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Electronic Signals

Model: All

Production Date: All

Objective

After completion of this module you will be able to:

- Explain the operation of an Inductive Sensor.
- Understand the difference between analog and digital signals.
- Know the difference between NTC and PTC type sensors.
- Explain the operation and use of different types of signals
- Recognize signal types on the oscilloscope.

Electronic Signals

Purpose of Electronic Signals

Electronic signals move information much like cars move passengers down the highway. It would be difficult to get to work without transportation, and there would be no transportation without signals.

Signals allow devices (e.g. sensors or switches) to communicate with control modules (either complicated processors or simple relays) which in turn perform or request (through more signaling) other functions to be carried out.

Signals inform the Climate Control of the outside air temp or tell the brake lights the right time to illuminate.

The use of electronic signals goes far beyond the basic application of electron flow to control components, enabling complex information to be passed from one component to another.

The data (input or output) is conveyed through various forms of changing voltages, resistances, current or frequency modulation.

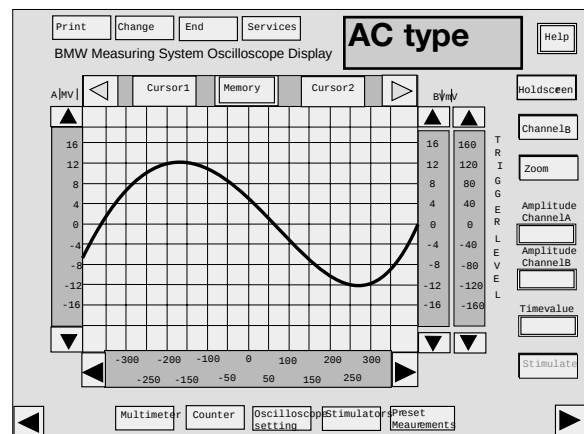
1. AC Voltage Signals

- A.) Inductive Signals
- B.) Phase Shifted Signals

2. DC Voltage Signals

- A.) Analog Signals
- B.) Digital Signals
 - 1. Switched (High/Low) Signals
 - 2. Modulated Square Wave Signals
 - a. Frequency Controlled Signals
 - b. Pulse Width Controlled Signals
 - c. Duty Cycle Controlled Signals
- C.) Designated Value Signals
- D.) Coded Ground Signals
- E.) Transistor Signals
 - 1. Modulated B+/B- Signals
 - 2. Momentary B+/B- Signals
 - 3. Constant B+/B- Signals

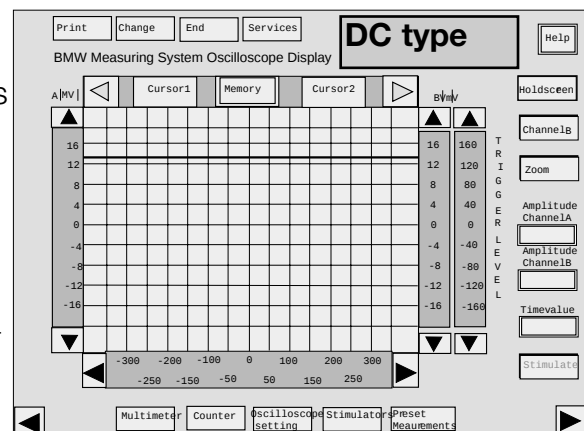
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Signals are divided into TWO main groups:

- AC type signals
- DC type signals

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AC Voltage Signals

Two types of AC Voltage signals are used:

- Inductive Signals (Induced Voltage)
- Phase Shifted Signals (Angle Pulse Generator)

Inductive Sensors

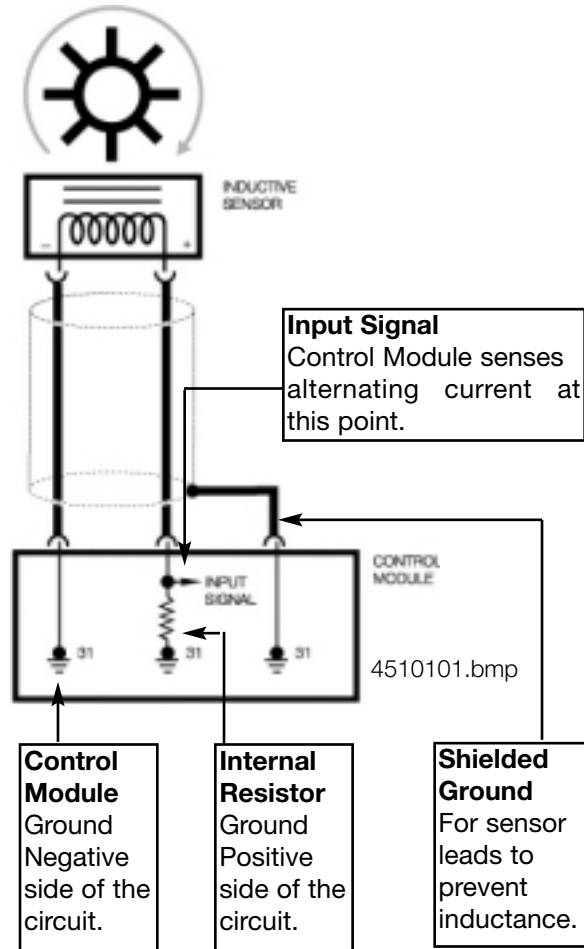
Inductive sensors produce an AC Sine Wave signal. The AC voltage is induced by the shifting of a magnetic field. The sensor consists of an impulse wheel (the moving part) and a coil wound magnetic core (the stationary part).

As each tooth of the impulse wheel approaches the sensor tip, the magnetic field of the sensor shifts toward the impulse wheel and induces a voltage pulse in the windings.

As the teeth move away from the sensor, the magnetic field shifts back inducing a voltage pulse in the opposite direction.

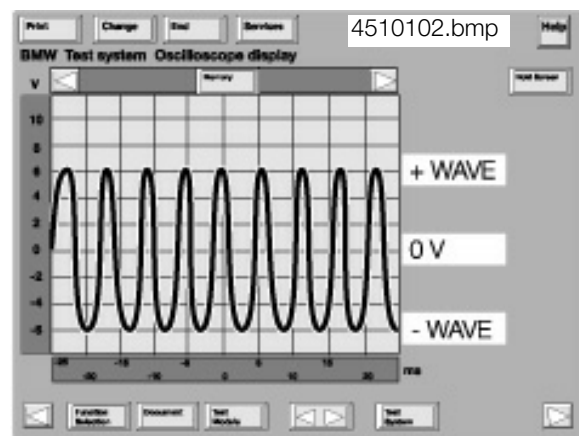
This shifting of the magnetic field produces an alternating current (positive to negative).

Control modules which receive this alternating current, count the impulses (shifts from positive to negative) and interpret the speed of rotation of the impulse wheel.



Typical Application of Inductive Sensors

- Crankshaft Speed Sensor
- Camshaft Speed Sensor
- Transmission Input/Output Speed Sensor
- Wheel Speed Sensor



Voltage levels are dependent on sensor design. Not all inductive sensors produce 12 volts.

Angle Pulse Generator

An Angle Pulse Generator Sensor acts on an existing AC voltage signal rather than produce a new one.

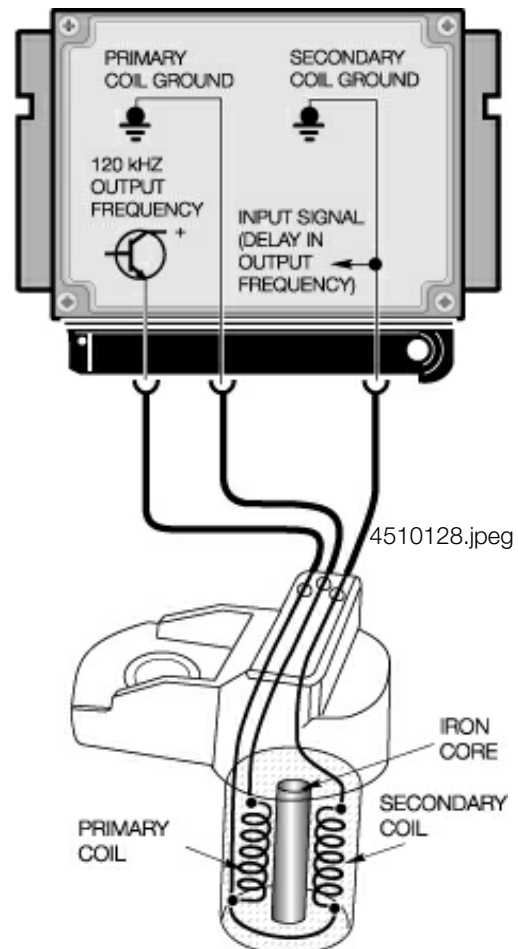
The sensor consists of two windings (primary and secondary) that are connected together at one end and a magnetic iron core (stationary) along with a trigger wheel (movable).

The primary winding (coil) is supplied with a 120kHz AC signal by the control module. The magnetic coupling (core) causes a voltage at the same frequency to be induced in the secondary winding. The induced frequency has a slight phase shift due to the induction time delay.

The trigger wheel influences the magnetic field of the sensor and causes the phase shift to increase as the disc of the wheel moves closer to the sensor.

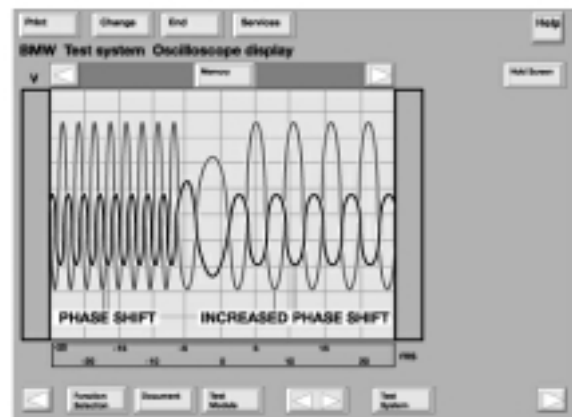
This changing of the phase shift (time delay) from a smaller time period to a larger time period and back again provides the control module with trigger wheel position.

The angle pulse generator provides position information regardless of movement. Trigger wheel position is established with the application of an output frequency from the control module and the return of the phase shifted signal.



Typical Application of Angle Pulse Generator

- Camshaft Sensor MS41.1
- Pedal Request Sensor EML (a bank of three)



Workshop Exercise

1.

Vehicle Model: _____

Capture on oscilloscope an Inductive Wave signal: _____
(Hint: Cranksensor on M62TU, M73TU)

What is the operating range of the signal: _____

What is the frequency of the signal with engine at idle, at 2500 RPM: _____

Freeze signal and print at idle: _____

Perform test plan on crank sensor: _____

2.

Vehicle Model: _____

Capture on oscilloscope an Inductive Wheel speed signal: _____
(Hint: E46)

What is the operating range of the signal: _____

What is the frequency of the signal while turning the wheel by hand: _____

Turning the wheel faster has what effect on the frequency: _____

Freeze signal and print while turning by hand: _____

Perform test plan on wheel speed sensor: _____

Workshop Exercise

3.

Vehicle Model: _____

Capture on oscilloscope an Angle Pulse Generator Signal: _____

With engine off turn key on, what is the effect on the signal: _____

Bump starter over without starting car, what happens to the signal: _____

Observe status of sensor input in DME: _____

4. (Optional Vehicle)

Vehicle Model: _____

Capture on oscilloscope and Angle Pulse Generator Signal: _____

From what control module was this signal captured: _____

What other method is available to check status of sensor: _____

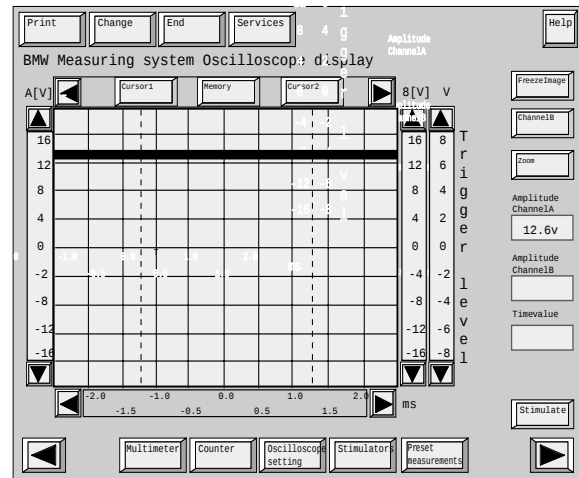
Perform Test Modules 280 and 281: _____

DC Voltage Signals

Five Types of DC Voltage Signals Are Used:

- Analog Signals
- Digital Signals
- Designated Value Signals
- Coded Ground Signals
- Transistor Signals

DC voltage signals are based on either 5 volts or 12 volts.



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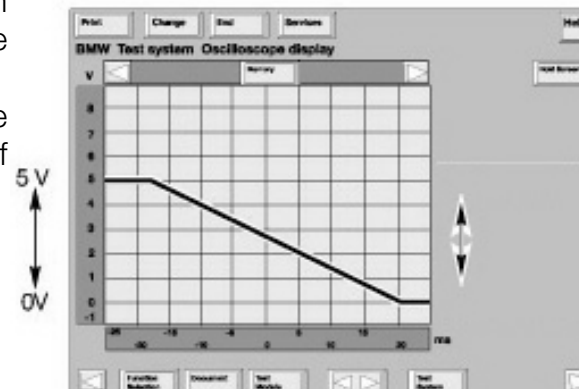
Analog Signals

Analog signals transmit information through an electrical circuit by regulating or changing the current or voltage.

The voltage of the signal has no fixed value. The value may be anywhere in the operating range of the signal.

Three sources of analog signals are:

- NTC Sensors
- PTC Sensors
- Potentiometers

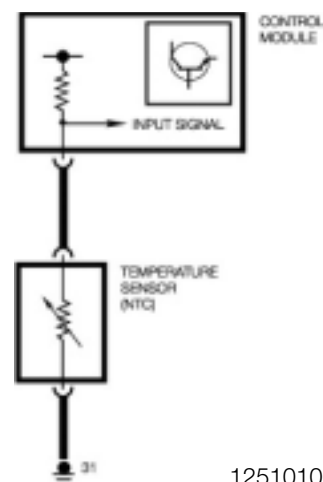


Typical Analog Signal

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NTC Sensors

NTC (Negative Temperature Coefficient) sensors change resistance based on temperature. As the temperature goes up the resistance goes down. This decrease in resistance causes the voltage drop across the sensor to decrease and the input signal voltage at the control module decreases.



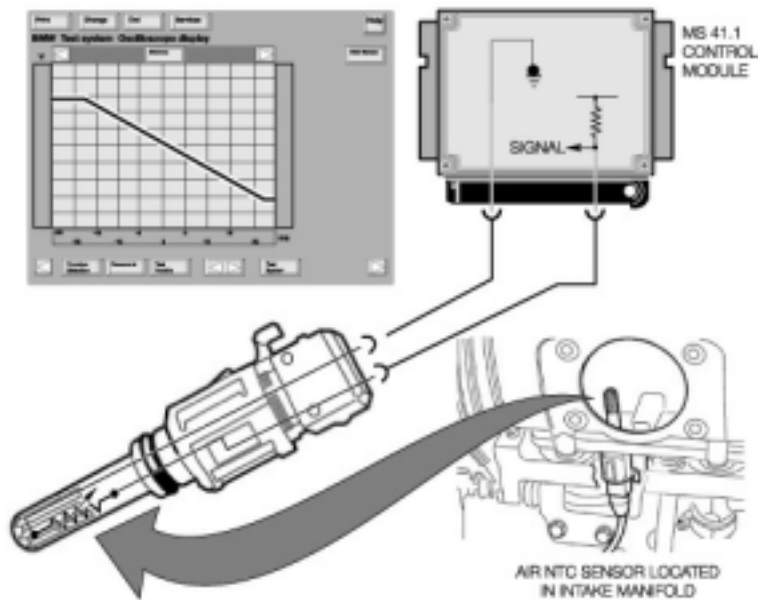
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Examples of NTC sensors

Intake Air Temperature Sensor

The intake air temp sensor provides a 0-5 volt analog signal to the DME indicating temperature of the incoming air.

The intake air temp sensor is located either in the intake manifold or integrated in the mass air flow meter.



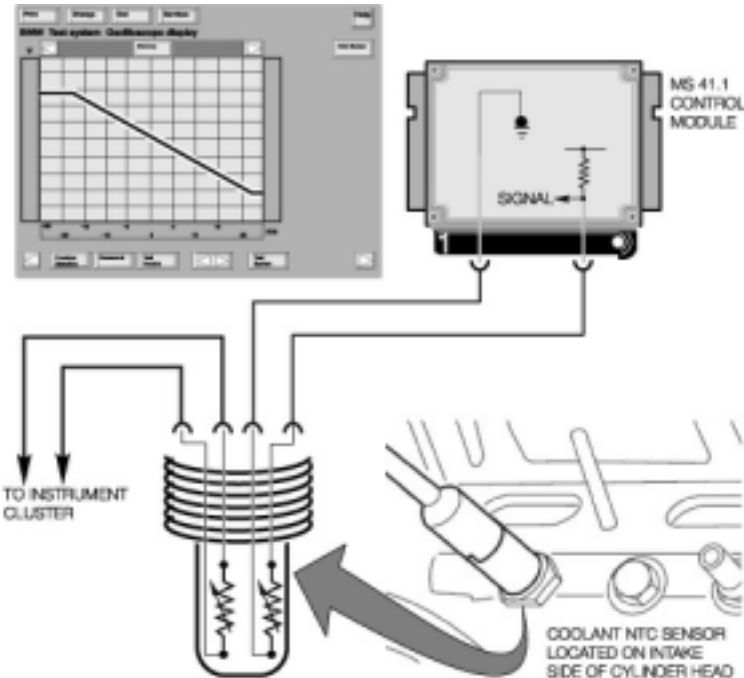
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Engine Coolant Temperature Sensor

A dual sensor is used for engine temp. Operation is the same as other NTC sensors, 0-5 volt operating range, except that two independent sensors are housed in one assembly.

One is for the engine temperature input to the DME.

The other sensor is used to input engine temp to the instrument cluster..



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Typical Application of NTC Type sensor

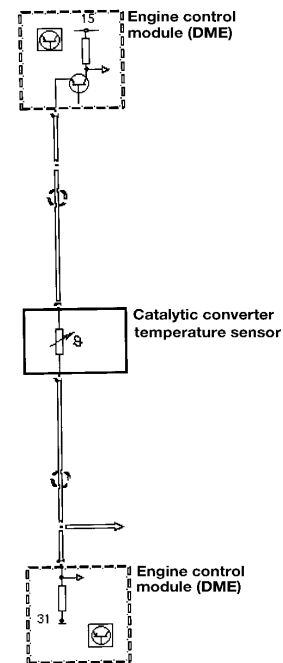
- Engine Coolant Temp Sensor
- Intake Air Temp Sensor
- Transmission Temp Sensor

PTC Sensor

PTC (Positive Temperature Coefficient) sensors also change resistance based on temperature. In a PTC sensor as the temperature goes up the resistance also goes up. The increase in resistance causes the voltage drop across the sensor to increase and the input voltage signal at the control module increases.

Typical Application of A PTC Type Sensor

- Exhaust Temp Sensor
- Transmission Temp Sensor



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Example of PTC Sensor

A M5 Catalytic Converter uses a PTC type sensor to monitor exhaust temperature. A 0-12v signal is supplied to the DME indicating catalyst temperature.

Workshop Hints NTC/PTC Sensors

When troubleshooting a faulty input display, the input signal must be verified as “good” BEFORE the control module is replaced.

When checking a NTC Sensor look for these voltages and problems:

0 volts = no supply voltage or shorted to ground.

2v = sensor is indicating a warm condition for system being measured.

4v = sensor is indicating a cold condition for system being measured.

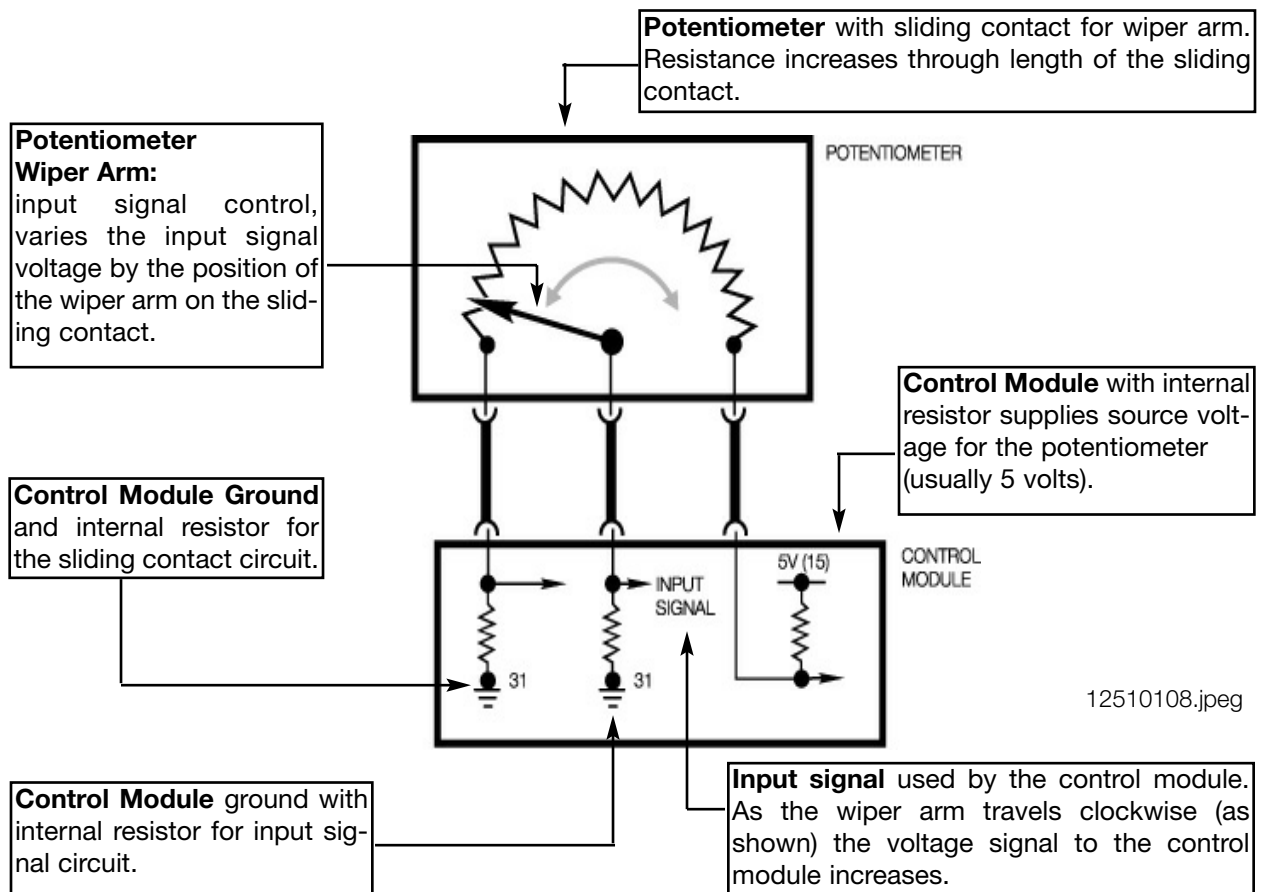
5v = sensor or wiring harness is open.

Remember a PTC type sensor will indicate opposite results on intermediate readings (i.e. 4 volts = warm).

Potentiometers

A Potentiometer produces a gradually changing voltage signal to a control module. The signal is infinitely variable within the operating range of the sensor.

This varying voltage reflects a mechanical movement or position of the potentiometer wiper arm and its related components.



Typical Application of Potentiometers

- Air Flow Meter
- Pedal Position Sensors
- Seat and Mirror Memory Position
- Throttle Position Sensors (Also Feedback Potentiometers)

Workshop Exercise

1.

Vehicle Model: _____

Capture signal from Engine Temp sensor on oscilloscope, using Two channel operation to capture both outputs from sensor: _____

Compare outputs: _____

Perform Test Plan on Engine Temp sensor: _____

What is the correct resistance of the sensor at 100° C: _____

2.

Vehicle Model: _____

Perform Test Plan for Intake Air Temp Sensor: _____

What is the correct resistance of the sensor at 80° C: _____

What is the Voltage value of the input to the DME at operating temp: _____

Workshop Exercise

3.

Vehicle Model: _____

Observe status of Transmission Temp Sensor:

What is the Voltage value of the input to the EGS at operating temp: _____

What is the nominal value of the sensor: _____

Where was the nominal value found: _____

4.

Vehicle Model: _____

Observe status of feedback potentiometers in Diagnosis Requests: _____

Capture on oscilloscope pattern of feedback potentiometer, use two channels, capture both signals and compare to each other: _____

Perform Preset measurement on Potentiometers: _____

5.

Vehicle Model: _____

Perform Test Plan on Potentiometers: _____

Digital Signals

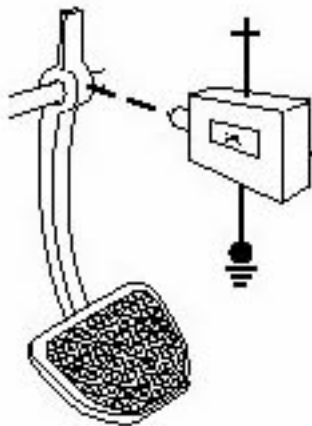
Digital Signals transfer information through an electrical circuit by switching the current on or off. Unlike analog signals which vary voltage, a digital signal has only two possible states, control voltage or 0 voltage.

Two types of Digital Signals:

- Switched (High/Low) Signals
- Modulated Square Wave signals

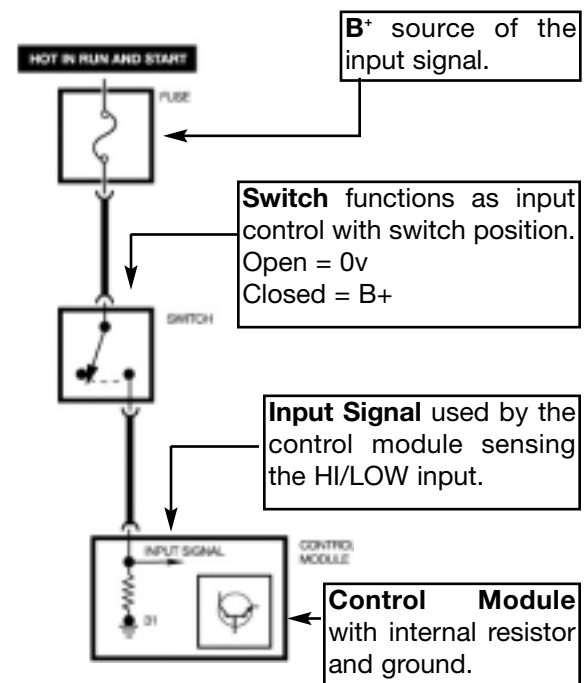
Switched B⁺ (High/Low) Signal

This DC voltage signal produces a YES/NO type input to the control module. The voltage level will indicate a specific operating condition.

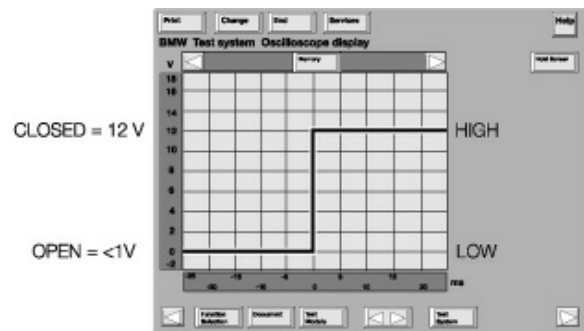


Hall effect Brake Light Switch

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4510110.jpeg



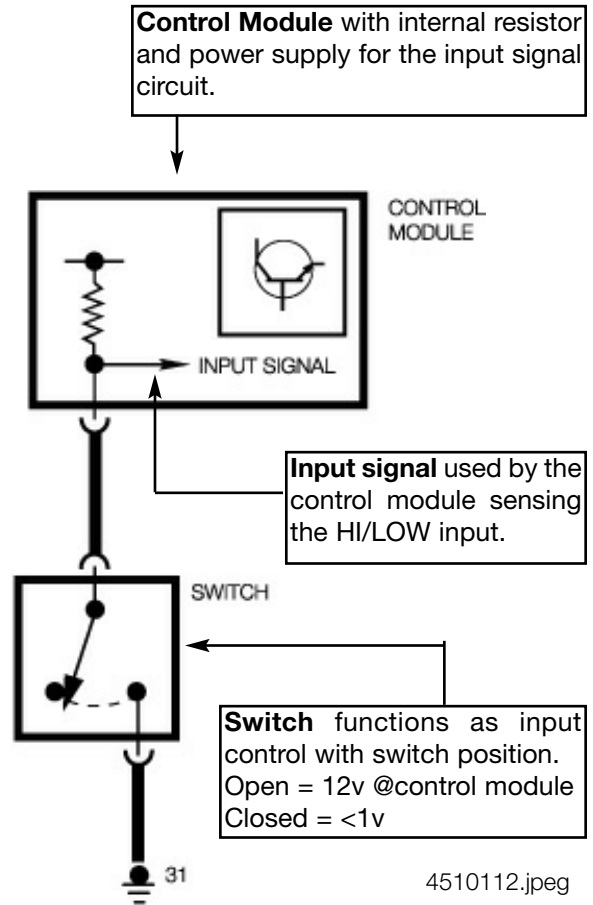
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Typical Application of Switched B⁺

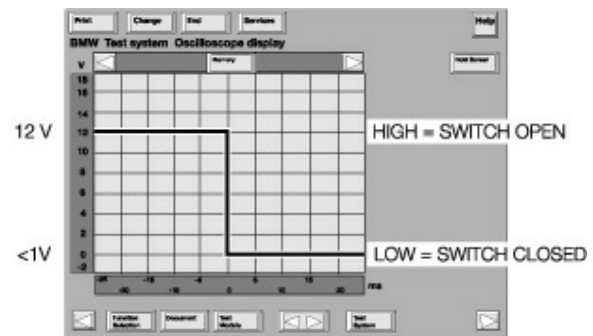
- Ignition Switch
- Light Switch
- Reed Switch
- Seat Belt Switch
- Hall Effect Switch (e.g. Brake Light Switch)

Switched B⁺ (High/Low) Signal

This Ground Signal produces a YES/NO type input to the control module. The voltage level will indicate a specific operating condition.



4510112.jpeg



4510113.jpeg

Typical Application of Switched B⁺

- Door Position Switch
- Kickdown Position Switch
- A/C Pressure Switch

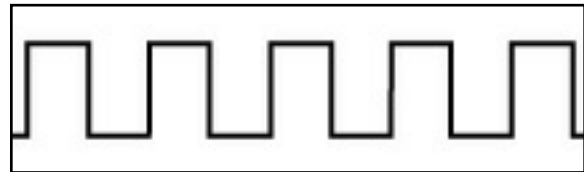
Modulated Square Wave

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A Modulated Square Wave is a series of High/Low signals repeated rapidly.

Like the switched signals (B+, B-) the square wave has only two voltage levels.

A high level and a low level.



A **Modulated Square Wave** appears as a High/Low signal repeated rapidly over and over.

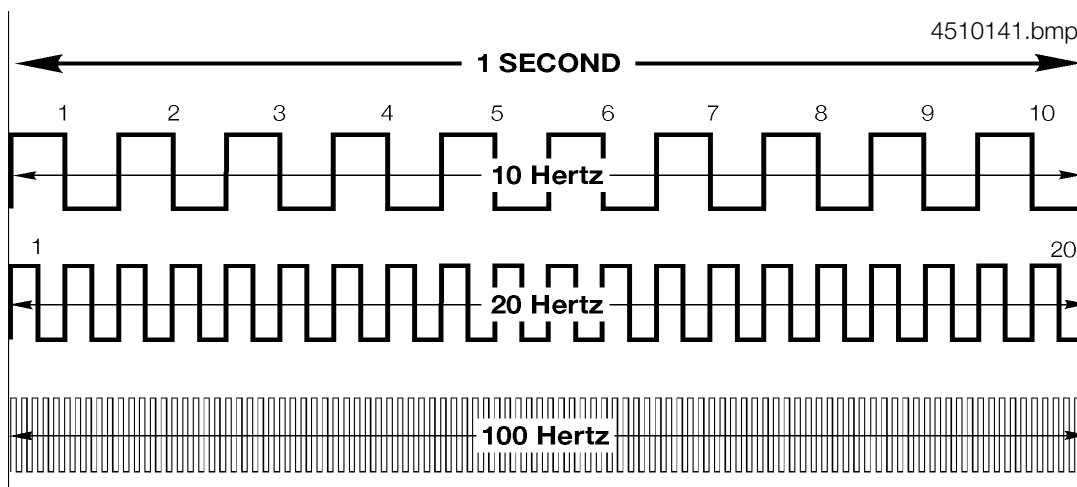
A modulated square wave has 3 characteristics that can be modified to vary the signal:

- Frequency
- Pulse Width
- Duty Cycle

Frequency

The frequency of a modulated square wave signal is the number of complete cycles or pulses that occur in one second. This number of cycles or frequency is expressed in **Hertz (Hz)**. 1Hz = 1 complete cycle per second.

An output function may use a fixed or varied frequency.



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Typical Application of Fixed and Varied Frequency

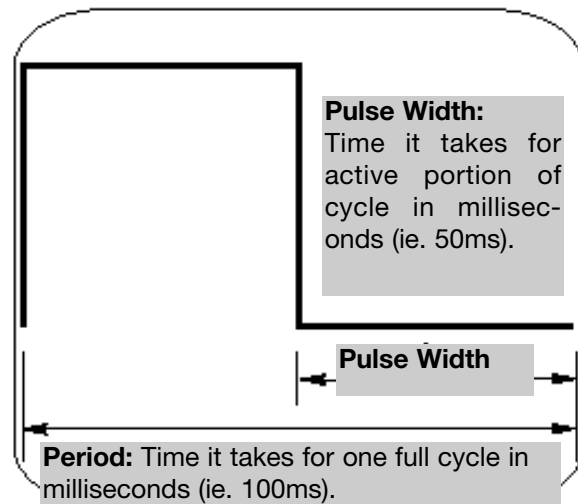
Fixed Throttle command DME to EDK/MDK
Idle motor controls from DME
DKT signal from DME

Note: Most fixed frequencies are 100 Hz.

Varied Hall effect crank sensor
Hall effect wheel speed sensor
Hall effect camshaft sensor

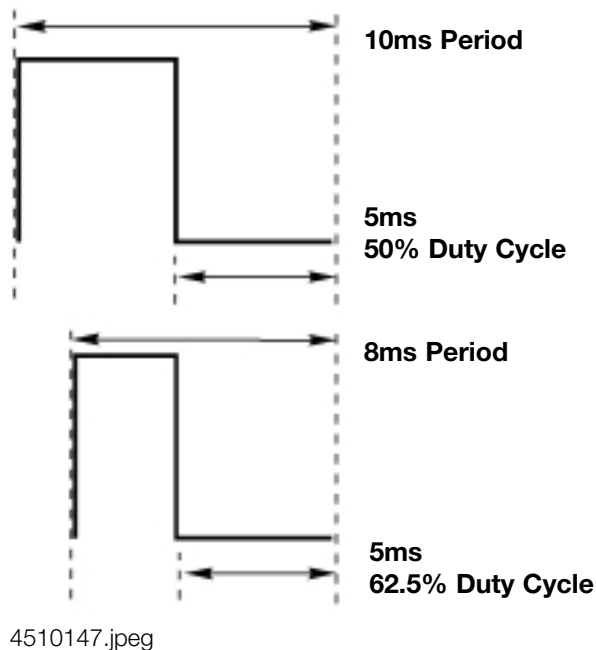
Pulse Width

The Pulse Width of a square wave is the length of time one pulse is ON. Vehicle systems may use fixed or varied ON times or pulse width. Pulse width is expressed in **milliseconds** (ms).



Duty Cycle

The Duty Cycle of a square wave is the ratio of ON time to OFF time for one cycle. Duty cycle is expressed in %. Vehicle systems use both fixed duty cycle signals and variable duty cycle signals.



Time

1 second = 1000 milliseconds (ms)
1/2 second = 500 milliseconds
1/4 second = 250 milliseconds
1/10 second = 100 milliseconds
1/100 second = 10 milliseconds
1/1000 second = 1 millisecond

Workshop Exercise

1.

Vehicle Model: _____

Capture on oscilloscope idle motor control signals from DME, use two channels, capture two signals and compare: _____

Compare Duty Cycle of signals using Counter Function: _____

What is the frequency of these signals: _____

At approx. 40% Duty cycle what is the on time in ms. of the signal: _____

2.

Vehicle Model: _____

Capture on oscilloscope control signals from DME to EDK, use two channels, capture two signals and compare: _____

What is the pulse width of the signals: _____

What is the frequency of the signals: _____

What is the voltage range of the signals: _____

What type of signals are these: _____

Hall Effect Sensors

Hall Effect Sensors produce a modulated square wave.

Hall Effect Sensors are electronic switches that react to magnetic fields to rapidly control the flow of current or voltage ON and OFF.

The Hall Sensor consists of an epoxy filled non-magnetic housing containing a hall element and a magnet, and a trigger wheel.

The Hall element is a thin non-magnetic plate which is electrically conductive. (Voltage will flow through the plate.) Electron flow is equal on both sides of the plate.

Since everything between the magnet and the hall element is non-magnetic the magnet (magnetic field) has no effect on the current flow.

As a metal disk or solid area of a toothed wheel, flywheel or other trigger device approaches the sensor, a magnetic field is created between the magnet and the disk.

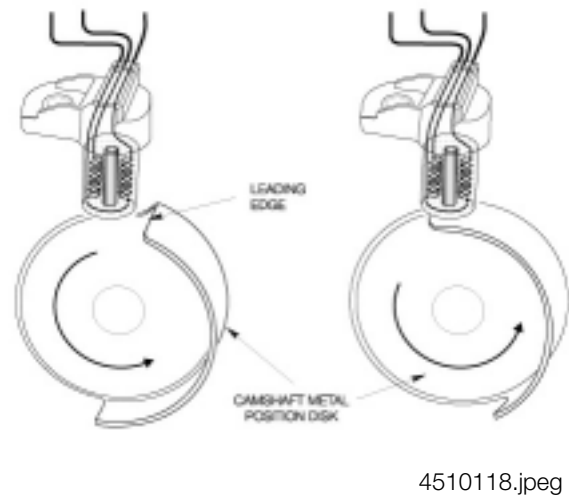
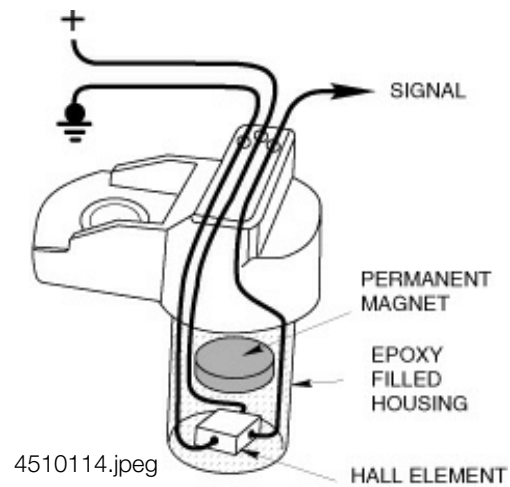
The magnetic field cause the electron flow to stop on one side of the plate. Electrons continue to flow on the the other side of the plate.

The Hall Sensor Signal is a measurement of the voltage drop between the two sides of the plate or element.

When the magnetic field increases (disc or solid toothed area in front of sensor) the voltage drop across the two sides of the element increases. High voltage on one side, little on the other. The signal output from the sensor is High.

As the disc moves away from the sensor the magnetic fields weakens and is lost. The loss of the magnetic field (blank toothed or open area of the wheel in front of the sensor) produces very little voltage drop across the two sides of the element. The output signal is Low.

This rapid switching of the voltage ON/OFF produces a HIGH/LOW signal that the control module uses to recognize speed and position.



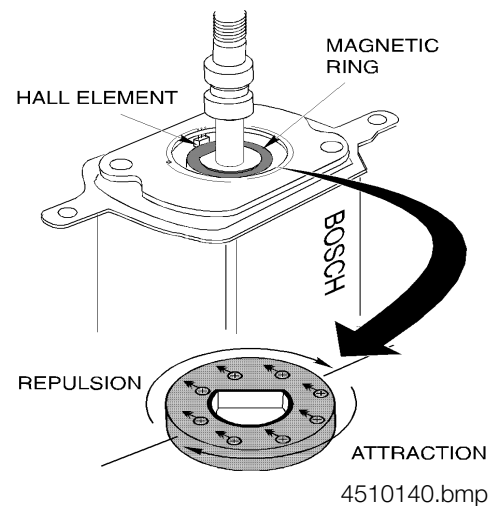
Examples of Hall Effect Sensors

Motor Position Hall Sensors

Hall sensors are used on many electric motors to monitor speed and position. (i.e. electric window motors and sunroof motors.)

The Hall Effect principal is the same except the magnet is placed on the shaft of the motor.

The magnet is aligned to rotate in a precise position in front of the element. The polarization of the magnetic ring causes a polarity switch in the Hall element to occur as it rotates



The square wave produced provides speed and position information to the control module.

Wheel Speed Hall Effect Sensors

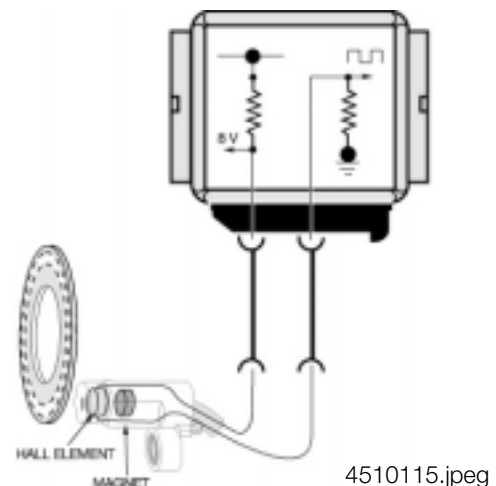
Hall Effect sensors are used to indicate wheel speed.

Conventional Hall Effect Sensors use three wires, power supply (usually 5v or 12v) a ground wire and a signal wire back to the control module.

The Hall Effect sensors used as wheel speed sensors are unique in that they are two wire Hall Effect Sensors.

The two wire sensors eliminate the separate ground wire and the signal wire functions as the ground also.

The unique two wire arrangement provides the control module with a HIGH/LOW signal having a low voltage of .75 volts and a high voltage of 2.5 volts.



Typical Application of Hall Effect sensors

- Crankshaft Sensors
- Camshaft Sensors
- Wheel Speed Sensors
- Motor Position and Speed Sensors (e.g. Window Motor, Sunroof Motor)

Workshop Exercise

1.

Vehicle Model: _____

Capture Camshaft sensor on oscilloscope: _____

Explain shape of signal: _____

The high voltage portion of the signal means the toothed or blank portion of the wheel is in front of the sensor: _____

Draw shape of sensor wheel:

What is the frequency of this signal at idle: _____

As engine RPM is increased what happens to the frequency: _____

Observe status of sensor in Diagnosis Requests: _____

2.

Vehicle Model: _____

Observe Status of wheel speed sensor in Diagnosis Requests: _____

Perform Test Plan for Wheel Speed sensor: _____

What is the shape of the wheel speed sensor signal: _____

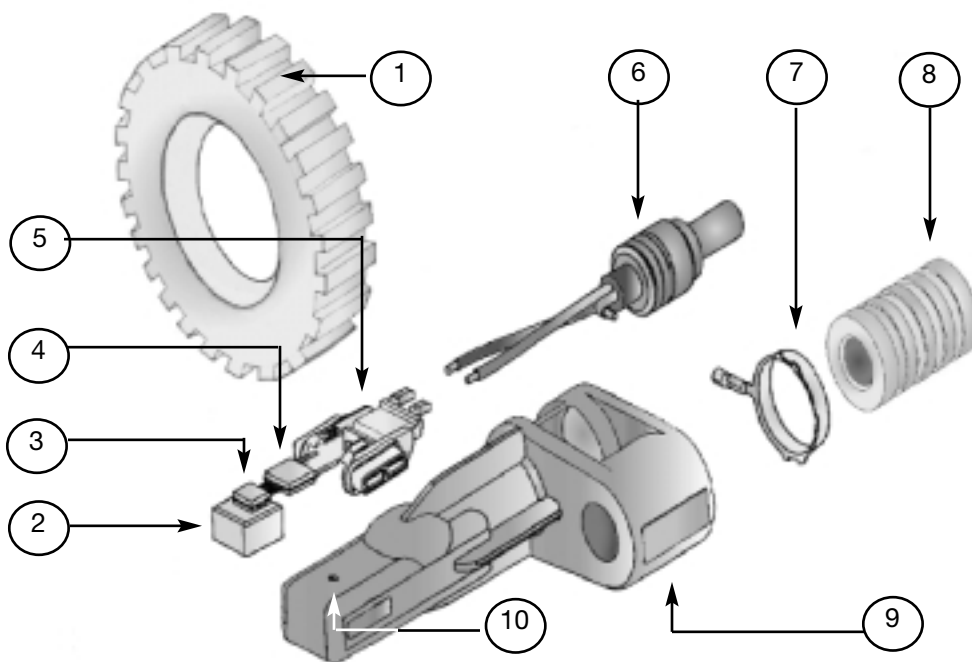
What is the accepted frequency range of the wheel speed sensor: _____

What is the operating voltage range of the wheel speed sensor: _____

Magnetoresistive Sensors

The active sensing of the Magnetoresistive Sensor is particularly suitable for advanced stability control applications in which sensing at zero or near zero speed is required.

A permanent magnet in the sensor produces a magnetic field with the magnetic field stream at a right angle to the sensing element.



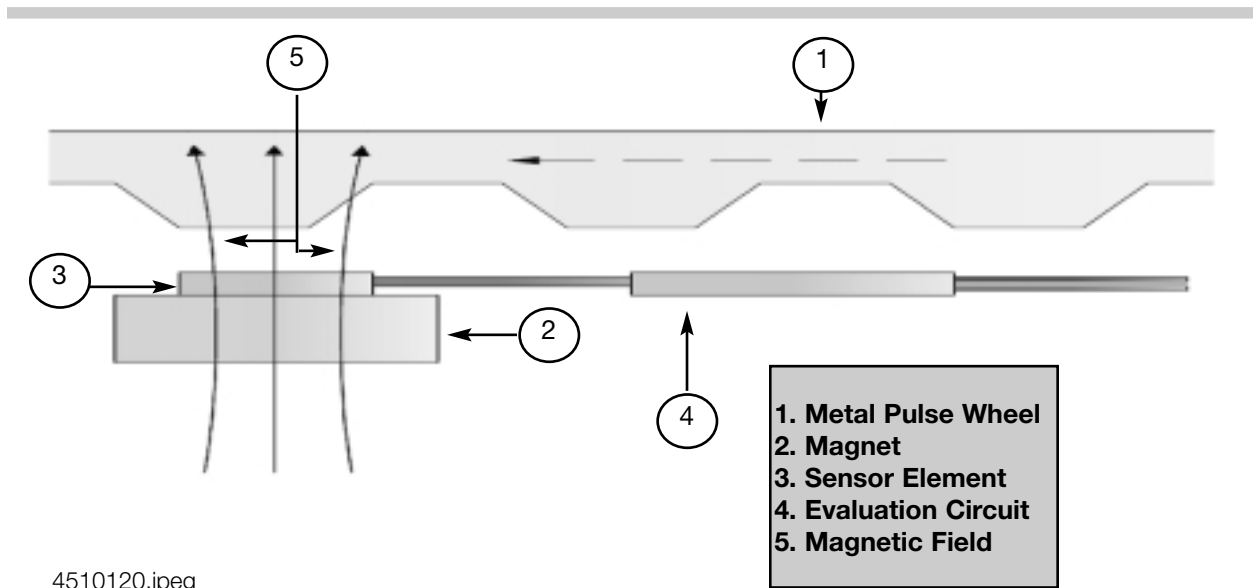
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- 1. Metal Pulse Wheel
- 2. Magnet
- 3. Sensor Element
- 4. Evaluation Module
- 5. Support for Sensor Element

- 6. Sensor Wiring With Weather Boot
- 7. Ground Contact Ring
- 8. Fastening Element
- 9. Sensor Housing
- 10. Pick-Up Surface

The sensor element is a ferromagnetic alloy that changes its resistance based on the influence of magnetic fields.

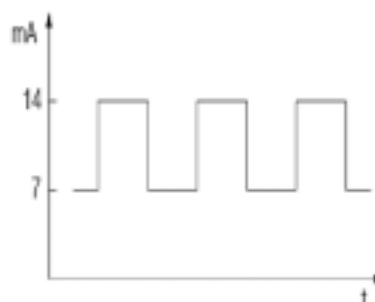
As the high portion of the pulse wheel approaches the sensing element a deflection of the magnetic field stream is created. This creates a resistance change in the thin film ferromagnetic layer of the sensor element.



The sensor element is affected by the direction of the magnetic field, not the field strength. The field strength is not important as long as it is above a certain level. This allows the sensor to tolerate variations in the field strength caused by age, temperature, or mechanical tolerances.

The resistance change in the sensor element affects the voltage that is supplied by the evaluation circuit. The small amount of voltage provided to the sensor element is monitored and the voltage changes (1 to 100mv) are converted into current pulses by the evaluation module.

- Signal Low-**7mA**
- Signal High-**14mA**



The sensor is supplied 12V by the control unit. Output voltage from the sensor is approximately 10V. The control unit counts the high and low current pulses to determine the wheel speed.

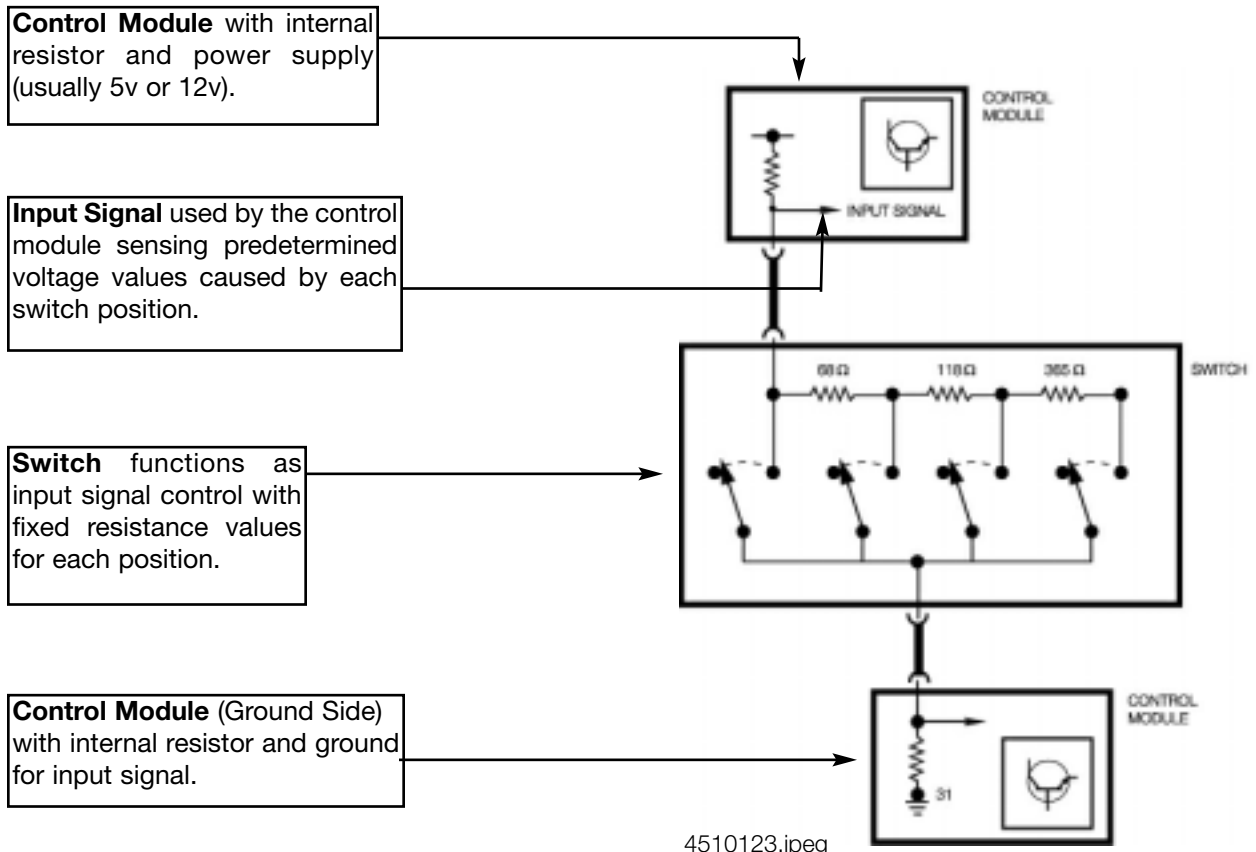
Typical Application of Magnetoresistive Sensor

- Found Currently on E46 with Teves DSCIII MK-60

Designated Value Signals

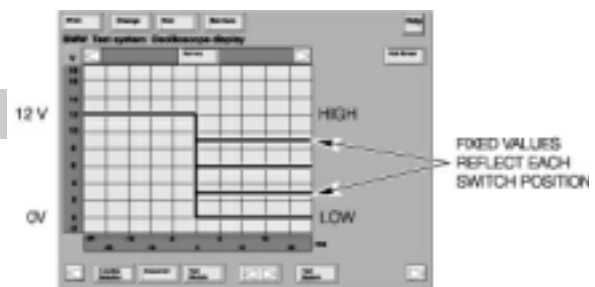
Designated values are produced through fixed resistance positions of a multi-position switch. As the switch is operated the voltage drop across the resistor(s) of each switch position causes the voltage level of the input signal to change to a predetermined voltage value.

These predetermined (designated) voltages signal the control module to perform specific functions.



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Voltage Values seen as input by control module.



Typical Application of Designated Values

- Cruise Control Switch On E 32
- Seat and Mirror Memory Position Buttons

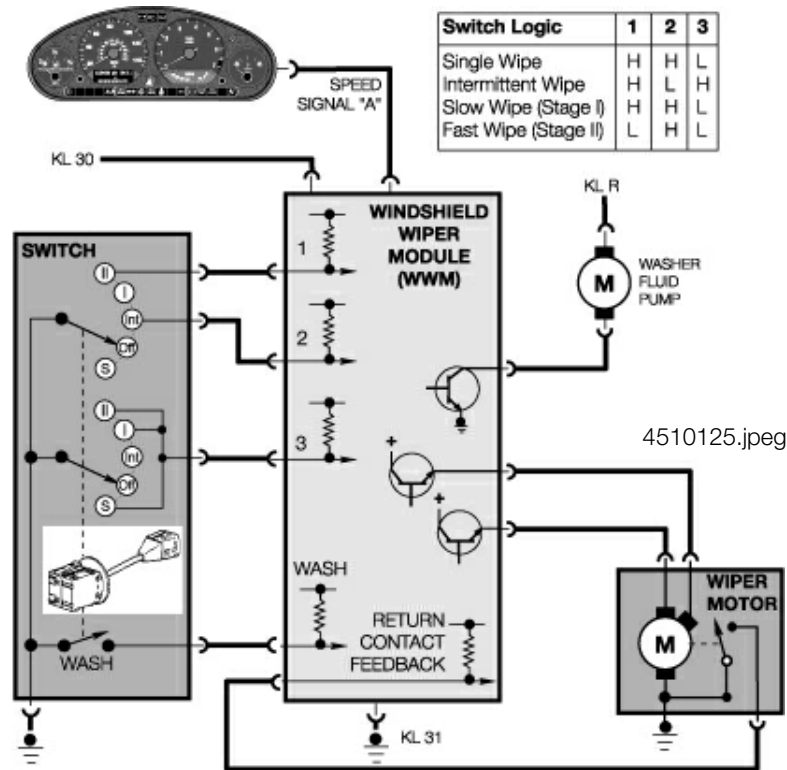
Coded Ground Signals

Coded ground signals produce a set of High/Low requests, the combination (pattern) of which is interpreted by the control module to perform a specific function.

Coded ground signals are generated through a switch or series of switches signaling the control module requests for operation.

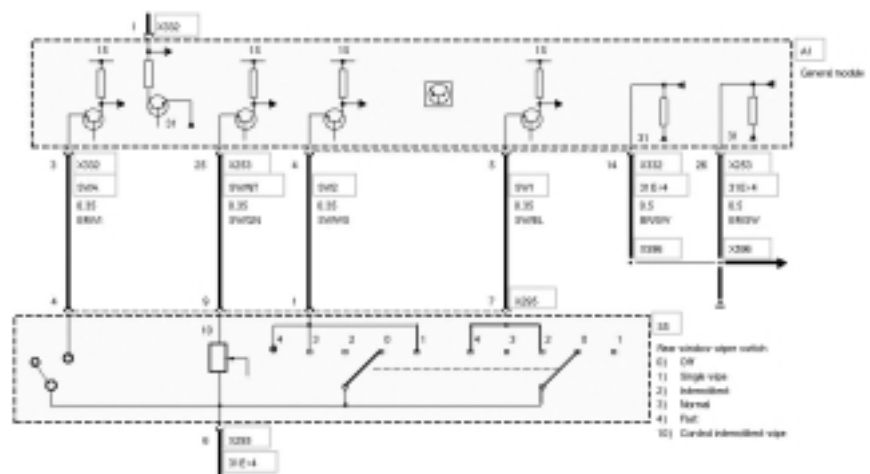
E 36 Wiper Circuit

3 Circuits to wiper switch provide coded ground signals to Wiper Module for operation requests.



E 39 Wiper

2 circuits to wiper switch provide coded requests to General Module.



Switch Logic	1	2
Single Wipe		
Intermittent		
Normal		
Fast		

Typical Applications of Coded Ground Signals

- Wiper Switch

Transistor Final Stage Function

The transistor takes on a number of applications that must be understood to effectively analyze a circuit.

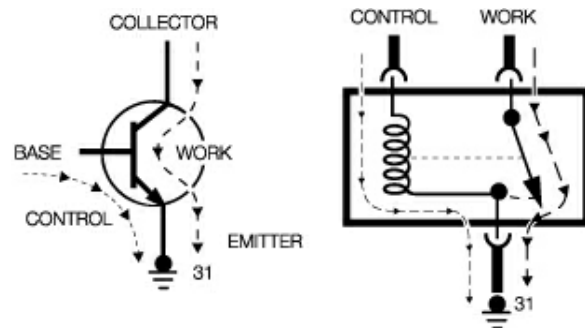
The transistor in operation functions as two parts much like a relay. Both the relay and the transistor control high currents with a low current signal.

The base/emitter path functions as the control circuit activated by the control module to oversee or control the work.

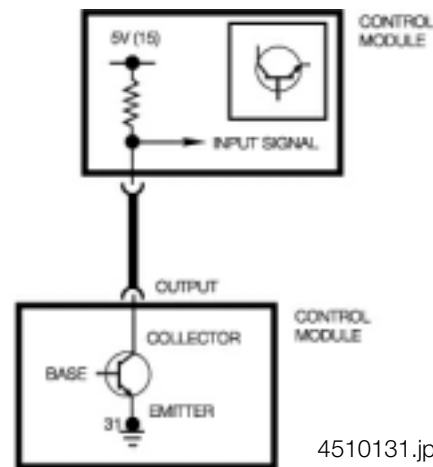
The collector/emitter path functions as the work side of the circuit, supplying power or switching on the work.

In operation the transistor can be switched ON momentarily, or supply a constant power or ground.

The transistor can also be modulated or pulsed to supply a modulated square wave signal.



4510129.jpeg

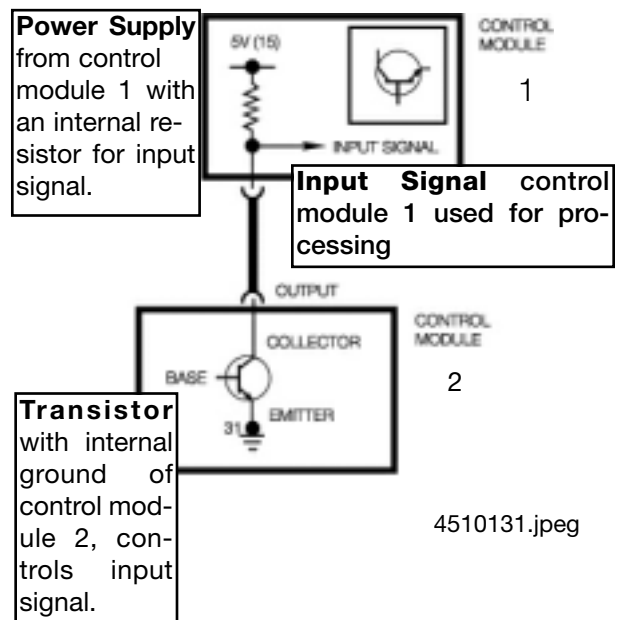


4510131.jpeg

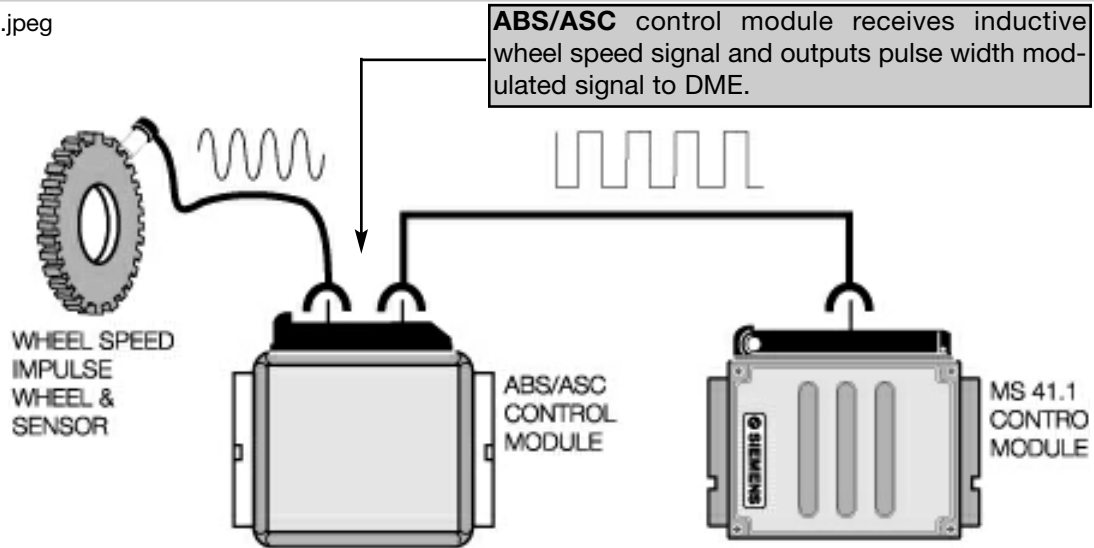
Modulated, Momentary, Constant B⁻ as Input/Output

The input signal of control module 1 is an output signal of control module 2. Control module 2 through activation of its internal transistor provides a ground input for control module 1.

The input signal at control module 1 is either a momentary/constant signal (i.e torque converter signal from TCM to DME) or a modulated signal (i.e. vehicle speed signal ASC to DME).



4510131.jpeg



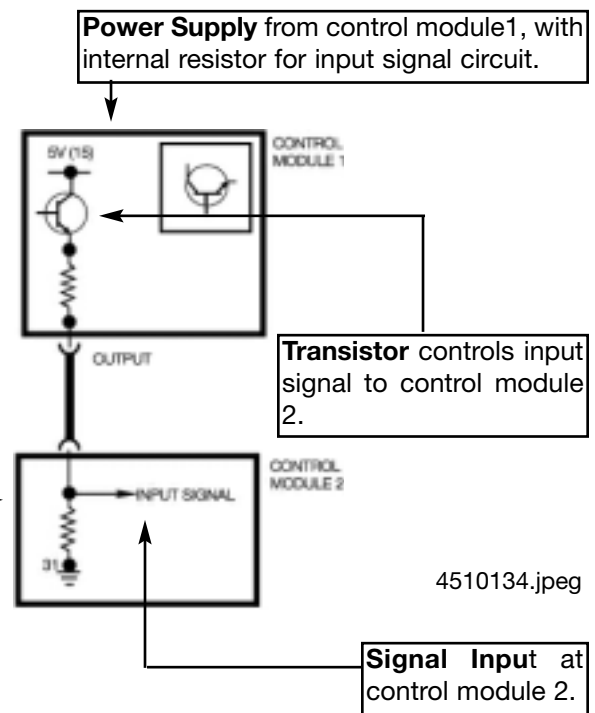
Typical Application of Modulated, Momentary, Constant B- as Input/Output Signal

- A/C KO Signal
- Speed Signal From ABS/ASC
- TI/TD Output Signal From DME

Momentary/Constant B⁺ as an Input/Output Signal

The input of control module 2 is controlled by control module 1 through internal activation of the transistor. Control module 1 provides power for the input circuit of control module 2.

Control module 2 with internal resistor and ground for input signal.



4510134.jpeg

Typical Application of Momentary/Constant B⁺ as an Input/Output Signal

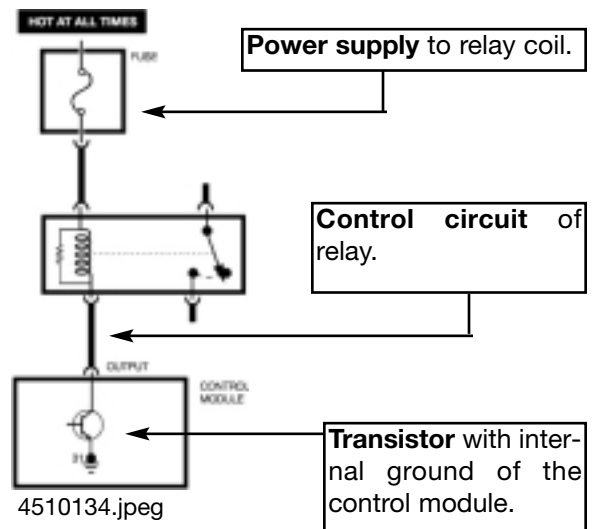
- OBC Code Signal to DME
- A/C Signal to DME

Constant B-/B+ To Energize a Component

Constant B-

Output function to energize a component.

Relay is energized by control module.
Internal activation of the transistor provides a ground for the relay coil.

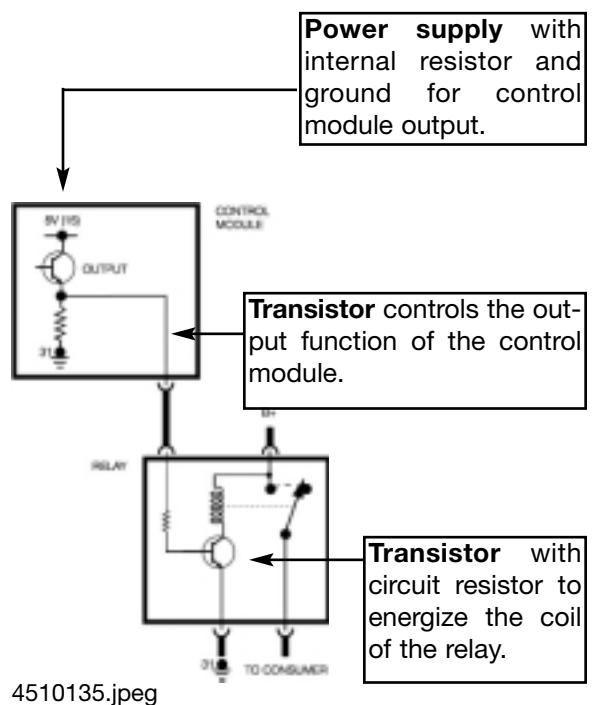


Constant B+

Control module output function to energize a component.

Transistor controls output function of the control module.

Control module supplies power to the relay.
The relay is activated by the control module through internal activation of the transistor which provides a ground for the relay coil.



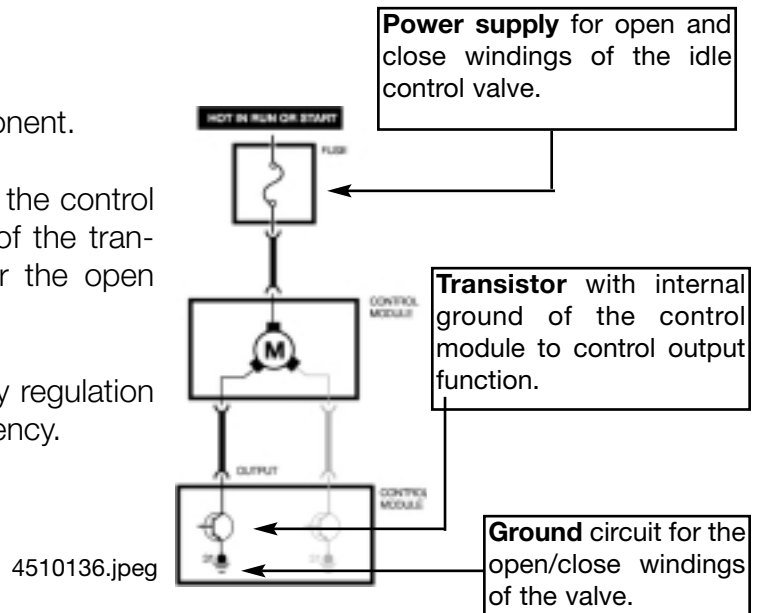
Modulated B-/B+ To Operate A Component

Modulated B-

Output function to operate a component.

The idle valve motor is operated by the control module through internal activation of the transistor which provides a ground for the open winding of the valve.

The idle control valve is operated by regulation of the duty cycle at a specific frequency.



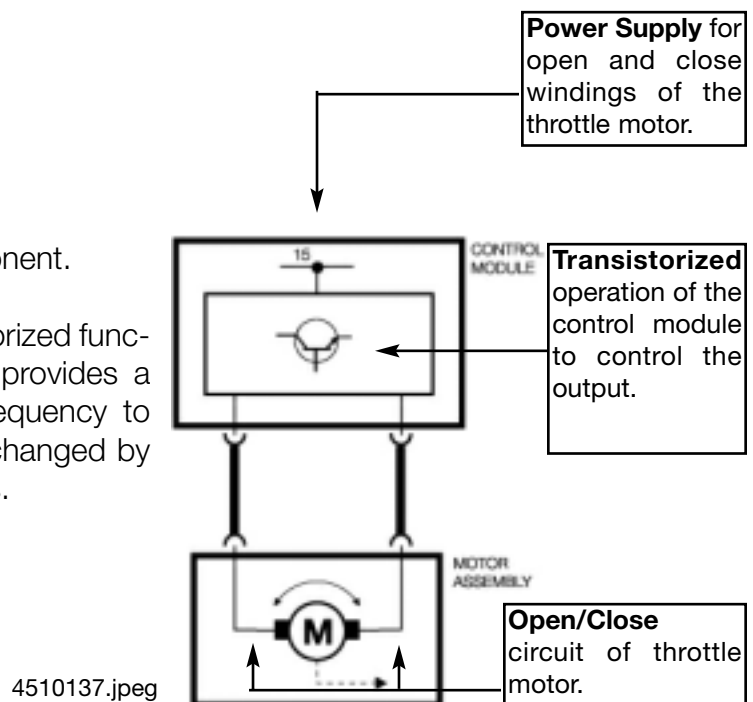
Typical Application of modulated B-

- Idle Control Motor
- Purge Valve
- Injector
- Ignition Coil

Modulated B+

Output function to operate a component.

The motor is controlled by a transistorized function of the control module, which provides a modulated voltage at a specific frequency to the motor. The throttle position is changed by altering the Duty Cycle of the pulses.



Workshop Exercise

1.

Vehicle Model: _____

Perform Test Plan for wheel speed sensor: _____

What is the operating frequency range for this type of sensor: _____

What color is the coded connection for this sensor: _____

2.

Vehicle Model: _____

Capture on oscilloscope TI signal at DME: _____

Is this signal an input or output: _____

3.

Observe status in Diagnosis Request of Wiper Switch: _____

Operate switch and observe all functions: _____

4.

Vehicle Model: _____

Capture on oscilloscope injection pattern of injector#1: _____

What is the pulse width of this signal: _____

What causes the voltage spike to be present: _____

How is the signal pulse width effected as RPM increases: _____

Diagnostic Exercise Worksheet #1

Vehicle Model: _____

Customer Complaint: Wipers not functioning

Observations/Symptoms/Faults stored: _____

Test steps/modules recommended by diagnostic program: _____

Test steps/modules performed: _____

Results: _____

Repair Recommendation: _____

Notes: _____

Diagnostic Exercise Worksheet #2

Vehicle Model: _____

Customer Complaint: Rear windows do not one touch up.

Observations/Symptoms/Faults stored: _____

Test steps/modules recommended by diagnostic program: _____

Test steps/modules performed: _____

Results: _____

Repair Recommendation: _____

Notes: _____

Diagnostic Exercise Worksheet #3

Vehicle Model: _____

Customer Complaint: Rear hatch or window will not open

Observations/Symptoms/Faults stored: _____

Test steps/modules recommended by diagnostic program: _____

Test steps/modules performed: _____

Results: _____

Repair Recommendation: _____

Notes: _____

Diagnostic Exercise Worksheet #4

Vehicle Model: _____

Customer Complaint: Wipers do not function

Observations/Symptoms/Faults stored: _____

Test steps/modules recommended by diagnostic program: _____

Test steps/modules performed: _____

Results: _____

Repair Recommendation: _____

Notes: _____

Review Questions

1. What are the two main groups of signals ? _____

2. The two parts of an inductive sensor are: _____

3. The frequency of a signal indicates _____
4. In a NTC sensor as Temperature increases, Resistance _____
5. The operating voltage range of an Intake Air Temp Sensor is ? _____
6. High resistance in a PTC sensor indicates hot or cold? _____
7. A 5V measurement in a NTC sensor means ? _____
8. Describe the purpose of the three wires used on a potentiometer ? _____
9. How do digital signals transfer information ? _____
10. How many voltage level possibilities does a Modulated Square Wave contain? _____
11. The duty cycle of a square wave is the ratio of _____ to _____.
12. Duty cycle is expressed in _____
13. 1ms is equal to _____ seconds.
14. When is the signal on a Hall Effect Sensor high? _____
15. The base/emitter path of a transistor functions as _____

