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(54) **MODULAR AUTOMOTIVE DIAGNOSTIC SYSTEM**

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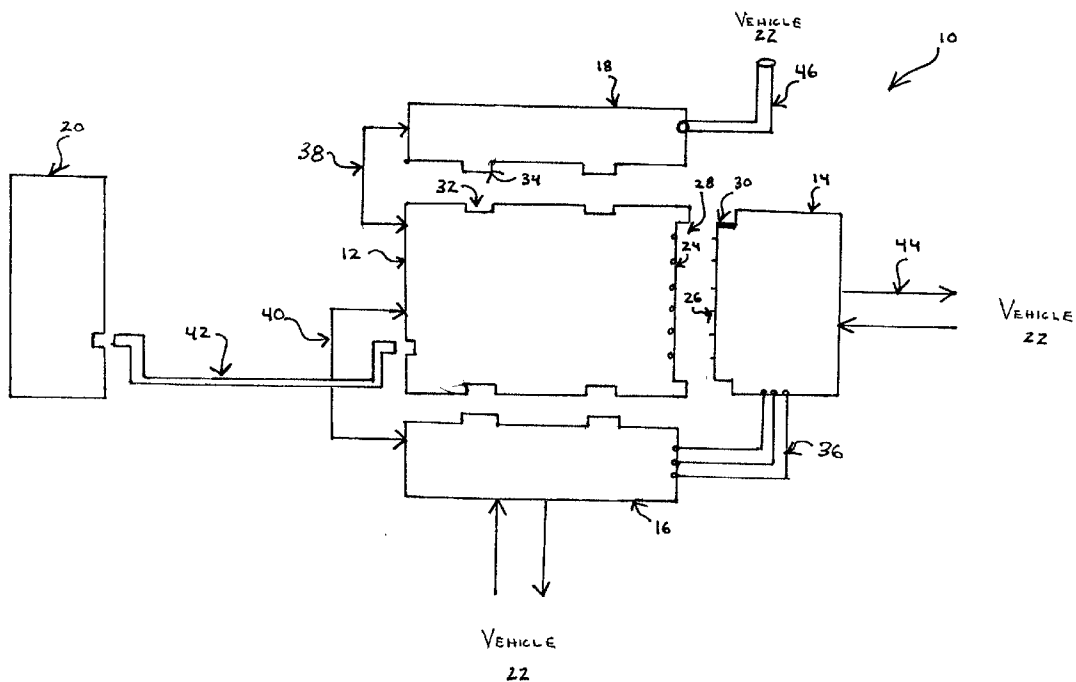(22) Filed: **Dec. 4, 1998**

Related U.S. Application Data

(63) Non-provisional of provisional application No. 60/067,818, filed on Dec. 5, 1997.

Publication Classification

(51) **Int. Cl.**^{7} **G06F 13/00**; **G01M 17/00**
(52) **U.S. Cl.** **701/29**; **702/183**

(57) **ABSTRACT**

A modular vehicle diagnostic system includes a plurality of devices substantially enclosed by individual housings are selectively interconnected for sensing or receiving selected signals from a vehicle, for selecting vehicle parameters for vehicle diagnosis or evaluation, for processing the signals, and for displaying the vehicle parameters. The devices are interconnected by conjoining mechanisms associated with the individual housings and/or by having communication channels established between them.
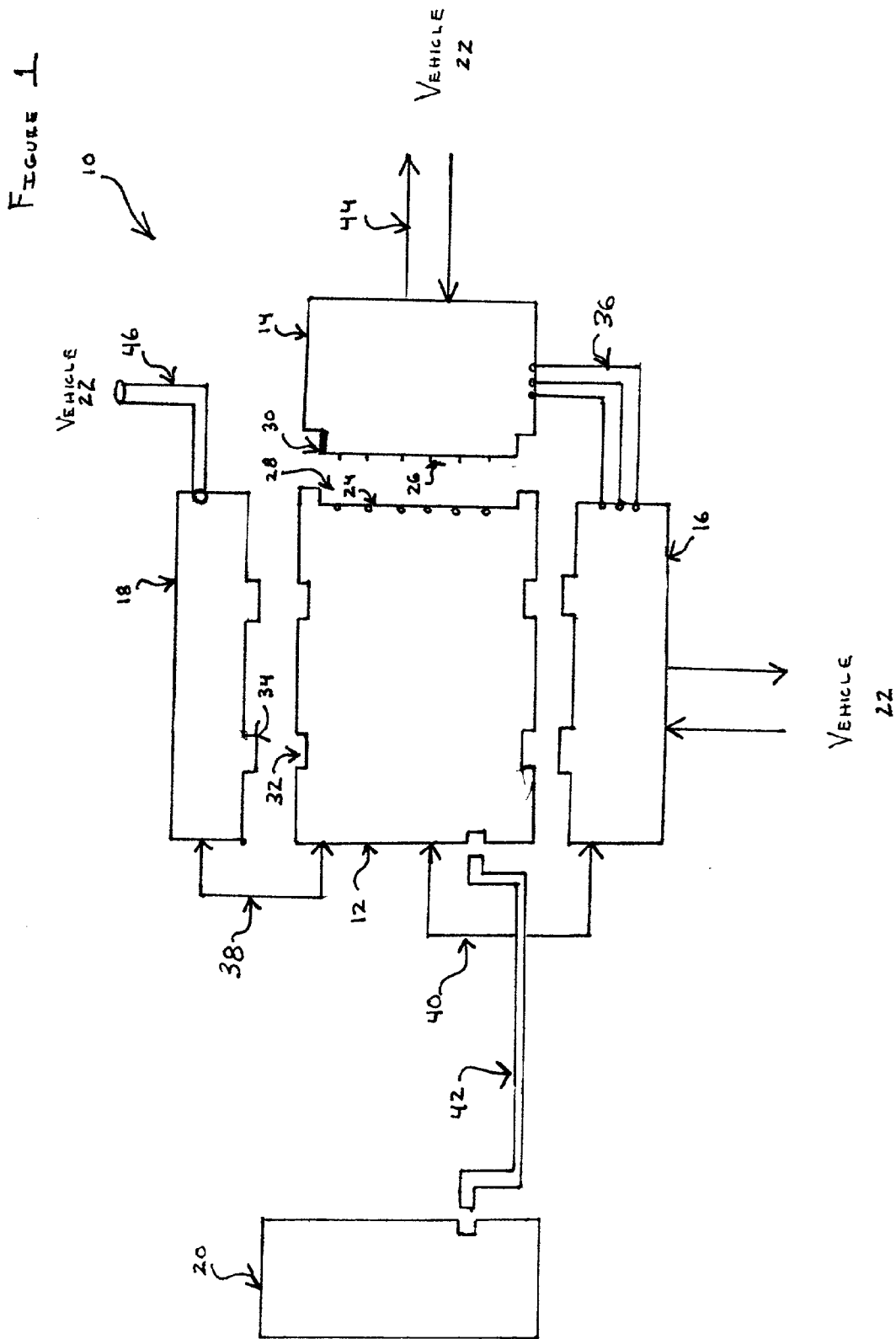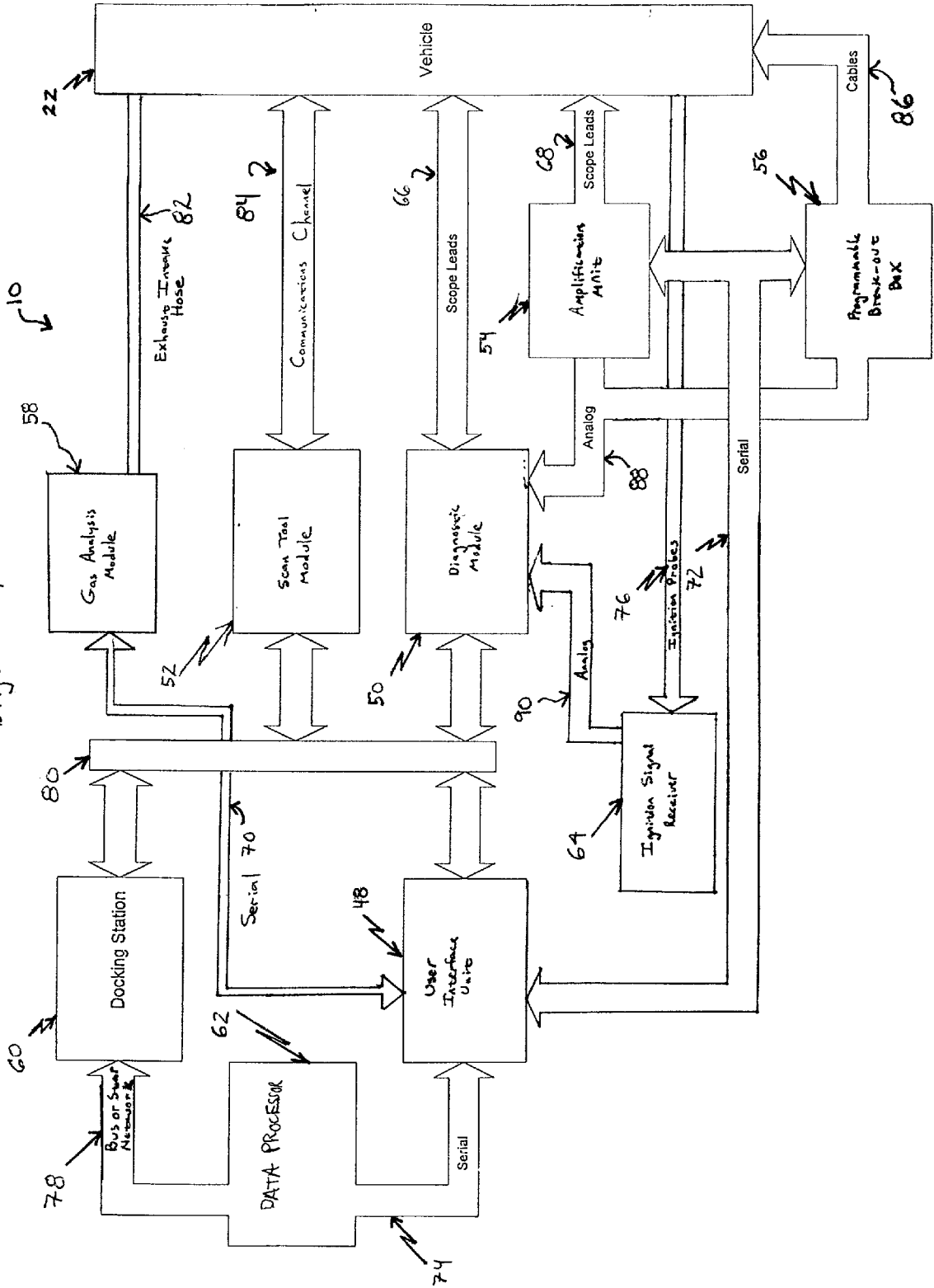
FIGURE 1

Figure 2

Figure 3

48

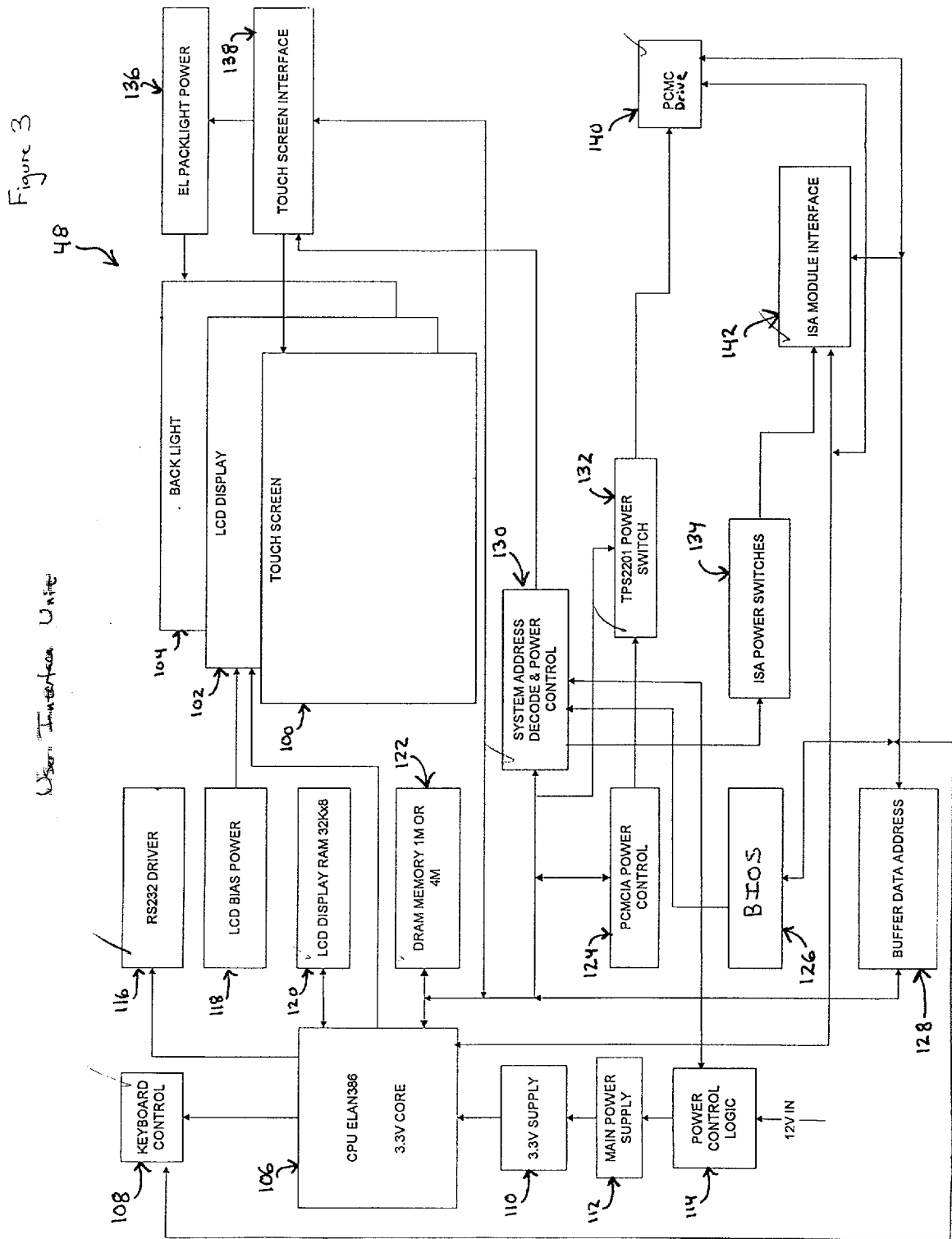User Interface Unit

136 EL PACKLIGHT POWER

138 TOUCH SCREEN INTERFACE

104 BACK LIGHT

102 LCD DISPLAY

100 TOUCH SCREEN

116 RS232 DRIVER

118 LCD BIAS POWER

120 LCD DISPLAY RAM 32k×8

122 DRAM MEMORY 1M OR 4M

130 SYSTEM ADDRESS DECODE & POWER CONTROL

132 TPS2201 POWER SWITCH

134 ISA POWER SWITCHES

140 PCMC Drive

142 ISA MODULE INTERFACE

124 PCMCIA POWER CONTROL

126 BIOS

128 BUFFER DATA ADDRESS

108 KEYBOARD CONTROL

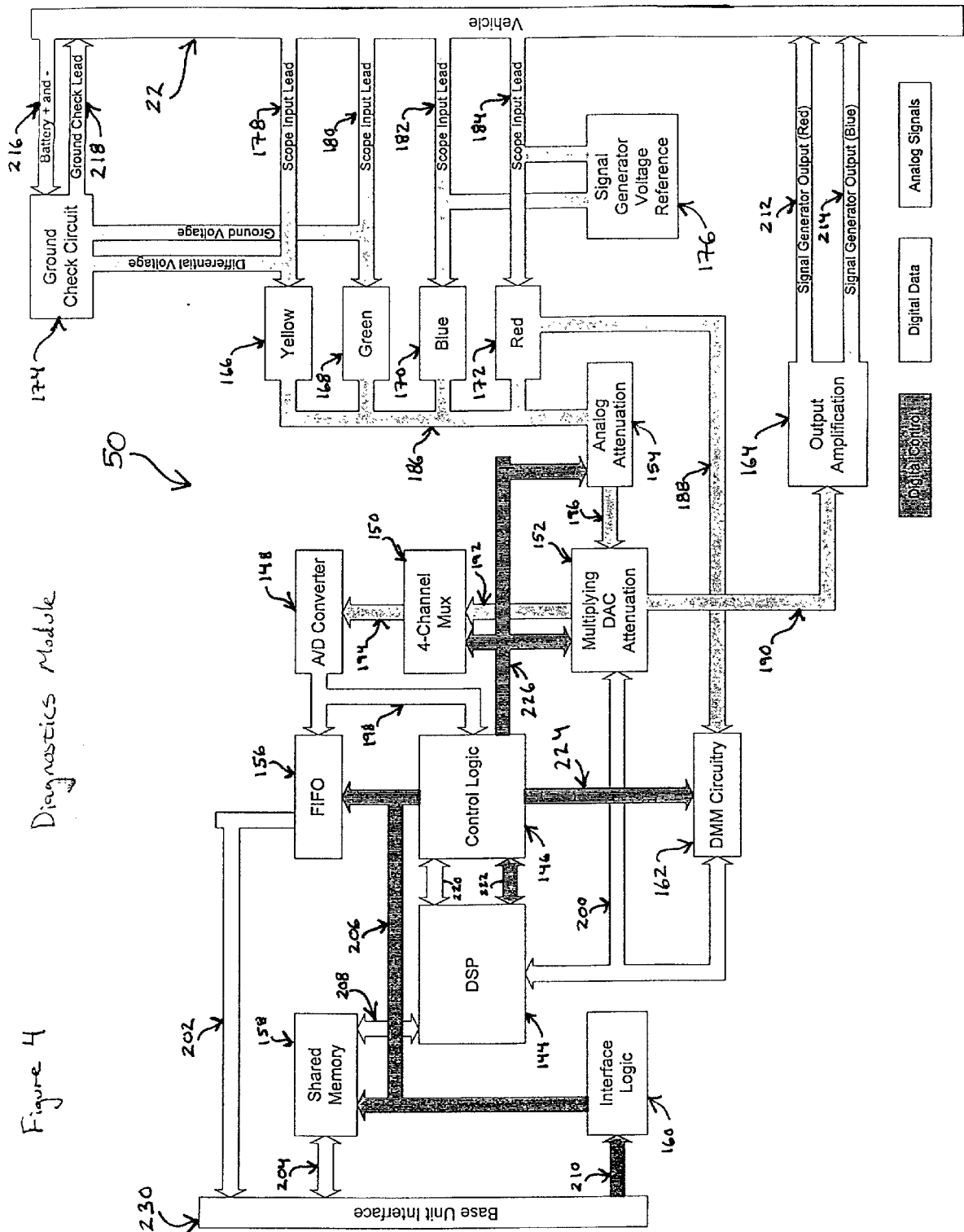106 CPU ELAN386 3.3V CORE

110 3.3V SUPPLY

112 MAIN POWER SUPPLY

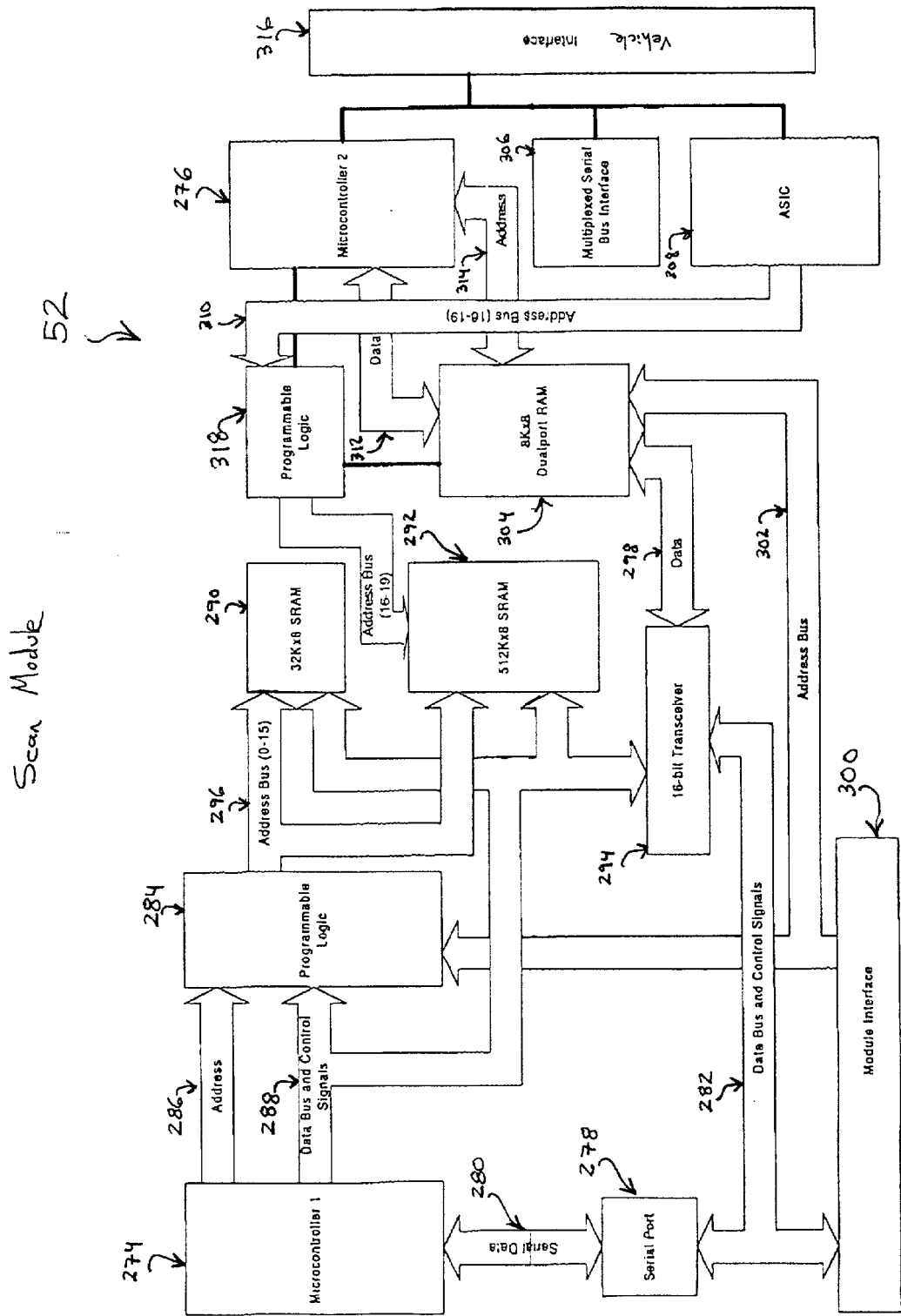114 POWER CONTROL LOGIC

12V IN

Figure 4

Figure 5

FIGURE 6

240

242

FIGURE 7

240

FIGURE 8

Figure 9

Amplification Module

Figure 10

400

MCU

22

Vehicle

56

402

J1 and J2 connectors   CABLE ID

406

Input Circuit

408

80 to 4 multiplexer

414

HARDWARE ID

Microcontroller

404

416

410

4 BUFFERS

4 analog inputs   PAC

Figure 11

408

Stage 1   412

To
Input
Circuit

16   3494

16   3494   Stage 2

16   3494   4   Stage 3

16   3494   4   4   3494   4   3494

16   3494

RESET, DATA, STROBE1

CHIP SELECT

XA0-XA3

YA0-YA2

From
Microcontroller

4

To Buffers

Figure 12

Figure 13

58

500

82

508

506

504

502

70

510

FIGURE 14

Figure 15

Handshake flowcharts

Host

Figure 16

Send message

Figure 17

Target

Figure 18

600

610

608

606

604   612   614

602

Figure 19

616

618

Figure 20

620

Figure 21

624

620

622

628

626

630

Figure 22

624

600

Figure 23

624

632

634

636

638

600

Figure 24

632

624

634

600

Figure 25

620

600

640

Figure 26

620

600

642

644

62

Figure 27

48

646

648

650   658   656

654

652

Figure 28

54

Figure 29.

Figure 30

606

602

610

608

604

612

Figure 31

624

622

628

626

MODULAR AUTOMOTIVE DIAGNOSTIC SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to provisional U.S. application No. 60/067,818, filed Dec. 5, 1997.

TECHNICAL FIELD

[0002] This invention is within the field of automotive diagnostics and pertains to a modular vehicle diagnostic system. As described below, this invention includes a changeable apparatus for sensing, measuring, calculating, processing, and displaying vehicle data and performance parameters.

BACKGROUND OF THE INVENTION

[0003] The industry of automotive diagnostics and repair has changed significantly over the last twenty-five years. Vehicles and engines have become more complicated and vehicle performance standards have increased. Consequently, the complexity of vehicle diagnostic equipment has increased. In addition, vehicle parameters that should be tested have increased and continue to change.

[0004] The continual improvement of the automobile has created a challenge for diagnostic and repair shops. Much of the diagnostic equipment that is cutting edge today will very likely have to be updated within a few years. In extreme cases, repair shops abandon or sell (usually at a loss) old equipment and obtain new equipment.

[0005] Some repair shops contend with the expense of maintaining modern diagnostic and repair equipment by specializing in particular lines of repair. For example, some automotive repair shops perform ignition system diagnostics but do not perform emissions, electronic control module, or other diagnosis. Specializing in one particular line of repair spares the cost and risk of regularly updating an array of other analysis or repair equipment.

[0006] Many repair shops that service a variety of vehicle repair needs find that the service equipment takes up a lot of floor space. This may be because some vehicle repair equipment manufacturers prefer to continue to house the equipment in large, floor standing housings. Also, each piece of service equipment may have its own sets of vehicle probes, keyboard, and display screen. Obviously, if more equipment is present, more time and money will be required to keep the equipment functional and more training will be required to keep service people familiar with the different service equipment protocols.

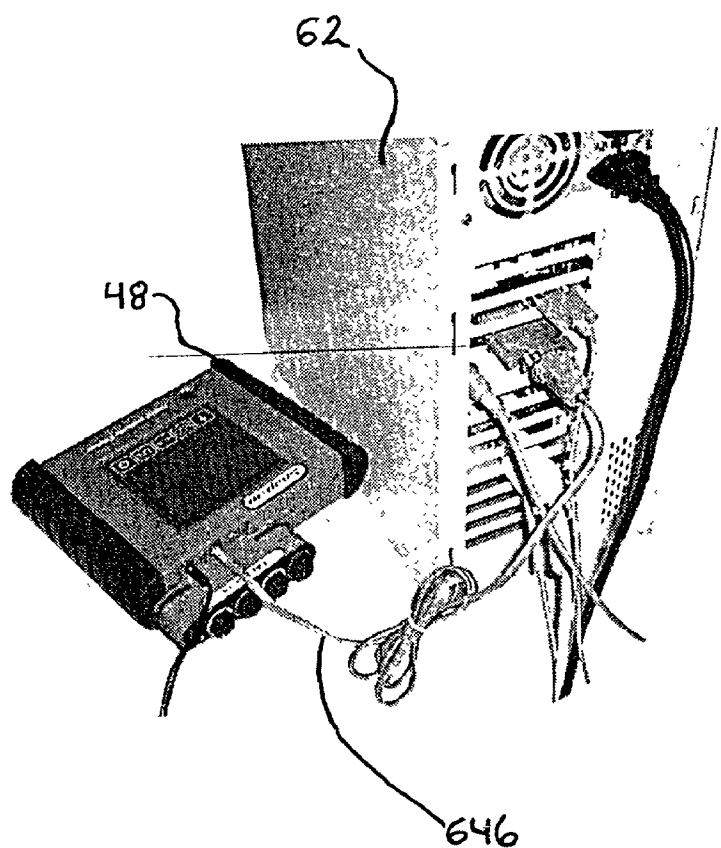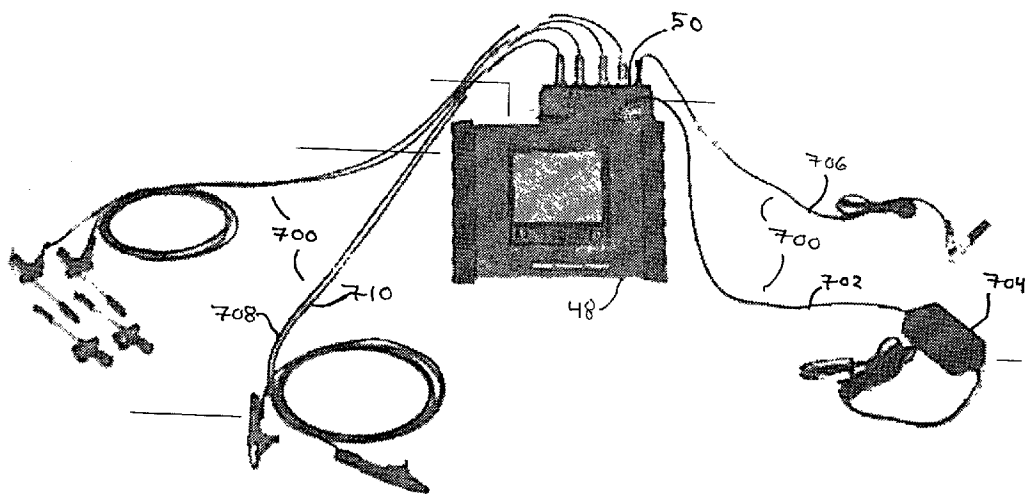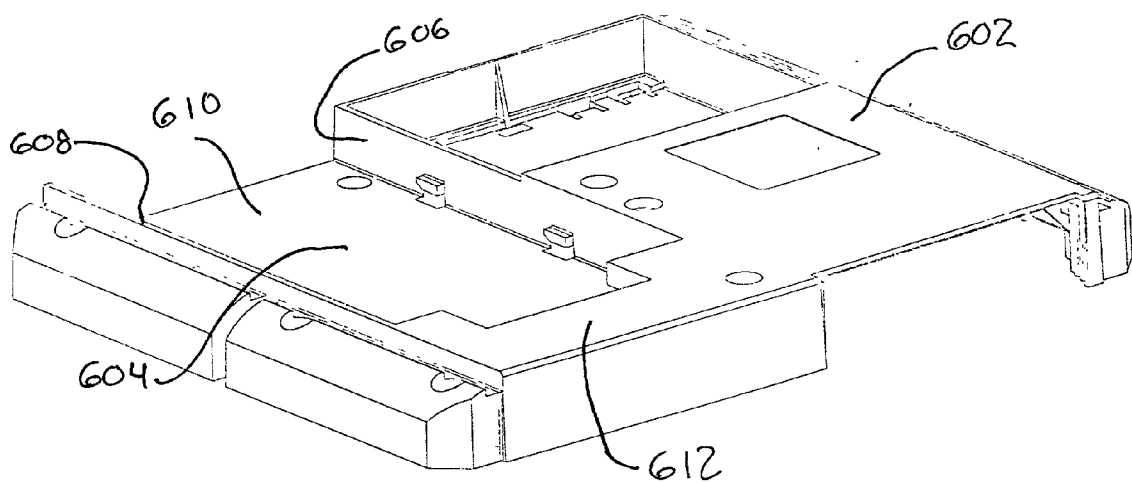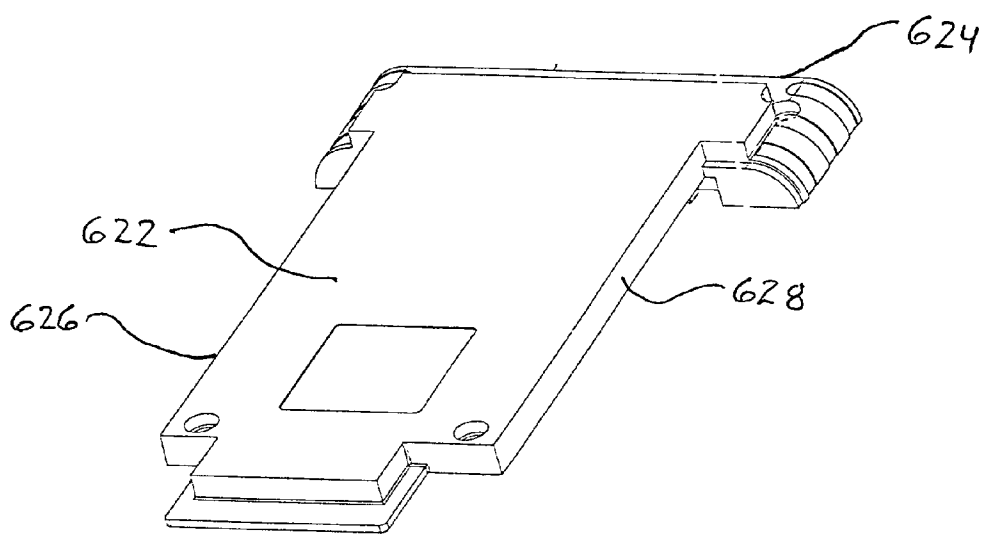[0007] When working with diagnostic equipment, it is desirable to be able to work with the vehicle probes, view the display screen, and input commands quickly and efficiently. It is also desirable to be able to easily move the diagnostic equipment to different service ports within the service station and to move the equipment around a vehicle under inspection, large or small.

OBJECTS OF THE INVENTION

[0008] It is a general object of the present invention to make a modular vehicle diagnostic system that accommodates the needs of the modern vehicle service technician.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In describing a preferred embodiment of the present invention, reference is made to accompanying drawings, wherein:

[0010] FIG. 1 is an illustration showing the possible interconnections between several devices of a modular vehicle diagnostic system according to the present invention.

[0011] FIG. 2 is an illustration showing the relationships between modular vehicle diagnostic system devices of the preferred embodiment.

[0012] FIG is a detailed illustration of the user interface unit of FIG. 2.

[0013] FIG. 4 is a detailed illustration of the diagnostics module of FIG. 2.

[0014] FIG. 5 shows a schematic of a ground check test circuit that is part of another aspect of the present invention.

[0015] FIG. 6 is a detailed illustration of the scan module of FIG. 2.

[0016] FIG. 7 is an illustration of the preferred data cable and one interchangeable test adapter for interconnecting the scan module of the preferred embodiment to vehicle's communication link connector.

[0017] FIG. 8 is an illustration showing the preferred connection of the data cable of FIG. 7 to the scan module.

[0018] FIGS. 9 is a detailed illustration of the amplification module of FIG. 2.

[0019] FIG. 10 is a block diagram showing the flow of selected signals from the vehicle computer through the break-out box of FIG. 2.

[0020] FIG. 11 is a illustration of the 80 to 4 multiplexer of FIG. 10.

[0021] FIG. 12 is a detailed illustration of the ignition signal receiver of FIG. 2.

[0022] FIG. 13 is a block diagram of the gas analysis module of FIG. 2.

[0023] FIG. 14 is a detailed illustration of the docking station of FIG. 2.

[0024] FIG. 15 is a partial flowchart of the preferred serial communications protocol for the modular vehicle diagnostic system of FIG. 2.

[0025] FIG. 16 is a partial flowchart of the preferred serial communications protocol for the modular vehicle diagnostic system of FIG. 2.

[0026] FIG. 17 is a partial flowchart of the preferred serial communications protocol for the modular vehicle diagnostic system of FIG. 2.

[0027] FIG. 18 is a drawing showing the bay structure included in the preferred housing assembly for the user interface unit of FIG. 2.

[0028] FIG. 19 is a drawing showing further aspects of the housing assembly shown in FIG. 18.

[0029] FIG. 20 is a drawing showing the conjoining relation between the user interface unit housing and the housings for the diagnostics and scan tool modules of FIG. 2.

[0030] FIG. 21 is a drawing showing the preferred housing assembly for the diagnostics and scan tool modules of FIG. 2.

[0031] FIG. 22 is a drawing further showing the conjoining relation between the user interface unit housing and the housings for the diagnostics and scan tool modules of FIG. 2.

[0032] FIG. 23 is a drawing showing tabs and latches of the scan tool module housing and the diagnostics module housing of the preferred embodiment.

[0033] FIG. 24 is a drawing showing the housings of FIG. 23 in a locked position.

[0034] FIG. 25 is a drawing of the housing for the amplification unit of FIG. 2 conjoined to the user interface unit housing.

[0035] FIG. 26 is an drawing of the conjoining mechanism of the user interface unit housing of FIG. 25.

[0036] FIG. 27 is a drawing showing a communication channel interconnecting a data processor to the user interface unit of FIG. 2.

[0037] FIG. 28 is a drawing showing several communication channels illustrated in FIG. 2.

[0038] FIG. 29 is a drawing of an assembly that includes a user interface unit and a diagnostic module.

[0039] FIG. 30 shows the conjoining features of the user interface unit housing of the preferred embodiment.

[0040] FIG. 31 shows the conjoining features of the diagnostic and scan module housings of the preferred embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0041] This invention pertains to modular vehicle diagnostic systems for sensing or receiving selected signals from a vehicle, for selecting vehicle parameters for vehicle diagnosis or evaluation, for accordingly processing the signals, and for displaying the vehicle parameters.

[0042] The modular vehicle diagnostic system has a plurality of constituent diagnostic and/or signal processing devices that may be selectively combined to form a vehicle diagnostic assembly. A device may be associated with vehicle diagnosis or performance evaluation or may be associated with some other facet of signal processing and/or interfacing. Two or more devices may be interconnected to produce a single-function or multi-functional vehicle diagnostic assembly unit.

[0043] The constituent data processing and diagnostic devices of the modular system may be selectively interconnected to compose a singular vehicle diagnostic assembly unit. Diagnostic assembly units may perform vehicle testing, signal processing, data interfacing and/or other functions.

[0044] Diagnostic assembly units may receive signals from a vehicle, process the signals, and/or generate vehicle performance data. Performance data may correspond to ignition system diagnosis, electronic control module (ECM) analysis, emissions or exhaust gas analysis, electrical ground quality, selective component performance evaluations and/or other vehicle operations, systems or components.

[0045] Diagnostic assembly units may receive, generate, and transmit vehicle signals for performing signal processing functions including signal multiplexing, artificial signal generating, and vehicle signal modulating.

[0046] Diagnostic assembly units may perform data interface functions such as provide a display of vehicle parameters or signal waveforms, receive input from a user, and transfer data to and from external processors or memory storage devices.

[0047] Two or more constituent devices may be interconnected by conjoining integral parts of the devices, such as the housings, and/or by providing or establishing one or more electronic communication channel(s) between the devices.

[0048] The constituent devices may be conjoined a number of ways. It is preferred that the devices are conjoined with interlocking mechanisms of the type that are at least partially securable to prevent the devices from separating under normal use. For example, in a handheld system, such a secure interlock would allow the operator to grasp any part of an assembly unit and thereby obtain control of all of the interlocked devices. The devices may be conjoined by mating, joining, locking, linking, binding, clasping, or through some other connecting mechanism or technique. For example, the devices may include complementary channels for mating and rotary locking latches, slot and tab assemblies, or Velcro™ strips affixed to the housings. While the above examples provide interlocks that may be relatively easily disengaged, the devices may be conjoined through other means such as screws or nut and bolt assemblies. It should be understood that more than one mechanism may be employed to conjoin devices within an assembly as explained in more detail below.

[0049] An interconnection may also be established by providing communication channels between two or more devices. Communication channels may be established in conjunction with, separate from, or exclusive of the conjoining mechanism.

[0050] Communication channels allow digital and analog signals to be input to and output from the devices. Digital and analog signals may correspond to data, control, or other information. The devices may transmit and receive automotive-type signals. Automotive-type signals may originate from a vehicle, a memory device, or may be fabricated within the system, with or without input from an operator.

[0051] More specifically, a block diagram of a modular vehicle diagnostic system 10 is shown in FIG. 1 and includes several devices 14, 16, 18, and 20 that may be interconnected by being conjoined together and/or through a communication channel.

[0052] The devices of the modular vehicle diagnostic system 10 may be selectively interconnected. Either one or several of the devices 12-20 and/or other devices, not shown, may be interconnected to compose an assembly or a device for testing or evaluating vehicle performance. Con-

sequently, each individual device **12-20** may support one or more application(s) for a vehicle diagnostic/evaluation system. For example, the devices within the diagnostic system may include a user interface unit, vehicle signal and data interfacing modules, vehicle signal and data preconditioning modules, and auxiliary components.

[0053] A user interface unit may perform one or several universal functions, e.g., displaying test results to an operator on a display and/or receiving input data or information. Consequently, a user interface unit may have application in a majority of diagnostic system applications.

[0054] Vehicle signal and data interfacing modules may be provided for performing one or several diagnostic functions, e.g., sensing analog signals from a vehicle and providing an indication of the magnitude of the signals. Such modules may have other applications, e.g., reading data from the vehicle's computer. Interfacing modules may be dedicated to one or several other functions. One, several, or many interfacing modules may be included in the modular vehicle diagnostic system.

[0055] Vehicle signal and data preconditioning modules may be provided for performing one or several signal processing functions, e.g., enhancing signals for input to a vehicle component or module vehicle diagnostic system device. Like the interfacing modules, preconditioning modules may have multiple applications. Several preconditioning modules may be included in an assembly unit.

[0056] Auxiliary components may be provided for performing other functions. For example, an auxiliary component may be dedicated to analyzing a vehicle's exhaust gas concentrations. One or several auxiliary components may be included in an assembly unit.

[0057] It should be understood that the requisite devices for performing vehicle diagnosis or evaluation is dependent upon the type of diagnosis or evaluation performed and the functionality provided by the devices within the modular vehicle diagnostic system.

[0058] Returning to **FIG. 1**, devices **14-20** may interconnect to **12** as shown. Other configurations are possible. For example, device **16** may interconnect to device **18** only or devices **16** and **18** may each be configured to interconnect to device **12** at a single location, so that only one may be interconnected to device **12** at a time.

[0059] It is contemplated that different vehicle tests may be performed by various combinations of the devices of **FIG. 1**. For example, the combination formed by interconnecting devices **12** and **18** may provide an exhaust gas analyzer for providing a display of the concentrations of particular gases present in the exhaust. Alternatively, interconnecting devices **12** and **14** may provide a system for testing the ignition system. As discussed below, further combinations provide assemblies that may test other systems or components of a vehicle.

[0060] As illustrated in **FIG. 1**, the devices of the preferred embodiment are configured to facilitate interconnection. The devices may include reciprocating structure, as illustrated by tabs **30** and **34** and slots **28** and **32**, for conjoining the housings of two or more devices. The devices may also be interconnected through communication channels.

[0061] Exclusive communication channels may be provided for establishing a signal path between two devices if the devices are otherwise not interconnected. For example, exclusive communication channel **42** may be used to transfer diagnostic data from a memory device within device **12** to memory within device **20**.

[0062] Preferably, integrated communication channels are associated with the interlocking mechanisms of two or more devices. For example, an integrated communication channel is established between device **12** and device **14** when pins **26** contact slots **24** when tab **30** engages slot **28**. Integrated communication channels are preferable if the transfer of large quantities of data between two devices must be fast and/or bidirectional. An integrated communication channel may support a parallel data port without unduly increasing the size or complexity of the system.

[0063] Separate communication channels may be provided between two devices if the devices are not otherwise interlocked or the interlocking mechanism does not provide a suitable structure for incorporating a communication channel. For example, separate communication channel **36** interconnects device **14** and device **16**, although these devices, while conjoined to other devices within the system, are not conjoined to one another.

[0064] Each device within the modular vehicle diagnostic system may execute functions that are related to vehicle diagnosis and/or signal processing. A device may have a local control system, i.e., all of the hardware and/or software for controlling the device is within the device, or may receive control commands or a control program from another module or device.

[0065] FIG **2** shows, in block diagram form, the preferred embodiment for the modular vehicle diagnostic system of the present invention. The block units represent the devices that may be selectively interconnected. The arrows represent electronic communication channels that may be selectively established. The devices may be conjoined to the same devices with which communication channels are shared or may be conjoined according to some other organizational structure. Conjoining mechanisms are not illustrated in **FIG. 2**. In the preferred embodiment, selected devices conjoin to the user interface unit **48**. In addition, some selected devices, while sharing communication channels, do not conjoin to vehicle diagnostic system devices.

[0066] In general, the devices of **FIG. 2** include a user interface unit **48**, vehicle signal and data interfacing modules **50** and **52**, vehicle signal and data preconditioning modules **54, 56**, and **64**, and auxiliary components **58, 60**, and **62** that may be selectively combined.

[0067] A user interface unit **48** may have a data processor, display, operator input components, and communication ports for inputting and outputting data and operating commands to and from devices within the system and/or other devices. The user interface unit may have a housing that facilitates selective interconnection to system devices.

[0068] Vehicle signal and data interfacing modules **50** and **52** may input and output operating commands, data, and signals. Accordingly, the interfacing modules may transfer data and signals between vehicle format and user interface unit format and may also include preprogrammed memory.

An interfacing module may also include a data processor for calculating vehicle performance parameters or performing other functions.

[0069] Vehicle signal and data preconditioning modules **54, 56,** and **64** may process signals between a vehicle and vehicle signal and data interfacing modules. The preconditioning modules may process data and signals between forms suitable for vehicle or vehicle components and forms suitable for vehicle signal and data interface modules as explained more fully below.

[0070] Auxiliary components **58, 60,** and **62** may include devices such as digital processors, microprocessors, signal generators, and memory components for transferring, storing, and/or processing diagnostic data and/or control signals from/to the user interface unit, system devices, or vehicle.

The User Interface

[0071] The user interface unit may include a display for displaying vehicle parameters and other information. Displayed information may also include instructions on how to interconnect devices or connect probes to the system, an interactive menu for selecting tests to be performed by the diagnostic assembly and selecting other preferences, such as the preferred display format. Additional information may include the condition or status of components within the system and operator information. For example, the display could request a user id-code from the operator. The display may be a liquid crystal display, cathode ray tube, one or more light emitting diodes, or some other device suitable for communicating information to an operator.

[0072] The user interface may also include a device for inputting information. Input information may include the selection of tests to be performed, operating commands, a user-id, format preferences, vehicle information, and other data or commands. An input device may include a touch screen, a keyboard or keypad, up/down buttons, a magnetic signal reader, voice recognition, or other device suitable for receiving operator input.

[0073] The user interface may also include a data processor. A data processor may control operation of the user interface unit and/or may control some or all of the interconnected devices. The data processor may include memory for storing or displaying vehicle test data and/or other vehicle information. The data processor may also include memory for storing diagnostic system operation software.

[0074] A block diagram of the user interface unit **48** of the preferred embodiment is shown in **FIG. 3**. User interface unit **48** includes a central processing unit **106** for executing user interface and vehicle diagnostic functions. Central processing unit **106** is interconnected to bus driver **116,** bus module interface **142,** PCMCIA card slot **140,** DRAM memory **122,** LCD display RAM **120,** keyboard control **108,** system address decode & power control **130,** and power switch **132**. In the preferred embodiment, bus driver **116** is an RS232 driver and module interface **142** is an ISA module interface. Power switch **132** controls PCMCIA power control unit **124** and has a manufacturers part number TPS2201.

[0075] Central processing unit **106** is also interconnected to LCD **102** and touch screen interface **100**. LCD **102** displays information in alphanumerical and graphical dis-

play formats. Information may be input to the modular vehicle diagnostic system through touch screen interface **100**.

[0076] Central processing unit **106** is also interconnected to PCMCIA power control **124,** data and address bus buffers **128,** and voltage regulator **110**. Voltage regulator **110** is supplied by main power supply **112** under the control of power control logic **114**. In the presently preferred embodiment, user interface unit **48** receives power from the vehicle battery via the vehicle's cigarette lighter. The user interface unit may also receive power from a device that receives power from the vehicle battery or from an AC power supply through a DC adapter. User interface unit **48** may also include a battery pack. Batteries may provide operating power and/or backup power during testing.

[0077] In the present embodiment, memory device **126** is a basic input/output system (BIOS) and communicates with CPU **106** through buffer data address **128** and system address decode & power control **130**. BIOS **126** may include a ROM and/or flash memory chip.

[0078] The user interface unit may include other components for vehicle diagnosis. In an alternate embodiment, the user interface unit includes ports for directly receiving vehicle signal scope lead input signals.

[0079] The vehicle signal and data interfacing modules may include a diagnostics module and a scan module.

[0080] Returning to **FIG. 2,** diagnostics module **50** inputs analog signals from vehicle **22,** processes the signals, and outputs digital data to user interface unit **48**. Diagnostics module **50** may also provide signals to vehicle **22** or to other devices within the modular vehicle diagnostic system.

[0081] Assuming the devices are interconnected as illustrated in **FIG. 2,** scope probes and leads **66** sense and transmit analog vehicle signals to diagnostics module **50**. Diagnostics module **50** may also receive conditioned analog vehicle signals from amplification unit **54** or programmable break-out box **56**. Diagnostics module **50** processes and converts the analog signals to digital data. The digital data may be output through bus **80** to user interface unit **48**. Diagnostics module **50** may also output analog signals to amplification unit **54** or directly to vehicle **22**.

A Diagnostics Module

[0082] The diagnostics module **50** of the preferred embodiment is shown in **FIG. 4**. Diagnostic module **50** includes digital signal processor **144** interconnected via digital data communication channel **208** to shared memory device **158** and via digital data communication channel **200** to digital multimeter (DMM) circuitry **162** and DAC multiplying/attenuating circuit **152**. Digital signal processor **144** is interconnected via digital data channel **220** and digital control channel **222** to control logic **146**.

[0083] Control logic **146** is interconnected to DMM circuitry **162,** 4-channel multiplexer **150,** digital to analog converter (DAC) multiplying/attenuating circuit **152,** analog attenuation circuit **154,** first-in-first-out memory **156,** and shared memory device **158** via digital control channels **206, 224,** and **226,** as shown. Analog attenuation circuit **154** receives signals from vehicle **32** via four scope lead input channels **166, 168, 170,** and **172,** designated yellow, green,

blue, and red. Vehicle signals are also provided to DMM circuitry **162**. Analog attenuation circuit **154** provides analog vehicle signals to DAC multiplying/attenuating circuit **152**. Multiplying/attenuating circuit **152** provides vehicle analog signals to output amplification circuit **164** and 4-channel multiplexer **150**. 4-channel multiplexer **150** provides vehicle signals to analog-to-digital converter **148**. Signal generator voltage reference **176** provides a reference voltage to input channels **170** and **172**. In the preferred embodiment, signal generator voltage reference **176** provides +1.2 volts. Ground check circuit **174** may receive battery terminal signals and signals from ground check lead **218**. Ground check circuit **174** provides differential voltage signals to input channel **166** and ground voltage signal to input channel **168**. Output amplification circuit **164** may provide simulated vehicle signals to vehicle **32**. The remaining components may be interconnected as shown in **FIG. 4**.

[0084] As shown in **FIG. 2**, user interface unit **48** and diagnostics module **50** may be interconnected via bus **80**. Returning to **FIGS. 3 and 4**, user interface unit **48** and diagnostics module **50** communicate via module interface **142** and base unit interface **230**.

[0085] A vehicle diagnostic assembly including user interface unit **48** and diagnostics module **50** may perform a variety of data processing and vehicle diagnostic functions. Vehicle diagnostic functions may include displaying the magnitudes or frequencies of input signals, measuring resistance, and/or functioning as a digital multi-meter or signal generator.

Diagnostic Processing Modes

[0086] In the present embodiment, the diagnostic module **50**—user interface unit **48** assembly may operate to provide a display of an input signal from any one of the four input channels **166-172**. In the present embodiment, data may be processed in either one of two modes, (1) normal and (2) FIFO (first-in, first-out). In normal operation mode, an analog signal is digitized and temporarily stored in memory, where it may be accessed by the user interface unit for display. In the FIFO mode, an analog signal is digitized and processed to a register where the data may be accessed by the user interface for display. The FIFO mode is more suitable if a period or segment of an analog signal is digitized to a relatively large number of data points. In an alternate mode, data may be stored in memory and processed to the FIFO register for access by the user interface unit or other module.

[0087] If an operator selects the normal mode of operation, firmware from the user interface unit **48** is downloaded to digital signal processor (DSP) **144**. Diagnostics module **50** is configured to operate in the normal mode via digital control by the user interface unit **48**.

[0088] In the normal mode of the present embodiment, analog signals from the input channels are processed to A/D converter **148** via analog attenuation circuit **154** and multiplying/attenuating DAC circuit **152**. Digital signals are processed from A/D converter **148** to control logic circuit **146**. Digital data is processed in control logic **146** to provide data that is suitable for alphanumeric or graphical display. Control logic **146** outputs data to DSP **144**. DSP **144** outputs data to shared memory **158** wherein the data is accessed by the base unit for display on LCD **102**. In the preferred

embodiment, DSP **144** may process either scope data (i.e., process the digital data samples and output data in a form suitable for a graphical display), or meter data (i.e., calculate average voltage, RMS voltage, frequency, duty cycle, and pulse width), dependent upon the format selected by the operator.

[0089] A second mode of operation, referred to as FIFO data mode, is suitable for collecting high concentrations of data. In the FIFO mode, analog signals from the input channels are processed to A/D converter **148** via analog attenuation circuit **154** and multiplying/attenuating DAC circuit **152**. Digital signals are processed from A/D converter **148** to FIFO memory **156**. Data from FIFO memory **156** may be output directly to user interface unit **48** display. If required by a particular application, data may also be processed by DSP **144** and output to shared memory **158**.

Ground Check

[0090] In the present embodiment, the assembly formed by conjoining diagnostic module **50** with user interface unit **48** preferably also operates to provide a display of measurements of the resistance of a vehicle ground circuit. Referring to **FIG. 4**, diagnostics module **50** is shown to include ground check circuit **174**. Ground check circuit **174** may provide up to 250 mA of current for testing the integrity of a ground path.

[0091] **FIG. 5** shows a block diagram of ground check circuit **174** including vehicle battery **232**. The loaded ground test of the present embodiment measures the quality of the ground path from a component to the negative terminal of battery **232**. In the test, a fixed amount of current is provided to the vehicle electrical system at the point being tested. Using the vehicle battery as a current source, the ground check circuit may simulate operating conditions by providing up to 250 mA of current through a vehicle component.

[0092] The positive terminal of vehicle battery **232** provides current for ground check circuit **174**. Current from vehicle battery **232** is routed through known resistance **236** and to the vehicle at the test point. Differential amp **238** provides a differential voltage V3, as a function of the drop in voltage from V1 to V2. The voltage levels at V3 and V2 are provided to scope lead input channels **166** and **168**, respectively. A/D converter **148** digitizes the voltages. User interface unit **48** further processes the ground check data according to the following formula:

$$R2 = (V2/V3) \times R1$$

[0093] User interface unit **48** may display the resistance of the ground path to the negative terminal of the battery, thus providing a check of the integrity of the ground circuit under test.

Other Functions of the Assembly

[0094] The assembly formed by conjoining diagnostic module **50** with user interface unit **48** preferably also functions as a digital multi-meter (DMM) for measuring resistance, current, and DC and AC voltages. In the DMM mode, scope input lead **184** senses electrical signals from vehicle **22**. The sensed signals are received by DMM circuitry **162** from analog signals channel **188**. DMM circuitry **162** is controlled by control logic **146** and provides to digital signal processor **144** digital data that corresponds to

the analog signals from vehicle **22**. Digital signal processor **144** processes the digital data to shared memory **158** for access by the user interface unit **48**. The base unit displays DMM parameters, including DC voltage, RMS voltage, resistance and current.

[0095] The assembly formed by conjoining diagnostic module **50** with user interface unit **48** preferably also functions as a signal generator for simulating vehicle signals. Signals generated by the assembly may be substituted for actual vehicle signals and may be displayed on display **102**. At the same time, signals from vehicle sensors, actuators, and/or other vehicle components may be sensed and displayed on display **102**. A mechanic may examine the response of a vehicle component under test to a simulated good or bad input signal.

[0096] In the signal generator mode, a digitized waveform is output from user interface unit **48** to shared memory **158**. The digitized waveform may be read from a personal computer memory card inserted into personal computer memory card drive **140** or may originate at the user interface unit under control of an operator. The user interface unit may be programmed to receive waveform parameters via touch screen **100**. The user interface unit may generate one or several periods of the digital waveform to shared memory **158** via module interface **142**. A digitized waveform read from a memory card may also be modified by an operator through commands entered on the touch screen.

[0097] A digital waveform entered into shared memory **158** may be read by DSP **144**. DSP **144** outputs the digital waveform data to multiplying/attenuating DAC **152**. DAC **152** outputs the simulated analog waveform to output amplification circuit **164**. The simulated waveform may be amplified or modulated and provided to a component of vehicle **10** via signal generator output leads **212** and **214**. The simulated waveform may be provided to an actuator, sensor or some other vehicle component while the digitized version of the waveform may be displayed on display **102**.

[0098] As simulated analog signals are output through leads **212** and **214**, vehicle signals may be sensed by input leads **178-184** and processed by diagnostics module **50** to shared memory **158**. Operating under the control of DSP **144**, multiplying/attenuating DAC **152** may both receive analog signals from analog attenuation circuit **154** and provide an analog signal to output amplification circuit **164**.

[0099] An alternate method for displaying simulated signals on display **102** includes outputting the simulated signals from output amplification circuit **164** and simultaneously sensing the signals at input channels. The signals may be processed to user interface unit **48** for display on LCD display **68**, as described above.

The Scan Module

[0100] Interfacing modules may also include a scan module. A user interface unit **48**—scan module **52** assembly communicates with the vehicle via the vehicle's on-board data communication link connector and displays collected information regarding vehicle systems, including engine control, automatic breaking, cruise control, electronic ride control, and transmission control systems. The scan assembly may allow an operator to retrieve trouble codes, run tests, record data, and display information in text, chart, or graphic format.

[0101] The scan assembly may receive vehicle information from vehicle data communication links and may thereby monitor sensor, switch and actuator inputs and outputs, run tests, including road tests, and receive and record trouble codes, data lists, component parameters, and control module information.

[0102] Scan module **52** may further provide access to vehicle data lists for display of both discrete (e.g., on/off, open/closed) and analog (e.g., magnitude) parameters. The parameters may correspond to input and/or output programmable control module signals. For example, control module data parameters may correspond to engine speed, brake switches, fuel metering, throttle position, engine and engine coolant temperature, barometric and manifold pressure, air temperature, airflow rate, battery voltage, fuel pump relay voltage, spark timing, emissions, transmission and cruise control, and heating, ventilation, and air conditioning systems.

[0103] The assembly formed by interconnecting the scan module preferably includes touch screen **100** on the user interface unit **48** (see **FIG. 3**) for inputting information such as the identity or make of the vehicle, the vehicle system to be tested, and preferred or selected display formats. The scan assembly also includes LCD display **102** for displaying scan test information and other information such as identifying the correct vehicle test adapter and/or providing instructions of how to connect the scanner to the vehicle.

[0104] Turning to **FIG. 2**, therein is shown scan module **52** in communication with bus **80** and interconnected to vehicle **22** via communications channel **84**. In the present embodiment, communications channel **84** is a serial communications channel.

[0105] A block diagram of scan module **52** is shown in **FIG. 6**. Scan module **52** communicates with user interface unit **48** via serial port **278** and module interface **142**. Serial port **278** is interconnected to serial data channel **280** and data bus and control signal channel **282**. Serial data channel **280** is interconnected to microcontroller **274**. Microcontroller **274** communicates with programmable logic device **284** via address bus **286** and data bus and control signal channel **288**. Microcontroller **274** also communicates with 16-bit transceiver **294** and static RAM devices **290** and **292** via address data bus and control signal channel **288**.

[0106] Microcontroller **274** controls the overall operation of scan module **52**. Programmable logic **284** and programmable logic **318** provide control logic, address decode and other control signals. 16-bit transceiver **294** communicates with serial port **278** and module interface **300** via data bus and control signal channel **282**. Programmable logic device **284** transmits memory address data to static RAM **290** and **292** via address bus **296**.

[0107] Microcontroller **276** implements all of the vehicle-specific serial communication protocols established by the different vehicle manufacturers.

[0108] In the presently-preferred embodiment, software for the scan assembly is stored on memory cards. A first memory card may contain all the scan module program software and support for generic and enhanced OBD-II engine control tests. The first card may also contain tests for electronic systems such as ABS, cruise control, electronic ride control, and transmission control. A second memory

card may contain engine control system tests for American and foreign vehicles, and tests for other electronic systems on late model vehicles which may also include ABS, cruise control, electronic ride control, and transmission control. The memory cards are read by user interface unit **48** which downloads the information to the scanner module.

[0109] Vehicle interface **316** may include a data cable **240** and an interchangeable test adapter **242**, shown in **FIGS. 7 and 8**, for facilitating interconnection to a vehicle. An interchangeable test adapter of the present invention may include any one of a plurality of adapters configured to attach to a vehicle's communication link connector.

[0110] Vehicle signal and data preconditioning modules may include an ignition system signal module, an amplification module, and a programmable break-out box module.

An Amplification Module

[0111] An amplification module may enhance and/or modify modular diagnostic system signals. By enhancing signals, the module vehicle device system widens the range of signal output options for simulating a greater number of vehicle engine control and other signals. An amplification unit may also provide power and ground sources for activating injectors and other devices.

[0112] Turning once again to **FIG. 2**, an amplification unit **54** may receive signals from diagnostic module **50** via analog channel **88**. The amplification unit enhances and/or modifies signals under control of user interface unit **48** via serial communication channel **72**. Processed analog signals may be output to vehicle **22** via scope leads **68**.

[0113] **FIG. 9** shows a block diagram of the amplification unit **26** for the presently-preferred embodiment. Amplification unit **26** receives signals from diagnostic module **50** at input terminals **344** and **346** and outputs amplified or modified signals at output terminals **352** and **354**. Microcomputer **342** may receive commands from user interface unit **48** at serial interface **340**. Microcomputer **342** may also send status messages to the user interface unit via serial interface **340**.

[0114] Amplification unit **54** may have several selectable operation modes. For example, amplification unit **54** may receive and amplify signals through several ranges. For example, in a first mode amplification unit may output a signal having a voltage range of ±6 v and in a second mode may output a signal having a voltage range of ±16 v. In a third mode, power and/or ground sources may be provided for example, to activate selected vehicle components. The amplification unit may include further modes of operation to amplify or modify signals in additional ways, depending upon a desired application. Preferably, an operator may select a desired mode through touch screen interface **100**.

[0115] Signals input to amplification unit **54** may include pre-configured signal patterns stored as digital data within the modular vehicle diagnostic system or on a disk or memory card. Input signals may also be programmed or input by an operator or through an external source. The signals may be displayed on LCD display **102** for operator verification or for other purposes. In the preferred embodiment, digital signals (or waveforms) are converted to analog signals by diagnostic module **50**. Analog signals are amplified or modified by amplification unit **54** for input to vehicle

22. For example, analog signals may be provided by the modular vehicle diagnostic system to drive one or several fuel injectors, activate an automatic breaking system solenoid, or may be provided to a vehicle computer, digital or analog CAM sensor, air temperature sensor, or other device.

[0116] Amplification module **54** may include a data processor such as a microprocessor, digital signal processor, or digital controller for controlling or regulating the amplification or modification of signals received.

[0117] Referring to **FIG. 9**, amplification module **54** includes microcomputer **342** for receiving data or information from user interface unit **48** via serial interface **340** and serial driver **116**. The data or information received by microcomputer **342** may pertain to the input signals received at inputs **344** and **346**, amplification or modification parameters, control parameters for configuring the components within the amplification unit, or some additional aspect of signal modification or amplification. Microcomputer **342** outputs configuration or control signals for configuring amplification unit **54**.

[0118] In the signal amplification mode, microcomputer **342** receives signals from user interface unit **48** that correspond to the voltage range of the desired amplification module output signal. Microcomputer **342** responsively provides a corresponding reference voltage signal to output lead **356**. Assuming the system is interconnected in a manner consistent with the present description, output lead **356** provides a reference voltage signal to signal generator voltage reference circuit **176** of diagnostics module **50**. In the presently-preferred embodiment, the reference voltage provided by microcomputer **342** corresponds to the desired output signal voltage range as follows:

Output signal voltage range	Reference voltage
±6 v	.72
±16 v	.96

[0119] Diagnostics module **50** receives from the user interface unit digital data that corresponds to the shape of the desired output signal. The digital data is converted to an analog signal at digital to analog converter **152**. The analog signal is amplified to within a predefined voltage range at output amplification circuit **164**. The predefined voltage range corresponds to the reference voltage at signal generator voltage reference **176** as follows:

Reference voltage	Voltage range of output signal
.72	0–6 v
.96	0–8 v

[0120] In addition to providing a reference voltage to the diagnostics module, microcomputer **342** configures amplification module buffer amplifiers **348** and **350** to provide a voltage shift of the signal output by output amplification circuit **164**. Microcomputer **342** also configures power amplifiers **378** and **380** to provide a voltage gain. The

voltage shift and voltage gain are dependent upon the parameters of the desired output signal, as follows:

Output signal range	Gain Formula
±6 v	output = 2*(input − 3)
±16 v	output = 4*(input − 4)

[0121] The signal amplified at power amplifier **380** is output at signal output lead **354**. The signal amplified at power amplifier **378** is provided to relay **382** for selective output to output lead **352**. In signal amplification mode, relay **384**, under control of microcomputer **342**, provides the output of buffer amplifier **348** to power amplifier **378**. In a different mode, described below, relay **384** provides the output of buffer amplifier **348** to decoder logic circuit **386**.

[0122] Amplification module **54** may also operate in a driver mode. In the driver mode of the present embodiment, amplification module **54** outputs half-bridge driving signals (i.e., source or sink current waveforms).

[0123] Amplification module **54** generates source and/or sink currents through microcomputer control of decoder logic circuit **386**. Decoder logic circuit **386** controls the status of high current drivers **388** and **390** for providing an output signal at output lead **352**.

[0124] In the present embodiment, microcomputer **342** configures decoder logic **386** to be responsive to signals provided by diagnostics module **50** and received at amplification module input channel **344**. Decoder logic **386** controls current drivers **388** and **390** to provide the following outputs to relay **382** in response to the voltage received at input channel **344**:

Voltage from Diagnostics Module	Output Current Source or Sink
10 V	15 A source
8 V	5 A source
6 V	0 A
4 V	5 A sink
2 V	15 A sink

[0125] In the driver mode, microcomputer **342** controls relay **384** to provide an output signal to decoder logic **386** and controls relay **382** to receive an input signal from the high current driver circuit.

[0126] It should be clear that, in the present embodiment, the amount of source or sink current provided by the modular vehicle diagnostic system at output **352** is determined by the magnitude of the voltage provided by diagnostics module **50**. The voltage magnitude parameter may be provided by an operator, an external memory device, the diagnostics module, or some other device.

[0127] In the driver mode, the modular vehicle diagnostic system may measure and provide a display of the magnitude of the source or sink current. To determine the source current, differential operational amplifier **392** inputs the voltage differential across resistor **396** and outputs the magnitude thereof at output lead **368**. Diagnostic module **50**

receives the voltage magnitude, converts the analog magnitude to a digital value and provides the digital value to user interface unit **48**. User interface unit **48** calculates the source current and may provide a display thereof on LCD display **102**.

[0128] Similarly, the magnitude of the sink current may be determined by providing the voltage differential across resistor **398** to the user interface unit.

[0129] Amplification module output signals may be displayed on LCD display **68**. The "ideal", or expected, waveform may be displayed by detecting the output of DAC circuit **152**, converting the analog signal to a digital signal, and providing the digital signal to user interface unit **48** for display. The "actual" waveform may be observed by coupling amplification unit input lead **374** or **376** to amplification unit signal output lead **352** or **354**. Amplification unit input leads **374** and **376** are output to diagnostics module **50** at communication channels **366** and **372**, respectively. Diagnostics module **50** may digitize the input signals and provide the signals to user interface unit **48** for display, as described above. Driver mode output waveforms may also be displayed.

[0130] In a further aspect of the present invention, the modular vehicle diagnostic system may sense and display the input or output voltage signal from a vehicle component. Amplification unit input leads **374** and **376** may be coupled to a vehicle component lead to sense input or output signals and provide the signals to diagnostic module **50** via leads **366** and **372**, as described above.

[0131] In summary, a modular vehicle device assembly that includes an amplification module as described may drive a high powered vehicle component, detect the response of the driven component or of some other component in the vehicle, and display the driving signal and detected response signals on the same display screen. Therefore, a mechanic may methodically analyze an engine by injecting known (good or bad) signals directly to one or more vehicle components. Vehicle components may thereby be tested without being removed.

Break-Out Box

[0132] In a further aspect of the invention, a programmable break-out box module may be interconnected to a modular vehicle diagnostic assembly. A programmable break-out box module may sense all or several signals at the vehicle computer and output selected signals to other devices for processing, display, or performing diagnostic functions.

[0133] In the presently-preferred embodiment, signals between vehicle **22** and vehicle computer **400** are sensed by connectors **402**, as illustrated in **FIG. 10**. In the present embodiment, the configuration of the connectors is dependent upon the vehicle model. The connectors provide programmable break-out box module **56** a binary code correspondent to the connector configuration and, hence, the vehicle model. As explained below, the programmable break-out box module **56** utilizes the binary code to control operation. Programmable break-out box module **56** receives control signals from user interface unit **48** and provides selected vehicle signals to diagnostic module **50**. While the selected vehicle signals may be either analog or digital

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vehicle signals, programmable breakout box **56** provides the vehicle signals as analog signals to diagnostic module **50**, where the signals are digitized, processed, and output to user interface unit **48**.

[0134] In the presently preferred embodiment, user interface unit **48** provides control signals to programmable break-out box **56** through serial communication channel **72**. Break-out box **56** detects signals at the vehicle computer and provides up to four signals to diagnostic module **50**.

[0135] Referring to **FIG. 10**, therein is illustrated a block diagram of a break-out-box **56** of the present embodiment. Generally speaking, break-out-box **56** is a controllable analog multiplexer with buffered protected inputs and internal voltage dividers.

[0136] The signals detected by the connectors **402** are provided to an input circuit **406**. Input circuit **406** protects break-out box module circuitry from excessive vehicle voltage signals. In the presently preferred embodiment, input circuit **406** includes 80 channels, each having a voltage follower and voltage divider circuit. Each channel may process an input signal having a magnitude of up to 50V and is protected to 100V for constant voltage signals and to 300V for short-term voltage spikes. Input circuit **406** also includes 1:12 voltage dividers for scaling down the input voltages.

[0137] In the present embodiment, break-out-box **56** functions as a 79-by-4 serially controlled analog multiplexer. An 80-to-4 multiplexer **408** receives input signals from input circuit **406**. Seventy-nine (79) of the inputs are vehicle computer signals and one input is provided by the vehicle battery. Under the control of microcontroller **404**, multiplexer **408** provides up to four input signals to buffer circuit **410**.

[0138] As shown in **FIG. 11**, multiplexer **408** includes seven cross-point switches **412** arranged in three stages. In the first stage, the input signals are provided to five 16-to-4 multiplexers. The outputs of four of the multiplexers are provided to a single 16-to-4 multiplexer in stage two. Stage 3 receives the output of stage 2 and the output of the remaining multiplexer of stage 1. Microcontroller **404** controls the operation of multiplexer **408** via control channel **414**.

[0139] Microcontroller **404** may control multiplexer **408** according to a program stored in memory within microcontroller **404** or received from some other device within the vehicle diagnostic system. Microcontroller **404** may also operate according to control signals received via communication channel **416**.

[0140] In the presently-preferred embodiment, user interface unit **48** issues to microcontroller **404** commands via serial interface **72**. Each command is translated by microcontroller **404** into a sequence of control signals so that multiplexer **408** outputs selected vehicle computer signals to buffer circuit **410**.

Ignition System Module

[0141] In a further aspect of the invention, an ignition system signal module is provided for receiving, conditioning and processing ignition system signals. The ignition system signal module may function as a buffer between a vehicle's

ignition system and the modular vehicle diagnostic system. The ignition system signal module may also adjust ignition system signal magnitudes to within ranges suitable for processing by other devices within the modular vehicle diagnostic system. The ignition system signal module may also output selected ignition signals. The ignition system signal module may perform other functions, such as comparing signal magnitudes, frequencies, or other attributes.

[0142] In the presently-preferred embodiment, an ignition signal receiver module may receive selected ignition signals from an ignition lead set **76** and provide selected, conditioned signals to diagnostic module **50**, as illustrated in **FIG. 2**. Diagnostic module **50** processes the received signals and generates representative signals in digital format therefrom for output to user interface unit **48**, as explained above.

[0143] The ignition signal receiver module of the present embodiment may receive a plurality of ignition signals from both conventional and distributorless ignition systems, including primary ignition signals, positive and/or negative secondary signals, number one cylinder signals, battery voltage and current signals, and vacuum and pressure device signals. The ignition signal receiver module processes ignition signals under the control of a microprocessor.

[0144] Referring to **FIG. 12**, ignition signal receiver module **64** may receive distributorless secondary ignition signals at terminals **420A** and **422A** and/or conventional secondary ignition signals at terminals **420B** and **422B**. Primary ignition signals may be received at terminals **424A** and **424B** for conventional and distributorless ignition systems, respectively. Primary and secondary ignition signals may be processed to respective signal interface networks **426-436** for conditioning. For example, in the present embodiment, the signal interface networks operate under control of a processor **440** to adjust the primary and secondary input signals to within a 0-6.5 volt range. Spark gap circuit protection components **480-490** may be provided to protect the ignition signal receiver module from excessive voltage signals from vehicle **22**.

[0145] Microprocessor **440** may control the ignition signal receiver module according to a program stored in memory within microprocessor **440** or received from some other module within the vehicle diagnostic system. In the presently preferred embodiment, microprocessor **440** receives operational software from user-interface unit **48** via a serial communication channel.

[0146] Conditioned primary and secondary input signals may be buffered by buffers **442-446** and input to analog cross-point switch network **438** for selective output to signal drivers **448-454**. Cross-point switch network **438**, switches **442-446**, and drivers **448-454** operate under control of microprocessor **440**. The ignition signal receiver module outputs selected ignition signals to the modular vehicle diagnostic assembly. In the presently preferred embodiment, the ignition signal receiver module, when interconnected to a modular vehicle diagnostic assembly, outputs selected ignition signals to diagnostics module **50** input leads **178-184**.

[0147] Ignition signal receiver module **64** may also include an input terminal dedicated to receiving a vehicle's number-one cylinder ignition signal. A dedicated number-one cylinder ignition terminal allows the modular vehicle

diagnostic assembly to identify primary and secondary ignition signals by cylinder number.

[0148] The number-one cylinder signal may be received at input terminal **456**, buffered at buffer **458**, and input to analog cross-point switch circuit **438**. Cross-point switch circuit **438** may output a number-one cylinder signal to a signal driver **448-454** under control of microprocessor **440**.

[0149] Ignition signal receiver module **64** may also include input leads for receiving signals related to vacuum and pressure components of an ignition system. In the present embodiment, input lead **456** may receive signals from a vacuum probe and input lead **470** may receive signals from a pressure probe. Vacuum and pressure input signals processed through signal buffers, analog cross-point switch circuit, and signal divers, are output to the diagnostic module, as described above.

[0150] The ignition signal receiver module **64** may also include a current probe for monitoring battery current for testing the performance of vehicle systems such as the cranking and charging systems. In the present embodiment, a current probe detects battery current and outputs a differential voltage to differential amplifier **464**. The differential voltage signal is processed to analog cross-point switch circuit **438** and to output drivers **448-454**, as described above.

[0151] The ignition signal receiver module **64** may also include battery voltage circuit **474** for monitoring battery voltage and a diode ripple circuit **476** for detecting the effects of the alternator on the battery output voltage.

[0152] Battery voltage may be monitored by battery voltage circuit **474** to test the charging system and/or the output of the battery when the ignition switch is engaged.

[0153] The diode ripple circuit includes a bandpass filter for filtering out the DC and high frequency components of the battery voltage. The diode ripple circuit **476** provides the filtered battery waveform to analog cross-point switch circuit **438**.

[0154] While the ignition signal receiver module of the present invention may be powered by internal or external power supplies, the present embodiment includes a DC-DC converter **478**, as shown in **FIG. 12**, for powering ignition module components from the vehicle battery.

[0155] Auxiliary components of the present invention may include a gas analysis module, a docking station, and/or data processing and display devices.

Gas Analysis Module

[0156] A gas analysis module may receive vehicle emission gases, measure the amount or concentration of one or several selected gases, and output a signal or signals representative thereof. Referring to **FIG. 2**, gas analysis module **58** receives samples of vehicle exhaust via exhaust intake hose **82**. Gas analysis module **58** may analyze emission samples, generate data signals, and/or provide signals to other devices within the modular vehicle diagnostic system. The modular vehicle diagnostic system may process the signals and generate data for display or may process the data in conjunction with data received from other tests to provide vehicle performance or condition parameters. Gas analysis module **58** outputs digital data signals representative of

exhaust gas concentrations to user interface unit **48** via serial communications channel **70**. Gas analysis module data includes concentrations of hydrocarbons, carbon monoxide, carbon dioxide, oxygen, and oxides of nitrogen. In the present embodiment, gas analysis module **58** is manufactured by Andros (model 6600).

[0157] The gas analysis module **58** of the preferred embodiment is shown in **FIG. 13**. Exhaust samples received from exhaust intake hose **82** are provided to Andros gas analyzer **500**. Sampled gases are discharged through outlet **508**. Andros gas analyzer **500** is in serial communication with Andros board **502** via communication channel **504**. Andros board **502** communicates with the modular vehicle diagnostic system via communication channel **70**. In the preferred embodiment, gas analysis module **58** is in serial communication with user interface unit **48**, as shown in **FIG. 2**. User interface unit **48** provides control signals to gas analysis module **58**. Gas analysis module **58** responsively generates and outputs exhaust sample data. Exhaust data is processed by the user interface unit for display or vehicle condition or performance evaluation.

[0158] Gas analysis module **58** may also provide power to other modular vehicle diagnostic system devices. In the presently-preferred embodiment, the gas analysis module receives power from the vehicle battery. Power for the other devices is provided at power terminal **510**.

Data Processing with A Docking Station

[0159] Auxiliary components of the present invention may also include a data processing device for functioning with one or several devices within the modular vehicle diagnostic system. For example, a personal computer may communicate with selected devices for performing selected tests and for receiving and displaying diagnostic data and/or inputting control commands.

[0160] The data processing device may also perform other functions related to automotive performance evaluation but not associated with the modular vehicle diagnostic system. For example, the data processing device may also interact with other equipment in an automotive repair shop and/or function as a central hub of vehicle diagnosis, sales and inventory.

[0161] The data processing device may further perform functions not unique to automotive performance evaluation, such as work processing, accessing remote data bases, and/or driving peripheral devices, such as a printer or sound system.

[0162] In furtherance of this aspect of the present invention, a docking station **60** is provided through which a communications link between a data processing device and selected devices within the modular vehicle diagnostic system may be established. In the presently-preferred embodiment, a docking station is provided for converting data and control information between communication formats implemented by the data processing device and communication formats, discussed below, of other vehicle diagnostic system devices.

[0163] Turning once again to **FIG. 2**, therein is shown a docking station **60** in communication with the modular vehicle diagnostic system and data processing device **62**. Data processing device **62** may include a display for dis-

playing menu and control information and diagnostic data associated with the vehicle diagnostic system. Data processing device **62** may also include an input device, such as a keyboard or touch screen display, for inputting operator commands and other information.

[0164] Docking station **60** may include several ports for interconnection to various modular devices, including data processor **62**, and may include memory and processing devices for converting between different communication formats, such as bit processing formats.

[0165] A block diagram of docking station **60** of the present embodiment is shown in **FIG. 14**. Docking station **60** includes several ports for interconnecting to different modular vehicle diagnostic system devices for receiving and providing signals in different formats. In the present embodiment, docking station ports have interface circuits associated therewith for adjusting output signals. For example, interface circuits **520, 522, 542,** and **544** may be level shifters for providing a desired shift in voltage between input and output signals.

[0166] Docking station port **520** may receive or provide digital signals transferred serially from/to data processor **62**. Docking station ports **522, 542,** and **544** may receive or provide digital signals serially transferred from/to other devices within modular vehicle diagnostic system **10**. In the present embodiment, docking station ports **520, 522, 542,** and **544** are RS-232 serial data voltage level shifters. Devices that utilize parallel bit processing may be interconnected to docking station **60** at header **524**.

[0167] The docking station **60** of the present embodiment includes a processing unit **526** for translating modular vehicle diagnostic system data between different bit processing formats. In the present embodiment, processing unit **526** translates between parallel and serial bit processing formats. Processing unit **526** is interconnected to data bus **532** and address bus **534**. Data bus **532** and address bus **534** are interconnected to memory devices **528** and **530**. Memory device **530** may provide memory for program storage and non-volatile data storage and memory device **530** may provide memory for use by processing unit **526** for program execution. In the presently preferred embodiment, memory device **528** is a static RAM and memory device **530** is a flash memory chip.

[0168] In the presently preferred embodiment, processing unit **526** includes a device for converting input/output signals to desired bit processing formats. In addition, dual UART (DUART) **540** may also, under the control of data processor **526**, convert signals to desired bit processing formats. Both data processor **526** and DUART **540** are connected directly to data bus **532** and address bus **534**, which, in turn, are connected to translator buffer **536** for processing data in parallel format to/from debug header **524** via module bus **538**.

[0169] Docking station **60** further includes a logic circuit **546** and display **548** for providing an indication of the state of the device. For example, display **548** may include a series of light emitting diodes and provide a signal when the docking station is converting data.

[0170] As illustrated in **FIG. 14**, docking station **60** further includes a power supply circuit **550** for providing docking station **60** with power. In the presently preferred

embodiment, power supply circuit **550** is interconnected to a 12 volt DC external power source at input **554** and provides 5 volt and +/−12 volt voltages to docking station components.

[0171] Docking station **60** may further include a reset circuit **552** for providing a reset signal to data processor **526**.

[0172] In the preferred embodiment, data processor **526** is an AM186ES microcontroller.

[0173] A data processing device may also be interconnected to other devices within the modular vehicle diagnostic system **10**. For example, a desktop PC may be serially linked to one of the modules, such as the user interface unit **48**, for receiving diagnostic data. The diagnostic data may be transmitted to the desktop PC as it is acquired or may be transmitted from memory. The data processing device may utilize, store, process, or further transfer the information.

[0174] In the preferred embodiment of the present invention, a data processor **62** may be serially linked directly to the user interface unit **48** via a serial data cable **74**. The serial link allows the transfer of selected diagnostic data, stored as files within the user interface unit **48**, from the user interface unit to the data processor. In the present embodiment, data is transferred in accordance with the modular vehicle diagnostic system serial communications protocol, discussed below. It is preferred that the data processor **62** support the diagnostic functions provided by the other modules, so that diagnostic data may be similarly presented on the user interface unit and the data processor **62** displays.

Communication Channels

[0175] As described above, the modular vehicle diagnostic system of the present embodiment includes a plurality of devices that may be selectively interconnected. An interconnection, for purposes of the present invention, includes establishing at least one communication channel between a selected device and at least one other device within the modular vehicle diagnostic system. A communication channel may require a solid medium, such as a conductive metal. Data may also be communicated between devices by other modes such as through radio waves or electromagnetic radiation.

[0176] As described above, several pairs of devices, if interconnected, communicate serially. Because different devices may be connected to a serial port and selected serial communications may be bi-directional, it is preferred that one serial communications protocol be implemented for all devices that input/output data serially.

[0177] In the present embodiment, communications between user interface unit **48** and programmable break-out-box **56**, amplification unit **54**, gas analysis module **58**, and data processor **62** occur via serial communication channels. In keeping with the invention, a universal serial communications protocol for all serial communications is defined, thus simplifying the communications code and providing the user interface unit **48** with a consistent mechanism through which to identify devices.

[0178] For purposes of the present discussion, user interface unit **48** is the host when communicating with programmable break-out-box **56**, gas analysis module **58**, or ampli-

fication unit **54**. Data processor **62** is the host when communicating serially with any device.

[0179] In the preferred serial communications protocol, the host always initiates communications. A flowchart of the handshake protocol for the host is shown in **FIGS. 15 and 16**. As shown in **FIG. 15**, if the transmission of a message is not successful, the host will resend the message up to two more times. If three successive attempts are not successful, the host records a communication failure.

[0180] As shown in **FIG. 16**, the host requires an acknowledge message from a target device after transmitting a message. If the acknowledge message is negative, the host will retransmit the message. If the acknowledge is positive, the host waits for a response. If a response is received within a predetermined period of time, the host determines if the checksum byte is valid. If the checksum byte is valid, the message was successfully sent. If the message was not successfully sent, the host may resend the message or record a communication failure, as discussed above.

[0181] A flowchart for the handshake protocol for a target is shown in **FIG. 17**. As shown therein, upon receipt of a message, the target determines if the checksum byte is valid. If checksum is valid, the target transmits a positive acknowledge (ACK) signal, processes the message, and sends a response. Upon receipt of a response message, the host does not send an acknowledgment. However, if checksum is not valid, the target transmits a negative acknowledge (NAK). As discussed above, if the transfer of a message is not successful, the host will resend the message up to two more times. If the target receives a defective message, it waits until the host stops transmitting before sending NAK.

[0182] The host and response message structures for the preferred embodiment are as follows:

Host message structure	
Header:	message size - 2 bytes
	target id - 1 byte
	opcode - 1 byte
	checksum - 1 byte
Message:	Length is opcode specific

[0183]

Response message structure	
Header:	message size - 2 bytes
	target id - 1 byte
	status - 1 byte
	checksum - 1 byte
Message:	Optional

[0184] The target identification bytes for the preferred embodiment are defined as follows ("$" denotes hexadecimal):

Target id byte	
$00	Any - all targets respond
$01	programmable break-out-box
$02	amplification unit
$03	computer
$04	slave PAC

[0185] The status byte in the preferred embodiment is defined as follows:

Status Byte	
$00–$0F	Reserved for universal codes
$00	OK
$01	Wrong target id
$02	Invalid opcode
$03	Target has been reset
$04	Invalid parameter
$10–$2F	programmable break-out-box error codes
$30–$4F	amplification unit error codes
$50–$6F	computer error codes
$70–$8F	slave error codes

[0186] The serial communications protocol of the preferred embodiment thus allows bi-directional communication between two selected devices and includes a mechanism that verifies the identification of the device and message. The preferred protocol further allows for an expansion of the modular vehicle diagnostic system to include additional modules.

Modularity

[0187] As discussed above, the devices of the modular vehicle diagnostic system may be selectively conjoined. One or more mechanisms may be used to conjoin the selected devices. A conjoining mechanism may provide or facilitate a desired feature of the modular vehicle diagnostic system. For example, a mechanism may facilitate the establishment of a hardware communication channel and/or maintain a structural concept. For example, it is desirable that the vehicle diagnostic assemblies of the preferred embodiment be portable and readily operable by a single operator, i.e., handheld.

[0188] The several devices of the preferred embodiment are housed separately. User interface unit housing **600** is shown in **FIGS. 18 and 19**. Housing assembly **600** is of a generally rectangular shape that includes side surface **602** opposite user interface surface **616**. User interface surface **616** includes display and touch screen interface **618**.

[0189] Side surface **602**, further illustrated in **FIG. 30**, has a slot or aperture **604** formed therein. In the present embodiment, aperture **604** includes a left side **606** and a right side **608** and terminates at an open end **610** and closed end **612**. Closed end **612** includes a male electric connector **614**, discussed below, that provides a hardware interface for interconnection to other devices of the modular vehicle diagnostic assembly. Aperture **604** is formed to provide an opening that corresponds to the shape of one or several other

modular vehicle diagnostic system devices. For example, in the present embodiment, aperture **604** corresponds to the shape of the housings of diagnostic module **50** and scan tool module **52**.

[0190] Turning to **FIGS. 20 and 21**, therein is shown the shape of the housing **620** for both diagnostic module **50** and scan tool module **52**. Housing assembly **620**, is analogous to a key that includes two portions, as further illustrated in **FIG. 31**. The first portion may be referred to as mating segment **622** and the second portion may be referred to as the access segment **624**. Mating segment **622** is of a shape complimentary to aperture **604**, discussed above. In the present embodiment, mating segment **622** includes a left side and a right side, **626** and **628**, respectively, having apertures formed therein to complement the ridges formed in sides **606** and **608** of aperture **604**. The width of mating segment **622** is equal to the depth of aperture **604**. The horizontal and vertical lengths of mating segment **622** correspond to the horizontal and vertical lengths of aperture **604**. Mating segment **622** further includes female electronic connector **630**, shaped complementary to male electronic connector **614**, discussed above.

[0191] Housing **620** may be conjoined to user interface unit housing **600** by sliding mating segment **622** adjacent to and along the length of aperture **604**. When housing **620** is fully inserted in aperture **604**, female electric connector **630** is in contact with male electric connector **614**, mating segment **622** and side surface **602** form a substantially flat surface, and access segment **624** is accessible atop user interface unit housing **600**, as shown in **FIG. 22**.

[0192] The present embodiment of user interface unit housing **600** includes a pair of rectangular apertures for receipt of a pair of rotating tabs **636** and **638** associated with locking latches **632** and **634** integrated with access segment **624**. When housing **620** is fully inserted into user interface unit housing **600**, manual rotation of tabs **632** and **634** locks housing **620** in the fully inserted position, as shown in **FIGS. 22 and 24**. In the presently preferred embodiment, locking the latches allows an operator to handle user interface unit **48** and diagnostic module **50** or scan tool module **52** as a single device. Of course, other modular vehicle diagnostic system devices may be conjoined and interconnected as described. Diagnostic module **50** and/or scan tool module **52** may be conjoined and/or interconnected through other mechanisms known in the art.

[0193] The devices of the modular vehicle diagnostic system may be conjoined by other mechanisms. Referring to **FIG. 25**, the amplification housing **640** for the amplification unit **54** is shown in its preferred position as conjoined to user interface unit housing **600**. Housing **620** is also shown conjoined to user interface unit housing **600**, to illustrate the preferred relation of amplification unit **54** to diagnostic module **50** and user interface unit **48**, discussed above.

[0194] Amplification housing **640** may be conjoined to other devices within the modular vehicle diagnostic assembly through a number of different mechanisms. As shown in **FIG. 26**, the preferred mechanism includes a bracket **642** secured to the back of the user interface unit housing **600** securing amplification housing **640** to user interface unit **48**. Bracket **642** includes a slot **644** for receipt of key tabs affixed to the back of amplification housing **640**. The key tabs may be slid into slot **644**. Amplification housing **640**

may also include spring loaded nylon balls for exerting a constant force between amplification housing **640** and user interface unit housing **600** when the key tabs are inserted into slot **644**. The force exerted by the spring holds amplification housing **640** in a fixed position relative user interface unit housing **600**.

[0195] In the present embodiment, gas analysis module **58** also has a housing with key tabs for insertion in slot **644**, as described above.

[0196] As discussed earlier, modular vehicle diagnostic system devices may conjoin through other mechanisms. For example, devices may be conjoined by a threaded stud and nut assembly. One or several threaded studs may be affixed to one or several devices. Corresponding apertures may be associated with other devices. Two or several devices may be conjoined by inserting a stud through an aperture. The devices may be secured together by tightening a nut on the stud.

[0197] As illustrated in **FIG. 2** and explained in detail above, it may be necessary to establish communication channels between selected devices. The communication channels may, in certain applications, be associated with the conjoining mechanism. For example, as shown above, a parallel communication channel between user interface unit **48** and diagnostic module **50** or scan tool module **52** is established when housing **620** is fully inserted in aperture **604** and female electronic connector **630** contacts male electric connector **614**. Other types of communication channels may be established between devices. For example, a serial communication channel may be established between devices when a housing is inserted into an aperture.

[0198] Communication channels may be established through mechanisms not associated with the device housings. As shown in **FIG. 2**, user interface unit **48** may communicate with data processor **62** via serial communication channel **74**. Data processor **62** may or may not conjoin user interface unit **48**. For example, as shown in **FIG. 27**, serial data cable **646** may provide the only physical link between data processor **62** and user interface unit **48**. Alternatively, separate communication links may be established between devices that are conjoined. As shown in **FIG. 2**, user interface unit **48** may communicate with amplification unit **54** via serial communication channel **72** and diagnostic module **50** may communicate with amplification unit **54** via analog channels **88**. Amplification unit **54** may also conjoin user interface unit **48**, as shown in **FIG. 25**. Turning to **FIG. 28**, therein is shown interface cable **650** interconnected to amplification unit **54**. Interface cable **650** also includes serial data cable **648** for establishing serial communication channel **72** between user interface unit **48** and amplification unit **54**. Analog channels **88** may be established between diagnostic module **50** and amplification unit **54** via analog cables **652-658**.

Conclusion

[0199] The modular system described herein permits a user to select which modules or devices to conjoin in a plug-in system. The system provides an automotive service professional with all the tools necessary to perform precision fault analysis of sophisticated vehicle components.

[0200] As discussed above, the modular vehicle diagnostic system is preferably handheld. A handheld system accords

an operator of the device the mobility to easily access different vehicle components while maintaining immediate control of the system. As test results are reviewed, new connections to the vehicle under test may be made. An operator may thereby perform vehicle tests without having to walk away from the vehicle.

[0201] To diagnose a vehicle, a mechanic chooses the component or system to be tested and interconnects the modules or devices for performing the desired test. For example, a mechanic that would like a display of the secondary ignition signals of a distributorless ignition system would first conjoin the diagnostics module to the user interface unit. The mechanic would also plug the diagnostic module lead set into the diagnostic module and provide a connection from a power source to the user interface unit. FIG. 29 shows the user interface unit 48 conjoined with the diagnostics module 50 and the lead set 700. The lead set includes power lead 702 connecting AC power supply adapter 704 to the user interface unit 48. The AC power supply adapter includes a plug for connection to an AC power supply.

[0202] The lead set further includes a ground lead 706 for connection to vehicle ground. Secondary leads 708 and 710 are connected to the diagnostic module 50 channels as shown. After selecting the DIS ignition system display from the touch screen of user interface 48, the mechanic follows the instructions provided on the display for configuring the diagnostic module 50 and connecting the leads to the vehicle. After the user interface unit is properly configured and the test leads are properly connected, the mechanic is prompted to start the test.

[0203] Upon starting the test, the user interface provides a display of DIS signals to the mechanic. The mechanic may select a graphical or digital display of data.

[0204] A user interface unit serves as a base unit for various assemblies. Additional modules or devices may be obtained at the discretion of a mechanic. For example, a mechanic dedicated to ignition system repair may obtain or purchase only an ignition signal receiver and a diagnostics module. Additional modules, such as a gas analysis module or a scan tool module, may be obtained if the need or desire to expand the capacity of the diagnostic system arises. Further, if advances in automotive or diagnostic technology render a particular module or device out-of-date, that module or device may be replaced without having to replace other devices or modules, such as the user interface unit.

[0205] While the invention has been particularly shown and described with reference to certain preferred embodiments, it will be understood by those skilled in the art that various alterations and modifications in form and in detail may be made therein without departing from the spirit and scope of the invention.

I claim:

1. A modular automotive diagnostic system comprising:

a plurality of devices for selective interconnection to compose a diagnostic assembly unit;

a first one of said devices substantially enclosed by a first housing and having a first conjoining mechanism associated therewith;

a second one of said devices substantially enclosed by a second housing and having a second conjoining mechanism associated therewith; and

wherein said first conjoining mechanism is configured to mate with said second conjoining mechanism so that said first and said second devices can be selectively conjoined.

2. The modular automotive diagnostic system of claim 1 further comprising:

a first communication channel selectively established between selected ones of said plurality of devices.

3. The modular automotive diagnostic system of claim 2 wherein said first one of said devices includes a user interface having a display and an input device and said second one of said devices senses signals from a vehicle engine and provides digital representations thereof to said first one of said devices.

4. The modular automotive diagnostic system of claim 2 wherein said first communication channel is established when said first housing is conjoined to said second housing.

5. The modular automotive diagnostic system of claim 2 wherein said first communication channel comprises a serial data cable having a first end for connection to said first one of said devices and having a second end for connection to said second one of said devices.

6. The modular automotive diagnostic system of claim 1 wherein said plurality of devices includes at least one signal processing device selected from the group comprising:

(a) a user interface unit;

(b) a diagnostic module;

(c) a scan tool module;

(d) a gas analysis module;

(e) an ignition signal receiver;

(f) an amplification unit;

(g) a programmable break-out box;

(h) a docking station; and

(i) a data processor.

7. The modular automotive diagnostic system of claim 2 further comprising at least one serial communication channel selectively established between a first selected pair of said plurality of devices and at least one parallel communication channel selectively established between a second selected pair of said plurality of devices.

8. The modular automotive diagnostic assembly of claim 1 wherein said diagnostic assembly unit is a handheld device.

9. In a modular automotive diagnostic system, a processing device for conjoining to a user interface unit substantially enclosed by a user interface housing having a receiving aperture formed therein, said processing device comprising:

a device housing shaped complementary to said receiving aperture; and

a modular interface for establishing a communication link between said user interface unit and said processing device when said processing device housing is conjoined to said user interface housing.

10. The modular automotive diagnostic system of claim 9 wherein said user interface housing has a rectangular aperture formed therein and said processing device housing further comprises:

a mating segment having sides having apertures formed therein for engagement to said user interface housing; and

an access segment abutting said mating segment and having at least one rotating tab having at least a first position for insertion into said rectangular aperture and a second position for locking said device housing in conjoinment with said user interface housing.

11. The automotive diagnostic system of claim 9 wherein conjoining said processing device housing to said user interface housing comprises a handheld diagnostic assembly unit.

12. A first processing device suitable for selective interconnection to a second processing device in a modular automotive diagnostic system for composing handheld diagnostic assembly units, said first processing device comprising:

a housing substantially defining a first processing device periphery and having a portion suitable for abutting said second processing device in a first relative position to said second processing device; and

a conjoining mechanism for securing said housing to said second processing device in said first relative position.

13. The first processing device of claim 12 wherein said conjoining mechanism secures said housing to a second processing device selected from the group comprising:

(a) a user interface unit;

(b) a diagnostic module;

(c) a scan tool module;

(d) a gas analysis module;

(e) an ignition signal receiver;

(f) an amplification unit;

(g) a programmable break-out box;

(h) a docking station; and

(i) a data processor.

14. A handheld modular automotive diagnostic tool comprising:

a user interface unit having a user interface housing that substantially encompasses a processor, an operating system, and a display;

a vehicle signal and data interfacing module for performing selected automotive diagnostic functions and for providing diagnostic data;

a first interconnecting mechanism conjoining said vehicle signal and data interfacing module to said user interface module for composing a vehicle diagnostic assembly; and

wherein said vehicle signal and data interfacing module is outside said user interface housing.

15. The handheld modular automotive diagnostic tool of claim 14 further comprising:

a vehicle signal and data preconditioning module for performing selected automotive diagnostic signal processing functions; and

a second interconnecting mechanism conjoining said vehicle signal and data preconditioning module to said vehicle diagnostic assembly.

16. The handheld modular automotive diagnostic tool of claim 14 further comprising:

an auxiliary component; and

a third interconnecting mechanism conjoining said auxiliary component to said vehicle diagnostic assembly.

17. A method for measuring the conductivity of a circuit from a selected point in the electrical system of a vehicle to the negative terminal of a vehicle battery, comprising the steps of:

connecting the positive terminal of a vehicle battery to a known resistance connected in series to the selected point in the electrical system;

measuring the resultant drop in voltage across said known resistance; and

calculating the resistance from the selected point to the negative terminal of the vehicle battery based upon said resultant voltage drop, the voltage at the selected point, and said known resistance.

18. An apparatus for measuring the conductivity of a circuit defined by a path from a selected point in the electrical system of a vehicle to the negative terminal of a vehicle battery, comprising:

a vehicle battery having a positive terminal and a negative terminal;

a known resistance having a first terminal interconnected to the positive terminal of said battery and having a second terminal interconnected to said selected point;

a differential amplifier for providing a voltage magnitude defined by a drop in voltage across said known resistance; and

a processor for calculating said conductivity of said circuit based upon the voltage at said second terminal of said known resistance, said voltage magnitude, and said known resistance.

19. An apparatus for providing a simulated signal for testing automobile components, comprising:

digital data representative of the time varying magnitude of said signal;

a converter for converting said digital data to an analog waveform;

an amplification circuit for amplifying said analog waveform to within a first predetermined voltage range;

a voltage shift circuit for shifting said analog waveform a predetermined voltage; and

a voltage gain circuit for amplifying said analog waveform to within a second predetermined voltage range.

20. The apparatus of claim 19 wherein said digital data is provided by a digital data recording device selected from the group consisting of:

(a) random access memory;

(b) read only memory;

(c) flash card memory; and

(d) digital signal processor.

21. The apparatus of claim 19 wherein said second predetermined voltage range is from negative sixteen volts to positive sixteen volts.

22. An apparatus for providing selectable driving signals for input to an automobile component for controlling the operation of the automobile component, said apparatus comprising:

a processor for receiving a voltage signal representative of said driving signal and for providing control signals;

a first high current driver interconnected to a high current source and responsive to said control signals for outputting first driving signals;

a second high current driver interconnected to a high current sink and responsive to said control signals for outputting second driving signals; and

wherein said first driving signals and said second driving signals comprise said selectable driving signals.

23. The apparatus of claim 22 further comprising:

a first resistor interconnected between said high current source and said first high current driver;

a first differential amplifier for providing a first voltage drop magnitude across said first resistor; and

a processing device for receiving said first voltage drop magnitude and for determining the magnitude of said first driving signal therefrom.

24. The apparatus of claim 23 further comprising:

a second resistor interconnected between said high current sink and said second high current driver;

a second differential amplifier for providing a second voltage drop magnitude across said second resistor; and

a processing device for receiving said second voltage drop magnitude and determining the magnitude of said second driving signal therefrom.

25. The apparatus of claim 22 wherein said apparatus is comprised within a diagnostic assembly unit of a modular automotive diagnostic system.

26. A modular automotive diagnostic system comprising:

first and second modular diagnostic devices substantially contained in first and second housings, respectively,

said first and second housings being selectively engagable by conjoining respective housings or portions thereof.

27. A handheld modular automotive diagnostic system comprising:

a plurality of devices for selective interconnection for processing automotive diagnostic information;

a communication channel selectively established between a first one of said devices and a second one of said devices.

28. The handheld modular automotive diagnostic system of claim 27 wherein said first one of said devices is suitable for handheld operation and includes a user interface as an integral part thereof for receiving operator input and for providing a display.

29. The handheld modular automotive diagnostic system of claim 27 wherein said communication channel is a digital communication channel.

30. The handheld modular automotive diagnostic system of claim 27 wherein said communication channel is an analog communication channel.

31. The handheld modular automotive diagnostic system of claim 29 wherein said digital communication channel transmits serial data signals.

32. The handheld modular automotive diagnostic system of claim 27 wherein said communication channel transmits electromagnetic radiation signals.

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