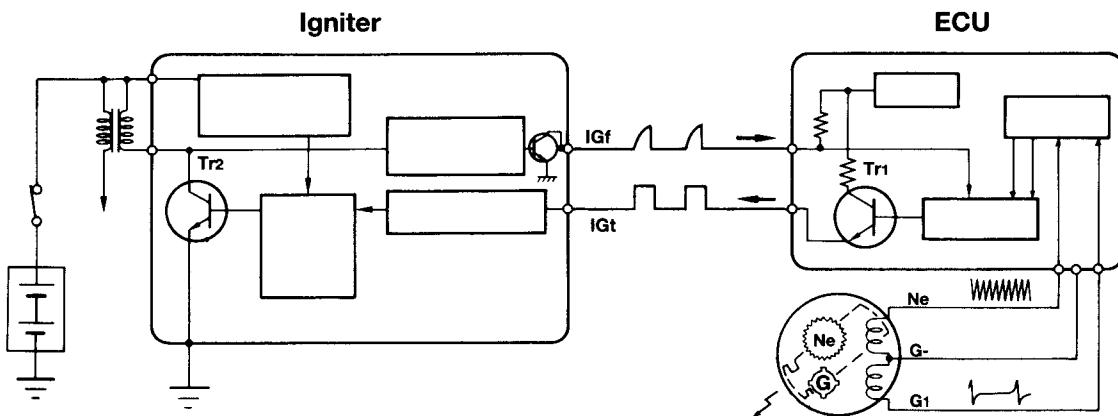


The EFI/TCCS Ignition System



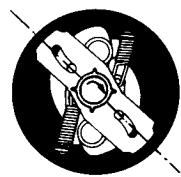
Overview of Toyota EFI/TCCS Ignition Control

The ignition systems used on today's EFI/TCCS equipped engines are not that much different from the ignition system used on the original 4M-E EFI engine. Primary circuit current flow is controlled by an igniter based on signals generated by a magnetic pickup (pickup coil) located in the distributor.

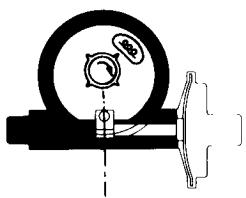
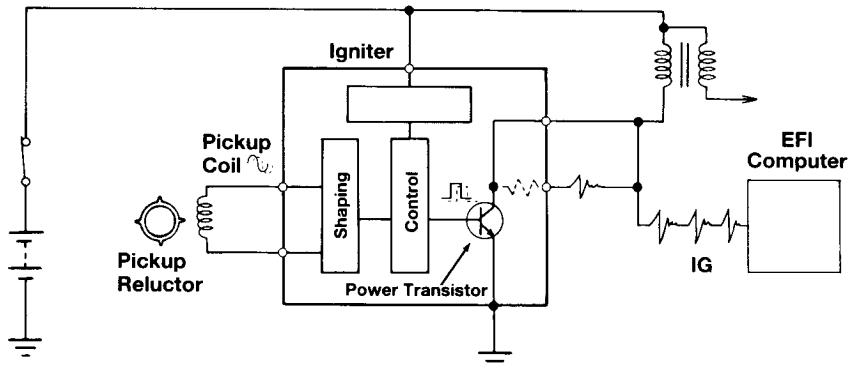
The ignition system has a dual purpose, to distribute a high voltage spark to the correct cylinder and to deliver it at the correct time. Ideal ignition timing will result in maximum combustion pressure at about 10° ATDC.

The most significant difference between TCCS and Conventional EFI ignition systems is the way spark advance angle is managed. The Conventional EFI system uses mechanical advance weights and vacuum diaphragms to accomplish this. Starting with the 5M-GE engine in 1983, the TCCS system controls ignition spark timing electronically and adds an ignition confirmation signal as a fail-safe measure.

There are two versions of electronic spark management used on TCCS equipped engines, the Electronic Spark Advance (ESA) and the Variable Advance Spark Timing (VAST) systems.



Greater Speed
Greater Advance



Less Vacuum
Less Advance

Conventional EFI Ignition System

Spark Advance Angle Control

In the Conventional EFI system, spark advance angle is determined by the position of the distributor (initial timing), position of the magnetic pickup **relector** teeth (centrifugal advance), and position of the breaker plate and pickup coil winding (vacuum advance). The spark advance curve is determined by the calibration of the centrifugal and vacuum advance springs.

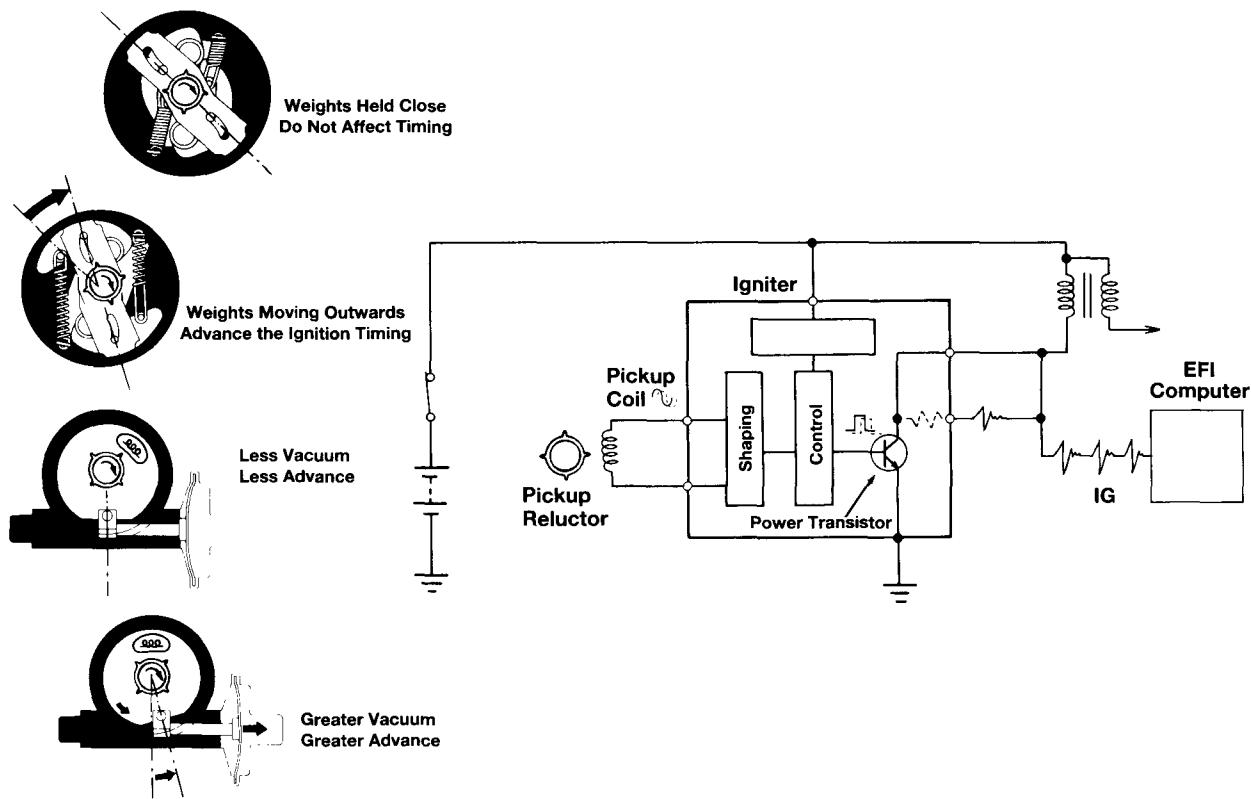
Besides being subject to mechanical wear and mis-calibration, this type of spark advance calibration is very limited and inflexible when variations in coolant temperature and engine

detonation characteristics are considered. Mechanical control of a spark curve is, at best, a compromise. In some cases the timing is optimal; in most cases it is not.

Engine RPM Signal

To indicate engine rpm to the EFI computer, the Conventional EFI system uses the signal generated at the coil negative terminal (**IG-**). Because this system does not use ECU controlled timing, the rpm signal to the ECU has no impact on spark timing whatsoever. The **IG** signal is used as an input for fuel injection only.

CONVENTIONAL EFI IGNITION SYSTEM



Conventional EFI Ignition System Operation

When the engine is cranked, an **alternating current** signal is generated by the pickup coil. This signal is shaped in the igniter and then relayed through a control circuit to the base of the primary circuit **power transistor**.

When the voltage at the base of this transistor goes high, current begins to flow through the coil primary windings. When this signal goes low, coil primary current stops flowing, and a high voltage is induced into the secondary winding. At cranking speed, spark plugs fire at initial timing, a function of distributor position in the engine.

When the engine is running, spark timing is determined by the relative positions of the

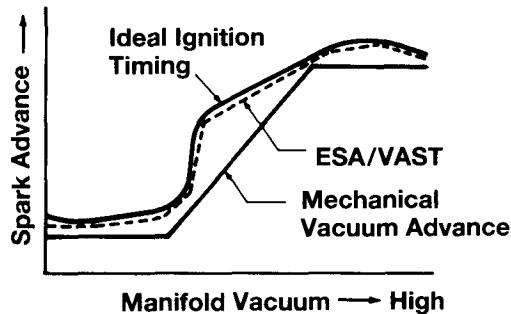
pickup **reluctor** (signal rotor) and the pickup coil winding to each other. This relative position is controlled by the centrifugal advance weights and vacuum advance diaphragm positions.

As engine speed increases, the reluctor advances in the same direction as distributor shaft rotation. This is a result of the centrifugal advance operation.

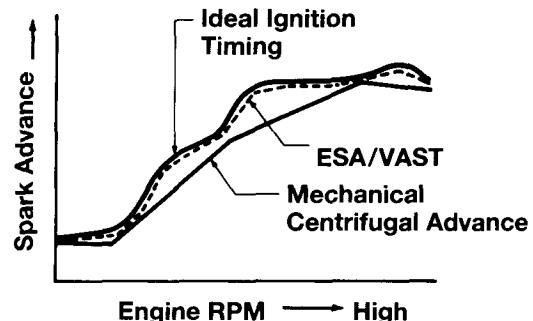
As manifold vacuum applied to the vacuum controller is increased, the pickup coil winding is moved opposite to distributor shaft rotation.

Both of these conditions cause the signal from the pick-up coil to occur sooner, advancing timing.

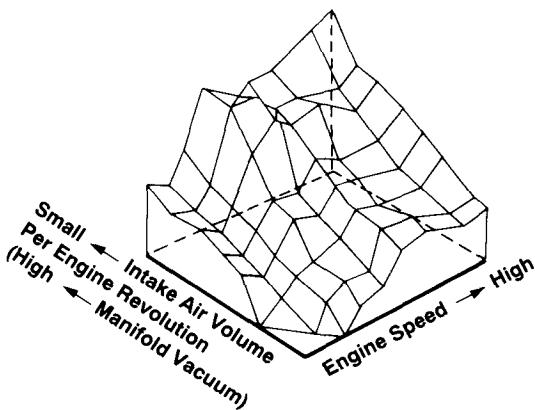
**VACUUM ADVANCE
(Load Sensitive)**



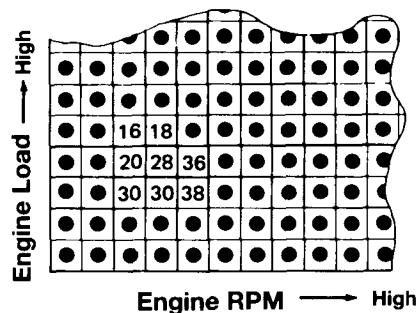
**CENTRIFUGAL ADVANCE
(RPM Sensitive)**



ESA/VAST SPARK MAP



**ESA/VAST LOOK UP TABLE
(Basic Spark Advance)**



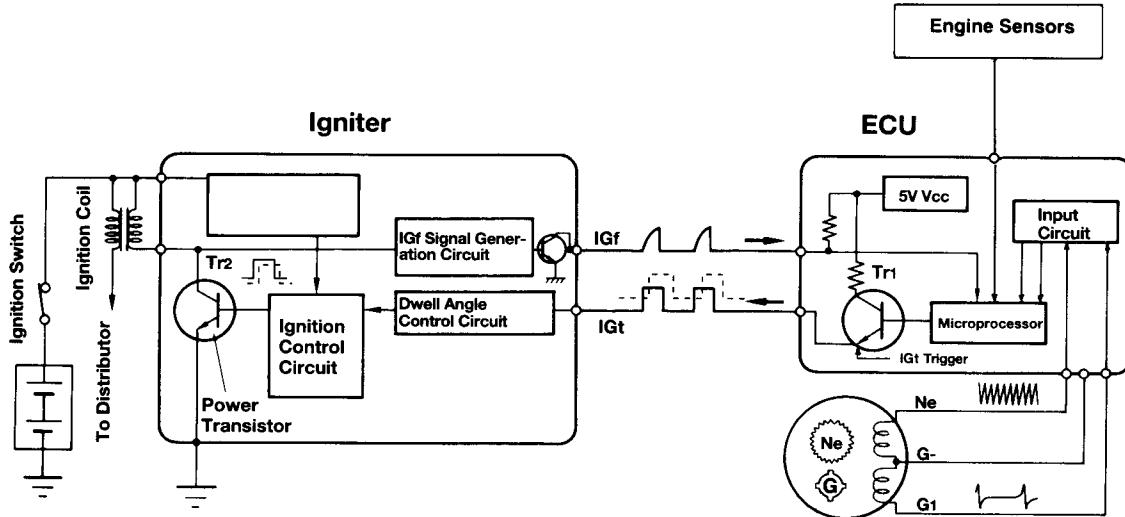
TCCS Ignition Spark Management, Electronic Spark Advance (ESA), and Variable Advance Spark Timing (VAST)

The advent of ECU spark management systems provides more precise control of ignition spark timing. The centrifugal and vacuum advances are eliminated; in their place are the engine sensors which monitor engine load (V_s or PIM) and speed (N_e). Additionally, coolant temperature, detonation, and throttle position are monitored to provide better spark accuracy as these conditions change.

To provide for optimum spark advance under a wide variety of engine operating conditions, a **spark advance map** is developed and stored in a **look up table** in the ECU. This map provides for accurate spark timing during any combination of engine speed, load, coolant temperature, and throttle position while using feedback from a knock sensor to adjust for variations in fuel octane.

TCCS engines use two versions of ECU controlled spark management, Electronic Spark Advance (ESA) and Variable Spark Timing (VAST).

ESA IGNITION SYSTEM



To monitor engine rpm, the TCCS system uses the signal from a magnetic pickup called the **Ne** pickup. The Ne pickup is very similar to the magnetic pickup coil used with Conventional EFI. It has either four or 24 reluctor teeth, depending on engine application.

Engines equipped with the ESA system (and the 4A-GE engine with VAST) use a second pickup in the distributor called the **G** sensor. The G sensor supplies the ECU with crankshaft position information which is used as a reference for ignition and fuel injector timing. Some engines use two G sensors, identified as G1 and G2.

ESA Ignition System Operation

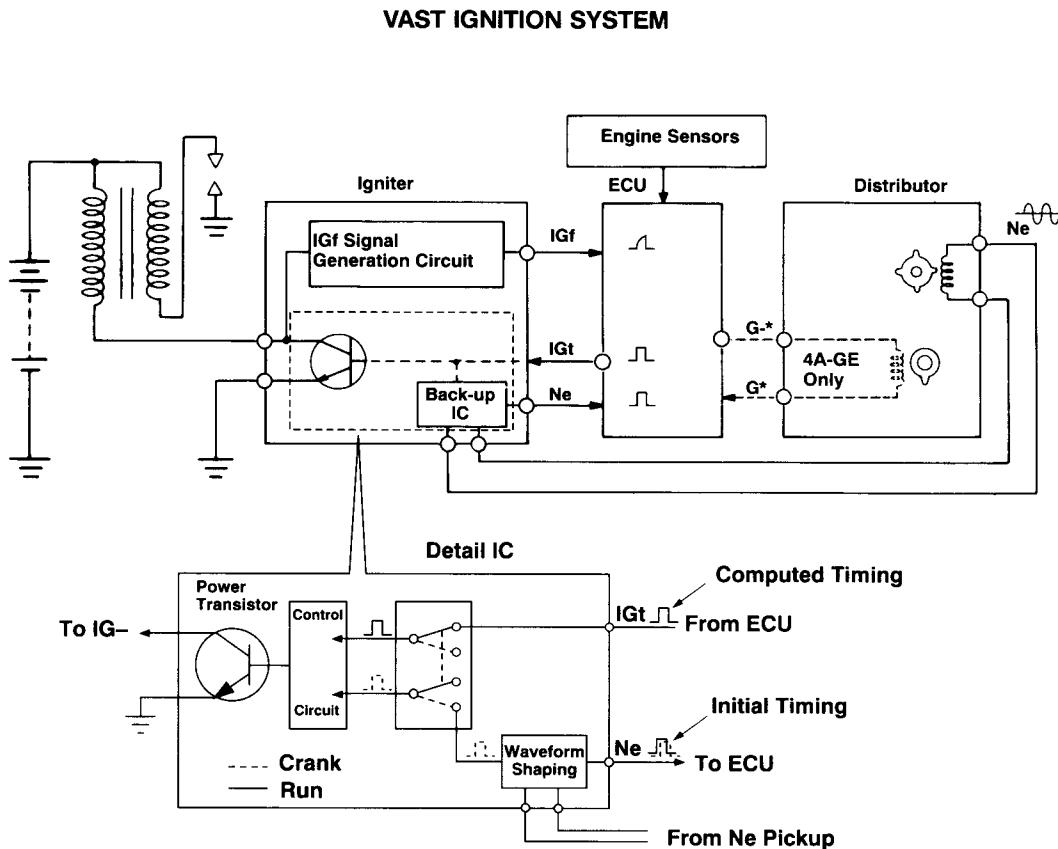
In the example above, when the engine is cranked, an alternating current signal is generated by a 24-tooth Ne pickup and a four-tooth G pickup. These signals are sent to the ECU where they are conditioned and relayed to the microprocessor.

The microprocessor drives a **trigger circuit**, referred to as **IGt** (TR1). The IGt signal is sent to the igniter to switch the primary circuit power transistor on and off.

While cranking, IGt fixes spark timing at a predetermined value. When the engine is running, timing is calculated based on signals from engine speed, load, temperature, throttle position, and detonation sensors.

The IGt signal is advanced or retarded depending on the final calculated timing. ESA calculated timing is considered the ideal ignition time for a given set of engine conditions.

If the ECU fails to see an Ne or G signal while it is cranking, it will not produce an IGt signal, thus preventing igniter operation.



VAST System Operation

When the engine is cranked, an alternating current signal is generated by a four-tooth magnetic pickup in the distributor. This alternating current signal is sent directly to the igniter where it is conditioned into a **square wave** by a **waveform shaping circuit**.

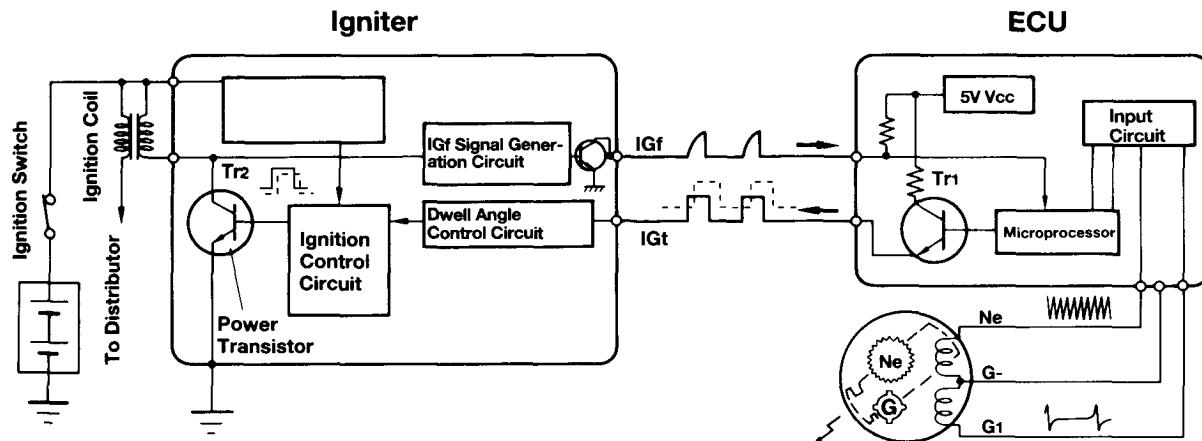
While cranking, this square wave signal is sent to the ECU on the Ne wire and to the igniter power transistor. The ignition system delivers spark at initial timing under this condition.

When the engine starts and exceeds a predetermined rpm, the ECU begins sending the IGt signal to the igniter. The igniter switches to computed timing mode

and uses the IGt signal to operate the power transistor. Timing of IGt is based on information from various engine sensors.

Because the VAST system triggers the igniter directly from the magnetic pickup while cranking, the engine will start even if the IGt circuit to the igniter is open. If IGt signals are not received by the igniter once the engine has started, it will continue to run, defaulted at initial timing, using signals from the magnetic pickup.

The VAST system is only used on the 2S-E, 22R-E, 22R-TE, 4Y-E, and 4A-GE engines.



Igniter Operation

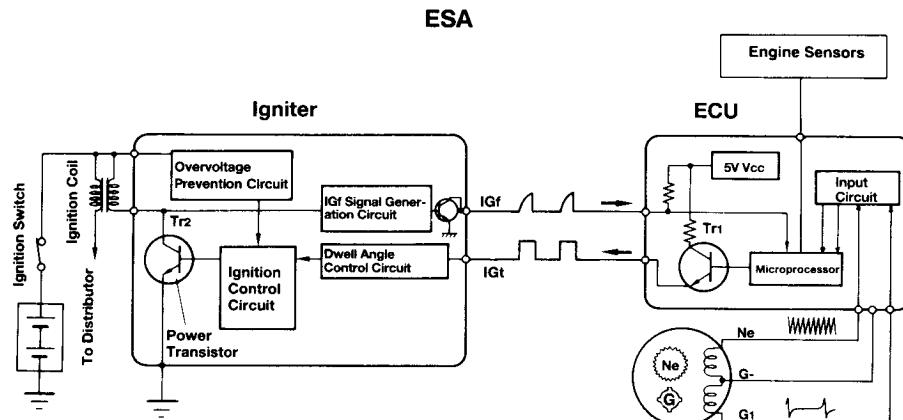
When the IGt signal goes high, the primary circuit power transistor TR2 turns on, allowing current to flow in the coil primary winding. When the IGt signal goes low, the igniter interrupts primary circuit current flow, causing voltage induction into the coil secondary winding.

With the ESA system, the time at which the power transistor in the igniter turns on is further influenced by a **dwell control circuit** inside the igniter. As engine rpm increases, coil dwell time is increased by turning the transistor on sooner. Therefore, the time at which the transistor is turned on determines dwell while the time the transistor is turned off determines timing. Timing is controlled by the ECU; dwell is controlled by the igniter.

Controlling dwell within the igniter allows the same control over coil saturation time as the ballast resistance does with the Conventional EFI ignition system. It allows maximum coil saturation at high engine speeds while limiting coil and igniter current, reducing heat, at lower speeds.

Spark Confirmation IGf

Once a spark event takes place, an ignition confirmation signal called **IGf** is generated by the igniter and sent to the ECU. The IGf signal tells the ECU that a spark event has actually occurred. In the event of an ignition fault, after approximately eight to eleven IGt signals are sent to the igniter without receiving an IGf confirmation, the ECU will enter a fail-safe mode, shutting down the injectors to prevent potential catalyst overheating.

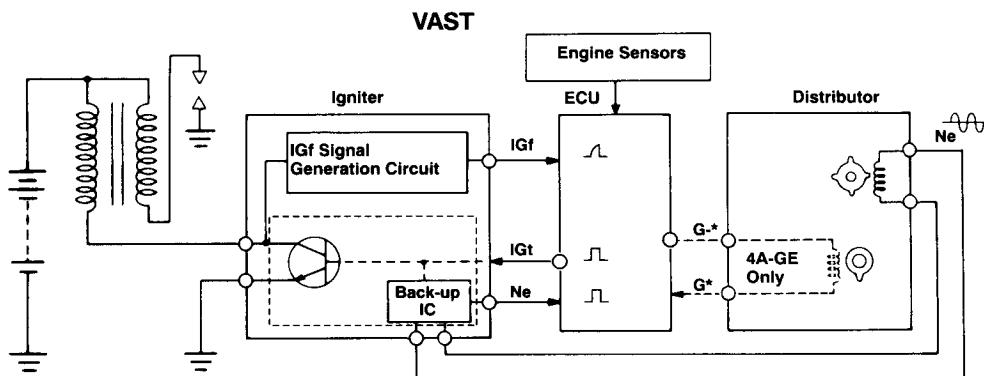


ECU Detection Of Crankshaft Angle

ESA System

In order to correctly time spark and injection events, the ECU monitors the relationship between the Ne and G signals. With most engines, the ECU determines the crankshaft

has reached 10° BTDC of the compression stroke when it receives the first Ne signal following a G1 (or G2). Initial timing adjustment is critical as all ECU timing calculations assume this initial 10° BTDC as a reference point for the entire spark advance curve.



VAST System

Because all engines which use this system have a simultaneous injection pattern (except the 4A-GE), a G signal is not necessary. The four-toothed pickup is designed to produce a pulse once every 180° of crankshaft rotation, signal timing determined by the position of the distributor in the engine. Distributor position determines Ne signal timing and, therefore, initial timing reference. The 4A-GE engine with VAST, because it uses grouped injection, utilizes a G sensor signal indicating camshaft position so the ECU can properly time each injector group.

Ignition Timing Strategy

The ECU determines ignition timing by comparing engine operating parameters with spark advance values stored in its memory. The general formula for ignition timing follows:

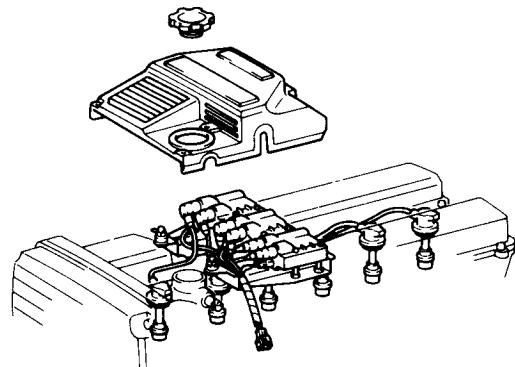
$$\text{Initial timing} + \text{Basic advance angle} + \text{Corrective advance angle} = \text{Total spark advance.}$$

Basic advance angle is computed using signals from crankshaft angle (G1), crankshaft speed (Ne), and engine load (Vs or PIM) sensors. Corrective timing factors include adjustments for coolant temperature (THW) and presence of detonation (KNK).

Distributor-Less Ignition System (DLI)

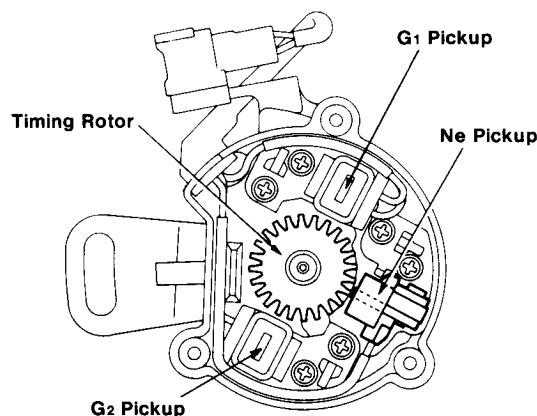
Used only on the 7M-GTE engine, DLI, as the name implies, is an electronic spark distribution system which supplies secondary current directly from the ignition coils to the spark plugs without the use of a conventional distributor. The DLI system contains the following major components:

- 1) Cam Position Sensor
- 2) Igniter
- 3) Ignition Coils (3)



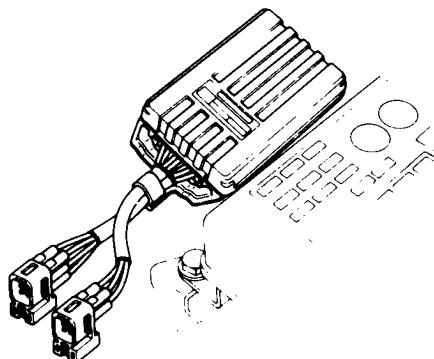
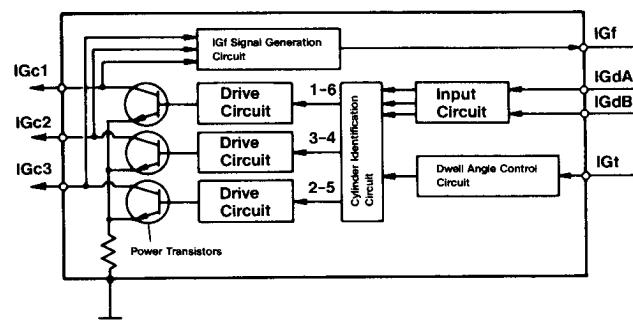
Cam Position Sensor

Very similar to the 7M-GE distributor without the secondary distribution system, the cam position sensor houses the Ne, G1, and G2 pickups. The Ne pickup reluctor has 24 teeth, its signal representing crankshaft speed. The G1 and G2 pickups produce signals near TDC compression stroke for cylinders #6 and #1, respectively. These signals represent standard crankshaft angle and cylinder identification.



Igniter

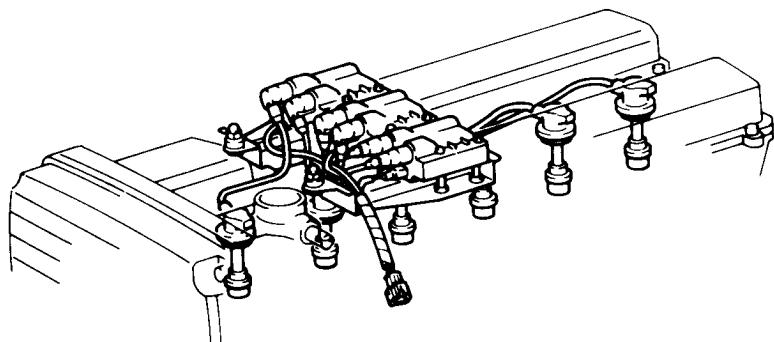
The igniter is similar to those used on distributor type ignition systems but incorporates three separate primary circuits. The igniter determines timing of three primary circuits by the combination of **IGdA** and **IGdB** input signals from the ECU. The **IGt** signal is relayed by the igniter to the proper power transistor circuit to trigger the ignition event at the proper coil. The igniter also sends the standard **IGf** confirmation signal to the ECU for each ignition event which takes place.



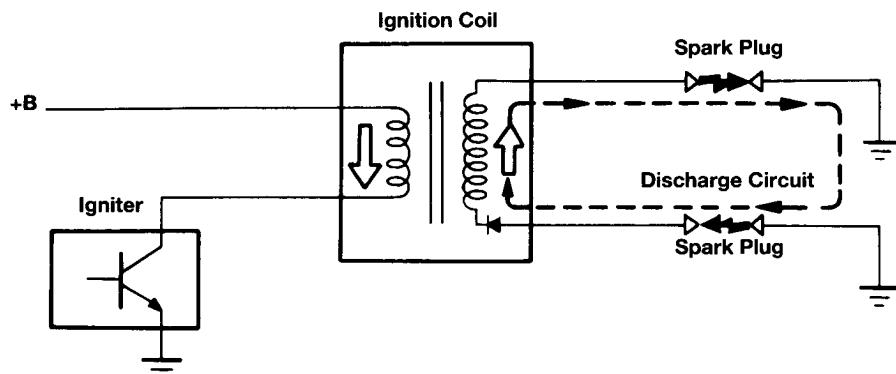
Ignition Coils

Each coil is connected in series between spark plugs of companion cylinders. For every engine cycle (720° of crankshaft rotation), ignition is carried out twice at each coil, both spark plugs firing simultaneously. One plug fires before TDC on the compression stroke while the companion fires at the same position before TDC on the exhaust stroke. This type of secondary distribution is referred to as **waste spark**.

The three ignition coils are mounted on the top of the engine to the upper section of the head cover. As you face the engine, the coil for the 1-6 cylinder pair is on your left. The coil in the center serves the 3-4 cylinder pair, and the coil to the right serves cylinder pair 2-5.



WASTE SPARK DISTRIBUTION



DLI System Operation

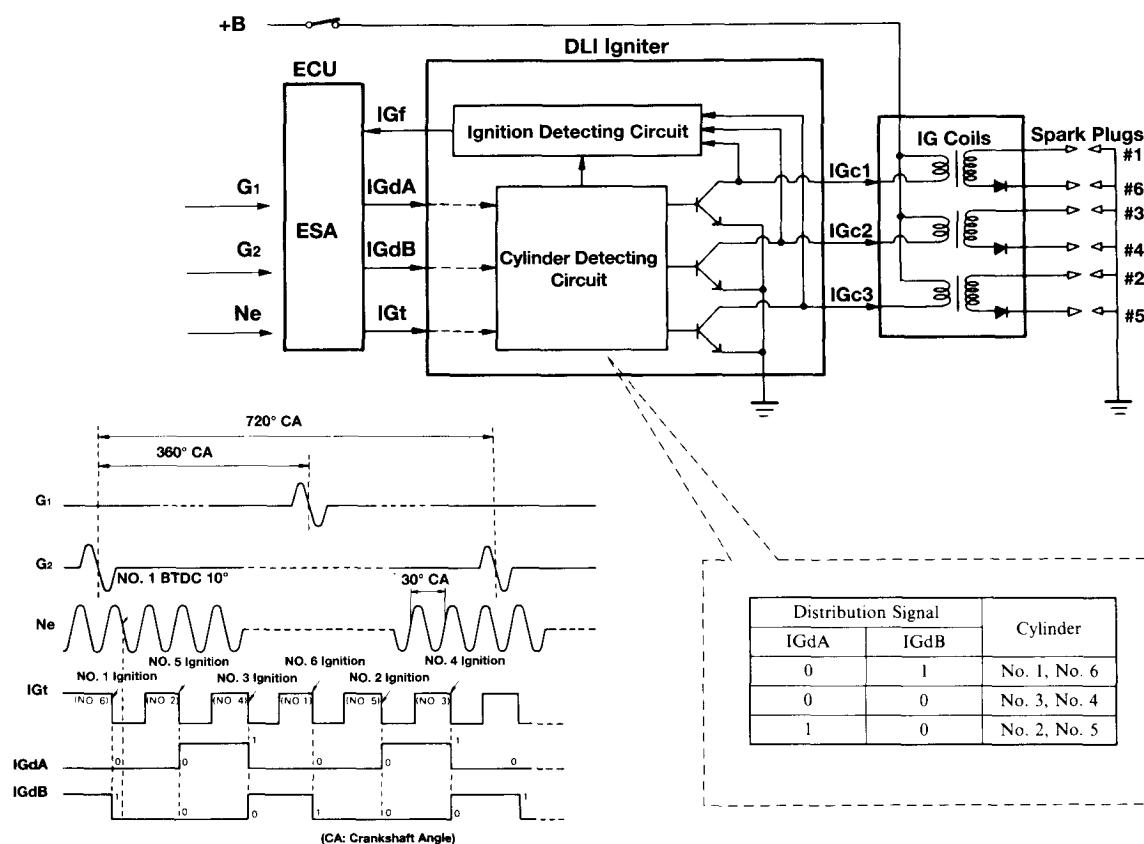
When the engine is cranked, alternating current signals are generated by the 24-tooth Ne sensor and the two G sensors (G1 and G2). The G sensors are 360° out of phase.

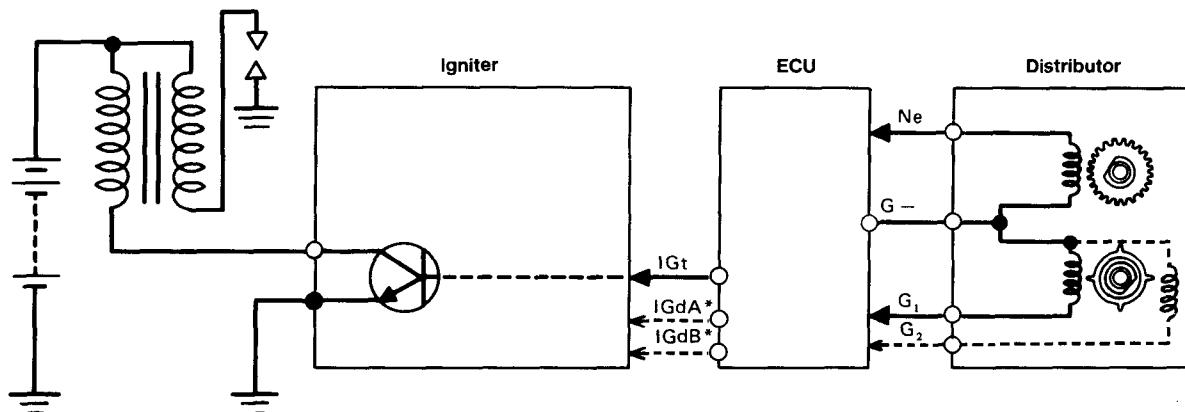
The G sensors represent #1 and #6 pistons approaching TDC on the compression stroke. These signals are received by the ECU where they are conditioned and processed by the ESA microprocessor.

The ESA microprocessor serves two functions. It generates an IGt signal and generates cylinder identification signals, IGdA and IGdB, which allow the DLI igniter to trigger the correct coil while cranking the engine.

These signals are sent to the DLI igniter which electronically determines proper primary signal distribution based on the combination of IGdA and IGdB signals. The igniter distributes the IGt signal to the proper coil driver circuit and determines dwell period based on coil primary current flow. The ESA calculations for spark advance angle work the same as with distributor type ignition systems.

The table below shows how the igniter is able to calculate crankshaft position and properly distribute the IGt signal to the transistor driver circuit connected to the relevant ignition coil.





Ignition System Service

Troubleshooting the Ignition System

No Spark Output

The following procedures assume that a spark tester reveals no spark at two different cylinders while the engine is cranked. These procedures and specifications are general guidelines. Consult the appropriate repair manual for more specific information about the vehicle you are troubleshooting.

Preliminary checks

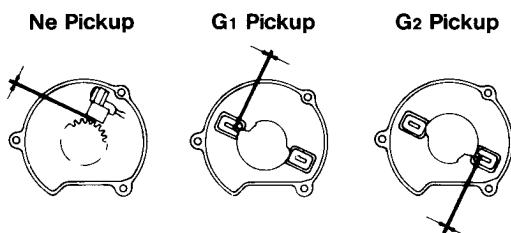
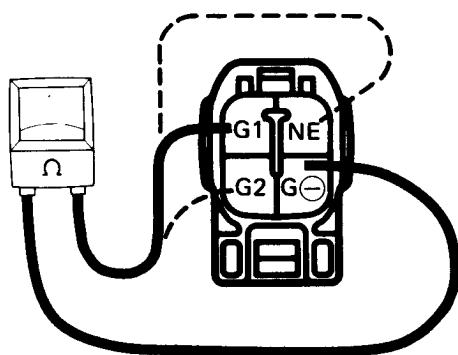
- 1) Ensure battery condition prior to ignition system analysis.
- 2) Check and confirm good connections at distributor, igniter, and coil.
- 3) Basic secondary leakage checks at coil and coil wire.

Primary circuit checks

- 1) Confirm power supply to igniter and coil positive (+) terminal. Confirm connections at coil positive and negative (-) terminals.
- 2) Using a test light or logic probe, check for primary switching at the coil (-) terminal while cranking engine. Blinking light confirms primary switching is taking place; check coil wire, coil secondary winding resistance, or secondary leakage in distributor cap.

- 3) The power transistor(s) in the igniter get their ground through the igniter case to the vehicle chassis; always confirm good ground continuity prior to trouble shooting.
- 4) Confirm coil primary and secondary windings resistance. Confirm primary windings are not grounded.
- 5) Confirm signal status from Ne and G pickups to ECU (ESA system) or to igniter (VAST system) using an oscilloscope or logic probe.
 - If a fault is detected, check pickup(s) for proper resistance and shorts to ground. Check electrical connections.
 - If signal amplitude is low, check signal generator gap(s).
- 6) Confirm signal status from ECU IGt circuit to igniter using an oscilloscope or logic probe.
- 7) On 7M-GTE, check power transistor in igniter. Bias transistor base using a remote 3 volt battery as power source. Use ohmmeter to check for continuity from primary circuit to ground (see procedure in repair manual for details).

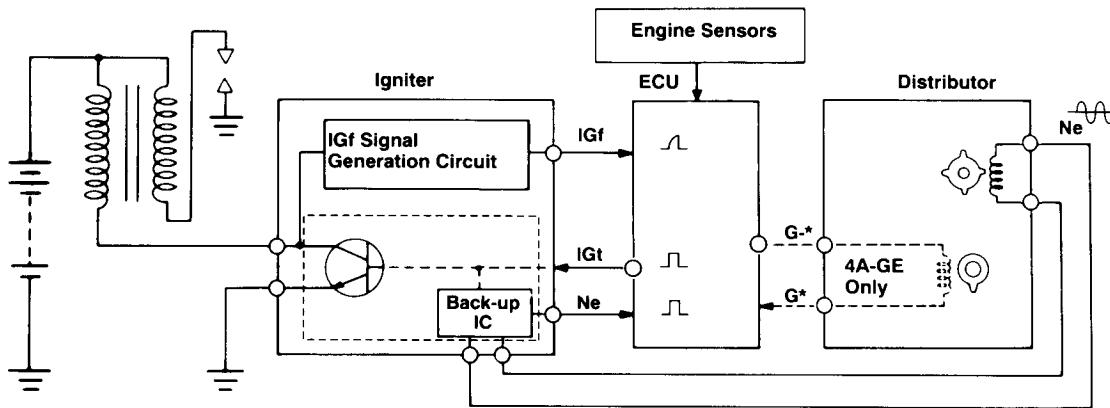
- 8) Check pickup gaps and coil resistances against specifications. If gap and/or resistance is not within specification, replace faulty component.


DISTRIBUTOR CONNECTOR

Signal Generator Resistance Specifications

Engine Type	Coil Color ID	Resistance Specification (Ω @ 14°F to 104°F)
7M-GE, 3S-GE 2TZ-FE, 3S-GTE	Black	Ne: 155 - 240 G1, G2: 125 - 190
5S-FE	Black	Ne: 150 - 230 G: 150 - 230
3E-E, 5E-FE	Gray	265 - 420
	Green	370 - 530
All Other Engines	Gray	130 - 210
	Green	185 - 265

Ignition Coil and Sensor Gap Specifications

Engine Type	Coil Secondary @70°F	Coil Primary @70°F	Pickup Gap
7M-GE	9.2K Ω to 12.4K Ω	.24V to .30 Ω	.008" - .016"
7M-GTE	Cannot be measured	.34 Ω to .42 Ω	.008" - .016"
4A-FE	10.4K Ω to 14.0K Ω	1.28 Ω to 1.56 Ω	.008" - .016"
22R-E	11.4K Ω to 15.6K Ω	.52 Ω to .64 Ω	.008" - .016"
All Others	10.0K Ω to 14.0K Ω	.40 Ω to .50 Ω	.008" - .016"



Timing Will Not Advance Properly (VAST System)

The following checks assume that the engine runs but timing will not advance.

The design of the VAST system will allow the ignition system to function at initial timing in the event that the IGt signal does not reach the igniter. If this condition occurs, the ignition system will be locked at initial timing regardless of engine speed or load. The ECU has no way to monitor for this fault, so there will be no indication of this condition other than a loss of engine performance.

To check for this condition:

- 1) Monitor the IGt wire at the igniter using an oscilloscope or logic probe.
- 2) If a good signal is being sent out on IGt, check the connection at the igniter.
- 3) Once connections are confirmed, the igniter is the last item left which can cause the problem.

Timing Seems Out of Range For Conditions (VAST or ESA)

In some cases, driveability symptoms or a check of timing reveal advance which is out of range for input conditions. This situation could be caused by incorrect sensor information reaching the ECU.

An example of this type of problem can be illustrated by a manifold pressure sensor which is out of range low. Lower than normal voltage from the sensor would indicate a light load condition to the ECU. The ECU responds to light load operation by advancing the timing. If the vehicle is being operated under moderate to heavy load with too much spark advance, detonation will likely result.

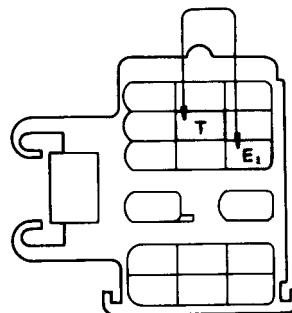
When this type of condition is suspected, it is recommended to perform a standard voltage check of all major sensor inputs to the ECU. If any sensor is found out of normal range, it is a likely cause of the problem. The subject of sensor signal values is addressed in, "Electronic Engine Controls."

Adjustment Of Initial Ignition Timing

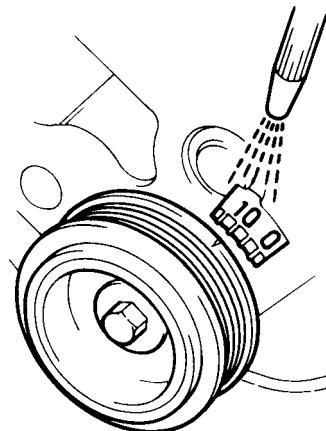
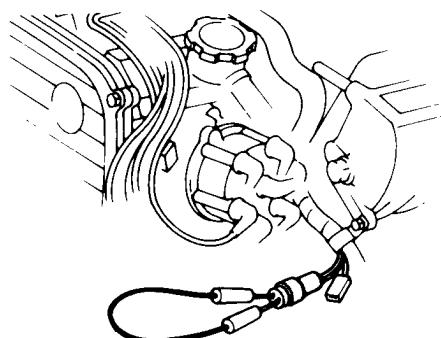
All engines equipped with TCCS utilize a test terminal (T or TE1) somewhere under the hood. Early TCCS utilizes a two-terminal check connector in the wiring harness. This yellow body connector contains circuits T and E1, which when jumpered, default the TCCS system to initial timing. The location of this test terminal varies between applications. Refer to the appropriate repair manual for connector location.

A new design multipurpose check connector began phase-in starting with 1985 models. By 1986 model year, all vehicles are equipped with this new style connector. Connectors are typically located in the fender area on either side, or near the bulkhead, in plain view. With the advent of test terminals for the ECT, TEMS, SRS, and etc., the TCCS test terminal has been renamed TE1 to distinguish it from the others.

LATE DESIGN CHECK CONNECTOR



EARLY DESIGN CHECK CONNECTOR



To check timing on any TCCS equipped engine:

- 1) Engine at normal operating temperature.
- 2) Jumper T (TE1) to E1 using SST 09843-18020 (or equivalent).
- 3) Wait for engine rpm to stabilize (speed may rise to 1 K to 1.3 K rpm for 5 seconds).
- 4) Use timing light to confirm initial timing as per repair manual procedure.
 - Make sure rpm is within specified range.
 - Adjust timing as necessary by rotating the distributor (cam position sensor on 7M-GTE).
- 5) Remove SST jumper.
- 6) Recheck timing; it should be advanced (at least 3' to 18') from initial with SST removed.

Summary

In this chapter you have learned how the ECU electronically controls ignition timing, delivering spark at the optimum moment based on engine speed, load, temperature and quality of fuel. The spark advance curve is stored in a look up table in the ECU memory.

There are two types of ECU controlled spark advance systems used on Toyota TCCS equipped engines, the Variable Advance Spark Timing system (VAST) and the Electronic Spark Advance system (ESA). The main difference between these systems is the magnetic pickup in the distributor (Ne pickup) reports to the igniter on the VAST system and directly to the ECU on the ESA system.

An ignition confirmation signal is generated by the igniter which signals the ECU with each ignition event. The IGf signal is used to provide the ECU with a fail-safe fuel cutoff if ignition spark is lost.

The Distributorless Ignition system (DLI) provides secondary distribution by means of a three-coil waste spark system. Two companion spark plugs are connected to each end of the ignition coil secondary windings. These plugs fire simultaneously each time the cylinder pair approaches TDC, one spark igniting the mixture, the other wasted on the exhaust stroke.

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