FirstLook®

DIAGNOSTIC PULSE SENSORS

User's Guide for Spark Plug Engines

FirstLook® Automotive Engine Diagnostic Sensor
"The Pulse of Your Engine!"

Model ADS ES 100

from

SenX TECHNOLOGY

5315 Sunset Drive
Midland, MI 48640
www.Senxtech.com

U.S. Patent No. 6,484,589
Made in the U.S.A.

Introduction

Congratulations on your purchase of the FirstLook® automotive engine diagnostic sensor.

This is your first step down a road of easier and more accurate engine diagnostics. The FirstLook® sensor will give you a picture of an engine's performance *while it is running*.

Tests can be set up and run within minutes of parking the vehicle in your service bay. You simply attach the sensor to the exhaust pipe or to the oil level indicator tube and run the test.

Once you have learned how to "read" the sensor displays, you will be able to find burnt valves, worn rings and other engine performance problems as quickly as you can run the tests.

When a customer says the engine is "acting funny", FirstLook® can help you identify the problem more quickly and complete the job in less time. This helps your bottom line and it can make a happier customer.

You can make FirstLook® part of your routine service work. Then, you can include engine performance when you review your service checklist with your customer:

"*We tested engine operation. Compression across cylinders, valves, rings all seemed to be working normally during the tests*." (Or not.)

You will find FirstLook® to be a valuable addition to your diagnostic tool kit.

Before we go further, check the website, www.SenXTech.com, to see if there is now a more recent version of this Users Guide.

Now, let's turn the page and get started.

Warranty

SenX Technology, LLC warranties the products described herein for a period of 1 year under normal use and service from the date of purchase, that the product will be free of defects in material and workmanship. This warranty does not cover ordinary wear and tear, abuse, misuse, overloading, altered products, or damage caused by the purchaser connecting the unit incorrectly.

THERE IS NO WARRANTY OF MERCHANTABILITY. THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION HEREIN. THERE ARE NO WARRANTIES EXPRESSED OR IMPLIED OR ANY AFFIRMATION OF FACT OR REPRESENTATION EXCEPT AS SET FORTH HEREIN.

REMEDY

SenX Technology, LLC sole responsibility and liability, and purchaser's exclusive remedy shall be limited to the repair or replacement at SenX Technology option, of a part or parts not conforming to the warranty. All products requiring warranty service shall be returned to SenX Technology within 1 year of purchase, shipping prepaid. SenX Technology will return repaired or replaced products to the purchaser via prepaid ground transportation. In no event shall SenX Technology be liable for damages of any nature, including incidental or consequential damages, including but not limited to any damages resulting from non-conformity, defect in material or workmanship.

Neither SenX Technology LLC nor its affiliates shall be liable to the purchaser of this product or third parties for damages, losses, costs, or expenses incurred by the purchaser or third parties as a result of: accident, misuse, or abuse of this product or unauthorized modifications, repairs, or alterations to this product, or failure to strictly comply with SenX Technology's operating and maintenance instructions.

Table of Contents

Test Summary

Like living creatures, each cylinder on the engine breathes in (intakes) and breathes out (exhausts) every cycle. The FirstLook® sensor measures these puffs of air, or air pulses, and displays the 'pulse signature' on your lab scope.

This table shows the tests you may run with your FirstLook® sensor system and the purposes of each test.

Test Condition	**Sensor Placement**		
	Exhaust	**Crankcase**	**Intake Vacuum**
Cold Crank	Use to check: exhaust valve train operation; possible piston blow by; relative compression between cylinders	Use to check: confirm piston blow by	Use to check: intake valve train operation; heads; head gaskets
Idle	Use to check: possible misfires; possible piston blow by; relative compression between cylinders	Use to check: confirm piston blow by	Use to check: intake valve train operation; heads; head gaskets
Power Brake	Use to check: same as 'Idle" but for problems that show up under load or only intermittently	Use to check: confirm piston blow by	Use to check: same as 'Idle" but for problems that show up under load or only intermittently

SenX recommends including a trigger signal when testing engines with spark-ignited combustion (spark plug engines). This will identify suspected problems by cylinder. The spark signal to cylinder #1 is usually used for the trigger. However, triggers are not required. Any test may be run without a trigger signal.

You could run all the tests for a given test condition at the same time. For example, you could run all three hot engine tests: Exhaust, Crankcase and Intake, with a trigger at the same time. This requires two additional sensors (sold separately), the trigger, and a 4-channel scope.

With just one additional sensor, you could run two tests at the same time with a 2-channel scope. In this case, you will run the test without a trigger signal. This will still identify problems, but will not identify which cylinders have the problems.

Basics of Reading Pulse Signatures

Reading pulse signatures is the key to diagnosing engine problems. There are four basic things you need to know about reading pulse signatures:

1. You need to understand what pulse signatures mean.
2. You need to understand separating the pulse signal from the signal noise.
3. You need to know how to identify pulses by cylinder number.
4. You need to know how to separate pulses by cylinder.

Please refer to the narrative and diagrams on pages 30 & 31 to help explain the origin, sequence and offsets on the various signatures of the different tests of a 4-stroke internal combustion engine.

SenX recommends you practice using the sensor by running tests on engines without problems. This will help you learn how to separate pulse signals from the noise and learn how to identify pulses by cylinder. It will also give you a feel for how much pulse deviation is 'OK.' You may even consider creating engine problems just to see what they do to the pulse signatures.

1. Basic Pulse Signature Analysis

The pulses in the pulse signatures for a perfect engine will be very uniform. They will all have the same general size, shape and spacing. You are looking for deviations in the pulses that indicate engine problems.

There are very few perfect engines. Expect to see *some* deviation in the pulses. So, look for non-uniform pulse signatures and LARGE pulse deviations. Accept some pulse deviations and ignore the noise. Especially pay attention to non-uniform patterns and pulses that repeat from cycle to cycle.

Take a minute here to review the example pulses and reference pulse signatures in the Appendix. Remember, pulses can be either positive (peaks) or negative (valleys). The table below describes the two most common pulse deviations and some of the possible causes.

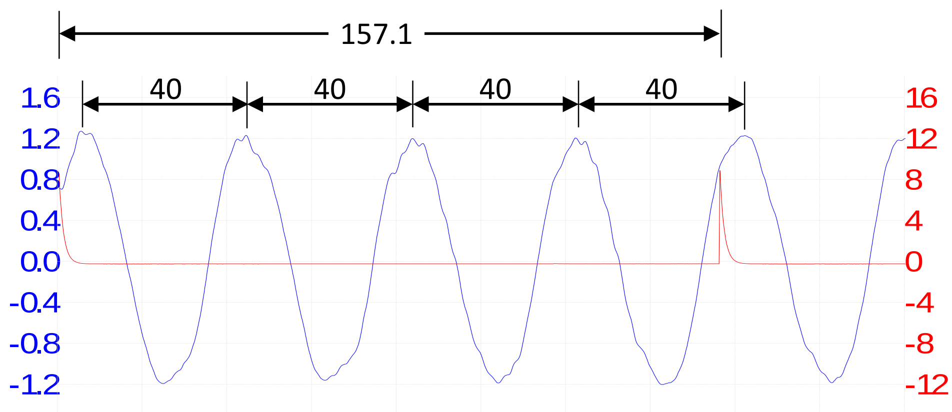
	Exhaust Tests	**Crankcase Tests**	**Intake Vacuum Tests**
undersize or missing pulses	possible misfire possible head or head gasket issue possible piston blow by		possible head or head gasket issue
oversize pulses	probable excess fuel possible head or head gasket issue possibly intentional extra fuel to heat up the catalytic converter	probable piston blow by	possible valve train issue possible head or head gasket issue

1. Basic Pulse Signature Analysis (continued)

You can also see timing problems from deviations in the pulse signatures. The time between pulses should be the same for all cylinders. When the pulse signature is clean, with little noise, you may also be able to see and measure the time between valve openings and closings.

To see timing issues, first, use your cursor to measure the time between trigger signals on the scope. This is the total time for one firing cycle of the engine. Then use the ES 100 Timing Chart in the Appendix to estimate the time per cylinder and the engine rpm.

This is an exhaust pulse signature for a 4-cylinder engine. The time between triggers is 157.1ms. This is the time for one firing cycle.



Using the Timing chart, read down the second column until you find the time that most closely matches the measured cycle time. Next, read across to the right until you get to the column for the number of cylinders in the engine. Use this value as the approximate time for each cylinder.

In this example, 157.1ms most closely matches 160ms in the Timing Chart. Now, follow this row across to the right and find the column for 4-cylinder engines. The table shows the estimated time per cylinder is 40ms. Use this estimated time to the compare pulse spacing. You have timing problems when the pulses are not equally spaced.

You can also estimate the engine rpm with the Timing Chart. Read down the second column in the chart and again find the time that most closely matches the measured cycle time. The estimated engine rpm in this example, 750 rpm, is in the first column, just to the left of the cycle time.

Of course, you *could* divide the time for one firing cycle by the number of cylinders to get a precise time for each cylinder. And you *could* calculate the exact engine rpm for the pulse signature displayed. (Engine rpm = 120,000 / time for 1 firing cycle in ms).

It is generally easier to estimate the time and rpm using the Timing Chart. However, if you suspect timing belt issues you may want the precise cylinder timing measurement to see the variation.

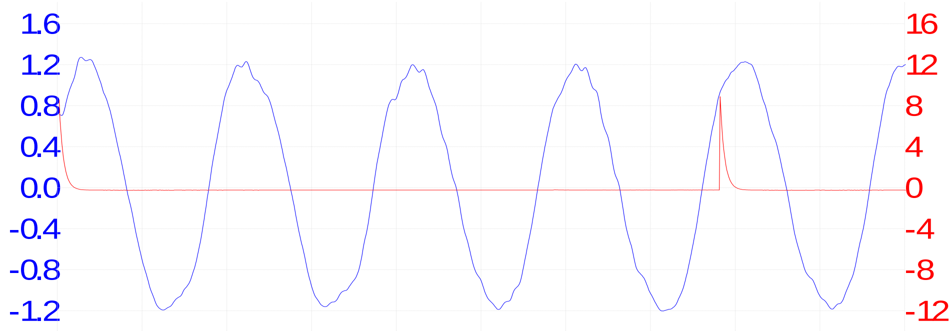
2. Signal and Signal Noise

Generally, it is best to step back and look at the ‘big picture’ when reading pulse signatures. Air pulses flow smoothly through some engines. In other engines, they seem to ricochet and echo off every elbow and sidewall they can find. This causes signal noise, and you need to ignore it.

The one exception is when you are looking at valve action. At first, valve issues may look like signal noise to you. With experience, you will learn you *can* pick out valve chatter from the background noise. Valve signals will just look different.

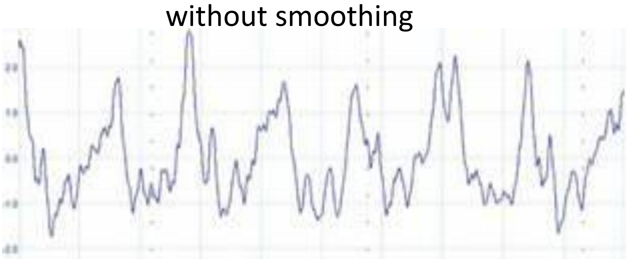
You may consider reducing the noise in Exhaust Test pulse signatures with the vacuum line adapter as described in ‘Sensor Set Up for Exhaust Tests.’ This, however, can smooth out and hide valve issues.

These exhaust pulse signatures illustrate smooth flow, noisy flow, and noisy flow smoothed by using the vacuum line adapter.

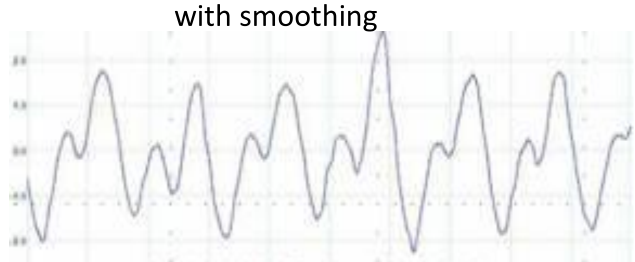


This is a well-running 4-cylinder engine with very smooth exhaust airflow. The uniformity of the pulses suggests the relative compression across the cylinders is also uniform.

without smoothing



with smoothing



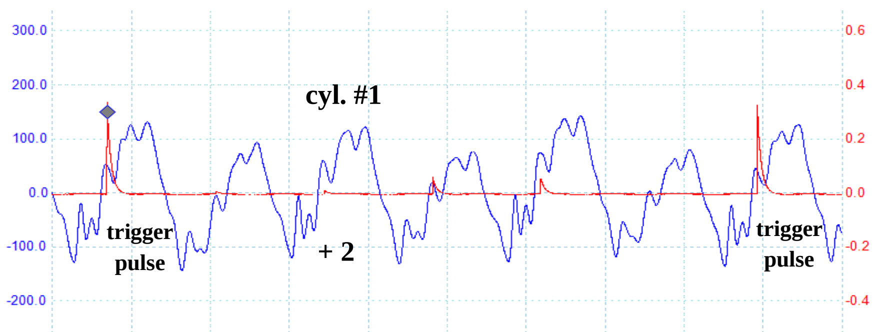
These pulse signatures are both from the same 6-cylinder engine and show the effect of using the vacuum line adapter for smoothing. The engine is running reasonably well. The pulse signature is fairly uniform and the pulses are fairly close in size.

3. Pulse - to - Cylinder Identification

Use a trigger signal to identify the pulses by cylinder number. Knowing the location of the trigger cylinder pulses and the firing order of the engine, you can identify all the pulses in the pulse signature. Whenever possible, use the first cylinder in the firing order, cylinder 1, for the trigger cylinder.

The trigger signal shows you when the trigger cylinder fires, but you still need to identify the pulses. The exhaust and intake pulses for the trigger cylinder are offset from the trigger pulse as shown in the Offset Table.

	Exhaust Pulse Offset, from Trigger Pulse	Crankcase Pulse Offset, from Trigger Pulse	Intake Vacuum Pulse Offset, from Trigger Pulse
4-Cylinder Engines	+ 1	0	+ 2
5-Cylinder Engines	+ 1	0	+3
6-Cylinder Engines	+ 2	0	+ 3
8-Cylinder Engines	+ 2	0	+4



This example shows an Idle Exhaust pulse signature (blue line) from a 6-cylinder engine run with a trigger signal (red line) attached to cylinder 1. From the table, for 6-cylinders, the exhaust pulse for the trigger cylinder is the second air pulse to right (+2) of the trigger pulse. Here, cylinder 1 was the trigger cylinder. Knowing this and the firing order, you can now identify all the pulses in the pulse signature. If cylinder 2 were the trigger cylinder, then cylinder 2 would be in the (+2) offset position.

Make sure you use the correct offset for the engine and the type of test. It does not matter which trigger you count from. Just remember the trigger pulse is the pulse just to the right of the trigger signal. And remember what cylinder is the trigger cylinder.

The trigger pulse *is* the crankcase pulse for the trigger cylinder. There are no offsets for crankcase pulses.

Please see ‘Offset Diagrams’ in the Appendix for a more detailed explanation.

4. Separate Pulses by Cylinder

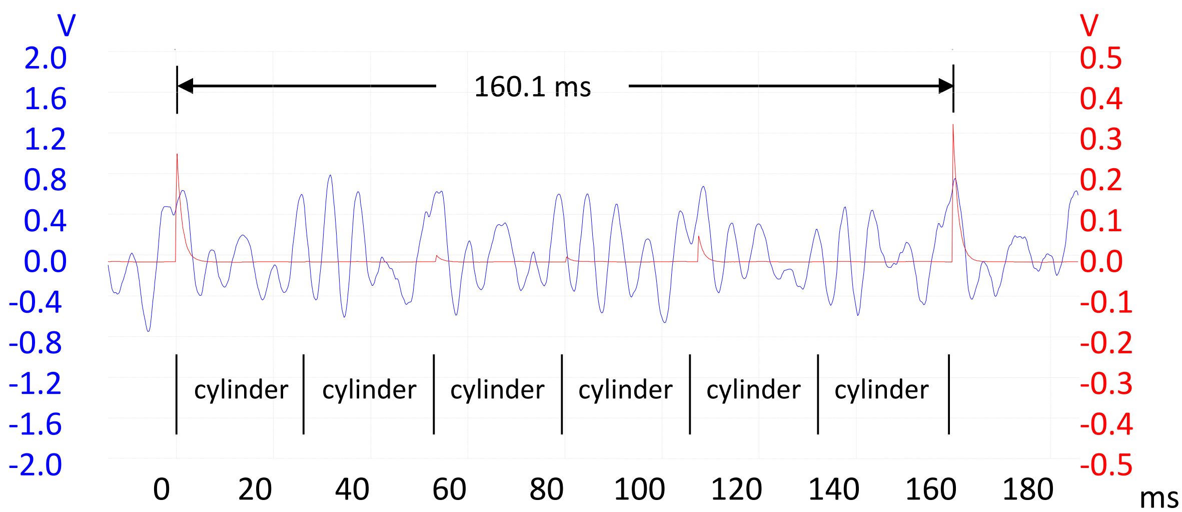
Sometimes it is easy to separate pulses by cylinder, as in the previous examples. Other times it can be difficult. When it is difficult, divide the pulse signature into time segments for each cylinder.

Estimate the time per cylinder as you did for checking timing issues in the pulse signature.

Use the cursor to measure the time between trigger signals on the scope and use the ES 100 Timing chart in the Appendix. Read down the second column in the Timing chart until you find the time that most closely matches the measured cycle time. Then read across to the right until you get to the column for the number of cylinders in the engine. Use this estimated time to separate the pulse signature into cylinders.

Again, you *could* divide the total time for one firing cycle by the number of cylinders to get a precise time for each cylinder. Again, it is generally easier to use the Timing Chart.

This is a pulse signature from a 6-cylinder engine. The time for one firing cycle, the time between triggers, is 160.1ms. From the table, the estimated time per cylinder is 26.7ms (OK, *precisely* 26.68ms if you insist on calculating it). Now you can separate the pulses by cylinder. Every 26.7ms represents one cylinder. Use the correct offset to identify the cylinders by number.



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Diagnostic Test Plans

The FirstLook® sensor is used in conjunction with the vehicle's OBDII. Begin by reviewing the stored codes in the OBDII and then use FirstLook® to zero in on the problems.

With experience, you will develop your own preferred testing strategies. Until then, here is a quick and easy test plan.

Start with the Cold Crank Exhaust Test. There are no misfires in this test because the engine is not firing. A rough or irregular pulse outline may indicate an exhaust valve train issue. Exhaust air pulses that are significantly smaller, or different from the others, either could not exit the cylinder properly (valve issue) or went somewhere else, not through the exhaust system (head gasket or rings). If the Cold Crank Exhaust pulse signature indicates one of these problems, run the Idle Crankcase Test.

In the Idle Crankcase Test, a significantly oversized pulse in the crankcase means 'extra' air is entering the crankcase. Suspect piston blow by.

Run the Cold Crank Intake Vacuum test when the Idle Crankcase pulse signature looks uniform. The Intake Vacuum tests are on the vacuum side, so look more at the valleys than the peaks. Pulses (valleys) that are significantly smaller than the others show air is leaking into the cylinder in addition to the air through the intake valves. Here, suspect head gaskets. An oversize pulse (valley) shows too much vacuum, not enough air, in the cylinder. This may be a valve problem.

Valve train issues are usually easier to see in Cold Crank tests, as there will be no noise in the pulse signature from fuel combustion in the engine.

If the Cold Crank Exhaust pulse signature looks uniform, run the Idle Exhaust Test. Now, the smaller air pulses indicate misfires. You have already ruled out piston blow by, head gasket and valve train issues. The smaller pulses could be either a fuel delivery issue or an ignition system problem. Larger air pulses point to extra fuel.

A small air pulse by itself indicates a misfire from a lean burn, a possible fuel delivery problem.

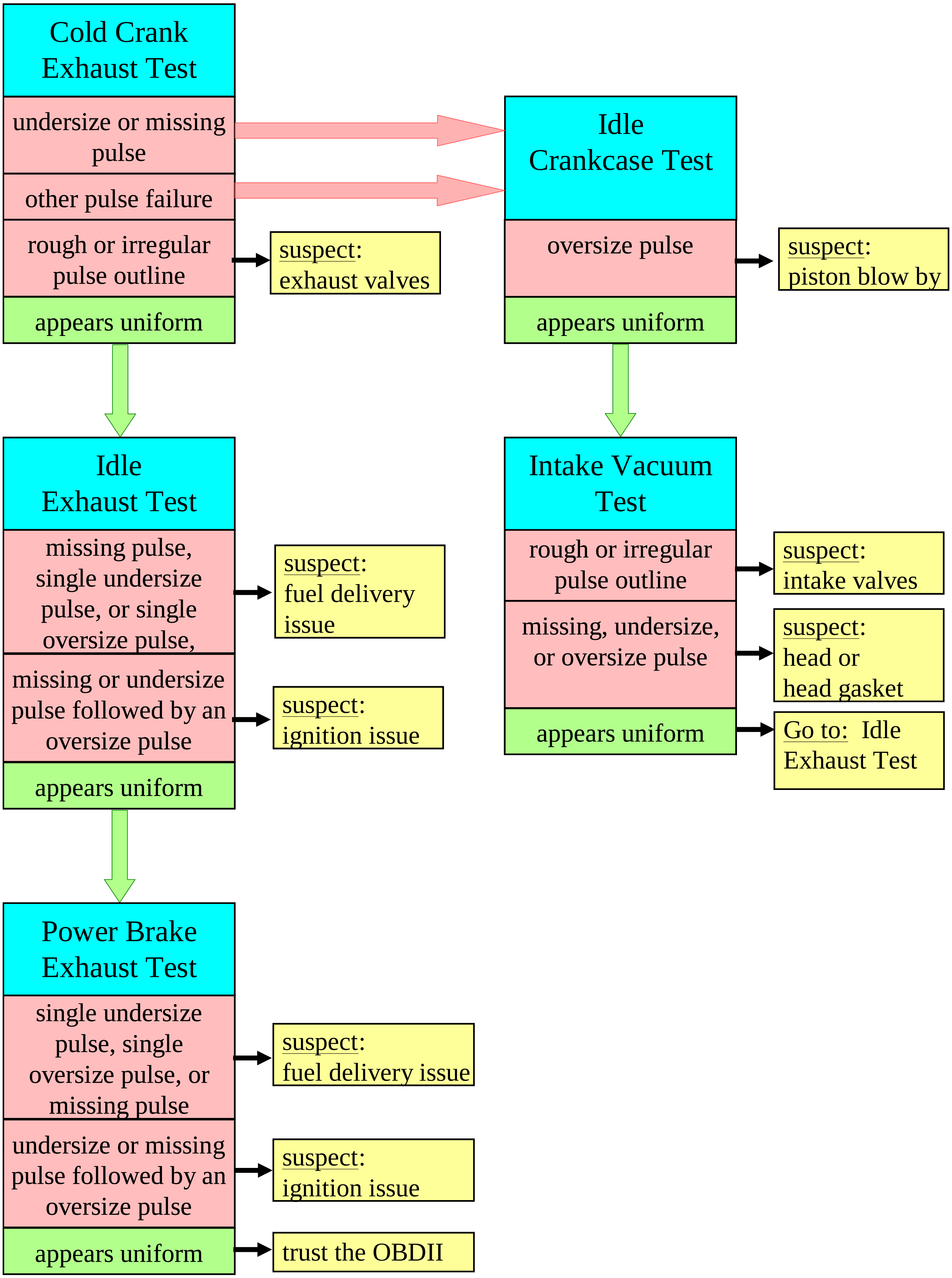
Suspect ignition problems when a smaller air pulse is immediately followed by a larger air pulse. Fuel was delivered but did not burn. This caused the first 'small' pulse. The unburned fuel ignites in the exhaust of following pulse and makes it larger.

A large pulse all by itself indicates a fat burn. More fuel was delivered than for the other pulses. This could be an injector problem. It could also be intentional. The engine system may do this when needed to keep the catalytic converter hot.

If the Idle Exhaust Test looks uniform, continue on to the Power Brake Exhaust Test. This puts more stress on the engine, and misfires are more likely to occur. As always, you are looking non-uniform pulse signatures and for pulses that are significantly smaller or larger than the others.

Diagnostic Test Plan: Flow Chart

This flow chart illustrates the test plan described on the previous page.



Test Equipment Required

You will need the following equipment to run these diagnostic tests:

A FirstLook® Basic Sensor Kit containing: (pictured below)

1. One Model ADS ES 100 Diagnostic Sensor
2. One rubber exhaust pipe hose with spring retainer
3. One 25 foot Male BNC to Male BNC cable
4. One 45 inch Male BNC to Banana Jack Plug cable
5. One BNC to BNC adapter
6. One vacuum line adapter with short hose
7. One oil dipstick tube adapter to fit the threaded FirstLook® sensor
8. One User's Guide for Spark Plug Engines

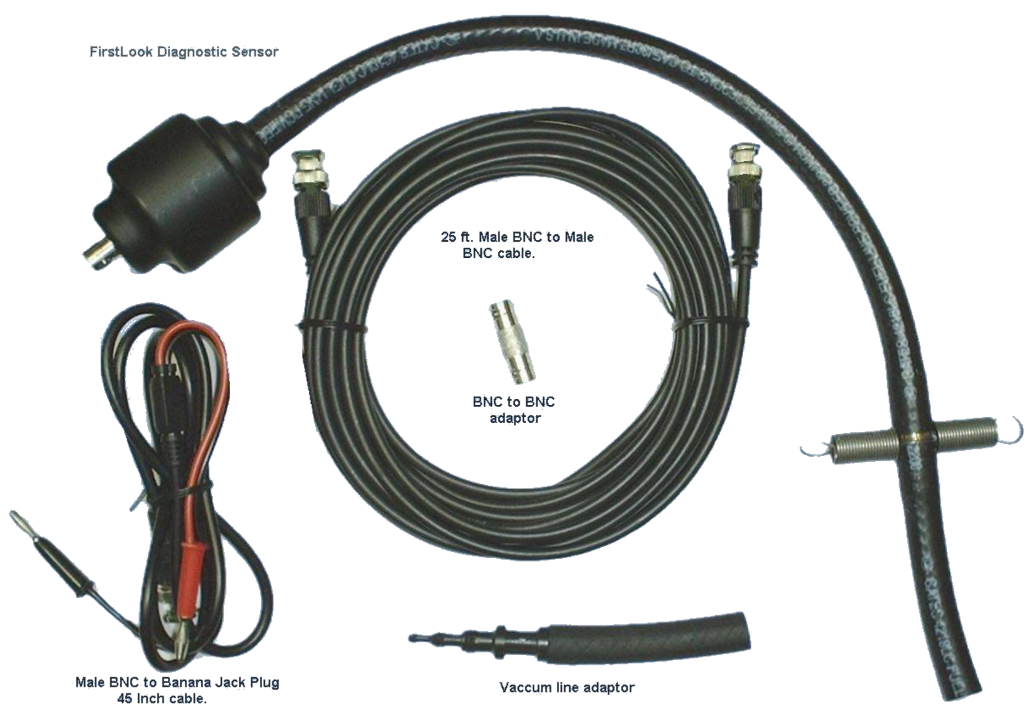
You will also need:

9. an inductor clamp or a COP (Coil on Plug) sensor
10. a 2-channel lab scope, minimum
11. a fuse puller

Optionally, you may want:

12. a 4-channel lab scope
13. additional sensors and cables (sold separately)

Package Contents



Test Equipment Handling and Care

Your FirstLook® sensor is mounted inside a rigid plastic housing. While reasonably sturdy, use standard care when handling the sensor so as to not crack or break the housing.

The FirstLook® sensor has a knobbed head to fit tightly onto a 3/8" diameter hose such as for the exhaust hose or to attach the vacuum line adapter. SenX does also provide a sensor with a threaded nipple to enable tight fit attachments for easy connection. **Push the knobbed FirstLook® sensor into the hose, or screw the threaded sensor snugly to the needed hose or attachment.**

Use standard care with the connector cables. Avoid driving or standing on them. Avoid kinking them during use and when coiling for storage.

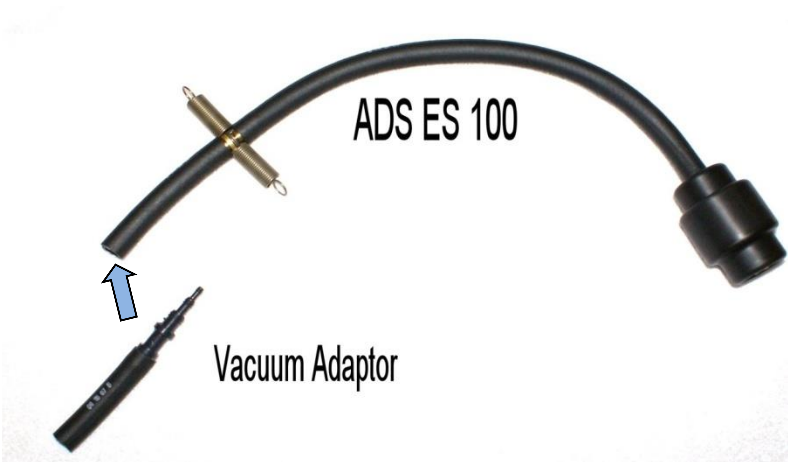
During use in Exhaust Tests, moisture in the exhaust air can condense inside the pulse sensor and exhaust hose. When done with Exhaust tests, store the pulse sensor and exhaust hose so that water can drain out.

ALLOW THE PULSE SENSOR TO AIR DRY NATURALLY! Using an air hose to blow out the sensor can damage it beyond repair.

Sensor Set Up for Exhaust Tests

To install the sensor in the exhaust:

1. Attach the sensor into the rubber exhaust pipe hose.
2. Select the correct sensor cable for your scope and attach the cable to the sensor.
3. Insert the sensor exhaust pipe hose about 4 inches into the exhaust pipe. Bend the springs attached to the hose so they fit inside the exhaust pipe. This holds the sensor hose in place.
4. Attach the sensor cable to **Channel A** on your scope.
5. (Optional) Insert the vacuum adapter into the end of sensor hose before insertion in the exhaust pipe. This can reduce some of the signal noise, giving you a smoother display. However, it may make the display too smooth to see valve problems.



Sensor Set Up for Crankcase Tests

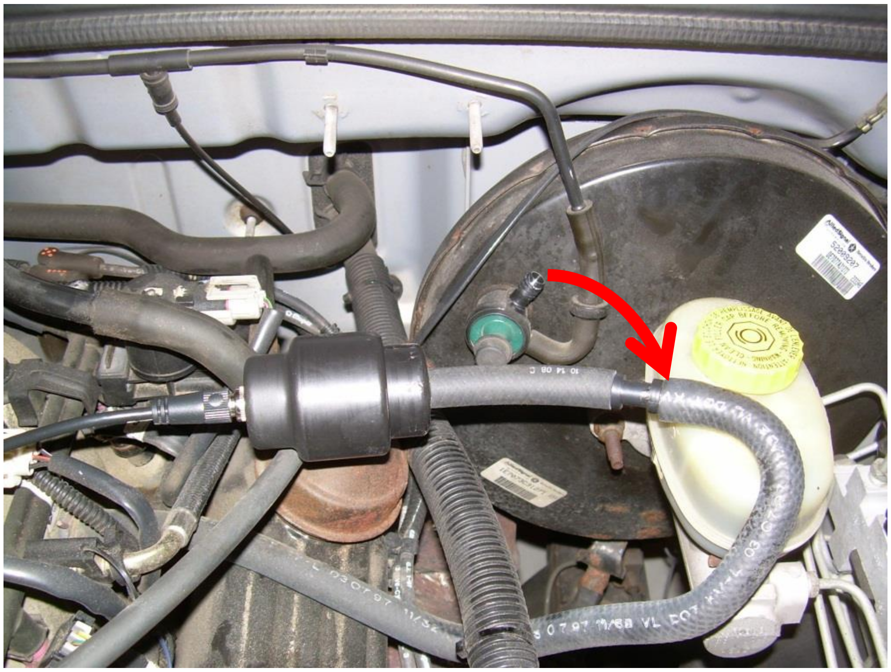
To install the sensor in the crankcase:

1. Insert or screw the sensor into the threaded oil dipstick tube adapter.
2. Select the correct sensor cable for your scope and attach the cable to the sensor.
3. Remove the oil level indicator stick.
4. Insert the sensor with the oil dipstick tube adapter into the oil level indicator tube. If the sensor adapter does not fit inside oil level indicator tube, insert the adapter into the short piece of hose and put the other end of the hose around the oil dipstick tube. **Note**: Some engines will generate error codes if the oil level indicator tube is not sealed sufficiently. An insufficient seal may also cause a misdiagnosis in the test.
5. Attach the sensor cable to **Channel A** on your scope, when using a 2-channel scope and a trigger. *See* Lab Scope Set Up.

Sensor Set Up for Intake Vacuum Tests

To install the sensor in a vacuum line:

1. Insert or screw the sensor into the vacuum adapter hose.
2. Select the correct sensor cable for your scope and attach the cable to the sensor.
3. Select a convenient manifold vacuum source. Do not use a ported vacuum source. SenX recommends using the brake booster.
4. Detach the selected vacuum line.
5. Insert the sensor vacuum adapter into the open vacuum line.
6. Attach the sensor cable to **Channel A** on your scope, when using a 2-channel scope and a trigger. *See* Lab Scope Set Up.



Here the sensor is attached to the power brake canister vacuum line using the vacuum line adapter shown on page 14.

Trigger Set Up

1. Attach your inductor clamp or a COP (Coil on Plug) sensor to a convenient cylinder. Usually this will be cylinder #1.
2. Connect your inductor clamp or COP to Channel B on your scope when using a 2-channel scope.

Lab Scope Set Up

The lab scope set up should be standardized as shown.

Channel Set Up

2-Channel Scopes

sensor in the exhaust pipe	Channel A
sensor in the crankcase	Channel A (Channel B if two sensors; no trigger)
sensor in the intake vacuum	Channel A (Channel B if two sensors; no trigger)
trigger sensor	Channel B

4-Channel Scopes

sensor in the exhaust pipe	Channel A
sensor in the crankcase	Channel B
sensor in the intake vacuum	Channel C
trigger sensor	Channel D

Scope Voltage and Time Scales

Set the scope voltage scale to display pulses for easy viewing. Set the time scale so at least one entire firing cycle is displayed on the screen. This means at least four pulses for a 4-cylinder engine or at least eight pulses for an 8-cylinder engine are displayed. Once you have looked at a single firing cycle, adjust the time scale to display two or three firing cycles at the same time to look for repeating patterns.

Use the following settings as starting points and adjust as needed.

Test Condition		Starting Voltage	Starting Time Scale
Cold Crank Tests		2v AC	1000ms, full scale
Idle Tests		5v AC	500ms, full scale
Power Brake Tests		10v AC	200ms, full scale

Trigger		5v AC for all tests	(same as for test condition)

Data Capture and Storage for Later Reference

In a busy shop, it is important to keep track of the signatures captured for ‘second looks’ and comparison for a quality check after repairs have been completed. Most PC oscilloscopes allow you to save the data captured in a file with a default name consisting of date and a sequence number, but also allow you to provide a file name in a directory of your choice. This approach is fine unless there are several PCs with oscilloscopes such that the sequence numbers might be repeated in one day on more than one PC.

Data that may be important are:

1. Date of the tests being conducted
2. Name of the mechanic doing the tests
3. PC identification and Directory name holding the file

For each test:

4. File sequence number (Seq#)
5. Vehicle identification: either a number assigned to the vehicle when it was brought in, or perhaps the license plate “number”

Engine data:

6. Engine configuration: {I = straight line (in-line), V = 2 banks of cylinders, …}
7. Number of cylinders in the engine
8. Manufacturer: {Chevy, Ford, Plymouth, Honda, Toyota, Volkswagen, etc.}
9. Displacement: {CID = cubic inch displacement; cc = cubic cm.; l = liters}
10. Odometer reading in miles or km

Signature data:

11. Condition: {c-c = cold crank; idle; load = 1500rpm; power = power brake}
12. RPM = revolutions per minute
13. Scope channel: (for up to 4 channels) {ex = exhaust; in = intake manifold; oil = oil level indicator tube; trig = trigger; none = no sensor attached}

We include a sample spreadsheet for you to record your tests on the following page. You may download the spreadsheet from our web-site at www.senxtech.com.

Engine Polygraph (formerly, SenX Signature Manager):

An alternative is to subscribe to the web application, Engine Polygraph, to store, index, and retrieve your signatures. In addition, the Engine Polygraph can provide an analysis report of your engine for simultaneous readings from the exhaust and crankcase. You can find more about the application at www.EnginePolygraph.com.

SenX FirstLook® Signature Log

Date (yyyymmdd)	**Mechanic**	**PC + Directory**

Seq#	**Vehicle**	**Config.**	**# Cyl**	**Mfg**	**Displ.**	**Odometer**	**Condition**	**RPM**	**Scope Channel**			
									A	**B**	**C**	**D**
nnnnn, or filename	Id# or plates	{I, V, ..}	n	{Chevy, Ford, Ply, ...}	{CID, cc, l}	{mi, km}	{c-c, idle, power}	nnnn	{ex, in, oil, trig, none}			

Cold Crank Exhaust Test (Spark Plug Engines)

Do not run this test on a carbureted engine.

To run this test:

1. Place the pulse sensor in the exhaust pipe and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 1000ms.
4. Set the voltage scale for Channel A to 2v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. **DISABLE the FUEL SYSTEM.**
7. Make sure all cables, hoses fingers, and hands are secure and clear of moving or rotating parts before starting the test.
8. Crank the engine until the display pattern stabilizes.
9. Adjust the voltage scale as needed for viewing pulses.
10. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
11. Freeze or Save the patterns.
12. Remember to re-enable the fuel system when the test is done.
13. Save the information about the vehicle and the filename with the signature.

Cold Crank Crankcase Test (Spark Plug Engines)

Do not run this test on a carbureted engine.

To run this test:

1. Place the pulse sensor in the oil level indicator tube and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 1000ms.
4. Set the voltage scale for Channel A to 2v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. **DISABLE the FUEL SYSTEM.**
7. Make sure all cables, hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test.
8. Crank the engine until the display pattern stabilizes.
9. Adjust the voltage scale as needed for viewing pulses.
10. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
11. Freeze or Save the patterns.
12. Remember to replace the oil level indicator stick and re-enable the fuel system when the test is done.
13. Save the information about the vehicle and the filename with the signature.

Cold Crank Intake Vacuum Test (Spark Plug Engines)

Do not run this test on a carbureted engine.

To run this test:

1. Attach the pulse sensor to the brake booster line, or other manifold vacuum source, and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 1000ms.
4. Set the voltage scale for Channel A to 2v AC.
5. Set the voltage scale for Channel B to 5v AC for trigger.
6. **DISABLE the FUEL SYSTEM.**
7. Make sure all cables, hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test.
8. Crank the engine until the display pattern stabilizes.
9. Adjust the voltage scale as needed for viewing pulses.
10. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
11. Freeze or Save the patterns.
14. Remember to re-attach the vacuum line and re-enable the fuel system when the test is done.
12. Save the information about the vehicle and the filename with the signature.

Idle Exhaust Test (Spark Plug Engines)

To run this test:

1. Place the pulse sensor in the exhaust pipe and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 500ms.
4. Set the voltage scale for Channel A to 5v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. Make sure all cables, hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test.
7. Start the engine and allow the idle and the pulse display pattern to stabilize.
8. Adjust the voltage scale as needed for viewing pulses.
9. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
13. Freeze or Save the patterns.
10. Save the information about the vehicle and the filename with the signature.

Idle Crankcase Test (Spark Plug Engines)

To run this test:

1. Place the pulse sensor in the oil level indicator tube and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 500ms.
4. Set the voltage scale for Channel A to 5v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. Make sure all lines, hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test.
7. Start the engine and allow the idle and the pulse display pattern to stabilize.
8. Adjust the voltage scale as needed for viewing pulses.
9. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
10. Freeze or Save the patterns.
14. Remember to replace the oil level indicator stick when the test is done.
11. Save the information about the vehicle and the filename with the signature.

Idle Intake Vacuum Test **(Spark Plug Engines)**

To run this test:

1. Attach the pulse sensor to the brake booster line, or other manifold vacuum source, and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 500ms.
4. Set the voltage scale for Channel A 5v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. Make sure all lines, hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test
7. Start the engine and allow the idle and the pulse display pattern to stabilize.
8. Adjust the voltage scale as needed for viewing pulses.
9. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
10. Freeze or Save the patterns.
11. Remember to re-attach the vacuum line when the test is done.
12. Save the information about the vehicle and the filename with the signature.

Power Brake Exhaust Test (Spark Plug Engines)

Important Safety Note: Run this test only when the vehicle is on a hoist, or the wheels are blocked, and with two people. One person runs the diagnostic equipment outside the vehicle while the other person operates the vehicle.

To run this test:

1. Place the pulse sensor in the exhaust pipe and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 200ms.
4. Set the voltage scale for Channel A to 10v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. Make sure all cables, hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test.
7. Lift the vehicle until the wheels are suspended in the air, or place chocks on the wheels.
8. Start the engine and allow the idle and the pulse display pattern to stabilize.
9. Apply foot pressure on the brake pedal and place the transmission in DRIVE.
10. Press the accelerator while keeping foot pressure on the brake pedal.
11. Raise engine rpm until problems appear but no higher than 1500 rpm maximum
12. Adjust the voltage scale as needed for viewing pulses.
13. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
14. Watch for and Freeze or Save pulse deviation patterns.
15. Return engine to idle and place the transmission in PARK.
16. Save the information about the vehicle and the filename with the signature.

Power Brake Crankcase Test (Spark Plug Engines)

Important Safety Note: Run this test only when the vehicle is on a hoist, or the wheels are blocked, and with two people. One person runs the diagnostic equipment outside the vehicle while the other person operates the vehicle.

To run this test:

1. Place the pulse sensor in the oil level indicator tube and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 200ms.
4. Set the voltage scale for Channel A to 10v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. Make sure all lines, hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test.
7. Lift the vehicle until the wheels are suspended in the air, or place chocks on the wheels.
8. Start the engine and allow the idle and the pulse display pattern to stabilize.
9. Apply foot pressure on the brake pedal and place the transmission in DRIVE.
10. Press the accelerator while keeping foot pressure on the brake pedal.
11. Raise the engine rpm until problems appear but no higher than 1500 rpm maximum
12. Adjust the voltage scale as needed for viewing pulses.
13. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
14. Watch for and Freeze or Save pulse deviation patterns.
15. Return the engine to idle and place the transmission in PARK.
16. Remember to replace the oil level indicator stick when the test is done.
17. Save the information about the vehicle and the filename with the signature.

Power Brake Intake Vacuum Test **(Spark Plug Engines)**

Important Safety Note: Run this test only when the vehicle is on a hoist, or the wheels are blocked, and with two people. One person runs the diagnostic equipment outside the vehicle while the other person operates the vehicle.

To run this test:

1. Attach the pulse sensor to the brake booster line, or other manifold vacuum source, and connect it to Channel A on your scope.
2. Connect the ignition trigger from cylinder #1 to Channel B on your scope.
3. Set the time base scale on your scope to 200ms.
4. Set the voltage scale for Channel A to 10v AC.
5. Set the voltage scale for Channel B to 5v AC for the trigger.
6. Make sure all cables & hoses, fingers and hands are secure and clear of moving or rotating parts before starting the test.
7. Lift the vehicle until the wheels are suspended in the air, or place chocks on the wheels.
8. Start the engine and allow the idle and the pulse display pattern to stabilize.
9. Apply foot pressure on the brake pedal and place the transmission in DRIVE.
10. Press the accelerator while keeping foot pressure on the brake pedal.
11. Raise the engine rpm until problems appear but no higher than 1500 rpm maximum.
12. Adjust the voltage scale as needed for viewing pulses.
13. Adjust the time base as needed to display both a single firing cycle and then to display several firing cycles.
14. Watch for and Freeze or Save pulse deviation patterns.
15. Return the engine to idle and place the transmission in PARK.
16. Remember to re-attach the vacuum line when the test is done.
17. Save the information about the vehicle and the filename with the signature.

Appendix

Troubleshooting

If you cannot get a pulse signature during a test:

1. Verify your lab scope has power and is set up and functioning properly.
2. If the lab scope is OK, verify the sensor cable connections are tight.
3. If your scope and the cable connections are OK, check the continuity in the sensor cable. If there is a problem with the cable, contact SenX about cable replacement.
4. If both the lab scope and the cable are OK, there is a sensor problem. Please contact SenX about sensor repair or replacement.

If you cannot get a trigger signal during a test:

1. Verify your trigger sensor is set up and functioning properly.
2. Verify the trigger sensor connections are tight.
3. Verify there is actually a spark going to the trigger cylinder.

If you create 'Check Engine' codes during a crankcase test:

1. Make sure the sensor in the oil level indicator tube is sealed enough to prevent airflow into the crankcase.

Contact Us

Please contact us with any questions or problems that are not addressed in this User's Guide.

SenX Technology LLC
5315 Sunset Drive
Midland, MI 48640
Phone 866-832-8898
Fax 989-832-8908

Visit our Web Site

http://senxtech.com

Our web site includes

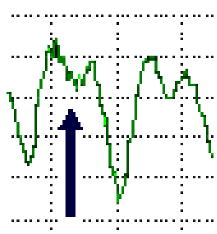
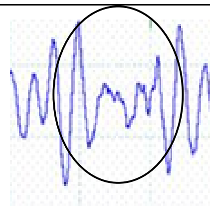
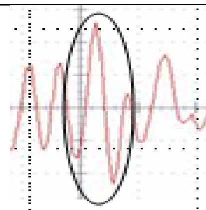
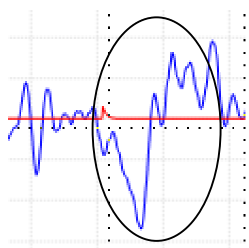
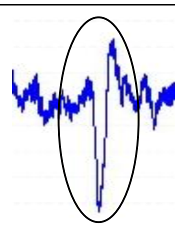
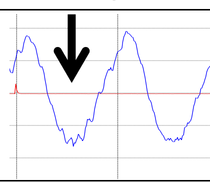
FAQs
Additional reference pulse signatures
Additional technical information about the FirstLook® sensor

ES 100 Timing Chart for 4-Stroke Engines

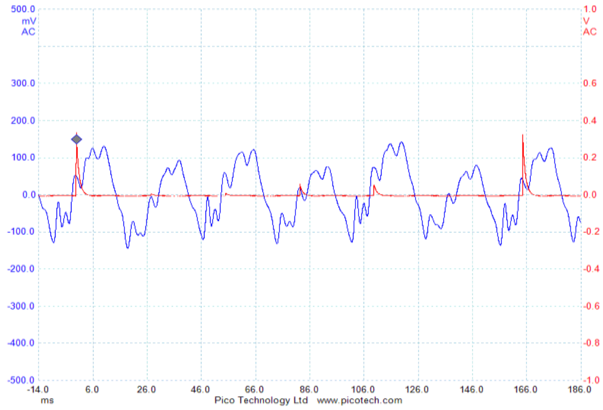
	Time Between Valve Opening Events (milliseconds)							
Engine Speed (rpm)	Time to Complete 1 Cycle in 4 Stroke Engine (ms)	A 2 Cylinder	B 3 Cylinder	C 4 Cylinder	D 5 Cylinder	E 6 Cylinder	F 8 Cylinder	Starting Time Base Reference (ms)
150	800.0	400.0	266.7	200.0	160.0	133.3	100.0	
175	685.7	342.9	228.6	171.4	137.1	114.3	85.7	Cold Crank
200	600.0	300.0	200.0	150.0	120.0	100.0	75.0	600
225	533.3	266.7	177.8	133.3	106.7	88.9	66.7	
250	480.0	240.0	160.0	120.0	96.0	80.0	60.0	
300	400.0	200.0	133.3	100.0	80.0	66.7	50.0	
350	342.9	171.4	114.3	85.7	68.6	57.1	42.9	
400	300.0	150.0	100.0	75.0	60.0	50.0	37.5	
450	266.7	133.3	88.9	66.7	53.3	44.4	33.3	
500	240.0	120.0	80.0	60.0	48.0	40.0	30.0	
550	218.2	109.1	72.7	54.5	43.6	36.4	27.3	Idle Start
600	200.0	100.0	66.7	50.0	40.0	33.3	25.0	200
650	184.6	92.3	61.5	46.2	36.9	30.8	23.1	
700	171.4	85.7	57.1	42.9	34.3	28.6	21.4	
750	160.0	80.0	53.3	40.0	32.0	26.7	20.0	
800	150.0	75.0	50.0	37.5	30.0	25.0	18.8	
850	141.2	70.6	47.1	35.3	28.2	23.5	17.6	
900	133.3	66.7	44.4	33.3	26.7	22.2	16.7	
950	126.3	63.2	42.1	31.6	25.3	21.1	15.8	
1000	120.0	60.0	40.0	30.0	24.0	20.0	15.0	
1100	109.1	54.5	36.4	27.3	21.8	18.2	13.6	Low RPM
1200	100.0	50.0	33.3	25.0	20.0	16.7	12.5	100
1300	92.3	46.2	30.8	23.1	18.5	15.4	11.5	
1400	85.7	42.9	28.6	21.4	17.1	14.3	10.7	
1500	80.0	40.0	26.7	20.0	16.0	13.3	10.0	
1600	75.0	37.5	25.0	18.8	15.0	12.5	9.4	
1700	70.6	35.3	23.5	17.6	14.1	11.8	8.8	
1800	66.7	33.3	22.2	16.7	13.3	11.1	8.3	
1900	63.2	31.6	21.1	15.8	12.6	10.5	7.9	
2000	60.0	30.0	20.0	15.0	12.0	10.0	7.5	
2100	57.1	28.6	19.0	14.3	11.4	9.5	7.1	
2200	54.5	27.3	18.2	13.6	10.9	9.1	6.8	
2300	52.2	26.1	17.4	13.0	10.4	8.7	6.5	Mid Range RPM
2400	50.0	25.0	16.7	12.5	10.0	8.3	6.3	50

Example Pulses

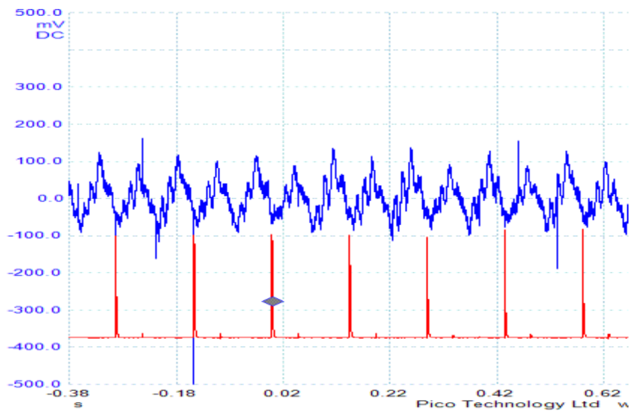
This is a starting point for reading the pulse signature. With experience, you will soon know more about reading pulse signatures than can ever be written in a table like this, but start here.

Pulse	Image	Possible Causes
saw-toothed shape across the top of an exhaust pulse		suspect dirty or sticky exhaust valves
undersize or missing exhaust pulse(s)		suspect a lean burn, less fuel was delivered: possible injector issue
oversize exhaust pulse(s)		suspect a fat burn, extra fuel was delivered: possible injector issue or possibly intentional to keep the catalytic converter hot
undersize or missing pulse followed by an oversize pulse example shows a missing pulse		suspect an ignition misfire: fuel was delivered, but did not burn until in the exhaust of the following pulse
oversize or non-uniform crankcase pulse		probable cause: piston blow-by
saw-toothed shape across the bottom of a vacuum pulse		suspect dirty or sticky intake valves

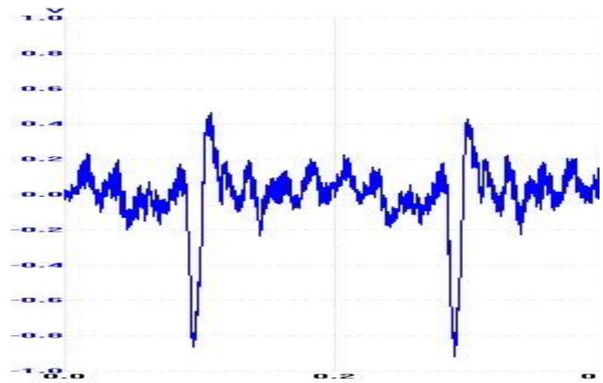
Reference Pulse Signatures



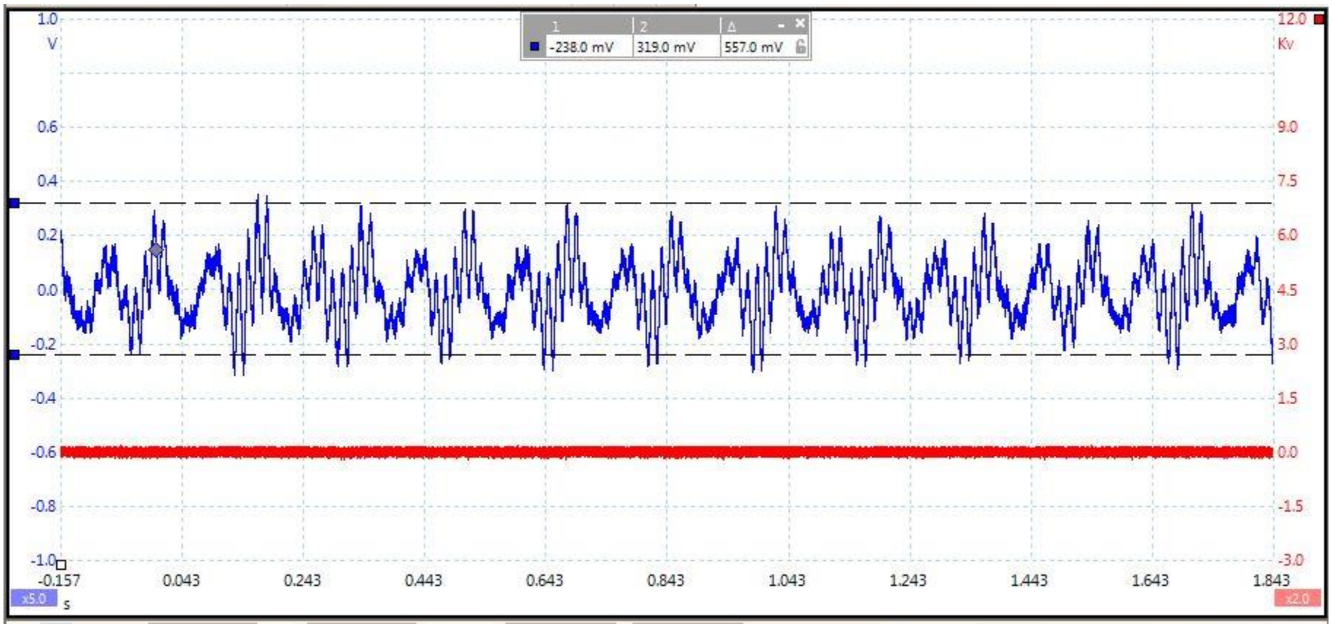
Exhaust Test – Reasonable V6 Engine



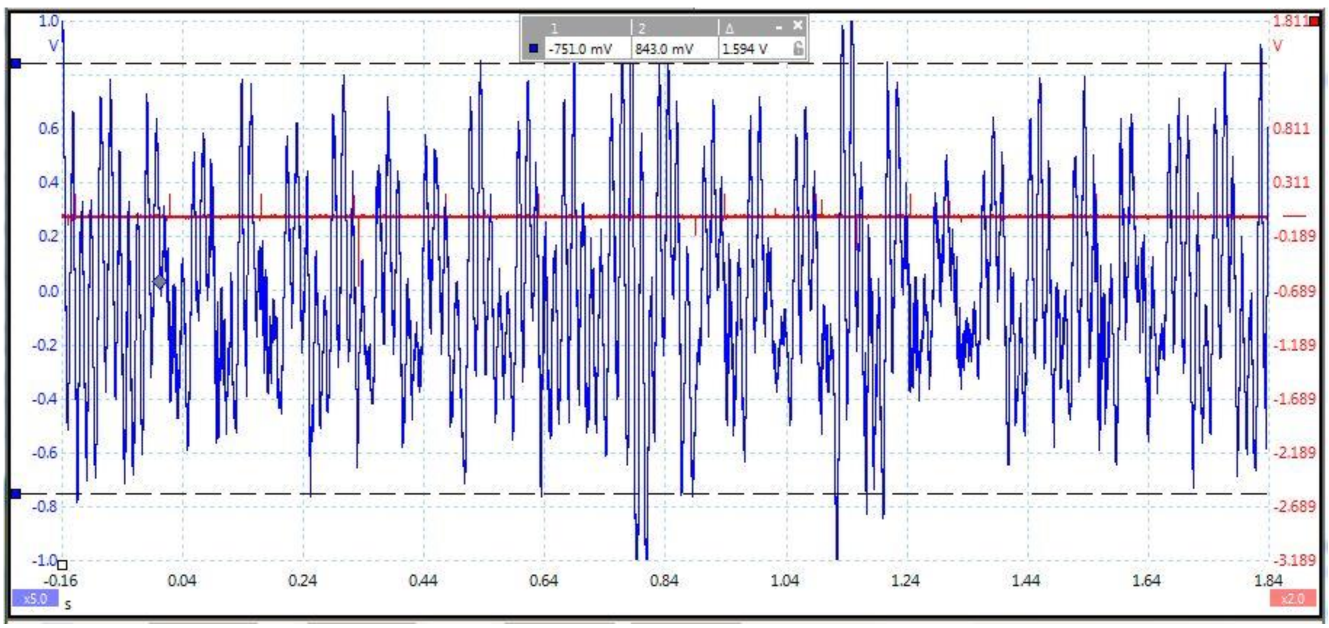
Crankcase Test – Good Cylinders Diesel



Crankcase Test – Bad Cylinder Diesel Idle



Crankcase signature from Cadillac with 130,000 miles, voltage (-0.25, +0.3); **rings not bad**



Crankcase signature from Cadillac with 192,000 miles, voltage (-0.75, +0.85): **bad rings**

Offset Diagrams

4-Cylinder Engine Offsets

The 4-Cylinder Offset Diagram is shown on the next page. An exhaust pulse signature is included for illustration. The trigger signal is attached to cylinder 1.

Exhaust pulses start when exhaust valves open just before dead bottom center (DBC) of the power stroke. They continue as the piston pushes exhaust gases out of the cylinder during its exhaust stroke. Notice how the exhaust pulses in the pulse signature start increasing before the end of the power stroke.

Find the exhaust stroke for cylinder 1 in the diagram and track it down to the exhaust pulse signature. This shows the exhaust pulse from cylinder 1 is offset one pulse to the right of the trigger pulse (+1).

You can identify the rest of the exhaust pulses the same way. Or you could just count them since you know both the firing order and the location of the exhaust pulse for cylinder #1.

A crankcase pulse signature is not shown. However, crankcase pulses are created when the piston strokes down during its power stroke.

Find the power stroke for cylinder 1 in the diagram and track it down. This shows the crankcase pulse is right at the trigger. There is no offset. Identify the other crankcase pulses the same way. Or again, you could just count them since you know both the firing order and the location of the exhaust pulse for cylinder #1.

Technically, in this 4-cylinder engine example, the trigger crankcase pulse is the sum of the pulses for pistons 1 and 3, which are both stroking down, minus the pulses for pistons 2 and 4, which are both stroking up. However, pulse deviations will be a result of the very high pressure in the cylinder that is firing. So, for test purposes we can identify the pulse as being only the power stoke piston.

Intake vacuum pulses are created when the piston strokes down during its intake stroke. Find the intake stroke for cylinder 1 and track it down. This shows the intake pulse for cylinder 1 would be offset two pulses to right of the trigger pulse.

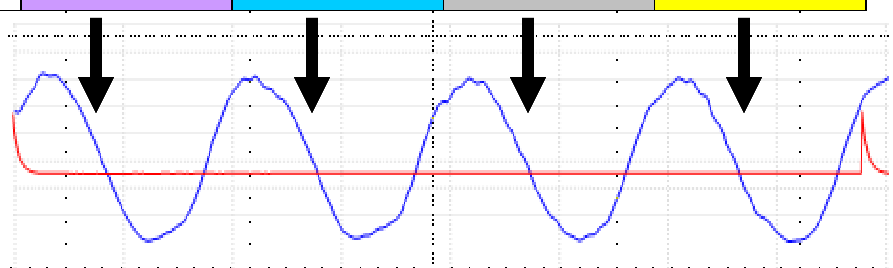
The offsets work no matter what cylinder you use for the trigger. Just remember you will identify the pulses for the trigger cylinder. When you attach the trigger to cylinder 2, for example, the offsets will identify the pulses for cylinder 2. And knowing the firing order, you can still identify the rest of the pulses.

Also, it does not matter which trigger you count from. The important thing is to remember the trigger pulse is the pulse just to the right of the trigger signal.

4-Cylinder Offset Diagram

A 4-cylinder engine with firing order: 1 – 4 – 3 – 2

crankshaft rotation		0 to 180°	180 to 360°	360 to 540°	540 to 720°
Fire Seq. 1	Cyl. #1	Power Stroke	Exhaust Stroke	Intake Stroke	Compression Stroke
Fire Seq. 2	Cyl. #4	Compression Stroke	Power Stroke	Exhaust Stroke	Intake Stroke
Fire Seq. 3	Cyl. #3	Intake Stroke	Compression Stroke	Power Stroke	Exhaust Stroke
Fire Seq. 4	Cyl. #2	Exhaust Stroke	Intake Stroke	Compression Stroke	Power Stroke



The blue line is an exhaust pulse signature. The red line is the trigger signal.

	trigger pulse	+1	+2	+3
exhaust pulses	#2 exhaust	#1 exhaust	#4 exhaust	#3 exhaust
crankcase pulses	#1 crankcase	#4 crankcase	#3 crankcase	#2 crankcase
intake vacuum pulses	#3 intake	#2 intake	#1 intake	#4 intake

6-Cylinder Engine Offsets

Please review the 4-Cylinder Engine Offset Diagram and explanation if you have not already done so. It will be easier to see and understand the offsets here once you understand the 4-Cylinder Offset Diagram.

The 6-Cylinder Offset Diagram is shown on the next page. The first thing you will notice is that the 'extra' cylinders cause the pistons to overlap each other during their strokes. This makes the diagram look more complicated, but the analysis is the same.

An intake vacuum pulse signature, with a trigger on cylinder 1, is included for illustration. Remember, this is the vacuum side. You need to look at the 'negative peaks,' or 'valleys,' when reading these pulse signatures.

The diagram identifies the trigger pulse as being the intake pulse from cylinder 4. There is overlap with cylinder 5 at the start, but the trigger pulse is *mostly* cylinder 4. The intake pulse just to the right of the trigger pulse is cylinder 3. Again, you can see the overlap with cylinder 4, but the pulse is going to be *mostly* cylinder 3.

If you need to, use the columns in table at the bottom under the pulse signature to divide the pulse signature into cylinders.

Now, find the intake stroke for cylinder 1 and track it down to the pulse signature. The intake pulse (valley) that is *mostly* cylinder 1 is three pulses to the right (+3) of the trigger pulse.

It is the same when you have exhaust and crankcase pulse signatures. For exhaust pulse signatures, find the exhaust stroke for the trigger cylinder (usually cylinder 1) and track it down. Exhaust pulses for a 6-cylinder engine will be offset two pulses to the right of the trigger pulse (+2). Follow the power stroke down to see the crankcase pulse will be right at the trigger with no offset.

3-, 5- and 8-Cylinder Engine Offsets

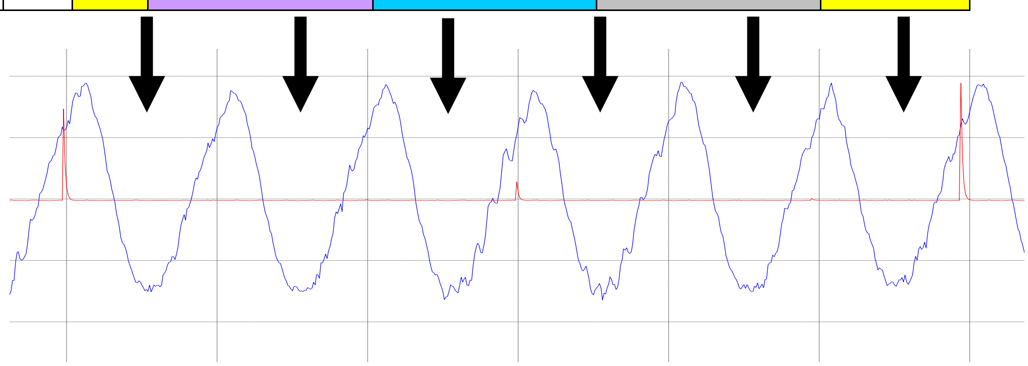
The 3-Cylinder, 5-Cylinder and the 8-Cylinder Offset Diagrams are included. The 8-Cylinder Engine Offset Diagram appears even more complicated than the 6-cylinder because there is more overlap.

Still, the analysis is the same as with the 4-cylinder and the 6-cylinder diagrams.

6-Cylinder Offset Diagram

A 6-cylinder engine with firing order: 1 – 6 – 5 – 4 – 3 – 2

<table>
<tr><td colspan="2" rowspan="2">crankshaft rotation</td><td colspan="3">0 to 180°</td><td colspan="3">180 to 360°</td><td colspan="3">360 to 540°</td><td colspan="3">540 to 720°</td></tr>
<tr><td>60</td><td>120</td><td>180</td><td>240</td><td>300</td><td>360</td><td>420</td><td>460</td><td>540</td><td>600</td><td>660</td><td>720</td></tr>
<tr><td>Fire Seq. 1</td><td>Cyl. #1</td><td colspan="3">Power Stroke</td><td colspan="3">Exhaust Stroke</td><td colspan="3">Intake Stroke</td><td colspan="3">Compression Stroke</td></tr>
<tr><td>Fire Seq. 2</td><td>Cyl. #6</td><td colspan="2">Comp. Stroke</td><td colspan="3">Power Stroke</td><td colspan="3">Exhaust Stroke</td><td colspan="3">Intake Stroke</td><td></td></tr>
<tr><td>Fire Seq. 3</td><td>Cyl. #5</td><td></td><td colspan="3">Compression Stroke</td><td colspan="3">Power Stroke</td><td colspan="3">Exhaust Stroke</td><td colspan="2">Intake Stroke</td></tr>
<tr><td>Fire Seq. 4</td><td>Cyl. #4</td><td colspan="3">Intake Stroke</td><td colspan="3">Compression Stroke</td><td colspan="3">Power Stroke</td><td colspan="3">Exhaust Stroke</td></tr>
<tr><td>Fire Seq. 5</td><td>Cyl. #3</td><td colspan="2">Exhaust Stroke</td><td colspan="3">Intake Stroke</td><td colspan="3">Compression Stroke</td><td colspan="3">Power Stroke</td><td></td></tr>
<tr><td>Fire Seq. 6</td><td>Cyl. #2</td><td></td><td colspan="3">Exhaust Stroke</td><td colspan="3">Intake Stroke</td><td colspan="3">Compression Stroke</td><td colspan="2">Power Stroke</td></tr>
</table>



The blue line is an intake vacuum pulse signature. The red line is the trigger signal.

	trigger pulse	+1	+2	+3		
exhaust pulses	#3 exhaust	#2 exhaust	#1 exhaust	#6 exhaust	#5 exhaust	#4 exhaust
crankcase pulses	#1 crankcase	#6 crankcase	#5 crankcase	#4 crankcase	#3 crankcase	#3 crankcase
intake vacuum pulses	#4 intake	#3 intake	#2 intake	#1 intake	#6 intake	#5 intake

3-Cylinder Engine Offset Diagram

A 3-cylinder engine with firing order: 1 – 2 –3

Crankshaft rotation:		0 to 180˚			180 to 360˚			360 to 540˚			540 to 720˚		
		60	120	180	240	300	360	420	480	540	600	660	720
Fire Seq 1	Cyl 1	Power Stroke			Exhaust Stroke			Intake Stroke			Compression Stroke		
Fire Seq 2	Cyl 2		Compression Stroke			Power Stroke			Exhaust Stroke			Intake	
Fire Seq 3	Cyl 3	Exhaust		Intake Stroke			Compression Stroke			Power Stroke			

	Trigger pulse				+1				+2			
Exhaust pulses	#3			#1				#2				#3
Crankcase pulses	#1				#2				#3			
Intake vacuum pulses	#2		#3				#1				#2	

5-Cylinder Engine Offset Diagram

A 5-cylinder engine with firing order: 1 – 2 – 4 – 5 – 3

<table>
<tr><td colspan="2" rowspan="2">crankshaft rotation</td><td colspan="5">0 to 180º</td><td colspan="5">180 to 360º</td><td colspan="5">360 to 540º</td><td colspan="5">5400 to 720º</td></tr>
<tr><td colspan="2">72</td><td colspan="2">144</td><td colspan="2">216</td><td colspan="2">288</td><td colspan="2">360</td><td colspan="2">432</td><td colspan="2">504</td><td colspan="2">576</td><td colspan="2">648</td><td colspan="2">720</td></tr>
<tr><td>Fire Seq. 1</td><td>Cyl. #1</td><td colspan="5">power stroke</td><td colspan="5">exhaust stroke</td><td colspan="5">intake stroke</td><td colspan="5">compression stroke</td></tr>
<tr><td>Fire Seq. 2</td><td>Cyl. #2</td><td colspan="4">compression stroke</td><td colspan="5">power stroke</td><td colspan="5">exhaust stroke</td><td colspan="5">intake stroke</td><td colspan="1"></td></tr>
<tr><td>Fire Seq. 3</td><td>Cyl. #4</td><td colspan="3">intake stroke</td><td colspan="5">compression stroke</td><td colspan="5">power stroke</td><td colspan="5">exhaust stroke</td><td colspan="2"></td></tr>
<tr><td>Fire Seq. 4</td><td>Cyl. #5</td><td colspan="2"></td><td colspan="5">intake stroke</td><td colspan="5">compression stroke</td><td colspan="5">power stroke</td><td colspan="3">exhaust stroke</td></tr>
<tr><td>Fire Seq. 5</td><td>Cyl. #3</td><td colspan="1"></td><td colspan="5">exhaust stroke</td><td colspan="5">intake stroke</td><td colspan="5">compression stroke</td><td colspan="4">power stroke</td></tr>
</table>

	trigger pulse	+1	+2	+3	
exhaust pulses	#3 exhaust	#1 exhaust	#2 exhaust	#4 exhaust	#5 exhaust
crankcase pulses	#1 crankcase	#2 crankcase	#4 crankcase	#5 crankcase	#3 crankcase
intake vacuum pulses	#4-5	#5-3	#3-1	#1-2	#2-4

Notice that the intake strokes cover neighboring ‘cylinder assignments’, so consider this in doing your diagnosis.

8-Cylinder Offset Diagram

An 8-cylinder engine with firing order: 1 – 8 – 4 – 3 – 6 – 5 – 7 – 2

<table>
<tr><th colspan="2" rowspan="2">crankshaft rotation</th><th colspan="4">0 to 180º</th><th colspan="4">180 to 360º</th><th colspan="4">360 to 540º</th><th colspan="4">540 to 720º</th></tr>
<tr><th>45</th><th>90</th><th>135</th><th>180</th><th>225</th><th>270</th><th>315</th><th>360</th><th>405</th><th>450</th><th>495</th><th>540</th><th>585</th><th>630</th><th>675</th><th>720</th></tr>
<tr><td>Fire Seq 1</td><td>Cyl 1</td><td colspan="4">Power Stroke</td><td colspan="4">Exhaust Stroke</td><td colspan="4">Intake Stroke</td><td colspan="4">Compression Stroke</td></tr>
<tr><td>Fire Seq 2</td><td>Cyl 8</td><td colspan="2"></td><td colspan="4">Power Stroke</td><td colspan="4">Exhaust Stroke</td><td colspan="4">Intake Stroke</td><td colspan="2">Comp. Stroke</td></tr>
<tr><td>Fire Seq 3</td><td>Cyl 4</td><td colspan="4">Compression Stroke</td><td colspan="4">Power Stroke</td><td colspan="4">Exhaust Stroke</td><td colspan="4">Intake Stroke</td></tr>
<tr><td>Fire Seq 4</td><td>Cyl 3</td><td colspan="2"></td><td colspan="4">Compression Stroke</td><td colspan="4">Power Stroke</td><td colspan="4">Exhaust Stroke</td><td colspan="2">Intake Stroke</td></tr>
<tr><td>Fire Seq 5</td><td>Cyl 6</td><td colspan="4">Intake Stroke</td><td colspan="4">Compression Stroke</td><td colspan="4">Power Stroke</td><td colspan="4">Exhaust Stroke</td></tr>
<tr><td>Fire Seq 6</td><td>Cyl 5</td><td colspan="2"></td><td colspan="4">Intake Stroke</td><td colspan="4">Compression Stroke</td><td colspan="4">Power Stroke</td><td colspan="2">Exhaust Stroke</td></tr>
<tr><td>Fire Seq 7</td><td>Cyl 7</td><td colspan="4">Exhaust Stroke</td><td colspan="4">Intake Stroke</td><td colspan="4">Compression Stroke</td><td colspan="4">Power Stroke</td></tr>
<tr><td>Fire Seq 8</td><td>Cyl 2</td><td colspan="2"></td><td colspan="4">Exhaust Stroke</td><td colspan="4">Intake Stroke</td><td colspan="4">Compression Stroke</td><td colspan="2">Power Stroke</td></tr>
</table>

	trigger pulse	+1	+2	+3	+4			
exhaust pulses	#7-5 exhaust	#2-7 exhaust	#1-2 exhaust	#8-1 exhaust	#4-8 exhaust	#3-4 exhaust	#6-4 exhaust	#5-6 exhaust
crankcase pulses	#1-2	#8-1	#4-8	#3-4	#6-3	#5-6	#7-5	#2-7
intake vacuum pulses	#6-3	#5-6	#7-5	#2-7	#1-2	#8-1	#4-8	#3-4

Each 1/8th of the 2 rotations of the crankshaft provides visibility of two cylinders: the first 45° is mostly from the first cylinder noted; the second 45° is largely from the second cylinder noted. We are assigning ring blow-by primarily to the first half of the power stroke.

10-Cylinder Offset Diagram

Firing order:		1	6	5	10	2	7	3	8	4	9										
Crankshaft rotation:		0 to 180˚					180 to 360˚					360 to 540˚					540 to 720˚				
		36	72	108	144	180	216	252	288	324	360	396	432	468	504	540	576	612	648	684	720
Fire Seq 1	Cyl 1	Power Stroke					Exhaust Stroke					Intake Stroke					Compression Stroke				
Fire Seq 2	Cyl 6			Power Stroke					Exhaust Stroke					Intake Stroke					Comp. Stroke		
Fire Seq 3	Cyl 5	Compression Strok				Power Stroke					Exhaust Stroke					Intake Stroke					
Fire Seq 4	Cyl 10		Compression Stroke					Power Stroke					Exhaust Stroke					Intake			
Fire Seq 5	Cyl 2	Intake Stroke			Compression Stroke					Power Stroke					Exhaust Stroke						
Fire Seq 6	Cyl 7	Intake Stroke					Compression Stroke					Power Stroke					Exhaust Stroke				
Fire Seq 7	Cyl 3	Exhaust		Intake Stroke					Compression Stroke					Power Stroke					Exhaust Stroke		
Fire Seq 8	Cyl 8	Exhaust Stroke				Intake Stroke					Compression Stroke					Power Stroke					
Fire Seq 9	Cyl 4		Exhaust Stroke					Intake Stroke					Compression Stroke					Power Stroke			
Fire Seq 10	Cyl 9	Power Stroke			Exhaust					Intake Stroke					Compression Stroke						

	Trigger pulse	+1	+2	+3	+4					
Exhaust pulses	#4-8	#9-4	#1-9	#6-1	#5-6	#10-5	#2-10	#7-2	#3-7	#8-3
Crankcase pulses	#1-9	#6-1	#5-6	#10-5	#2-10	#7-2	#3-7	#8-3	#4-8	#9-4
vacuum pulses	#7-2	#3-7	#8-3	#4-8	#9-4	#1-9	#6-1	#5-6	#2-10	#2-10