Training

Pressure Transducers

by Bernie Thompson - ATS

Fig. 1

It was black with a two inch brim; the inside had a red satin liner. By all accounts it looked like a normal top hat that anyone could be wearing. The man placed the top hat on the table where, in an instant, he had reached into the hat and out came a white rabbit! How did the rabbit appear, was it magic or mechanics? Once there is an understanding of what has happened it is no longer magic; but only physics.

For over one hundred years mechanics have been diagnosing the internal combustion engine. Over the years many tools have been developed to help with this process and with the advent of the modern automobile have come modern high tech diagnostics. Now, let us pull a rabbit out of the hat and examine the magic behind one of these high tech diagnostic tools; the modern pressure transducer.

A pressure transducer is a device that takes a physical quantity and changes it into an electrical signal. The pressure transducer can measure physical quantities such as; oil pressure, fuel pressure, engine compression, exhaust pressure, intake pressure, crankcase pressure, and radiator pressures to just name a few. By viewing this electrical signal on an oscilloscope, a large amount of information can quickly be conveyed to the technician. These devices will change the way that the modern technician will diagnose the internal combustion engine.

Now let us examine a Dodge Caravan with a 3 liter V-6 engine with overhead camshafts. This vehicle was brought in exhibiting a rough idle condition. The complaint was verified and the PCM codes were pulled. There were no pending or mature DTCs recorded and all of the monitors had run. A pressure transducer was placed into the exhaust tailpipe (Figure 1). This pressure transducer is a special type of transducer called a differential pressure transducer which can read the exhaust pulses from the tailpipe. For years technicians have used their hand or a dollar bill to feel or see these exhaust pulses in order to determine whether the exhaust pulses were even. This can help with the diagnosis of the engine. If the differential pressure transducer is connected to an oscilloscope, these exhaust fluctuations can be viewed as a waveform, which will help the modern technician in diagnosing the engine.

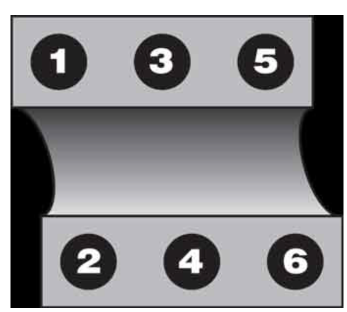

Fig. 2

This waveform, however, cannot be understood without a trigger to locate the exhaust pulsations. If the ignition is used as the trigger, the exhaust pulsations can be related to each individual cylinder. To accomplish this, the firing order must first be known (Figure 2). There will also be a timing issue when applying the trigger to the exhaust waveform. In a four cycle engine, the ignition spark occurs at the end of the compression stroke. During the compression stroke and power stroke both the intake and exhaust valves are closed. At the point the spark ionized the spark plug electrodes; the air/fuel mixture is ignited. In turn, the burning air/fuel mixture creates an expanding force that drives the piston away from the cylinder head. As the piston approaches the bottom of its stroke the exhaust valve opens. The high pressure inside the cylinder moves to the low pressure area outside of the cylinder which creates a pulse as it moves through the exhaust pipe.

The piston now starts to move toward the head on the exhaust stroke, pushing out the remaining content of the cylinder into the exhaust system. If you are using the ignition as the trigger for the exhaust pulse there will be a delay between the spark ionizing the spark plug electrodes and the exhaust stroke. To compensate for this delay, the trigger will need to be moved from cylinder 1 to cylinder 3. By moving the trigger, two firing events after the firing event in cylinder 1, the exhaust pulse for the number 1 cylinder will align with the triggered event. Therefore, on a 4 cylinder engine, the trigger is moved 1 cylinder after number 1.

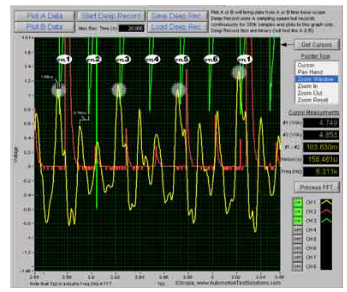
Fig. 3

On a six cylinder engine, the trigger is moved 2 cylinders after number 1. On an 8 cylinder engine, the trigger is moved 3 cylinders after number 1.
In Figure 3, the yellow trace is the waveform produced by the differential pressure transducer. The red trace is the waveform produced by an inductive clamp around cylinder number 3 spark plug wire. The green trace is the waveform produced by the ignition coil primary signal. With the addition of the ignition triggers, this will divide the exhaust waveform into individual cylinders. Once the waveform can be isolated into individual units, the waveform can be analyzed to determine where the problem cylinder or cylinders are located. At this point the firing order must be known so an association can be made between the exhaust pulse and the cylinder that created it.
When examining the exhaust waveform, two things will need to be checked; the amplitude of the signal and the timing placement of the exhaust pulse.
Of these two items, the timing placement is the most important. When analyzing Figure 3 the peak amplitude (vertical) on cylinders 1-3-5 are greater than the peak amplitude on cylinders 2-4-6. Now check the timing placement of the peaks on cylinder 1 and 2.

The peak on cylinder 1 comes very close in time (horizontal) to the green primary ignition turn on signal. The time between the cylinder 1 peak and the green primary falling edge is 1.69ms. On cylinder 2 the peak is much further away from the green primary falling edge at 6.76ms. Now check the other cylinders. Upon further analysis, it becomes clear that cylinders 1-3-5 are very close in time to the primary falling edge, whereas, cylinders 2-4-6 are further away from the primary falling edge. In figure 2, the firing order is given as 1-2-3-4-5-6. 1-3-5 are all from bank 1 and 2-4-6 are all from bank 2. These data would indicate that there is a difference from bank to bank. One complete bank has a problem.


Fig. 4

Many things could affect a complete bank and create a problem. To narrow down the problem very quickly, we will install the differential pressure transducer in the brake booster hose (figure 4). This will allow us to view the intake pressure pulses (figure 5). It will be necessary to use the ignition triggers so the intake waveform can be divided. Once the intake waveform has been broken down into individual cylinders, the pulses can then be analyzed. However, there is a timing issue between the ignition ionizing the sparkplug electrodes and the intake valve opening. The intake stroke occurs before the ignition event. In order to time the intake pulse to the cylinder that created it, the trigger must be installed around the cylinder 5 ignition wire. This will align the inductive red trace with the cylinder 1 intake valve pulse (yellow trace).

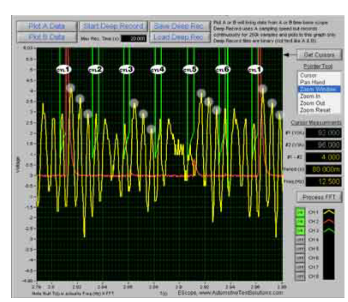
Fig. 5

Therefore, on a 4 cylinder engine the trigger is moved one cylinder before cylinder 1. On a 6 cylinder engine the trigger is moved two cylinders before cylinder 1. On an 8 cylinder engine the trigger is moved three cylinders before cylinder 1.
In figure 5, the engine is at idle and the intake waveform is divided into individual cylinders by the ignition. Let us examine cylinder 1 and cylinder 2. In cylinder 1 there are three distinct positive pulses between the primary green trace of cylinder 1 and

cylinder 2. In cylinder 2 there are two distinct positive pulses between the ignition primary on cylinder 2 and cylinder 3. The amplitude of cylinder 1 is also greater than cylinder 2. Now examine the other cylinders in figure 5. It becomes clear that cylinders 1-3-5 all have 3 distinct positive peaks with higher amplitudes. Whereas, cylinders 1-4-6 have 1 or 2 peaks of lower amplitude and a different waveform shape. In figure 2, the firing order is shown as 1-2-3-4-5-6. This confirms the exhaust data that we had previously gathered; bank 1 is different from bank 2. These data would indicate that a camshaft is out of time with the crankshaft.

Fig. 6

It can take hours to remove the camshaft timing covers to confirm this finding. The problem with this is that if the camshaft has moved from the gear it may be hard to confirm the camshaft timing by only checking the gear timing marks. There is an easier, faster and more accurate way to confirm camshaft to crankshaft timing. To accomplish this, remove the spark plug from cylinder 1. Install a compression adapter into the sparkplug hole. Before installing the compression adapter remove the check valve from the adapter. This will allow the air pressure to move freely in and out of the adapter hose. Now install a 300psi pressure transducer on the compression hose. The oscilloscope will now display a waveform of the pressure changes within the cylinder. Before starting the engine, install a spark tester on the #1 ignition wire. It will only be necessary to allow the engine to run a very short time to capture the data. Once the data is captured, turn off the engine. Install the sparkplug and ignition wire back into the #1 cylinder. Remove the #2 sparkplug and install the spark tester on the ignition wire. Install the compression adapter and 300psi pressure transducer into the #2 sparkplug hole. Start the engine and capture the data. Now shut off the engine so the data can be analyzed. Figure 7 is from cylinder 1 and figure 8 is from cylinder 2. Let us examine these cylinder pressure waveforms.

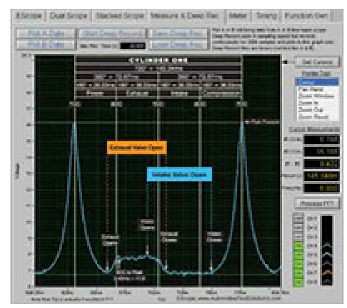

Fig. 7

The first thing that will need to be done is to measure from compression peak to compression peak. In figure 7 the peak to peak time is 145.34ms. This is equal to 2 crankshaft revolutions or 720° of revolution. By dividing 145.34ms by 4 the time for each stroke can be calculated. This time is 36.33ms, which is equal to 180° of crankshaft rotation. Now move the cursor 36.33ms from the 1st compression peak. This is when the piston has reached the bottom of its stroke or bottom dead center (BDC) after the power stroke. The exhaust valve will open at the end of the power stroke before BDC. This is where the waveform changes due to the exhaust valve movement. This pressure change will cause the waveform to rise until it hits its peak. This peak should be very close to the BDC mark. On most engines, the BDC mark will fall between half way up the ramp and close to the top of the ramp when the cam timing is correct. By measuring the time from BDC to the exhaust waveform peak, the crankshaft degrees can be calculated. 720° of crankshaft rotation divided by 145.34ms of time will equal 4.95° of crankshaft rotation for 1ms of time. In figure 7, the time from BDC to the peak of the exhaust waveform is 2.42ms. To calculate the crankshaft degrees, take the time (2.42ms) and multiply it by 4.95° and it will equal 11.97° or 12° of crankshaft rotation.

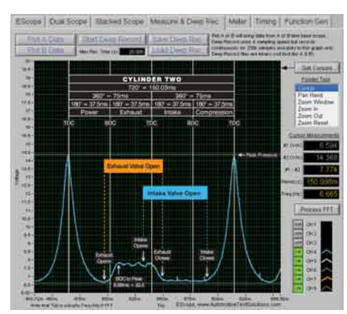

Fig. 8

Now let us examine figure 8. First measure the compression peak to peak. This is equal to 150ms of time. Now divide 150ms by 4 which equals 37.5ms. This will give you the time for each stroke. Now move the cursor 37.5ms from the 1st compression peak. Notice that the BDC mark occurs below the half way point on the exhaust ramp waveform. There is a delay in building the pressure of the exhaust ramp so it takes much longer for the peak to form. Also notice that the waveform before the BDC mark is much more rounded. This is due to the exhaust valve opening later which is an indication of a retarded camshaft. Once the cursor is in place; measure the time from the BDC mark to the exhaust waveform peak. This time on cylinder 2 is 6.99ms. To calculate the time per degree, divide 720° by 150ms.