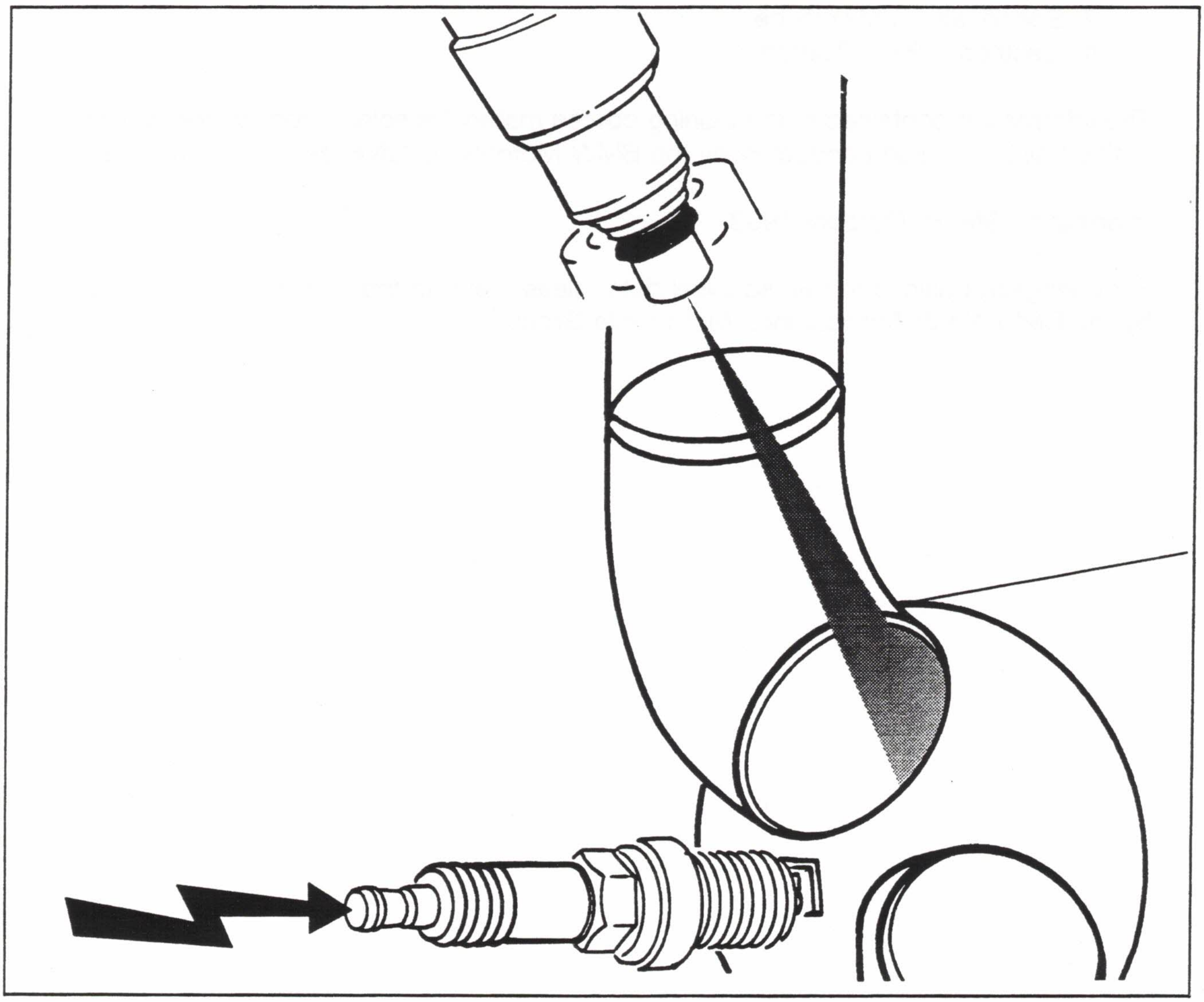
Level 2:

LE Jetronic

Training
Reference
Book



BMW of North America, Inc.
Motorcycle Service Department

Disclaimer

This training reference book is not intended to be a complete and all inclusive source for repair and maintenance data. It is only part of a training information system designed to assure that uniform procedures and information are presented to all participants at the BMW Motorcycle Service Training Center.

The technician must always refer to and adhere to the following official BMW service publications:

1. Service Information Bulletins
2. Repair Manuals/Microfiche
3. Specifications Microfiche
4. Electrical Wiring Diagrams

The information contained in the training course material is solely intended for participants in this training course conducted by the BMW Motorcycle Advanced Level Training.

Information Status, October 1993.

For changes/additions to the technical data, please refer to the current information issued by the BMW North Anerica, Inc., Motorcycle Group.

Contents

Introduction

Advantages of Electronically Controlled Fuel Injection Systems

Fuel Injection when compared to carburetor fuel systems, has many benefits and advantages.

Increased Fuel Economy

With a carburetor fuel system, the air fuel mixtures arriving at the individual cylinders is not metered as precisely as electronic fuel injection is.

Higher Horsepower Output

Electronic fuel injection systems allow optimum intake passage design due to the lack of a restrictive carburetor in the intake air stream. This allows for improved cylinder filling dynamics and provides higher torque.

Immediate Throttle Response

An electronically controlled fuel system responds to changing load conditions virtually without any lag because the injection valves inject fuel directly intake valves.

Improved Cold Start & Warm-up

Due to the precise metering of the fuel, with the consideration of electronic monitoring of engine temperature and engine cranking speed, start up and warm up periods are reduced. During warm-up the injection quantity will reduce based on engine temperature. The electronics can monitor this temperature and proportionally reduce the injected fuel amount. This results in smooth running and immediate throttle response.

Lower Exhaust Emissions

The concentration of exhaust pollutants is directly related to the air/fuel mixture being delivered for combustion. A carburetor has limitations to its mechanical mixture control. Electronically controlled fuel injection system's monitor the engines operating conditions and delivers only the required amount of fuel needed to meet the proper air fuel ratio.

Result: Lower exhaust emissions.

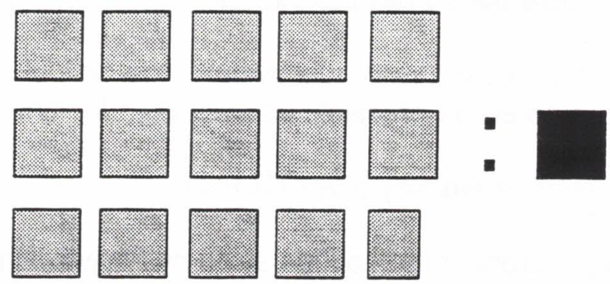
Basic Theory of Electronically Controlled Fuel Injection

Air/Fuel Mixture

The gasoline internal combustion engine inducts a mixture of gasoline and air. It mechanically compresses this mixture in a combustion chamber and ignites it to convert the energy contained in the fuel to a kinetic energy (mechanical movement).

Theoretically, the required air/fuel ratio for complete, efficient combustion is **14.7:1** by weight (stoichiometric ratio).

Complete combustion using this ratio in an engines combustion chamber is not possible. Engine speeds are to fast to allow for complete combustion to occur at 14.7:1.



STOICHIOMETRIC RATIO

For modern gasoline engines, minimum fuel consumption occurs at a ratio of 15..18 parts of air to one part of fuel (15...18:1). Because engines are operated most of the time at part load the ratio is calculated for lowest fuel consumption in this range. The span between 15 and 18 parts of air takes into account the engine's varying operating conditions such as:

- Cold Starting
- Post Starting
- Engine Warm Up
- Idling
- Accelerating
- Full Load

Electronic Control

Basically, the two electronic fuel injection system's covered in this course both maintain this air fuel ratio by electronically monitoring or calculating the engines:

- Inducted intake air volume
- Mechanical speed (RPM)

These two variables are the main basis for all calculations and control functions the fuel injection control unit will undertake to maintain the correct air/fuel ratio.

The fuel injection control unit continually compares these two variables to it's pre-programmed information (MAP). The MAP allocates an amount of fuel to correspond with:

- "X" (amount of air)
- "Y" (speed of engine)

It also accounts for minor correction factors (minor variables covered further on in this manual) that will increase or decrease the basic injection time "Ti" (length of time the control unit opens the fuel injector) ultimately effecting the air fuel ratio.

Model Coverage

BMW uses two electronically controlled fuel Injection system's: LE Jetronic and Motronic. The chart below will assist you in determining the type of fuel injection system found on the various motorcycle models.

MODEL	LE - JETRONIC	MOTRONIC
K 75's (ALL)	●	
K100's (ALL Except K100RS - 16 Valve)	●	
K1		● Version M2.1
K100 RS - 16 Valve		● Version M2.1
K1100 RS, LT		● Version M2.2
R1100 RS		● Version M2.2

R11S R12C K12 2.4

The following section will start the LE Jetronic system description. Motronic will be covered in the next manual.

MO 2.4 - has adaptation values - adjusts to rider input / riding style

after battery change - bike may not run quite normally

LE Jetronic System Overview

General

With the introduction of the 1985 K100, LE Jetronic made its debut. LE Jetronic was the first electronically controlled fuel injection system on a production U.S. market BMW Motorcycle.

The designation; **L =** "*Luft*" , the German word for air.
E = "*European*", first appeared in the European market
Jetronic = Trade name given to the system by the manufacturer; Bosch.

LE Jetronics primary functions are:

- Deliver filtered, metered fuel, proportional to measured intake air at specific engine speeds.

- Ignite the air/fuel mixture at precisely the right time to achieve optimum combustion.

The three elements needed for the LE Jetronic system to perform its primary functions are:

- **Air**
- **Fuel**
- **Electricity**

These three elements are measured (air), metered (fuel) and controlled or monitored (electronically) by LE Jetronic.

The controlled functions of the LE Jetronic system is managed by two electronic control modules:

- Fuel Injection control module
- Ignition control module

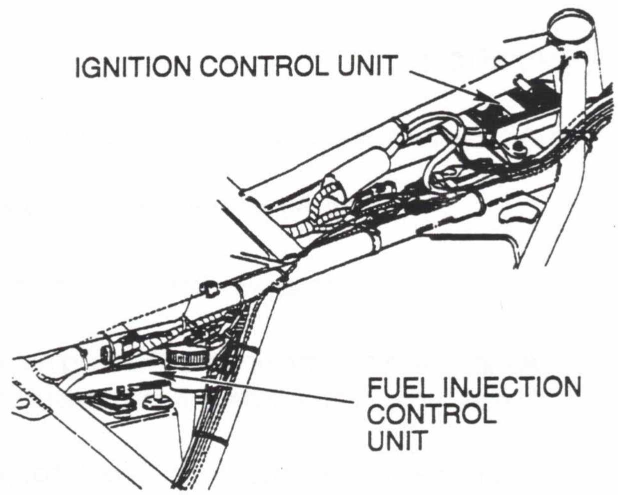
Together, these control modules are LE Jetronic. But, at the same time they are both separate systems (see system IPO illustration at right).

Though the heart of LE Jetronic is an electronically controlled system, it utilizes and controls mechanical devises to acquire data and to carry out its functions. Page 4 of this section will begin to cover all of the individual inputs (data) and outputs (functions) LE Jetronic requires or controls to function. These inputs and outputs will be grouped by their respective elements, ie: *air, fuel, electrical.*

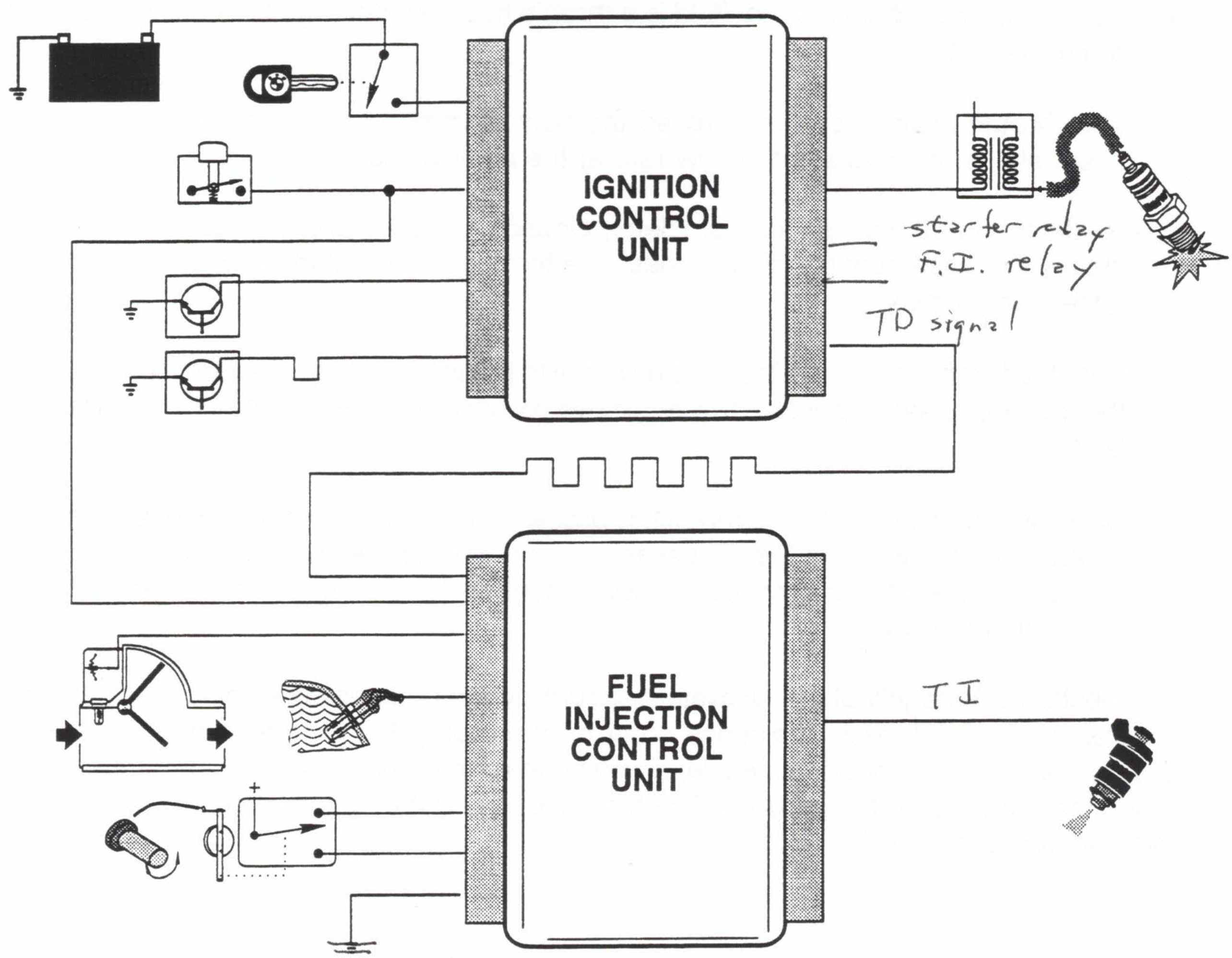
LE Jetronic Control Units

The ignition control unit is located under the fuel tank just below the forward tank rubber mounts. It has a 15 pin multi-plug.

The Fuel Injection Control unit is located under the seat, just above the battery. It is accessible from the left side of the cycle with the side cover removed. It has a 25 pin multiplug.



LE Jetronic Basic IPO



ground is critical

LE Jetronic Air System

Operation

The Air System is comprised of the following components:

- Air Filter Housing
- Air Flow Meter
- Intake Ducting
- Intake Air Collector
- Intake Manifolds
- Throttle Housings

1. As intake air is drawn into the engine it first passes through the air filter, then through the air flow meter where it is measured and monitored of its ambient temperature.

2. From the air flow meter it flows through the intake system rubber ducts and into the intake air collector which is a reserve stabilization chamber.

3. The air is then drawn into each intake manifold as needed per cylinder.

4. At the end of each intake manifold is a throttle housing that regulates the intake air with a throttle plate.

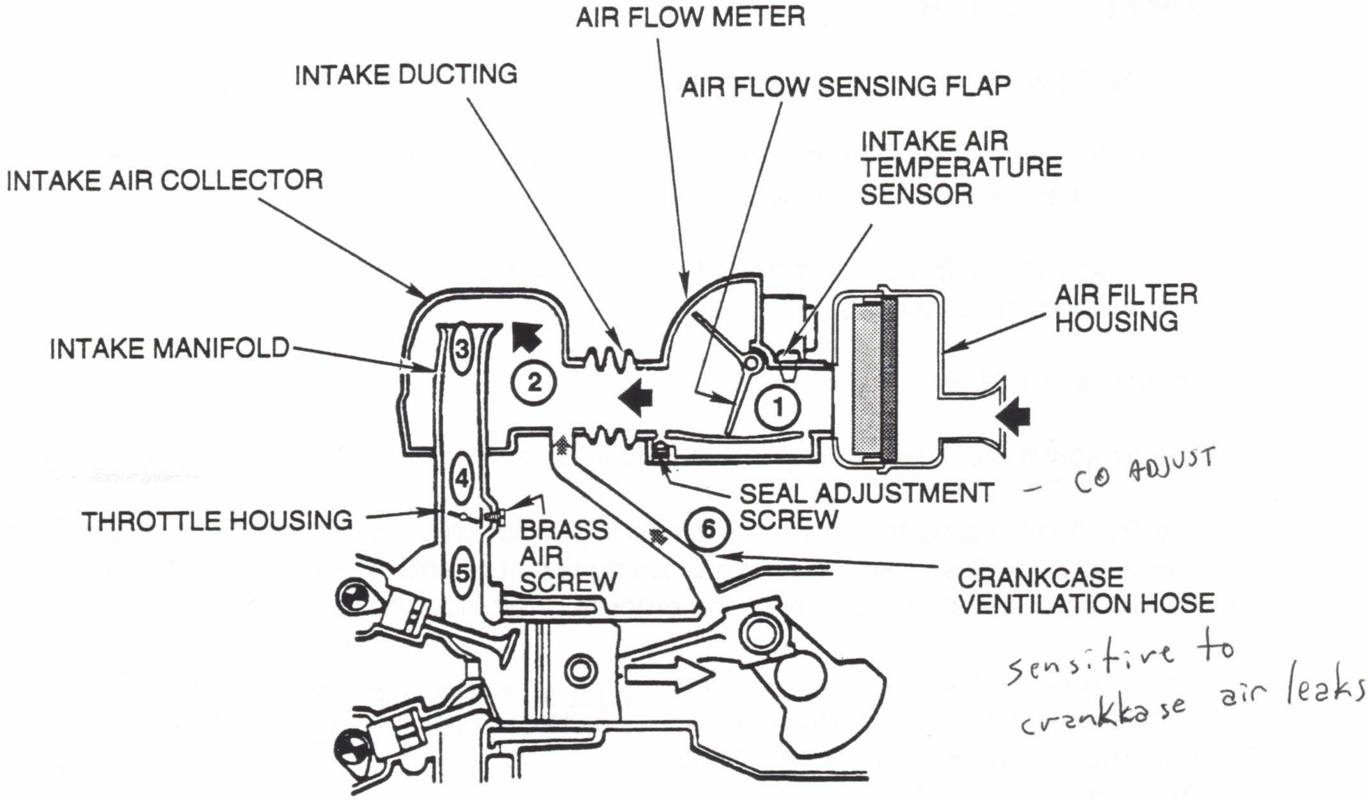
   The throttle plates slow or increase the flow of intake air to each cylinder, which in effect slows or increases the flow rate at the air flow meter.

   At idle the throttle plates are completely closed. A bypass port in each throttle housing allows a precise quantity of air to pass the throttle plate and maintain the engine's idle speed air quantity.

5. Past the throttle housings the air is mixed with a fine mist of injected fuel where it enters the cylinder head, passes the intake valve and into the combustion chamber for ignition.

6. Blow-by gasses from the combustion process accumulate in the engines crankcase. A ventilation hose allows these gasses to be drawn into the intake air stream for re-use. This ensures a cleaner crankcase environment and recycles the unburned portions of the air/fuel mixture.

The mechanical integrity of the Air system should always be considered before any electrical troubleshooting is started. If a repair order on a motorcycle indicates a mixture problem, **ie:** poor performance or unstable idle, always consider a false air leak. Un-metered intake air will lean out the air/fuel mixture. The fuel injection control unit has no way of detecting and compensating for this.


AIR FLOW METER
INTAKE DUCTING
AIR FLOW SENSING FLAP
INTAKE AIR TEMPERATURE SENSOR
INTAKE AIR COLLECTOR
AIR FILTER HOUSING
INTAKE MANIFOLD
1
2
3
4
5
6
SEAL ADJUSTMENT SCREW
CO ADJUST
THROTTLE HOUSING
BRASS AIR SCREW
CRANKCASE VENTILATION HOSE
sensitive to crankcase air leaks

Air System Components

AIR FLOW METER

The Air Flow Meter has two functions:

- **Measure Air Flow:** Mechanically measure volume of intake air and convert measurement to an electrical signal.

- **Monitor Air Temperature:** Monitor intake air ambient temperature and convert to an electrical signal.

Measure Air Flow

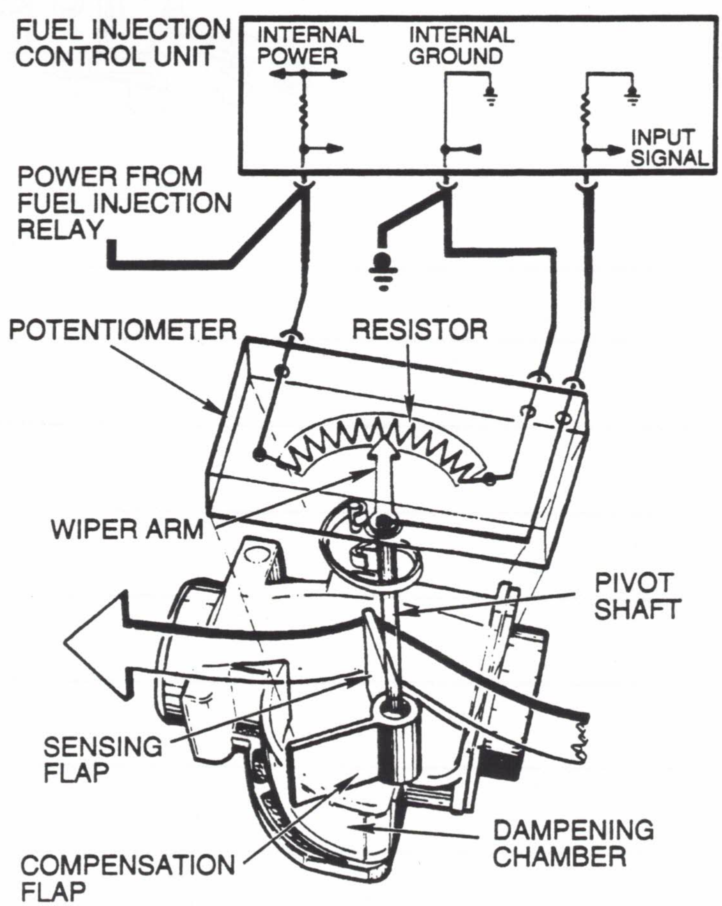
The air flow meter has a spring loaded, dual flap assembly that is mounted to a pivot shaft.

The first flap is called the sensing flap and is positioned in the stream of intake air. The flap is moved when the intake air flow pushes against it to enter the engine. It is held by the air flow in a position that represents the amount of air induced by the engine.

The second flap is called the compensation flap. The compensation flap moves within the dampening chamber. This compensates for normal intake air pulsations that are present in an intake air port and prevents the flap from jittering.

Attached directly to the pivot shaft is the wiper arm of a potentiometer. The wiper arm has a sliding contact on the resistor of the potentiometer and sends a varying DC voltage input signal to the Fuel injection Control Unit. This varying DC voltage is directly proportional to the amount of intake air.

The Fuel Injection Control Unit needs this signal to establish and maintain "Ti" (length of time fuel injector is injecting fuel) to correspond with the correct air/fuel ratio.



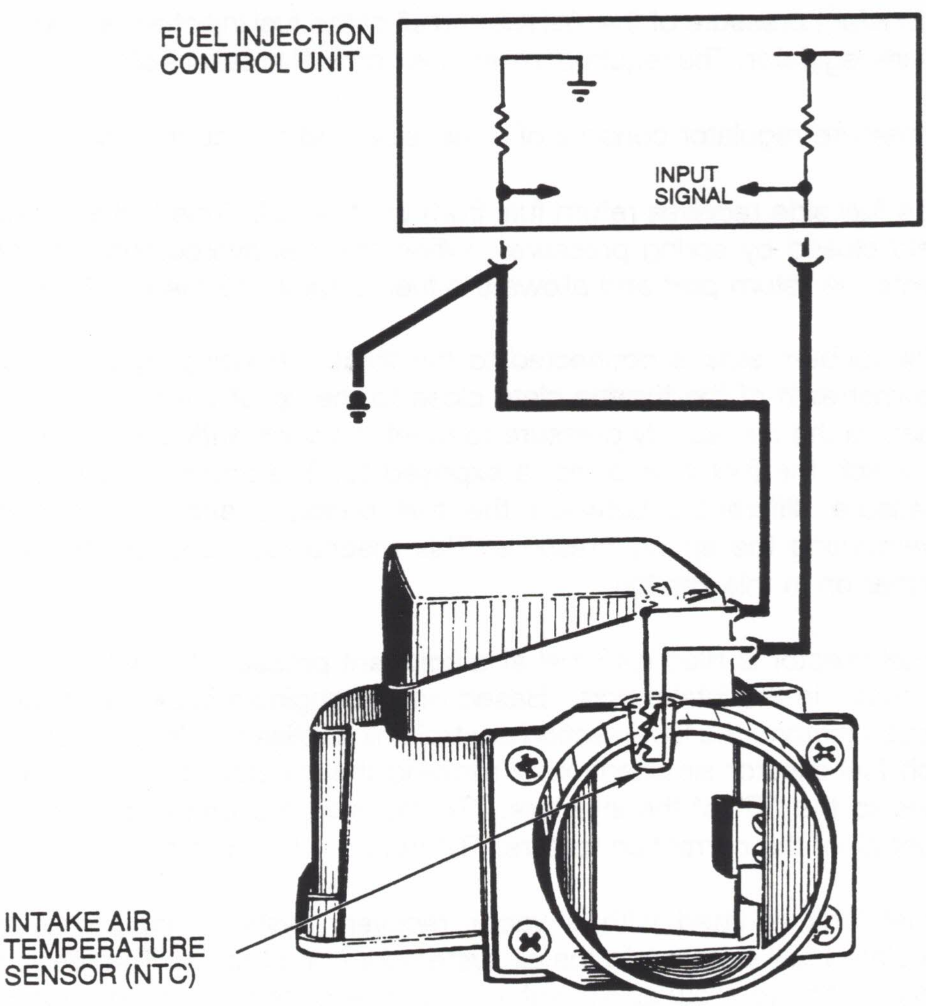
Monitor Air Temperature

Also housed in the Air Flow Meter is an Intake Air Temperature Sensor. This sensor is an NTC (Negative Temperature Coefficient) resistor.

- Increase in air temperature = Decrease in resistance value.
- Decrease in air temperature = Increase in resistance value.

Cold air is denser than warm air of the same volume. When intake air temperature changes, the fuel injection control unit must make slight corrections for "Ti" to maintain the correct air / fuel mixture.

The slightest change in the intake air temperature is detected by the sensor. The control unit receives a varying DC voltage input signal that is directly proportional to the air temperature .



LE Jetronic Fuel System

Operation

The Fuel System is comprised of the following components:

- Fuel Tank
- In Tank Electric Fuel Pump
- In Line Fuel Filter
- Fuel Hoses
- Fuel Rail
- Pressure Regulator
- Fuel Injectors

1. The Electric Fuel Pump located in the fuel tank is energized by the fuel injection relay. It pumps fuel through a fuel filter and out of the fuel tank through a fuel hose.

2. From the fuel hose the pressurized fuel flows into the fuel rail. The fuel rail is a manifold that links the fuel injectors to one common fuel supply at a constant pressure.

3. The constant pressure of the fuel rail and all of the fuel injectors is maintained by the fuel pressure regulator. The regulator maintains nominal pressure of 2.5 ± .05bar (36 ± .7psi).

   The pressure regulator consists of a fuel side and a vacuum side.

3a. The fuel side receives return fuel from the fuel rail. This fuel is regulated by a valve held closed by spring pressure. When the fuel overcomes the spring pressure it vents the return port and allows the fuel to return to the fuel tank.

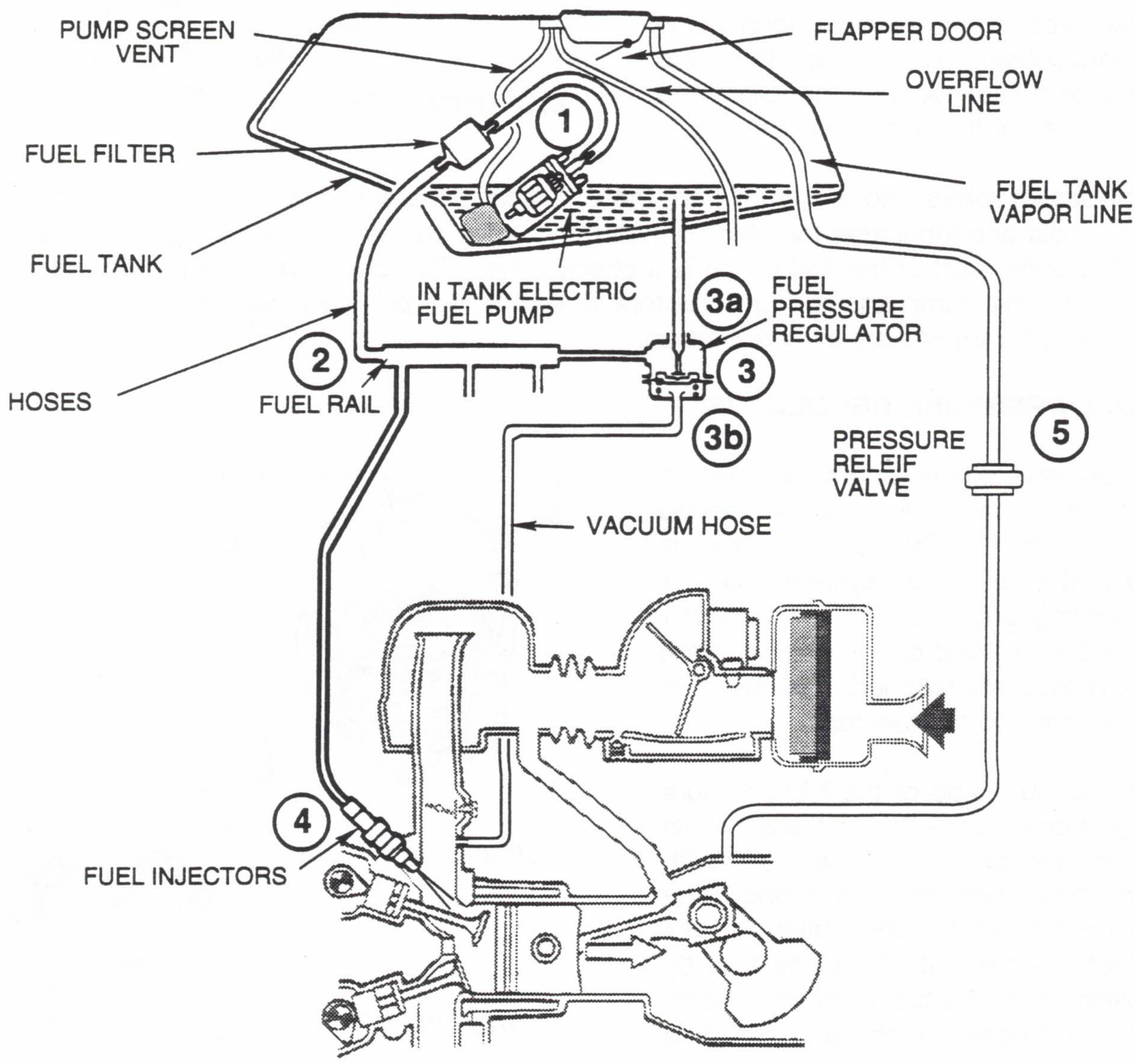
3b. The vacuum side is connected to the throttle housing by a vacuum port located downstream of the throttle plate close to the tip of the fuel injector. This location enables the fuel supply pressure to meet the constantly changing vacuum pressure at which the fuel injector tip is exposed to. The vacuum source will maintain the pressure differential between the fuel pressure and the vacuum pressure by overcoming the spring pressure. This mechanical function will be fully explained further on in this section.

4. The Fuel injector is filled with fuel at a constant pressure to match that of the vacuum environment in the intake port. Based on the engine's intake air quantity, speed and correction factors, the fuel injection control unit applies a pulsed ground to the solenoids in each fuel injector simultaneously allowing the injector to open. The pulsed ground equates to the "Ti" of the injectors. To maintain the proper air/fuel ratio, taking into account all of the correction factors, "Ti" will be 1.5 to 9 ms (milli-seconds).

5. The fuel tank is fitted with a vapor recovery system that stores and introduces accumulated fuel vapors into the air system for combustion. The filler cap incorporates two valves; one to allow air to vent in to compensate for consumption of fuel (0.1 bar), the other is a safety vent to allow high excess pressure to vent out (0.2 bar).

The filler cap also incorporates a funneled neck with a one way flap. This eases fuel filling by not having to remove the cap and it prevents overfilling the tank. The filler cap is sealed when closed to prevent fuel vapors from escaping to the atmosphere

The pressure relief valve between the fuel tank and crankcase prevents pressure from the crankcase from blowing into the fuel tank. When the engine is not running, no crankcase pressure is present and the valve will allow accumulated fuel tank vapors to escape into the crankcase (0.1 bar). When the engine is started, these vapors are inducted into the intake air stream through the crankcase vent hose.

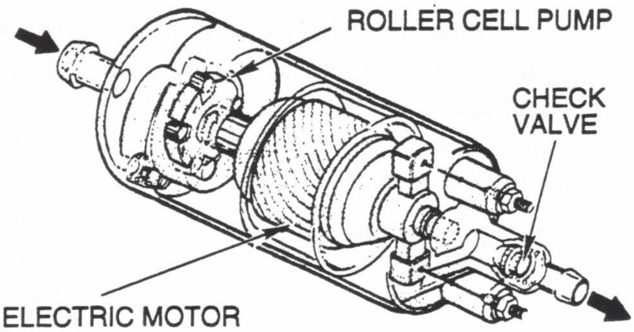


The fuel system is an area to consider when diagnosing a problem related to poor response and performance. Fuel pressures not within specification will change the final air/fuel ratio. Areas to consider, clogged fuel filter, pinched or crimped feed or return hoses, poor or no vacuum connection to the pressure regulator, defective pressure regulator, mechanically defective fuel injectors.

Fuel System Components

ELECTRIC FUEL PUMP

Located in the fuel tank is an electric fuel pump. It is a roller cell type driven by a permanent magnet electric motor. The pump rotor is attached to the motor shaft. When the motor is energized, the rotor spins forcing the rollers outward by centrifugal force and creates a seal between the rollers and inner wall of the pump housing.

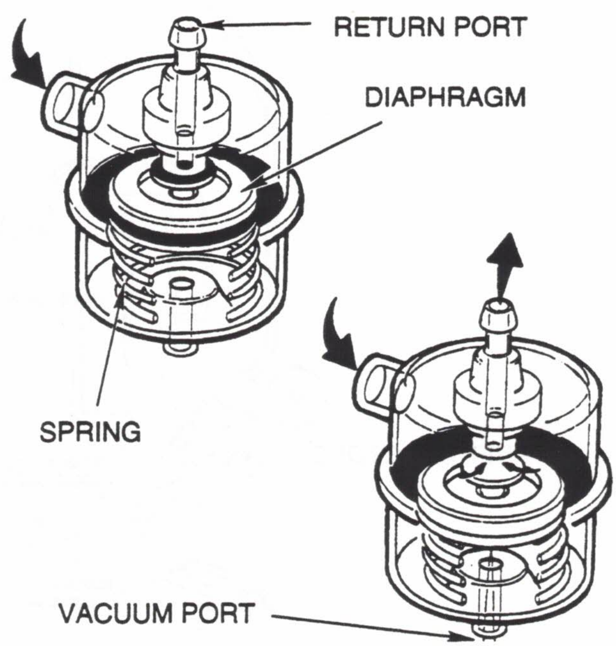


The sealed rollers move the fuel from the inlet side of the pump to the pressure side. The fuel cools and lubricates the electric motor and roller cell as it flows through the housing. In the outlet port of the fuel pump is a check valve. This check valve locks fuel pressure between the pump and the fuel injectors when the pump is switched off to maintain fuel pressure for immediate engine start up.

FUEL PRESSURE REGULATOR

As pressurized fuel enters the pressure regulator it acts on a spring loaded diaphragm. The spring rate is calibrated to the fuel systems nominal operating pressure (2.5 ± 0.05 bar / 36± 0.7 psi) and opens a valve when the pressure is reached. The fuel then flows back to the fuel tank.

The vacuum side of the fuel pressure regulator is connected to the a throttle housing vacuum port via a hose. With out this vacuum monitoring, the vacuum present in the intake port will effect the amount of fuel injected by pulling additional fuel from the injector when it is open in high vacuum engine conditions.



With the vacuum side of the pressure regulator monitoring the constantly changing value of vacuum, it maintains the required pressure differential in the fuel supply to match the intake port vacuum. The actual fuel system pressure is constantly varying between 1.8 bar and 2.5 bar based on engine operating conditions.

should hold 80% of full pressure for 40 minutes

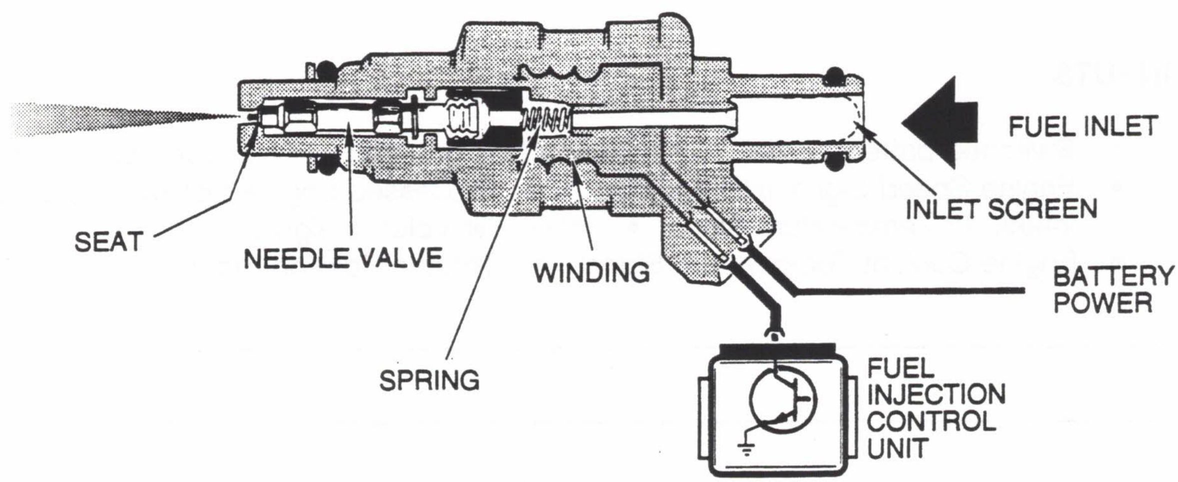
R115 injectors use ball instead of needle valve

FUEL INJECTOR

The fuel injectors are responsible to deliver the proper amount of fuel to the intake ports from the fuel rail. This includes;

- Hold the pressurized fuel supplied from the fuel rail, which must atomize and mix with the intake air for combustion when injected.
- Regulate the proper amount of fuel delivered for combustion through the electronic control of the fuel injection control unit.

The injectors are solenoid type valves and are opened by electric pulses to ground from the fuel injection control unit.



When the injector is **not opened**, there is no current flowing through the coil winding. The needle valve is pressed against its seat by a spring. No fuel will flow.

When the injector is **opened**, current is passed through the coil winding, the needle valve is lifted from it's seat against the spring pressure allowing fuel to flow through the outlet tip of the fuel injector. The tip of the needle valve has a flared pintle for atomizing the fuel as it exits the injector.

The fuel injectors are mounted in rubber which,

- insulates the injectors form engine heat to prevent vapor lock and minimize poor hot starting.
- ensures the injectors are not subjected to excessive vibration.
- provides a seal for the injector
  - at the inlet for mounting to the fuel rail,
  - at the outlet tip to prevent intake air leaks.

LE Jetronic Electrical System

General

The electrical system is comprised of the following components, signals and signal paths. They are grouped by:

- **Inputs** (operating power, grounds and electrical signals required)
- **Processing** (electronic control units)
- **Outputs** (electrical control of components)

INPUTS

- Switched battery power
- Control Unit grounds
- Starting Signal (Cranking)
- Engine Speed Signal (Hall Sensor)
- Processed Engine Speed Signal (TD)
- Intake Air Temperature Signal
- Intake Air Volume Signal
- Engine Coolant Temperature Signal
- Throttle Position Signal

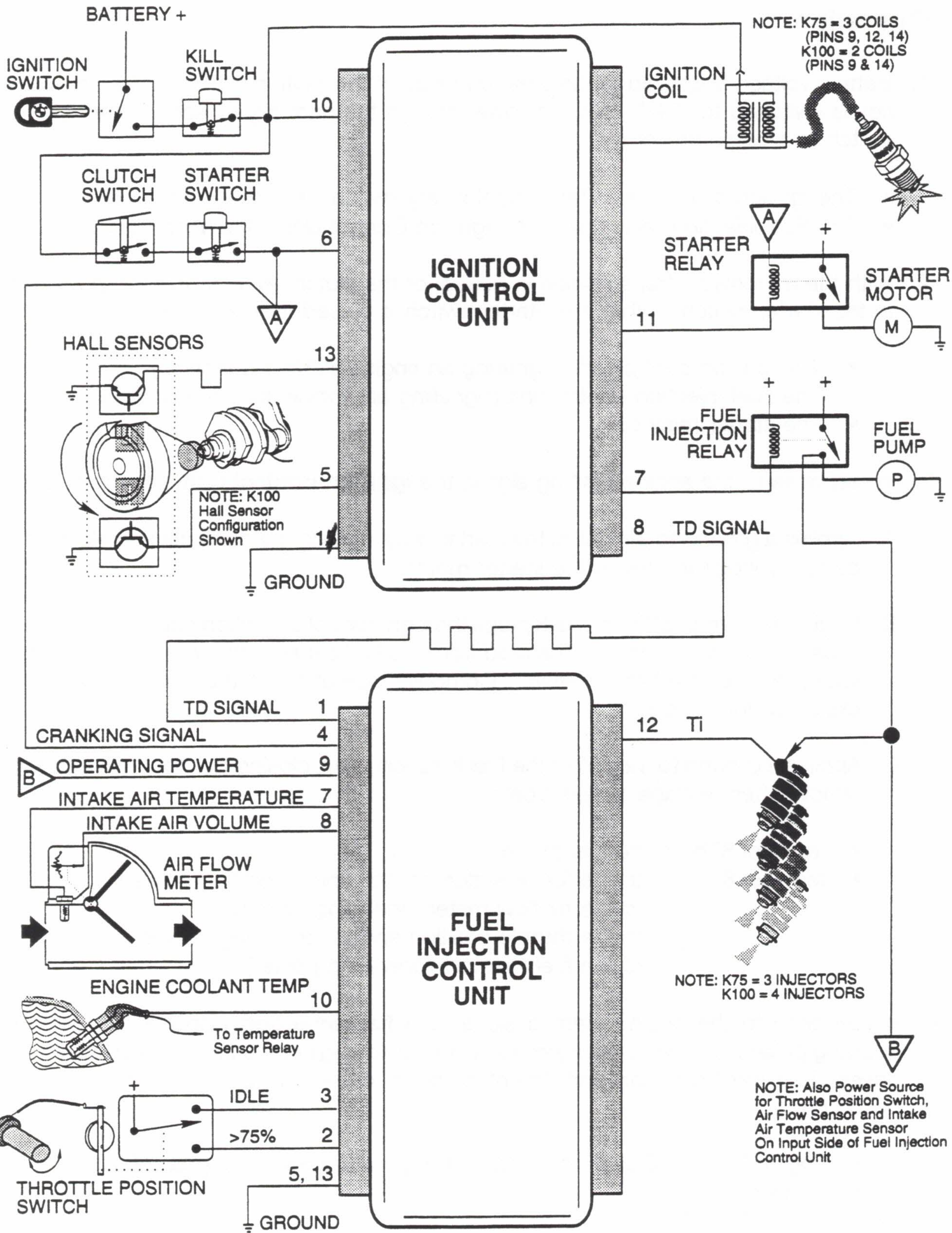
PROCESSING

- Ignition Control Unit
- Fuel Injection Control Unit

OUTPUTS

- Control of Primary Side of Ignition Coils
- Control of Starter Relay
- Control of Fuel Injection Relay (Power Distribution and Fuel Pump Operation)
- Processed Engine Speed Signal
- Control of Fuel Injectors

LE Jetronic IPO (Input-Processing-Output)



LE Jetronic Electrical System

Operation

1. Battery voltage is applied to the open contacts of the ignition switch. When the ignition key is switched to "ON", 12 volts flows through the normally closed contact of the kill switch to provide power to:

   - The ignition coils
   - The Neutral safety switch
   - Instrument cluster
   - The Fuel injection relay coil
   - Ignition Control Unit (Operating power)

2. With the motorcycle transmission in neutral or the clutch lever depressed power flows to the starter switch. When the starter switch is closed, power flows to:

   - The ignition control unit (signalling an engine starting condition)
   - The Fuel Injection control unit (signalling an engine starting condition)
   - The starter relay coil

3. In response to the engine starting signal, the **ignition control unit** simultaneously:

   A. Applies a ground to the coil of the starter relay, closing the contacts and allows direct battery voltage to flow to the starter motor.

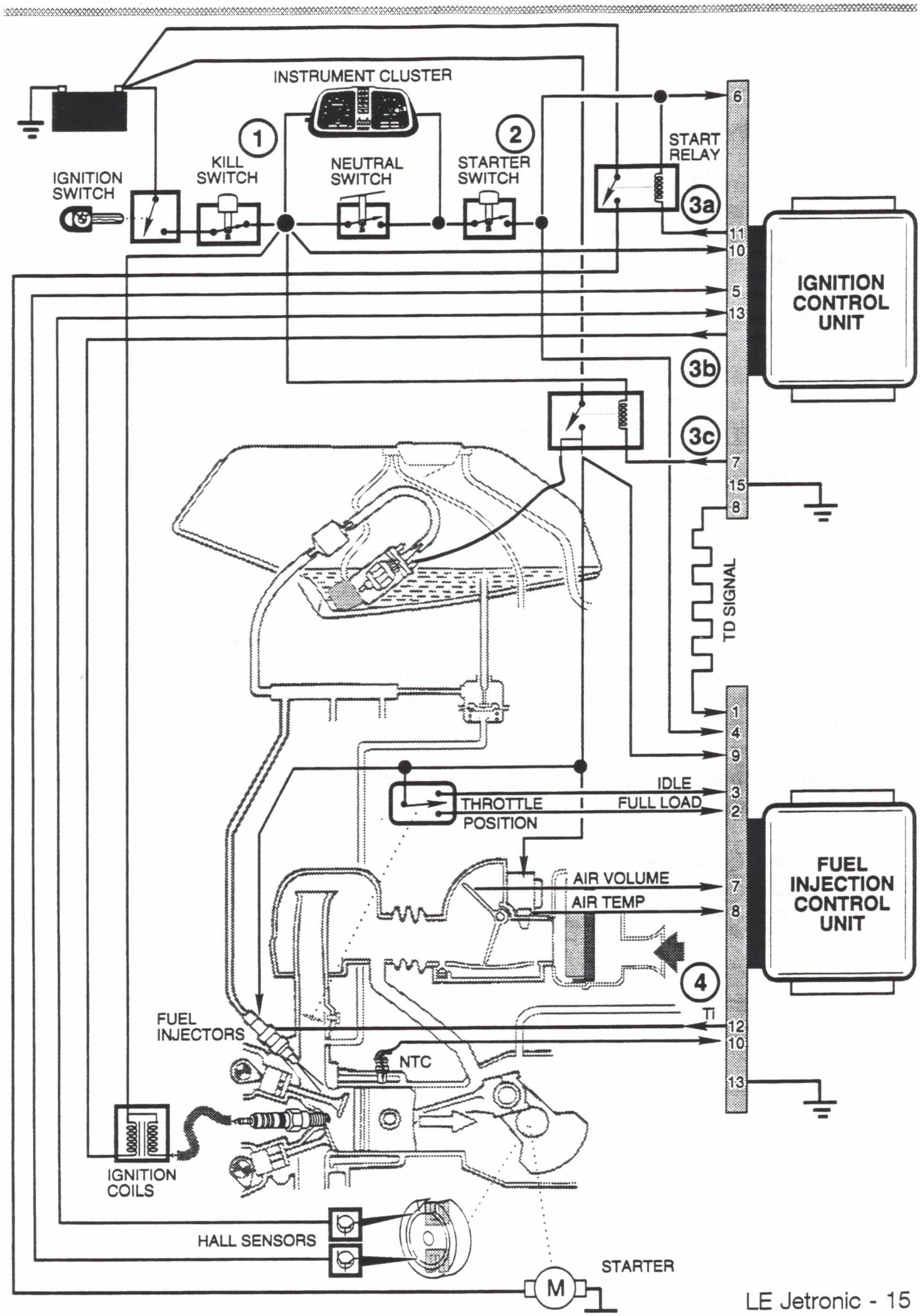
   B. Begins sequence of firing spark plugs through control of ignition coils. This sequence is based on input signals generated from the hall sensors that are indicating engine speed and crankshaft position. Complete operation of the hall sensors will be explained further on.

   C. Applies a ground to the coil of the fuel injection relay, closing the contacts and allows direct battery voltage to flow from:

   - terminal 87b, to the fuel pump
   - terminal 87,
     - to the fuel injection control unit (operating power)
     - to the air flow meter (operating power)
     - to the throttle position switch (operating power)
     - to the fuel injectors (operating power)

4. In response to the engine starting signal, the **fuel injection control** unit will begin applying pulsed ground to the injectors. With a cold engine, the fuel injection control unit bases Ti on the Cold Start enrichment program in the control unit. This sequence is based on:

   - Engine Starting Signal
   - Engine Temperature Sensor Signal (NTC)
   - TD signal


INSTRUMENT CLUSTER
1
2
IGNITION SWITCH
KILL SWITCH
NEUTRAL SWITCH
STARTER SWITCH
START RELAY
3a
6
11
10
5
13
IGNITION CONTROL UNIT
3b
3c
7
15
8
TD SIGNAL
1
4
9
IDLE
3
THROTTLE POSITION
FULL LOAD
2
AIR VOLUME
7
AIR TEMP
8
FUEL INJECTION CONTROL UNIT
4
FUEL INJECTORS
TI
12
10
NTC
13
IGNITION COILS
HALL SENSORS
STARTER
M

5. With the engine running, the start button is released, the engine starting signal is removed and the:

   A. Ignition control unit

      - Removes the ground from the starter relay coil.
      - Maintains the ground for the fuel injection relay coil as long as TD is present.
      - Continues firing spark plugs through control of the ignition coils. Ignition timing based on input from Hall sensors processed into TD.

   B. Fuel Injection control unit

      - Continues injecting fuel by controlling the fuel injectors. Ti is now based on TD and intake air volume but continues delivering an enriched fuel charge based primarily on engine temperature signal (NTC).

        With an increase in engine temperature, Ti will decrease.

        Other contributing factors,

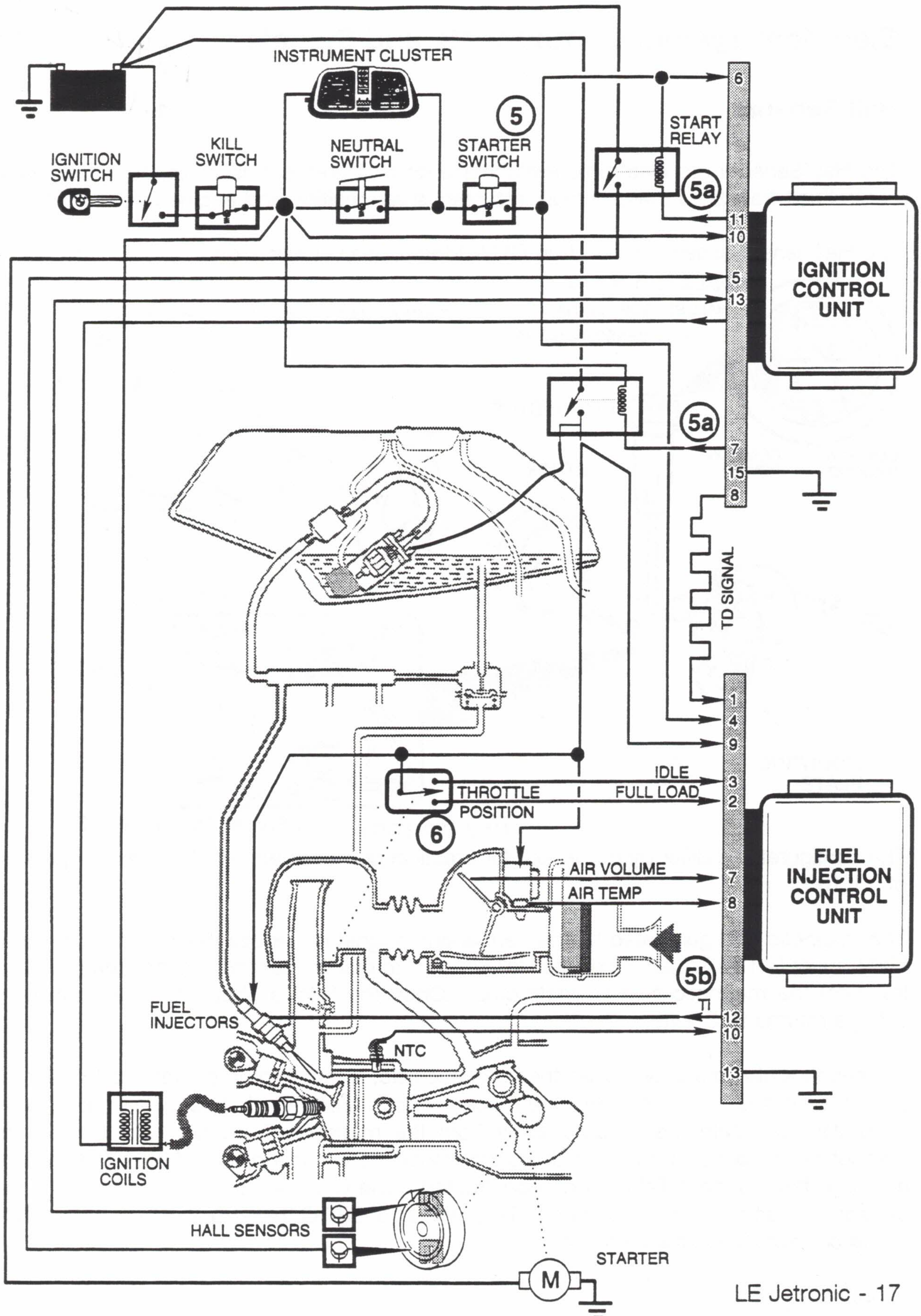
        - Air Temperature
        - Throttle position

   Note: With the engine running (>500RPM) additional enrichment can be achieved by holding down the start button. The fuel injection control unit perceives this as a start signal and initiates additional enrichment. The ignition control unit will not activate the starter relay with the presence of TD > 500 RPM.

6. The throttle position switch input to the fuel injection control unit effects the air/fuel ratio by signalling the fuel injection control unit:

   - Idle - Ti reduced
   - Mid range throttle
   - Full Throttle (>75% throttle position) - Ti increased

How the control units perceive the correction factors generated by the presence or lack of the input signals will be covered further on.


INSTRUMENT CLUSTER
5
START RELAY
KILL SWITCH
NEUTRAL SWITCH
STARTER SWITCH
IGNITION SWITCH
5a
6
11
10
5
13
IGNITION CONTROL UNIT
5a
7
15
8
TD SIGNAL
1
4
9
IDLE
3
THROTTLE
FULL LOAD
2
POSITION
6
AIR VOLUME
7
AIR TEMP
8
FUEL INJECTION CONTROL UNIT
5b
TI
FUEL INJECTORS
12
10
NTC
13
IGNITION COILS
HALL SENSORS
STARTER
M

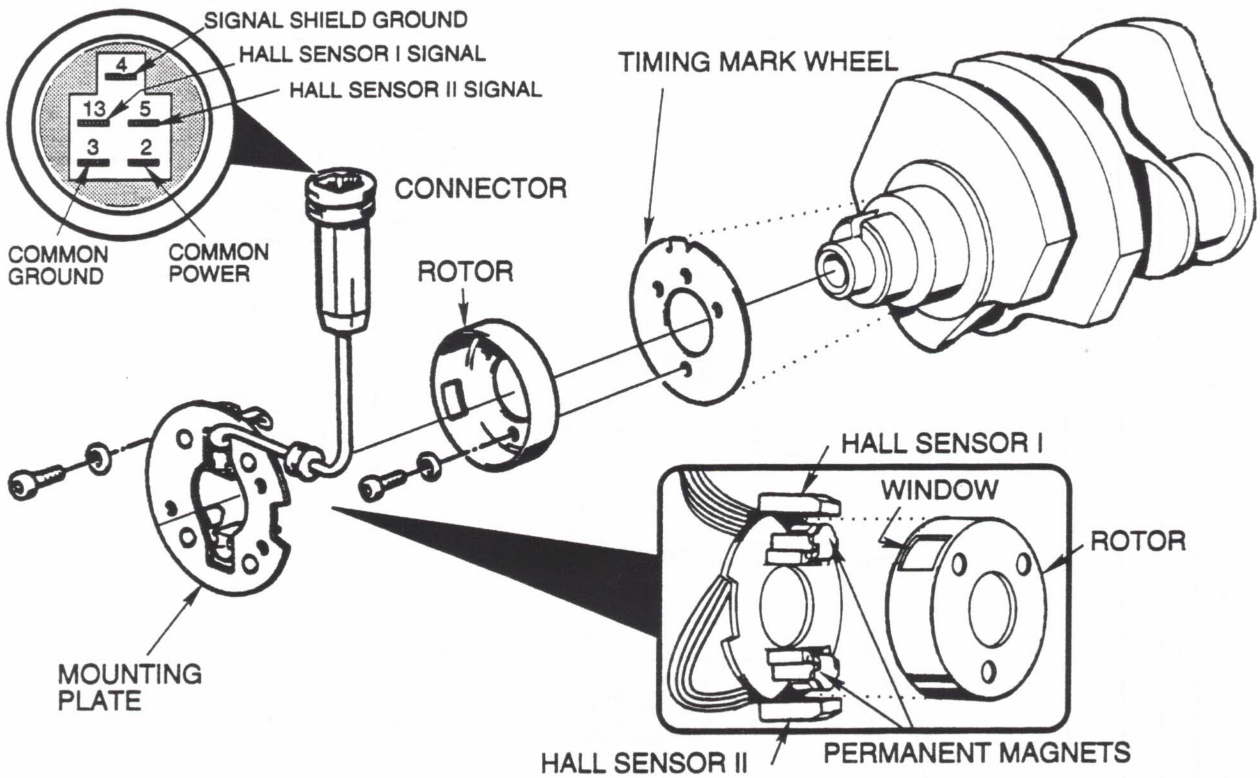
4 cyl firing
1-3-4-2 - 3 cyl
3-1-2

Electrical System Components and Signals

Hall Sensors

The Hall Sensors are electronic switching units that create pulsed signals. The ignition control unit translates these signals into crankshaft position and engine speed (RPM).

The Hall sensor assembly found on BMW Motorcycles consists of:



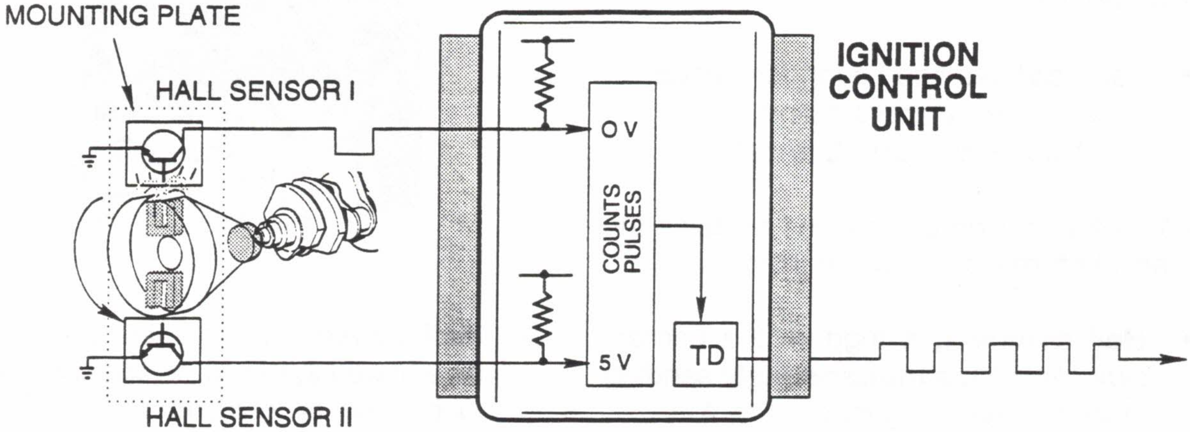
The configurations differ by model but for practical purposes we will discuss the operation of a K100.

The magnetic field generated by the permanent magnet influences the integrated circuit in Hall Sensor I. This influence causes Hall Sensor I to pull the control unit monitoring voltage low until the magnetic field is obstructed. Once the field is obstructed the monitoring voltage returns to 5 volts.

To mechanically "make or break" the magnetic field, a metal rotor is attached to the front of the crankshaft. In it's side is an opening or "window" that is 37° of the rotors circumference. With the window away from the magnet/sensor, the rotor breaks the magnetic field, but as it rotates with the crankshaft the window passes the magnet/sensor, allowing the magnetic field to be unobstructed. The windows position in relation to Hall Sensor I's position is directly related to TDC (actual: 6° BTDC "basic ignition timing") position of the crankshaft for cylinders 1-4.

Rapidly "making or breaking" the magnetic influence, creates a square wave signal that the control unit interprets as one pulse for every 360° of crankshaft rotation with cylinders 1 & 4 at TDC.

Located 180° from Hall Sensor I is Hall Sensor II. It functions identically as described above except for its location and mechanical relation to cylinders 2 & 3.



The control unit counts each pulse from both sensors and establishes:

- Engine Speed (together, two pulses for each complete crankshaft rotation)
- Crankshaft reference (individually, each pulse indicates TDC for monitored cylinders).

From this data the ignition control unit also produces the TD signal

K75

The K 75 Hall Sensors differ only in the positioning of the sensors and an additional window is added to the rotor. The Hall sensors are positioned 120° from each other on the mounting plate. The windows are also positioned 120° apart and are each 44° of the rotors circumference compared to the K100's 37°.

- As window # 1 of the rotor passes Hall Sensor I it triggers a pulse at the control unit.

- The rotor continues to spin (120° crankshaft rotation) and **simultaneously;**
  - window #1 passes Hall Sensor II, "*pulse*"
  - window #2 passes Hall Sensor I, "*pulse*"

- The rotor continues to spin (another 120° crankshaft rotation), window #2 passes Hall sensor II, "*pulse*".

- Another 120° of crankshaft rotation will align window #1 with Hall sensor #1 and the cycle will start over again.

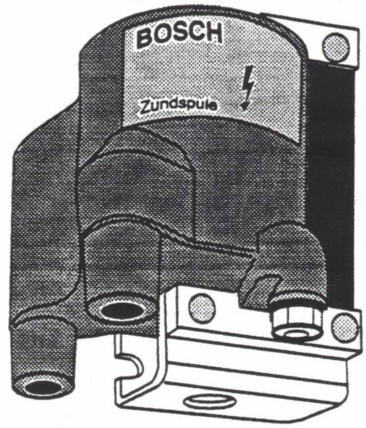
The ignition control unit equates the dual pulse to cylinder three for cylinder reference. This reference is necessary to establish the synchronization of ignition coil control.

Ignition Coils

K100

This model utilizes two double spark ignition coils to ignite the air fuel mixture in four cylinders.

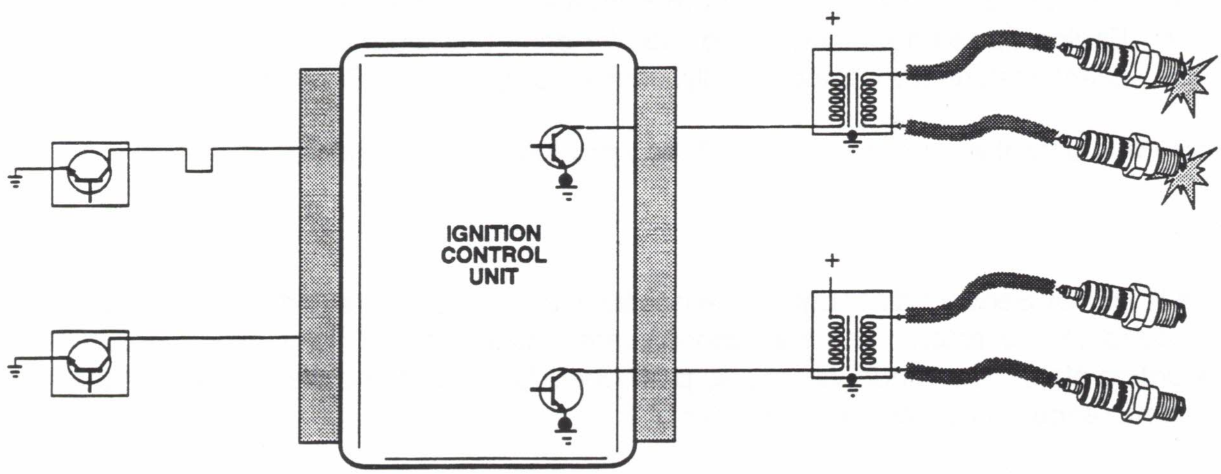
- Each coil has two secondary leads;
  - Coil **1 =** cylinders **1** and **4.**
  - Coil **2 =** cylinders **2** and **3**.



When the ignition control unit receives the crankshaft reference signal from:

- **Hall sensor I,** it triggers the primary side of **coil 1, simultaneously** sending ignition spark to cylinders 1 & 4.

- **Hall Sensor II,** it triggers the primary side of **coil 2, simultaneously** sending ignition spark to cylinders 2 & 3.



This arrangement reduces the total quantity of ignition coils and the complexity of the ignition control units programming. This arrangement will only work on an engine with an even amount of cylinders (2 or 4).

Using coil 1 as an example: when cylinder 1 is at TDC of the compression stroke , cylinder 4 is at TDC of the exhaust stroke. Cylinder 1 will utilize the spark for igniting the compressed air fuel mixture, cylinder 4 will not be effected by the spark.

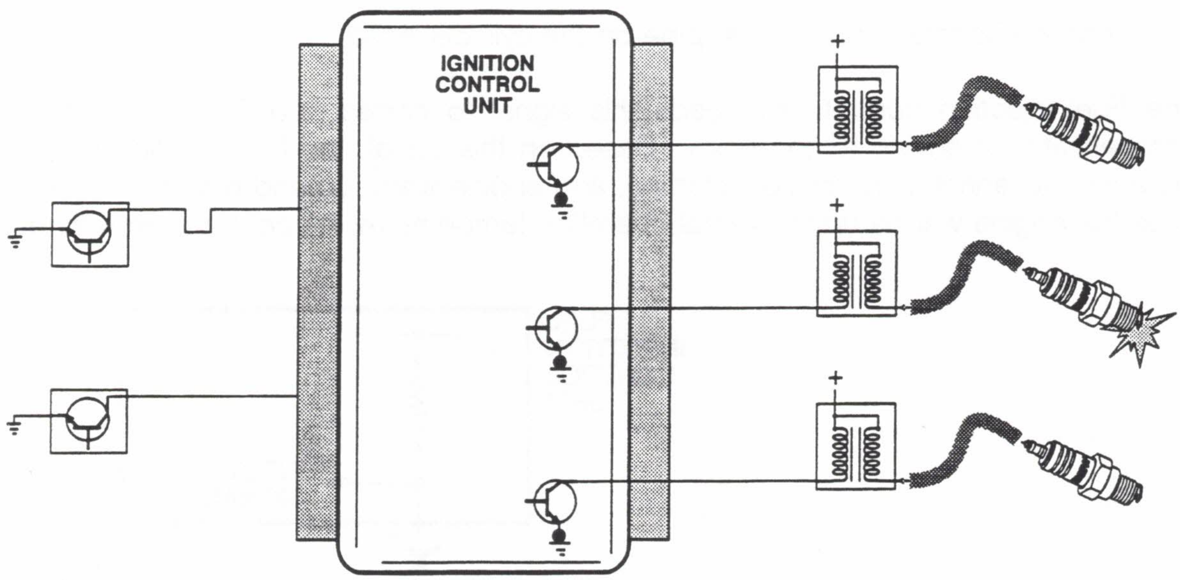
With 180° of crankshaft rotation, cylinder 3 is at TDC of compression stroke, cylinder 2 is at TDC of the exhaust stroke. Cylinder 3 utilizes the spark for ignition, cylinder 2 will not be effected.

K75

The K75, with three cylinders must have an ignition coil per cylinder. The ignition control unit receives the crank shaft reference signals from two hall sensors as described before.

The control unit recognizes the dual pulse as cylinder three at TDC (actual: 4° BTDC, "basic ignition timing") and activates the primary side of cylinder 3's ignition coil. This causes the secondary side to send the ignition spark to the cylinder.

The dual pulse also establishes the synchronization for the firing order ~~1-3-2~~ 3 - 1 - 2



The ignition control unit has no way of monitoring when the pistons are at TDC of the compression stroke or exhaust stroke. As with the 4 cylinder engines, the control unit will activate each coil when its respective piston is at TDC of both compression and exhaust strokes.

4° = .10 mm K75 + 88 → 2v K-models

6° = .24 mm 85-87 K100 + all motronic K's

K75 - air gap plug wires - prevents hi-tension voltage bleed btwn cyls

K100 - 5K Ω plug wires

don't swap wires

Engine Coolant Temperature Sensor (NTC)

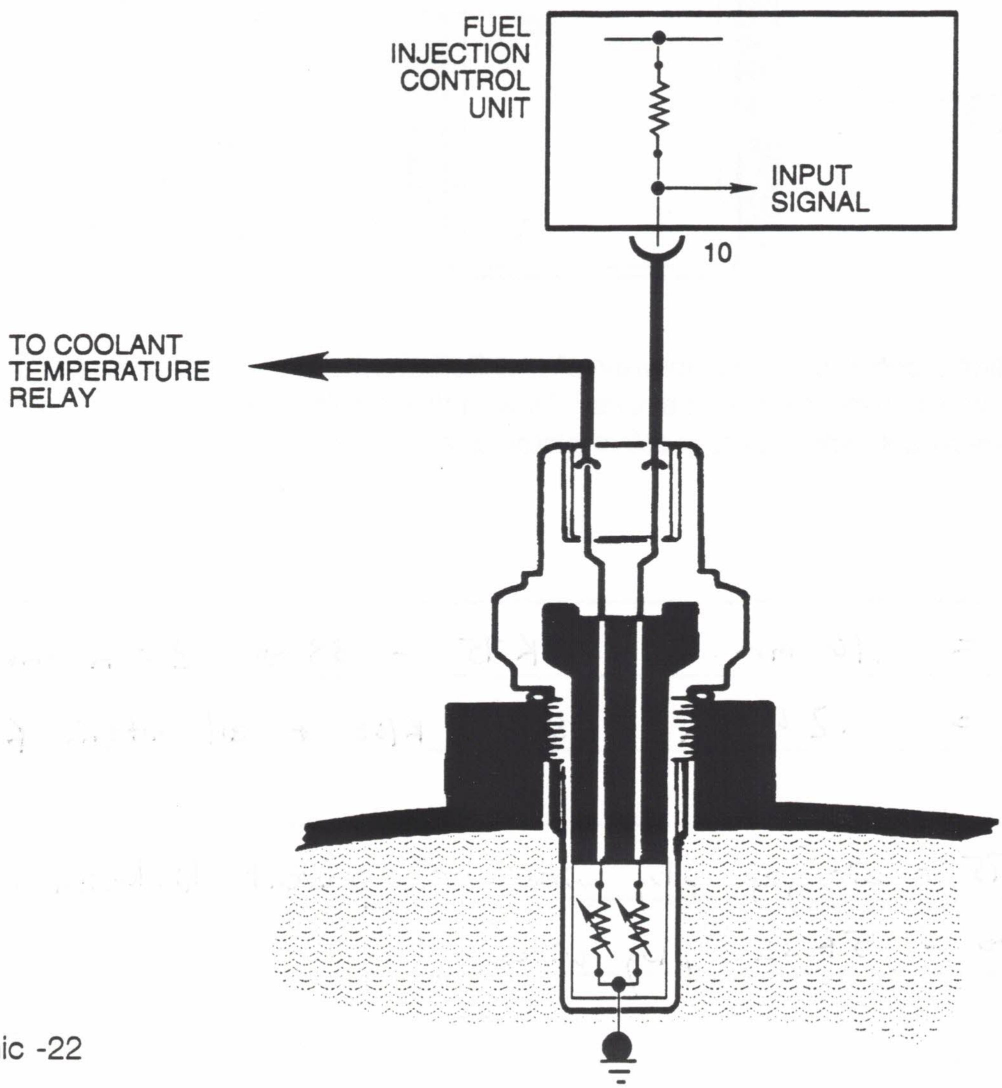
The Coolant temperature sensor is an NTC resistor. It incorporates two separate NTC resistors:

- One of the NTC's produces a signal proportional to engine temperature for the coolant temperature relay (description in Ancillary Electrical Equipment further on)

- The other provides a varying DC voltage signal proportional to engine temperature to the Fuel injection control unit.

The Sensor is located in the outlet pipe on the cylinder head.

The Fuel injection control unit needs this signal to correct the Ti of the injectors to compensate for engine temperature. Based on this signal, the fuel injection control unit provides fuel enrichment for cold starting, and engine warm up and reduces the length of Ti as the engine warms up to normal operating temperature. **ie:** cold engine = longer Ti.



Throttle Position Switch

The throttle position switch is mechanically connected to the throttle plate of throttle housing #4 on a K100 and #3 on a K75. When the throttle grip is moved, the switch detects it's movement.

The switch consists of a micro-switch for the idle contact and a set of contacts for the full load contact. The switches are activated by an internal cam that is connected to the throttle plate shaft.

The throttle position is required by the fuel injection control unit for recognition of:

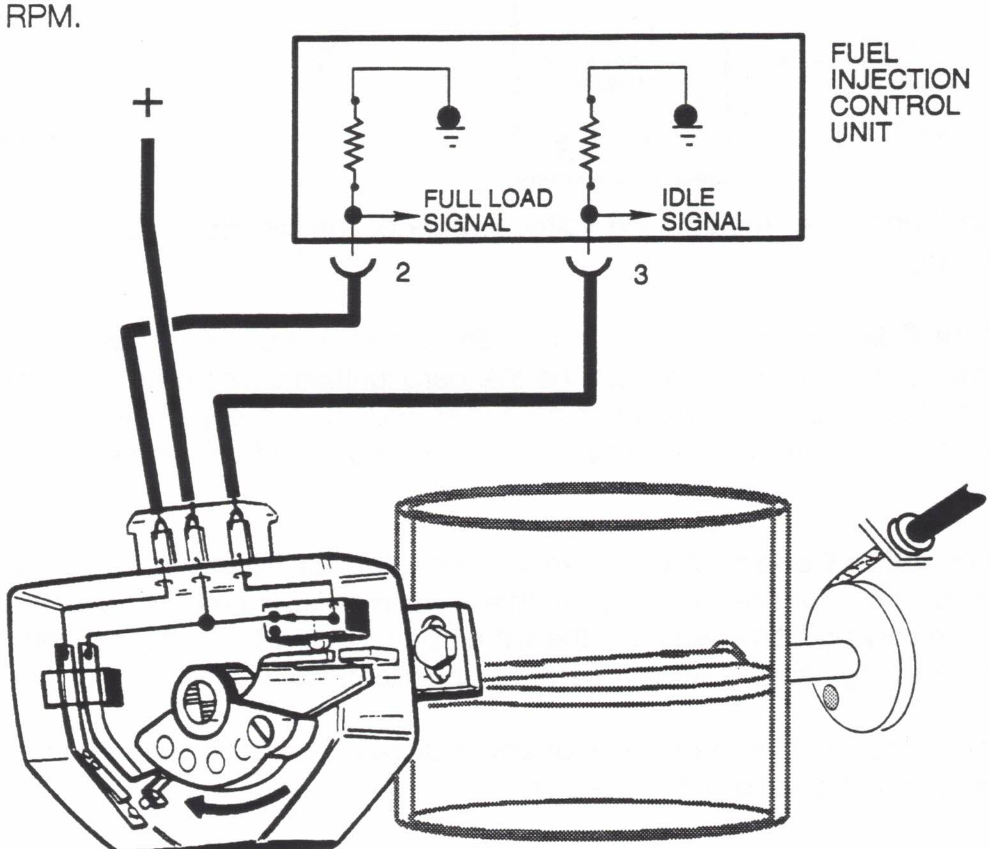
- position 1 • Idle position
- position 3 • Full Load (>75% throttle)
- position 2 • Part Load
- position 1 • Decel Fuel cutoff (suppresses Ti)

The fuel injection control unit receives a 12 volt DC signal at:

- pin 3 with the **Idle** switch closed
- pin 2 with the **Full load** contacts closed

A part load operating condition exists when no signals are present at pins 2 & 3.

Decel Fuel cutoff occurs with the throttle at idle position (idle signal high) and a TD signal of > 2000 RPM.



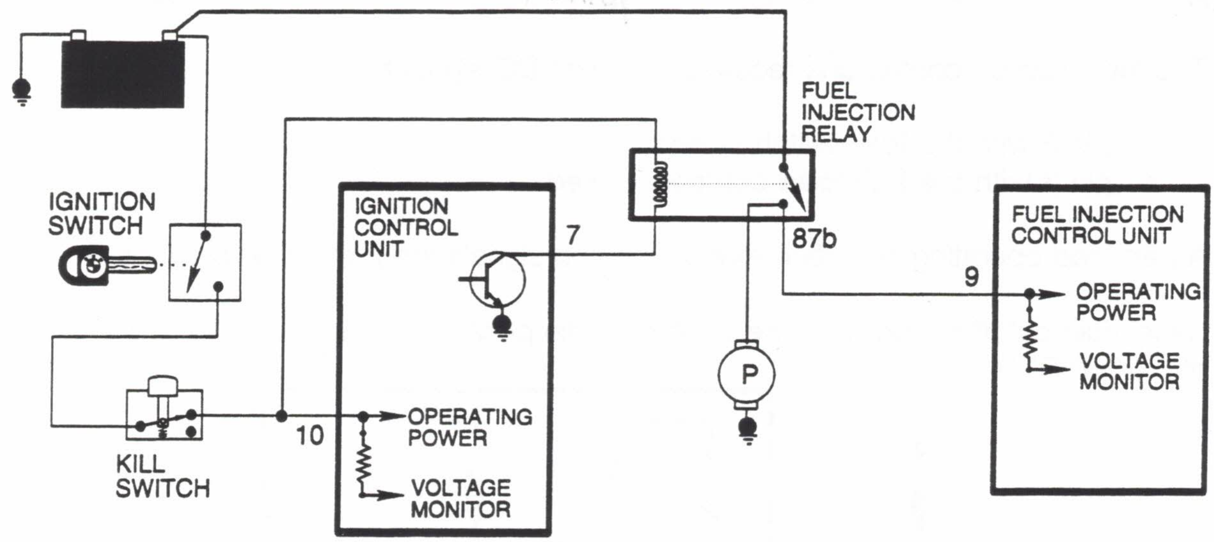
Operating Power

Both the ignition control unit and the fuel injection control unit require operating power (12 volts DC) to function.

Operating power is supplied as follows:

- **The Ignition Control Unit** receives operating power from the ignition switch through the normally closed contacts of the kill switch to pin 10.

- **The Fuel Injection Control Unit** receives operating power from terminal 87b of the Fuel injection Relay when activated by the ignition control unit. Power is received at pin 9 of the fuel injection control unit.



The control units also monitor the voltage value of the battery as a correction factor of programming.

- **Ignition Control Unit:** With a lower than normal operating voltage (< 11.5 volts) the ignition control unit deviates from the standard ignition timing map. The control unit will activate the ignition coil primary side earlier and keep it pulled low longer (change in dwell angle) to allow the available voltage to produce and deliver an adequate spark for ignition.

- **Fuel Injection Control Unit:** When activated, the fuel injectors create a self induction. This means the voltage used to open them, when switched off lingers in the coil winding and for a very brief time will keep the valve open. This effect is figured into the map for Ti with a voltage supply within operating specifications.

  The Ti is modified to compensate for any change in operating voltage, and its influence on the opening/closing of the injector.

Engine Cranking Signal

This signal is supplied to both control units as follows:

- **Ignition Control Unit.** With the ignition switch On and the Start button depressed, a 12 volt DC signal is supplied to pin 6.

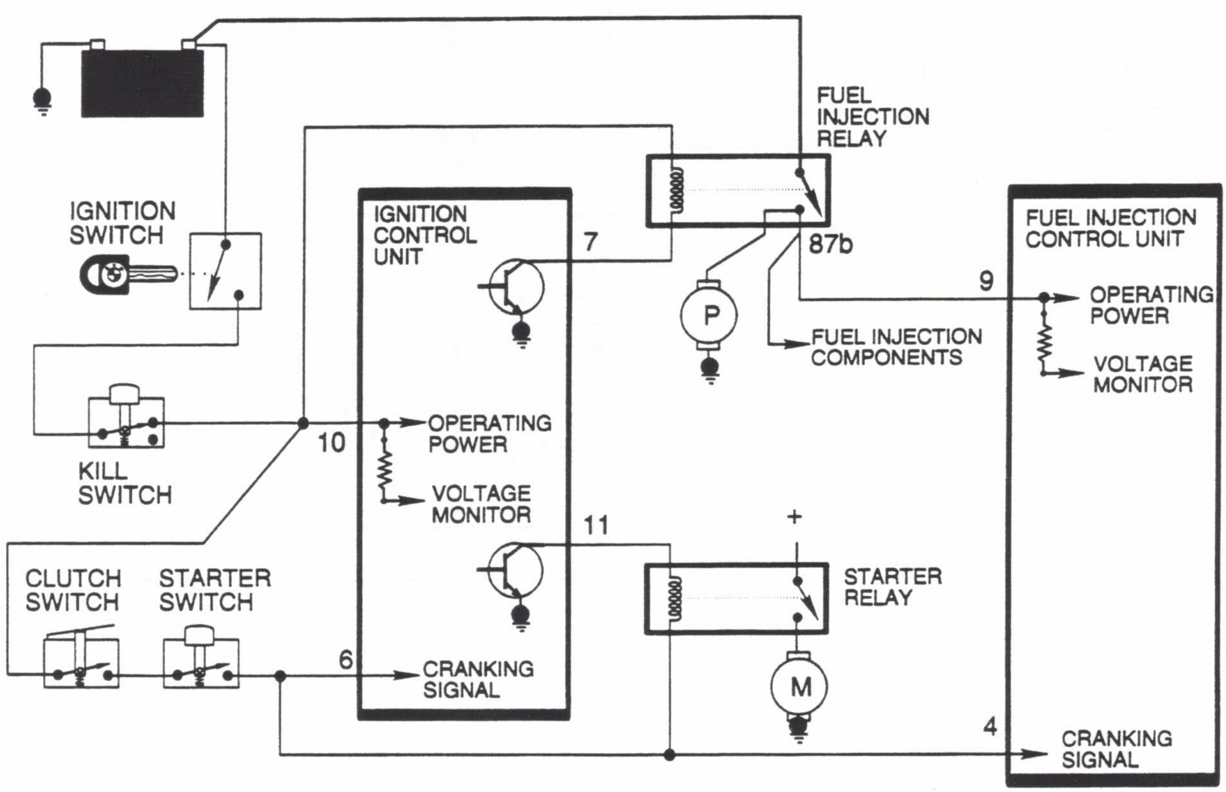
  The control unit will:

  - Activate the starter relay coil
  - Activate the ignition coil primary sides based on Hall Sensor signals
  - Activate the fuel injection relay coil (supply power to the Fuel injection control unit and components). The relay will remain active after the engine cranking signal is removed as long as the Hall sensor signals are active.

- **Fuel Injection Control Unit:** With the Ignition switch ON and the start button depressed, 12 volts DC is applied to pin 4 of the fuel injection control unit.

  The control unit will:

  - Begin pulsing the fuel injectors to a specific Ti based on all of its input signals and programs.



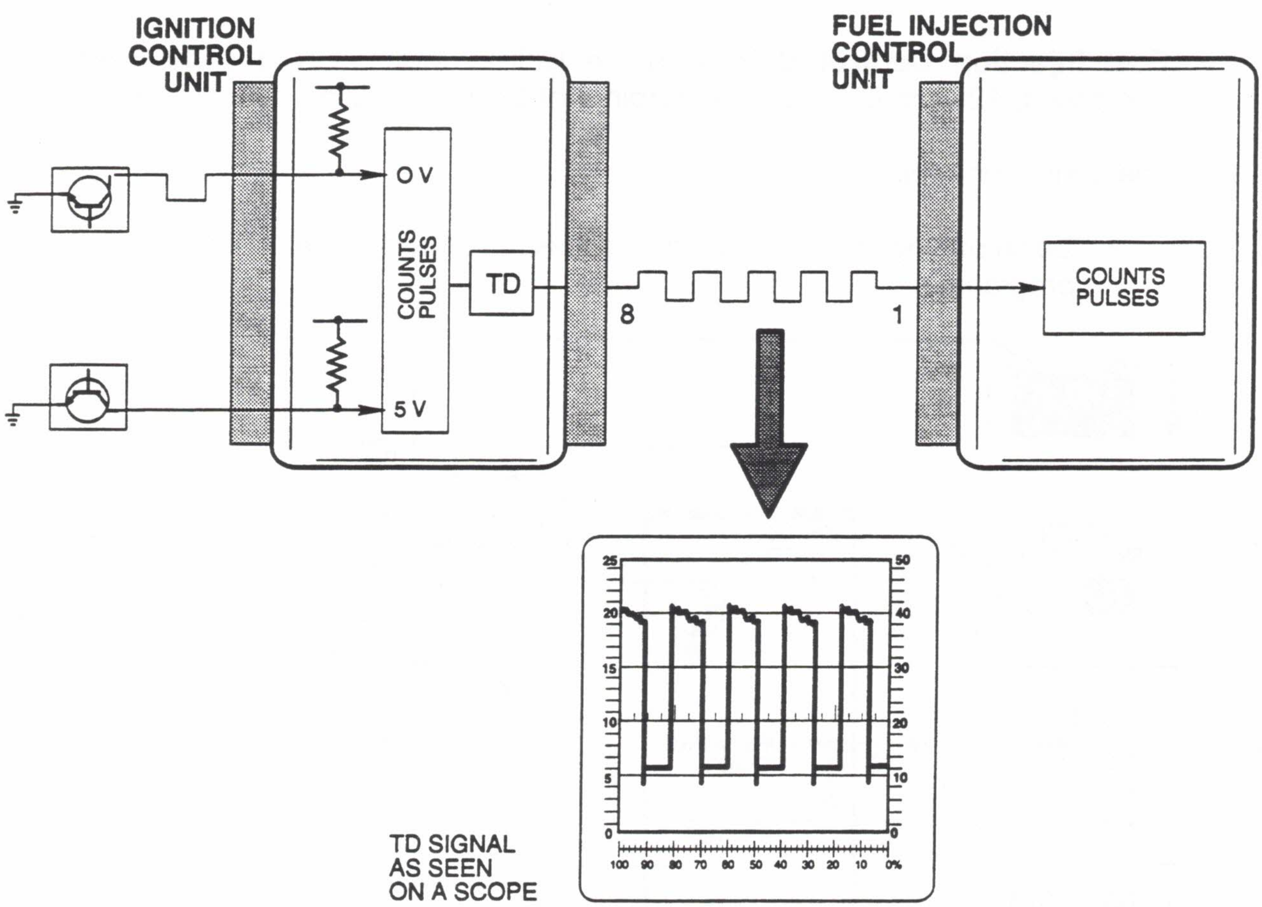
TD Signal

The TD signal is produced by the ignition control unit as an output signal at pin 8. The formulation of TD is based on the Hall sensor's input which directly relates to engine speed. TD is a processed square wave signal that represents and is directly proportional to engine speed.

The TD signal is input to the fuel injection control unit at pin 1. The fuel injection control unit simply counts the pulses to calculate engine speed

- K100: 2 pulses = 1 revolution of the crankshaft
- K75: 3 pulses = 1 revolution of the crankshaft

The TD signal has a fixed pulse width, Its frequency increases with increased engine speed, and its duty cycle decreases with increased engine speed.

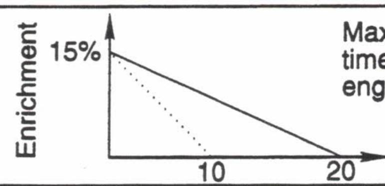
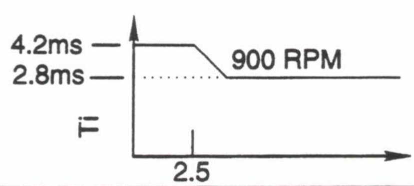


Control Unit Programming

The control units are programmed with operating instructions (MAP) to control the output components based on the information received from the input components.

Ignition Control Unit: The ignition timing map is influenced by monitoring of battery voltage (dwell angle) and TD (° of advance).

Fuel Injection Control Unit: The chart below depicts the influences of the input signals on the fuel injection control unit's maps.

	Air Flow Meter	Throttle Position Switch	Engine Coolant Temperature Sensor (NTC)	TD Signal	Engine Cranking Signal / Start Button	
Start Up					X	Additional 10% Enrichment (Ti increased 10%)
Post Start			X		X	 Enrichment; 15%; 10; 20; Time (sec) Max enrichment time = 20 sec. time reduced with increase in engine temperature.
Cold Start			X	X	X	 Ti; 4.2ms; 2.8ms; 900 RPM; 2.5; Time (sec) Air Flow Meter takes over
Warm Up			X			@ 0° C, 20% Enrichment/@ approx 60° C, 0% (program stops)
Acceleration	X		X			0° to 60° C = 30% / Above 60° C = 20% enrichment. Whenever voltage at pin 7 of fuel injection control unit increases faster than 1[illegible] volts per second.
Full Load Signal	X	X		X		K100: 12% enrichment / K75: 8% enrichment. This occurs @ approx. 4000 - 5000 RPM. The Air Flow Meter is the major control after the full load throttle switch is closed.
Engine Over Run				X		K100: TD >8700 RPM, injectors stop injecting fuel (Ti suppressed). K75: TD >8905 RPM, same as above.
Decel Fuel Cut Off		X		X		With idle contact closed and TD >2000 RPM, injectors stop injecting fuel (Ti suppressed). With TD @< 2000 RPM injection is restored to 75% required Ti for 1 second then to 100% (1 second progresion prevents power surge)

5. With the engine running, the start button is released, the engine starting signal is removed and the:

A. Ignition control unit:

- Removes the ground from the starter relay coil.
- Maintains the ground for the fuel injection relay coil as long as TD is present.
- Continues firing spark plugs through control of the ignition coils. Ignition timing based on input from Hall sensors processed into TD.

B. Fuel Injection control unit:

- Continues injecting fuel by controlling the fuel injectors. Ti is now based on TD and intake air volume but continues delivering an enriched fuel charge based primarily on engine temperature signal (NTC).

With an increase in engine temperature, Ti will decrease.

Other contributing factors:
- Air Temperature
- Throttle position

Note: With the engine running (>700RPM) additional enrichment can be achieved by holding down the start button. The fuel injection control unit perceives this as a start signal and initiates additional enrichment. The ignition control unit will not activate the starter relay with the presence of TD > 700 RPM.

6. The throttle position switch input to the.fuel injection control unit effects the air/fuel ratio by signalling the fuel injection control unit:

- Idle - Ti reduced
- Mid range throttle
- Full Throttle (>75% throttle position) - Ti increased

How the control units perceive the correction factors generated by the presence or lack of the input signals will be covered further on.