Multi-spark Ignition Systems- Inductive

Article Context:

Multi sparking is the firing of the spark plug multiple times in rapid close succession to create an ‘overall’ spark of longer duration and energy.

The discussion centres on inductive ignition systems, not Capacitor Discharge Ignition systems (CDI). Multi-sparking has been incorporated into CDI systems in production vehicles but is most well known in the performance industry (e.g. MSD ignitions). Due to the very short spark duration inherent in CDI they benefit greatly from multi-sparking, particularly at low rpm where this function remains possible.

Many production vehicles with ‘standard’ inductive ignitions now perform a multi-spark function and it is available in some aftermarket ECU’s (eg. Motec). European (cold climate) applications go back several decades.

The energy available from an ignition coil is generally enough to achieve the minimum spark duration required and still have enough in reserve for 1 or 2 more firings. This can happen when cylinder turbulence pushes the spark away from the plug and 'blow’s it out' , the coil voltage goes so high it 're-strikes'. This is not multi-sparking, it just relates to a normal ignition characteristic.

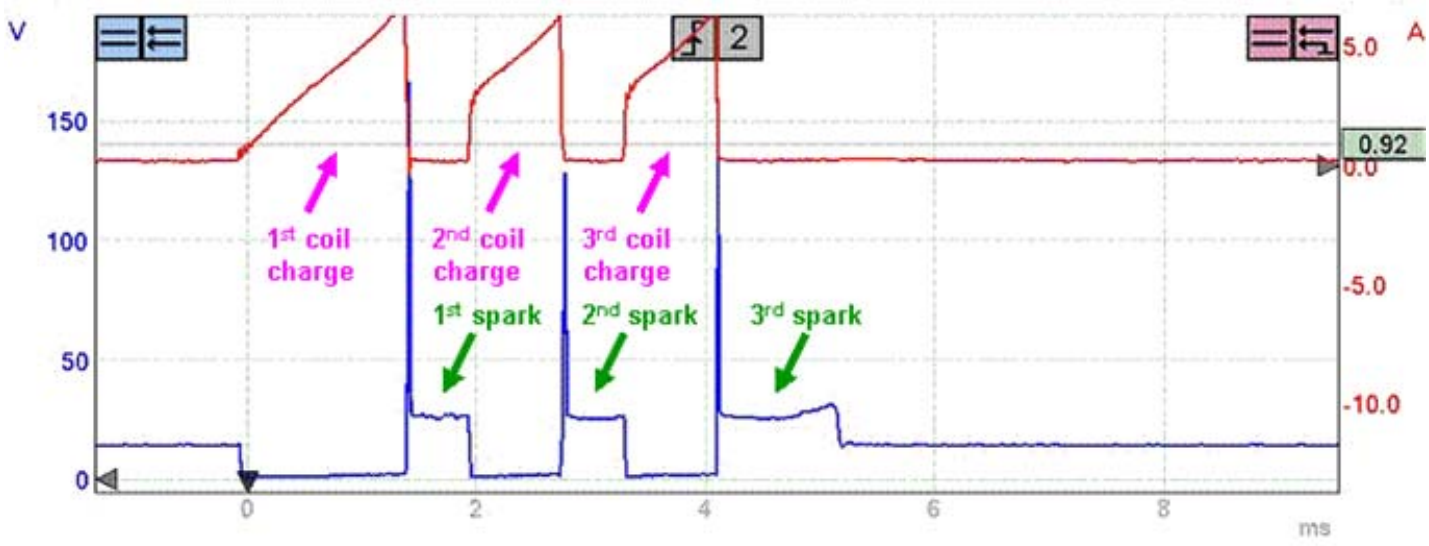
This article will discus the merits of multi sparking with an inductive system and may explain why not all manufacturers adopt the strategy. After all, it’s just implemented in software, no extra hardware required!

Please read the article on dwell mapping at www.dtec.net.au for background information.

Production Vehicles that Multi-spark:

There are many examples of production vehicles that implement multi-sparking, current large volume examples that come to mind are the Ford and BMW applications.

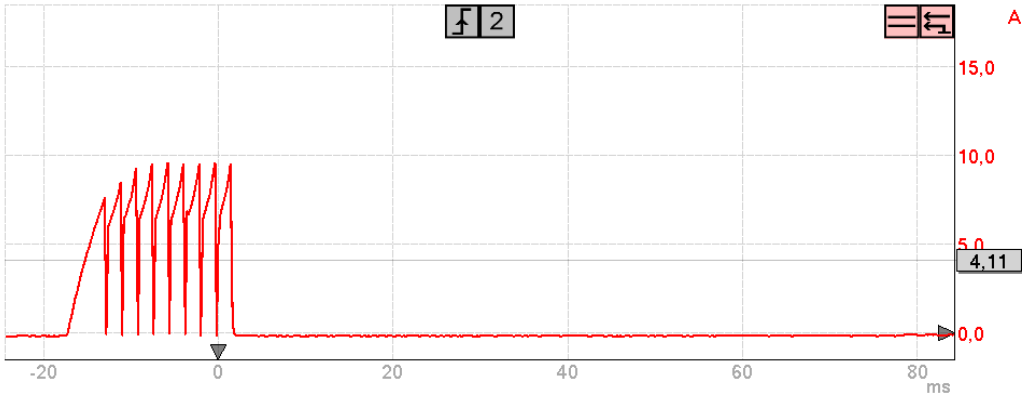
Below is a Ford BA Falcon 6 cyl (certain V8 Falcons also) showing a multi spark (3 times when <1500 rpm)!



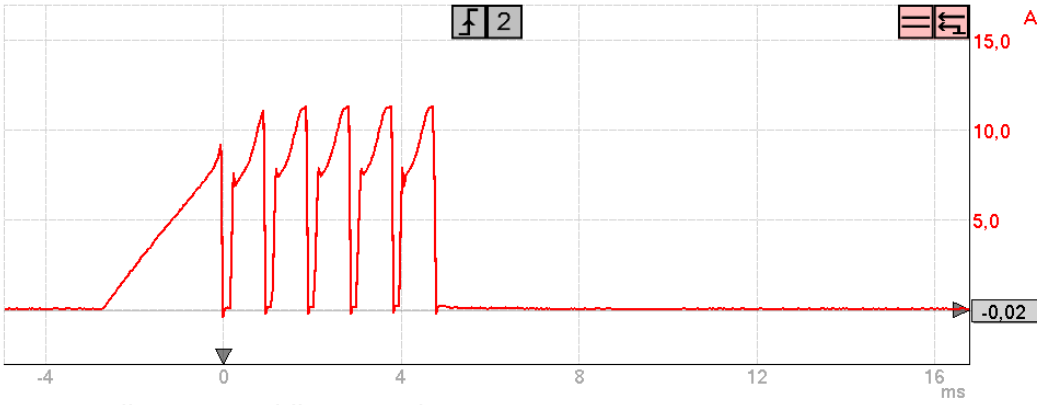
Top trace is coil current, lower trace is coil primary voltage. It can be seen how the first spark is only allowed to sustain for approximately 0.5ms (shown in the primary pattern) and then the coil is turned back on again to ‘top up’ for about 0.75ms. After the third and final coil charge up the resultant spark is allowed to extinguish naturally (duration > 1ms as shown)

Inductive Multi-spark Ignition

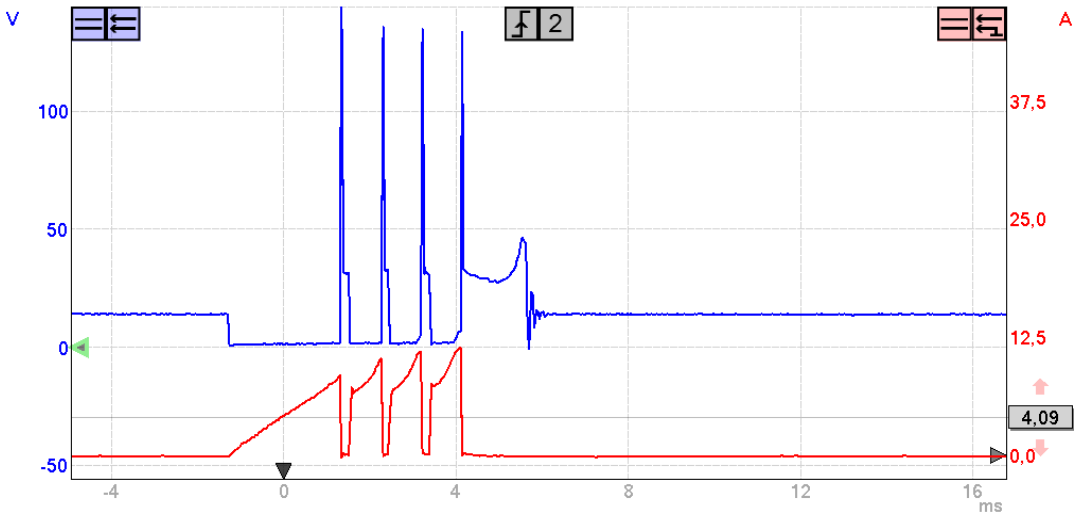
The late model BMW ignition scope patterns below show varied numbers of firings, they altered with temperature, rpm and running mode (i.e. cranking), above approximately 1500 rpm it reverts back to a single spark.



BMW coil current during cranking, 9 sparks!



BMW coil current at idle, 6 sparks



BMW coil current and primary voltage at idle, 4 sparks

Multi-sparking Benefits:

Multi-sparking allows sufficient energy over enough time to ensure complete and consistent combustion.

It is often employed to improve cycle to cycle variation in cylinder pressure (often expressed as coefficient of variation COV = standard deviation/mean pressure*100 [%]). In other words, to keep the engine smooth due to consistent cylinder pressure. Improving COV will allow lower emissions, allow lower idle speeds (therefore less fuel consumption, CO2) and also improve customer perception of the vehicles noise/vibration/harshness.

Instability comes about when mixtures are leaner than that for smoothest operation, there is poor mixture formation (rich and lean 'pockets' as not fully homogenous) or low ignition energy. At higher rpm it's not needed due to cylinder turbulence creating better mixture formation and COV isn't an issue as engine loads get higher.

The combustion stabilising needed is a large function of temperature. Cold start mixture can be very inconsistent and the plug may not have access to an optimal ignitable mixture initially. There are so many variables that it's simply not possible to determine exactly what ignition angle would be the best to fire the plug. Multi spark can help overcome this problem.

Manufacturers that use multi-sparking often place an emphasis on it for these cold start/run conditions! Some even phase it out at higher temperatures (or reduce number of sparks at least). An example of this is in the old Holden V6 Calibra's with Bosch Motronic, they used to multi spark only when cold and stoped completely when warm.

Multi-sparking has several positive attributes but also has some constraints that designers must carefully consider.

Time Constraints on Multi-sparking:

There are time issues and processor loading considerations when implementing multi-spark (time to calculate it and actually effectively do it).

The burning mixture can be drawn away from the plug by turbulence and if fresh un-combusted mixture is present it may be ignited with another spark. Research has shown that the sparks needed to be less than a couple of degrees apart to work effectively (you can see now where time issues start arising)

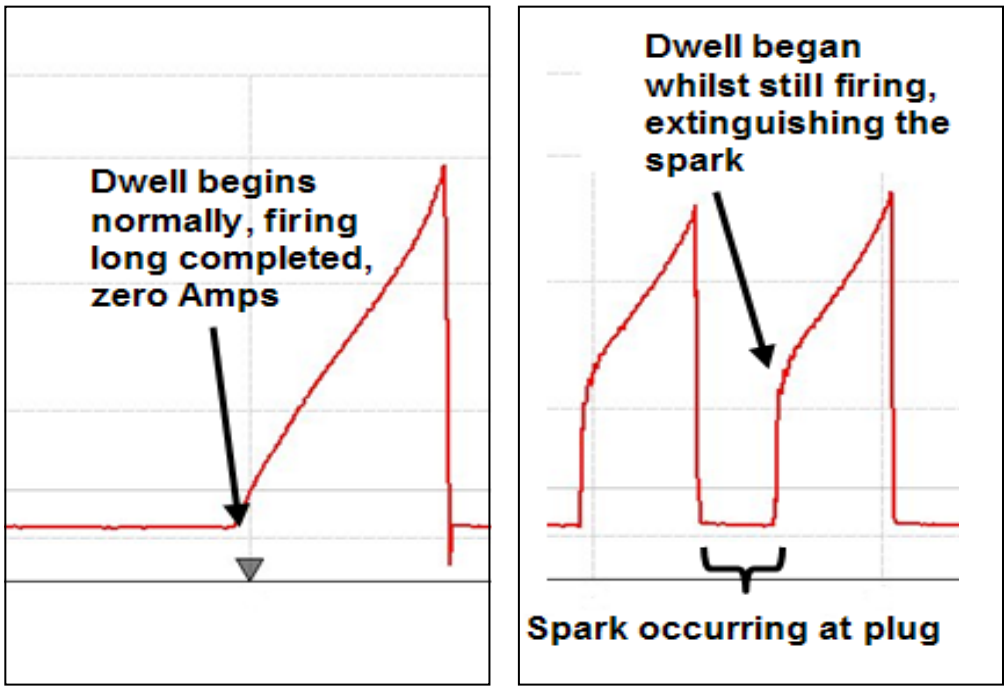
If you start to consider the relationship between degrees, time and rpm you can understand the time constraints imposed.

At 1000 rpm the crank travels 6 degrees in just 1ms (this may well be the time required to charge the coil up again). 1 degree pass's in just 0.17ms!

Its obvious multi-sparking can only be effective at very low engine speeds.

Thermal Constraints on Multi-sparking:

When extinguishing a spark early by turning on the coil we are only 'topping up' the energy, as you can seen in the current traces of the seceding ignitions above, they didn't start from 0 Amps each time like the first dwell period ('dwell' is the name given to coil charge time). This is a real problem as the amount of left over energy is unknown and depends on how much energy was just used (this is effected by the firing voltage and spark conditions during the combustion process). If we're not careful we end up with too little dwell and poor spark energy for the following spark or too much dwell and following dwell period will cause the coil to magnetically saturate, this will cause a sharp rise in the current drawn in a given time period. As the dwell is pre programmed high currents could flow and this can lead to thermal issues.



Manufacturers are often conservative with their dwell settings when multi-sparking and successive coil charges can sometimes deliberately be done at progressively lower current levels. The fortunate fact is that although the coil is being operated under difficult sustained conditions, it is only at low rpm and this leaves the coil a cooling period before it is required to fire the cylinder again on the next cycle (2 crank rotations).

Single 'coil on plug' applications are often already driven fairly hard to extract good spark energy (from often compromised designs) and therefore are more likely to suffer from thermal issues that arise if the duty is too great.

Thermal overload is a real problem. Manufacturers seldom use multi-sparking if not really required on a project, lots of application measurements and confirmation tests are needed to ensure their rigid durability requirements are met.

Many factory ECU's also have a compensation table to adjust coil dwell based on predicted coil temperatures, thus assisting with keeping thermal issues in check.

Additional Constraints:

If a new spark is to occur soon enough then first spark must be terminated to allow the coil to charge up ready for a new spark. There will therefore be a time period without a spark occurring (as the coil charges again) and also premature termination of first spark may lead to poor combustion! We also need to consider that the low cranking voltage makes the coils charge time considerably longer as well. Whilst most of the energy from a spark is transferred in the initial 'head' discharge, the rest (spark duration basically) still provides significant energy and is therefore important.

Generally spark duration needs to be at least 0.5- 0.6ms or ignition suffers. Hydrocarbon (HC) can rise in engines with short duration sparks and lean burning designs may need greater than 1.5ms or the negative effects can be measured.

'Duel fire' coil ignition systems (two leads from a single coil going to opposing cylinders) has its own issues in that the delayed sparks could be occurring during valve overlap and therefore cause manifold backfiring in the companion cylinder. Even single coil per plug systems have to consider when last spark occurs relative to any valve timing events, this will involve investigating the full range of valve timing events if variable cam timing is used.

Summary:

Aiding combustion by the additional ignition of un-burnt fuel is limited to narrow range if it happens at all. The flame front will spread through the whole chamber in due course anyway!

Often the second coil recharge takes so long that the ignition has already progressed so there is very little benefit left. With rising temperatures and engine speed multi-sparking has little effect. Most production vehicle's abandon any multi sparking strategies when the rpm goes much above an idle (eg. Ford BA Falcon at approximately 1500 rpm).

Manufacturers don't generally waste their time/money on features the customer will never ever know about, yet alone understand. It most certainly serves its purpose when required.

If multi-sparking can be done with due consideration for any thermal issues (not as bigger concern for the aftermarket) and the time involved in doing the application is available, then there's certainly a positive benefit.

Darren Todd
DTec devices