"Dx Panel" tool

Diagnosing a valve train by observing the pressure pulsations in the intake manifold of a running engine.

To assess the condition or state of a valve train, it was previously recommended to measure the pressure waveform in the intake manifold using the low pressure transducer Dx from the USB Autoscope kit, while cranking the engine using the starter. In addition, using the high-pressure transducer Px from the same kit, valve timing could also be measured.

Another method of assessing the condition of a valve train is by observing the pulsations in the intake manifold of a running engine. This method makes it possible to measure and compare the opening and closing of the intake valves as well as the opening and closing of the exhaust valves of the engine, to determine the duration of the valve overlap and valve timing for each cylinder of the engine.

The basics of this method.

Exhaust from an engine cylinder is moved out through the exhaust port, the opening in the exhaust port is opened by the exhaust valve and connects the internal volume of the cylinder to the exhaust manifold of the engine. The flow of exhaust gases from the cylinder to the exhaust manifold is due to the "pushing" of the gases from the cylinder by the piston. The piston is moving towards the cylinder head during the exhaust stroke. This movement causes the cylinders' internal volume to decrease, thus causing the pressure in the cylinder to be higher than the ambient pressure.

A new air / fuel charge in the engine cylinder is moved through the channel which is opened by the intake valve, thereby connecting the inner volume of the engine intake manifold with the cylinder. The air/fuel mixture is pushed into the cylinder by the atmospheric pressure. This is because the piston is moving down in the cylinder during the intake stroke, increasing the cylinders' internal volume, thus causing low pressure to form in the cylinder. A pressure lower than atmospheric pressure is often called "vacuum".

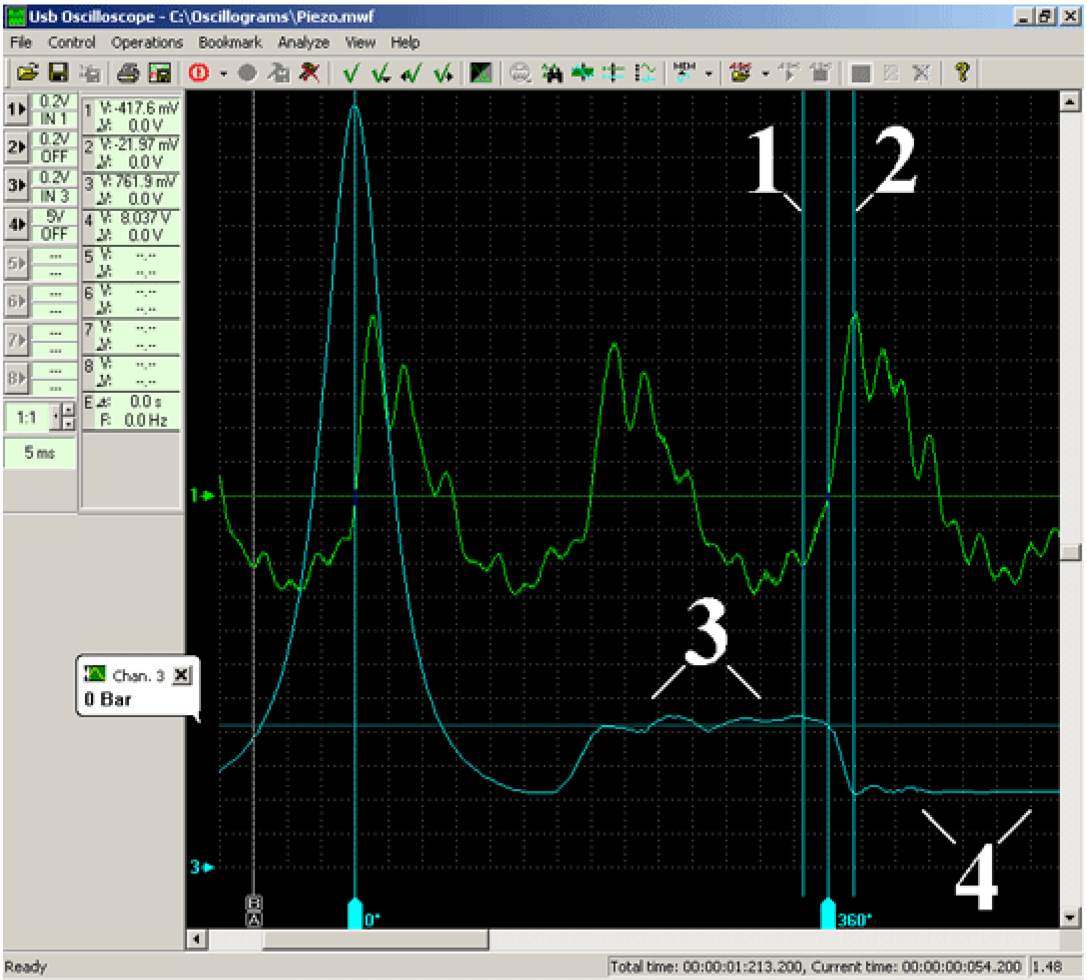
In most all engines, the intake of the air / fuel mixture begins before the end of the exhaust stroke. That is, the intake and the exhaust valves of the same cylinder, are open at the same time. The interval between the opening of the intake valve and the closing of the exhaust valve is called valve overlap. The beginning and end of the valve overlaps are shown in manifold pressure waveforms as peak and valleys. The technique discussed here is based on detecting and measuring the relative position of those peaks and valleys.

Note.

This method assumes that the intake valve opens before the exhaust valve and that the engine is not equipped with a turbo or super charger.

Description of the underpressure waveform.

Because the opening and closing of the intake and exhaust valves is shown in the low pressure waveform obtained from the intake manifold, the actual moment of valve opening and closing can be determined. The beginning and end of valve overlap can also be found. The beginning and end of the valve overlap, however, is best done by using a high pressure transducer in one or more engine cylinders.



*Low pressure (or vacuum) waveforms in the intake manifold of a running engine (shown **green**) and the pressure in a cylinder (shown **blue**).*
1 *– The intake valve of the cylinder opens; the pressure waveform in this cylinder is shown in blue.*
2 *– The exhaust valve of the cylinder closes; the pressure waveform in this cylinder is shown in blue.*
3 *– Exhaust gas from the cylinder is expelled; the pressure waveform in this cylinder is shown in blue.*
4 *– The air / fuel mix is flowing in to the cylinder; the pressure waveform in this cylinder is shown in blue.*
360° *– TDC 360° (Top Dead Center) of the cylinder stroke; the pressure waveform in this cylinder is shown in blue.*

Exhaust stroke.

During the exhaust stroke the piston is moving towards the closed end of the cylinder. Because the exhaust valve is open, the exhaust is pushed out of the cylinder and in to the exhaust system. Since the exhaust valve is open, the pressure is close to atmospheric pressure. At idle, no load, the pressure in the cylinder is approximately 0,1…0,3 Bar.

Intake stroke.

During the intake stroke the piston is moving away from the closed end of the cylinder. This expansion of the cylinder volume causes low pressure to develop in the cylinder. Because the intake valve is open, air from the intake system flows in to the low pressure area in the cylinder. If the engine is at idle, the throttle valve is almost completely closed and creates resistance to the flow of air. With the throttle closed, the pressure in the intake manifold, and thus the cylinder, will be much less than atmospheric pressure.

As the piston moves down in the cylinder, the pressure gets lower and reaches its minimum when the piston is about halfway down the cylinder.

The beginning of the valve overlap period.

During the exhaust cycle, and before the beginning of the valve overlap, the pressure inside the cylinder is close to atmospheric because the internal volume of the cylinder is exposed to the atmosphere through the open exhaust valve, exhaust manifold, and exhaust system. At the beginning of valve overlap, the intake valve begins to open. This opens a connection between the internal volume of the cylinder and the internal volume of the intake manifold.

As discussed, at the beginning of valve overlap – when the intake valve begins to open and while the exhaust valve is still open - the pressure inside the cylinder is close to atmospheric pressure, However, the intake manifold pressure is much less than atmospheric, the intake manifold has low pressure(or vacuum) present. The gases in the cylinder, being close to atmospheric pressure, will flow through the open intake valve and in to the low pressure area in the intake manifold.

The pressure in the intake manifold will therefore start to increase. The moment of the beginning of the pressure increase is shown on the waveform by the marker "**1**".

Area between the beginning of the valve overlap and TDC 360°.

The pressure waveform in the cylinder (**blue**), shows that the pressure in the cylinder is decreasing. This is caused by the flow of gases from the cylinder into the intake manifold. The amount of pressure decrease is small, at least until the piston reaches TDC 360°. The pressure decrease is small, for the following reasons:

- the piston is still moving towards the cylinder head, reducing the internal volume in the cylinder. This offsets the decrease caused by the internal volume of the cylinder being exposed to the intake manifold;
- the exhaust valve is still open and the internal volume of the cylinder is open to the exhaust manifold where the pressure is close to atmospheric pressure. The pressure drop that is caused by the intake manifold is offset by gases flowing into the cylinder from the exhaust manifold.

As long as the exhaust valve is open, the underpressure in the intake manifold will continue to decrease.

TDC 360°.

As shown, the rising edge of the waveform in the intake manifold (**green graph**) intersects with the horizontal zero line of the graph (the zero line shows the average DC level of the signal.) The actual signal can be very close to the reference level. This occurs when the piston is at TDC 360°, (at the end of the exhaust stroke and at the beginning of the intake stroke). The reference line allows you to determine when the pressure in the cylinder falls below ambient or atmospheric pressure. The position of the low pressure points on the graph coincides with acceptable accuracy with the moments when the engine pistons are at TDC 360°.

Area between point TDC 360° and the end of valve overlap.

Noticeable decrease of pressure inside the cylinder (increasing underpressure) starts from the point TDC 360° and continues until the end of the valve overlap phase. This phenomena happens due to the following reasons:

- exhaust valve has started to close, and the amount of gas flow from the exhaust manifold to the cylinder is being limited;

- piston changed its direction of travel. It is now moving away from the cylinder head and the internal volume of the cylinder increases. Since the volume is increasing, the pressure inside the cylinder is decreasing;
- the intake valve continues to open, increasing passage between the internal volume of the cylinder and the internal volume of intake manifold. The process of flowing gases from the cylinder into the intake manifold continues.

Due to the flow of gases from the exhaust manifold into the cylinder and thence into the intake manifold, the pressure inside the intake manifold continues to increase. The decrease of underpressure in the intake manifold continues until the complete closure of the exhaust valve.

End the valve overlap phase.

As the exhaust valve closes, the flow of gases into the intake manifold from the exhaust manifold through the partially open exhaust valve through the cylinder and through the partially open intake valve stops.

Piston continues to move away from the cylinder head, thus increasing the internal volume of the cylinder. The increasing volume of the cylinder causes some pressure drop inside the cylinder, which is offset by the inflow of gases into the cylinder from the intake manifold.

Thus, when the exhaust valve closes, (at the end of the valve overlap period) the flow of gases into the intake manifold from the cylinder stops and the outflow of gases from the intake manifold to the cylinder starts. Due to the outflow of gases from the intake manifold to the cylinder, the pressure inside the intake manifold begins to decrease. This decrease in pressure in the intake manifold (**green line**) is marked on the waveform by the marker "**2**".

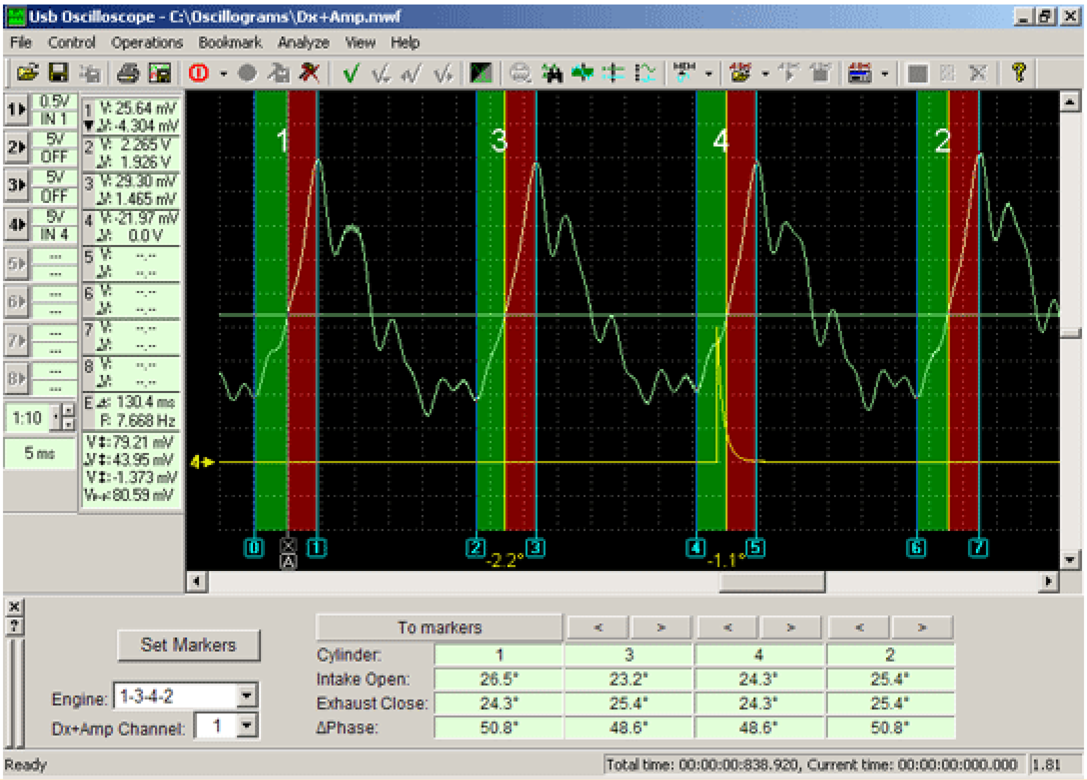
Note.

It should be noted that the valve lift during valve overlap is very small. The exhaust valve is almost closed and the inlet valve has just started to open. Accordingly, the amount of gas flowing during the valve overlap period from the exhaust manifold into the intake manifold is also very small.

Description of the tool "Dx Panel".

By observing the pulsating waveform in the intake manifold while the engine is running, we can see the points that indicate when the engine pistons are at TDC 360°, when the intake valves start to open, and when the exhaust valve closes.

To aid in measuring the degrees of crankshaft rotation between the various points on the waveform, the USB Oscilloscope program has an utility called the "Dx Panel".



The "Dx Panel" tool.

The "Dx Panel" tool calculates the opening of the intake valve, the closing of the exhaust valves, and the duration of the valve overlap.

Measurements.

- Obtain the (low) pressure waveform in the intake manifold while the engine is at operating temperature and at no-load idle. To do this:
  - connect the Dx underpressure transducer to the Dx Amplifier;
  - connect the power supply wiring of the pressure transducer Dx and the Dx Amplifier to the vehicle battery. The black clip connects to the negative or "–" terminal of the battery. The red clip connects to the positive or "+" of the battery;
  - connect the inlet connection of underpressure transducer Dx via a short vacuum line to the intake manifold of the vehicle being diagnosed (a long vacuum line tends to weaken the signal from the intake manifold);
  - connect the output connector of the Dx Amplifier to any of the analog inputs № 1-3 of the USB Autoscope;
  - connect the **Ignition Adapter** to the vehicle battery in the same manner;
  - connect the **Ignition Adapter** to the USB Autoscope;
  - attach the **Sync** (black) transducer to the spark plug wire of cylinder №1 (or timing cylinder) and connect it to the input**In Synchro** on the **Ignition Adapter**;
  - allow the engine of the diagnosed car to idle;

- in the "USB Oscilloscope" program, choose "Control => Load user preset => Phases => Phases_Run_Sync";
- to start recording the signal, in the "USB Oscilloscope" program, choose "Control => Record";
- To end recording the signal choose "Control => Record".

- Load measuring panel "Dx Panel", in the program window "USB Oscilloscope" select "Analyze => Load analyze panel => Dx_Panel.apn"
(the file "Dx_Panel.apn" is usually in the directory "C:\Program Files\USB Oscilloscope\AnalyserScriptFiles\Dx_Panel").
- Enter the firing order in the line "Engine:" on the panel of the analyzer.
- Enter the channel number in the line "Dx+Amp Channel:" which corresponds to the channel number where the signal from underpressure sensor Dx with Dx Amplifier is connected.
- The program automatically calculates and shows the voltage level corresponding to the average DC voltage signal of the selected channel. The intersection points of the falling edge of the underpressure waveform in the intake manifold with the line set by the level of the DC bias coincide with TDC 360°.

  To analyze select a section of the waveform corresponding to one complete cycle of the engine as shown in the illustration below. Markers "A" and "B" must be aligned with the rising edge of waveform where it crosses the DC bias line. The synchronizing pulse from the №1 cylinder sensor should be centered between markers "A" and "B".

Aligning markers "A" and "B" on the low pressure waveform from the intake manifold. Note that the synch signal from the №1 cylinder is centered in the wave form.

- Click the button "Set Markers" on the analyzer screen panel. The program will recalculate and use the level of DC bias of selected channel signal for the selected piece for waveform. This can cause the level to shift some. If this is the case, adjust the positions of the markers "A" and "B" so that they are at the points of intersection of the rising edge with the recalculated average DC bias. Then click again on the "Set Markers" on the panel of the analyzer. Note that the synch pulse for the first cylinder must remain centered between the "A" and "B" markers.

- If necessary, using the buttons "<" and ">" at the measuring panel "Dx Panel", adjust the position of points TDC 360° for each of the cylinders so that the vertical yellow lines, which mark these points, aligns with the falling edge of the waveform at the DC bias line. This correction may be necessary due to the uneven speed of the engine crankshaft.
- Set markers "0"…"7"… on the appropriate points on the waveform from the intake manifold.
- Compare the angle values:
    - the calculated values of the start of the opening of the intake valves are displayed in the "Intake Open:" of measuring panel "Dx Panel";
    - the calculated values of the closing of the exhaust valves are displayed in the "Exhaust Close:" of measuring panel "Dx Panel";
    - the calculated duration of the valve overlap appears as "Valve Overlap:" in the measuring panel "Dx Panel".

Disadvantages of the method.

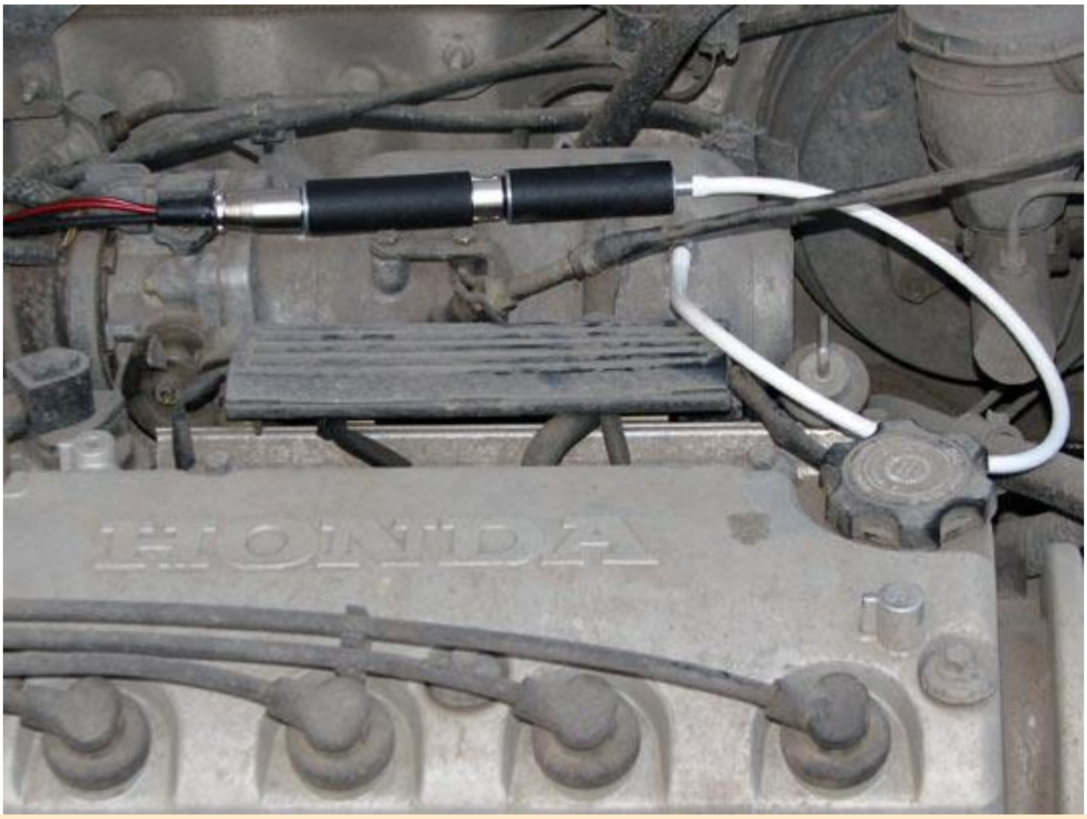
The actual waveform depends greatly on certain aspects of the engine design.

The intake manifold design increases the amplitude of the signal in the manifold at some frequencies and decreases the amplitude of gases at other frequencies. This is because the intake manifold will have resonance at certain frequencies, but not others. The nature of this influence will be different between different manifold designs, Also, the location of the vacuum ports used to obtain the waveform will greatly influence the shape of the waveform. And, of course, the number of engine cylinders will have a great impact.

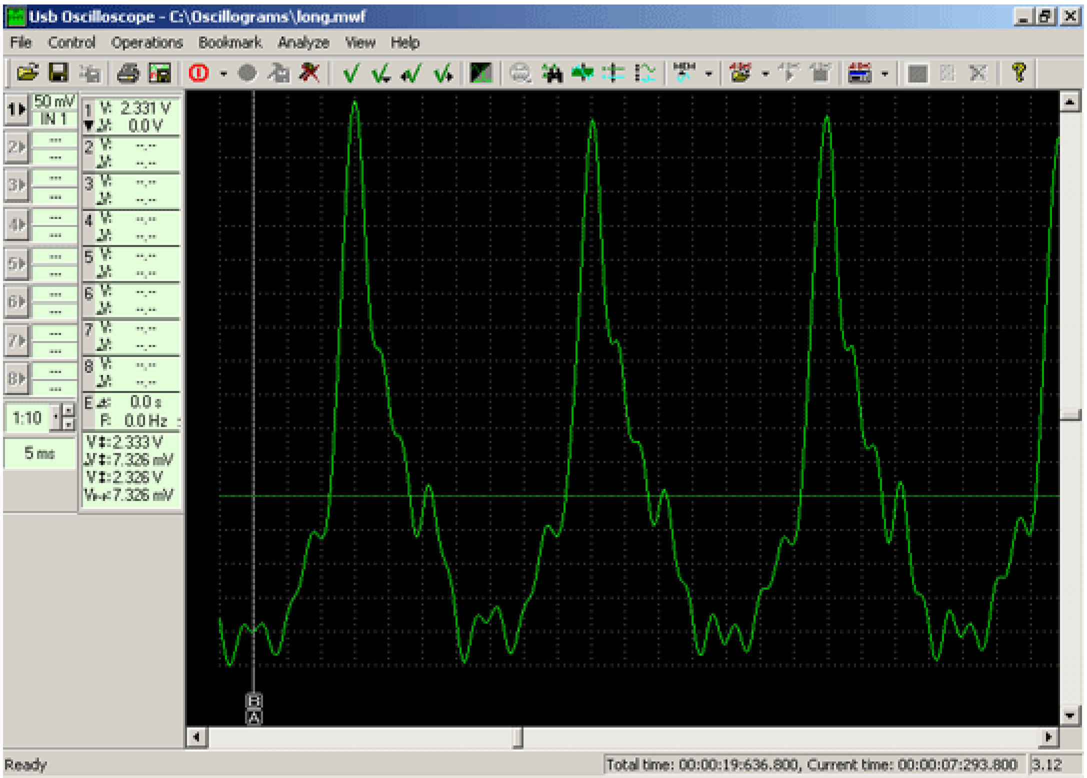
The manner in which the vacuum transducer is connected will also influence the signal obtained.

The connection between the intake manifold and the pressure transducer will affect the signal as well. Things to consider are:

- the length of the tube used;
- the diameter of the tube used;
- the softness (or pliability) of the tube.

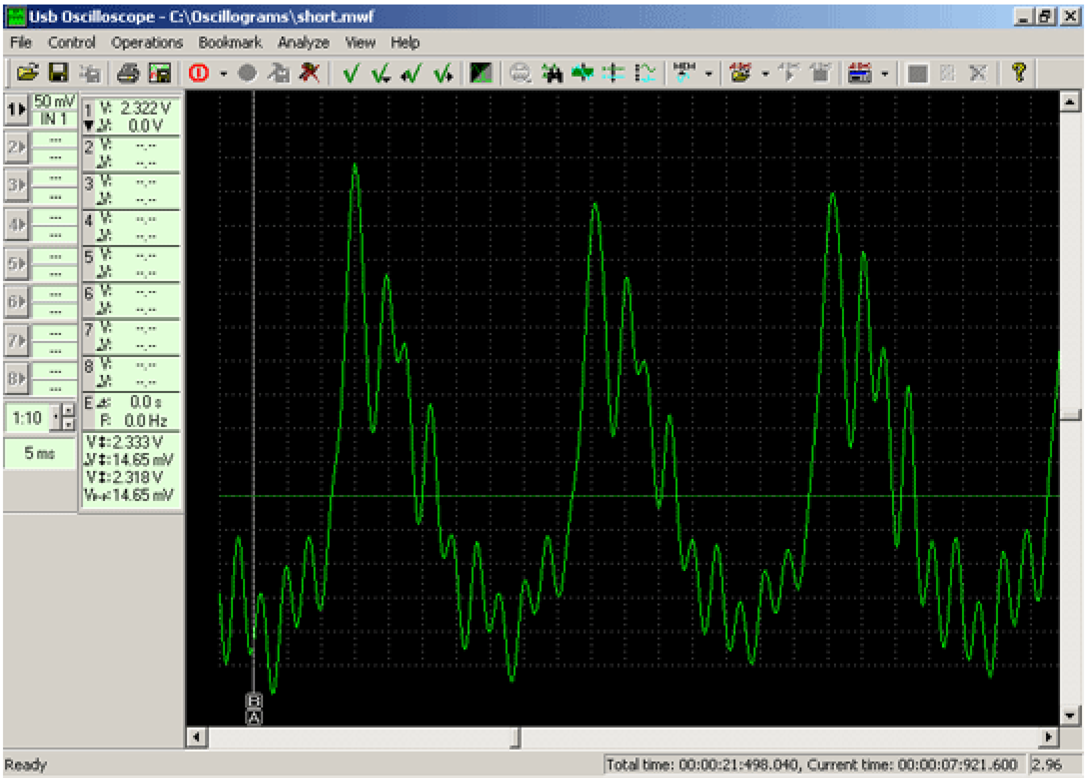


The low pressure transducer Dx with Dx Amplifier is connected to the intake manifold using a long vacuum tube.



The pressure waveform in the intake manifold, obtained by using a long connecting vacuum tube.

The low pressure transducer Dx with Dx Amplifier is connected to the intake manifold using a short vacuum tube.



Pressure waveform the intake manifold, obtained using a short connecting vacuum tube.

As we can see on the waveforms, using shorter vacuum tube leads to increasing "detail" of the resulting waveform.

Using a longer vacuum tube, not only leads to perceived change in the low pressure waveform the intake manifold, but can also cause a delay in the display of the various points on the waveform. Because of this, the error of coinciding these points with the pistons at TDC 360°, increases. In some cases it may even cause a perceived displacement of angle and time relating to valve timing and valve overlap.

Methods of reducing the value of the measurement error.

To reduce the measurement error, it is recommended to use short connecting vacuum tubes. Recommended length of the connecting tube is no more than 50…100 mm. The largest vacuum port on the intake manifold should be used, if at all possible.

The use of a short connecting vacuum tube does not always guarantee a sufficient decrease in the measurement error. Therefore, the method shown here does not always allow to measure absolute values of the angles of the beginning of the intake valve opening and closing the end of the exhaust valve. The method is, however, reliable for comparing the valve mechanism between the different cylinders on the same engine.

A vacuum tube that is too pliable will also dampen or weaken the vacuum signal.

Distortion of the waveform due to vibrations of the transducer body.

The voltage of the output signal from the low pressure transducer is somewhat responsive to the vibration sensor body. Impacts to the sensor body causes output signal voltage fluctuations. Exhaust pulsations can cause signal voltage variations, due to the sensitivity to vibrations. Note that different sensors will display different levels of sensitivity to vibrations.

To avoid vibration induced errors, keep the sensor body from touching engine parts.

Disadvantages of using piezoelectric-type sensors.

Piezoelectric transducers are commonly used to obtain pressure wave forms. However, this type of sensor has several disadvantages. Most important disadvantages:

- large variability in the characteristics of the sensor wafer makes it necessary to individually calibrate the sensor and the air inlet during manufacture;
- the actual volume of the air column working on the piezoelectric wafer has a significant effect on the signal produced. The sensor is therefore sensitive to the diameter and length of the vacuum tube used;
- The design of the pressure transducer with the piezoelectric wafer is very similar to a knock sensor. This is the reason for the large sensitivity to vibration.

Using the pressure sensors with Dx Amplifier.

The sensitivity of the underpressure transducer from the USB Autoscope kit is insufficient for using the sensor in any low pressure diagnosis. To remedy this situation, Dx Amplifier was developed. This amplifier will significantly increase the sensors sensitivity to underpressure variations, because it is designed to amplify signal variations only (the amplifier is AC coupled).

Dx Amplifier for underpressure transducer Dx.

Advantages of using the Dx Amplifier with the low pressure transducer Dx.

Using the Dx Amplifier with the low pressure transducer Dx significantly increases the sensors sensitivity. This can be very helpful when working with pressure waveforms having very small variations. This amplifier also makes the sensor less sensitive to the length and type of vacuum tubing used to connect the sensor. Additionally, the sensor will be less sensitive to vibrations.