

# Ignition Systems

## Application Manual



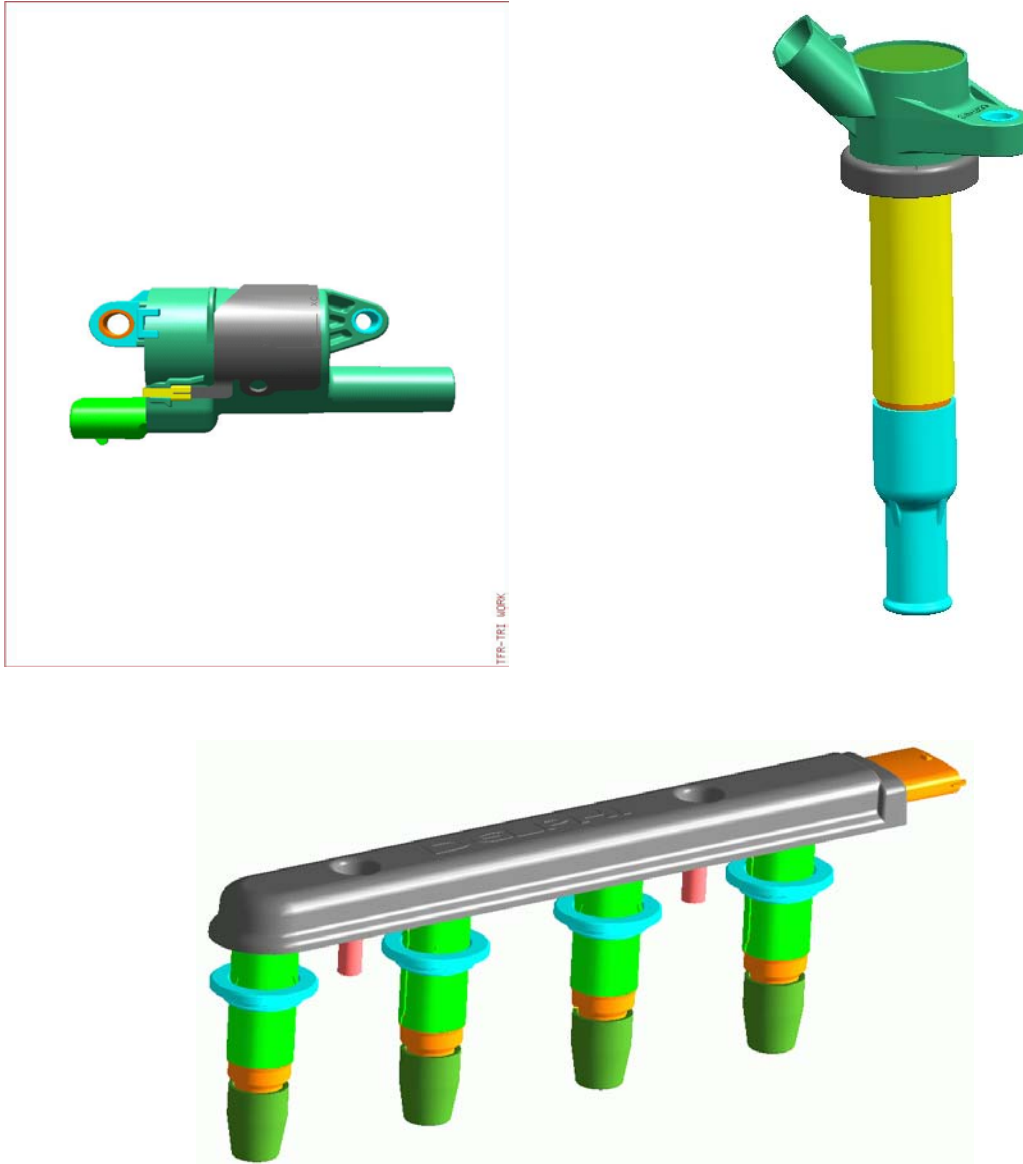
**DELPHI**

**Energy and Chassis**



# IGNITION SYSTEMS APPLICATION MANUAL

*Revised Jan 2005*



Ignition Systems  
Delphi Energy and Chassis Systems  
Tech Center Brighton  
12501 E. Grand River  
Brighton, Mi., 48114, USA

© 1999 Delphi Automotive Systems  
Updated January 2005

# Ignition Systems Application Manual Release/Revision Summary Sheet

CHANGE NO.	DATE	REASON FOR CHANGE	Originator	PAGE(S)
Original	30/AUG/99	Released	C.R. Strange	N/A
1	Jan 2005	Update, pencil coil information added	B. Griffith	3-15 – 3-19
		Information and graphics added, Ion Sense.		Various

<b>1.0 INTRODUCTION.....</b>	<b>1-1</b>
1.1 SCOPE OF DOCUMENT .....	1-1
1.2 CLASSIFICATION .....	1-1
1.3 DOCUMENT MANAGEMENT .....	1-1
1.3.1 Document Release and Updates .....	1-1
1.3.2 Mailing List.....	1-2
1.3.3 Document Revision Procedure.....	1-2
1.4 COMMERCIAL CONSIDERATIONS .....	1-2
1.5 OBJECTIVES OF THIS MANUAL .....	1-3
1.6 HOW THIS MANUAL IS ARRANGED.....	1-4
1.7 CONVENTIONS USED IN THIS MANUAL.....	1-6
1.8 APPLICABLE DOCUMENTS .....	1-7
1.8.1 Order of Precedence .....	1-7
1.8.2 Government Documents.....	1-7
1.8.3 Other Delphi-E Reference Documents.....	1-7
1.8.3.1 Ignition System Components P/N's.....	1-7
1.8.3.2 Delphi-E Engineering Specification, Number, Date .....	1-7
1.8.3.3 SFMEA .....	1-7
1.8.3.4 DFMEA .....	1-7
1.8.3.5 OBD-II Diagnostic Procedures .....	1-7
1.8.3.6 Validation Plan ACR #2066.....	1-7
1.8.4 Industry Documents.....	1-7
1.8.4.1 SAE Standard Procedure J1829 .....	1-7
<b>2.0 FUNDAMENTALS .....</b>	<b>2-1</b>
2.1 GENERAL .....	2-1
2.2 ENGINE COMBUSTION FUNDAMENTALS .....	2-2
2.2.1 Air/Fuel Ratio Effects on Combustion.....	2-2
2.2.1.1 Stoichiometric "Ideal" Combustion Mixtures .....	2-3
2.2.1.2 Rich Mixtures.....	2-4
2.2.1.3 Lean Mixtures.....	2-4
2.3 ELECTROMAGNETIC INDUCTION .....	2-5
2.3.1 Self-Induction.....	2-6
2.3.2 Mutual Induction .....	2-7
2.4 AVAILABLE VOLTAGE .....	2-8
2.4.1 Coil Current Limiting and Dwell Control .....	2-11
2.4.2 Increased Ignition Energy.....	2-13
2.5 RADIO FREQUENCY (RF) SUPPRESSION .....	2-14
2.6 GENERAL DESCRIPTION .....	2-16

<b>3.0 PRODUCT DESCRIPTION</b>	<b>3-1</b>
3.1 DELPHI IGNITION MILESTONES	3-1
3.2 IGNITION COIL - FUNCTION	3-2
3.3 APPEARANCE	3-2
3.4 EXTERIOR OUTLINE	3-2
3.5 IGNITION TYPES	3-3
3.5.1 Ignition Specifications	3-3
3.5.2 High Voltage Switch (HVS) System	3-4
3.5.2.1 High Value Ignition Features	3-6
3.5.2.2 High Value Ignition Performance	3-6
3.5.3 Waste Spark Ignition Concept	3-6
3.5.3.1 Direct Ignition System (DIS)	3-9
3.5.3.2 ICE	3-9
3.5.3.3 Dual Coil Pack (DCP)	3-10
3.5.3.4 Features- Gen 2 ICE and DCP	3-10
3.5.3.5 Dual Pencil Coil Pack	3-12
3.5.4 Coil Per Cylinder (CPC)	3-13
3.5.4.1 Coil Near Plug	3-13
3.5.4.2 Plug Top Coil	3-15
3.5.4.3 Pencil Coil (in plug hole)	3-17
3.5.5 Ion Sense	3-20
3.5.5.1 Knock Control	3-23
3.6 SPARK PLUG	3-24
3.6.1 Spark Plug Design	3-24
3.6.2 Spark Plug Types	3-25
3.7 SENSOR FUNCTION	3-25
3.7.1 Variable Reluctance (VR) Sensor	3-26
3.7.2 Hall Effect Sensor	3-28
3.7.3 Magneto Resistor (MR)	3-31
3.8 ELECTRICAL WIRES	3-32
3.8.1 Secondary Wires - Function	3-32
3.8.2 Features	3-33
3.8.3 Primary Wires - Function	3-34
3.9 ELECTRONIC CONTROL MODULE	3-34
<b>4.0 SYSTEM INTERFACE</b>	<b>4-1</b>
4.1 GENERAL	4-1
4.2 MECHANICAL INTERFACES	4-2
4.2.1 Locating the Ignition System	4-2
4.2.2 Vibration Levels	4-2
4.2.2.1 Vibration Durability Requirements	4-2
4.3 ELECTRICAL INTERFACE	4-4
4.3.1 Electromagnetic Compatibility	4-4
4.3.2 Wire Routing	4-4
4.3.3 Ignition System Connector(s)	4-5
<b>5.0 SOFTWARE</b>	<b>5-1</b>
5.1 GENERAL	5-1
5.2 IGNITION CONTROL ALGORITHMS	5-1
5.3 COMPUTER CONTROLLED COIL IGNITION SYSTEM	5-1
5.3.1 Ignition System Description	5-2
5.3.2 Input and Output Signals	5-2
5.3.2.1 Input Signals	5-2
5.3.2.2 Output Signals	5-3

<b>6.0 PRODUCT HANDLING .....</b>	<b>6-1</b>
6.1 PRODUCT USAGE AND HANDLING GUIDELINES .....	6-1
6.1.1 Product Packaging and Shipping .....	6-4
<b>7.0 RECOMMENDATIONS AND PRECAUTIONS .....</b>	<b>7-1</b>
7.1 VIBRATION .....	7-1
7.2 TEMPERATURE PROFILE .....	7-2
7.3 IGNITION HIGH VOLTAGE REQUIREMENTS .....	7-3
7.4 SPARK ENERGY .....	7-4
7.5 SPARK ENERGY VERSUS ENGINE ENERGY REQUIREMENTS (PROGRAMMABLE SPARK ENERGY) .....	7-5
7.6 ELECTRO-MAGNETIC COMPATIBILITY (EMC) .....	7-5
<b>8.0 TESTING RECOMMENDATIONS AND PRECAUTIONS .....</b>	<b>8-1</b>
8.1 DYNAMOMETER TESTING .....	8-1
8.1.1 Cylinder-to-Cylinder Distribution .....	8-1
8.2 DURABILITY TESTING .....	8-1
8.3 DYNAMIC VEHICLE TESTING .....	8-1
8.4 STANDARD VEHICLE DEVELOPMENT TESTS .....	8-2
8.4.1 Cold Driveability and Startability .....	8-2
8.4.2 Altitude Driveability and Emissions .....	8-2
8.4.3 Driveability Index Fuel Sensitivity .....	8-2
8.4.4 Spark Plug Fouling Tests .....	8-3
8.4.5 Voltage Sensitivity .....	8-3
8.4.6 Standard Durability Tests .....	8-3
<b>9.0 VALIDATION REQUIREMENTS .....</b>	<b>9-1</b>
9.1 GENERAL .....	9-1
9.2 VERIFICATION .....	9-3
9.3 VALIDATION TEST DESCRIPTIONS .....	9-3
9.3.1 Vibration .....	9-3
9.3.2 Temperature Profile .....	9-3
9.3.3 Spark Plug Ignition Voltage Requirements .....	9-3
9.3.4 Delivered Spark Energy Versus Actual Required Spark Energy .....	9-4
9.4 IGNITION SYSTEM VALIDATION TESTING RECOMMENDATIONS .....	9-4
9.4.1 High Temperature Operation .....	9-4
9.4.2 Salt (Fog) Spray .....	9-4
9.4.3 Vibration .....	9-4
9.4.4 Impact Shock .....	9-4
9.4.5 Thermal Cycle .....	9-5
9.4.6 Thermal Shock .....	9-5
9.4.7 Storage Temperature .....	9-5
9.4.8 Humidity .....	9-5
9.4.9 Drop .....	9-5
9.4.10 Reverse Voltage .....	9-5
9.4.11 Jump Start .....	9-5
9.4.12 Load Dump .....	9-5
9.4.13 Transients .....	9-6
9.4.14 Open Secondary .....	9-6
9.4.15 Fluid Compatibility .....	9-6
<b>10.0 APPENDIX .....</b>	<b>10-1</b>
10.1 INITIAL CUSTOMER CONTACT CHECKLIST .....	10-1
10.2 TECHNICAL GLOSSARY OF TERMS AND ABBREVIATIONS .....	10-7
<b>11.0 INDEX .....</b>	<b>11-1</b>





# 1. 0 Introduction

---

## 1.1 Scope of Document

This Application Manual communicates Ignition Systems application guidelines for spark ignition engines.

## 1.2 Classification

The information and specifications in this manual cover the following Ignition Systems:

- High Voltage Switch (HVS)
- Direct Ignition System (DIS)
- Integrated Coil Electronics (ICE)
- Compression Sense
- Coil Near Plug
- Ion Sense
- Coil Per Cylinder (CPC)
  - Plug Top Coil (PTC)
  - Pencil Coil

## 1.3 Document Management

This document shall be maintained by Delphi E&C. Expressed written consent of Delphi must be obtained before any modification of this document is permitted.

### 1.3.1 Document Release and Updates

The information contained in this manual is accurate and current as of the date of publication. As changes occur that update the content of the manual, a dated *Release/Revision Summary Sheet* and the revised pages will be distributed to users whose names appear on the document mailing list (see Section 1.3.2). All updates shall be issued and distributed by Delphi E&C.

Releases/Revisions Summary Sheets shall contain the following information:

- Sequential number of the revision
- Date the revision is implemented
- Discussion:
  - The reason the revision was made
  - The present parameter prior to revision
  - The desired or revised parameter
- The last name of the change originator
- The section numbers affected

### 1.3.2 Mailing List

The Delphi-E&C Application Engineer responsible for this publication will maintain the document mailing list. ***The user is responsible for informing the Application Engineer of name and address changes.*** The point of contact for the Application Engineer appears on the title page of this document.

### 1.3.3 Document Revision Procedure

Change requests may originate within Delphi-E&C or by users. All suggested changes must be directed to the Delphi E&C Systems Applications Group.

On receiving a revision request, the Delphi-E&C Applications Group will submit the request to the appropriate individuals for review. Approved requests will result in revision of the affected section(s). Users will be notified of document changes and receive updates through the process in Section 1.3.1.

## 1.4 Commercial Considerations

All commercial considerations/cost and scheduling requirements shall be handled by the Delphi Sales and Marketing Group.

## 1.5 Objectives of this Manual

Delphi provides advanced emissions-control technology to the automotive industry. Our Ignition Systems are an example of Delphi leadership and our commitment to continuous improvement and world-class quality.

This Ignition Systems Application Manual has been developed to support your work as you evaluate the benefits of Delphi Ignition Systems technology or apply it to your power train control system.

The objectives of this document are to help you:

- Obtain maximum value and optimum performance from the Ignition System
- Integrate the Ignition System within your control system (hardware and software)
- Protect the Ignition System from damage caused by improper usage, mounting, handling, or installation
- Prevent testing errors that might result in an inaccurate evaluation of Ignition System performance
- Prevent calibration errors that may interfere with the proper operation of the Ignition System

To accomplish these objectives, this manual provides the following:

- A description of the components, features and requirements of the Ignition System offered by Delphi E&C
- A description of the Ignition System operational parameters
- A description of the options for packaging and mounting, as well as the optional features available to meet underhood packaging, serviceability and diagnostic requirements
- Calibration and testing guidelines
- A checklist of interface details required for Delphi E&C to ensure that the proper ignition system selection is made to meet customer requirements. The ignition system is to be specified regarding the power train control module (engine, controller and software) and the power train configuration

## 1.6 How this Manual is Arranged

An overview of each section in this manual is provided below.

### Section 1.0 — Introduction

Section 1.0 provides an overview of the scope, objectives, and format of this manual and lists documents on which it is based. You may wish to refer to the listed documents for additional detail to aid in understanding the requirements set forth in this manual.

### Section 2.0 — Fundamentals

Section 2.0 describes the characteristics and requirements of the Ignition System and its related components. Also discussed is an overview of electricity and magnetism fundamentals with a detailed description of how the ignition system works together with the air/fuel delivery system to meet vehicle emissions requirements.

### Section 3.0 — Product Description

Section 3.0 provides an overview of ignition system construction, materials and performance. Physical and electrical specifications for standard assemblies are defined and performance specifications for commonly available ignition systems are provided. Also discussed is the process Delphi E&C uses to provide custom products.

### Section 4.0 — System Interface

Section 4.0 describes and illustrates the mechanical and electrical interfaces required to obtain optimum performance from the ignition system. The electrical and mechanical interface, chassis and software interface are also described.

## **Section 5.0 — Software**

Section 5.0 provides both an overview and specific detail on the software requirements to operate the Ignition System. Various control algorithms commonly used to achieve optimum performance under varying engine conditions are described, and additional algorithms, which are based on emissions and drivability requirements, are recommended. Calibration and diagnostics are also discussed. Understanding this section is critical to achieving optimum performance from the Ignition Systems.

## **Section 6.0 — Product Handling**

Section 6.0 presents Delphi E&C recommendations for the handling, storage, installation, and servicing of the Ignition System components. Proper handling of the product, from the time it arrives on the receiving dock until it is installed in the vehicle, reduces the risk of accidental damage and helps ensure that the Ignition System will function as intended.

## **Section 7.0 — Recommendations and Precautions**

Section 7.0 provides a summary of Delphi E&C recommendations and precautions for proper Ignition System use. Common misuses are identified and alternate solutions presented.

## **Section 8.0 — Testing Recommendations and Precautions**

Section 8.0 discusses testing procedures which are based on the experience of Delphi-E and its customers. By adhering to the recommendations contained in this section, you will ensure that the Ignition System is evaluated correctly under conditions that parallel normal use and operation.

## **Section 9.0 — Validation Requirements**

Section 9.0 outlines the process for validating the Ignition System, i.e., ensuring that it meets specified quality, reliability, and durability goals and conforms to governmental standards/regulations.

**Section 10.0 — Appendix****10.1 — Initial Customer Contact Checklist****10.2 — Technical Glossary of Terms and Abbreviations****Section 11.0 — Index****1.7 Conventions Used in this Manual**

Important information is shown in italic type and is preceded with the boldface word **NOTE**, **CAUTION**, or **WARNING**.

- **Note**—Indicates important technical detail that is relevant to the topic being discussed.
- **Caution**—Indicates information about a condition or an activity that must be performed to prevent damage to the Ignition Systems, the engine, the power train control system, or the vehicle.
- **Warning**—Indicates a condition which might pose a risk to your personal safety and/or the safety of others.

**Note:** Unless otherwise noted, the numbered figures displayed in this manual are illustrations, not technical drawings. As such, these illustrations may not reflect actual dimensions. All final critical dimensions should be confirmed on part prints.

## **1.8 Applicable Documents**

### **1.8.1 Order of Precedence**

When there appears to be a contradiction between this application manual and an outline drawing or other document, the conflict must be formally resolved through the Delphi E&C application engineer. Until the contradiction can be resolved, the part outline drawing will take precedence.

### **1.8.2 Government Documents**

To be supplied by customer for specific country.

### **1.8.3 Other Delphi Reference Documents**

#### **1.8.3.1 Ignition System Components P/N's**

#### **1.8.3.2 Delphi E&C Engineering Specification, Number, Date**

#### **1.8.3.3 PFMEA**

#### **1.8.3.4 DFMEA**

#### **1.8.3.5 OBD-II Diagnostic Procedures**

#### **1.8.3.6 Validation Plan ACR #2066**

### **1.8.4 Industry Documents**

#### **1.8.4.1 SAE Standard Procedure J1829**



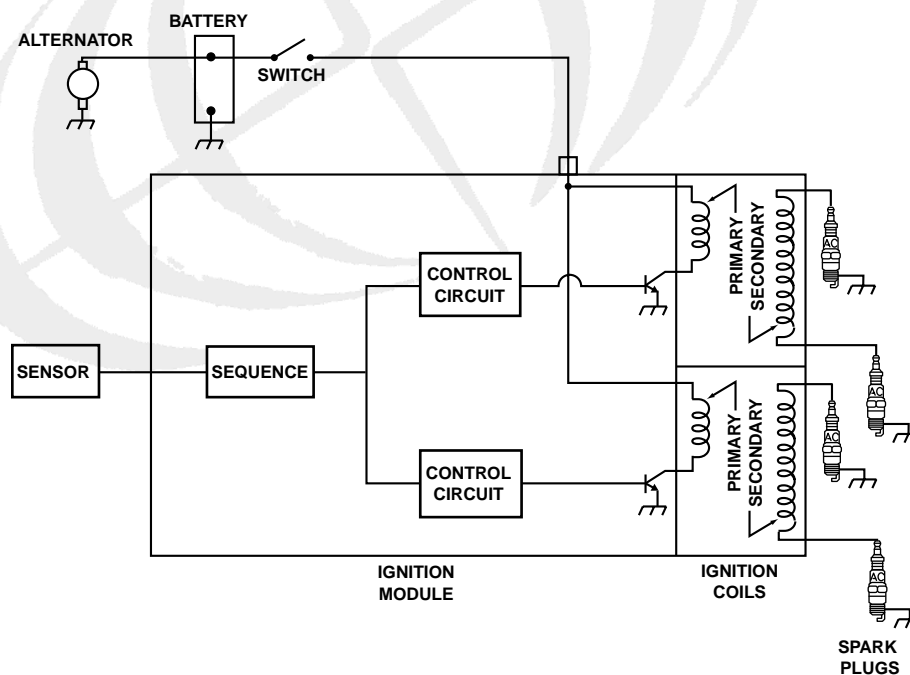


## 2. 0 Fundamentals

### 2.1 General

The Ignition System is a component of the Engine Management System. Its function is to provide the required spark to the engine's cylinders to meet vehicle performance and emissions requirements over a wide range of operating conditions. In many cases, to meet more stringent emission and performance goals, it works within a closed-loop control system that consists of the engine controller and many engine condition sensors.

The ignition system consists of the spark plug, spark plug wire (if applicable), ignition coil and driver, and the spark timing device. It must interface with an engine controller to obtain control signals as well as the vehicle electrical system in order to supply the specified voltage and energy to the spark plugs at the desired time.



**FULL FUNCTION DIRECT IGNITION SYSTEM**

Figure 2-1. Typical ignition system.

## 2.2 Engine Combustion Fundamentals

Internal combustion is a complex process involving interactions of many engine subsystems over widely changing conditions. A complete explanation of these interactions and requirements and the theory of combustion is outside the scope of this manual. The following sub-sections summarize the major considerations involved with the air/fuel system's impact on combustion. If a more detailed explanation is required on any of these topics, please contact Delphi Energy and Chassis.

### 2.2.1 Air/Fuel Ratio Effects on Combustion

The goal of the Ignition System is to supply the correct spark at the correct time to the correct cylinder. Complete combustion and optimum performance occur when both air and fuel are each completely consumed in the combustion reaction. The air and fuel must be in the vapor phase (liquid fuel is not combustible) and have the proper proportions for this to happen. For non-oxygenated "standard" fuels, this is achieved when a ratio of 14.6 – 14.7 grams of air per gram of fuel exists. Mixtures with excess fuel (air/fuel ratios less than 14.6:1) are considered rich, and mixtures with excess air (air/fuel ratios greater than 14.7:1) are considered lean. Air/fuel ratios outside the combustible mixture limits (too rich or too lean) may cause engine misfire, reduced power, a significant increase in emissions (primarily HC) and poor overall engine performance. Combustible mixture limits are dependent on many factors, some of which are combustion chamber design, ignition system energy, fuel composition, amount of EGR, etc.

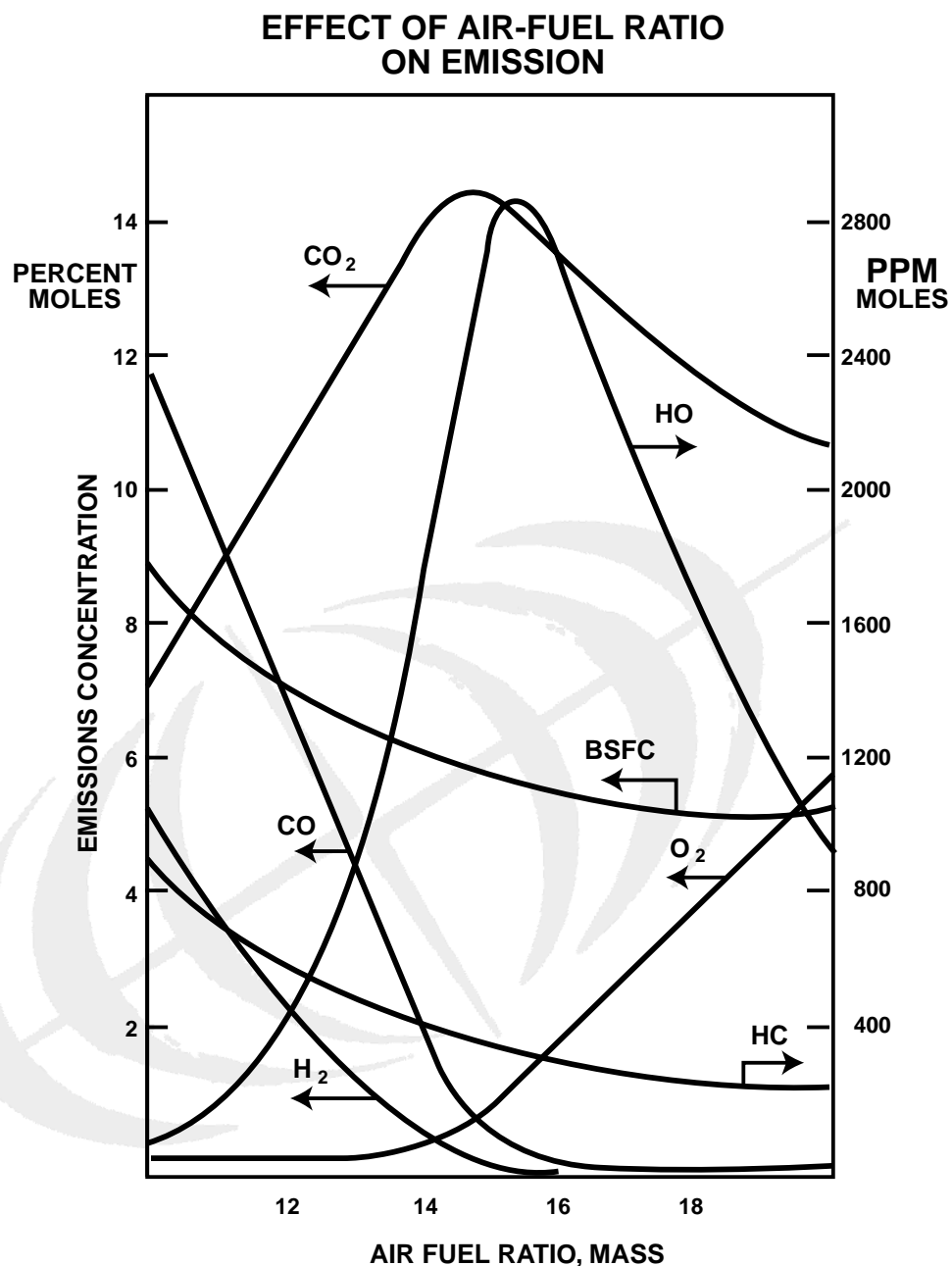


Figure 2-2. Engine out emissions vs. air/fuel ratio.

### 2.2.1.1 Stoichiometric “Ideal” Combustion Mixtures

The Stoichiometric mixture, 14.7 to 1, provides the ideal condition for fuel and air to completely react. Complete or “ideal” combustion produces environmentally safe by-products of carbon dioxide (CO<sub>2</sub>), nitrogen (N<sub>2</sub>) and water (H<sub>2</sub>O). Unfortunately, actual engine combustion can never be “ideal” for a variety of reasons, some of which are time limitations (time available for combustion limited by engine rpm), imperfect combustion chambers, imperfect fuels, chemical reactions occurring at high temperature, etc.

### 2.2.1.2 Rich Mixtures

Fuel will not burn completely when the mixture is over rich, resulting in a decrease in fuel economy and an increase in hydrocarbon (HC) emissions. Spark plug fouling can result if mixtures are excessively rich, causing misfire. The lack of oxygen to complete CO<sub>2</sub> formation during combustion results in a significant increase in carbon monoxide (CO) emissions. Rich mixtures also produce NO<sub>x</sub> due to the dissociation of nitrogen and oxygen molecules at high temperatures and the complex chemical reactions between these and other elemental gases during the combustion process. Formation rates drop as mixtures become rich enough to reduce combustion temperatures. Refer to Figure 2-2.

### 2.2.1.3 Lean Mixtures

Lean mixtures have excess oxygen and higher combustion temperatures resulting in increased oxides of nitrogen (NO<sub>x</sub>) emissions. Nitric oxide (NO) is the primary oxide created. It forms at a significant rate when combustion chamber temperatures are above 650°C. The rate of NO formation increases with excess oxygen concentration, temperature and time at temperature. Lean mixtures above a 15 or 16 to 1 air/fuel ratio decrease NO<sub>x</sub> production due to the lowering of combustion temperatures.

## 2.3 Electromagnetic Induction

The principle of electromagnetic induction states that a voltage will be induced in a conductor whenever a magnetic field is moved so that its lines of force cut across the conductor. The resulting direction of current flow in the conductor can be determined by observing the polarity of the magnetic lines and their direction of motion with respect to the conductor. In Figure 2-3, the polarity of the magnetic lines is upward, since lines leave the N pole and enter the S pole. Also, the magnetic lines are striking the conductor on its left side which is called the leading side. By applying the Right Hand Rule — grasping the conductor with the fingers on the leading side and pointed in the direction of the magnetic lines — the thumb will then point in the direction of current flow, toward the positive (+) end of the conductor (Figure 2-4).

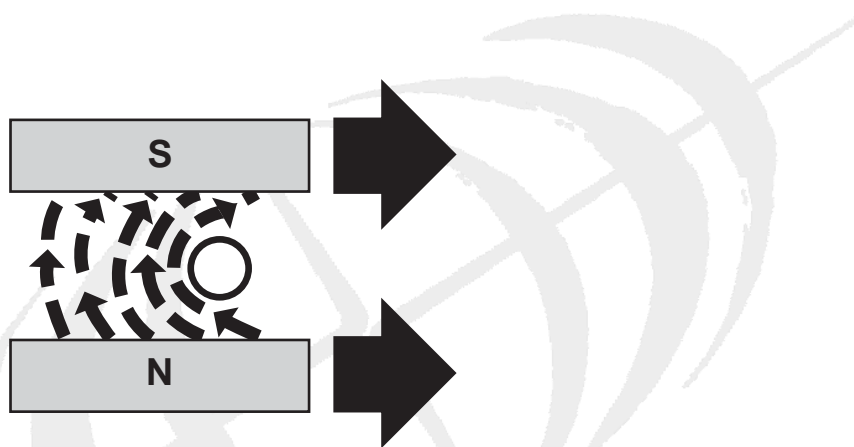


Figure 2-3. Electromagnetic induction.

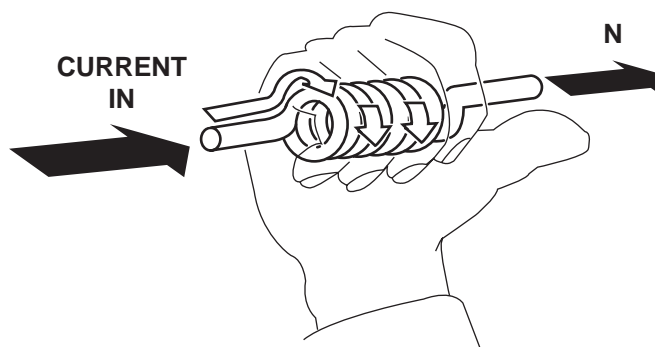


Figure 2-4. Right Hand Rule.

### 2.3.1 Self-Induction

The principle of self-induction is defined as the inducing of a voltage in a current-carrying wire when the current in the wire itself is changing. The reason for this occurrence can be explained as follows: Since the current creates a magnetic field consisting of concentric circles around the wire which expand and contract as the current increases and decreases, these magnetic circles cut across the conductor and thereby induce a voltage in the conductor.

To illustrate this principle, consider a coil of wire wound over an iron core that is connected in a circuit as shown in Figure 2-5. When the switch is closed, the current will increase from zero to its final value of four amperes. As the current changes, a voltage will be induced in the coil. The polarity of the induced voltage will be such as to oppose the change in current that produced it. Since the coil itself becomes a source of voltage, the polarity of the induced voltage in order to oppose the increasing current will be positive at A and negative at B. With this polarity, the coil as a source of voltage would tend to send current out of A, which is in direct opposition to the increasing current supplied by the battery.

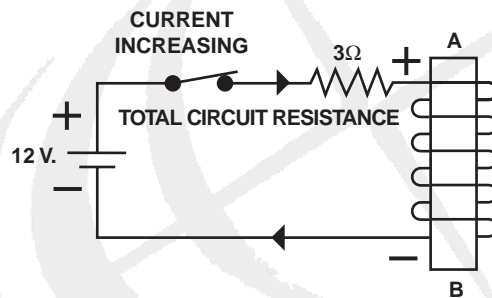


Figure 2-5. Self-induction.

It is because of the principle of self-induction that the current does not reach its final value of four amperes immediately when the switch is closed. Instead, a time lag exists which causes the current to steadily rise to its final value. To illustrate, a current curve with a time lag of 0.01 seconds is shown in Figure 2-6.

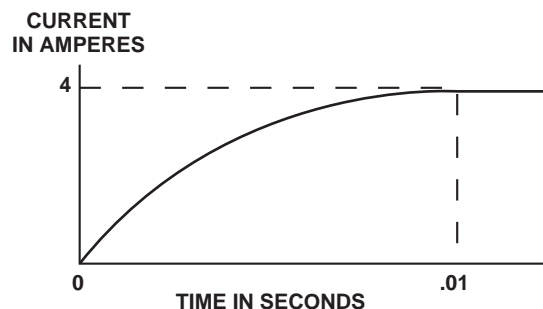


Figure 2-6. Current time lag.

To illustrate self-induction further, the coil current decreases from four amperes to zero amperes when the switch is opened. This changing current induces a voltage in the coil that attempts to keep the current flowing at the four ampere value. The polarity of the induced voltage therefore is as shown in Figure 2-7, because the coil attempts to supply current in the same direction as originally supplied by the battery. It is this principle that causes an arc to appear across the switch whenever it is opened in an inductive circuit.

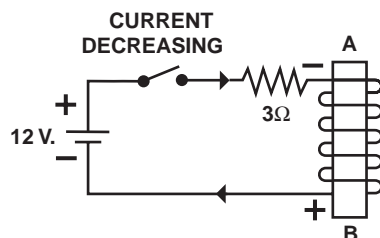


Figure 2-7. Reduction of self-induction.

### 2.3.2 Mutual Induction

If a changing magnetic flux created by current flow in one coil links or cuts across the windings of a second coil, a voltage will be induced in the second coil. The property whereby a voltage is induced in one coil because of a changing current in another coil is called **mutual induction**.

In order to illustrate the principle of mutual induction, consider the illustrated circuit in Figure 2-8, where the secondary winding is wound over an iron core, and the primary winding is wound over the secondary winding. When the switch is closed, current will increase in the primary, and the expanding lines of force will cut across the secondary, causing a voltage to be induced in the secondary. Similarly, when the switch is opened, the sudden decrease in current in the primary will induce a voltage in the secondary. The secondary winding then becomes a source of voltage, and will impress this voltage across the resistor R.

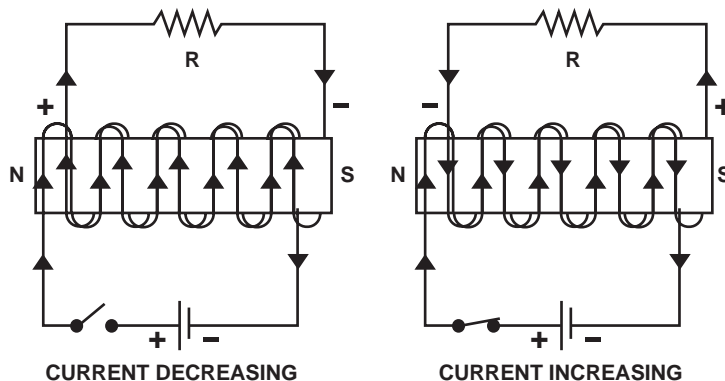


Figure 2-8. Mutual induction.

The magnitude of the voltage induced in the secondary winding is determined primarily by the number of turns in the primary and in the secondary. If when the switch is opened a self-induced voltage of 350 volts occurs in the primary, and the secondary has 100 times as many turns as the primary, the secondary voltage will be  $350 \times 100 = 35,000$  volts.

The typical example just discussed is applicable in the construction and operation of an ignition coil, and explains how the battery voltage can be increased by self-induction in the primary to 350 volts, which is then increased by mutual induction to 35,000 volts in the secondary winding for firing the spark plugs.

## 2.4 Available Voltage

The basic function of an ignition system is to produce an arc between the electrodes of the spark plug which in turn ignites the compressed air and fuel mixture during the compression stroke of a four-cycle engine. The voltage required to break down the spark plug electrode gap can range from 5 kV to 30 kV depending on such factors as the engine compression ratio, cylinder pressure (spark timing), spark plug gap, spark plug electrode shape, vehicle load, fuel mixture, and operating temperature.

Parameter	Compression Pressure	Spark Plug Gap	A/F Ratio	Ignition Polarity	Electrode Shape	Operating Temperature
<b>Higher Required Secondary Voltage</b>	High	Wide	Lean or Rich	Positive	Rounded Massive	Cold
<b>Lower Required Secondary Voltage</b>	Low	Narrow	Stoichiometric	Negative	Sharp	Hot

Table 2-1 — System Parameters



Holding the parameters mentioned in Table 2-1 constant, the voltage required to produce a spark across the plug electrodes will decrease as engine speed increases. A high energy spark plug design can be used, which includes a fine wire electrode to reduce the required voltage. A 4 mH ignition coil can be used to improve available voltage performance at higher engine speeds. Figure 2-9 shows how the available kV decreases as engine speed increases. At engine speeds above 3200 rpm, the 4 mH coil has more available kV. This allows engine calibrators more freedom to retard the spark timing. As the spark timing is retarded toward TDC, the pressures in the cylinder at the time of firing are increased. The increased pressure demands a higher kV to break down the spark gap. The engine calibrators may retard the spark timing at higher engine speeds to effectively reduce the engine torque for smoother transmission shifting.

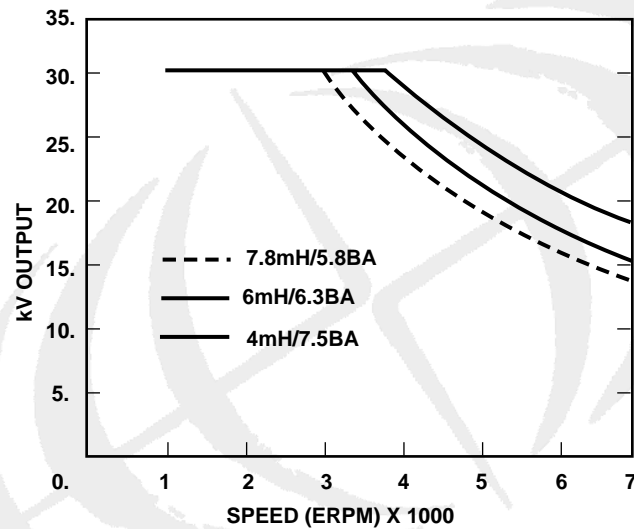


Figure 2-9. Available kV output vs. ERPM.

The ignition system provides spark through the use of an inductive ignition coil. The objective is to make the ignition system available voltage exceed the spark plug gap voltage requirement under all engine operating conditions (Figure 2-10). The difference between the available and required voltage is called reserve voltage. If the required voltage exceeds the available voltage, the engine will misfire. The required voltage increases with increasing cylinder gas pressure.

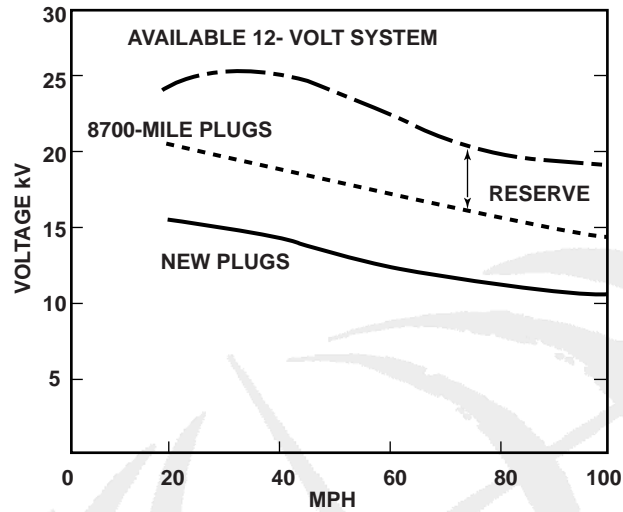


Figure 2-10. Ignition performance on a 10:1 compression ratio engine.

### 2.4.1 Coil Current Limiting and Dwell Control

The coil primary current is controlled by two methods. Both methods use dwell control for switching the coil current on and off. One method for limiting coil current is integrated into the coil driver circuitry. It limits the maximum amount of primary current regardless of the amount of dwell applied. Refer to Figure 2-11.

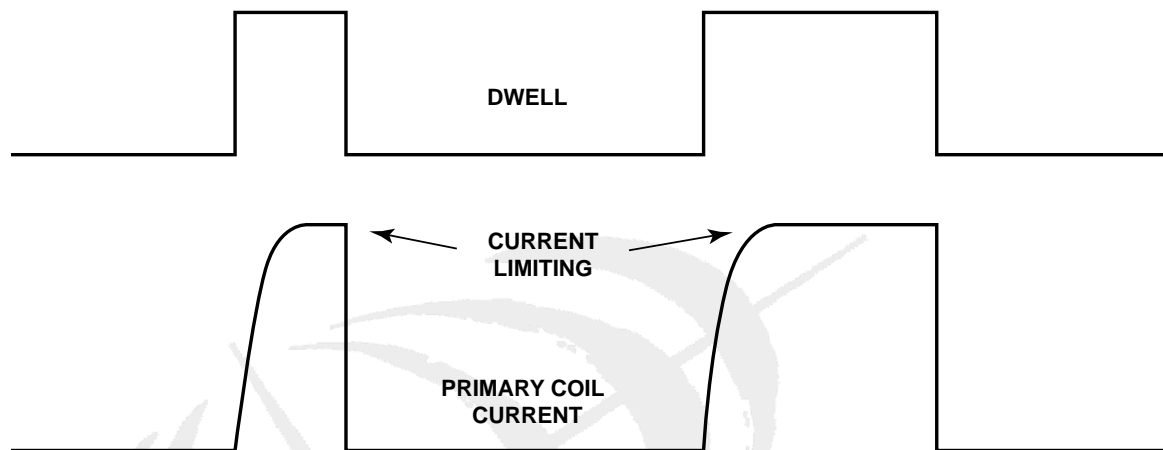


Figure 2-11. Coil Primary Current Controlled By Current Limiting Circuitry.

The other method uses dwell control to adjust the coil current to produce a desired output performance. The longer the dwell the more current in the primary coil circuit, thus producing more deliverable energy and kV. The dwell is derived from calibration tables stored inside the ECM. This method is sometimes referred to as “Ramp and Fire” technology. Refer to Figure 2-12.

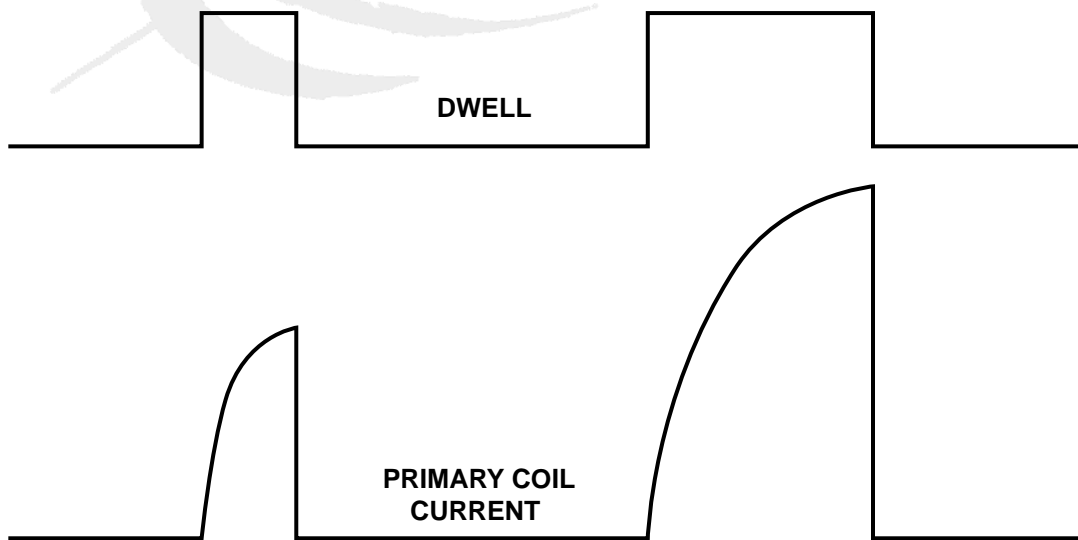
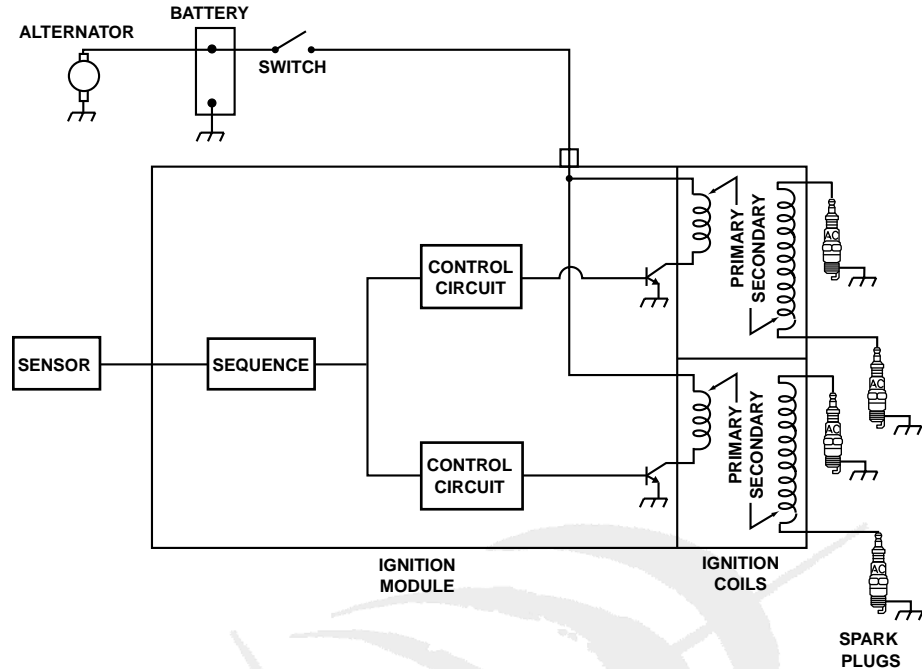


Figure 2-12. Coil Current Controlled By Dwell “Ramp and Fire”.



### FULL FUNCTION DIRECT IGNITION SYSTEM

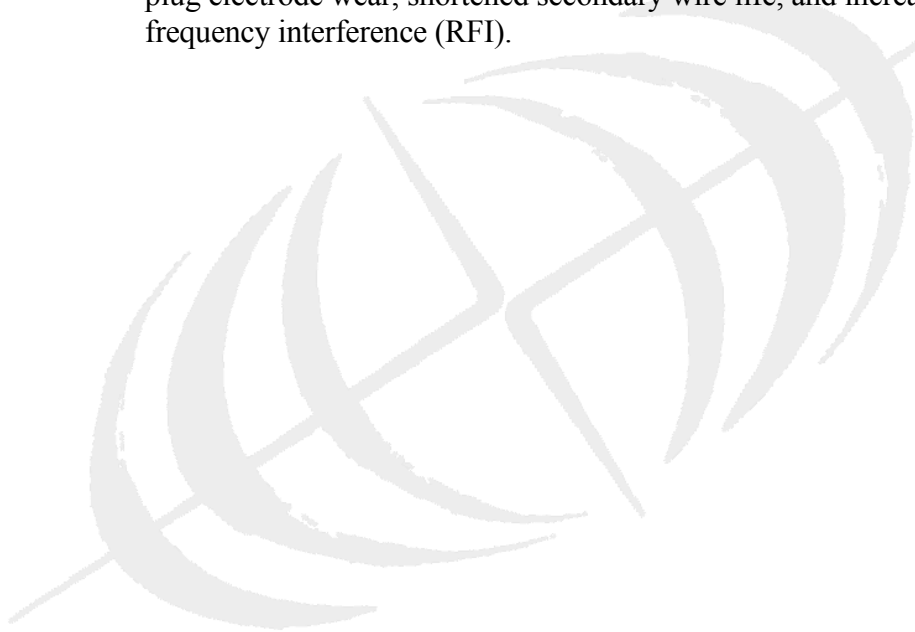
Figure 2-13. Direct ignition system.

Both of the methods described in Figures 2-11 and 2-12 are used in conjunction with a full function Distributorless Ignition System (DIS) shown in Figure 2-13. Another method which is utilized today is referred to as a min- function DIS. In this case, the coil electronics consists of two (four cylinder) or three (six cylinder) or four (8 cylinder) individual coil drivers. The complete function of the DIS is controlled by the ECM.

## 2.4.2 Increased Ignition Energy

Engine studies have shown that ignition energy plays an important part in the area of exhaust gas recirculation (EGR) dilution tolerance. EGR reduces oxides of nitrogen (NO<sub>x</sub>) emission levels by recirculating exhaust gases, which are low in oxygen, into the intake manifold. This lowers the oxygen content of intake gases and inhibits combustion, lowering cylinder temperatures and reducing NO<sub>x</sub> levels. Having more energy available at the spark gap makes the system more tolerant of changes in dilution levels of exhaust in the intake gases.

While one solution might be to increase the output energy of the coil, Delphi E&C testing shows that doubling the coil output typically results in a 33% increase in energy at the spark gap. Other side effects of higher energy (increased I<sub>S</sub>) can include more rotor wear (High Voltage Switch), more spark plug electrode wear, shortened secondary wire life, and increased radio frequency interference (RFI).



## 2.5 Radio Frequency (RF) Suppression

The ignition system radiates various amounts of radio frequency (RF) energy, acting like a radio transmitter. Without proper shielding or suppression, the RF energy can cause interference and disruption in TV signals, home radios, automobile AM and FM radios, radar systems, two-way radios, and even headlight dimmers or garage door openers.

Tests have shown the value of combining Television Radio Suppression (TVRS) resistance cable (Figure 2-14) with resistor-type spark plugs. Additional suppression in RFI has been noted through the use of short secondary cables, noise blanking circuits in the ECM, proper application of ground straps, and radio antenna placement.

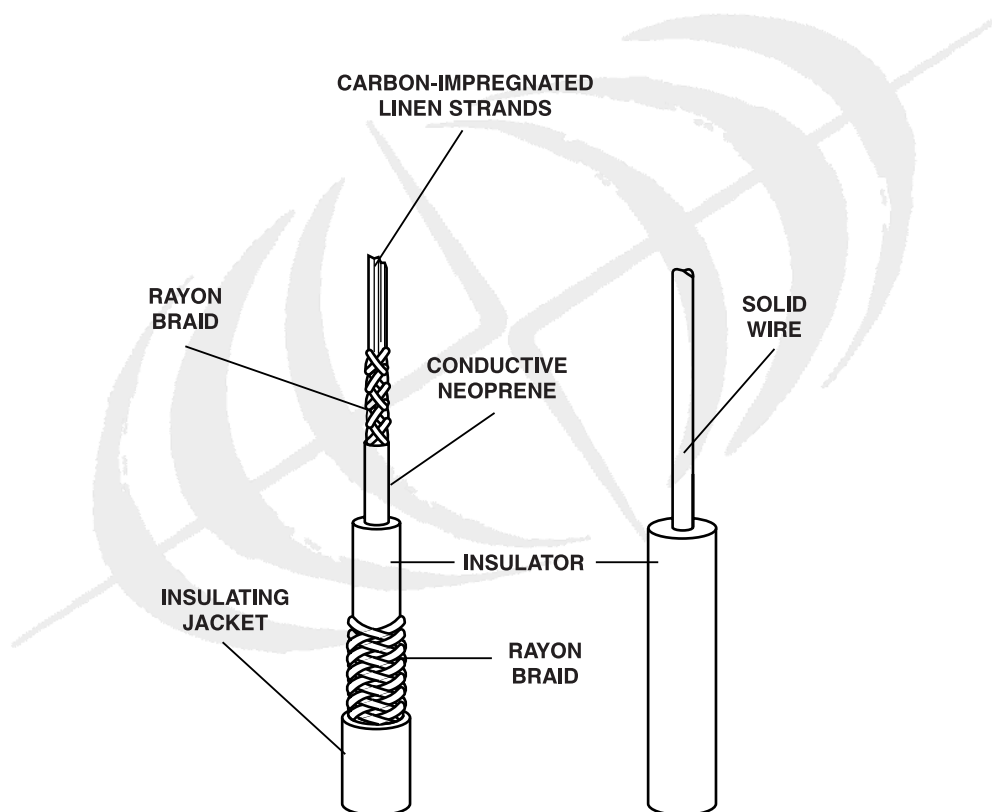


Figure 2-14. TVRS cable and solid conductor cable.

The resistor spark plug has a one-piece integral suppressor fused into a gas-tight mass in the center conductor seal area of the insulator (Figure 2-15). Spark Plug internal resistance is a key determiner of overall ignition system power loss ( $I^2/R$ ) but also contributes to electrical noise suppression (RFI, etc). A typical nominal value for a resistor type plug is 5 Kohms.

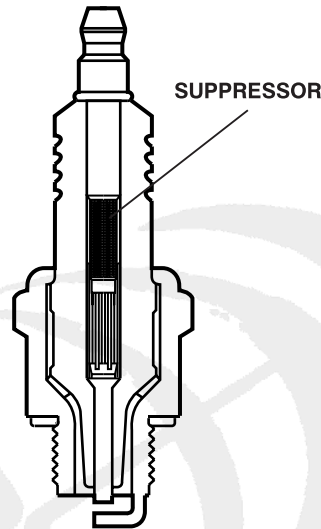


Figure 2-15. A one-piece integral suppressor reduces RF interference.

## 2.6 General Description

The basic function of the ignition system is to produce an arc between the electrodes of the spark plug which in turn ignites the compressed air and fuel mixture during the compression stroke of a four-cycle engine. Fuel atomization and ignition timing play critical roles in achieving complete combustion. The accuracy of the ignition system has a direct effect on emissions, fuel economy, power, driveability, start quality and idle quality.

In a four-cycle gasoline engine, each piston goes through four strokes for every two complete revolutions of the crankshaft. These strokes are intake, compression, power and exhaust. See Figure 2-15.

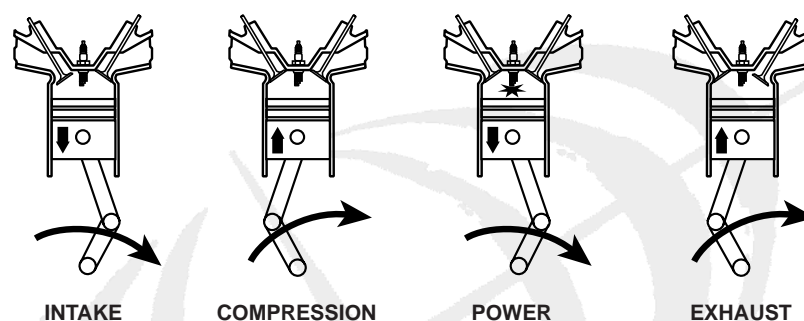


Figure 2-15. Four Stroke Combustion Process.

The intake stroke occurs as the piston moves downward and with the intake valve open, a air-fuel mixture is drawn into the cylinder. During the upward or compression stroke, the piston compresses the mixture which must be ignited by the spark plug when the piston nears the upward limit of its travel.

The burning mixture then forces the piston downward to comprise the power stroke. The gases are then exhausted or expelled through the exhaust valve opening by the upward movement of the piston to complete the cycle.

In an eight-cylinder engine there are four power strokes for every revolution of the crankshaft. This means that the ignition system must fire four spark plugs for every crankshaft revolution. At 4500 engine revolutions per minute, or 75 revolutions per second, the ignition system will deliver 300 high voltage surges every second to the spark plugs.

The voltage required to break down the spark plug electrode gap can range from 5 kV to 35 kV depending on such factors as the engine compression ratio, cylinder pressure (spark timing), spark plug gap, spark plug electrode shape, vehicle load, fuel mixture, and operating temperature.

The next section will basically describe various types of ignition systems being produced today or ones that are currently under development.



## 3.0 Product Description

---

As they have evolved, Delphi Ignition Systems have met and surpassed the challenges posed by increasingly stringent emissions-control legislation. Engineering efforts to enhance ignition system component design and construction are ongoing. This section addresses these topics.

**Note:** Due to the unique requirements of emerging power train systems and platforms, the process of determining optimum ignition system characteristics requires a joint effort between the responsible Delphi E&C Application Engineer and the customer's Release Engineer. The information presented in this section provides technical guidance only. Detailed product specifications and design result from the collaboration of Delphi-E with customer engineering and design teams.

### 3.1 Delphi Ignition Milestones

- 1899 Automotive Magnetos
- 1919 Breaker Point System
- 1953 12-Volt Electrical System
- 1962 Electronics Ignition System
- 1966 Capacitive Discharge System
- 1969 Dial-A-Curve Ignition System
- 1971 Unitized Ignition System
- 1974 High Energy Ignition System
- 1977 MISAR: Automotive Digital Computer
- 1980 EST with Total Engine Control
- 1988 Integrated Direct Ignition
- 1991 Composite Iron DIS with Integrated Electronics
- 1992 Optispark Distributor
- 1995 High Voltage Switch
- 1998 Compression Sense Ignition
- 1999 Ion Sense Coil on Plug
- 2000 Coil near Plug
- 2001 Pencil Coil
- 2004 Dual Pencil Coil Pack
- 2005 Dual Output Pencil Coil

## 3.2 Ignition Coil - Function

The function of the ignition coil is to provide the required voltage and energy to overcome the secondary resistances and fire the spark plug gap.

The engine controller sends out an Electronic Spark Timing (EST) signal that controls the ignition spark timing. The EST signal rises to induce the ignition coil module to turn the coil on for a determined time called “dwell” and then the EST signal falls at the desired spark timing point to induce the module to turn the coil off. Turning off the coil collapses the magnetic field and transfers the energy stored in the primary windings during the dwell period into the secondary. The secondary energy charges up the parasitic capacitance in the coil and secondary wires, then breaks down the spark plug gap and ignites the fuel mixture.

The ignition coil is designed with a lower primary inductance. The lower primary inductance allows the coil to charge up to full energy in a shorter time period. The end result is that the coil has more energy at higher engine speeds, thus reducing the chance of misfires.

Because the underhood temperatures are continuing to increase, control module dwell tables are developed to improve the dwell time accuracy. The result is that the ignition coil and ignition module operating temperatures are reduced, leading to improved durability.

## 3.3 Appearance

Because of the variations in components, only typical information is shown in this manual. Consult your specific Delphi-E Application Engineer for more information.

## 3.4 Exterior Outline

The ignition systems exterior outline meets underhood packaging constraints per the vehicle specifications. These requirements shall be defined in approved engine/induction layouts from the customer.

## 3.5 Ignition Types

Although there are many different ignition component designs, it is important to remember that they are all basically doing the same thing. Their function is to deliver sufficient energy to the correct spark plug at the right time to provide the optimum balance between fuel efficiency and particulate emissions. This is a very narrow band of control and must be done during all stages of the vehicle cycle: cold starting, stopping, accelerating, hard acceleration or deceleration, etc.

It should be noted that there are several components in today's ignition system other than the spark distributing element that directly affect the driveability of the vehicle. Some of these are the control module, and the various sensors — oxygen, crankshaft, cam, coolant, knock, throttle position, MAP, etc. Driveability is also affected by the fuel system components, so it is important to follow the diagnostic charts in the service manuals.

Several ignition types were introduced to comply with tighter and tighter emission and fuel economy standards and to meet specific customer requirements.

### 3.5.1 Ignition Specifications

Physical, electrical, and environmental specifications are defined by the customer via the Customer Contact Checklist, Section 10.1. The validation requirements are discussed in Section 9.0.

### 3.5.2 High Voltage Switch (HVS) System

The High Value Ignition System replaces the previous High Energy Ignition System, HEI, distributor with a High Voltage Switch, HVS. The HVS (Figure 3-2) acts only as a switch which transfers the energy from a single separately mounted ignition coil to the correct cylinder. Adjustments for crossfire limits after installation of the HVS is required on 8 cylinder engines due to distance between the HVS cap secondary inserts which is a function of the 45 degree angle for each of the inserts. 6 cylinder engines do not require this adjustment due to the wider 60 degree angle between inserts. The proper relationship between the crank and cam signals is critical to avoiding crossfire to an improper cylinder and the potential for poor engine performance. In addition, The HVS contains a Camshaft Position Sensor. This sensor generates a signal which the Engine Control Module (ECM) uses for cylinder identification, crossfire operating window calibration, and misfire diagnostics. The spark timing is controlled by the ECM based on speed, load, temperature, knock conditions, etc.

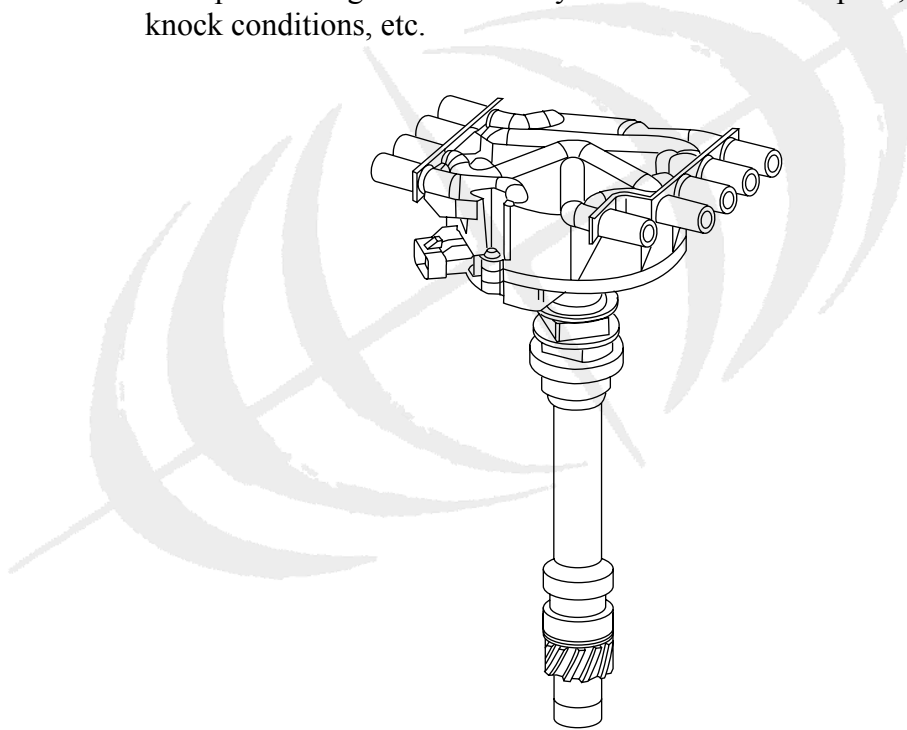


Figure 3-2. High Voltage Switch.

The HVS cap is designed to improve the routing of the secondary wires. The right side towers go the right side of the engine. The left side towers go the left side of the engine. (Figure 3-3) The towers exit the side of the cap to provide for a low profile unit. The cylinder numbers are easily identified on the top of the cap. The tower design has also been changed so that the metal terminal is inside a plastic cylinder. This provides the system with a longer dielectric arc path and reduces the chances of an arc breaking down to a ground potential and degrading the interface.

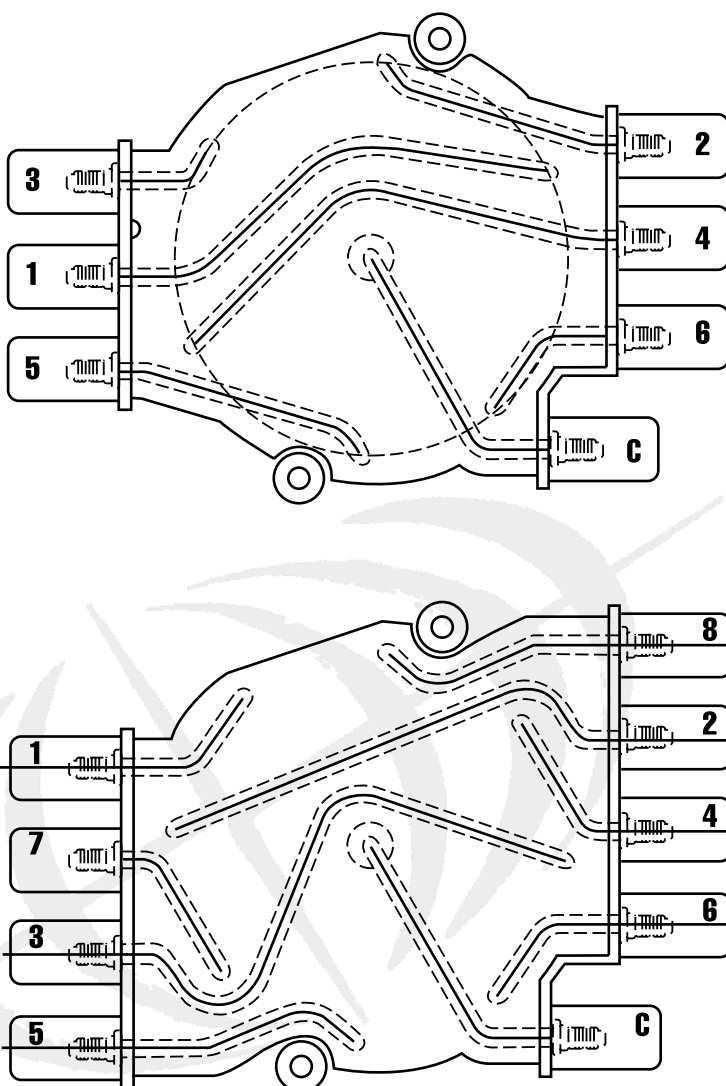


Figure 3-2. V-6 and V-8 High Voltage Switch Cap With Terminal Routings.

The HVS system uses a separately mounted coil and coil driver electronics assembly. The function of the coil is to provide the required voltage and energy to overcome the secondary resistances and fire the spark plug gap.

The ECM sends out an EST signal that controls the ignition spark timing. The EST signal rises to induce the ignition coil module to turn the coil on for a determined time call “dwell”. The EST signal then falls at the desired spark timing point to induce the module to turn the coil off. Turning off the coil collapses the magnetic field and transfers the energy stored in the primary windings during the dwell period into the secondary. The secondary energy charges up the parasitic capacitance in the coil and the secondary wires, then breaks down the spark gap and ignited the fuel mixture.

### 3.5.2.1 High Value Ignition Features

- One coil per engine (uses a high voltage switch or distributor)
- Assembled to spark plug with low resistance secondary
- Designed for efficient assembly to engine
- Corrosion Resistant
- Designed for electronic drivers at 7.4 A nominal
- On engine and off engine mounting capability (coil)
- High energy delivery
- Efficient energy delivery
- Reduced RFI emissions
- Epoxy encapsulated (coil)

### 3.5.2.2 High Value Ignition Performance

Measurement Description	Typical Value	
Energy (mJ)	70	#
Peak secondary current (mA)	74	#
Secondary voltage available (kV)	32.0	*
Spark duration (mS)	2.6	#
Secondary resistance (Ohm)	5800	
Primary resistance (Ohm)	0.20	
Primary charge time @ 14V (mS)	2.50	
Weight (gr)	600	
Primary Current (A)	9.20	
Sample Availability	production	

# = 800 Volt Zenor test, no secondary load.

\* = with 50 PF Secondary Load

Table 3-1. High Voltage Ignition System Specifications.

### 3.5.3 Waste Spark Ignition Concept

In a waste spark ignition system, an ignition coil with two secondary towers is used. A spark plug is attached to each end of the ignition coil secondary. Each coil secondary fires the plugs in two companion cylinders: cylinders that reach Top Dead Center (TDC) at the same time. The cylinder that is at TDC on the compression stroke is referred to as the “**event**” cylinder while the cylinder at TDC on the exhaust stroke is the “**waste**” cylinder. When the coil discharges, both plugs fire at the same time to complete the series circuit.

Since the polarities of the ignition primary and secondary windings are fixed, the plug closer to the coil positive tower always fires in a positive direction while the plug closer to the coil negative tower always fires in a negative direction. This can have a significant effect on the durability of the negatively firing plug's electrodes. Platinum or other precious metal electrode materials may be required to maintain long life.

No ignition coil is designed to be run with the secondary unloaded. However, this is particularly true with distributor less ignition systems. The high voltage produced by these systems can cause personal injury and/or equipment damage.

Since both plugs in companion cylinders fire at the same time, it is not necessary for the module to recognize which cylinder is on which stroke. Because of lower pressure in the exhaust cylinder, the plug on the waste cylinder requires less voltage to produce an arc. Therefore, most of the available voltage is used to fire the plug on the compression cylinder. If the firing order was 1-2-3-4-5-6, the companion cylinder firing sequence would be 1-4, 2-5 and 3-6 (Figure 3-3).

Most four-cylinder engines have the same 1-3-4-2 firing order. At initial setup, the module energizes the 3-2 coil first, as seen in Figure 3-3.

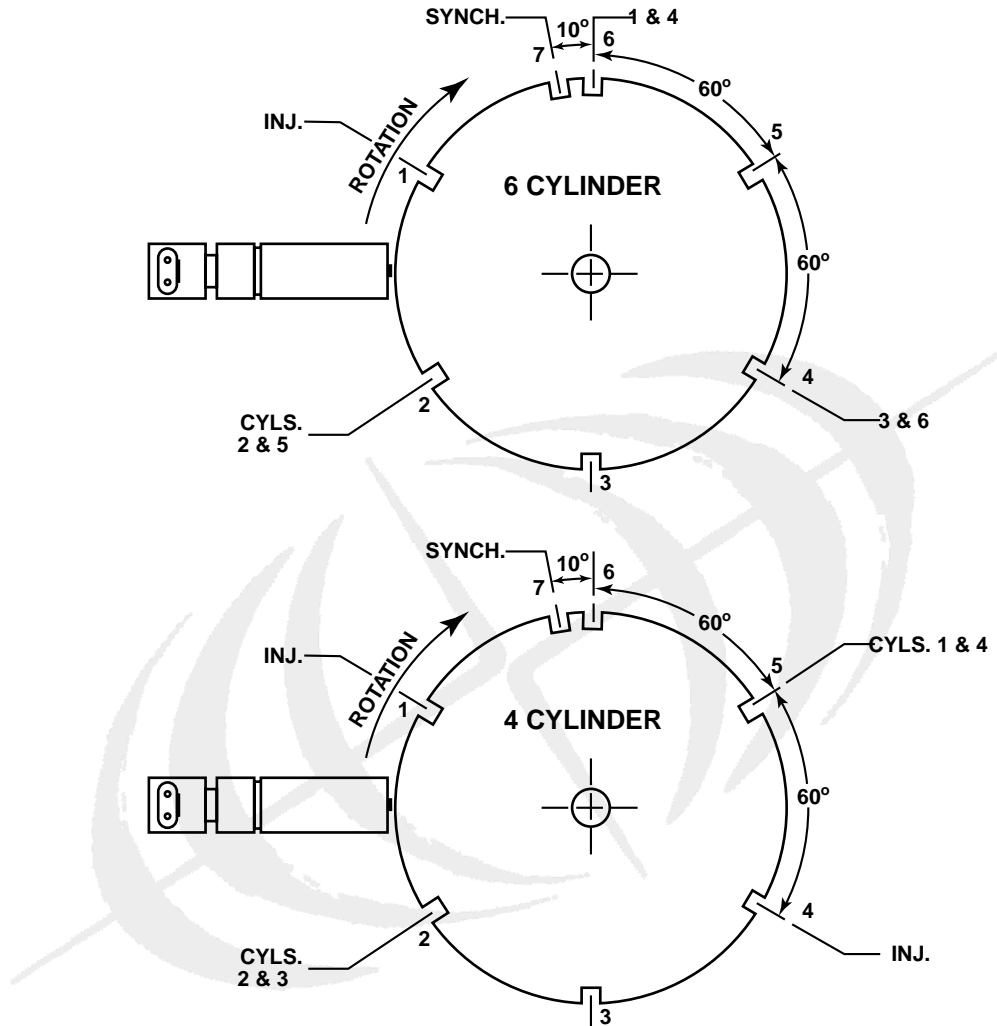


Figure 3-3. Firing order.

The primary coil current for waste spark ignition systems is controlled by various methods. There are two basic concepts, full function and min- function. Full function can be broken into two individual methods, closed or open loop dwell control.



### 3.5.3.1 Direct Ignition System (DIS)

The requirements for 4, 6, and 8 cylinder engine applications dictate the specific coil and electronics for meeting the ignition requirements.

This Direct Ignition System (DIS) consists of an ignition module, one 2-tower inductive coil for each cylinder pair. Each 2-tower coil's secondary ends are connected to a spark plug in cylinders that are 360 engine degrees apart. When high voltage is produced in the secondary windings of the coil, both plugs connected to that coil will fire at the same time in series. One cylinder will be on the compression stroke while the other cylinder is on the exhaust stroke.

### 3.5.3.2 ICE

#### Description

The Integrated Coil and Electronics (ICE) Direct Ignition System is a totally encapsulated assembly that contains a double tower coil for each cylinder pair, (refer to section 2.4.2) on waste spark ignition, and an ignition module. To help explain this further, the coils, towers and module are all sealed in one package. This eliminates the need for interconnect wires that are necessary on systems with an external driver electronic module.

ICE Ignition systems use Delphi's exclusive composite iron technology for the primary core. The surface finish of this composite iron core allows winding of the copper wire directly on to the core without any plastic spool or tape layer, which enhances heat dissipation.

ICE systems can be designed for 4-cylinder, 6-cylinder, and 8-cylinder gasoline engines. These system provide high voltage directly to each spark plug electrically, not mechanically, as does a distributor.

The ICE system modifies partitioning of the electronics, compared to full-function direct ignition systems, so that more functions are performed by the engine controller and fewer by the ICE system. Engine speed and position information is determined by a sensor that is directly connected to the engine controller. The engine controller uses the direct sensor signal, along with various other inputs, to determine Electronic Spark Timing (EST). For each coil in the ICE ignition system, the engine controller outputs an EST signal. The EST signal tells the ICE module, containing the coil driver electronics, to turn on and off coil primary current. The rising edge of the EST signal typically dictates the start of the coil dwell period and the falling edge of EST dictates the end of the coil dwell period and consequently the spark timing. Since the ICE is dependent on the engine controller for Electronic Spark Timing signals, it is known as a min-function ignition system.

### 3.5.3.3 Dual Coil Pack

Dual Coil Pack (DCP) Ignition systems are the same as ICE systems but without the electronics, i.e., coil drivers and circuits. DCPs are used in systems where the drivers reside elsewhere in the mechanization, usually in the ECM.

### 3.5.3.4 Gen II Integrated Coil and Electronics and Dual Coil Pack Features

- Half the number of coil drivers compared to coil near plug
- Size and mass reduction
- Reduced RFI emissions
- Fully encapsulated composite iron core
- Mount anywhere in engine compartment
- One coil per two engine cylinders, using a double-ended coil
- Voltage routed to spark plugs with secondary cables

Measurement Description	Typical Value
Energy (mJ)	69
Peak secondary current (mA)	97
Secondary voltage available (kV)	37 *
Spark duration (mS)	1.1
Secondary resistance (Ohm)	5100
Primary resistance (Ohm)	0.50
Primary charge time @ 14V (mS)	2.6
Weight (gr)	950
Primary Current (A)	9.5
Sample Availability	current

# = 1500 Volt Zener test with no secondary load.

\* = with 50 PF Secondary Load

Table 3-2. I.C.E. Specifications.

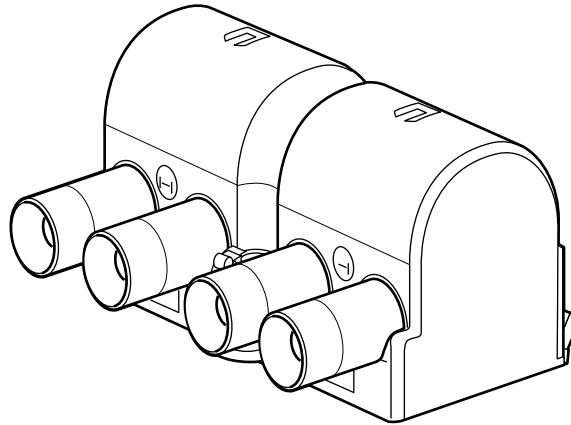


Figure 3-4. Integrated Coil and Electronics Assembly.

3.5.3.5 Dual Pencil Coil Pack (PCP).



Figure 3-5. Pencil Coil Pack.

Measurement Description	Typical Value	
Energy (mJ) (Min)	34	#
Peak secondary current (mA)	90	#
Sec. voltage available (kV) (min)	34	*
Spark duration (msec) (min)	1.10	#
Secondary resistance (ohm)	9660	
Primary resistance (ohm)	0.52	
Turns Ratio	90:1	
Primary charge time @ 14V (msec)	3.36	
Primary Break Current (A)	9.50	
Weight (gr)	500	

# = ISO 6518-2 test: 1000V & 500V Zener + 10kohms

\* = with 50 pF Secondary Load

Table 3-3 PCP Typical Performance.

### 3.5.4 Coil Per Cylinder (CPC)

Various types of CPC ignition are:

- Coil Near Plug (CNP)
- Plug Top Coil (PTC)
- Plug Hole Coil (Pencil Coil)

#### 3.5.4.1 Coil Near Plug Features

- Reduced RFI emissions
- Fully encapsulated composite iron core
- Programmable energy capable
- Ramp and fire dwell capable
- Efficient energy delivery
- Internal over dwell protection (current trip)
- One coil per engine cylinder
- Mounted near spark plug (short secondary cable)
- Integrated driver electronics

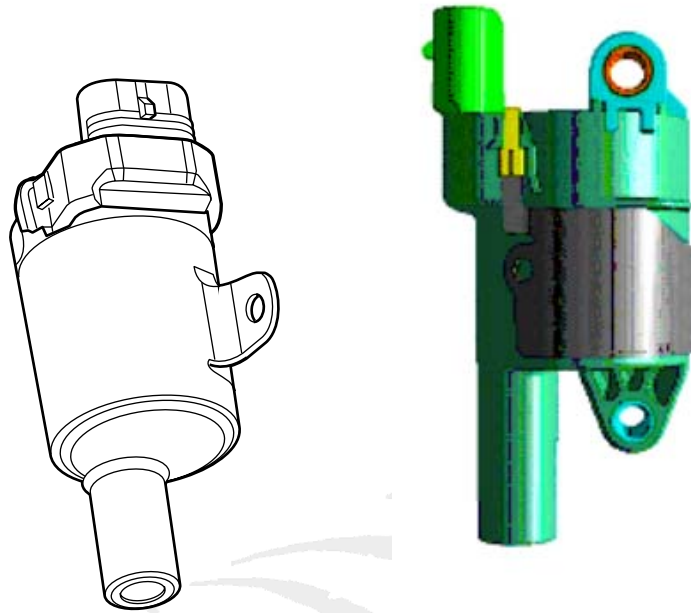


Figure 3-7. Coil Near Plug Ignition Coil.

Measurement Description	Typical Value
Energy (mJ)	60
Peak secondary current (mA)	115
Secondary voltage available (kV)	>37 *
Spark duration (mS)	1.9
Secondary resistance (Ohm)	5100
Primary resistance (Ohm)	0.75
Primary charge time @ 14V (mS)	4.4
Weight (gr)	310
Primary Current (A)	6.5
Sample Availability	Yes

# = 800 Volt Zener test with no secondary load.

\* = with 30 PF Secondary Load

Table 3-4. Coil Near Plug Specifications.

### 3.5.4.2 Plug Top Coil Features - Standard Burn

- Efficient energy delivery
- Reduced RFI emissions
- Fully encapsulated composite iron core
- Programmable energy capable
- Ramp and fire dwell capable
- Voltage suppression diode capable
- Small package volume, low mass
- One coil per engine cylinder
- Secondary cables are eliminated
- Ion Sense compatible if specified.

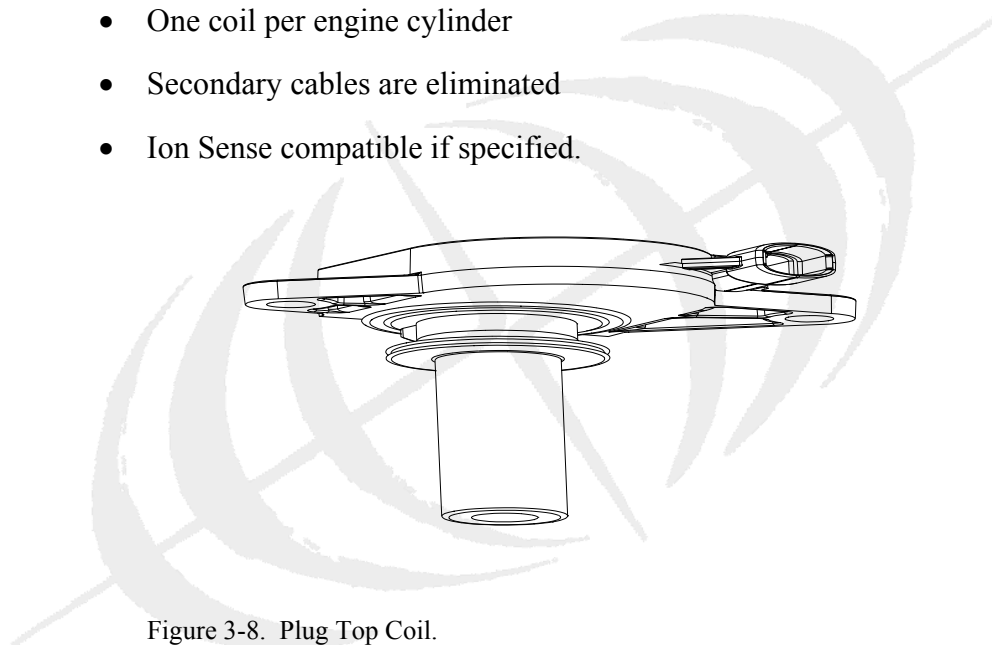


Figure 3-8. Plug Top Coil.

Plug Top Coil Performances (typical):

Measurement Description	Typical Value	
	Ion Sense / Long burn	
Energy (mJ)	38 / 49	#
Peak secondary current (mA)	180 / 83	#
Secondary voltage available (kV)	38 / 38	*

Spark duration (mS)	0.5 / 1.9	#
Secondary resistance (Ohm)	3000 / 10,190	
Primary resistance (Ohm)	0.41 / 0.72	
Primary charge time @ 14V (mS)	1.5 / 3.3	
Weight (gr)	250	
Primary Current (A)	10 / 7.5	
Sample Availability	YES	

# = 800 Volt Zenor test, no secondary load.

\* = with 25 PF Secondary Load.

Table 3-5. Plug Top Coil Specifications

### 3.5.4.3 Pencil Coil Features - Standard Burn

- Efficient energy delivery
- Reduced RFI emissions
- Fully encapsulated core
- Programmable energy capable



- Ion Sense compatible if specified
- Ramp and fire dwell capable
- Voltage suppression diode capable
- Small package volume, low mass
- One coil per engine cylinder
- Secondary cables are eliminated
- Coil fits in spark plug well onto spark plug (19 - 24 mm dia.)

Parameter	Typical Value
Input Voltage	5 - 16 V
Input Signal	5mA, 5 V
Ambient Temperature Above Coil	-40 /+130 °C
Coil Body Temperature	-40 /+150 °C
Primary Current	8.0 A
Charge Time (14V, 0 - 8.0 A)	2.3 ms
Secondary Voltage (20pF//100MΩ)	35.2 kV
Secondary Energy (800V)	44.8 mJ
Peak Secondary Current (800V)	77.5 mA
Secondary Current Duration (800V)	1.7 ms
Mass	~215 g

Performance values are for bench operation in a steel tube at 25 °C with 0.094 Ω harness resistance.

Table 3-6. Pencil Coil Specifications

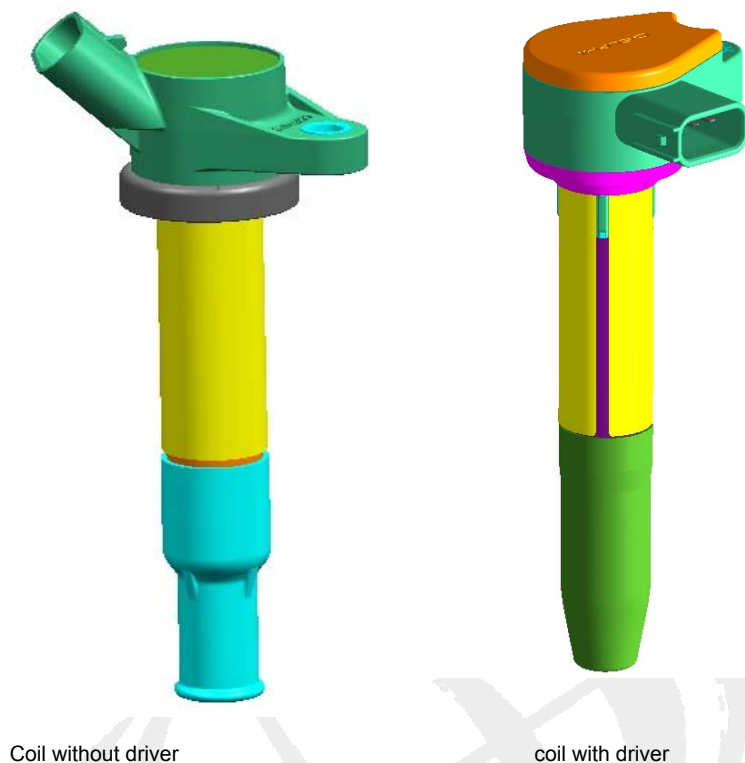


Figure 3-9. Pencil Coils.

These systems use a separate coil for each engine cylinder. This provides for maximum spark energy availability for higher RPM engines. At 10,000 rpm on a four-cylinder engine, only 0.030 seconds per spark is available. Thus, the coil only has a micro amount of time to build up its energy and to dissipate it, which is equally important. Timing and dwell are controlled by the vehicle's engine controller.

The Coil Per Cylinder (CPC) ignition is an electronic engine-sensing and spark control system that operates electronically, not mechanically. Like Direct Ignition System (DIS), it has no moving parts and does not require timing adjustments. A typical mechanization includes a coil for each cylinder, a coil driver for each coil, crankshaft position sensors, and a camshaft position sensor. The coils can be mounted as individual coil per cylinder systems or integrated into cassettes. The coil drivers may be integrated into the ECM or integral with the coils. Unlike DIS, waste spark is eliminated because of the coil per cylinder concept. Eliminating the waste spark along with high efficiency spark plugs results in three times higher energy delivered to the cylinder combustible mixture while drawing the same power from the vehicle's electrical system. Higher energy delivered results in cleaner and more consistent combustion for meeting OBD II misfire requirements. CPC

systems are known as “up integrated” because they are totally dependent on the engine controller for timing information. Sensor information is sent directly to the engine controller which results in an ignition system that is functioning before the engine rotates 180 degrees due to the CPC system architecture. Timing, dwell, and dwell overlap are controlled by the vehicle’s engine controller similar to waste spark min-function previously described with the exception of each cylinder having its own coil for the ignition event. Pencil Coil boltless mounting:

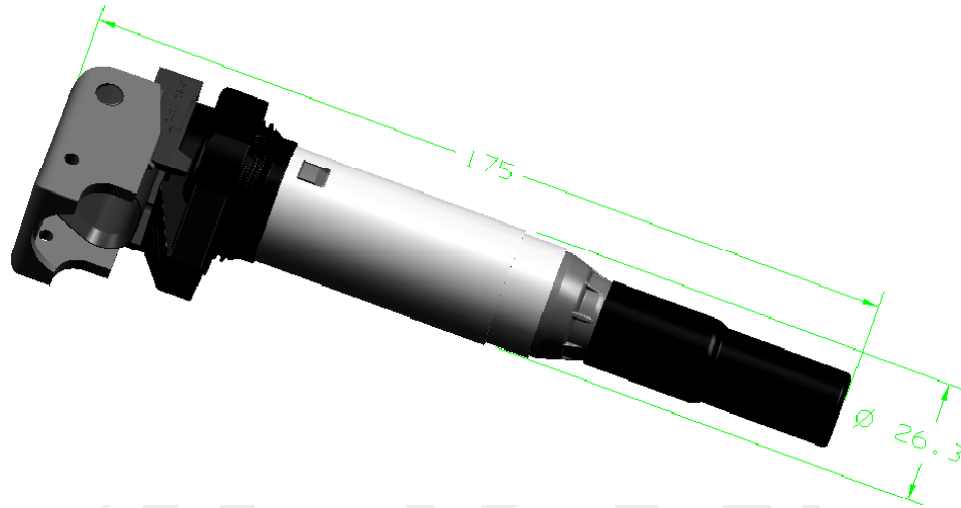


Figure 3-10. Boltless Pencil Coil.

- Four legs spring clip design
- Designed for 11° angle max. between coil and spark plug
- No need for mounting screw
- Efficient energy delivery
- High energy coil
- Reduced radio frequency interference
- Low mass

Parameter	Typical Value
Input Voltage	8-16 V
Coil Body Temperature	-40 - 165 °C
Primary Current (normal mode)	8.0 A
Primary Current (Boost mode)	10.5 A
Charge Time (normal mode)	2.6 ms
Charge Time (boost mode)	3.3 ms
Secondary Voltage (1M $\Omega$ //25pF)	>28 kV
Sec. Energy (normal mode)	50 mJ
Sec. Energy (boost mode)	70 mJ
Peak Sec. Curr. (normal mode)	90 mA
Peak Sec. Curr. (boost mode)	100 mA
Sec. Curr. Duration (normal mode)	>1.5 ms
Sec. Curr. Duration (boost mode)	>1.8 ms
Mass	235 g

Table 3-7. Boltless Pencil Coil specifications.

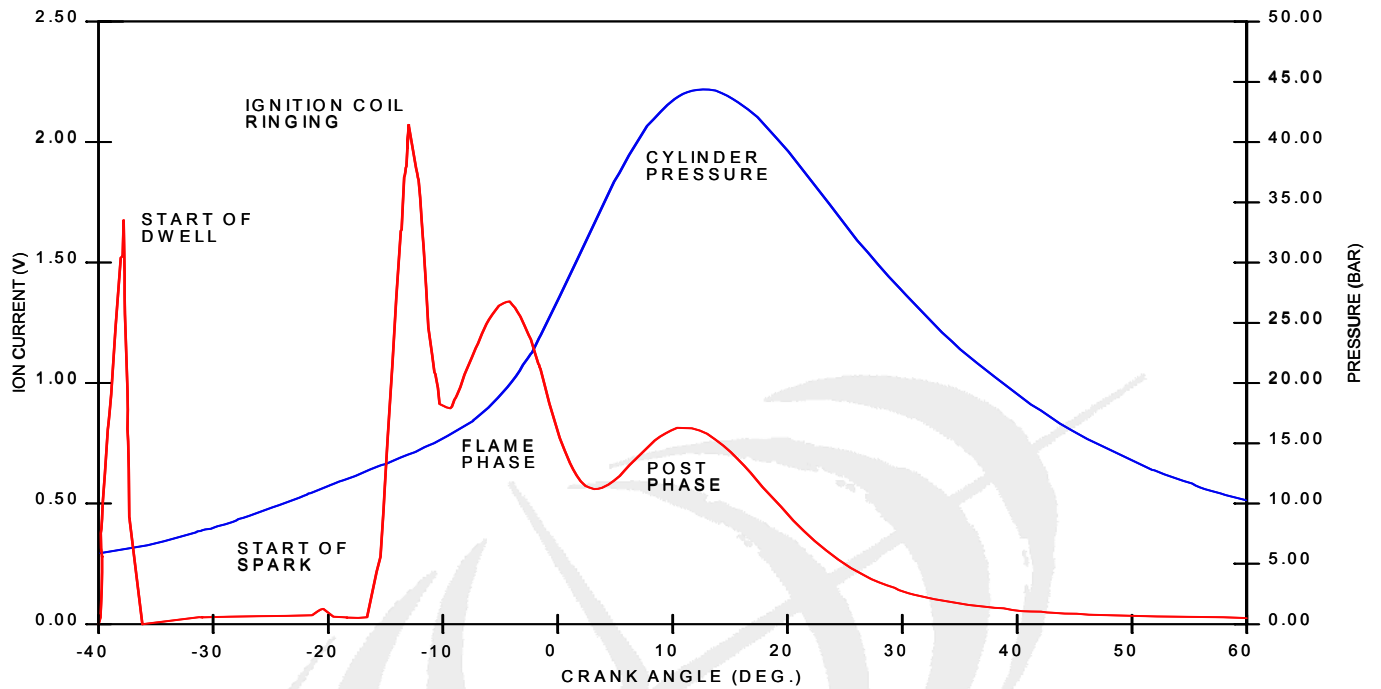
### 3.5.5 Ion Sense

- **Ion Sense Ignition (ISI) Definition**
  - An ignition system capable of
    - » Electrically biasing the spark plug gap *after* the plug has fired
    - » Monitoring the combustion event by measuring spark gap current
  - The spark plug becomes an “in-cylinder” combustion sensor
    - » Current flow in an ionized gas is proportional to the flame electrical conductivity
- **Ion Sense Ignition facilitated by coil per cylinder**
- **Mechanization determined by application needs**
  - Allows balance of functionality, cost, complexity and capability
    - » Production mechanization optimizes risk and timing
- **Time is required to make ion current measurements**
  - Can be done by limiting spark duration or using multicharge
- **Secondary circuit integrity must be maintained**
  - Micro-gaps or intermittent connections will block ion current flow
- **Ion Sense Ignition Production Functionality**
  - Ignition
  - Cylinder identification (cam sensor delete)
  - Cylinder misfire detection
  - Cylinder knock detection (knock sensor delete)

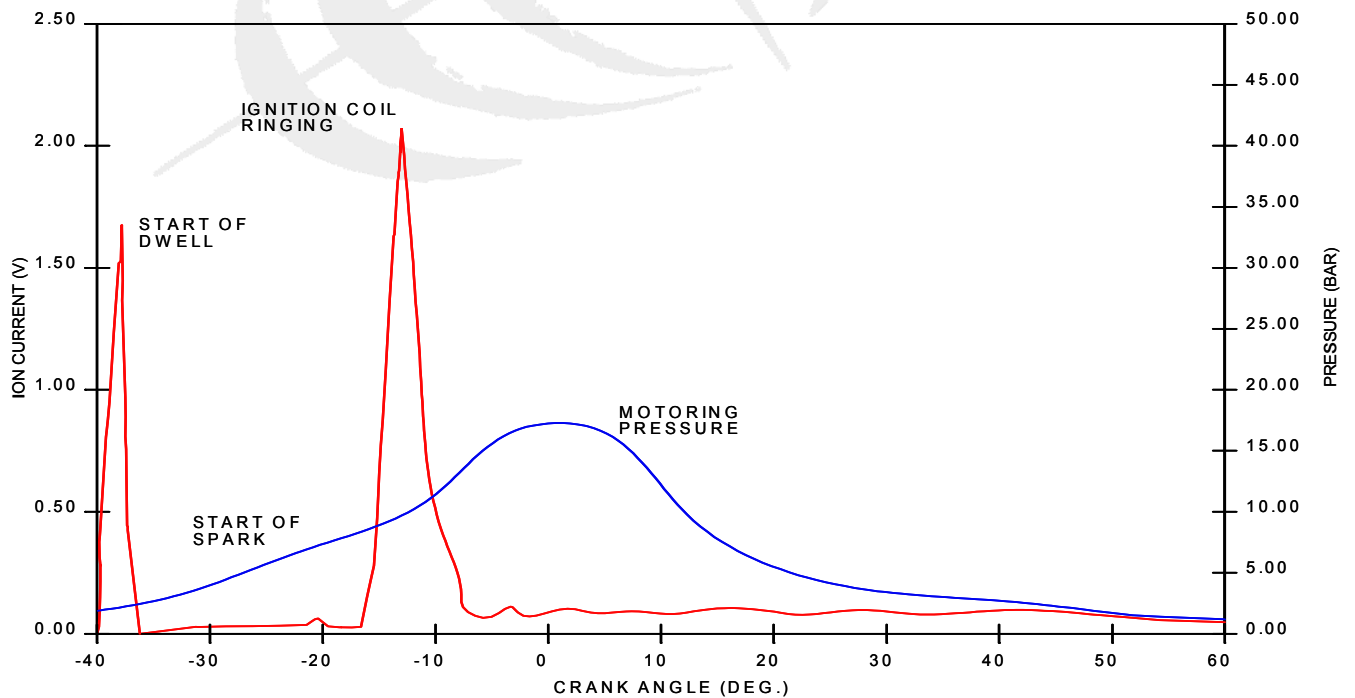
**Typical Ion Current Waveforms**

Figure 3-11.

# Normal Combustion



# Misfire



The signal following ignition coil ringout is the Ion Current  
Integration of the Ion Current signal has proven to be a robust measure of combustion quality.

- **Ion Sense Ignition System Benefits**
  - Direct in-cylinder measurement of combustion
    - » Improved misfire detection over wider engine speed & load range
      - Misfire determined by combustion results instead of speed calculation
    - » Improved knock detection
      - A "knock sensor" in each cylinder compared to 1 or 2 sensors per engine
      - Knock is measured using combustion signal, not engine vibration
  - Potential for improved functionality at minimal cost
    - » Elimination of knock and cam sensors
    - » Reduced calibration and development time
  - Potential for added functionality with continued development
    - » Pre-ignition, Location of Peak Pressure (LPP), Cold Start Compensation, Dilution Control
- **ISI is a proven combustion measurement option**
  - Technical challenges met providing a robust production system
  - Demonstration of Delphi's ignition system and component capability
  - Mechanizations to meet varying customer needs being developed
  -
- **Delphi is developing ISI as a means to reduce real world cold start emission and driveability variation. This would certainly be an area for a potential joint development project. Delphi has been focusing on cold start variation caused by the fuel's Drivability Index and other start-to-start variations on an individual cylinder basis.**
- **Advanced functionality being developed for future model years**

### 3.5.5.1 Ion Current Signal Processing – Knock Intensity (KI) Signal

Knock control can be calibrated to use information immediately. Knock control is capable of global or individual cylinder control

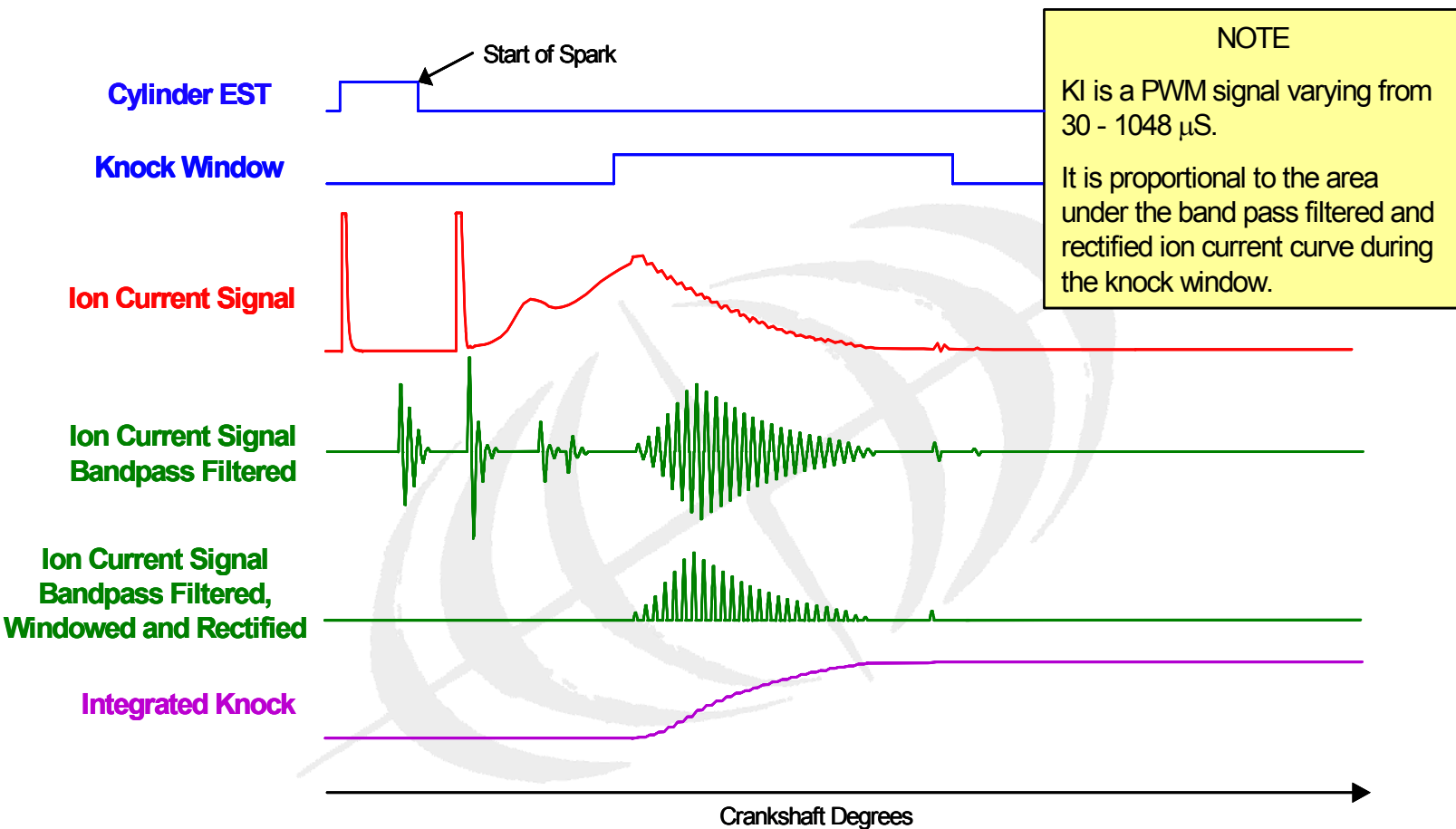


Figure 3-12.

## 3.6 Spark Plug

The primary function of a spark plug is to efficiently ignite the fuel/air mixture in an internal combustion engine. This is accomplished by allowing high voltage, in excess of 25,000 volts, to pass from the ignition coil through the spark plug and cylinder head to the spark gap. In addition, the spark plug must seal the combustion chamber and be able to withstand the combustion pressure along with vibration and cycling forces found in the engine. Exposed to flame temperatures in excess of 1650°C, and to a highly corrosive atmosphere, the electrodes must resist the erosion of millions of spark discharges. Spark plugs must also operate within a defined temperature range to insure self-cleaning by burning off conductive tip deposits, and yet cold enough to maintain an adequate preignition safety margin.

### 3.6.1 Spark Plug Design

Spark plug firing location (gap projection), gap size, electrode size, and, series resistance can have an effect on combustion and dilution tolerance and should be developed or chosen before calibration. Firing location can be altered by changing the seat and thread depth on cylinder head spark plug boss, or by using an extended gap spark plug. Gap size is sometimes increased to improve idle stability; however, wide gap settings may have a negative impact on cold start performance and spark plug durability. Large diameter electrodes are sometimes used to improve durability in severe heavy duty applications. But, large electrodes tend to shroud the spark and are more likely to quench the initial flame kernel, resulting in reduced idle stability and lower dilution tolerance. To improve performance of ignition systems having increased secondary current, attention has been recently focused on reducing the amount of series resistance in spark plugs and secondary wires for the purpose of delivering more energy to the spark gap.



### 3.6.2 Spark Plug Types

Conventional spark plugs having nickel alloy electrodes are subject to gap wear, which can be severe in some cases, and are more susceptible to the other limitations described above. The typical life of the conventional spark plug is 30,000 miles or less depending upon the fuel being used.

Premium spark plugs, targeted mainly for the aftermarket, generally have a variation of the conventional electrode size or shape, and/or the use of a precious metal in one of the electrodes. The AC "RapidFire" having a shaped and knurled center electrode, and a shaped nickel-silver side electrode is an example. Depending upon the design, premium spark plug life may range from the same, to moderately improved, compared to the conventional plug.

Platinum spark plug development was aimed at world class powertrain goals requiring reliable and consistent combustion initiation throughout the life of a vehicle. Delphi-E's High Efficiency Spark Plugs (HE1, HE2) have design features that significantly improve resistance to spark erosion, fouling, and the corrosive environment of the combustion chamber. The fine wire electrodes further lower the ignition demand voltage and also reduce the possibility of flame kernel quenching. These design features help to meet the increased performance and reliability requirements of the automotive industry, including extended service life objectives beyond 100,000 miles.

## 3.7 Sensor Function

Sensors are non-contact transducers that translate mechanical motion into electrical signals. The ignition module and engine controller use these signals to maintain the correct spark and fuel injection timing. Some engines use crank sensors mounted on the front of the engine beside the harmonic balancer/crankshaft pulley. Other engines may use both a crank sensor and a cam sensor.

This section will briefly discuss the various sensor designs and functions. For a more in-depth review, which includes target wheel design criteria, refer to the Sensor Application Manual.

### 3.7.1 Variable Reluctance (VR) Sensor

The VR sensor has no mechanical components. The main components of a VR sensor are the magnet, pole piece, coil, housing, and the raised portions on the circumference of the reluctor wheel or target to be sensed. These components are shown in Figure 3-13. The magnet is a permanent magnet and the source of the magnetic flux on which the sensor operates. The pole piece concentrates the flux from the magnet through the center of the coil to the tip of the pole piece. The coil is a bobbin around the pole piece into which magnet wire is wrapped. The housing provides protection and mounting for the other components. The target rotates close to the tip of the pole piece and acts as an “exciter” to the sensor by changing the strength of the flux through the pole piece. This change in flux through the pole piece will induce a voltage and a current in the windings of magnet wire generating the desired signal.

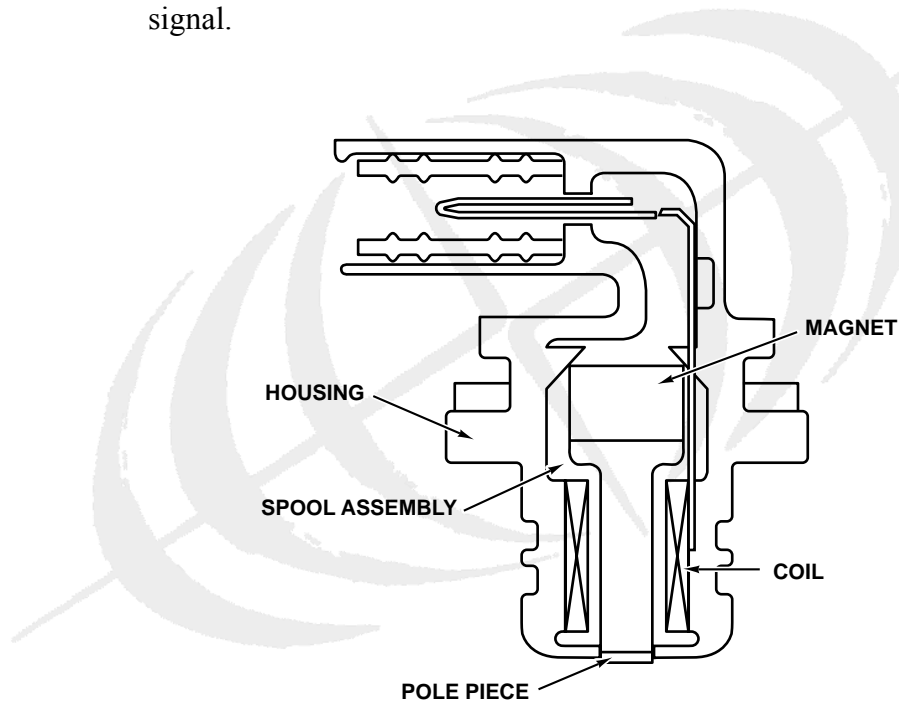


Figure 3-13. VR sensor components.

This signal when used with a target wheel specifically designed for an engine application, will produce a signal which can be utilized by the engine control module to determine cylinder position. The shape of the generated waveform is a function of the target wheel tooth profile (Figure 3-14) The amplitude of the waveform will vary with sensor to target wheel air gap and engine speed. (Figure 3-15).

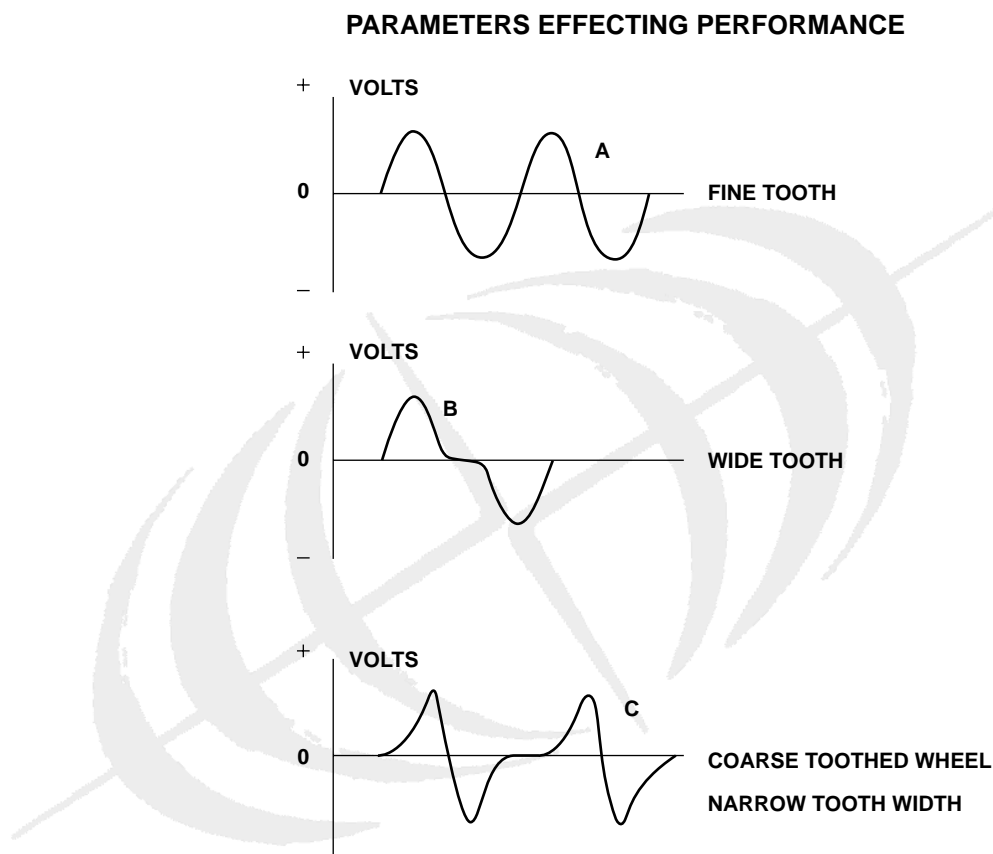


Figure 3-14. Sensor output waveforms for different target geometry's.

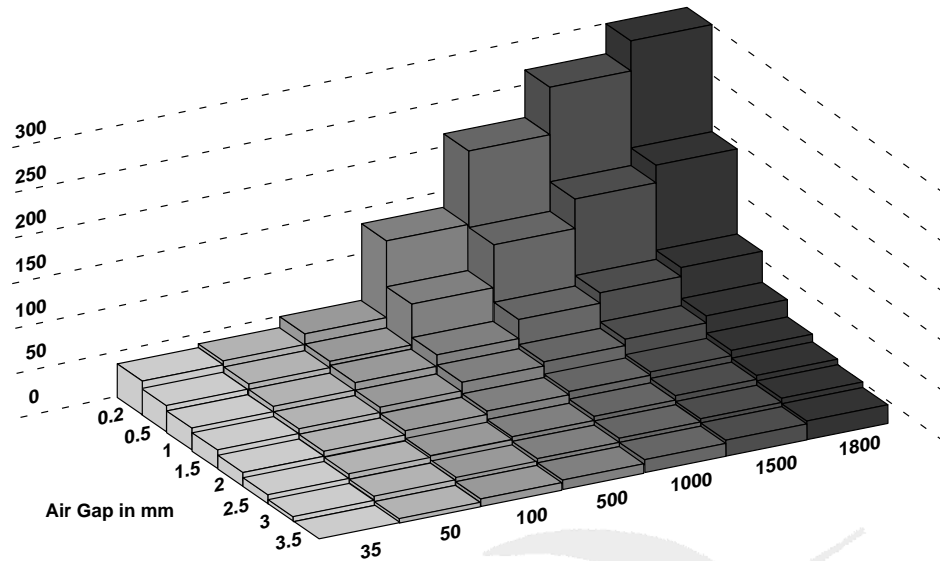


Figure 3-15. Sensor voltage output at various target surface speeds and increasing air gaps.

### 3.7.2 Hall Effect Sensor

Some engines use signals from “Hall effect” sensors/switches to synchronize and fire the coils at the proper time. The sensors vary in appearance and in the locations they are used, but their basic end result is the same as the VR design. Hall effect sensors are currently used for both crank and cam position sensing

The “Hall effect” or “Hall voltage” is named for Dr. Edward Hall, the physicist who discovered it. He found that when a magnetic field is introduced perpendicular to a current flowing through a solid conductor, a measurable voltage is induced at the sides of the conductor, at right angles to the main current flow (Figure 3-16).

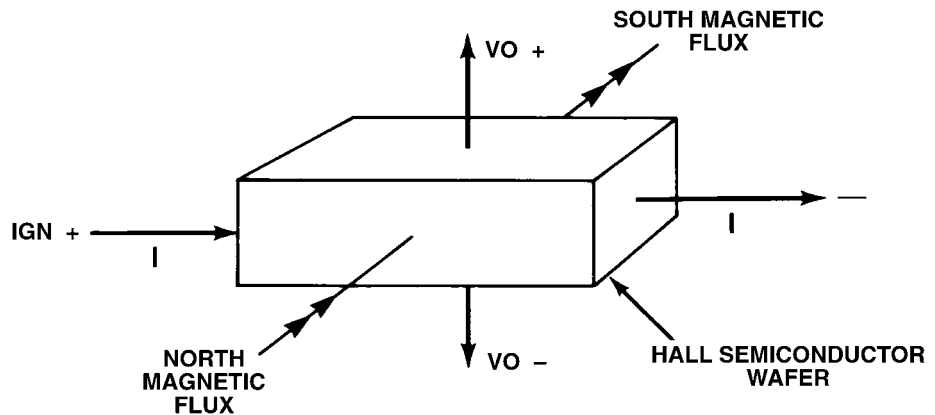


Figure 3.-16. Hall effect.



In the Hall effect crank sensor, a regulated signal voltage from the ignition module is passed through a semiconductor wafer in the Hall switch. A permanent magnet, mounted beside the semiconductor, induces Hall voltage across the semiconductor (Figure 3-17). The crank sensor is positioned so that metal blades or “vanes” of an interrupter ring mounted on the crankshaft harmonic balancer/damper pass between the semiconductor and the permanent magnet. When a metal vane comes between the magnet and the semiconductor, the magnetic field is interrupted and Hall voltage drops off (Figure 3-18).

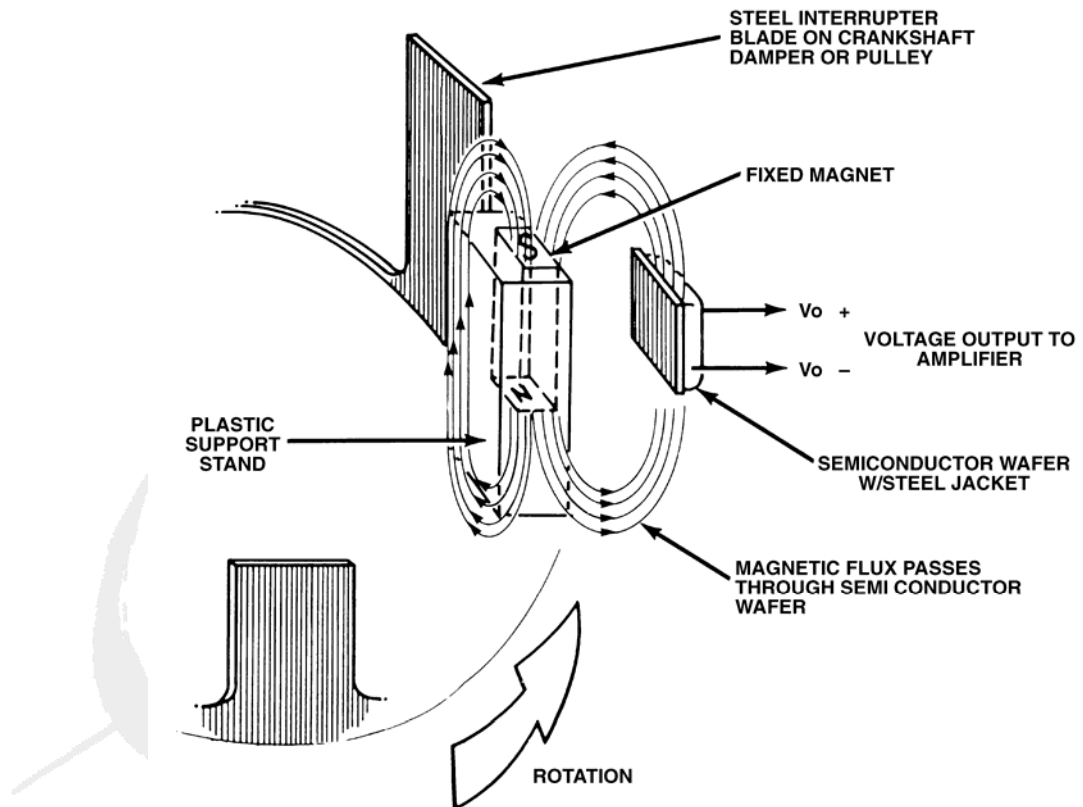


Figure 3-17. Hall switch on.

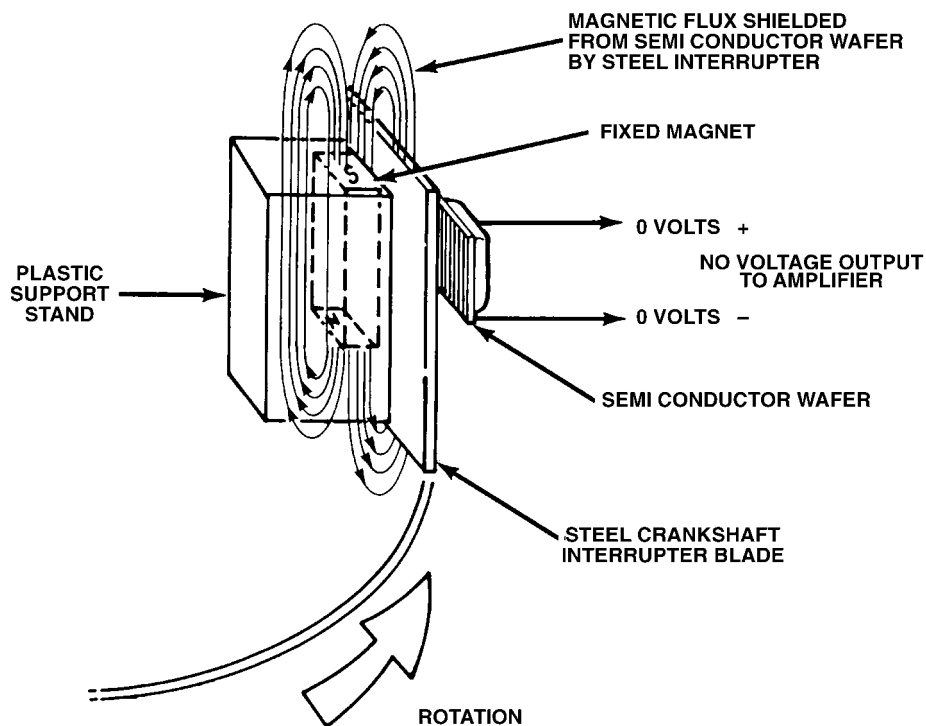


Figure 3-18. Hall switch off.

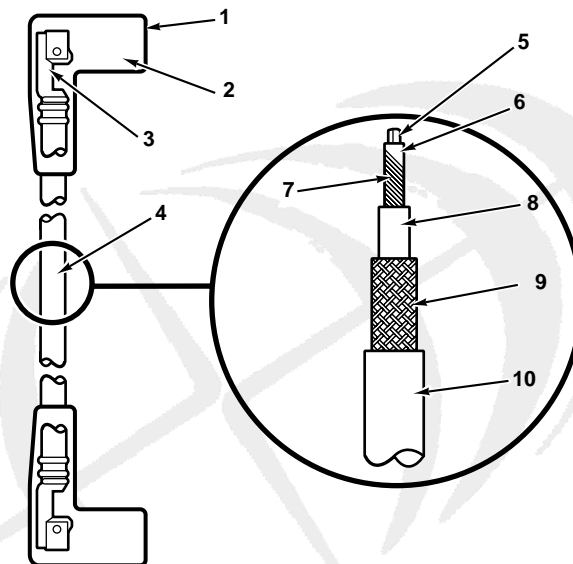
### 3.7.3 Magneto Resistor (MR)

A magneto resistor (MR) sensor consists of two parts: a magneto resistor element, and a magnetic circuit which provides a bias flux to the sensor element and produces a desired variation of flux density in response to position. The major application of these sensors is in non-contact gear tooth sensing, and in the measurement of small displacements ( $\leq 1.5\text{mm}$ ). One interesting aspect is that the magnitude of the output signal is independent of the operating frequency, hence, rotations from zero speed upwards can be recorded. The output wave form approximates to a sine wave, where the harmonic effect increases with decreasing air gap.

## 3.8 Electrical Wires

### 3.8.1 Secondary Wires - Function

The function of the secondary wires is to transfer the energy from the ignition coil to the spark plugs. TVRS (Television Radio Suppression) secondary wire, marketed by Delphi P under the trade name Delcore™, is an inductive (wirewound) secondary wire. Figure 3-19 shows the construction of the inductive wire.



- |  |  |
|--|--|
| 1. Improved release agent material to minimize the bonding of the sparkplug to the boot. | 4. Wire wound inductive cable for increased energy delivery and reduced RFI. |
| 2. Right angle boot for reliable assembly and improved durability.                       | 5. Aramid fiber  |
| 3. Double dimple sparkplug terminal for improved engage/disengage.                       | 6. Ferrite layer   |
|  | 7. Inductive wire wound  |
|  | 8. Silicone insulation   |
|  | 9. Fiberglass braid  |
|  | 10. Silicone jacket  |

Figure 3-19. Inductive (wirewound) ignition wire.



### 3.8.2 Features

Design improvements include reduced resistance, an enhanced nipple design, an improved spark plug boot releasing agent, and a double dimple spark plug terminal.

An advantage of the inductive cable is that it is possible to reduce the series resistance in the cable while still maintaining RFI (Radio Frequency Interference) suppression. The reduction in the series resistance allows more of the coil energy to be supplied to the spark gap.

RFI suppression in TVRS wires is obtained by a low pass filter formed by the core series resistance and the shunt capacitance between the cable and the engine ground plane. The core resistance is a function of cable construction. The shunt capacitance is a function of how closely the cable is routed to the engine block.

Inductive cables are designed with a non-corrosive conductor wrapped around the ferrite layer. RFI suppression is obtained by a low pass filter which is formed by the series resistance, series inductance, interwinding capacitance, and the shunt capacitance. The ferrite acrylic latex layer design enhances the suppression properties.

The outer jacket of the cable provides an environmental barrier. The silicon material offers high temperature performance as well as compatibility with underhood automotive fluids and chemicals. A fiberglass braid under the silicon jacket adds reinforcement and strength to the cable. A high temperature silicon polymer layer is designed for high dielectric strength and also helps to lower the cable capacitance and energy losses. Further strength and reinforcement is provided by a non-conductive aramid fiber. Delcore™ cable is designed to withstand 175°C continuous and peak excursions to 200°C.

The enhanced nipple design improves the engagement and disengagement forces. It has improved dielectric strength over the previous male tower design which eliminates carbon tracking of the tower. Carbon tracking is a permanent, low resistance path formed on a plastic surface by a high voltage arc. The carbon tracked plastic allows the spark to be misdirected between the tower and boot to a nearby ground leading to misfires and poor engine performance.

The extreme temperatures around the spark plug can cause the spark plug boot to bond to the spark plug, making it difficult to pull the boot off. The improved spark plug boot releasing agent minimizes the bonding which occurs between the spark plug boot and the spark plug.

The double dimple terminal is designed to improve the retention properties of the terminal to the nipple as well as improve the engage and disengage forces.

### 3.8.3 Primary Wires - Function

The function of the ignition primary wiring harness is to provide battery (B+), ground, Coil C-, and low voltage level signals to and from the vehicle computer. The wire gauge for each lead depends on the total length of the cable, number of interconnects, and total (battery-to-ignition system) cable voltage drop. Each harness design is developed individually using the vehicle specification as a guide. For proper wiring harnesses designs, consult you Delphi P representative.

## 3.9 Electronic Control Module

The electronic control module (ECM) is basically an onboard computer responsible for receiving engine data from various sensing devices then, using the provided data, calculating correct spark advance and air/fuel delivery. Engine speed, coolant temperature, manifold pressure, cylinder position, and throttle position are some of the inputs which can be used. Proper spark timing and an ideal air/fuel (A/F) ratio provides minimum emissions and maximum fuel economy and driveability.

The operation of the ECM is essential to the operation of the ignition system. The Ignition and ECM engineering groups will need to work together to properly develop the ignition dwell and spark advance tables.

# 4.0 System Interface

## 4.1 General

The Ignition System interfaces with the other Powertrain Subsystems as described in this section and shown in Figure 4-1.

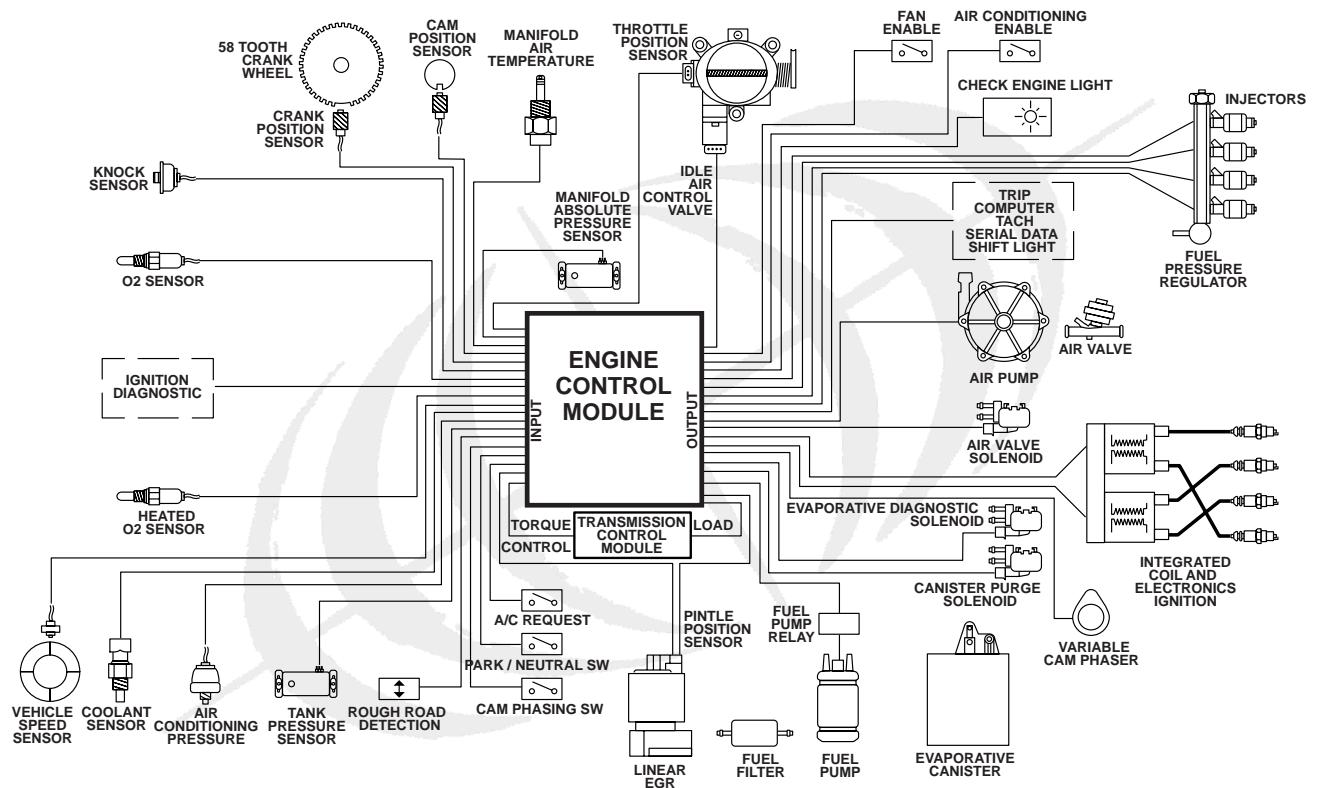


Figure 4-1. Ignition System Interfaces.

## 4.2 Mechanical Interfaces

### 4.2.1 Locating the Ignition System

Properly locating the Ignition System on the engine contributes to satisfactory long-term operation. The recommendations provided below should serve as a guide for hardware planning.

- Provide adequate air circulation to cool the ignition system and prevent heat transfer from the surrounding components, e.g., cylinder head and the intake manifold.
- Avoid mounting the ignition system in a location where it will be exposed to excessive road splash or where water puddling can occur.

### 4.2.2 Vibration Levels

#### 4.2.2.1 Vibration Durability Requirements

Before a validation statement can be signed, the vibration levels need to be analyzed for each application.

Vibration levels should be determined as soon as proper hardware is available to ensure that engine vibration is within acceptable limits.

If resistance to dynamometer levels (usually higher than vehicle levels) is required, this should be communicated to the Systems Design Engineer.

- Stable averaging and peak hold averaging for a minimum of 50 events
- Overall RMS Level in a 20-2500 Hz frequency band
- Identification of peak frequencies and level
- Display graphs in Power Spectral Density (PSD in  $g^2/Hz$ ) vs. Frequency (linear frequency axis and both log and linear axis for amplitudes).

This procedure should be performed for each operating condition and axis. Figure 4-2 shows an example of how the data should be presented for steady state rpm conditions. Figure 4-3 shows a typical spectral map.

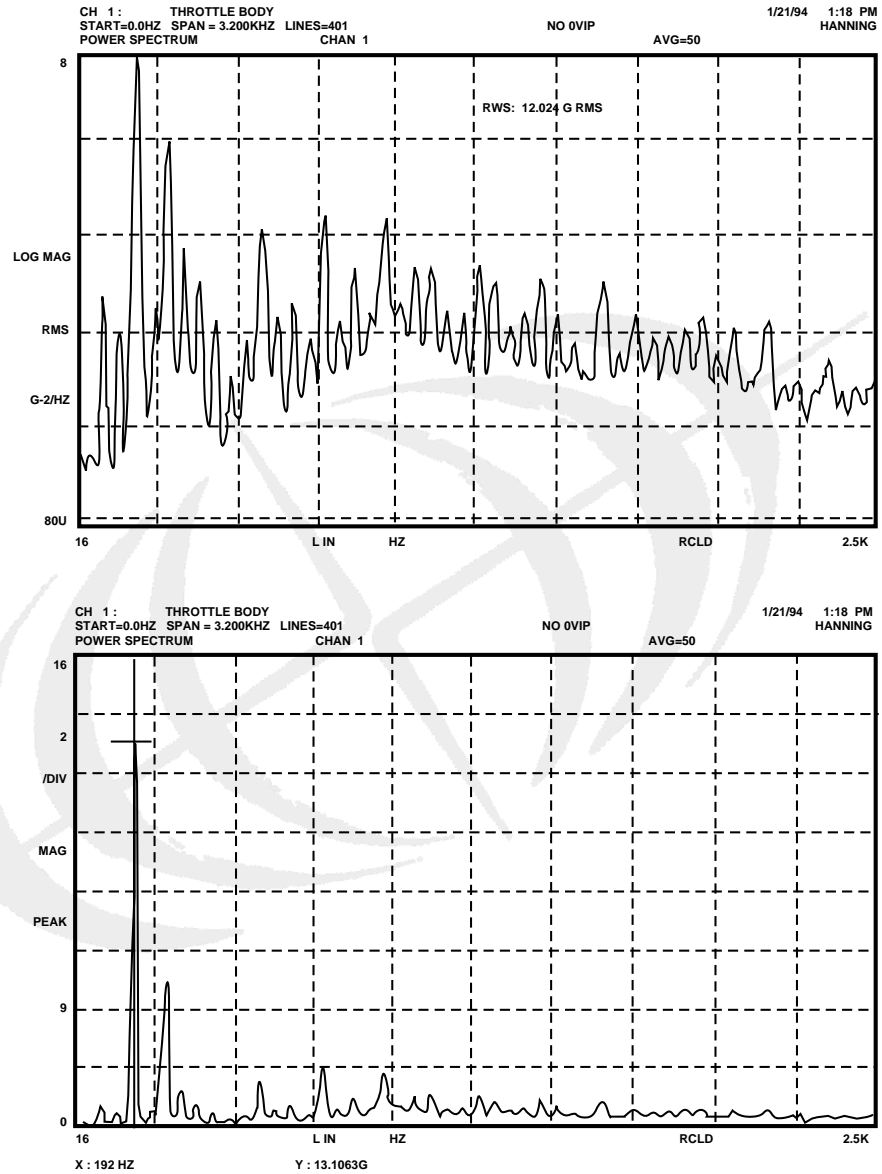


Figure 4-2. Example of data presentation for steady state rpm.

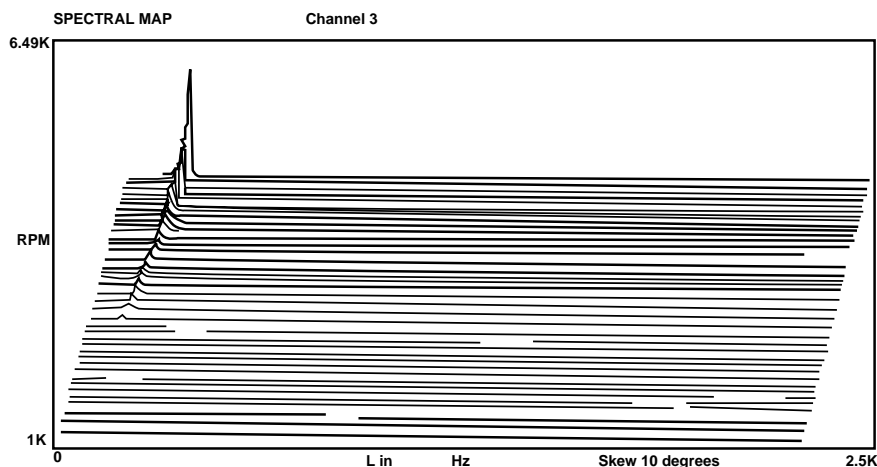


Figure 4-3. Typical spectral map.

## 4.3 Electrical Interface

### 4.3.1 Electromagnetic Compatibility

#### Generation:

The ignition system should not produce any objectionable RFI in AM, FM, and CB bands. EMI/RFI can occur in two ways: radiated through surrounding air and conducted through connecting wires.

#### Susceptibility:

The ignition system should be isolated in such a manner that other electronics cannot induce excess interference (EMI/RFI) levels into the injector's controls.

### 4.3.2 Wire Routing

Electrical wiring to the ignition system should be routed so that conductors are protected from excessive heat, damage, and wear.

Avoid excess handling (disconnecting and connecting) of the electrical connectors.

For systems where the driver is remote from the ignition coil, C- wire routing is critical especially if the low side of the secondary is not grounded as the primary reflected voltage spike could be picked up by other devices such as sensors. Delphi also advises that the EST wires be isolated from other load and signal carrying wires. See Figure 4-4.

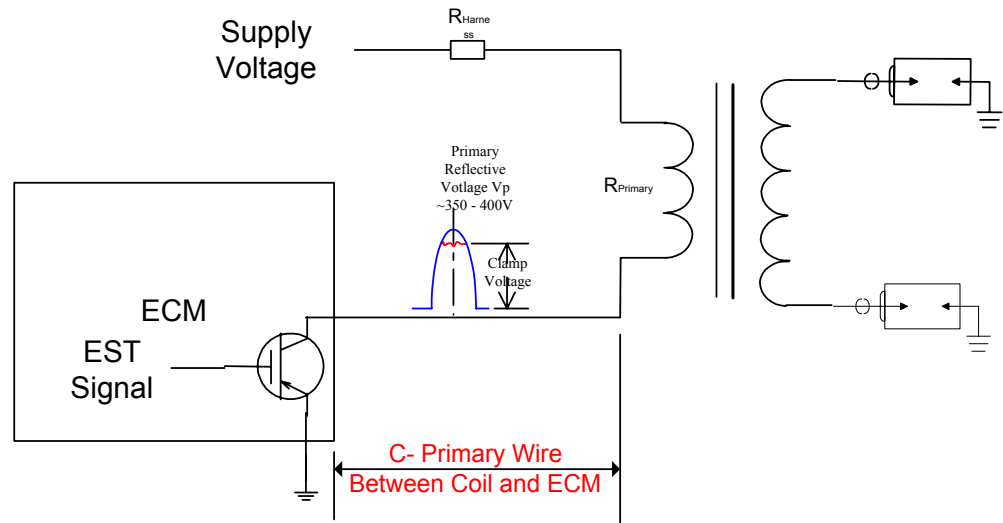


Figure 4-4. A typical reflected primary voltage for a coil where the driver is in the ECM

Do not share ignition component wiring with other components. Dedicated wiring is required. For other types of applications consult your Delphi-E application engineer.

### 4.3.3 Ignition System Connector(s)

Connectors are specific to application. Consult your Delphi-E Application Engineer.





## 5. 0 Software

---

### 5.1 General

An ideal air fuel (A/F) ratio provides minimum emissions and maximum fuel economy and driveability. For any given engine and vehicle operating condition, there is an optimum A/F ratio. It is the function of the engine controller's software to calculate the optimum A/F ratio for the existing conditions. The engine controller monitors the output of the engine and vehicle sensors, and uses this data to determine the correct spark timing for the existing conditions. It manipulates the data using equations, look-up tables and injector characteristics to calculate the required spark timing.

### 5.2 Ignition Control Algorithms

The following closed-loop and open-loop software sections briefly describe engine and engine management system components that typically influence air/fuel control and thereby impact control of spark timing.

The system software has control algorithms to make corrections to spark timing. Corrections are determined using closed-loop and open-loop feedback. Each correction has its own algorithm within the performance characteristics of the application specific software.

*Note: The complexity and size of control system software and algorithms are driven by emissions and diagnostic requirements. The use of the following algorithms is dependent on government and customer requirements (some systems do not require closed-loop correction to meet performance and emissions goals).*

### 5.3 Computer Controlled Coil Ignition System

The following is a generic functional description of the Ignition System. It will briefly describe the different component blocks of the ignition system as well as the overall operation and features of the system. This description is not intended to be an all-inclusive summary of the features and functions of this system or any other ignition system.

### 5.3.1 Ignition System Description

Most Delphi Ignition Systems are designed to operate in the underhood environment of an automobile with backplate temperatures of -40°C to 125°C. The battery voltage requirements range from 4.5 volts to 16 volts. The system begins with sensors which provide different pieces of information to the module. The combination of the inputs provide the controller with the information needed to determine the position of the crankshaft and thus which spark plugs need to be fired. The controller takes the information from the inputs and selects the proper coil to be fired as well as providing various output signals based upon this and other module inputs.

### 5.3.2 Input and Output Signals

#### 5.3.2.1 Input Signals

The ignition system uses input signals to determine the position of the engine crankshaft.

- **Crank Signal** The crank signal is a signal derived from a wheel that passes by a sensor.
- **Cam Signal** The cam signal provides information to the engine controller for sequential fueling.
- **EST Signal** The EST signal, which is generated by the engine/ignition controller, provides the Ignition System with timing information during normal operation. This signal goes high when it is desired to start the dwell and it goes low when the end of dwell is wanted. The end of dwell is the point at which a selected coil will fire a single or pair of spark plugs. Note: The start of dwell does not necessarily coincide with the rise of the EST signal at all engine rpms. Specific dwell algorithms are a result of the calibration engineer and the Delphi product engineer working together to insure proper product and system functionality.
- **Bypass Signal** The bypass signal is provided by the engine controller and commands the module to either operate in the bypass or EST mode of operation. When the Bypass signal is low, the module will be guaranteed to be in the bypass mode. If the Bypass signal is high, the module will operate in the EST mode if and when several other conditions are met.

### 5.3.2.2 Output Signals

The system provides outputs for use by the engine controller. The following gives a description of each output:

- **Crankshaft Reference Signal** This signal provides the engine controller with a symmetrical reference that can be used for calculating fuel and spark timing.
- **Cam Signal** The cam signal is a buffered output. This signal is used by the engine controller for sequential fueling since it will provide a signal once every 720 engine degrees.
- **Tach Signal** The tach signal in a full functional system is a normally low signal that goes to the high state whenever primary coil current is flowing. It is in most cases sent directly to the tachometer in the instrument panel. This signal is also useful for diagnostics if a current probe is unavailable or cannot be used since it will be high whenever any coil primary is energized.



## 6.0 Product Handling

### 6.1 Product Usage and Handling Guidelines

Recommendation	Reason
<b>Application Basics</b>	
Vehicles used for testing need to be as close to the final production version as possible. Wiring harness routings, wire gauge size, system loads, and body fascias which affect underhood air flow are especially important.	The ignition performance degradation might happen if vehicle modifications occur. Temperature extremes and vibration profiles might also be affected, which could impact component durability. Any vehicle design changes need to be reviewed and the possible affects discussed with the component application engineer
Operator due care needs to be exercised when working around the ignition system.	The high voltage produced by the coil secondary circuit can cause personal injury and/or damage test equipment
Never install the low voltage connectors with the power applied	This might cause an unwanted secondary firing, possibly leading to personal injury
Install the secondary leads before connecting the primary leads.	In the event the low voltage connection has been made and the power applied, unwanted secondary output might occur possibly resulting in injury, damage the ignition component, and test equipment
Do not use a screw driver to asset in removing secondary boots from the secondary tower. Use tools designed for secondary removal.	It is possible to damage a secondary lead in such a manner that creates an electrical path to outside the system permitting improper system operation, misfire, or even possible personal injury if arcing occurs.
Proper handling and shipping methods need to be in place to reduce the risk of damage due to impact, moisture, or contamination	Damaged components can lead to premature failure.
Do not use parts that have been dropped or display physical damage	Damaged components can lead to premature failure.
Do not scratch or apply any non approved material to the surface of the high voltage tower which mates with the high voltage secondary leads.	This can jeopardize the seal integrity of the mating surfaces which in turn can create a secondary high voltage leak path.
Never strike any part of the ignition system with a tool or other object.	This can lead to physical damage which can cause a system malfunction or failure.
Do not permit paint or other sprayed materials to be sprayed onto the electrical connectors.	Insulating type sprays can create a high resistance or open connection. And, a conductive type spray can create an electrical short condition.
Do not support the ignition system by the wiring harness or plug wire.	These leads are not designed to support the weight of the ignition system. It can create a poor electrical connection Or become disconnected allowing the system to fall and be subjected to physical damage
Avoid unnecessary disconnecting and connecting of the electrical components.	The electrical connections are not designed for repeated connection and disconnection.
Always insure the low voltage connectors are entirely seated and the locking mechanism is engaged.	This prevents intermittent electrical connections leading to an improper ignition system operation.
Do not pierce or probe the secondary leads.	This creates an electrical path to outside the system permitting improper system operation, misfire, or even possible personal injury if arcing occurs.
Use approved connector breakouts when testing the ignition system.	Connector and/or component damage may occur.
Always insure the appropriate seals are included in the connector system.	Liquid intrusion into the terminal connection area might occur causing an electrical intermittent or short condition. In the event of severe terminal corrosion, an open condition might occur.

<b>Vehicle Level Guidelines</b>	
Mechanic, or technician due care needs to exercised when working around ignition systems	High voltage produced by the coil can cause personal injury and/or equipment damage.
No ignition system is designed to be operated without the spark plug attached.	If a technician or mechanic comes in contact with the high voltage generated during operation, personal injury may occur. Or, if the engine is operated under this condition, unburned fuel may fill the converter area creating a potential hazard
Delphi E ignition systems are typically designed to operate with gasoline based internal combustion engines.	Other fuels or combustion designs may require additional design considerations.
The power feed line should be fused.	This could protect the system in the event of an electrical short
The module heatsink and backplate must not be used as a connection point when jump starting the engine	The high level of voltage and current which the module could be subjected to, could cause module performance degradation or failure.
Connection of the module backplate to vehicle ground is desirable whenever possible	This greatly reduce potential ground loops and acts as a heat transfer source from the module.
The ignition system ground wire should be kept as short as possible. And, when permissible, should be grounded at the same engine block position as the engine controller	The would greatly reduce the possible of unwanted electrical ground loops.
The electrical wiring to the ignition system should be routed so that the conductors are protected from excessive heat, damage, and wear.	Helps prevent electrical intermittent, open or shorted operating conditions.
Do not share ignition component wiring with other components, Dedicated wiring is required.	This prevents electrical cross talking between components which can lead to component malfunction.
Ignition secondary leads should not be routed with the ignition primary harness or any other electrical harness.	Voltage spikes can be transmitted from the secondary cables into other leads which are in close proximity . This could create a component performance degradation or failure condition
Spark plug wires(secondary leads) & primary wiring: - must not contact sharp surface - must not be under tension between fixed points - must be clear of moving parts (belts, fan, etc...) - must be protected from or kept at least 125 mm away from radiant heat source exceeding 400 F. - must be protected from environmental damage (dirt, splash, oils, fluids, etc....) - must be retained, secured or insulated to prevent pinching, mis-routing, rattles, and squeaks	- Spark plug wires carry very high voltage (30,000 volt). If the secondary lead loses its dielectric characteristics thru being nicked, cut , chaffed, then an arc thru to a near by ground could take place. This kind of condition could lead to misfire, no start, or premature failure of ignition system.
Adequate clearance between ignition system and the engine lift hooks and/or the vehicle engine compartment should be maintained.	This is to prevent damage to the ignition system.
Never apply voltage to the ignition system other than vehicle system voltage for testing purposes.	This can cause reduced performance or an electrical malfunction of the ignition system.
Not all fasteners are designed for repeat use. Beware of fastener specifications.	Adequate retention force might not be achieved if the fastener is not designed to be reused.
All harnesses should be supported within 6" of a mating connection.	Mating connections are not designed to support the weight of the harness assembly.
Do not use high impact tools to apply the spark plug boot to the ignition secondary towers. Installation of the high voltage secondary leads by hand is preferred.	Damage to the coil tower, secondary boot, or mating connection surfaces might occur.

For removing spark plugs follow the following steps: 1- Grasp the spark plug boot and gently rotate 90°; and then pull the spark plug boot and cable away from the spark	To remove spark plugs from Aluminum heads, allow the engine to cool. The heat of the engine, in combination with a spark plug that is still hot, may cause the spark plug threads to strip the cylinder head
---	--

<p>plug</p> <p>2- Before removing spark plug, brush or air blast dirt away from the well areas</p> <p>3- Use correct size deep socket wrench to loosen each spark plug one or two turns</p>	<p>upon removal</p> <p>Use goggles to protect eyes from dirt when applying compressed air to spark plug wells</p>
<p>Cleaning a spark plug could be done as follow:</p> <p>1- wipe all spark plug surfaces clean...remove oil, water, dirt and moist residues.</p> <p>2- If the firing end of spark plug has oily or wet deposit, brush the spark plug in an approved, non-flammable and non-toxic solvent. Then dry the spark plug thoroughly with compressed air</p> <p>3- Use a propane torch to dry wet-fuel fouled plugs. Allow the torch flame to enter up the center electrode insulator. Allow plug to cool down</p> <p>4- If the spark plug threads have carbon &amp; scale deposits, clean with wire brush, taking care not to injure the electrode or the insulator tip</p>	<ul style="list-style-type: none"> <li>- Cleaning a spark plug will reduce the voltage required for an electrical arc(spark) across the electrodes</li> <li>- Cleaning &amp; re-gapping will not restore a used spark plug to a new condition. It may be more economical and efficient to replace used spark plugs with new plugs instead of cleaning.</li> <li>- Sooted plugs should be replaced</li> <li>- Do not cool by using water or any liquid</li> <li>- Clean threads permit easier installation and proper seating which will maximize transfer heat away from the plug</li> </ul>
<p>Regap spark plugs to the exact measurement specified by the engine manufacturer to keep the best fuel economy and proper engine performance</p> <ul style="list-style-type: none"> <li>- Use round wire-type gauge for an accurate measure of gap on all used spark plugs</li> <li>- when gapping a spark plug only the side electrode is moved. The center electrode must not be moved</li> </ul>	<ul style="list-style-type: none"> <li>- Too wide a gap could cause the plug to misfire(higher required ignition voltage).</li> <li>- Too narrow of a gap could affect idle stability</li> <li>- A flat gauge can't accurately measure the spark plug on used plugs</li> </ul>
<p>When replacing spark plugs with new ones, always use equivalent plugs with same heat range, thread, size, etc....</p>	<ul style="list-style-type: none"> <li>- Higher heat range plug(hotter plug) could lead to pre-ignition &amp; possible piston damage</li> <li>- Lower heat range (colder plug) could lead to cold fouling &amp; emission problem</li> </ul>
<p>For installing spark plugs follow the following steps:</p> <p>1- make sure the cylinder head threads and spark plug threads are clean. Make sure the spark plug thread is free of dings and burrs. If necessary, use a thread chaser and seat cleaning tool.</p> <p>2- Make sure the spark plug gasket seat is clean, then thread the gasket to fit flush against the gasket seat. Tapered seat plugs do not require gaskets</p> <p>3- Screw the spark plugs finger-tight into the cylinder head. Then, use a torque wrench to tighten spark plugs following manufacturer's recommendation).</p> <p>Torque is different for various plug type &amp; cyl head mtrl</p>	<ul style="list-style-type: none"> <li>- If the thread is damage, it prevents a good heat transform from the shell to the cylinder head</li> <li>- Do not use any type of anti-seize compound on spark plug threads. Doing this will decrease the amount of friction between the threads. The result of the lowered friction is that when the spark plug is torqued to the proper specification, the spark plug is turned too far into the cylinder head. This increases the likelihood of pulling or stripping the threads in the cylinder head</li> <li>- Over-tightening of a spark plug can cause stretching of the spark plug shell and could allow blowby to pass thru the gasket seal between the shell and insulator. Over-tightening also results in extremely difficult removal</li> </ul>
<p>When using <b>vehicle instrumentation</b> (MDS, ETAS, etc...) use coil &amp; integrated driver in one package. If you are using a coil by its self without the driver, it is highly recommended to use a driver that could be mounted close to the coil area. Especially if the driver is in the ECM, and the ECM is placed in the trunk.</p> <ul style="list-style-type: none"> <li>- Always use the correct dwell table for the coil.</li> <li>- Never use old dwell table without verification</li> </ul>	<ul style="list-style-type: none"> <li>- The C- lead that goes from the coil primary coil to the driver could have 200 – 300 peak voltage. This spike due to the primary reflected voltage (a normal characteristics of any ignition coil). This 200 some voltage could be picked up by any near by pick up coil (crank sensor, etc..). it could also induce unnecessary pulse / noise that could lead to a no start condition</li> <li>- Dwell values to be obtained from the ignition application engineer</li> </ul>
<p>When using <b>Ion Sense ignition system</b>. Special attention should be paid to system and circuit grounding. Sec lines should be shielded</p>	<ul style="list-style-type: none"> <li>- Shielded leads add capacitance to the secondary circuit</li> <li>- Noise can be coupled into the amplifier in the ECM</li> <li>- SEC lines are sensitive to external noise.</li> </ul>

### **6.1.1 Product Packaging and Shipping**

The type of dunnage, whether it is to be returnable or disposable, is designed for each product and tailored to meet both the customer and suppliers manufacturing facilities requirements. If required, Delphi can provide the dunnage design, source, and validation.





# 7. 0 Recommendations and Precautions

---

The following tests are required to ensure the ignition system not only meets the needs of the application, but that the application does not subject the ignition system to operating parameters outside its designed capabilities. The tests can be tailored to meet individual customer needs. As to who actually runs the tests needs to be agreed to by the customer and the Delphi-E Application Engineer. In some cases, the customer can run a particular test or series of tests in conjunction with other required vehicle tests. In the case of customer conducted tests, the Delphi-E Application Engineer will provide ignition components suitable for testing and offer direction as to the type of test data required. In the case of Delphi-E conducting the tests, test vehicles need to be procured for testing purposes.

It is important to note that engine vibration levels, operating temperatures, and electrical load characteristics can affect ignition system performance. Vehicles used for testing need to mirror the final production version as closely as possible with particular emphasis on wiring harness routings, system loads (i.e., air conditioning, fuel injectors, power windows, rear window defogger, windshield wipers, etc.), and body fascias (i.e., air dams, scoops, spoilers, rock shields, splash guards, etc.) which affect underhood air flow. Any modifications or additions to the vehicle, once the ignition system application has been validated, need to be brought to the attention of the Delphi-E Application Engineer for consideration of possible affect on the ignition system performance.

## 7.1 Vibration

Vibration data is recorded on the ignition component at a location determined to be the most severe. Analysis of this data helps ensure the component is not subjected to vibration levels greater than the product is designed to withstand. It also aids the Product Design Engineers to determine if a design change is required. It can also be used to verify a particular mounting configuration or a mounting bracket's design integrity.

## 7.2 Temperature Profile

The temperature profile of the ignition component needs to be recorded to ensure the maximum level does not exceed the product's design capabilities. The way the test is conducted should be discussed with and agreed to by the Customer Release Engineer. In many cases, an established high temperature profile test procedure, which has been developed by the customer, may already exist. To obtain maximum conditions, the use of a vehicle towing dyno may be required. Testing should be conducted at high ambient temperature conditions, which is typically 90°F minimum.

Thermocouples need to be attached to the ignition component at various locations as directed by the Product Engineer. Additional thermocouples which record the following may also be desirable:

- Outside and underhood ambient temperatures
- Ignition component to vehicle mounting surface temperature
- Coolant in and out temperatures
- Engine and transmission oil temperatures

### 7.3 Ignition High Voltage Requirements

To ensure the ignition system is delivering adequate secondary voltage across the spark plug gap to establish and maintain a burn condition in each of the cylinders, a secondary high voltage availability versus spark plug requirements study needs to be conducted. These tests need to be performed at nominal ambient as well as cold ambient temperatures. These tests can be conducted on an engine mounted on a dynamometer. However, vehicle level testing ultimately needs to be conducted to ensure production vehicle operating and load conditions are factored into the test. A series of documented procedures are as follows. They are Delphi-E proprietary in nature and can be modified to meet individual customer needs.

<u>Procedure #</u>	<u>Procedure Title</u>
DR-IT001	Secondary High Voltage Availability and requirements at the input of the Spark Plug, Direct Ignition System, Vehicle Level/ Engine Level Test
DR-IT003	Secondary High Voltage Availability and requirements at the input of the Spark Plug, Distributor Ignition System, Vehicle Level/Engine Level Test
DR-IT005	Secondary High Voltage Availability and requirements at the input of the Spark Plug, Coil At/Near Spark Plug Ignition System, Vehicle Level/Engine Level Test
DR-IT007	Secondary High Voltage Availability and requirements at the input of the Spark Plug at cold temperatures during cranking and starting, Vehicle Level/Engine Level Test

## 7.4 Spark Energy

To determine the amount of spark energy being delivered by the ignition system to the plug gap. Laboratory procedures have been written which describe how the test is to be conducted. These are Delphi-E proprietary in nature and can be modified to meet individual customer needs. Testing can be conducted on an engine mounted on a dynamometer. However, vehicle level testing ultimately needs to be conducted to ensure production vehicle operating and load conditions are factored into the test. A series of documented procedures are as follows. As a part of calculating the energy in the plug gap, the spark plug resistance needs to be factored in. A procedure for measuring plug resistance is also listed.

<u>Procedure #</u>	<u>Procedure Title</u>
DR-IT002	Ignition System Secondary Energy Evaluation, Direct Ignition System, using Digital Signal Acquisition Equipment
DR-IT004	Ignition System Secondary Energy Evaluation, Distributor/High Voltage Switch type Ignition System, using Digital Signal Acquisition Equipment
DR-IT006	Ignition System Secondary Energy Evaluation, Coil At/Near Plug type Ignition System, using Digital Signal Acquisition Equipment
DR-IT011	Measurement of Spark Plug Resistance at 50 mA using a Tektronix Model 577 Curve Tracer

## **7.5 Spark Energy Versus Engine Energy Requirements (Programmable Spark Energy)**

It is possible that the customer may require the ignition system to deliver varying levels of spark energy based on the engine's needs. When varying the delivered energy, the energy requirements of the engine at varying loads, idle stability, and determining the amount of allowable EGR dilution must be determined. The Delphi-E Application Engineer with input from the Delphi-E Product and Test Engineering Groups will suggest a test plan to the customer. Some of the Spark Energy test procedures previously outlined may be included as part of this test plan.

## **7.6 Electro-Magnetic Compatibility (EMC)**

The ignition system is not only a potential EMC source but its operation can be affected by EMI generated by other sources. Therefore, component and vehicle level tests need to be conducted. Component level testing can be run at the appropriate Delphi facility, whereas the vehicle level tests need to be conducted at a test facility designed for EMC testing. These tests should be conducted per the GM proprietary GM9110 procedure or the SAE/ISO Specifications. When tailoring EMC testing to meet specific customer requirements, the Delphi-E Application and Product Engineering Test Groups should be consulted.



# 8. 0 Testing Recommendations and Precautions

---

Every vehicle/engine manufacturer has a developed set of standard test procedures for component validation. Since most are unique and proprietary to the manufacturing company, there will not be an attempt to list them all here. Instead, some general examples specific to ignition systems are provided.

## 8.1 Dynamometer Testing

It is critically important that the Ignition Systems be tested under conditions that approximate normal operating conditions to ensure that spark is accurate. A dynamometer is an ideal facility to set steady state engine conditions for evaluation. The following are a few topics that are important to investigate.

### 8.1.1 Cylinder-to-Cylinder Distribution

Cylinder-to-cylinder spark distribution should be tested in a dynamometer environment. Thermocouples should be inserted into each exhaust port so temperature can be monitored, along with air/fuel ratio, HC and emission variation.

## 8.2 Durability Testing

Durability tests are performed in an application environment and conditions need to be specified by the manufacturer (i.e., on vehicles). In addition, Delphi-E conducts generic bench durability testing to determine ignition system useful life.

## 8.3 Dynamic Vehicle Testing

Dynamic Vehicle Testing is conducted at the vehicle assembly plant and should be performed to the same specifications that are used when the vehicle is calibrated. Any change in tolerance requirements should be reviewed with the Delphi-E Application Engineer.

## 8.4 Standard Vehicle Development Tests

This section contains an overview of a number of recommended development tests that should be conducted during the vehicle development process to determine calibrations and or conformance to requirements. This manual provides rough guidelines only, as procedures vary from manufacturer to manufacturer.

### 8.4.1 Cold Driveability and Startability

The purpose of cold driveability and startability testing is to determine the affects of extreme low ambient conditions on vehicle driveability and startability. Tests typically consist of a prep of the vehicle to stabilize temperatures followed by a 6 to 8 hour soak. After the soak the vehicle is started and driven away, and the performance compared to baseline results. Temperatures for testing are typically less than -20°F, and the test should be done using high RVP fuel in the 12 to 15 PSI range. Temperatures, pressures and engine control parameters should be recorded during testing to assure consistency and for a record of results.

### 8.4.2 Altitude Driveability and Emissions

It is necessary to verify emissions and driveability at altitude as well as sea level during the development process. In addition to emissions, driveability would consist of cold starts, hot starts, gradeability, etc. Temperatures, pressures, and engine control parameters should always be recorded.

### 8.4.3 Driveability Index Fuel Sensitivity

In addition to the normal cold start testing, it is necessary to verify calibration sensitivity to high driveability index (DI) fuels. Driveability index is a measure of the distillation curve, and is somewhat independent of the RVP of the fuel. High DI fuel typically result in sags and stalls during warm up as a result of leaner operation due to less evaporation of the fuel. Normal cold start procedures would be used for evaluation.



#### **8.4.4 Spark Plug Fouling Tests**

Spark plug fouling tests are conducted to verify the calibrations robustness to short start and run cycles at low ambient temperatures. These are conditions that might be experienced on a new car dealer lot, or by someone driving short distances in the winter. In either case, the vehicle is not allowed to fully warm up and stabilize between soaks and starts. Testing consists of soaks, starts, and short drives at a low ambient temperature, typically -20°F.

#### **8.4.5 Voltage Sensitivity**

This testing would verify on the vehicle the voltage correction tables previously developed on the dynamometer. This should be done with characterized ignition systems. System voltage would be varied, and long and short term correction factors monitored.

#### **8.4.6 Standard Durability Tests**

These are vehicle manufacturer specific, but would typically include tests such as: rapid mileage accumulation, salt spray, water intrusion, rough roads, high speed, taxi fleets, etc.



# 9. 0 Validation Requirements

---

## 9.1 General

This section outlines the validation requirements for Ignition Systems.

Validation is the process whereby the components and/or system are evaluated through methods of testing, analysis, inspection, and/or demonstration, to ensure that the component/system meets the specified quality/reliability/durability goals and conforms to governmental standards/requirements. The evaluation aims to verify the design, manufacturing, and usage of the component/system.

The validation process could entail various types of evaluation based on three levels – component, system, and vehicle. The component Design Failure Mode and Effects Analysis (DFMEA) and System Failure Mode and Effects Analysis (SFMEA) should be used to pinpoint component/system strengths, weaknesses, and possible failure modes, relative to actual vehicle operation. Laboratory tests (arranged in a synergistic manner) can be used in evaluating component and/or system conformance to Quality Requirements Document (QRD) performance goals and government standards. Delphi-E schedules and past experience, along with field/road tests, are procedures used to provide validation data for the component/system/vehicle relative to the “overall” package. Evaluation of limit parts is crucial and will enhance comprehension of the scope of ignition component performance under all conditions.

## Environmental Conditions

The Ignition Systems are designed to operate in a certain range of conditions but can withstand extreme operating conditions, for short periods of time. The following are typical examples of normal operating conditions.

Ambient air temperature	-29 to +49°C
Underbody air temperature	-29 to +90°C
Underhood air temperature	-29 to +121°C
Relative humidity	0 to 100% @ 40°C
Barometric pressure	65 to 105 kPa
Ignition control module temperature	-40 to +65°C
Engine intake manifold pressure	15 to 105 kPa
Air flow	0 to 0.15 velocity ratio or 1/7 of the free stream velocity

Table 9-1. Operating Conditions.

**Note:** Underhood air flow is a very complex phenomenon. The air velocity at a specific point in a given platform can vary depending on the specific powertrain, vehicle velocity, temperature, option content, etc. The velocity ratio is defined as the ratio of the air velocity at a specific point relative to the free stream velocity or vehicle speed. In order to quantify the underhood velocity profile with any accuracy, complete vehicles and/or test bucks are required for wind tunnel testing.

## Environmental Exposure

The Ignition Systems meet performance and physical requirements for environmental conditions they may be exposed to, as defined by Delphi-E Validation Plans. The ignition system is compatible with specifications for:

Dust	Humidity	Pressure	Temperature
Salt Spray	Contamination	Vibration	Fuel Compatibility

## 9.2 Verification

A validation matrix has been compiled which contains Ignition Systems Requirements addressed in the Specific Component Requirements Document. The matrix shows these requirements with a corresponding method of evaluation and the respective responsibility level for performing the validation process. The matrix should be used as a guideline when setting up a complete validation analysis.

## 9.3 Validation Test Descriptions

### 9.3.1 Vibration

The vibration levels the ignition product are subjected to need to be verified. The levels for the three-axis, x-y-z, are recorded at both the product and the product mounting locations. The vibration profile is stored on a VCR tape recorder in conjunction with a tri-axis sensor. Analysis of this data helps ensure the component is not subjected to vibration levels greater than the product is designed to withstand. It also aids the Product Design Engineers to determine if a design change is required. It can also be used to verify a particular mounting configuration or a mounting bracket's design integrity.

### 9.3.2 Temperature Profile

Thermocouples are attached to the ignition product at various locations as directed by the Product Engineer. Additional thermocouples which record outside and underhood ambient temperatures, ignition product to application mounting interface surface temperatures, coolant in and out temperatures, plus any additional relevant temperatures need to be installed on the application.

The way the test is conducted should be discussed with and agreed to by the Customer Release Engineer.

### 9.3.3 Spark Plug Ignition Voltage Requirements

The voltage required to break down and sustain a voltage arc across the spark plug gap needs to be determined during normal operating and cold cranking temperatures.

### 9.3.4 Delivered Spark Energy Versus Actual Required Spark Energy

It is possible that the customer may require the ignition system to deliver varying levels of spark energy based on the engine's needs. When varying the delivered energy, the energy requirements of the engine at varying loads, idle stability, and determining the amount of allowable EGR dilution must be determined. The Delphi-E Application Engineer with input from the Delphi-E Product and Test Engineering Groups will suggest a test plan to the customer. Some of the Spark Energy test procedures previously outlined may be included as part of this test plan.

## 9.4 Ignition System Validation Testing Recommendations

The parameters each of the tests can be tailored to meet the customers requirements. These parameters include number of samples tested, length of test, temperatures the samples are subjected to, and the profile for vibration and thermal cycle tests. Pre and post test component performance data would also be recorded as specified.

### 9.4.1 High Temperature Operation

Parts typically operated in an ambient temperature of 125°C, or customer specified temperature, which resulted in an approximate baseplate temperature of 136°C. The test duration is 500 hours. Actual specifications are defined by customer.

### 9.4.2 Salt (Fog) Spray

Samples subjected to salt fog storage and drying intervals as outlined in the applied specifications. Parts were under continuous operation during the salt fog storage and were unpowered during the drying times. The quantity and orientation of the units under test will be agreed to with the customer.

### 9.4.3 Vibration

A sine on random vibration profile is used to represent the engine-mounted application. Typically 4 units are subjected to 40 hours of this profile per the three axis. The ignition units are performance tested both pre and post durability.

### 9.4.4 Impact Shock

Typically two units are subjected to shock impact testing for both directions on all three mutually perpendicular axes. The height the test is conducted at, is to be mutually agreed to with the customer. The units are performance tested both pre

and post durability. Comments on physical condition are also recorded.

#### **9.4.5 Thermal Cycle**

Samples are typically subjected to temperature ranges of  $-40^{\circ}\text{C}$  to  $125^{\circ}$ , or customer specified temperature, operating using 45-minute ramps. 2 hours cold, 2 hours hot, 2 hours cold, 15 hours hot for ten days. The units are performance tested both pre and post durability. The quantity and orientation of the units under test will be agreed to with the customer.

#### **9.4.6 Thermal Shock**

Samples are typically subjected to temperature ranges of  $-40^{\circ}\text{C}$  to  $140^{\circ}\text{C}$ , or customer specified temperature, operating during cold soaks using 15-minute ramps. 2 hours cold, 2 hours hot for ten days. The units are performance tested both pre and post durability. The quantity and orientation of the units under test will be agreed to with the customer.

#### **9.4.7 Storage Temperature**

Samples are typically stored for 24 hours at  $-40^{\circ}\text{C}$  and  $155^{\circ}\text{C}$ . The units are performance tested both pre and post durability. The quantity and orientation of the units under test will be agreed to with the customer.

#### **9.4.8 Humidity**

$40^{\circ}\text{C}$  at 100% relative humidity, operating for 3 days. The units are performance tested both pre and post durability. The quantity and orientation of the units under test will be agreed to with the customer.

#### **9.4.9 Drop**

Dropped using various customer specified orientations from 1 meter onto a concrete floor. All sustained obvious damage which waives them from failure for any electrical criteria.

#### **9.4.10 Reverse Voltage**

-5.0 V for 60 seconds at room temperature, then with parts soaked at  $-40^{\circ}\text{C}$ . Optional -12 V operation available.

#### **9.4.11 Jump Start**

60 seconds operating at 24 V, 500 rpm, and 1.3 ms on time at room temperature, then repeated with parts soaked at  $-40^{\circ}\text{C}$ .

#### **9.4.12 Load Dump**

Samples subjected to repeated pulses of waveshape outlined in specification.

Ten pulses applied 5 seconds apart at room temperature, then repeated with parts soaked at 40°C.

### 9.4.13 Transients

Samples subjected to repeated pulses of waveshape outlined in specification. Ten pulses applied 1 second apart at room temperature, then repeated with parts soaked at 40°C.

### 9.4.14 Open Secondary

Each high voltage terminal run for 10 minutes at room temperature into a 50 pF load at 14.0 V, 2000 rpm, and 3.9 ms on time.

### 9.4.15 Fluid Compatibility

The ignition system is designed to maintain its package integrity when exposed to various fluids. Typically the ignition system is temperature stabilized at 100°C, then immersed in each of the fluids for a minimum of 30 seconds. The fluids are to be at 25°C unless otherwise specified. After being air dried at room temperature for approximately 1 hour, the ignition system electrical performance shall meet its designed parameters:

- Gasoline (leaded/unleaded/alcohol additive)
- Engine coolant
- Windshield Washer Fluid
- Transmission Fluid
- Brake Fluid
- Car Wash Detergent
- Engine Degreaser
- Engine Cleaner
- Choke Cleaner
- Heat Valve Lubricant



# 10. 0 Appendix

## 10.1 Initial Customer Contact Checklist

Customer: Customer Contact Name: Revision Date: Project Number: Application Engineer:					
DELPHI -E Contacts					
	Name			Phone	
Delphi-E Marketing Manager					
Delphi-E Account Manager					
Delphi-E Application Engineer					
Delphi-E Program Manager					
Customer Contacts					
	Name	Position	Phone		
Engineering					
Purchasing					
Other					
Program Definition					
Program Description					
Reason for Initiating Program					
Model Year					
Life Cycle					
Model Year					
Volume					
Platform(s)					
Powertrain(s)					
Program Timing					
	Date		Quantity		
Mule Samples					
Alpha Samples					
Beta Samples					
Prototype Samples					
GP3 Samples					
Pilot					
SOP - Engine					
Sourcing Date					
Competitive Data					
Potential Competitors	Component / System		Price		

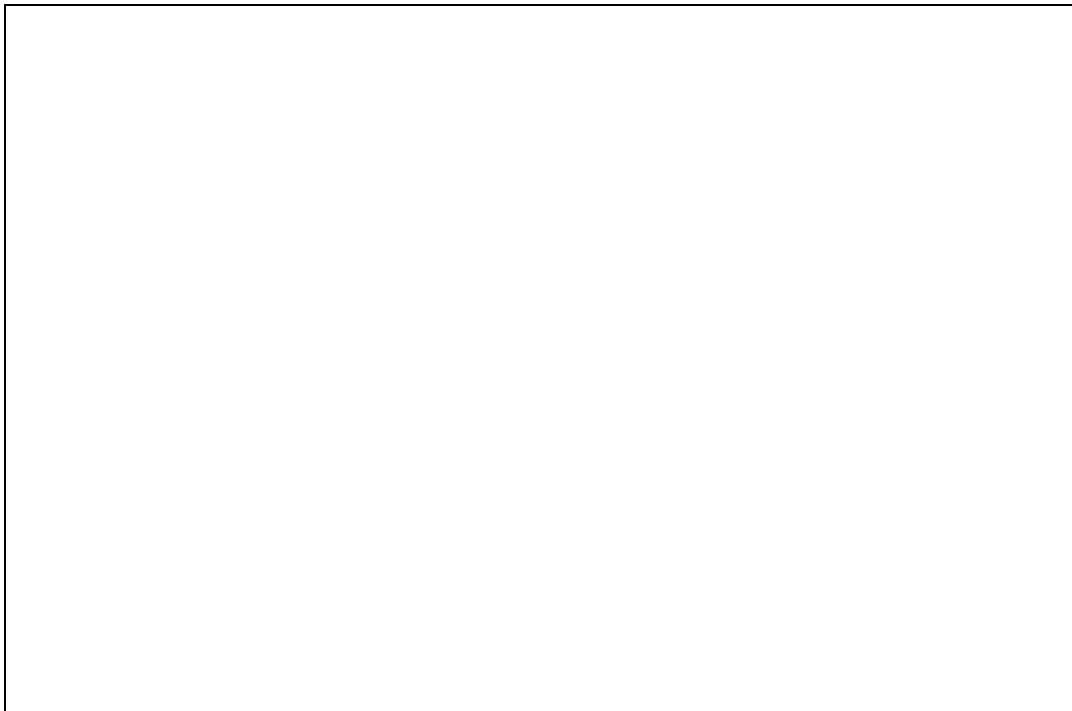
Customer:		
Customer Contact Name:		
Revision Date:		
Project Number:		
Application Engineer:		
Engine Information		
Item	Definition	Data
Number of Cylinders	#	
Valves	# per cyl.	
Displacement	(CC)	
Engine Family	R.P.O. code	
Engine Type	# cycles (2 or 4)	
Maximum RPM	#	
Min. Cold Crank	#	
Speed		
Compression Ratio		
Engine Configuration	V or In-line	
Spark Plug Location		
Turbocharged / Supercharged	Y or N	
Fuel Delivery	Source	
Fuel Type Used	Lead / Alcohol	
Firing Order		
Emission Level		
PCM/ ECU Information		
Item	Definition	Data
PCM Family / Type	Supplier/Part #	
Input Requirements	Digital / Analog	
Diagnostic Requirements	Type	
EST'S available	# & Polarity	
Max. allowed primary current	Driver Capability	
Decodes Position Sensors		
Misfire Detection	Type/Method	
Integrated Drivers	Y or N (quantity)	
Drivers Clamp voltage (range)	If drivers in PCM	
Min EST output voltage	V @ mA	
Environmental		
Item	Definition	Data
Customer Spec. #	#	
Min/Max Continuous Temp.	° C	
Max Excursion Temp.	° C	
Splash Level	(submerge or not)	
Corrosion Requirements		
Vibration Level		

Underhood Airflow Expected		
Ignition System Information		
Item	Definition	Data
Model #		
Reason for New System		
System Type Desired		
Sealing Requirements	Type	
RFI Suppression Requirements		
Trademark	Cust /None/ Delphi	
Ignition System Information (continued)		
Item	Definition	Data
Durability	Miles / Yrs.	
Current Limit Req'd		
Secondary Tower Type		
Bypass Spark Req'd	Y / N	
Mounting/Pkg. Constraints		
Bypass Curve or Fixed Adv.		
Oil Pump Drive Req'd	Y or N	
Serviceability – Coils / Electrncs	Y or N	
CPA required	Y or N	
Spark Plug Information		
Item	Definition	Data
Part #/Source if Current		
Spark Plug Type	Part Available?	
Plug electrodes shape & type (double pads, 1 pad, precious metal, etc.)	Center Electrode type Platinum or Iridium	
Spark Plug Resistance	Ohms + & - / length	
Spark Plug Gap	mm	
Insulator Ribs or Coating	Y / N	
Plug Cable Type	Resistance	
Spark Plug well mat'l (pencil coil application)	Steel, Alum. or Composite	
Coil Information		
Item	Definition	Data
Type of desired coil	CNP, PTC, pencil, etc.	
Coil output type	1(+, -), or 2(-)	
Coils/Drivers Integrated	Y or N	
Programmable Energy	Y or N	
Mounting bolt	Captured? / thd size	

Primary Connector (# of pin)	Source / Part #					
<b>Coil Design (Detail)</b> Gather the following information at Crank Speed:						
	Room Temperature		Max. Temperature		Min. Temperature	
	Kv.	Energy	Kv.	Energy	Kv.	Energy
6V.						
7V.						
8V.						
9V.						
10V.						
11V.						
12V.						
13V.						
14V.						
Gather the following information at 14 V.:						
	Room Temperature		Max. Temperature		Min. Temperature	
	Kv.	Energy	Kv.	Energy	Kv.	Energy
1000 RPM						
2000 RPM						
3000 RPM						
4000 RPM						
5000 RPM						
6000 RPM						
7000 RPM						
Coil Information (continued)						
<b>Item</b>	<b>Definition</b>	<b>Data</b>				
Constraints on Ø, length or weight						
Ign. on make voltage max. @ what Vsys.						
Mounting Interface Engine Gnd.	Y or N					
Max. Cross Couple Limits						
Spark Duration	mSec					
Access to Secondary	Y or N					
Max. peak Sec Current						
Coil Electronics						
<b>Item</b>	<b>Definition</b>	<b>Data</b>				
Total Series Resistance(driver, wiring, connections)	Ohms					
Soft Shut Down	Y or N					
Soft phase turn-on (replace diode)	Y or N					
Time Out (Y / N)	mSec					
<b>Coil Driver in PCM (Detail)</b>						
Range of Clamp Voltage	V					
Range of Current Limit						

Power Dissipation Concerns		
Ability to overlap dwell		
Saturation Characteristics		
Reverse Voltage: Max Current for reverse voltage period	I / t	
Blocked by Driver		
Blocked by Coil		
<b>DELPHI Coil Driver (Detail):</b>		
Overlap capability		
Max. Peak Primary current		
PCM always under dwell control	Y or N	
<b>Type of interface to PCM</b>		
1. Voltage Signal		
Input impedance range		
positive threshold range		
negative threshold range		
hysteresis minimum		
2. Current Signal		
Range of current supplied vs. temp. @ expected input impedance.		
Mounting (Heat transfer method)		
Fastened to "heatsink"-conduction		
"free standing"-convection		
<b>Other Functions</b>		
<b>Item</b>	<b>Definition</b>	<b>Data</b>
Ion Sense (Knock, mis-fire, etc.)	Y or N	
Compression Sense	Y or N	
Cylinder Present	Y or N	
Other		
<b>Crank Sensor Information</b>		
<b>Item</b>	<b>Definition</b>	<b>Data</b>
Part #/Source if Current		
Crank Sensor Resolution		
Valid Ref. Signal Within		
Analog/Digital Crank		
<b>Cam Sensor Information</b>		
<b>Item</b>	<b>Definition</b>	<b>Data</b>
Part #/Source if Current		
Cam Sensor Resolution/Coding		
Analog/Digital cam signal		

System Mechanization





## Technical Glossary of Terms and Abbreviations

Abbreviations are listed below in alphabetical order with an explanation of the abbreviation. There are some variations in the use of periods and in capitalization (such as mph, m.p.h., Mph, and MPH) for abbreviations, but all types are acceptable.

**A/C** - Air Conditioner

**A.C. - Alternating Current** - An electronic current that is constantly changing polarity from positive to negative and back again.

**A/F** - Air/Fuel

**BTDC** - Before Top Dead Center

**C<sup>3</sup>I Computer Controlled Coil Ignition** - (Used on 3.0L, 3.8L, 3.8L turbo, 3300 and 3800 engines) Produces the ignition spark without the aid of an ignition distributor.

**Conventional Theory** - The flow of current in an electrical circuit in which direction is from positive to negative.

**CCW** - Counter-clockwise

**CKP** - Crankshaft Position Sensor

**C/L** - Closed-Loop

**CMP** - Camshaft Position Sensor

**CW** - Clockwise

**D.C. - Direct Current** - An electrical current which flows in one direction only.

**DLC** - Data Link Connector

**DFCO** - Decel Fuel Cut Off

**DFMEA** - Design Failure Mode Effects Analysis

**Digital Signal** - An electrical signal that is either ON or OFF, High or Low, or 1 or 0. Only two states of logic are detected.

**DIS - Direct Ignition System** - (Used on 2.0L, 2.5L, 2.8L and 3.1L engines) Produces the ignition spark without the aid of an ignition distributor.



**DIS - Distributorless Ignition System** - A generic description for any ignition system that produces ignition spark without the aid of an ignition distributor.

**Duty Cycle** - The relative amount of circuit on time (usually expressed in percent).

**DVOM (10 Meg.)** - Digital volt-ohmmeter with a minimum of 10 million ohms resistance. Allows measurement of values in a circuit without affecting circuit operation.

**DVT** - Dynamic Vehicle Testing

**Dwell** - The amount of time (recorded on a dwell meter in degrees) that current passes through a closed switch; for example, ignition contact points or internal switches in an electronic control module.

**ECM - Engine Control Module** - A microprocessor-based device which contains electronic circuitry to control and monitor air/fuel and emission systems, and aid in diagnostics.

**ECT** - Engine Coolant Temperature

**EGR** - Exhaust Gas Recirculation

**EIP** - External Ignition Protection

**EMC** - Electro Magnetic Compatibility

**EMI - Electromagnetic Interference or Noise** - An unwanted signal interfering with another needed signal, like an electric razor upsets a television picture, or driving under high-voltage power lines upsets the AM radio in a car.

**ERPM** - Engine Revolutions Per Minute

**ESC - Electronic Spark Control** - Used to retard spark advance if detonation occurs.

**EST - Electronic Spark Timing** - ECM-controlled timing of ignition spark.

**Ferrous** - A metal which responds to the influence of a magnetic field.

**Ground** - A reference point from which voltage measurements may be made. Also, a return path for current flow back to the source.

**HEI - High-Energy Ignition Distributor** - A Delphi E ignition distributor that uses an electronic module and pickup coil in place of contact points, and is capable of producing secondary output of 40,000 volts.

**High** - A voltage greater than ground or zero, like the output wire of an oxygen sensor is called O2 High, as compared to the ground which is called O2 Low. In digital signals, High is ON and Low is OFF.

**High-Impedance Voltmeter** - Has high opposition to the flow of electrical current. Good for reading circuits with low current flow, such as those found in electronic systems.

**HVS** - High Voltage Switch Distributor

**IAC** - Idle Air Control

**IAT** - Intake Air Temperature

**IC** - Ignition Control

**ICE** - Integrated Coil and Electronics

**IDI - Integrated Direct Ignition** - (Used on 2.3L Quad 4 engine) Produces the ignition spark without the aid of an ignition distributor.

**IGN** - Ignition

**Induction** - The establishment of an electric charge or a magnetic field in a substance by the proximity of an electrified source, a magnet or magnetic field.

**Ion Sense Ignition** – An Ignition system capable of electronically biasing the spark plug gap after the plug has fired in order to measure engine characteristics such as combustion quality and knock.

**Ionization** - The state of an insulator which allows the passage of current due to the presence of charged particles.

**kV - Kilo Volt** - Equal to 1,000 volts.

**MAF** - Mass Air Flow

**MAP** - Manifold Absolute Pressure

**MIL** - Malfunction Indicator Lamp

**Mode** - A state of operation (i.e., open loop vs. closed-loop).

**MFI - Multi-Port Fuel Injection** - Individual injectors for each cylinder are mounted in the intake manifold. The injectors are pulsed in groups rather than individually.

**MPFI** - Multi-Port Fuel Injection

**Multi-Meter** - A test instrument with suitable switching facilities to measure voltage, current, and resistance. Also called a volt-ohm-millimeter.

**NO<sub>x</sub>** - Oxides of Nitrogen

**OBD II** - On-Board Diagnostics Generation II

**PAD** - Product Assembly Document

**Pencil Coil** – Ignition coil configured as a cylindrical shape to fit inside the spark plug well of a dual overhead cam engine. Also called Cigar coil and Plug Hole Coil (PHC).

**PFI** - Port Fuel Injection.

**PTC** – Plug Top Coil. Ignition coil mounted directly on top of the spark plug well of a dual overhead cam engine and using a boot with an internal spring connection to the spark plug.

**Pull Down** - Reference to grounding a voltage source in order to signal an event or control a device.

**Pull Up** - Reference to applying voltage to a device in order to signal an event or control that device.

**PWM** - Pulse-Width Modulation

**QA** - Quality Assurance

**Reluctor** - Any device that causes a change in reluctance of a material to pass magnetic lines of force.

**Resistance** - The opposite to the flow of current.

**RF** - Radio Frequency

**RFI** - Radio Frequency Interference

**Saturation** - The state of a coil when current flow has reached the design maximum and the magnetic field has reached its maximum strength.

**SCR** - Specific Component Requirements

**SFI** - Sequential Fuel Injection

**SFMEA** - System Failure Mode Effects Analysis

**Square Wave** - An essentially square- or rectangular-shaped wave. A wave

that alternately assumes one of two fixed values with a negligible transition time between the two values.

**TCC** - Torque Converter Clutch

**T/C** - Thermocouple

**TDC - Top Dead Center** - Refers to piston position.

**TPI** - Tuned Port Injection

**TPS** - Throttle Position Sensor

**Transistor** - A semiconductor device that can control an electrical current by varying a smaller-base current. This device acts like a mechanical relay with a variable resistor at the points.

**VCM** - Vehicle Control Module

**Voltage Potential** - An electrical pressure that creates an imbalance of electrons between two points and is capable of producing a flow of current if a current path or circuit is provided.

**VSS** - Vehicle Speed Sensor





# 11. 0 Index

## A

Air Flow .....	9-2
Air Temperature	
Ambient .....	9-2
Underbody .....	9-2
Underhood .....	9-2
Air/Fuel Ratio	
Effects on Combustion .....	2-2
Altitude Driveability and Emissions .....	8-2
Appearance .....	3-2
Applicable Documents .....	1-7

## B

Barometric Pressure .....	9-2
Bypass Signal .....	5-2

## C

Calibration .....	1-3
Cam Position .....	3-28
Cam Signal .....	5-2
Camshaft Position Sensor .....	3-4
Carbon Monoxide (CO) Emissions .....	2-4
Caution .....	1-6
Classification .....	1-1
Closed-Loop .....	5-1
Control System .....	2-1
Cold Driveability and Startability .....	8-2
Combustion Mixtures .....	2-3
Commercial Considerations .....	1-2
Contamination .....	9-2
Control Algorithms .....	1-5, 5-1
Conventions Used in this Manual .....	1-6
Crank Signal .....	5-2
Crankshaft Reference Signal .....	5-3
Cylinder-to-Cylinder Distribution .....	8-1

## D

Delphi-E Engineering Specification .....	1-7
DFMEA .....	1-7, 9-1
Document Management .....	1-1
Document Release and Updates .....	1-1
Document Revision Procedure .....	1-2
Driveability Index Fuel Sensitivity .....	8-2
Dunnage .....	6-4
Durability Testing .....	8-1
Dust .....	9-2
Dynamic Vehicle Testing .....	8-1
Dynamometer .....	7-4, 8-1
Dynamometer Testing .....	8-1

## E

EGR .....	2-13
Electrical Interface .....	4-4
Electrical Specifications .....	1-4
Electromagnetic Compatibility .....	4-4
Electronic Spark Timing .....	3-2
Engine Combustion Fundamentals .....	2-2
Engine Controller .....	1-3, 2-1
Engine Intake Manifold Pressure .....	9-2
Environmental Conditions .....	9-2
Environmental Exposure .....	9-2
EST Signal .....	5-2
Event Cylinder .....	3-6
Exhaust Gas Recirculation .....	2-13
Exterior Outline .....	3-2

## F

Firing Order .....	3-7, 3-8
Fuel Atomization .....	2-16
Fuel Compatibility .....	9-2
Fuel Temperature .....	9-2
Fundamentals .....	2-1

## G

Gap Size .....	3-24
General Description .....	2-16
Government Documents .....	1-7

## H

Hall Effect .....	3-28
High Efficiency Spark Plugs .....	3-25
High Voltage Switch Cap .....	3-5
How this Manual is Arranged .....	1-4
Humidity .....	9-2
Hydrocarbon (HC) Emissions .....	2-4

**I**

Ignition Coil - Function .....	3-2
Ignition System .....	2-1
Ignition Systems	
P/N .....	1-7
Ignition Timing .....	2-16
Inductive Cable .....	3-31
Industry Documents .....	1-7
Interface	
Electrical .....	1-4
Mechanical .....	1-4, 4-2
Interfaces .....	4-1
Introduction .....	1-1
Ionization Current .....	3-20

**L**

Lean Mixtures .....	2-4
Locating the Ignition System .....	4-2

**M**

Magnetic Flux .....	2-7
Magnetic Lines .....	2-5
Mailing List .....	1-2
Misfire Detection .....	3-20

**N**

Nitrogen (NOx) Emissions .....	2-4
Note .....	1-6
NOx .....	2-13

**O**

OBD-II Diagnostic Procedures .....	1-7
Objectives of this Manual .....	1-3
Open-Loop .....	5-1
Order of Precedence .....	1-7
Oxides of Nitrogen .....	2-13

**P**

Physical Specifications .....	1-4
Powertrain Subsystems .....	4-1
Pressure .....	9-2
Product Description .....	3-1
Product Handling .....	6-1

**Q**

QRD .....	9-1
Quality Requirements Document .....	9-1
Quality/Reliability/Durability .....	9-1

**R**

RapidFire .....	3-25
Recommendations and Precautions .....	7-1
Relative Humidity .....	9-2
Reluctor Wheel .....	3-26
Rich Mixtures .....	2-4
Right Hand Rule .....	2-5
Road Splash .....	4-2
RVP Fuel .....	8-2

**S**

Salt Spray .....	9-2
Scope of Document .....	1-1
Secondary High Voltage Availability .....	7-3
SFMEA .....	1-7, 9-1
Software .....	1-3
Specific Component Requirements Document .....	9-3
Spectral Map .....	4-3
Stoichiometric .....	2-3
System Interface .....	4-1
Systems Design Engineer .....	4-2

**T**

Tach Signal .....	5-3
Target Wheel .....	3-27
Television Radio Suppression .....	3-31
Temperature .....	9-2
Testing .....	1-3
Testing Recommendations and Precautions .....	8-1
Tests	
Spark Plug Fouling .....	8-3
Standard Durability .....	8-3
Standard Vehicle Development .....	8-2
Thermocouples .....	7-2
TVRS .....	3-31

**V**

Validation .....	9-1
Validation Matrix .....	9-3
Validation Plan ACR #2066 .....	1-7
Validation Requirements .....	9-1
Vibration .....	9-2
Vibration Durability Requirements .....	4-2
Vibration Levels .....	4-2
Voltage Sensitivity .....	8-3

**W**

Warning .....	1-6
Waste Cylinder .....	3-6
Wire Routing .....	4-4