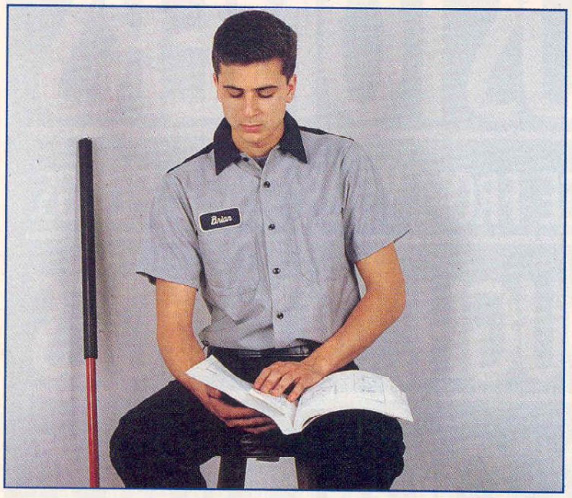


An article by Jorge Menchu that originally appeard in the October, 1995 issue of

IMPORT SERVICE

INFORMATION FOR THE PROFESSIONAL AUTOMOTIVE REPAIR TECHNICIAN

APPRENTICE CORNER



Understanding Waveforms

Elsewhere in this issue, you will find coverage on the latest hand-held digital storage oscilloscopes (DSOs). Each of these oscilloscopes will provide you with a wealth of information that can be used to troubleshoot cars you might not have been able to fix before. This article will give you a better understanding of the waveforms that will be found when you hook a DSO to automotive electronic circuits.

What can we learn from waveforms on an oscilloscope? Waveforms give us an additional source of information about the engine management systems or other vehicle systems we are working on. In many cases, there is no other way to get this "System Information."

The engine management system uses System Information to make decisions or to cause an action. An example of System Information used to make a decision would be coolant temperature sensor telling the PCM the temperature of the engine. The PCM needs this information before it can make decisions about the fuel mixture.

Once the PCM has digested the System Information from the coolant temperature sensor, it acts by sending a signal to the injectors that causes the injectors to open. Understanding how different signals carry System Information, and how the engine management system reacts to this information, is probably the most important aspect of fixing cars "right now."

Classifying Waveforms

There are many ways to classify waveforms. Probably the easiest way is to divide the waveforms based on functions they perform in the system, then look at how they carry System Information. Using this classification system, there are four basic types of system waveforms or signals which we'll classify as: **Support, Sensor, Logic, and Action** signals.

APPRENTICE CORNER

Here are the four types of signals.

1) Support Signals

Support signals provide the most basic forms of System Information. They provide the system with a steady source of power, ground, and bias voltage. These signals should normally operate at a steady, fixed voltage level that provides the foundation for all of the other system signals. The PCM assumes that these signals are correct, and makes all of its decisions based on that assumption.

For example, if the reference voltage supply to a sensor has noise on it, it's likely that the sensor signal returning to the PCM will have noise on it too. And if the sensor signal is bad, the related output signals from the PCM will probably be bad too.

2) Sensor Signals

These signals are sent from the system sensors to report information about the environment around the system, or to report actions or conditions. A typical sensor signal might tell the PCM what temperature the intake air is, the position of the crankshaft, or the position of the throttle plate. The waveforms for these signals vary in shape and size.

Most sensor signals have low current flow, unlike many actuator signals which must carry the information as well as the energy to cause an action. Sensor signals are the next link in the System Information chain. Any weak links in the information from the sensor signals will cause a breakdown in the chain of command to the system's output signals.

3) Logic Signals

Logic signals pass information from module to module. A computer-controlled timing signal is an example of a logic signal. On many systems, the PCM uses input sensor signals to calculate what the ignition timing should be. Next it sends a logic signal to an ignition module, and the ignition module fires the coil. The logic signal is passed from the PCM to the ignition module, before the action (ignition coil discharge) is carried out.

Like sensor signals, logic signals usually operate at low current levels. These signals are the next link in the chain of System Information.

4) Action Signals

Action signals are often referred to as output or actuator signals. These signals generally originate at the PCM, a control module, a relay, or a switch. Because these signals cause an action, they must carry the System Information, as well as sufficient energy or current flow to cause the action.

For example, injector pulse width signals from the PCM to the injectors contain System Information (how long the pulse should be). Because the injector circuit has low resistance, the PCM must also allow enough current to flow to overcome the fuel and spring pressure and open the injector (action). Action signals tell the actuators when and/or how long to do something, and they must also provide enough current flow to get the job done.

APPRENTICE CORNER

Waveform Types

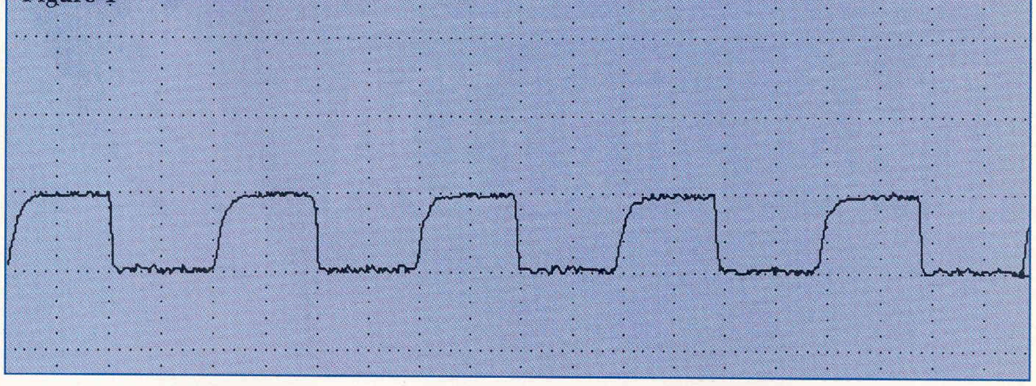
We've looked at what each of the different systems signals does. Next we need to understand what their waveforms look like while they are doing it. There are just four basic waveform types, if we divide them according to their basic shapes and how they carry information.

Repetitive Signals

Repetitive signals usually appear on the scope as a series of pulses. The combination of a positive, and the following negative going pulse, is called a cycle. These signals can be either digital or analog.

Repetitive digital signals usually "switch" between two voltages, such as 5 and 0 volts, and are usually produced by a transistor in some type of module or integrated circuit sensor. An example of a repetitive digital air flow sensor signal is shown in **Figure 1**. The load information the air flow sensor has received has been converted into a repetitive digital signal that can be interpreted by the PCM.

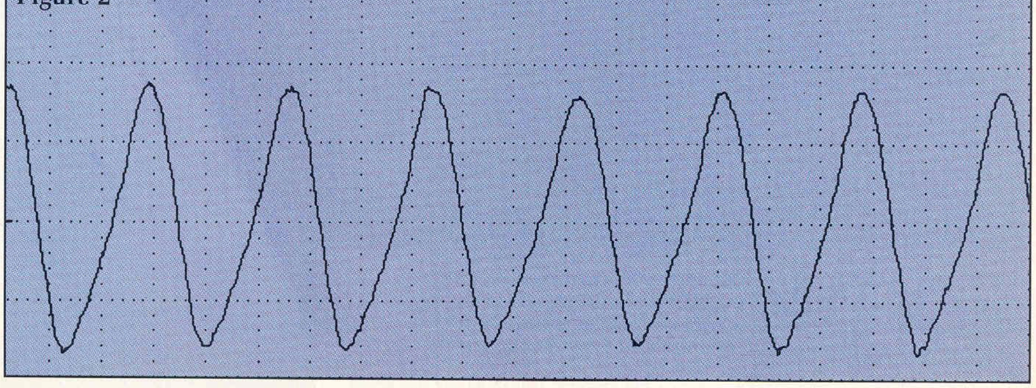
Figure 1



Repetitive analog signals build their pulses by producing linear voltage changes. Repetitive signals may be referred to as sine or saw-tooth waves, and are often produced by magnetic pickup sensors. An example of a repetitive analog signal, produced by an AC speed sensor, is shown in **Figure 2**. The waveform makes gradual, rather than abrupt, changes between its repetitive high and low voltage pulses.

Repetitive signals, regardless of whether they are digital or analog, carry System Information by changing their frequency, duty cycle, and/or pulse width.

Figure 2



Analog Signals

Analog signals change voltage levels in a linear fashion, unlike the strict ON and OFF switching of a digital signal. There's a little bit of overlap between signal types here, as the term analog signal can be used to describe the repetitive sine wave signals we've just discussed, as well as more random signals such as the waveform produced by an analog, vane-style air flow sensor.

The waveform shown in **Figure 3** represents the analog signal produced by the air flow sensor as the throttle plate is opened and closed and the engine load increases and decreases. This signal should show a voltage level that gradually increases and decreases to reflect changes in throttle opening and load. As we can see from the waveform in **Figure 3**, this air flow sensor has an intermittent open circuit. Rather than changing voltage levels in a linear fashion, the voltage level intermittently drops out as the air flow sensor goes open.

Figure 3

Step Signals

Step signals usually have two voltage levels that turn something ON or OFF. A step signal can also represent some kind of logic. If certain parameters are met, the signal will be ON. If the same parameters are not met, the signal will be OFF. A command from the PCM to turn on a cooling fan is an example of an ON or OFF output signal.

A throttle position switch (not a throttle position sensor) is a good example of a logic input signal. These signals do not change from OFF to ON very rapidly, so a scope may not be necessary to check them. A simple DMM may allow you to see what state they are in.

What Is A Waveform?

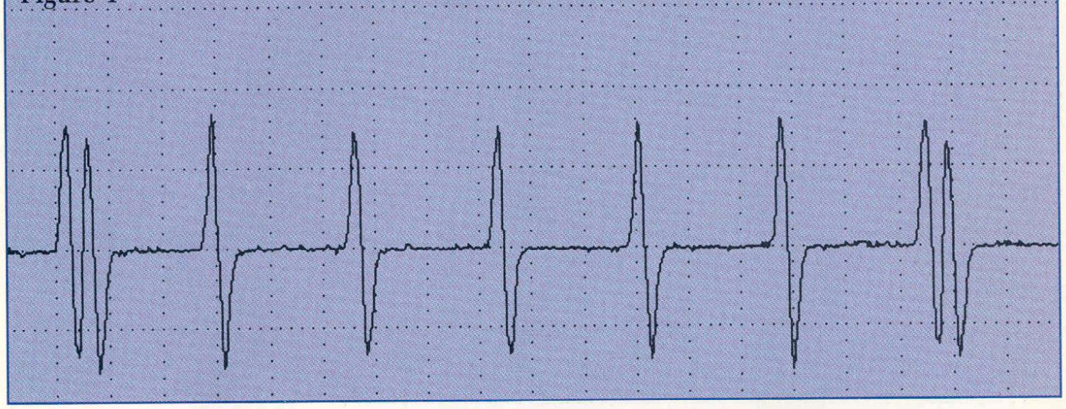
A waveform is a visual representation of the voltage present in a circuit, measured over time. Each of the points in the trace on the oscilloscope display represent a specific voltage at a very specific period in time. As we watch the trace travel across the screen, the scope tells us the voltage level at the present time, as well as the voltage level during the period of time immediately preceding the present time.

APPRENTICE CORNER

Unique Signals

Unique signals (or signatures) can take many forms and may be described as a unique blip in a signal. These signals may be used to mark a specific event or action. A good example is the TDC mark in a crank sensor signal, an example of which is shown in **Figure 4.** The "double kick" we see at the beginning and end of this waveform is used as a crank angle signal to tell the PCM about crankshaft location. Since these special signals last for such a short time, unique signatures can be very hard, if not impossible, to detect without an oscilloscope.

Figure 4



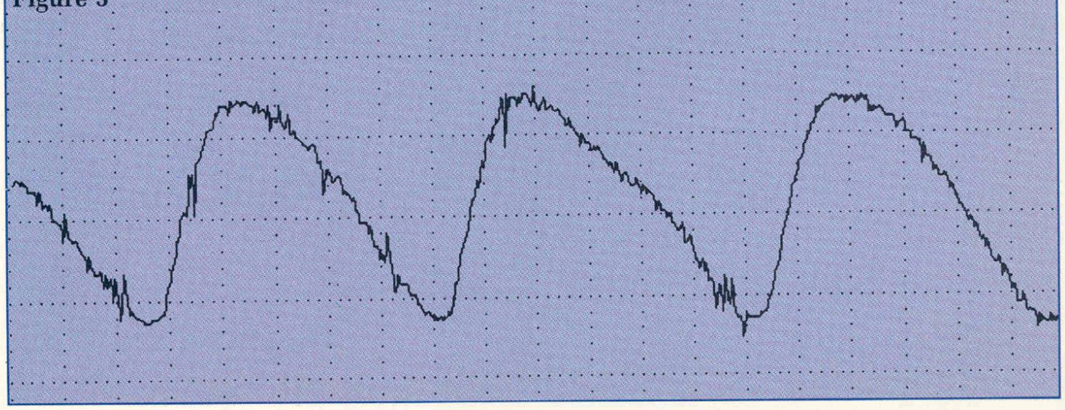
Waveform Integrity

A signal must reach certain parameters and must be properly calibrated in order to deliver its information successfully. This is especially true for input sensor signals. If the input sensor signal is scrambled, the PCM will either be confused or it will be unable to properly process the information from the sensor.

An oxygen sensor signal is shown in **Figure 5**. The signal the oxygen sensor generates is a very weak—never more than one volt. Any interference on the oxygen sensor line to the PCM, caused by a damaged shield or a poor connection, could easily confuse the PCM and cause other problems.

Properly calibrated output signals are important too. Output signals don't carry System Information to the PCM as input sensor signals do. But if they are improperly calibrated or distorted by damaged components or other outside forces along the way, the output signals may lack the energy or the proper information to carry out the tasks the PCM expects of them.

Figure 5



APPRENTICE

The ways that waveforms carry information and the forces that shape them are very similar from system to system. But there are always exceptions to the rules. It's important to keep your wits about you so you don't get stuck on "something new". This is why an understanding of circuit information is valuable. Use all your resources when confronted with a waveform that doesn't seem to make sense. Service manuals, system descriptions, and diagnostic trouble trees hold clues to the dynamics of the circuit and its strategy. Wiring diagrams are also full of information that can help you determine how one circuit can affect another. The symbols in the diagram can also help to identify the components in a circuit.

Conclusion

Are you ready to get to work? The only way to make the oscilloscope a productive tool is to take time to learn to use it. Regardless of how confusing this may seem at first, you must take that first step. Install a breakout box and start probing with your oscilloscope leads. You will be surprised by how easy it is to identify a signal.

Suppose you probe a wire and find a repetitive digital wave signal. Revving the engine causes the waveform to change frequency but the duty cycle remains the same. Must be a crankshaft or camshaft sensor signal.

In many cases simply sampling a signal and watching how it changes can give you good clues about the signal type. Don't be afraid to experiment. Our challenge is to stay up to date with the strategies and relationships for all the different systems offered by different manufacturers.

And in many cases the best way to do this is through experimentation and continued practice. Catch a wave!

—By Jorge Menchu

DEALER DIRECT

CONNECTING ROD DIFFERENCES

The connecting rods on some Mazda 2.0 liter engines use a cap that is narrower than the rod itself. Usually, the rod caps are as wide as the mating part of the connecting rods.

The difference in width means that connecting rod side clearance on the crankshaft journal is controlled by the top portion of the connecting rod only. All clearance measurements must be taken at the upper half of the rod's big end.

Mazda has manufactured many different versions of the 2.0 liter engine and only some of these are equipped with the rod design described. Using either style of connecting rod (in sets) is acceptable.

ACURA SNAPPING NOISES

Improperly torqued cylinder head bolts may cause a snapping noise on 1990-91 Acura 1.8 liter engines. The best description of the noise is a sharp snapping sound, similar to the sound of a spark plug wire arcing.

Incorrect head bolt torque may permit the cylinder head to move as the engine reaches operating temperature. If this noise is detected and no other cause can be found, verify the cylinder head bolt torque with the following procedure:

- Allow the engine to completely cool, then remove both camshafts.
- In the reverse sequence, loosen the cylinder head bolts, one bolt at a time, then torque each bolt **immediately** to 7 ft-lb.
- After all bolts have been tightened to 7 ft-lb, in sequence, tighten all bolts to 22 ft-lb.
- Follow the torque sequence to tighten the head bolts to 43 ft-lb, then 61 ft-lb.
- Reinstall the camshafts and adjust the valve clearance to 0.006-inch for intake valves and 0.007-inch for exhaust valves.

REVISED HEAD GASKET

A revised head gasket is available for all 1992-94 Mazda 2.6 liter engines. The revised gasket features improved sealing at the engine's right side, rear corner. The earlier head gasket design may allow an exteranal coolant leak at this location.

The revised head gasket (P/N G601 10271C) is interchangeable with the previous gasket. Mazda recommends that only this new gasket be used when servicing the engine.

TOYOTA COOLANT LOSS

An eroded head casting may caused coolant leakage on 1981-92 2.4 liter Toyota engines. Over time, hot exhaust gases may erode the exhaust port area and create a hole into the cooling passage between the ports. Depending on the amount of coolant loss, there may be evidence of white smoke coming out of the tail pipe.

In some instances, pushing on a suspect area with an awl or punch will expose the water jacket. If the head is still on the vehicle, dropping the exhaust manifold will usually reveal coolant droplets hanging on the problem areas. Pressure testing the head will also reveal the areas that are leaking.

Part Number Correction

The ENGINE DETONATION bulletin in the august 1995 edition of Dealer Direct contained an incorrect part number. The correct part number for the Nissan 300ZX replacement camshaft is 13020-F6515.

Information for Dealer Direct provided courtesy of the ALLDATA Corporation.