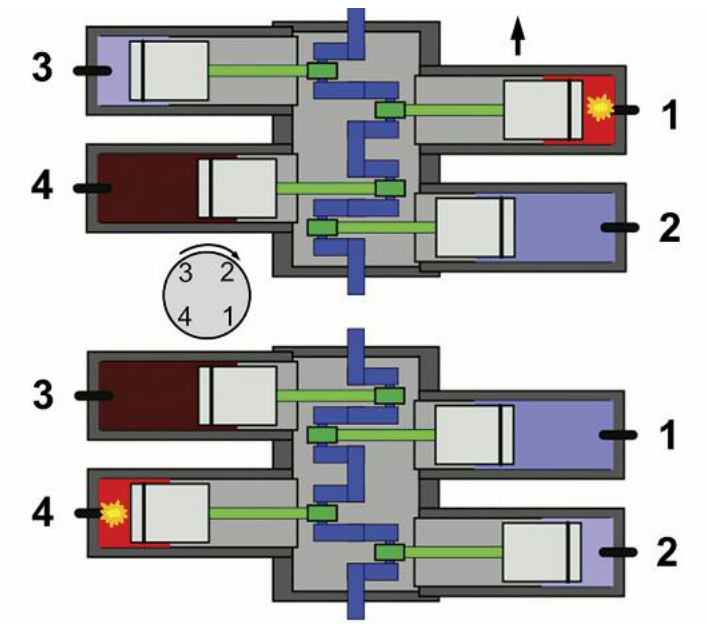
Timing is Everything

The Basics of Ignition Dwell and Timing Advance

By Bruce Smith

When your ignition system is off, not much else about your motor is going to run very well. Spark distribution, timing, advance, and dwell are popular discussion topics where opinions sometimes vary. But most issues can be separated from speculation since there will only be a small range of optimum settings for any given engine. The goal is to achieve the ideal, which is sometimes difficult without a full diagnostic setup, including a dyno. But the DIY mechanic can get pretty close, especially with an old Porsche that isn't highly modified beyond its original state.



Opposing pistons of the four-stroke flat-four engine reach TDC at the same time. Firing order (inset) is 1-4-3-2 with distributor rotor and crank rotating clockwise. The firing of cylinder #1 is shown at the top and #4 at the bottom.

Ignition Fundamentals

Flat-four or boxer Porsche motors are inherently well balanced with a nice low center of gravity. As with any four-stroke, the engine's ignition system needs to time a spark to achieve peak chamber combustion and power to the crank. At idling rpm, when very little fuel and air are drawn into the cylinders, the spark should occur just before a piston reaches the top dead center (TDC) of its stroke. The fuel mixture burns quickly and most efficiently if ignited a bit early. If the spark is too late, ignition will occur as the piston is coming down, reducing its power and effectiveness. Adjusting idle at the carburetor can keep the car running but it would be very rich and inefficient. If timing is too early (i.e. too advanced), the pressure from combustion will work to counteract the momentum of the still-rising piston. Trying to start an engine in this condition becomes a battle between the starter and combustion where neither will win.

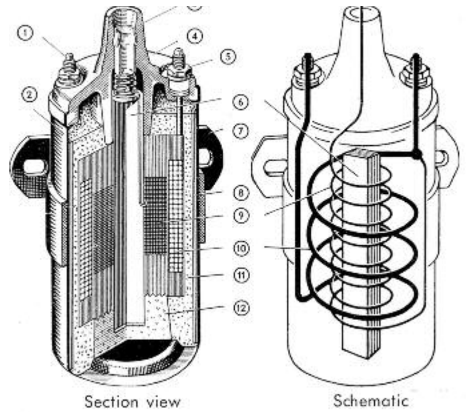
When revs are higher, the time interval between strokes is decreased. Combined with heavier loads, more fuel is burned and complete combustion will take longer. These two factors require that the spark be fired sooner, further advanced from TDC than at idle. But care must be taken to deliver a spark that's timed so that the fuel mixture is burned within the piston's cycle and power is maximized. As with running at lower revs, too little advance won't achieve full power. Too much advance can lead to detonation as cylinder pressure rises too rapidly. But all of this requires a spark. And the timing of the induction system has got to be right as well.

Spark and Dwell Timing

A car's induction system consists of a coil, points and a condenser. The well-known Kettering system from Delco was patented in 1917 and has been used in most engines since then. Inside the motor's distributor are the points (a contact breaker) which open and close to direct current to and from the coil. When the points are closed, current flows through the coil's primary windings to generate a magnetic field in the core. When the points are open, the collapsing magnetic field induces a current in the secondary windings at voltages in the kV range. This collapse is slowed by the condenser, absorbing the initial current which would otherwise arc across and destroy the points. The job of the rotor is to distribute the high voltage from the secondary windings to spark each plug.

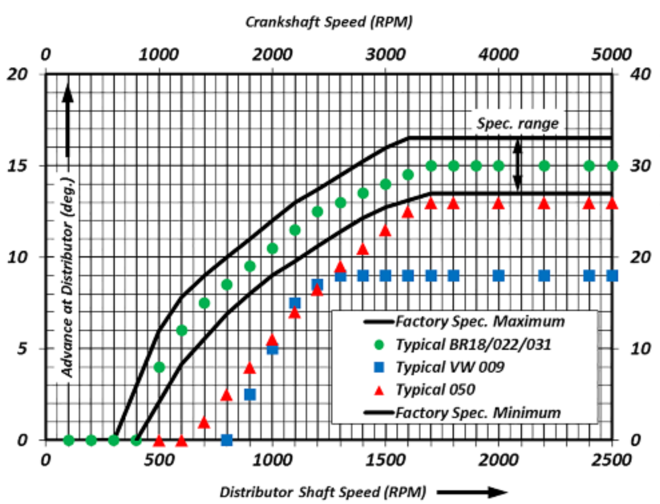
The timing necessary for induction and spark can be calculated with some basic math. Let's start with the engine idling at 800 rpm. For a four-stroke, four cylinder engine, a spark is distributed to a cylinder every 37.5 milliseconds. This number can be calculated as (2 revs/cycle x 60 sec/min) / (800 rpm x 4 cyl), which is measured at the crank. The required duration of the spark is a few milliseconds at most, well within the 37.5 millisecond distribution period. The dwell is the amount of time within each cycle that the points remain closed and the coil is energized. Dwell can be measured in time or the angle at the distributor, where the distributor angle is half of the crank angle. In a four cylinder engine, there is ample time to energize the coil four times within the full 360° distributor rotation. Allowing for point opening and closing times, discharge time and point wear, the dwell needs to be somewhat less than the 90° separation between the corresponding rotor positions. And it should be no longer than what is necessary to prevent coil overheating. The dwell angle specified for older Bosch four cylinder ignition systems is 50° +/- 3°, resulting in about 21 milliseconds of dwell time at 800 rpm. This is best adjusted by using a dwell meter or a distributor tester but it can be approximated by gapping the points to 0.016 inch. Simply setting the gap isn't assurance of the correct angle though, as it will be influenced by the point geometry, alignment, spring tension and other factors. At 50° dwell, the resulting 21 milliseconds is plenty long to energize the coil at idle but it becomes a more important question at high rpm. The same angle at 5000 rpm results in dwell time of just about 3 milliseconds. Too little dwell gives insufficient time to maximize the magnetic field in the coil's core. On the other end, excessive dwell can close the points too soon, leaving insufficient time for the magnetic field in the core to collapse. Each condition can reduce the current from the coil. Dwell depends also on the charging current but the dwell times for a four cylinder motor are still quite long compared to what's needed for a high revving eight-plus cylinder motor where values fall well below a millisecond. So dwell can be considered the first part of the timing equation. The second part is the distribution timing.

The Bosch ignition coil found in Porsche 1600 and similar motors. The ignition points work to create a magnetic field in the core (6) through the primary windings (10) and discharge high voltage through the secondary windings (9).



Distributor and Advance Timing

Ignition advance can be explained using a timing advance curve like the one shown below. The plots show distributor advance on the left and bottom with the corresponding 2X factors for crankshaft angle and speed on the right and top. Timing values can be relative to the distributor or the crank and it's usually easy to convert between the two - until you start adding the static advance, referring to the crank. There are several objectives to achieving proper timing advance. At idle, the advance should be just before TDC by a few degrees. Total advance should be set to produce maximum power without detonation. And the transition in the mid-range should come up quickly before reaching the maximum. Setting timing at idle can be a dangerous game if you don't know how your distributor is behaving through the entire rev range. Sometimes you can assume that the factory specs are close but if your distributor hasn't been serviced in a while, it's probably not the case.



Typical timing advance curves for distributors used in Porsche 1600 motors.

Setting it Right

The factory specification for the Bosch BR18/022/031 distributors used in Porsche 1600 motors was common to 356 A/B/C normals, supers, SCs and 912s. The data above shows the factory range, which can be achieved with these distributors and nearly so with older 383s and BR9s. The BR18 type advance curve is a bit different from those for many other cars because of the lack of one or more straight-line regions. VW 009 and 050 distributors exhibit this straight-line, which is a result of a single spring or two identical springs countering the advance arms in the distributor. Spring flexure of the BR18 type adds a more aggressive transition through the advance curve, which is described in detail in an earlier article in the July/August 2014 *356 Registry*. The result is a starting mechanical advance of about 6° which comes up quickly off of idle. A quick advance is important for power in the mid-range, which then levels out over 3000 rpm. To set timing, it's usually best to start at full advance. At 3500 rpm, a range of 33° +/- 2° is often close to maximizing power. This is a bit lower than original factory recommendations, but back then our cars were burning gas quite different from today's. Short of a dynamometer, it's challenging to find the optimum total advance for peak power. But some tuning can be done by driving test trials at top speeds. By starting at a baseline advance and increasing in small amounts between runs, top achievable speed will correlate to the best setting. Advancing too far though, will lead to detonation, so keeping below 37° is safest.

Once total advance is set, the initial or static advance becomes the amount that's been added to the mechanical advance. In other words, for the BR18 shown above, a total advance of 33° would result from the 30° mechanical advance plus 3° initial. The advance at 800 rpm is also this static 3° amount, though it would be larger at higher idle. If static advance was set instead at 1000 rpm idle, the total advance could be lower by up to 8°. Without checking or setting at high revs, the resulting power loss might never be realized. So it's always best to set at full advance.

In the end, guided by basic induction and ignition principles, careful timing of your car's engine might gain some power that you never knew it had. Just in time for summer!

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